Dynamics of Ecosystems

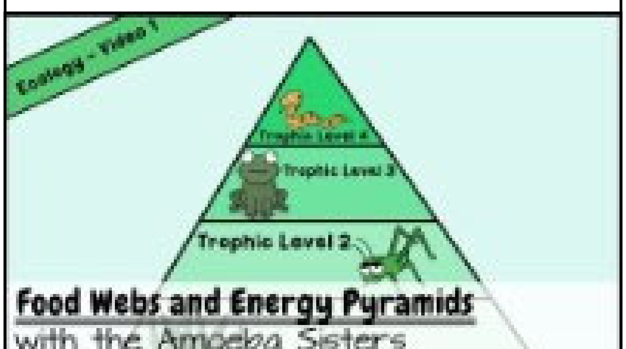
Lake District landscape – barnyz (CC BY-NC-ND 2.0)

Ecosystem

- All the organisms in an area that interact with each other and with their environment of energy and matter.

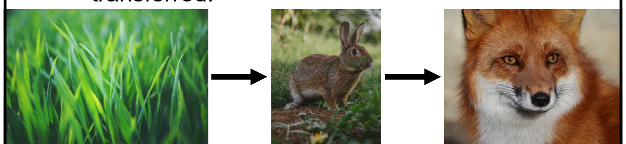
Ecosystem – Scott McCracken (CC BY-NC-ND 2.0)

Food Webs and Energy Pyramids



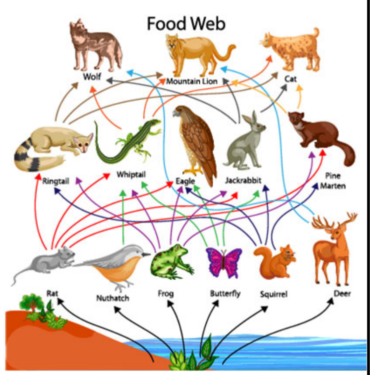
https://youtu.be/-oVavgmveyY

- The energy passes through the ecosystem from species to species.
  - Herbivores eat plants
  - Carnivores eat herbivores
- A food chain shows a single pathway for the passing of energy.
  - The arrows represent energy being transferred.



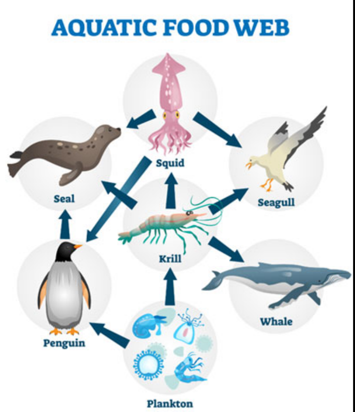
Credit: Grass – kaboompics.com; Rabbit – Denniz Futalan; Fox – Funny Foxy Pride (Pexels)

- A food web is a network of food chains by which energy and nutrients are passed on from one living organism to another.
- It shows multiple pathways.



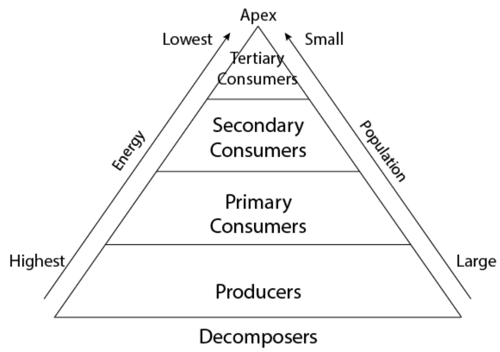
vecton (Adobe Stock)

- The arrows represent energy being transferred.
- Energy is greatest at the bottom of the food web.



VectorMine (Adobe Stock)

- An energy pyramid is a graphical model of energy flow in a community.



- All organisms in an ecosystem have a specific role or **trophic level**.

Producers
(Autotrophs)
- make their own food
  - plants

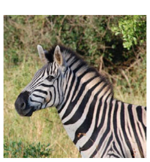
Consumers
(Heterotrophs)
- get energy from eating other organisms

Decomposers
- recycle dead organisms into chemical nutrients used in soil, air, and water

Credit: Plant – Julia Zolotova; Tree – Michael (Pexels); Rabbit – Denniz Futalan; Fox – Funny Foxy Pride (Pexels); Mushrooms – Ashish Raj (Pexels); Earthworm – Eukalyptus (Pixabay)

- Consumers (heterotrophs) are categorized according to what they eat.

Herbivores
- eat only plants
- Primary consumers are all herbivores.



Carnivores
- Eat only meat
- Most secondary consumers are carnivores.
- Tertiary consumers eat secondary consumers.

