Lecture: **Ecosystem Dynamics**

Ref book: Biology for Engineers - Arthur T. Johnson [2nd edition]
Biology for Engineers – G. K. Suraishkumar

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Web ref provided on slides
Images: From google image

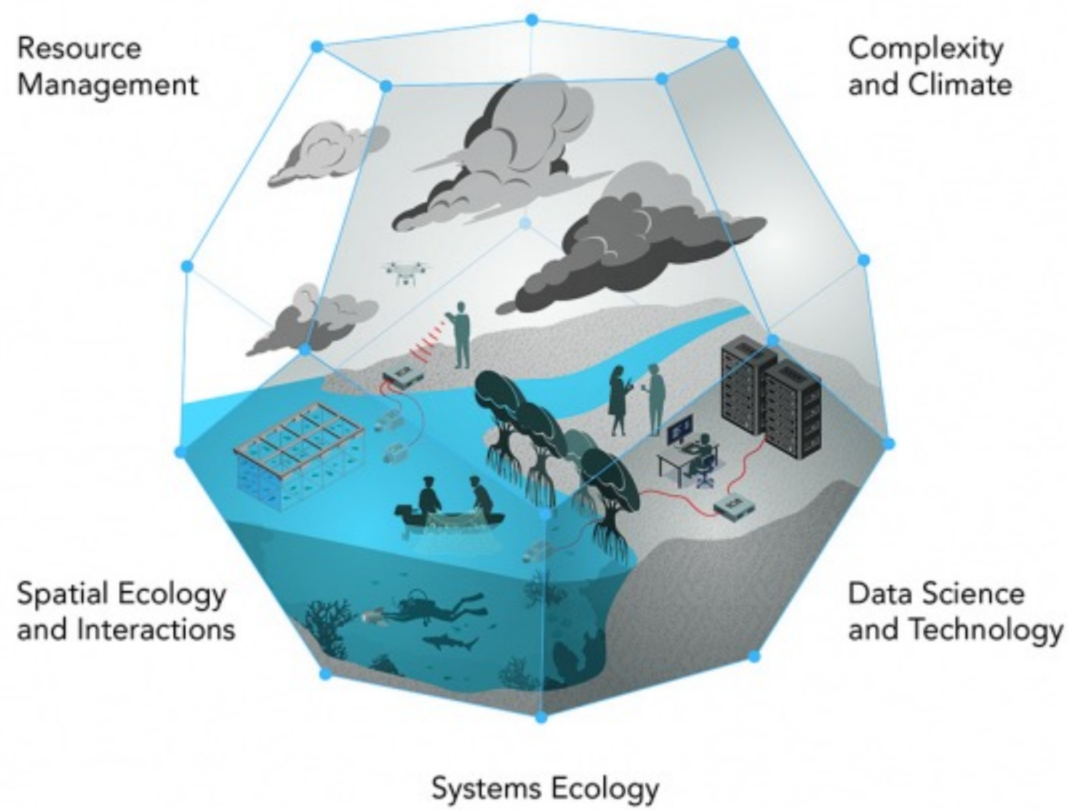
Ecosystem Dynamics

- **Ecology of Ecosystems**
- **Ecosystems and Disturbance**
- **Food Chains and Food Webs**
- **Organisms Acquire Energy in a Food Web**
- **Consequences of Food Webs**
- **Ecosystem Dynamics**
- **Internal and External Factors**
- **Resistance and Resilience**
- **The Sin Nombre Virus: Ecosystem Dynamics in a Human Population**

Ref: wikipedia

Ecology of Ecosystems

Life in an ecosystem often involves competition for limited resources, which occurs both within a single species and between different species. Organisms compete for food, water, sunlight, space, and mineral nutrients. These resources provide the energy for metabolic processes and the matter to make up organisms' physical structures. Other critical factors influencing community dynamics are the components of its physical environment: a habitat's climate (seasons, sunlight, and rainfall), elevation, and geology. These can all be important environmental variables that determine which organisms can exist within a particular area.



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Ecology of Ecosystems

- Freshwater ecosystems are the least common, occurring on only 1.8 percent of Earth's surface. These systems comprise lakes, rivers, streams, and springs; they are quite diverse, and support a variety of animals, plants, fungi, protists and prokaryotes.
- Marine ecosystems are the most common, comprising 75 percent of Earth's surface and consisting of three basic types: shallow ocean, deep ocean water, and deep ocean bottom. Shallow ocean ecosystems include extremely biodiverse coral reef ecosystems, yet the deep ocean water is known for large numbers of plankton and krill (small crustaceans) that support it. These two environments are especially important to aerobic respirators worldwide, as the phytoplankton perform 40 percent of all photosynthesis on Earth. Although not as diverse as the other two, deep ocean bottom ecosystems contain a wide variety of marine organisms. Such ecosystems exist even at depths where light is unable to penetrate through the water.

(a)

(b)

A (a) tidal pool ecosystem in Matinicus Island, Maine, is a small ecosystem, while the (b) Amazon rainforest in Brazil is a large ecosystem. (credit a: modification of work by Jim Kuhn; credit b: modification of work by Ivan Mlinaric)

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Ecology of Ecosystems

(a)

(b)

Desert ecosystems, like all ecosystems, can vary greatly. The desert in (a) Saguaro National Park, Arizona, has abundant plant life, while the rocky desert of (b) Boa Vista island, Cape Verde, Africa, is devoid of plant life. (credit a: modification of work by Jay Galvin; credit b: modification of work by Ingo Wölbern)

Terrestrial ecosystems, also known for their diversity, are grouped into large categories called biomes. A biome is a large-scale community of organisms, primarily defined on land by the dominant plant types that exist in geographic regions of the planet with similar climatic conditions. Examples of biomes include tropical rainforests, savannas, deserts, grasslands, temperate forests, and tundras. Grouping these ecosystems into just a few biome categories obscures the great diversity of the individual ecosystems within them. For example, the saguaro cacti (*Carnegiea gigantean*) and other plant life in the Sonoran Desert, in the United States, are relatively diverse compared with the desolate rocky desert of Boa Vista, an island off the coast of Western Africa.

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Ecosystems and Disturbance

Ecosystems are complex with many interacting parts. They are routinely exposed to various disturbances: changes in the environment that affect their compositions, such as yearly variations in rainfall and temperature. Many disturbances are a result of natural processes. For example, when lightning causes a forest fire and destroys part of a forest ecosystem, the ground is eventually populated with grasses, followed by bushes and shrubs, and later mature trees: thus, the forest is restored to its former state. This process is so universal that ecologists have given it a name—succession. The impact of environmental disturbances caused by human activities is now as significant as the changes wrought by natural processes. Human agricultural practices, air pollution, acid rain, global deforestation, overfishing, oil spills, and illegal dumping on land and into the ocean all have impacts on ecosystems.

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Ecosystems and Disturbance

Equilibrium is a dynamic state of an ecosystem in which, despite changes in species numbers and occurrence, biodiversity remains somewhat constant. In ecology, two parameters are used to measure changes in ecosystems: resistance and resilience. The ability of an ecosystem to remain at equilibrium in spite of disturbances is called resistance. The speed at which an ecosystem recovers equilibrium after being disturbed is called resilience. Ecosystem resistance and resilience are especially important when considering human impact. The nature of an ecosystem may change to such a degree that it can lose its resilience entirely. This process can lead to the complete destruction or irreversible altering of the ecosystem.

