KEY CONCEPT

11.1 Water continually cycles.

BEFORE, you learned

- The force of running water causes erosion
- Water can be solid

NOW, you will learn

- What makes water important
- How much of Earth's water is salt water
- How water moves throughout Earth and its atmosphere

VOCABULARY

fresh water p. 363
salt water p. 363
water cycle p. 364
evaporation p. 365
condensation p. 365
precipitation p. 365

EXPLORE Water Vapor

Where does the water come from?

PROCEDURE

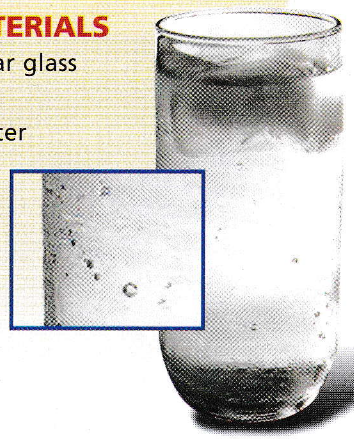
1. Put the ice in the glass and fill it with water.
2. Observe what happens to the outside of the glass.

WHAT DO YOU THINK?

- Where did the water on the outside of the glass come from?
- What does this activity tell you about the air surrounding you? What conclusion can you draw?

MATERIALS

- clear glass
- ice
- water



Water is a unique substance.

MAIN IDEA AND DETAILS Make a two-column chart to start organizing information about water.

Seen from outer space, Earth glistens like a beautiful blue and white marble. Welcome to the "water planet," the only planet in our solar system with a surface covered by a vast amount of liquid water. Because of water, a truly amazing substance, life can exist on Earth.

What is so amazing about water? In the temperature ranges we have on Earth, it exists commonly as a solid, a liquid, and a gas. At a low temperature, water freezes. It becomes a solid, which is ice. At a higher temperature, it flows easily in liquid form. Liquid water can become a gas, especially at higher temperatures. If you have ever noticed how something wet dries out in the hot sunlight, you have observed the effect of liquid water changing into a gas. The gas form is the invisible water vapor in our atmosphere.

Liquid water can fit any container. It can hold its shape in a raindrop, then merge with other drops to flow down a hill or slow down and sit for centuries in a lake.

Water covers most of Earth.

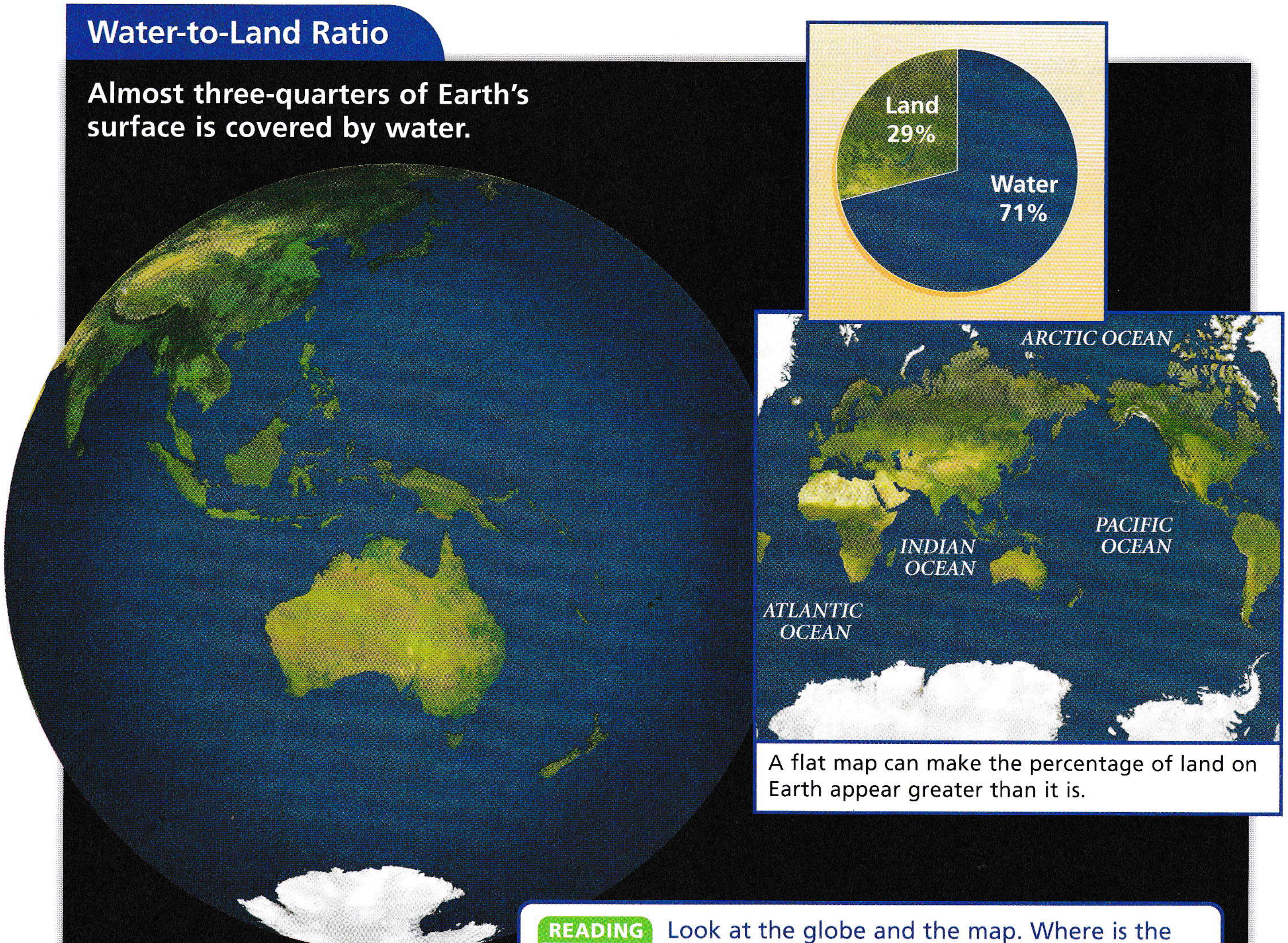
Earth looks bluish from space because most of Earth's surface is ocean. If you look at a globe or a world map, you will see the names of four oceans—Atlantic, Pacific, Indian, and Arctic. If you look more closely or trace the four named oceans with your finger, you will see that they are connected to one another. Together they form one huge ocean. Any part of this ocean is called the sea.

The global ocean covers 71 percent, or almost three-quarters, of Earth's surface. Most of the ocean is in the Southern Hemisphere. The ocean is, on average, 3.8 kilometers (2.4 mi) deep. Although most of the water covering Earth is ocean, water also covers some land areas, as rivers, lakes, and ice.

CHECK YOUR READING Where is most of Earth's water?

Water-to-Land Ratio

Almost three-quarters of Earth's surface is covered by water.



A flat map can make the percentage of land on Earth appear greater than it is.

READING VISUALS Look at the globe and the map. Where is the amount of land most exaggerated on the map?

Water moves in a worldwide cycle.

MAIN IDEA AND DETAILS Record in your notes this main idea and important details about the water cycle.

Water continually moves and changes form. Water from clouds falls over the oceans and on land. Water flows in rivers and collects in lakes and under the ground. Water can be a solid in the form of ice, or it can be an invisible vapor in the atmosphere.

The Water Cycle

Water's movement on Earth is a cycle, or continually repeating process. The **water cycle** is the continuous movement of water through the environment of Earth. In the water cycle, water is constantly changing form, from a liquid on land, to a vapor in the atmosphere, and again to a liquid that falls to the surface. The flow of water on land and underground is also part of the water cycle. As water moves in the water cycle, the total amount of water in Earth's system does not change very much. The water cycle involves three major processes: evaporation, condensation, and precipitation.

INVESTIGATE The Water Cycle

How does water cycle through an environment?

DESIGN YOUR OWN

PROCEDURE

1. Construct an environment in a jar with a lid. You can use plants, soil, water, and containers.
2. Find the mass of your closed jar after you construct it.
3. Draw a detailed, colored picture of your jar.
4. Let your jar sit for several days.
5. Find the mass of your jar again, and draw another picture of it.

WHAT DO YOU THINK?

- How did the jar's appearance change over several days?
- How did its mass change?
- What can you conclude about how water cycles through an environment?

CHALLENGE How could you change your environment so that the jar's appearance would change at a faster rate?

SKILL FOCUS
Modeling

MATERIALS
- jar with lid
- soil
- rocks or pebbles
- sand
- smaller containers
- water
- small plants
- triple-beam balance

TIME
30 minutes (for construction; 20 minutes for analysis)

Water and Life

Without water, nothing would live on Earth. Living things need water to function. Your own body is two-thirds water. In your body, your blood—which is mostly water—carries nutrients that give you energy and flushes wastes away. Many forms of life live in water. Oceans, lakes, and rivers are home to fish, mammals, plants, and other organisms. Even a single drop of water may contain tiny forms of life.

Fresh Water and Salt Water

When you hear the word *water,* you might imagine a cool drink that quenches your thirst. The water that you drink and depend on for survival is fresh water. **Fresh water** is water that is not salty and has little or no taste, color, or smell. Most rivers and lakes are fresh water.

The water in the ocean is salt water. **Salt water** is water that contains dissolved salts and other minerals. Human beings and most other land animals cannot survive by drinking salt water, although many other forms of life can live in salt water.

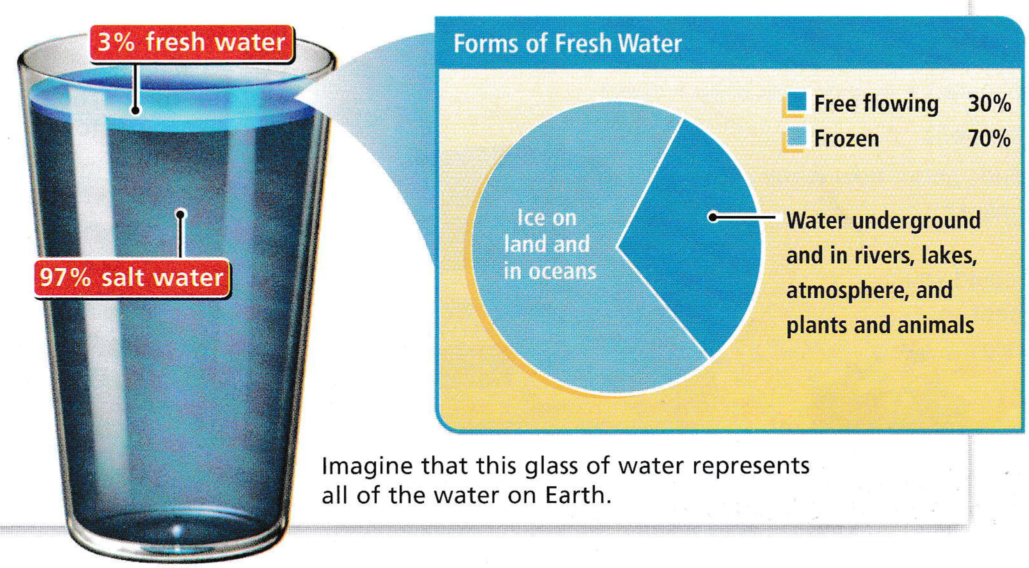
VOCABULARY
Remember to write the terms *fresh water* and *salt water* in four-square diagrams in your notebook.

You may be surprised to learn that even though fresh water is important for life, fresh water is actually scarce on Earth. Because most of Earth's water is in the ocean, most of the water on Earth is salt water. The illustration below compares the amounts of fresh water and salt water on Earth. Almost all—about 97 percent—of Earth's water is salt water in the ocean. Only about 3 percent of Earth's water, at any given time, is fresh water.

CHECK YOUR READING What is the difference between fresh water and salt water?

Salt Water vs. Fresh Water

Most water on Earth is salt water.



Imagine that this glass of water represents all of the water on Earth.

