

4 Ecosystems and Communities

**Big
idea**

Interdependence in Nature

Q: How do abiotic and biotic factors shape ecosystems?

Cheetah looking out across the savanna at the Masai Mara National Reserve in Kenya

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Chapter 4

GO

• Flash Cards

INSIDE:

- 4.1 Climate
- 4.2 Niches and Community Interactions
- 4.3 Succession
- 4.4 Biomes
- 4.5 Aquatic Ecosystems



CHAPTER MYSTERY

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.



4.1

Climate

Key Questions

 **What is climate?**

 **What factors determine global climate?**

Vocabulary

weather
climate
microclimate
greenhouse effect

Taking Notes

Preview Visuals Before you read, look at **Figure 4–2**. What questions do you have about this diagram? Write a prediction that relates this figure to climate.

BUILD Vocabulary

PREFIXES The prefix *hemi-* in *hemisphere* means “half.” The Northern Hemisphere encompasses the northern half of Earth.

THINK ABOUT IT When you think about climate, you might think of dramatic headlines: “Hurricane Katrina floods New Orleans!” or “Drought parches the Southeast!” But big storms and seasonal droughts are better described as *weather* rather than *climate*. So, what *is* climate, and how does it differ from weather? How do climate and weather affect organisms and ecosystems?



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?

Solar Energy and the Greenhouse Effect

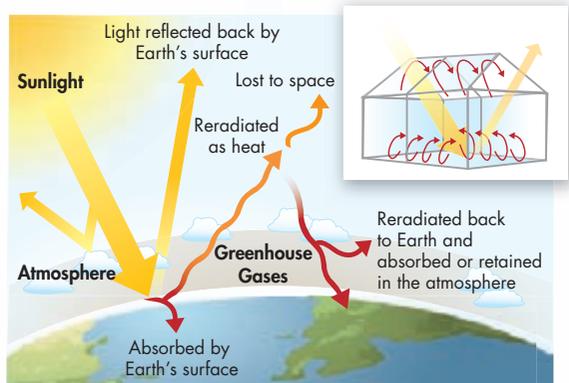
Effect The main force that shapes our climate is solar energy that arrives as sunlight and strikes Earth's surface. Some of that energy is reflected back into space, and some is absorbed and converted into heat. Some of that heat, in turn, radiates back into space, and some is trapped in the biosphere. 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 fall, 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.

VISUAL ANALOGY



THE GREENHOUSE EFFECT

FIGURE 4–1 Greenhouse gases in the atmosphere allow solar radiation to enter the biosphere but slow down the loss of reradiated heat to space. **Use Analogies** *What part of a greenhouse is analogous to the greenhouse gases in Earth's atmosphere?*

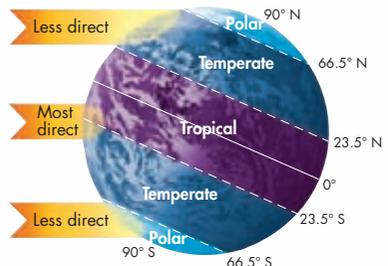


FIGURE 4–2 Climate Zones Earth's climate zones are produced by unequal distribution of the sun's heat on Earth's surface. Polar regions receive less solar energy per unit area, and so less heat, than tropical regions do. The tilt of Earth's axis causes the distribution of sunlight to change over the course of the year.

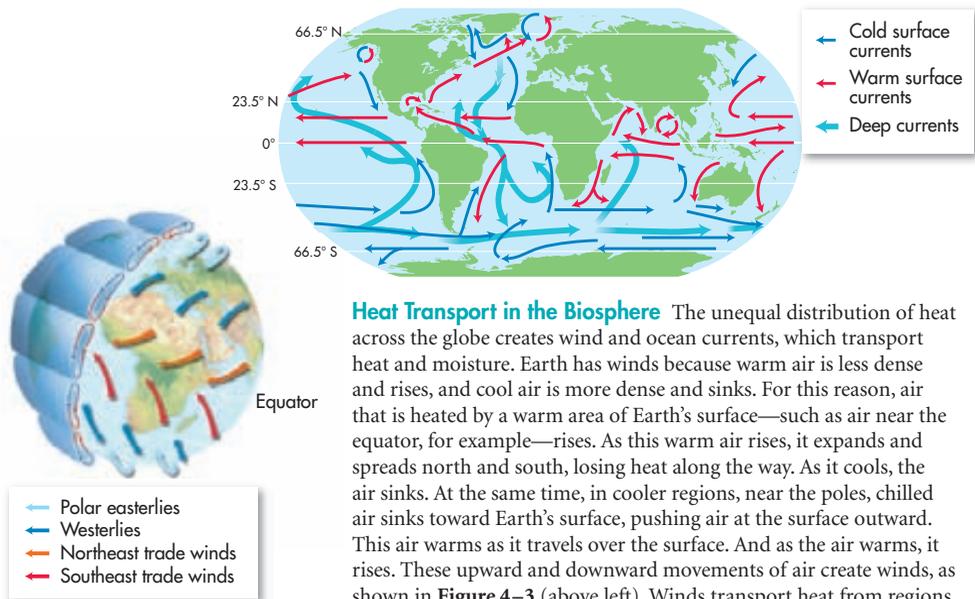


FIGURE 4-3 Winds and Currents

Earth's winds (above left) and ocean currents (above right) interact to help produce climate patterns. The paths of winds and currents are the result of heating and cooling, Earth's rotation, and geographic features.

Interpret Visuals In what direction do cold currents in the Northern Hemisphere generally move?

Heat Transport in the Biosphere The unequal distribution of heat across the globe creates wind and ocean currents, which transport heat and moisture. Earth has winds because warm air is less dense and rises, and cool air is more dense and sinks. For this reason, air that is heated by a warm area of Earth's surface—such as air near the equator, for example—rises. As this warm air rises, it expands and spreads north and south, losing heat along the way. As it cools, the air sinks. At the same time, in cooler regions, near the poles, chilled air sinks toward Earth's surface, pushing air at the surface outward. This air warms as it travels over the surface. And as the air warms, it rises. These upward and downward movements of air create winds, as shown in **Figure 4-3** (above left). Winds transport heat from regions of rising warmer air to regions of sinking cooler air. Earth's rotation causes winds to blow generally from west to east over the temperate zones and from east to west over the tropics and the poles.

Similar patterns of heating and cooling occur in the oceans. Surface water is pushed by winds. These ocean currents transport enormous amounts of heat. Warm surface currents add moisture and heat to air that passes over them. Cool surface currents cool air that passes over them. In this way, surface currents affect the weather and climate of nearby landmasses. Deep ocean currents are caused by cold water near the poles sinking and flowing along the ocean floor. This water rises in warmer regions through a process called upwelling.

4.1 Assessment

Review Key Concepts

- a. Review** What is climate?

b. Compare and Contrast How are climate and weather different?

c. Infer Based on **Figure 4-3**, which do you think has a cooler climate: the east or west coast of southern Africa? Why?
- a. Review** What are the main factors that determine climate?

b. Relate Cause and Effect Explain what would likely happen to global climate if there was a dramatic decrease in greenhouse gases trapped in the atmosphere.

ANALYZING DATA

- Research average monthly precipitation (in mm) and temperature (in °C) for Quito, Ecuador, a city on the equator. Create a bar graph for the precipitation data. Plot the temperature data in a line graph.

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

Key Question 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.

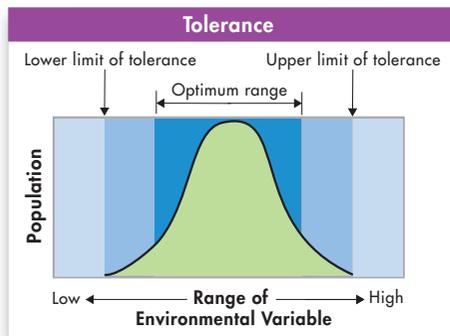


FIGURE 4–4 Tolerance

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

Key Question 1 What is a niche?