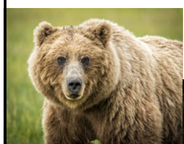
Zebra – Pixabay (Pexels)
Hyena – Frans Van Heerden (Pexels)
Lion – Gareth Davies (Pexels)

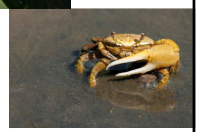
Omnivores

- eat both plants and meat
- Many tertiary consumers are omnivores.

Scavengers

- eat bodies of dead organisms
- Scavengers exist at all trophic levels.



Images: Grizzly Bear – jdaypix (Pixabay); Raccoon – David Selbert (Pexels); Vulture – Harry Lette (Pexels); Crab – David Mark (Pixabay)

____

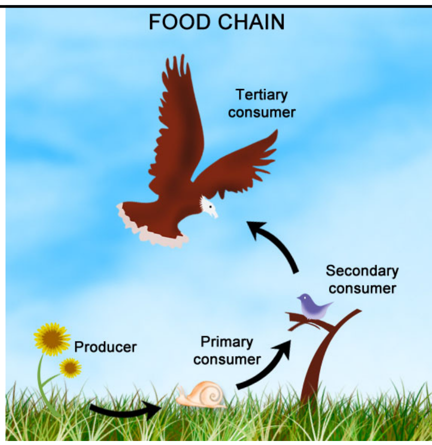
____

____

____

____

____



Food chain – Zappys Technology Solutions (CC BY 2.0)

____

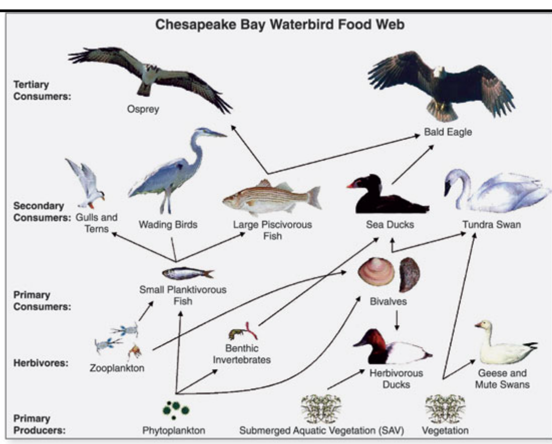
____

____

____

____

____



Chesapeake Waterbird Food Web – Matthew C. Perry, US Geological Survey (public domain)

____

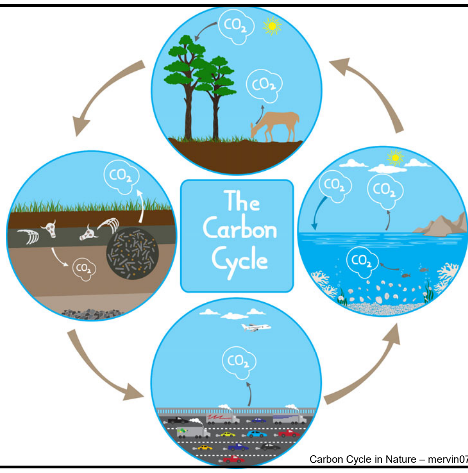
____

____

____

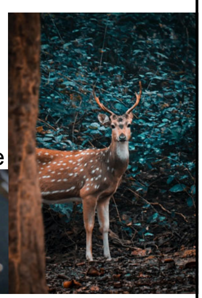
____

____



Carbon Cycle in Nature – mervin07 (Adobe Stock)

- Carbon is the fourth most abundant element in the universe and is essential for life on Earth.
- Carbon appears in many forms
  - Solid
    - limestone, wood, diamonds, coal, plant and animal tissue



Brown deer in forest – Future Kiiid (Pexels)
Coal – Pixabay (Pexels)
Diamond Herkimer – Mariusz Kasio (CC-BY-NC-ND 2.0)

- Liquid
  - oil, gasoline
- Gas
  - carbon dioxide, methane (natural gas), propane

- The carbon cycle is a system that transfers carbon from one part of the environment (reservoir) to another.
- The carbon cycle consists of two cycles:
  - Biological Carbon Cycle
  - Geochemical Carbon Cycle

Biological Carbon Cycle

- The biological carbon cycle deals with rapid carbon exchange among living organisms.

