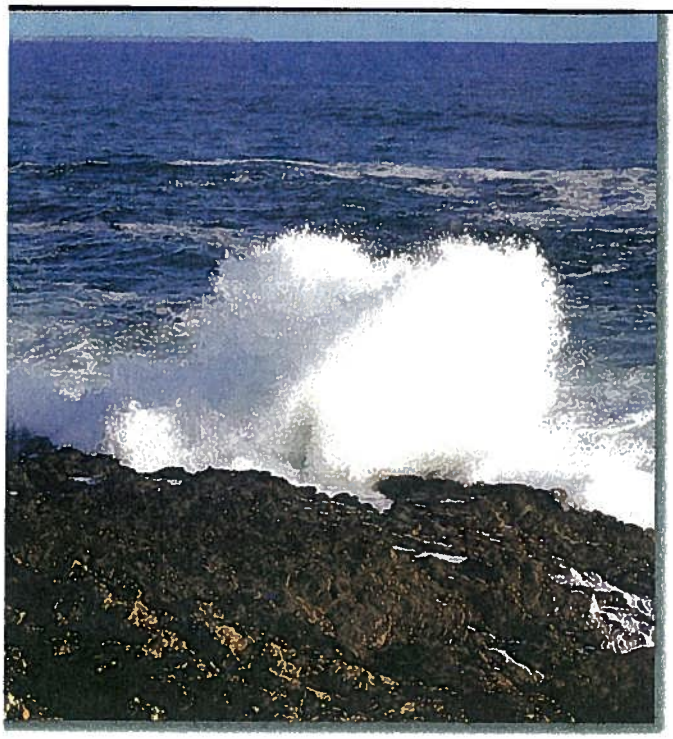


CHAPTER 6

# KINDS OF ECOSYSTEMS AND COMMUNITIES

*Ecosystems are functional units that involve interactions between organisms and their physical environment. The many organisms that inhabit a rocky shore are firmly attached and are able to withstand the pounding of ocean waves.*

## CHAPTER OUTLINE


Succession
- Primary Succession
- Secondary Succession
- Modern Concepts of Succession and Climax

Biomes Are Determined by Climate
- Precipitation and Temperature
- The Effect of Elevation on Climate and Vegetation

Major Biomes of the World
- Desert
- Temperate Grassland
- Savanna
- Mediterranean Shrublands (Chaparral)
- Tropical Dry Forest
- Tropical Rainforest
- Temperate Deciduous Forest
- Temperate Rainforest
- Taiga, Northern Coniferous Forest, or Boreal Forest
- Tundra

Major Aquatic Ecosystems
- Marine Ecosystems
- Freshwater Ecosystems

**ISSUES & ANALYSIS**
Ecosystem Loss in North America 137

**CASE STUDY**
Grassland Succession 124

**CAMPUS SUSTAINABILITY INITIATIVE**
The Blue Oak Ranch Reserve of the University of California–Berkeley 119

**GOING GREEN**
Conservation Easements 117

**WATER CONNECTIONS**
Varzea Forests—Where the Amazon River and Land Meet 134


## OBJECTIVES

After reading this chapter, you should be able to:

- Recognize the difference between primary and secondary succession.
- Describe the process of succession from pioneer to climax community in both terrestrial and aquatic situations.
- Associate typical plants and animals with the various terrestrial biomes.
- Recognize the physical environmental factors that determine the kind of climax community that will develop.
- Differentiate the forest biomes that develop based on temperature and rainfall.
- Describe the various kinds of aquatic ecosystems and the factors that determine their characteristics.

A Global Perspective on "Tropical Rainforests—A Special Case?" can be found on the book's website at www.mhhe.com/enger12e along with other interesting readings.

# SUCCESSION

Ecosystems are dynamic, changing units. On a daily basis, plants grow and die, animals feed on plants and on one another, and decomposers recycle the chemical elements that make up the biotic portion of any ecosystem. Abiotic factors (such as temperature, rainfall, intensity of sunlight, and seasonality) also have a major influence on the kind of community that will be established. Since all organisms are linked together in a community, any change in the community affects many organisms within it. Certain conditions within a community are keys to the kinds of organisms that are found associated with one another. Grasshoppers need grass for food, robins need trees to build nests, and herons need shallow water to find food. Each organism has specific niche requirements that must be met in the community, or it will not survive.

Over long time periods, it is possible to see trends in the way the structure of a community changes and to recognize that climate greatly influences the kind of community that becomes established in an area. Generally, this series of changes eventually results in a relatively long-lasting, stable combination of species that is self-perpetuating. These observations led ecologists to develop the concepts of succession and climax communities.

**Succession** is the concept that communities proceed through a series of recognizable, predictable changes in structure over time. Succession occurs because the activities of organisms cause changes in their surroundings that make the environment suitable for other kinds of organisms. When new species become established, they compete with the original inhabitants. In some cases, original species may be replaced completely. In other cases, early species may not be replaced but may become less numerous as invading species take a dominant role. Slowly, over time, it is recognized that a significantly different community has become established. Several factors determine the pace and direction of the successional process. For example, climate, locally available seed sources, frequency of disturbance, and invasions of organisms from outside the area all greatly affect the course of succession.

A **climax community** is a relatively stable, long-lasting community that is the result of succession. In the traditional view of succession, the kind of climax community that develops is primarily determined by climate. Some communities will be forests, while others will be grassland or deserts.

As ecologists have studied the process of succession, they have come to recognize that the process is not always as predictable as they once believed it was. However, to begin to understand the process of succession, we must look at general models before looking at the exceptions. Ecologists have traditionally recognized two kind of succession: primary and secondary succession.

**Primary succession** is a successional progression that begins with a total lack of organisms and bare mineral surfaces or water. Such conditions can occur when volcanic activity causes lava flows or glaciers scrape away the organisms and soil. Similarly, a lowering of sea level exposes new surfaces for colonization by terrestrial organisms. Primary succession takes an extremely long time because often there is no soil and few readily available nutrients for plants to use for growth.

**Secondary succession** is a successional progression that begins with the destruction or disturbance of an existing ecosystem. It is much more commonly observed and generally proceeds more rapidly than primary succession. This is true because, although fire, flood, windstorm, or human activity can destroy or disturb a community of organisms, there is at least some soil and often there are seeds or roots from which plants can begin growing almost immediately.

## PRIMARY SUCCESSION

Primary succession can begin on a bare rock surface, in pure sand, or in standing water. Since succession on rock and sand is somewhat different from that which occurs with watery situations, we deal with them separately. We discuss terrestrial succession first.

### *Terrestrial Primary Succession*

Several factors determine the rate of succession and the kind of climax community that will develop in an area. The kind of substrate (rock, sand, clay) will greatly affect the kind of soil that will develop. The kinds of spores, seeds, or other reproductive structures will determine the plant species available to colonize the area. The climate will determine the species that will be able to live in an area and how rapidly they will grow. The rate of growth will determine how quickly organic matter will accumulate in the soil. The kind of substrate, climate, and amount of organic matter will influence the amount of water available for plant growth. Finally, the kinds of plants will determine the kinds of animals able to live in the area. Let's look at a specific example of how these factors are interrelated in an example of primary succession from bare mineral surfaces. (See figure 6.1.)

**1. Pioneer Stages** Bare rock or sand is a very inhospitable place for organisms to live. The temperature changes drastically, there is no soil, there is little moisture, the organisms are exposed to the damaging effect of the wind, few nutrients are available, and few places are available for organisms to attach themselves or hide. However, windblown spores or other tiny reproductive units of a few kinds of organisms can become established and survive in even this inhospitable environment. This collection of organisms is known as the **pioneer community** because it is the first to colonize bare rock. (See figure 6.2.)

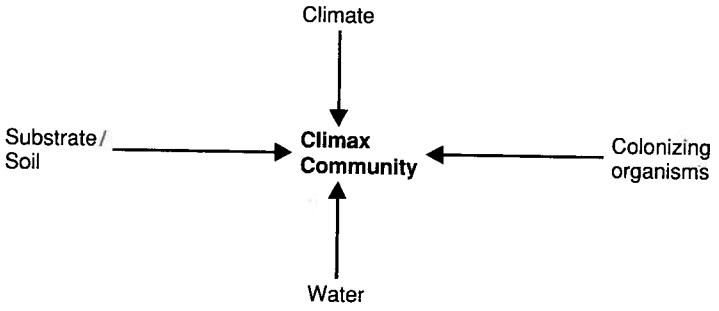



**FIGURE 6.1 Factors That Determine the Kind of Climax Community** There are many biotic and abiotic factors that interact to determine the kind of climax community that will develop in any place.

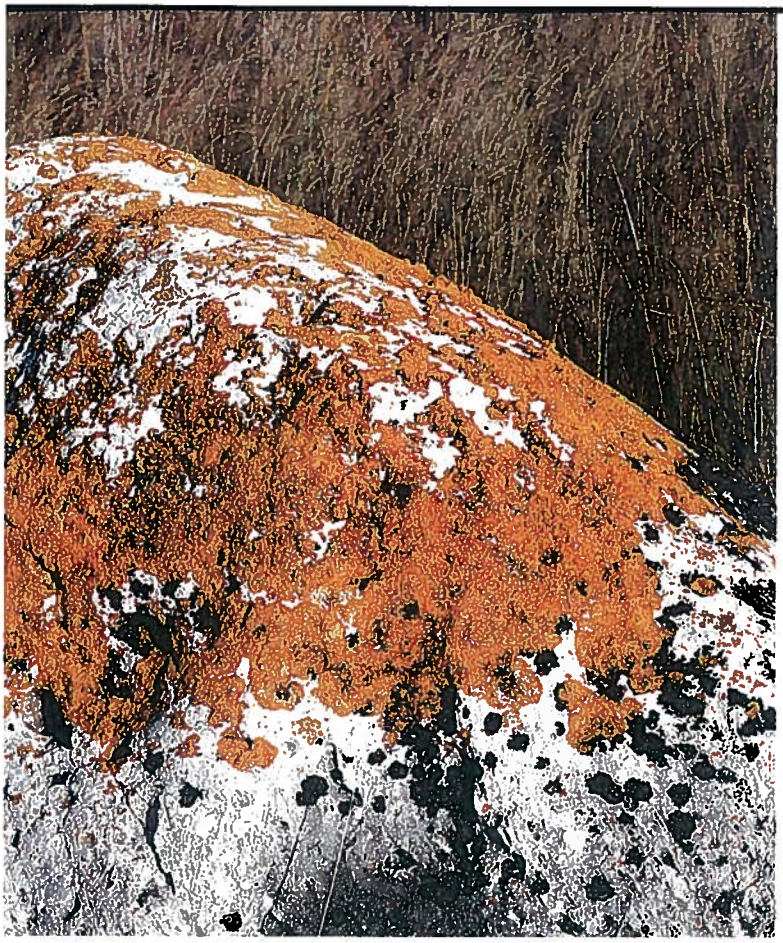


**FIGURE 6.2 Pioneer Organisms** The lichens growing on this rock are able to accumulate bits of debris, carry on photosynthesis, and aid in breaking down the rock. All of these activities contribute to the formation of a thin layer of soil, which is necessary for plant growth in the early stages of succession.

