3

The Biosphere

3 The Biosphere

- *Case Study*: The American Serengeti: Twelve Centuries of Change in the Great Plains
- Terrestrial Biomes
- Freshwater Biological Zones
- Marine Biological Zones
- *Case Study Revisited*
- *Connections in Nature*: Long-Term Ecological Research

Case Study: The American Serengeti: Twelve Centuries of Change in the Great Plains

The Serengeti Plain of Africa has a high diversity of wild animals.

In contrast, the Great Plains of North America have very low diversity: Large stands of uniform crop plants and a few species of domesticated herbivores.

Figure 3.1 The Serengeti Plain of Africa

In North America, the last continental glaciers were receding about 13,000 years ago, and the Great Plains supported a high diversity of megafauna:

Woolly mammoths and mastodons, several species of horses, camels, giant ground sloths, saber-toothed cats, cheetahs, lions, and giant short-faced bears.

Figure 3.2 Pleistocene Animals of the Great Plains

ECOLOGY, Figure 3.2

Case Study: The American Serengeti: Twelve Centuries of Change in the Great Plains

About 10,000–13,000 years ago, many of the large mammals of North America went extinct.

Approximately 28 genera (40–70 species) went extinct over a short time period.

Nearly all the animals that went extinct were large mammals.

Case Study: The American Serengeti: Twelve Centuries of Change in the Great Plains

The causes of the extinction are a mystery to paleontologists.

Hypotheses include rapid climate change and the arrival of humans in North America.

The role of humans in these extinctions has been controversial.

Introduction

Living things are found on every part of the Earth, from the highest mountains to the deepest oceans.

Bacteria and archaea are found everywhere, even on dust high in the atmosphere.

But most organisms occur within a thin veneer of Earth’s surface, from the tops of trees to the surface soil layers, and within 200 meters of the surface of the oceans.

Introduction

The **biosphere** is the zone of life on Earth.

It lies between the **lithosphere**—Earth’s surface crust and upper mantle, and the *troposphere*—the lowest layer of the atmosphere.

Biological communities can be categorized at multiple scales of varying complexity.

Concept 3.1: Terrestrial biomes are characterized by the dominant growth forms of vegetation.

Biomes are large biological communities shaped by the physical environment, particularly climatic variation.

Terrestrial Biomes

Biomes are based on similarities in the morphological responses of organisms to the physical environment, not on taxonomic similarities.

Terrestrial biomes are classified by the growth form of the most abundant plants.

Characteristics of the leaves may be used:

- *Deciduousness*—seasonal shedding of leaves.
- Thickness.
- *Succulence*—development of fleshy water storage tissues.

Figure 3.3 Plant Growth Forms (Part 1)

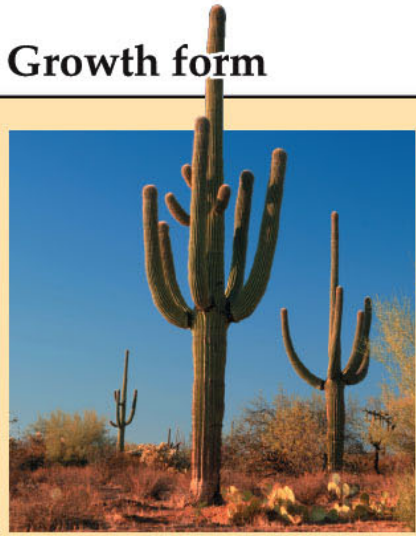
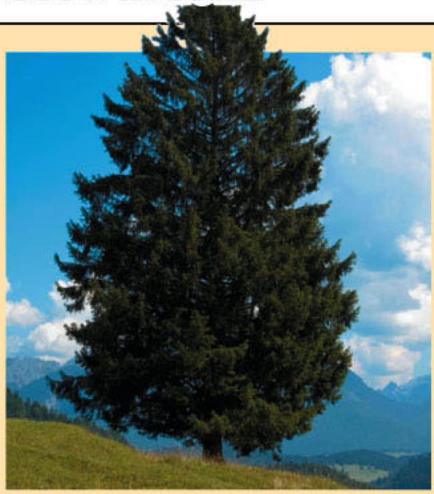
Growth form	Environment
 *Sclerophyllous* shrubs	Seasonally dry/moist and warm/cool
 Deciduous trees	Moist, seasonally warm/cool, or cool/cold on fertile soils or warm, seasonally wet/dry
 Cacti and shrubs; succulent stems or leaves	Dry, seasonally hot/cool

Figure 3.3 Plant Growth Forms (Part 2)

Growth form	Environment
 Needle-leaved evergreen trees	Moist, seasonally warm/cool or cool/cold on infertile soils
 Grasses, sedges	Moist, seasonally warm/cool, with fire
 Evergreen broad-leaved trees	Wet, warm year–round
 Forbs	Seasonally cool/cold

ECOLOGY, Figure 3.3 (Part 2)

Terrestrial Biomes

Biomes provide an introduction to the diversity of life on Earth.

They are a convenient unit for modelers simulating the effects of climate change and effects of biota on the climate system.

Plant growth forms are good indicators of the physical environment, reflecting climatic zones and rates of disturbance.

Because plants are immobile, they must be able to cope with environmental extremes and biological pressures, such as competition, to successfully occupy a site for a long time.

Selection pressures of the terrestrial environment include aridity, high and subfreezing temperatures, intense solar radiation, grazing by terrestrial animals, and crowding by neighbors.

Plants have adapted to these pressures in many ways. For example, deciduous leaves are a way to deal with seasonal aridity or cold.

Perennial grasses are tolerant of grazing, fire, subfreezing temperatures, and dry soils, because their vegetative and reproductive buds are below the soil surface.

Similar growth forms can be found on different continents, even though the plants are not genetically related.

Convergence: Evolution of similar growth forms among distantly related species in response to similar selection pressures.

Terrestrial Biomes

The climatic zones that are a consequence of atmospheric and oceanic circulation patterns are the major determinants of the distribution of terrestrial biomes.

For example, the major deserts of the world are associated with zones of high pressure at about 30° N and S.

Terrestrial Biomes

Temperature influences distribution of plant growth forms directly through physiological effects.

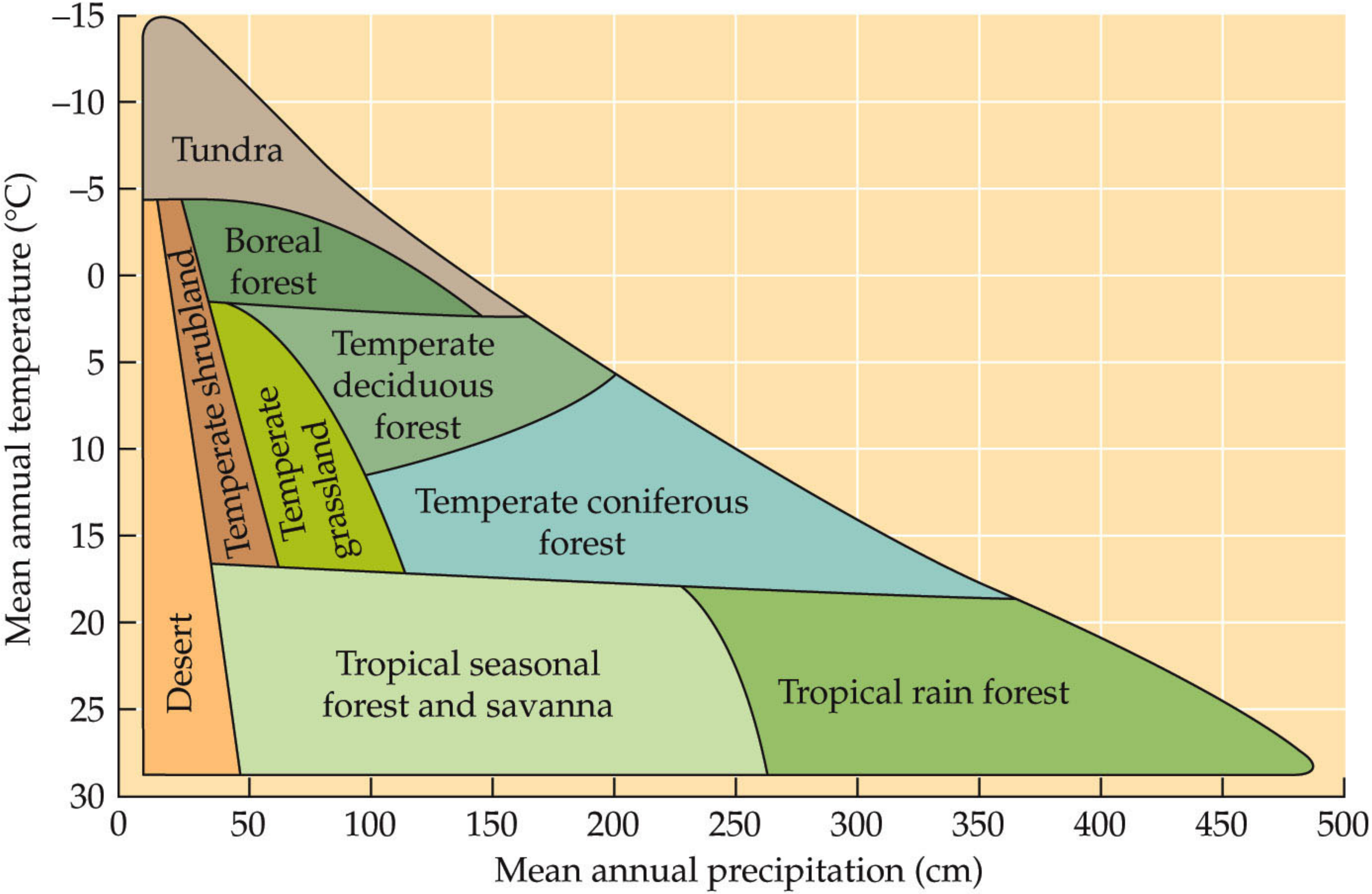
Precipitation and temperature act together to influence water availability and water loss by plants.

Water availability and soil temperature determine the supply of nutrients in the soil.

Average annual temperature and precipitation can predict biome distributions quite well, but seasonal variation is also important.

Climatic extremes can sometimes be more important than average conditions.

Figure 3.4 Biomes Vary with Mean Annual Temperature and Precipitation



ECOLOGY, Figure 3.4

Human activities influence the distribution of biomes.

Land use change: Conversion of land to agriculture, logging, resource extraction, urban development.

The potential and actual distributions of biomes are markedly different.

Figure 3.5 A Global Biome Distributions Are Affected by Human Activities

(A)

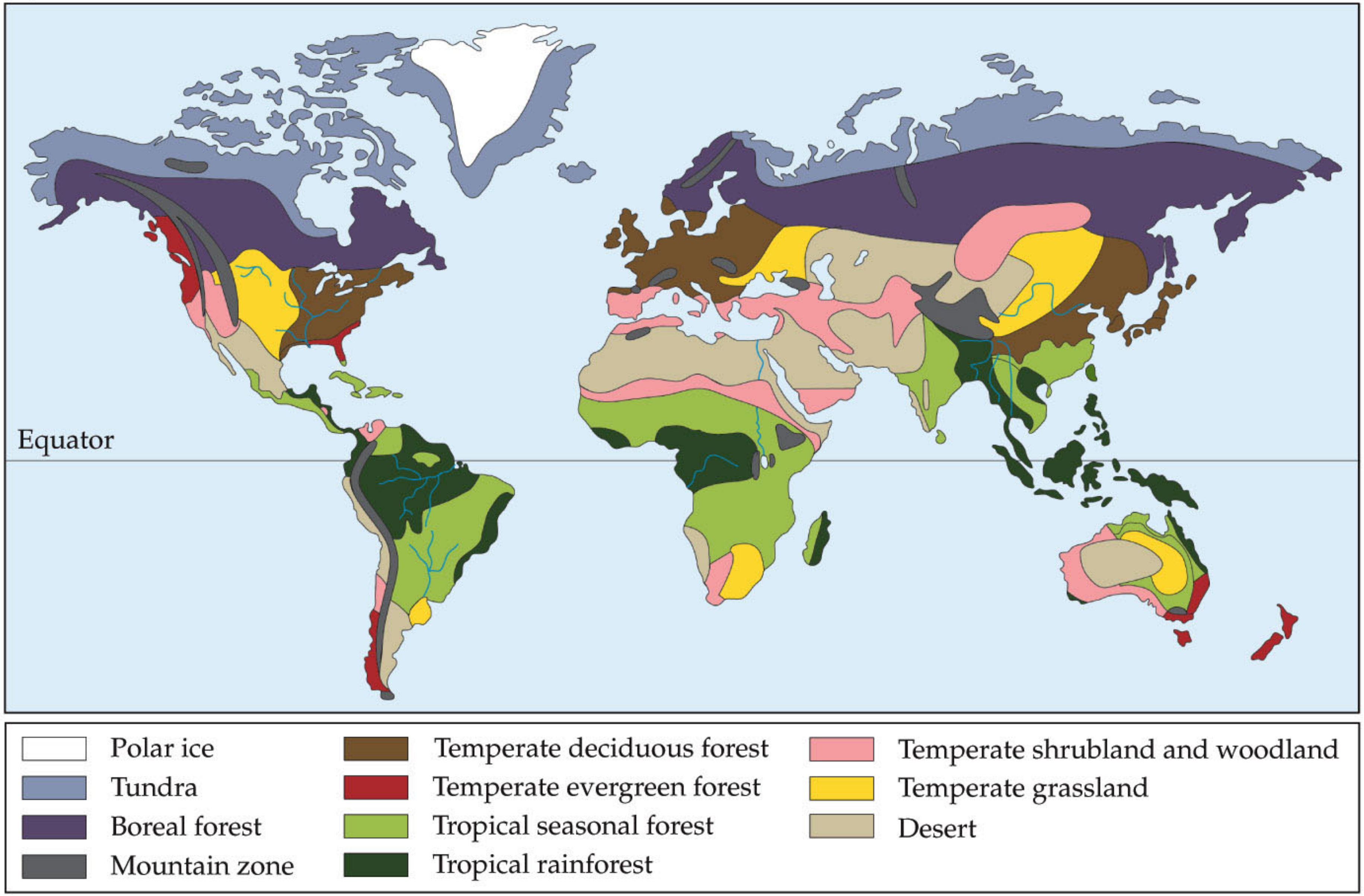
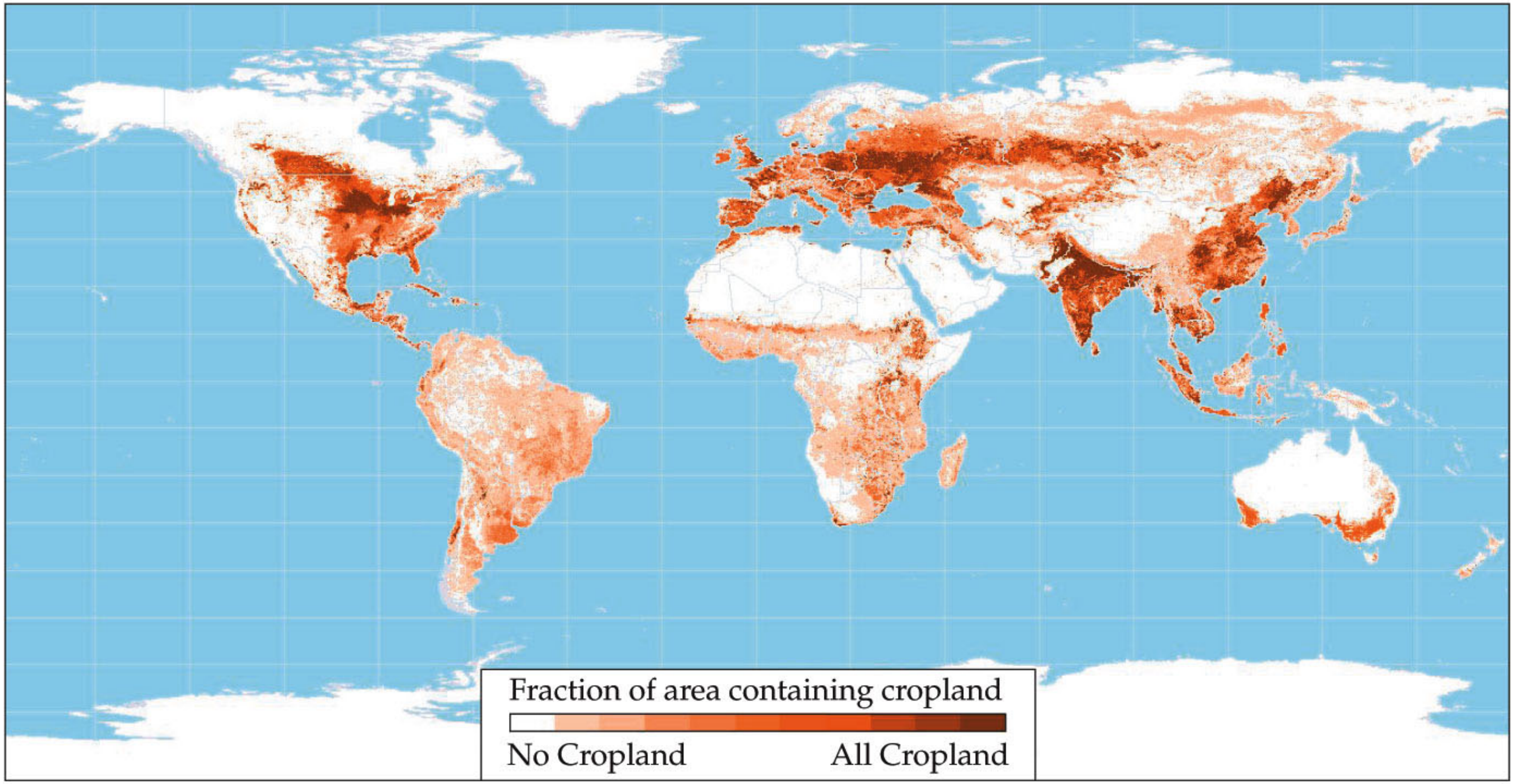


