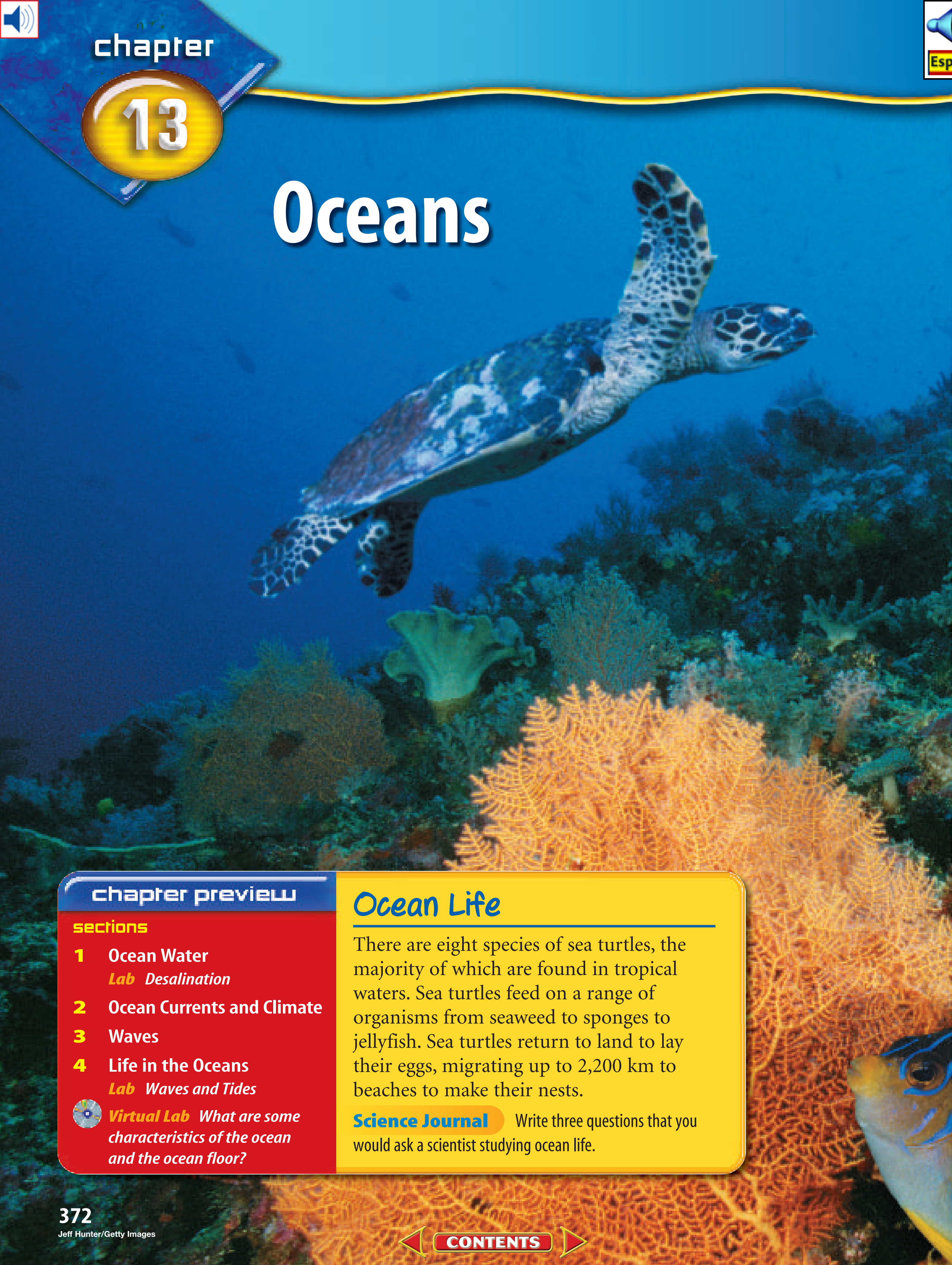
chapter 13

Oceans



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chapter preview

sections

Ocean Life

There are eight species of sea turtles, the majority of which are found in tropical waters. Sea turtles feed on a range of organisms from seaweed to sponges to jellyfish. Sea turtles return to land to lay their eggs, migrating up to 2,200 km to beaches to make their nests.

Science Journal Write three questions that you would ask a scientist studying ocean life.

Start-Up Activities

Launch LAB

Why are oceans salty?

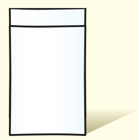
Ocean water tastes different from the water in most lakes. Its salty taste comes from salts that are dissolved in the water. In the lab below, you will experiment to find out how some of those salts end up dissolved in ocean water.

1. Mix five spoonfuls of dry sand with one spoonful of salt in a pie pan.
2. Bend a small section of the edge of the pie pan down so it is level with the bottom of the pan.
3. Hold the edge of the pie pan over a small bowl and sprinkle water on the salt and sand mixture. Don't wash the sand and salt out of the pie pan. Let the water filter through the mixture. Allow the water to collect in the bowl.
4. Place the bowl in sunlight or under a hot lamp and let the water evaporate. Observe what remains.
5. **Think Critically** Describe in your Science Journal which material the water dissolved as it filtered through the salt and sand. Infer where some of the salt in the oceans comes from.

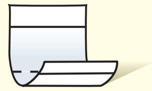
FOLDABLES™ Study Organizer

Oceans Make the following Foldable to help you identify the major topics about oceans.

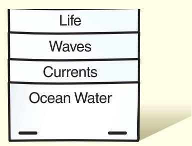
STEP 1 **Collect** 2 sheets of paper and layer them about 2.5 cm apart vertically. Keep the edges level.



STEP 2 **Fold** up the bottom edges of the paper to form 4 equal tabs.



STEP 3 **Fold** the papers and crease well to hold the tabs in place. Staple along the fold. **Label** the tabs as shown.



Find Main Ideas As you read the chapter, write information about the main ideas of each topic on the appropriate tab.

Science Online — Preview this chapter's content and activities at red.msscience.com

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section 1

Ocean Water

as you read

What You'll Learn

- **State** the importance of Earth's oceans.
- **Discuss** the origin of the oceans.
- **Describe** the composition of seawater.
- **Explain** how temperature and pressure vary with depth.

Why It's Important

Oceans affect all people's lives, even those who don't live near an ocean.

Review Vocabulary

atmosphere: Earth's air; forms a protective layer around the planet and is divided into five layers

New Vocabulary

- salinity
- photosynthesis
- thermocline

Importance of Oceans

Have you looked at a globe and noticed that oceans cover almost three-fourths of the planet's surface? A better name for Earth might be "The Water Planet." You might live far away from an ocean, or maybe you've never seen the ocean. But oceans affect all living things—even those far from the shore.

Oceans provide a place for many organisms to live. Oceans transport seeds and animals and allow materials to be shipped across the world. Oceans also furnish people with resources including food, medicines, and salt. Some examples of resources from the ocean are shown in **Figure 1.** The water for most of Earth's rain and snow comes from the evaporation of ocean water. In addition, 70 percent of the oxygen on Earth is given off by ocean organisms.

Figure 1 Oceans provide many resources.

Sea sponges are used in medicines for treating asthma and cancer.

Fish and other creatures provide many people with food.

Salt is obtained by evaporating seawater.

CONTENTS

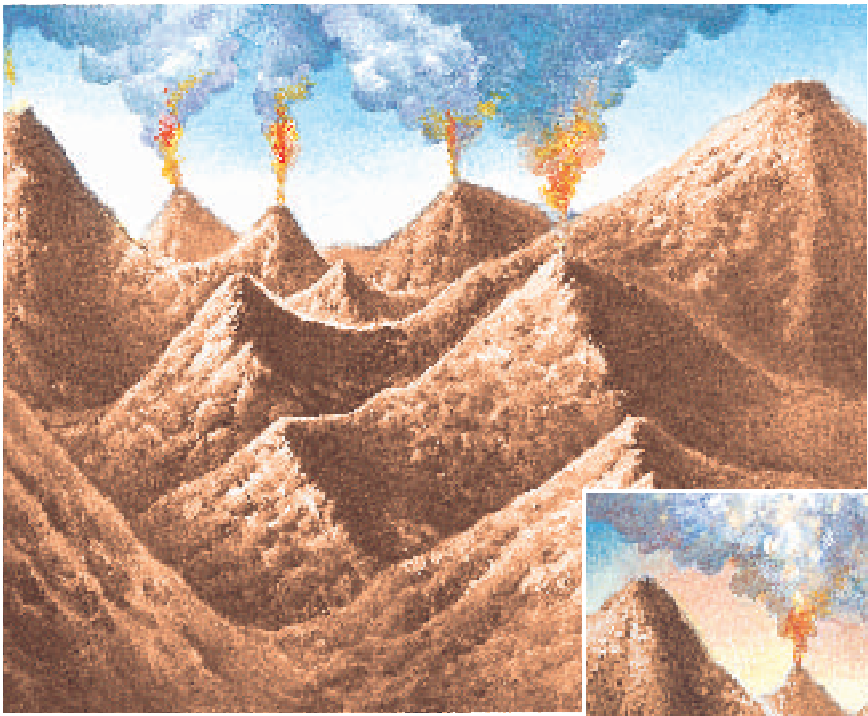


Figure 2 Oceans could have formed from water vapor that was released by volcanoes into Earth's atmosphere.

When the water vapor cooled enough to form clouds and rain, water collected in low areas and formed oceans.

Formation of Oceans

When Earth was still a young planet, many active volcanoes existed, as shown in **Figure 2.** As they erupted, lava, ash, and gases were released from deep within Earth. The gases entered Earth's atmosphere. One of these gases was water vapor. Scientists hypothesize that about 4 billion years ago, water vapor began accumulating in the atmosphere. Over millions of years, the water vapor cooled enough to condense and form clouds. Then torrential rains began to fall from the clouds. Over time, more and more water accumulated in the lowest parts of Earth's surface, as you can see in **Figure 2.** Eventually, much of the land was covered by water that formed oceans. Evidence indicates that Earth's oceans formed more than 3 billion years ago.

Composition of Ocean Water

If you taste seawater, you'll know immediately that it tastes different from water you normally drink. As a matter of fact, you really can't drink seawater. Dissolved substances cause the salty taste. Rivers and groundwater dissolve elements such as calcium, magnesium, and sodium from rocks and carry them to the ocean, as you saw in the Launch Lab. Erupting volcanoes add elements such as bromide and chlorine to ocean water.

Salinity The two most abundant elements in the dissolved salts in seawater are sodium and chlorine. If seawater evaporates, the sodium and chloride ions combine to form a salt called halite. You use this salt to season food. Halite, as well as other salts and substances, give ocean water its unique taste.

Salinity (say LIH nuh tee) is a measure of the amount of solids, or salts, dissolved in seawater. It is measured in grams of dissolved solids per kilogram of water. One kilogram of ocean water usually contains about 35 g of dissolved solids, or 3.5 percent. **Figure 3** shows the most abundant salts in ocean water.

Reading Check *What is salinity?*

The proportions and amount of dissolved salts in seawater remain in equilibrium. This means that the composition of the oceans is in balance. Despite the fact that rivers, volcanoes, and the atmosphere constantly add substances to the ocean, its composition has remained nearly constant for hundreds of millions of years. Biological processes and chemical reactions remove many of the substances, such as calcium, from ocean water. For example, many organisms, such as oysters and clams, use calcium to make their shells. Other marine animals use calcium to make bones. Calcium also can be removed from ocean water through chemical reactions, forming sediment on the ocean floor.

Figure 3 Every kilogram of ocean water contains about 35 g of dissolved solids. Sodium and chloride make up nearly 86 percent of this mass. This circle graph shows the most abundant dissolved solids.