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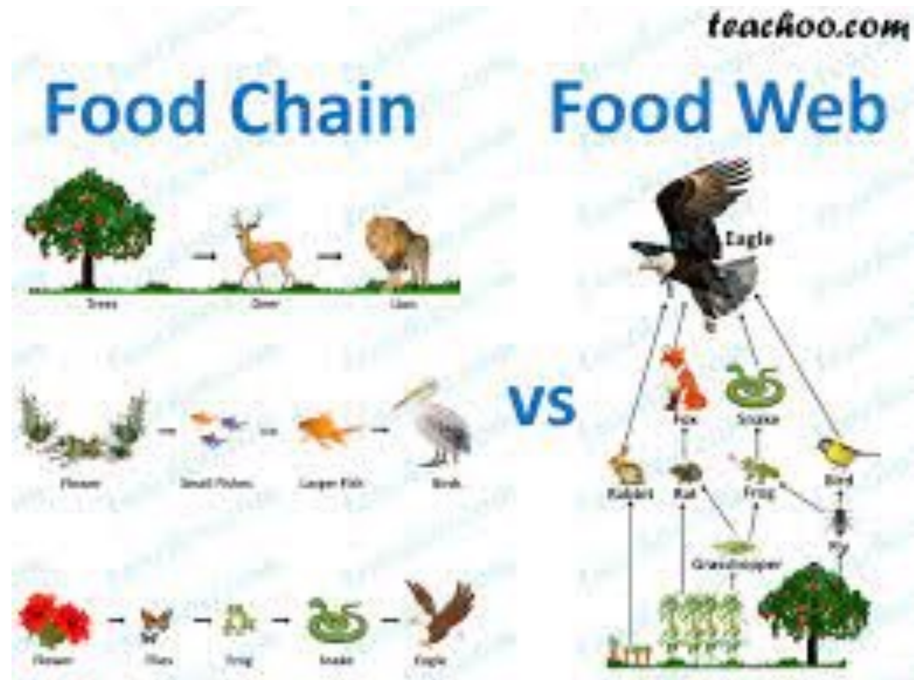
Food Chains and Food Webs

A food chain is a linear sequence of organisms through which nutrients and energy pass as one organism eats another; the levels in the food chain are producers, primary consumers, higher-level consumers, and finally decomposers. These levels are used to describe ecosystem structure and dynamics. There is a single path through a food chain. Each organism in a food chain occupies a specific trophic level (energy level), its position in the food chain or food web.

In many ecosystems, the base, or foundation, of the food chain consists of photosynthetic organisms (plants or phytoplankton), which are called producers. The organisms that consume the producers are herbivores: the primary consumers. Secondary consumers are usually carnivores that eat the primary consumers. Tertiary consumers are carnivores that eat other carnivores. Higher-level consumers feed on the next lower trophic levels, and so on, up to the organisms at the top of the food chain: the apex consumers. In the Lake Ontario food chain, the Chinook salmon is the apex consumer at the top of this food chain.



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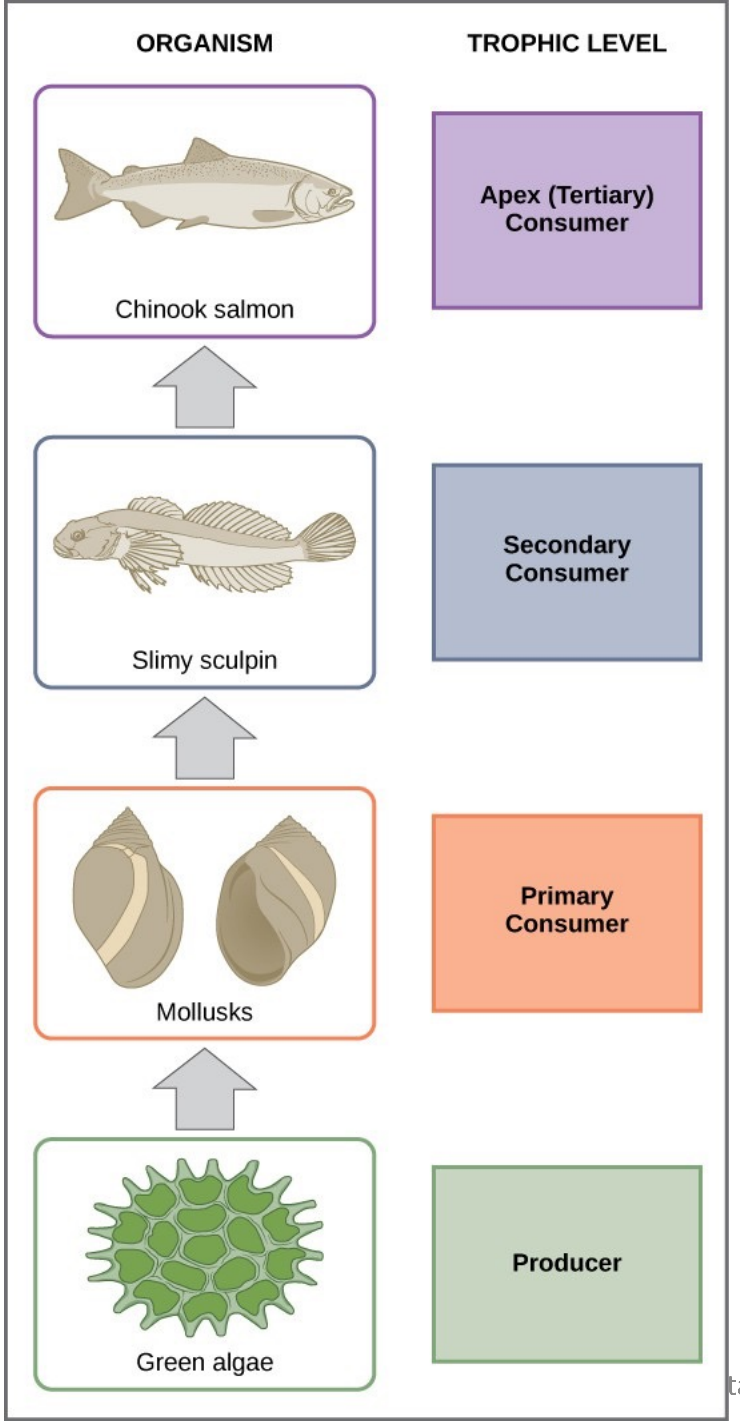

These are the trophic levels of a food chain in Lake Ontario at the United States–Canada border. Energy and nutrients flow from photosynthetic green algae at the base to the top of the food chain: the Chinook salmon. (credit: modification of work by National Oceanic and Atmospheric Administration/NOAA)