Figure 3.5 B Global Biome Distributions Are Affected by Human Activities

(B)



ECOLOGY, **Figure 3.5 (Part 2)**

Figure 3.5 C Global Biome Distributions Are Affected by Human Activities

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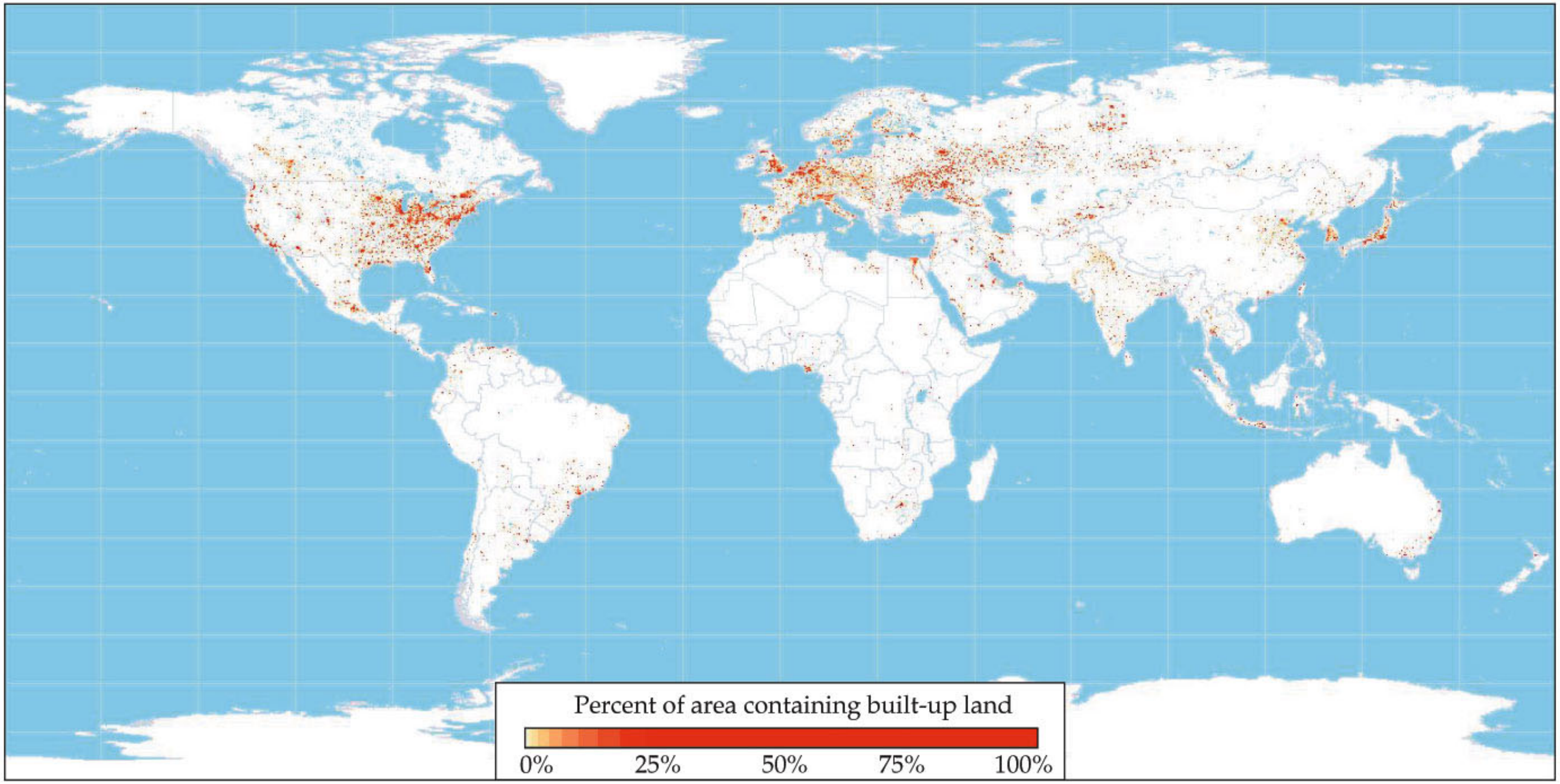
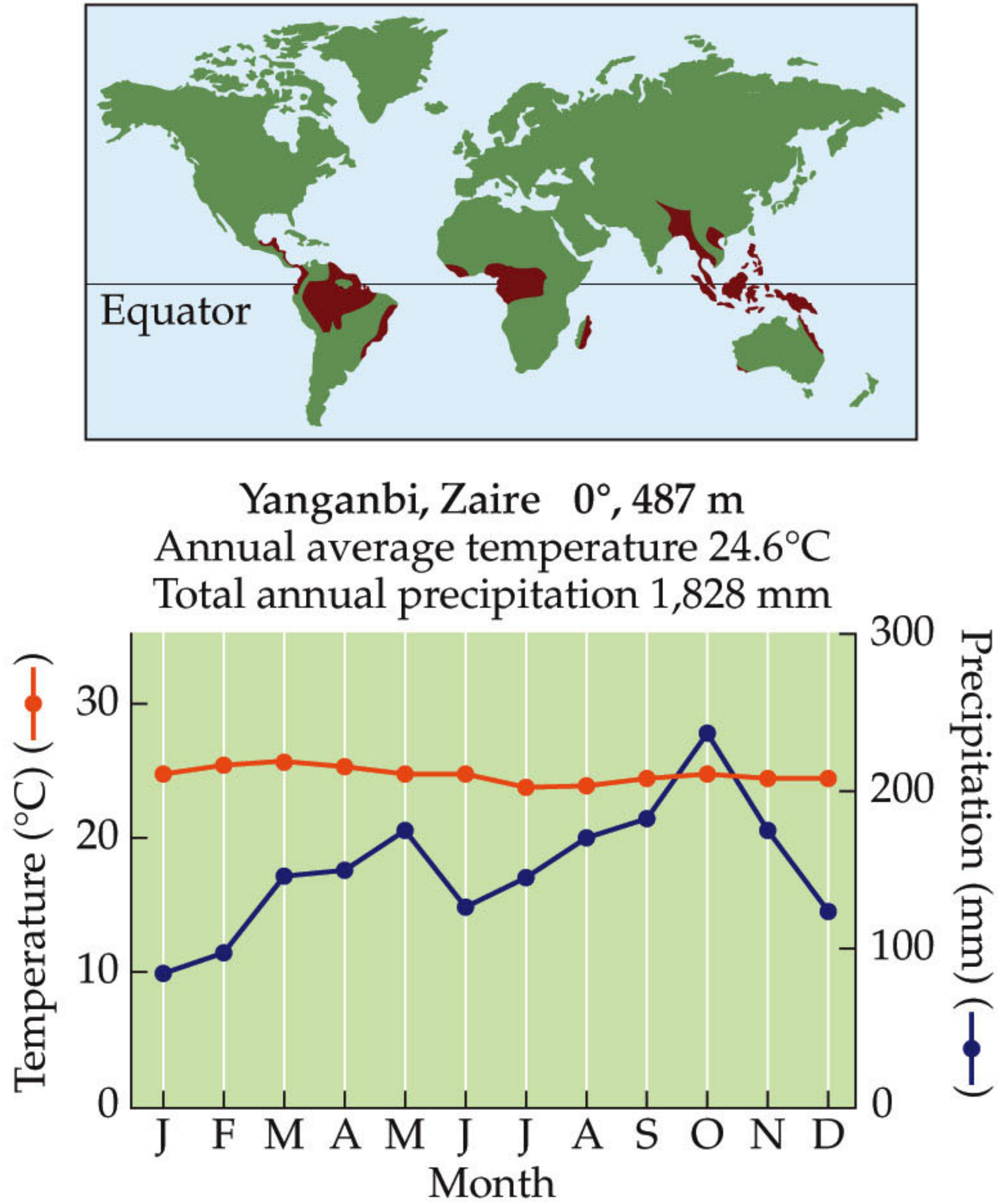


TROPICAL RAINFORESTS



ECOLOGY, Figure 3.A (Part 1)

TROPICAL RAINFORESTS

Emergent tree with epiphytes rises above the forest canopy, Borneo

Trees, shrubs, and epiphytes crowd a rainforest below the canopy, Napo, Ecuador

Tropical Rainforests:

- Between 10° N and S.
- Annual precipitation > 200 cm.
- No seasonal changes.
- High biomass, high diversity—about 50% of Earth’s species.
- Broadleaved evergreen and deciduous trees.

Light is an important factor—plants grow very tall above their neighbors or must adjust to low light levels.

Emergents rise above the *canopy*—a continuous layer about 30–40 m high.

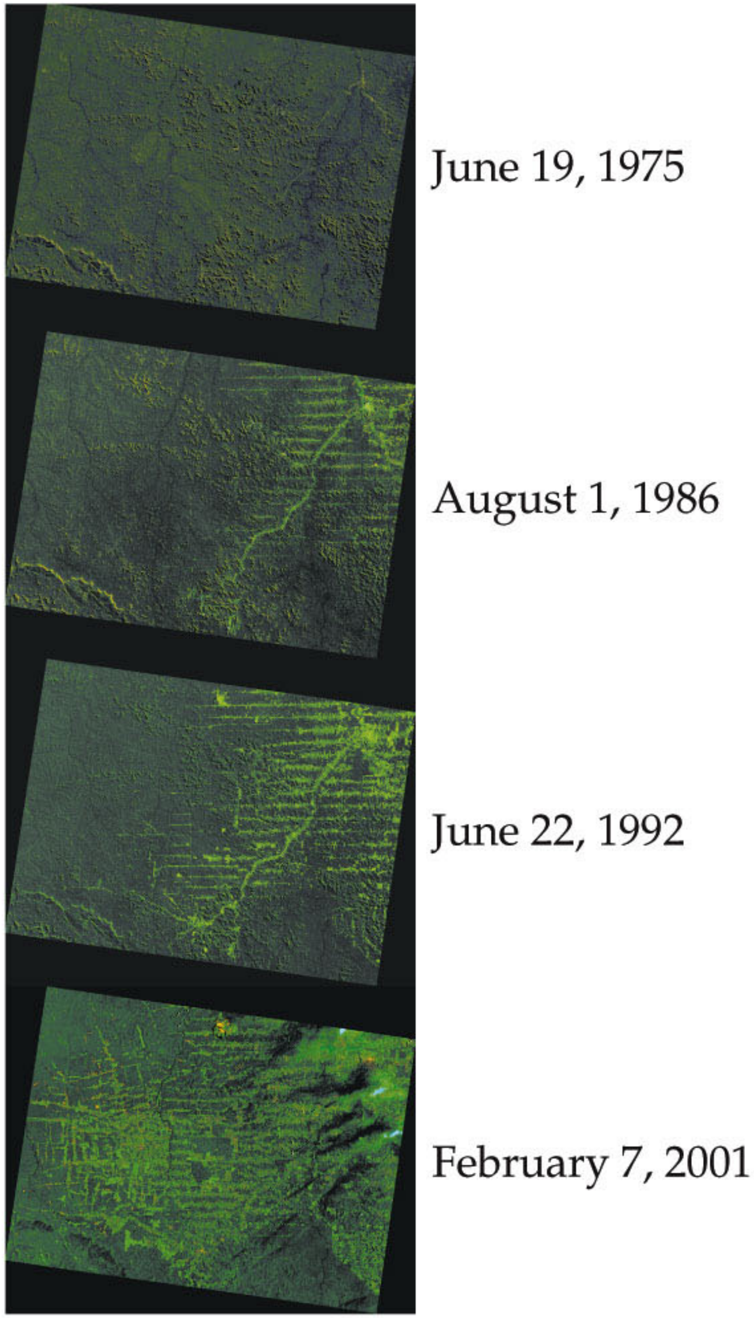
Lianas (woody vines) and *epiphytes* use the trees for support.

Understory trees grow in the shade of the canopy, and *shrubs* and *forbs* occupy the forest floor.

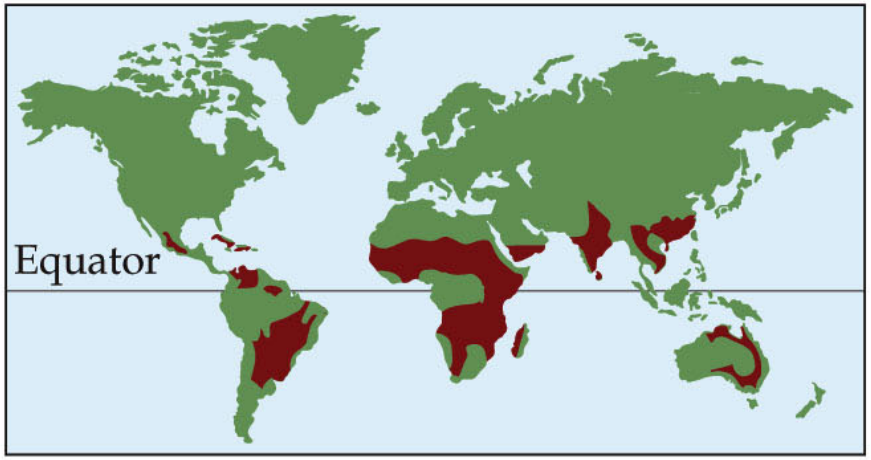
Tropical rainforests are disappearing rapidly due to logging and conversion to pasture and croplands.

