weighing the ISSUES

Restoring "Natural" Communities

Practitioners of ecological restoration aim to restore communities to their natural state. But what does "natural" mean? Does it mean the state of a community before industrialization? Before Europeans came to the New World? Before any people laid eyes on the community? Native Americans modified many forests starting thousands of years ago by burning underbrush to improve hunting. Should restorationists try to re-create forests that existed before Native Americans arrived? What values do you think underlie the desire for restoration?

the native fauna. Moreover, the ambitious project has struggled against budget shortfalls and political interference, and most of its goals have not yet been met. (We will explore ecological restoration projects further in Chapter 11; p. 296.)

As our population grows and development spreads, ecological restoration is becoming an increasingly vital conservation strategy. However, restoration is difficult, time-consuming, and expensive, and it is not always successful. It is therefore best, whenever possible, to protect natural systems from degradation in the first place.

Earth's Biomes

Across the world, each location is home to different assemblages of species, leading to endless variety in community composition. However, communities in far-flung places often share strong similarities in their structure and function. This allows us to classify communities into broad types. A **biome** is a major regional complex of similar communities—a large-scale ecological unit recognized primarily by its dominant plant type and vegetation structure. The world contains a number of terrestrial biomes, each covering large geographic areas (**FIGURE 4.16**).

Climate helps determine biomes

Which biome covers each portion of the planet depends on a variety of physical factors, including temperature, precipitation, soil conditions, and the circulation patterns of wind in the atmosphere and water in the oceans. Among these factors, temperature and precipitation exert the greatest influence (**FIGURE 4.17**). Global climate patterns cause biomes to occur in large patches in different parts of the world. For instance, temperate deciduous forest occurs in Europe, China, and eastern North America. Note in Figure 4.16 that patches of any given terrestrial biome tend to occur at similar latitudes. This is due to Earth's north–south gradients in temperature and to atmospheric circulation patterns (p. 451).

Mountainous areas host complex mixes of biomes because climate varies with elevation. At higher altitudes, temperature, atmospheric pressure, and oxygen all decline, whereas ultraviolet radiation increases. A hiker scaling one of the great peaks of the Andes in Ecuador, near the equator, might climb from tropical rainforest through cloud forest up to alpine tundra and glaciers. Mountain ranges can also alter climate through the **rainshadow** effect. When moisture-laden air ascends a steep slope, it releases precipitation as it cools. By the time it flows over the top and down the other side, it can be very dry, creating an arid region in the rainshadow.

