

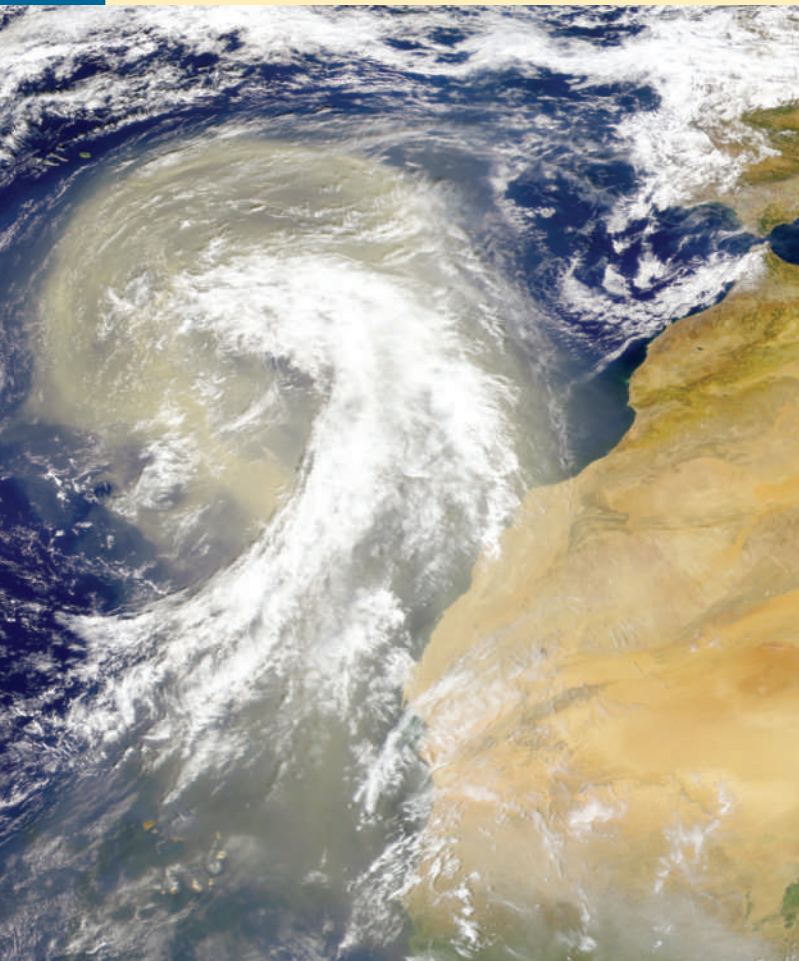
## 7

# Climate and Terrestrial Biodiversity

## CORE CASE STUDY

### Blowing in the Wind: Connections between Wind, Climate, and Biomes

Terrestrial biomes such as deserts, grasslands, and forests make up one of the components of the earth's biodiversity (Figure 4-2, p. 79). Why is one area of the earth's land surface a desert, another a grassland, and another a forest? The general answer lies in differences in *climate*, resulting mostly from long-term differences in average temperature and precipitation caused by global air circulation, which we discuss in this chapter.



Seawifs Project/Nasa/GSFC, Nasa

**Figure 7-1** Some of the dust blown from West Africa, shown here, can end up as soil nutrients in Amazonian rain forests and toxic air pollutants in the U.S. state of Florida and in the Caribbean. It may also help to suppress hurricanes in the western Atlantic.

Wind—an indirect form of solar energy—is an important factor in the earth's climate. It is part of the planet's circulatory system for heat, moisture, plant nutrients, soil particles, and long-lived air pollutants. Without wind, the tropics would be unbearably hot and most of the rest of the planet would freeze.

Winds transport nutrients from one place to another. For example, winds carry dust that is rich in phosphates and iron across the Atlantic Ocean from the Sahara Desert in West Africa (Figure 7-1). These deposits help to build agricultural soils in the Bahamas and to supply nutrients for plants in the upper canopies of rain forests in Brazil. A 2007 study indicated that in 2006, such dust might have helped to reduce hurricane frequency in the southwestern North Atlantic and Caribbean by blocking some energizing sunlight. Dust blown from China's Gobi Desert deposits iron into the Pacific Ocean between Hawaii and Alaska. The iron stimulates the growth of phytoplankton, the minute producers that support ocean food webs. Wind is also a rapidly growing source of renewable energy, as discussed in Chapter 16.

Winds also have a downside. They transport harmful substances. Particles of reddish-brown soil and pesticides banned in the United States are blown from Africa's deserts and eroding farmlands into the sky over the U.S. state of Florida. Some types of fungi in this dust may play a role in degrading or killing coral reefs in the Florida Keys and in the Caribbean.

Particles of iron-rich dust from Africa also enhance the productivity of algae, and have been linked to outbreaks of toxic algal blooms—referred to as *red tides*—in Florida's coastal waters. People who eat shellfish contaminated by a toxin produced in red tides can become paralyzed or can even die. These red tides can also cause fish kills.

Dust, soot, and other long-lived air pollutants from rapidly industrializing China and central Asia are blown across the Pacific Ocean and degrade air quality over parts of the western United States. Asian pollution makes up as much as 10% of West Coast smog—a problem that is expected to get worse as China continues to industrialize. A 2007 study, led by Renyl Zhang, linked such Asian air pollution to intensified storms over the North Pacific Ocean and to increased warming in the polar regions.

The ecological lesson: *Everything we do affects some other part of the biosphere because everything is connected.* In this chapter, we examine the key role that climate, including winds, plays in the formation and location of the deserts, grasslands, and forests that make up an important part of the earth's terrestrial biodiversity.

## Key Questions and Concepts

### 7-1 What factors influence climate?

**CONCEPT 7-1** An area's climate is determined mostly by solar radiation, the earth's rotation, global patterns of air and water movement, gases in the atmosphere, and the earth's surface features.

### 7-2 How does climate affect the nature and locations of biomes?

**CONCEPT 7-2** Differences in average annual precipitation and temperature lead to the formation of tropical, temperate, and cold deserts, grasslands, and forests, and largely determine their locations.

### 7-3 How have we affected the world's terrestrial ecosystems?

**CONCEPT 7-3** In many areas, human activities are impairing ecological and economic services provided by the earth's deserts, grasslands, forests, and mountains.

*Note:* Supplements 2 (p. S4), 4 (p. S20), 5 (p. S31), 8 (p. 47), 10 (p. S59), and 13 (p. S78) can be used with this chapter.

*To do science is to search for repeated patterns,  
not simply to accumulate facts,  
and to do the science of geographical ecology  
is to search for patterns of plant and animal life  
that can be put on a map.*

ROBERT H. MACARTHUR

## 7-1 What Factors Influence Climate?

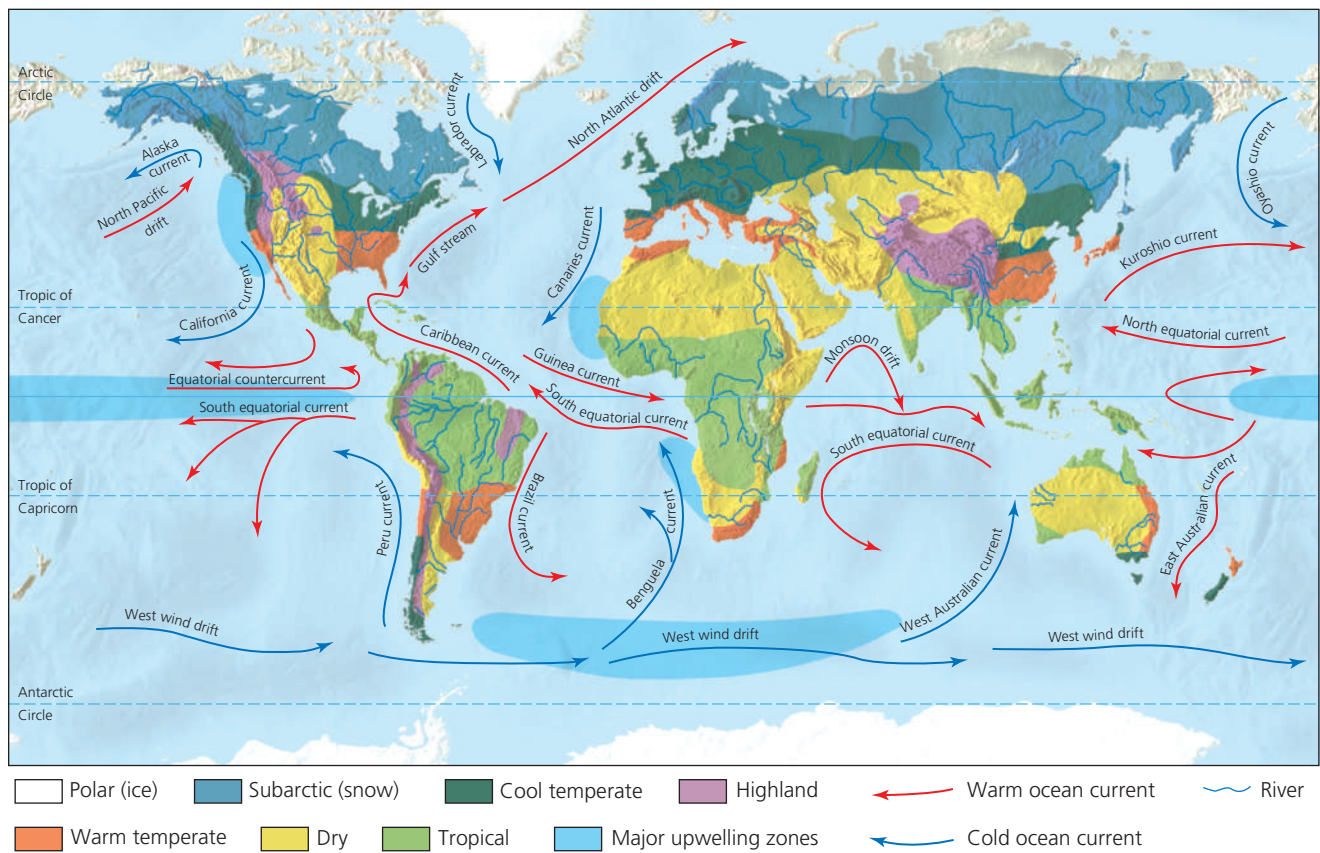
► **CONCEPT 7-1** An area's climate is determined mostly by solar radiation, the earth's rotation, global patterns of air and water movement, gases in the atmosphere, and the earth's surface features.

### The Earth Has Many Different Climates

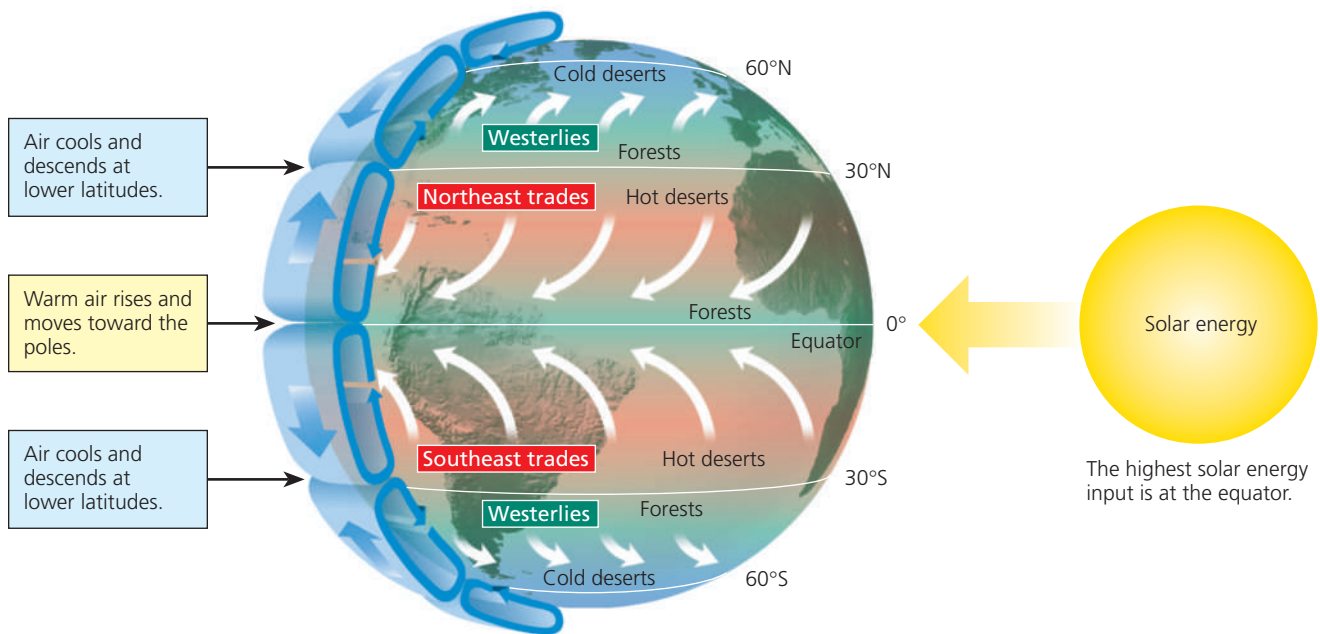
**Weather** is a local area's short-term temperature, precipitation, humidity, wind speed, cloud cover, and other physical conditions of the lower atmosphere as measured over hours or days. (Supplement 8, p. S47, introduces you to weather basics.) **Climate** is an area's general pattern of atmospheric or weather conditions measured over long periods of time ranging from decades to thousands of years. As American writer and humorist Mark Twain once said, "Climate is what we expect, weather is what we get." Figure 7-2 (p. 142), depicts the earth's major climate zones, an important component of the earth's natural capital (Figure 1-3, p. 8).