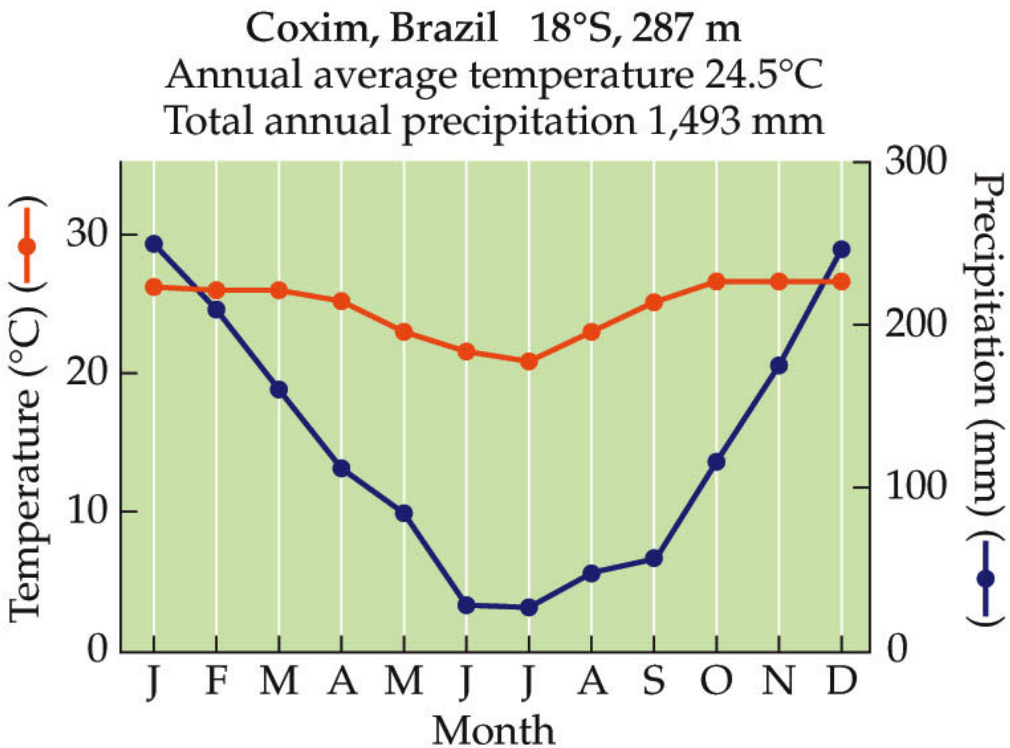
About half of the tropical rainforest biome has been altered.

Recovery of rainforests is uncertain; soils are often nutrient-poor, and recovery of nutrient supplies may take a very long time.


June 19, 1975
August 1, 1986
June 22, 1992
February 7, 2001

TROPICAL SEASONAL FORESTS AND SAVANNAS





ECOLOGY, Figure 3.B (Part 1)

TROPICAL SEASONAL FORESTS AND SAVANNAS

Savanna in Natal, South Africa

Semi-evergreen forest including Pijio trees (*Cavanillesia platanifolia*), during the dry season, Cerro Blanco, Ecuador

ECOLOGY, **Figure 3.B (Part 2)**

Tropical Seasonal Forests and Savannas:

- From 10° to the Tropics of Capricorn (23.5°S) and Cancer (23.5°N).
- Wet and dry seasons associated with movement of the ITCZ.
- Shorter trees, deciduous in dry seasons, more grasses and shrubs.

This biome includes a complex of tree-dominated systems:

- *Tropical dry forests*.
- *Thorn woodlands*—trees have heavy thorns to protect from herbivores.
- *Tropical savannas*—grasses with intermixed trees and shrubs.

Fires promote establishment of savannas; some are set by humans.

In Africa, large herds of herbivores—wildebeests, zebras, elephants, and antelopes—also influence the balance of grass and trees.

On the Orinoco River floodplain, seasonal flooding promotes savannas.

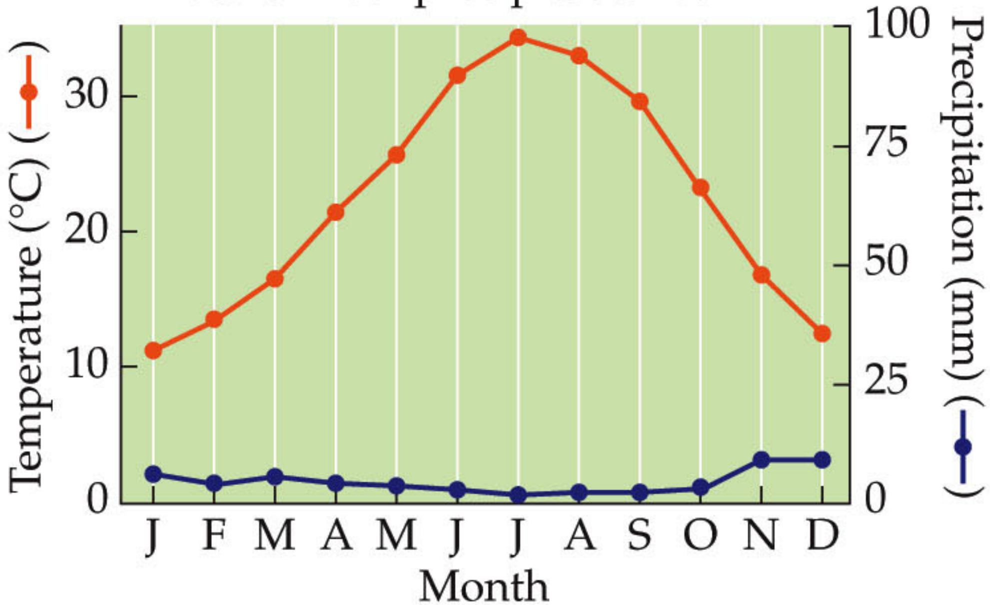
Loss of seasonal tropical forests and savannas is equal to or greater than the loss of tropical rainforests.

Human population growth in this biome has had a major influence.

Large tracts have been converted to cropland and pasture.

HOT DESERTS

Ouargla, Algeria 31°N, 150 m
Annual average temperature 22.3°C
Total annual precipitation 39 mm



***ECOLOGY*, Figure 3.C (Part 1)**

HOT DESERTS

Palm trees growing out of sand, Oasis Dakhia, Sahara Desert, Egypt

Sonoran desert in bloom, Ajo Mountains, Organ Pipe National Monument, Arizona

Hot Subtropical Deserts:

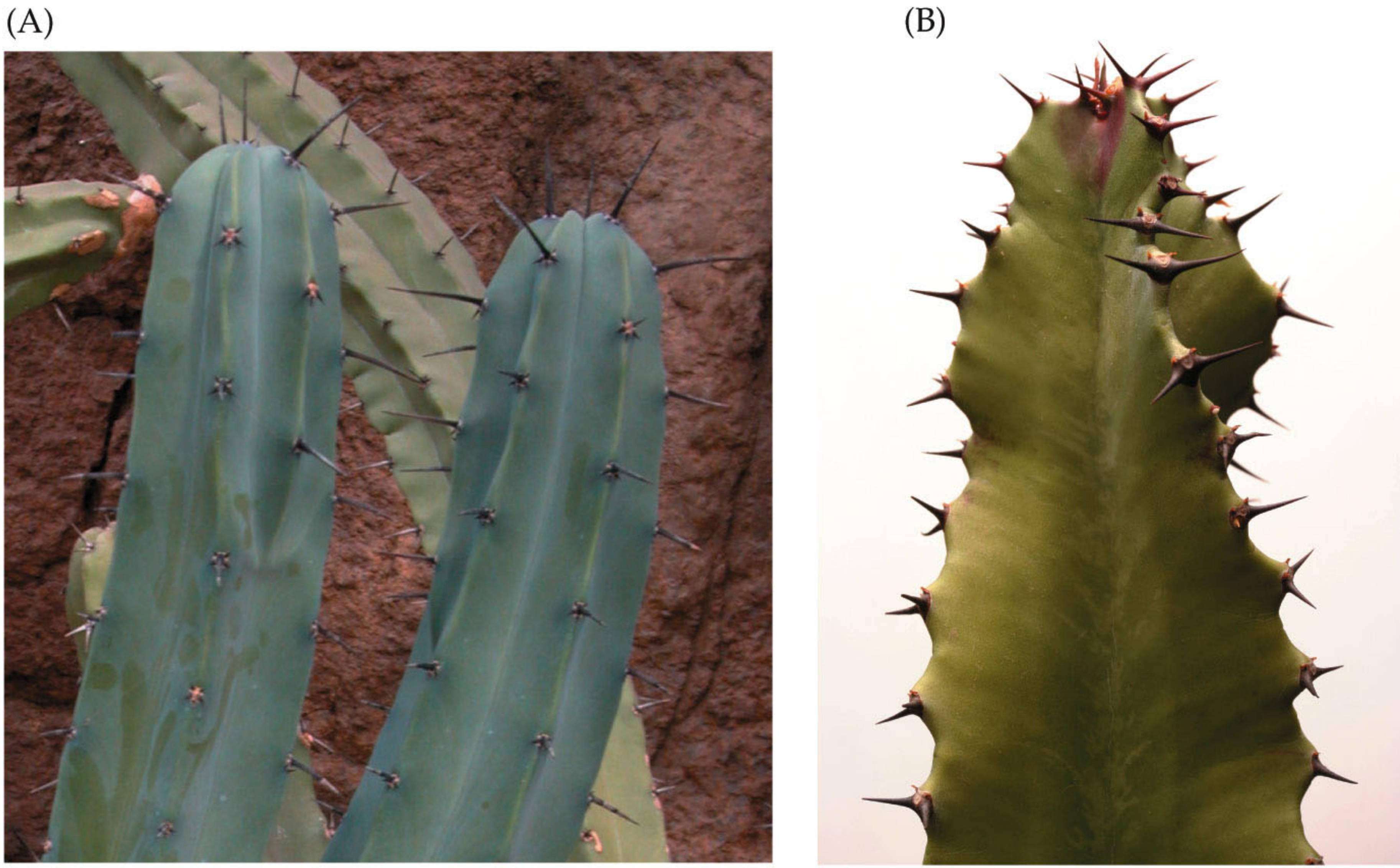
- Associated with high pressure zones around 30° N and S.
- High temperatures, low water availability.
- Sparse vegetation and animal populations.
- Many plants exhibit stem succulence—cacti in the Western Hemisphere, euphorbs in the Eastern Hemisphere.

Plants with succulent stems can store water in their tissues.

Desert plants also include drought-deciduous shrubs, grasses, and short-lived annual plants that are active only after a rain.

Abundance may be low but species diversity can be high.

Figure 3.7 Convergence in the Forms of Desert Plants

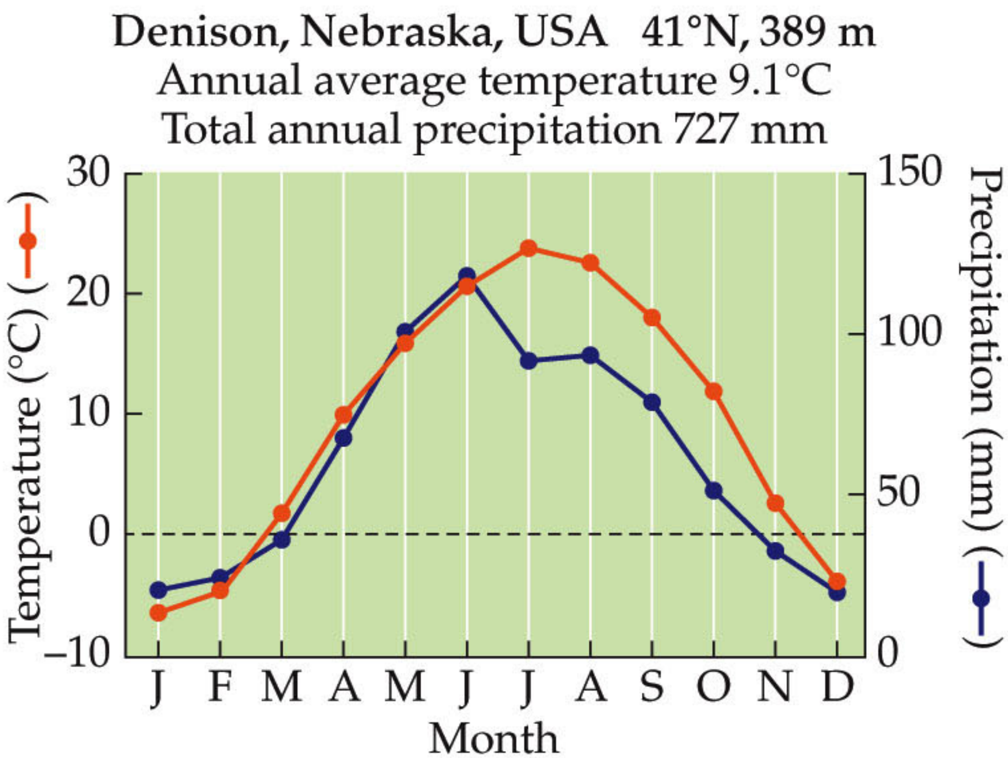


Humans have used deserts for agriculture and livestock grazing.

Agriculture depends on irrigation, and results in soil salinization.

Long-term droughts in association with unsustainable grazing can result in **desertification**—loss of plant cover and soil erosion.

TEMPERATE GRASSLANDS



ECOLOGY, Figure 3.D (Part 1)

TEMPERATE GRASSLANDS

Western edge of the Great Plains, Arapaho National Wildlife Refuge, Colorado

Grassland with camomile flowers, Altai Plateau, Russia

ECOLOGY, **Figure 3.D (Part 2)**

Temperate Grasslands:

- Between 30° and 50° latitude.
- Seasonal temperature variation—warm, moist summers and cold, dry winters.
- Grasses dominate; maintained by frequent fires and large herbivores such as bison.

Grasses grow more roots than stems and leaves, to cope with dry conditions.

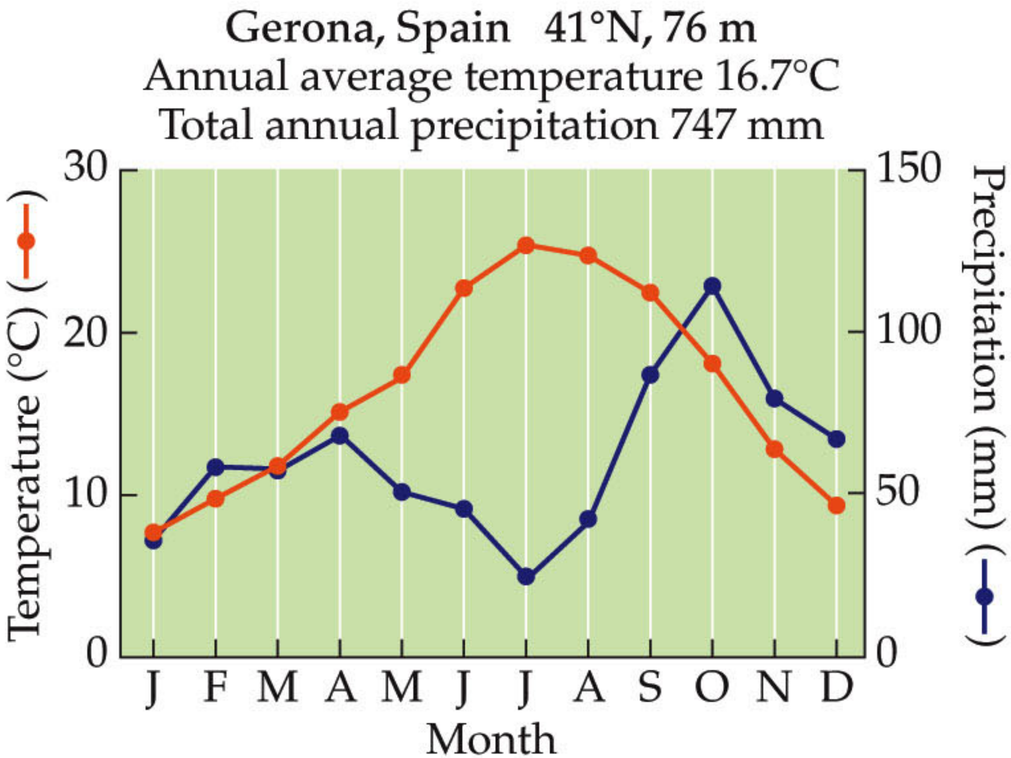
This results in accumulation of organic matter and high soil fertility.