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- sand
- smaller containers
- water
- small plants
- triple-beam balance

TIME
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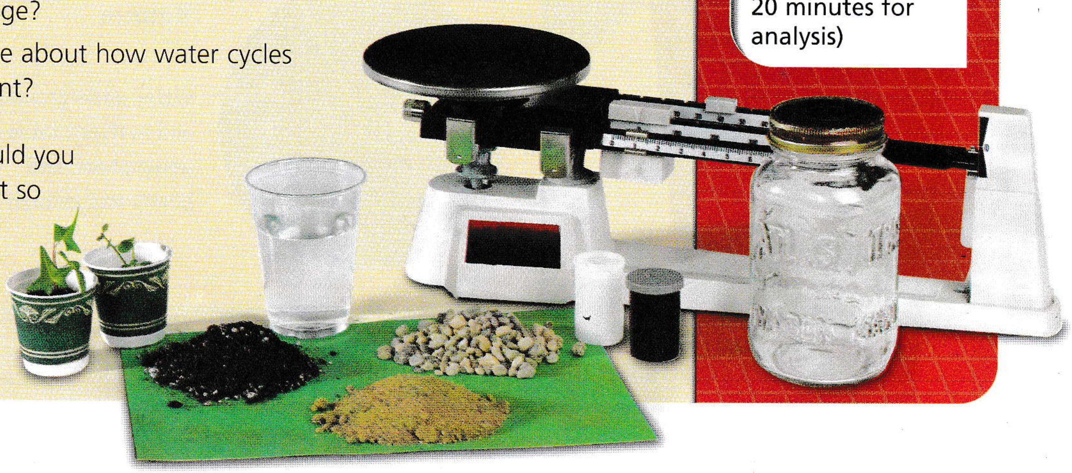
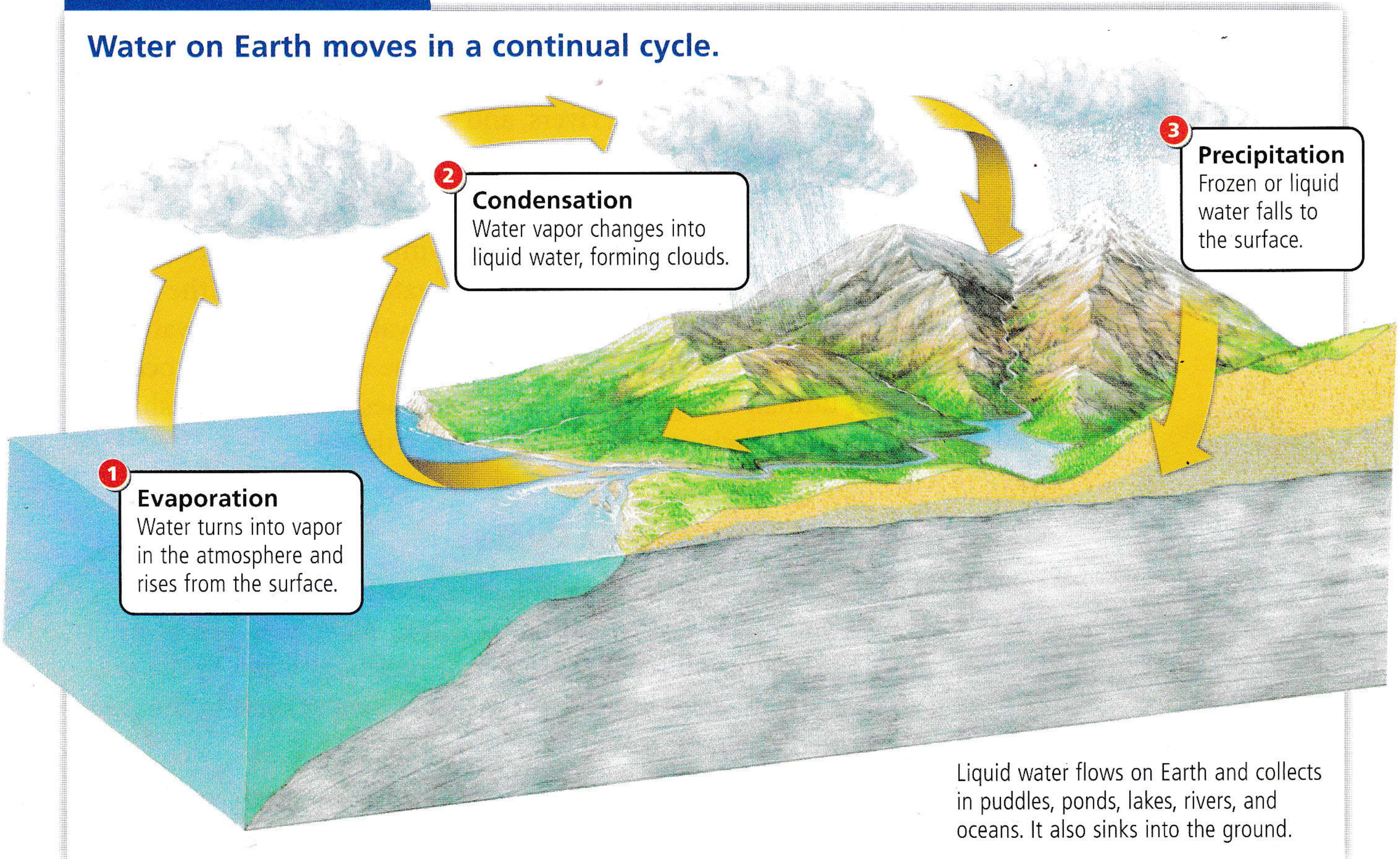


The Water Cycle

Water on Earth moves in a continual cycle.



1. The process in which water changes from liquid to vapor is called **evaporation.** Heat energy from the Sun warms up the surface of the ocean or another body of water. Some of the liquid water evaporates, becoming invisible water vapor, a gas.

2. The process in which water vapor in the atmosphere becomes liquid is called **condensation.** Condensation occurs as air cools. Because cold air can have less water vapor than warm air, some of the vapor condenses, or turns into droplets of liquid water. These droplets form clouds. At high altitudes clouds are made of ice crystals. Unlike water vapor, clouds are visible evidence of water in the atmosphere.

3. Water that falls from clouds is **precipitation.** Inside a cloud, water droplets bump together and merge into larger droplets. They finally become heavy enough to fall as precipitation—such as rain or sleet. The water from precipitation sinks into the soil or flows into streams and rivers in the process called runoff. The force of gravity pulls the flowing water downward and, in most cases, eventually to the ocean.

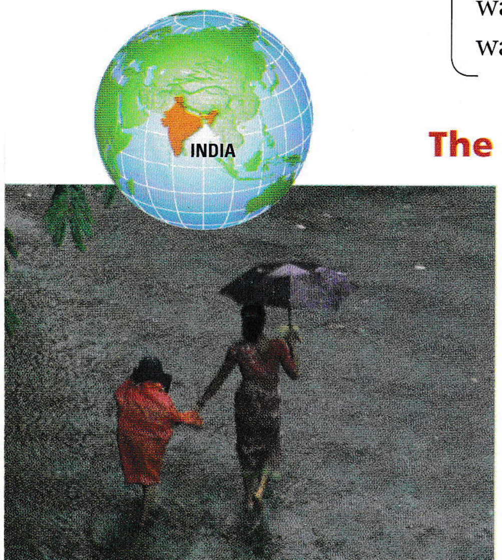
VISUALIZATION CLASSZONE.COM

See how water moves through Earth's system in the water cycle.

CHECK YOUR READING Why does water vapor in air condense into liquid droplets?

Most of the water that evaporates on Earth—85 percent of it—evaporates from the ocean. (About 75 percent of this condenses into cloud droplets and falls right back into the ocean.) The remaining 15 percent of evaporating water comes from such sources as damp ground, lakes, wet sidewalks, rivers, and sprinklers. Plants are also part of the water cycle. They pull up water from the ground and then release much of it into the air through their leaves.

Even though the water that evaporates into the atmosphere comes from both the salty ocean and from fresh water on land, all the precipitation that falls back to the surface is fresh water. When salt water evaporates, the salt is left behind. Through the water cycle the ocean water that human beings cannot drink becomes a source of fresh water for human beings and other life on Earth.



Flooding usually occurs during India's annual rainy season.

The Impact of the Water Cycle

The action of the water cycle is easy to spot. When it rains or snows, you can see precipitation in action. When you look at a flowing stream, you see the water cycle returning water to the sea. When a stream dries up, you know that the water cycle in the area has slowed down for a while.

Wet weather can fill reservoirs with drinking water and pour needed water on crops. Wet weather can also bring too much rain. For example, during the wet season in India, winds blow moist air inland from the Indian Ocean. Tremendous rains fall over the land for months. The rain is usually welcome after a long and hot dry season. However, these seasonal rains frequently cause devastating floods, covering acres and acres of land with water.

11.1 Review

KEY CONCEPTS

1. Name three things about water that make it unique or important.
2. How much of Earth's water is fresh water?
3. Explain the three processes that make up the water cycle.

CRITICAL THINKING

4. **Apply** How can a drop of salt water once have been a drop of fresh water?
5. **Compare and Contrast** What are two differences between salt water and fresh water?

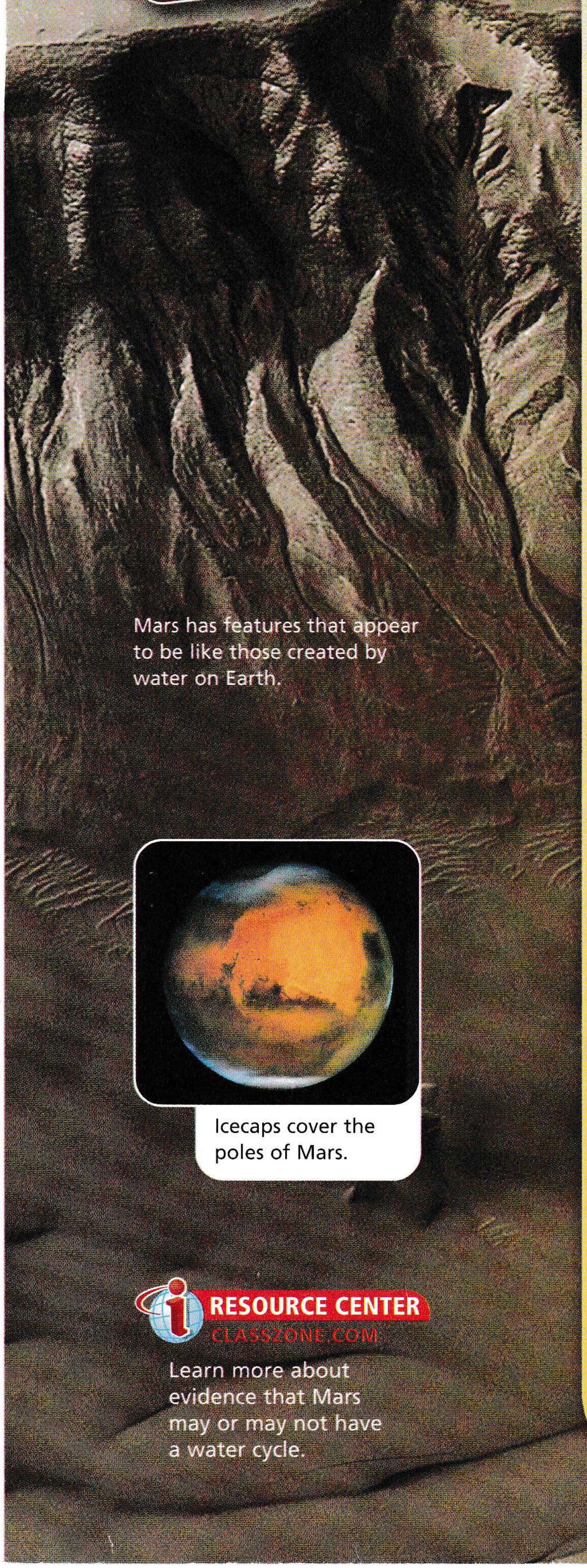
CHALLENGE

6. **Infer** In 1996, the *Galileo* space probe sent back photographs that showed ice on the surface of one of the moons of Jupiter. Scientists suspected there was water under the ice. Why did this discovery excite some people who thought there was a chance of finding life on that moon?

