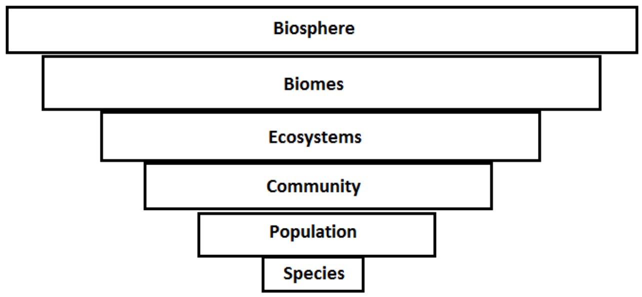
Biology 2211

Unit 1: Interactions among living things

Ecology: the study of interactions of organisms with one another and their environment.

Ecological hierarchy



Species: a group of structurally similar individuals who can successfully interbreed to produce fertile offspring.

Population: A group of individuals of the same species living in the same geographical area

Community: All of the organisms of all the interacting populations in a given area

Ecosystem: A community of living organisms, together with the biotic and abiotic factors that surround and affect the community.
Although people often think of ecosystems as being quite large, they can be small. In fact, the size of an ecosystem depends on what you are studying. There are small ecosystems within large ecosystems, which are within even larger ecosystems.

Biomes: Identifiable ecosystem found in a specific region on Earth that has a particular combination of biotic and abiotic factors

Biosphere: all ecosystems and their interactions on Earth.

Sustainability: maintaining a system that can meet the needs not only of our present human population, but also those of the future.

For Discussion: What factors such as abiotic or biotic would be needed to sustain populations within ecosystems?

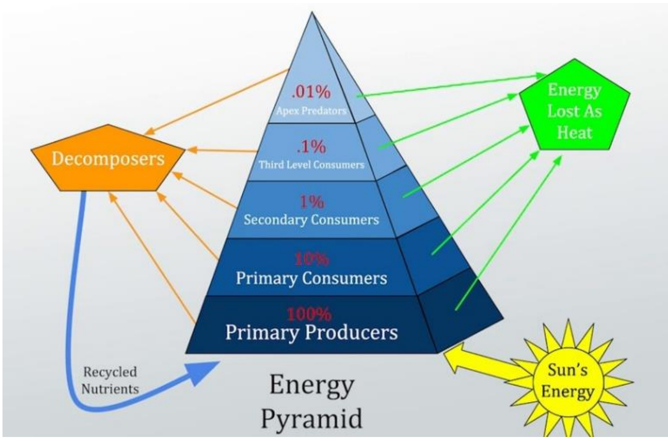
Production/Distribution of energy.

Recall from science 1206 how energy enters a system through photosynthesis and chemosynthesis through the work of **producers (autotrophs).** This energy is then transferred through the ecosystem by **consumers (heterotrophs).**

Energy Pyramids:

As the food is passed through the food web, most of the energy is lost. In general terms, about 10% of the energy stored in one trophic level (such as producers) is actually transferred to the next trophic level (for example the herbivores). The remaining 90% energy is lost to the atmosphere as heat or used by the organism for metabolic or reproductive purposes.

Eventually there is so little energy remaining in the top trophic level that no higher trophic level can be supported. This is why there are so few if any fourth order consumers in an ecosystem.



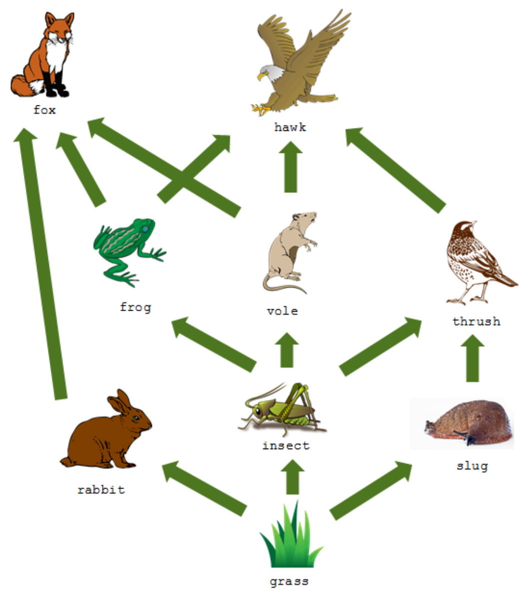
Local Example of food chain:

Algae→ insect→ Frog→ Eagle

Food Chains and food webs: What happens when things go wrong?