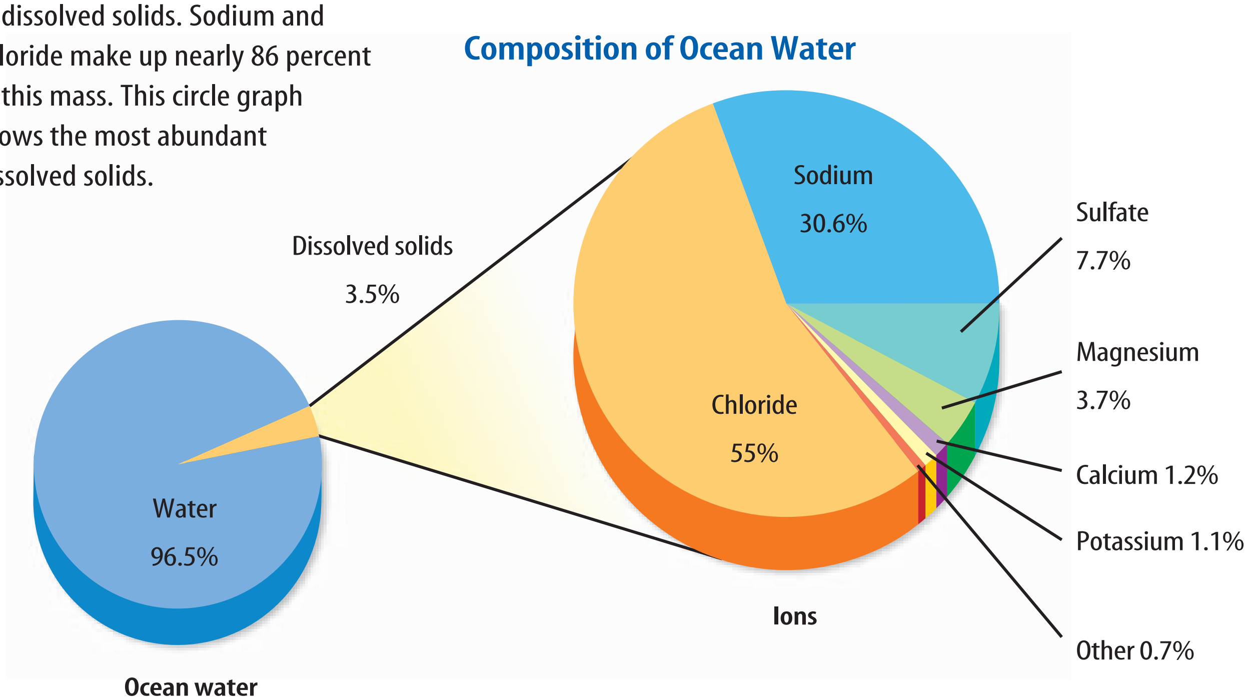


Figure 4 Kelp growing in shallow water use sunlight to photosynthesize. During photosynthesis, oxygen is given off and dissolves in the water.
Describe *How does carbon dioxide enter seawater?*

Carbon dioxide + Water —Sunlight→ Food + Oxygen

Dissolved Gases Although all of the gases in Earth's atmosphere dissolve in seawater, three of the most important are oxygen, carbon dioxide, and nitrogen.

The greatest concentration of dissolved oxygen is near the surface of the ocean. There, oxygen enters seawater directly from the atmosphere. Also, organisms like the kelp in **Figure 4** produce oxygen by photosynthesis—a process in which organisms use sunlight, water, and carbon dioxide to make food and oxygen. Because sunlight is necessary for photosynthesis, organisms that carry on **photosynthesis** are found only in the upper 200 m of the ocean, where sunlight reaches. Below 200 m, the level of dissolved oxygen drops rapidly. Here, many animals use oxygen for respiration and it is not replenished. However, more dissolved oxygen exists in very deep water than in water just below 200 m. This cold, deep water originates at the surface in polar regions and moves along the ocean floor to other regions.

Reading Check *How does oxygen get into seawater?*

A large quantity of carbon dioxide is absorbed directly into seawater from the atmosphere. Carbon dioxide reacts with water molecules to form a weak acid called carbonic acid. Carbonic acid helps control the acidity of the oceans. In addition, during respiration, organisms use oxygen and give off carbon dioxide, adding more carbon dioxide to the oceans.

Nitrogen is the most abundant dissolved gas in the oceans. Some types of bacteria combine nitrogen with oxygen to form nitrates. These nitrates are important nutrients for plants. Nitrogen is also one of the important building blocks of plant and animal tissue.

Science Online

Topic: Dissolved Gases
Visit red.msscience.com for Web links to information about dissolved gases in the ocean.

Activity Make a profile of how the concentration of a dissolved gas such as oxygen or carbon dioxide changes with water depth. Present the results on a poster to share with your class.

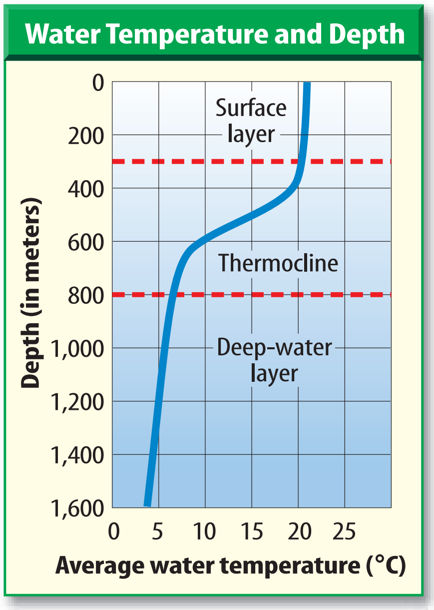


Figure 5 The depth of the thermocline varies with location. In the location shown on this graph, the thermocline layer begins at 300 m.
Determine *How deep does the thermocline extend?*

Water Temperature and Pressure

Oceans have three temperature layers—the surface layer, the thermocline layer, and the deep-water layer, shown in **Figure 5.** The surface layer is warm because it receives solar energy. The warmest surface water is near the equator where the Sun's rays strike Earth at a direct angle. Water near the poles is cooler because the Sun's rays strike Earth at a lower angle.

The **thermocline** often begins at a depth of about 200 m, but this varies. In this layer, temperature drops quickly with increasing depth. This occurs because solar energy cannot penetrate this deep. Below the thermocline lies the deep-water layer, which contains extremely cold water.

INTEGRATE Physics Pressure, or force per unit area, also varies with depth. At sea level, the pressure of the atmosphere pushing down on the ocean surface is referred to as 1 atmosphere (atm) of pressure. An atmosphere is the pressure exerted on a surface at sea level by the column of air above it. As you go below the ocean's surface, the pressure increases because of the force of the water molecules pushing down. The pressure increases by about 1 atm for each 10-m increase in depth.

For example, at a depth of 20 m, a scuba diver would experience a pressure of 3 atm (1 atm of air + 2 atm of water). Divers must carry tanks that supply their lungs with air at the same pressure as the water around them. If they didn't, the water pressure would keep their lungs from inflating when they tried to inhale.

section 1 review

Summary

Importance of Oceans

- Oceans cover almost three-fourths of Earth's surface. A variety of organisms live in the ocean.

Formation of Oceans

- Scientists hypothesize that oceans formed as water from torrential rains filled Earth's basins.

Composition of Ocean Water

- Ocean water contains both dissolved salts and dissolved gases.

Water Temperature and Pressure

- The warmest water is at the ocean surface. As depth increases, water temperature decreases.
- As water depth increases, pressure increases.

Self Check

1. **List** at least four reasons why oceans are important to you.
2. **Explain** the relationship between volcanic activity and the origin of Earth's oceans.
3. **Describe** how and why temperature and pressure vary with ocean depth.
4. **Think Critically** Why are the compositions of river water and ocean water not the same?

Applying Skills

5. **Recognize Cause and Effect** How does animal respiration affect the amount of dissolved oxygen in deeper water?

Science Online red.msscience.com/self_check_quiz

LAB

Desalination

Many people in the world do not have enough freshwater to drink. What if you could remove freshwater from the oceans and leave the salt behind? That's called desalination.

Real-World Question

How does desalination produce freshwater?

Goals

- **Observe** how freshwater can be made from salt water.
- **Recognize** that water can be separated from salt by the process of evaporation.

Materials

large spoon	large bowl
table salt	plastic wrap
water	tape
250-mL beakers (2)	large marble

Safety Precautions

Wear your safety goggles and apron throughout the experiment.

Procedure

1. Mix a spoonful of salt into a beaker of water.
2. Pour a thin layer of salt water in the bowl.
3. Place the clean beaker in the center of the bowl.
4. Cover the bowl loosely with plastic wrap so the wrap sags slightly in the center. Do not let the plastic wrap touch the beaker.
5. Tape the plastic wrap to the bowl to hold it in place.
6. Place the marble on the plastic wrap over the center of the beaker.

7. Leave the bowl in sunlight until water collects in the beaker. You might have to tap the marble on the plastic wrap lightly to get the water to drop into the beaker.
8. After some water has collected in the beaker, remove the plastic wrap. Let the water in the beaker and the bowl evaporate.
9. After the water has evaporated, rub the bottom of the beaker and the bottom of the bowl with your finger. Notice what you feel.

Conclude and Apply

1. **Describe** what you found remaining in the bowl and in the beaker after all the water had evaporated.
2. **Explain** what kind of water collected in the beaker—salt water or freshwater? How do you know?

Communicating Your Data

Make a poster that illustrates how you would make water that you could drink if you were stranded on a deserted island in the middle of the ocean. **For more help, refer to the Science Skill Handbook.**

Mark Burnett

Ocean Currents and Climate

section 2

as you read

What You'll Learn

- **State** how wind and Earth's rotation influence surface currents.
- **Explain** how ocean currents affect weather and climate.
- **Describe** the causes and effects of density currents.
- **Explain** how upwelling occurs.

Why It's Important

Ocean currents affect weather and climate.

Review Vocabulary

current: a fluid moving continuously in a certain direction

New Vocabulary

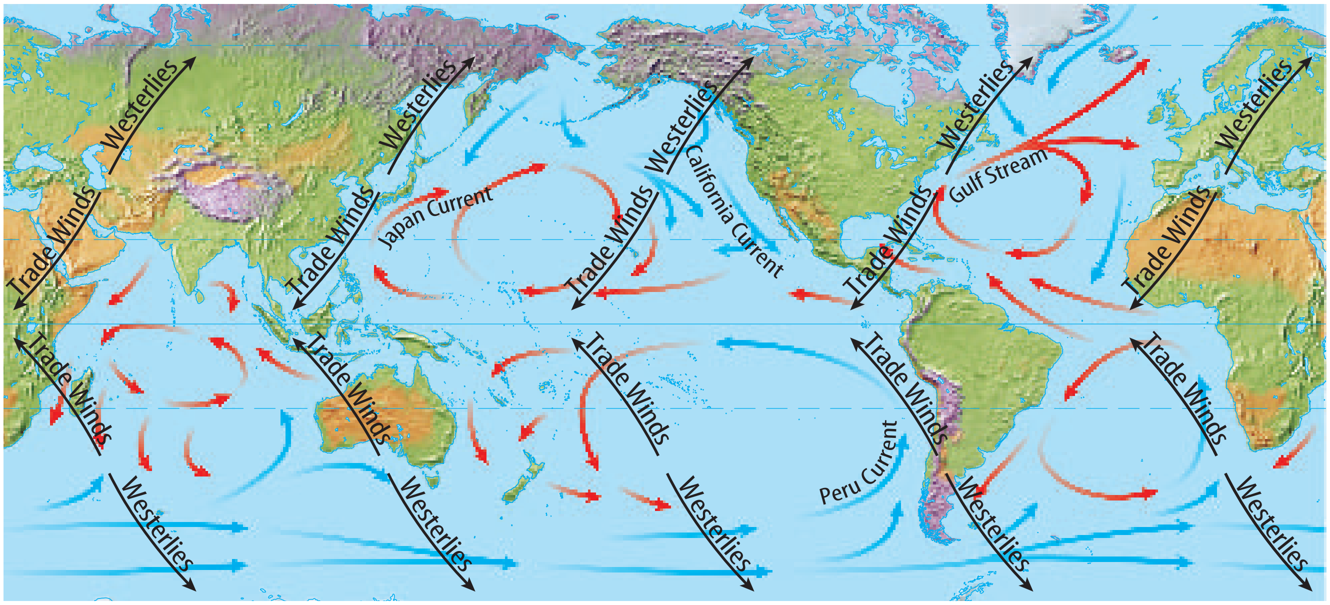
- surface current
- upwelling
- density current

Surface Currents

Ocean water never stands still. Currents move the water from place to place constantly. Ocean currents are like rivers that move within the ocean. They exist both at the ocean's surface and in deeper water. Major surface currents and winds are shown in **Figure 6.**

Causes of Surface Currents Powered by wind, **surface currents** usually move only the upper few hundred meters of seawater. When the global winds blow on the ocean's surface, they can set ocean water in motion. Because of Earth's rotation, the ocean currents that result do not move in straight lines. Earth's rotation causes surface ocean currents in the northern hemisphere to curve to the right and surface ocean currents in the southern hemisphere to curve to the left. You can see this in **Figure 6.** This turning of ocean currents is an example of the Coriolis effect.

