Connect to the Big Idea

Discuss the scene in the photograph to introduce the Big Idea of Interdependence in Nature.

Ask What organisms do you see in the photograph in addition to the cheetah? (plants)

Ask What do you think the cheetah eats and what eats the plants? (zebras or other herbivores)

Ask What would happen to the cheetah if the plants died because of drought? (The herbivores it hunts would have nothing to eat and might die or move to another area, so the cheetah would have no food.)

Lead students to anticipate the answer to the question, **How do abiotic and biotic factors shape ecosystems?**

After students have read through the Chapter Mystery, ask them to explain why scientists predicted that reintroducing wolves to Yellowstone National Park would lead to a decline in the number of elk in the park. (Wolves hunt elk.) Then, have them predict how fewer elk might affect other organisms in the park. (Sample answer: Elk eat plants, so with fewer elk, there might be more of some types of plants.)

Have students preview the chapter vocabulary using the Flash Cards.

**Understanding by Design**

Chapter 4 continues to explore the unit’s Enduring Understanding: *The existence of life on Earth depends on interactions among organisms and between organisms and their environment.* As the graphic organizer at the right shows, the chapter explains how interactions between abiotic factors like climate and biotic factors like organisms shape ecosystems.

**Performance Goals**

Students will demonstrate their knowledge of ecosystems and communities by analyzing data, interpreting diagrams and graphs, and describing phenomena such as competition and succession. At the end of the chapter, students will create a scrapbook highlighting interactions among organisms and between organisms and their environment in a specific land biome or aquatic ecosystem. They will also create a Web site about a threatened region in a biome and how it can be protected.
**THE WOLF EFFECT**

During the 1920s, hunting and trapping eliminated wolves from Yellowstone National Park. For decades, ecologists hypothesized that the loss of wolves—important predators of elk and other large grazing animals—had changed the park ecosystem. But because there were no before-and-after data, it was impossible to test that hypothesis directly.

Then, in the mid-1990s, wolves were reintroduced to Yellowstone. Researchers watched park ecosystems carefully and sure enough, the number of elk in parts of the park began to fall just as predicted. But, unpredictably, forest and stream communities have changed, too. Could a “wolf effect” be affecting organisms in the park’s woods and streams?

As you read this chapter, look for connections among Yellowstone’s organisms and their environment. Then, solve the mystery.

Never Stop Exploring Your World.

The mystery of the Yellowstone wolves is just the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where this mystery leads.

**What’s Online**

Extend your reach by using these and other digital assets offered at Biology.com.

**CHAPTER MYSTERY**

Students will explore community interactions in Yellowstone National Park since the reintroduction of wolves in the mid-1990s.

**UNTAMED SCIENCE VIDEO**

A volcanic eruption can quickly obliterate an existing ecosystem, but it also paves the way for a new one to develop.

**VISUAL ANALOGY**

Students find out how Earth’s atmosphere acts like the glass in a greenhouse.

**DATA ANALYSIS**

Students analyze tolerance data to explain the zonation patterns of intertidal species.

**ART IN MOTION**

An animation of primary and secondary succession helps students understand the processes.

**ART REVIEW**

Students can show an understanding of the ocean’s zones with this drag-and-drop activity.
Getting Started

Objectives

4.1.1 Differentiate between weather and climate.
4.1.2 Identify the factors that influence climate.

Student Resources

Study Workbooks A/B, 4.1 Worksheets
Spanish Study Workbook, 4.1 Worksheets

Answers

IN YOUR NOTEBOOK Descriptions will vary depending on the climate where students live. They might describe seasonal variations, amounts of precipitation, and high and low temperatures. They may also identify factors such as distance from the equator and presence of bodies of water or mountain ranges.

Weather and Climate

What is climate?
Weather and climate both involve variations in temperature, precipitation, and other environmental factors. Weather is the day-to-day condition of Earth’s atmosphere. Weather where you live may be clear and sunny one day but rainy and cold the next. Climate, on the other hand, refers to average conditions over long periods. A region’s climate is defined by year-after-year patterns of temperature and precipitation.

It is important to note that climate is rarely uniform even within a region. Environmental conditions can vary over small distances, creating microclimates. For example, in the Northern Hemisphere, south-facing sides of trees and buildings receive more sunlight, and are often warmer and drier, than north-facing sides. We may not notice these differences, but they can be very important to many organisms.

Factors That Affect Climate

What factors determine global climate?
A person living in Orlando, Florida, may wear shorts and a T-shirt in December, while someone in Minneapolis, Minnesota, is still wearing a heavy coat in April. It rarely rains in Phoenix, Arizona, but it rains often in Mobile, Alabama. Clearly, these places all have different climates—but why? What causes differences in climate? Global climate is shaped by many factors, including solar energy trapped in the biosphere, latitude, and the transport of heat by winds and ocean currents.

In Your Notebook Describe the climate where you live. What factors influence it?

Teach for Understanding

ENDURING UNDERSTANDING The existence of life on Earth depends on interactions among organisms and between organisms and their environment.

GUIDING QUESTION What factors affect global climate?

EVIDENCE OF UNDERSTANDING After completing the lesson, assign students the following assessment to show they understand the factors that affect global climate. Have groups of three students create three labeled diagrams to explain (1) how greenhouse gases trap heat in the atmosphere, (2) why solar energy varies with latitude, and (3) how heat is transported in the biosphere. Students should brainstorm ideas for their diagrams as a group. Then, each student in the group should draw one of the diagrams.
Solar Energy and the Greenhouse Effect  The main force that shapes our climate is solar energy that arrives as sunlight and strikes Earth's surface. Some of that energy is reflected back into space, and some is absorbed and converted into heat. Some of that heat, in turn, radiates back into space, and some is trapped in the biosphere. The balance between heat that stays in the biosphere and heat lost to space determines Earth's average temperature. This balance is largely controlled by concentrations of three gases found in the atmosphere—carbon dioxide, methane, and water vapor.

As shown in Figure 4–1, these gases, called greenhouse gases, function like glass in a greenhouse, allowing visible light to enter but trapping heat. This phenomenon is called the greenhouse effect. If greenhouse gas concentrations rise, they trap more heat, so Earth warms. If their concentrations fell, more heat escapes, and Earth cools. Without the greenhouse effect, Earth would be about 30° Celsius cooler than it is today. Note that all three of these gases pass in and out of the atmosphere as part of nutrient cycles.

Latitude and Solar Energy  Near the equator, solar energy is intense as the sun is almost directly overhead at noon all year. That's why equatorial regions are generally so warm. As Figure 4–2 shows, the curvature of Earth causes the same amount of solar energy to spread out over a much larger area near the poles than near the equator. Thus, Earth's polar areas annually receive less intense solar energy, and therefore heat, from the sun. This difference in heat distribution creates three different climate zones: tropical, temperate, and polar.

The tropical zone, or tropics, which includes the equator, is located between 23.5° north and 23.5° south latitudes. This zone receives nearly direct sunlight all year. On either side of the tropical zone are the two temperate zones, between 23.5° and 66.5° north and south latitudes. Beyond the temperate zones are the polar zones, between 66.5° and 90° north and south latitudes. Temperate and polar zones receive very different amounts of solar energy at different times of the year because Earth's axis is tilted. As Earth revolves around the sun, solar radiation strikes different regions at angles that vary from summer to winter. During winter in the temperate and polar zones, the sun is much lower in the sky, days are shorter, and solar energy is less intense.

Climate Change and Earth's Organisms  While human actions only enhance the natural greenhouse effect, even a small change in its intensity can cause great disruption in ecosystems worldwide. Not only will global temperatures rise, but an enhanced greenhouse effect can change the precipitation and other weather patterns that are fueled by the temperature differential between equatorial and polar regions. At the current rate of global warming, some of Earth's present climates may disappear and be replaced by different climates over the next century. Many scientists predict these changes to be most pronounced in tropical and subtropical regions. As climates change, so will Earth's organisms. There is already evidence that the ranges of some species, including certain butterflies, are shifting toward the poles. Many other species, which will be unable to move to new areas when climates change, are likely to go extinct.

Teach
Use Models
Have students model the relationship between latitude and solar energy with a globe and flashlight. Ask one student to hold the globe in the same position as the drawing of Earth in Figure 4–2. Ask another student to shine the flashlight straight ahead onto northern North America. Ask the class to observe the size of the area that is receiving light. Then, have the student shine the flashlight straight ahead onto the equator. Point out how a smaller area is now receiving the same amount of light.

Differentiated Instruction
Advanced Students  Point out that the “beams” of sunlight shown in Figure 4–2 create different shapes when they hit Earth at different angles—a circle near the equator and an ellipse near the poles. Demonstrate mathematically the difference between the areas of light received at these locations. Use an overhead projector and a piece of paper with a circular cutout to project a circle of light onto a piece of cardboard. Have students trace the shape of the projected circle of light onto the cardboard when it is upright. Then, have them tilt the cardboard 45 degrees back so that the light forms an ellipse. Have students trace this shape. Next, have them measure the lengths of the radius \( r \) of the circle and the semi-major \( r_1 \) and semi-minor \( r_2 \) axes of the ellipse. Finally, have them compare the areas of the two shapes using these formulas:

Area of a circle = \( \pi r^2 \)

Area of an ellipse = \( \pi r_1 r_2 \)

Visual Analogy
Help students understand why only some of the radiation represented by arrows in Figure 4–1 is reflected by Earth and passes back to space through the atmosphere. Tell them that the arrows represent either visible light or infrared light, which humans perceive as heat. Explain that visible light has shorter wavelengths and can pass through the atmosphere, whereas infrared light has longer wavelengths and can be absorbed by greenhouse gases.

Answers
Figure 4–1  the glass
When the molecules of a gas spread out, the gas rises at the top of mountains, so its molecules spread out. Give them the background information they need to infer the answer. Explain that air is under less pressure at higher altitudes, so it rises and spreads out. If students have trouble answering Question 1c, give them the information they need to infer the answer. Explain that air is under less pressure at higher altitudes, so it rises and spreads out.

**REMEDIAL SUGGESTION**

- **Struggling Students**: If students have trouble answering Question 1c, give them the background information they need to infer the answer. Explain that air is under less pressure at higher altitudes, so it rises and spreads out. If students have trouble answering Question 1c, give them the information they need to infer the answer. Explain that air is under less pressure at higher altitudes, so it rises and spreads out.

Students can check their understanding of lesson concepts with the Self-Test assessment. They can then take an online version of the Lesson Assessment.

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**Answers**

**FIGURE 4-3** Cold currents in the Northern Hemisphere generally move southward, away from the North Pole and toward the equator.

**Assessment Answers**

1a. Climate is the average conditions of a location and is defined by year-after-year temperature and precipitation patterns.

1b. Weather is the day-to-day condition of Earth’s atmosphere, whereas climate refers to average conditions over long periods.

1c. The figure shows cold surface currents moving up along the western coast and warm surface currents moving down the eastern coast; this pattern suggests that the west coast of southern Africa has a cooler climate.

2a. Climate is determined by solar energy trapped in the biosphere, latitude, and the transport of heat by winds and ocean currents.

2b. A decrease in greenhouse gases would allow more reradiated heat to escape to space, rather than being absorbed by the atmosphere, so global climate would become cooler.

**ANALYZING DATA**

3. Graphs should show that average monthly temperatures are very similar from month to month for the entire year, with an average temperature of about 15°C. Precipitation is much more variable. It is low from June through September and high from October through May, ranging from about 25 mm on average for the driest month to about 175 mm on average for the wettest month.
4.2 Niches and Community Interactions

THINK ABOUT IT If you ask someone where an organism lives, that person might answer “on a coral reef” or “in the desert.” These answers are like saying that a person lives “in Miami” or “in Arizona.” The answer gives the environment or location. But ecologists need more information to understand fully why an organism lives where it does and how it fits into its surroundings. What else do they need to know?

The Niche

What is a niche?
Organisms occupy different places in part because each species has a range of conditions under which it can grow and reproduce. These conditions help define where and how an organism lives.

Tolerance
Every species has its own range of tolerance, the ability to survive and reproduce under a range of environmental circumstances, as shown in Figure 4–4. When an environmental condition, such as temperature, extends in either direction beyond an organism’s optimum range, the organism experiences stress. Why? Because it must expend more energy to maintain homeostasis, and so has less energy left for growth and reproduction. Organisms have an upper and lower limit of tolerance for every environmental factor. Beyond those limits, the organism cannot survive. A species’ tolerance for environmental conditions, then, helps determine its “address” or habitat—the general place where an organism lives.

