Section 1

Exploring the Ocean

Reading Preview

Key Concepts

- For what reasons have people studied the ocean?
- What are the main sections of the ocean floor?
- What are the different ocean zones?

Key Terms

- sonar • continental shelf
- continental slope
- abyssal plain
- mid-ocean ridge • trench
- intertidal zone • neritic zone
- open-ocean zone

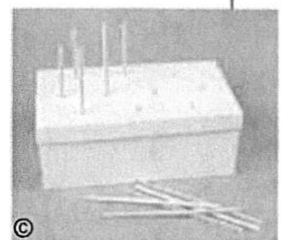
Target Reading Skill

Building Vocabulary

A definition states the meaning of a word or phrase by telling about its most important feature or function. After you read the section, reread the paragraphs that contain definitions of key terms. Use all the information you have learned to write a definition of each key term in your own words.

Lab zone Discover **Activity**

What Can You Learn Without Seeing?



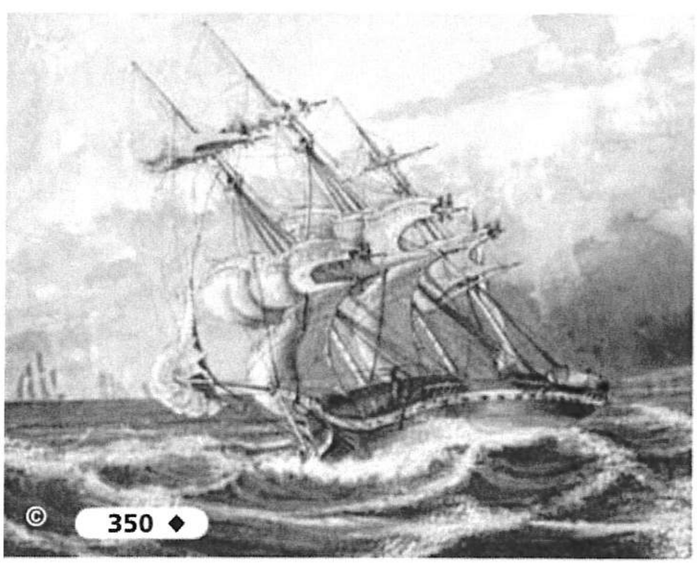
1. Your teacher will provide your group with ten plastic drinking straws and a covered box containing a mystery object. The top of the box has several holes punched in it. Using the straws as probes, try to determine the size, shape, and location of the object inside the box.
2. Based on the information you gathered, describe your object. What can you say about its length, shape, and position? Write down your hypothesis about the identity of the object.
3. Remove the box top to reveal the object.

Think It Over

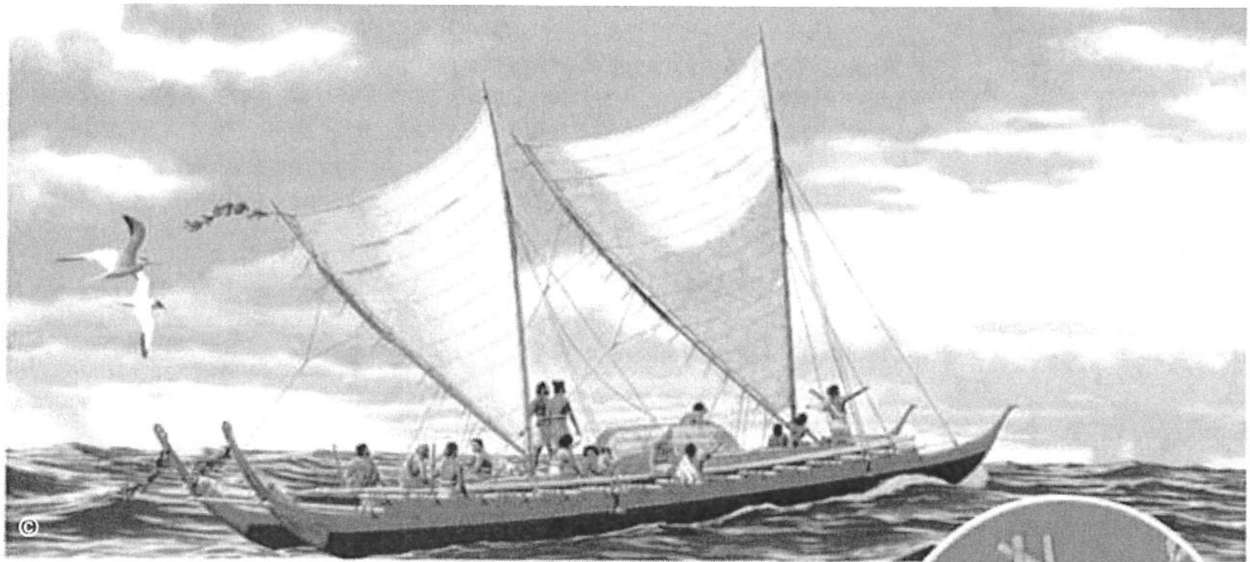
Inferring Explain how you used the method of indirect observation to learn about the object.

Imagine going on a voyage around the world that will last three and a half years. Your assignment: to investigate everything about the sea. Your vessel: a ship powered by sails and a steam engine. On board there are thermometers for measuring the temperature of ocean water and cable for lowering dredges beneath the surface. With the dredges, you scrape sand, muck, and rock from the ocean floor. You drag nets behind the ship to collect ocean organisms.

The crew of a British ship, HMS *Challenger*, began such a voyage in 1872. By the end of the journey, scientists on the ship had gathered enough data to fill 50 volumes and had collected more than 4,000 new organisms! The scientists learned about ocean-water chemistry, currents, ocean life, and the shape of the ocean floor. The voyage of the *Challenger* was so successful that it became the model for many later ocean expeditions.



◄ HMS *Challenger*



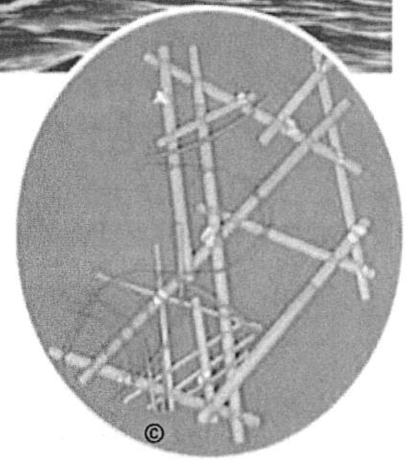


FIGURE 1
Polynesian Explorers
Around 2,000 years ago, Polynesians explored the Pacific Ocean in boats such as the one above. They used stick charts (above right) to navigate.
Inferring *Why is careful navigation important to explorers?*

Learning About the Ocean

People have explored the ocean for thousands of years. Knowledge of the ocean has always been important to the people living along its coasts. **People have studied the ocean since ancient times, because the ocean provides food and serves as a route for trade and travel. Modern scientists have studied the characteristics of the ocean's waters and the ocean floor.**

Trading Routes The Phoenicians, who lived along the Mediterranean Sea, were one of the earliest cultures to explore the oceans. By about 1200 B.C., they had established sea routes for trade with other nations around the Mediterranean. After the Phoenicians, people of many European, African, and Asian cultures sailed along the coasts to trade with distant lands.

In the Pacific Ocean around 2,000 years ago, the Polynesians left the safety of their islands and boldly sailed into the open ocean. Their knowledge of winds and currents enabled the Polynesians to settle the widely scattered islands of Hawaii, Tahiti, and New Zealand. To navigate the ocean, they used devices such as the one shown in Figure 1.

Scientific Discoveries As modern science developed and trade increased, ocean exploration changed. Nations needed accurate maps of the oceans and lands bordering them. Governments also wanted their countries to be known for new scientific discoveries. For example, in the late 1700s, the British government hired Captain James Cook to lead three voyages of exploration. Cook's crew included scientists who studied the stars and those who collected new species of plants and animals.

Within a century of Cook's voyages, almost all of Earth's coastlines had been mapped. Scientists then turned to the study of the ocean's waters. The *Challenger* expedition marked the beginning of the modern science of oceanography.

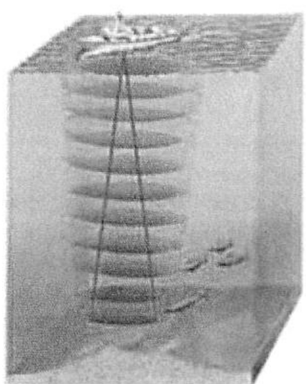
Exploring the Ocean Floor Until recently, the ocean floor was unexplored. Why did it take so long to reach the ocean floor? Studying the ocean floor is difficult because the ocean is so deep—3.8 kilometers deep on average, more than twice as deep as the Grand Canyon. At such depths, conditions are very harsh. First, because sunlight does not penetrate far below the surface, the deep ocean is in total darkness. Second, the water is very cold. Finally, deep ocean water exerts tremendous pressure due to the mass of water pushing down from above.

Humans cannot survive the darkness, cold temperatures, and extreme pressure of the deep ocean. So scientists have had to develop technology to study the ocean floor. Many of the inventions have involved indirect methods of gathering information.

• Tech & Design in History •

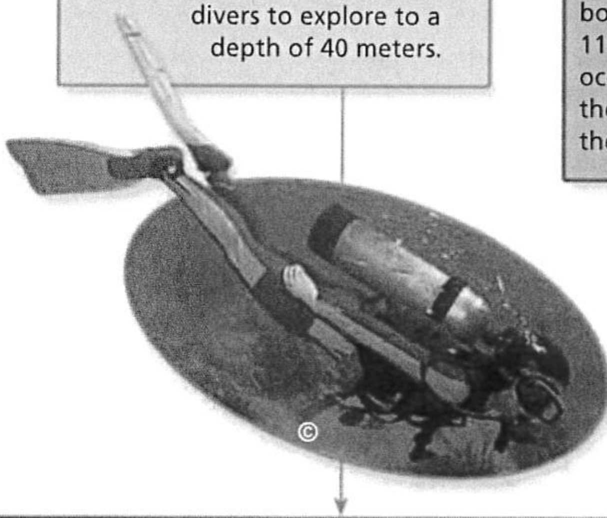
Ocean Exploration

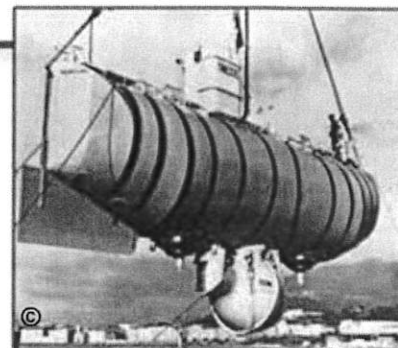
The timeline includes several inventions that have helped scientists overcome the challenges of studying the oceans.



1925 Sonar
Scientists aboard the German ship *Meteor* used sonar to map the ocean floor. They used a device called an echo sounder to produce pulses of sound. The ship's crew then timed the return of the echoes.

1943 SCUBA
Jacques Cousteau and Emile Gagnan invented SCUBA, which stands for "**s**elf **c**ontained **u**nderwater **b**reathing **a**pparatus." A tank containing compressed air is strapped to the diver's back and connected by a tube to a mouthpiece. SCUBA enables divers to explore to a depth of 40 meters.





1960 Submersibles
Explorers traveled to the bottom of Challenger Deep, 11 kilometers below the ocean surface, protected by the thick metal hull of the submersible *Trieste*.

1920 1940 1960

One of the simplest methods, used by the *Challenger*'s crew, was to lower a weight on a long line into the water until the weight touched the bottom. The length of line that got wet was approximately equal to the water's depth. However, this method was slow and often inaccurate.

A major advance in ocean-floor mapping was **sonar,** which stands for **so**und **na**vigation and **r**anging. Sonar is a system that uses sound waves to calculate the distance to an object. The sonar equipment on a ship sends out pulses of sound that bounce off the ocean floor. The equipment then measures how quickly the sound waves return to the ship. Sound waves return quickly if the ocean floor is close. Sound waves take longer to return if the ocean floor is farther away.

Reading Checkpoint **What conditions exist in the depths of the ocean?**

Writing in Science

Research and Write Each of the inventions shown in this timeline helped solve a challenge of ocean exploration. Find out more about one of these inventions. Write a short newspaper article telling the story of its development. Include details about the people who invented it and how it added to people's knowledge of the oceans.

1978 Satellites

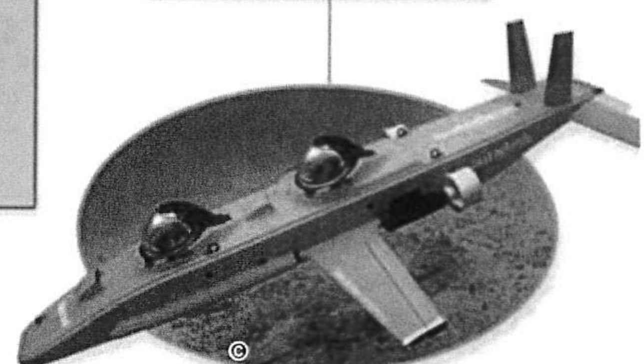
Seasat A was the first satellite in Earth's orbit to study the oceans. Since satellites make millions of observations a day, they can provide data on rapidly changing ocean conditions. Such data include temperatures, algae growth patterns, and even the movement of large schools of fish.

1986 Remote Underwater Manipulator

The Remote Underwater Manipulator, or RUM III, is about the size of a small car. It is controlled by a computer aboard a ship at the surface. The RUM III can collect samples, take photographs, and map the ocean floor—all without a crew.

2003 Deep Flight Aviator

The Deep Flight Aviator, a new type of submersible, is launched in San Francisco Bay. Deep Flight Aviators maneuver faster and much more easily than other submersibles. Passengers can see much more, too.



1980 2000 2020

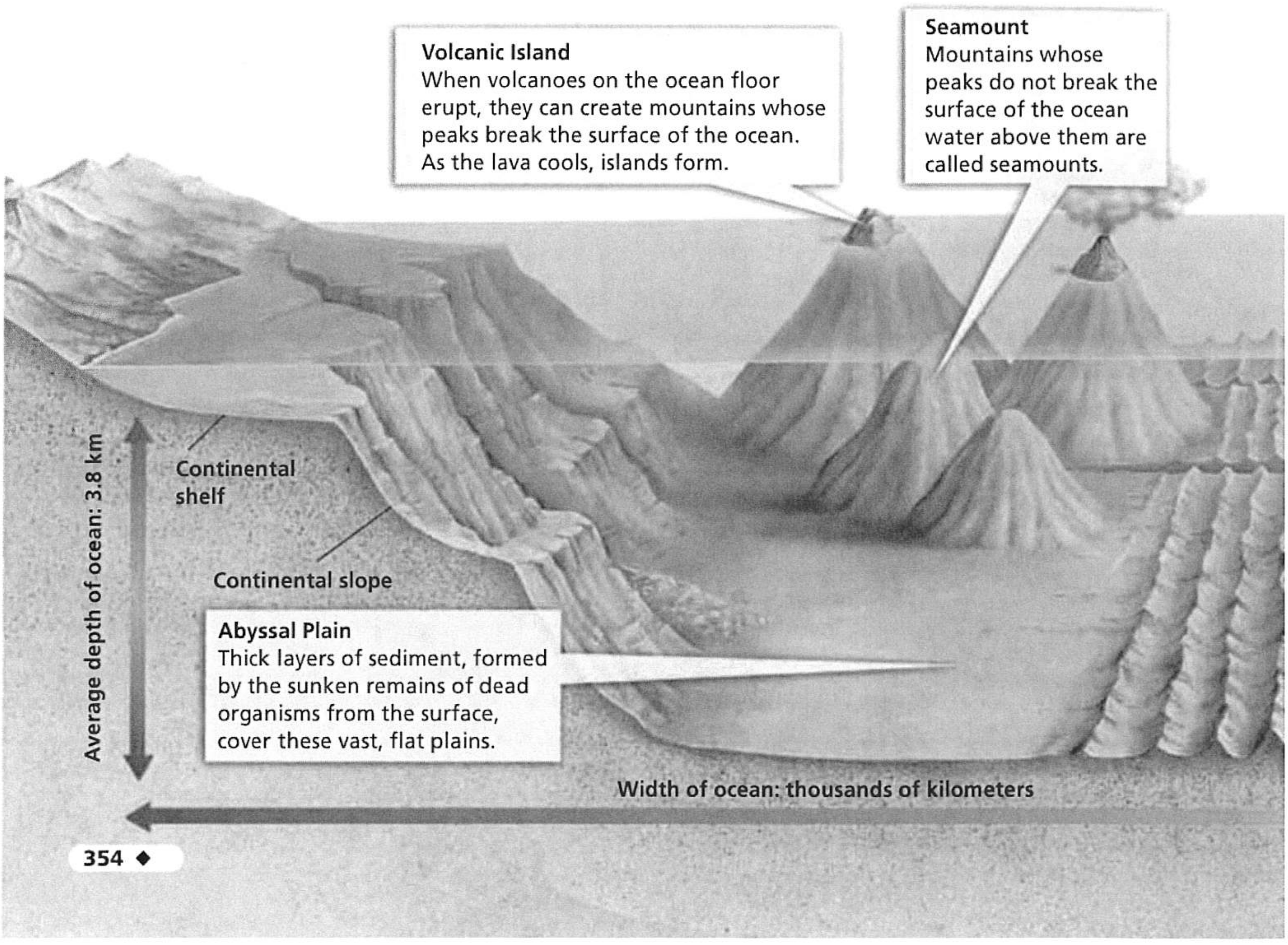
The Ocean Floor

You might be surprised to find that the ocean floor is not a flat, sandy plain. If you could take a submarine voyage along the ocean floor, what would you see? **If you could travel along the ocean floor, you would see the continental shelf, the continental slope, the abyssal plain, and the mid-ocean ridge.** Trace your journey in Figure 2.

