CHAPTER 15 Earth's Oceans

BIG Idea Studying oceans helps scientists learn about global climate and Earth's history.

15.1 An Overview of Oceans

MAIN Idea The global ocean consists of one vast body of water that covers more than two-thirds of Earth's surface.

15.2 Seawater

MAIN Idea Oceans have distinct layers of water masses that are characterized by temperature and salinity.

15.3 Ocean Movements

MAIN Idea Waves and currents drive the movements of ocean water and lead to the distribution of heat, salt, and nutrients from one region of the ocean to another.

GeoFacts

- Tidal pools are formed on rocky shores when water remains on shore after the tide recedes.
- The largest tidal range in the world is found in Nova Scotia, Canada, with a 16.8-m difference between high tide and low tide.
- A sea star can extend its stomach outside of its mouth to digest prey that live in shells.

(t)Stuart Westmorland/CORBIS, (b)age fotostock/SuperStock, (bkgd)Philip James Corwin/CORBIS

LAUNCH Lab

How much of Earth's surface is covered by water?

Earth is often referred to as the blue planet because so much of its surface is covered by water. If you study a globe or a photograph of Earth taken from space, you can see that oceans cover much more of Earth than landmasses do.

Procedure

1. Read and complete the lab safety form.
2. Stretch a **piece of string** about 1 m in length around the equator of a **globe.**
3. Use a **blue marker** to color the sections of the string that cross the oceans.
4. Using a **ruler,** measure the length of the globe's equator, then measure the length of each blue section on the string. Add the lengths of the blue sections.
5. Divide the total length of the blue sections by the length of the globe's equator.

Analysis

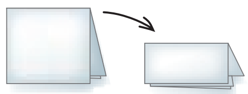
1. **Calculate** What percentage of the globe's equator is made up of oceans? What percentage of the globe's equator is made up of land?
2. **Observe** Study the globe again. Which hemisphere is covered with more water?

FOLDABLES™ Study Organizer

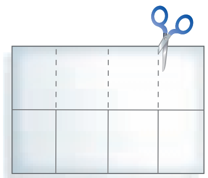
Wave Characteristics Make this Foldable to show the characteristics of waves.

STEP 1 Fold a sheet of paper in half lengthwise.

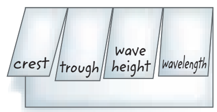
STEP 2 Fold in half and then in half again, as shown.



STEP 3 Unfold and cut along the fold lines of the top flap to make four tabs.



STEP 4 Label the tabs *crest, trough, wave height,* and *wavelength.*



FOLDABLES **Use this Foldable with Section 15.3.** As you read this section, sketch and explain the physical properties associated with waves on the tabs. Under the tabs, illustrate and label the movement of ocean water.

Earth Science Online

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Section 15.1

Objectives

- **Identify** methods used by scientists to study Earth's oceans.
- **Discuss** the origin and composition of the oceans.
- **Describe** the distribution of water at Earth's surface.

Review Vocabulary

lake: natural or human-made body of water that can form when a depression on land fills with water

New Vocabulary

side-scan sonar
sea level

An Overview of Oceans

MAIN Idea **The global ocean consists of one vast body of water that covers more than two-thirds of Earth's surface.**

Real-World Reading Link How could you tell a person's age by only looking at him or her? The presence of wrinkles can signify age as skin changes over time. Similarly, scientists look for clues about changes in rocks formed at the bottom of the ocean to estimate the age of the ocean.

Data Collection and Analysis

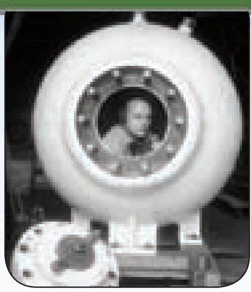
Oceanography is the scientific study of Earth's oceans. In the late 1800s, the British ship *Challenger* became the first research ship to use relatively sophisticated measuring devices to study the oceans. Since then, oceanographers have been collecting data with instruments both at the surface and from the depths of the ocean floor. Technologies such as sonar, floats, satellites, submersibles, and computers have become central to the continuing exploration of the ocean. **Figure 15.1** chronicles some of the major discoveries that have been made about oceans.

At the surface Sonar, which stands for **so**und **na**vigation and **r**anging, is used by oceanographers to learn more about the topography of the ocean floor. To determine ocean depth, scientists send a sonar signal to the ocean floor and time how long it takes for the sound to reach the bottom and return to the surface as an echo. Knowing that sound travels at a constant velocity of 1500 m/s through water, scientists can determine the depth by multiplying the total time by 1500 m/s, then dividing the answer by 2.

Figure 15.1
Developments in Oceanography
Technological development has led to many new discoveries in oceanography over time.

1900 · 1925 · 1950

1872 The *Challenger* expedition marks the beginning of oceanography. Scientists measure sea depth, study the composition of the seafloor, and collect a variety of oceanic data.



1925 The German *Meteor* expedition surveys the South Atlantic floor with sonar equipment and discovers the Mid-Atlantic Ridge.

1932–1934 The first deep-ocean dives use a tethered bathysphere. The dives uncover luminescent creatures and provide sediment samples.

1943 In France, the first diving equipment is invented from hoses, mouthpieces, air tanks, and a redesigned car regulator that supplies compressed air to divers.

1955 A survey ship detects linear magnetic stripes along the ocean floor. These magnetic patterns lead to the formulation of the theory of plate tectonics.

(l)Bettmann/CORBIS, (r)Archival Photography by Steve Nicklas/NOS/NGS

Large portions of the seafloor have been mapped using **side-scan sonar,** a technique that directs sound waves to the seafloor at an angle, so that the sides of underwater hills and other topographic features can be mapped.

Oceanographers use floats that contain sensors to learn more about water temperature, salinity, and the concentration of gases and nutrients in surface water. Floats can also be used to record wave motion and the speed at which currents are moving. Satellites such as the *TOPEX/Poseidon*, which you read about in Chapter 2, continually monitor the ocean's surface temperatures, currents, and wave conditions.

■ **Figure 15.2** *Alvin* is a deep-sea submersible that can hold two scientists and a pilot.

In the deep sea Submersibles, underwater vessels which can be remotely operated or carry people to the deepest areas of the ocean, have allowed scientists to explore new frontiers. *Alvin,* shown in **Figure 15.2,** is a modern submersible that can take two scientists and a pilot to depths as deep as 4500 m. *Alvin* has been used to discover geologic features such as hydrothermal vents and previously unknown sea creatures. It can also be used to bring sediments and water samples to the surface.

Reading Check **List** some discoveries made using submersibles.

Computers An integral tool in both the collection and analysis of data from the ocean is computers. Information from satellites and float sensors can be transmitted and downloaded directly to computers. Sophisticated programs use mathematical equations to analyze data and produce models. When combined with observations, ocean models provide information about subsurface currents that are not observed directly. Operating in a fashion similar to weather forecasting models, global ocean models play a role in simulating Earth's changing climate. Ocean models are also used to simulate tides, tsunamis, and the dispersion of coastal pollution.

1962 France builds the first underwater habitat where scientists live for days at a time conducting experiments.

1984 An observation system in the Pacific Ocean helps scientists predict El Niño and begin to understand the connection between oceanic events and weather.

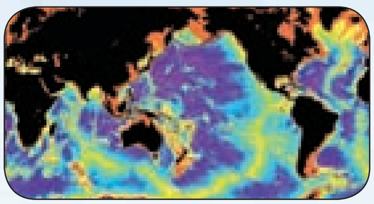
2002 Data collected from the seafloor reveals a new ocean wave associated with earthquakes.

2006 An internet portal provides scientists around the world with access to live data collected from ocean-floor laboratories.

1960 1980 2000

1977 The submersible *Alvin* discovers hydrothermal vents and a deep-sea ecosystem including giant worms and clams that can survive without energy from the Sun.

1995 Scientists map the entire seafloor using satellite data.



Concepts In Motion

Interactive Time Line To learn more about these discoveries and others, visit glencoe.com. Earth Science Online

(tr)Donna C. Rona/Bruce Coleman, Inc., (bl)Jeffrey L. Rotman/CORBIS, (br)W.H.F.Smith/D.T. Sandwell/NOAA/NGDC

Origin of the Oceans

Several geologic clues indicate that oceans have existed almost since the beginning of geologic history. Studies of radioactive isotopes indicate that Earth is about 4.56 billion years old. Scientists have found rocks nearly as old that formed from sediments deposited in water. Ancient lava flows are another clue—some of these lava flows have glassy crusts that form only when molten lava is chilled rapidly underwater. Radioactive studies and lava flows offer evidence that there has been abundant water throughout Earth's geologic history.

Reading Check **Explain** the evidence that suggests that oceans have existed almost since the beginning of Earth's geologic history.

Where did the water come from? Scientists hypothesize that Earth's water originated from either a remote source or a local source, or both. Comets and meteorites are two remote sources that could have contributed to the accumulation of water on Earth. Comets, such as the one shown in **Figure 15.3,** travel throughout the solar system and occasionally collide with Earth. These impacts release enough water over time that they could have contributed to filling the ocean basins over geologic time.

Meteorites, such as the one shown in **Figure 15.3,** are composed of the same material that might have formed the early planets. Studies indicate that meteorites contain up to 0.5 percent water. Meteorite bombardment releases water into Earth's systems.

If early Earth contained the same percentage of water as meteorites, it would have been sufficient to form early oceans. However, some mechanism must have existed to allow the water to rise from Earth's interior to its surface. Scientists theorize that this mechanism was volcanism.

CAREERS IN EARTH SCIENCE

Oceanographer Scientists who investigate oceans are called oceanographers. Oceanographers might investigate water chemistry, wave action, marine organisms, or sediments. To learn more about Earth science careers, visit glencoe.com.

Figure 15.3 Comets are composed of dust and rock particles mixed with frozen water and gases. Comet impacts with Earth may have released enough water to help fill ocean basins. Meteorites contain up to 0.5 percent water.


Comet


Meteorite

(l)David Nunuk/Photo Researchers, (r)Ken Lucas/Visuals Unlimited

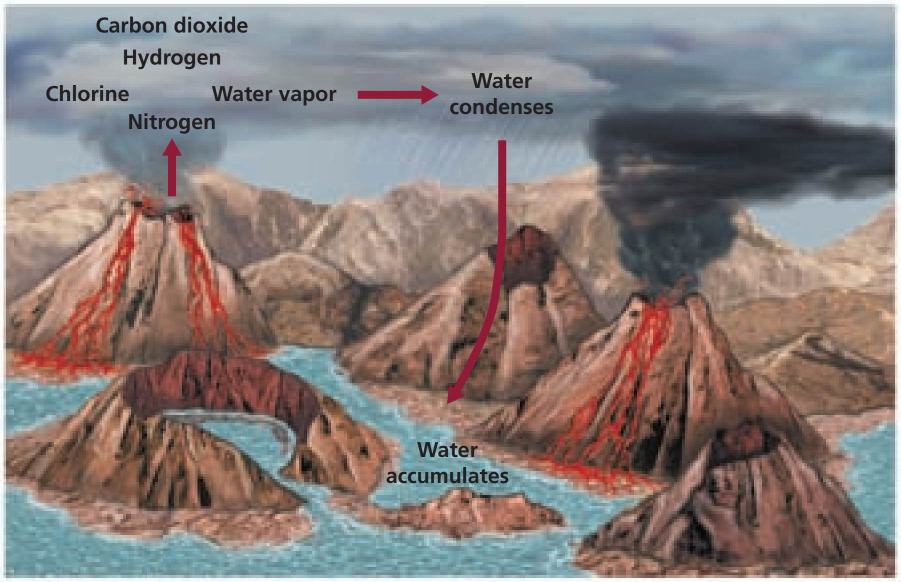


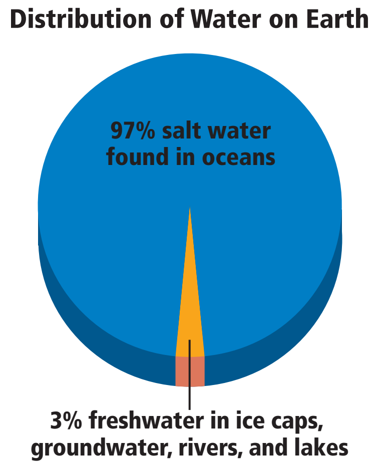
Figure 15.4 In addition to comets, water for Earth's early oceans might have come from volcanic eruptions. An intense period of volcanism occurred shortly after the planet formed. This volcanism released large quantities of water vapor and other gases into the atmosphere. The water vapor eventually condensed into oceans.

Volcanism During volcanic eruptions, significant quantities of gases are emitted. These volcanic gases consist mostly of water vapor and carbon dioxide. Shortly after the formation of Earth, when the young planet was much hotter than it is today, an episode of massive, violent volcanism took place over the course of perhaps several hundred million years. As shown in **Figure 15.4,** this volcanism released huge amounts of water vapor, carbon dioxide, and other gases, which combined to form Earth's early atmosphere. As Earth's crust cooled, the water vapor gradually condensed, fell to Earth's surface as precipitation, and accumulated to form oceans. By the time the oldest known crustal rock formed about 4 bya, Earth's oceans might have been close to their present size. Water is still being added to the hydrosphere by volcanism, but some water molecules in the atmosphere are continually being destroyed by ultraviolet radiation from the Sun. These two processes balance each other.

