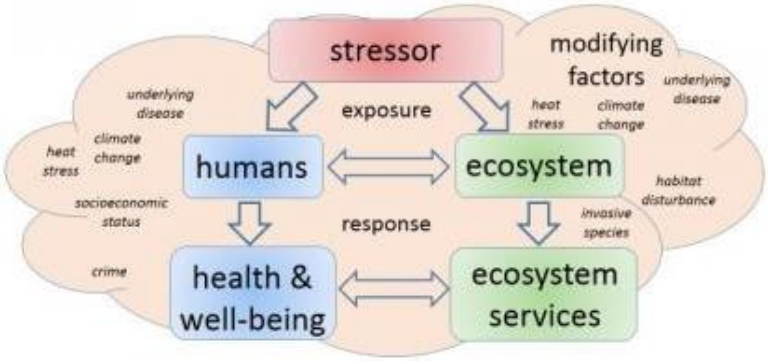
Bodensee Naturmuseum Konstanz

Name: _____

Introduction to Ecology

Simply put, **ecology** is the study of the relationships between living things and their environments. Ecological studies are important because they provide valuable insight about how to conserve global biodiversity, improve our environment, manage our natural resources, and mitigate damage that has been previously done to the environment. Understanding how individual organisms interact with their environment is key to conserving biodiversity because it helps us to 1) identify the factors that influence what organisms must do to survive in the natural world and 2) understand the "natural" factors that determine whether the populations increase or decrease. Extinction happens effectively when a population decreases to zero, so understanding what increases or decreases a population is also important. Population processes determine whether a species survives. Individual organisms continually are born and die, but if all populations of a species go extinct, that is forever. So, we have to think about the population consequences of factors such as individual behaviors and presence of other species. Humans also depend on ecosystem services such as clean air, water, and an environment where we can produce food. Understanding how species and especially whole ecosystems contribute to a healthy environment is critical to maintaining processes that are necessary for the continuation of the human species**.**



1) Vital Signs is a Gulf of Maine Research Institute Program. Creative Commons Attribution (CC-BY) 3.0 License. 2) https://www.epa.gov/research-grants/integrating-human-health-and-well-being-ecosystem-services

Levels of Organization

Ecology is defined as the scientific study of the processes influencing the distribution and abundance of organisms, and the interactions between organisms and the transformation as well as flux of energy and matter. There are many levels at which ecologists ask questions. The largest is at the level of the **biosphere**. The biosphere consists of all of the regions of the surface and atmosphere of the earth occupied by living organisms. One step below the biosphere is the **ecosystem**, which consists of a biological community of interacting organisms and their physical environment. The next level is the **community**, a group of actually or potentially interacting species living in the same place. The next level of organization is the **population**, a group of interbreeding individuals of the same species, which is isolated from other groups. The final level of organization is the **individual**. An individual is any single living thing or organism distinguished from others of the same kind.

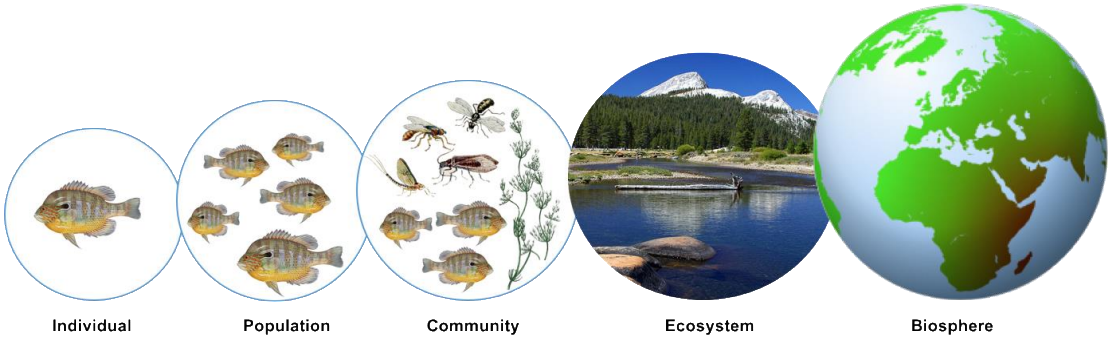


Diagram adapted from MyEnvironmentalScience.com, Pearson Education, Inc. Images are public domain in the U.S.

Fill in the blank. *On the line provided, fill in the level of ecological organization that the given example represents.*

1. All of the sticklebacks that live in Lake Konstanz. _____

2. All of the biotic and abiotic components of Lake Konstanz. _____

3. All of the species of phytoplankton that live in Lake Konstanz. _____

4. A catfish swimming in Lake Konstanz. _____

Individuals: Behaviors, Niches, and Evolutionary History

The relationship between ecology and evolutionary biology is important to understand. One of the most central things to consider when studying ecology is how evolution structures the form, function, and behaviors of organisms. The interactions that organisms have with each other and the environment can result in genetic changes in a population over time. This is called evolution. So it is important to understand how changes happening on an ecological time scale can result in adaptations on an evolutionary time scale.

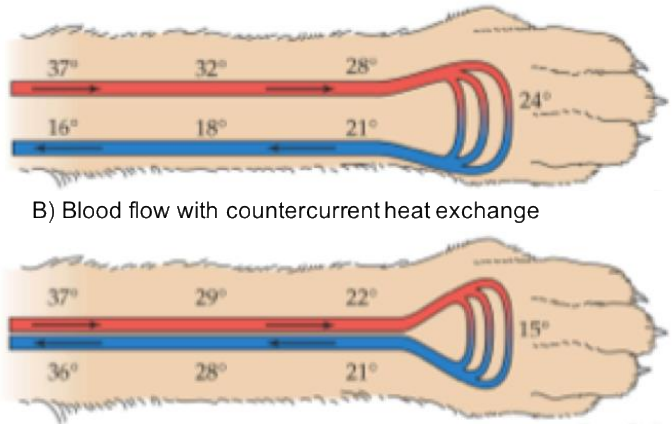
Evolutionary History

Adaptation is defined as any alteration to the behavior, physiology, or structure of an organism or any of its parts that results from natural selection and by which the organism becomes better fitted to survive and multiply in its environment.

