

Chapter 52

An Introduction to Ecology and the Biosphere



AP Biology

Overview: The Scope of Ecology

- **Ecology** is the scientific study of the interactions between organisms and the environment
 - These interactions between organisms and their environments can occur at a various levels, including:
 - Organismal ecology (Ch. 52)
 - Population ecology (Ch. 53)
 - Community ecology (Ch. 54)
 - Ecosystem ecology (Ch. 55)
 - Landscape ecology (Ch. 56)
 - Global ecology (Ch. 56)

- **Organismal ecology** studies how an organism's structure, physiology, and behavior meets environmental challenges



- Ex) How do hammerhead sharks select a mate?

- **Population ecology** focuses on factors affecting how many individuals of a species live in an area

- A **population** is a group of individuals of the same species living in an area
 - Ex) What environmental factors affect the reproductive rate of deer mice?



- **Community ecology** examines how interactions between species (ex: predation, competition) affect community structure and organization

- A **community** is a group of populations of different species in an area

- Ex) What factors influence the diversity of species that make up a forest?



- **Ecosystem ecology** emphasizes energy flow and chemical cycling between organisms and the environment

- An **ecosystem** is the community of organisms in an area and the physical factors with which they interact

- Ex) What factors control photosynthetic productivity in a temperate grassland ecosystem?



- **Landscape ecology** focuses on factors controlling exchanges of energy, materials, and organisms across multiple ecosystems



- A **landscape** is a mosaic of ecosystems

- Ex) To what extent do trees

lining a river serve as corridors of dispersal for animals?

- **Global ecology** examines how regional exchange of energy and materials influences the functioning and distribution of organisms across the biosphere

- The **biosphere** is the global ecosystem, the sum of all the planet's ecosystems

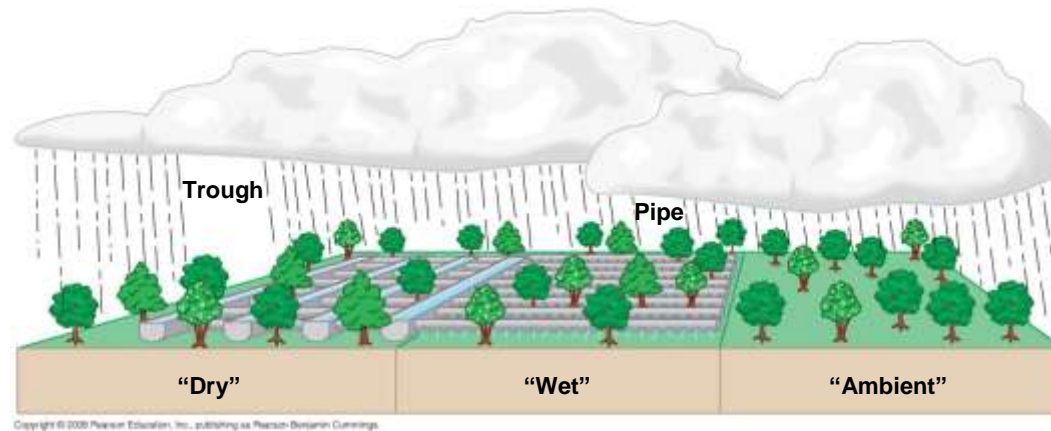
- Ex) How does ocean circulation affect the global distribution of crustaceans?



Concept 52.1:

**Ecology Integrates All Areas of Biological Research
and Informs Environmental Decision Making**

- Modern ecology has come about using a combination of 2 approaches:
 - 1) A descriptive approach, called *natural history*
 - Scientists observe organisms in nature and record their observations
 - 2) A more quantitative approach involving rigorous experimental science
 - Ecologists use the scientific method to generate hypotheses, manipulate the environment, and observe the outcome
 - Ex) Experimental manipulation of forests to determine the effects of climate change on tree survival



Linking Ecology and Evolutionary Biology

- There is a strong link between ecology and evolution:
 - The differential survival and reproduction of individuals in an ecosystem ultimately leads to evolutionary change over many generations
 - The differential survival and reproduction of individuals that leads to evolution occurs in *ecological time* (the minute-to-minute time frame of interactions between organisms and the environment)
 - The adaptation that occurs over many generations occurs in the time frame of *evolutionary time*
 - Ex) As a farmer applies a new fungicide to protect his wheat crop from fungus, the frequency of fungicide resistance increases in a population of fungus over time

Ecology and Environmental Issues

- Ecology also provides the scientific understanding needed to help conserve and sustain life on Earth
 - Because ecology is useful in conservation and environmental efforts, many people associate ecology with *environmentalism* (advocating the protection of nature)
 - There is, however, an important distinction between science and advocacy
 - Many ecologists feel a responsibility to educate legislators and the public about environmental issues
 - How society uses this ecological knowledge, however, depends on much more than science alone
 - Policymakers must weigh environmental concerns against social and financial costs

Concept Check 52.1

- 1) Contrast the terms ecology and environmentalism. How does ecology relate to environmentalism?
- 2) How can an event that occurs on the ecological time scale affect events that occur on an evolutionary time scale?
- 3) A wheat farmer tests four fungicides on small plots and finds that the wheat yield is slightly higher when all four fungicides are used together than when any one fungicide is used alone. From an evolutionary perspective, what would be the likely long-term consequence of applying all four fungicides together?

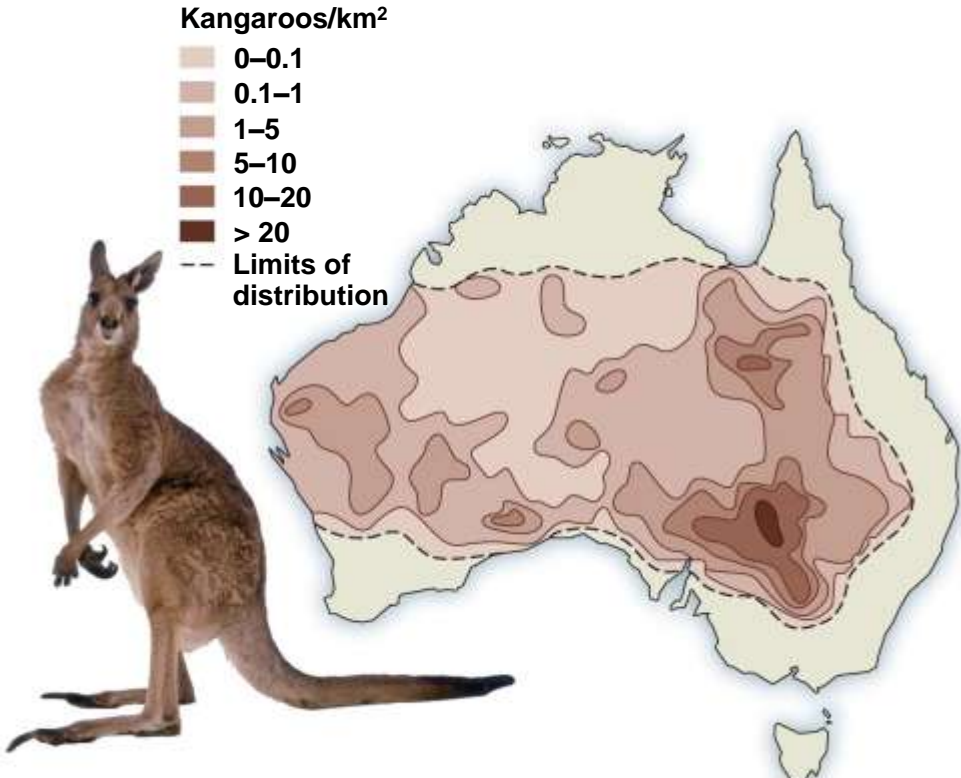
Concept 52.2:

Interactions between organisms and the environment limit the distribution of species

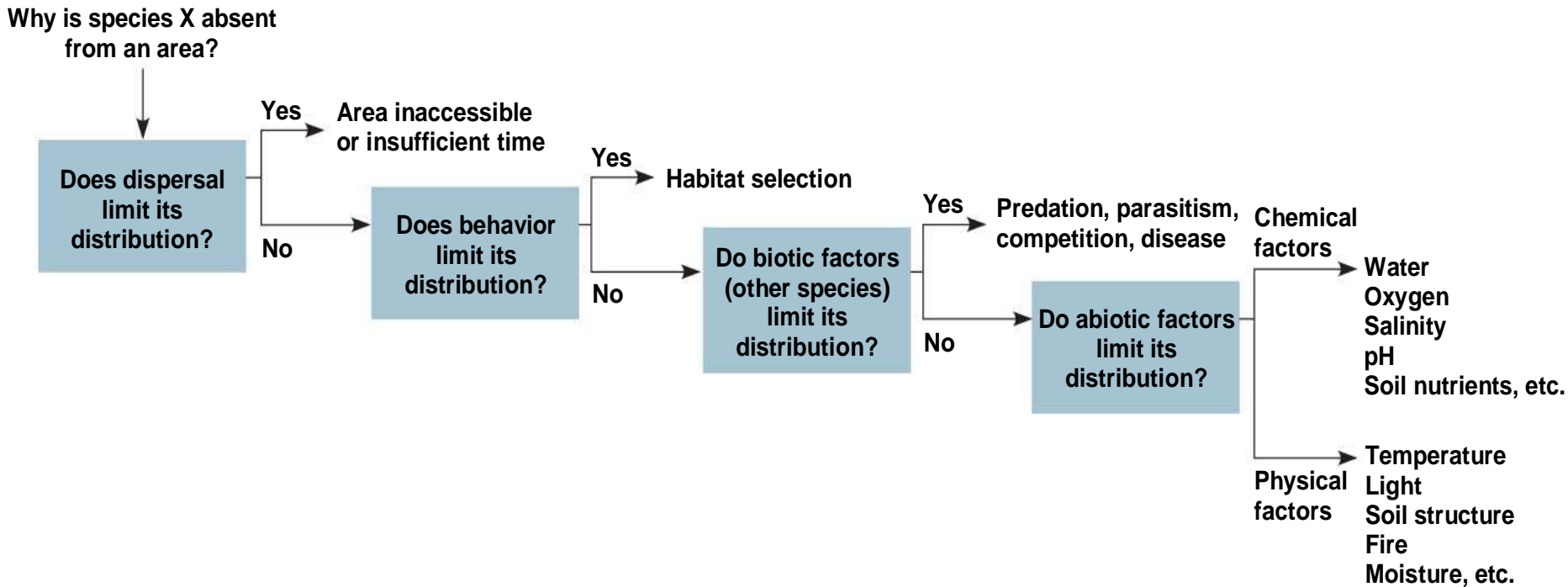
- Ecologists have long recognized global and regional patterns of distribution of organisms within the biosphere
 - Ex) Kangaroos are found only in Australia;
- Ecologists recognize two kinds of factors that determine distribution of organisms:
 - 1) **Biotic** (living) factors: all the organisms that are part of an individual's environment
 - Ex) Food availability, competition, predators
 - 2) **Abiotic** (nonliving) factors: all the chemical and physical factors that influence distribution and abundance of organisms
 - Ex) Temperature, light, water, nutrients

