4–1 The Role of Climate

If you live in Michigan, you know you cannot grow banana trees in your backyard. Bananas are tropical plants that need plenty of water and heat. They won't survive in freezing temperatures. It may not be as obvious that cranberries won't grow in the Rio Grande Valley of Texas. Cranberries need plenty of water and a cold rest period. They cannot tolerate the months of very hot weather that often occur in the Rio Grande Valley.

Bananas and cranberries, like other plants and animals, vary in their adaptations to temperature, rainfall, and other environmental conditions. Species also vary in their tolerances for conditions outside their normal ranges. That's why climate is important in shaping ecosystems—and why understanding climate is important in ecology.

What Is Climate?

In the atmosphere, temperature, precipitation, and other environmental factors combine to produce weather and climate. **Weather** is the day-to-day condition of Earth's atmosphere at a particular time and place. The weather where you live may be clear and sunny one day but cloudy and cold the next. **Climate,** on the other hand, refers to the average, year-after-year conditions of temperature and precipitation in a particular region.

Climate is caused by the interplay of many factors, including the trapping of heat by the atmosphere, the latitude, the transport of heat by winds and ocean currents, and the amount of precipitation that results. The shape and elevation of landmasses also contribute to global climate patterns.

The energy of incoming sunlight drives Earth's weather and helps determine climate. As you might expect, solar energy has an important effect on the temperature of the atmosphere. At the same time, the presence of certain gases in the atmosphere also has an effect on its temperature.

The Greenhouse Effect

Temperatures on Earth remain within a range suitable for life because the biosphere has a natural insulating blanket—the atmosphere. **Carbon dioxide, methane, water vapor, and a few other atmospheric gases trap heat energy and maintain Earth's temperature range.** These gases function like the glass windows of a greenhouse. Just as the glass keeps the greenhouse plants warm, these gases trap the heat energy of sunlight inside Earth's atmosphere. The natural situation in which heat is retained by this layer of greenhouse gases is called the **greenhouse effect,** shown in **Figure 4–1.**

Guide for Reading

Key Concepts

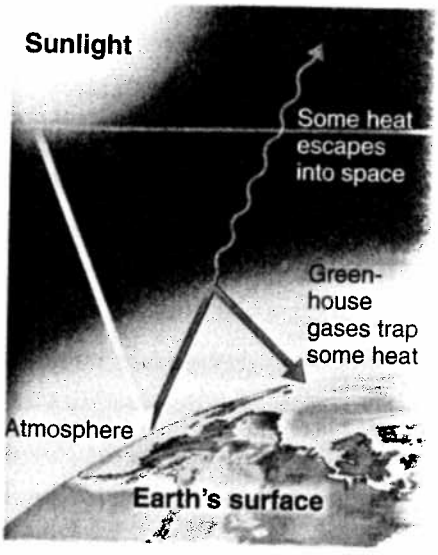
- How does the greenhouse effect maintain the biosphere's temperature range?
- What are Earth's three main climate zones?

Vocabulary

weather • climate
greenhouse effect • polar zone
temperate zone • tropical zone

Reading Strategy: Outlining Before you read, use the headings in this section to make an outline about climate. As you read, fill in the subtopics and smaller topics. Then, add phrases or a sentence after each subtopic to provide key information.

▼ Figure 4–1 Carbon dioxide, water vapor, and several other gases in the atmosphere allow solar radiation to enter the biosphere but slow down the loss of heat to space. These greenhouse gases cause the greenhouse effect, which helps maintain Earth's temperature range.



Go Online
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Visit: www.SciLinks.org
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Greenhouse gases allow solar energy to penetrate the atmosphere in the form of sunlight. Much of the sunlight that hits the surface of our planet is converted into heat energy and then radiated back into the atmosphere. However, those same gases do not allow heat energy to pass out of the atmosphere as readily as light energy enters it. Instead, the gases trap heat inside Earth's atmosphere. If these gases were not present in the atmosphere, Earth would be 30 degrees Celsius cooler than it is today.

The Effect of Latitude on Climate

Because Earth is a sphere that is tilted on its axis, solar radiation strikes different parts of Earth's surface at an angle that varies throughout the year. At the equator, the sun is almost directly overhead at noon all year. At the North and South poles, however, the sun is much lower in the sky for months at a time. Look at **Figure 4–2**, and you will see that differences in the angle of sunlight directed at different latitudes result in the delivery of more heat to the equator than to the poles. The difference in heat distribution with latitude has important effects on Earth's climate zones.

As a result of differences in latitude and thus the angle of heating, Earth has three main climate zones: polar, temperate, and tropical. The **polar zones** are cold areas where the sun's rays strike Earth at a very low angle. These zones are located in the areas around the North and South poles, between 66.5° and 90° North and South latitudes. The **temperate zones** sit between the polar zones and the tropics. Because temperate zones are more affected by the changing angle of the sun over the course of a year, the climate in these zones ranges from hot to cold, depending on the season. The **tropical zone,** or tropics, is near the equator, between 23.5° North and 23.5° South latitudes. The tropics thus receive direct or nearly direct sunlight year-round, making the climate almost always warm. **Figure 4–2** shows Earth's main climate zones.

CHECKPOINT *What effect does latitude have on climate?*

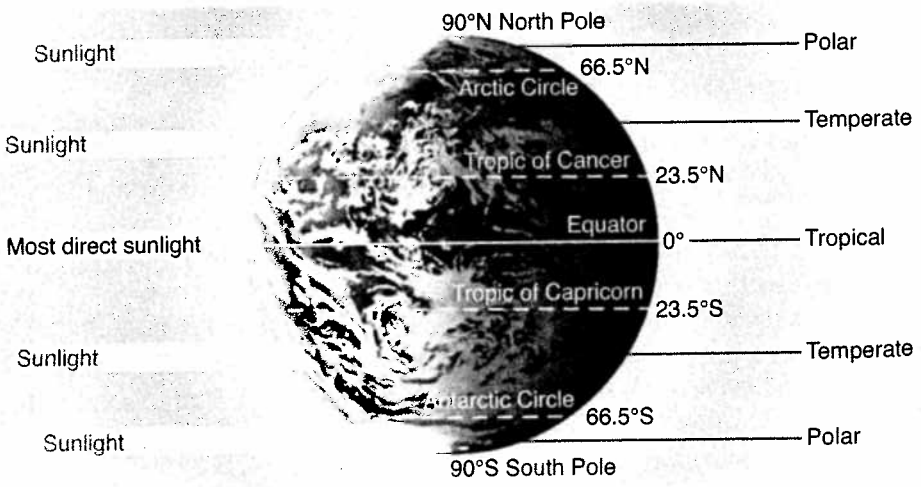


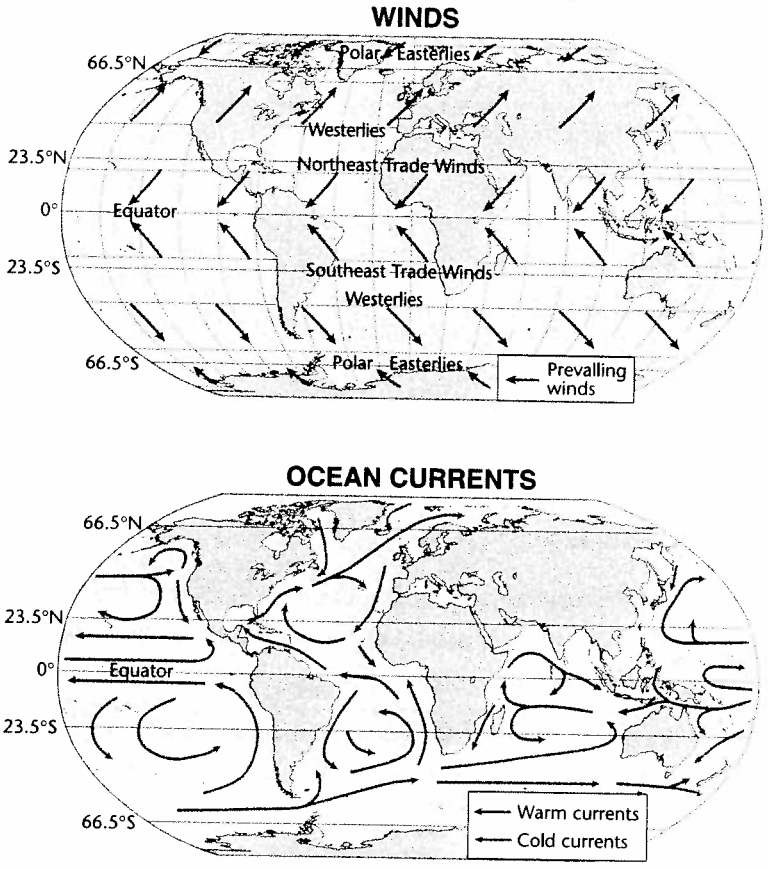
Figure 4–2 Earth has three main climate zones. These climate zones are caused by the unequal heating of Earth's surface. Near the equator, energy from the sun strikes Earth almost directly. Near the poles, the sun's rays strike Earth's surface at a lower angle. The same amount of solar energy is spread out over a larger area, heating the surface less than at the equator.

Heat Transport in the Biosphere

The unequal heating of Earth's surface drives winds and ocean currents, which transport heat throughout the biosphere. Winds form because warm air tends to rise and cool air tends to sink. Consequently, air that is heated near the equator rises. At the same time, cooler air over the poles sinks toward the ground. The upward movement of warm air and the downward movement of cool air create air currents, or winds, that move heat throughout the atmosphere, from regions of sinking air to regions of rising air. The prevailing winds, shown in **Figure 4–3,** bring warm or cold air to a region, affecting its climate.

Similar patterns of heating and cooling occur in Earth's oceans. Cold water near the poles sinks and then flows parallel to the ocean bottom, eventually rising again in warmer regions through a process called upwelling. Meanwhile, surface water is moved by winds. In both cases, the water flow creates ocean currents. Like air currents, ocean currents transport heat energy within the biosphere. Surface ocean currents warm or cool the air above them, thus affecting the weather and climate of nearby landmasses.

Continents and other landmasses can also affect winds and ocean currents. Landmasses can interfere with the movement of air masses. For example, a mountain range causes a moist air mass to rise. As this happens, the air mass cools and moisture condenses, forming clouds that bring precipitation to the mountains. Once the air mass reaches the far side of the mountains, it has lost much of its moisture. The result is a rain shadow—an area with a dry climate—on the far side of the mountains.



▲ **Figure 4–3** Earth's winds (top) and ocean currents (bottom) interact to help produce Earth's climates. The curved paths of some currents and winds are the result of Earth's rotation. **Interpreting Graphics** *In what direction do cold currents in Earth's oceans generally move?*

4–1 Section Assessment

1. **Key Concept** What is the greenhouse effect?
2. **Key Concept** Describe Earth's three main climate zones.
3. What are the main factors that determine Earth's climate?
4. Describe two ways in which heat is transported in the biosphere.
5. **Critical Thinking Applying Concepts** A biologist recorded the bird species in her region. Then, she spotted a bird that was not supposed to live in the region. How might variations relate to this occurrence?

Sharpen Your Skills

Modeling

Earth rotates daily on its axis and is tilted at an angle of 23.5° in relation to the sun. Using a flashlight to represent the sun and a globe to represent Earth, demonstrate different levels of light in Earth's three climate zones.

4–2 What Shapes an Ecosystem?

5 5.c. Students know populations or organisms can be categorized by the functions they serve in an ecosystem.
5 5.e. Students know the number and types of organisms an ecosystem can support depend on the resources available and on abiotic factors, such as quantities of light and water, a range of temperatures, and soil composition.

Guide for Reading

Key Concepts
- How do biotic and abiotic factors influence an ecosystem?
- What interactions occur within communities?
- What is ecological succession?

Vocabulary
biotic factor
abiotic factor
habitat
niche
resource
competitive exclusion principle
predation
symbiosis
mutualism
commensalism
parasitism
ecological succession
primary succession
pioneer species
secondary succession

Reading Strategy: Building Vocabulary Before you read, preview new vocabulary terms by skimming the section and making a list of the highlighted, boldface terms. Leave space to make notes as you read.

If you ask an ecologist where a particular organism lives, that person might say the organism lives on a Caribbean coral reef, or in an Amazon rain forest, or in a desert in the American Southwest. Those answers provide a kind of ecological address not unlike a street address in a city or town. An ecological address, however, tells you more than where an organism lives. It tells you about the climate the organism experiences and what neighbors it is likely to have. But what shapes the ecosystem in which an organism lives?

Biotic and Abiotic Factors

Ecosystems are influenced by a combination of biological and physical factors. The biological influences on organisms within an ecosystem are called **biotic factors.** These include the entire living cast of characters with which an organism might interact, including birds, trees, mushrooms, and bacteria—in other words, the ecological community. Biotic factors that influence a bullfrog, for example, might include the tiny plants and algae it eats as a tadpole, the herons that eat the adult frog, and other species that compete with the bullfrog for food or space.

Physical, or nonliving, factors that shape ecosystems are called **abiotic** (ay-by-AHT-ik) **factors**. For example, the climate of an area includes abiotic factors such as temperature, precipitation, and humidity. Other abiotic factors are wind, nutrient availability, soil type, and sunlight. For example, the bullfrog in **Figure 4–4** is affected by abiotic factors such as the availability of water and the temperature of the air. **Together, biotic and abiotic factors determine the survival and growth of an organism and the productivity of the ecosystem in which the organism lives.** The area where an organism lives is called its **habitat.** A habitat includes both biotic and abiotic factors.

CHECKPOINT *Give an example of an abiotic factor.*

Figure 4–4 **Like all ecosystems, this pond is shaped by a combination of biotic and abiotic factors.** The bullfrog, plants, and other organisms in the pond are biotic factors. The water, the air, and the rock on which the bullfrog sits are abiotic factors.

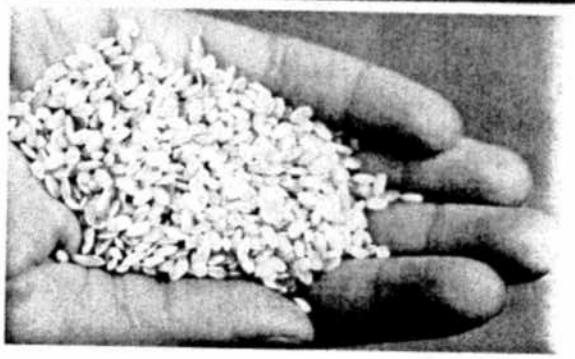
Quick Lab

How do abiotic factors affect different plant species?

Materials presoaked rye and rice seeds, sand, potting soil, 4 paper cups

Procedure

1. Use a pencil to punch three holes in the bottom of each cup. Fill 2 cups with equal amounts of sand and 2 cups with the same amount of potting soil.
2. Plant 5 rice seeds in one sand-filled cup and 5 rice seeds in one soil-filled cup. Plant 5 rye seeds in each of the other 2 cups. Label each cup with the type of seeds and soil it contains.
3. Place all the cups in a warm, sunny location. Each day for 2 weeks, water the cups equally and record your observations of any plant growth. **CAUTION:** *Wash your hands well with soap and warm water after handling plants or soil.*



Analyze and Conclude

1. **Analyzing Data** In which medium did the rice grow best—sand or soil? Which was the better medium for the growth of rye?
2. **Inferring** Soil retains more water than sand, providing a moister environment. What can you infer from your observations about the kind of environment that favors the growth of rice? The growth of rye?
3. **Drawing Conclusions** Which would compete more successfully in a dry environment—rye or rice? In a moist environment?

The Niche

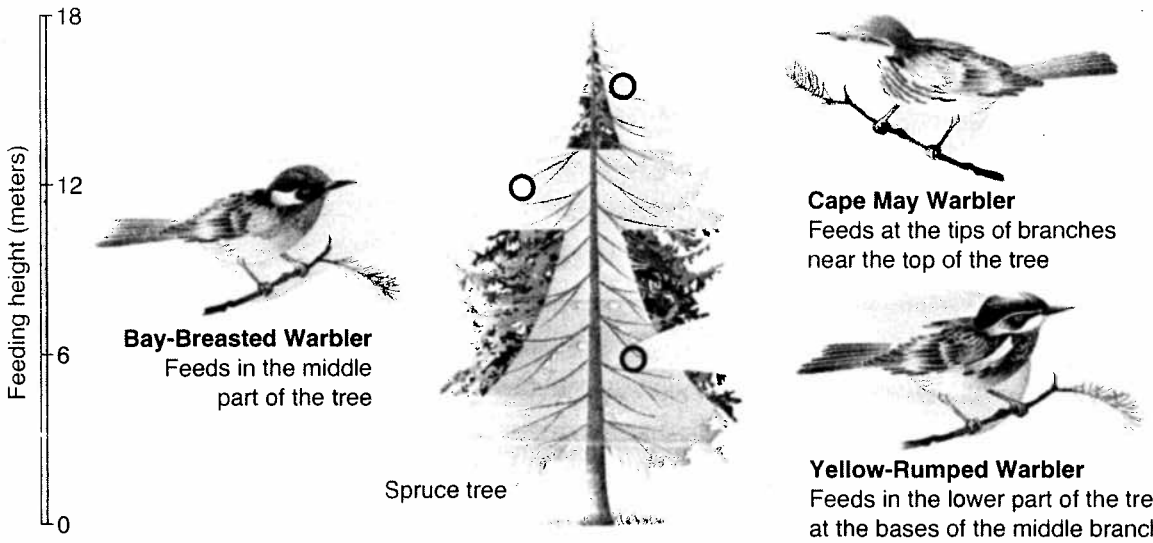
6 5.c

If an organism's habitat is its address, its niche is its occupation. A **niche** (NITCH) is the full range of physical and biological conditions in which an organism lives and the way in which the organism uses those conditions. For instance, part of the description of an organism's niche includes its place in the food web. Another part of the description might include the range of temperatures that the organism needs to survive. The combination of biotic and abiotic factors in an ecosystem often determines the number of different niches in that ecosystem.