Key Question 2 How does competition shape communities?

Key Question 3 How do predation and herbivory shape communities?

Key Question 4 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.

Defining the Niche Describing a species' "address" tells only part of its story. Ecologists also study a species' ecological "occupation"—where and how it "makes a living." This idea of occupation is encompassed in the idea of an organism's niche (nich). A **niche** describes not only what an organism does, but also how it interacts with biotic and abiotic factors in the environment.  **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.** Understanding niches is important to understanding how organisms interact to form a community.

▶ **Resources and the Niche** The term **resource** can refer to any necessity of life, such as water, nutrients, light, food, or space. For plants, resources can include sunlight, water, and soil nutrients—all of which are essential to survival. For animals, resources can include nesting space, shelter, types of food, and places to feed.

▶ **Physical Aspects of the Niche** Part of an organism's niche involves the abiotic factors it requires for survival. Most amphibians, for example, lose and absorb water through their skin, so they must live in moist places. If an area is too hot and dry, or too cold for too long, most amphibians cannot survive.

▶ **Biological Aspects of the Niche** Biological aspects of an organism's niche involve the biotic factors it requires for survival. When and how it reproduces, the food it eats, and the way in which it obtains that food are all examples of biological aspects of an organism's niche. Birds on Christmas Island, a small island in the Indian Ocean, for example, all live in the same habitat but they prey on fish of different sizes and feed in different places. Thus, each species occupies a distinct niche.

BUILD Vocabulary

ACADEMIC WORDS The noun **aspect** means "part." There are two aspects—or parts—of an organism's niche: physical aspects and biological aspects.

FIGURE 4-5 Competition Animals such as these two male stag beetles compete for limited resources.

Infer What resource do you think these two males are fighting over?



Competition

 **How does competition shape communities?**

If you look at any community, you will probably find more than one kind of organism attempting to use various essential resources. When organisms attempt to use the same limited ecological resource in the same place at the same time, competition occurs. In a forest, for example, plant roots compete for water and nutrients in the soil. Animals, such as the beetles in **Figure 4-5**, compete for resources such as food, mates, and places to live and raise their young. Competition can occur both among members of the same species (known as intraspecific competition) and between members of different species (known as interspecific competition).

 **In Your Notebook** Look at the beetles in **Figure 4-5**. Is this an example of intraspecific or interspecific competition? How do you know?

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.

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?

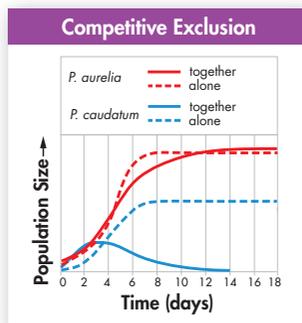
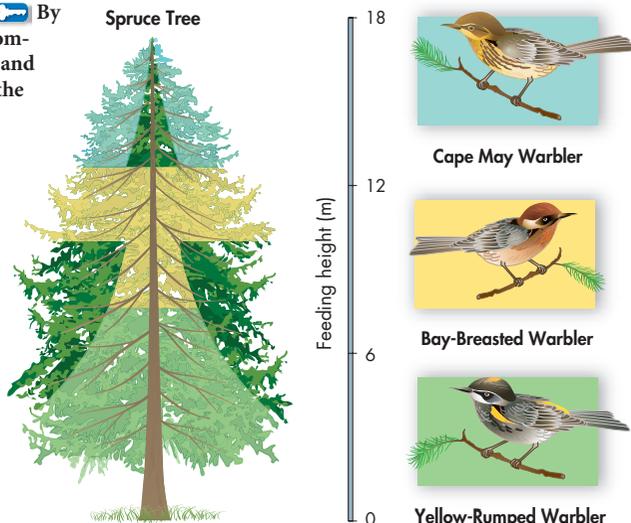


FIGURE 4–6 Competitive Exclusion The two species of paramecia *P. aurelia* and *P. caudatum* have similar requirements. When grown in cultures separately (dashed lines), both populations grow quickly and then level off. When grown together under certain conditions (solid lines), however, *P. aurelia*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

Predation, Herbivory, and Keystone Species

FIGURE 4–8 Herbivory The ring-tailed lemur is an herbivore—meaning that it obtains its energy and nutrients from plants like the cactus it’s eating here.



How do predation and herbivory shape communities?

Virtually all animals, because they are not primary producers, must eat other organisms to obtain energy and nutrients. Yet if a group of animals devours all available food in the area, they will no longer have anything to eat! That’s why predator-prey and herbivore-plant interactions are very important in shaping communities.

Predator-Prey Relationships An interaction in which one animal (the predator) captures and feeds on another animal (the prey) is called **predation** (pree DAY shun). **Predators can affect the size of prey populations in a community and determine the places prey can live and feed.** Birds of prey, for example, can play an important role in regulating the population sizes of mice, voles, and other small mammals.

Herbivore-Plant Relationships Interactions between herbivores and plants, like the one shown in **Figure 4–8**, are as important as interactions between predators and prey. An interaction in which one animal (the herbivore) feeds on producers (such as plants) is called **herbivory**. **Herbivores can affect both the size and distribution of plant populations in a community and determine the places that certain plants can survive and grow.** Herbivores ranging from caterpillars to elk can have major effects on plant survival. For example, very dense populations of white-tailed deer are eliminating their favorite food plants from many places across the United States.

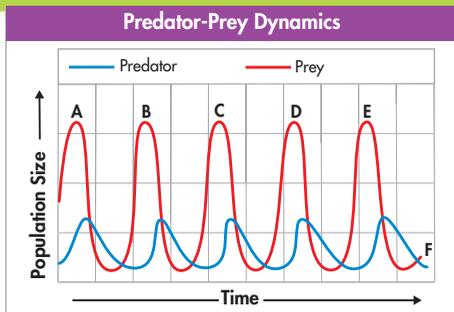
Analyzing Data

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 growth curves at point C? At point D?

2. Predict Suppose a sudden extended cold spell destroys almost the entire predator population at point F 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 growth curves 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?

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. Armies 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.*

MYSTERY CLUE

One of the favorite prey species of the wolves in Yellowstone is elk. How do you think this relationship could affect the ability of certain plants to grow in Yellowstone?



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 by ON 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?*

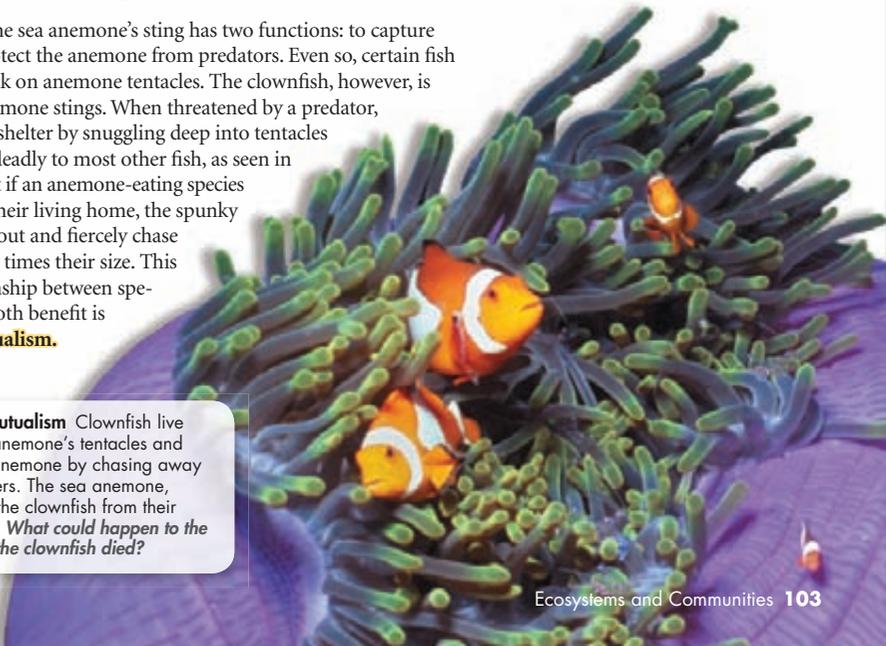




FIGURE 4-10 Parasitism
This brown leech is feeding on the blood of its host, a human. In a parasitic relationship, the parasite benefits while the host is harmed.

