

# Ocean Motion

## chapter preview

### sections

- 1 Ocean Water
- 2 Ocean Currents
- 3 Ocean Waves and Tides

**Lab** *Wave Properties*

**Lab** *Sink or Float?*



**Virtual Lab** *How are tides affected by phases of the Moon?*

## The Power of Waves

Surfers from around the world experience firsthand the enormous power of moving water. Wind blowing across the ocean surface can create small ripples, the wave shown above in Fiji, and even the giant waves of hurricanes.

**Science Journal** Record in your Science Journal some facts you know about ocean currents, waves, or tides. Include some pictures to show your ideas.

# Start-Up Activities



## Explore How Currents Work

Surface currents are caused by wind. Deep-water currents are created by differences in the density of ocean water. Several factors affect water density. One is temperature. Do the lab below to see how temperature differences create deep-water currents.



1. In a bowl, mix ice and cold water to make ice water.
2. Fill a beaker with warm tap water.
3. Add a few drops of food coloring to the ice water and stir the mixture.
4. Use a dropper to place some of this ice water on top of the warm water.
5. **Think Critically** In your Science Journal, describe what happened. Did adding cold water on top produce a current? Look up the word *convection* in a dictionary. Infer why the current you created is called a convection current.



Preview this chapter's content and activities at [earth.msscience.com](http://earth.msscience.com)

## FOLDABLES™ Study Organizer

**Ocean Motion** Make the following Foldable to help you understand the cause-and-effect relationship of ocean motion.

- STEP 1** **Fold** a vertical sheet of paper in half from top to bottom.



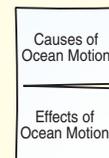
- STEP 2** **Fold** in half from side to side with the previous fold at the top.



- STEP 3** **Unfold** the paper once. **Cut** only the fold of the top flap to make two tabs.



- STEP 4** **Turn** the paper vertically and **label** the front tabs as shown.



**Read and Write** As you read the chapter, write what you learn about why the ocean moves and the effects of ocean motion under the appropriate tabs.

# Ocean Water

## as you read

### What You'll Learn

- **Identify** the origin of the water in Earth's oceans.
- **Explain** how dissolved salts and other substances get into seawater.
- **Describe** the composition of seawater.

### Why It's Important

Oceans are a reservoir of valuable food, energy, and mineral resources.

### Review Vocabulary

**resource:** a reserve source of supply, such as a material or mineral

### New Vocabulary

- basin
- salinity

## Importance of Oceans

Imagine yourself lying on a beach and listening to the waves gently roll onto shore. A warm breeze blows off the water, making it seem as if you're in a tropical paradise. It's easy to appreciate the oceans under these circumstances, but the oceans affect your life in other ways, too.

**Varied Resources** Oceans are important sources of food, energy, and minerals. **Figure 1** shows two examples of food resources collected from oceans. Energy sources such as oil and natural gas are found beneath the ocean floor. Oil wells often are drilled in shallow water. Mineral resources including copper and gold are mined in shallow waters as well. Approximately one-third of the world's table salt is extracted from seawater through the process of evaporation. Oceans also allow for the efficient transportation of goods. For example, millions of tons of oil, coal, and grains are shipped over the oceans each year.



### Reading Check

*What resources come from oceans?*

**Figure 1** People depend on the oceans for many resources.



Krill are tiny, shrimplike animals that live in the Antarctic Ocean. Some cultures use krill in noodles and rice cakes.



Kelp is a fast-growing seaweed that is a source of algin, used in making ice cream, salad dressing, medicines, and cosmetics.

## Origin of Oceans

During Earth's first billion years, its surface, shown in the top portion of **Figure 2**, was much more volcanically active than it is today. When volcanoes erupt, they spew lava and ash, and they give off water vapor, carbon dioxide, and other gases. Scientists hypothesize that about 4 billion years ago, this water vapor began to be stored in Earth's early atmosphere. Over millions of years, it cooled enough to condense into storm clouds. Torrential rains began to fall. Shown in the bottom portion of **Figure 2**, oceans were formed as this water filled low areas on Earth called **basins**. Today, approximately 70 percent of Earth's surface is covered by ocean water.

## Composition of Oceans

Ocean water contains dissolved gases such as oxygen, carbon dioxide, and nitrogen. Oxygen is the gas that almost all organisms need for respiration. It enters the oceans in two ways—directly from the atmosphere and from organisms that photosynthesize. Carbon dioxide enters the ocean from the atmosphere and from organisms when they respire. The atmosphere is the only important source of nitrogen gas. Bacteria combine nitrogen and oxygen to create nitrates, which are important nutrients for plants.

If you've ever tasted ocean water, you know that it is salty. Ocean water contains many dissolved salts. Chloride, sodium, sulfate, magnesium, calcium, and potassium are some of the ions in seawater. An ion is a charged atom or group of atoms. Some of these ions come from rocks that are dissolved slowly by rivers and groundwater. These include calcium, magnesium, and sodium. Rivers carry these chemicals to the oceans. Erupting volcanoes add other ions, such as bromide and chloride.



*How do sodium and chloride ions get into seawater?*

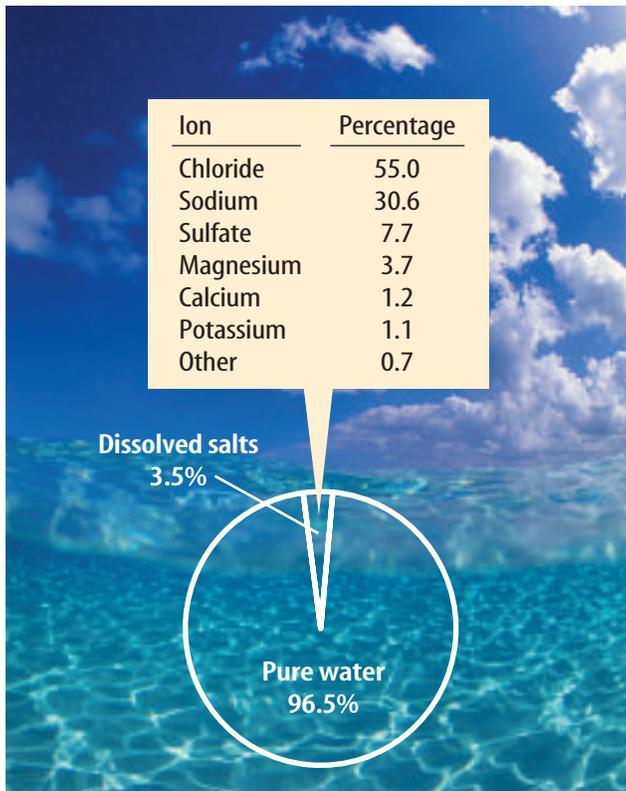
**Figure 2** Earth's oceans formed from water vapor.



Water vapor was released into the atmosphere by volcanoes that also gave off other gases, such as carbon dioxide and nitrogen.



Condensed water vapor formed storm clouds. Oceans formed when basins filled with water from torrential rains.



**Figure 3** Ocean water contains about 3.5 percent dissolved salts.

**Calculate** If you evaporated 1,000 g of seawater, how many grams of salt would be left?

**Salts** The most abundant elements in sea water are the hydrogen and oxygen that make up water. Many other ions are found dissolved in seawater. When seawater is evaporated, these ions combine to form materials called salts. Sodium and chloride make up most of the ions in seawater. If seawater evaporates, the sodium and chloride ions combine to form a salt called halite. Halite is the common table salt you use to season food. It is this dissolved salt and similar ones that give ocean water its salty taste.

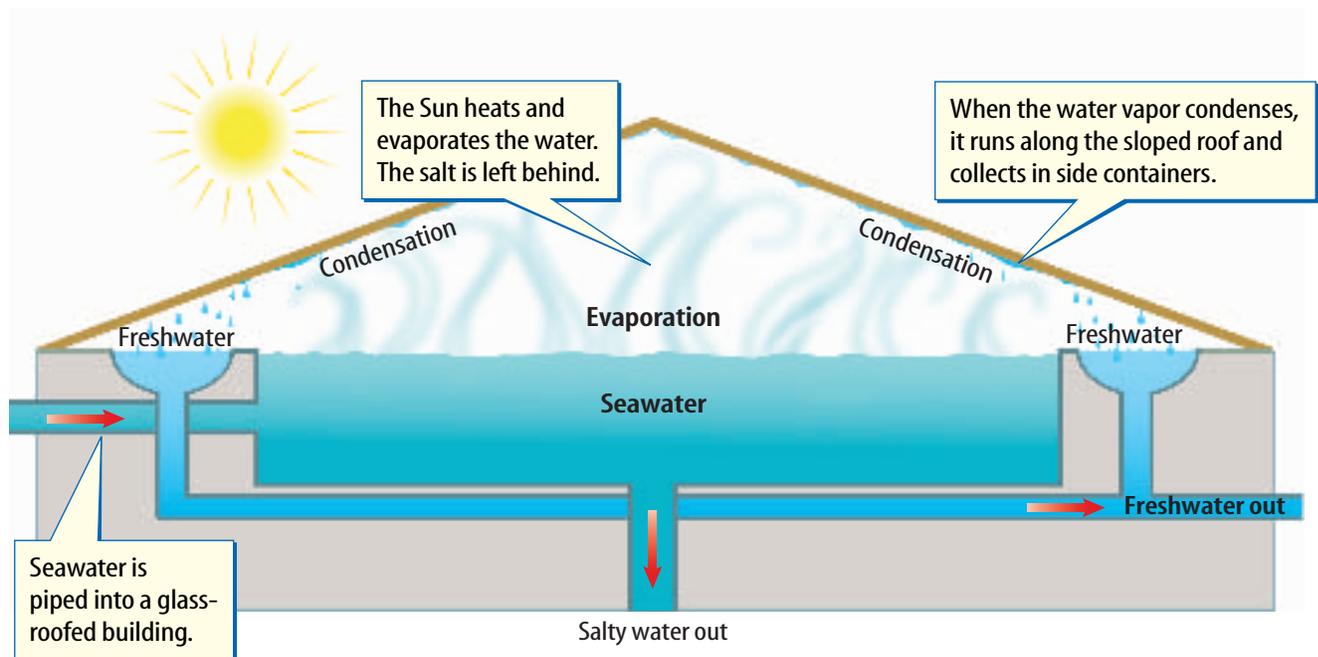
**Salinity** (say LIH nuh tee) is a measure of the amount of salts dissolved in seawater. It usually is measured in grams of dissolved salt per kilogram of seawater. One kilogram of ocean water contains about 35 g of dissolved salts, or 3.5 percent. The chart in **Figure 3** shows the most abundant ions in ocean water. The proportion and amount of dissolved salts in seawater remain nearly constant and have stayed about the same for hundreds of millions of years. This tells you

that the composition of the oceans is in balance. Evidence that scientists have gathered indicates that Earth’s oceans are not growing saltier.