When examining the transfer of energy within food chains and food webs it is important to note how they are interconnected and determine the effects of losing a species within a food web/chain.

For discussion: What happens to the following food web if we remove the insect?



Video: Reintroduction of wolves to Yellowstone national park

https://www.youtube.com/watch?v=ysa5OBhXz-Q

Canadian Biomes

A **biome** is defined as a large geographical region that has a particular type of climax community. A biome is therefore a distinct ecological community of plants and animals living together in a particular climate.

The distribution of biomes is largely determined by abiotic factors such as:

- Annual patterns of temperature
- Precipitation
- Radiant energy (amount of sunlight)
- Soil composition

The biomes are generally distributed over the earth in horizontal bands that are linked to these conditions and associated with ***latitude*** and ***altitude*** along with other geographical features such as the proximity to large bodies of water or mountain ranges.

Range of tolerance - the range of environmental conditions that are tolerable for survival in a species. This determines which organisms can survive in each environment. Unfavorable abiotic and biotic factors can get a species out of its range of tolerance to the zone of physiological stress or zone of intolerance.

For Discussion: Why are there very few reptiles found in Newfoundland?

Terrestrial (land) biomes are defined by the dominant type of plant life (climax community). The terrestrial biomes of Canada include

- Tundra.
- Boreal Forest
- Temperate Deciduous Forest
- Prairie grasslands

There are also three types of **Aquatic** biomes:

- Marine (saltwater or ocean) biome
  - Intertidal zone
  - Neritic zone
  - Bathyal zone
  - Abyssal zone
- Freshwater biomes (rivers, lakes, ponds, swamps, bogs, etc.).
  - Littoral zone
  - Limnetic zone
  - Benthic zone
- Estuaries

Tundra Biome:

• found in the northern most latitudes - arctic circumpolar regions.
• has low average temperature and low annual precipitation (less than 12 cm/year)
• Precipitation is mostly in the form of snow.
• Permafrost- permanently frozen soil exists few meters below surface. This prevents drainage and the rooting of large plants.
• Short growing season (4 to 6 weeks) also prevents development of forests.
• Plant life includes lichens like reindeer moss, true mosses, and low stunted shrubs.
• Animals include mice, moles, lemmings, snowshoe hare, polar bear, caribou, foxes, mosquitoes.

Boreal Forest (Taiga) Biome:

• located south of the tundra
• extends in a broad zone from Western Alaska across Canada in North America
• World's largest terrestrial biome.
• has an average precipitation of 35 - 40 cm/year, most in the form of rain.
• Trees are small with only a few species including many conifers like; spruce, fir, larch, hemlock and pine. Some deciduous trees also exist, including; aspen, birch and willow.
• Animal life includes moose, caribou, black bear, weasels, mink, foxes, wolves, beavers, snowshoe hare, ducks, loons, owls, woodpeckers.
• Climate is characterized by long cold winters with short, cool summers. Has a short growing season (3 to 5 months).
• Soil is full of water and acidic.

Temperate Deciduous Forests

• found in Eastern Canada below the Boreal Forest.
• Average precipitation of 100 cm/year.
• Trees include deciduous trees which lose their leaves each year like; beech, maple, oak, hickory
• has distinct seasons, with more temperate winter conditions and warmer summers than Taiga
• A 4 to 6 month growing season
• Rich fertile soil
• Animals include deer, black bears, opossums, salamanders, squirrels, raccoons etc.

Prairie

• Occurs at same latitudes as temperate deciduous forests.
• In Canada they are found in the Prairie Provinces, Alberta, Saskatchewan and Manitoba.
• Average precipitation between 25-75cm/year.
• A 4 to 6 month growing season
• Grasses are major species of plants and form the natural climax community.
• Animals include grazers like bison, antelope jackrabbits, gophers, ground squirrels.
• Much of the grasslands has been used for agriculture.