Most of the fertile grasslands of central North America and Eurasia have been converted to agriculture.

In more arid grasslands, grazing by domesticated animals can exceed capacity for regrowth, leading to grassland degradation, and desertification.

Irrigation of some grassland soils has resulted in salinization.

TEMPERATE SHRUBLANDS AND WOODLANDS



ECOLOGY, Figure 3.E (Part 1)

TEMPERATE SHRUBLANDS AND WOODLANDS

Maquis shrubland, Mediterranean coast, Majorca, Spain

Fynbos landscape with everlastings (*Helichrysum* sp.), Kogelberg Nature Reserve, South Africa

ECOLOGY, Figure 3.E (Part 2)

Temperate Shrublands and Woodlands:

- Wet season in winter; hot, dry summers.
- *Mediterranean-type climates*—west coasts of the Americas, Africa, Australia, and Europe, between 30°–40° N and S.
- Vegetation is evergreen shrubs and trees.
- Fire is a common feature.

Evergreen leaves allow plants to be active during cooler, wetter periods.

Also lowers nutrient requirements—they do not have to develop new leaves every year.

Sclerophyllous leaves—tough and leathery—deter herbivores and prevent wilting.

Mediterranean-type zones include the *mallee* of Australia, the *fynbos* of South Africa, the *matorral* of Chile, the *maquis* around the Mediterranean Sea, and the *chaparral* of North America.

Fires may contribute to the persistence of these biomes.

After fires, some shrubs sprout from underground storage organs, others produce seeds that sprout and grow quickly after fire.

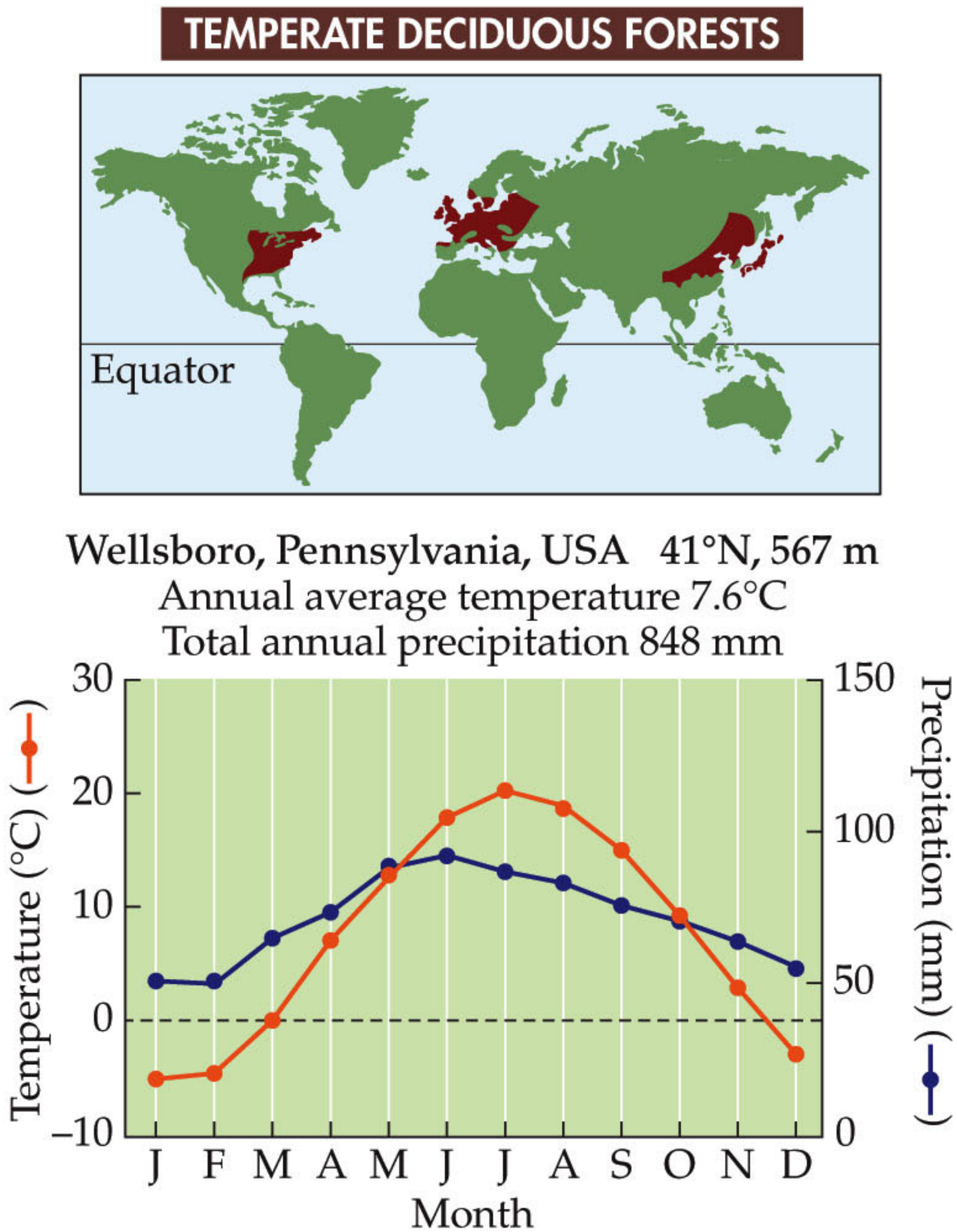
Without regular fires at 30–40-year intervals, some shrublands may be replaced by forests.

Shrublands are also found in continental interiors, associated with rain shadows and seasonally cold climates.

An example is the Great Basin between the Sierra Nevada and Cascade Mountains, with large expanses of sagebrush, saltbush, creosote bush, and piñon pine and juniper woodland.

Some temperate shrublands have been converted to crops and vineyards, but the soils are nutrient-poor.

Urban development has reduced the biome in some areas, such as southern California. Increased fire frequency reduces the ability of the vegetation to recover, and invasive grasses can move in.



ECOLOGY, Figure 3.F (Part 1)

TEMPERATE DECIDUOUS FORESTS

Autumn foliage prior to leaf fall, Great Smoky Mountains, Tennessee

Beech forest in summer, Japan

Temperate Deciduous Forests:

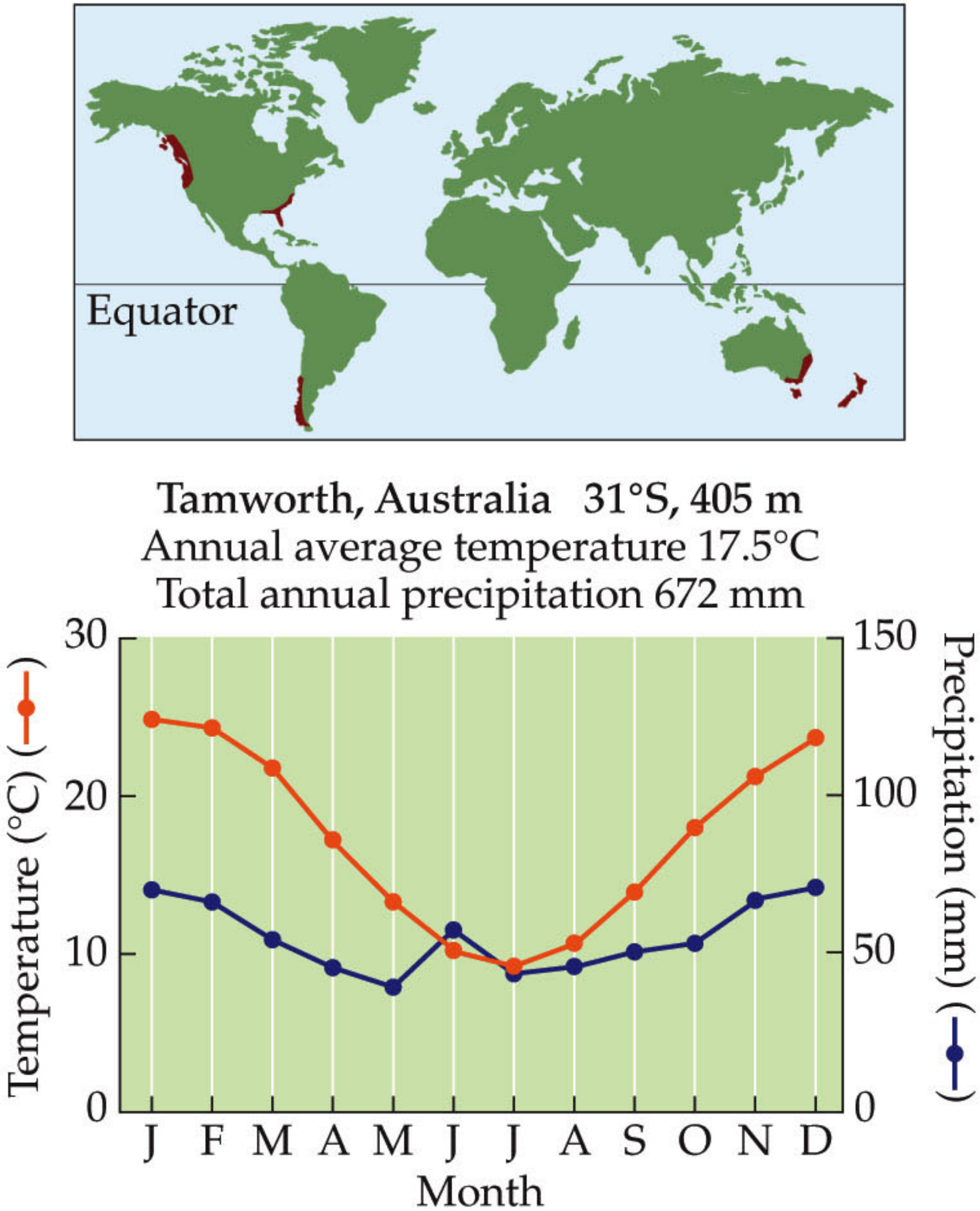
- Occur at 30° to 50° N, on continental edges, in areas with rainfall to support tree growth.
- Leaves are dropped during winter.
- Oaks, maples, and beeches occur everywhere in this biome.
- Species diversity lower than tropical rainforests.

Soils are fertile and agriculture has been a focus for centuries. Very little old-growth temperate forest remains.

As agriculture shifts to the tropics, temperate forests have regrown, with shifts in species composition.

Species shifts are due to nutrient depletion by agriculture and invasives such as the chestnut blight.

TEMPERATE EVERGREEN FORESTS



ECOLOGY, Figure 3.G (Part 1)

TEMPERATE EVERGREEN FORESTS

Grove of giant sequoias, *Sequoiadendron giganteum*, with douglas fir (*Pseudotsuga menziesii*), Mariposa Grove, Yosemite National Park, California

Araucaria (monkey puzzle tree) forest, Lanin National Park, Argentina

Temperate Evergreen Forests:

- At 30° to 50° N and S, in coastal and maritime zones.
- Lower diversity than tropical and deciduous forests.
- Leaves tend to be acidic, and soils nutrient-poor.
- Temperate rainforests receive 50–400 cm rain per year.

Figure 3.8 Temperate Rainforest in Tasmania

Evergreen trees are used for wood and paper pulp, thus this biome has been logged extensively.

Very little old-growth temperate evergreen forest remains.

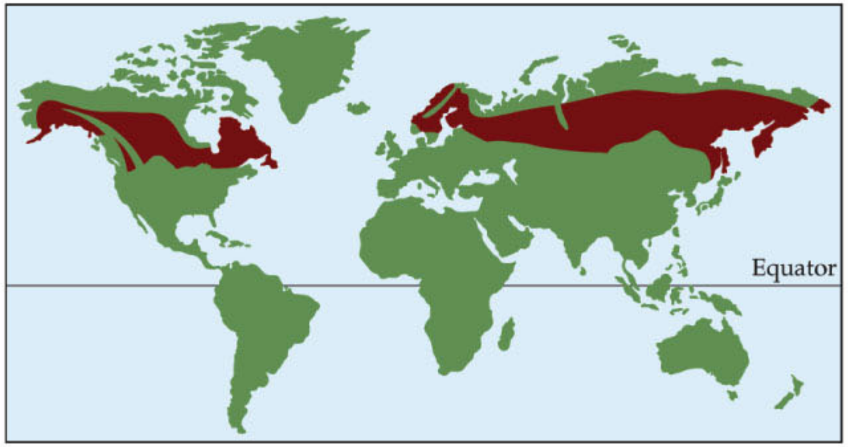
In some areas, planting of non-native species and uniformly aged stands has resulted in very different ecological conditions.

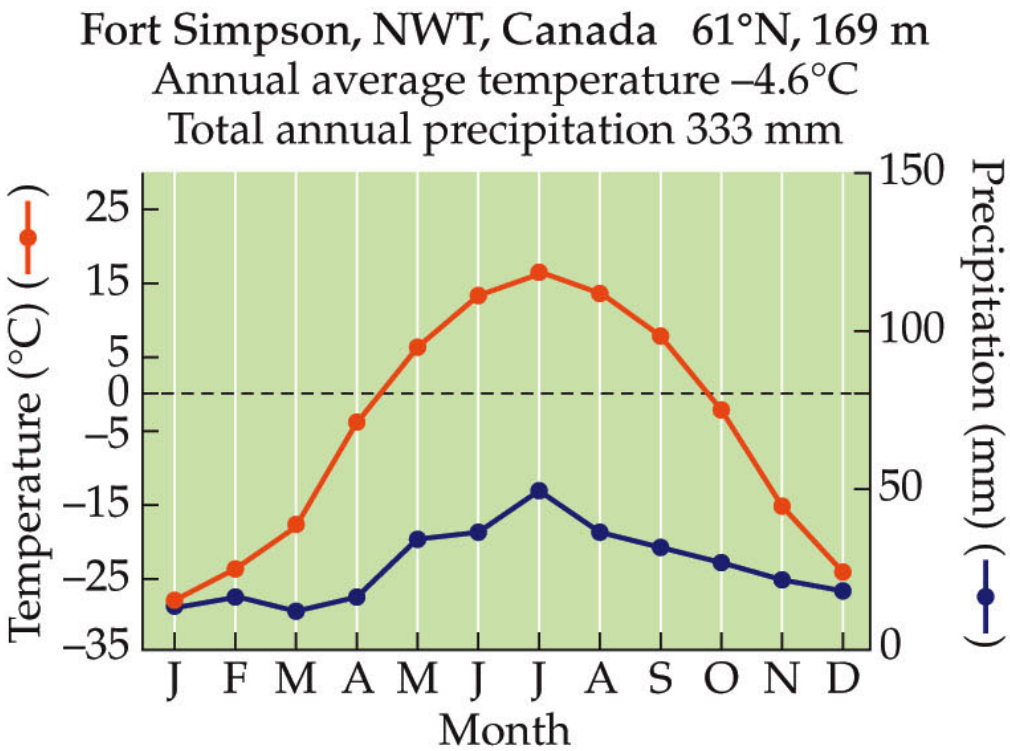
Suppression of fires in western North America has increased the density of forest stands, which results in more intense fires when they do occur.

It also increases the spread of insect pests and pathogens.

Air pollution has damaged some temperate evergreen forests.

BOREAL FORESTS





***ECOLOGY,* Figure 3.H (Part 1)**

BOREAL FORESTS

Spruce trees on the margin of a bog in autumn, Denali National Park, Alaska

Boreal forest landscape, Canadian shield, northern Quebec

Boreal Forests (Taiga):

- Between 50° and 65° N.
- Long, severe winters.
- **Permafrost** (subsurface soil that remains frozen year-round) impedes drainage and causes soils to be saturated.
- Trees are conifers—pines, spruces, larches.