Exercise. *Label the following examples of adaptation as either "behavioral", "structural", or "physiological".*

Example 1: _____

Countercurrent heat exchange in the paws of an Eisfuchs (*Alopex lagopus*).

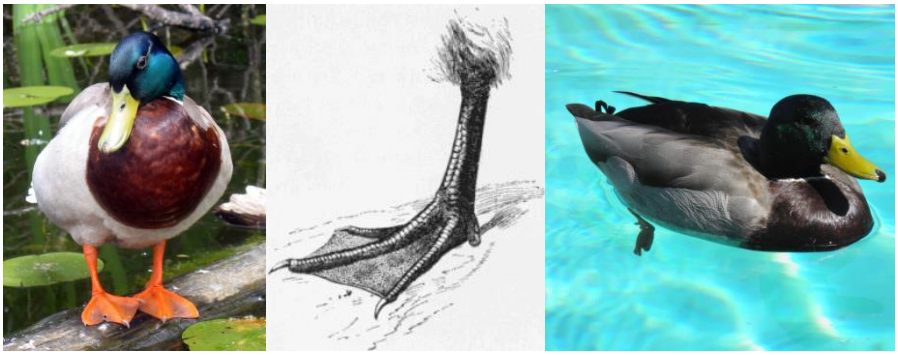


Countercurrent heat exchange in the paws of an Eisfuchs. Countercurrent heat exchange is a mechanism in which there is a crossover of some property, usually heat, between two flowing bodies moving in opposite directions to each other. For the Eisfuchs, this means that blood entering the paws is used to heat up blood that is leaving the paws.

Diagram adapted from Animal Physiology 2004, Sinauer Associates.

Example 2: _____

The webbed feet of ducks that help them swim easily and quickly.



Mallard: By Emily Diehl - Own work, CC BY-SA 3.0, Foot drawing: published before 1923 and is public domain in the U.S. Mallard swimming: By Michael W. Kolton (Own work), via Wikimedia Commons

Example 3: _____

The winter migration of giant pandas. Instead of hibernating during the winter like other species of bear, the giant panda moves to lower, warmer altitudes.

By Rob (Flickr profile) [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons.
By Chen Wu from Shanghai, China

Exercise. *Provide one more example of an adaptation from each category. Walk around the museum and take a close look at the specimens for ideas.*

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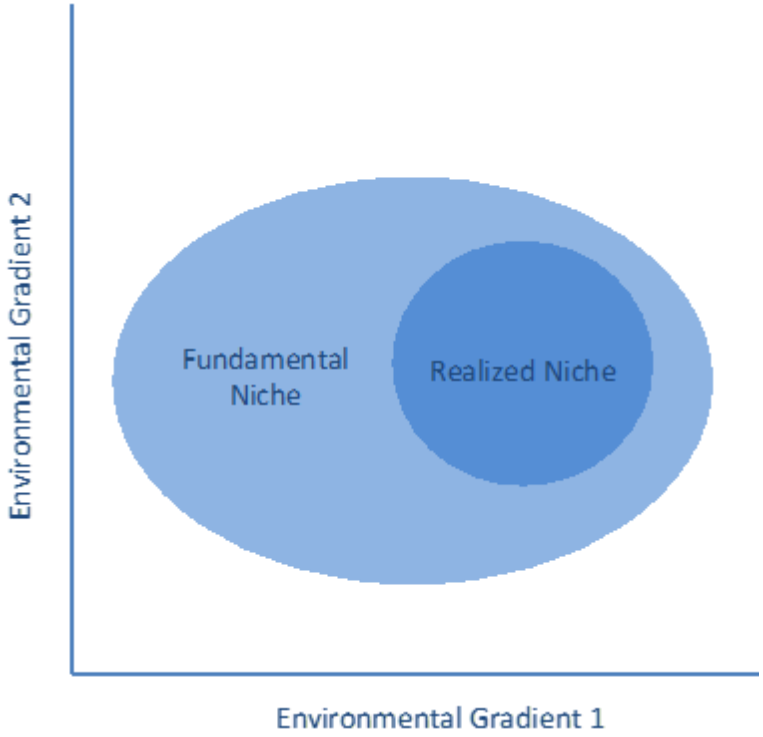
Niches

One of the most central concepts in ecology is that of the **ecological niche**. A species' ecological niche is the role and position that species has in its environment, how it meets its needs for food and shelter, how it survives, and how it reproduces. A species' **niche** includes all of its interactions with the biotic and abiotic factors of its environment. Sometimes a species is not able to occupy its entire niche. This is often due to the presence or absence of other species competing for the available resources. So, we can break the concept of an ecological niche down into the **fundamental niche** and the **realized niche.** The fundamental niche is the total potential niche a species if no other species were using the same resources it uses, while the realized niche is the actual niche an organism occupies as a result of competition for its resources and problems in acquiring those resources. The fundamental niche is always larger than the realized niche.



The introduction of the gray squirrel (*Sciurus carolinensis*) to Europe, and how that affected the realized niche of the Red squirrel (*Sciurus vulgaris*) provides a good example of factors that can influence the realized niche of a species. The American gray squirrel was introduced to Britain in 1876 as an ornamental species, and has since replaced the native red squirrel throughout most of its historical range. These species occupy a similar niche. They both live in trees and feed on similar food resources. The gray squirrel is about twice the size of the red squirrel, and live in much denser populations than the red squirrels. The gray squirrels have also evolved a tolerance to unpalatable chemicals produced by unripe acorns (tannins), while the red squirrels have not. This means that the gray squirrels can eat all of the acorns early in the season, leaving the red squirrels without many food resources. All of these factors give the gray squirrels a competitive advantage over the red squirrels. This competitive advantage reduces the realized niche of the red squirrel, and may eventually cause the red squirrel to go extinct in some areas.

1) By Peter Trimming [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons.
2) By Troydj (Own work), via Wikimedia Commons

Questions.

1) Name one way the realized niche of the red squirrel would be greater in places where the grey squirrel has not invaded.

2) How do you think the gray squirrels became tolerant to the tannins in acorns? (Hint: where did the gray squirrels come from?)

