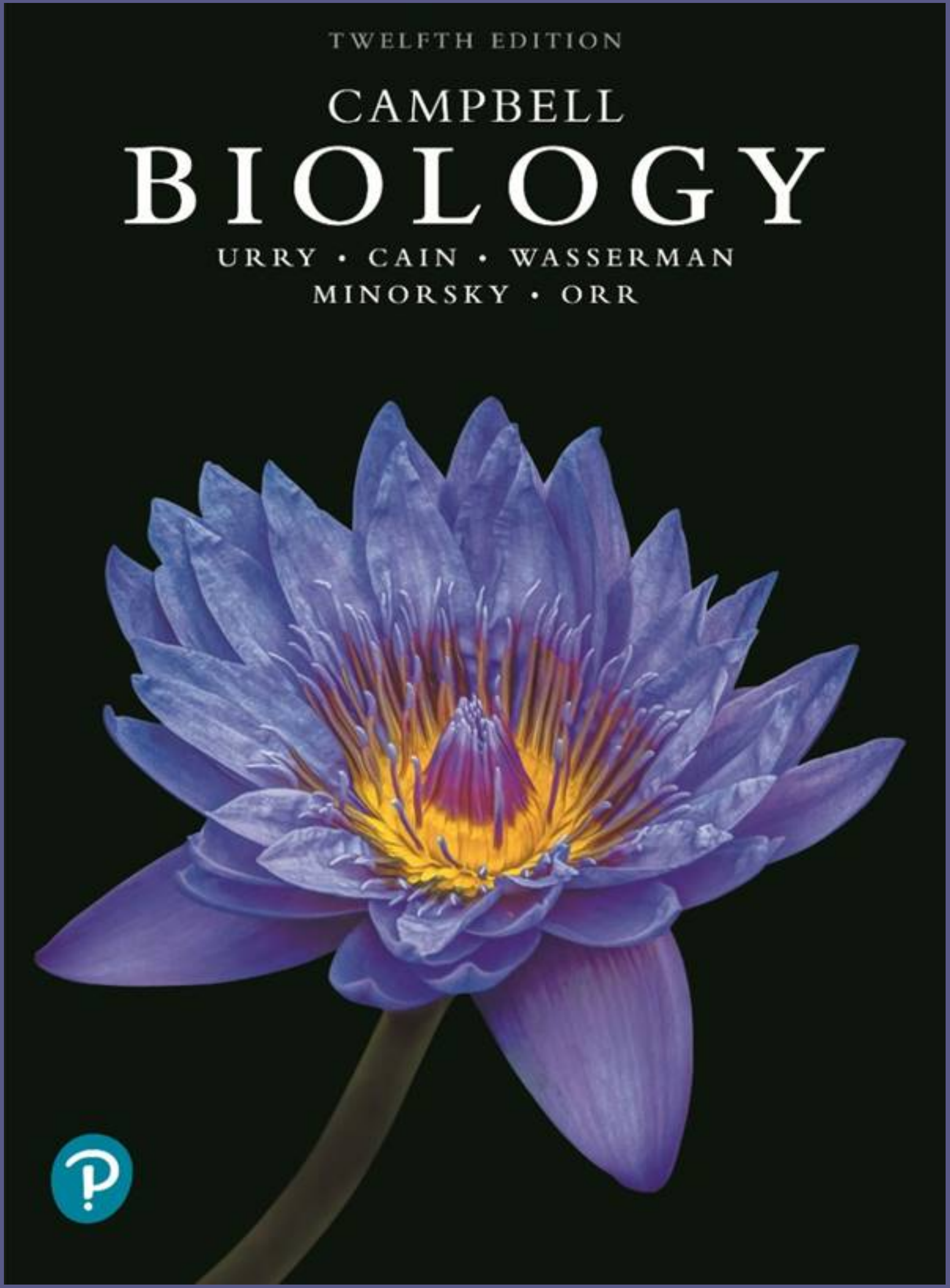


Chapter 52

An Introduction to Ecology and the Biosphere

Lecture Presentations by
Nicole Tunbridge and
Kathleen Fitzpatrick

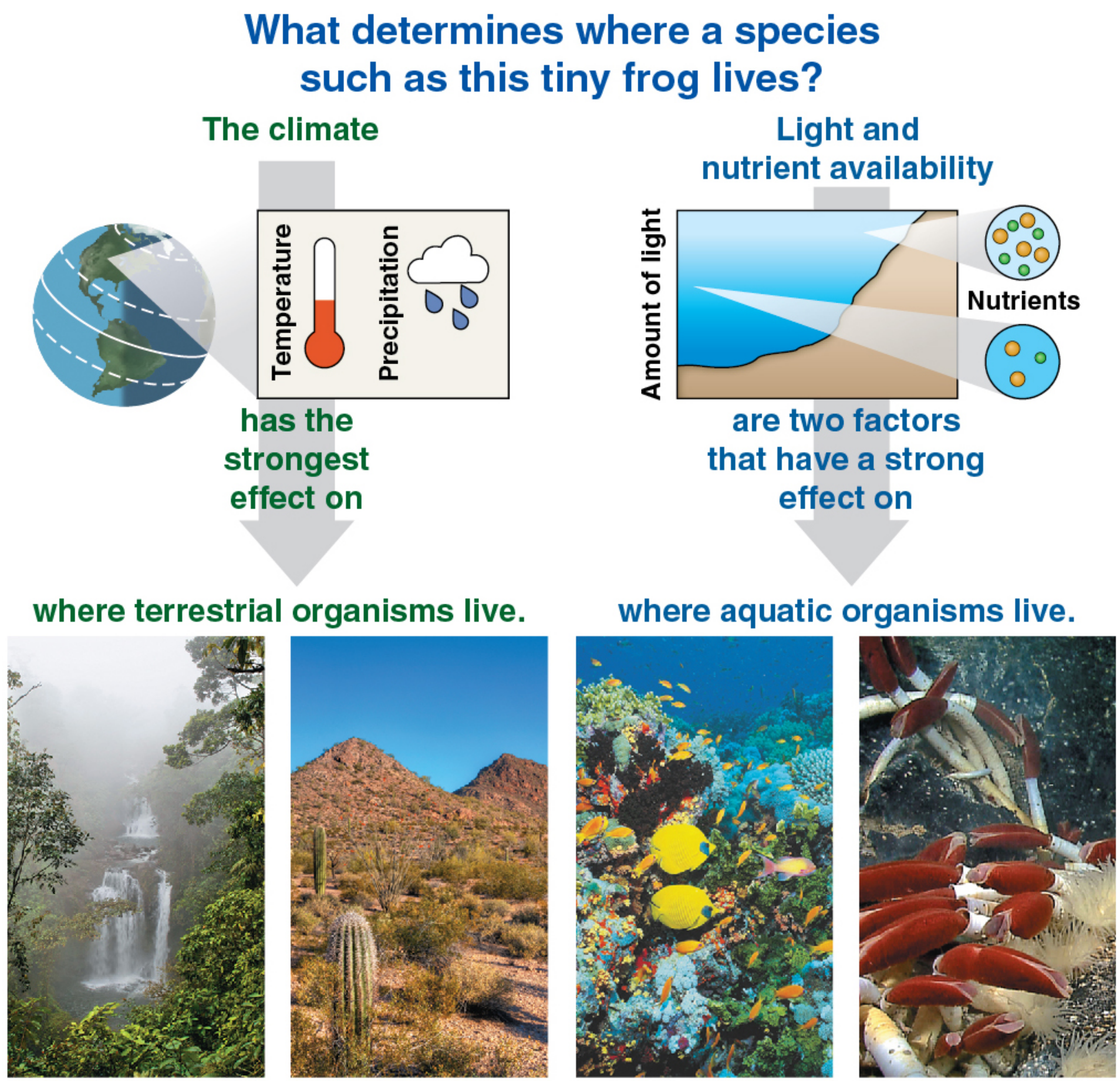
What determines where a species such as this tiny frog lives?

- Scientists often begin studying species by asking what environmental factors limit where it is found
  - Climate, including temperature and precipitation, has the strongest effect on where terrestrial organisms live
  - Light and nutrient availability are two factors that have a strong effect on where aquatic organisms live

Figure 52.1a

Figure 52.1b

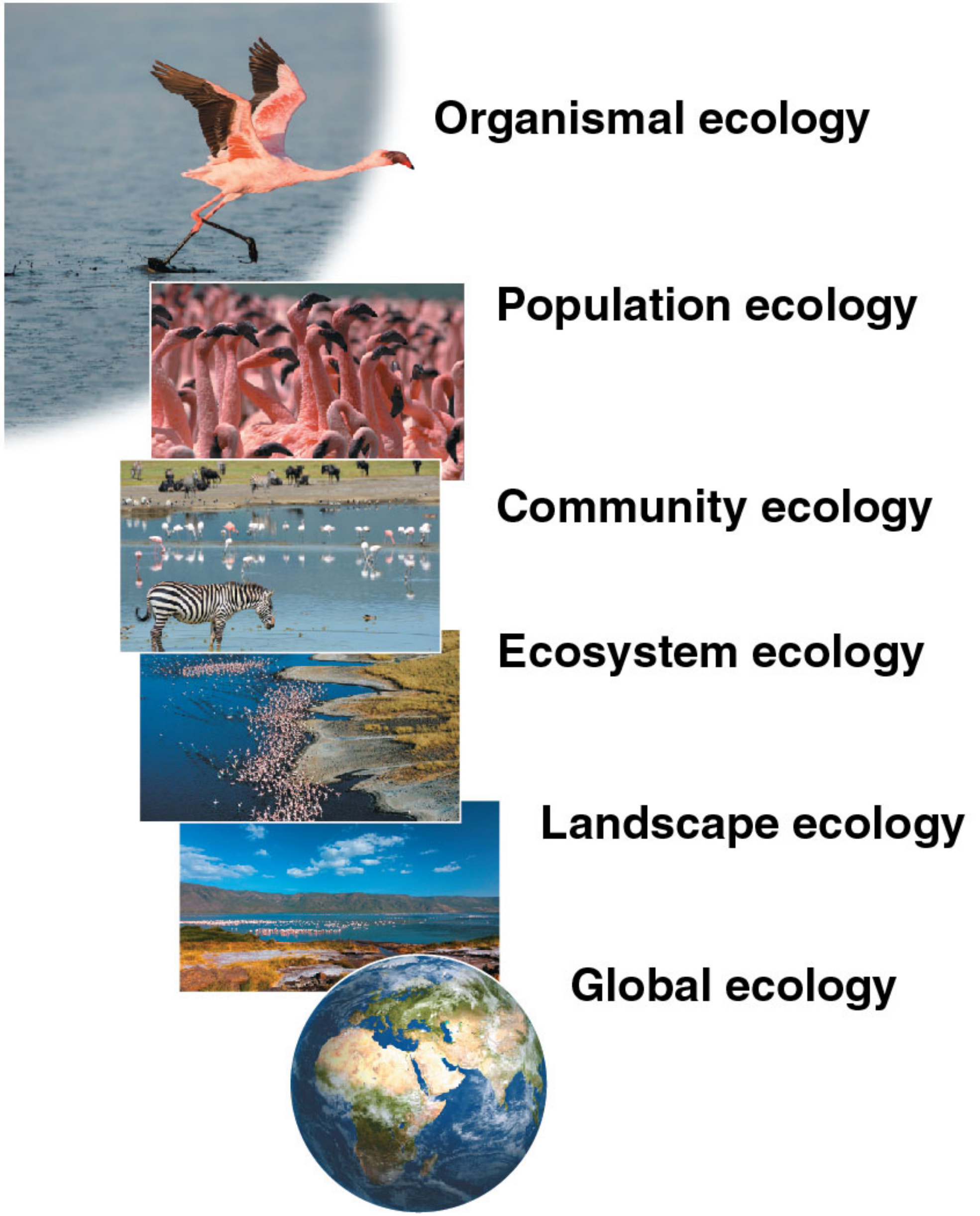
Figure 52.1



Dispersal and interactions among organisms also affect where species live.

- **Ecology** is the scientific study of the interactions between organisms and the living and nonliving components of their environment
- These interactions determine the distribution of organisms and their abundance
- Ecologists ask research questions at different levels in the biological hierarchy

Figure 52.2



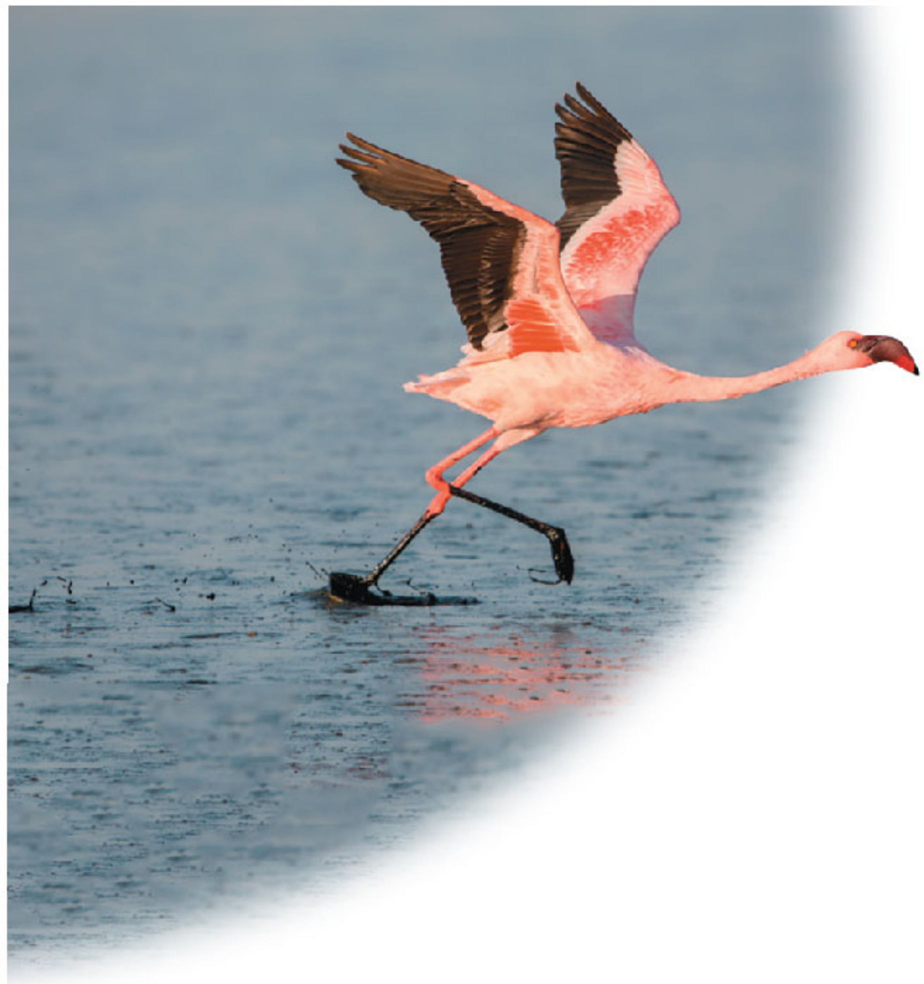
Organismal ecology
Population ecology
Community ecology
Ecosystem ecology
Landscape ecology
Global ecology

Figure 52.2 Exploring the Scope of Ecological Research

Organismal Ecology

- **Organismal ecology** is concerned with how an organism's structure, physiology, and behavior meet the challenges of the environment
- Organismal ecology includes physiological, evolutionary, and behavioral ecology
  - Example question: How do flamingos select a mate?

Figure 52.2a



Organismal ecology

Population Ecology

- A **population** is a group of individuals of the same species living in an area
- **Population ecology** analyzes factors affecting population size and why it changes over time
  - Example question: What environmental factors affect the reproductive rate of flamingos?

Figure 52.2b

Population ecology

Community Ecology

- A **community** is a group of populations of different species in an area
- **Community ecology** examines the affect of interspecific interactions on community structure and organization
  - Example question: What factors influence the diversity of species that interact at an African lake?

Figure 52.2c

Community ecology

Ecosystem Ecology

- An **ecosystem** is the community of organisms in an area and the physical factors with which they interact
- **Ecosystem ecology** emphasizes energy flow and chemical cycling between organisms and the environment
  - Example question: What factors control photosynthetic productivity in an aquatic ecosystem?

Figure 52.2d

Ecosystem ecology

Landscape Ecology

- A **landscape** (or seascape) is a mosaic of connected ecosystems
- **Landscape ecology** focuses on the exchanges of energy, materials, and organisms across multiple ecosystems
  - Example question: To what extent do nutrients from terrestrial ecosystems affect organisms in a lake?

Landscape ecology

Global Ecology

- The **biosphere** is the global ecosystem—the sum of all the planet's ecosystems and landscapes
- **Global ecology** examines how the exchange of energy and materials influences the function and distribution of organisms across the biosphere
  - Example question: How do global patterns of air circulation affect the distribution of organisms?