Figure 6 Earth's global winds create surface currents in the oceans.
Observe *Which way do currents rotate in the northern hemisphere?*



The Gulf Stream Much of what is known about surface currents comes from records kept by early sailors. Sailing ships depended on certain surface currents to carry them west and others to carry them east. One of the most important currents for sailing east across the North Atlantic Ocean is the Gulf Stream. This 100-km wide current was discovered in the 1500s by Ponce de Leon and his pilot Anton de Alaminos. In 1770, Benjamin Franklin published a map of the Gulf Stream drawn by Captain Timothy Folger, a Nantucket whaler.

The Gulf Stream, shown in **Figure 7,** flows from Florida northeastward toward North Carolina. There it curves toward the east and becomes slower and broader. Because the Gulf Stream originates near the equator, it is a warm current. Look back at **Figure 6.** Notice that currents on eastern coasts of continents, like the Gulf Stream, are usually warm, while currents on western coasts of continents are usually cold. Surface currents like the Gulf Stream distribute heat from equatorial regions to other areas. This can influence the climate of regions near these currents.

Reading Check *What kind of current is the Gulf Stream?*

Science Online

Topic: Surface Currents

Visit red.msscience.com for Web links to information about the Gulf Stream and other surface currents.

Activity Investigate what type of ongoing research is taking place on other surface currents such as the California Current or the Peru Current. Present your results to the class.

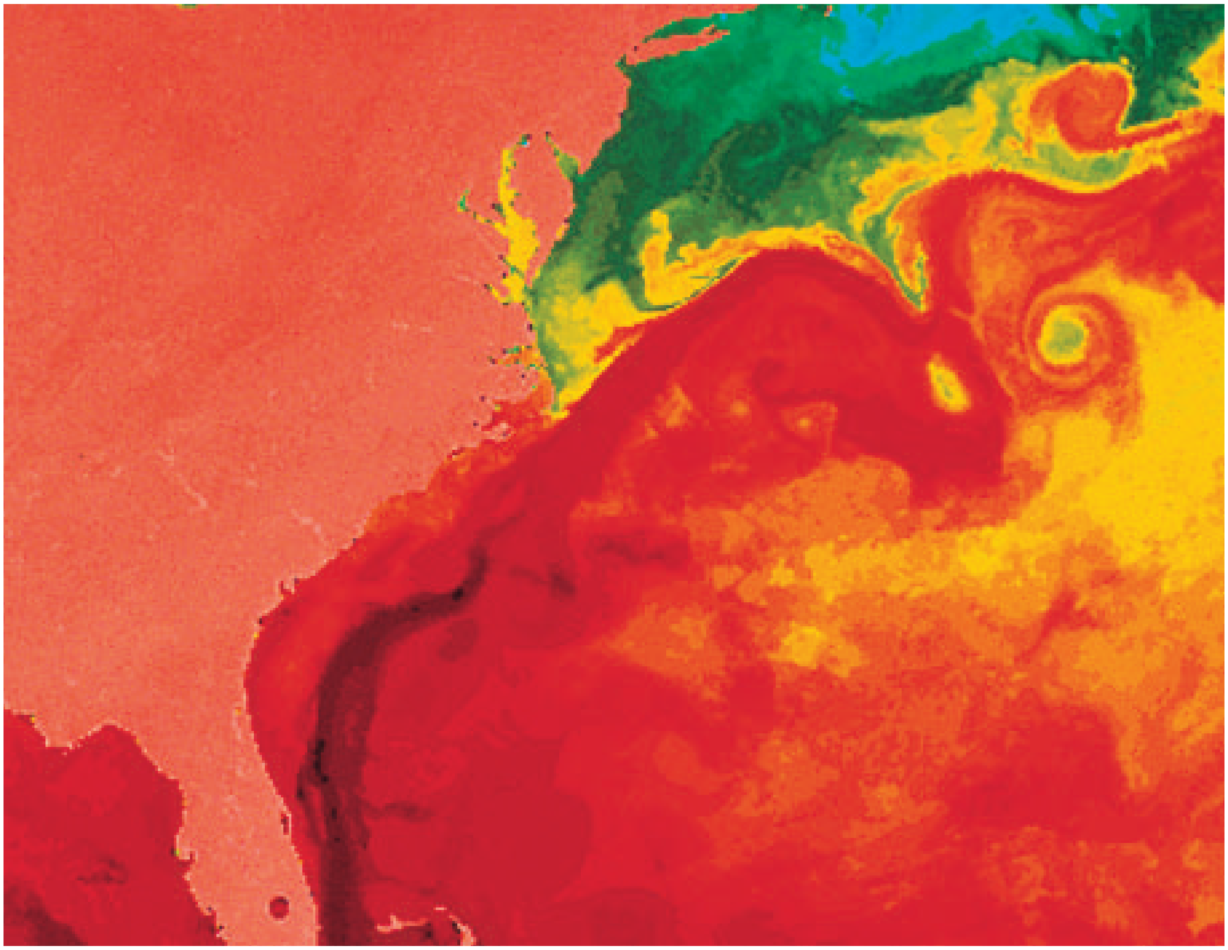


Figure 7 In this satellite image, the warm water of the Gulf Stream appears red and orange.

TSADO/GSFC/Tom Stack & Assoc.

The harbor at Reykjavik (RAY kyuh vihk), Iceland's capital, remains free of ice all year long.

Figure 8 The warm water of the Gulf Stream helps moderate Iceland's climate.
Describe *how the California Current affects the climate of coastal cities.*

Climate As an example of how surface currents affect climate, locate Iceland on the map in **Figure 8.** Based on its location and its name, you might expect it to have a cold climate. However, the Gulf Stream flows past Iceland. The current's warm water heats the surrounding air and keeps Iceland's climate mild and its harbors ice free year-round, as shown in **Figure 8.**

Cold Surface Currents The currents on the western coasts of continents carry colder water back toward the equator. In **Figure 6,** find the California Current off the west coast of North America and the Peru Current along the west coast of South America. They are examples of cold surface currents. The California Current affects the climate of coastal cities. For example, San Francisco has cool summers and many foggy days because of the California Current.

INTEGRATE Chemistry

Seawater Density The formula for determining density is mass/volume. When salinity increases, does it affect mass or volume? When temperature increases, does it affect mass or volume?

Density Currents

In water at a depth of more than a few hundred meters, winds have no effect. Instead, currents develop because of differences in the density of the water. A **density current** forms when more dense seawater sinks beneath less dense seawater. Seawater becomes more dense when it gets colder or becomes more salty.

A density current exists in the Mediterranean Sea. In this sea, lots of water evaporates from the surface, leaving salts behind. Therefore, the remaining water is high in salinity. This more dense water sinks and moves out into the less dense water of the Atlantic Ocean. At the surface, less dense water from the Atlantic flows into the Mediterranean Sea.

Cold and Salty Water An important density current that affects many regions of Earth's oceans begins north of Iceland. In the winter months, the water at the surface starts to freeze. When water freezes, dissolved salts are left behind in the unfrozen water. Therefore, this unfrozen water is very dense because it is cold and salty. It sinks and slowly flows along the ocean floor toward the southern Atlantic Ocean, as shown in blue in **Figure 9.** There it spreads into the Indian and Pacific Oceans. As the water is sinking near Iceland, warm surface water of the Gulf Stream, shown in red, moves northward from the equator to replace it. The Gulf Stream water warms the continents that border the North Atlantic.

Density Currents and Climate Change Suppose density currents near Iceland stopped forming. Some scientists hypothesize that this has happened in Earth's past and could happen again. Increasing carbon dioxide concentrations in Earth's atmosphere could trap more of the Sun's heat, raising Earth's temperature. If Earth's temperature rose enough, ice couldn't easily form near the polar regions. Freshwater from melting glaciers on land also could reduce the salinity of the ocean water. The density currents would weaken or stop. Scientists hypothesize that if dense water stopped flowing along the ocean bottom toward the southern Atlantic Ocean, warm water would no longer flow northward on the surface to replace the missing water. All of Earth could experience drastic climate shifts, including changing rainfall patterns and temperatures.

Mini LAB

Modeling a Density Current

Procedure

1. Fill a **paper** cup three-fourths full with **water**.
2. Add two spoonfuls of **salt** and three drops of **food coloring** to the water. Stir with a **spoon** to dissolve the salt.
3. Push one **thumbtack** into the cup 1 cm from the bottom of the cup and another 3 cm from the bottom.
4. Carefully place the cup into a **clear-plastic box** and fill the box with water until the water level in the box is about 0.5 cm above the top tack.
5. Remove both tacks at the same time and record in your **Science Journal** what you observe.

Analysis

1. Infer what is happening at the two holes in the cup.
2. Make a sketch to describe the current's direction.
3. Explain what causes the density current to form.

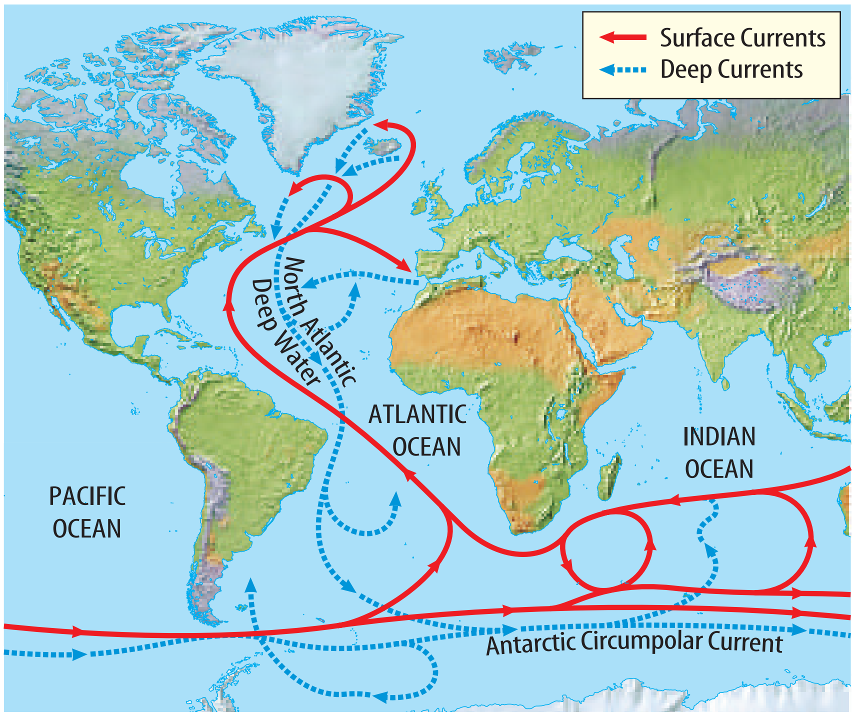


Figure 9 Like a giant conveyor belt, cold, salty water sinks in the northern Atlantic Ocean and flows southward, while warm surface water flows northward from the equator to replace it.

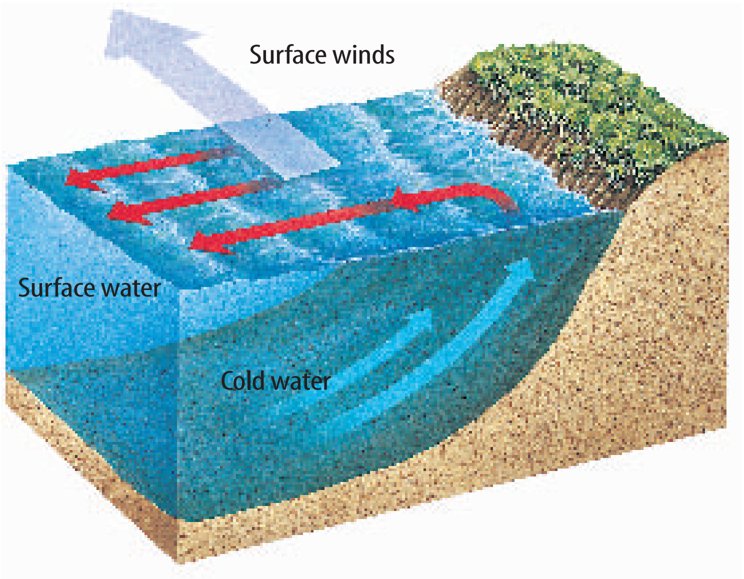


Figure 10 Winds push water away from shore along the South American coastline. This creates an upwelling of cold water.