Climate varies in different parts of the earth mostly because patterns of global air circulation and ocean currents distribute heat and precipitation unevenly (Figure 7-3, p. 142). Three major factors determine how air circulates in the lower atmosphere, which helps to distribute heat and moisture from the tropics to other parts of the world:

- *Uneven heating of the earth's surface by the sun.* Air is heated much more at the equator, where the sun's rays strike directly, than at the poles, where sunlight strikes at a slanted angle and spreads out over a much greater area (Figure 7-3, right). These differences in the distribution of incoming solar energy help to explain why tropical regions near the equator are hot, why polar regions are cold, and why temperate regions in between generally have intermediate average temperatures.
- *Rotation of the earth on its axis.* As the earth rotates around its axis, its equator spins faster than its polar regions. As a result, heated air masses rising above the equator and moving north and south to cooler areas are deflected to the west or east over different parts of the planet's surface (Figure 7-3). The atmosphere over these different areas is divided into huge regions called *cells*, distinguished by direction of air movement. And the differing directions of air movement are called *prevailing winds*—major surface winds that blow almost continuously



**CENGAGENOW™ Active Figure 7-2 Natural capital:** generalized map of the earth's current climate zones, showing the major contributing ocean currents and drifts and upwelling areas (where currents bring nutrients from the ocean bottom to the surface). Winds play an important role in distributing heat and moisture in the atmosphere, which leads to such climate zones. Winds also cause currents that help distribute heat throughout the world's oceans. See an animation based on this figure at CengageNOW™. **Question:** Based on this map what is the general type of climate where you live?



**Figure 7-3 Global air circulation.** The largest input of solar energy occurs at the equator. As this air is heated it rises and moves toward the poles. However, the earth's rotation deflects the movement of the air over different parts of the earth. This creates global patterns of prevailing winds that help distribute heat and moisture in the atmosphere.

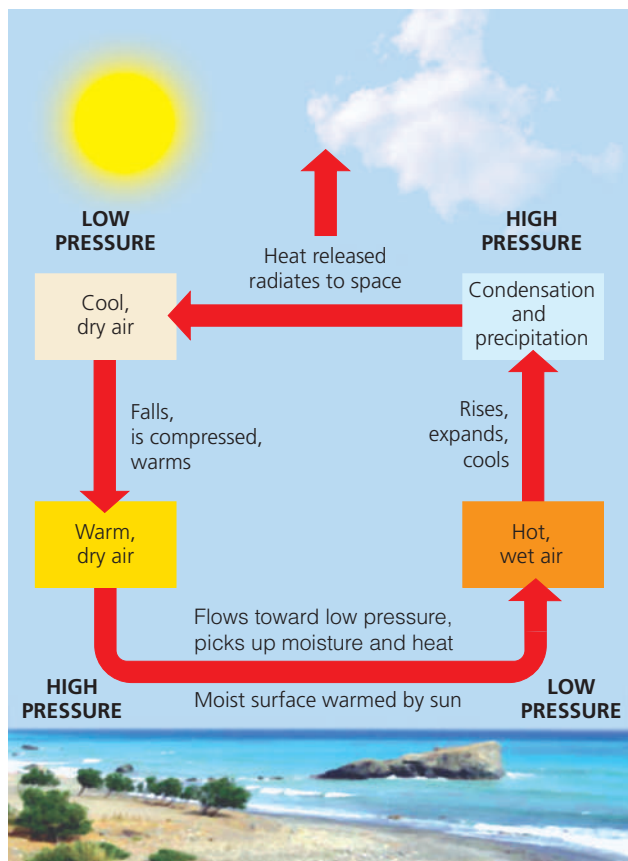
and help distribute air, heat, moisture, and dust over the earth's surface (**Core Case Study**).



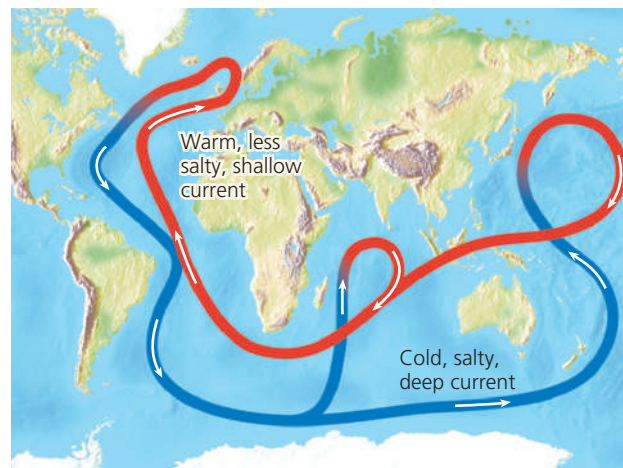
- *Properties of air, water, and land.* Heat from the sun evaporates ocean water and transfers heat from the oceans to the atmosphere, especially near the hot equator. This evaporation of water creates giant cyclical convection cells that circulate air, heat, and moisture both vertically and from place to place in the atmosphere, as shown in Figure 7-4.

Prevailing winds (Figure 7-3) blowing over the oceans produce mass movements of surface water called **currents**. Driven by prevailing winds and the earth's rotation, the earth's major ocean currents (Figure 7-2) redistribute heat from the sun from place to place, thereby influencing climate and vegetation, especially near coastal areas.

The oceans absorb heat from the earth's air circulation patterns; most of this heat is absorbed in tropical waters, which receive most of the sun's heat. This heat and differences in water *density* (mass per unit volume) create warm and cold ocean currents. Prevailing winds and irregularly shaped continents interrupt these cur-



**Figure 7-4** Energy transfer by convection in the atmosphere. *Convection* occurs when hot and wet warm air rises, cools, and releases heat and moisture as precipitation (right side). Then the denser cool, dry air sinks, gets warmer, and picks up moisture as it flows across the earth's surface to begin the cycle again.



**Figure 7-5** *Connected deep and shallow ocean currents.* A connected loop of shallow and deep ocean currents transports warm and cool water to various parts of the earth. This loop, which rises in some areas and falls in others, results when ocean water in the North Atlantic near Iceland is dense enough (because of its salt content and cold temperature) to sink to the ocean bottom, flow southward, and then move eastward to well up in the warmer Pacific. A shallower return current aided by winds then brings warmer, less salty—and thus less dense—water to the Atlantic. This water can cool and sink to begin this extremely slow cycle again.  
**Question:** How do you think this loop affects the climates of the coastal areas around it?

rents and cause them to flow in roughly circular patterns between the continents, clockwise in the northern hemisphere and counterclockwise in the southern hemisphere.

Heat is also distributed to the different parts of the ocean and the world when ocean water mixes vertically in shallow and deep ocean currents, mostly as a result of differences in the density of seawater. Because it has a higher density, colder seawater sinks and flows beneath warmer and less dense seawater. This creates a connected loop of deep and shallow ocean currents, which act like a giant conveyor belt that moves heat to and from the deep sea and transfers warm and cold water between the tropics and the poles (Figure 7-5).

The ocean and the atmosphere are strongly linked in two ways: ocean currents are affected by winds in the atmosphere (**Core Case Study**), and heat from the ocean affects atmospheric circulation (Figure 7-4). One example of the interactions between the ocean and the atmosphere is the *El Niño–Southern Oscillation*, or *ENSO*, as discussed on pp. S48–S49 in Supplement 8 and in *The Habitable Planet*, Video 3, at [www.learner.org/resources/series209.html](http://www.learner.org/resources/series209.html). This large-scale weather phenomenon occurs every few years when prevailing winds in the tropical Pacific Ocean weaken and change direction. The resulting above-average warming of Pacific waters can affect populations of marine species by changing the distribution of plant nutrients. It also alters the weather of at least two-thirds of the earth for one or two years (see Figure 5, p. S49, in Supplement 8).



**CENGAGENOW™** Learn more about how oceans affect air movements where you live and all over the world at CengageNOW™.

The earth's air circulation patterns, prevailing winds, and configuration of continents and oceans result in six giant convection cells (like the one shown in Figure 7-4) in which warm, moist air rises and cools, and cool, dry air sinks. Three of these cells are found north of the equator and three are south of the equator. These cells lead to an irregular distribution of climates and deserts, grasslands, and forests, as shown in Figure 7-6 (**Concept 7-1**).

**CENGAGENOW™** Watch the formation of six giant convection cells and learn more about how they affect climates at CengageNOW.

**THINKING ABOUT**  
**Winds and Biomes**

How might the distribution of the world's forests, grasslands, and deserts shown in Figure 7-6 differ if the prevailing winds shown in Figure 7-3 did not exist?



## Greenhouse Gases Warm the Lower Atmosphere

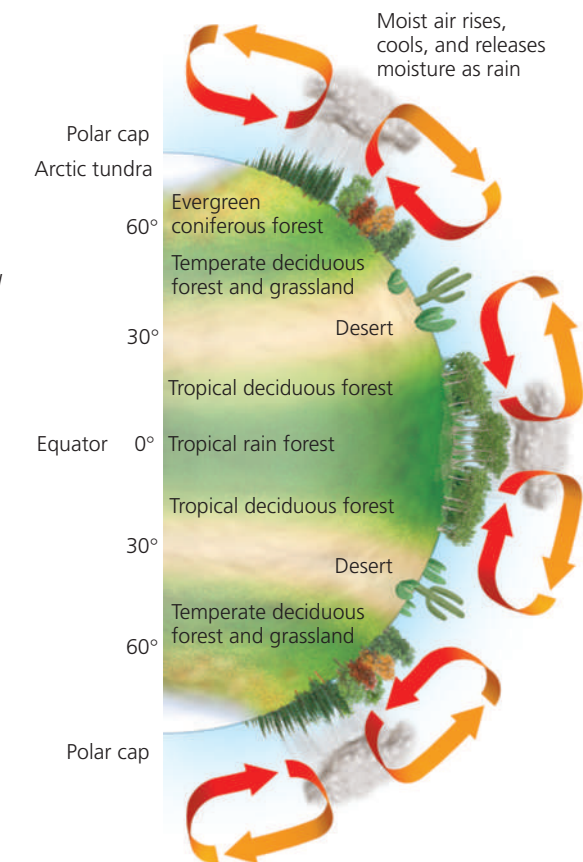
Figure 3-8 (p. 56) shows how energy flows to and from the earth. Small amounts of certain gases, including water vapor (H<sub>2</sub>O), carbon dioxide (CO<sub>2</sub>), methane

(CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O), in the atmosphere play a role in determining the earth's average temperatures and its climates. These **greenhouse gases** allow mostly visible light and some infrared radiation and ultraviolet (UV) radiation from the sun to pass through the atmosphere. The earth's surface absorbs much of this solar energy and transforms it to longer-wavelength infrared radiation (heat), which then rises into the lower atmosphere.