A niche includes the type of food the organism eats, how it obtains this food, and which other species use the organism as food. For example, a mature bullfrog catches insects, worms, spiders, small fish, or even mice. Predators such as herons, raccoons, and snakes prey on bullfrogs.

The physical conditions that the bullfrog requires to survive are part of its niche. Bullfrogs spend their lives in or near the water of ponds, lakes, and slow-moving streams. A bullfrog's body temperature varies with that of the surrounding water and air. As winter approaches, bullfrogs burrow into the mud of pond or stream bottoms to hibernate.

The bullfrog's niche also includes when and how it reproduces. Female bullfrogs lay their eggs in water during the warmer months of the year. The young frogs, called tadpoles, live in the water until their legs and lungs develop.



▲ **Figure 4–5** 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 with one another for food. **Inferring** *What would happen if two of the warbler species attempted to occupy the same niche?*

As you will see, no two species can share the same niche in the same habitat. However, different species can occupy niches that are very similar. For instance, the three species of North American warblers shown in **Figure 4–5** live in the same spruce trees but feed at different elevations and in different parts of those trees. The species are similar, yet each warbler has a different niche within the forest.

✓CHECKPOINT *What is a niche?*

Community Interactions

When organisms live together in ecological communities, they interact constantly. These interactions help shape the ecosystem in which they live. **Community interactions, such as competition, predation, and various forms of symbiosis, can powerfully affect an ecosystem.**

Competition Competition occurs when organisms of the same or different species attempt to use an ecological resource in the same place at the same time. The term **resource** refers to any necessity of life, such as water, nutrients, light, food, or space. In a forest, for example, broad-leaved trees such as oak or hickory may compete for sunlight by growing tall, spreading out their leaves, and blocking the sunlight from shorter trees. Similarly, two species of lizards in a desert might compete by attempting to eat the same type of insect.

Direct competition in nature often results in a winner and a loser—with the losing organism failing to survive. A fundamental rule in ecology, the **competitive exclusion principle,** states that no two species can occupy the same niche in the same habitat at the same time. Look again at the distribution of the warblers in **Figure 4–5.** Can you see how this distribution avoids direct competition among the different warbler species?

Predation An interaction in which one organism captures and feeds on another organism is called **predation** (pree-DAY-shun). The organism that does the killing and eating is called the predator (PRED-uh-tur), and the food organism is the prey. Cheetahs are active predators with claws and sharp teeth. Their powerful legs enable them to run after prey. Other predators, such as anglerfishes, are more passive. An anglerfish has a fleshy appendage that resembles a fishing lure, which it uses to draw unsuspecting prey close to its mouth.

Symbiosis Any relationship in which two species live closely together is called **symbiosis** (sim-by-OH-sis), which means "living together." Biologists recognize three main classes of symbiotic relationships in nature: mutualism, commensalism, and parasitism. Examples of these three symbiotic relationships are shown in **Figure 4–6.**

Mutualism In **mutualism** (MYOO-choo-ul-iz-um), both species benefit from the relationship. Many flowers, for example, depend on certain species of insects to pollinate them. The flowers provide the insects with food in the form of nectar, pollen, or other substances, and the insects help the flowers reproduce.

Commensalism In **commensalism** (kuh-MEN-sul-iz-um), one member of the association benefits and the other is neither helped nor harmed. Small marine animals called barnacles, for example, often attach themselves to a whale's skin. The barnacles perform no known service to the whale, nor do they harm it. Yet, the barnacles benefit from the constant movement of water past the swimming whale, because the water carries food particles to them.

Parasitism In **parasitism** (PAR-uh-sit-iz-um), one organism lives on or inside another organism and harms it. The parasite obtains all or part of its nutritional needs from the other organism, called the host. Generally, parasites weaken but do not kill their host, which is usually larger than the parasite. Tapeworms, for example, are parasites that live in the intestines of mammals. Fleas, ticks, and lice live on the bodies of mammals, feeding on the blood and skin of the host.

Mutualism The ant cares for the aphids and protects them from predators. The aphids produce a sweet liquid that the ant drinks.

Commensalism The orchid benefits from its perch in the tree as it absorbs water and minerals from rainwater and runoff, but the tree is not affected.

Parasitism A tick feeds on the blood of its host and may also carry disease-causing microorganisms.

Figure 4–6 Three examples of symbiosis are shown: mutualism, commensalism, and parasitism. **Predicting** *What would happen to the aphids if the ant died?*

Ecological Succession

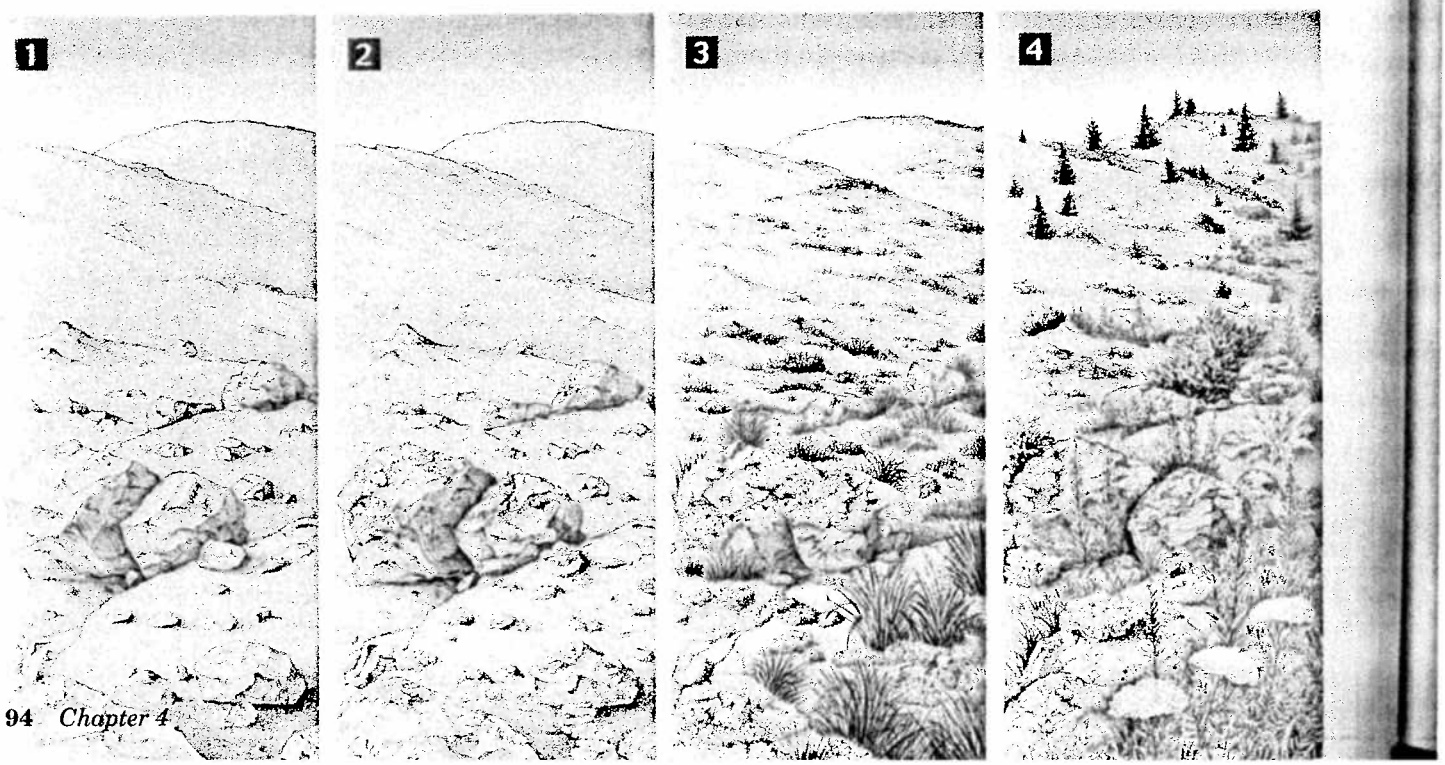
On the time scale of a human life, some ecosystems may seem stable. The appearance of stability is often misleading, because ecosystems and communities are always changing. Sometimes, an ecosystem changes in response to an abrupt disturbance, such as a severe storm. At other times, change occurs as a more gradual response to natural fluctuations in the environment.

Ecosystems are constantly changing in response to natural and human disturbances. As an ecosystem changes, older inhabitants gradually die out and new organisms move in, causing further changes in the community. This series of predictable changes that occurs in a community over time is called **ecological succession.** Sometimes succession results from slow changes in the physical environment. A sudden natural disturbance from human activities, such as clearing a forest, may also be a cause of succession.

Primary Succession On land, succession that occurs on surfaces where no soil exists is called **primary succession.** For example, primary succession occurs on the surfaces formed as volcanic eruptions build new islands or cover the land with lava rock or volcanic ash. Primary succession also occurs on bare rock exposed when glaciers melt.

In **Figure 4–7,** you can follow the stages of primary succession after a volcanic eruption. When primary succession begins, there is no soil, just ash and rock. The first species to populate the area are called **pioneer species.** The pioneer species on volcanic rocks are often lichens (LY-kunz). A lichen is made up of a fungus and an alga and can grow on bare rock. As lichens grow, they help break up the rocks. When they die, the lichens add organic material to help form soil in which plants can grow.

CHECKPOINT *What are pioneer species?*



▼ **Figure 4–7** Primary succession occurs on newly exposed surfaces, such as this newly deposited volcanic rock and ash. (1) A volcanic eruption destroys the previous ecosystem. (2) The first organisms to appear are lichens. (3) Mosses soon appear, and grasses take root in the thin layer of soil. (4) Eventually, tree seedlings and shrubs sprout among the plant community. **Predicting** *What types of animals would you expect to appear at each stage, and why?*

Secondary Succession Components of an ecosystem can be changed by natural events, such as fires, or by human activities, such as farming. These changes may affect the ecosystem in predictable or unpredictable ways. When the disturbance is over, community interactions tend to restore the ecosystem to its original condition through **secondary succession.** For example, secondary succession occurs after wildfires burn woodlands and when land cleared for farming is abandoned. **Figure 4–8** shows trees regrowing after a wildfire. In fact, fires set by lightning occur in many ecosystems, and some plants are so adapted to periodic fires that their seeds won't sprout unless exposed to fire!

Ecologists used to think that succession in a given area always proceeded through predictable stages to produce the same stable "climax community." Old-growth forests in the Pacific Northwest, for example, were considered climax communities. But natural disasters, climate change, and human activity such as introduction of nonnative species profoundly affect these communities today. Healthy ecosystems usually recover from natural disturbances because of the way components of the system interact. Ecosystems may or may not recover from long-term, human-caused disturbances.

▲ **Figure 4–8** Ten years after wildfires burned regions of Yellowstone National Park, small evergreen trees have begun to regenerate the forest. **Predicting** ***How do you think this region will look 20 years after the fires?***

Careers in Biology

Forestry Technician

Job Description: work outdoors to help maintain, protect, and develop forests (by planting trees, fighting insects and diseases that attack trees, and controlling soil erosion)

Education: two- or four-year college degree in forestry, wildlife, or conservation; summer work in parks, state and national forests; and private industry provides on-the-job training

Skills: knowledge of the outdoors and basic safety precautions; communication skills for working with the public; keen observational skills; physical fitness for jobs that require walking long distances through forests

Highlights: help to manage and conserve forest biomes by analyzing data, planting trees, and managing fires when necessary; contribute to people's enjoyment of outdoor recreation

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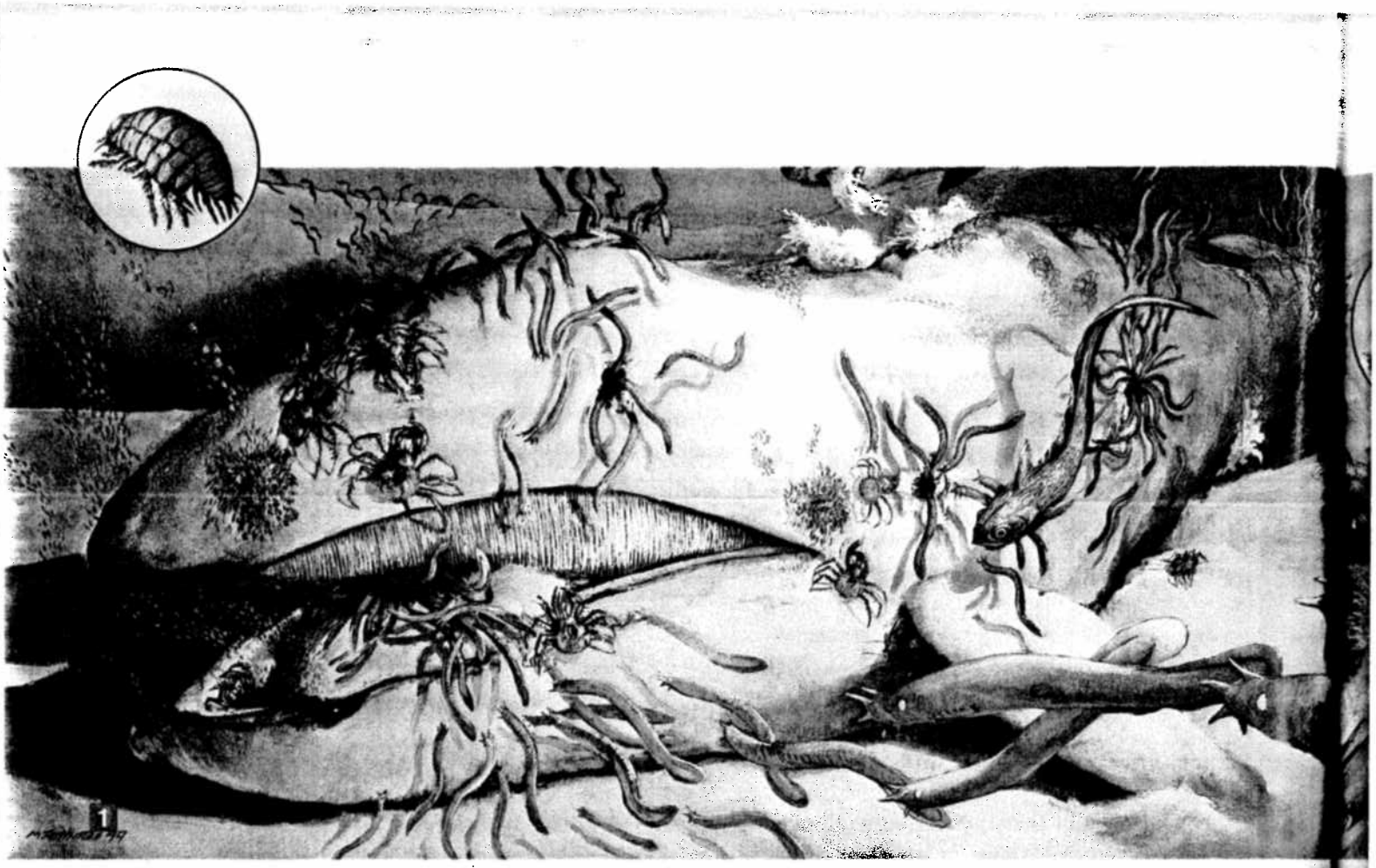
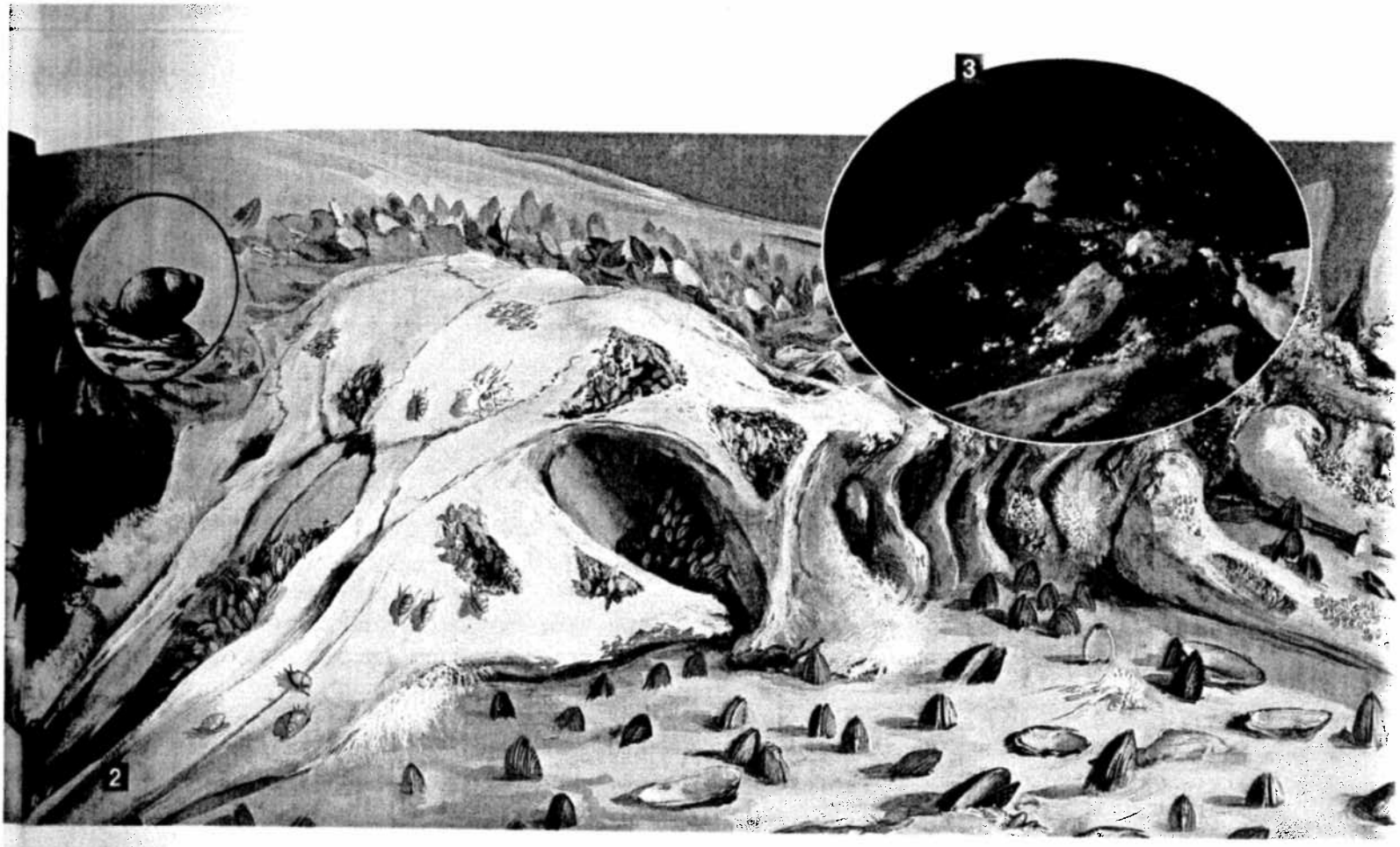