FIGURE 4–4 Tolerance
This graph shows the response of a hypothetical organism to different values of a single environmental variable such as sunlight or temperature. At the center of the optimum range, organisms are likely to be most abundant. They become more rare in zones of physiological stress (medium blue), and are absent from zones of intolerance (light blue).

Key Questions
- What is a niche?
- How does competition shape communities?
- How do predation and herbivory shape communities?
- What are the three primary ways that organisms depend on each other?

Vocabulary
tolerance • habitat • niche • resource • competitive exclusion principle • predation • herbivory • keystone species • symbiosis • mutualism • parasitism • commensalism

Taking Notes
Concept Map Use the highlighted vocabulary words to create a concept map that organizes the information in this lesson.

THINK ABOUT IT
If you ask someone where an organism lives, that person might answer “on a coral reef” or “in the desert.” These answers are like saying that a person lives “in Miami” or “in Arizona.” The answer gives the environment or location. But ecologists need more information to understand fully why an organism lives where it does and how it fits into its surroundings. What else do they need to know?

Getting Started

Objectives
4.2.1 Define niche.
4.2.2 Describe the role competition plays in shaping communities.
4.2.3 Describe the role predation and herbivory play in shaping communities.
4.2.4 Identify the three types of symbiotic relationships in nature.

Student Resources
Study Workbooks A/B, 4.2 Worksheets
Spanish Study Workbook, 4.2 Worksheets
Lab Manual B, 4.2 Data Analysis Worksheet, Hands-On Activity Worksheet

Teach for Understanding

ENDURING UNDERSTANDING The existence of life on Earth depends on interactions among organisms and between organisms and their environment.

GUIDING QUESTION How do organisms interact with one another?

EVIDENCE OF UNDERSTANDING After completing the lesson, give students the following assessment to show they understand the types of interactions that can occur between organisms. Have each student create a crossword puzzle using all of the lesson vocabulary terms. Then, pair students and have partners exchange crossword puzzles and try to solve each other’s puzzle.

ENDURING UNDERSTANDING The existence of life on Earth depends on interactions among organisms and between organisms and their environment.

GUIDING QUESTION How do organisms interact with one another?

EVIDENCE OF UNDERSTANDING After completing the lesson, give students the following assessment to show they understand the types of interactions that can occur between organisms. Have each student create a crossword puzzle using all of the lesson vocabulary terms. Then, pair students and have partners exchange crossword puzzles and try to solve each other’s puzzle.
**Lead a Discussion**

Work with students to apply the concepts of habitat and niche to organisms they are familiar with. On the board, write the names of several organisms. Choose a wide range of organisms, such as pine trees, dandelions, raccoons, frogs, and butterflies. Call on students to identify factors that help determine each organism’s habitat or describe its niche. Use the exercise to reinforce the differences between habitat and niche and to clarify that niche is a property of organisms, not ecosystems.

**DIFFERENTIATED INSTRUCTION**

**Struggling Students** Give students an analogy to help them understand the concept of niche. Tell them that an animal’s niche is like the position an athlete plays in a team sport. Ask a student to name a player position for their favorite sport. Then, explain how this position is like a niche. For example, discuss the role a player in a given position fulfills for the team, the physical space the player occupies, and how the player interacts with fellow teammates and competitors.

**Focus on ELL: Extend Language**

**ALL SPEAKERS** Ask students to write each of the lesson vocabulary terms on an index card. Then, have them divide each term into parts and read the sentence in which it is highlighted in the text. Tell beginning and intermediate speakers to write a phrase explaining what they think each term means and to make a drawing to illustrate it. Use examples to give them a clearer idea of any terms they do not understand. Instruct advanced and advanced high speakers to write the definition of each term based on its context in the paragraph where it is introduced. Review their definitions and correct any misunderstandings they might have.

**Answers**

**FIGURE 4–5** Sample answer: I think they are fighting over food, living space, mates, or a place to raise their young.

**IN YOUR NOTEBOOK** It is probably an example of intraspecific competition, because both beetles appear to belong to the same species.
The Competitive Exclusion Principle

Direct competition between different species almost always produces a winner and a loser—and the losing species dies out. One series of experiments demonstrated this using two species of single-celled organisms. When the species were grown in separate cultures under the same conditions, each survived, as shown in Figure 4–6. But when both species were grown together in the same culture, one species outcompeted the other. The less competitive species did not survive.

Experiments like this one, along with observations in nature, led to the discovery of an important ecological rule. The competitive exclusion principle states that no two species can occupy exactly the same niche in exactly the same habitat at exactly the same time. If two species attempt to occupy the same niche, one species will be better at competing for limited resources and will eventually exclude the other species. As a result, if we look at natural communities, we rarely find species whose niches overlap significantly.

Dividing Resources

Instead of competing for similar resources, species usually divide them. For instance, the three species of North American warblers shown in Figure 4–7 all live in the same trees and feed on insects. But one species feeds on high branches, another feeds on low branches, and another feeds in the middle. The resources utilized by these species are similar yet different. Therefore, each species has its own niche. This division of resources was likely brought about by past competition among the birds. By causing species to divide resources, competition helps determine the number and kinds of species in a community and the niche each species occupies.

In Figure 4–6, the two species of paramecia, *P. aurelia* and *P. caudatum*, have similar requirements. When grown in cultures separately (dashed lines), both populations grow quickly and then level off. When grown together under certain conditions (solid lines), however, *P. aurelia* outcompetes *P. caudatum* and drives it to extinction.

In Figure 4–7, one species would be better at competing for food in that niche and would eventually exclude the other species.

**FIGURE 4–6 Competitive Exclusion**
The two species of paramecia, *P. aurelia* and *P. caudatum*, have similar requirements. When grown in cultures separately (dashed lines), both populations grow quickly and then level off. When grown together under certain conditions (solid lines), however, *P. aurelia* outcompetes *P. caudatum* and drives it to extinction.

**FIGURE 4–7 Resource Sharing**
Each of these warbler species has a different niche in its spruce tree habitat. By feeding in different areas of the tree, the birds avoid competing directly with one another for food. Infer: What would happen if two of the warbler species tried to occupy the same niche in the same tree at the same time?

**Answers**

**FIGURE 4–7** One species would be better at competing for food in that niche and would eventually exclude the other species.

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**Check for Understanding**

**ONE-MINUTE RESPONSE**

Ask students to write a one-minute response explaining how competition for some, but not all, resources defines the different niches that two competing species occupy. (The two species must divide or compete for only some of the resources that are available in a habitat. If they competed for all of the same exact resources, then the competitive exclusion principle would predict that one species would eventually die out. Both the resources that they compete for and the resources that they do not have to compete with one another for determine the species’ niches.)

**ADJUST INSTRUCTION**

Collect and review students’ responses. Read aloud a few of the accurate explanations and also any that reveal misunderstandings. Call on volunteers to identify and correct the misunderstandings.
**LESSON 4.2**

**Lead a Discussion**

If you ask students to name predators and herbivores, they are likely to mention mammals such as wolves and deer. Widen their perspective by discussing examples of the more prevalent yet often less familiar predators and herbivores of the insect world. Tell students that insect herbivores, such as beetles and caterpillars, destroy large numbers of crops worldwide, and insect predators, such as ladybeetles and lacewings, eat many of these crop pests. Ask students to predict how the use of chemical pesticides to kill insect herbivores might affect insect predators. (Sample answer: The pesticides might kill both types of insects. Then, if insect herbivores increase in numbers again, there might not be enough predators left to control them.)

**DIFFERENTIATED INSTRUCTION**

**ELL English Language Learners** Tell students that the word **prey** is both a noun and a verb. Have students write sentences using each form of the word. Then, explain that, as a noun, it is an uncountable word, which means it cannot be plural or described using numbers. Compare the word **prey** to another uncountable noun, such as **information**, and as a class come up with sentences that demonstrate how these words do not have a plural form.

**L2 Advanced Students** Encourage students to research defenses that have evolved in organisms as protection against predators and herbivores. Such defenses might include camouflage, quills or thorns, toxins, warning coloration, or mimicry. Have students share their findings with the class in oral reports, posters, or displays.

**ANALYZING DATA**

**Predator-Prey Dynamics**

The relationships between predator and prey are often tightly intertwined, particularly in an environment in which each prey has a single predator and vice versa. The graph here shows an idealized computer model of changes in predator and prey populations over time.

1. **Predict** Suppose a bacterial infection kills off most of the prey at point B on the graph. How would this affect the predator and prey population over time?
2. **Predict** Suppose a sudden extended cold spell destroys almost the entire predator population at point C on the graph. How would the next cycle of the prey population appear on the graph?
3. **Relate Cause and Effect** Suppose a viral infection kills all the prey at point D on the graph. What effect would this have on the predator and prey population numbers at point E? What will happen in future years to the predator population? How could ecologists ensure the continued survival of the predators in this ecosystem?

**PURPOSE** Students will interpret an idealized computer model to infer relationships between predator and prey populations.

**PLANNING** Before students answer the questions, discuss why there is a time lag between the predator and prey population changes shown in the graph.

**ANSWERS**

1. If most of the prey were killed off at point B, the predator population would decline between points B and C, allowing the prey population to increase again by point C.
2. The prey population would increase in the next cycle, reaching a peak that is potentially even higher than the previous peaks.
3. Sample answer: If a viral infection kills all the prey at point D, at point E, the prey population will be zero and the predator population would be decreased, possibly to zero. In future years, if the predators find another food resource, the population may recover. The predator population would not recover in future years without any prey to feed on. To ensure continued survival of the predators in this ecosystem, ecologists could control the viral infection in the prey so that not all of them are killed by the virus, or they could introduce new prey animals to the ecosystem.
Keystone Species Sometimes changes in the population of a single species, often called a **keystone species**, can cause dramatic changes in the structure of a community. In the cold waters off the Pacific coast of North America, for example, sea otters devour large quantities of sea urchins. Urchins, in turn, are herbivores. Their favorite food is kelp, giant algae that grow in undersea “forests.” A century ago, sea otters were nearly eliminated by hunting. Unexpectedly, the kelp forest nearly vanished. What happened? Without otters as predators, the sea urchin population skyrocketed. Arms of urchins devoured kelp down to bare rock. Without kelp to provide habitat, many other animals, including seabirds, disappeared. Clearly, otters were a keystone species in this community. After otters were protected as an endangered species, their population began to recover. As otters returned, the urchin populations dropped, and kelp forests began to thrive again. Recently, however, the otter population has been falling again, and no one knows why.

In Your Notebook Not all keystone-species effects are due to predation. Describe the dramatic effects that the dam-building activities of beavers, a keystone species, might have on other types of organisms.

**Symbioses**

What are the three primary ways that organisms depend on each other?

Any relationship in which two species live closely together is called **symbiosis** (sim bsi o sis), which means “living together.” Biologists recognize three main classes of symbiotic relationships in nature: mutualism, parasitism, and commensalism.

**Mutualism** The sea anemone’s sting has two functions: to capture prey and to protect the anemone from predators. Even so, certain fish manage to snack on anemone tentacles. The clownfish, however, is immune to anemone stings. When threatened by a predator, clownfish seek shelter by snuggling deep into tentacles that would be deadly to most other fish, as seen in Figure 4–9. But if an anemone-eating species tries to attack their living home, the spunky clownfish dart out and fiercely chase away fish many times their size. This kind of relationship between species in which both benefit is known as **mutualism**.

**FIGURE 4–9 Mutualism** Clownfish live among the sea anemone’s tentacles and protect the sea anemone by chasing away would-be attackers. The sea anemone, in turn, protects the clownfish from their predators. **Infer** What could happen to the sea anemone if the clownfish died?

Quick Facts

**THE HUMAN SUPERORGANISM**

Humans and the bacteria that live in and on the human body are involved in numerous symbiotic relationships—many of them mutualistic. An example of one mutualistic human-bacterial relationship involves certain bacteria on the skin that process fats produced by the skin and help keep the skin moist. This is just one of an estimated 20 or more different niches of bacteria on the human skin alone. Other mutualistic relationships involve bacteria in the gut, which feast on the products of digestion while helping to break down carbohydrates. Because of the important roles bacteria play in the human animal and the huge numbers of bacteria that inhabit the human body, some microbiologists think that each person should be thought of as a superorganism, composed of one human and trillions of bacteria.

Use Visuals

Use Figure 4–9, Figure 4–10, and Figure 4–11 to introduce the three main classes of symbiotic relationships. For each figure, call on students to identify the two organisms that are involved in the relationship and how they interact. Describe several additional examples of symbiotic relationships, and ask students to identify the class of relationship each example represents. Examples might include flowering plants and their insect pollinators (mutualism); mistletoe and its plant hosts, trees and shrubs (parasitism); and burdock plants and animals with fur that transport their seeds (commensalism). Choose one example of each type of relationship. Then, for each example, discuss with the class how a change in numbers of one species in the relationship might affect numbers of the other species.