Some of this heat escapes into space, but some is absorbed by molecules of greenhouse gases and emitted into the lower atmosphere as even longer-wavelength infrared radiation. Some of this released energy radiates into space, and some warms the lower atmosphere and the earth's surface. This natural warming effect of the troposphere is called the **greenhouse effect** (see Figure 3-8, p. 56, and *The Habitable Planet*, Video 2, at [www.learner.org/resources/series209.html](http://www.learner.org/resources/series209.html)). Without the warming caused by these greenhouse gases, the earth would be a cold and mostly lifeless planet.

Human activities such as burning fossil fuels, clearing forests, and growing crops release carbon dioxide, methane, and nitrous oxide into the atmosphere. Considerable evidence and climate models indicate that there is a 90–99% chance that the large inputs of greenhouse gases into the atmosphere from human activities are enhancing the earth's natural greenhouse effect. This *human-enhanced global warming* (Science Focus, p. 33) could cause climate changes in various places on the earth that could last for centuries to thousands of years. As this warming intensifies during this century, climate scientists expect it to alter precipitation patterns, shift areas where we can grow crops, raise average sea levels, and shift habitats for some types of plants and animals, as discussed more fully in Chapter 19.

**CENGAGENOW™** Witness the natural greenhouse effect and see how human activities have affected it at CengageNOW.

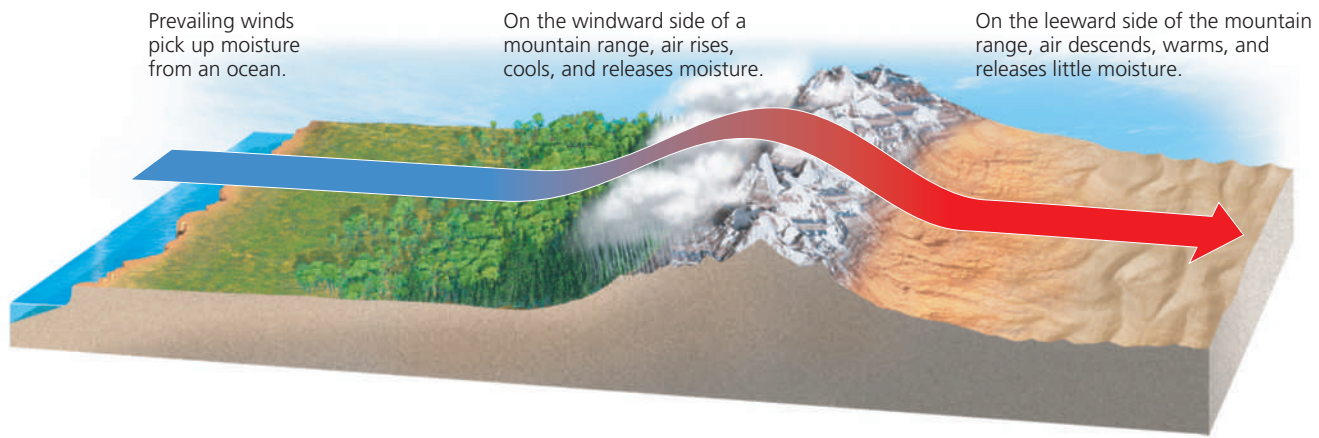


**Figure 7-6** Global air circulation, ocean currents, and biomes. Heat and moisture are distributed over the earth's surface via six giant convection cells (like the one in Figure 7-4) at different latitudes. The resulting uneven distribution of heat and moisture over the planet's surface leads to the forests, grasslands, and deserts that make up the earth's terrestrial biomes.

## The Earth's Surface Features Affect Local Climates

Heat is absorbed and released more slowly by water than by land. This difference creates land and sea breezes. As a result, the world's oceans and large lakes moderate the weather and climates of nearby lands.

Various topographic features of the earth's surface create local and regional weather and climatic conditions that differ from the general climate of a region. For example, mountains interrupt the flow of prevailing surface winds and the movement of storms. When moist air blowing inland from an ocean reaches a mountain range, it is forced upward. As it rises, it cools and expands and then loses most of its moisture as rain and snow on the windward slope of the mountain (the side from which the wind is blowing).



**Figure 7-7** The *rain shadow effect* is a reduction of rainfall and loss of moisture from the landscape on the side of a mountain facing away from prevailing surface winds. Warm, moist air in onshore winds loses most of its moisture as rain and snow on the windward slopes of a mountain range. This leads to semiarid and arid conditions on the leeward side of the mountain range and the land beyond. The Mojave Desert in the U.S. state of California and Asia's Gobi Desert are both produced by this effect.

As the drier air mass passes over the mountaintops it flows down the leeward (away from the wind) slopes, warms up (which increases its ability to hold moisture), and sucks up moisture from the plants and soil below. The loss of moisture from the landscape and the resulting semiarid or arid conditions on the leeward side of high mountains create the **rain shadow effect** (Figure 7-7). Sometimes this leads to the formation of deserts such as Death Valley in the United States, which is in the rain shadow of Mount Whitney, the highest mountain in the Sierra Nevadas. In this way, winds (**Core Case Study**) play a key role in forming some of the earth's deserts.

Cities also create distinct microclimates. Bricks, concrete, asphalt, and other building materials absorb and hold heat, and buildings block wind flow. Motor vehi-

cles and the climate control systems of buildings release large quantities of heat and pollutants. As a result, cities tend to have more haze and smog, higher temperatures, and lower wind speeds than the surrounding countryside.

**THINKING ABOUT  
Winds and Your Life**

What are three changes in your lifestyle that would take place if there were no winds where you live?



**RESEARCH FRONTIER**

Modeling and other research to learn more about how human activities affect climate. See [academic.cengage.com/biology/miller](http://academic.cengage.com/biology/miller).

## 7-2 How Does Climate Affect the Nature and Locations of Biomes?

► **CONCEPT 7-2** Differences in average annual precipitation and temperature lead to the formation of tropical, temperate, and cold deserts, grasslands, and forests, and largely determine their locations.

### Climate Affects Where Organisms Can Live

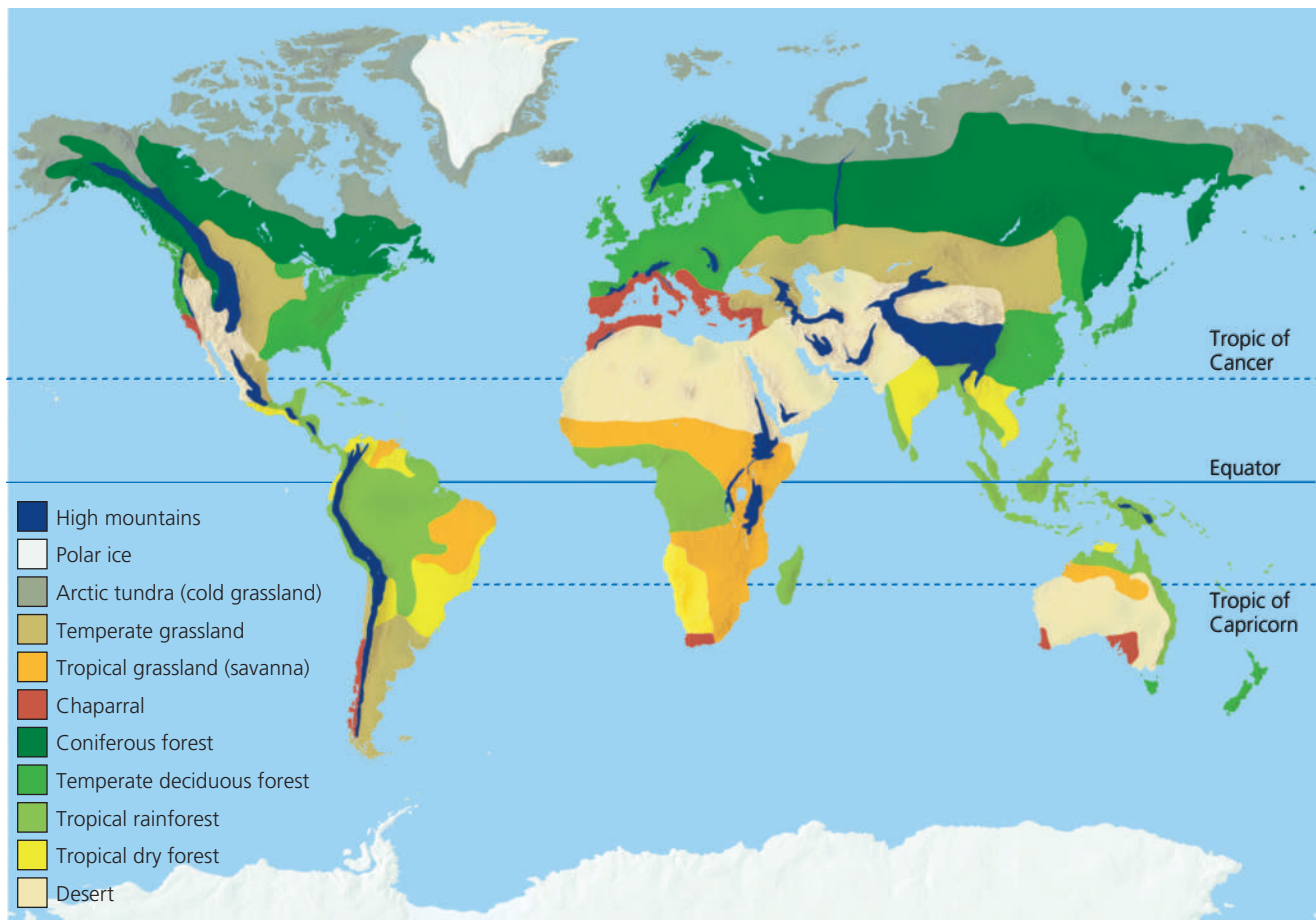
Different climates (Figure 7-2) explain why one area of the earth's land surface is a desert, another a grassland, and another a forest (Figure 7-6) and why global air circulation (Figure 7-3) accounts for different types of deserts, grasslands, and forests (**Concept 7-2**).

Figure 7-8 (p. 146) shows how scientists have divided the world into several major **biomes**—large ter-

restrial regions characterized by similar climate, soil, plants, and animals, regardless of where they are found in the world. The variety of terrestrial biomes and aquatic systems is one of the four components of the earth's biodiversity (Figure 4-2, p. 79, and **Concept 4-1A**, p. 78)—a vital part of the earth's natural capital.

By comparing Figure 7-8 with Figure 7-2 and Figure 1 on pp. S20–S21 in Supplement 4, you can see how the world's major biomes vary with climate.





CENGAGENOW™ **Active Figure 7-8 Natural capital:** the earth's major *biomes*—the main types of natural vegetation in various undisturbed land areas—result primarily from differences in climate. Each biome contains many ecosystems whose communities have adapted to differences in climate, soil, and other environmental factors. Figure 5 on p. S27 in Supplement 4 shows the major biomes of North America. Human activities have removed or altered much of the natural vegetation in some areas for farming, livestock grazing, lumber and fuelwood, mining, and construction of towns and cities (see Figure 3, pp. S24–S25, and Figure 7, pp. S28–S29, in Supplement 4). See an animation based on this figure at CengageNOW. **Question:** If you factor out human influences such as farming and urban areas, what kind of biome do you live in?

Figure 3-7 (p. 55) shows how major biomes in the United States (Figure 5, p. S27, in Supplement 4) are related to its different climates.

On maps such as the one in Figure 7-8, biomes are shown with sharp boundaries, each being covered with one general type of vegetation. In reality, *biomes are not uniform*. They consist of a *mosaic of patches*, each with somewhat different biological communities but with similarities typical of the biome. These patches occur mostly because the resources that plants and animals need are not uniformly distributed and because human activities remove and alter the natural vegetation in many areas.