Upwelling

An **upwelling** is a current in the ocean that brings deep, cold water to the ocean surface. This occurs along some coasts where winds cause surface water to move away from the land. Wind blowing parallel to the coast carries water away from the land because of the Coriolis effect. **Figure 10** shows upwelling as it occurs off the coast of Peru. Notice that when surface water is pushed away from the coast, deep water rises to the surface to take its place. This cold, deep water continually replaces the surface water that is pushed away from the coast. The cold water contains high concentrations of nutrients produced when dead organisms decayed at depth. This concentration of nutrients causes tiny marine organisms to flourish and fish to be attracted to areas of upwelling. Upwelling also affects the climate of coastal areas. Upwelling contributes to San Francisco's cool summers and famous fogs.

El Niño During an El Niño (el NEEN yoh) event, the winds blowing water from the coast of Peru slacken, the eastern Pacific is warmed, and upwelling is reduced or stops. Without nutrients provided by upwelling, fish and other organisms cannot find food. Thus, the rich fishing grounds off of Peru are disrupted.

section 2 review

Summary

Surface Currents

- As global winds blow along the ocean's surface, they can set surface water in motion. Due to the Coriolis effect, ocean surface currents do not move in straight lines.
- Surface currents can influence local climate.

Density Currents

- Density currents form when more dense seawater sinks beneath less dense seawater.

Upwelling

- Upwelling brings deep, cold water to the ocean surface. The concentration of nutrients in upwelled water is high.

Self Check

1. **Explain** how winds create surface currents.
2. **Describe** how the rotation of Earth modifies ocean currents in the northern hemisphere.
3. **Summarize** what causes the density current in the Mediterranean Sea.
4. **Think Critically** Why is the surface water cooler near San Diego, California, compared to that off the coast of Charleston, South Carolina?

Applying Skills

5. **Compare and contrast** density currents and upwelling in the ocean.

Science Online red.msscience.com/self_check_quiz

CONTENTS

section 3

Waves

Waves Caused by Wind

Have you ever wanted to surf? By catching a high, curled wave, you can ride all the way to the beach. A **wave** in water is a rhythmic movement that carries energy through the water. Waves that surfers ride could have originated halfway around the world. Whenever wind blows across a body of water, friction pushes the water along with the wind. If the wind speed is great enough, the water begins piling up, forming a wave. Three things affect the height of a wave: the speed of the wind, the length of time the wind blows, and the distance over which the wind blows. A fast wind that blows over a long distance for a long time creates huge waves. Once a wave forms, it can travel a great distance. But when winds stop blowing, waves stop forming.

Parts of a Wave Each wave has a crest, its highest point, and a trough, its lowest point. Wave height is the vertical distance between the crest and trough. The wavelength is the horizontal distance between the crests or troughs of two successive waves. **Figure 11** shows the parts of a wave.

In the open ocean, most waves have heights of 2 m to 5 m. Ocean waves rarely reach heights of more than 15 m. However, storm winds can produce waves more than 30 m high—taller than a six-story building—that can capsize even large ships.

as you read

What You'll Learn

- **Describe** how wind can form ocean waves.
- **Explain** the movement of water molecules in a wave.
- **Describe** how the Moon and Sun cause Earth's tides.
- **List** the forces that cause shoreline erosion.

Why It's Important

Wave erosion affects life in coastal regions.

Review Vocabulary

sediments: loose materials, such as rock fragments, mineral grains, and the remains of once-living plants and animals, that are moved by wind, water, ice, or gravity

New Vocabulary

- wave
- tide

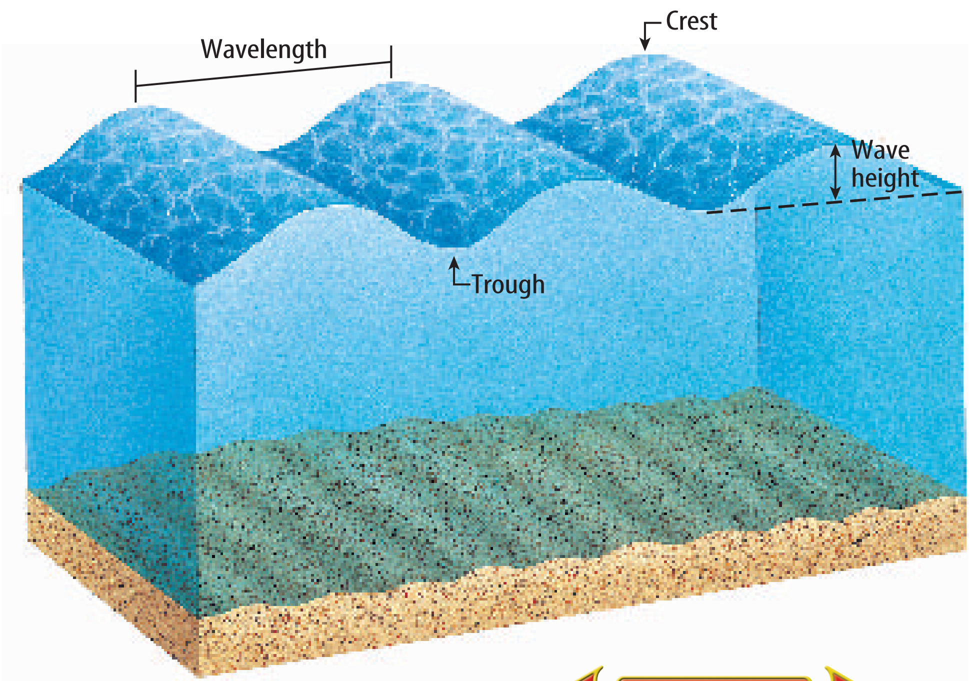
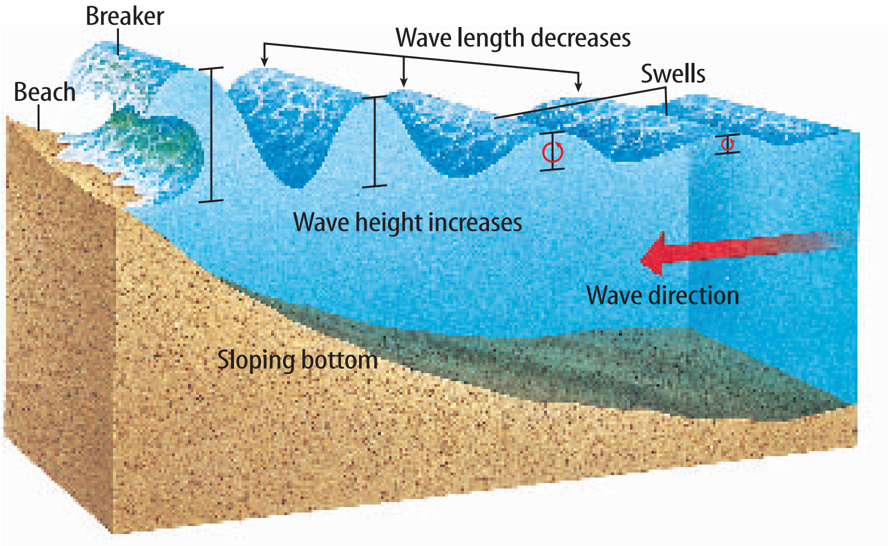


Figure 11 Every wave has a crest, trough, wavelength, and wave height.

Figure 12 As a wave moves by, individual molecules of water move around in circles. As a wave approaches shore, wavelength decreases and wave height increases. Eventually the bottom of the wave cannot support the top, and the wave falls over on itself, creating a breaker.



Wave Motion When you observe 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 stays in about the same place in a passing wave. If you want to demonstrate how molecules move in a wave, tie a ribbon to the middle of a rope. Then hold one end of the rope and have someone else hold the other end. Wiggle the rope until a wave starts moving toward the other person. Notice that the wave travels through the rope to the other person, but the ribbon moves only in small circles, not forward.

Breakers As a wave approaches a shore, it changes shape. Friction with the ocean floor slows the water at the bottom of the wave. Notice in **Figure 12** that as the bottom of the wave slows, the crest and trough come closer together and the wave height increases. Because the top of the wave is not slowed by friction, it moves faster than the bottom. Eventually, the wave top overtakes the bottom, and the wave collapses. Water tumbles over on itself. This collapsing wave is called a breaker. Breakers make the best waves for surfers to ride. After a wave breaks onto shore, gravity pulls the water back into the sea.

Reading Check *What causes breakers to form?*

Along smooth, gently sloping coasts, waves deposit eroded sediments on shore, forming beaches. Beaches extend inland as far as the tides and waves are able to deposit sediments.

Waves usually approach a shore at slight angles. This creates a longshore current of water, which runs parallel to the shore. As a result, beach sediments are moved sideways. Longshore currents carry many metric tons of loose sediment from one beach to another.

Mini LAB

Modeling Water Particle Movement

Procedure

1. Fill a large **bowl** with **water** and place a **penny** on the bottom in the center of the bowl.
2. Float a small piece of **toothpick** in the bowl directly above the penny.
3. Gently dip a **spoon** into the water to make small waves.

Analysis

1. Compare and contrast the movement of the waves and the toothpick.
2. Compare the movement of the toothpick with the movement of water particles in a wave.

Try at Home

Tides

Throughout a day, the water level at the ocean's edge changes. This rise and fall in sea level is called a **tide.** A tide is a giant wave that can be thousands of kilometers long but only 1 m to 2 m high in the open ocean. As the crest of this wave reaches shore, sea level rises to form high tide. Later in the day, the trough of the wave reaches shore and sea level drops. This is low tide. The difference between sea level at high tide and low tide is the tidal range. The tidal range in some coastal areas can be as much as 20 m.

Causes of Tides Tides are not created by wind. They are created by the gravitational attraction of Earth and the Moon and of Earth and the Sun. The Moon and Earth are relatively close together in space, so the Moon's gravity exerts a strong pull on Earth. This gravity pulls harder on particles closer to the Moon than on particles farther from the Moon, causing two bulges of water to form. One bulge forms directly under the Moon and one on the opposite side of Earth. As Earth rotates, these bulges move to follow the Moon on its daily passage. The crests of these bulges are high tides. Between these bulges are troughs that create low tides.

The Sun's gravity also affects the tides. When the Moon, Earth, and Sun line up together, the high tides are higher and the low tides are lower than normal, creating spring tides. When the Sun, Earth, and Moon form a right angle, high tides are lower and low tides are higher than normal, creating neap tides. **Figure 13** illustrates this effect.

Science Online

Topic: Tidal Ranges

Visit red.msscience.com for Web links to information about tidal ranges around the world.

Activity Select a coastal location and find one month's worth of tidal data for that area. Graph the data. Calculate the tidal range for that month.

Figure 13 As the Moon and Earth revolve around a common center of mass, a bulge of water forms on the side of Earth closest to the Moon and on the side opposite the Moon.