Terrestrial Biomes

Cold, wet conditions in boreal soils limits decomposition, so soils have high organic matter.

In summer droughts, forest fires can be set by lightning, and burn both trees and soil.

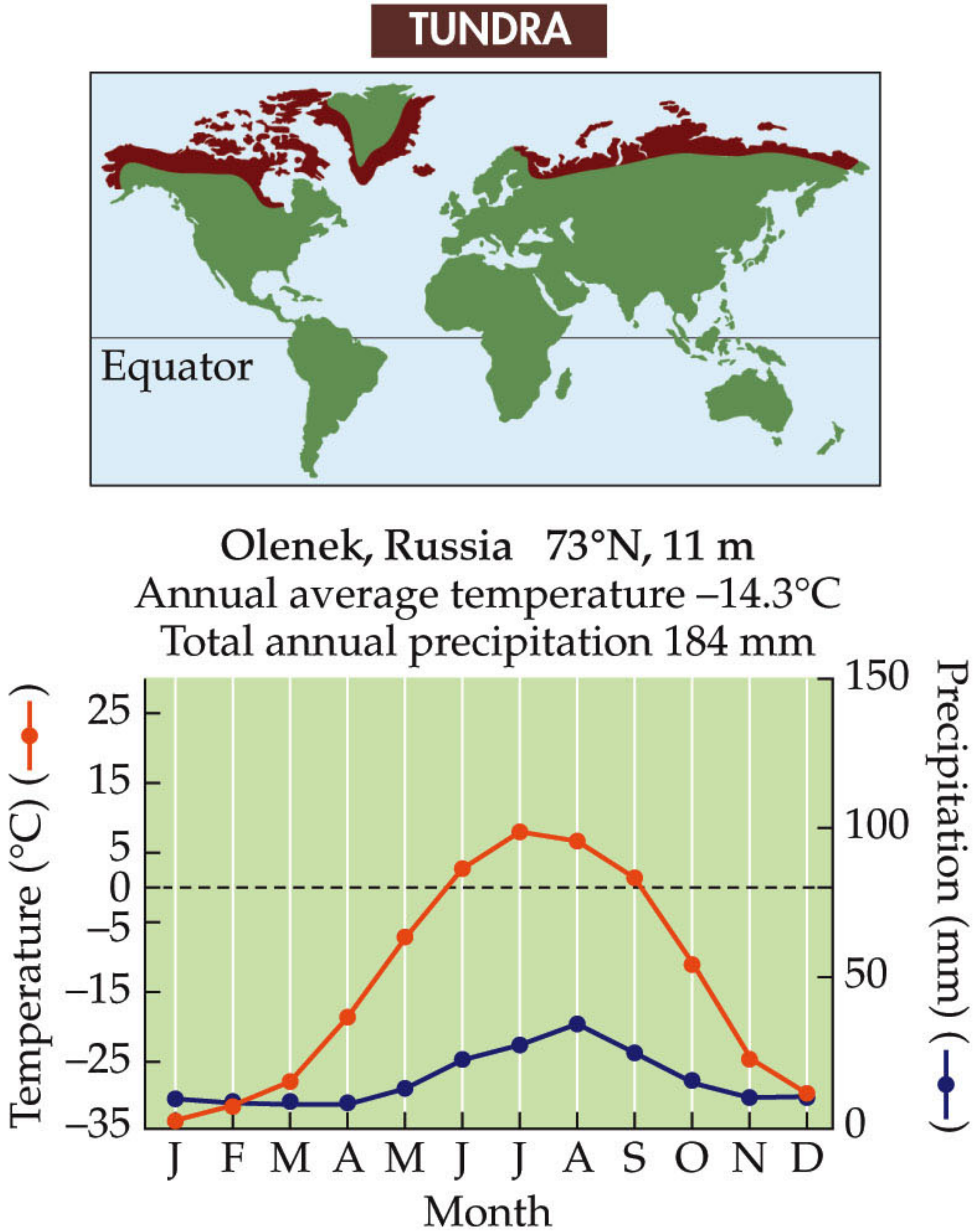
In low-lying areas, extensive peat bogs form.

Figure 3.9 Fire in the Boreal Forest

Boreal forests have not been as affected by human activities.

Logging, and oil and gas development, occur in some regions. Impacts will increase as energy demands increase.

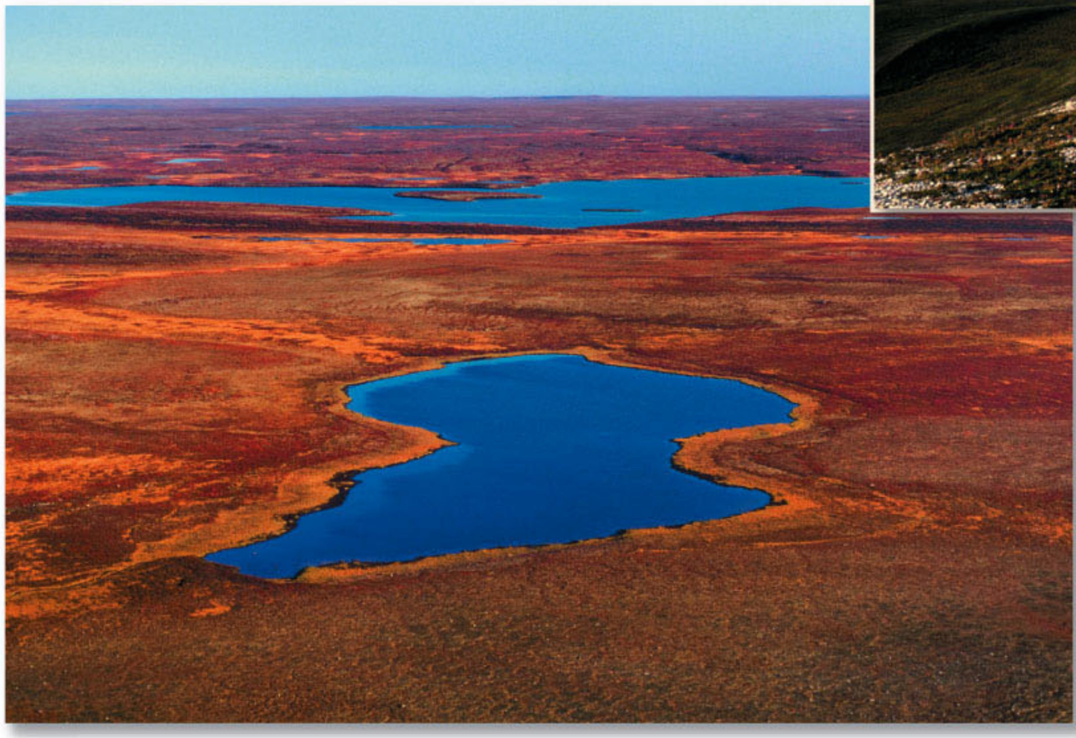
Climate warming may result in release of carbon stored in boreal soils, creating a positive feedback to warming.



ECOLOGY, Figure 3.I (Part 1)

TUNDRA

Looking out to the Arctic plain at midnight from the northern edge of the Brooks Range, Alaska



Arctic tundra of Thelon barrenlands in early autumn color, Northwest Territories, Canada

ECOLOGY, **Figure 3.I (Part 2)**

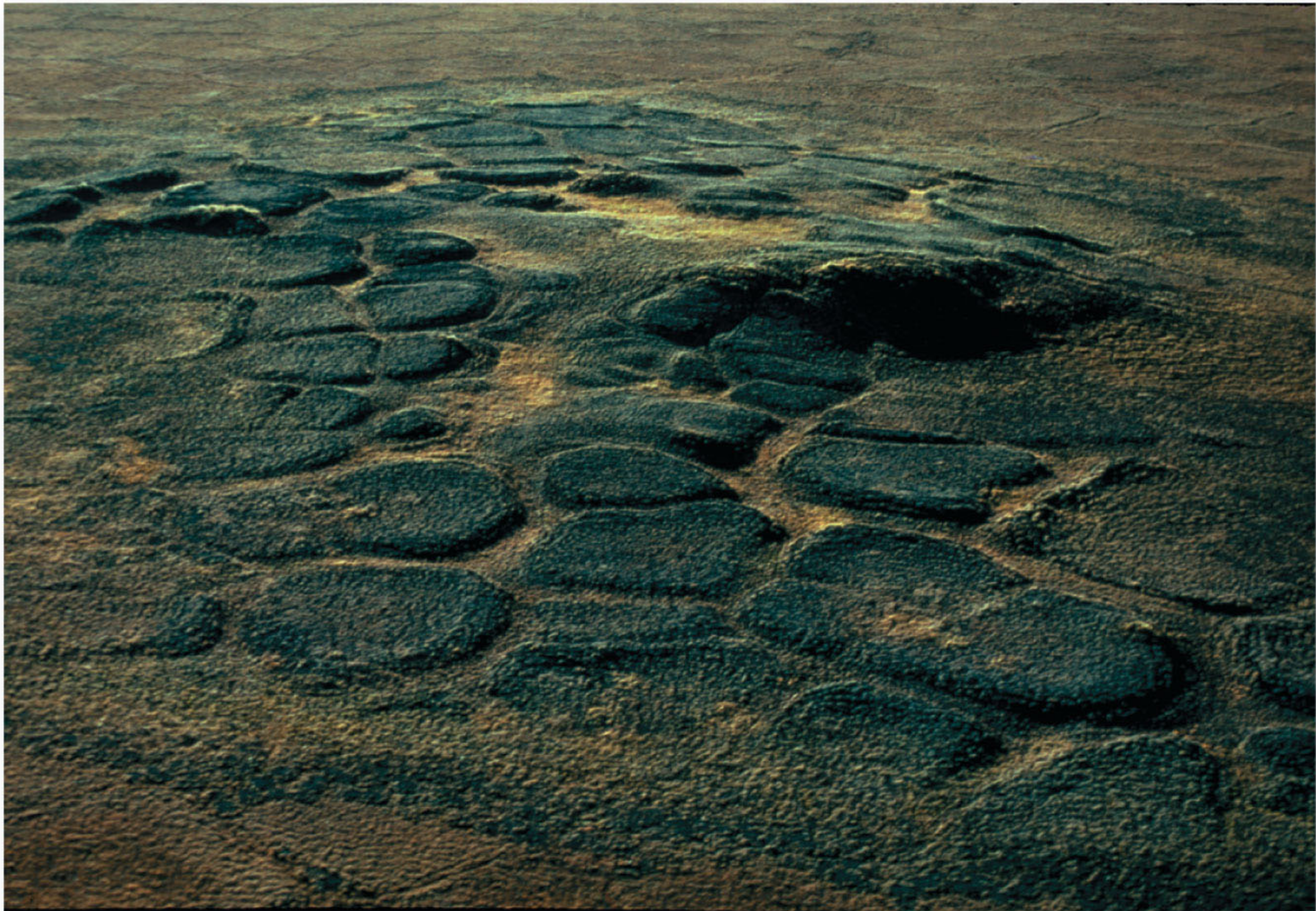
Tundra:

- Above 65° latitude, mostly in the Arctic.
- Cold temperatures, low precipitation.
- Short summer with long days.
- Vegetation is sedges, forbs, grasses, low-growing shrubs, lichens, and mosses.
- Permafrost is widespread.

Repeated freezing and thawing of surface soil layers results in sorting of soil materials according to texture.

Polygons of soil form at the surface, with upraised rims and depressed centers.

Figure 3.10 Soil Polygons and Pingo



Human settlements are sparse in the tundra, thus it contains some of the most pristine habitats on Earth.

Animals include caribou and musk oxen, and many migratory birds nest there.

Also predators such as wolves and brown bears, which have been extirpated throughout much of their previous range in other biomes.

Human influence on the tundra is increasing, as exploration and development of energy resources increases.

The Arctic has experienced significant climate change during the late 20th and early 21st centuries, with warming almost double the global average.

Terrestrial Biomes

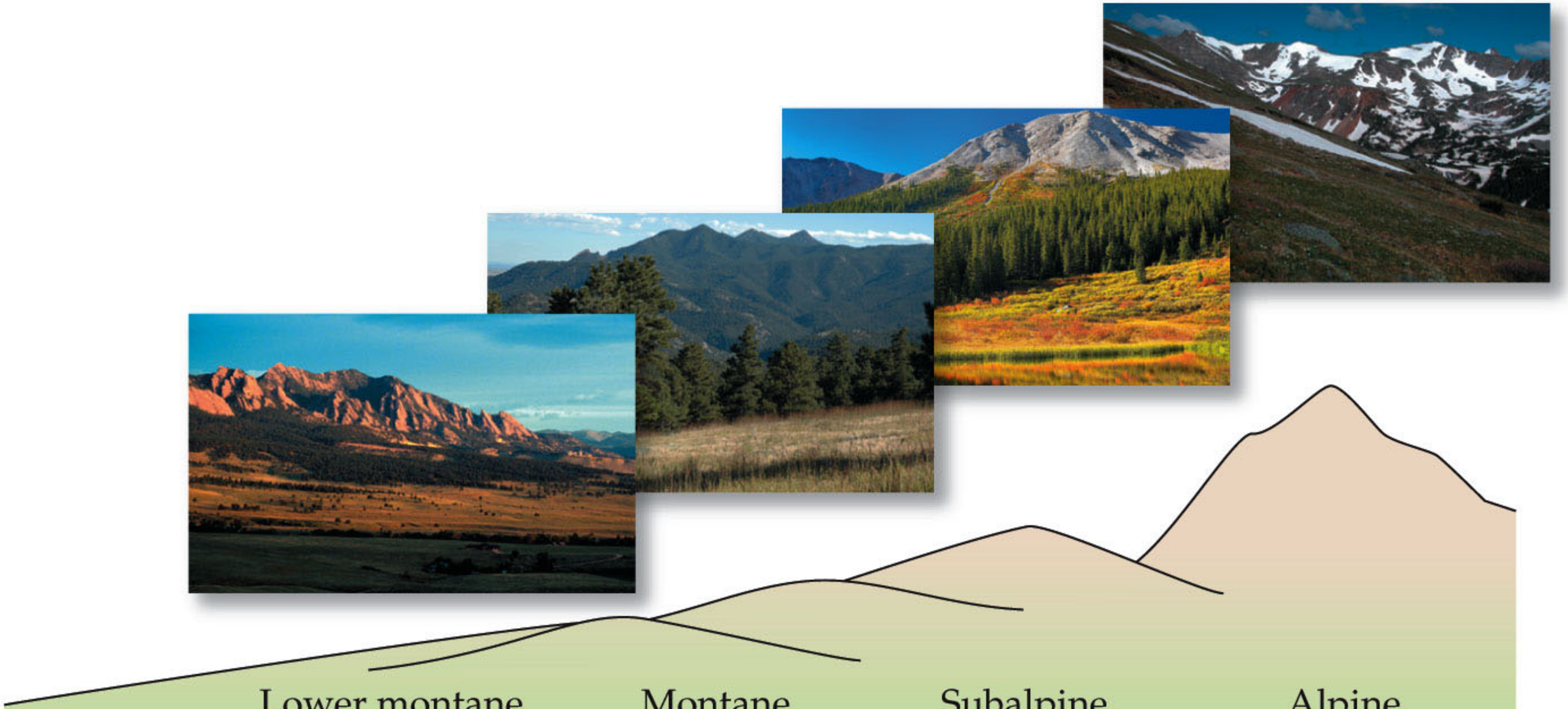
On mountains, temperature and precipitation change with elevation, resulting in bands of biotic assemblages similar to biomes.

There are also smaller scale variations associated with slope aspect, proximity to streams, and prevailing winds.