Lichens are common organisms in many pioneer communities. Lichens are actually mutualistic relationships between two kinds of organisms: algae or bacteria that carry on photosynthesis and fungi that attach to the rock surface and retain water. The growth and development of lichens is often a slow process. It may take lichens 100 years to grow as large as a dinner plate. Lichens are the producers in this simple ecosystem, and many tiny consumer organisms may be found associated with lichens. Some feed on the lichen and many use it as a place of shelter, since even a drizzle is like a torrential rain for a microscopic animal. Since lichens are firmly attached to rock surfaces, they also tend to accumulate bits of airborne debris and store small amounts of water that would otherwise blow away or run off the rock surface. Acids produced by the lichen tend to cause the breakdown of the rock substrate into smaller particles. This fragmentation of rock, aided by physical and chemical weathering processes, along with the trapping of debris and the contribution of organic matter by the death of lichens and other organisms, ultimately leads to the accumulation of a very thin layer of soil.

**2. Later Stages** This thin layer of soil is the key to the next stage in the successional process. The layer can retain some water and support some fungi, certain small worms, insects, bacteria, protozoa, and perhaps a few tiny annual plants that live for only one year but produce flowers and seeds that fall to the soil and germinate the following growing season. Many of these initial organisms or their reproductive structures are very tiny and will arrive as a result of wind and rain. As these organisms grow, reproduce, and die, they contribute additional organic material for the soil-building process, and the soil layer increases in thickness and is better able to retain water.

This stage, which is dominated by annual plants, eliminates the lichen community because the plants are taller and shade the lichens, depriving them of sunlight. This annual plant stage is itself replaced by a community of small perennial grasses and herbs. The perennial grasses and herbs are often replaced by larger perennial woody shrubs, which are often replaced by larger trees that require lots of sunlight, which often are replaced in turn by trees that can tolerate shade. Sun-loving (shade-intolerant) trees are replaced by shade-tolerant trees because the seedlings of shade-intolerant trees cannot grow in the shade of their parents, while seedlings of shade-tolerant trees can. Eventually, a relatively stable, long-lasting, complex, and interrelated climax community of plants, animals, fungi, and bacteria is produced. Each step in this process from pioneer community to climax community is called a **successional stage,** or **seral stage,** and the entire sequence of stages—from pioneer community to climax community—is called a **sere.** (See figure 6.3.)

Although in this example we have described a successional process that began with a lichen pioneer community and ended with a climax forest, it is important to recognize that the process of succession can stop at any point along this continuum. In certain extreme climates, lichen communities may last for hundreds of years and must be considered climax communities. Others reach a grass-herb stage and proceed no further. The specific kind of climax community produced depends on such things as climate and soil type, which are discussed in greater detail later in this chapter.

**3. Differences Between Successional and Climax Communities** When successional communities are compared to climax communities, climax communities show certain characteristics.

1. Climax communities maintain their mix of species for a long time, while successional communities are temporary.
2. Climax communities tend to have many specialized ecological niches, while successional communities tend to have more generalized niches.
3. Climax communities tend to have many more kinds of organisms and kinds of interactions among organisms than do successional communities.
4. Climax communities tend to recycle nutrients and maintain a relatively constant biomass, while successional communities tend to accumulate large amounts of new material.

The general trend in succession is toward increasing complexity and more efficient use of matter and energy compared to the successional communities that preceded them.

### *Aquatic Primary Succession*

The principal concepts of land succession can be applied to aquatic ecosystems. Except for the oceans, most aquatic ecosystems are considered temporary. Certainly, some are going to be around for

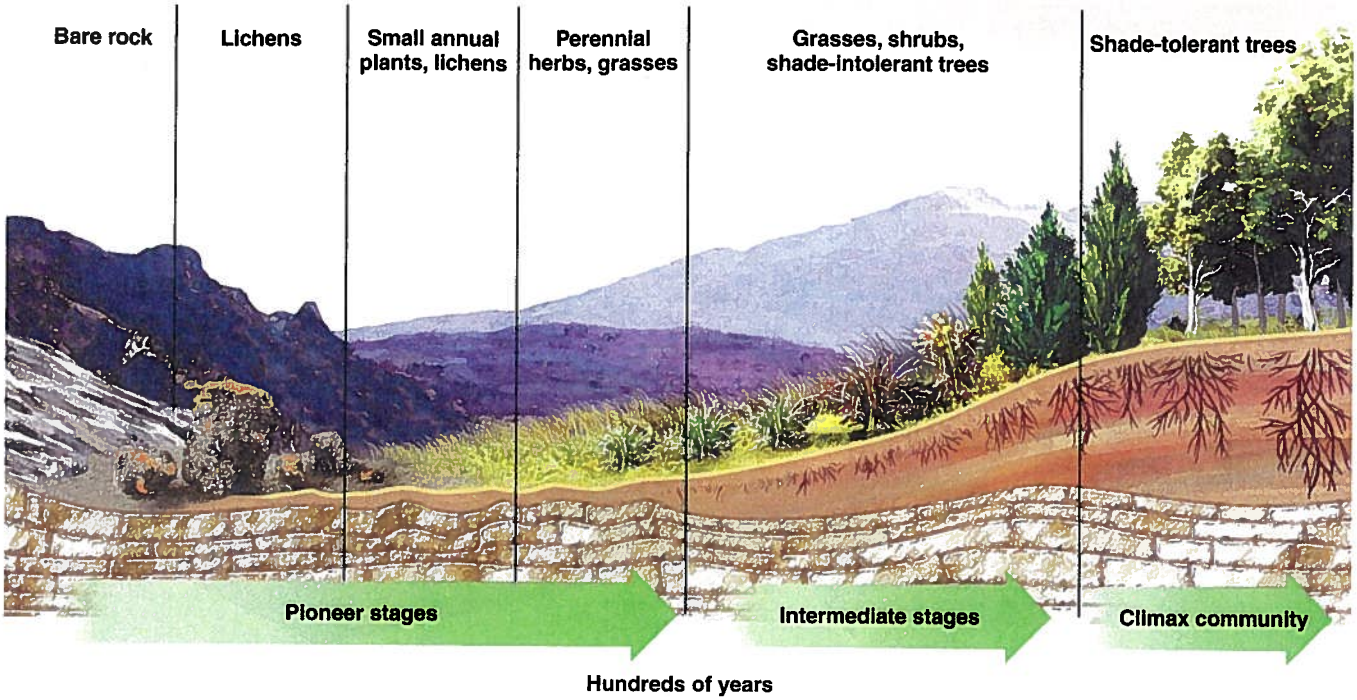



**FIGURE 6.3 Primary Succession on Land** The formation of soil is a major step in primary succession. Until soil is formed, the area is unable to support large amounts of vegetation, which modify the harsh environment. Once soil formation begins, the site proceeds through an orderly series of stages toward a climax community.

thousands of years, but eventually they will disappear and be replaced by terrestrial ecosystems as a result of normal successional processes. All aquatic ecosystems receive a continuous input of soil particles and organic matter from surrounding land, which results in the gradual filling in of shallow bodies of water such as ponds and lakes.

**1. Early Stages—Aquatic Vegetation** In deep portions of lakes and ponds, only floating plants and algae can exist. However, as sediment accumulates, the water depth becomes less, and it becomes possible for certain species of submerged plants to establish their roots in the sediments of the bottom of shallow bodies of water. They carry on photosynthesis, which results in a further accumulation of organic matter. These plants also tend to trap sediments that flow into the pond or lake from streams or rivers, resulting in a further decrease in water depth. Eventually, as the water becomes shallower, emergent plants become established. They have leaves that float on the surface of the water or project into the air. The network of roots and stems below the surface of the water results in the accumulation of more material, and the water depth decreases as material accumulates on the bottom. As the process continues, a wet soil is formed and grasses and other plants that can live in wet soil become established. This successional stage is often called a wet meadow.

**2. Later Stages—Transition to Terrestrial Communities** The activities of plants in a wet meadow tend to draw moisture from the soil, and, as more organic matter is added to the top layer of the soil, it becomes somewhat drier. Once this occurs, the stage is set for a typical terrestrial successional series of changes, eventually resulting in a climax community typical for the climate of the area. (See figure 6.4.)

**3. Observing Aquatic Succession** Since the shallower portions of most lakes and ponds are at the shore, it is often possible to see the various stages in aquatic succession from the shore. In the central, deeper portions of the lake, there are only floating plants and algae. As we approach the shore, we first find submerged plants such as *Elodea* and algal mats, then emergent vegetation such as water lilies and cattails, then grasses and sedges that can tolerate wet soil, and on the shore, the beginnings of a typical terrestrial succession resulting in the climax community typical for the area.