Figure 4–9 **Ecosystems are constantly changing in response to disturbances.** In natural environments, succession occurs in stages. A dead whale that falls to the ocean floor is soon covered with scavengers. After a time, only bare bones are left. The bones contain oil that supports several types of deep-sea bacteria. In the next stage of succession, the bacteria provide energy and nutrients for a different community of organisms that live on the bones and in the surrounding sediments.

Succession in a Marine Ecosystem Succession can occur in any ecosystem—even in the permanently dark, deep ocean. In 1987, scientists found an unusual community of organisms living on the remains of a dead whale in the deep waters off the coast of southern California. At first, ecologists did not know what to make of this extraordinary community. After several experiments and hours of observation, the ecologists found that the community represented a stage in succession amid an otherwise stable and well-documented deep-sea ecosystem. Since that discovery, several more whale carcasses have been found in other ocean basins with similar organisms surrounding them. **Figure 4–9** illustrates three stages in the succession of a whale-fall community.

1 The disturbance that causes this kind of succession begins when a large whale, such as a blue or fin whale, dies and sinks to the normally barren ocean floor. The whale carcass attracts a host of scavengers and decomposers, including amphipods (inset), hagfishes, and sharks, that feast on the decaying meat.

2 Within a year, most of the whale's tissues have been eaten. The carcass then supports only a much smaller number of fishes, crabs, marine snails (inset), and other marine animals. The decomposition of the whale's body, however, enriches the surrounding sediments with nutrients, forming an oasis of sediment dwellers, including many different species of marine worms.



3 When only the whale's skeleton remains, a third community moves in. Heterotrophic bacteria begin to decompose oils inside the whale bones. In doing so, they release chemical compounds that serve as energy sources for other bacteria that are chemosynthetic autotrophs. The chemosynthetic bacteria, in turn, support a diverse community of mussels, limpets, snails, worms, crabs, clams, and other organisms that live on the bones and within the nearby sediments.

4–2 Section Assessment

1. **Key Concept** What is the difference between a biotic factor and an abiotic factor?
2. **Key Concept** Name three types of community interactions that can affect an ecosystem.
3. **Key Concept** What is the difference between primary succession and secondary succession?
4. How is an organism's niche determined?
5. **Critical Thinking Comparing and Contrasting** How are the three types of symbiotic relationships different? Similar?
6. **Critical Thinking Applying Concepts** Summarize the role of organisms, including microorganisms, in maintaining the equilibrium of a marine ecosystem while a dead whale decays on the ocean floor.

Writing in Science

Creative Writing

Use the information from this section to write a short story about an ecosystem that is disturbed and undergoes succession. *Hint*: Include a flowchart with your story to show the main stages of change.

4–3 Biomes

6 5.e. Students know the number and types of organisms an ecosystem can support depend on the resources available and on abiotic factors, such as quantities of light and water, a range of temperatures, and soil composition.

Guide for Reading

Key Concept
- What are the unique characteristics of the world's major biomes?

Vocabulary
biome • tolerance
microclimate • canopy
understory • deciduous
coniferous • humus
taiga • permafrost

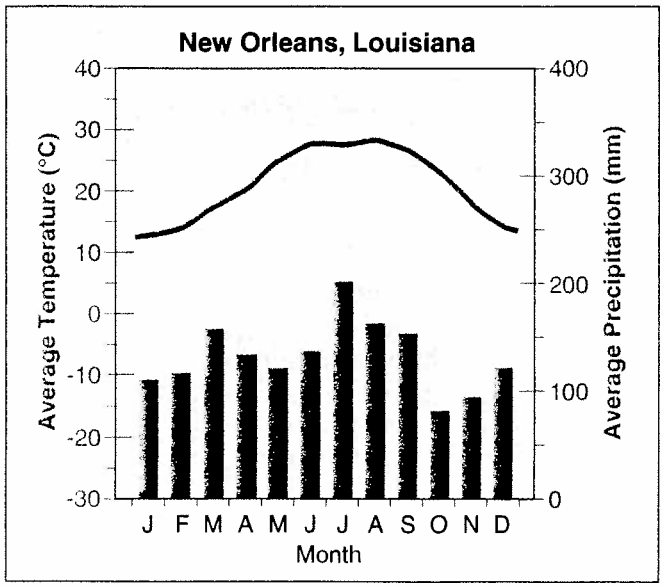
Reading Strategy: Using Visuals Before you read, preview **Figure 4–11.** Write down the names of the different biomes. As you read, examine the photographs and list the main characteristics of each biome.

Ecologists group Earth's diverse environments into biomes. A **biome** is a complex of terrestrial communities that covers a large area and is characterized by certain soil and climate conditions and particular assemblages of plants and animals.

Can all kinds of organisms live in every biome? No. Species vary in their adaptations to different conditions. An adaptation is an inherited characteristic that increases an organism's ability to survive and reproduce.

The leaves of the saguaro cactus, for example, are reduced to spines to minimize water loss, and its stems store water during dry spells. Its shallow, wide-spreading roots absorb water rapidly. Desert rodents, such as kangaroo rats, have adaptations in their kidneys that help conserve water, and they extract water from food. Many rain forest plants, such as certain anthuriums, have long, thin leaves whose pointed tips help shed excess water. Some rain forest animals, such as certain tree frogs, spend their life in trees—their tadpoles grow in water pockets in leaf bases of plants such as bromeliads.

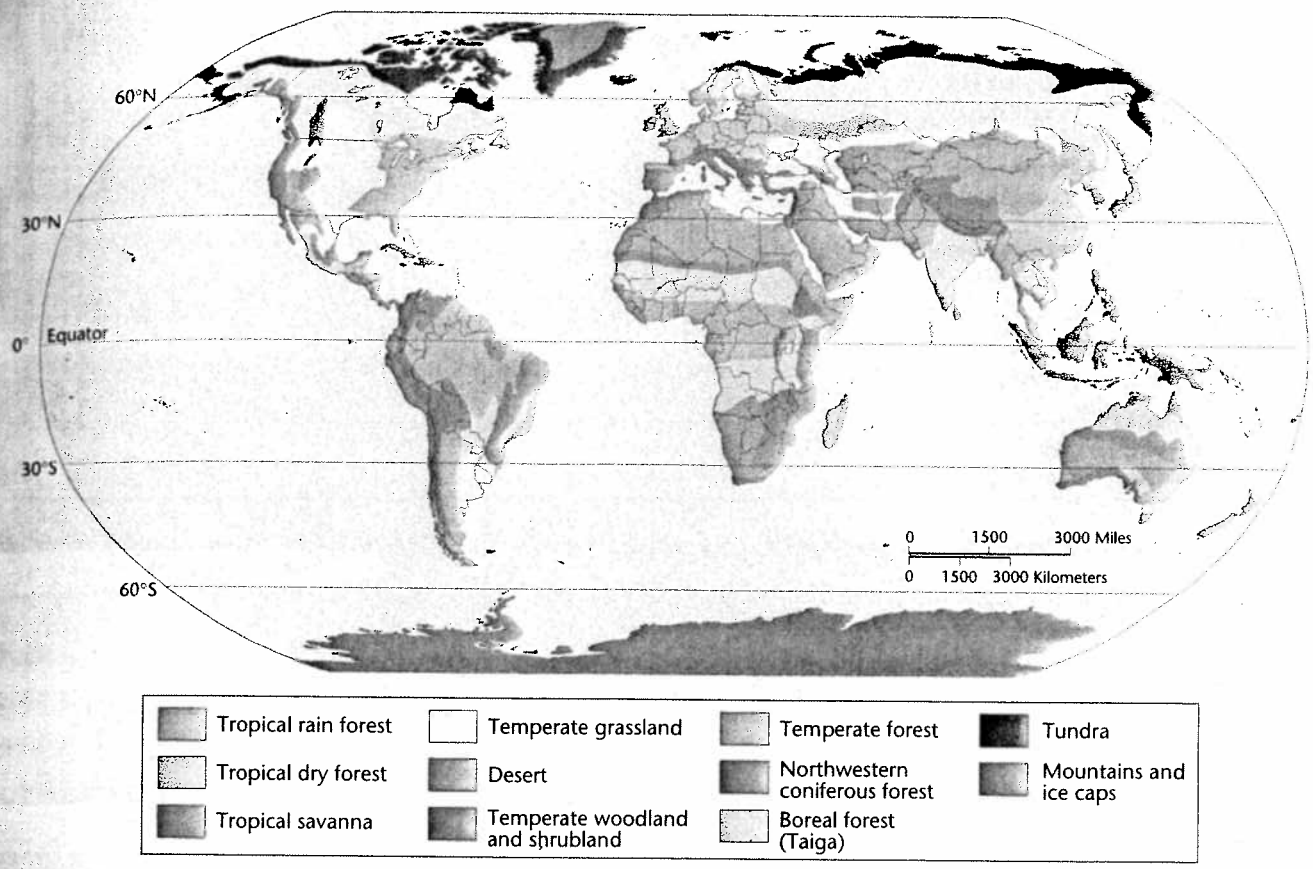
These sorts of variations in plants and animals help different species survive under different conditions in different biomes. Plants and animals also exhibit variations in **tolerance,** or ability to survive and reproduce under conditions that differ from their optimal conditions. Plants and animals of the Arizona desert, for example, can tolerate temperatures that range from blisteringly hot to below freezing. Some rain forest plants and animals, by comparison, die quickly if the temperature drops below freezing or rises above 34°C for long. Either too much or too little of any environmental factor can make it difficult for an organism to survive. A saguaro would rot and die in a rain forest as surely as an anthurium or rain forest tree frog would shrivel and die in the desert!



▼ **Figure 4–10** Climate diagrams show the average temperature and precipitation at a given location during each month of the year. In this graph, and the others to follow, temperature is plotted as a red line. Precipitation is shown as vertical purple bars. **Interpreting Graphics** *What is the approximate average temperature and precipitation in New Orleans during the month of July?*

Biomes and Climate

Because each species is adapted to certain conditions, the climate of a region is an important factor in determining which organisms can survive there. Even within a biome, precise conditions of temperature and precipitation can vary over small distances. The climate in a small area that differs from the climate around it is called a **microclimate.** For example, certain streets in San Francisco are often blanketed in fog while the sun shines brightly just a few blocks away. Two main components of climate—temperature and precipitation—can be summarized in a graph called a climate diagram, as shown in **Figure 4–10.**



The Major Biomes

Ecologists recognize at least ten different biomes. **The world's major biomes include tropical rain forest, tropical dry forest, tropical savanna, desert, temperate grassland, temperate woodland and shrubland, temperate forest, northwestern coniferous forest, boreal forest, and tundra. Each of these biomes is defined by a unique set of abiotic factors—particularly climate—and a characteristic assemblage of plants and animals.** The distribution of major biomes is shown in **Figure 4–11**, and some of their most important characteristics are summarized over the next five pages.

There is often ecological variation within a biome. Sometimes, this variation is due to changes in microclimate caused by differences in exposure or elevation above sea level. Other times, variation may be related to geological factors such as local soil conditions or the presence of rock outcroppings. Note also that although boundaries between biomes on this map appear to be sharp, there are often transitional areas in which one biome's plants and animals become less common, whereas organisms of the adjacent biome become more common. These variations in distribution often can be related to the ranges of tolerances of plants and animals for different environmental factors. As you look at **Figure 4–11** and the following pages, see if you can relate the characteristics and locations of biomes to the patterns of global winds and ocean currents in **Figure 4–3.**

▲ **Figure 4–11** This map shows the locations of the world's major biomes. Other parts of Earth's surface are classified as mountains or ice caps. **Each biome has a characteristic climate and community of organisms.** These characteristics are shown on the pages that follow.