Eagle – Capri23auto (Pixabay)

Photosynthesis

- Occurs in autotrophs (plants)
- Uses carbon dioxide to produce oxygen and glucose (carbohydrates)
  - $6CO_2 + 6\,H_2O + \text{energy} \rightarrow 6O_2 + C_6H_{12}O_6$

Trees – Stanley Zimny (CC BY-NC 2.0)

Cellular Respiration

- Occurs in all living cells
- Uses oxygen and glucose (carbohydrates) to produce carbon dioxide
  - $6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O$ + energy


Ice plant – Mike Finn (CC BY 2.0)
Animals – kathleen.bence (CC BY-NC 2.0)

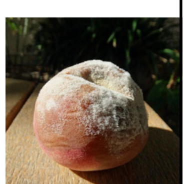
Consumption

- Consumers get the glucose necessary for cellular respiration by ingesting plants and/or animals.

Eel – NOAA Ocean Exploration & Research (CC BY-SA 2.0)

Decomposition

- Carbon enters the soil as dead plant matter.
- It is broken down by microorganisms during decay.




Rotting wood with fungi – Jake Slagel (CC BY-NC 2.0)
White peach: Brown rot of fruit – Scot Nelson (public domain)

- Over long periods of time the organic matter forms deposits of coal, gas and oil (fossil fuels).



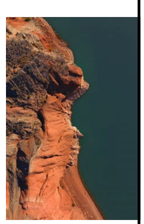
Blueish – Bart Bernardes (CC BY-NC-ND 2.0)
Conventional Natural Gas Well – Andy Arthur (CC BY 2.0)
Oil well in Bahrain – Bart Lackey (CC BY 2.0)

Geochemical Carbon Cycle

- The geochemical carbon cycle deals with the long-term cycling of carbon through geologic processes.

Credit: ArtTower (Pixabay)

Precipitation



- Carbonic acid forms when water (rain) reacts with the carbon dioxide in the atmosphere.
- The weakly acidic rain reacts with minerals on the earth's surface dissolving them.
- The dissolved minerals are carried by rivers and streams to the ocean where they precipitate out.

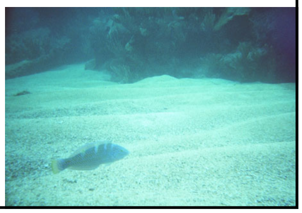
Rock - Tomas Anunziata (Pexels)

- Marine animal shells contain carbon (calcium carbonate).
- Shells settle to the ocean floor when the animals dies where they eventually form limestone.


Seashells – Skitterphoto (Pexels)
Crab - Alexsandro Rosa de Mello (Pexels)

Burial

- Carbon bearing sediment is continually being deposited on the sea floor forming new rock.
- Seafloor spreading pushes the seafloor under the continents.
  - subduction



A Fish and the Floor – Meridith P. (CC BY-ND 2.0)

Volcanoes

- Volcanoes, hot springs, and tectonic uplift all release carbon dioxide back into the atmosphere.


Volcano - Björn Austmar Þórsson (Pexels)
Geyser Yellowstone Wyoming – Steve Wilson (Pixabay)

Diffusion

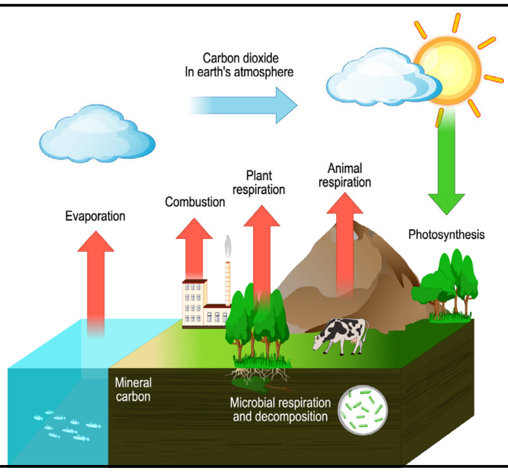
- Carbon dioxide is absorbed and released where the ocean's surface meets the air.

Waves – Dimitris Vetsikas (Pixabay)

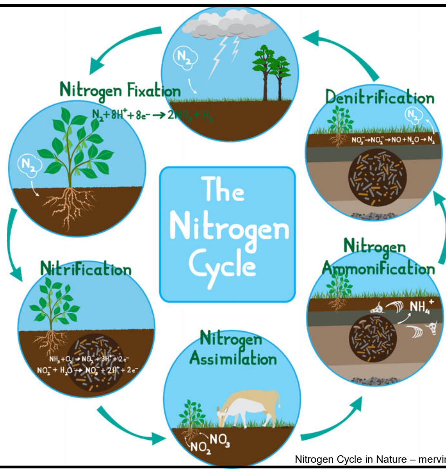
Combustion

- The burning of fossil fuels and any organic material releases carbon dioxide into the atmosphere.

