Chapter 52

An Introduction to Ecology and the Biosphere

Lecture Outline

Overview: The Scope of Ecology

* Biologists record and transmit data on the annual 8,000-km migration of gray whales that calve in Baja California,collecting information that has helped this population recover from the brink of extinction.
* A century ago, whaling had reduced this population to a few hundred individuals.
* After 70 years of protection, more than 20,000 gray whales travel to the Arctic each year.
* What environmental factors determine the geographic distribution of gray whales? How do variations in their food supply affect the size of the gray whale population?
* These questions are the subject of **ecology**, the scientific study of the interactions between organisms and their environment.
* These interactions occur on a hierarchy of scales from organismal to global.

Concept 52.1 Ecology integrates all areas of biological research and informs environmental decision making.

* Ecology’s roots are in discovery science.
* Naturalists have long observed organisms in nature and recorded their observations.
* Natural history remains a fundamental part of the science of ecology.
* Modern ecology is also a rigorous experimental science.
* Ecologists generate hypotheses, manipulate the environment, and systematically record their observations.
* For example, Paul Hanson and his colleagues at Oak Ridge National Laboratory created drought and wet conditions on experimental plots of native Tennessee forest.
* By comparing the growth and survival of trees in each plot, the researchers found that flowering dogwoods, *Cornus florida*, were more likely to die in drought conditions than were members of any other woody species examined.

Ecology and evolutionary biology are closely related sciences.

* Organisms adapt to their environment over many generations through the process of natural selection.
* The differential survival and reproduction of individuals that lead to evolution occur in *ecological time* (minutes to years).
* 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.
* The link between ecology and evolution is evident in the world around us.
* For example, a farmer applies a fungicide to protect a wheat crop from a fungus, thus increasing crop yield.
* After a few years, the farmer has to apply more and more fungicide to obtain the same protection.
* The fungicide has altered the gene pool of the fungus—an evolutionary effect—by selecting for individuals that are resistant to the chemical.
* Eventually, the fungicide works so poorly that the farmer needs a different, more potent chemical to control the fungus.

Ecological research ranges from the adaptations of individual organisms to the dynamics of the biosphere.

* Ecology can be divided into different areas of study.
* **Organismal ecology** is concerned with the behavioral, physiological, and morphological ways individuals interact with the environment.
* A *population* is a group of individuals of the same species living in a particular geographic area. **Population ecology** examines factors that affect population size and composition.
* A *community* consists of all the organisms of all the species that inhabit a particular area. **Community ecology** examines the interactions between species and considers how factors such as predation, competition, disease, and disturbance affect community structure and organization.
* An *ecosystem* consists of all the abiotic factors in addition to the entire community of species that exist in a certain area. **Ecosystem ecology** studies energy flow and cycling of chemicals among the various abiotic and biotic components.
* A *landscape* or *seascape* consists of several different ecosystems linked by exchanges of energy, materials, and organisms. **Landscape ecology** deals with arrays of ecosystems and their arrangement in a geographic region.
* Each landscape or seascape consists of a mosaic of different types of patches, an environmental characteristic ecologists refer to as *patchiness.*
* Landscape ecological research focuses on the factors that control exchanges of energy, materials, and organisms among ecosystem patches.
* The **biosphere** is the global ecosystem, the sum of all of the planet’s ecosystems. The biosphere includes the entire portion of Earth inhabited by life, ranging from the atmosphere to a height of several kilometers to the oceans and water bearing rocks to a depth of several kilometers.

Ecology provides a scientific context for evaluating environmental issues.

* Because of ecology’s usefulness in conservation and environmental efforts, many people associate ecology with *environmentalism*, advocacy for the protection of nature.
* Ecologists distinguish between science and advocacy, however.
* How society uses ecological knowledge does not depend solely on science.
* The distinction between knowledge and advocacy is clear in the guiding principles of the Ecological Society of America, a scientific organization that strives to “ensure the appropriate use of ecological science in environmental decision making.”
* In her 1962 book *Silent Spring,* Rachel Carson wrote: “The ‘control of nature’ is a phrase conceived in arrogance, born of the Neanderthal age of biology and philosophy, when it was supposed that nature exists for the convenience of man.”
* Carson warned that the widespread use of pesticides such as DDT was causing population declines in many organisms besides the insects targeted for control.
* Her efforts led to a ban on DDT use in the United States and more stringent controls on the use of other chemicals.

Concept 52.2 Interactions between organisms and the environment limit the distribution of species.