Shallow Water As you leave the harbor, your submarine first passes over a section of the ocean floor called the **continental shelf.** This gently sloping, shallow area of the ocean floor extends outward from the edge of a continent. At a depth of about 130 meters, the slope of the ocean floor gets steeper. This incline beyond the edge of the continental shelf is called the **continental slope.**

Open Ocean As you follow the ocean floor, it slopes gradually toward the deep ocean. Soon, you encounter mountains tall enough to break the ocean's surface, forming islands. Other mountains, called seamounts, are completely underwater.

FIGURE 2
The Ocean Floor
The floor of the ocean has mountains, slopes, and other features. To show the major features of the ocean floor, thousands of kilometers have been "squeezed" into one illustration.
Interpreting Diagrams *Which is steeper, the continental slope or the continental shelf?*

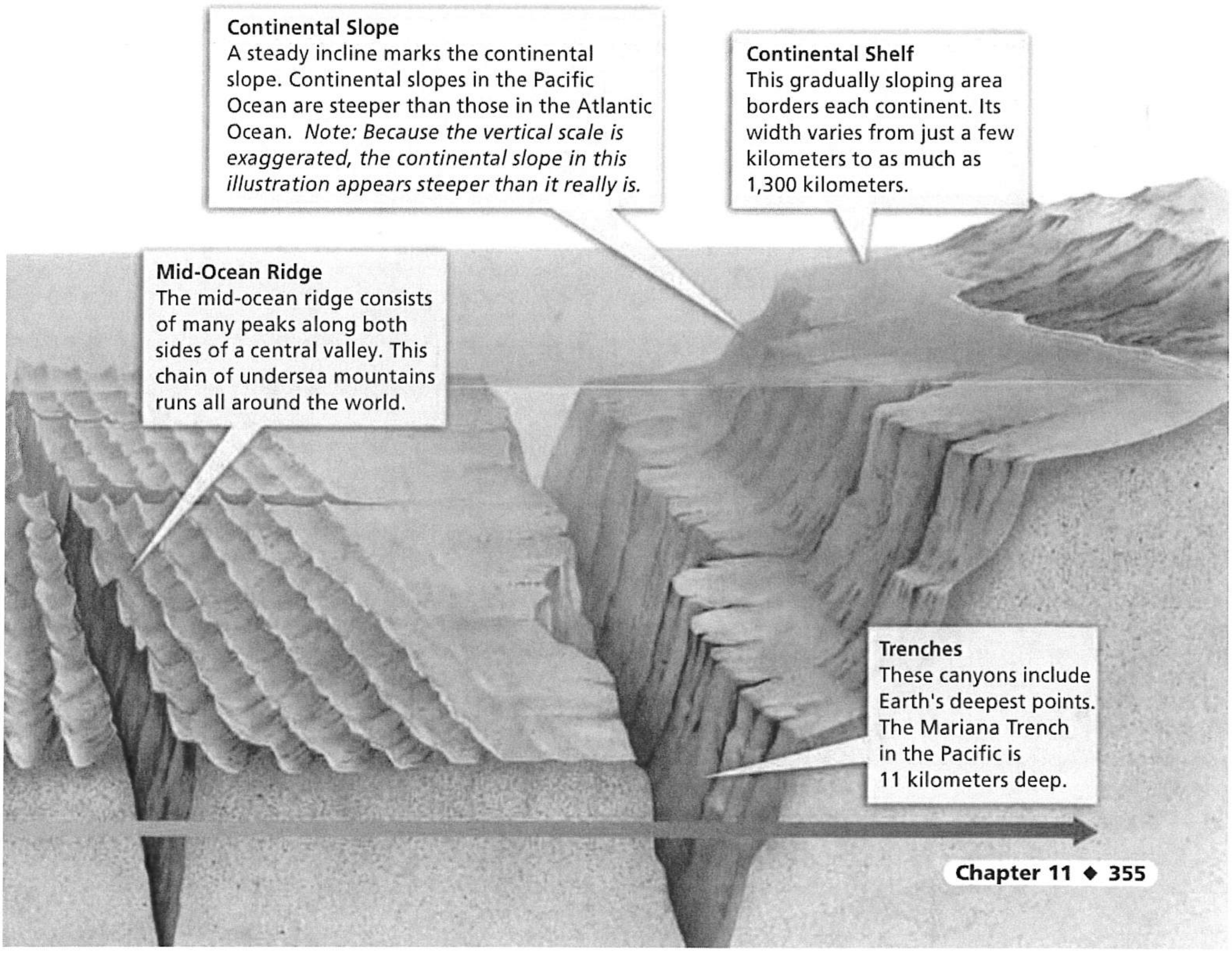


Next you cross a broad area covered with thick layers of mud and silt. This smooth, nearly flat region of the ocean floor is called the **abyssal plain** (uh BIHS ul). After gliding over the abyssal plain for many kilometers, you see a mountain range ahead. The **mid-ocean ridge** is made up of a range of mountains that winds through the oceans, much as the line of stitches winds around a baseball.

Deepest Depths You cross the ocean floor from the mid-ocean ridge toward the abyssal plain. Soon your submarine's lights reveal a dark gash in the ocean floor ahead of you. As you pass over it, you look down into a canyon in the ocean floor called a **trench.** The trench is so deep you cannot see the bottom.

Then your submarine slowly climbs the continental slope. You cross the continental shelf on this side of the ocean and maneuver the submarine into harbor.

Reading Checkpoint **Which ocean-floor feature makes up the deepest parts of the ocean?**



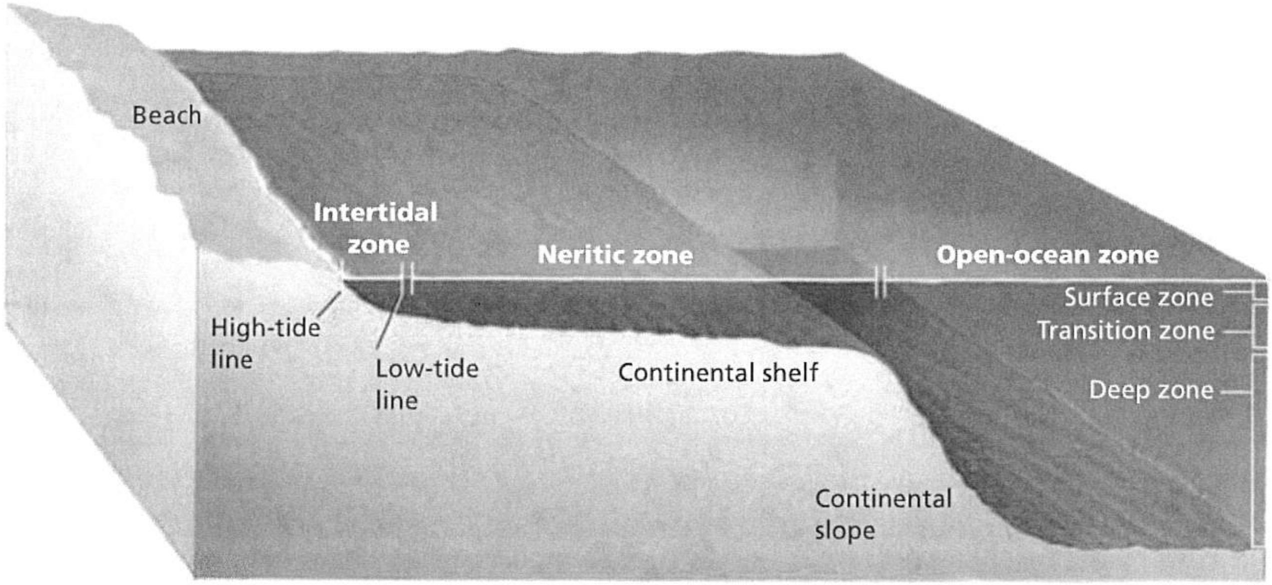


FIGURE 3
Ocean Zones
The three ocean zones are the intertidal zone, the neritic zone, and the open-ocean zone.
Classifying *Into what three zones is the open-ocean zone divided?*

Ocean Zones

Just as the ocean floor can be divided into sections, the ocean can be divided into zones. **Ocean zones include the intertidal zone, the neritic zone, and the open-ocean zone.** At the highest high-tide line, the **intertidal zone** begins. The intertidal zone stretches out to the point exposed by the lowest low tide. The **neritic zone** extends from the low-tide line out to the edge of the continental shelf. Beyond the edge of the continental shelf lies the **open-ocean zone.** This zone includes the deepest, darkest part of the ocean. The physical conditions of each ocean zone help determine which organisms can live in that zone.

Section 1 Assessment

Vocabulary Skill Use Context to Determine Meaning Reread the definition of *intertidal zone.* Identify two phrases that help you understand what the *intertidal zone* is.

Reviewing Key Concepts

HINT 1. a. Reviewing Why have people in ancient and modern times explored the oceans?
HINT b. Explaining Why did the ocean floor remain unexplored until recently?
HINT c. Summarizing What is sonar? How did it finally enable scientists to map the ocean floor?
HINT 2. a. Listing List four sections of the ocean floor.
HINT b. Interpreting Diagrams Refer to Figure 2. Describe the characteristics of each of the four sections of the ocean floor that you listed above.
HINT c. Sequencing Put the following in order from steepest to least steep: continental slope, continental shelf, trench, abyssal plain.

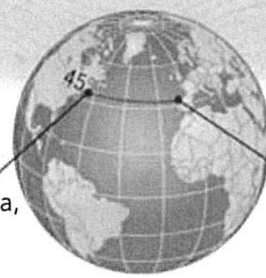
3. a. Identifying Identify the three ocean zones. HINT
b. Sequencing Put the ocean zones in order from the shallowest to the deepest. HINT

Lab zone At-Home Activity

Mapping the Ocean Choose a room in your house and make a "room-floor" map. The ceiling is the ocean surface and the floor is the ocean bottom. Choose a straight path across the room. At regular intervals take a depth reading from the ceiling to the floor or to the top of any furniture in that spot. Plot the depths on a graph. Then challenge others to identify the room by looking at the graph.

Lab zone **Skills Lab**

The Shape of the Ocean Floor



Problem

Imagine you are an oceanographer traveling across the Atlantic along the 45° N latitude line marked on the map. You are gathering data on the depth of the ocean between Nova Scotia, Canada, and Soulac, France. How can you use data to determine the shape of the ocean floor?

Skills Focus

graphing, predicting, inferring

Materials

- pencil
- graph paper

Procedure

1. Draw the axes of a graph. Label the horizontal axis *Longitude*. Mark from 65° W to 0° from left to right. Label the vertical axis *Ocean Depth*. Mark 0 meters at the top of the vertical axis to represent sea level. Mark −5,000 meters at the bottom to represent the depth of 5,000 meters below sea level. Mark depths at equal intervals along the vertical axis.
2. Examine the data in the table. The numbers in the Longitude column give the ship's location at 19 points in the Atlantic Ocean. Location 1 is Nova Scotia, and Location 19 is Soulac. The numbers in the Ocean Depth column give the depth measurements recorded at each location. Plot each measurement on your graph. Remember that the depths are represented on your graph as numbers below 0, or sea level.
3. Connect the points you have plotted with a line to create a profile of the ocean floor.

Analyze and Conclude

1. **Graphing** On your graph, identify and label the continental shelf and continental slope.
2. **Predicting** Label the abyssal plain on your graph. How would you expect the ocean floor to look there?
3. **Graphing** Label the mid-ocean ridge on your graph. Describe the process occurring there.
4. **Inferring** What might the feature at 10° W be? Explain.
5. **Communicating** Imagine you are traveling along the ocean floor from Nova Scotia, Canada, to Soulac, France. Describe the features you would see along your journey.

More to Explore

Use the depth measurements in the table to calculate the average depth of the Atlantic Ocean between Nova Scotia and France.

Ocean Depth Sonar Data

Longitude	Ocean Depth (m)	Longitude	Ocean Depth (m)
1. 64° W	0	11. 28° W	1,756
2. 60° W	91	12. 27° W	2,195
3. 55° W	132	13. 25° W	3,146
4. 50° W	73	14. 20° W	4,244
5. 48° W	3,512	15. 15° W	4,610
6. 45° W	4,024	16. 10° W	4,976
7. 40° W	3,805	17. 05° W	4,317
8. 35° W	4,171	18. 04° W	146
9. 33° W	3,439	19. 01° W	0
10. 30° W	3,073		

Section 2 Wave Action

Reading Preview

Key Concepts

- How does a wave form?
- How do waves change near the shore?
- How do waves affect shorelines and beaches?

Key Terms

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

Target Reading Skill

Using Prior Knowledge Before you read, look at the section headings and visuals to see what this section is about. Then write what you know about waves in a graphic organizer like the one below. As you read, continue to write in what you learn.

What You Know
1. There are waves in the ocean. 2.

What You Learned
1. 2.

Lab zone Discover Activity

How Do Waves Change a Beach?

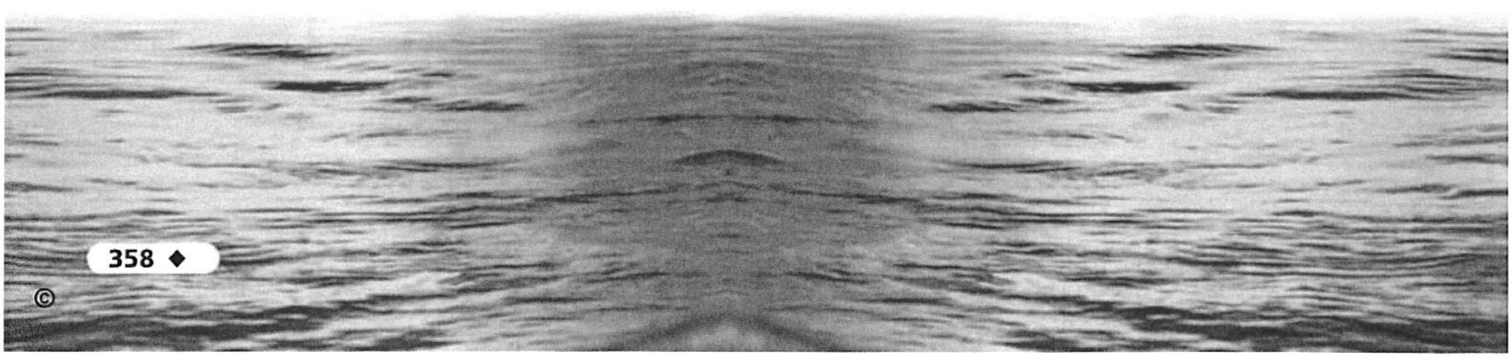
1. In one end of an aluminum pan, build a "beach" of sand and pebbles. Put a book under that end of the pan to raise it about 5 centimeters.
2. Pour water slowly into the other end of the pan until it covers the edge of the sand, just as water touches the edge of a beach.
3. Place a wooden tongue depressor in the water. Move it back and forth gently in a regular rhythm to make waves in the pan. Continue for about 2 minutes.
4. Once the water has stopped moving, observe what has happened to the beach. Wash your hands after completing this activity.

Think It Over

Observing How has the motion of the water changed the edge of the beach?

Hundreds of years ago, kings and queens ruled the islands of Hawaii. If you could travel back in time, you could watch the royal family engaging in the islands' favorite sport. It wasn't baseball or tennis or polo. Instead, the ancient rulers paddled into the ocean on heavy wooden boards to catch the perfect wave. They were "wave-sliding," a sport we know today as surfing.

If you've ever seen a surfer like the one in Figure 4, you know that they make this difficult sport look almost easy. But even experienced surfers can seldom predict when the next good wave will roll into shore. As you will read in this section, many different forces influence the size, shape, and timing of waves.



What Is a Wave?

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.**

Wave Size Waves start in the open ocean. 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. Winds blowing across the Pacific Ocean can create bigger waves than winds blowing across the narrower Atlantic Ocean.

Wave Energy Although waves may appear to carry water toward shore, the water does not 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.

