Chapter 52
An Introduction to Ecology and the Biosphere

Lecture Outline

Overview: Discovering Ecology

- When University of Delaware undergraduate Justin Yeager spent his summer abroad in Costa Rica, he rediscovered the variable harlequin toad (*Atelopus varius*), a species thought to be extinct in the mountain slopes of Costa Rica and Panama where it once lived.
  - During the 1980s and 1990s, roughly two-thirds of the 82 known species of harlequin toads vanished.
  - Scientists think that a fungal pathogen, *Batrachochytrium dendrobatidis*, contributed to many of these extinctions.
- Why did the fungus suddenly thrive in the rainforest habitat?
  - Cloudier days and warmer nights associated with global warming appear to have created an environment ideal for its success.
- As of 2009, the species that Yeager found was surviving as a single known population of fewer than 100 individuals.
- What environmental factors limit the geographic distribution of harlequin toads?
  - How do variations in their food supply or interaction with other species such as pathogens affect the size of their population?
- These questions are the subject of **ecology**, the scientific study of the interactions between organisms and their environment.
  - Ecological interactions occur on a hierarchy of scales from single organisms to the globe.
- Ecology's roots are in discovery science.
  - Naturalists have long observed organisms in nature and recorded their observations.
- Modern ecology is also a rigorous experimental science.
  - Ecologists generate hypotheses, manipulate environmental variables, and observe the outcome.

Concept 52.1 Earth's climate varies by latitude and season and is changing rapidly.

- The most significant influence on the distribution of organisms on land and in the oceans is climate.
  - **Climate** is the long-term, prevailing weather conditions in a given area.
- Four physical factors—temperature, water, sunlight, and wind—are particularly important components of climate.
- Climate patterns can be described on two scales.
- **Macroclimate patterns** are on the global, regional, or landscape level.
- **Microclimate patterns** are very fine patterns, such as the conditions experienced by a community of organisms under a fallen log.

- Global climate patterns are determined by sunlight and Earth's movement in space.
- The sun's warming effect on the atmosphere, land, and water establishes the temperature variations, cycles of air movement, and evaporation of water that are responsible for latitudinal variations in climate.

Climate patterns can be modified by many factors, including seasonal variation in climate, large bodies of water, and mountain ranges.

- Earth's tilted axis of rotation and its annual passage around the sun cause strong seasonal cycles in middle to high latitudes.
  - In addition to global changes in day length, solar radiation, and temperature, the changing angle of the sun over the course of the year affects local environments.
  - Belts of wet and dry air on either side of the equator move slightly northward and southward with the changing angle of the sun, producing marked wet and dry seasons around 20° north and 20° south latitude, where many tropical deciduous forests grow.
- Seasonal changes in wind patterns alter ocean currents, sometimes causing the upwelling of cold water from deep ocean layers.
  - This nutrient-rich water stimulates the growth of surface-dwelling phytoplankton and the organisms that feed on them.
- Ocean currents influence climate along the coast by heating or cooling overlying air masses, which may pass over land.
  - Coastal regions are generally moister than inland areas at the same latitude.
  - In general, oceans and large lakes moderate the climate of nearby terrestrial environments.
- In certain regions, cool, dry ocean breezes are warmed when they move over land, absorbing moisture and creating a hot, rainless climate slightly inland.
  - This pattern draws a cool breeze from the water across the land.
  - At night, air over the ocean rises, drawing cooler air from the land back out over the water and replacing it with warmer offshore air.
  - This *Mediterranean climate* pattern occurs inland from the Mediterranean Sea.
- Like large bodies of water, mountains influence air flow over land.
- As moist, warm air approaches a mountain, it rises and cools, releasing moisture on the windward side of the peak.
  - On the leeward side of the mountain, cool, dry air descends, absorbing moisture and producing a "rain shadow."
  - Deserts are commonly on the leeward side of mountain ranges.
- Mountains have a significant effect on the amount of sunlight reaching an area as well as on local temperature and rainfall.
  - In the Northern Hemisphere, south-facing slopes receive more sunlight than north-facing slopes and are therefore warmer and drier.
  - These environmental differences affect local species distribution.
- At any given latitude, air temperature declines 6°C with every 1,000-m increase in elevation.
  - This temperature change is equivalent to the change caused by an 880-km increase in latitude.
  - Biological communities on mountains are similar to those at lower elevations farther from the equator.