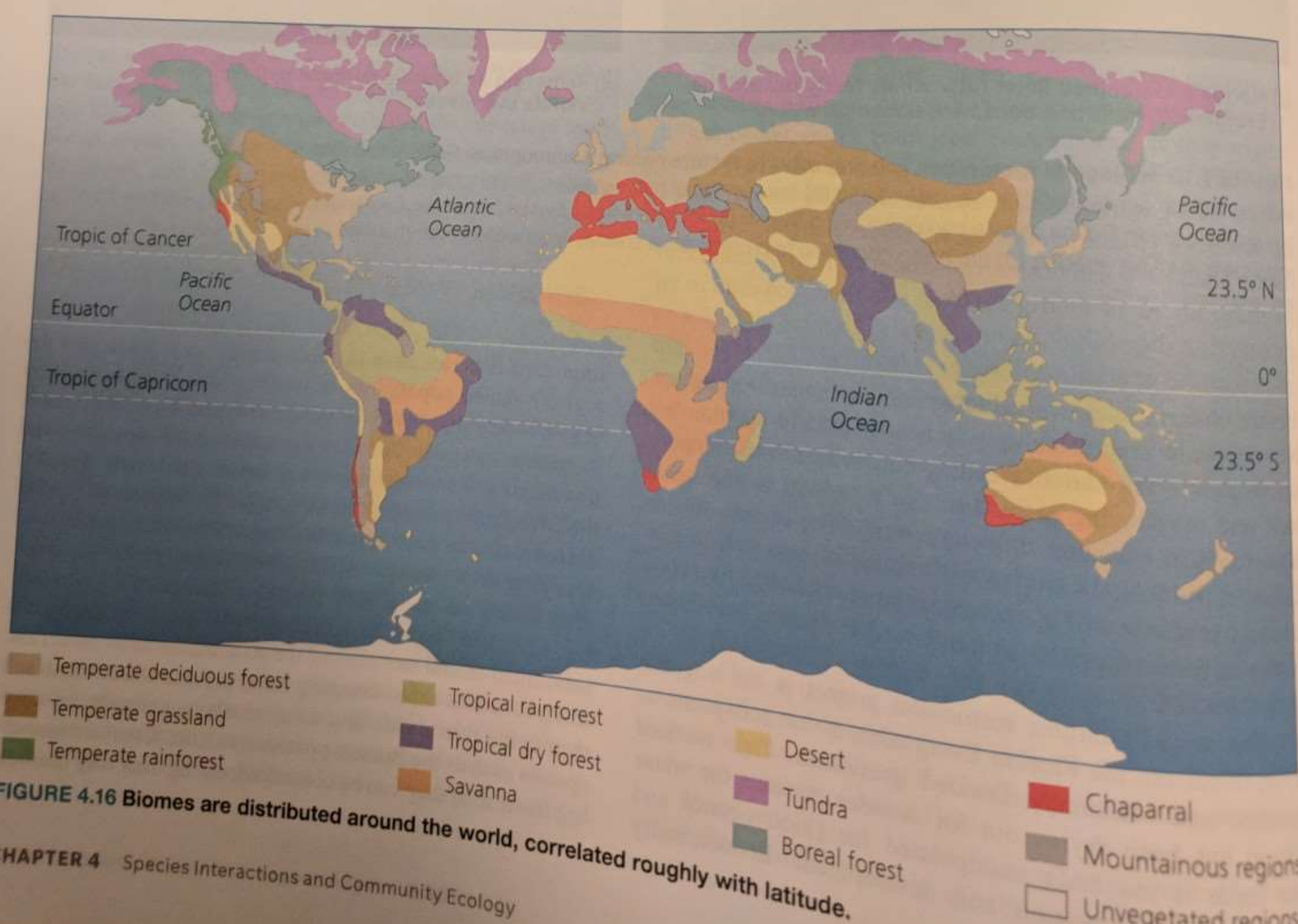


FIGURE 4.16 Biomes are distributed around the world, correlated roughly with latitude.