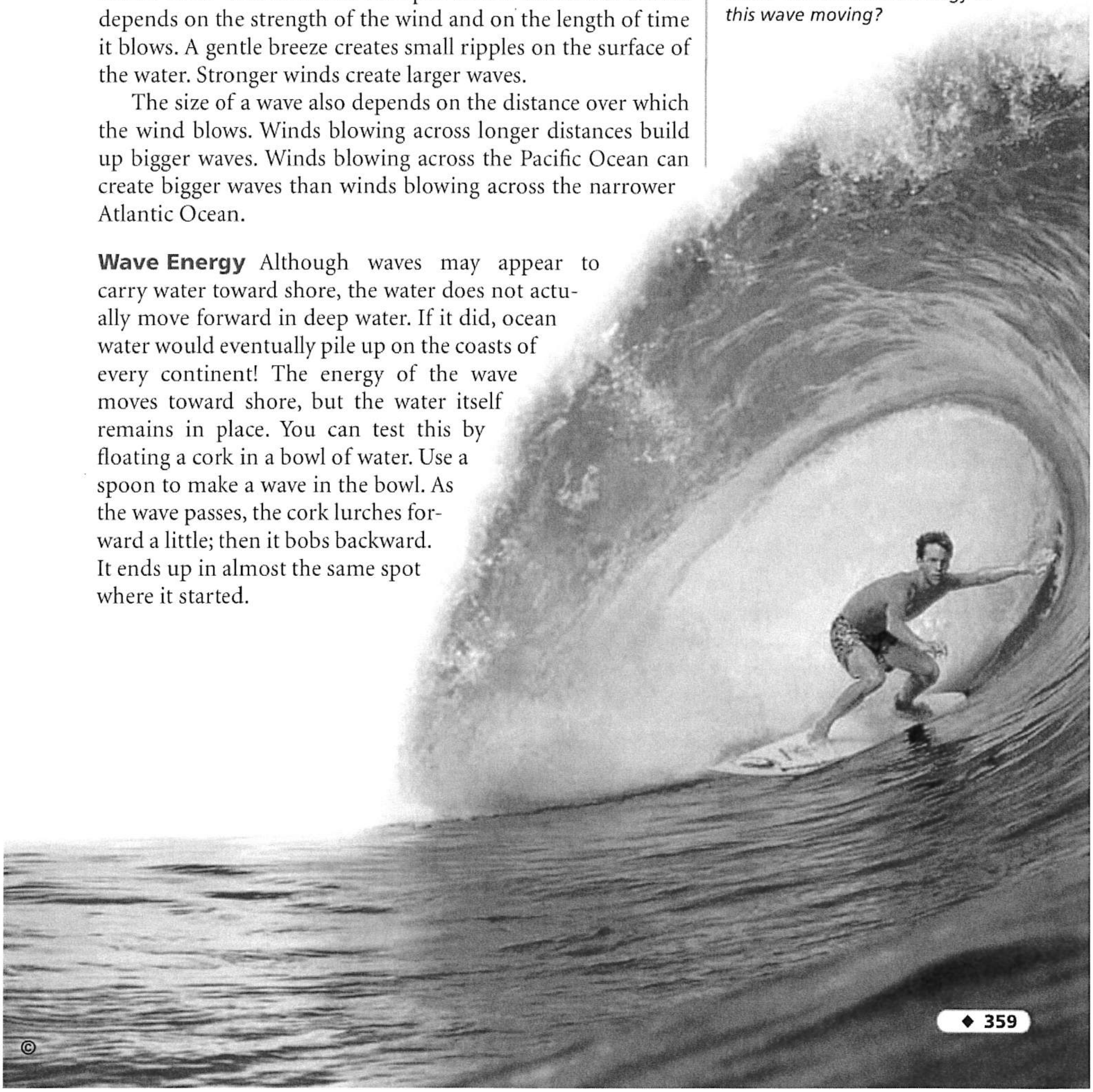


FIGURE 4
Wave Energy
A surfer cruises along a cresting wave. The wave's energy moves, but the water mostly stays in one place. **Applying Concepts** *In which direction is the energy of this wave moving?*

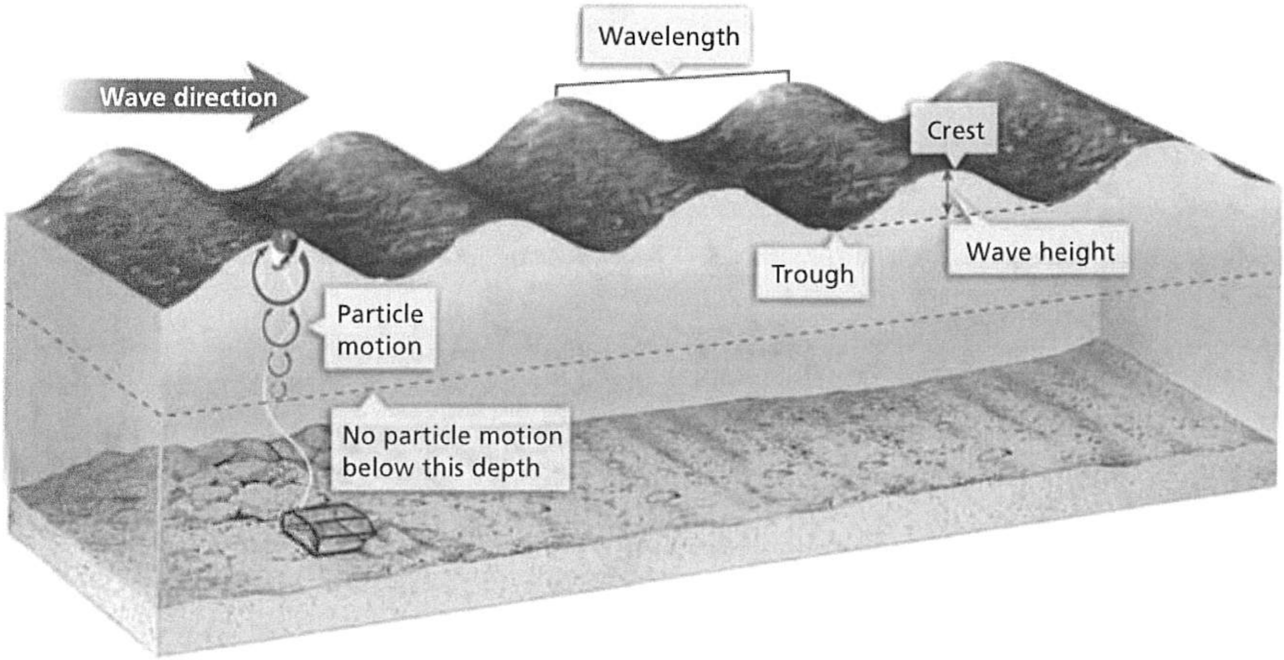


FIGURE 5
Water Motion
As a wave passes, water particles move in a circular motion. The buoy on the surface swings down into the trough of one wave, then back up to the crest of the next. Below the surface, water particles move in smaller circles. At a depth equal to about one half the wavelength, water particles are not affected by the surface wave.

Go Online
active art
For: Water Motion activity
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Water Motion Figure 5 shows what happens to the water as a wave travels along. 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.

Notice that the deeper water particles move in smaller circles than those near the surface. The wind affects the water at the surface more than it affects the deep water. Below a certain depth, the water does not move at all as the wave passes. If you were inside a submarine in deep water, you would not be able to tell whether the water above you was rough or calm.

Other Wave Characteristics Scientists have a vocabulary of terms 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.

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.

Reading Checkpoint **Which have longer wavelengths—waves that are close together or waves that are far apart?**

How Waves Change Near Shore

Have you ever seen an area of ocean water swell, resulting in a wave? Waves begin this way out in the ocean, but as they approach the shore, they change.

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. Follow the waves in Figure 6 as they enter the shallow water. 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 the 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 had 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.

Lab zone Try This **Activity**

Wave Motion

This activity shows how waves that form at the surface affect deeper water.

1. Fill an aquarium about three-quarters full of water.
2. Tie enough metal washers to a cork so that the cork floats about 3 cm from the bottom of the tank.

3. Repeat Step 2 with more corks so that they float 9 cm from the bottom, 15 cm from the bottom, and so on, until the last cork floats on the surface.
4. Make small, steady waves in the tank by moving your hand up and down in the water. Note what happens to each cork.
5. Repeat Step 4, increasing the height of the waves by moving your hand faster.

Observing How does increasing the wave height affect the motion of each cork?

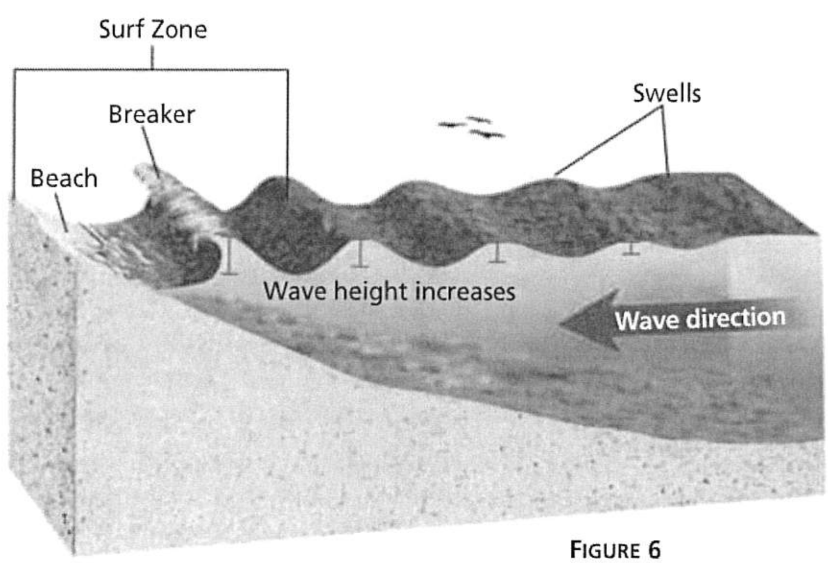


FIGURE 6
How Breakers Change Near Shore
Friction with the ocean floor causes waves to slow down in the shallow water near shore. The wave height increases until the waves break, forming surf.
Comparing and Contrasting *How do swells and breakers differ?*

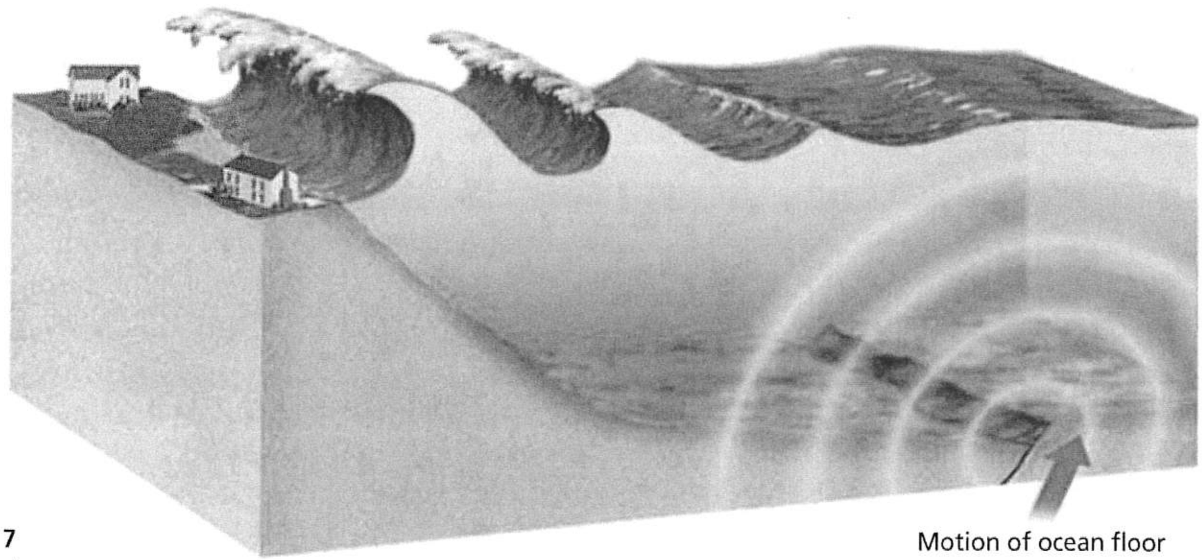


FIGURE 7
Tsunamis
At sea, a tsunami travels as a long, low wave. Near shore, the wave height increases suddenly. The wall of water smashes onto land, tossing ships onto the shore and destroying buildings.

Discovery Channel School

Ocean Motions

Video Preview
▶ Video Field Trip
Video Assessment

Tsunamis So far you have been reading about waves that are caused by the wind. Another kind of wave, shown in Figure 7, forms far below the ocean surface. This type of wave, called a **tsunami,** is usually caused by an earthquake beneath the ocean floor. The abrupt movement of the ocean floor sends pulses of energy through the water above it. When tsunamis reach the coast, they can be as devastating as an earthquake on land, smashing buildings and bridges.

Despite the tremendous 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." The tsunami becomes a towering wall of water. 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 to an approaching tsunami.

But not all tsunamis occur in the Pacific Ocean. On December 26, 2004, a major earthquake in the Indian Ocean caused tremendous tsunamis that struck 11 nations. Tragically, these tsunamis took the lives of more than 230,000 people. Several nations are now developing a tsunami warning system for the Indian Ocean.

How Waves Affect the Shore

What happens on shore as waves pound the beach? Figure 8 shows some of their effects. Because 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. The water and sand then run straight back 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 in a long ridge called a sandbar.

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.

Reading Checkpoint **In what direction does a rip current pull a swimmer?**

Lab zone **Skills Activity**

Making Models

Half fill an aluminum pan with water. The pan represents the ocean floor. Make the "ocean floor" slope by placing a book or other object under one long end of the pan. Add enough sand in the middle of the pan to create a sandbar. Then pour water from a beaker onto the sand to model a rip current. Use the model to explain why rip currents can be dangerous to swimmers.

FIGURE 8
Longshore Drift
Waves approach the shore at an angle. This results in a gradual movement of sand along the beach. **Interpreting Diagrams** *In which direction is longshore drift moving the sand along this beach?*

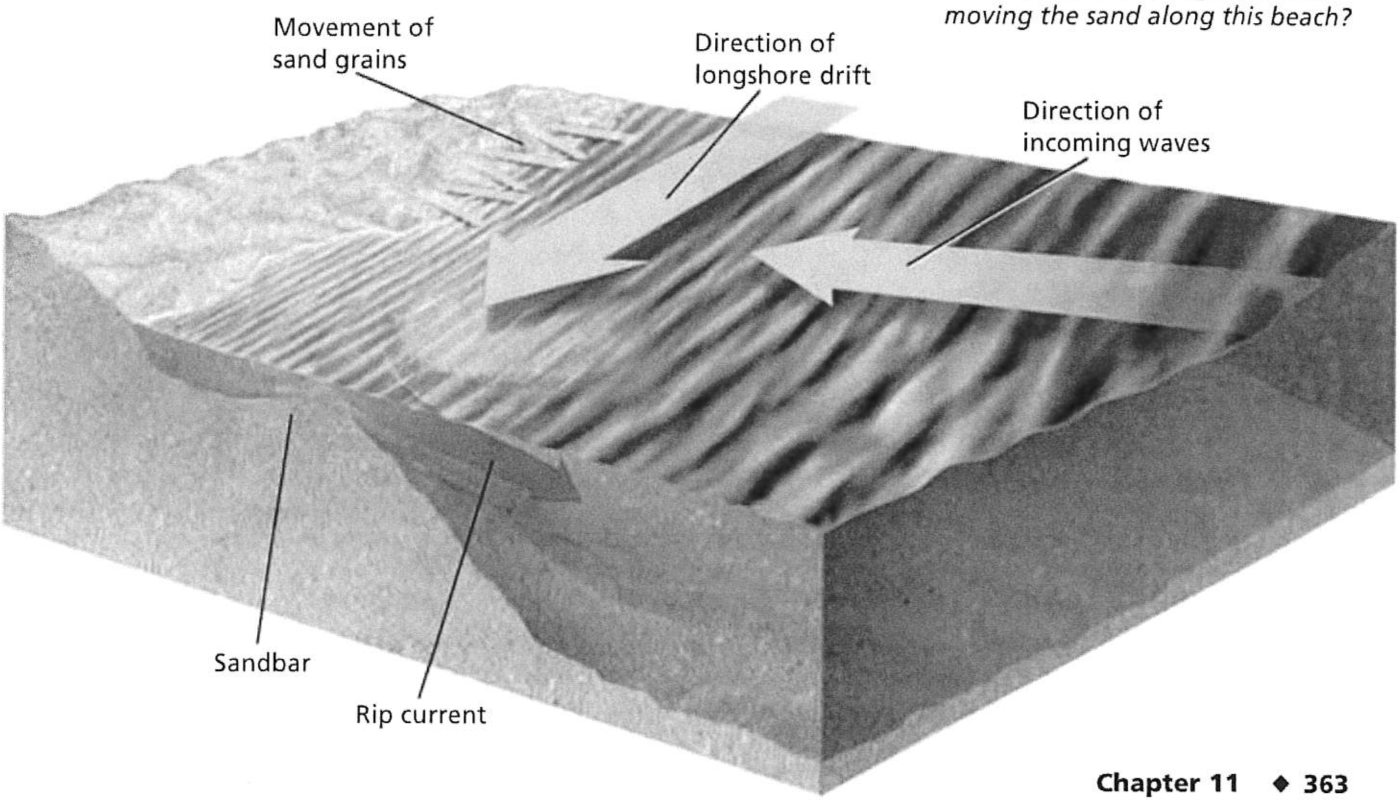
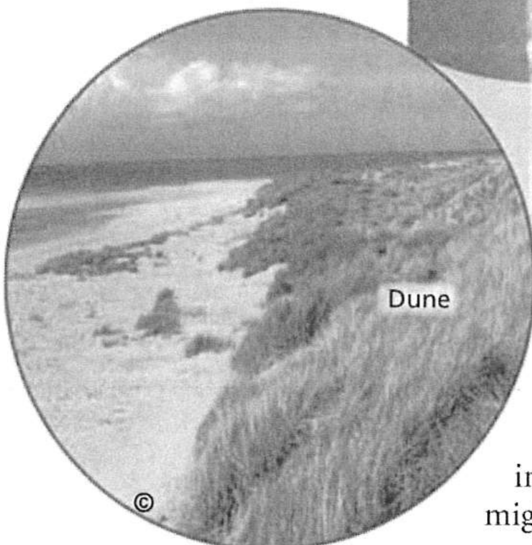


FIGURE 9
A Barrier Beach
Barrier beaches are sand deposits that form parallel to a shore. Sand dunes are hills of wind-blown sand that help protect the beach.
Interpreting Photographs *How does a barrier beach protect the mainland from erosion by waves?*



Waves and Beach Erosion

The boundary between land and ocean is always changing shape. If you walk on the same beach every day, you might not notice that it is changing. From day to day, waves remove sand and bring new sand at about the same rate. But if you visit a beach just once each year, you might be startled by what you see. **Waves shape a beach by eroding the shore in some places and building it up in others.**

At first, waves striking a rocky shoreline carve the rocks into tall cliffs and arches. Over many thousands of years, waves break the rocks into pebbles and grains of sand. A wide, sandy beach forms. Then the waves begin to eat away at the exposed beach. The shoreline slowly moves farther inland. Longshore drift carries the sand along the coast and deposits it elsewhere. This process of breaking up rock and carrying it away is known as erosion.