Many features in the environment influence microclimates.

- Forest trees moderate the microclimate beneath them.
  - Cleared areas experience greater temperature extremes than the forest interior.
- Within a forest, low-lying ground is usually wetter than high ground and tends to be occupied by different species of trees.
- A log or large stone shelters organisms, buffering them from temperature and moisture fluctuations.
- Every environment on Earth is characterized by a mosaic of small-scale differences in **abiotic**, or nonliving, factors that influence the distribution and abundance of organisms.
  - **Biotic** or living factors also influence the distribution and abundance of organisms.

Long-term climate change profoundly affects the biosphere.

- The burning of fossil fuels and deforestation are increasing the concentrations of carbon dioxide and other greenhouse gases in the atmosphere.
  - As a result, Earth has warmed an average of 0.8ºC since 1900 and is projected to warm 1 to 6 ºC more by 2100.
- One way to predict the possible effects of current climate changes is to consider the changes that have occurred in temperate regions since the end of the last ice age.
- Until about 16,000 years ago, continental glaciers covered much of North America and Eurasia.
- As the climate warmed and the glaciers melted, tree distribution expanded northward.
  - A detailed record of these migrations is captured in fossil pollen in lake and pond sediments.
- If researchers can determine the climatic limits of current geographic distributions for individual species, they can predict how that species distribution will change with global warming.
- A major question for tree species is whether seed dispersal is rapid enough to sustain the migration of the species as climate changes.
  - Fossil pollen shows that species with winged seeds that disperse relatively far from a parent tree, such as sugar maple (*Acer saccharum*), expanded rapidly into the northeastern United States and Canada after the last ice age ended.
  - The northern movement of Eastern hemlock was delayed nearly 2,500 years at the end of the last ice age. This delay in seed dispersal was partly attributable to the lack of "wings" on the seeds, which tend to fall close to the parent tree.
- Will plants and other species be able to keep up with the much more rapid warming projected for this century?
  - The fossil record can inform predictions about the biological impact of current global warming trends on the geographic range of the American beech, *Fagus grandifolia*.
- Two different climate-change models are used to compare the current and predicted geographic ranges of this tree.
  - These models predict that the northern limit of the beech's range will move 700–900 km north over the next century and its southern range will move northward even farther.
  - The beech will have to migrate 7–9 km per year to maintain its distribution in a warming climate.

- However, since the ice age, the beech has migrated into its present range at a rate of only 0.2 km per year.

- Some species are already on the move in the face of climate change today.
  - Ecologist Camille Parmesan and her colleagues showed that 22 of 35 European butterfly species, including the silver-washed fritillary (*Argynnis paphia*), have shifted their ranges northward by 35–240 km since 1900.
- Other scientists reported that the Pacific diatom, *Neodenticula seminae*, recently colonized the Atlantic Ocean for the first time in 800,000 years.
  - With the loss of arctic sea ice in the past decade, increased flows of Pacific water carried the diatom around Canada and into the Labrador Sea, where it has become established.
- Overall, changes in animal and plant distributions are evident in all well-studied groups of marine, freshwater, and terrestrial organisms, consistent with the signature of a warmer world.

Concept 52.2 The structure and distribution of terrestrial biomes are controlled by climate and disturbance.