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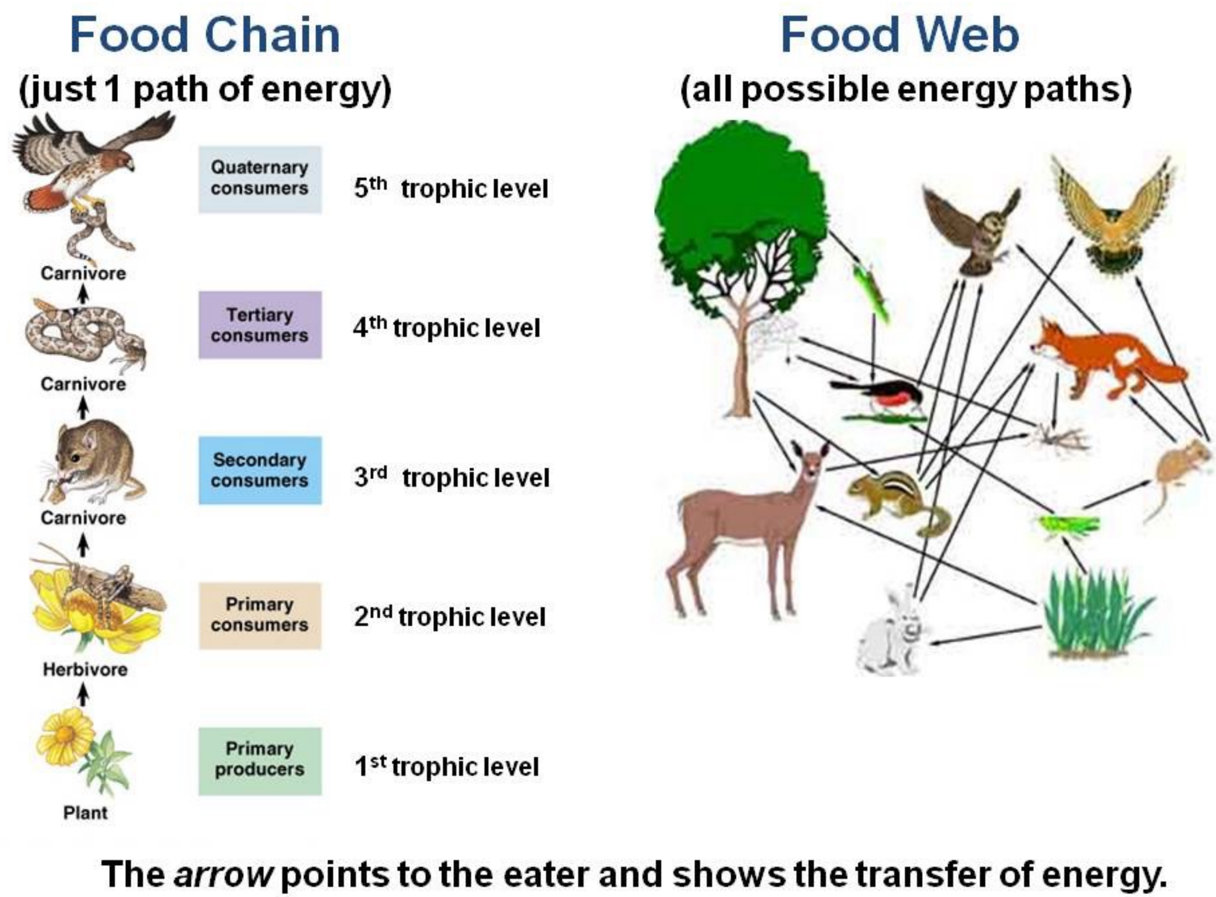
Food Chains and Food Webs

One major factor that limits the number of steps in a food chain is energy. Energy is lost at each trophic level and between trophic levels as heat and in the transfer to decomposers. Thus, after a limited number of trophic energy transfers, the amount of energy remaining in the food chain may not be great enough to support viable populations at yet a higher trophic level.



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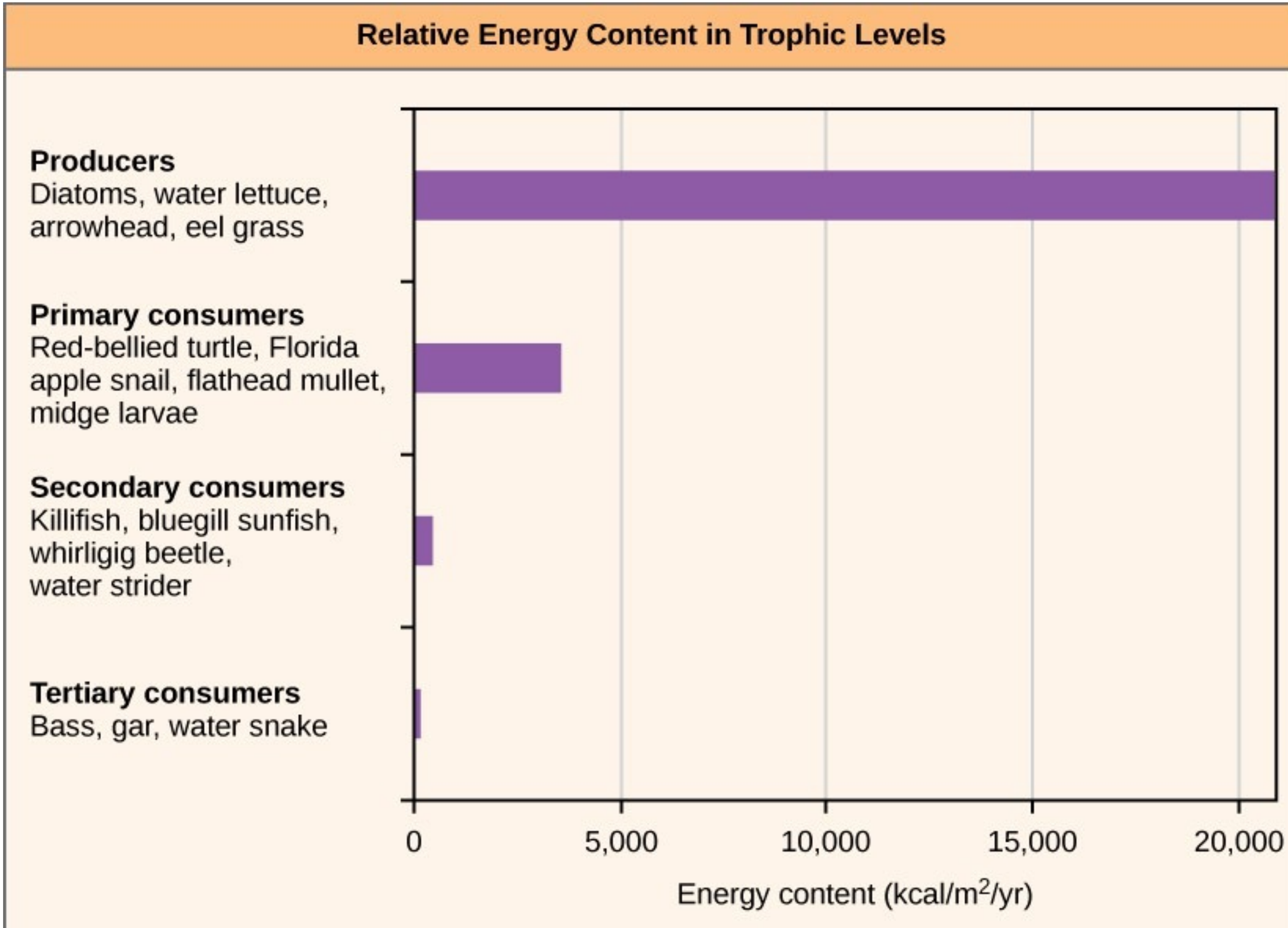

The relative energy in trophic levels in a Silver Springs, Florida, ecosystem is shown. Each trophic level has less energy available, and usually, but not always, supports a smaller mass of organisms at the next level.