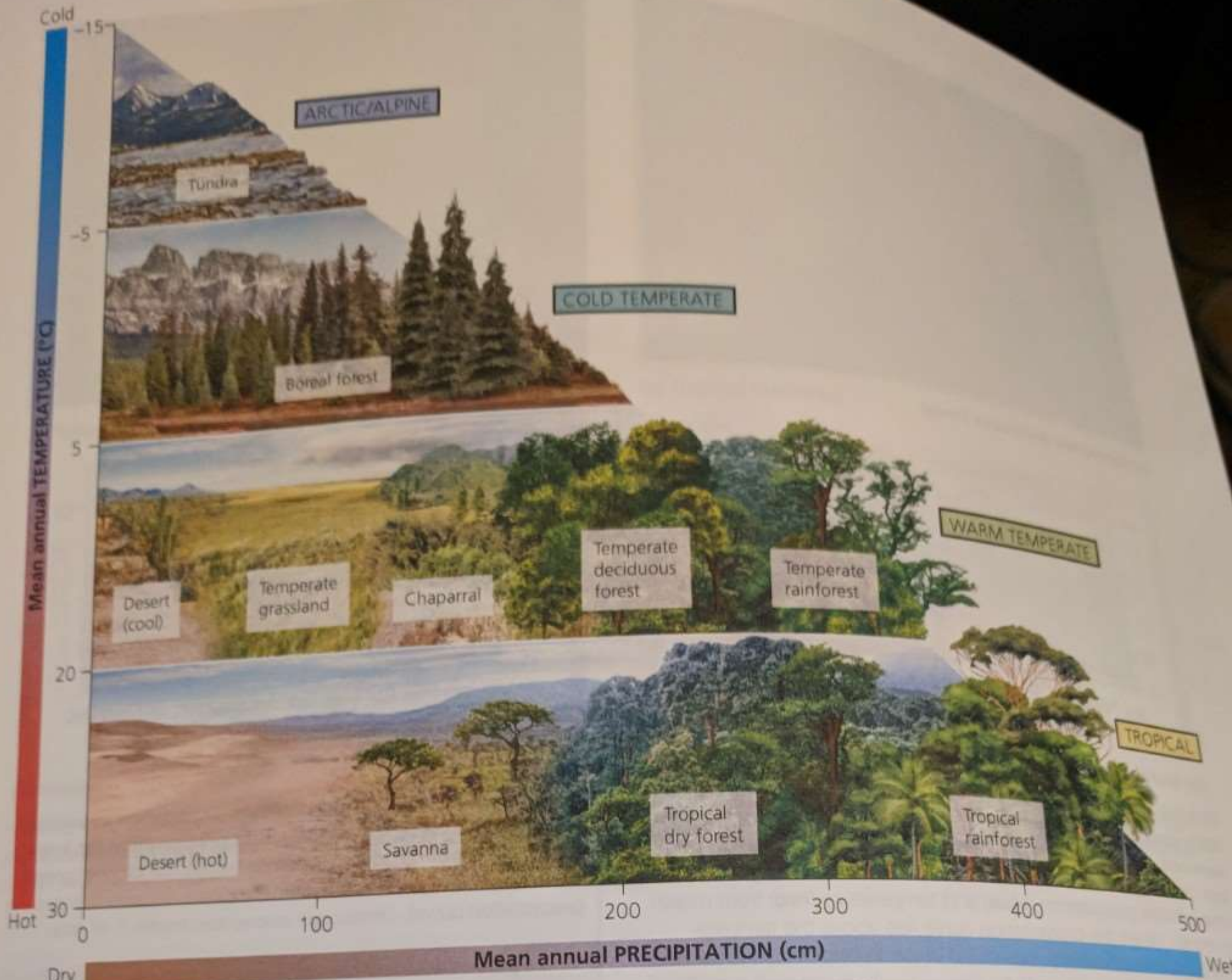


FIGURE 4.17 Temperature and precipitation are the main factors determining where biomes occur. As precipitation increases, vegetation becomes taller and more luxuriant. As temperature increases, types of plant communities change. For instance, deserts occur in dry regions; tropical rainforests occur in warm, wet regions; and tundra occurs in the coldest regions.

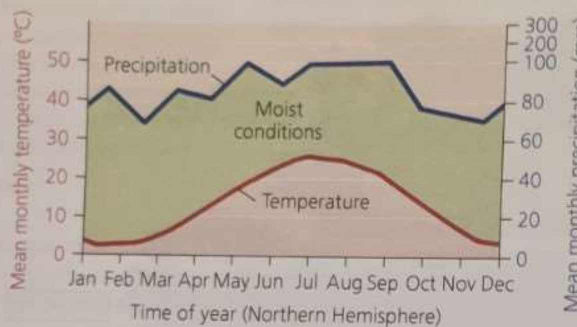
Because biomes are largely a function of climate, and because temperature and precipitation are the best indicators of an area's climate, scientists use **climate diagrams,** or *climatographs,* to depict such information. As we tour the world's terrestrial biomes on the following pages, you will see climatographs from specific localities. The data in each graph are typical of the climate for the biome the locality lies within.

Aquatic and coastal systems resemble biomes

In our discussion of biomes, we focus exclusively on terrestrial systems because the biome concept, as traditionally developed and applied, has done so. However, areas equivalent to biomes also exist in the oceans, along coasts, and in freshwater systems. One might consider the shallows along the world's coastlines to represent one aquatic system, the continental shelves another, and the open ocean, the deep sea, coral reefs, and kelp forests as still others. Many coastal systems—such as salt marshes, rocky intertidal communities, mangrove forests, and estuaries—share terrestrial and aquatic components. And freshwater systems such as those of the Great Lakes are widely distributed throughout the world.