- Climate plays an important role in determining the nature and location of Earth's **biomes**, major life zones characterized by vegetation type (in terrestrial biomes) or by the physical environment (in aquatic biomes).
- Because there are latitudinal patterns of climate over Earth's surface, there are also latitudinal patterns of biome distribution.
- A **climograph** plots the annual mean temperature and precipitation of a particular region.
- Temperature and rainfall are well correlated with different terrestrial biomes, and each biome has a characteristic climograph.
  - For example, the ranges of precipitation of northern coniferous forests and temperate forests are similar, but their temperature ranges are different.
  - Grasslands are generally drier than either kind of forest, and deserts are drier still.
- The climograph is based on annual *averages*, but often the *pattern* of climatic variation is as important as the average climate.
  - For example, two areas may receive the same annual precipitation. One area may receive regular precipitation throughout the year, whereas the other area has distinct wet and dry seasons.
- Factors other than mean temperature and precipitation also play a role in determining where biomes exist.
  - Environmental characteristics such as bedrock in an area may affect mineral nutrient availability and soil structure, which in turn affect the kind of vegetation that can grow.
- Most terrestrial biomes are named for major physical or climatic features or for their predominant vegetation.
  - For example, temperate grasslands are generally found in middle latitudes, where climate is more moderate than in the tropics or polar regions.
- Each biome is also characterized by the microorganisms, fungi, and animals adapted to that environment.
  - For example, temperate grasslands are often populated by large grazing mammals and have arbuscular mycorrhizal fungi.

- Terrestrial biomes usually grade into each other without sharp boundaries.
  - The area of intergradation, called the **ecotone,** may be narrow or wide.
- Vertical layering, largely defined by the shapes and sizes of plants, is an important feature of terrestrial biomes.
  - The **canopy** of a forest is the top layer, covering the low-tree layer, shrub understory, ground layer of herbaceous plants, forest floor (litter layer), and root layer.
  - Grasslands have a 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.
- The species composition of any biome differs from location to location.
  - For example, red spruce is common in the northeastern coniferous forest or taiga, while black and white spruce are found in other regions of taiga.
  - In an example of convergent evolution, North American desert cacti are very similar to African desert euphorbs, although cacti and euphorbs are not closely related.
- Biomes are dynamic, and natural disturbance rather than stability tends to be the rule.
- In ecological terms, **disturbance** is an event such as a storm, fire, or human activity that changes a community, removing organisms from it and altering resource availability.
  - Hurricanes create openings for new species in tropical and temperate forests.
  - Fires and outbreaks of pests, such as pine beetles and spruce budworms, produce gaps in northern coniferous forests that allow deciduous species, including aspen and birch, to grow.
- As a result of disturbances, biomes exhibit patchiness, with several different communities represented in a single area.
- In many biomes, the dominant plants depend on periodic disturbance.
  - For example, natural wildfires are an integral component of grasslands, savannas, chaparral, and many coniferous forests.
- Human activity has radically altered the natural patterns of periodic physical disturbance.
  - Fires are now controlled for the sake of agricultural land use.
  - Without periodic burning, however, broadleaf trees tend to replace the native longleaf pines of the southeastern United States.
  - Forest managers use fire as a tool to maintain many coniferous forests.
- Humans have altered much of Earth's surface, replacing original biomes with urban or agricultural ones.
  - Most of the eastern United States is classified as temperate broadleaf forest, but little of that original forest remains.
- The major terrestrial biomes are tropical forest, desert, savanna, chaparral, temperate grassland, coniferous forest, temperate broadleaf forest, and tundra.
- **Tropical forests** are found close to the equator.
  - Tropical rain forests receive constant high amounts of rainfall (200–400 cm annually).
  - In tropical dry forests, precipitation is seasonal.
  - In both rain and dry forests, air temperatures range between 25°C and 29°C year-round.
  - Tropical forests are stratified, and competition for light is intense.
  - There is more animal diversity in tropical forests than in any other terrestrial biome.