Niche Construction is the process in which an organism actively modifies its own and/or another organism's evolutionary niche. This often results in an increased chance of survival for the organism. A possible outcome of niche construction is "ecological inheritance". This happens when such modifications alter natural selection pressures.

The dam building activities of the Eurasian Beaver (*Castor fiber*) provide a great example of niche construction. When a beaver builds its dam and lodge it greatly alters the local environment. These alterations have many indirect effects on other animals and plants. These effects include changes in nutrient cycling, decomposition dynamics, additionally the structure of the riparian zone, community composition and diversity. Beavers cut down trees to build their dams, which alters the composition of the forest habitat near the stream. The beavers cut down only the species of trees that they prefer for food and dam construction, leaving the undesirable species standing. Over time, the forest near a beaver pond becomes dominated by different species of trees than before, and the gaps left by the fallen trees are inhabited by smaller saplings and bushes and the animal species that accompany those trees. When the beavers dam the stream it slows the movement of water and creates a pond of still water. This impoundment drastically alters the local hydrology and consequently the composition of the riparian zone. The pond also creates habitat for aquatic plants and animals that normally are only found in non-flowing habitats such as lakes. This causes the animals adapted to fast flowing water to die out or to move downstream.

iStockphoto.com/Steve Greer

By Hugo.arg - Jūsų darbas (own work), GFDL, https://commons.wikimedia.org/w/index.php?curid=4270825

Questions.

1) Can you think of any other examples of niche construction?

2) How long do you think the ecological effects of the beaver dam last after the beavers have moved on?

Exercise. *Find another example of an organism that modifies its niche in the museum. Draw a picture of what you think the habitat would look like before and after it has been modified by the organism. What are the main differences? How long do you think the modifications would last in your example?*

Behaviors

Individuals are constantly interacting with other individuals within populations and communities. The branch of ecology that tries to understand the dynamics of these interactions is called **behavioral ecology**. Behavioral ecology focuses on how animal behavior is influenced by ecological pressures in an evolutionary context. As discussed previously, genetic variation among individuals can lead to changes in a population of individuals (adaptation) over several generations via natural selection. Sometimes these changes are behavioral. There are several behavioral factors that can influence the success of an individual. For example, competition for resources and mates, reproductive behaviors such as mate choice, mating systems, and parental investment, and social behaviors can all significantly impact an individual's fitness.

Competition is an interaction between organisms in which the fitness of one is lowered by the presence of another. Organisms compete for the resources they need to survive- air, water, food, and space. Competition can occur within (intraspecific) and between (interspecific) species.

The interactions of the Musk Ox (*Ovibos moschatus*) within members of its own species, and also with members of other species (caribou in our example) provide great examples of both intraspecific and interspecific competition.

Intraspecific: During the breeding season, dominant males will fight each other for access to females. The fighting males will begin with a display of their horns, and then charge each other from distances of up to 20 meters. They will continue to charge into one another until one of them gives up. The winning male will then establish a harem of 6-7 females to mate with.

1) By Quartl (Own work), via Wikimedia Commons 2) By Bering Land Bridge National Preserve (Muskox BELA Two Adults and COY by Jason Gablask), via Wikimedia Commons 3) © **Wild Wonders of Europe / Munier / naturepl.com**

Interspecific: Both the musk ox and caribou (*Rangifer tarandus*) inhabit the arctic tundra, and feed on plants such as grasses and sedges. These species are normally able to coexist peacefully. The musk oxen are able to survive on poorer quality foods, and during the winter when food resources are at a minimum, the caribou migrate to wooded areas and feed mostly on lichens. However, when abnormal weather conditions reduce the amount of available food resources, these species must compete for the same food resources.

Questions.

1) What resource is the musk ox competing for in the example of intraspecific competition?

2) What resource is the musk ox competing for in the example of interspecific competition?

Mating Systems are the way in which a group is structured in relation to sexual behavior. With respect to animals, the term describes which males and females mate, and under which circumstances. Recognized systems include monogamy, polygamy, and promiscuity, all of which lead to different mate choice outcomes and thus these systems affect how sexual selection works in the species that practice them.

- Monogamy Examples: Eurasian Beaver (*Castor fiber*). The Eurasian beaver is a monogamous species, meaning they only have a sexual relationship with one partner. Beavers begin to reproduce at about three years of age, and stay together for multiple breeding seasons. Only one adult pair per colony mates, while the other family members help take care of the young. The potential benefits of monogamy are extended parental care of offspring and mutual defense. This mating system likely evolves when the survival of offspring requires more care than one parent is able to provide and/or the cost of acquiring a mate is high.

- Polygamy (Polyandry) Example: European Perch (*Perca fluviatilis*). The European perch is a predatory fish distributed widely throughout Europe and Asia, and can be found in Lake Constance. This species practices polyandry, a mating system where one female mates with several males. During the breeding season, 15-25 mature males will wait in the spawning area for

females. Upon a female's arrival, she is chased down by up to two males. The males will then prod her belly with their snouts, and she will release a ribbon of eggs. The two males will then fertilize the egg ribbon, and the eggs will hatch in 8-16 days. There are many potential benefits of polyandry. By mating with several males, a female is able to ensure that a high percentage of her eggs are fertilized. Additionally, by having multiple partners, a female has more potential males to help care for offspring and protect her from predators.

- Polygamy (Polygyny) Example: Musk Ox (*Ovibos moschatus***).** The musk ox practices polygyny, a mating system where one male mates with several females. During the rutting season, mature males will fight for access to females. The winning male will then establish a harem of 6-7 females that he will mate with throughout the breeding season. The females will then become pregnant, and the herd will reassemble. The primary benefit of polygyny for males is high reproductive success, since they are able to mate with several females and father all of the offspring. The primary benefit for females is access to resources such as food or territory that is controlled by the male. The female also receives protection for herself and any offspring.

- Promiscuity Example: European Hare (*Lepus europaeus*). The European hare is a promiscuous species, meaning that both males and females have sex frequently with different partners and are indiscriminate in their choice of sexual partners. European hares reach sexual maturity at 6-8 months of age, and breed frequently throughout the year. A female hare can have up to three litters in one year. One potential benefit of promiscuity is the maximization of the genetic diversity of the offspring. By maximizing the genetic diversity of the offspring, the chance of a beneficial adaptation is more likely. High genetic diversity can also compensate for the negative consequences of inbreeding in small populations.