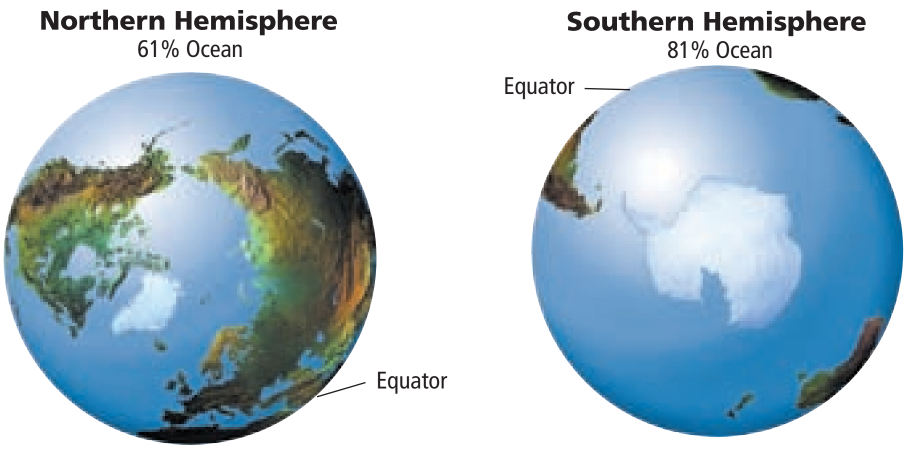
Distribution of Earth's Water

As shown in **Figure 15.5,** the oceans contain 97 percent of the water found on Earth. Another 3 percent is freshwater located in the frozen ice caps of Greenland and Antarctica and in rivers, lakes, and underground sources. The percentage of ice on Earth has varied over geologic time from near zero to perhaps as much as 10 percent of the hydrosphere. As you read further in this section, you will learn more about how these changes affect sea level.

Figure 15.5 About 97 percent of water on Earth is salt water found in the oceans.



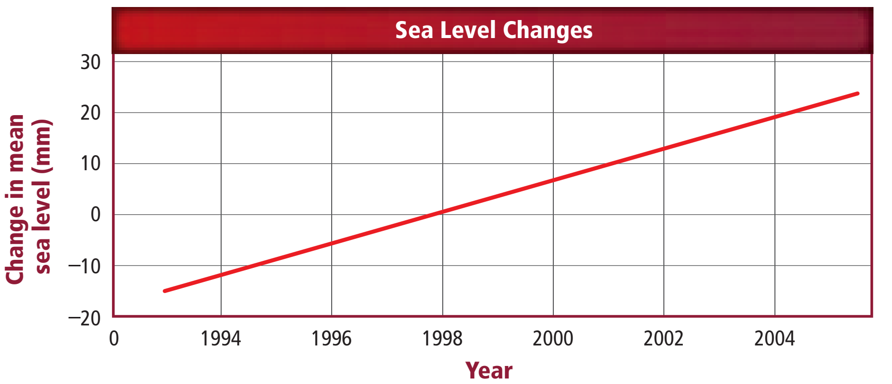
■ **Figure 15.6** The northern hemisphere is covered by slightly more water than land. The southern hemisphere, however, is almost completely covered by water.

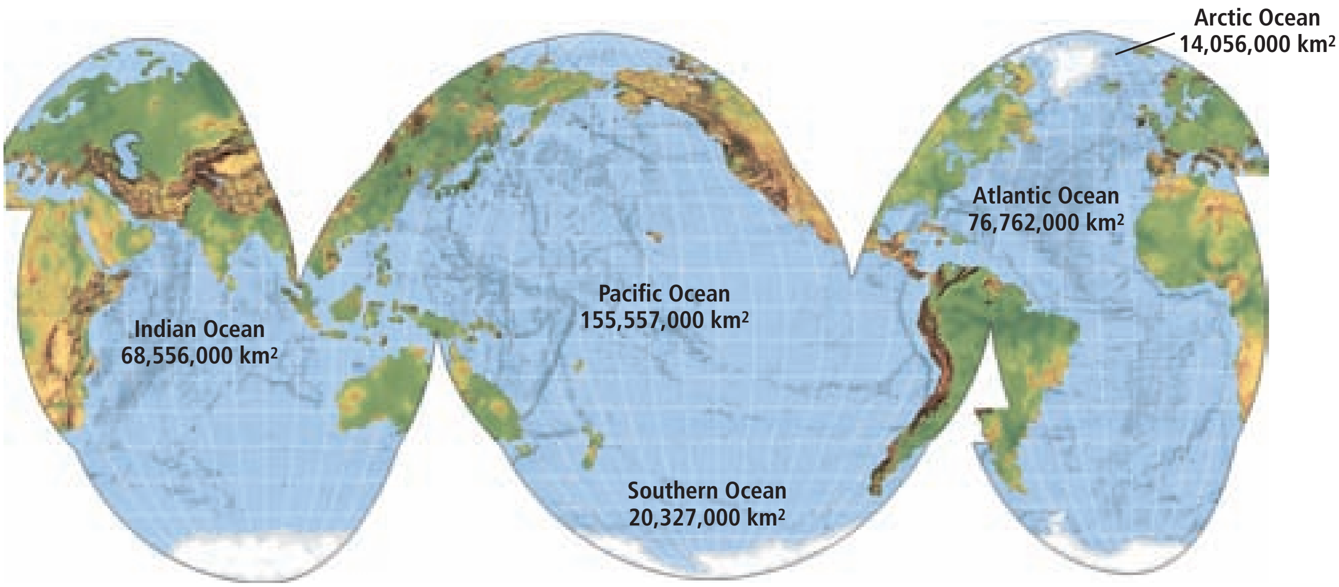


The blue planet Earth is known as the blue planet for good reason—approximately 71 percent of its surface is covered by oceans. The average depth of these oceans is 3800 m. Earth's landmasses are like huge islands, almost entirely surrounded by water. Because most landmasses are in the northern hemisphere, oceans cover only 61 percent of the surface there. However, 81 percent of the southern hemisphere is covered by water. **Figure 15.6** shows the distribution of water in the northern and southern hemispheres. Note that all the oceans are one vast, interconnected body of water. They have been divided into specific oceans and seas largely because of historic and geographic considerations.

Sea level Global **sea level,** which is the level of the oceans' surfaces, has risen and fallen by hundreds of meters in response to melting ice during warm periods and expanding glaciers during ice ages. Other processes that affect sea level are tectonic forces that lift or lower portions of Earth's crust. A rising seafloor causes a rise in sea level, while a sinking seafloor causes sea level to drop. **Figure 15.7** shows that sea level rose at a rate of about 3 mm per year between 1994 and 2004. Scientists hypothesize that this rise in sea level is related to water that has been released by the melting of glaciers and thermal expansion of the ocean due to warming.

■ **Figure 15.7** Scientists at NASA used floats and satellites to collect data on sea level changes over the period 1994 to 2004.
Infer ***What is a possible cause for glaciers melting over this period?***





■ **Figure 15.8** The Pacific, Atlantic, and Indian Oceans stretch from Antarctica to the north. The smaller Arctic Ocean and Southern Ocean are located near the north and south poles respectively.

Major oceans As **Figure 15.8** shows, there are three major oceans: the Pacific, the Atlantic, and the Indian. The Pacific Ocean is the largest. Containing roughly half of Earth's seawater, it is larger than all of Earth's landmasses combined. The second-largest ocean, the Atlantic, extends for more than 20,000 km from Antarctica to the Arctic Circle. North of the Arctic Circle, the Atlantic Ocean is often referred to as the Arctic Ocean. The third-largest ocean, the Indian, is located mainly in the southern hemisphere. The storm-lashed region surrounding Antarctica, south of about 50° south latitude, is known as the Southern Ocean.

Reading Check **Identify** the largest ocean.

Polar oceans The Arctic and Southern oceans are covered by vast expanses of sea ice, particularly during the winter. In summer, the ice breaks up somewhat. Because ice is less dense than water, it floats. When sea-ice crystals first form, an ice-crystal slush develops at the surface of the water. The thickening ice eventually solidifies into individual round pieces called pancake ice, shown in **Figure 15.9.** Eventually, these pieces of pancake ice thicken and freeze into a continuous ice cover called pack ice. In the coldest parts of the Arctic and Southern oceans, there is no summer thaw, and the pack ice is generally several meters thick. In the winter, the pack-ice cover can be more than 1000 km wide.

■ **Figure 15.9** These pieces of pancake ice will eventually thicken and freeze into pack ice.

Maria Stenzel/National Geographic Image Collection

Table 15.1	Ocean-Atmospheric Interactions
Example	**Description**
Oceans are a source of atmospheric oxygen.	Fifty percent of oxygen in the atmosphere comes from marine phytoplankton, which release oxygen into surface waters as a product of photosynthesis.
Oceans are a reservoir for carbon dioxide.	When cold, dense surface water in polar oceans sinks, dissolved carbon dioxide moves to the bottom of the ocean.
Oceans are a source of heat and moisture.	Warm ocean water in equatorial regions heats the air above it, fueling hurricanes.

Ocean and atmospheric interaction Oceans provide moisture and heat to the atmosphere and influence large-scale circulation patterns. In Chapter 13, you learned that warm ocean water energizes tropical cyclones, influences the position and strength of jet streams, and plays a role in El Niño events.

Oceans are also a vast reservoir of carbon dioxide. Dissolved carbon dioxide in surface waters sinks in water masses to the deep ocean, returning to the surface hundreds of years later. Without this natural uptake by the ocean, the accumulation of carbon dioxide in the atmosphere would be much larger than currently observed. There is also an uptake of carbon dioxide by phytoplankton during photosynthesis in the sunlit surface ocean. In the process, carbon is stored in the ocean and excess oxygen is released to the atmosphere to make Earth habitable. **Table 15.1** summarizes some of the interactions between oceans and the atmosphere.

Section 15.1 Assessment

Section Summary

- Scientists use many different instruments to collect and analyze data from oceans.
- Scientists have several ideas as to where the water in Earth's oceans originated.
- A large portion of Earth's surface is covered by ocean.
- Earth's oceans are the Pacific, the Atlantic, the Indian, the Arctic, and the Southern.

Understand Main Ideas

1. MAIN Idea **State** how much of Earth is covered by oceans. How is ocean water distributed over Earth's surface?
2. **Describe** two tools scientists use to collect data about oceans.
3. **Relate** What evidence indicates that oceans formed early in Earth's geologic history?
4. **Specify** Where did the water in Earth's early oceans originate?

Think Critically

5. **Predict** some possible consequences of rising sea level.
6. **Suggest** A recent study showed a 30 percent decrease in phytoplankton concentrations in northern oceans over the last 25 years. How might a significant decrease in marine phytoplankton affect atmospheric levels of oxygen and carbon dioxide?

MATH in Earth Science

7. Calculate the distance to the ocean floor if a sonar signal takes 6 s to return to a ship's receiver.

Earth Science Online Self-Check Quiz glencoe.com

Section 15.2

Objectives

- **Identify** the chemical and physical properties of seawater.
- **Illustrate** ocean layering.
- **Describe** the formation of deepwater masses.

Review Vocabulary

Feldspar: a rock-forming mineral that contains silicon and oxygen

New Vocabulary

salinity
estuary
temperature profile
thermocline

Seawater

MAIN Idea Oceans have distinct layers of water masses that are characterized by temperature and salinity.

Real-World Reading Link A person's accent can reveal a lot about his or her place of origin. Similarly, the temperature and salinity of water masses can often reveal when and where the water was first formed on the sea surface.

Chemical Properties of Seawater

Ocean water contains dissolved gases, including oxygen and carbon dioxide, and dissolved nutrients such as nitrates and phosphates. Chemical profiles of seawater vary based on both location and depth, as shown in **Figure 15.10,** Factors that influence the amount of a substance in an area of ocean water include wave action, vertical movements of water, and biological activity.

Figure 15.10 shows that oxygen levels are high at the surface in both the Atlantic and Pacific oceans. This occurs in part because oxygen is released by surface-dwelling photosynthetic organisms. Silica levels for both oceans are also shown in **Figure 15.10.** Because many organisms remove silica from ocean water and use it to make shells, silica levels near the surface are usually low. Silica levels usually increase with depth because decaying organisms sink to the ocean bottom, returning silica to the water.

Salinity The measure of the amount of dissolved salts in seawater is **salinity.** Oceanographers express salinity as grams of salt per kilogram of water, or parts per thousand (ppt). The total salt content of seawater averages 35 ppt, or 3.5 percent. The most abundant salt in seawater is sodium chloride. Other salts in seawater are chlorides and sulfates of magnesium, potassium, and calcium.