- **Deserts** occur in a band near 30° north and south latitudes and in the interior of continents.
  - Deserts have low and highly variable rainfall, generally less than 30 cm per year.
  - Temperature varies greatly both seasonally and daily.
  - Desert vegetation is usually sparse and includes succulents, such as cacti, and deeply rooted shrubs.
  - Many desert animals are nocturnal, so they can avoid the heat.
  - Desert organisms display adaptations that allow them to resist or survive desiccation.
- **Savanna** is found in equatorial and subequatorial regions.
  - Rainfall is seasonal, averaging 30–50 cm per year.
  - The savanna is warm year-round, averaging 24–29°C with some seasonal variation.
  - Savanna vegetation is grassland with scattered trees.
  - Large herbivorous mammals are common inhabitants.
  - The dominant herbivores are insects, especially termites.
  - Fire is important in maintaining savanna biomes.
- **Chaparrals** have annual precipitation ranging from 30 to 50 cm, with mild, wet winters and dry, hot summers.
  - Chaparral is dominated by shrubs and small trees, with a diversity of grasses and herbs.
  - Plant and animal diversity is high.
  - Adaptations to fire and drought are common.
- **Temperate grasslands** exhibit seasonal drought, occasional fires, and seasonal variation in temperature.
  - Large grazers and burrowing mammals are native to temperate grasslands.
  - Deep fertile soils make temperate grasslands ideal for agriculture, especially for growing grain.
  - Most grassland in North America and Eurasia has been converted to farmland.
- **Coniferous forest,** or *taiga,* is the largest terrestrial biome on Earth.
  - Coniferous forests have long, cold winters and short, wet summers.
  - The conifers that inhabit these forests are adapted for snow and periodic drought.
  - Coniferous forests are home to many birds and mammals.
  - These forests are being logged intensively, and old-growth stands of conifers may soon disappear.
- **Temperate broadleaf forests** have very cold winters, hot summers, and considerable precipitation.
  - A mature temperate broadleaf forest has distinct vertical layers, including a closed canopy, one or two strata of understory trees, a shrub layer, and an herbaceous layer.
  - The dominant deciduous trees in Northern Hemisphere broadleaf forests drop their leaves and become dormant in winter.
  - In the Northern Hemisphere, many mammals in this biome hibernate in the winter, while many bird species migrate to warmer climates.
  - Humans have logged many temperate broadleaf forests around the world.
- **Tundra** covers large areas of the Arctic, up to 20% of Earth's land surface.
  - Alpine tundra is found on high mountaintops at all latitudes, including the tropics.
  - The plant communities in alpine and Arctic tundra are very similar.

- The Artic tundra winter is long and cold, while the summer is short and mild. The growing season is very short.
- Tundra vegetation is mostly herbaceous, consisting of a mixture of lichens, mosses, grasses, forbs, and dwarf shrubs and trees.
- A permanently frozen layer of permafrost prevents water infiltration and restricts root growth.
- Large grazing musk oxen are resident in Arctic tundra, whereas caribou and reindeer are migratory.
- Migratory birds use Arctic tundra extensively during the summer as nesting grounds.
- Arctic tundra is sparsely settled by humans but has recently become the site of significant mineral and oil extraction.

Concept 52.3 Aquatic biomes are diverse and dynamic systems that cover most of Earth.

- Unlike terrestrial biomes, aquatic biomes are characterized primarily by their physical environment.
  - They show far less latitudinal variation, with all types found across the globe.
- Ecologists distinguish between freshwater and marine biomes on the basis of physical and chemical differences.
- Marine biomes generally have salt concentrations that average 3%, whereas freshwater biomes have salt concentrations of less than 0.1%.
- Marine biomes cover approximately 75% of Earth's surface and have an enormous effect on the biosphere.
  - The evaporation of water from the oceans provides most of Earth's rainfall.
  - Ocean temperatures have a major effect on world climate and wind patterns.
  - Photosynthesis by marine algae and photosynthetic bacteria produces a substantial proportion of Earth's oxygen; respiration by these organisms consumes huge amounts of atmospheric carbon dioxide.
- Freshwater biomes are closely linked to the soils and biotic components of the terrestrial biomes through which they pass.
- The pattern and speed of water flow and the surrounding climate are also important factors.

Most aquatic biomes are physically and chemically stratified.

- Light is absorbed by the water and by photosynthetic organisms, so light intensity decreases rapidly with depth.
- There is sufficient light for photosynthesis in the upper **photic zone**.
- Very little light penetrates to the lower **aphotic zone**.
- The photic and aphotic zones together make up the **pelagic zone**.
- The most extensive part of the open ocean is the **abyssal zone**, regions where the water is 2,000–6,000 m deep.
- The substrate at the bottom of an aquatic biome is the **benthic zone**.
  - The benthic zone is made up of sand and sediments and is occupied by communities of organisms called **benthos**.

- A major food source for benthos is dead organic material or **detritus**, which "rains" down from the productive surface waters of the photic zone.