Parental Care is an investment of resources provided by the parent to increase the fitness of the offspring, at the expense of the parent. This includes the time and energy the parents spend raising the offspring, as well as the risks the parents incur to protect the offspring.

Exercise*. Rank the following types of organisms with what you think their general level of parental investment is from the least to the most.*

Reptiles, Mammals, Birds, Arthropods, Fishes

Walk around the museum and find an example of an animal that provides parental care. List three ways in which it invests in the fitness of its offspring.

Kin Selection is an example of a social behavior in which organisms cooperate to increase their own fitness. Because relatives share some proportion of the same genetic material, they will help individuals that are closely related even when there is a cost to their own survival. Helping relatives increases your 'inclusive fitness', or the passing on of your genes indirectly through close relatives that share those genes. An organism's inclusive fitness includes its own offspring ('fitness') plus the genes reproduced in other closely related offspring.

The concept of kin selection explains altruistic behavior in highly social insect groups. For example, in ants and bees' workers are sterile and have evolved to forgo reproduction so that the queen, their sister, can reproduce in social insect groups. This phenomenon also explains why a honeybee would sting something and sacrifice its life to defend the colony made up of its sisters. At first glance, it would seem that altruistic behavior is at odds with the theory of natural selection. However, the theory of kin selection explains that this behavior can be advantageous because it still allows an organism's genes to be passed on not directly through its own offspring but instead through the offspring of its relatives.

Populations: Growth and Regulation

Population ecology is the study of how and why populations change over time. By studying the characteristics of populations, we can make predictions on how their dynamics may change in the future. There are several practical applications of understanding the dynamics of populations such as managing food stocks and renewable resources, understanding and being able to predict outbreaks of pests and diseases, and managing threatened or endangered species. There are several factors that influence how a population will grow and decline over time. These include the population density, spatial distribution, sex ratios, structure, and birth and death rates.

Important Definitions:

Population Size: the actual number of individual organisms in a population.

Population Density: the number of individual organisms per unit area or unit volume.

Spatial Distribution: how a species is spatially arranged, i.e. uniform, random, or clustered.

Sex Ratio: the ratio of males to females in a population.

Geographic Range: the geographical area in which a species can be found.

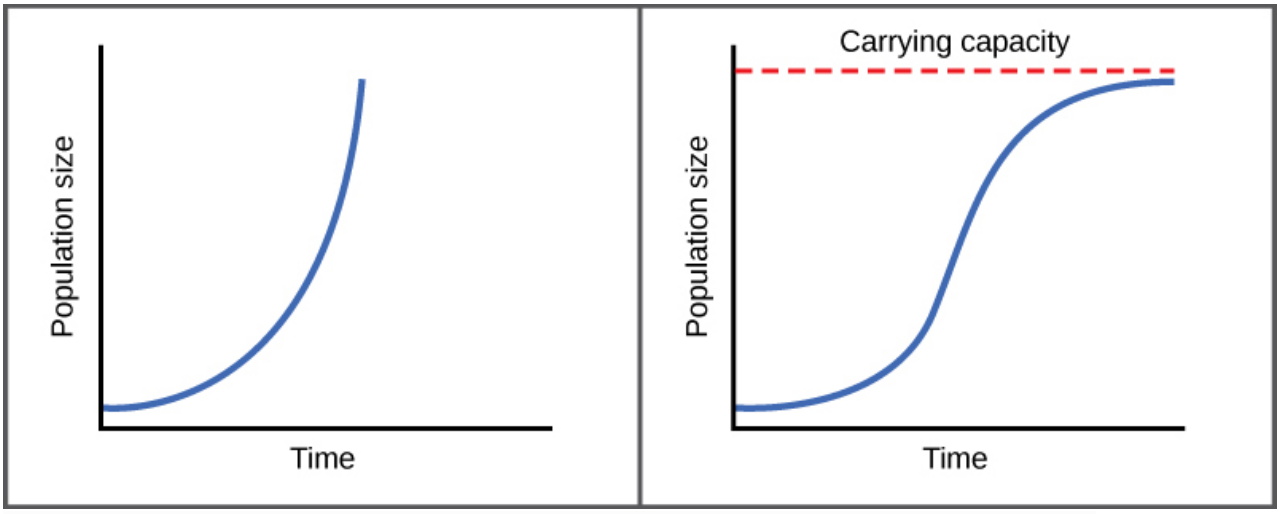
Population Growth: the increase in the number of individuals in a population.

Exponential Growth: growth whose rate becomes ever more rapid in proportion to the growing total number or size, i.e. continuous growth.

Logistic Growth: growth whose rate decreases as the population reaches **carrying capacity**.

Carrying Capacity: the maximum population size of the species that the environment can sustain indefinitely, given the food, habitat, water, and other necessities available in the environment.

Exercise. *Label each of the following graphs as either "logistic growth" or "exponential growth".*



Source: Boundless. "Exponential Population Growth." *Boundless Biology* Boundless, 08 Aug. 2016. Retrieved 19 Feb. 2017 from https://www.boundless.com/biology/textbooks/boundless-biology-textbook/population-and-community-ecology-45/environmental-limits-to-population-growth-251/exponential-population-growth-929-12185/

_____ _____

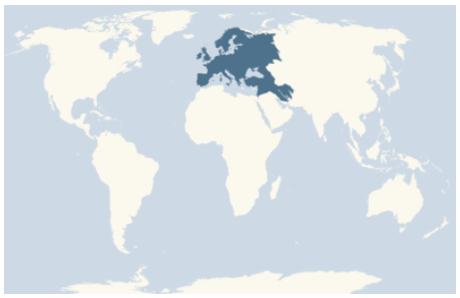
Questions.

1) Which graph do you think most accurately represents the growth seen in natural populations?

2) What are some factors that could potentially influence population growth?

