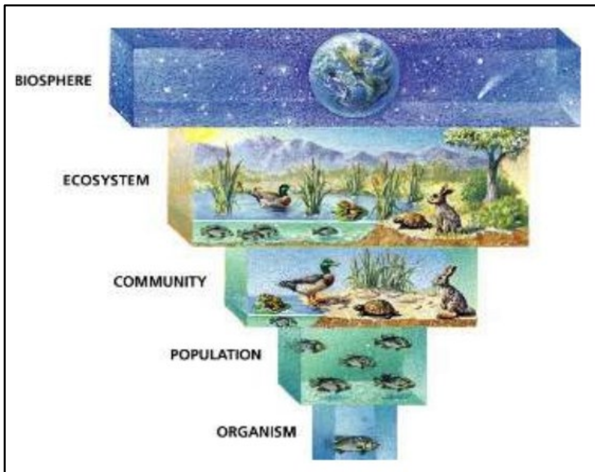
An Overview of Ecology

Introduction

Ecology is the study of how organisms interact with one another and with their physical environment. Ecology is studied at many levels, including: organism, population, community, ecosystem, and biosphere. **Organism** ecology focuses on studying the adaptations an organism has to live in their specific habitats. These adaptations can be morphological, physiological, or behavioral. **Population ecology** focuses on interactions within a population. **Community ecology** focuses on interactions among populations, including **symbiotic relationships**. **Ecosystem ecology** focuses on the **biotic** and **abiotic** factors that influence communities. **Biosphere ecology** focuses on the entire planet Earth, viewing it as an ecological system.



A **population** is a group of individuals that occur together at one place and time. The overall species that occur at any particular locality is a **community.**

Image credit: https://www.slideshare.net/jincynj/ecological-equilibrium-seminor

Biotic factors, living factors of an environment, as well as **abiotic factors,** non-living components of an environment, shape the distribution and abundance of organisms on Earth. Some abiotic factors include:

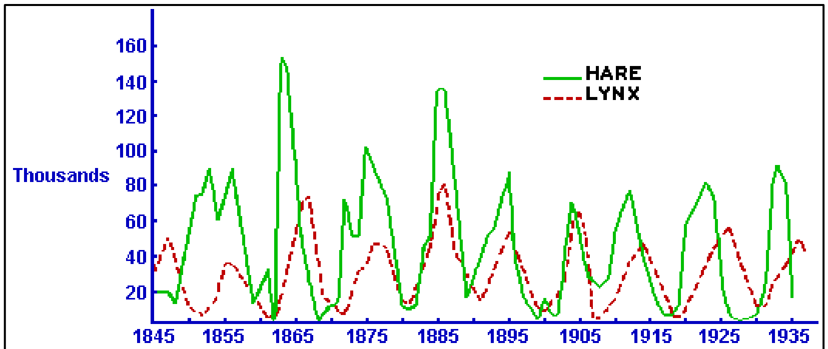
- **Temperature**: The majority of organisms are adapted to live within relatively narrow ranges of temperatures and will not thrive if temperatures are colder or warmer.
- **Water**: All organisms require water. Water is often scarce on land, thus patterns of rainfall have a major impact on life.
- **Sunlight**: Most ecosystems rely on energy captured by photosynthesis. Because of this, the availability of sunlight influences the amount of life a particular ecosystem can support.
- **Soil**: pH, soil consistency, and mineral composition can severely limit plant growth, particularly the availability of nitrogen and phosphorous.

Ecological Niche

The total of all the ways an organism uses the resources in its environment is termed its **niche**. The niche may encompass such things as space utilization, food consumption, temperature range, appropriate conditions for mating, requirements for moisture, and other factors not listed here. Based on its physiological tolerance limits and the resource needs of an organism, the entire niche a species is capable of using is its **fundamental niche.** A species may not be able to occupy its full fundamental niche due to the presence or absence of other species. This actual set of environmental conditions in which a species can establish a stable population is its **realized niche.**

Predator-Prey Relationships

Predation is the consumption of one organism by another. Using this phrasing, predation includes everything from a leopard capturing and eating an antelope, to a deer grazing on a shrub. Predators often have large effects on prey populations. Though this interaction is also a two-way street; the abundance of prey can affect the population dynamics of predators.



An example of predator-prey population dynamics. The Hudson's Bay Company used to be heavily involved in the fur trade and would keep records of snowshoe hare and Canada lynx pelts collected each season. Thus, they noted a rise and fall in each population. Charles Gordon Hewitt analyzed the data and published it in 1921. Subsequent analyses have not definitively determined the cause(s) of cyclical fluctuations in the snowshoe hare populations, but it is most likely due to exposure to stress, through predation, disease, or the scarcity of food.