In many northern ponds and lakes, sphagnum moss forms thick, floating mats. These mats may allow certain plants that can tolerate wet soil conditions to become established. The roots of the plants bind the mat together and establish a floating bog, which may contain small trees and shrubs as well as many other smaller, flowering plants. (See figure 6.5.) Someone walking on such a mat would recognize that the entire system was floating when they noticed the trees sway or when they stepped through a weak zone in the mat and sank to their hips in water. Eventually, these bogs will become increasingly dry and the normal climax vegetation for the area will succeed the more temporary bog stage.

## Secondary Succession

The same processes and activities drive both primary and secondary succession. The major difference is that secondary succession occurs when an existing community is destroyed but much of the soil and some of the organisms remain. A forest fire, a flood, or the conversion of a natural ecosystem to agriculture may be the cause. Since much of the soil remains and many of the nutrients necessary for plant growth are still available, the process of

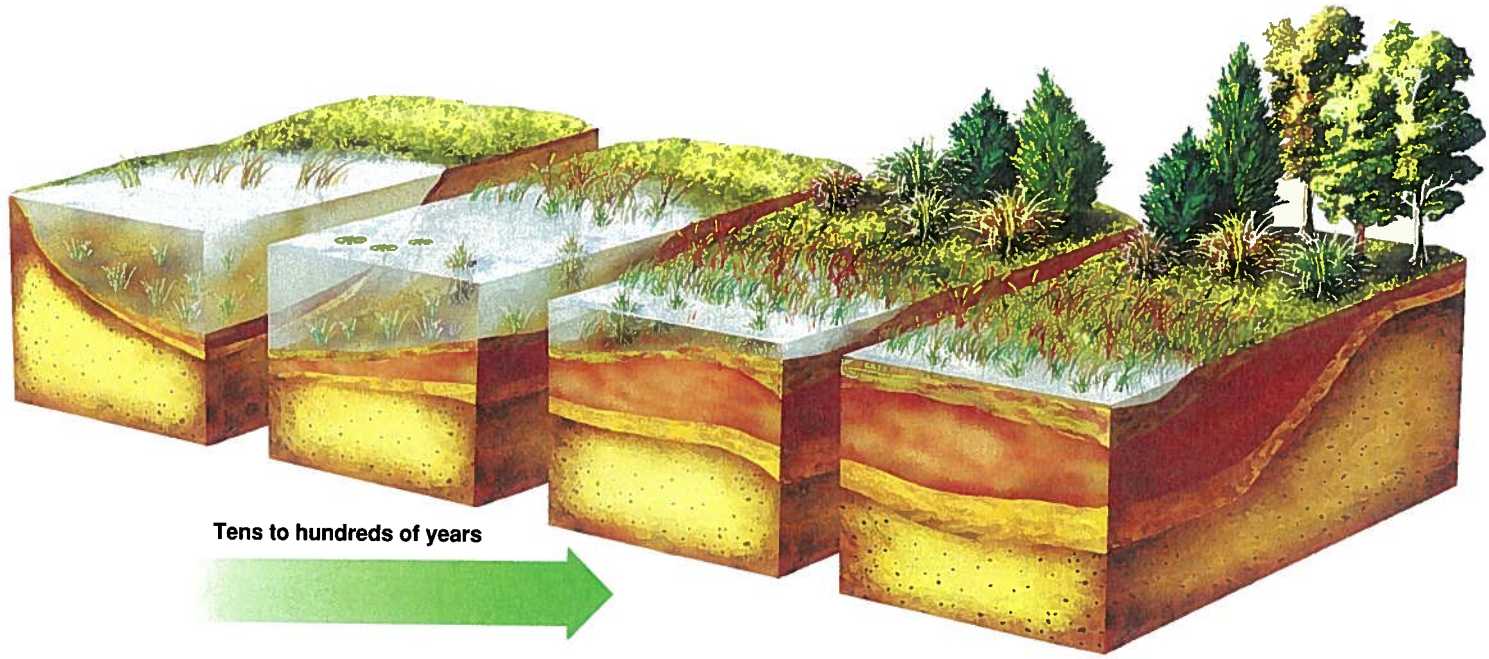



**FIGURE 6.4 Primary Succession from a Pond to a Wet Meadow** A shallow pond will fill slowly with organic matter from producers in the pond. Eventually, a wet soil will form and grasses will become established. In many areas, this will be succeeded by a climax forest.

**FIGURE 6.5 Floating Bog** In many northern regions, sphagnum moss forms a floating mat that can be colonized by plants that tolerate wet soils. A network of roots ties the mat together to form a floating community.

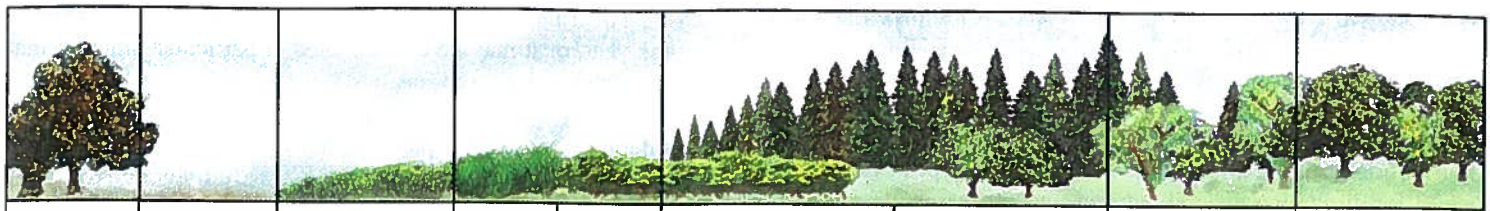
succession can advance more rapidly than primary succession. In addition, because some plants and other organisms may survive the disturbance and continue to grow and others will survive as roots or seeds, they can quickly reestablish themselves in the area. Furthermore, undamaged communities adjacent to the disturbed area can serve as sources of seeds and animals that migrate into the disturbed area. Thus, the new climax community is likely to resemble the one that was destroyed. Figure 6.6 shows old field succession—the typical secondary succession found on abandoned farmland in the southeastern United States.

Similarly, when beavers flood an area, the existing terrestrial community is replaced by an aquatic ecosystem. As the area behind the dam fills in with sediment and organic matter, it goes through a series of changes that may include floating plants, submerged plants, emergent plants, and wet meadow stages, but it eventually returns to the typical climax community for the area.

Many kinds of communities exist only as successional stages and are continually reestablished following disturbances. Many kinds of woodlands along rivers exist only where floods remove vegetation, allowing specific species to become established on the disturbed floodplain. Some kinds of forest and shrub communities exist only if fire occasionally destroys the mature forest. Windstorms such as hurricanes are also important in causing openings in forests that allow the establishment of certain kinds of plant communities.

## Modern Concepts of Succession and Climax

The discussion of the nature of succession and climax communities in the "Succession" section is an oversimplification of the true nature of the process. Some historical perspective will help to clarify how ecologists have altered their concept of successional change. When European explorers traveled across the North American continent, they saw huge expanses of land dominated by specific types of communities: hardwood forests in the east, evergreen forests in the north, grasslands in central North America, and deserts in the southwest. These regional communities came to be considered the steady-state or normal situation for those parts of the world. When ecologists began to explore



| Mature oak/hickory forest destroyed | Farmland abandoned | Annual plants | Grasses and biennial herbs | Perennial herbs and shrubs begin to replace grasses and biennials | Pines begin to replace shrubs | Young oak and hickory trees begin to grow | Pines die and are replaced by mature oak and hickory trees | Mature oak/hickory forest |
|---|---|---|---|---|---|---|---|---|
| | | 1–2 years | 3–4 years | 4–15 years | 5–15 years | 10–30 years | 50–75 years | |

**FIGURE 6.6** **Secondary Succession on Land** A plowed field in the southeastern United States shows a parade of changes over time, involving plant and animal associations. The general pattern is for annual weeds to be replaced by grasses and other perennial herbs, which are replaced by shrubs, which are replaced by trees. As the plant species change, so do the animal species.

the way in which ecosystems developed over time, they began to think of these ecosystems as the end point or climax of a long journey, beginning with the formation of soil and its colonization by a variety of plants and other organisms.

As settlers removed the original forests or grasslands and converted the land to farming, the original "climax" community was destroyed. Eventually, as poor farming practices destroyed the soil, many farms were abandoned and the land was allowed to return to its "original" condition. This secondary succession often resulted in forests that resembled those that had been destroyed. However, in most cases, these successional forests contained fewer species and in some cases were entirely different kinds of communities from the originals. These new stable communities were also called climax communities, but they were not the same as the original climax communities.

In addition, the introduction of species from Europe and other parts of the world changed the mix of organisms that might colonize an area. Many grasses and herbs that were introduced either on purpose or accidentally have become well established. Today, some communities are dominated by these introduced species. Even diseases have altered the nature of climax communities. Chestnut blight and Dutch elm disease have removed tree species that were at one time dominant species in certain plant communities.

Ecologists began to recognize that there was no fixed, predetermined community for each part of the world, and they began to modify the way they looked at the concept of climax communities. The concept today is a more plastic one. It is still used to talk about a stable stage following a period of change, but ecologists no longer feel that land will eventually return to a "preordained" climax condition. They have also recognized in recent years that the type of climax community that develops depends on many factors other than simply climate. One of these is the availability of seeds to colonize new areas. Some seeds may lie dormant in the soil for a decade or more, while others may be carried to an area by wind, water, or animals. Two areas with very similar climate and soil characteristics may develop very different successional and "climax" communities because of the seeds that were present in the area when the lands were released from agriculture.

Furthermore, we need to recognize that the only thing that differentiates a "climax" community from a successional one is the timescale over which change occurs. "Climax" communities do not change as rapidly as successional ones. However, all communities are eventually replaced, as were the swamps that produced coal deposits, the preglacial forests of Europe and North America, and the pine forests of the northeastern United States.

Many human activities alter the nature of the successional process. Agricultural practices obviously modify the original community to allow for the raising of crops. However, several other management practices have also significantly altered communities. Regular logging returns a forest to an earlier stage of succession. The suppression of fire in many forests has also changed the mix of organisms present. When fire is suppressed, those plants that are killed by regular fires become more common and those that are able to resist fire become less common. Changing the amount of water present will also change the kind of community. Draining an area makes it less suitable for the original inhabitants and more suitable for those that live in drier settings. Similarly, irrigation and flooding increase the amount of water present and change the kinds of organisms that can live in an area.