**DIFFERENTIATED INSTRUCTION**

**ELL** English Language Learners Suggest students fill in a Compare/Contrast Table on symbiosis as they read about it in the lesson. Their tables should have a row for each of the three main classes of symbiotic relationships. Columns should address which of the organisms benefit from the relationship and provide examples.

**Study Wkbks A/B, Appendix S20, Compare/Contrast Table. Transparencies, GO3.**

**REMIND** Remind students that elk are herbivores. Have them reread the paragraph with the blue heading, Herbivore-Plant Relationships, to help them answer the question. Students are likely to respond that a declining elk population due to wolf predation would give certain plants a better chance of growing, because fewer of them would be eaten by elk. Students can go online to Biology.com to gather their evidence.

Answers

**FIGURE 4–9** The sea anemone might be killed by predators if the clownfish died.

**IN YOUR NOTEBOOK** Sample answer: Dam building might flood land upstream from the dam and reduce the flow of water downstream from the dam. Land organisms living upstream might die out because their habitats are flooded, and aquatic organisms living downstream might die out because their habitats dry up. Beavers also might destroy most of the trees near the water’s edge to build their dams, and this could increase runoff and erosion, which could change the habitat of species that rely on soil.
LESSON 4.2

Assess and Remediate

EVALUATE UNDERSTANDING

On the board, list the six types of community interactions described in the lesson (competition, predation, herbivory, mutualism, parasitism, and commensalism). For each interaction, call on a student to give a definition and another student to give an example. Then, have students complete the 4.2 Assessment.

REMEDIATION SUGGESTION

L Struggling Students If students have trouble with Question 4c, tell them to think about what happens to people when they are bitten by parasites such as mosquitoes.

Students can check their understanding of lesson concepts with the Self-Test assessment. They can then take an online version of the Lesson Assessment.

Assessment Answers

1a. A habitat is the general place where an organism lives. A niche also describes how the organism interacts with its environment.

1b. A profession is the role a person plays in his or her community. Like a profession, a niche is the role an organism plays in its community. Students should describe the physical and biological aspects of their own niche.

2a. Competition is an interaction between organisms in which both organisms attempt to use the same limited ecological resource in the same place at the same time. Two organisms that live in different habitats can’t compete because they do not live in the same place.

2b. All three warbler species live in the same trees and feed on insects, but each species has its own niche because it uses resources in a different part of the tree.

3a. A keystone species is a species that causes dramatic changes in the structure of a community if its population changes.

3b. A decrease in vegetation could reduce the number of herbivores. With fewer herbivores, there would be less food for predators, so the predators might decrease in numbers, as well.

Parasitism Tapeworms live in the intestines of mammals, where they absorb large amounts of their hosts’ food. Fleas, ticks, lice, and leeches live on the bodies of mammals, feeding on their blood and skin, as seen in Figure 4–10. These are examples of parasitism (pahr uh sit iz um), relationships in which one organism lives inside or on another organism and harms it. The parasite obtains all or part of its nutritional needs from the host organism. Generally, parasites weaken but do not kill their host, which is usually larger than the parasite.

Commensalism Small marine animals called barnacles often attach themselves to a whale’s skin, as seen in Figure 4–11. The barnacles perform no known service to the whale, nor do they harm it. Yet the barnacles benefit from the constant movement of water—that is full of food particles—past the swimming whale. This is an example of commensalism (kuh men sul iz um), a relationship in which one organism benefits and the other is neither helped nor harmed.

4a. Symbiosis is any relationship in which two species live closely together. The three major types of symbiosis are mutualism, parasitism, and commensalism.

4b. This is an example of mutualism, because both the cow and the bacteria benefit from the relationship.

4c. A predator usually kills its prey. A parasite generally only weakens its host.

BUILD VOCABULARY

5. Mutual means “shared, or in common.” So mutualism can be defined as “the act of sharing in common.”
Do you enjoy being outdoors? If you do, you might want to consider one of these careers.

MARINE BIOLOGIST
Ocean ecosystems cover over 70 percent of Earth’s surface. Marine biologists study the incredible diversity of ocean life. Some marine biologists study organisms found in deep ocean trenches to understand how they survive in extreme conditions. Others work in aquariums, where they might conduct research, educate the public, or rehabilitate rescued marine wildlife.

PARK RANGER
For some people, camping and hiking aren’t just recreational activities—they’re work. Park rangers work in national, state, and local parks caring for the land and ensuring the safety of visitors. Park rangers perform a variety of tasks, including maintaining campsites and helping with search and rescue. Rangers are also responsible for looking after park wildlife.

WILDLIFE PHOTOGRAPHER
Wildlife photographers capture nature “in action.” Their photographs can be used in books, magazines, and on the Internet to educate and entertain the public. Successful wildlife photographers need to be observant and adventurous. They also need to be patient enough to wait for the perfect shot.

CAREER CLOSE-UP
Dudley Edmondson, Wildlife Photographer
Dudley Edmondson began bird-watching at a young age. After high school, he began traveling and photographing the birds he observed. Mr. Edmondson has since been all over the United States taking pictures of everything from the landscapes and grizzly bears of Yellowstone Park to the butterflies that inhabit his own backyard. Through his work, he hopes to inspire people to travel and experience nature for themselves. This, he believes, will encourage a sense of responsibility to protect and preserve the environment.

“What I like most about my work is the unique perspective it gives me on the world. Birds, insects, and plants are totally unaware of things like clocks, deadlines, and technology. When you work with living things, you work on their terms.”

WRITE Where have you seen nature photography used or displayed? How do those photos, or Mr. Edmondson’s, help the public learn about the natural world?

Quick Facts
THE BEST OF BOTH FIELDS
Some people have more than one career at the same time or multiple careers in sequence. One example is Ron Austing, who pursued his love of nature by becoming both a park ranger and a wildlife photographer. Although he is now retired from his job as wildlife manager of a 16,000-acre park, Austing is still active as a wildlife photographer. His nature photographs have appeared in numerous publications, including National Geographic, Audubon, National Wildlife, Sports Illustrated, and many books. Like Dudley Edmondson, Ron Austing especially enjoys taking photographs of birds.

Answers
WRITE Sample answer: I have seen nature photography on television shows and in nature magazines and science textbooks. The photos help the public learn about the diversity of life by showing how different organisms look and behave in their natural environment.

DIFFERENTIATED INSTRUCTION
LPR Less Proficient Readers Before students read about the careers described on this page, have them write a question they would like to have answered about each career. Tell them to try to find the answer to their question as they read. If any of their questions remain unanswered, discuss how they could find the answers. Encourage them to follow their plan to locate the information.

L Advanced Students Ask interested students to learn more about one of the biology careers described on this page. Then, have them write a short, fictionalized account, based on what they learn, in which they describe a typical workday for a person in that career. Ask students to share their accounts with the class.

Teach
Lead a Discussion
After students read the feature, divide the class into three groups, and assign each group one of the careers. Ask students to brainstorm why a person in that career should know about the interactions of organisms in communities. Give groups a chance to share their ideas. Then, use their ideas to start a class discussion of how knowledge of community interactions might benefit anyone with an interest in nature.

NATIONAL SCIENCE EDUCATION STANDARDS
UCP I, II, III
CONTENT C.4.d, C.4.e, F.3, F.4, G.1
INQUIRY A.2.b
**Getting Started**

**Objectives**

4.3.1 Describe how ecosystems recover from a disturbance.

4.3.2 Compare succession after a natural disturbance with succession after a human-caused disturbance.

**Student Resources**

Study Workbooks A/B, 4.3 Worksheets
Spanish Study Workbook, 4.3 Worksheets

**Build Background**

Describe or show photographs of a local area, familiar to students, that was recently disturbed by a natural event or human actions. Ask students to predict how the area would look in ten years if it were left undisturbed. Tell them they will learn what happens to such disturbed areas in this lesson.

Have students watch animations of succession in *Art in Motion: Primary and Secondary Succession.*

**NATIONAL SCIENCE EDUCATION STANDARDS**

**UNIFYING CONCEPTS AND PROCESSES**

I, II, III, IV

**CONTENT**

C.4.c, C.4.e, F.5, G.2

**INQUIRY**

A.1.b, A.1.c, A.1.d, A.1.f

**THINK ABOUT IT**

In 1883, the volcanic island of Krakatau in the Indian Ocean was blown to pieces by an eruption. The tiny island that remained was completely barren. Within two years, grasses were growing. Fourteen years later, there were 49 plant species, along with lizards, birds, bats, and insects. By 1929, a forest containing 300 plant species had grown. Today, the island is blanketed by mature rain forest. How did the island ecosystem recover so quickly?

**Primary and Secondary Succession**

**How do communities change over time?**

The story of Krakatau after the eruption is an example of ecological succession—a series of more-or-less predictable changes that occur in a community over time. Ecosystems change over time, especially after disturbances, as some species die out and new species move in. Over the course of succession, the number of different species present typically increases.

**Primary Succession**

Volcanic explosions like the ones that destroyed Krakatau in 1883 and blew the top off Mount Saint Helens in Washington State in 1980 can create new land or sterilize existing areas. Retreating glaciers can have the same effect, leaving only exposed bare rock behind them. Succession that begins in an area with no remnants of an older community is called primary succession. An example of primary succession is shown in Figure 4–12.

**Key Questions**

- How do communities change over time?
- Do ecosystems return to "normal" following a disturbance?

**Vocabulary**

- ecological succession
- primary succession
- pioneer species
- secondary succession

**Taking Notes**

- Compare/Contrast Table
  As you read, create a table comparing primary and secondary succession.

**FIGURE 4–12 Primary Succession**

Primary succession occurs on newly exposed surfaces. In Glacier Bay, Alaska, a retreating glacier exposed barren rock. Over the course of more than 100 years, a series of changes has led to the hemlock and spruce forest currently found in the area. Changes in this community will continue for centuries.

**ENDURING UNDERSTANDING**

The existence of life on Earth depends on interactions among organisms and between organisms and their environment.

**GUIDING QUESTION**

How do ecosystems change over time?

**EVIDENCE OF UNDERSTANDING**

After completing the lesson, assign students the following assessment to show they understand how succession changes ecosystems over time. Tell students to use the information from the lesson to write a short story about an ecosystem that is disturbed and undergoes either primary or secondary succession. Remind them to write about both biotic and abiotic factors.
The first species to colonize barren areas are called **pioneer species**—named after rugged human pioneers who first settled the wilderness. After pioneers created settlements, different kinds of people with varied skills and living requirements moved into the area. Pioneer species function in similar ways. One ecological pioneer that grows on bare rock is lichen—a mutualistic symbiosis between a fungus and an alga. Over time, lichens convert, or fix, atmospheric nitrogen into useful forms for other organisms, break down rock, and add organic material to form soil. Certain grasses, like those that colonized Krakatau early on, are also pioneer species.

**Secondary Succession** Sometimes, existing communities are not completely destroyed by disturbances. In these situations, where a disturbance affects the community without completely destroying it, **secondary succession** occurs. Secondary succession proceeds faster than primary succession, in part because soil survives the disturbance. As a result, new and surviving vegetation can regrow rapidly. Secondary succession often follows a wildfire, hurricane, or other natural disturbance. We think of these events as disasters, but many species are adapted to them. Although forest fires kill some trees, for example, other trees are spared, and fire can stimulate their seeds to germinate. Secondary succession can also follow human activities like logging and farming. An example of secondary succession is shown in Figure 4–13.

**Why Succession Occurs** Every organism changes the environment it lives in. One model of succession suggests that as one species alters its environment, other species find it easier to compete for resources and survive. As lichens add organic matter and form soil, for example, mosses and other plants can colonize and grow. As organic matter continues to accumulate, other species move in and change the environment further. For example, as trees grow, their branches and leaves produce shade and cooler temperatures nearer the ground. Over time, more and more species can find suitable niches and survive.

**BUILD Vocabulary**

**VOCABULARY TERMS**

** succession**

**WORD ORIGINS** The origin of the word succession is the Latin word successus, meaning “to come after.” Ecological succession involves changes that occur one after the other as species move into and out of a community.

**BUILD Vocabulary**

**VOCABULARY TERMS**

**succession**

**WORD ORIGINS** The origin of the word succession is the Latin word successus, meaning “to come after.” Ecological succession involves changes that occur one after the other as species move into and out of a community.