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** (PAR uh siz i 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.



FIGURE 4-11 Commensalism
The barnacles attached to the skin of this grey whale are feeding on food in the water that passes over them as the whale swims. Although the barnacles clearly benefit from their relationship with the whale, they do not appear to affect the whale positively or negatively.

4.2 Assessment

Review Key Concepts

- a. Review** What is the difference between a habitat and a niche?
b. Use Analogies How is a niche like a profession? In ecological terms, describe your niche.
- a. Review** What is competition? Why can't two organisms compete if they live in different habitats?
b. Interpret Visuals Look at **Figure 4-7** and describe how the three species of warblers have divided their resources. Does each warbler have its own niche?
- a. Review** What is a keystone species?
b. Infer How might a dramatic decrease in vegetation lead to a decrease in a prey species? (*Hint:* Think of how the vegetation, prey, and predator could be connected in a food chain.)

- a. Review** What is symbiosis? What are the three major types of symbiosis?
b. Explain Bacteria living in a cow's stomach help the cow break down the cellulose in grass, gaining nutrients in the process. Is this an example of commensalism or mutualism? Explain your answer.
c. Apply Concepts What is the difference between a predator and a parasite? Explain your answer.

BUILD VOCABULARY

- The suffix *-ism* means "the act, practice, or result of." Look up the meaning of *mutual*, and write a definition for *mutualism*.

Careers & BIOLOGY

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

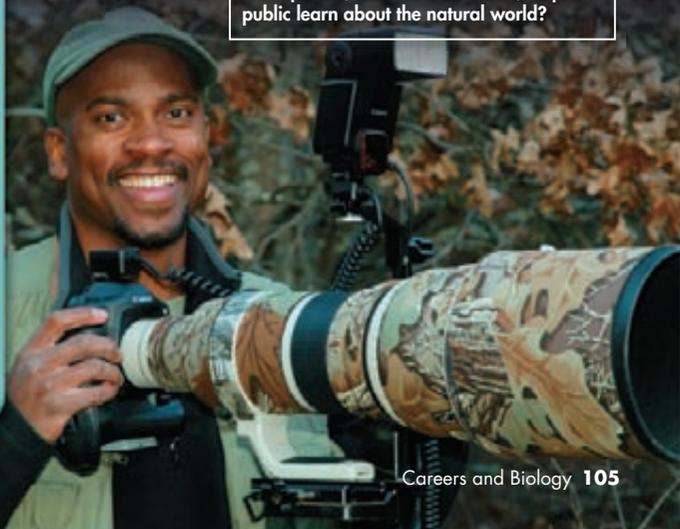
Dudley Edmondson, Wildlife Photographer

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.”

WRITING

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?



4.3

Succession

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.

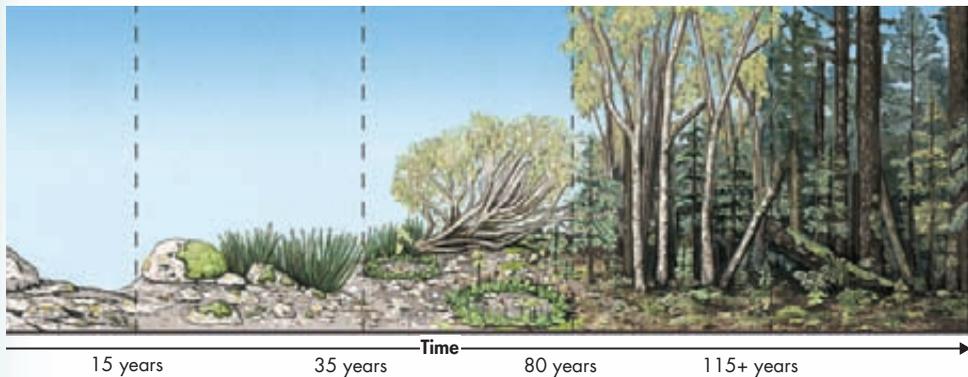
THINK ABOUT IT In 1883, the volcanic island of Krakatau in the Indian Ocean was blown to pieces by an eruption. The tiny island that remained was completely barren. Within two years, grasses were growing. Fourteen years later, there were 49 plant species, along with lizards, birds, bats, and insects. 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**.



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**.

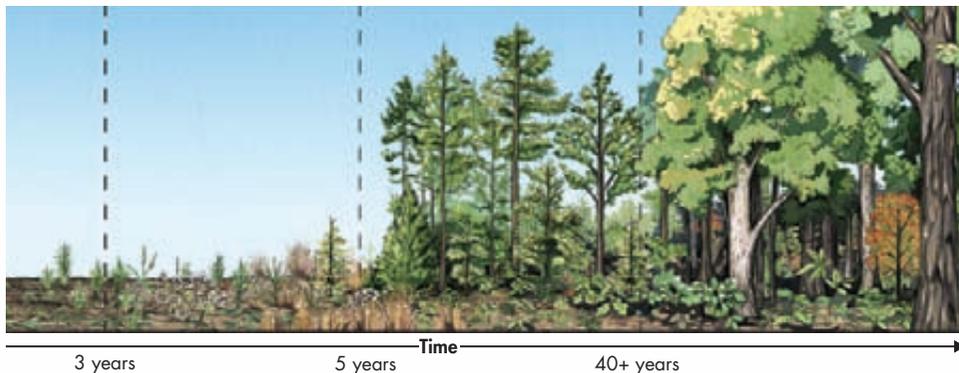
Why Succession Occurs Every organism changes the environment it lives in. One model of succession suggests that as one species alters its environment, other species find it easier to compete for resources and survive. As lichens add organic matter and form soil, for example, mosses and other plants can 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.

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

BUILD Vocabulary

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

FIGURE 4–13 Secondary Succession Secondary succession occurs in disturbed areas where remnants of previous ecosystems—soil and even plants—remain. This series shows changes taking place in abandoned fields of the Carolinas’ Piedmont. Over the last century, these fields have passed through several stages and matured into oak forests. Changes will continue for years to come.



Successful Succession?



- 1 Place a handful of dried plant material into a clean jar.
- 2 Fill the jar with boiled pond water or sterile spring water. Determine the initial pH of the water with pH paper.
- 3 Cover the jar and place it in an area that receives indirect light.
- 4 Examine the jar every day for the next few days.
- 5 When the water in the jar appears cloudy, prepare microscope slides of water from various levels of the jar. Use a pipette to collect the samples.

- 6 Look at the slides under the low-power objective lens of a microscope and record your observations.

Analyze and Conclude

1. **Infer** Why did you use boiled or sterile water?
2. **Infer** Where did the organisms you saw come from?
3. **Draw Conclusions** Was ecological succession occurring? Give evidence to support your answer.
4. **Evaluate and Revise** Check your results against those of your classmates. Do they agree? How do you explain any differences?

FIGURE 4–14 Recovery From a Natural Disaster These photos show El Yunque Rain Forest in Puerto Rico, immediately following Tropical Storm Jeanne in September 2004, and then again in May, 2007.