Marine Biome

The largest of all the ecosystems, oceans are very large bodies of water that dominate the Earth's surface. Like ponds and lakes, the ocean regions are separated into separate zones. All four zones have a great diversity of species.

- *The **intertidal zone** is where the ocean meets the land — sometimes it is submerged and at other times exposed, as waves and tides come in and out. Because of this, the communities are constantly changing.*
- *The **neritic zone** is the part of the ocean environment that extends inshore at high tide to the edge of the continental shelf. Characteristics of the neritic zone include shallow waters and lots of light penetrating to the sea floor. A diverse range of aquatic animals and plants live in the neritic zone, making it a rich source of food for both ocean-dwelling animals and animals that live on shore.*
- *The **bathyal zone** is the area below the neritic zone, but does not include the very deepest parts of the ocean. The bottom of the zone consists of sand, slit, and/or dead organisms. Here temperature decreases as depth increases toward the abyssal zone, since light cannot penetrate through the deeper water. Flora are represented primarily by seaweed while the fauna, since it is very nutrient-rich, include all sorts of bacteria, fungi, sponges, sea anemones, worms, sea stars, and fishes.*
- *The deep ocean is the **abyssal zone.** The water in this region is very cold (around 3° C), highly pressured, high in oxygen content, but low in nutritional content. The abyssal zone supports many species of invertebrates and fishes. Mid-ocean ridges (spreading zones between tectonic plates), often with hydrothermal vents, are found in the abyssal zones along the ocean floors. Chemosynthetic bacteria thrive near these vents because of the large amounts of hydrogen sulfide and other minerals they emit. These bacteria are thus the start of the food web as they are eaten by invertebrates and fishes.*

Freshwater Biome

Is defined as having a low salt concentration — usually less than 1%. Plants and animals in freshwater regions are adjusted to the low salt content and would not be able to survive in areas of high salt concentration

Lakes and ponds are divided into three different “zones” which are usually determined by depth *and distance from the shoreline.*

- *The topmost zone near the shore of a lake or pond is the **littoral zone**. This zone is the warmest since it is shallow and can absorb more of the Sun's heat. It sustains a fairly diverse community, which can include several species of algae (like diatoms), rooted and floating aquatic plants, grazing snails, clams, insects, crustaceans, fishes, and amphibians. In the case of the insects, such as dragonflies and midges, only the egg and larvae stages are found in this zone. The vegetation and animals living in the littoral zone are food for other creatures such as turtles, snakes, and ducks.*
- *The near-surface open water surrounded by the littoral zone is the **limnetic zone**. The limnetic zone is well-lighted (like the littoral zone) and is dominated by plankton, both phytoplankton and zooplankton. Plankton are small organisms that play a crucial role in the food chain. Without aquatic plankton, there would be few living organisms in the world, and certainly no humans. A variety of freshwater fish also occupy this zone.*
- *The deep-water part of the lake/pond is the **benthic zone**. This zone is much colder and denser than the* other two. Little light penetrates all the way through the limnetic zone into this zone. The fauna are heterotrophs, meaning that they eat dead organisms and use oxygen for cellular respiration.

For Discussion: How do the abiotic factors found in these zones affect the types of species found here? (Range of tolerance)

Estuaries

An estuary is a water body where freshwater from rivers and streams mixes with salt water from the ocean. Estuaries are places of transition from land to sea. Estuarine environments are among the most productive on earth, creating more organic matter each year than comparably-sized areas of forest, grassland or agricultural land. The sheltered waters of estuaries also support unique communities of plants and animals specially adapted for life at the margin of the sea.

Ecotones

An **ecotone** is a transition area between two biomes. It is where two communities meet and integrate. It may be narrow or wide, and it may be local (the zone between a field and forest) or regional (the transition between forest and grassland ecosystems). An ecotone area often has a higher density of organisms of one species and a greater number of species than are found in either flanking community as they contain species from both bordering ecosystems. These areas with greater biodiversity tend to be less fragile as there may be alternate food sources for each predator and thus are important areas in guarding against extinction.

Research Assignment- Investigation 1B page 38

Population Ecology

All populations can be described in terms of two fundamental characteristics: density and distribution.
Ecologists use various sampling methods to estimate the density of a population. Then they use their estimate to determine the number of individuals in, and thus the size of, the population.