Barrier Beaches A natural landform that protects shorelines from wave action occurs along low-lying beaches. Long sand deposits called barrier beaches form parallel to the shore. Such beaches are separated from the mainland by a shallow lagoon. Waves break against the barrier beach instead of against the land inside. For this reason, people are working to preserve natural barrier beaches like those off Cape Cod, the New Jersey shore, and the Georgia and Carolina coasts.

Sand Dunes Other natural landforms also help protect beaches and reduce erosion, although they can't completely stop the movement of sand. Sand dunes, which are hills of windblown sand, can make a beach more stable and protect the shore from erosion. The strong roots of dune plants, such as beach grass and sea oats, hold the sand in place. These plants help to slow erosion caused by wind and water. But the dunes and plants can be destroyed by cars, bicycles, or even by many people walking over them. Without plants to hold the sand in place, dunes can be easily washed away by wave action.

Groins Many people like to live near the ocean. But over time, erosion can wear away the beach. This threatens the homes and other buildings near the beach. To avoid losing their property, people look for ways to reduce the effect of erosion.

One method of reducing erosion along a stretch of beach is to build a wall of rocks or concrete, called a **groin,** outward from the beach. Sand carried by the water piles up against the groins instead of moving along the shore. Figure 10 shows how groins interrupt the movement of water. However, groins increase the amount of erosion farther down the beach.

Reading Checkpoint **Name two natural landforms that help reduce beach erosion.**

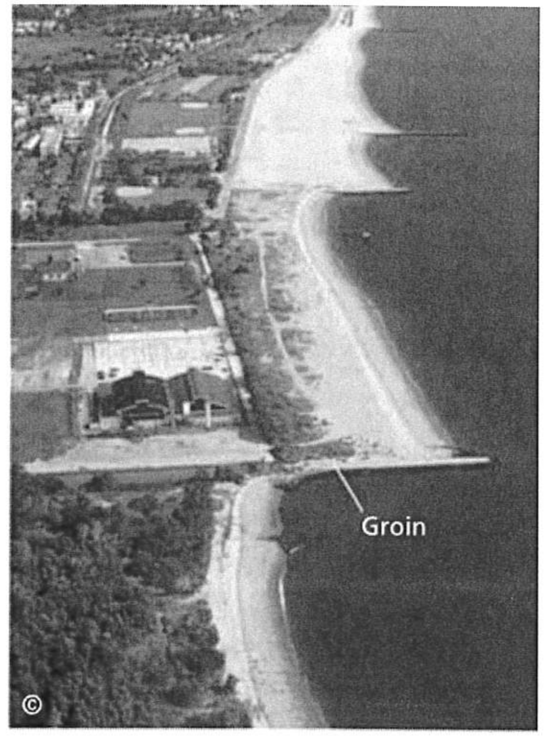


FIGURE 10
Groins
Sand piles up against a series of groins people have built along the New Jersey coast. Building groins to stop longshore drift is one way to reduce beach erosion.

Section 2 Assessment

Target Reading Skill **Using Prior Knowledge** Review your graphic organizer and revise it based on what you just learned in the section.

Reviewing Key Concepts

HINT 1. a. **Reviewing** How do waves form?

HINT b. **Explaining** Explain how both a wave's energy and the water in a wave move.

HINT c. **Applying Concepts** Why does an ocean buoy bob up and down as a wave passes by?

HINT 2. a. **Defining** What is the wavelength of a wave? What is wave height?

HINT b. **Describing** How do wavelength and wave height change as a wave enters shallow water?

HINT c. **Developing Hypotheses** Using what you know about the wavelength and wave height of tsunamis, propose an explanation of why tsunamis can cause so much damage when they reach the shore.

3. a. **Explaining** What is longshore drift, and how does it affect a shoreline? HINT

b. **Relating Cause and Effect** Explain how building a groin affects longshore drift. What happens to the beach on each side of the groin? HINT

Lab zone **At-Home Activity**

Wave Model With a family member, make a construction paper model of a wave. Your model should show the wave from the time it develops in the ocean to the time it breaks on the shore. Be sure to label the features of the wave, including crests, troughs, wavelengths, wave heights, swells, and breakers.

Section 3

Integrating Space Science

Tides

Reading Preview

Key Concepts

- What causes tides?
- What affects the heights of tides?
- How are tides a source of energy?

Key Terms

- tides • spring tide • neap tide

Target Reading Skill

Previewing Visuals Before you read, preview Figure 14. Then write two questions that you have about the diagram in a graphic organizer like the one below. As you read, answer your questions.

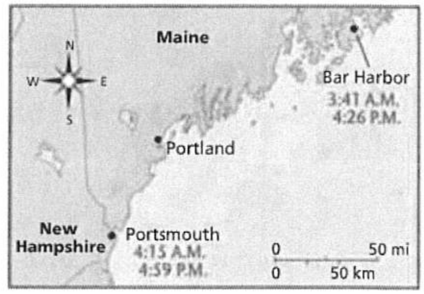
Spring and Neap Tides

Q. When do spring tides occur?
A.
Q.

Lab zone Discover Activity

When Is High Tide?

Twice a day, the ocean rises and falls on Earth's coasts. These changes in water level are called tides. The map shows the times of the two high tides in two cities on a specific day.



1. Calculate the length of time between the two high tides for each city. Remember to consider both hours and minutes.
2. Compare the times of the high tides in Bar Harbor and in Portsmouth. Do you see a pattern?

Think It Over

Predicting Based on the times of the high tides in Bar Harbor and Portsmouth, predict when the high tides will occur in Portland.

You're standing on a riverbank in the town of Saint John, New Brunswick, in Canada. In the distance there's a roaring sound. Suddenly a wall of water twice your height thunders past. The surge of water rushes up the river channel so fast that it almost looks as if the river is flowing backward!

This thundering wall of water is an everyday event at Saint John. The town is located where the Saint John River enters the Bay of Fundy, an arm of the Atlantic Ocean. The Bay of Fundy is famous for its dramatic daily tides. When the tide comes in, fishing boats float on the water near the piers. But once the tide goes out, the boats are stranded on the muddy harbor bottom!

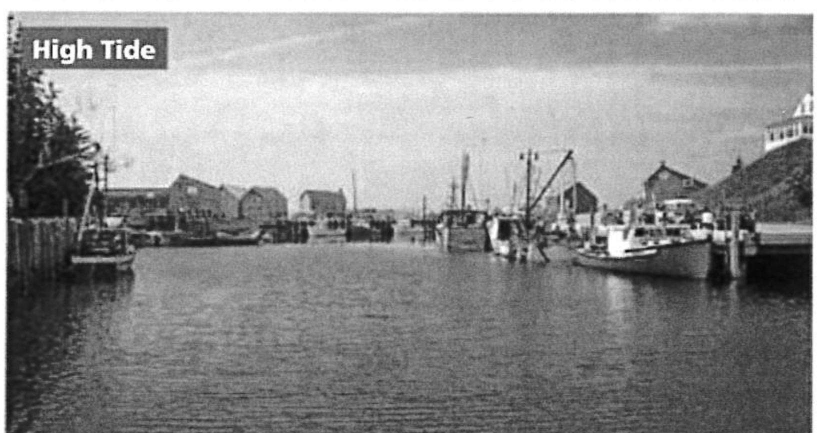


FIGURE 11
Differences in Tides
The Bay of Fundy in Canada is noted for the great differences between its high and low tides. Near the mouth of the bay, boats float at high tide (left). At low tide, the boats are grounded (right).

What Causes Tides?

The daily rise and fall of Earth's waters on its coastlines are called **tides.** As the tide comes in, the level of the water on the beach rises gradually. When the water reaches its highest point, it is high tide. Then the tide goes out, flowing back toward the sea. When the water reaches its lowest point, it is low tide. Unlike the surface waves you read about earlier, tides happen regularly no matter how the wind blows. Tides occur in all bodies of water, but they are most noticeable in the ocean and large lakes.

Gravity and Tides **Tides are caused by the interaction of Earth, the moon, and the sun.** How can distant objects like the moon and sun influence water on Earth? The answer is gravity. Gravity is the force exerted by an object that pulls other objects toward it. Gravity keeps you and everything around you on Earth's surface. As the distance between objects increases, however, gravity's pull grows weaker.

Figure 12 shows the effect of the moon's gravity on the water on Earth's surface. The moon pulls on the water on the side of Earth closest to it more strongly than it pulls on the center of the Earth. This pull creates a bulge of water, called a tidal bulge, on the side of Earth facing the moon. The water farthest from the moon is pulled toward the moon less strongly than are other parts of Earth. The water farthest from the moon is "left behind," forming a second bulge.

In the places where there are tidal bulges, high tide is occurring along the coastlines. In the places between the bulges, low tide is occurring. Earth's rotation through the tidal bulges causes most coastlines to experience two high tides and two low tides about every 25 hours.

Reading Checkpoint **What force causes tides to occur on Earth's surface?**

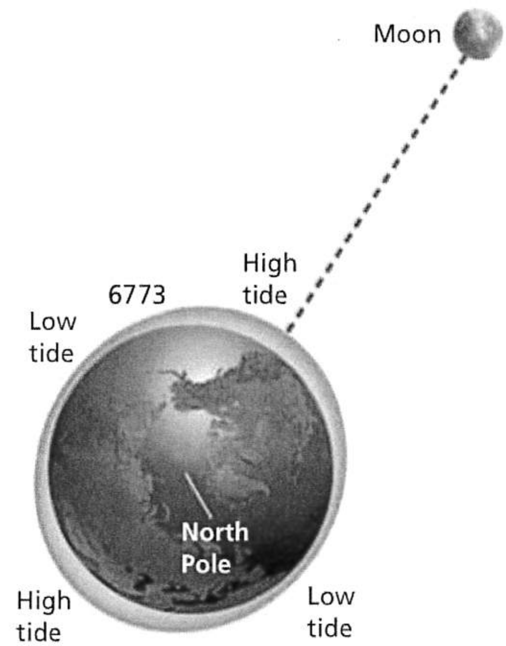
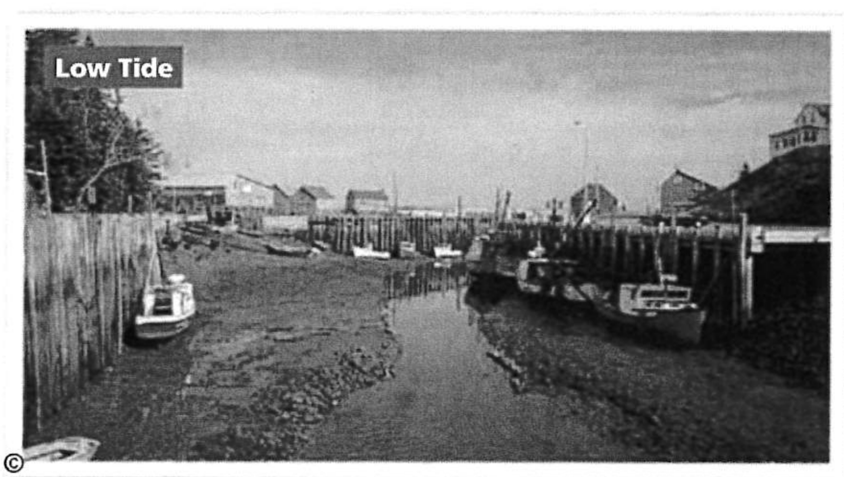


FIGURE 12
How the Moon Causes Tides
The pull of the moon's gravity on Earth's water causes tidal bulges to form on the side closest to the moon and the side farthest from the moon. **Inferring** *Why is the water level high on the side of Earth farthest from the moon?*



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Visit: PHSchool.com
Web Code: cfd-3032

The Daily Tide Cycle As Earth turns completely around once each day, people on or near the shore observe the rise of tides as they reach the area of a tidal bulge. High tides occur about 12 hours and 25 minutes apart in any location. As Earth rotates, easternmost points pass through the area of the tidal bulge before points farther to the west. Therefore, high tide occurs later the farther west you travel along the coast.

In some places, the two high tides and two low tides are easy to observe each day. But in other places, the difference between high tide and low tide is less dramatic. One set of tides may even be so minimal that there appears to be only one high tide and one low tide per day.

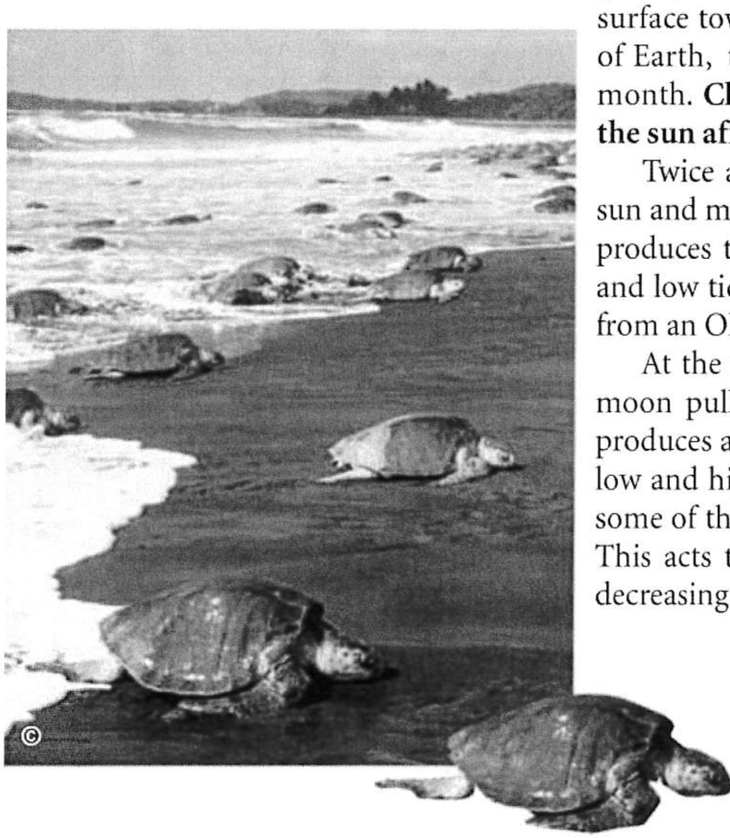
Several factors affect the height of a tide in any particular location. For example, certain landforms can interrupt the water's movements. A basin at the mouth of a river can also increase the difference between high and low tide. The speed and depth of moving water increases as it flows into a narrower channel. That is what causes the dramatic tides in the mouth of the Saint John River you read about earlier.

The Monthly Tide Cycle Even though the sun is about 150 million kilometers from Earth, it is so massive that its gravity affects the tides. The sun pulls the water on Earth's surface toward it. In Figure 14, you can follow the positions of Earth, the moon, and the sun at different times during a month. **Changes in the positions of Earth, the moon, and the sun affect the heights of the tides during a month.**

Twice a month, at the new moon and the full moon, the sun and moon are lined up. Their combined gravitational pull produces the greatest difference between the heights of high and low tide, called a **spring tide.** These tides get their name from an Old English word, *springen*, which means "to jump."

At the first and third quarters of the moon, the sun and moon pull at right angles to each other. This arrangement produces a **neap tide,** a tide with the least difference between low and high tide. During a neap tide, the sun's gravity pulls some of the water away from the tidal bulge facing the moon. This acts to "even out" the water level over Earth's surface, decreasing the difference between high and low tides.

FIGURE 13
Sea Turtles and Spring Tides
Some animals are very dependent on tide cycles. Sea turtles can only come to shore to lay their eggs during certain spring tides.