So what should we do with these concepts of succession and climax communities? Although the climax concept embraces a false notion that there is a specific end point to succession, it is still important to recognize that there is an identifiable, predictable pattern of change during succession and that later stages in succession are more stable and longer lasting than early stages. Whether we call a specific community of organisms a climax community is not really important.

# BIOMES ARE DETERMINED BY CLIMATE

**Biomes** are terrestrial climax communities with wide geographic distribution. (See figure 6.7.) Although the concept of biomes is useful for discussing general patterns and processes, it is important to recognize that when different communities within a particular biome are examined, they will show differences in the exact species present. However, in broad terms, the general structure of the ecosystem and the kinds of niches and habitats present are similar.

## Precipitation and Temperature

Patterns of precipitation and temperature are two primary nonbiological factors that have major impacts on the kind of climax community that develops in any part of the world. Several aspects of precipitation are important: the total amount of precipitation per year, the form in which it arrives (rain, snow, sleet), and its seasonal distribution. Precipitation may be evenly spaced throughout the year, or it may be concentrated at particular times so that there are wet and dry seasons.

The temperature patterns are also important and can vary considerably in different parts of the world. Tropical areas have warm, relatively unchanging temperatures throughout the year. Areas near the poles have long winters with extremely cold temperatures and relatively short, cool summers. Other areas are more evenly divided between cold and warm periods of the year. (See figure 6.8.)

Although temperature and precipitation are of primary importance, several other factors may influence the kind of climax community present. Periodic fires are important in maintaining some grassland and shrub climax communities because the fires prevent the establishment of larger, woody species. Some parts of the world have frequent, strong winds that prevent the establishment of trees and cause rapid drying of the soil. The type of soil present is also very important. Sandy soils tend to dry out quickly and may not allow the establishment of more water-demanding species such as trees, while extremely wet soils

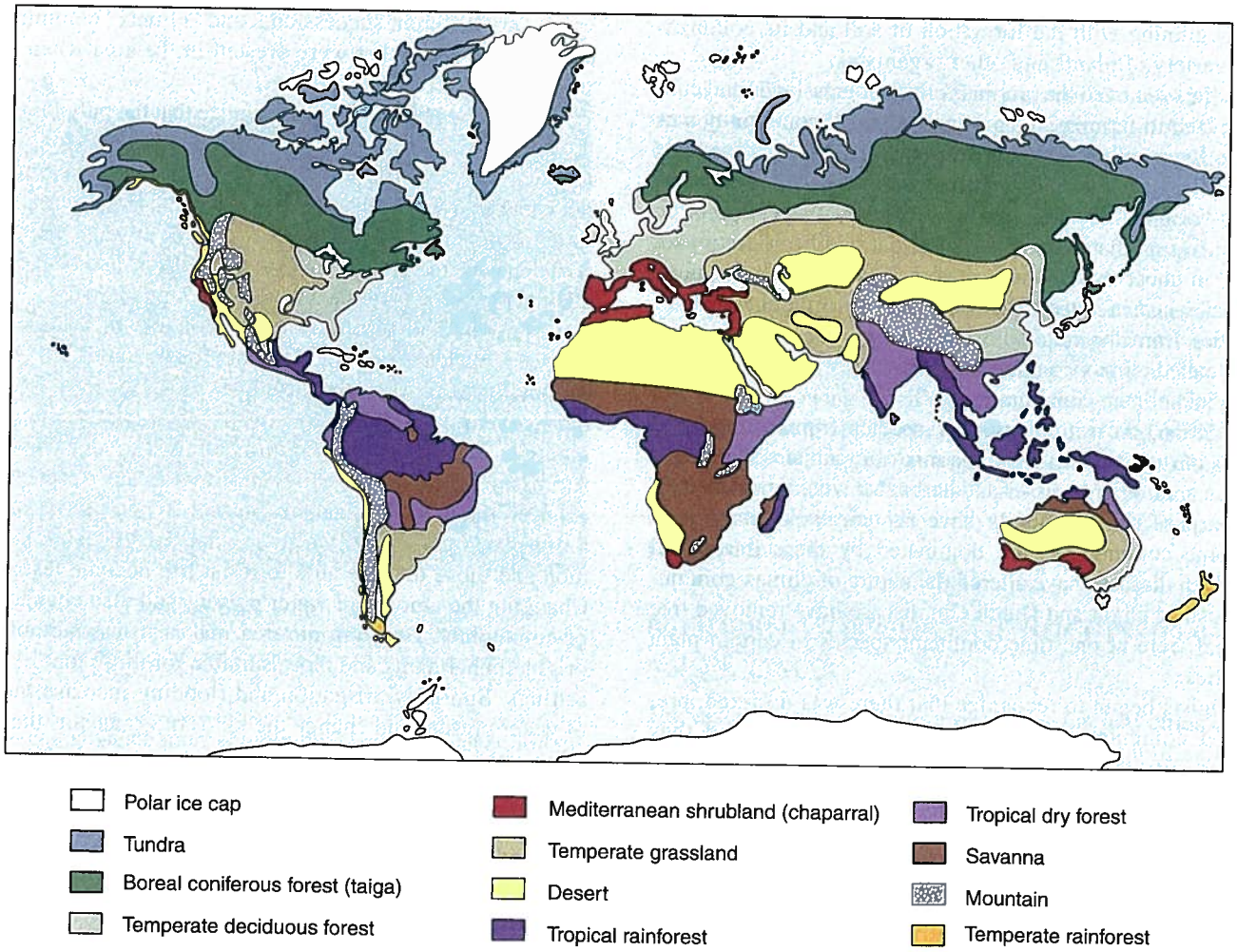



**FIGURE 6.7 Biomes of the World** Although most biomes are named for a major type of vegetation, each also includes a specialized group of animals adapted to the plants and the biome's climatic conditions.

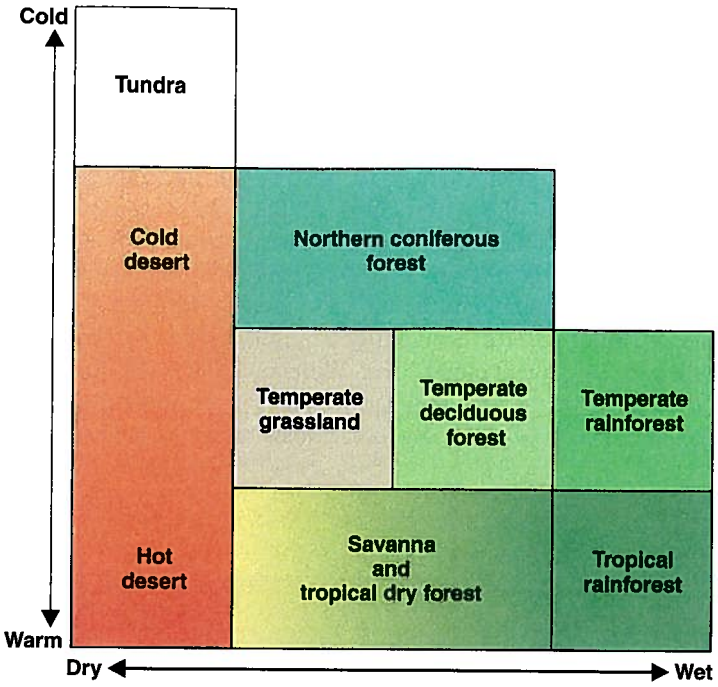



**FIGURE 6.8 Influence of Precipitation and Temperature on Vegetation** Temperature and moisture are two major factors that influence the kind of vegetation that can occur in an area. Areas with low moisture and low temperatures produce tundra; areas with high moisture and freezing temperatures during part of the year produce deciduous or coniferous forests; dry areas produce deserts; moderate amounts of rainfall or seasonal rainfall support temperate grasslands or savannas; and areas with high rainfall and high temperatures support tropical rainforests.

may allow only certain species of trees to grow. Obviously, the kinds of organisms currently living in the area are also important, since their offspring will be the ones available to colonize a new area.

## The Effect of Elevation on Climate and Vegetation

The distribution of terrestrial ecosystems is primarily related to precipitation and temperature. The temperature is warmest near the equator and becomes cooler toward the poles. Similarly, as the height above sea level increases, the average temperature decreases. This means that even at the equator, it is possible to have cold temperatures on the peaks of tall mountains. As one proceeds from sea level to the tops of mountains, it is possible to pass through a series of biomes that is similar to what would be encountered as one traveled from the equator to the North Pole. (See figure 6.9.)

# MAJOR BIOMES OF THE WORLD

In the next sections, we will look at the major biomes of the world and highlight the abiotic and biotic features typical of each biome.