Aquatic systems are shaped not by air temperature and precipitation but by water temperature, salinity, dissolved nutrients, wave action, currents, depth, light levels, and type of substrate (e.g., sandy, muddy, or rocky bottom). Marine communities are also more clearly delineated by their animal life than by their plant life. (We will examine freshwater, marine, and coastal systems in the greater detail they deserve in Chapters 15 and 16.)

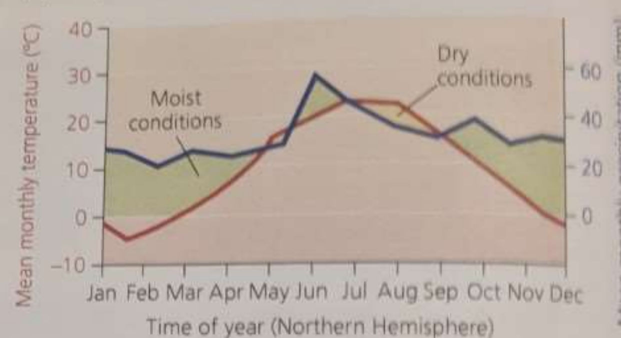
(a) Temperate deciduous forest



(b) Washington, D.C., USA

FIGURE 4.18 Temperate deciduous forests (a) experience fairly stable precipitation but temperatures that vary with the seasons. Scientists use climate diagrams **(b)** to illustrate average monthly precipitation and temperature. In these diagrams, the lines indicate precipitation (**blue**) and temperature (**red**) from month to month. When the precipitation curve lies above the temperature curve (as is the case year-round in the temperate deciduous forest around Washington, D.C., shown here), the region experiences relatively "moist" conditions, indicated with green coloration. *Climatograph here and in the following figures adapted from Breckle, S.-W. 2002. Walter's vegetation of the Earth: The ecological systems of the geo-biosphere, 4th ed. Berlin, Heidelberg: Springer-Verlag.*

(a) Temperate grassland



(b) Odessa, Ukraine

FIGURE 4.19 Temperate grasslands experience seasonal temperature variation and too little precipitation for trees to grow. This climatograph indicates "moist" conditions (**green**) as well as "dry" (**yellow**, when the temperature curve is above the precipitation curve). *Climatograph adapted from Breckle, S.-W. 2002.*

DATA Q How would you explain the dry conditions from July to September? Given the temperature and precipitation patterns shown, what role do you think evaporation might play, and why?

Go to **Interpreting Graphs & Data** on MasteringEnvironmentalScience®.

We can divide the world into ten terrestrial biomes

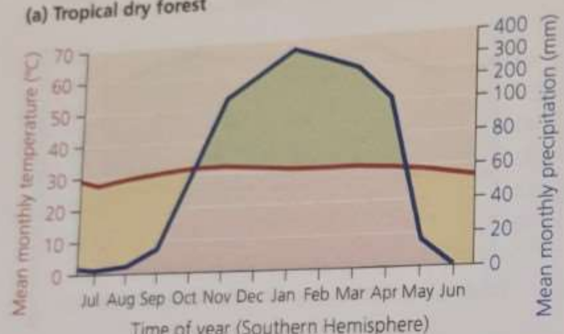
Temperate deciduous forest The **temperate deciduous forest** (FIGURE 4.18) that dominates the landscape around the southern Great Lakes is characterized by broad-leafed trees that are *deciduous*, meaning they lose their leaves each fall and remain dormant during winter, when hard freezes would endanger leaves. These midlatitude forests occur in much of Europe and eastern China as well as in eastern North America—all areas where precipitation is spread relatively evenly throughout the year.