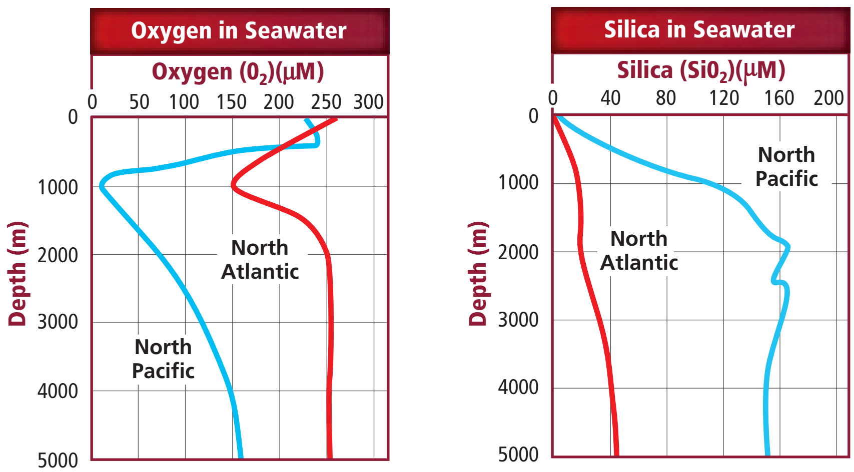
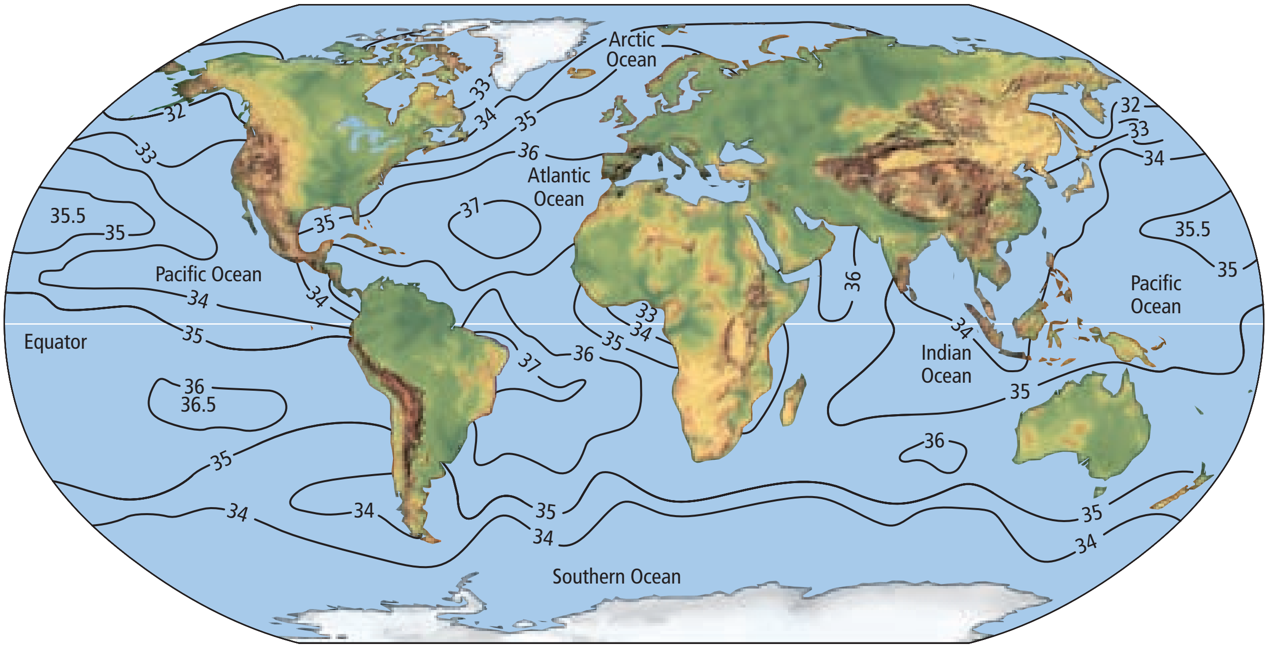


Figure 15.10 Levels of dissolved gases and nutrients in seawater vary by location and depth.
Examine *How do oxygen levels differ between the North Atlantic and North Pacific oceans?*

Ocean Salinity



*All values are given in parts per thousand (ppt)

Figure 15.11 Ocean salinity varies from place to place. High salinity is common in areas with high rates of evaporation. Low salinity often occurs in estuaries.

Variations in salinity Although the average salinity of the oceans is 35 ppt, actual salinity varies from place to place, as shown in **Figure 15.11.** In subtropical regions where rates of evaporation exceed those of precipitation, salt left behind by the evaporation of water molecules accumulates in the surface layers of the ocean. There, salinity can be as high as 37 ppt. In equatorial regions where precipitation is abundant, salinity is lower. Even lower salinities of 32 or 33 ppt occur in polar regions where seawater is diluted by melting sea ice. The lowest salinity often occurs where large rivers empty into the oceans, creating areas of water called **estuaries.** Even though salinity varies, the relative proportion of major types of sea salts is constant because all ocean water continually intermingles throughout Earth's oceans.

Reading Check **Describe** the factors that affect the salinity of water.

Sources of sea salt Geologic evidence indicates that the salinity of ancient seas was not much different from that of today's oceans. One line of evidence is based on the proportion of magnesium in the calcium-carbonate shells of some marine organisms. That proportion depends on the overall salinity of the water in which the shells formed. Present-day shells contain about the same proportion of magnesium as similar shells throughout geologic time.

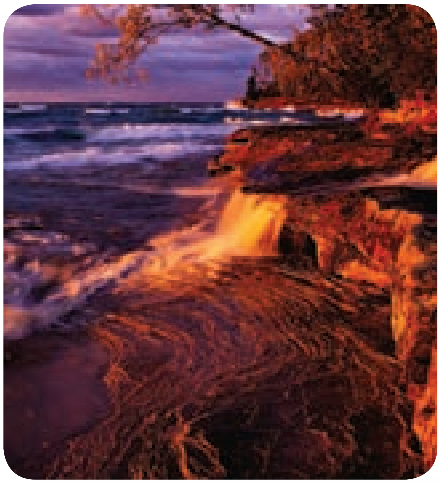
Sources of sea salts have also stayed the same over time. Sulfur dioxide and chlorine, gases released by volcanoes, dissolve in water, forming sulfate and chlorine ions. Most of the other ions in seawater, including sodium and calcium, come from the weathering of crustal rocks, such as feldspars. Iron and magnesium come from the weathering of rocks rich in these elements. These ions enter rivers and are transported to oceans, as shown in **Figure 15.12.**

Visualizing the Salt Cycle

NATIONAL GEOGRAPHIC

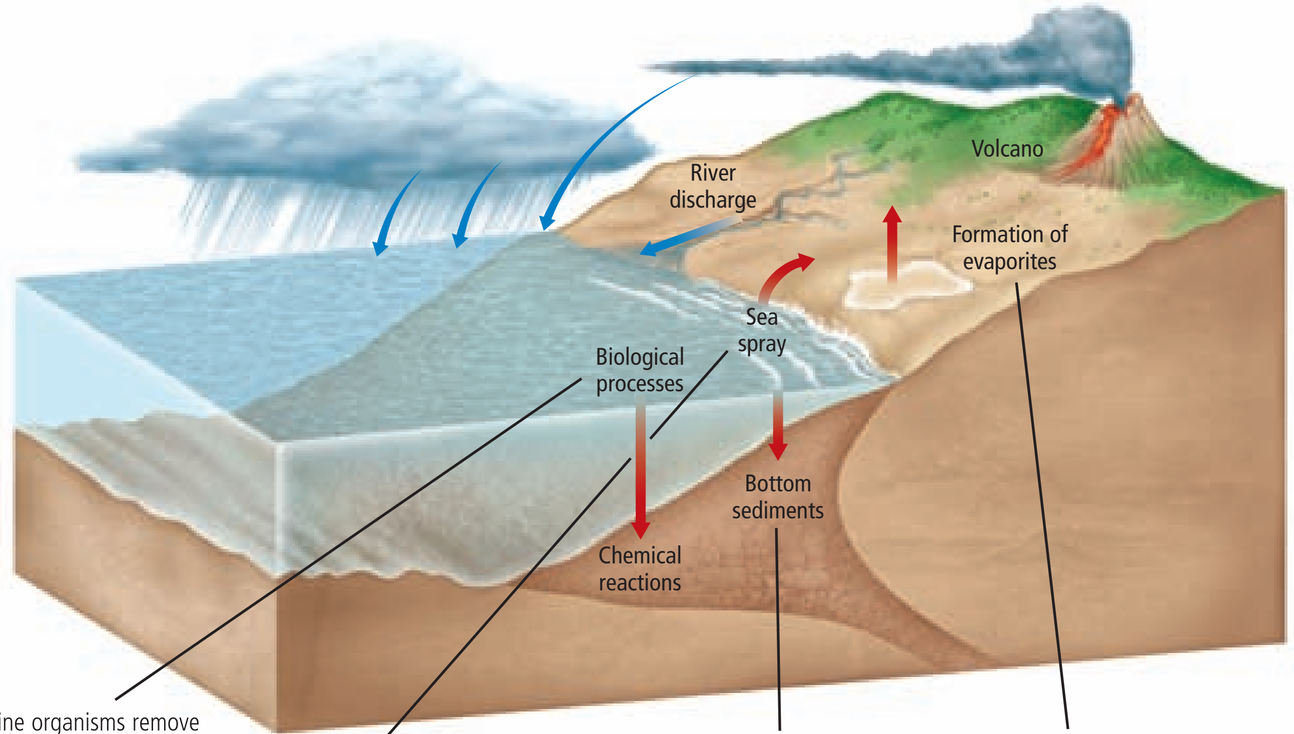
(l)Conrad Zobel/CORBIS, (r)Dr. Morley Read/Photo Researchers

Figure 15.12 Salts are added to seawater by volcanic eruptions and by the weathering and erosion of rocks. Salts are removed from seawater by biological processes and the formation of evaporites. Also, wind carries salty droplets inland.



Ions, such as sodium, calcium, iron, and magnesium, enter oceans in river runoff as the weathering of rocks releases them.

Gases from volcanic eruptions contain water vapor, chloride, and sulfur dioxide. These gases dissolve in water and form the chloride and sulfate ions in seawater.



Marine organisms remove ions from seawater through chemical reactions to build their shells, bones, and teeth.

Small droplets of sea spray that contain salt are carried inland by winds.

When organisms die, their solid parts sink, returning salts to the bottom sediments.

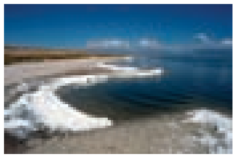
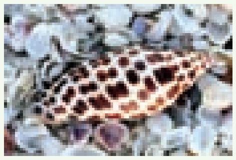
Salt precipitates when seawater evaporates in coastal areas that are hot and dry.

Concepts In Motion To explore more about the salt cycle, visit glencoe.com.

Earth Science Online

Concepts In Motion **Interactive Table** To explore more about salts in the ocean, visit glencoe.com.

Table 15.2 Removal of Sea Salts

Process	Description	Example
Evaporate formation	Solid salt is left behind when water evaporates from concentrated solutions of salt water.	
Biological activity	Organisms remove calcium ions from water to build shell, bones, and teeth.	

(t)Tony Hamblin/Frank Lane Picture Agency/CORBIS, (b)Gary Meszaros/Photo Researchers

Removal of sea salts Although salt ions are continuously added to seawater, salinity does not increase because salts are also continuously removed. **Table 15.2** describes two processes through which sea salts are removed. Recall from Chapter 6 that evaporites form when water evaporates from concentrated solutions. In arid coastal regions, water evaporates from seawater and leaves solid salt behind. Marine organisms remove ions from seawater to build shells, bones, and teeth. As organisms die, their solid parts accumulate on the seafloor and become part of bottom sediments. Winds can also pick up salty droplets from breaking waves and deposit the salt further inland. The existing salinity of seawater represents a balance between the processes that remove salts and those that add them.

MiniLab

Model Seawater

What is the chemical composition of seawater? Determine the chemical composition of seawater using the ingredients listed in the table. The salinity of seawater is commonly measured in parts per thousand (ppt).

Procedure

1. Read and complete the lab safety form.
2. Carefully measure the **ingredients** listed in the table on the right and combine them in a **large beaker.**
3. Add 965.57 g of **distilled water** and mix.

Analysis

1. **Calculate** How many grams of solution do you have? What percentage of this solution is made up of salts?
2. **Apply** What is the salinity of your solution in ppt?
3. **Identify** the ions in your solution.
4. **Infer** how your solution differs from actual seawater.

Ingredient	Amount
Sodium chloride ($NaCl$)	23.48 g
Magnesium chloride ($MgCl_2$)	4.98 g
Sodium sulfate (Na_2SO_4)	3.92 g
Calcium chloride ($CaCl_2$)	1.10 g
Potassium chloride (KCl)	0.66 g
Sodium bicarbonate ($NaHCO_3$)	0.19 g
Potassium bromide (KBr)	0.10 g

O.S.F./Animals Animals

Physical Properties of Seawater

The presence of various salts causes the physical properties of seawater to be different from those of freshwater.

Density Freshwater has a maximum density of 1.00 g/cm^3. Because salt ions add to the overall mass of the water in which they are dissolved, they increase the density of water. Seawater is therefore more dense than freshwater, and its density increases with salinity. Temperature also affects density—cold water is more dense than warm water. Because of salinity and temperature variations, the density of seawater ranges from about 1.02 g/cm^3 to 1.03 g/cm^3. These variations might seem small, but they are significant. They affect many oceanic processes, which you will learn about in Chapter 16.

Reading Check **Explain** how temperature and salinity affect the density of seawater.

Freezing point Variations in salinity also cause the freezing point of seawater to be somewhat lower than that of freshwater. Freshwater freezes at 0°C. Because salt ions interfere with the formation of the crystal structure of ice, the freezing point of seawater is –2°C.

Absorption of light If you have ever swum in a lake, you might have noticed that the intensity of light decreases with depth. The water might be clear, but if the lake is deep, the bottom waters will be dark. Water absorbs light, which gives rise to another physical property of oceans—darkness. In general, light penetrates only the upper 100 m of seawater. Below that depth, all is darkness.

Figure 15.13 illustrates how light penetrates ocean water. Notice that red light does not penetrate as far as blue light. Red objects, such as the giant red shrimp shown in **Figure 15.13,** appear black below a certain depth and other reflecting objects in the water appear green or blue. Although some fading blue light can reach depths of a few hundred meters, light sufficient for photosynthesis exists only in the top 100 m of the ocean. In the darkness of the deep ocean, some organisms, including some fishes, shrimps, and crabs, are blind. Other organisms attract prey by producing light, called bioluminescence, through a chemical reaction.