Food Chains and Food Webs

There is a one problem when using food chains to describe most ecosystems. Even when all organisms are grouped into appropriate trophic levels, some of these organisms can feed on more than one trophic level; likewise, some of these organisms can also be fed on from multiple trophic levels. In addition, species feed on and are eaten by more than one species. In other words, the linear model of ecosystems, the food chain, is a hypothetical, overly simplistic representation of ecosystem structure. A holistic model—which includes all the interactions between different species and their complex interconnected relationships with each other and with the environment—is a more accurate and descriptive model for ecosystems. A food webis a concept that accounts for the multiple trophic (feeding) interactions between each species and the many species it may feed on, or that feed on it. In a food web, the several trophic connections between each species and the other species that interact with it may cross multiple trophic levels. The matter and energy movements of virtually all ecosystems are more accurately described by food webs.

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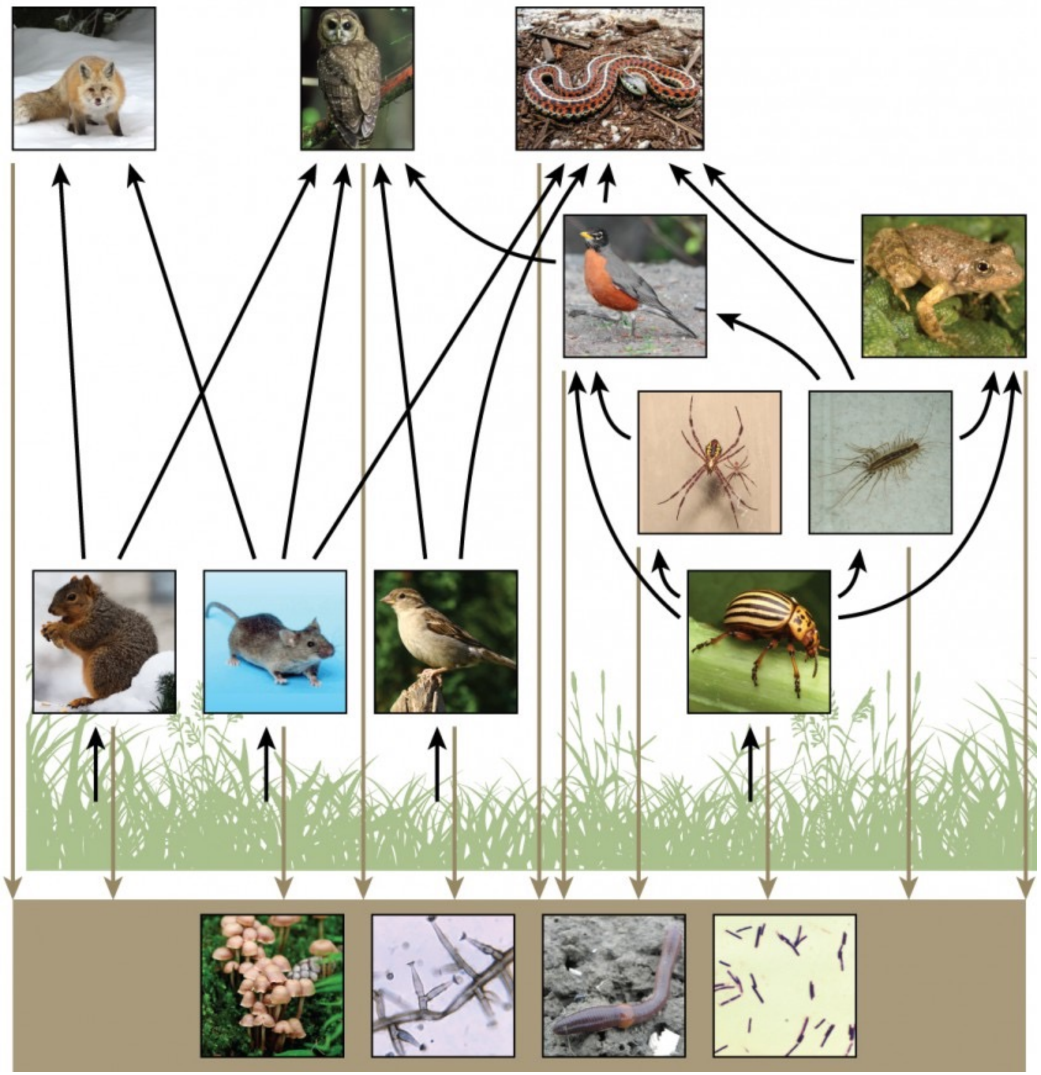
Food Chains and Food Webs



This food web shows the interactions between organisms across trophic levels. Arrows point from an organism that is consumed to the organism that consumes it. All the producers and consumers eventually become nourishment for the decomposers.

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Food Chains and Food Webs

Two general types of food webs are often shown interacting within a single ecosystem. A grazing food web has plants or other photosynthetic organisms at its base, followed by herbivores and various carnivores. A detrital food web consists of a base of organisms that feed on decaying organic matter (dead organisms), including decomposers (which break down dead and decaying organisms) and detritivores (which consume organic detritus). These organisms are usually bacteria, fungi, and invertebrate animals that recycle organic material back into the biotic part of the ecosystem as they themselves are consumed by other organisms. As ecosystems require a method to recycle material from dead organisms, grazing food webs have an associated detrital food web. For example, in a meadow ecosystem, plants may support a grazing food web of different organisms, primary and other levels of consumers, while at the same time supporting a detrital food web of bacteria and fungi feeding off dead plants and animals. Simultaneously, a detrital food web can contribute energy to a grazing food web, as when a robin eats an earthworm.

Head to this online interactive simulator to investigate food web function. In the *Interactive Labs* box, under Food Web, click **Step 1**. Read the instructions first, and then click **Step 2** for additional instructions. When you are ready to create a simulation, in the upper-right corner of the *Interactive Labs* box, click **OPEN SIMULATOR**.