**Removal of Elements** Although rivers, volcanoes, and the atmosphere constantly add material to the oceans, the oceans are considered to be in a steady state. This means that elements are added to the oceans at about the same rate that they are removed. Dissolved salts are removed when they precipitate out of ocean water and become part of the sediment. Some marine organisms use dissolved salts to make body parts. Some remove calcium ions from the water to form bones. Other animals, such as oysters, use the dissolved calcium to form shells. Some algae, called diatoms, have silica shells. Because many organisms use calcium and silicon, these elements are removed more quickly from seawater than elements such as chlorine or sodium.

**Desalination** Salt can be removed from ocean water by a process called desalination (dee sa luh NAY shun). If you have ever swum in the ocean, you know what happens when your skin dries. The white, flaky substance on your skin is salt. As seawater evaporates, salt is left behind. As demand for freshwater increases throughout the world, scientists are working on technology to remove salt to make seawater drinkable.



**Desalination Plants** Some methods of desalination include evaporating seawater and collecting the freshwater as it condenses on a glass roof. **Figure 4** shows how a desalination plant that uses solar energy works. Other plants desalinate water by passing it through a membrane that removes the dissolved salts. Freshwater also can be obtained by melting frozen seawater. As seawater freezes, the ice crystals that form contain much less salt than the remaining water. The salty, unfrozen water then can be separated from the ice. The ice can be washed and melted to produce freshwater.

**Figure 4** This desalination plant uses solar energy to produce freshwater.

## section 1 review

### Summary

#### Importance of Oceans

- Oceans are a source of food, energy, and minerals.
- Oceans allow for the efficient transportation of goods such as oil, coal, and grains.

#### Origin of Oceans

- Scientists hypothesize that about 4 billion years ago, water vapor from volcanic eruptions cooled and condensed into storm clouds. Oceans formed as water from torrential rains filled Earth's basins.

#### Composition of Oceans

- Ocean water contains dissolved gases and salts.
- Oceans are considered to be in a steady state.

### Self Check

1. **Describe** five ways Earth's oceans affect your life.
2. **Explain** the relationship between volcanic activity and the origin of Earth's oceans.
3. **Identify** the components of seawater. How do dissolved salts enter oceans? How does oxygen enter oceans?
4. **Think Critically** Organisms in the oceans are important sources of food and medicine. What steps can humans take to ensure that these resources are available for future generations?

### Applying Math

5. **Use Proportions** If the average salinity of seawater is 35 parts per thousand, how many grams of dissolved salts will 500 g of seawater contain?

# Ocean Currents

as you read

**What You'll Learn**

- **Explain** how winds and the Coriolis effect influence surface currents.
- **Discuss** the temperatures of coastal waters.
- **Describe** density currents.

**Why It's Important**

Ocean currents and the atmosphere transfer heat that affects the climate you live in.

**Review Vocabulary**

**circulation:** a water current flow occurring in an area in a closed, circular pattern

**New Vocabulary**

- surface current
- Coriolis effect
- upwelling
- density current

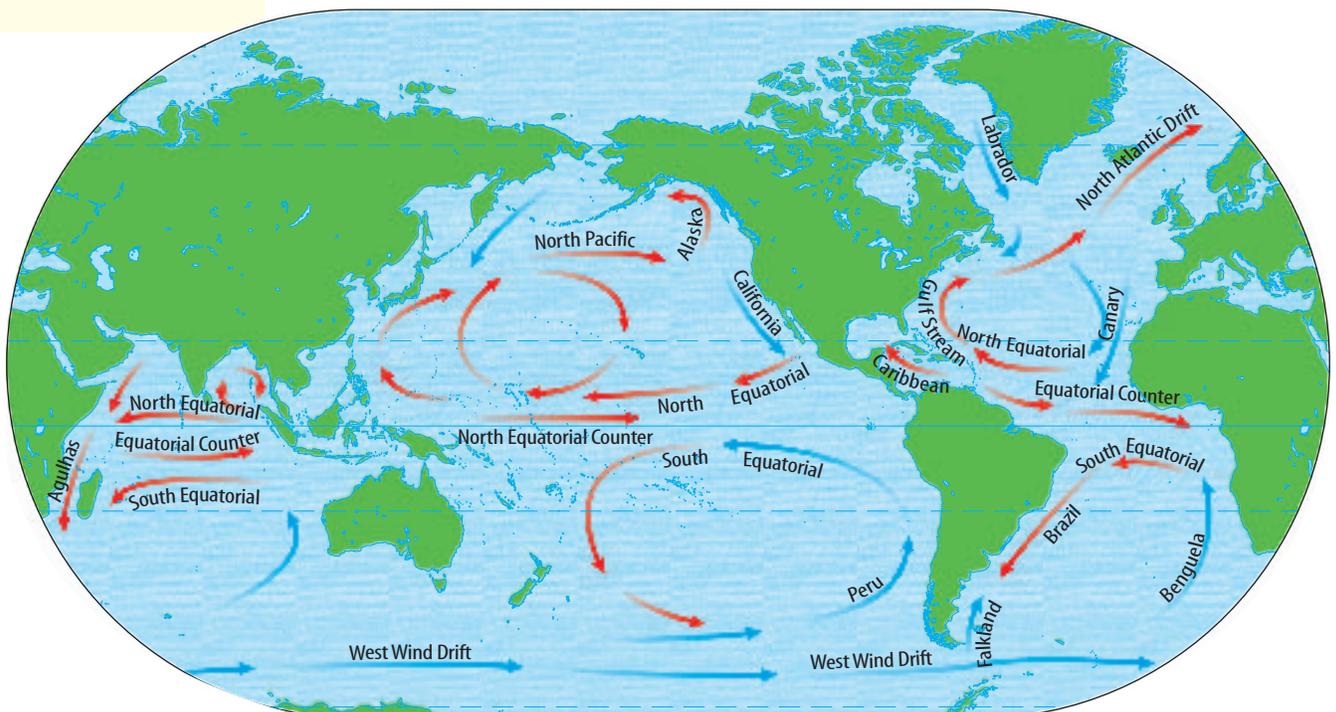
## Surface Currents

When you stir chocolate into a glass of milk, do you notice the milk swirling around in the glass in a circle? If so, you've observed something similar to an ocean current. Ocean currents are a mass movement, or flow, of ocean water. An ocean current is like a river within the ocean.

**Surface currents** move water horizontally—parallel to Earth's surface. These currents are powered by wind. The wind forces the ocean to move in huge, circular patterns. **Figure 5** shows these major surface currents. Notice that some currents are shown with red arrows and some are shown with blue arrows. Red arrows indicate warm currents. Blue arrows indicate cold currents. The currents on the ocean's surface are related to the general circulation of winds on Earth.

Surface currents move only the upper few hundred meters of seawater. Some seeds and plants are carried between continents by surface currents. Sailors take advantage of these currents along with winds to sail more efficiently from place to place.

**Figure 5** These are the major surface currents of Earth's oceans.



## How Surface Currents Form

Surface ocean currents and surface winds are affected by the Coriolis (kor ee OH lus) effect. The **Coriolis effect** is the shifting of winds and surface currents from their expected paths that is caused by Earth's rotation. Imagine that you try to draw a line straight out from the center of a disk to the edge of the disk. You probably could do that with no problem. But what would happen if the disk were slowly spinning like the one in

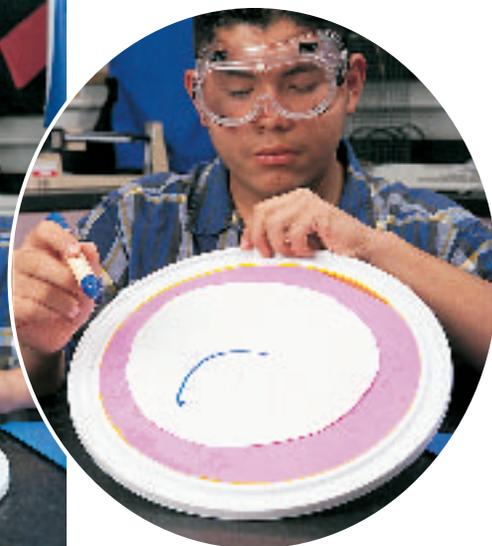


**Figure 6?** As the student tried to draw a straight line, the disk rotated and, as shown in **Figure 6**, the line curved.