Population density (D_P) is defined as the number of individual organisms (*N*) in a given area (*A*) or volume (*V*). As an equation, population density is expressed as:

$$D_p = \frac{N}{A} \quad \text{or} \quad D_p = \frac{N}{V}$$

Population size: The total number of individuals (N) in a population.

Measuring Population Density

There are several methods that can be used to measure population density:

(1) **Census:** complete count of all the members of a given population

(2) **Sampling methods**

- Transect: In transect sampling, a starting point and direction is randomly selected and a line of a certain length is marked out. The occurrence of any individual within a certain distance of this line is recorded. (may be 1m or 50m depending on the species)
- Quadrat sampling: Commonly used for plants, quadrats are done by first choosing random locations and at each site a quadrat of known size (example, 1m2) is marked out. The number of individuals of a species within the quadrat is then counted. The density can therefore be determined by dividing the number of individuals by the size of the quadrat. We can then extrapolate for larger areas.
- Mark-recapture: This technique is commonly used by fish and wildlife managers to estimate population sizes before fishing or hunting seasons. The mark and recapture method involves marking a number of individuals in a natural population, returning them to that population, and subsequently recapturing some of them as a basis for estimating the size of the population at the time of marking and release. It is based on the principle that if a proportion of the population was marked in some way, returned to the original population and then, after complete mixing, a second sample was taken, the proportion of marked individuals in the second sample would be the same as was marked initially in the total population. That is,

$$\frac{\mathbf{R}\text{ (marked recaptures)}}{\mathbf{T}\text{ (total in second sample)}} = \frac{\mathbf{M}\text{ (marked initially)}}{\mathbf{N}\text{ (total pop. size)}}$$

$$\mathbf{N} = \frac{\mathbf{M{*}T}}{\mathbf{R}}$$

Activity 2.4 -distribution patterns and population size estimates- page 53 **or** Outdoor line transect.

Outdoor Quadrat sampling lab

Marked- recapture simulation : https://lc.gcumedia.com/bio320l/catch-and-release-simulation/v1.1/#/

Patterns of population distribution

Distribution patterns are influenced by the distribution of resources in a habitat and the interactions among members of a population, or members of a community.

There are three theoretical distribution patterns for populations: ***uniform***, ***random***, and ***clumped***

- ***Uniform distribution***: This type is found in artificial populations, such as plants growing in orchards or agricultural fields in which individuals are evenly spaced over a defined area. This pattern of distribution is also seen in birds of prey and other organisms that behave territorially to defend their resources and protect their young.

- ***Random distribution****:* can occur when resources are very abundant and population members do not have to compete with one another or, conversely, group together for survival. When a population exhibits random distribution, individuals or pairs of organisms are distributed throughout a suitable habitat with no identifiable pattern. Generally, however, random distribution in nature is rare.

- ***Clumped distribution***: A more common type of distribution in which members of a population are found in close proximity to each other in various groups within their habitat. Most populations, including humans, exhibit a clumped pattern of distribution, congregating in an area where food, water, or shelter is most abundant.

Note: In nature, most populations do not perfectly fit any one pattern of distribution. Or, a particular pattern of distribution may be characteristic of a given population, but only at a particular time. Mosquito larvae, for example, tend to exhibit clumped distribution. When they mature into adult mosquitoes, however, they are likely to fly away and distribute randomly. Similarly, moose may congregate in small groups near food and shelter for periods of time during the winter.

Population Growth

A population's size directly depends on how much and how fast it grows.

Fecundity: is the ability to produce offspring. It can also describe the reproductive rate of an individual organism. Fecundity can be influenced by the availability of resources and the presence of potential mates. The number of offspring produced is often related to the amount of parental care. Typically, the higher fecundity, the lower the amount of time parents devote to caring for the offspring

Survivorship: the number or proportion of individuals surviving to each age for a given species or group.

In order to measure survivorship, ecologists identify a **Cohort**, which is a group of individuals of the same species, in the same population, born at the same time. Data is then collected on when each individual in a population dies. Survivorship curves can then be used to compare generations, populations, or even different species. It helps us answer questions such as:

How long do we live? How long do individuals in other species live? Do most individuals die young or live to ripe old ages?