The Roe deer (*Capreolus capreolus*) provides a great example for examining fluctuations in population size. The roe deer is a small species of deer that is native to Eurasia. Roe deer have an estimated population size of about 15 million individuals in Europe. However, their population size has fluctuated greatly over time and throughout their geographic range as a result of several factors such as habitat and resource availability, the introduction/removal of predators, and management efforts of humans. This has led to them almost becoming extinct in certain parts of their range, and considered pests in other parts. Below is a photograph of a small herd of roe deer and a map highlighting their geographic range in Europe.

By Olavfin [Public domain], via Wikimedia Commons



WWF's Wildfinder

The roe deer provide a good example of the importance of understanding the dynamics of a population from a conservation and management standpoint. The roe deer is valued for its meat, making it an important conservation priority for sportsmen, but can also become a pest and devastate natural habitats if the population becomes too large. There are several factors that influence the growth rate of populations. As mentioned above, the things that influence population growth include competition for space and food, the capacity of an ecosystem to recycle nutrients and waste, the presence/absence of parasites and/or predators, and human activities such as habitat destruction or pollution.

Critical Thinking.

1) Can you think of any other limiting factors that could influence the population growth of roe deer or other organisms?

2) Below is a graph of the population growth of European roe deer. Study the graph and answer the following questions.

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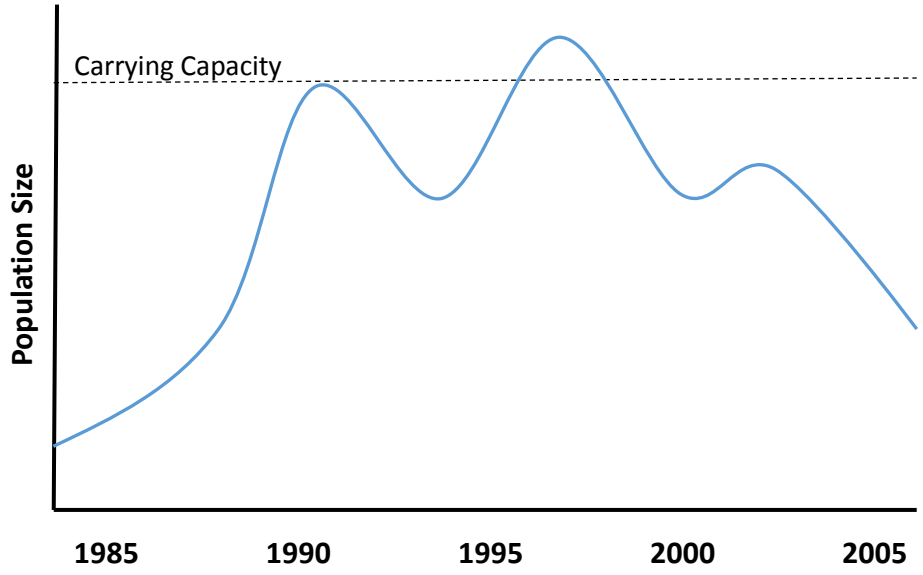


Questions.

A) During which period of time was the population of roe deer growing exponentially?

B) Can you give one hypothesis as to why the roe deer population exceeded its carrying capacity between 1995 and 2000?

C) Can you give one hypothesis as to why the population of roe deer started decreasing in the 2000s?

*For another example make sure to check out the exhibit on the back wall of the museum to see how pollution in the 1960's and 1970's influenced fish populations in the Bodensee.

Communities: Species Interactions, Food Chains, and Community Dynamics

An ecological community can be defined as an assemblage of populations of two or more species that occupy a particular area and interact with each other and the environment.

Species Interactions

The ways that different species interact and influence each other play a major role in the dynamics of a community. It is important to understand these interactions, as it may not be initially obvious how impacts on one species may affect the other species in a community.

Type of Interaction	Species A	Species B	Effects
Mutualism	+	+	Both species benefit
Commensalism	+	0	One species benefits, one is unaffected
Antagonism (Predation/Parasitism)	+	-	One species benefits, one is negatively affected
Amensalism	-	0	One species is negatively affected, the other is unaffected
Competition	-	-	Both species negatively affected

The table above summarizes the major two-way interactions between species.

Questions.

1) Can you think of any examples of these types of species interaction?

2) Given the way that species interact, do you think that an event that affected one species in a community would also have an impact on the rest of the community?

Exercise. *Label the following examples of species interactions.*

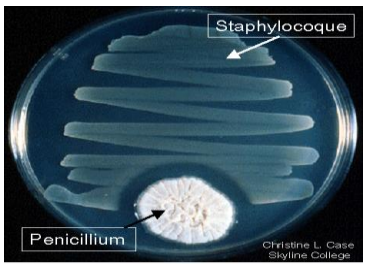
The bees fly from flower to flower and collect nectar that they then turn into food. During this process, pollen gets stuck in the hairs on the bodies of the bees and gets transferred from flower to flower, ultimately pollinating the plant.

This is a picture of a human infected with a species of roundworm. The roundworm lives in and feeds on the host, but does not kill the host. So in this relationship the parasite benefits and the host suffers.

Lions and hyenas inhabit the same geographic range and depend on the same prey for food. This often leads to them fighting and occasionally killing the young of each other.

_____ _____ _____

This orchid is an epiphyte, or a plant that grows on another plant, such as on the trunk or branches of trees. Living on the trees allows them to reach the sunlight easier, which they need for photosynthesis. The orchids remain relatively small, so their presence does not affect the trees.