- Both biotic and abiotic factors can affect the distribution of a species
 - Red kangaroos are most abundant in Australia’s semi-arid interior, where precipitation is relatively low from year to year (abiotic)
 - The dry climate also influences red kangaroo populations indirectly through biotic factors, including pathogens, parasites, predators, competitors, and food availability

- Ecologists generally need to consider multiple factors and alternative hypotheses when attempting to explain the distribution of species



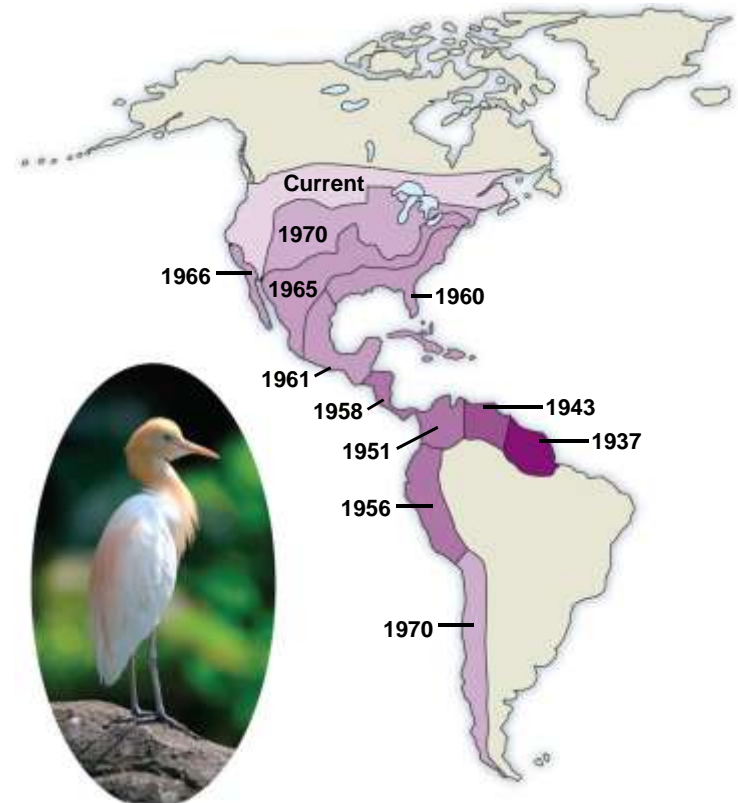
- One factor that ecologists consider when attempting to explain the distribution of species is dispersal
 - **Dispersal** is movement of individuals away from centers of high population density or from their area of origin
 - Ex) A scientist might hypothesize that there are no kangaroos in North America because a barrier to their dispersal existed



Natural Range Expansions

- Some organisms can disperse more readily than others, leading to natural range expansion
 - In natural range expansion, organisms reach areas where they did not exist previously

- Ex) In the last 200 years, cattle egrets expanded their natural range from Africa, across the Atlantic Ocean, to the United States and southern Canada



Species Transplants

- Opportunities to observe natural range expansions directly are rare
 - To determine if dispersal is the key factor limiting the distribution of a species, ecologists therefore often turn to experimental methods
 - Species can be transplanted, either intentionally or accidentally, relocating them from their original distribution to areas where they were previously absent
 - For these transplants to be successful, some of the relocated organisms must survive and reproduce in the new area
 - If the transplant is successful, then the *potential* range of the species is larger than its *actual* range
 - Ecologists can thus conclude that dispersal is not the limiting factor in the dispersal of that species

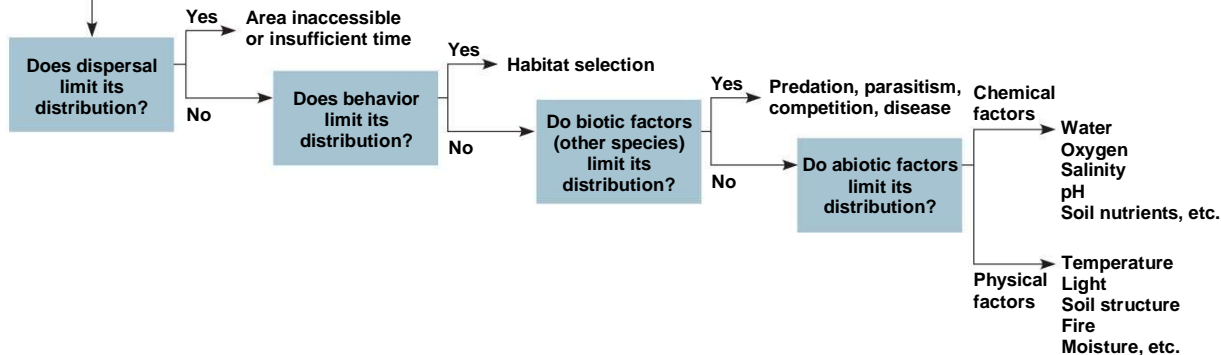
Consequences of Species Transplants

- Species transplants can have negative consequences, however, and often disrupt the communities or ecosystems to which they have been introduced
 - Therefore, scientists rarely conduct transplant experiments across geographic regions
 - Instead, they document outcomes of species that have been transplanted for other reasons
 - Ex) Introduction of game animals or predators of pest animals

Behavior and Habitat Selection

- If organisms do not occupy all of their potential range, other factors must be considered:
 - Does behavior limit the distribution of a species?
- When individuals seem to avoid potentially suitable habitats, the distribution of these organisms may be limited by habitat selection behavior
 - Ex) Female insects often deposit eggs only in response to a very narrow set of stimuli, thus restricting distribution of these insects to certain host plants
 - For example, egg-laying females of the European corn borer species are attracted to odors produced only by maize, even though its larvae can feed on a variety of plants

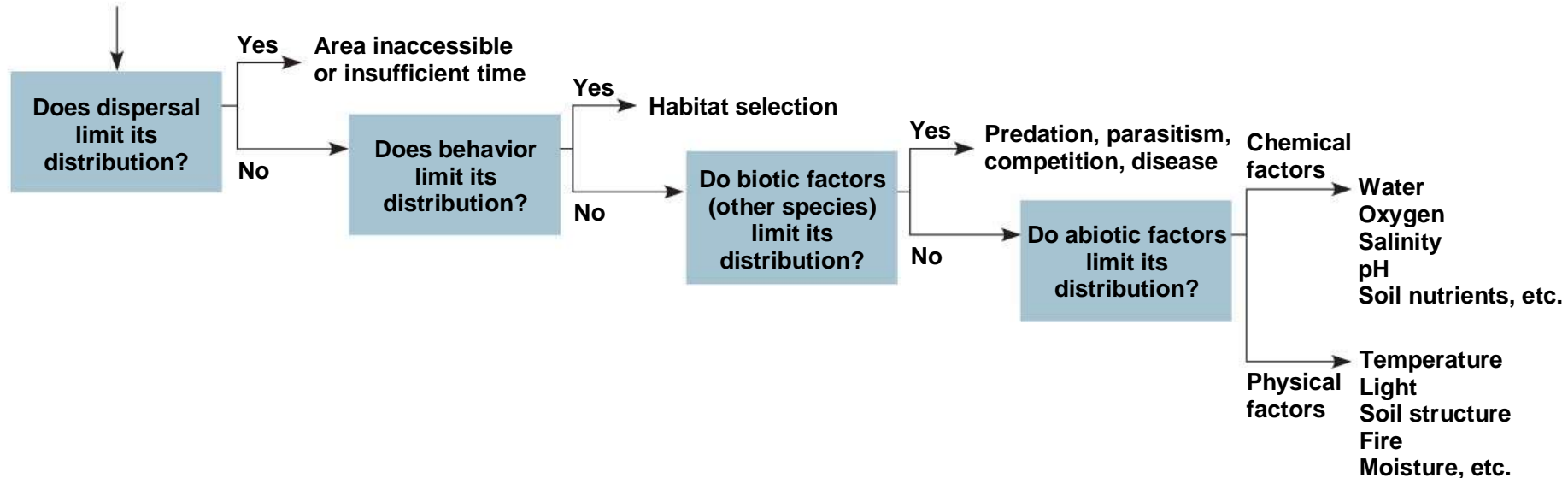
Why is species X absent from an area?



Biotic Factors

- If behavior does not limit distribution of a species, the next factor must be examined:
 - 3) Do biotic factors (other species) limit its distribution?
 - Biotic factors that affect the distribution of organisms may include:
 - Beneficial interactions with other species
 - Ex) Pollinators for flowering plants
 - Negative interactions with other organisms
 - Ex) Competition, predation

Why is species X absent from an area?



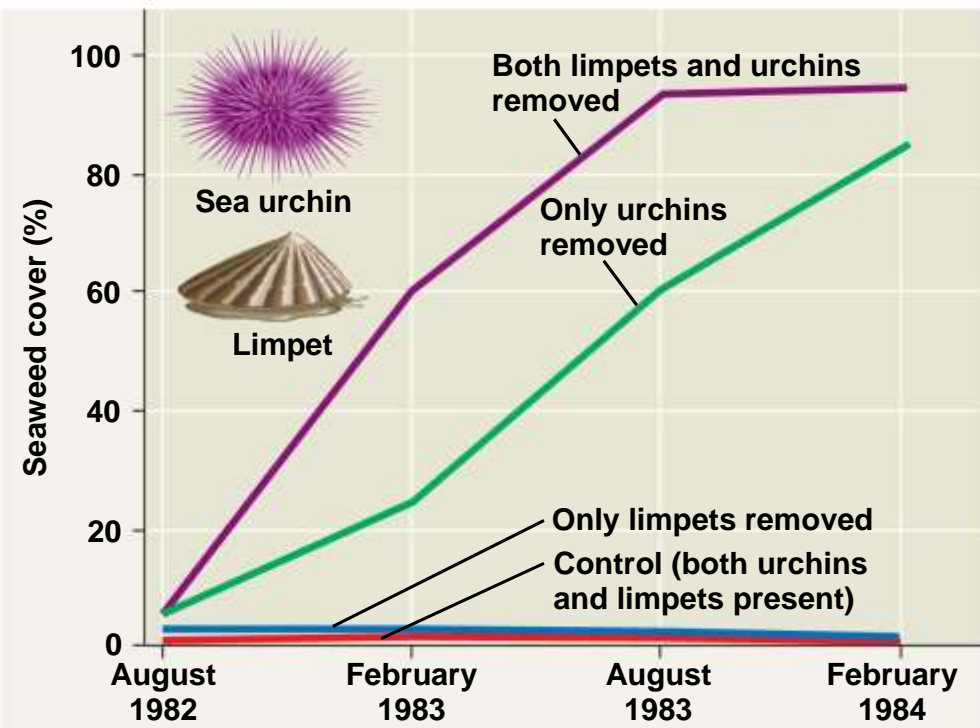
- **Experiment:** Does feeding by sea urchins limit seaweed distribution?
 - Researchers reasoned that, if sea urchins are the limiting biotic factor in seaweed distribution, then more seaweed should invade an area from which sea urchins have been removed
 - To isolate the effects of sea urchins from other seaweed-eating animals (limpets), researchers created 3 experimental groups adjacent to a control site:
 - Only sea urchins removed
 - Only limpets removed
 - Both sea urchins and limpets removed