Launch Lab: Reproductive Strategies and Population Growth page 45

Demography: the study of populations, especially population size, density, age structure, and growth.
Population ecologists describe changes in the size of a population, its abundance, as time passes. They might also study the rate at which a population changes in size, and what factors determine the relative numbers of males and females (or young and old) in a population.

Factors that influence population growth.

There are four processes that can change the size (number of individuals) of a population (ΔN).

Births (*B*) and **immigration (*I*)** (the movement of individuals into a population) cause increases in population size.
Deaths (*D*) and **emigration (*E*)** (the movement of individuals out of a population) cause decreases in population size.

Therefore, change in population size can be calculated using the following equation:

$$N = (B + I) - (D + E)$$

In order for populations to grow, birth rate plus immigration must be greater than death rate and emigration. In most species of living organisms, immigration and emigration rates are very low and can be ignored.

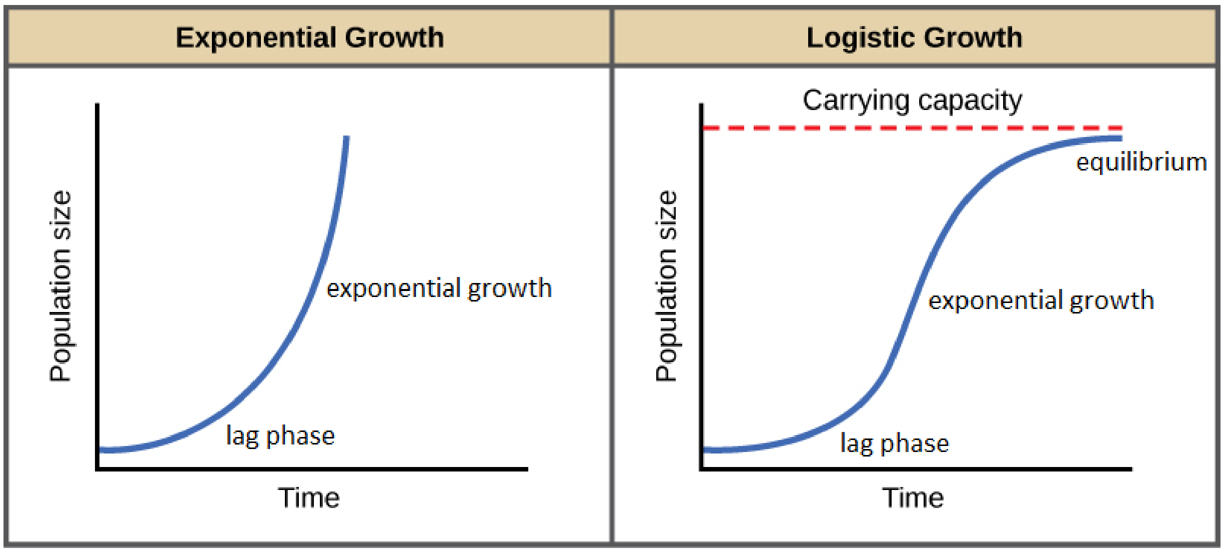
Just as important as the change in the size of a population is the speed at which the change occurs. The change in the number of individuals in a population (ΔN) over a specific time frame (Δt) is known as a population's **growth rate (*GR*)**

$$GR = \frac{\triangle N}{\triangle T}$$

Exponential growth: Under ideal conditions, organisms could undergo exponential growth which is defined as the growth of a population that occurs in an environment with unlimited resources. Organisms undergoing exponential growth quickly increase in population size, forming a **J-shaped curve** pattern.

However, in the real world resources are limited so populations cannot grow exponentially forever. Instead, many populations grow exponentially for a while until resources become limited or other factors affect population growth.

Logistic growth: the type of population change that occurs in an environment in which resources are limited. Logistic growth tends to show an **S-shaped curve** pattern.