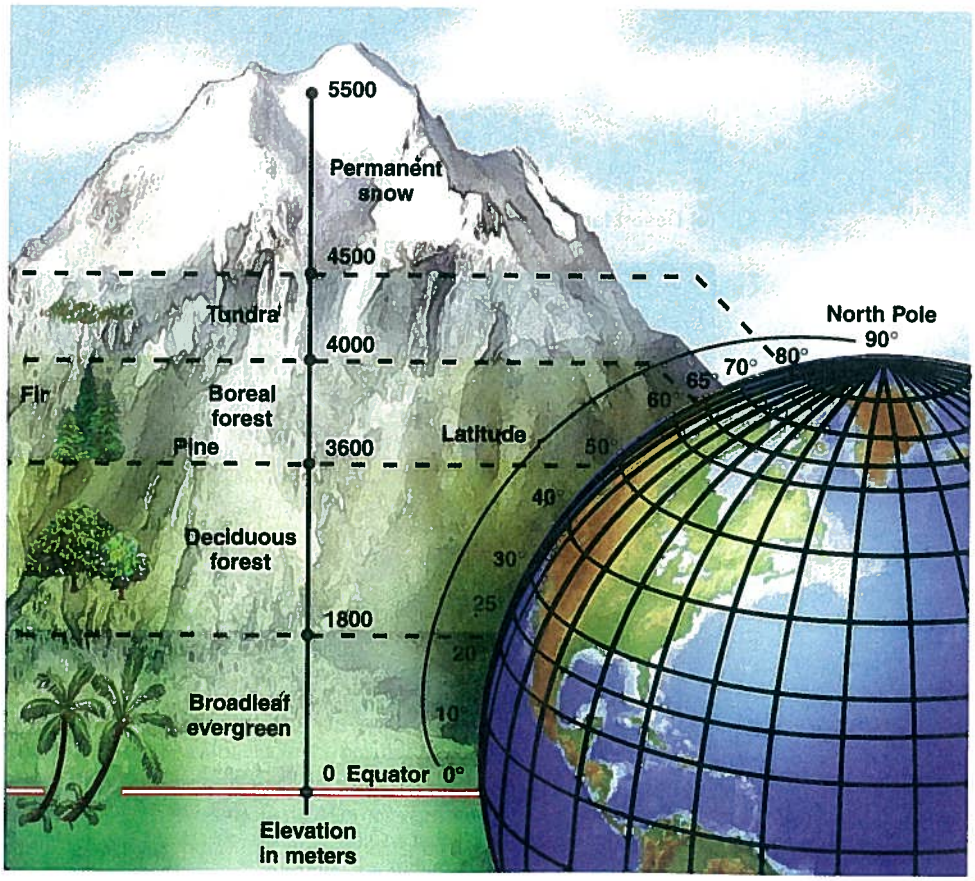



**FIGURE 6.9 Relationship Among Height above Sea Level, Latitude, and Vegetation** As one travels up a mountain, the climate changes. The higher the elevation, the cooler the climate. Even in the tropics, tall mountains can have snow on the top. Thus, it is possible to experience the same change in vegetation by traveling up a mountain as one would experience traveling from the equator to the North Pole.

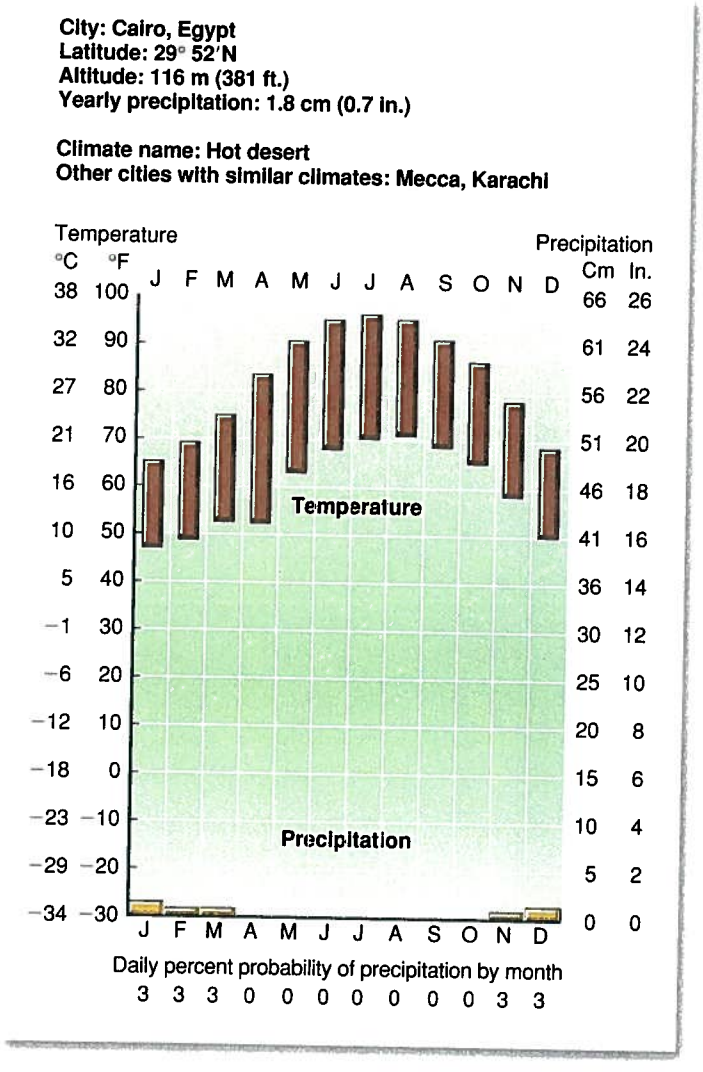
## Desert

Deserts are found throughout the world.

### *Climate*

A lack of water is the primary factor that determines that an area will be a desert. **Deserts** are areas that generally average less than 25 centimeters (10 inches) of precipitation per year. (See figure 6.10.) When and how precipitation arrives is quite variable in different deserts. Some deserts receive most of the moisture as snow or rain in the winter months, while in others rain comes in the form of thundershowers at infrequent intervals. If rain comes as heavy thundershowers, much of the water does not sink into the ground but runs off into gullies. Also, since the rate of evaporation is high, plant growth and flowering usually coincide with the periods when moisture is available. Deserts are also likely to be windy.

We often think of deserts as hot, dry wastelands devoid of life. However, many deserts are quite cool during a major part of the year. Certainly, the Sahara Desert and the deserts of the southwestern United States and Mexico are hot during much of the year, but the desert areas of the northwestern United States and the Gobi Desert in Central Asia can be extremely cold during winter months and have relatively cool summers. Furthermore, the temperature can vary greatly during a 24-hour period. Since deserts receive little rainfall, it is logical that most will have infrequent cloud cover. With no clouds to block out the sun, during the day the soil surface and the air above it tend to heat up rapidly. After the sun has set, the absence of an insulating




(a)

(b) Desert landscape

(c) Coyote

(d) Collared lizard

**FIGURE 6.10 Desert** (a) Climagraph for Cairo, Egypt. (b) The desert receives less than 25 centimeters (10 inches) of precipitation per year, yet it teems with life. Cactus, sagebrush, lichens, snakes, small mammals, birds, and insects inhabit the desert. (c) Coyotes are common in North American deserts. (d) Collared lizards are common reptiles in many deserts of the United States. Because daytime temperatures are often high, most animals are active only at night, when the air temperature drops significantly. Cool deserts also exist in many parts of the world, where rainfall is low but temperatures are not high.

## Going Green

## Conservation Easements

There are over 1600 private organizations in the United States that are involved in conservation of land. Some are small, single-purpose organizations that protect a small parcel of land with special conservation value. On the other hand, The Nature Conservancy is an international organization that has protected millions of acres.

People often develop an attachment to their land and wish to see it preserved even after they have died. People may have a long family history of using the land for farming or ranching and want to see that use continue. Others may recognize that their land has special conservation value because of its geology, scenic value, or biodiversity and wish to see it protected for the public good. Others may simply have a purely emotional reason for wanting to preserve their land. One of the tools used by land conservation organizations is a legal tool known as a *conservation easement.*

A conservation easement is a legally binding agreement placed on a piece of privately held land that limits the future use or development even when the land is passed to heirs or sold. For example, a conservation easement may prohibit the subdividing of a piece of land or restrict buildings to a specific portion of the property, or an easement may specify that the public must have access to view significant biological or geological features. Alternatively, the easement may restrict access to protect endangered species or archeological sites.

Regardless of their motivation, when people enter into a conservation easement they give up something. In some cases, people donate a conservation easement and receive no financial benefit. In other cases, they may sell a conservation easement to an organization that agrees to provide stewardship of the property into the future. In nearly all cases the placement of a conservation easement on property diminishes its economic value, since its future use is restricted. Yet, thousands of people have entered into such arrangements. As of 2005, in the United States, over 6 million acres of land (an area about the size of Vermont) had been protected by conservation easements.

layer of clouds allows heat energy to be reradiated from the Earth, and the area cools off rapidly. Cool to cold nights are typical even in "hot" deserts, especially during the winter months.

### *Organisms*

Another misconception about deserts is that few species of organisms live in the desert. There are many species, but they typically have low numbers of individuals. For example, a conspicuous feature of deserts is the dispersed nature of the plants. There is a significant amount of space between them. Similarly, animals do not have large, dense populations. However, those species that are present are specially adapted to survive in dry, often hot environments. For example, water evaporates from the surfaces of leaves. As an adaptation to this condition, many desert plants have very small leaves that allow them to conserve water. Some even lose their leaves entirely during the driest part of the year. Some, such as cactus, have the ability to store water in their spongy bodies or their roots for use during drier periods. Other plants have parts or seeds that lie dormant until the rains come. Then they germinate, grow rapidly, reproduce, and die, or become dormant until the next rains. Even the perennial plants are tied to the infrequent rains. During these times, the plants are most likely to produce flowers and reproduce. Many desert plants are spiny. The spines discourage large animals from eating the leaves and young twigs.

The desert has many kinds of animals. However, they are often overlooked because their populations are low, numerous species are of small size, and many are inactive during the hot part of the day. They also aren't seen in large, conspicuous groups. Many insects, lizards, snakes, small mammals, grazing mammals, carnivorous mammals, and birds are common in desert areas. All of the animals that live in deserts are able to survive with a minimal amount of water. Some receive nearly all of their water from the moisture in the food they eat. They generally have an outer skin or cuticle that resists water loss, so they lose little water by evaporation. They also have physiological adaptations, such as extremely efficient kidneys, that allow them to retain water. They often limit their activities to the cooler part of the day (the evening), and small mammals may spend considerable amounts of time in underground burrows during the day, which allows them to avoid extreme temperatures and to conserve water.

### *Human Impact*

Throughout history, deserts have been regions where humans have had little impact. The harshness of the climate does not allow for

agriculture. Therefore, hunter-gatherer societies were the most common ones associated with deserts. Some deserts support nomadic herding in which herders move their livestock to find patches of vegetation for grazing. Modern technology allows for the transport of water to the desert. This has resulted in the development of cities in some desert areas and some limited agriculture as a result of irrigation.