Soils of the temperate deciduous forest are relatively fertile, but this biome consists of far fewer tree species than are found in tropical rainforests. Oaks, beeches, and maples are a few of the most common types of trees in these forests. Some typical animals of the temperate deciduous forest of eastern North America are shown in Figure 4.11 (p. 81).

Temperate grassland Traveling westward from the Great Lakes, temperature differences between winter and summer become more extreme, rainfall diminishes, and we find **temperate grasslands** (FIGURE 4.19). This is because the limited precipitation in the Great Plains region west of the Mississippi River supports grasses more easily than trees. Also known as steppe or prairie, temperate grasslands were once widespread in much of North and South America and central Asia.

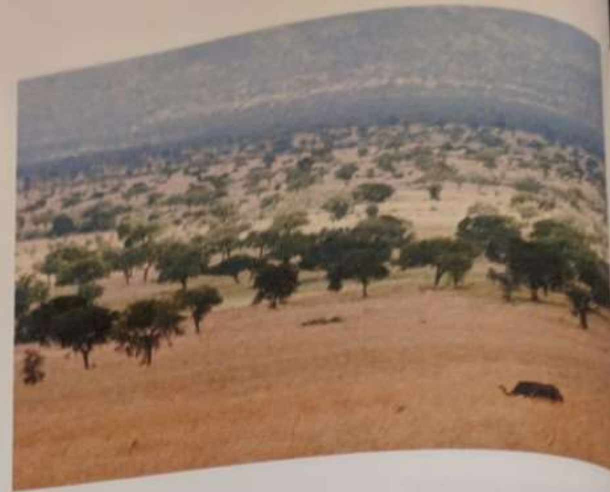
Vertebrate animals of North America's native grasslands include American bison, prairie dogs, pronghorn antelope, and ground-nesting birds such as meadowlarks and prairie chickens.

(a) Tropical dry forest

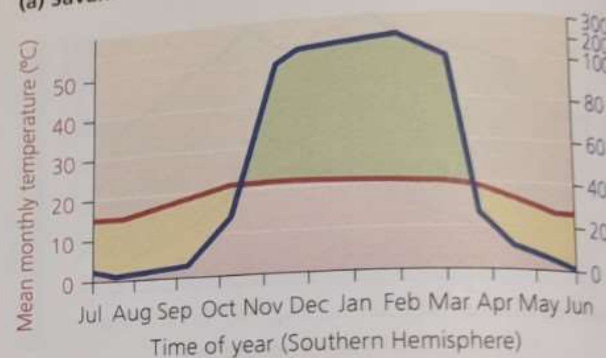


(b) Darwin, Australia

FIGURE 4.22 Tropical dry forests experience significant seasonal variation in precipitation but relatively stable, warm temperatures. *Climatograph adapted from Breckle, S.-W. 2002.*



(a) Savanna



(b) Harare, Zimbabwe

FIGURE 4.23 Savannas are grasslands with clusters of trees. They experience slight seasonal variation in temperature but significant variation in rainfall. *Climatograph adapted from Breckle, S.-W. 2002.*

soil. An unfortunate consequence is that once tropical rainforests are cleared, the nutrient-poor soil can support agriculture for only a short time (p. 215). As a result, farmed areas are abandoned quickly, and farmers move on and clear more forest.

Tropical dry forest Tropical areas that are warm year-round but where rainfall is lower overall and highly seasonal give rise to **tropical dry forest,** or *tropical deciduous forest* (FIGURE 4.22), a biome widespread in India, Africa, South America, and northern Australia. Wet and dry seasons each span about half a year in tropical dry forest. Organisms that inhabit tropical dry forest have adapted to seasonal fluctuations in precipitation and temperature. For instance, many plants are deciduous and leaf out and grow profusely with the rains, then drop their leaves during dry times of the year.