Figure 52.2f

Global ecology

CONCEPT 52.1: Earth’s climate varies by latitude and season and is changing rapidly

- The long-term prevailing weather conditions in an area constitute its **climate**
- Climate is the most significant influence on the distribution of organisms on land
- The four major physical components of climate are temperature, precipitation, sunlight, and wind

Global Climate Patterns

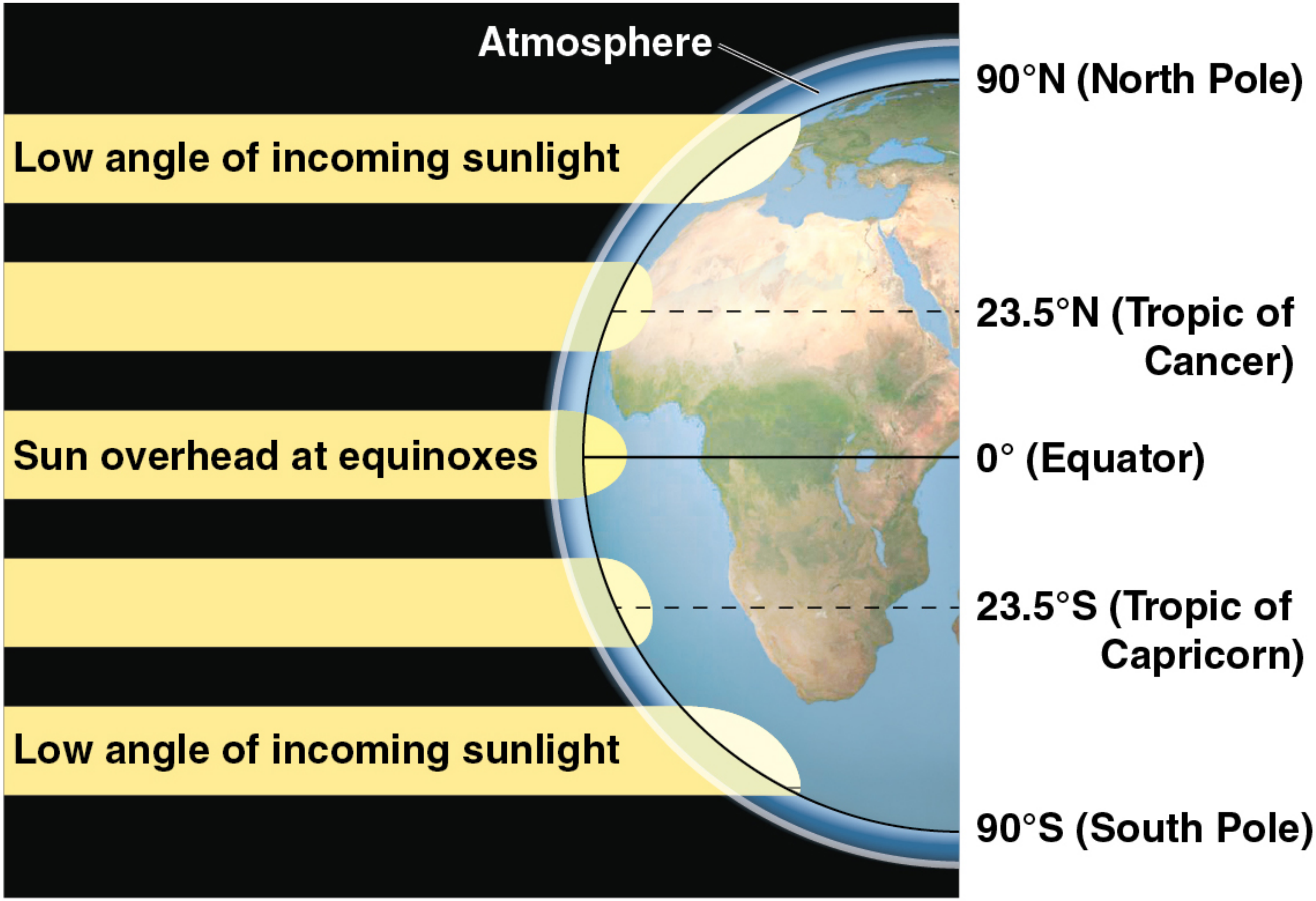
- Global climate patterns are determined largely by solar energy and Earth's movement in space
- The warming effect of the sun establishes temperature variations, circulation of air and water, and evaporation of water
- This causes latitudinal variations in climate

Figure 52.3 Exploring Global Climate Patterns

Latitudinal Variation in Sunlight Intensity

- The intensity of sunlight—the amount of heat and light per unit surface area—is affected by the angle of impact
  - Sunlight is most direct and therefore most intense in the tropics (23.5º north to 23.5º south latitude)
  - At higher latitudes, sunlight hits at an oblique angle, making the light energy more diffuse and less intense

Figure 52.3a



Latitudinal variation in sunlight intensity

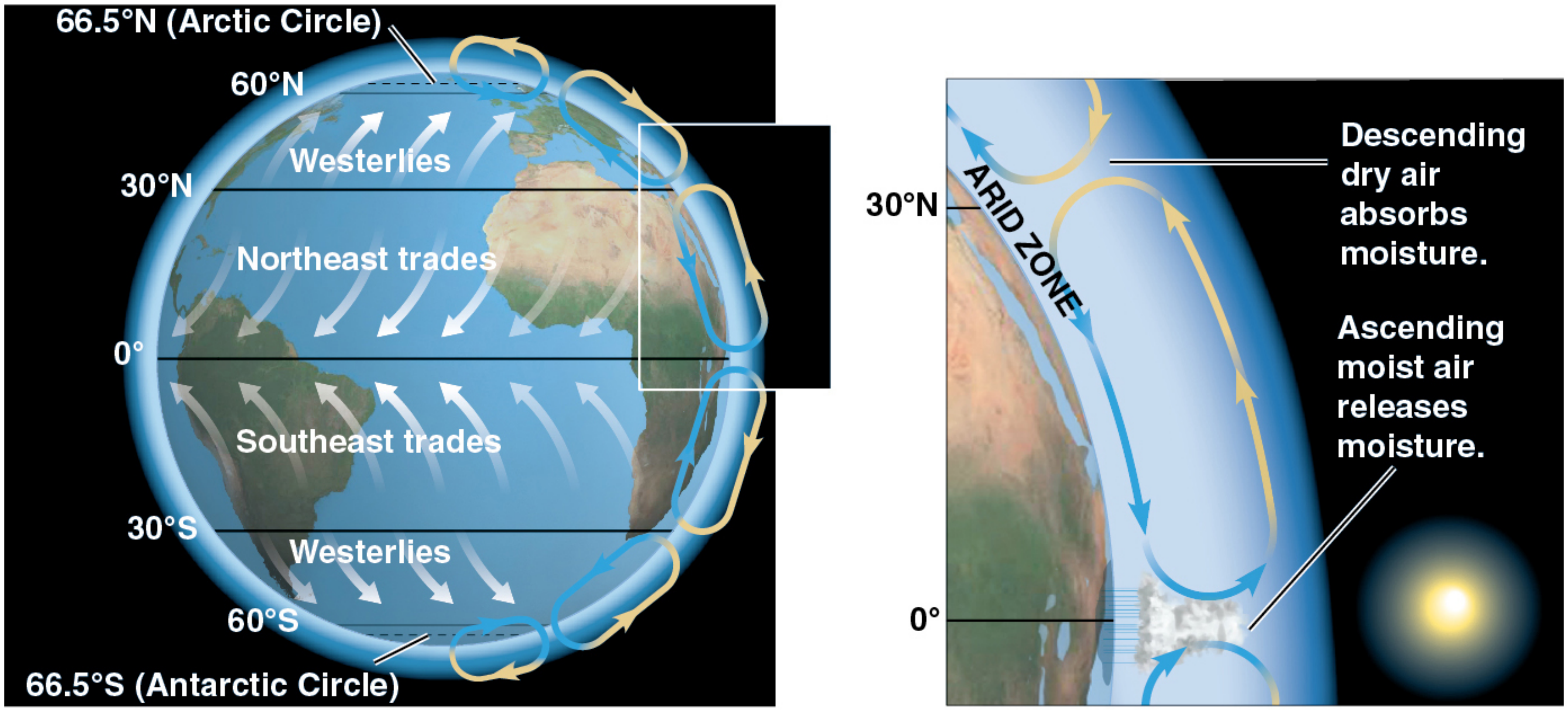
Global Air Circulation and Precipitation Patterns

- Global air circulation and precipitation patterns play major roles in determining climate patterns
- Intense sunlight causes water to evaporate in the tropics, and warm, wet air masses rise and flow from the tropics toward the poles
- Rising air masses release water and cause high precipitation, especially in the tropics

- Dry, descending air masses create arid climates, especially near 30º north and south
- Air masses rise again at 60º north and south, and release abundant precipitation
- Cold, dry rising air flows to the poles and descends, absorbing moisture and creating dry, cold climate at polar regions

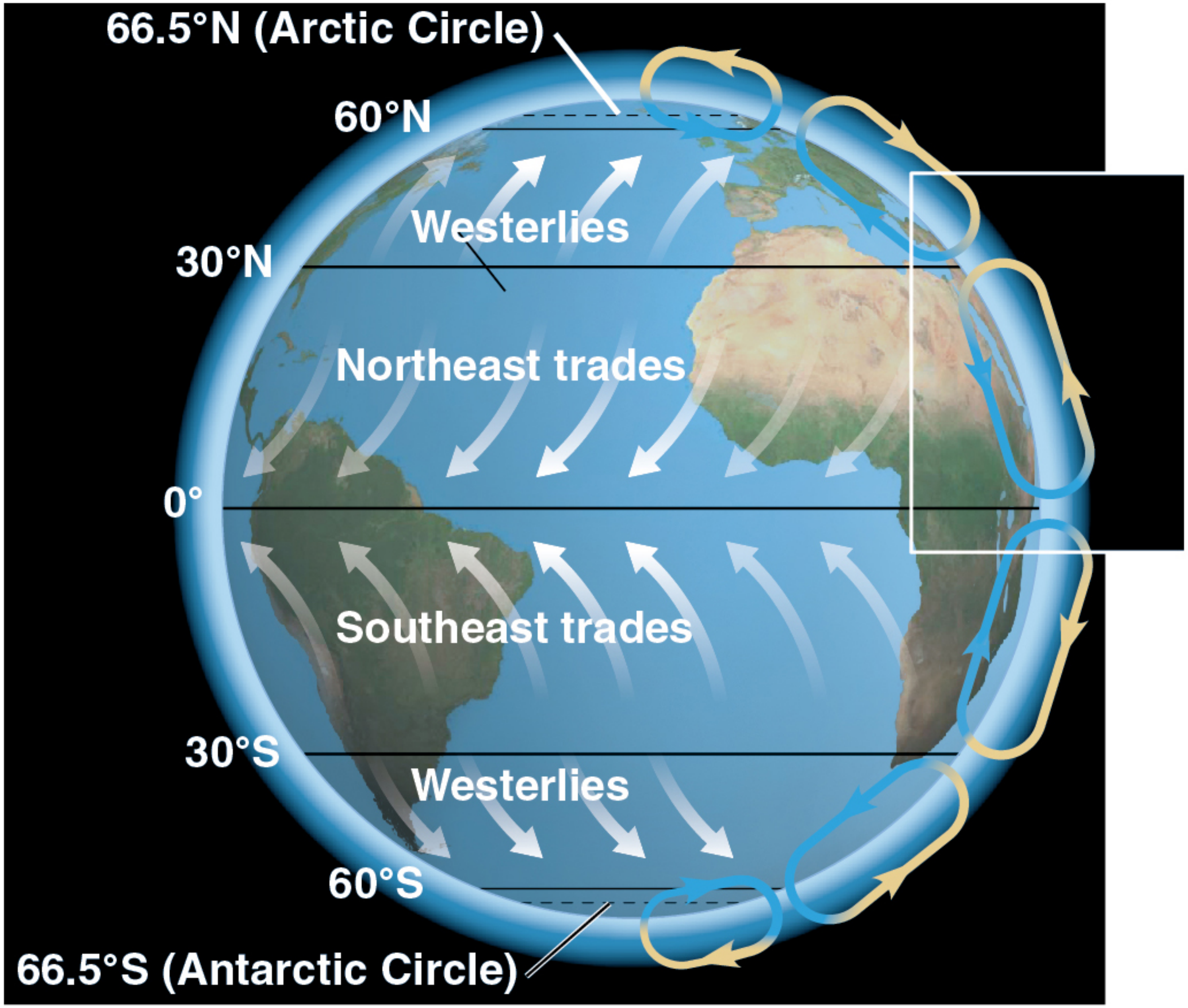
- Air flowing close to Earth's surface creates predictable global wind patterns
- The speed of Earth's rotation is faster near the equator, causing the deflection of winds from the vertical path
- Cooling trade winds blow from east to west in the tropics; prevailing westerlies blow from west to east in the temperate zones

Figure 52.3b



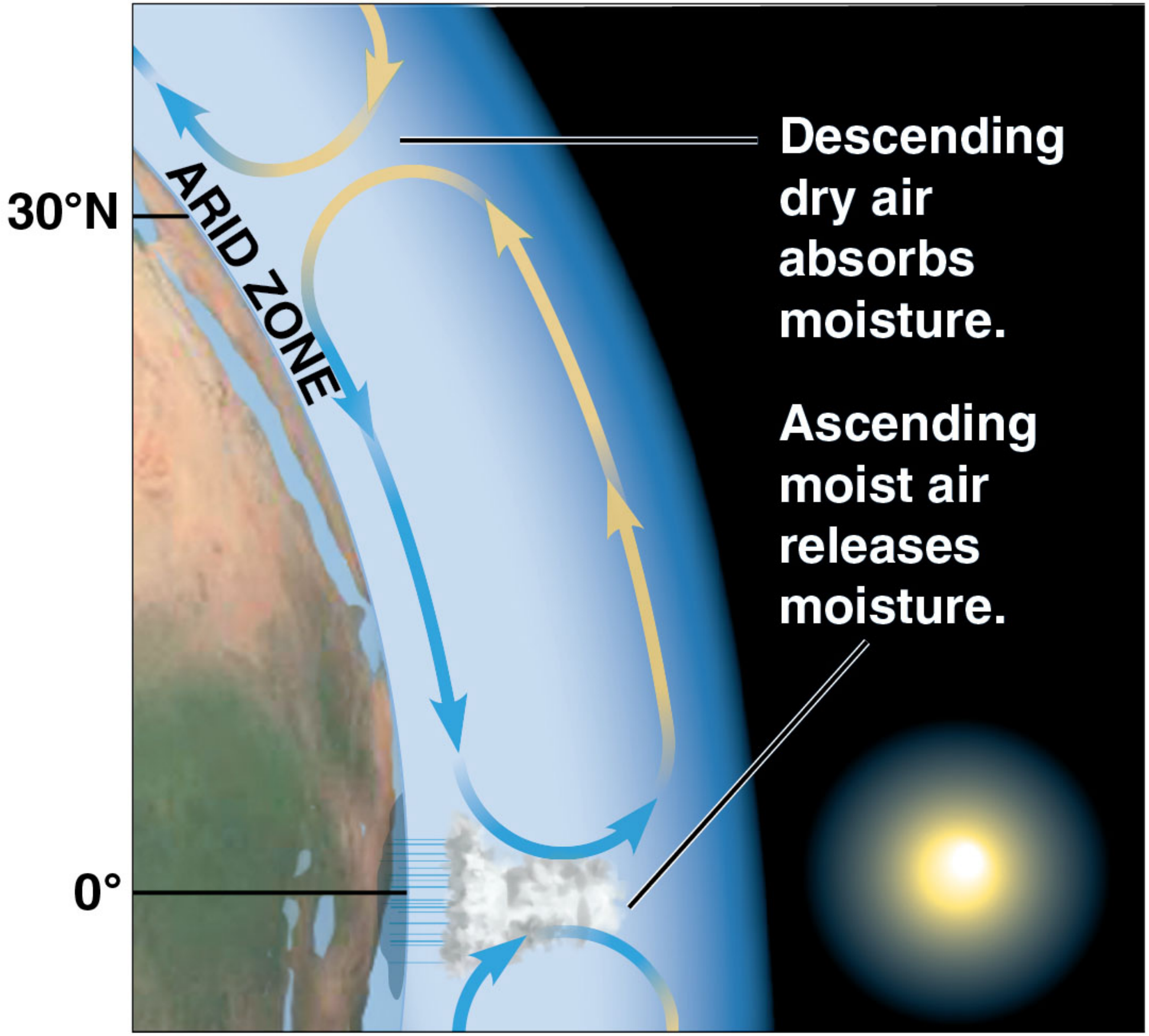
Global air circulation and precipitation patterns

Figure 52.3ba



Global air circulation and precipitation patterns

Figure 52.3bb



Global air circulation and precipitation patterns

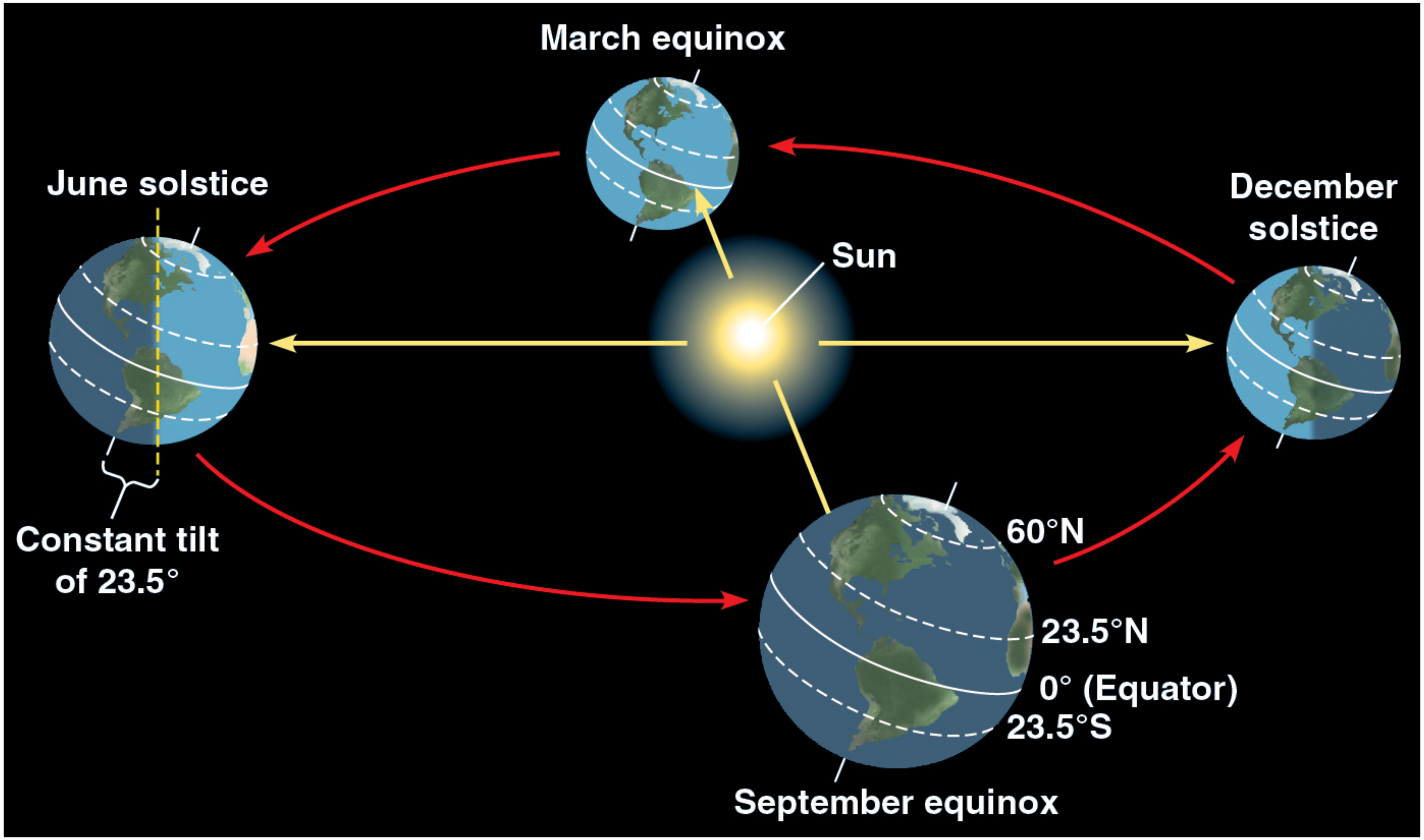
Regional and Local Effects on Climate

- Climate varies seasonally and is modified by other factors including large bodies of water and mountain ranges

Seasonality

- Seasonality in middle to high latitudes is caused by the tilt of Earth’s axis of rotation and its annual passage around the sun
- Seasonal variations in day length, solar radiation, and temperature increase steadily toward the poles

Figure 52.4


March equinox
June solstice
December solstice
Sun
Constant tilt of 23.5°
60°N
23.5°N
0° (Equator)
23.5°S
September equinox