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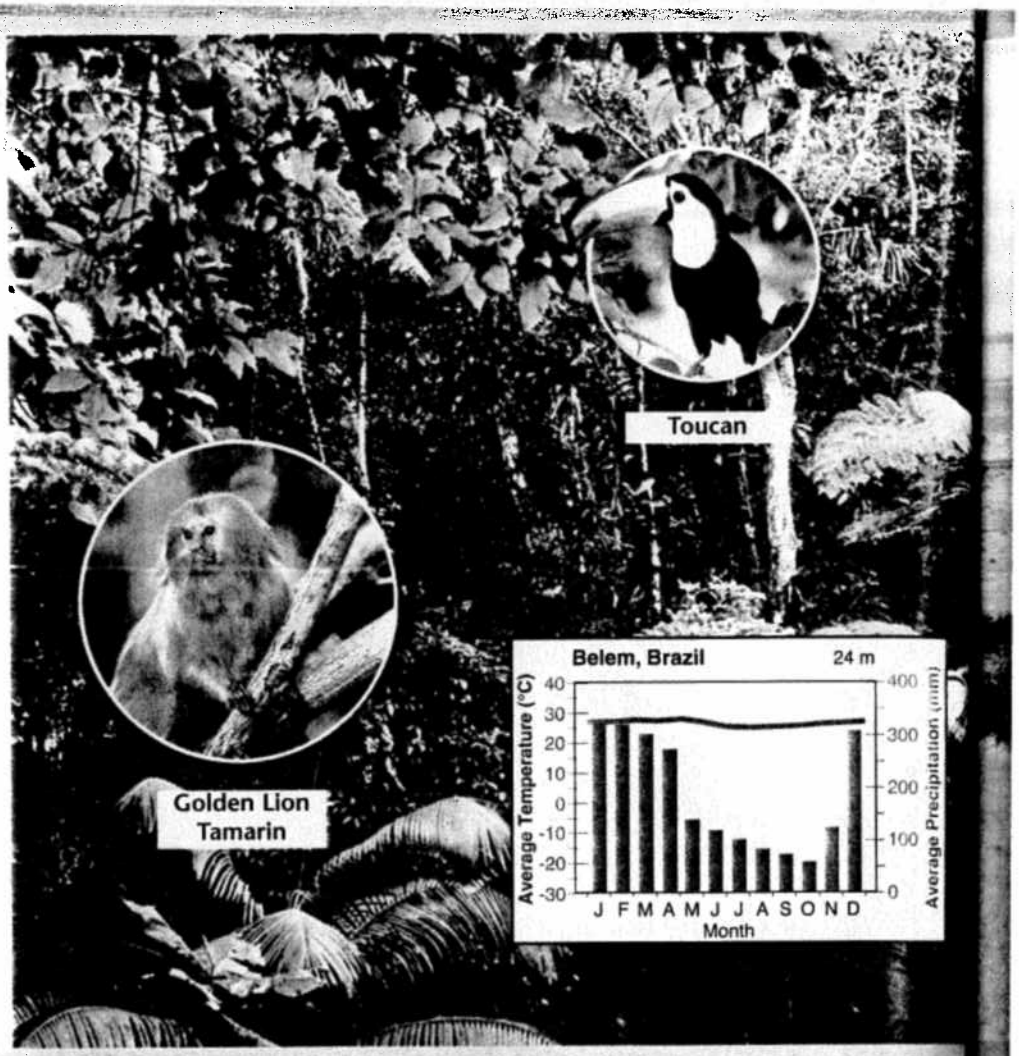
Tropical rain forests are home to more species than all other biomes combined. The leafy tops of tall trees—extending from 50 to 80 meters above the forest floor—form a dense covering called a **canopy.** In the shade below the canopy, a second layer of shorter trees and vines forms an **understory.** Organic matter that falls to the forest floor quickly decomposes, and the nutrients are recycled.

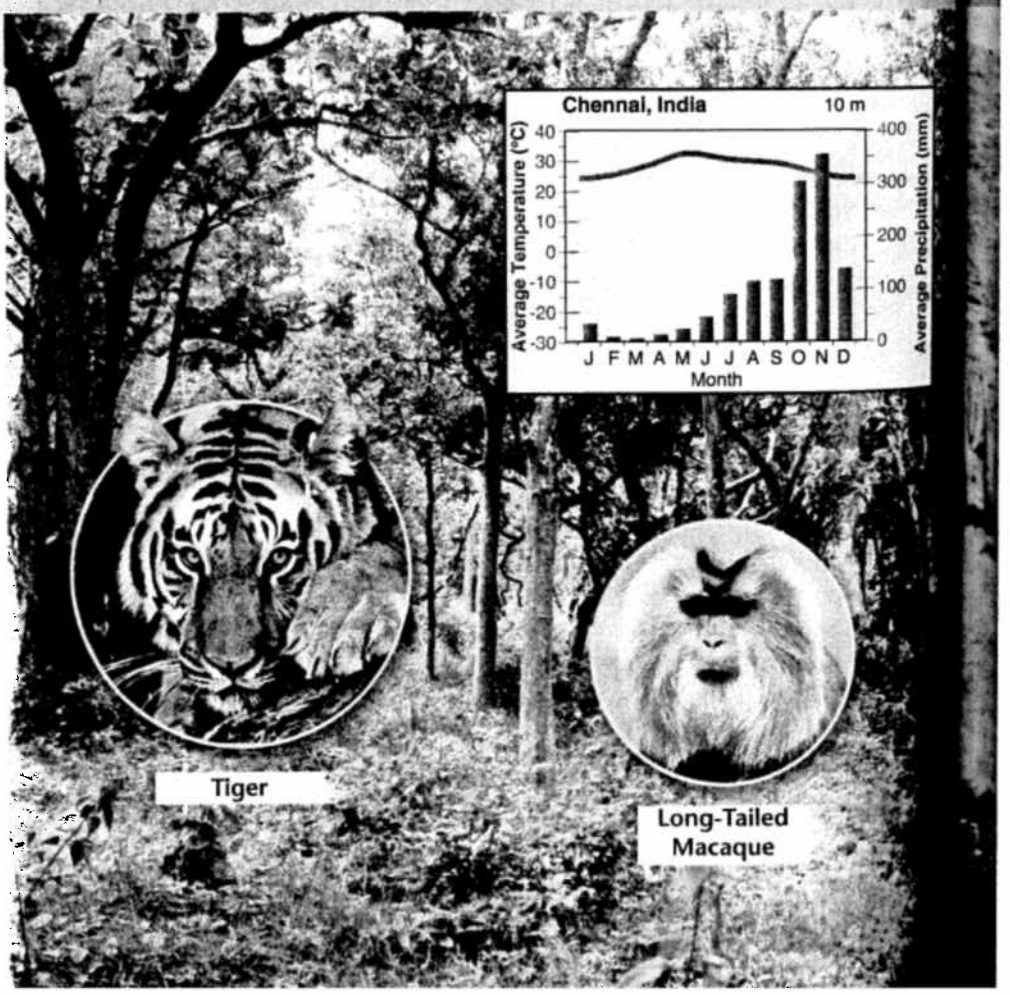
- **Abiotic factors:** hot and wet year-round; thin, nutrient-poor soils
- **Dominant plants:** broad-leaved evergreen trees; ferns; large woody vines and climbing plants; orchids and bromeliads
- **Dominant wildlife:** herbivores such as sloths, tapirs, and capybaras; predators such as jaguars; anteaters; monkeys; birds such as toucans, parrots, and parakeets; insects such as butterflies, ants, and beetles; piranhas and other freshwater fishes; reptiles such as caymans, boa constrictors, and anacondas
- **Geographic distribution:** parts of South and Central America, Southeast Asia, parts of Africa, southern India, and northeastern Australia



Tropical Dry Forest

Tropical dry forests grow in places where rainfall is highly seasonal rather than year-round. During the dry season, nearly all the trees drop their leaves to conserve water. A tree that sheds its leaves during a particular season each year is called **deciduous.**

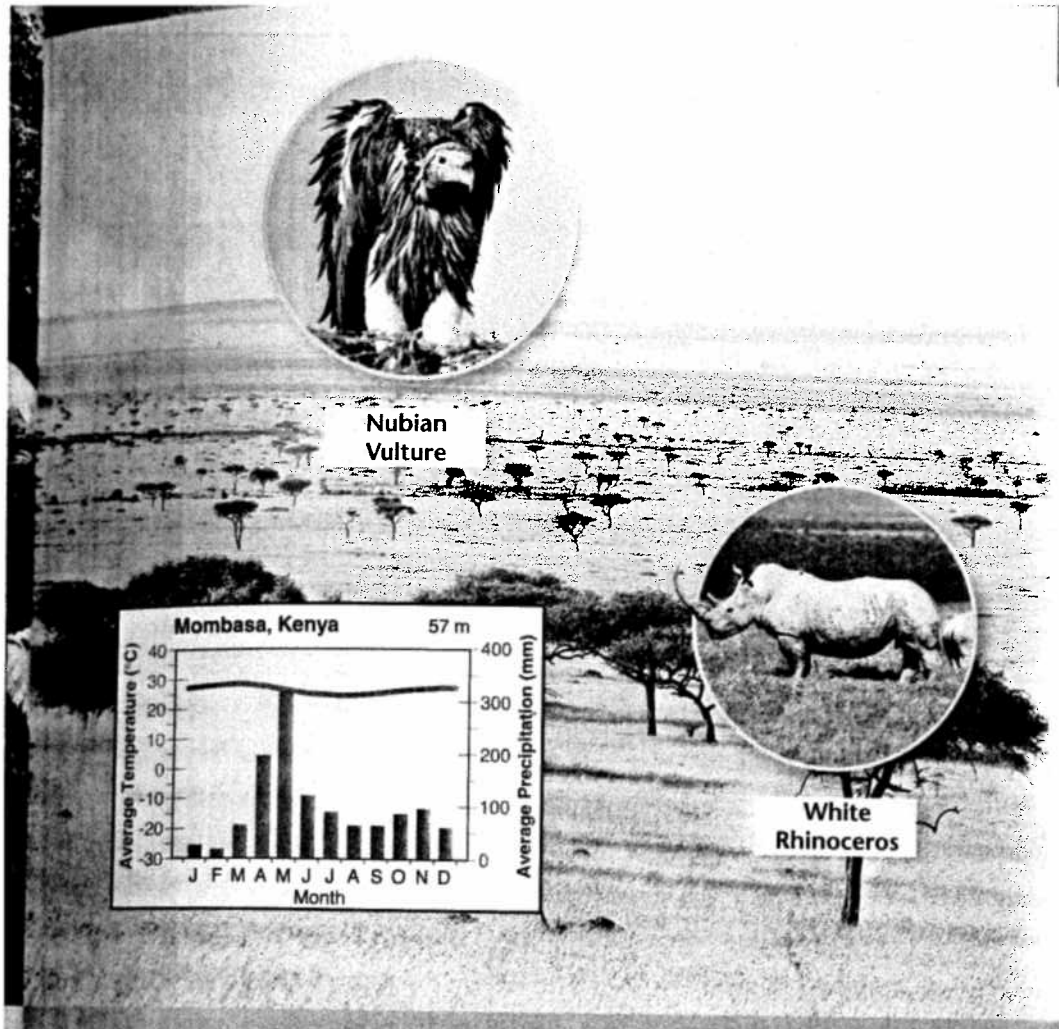
- **Abiotic factors:** generally warm year-round; alternating wet and dry seasons; rich soils subject to erosion
- **Dominant plants:** tall, deciduous trees that form a dense canopy during the wet season; drought-tolerant orchids and bromeliads; aloes and other succulents
- **Dominant wildlife:** tigers; monkeys; herbivores such as elephants, Indian rhinoceroses, hog deer; birds such as great pied hornbills, pied harriers, and spot-billed pelicans; insects such as termites; reptiles such as snakes and monitor lizards
- **Geographic distribution:** parts of Africa, South and Central America, Mexico, India, Australia, and tropical islands



Tropical Savanna

Receiving more seasonal rainfall than deserts but less than tropical dry forests, tropical savannas, or grasslands, are characterized by a cover of grasses. Savannas are spotted with isolated trees and small groves of trees and shrubs. Compact soils, fairly frequent fires, and the action of large animals such as rhinoceroses prevent some savanna areas from turning into dry forest.

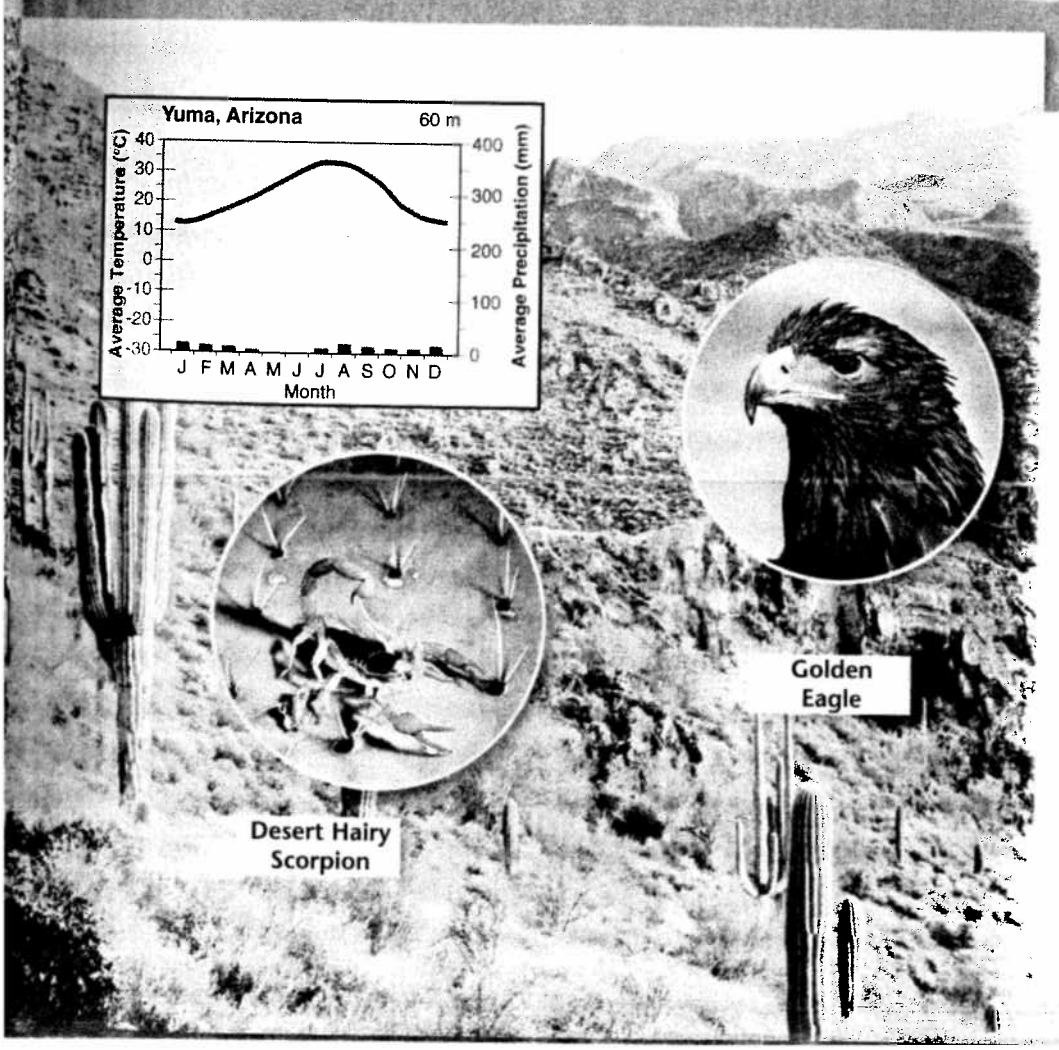
- **Abiotic factors:** warm temperatures; seasonal rainfall; compact soil; frequent fires set by lightning
- **Dominant plants:** tall, perennial grasses; sometimes drought-tolerant and fire-resistant trees or shrubs
- **Dominant wildlife:** predators such as lions, leopards, cheetahs, hyenas, and jackals; aardvarks; herbivores such as elephants, giraffes, antelopes, and zebras; baboons; birds such as eagles, ostriches, weaver birds, and storks; insects such as termites
- **Geographic distribution:** large parts of eastern Africa, southern Brazil, and northern Australia



Desert

All deserts are dry—in fact, a desert biome is defined as having annual precipitation of less than 25 centimeters. Beyond that, deserts vary greatly, depending on elevation and latitude. Many undergo extreme temperature changes during the course of a day, alternating between hot and cold. The organisms in this biome can tolerate the extreme conditions.

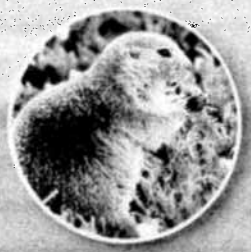
- **Abiotic factors:** low precipitation; variable temperatures; soils rich in minerals but poor in organic material
- **Dominant plants:** cacti and other succulents; creosote bush and other plants with short growth cycles
- **Dominant wildlife:** predators such as mountain lions, gray foxes, and bobcats; herbivores such as mule deer, pronghorn antelopes, desert bighorn sheep, and kangaroo rats; bats; birds such as owls, hawks, and roadrunners; insects such as ants, beetles, butterflies, flies, and wasps; reptiles such as tortoises, rattlesnakes, and lizards
- **Geographic distribution:** Africa, Asia, the Middle East, United States, Mexico, South America, and Australia



Temperate Grassland

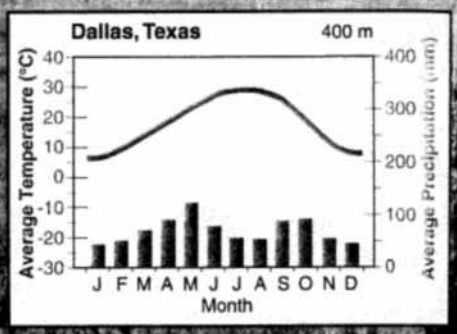
Characterized by a rich mix of grasses and underlaid by some of the world's most fertile soils, temperate grasslands—such as plains and prairies—once covered vast areas of the midwestern and central United States. Since the development of the steel plow, however, most have been converted to agricultural fields. Periodic fires and heavy grazing by large herbivores maintain the characteristic plant community.