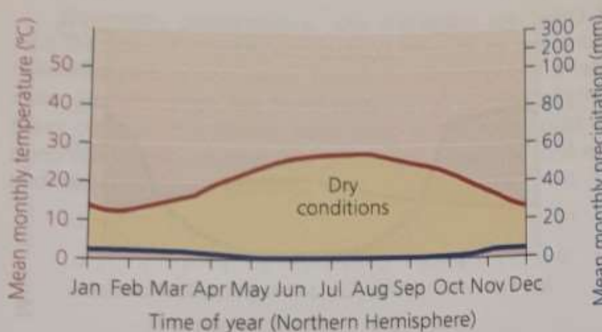
Rains during the wet season can be heavy and, coupled with erosion-prone soils, can lead to severe soil loss where people have cleared forest. Across the globe, we have converted a great deal of tropical dry forest to agriculture. Clearing for farming or ranching is straightforward because vegetation is lower and canopies less dense than in tropical rainforest.

Savanna Drier tropical regions give rise to **savanna** (FIGURE 4.23), tropical grassland interspersed with clusters of acacias or other trees. The savanna biome is found across stretches of Africa, South America, Australia, India, and other dry tropical regions. Precipitation usually arrives during distinct rainy seasons, whereas in the dry season grazing animals concentrate near widely spaced water holes. Common herbivores on the African savanna include zebras, gazelles, and giraffes. Predators of these grazers include lions, hyenas, and other highly mobile carnivores.

Desert Where rainfall is very sparse, **desert** (FIGURE 4.24) forms. The driest biome on Earth, most deserts receive well under 25 cm (9.8 in.) of precipitation per year, much of it during isolated storms months or years apart. Some deserts, such as Africa's Sahara and Namib deserts, are mostly bare sand dunes; others, such as the Sonoran Desert of Arizona and northwest Mexico, receive more rain and are more heavily vegetated.

Deserts are not always hot; the high desert of the western United States is positively cold in winter. Because deserts have low humidity and little vegetation to insulate them from temperature extremes, sunli

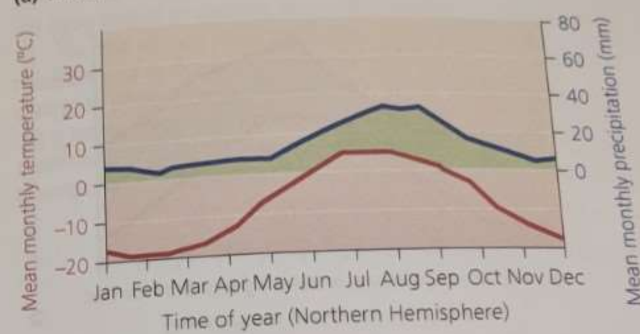
(a) Desert



(b) Cairo, Egypt

FIGURE 4.24 Deserts are dry year-round. The precipitation curve is consistently below the temperature curve in this climatograph for Cairo, Egypt, indicating that the region experiences "dry" conditions all year. *Climatograph adapted from Breckle, S.-W. 2002.*

(a) Tundra



(b) Vaigach, Russia

FIGURE 4.25 Tundra is a cold, dry biome found near the poles. Alpine tundra occurs atop high mountains at lower latitudes. *Climatograph adapted from Breckle, S.-W. 2002.*

daytime, but heat is quickly lost at night. As a result, temperatures vary greatly from day to night and from season to season. Desert soils can be saline and are sometimes known as lithosols, or stone soils, for their high mineral and low organic-matter content.

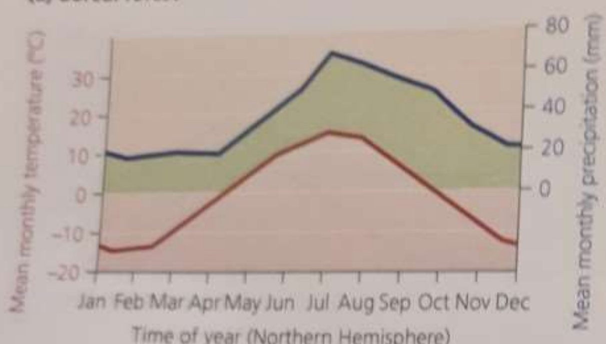
Desert animals and plants show many adaptations to deal with a harsh climate. Most reptiles and mammals, such as rattlesnakes and kangaroo mice, are active in the cool of night. Many Australian desert birds are nomadic, wandering long distances to find areas of recent rainfall and plant growth. Desert plants tend to have thick, leathery leaves to reduce water loss, or green trunks so that the plant can photosynthesize without leaves, minimizing the surface area prone to water loss. The spines of cacti and other desert plants guard them from being eaten by herbivores desperate for the precious water these plants hold. Such traits have evolved by convergent evolution in deserts across the world (see Figure 3.4b, p. 50).