For example, in the southern Rocky Mountains, vegetation changes from grassland to alpine over 2200 m elevation, comparable to 27° of latitude.

The alpine zone is similar to Arctic tundra, but with higher winds, more intense solar radiation, and lower atmospheric pressure.

Figure 3.11 Mountain Biological Zones



	Lower montane zone	Montane zone	Subalpine zone	Alpine zone
Median elevation (m)	1,500	2,400	3,000	3,700
Mean annual temperature (°C)	9	5.5	2.5	–3.5
Mean annual precipitation (mm)	450	600	750	1,000

Some mountain communities have no biome analogs.

For example, tropical alpine vegetation does not resemble tundra—daily temperature variation is greater than seasonal variation.

Figure 3.12 Tropical Alpine Plants

Freshwater Biological Zones

Concept 3.2: Biological zones in freshwater systems are associated with the velocity, depth, temperature, clarity, and chemistry of the water.

Freshwater streams and lakes are a key connection between terrestrial and marine ecosystems.

They process inputs of chemical elements and energy from terrestrial systems and transport them to the oceans.

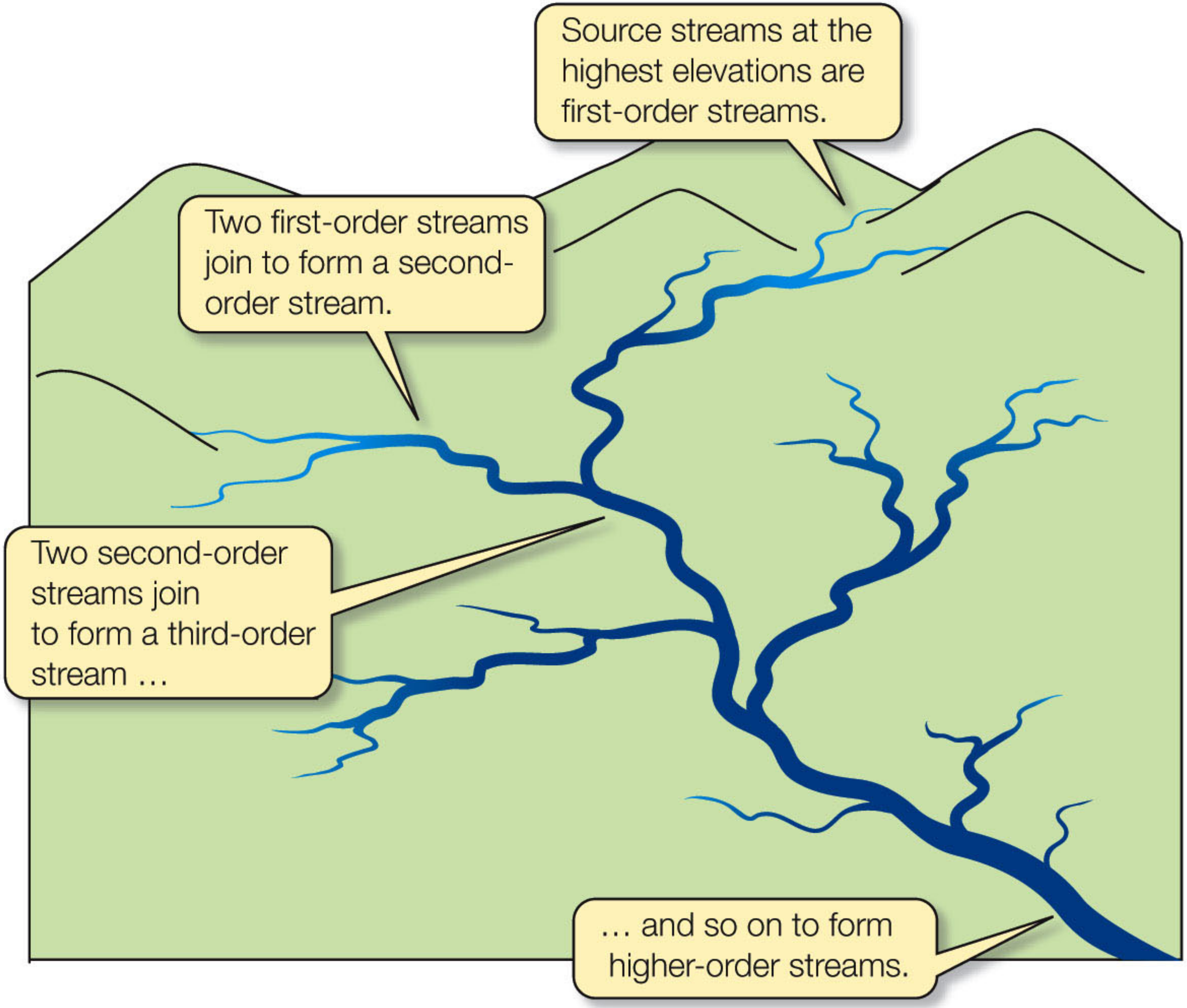
Freshwater Biological Zones

Land surfaces are partly shaped by the erosional power of water flowing downhill.

Streams and rivers are **lotic** (flowing water) systems.

The smallest streams at high elevation are first-order streams. These converge to form second-order streams. The large rivers are sixth-order streams or greater.

Figure 3.13 Stream Orders



ECOLOGY, Figure 3.13

Freshwater Biological Zones

A pattern of riffles and pools tends to form in streams.

Riffles: Fast moving water with coarse particles on the stream bed.

Pools: Deeper and slower flow; finer sediments.

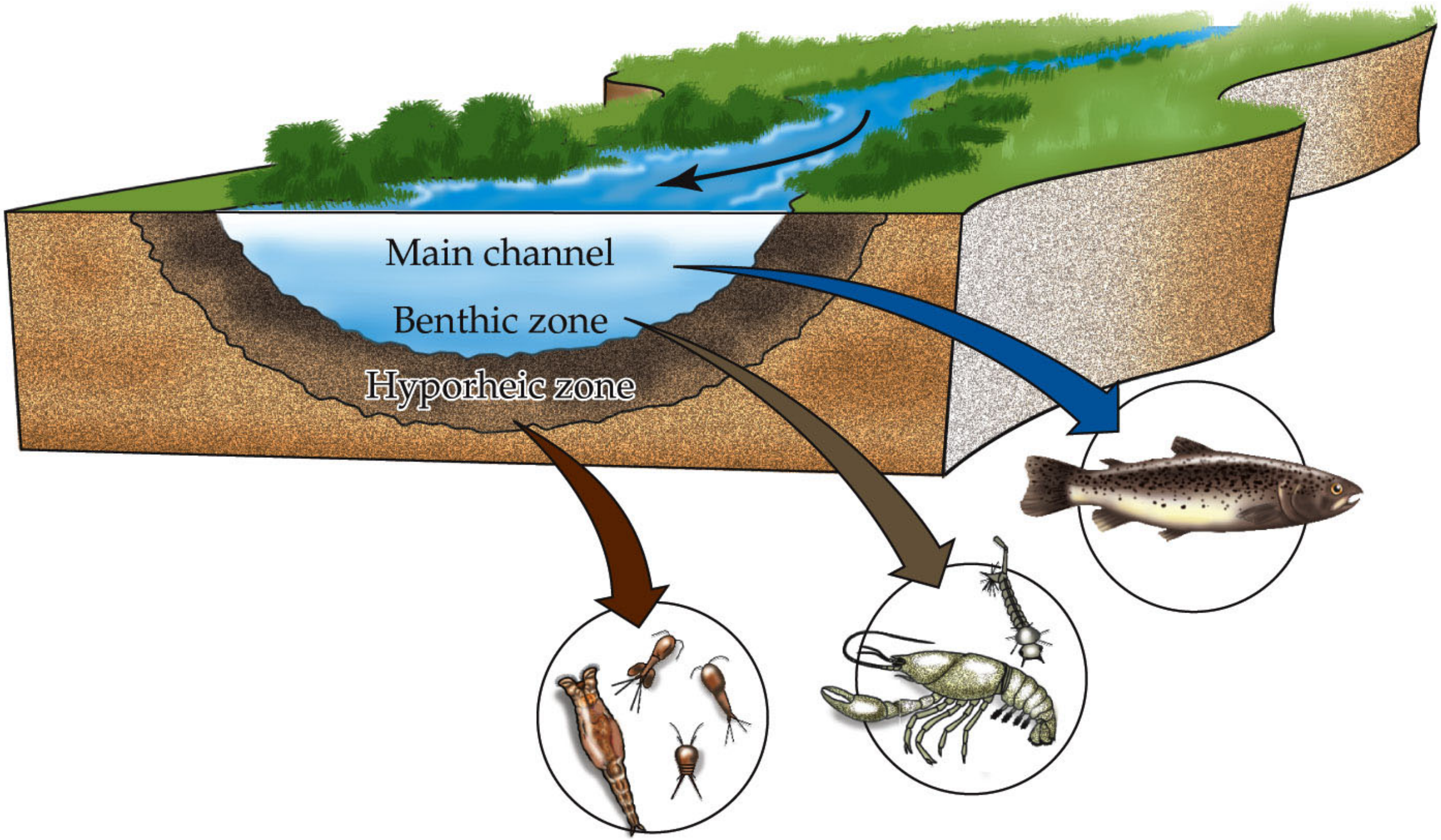
Freshwater Biological Zones

Benthic organisms are bottom dwellers, and include many kinds of invertebrates.

Some feed on **detritus** (dead organic matter), others are predators.

Some live in the **hyporheic zone**—the substratum below and adjacent to the stream, where there is water movement from the stream or from groundwater.

Figure 3.14 Spatial Zonation of a Stream



Freshwater Biological Zones

The *river continuum concept* describes the compositional changes of biological communities with stream order and channel size (Vannote et al. 1980).

As streams increase in size, detrital input from riparian vegetation decreases and the importance of this as a food source decreases.

Freshwater Biological Zones

Downstream, the importance of fine organic matter, algae, and **macrophytes** (rooted aquatic plants) as food sources increases.

Feeding styles of organisms also change: From *shredders* (tear up and chew leaves) to *collectors* (collect fine particles from the water).

Freshwater Biological Zones

The river continuum concept applies best to temperate river systems, and not so well to Arctic/boreal and tropical rivers, and those with high humic acids in wetlands.

But it provides a basic model for the study of stream systems.

Human effects on streams include pollution, sediment inputs, and introduced species.

Streams have always been used for disposal of sewage and industrial wastes. These can often reach levels toxic to organisms.

Excessive fertilizer use in croplands results in runoff and leaching of nutrients to streams and groundwater.

Deforestation increases sediment inputs into streams, which can reduce water clarity, alter benthic habitat, and inhibit gill function in many aquatic organisms.

Freshwater Biological Zones

Non-native species, including sport fishes, have lowered biodiversity in streams and lakes.

Construction of dams tremendously alters the physical and biological properties of streams, converting them to “stillwater” systems.

Freshwater Biological Zones

Lakes and still waters (**lentic**) occur where depressions in the landscape fill with water.

Lakes can be formed by glacial processes, from river oxbows, in volcanic craters, in tectonic basins, or by animal activities, including humans and beavers.

Freshwater Biological Zones

Lakes vary greatly in size.

The depth and area of a lake has important consequences for the composition of its biological communities.

Deep lakes with a relatively small surface area tend to be nutrient-poor compared with shallow lakes with a relatively large surface area.

Freshwater Biological Zones

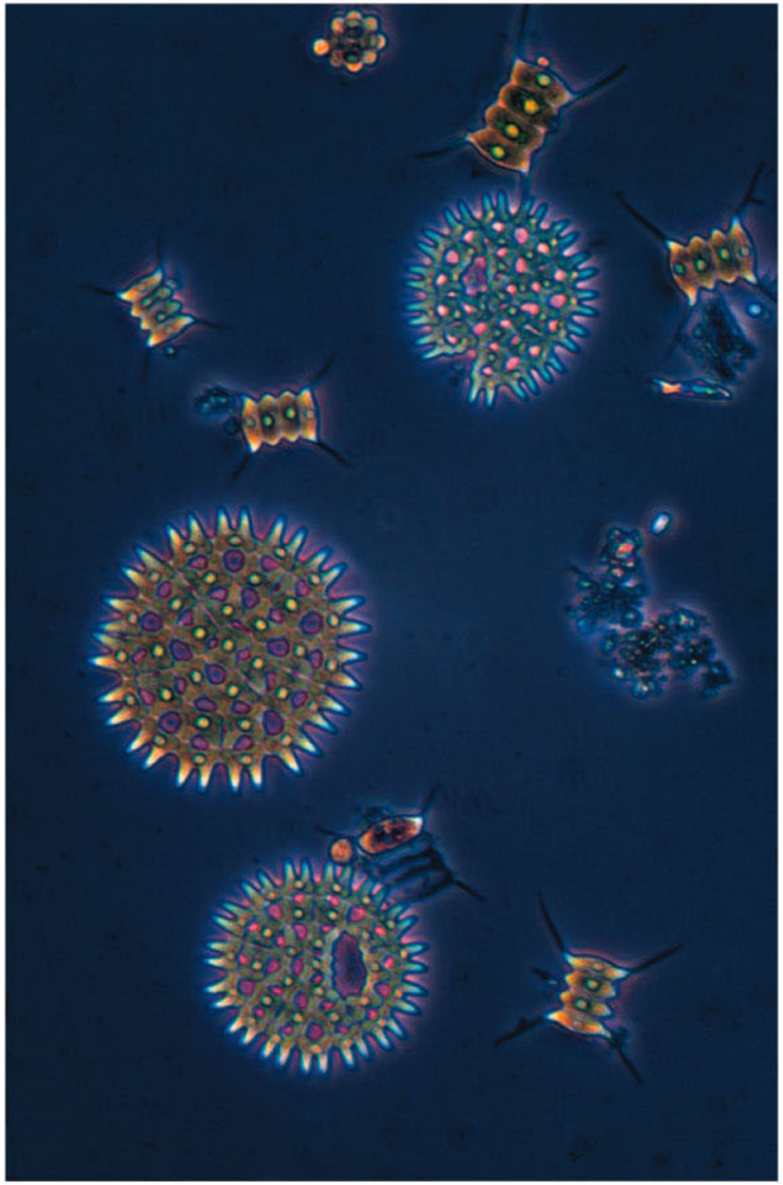
Biological assemblages are determined by depth and degree of light penetration.

Pelagic zone: Open water; dominated by **plankton** (small and microscopic organisms suspended in the water).