A similar thing happens to wind and surface currents. Because Earth rotates toward the east, winds appear to curve to the right in the northern hemisphere and to the left in the southern hemisphere. These surface winds can cause water to pile up in certain parts of the ocean. When gravity pulls water off the pile, the Coriolis effect turns the water. This causes surface water in the oceans to spiral around the piles of water. The Coriolis effect causes currents north of the equator to turn to the right. Currents south of the equator are turned to the left. Look again at the map of surface currents in **Figure 5** to see the results of the Coriolis effect.

**The Gulf Stream** Although satellites provide new information about ocean movements, much of what is known about surface currents comes from records that were kept by sailors of the nineteenth century. Sailors always have used surface currents to help them travel quickly. Sailing ships depend on some surface currents to carry them to the west and others to carry them east. During the American colonial era, ships floated on the 100-km-wide Gulf Stream current to go quickly from North America to England. Find the Gulf Stream current in the Atlantic Ocean on the map in **Figure 5**.

In the late 1700s, Deputy Postmaster General Benjamin Franklin received complaints about why it took longer to receive a letter from England than it did to send one there. Upon investigation, Franklin found that a Nantucket whaling captain's map furnished the answer. Going against the Gulf Stream delayed ships sailing west from England by up to 110 km per day.



**Figure 6** The student draws a line straight out from the center while spinning the disk. Because the disk was spinning, the line is curved.

**Describe** how the Coriolis effect influences surface currents in the southern hemisphere.



### Topic: Ocean Currents

Visit [earth.msscience.com](http://earth.msscience.com) for Web links to information about ocean currents.

**Activity** Choose an area of the world's oceans and make a map of the currents in that area. In which direction do they travel? What are the currents named?



**Figure 7** Bottles and other floating objects that enter the ocean are used to gain information about surface currents.

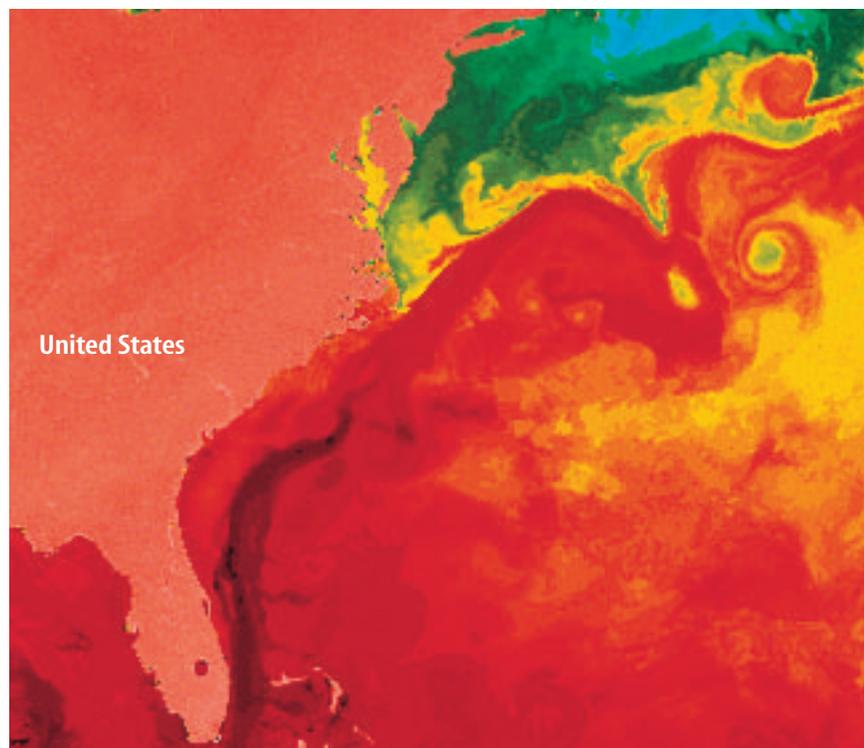
**Tracking Surface Currents** Items that wash up on beaches, such as the bottle shown in **Figure 7**, provide information about ocean currents. Drift bottles containing messages and numbered cards are released from a variety of coastal locations. The bottles are carried by surface currents and might end up on a beach. The person who finds a bottle writes down the date and the location where the bottle was found. Then the card is sent back to the institution that launched the bottle. By doing this, valuable information is provided about the current that carried the bottle.

**Warm and Cold Surface Currents** Notice in **Figure 5** that currents on the west coasts of continents begin near the poles where the water is colder. The California Current that flows along the west coast of the United States is a cold surface current. East-coast currents originate near the equator where the water is warmer. Warm surface currents, such as the Gulf Stream, distribute heat from equatorial regions to other areas of Earth. **Figure 8** shows the warm water of the Gulf Stream in red and orange. Cooler water appears in blue and green.

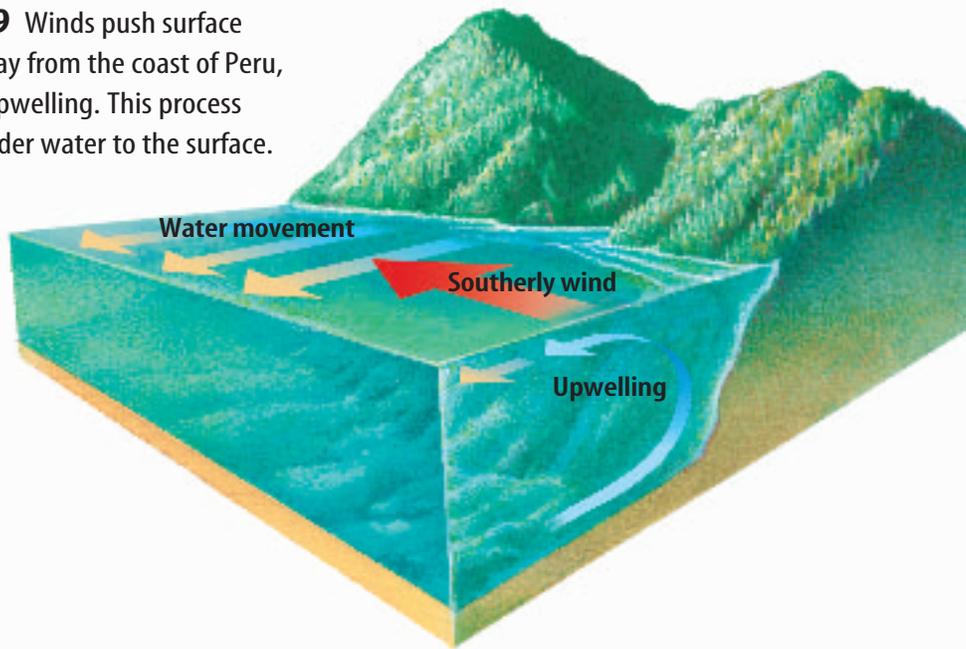
As warm water flows away from the equator, heat is released to the atmosphere. The atmosphere is warmed. This transfer of heat influences climate.

**Figure 8** Data about ocean temperature collected by a satellite were used to make this surface-temperature image of the Atlantic Ocean.

**Infer** *Where does the Gulf Stream originate?*



**Figure 9** Winds push surface water away from the coast of Peru, causing upwelling. This process brings colder water to the surface.



## Upwelling

**Upwelling** is a vertical circulation in the ocean that brings deep, cold water to the ocean surface. Along some coasts of continents, wind blowing parallel to the coast carries water away from the land because of the Coriolis effect, as shown in **Figure 9**. Cold, deep ocean water rises to the surface and replaces water that has moved away from shore. This water contains high concentrations of nutrients from organisms that died, sank to the bottom, and decayed. Nutrients promote primary production and plankton growth, which attracts fish. Areas of upwelling occur along the coasts of Oregon, Washington, and Peru and create important fishing grounds.

## Density Currents

Deep in the ocean, waters circulate not because of wind but because of density differences. A **density current** forms when a mass of seawater becomes more dense than the surrounding water. Gravity causes more dense seawater to sink beneath less dense seawater. This deep, dense water then slowly spreads to the rest of the ocean.

The density of seawater increases if salinity increases, as you can see if you perform the MiniLAB on this page. It also increases when temperature decreases. In the Launch Lab at the beginning of the chapter, the cold water was more dense than the warm water in the beaker. The cold water sank to the bottom. This created a density current that moved the food coloring.

Changes in temperature and salinity work together to create density currents. Density currents circulate ocean water slowly.

### Mini LAB

#### Modeling a Density Current

##### Procedure

1. Fill a clear-plastic storage box (shoe-box size) with room-temperature water.
2. Mix several spoonfuls of table salt into a glass of water at room temperature.
3. Add a few drops of food coloring to the saltwater solution. Pour the solution slowly into the freshwater in the large container.

##### Analysis

1. Describe what happened when you added salt water to freshwater.
2. How does this lab model density currents?





## INTEGRATE Career

**Oceanographer** An oceanographer studies the composition of ocean water; ocean currents, waves, and tides; and marine life. Dr. Robert D. Ballard is an oceanographer who revolutionized deep-sea archaeology. He developed several high-tech vessels that can explore ocean bottoms previously out of reach.