Think SCIENCE

SKILL: DETERMINING RELEVANCE

Does Mars Have a Water Cycle?



Mars has features that appear to be like those created by water on Earth.

Icecaps cover the poles of Mars.

RESOURCE CENTER
CLASSZONE.COM

Learn more about evidence that Mars may or may not have a water cycle.

Mars once had water flowing on its surface. Today, it is a frozen desert. Most astronomers think that there has been no liquid water on Mars for the past 3.9 billion years. Others, though, think that Mars has had flowing water recently—in the last 10 million years. They suggest that Mars may have a multimillion-year water cycle. According to their hypothesis, occasional volcanic activity melts ice, releasing floods of water. After the water evaporates, condenses, and falls as rain, it becomes ice again. And if Mars does have a water cycle, it could have something else that goes with water on Earth: life.

Issues

For Mars to have a water cycle, it would need several features.

- a source of energy for melting ice into water
- conditions for water to evaporate
- conditions for water vapor to condense

Observations

Astronomers have observed several facts about Mars.

- Mars has water ice at its north and south poles.
- Mars has had very large volcanoes in the past, although it seems to have no active volcanoes today.
- Mars takes about 687 Earth days to orbit the Sun.
- Mars is the fourth planet from the Sun.
- Mars has an atmosphere that is 100 times thinner than the atmosphere of Earth.
- Mars has an average surface air temperature of -55°C (-67°F).
- Mars has features that look like ones shaped by water on Earth: ocean shorelines, river valleys, and gullies.
- Mars has many visible craters—unlike Earth, where most craters get washed away, filled with water, or covered up.

Determine the Relevance of Each Observation

On Your Own Decide whether each observation is relevant in determining whether Mars has a water cycle.

As a Group Discuss the relevance of each observation to the idea of a water cycle on Mars. List other information that might be helpful.

CHALLENGE Research information about Mars. Identify facts that support or oppose the idea of a Martian water cycle.

KEY CONCEPT

11.2 Fresh water flows and freezes on Earth.

BEFORE, you learned
- Water covers most of Earth's surface
- Water continually cycles
- Water falls to Earth's surface as precipitation

NOW, you will learn
- How fresh water flows and collects on land
- How surface water forms lakes
- How frozen water exists on Earth

VOCABULARY

divide p. 369
drainage basin p. 369
turnover p. 371
eutrophication p. 372
iceberg p. 374

EXPLORE Water Collection

How does water flow and collect?

PROCEDURE

1. With the open egg carton on a level tray, pour water slowly into the center of the carton until the cups are three-quarters full.
2. Empty the carton. Tip it slightly, as shown in the photograph, and pour water into the higher end. Stop pouring when the carton is about to overflow.

MATERIALS
- plastic-foam egg carton
- tray or pan
- plastic bottle
- water

WHAT DO YOU THINK?
- How did the water flow when you poured it into the level carton? into the tilted carton? Where did it collect in the carton? Where did it not collect?
- What might your observations tell you about how water flows when it falls on land?

MAIN IDEA AND DETAILS
Record in your notebook this main idea and details about it.

Water flows and collects on Earth's surface.

Imagine you are in a raft on a river, speeding through whitewater rapids. Your raft splashes around boulders, crashing its way downriver. Then the raft reaches a lake. You glide across the surface, slowing down. At the end of the lake, your raft enters a river again and floats down it.

In your raft you are following the path a water drop might take on its way to the ocean. All over the planet, the force of gravity pulls water downhill. Fresh water flows downhill in a series of streams and rivers, collects in lakes and ponds, and eventually flows into the ocean. All of this water flows between high points called divides, in areas called drainage basins.

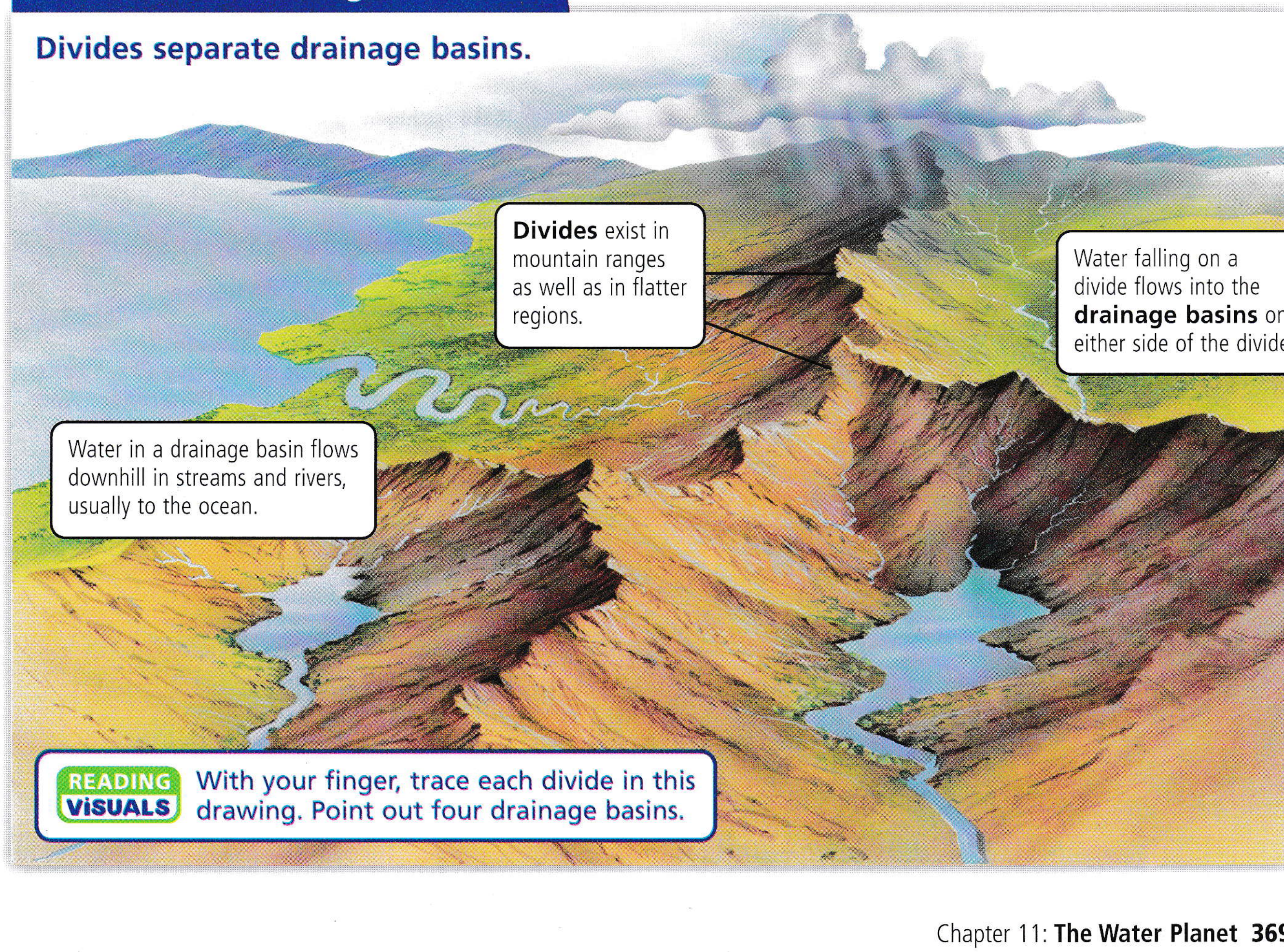
Divides and drainage basins affect the way water flows on land. A **divide** is a ridge, or continuous line of high land, from which water flows in different directions. If you were on a skateboard and began at the top of a hill, you would ride in one general direction down the hillside. On the other side of the hill, you would ride downhill in a completely different direction. The top of the hill is like a divide. A divide can be a continuous ridge of high mountains. On flatter ground, a divide can simply be the line of highest ground.

A **drainage basin,** or watershed, is an area into which all of the water on one side of a divide flows. If you pour water into the basin of your bathroom sink, it will flow down the side from high points to low, and eventually down the drain, which is at the lowest point. In mountainous areas, hills and mountains form the sides of basins, and valleys form the low points. Flatter regions also have basins. The basins may not be obvious in these regions, but they still drain water.

When it rains in a drainage basin, the water forms streams and rivers or sinks into the ground. Every stream, river, and lake is in a basin. In most places, the water eventually flows to the sea. In a bowl-shaped basin, the water may collect at the bottom of the basin or evaporate.

Divides and Drainage Basins

Divides separate drainage basins.



READING VISUALS With your finger, trace each divide in this drawing. Point out four drainage basins.

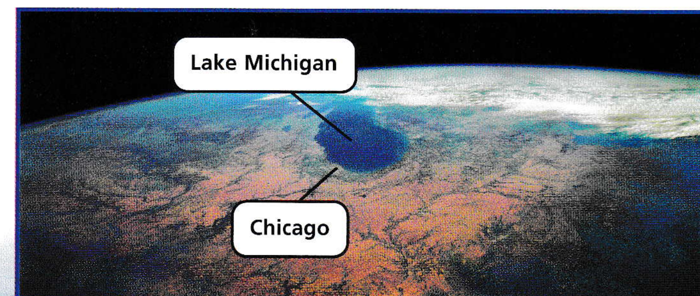
Surface water collects in ponds and lakes.

Lakes and ponds form where water naturally collects in low parts of land. Some lakes were formed during the last ice age. For example, the Great Lakes were formed when huge sheets of ice scraped out a series of giant depressions. Other lakes, such as Crater Lake in Oregon, were formed when water collected inside the craters of inactive volcanoes.

Water can fill a lake in several ways. Where the land surface dips below the level of underground water, the low land area fills with water. Rainfall and other precipitation contribute water to all lakes. Water may flow through a lake from a stream or river. Water may also flow away from a lake through a stream running downhill from the lake. Many lakes maintain fairly steady levels because of the balance of flow in and flow out.

The main difference between a pond and a lake is in their overall size. A pond is smaller and shallower than a lake, and there are many plants, such as water lilies and cattails, rooted in its muddy bottom. A lake may have water so deep that sunlight can't reach the bottom. In the deeper part of the lake, plants can't take root, so they grow only around the lake's edges. Ponds and lakes provide homes for many kinds of fish, insects, and other wildlife. They also provide resting places for migrating birds.

CHECK YOUR READING Name two differences between a pond and a lake.



Lake Michigan is the third largest of the five Great Lakes, which border eight states and Canada's Ontario province.

Chicago, Illinois, at the southwest corner of Lake Michigan, is the largest city on a Great Lake. Note that the lake is so wide that from Chicago you cannot see Michigan on the other side.