**In Your Notebook** Summarize what happens in primary and secondary succession.

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**Teach**

**Use Visuals**

Guide students in using Figures 4–12 and 4–13 to compare and contrast primary and secondary succession.

**Ask** How are the two areas different when succession first begins? (The area in Figure 4–12 is nothing but bare rock and some lichen. The area in Figure 4–13 already has soil and a few small plants.)

**Ask** How long does it take for young trees to grow in each case? (35 to 80 years for primary succession, and 3 to 5 years for secondary succession)

**DIFFERENTIATED INSTRUCTION**

**ELL** Focus on ELL: Build Background

**ADVANCED AND ADVANCED HIGH SPEAKERS**

Read a description of the aftermath of the volcanic eruption on Krakatau in 1883. As you read, have students draw a sketch of what you are describing. Encourage them to discuss the description. Then, ask them to fill in column B of a BKWL Chart with background from the discussion. Tell them to list anything they can infer about succession after a volcanic explosion in column K and questions they have about it in column W. After students read the lesson, have them complete column L and describe what they have learned.

**Study Wkbks A/B, Appendix S27, BKWL Chart, Transparencies, GO8.**

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**Answers**

**IN YOUR NOTEBOOK** Primary succession occurs in areas with no previous community. After pioneer species move in and help form soil, other species gradually colonize. Secondary succession occurs when a community is disturbed but soil remains. Surviving vegetation regrows, and new vegetation moves in.
Lead a Discussion

Help students understand how ideas about succession have changed over the years.

Ask How have ecologists’ ideas about climax communities changed? (Formerly, they thought that the stages of succession were always the same and that stable climax communities were always the end result.)

Ask What types of information changed their thinking? (Climax communities resulting from multiple disturbances were more like patchwork quilts than like the original climax community.)

DIFFERENTIATED INSTRUCTION

L1 Struggling Students Help students understand how climax communities can be unstable. Provide students with visuals of regrowth after a forest fire or lava flow. Then, have them compare these examples with images of the growth of weeds or trees through concrete or asphalt. Ask them to infer why the plants that appear after the forest fire or lava flow are more likely to reach maturity and provide niches for other species than the plants that appear after an area is paved by humans. Compare the periodic maintenance of a road to an area in nature that undergoes frequent disturbances. In both situations the resulting climax community is not stable.

Answers

FIGURE 4–14 Secondary succession occurred, since soil and a few plants remained in the area after the storm.

IN YOUR NOTEBOOK Instability in some climax communities is caused by frequent disturbances.

Quick Lab

PURPOSE Students will conclude whether ecological succession has occurred in a closed aquatic community.

MATERIALS dried plant material, jar with lid, boiled pond water or sterile spring water, pH paper, microscope, slides, coverslips, pipette

SAFETY Remind students to handle the slides and pipette carefully and to wash their hands thoroughly after completing the lab.

PLANNING Obtain aquatic plants from a pet or aquarium store and spread them out to dry on baking sheets for a few days. Quart-sized canning jars are a good choice for the lab. You can sterilize them by filling them with boiling water and letting them air dry.

ANALYZE AND CONCLUDE

1. I used boiled water to avoid introducing organisms with the water added to the jar.
2. The organisms came from the dried plant material.
3. Sample answer: Yes, ecological succession was occurring, because the habitat inside the jar was changed by the living things in the jar. Tiny organisms grew in the water, turning it cloudy.

4. Sample answer: We all had organisms growing in the water in our jars, but we observed different numbers and types of organisms. The differences could be due to chance. There may have been different types of organisms in the dried plant material we started with, or we may have sampled different organisms when we prepared the slides.

Climax Communities

Do ecosystems return to “normal” following a disturbance?

Ecologists used to think that succession in a given area always proceeds through the same stages to produce a specific and stable climax community like the mature spruce and hemlock forest that is developing in Glacier Bay. Recent studies, however, have shown that succession doesn’t always follow the same path, and that climax communities are not always uniform and stable.

Succession After Natural Disturbances Natural disturbances are common in many communities. Healthy coral reefs and tropical rain forests recover from storms, as shown in Figure 4–14. Healthy temperate forests and grasslands recover from wildfires. Secondary succession in healthy ecosystems following natural disturbances often reproduces the original climax community. But detailed studies show that some climax communities are not uniform. Often, they look more like patchwork quilts with areas in varying stages of secondary succession following multiple disturbances that took place at different times. Some climax communities are disturbed so often that they can’t really be called stable.

In Your Notebook Describe what causes instability in some climax communities.
Succession After Human-Caused Disturbances In North America, land cleared for farming and then abandoned often passes through succession that restores the original climax community. But this is not always the case. Ecological recovery may or may not recover from extensive human-caused disturbances. Clearing and farming of tropical rain forests, for example, can change the microclimate and soil enough to prevent regrowth of the original community.

Studying Patterns of Succession Ecologists, like the ones seen in Figure 4–15, study succession by comparing different cases and looking for similarities and differences. Researchers who swarmed over Mount Saint Helens as soon as it was safe might also have studied Krakatau, for example. In both places, primary succession proceeded through predictable stages. The first plants and animals that arrived had seeds, spores, or adult stages that traveled over long distances. Hardy pioneer species helped stabilize loose volcanic debris, enabling later species to take hold. Historical studies in Krakatau and ongoing studies on Mount Saint Helens confirm that early stages of primary succession are slow, and that chance can play a large role in determining which species colonize at different times.

FIGURE 4–15 Studying Succession These Forest Service rangers are surveying some of the plants and animals that have returned to the area around Mount Saint Helens. The volcano erupted in 1980, leaving only barren land for miles.

4.3 Assessment

Review Key Concepts
1. a. Review What effects do pioneer species have on an environment undergoing primary succession?
   b. Explain Why do communities change over time?
   c. Apply Concepts When a whale or other large marine mammal dies and falls to the ocean floor, different waves of decomposers and scavengers feed off the carcass until nothing remains. Do you think this is an example of succession? Explain your reasoning.

2. a. Review What is a climax community?
   b. Relate Cause and Effect What kinds of conditions might prevent a community from returning to its predisturbance state?

Visual Thinking
3. Look at the photo below. If you walked from this dune in a straight line away from the beach, what kinds of changes in vegetation would you expect to see? What sort of succession is this?

Assessment Answers
1a. Pioneer species fix atmospheric nitrogen into useful forms for other organisms, break down rock, and add organic material to form soil.

1b. Communities change over time because of natural or human disturbances and because organisms alter their environment and pave the way for other species. For example, when trees grow in an area, they provide shade and cooler temperatures near the ground, allowing shade-loving organisms to move in.

1c. Sample answer: Yes, I think this is an example of succession, because the whale carcass changes over time as each new species creates new niches for other species.

2a. A climax community is the community that is the end result of ecological succession.

2b. A community might not change back to its original state due to repeated disturbances, dramatic changes in the microclimate and soil that prevent regrowth of the original climax community, or chance events that determine which species colonize an area.

Visual Thinking
3. Sample answer: You would expect to see increasing numbers and greater diversity of vegetation species and the appearance of slower-growing vegetation such as trees. This is primary succession because the dune starts out without soil or plants.

Address Misconceptions
The Nature of Succession Students commonly think that succession always leads to a predetermined climax community. Address this misconception by describing how random factors can influence the outcome of succession. For example, you might discuss such factors as wind direction, rainfall, and the organisms that happen to be actively breeding immediately after a disturbance.

Assess and RemEDIATE

EVALUATE UNDERSTANDING
Ask students to make a series of labeled sketches to show how either primary or secondary succession occurs. Then, have students complete the 4.3 Assessment.

REMEDIATION SUGGESTION
For Struggling Students If students have trouble with Question 1c, have them reread Why Succession Occurs. Then, ask them whether a whale carcass changes the environment of the ocean floor and whether the types of organisms that live off of it change over time.

Students can check their understanding of lesson concepts with the Self-Test assessment. They can then take an online version of the Lesson Assessment.
**Getting Started**

**Objectives**

**4.4.1 Describe** and compare the characteristics of the major land biomes.

**4.4.2 Identify** the areas that are not classified into a major biome.

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**Student Resources**

- Study Workbooks A/B, 4.4 Worksheets
- Spanish Study Workbook, 4.4 Worksheets
- Lab Manual B, 4.4 Data Analysis Worksheet

**Build Background**

Ask students who have lived in or visited other parts of the country to describe their climate and vegetation. Try to get descriptions of different biomes, such as southwestern deserts, prairie grasslands, and northwestern coniferous forests. Tell students they will read in this lesson why other parts of the country differ.

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**NATIONAL SCIENCE EDUCATION STANDARDS**

**UNIFYING CONCEPTS AND PROCESSES**

I, III, V

**CONTENT**

C.4.c, C.6.b, D.1

**INQUIRY**

A.1.c, A.2.d

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**Biomes**

**THINK ABOUT IT**

Why does the character of biological communities vary from one place to another? Why, for example, do temperate rain forests grow in the Pacific Northwest while areas to the east of the Rocky Mountains are much drier? How do similar conditions shape ecosystems elsewhere?

**The Major Biomes**

**What abiotic and biotic factors characterize biomes?**

In Lesson 1, you learned that latitude and the heat transported by winds are two factors that affect global climate. But Oregon, Montana, and Vermont have different climates and biological communities, even though those states are at similar latitudes and are all affected by prevailing winds that blow from west to east. Why? The reason is because other factors, among them an area’s proximity to an ocean or mountain range, can influence climate.

**Regional Climates**

Oregon, for example, borders the Pacific Ocean. Cold ocean currents that flow from north to south have the effect of making summers in the region cool relative to other places at the same latitude. Similarly, moist air carried by winds traveling west to east is pushed upward when it hits the Rocky Mountains. This air expands and cools, causing the moisture in the air to condense and form clouds. The clouds drop rain or snow, mainly on the upwind side of the mountains, as seen in Figure 4–16. West and east Oregon, then, have very different regional climates, and different climates mean different plant and animal communities.

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**Teach for Understanding**

**ENDURING UNDERSTANDING**

The existence of life on Earth depends on interactions among organisms and between organisms and their environment.

**GUIDING QUESTION**

What are the characteristics of the major biomes?

**EVIDENCE OF UNDERSTANDING**

After completing the lesson, assign students the following assessment to show they understand the characteristics of major biomes. Randomly assign each student one of the major biomes described in the lesson. Then, ask students to make a travel brochure that portrays the biome, in which they describe some of its abiotic and biotic factors and give at least one example of how the two sets of factors are related. Have them illustrate their brochures with pictures that they find online or draw themselves.
Biomes are described in terms of abiotic factors like climate and soil type, and biotic factors like plant and animal life. Major biomes include tropical rain forest, tropical dry forest, tropical grassland/savanna/shrubland, desert, temperate grassland, temperate woodland and shrubland, temperate forest, northwestern coniferous forest, boreal forest/taiga, and tundra. Each biome is associated with seasonal patterns of temperature and precipitation that can be summarized in a graph called a climate diagram, like the one in Figure 4–17. Organisms within each biome can be characterized by adaptations that enable them to live and reproduce successfully in the environment. The pages that follow discuss these adaptations and describe each biome's climate.

The distribution of major biomes is shown in Figure 4–18. Note that even within a defined biome, there is often considerable variation among plant and animal communities. These variations can be caused by differences in exposure, elevation, or local soil conditions. Local conditions also can change over time because of human activity or because of the community interactions described in this chapter and the next.

In Your Notebook On the biome map in Figure 4–18, locate the place where you live. Which biome do you live in? Do your climate and environment seem to match the description of the biome on the following pages?

**Teach**

**VISUAL SUMMARY**

Use the map in Figure 4–18 to familiarize students with the distribution of the world's major land biomes. In addition to their own biome, ask students to identify the other biomes found in the continental United States, including Alaska.

Ask Which biomes are not found in the continental United States? (boreal forest/taiga, tundra, and tropical rain forest)

Ask Which biome is found only in the United States and Canada? (northwestern coniferous forest)

**DIFFERENTIATED INSTRUCTION**

**ELL** English Language Learners Write the term biome on the board, and tell students the word part bio- can be defined as “living things,” while the word part -ome is derived from the Greek word part -oma meaning “mass or group.” Have them discuss how the meanings of these word parts make sense with the definition of biome given in the text. Point out that biomes are comprised of both living and nonliving factors.

**Address Misconceptions**

**Importance of Abiotic Factors** Students may have the misconception that biomes are distinguished on the basis of biotic factors alone, because these factors are usually the most visible. Stress that the biotic factors of biomes depend largely on abiotic factors, especially temperature and precipitation. As students learn about the major biomes in the lesson, emphasize how organisms in each biome are adapted to the climatic factors of that biome.