Apply Concepts *What kind of succession occurred in this rain forest? How do you know?*



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.  **Ecosystems 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 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

- 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.
- 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

- 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?





4.4

Biomes

Key Questions

🔑 What abiotic and biotic factors characterize biomes?

🔑 What areas are not easily classified into a major biome?

Vocabulary

canopy • understory • deciduous • coniferous • humus • taiga • permafrost

Taking Notes

Preview Visuals Before you read, preview **Figure 4–18**. Write down the names of the different biomes. As you read, examine the photographs and list the main characteristics of each biome.

FIGURE 4–16 The Effect of Coastal Mountains As moist ocean air rises over the upwind side of coastal mountains, it condenses, cools, and drops precipitation. As the air sinks on the downwind side of the mountain, it expands, warms, and absorbs moisture.

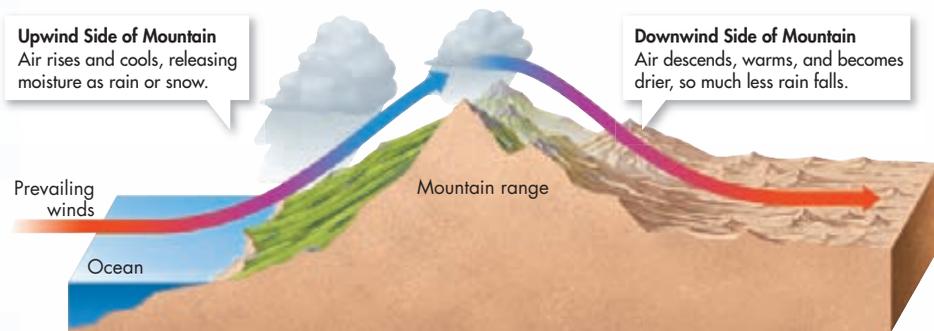
THINK ABOUT IT Why does the character of biological communities vary from one place to another? Why, for example, do temperate rain forests grow in the Pacific Northwest while areas to the east of the Rocky Mountains are much drier? How do similar conditions shape ecosystems elsewhere?

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—the side that faces the winds, 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.



Defining Biomes Ecologists classify Earth's terrestrial ecosystems into at least ten different groups of regional climate communities called biomes.  **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?

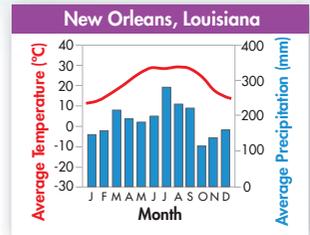
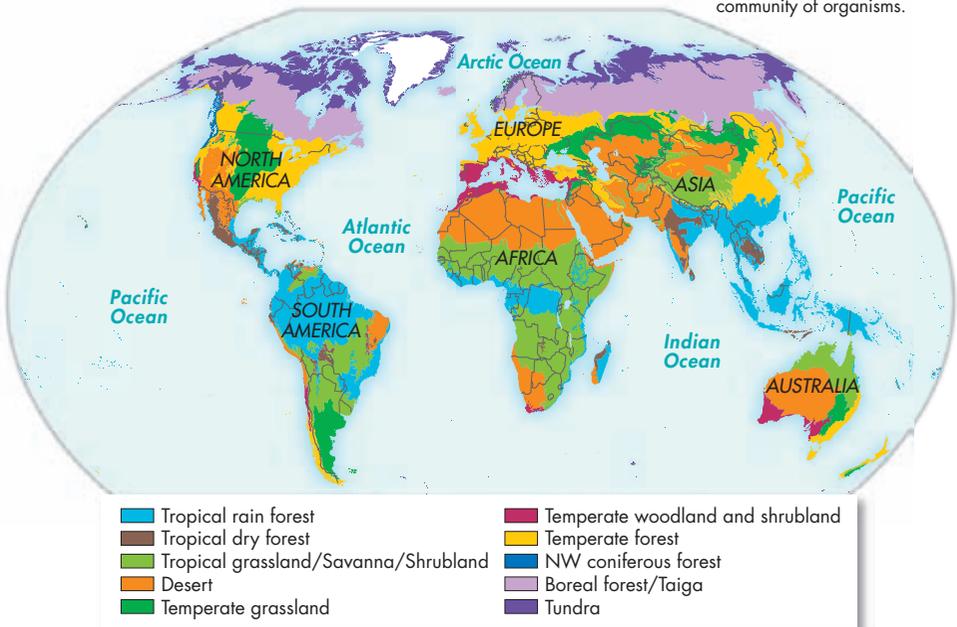


FIGURE 4–17 Climate Diagram A climate diagram shows the average temperature and precipitation at a given location during each month of the year. In this graph, and those to follow, temperature is plotted as a red line, and precipitation is shown as vertical blue bars.

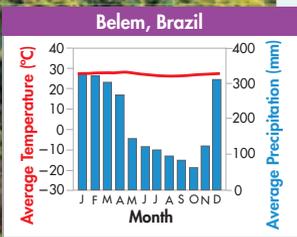
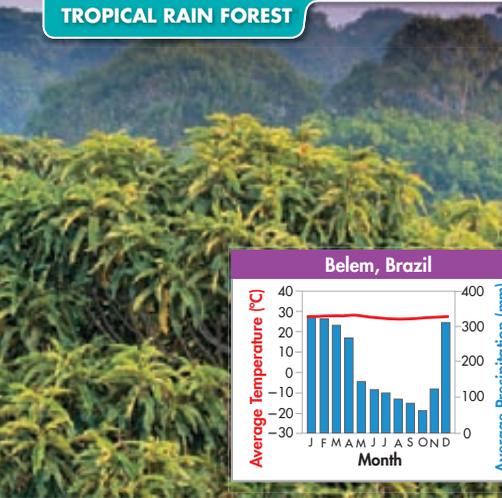
VISUAL SUMMARY

BIOMES

FIGURE 4–18 This map shows the locations of the world's major biomes. Each biome has a characteristic climate and community of organisms.



TROPICAL RAIN FOREST



Tropical rain forests are home to more species than all other biomes combined. As the name suggests, rain forests get a lot of rain—at least 2 meters of it a year! Tall trees form a dense, leafy covering called a **canopy** from 50 to 80 meters above the forest floor. In the shade below the canopy, shorter trees and vines form a layer called the **understory**. Organic matter on the forest floor is recycled and reused so quickly that the soil in most tropical rain forests is not very rich in nutrients.

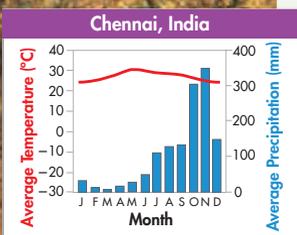
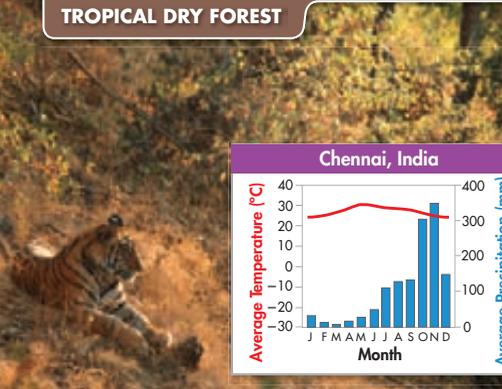
- **Abiotic factors** hot and wet year-round; thin, nutrient-poor soils subject to erosion

- **Biotic factors**

- **Plant life:** Understory plants compete for sunlight, so most have large leaves that maximize capture of limited light. Tall trees growing in poor shallow soil often have buttress roots for support. Epiphytic plants grow on the branches of tall plants as opposed to soil. This allows epiphytes to take advantage of available sunlight while obtaining nutrients through their host.