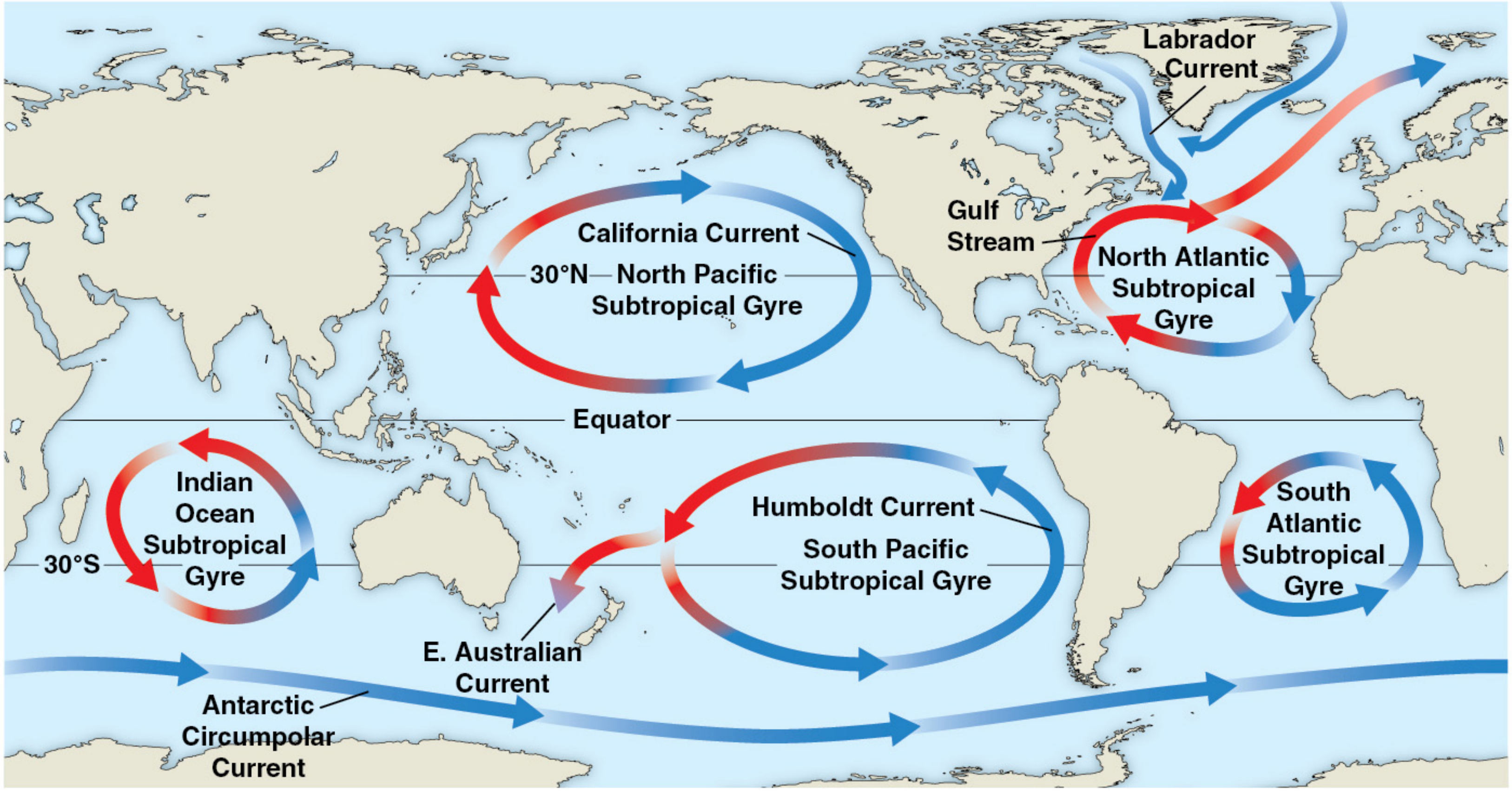
- The changing angle of the sun over the course of the year affects local environments
  - For example, belts of wet and dry air on either side of the equator shift as the angle of the sun changes
  - This causes wet and dry seasons at 20ºN and 20ºS latitudes, where tropical deciduous forests grow

- Seasonal changes in wind patterns alter ocean currents
- These changes can cause upwelling of cold, nutrient-rich water from deep ocean layers
- The influx of nutrients to surface waters stimulates population growth of phytoplankton and the organisms that feed on them

Bodies of Water

- Ocean currents influence the climate of nearby terrestrial environments by heating or cooling overlying air masses that pass over land
- Currents flowing toward the equator carry cold water from the poles; currents flowing away from the equator carry warm water toward the poles

Figure 52.5


Labrador Current
California Current
30°N
North Pacific Subtropical Gyre
Gulf Stream
North Atlantic Subtropical Gyre
Equator
Indian Ocean Subtropical Gyre
30°S
Humboldt Current
South Pacific Subtropical Gyre
South Atlantic Subtropical Gyre
E. Australian Current
Antarctic Circumpolar Current

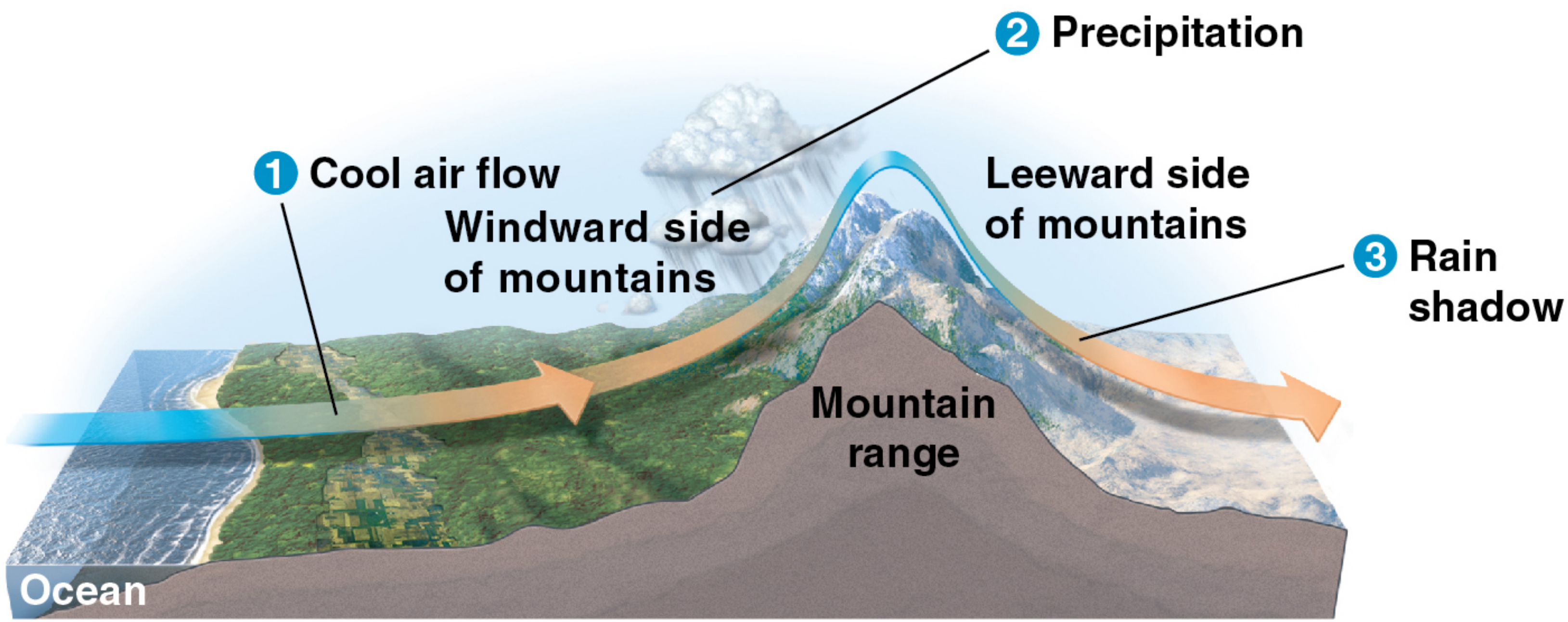
- Large bodies of water moderate the climate of nearby land due to the high specific heat of water
- During the day, air rises over warm land and draws a cool breeze from the water across the land
- At night, the land cools, and air now rises over the warmer water and draws cool air off the land, replacing it with warmer air from offshore

Mountains

- Mountains influence air flow over land and affect climate in surrounding areas
- Warm, moist air cools as it rises up a mountain and releases moisture on the windward side
- Cool, dry air absorbs moisture as it descends on the leeward side, creating a “rain shadow”
- Many deserts are found in the rain shadows of mountains

- Mountains also affect the amount of sunlight reaching an area
- In the Northern Hemisphere, south-facing slopes are warmer and drier because they receive more sunlight than north-facing slopes
- Every 1,000 m increase in elevation produces a temperature drop of approximately 6ºC

Figure 52.6



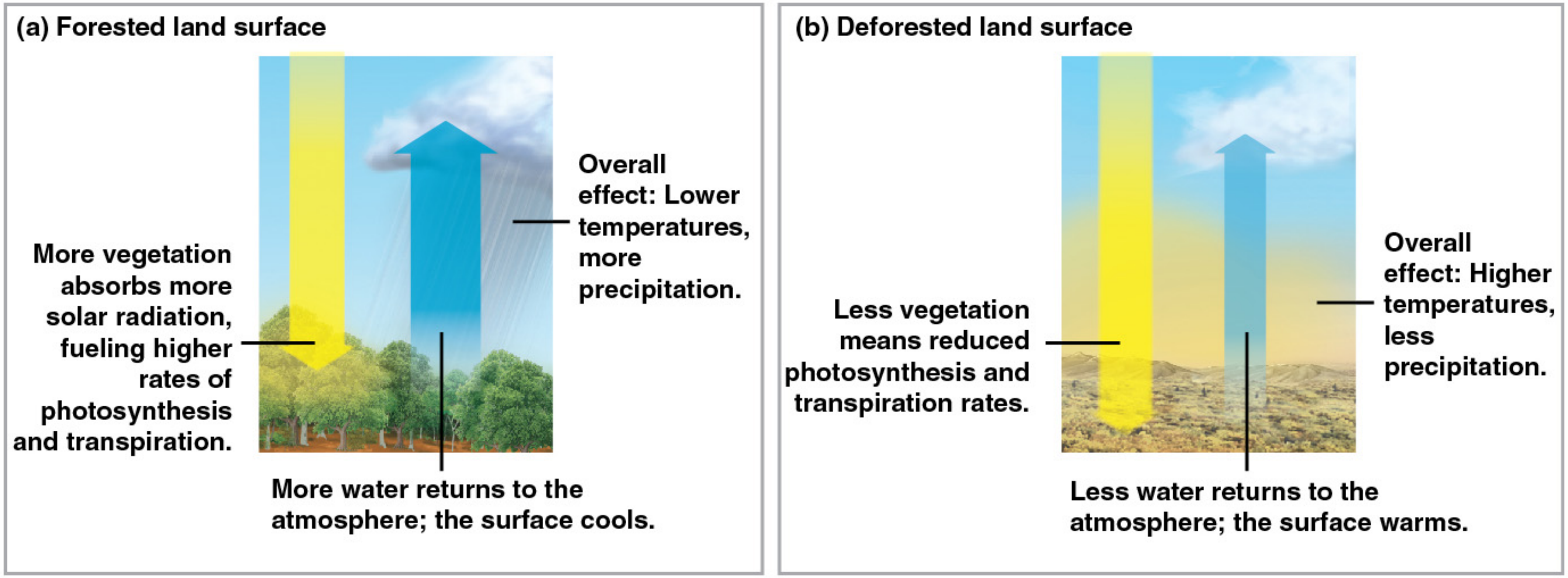
1 Cool air flow
2 Precipitation
Windward side of mountains
Leeward side of mountains
3 Rain shadow
Mountain range
Ocean

Effects of Vegetation on Climate

- Terrestrial organisms, particularly forests, can alter climate at local and regional scales
- The darker color of forests cause them to absorb more solar energy than deserts or grasslands
- This warming effect is offset by transpiration, which causes evaporative cooling, which reduces surface temperatures and increases precipitation rates

- The climate becomes hotter and drier in areas where humans have cut down large forests
- Where humans have restored large forests, the climate becomes cooler and wetter

Figure 52.7



(a) Forested land surface
More vegetation absorbs more solar radiation, fueling higher rates of photosynthesis and transpiration.
Overall effect: Lower temperatures, more precipitation.
More water returns to the atmosphere; the surface cools.
(b) Deforested land surface
Less vegetation means reduced photosynthesis and transpiration rates.
Overall effect: Higher temperatures, less precipitation.
Less water returns to the atmosphere; the surface warms.

Microclimate

- **Microclimate** refers to very fine, localized patterns in climate
- Many features of the environment influence surrounding areas by casting shade, altering evaporation from soil, or changing wind patterns
  - For example, forest trees moderate the microclimate below them

- Environments are characterized by differences in **abiotic**, or nonliving, factors such as temperature, light, water, and nutrients
- **Biotic**, or living, factors—other organisms that are part of an individual's environment—also influence the distribution and abundance of life on Earth

Global Climate Change

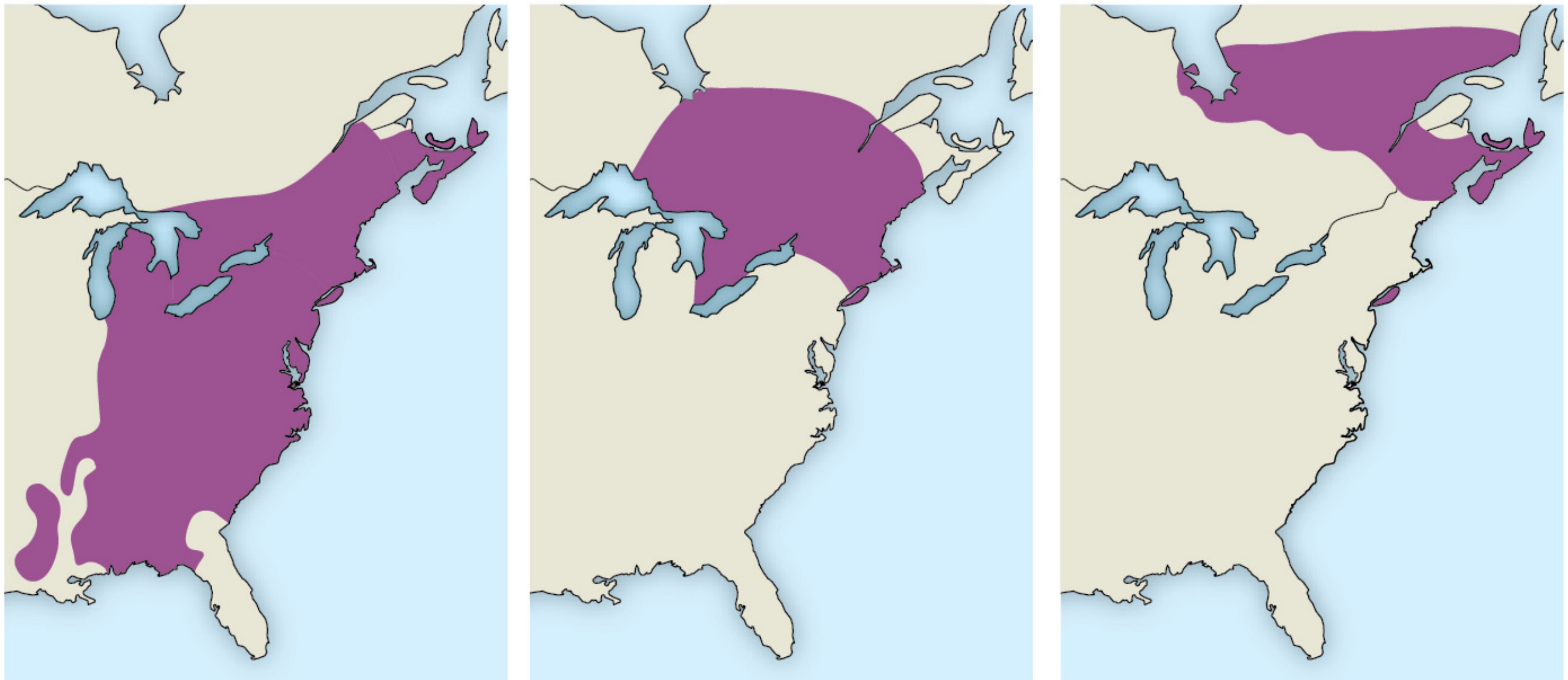
- The burning of fossil fuels and deforestation have increased the concentration of greenhouse gases in the atmosphere
- This has caused **climate change**, a directional change to the global climate lasting three decades or more

- Earth has warmed an average of 0.9°C (1.6°F) since 1900 and is projected to warm 1–6°C (2–11°F) more by the year 2100
- Wind and precipitation patterns are shifting, and extreme weather events are occurring more frequently

- Studies of response to change since the last ice age help predict effects of future global climate change
- Many tree species expanded northward following climate warming and glacial retreat
- Some responded rapidly, others lagged behind the change in suitable habitat by several thousand years

- Determining the location of suitable habitat under different climate scenarios can help predict future range shifts
- Studying the response of particular species to such shifts in the past can help determine if they will keep pace with shifting climates in the future

Figure 52.8



(a) Current range

(b) 4.5°C warming over next century

(c) 6.5°C warming over next century

- The geographic ranges of hundreds of organisms have already been impacted by climate change
  - The range of 22 of 35 European butterfly species have shifted north by 35–240 km
  - Nearly 200 plant species have moved to lower elevations in North America
  - A Pacific diatom, *Neodenticula seminae*, recently colonized the Atlantic Ocean for the first time in 800,000 years

- Movement of organisms to new geographic areas can harm the organisms already living there
- Species with poor dispersal or a shortage of suitable habitat may reduce their range or become extinct
  - For example, the geographic ranges of 67 bumblebee species in the Northern Hemisphere have decreased

Figure 52.9

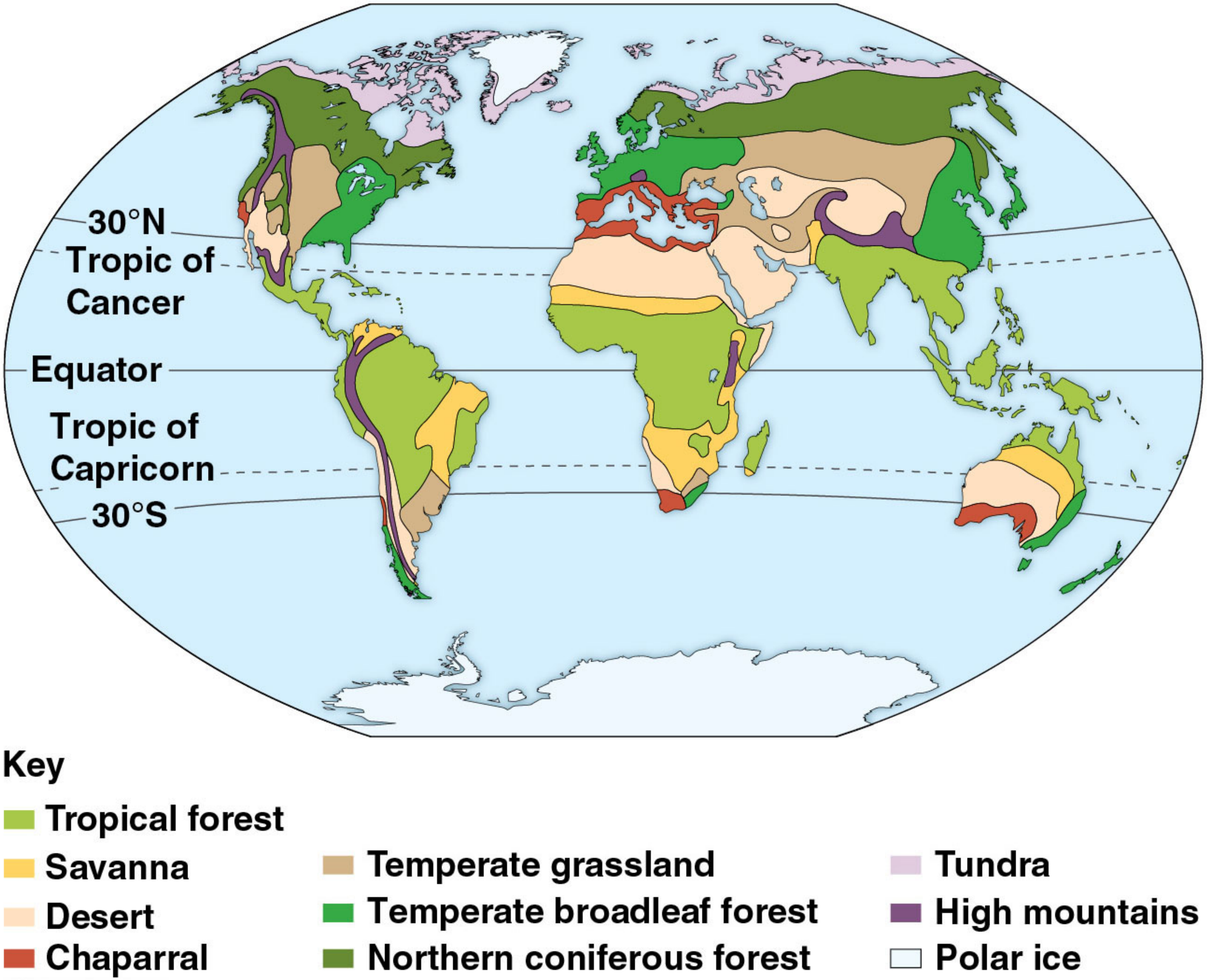
CONCEPT 52.2: The distribution of terrestrial biomes is controlled by climate and disturbance