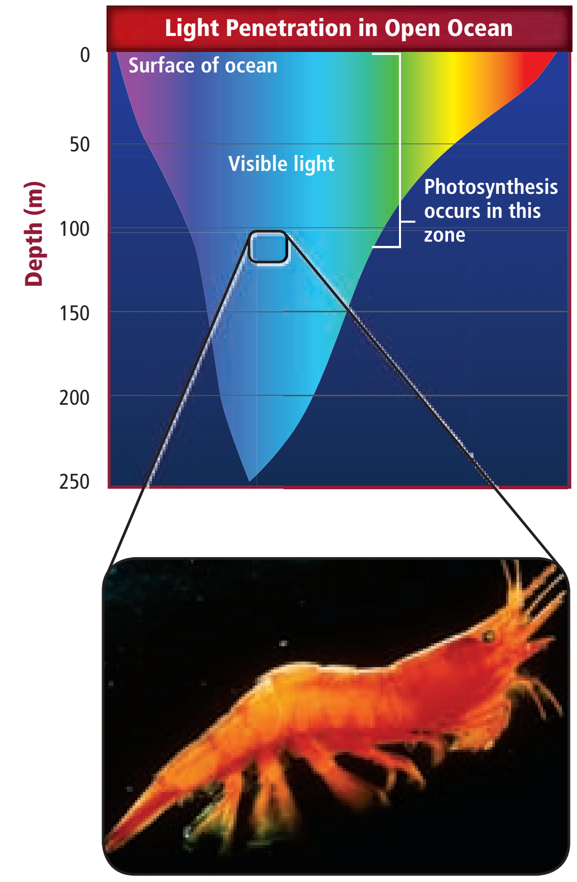
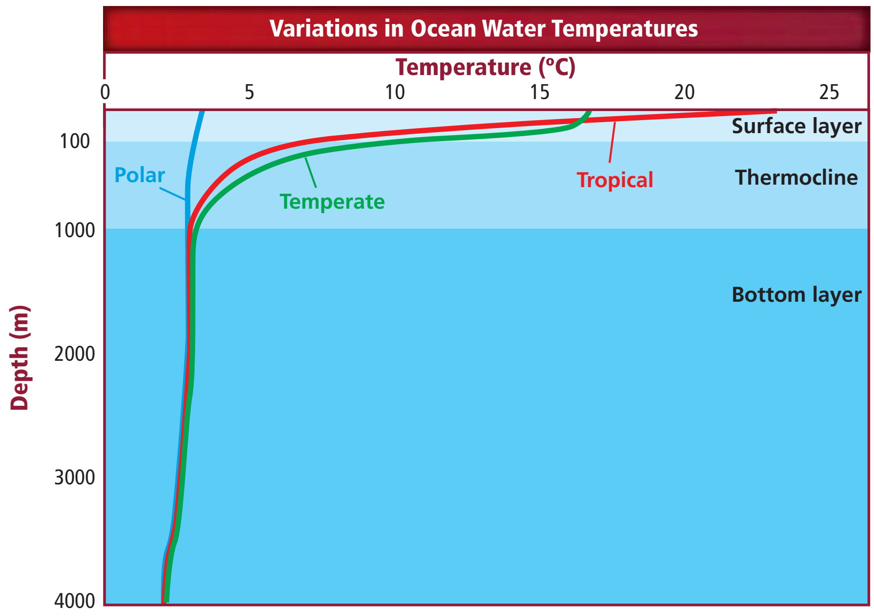


Figure 15.13 Red light does not penetrate as far as blue light in the ocean. Marine organisms that are some shades of red, such as deep-sea shrimp, appear black below a depth of 10 m. This helps them escape predators.
Identify *To what depth does blue light penetrate ocean water?*

■ **Figure 15.14** Ocean water temperatures decrease with depth. Tropical areas have warmer ocean surface temperatures than do temperate or polar areas.



Ocean Layering

Ocean surface temperatures range from −2°C in polar waters to 30°C in equatorial regions, with the average surface temperature being 15°C. Ocean water temperatures, however, decrease significantly with depth. Thus, deep ocean water is always cold, even in tropical oceans.

Temperature profiles **Figure 15.14** shows typical ocean **temperature profiles,** which plot changing water temperatures against depth. Such profiles vary, depending on location and season. In the temperature profiles shown here, beneath roughly 100 m, temperatures decrease continuously with depth to around 4°C at 1000 m. The dark waters below 1000 m have fairly uniform temperatures of less than 4°C. Based on these temperature variations, the ocean can be divided into three layers, also shown in **Figure 15.14.** The first is a relatively warm, sunlit surface layer approximately 100 m thick. Notice that tropical areas have warmer surface temperatures than temperate or polar areas. Under the surface layer is a transitional layer known as the **thermocline,** which is characterized by rapidly decreasing temperatures with depth. The bottom layer is cold and dark with temperatures near freezing. Both the thermocline and the warm surface layer are absent in polar seas, where water temperatures are cold from top to bottom. In general, ocean layering is caused by density differences. Because cold water is more dense than warm water, cold water sinks to the bottom, while less-dense, warm water is found near the ocean's surface.

VOCABULARY

ACADEMIC VOCABULARY

Variation
the range in which a factor changes
The variation in temperature in New York was a shock for the person from California.

Reading Check **Describe** the three main layers of water in oceans.

Water Masses

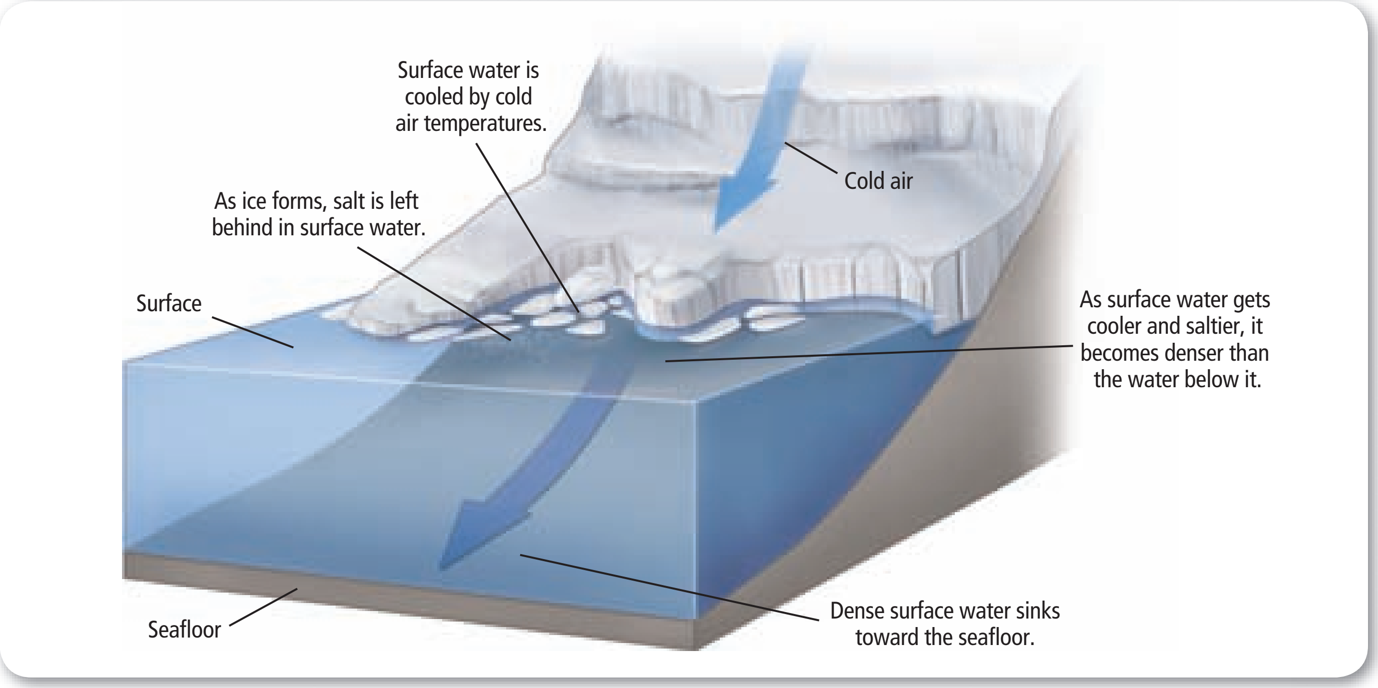
The temperature of the bottom layer of ocean water is near freezing. This is true even in tropical oceans, where surface temperatures are warm. Where does all this cold water come from?

Deepwater masses Cold water comes from Earth's polar seas. Recall that high salinity and cold temperatures cause seawater to become more dense. Study **Figure 15.15,** which shows how deepwater masses are formed. When seawater freezes during the arctic or antarctic winter, sea ice forms. Because salt ions are not incorporated into the growing ice crystals, they accumulate beneath the ice. Consequently, the cold water beneath the ice becomes saltier and more dense than the surrounding seawater, and this saltier water sinks. This salty water then migrates toward the equator as a cold, deepwater mass along the ocean floor. Other cold, deepwater masses form when surface currents in the ocean bring relatively salty midlatitude or subtropical waters into polar regions. In winter, these waters become colder and denser than the surrounding polar surface waters, and thus, they sink.

Three water masses account for most of the deepwater masses in the oceans—Antarctic Bottom Water, North Atlantic Deep Water, and Antarctic Intermediate Water. Antarctic Bottom Water forms when antarctic seas freeze during the winter. With temperatures below 0°C, this deepwater mass is the coldest and densest in all the oceans, as shown in **Figure 15.16** on page 420. North Atlantic Deep Water forms in a similar manner offshore from Greenland. Antarctic Bottom Water is colder and denser than North Atlantic Deep Water, so it sinks below it.

Reading Check **Identify** the three water masses that make up most of the deepwater masses in the oceans.

Figure 15.15 Dense polar water sinks, producing a deepwater mass.
Explain ***the relationship between the density of water and the formation of deepwater masses.***



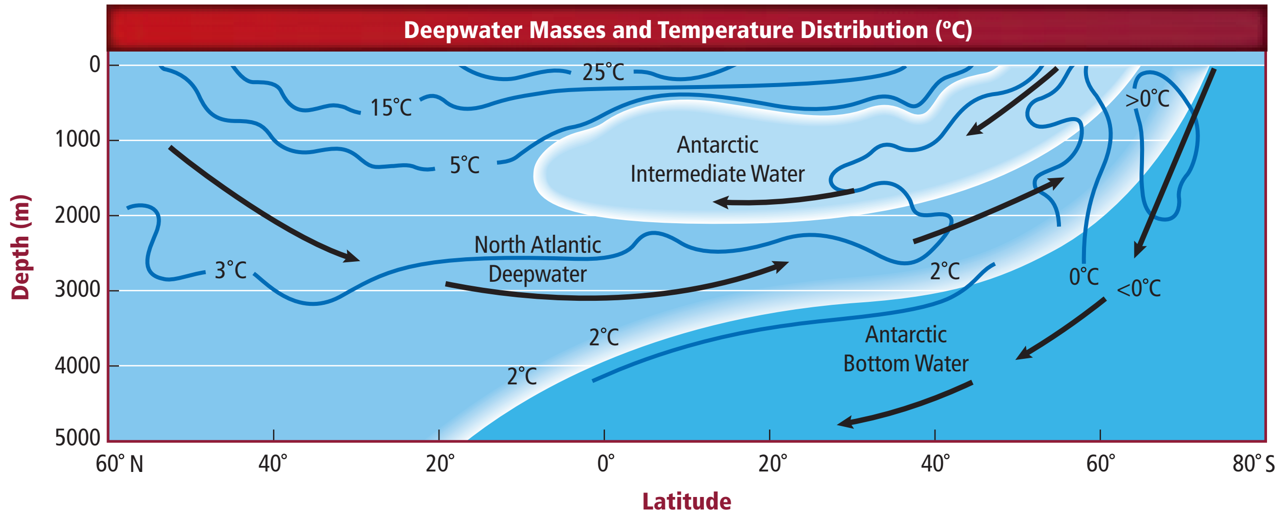


Figure 15.16 Antarctic Bottom Water is the densest and coldest deepwater mass. It is overridden by the slightly warmer and less dense North Atlantic Deep Water. Antarctic Intermediate Water is still warmer and less dense, and thus it overrides the other two deepwater masses.

Intermediate water masses Antarctic Intermediate Water, shown in **Figure 15.16,** forms when the relatively salty waters near Antarctica decrease in temperature and sink during winter. Because Antarctic Intermediate Water is slightly warmer and less dense than North Atlantic Deep Water, it does not sink as deep as the other two deepwater masses. While the Atlantic Ocean contains all three major deepwater masses, the Indian and Pacific Oceans contain only the two Antarctic deepwater masses. In Section 15.3, you will learn about other water movements in the ocean.

Section 15.2 Assessment

Section Summary

- Ocean water contains dissolved gases, nutrients, and salts.
- Salts are added to and removed from oceans through natural processes.
- Properties of ocean water, including temperature and salinity, vary with location and depth.
- Many of the oceans' deepwater masses sink from the surface of polar oceans.

Understand Main Ideas

1. MAIN Idea **Compare and contrast** North Atlantic Deep Water and Antarctic Bottom Water.
2. **Identify** What factors affect the chemical properties of seawater?
3. **Illustrate** the three layers into which ocean water is divided based on temperature.
4. **Sequence** the steps involved in the formation of deepwater masses.