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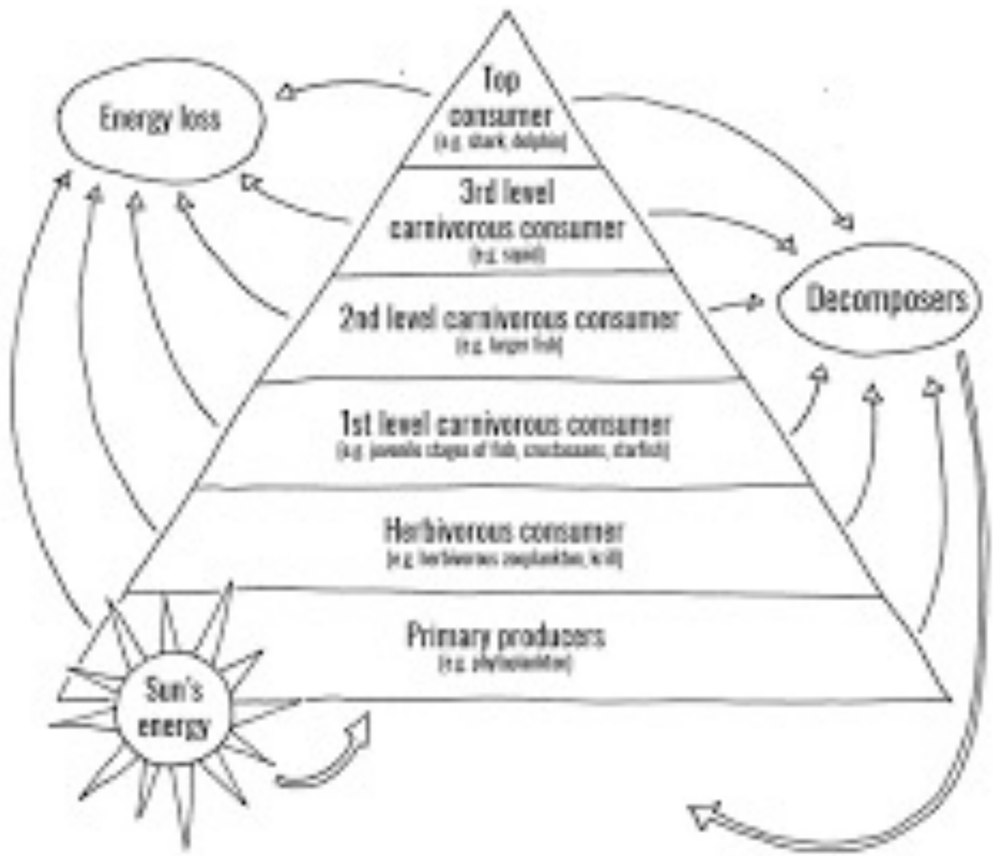
Organisms Acquire Energy in a Food Web

- All living things require energy in one form or another. Energy is used by most complex metabolic pathways (usually in the form of ATP), especially those responsible for building large molecules from smaller compounds. Living organisms would not be able to assemble macromolecules (proteins, lipids, nucleic acids, and complex carbohydrates) from their monomers without a constant energy input.
- Food-web diagrams illustrate how energy flows directionally through ecosystems. They can also indicate how efficiently organisms acquire energy, use it, and how much remains for use by other organisms of the food web. Energy is acquired by living things in two ways: autotrophs harness light or chemical energy and heterotrophs acquire energy through the consumption and digestion of other living or previously living organisms.



For energy flow, we can look [here]() how the energy comes to the system.

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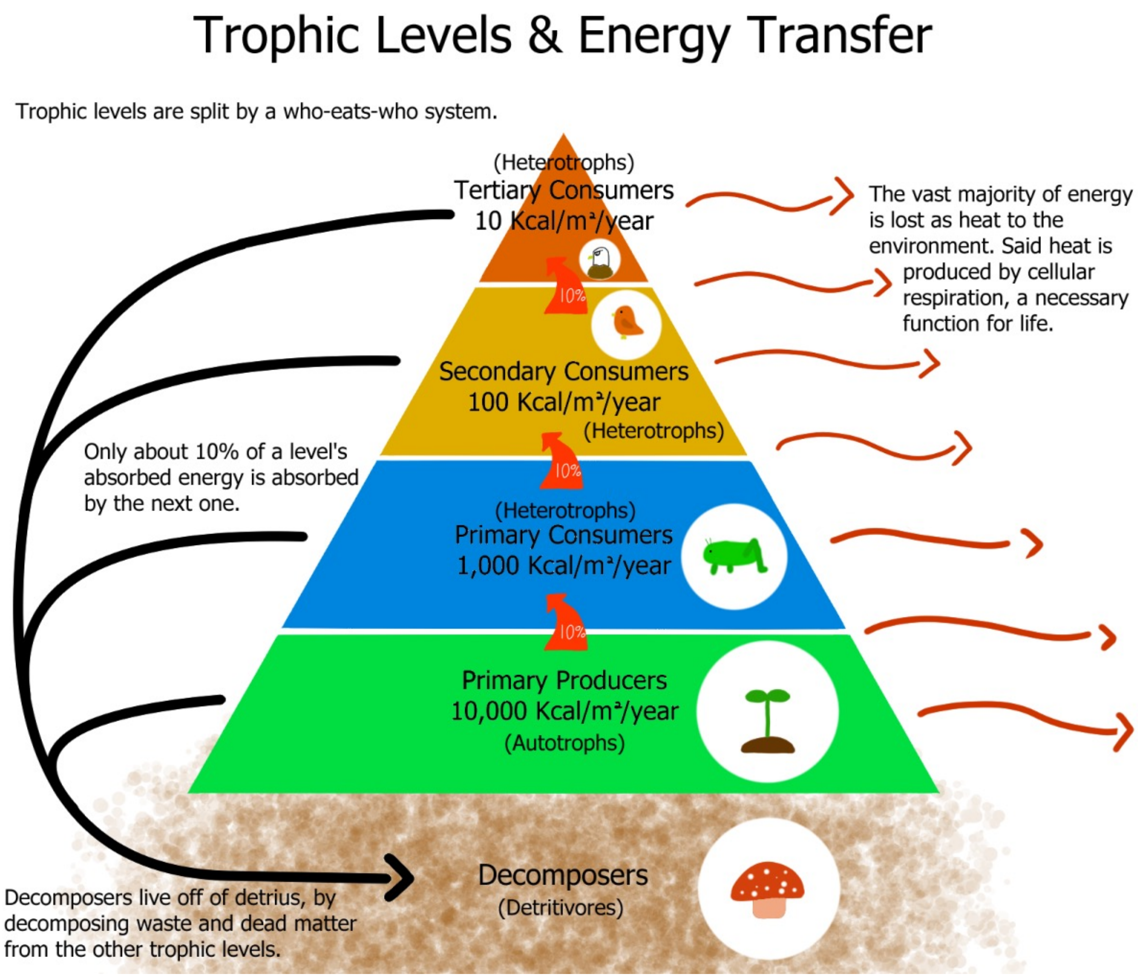
Organisms Acquire Energy in a Food Web

Photosynthetic and chemosynthetic organisms are autotrophs, which are organisms capable of synthesizing their own food (more specifically, capable of using inorganic carbon as a carbon source). Photosynthetic autotrophs (photoautotrophs) use sunlight as an energy source, and chemosynthetic autotrophs (chemoautotrophs) use inorganic molecules as an energy source. Autotrophs are critical for most ecosystems: they are the producer trophic level. Without these organisms, energy would not be available to other living organisms, and life itself would not be possible.