In the beginning, the growth of a small population is slow, since there are only a few individuals to reproduce. This initial stage is called the ***lag phase***. As the numbers of individuals in the population increase, the population will experience an exponential rate of growth. The birth rate during the **exponential growth** phase is much greater than the death rate, so the population size will increase rapidly. Under natural conditions, however, this rapid growth rate cannot continue indefinitely. Eventually, competition for resources and other limiting factors will slow the rate of growth. Lack of food, for example, will limit the energy that is available for reproduction. At this stage, called the *stationary phase*, the birth rate and death rate are equivalent and the population has reached **equilibrium.**

The line running through this curve represents the habitat's **carrying capacity-** the theoretical maximum population size that the environment can sustain over an extended period of time. In other words, the **carrying capacity** represents the number of individuals in a population that can live in a given environment without depleting the resources they need or harming their habitat or themselves.

Biotic potential: the highest potential per capita growth rate possible for a given population (under ideal conditions)

Factors that determine a species' biotic potential include

• The number of offspring per reproductive cycle
• The number of offspring that survive long enough to reproduce
• The age of reproductive maturity and the number of times that the individuals reproduce in a life span
• The life span of the individuals

In essence, fecundity and survivorship.

Growth Strategies

In an unstable environment, it can be advantageous to expend energy in order to reproduce rapidly while conditions are favourable.
In contrast, the long life span of some species and a small number of offspring per parent may be more useful adaptations in a relatively stable environment.

Species that reproduce close to their biotic potential (*r*), represent one end of the continuum. Such species are said to have ***r*-selected strategies**. Species with *r*-selected strategies have a short life span and an early reproductive age, and they produce large broods of offspring that receive little or no parental care. Insects, annual plants, and algae typically have *r*-selected strategies. They take advantage of favourable environmental conditions, such as the availability of food, sunlight, or warm summer temperatures, to reproduce quickly

At the other end of the continuum are populations that live close to the carrying capacity (*K*) of their habitats, and thus are described as having ***K*-selected strategies**. They have few offspring per reproductive cycle, and one or both parents care for the offspring when young. The offspring take a relatively long time to mature and reach reproductive age, and they live a relatively long time. Also, they tend to have large bodies, compared with organisms that have *r*-selected strategies. A typical *K*-selected life strategy is to produce few offspring, but to invest a large amount of energy into helping the offspring reach reproductive age.

Factors Limiting Natural Population Growth – Environmental resistance

Two types of general factors affect population growth:

- Density-independent factors
    - Variables that affect the growth of a population regardless of the number of individuals in the population in a given area
    - Usually abiotic factors like floods, droughts, climate, forest fires, and hurricanes

- Density-dependent factors
    - Variables that affect growth of populations when there is an increased number of individuals in an area
    - Usually caused by biotic factors
        - Competition
        - Disease

The combined effects of various interacting limiting factors is described as the **environmental resistance.**

Two types of competition:

- **Intraspecific competition**: competition between or among members of the same species for resources.
    - Ex. Two bears competing for salmon

- **Interspecific competition**: competition among or between members of different species for food.
    - ex. Coyote and foxes which both hunt rabbits

For discussion: How can these types of competition influence population size?

Due to interspecific competition, no two species can share the exact same ecological niche. When populations share overlapping niches, they compete for limited resources. Interspecific competition is less fierce, however, if the populations have even slightly different niches.

Competitive exclusion principle: theory stating that species with niches that are exactly the same cannot co-exist.

Non- native species
Often, when a non-native species is introduced into an environment, it competes with the native species. Sometimes, the native species compete successfully against the introduced species, which dies out. Other times, however, the introduced species takes over the niches of the native species, thereby changing the structure of the ecological community.

Invasive species can out-compete native species in an ecosystem very quickly.
What would be the effects of intraspecific and interspecific competition on the growth of plants?

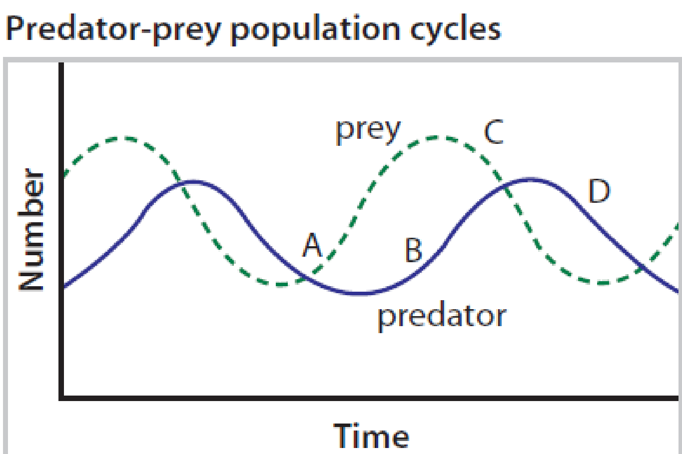
Investigation 2B Interspecific and intraspecific competition among seedlings. Page 70

Investigation 2.E, p. 78 Biological Control or Damage Control?