**Deep Waters** An important density current begins in Antarctica where the most dense ocean water forms during the winter. As ice forms, seawater freezes, but the salt is left behind in the unfrozen water. This extra salt increases the salinity and, therefore, the density of the ocean water until it is very dense. This dense water sinks and slowly spreads along the ocean bottom toward the equator, forming a density current. In the Pacific Ocean, this water could take 1,000 years to reach the equator.

In the North Atlantic Ocean, cold, dense water forms around Norway, Greenland, and Labrador. These waters sink, forming North Atlantic Deep Water. In about the northern one-third to one-half of the Atlantic Ocean, North Atlantic Deep Water forms the bottom layer of ocean water. In the southern part of the Atlantic Ocean, it flows at depths of about 3,000 m, just above the denser water formed near Antarctica. The dense waters circulate more quickly in the Atlantic Ocean than in the Pacific Ocean. In the Atlantic, a density current could circulate in 275 years.

## Applying Math

## Calculate Density

**DENSITY OF SALT WATER** You have an aquarium full of freshwater in which you have dissolved salt. If the mass of the salt water is 123,000 g and its volume is 120,000 cm<sup>3</sup>, what is the density of the salt water?

### Solution

- 1 *This is what you know:*
  - volume:  $v = 120,000 \text{ cm}^3$
  - mass of salt water:  $m = 123,000 \text{ g}$
- 2 *This is what you need to find:* density of water:  $d$
- 3 *This is the equation you need to use:*  $d = m/v$
- 4 *Substitute the known values:*  $d = 123,000\text{g} / 120,000\text{cm}^3 = 1.025 \text{ g/cm}^3$
- 5 *Check your answer:* Multiply your answer by the volume. Do you calculate the same mass of salt water that was given?

## Practice Problems

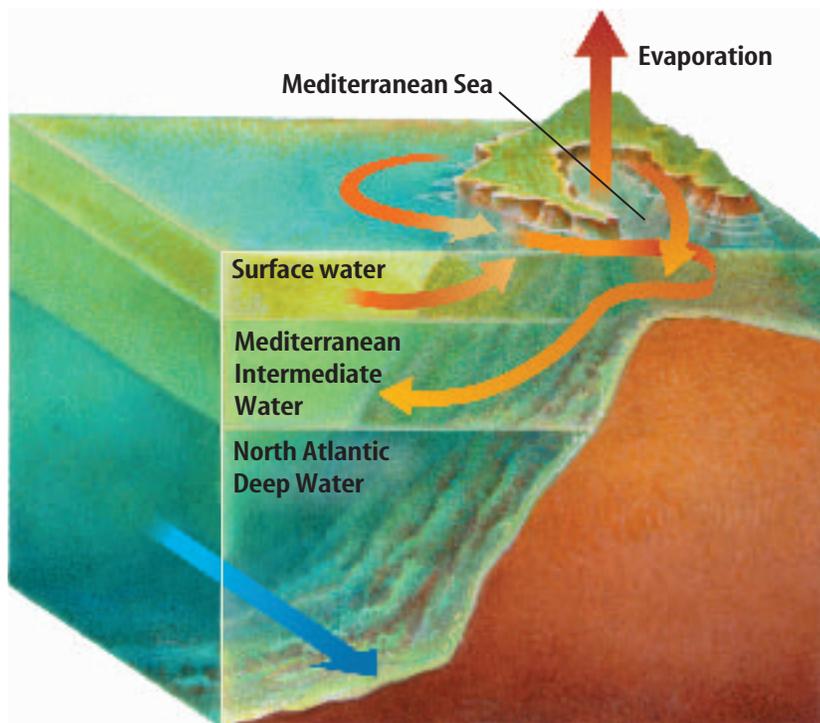
1. Calculate the density of 78,000 cm<sup>3</sup> of salt water with a mass of 79,000 g.
2. If a sample of ocean water has a density of 1.03 g/cm<sup>3</sup> and a mass of 50,000 g, what is the volume of the water?



For more practice, visit  
[earth.msscience.com/  
math\\_practice](http://earth.msscience.com/math_practice)

## Intermediate Waters

A density current also occurs in the Mediterranean Sea, a nearly enclosed body of water. The warm temperatures and dry air in the region cause large amounts of water to evaporate from the surface of the sea. This evaporation increases the salinity and density of the water. This dense water from the Mediterranean flows through the narrow Straits of Gibraltar into the Atlantic Ocean at a depth of about 320 m. When it reaches the Atlantic, it flows to depths of 1,000 m to 2,000 m because it is more dense than the water in the upper parts of the North Atlantic Ocean. However, the water from the Mediterranean is less dense than the very cold, salty water flowing from the North Atlantic Ocean around Greenland, Norway, and Labrador. Therefore, as shown in **Figure 10**, the Mediterranean water forms a middle layer of water—the Mediterranean Intermediate Water.



**Figure 10** Dense layers of North Atlantic Deep Water form in the Greenland, Labrador, and Norwegian Seas. This water flows southward along the North Atlantic seafloor. Less dense water from the Mediterranean Sea forms Mediterranean Intermediate Water.

### ✓ Reading Check

What causes the Mediterranean Intermediate Water to form?

## section 2 review

### Summary

#### Surface Currents

- Surface currents are wind-powered ocean currents that move water horizontally.

#### Upwelling

- Upwelling is vertical circulation that brings deep, cold water to the ocean surface.

#### Density Currents

- Gravity acts on masses of seawater that are denser than surrounding water, causing the denser water to sink.
- Density currents slowly circulate deep ocean water.

### Self Check

1. **Explain** how winds and the Coriolis effect influence surface currents.
2. **Summarize** why upwelling is important.
3. **Describe** how density currents circulate water.
4. **Think Critically** The latitudes of San Diego, California, and Charleston, South Carolina, are exactly the same. However, the average yearly water temperature in the ocean off Charleston is much higher than the water temperature off San Diego. Explain why.

### Applying Skills

5. **Predict** what will happen to a layer of freshwater as it flows into the ocean. Explain your prediction.

# Ocean Waves and Tides

Jack Fields/Photo Researchers

## as you read

### What You'll Learn

- **Describe** wave formation.
- **Distinguish** between the movement of water particles in a wave and the movement of the wave.
- **Explain** how ocean tides form.

### Why It's Important

Waves and tides affect life and property in coastal areas.

### Review Vocabulary

**energy:** the ability to cause change

### New Vocabulary

- wave
- crest
- trough
- breaker
- tide
- tidal range

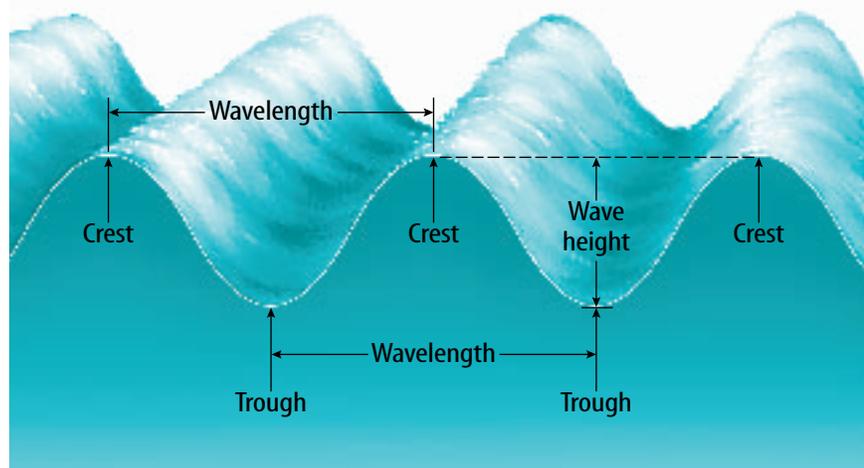
**Figure 11** Ocean waves carry energy through seawater.

## Waves

If you've been to the seashore or seen a beach on TV, you've watched waves roll in. There is something hypnotic about ocean waves. They keep coming and coming, one after another. But what is an ocean wave? A **wave** is a rhythmic movement that carries energy through matter or space. In the ocean, waves like those in **Figure 11** move through seawater.

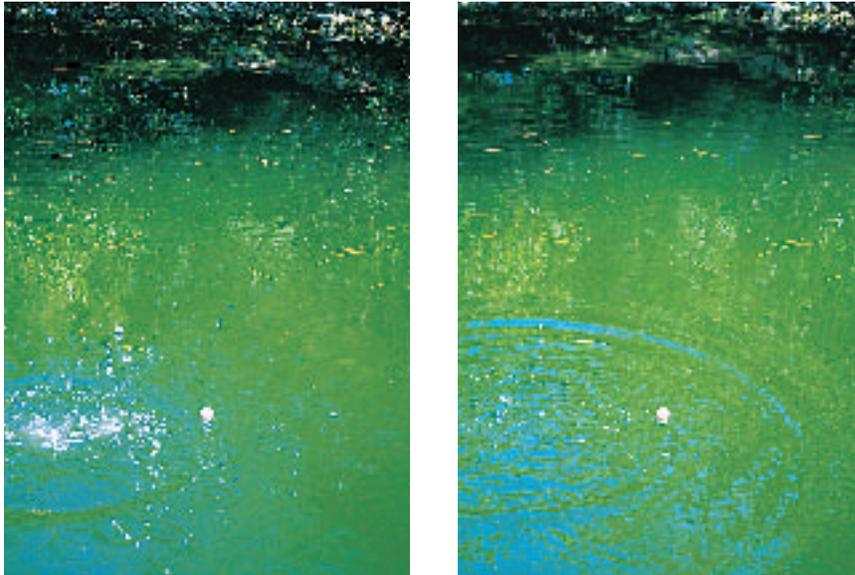
**Describing Waves** Several terms are used to describe waves, as shown in **Figure 11**. Notice that waves look like hills and valleys. The **crest** is the highest point of the wave. The **trough** (TRAWF) is the lowest point of the wave. Wavelength is the horizontal distance between the crests or between the troughs of two adjacent waves. Wave height is the vertical distance between crest and trough.