- **Abiotic factors:** warm to hot summers; cold winters; moderate, seasonal precipitation; fertile soils; occasional fires
- **Dominant plants:** lush, perennial grasses and herbs; most are resistant to drought, fire, and cold
- **Dominant wildlife:** predators such as coyotes and badgers—historically included wolves and grizzly bears; herbivores such as mule deer, pronghorn antelopes, rabbits, prairie dogs, and introduced cattle—historically included bison; birds such as hawks, owls, bobwhites, prairie chickens, mountain plovers; reptiles such as snakes; insects such as ants and grasshoppers
- **Geographic distribution:** central Asia, North America, Australia, central Europe, and upland plateaus of South America



Black-Tailed Prairie Dog

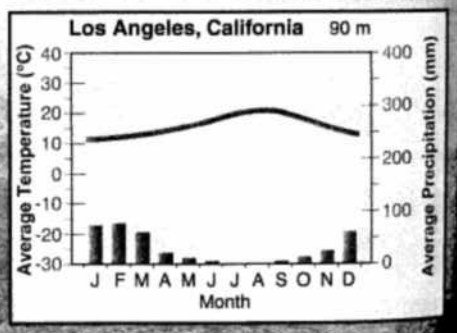
Prairie Chicken



Temperate Woodland and Shrubland

This biome is characterized by a semiarid climate and a mix of shrub communities and open woodlands. In the open woodlands, large areas of grasses and wildflowers such as poppies are interspersed with oak trees. Communities that are dominated by shrubs are also known as chaparral. The growth of dense, low plants that contain flammable oils makes fires a constant threat.

- **Abiotic factors:** hot, dry summers; cool, moist winters; thin, nutrient-poor soils; periodic fires
- **Dominant plants:** woody evergreen shrubs with small, leathery leaves; fragrant, oily herbs that grow during winter and die in summer
- **Dominant wildlife:** predators such as coyotes, foxes, bobcats, and mountain lions; herbivores such as blacktailed deer, rabbits, and squirrels; birds such as hawks, California quails, warblers and other songbirds; reptiles such as lizards and snakes; butterflies
- **Geographic distribution:** western coasts of North and South America, areas around the Mediterranean Sea, South Africa, and Australia



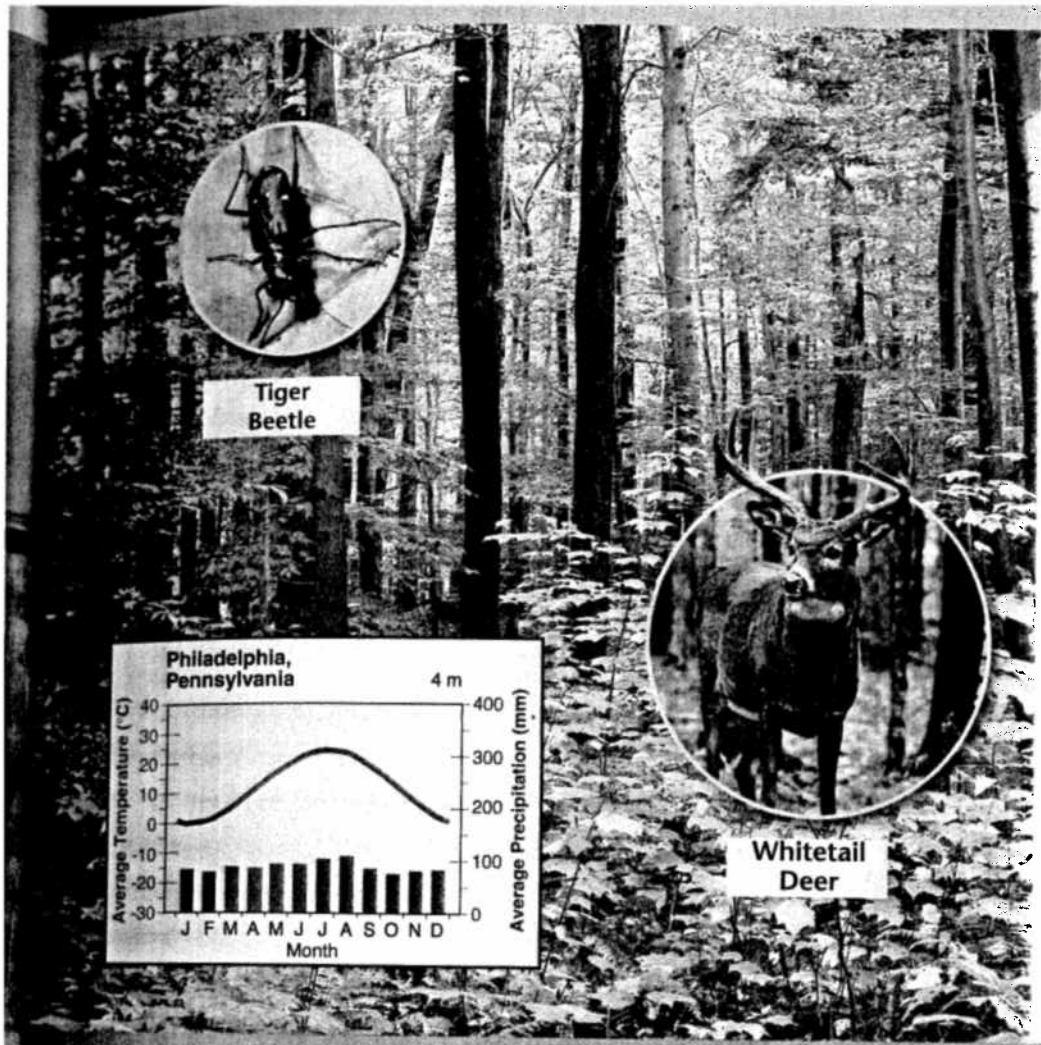
Coyote

California Slender Salamander

Temperate Forest

Temperate forests contain a mixture of deciduous and coniferous (koh-NIF-ur-us) trees. **Coniferous** trees, or conifers, produce seed-bearing cones, and most have leaves shaped like needles. These forests have cold winters that halt plant growth for several months. In autumn, the deciduous trees shed their leaves. In the spring, small plants burst out of the ground and flower. Soils of temperate forests are often rich in **humus** (HYOO-mus), a material formed from decaying leaves and other organic matter that makes soil fertile.

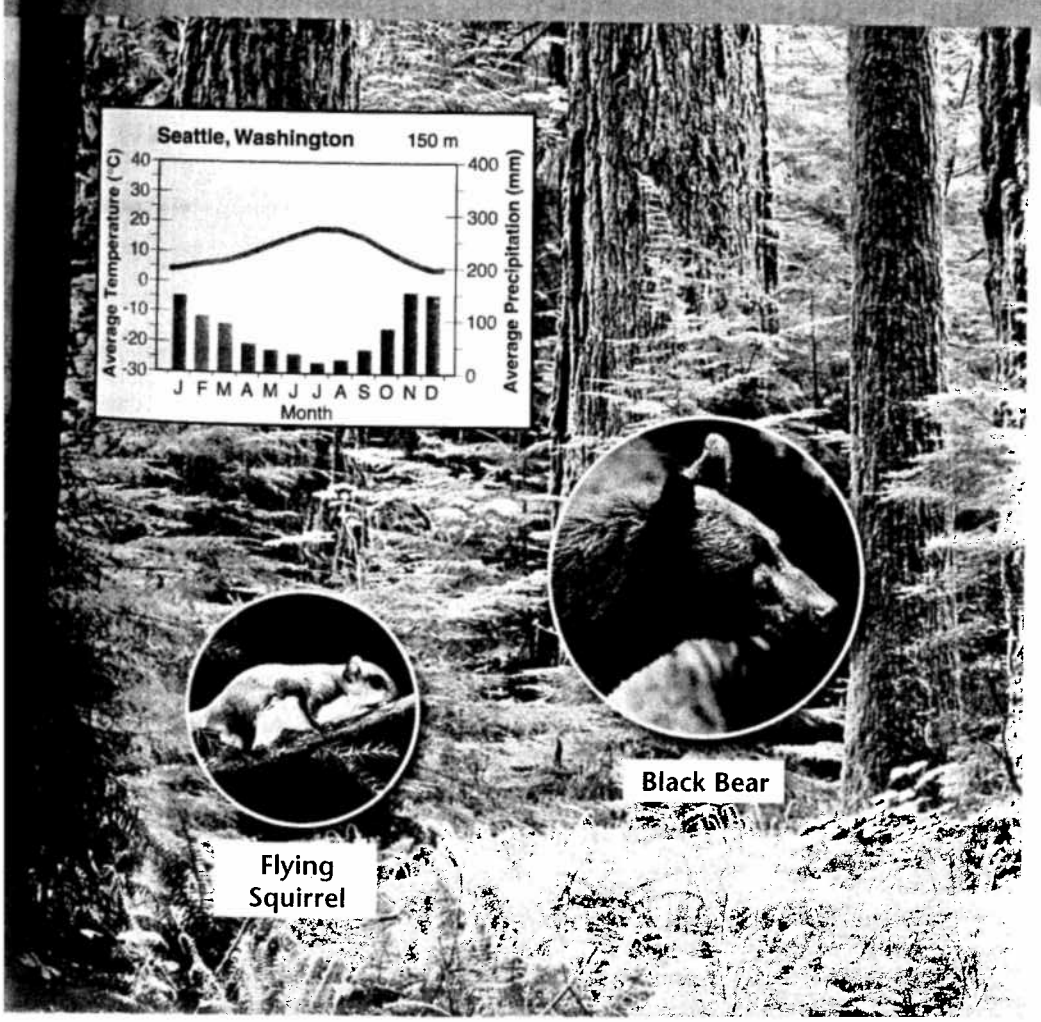
- **Abiotic factors:** cold to moderate winters; warm summers; year-round precipitation; fertile soils
- **Dominant plants:** broadleaf deciduous trees; some conifers; flowering shrubs; herbs; a ground layer of mosses and ferns
- **Dominant wildlife:** Deer; black bears; bobcats; nut and acorn feeders such as squirrels; omnivores such as raccoons and skunks; numerous songbirds; turkeys
- **Geographic distribution:** eastern United States; southeastern Canada; most of Europe; and parts of Japan, China, and Australia



Northwestern Coniferous Forest

Mild, moist air from the Pacific Ocean provides abundant rainfall to this biome. The forest is made up of a variety of conifers, ranging from giant redwoods along the coast of northern California to spruce, fir, and hemlock farther north. Moss often covers tree trunks and the forest floor. Flowering trees and shrubs such as dogwood and rhododendron are also abundant. Because of its lush vegetation, the northwestern coniferous forest is sometimes called a "temperate rain forest."

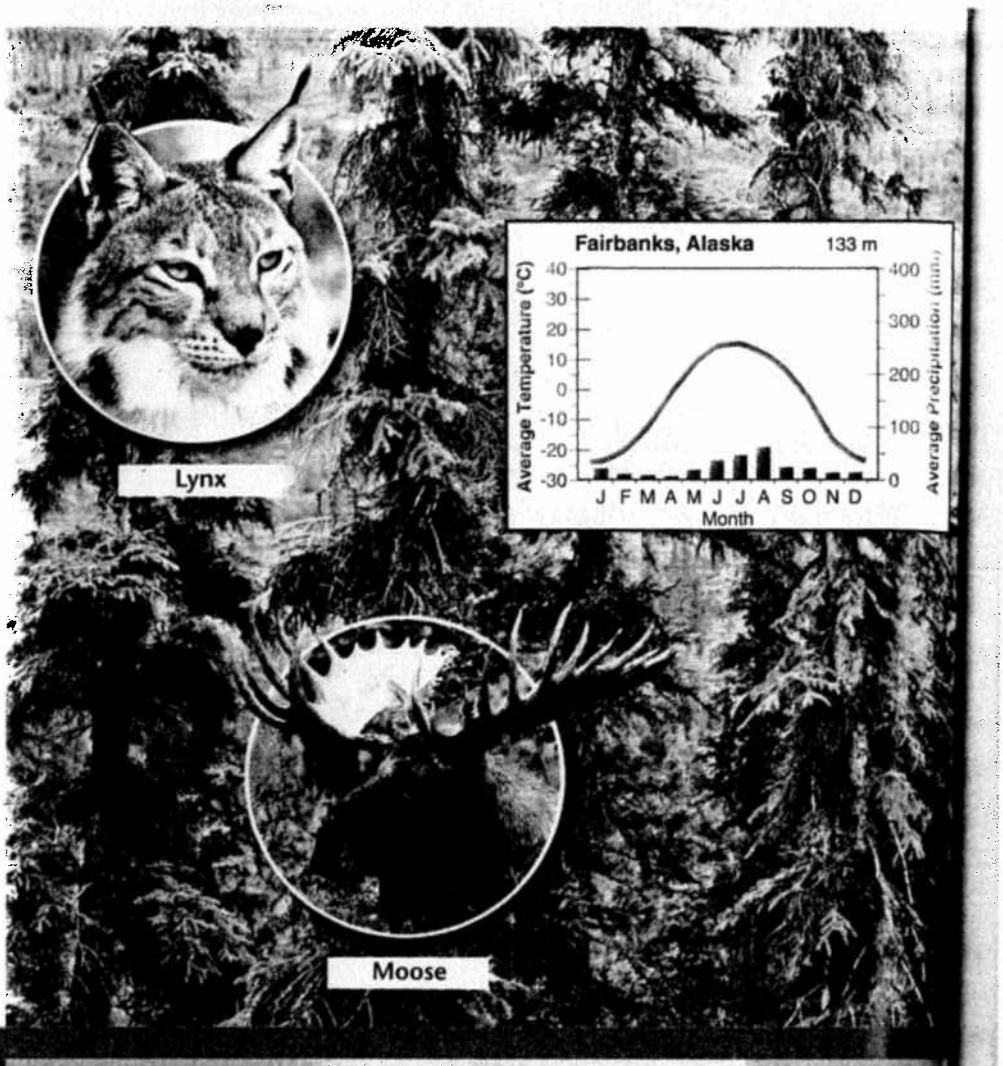
- **Abiotic factors:** mild temperatures; abundant precipitation during fall, winter, and spring; relatively cool, dry summer; rocky, acidic soils
- **Dominant plants:** Douglas fir, Sitka spruce, western hemlock, redwood
- **Dominant wildlife:** bears; large herbivores such as elk and deer; beavers; predators such as owls, bobcats, and members of the weasel family
- **Geographic distribution:** Pacific coast of northwestern United States and Canada, from northern California to Alaska



Boreal Forest

Along the northern edge of the temperate zone are dense evergreen forests of coniferous trees. These biomes 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 Hemisphere.

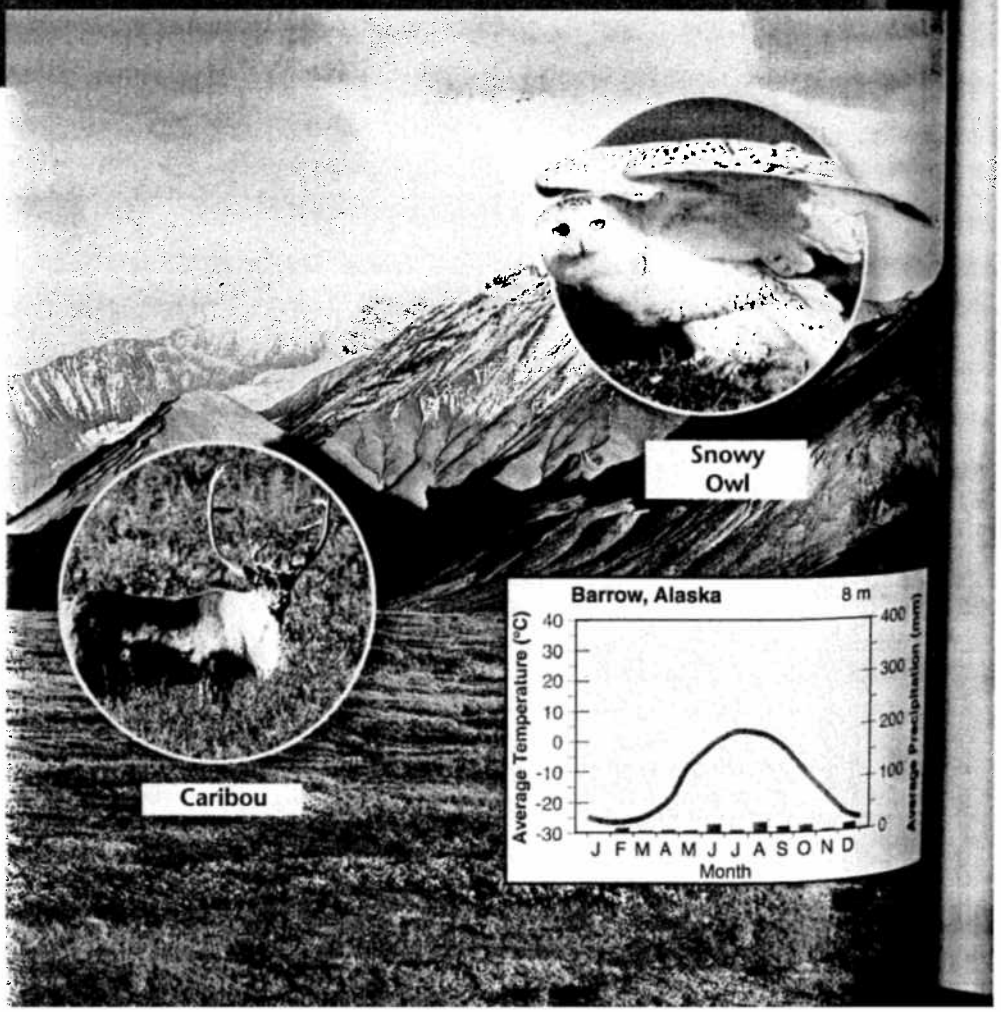
- **Abiotic factors:** long, cold winters; short, mild summers; moderate precipitation; high humidity; acidic, nutrient-poor soils
- **Dominant plants:** needleleaf coniferous trees such as spruce and fir; some broadleaf deciduous trees; small, berry-bearing shrubs
- **Dominant wildlife:** predators such as lynxes and timber wolves and members of the weasel family; small herbivorous mammals; moose and other large herbivores; beavers; songbirds and migratory birds
- **Geographic distribution:** North America, Asia, and northern Europe



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 and wet. In winter, the topsoil 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, the short growing season, and humus-poor soils also limit plant height.