- **Biomes** are major life zones characterized by vegetation type (terrestrial biomes) or physical environment (aquatic biomes)

Climate and Terrestrial Biomes

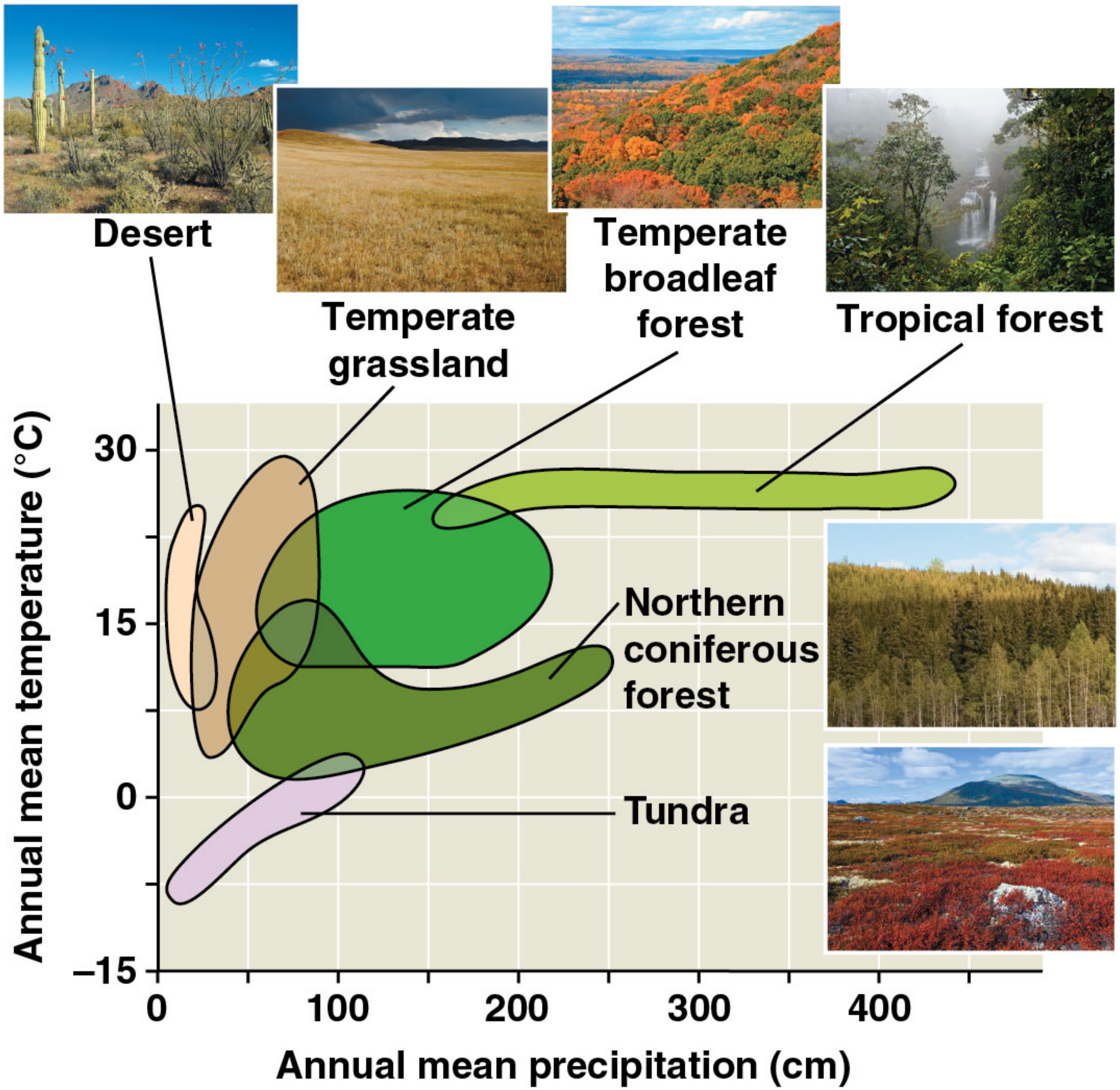
- Climate is a major factor determining the locations of terrestrial biomes because it strongly influences the distribution of plants

Figure 52.10


30°N
Tropic of Cancer
Equator
Tropic of Capricorn
30°S
Key
Tropical forest
Savanna
Desert
Chaparral
Temperate grassland
Temperate broadleaf forest
Northern coniferous forest
Tundra
High mountains
Polar ice

- A **climograph** plots the annual mean temperature and precipitation in a region
- Biomes are affected not just by mean temperature and precipitation, but also by the pattern of temperature and precipitation through the year

Figure 52.11



Desert
Temperate grassland
Temperate broadleaf forest
Tropical forest
Northern coniferous forest
Tundra
Annual mean temperature (°C)
30
15
0
–15
0
100
200
300
400
Annual mean precipitation (cm)

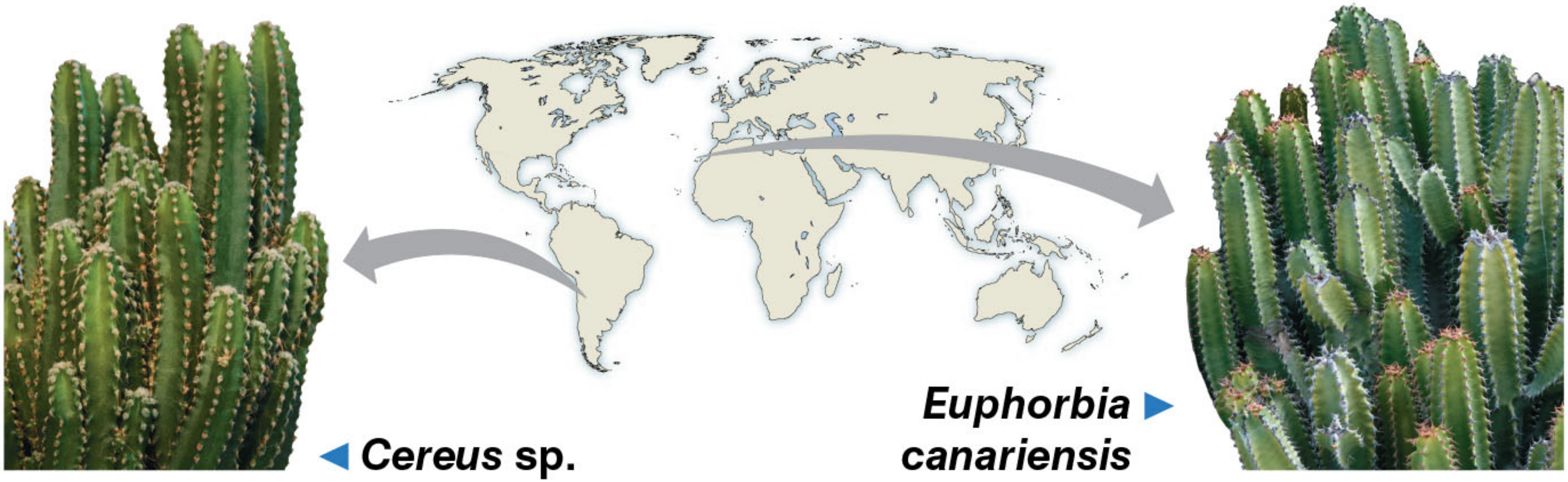
General Features of Terrestrial Biomes

- Terrestrial biomes are named for major physical or climatic features and predominant vegetation
- Terrestrial biomes usually grade into each other, without sharp boundaries
- The area of intergradation, called an **ecotone**, may be wide or narrow

- Vertical layering of vegetation provides diverse habitats for animals in terrestrial biomes
- In a forest, vertical layering may consist of an upper **canopy**, low tree layer, shrub understory, herbaceous plants, forest floor, and root layer

- The species composition of each kind of biome varies from one location to another
- Similar characteristics can arise in distant biomes through convergent evolution
  - For example, cacti in North and South America and euphorbs in African deserts appear similar but arise from different evolutionary lineages

Figure 52.12



Disturbance and Terrestrial Biomes

- **Disturbance** is an event such as a storm, fire, or human activity that changes a community
  - For example, frequent fires can kill woody plants and maintain the characteristic vegetation of a savanna
  - For example, hurricanes create openings in forest canopies that allow different species to grow
- In many biomes, even dominant plants depend on periodic disturbance

- Terrestrial biomes can be described by their distribution, precipitation, temperature, and the plants and animals that inhabit them
- Humans have altered much of Earth’s surface, and have important impacts on most terrestrial biomes

Figure 52.13 Exploring Terrestrial Biomes

Tropical Forest

- Occurs in equatorial and subequatorial regions
- In **tropical rain forests**, rainfall is relatively constant, about 200–400 cm annually
- In **tropical dry forests**, precipitation is seasonal, about 150–200 cm annually with a long dry season
- Temperature is high year-round (25–29ºC) with little seasonal variation

- Tropical rain forests are dominated by broadleaf evergreen trees; tropical dry forests are dominated by deciduous trees
- Tropical forests are vertically layered and competition for light is intense
- Animal diversity is higher in tropical forests than any other terrestrial biome

- The major human impact on tropical forests is deforestation
- Forested land is converted to farmland, urban areas, and other types of land use

Figure 52.13a

Tropical Forest

A tropical rain forest in Costa Rica

Desert

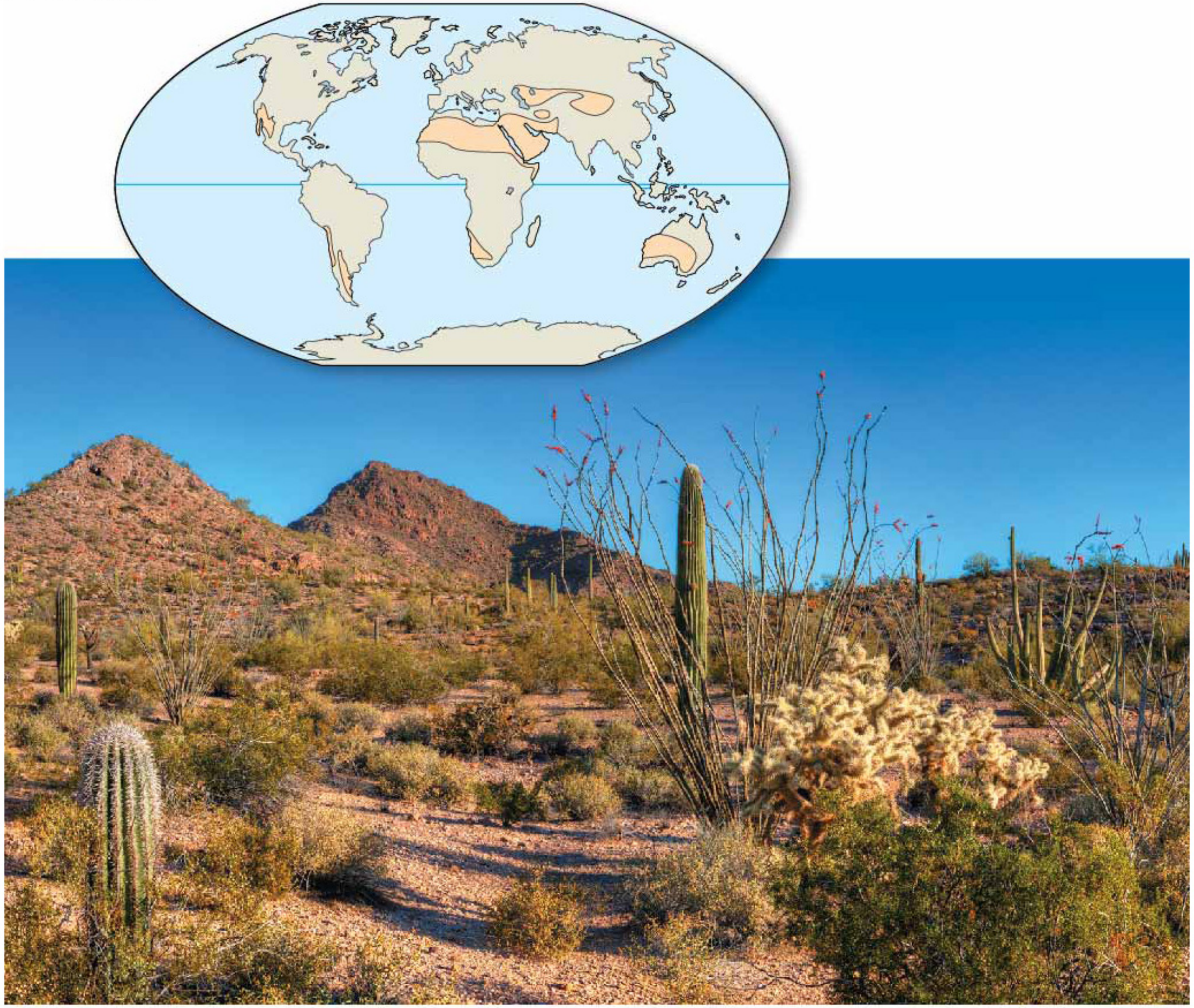
- **Deserts** occur in bands near 30º north and south of the equator and in the interior of continents
- Precipitation is low and highly variable, generally less than 30 cm per year

- Desert temperature varies seasonally and daily
- Maximum temperature in hot deserts can exceed 50°C; in cold deserts it may fall below –30°C
- Desert plants are adapted for heat and desiccation tolerance, water storage, and reduced leaf surface area; many have C_4 or CAM photosynthesis

- Plants have physical defenses, such as spines, and chemical defenses, such as toxins, to prevent feeding by animals
- Many desert animals are nocturnal, and have adaptations for water conservation
- Humans have reduced biodiversity in deserts through urbanization and irrigated agriculture

Figure 52.13b

Desert



Organ Pipe Cactus National Monument, Arizona

Savanna

- Occurs in equatorial and subequatorial regions
- Precipitation is seasonal (average 30–50 cm per year) with dry seasons lasting eight to nine months
- **Savanna** is warm year-round, with annual temperature averages 24–29ºC, but is more seasonally variable than in the tropical forests

- Dominant plant species, including grasses and forbs, are fire-adapted and tolerant of seasonal drought
- Large herbivores such as wildebeests and zebras are common, but insects are the dominant herbivores
- Human-induced fires help maintain the savanna, but cattle ranching and overhunting threaten large-mammal populations

Figure 52.13c

Savanna

A savanna in Kenya

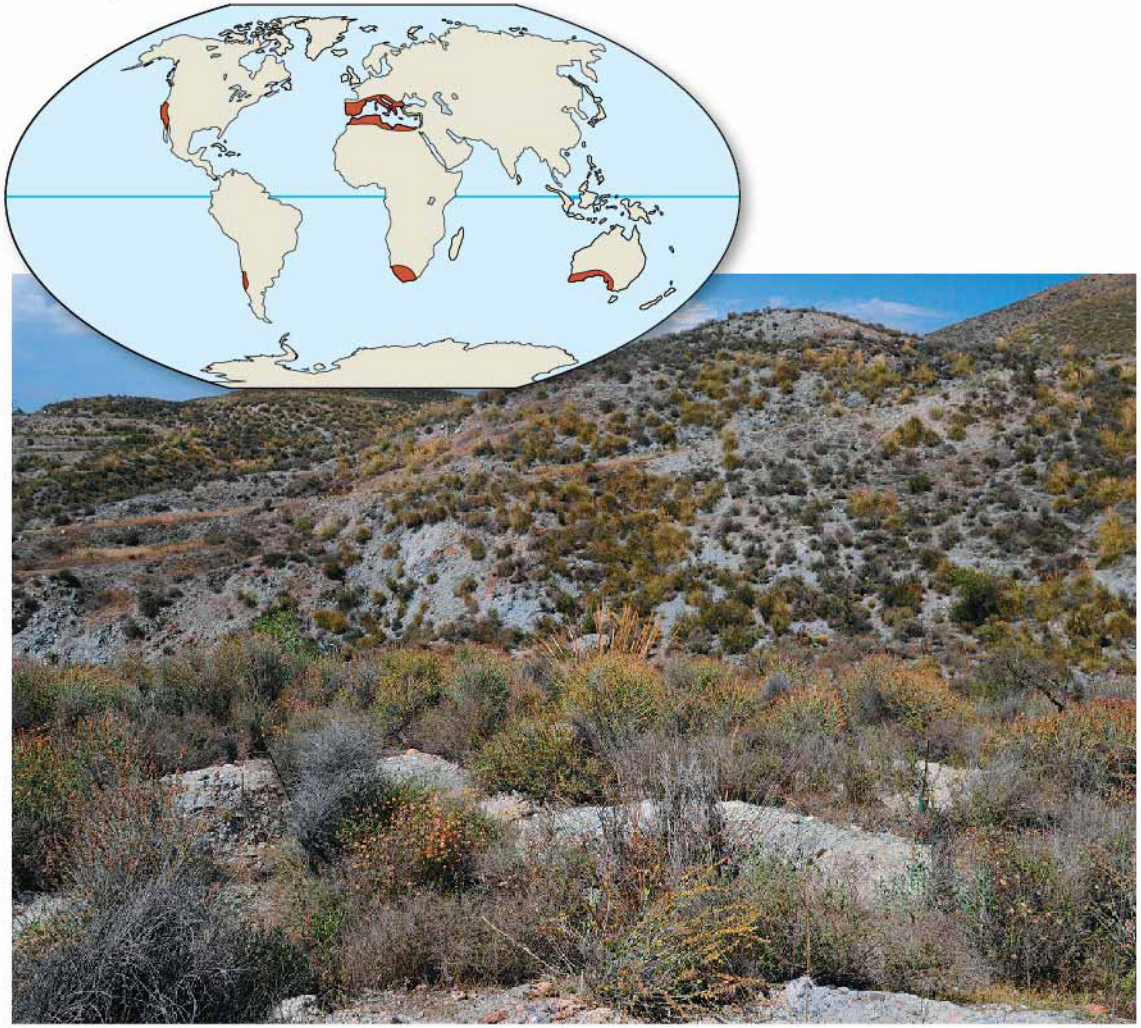
Chaparral

- **Chaparral** occurs in midlatitude coastal regions on several continents
- Precipitation is highly seasonal with rainy winters and dry summers, annual average about 30–50 cm
- Summer is hot (30–40ºC); fall, winter, and spring are cool (10–12ºC)

- Chaparral is dominated by shrubs, small trees, grasses, and herbs; many plants are adapted to fire and drought
- Animals include amphibians, birds and other reptiles, insects, browsing mammals, and a diversity of small mammals
- Humans have reduced chaparral areas through agriculture and urbanization