- Sunlight warms surface waters, while deeper waters remain cold.
  - As a result, water temperature in lakes is stratified, especially in summer and winter.
  - In the ocean and most lakes, a narrow stratum of rapid temperature change called a **thermocline** separates the more uniformly warm upper layer from more uniformly cold deeper waters.
- Lakes tend to be particularly layered with respect to temperature, especially during summer and winter.
  - Many temperate lakes undergo a semiannual **turnover** of oxygenated surface waters and nutrient-rich bottom waters in spring and autumn.
  - This turnover is essential to the survival and growth of shallow and deep-water organisms.
- In aquatic biomes, community distribution is determined by the depth of the water, degree of light penetration, distance from shore, and open water versus bottom.
  - In marine and deep lake communities, phytoplankton, zooplankton, and many fish species live in the relatively shallow photic zone.
  - The aphotic zone contains little life, except for microorganisms and relatively sparse populations of luminescent fishes and invertebrates.
- The major aquatic biomes include lakes, wetlands, streams, rivers, estuaries, intertidal biomes, oceanic pelagic biomes, coral reefs, and marine benthic biomes.
- Freshwater lakes vary greatly in oxygen and nutrient content.
  - Oligotrophic lakes are deep, nutrient-poor, and oxygen-rich and contain little life.
  - Eutrophic lakes are shallow, nutrient-rich, and oxygen-poor.
- In lakes, the **littoral zone** is the shallow, well-lit water close to shore.
  - The **limnetic zone** is the open surface water.
- **Wetlands** are areas covered with sufficient water to support aquatic plants.
  - Wetlands can be saturated or periodically flooded.
  - Wetlands include marshes, bogs, and swamps.
  - They are among the most productive biomes on Earth and home to a diverse community of invertebrates and birds.
  - Because of the high organic production and decomposition in wetlands, their water and soil are low in dissolved oxygen.
  - Wetlands have a high capacity to filter dissolved nutrients and chemical pollutants.
  - Humans have destroyed many wetlands, but some are now protected.
- **Streams** and **rivers** are bodies of water that move continuously in one direction.
  - Headwaters are cold, clear, turbulent, and swift.
  - Streams and rivers carry little sediment and relatively few mineral nutrients.
  - As water travels downstream, it picks up O_2 and nutrients on the way.
  - The nutrient content is largely determined by the terrain and vegetation of the area.
  - Many streams and rivers have been polluted by humans, degrading water quality and killing aquatic organisms.
  - Damming and flood control impair the natural functioning of streams and rivers and threaten migratory species such as salmon.

- **Estuaries** are areas of transition between river and sea.
  - The salinity of these areas can vary greatly.
  - Estuaries have complex flow patterns, with networks of tidal channels, islands, levees, and mudflats.
  - Estuaries support an abundance of fish and invertebrate species and are crucial feeding areas for many species of waterfowl.
- An intertidal **zone** is a marine biome that is periodically submerged and exposed by the tides.
  - The upper intertidal zone experiences longer exposure to air and greater variation in salinity and temperature than do the lower intertidal areas.
  - Many organisms live only at a particular stratum in the intertidal zone.
- The **oceanic pelagic biome** is the open blue water, mixed by wind-driven oceanic currents.
  - The surface waters of temperate oceans turn over during fall through spring.
  - The open ocean has high oxygen levels and low nutrient levels.
  - This biome covers 70% of Earth's surface and has an average depth of 4,000 m.
- **Coral reefs** are limited to the photic zone of stable tropic marine environments with high water clarity. They are found at temperatures between 18°C and 30°C.
  - Coral reefs are formed by the calcium carbonate skeletons of coral animals.
  - Mutualistic dinoflagellate algae live within the tissues of the corals.
  - Coral reefs are home to a diverse assortment of vertebrates and invertebrates.
  - Collecting of coral skeletons and overfishing for food and the aquarium trade have reduced populations of corals and reef fishes.
  - Global warming and pollution contribute to large-scale coral mortality.
- The **marine benthic zone** consists of the seafloor below the surface waters of the coastal or **neritic zone** and the offshore **pelagic zone.**
  - Most of the ocean's benthic zone receives no sunlight.
  - Organisms in the very deep abyssal zone are adapted to continuous cold (about 3°C) and extremely high pressure.
  - Unique assemblages of organisms are associated with deep-sea hydrothermal vents of volcanic origin on mid-ocean ridges.
  - The primary producers in these communities are chemoautotrophic prokaryotes that obtain energy by oxidizing H_2S formed by a reaction of volcanically heated water with dissolved sulfate (SO_4^{2-}).