- **Results:** Researchers observed a large difference in seaweed growth between areas with and without sea urchins
- **Conclusion:** Removing both limpets and sea urchins resulted in the greatest increase in seaweed cover, indicating that both species limit seaweed distribution
 - Removing only urchins, however, compared to removing only limpets, resulted in more seaweed cover

- Thus, researchers concluded that sea urchins have a much greater effect than limpets on limiting seaweed distribution

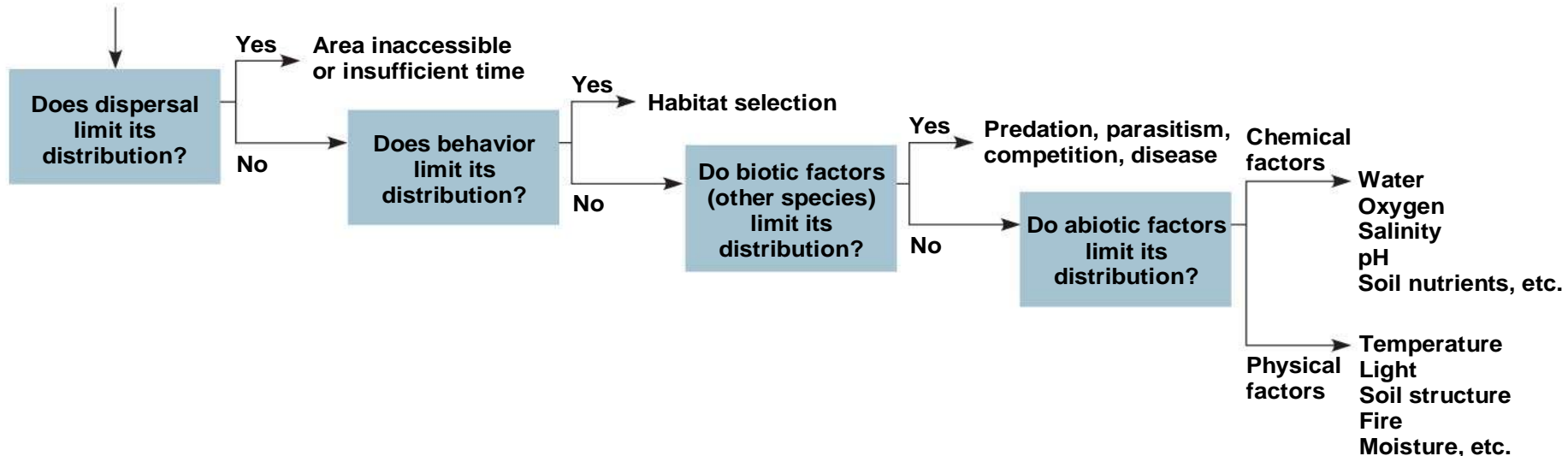
RESULTS



Abiotic Factors

- The final consideration for species distribution is: Do abiotic (nonliving) factors limit a species' distribution?
 - If the physical conditions in a particular area do not allow a species to survive and reproduce, then that species will not be found there
 - Abiotic factors affecting distribution of organisms include:
 - Temperature, water, sunlight, wind, rocks, and soil

Why is species X absent from an area?



Temperature

- Environmental temperature is an important factor in distribution of organisms because of its effects on biological processes
 - Cells (which contain water) may freeze and rupture below 0 C
 - Most proteins denature above 45 C
 - Few organisms can maintain active metabolisms at very low or high temperatures
 - Most organisms function best within a specific range of environmental temperature
 - Temperatures outside this range may force animals, including mammals and birds, to expend energy to regulate their internal temperature

Water

- Water availability in habitats is another important factor in species distribution
 - Species living at the seashore or in tidal wetlands can desiccate (dry out) as the tide recedes
 - Terrestrial organisms face a nearly constant threat of desiccation
 - Thus, the distribution of these terrestrial species reflects their ability to obtain and conserve water
 - Ex) Desert organisms exhibit adaptations for water conservation

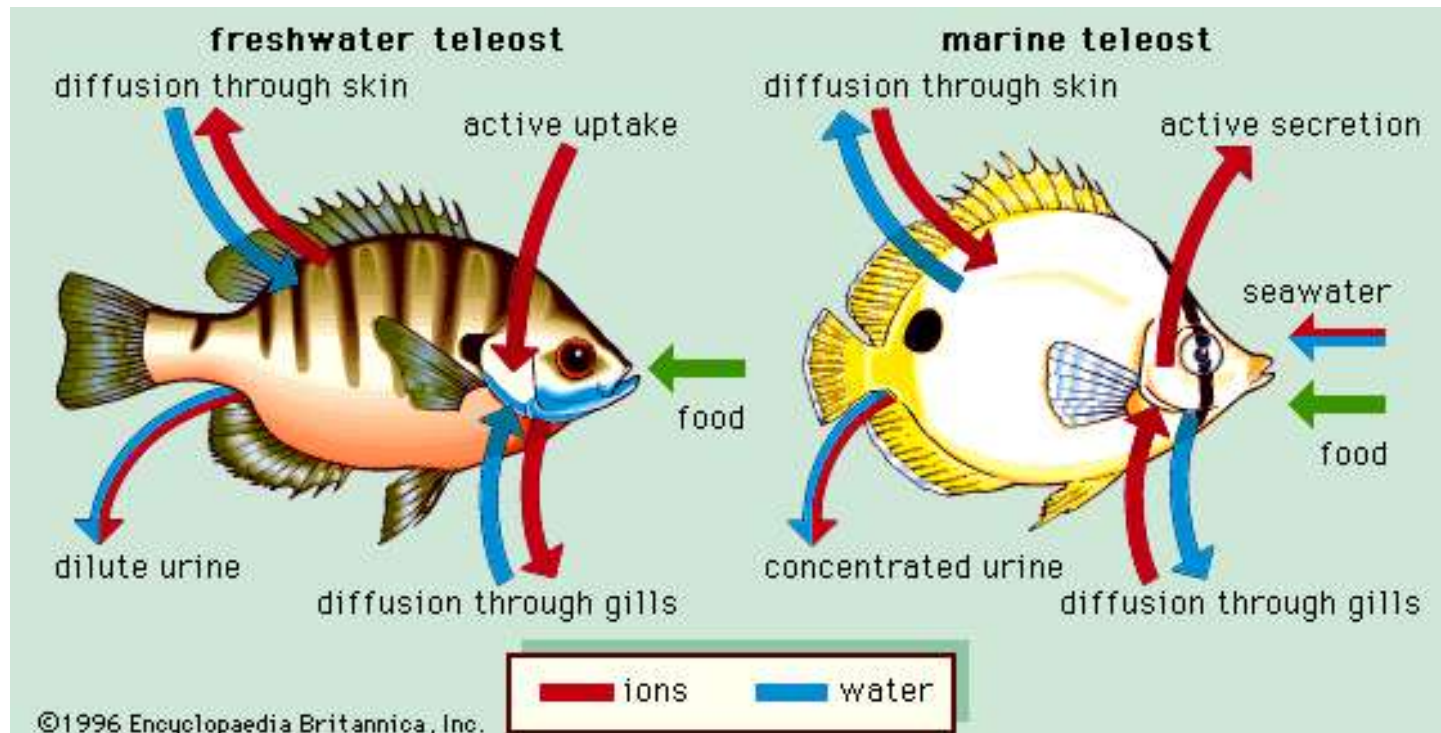


Salinity

- Salinity is another abiotic factor that may affect the distribution of species

- Salt concentration of water in the environment affects water balance of organisms through osmosis

- Most aquatic organisms are restricted to either freshwater or saltwater habitats by their limited ability to osmoregulate



Sunlight

- Light intensity and quality affect photosynthesis and thus the distribution of photosynthetic species
 - In forests, competition for light is particularly intense, especially for seedlings growing on the forest floor
 - In aquatic environments, most photosynthesis occurs near the surface because water absorbs light
 - Every meter of water depth selectively absorbs ~45% of red light and ~2% of blue light

Sunlight

- Too much light can also limit the survival and thus distribution of species
 - At high elevations (alpine environments) the atmosphere is thinner and absorbs less UV radiation
 - As a result, the sun's rays are much more likely to damage DNA and proteins
 - These organisms also face other challenges, including freezing temperatures and strong winds
 - In deserts, high light levels increase temperature and can stress plants and animals



Rocks and Soil

- Many characteristics of soil limit distribution of plants and thus the animals that feed upon them:
 - Physical structure
 - The structure of the substrate (bottom surface) of marine and freshwater environments determines which organisms can attach or burrow into it
 - pH
 - Extremely acidic or basic conditions are intolerable to most species
 - pH of soil and water can also affect the solubility of nutrients and toxins
 - Mineral composition
 - Many organisms, especially photosynthesizers, require specific minerals to undergo their normal life processes

Climate

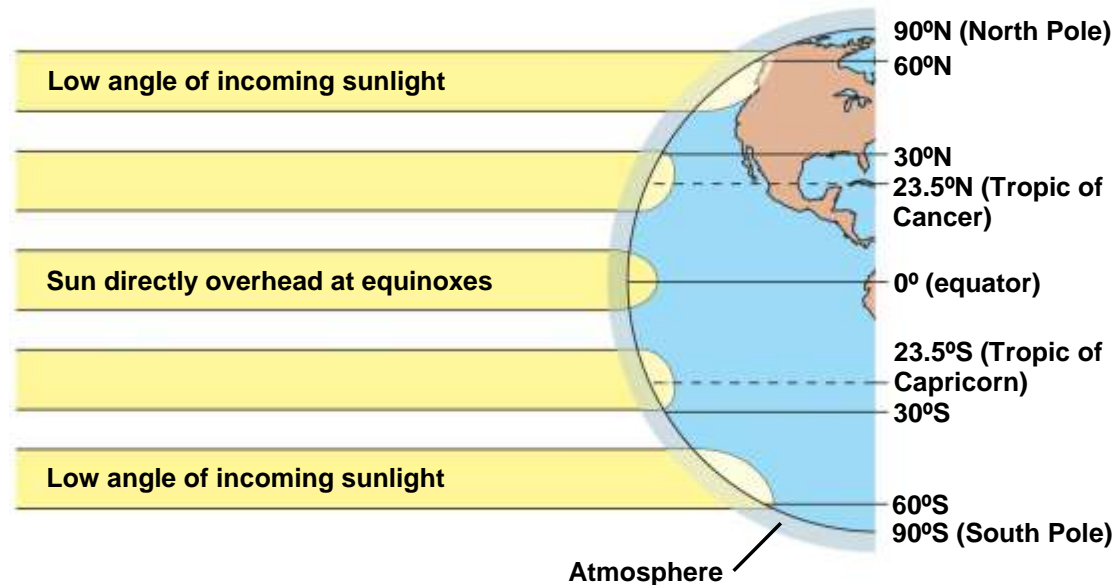
- **Climate**, the long-term, prevailing weather conditions in a particular area, is another major abiotic factor that limits the distribution of species
 - Four major abiotic components of climate are temperature, water, sunlight, and wind
- Climate patterns can be described on 2 scales:
 - 1) **Macroclimate** consists of patterns on the global, regional, and local level
 - 2) **Microclimate** consists of very fine patterns, such as those encountered by the community of organisms underneath a fallen log