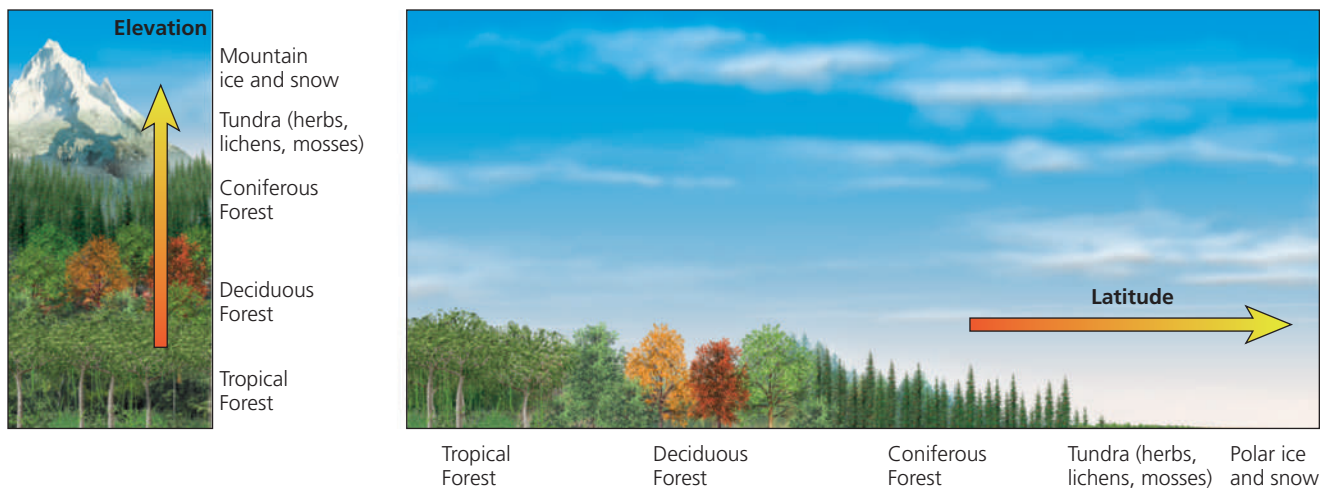
Figure 7-9 shows how climate and vegetation vary with *latitude* and *elevation*. If you climb a tall mountain from its base to its summit, you can observe changes in plant life similar to those you would encounter in traveling from the equator to one of the earth's poles. For example, if you hike up a tall Andes mountain in

Ecuador, your trek can begin in tropical rain forest and end up on a glacier at the summit.

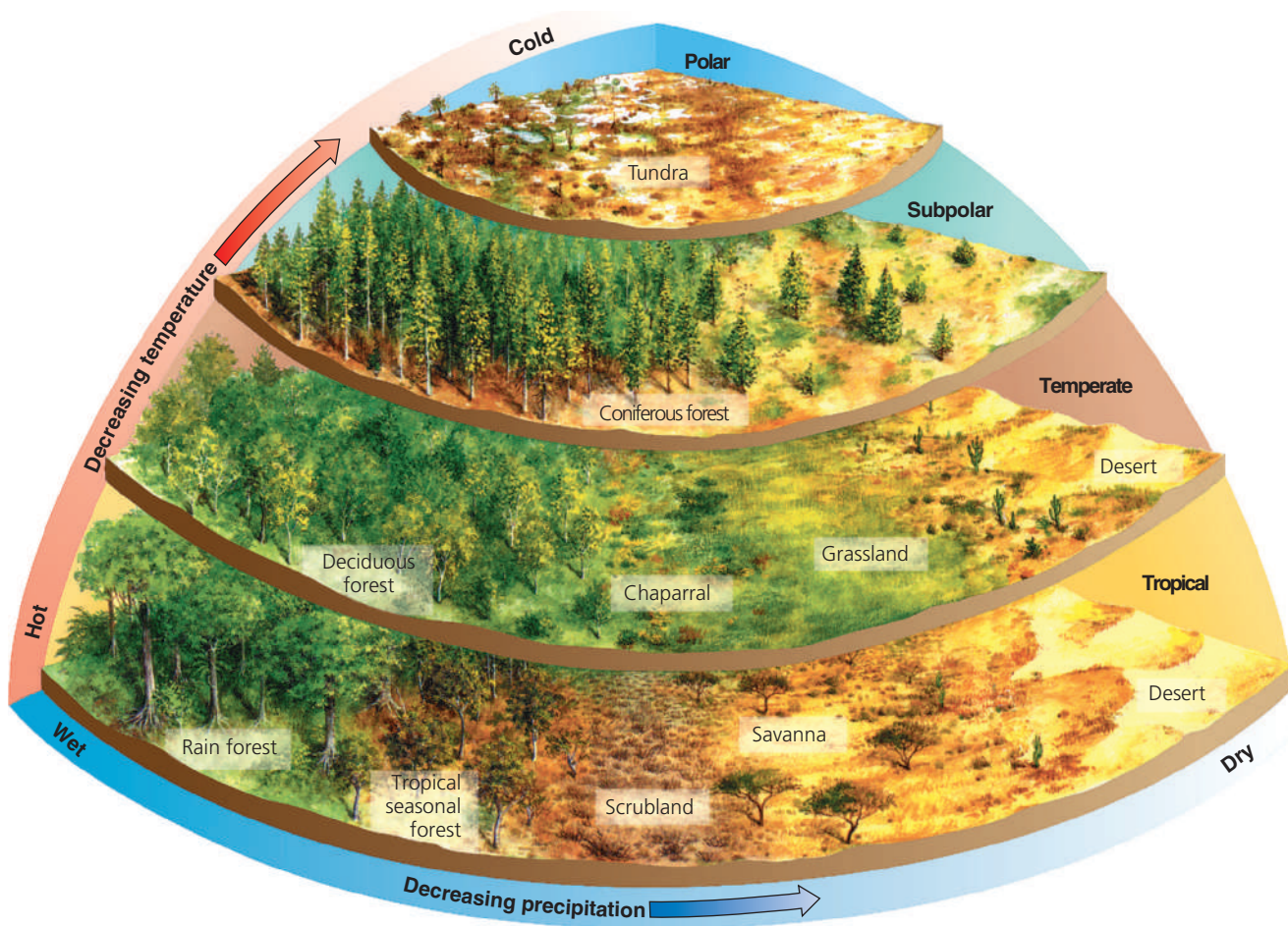
**THINKING ABOUT**  
**Biomes, Climate, and Human Activities**

Use Figure 7-2 to determine the general type of climate where you live and Figure 7-8 to determine the general type of biome that should exist where you live. Then use Figure 3, pp. S24–S25, and Figure 7, pp. S28–S29, in Supplement 4 to determine how human ecological footprints have affected the general type of biome where you live.

Differences in climate, mostly from average annual precipitation and temperature, lead to the formation of tropical (hot), temperate (moderate), and polar (cold) deserts, grasslands, and forests (Figure 7-10)—another important component of the earth's natural capital (**Concept 7-2**).



**Figure 7-9** Generalized effects of elevation (left) and latitude (right) on climate and biomes. Parallel changes in vegetation type occur when we travel from the equator to the poles or from lowlands to mountain-tops. **Question:** How might the components of the left diagram change as the earth warms during this century? Explain.



**Figure 7-10 Natural capital:** average precipitation and average temperature, acting together as limiting factors over a long time, help to determine the type of desert, grassland, or forest biome in a particular area. Although each actual situation is much more complex, this simplified diagram explains how climate helps to determine the types and amounts of natural vegetation found in an area left undisturbed by human activities. (Used by permission of Macmillan Publishing Company, from Derek Elsom, *The Earth*, New York: Macmillan, 1992. Copyright ©1992 by Marshall Editions Developments Limited).



## Staying Alive in the Desert

Adaptations for survival in the desert have two themes: *beat the heat*, and *every drop of water counts*.

Desert plants have evolved a number of strategies for doing this. During long hot and dry spells, plants such as mesquite and creosote drop their leaves to survive in a dormant state. *Succulent (fleshy) plants*, such as the saguaro (“sah-WAH-ro”) cactus (Figure 7-11, middle photo), have three adaptations: they have no leaves, which can lose water by evapotranspiration; they store water and synthesize food in their expandable, fleshy tissue; and they reduce water loss by opening their pores to take up carbon dioxide (CO<sub>2</sub>) only at night. The spines of these and many other desert plants guard them from being eaten by herbivores seeking the precious water they hold.

Some desert plants use deep roots to tap into groundwater. Others such as prickly pear

and saguaro cacti use widely spread, shallow roots to collect water after brief showers and store it in their spongy tissue.

Evergreen plants conserve water by having wax-coated leaves that reduce water loss. Others, such as annual wildflowers and grasses, store much of their biomass in seeds that remain inactive, sometimes for years, until they receive enough water to germinate. Shortly after a rain, these seeds germinate, grow, and carpet some deserts with dazzling arrays of colorful flowers that last for a few weeks.

Most desert animals are small. Some beat the heat by hiding in cool burrows or rocky crevices by day and coming out at night or in the early morning. Others become dormant during periods of extreme heat or drought. Some larger animals such as camels can drink massive quantities of water when it is available and store it in their fat for

use as needed. The camel is also covered with dense hair and does not sweat, which reduces heat gain and water loss through evaporation. Kangaroo rats never drink water. They get the water they need by breaking down fats in seeds that they consume.

Insects and reptiles (such as rattlesnakes and Gila monsters) have thick outer coverings to minimize water loss through evaporation, and their wastes are dry feces and a dried concentrate of urine. Many spiders and insects get their water from dew or from the food they eat.

### Critical Thinking

What are three things you would do to survive in the open desert?

## There Are Three Major Types of Deserts

In a **desert**, annual precipitation is low and often scattered unevenly throughout the year. During the day, the baking sun warms the ground and causes evaporation of moisture from plant leaves and soil. But at night, most of the heat stored in the ground radiates quickly into the atmosphere. Desert soils have little vegetation and moisture to help store the heat, and the skies above deserts are usually clear. This explains why, in a desert, you may roast during the day but shiver at night.

A combination of low rainfall and different average temperatures creates tropical, temperate, and cold deserts (Figures 7-10 and 7-11).

*Tropical deserts* (Figure 7-11, top photo), such as the Sahara and Namib of Africa, are hot and dry most of the year (Figure 7-11, top graph). They have few plants and a hard, windblown surface strewn with rocks and some sand. They are the deserts we often see in the movies. Wind-blown dust storms (**Core Case Study**) in the Sahara Desert have increased tenfold since 1950 mostly because of overgrazing and drought due to climate change and human population growth. Another reason is the *SUV connection*. Increasing numbers of four-wheel vehicles speeding over the sand (Figure 7-11, top photo) break the desert’s surface crust. Wind storms can then blow the dusty material into the atmosphere.

In *temperate deserts* (Figure 7-11, center photo), such as the Mojave in the southern part of the U. S. state of California, daytime temperatures are high in summer and low in winter and there is more precipitation than in tropical deserts (Figure 7-11, center graph). The sparse vegetation consists mostly of widely dispersed, drought-resistant shrubs and cacti or other succulents adapted to the lack of water and temperature variations. (Figure 1, p. S53, in Supplement 9 shows some components and food web interactions in a temperate desert ecosystem.)

In *cold deserts*, such as the Gobi Desert in Mongolia, vegetation is sparse (Figure 7-11, bottom photo). Winters are cold, summers are warm or hot, and precipitation is low (Figure 7-11, bottom graph). Desert plants and animals have adaptations that help them to stay cool and to get enough water to survive (Science Focus, above).

Desert ecosystems are fragile. Their soils take decades to hundreds of years to recover from disturbances such as off-road vehicles. This is because of their slow plant growth, low species diversity, slow nutrient cycling (due to low bacterial activity in the soils), and lack of water.

### THINKING ABOUT Winds and Deserts

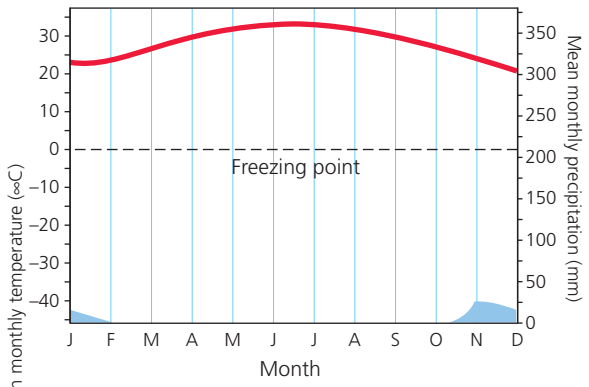
What roles do winds (**Core Case Study**) play in creating and sustaining deserts?