Forest fire in progress – gilitukha (Adobe Stock)

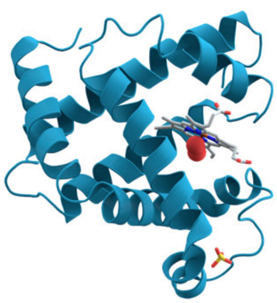


Carbon cycle – designua (Adobe Stock)

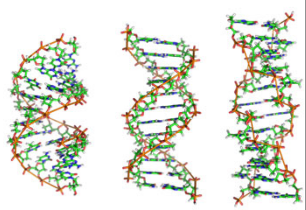


Nitrogen Cycle in Nature – mervin07 (Adobe Stock)

- All life requires nitrogen compounds.
  - proteins, nucleic acids

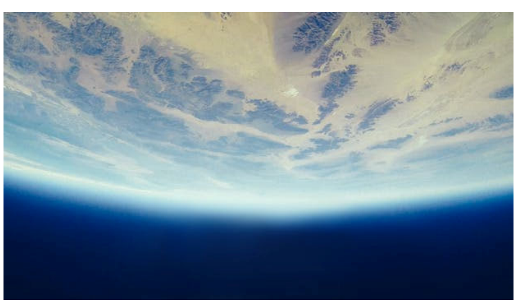


Myglobin – AzaToth (public domain)



A-DNA, B-DNA and Z-DNA – Richard Wheeler (Zephyris) (CC BY-SA 3.0)

- The atmosphere contains about 78% nitrogen but neither plant nor animal can use this nitrogen directly.



Jaymantri (public domain) (Pexels)

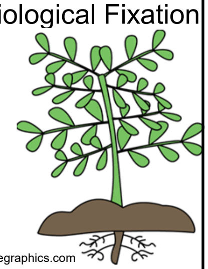
- Nitrogen must be converted to more chemically available forms for plants and animals to use.
  - ammonia (NH_3), ammonium (NH_4), nitrites (NO_2), and nitrates (NO_3)
- **Nitrogen fixation** is a process where nitrogen molecules (N_2) in the air break apart and combine with other atoms for form ammonium (NH_4).
- Plant nutrients are the result of nitrogen fixation.

- Autotrophs (plants) must have their nitrogen "fixed."
  - Nitrogen gets "fixed" when it combines with oxygen or hydrogen.
- **Nitrogen fixation** is a chemical process where nitrogen molecules (N_2) in the air break apart and combine with other atoms for form ammonium (NH_4) in soil or aquatic systems.
- Most nitrogen is fixed by bacteria, but it can also be fixed by lightning and artificially through industrial processes.

- There are three ways to "fix" nitrogen

Atmospheric Fixation

Biological Fixation



Industrial Fixation

Lightning bolt cloud – www.mycutegraphics.com

Plant with roots – www.mycutegraphics.com

Bags of fertilizer – Sharon Dowdy (UGA CAES/Extension) (CC BY-NC 2.0)

Atmospheric Fixation

- Energy from lightning causes nitrogen and oxygen molecules in the atmosphere to ionize and react with rain to form Nitrous acid (HNO_2).
- The nitrous acids seeps into the ground and forms nitrates (NO_3).

sethink (Pixabay)

Industrial Fixation

- A special process is used to combine nitrogen gas (N_2) with hydrogen (H_2) to form ammonia (NH_3).
- This is usually processed further to make ammonium nitrate (NH_4NO_3) .

Bags of fertilizer – Sharon Dowdy (UGA CAES/Extension) (CC BY-NC 2.0)

Biological Fixation

- Free living bacteria that live in the soil or water and combine nitrogen with hydrogen.
- Produce ammonium (NH_4).
- Free living bacteria fix about 30% of the nitrogen.

Cyanobacteria (blue-green algae)

Blue Green Algae 03 – Mark Sadowski (CC BY-SA 2.0)
Prairie Lake algae3 – MPCA Photos (CC BY-NC 2.0)
300bluegrealgaeLittle Rock Lake-impaired – MPCA Photos (CC BY-NC 2.0)

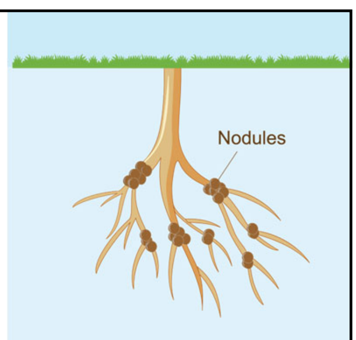
- Bacteria that live in a symbiotic relationship with plants.
  - Legumes
    - soybeans, alfalfa, beans, peas, clover, peanuts
  - Some non-leguminous
    - alder, bayberry

alfalfa

alder

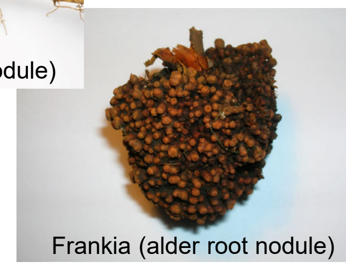
Alfalfa – Patrick J. Alexander, hosted by the USDA-NRCS PLANTS Database
Gray Alder – Joe F. Duft, hosted by the USDA-NRCS PLANTS Database / USDA NRCS. 1992. *Western wetland flora: Field office guide to plant species*. West Region, Sacramento.