Image credit: https://services.math.duke.edu/education/ccp/materials/engin/predprey/pred1.html

Prey populations experience strong selective pressures due to predation. Any adaptation that would decrease the likelihood of being captured should be strongly favored. In turn, the evolution of such adaptations results in natural selection favoring counter-adaptations in predator populations. This "evolutionary arms race" is a result of **coevolution**, in which these adaptations are selected for in a lockstep fashion in both predator and prey. Prey are constantly evolving better defenses against predation while predators are evolving better means of circumventing these defenses.

Animals have many adaptations to defend against predators, including:

- **Chemical defenses**: Animals are able to manufacture and use an array of defensive substances. Many arthropods, including bees, wasps, scorpions, and spiders use chemicals to defend themselves and kill their own prey. Various chemical defenses have also been identified in marine invertebrates as well as a variety of vertebrates such as: frogs, snakes, lizards, fishes, and some birds.
- **Warning coloration**: Bright, showy coloration is characteristic of animals that use poison and/or stings to repel predators. Organisms lacking specific chemical defenses are seldom brightly colored.
- **Camouflage**: Animals may have cryptic-coloration that blends well with the surroundings, working to hide the individual from predators. Camouflaged animals rarely live in groups, as a predator that discovers one individual gains a valuable clue into the location of others.
- **Mimicry**: Many species come to resemble distasteful ones that exhibit warning coloration during the course of their evolution. The mimic species gains an advantage by looking like the distasteful species.

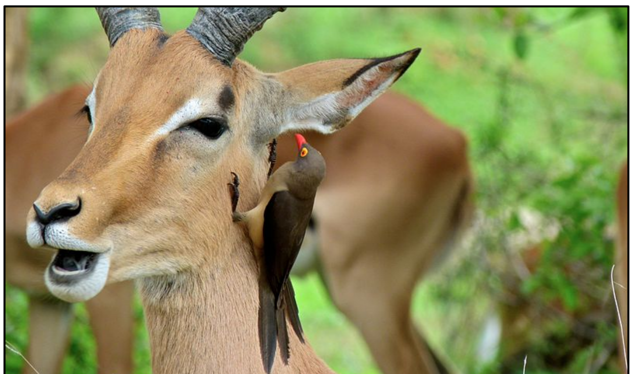
Poison-dart frogs produce toxic alkaloids in the mucus covering their brightly-colored skin. Their coloring is also an example of warning coloration, suggesting they have a poisonous nature.

Image credit: Photographed by Adrian Pingstone in May 2005

Symbiotic Relationships

When two or more kinds of organisms interact in more-or-less permanent relationships, those relationships are referred to as **symbiotic** (or symbiosis). Symbiotic relationships carry the potential for coevolution between the organisms involved. There are three major kinds of symbiotic relationships:

- **Commensalism** is when one species benefits while the other species neither benefits nor is harmed.
- **Mutualism** occurs when both participating species benefit from the relationship.
- **Parasitism** is a form of symbiosis in which one species benefits, while the other is harmed. Parasitism may also be viewed as a form of predation, though the preyed upon species does not necessarily die.



Red-billed oxpecker on and impala.

Photo credit: Bernard Dupont

The type of relationship may not always be clear. For example, Oxpeckers (family Buphagidae) in Africa do not have a clear relationship with their host organism. Oxpeckers spend most of their time clinging to grazing animals on the savanna picking off parasites and other insects, essentially carrying out their entire life cycle in close association with their host animals. In this sense, the relationship may be beneficial, as the host is having ticks or other parasites removed. On the other hand, oxpeckers have been known to pick at scabs, causing blood loss and possible infection, thus their relationship could be considered parasitic.

Other examples of symbiotic relationships:

- Remora-shark: commensalism
- Aphids-ants: mutualism
- Flea-dog: parasite/host
- Bird-tree: commensalism
- Hawk-snake: predator/prey
- Aphids-tomato plants: parasite/host
- Toad-spider: predator/prey
- Virus-human: parasite/host
- Bacteria-clover: mutualism

Some species may have more effects on the composition of their communities than one might expect based on their abundance. These species are called **keystone species.**

Sea otters are a keystone species. They help to control sea urchin populations that would otherwise destroy kelp forests.