Global Climate Patterns

- Earth's global climate (macroclimate) patterns are determined largely by solar energy and the planet's movement in space
 - Fluctuations in climates are caused primarily by:
 - Latitudinal variations in sunlight intensity
 - Seasonal variation in sunlight intensity
 - Global air circulation and precipitation patterns
 - Global wind patterns

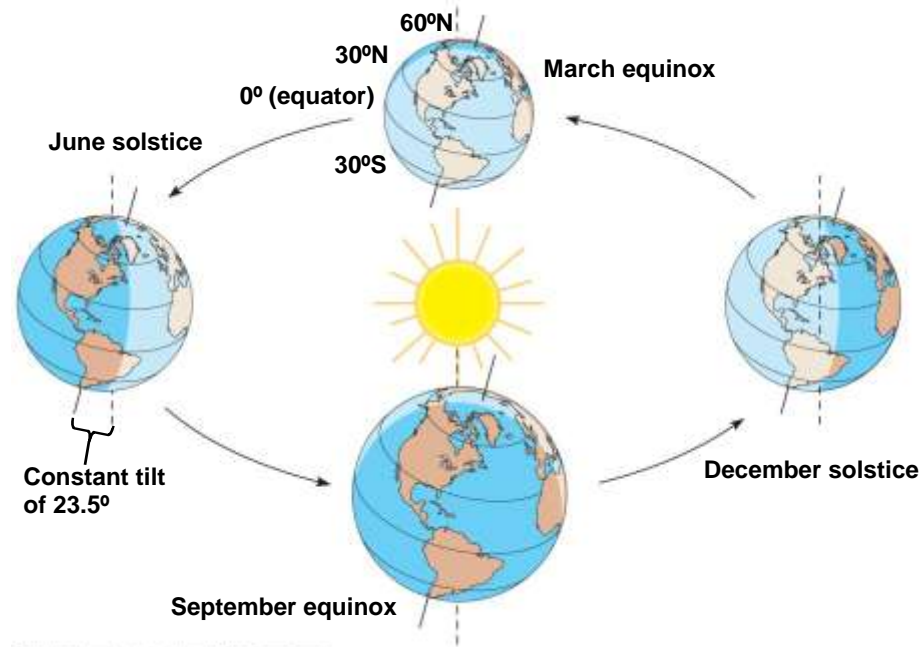
Latitudinal Variation in Sunlight Intensity

- Earth's curved shape causes latitudinal variation in the intensity of sunlight
 - In those regions where sunlight strikes most directly, more heat and light per unit of surface area are delivered
 - Sunlight strikes most directly in the **tropics** (regions that lie between 23.5 north latitude and 23.5 south latitude)
 - At higher latitudes, sunlight strikes Earth at an oblique angle, thus providing less light energy to these regions



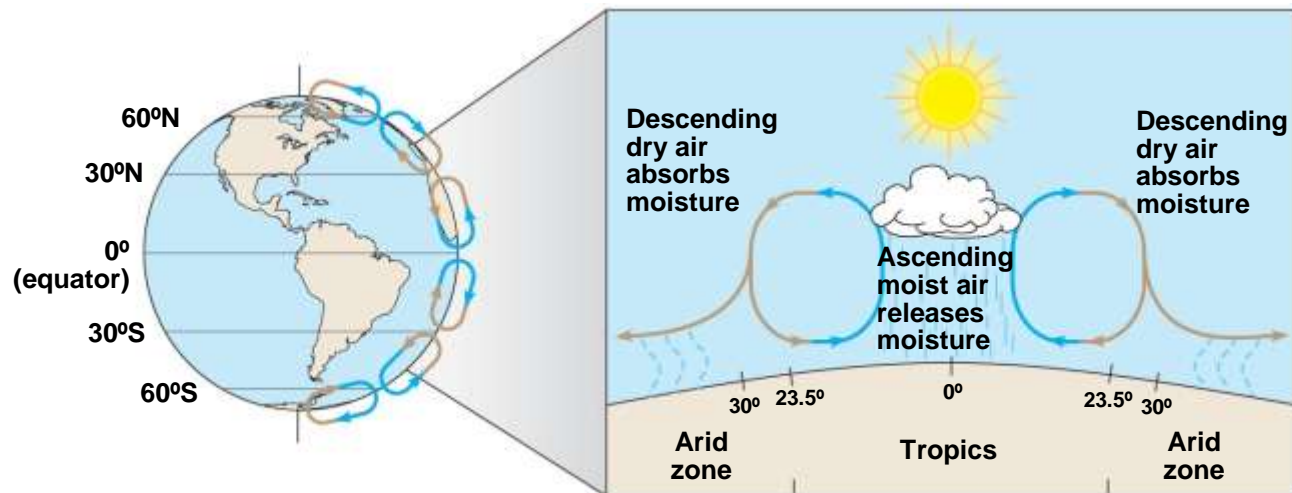
Seasonal Variation in Sunlight Intensity

- Earth's tilt (23.5° relative to its plane of orbit around the sun) causes seasonal variation in the intensity of solar radiation
 - The tropics experience the greatest annual input of solar radiation and the least seasonal variation
 - Seasonal variations of light and temperature increase toward the poles
 - Ex) The Northern hemisphere tilts away from the sun, and thus has the shortest day and longest night during the December solstice

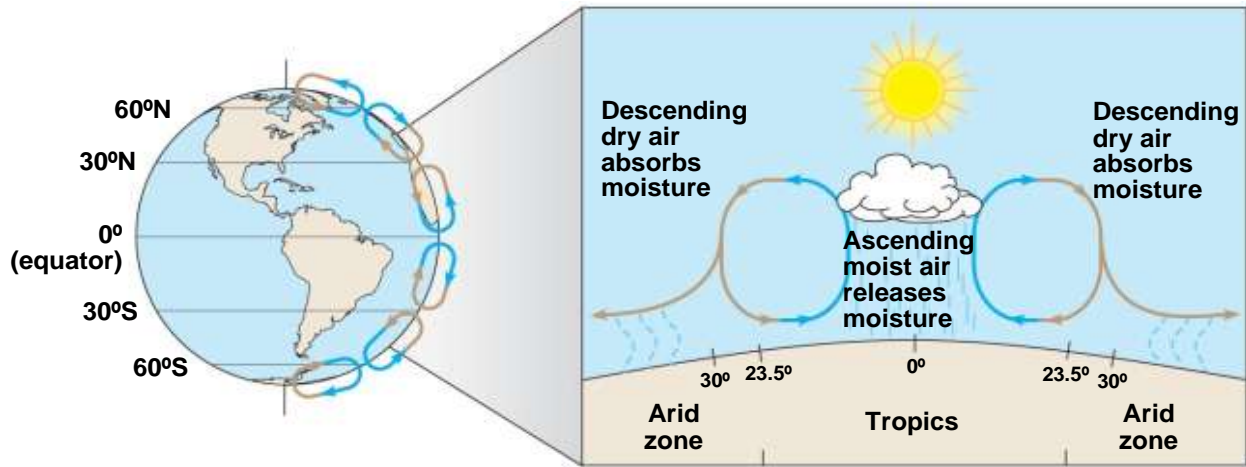


Global Air Circulation and Precipitation Patterns

- Global air circulation and precipitation patterns play major roles in determining climate patterns
 - Intense solar radiation near the equator initiates these patterns
 - High temperatures in the tropics evaporate water from Earth's surface and cause wet, warm air masses to rise (blue arrows) and flow toward poles
 - These rising air masses release much of their water content, creating abundant precipitation in the tropics

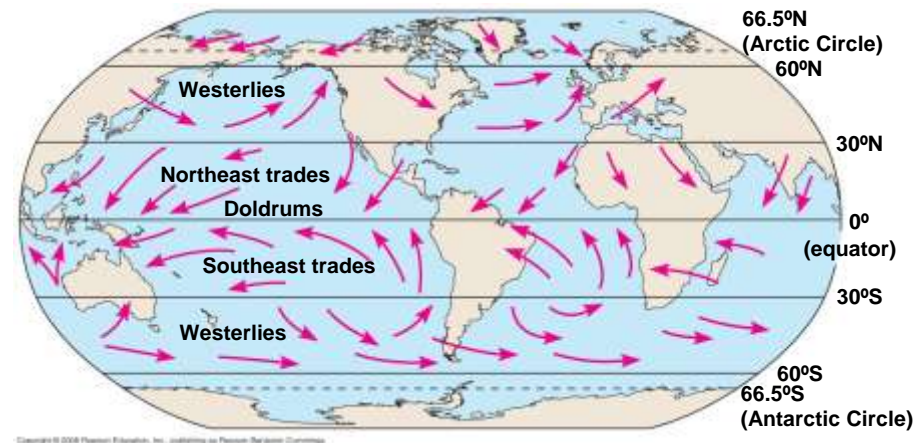


- By the time these air masses reach high altitudes, they are dry and thus absorb moisture from the land and they descend back down
 - This creates an arid climate characteristic of deserts that are commonly found at latitudes around 30° north and south
- Some of this descending air then flows toward the poles
 - At latitudes around 60° north and south, the air masses rise again and release abundant precipitation (though less than in the tropics)
- Then, this cold, dry air rises and flows to the poles
 - Here, it descends and flows back toward the equator, absorbing moisture as it goes, thus creating the dry and bitterly cold climates of the polar regions



Global Wind Patterns

- Predictable global air patterns also cause variations in climate patterns
 - As Earth's rotates on its axis, land near the equator moves faster than than at the poles
 - This deflects winds from their vertical paths and creates more easterly and westerly flows
 - Cooling trade winds blow from east to west in the tropics
 - Prevailing westerlies blow from west to east in the temperate zones
 - Temperate zones are defined as regions between:
 - The Tropic of Cancer and the Arctic Circle
 - The Tropic of Capricorn and the Antarctic Circle

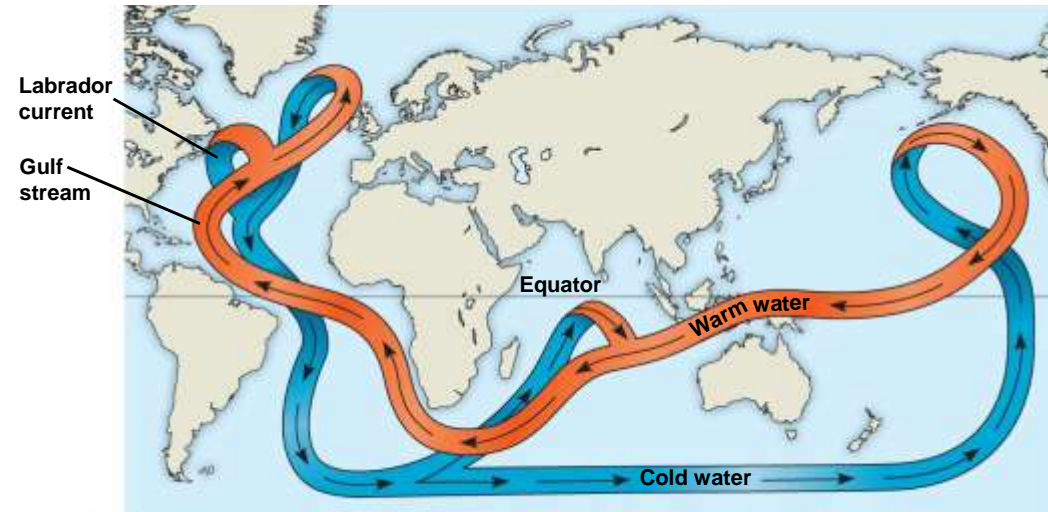


Regional, Local, and Seasonal Effects on Climate

- Proximity to bodies of water and topographic features (ex: mountain ranges) also contribute to local variations in climate
 - Seasonal variation also influences climate