Predator- prey Interactions.

Predators are organisms that kill and consume other organisms, known as **prey**.
The producer-consumer relationship puts selective pressure on both partners, with the more successful consumers driving the natural selection of the producers. In other words, producers that are more difficult to catch or less desirable to consume are more likely to survive. In addition, like any important food source, the scarcity of a producer species is a factor that can limit a consumer species' population.

Hypothetically, the larger a prey population is, the more food that is available to its predators. Thus, the predators have more energy to reproduce and care for their young. This allows the predator population to increase. With a greater number of predators, the prey population will decline, resulting in more intense competition among the predators for food, which becomes a limiting factor. The predator population therefore declines, and, with fewer predators, the prey population increases.



A simplified graph of predator-prey population cycles. An increase in prey increases the resources that are available to the predators **(A)**, so the predator population increases **(B)**. This leads to a reduction in the prey population **(C)**, followed by a reduction in the predator population **(D)**. And the cycle continues.

Symbiotic relationships are biotic relationships in which two different organisms live in close association with each other to the benefit of at least one. There are five types of symbiotic relationships including: mutualism, commensalism, parasitism, parasitoids and predation.

> **Mutualism** is the type of symbiosis resulting in mutual benefit to both of the organisms in the relationship.
>
> **Commensalism** is a relationship in which one organism benefits from the relationship but the other organism seems to neither be harmed nor benefited.

Parasitism is a symbiotic relationship in which one organism benefits and the other is harmed. The organism that benefits is called the parasite, the organism that is harmed is called the host. Some parasites only cause slight damage to their host, while others kill them. Therefore one organism is injured in satisfying the needs of the other.

Parisitoidism is similar to parasitism. One organism benefits but the other is eventually killed - a sort of slow death.

Predation is where the interaction is beneficial to one species and detrimental to the other. This is not always considered a symbiotic relationship, although it is quite similar to parasitism, except for the degree of harm to the host or prey. With predation, the prey is killed.

For discussion: What are some possible impacts of humans on animal populations?

Investigation 2D: What limits growth of grizzly bear populations? –page 77

Human population growth

The human population is currently in a state of exponential growth. How close is the human population to reaching its **bio-capacity**? Currently, humans have many *K*-selected life strategies, such as long life spans, a relatively low reproductive rate, and parental care of their young.

World Population (2018 and historical)

Year (July 1)	Population	Fertility Rate
2018	**7,632,819,325**	2.51
2017	**7,550,262,101**	2.51
2016	**7,466,964,280**	2.51
2015	**7,383,008,820**	2.52

Questions to ask ourselves:

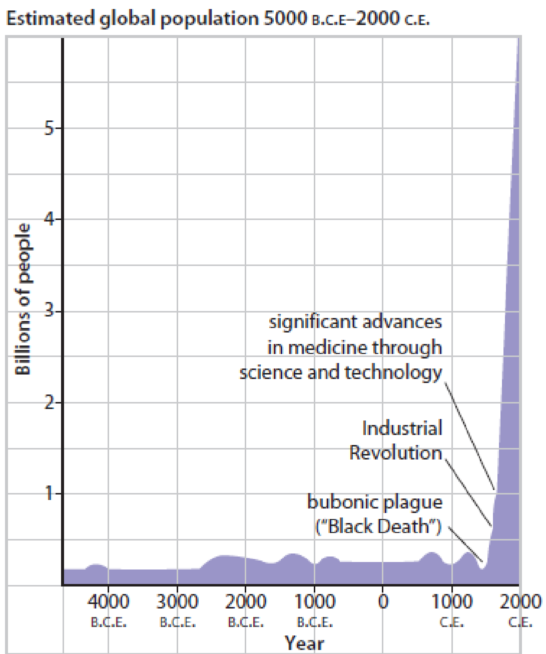
How is the human population affected by density-dependent limiting factors?
How might intraspecific competition and disease affect the human population?
What will happen to the human population as resources become scarce?