## Temperate Grassland

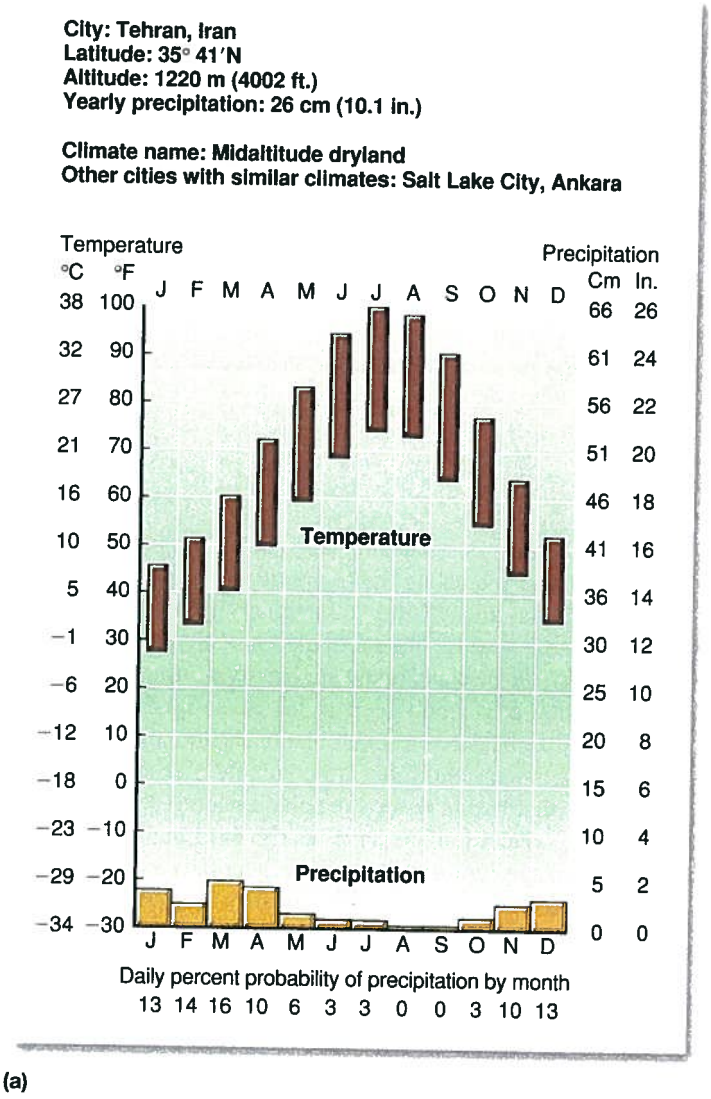
**Temperate grasslands,** also known as **prairies** or **steppes,** are widely distributed over temperate parts of the world.

### *Climate*

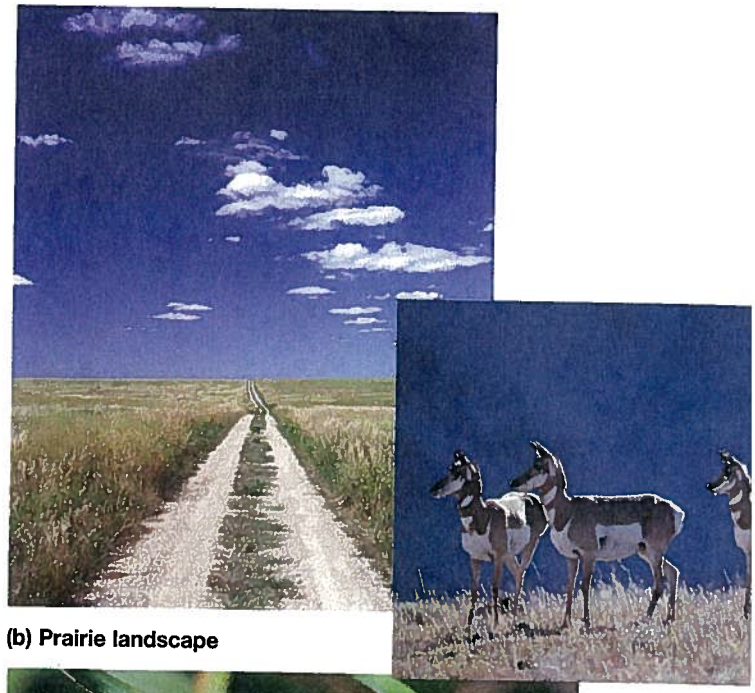
As with deserts, the major factor that contributes to the establishment of a temperate grassland is the amount of available moisture. Grasslands generally receive between 25 and 75 centimeters (10 to 30 inches) of precipitation per year. These areas are windy with hot summers and cold-to-mild winters. In many grasslands, fire is an important force in preventing the invasion of trees and releasing nutrients from dead plants to the soil.

### *Organisms*

Grasses make up 60 to 90 percent of the vegetation. Many other kinds of flowering plants are interspersed with the grasses. (See figure 6.11.) Typically, the grasses and other plants are very




(a)



(b) Prairie landscape



(c) Pronghorn

(d) Grasshopper

(e) Meadowlark

**FIGURE 6.11 Temperate Grassland** (a) Climagraph for Tehran, Iran. (b) Grasses are better able to withstand low water levels than are trees. Therefore, in areas that have moderate rainfall, grasses are the dominant plants. (c & d) Pronghorns and grasshoppers are common herbivores and (e) meadowlarks are common consumers of insects in North American grasslands.

# CAMPUS SUSTAINABILITY INITIATIVE

## The Blue Oak Ranch Reserve of the University of California–Berkeley

The Blue Oak Ranch Reserve is located in the Mount Hamilton Range near San Jose, California. The 3260-acre (1300 hectare) reserve is protected by a conservation easement held by The Nature Conservancy and is the newest of 36 California reserves overseen by the University of California's Natural Reserve System. The reserve has special research and education value because it has remained undeveloped for its entire history.

The reserve helps protect many species of plants and wildlife and provides many research opportunities. There are more than 430 species of plants, 130 species of birds, 41 species of mammals, 14 species of reptiles, 7 species of amphibians—including the rare Foothill yellow-legged frogs and the endangered California tiger salamander—7 species of fish, and hundreds of species of invertebrates that make use of the reserve. The reserve contains mature blue oaks, valley oaks, and two species of live oak. The reserve has many mature oaks, but few oak seedlings. One avenue of research would be to try to find out why these oak woodlands are not regenerating.

Because the reserve is part of a much larger area of protected land, it is an important link for migratory wildlife. Thus, its location provides opportunities for major research projects that address large-scale conservation and land management issues of regional, state, and national concern.

The reserve's location near a fast-growing urban area also makes it ideal for studying issues like nitrogen deposition and loss of biodiversity that are particularly acute at the interface between wild land and urban development.

close together, and their roots form a network that binds the soil together. Trees, which generally require greater amounts of water, are rare in these areas except along watercourses.

The primary consumers are animals that eat the grasses, such as large herds of migratory, grazing mammals such as bison, wildebeests, wild horses, and various kinds of sheep, cattle, and goats. While the grazers are important as consumers of the grasses, they also supply fertilizer from their dung and discourage invasion by woody species of plants because they eat the young shoots.

In addition to grazing mammals, many kinds of insects, including grasshoppers and other herbivorous insects, dung beetles (which feed on the dung of grazing animals), and several kinds of flies are common. Some of these flies bite to obtain blood. Others lay their eggs in the dung of large mammals. Some feed on dead animals and lay their eggs in carcasses. Small herbivorous mammals, such as mice and ground squirrels, are also common. Birds are often associated with grazing mammals. They eat the insects stirred up by the mammals or feed on the insects that bite them. Other birds feed on seeds and other plant parts. Reptiles (snakes and lizards) and other carnivores such as coyotes, foxes, and hawks feed on small mammals and insects.

### *Human Impact*

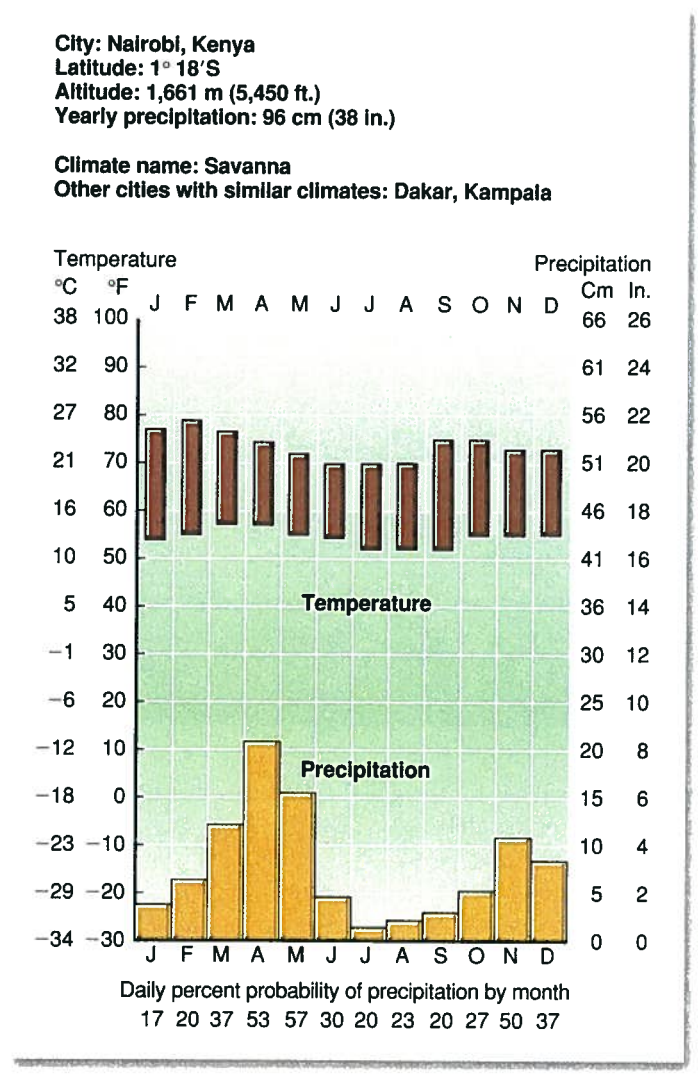
Most of the moist grasslands of the world have been converted to agriculture, since the rich, deep soil that developed as a result of the activities of centuries of soil building is useful for growing cultivated grasses such as corn (maize) and wheat. The drier grasslands have been converted to the raising of domesticated grazers such as cattle, sheep, and goats. Therefore, little undisturbed grassland is left, and those fragments that remain need to be preserved as refuges for the grassland species that once occupied huge portions of the globe.