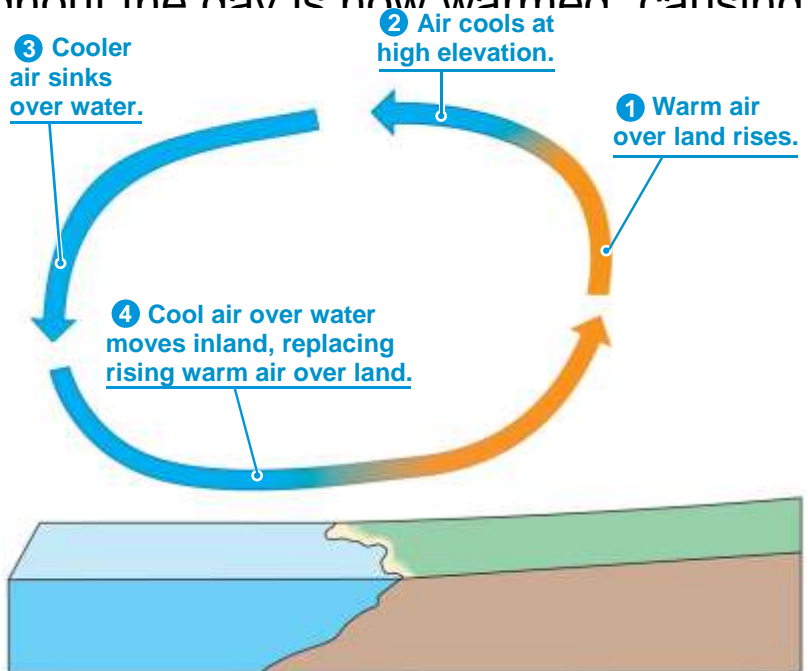
- Ocean currents influence climate along the coasts of continents by heating or cooling overlying air masses that pass over land
 - A system of deep ocean circulation called the great ocean conveyor belt is also particularly influential
 - Water is warmed at the equator and flows along the ocean surface to the North Atlantic
 - As the water moves to higher latitudes, it cools and becomes denser, sinking thousands of meters and displacing warmer water back toward the surface
 - Warmer water near the equator heats overlying air masses, while colder water at increasing latitudes cools the air, which may then pass across the land

- Ex) The west coast of northern Europe has a mild climate because the Gulf Stream carries warm water from the equator to the North Atlantic



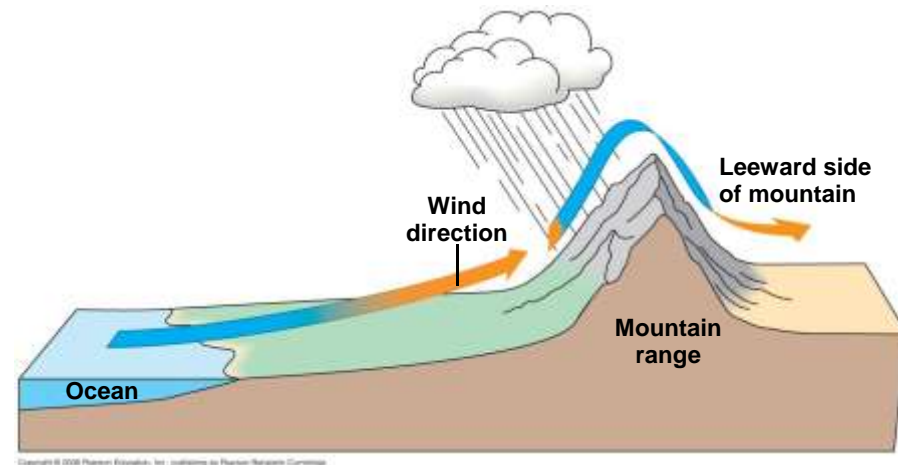
- The high specific heat of water (its ability to retain heat) also helps to moderate climate of coastal regions
 - On a hot day, the land is warmer than nearby bodies of water, causing air over the land to heat up
 - As this air heats, it rises to high elevations and is replaced by cooler air from over the water
 - The opposite effect is seen at night
 - Water that has absorbed heat throughout the day is now warmed, causing the overlying air to

- This warmer air rises, drawing cooler air from back over the water
- The cooler air is then replaced with warmer air from offshore



- Mountains also affect climate because they have a significant effect on:
 - The amount of sunlight reaching an area
 - South-facing slopes in the Northern Hemisphere receive more sunlight than nearby north-facing slopes, creating warmer and drier conditions
 - These abiotic differences influence species distribution
 - Ex) In many mountains of western North America, spruce and conifers occupy the cooler, north-facing slopes, while shrubby, drought-resistant plants inhabit the south-facing slopes
 - Local temperature
 - Every 1000 meter increase in elevation produces a temperature drop of ~ 6 C, equivalent to the decrease in temperature caused by an 880 km increase in latitude

- Mountains also have a significant effect on rainfall
 - As moist air moves in off the ocean and encounters the windward side of a mountain, it flows upward
 - This ascending air cools at higher altitudes and drops a large amount of water in the form of precipitation
 - By the time this air reaches the leeward side of the mountain, it is cooler and drier
 - This creates a “rain shadow” on this side of the mountain as dry air picks up any available moisture from the area below
 - As a result, deserts commonly occur on the leeward side of mountain ranges



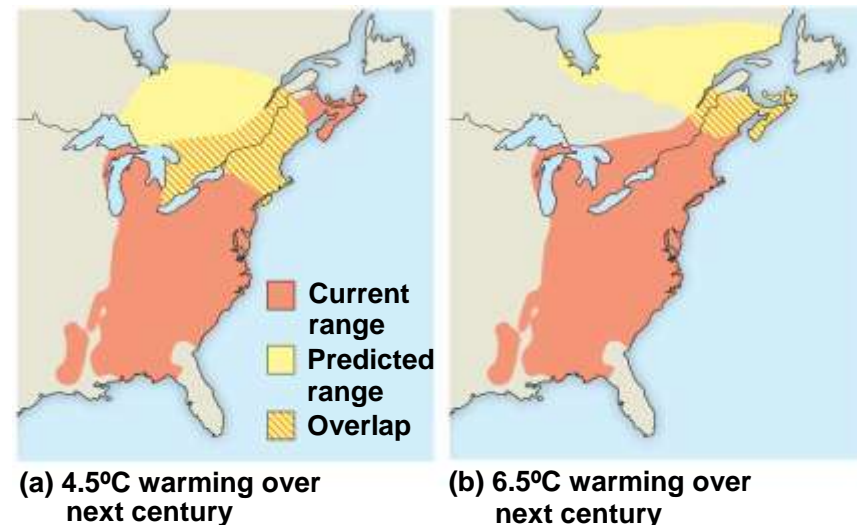
- Seasonal changes also influence climate
 - The angle of the sun produced by Earth's tilted axis leads to many global changes, especially in middle to high latitudes:
 - Changes in day length
 - Variation in amounts of solar radiation
 - Changes in temperature
 - The changing angle of the sun over the course of a year also affects local environments
 - The belts of warm and dry air on either side of the equator move slightly with the changing angle of the sun
 - This produces the “wet” and “dry” seasons characteristic of the tropical regions that lie around 20 N and 20 S of the equator

Microclimate

- Microclimate refers to the climate of a small, specific place in contrast with that of the surrounding area
 - These local variations in climate are caused by:
 - Casting of shade
 - Evaporation from soil
 - Changing wind patterns
 - Consider a forest as an example:
 - Low-lying ground within the forest, which are less exposed to solar radiation and wind currents, is usually wetter than higher ground
 - Large stones or logs can create buffers against extremes of temperature and moisture

Long-Term Climate Change

- Global climate changes currently under way will profoundly affect the biosphere
 - One way to predict the effects of future global climate change is to study previous changes, since the last ice age ended
 - As glaciers began retreating 16,000 years ago, for example, tree distribution patterns changed, expanding northward
 - Based on climate-change models, as climate continues to warm, many species will be forced to expand their natural ranges in order to survive
 - Ex) The American beech will need to move 7-9 km per year northward to keep pace with the warming climate
 - Since the end of the last ice age, however, the beech has migrated only ~0.2 km per year
 - Thus, species that have difficulty dispersing may have smaller ranges or could become extinct



Concept Check 52.2

- 1) Give examples of human actions that could expand a species' distribution by changing its (a) dispersal or (b) biotic interactions.
- 2) Explain how the sun's unequal heating of Earth's surface influences global climate patterns.
- 3) You suspect that deer are restricting the distribution of a tree species by preferentially eating the seedlings of the tree. How might you test that hypothesis?

Concept 52.3:

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

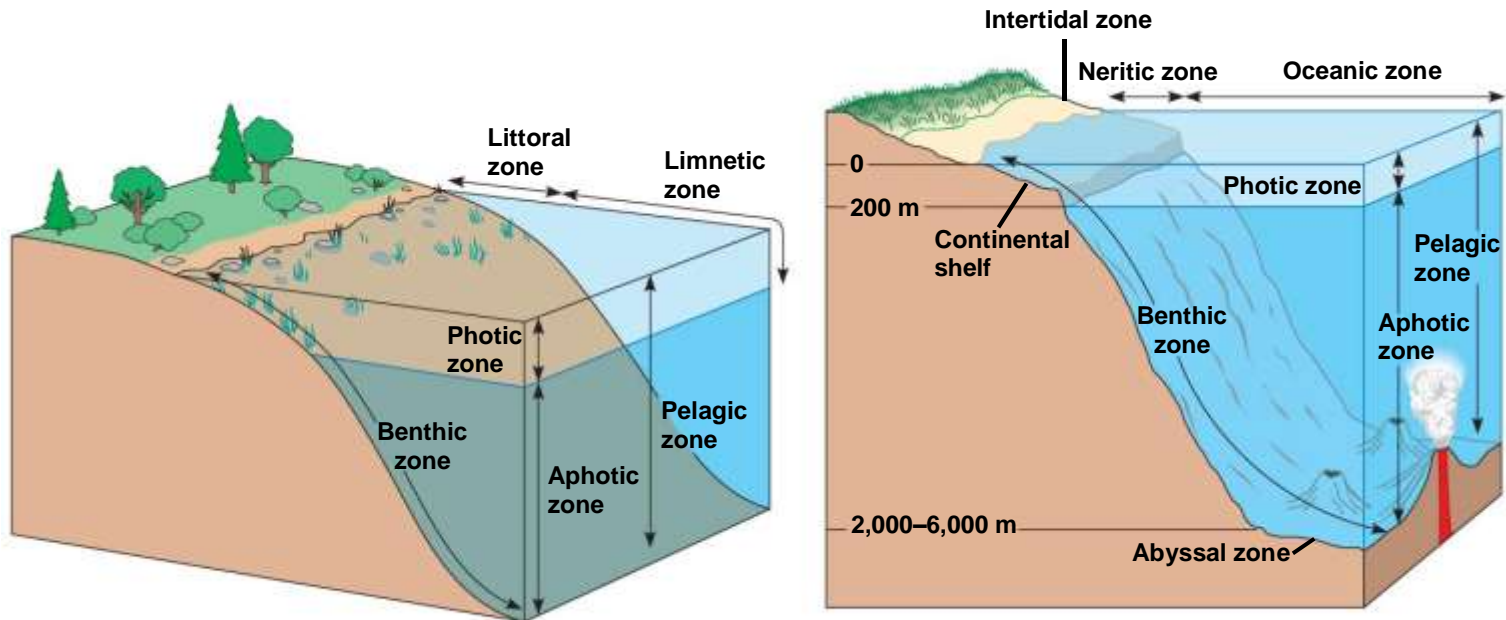
- Varying combinations of biotic and abiotic factors determine the nature of Earth's many biomes
 - **Biomes** are the major ecosystems that occupy broad geographic regions of land or water
 - Terrestrial biomes are generally characterized by vegetation type
 - Aquatic biomes are classified based on the physical environment