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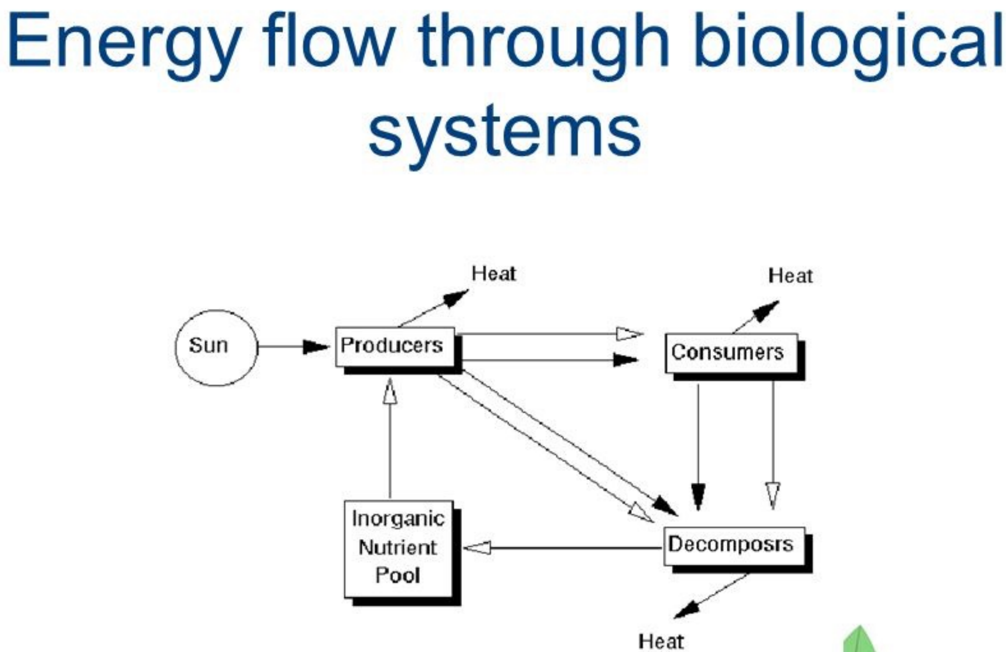
Organisms Acquire Energy in a Food Web

Photoautotrophs, such as plants, algae, and photosynthetic bacteria, are the energy source for a majority of the world's ecosystems. These ecosystems are often described by grazing and detrital food webs. Photoautotrophs harness the Sun's solar energy by converting it to chemical energy in the form of ATP (and NADP). The energy stored in ATP is used to synthesize complex organic molecules, such as glucose. The rate at which photosynthetic producers incorporate energy from the Sun is called gross primary productivity. However, not all of the energy incorporated by producers is available to the other organisms in the food web because producers must also grow and reproduce, which consumes energy. Net primary productivity is the energy that remains in the producers after accounting for these organisms' respiration and heat loss. The net productivity is then available to the primary consumers at the next trophic level.



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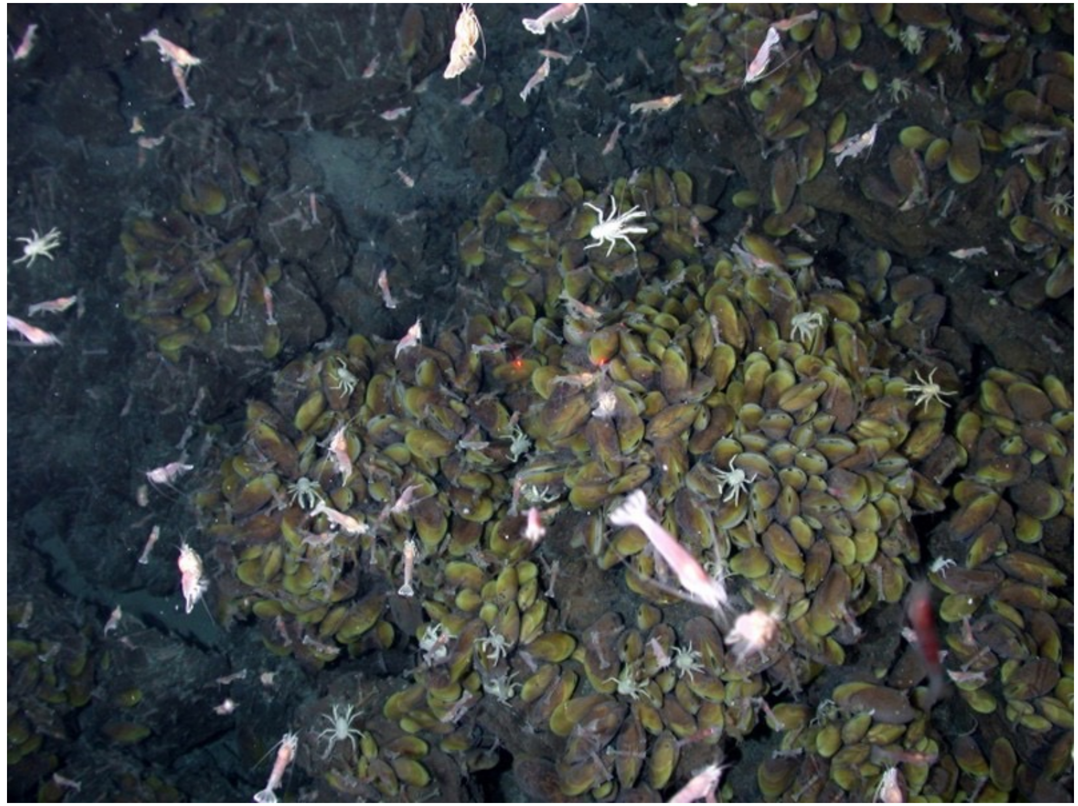
Organisms Acquire Energy in a Food Web

- Chemoautotrophs are primarily bacteria and archaea that are found in rare ecosystems where sunlight is not available, such as those associated with dark caves or hydrothermal vents at the bottom of the ocean. Many chemoautotrophs in hydrothermal vents use hydrogen sulfide (H_2S), which is released from the vents as a source of chemical energy; this allows them to synthesize complex organic molecules, such as glucose, for their own energy and, in turn, supplies energy to the rest of the ecosystem.



Swimming shrimp, a few squat lobsters, and hundreds of vent mussels are seen at a hydrothermal vent at the bottom of the ocean. As no sunlight penetrates to this depth, the ecosystem is supported by chemoautotrophic bacteria and organic material that sinks from the ocean's surface. This picture was taken in 2006 at the submerged NW Eifuku volcano off the coast of Japan by the National Oceanic and Atmospheric Administration (NOAA). The summit of this highly active volcano lies 1535 m below the surface.

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Consequences of Food Webs

One of the most important consequences of ecosystem dynamics in terms of human impact is biomagnification. Biomagnification is the increasing concentration of persistent, toxic substances in organisms at each successive trophic level. These are substances that are fat soluble, not water soluble, and are stored in the fat reserves of each organism. Many substances have been shown to biomagnify, including classical studies with the pesticide dichlorodiphenyltrichloroethane (DDT), which were described in the 1960s bestseller, *Silent Spring* by Rachel Carson. DDT was a commonly used pesticide before its dangers to apex consumers, such as the bald eagle, became known. In aquatic ecosystems, organisms from each trophic level consumed many organisms in the lower level, which caused DDT to increase in birds (apex consumers) that ate fish. Thus, the birds accumulated sufficient amounts of DDT to cause fragility in their eggshells. This effect increased egg breakage during nesting and was shown to have devastating effects on these bird populations. The use of DDT was banned in the United States in the 1970s.