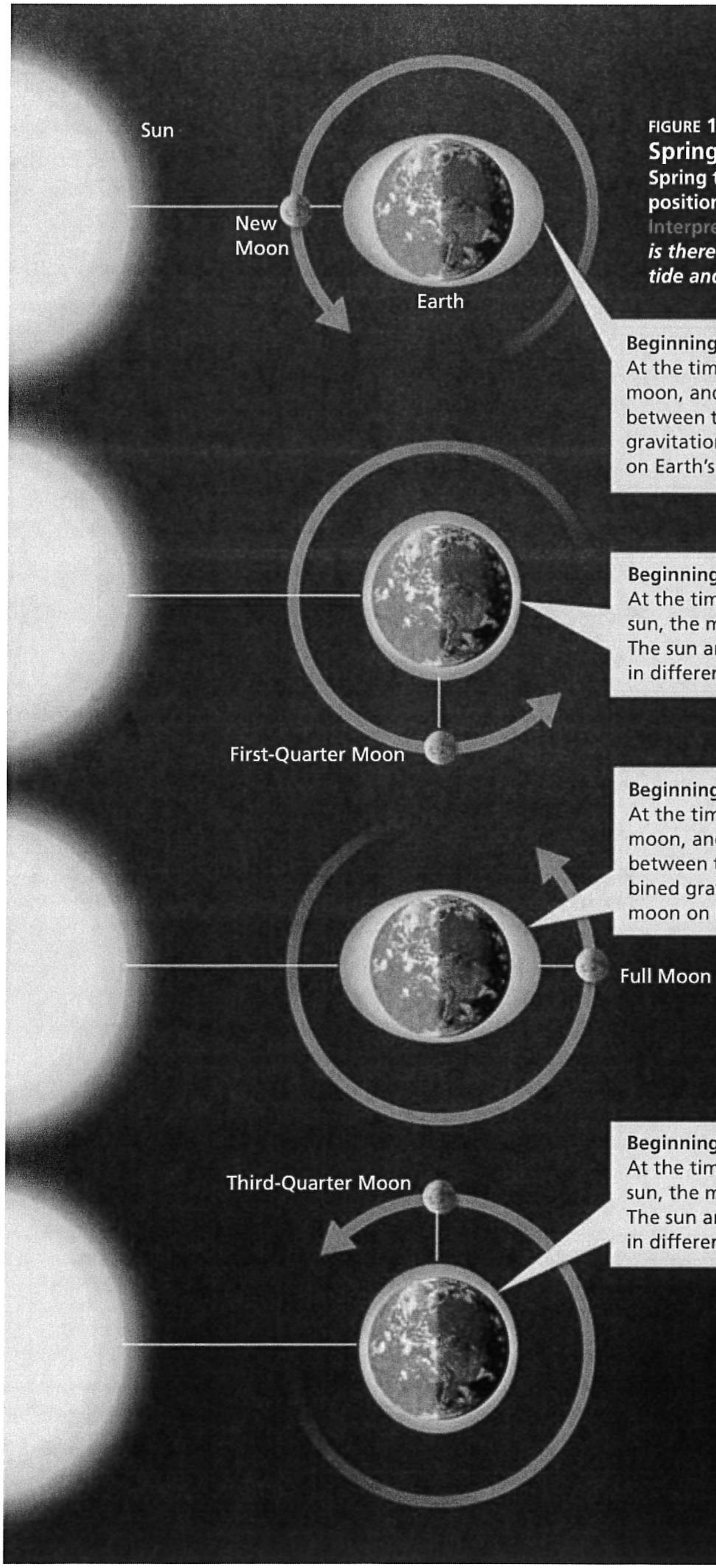


FIGURE 14
Spring and Neap Tides
Spring tides and neap tides are caused by the positions of Earth, the sun, and the moon.
Interpreting Diagrams ***In which two alignments is there the greatest difference between high tide and low tide?***

Beginning of Week 1: Spring Tide
At the time of the new moon, the sun, the moon, and Earth are aligned, with the moon between the sun and Earth. The combined gravitational pull of the sun and the moon on Earth's waters causes a spring tide.

Beginning of Week 2: Neap Tide
At the time of the first-quarter moon, the sun, the moon, and Earth form a right angle. The sun and the moon pull on Earth's waters in different directions, causing a neap tide.

Beginning of Week 3: Spring Tide
At the time of the full moon, the sun, the moon, and Earth are aligned, with Earth between the sun and the moon. The combined gravitational pull of the sun and the moon on Earth's waters causes a spring tide.

Beginning of Week 4: Neap Tide
At the time of the third-quarter moon, the sun, the moon, and Earth form a right angle. The sun and the moon pull on Earth's waters in different directions, causing a neap tide.

Math Analyzing Data

Plotting Tides

This table lists the highest high tides and the lowest low tides for one week at the mouth of the Savannah River, where it meets the Atlantic Ocean in Georgia.

1. **Graphing** Use the data in the table to make a graph. On the horizontal axis, mark the days. On the vertical axis, mark tide heights ranging from 3.0 to –1.0 meters. (*Hint:* Mark the negative numbers below the horizontal axis.)
2. **Graphing** Plot the tide heights for each day on the graph. Connect the high tide points with one line and the low tide points with another line.

Tide Table

Day	Highest High Tide (m)	Lowest Low Tide (m)
1	1.9	0.2
2	2.1	0.1
3	2.3	0.0
4	2.4	–0.2
5	2.5	–0.2
6	2.6	–0.3
7	1.9	0.3

3. **Interpreting Data** How do the high and low tides change during the week?
4. **Inferring** What type of tide might be occurring on Day 6? Explain.

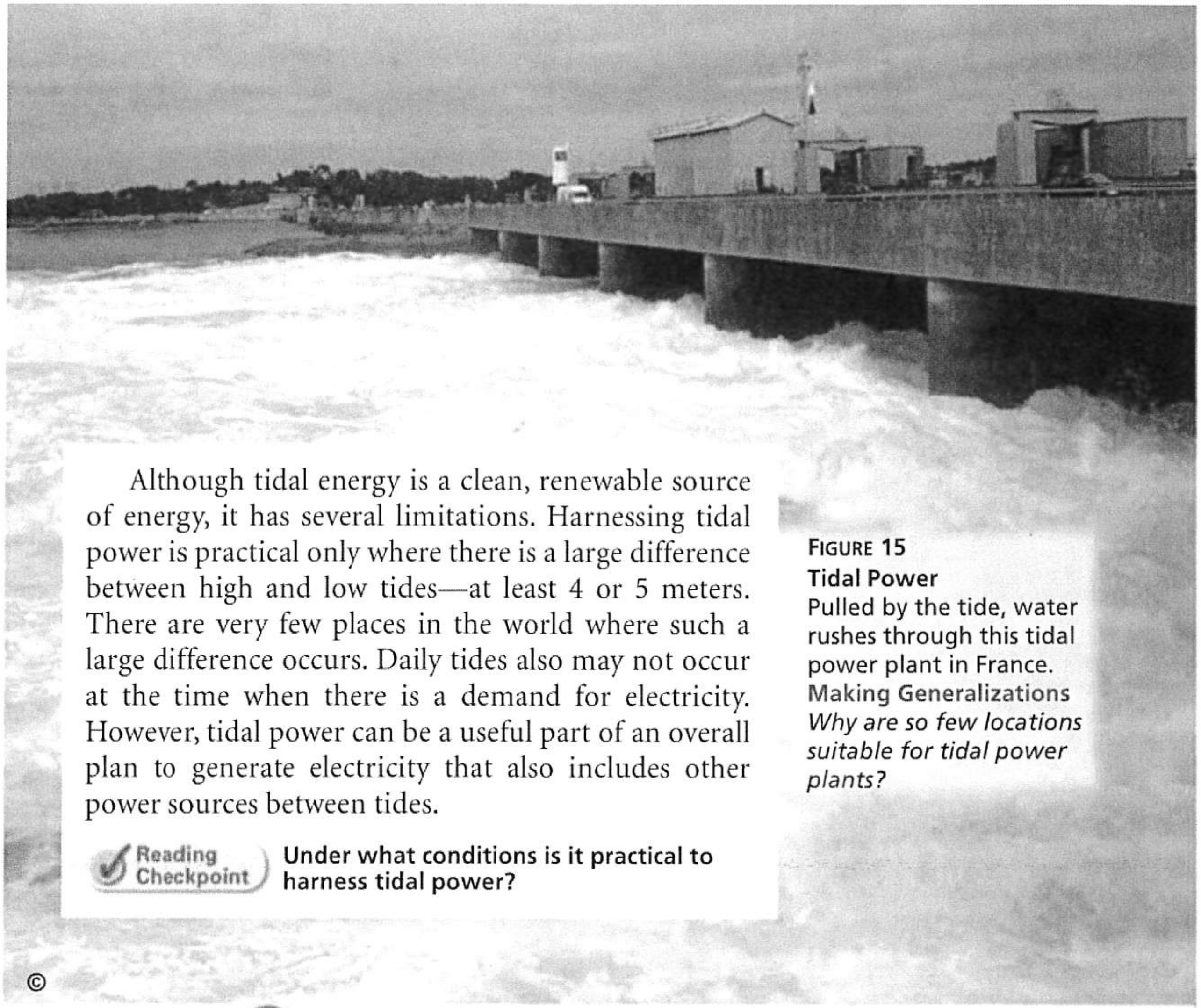
Tide Tables Despite the complex factors affecting tides, scientists can predict tides quite accurately for many locations. They combine knowledge of the movements of the moon and Earth with information about the shape of the coastline and other local conditions. If you live near the coast, your local newspaper probably publishes a tide table. Knowing the times and heights of tides is important to sailors, marine scientists, people who fish, and coastal residents.

Reading Checkpoint **What two types of information help scientists predict the times of tides?**

Energy From Tides

Look at Figure 15. Can you almost hear the roar of the rushing water? **The movement of huge amounts of water between high and low tide is a source of potential energy—energy that is stored and can be used.** Engineers have designed tidal power plants that capture some of this energy as the tide moves in and out.

The first large-scale tidal power plant was built in 1967 on the Rance River in northwestern France. As high tide swirls up the river, the plant's gates open so that the water flows into a basin. As the tide retreats, the gates shut to trap the water. Gravity pulls the water back to sea through tunnels. The energy of the water moving through the tunnels powers generators that produce electricity, just as in a hydroelectric dam on a river.



Although tidal energy is a clean, renewable source of energy, it has several limitations. Harnessing tidal power is practical only where there is a large difference between high and low tides—at least 4 or 5 meters. There are very few places in the world where such a large difference occurs. Daily tides also may not occur at the time when there is a demand for electricity. However, tidal power can be a useful part of an overall plan to generate electricity that also includes other power sources between tides.

Reading Checkpoint **Under what conditions is it practical to harness tidal power?**

FIGURE 15
Tidal Power
Pulled by the tide, water rushes through this tidal power plant in France.
Making Generalizations *Why are so few locations suitable for tidal power plants?*

Section 3 Assessment

Target Reading Skill **Previewing Visuals** Refer to your questions and answers about Figure 14 to help you answer Question 2 below.

Reviewing Key Concepts

1. a. **Defining** What is a tide? What causes tides?
   b. **Explaining** Explain why the moon causes a tidal bulge to form on the side of Earth closest to it.
   c. **Inferring** The sun is much bigger than the moon. Why doesn't the sun affect tides more than the moon does?
2. a. **Reviewing** Why do the heights of tides change during the course of a month?
   b. **Describing** Describe the positions of the sun, moon, and Earth during a spring tide and during a neap tide.
   c. **Applying Concepts** Imagine that you are the captain of a fishing boat. Why would it be helpful to consult a monthly tide table?
3. a. **Reviewing** How can tides be used to generate electricity?
   b. **Predicting** Do you think that tidal power will ever be a major source of energy worldwide? Why or why not?

Writing in Science

Firsthand Account Imagine that you are fishing on a pier on the Bay of Fundy in Canada. It was high tide when you began fishing. Now it is low tide. Write a firsthand account describing the changes that you observed as the tide went out. Use clear, descriptive language in your writing.

Section 4

Ocean Water Chemistry

Reading Preview

Key Concepts

- How salty is ocean water?
- How do the temperature and gas content of ocean water vary?
- How do conditions in the ocean change with depth?

Key Terms

- salinity • submersible

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *how* or *what* question for each heading. As you read, answer your questions.

Ocean Water Chemistry

Question	Answer
How salty is the ocean?	One kilogram of ocean water has . . .

Lab zone Discover Activity

Will the Eggs Sink or Float?

1. Fill two beakers or jars with tap water.
2. Add three teaspoons of salt to one beaker. Stir until it dissolves.
3. Place a whole, uncooked egg in each jar. Handle the eggs gently to avoid breakage. Observe what happens to each egg.
4. Wash your hands when you are finished with this activity.

Think It Over

Observing Compare what happens to the two eggs. What does this tell you about the difference between salt water and fresh water?

If you've ever swallowed some water while you were swimming in the ocean, you know that the ocean is salty. Why? According to an old Swedish legend, it's all because of a magic mill. This mill could grind out anything its owner wanted, such as herring, porridge, or even gold. A greedy sea captain once stole the mill and took it away on his ship, but without finding out how to use it. He asked the mill to grind some salt but then could not stop it. The mill ground more and more salt, until the captain's ship sank from its weight. According to the tale, the mill is still at the bottom of the sea, grinding out salt!

Salt storage area ▼

The Salty Ocean

Probably no one ever took this legend seriously, even when it was first told. The scientific explanation for the ocean's saltiness begins with the early stages of Earth's history, when the ocean covered much of the surface of the planet. Undersea volcanoes erupted, spewing chemicals into the water. Gradually, the lava from these volcanic eruptions built up areas of land. Rain fell on the bare land, washing more chemicals from the rocks into the ocean. Over time, these dissolved substances built up to the levels present in the ocean today.

Salinity Just how salty is the ocean? If you boiled a kilogram of ocean water in a pot until all the water was gone, there would be about 35 grams of salts left in the pot. **On average, one kilogram of ocean water contains about 35 grams of salts—that is, 35 parts per thousand.** The total amount of dissolved salts in a sample of water is the **salinity** of that sample.

The substance you know as table salt—sodium chloride—is the salt present in the greatest amount in ocean water. When sodium chloride dissolves in water, it separates into sodium and chloride particles called ions. Other salts, such as magnesium chloride, form ions in water in the same way. Together, chloride and sodium make up almost 86 percent of the ions dissolved in ocean water. Ocean water also contains smaller amounts of about a dozen other ions, including magnesium and calcium, and other substances that organisms need, such as nitrogen and phosphorus.

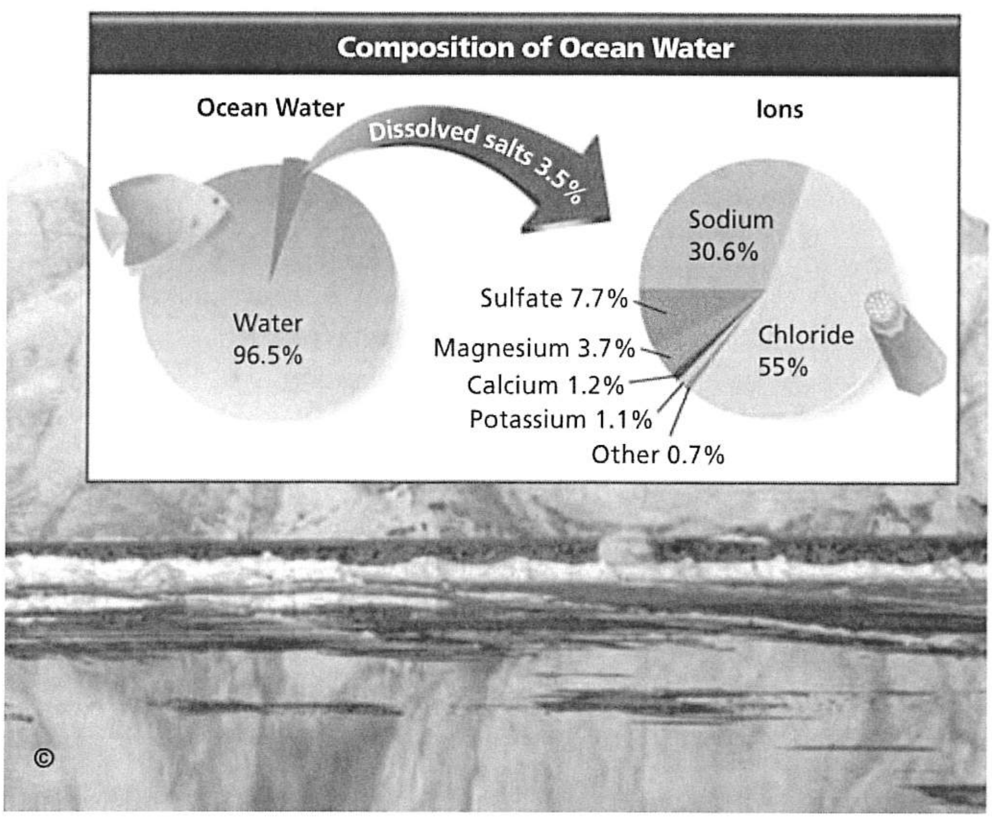
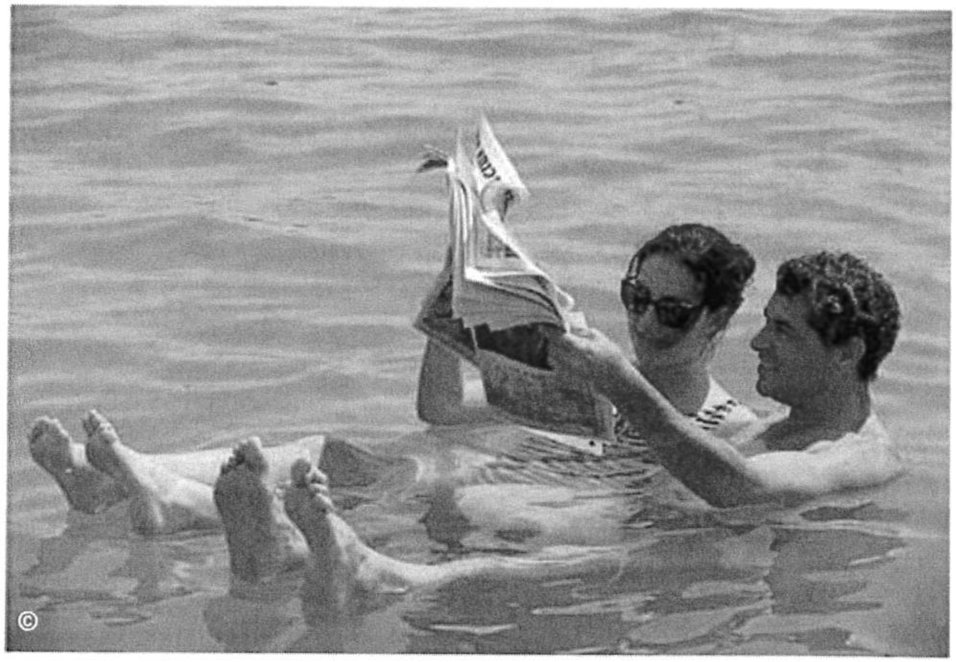


FIGURE 16
Composition of Ocean Water
Ocean water contains many different dissolved salts. When salts dissolve, they separate into particles called ions.
Reading Graphs *Which ion is most common in ocean water?*

FIGURE 17
Salinity and Density
These people are relaxing with the paper while floating in the water! The Dead Sea between Israel and Jordan is so salty that people float easily on its surface.
Relating Cause and Effect
How is the area's hot, dry climate related to the Dead Sea's high salinity?