- **Abiotic factors:** strong winds; low precipitation; short and soggy summers; long, cold, and dark winters; poorly developed soils; permafrost
- **Dominant plants:** ground-hugging plants such as mosses, lichens, sedges, and short grasses
- **Dominant wildlife:** a few resident birds and mammals that can withstand the harsh conditions; migratory waterfowl, shore birds, musk ox, Arctic foxes, and caribou; lemmings and other small rodents
- **Geographic distribution:** northern North America, Asia, and Europe



Other Land Areas

Some areas of land on Earth do not fall neatly into the major biome categories described on the previous pages. These areas include mountain ranges and polar ice caps.

Mountain Ranges Mountain ranges can be found on all continents. On mountains like the one in **Figure 4–12,** the abiotic and biotic conditions vary with elevation. As you move up from base to summit, temperatures become colder and precipitation increases. Therefore, the types of plants and animals also change. If you were to climb the Rocky Mountains in Colorado, for example, you would begin in a grassland. Then, you would pass through an open woodland of pines. Next, you would hike through a forest of spruce and other conifers. Near the summit, you would reach open areas of wildflowers and stunted vegetation resembling tundra. In the Canadian Rockies, ice fields occur at the peaks of some ranges.

Polar Ice Caps The icy polar regions that border the tundra are cold year-round. Outside of the ice and snow, plants and algae are few but do include mosses and lichens. In the north polar region, the Arctic Ocean is covered with sea ice, and a thick ice cap covers most of Greenland. Polar bears, seals, insects, and mites are the dominant animals. In the south polar region, the continent of Antarctica is covered by a layer of ice that is nearly 5 kilometers thick in some places. There, the dominant wildlife includes penguins and marine mammals.

▲ **Figure 4–12** Washington's Mount Rainier towers above the tree line. **Applying Concepts** *Based on what you have seen in the previous pages, which biome lies at the base of this mountain?*

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4–3 Section Assessment

1. **Key Concept** List the major biomes, and give one characteristic feature of each.
2. How are biomes classified?
3. What are the two types of tropical forest? How do they differ?
4. How might a mountain range affect the types of plants and animals found in an area?
5. **Critical Thinking Inferring** What characteristics would you expect tundra animals to have?
6. **Critical Thinking Comparing and Contrasting** Choose two very different biomes. From each biome, select a plant and an animal that are dominant. Compare how these plants' adaptations are suited to their biomes. Compare how these animals' adaptations are suited to their biomes.

Focus on the BIG Idea

Interdependence in Nature Choose one of the biomes discussed in this section. Then, depict the biome in a piece of artwork. Include the biome's characteristic plant and animal life in your art. Add labels to identify the organisms, and write a caption describing the content of the artwork.

4–4 Aquatic Ecosystems

6 5.e. Students know the number and types of organisms an ecosystem can support depend on the resources available and on abiotic factors, such as quantities of light and water, a range of temperatures, and soil composition.

Guide for Reading

Key Concepts

- What are the main factors that govern aquatic ecosystems?
- What are the two types of freshwater ecosystems?
- What are the characteristics of the different marine zones?

Vocabulary

plankton • phytoplankton
zooplankton • wetland
estuary • detritus • salt marsh
mangrove swamp
photic zone • aphotic zone
zonation • coastal ocean
kelp forest • coral reef
benthos

Reading Strategy: Making Comparisons As you read, write down statements about similarities and differences among the different types of aquatic ecosystems.

Nearly three-fourths of Earth's surface is covered with water, so it is not surprising that many organisms make their homes in aquatic habitats. Oceans, streams, lakes, and marshes—indeed, nearly any body of water—contain a wide variety of communities. These aquatic communities are governed by biotic and abiotic factors, including light, nutrient availability, and oxygen.

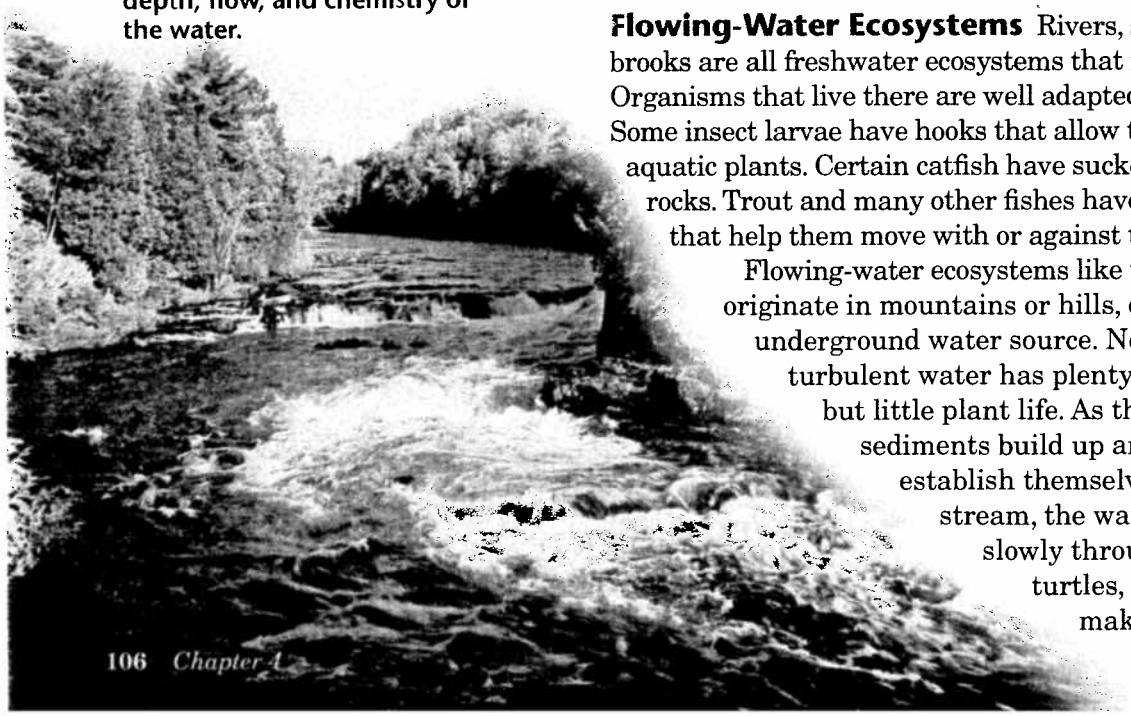
Aquatic ecosystems are determined primarily by the depth, flow, temperature, and chemistry of the overlying water. In contrast to land biomes, which are grouped geographically, aquatic ecosystems are often grouped according to the abiotic factors that affect them. One such factor is the depth of water, or distance from shore. The depth of water, in turn, determines the amount of light that organisms receive. Water chemistry refers primarily to the amount of dissolved chemicals—especially salts, nutrients, and oxygen—on which life depends. For example, communities of organisms found in shallow water close to shore can be very different from the communities that occur away from shore in deep water. One abiotic factor that is important both to biomes and aquatic ecosystems is latitude. Aquatic ecosystems in polar, temperate, and tropical oceans all have distinctive characteristics.

Freshwater Ecosystems

It may surprise you to know that only 3 percent of the surface water on Earth is fresh water. **Freshwater ecosystems can be divided into two main types: flowing-water ecosystems and standing-water ecosystems.**

Flowing-Water Ecosystems Rivers, streams, creeks, and brooks are all freshwater ecosystems that flow over the land. Organisms that live there are well adapted to the rate of flow. Some insect larvae have hooks that allow them to take hold of aquatic plants. Certain catfish have suckers that anchor them to rocks. Trout and many other fishes have streamlined bodies that help them move with or against the current.

Flowing-water ecosystems like the river in **Figure 4–13** originate in mountains or hills, often springing from an underground water source. Near the source, the turbulent water has plenty of dissolved oxygen but little plant life. As the water flows downhill, sediments build up and enable plants to establish themselves. Farther downstream, the water may meander more slowly through flat areas, where turtles, beavers, or river otters make their homes.



▼ **Figure 4–13** The Menominee River in Michigan is a flowing-water ecosystem. **Like all aquatic ecosystems, this river's communities are determined by the depth, flow, and chemistry of the water.**

Standing-Water Ecosystems Lakes and ponds are the most common standing-water ecosystems. In addition to the net flow of water in and out of these systems, there is usually water circulating within them. This circulation helps to distribute heat, oxygen, and nutrients throughout the ecosystem.

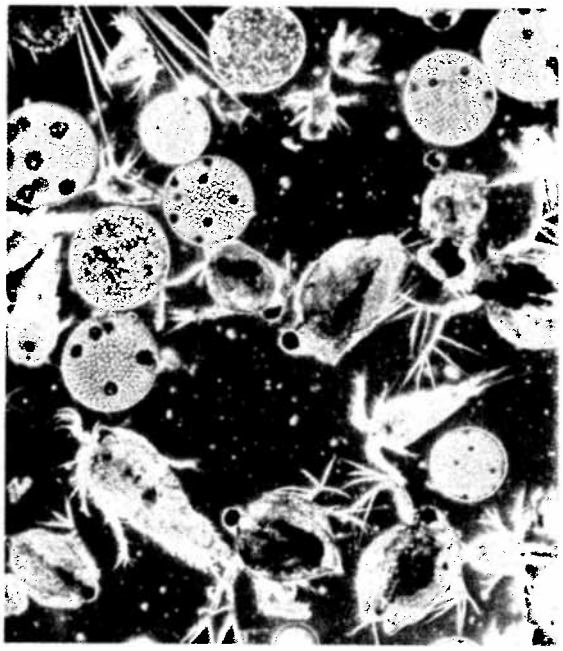
The relatively still waters of lakes and ponds provide habitats for many organisms, such as plankton, that would be quickly washed away in flowing water. **Plankton** is a general term for the tiny, free-floating organisms that live in both freshwater and saltwater environments. See **Figure 4–14** for examples. Unicellular algae, or **phytoplankton** (fyt-oh-PLANK-tun), are supported by nutrients in the water and form the base of many aquatic food webs. Planktonic animals, or **zooplankton** (zoh-oh-PLANK-tun), feed on the phytoplankton.

CHECKPOINT *What are phytoplankton?*

Freshwater Wetlands A **wetland** is an ecosystem in which water either covers the soil or is present at or near the surface of the soil for at least part of the year. The water in wetlands may be flowing or standing and fresh, salty, or brackish, which is a mixture of fresh and salt water. Many wetlands are very productive ecosystems that serve as breeding grounds for insects, fishes and other aquatic animals, amphibians, and migratory birds.

The three main types of freshwater wetlands are bogs, marshes, and swamps. Bogs, which are wetlands that are often dominated by sphagnum moss, typically form in depressions where water collects. The water in sphagnum bogs is often very acidic. Marshes are shallow wetlands along rivers. They may be underwater for all or part of the year. Marshes often contain cattails, rushes, and other tall, grasslike plants. Water flows slowly through swamps, which often look like flooded forests. The presence of trees and shrubs is what distinguishes a swamp from a marsh.

Some wetlands, such as the swamp shown in **Figure 4–15**, are wet year-round. Other kinds of wetlands, however, may not always be covered in standing water. Such areas may be classified as wetlands because they have certain kinds of soils and are wet enough to support a specific community of water-loving plants and animals.



▲ **Figure 4–14** Both freshwater and saltwater ecosystems often include plankton. This photograph shows phytoplankton, zooplankton, and larger animals called water fleas. **Predicting** *What might happen to an aquatic food web if phytoplankton were removed from the ecosystem?*

▼ **Figure 4–15** **Freshwater ecosystems can be divided into two main types: flowing-water ecosystems and standing-water ecosystems.** Although this swamp along the Loxahatchee River in Florida appears stagnant, water actually flows through it slowly. The swamp is home to turtles, otters, alligators, and herons that live among the baldcypress trees.

Word Origins

Detritus is a Latin word meaning "worn away." In ecology, detritus refers to particles that have worn away from decaying organic material. **If the Latin word *vorare* means "to devour," what is a *detritivore?***

Estuaries

Estuaries (ES-tyoo-ehr-eez) are wetlands formed where rivers meet the sea. Estuaries thus contain a mixture of fresh water and salt water, and are affected by the rise and fall of ocean tides. Many are shallow, so sufficient sunlight reaches the bottom to power photosynthesis. Primary producers include plants, algae, and both photosynthetic and chemosynthetic bacteria. Estuary food webs differ from those of more familiar ecosystems because most primary production is not consumed by herbivores. Instead, much of that organic material enters the food web as detritus. **Detritus** is made up of tiny pieces of organic material that provide food for organisms at the base of the estuary's food web. Organisms that feed on detritus include clams, worms, and sponges.

Estuaries support an astonishing amount of biomass, although they usually contain fewer species than freshwater or marine ecosystems. Estuaries serve as spawning and nursery grounds for commercially important fishes and for shellfish such as shrimps and crabs. Many young animals feed and grow in estuaries, then head out to sea to mature, and return to reproduce. Many waterfowl use estuaries for nesting, feeding, and resting during migrations.

Salt marshes are temperate-zone estuaries dominated by salt-tolerant grasses above the low-tide line, and by seagrasses under water. Salt marshes like the one shown in **Figure 4–16** (left) are (or were once) found along great stretches of eastern North America from southern Maine to Georgia. One of the largest systems of connected salt marshes in America surrounds the Chesapeake Bay estuary in Maryland.

Mangrove swamps, shown in **Figure 4–16** (right), are coastal wetlands that are widespread across tropical regions, including southern Florida and Hawaii. Here, the dominant plants are several species of salt-tolerant trees, collectively called mangroves. Seagrasses are also common below the low-tide line. Like salt marshes, mangrove swamps are valuable nurseries for fish and shellfish. The largest mangrove area in the continental United States is within Florida's Everglades National Park.