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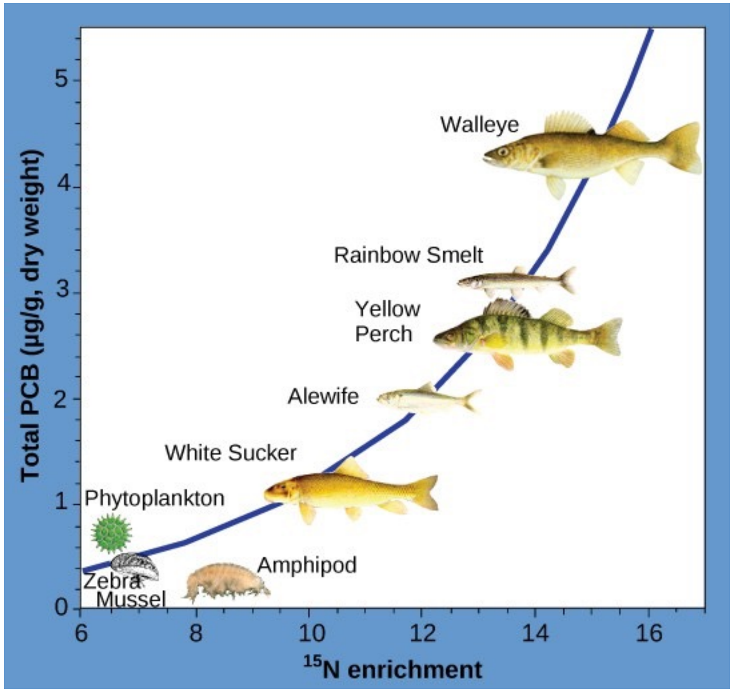
Consequences of Food Webs

Other substances that biomagnify are polychlorinated biphenyls (PCB), which were used as coolant liquids in the United States until their use was banned in 1979, and heavy metals, such as mercury, lead, and cadmium. These substances are best studied in aquatic ecosystems, where predatory fish species accumulate very high concentrations of toxic substances that are at quite low concentrations in the environment and in producers. As illustrated in a study performed by the NOAA in the Saginaw Bay of Lake Huron of the North American Great Lakes ([Figure]), PCB concentrations increased from the producers of the ecosystem (phytoplankton) through the different trophic levels of fish species. The apex consumer, the walleye, has more than four times the amount of PCBs compared to phytoplankton. Also, based on results from other studies, birds that eat these fish may have PCB levels at least one order of magnitude higher than those found in the lake fish.



This chart shows the PCB concentrations found at the various trophic levels in the Saginaw Bay ecosystem of Lake Huron. Notice that the fish in the higher trophic levels accumulate more PCBs than those in lower trophic levels. (credit: Patricia Van Hoof, NOAA)

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Consequences of Food Webs

- Concerns have been raised by the biomagnification of heavy metals, such as mercury and cadmium, in certain types of seafood. The United States Environmental Protection Agency recommends that pregnant women and young children should not consume any swordfish, shark, king mackerel, or tilefish because of their high mercury content. These individuals are advised to eat fish low in mercury: salmon, shrimp, pollock, and catfish. Biomagnification is a good example of how ecosystem dynamics can affect our everyday lives, even influencing the food we eat.

Section Summary

Ecosystems exist underground, on land, at sea, and in the air. Organisms in an ecosystem acquire energy in a variety of ways, which is transferred between trophic levels as the energy flows from the base to the top of the food web, with energy being lost at each transfer. There is energy lost at each trophic level, so the lengths of food chains are limited because there is a point where not enough energy remains to support a population of consumers. Fat soluble compounds biomagnify up a food chain causing damage to top consumers. even when environmental concentrations of a toxin are low.

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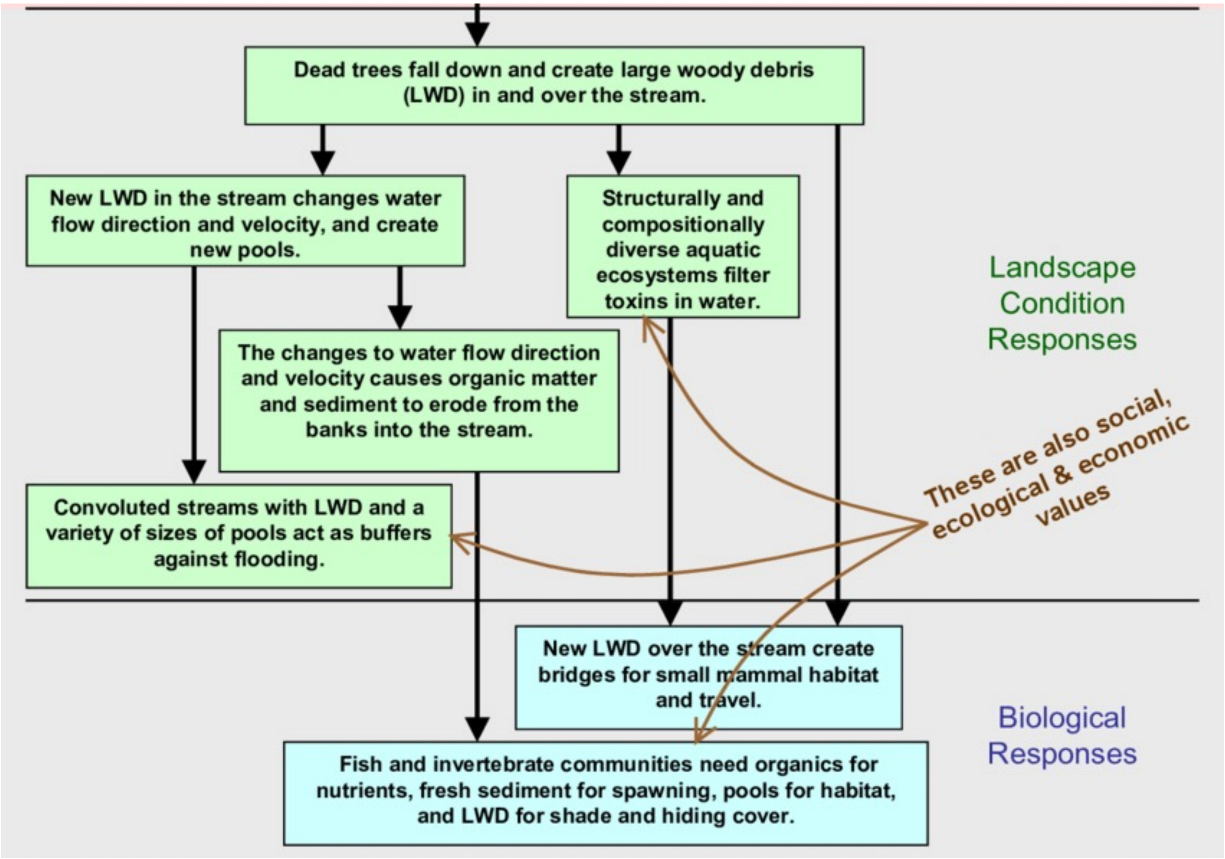
Ecosystem Dynamics

An ecosystem is a community of living organisms (plants, animals, and microbes) existing in conjunction with the nonliving components of their environment (air, water, and mineral soil), interacting as a system. These biotic and abiotic components are linked together through nutrient cycles and energy flows. As ecosystems are defined by the network of interactions among organisms, or between organisms and their environment, they can be of any size, but usually encompass specific, limited spaces.