Photo credit: Michael L. Baird, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=3101074

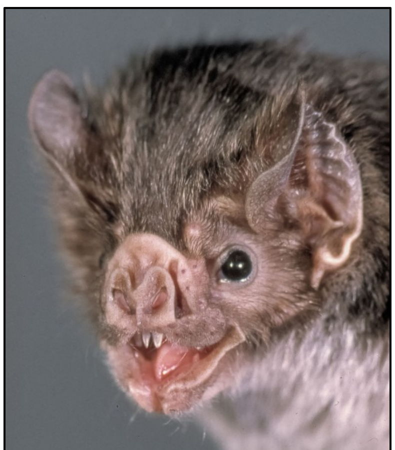
Cooperation

Cooperation in nature is known as **altruism**. An altruistic behavior is a behavior which is thought to increase the fitness of the recipient of that behavior while reducing the fitness of the actor. This seems counter-intuitive when compared to natural selection in which phenotypes with the highest fitness make it into the next generation, and yet altruism is quite common in many species. Warning calls are one example of an altruistic behavior. It is thought the individual giving the warning call is drawing attention to itself while giving the other members of its colony a chance to survive. The unwanted attention, and possible subsequent predation, would reduce the fitness of that individual while increasing the fitness of the rest of its colony.

Vervet monkeys will give out a warning call if a predator is nearby. Researchers have shown they give off different warning calls for different predators, letting their troop know where the threat is coming from.

Image credit: Bernard DUPONT. Wikimedia Commons.

Kin selection is one explanation for the evolution of altruism. If individuals in a population are related, they share a portion of their genes with other members of their population. For example, offspring share 50% of their genes with their parents (50% of their genes from mom and 50% from dad). Siblings also share roughly 50% of their genes. An individual can thus benefit from **inclusive fitness**. Because its relatives share a portion of their genes, the individual is still passing along its genes indirectly through relatives to the next generation.



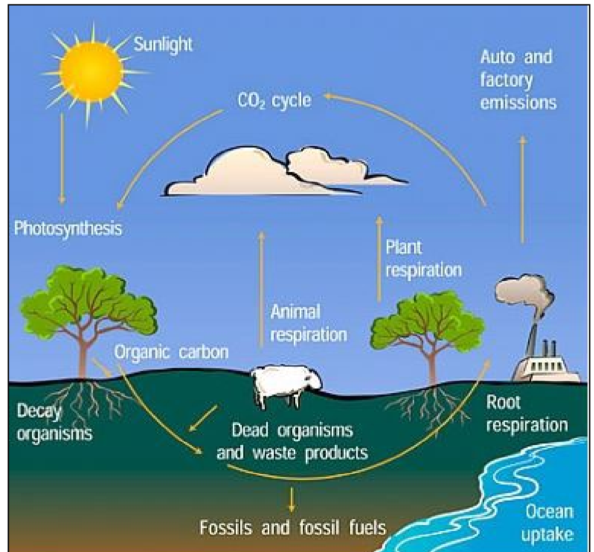
If a vampire bat is unable to feed, a member of its roost may share a blood meal with them. It is thought sharing a blood meal may compromise the health of the sharer. Over time, researchers observed former recipients of a blood meal sharing a meal with their former donor, exhibiting reciprocal altruistic behavior.

Image credit: Uwe Schmidt - File:Desmo-scan.tif and File:Desmo-boden.tif, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=48367424

Altruism also occurs between non-relatives, but is only likely to evolve when such behavior is reciprocal. Example: If individual 1 knows it will encounter individual 2 multiple times, it may benefit individual 1 to cooperate with individual 2 as individual 2 may reciprocate the behavior in the future. If individual 1 and individual 2 are unlikely to meet again in the future, it would not benefit individual 1 to cooperate with individual 2 as that behavior is not likely to be reciprocated and only harms individual 1’s fitness. Thus, **reciprocal altruism** is likely to evolve in close-knit, long-lived species.

Ecosystem Ecology

All the organisms that live in a particular area, plus the abiotic environment in which they live and interact with constitute an **ecosystem**. Ecosystems are dynamic and complex in how they process matter and energy. Matter flows through ecosystems in **biogeochemical cycles**, which include biological organisms and processes as well as geological (abiotic) systems and processes. Energy, though, is not recycled in ecosystems. Rather, it flows through the ecosystem, which will be discussed later.



A simple diagram of parts of the carbon cycle, emphasizing the terrestrial (land-based) parts of the cycle.