Half the distance of the wave height is called the amplitude (AM pluh tewd) of the wave. The amplitude squared is proportional to the amount of energy the wave carries. For example, a wave with twice the amplitude of the wave in **Figure 11** carries four times ( $2 \times 2 = 4$ ) the energy. On a calm day, the amplitude of ocean waves is small. But during a storm, wave amplitude increases and the waves carry a lot more energy. Large waves can damage ships and coastal property.



The crest, trough, wavelength, and wave height describe a wave. **Identify** the crests and troughs in the photo on the left.





**Figure 12** As a wave passes, only energy moves forward. The water particles and the bobber nearly return to their original positions after the wave has passed. **Describe** what happens to water movement below a depth equal to about half the wavelength.

**Wave Movement** You might have noticed that if you throw a pebble into a pond, a circular wave moves outward from where the pebble entered the water, as shown in **Figure 12**. A bobber on a fishing line floating in the water will bob up and down as the wave passes, but it will not move outward with the wave. Notice that the bobber returns to near its original position.

When you watch an ocean wave, it looks as though the water is moving forward. But unless the wave is breaking onto shore, the water does not move forward. Each molecule of water returns to near its original position after the wave passes. **Figure 13** shows this. Water molecules in a wave move around in circles. Only the energy moves forward while the water molecules remain in about the same place. Below a depth equal to about half the wavelength, water movement stops. Below that depth, water is not affected by waves. Submarines that travel below this level usually are not affected by surface storms.

**Breakers** A wave changes shape in the shallow area near shore. Near the shoreline, friction with the ocean bottom slows water at the bottom of the wave. As the wave slows, its crest and trough come closer together. The wave height increases. The top of a wave, not slowed by friction, moves faster than the bottom. Eventually, the top of the wave outruns the bottom and it collapses. The wave crest falls as water tumbles over on itself. The wave breaks onto the shore. **Figure 13** also shows this process. This collapsing wave is a **breaker**. It is the collapse of this wave that propels a surfer and surfboard onto shore. After a wave breaks onto shore, gravity pulls the water back into the sea.

 **Reading Check** What causes an ocean wave to slow down?

## Mini LAB

### Modeling Water Particle Movement

**Procedure**   

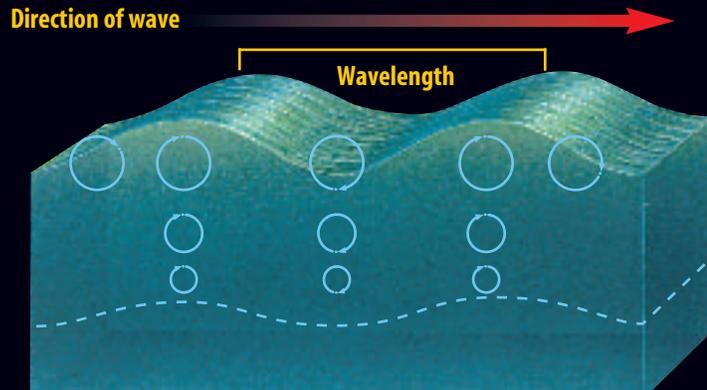
1. Put a piece of **tape** on the outside bottom of a **rectangular, clear-plastic storage box**. Fill the box with **water**.
2. Float a **cork** in the container above the piece of tape.
3. Use a **spoon** to make gentle waves in the container.
4. Observe the movement of the waves and the cork.

### Analysis

1. Describe the movement of the waves and the motion of the cork.
2. Compare the movement of the cork in the water with the movement of water molecules in a wave.

**Figure 13**

**A**s ocean waves move toward the shore, they seem to be traveling in from a great distance, hurrying toward land. Actually, the water in waves moves relatively little, as shown here. It's the energy in the waves that moves across the ocean surface. Eventually that energy is transferred—in a crash of foam and spray—to the land.

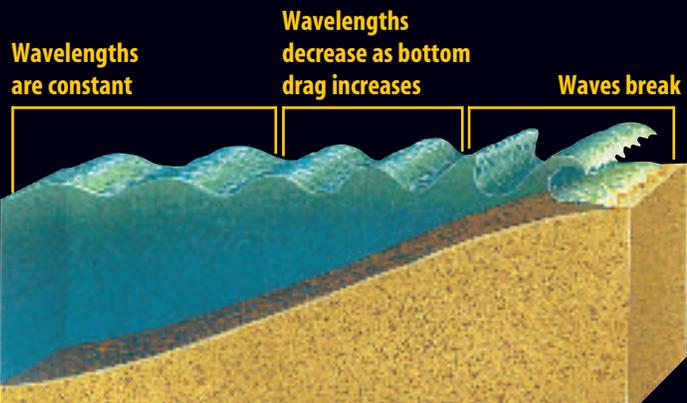


**A** Particles of water move around in circles rather than forward. Near the water's surface, the circles are relatively large. Below the surface, the circles become progressively smaller. Little water movement occurs below a depth equal to about one-half of a wave's length.

**B** The energy in waves, however, does move forward. One way to visualize this energy movement is to imagine a line of dominoes. Knock over the first domino, and the others fall in sequence. As they fall, individual dominoes—like water particles in waves—remain close to where they started. But each transfers its energy to the next one down the line.



**C** As waves approach shore, wavelength decreases and wave height increases. This causes breakers to form. Where ocean floor rises steeply to beach, incoming waves break quickly at a great height, forming huge arching waves.





**Figure 14** Waves formed by storm winds can reach heights of 20 m to 30 m.

**List** the three factors that affect wave height.

**How Water Waves Form** On a windy day, waves form on a lake or ocean. When wind blows across a body of water, wind energy is transferred to the water. If the wind speed is great enough, the water begins to pile up, forming a wave. As the wind continues to blow, the wave increases in height. Some waves reach tremendous heights, as shown in **Figure 14**. Storm winds have been known to produce waves more than 30 m high—taller than a six-story building.

The height of waves depends on the speed of the wind, the distance over which the wind blows, and the length of time the wind blows. When the wind stops blowing, waves stop forming. But once set in motion, waves continue moving for long distances, even if the wind stops. The waves you see lapping at a beach could have formed halfway around the world.

 **Reading Check** *What factors affect the height of waves?*

## Tides

When you go to a beach, you probably notice the level of the sea rise and fall during the day. This rise and fall in sea level is called a **tide**. A tide is caused by a giant wave produced by the gravitational pull of the Sun and the Moon. This wave has a wave height of only 1 m or 2 m, but it has a wavelength that is thousands of kilometers long. As the crest of this wave approaches the shore, sea level appears to rise. This rise in sea level is called high tide. Later, as the trough of the wave approaches, sea level appears to drop. This drop in sea level is referred to as low tide.



### Topic: Tides

Visit [earth.msscience.com](http://earth.msscience.com) for Web links to information about tides.

**Activity** There are three types of tides: diurnal, semidiurnal, and mixed. Define each type and give an example of where each type occurs.

**Figure 15** A large difference between high tide and low tide can be seen at Mont-Saint-Michel off the northwestern coast of France.



Incoming tides move very quickly, making Mont-Saint-Michel an island at high tide.

Mont-Saint-Michel lies about 1.6 km offshore and is connected to the mainland at low tide.

**Figure 16** The Bay of Fundy has the greatest tidal range in the world.

**Infer** Was this picture taken at high tide or low tide?



**Tidal Range** As Earth rotates, different locations on Earth's surface pass through the high and low positions. Many coastal locations, such as the Atlantic and Pacific coasts of the United States, experience two high tides and two low tides each day. One low-tide/high-tide cycle takes 12 h, 25 min. A daily cycle of two high tides and two low tides takes 24 h, 50 min—slightly more than a day. But because ocean basins vary in size and shape, some coastal locations, such as many along the Gulf of Mexico, have only one high and one low tide each day. The **tidal range** is the difference between the level of the ocean at high tide and low tide. Notice the tidal range in the photos in **Figure 15**.

**Extreme Tidal Ranges** The shape of the seacoast and the shape of the ocean floor affect the ranges of tides. Along a smooth, wide beach, the incoming water can spread over a large area. There the water level might rise only a few centimeters at high tide. In a narrow gulf or bay, however, the water might rise many meters at high tide.

Most shorelines have tidal ranges between 1 m and 2 m. Some places, such as those on the Mediterranean Sea, have tidal ranges of only about 30 cm. Other places have large tidal ranges. Mont-Saint-Michel, shown in **Figure 15**, lies in the Gulf of Saint-Malo off the northwestern coast of France. There the tidal range reaches about 13.5 m.

The dock shown in **Figure 16** is in Digby, Nova Scotia in the Bay of Fundy. This bay is extremely narrow, which contributes to large tidal ranges. The difference between water levels at high tide and low tide can be as much as 15 m.

**Tidal Bores** In some areas when a rising tide enters a shallow, narrow river from a wide area of the sea, a wave called a tidal bore forms. A tidal bore can have a breaking crest or it can be a smooth wave. Tidal bores tend to be found in places with large tidal ranges. The Amazon River in Brazil, the Tsientang River in China, and rivers that empty into the Bay of Fundy in Nova Scotia have tidal bores.