Lake Turnover

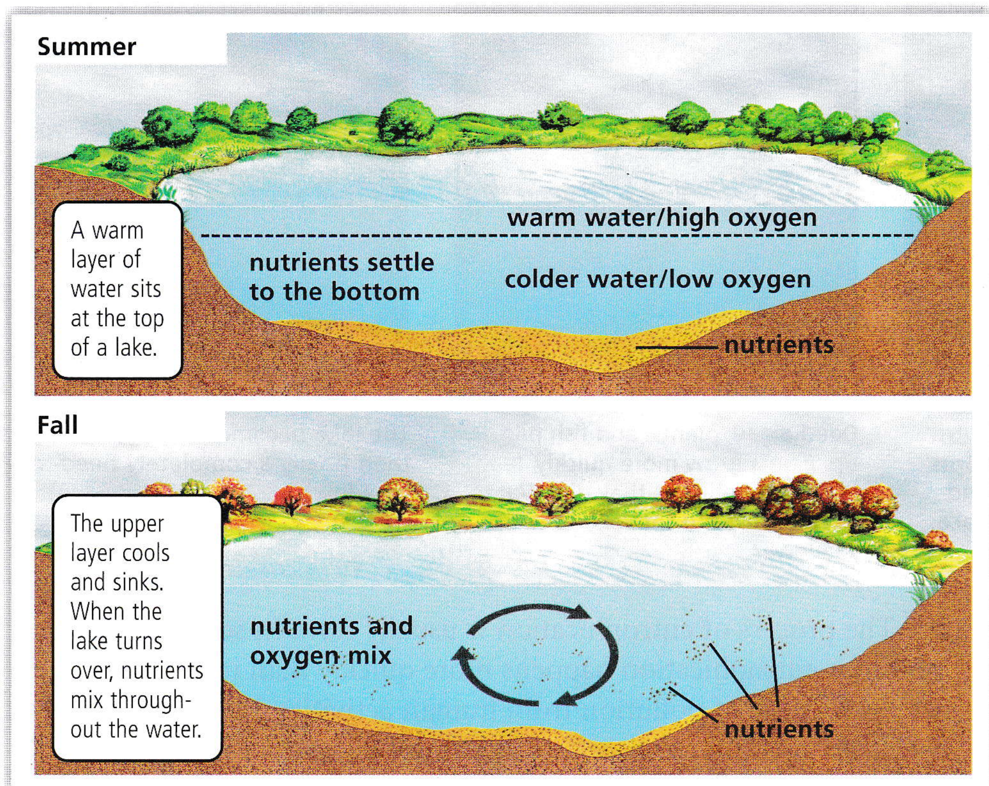
The water in a lake is not as still as it might appear. The changing temperatures of the seasons affect the water and cause it to move within the lake in a yearly cycle.

In a place with cold winters, ice may form on a lake, so that the wind cannot ruffle the surface. The water temperature in the lake remains steady, and the water stops moving. The water just below the surface ice is near freezing, so the fish move to the bottom, where the water is a bit warmer.

In many lakes the water temperatures at different levels vary as the seasons change. In the spring and summer, sunlight can warm a layer of water at the top of a lake. Because the colder water beneath the top layer is denser than the warmer water above it, the water levels do not mix easily. The warm water contains more oxygen, so fish may be more plentiful in the upper part of the lake.

READING TIP

Cold water is denser than (has more mass than the same amount of) warm water.



In the fall, days cool and the surface water cools too. The upper layer becomes heavy and sinks, so that the lake water "turns over." Nutrients from minerals and from dead plants and organisms are stirred up from the bottom. These nutrients are used by many life forms in the lake. The rising and sinking of cold and warm water layers in a lake is called **turnover.** Turnover occurs twice each year as the seasons change.

CHECK YOUR READING What happens to surface water when the weather cools in the fall?

Eutrophication

A lake does not remain a lake forever. Through natural processes that take thousands of years, most lakes eventually are filled in and become meadows—fields covered with grass and other plants. A lake can become filled in as sediments, including the remains of dead fish, plants, and other organisms, pile up on the bottom.

READING TIP

Eutrophication comes from the Greek word *eutrophos*, meaning "well-nourished."

The activity of life in a lake is affected by nutrients. Nutrients are the foods and chemicals that support living things. When the amounts of such nutrients as phosphorus and nitrogen in a lake increase, algae and other organisms in the water grow more rapidly. An increase of nutrients in a lake or pond is called **eutrophication** (yoo-TRAHF-ih-KAY-shuhn). As eutrophication occurs, algae form a thick scum on the water. The amount of oxygen in the water decreases, until fish and other organisms that require oxygen cannot survive. The illustration below shows what happens to a lake when nutrient levels increase.

1 When the amounts of such nutrients as nitrogen and phosphorus increase, algae grow faster and form a scum layer at the surface.

2 Dead algae, plants, and fish pile up. Plants grow more quickly, leaving more debris as they die. Water evaporates, and the lake becomes shallower.

3 The lake becomes a soggy marsh, then finally a completely filled-in meadow.

The process of eutrophication is usually slow. In some cases, however, eutrophication happens more quickly than it normally would because of pollution from human activities. Nitrogen in fertilizers used on farms and gardens may be washed into lakes. Phosphates from laundry detergents may be present in wastewater that reaches lakes. The extra nutrients cause algae and plants in lakes to grow faster and more thickly than they normally would grow. Eutrophication from pollution causes clear lakes to become clogged with algae and plants.

CHECK YOUR READING How does human activity contribute to eutrophication?

Most fresh water on Earth is frozen.

If you want fresh water, take a trip to Greenland or the South Pole. Two-thirds of the world's fresh water is locked up in the ice covering land near the poles.

The ice sheet that covers Antarctica is almost one and a half times as big as the United States and is in places more than a kilometer thick. Ice on Earth's surface contains more than 24 million cubic kilometers of fresh water. Just how much water is that? Imagine that you have three glasses of lemonade. If you take one sip from one of the glasses of lemonade, you have drunk the water in all the lakes and rivers on Earth. The rest of the glass represents liquid ground water. The other two glasses of lemonade represent all the frozen water on the planet.

Ice on Land

In Earth's coldest regions—near both poles and in high mountains—more snow falls each year than melts. This snow builds up to form glaciers. A glacier is a large mass of ice and snow that moves over land. There are two types of glaciers. The ice sheets of Antarctica and Greenland are called continental glaciers because they cover huge landmasses. The other type of glacier is a valley glacier, which builds up in high areas and moves slowly down between mountains.

RESOURCE CENTER
CLASSZONE.COM
Find out more about frozen fresh water.

INVESTIGATE Icebergs

Why do icebergs float?

PROCEDURE

1. Find the masses of the empty graduated cylinder and the ice cube.
2. Add 200 mL of water to the cylinder. Find the volume of the ice cube by measuring how much water it displaces. Make sure the water is extremely cold to prevent the ice cube from melting. Use the point of a paper clip to completely submerge the ice.
3. Remove the water and let the ice melt in the cylinder.
4. Calculate the density (Density = mass/Volume) of the ice cube. Now find the mass and volume of the liquid water from the melted ice and calculate its density.

WHAT DO YOU THINK?

- What was the density of the ice cube? the water?
- Why do icebergs float?

CHALLENGE Float a cork in water. How does its behavior compare with that of floating ice?

SKILL FOCUS
Calculating

MATERIALS
- balance
- ice cube
- water
- 250 mL graduated cylinder
- paper clip
- calculator

for Challenge:
- cork

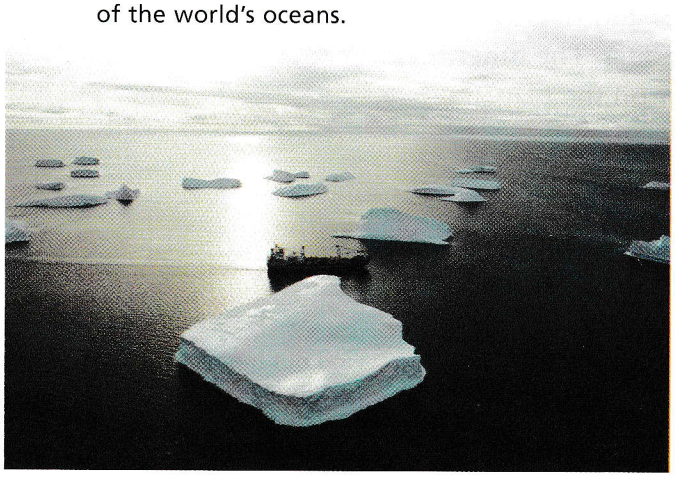
TIME
30 minutes

Icebergs

An **iceberg** is a mass of ice floating in the ocean. An iceberg starts out as part of a glacier. In places such as Antarctica and Greenland, glaciers form ice shelves that extend out over the ocean. When a large chunk of a shelf breaks off and floats away, it becomes an iceberg.

Thousands of icebergs break off from ice sheets each year. In the Northern Hemisphere, ocean currents push icebergs south into the warmer Atlantic Ocean. It may take an iceberg two to three years to float down to the area off the coast of Canada. In that region, it breaks apart and melts in the sea. A North Atlantic iceberg sank the *Titanic.*

Icebergs are masses of frozen fresh water floating in the salt water of the world's oceans.



How big is an iceberg? One iceberg that recently broke off an Antarctic ice shelf was the size of Connecticut. Off the coast of eastern Canada, some icebergs tower 46 meters (150 ft) above the surface of the ocean. This is impressive, because most of a floating iceberg is below the surface. Only about one-eighth of the total weight and volume of the iceberg can be seen above the surface of the sea. When people say "It's only the tip of the iceberg," they mean that a lot of something is unrevealed.

The water in an iceberg may have been frozen for 15,000 years. However, the ice in the center, if melted, can be clean, clear drinking water. And an iceberg can hold a lot of water. An iceberg as big as a city block holds enough drinking water to supply a city of 50,000 people for about ten years. Unfortunately, no one knows how to cheaply move icebergs to cities in order to use the frozen water.

CHECK YOUR READING How much of an iceberg is below the surface?

11.2 Review

KEY CONCEPTS

1. Why is it important that fresh water flows over Earth's surface?
2. Explain the relationship between a drainage basin and a divide.
3. Where and in what form is most of the fresh water on Earth?

CRITICAL THINKING

4. **Apply** If you were going on a fishing trip in a northern state, why would you want to know about lake turnover?
5. **Connect** Explain the connection between living things in a lake and eutrophication.

CHALLENGE

6. **Synthesize** How is the water in icebergs involved in the water cycle on Earth?

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PROCEDURE

1. Find the masses of the empty graduated cylinder and the ice cube.
2. Add 200 mL of water to the cylinder. Find the volume of the ice cube by measuring how much water it displaces. Make sure the water is extremely cold to prevent the ice cube from melting. Use the point of a paper clip to completely submerge the ice.
3. Remove the water and let the ice melt in the cylinder.
4. Calculate the density (Density = mass/Volume) of the ice cube. Now find the mass and volume of the liquid water from the melted ice and calculate its density.

WHAT DO YOU THINK?

- What was the density of the ice cube? the water?
- Why do icebergs float?

CHALLENGE Float a cork in water. How does its behavior compare with that of floating ice?

SKILL FOCUS
Calculating

MATERIALS
- balance
- ice cube
- water
- 250 mL graduated cylinder
- paper clip
- calculator

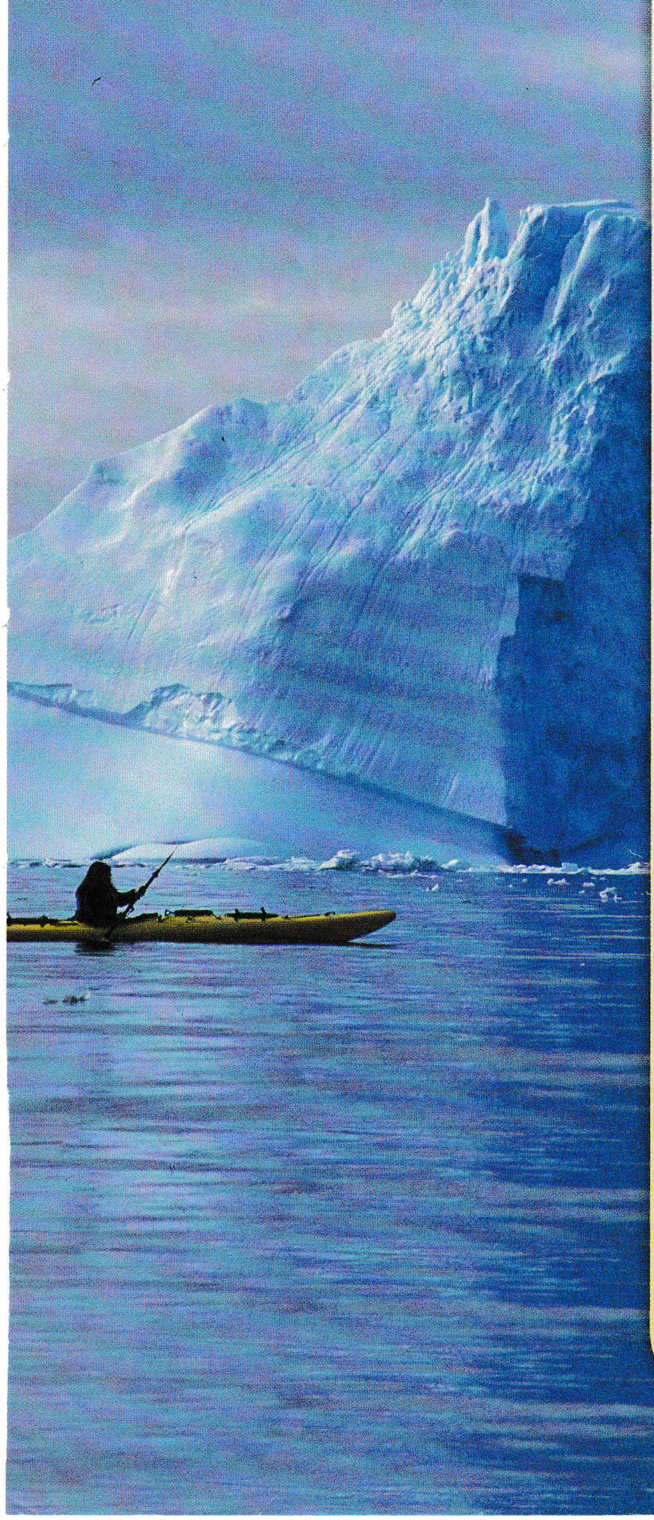
for Challenge:
- cork

TIME
30 minutes

MATH in SCIENCE

SKILL: MULTIPLYING FRACTIONS AND WHOLE NUMBERS

MATH TUTORIAL
CLASSZONE.COM
Click on Math Tutorial for help multiplying fractions and whole numbers.