Image credit: http://scied.ucar.edu/carbon-cycle

Carbon Cycle

Carbon atoms help form the framework of all organic compounds, making it a major constituent of the bodies of all organisms. In fact, almost 20% of the weight of the human body comes from carbon. Carbon is one element that cycles through an ecosystem. In terrestrial ecosystems, plants and other photosynthetic organisms take in carbon dioxide (CO_2) from the atmosphere and use it to synthesize carbon-containing organic compounds through photosynthesis. Animals then eat these photosynthetic organisms and build their own tissues using the carbon atoms from the organic compounds they ingest. Organisms obtain energy by breaking down some of the organic molecules available to them through aerobic cellular respiration and produce CO_2 through this process. Decaying organisms also produce CO_2. The carbon atoms returned to the ecosystem as CO_2 are then available to be used in photosynthesis and repeat the cycle.

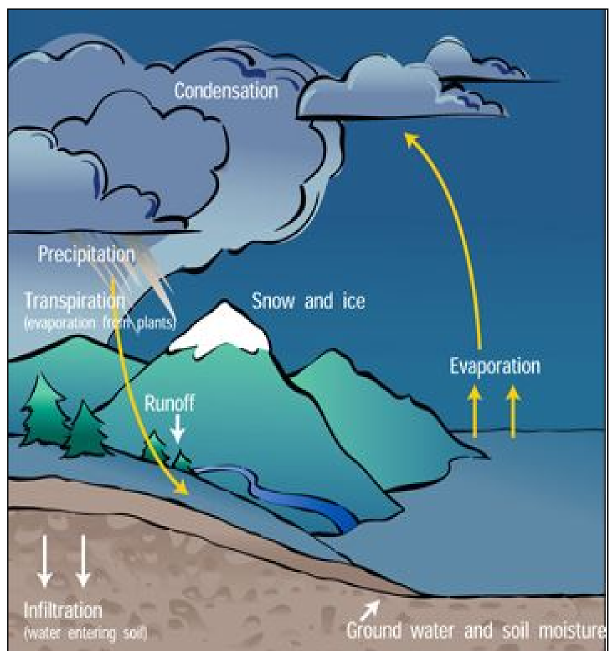


Image credit: https://eo.ucar.edu/kids/green/cycles3.htm

Water Cycle

A key part of the water cycle is that liquid water evaporates from the Earth's surface into the atmosphere. Water evaporates directly from the surface of oceans, lakes, and rivers. However, in terrestrial ecosystems, approximately 90% of the water reaching the atmosphere passes through plants, a process called **transpiration**. In the atmosphere, evaporated water exists as a gas which condenses back into liquid form, mostly due to the cooling of the air. The condensation of gaseous water into droplets or crystals results in the formation of clouds. If the droplets or crystals are large enough, they will fall to the surface of the Earth as precipitation (e.g. rain or snow).

Nitrogen Cycle

Nitrogen is required in substantial amounts by all organisms, as it is a component of nucleic acids (making up DNA) and proteins. In many ecosystems though, nitrogen is the element in shortest supply relative to the needs of organisms. Ironically, the atmosphere is 78% nitrogen by volume, but that nitrogen is unusable by the vast majority of organisms. Nitrogen in the atmosphere is found in its elemental form, N_2, which most organisms have no way to use. However, some plants and algae have a way to turn this elemental nitrogen into usable forms through a process called **nitrogen fixation**. Animals get their nitrogen from nitrogen-containing compounds synthesized by plants, algae, or other microbes.

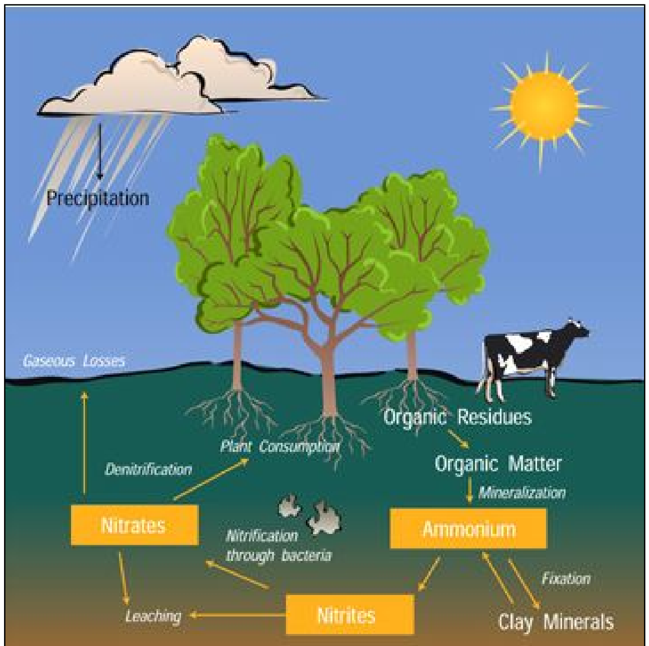
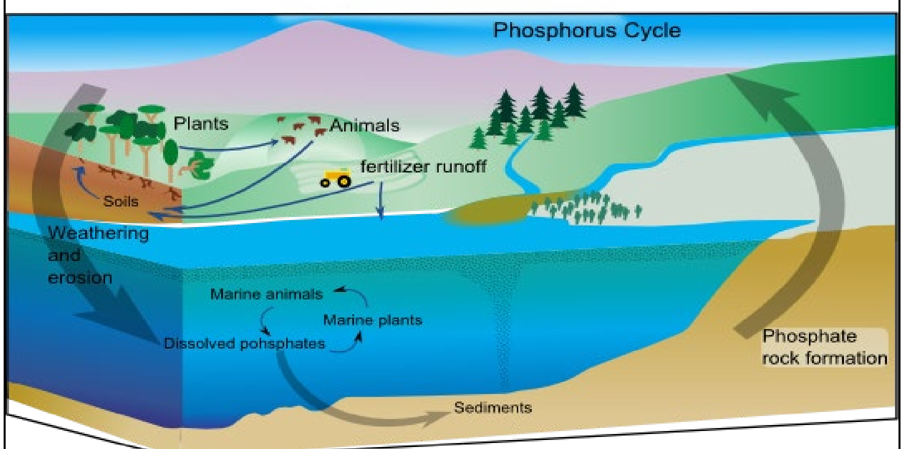