The bread mold *Penicillium* secretes penicillin, a chemical that kills and inhibits the growth of bacteria. By releasing this chemical into their shared environment, the *Penicillium* negatively affects the bacteria,

_____ _____

1) By John Severns Severnjc (Photo by John Severns.) [Public domain], via Wikimedia Commons; 2) Image found on the internet and believed to be within the public domain; 3) By lubye13 (IMG_1300) [CC BY-SA 2.0 (http://creativecommons.org/licenses/by-sa/2.0)], via Wikimedia Commons; 4) By Bernard Dupont from France (Leopard Orchid (Anselia africana)) via Wikimedia Commons; 5) Photo©CLCase (https://accounts.smccd.edu/case/antibiotics.html)

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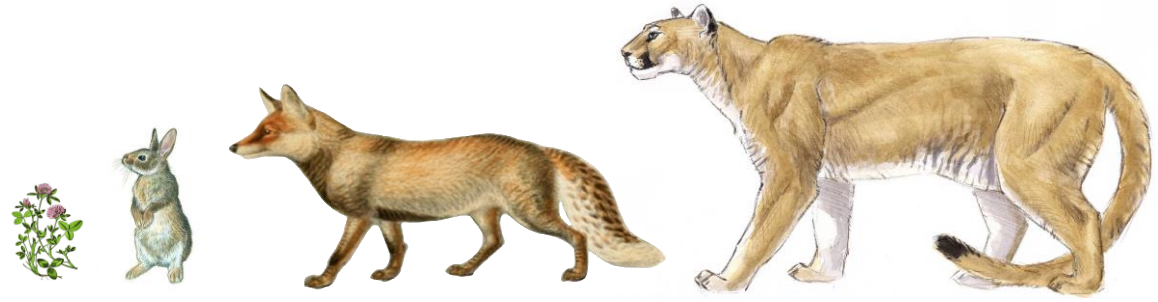
Food Chains

The trophic level of an organism is the position that an organism occupies in a food chain. Organisms such as plants, algae, and some bacteria capture energy from the sun and use it to produce plant material via a process called photosynthesis. These organisms are called **primary producers** because they make their own food. The organisms at the second trophic level are called **primary consumers**. These organisms are herbivores, meaning that they eat only plant material. The third trophic level consists of **secondary consumers**. These organisms are carnivores and eat the primary consumers. The fourth trophic level is made up of **tertiary consumers**. These organisms consume the secondary consumers.

Energy flows through the ecosystem from lower (primary producers) to higher (tertiary consumers) trophic levels. At each trophic level only a fraction of energy is available to be absorbed by the next level. The remaining energy is used for metabolic processes or lost as heat. This loss of energy is why ecosystems are usually limited to four trophic levels. Occasionally a fifth level is possible (quaternary consumers) but due to the lack of available energy, this is rare. Below is a simplified version of a terrestrial food chain.



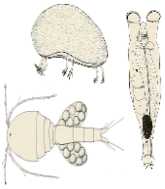
Clover: Wayside and Woodland 1895, Edward Step and F. Warner. Rabbit: Scan of image in the public domain believed to be free to use without restriction. Fox: By Mivart, St. George Jackson - Dogs, jackals, wolves, and foxes: a monograph of the Canidae. With woodcuts, and 45 coloured plates drawn from nature by J.G. Keulemans and hand-coloured., Public Domain, https://commons.wikimedia.org/w/index.php?curid=47444780 Cougar: John Muir Laws https://johnmuirlaws.com/draw-mammals

Questions.

1) What are the trophic levels of the organisms in the picture above?

2) How might an aquatic food chain differ from a terrestrial food chain?

The following organisms are common in aquatic food chains and are example of what you might find in Lake Konstanz. Organism A is *Coregonus lavaretus*, the European whitefish. This fish feeds on bottom dwelling invertebrates and zooplankton. The organisms depicted in picture B are common species of zooplankton. Zooplankton are usually microscopic and feed on phytoplankton. Organism C is a heron. These birds are carnivorous and feed on a wide variety of aquatic organisms. Finally, the organisms depicted in picture D are examples of phytoplankton. Phytoplankton are microscopic organisms that require sunlight to live and grow. They use photosynthesis to turn energy from the sun into food.

A)  B)  C)  D) 

Whitefish: By encyclopedia, "Pieni Tietosanakirja" [Public domain], via Wikimedia Commons. Zooplankton: By Internet Archive Book Images [No restrictions], via Wikimedia Commons. Heron: Public Domain. PhytoPlankton: Adapted from drawings and micrographs by Sally Bensusen, NASA EOS Project Science Office.

Exercise. *Label the organisms above with their trophic level in the food chain.*

Questions.

1) What do you hypothesize is the relationship between phytoplankton and zooplankton. For example, do you think the abundance of phytoplankton in a community influences the abundance of zooplankton?

2) Do you think that the abundance of primary producers ultimately has an effect on the abundance of tertiary consumers?

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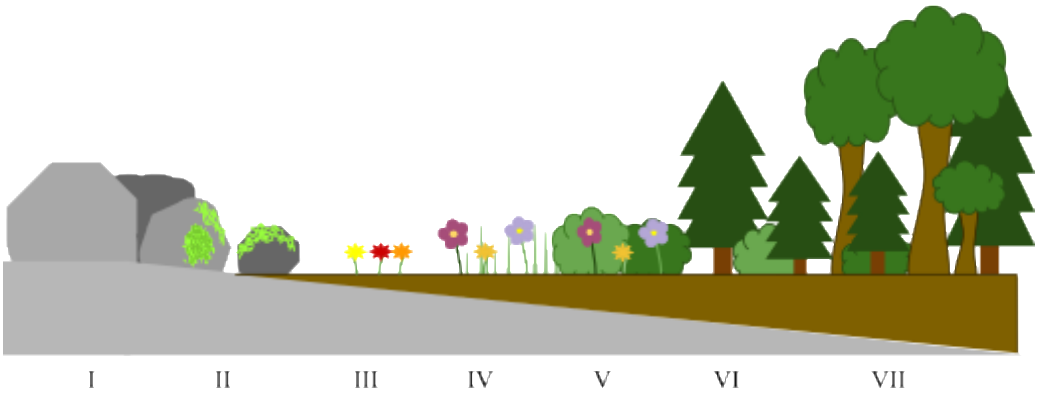
Community Dynamics

Due to the numerous ways in which the members of communities interact, community structure (species richness and diversity) and function are almost always changing. Things that might affect community structure include the introduction or removal of species and natural forces such as storms, fire, floods, etc. All of these events can initiate change in the way communities are structured and ultimately how they function. Two of the most common causes of changes in community structure are **disturbance** and **succession**.

An ecological disturbance is an event that causes a disruption in ecosystem, community, or population structure and alters the physical structure and resources of an environment. Basically, a disturbance creates an opening in an environment. Volcanoes, floods, hurricanes, and fires are all example of natural disturbances. Communities are also influenced by human disturbances such as agricultural activities, habitat fragmentation, pollution, fire prevention, and the introduction of non-native species.