Math Skills

Calculating Density

To calculate the density of a substance, divide the mass of the substance by its volume.

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

For example, 1 liter (L) of ocean water has a mass of 1.03 kilograms (kg). Therefore,

$$\text{Density} \quad \frac{1.03 \text{ kg}}{1.00 \text{ L}}$$

$$\text{Density} \quad 1.03 \text{ kg/L}$$

Practice Problems A 5-liter sample of one type of crude oil has a mass of 4.10 kg. What is its density? If this oil spilled on the ocean's surface, would it sink or float? Explain your answer in terms of density.

Variations in Salinity In most parts of the ocean, the salinity is between 34 and 37 parts per thousand. But near the ocean's surface, rain, snow, and melting ice add fresh water, lowering the salinity. Salinity is also lower near the mouths of large rivers such as the Amazon or Mississippi. These rivers empty great amounts of fresh water into the ocean. Evaporation, on the other hand, increases salinity, since the salt is left behind as the water evaporates. For example, in the Red Sea, where the climate is hot and dry, the salinity can be as high as 41 parts per thousand. 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 several properties of ocean water. For instance, ocean water does not 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 crystals. 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 has greater buoyancy. It lifts, or buoys up, less dense objects floating in it. This is why an egg floats higher in salt water than in fresh water, and why the people in Figure 17 float so effortlessly in the Dead Sea.

Reading Checkpoint **Why does salt water have greater buoyancy than fresh water?**

Other Ocean Properties

In New England, the news reports on New Year's Day often feature the shivering members of a "Polar Bear Club" taking a dip in the icy Atlantic Ocean. Yet on the same day, people enjoy the warm waters of a Puerto Rico beach. **Like temperatures on land, temperatures at the surface of the ocean vary with location and the seasons. Gases in ocean water vary as well.**

Temperature of Ocean Water Why do surface temperatures of the ocean vary from place to place? The broad surface of the ocean absorbs energy from the sun. Near the equator, surface ocean temperatures often reach 25°C, about room temperature. The temperature drops as you travel away from the equator.

Because warm water is less dense than cold water, warm water forms only a thin layer on the ocean surface. Generally, the deeper you descend into the ocean, the colder and denser the water becomes. When water temperature is lower, the water molecules stay closer together than at higher temperatures. So, a sample of cold water has more water molecules than a sample of warm water of the same volume. The sample of cold water is denser.

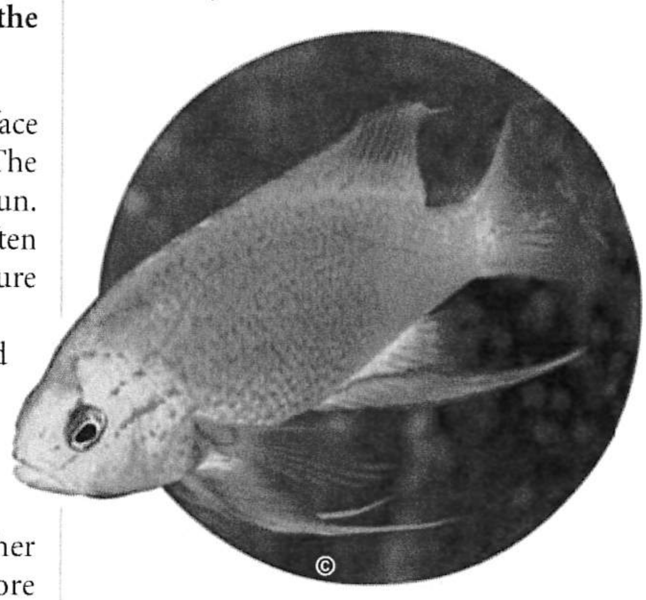
Gases in Ocean Water Just as land organisms use gases found in air, ocean organisms use gases found in ocean water. Two gases that ocean organisms use are carbon dioxide and oxygen.

Carbon dioxide is about 60 times as plentiful in the oceans as in the air. Algae need carbon dioxide for photosynthesis. Animals such as corals also use carbon dioxide, which provides the carbon to build their hard skeletons.

Unlike carbon dioxide, oxygen is scarcer in seawater than in air. Oxygen is most plentiful in seawater near the surface. Oxygen in seawater comes from the air and from algae in the ocean, as a product of photosynthesis. The amount of oxygen in seawater is affected by the water temperature. The cold waters in the polar regions contain more oxygen than warm, tropical waters. But there is still enough oxygen in tropical seas to support a variety of organisms.

Reading Checkpoint What are two sources of oxygen in ocean water?

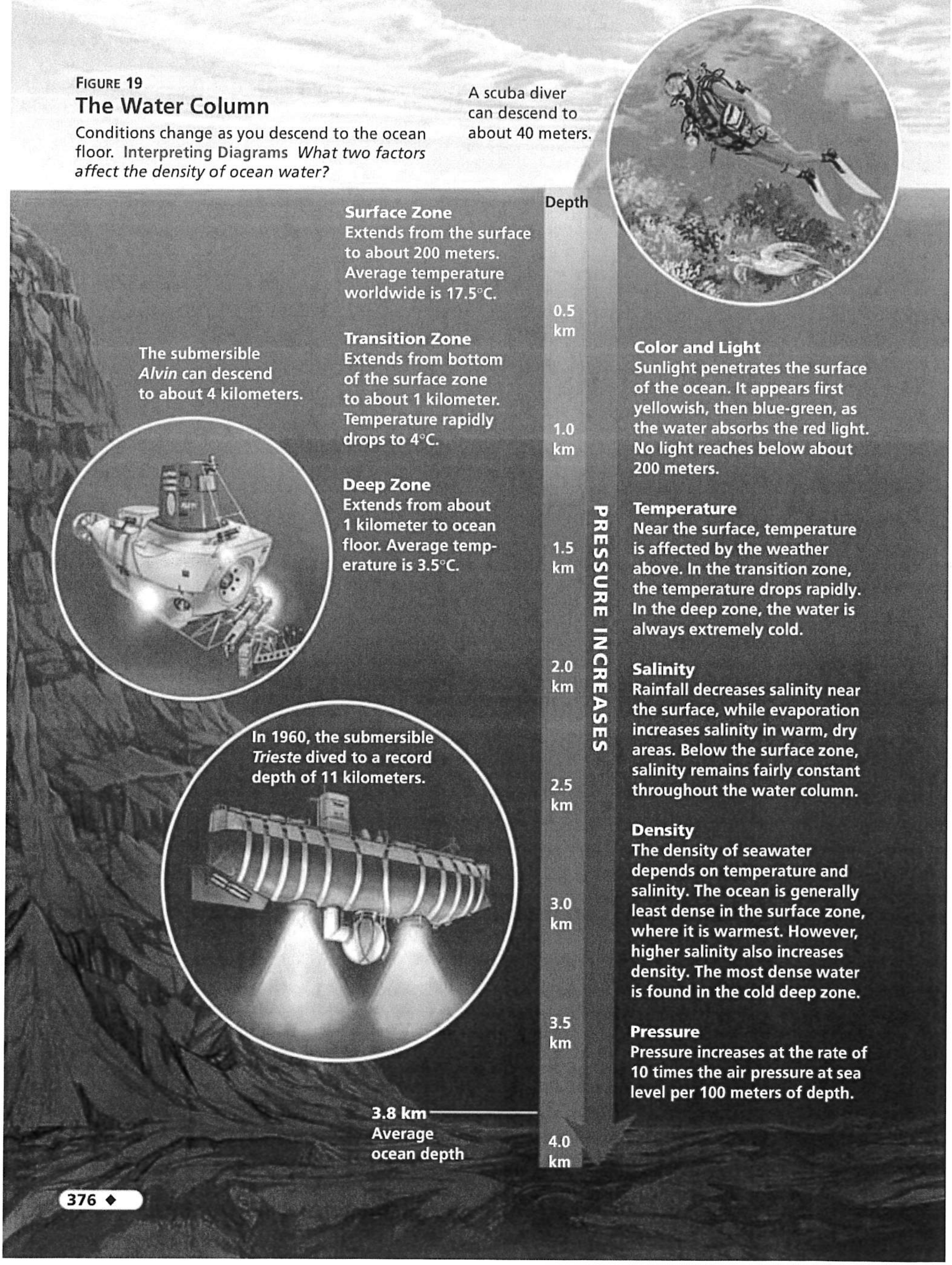
FIGURE 18
Organisms and Ocean Temperatures
From the warmest tropical waters to the coldest Antarctic sea, you can find organisms that are adapted to extreme ocean temperatures.



▲ This longfin anthias fish swimming near Hawaii lives in one of the warmest parts of the Pacific Ocean.

▲ This rockcod is swimming through a hole in an iceberg in near-freezing ocean water.

FIGURE 19
The Water Column
Conditions change as you descend to the ocean floor. **Interpreting Diagrams** *What two factors affect the density of ocean water?*



Changes With Depth

If you could descend from the ocean's surface to the ocean floor, you would pass through a vertical section of the ocean referred to as the water column. Figure 19 on the previous page shows some of the dramatic changes you would observe.

Decreasing Temperature **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 transition zone extends from the bottom of the surface zone to about 1 kilometer. Temperatures drop very quickly as you descend through the transition zone, to about 4°C. Below the transition zone is the deep zone. Average temperatures there are 3.5°C in most of the ocean.

Increasing Pressure Water pressure is the force exerted by the weight of water. **Pressure increases continuously with depth in the ocean.** Because of the high pressure in the deep ocean, divers can descend safely only to about 40 meters. To observe the deep ocean, scientists must use a **submersible**, an underwater vehicle built of materials that resist pressure.

Reading Checkpoint **What is a submersible?**

Go Online
SCI LINKS NSTA
For: Links on ocean water chemistry
Visit: www.SciLinks.org
Web Code: scn-0833

Section 4 Assessment

Target Reading Skill **Asking Questions** Use the questions you wrote about the headings to help you answer the questions below.

Reviewing Key Concepts

HINT **1. a. Defining** What is salinity? What is the average salinity of ocean water?

HINT **b. Describing** Describe one factor that increases the salinity of seawater and one factor that decreases its salinity.

HINT **c. Inferring** Would you expect the seawater just below the floating ice in the Arctic Ocean to be higher or lower in salinity than the water in the deepest part of the ocean? Explain.

HINT **2. a. Identifying** Where would you find the warmest ocean temperatures on Earth?

HINT **b. Comparing and Contrasting** How do carbon dioxide and oxygen levels in the oceans compare to those in the air?

c. Relating Cause and Effect How does the temperature of ocean water affect oxygen levels in the water? HINT

3. a. Reviewing How do temperature and pressure change as you descend in the ocean? HINT

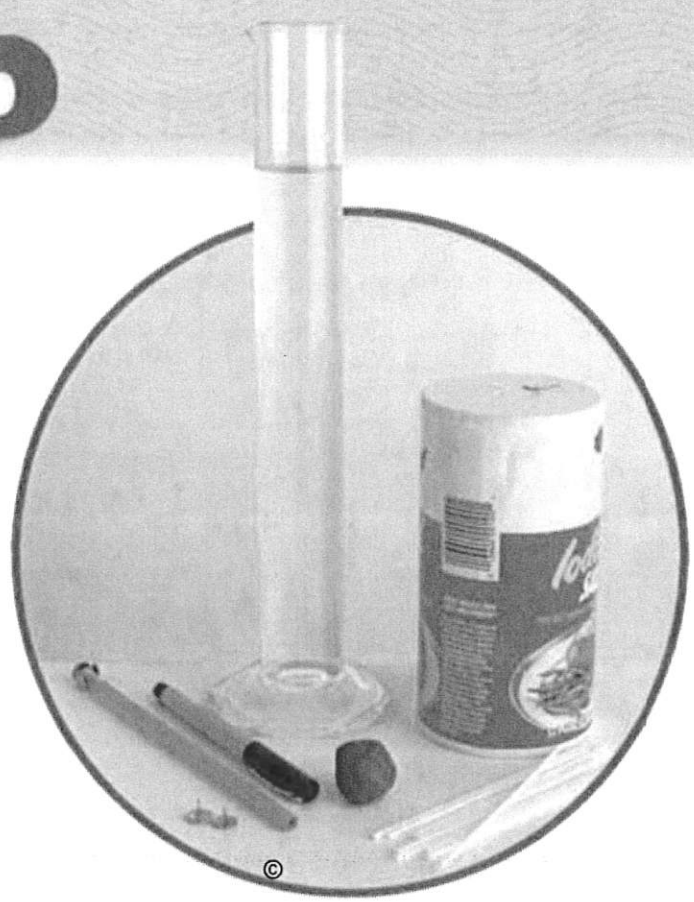
b. Predicting Where in the water column would you expect to find the following conditions: the highest pressure readings; the densest waters; the warmest temperatures? HINT

Math Practice

4. Calculating Density Calculate 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 would likely have the higher salinity? Explain.

Lab zone **Technology Lab**

• Tech & Design •



Investigating Changes in Density

Problem

Can you design and build an instrument that can detect differences in density?

Skills Focus

building a prototype, designing a solution, troubleshooting

Materials

- thumbtacks • 250-mL graduated cylinder
- unsharpened pencil with eraser • metric ruler
- fine-point permanent marker • thermometer
- ice • balance • water • spoon • salt
- additional materials provided by your teacher

Procedure

PART 1 Research and Investigate

1. One way to measure the density of a liquid is with a tool called a hydrometer. You can make a simple hydrometer using an unsharpened wooden pencil.
2. Starting at the unsharpened end of a pencil, use a permanent marker to make marks every 2 mm along the side of the pencil. Make longer marks for every whole centimeter. Continue until you have marked off 5 cm.
3. Label each of the long marks, starting at the unsharpened end of the pencil.
4. Insert 3 thumbtacks as weights into the eraser end of the pencil. **CAUTION:** *Be careful not to cut yourself on the sharp points of the thumbtacks.*
5. Fill the graduated cylinder with 250 mL of water at room temperature. Place the pencil in the water, eraser end down.
6. Add or remove thumbtacks and adjust their placement until the pencil floats upright, with about 2 cm sticking up above the surface of the water.
7. In your notebook, record the temperature of the water. Next to that number, record the reading on the pencil hydrometer at the surface of the water.
8. Fill the graduated cylinder with cold water. Place the pencil hydrometer into the water, eraser end down. Then repeat Step 7.

PART 2 Design and Build

9. Using what you learned in Part 1, design and build a hydrometer that can detect density differences among different samples of water. Your hydrometer should
    - be able to measure density differences between hot water and cold water
    - be able to measure density differences between salt water and fresh water
    - be constructed of materials approved by your teacher

10. Sketch your design in your notebook and make a list of the materials you will need. Write a plan for how you will construct your hydrometer. After you have received your teacher's approval for your design, build your hydrometer.