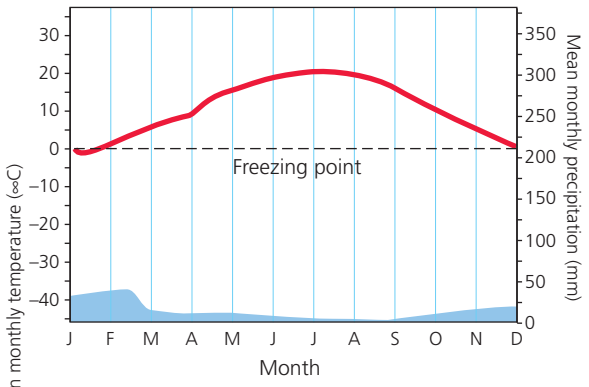
Oldrich Karasek/Peter Arnold, Inc.

**Tropical desert**



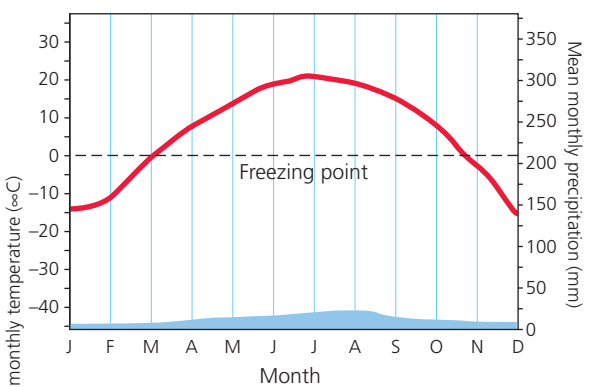
John Kieffer/Peter Arnold, Inc.

**Temperate desert**



SuperStock

**Cold desert**



**Figure 7-11** Climate graphs showing typical variations in annual temperature (red) and precipitation (blue) in tropical, temperate, and cold deserts. Top photo: a popular (but destructive) SUV rodeo in United Arab Emirates (tropical desert). Center photo: saguaro cactus in the U.S. state of Arizona (temperate desert). Bottom photo: a Bactrian camel in Mongolia’s Gobi Desert (cold desert). **Question:** What month of the year has the highest temperature and the lowest rainfall for each of the three types of deserts?

## There Are Three Major Types of Grasslands

**Grasslands** occur mostly in the interiors of continents in areas too moist for deserts and too dry for forests (Figure 7-8). Grasslands persist because of a combination of seasonal drought, grazing by large herbivores, and occasional fires—all of which keep large numbers of shrubs and trees from growing.

The three main types of grassland—tropical, temperate, and cold (arctic tundra)—result from combinations of low average precipitation and various average temperatures (Figures 7-10 and 7-12).

One type of tropical grassland, called a *savanna*, contains widely scattered clumps of trees such as acacia, (Figure 7-12, top photo), which are covered with thorns that help to keep herbivores away. This biome usually has warm temperatures year-round and alternating dry and wet seasons (Figure 7-12, top graph).

Tropical savannas in East Africa have herds of *grazing* (grass- and herb-eating) and *browsing* (twig- and leaf-nibbling) hooved animals, including wildebeests (Figure 7-12, top photo), gazelles, zebras, giraffes, and antelopes and their predators such as lions, hyenas, and humans. Herds of these grazing and browsing animals migrate to find water and food in response to seasonal and year-to-year variations in rainfall (Figure 7-12, blue region in top graph) and food availability.

In their niches, these and other large herbivores have evolved specialized eating habits that minimize competition among species for the vegetation found on the savanna. For example, giraffes eat leaves and shoots from the tops of trees, elephants eat leaves and branches farther down, wildebeests prefer short grasses, and zebras graze on longer grasses and stems. Savanna plants, like desert plants, are adapted to survive drought and extreme heat. Many have deep roots that can tap into groundwater.

In a *temperate grassland*, winters are bitterly cold, summers are hot and dry, and annual precipitation is fairly sparse and falls unevenly through the year (Figure 7-12, center graph). Because the aboveground parts of most of the grasses die and decompose each year, organic matter accumulates to produce a deep, fertile soil. This soil is held in place by a thick network of intertwined roots of drought-tolerant grasses (unless the topsoil is plowed up, which exposes it to be blown away by high winds found in these biomes). The natural grasses are also adapted to fires, which burn the plant parts above the ground but do not harm the roots, from which new grass can grow.

Two types of temperate grasslands are *tall-grass prairies* and *short-grass prairies* (Figure 7-12, center photo), such as those of the Midwestern and western United States and Canada. Short-grass prairies typically get about 25 centimeters (10 inches) of rain a year, and the grasses have short roots. Tall-grass prairies can get up to 88 centimeters (35 inches) of rain per year, and the

grasses have deep roots. Mixed or middle-grass prairies get annual rainfall between these two extremes.

In all prairies, winds blow almost continuously and evaporation is rapid, often leading to fires in the summer and fall. This combination of winds and fires helps to maintain such grasslands by hindering tree growth. (Figure 2, p. S54, in Supplement 9 shows some components and food-web interactions in a temperate tall-grass prairie ecosystem in North America.)

Many of the world's natural temperate grasslands have disappeared because their fertile soils are useful for growing crops (Figure 7-13, p. 152) and grazing cattle.

*Cold grasslands*, or *arctic tundra* (Russian for “marshy plain”), lie south of the arctic polar ice cap (Figure 7-8). During most of the year, these treeless plains are bitterly cold (Figure 7-12, bottom graph), swept by frigid winds, and covered by ice and snow. Winters are long and dark, and scant precipitation falls mostly as snow.

Under the snow, this biome is carpeted with a thick, spongy mat of low-growing plants, primarily grasses, mosses, lichens, and dwarf shrubs (Figure 7-12, bottom photo, and Figure 1-17, p. 23). Trees and tall plants cannot survive in the cold and windy tundra because they would lose too much of their heat. Most of the annual growth of the tundra's plants occurs during the 7- to 8-week summer, when the sun shines almost around the clock. (Figure 3, p. S55, in Supplement 9 shows some components and food-web interactions in an arctic tundra ecosystem.)

One outcome of the extreme cold is the formation of **permafrost**, underground soil in which captured water stays frozen for more than 2 consecutive years. During the brief summer, the permafrost layer keeps melted snow and ice from soaking into the ground. As a consequence, many shallow lakes, marshes, bogs, ponds, and other seasonal wetlands form when snow and frozen surface soil melt on the waterlogged tundra (Figure 7-12, bottom photo). Hordes of mosquitoes, black flies, and other insects thrive in these shallow surface pools. They serve as food for large colonies of migratory birds (especially waterfowl) that return from the south to nest and breed in the bogs and ponds.

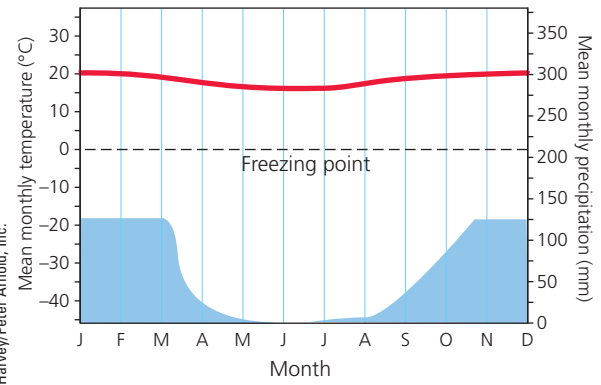
Animals in this biome survive the intense winter cold through adaptations such as thick coats of fur (arctic wolf, arctic fox, and musk oxen) and feathers (snowy owl) and living underground (arctic lemming). In the summer, caribou migrate to the tundra to graze on its vegetation (Figure 1-17, p. 23).

Global warming is causing some of the permafrost in parts of Canada, Alaska, China, Russia, and Mongolia to melt. This disrupts these ecosystems and releases methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) from the soil into the atmosphere. These two greenhouse gases can accelerate global warming and cause more permafrost to melt, which can lead to further warming and climate change. The melting permafrost causes the soil to sink



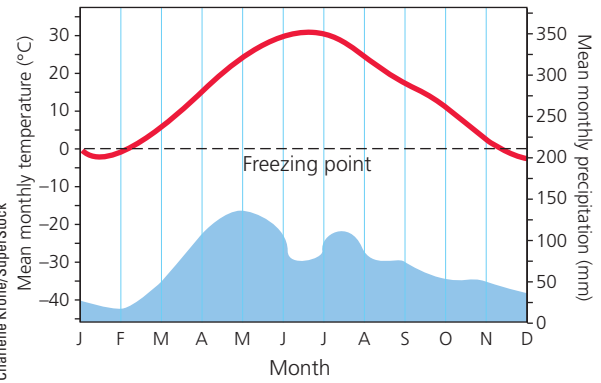
Martin Harvey/Peter Arnold, Inc.

### Tropical grassland (savanna)



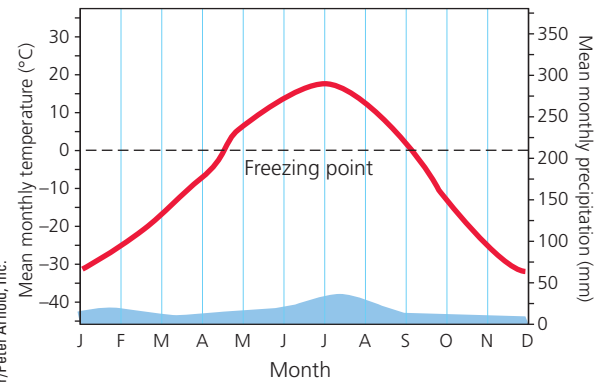
Kent & Charlene Krone/SuperStock

### Temperate grassland



M. Leder/Peter Arnold, Inc.

### Cold grassland (arctic tundra)



**Figure 7-12** Climate graphs showing typical variations in annual temperature (red) and precipitation (blue) in tropical, temperate, and cold (arctic tundra) grassland. Top photo: wildebeests grazing on a savanna in Maasai Mara National Park in Kenya, Africa (tropical grassland). Center photo: wildflowers in bloom on a prairie near East Glacier Park in the U. S. state of Montana (temperate grassland). Bottom photo: arctic tundra (cold grassland) in autumn in front of the Alaska Range, Alaska (USA). **Question:** What month of the year has the highest temperature and the lowest rainfall for each of the three types of grassland?



National Archives/EPA Documentica

**Figure 7-13 Natural capital degradation:** replacement of a biologically diverse temperate grassland with a monoculture crop in the U.S. state of California. When humans remove the tangled root network of natural grasses, the fertile topsoil becomes subject to severe wind erosion unless it is covered with some type of vegetation.

(subside), which can damage buildings, roads, power lines, and other human structures.

Tundra is a fragile biome. Most tundra soils formed about 17,000 years ago when glaciers began retreating after the last Ice Age (Figure 4-7, p. 85). These soils usually are nutrient poor and have little detritus. Because of the short growing season, tundra soil and vegetation recover very slowly from damage or disturbance. Human activities in the arctic tundra—mostly around oil drilling sites, pipelines, mines, and military bases—leave scars that persist for centuries.

Another type of tundra, called *alpine tundra*, occurs above the limit of tree growth but below the permanent snow line on high mountains (Figure 7-9, left). The vegetation is similar to that found in arctic tundra, but it receives more sunlight than arctic vegetation gets.



**Figure 7-14** Chaparral vegetation in the U.S. state of Utah and a typical climate graph.

During the brief summer, alpine tundra can be covered with an array of beautiful wildflowers.

**THINKING ABOUT**

**Winds and Grassland**

What roles do winds play in creating and sustaining grasslands?



**Temperate Shrubland: Nice Climate, Risky Place to Live**

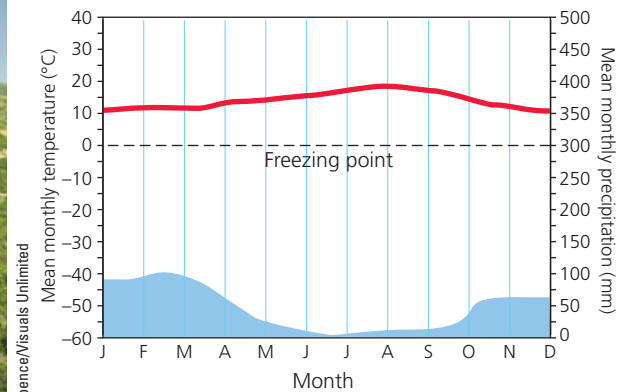
In many coastal regions that border on deserts we find fairly small patches of a biome known as *temperate shrubland* or *chaparral*. Closeness to the sea provides a slightly longer winter rainy season than nearby temperate deserts have, and fogs during the spring and fall reduce evaporation. These biomes are found along coastal areas of southern California in the United States, the Mediterranean Sea, central Chile, southern Australia, and southwestern South Africa (Figure 7-8).