**Biology In-Depth**

**BIOMES AND SOIL TYPES**

Each of the major land biomes has a characteristic type of soil, which is determined by several factors, including temperature, precipitation, and type of vegetation. For example, soils of both tropical rain forests and boreal forests have little humus and are nutrient-poor and acidic, but for different reasons. In tropical rain forests, year-round high temperatures cause rapid decomposition, which acidifies the soil and breaks down the humus before it can build up, while heavy rains leach minerals from the soil. In boreal forests, decomposition occurs slowly because of low temperatures, so little humus ever forms, while organic matter from coniferous trees forms an acidic solution that leaches minerals. In temperate forests, in contrast, soil is rich with humus and nutrients but not acidic. Broadleaf deciduous trees annually drop a thick layer of leaves, which decay to form humus without acidifying or leaching the soil.

**Answers**

**IN YOUR NOTEBOOK** Answers will depend on where students live. If students live near the edge of a biome, they may not be able to identify their biome from the map alone. In such cases, students should read about nearby biomes on the following pages to see if their climate and environment match one of the descriptions better than the others.
Focus on ELL: Access Content

ALL SPEAKERS Pair beginning and intermediate speakers with advanced or advanced high speakers. Have pairs write the following vocabulary terms in the left column of a T-Chart and, below each term, a prediction of what it means: canopy, understory, deciduous, coniferous, humus, taiga, permafrost. Then, have pairs find the terms where they are first introduced in the lesson, read the context of the terms, and discuss whether their predictions were correct. After students have decided on the correct definitions of the terms, they should write the definitions in the right column of the chart.

Study Wkbks A/B, Appendix S30, T-Chart. Transparencies, GO15.
Deserts have less than 25 centimeters of precipitation annually, but otherwise vary greatly, depending on elevation and latitude. Many deserts undergo extreme daily temperature changes, alternating between hot and cold.

- **Abiotic factors** low precipitation; variable temperatures; soils rich in minerals but poor in organic material
- **Biotic factors**
  
  **Plant life:** Many plants, including cacti, store water in their tissues, and minimize leaf surface area to cut down on water loss. Cactus spines are actually modified leaves. Many desert plants employ special forms of photosynthesis that enable them to open their leaf pores only at night, allowing them to conserve moisture on hot, dry days.
  
  **Animal life:** Many desert animals get the water they need from the food they eat. To avoid the hottest parts of the day, many are nocturnal—active only at night. Large or elongated ears and other extremities are often supplied with many blood vessels close to the surface. These help the animal lose body heat and regulate body temperature.

**CONVERGENT EVOLUTION AMONG DESERT ORGANISMS**

In open woodlands, large areas of grasses and wildflowers such as poppies are interspersed with oak and other trees. Communities that are more shrubland than forest are known as chaparral. Dense low plants that contain flammable oils make fire a constant threat. Animals tend to be browsers—meaning they eat varied diets of grasses, leaves, shrubs, and other vegetation. In exposed shrubland, camouflage is common.

**Plains and prairies,** underlain by fertile soils, once covered vast areas of the midwestern and central United States. Periodic fires and heavy grazing by herbivores maintained plant communities dominated by grasses. Today, most have been converted for agriculture because their soil is so rich in nutrients and is ideal for growing crops.

- **Abiotic factors** warm to hot summers; cold winters; moderate seasonal precipitation; fertile soils; occasional fires
- **Biotic factors**
  
  **Plant life:** Grassland plants—especially grasses, which grow from their base—are resistant to grazing and fire. Dispersal of seeds by wind is common in this open environment. The root structure and growth habit of native grassland plants help establish and retain deep, rich, fertile topsoil.
  
  **Animal life:** Because temperate grasslands are open, exposed environments, predation is a constant threat for smaller animals. Camouflage and burrowing are two common protective adaptations.

**TEMPERATE WOODLAND AND SHRUBLAND**

In open woodlands, large areas of grasses and wildflowers such as poppies are interspersed with oak and other trees. Communities that are more shrubland than forest are known as chaparral. Dense low plants that contain flammable oils make fire a constant threat.

- **Abiotic factors** hot dry summers; cool moist winters; thin, nutrient-poor soils; periodic fires
- **Biotic factors**
  
  **Plant life:** Plants in this biome have adapted to drought. Woody chaparral plants have tough waxy leaves that resist water loss. Fire resistance is also important, although the seeds of some plants need fire to germinate.
  
  **Animal life:** Animals tend to be browsers—meaning they eat varied diets of grasses, leaves, shrubs, and other vegetation. In exposed shrubland, camouflage is common.

**Sketching BIOME Graphs**

**Yuma, Arizona**

<table>
<thead>
<tr>
<th>Average Temperature (ºC)</th>
<th>Average Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

**Dallas, Texas**

<table>
<thead>
<tr>
<th>Average Temperature (ºC)</th>
<th>Average Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

**Los Angeles, California**

<table>
<thead>
<tr>
<th>Average Temperature (ºC)</th>
<th>Average Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

**Connect to Earth Science**

Tell students that soil forms when rocks break down through weathering and humus mixes with the weathered rock particles. Explain that weathering can occur when water seeps into cracks and rock expands and contracts through repeated cycles of freezing and thawing. Particles carried by water can also weather rocks. Plant roots and burrowing animals can cause additional weathering. Humus forms when dead plant and animal materials decompose. Too much rain can cause humus to leech from soil, but too little may prevent decomposition. Have students read about temperate grasslands and temperate woodlands/shrublands. Point out that grasslands have thick, humus-rich soils, whereas woodlands/shrublands have thin, humus-poor soils.

**Ask** What biotic and abiotic factors in the two temperate biomes might help explain these differences in their soils? [Sample answer: Grasslands are likely to have more weathering and soil formation due to cold winters, moderate precipitation, and abundant plant life; they probably have more humus forming due to their dense grassy vegetation. Woodlands/shrublands are likely to have less weathering and soil formation due to cool, but not cold, winters and lower overall precipitation. They probably have less humus forming due to their scattered woody vegetation.]

**DIFFERENTIATED INSTRUCTION**

**L1 Special Needs** Bring in several different soil mixtures, including a mixture of loam and humus, a mixture of sand and topsoil without humus, and a compacted mixture of clay and topsoil without humus. Let students handle the soils and inspect them with a hand lens to try to identify their components. Explain why the loam-humus mixture is the most fertile and why the other soil mixtures are not as fertile. Pack an equal amount of each soil sample into a funnel, and pour water through the samples to demonstrate how the loam-humus mixture retains water (unlike the sand-soil mixture) without becoming waterlogged (like the clay-soil mixture). Guide students in identifying biomes where the three different types of soil might be found and how soil type is related to the vegetation that grows in each biome.

**Biology In-Depth**

**CONVERGENT EVOLUTION AMONG DESERT ORGANISMS**

The selective pressures of extreme abiotic factors, such as the very low precipitation in deserts, has led to convergent evolution in organisms that are only distantly related but live in the same biome type. African euphorbias and American cacti are examples. Both types of plants have evolved almost identical adaptations to the aridity of their desert biomes. Both have compact spherical shapes, spines instead of leaves, sunken stomata, and thick outer walls, all of which help reduce water loss. Both also have thick, succulent stems that store water. Another example of convergent evolution in desert animals includes North American horned lizards and Australian thorny devil lizards. Both lizards are very similar morphologically but only distantly related taxonomically.
Use Visuals

Have students find the locations of North American temperate forests and northwestern coniferous forests on the map in Figure 4–18. Then, have them compare their climate diagrams on this page.

Ask How are the temperature and precipitation patterns different for the two biomes? (The summers in the temperate forest are warmer and wetter than those in the northwestern coniferous forest. The winters in the northwestern coniferous forest are warmer and wetter than those in the temperate forest.) Point out that the two forest biomes are found at some of the same latitudes but have different climates. Explain how the coastal location of northwestern coniferous forests leads to a different pattern of temperature and precipitation than that of temperate forests.

DIFFERENTIATED INSTRUCTION

ELL English Language Learners Pair English language learners with native English speakers. Have one partner read several sentences about each biome. Have the other partner try to identify which biome is being described. Then, have partners switch roles and repeat the exercise.

LPR Less Proficient Readers Some students may be overwhelmed by the detailed descriptions of the major biomes. Suggest they choose one biotic or abiotic factor at a time and read how it varies across biomes. Once they have a sense of the overall variation in each factor, details for the individual biomes should be more meaningful.

DIFFERENTIATED INSTRUCTION

TEACHER

Check for Understanding

USE VOCABULARY

Ask students to create acrostics based on the words BIOME FACTS. Each of the ten letters in the two words should be the first letter of a sentence about a different biome so that all ten biomes are covered. The sentences should include the lesson vocabulary terms. For example, for B students might write, Biotic factors in tropical dry forests include deciduous plants that shed their leaves during the dry season. For T they might write, Temperate forests often have soils that are rich in humus from decaying leaves.

ADJUST INSTRUCTION

Display the acrostics in the classroom, and give students a chance to read them. Discuss as a class any statements with which they disagree.
The tundra is characterized by permafrost, a layer of permanently frozen subsoil. During the short cool summer, the ground thaws to a depth of a few centimeters and becomes soggy. In winter, the top layer of soil freezes again. This cycle of thawing and freezing, which rips and crushes plant roots, is one reason that tundra plants are small and stunted. Cold temperatures, high winds, a short growing season, and humus-poor soils also limit plant height.

- **Abiotic factors**
  - strong winds; low precipitation; short and soggy summers; long, cold, dark winters; poorly developed soils; permafrost

- **Biotic factors**
  - Plant life: By hugging the ground, mosses and other low-growing plants avoid damage from frequent strong winds. Seed dispersal by wind is common. Many plants have adapted to growth in poor soil. Legumes, for example, have nitrogen-fixing bacteria on their roots.
  - Animal life: Many animals migrate to avoid long harsh winters. Animals that live in the tundra year-round display adaptations, among them natural antifreeze, small extremities that limit heat loss, and a varied diet.

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### How would this demonstration model the soil in a tundra biome?

_Tundra soil has a layer of permafrost, called permafrost. During the summer, only the top layer of the soil thaws, and it becomes soggy because water cannot seep down through the lower layers._

Explain how these features of the soil are related to the types of vegetation that grow in tundra biomes.

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### Differentiated Instruction

**L Struggling Students**

Show students pictures of animals with clearly apparent adaptations to a cold climate, such as thick fur, bulky body shapes, and short extremities. Explain how the adaptations help the animals survive in extreme cold. Ask them to name biomes where the animals in the pictures might be found, based on these adaptations.

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### Analysing Data

**Which Biome?**

An ecologist collected climate data from two locations. The graph shows the monthly average temperatures in the two locations. The total yearly precipitation in Location A is 273 cm. In Location B, the total yearly precipitation is 11 cm.

1. **Interpret Graphs**
   - What variable is plotted on the horizontal axis? On the vertical axis?

2. **Interpret Graphs**
   - How would you describe the temperature over the course of the year in Location A? In Location B?

3. **Draw Conclusions**
   - In which biome would you expect to find each location, given the precipitation and temperature data? Explain your answer.

4. **Analyze Data**
   - Look up the average monthly temperature last year in the city you live in. Plot the data. Then look up the monthly rainfall for your city, and plot those data. Based on your results, which biome do you live in? Did the data predict the biome correctly?

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### Answers

1. **Time of year by month is plotted on the horizontal axis. Average temperature in degrees Celsius is plotted on the vertical axis.**

2. **In Location A, the temperature is moderate throughout the year, with little variation. In Location B, the temperature is relatively cool from November through April and hot from May through October, with a peak in July and August.**

3. **You would expect to find Location A in a rain forest biome, because the total precipitation is close to 3 m, and the average temperature varies little from month to month. You would expect to find Location B in a desert biome, because precipitation is very low, and the temperature varies seasonally from warm to hot.**

4. **Answers will vary depending on the location where students live. Advise students to format their graphs like the climate diagrams in the lesson for ease of comparison. To improve accuracy, suggest they find average monthly climate data over a several-year period. To predict the biome in which they live, they should compare their completed climate diagram to those on pages 112–115. Then, they can find their biome on the map in Figure 4–18 to see if the climate data predicted the biome correctly.**
Assess and RemEDIATE

LESSON 4.4

Assess and Remediate

EVALUATE UNDERSTANDING

Make overhead transparencies of the climate diagrams for all ten major biomes. Show the transparencies, and call on students to identify each biome from the climate data. Call on other students to name plants and animals found in each biome. Then, have students complete the 4.4 Assessment.