PART 3 Evaluate and Redesign

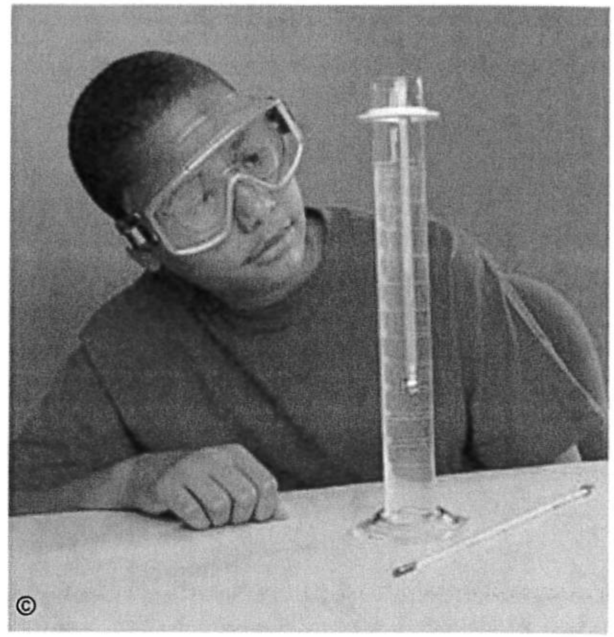
11. Test your hydrometer by using it to measure the density of water at different temperatures. Then test samples of water that have different salinities. Create a data table in which to record your results.

Data Table		
Temperature (°C)	Salinity $\left(\frac{\text{g salt}}{\text{L water}}\right)$	Hydrometer Reading

12. Based on your tests, decide how you could improve the design of your hydrometer. For example, how could you change your design so your hydrometer is able to detect smaller differences in density? Obtain your teacher's approval, then make the necessary changes, and test how your redesigned hydrometer functions.

Analyze and Conclude

1. **Inferring** Explain why cold water is more dense than hot water. Explain why salt water is more dense than fresh water.
2. **Building a Prototype** How well did the pencil hydrometer you built in Part 1 work? What problems did you encounter with the hydrometer?



3. **Designing a Solution** How did you incorporate what you learned in Part 1 into your hydrometer design in Part 2? For example, how did your hydrometer address the problems you encountered in Part 1?
4. **Troubleshooting** In Part 3, how well did your hydrometer perform when you measured water samples of different densities? How did you redesign your hydrometer to improve its function?
5. **Evaluating the Design** What limitations did factors such as buoyancy, materials, time, costs, or other factors place on the design and function of your hydrometer? Describe how you adapted your design to work within these limitations.

Communicate

Create an informative poster that describes how your hydrometer works. Include illustrations of your hydrometer and any important background information on density.

Section 5

Currents and Climate

Reading Preview

Key Concepts

- What causes surface currents and how do they affect climate?
- What causes deep currents and what effects do they have?
- How does upwelling affect the distribution of nutrients in the ocean?

Key Terms

- current
- Coriolis effect
- climate
- El Niño
- upwelling

Target Reading Skill

Relating Cause and Effect As you read, identify the main factors that cause surface and deep currents in the oceans. Write the information in graphic organizers like the one below.

Cause		Effect
	→	Surface currents

Cause		Effect
	→	Deep currents

Lab zone Discover **Activity**

Which Is More Dense?

1. Fill a plastic container three-quarters full with warm water. Wait for the water to stop moving.
2. Add several drops of food coloring to a cup of ice water and stir.
3. Gently dribble colored water down the inside of the container. Observe.

Think It Over

Inferring Describe what happened to the cold water. Which is more dense, warm water or cold water? Explain.

One spring day, people strolling along a beach in Washington State saw an amazing sight. Hundreds of sneakers of all colors and sizes were washing ashore from the Pacific Ocean! This "sneaker spill" was eventually traced to a cargo ship accident. Containers of sneakers had fallen overboard and now the sneakers were washing ashore.

But the most amazing part of the story is this—scientists could predict where the sneakers would wash up next. And just as the scientists had predicted, sneakers washed up in Oregon, and then thousands of kilometers away in Hawaii!

How did the scientists know that the sneakers would float all the way to Hawaii? The answer lies in a type of ocean movement known as a current. 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, while other currents move water deep in the ocean.

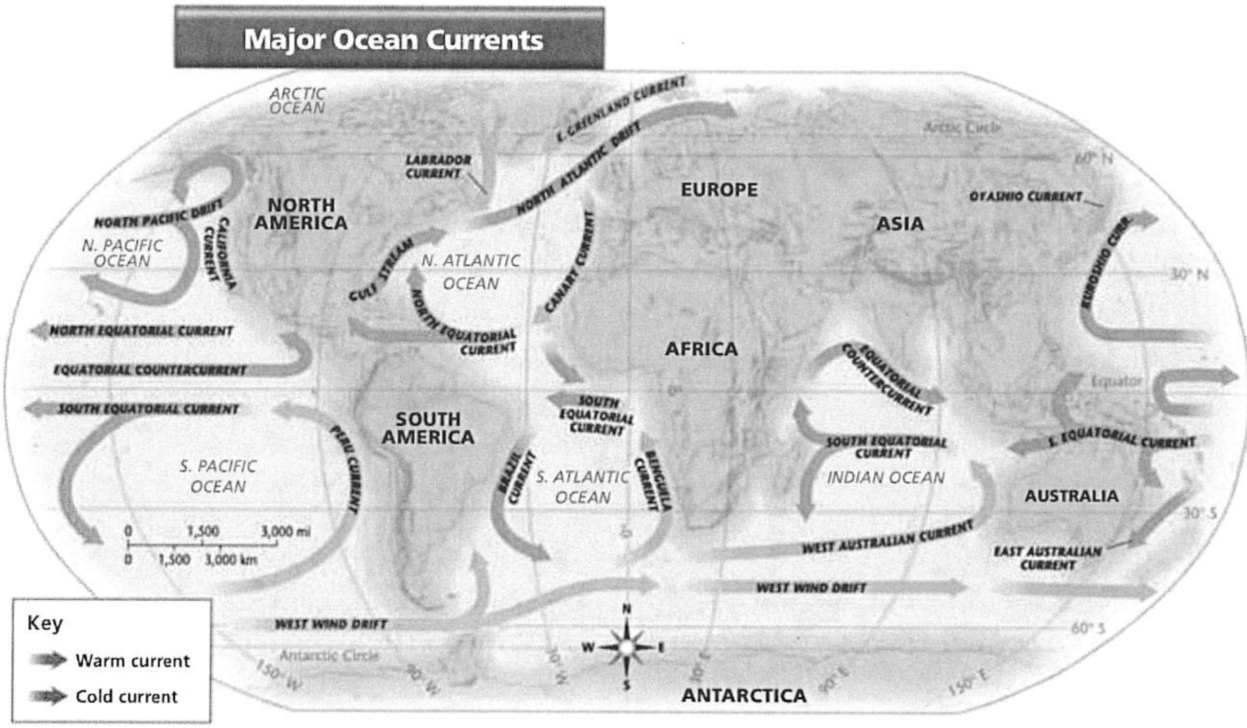


FIGURE 20
Large surface currents generally move in circular patterns in Earth's oceans. Interpreting Maps *Name four currents that flow along the coasts of North America. State whether each current is warm or cold.*

Surface Currents

Figure 20 shows the major surface currents in Earth's oceans. **Surface currents, which affect water to a depth of several hundred meters, are driven mainly by winds.** Following Earth's major wind patterns, surface currents move in circular patterns in the five major oceans. Most of the currents flow east or west, and then double back to complete the circle.

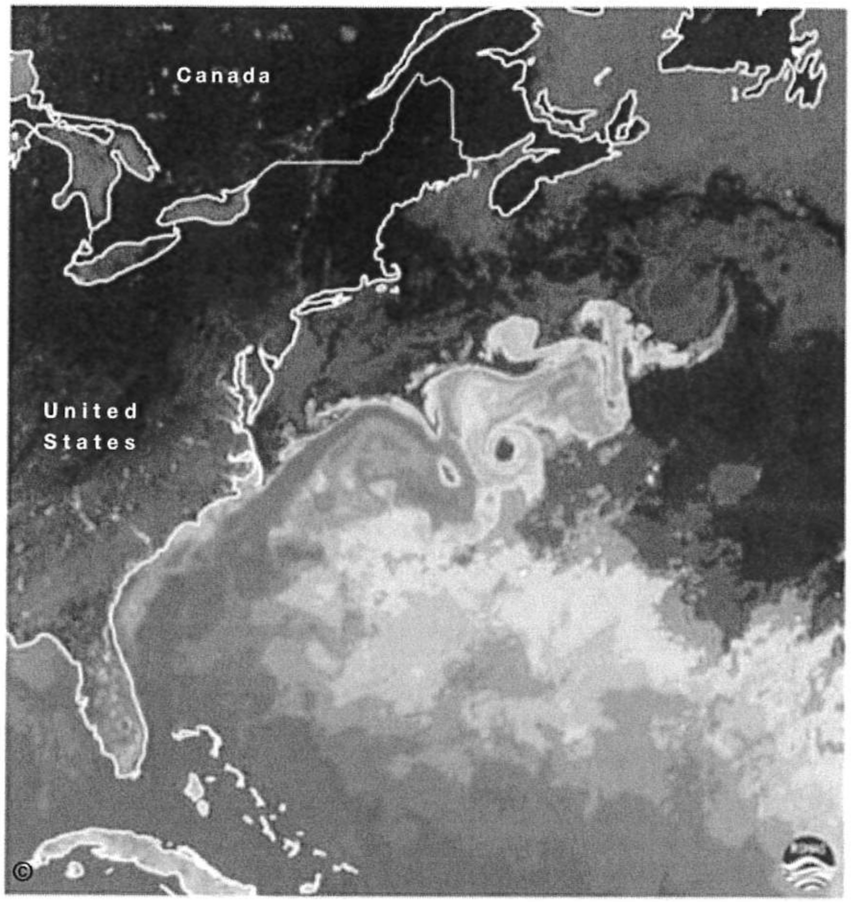
Coriolis Effect Why do the currents move in these circular patterns? If Earth were standing still, winds and currents would flow in straight lines between the poles and the equator. But as Earth rotates, the paths of the winds and currents curve. This effect of Earth's rotation on the direction of winds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

The largest and most powerful surface current in the North Atlantic Ocean, the Gulf Stream, is caused by strong winds from the west. It is more than 30 kilometers wide and 300 meters deep, and carries a volume of water 100 times greater than the Mississippi River. The Gulf Stream carries warm water from the Gulf of Mexico to the Caribbean Sea, then northward along the coast of the United States. Near Cape Hatteras, North Carolina, it curves eastward across the Atlantic, as a result of the Coriolis effect.

Go Online
SCILINKS NSTA

For: Links on ocean currents
Visit: www.SciLinks.org
Web Code: scn-0834

FIGURE 21
Surface Currents and Climate
This satellite image of the Atlantic Ocean has been enhanced with colors that show water temperature. Red and orange indicate warmer water, while green and blue indicate colder water.
Interpreting Maps *The Gulf Stream flows around Florida in the lower left of the map. Is the Gulf Stream warm or cold current?*



Effects on Climate The Gulf Stream and another warm current, the North Atlantic Drift, are very important to people in the city of Trondheim, Norway. Trondheim is located along Norway's western coast. Although it is very close to the Arctic Circle, winters there are fairly mild. Snow melts soon after it falls. And fortunately for the fishing boats, the local harbors are free of ice most of the winter. The two warm currents bring this area of Norway a mild climate. **Climate** is the pattern of temperature and precipitation typical of an area over a long period of time.

Currents affect climate by moving cold and warm water around the globe. In general, currents carry 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, influencing the climate of the land near the coast.**

Winds pick up moisture as they blow across warm-water currents. For example, the warm Kuroshio Current brings mild, rainy weather to the southern islands of Japan. In contrast, cold-water currents cool the air above them. Since cold air holds less moisture than warm air, these currents tend to bring cool, dry weather to the land areas in their path.

Lab zone **Skills Activity**

Drawing Conclusions

Locate the Benguela Current in Figure 20 on the previous page. Near the southern tip of Africa, the winds blow from west to east. Using what you have learned about surface currents and climate, what can you conclude about the impact of this current on the climate of the south-western coast of Africa?

El Niño When changes in wind patterns and currents occur, they can have a major impact on the oceans and neighboring land. One example of such changes is **El Niño,** an abnormal 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 eastward toward the South American coast. El Niño conditions can last for one to two years before the usual winds and currents return.

El Niño can have disastrous consequences. It causes shifts in weather patterns around the world, bringing unusual and often severe conditions to different areas. For example, a major El Niño occurred between 1997 and 1998 and caused an especially warm winter in the northeastern United States. However, it was also responsible for heavy rains, flooding, and mudslides in California, as well as a string of deadly tornadoes in Florida.

Although scientists do not fully understand the conditions that cause El Niño, they have been able to predict its occurrence using computer models of world climate. Knowing when El Niño will occur can reduce its impact. Scientists and public officials can plan emergency procedures and make changes to protect people and wildlife.

Reading Checkpoint **Why is it helpful to be able to predict when El Niño will occur?**

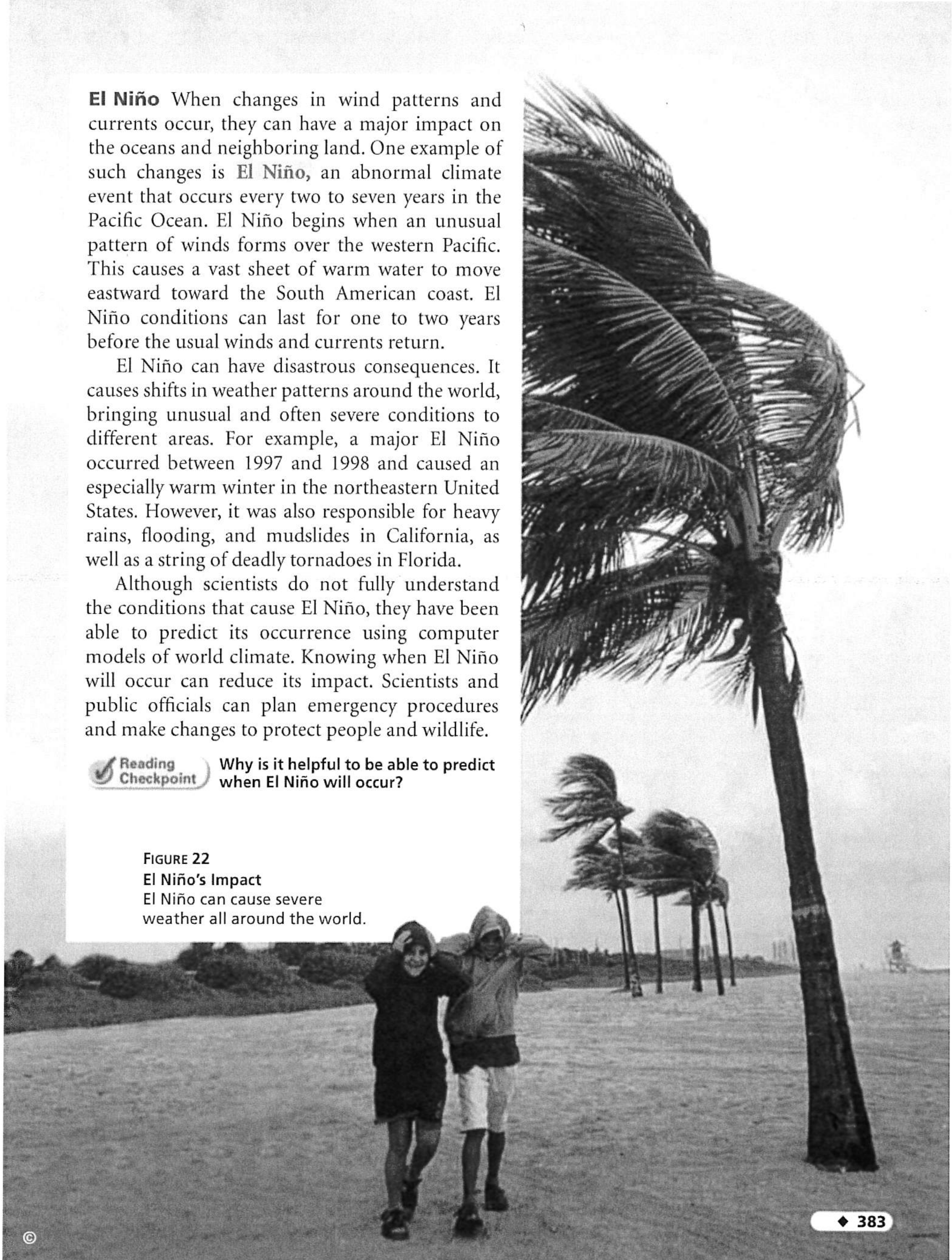


FIGURE 22
El Niño's Impact
El Niño can cause severe weather all around the world.

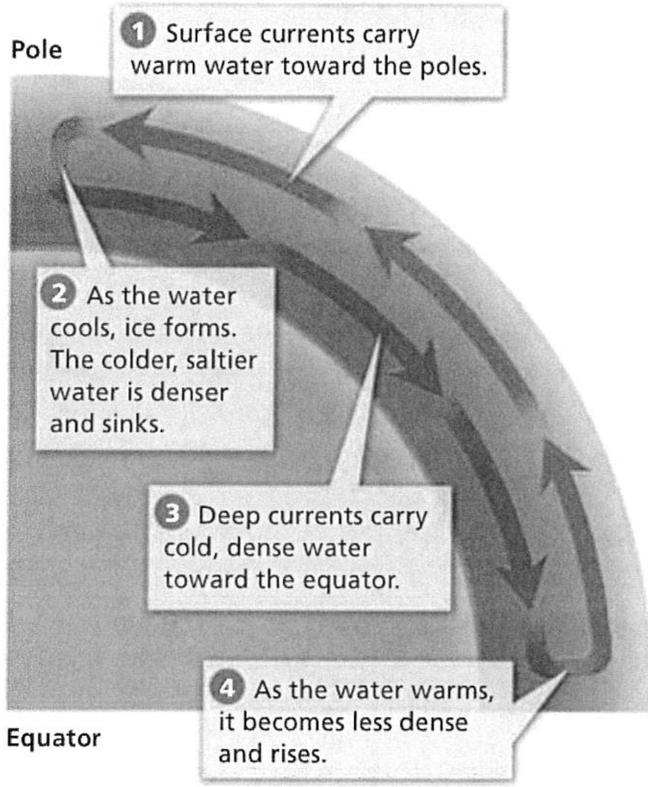


FIGURE 23
Deep Currents
Deep currents are caused by differences in the density of ocean water.