Think Critically

5. **Hypothesize** Which is more dense, cold freshwater or warm seawater?
6. **Predict** what color a yellow fish would appear to be in ocean water depths greater than about 50 m.

MATH in Earth Science

7. If the density of a sample of seawater is 1.02716 g/mL, calculate the mass of 4.0 mL of the sample.

Earth Science Online Self-Check Quiz glencoe.com

Section 15.3

Objectives

- **Describe** the physical properties of waves.
- **Explain** how tides form.
- **Compare and contrast** various ocean currents.

Review Vocabulary

prevailing westerlies: global wind system located between 30°N and 60°N that moves from the west to the east toward each pole

New Vocabulary

wave
crest
trough
breaker
tide
spring tide
neap tide
surface current
upwelling
density current

Concepts In Motion

Interactive Figure To see an animation of waves, visit glencoe.com.

■ **Figure 15.17** Wave characteristics include wave height, wavelength, crest, and trough. In an ocean wave, water moves in circles that decrease in size with depth. At a depth equal to half the wavelength, water movement essentially stops.

Ocean Movements

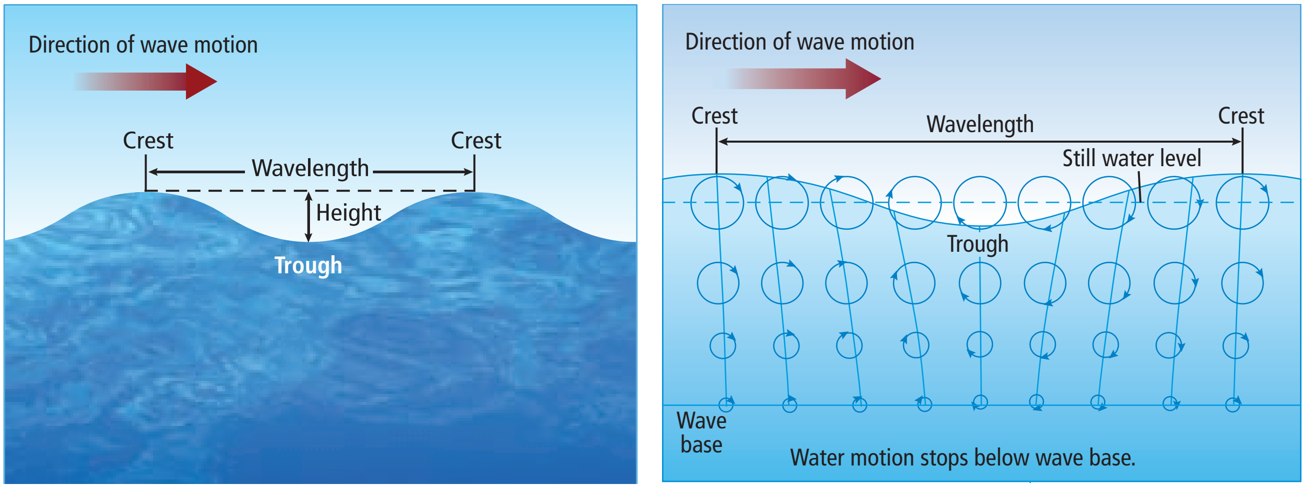
MAIN Idea Waves and currents drive the movements of ocean water and lead to the distribution of heat, salt, and nutrients from one region of the ocean to another.

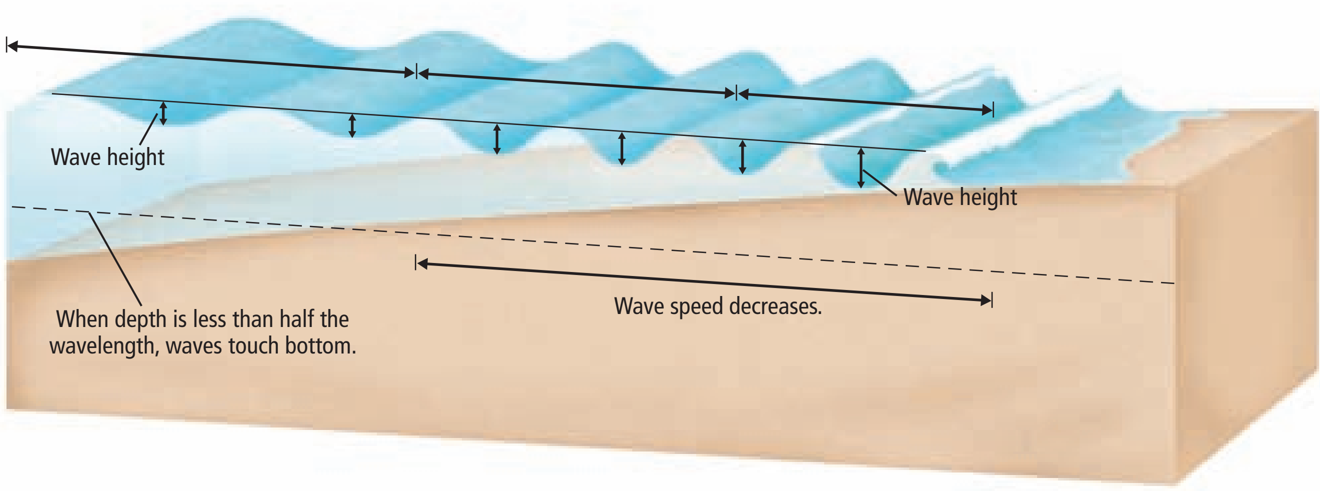
Real-World Reading Link Think about the last time you watched a sporting event and the audience did "the wave" to cheer players by standing up and sitting down at the right time. Even though the audience does not move around the stadium, the wave does. The same idea applies to ocean waves.

Waves

Oceans are in constant motion. Their most obvious movement is that of waves. A **wave** is a rhythmic movement that carries energy through space or matter—in this case, ocean water. Ocean waves are generated mainly by wind blowing over the water's surface. In the open ocean, a typical wave has the characteristics shown in **Figure 15.17.** The highest point of a wave is the **crest,** and the lowest point is the **trough.** The vertical distance between crest and trough is the wave height, and the horizontal crest-to-crest distance is the wavelength. The wavelength determines the speed with which waves move through deep water. Wave speed increases with wavelength.

As an ocean wave passes, the water moves up and down in a circular pattern and returns to its original position, as shown in **Figure 15.17.** Only the energy moves steadily forward. The water itself moves in circles until the energy passes, but it does not move forward. The wavelength also determines the depth to which the wave disturbs the water. That depth, called the wave base, is equal to half the wavelength.





■ **Figure 15.18** A breaker forms when wavelength decreases and wave height increases as the wave nears the shore.
Explain *what happens when waves become too steep and unstable.*

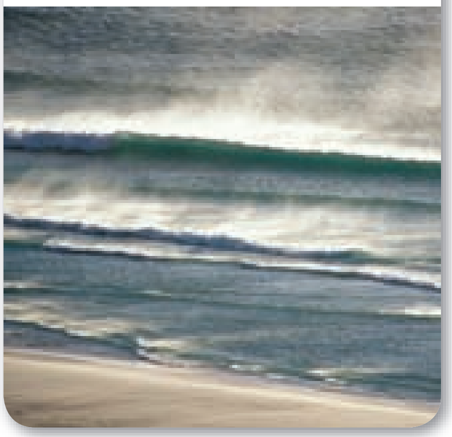
Wave height Wave height depends on three factors: fetch, wind duration, and wind speed. Fetch refers to the expanse of water that the wind blows across. The longer the wind can blow without being interrupted (wind duration) over a large area of water (fetch), the larger the waves will be. Also, the faster the wind blows (wind speed) for a longer period of time over the ocean, the larger the waves will be. The highest waves are usually found in the Southern Ocean, an area over which strong winds blow almost continuously. Waves created by large storms can also be much higher than average. For instance, hurricanes can generate waves more than 10 m high.

FOLDABLES Incorporate information from this section into your Foldable.

Reading Check **Identify** the three factors that affect the height of a wave.

Breaking waves Study **Figure 15.18.** It shows that as ocean waves reach the shallow water near shorelines, the water depth eventually becomes less than one-half of their wavelength. The shallow depth causes changes to the movement of water particles at the base of the wave. This causes the waves to slow down. As the water becomes shallow, incoming wave crests gradually catch up with the slower wave crests ahead. As a result, the crest-to-crest wavelength decreases. The incoming waves become higher, steeper, and unstable, and their crests collapse forward. Collapsing waves are called **breakers.** The formation of breakers is also influenced by the motion of wave crests, which overrun the troughs. The collapsing crests of breakers, like the one shown in **Figure 15.19,** move at high speeds toward shore and play a major role in shaping shorelines. You will learn more about breakers and shoreline processes in Chapter 16.

■ **Figure 15.19** As waves move into shallow water, breakers form.



Royalty-Free/CORBIS

Tides

Tides are the periodic rise and fall of sea level. The highest level to which water regularly rises is known as high tide, and the lowest level is called low tide. Because of differences in topography and latitude, the tidal range—the difference in height between high tide and low tide—varies from place to place. In the Gulf of Mexico, the tidal range is less than 1 m. In New England, it can be as high as 6 m. The greatest tidal range occurs in the Bay of Fundy between New Brunswick and Nova Scotia, Canada, where it is as much as 16.8 m. Generally, a daily cycle of high and low tides takes 24 hours and 50 minutes. Differences in topography and latitude cause three different daily tide cycles, as shown in **Figure 15.20.** Areas with semidiurnal cycles experience two high tides in about a 24-hour period. Areas with mixed cycles have one pronounced and one smaller high tide in about a 24-hour period. Areas with diurnal cycles have one high tide in about a 24-hour period.

Reading Check **Explain** the difference between semidiurnal tides and mixed tides.

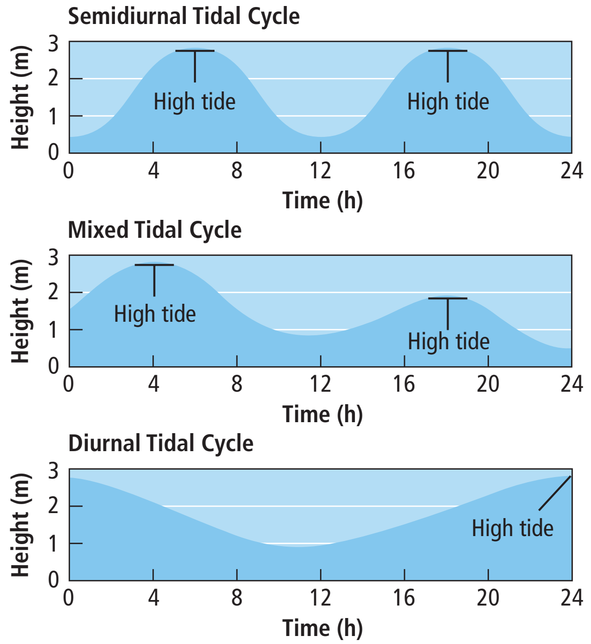


Figure 15.20 The three different daily tide cycles are semidiurnal, mixed, and diurnal.

DATA ANALYSIS LAB

Based on Real Data*

Graph Data

When does the tide come in? Tidal data is usually measured in hourly increments. The water levels shown in the data table were measured over a 24-hour period.

Think Critically

1. **Apply** Plot these water levels on a graph with time on the *x*-axis and water level on the *y*-axis.
2. **Estimate** the approximate times and water levels of high tides and low tides.
3. **Identify** the type of daily tidal cycle this area experiences.
4. **Determine** the tidal range for this area.
5. **Predict** the water level at the next high tide and estimate when it will occur.

*Data obtained from: The National Oceanic and Atmospheric Administration, Center for Operational Oceanographic Products and Services.