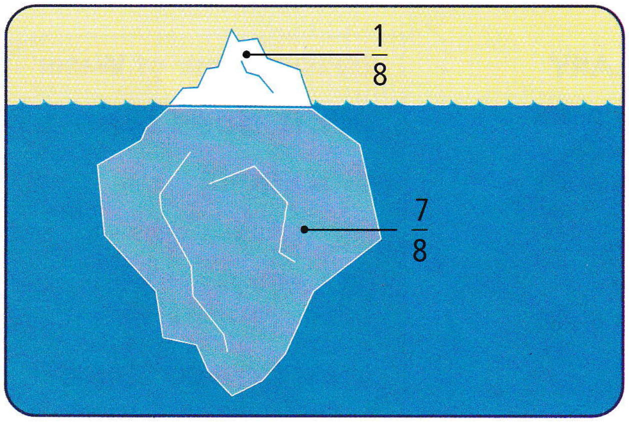


How Big Is an Iceberg?

In salt water, the part of an iceberg that is visible above water is only 1/8 of the whole iceberg. The remaining 7/8 of the iceberg is hidden under the water's surface. You can use fractions to estimate how much ice is underwater.

Example

An iceberg is made of 1000 cubic meters of ice. How much of the ice is underwater?



Solution

(1) Write a word equation.

$$\text{Volume of ice underwater} = \text{volume of iceberg} \cdot \text{fraction underwater}$$

(2) Substitute.

$$\text{Volume of ice underwater} = 1000 \text{ m}^3 \cdot \frac{7}{8}$$

(3) Multiply the numerator by the total volume.

$$= \frac{1000 \text{ m}^3 \cdot 7}{8}$$

(4) Calculate and simplify.

$$= \frac{7000 \text{ m}^3}{8} = 875 \text{ m}^3$$

ANSWER About 875 cubic meters of ice are underwater.

Calculate how much ice is underwater.

1. The iceberg is made of 1600 cubic meters of ice.
2. The iceberg is made of 1800 cubic meters of ice.
3. The iceberg is made of 12,000 cubic meters of ice.

CHALLENGE About 500 cubic meters of an iceberg is visible above the water. Estimate the total volume of the iceberg.

sand, and gravel are permeable because there are spaces between the particles. Water flows into and through these spaces. The bigger the particles, the more easily water can flow. Gravel and larger rocks have large spaces between them, so water flows quickly through. Sandy soil also has many pores, or spaces. Some rocks, such as sandstone, are permeable although the spaces in these rocks are extremely small.

An **impermeable** substance is a substance that liquids cannot flow through. A drinking glass holds orange juice because the material of the glass is impermeable. Rocks such as granite are impermeable. Unless granite has cracks, it has no spaces for water to go through. Many impermeable materials are hard, but not all of them. Clay is soft, but it is nearly impermeable. Water can get between its particles, but the overlapping of the particles stops the water from flowing through.

READING TIP
The prefix *im* in *impermeable* means "not."

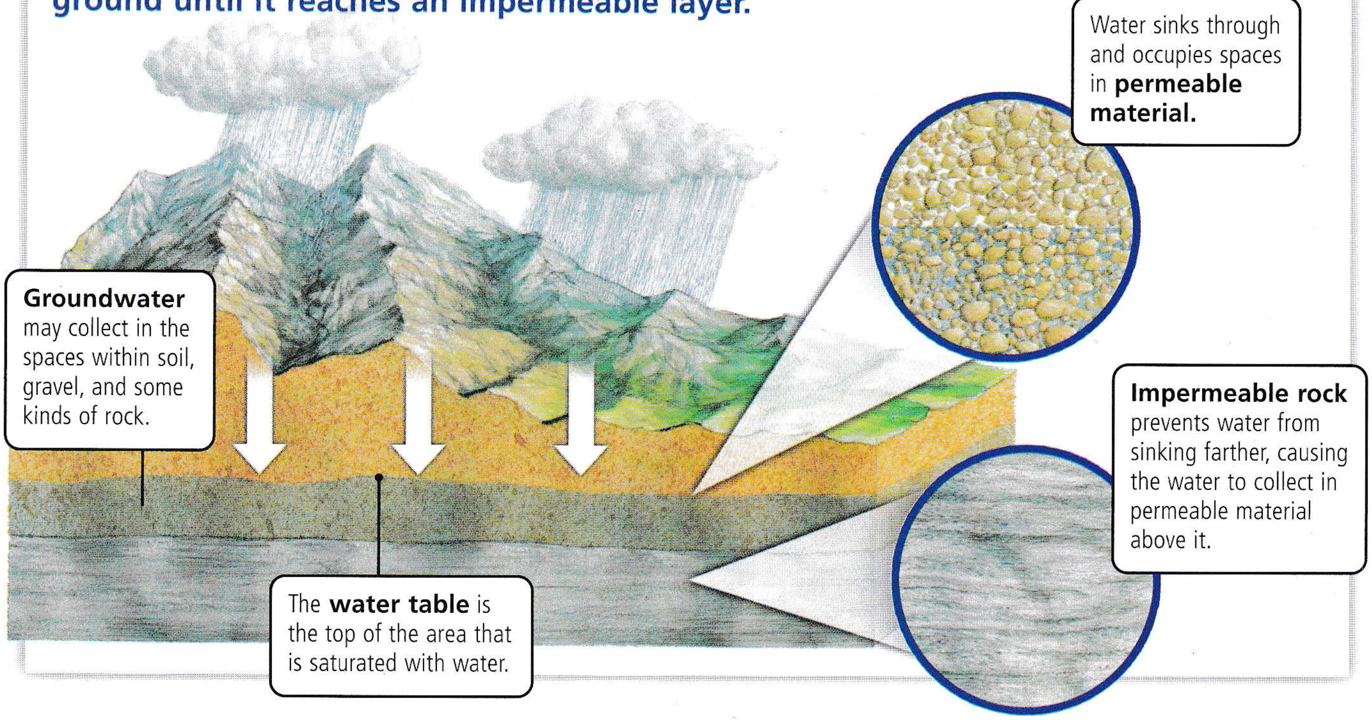
How does groundwater collect? Gravity causes rainwater to sink into the soil. If it rains heavily, all the spaces in the soil fill with water. Eventually the water reaches impermeable rock. There it is held in place or forced to flow in a different direction.

Even when the soil on Earth's surface is dry, huge amounts of groundwater may be stored below. The top of the region that is saturated, or completely filled with water, is called the **water table.** The saturated region below the water table is called the saturation zone.

CHECK YOUR READING What prevents groundwater from sinking farther down?

Groundwater

Pulled down by gravity, water sinks through permeable ground until it reaches an impermeable layer.



Aquifers

An **aquifer** is an underground layer of permeable rock or sediment that contains water. Some aquifers lie deep under layers of impermeable rock. Other aquifers lie just beneath the topsoil.

SIMULATION
CLASSZONE.COM

Explore how groundwater fills in aquifers.

Aquifers can be found all over the world. They lie under deserts as well as wet regions. As the map below shows, they are found in many areas of the United States. An aquifer might be a bed of sand or gravel only a few meters thick. Or it might be an enormous layer of sandstone, several hundred meters thick, holding water in countless pore spaces. The Ogallala Aquifer is the largest aquifer in North America. It covers 450,000 square kilometers (176,000 mi^2), from South Dakota to Texas.

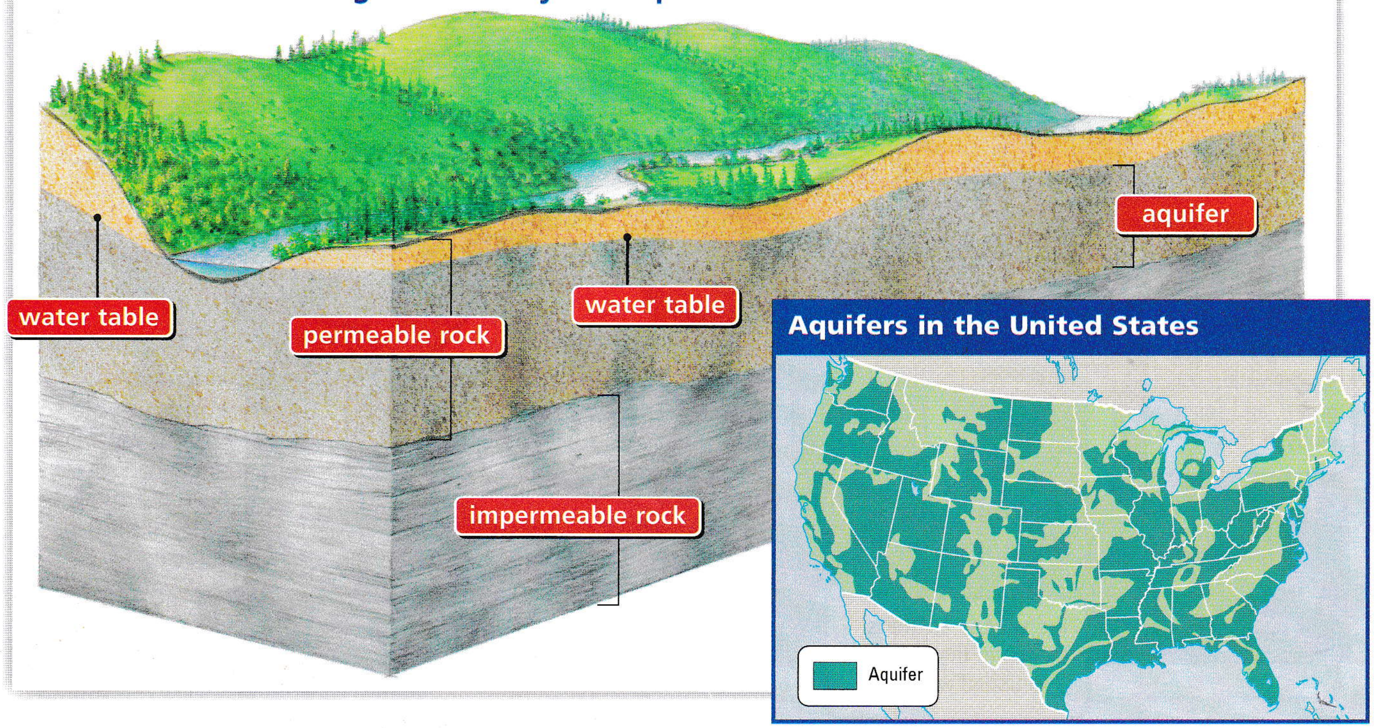
For an aquifer to form, three things are needed:

- A layer of permeable material holds the water. Groundwater is stored in the pore spaces of gravel, sand, or rock.
- A neighboring area of impermeable rock keeps the water from draining away. Sometimes impermeable rock lies both above and below an aquifer.
- A source of water replenishes or refills the aquifer. Like any body of water, an aquifer can be emptied.