Tundra Nearly as dry as desert, **tundra** (FIGURE 4.25) occurs at very high latitudes in northern Russia, Canada, and Scandinavia. Extremely cold winters with little daylight and summers with lengthy days characterize this landscape of lichens and low, scrubby vegetation without trees. The great seasonal variation in temperature and day length results from this biome's high-latitude location, angled toward the sun in summer and away from the sun in winter.

Because of the cold climate, underground soil remains permanently frozen and is called permafrost. During winter, surface soil freezes as well. When the weather warms, the soil melts and produces pools of surface water, forming ideal habitat for mosquitoes and other insects. The swarms of insects benefit bird species that migrate long distances to breed during the brief but productive summer. Caribou also migrate to the tundra to breed, then leave for the winter. Only a few animals, such as polar bears and musk oxen, can survive year-round in tundra.

Most tundra remains intact and relatively unaltered by human occupation and development. However, atmospheric circulation patterns (p. 451) bring our airborne pollutants to this biome, and global climate change is heating high-latitude regions more intensely than other areas (p. 501). Climate change is melting sea ice, altering seasonal cycles to which animals have adapted, and melting

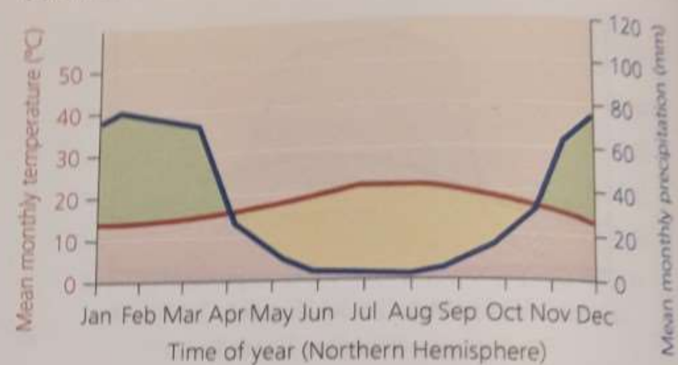
(a) Boreal forest



(b) Archangelsk, Russia

FIGURE 4.26 Boreal forest experiences long, cold winters; cool summers; and moderate precipitation. *Climatograph adapted from Breckle, S.-W. 2002.*

(a) Chaparral



(b) Los Angeles, California, USA

FIGURE 4.27 Chaparral is a seasonally variable biome dominated by shrubs, influenced by marine weather, and dependent on fire. *Climatograph adapted from Breckle, S.-W. 2002.*

permafrost, releasing methane gas that further worsens climate change.

Tundra also occurs as alpine tundra at the tops of tall mountains in temperate and tropical regions. Here, high elevation creates conditions similar to those of high latitude.

Boreal forest The northern coniferous forest, or **boreal forest,** often called *taiga* (FIGURE 4.26), extends across much of Canada, Alaska, Russia, and Scandinavia. A few species of evergreen trees, such as black spruce, dominate large stretches of forest, interspersed with bogs and lakes. Boreal forests develop in cooler, drier regions than do temperate forests, and they experience long, cold winters and short, cool summers.

Soils are typically nutrient-poor and somewhat acidic. As a result of strong seasonal variation in day length, temperature, and precipitation, many organisms compress a year's worth of feeding and breeding into a few warm, wet months. Year-round residents of boreal forest include mammals such as moose, wolves, bears, lynx, and rodents. Many insect-eating birds migrate here from the tropics to breed during the brief, intensely productive, summers.