Concept 52.4 Interactions between organisms and the environment limit the distribution of species.

- Species distributions are a consequence of both ecological and evolutionary interactions through time.
- The differential survival and reproduction of individuals that lead to evolution occur in *ecological time* (minutes to years). Through natural selection, organisms adapt to their environment over the time frame of many generations, in *evolutionary time*.
- Events in ecological time lead to evolutionary change in populations.
  - For example, a severe drought affected the survival of Galápagos finches through the evolution of larger beaks.

- Finches with bigger beaks were better able to eat the large, hard seeds available during the drought.
- Smaller-beaked birds, which could eat only the smaller, softer seeds that were in short supply, were less likely to survive.
- Because beak depth is hereditary in this species, the generation of finches born after the drought had beaks that were deeper than those of previous generations.

- Ecologists have long recognized distinct global and regional patterns in the distribution of organisms. *Biogeography* is the study of past and present distributions of individual species in the context of evolutionary theory.
- Ecologists ask questions about what limits the geographic distribution of any species.
- Ecologists ask *where* species occur and *why* species occur where they do, focusing on the factors that determine the distribution of species.
  - Ecologists focus on both bitotic and abiotic factors that influence the distribution and abundance of organisms.
- The red kangaroo *(Macropus rufus)* is abundant in areas of Australia that have sparse and variable rainfall.
  - An abiotic factor—precipitation—may determine where red kangaroos live.
  - It is also possible that climate influences red kangaroo populations indirectly, through biotic factors such as pathogens, parasites, predators, competitors, and food availability.

Species dispersal contributes to the global distribution of organisms.

- The movement of individuals away from centers of high population density or from their area of origin is called **dispersal**.
  - Perhaps there are no kangaroos in North America due to barriers to their dispersal.
- The dispersal of organisms is crucial to understanding geographic isolation in evolution and the broad patterns of current geographic distribution of species.
  - For example, cattle egrets were found only in Africa and southwestern Europe in the early 1800s.
  - After these birds crossed the Atlantic Ocean and colonized northeastern South America, they were able to spread throughout Central America, reaching Florida by the 1960.
  - Today, cattle egrets have breeding populations as far west as the Pacific Coast and as far north as southern Canada.
- In rare cases, such long-distance dispersal can lead to adaptive radiation, the rapid evolution of an ancestral species into new species that fill many ecological niches.
- One way to determine whether dispersal is a key factor limiting distribution is to observe the results when humans have accidentally or intentionally transplanted a species to areas where it was previously absent.
- For the transplant to be considered successful, the organisms must not only survive in the new area but also reproduce there sustainably.
  - If the transplant is successful, then the *potential* range of the species is larger than its *actual* range.
  - In other words, the species *could* live in areas where it currently does not.
- Ecologists rarely move species to new geographic areas, because transplanted species may disrupt the communities and ecosystems to which they are introduced.

- Instead, ecologists study the outcome when a species has been transplanted accidentally or for another purpose.

- Behavior and habitat selection contribute to the distribution of organisms.
- Sometimes organisms do not occupy all of their potential range but select particular habitats.
  - Does behavior play a role in limiting the distribution in such cases?
- Habitat selection is one of the least-understood ecological processes, but it appears to play an important role in limiting the distribution of many species.
  - Female insects often deposit eggs only in response to a very narrow set of stimuli, which may restrict distribution of the insect to certain host plants.
  - For example, the European corn borer can feed on a wide variety of plants but is found only on corn. Egg-laying females are attracted by the odors of corn plants.

Biotic factors affect the distribution of organisms.