What are some solutions to human overpopulation (e.g., one- and two-child policies, promoting family planning, female empowerment, education, urbanization?)

How does Earth's available bio-capacity impact sustainability and quality of life.

Determining the exact number of people in early times is not an easy task. Estimates made before 1650 are crude. However, demographers (people who study populations) generally think that the human population remained fairly stable until the beginning of the Industrial Revolution, with one exception. During the fourteenth century, a bacterial infection known as the Black Death killed millions of people.

From the mid-eighteenth century on, living conditions for many people began to improve. As new understandings about hygiene were put into practice, and medical and agricultural technologies were developed and refined, the death rate slowed and the rate of population growth accelerated immensely.



As this figure shows, it took 130 years for the global human population to grow from 1 billion (in 1800) to 2 billion individuals (in 1930). It took only 12 years, however, for the population to increase from 5 billion (in 1987) to 6 billion (in 1999).

Factors That Affect Growth

Many advances in technology occurred in a relatively short period of time and dramatically affected human population growth.

- Starting in the early 1700s in Europe and a little later in North America, humans were able to increase their food supply by improved methods and the domestication of animals.
- Breakthroughs in medicine in the late 1800s and early 1900s enabled people to be successfully treated for once-fatal illnesses.
- Better shelter protected people from the weather, and improvements in the storage capacity of food helped humans survive times when food was less plentiful.

All of these factors allowed humans to increase the carrying capacity of their environment and change from a logistic growth pattern to an exponential growth pattern.

Demographic transition: period of change in the growth rate (GR) of a population.

- Stage 1: High birth and death rates lead to slow population growth.
- Stage 2: The death rate falls but the birth rate remains high, leading to faster population growth.
- Stage 3: The birth rate starts to fall, so population growth starts to slow.
- Stage 4: The birth rate reaches the same low level as the death rate, so population growth slows to zero

Growth rates in various countries:

The growth rate has not been the same for all human populations. Britain, Japan, and more industrialized countries in Europe and North America were the first to experience a drop in death rate, especially among infants and children. As a result, after a few generations, people in these countries began to have fewer children, and the birth rate of these populations dropped. Less industrialized nations in Africa, Asia, and Latin America began to move through the same stages in the twentieth century. Human population growth rates are still changing in the twenty-first century.

Activity 2.6 Population Growth Rates in Different Countries. –page 85

Earth's Carrying Capacity

Advances in construction, medicine, sanitation, and agriculture have increased Earth's carrying capacity for the human population. In addition, some forms of biotechnology have improved crop yields, without taking up more space. Even so, scientists estimate that the world produces enough food to feed 10 billion people a vegetarian diet. Not all people are vegetarians, however. Furthermore, cities will have to expand to accommodate people moving from rural areas, and this may reduce the amount of land that is available for agriculture. To estimate Earth's carrying capacity, many things must be considered:

As well as needing resources, we will need effective ways to deal with garbage, sewage, and air pollution. How will the environment be affected by increasing amounts of waste and pollutants entering waterways from larger, denser populations? Will levels of carbon dioxide continue to rise, or will new technologies and habits help us limit the use of fossil fuels? Will countries share their resources to reduce poverty and combat disease? As the density of the human population increases, will we be more susceptible to pandemics, such as influenza, COVID-19?

For discussion: How has changes to the human population growth rate affected sustainability?

Local/ Canadian contributions to issues associated with population growth.

- Conservation measures put in place to improve population of species such as northern cod.
  - Food fishery restrictions, moratoriums, etc.
  - Don't derail cod's comeback in Canada, http:www.nature.com/articles/545412b

- Measures put in place to protect sea bird populations from industrial development.
  - Dr. Bill Montevecchi-Bird populations an NL environmental interactions with industry.

- Strategies to address food security.
  - Food First NL/Food Security Network of NL.

Final Research Assignment- see investigation 2.G page 92