Image credit: http://scied.ucar.edu/longcontent/biogeochemical-cycles

Phosphorous Cycle

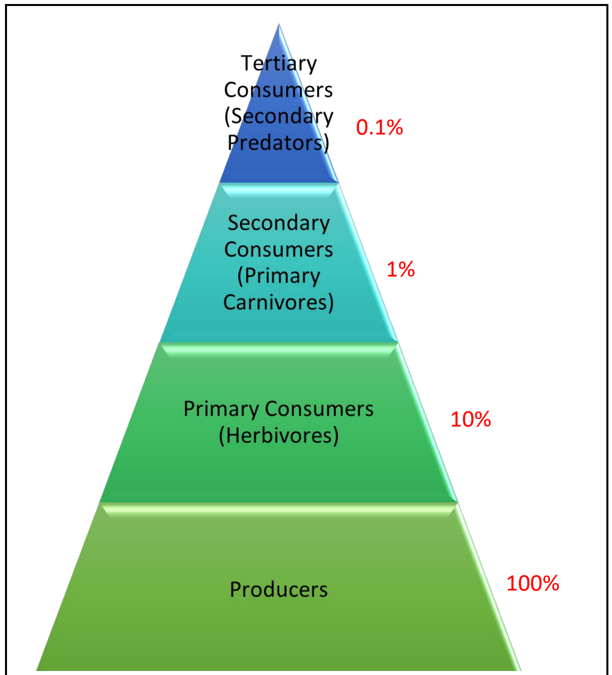
Phosphorous is also required in substantial quantities by all organisms as it occurs in nucleic acids, membrane phospholipids, and other essential compounds, such as adenine triphosphate (ATP, which cells use for energy). Phosphorous has no significant gaseous form, unlike water, carbon, and nitrogen. Phosphorous exists in ecosystems as PO_4^{3-}. Plants and algae use the free inorganic PO_4^{3-} found in soil or water to synthesize their phosphorous containing organic compounds. Animals can then get the phosphorous in plant or algal tissue to build their own phosphorous compounds. When organisms die, they release their phosphorous as inorganic PO_4^{3-}, which can then be used again by plants and algae.



By BonniemfIncorporates work by NASA Earth Science Enterprise - Reworked by Bonniemf from the public domain file File:Carbon cycle-cute diagram.svg, CC BY-SA 3.0,

Energy Transfer in Ecosystems

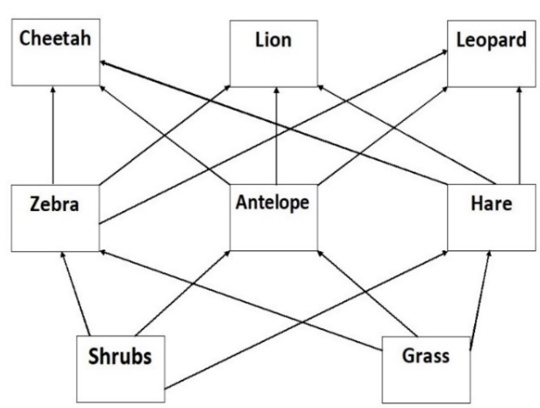
Unlike the elements in the biogeochemical cycles described previously, energy cannot be recycled. Rather, it changes through different forms to eventually be radiated back into space as heat. Energy exists in several different forms, such as light, chemical-bond energy, motion, and heat. Plants use light as their source of energy while animals use the chemical-bond energy they get from the foods they eat. In the process of using the energy, some of it will always be converted to heat and subsequently be lost. No organism is able to convert heat back into a usable form of energy, thus the energy is not recycled.