Chaparral consists mostly of dense growths of low-growing evergreen shrubs and occasional small trees with leathery leaves that reduce evaporation (Figure 7-14). The soil is thin and not very fertile. Animal species of the chaparral include mule deer, chipmunks, jackrabbits, lizards, and a variety of birds.

During the long, warm, and dry summers, chaparral vegetation becomes very dry and highly flammable. In the late summer and fall, fires started by lightning or human activities spread with incredible swiftness. Research reveals that chaparral is adapted to and maintained by fires. Many of the shrubs store food reserves in their fire-resistant roots and produce seeds that sprout only after a hot fire. With the first rain, annual grasses and wildflowers spring up and use nutrients released by the fire. New shrubs grow quickly and crowd out the grasses.

People like living in this biome because of its moderate, sunny climate with mild, wet winters and warm, dry summers. As a result, humans have moved in and

**Chaparral**



modified this biome considerably (Figure 3, pp. S24–S25, in Supplement 4). The downside of its favorable climate is that people living in chaparral assume the high risk of losing their homes and possibly their lives to frequent fires during the dry season followed by mud slides during rainy seasons.

## There Are Three Major Types of Forests

**Forest systems** are lands dominated by trees. The three main types of forest—*tropical*, *temperate*, and *cold* (northern coniferous and boreal)—result from combinations of the precipitation level and various average temperatures (Figures 7-10 and 7-15, p. 154).

*Tropical rain forests* (Figure 7-15, top photo) are found near the equator (Figure 7-8), where hot, moisture-laden air rises and dumps its moisture. These lush forests have year-round, uniformly warm temperatures, high humidity, and heavy rainfall almost daily (Figure 7-15, top graph). This fairly constant warm and wet climate is ideal for a wide variety of plants and animals.

Figure 7-16 (p. 155) shows some of the components and food web interactions in these extremely diverse ecosystems. Tropical rain forests are dominated by *broadleaf evergreen plants*, which keep most of their leaves year-round. The tops of the trees form a dense canopy, which blocks most light from reaching the forest floor, illuminating it with a dim greenish light.

The ground level in such a forest has little vegetation, except near stream banks or where a fallen tree has opened up the canopy and let in sunlight. Many of the plants that do live at the ground level have enormous leaves to capture what little sunlight filters through to the dimly lit forest floor.

Some trees are draped with vines (called lianas) that reach for the treetops to gain access to sunlight. Once in the canopy, the vines grow from one tree to another, providing walkways for many species living there. When a large tree is cut down, its lianas can pull down other trees.

Tropical rain forests have a very high net primary productivity (Figure 3-16, p. 64); they are teeming with life and boast incredible biological diversity. Although tropical rain forests cover only about 2% of the earth's land surface, ecologists estimate that they contain at least half of the earth's known terrestrial plant and animal species. For example, a single tree in a rain forest may support several thousand different insect species. Plants from tropical rain forests are a source of chemicals used as blueprints for making most of the world's prescription drugs. Thus, the plant biodiversity found in this biome saves many human lives.

Tropical rain forest life forms occupy a variety of specialized niches in distinct layers. For example, vegetation layers are structured mostly according to the plants' needs for sunlight, as shown in Figure 7-17 (p. 156). Stratification of specialized plant and animal

niches in a tropical rain forest enables the coexistence of a great variety of species (high species richness; see Photo 3 in the Detailed Contents). Much of the animal life, particularly insects, bats, and birds, lives in the sunny *canopy* layer, with its abundant shelter and supplies of leaves, flowers, and fruits. To study life in the canopy, ecologists climb trees, use tall construction cranes, and build platforms and boardwalks in the upper canopy. See *The Habitable Planet*, Videos 4 and 9, at [www.learner.org/resources/series209.html](http://www.learner.org/resources/series209.html) for information on how scientists gather information about tropical rain forests and the effects of human activities on such forests.

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CENGAGENOW™ Learn more about how plants and animals in a rain forest are connected in a food web at CengageNOW.

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Because of the dense vegetation, there is little wind in these forests to spread seeds and pollen. Consequently, most rain forest plant species depend on bats, butterflies, birds, bees, and other species to pollinate their flowers and to spread seeds in their droppings.

Dropped leaves, fallen trees, and dead animals decompose quickly because of the warm, moist conditions and the hordes of decomposers. This rapid recycling of scarce soil nutrients explains why there is so little plant litter on the ground. Instead of being stored in the soil, about 90% of plant nutrients released by decomposition are quickly taken up and stored by trees, vines, and other plants. This is in sharp contrast to temperate forests, where most plant nutrients are found in the soil.

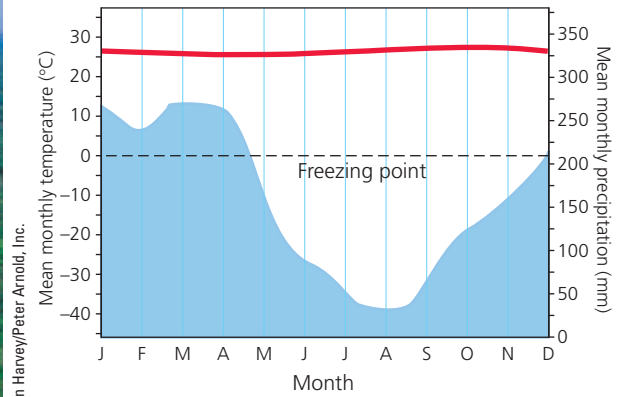
Because of these ecological processes and the almost daily rainfall, which leaches nutrients from the soil, the soils in most rain tropical forests contain few plant nutrients. This helps explain why rain forests are not good places to clear and grow crops or graze cattle on a sustainable basis. Despite this ecological limitation, many of these forests are being cleared or degraded for logging, growing crops, grazing cattle, and mineral extraction (Chapter 3 Core Case Study, p. 50).

So far, at least half of these forests have been destroyed or disturbed by human activities and the pace of destruction and degradation of these centers of terrestrial biodiversity is increasing (Figure 3-1, p. 50). Ecologists warn that without strong conservation measures, most of these forests will probably be gone within your lifetime, and with them perhaps a quarter of the world's species. This will reduce the earth's biodiversity and help to accelerate global warming and the resulting climate change by eliminating large areas of trees that remove carbon dioxide from the atmosphere (see *The Habitable Planet*, Video 9, at [www.learner.org/resources/series209.html](http://www.learner.org/resources/series209.html)).

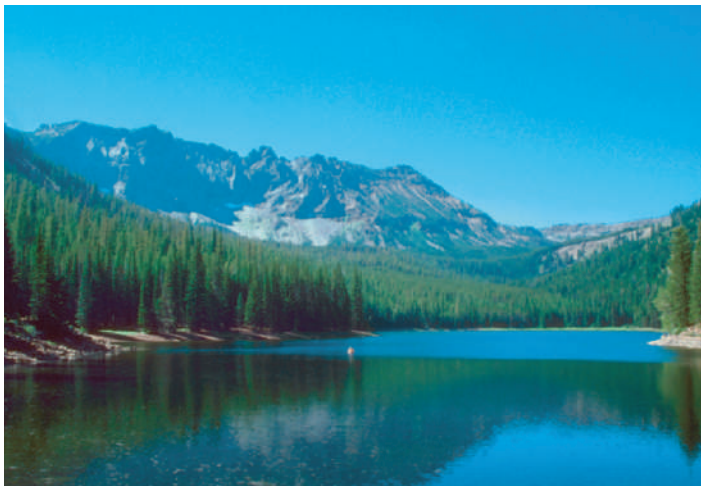
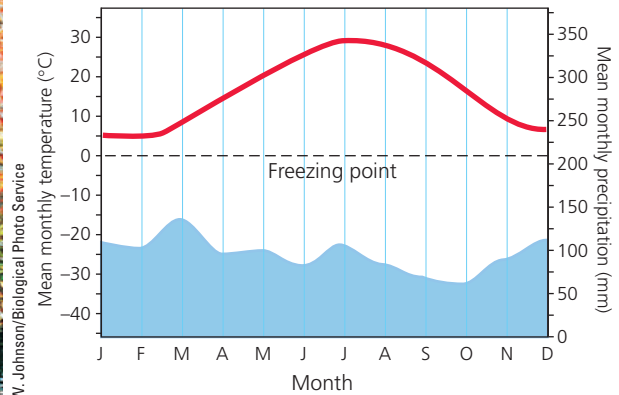
*Temperate deciduous forests* (Figure 7-15, center photo) grow in areas with moderate average temperatures that change significantly with the season. These areas have long, warm summers, cold but not too severe winters,



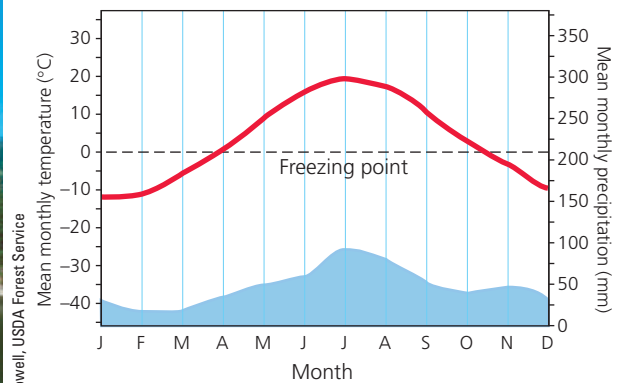
**Tropical rain forest**



**Temperate deciduous forest**



**Northern evergreen coniferous forest (boreal forest, taiga)**



**Figure 7-15** Climate graphs showing typical variations in annual temperature (red) and precipitation (blue) in tropical, temperate, and cold (northern coniferous and boreal) forests. Top photo: the closed canopy of a tropical rain forest in the western Congo Basin of Gabon, Africa. Middle photo: a temperate deciduous forest in the U.S. state of Rhode Island during the fall. (Photo 4 in the Detailed Contents shows this same area of forest during winter.) Bottom photo: a northern coniferous forest in the Malheur National Forest and Strawberry Mountain Wilderness in the U.S. state of Oregon. **Question:** What month of the year has the highest temperature and the lowest rainfall for each of the three types of forest?



**CENGAGENOW™ Active Figure 7-16** Some components and interactions in a tropical rain forest ecosystem. When these organisms die, decomposers break down their organic matter into minerals that plants use. Colored arrows indicate transfers of matter and energy between producers; primary consumers (herbivores); secondary, or higher-level, consumers (carnivores); and decomposers. Organisms are not drawn to scale. See an animation based on this figure at CengageNOW.



and abundant precipitation, often spread fairly evenly throughout the year (Figure 7-15, center graph).

This biome is dominated by a few species of *broad-leaf deciduous trees* such as oak, hickory, maple, poplar, and beech. They survive cold winters by dropping their leaves in the fall and becoming dormant through the winter (see Photo 4 in the Detailed Contents). Each spring, they grow new leaves whose colors change in the fall into an array of reds and golds before the leaves drop.