## Savanna

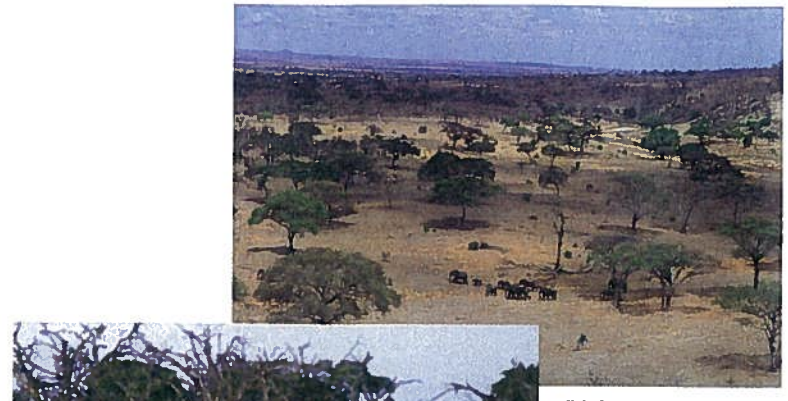
**Savannas** are found in tropical parts of Africa, South America, and Australia and are characterized by extensive grasslands spotted with occasional trees or patches of trees. (See figure 6.12.) Although savannas receive 50 to 150 centimeters (20 to 60 inches) of rain per year, the rain is not distributed evenly throughout the year. Typically, a period of heavy rainfall is followed by a prolonged drought. This results in a very seasonally structured ecosystem.

### *Organisms*

The plants and animals time their reproductive activities to coincide with the rainy period, when limiting factors are less severe. The predominant plants are grasses, but many drought-resistant, flat-topped, thorny trees are common. As with grasslands, fire is a common feature of the savanna, and the trees present are resistant to fire damage. Many of these trees are particularly important because they are legumes that are involved in nitrogen fixation. They also provide shade and nesting sites for animals. As with grasslands, the predominant mammals are the grazers. Wallabies in Australia, wildebeests, zebras, elephants, and various species of antelope in Africa, and capybaras (rodents) in South America are examples. In Africa, the large herds of grazing animals provide food for many different kinds of large carnivores (lions, hyenas, leopards). Many kinds of rodents, birds, insects, and reptiles are associated with this biome. Among the insects, mound-building termites are particularly common.



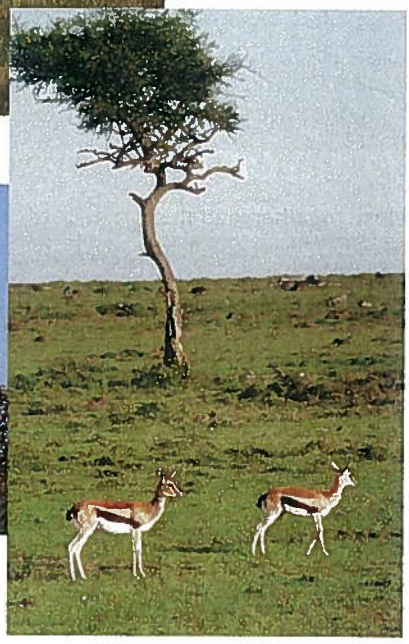

(a)



(b) Savanna landscape

(c) Lion

(d) Secretary birds



(e) Thomson's gazelles

**FIGURE 6.12** **Savanna** (a) Climagraph for Nairobi, Kenya. (b) Savannas develop in tropical areas that have seasonal rainfall. They typically have grasses as the dominant vegetation with drought- and fire-resistant trees scattered through the area. Grazing animals such as elephants and gazelles (b, e) are common herbivores and lions and secretary birds (c, d) are common carnivores in African savannas.

### *Human Impact*

Savannas have been heavily impacted by agriculture. Farming is possible in the more moist regions, and the drier regions are used for the raising of livestock. Because of the long periods of drought, the raising of crops is often difficult without irrigation. Some areas support nomadic herding. In Africa there are extensive areas set aside as parks and natural areas and ecotourism is an important source of income. However, there is a constant struggle between the people who want to use the land for agriculture or grazing and those who want to preserve it in a more natural state.

## Mediterranean Shrublands (Chaparral)

The **Mediterranean shrublands** are located near oceans and are dominated by shrubby plants.

### *Climate*

Mediterranean shrublands have a climate with wet, cool winters and hot, dry summers. Rainfall is 40 to 100 centimeters (15 to 40 inches) per year. As the name implies, this biome is typical of the Mediterranean coast and is also found in coastal southern

California, the southern tip of Africa, a portion of the west coast of Chile, and southern Australia.

### *Organisms*

The vegetation is dominated by woody shrubs that are adapted to withstand the hot, dry summer. (See figure 6.13.) Often the plants are dormant during the summer. Fire is a common feature of this biome, and the shrubs are adapted to withstand occasional fires. The kinds of animals vary widely in the different regions of the world with this biome. Many kinds of insects, reptiles, birds, and mammals are found in these areas. In the chaparral of California, rattlesnakes, spiders, coyotes, lizards, and rodents are typical inhabitants.

### *Human Impact*

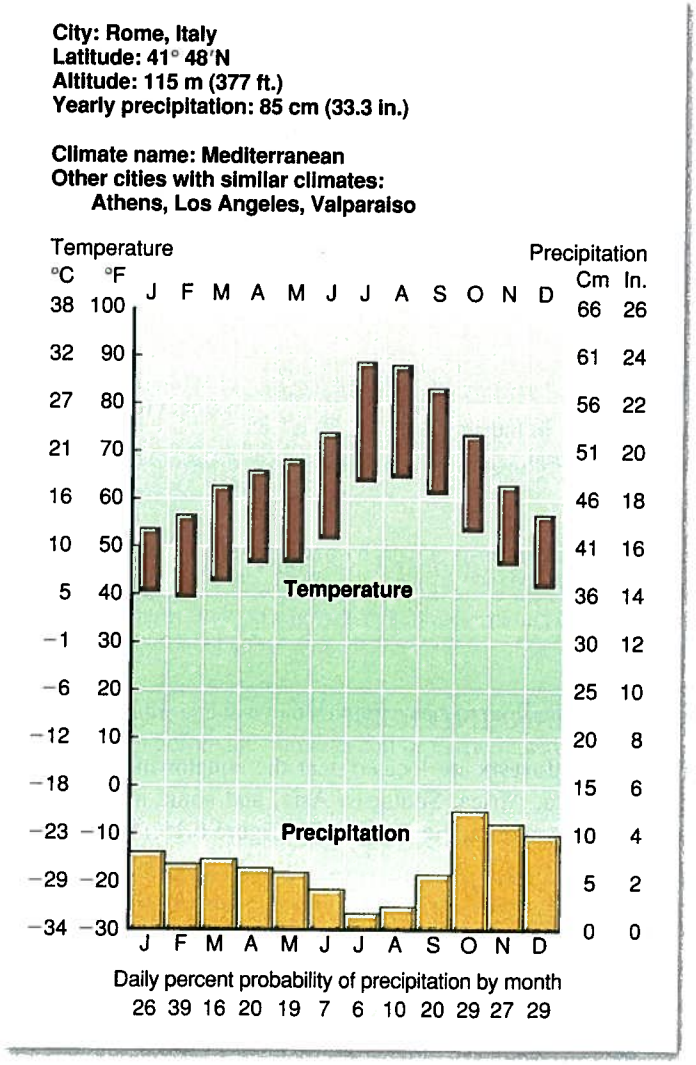
Very little undisturbed Mediterranean shrubland still exists. The combination of moderate climate and closeness to the ocean has resulted in all Mediterranean shrublands being heavily altered by human activity. Agriculture is common, often with the aid of irrigation, and many major cities are located in this biome.

## Tropical Dry Forest

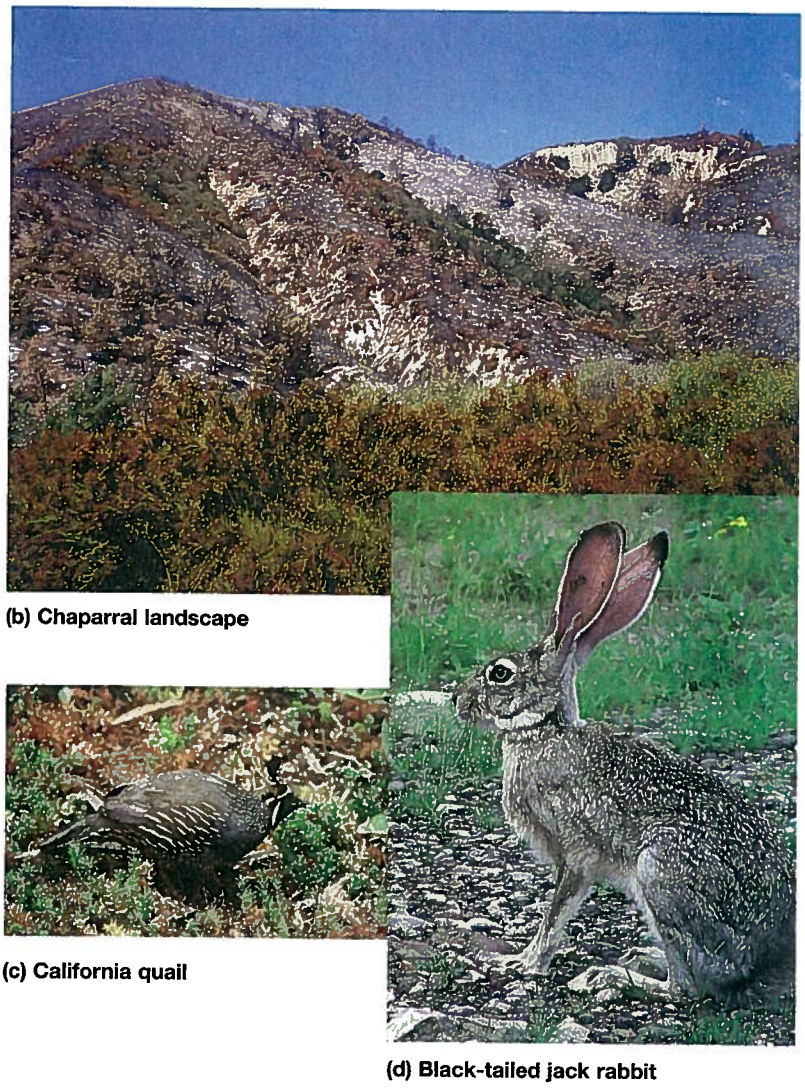
The **tropical dry forest** is another biome that is heavily influenced by seasonal rainfall. Tropical dry forests are found in parts of Central and South America, Australia, Africa, and Asia (particularly India and Myanmar).