Figure 52.13d

Chaparral



An area of chaparral in California

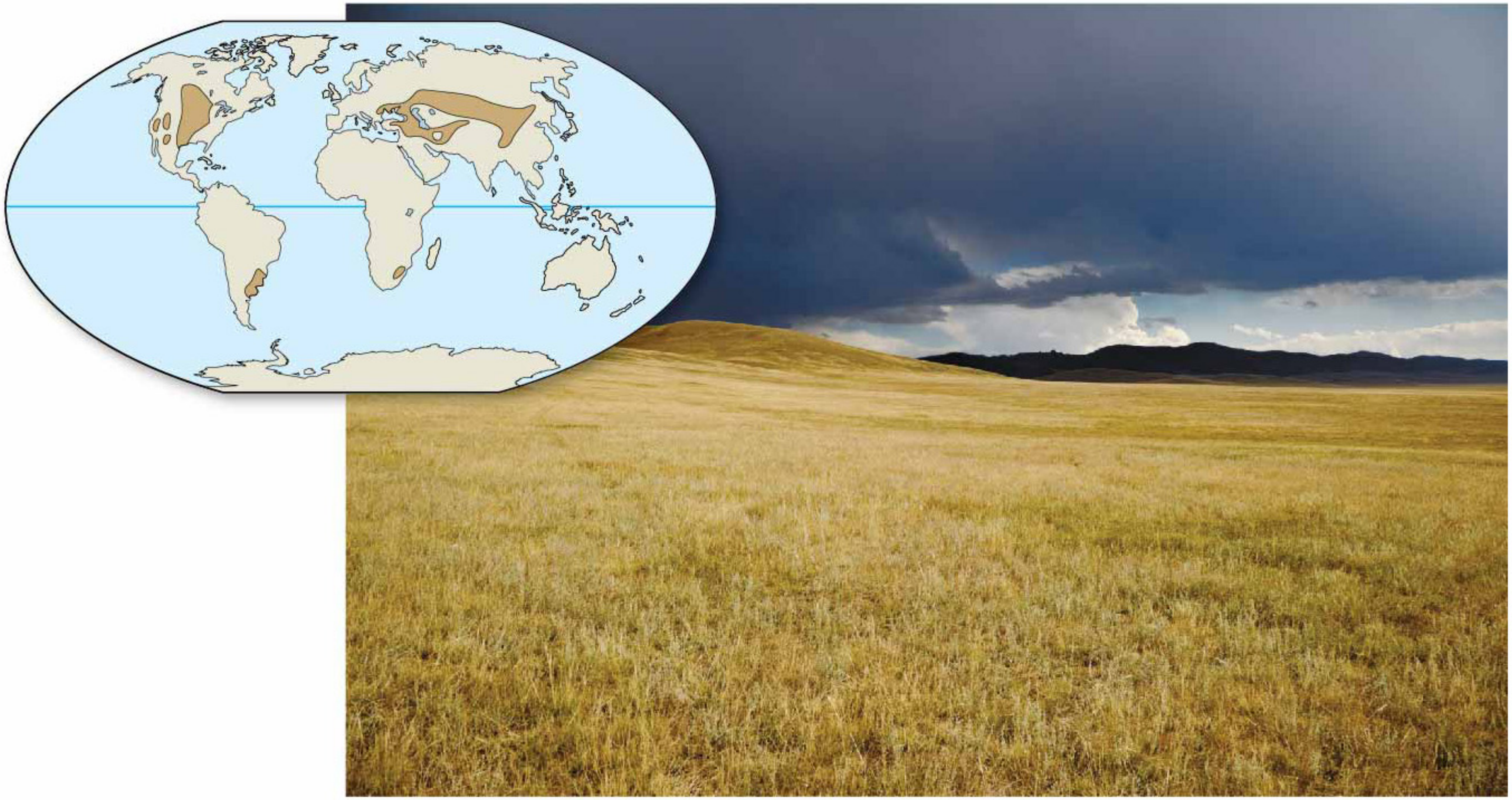
Temperate Grassland

- **Temperate grasslands** are found on many continents
- Precipitation is highly seasonal with dry winters and wet summers
- Annual precipitation averages 30–100 cm; periodic drought is common
- Winters are cold, often below –10ºC, whereas summers are hot, often near 30ºC

- The dominant plants, grasses and forbs, are adapted to droughts and fire
- Mammals include grazers, such as bison and wild horses, and small burrowers, such as prairie dogs
- Most grassland in North America and Eurasia has been converted to agricultural land
- Drier grasslands have been transformed to desert due to the activity of grazers, such as cattle

Figure 52.13e

Temperate Grassland



A grassland in Mongolia

Northern Coniferous Forest

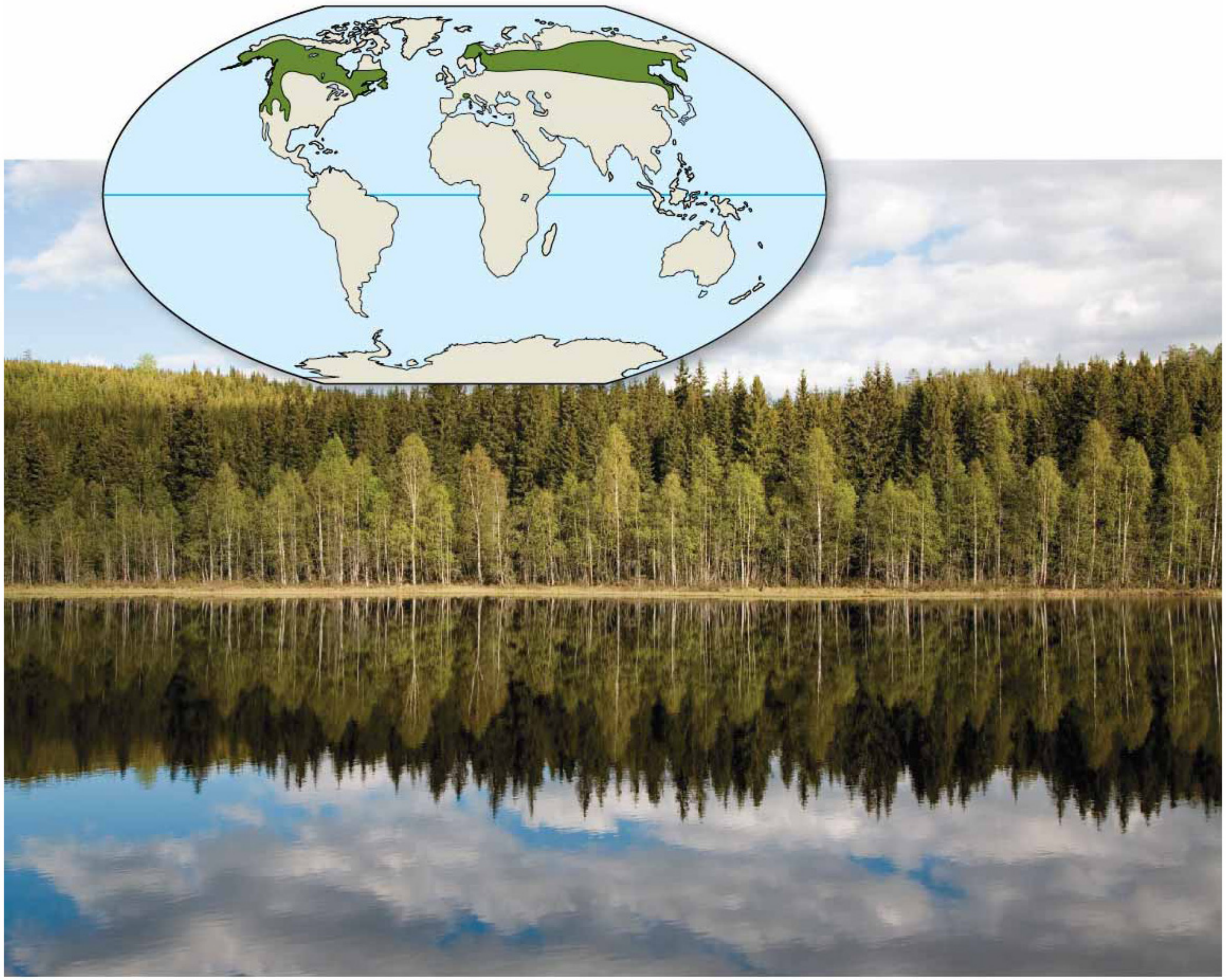
- The **northern coniferous forest**, or taiga, spans northern North America and Eurasia and is the largest terrestrial biome on Earth
- Annual precipitation is 30–70 cm, and periodic drought is common
- Coastal coniferous forests are temperate rain forests that may receive over 300 cm of annual precipitation

- Winters are usually cold, while summers may be hot
  - For example, coniferous forest in Siberia ranges from –50ºC in winter to over 20ºC in summer
- The dominant vegetation includes evergreen conifers such as pine, spruce, fir, and hemlock
- The conical shape of the trees is an adaptation to reduced branch breakage due to snow accumulation
- Needle- or scale-like leaves reduce water loss

- Animals include migratory and resident birds and large mammals such as moose, brown bears, and Siberian tigers
- Periodic insect outbreaks kill vast areas of forest
- Humans are logging old-growth stands at such a rapid rate that they may soon disappear

Figure 52.13f

Northern Coniferous Forest



A coniferous forest in Norway

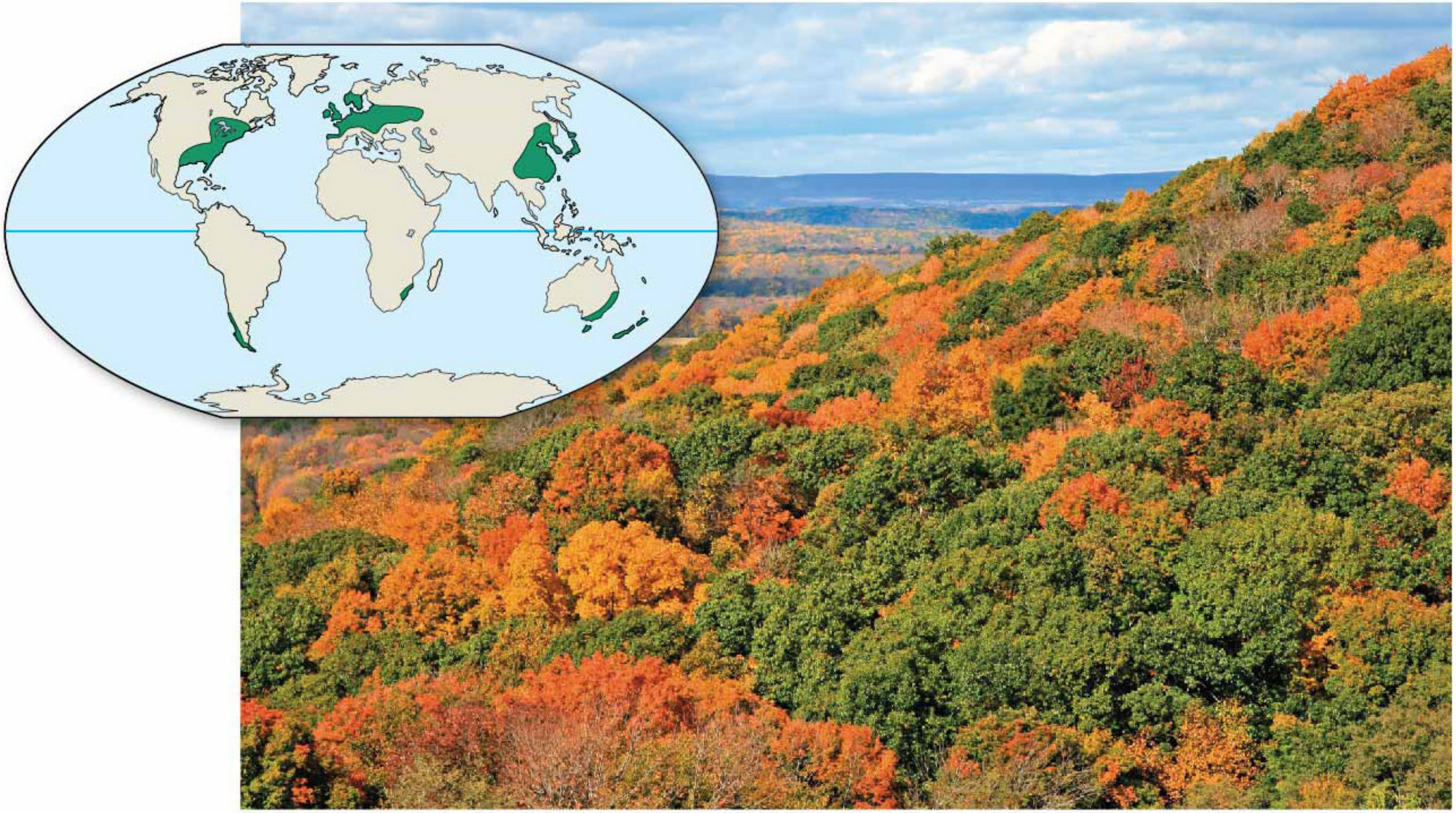
Temperate Broadleaf Forest

- Occurs primarily at midlatitudes in the Northern Hemisphere, with smaller areas in Chile, South Africa, Australia, and New Zealand
- Significant amounts of precipitation fall during all seasons as rain or snow; annual precipitation varies from 70 to over 200 cm
- Winter temperatures average 0ºC; summers are hot and humid with temperatures up to 35ºC

- A mature **temperate broadleaf forest** has vertical layers, including a closed canopy, understory trees, a shrub layer, and an herb layer
- The dominant plants are deciduous trees in the Northern Hemisphere and evergreen eucalyptus in Australia

- Mammals, birds, and insects make use of all vertical layers in the forest
- In the Northern Hemisphere, many mammals hibernate and many birds migrate in the winter
- These forests have been heavily settled by human populations on all continents but are returning over much of their former range

Broadleaf Forest



A temperate broadleaf forest in New Jersey

Tundra

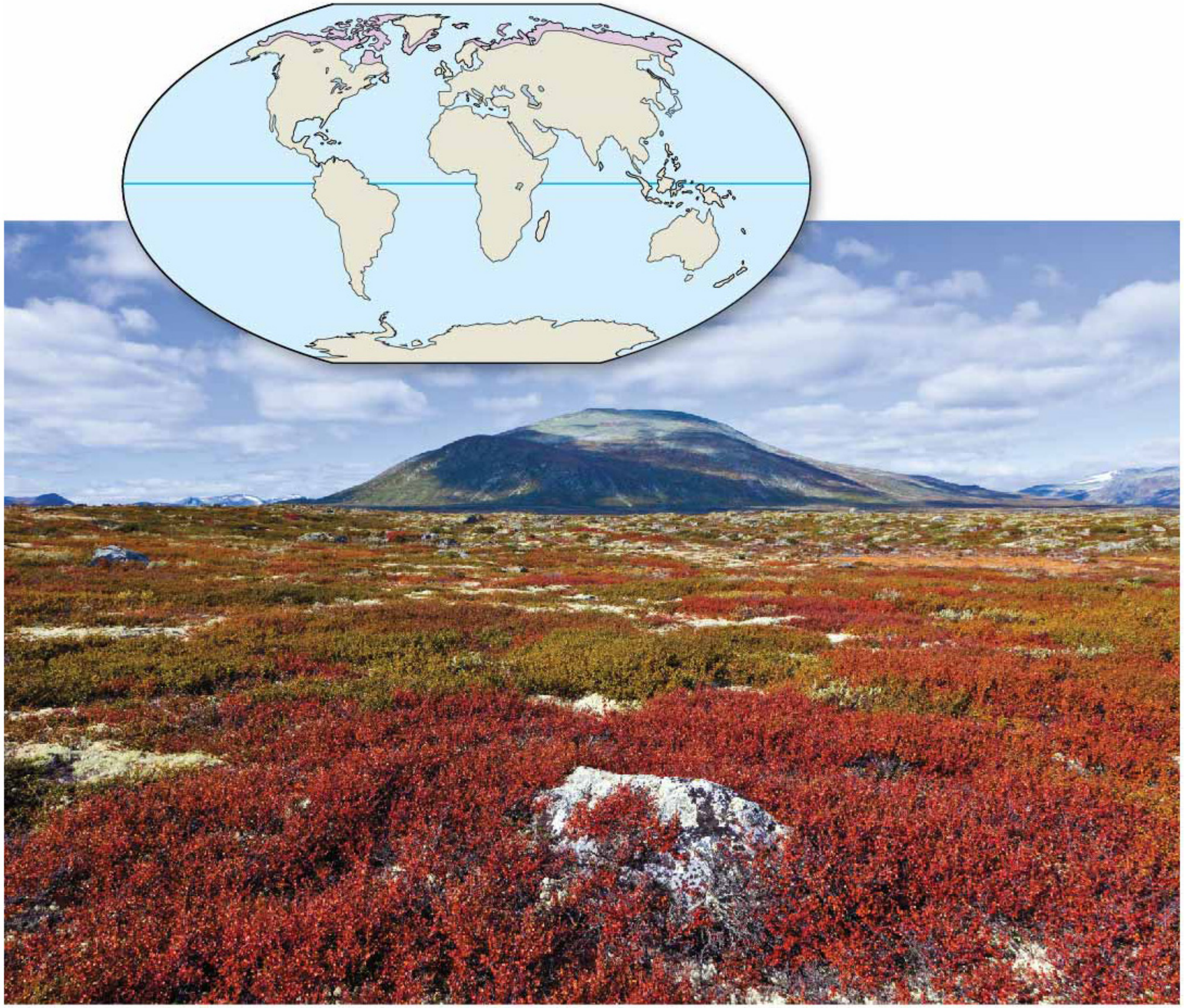
- **Tundra** covers expansive areas of the Arctic; alpine tundra exists on high mountaintops at all latitudes
- Annual precipitation is lower in arctic tundra (20–60 cm) than alpine tundra (>100 cm)
- Winters are cold, with averages below –30ºC; summers generally average less than 10ºC

- Vegetation is mostly herbaceous, including mosses, grasses, forbs, dwarf shrubs and trees, and lichens
- Permafrost, a permanently frozen layer of soil, restricts the growth of plant roots
- Mammals include musk oxen, caribou, reindeer, bears, wolves, and foxes
- Many migratory birds have summer nesting ground in the tundra

- Human settlement is sparse, but tundra has become the focus of oil and mineral extraction

Figure 52.13h

Tundra



Dovrefjell-Sunndalsfjella National Park, Norway, in autumn

CONCEPT 52.3: Aquatic biomes are diverse and dynamic systems that cover most of Earth

- Aquatic biomes have less latitudinal variation than terrestrial biomes
- They are characterized by their physical and chemical environment
  - For example, the average salt concentration in marine biomes is 3%, whereas in freshwater biomes it is less than 0.1%

- Oceans have a major impact on the biosphere because they cover about 75% of the Earth's surface
  - Water evaporated from the oceans provides most of the planet's rainfall
  - Photosynthetic marine organisms provide most of the planet's O_2 and consume large amounts of CO_2
  - Ocean temperatures effect global climate and wind patterns, and moderate the climate of nearby land