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Internal and External Factors

- Ecosystems are dynamic entities controlled both by external and internal factors. External factors, such as climate and the parent material that forms the soil, control the overall structure of an ecosystem and the way things work within it, but are not themselves influenced by the ecosystem. While the resource inputs are generally controlled by external processes, the availability of these resources within the ecosystem is controlled by internal factors such as decomposition, root competition, or shading. Other internal factors include disturbance, succession, and the types of species present. From one year to another, ecosystems experience variation in their biotic and abiotic environments. A drought, an especially cold winter, and a pest outbreak all constitute short-term variability in environmental conditions. Animal populations vary from year to year, building up during resource-rich periods, but crashing as the food supply becomes scarce.
- Equilibrium is the steady state of an ecosystem where all organisms are in balance with their environment and with each other. In equilibrium, any small changes to the system will be balanced by negative feedback, allowing the system to return to its original state.

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Resistance and Resilience

In ecology, two parameters are used to measure changes in ecosystems: resistance and resilience. Resistance is the ability of an ecosystem to remain at equilibrium despite disturbances. Resilience is the speed at which an ecosystem recovers to equilibrium after being disturbed. Humans may impact the nature of an ecosystem to such a degree that the ecosystem can lose its resilience entirely. In these cases, external human influences can lead to the complete destruction or irreversible altering of the ecosystem equilibrium.

Human intervention in ecosystem equilibrium: The Australian Aboriginal practice of "Fire-stick farming" has fundamentally modified Australian ecosystems. The legacy of this practice over long periods has resulted in forests being converted to grasslands. In this example, the forests became less and less resilient over time until the fundamental system equilibrium had changed.

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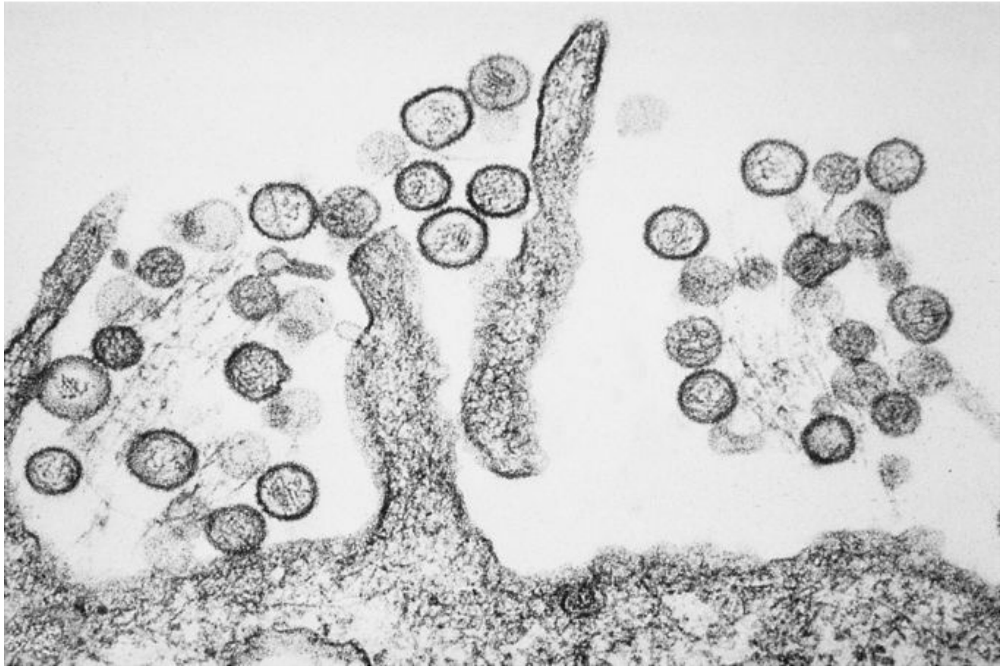
The Sin Nombre Virus: Ecosystem Dynamics in a Human Population

- In 1993, a change in ecosystem dynamics caused a disease outbreak in a human population. In May of 1993, an unexplained pulmonary illness struck inhabitants of the southwestern United States in an area shared by Arizona, New Mexico, Colorado and Utah known as “The Four Corners. ” A young, physically fit Navajo man suffering from shortness of breath was rushed to a hospital in New Mexico and died rapidly. After further investigation, state officials located another five young, healthy people who had all died after acute respiratory failure.
- When laboratory tests failed to identify the disease causing the deaths, New Mexico state health officials notified the Centers for Disease Control (CDC), the United States government agency responsible for managing potential epidemics. As additional cases of the disease were reported in the following weeks, physicians and scientists worked intensively to narrow down the list of possible causes. Virologists at the CDC linked the pulmonary syndrome with a virus – a previously unknown type of hantavirus. The hantavirus became known as *Sin Nombre*, the virus “with no name. ”



Sin Nombre hantavirus: After a series of sudden deaths in 1993, scientists in the Four Corners area of the Southwestern United States rushed to determine the cause. They isolated a previously unknown hantavirus that caused pulmonary failure or Hantavirus Pulmonary Syndrome (HPS). The new virus was named Sin Nombre, or virus with “no name. “

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The Sin Nombre Virus: Ecosystem Dynamics in a Human Population

- Although they identified the virus as the cause of the disease, researchers did not understand how it was transmitted. The researchers trapped and examined rodents that lived in and around the homes of the victims, and found that almost 30% of the deer mice were infected with the Sin Nombre hantavirus. The virus had been transmitted to humans via aerosolized mouse droppings, and a dramatic increase in the deer mouse population increased human infection rates.
- The Four Corners area had experienced a drought until early 1993, when there were heavy snows and rainfall. The end of the drought caused an increase in vegetation, and particularly pinon nut production. With the sudden increase in food supply, the local deer mice population exploded and reproduced so rapidly that there were ten times more mice in May 1993 than there had been in May of 1992. The higher population of deer mice meant more mouse droppings and more opportunities to transmit hantavirus to humans.

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The Sin Nombre Virus: Ecosystem Dynamics in a Human Population

As part of the effort to locate the source of the virus, researchers located and examined stored samples of lung tissue from people who had died of unexplained lung disease. Some of these samples showed evidence of previous infection with Sin Nombre virus, indicating that the earlier cases of the disease had not been recognized. The Navajo Native Americans recognize a similar disease in their medical traditions, and associate its occurrence with mice.

Ecosystem dynamics can affect human populations: The Four Corners area had been in a drought for several years. In early 1993, the rainfall caused an increase in vegetation, which caused an increase the local deer mice population. Hantavirus infected the high deer mouse population and was quickly transmitted to humans via aerosolized mouse droppings.

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