- **Animal life:** Animals are active all year. Many animals use camouflage to hide from predators; some can change color to match their surroundings. Animals that live in the canopy have adaptations for climbing, jumping, and/or flight.

TROPICAL DRY FOREST



Tropical dry forests grow in areas where rainy seasons alternate with dry seasons. In most places, a period of rain is followed by a prolonged period of drought.

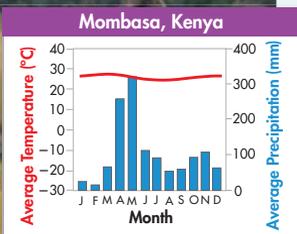
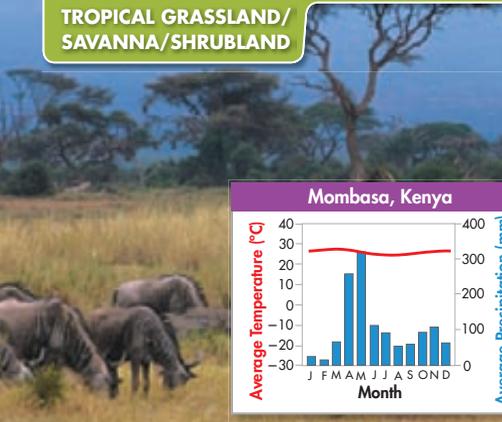
- **Abiotic factors** warm year-round; alternating wet and dry seasons; rich soils subject to erosion

- **Biotic factors**

- **Plant life:** Adaptations to survive the dry season include seasonal loss of leaves. A plant that sheds its leaves during a particular season is called **deciduous**. Some plants also have an extra thick waxy layer on their leaves to reduce water loss, or store water in their tissues.

- **Animal life:** Many animals reduce their need for water by entering long periods of inactivity called *estivation*. Estivation is similar to hibernation, but typically takes place during a dry season. Other animals, including many birds and primates, move to areas where water is available during the dry season.

TROPICAL GRASSLAND/ SAVANNA/SHRUBLAND



This biome receives more seasonal rainfall than deserts but less than tropical dry forests. Grassy areas are spotted with isolated trees and small groves of trees and shrubs. Compacted soils, fairly frequent fires, and the action of large animals—for example, rhinoceroses and elephants—prevent some areas from turning into dry forest.

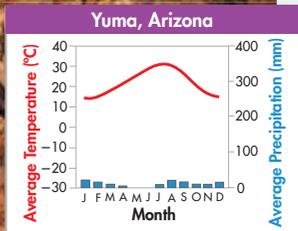
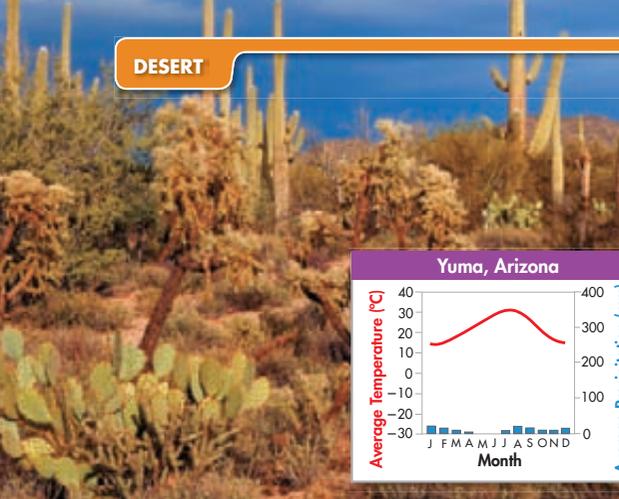
- **Abiotic factors** warm; seasonal rainfall; compact soils; frequent fires set by lightning

- **Biotic factors**

- **Plant life:** Plant adaptations are similar to those in the tropical dry forest, including waxy leaf coverings and seasonal leaf loss. Some grasses have a high silica content that makes them less appetizing to grazing herbivores. Also, unlike most plants, grasses grow from their bases, not their tips, so they can continue to grow after being grazed.

- **Animal life:** Many animals migrate during the dry season in search of water. Some smaller animals burrow and remain dormant during the dry season.

DESERT



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.

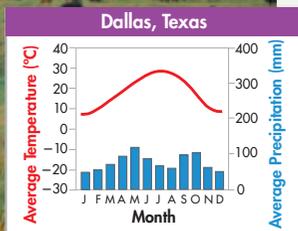
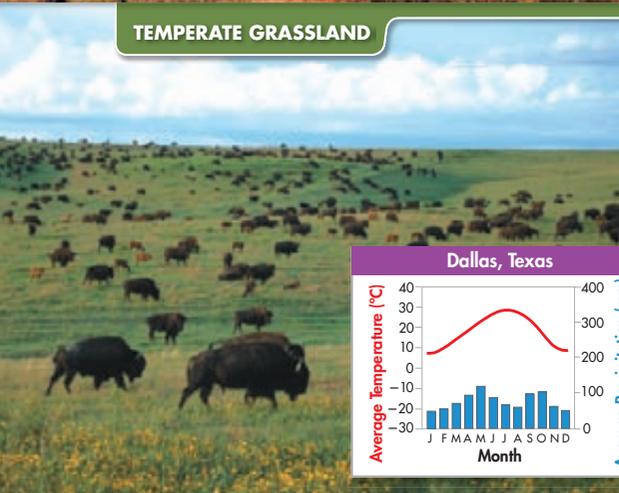
- **Abiotic factors** low precipitation; variable temperatures; soils rich in minerals but poor in organic material

- **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.

TEMPERATE GRASSLAND



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.

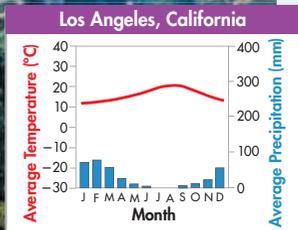
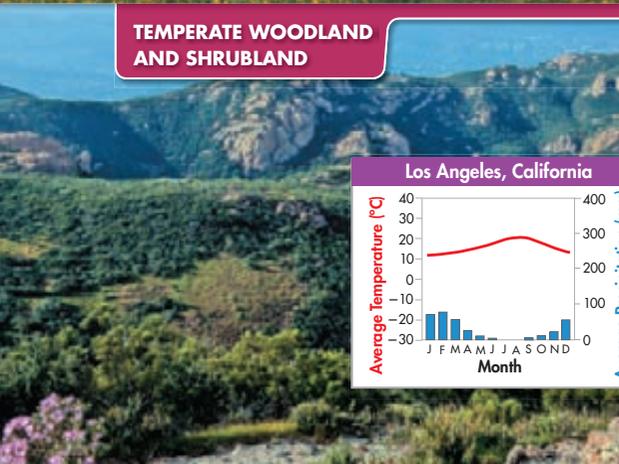
- **Abiotic factors** warm to hot summers; cold winters; moderate seasonal precipitation; fertile soils; occasional fires

- **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 helps establish and retain deep, rich, fertile topsoil.

Animal life: Because temperate grasslands are such 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.

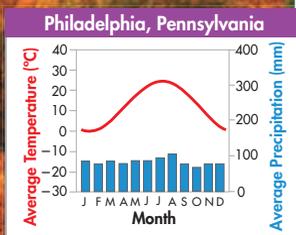
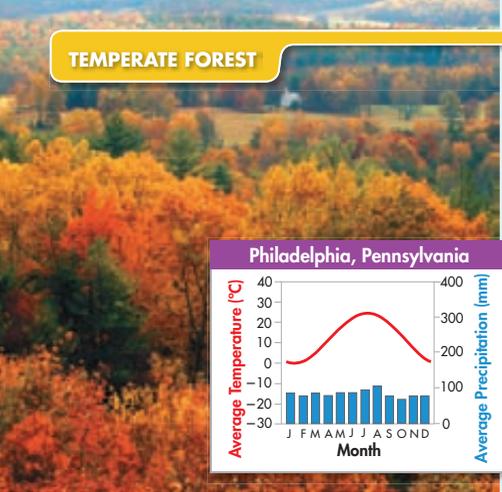
- **Abiotic factors** hot dry summers; cool moist winters; thin, nutrient-poor soils; periodic fires

- **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.