* 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 a series of questions to determine what limits the geographic distribution of any species.
* Ecologists ask *why* species occur where they do, focusing on the factors that determine the distribution of species.
* **Biotic** factors include all the living organisms in the individual’s environment.
* **Abiotic** factors are nonliving chemical and physical factors such as temperature, light, water, and nutrients that influence the distribution and abundance of organisms.
* For example, red kangaroos are 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 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 North America by the 1950s.
* Today, cattle egrets have breeding populations as far west as the Pacific Coast and as far north as southern Canada.
* 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.
* 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 conduct transplant experiments today because species introduced into new geographic locations 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.
* Survival and reproduction may also be limited by the absence of species on which the transplanted species depends, such as pollinators for flowering plants.
* Predators and herbivores are examples of biotic factors that 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.
* W. J. Fletcher tested the hypothesis that sea urchins are a biotic factor limiting seaweed distribution by removing sea urchins from experimental plots.
* He observed a dramatic increase in seaweed cover, showing that urchins limit seaweed distribution.
* The presence or absence of food resources, parasites, diseases, 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, and sunlight.
* The environment is characterized by *spatial heterogeneity* and *temporal heterogeneity*.
* 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.
* Very few organisms can maintain an active metabolism at very high or very low temperatures.
* Cells may rupture if the water they contain freezes, and most proteins denature at temperatures above 450C.
* Some organisms have extraordinary adaptations that allow them to live outside the temperature range habitable for most other living things, but more organisms function best within a specific range of temperatures.
* Endotherms may expend energy regulating their internal temperature at temperatures outside that range.
* 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.
* The salt concentration of 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.
* Sunlight provides the energy that drives nearly all ecosystems.
* Light intensity is not the most important factor limiting plant growth in most terrestrial environments, although 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.
* The atmosphere is thinner at higher elevations, absorbing less ultraviolet radiation. The sun’s rays are more likely to damage DNA and proteins in alpine environments.
* The physical structure, pH, and mineral composition of soils and rocks limit the distribution of plants and, thus, of the animals that feed on them, contributing to the patchiness of terrestrial ecosystems.
* The distribution of organisms at extreme acidic and basic conditions is limited.
* pH can also have indirect effects by altering the solubility of nutrients and toxins.
* In streams and rivers, substrate composition can affect water chemistry, thus influencing the distribution of organisms.
* In freshwater and marine environments, the structure of substrates limits the organisms that can attach to or burrow in those habitats.

Four abiotic factors are the major components of climate.

* **Climate** is the long-term, prevailing weather conditions in a particular area.
* Four abiotic factors—temperature, water, sunlight, and wind—are the major components of climate.
* Climatic factors, especially temperature and water, have a major influence on the distribution of organisms.
* Climate patterns can be described on two scales.
* **Macroclimate** **patterns** are on global, regional, or local levels, and **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.
* Bodies of water and topographic features such as mountain ranges create regional climatic variations, while smaller features of the landscape affect local climates.
* Seasonal variation may influence climate.
* 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.
* 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 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.
* 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.
* The changing angle of the sun over the course of a year affects local environments.
* Belts of wet and dry air on either side of the equator shift with the changing angle of the sun, producing marked wet and dry seasons at around 20° latitude, where many tropical deciduous forests grow.
* Seasonal changes in wind patterns produce variations in ocean currents, occasionally causing the upwelling of nutrient-rich, cold water from deep ocean layers.
* This nutrient-rich water stimulates the growth of surface-dwelling phytoplankton and the organisms that feed on them.
* 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 factors that influence the local distribution of organisms.
* Long-term climate changes profoundly affect the biosphere.
* 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, the distribution of trees 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.
* An example to consider is the eastern hemlock, whose movement north 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.
* 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.
* Without human assistance, the beech will have a much smaller range and may become extinct.

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 **biomes,** major types of ecological associations that occupy broad geographic regions of land or water.
* 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 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.
* The most extensive part of the open ocean is the **abyssal zone**, regions where the water is 2,000–6,000 m deep.
* 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 O2 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 H2S formed by a reaction of volcanically heated water with dissolved sulfate (SO42−).

Concept 52.4 The structure and distribution of terrestrial biomes are controlled by climate and disturbance.

* Because there are latitudinal patterns of climate over Earth’s surface, there are also latitudinal patterns of biome distribution.
* These biome patterns are modified by disturbance, an event such as a storm, fire, or human activity that changes a community, removing organisms and altering resource availability.
* A **climograph** denotes the annual mean temperature and precipitation of a 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 microbes, fungi, and animals adapted to that environment.
* For example, temperate grasslands are often populated by large grazing mammals.
* 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.
* Hurricanes create openings for new species in tropical and temperate forests.
* In northern coniferous forests, snowfall may break branches and small trees, producing gaps that allow deciduous species to grow.
* As a result, biomes exhibit patchiness, with several different communities represented in any particular 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.