- Aquatic biomes account for the largest part of the biosphere in terms of area
 - Ecologists classify these aquatic biomes on the basis of physical and chemical characteristics
 - Ex) They can contain fresh water or salt water (marine)
 - Oceans make up the largest marine biome, covering about 75% of Earth's surface
 - Their vast size accounts for the enormous impact they have on the biosphere
 - Evaporation of water from the oceans provides most of the planet's rainfall
 - Ocean temperatures have a major effect on world climate and wind patterns
 - Marine algae and photosynthetic bacteria supply a substantial portion of the world's oxygen and consume large amounts of atmospheric carbon dioxide



Stratification of Aquatic Biomes

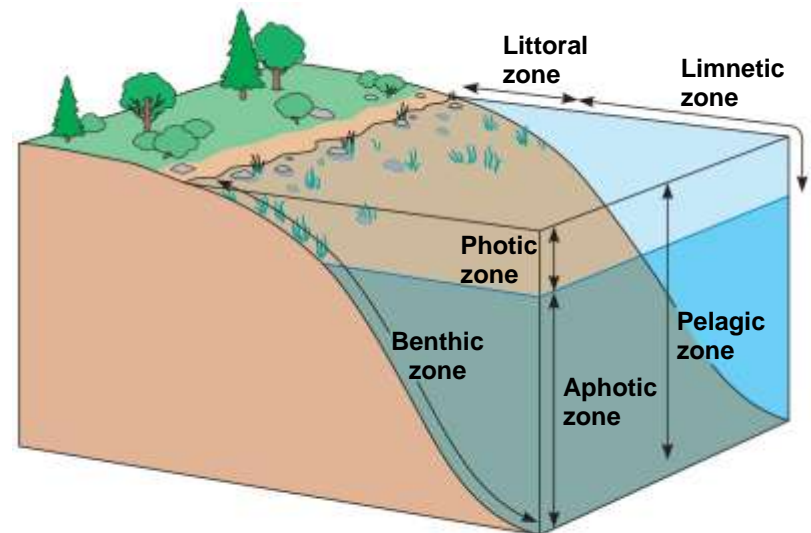
- Many aquatic biomes are stratified (layered) into zones defined by:
 - Light penetration
 - **Photic zone:** the upper portion of an aquatic biome where there is sufficient light for photosynthesis
 - **Aphotic zone:** the lower region of an aquatic biome where little light penetrates



(a) Zonation in a lake

(b) Marine zonation

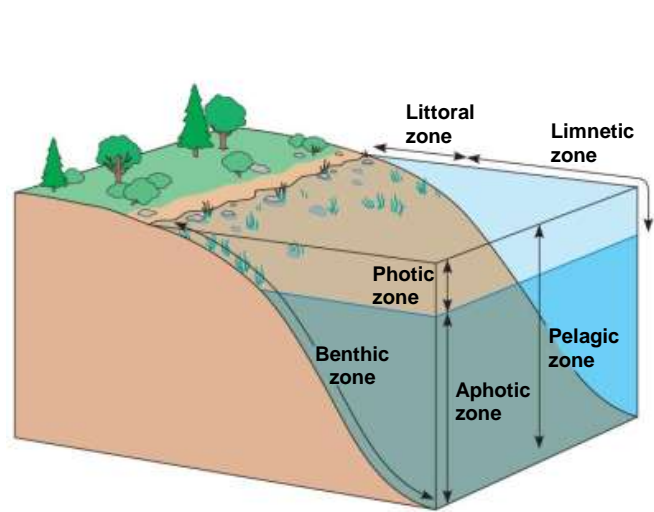
- The shallow, well-lighted waters close to the shore make up the **littoral zone** of lakes
 - This zone is home to rooted and floating aquatic plants
- Deeper water farther from shore makes up the **limnetic zone**
 - This zone is inhabited by a variety of phytoplankton and cyanobacteria, as well as small drifting heterotrophs, such as zooplankton
- The benthic zone is inhabited by assorted invertebrates whose species composition depends partly on oxygen levels
 - Fishes lives in all lake zones with sufficient oxygen



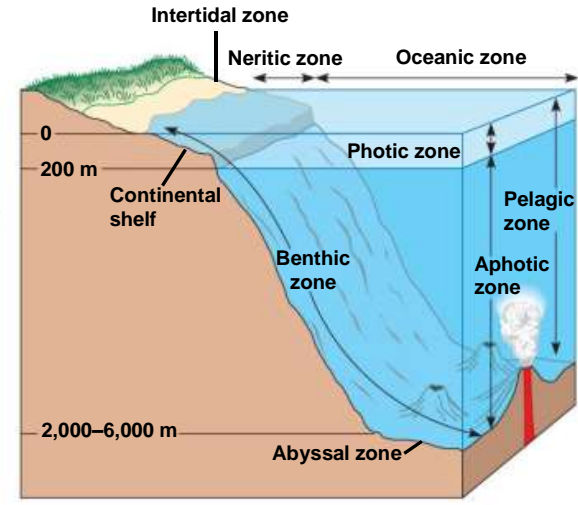
(a) Zonation in a lake

- Many aquatic biomes are stratified (layered) into zones defined by:
 - Depth
 - **Benthic zone:** the bottom portion of all aquatic biomes, composed of organic and inorganic sediment
 - The communities of organisms that inhabit the benthic zone are collectively called the *benthos*
 - A major source of food for many benthic species is dead organic matter that falls from the productive surface water called **detritus**

- **Abyssal zone:** the most extensive part of the ocean that lies within the benthic zone at a depth of between 2000 and 6000 meters

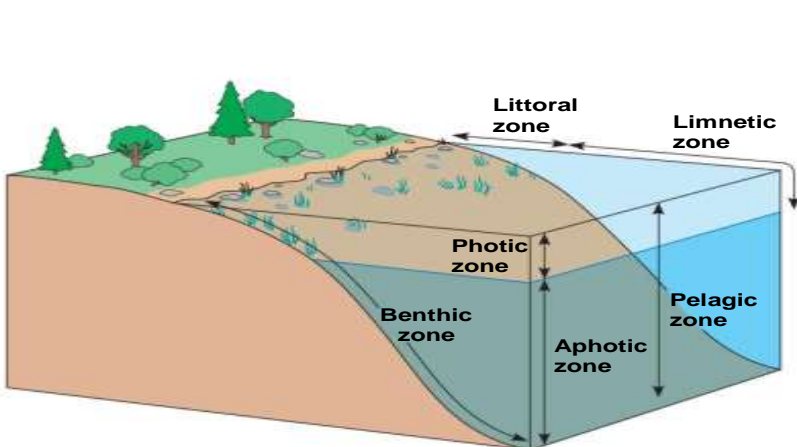


(a) Zonation in a lake



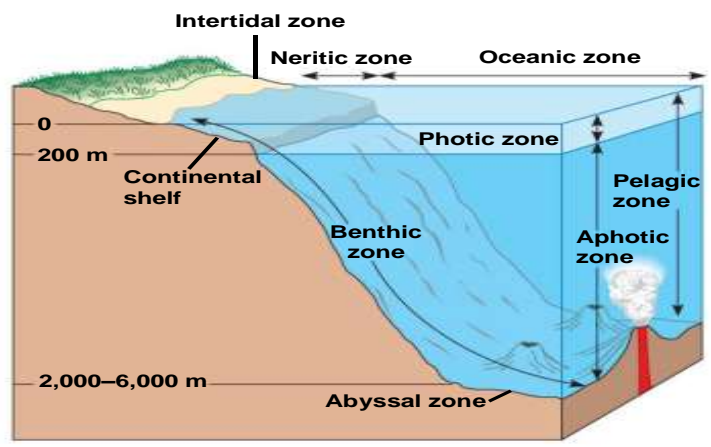
(b) Marine zonation

- Many aquatic biomes are stratified (layered) into zones defined by:
 - Temperature
 - **Thermocline:** a narrow layer of abrupt temperature change separating the more uniformly warm upper layer from the more uniformly cold deeper waters
 - The water temperature is determined by how much sunlight penetrates at a particular depth
 - Many lakes undergo a semiannual mixing of their waters called **turnover**
 - Turnover mixes oxygenated water from the surface with nutrient-rich water from the bottom



(a) Zonation in a lake

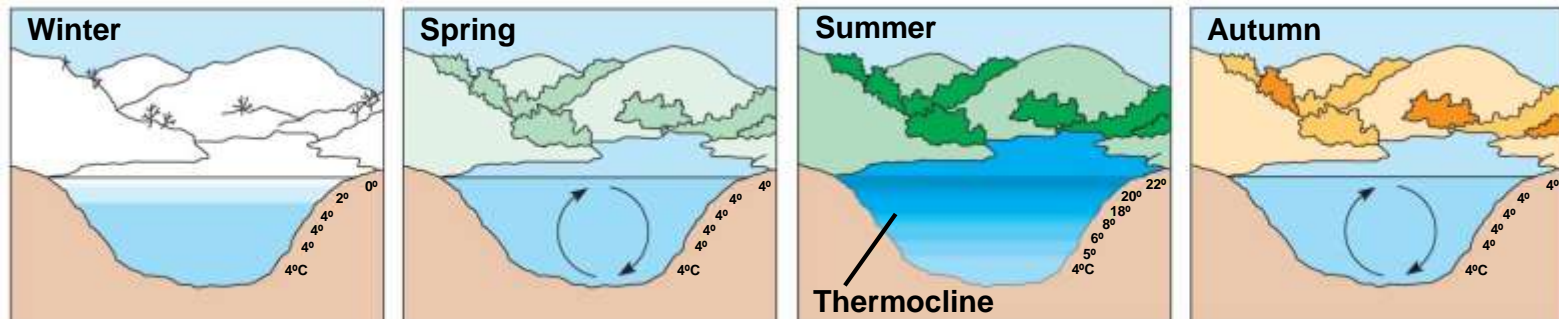
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(b) Marine zonation