- The bacteria live in root nodules and produce ammonia in exchange for carbohydrates and a protected home.



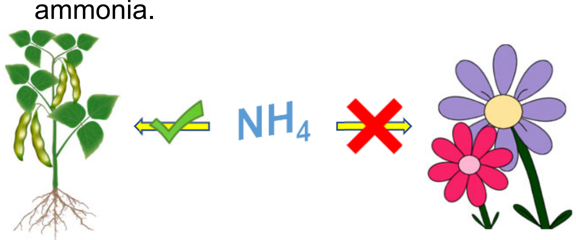
- These bacteria fix about 70% of the nitrogen.

Bacteria nodules of roots. (Sandip – Adobe Stock)



Rizobia (Rai Kitakami – Adobe Stock)
Alder root nodule (Roger Griffith – Public Domain)

- Only a few plants (legumes) can use ammonia.

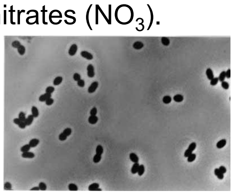


- Most of the ammonia must be converted to nitrates.

Bean plant (zxczxc80 – Adobe Stock)
Check mark (qubodup – openclipart)
X (Arnoud999 – openclipart)
Pink and purple flowers (mycutegraphics.com)

Nitrification

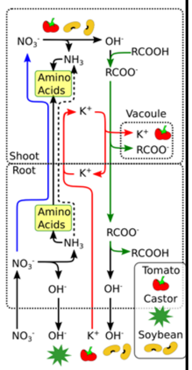
- Nitrifying bacteria in the ground combine ammonia with oxygen to form nitrites (NO_2).
- Another group of nitrifying bacteria coverts nitrites to nitrates (NO_3).



Nitrosomonas eutropha – Asw-hamburg (CC BY-SA 3.0)

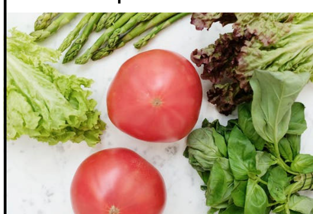
Assimilation

- Plants absorb the ammonia or nitrates and use them to produce the organic compounds needed.
  - amino acids, chlorophyll, and nucleic acid



Staticd (CC BY-SA 4.0)

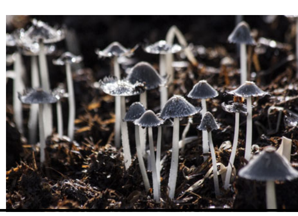
- Consumers eat plants (or other consumers) and absorb the nitrogen compounds.



Credit: Vegetables – ready made; steak – Kasumi Loffler (Pexels)

Ammonification

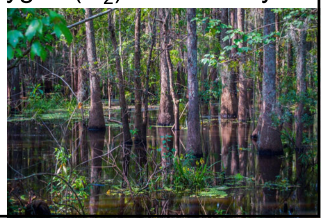
- Decomposers break down the molecules in excretions and dead organisms into ammonia.
- The ammonia is absorbed and stored in the soil.



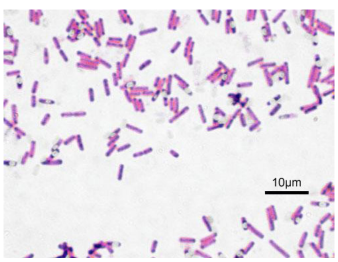
Mushroom (Pixabay-Pexels)