Chaparral In contrast to the boreal forest's broad, continuous distribution, **chaparral** (FIGURE 4.27) is limited to small patches widely flung around the globe. Chaparral consists mostly of evergreen shrubs and is densely thicketed. This biome is highly seasonal, with mild, wet winters and warm, dry summers—a climate induced by oceanic influences and often termed "Mediterranean." Besides ringing the Mediterranean Sea, chaparral occurs along the coasts of California, Chile, and southern Australia. Chaparral communities experience frequent fire, and their plants are adapted to resist fire or even to depend on it for germination of their seeds.

closing THE LOOP

Ecological communities are shaped by many forces. Within communities, species interact through competition, predation, parasitism, herbivory, and mutualism. Communities are stable only until disturbed—and in today's world, invasive species such as the zebra mussel and quagga mussel are a major and growing form of disturbance. Our economies are organized around established ecological systems and are supported by their services, so when invasive species alter ecological systems, our economies suffer, too.

Scientists, policymakers, and managers are trying to limit the spread of zebra and quagga mussels by preventing their transport to new areas, largely by raising public awareness. Experts most fear them establishing in the Columbia River basin in the Pacific Northwest, where they could do hundreds of millions of dollars of damage to salmon runs and hydroelectric power facilities.

Meanwhile, throughout the Great Lakes and other waterways of the East and Midwest where these invasive mussels are firmly established, people are forced to bear the costs and adapt as best as they can. Fortunately, in recent years some ecological communities are beginning to show resilience to the mussels. Some birds, crabs, and other species are learning to prey on them, the mussels are no longer growing as large, and some of the species they have harmed are rebounding. Indeed, for any invasive species, eventually its rate of spread slows and its population size levels off. Often, native species discover them and become predators, parasites, or competitors. Some long-established invasive species in North America have begun to decline, and a few have even disappeared.

No one knows what the future holds in the case of zebra mussels and quagga mussels, but they and many other species that people have moved from place to place are creating a topsy-turvy world of novel and modified communities. In response, through ecological restoration, we are increasingly attempting to undo some of the changes we have set in motion.

REVIEWING Objectives

You should now be able to:

Summarize and compare the major types of species interactions

Competition results when individuals or species vie for limited resources. Competition can occur within or among species and can result in coexistence or exclusion. In predation, an individual of one species kills and consumes an individual of another. In parasitism, an individual of one species derives benefit by harming (but usually not killing) an individual of another. Herbivory is an exploitative interaction in which an animal feeds on a plant. In mutualism, species benefit from one another. (pp. 74–78)

Describe feeding relationships and energy flow, and use them to identify trophic levels and navigate food webs

Energy is transferred among trophic levels in food chains. Lower trophic levels generally contain more energy, biomass, and individuals. Food webs illustrate feeding relationships and energy flow among species in a community. (pp. 78–81)

Discuss characteristics of a keystone species

Keystone species exert impacts on communities that are far out of proportion to their abundance. Top predators are frequently considered keystone species. Other types of organisms (such as ecosystem engineers) can also exert strong effects on communities. (pp. 80–82)

Characterize disturbance, succession, and notions of community change

Disturbances are varied, and communities respond to disturbance in different ways. Succession describes a typical pattern of community change through time. Primary succession begins with an area devoid of life. Secondary succession begins with an area that has been severely disturbed but where remnants of the original community remain. Ecologists today view succession as being less predictable and deterministic than they did in the past. If disturbance is severe enough, communities may undergo regime shifts involving irreversible change—or novel communities may form. (pp. 82–86, 88–89)

Predict the potential impacts of invasive species in communities, and suggest responses to biological invasions

People have introduced countless species to new areas. Some of these non-native species may become invasive if they do not encounter limiting factors on their population growth. Invasive species such as the zebra mussel have altered the composition, structure, and function of communities. We can respond to invasive species with prevention, control, and eradication measures. (pp. 86–87, 90)