Data and Observations

Tidal Record			
Time (h)	Water Level (m)	Time (h)	Water Level (m)
00:00	2.11	13:00	1.70
01:00	1.79	14:00	1.37
02:00	1.33	15:00	1.02
03:00	0.80	16:00	0.68
04:00	0.36	17:00	0.48
05:00	0.10	18:00	0.50
06:00	0.03	19:00	0.69
07:00	0.20	20:00	1.11
08:00	0.55	21:00	1.58
09:00	0.99	22:00	2.02
10:00	1.45	23:00	2.27
11:00	1.74	24:00	2.30
12:00	1.80		

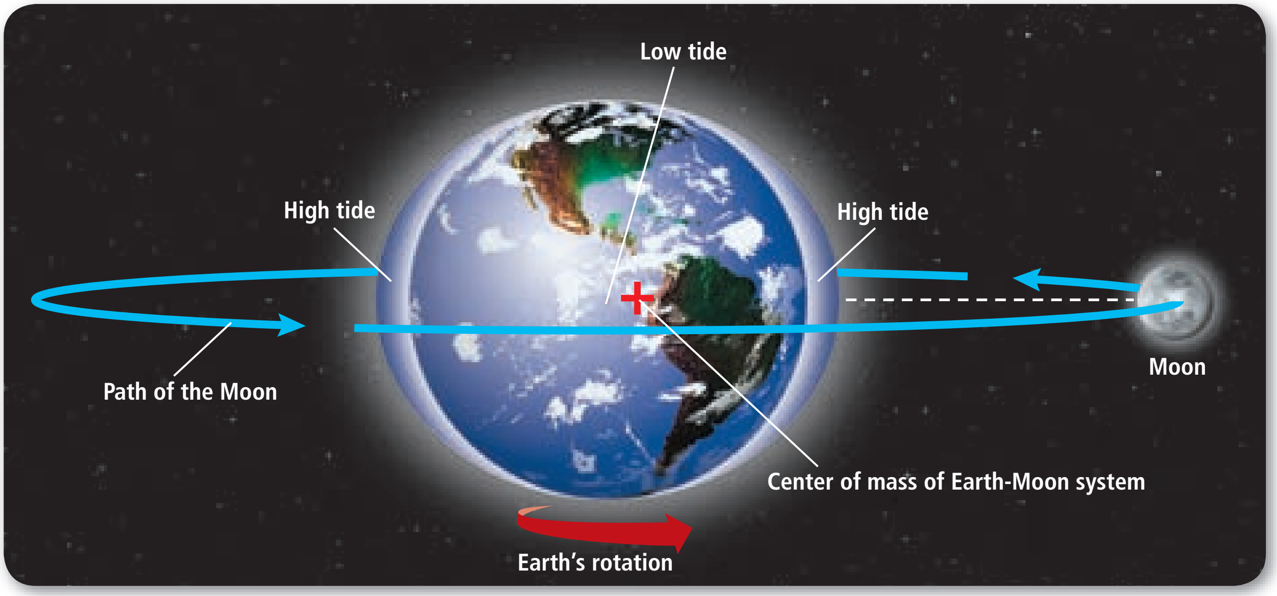


Figure 15.21 The Moon and Earth revolve around a common center of gravity and experience unbalanced gravitational forces. These forces cause tidal bulges on opposite sides of Earth. (Note: *diagram is not to scale.*)

The Moon's influence The basic causes of tides are the gravitational attraction among Earth, the Moon, and the Sun, as well as the differences in the force of gravity that are caused by distance. Consider the Earth-Moon system. Both Earth and the Moon orbit a common center of gravity, shown as a red plus sign in **Figure 15.21.** As a result of their motions, both Earth and the Moon experience differing gravitational forces. These unbalanced forces generate tidal bulges on opposite sides of Earth. The gravitational effect of the Moon on Earth's oceans is similar to what happens to the liquid in a coffee cup inside a car as the car goes around a curve. The liquid sloshes toward the outside of the curve.

The Sun's influence The gravitational attraction of the Sun and Earth's orbital motion around the Sun influences tides. However, even though the Moon is much smaller than the Sun, lunar tides are more than twice as high as those caused by the Sun because the Moon is much closer to Earth. Consequently, Earth's tidal bulges are aligned with the Moon.

Depending on the phases of the Moon, solar tides can either enhance or diminish lunar tides, as illustrated in **Figure 15.22.** Notice in **Figure 15.22** that during a full or new moon, the Sun, the Moon, and Earth are all aligned. When this occurs, solar tides enhance lunar tides, causing high tides to be higher than normal and low tides to be lower than normal. The tidal range is highest during these times. These types of tides are called **spring tides.** Spring tides have a greater tidal range during the winter in the northern hemisphere, when Earth is closest to the Sun. Study **Figure 15.22** again. Notice that when there is a first- or third-quarter moon, the Sun, the Moon, and Earth are at right angles to each other. When this occurs, solar tides diminish lunar tides, causing high tides to be lower and low tides to be higher than normal. The tidal range is lowest during these times. These types of tides are called **neap tides.** Spring and neap tides alternate every two weeks.

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Attraction

Science usage: a force acting between particles of matter, tending to pull them together

Common usage: something that pulls people in by appealing to their tastes

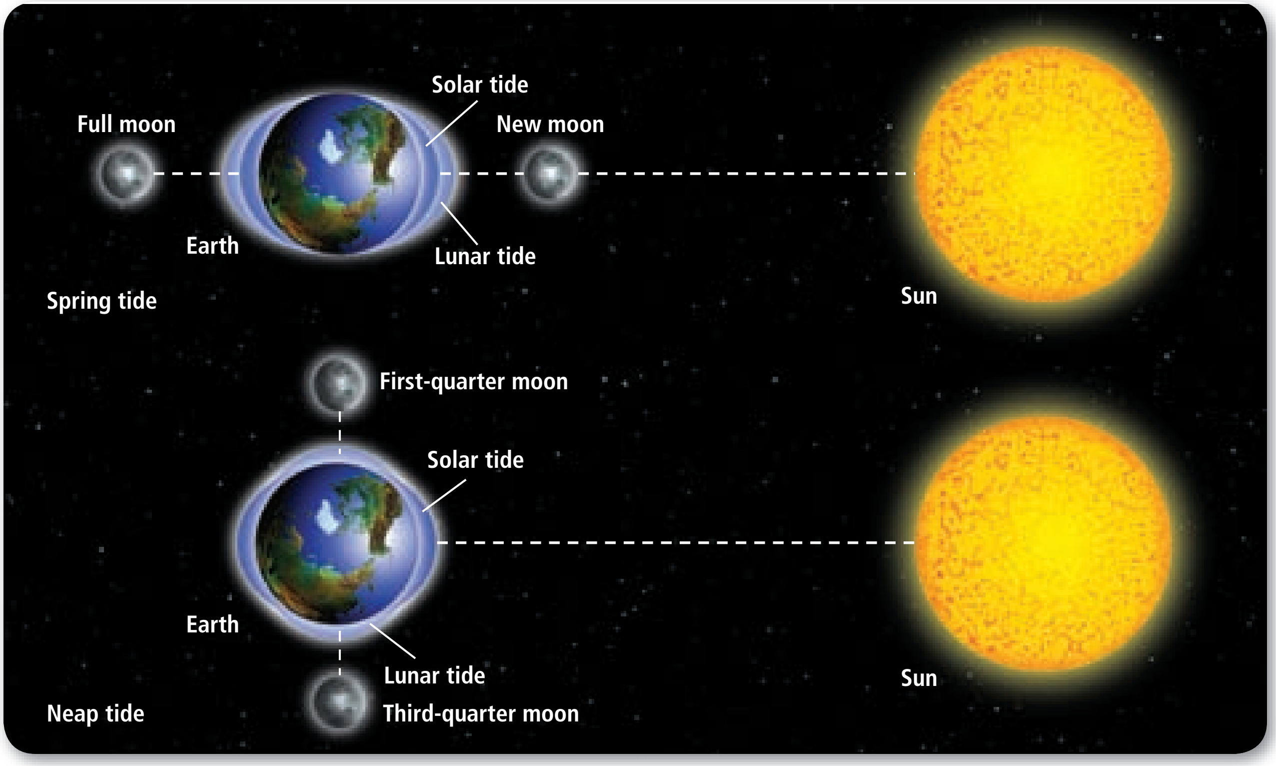


Figure 15.22 Spring tides occur when the Sun, the Moon, and Earth are aligned. Neap tides occur when the Sun, the Moon, and Earth form a right angle. (Note: *diagram is not to scale.*)

Currents

Currents in the ocean can move horizontally or vertically. They can also move at the surface or deep in the ocean. Currents at the surface are usually generated by wind. Some currents are the result of tides. Deep-ocean currents usually result from differences in density between water masses.

Surface currents Mainly the top 100 to 200 m of the ocean experience **surface currents,** which can move at a velocity of about 100 km per day. Surface currents follow predictable patterns and are driven by Earth's global wind systems. Recall from Chapter 12 that, in the northern hemisphere, tropical trade winds blow from east to west. The resulting tropical ocean surface currents also flow from east to west. In northern midlatitudes, the prevailing westerlies and resulting ocean surface currents move from west to east. In northern polar regions, polar easterly winds push surface waters from east to west.

The direction of surface currents can also be affected by landforms, such as continents, as well as the Coriolis effect. Recall from Chapter 12 that the Coriolis effect deflects moving particles to the right in the northern hemisphere and to the left in the southern hemisphere.

Reading Check **Explain** how winds influence surface currents.

Gyres If Earth had no landmasses, the global ocean would have simple belts of easterly and westerly surface currents. Instead, the continents deflect ocean currents to the north and the south so that closed circular current systems, called gyres (JI urz), develop.

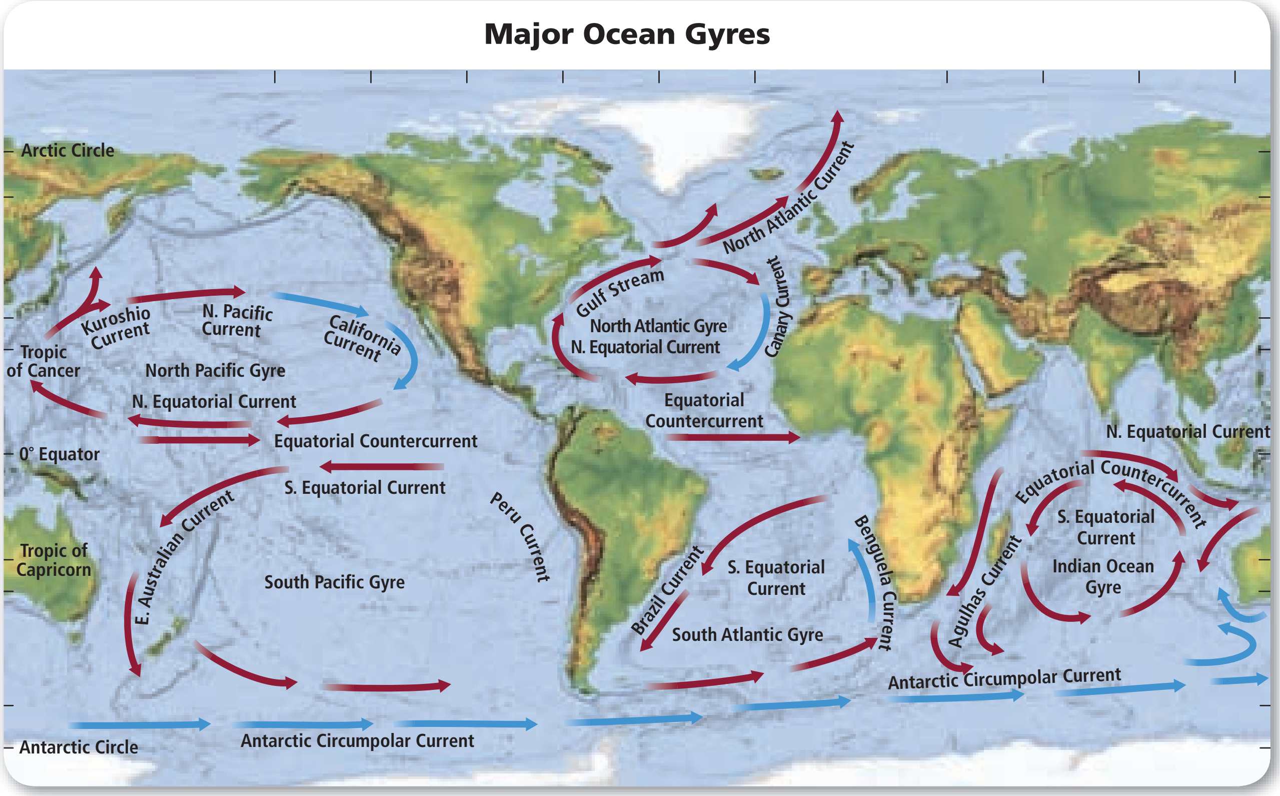


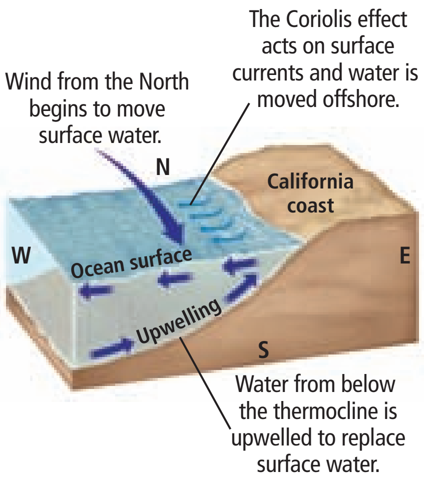
Figure 15.23 Large gyres in each ocean are formed by surface currents.
Identify ***the currents that make up the gyre in the South Atlantic Ocean.***

As shown in **Figure 15.23,** there are five major gyres—the North Pacific, the North Atlantic, the South Pacific, the South Atlantic, and the Indian Ocean. Because of the Coriolis effect, the gyres of the northern hemisphere circulate in a clockwise direction and those of the southern hemisphere circulate in a counterclockwise direction. The parts of all gyres closest to the equator move toward the west as equatorial currents. When these currents encounter a landmass, they are deflected toward the poles. These poleward-flowing waters carry warm, tropical water into higher, colder latitudes. An example of a warm current is the Gulf Stream Current in the North Atlantic.

After these warm waters enter polar regions, they gradually cool and, deflected by landmasses, move back toward the equator. The resulting currents then bring cold water from higher latitudes into tropical regions. An example of this kind of current is the California Current in the eastern North Pacific.

Upwelling In addition to moving horizontally, ocean water moves vertically. The upward motion of ocean water is called **upwelling.** Upwelling waters originate in deeper waters, below the thermocline, and thus are usually cold. Areas of upwelling exist mainly off the western coasts of continents in the trade-wind belts. For example, **Figure 15.24** shows what happens off the coast of California. Winds blowing from the north cause surface water to begin moving. The Coriolis effect acts on the moving water, deflecting it to the right of its direction of movement, which results in surface water being moved offshore. The surface water is then replaced by upwelling deep water.

Figure 15.24 Upwelling occurs when surface water is moved offshore and deep, colder water rises to the surface to replace it.