Ecologists estimate only about 10% of the energy available at one trophic level is passed along to the next level. Organisms use energy for cellular respiration, tissue repair, body movements, and other such functions. Energy used in these activities is converted to heat and not passed along to the next trophic level.

Organisms are grouped into feeding levels that ecologists refer to as **trophic levels.** Trophic levels consist of **autotrophs**, organisms that can produce their own food, and **heterotrophs**, organisms that cannot produce their own food and must eat to gain energy. The first tropic level in an ecosystem consists of the **primary producers**, all the autotrophs in the ecosystem. Heterotrophs that feed directly on the primary producers are grouped into the next trophic level of **herbivores**, or primary consumers. The heterotrophs that consume the herbivores are termed **primary carnivores** and those that consume the primary carnivores are **secondary carnivores. Scavengers** feed on carrion, dead plant material, or refuse in their environment. Additionally, **detritivores**, organisms that consume the remains of already-dead organisms, occupy their own trophic level. Scavengers and detritivores serve as recyclers in their ecosystems, helping return nutrients to the environment.

A **trophic cascade** is a powerful interaction that can control entire ecosystems. Predators impact prey abundance and behavior, which can trickle down one or more feeding levels to impact the density and/or behavior of the prey's prey. For example, the fur trade decimated sea otter populations, which in turn decimated the kelp forests they inhabited. Sea otters served to control the sea urchin populations in their ecosystem. In the absence of sea otters, sea urchin populations boomed, causing destruction of the kelp forests. Upon expansion of sea otter populations in later years, the sea urchin population was brought back under control and the kelp forest was able to flourish.



Energy transfer within an ecosystem may be organized into a **food chain**, showing organisms that eat each other sequentially. An example of a food chain may be: Shrub → Antelope → Lion. Organisms generally eat more than one type of food though and thus are a part of a **food web**.

Earth's Biomes

A **biome** is a major type of ecosystem on land. Individual biomes have a characteristic appearance and are distributed over wide areas of land that are largely defined by sets of regional climatic conditions. Biomes are named according to the vegetation that is present, but they also include the animals. Due to the broad definition of a biome, there are many ways to classify a given ecosystem into a biome. This has led to the conclusion that there are anywhere from six to fourteen biomes. The biomes listed below are adapted from The Nature Education Knowledge Project.

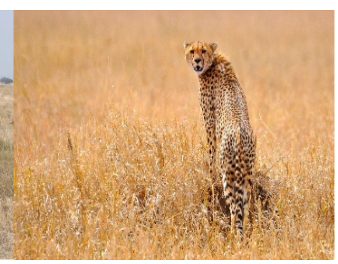
Tropical Forest



Tropical forest biomes are located in areas centered around the equator with South and Central America being home to half of the world's tropical forests. They experience little seasonal variation and have a high yearly rainfall average, with relatively constant warm temperatures. Because of the climate, tropical forests have the highest biodiversity and primary productivity of all terrestrial biomes. It is estimated that over half of the terrestrial species on Earth live within tropical forest biomes. Some common vegetation includes: vines, palm trees, orchids, and ferns. Common animals in tropical forests include: monkeys, colorful birds, tigers, jaguars, and pythons.

Savanna

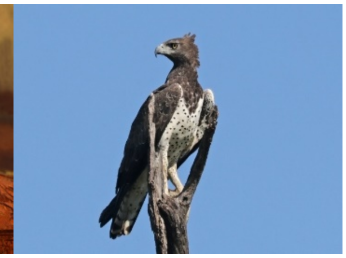




Located north and south of tropical forest biomes are savanna biomes, representing a transition from tropical forests to deserts. They experience a low yearly rainfall, with long dry seasons. Savanna covers 60% of Africa and is dominated by a mix of grasses and trees. A high herbivore diversity is mirrored by a great variety of predators and scavengers. Dung beetles play an important role in nutrient cycling in this biome by breaking down animal droppings. Some common animals include: giraffe, zebra, elephants, lions, cheetahs, hyenas, and a variety of antelope.