Seasonal Turnover

- In winter, the coldest water in the lake lies just below the surface ice
 - Water is progressively warmer at the deeper levels of the lake
- In the spring, the surface water warms as the sun melts the ice and sinks below the cooler layer immediately below, eliminating thermal stratification
 - Spring winds also mix the water to great depths, bringing oxygen to the bottom waters and nutrients to the surface
- In summer, the lake regains its thermal stratification, with warm surface water separated from cold bottom water by a thermocline
- In autumn, the surface water cools rapidly and sinks below the underlying layers
 - This remixes the water until the surface begins to freeze and the winter thermal stratification is reestablished



Aquatic Biomes

- Major aquatic biomes can be characterized by their:
 - Physical environment
 - Chemical environment
 - Geological features
 - Photosynthetic organisms
 - Heterotrophs

- **Lakes:** standing bodies of water ranging from ponds a few square meters in area to lakes covering thousands of square kilometers
 - The salinity, oxygen concentration, and nutrient content differ greatly among lakes
 - **Oligotrophic lakes** are nutrient-poor and generally oxygen-rich
 - These lakes generally have little decomposable organic matter in their bottom sediments
 - **Eutrophic lakes** are nutrient-rich and often depleted of oxygen
 - The large amounts of organic matter in bottom sediments is decomposed at high rates, leading to this periodic oxygen depletion
 - Oligotrophic lakes may become more eutrophic over time as runoffs add sediment and nutrients



An oligotrophic lake in Grand Teton National Park, Wyoming



A eutrophic lake in the Okavango Delta, Botswana

- A **wetland** is a habitat that is inundated (flooded) by water at least some of the time and that supports plants adapted to water-saturated soil
 - Some wetlands are inundated at all times, whereas others flood infrequently
- Both water and soils in wetlands are periodically low in dissolved oxygen
 - This is due to high organic production by plants and decomposition by microbes and other organisms
- Wetlands are among the most productive biomes on Earth
 - Their water-saturated soils favor growth of plants that have adaptations enabling them to grow in water or soil that is periodically anaerobic
 - Ex) Floating pond lilies
 - Wetlands are also home to a diverse community of invertebrates, birds, crustaceans, dragonflies, otters, alligators, and owls



Okefenokee National Wetland Reserve in Georgia

- Wetlands can be classified according to where they develop:
 - ***Basin wetlands***: develop in shallow basins, ranging from upland depressions to filled-in lakes and ponds
 - ***Riverine wetlands***: develop along shallow and periodically flooded banks of rivers and streams
 - ***Fringe wetlands***: occur along the coasts of large lakes and seas, where water flows back and forth because of rising lake levels or tidal action
 - Fringe wetlands include both freshwater and marine biomes



Okefenokee National Wetland Reserve in Georgia

- Streams and rivers are characterized primarily by their currents
 - Streams are generally cold, clear, turbulent, and swift
 - Rivers may form downstream, with the addition of numerous tributaries
 - River waters are generally warmer and more turbid
- The salt and nutrient content of rivers and streams increases from the headwaters (water source) to the mouth
 - Headwaters are generally rich in oxygen
 - Downstream waters may also contain substantial oxygen, except in areas enriched by organic matter
- Streams are often narrow with rocky bottoms and alternate between shallow sections and deeper pools
 - Rivers are generally wider and meandering, with silty sediments at their bottoms
- A diversity of fishes and invertebrates inhabit unpolluted rivers and streams



A headwater stream in the Great Smoky Mountains



The Mississippi River far from its headwaters

- An **estuary** is a transition area between river and sea
 - Seawater flows up the estuary channel during a rising tide and flows back during the falling tide
 - The higher-density seawater often occupies the bottom of these channels and mixes little with the lower-density river water at the surface
 - Salinity of estuaries varies with the rise and fall of the tides
- Estuaries are nutrient rich and highly productive
 - Saltmarsh grasses and algae, including phytoplankton, are the major producers in estuaries
 - An abundant supply of food attracts marine invertebrates and fish



An estuary in a low coastal plain of Georgia

- An **intertidal zone** is periodically submerged and exposed by the tides, twice daily on most marine shores
 - Upper zones experience longer exposures to air and greater variations in temperature and salinity
 - Oxygen and nutrient levels are generally high and are renewed with each turn of the tides
 - The substrates of intertidal zones are generally either rocky or sandy



Rocky intertidal zone on the Oregon coast

- Changes in physical conditions from the upper to the lower intertidal zones limit the distribution of many organisms to particular strata
 - Intertidal organisms are challenged by variations in temperature and salinity and by the mechanical forces of wave action
 - A high diversity of attached marine algae inhabit rocky intertidal zones, especially in the lower zones
 - Sandy intertidal zones exposed to vigorous wave action generally lack attached plants or algae
 - Sandy intertidal zones in protected bays or lagoons often support rich beds of sea grass and algae
 - Many animals of rocky intertidal environments have structural adaptations that enable them to attach to the hard substrate
 - Many animals in sandy or muddy intertidal zones, including worms, clams, and crustaceans, bury themselves as feed as the tide brings in sources of food

- The **oceanic pelagic biome** is a vast realm of open blue water, constantly mixed by wind-driven oceanic currents
 - This biome covers approximately 70% of Earth's surface and has an average depth of ~4000 meters
 - The deepest point in the ocean is more than 10,000 meters
 - Oxygen levels are generally high and nutrient concentrations are generally lower than in coastal waters
- Phytoplankton and zooplankton are the dominant organisms in this biome
 - Photosynthetic plankton account for about half of the photosynthetic activity on Earth
- Also found are free-swimming animals, such as large squids, fishes, sea turtles and marine mammals



Open ocean off the island of Hawaii

- **Coral reefs** are formed from the calcium carbonate skeletons of corals (phylum Cnidaria)
 - Shallow corals live in the photic zone of tropical marine environments with high water clarity
 - Deep-sea corals are also found 200-1500 meters below the water surface
- Corals require high oxygen levels as well as a solid substrate for attachment
 - A typical coral reef begins as a *fringing reef* on a young, high island
 - Later in the history of the island, it forms an offshore *barrier reef*
 - As the island gets older and submerges, it becomes a *coral atoll*
- Unicellular algae live within the tissues of the corals and form a mutualistic relationship that provides the corals with organic molecules
 - Fish and invertebrate diversity is also exceptionally high in these areas



A coral reef in the Red Sea

- The **marine benthic zone** consists of the seafloor below the surface waters of the coastal, or **neritic**, zone and the offshore pelagic zone
 - Except for the shallow coastal areas, the marine benthic zone receives no sunlight
 - Water temperature declines with depth, while pressure increases
 - Organisms in the very deep benthic, or abyssal, zone are adapted to continuous cold and very high water pressure
 - Oxygen is present at sufficient concentrations to support a variety of life forms
 - Photosynthetic organisms, mainly seaweeds and algae, are limited to shallow benthic areas with sufficient light
 - Chemoautotrophic prokaryotes are found near deep-sea hydrothermal vents
 - Neritic benthic communities include numerous invertebrates and fishes



A deep-sea hydrothermal vent community

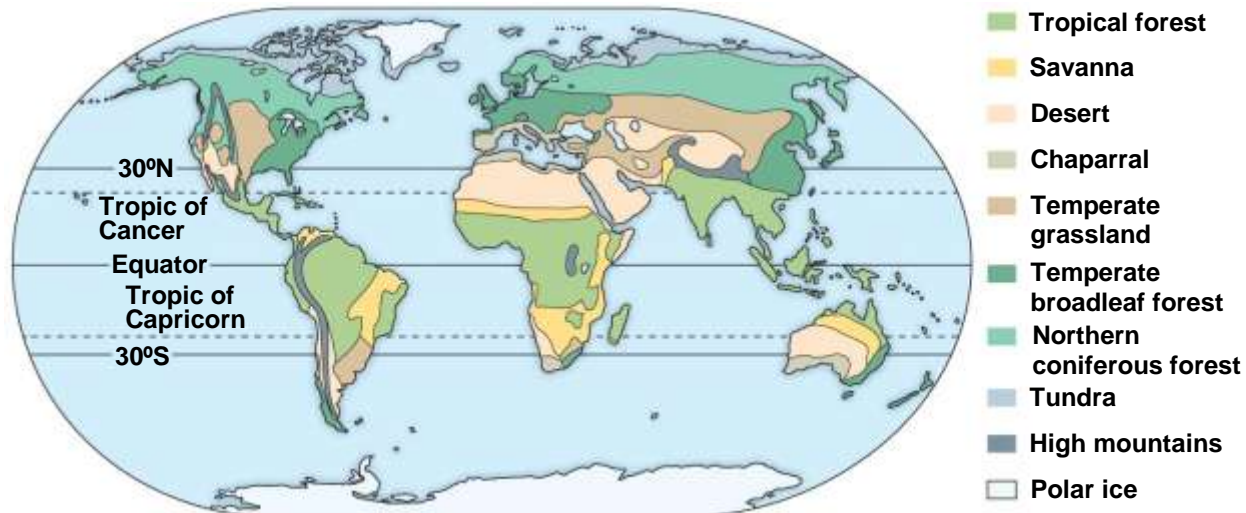
Concept Check 52.3

- 1) Many organisms living in estuaries experience fresh and saltwater conditions each day with the rising and falling of tides. What challenge does this pose for the physiology of the organisms?
- 2) Why are phytoplankton, and not benthic algae or rooted aquatic plants, the dominant photosynthetic organisms in the ocean pelagic zone?
- 3) Water leaving a reservoir behind a dam is often taken from deep layers of the reservoir. Would you expect fish found in a river below a dam in summer to be species that prefer colder or warmer water than fish found in the undammed river? Explain.

Concept 52.4:

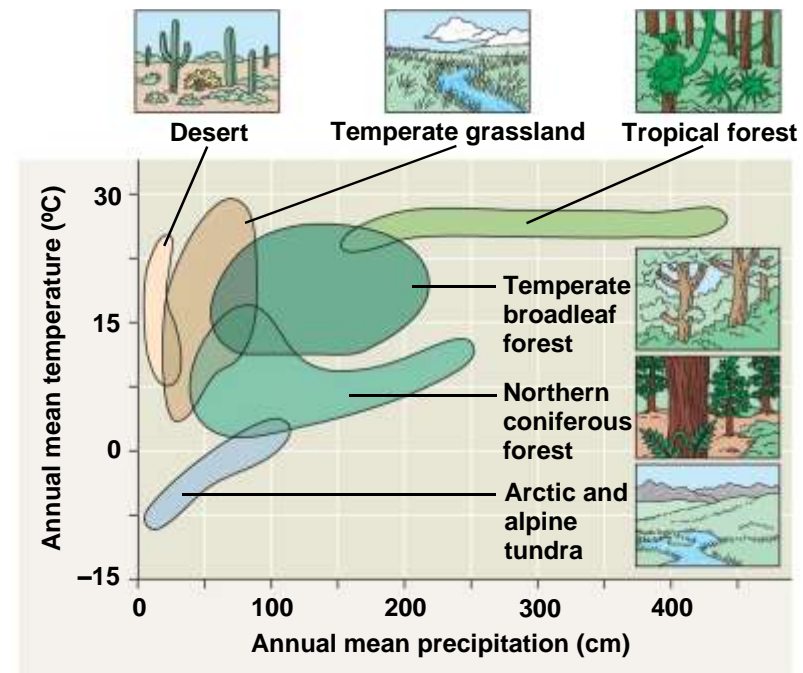
The structure and distribution of terrestrial biomes are controlled by climate and disturbance