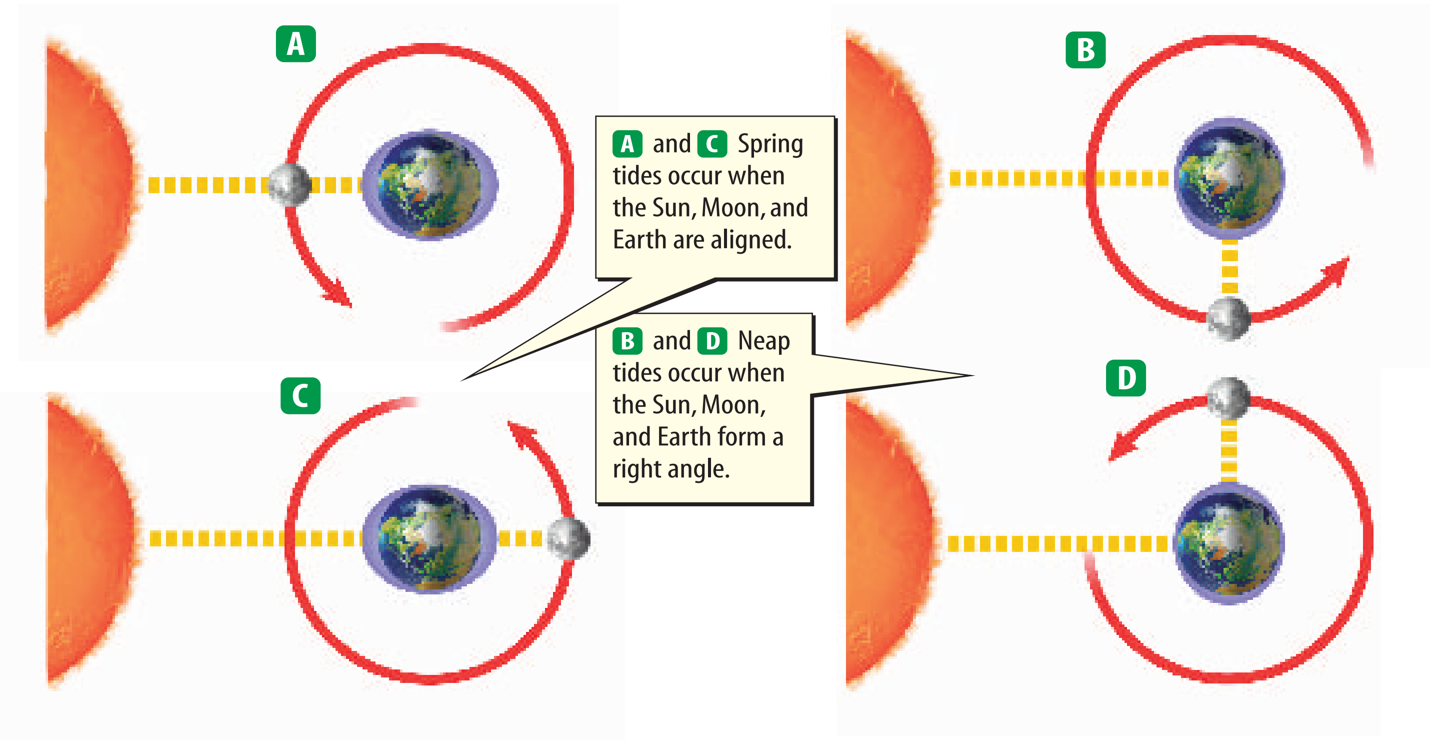


Figure 14 In a single day about 14,000 waves will crash onto this rocky shore.

Wave Erosion

Waves can erode many meters of land in a single season. They wear away rock at the base of rocky shorelines, as shown in **Figure 14.** Then overhanging rocks fall into the water, leaving a steep cliff. Houses built on ocean cliffs can be damaged or destroyed by the erosion below. At Tillamook Rock, Oregon, storm waves hurled a 61-kg rock high into the air. The rock crashed through the roof of a building 30 m above the water.

Beach Erosion Sandy shorelines also can be eroded by waves. Large storms and hurricanes can produce waves that move much of the sand from the beach and can destroy large parts of some nearshore islands. Longshore currents also can erode beaches. This happens most often when people build structures called groins that extend out into the water. Although groins may protect beaches in some places, they often cause erosion elsewhere.

section 3 review

Summary

Waves Caused by Wind

- Waves form as wind blows across a body of water.
- Although it appears as though water is moving forward in a wave, each molecule of water stays in approximately the same place as a wave passes.

Tides

- Tides are the rise and fall in sea level that can be measured along the shore.

Wave Erosion

- Waves can cause erosion to occur along rocky coasts as well as sandy shores. Longshore currents also can erode beaches.

Self Check

1. **Summarize** how wind creates waves. What factors determine the size of waves?
2. **Describe** how a water molecule moves in a wave. What causes a wave to break?
3. **Explain** what causes tides. How do spring tides and neap tides differ?
4. **Think Critically** If a storm arrives at a beach during high tide, why is erosion especially damaging?

Applying Skills

5. **Recognize Cause and Effect** The city of Snyderville keeps pumping sand onto its beach, but the sand keeps disappearing. Explain where it is going.

Science Online red.msscience.com/self_check_quiz

section 4

Life in the Oceans

Types of Ocean Life

Organisms live in many different areas of the ocean. Where an organism lives and how it moves from place to place determines whether it is classified as plankton, nekton, or a bottom dweller.

Plankton Tiny marine organisms that float in ocean currents are called **plankton.** Most plankton are one-celled organisms, such as the diatoms (DI uh tahmz) pictured in **Figure 15.** Some plankton can swim, but most drift with currents. You would need a microscope to see most of these organisms. Examples of animal plankton include eggs of ocean animals, very young fish, larval jellyfish and crabs, and tiny adults of some organisms. **Figure 15** shows a tiny jellyfish about 2 cm in diameter and the eggs of corals being released into the water where they will float.

as you read

What You'll Learn

- **Describe** the characteristics of plankton, nekton, and bottom-dwelling organisms.
- **Distinguish** among producers, consumers, and decomposers.
- **Discuss** how energy and nutrients are cycled in the oceans.
- **Explain** how organisms in the oceans interact in food chains.

Why It's Important

Marine organisms provide people with much of the food they need to survive.

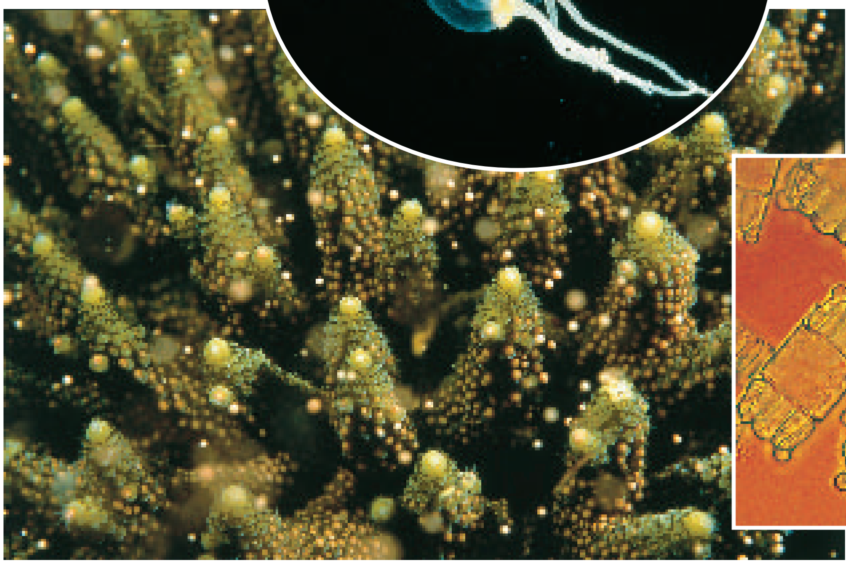
Review Vocabulary

nutrients: substances needed by organisms to carry out life processes

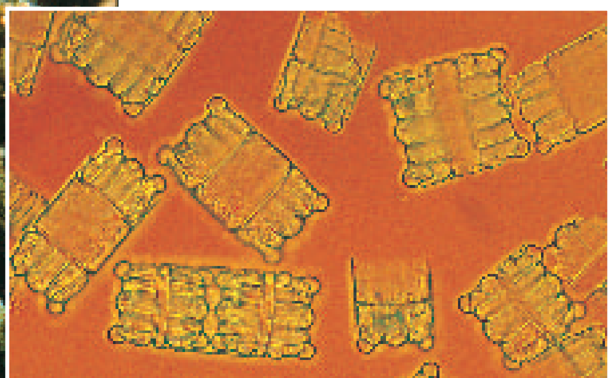
New Vocabulary

- plankton
- nekton
- ecosystem
- producer
- chemosynthesis
- consumer
- decomposer
- food chain

Figure 15 Plankton, such as this jellyfish, float in the upper layers of the ocean.



The eggs of corals become plankton when they are released into the water column.



Diatoms, shown above, are one-celled organisms that undergo photosynthesis.

CONTENTS

Figure 16 Swimming animals, such as this anglerfish (left), are nekton.
List *two other examples of nekton in the ocean.*

(t)Norbert Wu/Peter Arnold, Inc., (bl)Fred Bavendam/Minden Pictures, (br)Tom & Therisa Stack/Tom Stack & Assoc.

Nekton Animals that can actively swim, rather than drift in the currents, are called **nekton.** Fish, whales, shrimp, turtles, and squid are nekton. Swimming allows these animals to search more areas for food. Some nekton, such as herring, come to the surface to feed on plankton, but others remain in deeper water.

Some of the nekton that live in the dark abyss of the deepest parts of the ocean have organs that produce light, which attracts live food. Shown in **Figure 16,** an anglerfish dangles a luminous lure over its head. When small animals like shrimp bite at the lure, the anglerfish swallows them whole.

Bottom Dwellers Some organisms live on the ocean bottom. They can burrow in sediments, walk or swim on the bottom, or be attached to the seafloor.

Bottom-dwelling animals include anemones, crabs, corals, snails, starfish, and some fish. Many of these animals, such as sea cucumbers, eat the partially decomposed matter that sinks to the ocean floor. Some, such as the sea star in **Figure 17,** prey on other bottom dwellers. Others that are attached to the bottom, such as sponges, filter food particles from the water. Still others, such as anemones, corals, and the sea fans shown in **Figure 17,** are found in coral reefs. They capture organisms that swim by.

Figure 17 Bottom dwellers vary greatly. Many sea stars feed on other bottom dwellers such as clams. Sea fans, shown in the photo on the right, live attached to the bottom and cannot move from place to place.

CONTENTS

Ocean Ecosystems

The oceans are home to many different kinds of organisms. No matter where organisms live, they are part of an ecosystem. An **ecosystem** is a community of organisms and the nonliving factors that affect them, such as sunlight, water, nutrients, sediment, and gases. Every ecosystem has producer, consumer, and decomposer organisms.

Producers Producer organisms, such as those shown in **Figure 18,** form the base of all ecosystems. Producers are organisms that can make their own food. **Producers** near the ocean's surface contain chlorophyll. This allows them to make food and oxygen during photosynthesis.

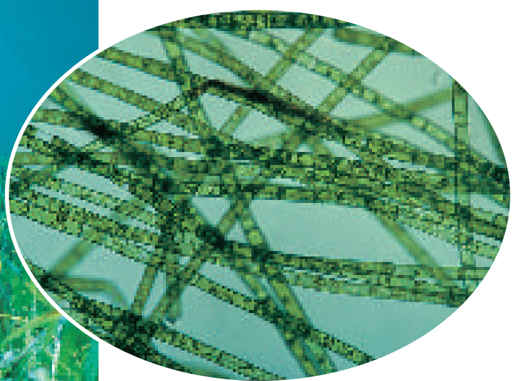
In deep water, where sunlight does not penetrate, producers that use chlorophyll can't survive. In this part of the ocean, producers make food by a process called **chemosynthesis.** *Chemo* means "chemical." This process often takes place along mid-ocean ridges where hot water circulates through the crust. Bacteria produce food using dissolved sulfur compounds that escape from hot rock. The bacteria then are eaten by organisms such as crabs and tube worms.

Consumers and Decomposers Consumer and decomposer organisms depend upon producers for survival. Organisms that eat, or consume, producers are called **consumers.** Consumers get their energy from the food stored in the producers' cells. Some also eat other consumers to get energy. When producers and consumers die, decomposers digest them. **Decomposers,** such as bacteria, break down tissue and release nutrients and carbon dioxide back into the ecosystem.

Reading Check *What is a consumer?*

INTEGRATE Social Studies

Economics and Fish Many coastal areas of the world depend on harvesting fish to keep the local economy healthy. Certain areas of the world such as the coast of Peru, the Gulf of Alaska and the Bering Sea, and the Grand Banks on the east coast of Canada, are well known for their fisheries. Events such as El Niño or the overharvesting of fish can greatly affect a fishing season.



Magnification: 100×

Figure 18 Producers can be large like the sea grass shown on the left. Sometimes they are as small as the microscopic algae shown on the right.
Infer *what all producers have in common.*

(l)Tom & Therisa Stack/Tom Stack & Assoc., (r)Dwight Kuhn/DRK Photo

Science Online

Topic: Food Webs

Visit red.msscience.com for Web links to information about ocean food chains and food webs.

Activity Find an example of an ocean food chain or food web. Display the information you find on a poster.