Because of a slow rate of decomposition, these forests accumulate a thick layer of slowly decaying leaf litter, which is a storehouse of nutrients. (Figure 4, p. S56, in Supplement 9, shows some components and food web interactions in a temperate deciduous forest ecosystem.) On a global basis, this biome has been disturbed by human activity more than any other terrestrial biome. Many forests have been cleared for growing crops or developing urban areas. However, within

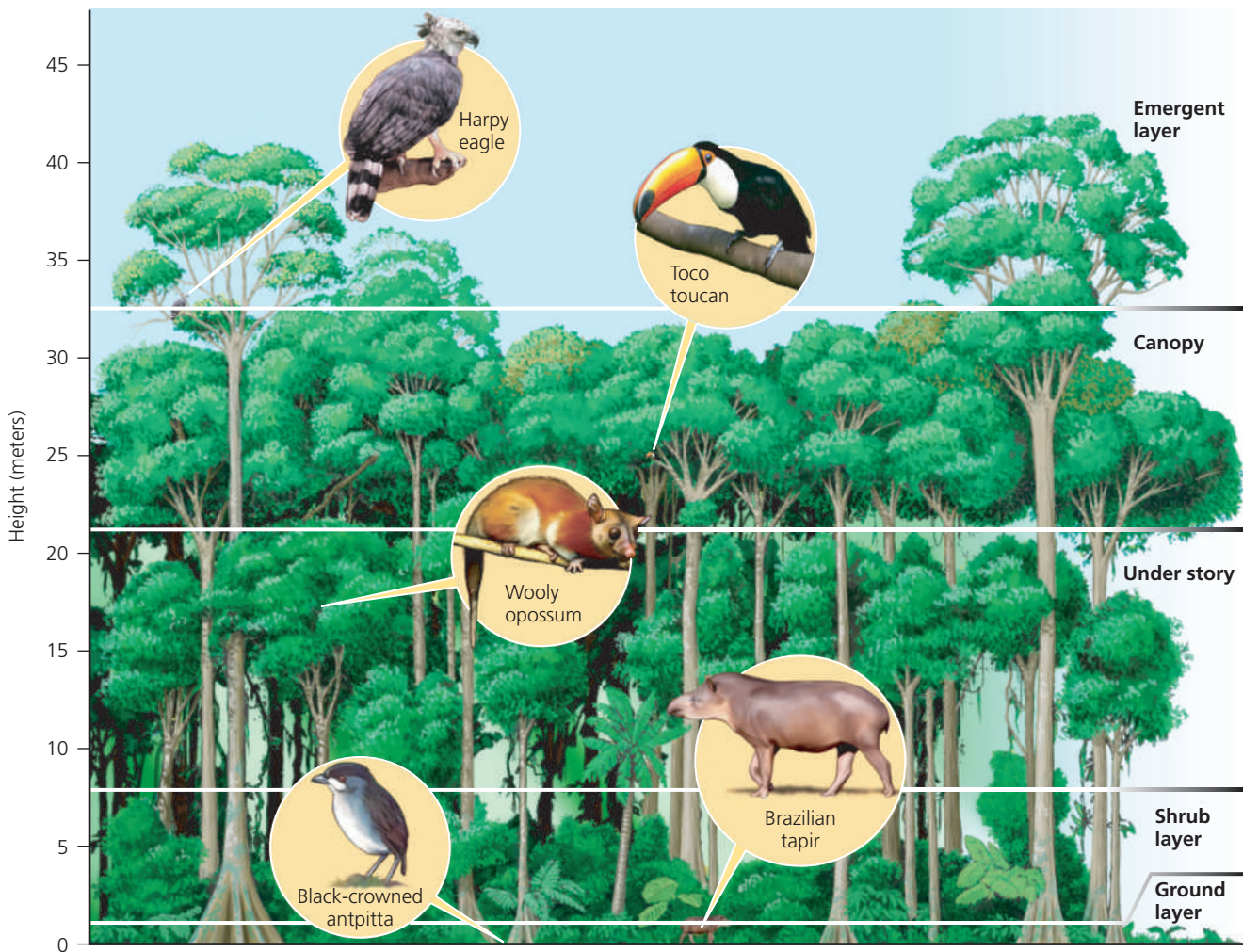
100–200 years, abandoned cropland can return to a deciduous forest through secondary ecological succession (Figure 5-17, p. 117).

The temperate deciduous forests of the eastern United States were once home to such large predators as bears, wolves, foxes, wildcats, and mountain lions (pumas). Today, most of the predators have been killed or displaced, and the dominant mammal species often is the white-tailed deer (Case Study, p. 114), along with smaller mammals such as squirrels, rabbits, opossums, raccoons, and mice.

Warblers, robins, and other bird species migrate to these forests during the summer to feed and breed. Many of these species are declining in numbers because of loss or fragmentation of their summer and winter habitats.

*Evergreen coniferous forests* (Figure 7-15, bottom photo) are also called *boreal forests* and *taigas* (“TIE-guhs”). These cold forests are found just south of the





**Figure 7-17** Stratification of specialized plant and animal niches in a *tropical rain forest*. Filling such specialized niches enables species to avoid or minimize competition for resources and results in the coexistence of a great variety of species.

arctic tundra in northern regions across North America, Asia, and Europe (Figure 7-8) and above certain altitudes in the High Sierra and Rocky Mountains of the United States. In this subarctic climate, winters are long, dry, and extremely cold; in the northernmost taigas, winter sunlight is available only 6–8 hours per day. Summers are short, with cool to warm temperatures (Figure 7-15, bottom graph), and the sun shines up to 19 hours a day.

Most boreal forests are dominated by a few species of *coniferous* (cone-bearing) *evergreen trees* such as spruce, fir, cedar, hemlock, and pine that keep most of their narrow-pointed leaves (needles) year-round (Figure 7-15, bottom photo). The small, needle-shaped, waxy-coated leaves of these trees can withstand the intense cold and drought of winter, when snow blankets the ground. Such trees are ready to take advantage of the brief summers in these areas without taking time to grow new needles. Plant diversity is low because few species can survive the winters when soil moisture is frozen.

Beneath the stands of these trees is a deep layer of partially decomposed conifer needles. Decomposition is

slow because of the low temperatures, waxy coating on conifer needles, and high soil acidity. The decomposing needles make the thin, nutrient-poor soil acidic, which prevents most other plants (except certain shrubs) from growing on the forest floor.

This biome contains a variety of wildlife. Year-round residents include bears, wolves, moose, lynx, and many burrowing rodent species. Caribou spend the winter in taiga and the summer in arctic tundra. During the brief summer, warblers and other insect-eating birds feed on hordes of flies, mosquitoes, and caterpillars. (Figure 5, p. S57, in Supplement 9 shows some components and food web interactions in an evergreen coniferous forest ecosystem.)

*Coastal coniferous forests* or *temperate rain forests* (Figure 7-18) are found in scattered coastal temperate areas that have ample rainfall or moisture from dense ocean fogs. Dense stands of large conifers such as Sitka spruce, Douglas fir, and redwoods once dominated undisturbed areas of this biome along the coast of North America, from Canada to northern California in the United States.



R. Eri/Peter Arnold, Inc.

**Figure 7-18** Temperate rain forest in Olympic National Park in the U.S. state of Washington.

**THINKING ABOUT**  
**Winds and Forests**

What roles do winds play in creating temperate and coniferous forests?



## Mountains Play Important Ecological Roles

Some of the world's most spectacular environments are high on *mountains* (Figure 7-19), steep or high lands which cover about one-fourth of the earth's land surface (Figure 7-8). Mountains are places where dramatic changes in altitude, slope, climate, soil, and vegetation take place over a very short distance (Figure 7-9, left).

About 1.2 billion people (18% of the world's population) live in mountain ranges or on their edges and 4 billion people (59% of the world's population) depend on mountain systems for all or some of their water. Because of the steep slopes, mountain soils are easily eroded when the vegetation holding them in place is removed by natural disturbances, such as landslides and avalanches, or human activities, such as timber cutting and agriculture. Many freestanding mountains are *islands of biodiversity* surrounded by a sea of lower-elevation landscapes transformed by human activities.

Mountains play important ecological roles. They contain the majority of the world's forests, which are habitats for much of the planet's terrestrial biodiversity. They often provide habitats for endemic species found

nowhere else on earth. They also serve as sanctuaries for animal species driven to migrate from lowland areas to higher altitudes.

Mountains also help to regulate the earth's climate. Mountaintops covered with ice and snow affect climate by reflecting solar radiation back into space. This helps to cool the earth and offset global warming. However, many of the world's mountain glaciers are melting, mostly because of global warming. While glaciers reflect solar energy, the darker rocks exposed by melting glaciers absorb that energy. This helps to increase global warming, which melts more glaciers and warms the atmosphere more—an example of a runaway positive feedback loop.

Mountains can affect sea levels by storing and releasing water in glacial ice. As the earth gets warmer, mountaintop glaciers and other land-based glaciers can melt, adding water to the oceans and helping to raise sea levels.

Finally, mountains play a critical role in the hydrologic cycle by serving as major storehouses of water. In the warmer weather of spring and summer, much of their snow and ice melts and is released to streams for use by wildlife and by humans for drinking and irrigating crops. As the earth warms, mountaintop snowpacks and glaciers melt earlier each year. This can lower food production if water needed to irrigate crops during the summer has already been released.

Despite their ecological, economic, and cultural importance, the fate of mountain ecosystems has not been a high priority for governments or for many environmental organizations.



Mark Hamblin/WW/Peter Arnold, Inc.

**Figure 7-19** Mountains such as these in Mount Rainier National Park in the U.S. state of Washington play important ecological roles.

## 7-3 How Have We Affected the World's Terrestrial Ecosystems?

**CONCEPT 7-3** In many areas, human activities are impairing ecological and economic services provided by the earth's deserts, grasslands, forests, and mountains.

### Humans Have Disturbed Most of the Earth's Land

The human species dominates most of the planet. In many areas, human activities are impairing some of the ecological and economic services provided by the world's deserts, grasslands, forests, and mountains (**Concept 7-3**).

According to the 2005 Millennium Ecosystem Assessment, about 62% of the world's major terrestrial ecosystems are being degraded or used unsustainably (see Figure 3, pp. S24–S25, and Figure 7, pp. S28–S29, in Supplement 4), as the human ecological footprint intensifies and spreads across the globe (Figure 1-10, p. 15, and **Concept 1-3**, p. 12). This environmental destruction and degradation is increas-



**Figure 7-20** Major human impacts on the world's deserts, grasslands, forests, and mountains. **Question:** Which two of the impacts on each of these biomes do you think are the most harmful?

ing in many parts of the world. Figure 7-20 summarizes some of the human impacts on the world's deserts, grasslands, forests, and mountains.

How long can we keep eating away at these terrestrial forms of natural capital without threatening our economies and the long-term survival of our own and other species? No one knows. But there are increasing signs that we need to come to grips with this vital issue.

This will require protecting the world's remaining wild areas from development. In addition, many of the land areas we have degraded need to be restored. However, such efforts to achieve a balance between exploitation and conservation are highly controversial because of timber, mineral, fossil fuel, and other re-

sources found in or under many of the earth's biomes. These issues are discussed in Chapter 10.

#### RESEARCH FRONTIER

Better understanding of the effects of human activities on terrestrial biomes and how we can reduce these impacts. See [academic.cengage.com/biology/miller](http://academic.cengage.com/biology/miller).

#### THINKING ABOUT Sustainability

Develop four guidelines for preserving the earth's terrestrial biodiversity based on the four **scientific principles of sustainability** (see back cover).



## REVISITING

### Winds and Sustainability



This chapter's opening **Core Case Study** described how winds connect parts of the planet to one another. Next time you feel or hear the wind blowing, think about these global connections. As part of the global climate system, winds play important roles in creating and sustaining the world's deserts, grasslands, and forests through the four **scientific principles of sustainability** (see back cover). Winds promote sustainability by helping to distribute solar energy and to recycle the earth's nutrients. In turn, this helps support biodiversity, which in turn affects species interactions that help control population sizes.

Scientists have made a good start in understanding the ecology of the world's terrestrial biomes. One of the major lessons from their research is: in nature, *everything is connected*. According to these scientists, we urgently need more research on the workings of the world's terrestrial biomes and on how they are interconnected. With such information, we will have a clearer picture of how our activities affect the earth's natural capital and of what we can do to help sustain it.