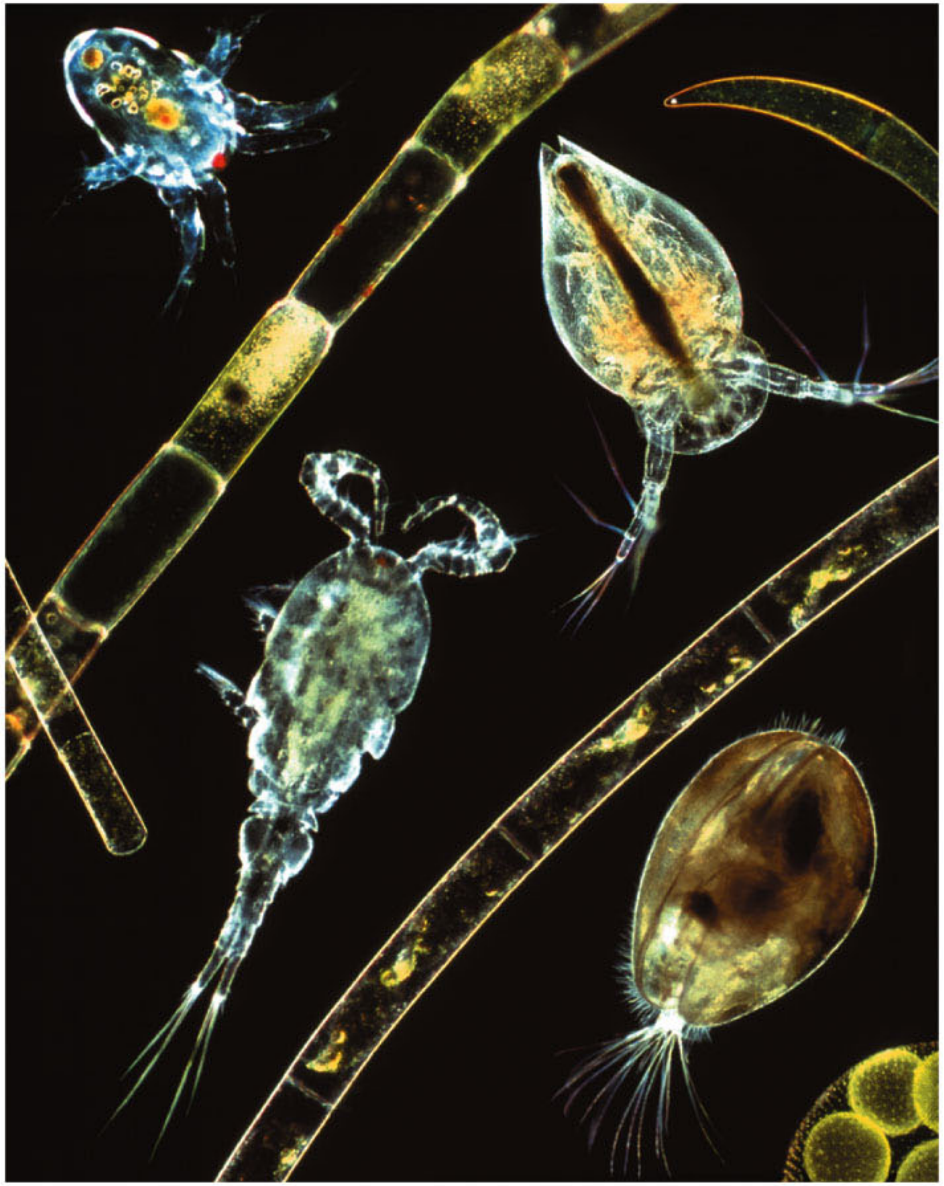
Photosynthetic plankton (**phytoplankton**) are limited to the upper layers through which light penetrates (**photic zone**).

Figure 3.15 Examples of Lake Plankton

(A) Phytoplankton



(B) Zooplankton



Freshwater Biological Zones

The **littoral zone** is near shore, where the photic zone reaches the bottom. Macrophytes occur in this zone.

In the benthic zone, detritus derived from the littoral and pelagic zones serves as an energy source for animals, fungi, and bacteria. This zone may be cold and have low oxygen.

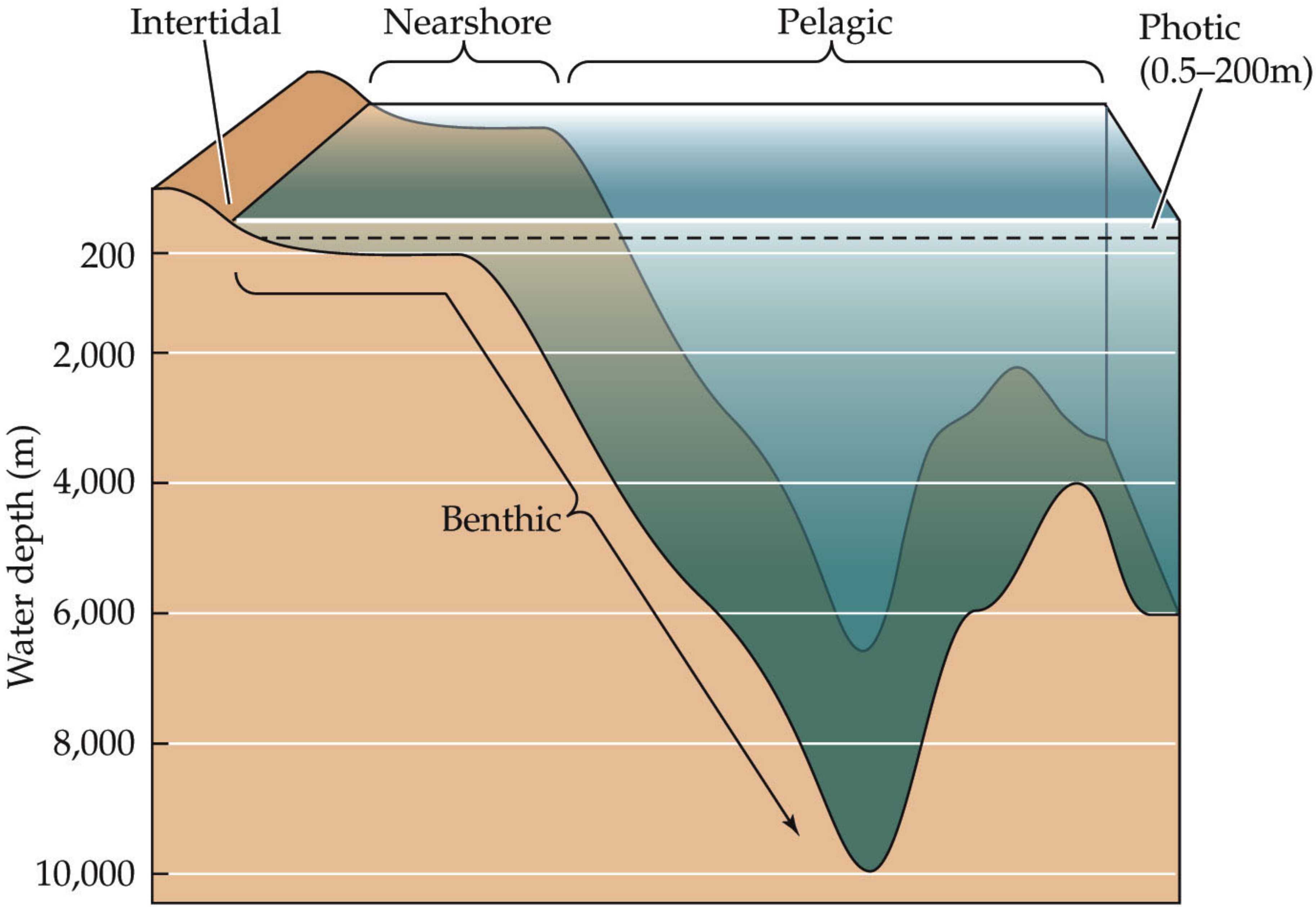
Marine Biological Zones

Concept 3.3: Marine biological zones are determined by ocean depth, light availability, and the stability of the bottom substratum.

Oceans cover 71% of Earth’s surface and contain a rich diversity of unique biota.

Marine zone are categorized by depth and relationship to shorelines.

Figure 3.16 Marine Biological Zones



Marine Biological Zones

Marine zones next to continents are influenced by the tides and wave action.

Tides are generated by the gravitational attraction between Earth and the moon and sun.

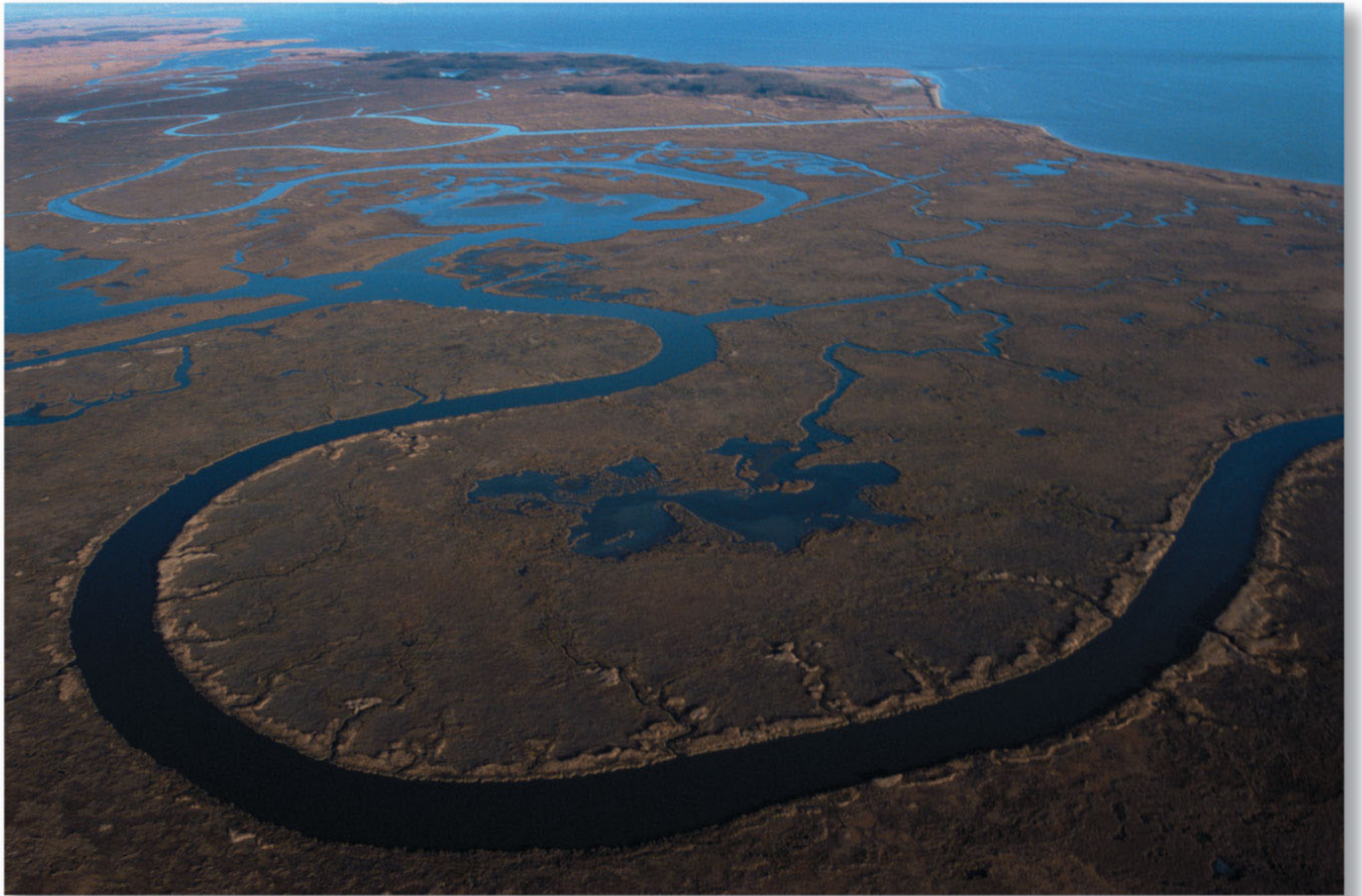
The magnitude of tidal ranges varies by location and is related to shoreline morphology and ocean bottom structure.

Estuaries occur at the junctions of rivers and oceans.

Salinity varies as fresh water flows in from the river and salt water flows in from the sea.

Rivers also bring terrestrial sediments and nutrients, contributing to the productivity of estuaries.

Figure 3.17 Estuaries Are Found at the Junction of Rivers and Oceans



Salinity variation influences organisms that live in estuaries.

Many fish species spend juvenile stages there, away from predators that cannot tolerate salinity change.

Many shellfish and other invertebrates also live in estuaries.

Marine Biological Zones

Estuaries are increasingly threatened by pollution carried in rivers.

Nutrients from agriculture can create local dead zones (anoxia), and loss of biodiversity.

Salt marshes are shallow coastal wetlands dominated by emergent plants such as grasses and rushes.

Terrestrial nutrients enhance productivity.

Plants occur in zones that reflect salinity gradients that result from periodic flooding at high tide. The highest zone is most saline (gets least flooding).

Figure 3.18 Salt Marshes are Characterized by Salt-Tolerant Vascular Plants

In the tropics and subtropics, coastal zones can be dominated by **mangrove forests**—salt-tolerant, evergreen trees and shrubs.

Mangroves include species from 16 different plant families.

Mangrove roots trap sediments carried by the water, which build up and modify the shoreline.

Figure 3.19 Salt-Tolerant Evergreen Trees and Shrubs Form Mangrove Forests

Mangrove forests provide nutrients to other marine ecosystems and habitat for many animals.

Several unique animals associated with mangroves include manatees, crab-eating monkeys, fishing cats, and monitor lizards.

Mangroves are threatened by human development, particularly shrimp farms, water pollution, diversion of inland freshwater sources, and cutting.

Marine Biological Zones

Rocky intertidal zones provide a stable substratum for a diverse collection of algae and animals.

The environment alternates between marine and terrestrial with the rise and fall of the tides.

Bands of organisms result, depending on their tolerance to drying, salinity, temperature, and interactions with other organisms.

Figure 3.20 The Rocky Intertidal Zone: Stable Substratum, Changing Conditions

Marine Biological Zones

Sessile organisms are fixed in place, and must have mechanisms to tolerate the daily changes—barnacles, mussels, seaweeds.

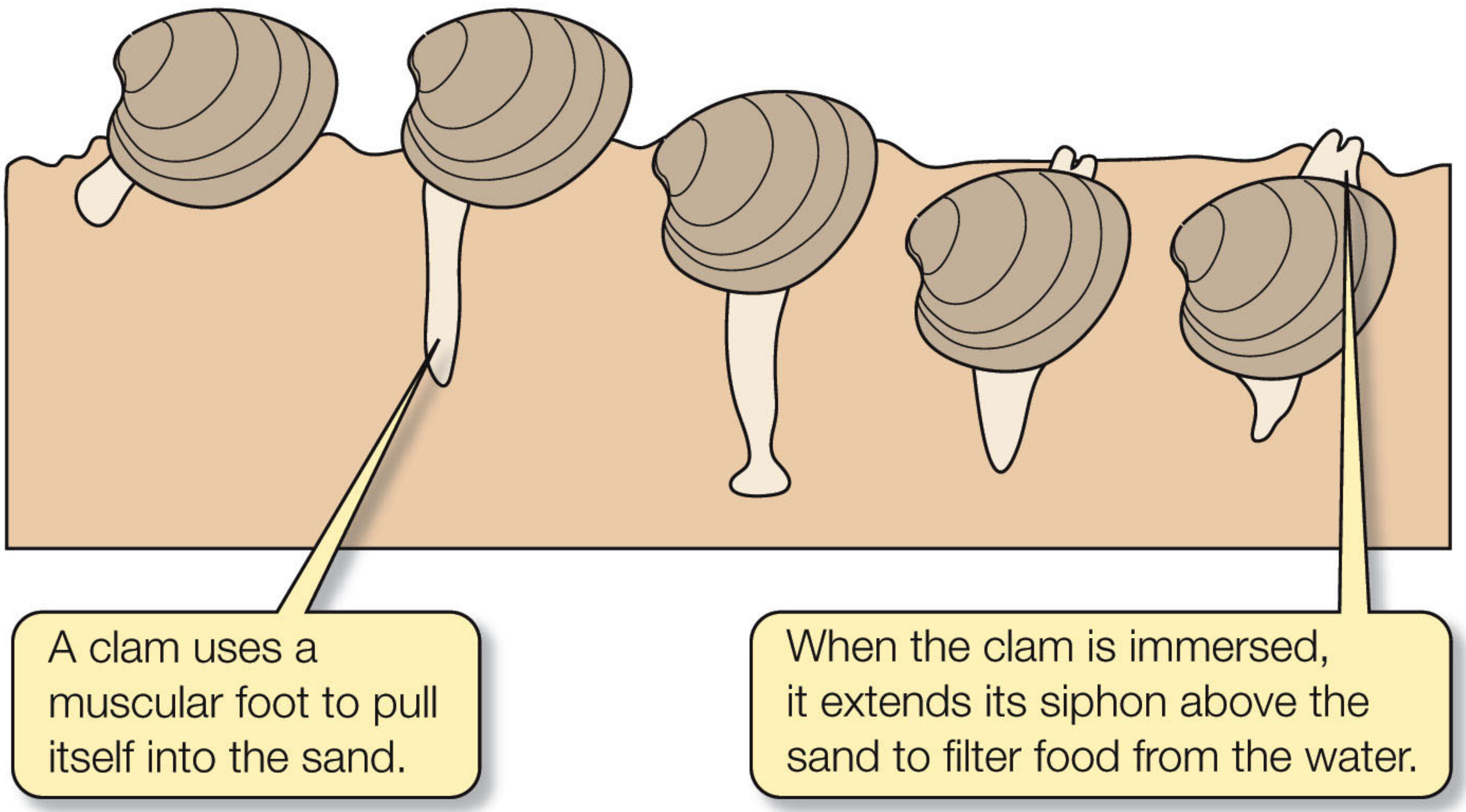
Mobile animals such as starfish and sea urchins can move to pools to avoid *desiccation*.