Food Chains Throughout the oceans, energy is transferred from producers to consumers and decomposers through **food chains**. In **Figure 19,** notice that algae (producers) are eaten by krill that are, in turn, eaten by Adélie penguins. Leopard seals eat the penguins, and killer whales eat the leopard seals. At each stage in the food chain, energy obtained from one organism is used by other organisms to move, grow, repair cells, reproduce, and eliminate wastes. Energy not used in these life processes is transferred along the food chain.

All ecosystems have many complex feeding relationships. Most organisms depend on more than one species for food. Notice in **Figure 19** that krill eat more than algae and in turn are eaten by animals other than Adélie penguins. In the Antarctic Ocean, as in all ecosystems, food chains are interconnected to form highly complex systems called food webs.

Applying Science

Are fish that contain mercury safe to eat?

When mercury, once used in pesticides, is added to oceans or bodies of freshwater, bacteria change it to methyl mercury, which is a more toxic form of mercury. Fish then absorb the methyl mercury from the water as it flows over their gills or as they feed on aquatic organisms. Larger fish feed on the smaller fish, and humans often eat larger fish. The table on the right lists the methyl mercury ranges for a variety of fish.

Methyl Mercury Content in Domestic Fish

Species	Range (ppm)	Average (ppm)
Catfish	ND–0.16	ND
Cod	ND–0.17	0.13
Crab	ND–0.27	0.13
Flounder	ND	ND
Halibut	0.12–0.63	0.24
Salmon	ND	ND
Tuna (canned)	ND–0.34	0.20
Tuna (fresh)	ND–0.76	0.38
Swordfish	0.36–1.68	0.88
Shark	0.30–3.52	0.84

Identifying the Problem

The average methyl mercury present in each fish is given in the chart in parts per million (ppm). The detection limit is 0.10 ppm. Any values less than 0.10 ppm are shown as ND (not detected). The FDA's (Food and Drug Administration) safe limit for human consumption is 1 ppm. Which species of fish could put you in danger of mercury poisoning if you eat them?

Solving the Problem

1. Which of the fish listed do not contain any methyl mercury? Explain.
2. The FDA limit of 1 ppm is 10 times lower than levels found in fish that have caused illness. The FDA recommends eating shark or swordfish no more than once a week. Does this appear consistent with the information given in the data table? Explain. Which fish could you safely eat as often as you wanted?

VISUALIZING FOOD CHAINS IN A FOOD WEB

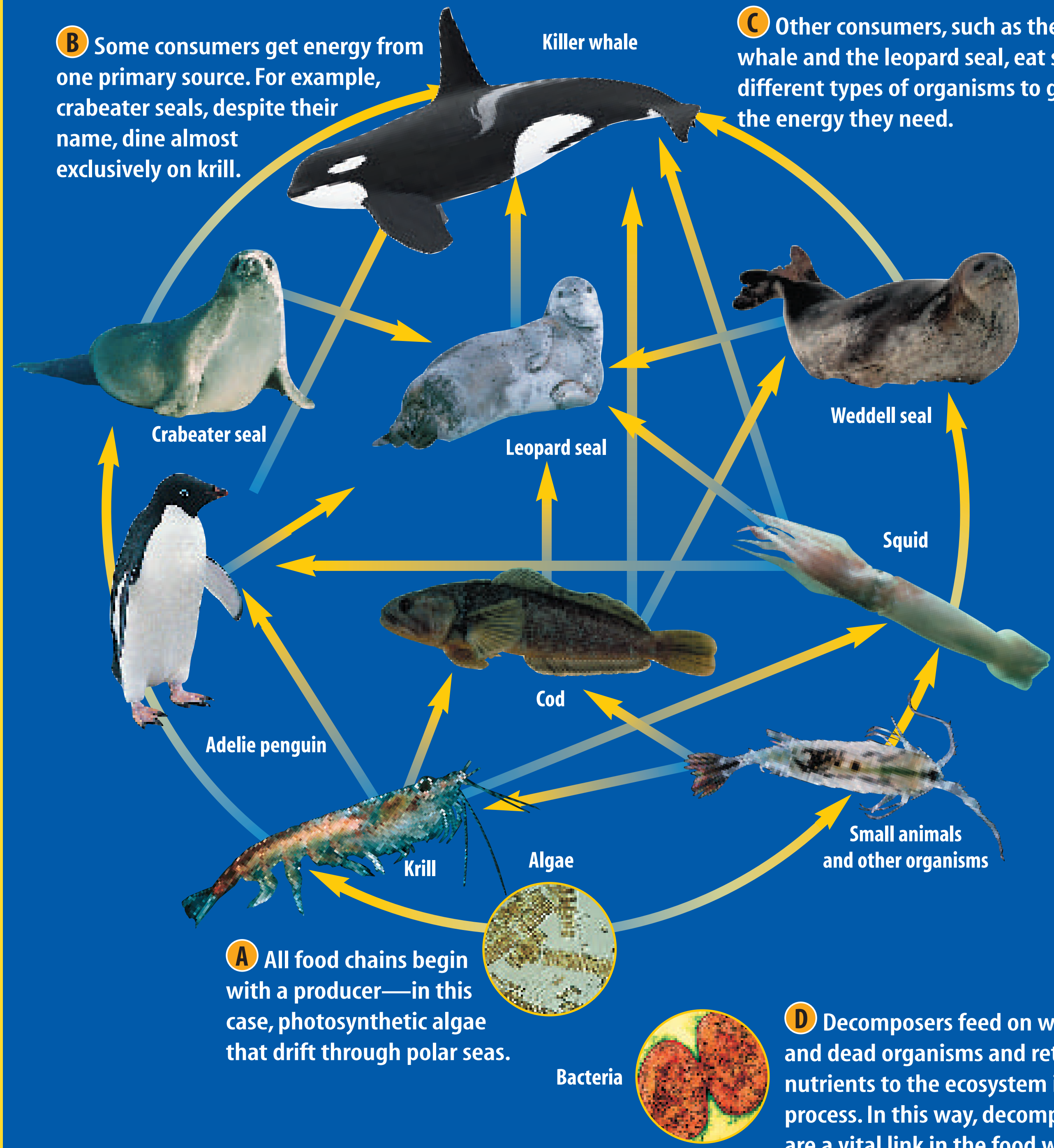
NATIONAL GEOGRAPHIC

Figure 19

A food web represents a network of interconnected food chains. It shows how energy moves through an ecosystem—from producers to consumers and eventually to decomposers. This diagram shows a food web in the Antarctic Ocean. Arrows indicate the direction in which energy is transferred from one organism to another.

B Some consumers get energy from one primary source. For example, crabeater seals, despite their name, dine almost exclusively on krill.

C Other consumers, such as the killer whale and the leopard seal, eat several different types of organisms to gain the energy they need.



A All food chains begin with a producer—in this case, photosynthetic algae that drift through polar seas.

D Decomposers feed on wastes and dead organisms and return nutrients to the ecosystem in the process. In this way, decomposers are a vital link in the food web.

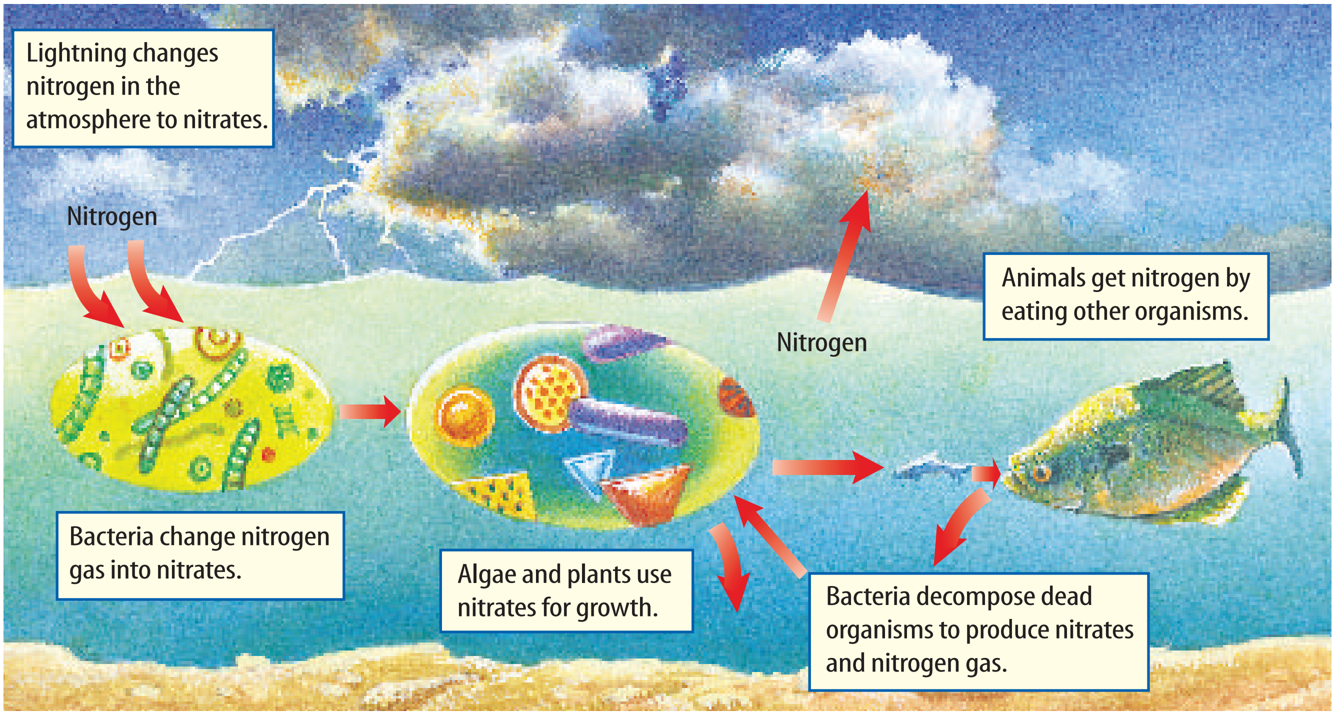
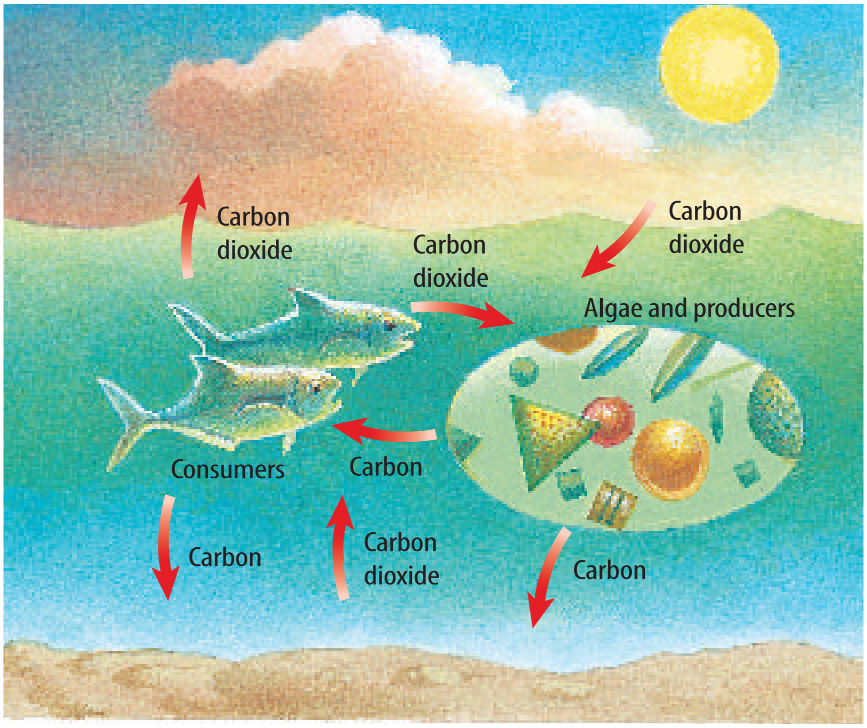


Figure 20 Nitrogen cycles from nitrogen gas in the atmosphere to nitrogen compounds and back again.

Figure 21 Carbon cycles through the ocean and between the ocean and the atmosphere.

Ocean Nutrients

Nearly everything in an ecosystem is recycled. When organisms respire, carbon dioxide is released back into the ecosystem. When organisms excrete wastes or die and decompose, nutrients are recycled. All organisms need certain kinds of nutrients in order to survive. For example, plants need nitrogen and phosphorus. **Figure 20** shows how nitrogen cycles through the ocean.