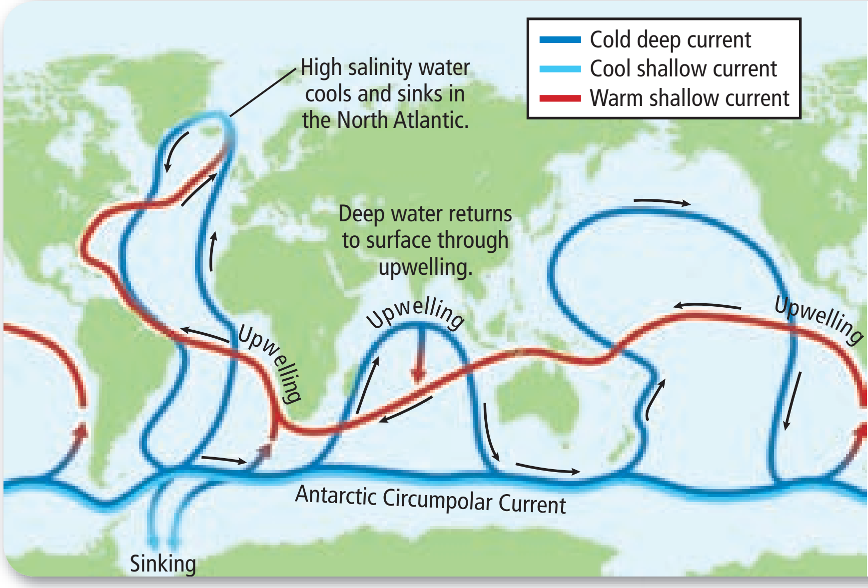


Figure 15.25 Differences in salinity and temperature generate density currents in the deep ocean. Most of the return flows upwell along Antarctic Circumpolar Current.

Density currents Recall the discussion of Antarctic Bottom Water in Section 15.2. The sinking of Antarctic Bottom Water is an example of an ocean current. In this case, the current is called a **density current** because it is caused by differences in the temperature and salinity of ocean water, which in turn affect density. Density currents move slowly in deep ocean waters, following a general path that is sometimes called the global conveyer belt.

The conveyor belt, a model of which is shown in **Figure 15.25,** begins when cold, dense water, including North Atlantic Deep Water and Antarctic Bottom Water, sinks at the poles. After sinking, these water masses slowly move away from the poles and circulate through the major ocean basins. After hundreds of years, the deep water eventually returns to the surface through upwelling. Once at the surface, the deep water is warmed by solar radiation.

Section 15.3 Assessment

Section Summary

- Energy moves through ocean water in the form of waves.
- Tides are influenced by both the Moon and the Sun.
- Surface currents circulate in gyres in the major ocean basins.
- Vertical currents in the ocean include density currents and upwelling.

Understand Main Ideas

1. MAIN Idea **Describe** how surface currents in gyres redistribute heat between the equator and the poles.
2. **Illustrate** a wave. Label the following characteristics: *crest, trough, wavelength, wave height,* and *wave base.*
3. **Explain** how tides form.
4. **Compare and contrast** surface currents and density currents.

Think Critically

5. **Predict** the effects on marine ecosystems if upwelling stopped.
6. **Assess** the difference between spring tides and neap tides.

WRITING in Earth Science

7. Write a step-by-step explanation of how upwelling occurs.

Earth Science and the Environment

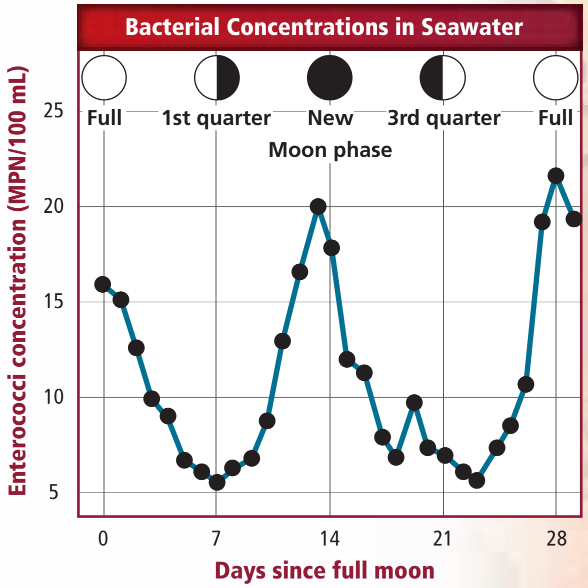
Bacterial Counts and Full Moons

You've been looking forward to going to the beach all week. Under the hot Sun—towel and lunch in hand—you head toward the sand. You can't wait to get in the cool, refreshing water. As you near the entrance of the beach, you see a posted sign that reads "Beach Closed: High Bacterial Counts in Water."

Bacteria in the water Although most of the bacteria in seawater are harmless to humans, some types are thought to cause gastrointestinal illnesses, with symptoms that include diarrhea and vomiting, in swimmers. Water is routinely tested on many beaches for a type of bacteria called enterococci (en tur oh KAHK i), which normally live in the intestines of mammals and birds. Although enterococci are usually harmless, their presence in the water is considered a strong indicator of the presence of other, illness-causing, bacteria. If enterococci counts rise above a certain level, authorities close beaches for the safety of swimmers.

Bacterial counts and moon phases
Scientists have found that higher levels of enterococci in seawater are associated with new moon and full moon phases, as shown in the graph on the right. Recall that spring tides occur during the new moon and full moon phases. During spring tides, high tides are at their highest levels and low tides are at their lowest, resulting in a large tidal range.

After compiling and analyzing data for 60 beaches along the Southern California coast, scientists found that at 50 of the 60 beaches there was a pattern of high bacterial counts during spring tides. Lower bacterial counts were associated with neap tides, which occur during first-quarter and three-quarter moon phases.



Bacterial counts in seawater vary with the phase of the Moon.

Data also showed that higher counts of bacteria were found specifically during an ebbing spring tide. The term *ebbing tide* refers to water that is receding after reaching its highest point.

Possible sources of bacteria Scientists have several hypotheses to explain possible sources for the bacteria in seawater during the spring tides. One is that the bacteria are present in high numbers in groundwater that only mixes with seawater during spring tides. Other possible sources include decaying organic material that collects on the sand, or bird droppings near the high tide line, both of which would mix with seawater during high spring tides.

WRITING in Earth Science

Newscast Suppose you are a newscaster presenting a story for the nightly news about bacterial levels at beaches. Present your story to the class, explaining results of scientific studies on patterns of bacteria and why these results are important to swimmers. To learn more about bacterial counts in seawater, visit glencoe.com.

GEOLAB

MODEL WATER MASSES

Background: **Water in oceans is layered because water masses with higher densities sink below those with lower densities. The density of seawater depends on its temperature and salinity.**

Question: *How do changes in salinity and temperature affect water density?*

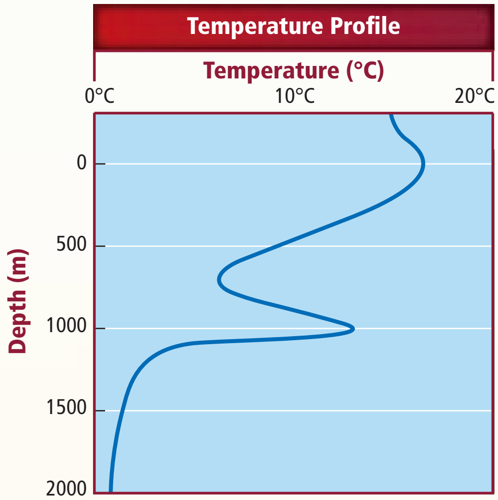
Materials

scale
graduated 500-mL cylinder
100-mL glass beakers (4)
water
red, yellow, and blue food coloring
salt
thermometer
eyedropper
graph paper
ruler
calculator

Safety Precautions

Procedure

1. Read and complete the lab safety form.
2. Mix 200 mL of water and 7.5 g of salt in the graduated cylinder. Pour equal amounts of the salt solution into two beakers. Fill each of the two other beakers with 100 mL of freshwater.
3. Put a few drops of red food coloring in one of the salt solutions. Put a few drops of yellow food coloring in the other salt solution. Put a few drops of blue food coloring in one of the freshwater beakers. Do not add food coloring to the other freshwater beaker.
4. Place the beakers with the red salt solution and the blue freshwater in the refrigerator. Refrigerate them for 30 min.
5. Measure and record the temperature of the water in all four beakers.
6. Put several drops of the cold, red salt water into the beaker with the warm, yellow salt water and observe what happens. Record your observations.
7. Put several drops of the cold, blue freshwater into the beaker with the warm, clear freshwater and observe what happens. Record your observations.
8. Put several drops of the cold, blue freshwater into the beaker with the warm, yellow salt water and observe what happens. Record your observations.



Analyze and Conclude

1. **Describe** the movement of the cold, red salt water in Step 6. Compare this to the movement of the cold, blue freshwater in Step 8. What accounts for the differences you observed?
2. **Identify** the water samples by color in order of increasing density.
3. **Explain** If you poured the four water samples into the graduated cylinder, how would they arrange themselves into layers by color, from top to bottom?
4. **Construct** Assume that four water masses in a large body of water have the same characteristics as the water in the four beakers. The warm water layers are 100 m thick, and the cold layers are 1000 m thick. Construct a graph that shows the temperature profile of the large body of water.

APPLY YOUR SKILL

Infer The temperature profile above was constructed from measurements taken in the Atlantic Ocean off the coast of Spain. Study the profile, then infer why a high-temperature layer exists beneath the thermocline. Is this layer denser than the colder water above? Explain.

CHAPTER 15

Study Guide

Download quizzes, key terms, and flash cards from glencoe.com.

BIG Idea Studying oceans helps scientists learn about global climate and Earth's history.

Vocabulary	Key Concepts
Section 15.1 An Overview of Oceans	
• sea level (p. 410) • side-scan sonar (p. 407)	**MAIN Idea** The global ocean consists of one vast body of water that covers more than two-thirds of Earth's surface. • Scientists use many different instruments to collect and analyze data from oceans. • Scientists have several ideas as to where the water in Earth's oceans originated. • A large portion of Earth's surface is covered by ocean. • Earth's oceans are the Pacific, the Atlantic, the Indian, the Arctic, and the Southern.
Section 15.2 Seawater	
• estuary (p. 414) • salinity (p. 413) • temperature profile (p. 418) • thermocline (p. 418)	**MAIN Idea** Oceans have distinct layers of water masses that are characterized by temperature and salinity. • Ocean water contains dissolved gases, nutrients, and salts. • Salts are added to and removed from oceans through natural processes. • Properties of ocean water, including temperature and salinity, vary with location and depth. • Many of the oceans' deepwater masses sink from the surface of polar oceans.
Section 15.3 Ocean Movements	
• breaker (p. 422) • crest (p. 421) • density current (p. 427) • neap tide (p. 424) • spring tide (p. 424) • surface current (p. 425) • tide (p. 423) • trough (p. 421) • upwelling (p. 426) • wave (p. 421)	**MAIN Idea** Waves and currents drive the movements of ocean water and lead to the distribution of heat, salt, and nutrients from one region of the ocean to another. • Energy moves through ocean water in the form of waves. • Tides are influenced by both the Moon and the Sun. • Surface currents circulate in gyres in the major ocean basins. • Vertical currents in the ocean include density currents and upwelling.

Earth Science Online Vocabulary PuzzleMaker glencoe.com

CHAPTER 15 Assessment

Vocabulary Review

Match each description below with the correct vocabulary term from the Study Guide.

1. the amount of dissolved salts in a fixed volume of seawater

2. a transitional layer in which temperature rapidly decreases with depth

3. plots changing water temperatures against depth

Complete the sentences below using vocabulary terms from the Study Guide.

4. The lowest point of a wave is the _________ .

5. The level of Earth's oceans is _________.

6. _________ sends sound waves to the seafloor at an angle.

7. _________ are the periodic rise and fall of sea level.

8. A _________ is caused by differences in the temperature and salinity of ocean water.

9. The upward motion of ocean water is called _________.

10. The highest point of a wave is the _________.

11. Waves that collapse near shore are called _________.

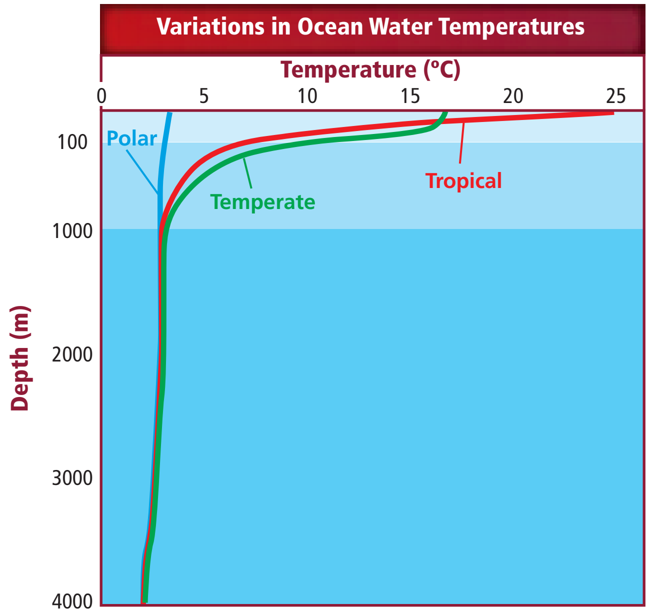
Understand Key Concepts

12. Which is used to measure ocean depth?
- **A.** bottom dredges
- **B.** nets
- **C.** sonar
- **D.** tidal patterns

13. What is the average depth of the oceans?
- **A.** 380 m
- **B.** 38 m
- **C.** 3800 m
- **D.** 3 km

14. Which are the most common gases emitted by volcanoes?
- **A.** hydrogen and helium
- **B.** oxygen and nitrogen
- **C.** water vapor and carbon dioxide
- **D.** chlorine and hydrogen

Use the graph below to answer Questions 15 and 16.