Ecological succession is the gradual process by which community composition changes over time. There are two main types of succession, **primary** and **secondary**. Primary succession occurs in new habitats that have not been colonized previously. For example, living things colonizing newly formed rock for the first time would be primary succession. Secondary succession is the gradual change in community composition following a disturbance in an area that was previously colonized by living things.



The drawing above depicts an example of primary succession. Let's imagine that in our example a glacier has recently receded and exposed a large area of rock. How do we get from newly exposed rock to a diverse forest?

The first species to colonize a habitat are called **pioneer species**. These are organisms such as algae, lichen, and fungi that along with natural factors such as water and wind break down the nutrients in the rock and form a thin layer of soil. The soil layer produced by the pioneer species then allows new species of vascular plants to colonize the area. These early species are usually adapted to living in thin and mineral rich soils. The biological processes of these early plants continues to add nutrients and decomposing material to the growing soil layer. As more and more organic material is produced, larger species of plants are able to colonize the area. This process repeats, with the new species often replacing the previous species, until a period of stability is reached. This relatively stable community is called a **climax community**.

Questions.

1) How do you think succession would differ in an aquatic community?

2) What are some examples of disturbances that could affect an aquatic community?

3) Can you find any examples of disturbances that have affected the community structure of Lake Konstanz in the museum?

4) In the last 100 years have the disturbances that have affected the community structure of Lake Konstanz been mostly natural disturbances or human disturbances?

Bodensee Naturmuseum Konstanz

Ecosystems: Flow of Energy and Matter

An ecosystem is made of a community of living organisms and their interactions with their physical environment. Ecosystems consist of **biotic** (living) and **abiotic** (non-living) factors. The cycling of energy and matter between the biotic and abiotic components of an ecosystem is vital to a functional ecosystem. The diagram below depicts a simplified ecosystem. The arrows represent some of the common interactions among/between the different components of the ecosystem.

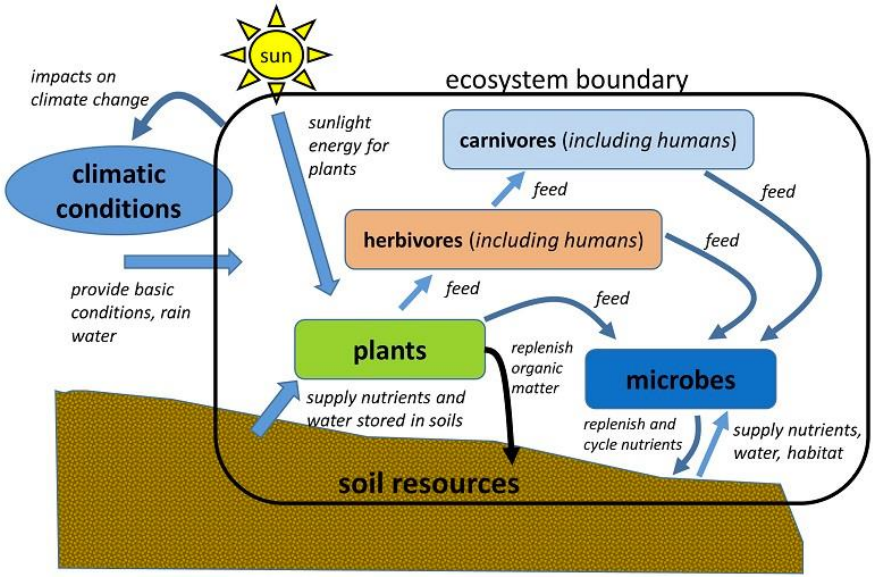


Image Credit: Steven Vanek (Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License)

Exercise. *Sort the components (climatic conditions, sunlight, plants, herbivores, carnivores, microbes, soil resources) of the above diagram as either abiotic or biotic factors.*

Abiotic	**Biotic**

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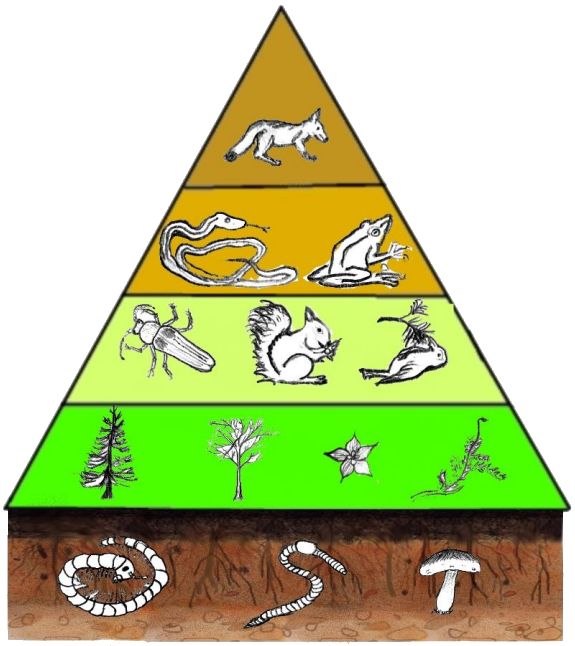
Energy Flow

As we covered in the community ecology section of this worksheet, most of the energy flowing through an ecosystem comes from the sun. Primary producers such as plants, algae, and some bacteria capture solar energy and convert it to chemical energy in order to produce organic material (biomass) through a process called photosynthesis. This energy then flows from organism to organism via the food chain. Decomposers complete the food chain as they receive their energy by breaking down plants and animals that were not consumed by other organisms as well as the wastes excreted by herbivores and carnivores. It is also important to remember that only about 10% of the captured energy is transferred to the next trophic level, while the remaining energy is lost to other processes. Some of the energy is lost as heat, and the rest is used by the organisms within that level for growth, metabolic processes, or survival. Because the energy flowing through an ecosystem is not recycled, it must be constantly replaced.

***Exercise**. Use the ecological pyramid below to complete the following activities/questions.*



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1) Label each level of the ecological pyramid with their tropic level (example: primary producer).

2) What is represented by the pyramid being larger and the bottom and narrowing as it goes up?