You know that fresh water on land flows toward the ocean. Water that is underground acts like slow-motion streams, rivers, and lakes. Underground water moves slowly. The water is under pressure

Aquifers

Water collects underground in layers of permeable material.



from all sides, and it must go around endless tiny corners and passageways in rock. Unlike the water in an aboveground river, groundwater moves sideways, down, and even up. In some areas, groundwater is pushed upward so that it flows from a hillside. Because it moves so slowly, much of the water in an aquifer may have been there for thousands of years.

The Importance of Aquifers

When water sinks into land, the ground acts like a giant filter. Stones and sand in the ground can filter out bacteria and other living organisms. This ground filter also removes some harmful chemicals and minerals. The filtering process can make groundwater clear and clean and ready to drink. If it is not polluted, groundwater may not need expensive treatment. It is one of our most valuable natural resources.

Many big cities collect water from rivers and store it in reservoirs above the ground. However, about one-fifth of the people in the United States get their fresh water from underground. Most people who live in rural areas pump groundwater from wells. In many desert regions people depend on sources of underground water.

INVESTIGATE Aquifer Filtration

How can the ground filter water?

PROCEDURE

1. Cap the top of the bottle. Invert it and add to it a layer of gravel, then a layer of sand, then a layer of soil.
2. Slowly pour water onto the soil until a water table becomes visible in the sand beneath it.
3. Add the pollutants pepper, cocoa, and food coloring to the bottle top. Slowly unscrew the cap so that water trickles into the bucket.
4. Observe the water that filtered through.
5. Pour more water onto the soil and let water trickle out.

WHAT DO YOU THINK?

- Which pollutants were filtered out before reaching the "aquifer"? Which ones reached the aquifer?
- What effect does pollution have on drinking water that comes from aquifers?

CHALLENGE What could you do to clean up an aquifer?

SKILL FOCUS
Making models

MATERIALS
- water
- 1L plastic bottle with bottom cut off
- gravel
- sand
- soil
- pepper
- cocoa
- food coloring
- bottle bottom or bucket

TIME
30 minutes

Underground water can be brought to the surface.

MAIN IDEA AND DETAILS
In your notebook, fill out a chart for this main idea.

If you had lived in colonial America or in ancient Greece, your daily chore might have been to haul water home from a well. You would have lowered a bucket into a pit until it reached the water table, then pulled the filled bucket up with a rope. Or you might have worked at digging a well, hacking away at the ground with a shovel until water flowed into the hole you dug.

Today's technology makes it easier to bring groundwater to the surface. Powerful drills bore through rock, and motors pump groundwater to the surface and to kitchen sinks. Scientists study the sizes and areas of aquifers. They know where to get water and how much to expect.

Springs and Wells

Groundwater can be collected from springs and wells. A **spring** is a flow of water from the ground at a place where the surface of the land dips below the water table. In some springs, the water bubbles up, then sinks back into the soil. In others, the water flows into a stream or lake. Spring water has a fresh clean taste, and many water companies bottle this water to sell.

Underground pressure causes this artesian well to shoot water 18 meters (60 ft) into the air.

A well is a hole in the ground that reaches down to the saturation zone—the wet region below the water table. Usually, a pump is used to draw the water out of the ground, and a screen is used to filter out particles of sand and gravel. If the water table is near the surface, a well can be dug by hand. The part of the well beneath the water table will fill with water.

Most modern wells are dug with motorized drills. A drill digs through soil and rock into the saturation zone; then a pipe is lowered into the drill hole. A pump is used to raise the water from the ground. Some wells are more than 300 meters (1000 ft) deep.

One kind of well does not need a pump. An **artesian well** is a well in which water flows to the surface naturally because it is under pressure. In places where impermeable rock dips into an aquifer, the water directly below the rock is pushed to a lower level than the water on either side. When a well is drilled into the water beneath the rock, the weight of the surrounding water pushes the water upward.

CHECK YOUR READING What makes water flow upward out of an artesian well?

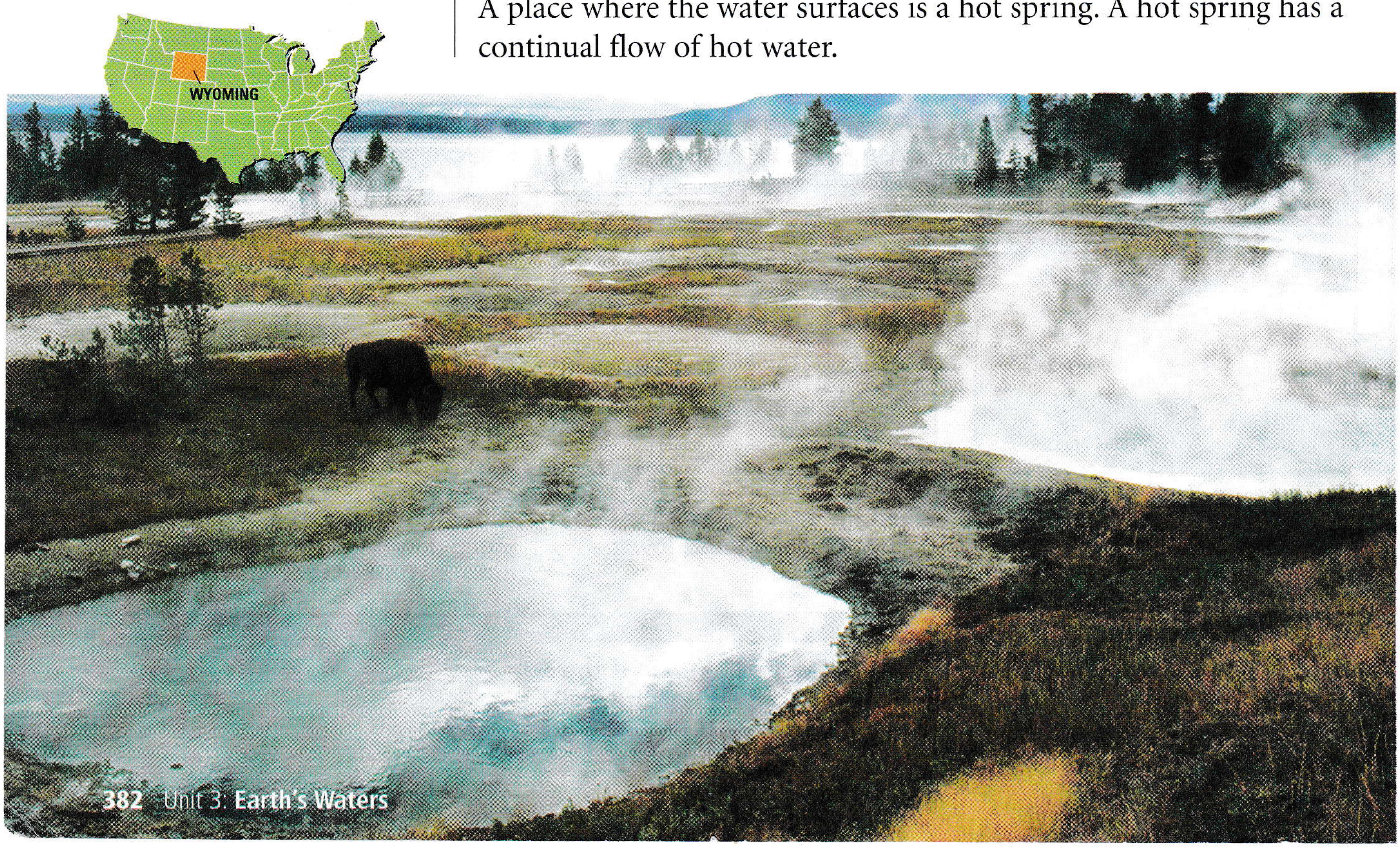
The depth of the water table in a particular place can vary from season to season, depending on how much rain falls and how much water is used. When water is taken from an aquifer, the water table might drop. When it rains or snows, some of the water filters back into the aquifer, replacing what has been taken. If water is used faster than it is replaced, wells may run dry. Low groundwater levels can also cause the ground to settle and damage the environment.

As more and more people live on Earth, the amounts of groundwater used to irrigate crops increase. In some states where crops are grown in dry areas, as much as 70 percent of all the groundwater brought to the surface is used for irrigation. Water used for irrigation is recycled back into the water cycle. In some places it sinks back into the ground and filters into aquifers. In other regions much of the water evaporates or flows away, and the groundwater levels are lowered.

Hot Springs

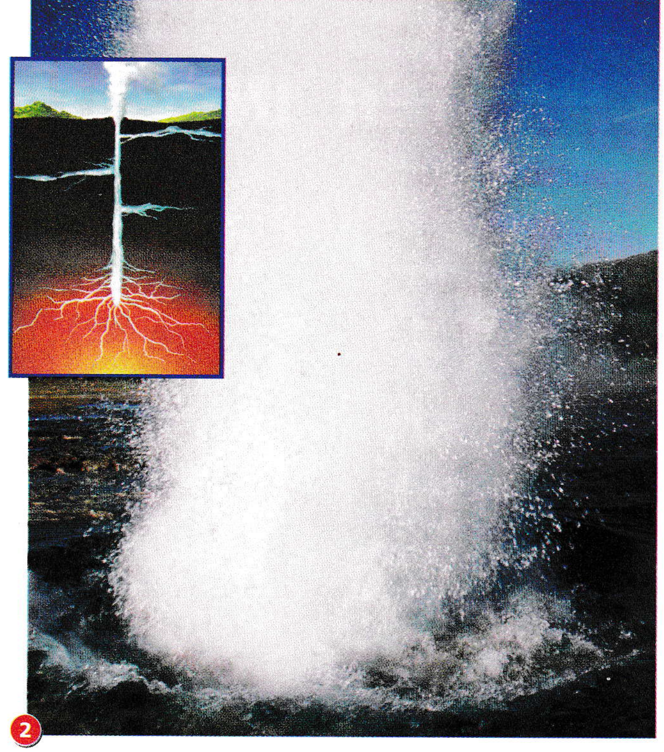
Yellowstone National Park sits atop the remains of an ancient volcano. The rain and melted snow that sink into the ground there eventually reach depths of more than 3000 meters (10,000 feet), where the rocks are extremely hot. The water heats up and reaches the boiling point. Then it becomes even hotter while remaining liquid because it is under such great pressure from the rocks pushing on it from all sides.

The hot water deep underground is like water in an enormous boiling pot—with a lid 3000 meters thick. The water expands the only way that it can, by pushing upward through weak places in the rocks. A place where the water surfaces is a hot spring. A hot spring has a continual flow of hot water.



Vapor rises from these hot springs in Yellowstone National Park in Wyoming.

In a geyser, water heats underground. The diagram shows the underground "plumbing" of a geyser in Iceland.



Hot water and steam are pushed up to the surface where they erupt.

A geyser is a kind of hot spring. The illustrations above show how a geyser works. Beneath the surface, there are underground channels in the rock. The rising hot water is forced to travel through these narrow passages. Like water in a garden hose, the water moves with force because it is under pressure. When it finally reaches Earth's surface, the pressure makes it burst out. It shoots into the air as a dramatic fountain of water and steam. In Yellowstone National Park there are more than 300 geysers. One of the largest, Old Faithful, shoots a jet of hot water and steam about 20 times a day. The eruptions last from 1.5 to 5 minutes, and reach heights of 30 to 55 meters (106 to 184 ft).

RESOURCE CENTER
CLASSZONE.COM
Learn more about geysers and hot springs.

CHECK YOUR READING Why does water shoot out of Old Faithful with such great force?