Desert





Desert biomes cover 26-35% of the land surface and occur in a band around the world between 15-30° North and South latitude. Deserts occur in a variety of types, such as hot deserts, cold deserts, high elevation deserts, and rain shadow deserts. Despite the variability, all deserts have a low precipitation rate in common. But because of the variability, there is a great deal of biodiversity and productivity among deserts. Plant life mostly consists of perennial shrubs with extensive roots and cacti. Many animals are nocturnal and some common species include: snakes, lizards, kangaroo rats, tortoises, meerkats, and eagles.

Grassland



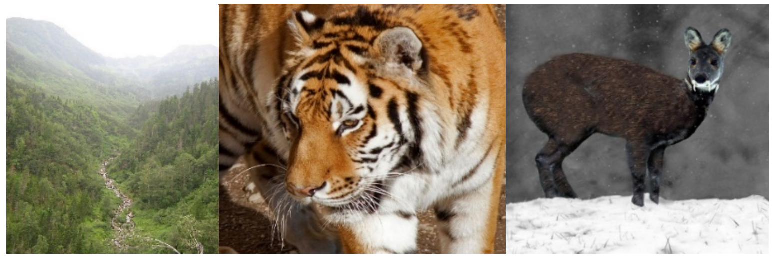
Similar to savannas, grassland biomes are dominated by grasses and trees, but wildflowers can also be found in these environments. Grassland biomes occur primarily in the interiors of continents and are characterized by large seasonal temperature variations with hot summers and cold winters. Precipitation varies throughout the year, though there is a strong peak in precipitation during the summer. On their wetter margins, grasslands grade into deciduous forests while on their drier margins, grasslands grade into deserts. The borders between biomes are dynamic and shift according to precipitation, environmental disturbance, fire, and drought. The type of grassland community that forms in an area is highly dependent on precipitation. Higher precipitation rates lead to tall grasses and a higher biodiversity, while lower precipitation rates lead to short grasses and a lower biodiversity. Some common animals that can be found in grasslands include: Kangaroos (in Australia), bison and horses in Eurasia and North America, and badgers, prairie dogs, and black-footed ferrets.

Temperate Deciduous Forest



Temperate deciduous forests occur in mid-latitudes where cool winters, warm summers, and high year-round precipitation occurs. The biome gets its name for the dominant trees in the ecosystems, which drop their leaves during the winter. These forests have an overstory layer made up of 20-30 meter tall trees, followed by an understory layer consisting of trees 5-10 meters tall. Under these, there is a shrub layer about 1-2 meters tall and an herbaceous plant layer covering the ground layer. The multiple forests layers allow for niche partitioning and a high biodiversity. Some common plants found in this biome include: wildflowers, ferns, mosses, oak, maple, and hickory trees. Common animals include: bear, deer, and foxes.

Northern Coniferous Forest



Northern coniferous forest biomes occur at higher latitudes and are characterized by long, cold winters with short, cool summers. Needle-leaved, drought-tolerant, evergreen trees dominate and create a two-layered forest consisting of an overstory of trees and a ground layer of herbs or mosses. Lower temperatures lead to slow decomposition and a low availability of nutrients in the soil. Because permafrost underlies much of the soil, trees have shallow roots. Plants found in these areas include spruces, fir trees, and pine trees. Animals found in these areas include deer, moose, bears, bighorn sheep, Amur tigers, and musk deer.

Tundra

The tundra occurs in latitudes beyond boreal (coniferous) forests in marshy areas where the growing season is very short. The growing season is typically 50-60 days long during the summer when the sun shines 24 hours a day. Temperatures are often below zero degrees Celsius for much of the year. Much of the soil is embedded in permafrost due to low temperatures. Biodiversity is low in these areas, containing only about 3% of the world's flora. Decomposition is slow and nutrients in the soil are low. Plants retain nutrients in long-lived evergreen tissues. Dominant plant life includes mosses, lichens, and low-growing perennial shrubs. Animals found in this area include reindeer, Arctic foxes, wolves, snowy owls, and polar bears. Many animals have extended hibernation periods or migrate seasonally.

Aquatic Biomes

Water covers nearly 75% of the Earth's surface and organisms have adapted to aquatic life, thus there are various aquatic biomes. Water temperatures vary widely, but generally aquatic areas tend to be more humid and air temperatures cooler. Aquatic biomes are divided into two different regions: freshwater regions and marine regions. Freshwater regions have a low salt concentration-less than 1% salinity. Plants and animals adapted to the low salt concentrations would be unable to survive in areas of higher salt concentrations. Marine regions cover about 70% of the Earth's surface. Marine algae supply much of the Earth's oxygen and take in huge amounts of atmospheric carbon dioxide. Evaporation of sea water provides rainwater for the land.