3) If a plant at the bottom of the pyramid captures 1000 calories of energy from the sun, how many calories will make it to a primary consumer? Secondary consumer? Tertiary consumer?

4) Walk around the museum and identify organisms from each trophic level. Draw and label them in an ecological pyramid below.

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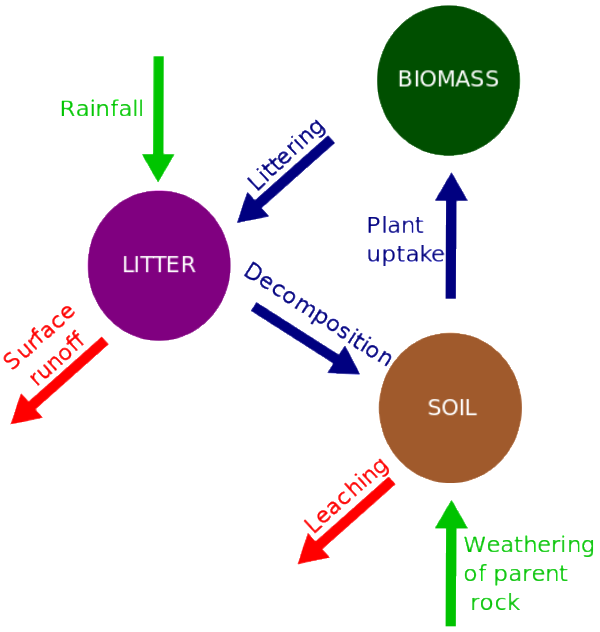
Nutrient Cycling

Nutrient cycling is the repeated movement of organic and inorganic matter back into the production of living matter. This is one of the most important processes in an ecosystem, as nutrients such as carbon, hydrogen, nitrogen and oxygen are vital to the existence of organisms and therefore must be recycled in order for organisms to exist. It is important to note that there are several chemical elements that are involved in the nutrient cycle, but in this explanation we will group them all under the general term ‘nutrients’.

Nutrient cycles are tied to food web pathways. Nutrients in the soil are taken up by plants, which are then either consumed by animals or die naturally. The nutrients are recycled back into the environment as decomposers break down the waste of the consumers or the organic matter from the dead organism. When the decomposers break this material down, it is returned to its mineral form, allowing it to be taken up once again by plants.



By Kayau (Own work), via Wikimedia Commons

The diagram above is a simplified example of the nutrient cycle. The two ways that nutrients enter the cycle (input) in this example are from rainfall (nutrients are absorbed in the rain drops) and the weathering of rock, which are shown with green arrows. Once the nutrients enter the cycle they are stored either in biomass, litter, or soil as shown by the circles. The blue arrows show how nutrients are cycled once they have entered the system. The ways in which nutrients are lost from the cycle (output), leaching and surface runoff, are shown in red.

Questions.

1) What is the major difference between the flow of energy and the flow of nutrients through an ecosystem?

2) In what ways can humans influence the flow of energy and nutrients through an ecosystem?

3) Can you find an example in the museum of a time that humans influenced the nutrient cycle in Lake Konstanz?

Biodiversity and Conservation: Ecosystem Services and Human Impact

Biodiversity is the biological diversity of life on Earth. It can be studied at many levels, including all of those that we have previously covered in this worksheet. Most commonly, you will hear about species diversity. However, ecological biodiversity, the diversity of ecosystems, and genetic diversity are equally significant. Biodiversity is important because ecosystems and their species provide several essential biological services called **ecosystem services**.

Ecosystem Services

Ecosystem services such as pollination, decomposition, water purification, erosion and flood control, carbon storage, and climate regulation are vital for keeping the planet fit for human life. Biodiversity also provides several economic benefits. For example, people receive many food resources, medicines, and textiles from the environment. There are also cultural benefits to biodiversity. For example, the tourism that Lake Konstanz attracts brings people happiness and also provides an economic benefit to the surrounding cities. Generally, greater biodiversity increases ecosystem productivity and benefits the economy.

For example, Lake Konstanz is a huge source of fresh water. Every year about 0.3% of the lake water is removed and processed into drinking water by 20 water supply plants. This supplies fresh water to almost all of Baden-Württemberg, which is about 3.7 million people. The lake can only be used as a source of drinking water when it meets certain environmental standards. For example, when the lake is polluted, the water quality drops substantially, and it is no longer a suitable resource. This is why it is important to protect the lake ecosystem.

Question*.*

1) What are some other ecosystem services provided by Lake Konstanz?

Human Impact on the Environment

Unfortunately, biodiversity is rapidly declining due to human activities. The main threats to biodiversity are human population growth and resource consumption, environmental degradation, pollution, and climate change. As the human population continues to grow, so do the negative consequences for biodiversity. These effects include increased resource consumption, habitat loss/destruction and habitat fragmentation, global warming, introduction of invasive species, over-exploitation of natural resources (over fishing, non-renewable resources, excess pumping of underground water tables), and increased pollution. The loss of biodiversity has negative effects on the entire planet and means that in the future resources like food, clean water, and medicine will be harder to obtain. It is estimated by the World Wildlife Fund that we are currently consuming about 25% more natural resources than the planet can sustain, so it is imperative that we find ways to conserve biodiversity.

How can we conserve biodiversity?

Since biodiversity is being lost at all levels, we need conservation efforts at all scales. There are things you can do as an individual, and also things we must do as a society to conserve biodiversity. The list below gives some examples of what we can do to slow biodiversity loss.

- Reduce, Reuse, and Recycle
- Conserve water
- Use only natural pesticides and fertilizers
- Do not eat endangered species
- Maintain natural areas and protect habitats for endangered species
- Support contraception and science education
- Encourage the government to make protecting biodiversity a number one priority

Questions.

1) Can you think of any other ways that you can help conserve biodiversity?

2) What is one small change that you personally can make in your daily routine that would contribute to slowing biodiversity loss?

Exercise. *Find an example in the museum of how human activities have impacted the biodiversity in or around Lake Konstanz in the past. Give a brief description of your example and if relevant, what actions were taken to remedy the impacts. If no actions were taken to remedy the impacts, give a suggestion of something that could be done.*