15. Between which depths is the thermocline?
- **A.** 0 and 100 m
- **B.** 100 and 1000 m
- **C.** 100 and 4000 m
- **D.** 1000 and 4000 m

16. What is the average temperature of deep water below the thermocline?
- **A.** 15°C
- **B.** more than 4°C
- **C.** less than 4°C
- **D.** 0°C

17. What basic motion does water follow during the passage of a wave?
- **A.** forward
- **B.** backward
- **C.** up and down
- **D.** circular

18. Which would have the largest impact on global ocean water density?
- **A.** strong winds
- **B.** increase in daylight hours
- **C.** long-term increase in air temperature
- **D.** thunderstorm with heavy precipitation

19. Which process does not remove salt from ocean water?
- **A.** precipitation of salt in dry, coastal regions
- **B.** evaporation of water in subtropical regions
- **C.** sea spray being carried inland by wind
- **D.** absorption by marine organisms

Use the diagram below to answer Question 20.

20. Which type of tides occur when the Sun, the Moon, and Earth are aligned as shown above?
A. spring tides
B. neap tides
C. lunar tides
D. solar tides

21. Which type of tides occur when the Sun, the Moon, and Earth are at right angles to each other?
A. spring tides
B. neap tides
C. lunar tides
D. solar tides

Constructed Response

22. Illustrate Make a diagram that shows how the ocean acts as a sink for carbon.

23. Relate Where in the oceans are the highest values of salinity found? What processes lead to areas of high salinity water?

24. Solve What would be the wave base for a wave that is 200 m long?

25. Interview Write several questions you would ask an oceanographer about the use of computers to analyze data from the ocean.

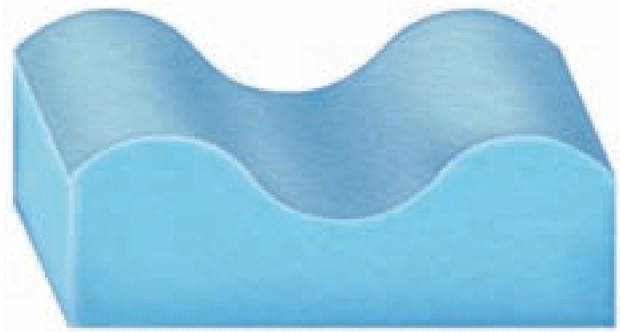
26. Determine Which gyre would have clockwise circulation: the North Pacific, the South Pacific, the South Atlantic, or the Indian Ocean? Explain.

27. Diagram Draw a diagram that shows how the Sun influences tides.

28. Analyze Why does a wave break?

29. Explain how the Moon influences tides.

Use the diagram below to answer Question 30.



30. Diagram Copy the illustration shown above. Then use the following terms to label the characteristics of an ocean wave: *crest, trough, wave height,* and *wavelength.*

31. Cause and Effect Cold water masses are generally denser than warm water masses, yet warm water from the Mediterranean Sea sinks to a depth of more than 1000 m when it flows into the Atlantic Ocean. What causes this effect?

Think Critically

32. Predict Based on what you have learned about water density, describe the movement of freshwater from a river as it flows into a sea.

33. Hypothesize Use your knowledge of global warming to hypothesize why sea level is rising.

34. Suggest a real-world application for adding salt to lower the melting point of ice.

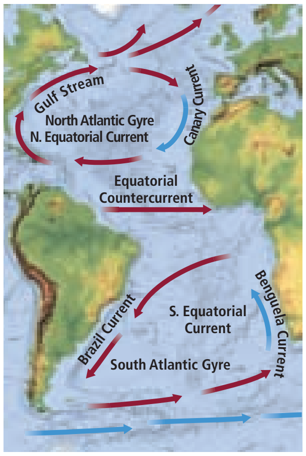
35. Plan Use **Figure 15.23** to plan the fastest round trip by ship from Boston, Massachusetts, to London, England. Will the return route be the same as the outbound trip? Explain.

36. CAREERS IN EARTH SCIENCE Suppose you are a lead scientist at NASA. Design an experiment that would allow you to test the hypothesis that Earth's water originated from comets.

37. Compare and contrast Antarctic Intermediate Water and North Atlantic Deep Water.

38. Explain how biological and physical processes affect levels of carbon dioxide in different areas of the ocean.

Use the diagram below to answer Question 39.



39. Assess Surface currents can affect coastal climates. Would the Gulf Stream and the Benguela Current, both of which are surface currents, have the same effect on coastal climate? Explain.

40. Predict One of the effects of El Niño, which you learned about in Chapter 14, is that the trade winds that blow across the equatorial Pacific Ocean weaken. Predict how this might affect upwelling off the coast of Peru.

41. Assess How do density currents and the conveyor belt help move dissolved gases, such as oxygen, and nutrients, such as nitrogen, from one area of the ocean to another?

Concept Mapping

42. Create a concept map using the following words or phrases that describe waves: *lowest point of a wave, wave characteristics, crest, wavelength, wave height, trough, horizontal crest-to-crest distance, highest point of a wave,* and *vertical distance between crest and trough.*

Challenge Question

43. Research the percentages of the different sources of freshwater on Earth, including glaciers, ice caps, rivers, lakes, and groundwater. Construct a new circle graph like the one shown in **Figure 15.5** that represents the new data.

Additional Assessment

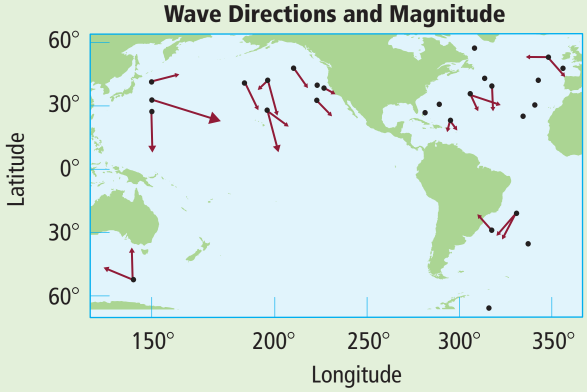
44. WRITING in **Earth Science** Write a summary about majoring in oceanography for a college brochure. Include information about the prerequisites, requirements for completion, and career opportunities in your summary.

DBQ Document–Based Questions

Data obtained from: Alford, M. 2003. The redistribution of energy available for mixing by long-range propagation of internal waves. *Nature* 423:159–162.

Ocean mixing due to waves is important for pollution dispersal, marine productivity, and global climate. In the figure below, the arrows represent the direction and magnitude of waves from different data collection sites (shown as black dots). The absence of arrows from the black dots means that the waves were small enough to ignore.

Wave Directions and Magnitude



45. In which direction do most of the waves in the northern hemisphere travel? How does this differ from waves in the southern hemisphere?

46. Given the number of collection sites in the southern hemisphere, can you draw any general conclusion about waves in this area?

Cumulative Review

47. What steps are usually included in a scientific method? **(Chapter 1)**

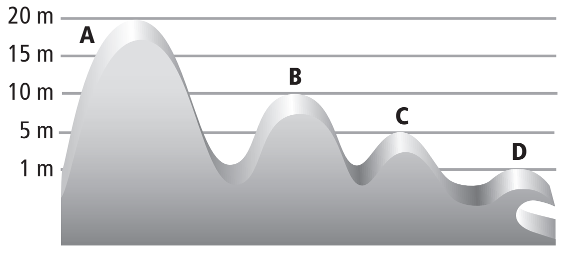
48. Name an example of a carbonate mineral. What is its chemical composition? **(Chapter 4)**

Standardized Test Practice

Multiple Choice

1. Why is deforestation often linked to global warming?
- **A.** It increases the amount of dry land on Earth's surface.
- **B.** It releases toxic gases and pollutants into the atmosphere.
- **C.** It increases the amount of CO_2 released into the atmosphere.
- **D.** It decreases the amount of CO_2 released into the atmosphere.

Use the illustration to answer Questions 2 and 3.



2. Which wave is most likely caused by a strong hurricane?
- **A.** A
- **B.** B
- **C.** C
- **D.** D

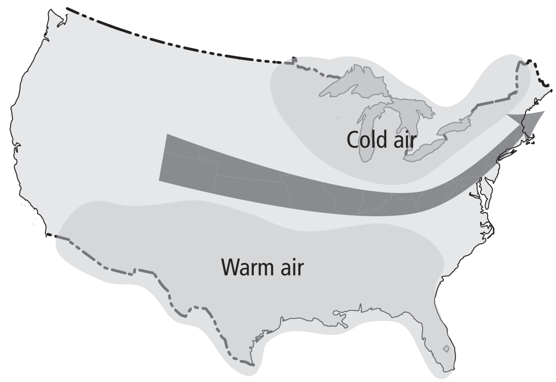
3. What is causing Wave D to collapse?
- **A.** friction from the ocean floor
- **B.** storm activity
- **C.** increased crest-to-crest wavelength
- **D.** opposing tidal movement

4. Where is a heat island most likely to be found?
- **A.** a farm
- **B.** a beach
- **C.** a mountain top
- **D.** an inner city

5. Which would be considered the best evidence that an area had been affected by continental glaciation?
- **A.** thick deposits of sediment
- **B.** long, snakelike ridges of sand and gravel
- **C.** plants and animals adapted to a cold climate
- **D.** large, shallow lakes

6. Which is NOT a characteristic the Fujita tornado intensity scale uses to rank tornadoes?
- **A.** funnel length
- **B.** wind speed
- **C.** path of destruction
- **D.** duration

Use the map below to answer Questions 7 and 8.



7. What air current is shown by the arrow?
- **A.** jet stream
- **B.** prevailing westerlies
- **C.** prevailing easterlies
- **D.** trade wind

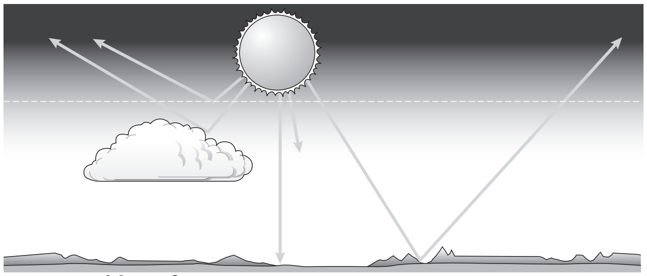
8. If the cold air were to dip down into the region of warm air, what prediction could be made about the type of weather that might result?
- **A.** cloudiness and precipitation
- **B.** some cloudiness with no precipitation
- **C.** clouds with showers and thunderstorms
- **D.** cool weather with no clouds

9. Which region's seawater is most likely to have the highest concentration of dissolved salts?
- **A.** an equatorial region
- **B.** a subtropical region
- **C.** a polar region
- **D.** a delta where rivers empty into oceans

10. If there is a period of calm during a hurricane, what should a person assume?
- **A.** The hurricane is over and it is safe to go out.
- **B.** The eye of the hurricane is over his or her area.
- **C.** The hurricane has weakened in intensity.
- **D.** The hurricane is over, but it is not safe to go out.

Short Answer

Use the illustration below to answer Questions 11–13.



11. Describe what is being represented in the above illustration.

12. What does the dotted line represent? What is its purpose?

13. Why is the Sun important to Earth?

14. Discuss what one-to-three day forecasts can and cannot do.

15. How does the rate of absorption differ on water than on land?

16. What is the benefit of using water vapor imagery?

Reading for Comprehension

Cooling with Seawater

Engineers have turned to the deep ocean as a cooling source. Because of the churning action of wind, waves, and currents, ocean water must be drawn from great depths to get consistently cold temperatures. The Natural Energy Laboratory of Hawaii Authority (NELHA) runs its own deep-source cooling plant to cool buildings on the agency's campus. The plant draws 42.8°F (6°C) seawater from a depth of 610 m. "NELHA saves about [U.S.] 3000 dollars a month in electrical costs by using the cold seawater air-conditioning process," said Jan War, an operations manager. "We still use a freshwater loop to cool our buildings, since seawater is so corrosive." So far deep-source cooling is only practical for communities with numerous buildings located near large bodies of water. But many of the world's major cities, settled during the golden age of sailing ships, are close to shore—something to think about the next time a dip in the ocean takes your breath away.

Article obtained from: Smith, J. The AC of tomorrow? Tapping deep water for cooling. *National Geographic News.* September 10, 2004.

17. What can be inferred from this passage?
    - **A.** Using seawater will only work in cities along the Pacific Ocean.
    - **B.** Using seawater to cool buildings is a good option, but the process needs more study and improvement.
    - **C.** Cooling with seawater is an expensive project.
    - **D.** Cooling with seawater will eventually take over cooling with freshwater all over.

18. Why would this new technology benefit many of the world's major cities?
    - **A.** Most cities have many buildings close to the shore.
    - **B.** Cities have the money to fund the new technology.
    - **C.** Cities are located along the Pacific Ocean.
    - **D.** Cities are not close to freshwater.

19. Discuss two reasons that a small farming town in Kansas would not benefit from this saltwater technology.

NEED EXTRA HELP?																
If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Review Section . . .	14.4	15.3	15.3	14.2	8.3	13.2	12.2	12.2	15.2	13.3	11.1	11.1	11.1	12.4	11.1	12.3