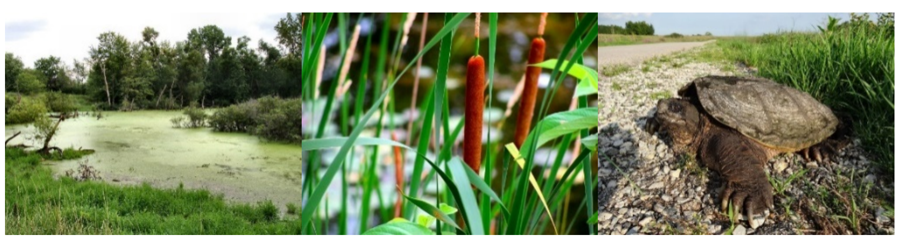
Ponds and Lakes

Ponds and lakes range in size from a few square meters to thousands of square kilometers. Many ponds are seasonal, while lakes are more permanent, lasting hundreds or thousands of years. Temperature in ponds and lakes varies seasonally and throughout water layers. In the summer, temperatures may be around 4°C (~40°F) near the bottom and 22°C (~72°F) near the top. In the winter, temperatures are around 4°C near the bottom and 0°C (32°F) at the top, resulting in a covering of ice. Algae and aquatic plants, such as water hyacinths are common vegetation. Fish, amphibians, turtles, and waterfowl are common animals found in ponds and lakes.

Streams and Rivers

Streams and rivers are bodies of flowing water moving in one direction. They start at a source, such as springs, snowmelts, or lakes. Each stream or river ends at its mouth: another water channel or the ocean. Along the course of the stream or river, the characteristics change from the source to the mouth. Species diversity tends to increase with the width of the stream or river, being highest at the widest parts. The temperature of the water tends to be cooler at the source than it is at the mouth. Because colder water holds more oxygen, the water at the source is more highly oxygenated at the source. Fish such as trout can be found in these areas. Toward the mouth, the water becomes murky due to the build up of sediments carried with the current. Here, the diversity of flora decreases and you can find animals such as catfish and carp, which require less oxygen. Other animals found in rivers and streams include: river dolphins, crocodilians, and waterfowl.

Wetlands



Wetlands, such as marshes, swamps, or bogs, which are areas of standing water that support aquatic plants. Hydrophytes, plant species adapted to very moist and humid conditions, are the dominant flora in these ecosystems. Common plants in wetlands include pond lilies, cattails, sedges, tamarack, and black spruce. Wetlands are inhabited by many species of amphibians, reptiles, birds (such as ducks and waders), and mammals. Areas with high salt concentrations, or salt marshes, are also considered wetlands, thus wetlands are not a freshwater ecosystem. Salt marshes support animals such as shrimp and shellfish, and a variety of grasses.

Oceans

Oceans are the largest of all ecosystems and are broken into separate zones: the intertidal, pelagic, benthic, and abyssal zones. The intertidal zone occurs where the ocean meets land. It may be submerged or exposed as waves and tides come in and out. Common fauna in the intertidal zone include algae, mollusks, snails, crabs, sea stars, and small fishes.

The open ocean makes up the pelagic zone. Plankton are abundant in this zone, making up the bottom of the food chain. Surface seaweeds can also be found here, along with many species of fish, whales, and dolphins.

Between the pelagic and the very deepest parts of the ocean is the benthic zone. As depth increases, temperature decreases because light cannot penetrate through deeper water. Organisms have adapted to this zone though and include species of seaweed, bacteria, fungi, sponges, sea anemones, worms, sea stars, and fishes.

The deepest parts of the ocean make up the abyssal zone. The water in this zone is extremely cold, only about 3°C. In addition to being cold, the water is also highly pressurized and high in oxygen content, though low in nutritional content. Despite the challenges, many species of invertebrates and fishes make a living in this zone. Hydrothermal vents near mid-ocean ridges provide a habitat for chemosynthetic bacteria to thrive in, using hydrogen sulfide and other minerals for energy.

Coral Reefs

Coral reefs are widely distributed in warm shallow waters around the world. There are three main types of coral reefs: fringing reefs, barrier reefs, and atolls. As the name implies, the dominant organism in coral reefs is coral. Corals are organisms that actually consist of a symbiotic relationship between the tissues of an animal polyp and zooxanthellae (a type of algae). Because reef waters tend to be nutritionally poor, the corals feed through photosynthesis done by the algae, though they also have tentacles to gather other algae in the water. Additional fauna found in coral reefs include microorganisms, invertebrates, fishes, sea urchins, octopuses, and sea stars.