REMEDIATION SUGGESTION

Struggling Students If students have trouble with Question 1c, suggest they choose two biomes for which they can identify a specific type of plant and animal based on their prior knowledge or the photographs in the text.

Assessment Answers

1a. The major biomes are tropical rain forest, tropical dry forest, tropical grassland/savanna/shrubland, desert, temperate grassland, temperate woodland and shrubland, temperate forest, northwestern coniferous forest, boreal forest, and tundra. For each biome, students can list any of the facts given for the biomes on pages 112–115.

1b. Biomes are classified in terms of abiotic factors like climate and soil type and biotic factors like typical plant and animal life.

1c. Sample answer: I chose tropical rain forests and deserts. Epiphytes grow in trees of tropical rain forests, which is an adaptation that lets them take advantage of available light. Monkeys live in the canopy of tropical rain forests, and they have adaptations for living in trees, such as hands for climbing. Cacti grow in deserts, and they have tissues that can store water, which is an adaptation to low precipitation. Some snakes that live in deserts are active only at night, which is an adaptation to high daytime temperatures.

2a. Mountain ranges and polar ice caps are not easily defined in terms of a typical community of plants and animals.

2b. Sample answer: I might begin in a grassland, pass through a pine woodland, go through a coniferous forest, and then pass through an open field of wildflowers and stunted vegetation resembling tundra. At the summit, I might find only glaciers and no plant life.

3. Students can sketch any of the biomes described in the lesson. Their sketch should include labeled drawings of typical plants and animals for that biome. It should also have a caption describing the sketch.

Other Land Areas

What areas are not easily classified into a major biome?

Some land areas do not fall neatly into one of the major biomes. Because they are not easily defined in terms of a typical community of plants and animals, mountain ranges and polar ice caps are not usually classified into biomes.

Mountain Ranges

Mountain ranges exist on all continents and in many biomes. On mountains, conditions vary with elevation. From river valley to summit, temperature, precipitation, exposure to wind, and soil types all change, and so do organisms. If you climb the Rocky Mountains in Colorado, for example, you begin in a grassland. You then pass through pine woodland and then a forest of spruce and other conifers. Thickets of aspen and willow trees grow along streambeds in protected valleys. Higher up, soils are thin. Strong winds buffet open fields of wildflowers and stunted vegetation resembling tundra. Glaciers are found at the peaks of many ranges.

Polar Ice Caps

Polar regions, like the one in Figure 4–19, border the tundra and are cold year-round. Plants are few, though some algae grow on snow and ice. Where rocks and ground are exposed seasonally, mosses and lichens may grow. Marine mammals, insects, and mites are the typical animals. In the north, where polar bears live, the Arctic Ocean is covered with sea ice, although more and more ice is melting each summer. In the south, the continent of Antarctica, inhabited by many species of penguins, is covered by ice nearly 5 kilometers thick in places.

4.4 Assessment

Review Key Concepts

1. a. Review List the major biomes, and describe one characteristic of each.

b. Explain How are biomes classified?

c. Compare and Contrast Choose two very different biomes. For each biome, select a common plant and animal. Compare how the plants and animals have adapted to their biomes.

2. a. Review Why aren’t mountain ranges or polar ice caps classified as biomes?

b. Sequence Imagine that you are hiking up a mountain in the temperate forest biome. Describe how the plant life might change as you climb toward the summit.

Apply the Big Idea

Interdependence in Nature

3. Choose one of the biomes discussed in this lesson. Then, sketch the biome. Include the biome’s characteristic plant and animal life in your sketch. Add labels to identify the organisms, and write a caption describing the content of the sketch.
Conditions Underwater

What factors affect life in aquatic ecosystems?

Like organisms living on land, underwater organisms are affected by a variety of environmental factors. Aquatic organisms are affected primarily by the water’s depth, temperature, flow, and amount of dissolved nutrients. Because runoff from land can affect some of these factors, distance from shore also shapes marine communities.

Water Depth

Water depth strongly influences aquatic life because sunlight penetrates only a relatively short distance through water, as shown in Figure 4-20. The sunlit region near the surface in which photosynthesis can occur is known as the photic zone. The photic zone may be as deep as 200 meters in tropical seas, but just a few meters deep or less in rivers and swamps. Photosynthetic algae, called phytoplankton, live in the photic zone. Zooplankton—tiny free-floating animals—eat phytoplankton. This is the first step in many aquatic food webs. Below the photic zone is the dark aphotic zone, where photosynthesis cannot occur.

Many aquatic organisms live on, or in, rocks and sediments on the bottoms of lakes, streams, and oceans. These organisms are called the benthos, and their habitat is the benthic zone. Where water is shallow enough for the benthos to be within the photic zone, algae and rooted aquatic plants can grow. When the benthic zone is below the photic zone, chemosynthetic autotrophs are the only primary producers.

Key Questions

What factors affect life in aquatic ecosystems?

What are the major categories of freshwater ecosystems?

Why are estuaries so important?

How do ecologists usually classify marine ecosystems?

Vocabulary

photic zone • aphotic zone • benthos • plankton • wetland • estuary

Taking Notes

Compare/Contrast Table: As you read, note the similarities and differences between the major freshwater and marine ecosystems in a compare/contrast table.

FIGURE 4-20 The Photic Zone

Sunlight penetrates only a limited distance into aquatic ecosystems. Whatever the depth of this photic zone, it is the only area in which photosynthesis can occur. Infer: Why do you think some photic zones are only a few meters deep and others are as much as 200 meters deep?

Answers

FIGURE 4-20 Sample answer: Photic zones vary in depth depending on how clear the water is. The clearer the water, the deeper sunlight can penetrate.
LESSON 4.5

Details Chart.

GO13. Transparencies, Appendix S28, Main Ideas and Study Wkbks A/B, both abiotic and biotic factors for each category. page and the next. They should include notes on water ecosystems as they read about them on this information about the major categories of fresh-

a to organize the Main Ideas and Details Chart.

IN YOUR NOTEBOOK

Sample answer: Water flows in streams, but it may stay in place in bogs. Bogs have more plants growing in them than streams do.

IN YOUR NOTEBOOK Sample answer: You would expect adaptations that help anchor organisms to rocks or help them to swim against the current.

Teach

Connect to the Real World

Assign each of three groups of students one of the categories of freshwater ecosystems. Have members of each group find photographs of the ecosystem (preferably of a local example) and information about the plants and animals found there. Have them share their research with the class in a brief presentation. Then, discuss as a class general characteristics of each category of ecosystem.

DIFFERENTIATED INSTRUCTION

LESS PROFICIENT READERS Have students use a Main Ideas and Details Chart to organize the information about the major categories of freshwater ecosystems as they read about them on this page and the next. They should include notes on both abiotic and biotic factors for each category.

Study Wkbks A/B, Appendix S28, Main Ideas and Details Chart. Transparencies, GO13.

Focus on ELL: Access Content

ALL SPEAKERS Pair beginning and intermediate speakers with advanced or advanced high speakers. Assign each pair one of the three paragraphs with blue headings under Freshwater Ecosystems. Tell partners to read their paragraph and make drawings to illustrate it. Then, ask each pair to present a brief oral report to the class in which they identify the most important points in their paragraph and share their illustrations.

Discuss with students the interconnectedness of terrestrial and aquatic organisms along stream banks. Have them reread the paragraph with the blue heading, Rivers and Streams, to help them answer the question. Students can go online to Biology.com to gather their evidence.

Answers

FIGURE 4-21 Sample answer: Water flows in streams, but it may stay in place in bogs. Bogs have more plants growing in them than streams do.

IN YOUR NOTEBOOK Sample answer: You would expect adaptations that help anchor organisms to rocks or help them to swim against the current.

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Quick Facts

SIGNIFICANCE AND LOSS OF WETLANDS

Wetlands can be invaluable ecosystems for surrounding human and natural communities. A single acre of wetland can hold up to 1.5 million gallons of floodwater. In spite of their ecological importance, wetlands were long thought to be synonymous with wastelands. They were filled in or drained for agriculture, development projects, mosquito control, and other purposes. As a result, more than half of the wetlands that once existed in the United States have been destroyed. Although destruction of wetlands has slowed since the 1970s, 60,000 acres of wetlands are still lost each year. Wetlands are almost as biologically diverse and productive as tropical rain forests. For example, as many as half of all North American bird species depend on wetlands for nesting sites or food, and almost a third of plant species live in wetlands. Loss of wetlands, therefore, is a significant cause of species extinctions.
**Lakes and Ponds** The food webs in lakes and ponds often are based on a combination of plankton and attached algae and plants. **Plankton** is a general term that includes both phytoplankton and zooplankton. Water typically flows in and out of lakes and ponds and circulates between the surface and the benthos during at least some seasons. This circulation distributes heat, oxygen, and nutrients.

**Freshwater Wetlands** A **wetland** is an ecosystem in which water either covers the soil or is present at or near the surface for at least part of the year. Water may flow through freshwater wetlands or stay in place. Wetlands are often nutrient-rich and highly productive, and they serve as breeding grounds for many organisms. Freshwater wetlands have important environmental functions: They purify water by filtering pollutants and help to prevent flooding by absorbing large amounts of water and slowly releasing it. Three main types of freshwater wetlands are freshwater bogs, freshwater marshes, and freshwater swamps. Saltwater wetlands are called estuaries.

**Estuaries**

**Why are estuaries so important?**

An **estuary** (es tyoo er ee) is a special kind of wetland, formed where a river meets the sea. Estuaries contain a mixture of fresh water and salt water, and are affected by the rise and fall of ocean tides. Many are shallow, which means that enough sunlight reaches the benthos to power photosynthesis. Estuaries support an astonishing amount of biomass—although they usually contain fewer species than freshwater or marine ecosystems—which makes them commercially valuable. **Estuaries serve as spawning and nursery grounds for many ecologically and commercially important fish and shellfish species including bluefish, striped bass, shrimp, and crabs.**

Salt marshes are temperate estuaries characterized by salt-tolerant grasses above the low-tide line and seagrasses below water. One of the largest salt marshes in America surrounds the Chesapeake Bay in Maryland (shown below). Mangrove swamps are tropical estuaries characterized by several species of salt-tolerant trees, collectively called mangroves. The largest mangrove area in America is in Florida's Everglades National Park (shown below).

**Lead a Discussion**

Discuss with students how the abiotic factors of freshwater wetlands and estuaries relate to the types of organisms that live in the two categories of ecosystems.

**Ask** How are the abiotic factors of freshwater wetlands and estuaries similar and different? (Both ecosystems have lots of water. Freshwater wetlands have fresh water while estuaries have a mix of fresh and salt water.)

**Ask** Do the same species of aquatic organisms live in both freshwater wetlands and estuaries, and if not, why not? (No—most species are adapted to certain abiotic factors, such as salt water or fresh water but not both.)

Give examples to show why most organisms adapted to fresh water cannot tolerate salt water, and vice-versa. For example, explain that saltwater fish have mechanisms for excreting excess salt from their body, whereas freshwater fish have mechanisms for concentrating salt in their body.

**DIFFERENTIATED INSTRUCTION**

**L Special Needs** Demonstrate the significance of salt tolerance in estuary plants by showing how salt-water affects a salt-intolerant plant. Place the root of a whole carrot with greens attached in a glass of fresh water. Place a second carrot in a glass of salt water. Have students compare the firmness of the leaves and stems and the flexibility of the roots over a period of a few days. Explain that carrots are not salt-tolerant plants, so salt water causes them to lose the fresh water inside their cells and become wilted. Have them infer how a salt-tolerant plant might fare under the same conditions.

**L Advanced Students** Ask students who have taken chemistry classes to learn about the mechanisms by which fish regulate salt balance by either pumping out sodium ions or actively taking up sodium ions, depending on whether they live in salt water or fresh water. Then, have students explain the basic chemistry underlying the mechanisms to the class.
Lesson 4.5

Use Visuals

Have students do library or Internet research to identify the organisms depicted in the figure and find others not depicted. Assign each student one of the seven ocean zones, and have them photocopy, print out, or sketch images of organisms from various sources. Be sure they identify each organism, note its zone, and describe some of its salient features. Assemble the images on a bulletin board similar to Figure 4–22.

Animals in Figure 4–22: Photic Zone sea lion, herring, blue whale, swordfish; 200–1000 m krill-like shrimp, ocean sunfish, bigeye tuna, cod, giant squid; 1000–4000 m vipershine, dragonfish, bathypelagic anglerfish, snipe eel; 4000–10,000 m rattail, gulper eel, tripod fish

Differentiated Instruction

Special Needs Students may not be able to identify many of the organisms in Figure 4–22. Show them additional visuals of organisms found in these zones. For comparison, provide them with visuals of nocturnal organisms and organisms that live in dark terrestrial environments. Have students identify some of the similar adaptive features that these organisms have evolved to survive in the dark.