Carbon also is recycled. You learned earlier in this chapter that oceans absorb carbon dioxide from the atmosphere. You also learned that producers use carbon dioxide to make food and to build their tissues. Carbon then can be transferred to consumers when producers are eaten. When organisms die and sink to the bottom, some carbon is incorporated into marine sediment. Over time, carbon is exchanged slowly between rocks, oceans, the atmosphere, and organisms, as seen in **Figure 21.**

Figure 22 Parrot fish are efficient recycling organisms. They turn coral into fine sand as they graze on the algae in the coral.

Coral Reefs and Nutrient Recycling Coral reefs are ecosystems that need clear, warm, sunlit water. Each coral animal builds a hard calcium carbonate capsule around itself. Inside the animals' cells live algae that provide the animals with nutrients and give them color. As corals build one on top of another, a reef develops. Other bottom-dwelling organisms and nekton begin living on and around the reef. Nearly 25 percent of all marine species and 20 percent of all known marine fish live on coral reefs. Coral reefs generally form in tropical regions in water no deeper than 30 m.

A healthy reef maintains a delicate balance of producers, consumers, and decomposers. Energy, nutrients, and gases are cycled among organisms in complex food webs in a coral reef. Look at **Figure 22** to see one example of how materials are cycled through a coral reef.

section 4 review

Summary

Types of Ocean Life

- Marine organisms can be classified based on where they live and how they move from place to place: plankton, nekton, or bottom dweller.

Ocean Ecosystems

- Ocean ecosystems contain producers, consumers, and decomposers.
- Energy in an ecosystem is transferred through a food chain or a food web.

Ocean Nutrients

- Nutrients are passed from producers to consumers when producers are eaten. When organisms die, decomposers release these nutrients back into the ecosystem.

Self Check

1. **List** the characteristics of plankton, nekton, and bottom-dwelling organisms.
2. **List** the characteristics of producers, consumers, and decomposers.
3. **Explain** how carbon is cycled through the oceans. How is nitrogen cycled?
4. **Think Critically** Why must every ecosystem include producers as well as other organisms?

Applying Skills

5. **Form Hypotheses** Write a hypothesis about how an increase in the amounts of ocean nutrients might affect producers. How would the increase in nutrients affect consumers?

Science Online red.msscience.com/self_check_quiz

LAB

Model and Invent

Waves and Tides

Goals

- **Construct** a model of the edge of the ocean.
- **Demonstrate** how you can simulate waves and tides in your model.
- **Predict** how erosion might occur in your model.

Possible Materials

large basin
water
boards
sand
**gravel*
bricks
rocks
plastic bottles
fan (battery-operated)

**Alternate materials*

Safety Precautions

Real-World Question

The water in the Gulf of Mexico is subject to the same forces as water in the open ocean. Daily high and low tides affect the water level, and waves are involved in shoreline erosion. How can you simulate ocean waves and represent tidal changes in water level? How will the tides affect the amount of erosion in various areas? How can you model ocean waves and tides in the classroom? Can you simulate waves and tides along the edge of an ocean using a basin of water in the classroom?

Make a Model

1. **Determine** how you are going to create a model of the edge of the ocean. Draw a picture of what your model will look like.
2. Decide how you will create waves and tides in your model. What can you use to move the water? How can you simulate tides by changing the height of the water level?
3. **Predict** where in your model erosion may occur and where it may not. How might you be able to see where erosion will occur?

Check the Model Plans

1. **Compare** your model plans with those of other students in the class. Discuss why each of you chose the design you did.
2. Make sure that your teacher approves your model plans before you construct your model.

Betsy R. Strasser/Visuals Unlimited

Test Your Model

1. **Construct** your model based on your design plans.
2. Create waves in your model and observe what happens. Record your observations in your Science Journal.
3. Change the tide by changing the water level and repeat step 2.

Analyze Your Data

1. **Describe** what you observed when you created waves and tides in your ocean model.
2. Were you able to see any evidence of erosion in your model? If so, in what areas of your model was erosion present and where was it absent? If not, where would you expect to see erosion over a longer period of time? Explain.

Conclude and Apply

1. Did the waves you created always look the same or did they seem to vary in wave height or wavelength? Explain.
2. Did you see anything that looked like breakers as the waves hit the shore?
3. In what ways was your model similar to and different from the edge of a real ocean?
4. What features were you able to simulate and what features were missing from your model?

Communicating Your Data

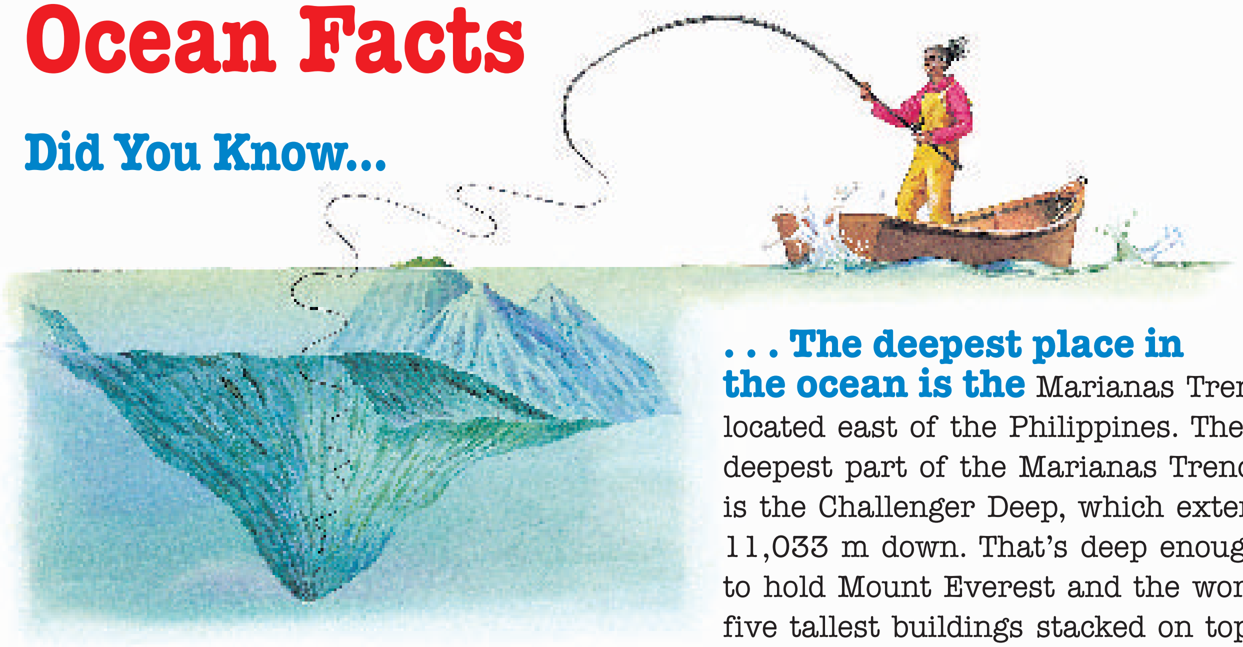
Discuss with your family or students in other classes how ocean waves and tides affect erosion along the edge of oceans. **For more help, refer to the Science Skill Handbook.**

KS Studios

SCIENCE Stats

Ocean Facts

Did You Know...

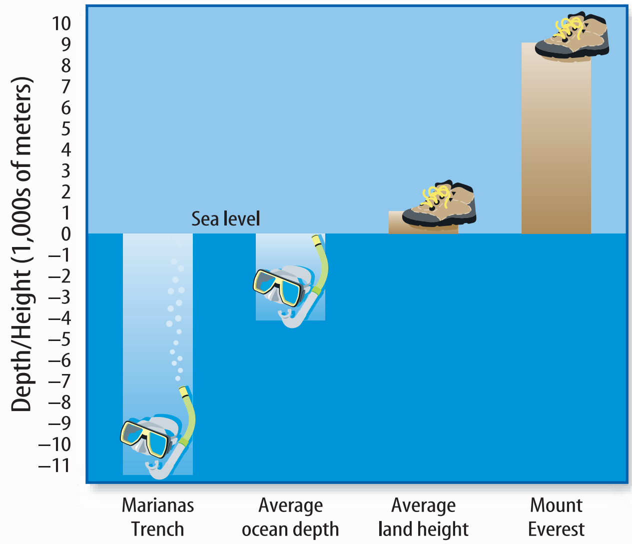


. . . The deepest place in the ocean is the Marianas Trench, located east of the Philippines. The deepest part of the Marianas Trench is the Challenger Deep, which extends 11,033 m down. That's deep enough to hold Mount Everest and the world's five tallest buildings stacked on top of one another.

Great Barrier Reef

. . . At more than 2,000 km long, the Great Barrier Reef in the Coral Sea is the largest organic structure on Earth and can be seen clearly from space.

Height and Depth Comparison of Land and Ocean



Applying Math Use the graph to find out about how much deeper the Marianas Trench is than Mount Everest is high.

Find Out About It

Visit red.msscience.com/science_stats to find the surface area of the three largest oceans. Make a graph showing the relative sizes of these oceans.

Reviewing Main Ideas

Section 1 Ocean Water

1. Oceans provide much of the oxygen and food for Earth's organisms. Oceans interact with the atmosphere to create weather and climate.
2. Scientists think early oceans formed when basins filled with water that condensed from the water vapor of erupting volcanoes.
3. Seawater is a combination of water, dissolved solids, and dissolved gases.
4. Ocean temperatures vary with latitude and depth. Water pressure is created by gravity pulling down water molecules.

Section 2 Ocean Currents and Climate

1. Winds blowing across oceans produce surface currents. Earth's rotation deflects surface currents.
2. Ocean surface currents can be warm or cold, and affect the climates of coastal regions.
3. Density currents develop because water masses have different temperatures and different salinity levels.

Section 3 Waves

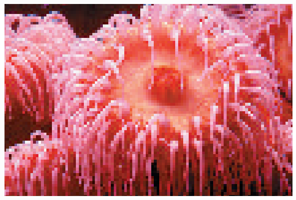
1. Winds cause water to pile up, forming waves.
2. Tides are created by the gravitational attraction of Earth and the Moon and of Earth and the Sun.

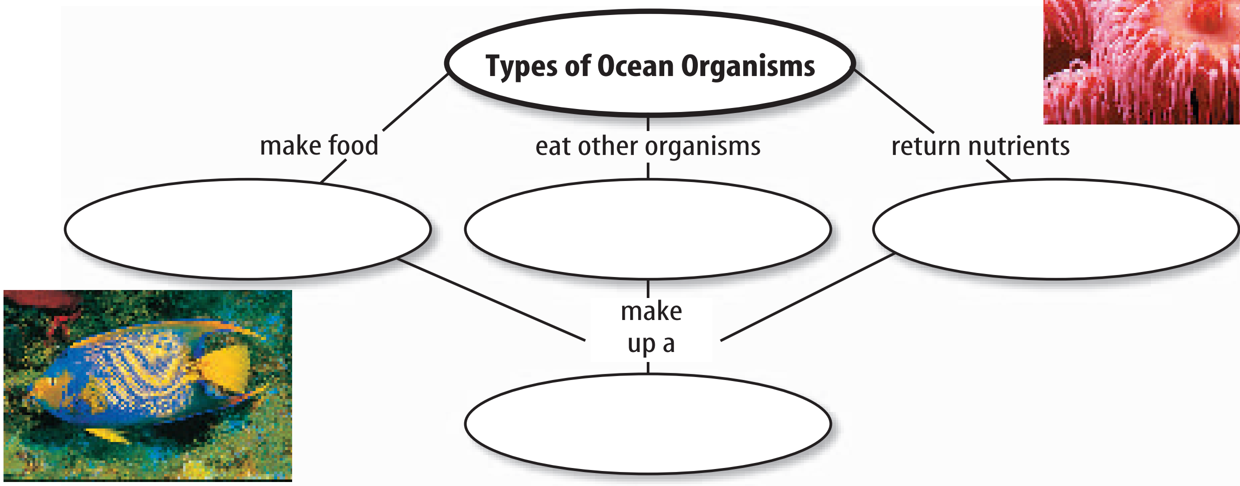
Section 4 Life in the Oceans

1. Plankton drift in ocean currents, and nekton actively swim. Some organisms live on the seafloor.
2. In an ecosystem, producers, consumers, and decomposers interact with each other and their surroundings.
3. Nutrients are cycled in the oceans.