TEMPERATE FOREST



Temperate forests are mostly made up of deciduous and evergreen coniferous (koh NIF ur us) trees. **Coniferous** trees, or conifers, produce seed-bearing cones, and most have leaves shaped like needles, which are coated in a waxy substance that helps reduce water loss. These forests have cold winters. In autumn, deciduous trees shed their leaves. In the spring, small plants burst from the ground and flower. Fertile soils are often rich in **humus**, a material formed from decaying leaves and other organic matter.

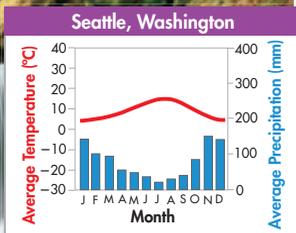
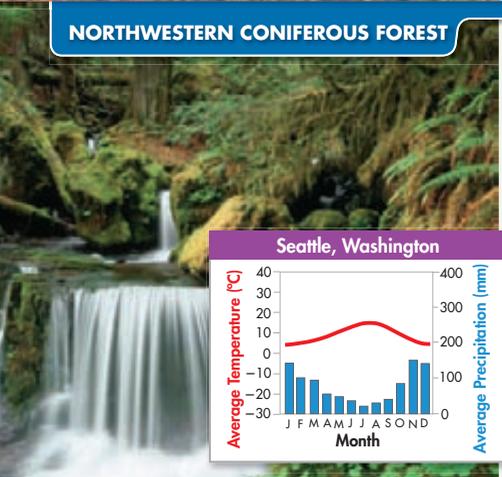
- **Abiotic factors** cold to moderate winters; warm summers; year-round precipitation; fertile soils

- **Biotic factors**

Plant life: Deciduous trees drop their leaves and go into a state of dormancy in winter. Conifers have needlelike leaves that minimize water loss in dry winter air.

Animal life: Animals must cope with changing weather. Some hibernate; others migrate to warmer climates. Animals that do not hibernate or migrate may be camouflaged to escape predation in the winter when bare trees leave them more exposed.

NORTHWESTERN CONIFEROUS FOREST



Mild moist air from the Pacific Ocean influenced by the Rocky Mountains provides abundant rainfall to this biome. The forest includes a variety of conifers, from giant redwoods to spruce, fir, and hemlock, along with flowering trees and shrubs such as dogwood and rhododendron. Moss often covers tree trunks and the forest floor. Because of its lush vegetation, the northwestern coniferous forest is sometimes called a “temperate rain forest.”

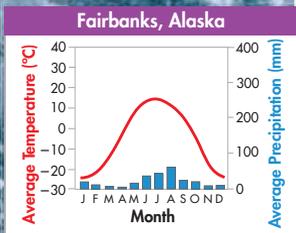
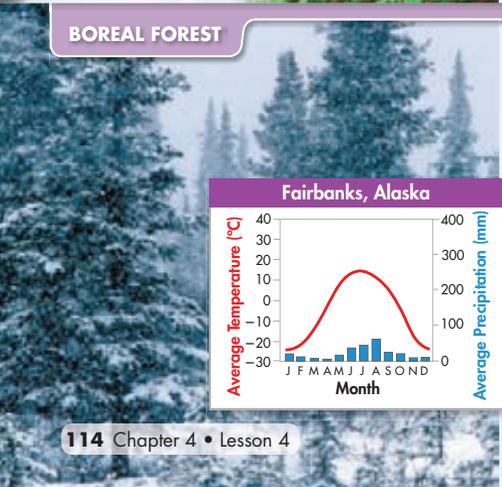
- **Abiotic factors** mild temperatures; abundant precipitation in fall, winter, and spring; cool dry summers; rocky acidic soils

- **Biotic factors**

Plant life: Because of seasonal temperature variation, there is less diversity in this biome than in tropical rain forests. However, ample water and nutrients support lush, dense plant growth. Adaptations that enable plants to obtain sunlight are common. Trees here are among the world’s tallest.

Animal life: Camouflage helps insects and ground-dwelling mammals avoid predation. Many animals are browsers—they eat a varied diet—an advantage in an environment where vegetation changes seasonally.

BOREAL FOREST



Dense forests of coniferous evergreens along the northern edge of the temperate zone are called boreal forests, or **taiga** (ty guh). Winters are bitterly cold, but summers are mild and long enough to allow the ground to thaw. The word *boreal* comes from the Greek word for “north,” reflecting the fact that boreal forests occur mostly in the northern part of the Northern Hemisphere.

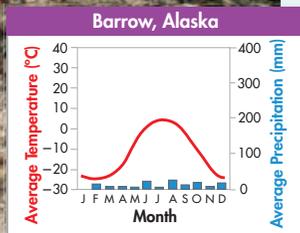
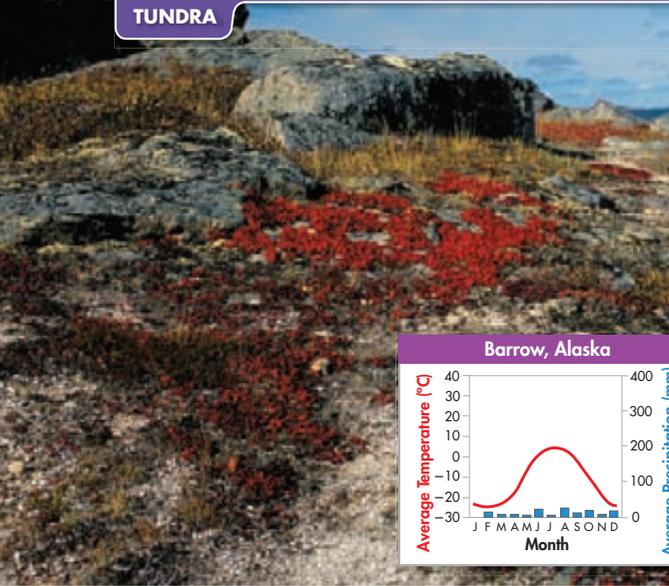
- **Abiotic factors** long cold winters; short mild summers; moderate precipitation; high humidity; acidic, nutrient-poor soils

- **Biotic factors**

Plant life: Conifers are well suited to the boreal-forest environment. Their conical shape sheds snow, and their wax-covered needlelike leaves prevent excess water loss. In addition, the dark green color of most conifers absorbs heat energy.

Animal life: Staying warm is the major challenge for animals. Most have small extremities and extra insulation in the form of fat or downy feathers. Some migrate to warmer areas in winter.

TUNDRA



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.

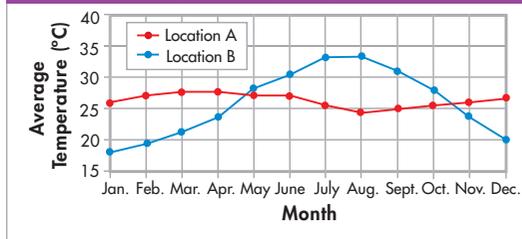
Analyzing Data

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?

Average Monthly Temperatures



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?

MYSTERY CLUE

Yellowstone has high mountain slopes and valleys with streams. Can you think of any reason why moose and elk might prefer to graze in one of those places rather than the other? How do you think their preference might affect Yellowstone's plant communities?