- Negative interactions with other organisms in the form of predation, parasitism, or competition may limit the ability of organisms to survive and reproduce.
  - Predators and herbivores may limit the distribution of species.
- In certain marine ecosystems, there is an inverse relationship between the abundances of sea urchins and seaweeds.
  - Sea urchins graze on seaweeds, preventing the establishment of large stands of seaweeds.
- Studies undertaken near Sydney, Australia tested the hypothesis that sea urchins are a biotic factor limiting seaweed distribution.
  - When sea urchins were removed from experimental plots, seaweed cover increased dramatically, showing that urchins limited seaweed distribution.
- The presence or absence of pollinators, food resources, parasites, pathogens, and competing organisms can act as biotic limitations on species distribution.

Abiotic factors affect the distribution of organisms.

- The global distribution of organisms broadly reflects the influence of abiotic factors such as temperature, water, oxygen, salinity, sunlight, and soil.
  - If the physical conditions at a site do not allow a species to survive and reproduce, the species will not be found there.
- Most abiotic factors vary substantially in space and time.
- Daily and annual fluctuations of abiotic factors may blur or accentuate regional distinctions.
- Organisms can *temporarily* avoid stressful conditions through behaviors such as dormancy or hibernation.
- Environmental temperature is an important factor in the distribution of organisms because of its effect on biological processes.
  - Cells may rupture if the water they contain freezes, and most proteins denature at temperatures above 45^0C.
- Most organisms function best within a specific range of temperatures.
  - Endotherms may expend energy regulating their internal temperature at temperatures outside that range.
- Some organisms (such as thermophilic prokaryotes) have extraordinary adaptations that allow them to live outside the temperature range habitable for most other living things.

- The variation in water availability among habitats is an important factor in species distribution.
  - Intertidal species may face desiccation as the tide recedes.
  - Terrestrial organisms face a nearly constant threat of desiccation and have adaptations that allow them to obtain and conserve water.
  - Desert organisms, for example, have a variety of adaptations for acquiring and conserving water in dry environments.
- Water and oxygen availability interact in aquatic habitats and through flooding on land.
  - Because oxygen diffuses slowly in water, its concentration can be low in certain aquatic systems and soils, limiting cellular respiration and other physiological processes.
- Oxygen concentrations can be particularly low in both deep ocean and deep lake waters and sediments where organic matter is abundant.
- Flooded wetland soils can also have low oxygen content.
  - Mangroves and other trees have specialized roots that project above the water and help the root system obtain oxygen.
- Unlike many flooded wetlands, the surface waters of streams and rivers tend to be well oxygenated because of rapid exchange of gases with the atmosphere.
- The salt concentration of water in the environment affects the water balance of organisms through osmosis.
  - Most aquatic organisms have a limited ability for osmoregulation and are restricted to either freshwater or marine habitats.
  - High-salinity habitats such as salt flats typically contain few species.
- Salmon that migrate between freshwater streams and the ocean use both behavioral and physiological mechanisms to osmoregulate.
  - They adjust the amount of water they drink to help balance their salt content, and their gills switch from taking up salt in fresh water to excreting salt in the ocean.
- Sunlight provides the energy that drives nearly all ecosystems.
  - In forests, shading by a forest canopy creates intense competition for light in the understory.
- In aquatic environments, light intensity limits the distribution of photosynthetic organisms.
  - Every meter of water depth selectively absorbs 45% of red light and 2% of blue light passing through it.
  - As a result, most photosynthesis in aquatic environments occurs near the surface.
- Too much light can also limit the survival of organisms.
  - In desert ecosystems, high light levels may increase temperature stress if animals and plants are unable to avoid the light or cool themselves through evaporation.
- The atmosphere is thinner at higher elevations, absorbing less ultraviolet radiation. In alpine environments, the sun's rays are more likely to damage DNA and proteins.
  - Damage from UV radiation, combined with other abiotic stresses, prevents trees from growing above a certain elevation, resulting in the appearance of a tree line on mountain slopes,
- The pH, mineral composition, and physical structure of rocks and soil limit the distribution of plants and, thus of the animals that feed on them, contributing to the patchiness of terrestrial ecosystems.

- The pH of soil and water can limit the distribution of organisms directly, through extreme acidic or basic conditions, or indirectly, by affecting the solubility of nutrients and toxins.

- In a river, the composition of the substrate (riverbed) can affect water chemistry, which in turn influences the resident organisms.
  - In freshwater and marine environments, the structure of the substrate determines the organisms that can attach to it or burrow into it.