When a tidal bore enters a river, it causes water to reverse its flow. In the Amazon River, the tidal bore rushes 650 km upstream at speeds of 65 km/h, causing a wave more than 5 m in height. Four rivers that empty into the Bay of Fundy have tidal bores. In those rivers, bore rafting is a popular sport.

**The Gravitational Effect of the Moon** For the most part, tides are caused by the interaction of gravity in the Earth-Moon system. The Moon's gravity exerts a strong pull on Earth. Earth and the water in Earth's oceans respond to this pull. The water bulges outward as Earth and the Moon revolve around a common center of mass. These events are explained in **Figure 17**.

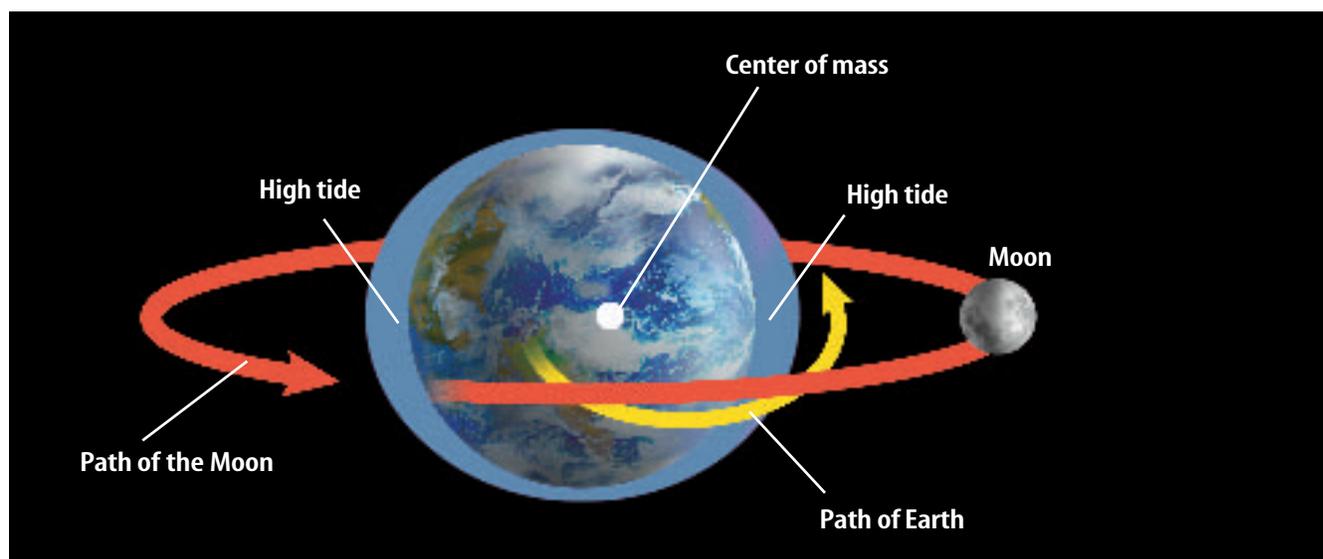
Two bulges of water form, one on the side of Earth closest to the Moon and one on the opposite side of Earth. The bulge on the side of Earth closest to the Moon is caused by the gravitational attraction of the Moon on Earth. The force of gravity here is greater than another, opposing force generated by the motion of Earth and the Moon. As a result, surface water is pulled in the direction of the Moon. The bulge on the opposite side of Earth is caused by the same opposing force that, here, is greater than the force of gravity. The imbalance in forces results in surface water being pulled away from the Moon. The ocean bulges are the high tides, and the areas of Earth's oceans that are not toward or away from the Moon are the low tides. As Earth rotates, different locations on its surface pass through high and low tide.

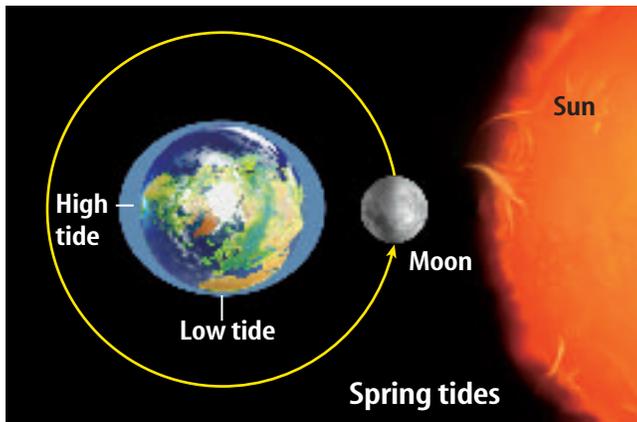


### Life in the Tidal Zone

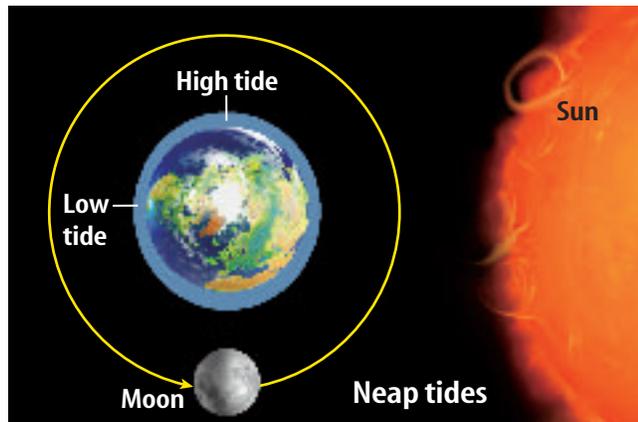
Limpets are sea snails that live on rocky shores. When the tide comes in, they glide over the rocks to graze on seaweed. When the tide goes out, they use strong muscles to pull their shells tight against the rocks. Find out how other organisms survive in the zone between high and low tides.

**Figure 17** The Moon and Earth revolve around a common center of mass. Because the Moon's gravity pulls harder on parts of Earth closer to the Moon, a bulge of water forms on the side of Earth facing the Moon and the side of Earth opposite the Moon.





When the Sun, the Moon, and Earth are aligned, spring tides occur.



When the Sun, Earth, and the Moon form a right angle, neap tides occur.

**Figure 18** The gravitational attraction of the Sun causes spring tides and neap tides.

**The Gravitational Effect of the Sun** The Sun also affects tides. The Sun can strengthen or weaken the Moon's effects. When the Moon, Earth, and the Sun are lined up together, the combined pull of the Sun and the Moon causes spring tides, shown in **Figure 18**. During spring tides, high tides are higher and low tides are lower than normal. The name *spring tide* has nothing to do with the season of spring. It comes from the German word *springen*, which means "to jump." When the Sun, Earth, and the Moon form a right angle, also shown in **Figure 18**, high tides are lower and low tides are higher than normal. These are called neap tides.

## section 3 review

### Summary

#### Waves

- A wave is a rhythmic movement that carries energy through matter or space.
- Water waves form as wind blows across a body of water.
- The height of a wave depends on the speed of the wind, the distance over which the wind blows, and the length of time the wind blows.

#### Tides

- Tides result from the gravitational pull of the Moon and the Sun on Earth.
- The shape of the seafloor and coast affect the range of tides in an area.
- Depending on the alignment of the Sun, the Moon, and Earth, spring tides or neap tides occur.

### Self Check

1. **Identify** the parts of an ocean wave.
2. **Explain** how wind creates water waves.
3. **Describe** what causes high tides. Describe what causes spring tides.
4. **Summarize** the movement of water molecules in a wave and wave movement.
5. **Think Critically** At the ocean, you spot a wave about 200 m from shore. A few seconds later, the wave breaks on the beach. Explain why the water in the breaker is not the same water that was in the wave 200 m away.

### Applying Skills

6. **Compare and contrast** the effects of the Sun and the Moon on Earth's tides.

## Wave Properties

Ocean wave energy impacts coastlines around the world. Understanding wave properties helps scientists predict the movement and effects of waves.

### Real-World Question

How are wave characteristics related to each other and to the energy source that causes waves?

#### Goals

- **Test** statements about wave properties.
- **Summarize** the relationship between wave properties and the energy source which causes waves.

#### Materials

rectangular, clear-plastic box  
 water  
 straw  
 metric ruler  
 3-cm chalk piece  
 3-cm ball aluminum foil

#### Safety Precautions

### Procedure

1. Copy the data table above.
2. Fill the clear, plastic box with water to a depth of about 5.5 cm.
3. Test statement 1. Hold the straw just above the water. Blow through the straw. Record your observations in your data table.
4. Test statement 2. Hold the straw just above the water at one end of the box. Blow gently and continuously. Use the metric ruler to compare the wavelengths close to the straw and on the other end of the box. Record your observations.

Statement	Observations
1. Wind causes waves.	
2. Wavelength increases as the distance from the energy sources increases.	
3. The effects of wave motion are felt relatively close to the surface only.	<b>Do not write in this book.</b>
4. Wave energy is transferred through the water: the water itself does not move forward with the wave.	

5. Test statement 3. Sink the chalk piece in the middle of the box. Hold the straw just above the water at one end of the box. Blow gently and continuously. Observe any movement of the chalk and record your observations.
6. Test statement 4. Float the aluminum foil ball in the middle of the box. Hold the straw just above the water at one end of the box. Blow gently and continuously. Observe and record any movement of the aluminum foil ball.

### Conclude and Apply

1. **Explain** how wind causes waves to form.
2. **Describe** Did your results support the statement *Wavelength increases as the distance from the energy source increases*? Why or why not?
3. **Explain** how you know the effects of wave motion are not felt below a certain depth.
4. **Infer** How did you prove that the water in a wave does not move forward with the wave? Did your observations surprise you? Why or why not?