11.3 Review

KEY CONCEPTS

1. Draw a diagram that shows how water collects underground.
2. What is the difference between a spring and a well?
3. What causes water to rise out of the ground in hot springs and geysers?

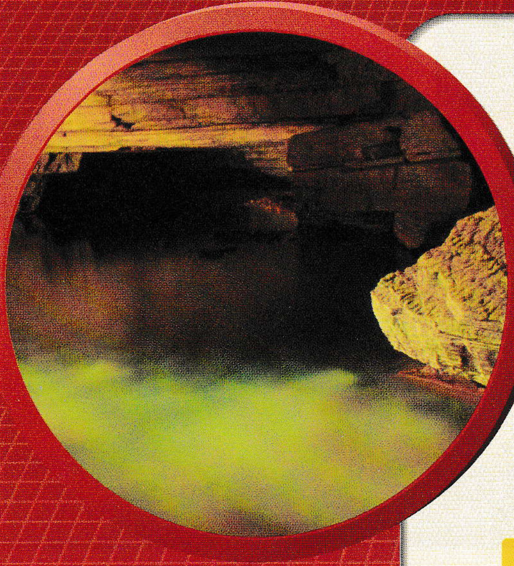
CRITICAL THINKING

4. **Connect** Is a T-shirt permeable or impermeable? How about a raincoat? Explain why.
5. **Infer** Would you expect to find a spring on the very top of a hill? Why or why not?

CHALLENGE

6. **Sequence** On a blank sheet of paper, draw a cartoon strip that shows how aquifers collect and store water and how people bring the water to the surface. Show at least five steps in the process. Write captions for your drawing to explain the steps.

CHAPTER INVESTIGATION



Water Moving Underground

DESIGN — YOUR OWN — EXPERIMENT

OVERVIEW AND PURPOSE

Many people rely on underground aquifers for their drinking water. Some aquifers are small and localized. Others can supply water to huge regions of the United States. Perhaps your own drinking water comes from an underground aquifer. In this investigation you will

- design an experiment to determine what types of materials best hold and transport water
- infer which types of Earth materials make the best aquifers

Problem

Write It Up

What types of materials will best hold and transport water?

Hypothesize

Write It Up

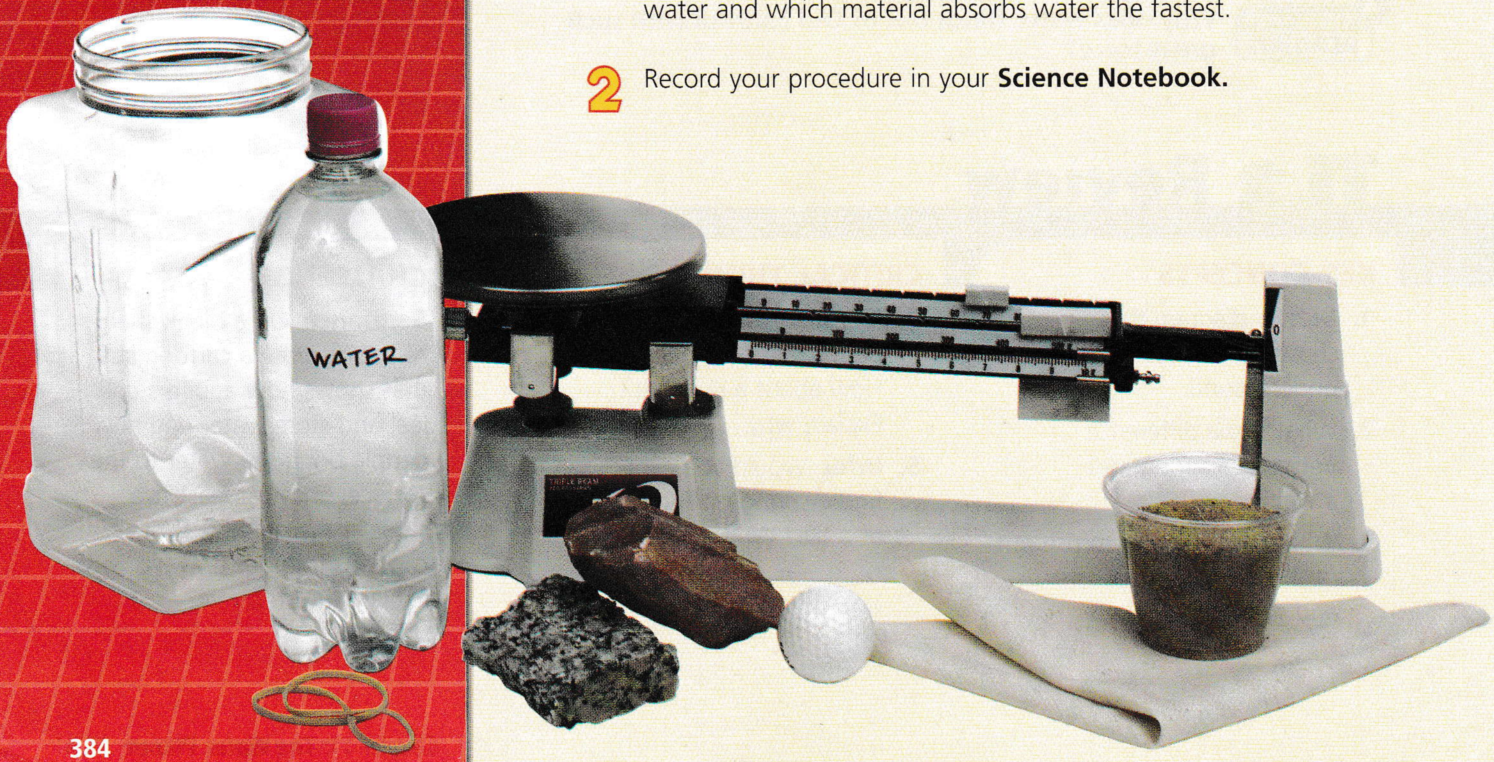
Write a hypothesis that answers the problem question in "If . . . , then . . . , because . . ." form.

Procedure

1. Design a procedure to test the materials samples to determine which will best hold and transport water. Your procedure should be designed to identify both which material absorbed the most water and which material absorbs water the fastest.
2. Record your procedure in your **Science Notebook.**

MATERIALS

- granite sample
- sandstone sample
- sand
- square piece of cotton muslin or cotton knit, measuring 30 cm per side
- rubber band
- golf ball
- scale
- large jar
- water



3. Create a data table to organize the data you will collect.

4. Be sure that you make both qualitative and quantitative observations.

5. Be sure to include a calculations section in your **Science Notebook.**

Observe and Analyze

Write It Up

1. **RECORD OBSERVATIONS** Draw a diagram of your experimental setup.
2. **CALCULATE** Which item absorbed the most water?
3. **SCIENTIFIC METHOD** How did you use the golf ball? What did it represent?

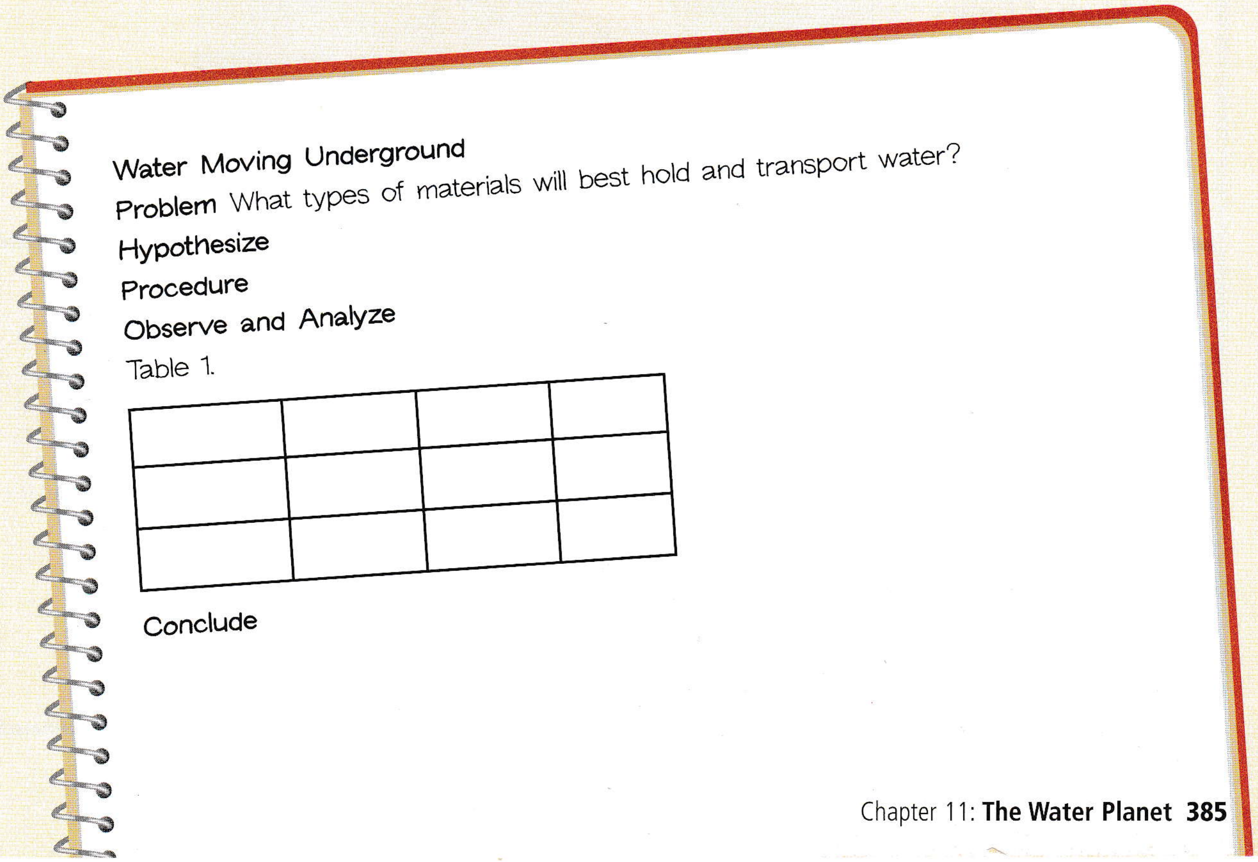
Conclude

Write It Up

1. **INTERPRET** Answer the problem question.
2. **COMPARE** Compare your results with your hypothesis. Do your data support your hypothesis?
3. **IDENTIFY LIMITS** In what ways was this activity limited in demonstrating how water moves underground? How might your experimental setup lead to incorrect conclusions?
4. **APPLY** Look over your data table. Your results should indicate both which material absorbed the most water and which material absorbed water the fastest. How do these two characteristics compare in terms of their importance for an aquifer?
5. **INFER** Which types of Earth materials make the best aquifers?

INVESTIGATE Further

CHALLENGE The data you gathered in this investigation reflect the permeability of each Earth material tested. What qualities and characteristics determine their permeabilities?



11 Chapter Review

the BIG idea

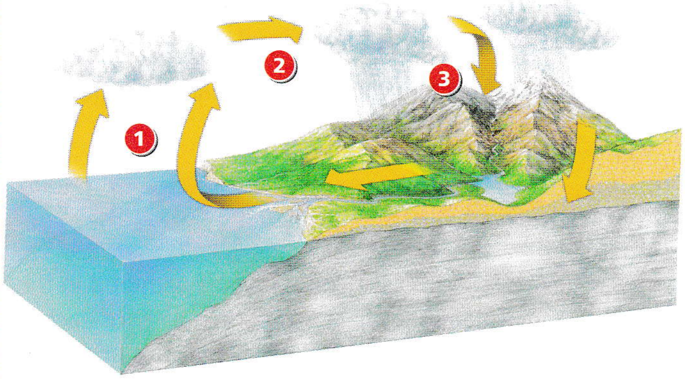
Water moves through Earth's atmosphere, oceans, and land in a cycle.

CONTENT REVIEW
CLASSZONE.COM

KEY CONCEPTS SUMMARY

1 Water continually cycles.

Water moves through Earth's environment in a continuous cycle.