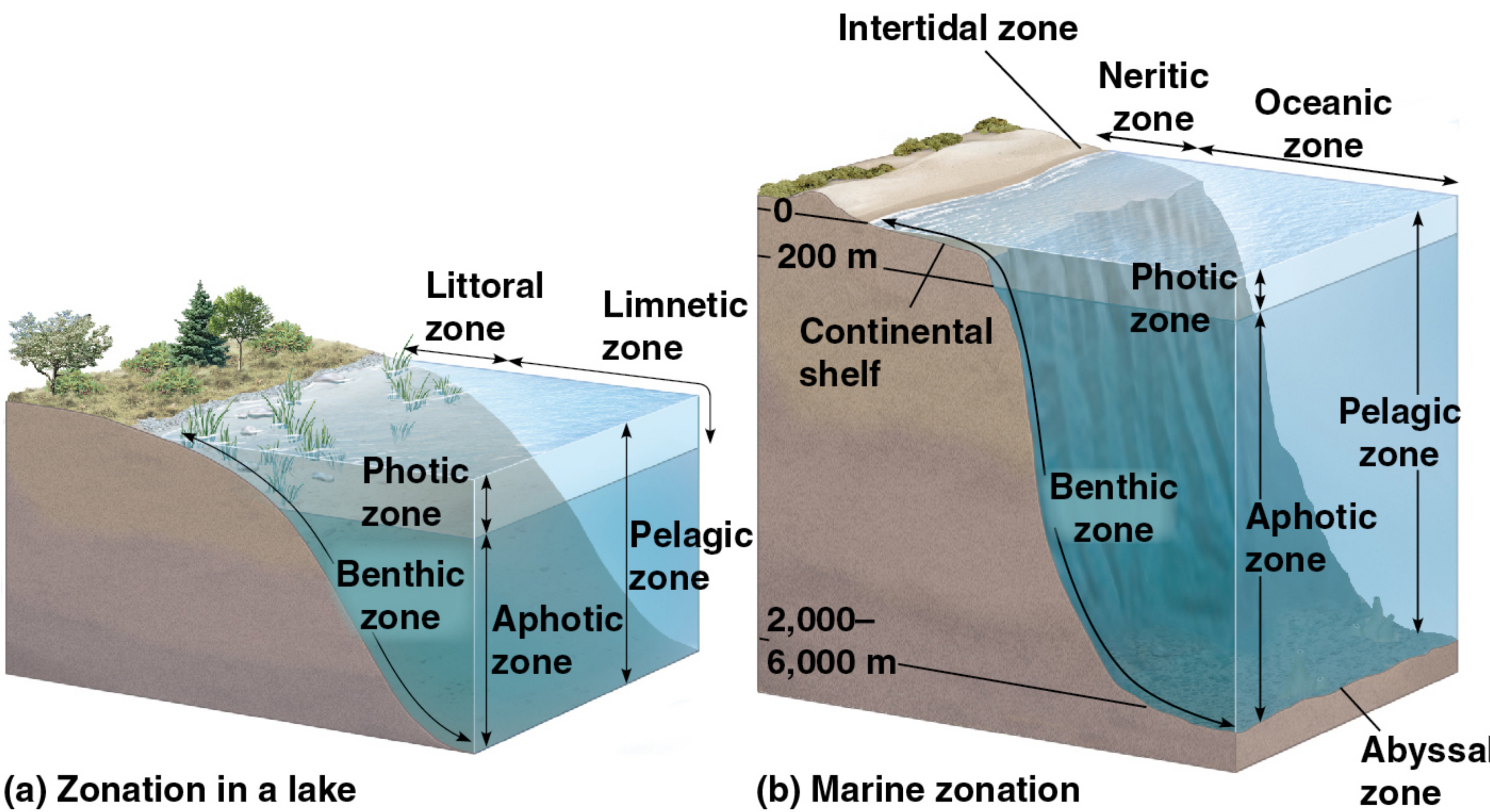
- Freshwater biomes are strongly influenced by the soil and biotic components of the surrounding terrestrial biome
- The pattern and speed of water flow, and climate are also important factors affecting freshwater biomes

Zonation in Aquatic Biomes

- Many aquatic biomes are stratified into zones defined by light penetration, temperature, and depth
- The upper **photic zone** has sufficient light for photosynthesis; the lower **aphotic zone** receives little light
- The photic and aphotic zones make up the **pelagic zone**

- The **abyssal zone** is located in the aphotic zone with a depth of 2,000–6,000 m
- The organic and inorganic sediment at the bottom of all aquatic zones is called the **benthic zone**
- The communities of organisms in the benthic zone are collectively called the **benthos**
- **Detritus**, dead organic matter, falls from the surface and forms an important food source for the benthos

Figure 52.14

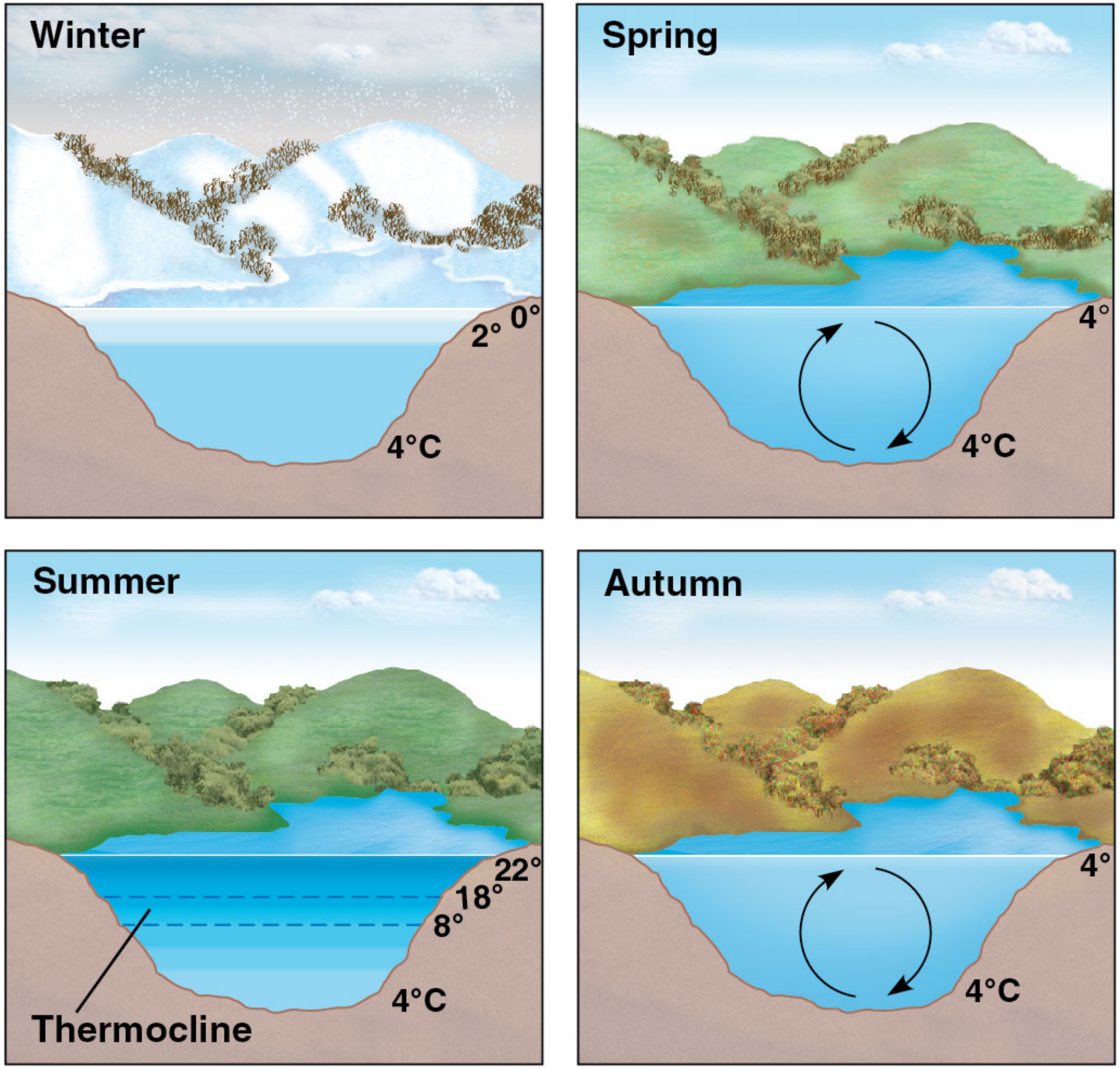


(a) Zonation in a lake

(b) Marine zonation

- In oceans and most lakes, a temperature boundary called the **thermocline** separates the warm upper layer from the cold deeper water
- Many lakes undergo mixing of their waters called turnover in the spring and autumn
- **Turnover** sends oxygenated water from the surface to the bottom and nutrient-rich water from the bottom to the surface

Figure 52.15



Winter
2°
0°
4°C
Spring
4°
4°C
Summer
22°
18°
8°
4°C
Thermocline
Autumn
4°
4°C

- Communities in aquatic biomes vary with depth, light penetration, distance from shore, and location in open water or near the bottom
- In marine communities, most organisms occur in the relatively shallow photic zone
- The aphotic zone in oceans is extensive but harbors little life

- Aquatic biomes can be described by their physical and chemical environments, geologic features, photosynthetic organisms, and heterotrophs
- Aquatic biomes are also impacted by human activities

Figure 52.16 Exploring Aquatic Biomes

Lakes

- Size varies from small ponds of a few square meters to very large lakes of thousands of square kilometers
- Temperate lakes may have a seasonal thermocline; tropical lowland lakes have a year-round thermocline

- Salinity, O_2 concentration, and nutrient content vary among lakes and between seasons
- **Oligotrophic lakes** are nutrient-poor and O_2-rich with low organic content in sediments
- **Eutrophic lakes** are nutrient-rich and high in organic content in sediments; O_2 is periodically depleted in deeper layers due to high rates of decomposition

- Oligotrophic lakes have less surface area relative to depth than eutrophic lakes
- Rooted and floating aquatic plants live in the shallow, well-lit **littoral zone** close to shore
- Phytoplankton inhabit the **limnetic zone**, where the water is too deep to support rooted plants

- Zooplankton are drifting heterotrophs that graze on the phytoplankton
- Invertebrates live in the benthic zone
- Fishes live in all zones with sufficient oxygen
- Human-induced nutrient enrichment can lead to algal “blooms,” oxygen depletion, and fish kills

Lakes

An oligotrophic lake in Jasper National Park, Alberta

A eutrophic lake in the Okavango Delta, Botswana

Wetlands

- **Wetlands** are inundated by water at least some of the time and support plants adapted to water-saturated soil
- Rapid organic production and decomposition periodically deplete dissolved oxygen
- Wetlands develop in shallow basins, along flooded river banks, or on the coasts of large lakes and seas

- Wetlands are among the most productive biomes
- Plants include lilies, cattails, sedges, bald cypress, and black spruce
- Woody plants are dominant in swamps, while bogs are dominated by sphagnum mosses
- Wetlands are home to diverse invertebrates and birds, as well as otters, frogs, and alligators

- Draining and filling by humans has destroyed up to 90% of wetlands in Europe
- Wetlands help to purify water and reduce flooding

Figure 52.16b

Wetlands

A basin wetland in the United Kingdom

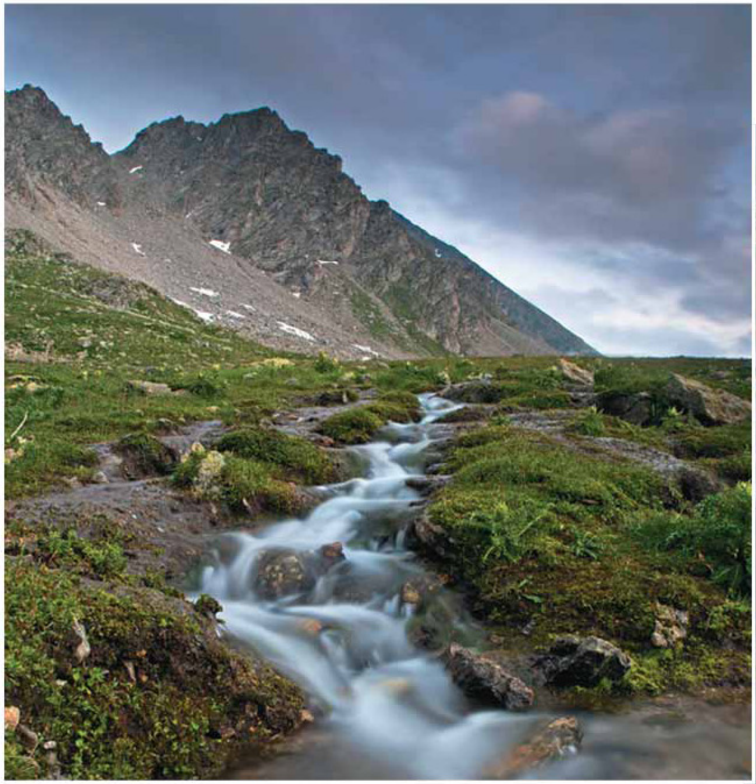
Streams and Rivers

- The most prominent physical characteristic of streams and rivers is current
- Headwater streams are usually cold, clear, swift, and turbulent; downstream rivers are warm and turbid

- Salt and nutrient content of streams and rivers increases from the headwaters to the mouth
- Streams and rivers are generally O_2-rich, but organic enrichment can deplete O_2 downstream
- Headwater streams are often narrow with rocky bottoms; downstream rivers are generally wide and meandering with silty bottoms

- Headwater streams may be rich in phytoplankton or rooted aquatic plants
- A diversity of fishes and invertebrates inhabit unpolluted rivers and streams
- Pollution degrades water quality and kills aquatic organisms
- Damming and flood control impair natural functioning of stream and river ecosystems

Streams and Rivers



A headwater stream in Washington

The Loire River in France, far from its headwaters

Estuaries

- An **estuary** is a nutrient rich and productive transition zone between a river and the sea
- Salinity varies spatially—from nearly fresh water to that of seawater—and with the changing tides
- Estuaries include a complex network of tidal channels, islands, natural levees, and mudflats

- Saltmarsh grasses and algae are the major producers
- Invertebrates, fish, waterfowl, and marine mammals are abundant
- Filling, dredging, and pollution upstream have disrupted estuaries worldwide

Estuaries

An estuary in southern Spain

Intertidal Zones

- An **intertidal zone** is periodically submerged and exposed by the tides
- Upper intertidal zones experience longer exposure to air and greater variation in temperature and salinity
- Physical differences between intertidal zones limit the organisms to particular strata

- Oxygen and nutrient levels are generally high in intertidal zones
- Substrates are generally either rocky or sandy
- The configuration of bays or coastlines influence the magnitude of tides and mechanical forces of waves

- Sandy intertidal zones tend not to have attached plants or algae, unless protected from vigorous waves in bays or lagoons
- Rocky intertidal zones support attached algae; protected sandy zones support seagrass and algae

- In rocky zones, many animals have structural adaptations for attaching to the hard substrate
- In sandy zones, worms, clams, and crustaceans bury themselves in sand
- Other animals include sponges, sea anemones, echinoderms, and small fishes

- Oil pollution has disrupted many intertidal areas
- Construction of rock walls and barriers to reduce erosion from waves also disrupts the intertidal zone

Intertidal Zones

A rocky intertidal zone on the Oregon coast

Oceanic Pelagic Zone

- The **oceanic pelagic zone** is an expanse of open water covering approximately 70% of Earth's surface
- It is constantly mixed by wind-driven oceanic currents

- Oxygen levels are generally high, but nutrient concentrations are lower than coastal waters
- In temperate oceans, seasonal turnover renews nutrients in the photic zone
- Nutrient concentrations are lower in tropical oceans due to year-round thermal stratification

- Phytoplankton and zooplankton are the dominant organisms
- Phytoplankton in this zone account for about half of the photosynthesis on Earth
- Fish, squid, turtles, and marine mammals are common
- Overfishing, pollution, ocean acidification, and global warming have all harmed this biome

Figure 52.16f

Oceanic Pelagic Zone

Open ocean near Iceland

Coral Reefs

- **Coral reefs** are formed from the calcium carbonate skeletons of corals
- Shallow reef-building corals live in the photic zone in warm (about 18–30ºC), clear water; deep-sea corals live at depths of 200–1,500 m

- Corals require high oxygen concentrations and a solid substrate for attachment
- A coral reef progresses from a fringing reef to a barrier reef to a coral atoll
- Corals form a mutualistic relationship with unicellular algae, which provide them with organic molecules
- In addition to corals, other invertebrates and fish are also exceptionally diverse

- Collection of coral skeletons, overfishing, global warming, pollution, and aquaculture are threats to coral reef ecosystems

Coral Reefs

A coral reef in the Red Sea

Video: Coral Reef

Video: Clown Fish and Anemone

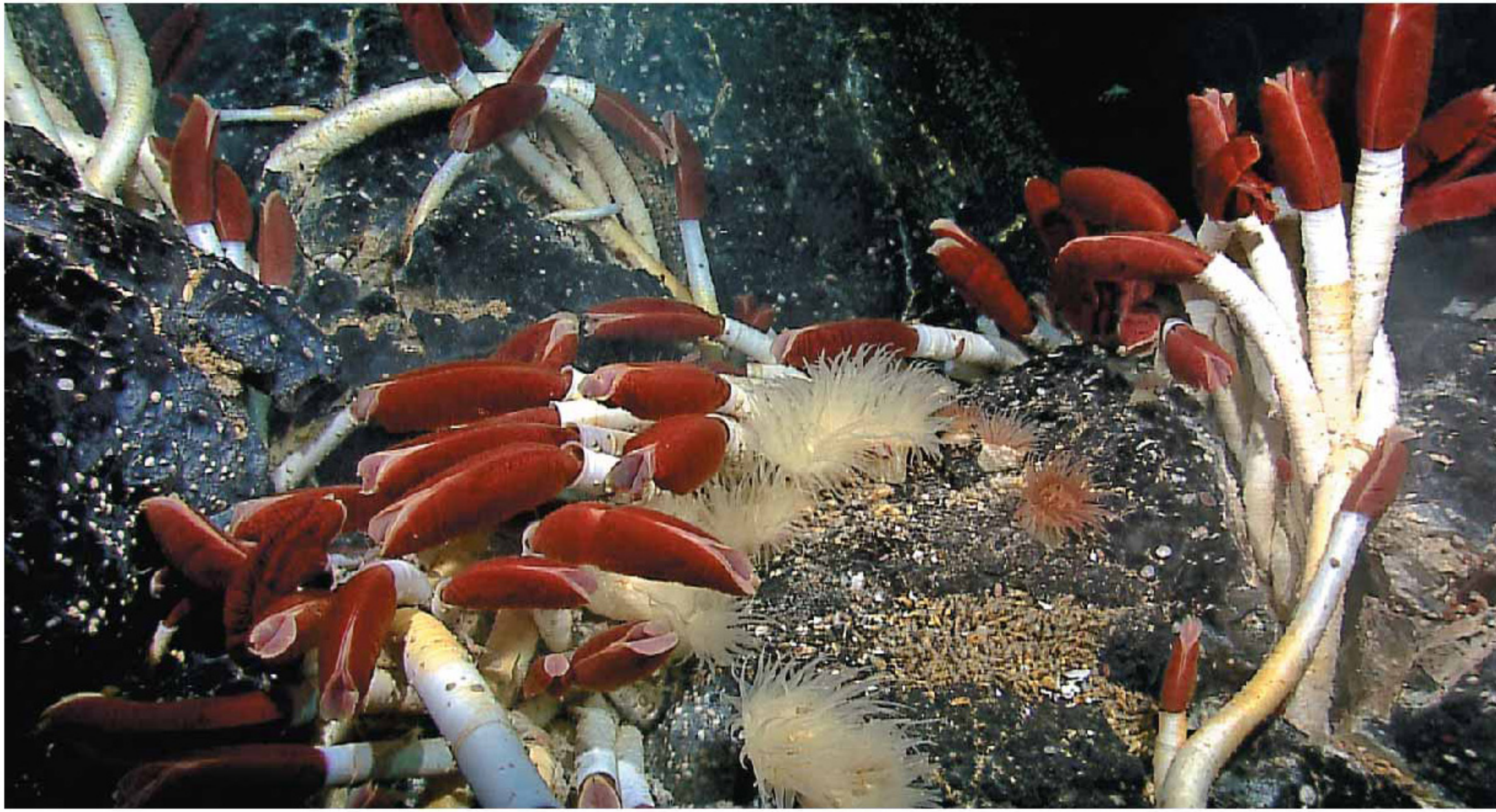
Marine Benthic Zone

- The **marine benthic zone** consists of the seafloor below the surface waters of the coastal, or **neritic**, zone and the offshore pelagic zone
- Organisms in the very deep benthic (abyssal) zone are adapted to continuous cold (about 3°C) and very high water pressure