- Climate is very important in determining why terrestrial biomes are found in certain areas
 - Latitudinal patterns of climate over Earth's surface produces the latitudinal patterns of biome distribution
 - These biome patterns can, in turn, be modified by **disturbances**, such as a storms, fires, or human activity



Climate and Terrestrial Biomes

- Climate also has a great impact on the distribution of organisms
 - This can be illustrated with a **climograph**, a plot of the temperature and precipitation in a region
 - Ex) Notice that the range of precipitation in northern coniferous forests is similar to that in temperate forests, but the temperatures are different
- Biomes are also affected by the pattern of temperature and precipitation through the year
 - Some areas may receive regular precipitation throughout the year, whereas other areas with the same annual precipitation have distinct wet and dry seasons
 - This explain why areas with similar values for annual temperature and precipitation contain different biomes



General Features of Terrestrial Biomes and the Role of Disturbance

- Terrestrial biomes are often named for major physical or climatic factors and for their predominant vegetation
 - Ex) Temperate grasslands are generally found in middle latitudes, where the climate is more moderate (temperate) than in the tropics or polar regions and are also dominated by various grass species
- Terrestrial biomes usually grade into each other, without sharp boundaries
 - The area of intergradation, called an **ecotone**, may be wide or narrow

- Vertical layering is also an important feature of terrestrial biomes
 - In many forests, the layers from top to bottom consist of:
 - The upper canopy
 - The low-tree area
 - The shrub understory
 - The ground layer of herbaceous plants
 - The forest floor (the litter area)
 - The root layer
 - Nonforest biomes have similar, though usually less pronounced, layers
 - Grasslands have an herbaceous layer of grasses and forbs (small broadleaf plants), a litter layer, and a root layer
- Layering of vegetation provides many different habitats for animals, which often occupy well-defined feeding areas
 - Ex) Insectivorous birds and bats feed above canopies, while small mammals, numerous worms, and arthropods search for food in the litter and root layers

Terrestrial Biomes

- Terrestrial biomes can be characterized by:
 - Distribution
 - Precipitation
 - Temperature
 - Plants
 - Animals

Tropical Forest

- Tropical forests are found in equatorial and subequatorial regions
 - **Tropical rain forests** are characterized by relatively constant rainfall (200-400 cm annually)
 - **Tropical dry forests** are characterized by precipitation that is highly seasonal (150-200 cm annually, with a 6-7 month dry season)
- Air temperatures are high year-round, averaging 25-29 C, with little seasonal variation



A tropical rain forest in Borneo

Tropical Forest

- Plants: tropical forests are vertically layered and competition for light is intense
 - The top layer includes emergent trees that grow above a closed canopy
 - The next layer includes a canopy of trees
 - Below, are one to two layers of subcanopy trees
 - Shrub and herb layers are found on the forest floor
 - Broadleaf evergreen trees are dominant in tropical rainforests
 - Tropical dry forest trees drop their leaves during the dry season
- Animals: animal diversity is higher in tropical forests than in any other terrestrial biome
 - Millions of animal species, including an estimated 5–30 million still undescribed species of insects, spiders, and other arthropods, live within these forests

Desert

- Deserts occur in bands near 30° north and south latitude or at other latitudes in the interior of continents
 - Precipitation is low and highly variable, generally less than 30 cm per year
 - Deserts may be hot (above 50°C) or cold (below -30°C), with temperatures varying seasonally and daily
- Plants: desert landscapes are dominated by low, widely scattered vegetation
 - Desert plants adaptations include heat and desiccation tolerance, water storage, and reduced leaf surface area
- Common desert animals include many kinds of snakes and lizards, scorpions, ants, beetles, migratory and resident birds, and seed-eating rodents
 - Many are nocturnal and have adaptations for water conservation



A desert in the southwestern United States

Savanna

- **Savannas** are found in equatorial and subequatorial regions
 - Precipitation and temperature are seasonal
 - Rainfall averages 30-50 cm per year, with a dry season that can last 8-9 months
 - Temperatures are warm year-round, averaging 24-29 C, but vary with the seasons
- Plants: grasses and forbs make up most of the ground cover
 - Scattered trees are often thorny with small leaves, an adaptation to the relatively dry conditions
- Animals: common inhabitants include insects and mammals such as wildebeests, zebras, lions, and hyenas



A savanna in Kenya



Chaparral

- **Chaparrals** occur in midlatitude coastal regions on several continents
 - Climate is highly seasonal, with cool (10-12 C) and rainy winters and hot (30-40 C) dry summers
 - Annual precipitation generally falls within the range of 30-50 cm
- Plants: the 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, small mammals and browsing mammals, such as deer and goats



An area of chaparral
in California



Temperate Grassland

- **Temperate grasslands** are found on many continents
 - Winters are cold (below -10 C) and dry, while summers are wet and hot (averaging 30 C)
 - Annual precipitation generally averages between 30-100 cm, with periodic drought
- Plants: the dominant plants, grasses and forbs, are adapted to droughts and fire
 - Grazing by large mammals helps prevent establishment of woody shrubs and trees
- Animals: native mammals include large grazers, such as bison and wild horses, and small burrowers, such as prairie dogs



Sheyenne National Grassland
in North Dakota

Northern Coniferous Forest

- The **northern coniferous forest**, or *taiga*, extends across northern North America and Eurasia and is the largest terrestrial biome on Earth
 - Annual precipitation generally ranges from 30-70 cm, with periodic drought
 - Some coastal coniferous forest of the U.S. Pacific Northwest are temperate rain forests that may receive over 300 cm of annual precipitation
 - Winters are cold and long while summers may be hot
 - Temperatures can vary from -50 C in winter to over 20 C in the summer in Siberian coniferous forests

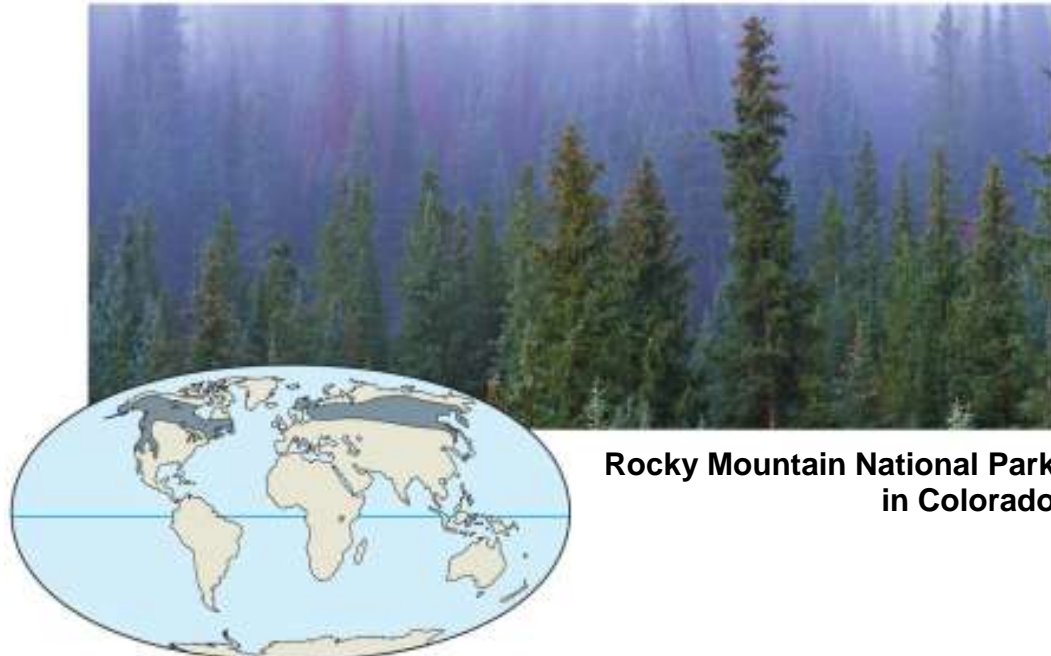


Rocky Mountain National Park
in Colorado



Northern Coniferous Forest

- Plants: cone-bearing trees, such as pines and firs, dominate these forests
 - The conical shape of many conifers prevents too much snow from accumulating and breaking their branches
- Animals: animals include migratory and resident birds, and large mammals, such as moose, brown bears, and Siberian tigers



**Rocky Mountain National Park
in Colorado**

Temperate Broadleaf Forest

- Temperate broadleaf forests are found mainly at midlatitudes in the Northern Hemisphere, with smaller areas in New Zealand and Australia
 - Winters are cool, averaging ~ 0 C, while summers are hot and humid, with maximum temperatures near 35 C
 - Significant precipitation falls year round as rain and snow, averaging around 70-200 cm annually
- Plants: these forests have vertical layers dominated by deciduous trees in the Northern Hemisphere and evergreen eucalyptus in Australia
 - Layers include a closed canopy, one or two strata of understory trees, a shrub layer, and an herbaceous strata
- Animals: mammals, birds, and insects make use of all vertical layers in the forest
 - In the Northern Hemisphere, many mammals hibernate in the winter, while many bird species migrate to warmer climates



Great Smoky Mountains National Park in North Carolina



Tundra

- **Tundra** covers expansive areas of the Arctic, amounting to ~20% of Earth's land surface
 - High winds and low temperatures create similar plant communities, called *alpine tundras*, on high mountaintops at all latitudes
 - Winters are long and cold (below -30 C) while summers are relatively cool (less than 10 C)
 - Precipitation varies, averaging 20-60 cm annually, but may exceed 100 cm in alpine tundra



Denali National Park, Alaska, in autumn



Tundra

- Plants: vegetation is mostly herbaceous, consisting of a mixture of mosses, grasses, and forbs
 - **Permafrost**, a permanently frozen layer of soil, prevents water infiltration and restricts the growth of plant roots
- Animals: large, grazing musk oxen remain resident year-round, while caribou and reindeer are migratory
 - Predators include bears, wolves, and foxes
 - Many bird species migrate to the tundra for summer nesting



Denali National Park, Alaska,
in autumn



Concept Check 52.4

- 1) Based in the climograph in Figure 52.20 (pp. 1167), what mainly differentiates dry tundra and deserts?
- 2) Identify the natural biome in which you live and summarize its abiotic and biotic characteristics. Do these reflect your actual surroundings? Explain.
- 3) If global warming increases average temperatures on Earth by 4°C in this century, predict which biome is most likely to replace tundra in some locations as a result. Explain your answer.

You should now be able to:

1. Distinguish among the following types of ecology: organismal, population, community, ecosystem, and landscape
2. Explain how dispersal may contribute to a species' distribution
3. Distinguish between the following pairs of terms: potential and actual range, biotic and abiotic factors, macroclimate and microclimate patterns

4. Explain how a body of water or mountain range might affect regional climatic conditions
5. Define the following terms: photic zone, aphotic zone, benthic zone, abyssal zone, thermal stratification, thermocline, seasonal turnover, climograph, disturbance
6. List and describe the characteristics of the major aquatic biomes

7. List and describe the characteristics of the major terrestrial biomes
8. Compare the vertical layering of a forest and grassland