Sandy shores are not very stable, have little available food, and lots of wave action.

But many invertebrates burrow into the sand, such as clams, sea worms, and mole crabs.

Smaller organisms, such as polychaete worms, hydroids, and copepods live on or among the grains of sand.

Figure 3.21 Burrowing Clams



Marine Biological Zones

Shallow ocean zones allow light to penetrate to the bottom and support photosynthetic organisms.

These organisms support a diverse community of other organisms by providing both energy and physical support.

Coral reefs are restricted to warm, shallow water.

Corals are related to jellyfish, form large colonies, and have associated algal partners.

Many corals extract calcium carbonate from seawater to build a skeleton-like structure that over time, forms large reefs.

Figure 3.22 A Coral Reef

Marine Biological Zones

Coral reefs develop a complex habitat that supports a huge diversity of marine life.

Although coral reefs grow slowly, over millions of years, corals have constructed thousands of kilometers of coastline and many islands.

Rates of production of biomass are some of the highest in the world.

Figure 3.23 Coral Reefs Can Be Seen from Outer Space

Coral reefs support up to a million species of organisms, the highest diversity on Earth.

Many economically important fishes rely on coral reefs for habitat, and reef fishes provide a source of food for fishes of the open ocean, such as jacks and tuna.

There is potential for development of medicines from coral reef organisms.

The U.S. National Institutes of Health established a laboratory in Micronesia to research this potential.

Many human activities threaten coral reefs.

Sediments carried by rivers can cover and kill the corals.

Excess nutrients increase the growth of algae on the surface of the corals, increasing mortality.

Warming ocean temperatures can result in the loss of the algal partners from the corals, resulting in *coral bleaching*.

Increased incidence of fungal infections may be related to increased dust associated with desertification.

Future changes in ocean chemistry may inhibit the ability of corals to form skeletons.

Kelp beds or forests support a diverse marine community, including sea urchins, lobsters, mussels, abalones, many other seaweeds, and sea otters.

Kelp are several genera of large brown algae, with leaf-like fronds, stems, and holdfasts which anchor to solid substrates.

ECOLOGY, Figure 3.24

Kelp abundance is influenced by interactions among the various organisms.

Grazers such as sea urchins can reduce kelp abundance.

Urchin abundance is tied to predation by sea otters, while sea otter abundance is in turn related to orca and human predation.

Seagrass beds are submerged flowering plants (not related to grasses), in subtidal marine sediments of mud or fine sand.

Algae and animals grow on the plants, and larval stages of some organisms, such as mussels, depend on them for habitat.

Nutrients from upstream agricultural activities can increase the algal growth in seagrass beds.

Marine Biological Zones

The open ocean beyond the continental shelves is called the **pelagic zone**.

The photic zone, which supports the highest densities of organisms, extends to about 200 m depth.

Below the photic zone, energy is supplied by falling detritus.

Organisms in the pelagic zone include:

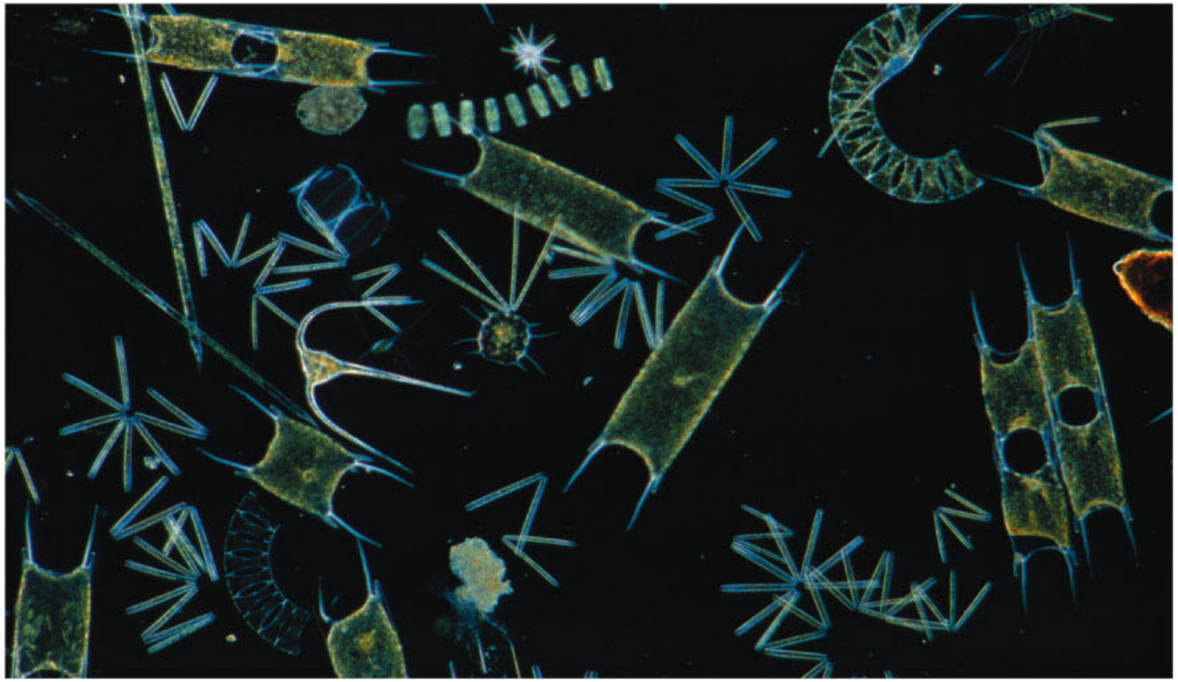
Nekton (swimming organisms capable of overcoming ocean currents)—fish, mammals, sea turtles, squid, octopus

Phytoplankton—green algae, diatoms, dinoflagellates, and cyanobacteria

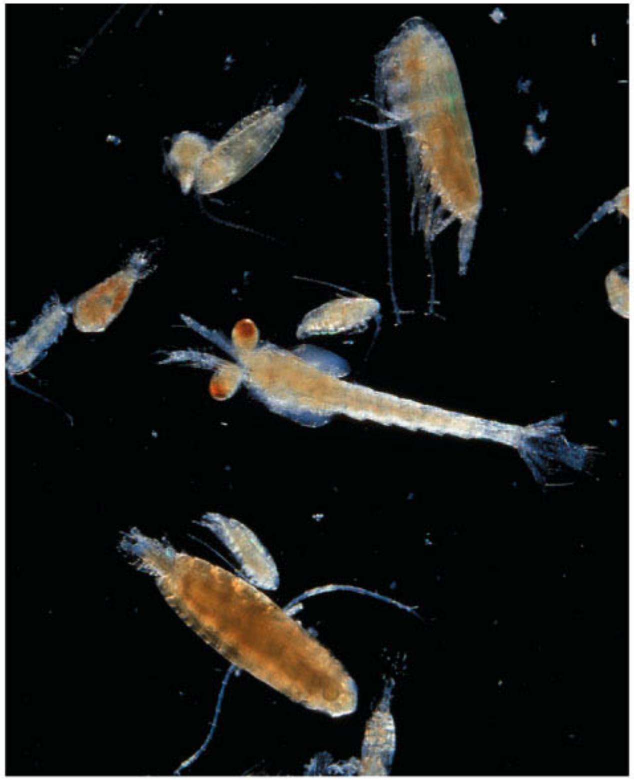
Zooplankton—protists (e.g., ciliates), crustaceans (e.g., copepods and krill), and jellyfishes

Figure 3.25 Plankton of the Pelagic Zone

(A) Marine phytoplankton



(B) Marine zooplankton



Pelagic seabirds, including albatross, petrels, fulmars, and boobies, spend most of their lives flying over open ocean waters, feeding on marine prey (fish and zooplankton) and detritus found on the ocean surface.

Organisms in the pelagic zone must have ways to prevent sinking out of the photic zone, such as swimming.

The seaweed *Sargassum* has gas-filled bladders to keep it afloat. It forms large floating islands that are habitat for other organisms.

Some plankton retard sinking by changing chemical composition to alter density relative to sea water.

Body shapes and projections can also slow sinking.

Below the photic zone, temperatures drop and pressure increases.

Crustaceans such as copepods graze on the rain of falling detritus from the photic zone.

Crustaceans, cephalopods, and fishes are the predators of the deep sea.

Figure 3.26 A Denizen of the Deep Pelagic Zone

Ocean bottoms (benthic zone) are sparsely populated, with temperatures near freezing, and very high pressure.

The sediments are rich in organic matter, contain bacteria, protists, and sea worms. Sea stars and sea cucumbers graze the ocean floor or filter food from the water.

Bioluminescence is also used by benthic predators to lure prey.

Case Study Revisited: The American Serengeti: Twelve Centuries of Change in the Great Plains

Paul Martin noted the correspondence between extinction events on several continents and the arrival of humans on those continents (Martin 1984, 2005).

The rapidity of the extinctions, and the number of large animals, suggested to him that hunting by humans caused the extinctions.

Case Study Revisited: The American Serengeti: Twelve Centuries of Change in the Great Plains

This “overkill hypothesis” has received increasing support.

Archeological evidence shows that humans butchered some of these extinct animals.

On small islands, human arrival and extinctions coincided. Humans also brought diseases as well as predators such as rats and snakes.

Case Study Revisited: The American Serengeti: Twelve Centuries of Change in the Great Plains

Other mechanisms may also have been involved.

These include spread of diseases by humans and dogs, climate change, and the loss of some species that depended on others, such as mastodons.

A combination of factors probably contributed to the extinctions.

Case Study Revisited: The American Serengeti: Twelve Centuries of Change in the Great Plains

Some large mammals did not go extinct. Bison, elk, pronghorn, and deer roamed the Great Plains and continued to be hunted by humans.

Humans began to use more fire to manage habitat and for small-scale agriculture.

Case Study Revisited: The American Serengeti: Twelve Centuries of Change in the Great Plains

Between 1700 and 1900, human activities caused profound changes.

Horses were brought by the Spanish, facilitating bison hunting.

Arrival of Euro-Americans and their conflicts with Native Americans led to the near extinction of bison.

Figure 3.27 Buffalo Hunting

Case Study Revisited: The American Serengeti: Twelve Centuries of Change in the Great Plains

After 1850, mechanized agriculture and domesticated animals transformed the landscape.

Today only 1% of the eastern tallgrass prairie remains.

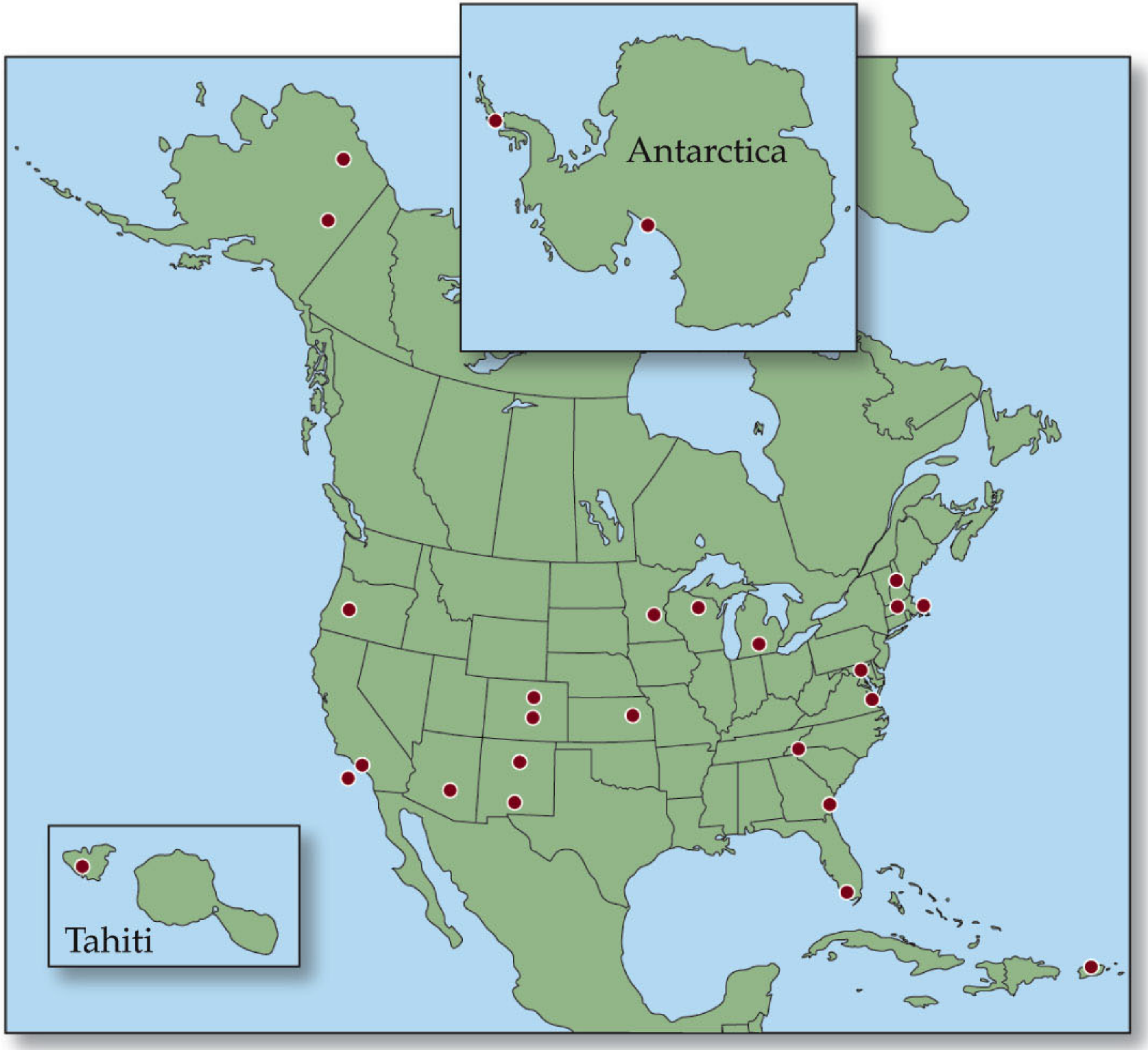
Overgrazing and unsustainable agricultural practices led to the “Dust Bowl” of the 1930s. Drought and windstorms resulted in substantial losses of fertile topsoil.

Connections in Nature: Long-Term Ecological Research

In 1980, the U.S. National Science Foundation established a network of long-term ecological research (LTER) sites to understand the effects of human activities on natural systems.

The mission is to provide the knowledge necessary to conserve, protect, and manage ecosystems, their biodiversity, and services.

Figure 3.28 Long-Term Ecological Research Programs



The Konza Prairie LTER in Kansas is in a remnant of the tallgrass prairie.

Research has focused on understanding the interaction of fire, grazing, and climate in this ecosystem.

Research on precipitation patterns has provided insights into possible effects of climate change.

Figure 3.29 Research at the Konza Prairie LTER Site