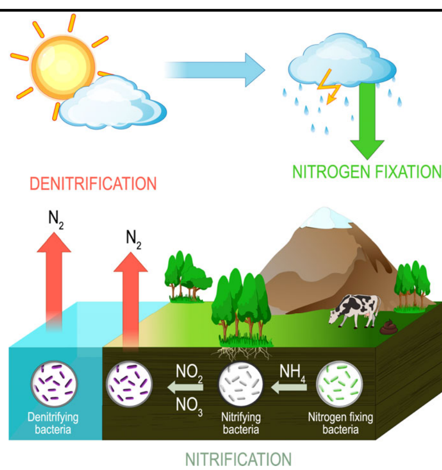
Denitrification

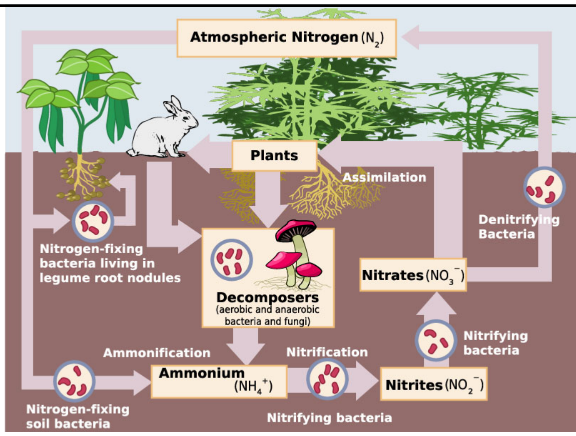
- **Denitrification** converts nitrates (NO_3) in the soil to nitrogen (N_2).
- Denitrifying bacteria live deep in swampy sediments where oxygen (O_2) is not easily accessible.



- These bacteria take oxygen (O_2) from nitrates (NO_3) leaving nitrogen gas (N_2).
- The nitrogen returns to the atmosphere to begin the cycle again.



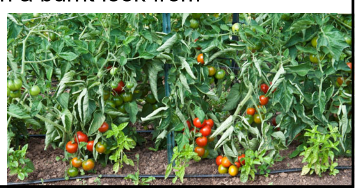




Nitrogen Cycle – Raeky (CC BY-SA 3.0)
derivative of Nitrogen_Cycle.jpg – Environmental Protection Agency (public domain)

Effects of Excess Nitrogen

- Excess nitrogen in the soil can lead to
  - Excess foliage growth
    - The plant may not produce flowers or fruit.
  - Burning and salt concentration
    - Leaves take on a burnt look from dehydration.

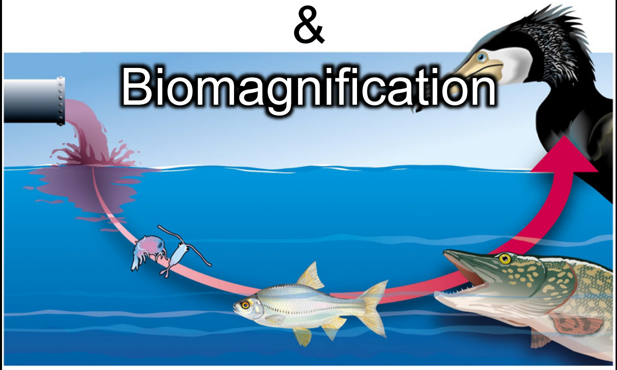


Tomato plants – Oregon State University (CC BY-SA 2.0)

- Stunted root growth
  - Roots may not grow properly
- Groundwater pollution
  - The excess nitrogen is carried to ground water, rivers, and lakes due to runoff.

Agricultural runoff – Lydia Betts/USDA NRCS (CC BY 2.0)

Bioaccumulation
&
Biomagnification



Pollution – Bio-accumulation – Graphithèque (Adobe Stock)

Bioaccumulation

- Increase in concentration of a substance in an organism over time
  - the substance (good or bad) is stored in the organism and broken down slowly
  - over time, the concentration increases

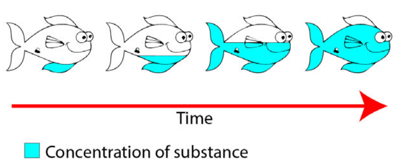


Image: David Libby

Biomagnification

- increase in concentration of a substance from one trophic level to the next

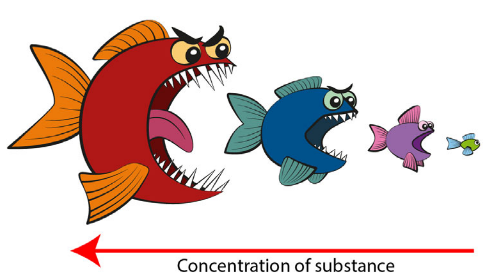


Image: David Libby

Biomagnification

https://youtu.be/TZk6vcmLcKw

- Biomagnification can only occur if the compound bioaccumulates.
  - The compound must be **fat soluble** as opposed to water soluble.
- Compounds that are stay in the environment for a long time without breaking down (**long-lived**) have a greater chance of being ingested by organisms.
- Compounds that cannot be contained to one location can be spread through the environment (**mobile**) increase the change of ingestion.

- Just because a compound bioaccumulates and biomagnifies does not make it harmful.
- Compounds must be hazardous to the organism (**biologically active**) to be a problem in the environment.