*When we try to pick out anything by itself,  
we find it hitched to everything else  
in the universe.*

JOHN MUIR

## REVIEW

1. Review the Key Questions and Concepts for this chapter on p. 141. Describe the environmentally beneficial and harmful effects of the earth's winds.
2. Distinguish between **weather** and **climate**. Describe three major factors that determine how air circulates in the lower atmosphere. Describe how the properties of air, water, and land affect global air circulation. How is heat distributed to different parts of the ocean? Explain how global air circulation and ocean currents lead to the forests, grasslands, and deserts that make up the earth's terrestrial biomes.
3. Define and give four examples of a **greenhouse gas**. What is the **greenhouse effect** and why is it important to the earth's life and climate? What is the **rain shadow effect** and how can it lead to the formation of inland deserts? Why do cities tend to have more haze and smog, higher temperatures, and lower wind speeds than the surrounding countryside?
4. What is a **biome**? Explain why there are three major types of each of the major biomes (deserts, grasslands, and forests). Describe how climate and vegetation vary with latitude and elevation.
5. Describe how the three major types of deserts differ in their climate and vegetation. How do desert plants and animals survive?
6. Describe how the three major types of grasslands differ in their climate and vegetation. What is a savanna? Why have many of the world's temperate grasslands disappeared? What is **permafrost**? Distinguish between arctic tundra and alpine tundra.
7. What is temperate shrubland or chaparral? Why is this biome a desirable place to live? Why is it a risky place to live?

8. What is a **forest system** and what are the three major types of forests? Describe how these three types differ in their climate and vegetation. Why is biodiversity so high in tropical rain forests? Why do most soils in tropical rain forests have few plant nutrients? Describe what happens in temperate deciduous forests in the winter and fall. What are coastal coniferous or temperate rain forests? What important ecological roles do mountains play?

9. Describe how human activities have affected the world's deserts, grasslands, forests, and mountains.

10. Describe the connections between the earth's winds, climates, and biomes (**Core Case Study**) and the four **scientific principles of sustainability** (see back cover).



Note: Key Terms are in bold type.

## CRITICAL THINKING

1. What would happen to **(a)** the earth's species and **(b)** your lifestyle if the winds stopped blowing (**Core Case Study**)?
2. List a limiting factor for each of the following ecosystems: **(a)** a desert, **(b)** arctic tundra, **(c)** temperate grassland, **(d)** the floor of a tropical rain forest, and **(e)** a temperate deciduous forest.
3. Why do deserts and arctic tundra support a much smaller biomass of animals than do tropical forests?
4. Why do most animals in a tropical rain forest live in its trees?
5. Why do most species living at high latitudes or high altitudes tend to have generalist ecological niches while those living in the tropics tend to have specialist ecological niches (Figure 4-11, p. 91)?
6. Which biomes are best suited for **(a)** raising crops and **(b)** grazing livestock? Use the four **scientific principles of sustainability** (see back cover) to come



up with four guidelines for growing food and grazing livestock in these biomes on a more sustainable basis.

7. What type of biome do you live in? List three ways in which your lifestyle is harming this biome?
8. You are a defense attorney arguing in court for sparing a tropical rain forest. Give your three most important arguments for the defense of this ecosystem.
9. Congratulations! You are in charge of the world. What are the three most important features of your plan to help sustain the earth's terrestrial biodiversity?
10. List two questions that you would like to have answered as a result of reading this chapter.

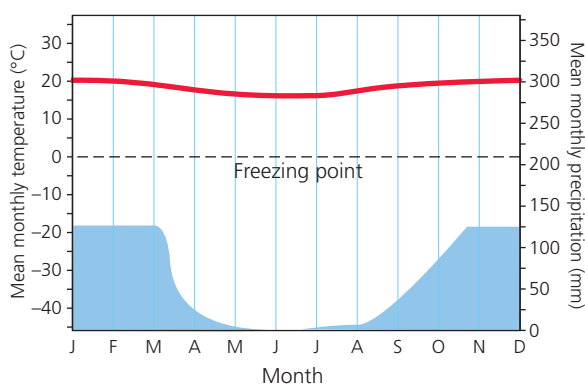
Note: See Supplement 13 (p. S78) for a list of Projects related to this chapter.

## DATA ANALYSIS

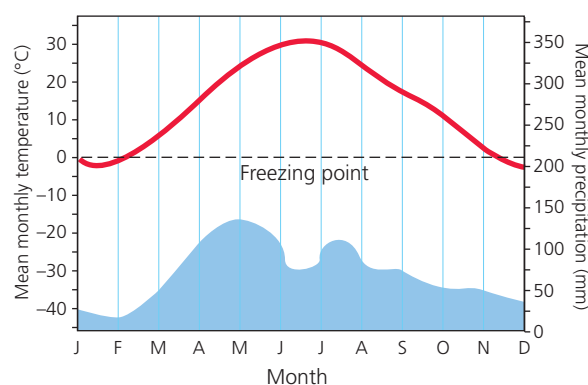
In this chapter, you learned how long-term variations in the average temperature and average precipitation play a major role in determining the types of deserts, forests, and grasslands

found in different parts of the world. Below are typical annual climate graphs for a tropical grassland (savanna) in Africa and a temperate grassland in the midwestern United States.

Tropical grassland (savanna)



Temperate grassland



1. In what month (or months) does the most precipitation fall in each of these areas?
2. What are the driest months in each of these areas?
3. What is the coldest month in the tropical grassland?
4. What is the warmest month in the temperate grassland?

## LEARNING ONLINE

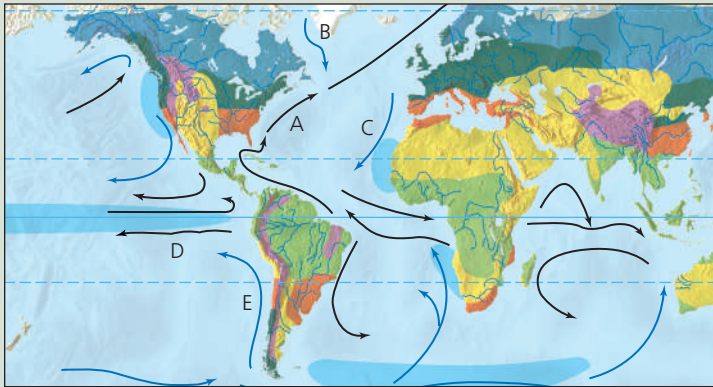
Log on to the Student Companion Site for this book at [academic.cengage.com/biology/miller](http://academic.cengage.com/biology/miller), and choose Chapter 7 for many study aids and ideas for further read-

ing and research. These include flash cards, practice quizzing, Weblinks, information on Green Careers, and InfoTrac® College Edition articles.

# AP\* Review Questions for Chapter 7

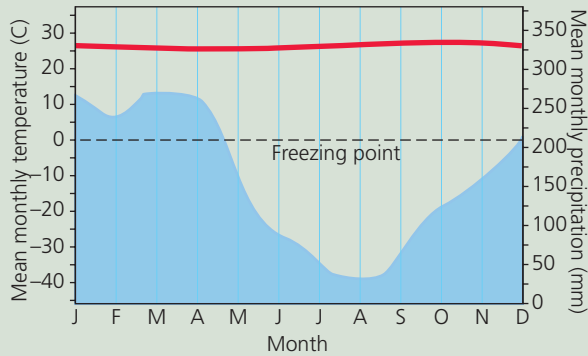
- Which of the events below is an example of the positive side effect of winds?
  - Tornadic winds redistributing energy across the Plains states
  - Winds carrying phosphate-rich dust across the Atlantic ocean fertilizing the rain forests of Brazil
  - Iron-rich dust from Africa carried across the Atlantic to the Caribbean causing red tide events
  - Fungal spores from Africa carried across the ocean to Caribbean reefs causing bleaching
  - Dust and soot carried from China to polar regions, causing increased warming
- Which of the events below is an example of a change in weather?
  - A large area changes from a grassland to a desert.
  - While climbing a mountain, one moves through several different biomes.
  - A thunderstorm forms and drops 1.5 cm of rain.
  - Increased greenhouse gases in the atmosphere cause atmospheric warming.
  - Desertification of an area causes the area to see increased annual temperatures.
- As one climbs a mountain, the elevation changes cause a change in biomes. Which of the changes below is caused by elevation?
  - Biomes are increasingly affected by prevailing winds as elevation increases.
  - Biomes receive more precipitation as elevation increases.
  - Biomes tend to be more tropical as elevation increases.
  - Biomes receive more solar radiation as elevation increases, causing an increase in temperature.
  - Biomes changes as one moves up a mountain are identical to the changes as one moves away from the equator.
- Which of the statements below about biomes is true?
  - Biomes cover large areas with clearly delineated boundaries.
  - Biomes are uniformly covered with similar vegetation.
  - Biomes consist of a mosaic of patches of different communities.
  - Biomes are unique from one continent to another.
  - Biomes are unaltered by human influences.

Questions 3–6 refer to the diagram of surface currents in the oceans.

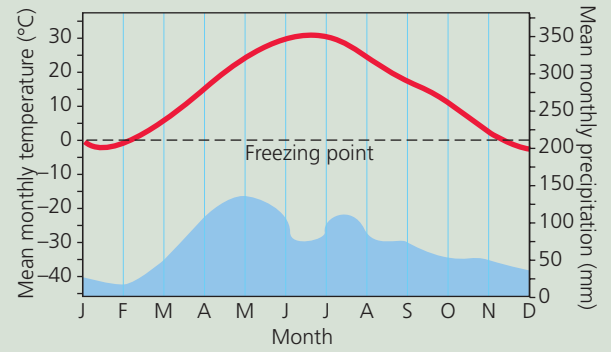


- A current responsible for moving heat away from the equator.
- The reversal of this current is associated with ENSO events.
- Cape Cod juts out from the eastern coast of North America. This current keeps the waters of Cape Cod very cool.
- This current causes offshore upwellings of nutrient-rich water that is responsible for plankton-rich waters sustaining a large anchovy fishery.

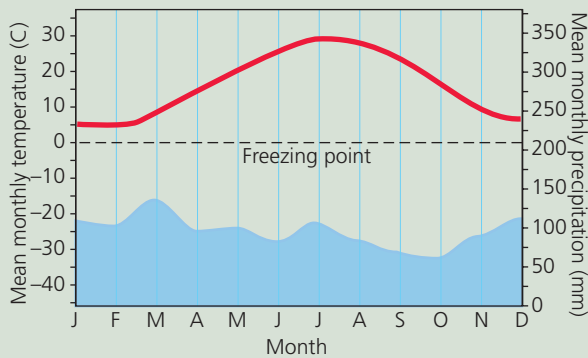
Questions 9–11 refer to the climate graphs below. The red line represents temperature and the blue represents precipitation.



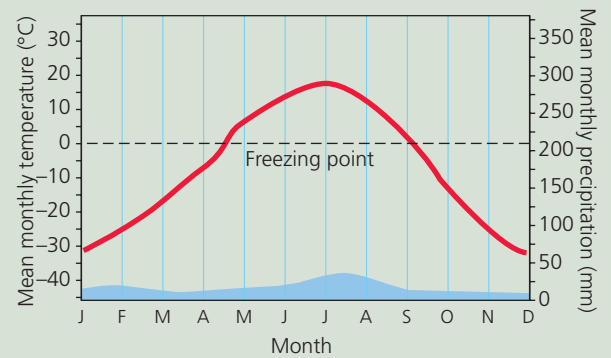
A



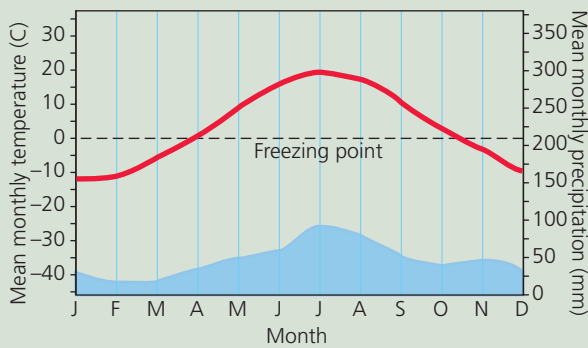
D



B



E



C

9. This biome is characterized by subfreezing temperatures much of the year, low precipitation rates, and the formation of permafrost.
10. This biome found in equatorial regions has large amounts of precipitation but has low levels of nutrients in the soil.
11. This biome often has snow, yet the average mean monthly temperature is always above the freezing point. Trees in this biome lose their leaves every fall, producing colorful displays.
12. Which of the adaptations below is NOT found in plants living in the desert?
  - (A) Deep roots to tap into groundwater
  - (B) Wax-coated leaves preventing water loss
  - (C) Storing much of their biomass as seeds and remaining inactive most of the year
  - (D) Breaking down stored fats to produce needed water
  - (E) Opening stomata (pores) only at night to absorb needed carbon dioxide