- Oxygen is typically abundant enough to support diverse animal life
- Soft sediments or rocks can form the substrate
- Photosynthetic organisms, seaweeds and filamentous algae, are restricted to shallow areas
- Deep-sea **hydrothermal vents** are found on mid-oceanic ridges

- Chemoautotrophic prokaryotes are the food producers surrounding hydrothermal vents
- Giant tube worms, echinoderms, and arthropods live around the hydrothermal vents
- Neritic benthic communities include invertebrates and fishes
- Overfishing and dumping of waste have depleted fish populations

Marine Benthic Zone



A deep-sea hydrothermal vent community

Video: Tubeworms

CONCEPT 52.4: Interactions between organisms and the environment limit the distribution of species

- Species distributions are the result of ecological factors and evolutionary history
  - For example, kangaroos occur only in Australia, in part because the lineage originated there when the continent was geographically isolated
  - Ecological factors also affect the kangaroo distribution; particular species occur in some habitats, but not others

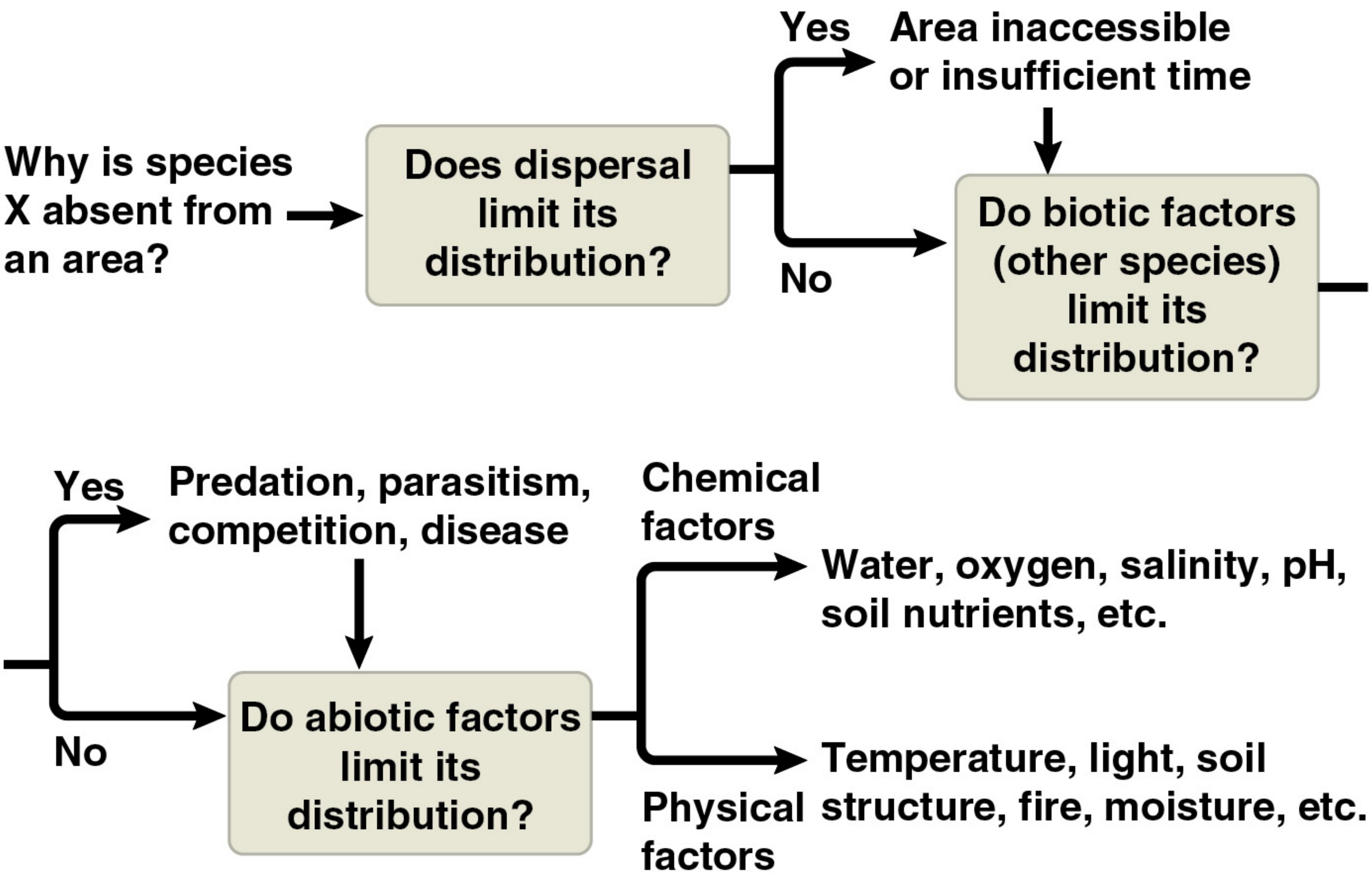
- Both biotic and abiotic factors influence species distribution
  - For example, temperature and water availability are abiotic factors limiting the distribution of the saguaro cactus in North America
  - Interactions with herbivores, pollinators, and pathogens also limit the distribution of this cactus

Figure 52.17

CALIFORNIA
ARIZONA
BAJA CALIFORNIA
SONORA
100 km
BAJA CALIFORNIA SUR
GULF OF CALIFORNIA
Sonoran desert
Saguaro cacti observed

- Ecologists explain the distribution of species by asking a series of questions about possible factors limiting distribution

Figure 52.18


Why is species X absent from an area?
Does dispersal limit its distribution?
Yes
Area inaccessible or insufficient time
No
Do biotic factors (other species) limit its distribution?
Yes
Predation, parasitism, competition, disease
No
Do abiotic factors limit its distribution?
Chemical factors
Water, oxygen, salinity, pH, soil nutrients, etc.
Physical factors
Temperature, light, soil structure, fire, moisture, etc.

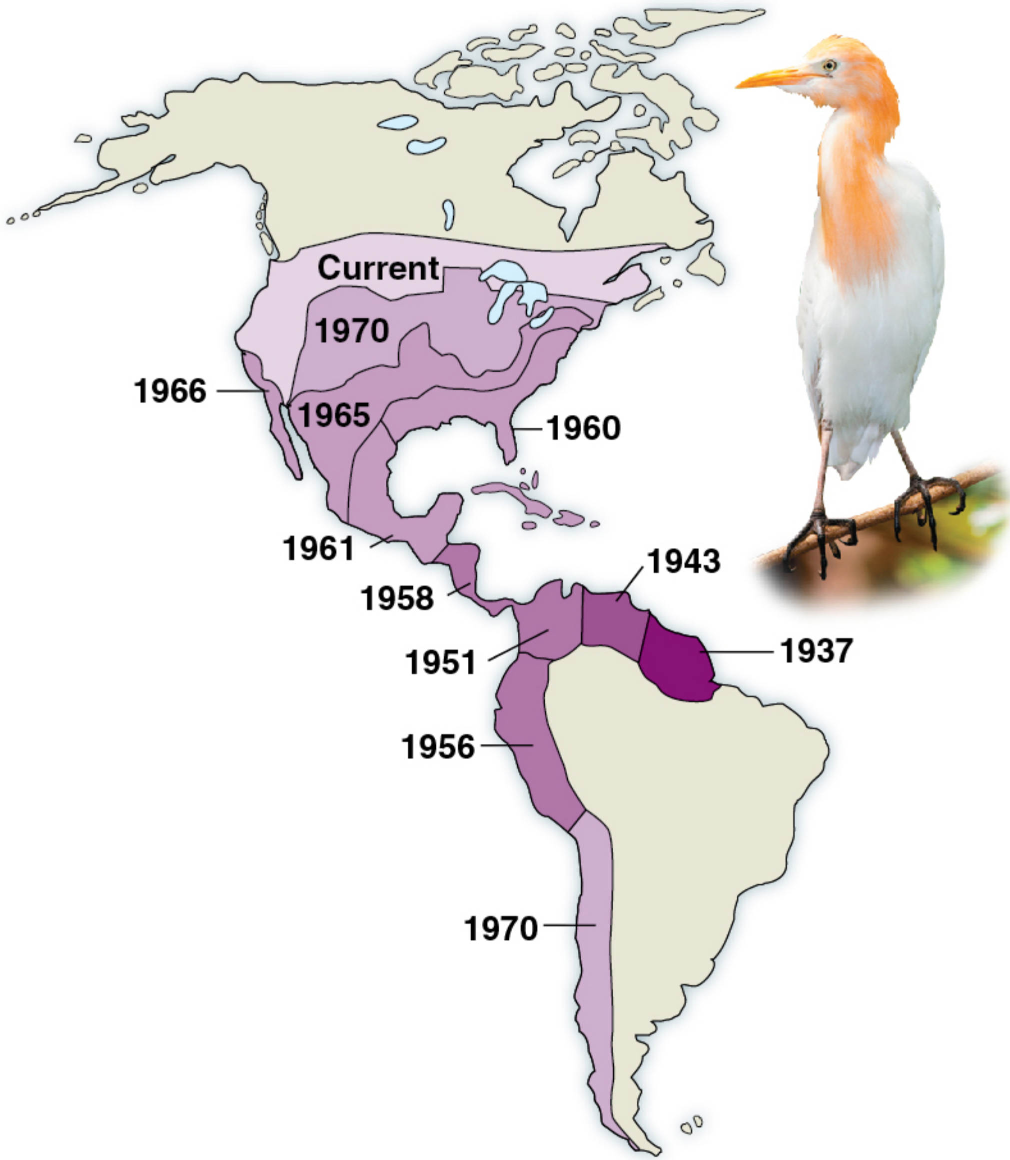
Dispersal and Distribution

- **Dispersal** is the movement of individuals or gametes away from their area of origin or centers of high population density
- Dispersal contributes to the global distribution of organisms

Natural Range Expansions and Adaptive Radiation

- Natural range expansions show the influence of dispersal on distribution
  - For example, cattle egrets dispersed to South America from Africa in the late 1800s and have since expanded their distribution into Central and North America

Figure 52.19


Current
1970
1966
1965
1960
1961
1958
1943
1951
1937
1956
1970

- In rare cases, long-distance dispersal can lead to adaptive radiation, the rapid evolution of an ancestral species into many ecologically diverse species
  - For example, Hawaiian silverswords are a diverse group descended from an ancestral North American tarweed

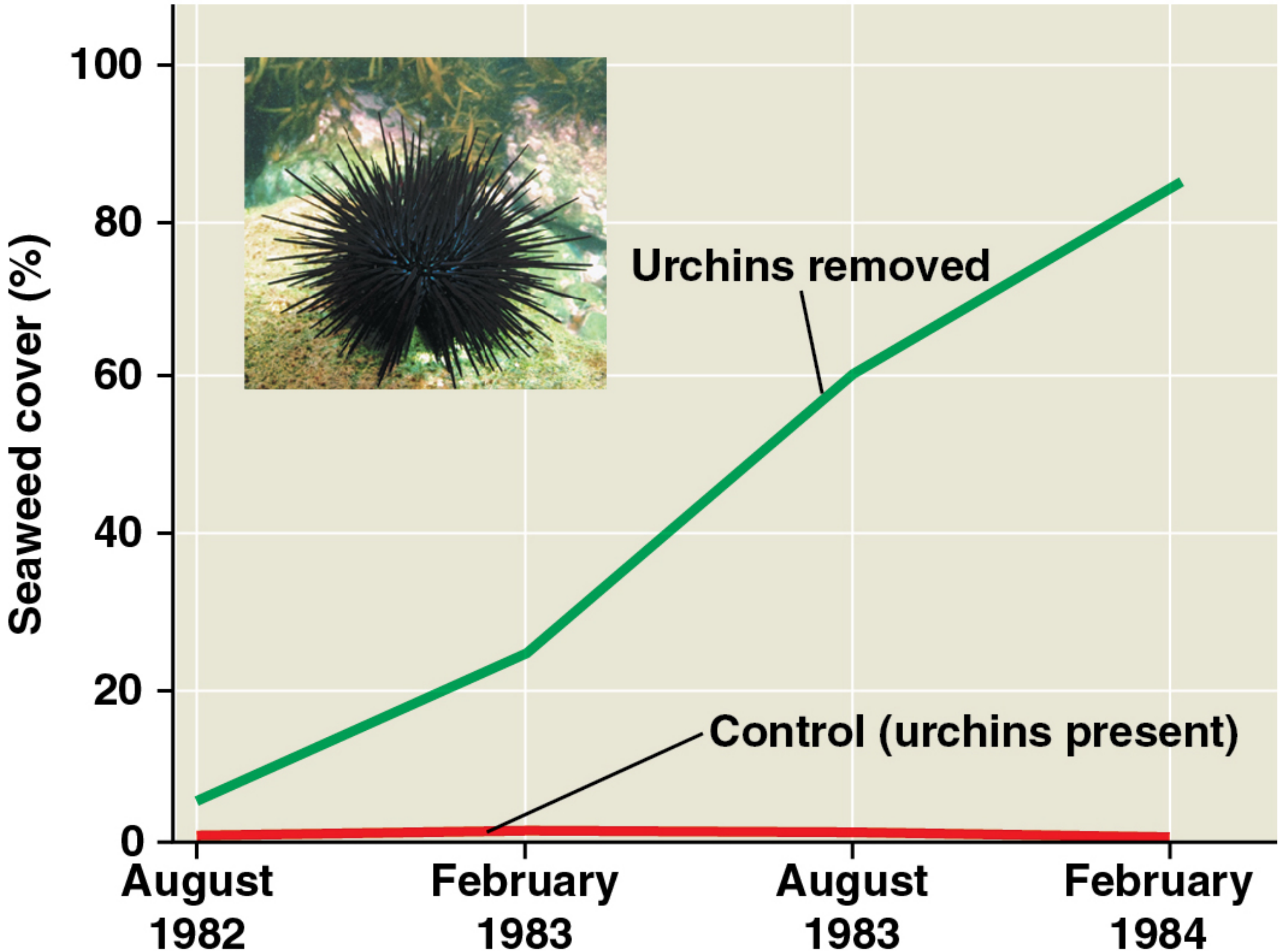
Species Transplants

- Species transplants are used to determine if dispersal is key factor limiting distribution
- They involve the intentional or accidental relocation of organisms from their original distribution
- A successful transplant indicates that the potential range of a species is larger than its actual range
- Species transplants can disrupt the communities or ecosystems to which they have been introduced

Biotic Factors

- Survival and reproduction of a species can be reduced by interactions with other species, such as predators or herbivores
  - For example, grazing by the long-spined sea urchin (*Centrostephanus rodgersii*) prevents the establishment of seaweed

Figure 52.20



Seaweed cover (%)
100
80
60
40
20
0
Urchins removed
Control (urchins present)
August 1982
February 1983
August 1983
February 1984

- In addition to predation and herbivory, other biotic factors may limit the distribution of species
  - Presence or absence of pollinators
  - Food resources
  - Parasites and pathogens
  - Competing organisms

Abiotic Factors

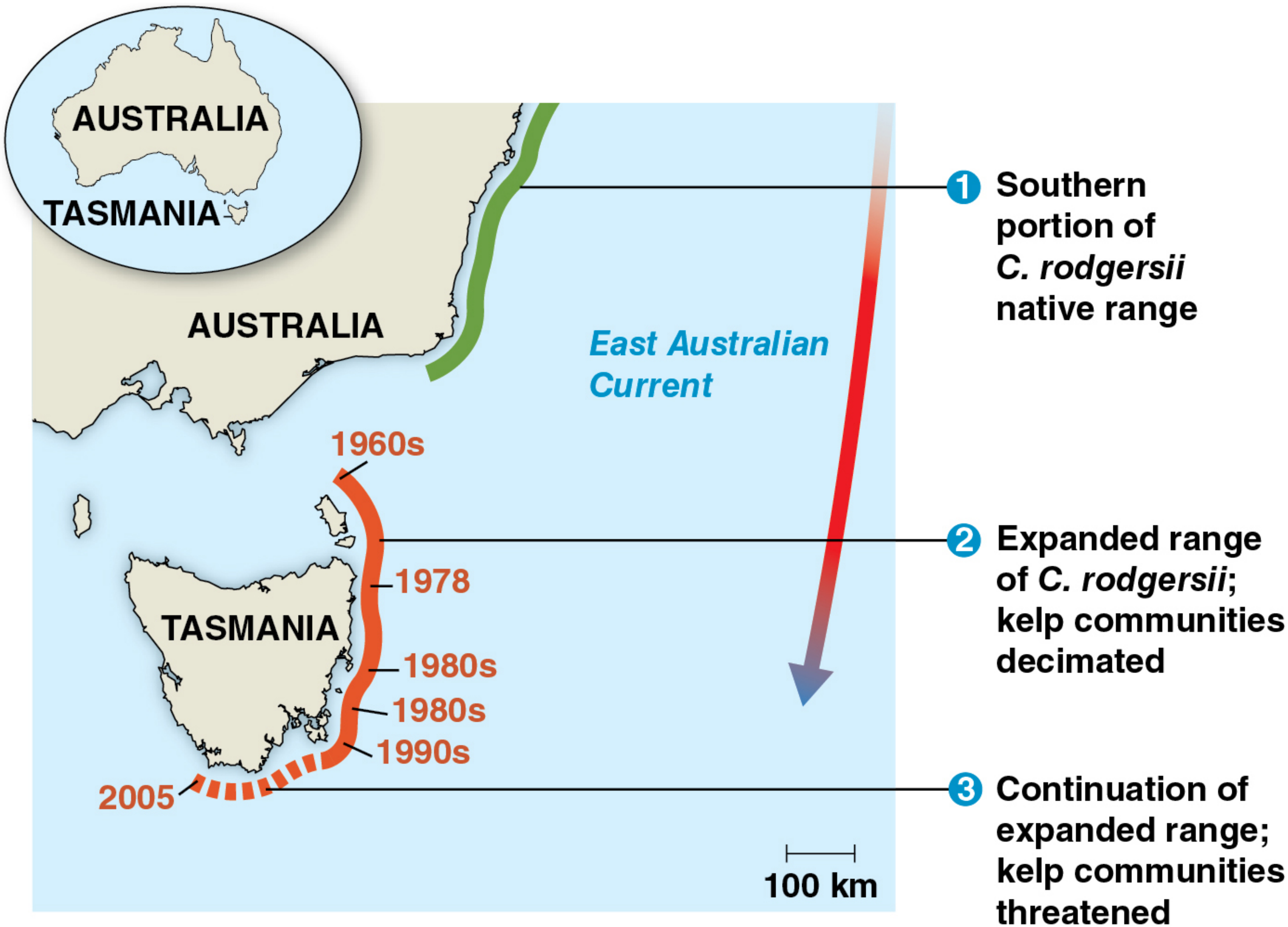
- Abiotic factors affecting the distribution of organisms include the following:
  - Temperature
  - Water
  - Oxygen
  - Salinity
  - Sunlight
  - Soil
- Most abiotic factors vary in space and time

Temperature

- Environmental temperature has an important impact on many biological processes
  - For example, cells may freeze and rupture below 0ºC, while most proteins denature above 45ºC
- Most organisms function best within a specific temperature range
- Mammals and birds expend energy to regulate their internal temperature within that range