Power line - SarahAndBoazPublishing (Pixabay)
Peach - Steve Buissinne (Pixabay)
Wire - Łukasz Klepaczewski (Pixabay)
Brazil nut - Adriano Gadini (Pixabay)

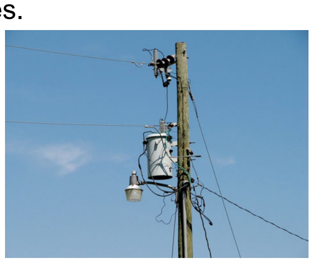
DDT
(dichloro, diphenyl trichloroethane)

- Insecticide used extensively in the western world to eliminate the mosquito that carries the malaria parasite
- Banned from use in 1972 due to several false claims including
  - Causes eggshell thinning
  - Causes liver and breast cancer
- Still carries the myth that it is hazardous

100 Things You Should Know About DDT (https://junkscience.com/1999/07/100-things-you-should-know-about-ddt/)

PCBs
(polychlorinated biphenyls)

- Used as coolant in transformers, sealing and caulking compounds, inks and paint additives.



Electrical Transformer – Bill Bradford (CC BY 2.0)

- Overexposure can cause a severe form of acne (chloracne), swelling of the upper eyelids, discoloring of the nails and skin, numbness in the arms and/or legs, weakness, muscle spasms, chronic bronchitis, and problems related to the nervous system.

PAH
(polycyclic aromatic hydrocarbons)

- Primarily found in natural sources such as bitumen (a sticky, black, highly viscous liquid or semi-solid form of petroleum - asphalt)

Natural formed Bitumen collected at the Dead Sea shore – Daniel Tzvi (public domain)

- PAHs have been linked to skin, lung, bladder, liver, and stomach cancers in well-established animal model studies.

Heavy Metals

- A group of metals and metalloids that have relatively high density
  - Pb, As, Hg, Cd, Zn, Cu, Fe, Cr, Ni, Pd, Pt, …
- Natural and anthropogenic sources
- Wide variety of commercial uses
  - Lead: storage batteries, ammunition, radiation shielding
  - Copper: wiring, water pipes
  - Iron: main component of steel
  - Chromium: component of stainless steel

- Many are nutritionally essential for humans
  - Copper: red blood cell production, neuron signaling, immunity
  - Chromium: maintain normal blood sugar levels
  - Iron: helps make hemoglobin, making amino acids
  - Magnesium: builds bones and teeth
  - Zinc: helps blood clot, bolsters immune system
- Overexposure can affect the nervous system

Cyanide

- Naturally found in small amounts in some foods
  - almonds, soy, spinach, apple seeds, cherry pits
- Naturally found in dangerous amounts in peach and apricot pits
- Uses include
  - making paper, textiles, plastics, electroplating, metal cleaning, removing gold from its ore, exterminating pests and vermin

- Survivors of serious cyanide poisoning may develop heart, brain and nerve damage

Selenium

- Trace element naturally present in many foods
  - Brazil nuts, yellowfin tuna, halibut, shrimp, ham, turkey, chicken, beef, eggs, spinach
- Nutritionally essential for humans
  - plays critical roles in reproduction, thyroid hormone metabolism, DNA synthesis, and protection from oxidative damage and infection

- Too much selenium can result in hair and nail loss, nausea, diarrhea, skin rashes, mottled teeth, fatigue, irritability, and nervous system abnormalities.

Populations

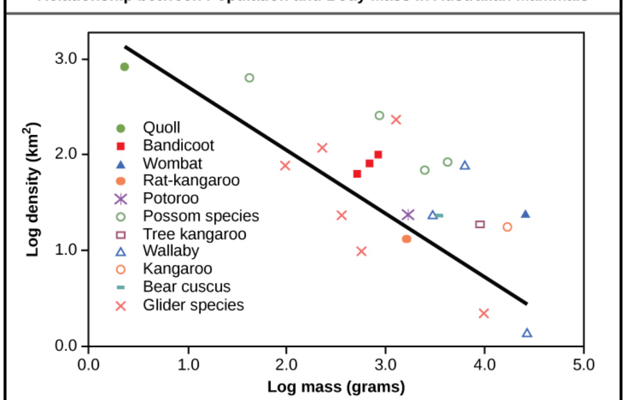
Images: Phil Fiddyment (CC BY 2.0), Doris Meta F (CC BY-NC 2.0), GPA Photo Archive (CC BY-NC 2.0), Manda (on and off) (CC BY 2.0)

Population

- Populations are characterized by their **population size** (total number of individuals) and their **population density** (number of individuals per unit area).
  - A population may have a large number of individuals that are distributed densely, or sparsely.
  - There are also populations with small numbers of individuals that may be dense or very sparsely distributed in a local area.