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.

FIGURE 4–19 Polar Ice Caps

The polar ice caps do not fit neatly into a biome classification. At the poles, it is cold year-round, and land is usually covered with thick ice sheets.



4.4 Assessment

Review Key Concepts

- 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.
- 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

- 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.

4.5

Aquatic Ecosystems

THINK ABOUT IT We call our planet “Earth,” yet nearly three-fourths of Earth’s surface is covered with water. Despite the vital roles aquatic ecosystems play in the biosphere, many of these ecosystems are only partly understood. What’s life like underwater?

Conditions Underwater

Key Question *What factors affect life in aquatic ecosystems?*

Like organisms living on land, underwater organisms are affected by a variety of environmental factors. **Key Concept** *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

Key Question *What factors affect life in aquatic ecosystems?*

Key Question *What are the major categories of freshwater ecosystems?*

Key Question *Why are estuaries so important?*

Key Question *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?*



Temperature and Currents Aquatic habitats, like terrestrial habitats, are warmer near the equator and colder near the poles. Temperature in aquatic habitats also often varies with depth. The deepest parts of lakes and oceans are often colder than surface waters. Currents in lakes and oceans can dramatically affect water temperature because they can carry water that is significantly warmer or cooler than would be typical for any given latitude, depth, or distance from shore.

Nutrient Availability As you learned in Chapter 3, organisms need certain substances to live. These include oxygen, nitrogen, potassium, and phosphorus. The type and availability of these dissolved substances vary within and between bodies of water, greatly affecting the types of organisms that can survive there.

Freshwater Ecosystems

 **What are the major categories of freshwater ecosystems?**

Only 3 percent of Earth's surface water is fresh water, but that small percentage provides terrestrial organisms with drinking water, food, and transportation. Often, a chain of streams, lakes, and rivers begins in the interior of a continent and flows through several biomes to the sea.  **Freshwater ecosystems can be divided into three main categories: rivers and streams, lakes and ponds, and freshwater wetlands.** Examples of these ecosystems are shown in **Figure 4–21**.

Rivers and Streams Rivers, streams, creeks, and brooks often originate from underground water sources in mountains or hills. Near a source, water has plenty of dissolved oxygen but little plant life. Downstream, sediments build up and plants establish themselves. Still farther downstream, water may meander slowly through flat areas. Animals in many rivers and streams depend on terrestrial plants and animals that live along their banks for food.

 **In Your Notebook** *What kinds of adaptations would you expect in organisms living in a fast-flowing river or stream?*

MYSTERY CLUE

What is one way in which life in Yellowstone's streams might be affected by the presence or absence of plants along stream banks?



FIGURE 4–21 Freshwater Ecosystems and Estuaries Freshwater ecosystems include streams, lakes, and freshwater wetlands (bogs, swamps, and marshes). Salt marshes and mangrove swamps are estuaries—areas where fresh water from rivers meets salt water.

Interpret Visuals *Based on these photos, what are two differences between streams and bogs?*



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.

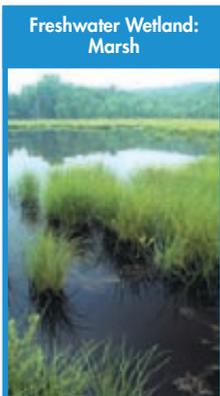
Freshwater Wetlands A **wetland** is an ecosystem in which water either covers the soil or is present at or near the surface for at least part of the year. Water may flow through freshwater wetlands or stay in place. Wetlands are often nutrient-rich and highly productive, and they serve as breeding grounds 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).



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 ocean, and the open ocean, as shown in **Figure 4–22**. Within these zones live a number of different communities.

BUILD Vocabulary

MULTIPLE MEANINGS The noun *subject* has many meanings, including “the main theme of a piece of work such as a novel” or “a course of study.” The verb *subject*, however, means “to expose” or “to tend toward.” Organisms are subjected, or exposed, to extreme conditions in the rocky intertidal zone.



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.

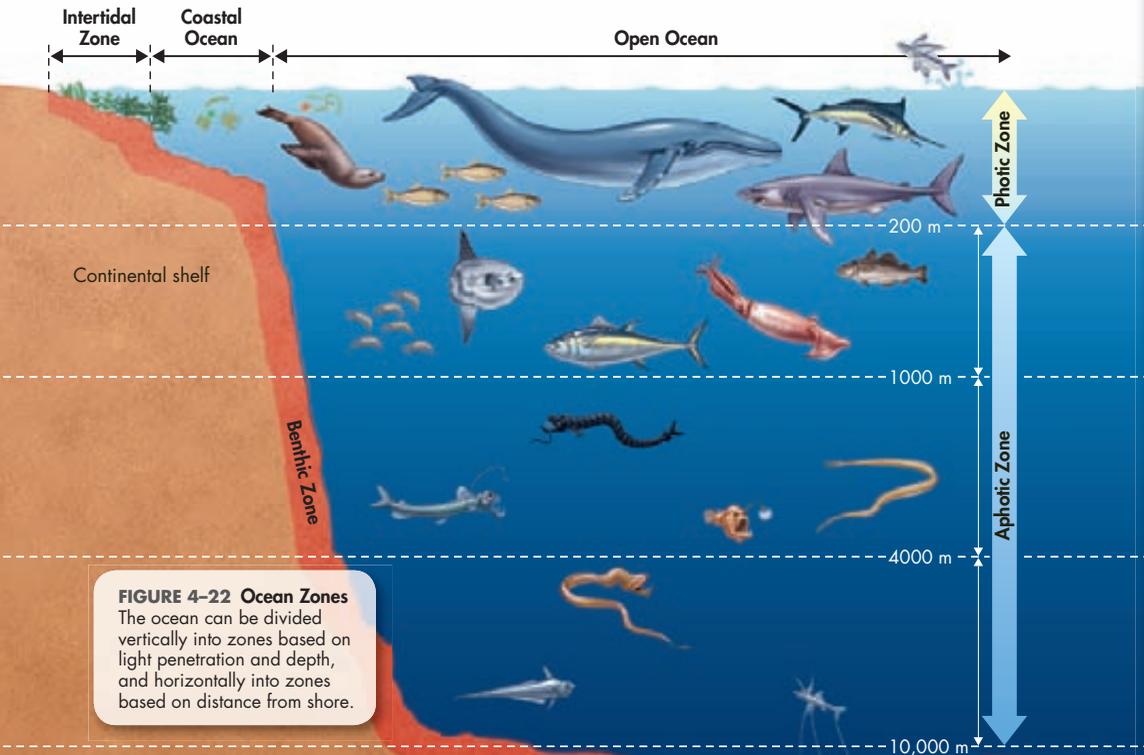


FIGURE 4–22 Ocean Zones
The ocean can be divided vertically into zones based on light penetration and depth, and horizontally into zones based on distance from shore.

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.



FIGURE 4–23 Creature From the Deep This slender hatchetfish lives in the aphotic zone of the Pacific Ocean off the coast of California. **Apply Concepts** What kinds of adaptations do you think this fish has that enable it to live in the harsh deep-ocean environment?

4.5 Assessment

Review Key Concepts

- a. Review** What are the primary abiotic factors that affect life underwater?
b. Compare and Contrast What are some ways in which life in an aphotic zone might differ from life in a photic zone?
- a. Review** What are the major categories of freshwater ecosystems?
b. Apply Concepts What is a wetland? Why are wetlands important?
- a. Review** Where are estuaries found? Why is it important to protect estuaries?
b. Predict How might a dam upriver affect an estuary at the river's mouth?