# Sink or Float?

## Goals

■ **Design** an experiment to identify how increasing salinity affects the ability of a potato to float in water.

## Possible Materials

small, uncooked potato  
teaspoon  
salt  
large glass bowl  
water  
balance  
large graduated cylinder  
metric ruler

## Safety Precautions



## Real-World Question

As you know, ocean water contains many dissolved salts. How does this affect objects within the oceans? Why do certain objects float on top of the ocean's waves, while others sink directly to the bottom? Density is a measurement of mass per volume. You can use density to determine whether an object will float within a certain volume of water of a specific salinity. Based on what you know so far about salinity, why things float or sink, and the density of a potato, plus what it looks and feels like, formulate a hypothesis. Do you think the salinity of water has any effect on objects that are floating in water? What kind of effect? Will they float or sink? How would a dense object like a potato be different from a less dense object like a cork?



## Test Your Hypothesis

### Make a Plan

1. As a group, agree upon and write your hypothesis statement.
2. Devise a method to test how salinity affects whether a potato floats in water.
3. List the steps you need to take to test your hypothesis. Be specific, describing exactly what you will do at each step.
4. Read over your plan for testing your hypothesis.
5. How will you determine the densities of the potato and the different water samples? How will you measure the salinity of the water? How will you change the salinity of the water? Will you add teaspoons of salt one at a time?



## Using Scientific Methods

- How will you measure the ability of an object to float? Could you somehow measure the displacement of the water? Perhaps you could draw a line somewhere on your bowl and see how the position of the potato changes.
- Design** a data table where you can record your results. Include columns/rows for the salinity and float/sink measurements. What else should you include?

### Follow Your Plan

- Make sure your teacher approves your plan before you start.
- Carry out the experiment.
- While conducting the experiment, record your data and any observations that you or other group members make in your Science Journal.

### Analyze Your Data

- Compare** how the potato floated in water with different salinities.
- How does the ability of an object to float change with changing salinity?

### Conclude and Apply

- Did your experiment support the hypothesis you made?
- A heavily loaded ship barely floats in the Gulf of Mexico. Based on what you learned, infer what might happen to the ship if it travels into the freshwater of the Mississippi River.

### Communicating Your Data

**Prepare** a large copy of your data table and share the results of your experiment with members of your class. For more help, refer to the **Science Skill Handbook**.



## “The Jungle of Ceylon”

from *Passions and Impressions*

by Pablo Neruda



The following passage is part of a travel chronicle describing the Chilean poet Pablo Neruda’s visit to the island of Ceylon, now called Sri Lanka, which is located southeast of India. The author considered himself so connected to Earth that he wrote in green ink.

Felicitous<sup>1</sup> shore! A coral reef stretches parallel to the beach; there the ocean interposes in its blues the perpetual white of a rippling ruff<sup>2</sup> of feathers and foam; the triangular red sails of sampans<sup>3</sup>; the unmarred line of the coast on which the straight trunks of the coconut palms rise like explosions, their brilliant green Spanish combs nearly touching the sky.

... In the deep jungle, there is a silence like that of libraries: abstract and humid.

1 Happy

2 round collar made of layers of lace

3 East Asian boats



### Respond to the Reading

1. What were his impressions of the island on arrival?
2. What words does the author choose to describe waves?
3. **Linking Science and Writing** Write a weather report for fishers and others who work at sea.

### Linking Science and Writing

**Imagery** Imagery is a series of words that evoke pictures to the reader. Poets use imagery to connect images to abstract concepts. The poet, here, wants to capture a particular feature of the reef and does so by describing it as a “ruff of feathers and foam,” invoking the image of a gentle place, without the author saying so.

Where else in the poem does the poet use imagery to convey a mood or feeling?



Sri Lanka often is plagued by monsoons, which affect ocean conditions and local climate. Monsoons are seasonal reversals of the regional winds. During the wet season, moist winds blow in from the sea, causing storms and producing waves. During the dry season, winds blow from the land and sunny days are common.

Reviewing Main Ideas

**Section 1 Ocean Water**

1. Earth's ocean water might have originated from water vapor released from volcanoes. Over millions of years, the water condensed and rain fell, filling basins.
2. The oceans are a mixture of water, dissolved salts, and dissolved gases.
3. Ions are added to ocean water by rivers, volcanic eruptions, and the atmosphere. When seawater is evaporated, these ions combine to form salts.

**Section 2 Ocean Currents**

1. Wind causes surface currents. Surface currents are affected by the Coriolis effect.

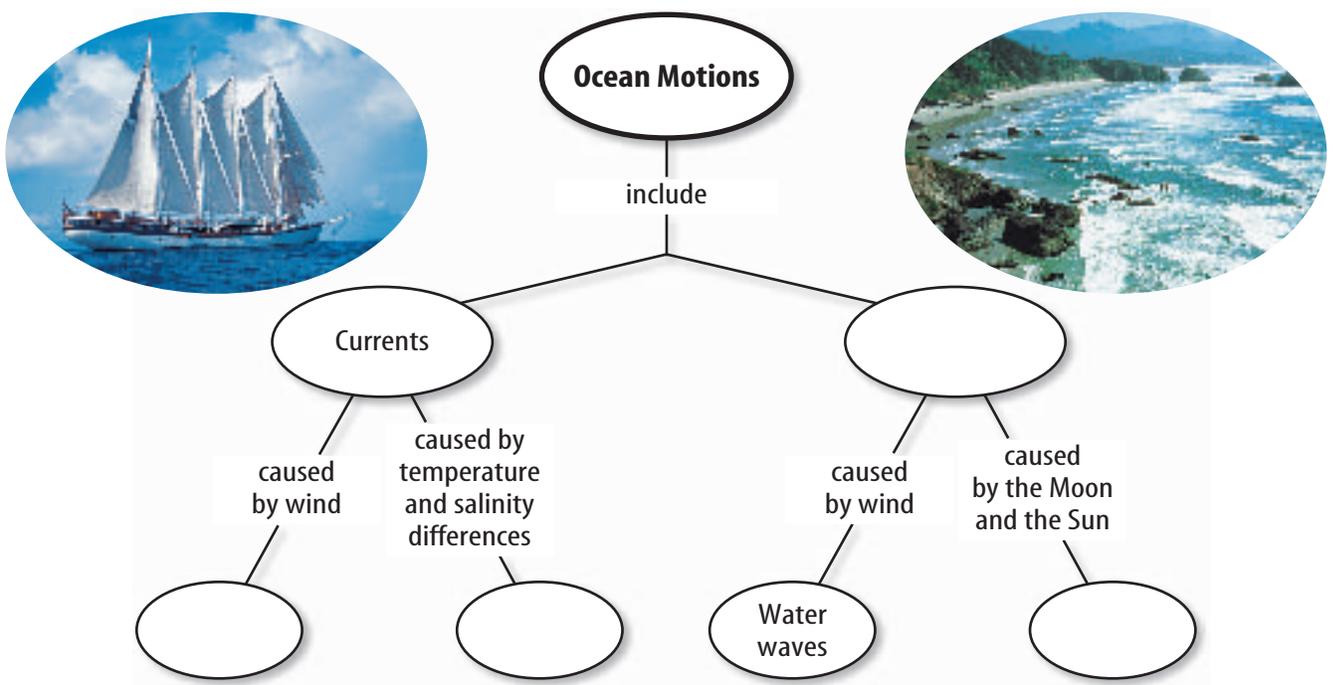
2. Cool currents off western coasts originate far from the equator. Warmer currents along eastern coasts begin near the equator.
3. Differences in temperature and salinity between water masses in the oceans set up circulation patterns called density currents.

**Section 3 Ocean Waves and Tides**

1. A wave is a rhythmic movement that carries energy.
2. In a wave, energy moves forward while water molecules move around in small circles.
3. Wind causes water to pile up and form waves. Tides are caused by gravitational forces.

Visualizing Main Ideas

Copy and complete the following concept map on ocean motions.



**Using Vocabulary**

basin p.515	surface current p.518
breaker p.525	tidal range p.528
Coriolis effect p.519	tide p.527
crest p.524	trough p.524
density current p.521	upwelling p.521
salinity p.516	wave p.524

Fill in the blanks with the correct vocabulary word or words.

- The \_\_\_\_\_ of seawater has stayed about the same for hundreds of millions of years.
- An area of \_\_\_\_\_ is a good place to catch fish.
- A(n) \_\_\_\_\_ is created when a mass of more dense water sinks beneath less dense water.
- Along most ocean beaches, a rise and fall of the ocean related to gravitational pull, or a(n) \_\_\_\_\_, is easy to see.
- The difference between the level of the ocean at high tide and low tide is \_\_\_\_\_.

**Checking Concepts**

Choose the word or phrase that best answers the question.

- Where might ocean water have originated?
 

A) salt marshes	C) basins
B) volcanoes	D) surface currents
- How does chloride enter the oceans?
 

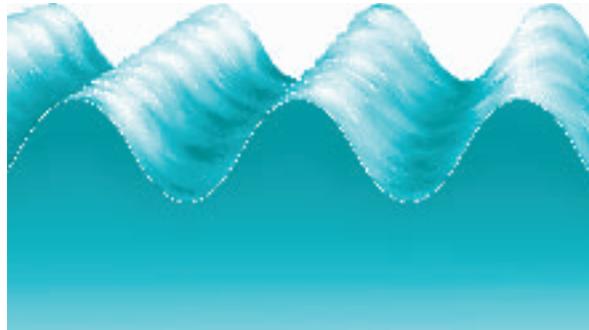
A) volcanoes	C) density currents
B) rivers	D) groundwater
- What is the most common ion found in ocean water?
 