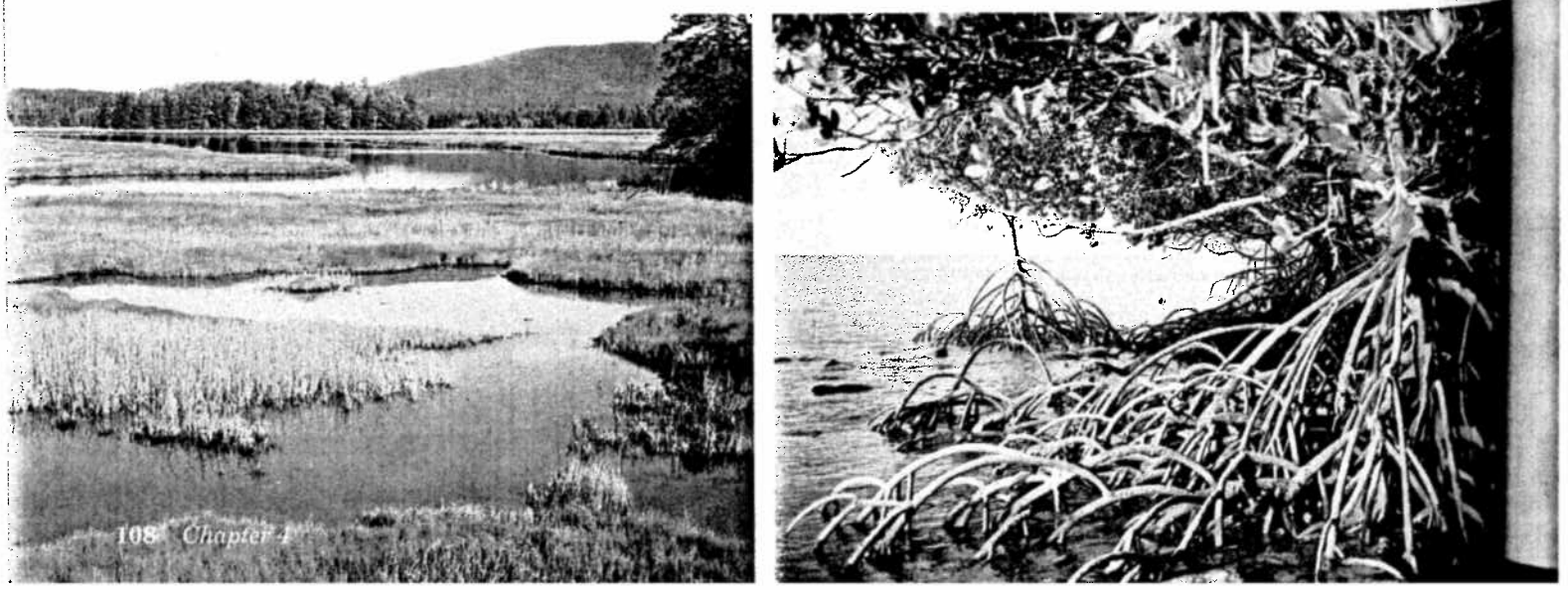
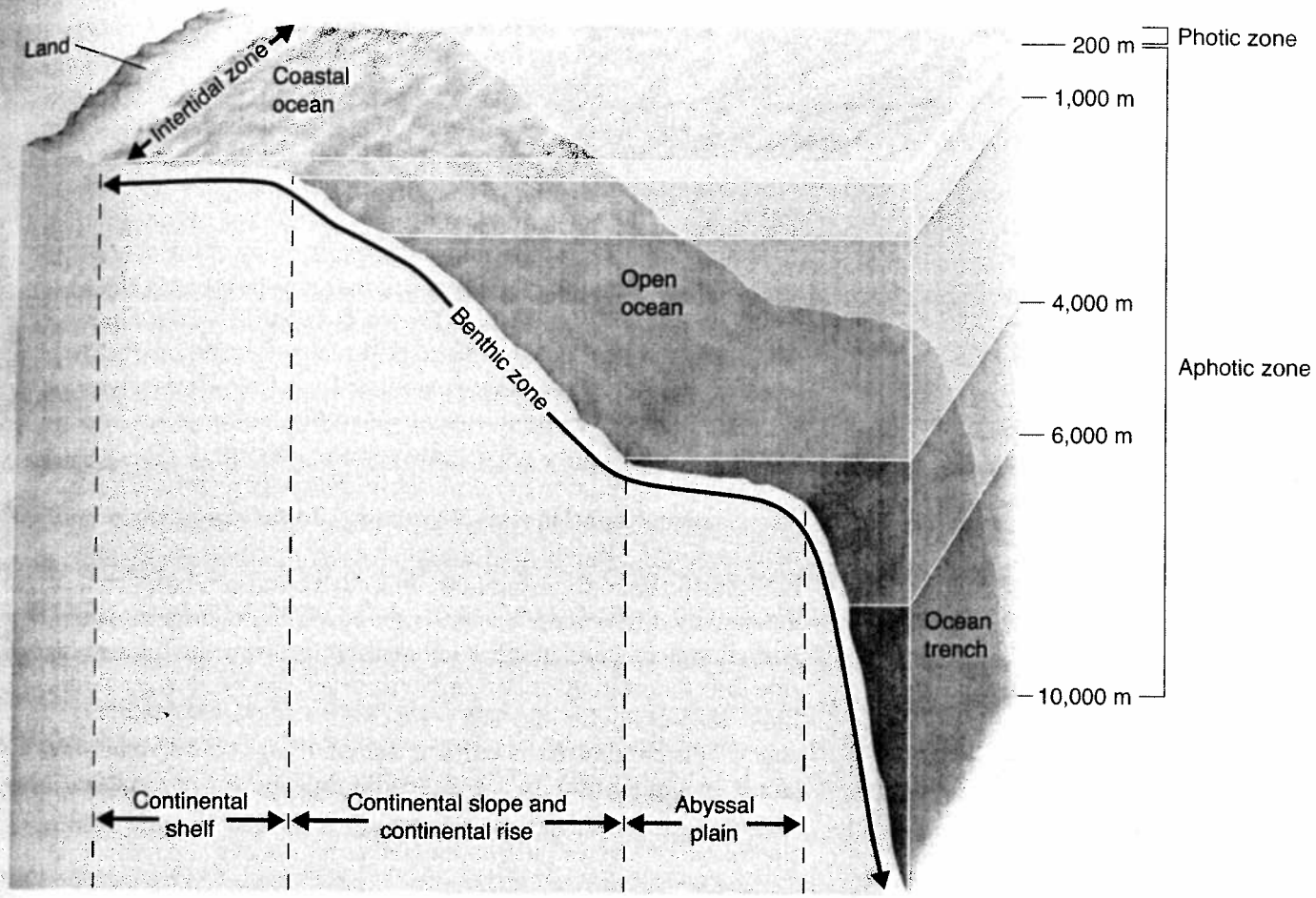


Figure 4–16 Salt marshes occur in estuaries along seacoasts in the temperate zone. Salt-tolerant grasses are the dominant plants in this salt marsh (left) along the coast of Mount Desert Island in Maine. Mangrove swamps (right) occur in bays and estuaries along tropical coasts. The stiltlike roots of mangrove trees trap sediment that accumulates as mud behind the trees. This allows other plants to take root and helps to build the mangrove forest out from the shoreline. **Predicting** ***Would you expect to find mangrove swamps or salt marshes on a coast exposed to large ocean waves? Explain.***



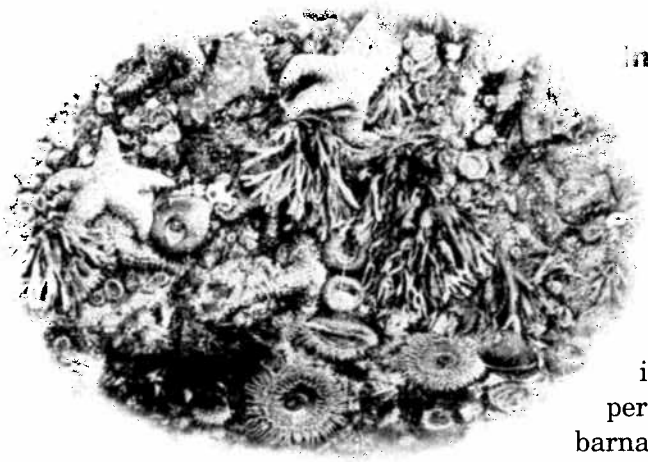
Marine Ecosystems

Unless you are an avid diver or snorkeler, it takes some imagination to picture what life is like in the vast, three-dimensional ocean. Sunlight penetrates only a relatively short distance through the surface of the water. Photosynthesis is limited to this well-lit upper layer known as the **photic** (FOH-tik) **zone.** Only in this relatively thin surface layer—typically down to a depth of about 200 meters—can algae and other producers grow. Below the photic zone is the **aphotic** (ay-FOH-tik) **zone,** which is permanently dark. Chemosynthetic autotrophs are the only producers that can survive in the aphotic zone.

There are several different classification systems that scientists use to describe marine ecosystems. **In addition to the division between the photic and aphotic zones, marine biologists divide the ocean into zones based on the depth and distance from shore: the intertidal zone, the coastal ocean, and the open ocean.** Each of these zones supports distinct ecological communities. The benthic zone covers the ocean floor and is, therefore, not exclusive to any of the other marine zones. **Figure 4–17** shows a generalized diagram of the marine zones.

✓CHECKPOINT *What factor is absent in the aphotic zone?*

▲ Figure 4–17 **The ocean can be divided into zones based on light penetration and into zones based on depth and the distance from shore.** Each zone contains a characteristic assemblage of organisms.

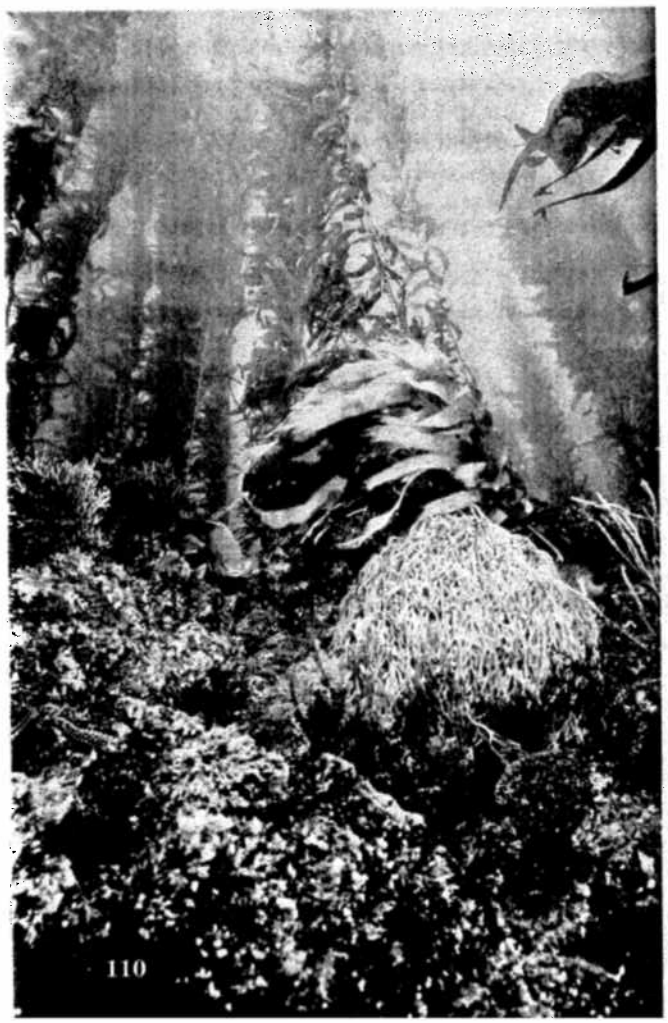


▲ **Figure 4–18** **The main divisions in the ocean based on depth and distance from shore are the intertidal zone, the coastal ocean, and the open ocean.** Along the coast of Vancouver Island in Canada, low tide reveals sea stars, seaweed, and other organisms adapted to life in the intertidal zone.

Intertidal Zone Organisms that live in the intertidal zone are exposed to regular and extreme changes in their surroundings. Once or twice a day, they are submerged in seawater. The remainder of the time, they are exposed to air, sunlight, and temperature changes. Often, organisms in this zone are battered by waves and sometimes by strong currents.

There are many different types of intertidal communities. One of the most interesting is the rocky intertidal, shown in **Figure 4–18,** which exists in temperate regions where exposed rocks line the shore. There, barnacles and seaweed permanently attach themselves to the rocks. Other organisms, such as snails, sea urchins, and sea stars, cling to the rocks by their feet or suckers.

Competition among organisms in the rocky intertidal zone often leads to zonation (zoh-NAY-shun). **Zonation** is the prominent horizontal banding of organisms that live in a particular habitat. In the rocky intertidal zone, each band can be distinguished by differences in color or shape of the major organisms. For example, a band of black algae might grow at the highest high-tide line, followed by encrusting barnacles. Lower down, clusters of blue mussels might stick out amid clumps of green algae. This zonation is similar to the pattern that you might observe as you climb up a mountain. In the intertidal zone, however, zonation exists on a smaller vertical scale—just a few meters compared to the kilometers you would ascend on a mountain.



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. The continental shelf is often shallow enough to fall mostly or entirely within the photic zone, so photosynthesis can usually occur throughout its depth. As a result, the coastal ocean is often rich in plankton and many other organisms.

One of the most productive coastal ocean communities is the kelp forest. **Kelp forests** are named for their dominant organism: a giant brown alga that can grow at extraordinary rates—as much as 50 centimeters a day. Huge forests of this seaweed are found in cold-temperate seas around the world, including those along the coasts of California and the Pacific Northwest. Kelp forests, like the one shown in **Figure 4–19,** support a complex food web that includes snails, sea urchins, sea otters, a variety of fishes, seals, and whales.

CHECKPOINT *What is the coastal ocean?*

◀ **Figure 4–19** Kelp forests are ecosystems that occur in coastal oceans. The long strands of kelp create a habitat that shelters a variety of organisms. This kelp forest off the coast of California is part of a larger zone of kelp forests found along the western coast of North America from Alaska to Mexico. **Comparing and Contrasting** *How is a kelp forest like a forest on land?*

Coral Reefs In the warm, shallow water of tropical coastal oceans are coral reefs, among the most diverse and productive environments on Earth. **Coral reefs** are named for the coral animals whose hard, calcium carbonate skeletons make up their primary structure. As you can see in **Figure 4–20,** an extraordinary diversity of organisms flourishes in these spectacular habitats.

Coral animals are tiny relatives of jellyfish that live together in vast numbers. Most coral animals are the size of your fingernail, or even smaller. Each one looks like a small sack with a mouth surrounded by tentacles. These animals use their tentacles to capture and eat microscopic creatures that float by. Coral animals cannot grow in cold water or water that is low in salt.

The types of corals that build reefs grow with the help of algae that live symbiotically within their tissues. These algae carry out photosynthesis using the coral animals' wastes as nutrients. In turn, the algae provide their coral hosts with certain essential carbon compounds. Because their algae require strong sunlight, most reef-building corals thrive only in brightly lit areas within 40 meters of the surface.

▶ **Figure 4–20** This coral reef off the island of New Britain in the Pacific Ocean supports a dazzling variety of corals and fishes. Reefs are most abundant around islands and along the eastern coasts of continents. In the United States, only the coasts of southern Florida and Hawaii have coral reefs. **Applying Concepts** *In what types of community interactions are coral animals involved?*

Analyzing Data

6IIE 7.c, 7IIE 7.c

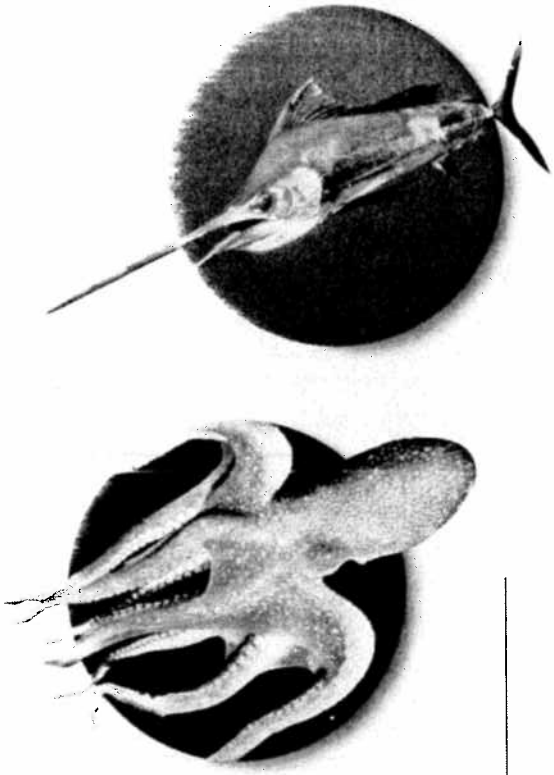
Ecosystem Productivity

The data table on the right compares the primary productivity of some of the world's ecosystems. Use the data table to answer the following questions:

1. **Using Tables and Graphs** Construct a bar graph to display the data. Use different colors to distinguish aquatic and land ecosystems.
2. **Using Tables and Graphs** According to your graph, which ecosystem is most productive? Use what you know to explain that fact.
3. **Inferring** Although the open ocean is among the least productive ecosystems, it contributes greatly to the overall productivity of the biosphere. How can this situation be explained?
4. **Applying Concepts** What are two abiotic factors that might account for the differences in productivity among the land ecosystems in the table? (*Hint:* Review the relevant biomes on pages 100–104.)

Productivity of Aquatic and Land Ecosystems

Ecosystem	Average Primary Productivity (grams of organic matter produced per square meter per year)
Aquatic Ecosystems:	
Coral reef	2500
Estuary	1800
Lake	500
Open ocean	125
Land Ecosystems:	
Tropical rain forest	2200
Temperate forest	1250
Tropical savanna	900
Tundra	90



▲ **Figure 4–21** In the open ocean, the swordfish (top) can sometimes be seen swimming near the surface, yet these fish can also dive to more than 600 meters to prey on fishes of the deep ocean. Some types of octopus (bottom) live in the depths of the open ocean, although other types live in shallow coastal waters.

Open Ocean The open ocean, often referred to as the oceanic zone, begins at the edge of the continental shelf and extends outward. It is the largest marine zone, covering more than 90 percent of the surface area of the world's oceans. The open ocean ranges from about 500 meters deep along continental slopes to more than 11,000 meters at the deepest ocean trench. Organisms in the deep ocean are exposed to high pressure, frigid temperatures, and total darkness.