- a. Review** List the three major marine ecological zones. Give two abiotic factors for each zone.
b. Apply Concepts Using **Figure 4–22** as a guide, draw a cross section of the ocean starting with a beach and ending with an ocean trench. Label the intertidal zone, coastal ocean, and open ocean. Subdivide the open ocean into photic and aphotic zones.

WRITE ABOUT SCIENCE

Explanation

- Choose three different aquatic ecosystems. For each of these ecosystems, select a plant and an animal, and explain how the organisms have adapted to their environment.

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



Lab Manual Chapter 4 Lab

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

- Review** What is an abiotic factor? List three examples other than temperature.
- Review** What kinds of resources do plants need?
- 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.

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

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



Visit Chapter 4 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Join the Untamed Science crew as they explore succession after a volcanic eruption on Hawaii.

Visual Analogy Compare Earth's atmosphere to a greenhouse.

Data Analysis Look at data on tolerance of intertidal zone species and use your analysis to explain the zonation patterns of intertidal species.

Art in Motion View a short animation that brings succession to life.

Art Review Review your understanding of ocean zones with this drag-and-drop activity.

4 Study Guide

Big idea Interdependence in Nature

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.

weather (96)
climate (96)

microclimate (96)
greenhouse effect (97)

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.

tolerance (99)
habitat (99)
niche (100)
resource (100)
competitive exclusion principle (101)
predation (102)

herbivory (102)
keystone species (103)
symbiosis (103)
mutualism (103)
parasitism (104)
commensalism (104)

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.

ecological succession (106) pioneer species (107)
primary succession (106) secondary succession (107)

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.

canopy (112) coniferous (114) permafrost (115)
understory (112) humus (114)
deciduous (112) taiga (114)

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.

photic zone (117) benthos (117) wetland (119)
aphotic zone (117) plankton (119) estuary (119)

Think Visually Create a concept map that includes the following terms: *abiotic factors, biotic factors, community interactions, predation, competition, symbiosis, nutrients, ecosystems, light, and oxygen.*

4 Assessment

4.1 Climate

Understand Key Concepts

- An increase in the greenhouse effect causes an increase in
 - carbon dioxide.
 - temperature.
 - oxygen.
 - water.
- A small valley where the average temperature is usually higher than that of the surrounding countryside has its own
 - weather.
 - climate.
 - rainfall.
 - microclimate.
- Distinguish between weather and climate.
- Describe the three primary abiotic factors that produce Earth's major climate zones.

Think Critically

- Apply Concepts** Based on the relative positions of the sun and Earth, explain why Earth has climate zones and seasons.
- Infer** A plant grower has a greenhouse where she grows plants in the winter. The greenhouse is exposed to direct sunlight and often gets too hot for the plants. She paints the inside of the glass with a chalky white paint, and the temperature drops to comfortable levels. Explain why this procedure works.

4.2 Niches and Community Interactions

Understand Key Concepts

- A relationship in which one organism is helped and another organism is neither helped nor hurt is called
 - parasitism.
 - mutualism.
 - competition.
 - commensalism.
- The relationship between a tick and its host is an example of
 - mutualism.
 - parasitism.
 - commensalism.
 - succession.



- What is the difference between an organism's habitat and its niche?
- What is the competitive exclusion principle?

Think Critically

- Compare and Contrast** How are predation and parasitism similar? How are they different?
- Infer** Competition for resources in an area is usually more intense within a single species than between two different species. How would you explain this observation?
- Apply Concepts** Write a description of your niche in the environment. Include details about your ecosystem, and the biotic and abiotic factors around you. Be sure to describe your feeding habits as well as any interactions you have with members of other species.

4.3 Succession

Understand Key Concepts

- Fires, hurricanes, and other natural disturbances can result in
 - commensalism.
 - competition.
 - parasitism.
 - succession.
- The first organisms to repopulate an area affected by a volcanic eruption are called
 - keystone species.
 - climax species.
 - primary producers.
 - pioneer species.
- What type of succession takes place after lava from a volcanic eruption covers an area?
- Describe two major causes of ecological succession.

Think Critically

- Predict** A windstorm in a forest blows down the large trees in one part of the forest. Soon, sun-loving plants sprout in the new clearing. What type of succession is this? What do you think this area will look like in 5 years? In 50 years?
- Relate Cause and Effect** Explain why secondary succession usually proceeds faster than primary succession.

4.4 Biomes

Understand Key Concepts

20. In a tropical rain forest, the dense covering formed by the leafy tops of tall trees is called the
- canopy.
 - taiga.
 - niche.
 - understory.
21. Permafrost characterizes the biome called
- taiga.
 - boreal forest.
 - savanna.
 - tundra.
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
- parasites.
 - benthos.
 - plankton.
 - 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?

solve the 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.

Think Critically

31. **Form a Hypothesis** The deep ocean lies within the aphotic zone and is very cold. Suggest some of the unique characteristics that enable animals to live in the deep ocean.
32. **Form an Opinion** A developer has proposed filling in a salt marsh to create a coastal resort. What positive and negative effects do you think this proposal would have on wildlife and local residents? Would you support the proposal?

Connecting Concepts

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.

Productivity of Aquatic and Land Ecosystems	
Ecosystem	Average Primary Productivity
Aquatic Ecosystems	
Coral reef	2500
Estuary	1800
Open ocean	125
Land Ecosystems	
Tropical rain forest	2200
Tropical savanna	900
Tundra	90

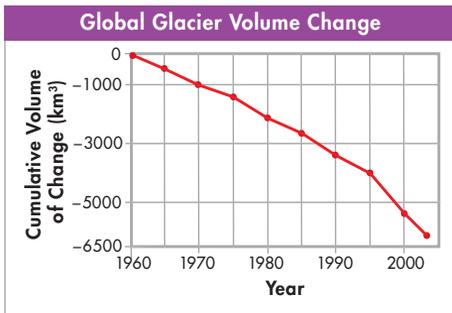
33. **Interpret Tables** According to the table, which ecosystem is most productive? Use what you know to explain that fact.
34. **Infer** The open ocean is among the least productive ecosystems, yet it contributes greatly to the overall productivity of the biosphere. How do you explain this paradox?
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?

Analyzing Data

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.



39. **Interpret Graphs** The greatest volume of glacial ice was lost
- between 1960 and 1970.
 - between 1980 and 1990.
 - between 1995 and 2000.
 - before 1960.
40. **Relate Cause and Effect** The most reasonable explanation for the loss of glacier mass since 1960 is
- an increase in the total productivity of the world's oceans.
 - a gradual rise in Earth's average temperature.
 - an increase in the total amount of ice at Earth's poles.
 - an increase in the sun's output of radiant energy.

Standardized Test Prep

Multiple Choice

- 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.
- All of the following are abiotic factors that affect global climate EXCEPT
A latitude. C solar energy.
B longitude. D ocean currents.
- 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. C lifestyle.
B niche. D biome.
- 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.
- 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.
- 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.
- In which biome do organisms have the greatest tolerance to dry conditions?
A tundra C tropical savanna
B desert D boreal forest

Questions 8–9

Month-by-month climate data for the city of Lillehammer, Norway, is shown in the table below.

Climate Data for Lillehammer, Norway		
Month	Average Temperature (°C)	Average Precipitation (mm)
Jan.	-8.1	38.1
Feb.	-6.2	27.9
Mar.	-3.9	30.5
Apr.	3.3	35.6
May	8.9	45.7
June	13.9	63.5
July	16.4	81.3
Aug.	14.2	88.9
Sept.	9.5	58.4
Oct.	3.9	63.5
Nov.	-3.8	50.8
Dec.	-6.1	48.3

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

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

If You Have Trouble With . . .

Question	1	2	3	4	5	6	7	8	9	10
See Lesson	4.1	4.1	4.2	4.2	4.5	4.5	4.4	4.1	4.1	4.3