Deep Currents

Deep below the ocean surface, another type of current causes chilly waters to creep slowly across the ocean floor. **These deep currents are caused by differences in the density of ocean water.**

As you read earlier, the density of water depends on its temperature and its 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 its 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 flow from the pole to the equator and back again!

Upwelling

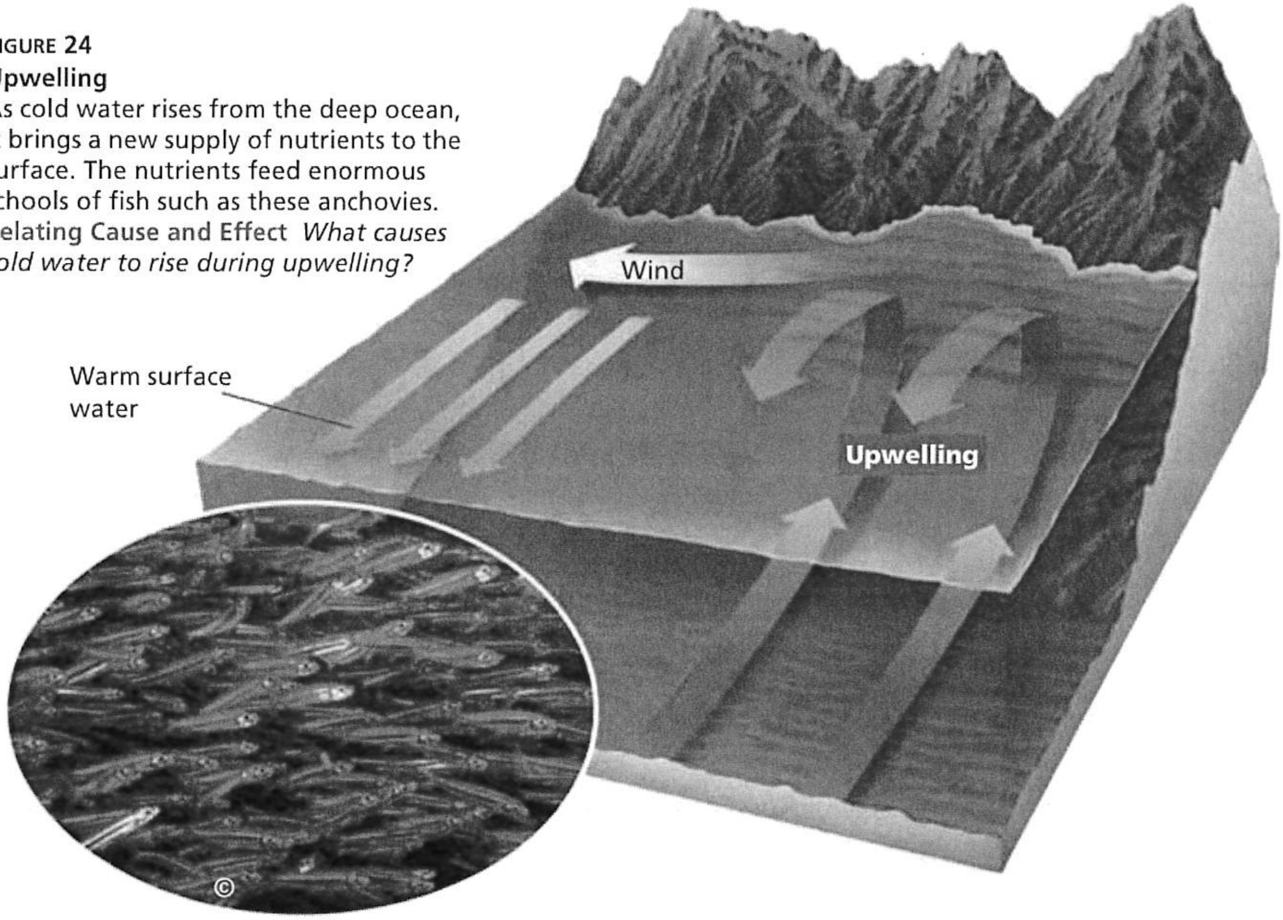
In most parts of the ocean, surface waters do not usually mix with deep ocean waters. However, mixing sometimes occurs when winds cause upwelling. **Upwelling** is the movement of cold water upward from the deep ocean. As winds blow away the warm surface water, cold water rises to replace it.

Upwelling brings up tiny ocean organisms, minerals, and other nutrients from the deeper layers of the water. Without this motion, the surface waters of the open ocean would be very scarce in nutrients. Because nutrients are plentiful, zones of upwelling are usually home to huge schools of fish.

One major area of upwelling lies in the Pacific Ocean off the west coast of South America. Many people depend on this rich fishing area for food and jobs. The arrival of El Niño prevents upwelling from occurring. Without the nutrients brought by upwelling, fish die or go elsewhere to find food, reducing the fishing catch that season and hurting people's livelihoods.

Reading Checkpoint **What is upwelling?**

FIGURE 24
Upwelling
As cold water rises from the deep ocean, it brings a new supply of nutrients to the surface. The nutrients feed enormous schools of fish such as these anchovies.
Relating Cause and Effect *What causes cold water to rise during upwelling?*



Section 5 Assessment

Target Reading Skill Relating Cause and Effect Refer to your graphic organizer about the causes of ocean currents to answer Questions 1 and 2 below.

Reviewing Key Concepts

HINT 1. a. **Defining** What is a current?

HINT b. **Describing** What causes surface currents to occur? How do surface currents affect the climate of coastal areas?

HINT c. **Predicting** What type of climate might a coastal area have if nearby currents are cold?

HINT 2. a. **Explaining** Explain how deep currents form and move in the ocean.

HINT b. **Comparing and Contrasting** Compare the causes and effects of deep currents and surface currents.

HINT 3. a. **Reviewing** What causes upwelling?

b. **Explaining** Why are huge schools of fish usually found in zones of upwelling? HINT

c. **Applying Concepts** Why would the ability to predict the occurrence of El Niño be important for the fishing industry on the western coast of South America? HINT

Lab zone At-Home Activity

Modeling the Coriolis Effect With the help of a family member, use chalk and a globe to model the Coriolis effect. Have your family member slowly rotate the globe in an easterly direction. As the globe rotates, draw a line from the North Pole to the equator. Use your knowledge of the Coriolis effect to explain why the line is curved.

Chapter 11 Study Guide

The BIG Idea

Earth's waters Most waves are caused by the wind. Surface currents are driven by winds and deep currents are caused by differences in water density. Tides are caused by the gravitational pull of the moon and sun.

1 Exploring the Ocean

Key Concepts

People have studied the ocean since ancient times, because the ocean provides food and serves as a route for trade and travel. Modern scientists have studied the characteristics of the ocean's waters and the ocean floor.

If you could travel along the ocean floor, you would see the continental shelf, the continental slope, the abyssal plain, and the mid-ocean ridge.

Ocean zones include the intertidal zone, the neritic zone, and the open-ocean zone.

Key Terms

• sonar • continental shelf • continental slope
• abyssal plain • mid-ocean ridge • trench
• intertidal zone • neritic zone • open-ocean zone

2 Wave Action

Key Concepts

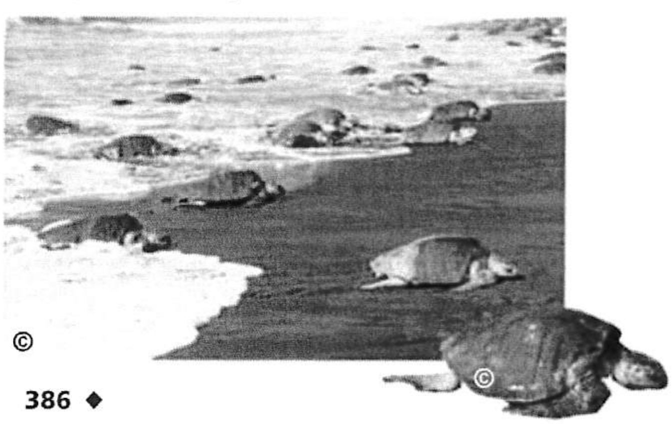
Most waves form when winds blowing across the water's surface transmit energy to the water.

Near shore, wave height increases and wavelength decreases.

As waves come ashore, water washes up the beach at an angle, carrying sand grains. Waves shape a beach by eroding the shore in some places and building it up in others.

Key Terms

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



3 Tides

Key Concepts

Tides are caused by the interaction of Earth, the moon, and the sun.

Changes in the positions of Earth, the moon, and the sun affect the heights of the tides during a month.

The movement of huge amounts of water between high and low tides is a source of potential energy.

Key Terms

• tides • spring tide • neap tide

4 Ocean Water Chemistry

Key Concepts

On average, one kilogram of ocean water contains about 35 grams of salts.

Like temperatures on land, temperatures at the surface of the ocean vary with location and the seasons. Gases in ocean water vary as well.

As you descend through the ocean, the water temperature decreases. Pressure increases continuously with depth in the ocean.

Key Terms

• salinity • submersible

5 Currents and Climate

Key Concepts

Surface currents are driven mainly by winds. A surface current warms or cools the air above it, influencing the climate of land near the coast.

Deep currents are caused by differences in the density of ocean water. Deep currents move and mix water around the world.

Upwelling brings up tiny ocean organisms, minerals, and other nutrients from the deeper layers of the water.

Key Terms

• current • Coriolis effect • climate • El Niño
• upwelling

Review and Assessment

Go Online
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Visit: PHSchool.com
Web Code: cpa-0011

Organizing Information

Sequencing Copy the flowchart about the movement of a wave onto a separate sheet of paper. Then complete it by putting the following three steps in the correct sequence: wave travels as low swell; wave breaks on shore; wavelength decreases and wave height increases. (For more on Sequencing, see the Skills Handbook.)

How Waves Move

Wind creates a ripple on the ocean surface.
↓
a. ___?___
↓
Wave touches the bottom in shallow water.
↓
b. ___?___
↓
c. ___?___

Reviewing Key Terms

Choose the letter of the best answer.

HINT
1. A smooth, nearly flat region of the ocean floor is called a(n)
   a. trench.
   b. mid-ocean ridge.
   c. abyssal plain.
   d. seamount.

HINT
2. Rolling waves with a large horizontal distance between crests have a long
   a. wave height.
   b. wavelength.
   c. frequency.
   d. trough.

HINT
3. At the full moon, the combined gravitational pulls of the sun and moon produce the biggest difference between low and high tide, called a
   a. surface current.
   b. neap tide.
   c. spring tide.
   d. rip current.

HINT
4. Ocean water is more dense than fresh water at the same temperature because of
   a. pressure.
   b. the Coriolis effect.
   c. upwelling.
   d. salinity.

HINT
5. Winds and currents move in curved paths because of
   a. the Coriolis effect.
   b. longshore drift.
   c. wave height.
   d. tides.

HINT
6. Cold and warm ocean water is carried around the world by
   a. spring tides.
   b. neap tides.
   c. currents.
   d. tsunamis.

Writing in Science

Essay Suppose you were planning to take part in an around-the-world sailing race. Write a short essay about the knowledge of currents that you will need to prepare for the race.

Discovery Channel School
Ocean Motions
Video Preview
Video Field Trip
▶ Video Assessment

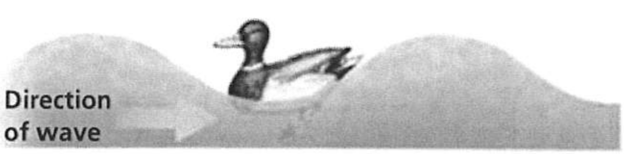
Review and Assessment

Checking Concepts

7. Why do scientists use indirect methods to study the ocean floor?
8. What is a seamount?
9. What factors influence the size of a wave?
10. Why does the height of a wave change as it approaches shore?
11. How does a rip current form?
12. Why are there two high tides a day in most places?
13. What is a spring tide? How does it differ from a neap tide?
14. Name two properties of ocean water affected by salinity. How does salinity affect each?
15. What is the Coriolis effect? How does it influence ocean currents?
16. What is El Niño? What are some of its effects?
17. Describe the cause and effects of upwelling.

Thinking Critically

18. **Drawing Conclusions** Mauna Kea projects about 4,200 meters above sea level. Its base is on the floor of the Pacific Ocean, about 6,000 meters below sea level. Mt. Everest rises 8,850 meters from base to summit. Its base is located on land. Which mountain is taller: Mauna Kea or Mt. Everest?
19. **Predicting** How will the duck's location change as the wave moves? Explain your answer.



20. **Comparing and Contrasting** In what ways is the ocean at 1,000 meters deep different from the ocean at the surface in the same location?
21. **Relating Cause and Effect** How does the movement of ocean currents explain the fact that much of western Europe has a mild, wet climate?

Math Practice

22. **Calculating Density** Two 1-liter samples of water were taken from the ocean. Both have the same salinity. Sample A has a mass of 1.02 kg. Sample B has a mass of 1.05 kg. Which sample was taken during the colder weather? Explain your answer.

Applying Skills

Use the data to answer Questions 23–25.

The temperature readings in the table were obtained in the Atlantic Ocean near Bermuda.

Ocean Temperatures

Depth (m)	Temp. (°C)	Depth (m)	Temp. (°C)
0	19	1,000	9
200	18	1,200	5
400	18	1,400	5
600	16	1,600	4
800	12	1,800	4

23. **Graphing** Construct a line graph using the data in the table. Plot depth readings on the horizontal axis and temperature readings on the vertical axis.
24. **Drawing Conclusions** Use your graph to identify the temperature range in the transition zone.
25. **Predicting** Predict how the ocean temperature at depths of 0 meters and at 1,400 meters would change with the seasons in this location. Explain your reasoning.

Lab zone Chapter Project

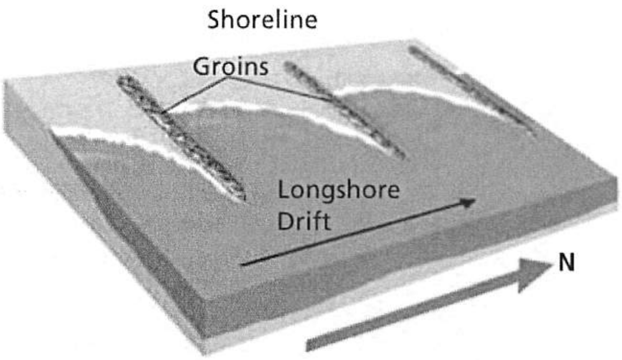
Performance Assessment Using your model, present your method of shoreline protection to the class. Show your classmates how the method you chose protects the lighthouse from ocean waves and the beach erosion that can result.

Preparing for the CRCT

Test-Taking Tip

Interpreting Diagrams

When answering questions about a diagram, examine the diagram carefully, including all the labels. For example, the labels on the diagram below identify the shoreline, a series of groins, and the longshore drift. The arrow labeled *Longshore Drift* shows the direction of the drift. The diagram also has an arrow indicating which way is north on the diagram. Study the diagram and answer the sample question below it.



Sample Question

Where will sand pile up against the groins shown in the diagram?

A on the north side of the groins
B on the west side of the groins
C on the south side of the groins
D No sand will pile up against the groins.

Answer

The correct answer is **C.** By looking at the direction of the longshore drift and the north arrow, you can see that sand has begun to pile up on the south side of the groins.

Choose the letter of the best answer.

1. A scientist plans to test the effect temperature has on the density of ocean water. What will the manipulated variable be in her experiment?

A density **B** salinity
C temperature **D** water depth

S6E3.c

2. In which of the following areas would the salinity of the ocean water be the highest?

A in a hot, dry area
B near a rainy coastal area close to the equator
C at the mouth of a large river
D in cold, deep water, near the ocean bottom

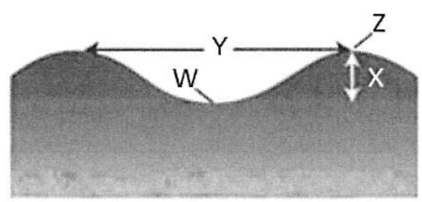
S6E3.c

3. 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 extremely hot and dry
B cool and dry
C extremely cool and wet
D mild and wet

S6E3.d

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



4. What is the wave feature labeled **W** in the diagram?

A wave crest
B wave trough
C wavelength
D wave height

S6E3.d

5. What is the wave feature labeled **Y** in the diagram?

A wave crest
B wave trough
C wavelength
D wave height

S6E3.d

Constructed Response

6. Some people refer to a tsunami as a tidal wave. Explain why this is incorrect. In your answer, describe what a tsunami is and how it forms.

S6E3.d