Address Misconceptions

Importance of Marine Phytoplankton A common misconception is that phytoplankton are too small to be important photosynthesizers. Tell students that oceans cover three quarters of Earth’s surface, and that each drop of ocean water down to a depth of 100 meters is home to thousands of phytoplankton. Then, tell them that phytoplankton produce 70 percent of Earth’s oxygen and are the main consumers of carbon dioxide, a greenhouse gas.

Answers

In Your Notebook Sample answer: I would expect communities in the open ocean to have lower concentrations of organisms, because there are low nutrient levels in the open ocean. Also, the organisms that live in the aphotic zone would have adaptations that help them survive in deep-water conditions.

Marine Ecosystems

How do ecologists usually classify marine ecosystems?

Just as biomes typically occupy certain latitudes and longitudes, marine ecosystems may typically occupy specific areas within the ocean. Ecologists typically divide the ocean into zones based on depth and distance from shore. Starting with the shallowest and closest to land, marine ecosystems include the intertidal zone, the coastal zone, and the open ocean, as shown in Figure 4–22. Within these zones live a number of different communities.

In Your Notebook How would you expect communities of organisms in the open ocean to differ from those along the coast?

Intertidal Zone Organisms in the intertidal zone are submerged in seawater at high tide and exposed to air and sunlight at low tide. These organisms, then, are subjected to regular and extreme changes in temperature. They also are often battered by waves and currents. There are many different types of intertidal communities. A typical rocky intertidal community exists in temperate regions where exposed rocks line the shore. There, barnacles and seaweed permanently attach themselves to the rocks.

How Science Works

Sylvia Earle: Ocean Explorer and Ground Breaker

Also called “Her Deepness” and named a “Hero for the Planet,” Dr. Sylvia Earle is a world-famous ocean explorer and marine biologist. For almost four decades, she has also been a trailblazer for women in science. For example, in 1970, when qualified women scientists often experienced difficulty obtaining positions alongside men on research teams, she led an all-female, two-week expedition to the ocean floor. In the 1990s, she was named the first female chief scientist of NOAA. During her exemplary career, Dr. Earle has led more than 60 marine expeditions and spent almost 7000 hours underwater. She has also been instrumental in developing cutting-edge technology for exploring the deep ocean—vehicles and equipment that will likely advance marine research for decades to come. A world record holder in deep sea diving, Dr. Earle is currently National Geographic Society’s Explorer-in-Residence and a vocal advocate for the oceans.
Coastal Ocean  The coastal ocean extends from the low-tide mark to the outer edge of the continental shelf—the relatively shallow border that surrounds the continents. Water here is brightly lit, and is often supplied with nutrients by freshwater runoff from land. As a result, coastal oceans tend to be highly productive. Kelp forests and coral reefs are two exceptionally important coastal communities.

Open Ocean  The open ocean begins at the edge of the continental shelf and extends outward. More than 90 percent of the world’s ocean area is considered open ocean. Depth ranges from about 500 meters along continental slopes to more than 10,000 meters in deep ocean trenches. The open ocean can be divided into two main zones according to light penetration: the photic zone and the aphotic zone.

The Open Ocean Photic Zone  The open ocean typically has low nutrient levels and supports only the smallest species of phytoplankton. Still, because of its enormous area, most photosynthesis on Earth occurs in the sunlit top 100 meters of the open ocean.

The Open Ocean Aphotic Zone  The permanently dark aphotic zone includes the deepest parts of the ocean. Food webs here are based either on organisms that fall from the photic zone above, or on chemosynthetic organisms. Deep ocean organisms, like the fish in Figure 4–23, are exposed to high pressure, frigid temperatures, and total darkness. Benthic environments in the deep sea were once thought to be nearly devoid of life but are now known to have islands of high productivity. Deep-sea vents, where superheated water boils out of cracks on the ocean floor, support chemosynthetic primary producers.

Assess and RemEDIATE

**EVALUATE UNDERSTANDING**

Play a quiz game with the class in which you name aquatic ecosystems and teams of students compete to identify their abiotic factors and the organisms that live in them. Then, have students complete the 4.5 Assessment.

**REMEDICATION SUGGESTION**

**Struggling Students** If students have difficulty with Question 5, model an appropriate answer. For example, describe the waves and currents in the intertidal zone and explain how organisms such as barnacles and seaweed adapt to the moving water by attaching themselves to rocks.

**Answers**

**FIGURE 4–23** Sample answer: The fish must have adaptations that allow it to endure high pressure, cope with frigid temperatures, and sense its surroundings in total darkness.

**Assessment Answers**

**1a.** the water’s depth, temperature, flow, and amount of dissolved nutrients

**1b.** Sample answer: In an aphotic zone, there are no phytoplankton to produce food, because no sunlight penetrates to this depth. Organisms in the aphotic zone must obtain food in some other way than by photosynthesis or by consuming plankton.

**2a.** rivers and streams, lakes and ponds, and freshwater wetlands

**2b.** A wetland is an ecosystem in which water either covers the soil or is present at or near the surface for at least part of the year. Wetlands are often highly productive and serve as breeding grounds for many organisms. They also purify water and help prevent flooding.

**3a.** Estuaries are found where rivers meet the sea. Estuaries serve as spawning and nursery grounds for many fish and shellfish.

**3b.** Sample answer: It might reduce the amount of freshwater entering an estuary, which would increase the salt concentration of the water.

**4a.** Sample answer: Intertidal zone: exposure to air and sunlight at low tides and extreme temperature changes; coastal ocean: brightly lit water and nutrients supplied by freshwater runoff; open ocean: low nutrient levels and lack of sunlight below 100 m

**4b.** Students’ drawings should show the intertidal zone, coastal ocean, open ocean, and an ocean trench. Photic and aphotic zones should be labeled.

**5.** Students can choose any three freshwater or marine ecosystems. For each, students should explain how a plant and an animal have adapted to its conditions.
Pre-Lab

Introduce students to the concepts they will explore in the chapter lab by assigning the Pre-Lab questions.

Lab

Tell students they will perform the chapter lab Abiotic Factors and Plant Selection described in Lab Manual A.

Struggling Students A simpler version of the chapter lab is provided in Lab Manual B.

SAFETY

Inform students that soil and sand sometimes contain harmful microorganisms, so they should wash their hands thoroughly after completing the lab.

Look online for Editable Lab Worksheets.

For corresponding pre-lab in the Foundation Edition, see page 100.

National Science Education Standards

CONTENT F.3, F.4

Pre-Lab: Abiotic Factors and Plant Selection

Problem How can you decide which plants will thrive in a garden?

Materials plant hardiness zone map, plant catalogs, graph paper, tape measure

Skills Focus Classify, Analyze Data, Use Models

Connect to the Big idea Why are white birch trees abundant in Minnesota, but not in the Florida Keys? Why do coconut palms grow in the Florida Keys, but not in Minnesota? Simply put, white birch trees could not tolerate the hot summers in the Keys and coconut palms could not tolerate the cold winters in Minnesota. A plant’s habitat is determined by its range of tolerance for temperature and other abiotic factors. In other words, abiotic factors limit where a given plant can live.

In this lab, you will plan a garden for a specific location. You will select plants for the garden that can tolerate the abiotic factors in this location.

Background Questions

a. Review What is an abiotic factor? List three examples other than temperature.

b. Review What kinds of resources do plants need?

c. Relate Cause and Effect Give an example of an adaptation that helps a plant survive in a biome with low precipitation.

Pre-Lab Questions

Preview the procedure in the lab manual.

1. Predict How will knowing the plant hardiness zone for your area help you plan a garden?

2. Relate Cause and Effect What is the relationship between the last frost and the length of the growing season?

3. Form a Hypothesis A plant species grows well in one location in a small garden but does not grow as well in another location. Suggest one possible reason for this difference.

Pre-Lab Answers

Background Questions

a. Abiotic factors are non-living factors that influence the growth of plants. Possible abiotic factors are sunlight, precipitation, wind, humidity, and soil type.

b. Sample answer: Plants need water, light, nutrients, and space to grow.

c. Possible answers include leaves with limited surface area or leaf pores that open only at night.

Pre-Lab Questions

1. Sample answer: Knowing the plant hardiness zone will provide information about some abiotic factors. (Some students may know that suppliers of seeds and plants usually provide a range of hardiness zones for each species.)

2. Sample answer: The earlier the last frost occurs, the longer the growing season.

3. Sample answer: One location may have direct sunlight all day and the other may be in the shade for most of the day.
An organism’s tolerance range for temperature, precipitation, and other abiotic factors helps determine where it lives. Biotic factors, such as competition, predation, and herbivory also help to determine an organism’s potential habitat and niche.

**4.1 Climate**

- A region’s climate is defined by year-after-year patterns of temperature and precipitation.
- Global climate is shaped by many factors, including solar energy trapped in the biosphere, latitude, and the transport of heat by winds and ocean currents.

**4.2 Niches and Community Interactions**

- A niche is the range of physical and biological conditions in which a species lives and the way the species obtains what it needs to survive and reproduce.
- By causing species to divide resources, competition helps determine the number and kinds of species in a community and the niche each species occupies.
- Predators can affect the size of prey populations in a community and determine the places prey can live and feed.
- Herbivores can affect both the size and distribution of plant populations in a community and can determine the places that certain plants can survive and grow.
- Biologists recognize three main classes of symbiotic relationships in nature: mutualism, parasitism, and commensalism.

**4.3 Succession**

- Ecosystems change over time, especially after disturbances, as some species die out and new species move in.
- Secondary succession in healthy ecosystems following natural disturbances often reproduces the original climax community. Ecosystems may or may not recover from human-caused disturbances.

**4.4 Biomes**

- Biomes are described in terms of abiotic factors like climate and soil type, and biotic factors like plant and animal life.
- Mountain ranges and polar ice caps are not usually classified into biomes because they are not easily defined in terms of a typical community of plants and animals.

**4.5 Aquatic Ecosystems**

- Aquatic organisms are affected primarily by the water’s depth, temperature, flow, and amount of dissolved nutrients.
- Freshwater ecosystems can be divided into three main categories: rivers and streams, lakes and ponds, and freshwater wetlands.
- Estuaries serve as spawning and nursery grounds for many ecologically and commercially important fish and shellfish species.
- Ecologists typically divide the ocean into zones based on depth and distance from shore.

**Performance Tasks**

**SUMMATIVE TASK** Have pairs of students select one of the land biomes or aquatic ecosystems described in the chapter and create a scrapbook highlighting its abiotic and biotic factors. Tell students to convey the information about their biome with photographs, maps, graphs, and short passages of text.

**TRANSFER TASK** Ask groups of students to choose a specific region of a land biome or aquatic ecosystem that is threatened by human actions and create a Web site about the problem and potential solutions. The Web site should include information on why the ecosystem is threatened, why it is important, what is being done to protect it, and what individuals can do to help.

**Answers**

**THINK VISUALLY**

Students’ concept maps should show that ecosystems are determined by abiotic factors, including nutrients, light, and oxygen; and by biotic factors, including the community interactions of predation, competition, and symbiosis.
Lesson 4.1

UNDERSTAND KEY CONCEPTS
1. b  2. d
3. Weather is the day-to-day condition of Earth’s atmosphere. Climate refers to average conditions over long periods.
4. solar energy trapped in the biosphere, latitude, and the transport of heat by winds and ocean currents

THINK CRITICALLY
5. The curvature of Earth’s surface causes sunlight to strike the surface near the poles at an angle, so solar energy is spread out over a larger area at the poles than at the equator. This difference in the distribution of solar energy at different latitudes explains climate zones. As Earth revolves around the sun, sunlight strikes different regions at angles that vary from summer to winter. This difference in the distribution of solar energy at different times of the year explains seasons.
6. The white paint reflects much of the sunlight so that it does not pass into the greenhouse where it would be trapped as heat.

Lesson 4.2

UNDERSTAND KEY CONCEPTS
7. d  8. b
9. An organism’s habitat is the general location where it lives. Its niche includes not only where it lives but also how it lives, including which abiotic factors it needs, how it reproduces, what it eats, and how it obtains its food.
10. No two species can occupy exactly the same niche at exactly the same time.