A) chloride	C) boron
B) calcium	D) sulfate

- What causes most surface currents?
 

A) density differences
B) the Gulf Stream
C) salinity
D) wind

Use the illustration below to answer question 10.



- What is the highest point on a wave called?
 

A) wave height	C) crest
B) trough	D) wavelength
- In the ocean, what is the rhythmic movement that carries energy through seawater?
 

A) current	C) crest
B) wave	D) upwelling
- Which of the following causes the density of seawater to increase?
 

A) a decrease in temperature
B) a decrease in salinity
C) an increase in temperature
D) a decrease in pressure
- In which direction does the Coriolis effect cause currents in the northern hemisphere to turn?
 

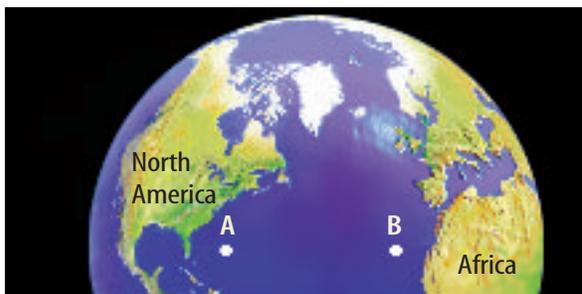
A) east	C) counterclockwise
B) south	D) clockwise
- Tides are affected by the positions of which celestial bodies?
 

A) Earth and the Moon
B) Earth, the Moon, and the Sun
C) Venus, Earth, and Mars
D) the Sun, Earth, and Mars

**Thinking Critically**

- 15. **Infer** If a sealed bottle is dropped into the ocean off the coast of California, where do you think it might wash up?
- 16. **Compare and contrast** the density of seawater at the mouth of the Mississippi River and in the Mediterranean Sea.
- 17. **Recognize Cause and Effect** What causes upwelling? What effect does it have? What can happen when upwelling stops?
- 18. **Compare and contrast** ocean waves and ocean currents.

Use the figure below to answer question 19.



- 19. **Predict** how drift bottles dropped into the ocean at points A and B will move. Explain.
- 20. **Recognize Cause and Effect** In the Mediterranean Sea, a density current forms because of the high rate of evaporation of water from the surface. How can evaporation cause a density current?
- 21. **Evaluate** One water mass has a temperature of 5°C and a salinity of 37 parts per thousand. Another water mass has a temperature of 10°C and a salinity of 35 parts per thousand. Which water mass will sit on top of the other? Why?
- 22. **Infer** In some areas tidal energy is used as an alternative energy source. What are some advantages and disadvantages of doing this?

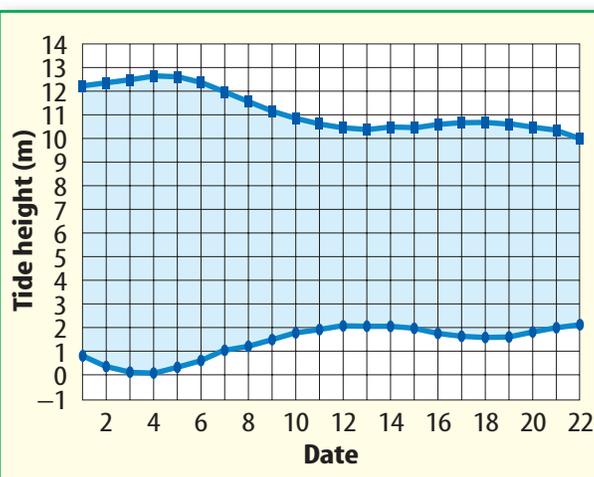
**Performance Activities**

- 23. **Invention** Design a method for desalinating water that does not use solar energy. Draw it, and display it for your class.
- 24. **Design and Perform an Experiment** Create an experiment to test the density of water at different temperatures.

**Applying Math**

- 25. **Wave Speed** Wave speed of deep water waves is calculated using the formula  $S = L/T$ , where  $S$  represents wave speed,  $L$  represents the wavelength, and  $T$  represents the period of the wave. What is the speed of a wave if  $L = 100$  m and  $T = 11$  s?
- 26. **Wave Steepness** The steepness of a wave is represented by the formula  $\text{Steepness} = H/L$ , where  $H =$  wave height and  $L =$  wavelength. When the steepness of a wave reaches  $1/7$ , the wave becomes unstable and breaks. If  $L = 50$  m, at what height will the wave break?

Use the graph below to answer question 27.



- 27. **Tides** The graph above shows the tidal ranges for each day. The maximum tidal range is called a spring tide. The minimum tidal range is referred to as a neap tide. Calculate the tidal range for the spring tide and the neap tide. On which date does each occur?

## Part 1 Multiple Choice

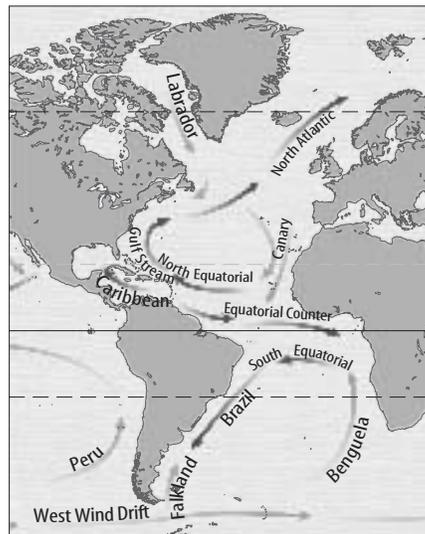
Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the table below to answer question 1.

Ions in Seawater	
Ion	Percentage
Chloride	55.0
Sodium	30.6
Sulfate	7.7
Magnesium	3.7
Calcium	1.2
Potassium	1.1
Other	0.7

- Which ion makes up 7.7 percent of the ions in seawater?
  - calcium
  - sulfate
  - chloride
  - sodium
- Which of the following dissolved gases enters ocean water both from the atmosphere and from organisms that photosynthesize?
  - carbon
  - nitrogen
  - hydrogen
  - oxygen
- Which of the following terms is used to describe the amount of dissolved salts in seawater?
  - density
  - temperature
  - salinity
  - buoyancy
- Which of the following describes upwelling?
  - horizontal ocean circulation that brings deep, cold water to the surface
  - vertical ocean circulation that brings deep, warm water to the surface
  - horizontal ocean circulation that brings deep, warm water to the surface
  - vertical ocean circulation that brings deep, cold water to the surface
- What is the lowest point on a wave called?
  - trough
  - wavelength
  - crest
  - wave height

Use the illustration below to answer questions 6 and 7.



- What is the direction of ocean currents in the southern hemisphere?
  - counterclockwise
  - north to south only
  - clockwise
  - east to west only
- Which of the following is a reasonable conclusion based on the information in the figure?
  - The oceans' currents only flow in one direction.
  - The oceans' waters are constantly in motion.
  - The Gulf Stream flows east to west.
  - The Atlantic Ocean is deep.
- What affects surface currents?
  - crests
  - upwellings
  - the Coriolis effect
  - tides

## Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

- Explain the difference between surface currents and density currents in the ocean.

Use the illustration below to answer questions 10 and 11.



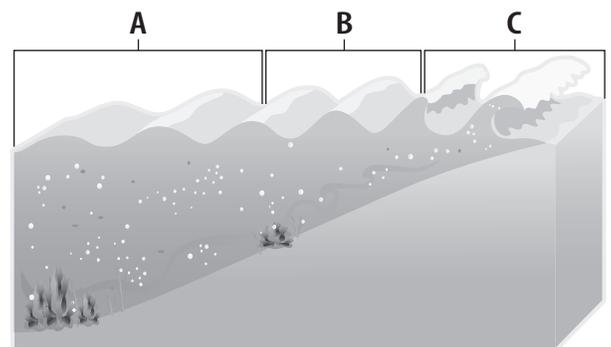
- Which type of tide occurs when the Sun, the Moon, and Earth are aligned?
- Describe how the Sun, the Moon, and Earth are positioned relative to each other during a neap tide.
- What is tidal range?
- On June 17th 2003, in Santa Barbara, California, the morning low tide was measured at  $-0.365$  m. High tide was measured at  $1.12$  m. Calculate the tidal range between these tides.
- Explain what the term *steady state* means in relation to ocean salinity. What processes keep ocean salinity in a steady state?
- Explain how the ocean can influence the climate of an area.

## Part 3 Open Ended

Record your answers on a sheet of paper.

- Draw a diagram that explains the process of upwelling. An area of upwelling exists off of the western coast of South America. During El Niño events, upwelling does not occur and surface water is warm and nutrient-poor. What effect could this change have on the marine organisms in this area?

Use the illustration below to answer question 17.



- Describe the changes that occur as a wave approaches shore. Explain how wavelength is affected at each stage—A, B, and C—on the diagram.
- What is the Coriolis effect? Explain how it affects ocean surface currents.
- Compare and contrast the formation of North Atlantic Deep Water and Mediterranean Intermediate Water.

### Test-Taking Tip

**Answer All Parts** Make sure each part of the question is answered when listing discussion points. For example, if the question asks you to compare and contrast, make sure you list both similarities and differences.

**Question 19** Be sure to list the similarities and differences between the formation of the two masses of water.