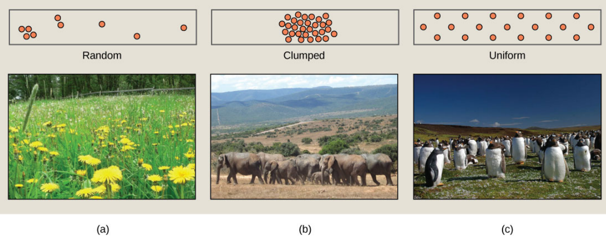
- Population **size** can affect potential for adaptation because it affects the amount of genetic variation present in the population.
- The size of a population will increase due to births and immigration.
- The size of a population will decrease due to deaths and emigration.

- **Density** can have effects on interactions within a population such as competition for food and the ability of individuals to find a mate.
  - Individuals in a low-density population are thinly dispersed; hence, they may have more difficulty finding a mate compared to individuals in a higher-density population.
  - High-density populations often result in increased competition for food.
  - Smaller organisms tend to be more densely distributed than larger organisms.



Species Distribution

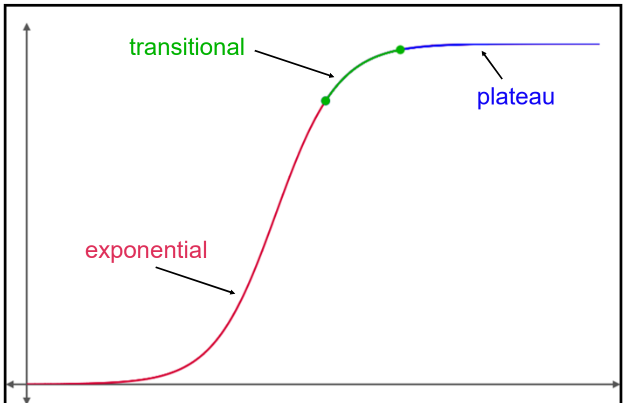
- A species distribution pattern is the distribution of individuals within a habitat at a particular point in time.
- Individuals within a population can be distributed at random, in groups, or equally spaced apart (more or less).



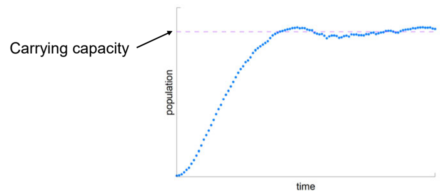
Plants such as (a) dandelions with wind-dispersed seeds tend to be randomly distributed. Animals such as (b) elephants that travel in groups exhibit a clumped distribution. Territorial birds such as (c) penguins tend to have a uniform distribution.

Population Growth

- Population growth goes through three phases:
  - Exponential
    - Quick growing (very few limiting factors)
  - Transitional
    - Slowing of growth rate as the population approaches the carrying capacity
  - Population plateau
    - The population remains stable (small variations over time)



- In real life, the plateau is not constant.
- The population will increase or decrease from one year to the next.
- The average value over several years is the carrying capacity.



Carrying Capacity

- The number of individuals of a species capable of surviving in an environment over long periods of time.
  - This number depends on numerous limiting factors in the ecosystem.

Limiting Factor

- Something which restricts population growth in some way.
  - The amount of space available for building nests would limit the number of birds who would live in an ecosystem; therefore, space can be a limiting factor.
- These factors can be biotic or abiotic.
- Some of the factors depend on the total size of the population density.

Density Dependent Factors

- The effect on a population is determined by the total size of the population.
  - Predation
    - The more predators there are, the more prey are eaten.
  - Disease
    - An illness will spread faster through a larger, denser population impacting more individuals.

- Resource availability
  - The more organisms there are, the less resources (food, water, shelter) there are to go around.
- Aggression
  - Too many dominant males (or females) can result in fights to the death.
- Stress
  - Overpopulation can lead to stress in females causing neglect of younger organisms.

- Competition
  - Organisms will compete for the limited resources available.
  - When populations of the same species compete, it is called **intraspecific competition.**
  - When populations of different species compete, it is called **interspecific competition.**

Density Independent Factors

- Limit the size of a population, but the effect is **not** dependent on the size of the population.
  - Natural disasters
    - Fire
    - Earthquakes
    - Volcanic eruptions
    - Drought
    - Flood
    - Cold winter

Biotic and Abiotic Factors

- Limiting factors can also be split into biotic and abiotic factors.
  - Biotic factors involve interactions between organisms such as predation, competition, parasitism and herbivory
  - Abiotic factors are interactions with the environment and include temperature, water availability, oxygen, light, food and nutrients.