### *Climate*

Many of the tropical dry forests have a monsoon climate in which several months of heavy rainfall are followed by extensive dry periods ranging from a few to as many as eight months. (See figure 6.14.) The rainfall may be as low as 50 centimeters (20 inches) or as high as 200 centimeters (80 inches).




(a)

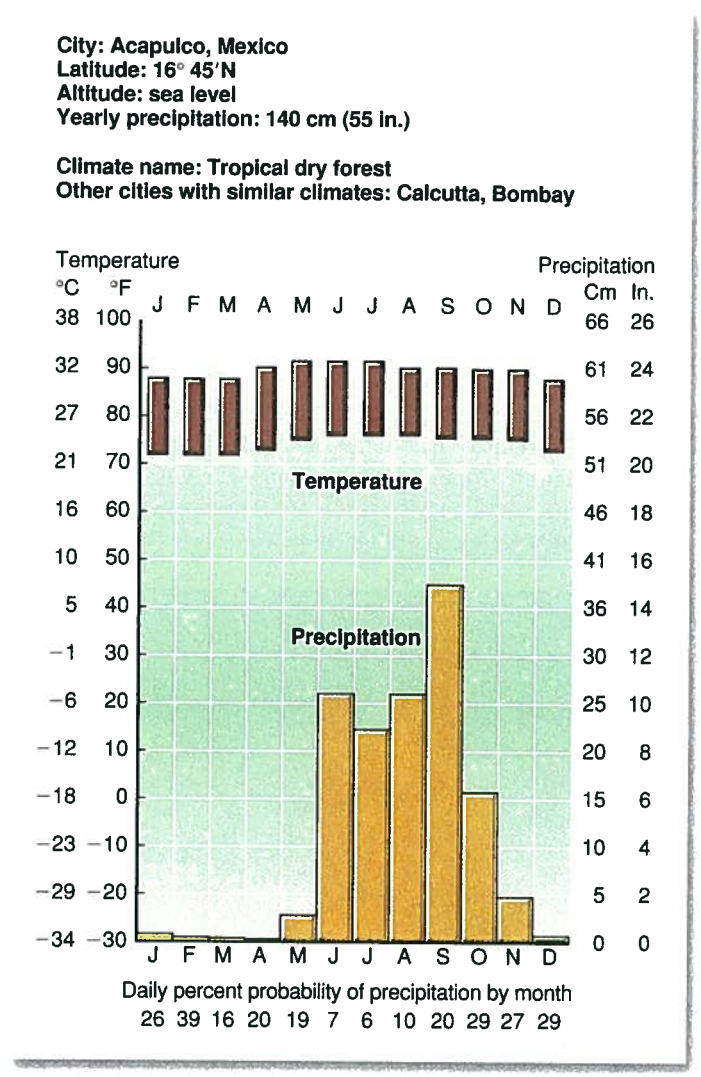


(b) Chaparral landscape

(c) California quail

(d) Black-tailed jack rabbit

**Figure 6.13** **Mediterranean Shrubland** (a) Climagraph for Rome, Italy. (b) Mediterranean shrublands are characterized by a period of winter rains and a dry, hot summer. The dominant plants are drought-resistant, woody shrubs. (c,d) Common animals in the Mediterranean shrubland (chaparral) of California are the California quail and black-tailed jack rabbit.




(a)

(b) Tropical dry forest landscape

(c) White-faced coati in Costa Rica

(d) Rhinoceros in Indian tropical dry forest

**FIGURE 6.14** **Tropical Dry Forest** (a) Climagraph for Acapulco, Mexico. (b) Tropical dry forests typically have a period of several months with no rain. In places where the drought is long, many of the larger trees lose their leaves. The coati (c) is a common animal in the tropical dry forests of the Americas. The endangered one-horned rhinoceros (d) is an inhabitant of the tropical dry forest of Asia.

### *Organisms*

Since the rainfall is highly seasonal, many of the plants have special adaptations for enduring drought. In many of the regions that have extensive dry periods, many of the trees drop their leaves during the dry period. Many of the species of animals found here are also found in more moist tropical forests of the region. However, there are fewer kinds in dry forests than in rainforests.

### *Human Impacts*

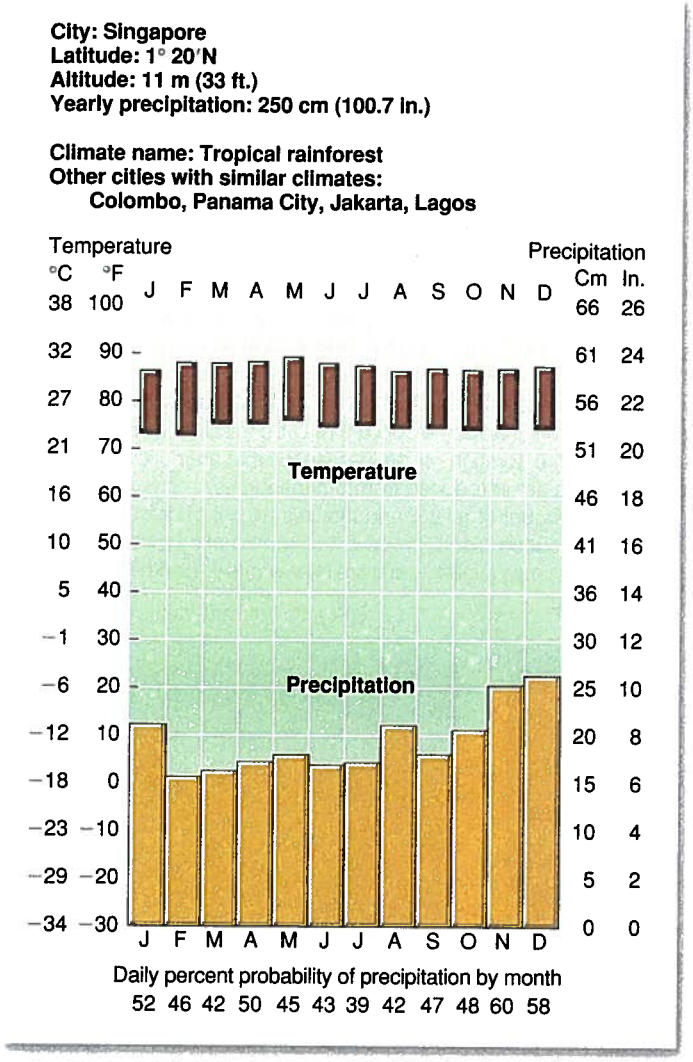
Many of these forests occur in areas of very high human population. Therefore, the harvesting of wood for fuel and building materials has heavily affected these forests. In addition, many of these forests have been converted to farming or the grazing of animals.

## Tropical Rainforest

**Tropical rainforests** are located near the equator in Central and South America, Africa, Southeast Asia, and some islands in the Caribbean Sea and Pacific Ocean. (See figure 6.15.)

### *Climate*

The temperature is normally warm and relatively constant. There is no frost, and it rains nearly every day. Most areas receive in excess of 200 centimeters (80 inches) of rain per year. Some receive 500 centimeters (200 inches) or more. Because of the warm temperatures and abundant rainfall, most plants grow very rapidly; however, soils are usually poor in nutrients because water tends to carry away any nutrients not immediately taken up by plants. Many of the trees have extensive root networks, associated with fungi (mycorrhizae), near




(a)

(b) Tropical rainforest landscape

(c) Blue morpho butterfly

(d) Squirrel monkey

**FIGURE 6.15 Tropical Rainforest** (a) Climagraph for Singapore. (b-d) Tropical rainforests develop in areas with high rainfall and warm temperatures. They have an extremely diverse mixture of plants and animals such as birds, butterflies, and monkeys.

the surface of the soil that allow them to capture nutrients from decaying vegetation before the nutrients can be carried away.

## *Organisms*

Tropical rainforests have a greater diversity of species than any other biome. More species are found in the tropical rainforests of the world than in the rest of the world combined. A small area of a few square kilometers is likely to have hundreds of species of trees. Furthermore, it is typical to have distances of a kilometer or more between two individuals of the same species. Balsa, teakwood, and many other ornamental woods are from tropical trees.

Each of those trees is home to a set of animals and plants that use it as food, shelter, or support. The canopy, which forms a solid wall of leaves between the sun and the forest floor, consists of two or three levels. A few trees, called emergent trees, protrude above the canopy. Below the canopy is a layer of understory tree species.

Since most of the sunlight is captured by the trees, only shade-tolerant plants live beneath the trees' canopy. In addition, the understory has many vines that attach themselves to the tall trees and grow toward the sun. When the vines reach the canopy, they can compete effectively with their supporting tree for available sunlight. In addition to supporting various vines, each tree serves as a surface for the growth of ferns, mosses, and orchids.

Recently, biologists discovered a whole new community of organisms that live in the canopy of these forests. Rainfall is a source of new nutrients, since atmospheric particles and gases dissolve as the rain falls. The canopy contains many kinds of epiphytic plants (plants that live on the surfaces of other plants) that trap many of these nutrients in the canopy before they can reach the soil.