THINK CRITICALLY
11. In predation, one organism captures, kills, and eats another organism. In parasitism, one organism lives in or on another organism and uses it for food or other purposes without killing it.
12. Members of the same species have exactly the same niche. Therefore, they are in direct competition for the same resources in their area. Members of two different species are likely to have somewhat different niches, so while they may need some of the same resources, they are likely to use them at different times or in different ways, which means that they do not compete so intensely for them.
13. Sample answer: I reside in a city with a temperate climate. I live in a house with other members of my family and a dog. I interact with many humans, and I take my dog for walks. I eat a variety of plant and animal foods that come from all over the world, and I buy them at local supermarkets and restaurants.

Lesson 4.3

UNDERSTAND KEY CONCEPTS
14. d  15. d
16. primary succession
17. natural disturbances and human-caused disturbances

THINK CRITICALLY
18. Secondary succession; in 5 years, small trees will probably have started to grow.
4.4 Biomes

**Understand Key Concepts**

20. a. canopy.  
   b. niche.  
   c. taiga.  
   d. understory.  
21. a. permafrost characterizes the biome called  
   b. taiga.  
   c. savanna.  
   d. boreal forest.  
22. What is a biome?  
23. Why are plants generally few and far between in a desert?

**Think Critically**

24. **Apply Concepts** Although the amount of precipitation is low, most parts of the tundra are very wet during the summer. How would you explain this apparent contradiction?

25. **Infer** Deciduous trees in tropical dry forests lose water through their leaves every day. During summers with adequate rain, the leaves remain on the trees. During the cold dry season, the trees drop their leaves. In an especially dry summer, how might the adaptation of dropping leaves enable a tree to tolerate the drought?

26. **Infer** Consider these two biomes: (1) the temperate grassland and (2) the temperate woodland and shrubland. Coyotes live in both biomes. Describe two adaptations that might enable coyotes to tolerate conditions in both biomes.

4.5 Aquatic Ecosystems

**Understand Key Concepts**

27. Organisms that live near or on the ocean floor are called  
   a. parasites.  
   b. plankton.  
   c. benthos.  
   d. mangroves.  
28. What is the meaning of the term plankton? Name the two types of plankton.

29. What are three types of freshwater wetlands?

30. How are salt marshes and mangrove swamps alike? How are they different?

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**Lesson 4.4**

**UNDERSTAND KEY CONCEPTS**

20. a 21. d

22. A biome is a group of regional climate communities described in terms of biotic and abiotic factors.

23. The low levels of precipitation in a desert can support only a few plants.

**THINK CRITICALLY**

24. Because of permafrost, only the top few centimeters of the ground thaw in the summer. What little precipitation that does fall cannot soak into the permanently frozen subsoil, so it makes the ground soggy.

25. By dropping its leaves during an especially dry summer, a tree loses less water and is more likely to tolerate a drought.

26. Sample answer: Coyotes might be able to tolerate conditions in these two different biomes by being adapted to hunt and eat a variety of different prey animals and by being able to withstand hot, dry summers as well as cold winters.

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**CHAPTER MYSTERY**

**THE WOLF EFFECT**

Eliminating wolves from Yellowstone National Park contributed to an increase in the number of elk. These elk grazed so heavily, especially along streams, that the seedlings and shoots of aspens and willows, and other trees, could not grow. Fewer trees led to fewer dams being built by beavers and to an increase in runoff and erosion. Aquatic food webs broke down, affecting birds, fish, and other animals. The recent reintroduction of wolves has caused a decrease in the overall elk population and seems to have reduced elk grazing along certain streams. That may be in part because wolves are killing more elk and in part because elk have learned to stay away from places like stream banks and valleys, where wolves can attack them most easily.

In recent years, researchers have shown that streamside vegetation is exhibiting secondary succession and that aspen and willow trees are starting to grow back. There have been numerous other changes as well. Fewer elk mean more food for smaller animals. The increase in small prey, in turn, has brought diverse predators into the community. Carcasses abandoned by the wolves provide food for scavengers. In short, organisms from every trophic level have been affected by the Yellowstone wolves.

1. **Predict** The Yellowstone wolf and elk are linked through a predator-prey relationship. If a disease were to strike the elk population, how would the wolves be affected?

2. **Form an Opinion** Yellowstone is owned by the federal government. The reintroduction of wolves there angered nearby farmers because they feared their animals would be hunted. What level of responsibility do you think national parks should have toward their neighbors?

3. **Connect to the Big Idea** Draw a food chain that connects Yellowstone’s wolves, aspen and willow trees, and elk. Then write a paragraph that explains why the Yellowstone wolves are a keystone species.

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**ASSESSMENT**

**CHAPTER MYSTERY ANSWERS**

1. If the disease reduced the number of elk, wolves would have less to eat and might decline in number.

2. Sample answer: I think national parks should be allowed to let ecosystems return to their natural state, even if it potentially creates problems for their neighbors, because it is important to preserve natural ecosystems for the sake of the environment and for the large numbers of people who visit the parks. However, the parks should also try to minimize or compensate for the risks. For example, they might plant thickets of brush to help keep wolves inside park boundaries, or they might reimburse neighbors if their domestic animals are killed by wolves.

3. Students’ food chains should show that aspen and willow tree seedlings and shoots are producers, which are consumed by elk, and that elk, in turn, are consumed by wolves. Wolves are a keystone species because reintroducing them had widespread effects on organisms at every trophic level and changed the structure of the Yellowstone community. In addition to reducing the number of elk, it led to regrowth of aspen and willow trees, more food for smaller animals, an increase in the number of predator species, and more food for scavengers.

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**Ecosystems and Communities 125**

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**Untamed Science: From Lava to Life.**

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After students have read through the Chapter Mystery, discuss why heavy grazing by elk along streams led to aquatic food webs breaking down. For example, explain that fewer plants would mean that other organisms that eat plants, such as insects, would also have less to eat. Organisms that prey upon these herbivores (like fish) would have less to eat, as well.

**Ask** Why would it be easier for wolves to attack elk in places such as stream banks and valleys? *(Sample answer: Wolves could hide in reeds and other dense vegetation and sneak up on elk.)*

**Ask** Why is secondary rather than primary succession occurring in these places? *(The grazing of elk prevented young trees from growing but did not remove the soil or all of the plants.)*

**Ask** Why would reintroducing wolves increase the number of decomposers? *(There would be more elk carcasses for decomposers to break down for food.)*

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**Students can learn more about succession by watching Untamed Science: From Lava to Life.**
Lesson 4.5

UNDERSTAND KEY CONCEPTS

27. b
28. Plankton is a combination of phytoplankton (photosynthetic algae) and zooplankton (tiny free-floating animals that eat phytoplankton).
29. rivers and streams, lakes and ponds, and freshwater wetlands
30. Both are estuaries formed where a river meets the sea. Salt marshes are temperate zone estuaries where salt-tolerant grasses and seagrasses grow. Mangrove swamps are tropical zone estuaries where salt-tolerant trees, called mangroves, grow.

THINK CRITICALLY

31. Sample answer: Some animals are able to produce light chemically in order to lure prey. Other animals have very sensitive feelers for detection in the dark. Still others have robust vascular systems that allow them to withstand great pressures and cold temperatures.
32. Sample answer: Filling in a salt marsh to create a coastal resort might bring money into the local economy. However, it would destroy the spawning and nursery grounds for fish and shellfish species, which could harm the local economy. Therefore, I would not support the proposal.

Connecting Concepts

USE SCIENCE GRAPHICS

33. A coral reef is most productive, probably because they are found in coastal ocean zones where the shallow water is brightly lit and often supplied with nutrients from freshwater runoff.
34. because it covers such a huge portion of Earth’s surface
35. Answers will vary. Check that students have correctly identified two abiotic factors that affect the productivity of each ecosystem.
36. Sample answer: I think its primary productivity is likely greater, because it gets abundant precipitation for three seasons of the year and is less susceptible to the frequent forest fires that decrease productivity in the savanna.

WRITE ABOUT SCIENCE

37. Answers will vary depending on which biomes students choose. They should identify the biome’s abiotic and biotic factors and explain how they are interrelated, using examples.
38. Abiotic factors determine the types of pioneer species that can live in an area and that are likely to be involved in primary succession following a volcanic eruption.

Use Science Graphics

The following table presents primary productivity (measured in grams of organic matter produced per year per square meter) for several ecosystems. Use the table below to answer questions 33 and 34.

<table>
<thead>
<tr>
<th>Ecosystem</th>
<th>Aquatic Ecosystems</th>
<th>Land Ecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coral reef</td>
<td>2500</td>
<td>1800</td>
</tr>
<tr>
<td>Estuary</td>
<td>1800</td>
<td>125</td>
</tr>
<tr>
<td>Open ocean</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>Tropical rain forest</td>
<td>2200</td>
<td>900</td>
</tr>
<tr>
<td>Tropical savanna</td>
<td>900</td>
<td>90</td>
</tr>
<tr>
<td>Tundra</td>
<td>90</td>
<td>90</td>
</tr>
</tbody>
</table>

The graph here summarizes the changes in the total volume of ice in all the world’s glaciers since 1960. Note that the volume changes on the y-axis are negative, meaning an overall loss of volume.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cumulative Volume of Ice (km³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>-5000</td>
</tr>
<tr>
<td>1970</td>
<td>-6000</td>
</tr>
<tr>
<td>1980</td>
<td>-7000</td>
</tr>
<tr>
<td>1990</td>
<td>-8000</td>
</tr>
<tr>
<td>2000</td>
<td>-9000</td>
</tr>
</tbody>
</table>

33. Interpret Tables According to the table, which ecosystem is most productive? Use what you know to explain that fact.
34. Infer The open ocean is among the least productive ecosystems, yet it contributes greatly to the overall productivity of the biosphere. How do you explain this paradox?
35. Apply Concepts For each set of ecosystems, aquatic and land, explain how abiotic factors may account for the differences in primary productivity seen. Give two examples.
36. Infer Review the description of the Northwest coniferous forest on page 114. Do you think its average primary productivity is greater or less than that of the tropical savanna? Explain your answer.

Write About Science

37. Explanation Choose one of the ten major biomes, and write an overview of its characteristics. Explain how abiotic factors and common plants and wildlife are interrelated. Support your explanation with specific examples.
38. Assess the Big Idea How do abiotic factors influence what kinds of organisms are involved in the primary succession in an area following a volcanic eruption?

39. Interpret Graphs The greatest volume of glacial ice was lost
b. between 1980 and 1990.
d. before 1960.

40. Relate Cause and Effect The most reasonable explanation for the loss of glacier mass since 1960 is
a. an increase in the total productivity of the world’s oceans.
b. a gradual rise in Earth’s average temperature.
c. an increase in the total amount of ice at Earth’s poles.
d. an increase in the sun’s output of radiant energy.

ANSWERS

39. c
40. b
**Multiple Choice**

1. The factor that generally has the greatest effect on determining a region’s climate is its
   A. longitude.
   B. abundant plant species.
   C. distance from the equator.
   D. closeness to a river.

2. All of the following are abiotic factors that affect global climate EXCEPT
   A. latitude.
   B. longitude.
   C. solar energy.
   D. ocean currents.

3. The way an organism makes its living, including its interactions with biotic and abiotic factors of its environment, is called the organism’s
   A. habitat.
   B. niche.
   C. lifestyle.
   D. mutualism.

4. If a newly introduced species fills a niche that is normally occupied by a native species, the two species compete. One of the species may die out as a result of
   A. competitive exclusion.
   B. predation.
   C. commensalism.
   D. mutualism.

5. Photosynthetic algae are MOST likely to be found in
   A. the open-ocean benthic zone.
   B. the aphotic zone.
   C. the photic zone.
   D. ocean trenches.

6. The water in an estuary is
   A. salt water only.
   B. poor in nutrients.
   C. fresh water only.
   D. a mixture of fresh water and salt water.

7. In which biome do organisms have the greatest tolerance to dry conditions?
   A. tundra
   B. desert
   C. tropical savanna
   D. boreal forest

8. Which type of graph would be BEST suited to showing the precipitation data from the table?
   A. bar graph
   B. pictograph
   C. pie chart
   D. scatter plot

9. For a given set of data, the range is the difference between highest and lowest points. The average annual temperature range, in °C, for Lillehammer is approximately
   A. −8.
   B. 8.5.
   C. 16.5.
   D. 24.5.

**Open-Ended Response**

10. Why are lichens especially well adapted to play the role of pioneer organisms in an ecological succession?

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**Answers**

1. C
2. B
3. B
4. A
5. C
6. D
7. B
8. A
9. D
10. Lichens are especially well adapted to play the role of pioneer organisms because they can grow on bare rock, fix atmospheric nitrogen into useful forms for other organisms, break down rock, and add organic material to form soil.