Typically, the open ocean has very low levels of nutrients and supports only the smallest producers. Productivity is generally low. Still, because of the enormous area, most of the photosynthetic activity on Earth occurs in the part of the open ocean within the photic zone. Fishes of all shapes and sizes dominate the open ocean. The swordfish and the octopus in **Figure 4–21** are just two examples of the organisms found in this zone. Marine mammals such as dolphins and whales also live there but must stay close to the surface to breathe.

Benthic Zone The ocean floor contains organisms that live attached to or near the bottom, such as sea stars, anemones, and marine worms. Scientists refer to these organisms as the **benthos.** That is why the ocean floor is called the benthic zone. This zone extends horizontally along the ocean floor from the coastal ocean through the open ocean.

Benthic ecosystems often depend on food from organisms that grow in the photic zone, particularly the producers. Animals that are attached to the bottom or do not move around much, such as clams and sea cucumbers, feed on pieces of dead organic material, or detritus, that drift down from the surface waters. Near deep-sea vents, where superheated water boils out of cracks on the ocean floor, dwell chemosynthetic primary producers that support life without light and photosynthesis.

4–4 Section Assessment

1. **Key Concept** List three characteristics that determine the structure of aquatic ecosystems.
2. **Key Concept** Compare standing-water ecosystems to flowing-water ecosystems. How are they alike? How are they different?
3. **Key Concept** List six distinct ecological zones that can be found in the ocean. Give two abiotic factors for each zone.
4. Define the terms *wetland* and *estuary*. Give at least one example of a freshwater wetland and of an estuary.
5. **Critical Thinking Predicting** How might the damming of a river affect an estuary at the river's mouth?

Writing in Science

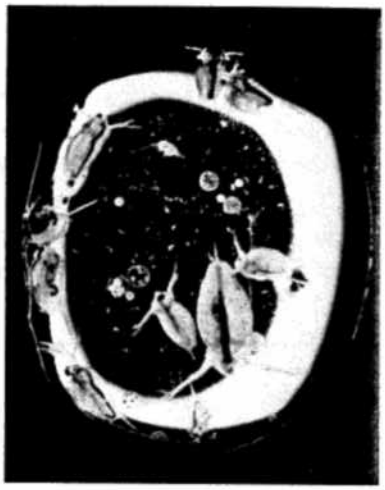
Comparing and Contrasting

Choose three different aquatic ecosystems. From each of these ecosystems, select a plant and an animal and describe how the organisms are adapted to their environments. Show comparisons. *Hint*: Create a table to organize your ideas.

Exploration

6IIE 7.c, BIIE 1.a, BIIE 1.i

Observing Succession



The most obvious examples of succession involve large organisms, such as plants and animals. In this investigation, you will determine whether succession also occurs in a community of microorganisms.

Problem What changes occur in a microscopic community over time?

Materials

- 1000-mL beaker or large jar
- soil
- grass clippings
- dried leaves
- 600 mL aged water
- 4 coverslips
- 4 glass slides
- 4 dropper pipettes
- microscope
- reference book or chart for identifying common microorganisms

Skills Using Tables and Graphs, Analyzing Data

Procedure

1. Place enough soil in the 1000-mL beaker to cover the bottom. Fill the beaker with a loosely packed mixture of grass clippings and dried leaves, and add the aged water.
2. Set the beaker aside in a cool place where it can remain undisturbed for 24 hours.
3. After 24 hours, check the water for signs of life. A strong odor or cloudy water is evidence of bacterial growth; fuzzy growths or threads indicate the presence of mold; and a green tint is due to algae. Record your observations.
4. Use a dropper pipette to transfer a drop of water from the beaker to a microscope slide. Add a coverslip.
5. Examine the slide under the low-power objective of the microscope to locate any microorganisms. Then, switch to high power. Use a reference book or chart to identify the organisms. Record the date and your observations, including labeled drawings, the number of each type of organism in your field of view, and the magnification.
6. Repeat steps 4 and 5 with water samples from several different areas of the beaker.
7. Repeat steps 3 through 6 every day for 2 weeks. Note any changes in the number or types of organisms in the beaker.
8. Wash your hands thoroughly with soap and warm water before leaving the lab.

Analyze and Conclude

1. **Using Tables and Graphs** Make a graph of the population of each type of organism. Plot time on the *x*-axis and number of organisms per field of view on the *y*-axis. With your teacher's guidance, select the equipment and technology to use—either graph paper or a graphing calculator.
2. **Observing** How did the number and variety of organisms in the beaker change over the 2-week period?
3. **Analyzing Data** What kinds of organisms appeared first in the microscopic water community? Which appeared last? How can you explain these changes?
4. **Drawing Conclusions** Do your observations support the idea that succession occurs in communities of microorganisms? Explain your answer.

Go Further

Analyzing Data With your teacher's approval, set up a simple community of only a few known species of microorganisms. Observe the community for two weeks, and try to explain any evidence of succession that you observe.

Chapter 4 Study Guide

4–1 The Role of Climate

Key Concepts

- Carbon dioxide, methane, water vapor, and a few other atmospheric gases trap heat energy and maintain Earth's temperature range.
- As a result of differences in latitude and thus the angle of heating, Earth has three main climate zones: polar, temperate, and tropical.

Vocabulary
weather, p. 87
climate, p. 87
greenhouse effect, p. 87
polar zone, p. 88
temperate zone, p. 88
tropical zone, p. 88

4–2 What Shapes an Ecosystem?

Key Concepts

6 5.c, 6 5.e

- Together, biotic and abiotic factors determine the survival and growth of an organism and the productivity of the ecosystem in which the organism lives.
- Community interactions, such as competition, predation, and various forms of symbiosis, can powerfully affect an ecosystem.
- Ecosystems are constantly changing in response to natural and human disturbances. As an ecosystem changes, older inhabitants gradually die out and new organisms move in, causing further changes in the community.

Vocabulary
biotic factor, p. 90
abiotic factor, p. 90
habitat, p. 90
niche, p. 91
resource, p. 92
competitive exclusion principle, p. 92
predation, p. 93
symbiosis, p. 93
mutualism, p. 93
commensalism, p. 93
parasitism, p. 93
ecological succession, p. 94
primary succession, p. 94
pioneer species, p. 94
secondary succession, p. 95

4–3 Biomes

Key Concept

6 5.e

- The world's major biomes include tropical rain forest, tropical dry forest, tropical savanna, temperate grassland, desert, temperate woodland and shrubland, temperate forest, northwestern coniferous forest, boreal forest, and tundra. Each of these biomes is defined by a unique set of abiotic factors—particularly climate—and has a characteristic ecological community.

Vocabulary
biome, p. 98 • tolerance, p. 98
microclimate, p. 98 • canopy, p. 100
understory, p. 100 • deciduous, p. 100
coniferous, p. 103 • humus, p. 103
taiga, p. 104 • permafrost, p. 104

4–4 Aquatic Ecosystems

Key Concepts

6 5.e

- Aquatic ecosystems are determined primarily by the depth, flow, temperature, and chemistry of the overlying water.
- Freshwater ecosystems can be divided into two main types: flowing-water ecosystems and standing-water ecosystems.
- In addition to the division between the photic and aphotic zones, marine biologists also divide the ocean into zones based on the depth and distance from shore: the intertidal zone, the coastal ocean, and the open ocean.

Vocabulary
plankton, p. 107 • phytoplankton, p. 107
zooplankton, p. 107 • wetland, p. 107
estuary, p. 108 • detritus, p. 108
salt marsh, p. 108 • mangrove swamp, p. 108
photic zone, p. 109 • aphotic zone, p. 109
zonation, p. 110 • coastal ocean, p. 110
kelp forest, p. 110 • coral reef, p. 111
benthos, p. 112

Thinking Visually

Using information from this chapter, create a concept map that includes the following terms: *abiotic factors, biotic factors, community interactions, predation, competition, symbiosis, nutrients, ecosystems, light, oxygen.*

Chapter 4 Assessment

Reviewing Content

Choose the letter that best answers the question or completes the statement.

1. The average, year-after-year conditions of temperature and precipitation within a particular region are its
   a. weather. **c.** greenhouse effect.
   b. climate. **d.** biotic factors.

2. The greenhouse effect causes an increase in
   a. carbon dioxide.
   b. temperature.
   c. oxygen.
   d. water.

3. All the biotic and abiotic factors in a pond form a(an)
   a. biosphere.
   b. ecosystem.
   c. community.
   d. niche.

4. A relationship in which one organism is helped and another organism is neither helped nor hurt is called
   a. mutualism.
   b. parasitism.
   c. competition.
   d. commensalism.

5. A form of symbiosis in which both organisms benefit is called
   a. mutualism.
   b. parasitism.
   c. commensalism.
   d. predation.

6. A type of symbiosis in which one organism benefits and the other is harmed is called
   a. mutualism.
   b. parasitism.
   c. commensalism.
   d. succession.

7. Natural disturbances, such as fires or hurricanes, can result in
   a. commensalism. **c.** parasitism.
   b. competition. **d.** succession.

8. In a tropical rain forest, the dense covering formed by the leafy tops of tall trees is called the
   a. canopy. **c.** niche.
   b. taiga. **d.** understory.

9. Organisms that live near or on the ocean floor are called
   a. parasites. **c.** plankton.
   b. benthos. **d.** mangroves.

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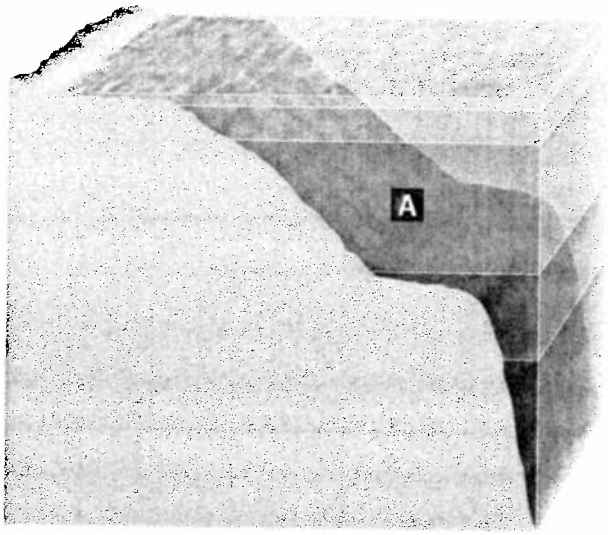
10. In the diagram of the ocean below, the feature labeled **A** is the
    a. open ocean. **c.** trench.
    b. coastal ocean. **d.** estuary.



Understanding Concepts

11. Distinguish between weather and climate.

12. Describe the major abiotic factors that produce Earth's main climate zones.

13. What is the difference between an organism's habitat and its niche?

14. What is the competitive exclusion principle?

15. What type of succession occurs after lava from a volcanic eruption covers an area?

16. Describe two major causes of ecological succession.

17. What is a biome?

18. What are two abiotic factors that cause deciduous trees to shed their leaves?

19. Describe the dominant vegetation found in a North American temperate forest.

20. Why are plants generally few and far between in a desert?

21. What is the meaning of the term *plankton*? Name the two types of plankton.

22. What are three types of freshwater wetlands?

23. How does the photic zone differ from the aphotic zone?

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

25. What are coral reefs? Explain.

Critical Thinking

26. **Using Tables and Graphs** Using graph paper, construct a climate diagram for Lillehammer. Base your diagram on the ones for the biomes in this chapter. Use the completed diagram to identify the biome that is most likely to occur in Lillehammer.

Climate Data for Lillehammer, Norway

Month	Average Temperature (°C)	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

27. **Applying Concepts** Although the amount of precipitation is low, most parts of the tundra are very wet during the summer. What characteristics would explain this apparent contradiction?

28. **Formulating Hypotheses** The deep ocean is within the aphotic zone and is also very cold. Suggest some of the unique characteristics that might enable animals to live in the deep ocean.

29. **Inferring** Certain deciduous trees grow in tropical dry forests and 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. Suppose there is an especially dry summer. How might the adaptation of dropping leaves enable a tree to tolerate the drought?

30. **Predicting** 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 might this area look like in 5 years? In 50 years?

31. **Inferring** Consider these two biomes: (1) the temperate grassland and (2) the temperate woodland and shrubland. Animals such as coyotes are known to live in both biomes. Describe two adaptations that might enable an animal to tolerate these two different biomes. Discuss the coyote or an animal of your choice.

32. **Making Judgments** A developer has proposed filling in a salt marsh to create a coastal resort. What positive and negative effects might this proposal have on wildlife and local residents? Would you support the proposal? Why or why not?

33. **Inferring** Competition for resources in an area is usually more intense within a single species than between two different species. Can you explain this observation? (*Hint*: Consider how niches help organisms of different species avoid competition.)

Focus on the BIG Idea

Interdependence in Nature Write a description of your niche in the environment. Include details about your ecosystem, including 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.

Writing in Science

Select one of the ten major biomes. Write an overview of the characteristics of that biome. Explain how the abiotic factors and the dominant plants and wildlife are interrelated. Support your explanation with specific examples. (*Hint:* Review the descriptions of the biomes on pages 100–104.)

Performance-Based Assessment

Creating a Web Site A travel agent has asked you to develop a Web site on a biome of your choice. The goal of the site is to encourage tourism to the biome. Present accurate scientific information and images depicting the biome. Create a storyboard for this site, including the home page and two hot links.

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Test-Taking Tip When you are asked to analyze a graph showing experimental data, first look at the shape of the curve. Identify the variables, and try to determine how they are related. Then, read and answer the questions about the graph.

Directions: Choose the letter that best answers the question or completes the statement.

1. Generally, which has the greatest effect on determining the climate of a region? **BI 6.b**
   - **A** longitude
   - **B** dominant plant species
   - **C** distance from the equator
   - **D** month of the year

2. Which is NOT an abiotic factor in an ecosystem? **6 5.e**
   - **A** amount of plants
   - **B** light
   - **C** temperature
   - **D** rainfall

3. What defines a species' niche?
   - **A** abiotic factors
   - **B** biotic factors
   - **C** food web
   - **D** all of the above

4. The disappearance of a population in a given niche as a result of direct competition with another species for a resource is called **BI 6.a**
   - **A** competitive exclusion.
   - **B** predation.
   - **C** parasitism.
   - **D** commensalism.

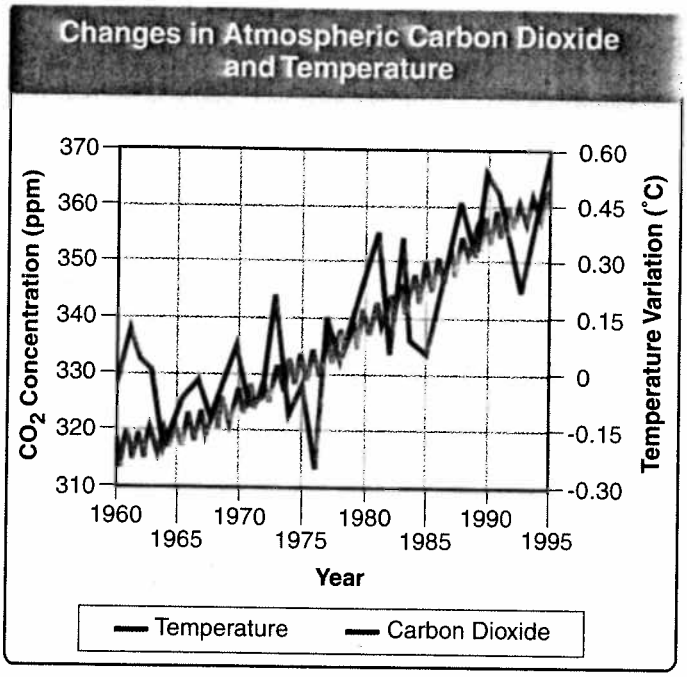
5. In which marine zone are you likely to find algae growing?
   - **A** intertidal zone
   - **B** photic zone
   - **C** aphotic zone
   - **D** both A and B

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

7. The attachment of barnacles to a whale's skin is an example of **6 5.c**
   - **A** competition.
   - **B** predation.
   - **C** mutualism.
   - **D** commensalism.

Questions 8–9

From 1960 to 1995, scientists recorded the concentration of carbon dioxide in the atmosphere and the average temperature at a remote site in Hawaii. Their data are shown in the graph.



8. Based on the graph, which of the following is most likely?
   - **A** Carbon dioxide levels and overall temperature will increase.
   - **B** Carbon dioxide levels will soon decline.
   - **C** Warm temperatures are increasing the carbon dioxide concentration.
   - **D** The variables are indirectly proportional.

9. Which of the following would most likely cause an increase in atmospheric carbon dioxide?
   - **A** increased biomass
   - **B** a faster rate of photosynthesis
   - **C** melting of the polar ice caps
   - **D** increased burning of fossil fuels