1 **Evaporation** Water becomes vapor.

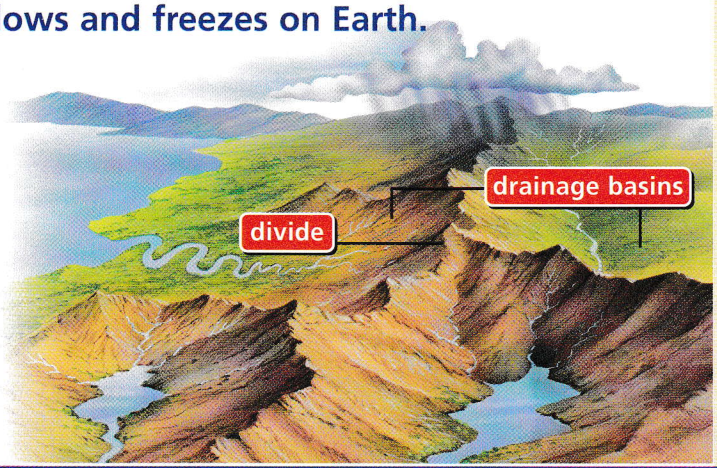
2 **Condensation** Vapor changes into liquid.

3 **Precipitation** Water falls to the surface.

VOCABULARY
fresh water p. 363
salt water p. 363
water cycle p. 364
evaporation p. 365
condensation p. 365
precipitation p. 365

2 Fresh water flows and freezes on Earth.

Water on land collects and flows in rivers and lakes. Much of Earth's fresh water is frozen.



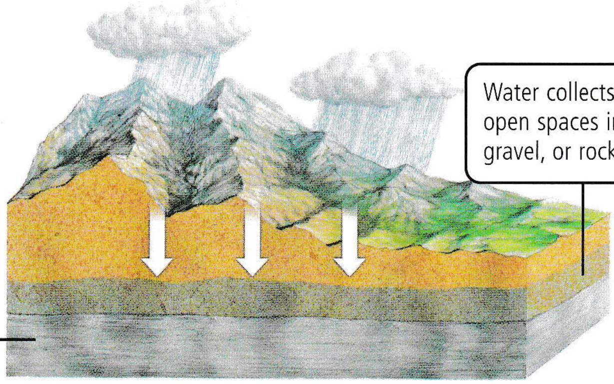
VOCABULARY
divide p. 369
drainage basin p. 369
turnover p. 371
eutrophication p. 372
iceberg p. 374

3 Fresh water flows underground.

Water collects and moves beneath the land surface.

Gravity pulls water down through **permeable** materials until it reaches an impermeable layer.

The **impermeable** layer prevents water from sinking farther down.



Water collects in open spaces in soil, gravel, or rock.

VOCABULARY
groundwater p. 376
permeable p. 376
impermeable p. 377
water table p. 377
aquifer p. 378
spring p. 380
artesian well p. 380

3. Create a data table to organize the data you will collect.

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Write It Up

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Conclude

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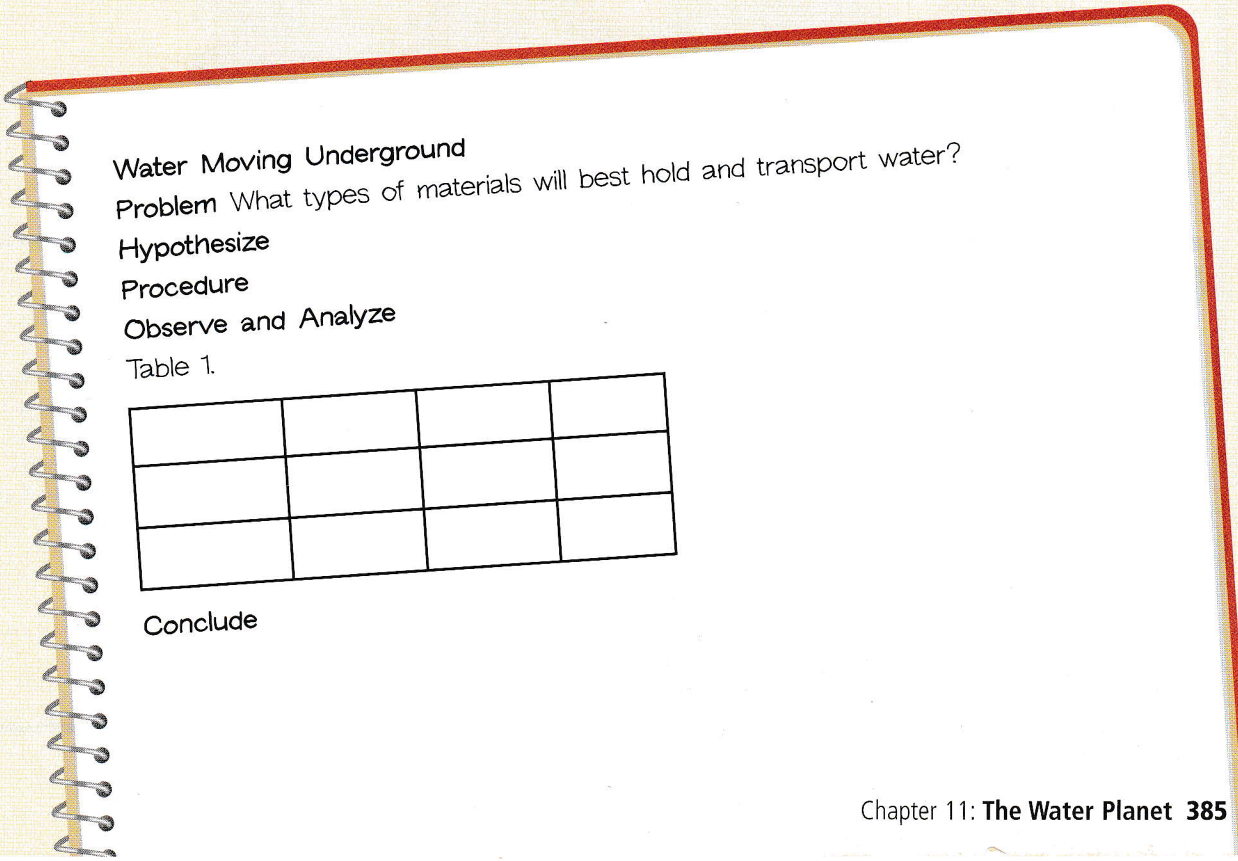
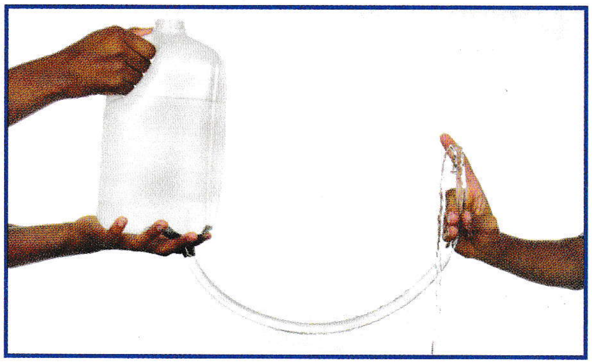
INVESTIGATE Further

CHALLENGE The data you gathered in this investigation reflect the permeability of each Earth material tested. What qualities and characteristics determine their permeabilities?



Thinking Critically

Use the photograph to answer the next four questions. There are four liters of water in the jug. The hose has been overflowing for about ten seconds.



21. OBSERVE Describe what the water in the hose is doing.

22. IDENTIFY EFFECTS Explain what effect the water in the jug has on the water in the hose. Why does the water rise in the hose?

23. PREDICT When will the water stop flowing from the hose? Why?

24. COMPARE AND CONTRAST How is what is happening in the hose like and unlike what happens in an artesian well?

25. EXPLAIN Explain why the water cycle matters to humans and animals.

26. CONNECT In a mountainous area, temperatures are lower at higher altitudes. Explain the connection between this fact and the existence of valley glaciers.

27. COMPARE AND CONTRAST Explain the difference between clouds and water vapor in the atmosphere.

28. INFER Explain why water in a bowl-shaped drainage basin does not eventually flow to the ocean.

29. APPLY Name at least two things that you think people could do to lessen eutrophication caused by pollution.

30. APPLY Explain why even though evaporation draws water but not salt from the ocean, the ocean does not become saltier.

PREDICT Fill in the chart with predictions of how water will collect under the stated conditions.

Conditions	Prediction
31. A bed of permeable rock lies atop a bed of impermeable rock; rainfall is plentiful.	
32. Heavy snows fall in a region that has year-round freezing temperatures.	
33. A large depression is left in impermeable rock by a glacier.	
34. Water from farm fields and gardens runs off into ponds.	

the BIG idea

35. SYNTHESIZE Explain why a raindrop that falls on your head may once have been water in the Pacific Ocean.

36. MODEL Draw a diagram of two drainage basins, showing how water flows and collects on the surface of Earth. Label the divide, as well as the bodies of water into which water flows.

UNIT PROJECTS

If you are doing a unit project, make a folder for your project. Include in your folder a list of the resources you will need, the date on which the project is due, and a schedule to keep track of your progress. Begin gathering data.

Reviewing Vocabulary

Use the terms in the box below to answer the next nine questions.

evaporation	precipitation	water cycle
turnover	eutrophication	artesian
iceberg	groundwater	permeable

1. Which word describes an increase in nutrients in a lake or pond?
2. Which kind of well does not need a pump?
3. Which term describes a seasonal change in a lake?
4. Which term describes a substance through which water can pass?
5. Which term names the continuous movement of water through Earth's environment?
6. What is the name for an enormous chunk of floating ice?
7. What word means the turning of liquid water into a gas?
8. What is the name of water stored in an aquifer?
9. What word is another name for rain, snow, sleet, and hail?

Reviewing Key Concepts

Multiple Choice *Choose the letter of the best answer.*

10. What are the three forms of water on Earth?
    - **a.** groundwater, lakes, and clouds
    - **b.** liquid water, frozen water, and water vapor
    - **c.** gas, steam, and vapor
    - **d.** groundwater, oceans, and ice
11. How much of Earth's water is fresh water?
    - **a.** almost all
    - **b.** about half
    - **c.** very little
    - **d.** none
12. Which process forms clouds?
    - **a.** evaporation
    - **b.** precipitation
    - **c.** condensation
    - **d.** dehydration
13. What ice formation covers Greenland and Antarctica?
    - **a.** iceberg
    - **b.** landmass
    - **c.** valley glacier
    - **d.** continental glacier
14. Which is a characteristic of a pond?
    - **a.** rooted plants covering the entire bottom
    - **b.** plants only near shore
    - **c.** a layer of impermeable rock
    - **d.** water heated by underground rock
15. How are glaciers like rivers?
    - **a.** They are made of liquid water.
    - **b.** Their water sinks into the ground.
    - **c.** They flow downhill.
    - **d.** They are a mile thick.
16. How is water stored in an aquifer?
    - **a.** in an open underground lake
    - **b.** in cracks and spaces in rocks
    - **c.** in impermeable rock
    - **d.** in wells and springs

Short Answer *Write a short answer to each question.*

17. Explain why most of the water cycle takes place over the ocean.
18. How does an iceberg form?
19. Why are aquifers valuable?
20. What is the difference between a valley glacier and a continental glacier?

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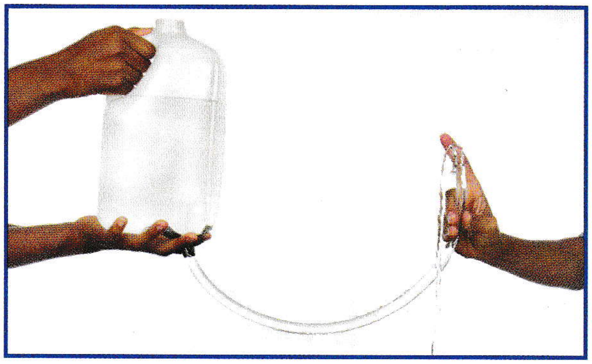

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