- Range shifts in response to climate change can dramatically affect the distribution of other species
  - For example, the long-spined sea urchin (*C. rodgersii*) expanded its range in response to increasing water temperature
  - *C. rodgersii* consumed the seaweed in its new range and destroyed the diverse communities that formerly inhabited the seaweed stands

Figure 52.21



AUSTRALIA
TASMANIA
AUSTRALIA
East Australian Current
1960s
1978
1980s
1980s
1990s
2005
TASMANIA
100 km
1 Southern portion of C. rodgersii native range
2 Expanded range of C. rodgersii; kelp communities decimated
3 Continuation of expanded range; kelp communities threatened

Water and Oxygen

- Water availability in habitats is another important factor in species distribution
- Desert organisms exhibit adaptations for water conservation
- Water affects oxygen availability in aquatic environments, as oxygen diffuses slowly in water

- Oxygen concentrations can be very low in deep ocean and deep lake waters
- Sediments high in organic matter and flooded wetland soils are also low in oxygen
- Surface waters of rivers and streams are well oxygenated due to rapid gas exchange with the atmosphere

Salinity

- Salt concentration affects the water balance of organisms through osmosis
- Most terrestrial organisms excrete salt from specialized glands or in feces or urine
- Few are adapted to high-salinity habitats

Figure 52.22

- Most aquatic organisms are restricted to either freshwater or saltwater habitats by limited ability to osmoregulate
- Salmon are able to migrate between freshwater and marine habitats by adjusting their water intake and switching gills from taking up to excreting salt

Sunlight

- Lack of sunlight can limit the distribution of photosynthetic species
- Shading by leaves makes competition for light intense on the forest floor
- In aquatic environments most photosynthesis occurs near the surface because water absorbs light

- Too much light can also limit survival of organisms
- In deserts, high light levels increase temperature and can stress plants and animals
- At high elevations, the atmosphere is thinner and absorbs less of the harmful ultraviolet (UV) radiation
- Damage from UV radiation combined with other stressors limits tree growth above a certain elevation

Figure 52.23

Rocks and Soil

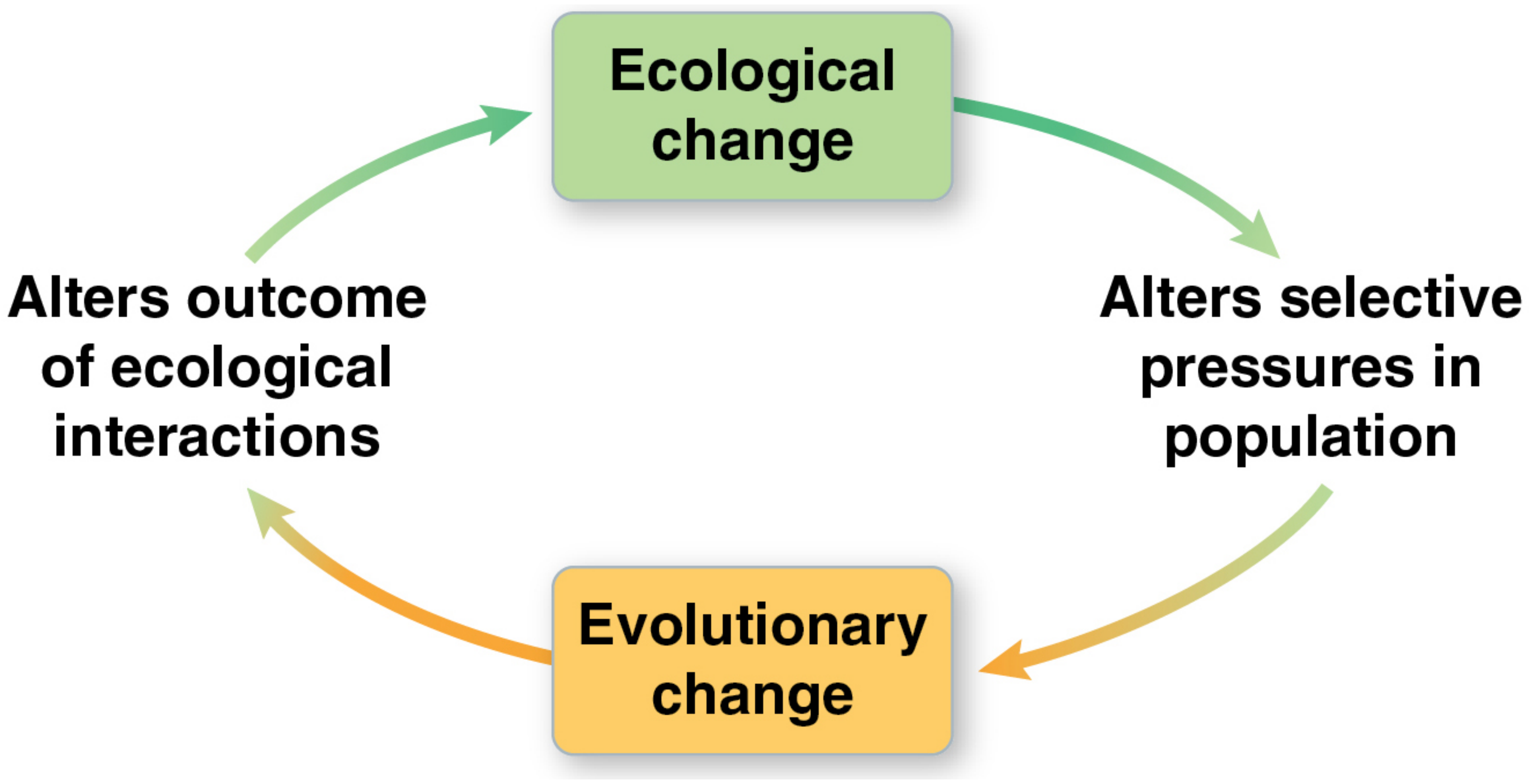
- The pH, mineral composition, and physical structure of rocks and soil limit the distribution of plants and the animals that feed on them
- The soil pH can limit distribution directly due to extreme acid or basic soil conditions or indirectly by affecting the solubility of toxins and nutrients

- The substrate of rivers can affect water chemistry
- In freshwater and marine environments, the structure of the substrate determines which organisms can burrow into or attach on to it

CONCEPT 52.5: Ecological change and evolution affect one another over long and short periods of time

- Ecological interactions can cause evolutionary change, and vice versa
  - For example, the diversification of plants on land provided new habitats and food sources for animals
  - In turn, new habitats and food sources stimulated bursts of speciation in an animals, leading to further ecological change

Figure 52.24


Ecological change
Alters selective pressures in population
Evolutionary change
Alters outcome of ecological interactions

- Ecological change and evolution have the potential to exert rapid feedback effects on each other
  - For example, color patterns, jaw morphology and feeding preference evolve rapidly in Trinidadian guppies when predators are removed
  - Guppies that evolved under different levels of predation have contrasting effects on algal abundance

Figure 52.25

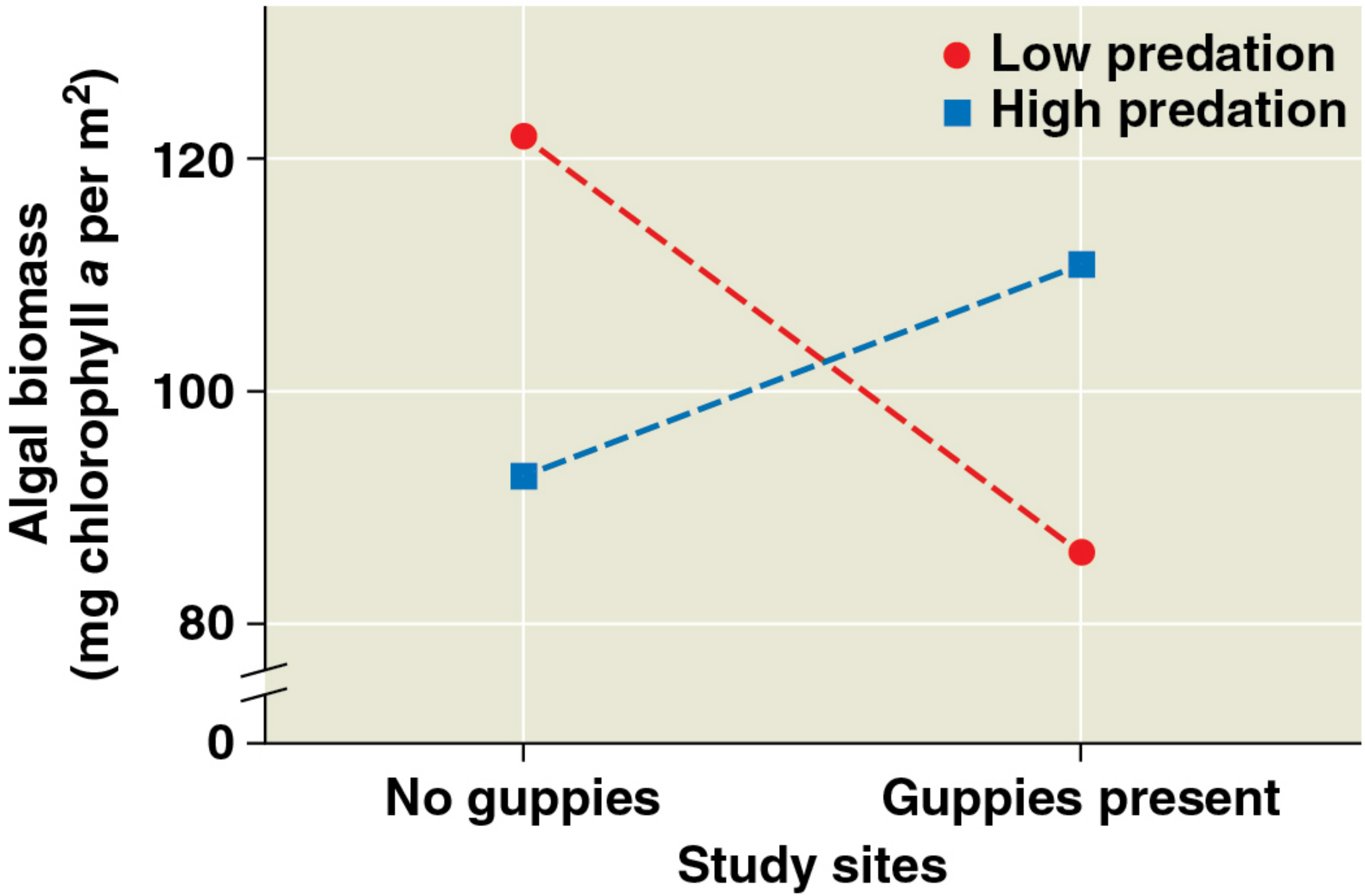

Low predation
High predation
120
100
80
0
Algal biomass
(mg chlorophyll a per m2)
No guppies
Guppies present
Study sites

Figure 52.UN01

Data from the Field Experiment
(averages of 16 replicate samples)

	Average Biomass (g/100 cm^2)			
	Spartina patens		*Typha angustifolia*	
	Salt Marshes	Freshwater Marshes	Salt Marshes	Freshwater Marshes
With neighbors	8	3	0	18
Without neighbors	10	20	0	33

Data from C. M. Crain et al., Physical and biotic drivers of plant distribution across estuarine salinity gradients, *Ecology* 85:2539–2549 (2004).

Figure 52.UN02

Data from the Greenhouse Experiment

Salinity (parts per thousand)	0	20	40	60	80	100
% maximum biomass (*S. patens*)	77	40	29	17	9	0
% maximum biomass (*T. angustifolia*)	80	20	10	0	0	0

Data from C. M. Crain et al., Physical and biotic drivers of plant distribution across estuarine salinity gradients, *Ecology* 85:2539–2549 (2004).

Figure 52.UN03

Spartina patens

Figure 52.UN04

Typha angustifolia

Figure 52.UN05

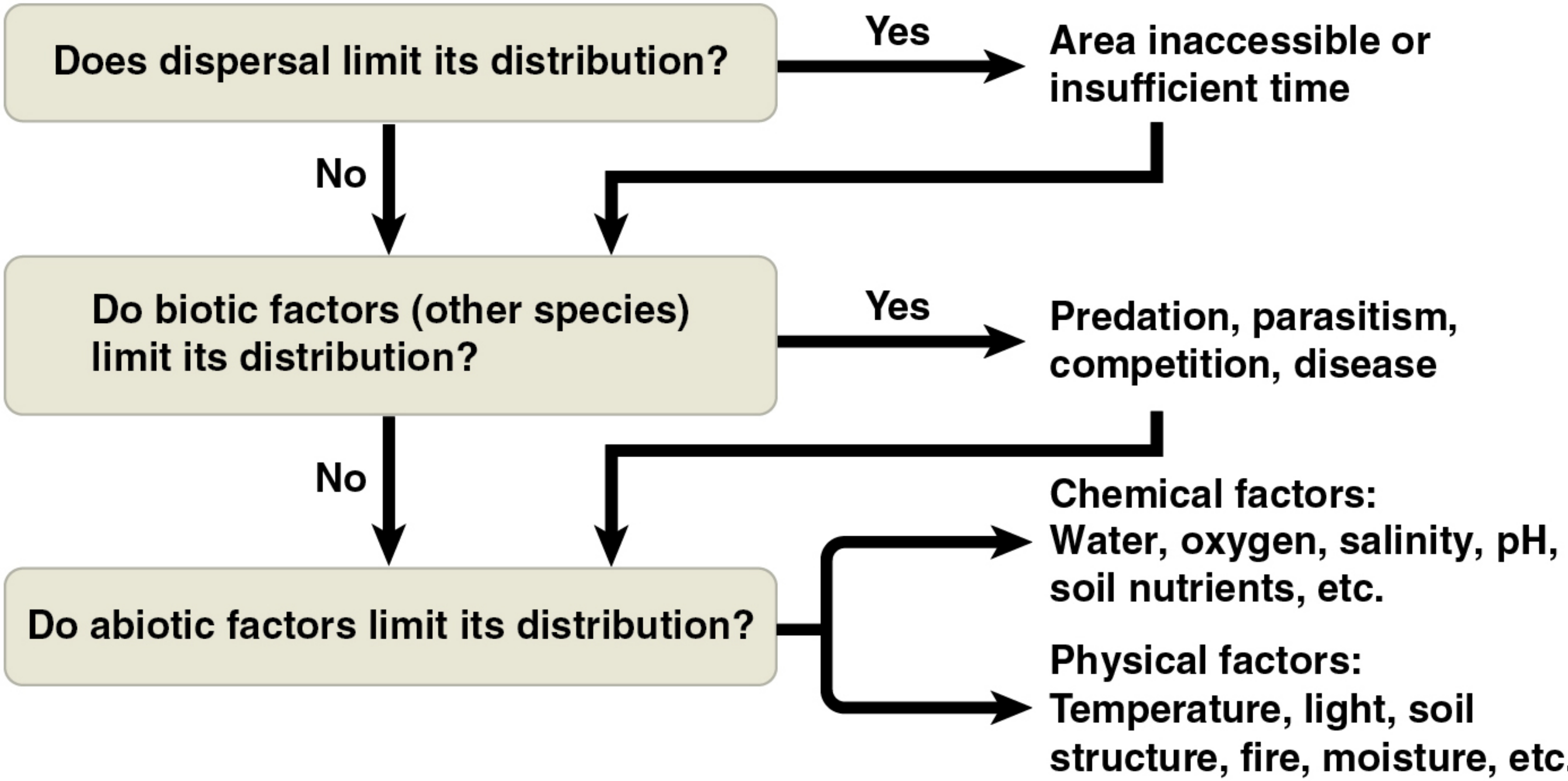
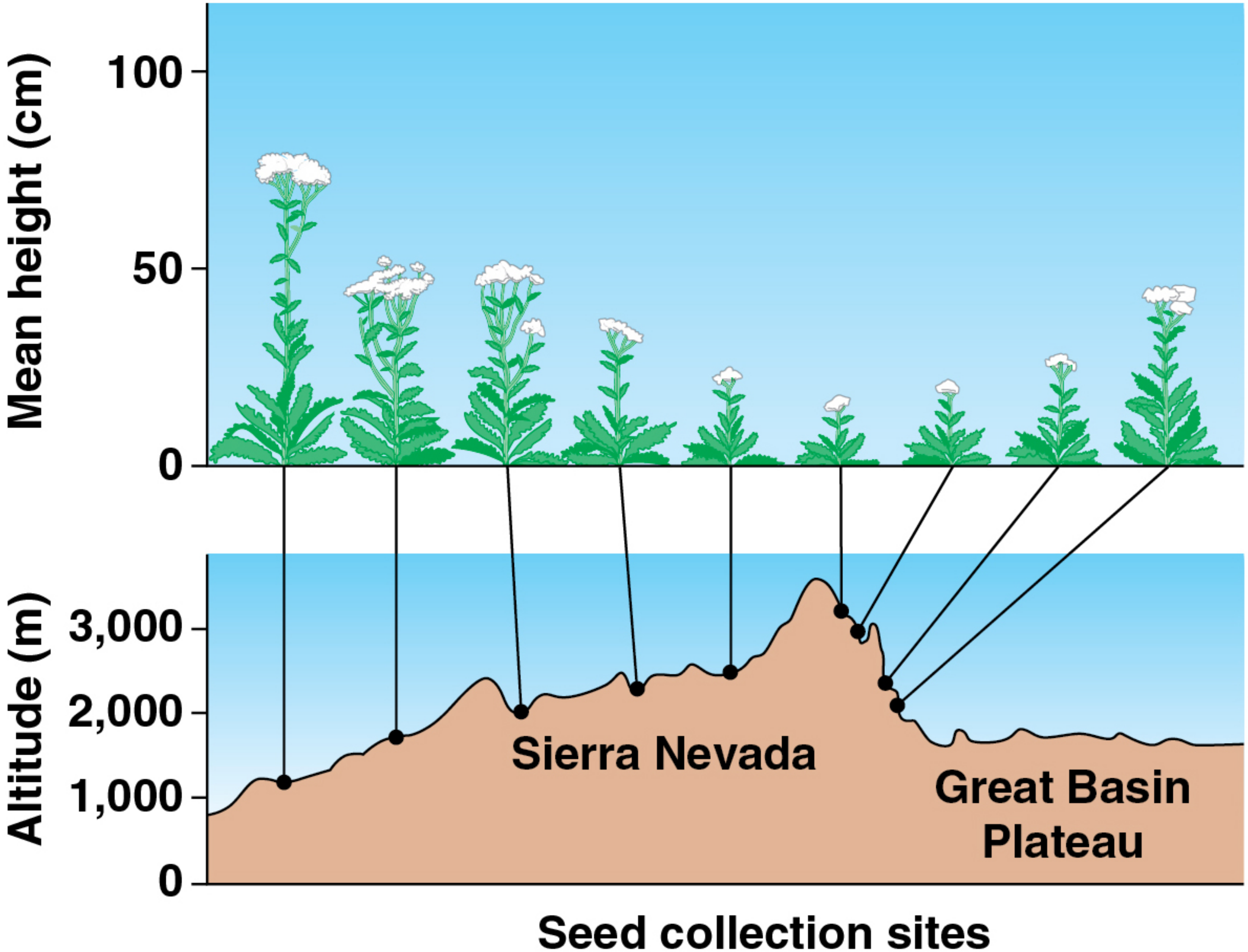


Figure 52.UN06

Site	Otter Density (# sightings per day)	Kelp Abundance (% cover)
1	98	75
2	18	15
3	85	60
4	36	25

Figure 52.UN07



Data from J. Clausen et al., Experimental studies on the nature of species. III. Environmental responses of climatic races of *Achillea*, Carnegie Institution of Washington Publication No. 581 (1948).

Figure 52.UN08