Visualizing Main Ideas

Copy and complete the following concept map about types of ocean organisms.





(l)Tom & Therisa Stack/Tom Stack & Assoc., (r)W. Wayne Lockwood/CORBIS

Using Vocabulary

chemosynthesis p. 391
consumer p. 391
decomposer p. 391
density current p. 382
ecosystem p. 391
food chain p. 392
nekton p. 390
photosynthesis p. 377
plankton p. 389
producer p. 391
salinity p. 376
surface current p. 380
thermocline p. 378
tide p. 387
upwelling p. 384
wave p. 385

Fill in the blanks with the correct vocabulary words.

1. _________ float in the upper layers of oceans.

2. Organisms that get their energy from eating other organisms are _________.

3. _________ are caused by wind blowing across oceans.

4. _________ are caused by differences in the ocean water's salinity.

5. The layer of ocean water where the temperature drops quickly with depth is the _________.

Checking Concepts

Choose the word or phrase that best answers the question.

6. Which of the following is a measure of dissolved solids in seawater?
A) density **C)** thermocline
B) nekton **D)** salinity

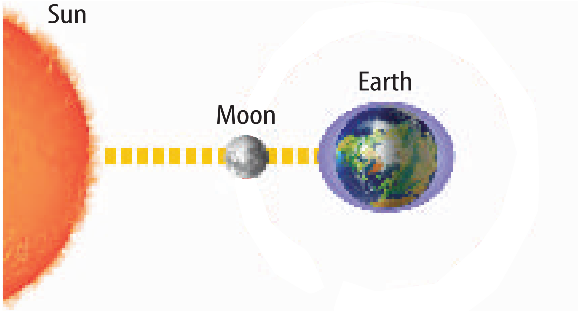
7. Which of these organisms is an example of a bottom dweller?
A) sea star **C)** shark
B) seal **D)** diatom

8. Which of these organisms is a producer?
A) sea star **C)** seal
B) coral **D)** algae

9. Which of the following terms is the high point of a wave?
A) wavelength **C)** trough
B) crest **D)** wave height

10. Which of the following terms is the low point of a wave?
A) wavelength **C)** trough
B) crest **D)** wave height

Use the figure below to answer question 11.



11. Which type of tide forms when the Sun, the Moon, and Earth are aligned as shown?
A) high tide **C)** spring tide
B) low tide **D)** neap tide

12. Which substance is found in the most common ocean salt?
A) calcium
B) chlorine
C) carbon
D) cobalt

13. Which of these gases is produced during photosynthesis?
A) oxygen
B) carbon dioxide
C) nitrogen
D) water vapor

14. Which of these terms describes the daily rhythmic rise and fall of sea level?
A) surface current
B) tide
C) density current
D) upwelling

Science Online red.msscience.com/vocabulary_puzzlemaker
CONTENTS

Thinking Critically

15. **Explain** why a boat tied to a dock bobs up and down in the water.

16. **Describe** why the water at a beach in southern California is much colder than the water at a beach in South Carolina.

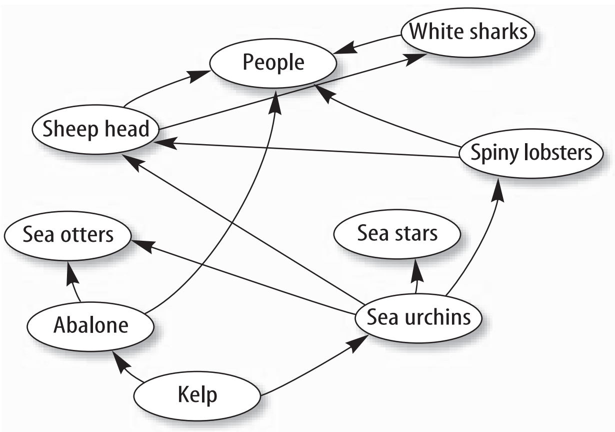
17. **Infer** How would other ocean life in an area be affected if an oil spill killed much of the plankton in that area?

18. **Discuss** reasons why more marine creatures live in shallow water near shore than in any other region of the oceans.

19. **Interpret Scientific Illustrations** Use **Figure 20** to describe how nitrogen is cycled from the atmosphere to marine organisms.

20. **Compare and contrast** the way that consumers and decomposers get their energy.

Use the illustration below to answer question 21.



21. **Interpret Scientific Illustrations** Infer what will happen to sea urchins and kelp if sea otters decline in number.

22. **Draw Conclusions** Place the organisms in the proper sequence in a food chain: krill, killer whale, algae, cod, leopard seal.

Performance Activities

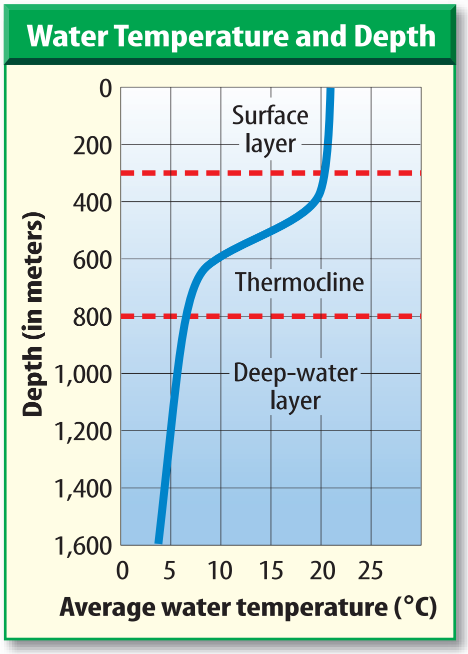
23. **Letter** Write to the National Wildlife Federation about coral bleaching. Ask what is being done to protect coral reefs.

24. **Pamphlet** Research beach nourishment, jetties, and other ways that people have tried to reduce beach erosion. Create a pamphlet of your findings and pass it out to your classmates.

Applying Math

25. **Pressure** The pressure at sea level is 1 atmosphere. If the pressure increases by 1 atmosphere for every 10 m in depth, what is the pressure at 200 m?

Use the figure below to answer question 26.



26. **The Thermocline** How much of a temperature change is there between the beginning of the thermocline and 1,200 m?

27. **The Area of Oceans** The Indian Ocean's total area is 73.6 million km^2. The Arctic Ocean's total area is 14.1 million km^2. How many times larger is the Indian Ocean than the Arctic Ocean?

chapter 13 Standardized Test Practice

Part 1 Multiple Choice

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

Use the table below to answer questions 1 and 2.

Ms. Mangan's class is studying different organisms. Here is a table of some of the organisms they have been studying.

Marine Organisms	
Producers	**Consumers**
Seaweed	Krill
Kelp	Squid
Algae	Seal

1. The producers are different from the consumers because only the producers are able to
   - **A.** swim in deep water.
   - **B.** make their own food.
   - **C.** contribute to the marine food web.
   - **D.** digest the nutrients in other organisms.

2. What would happen to consumers if all producers perished?
   - **A.** Consumers would also die.
   - **B.** Consumers would begin making their own food.
   - **C.** Consumers would decompose organic matter.
   - **D.** Consumers would move to a new environment.

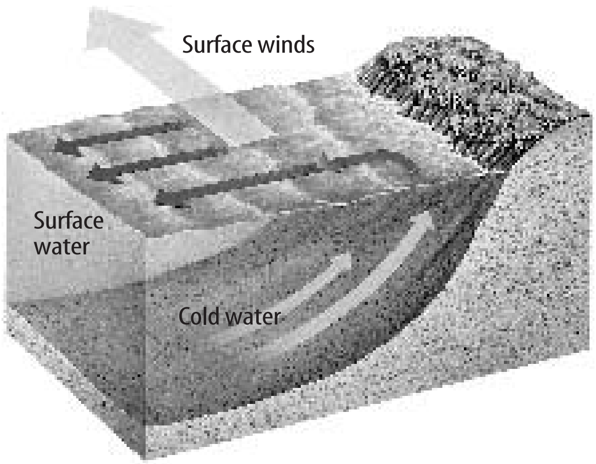
Test-Taking Tip

Never skip a question. If you are unsure of an answer, mark your best guess on your answer sheet and mark the question in your test booklet to remind you to come back to it at the end of the test.

3. The layer of water in which temperature drops quickly with increasing depth is the
   - **A.** surface layer.
   - **B.** thermocline layer.
   - **C.** deep-water layer.
   - **D.** bottom layer.

4. Organisms that break down tissue and release nutrients and carbon dioxide back into the ecosystem are called
   - **A.** producers.
   - **B.** consumers.
   - **C.** decomposers.
   - **D.** photosynthetic.

Use the diagram below to answer questions 5 and 6.



5. What process is shown in the figure?
   - **A.** downwelling
   - **B.** density currents
   - **C.** El Niño
   - **D.** upwelling

6. Wind blowing parallel to the coast carries water away from land because of
   - **A.** the Coriolis effect.
   - **B.** the gravitational pull of the Moon on Earth.
   - **C.** the gravitational pull of the Sun on Earth.
   - **D.** the speed of the wind.

Part 2 Short Response/Grid In

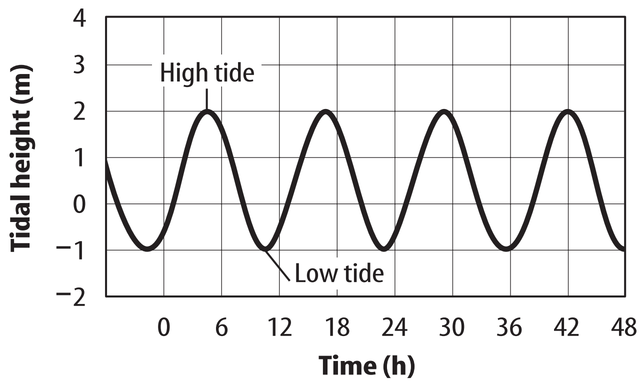
Record your answers on the answer sheer provided by your teacher or on a sheet of paper.

7. Ten percent of the total available energy is stored by a consumer at each level of the food chain. If 3,424 energy units are passed on to a salmon feeding on zooplankton, how many energy units will the salmon store?

8. The average depth of the ocean is 3,730 m. The Marianas Trench is 11,033 m deep. How many times deeper is the Marianas Trench than the average depth of the ocean? Round your answer to the nearest whole number.

9. Why aren't all ocean surface currents the same temperature?

Use the figure below to answer questions 10 and 11.



10. Some coastlines experience *semidiurnal tides*, or two high tides and two low tides in approximately a 24-hour period. Other coastlines experience *diurnal tides*, or one high tide and one low tide in approximately a 24-hour period. Which type of tide is shown in the graph above?

11. What is the tidal range during the period of time tidal data was recorded for the graph?

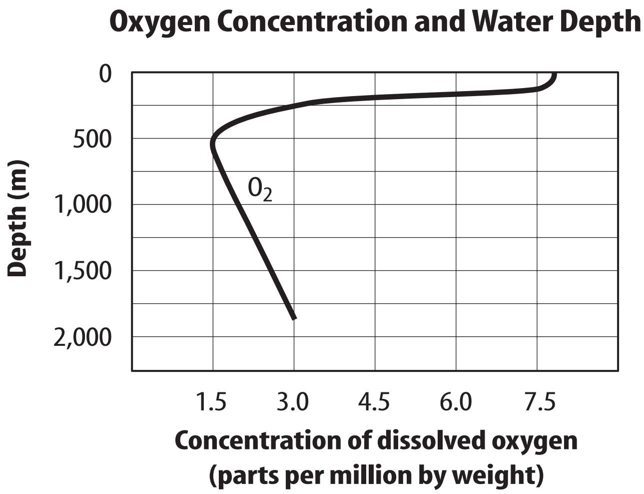
Part 3 Open Ended

Record your answer on a sheet of paper.

12. Explain why temperatures could decrease in some regions of Earth if global warming occurred.

13. Why are some organisms considered to be plankton in one stage of their life but nekton in another stage of their life?

Use the graph below to answer questions 14–17.



14. Describe what happens to the levels of oxygen concentration as water depth increases.

15. Why is oxygen concentration at its highest near the surface of the water? What accounts for the decrease in oxygen concentration between about 200 m and 500 m?

16. Explain why the concentration of oxygen increases between 500 m and 2,000 m.

17. Infer how the levels of carbon dioxide concentration would vary with depth. What biological processes affect the concentration of carbon dioxide?