Parent Background Information

Organization of Life

The biological levels of organization range from a single organelle all the way up to the biosphere in a highly structured hierarchy.

All the individuals of a species (group of organisms that can actually or potentially interbreed) living within a specific area are collectively called a population. For example, a forest may include many pine trees. All of these pine trees represent the population of pine trees in this forest. Different populations may live in the same specific area. For example, the forest with the pine trees includes populations of flowering plants and also insects and microbial populations. A community is the sum of populations inhabiting a particular area. For instance, all of the trees, flowers, insects, and other populations in a forest form the forest's community. The forest itself is an ecosystem. An ecosystem consists of all the living things in a particular area together with the abiotic, non-living parts of that environment such as nitrogen in the soil or rain water. At the highest level of organization, the biosphere is the collection of all ecosystems, and it represents the zones of life on earth. It includes land, water, and even the atmosphere to a certain extent. Taken together, all of these levels comprise the biological levels of organization, which range from organelles to the biosphere.

Food Chains, Food Webs & Trophic Levels

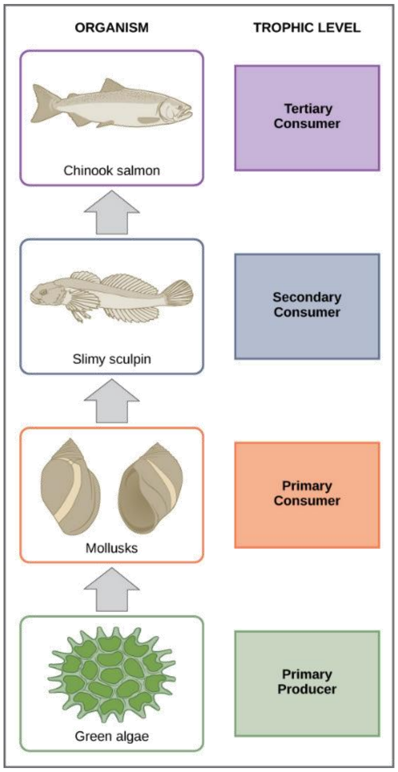
In ecology, a food chain is a series of organisms that eat one another so that energy and nutrients flow from one to the next. For example, if you had a hamburger for lunch, you might be part of a food chain that looks like this:

grass → cow → human

But what if you had lettuce on your hamburger? In that case, you're also part of a food chain that looks like this:

lettuce → human.

As this example illustrates, we can't always fully describe what an organism—such as a human—eats with one linear pathway. For situations like the one above, we may want to use a food web that consists of many intersecting food chains and represents the different things an organism can eat and be eaten by.



Autotrophs vs. heterotrophs

Some organisms, called autotrophs, also known as self-feeders, can make their own food—that is, their own organic compounds—out of simple molecules like carbon dioxide. There are two basic types of autotrophs:

Photoautotrophs, such as plants, use energy from sunlight to make organic compounds—sugars—out of carbon dioxide in photosynthesis. Other examples of photoautotrophs include algae and cyanobacteria. Chemoautotrophs use energy from chemicals to build organic compounds out of carbon dioxide or similar molecules. This is called chemosynthesis. For instance, there are hydrogen sulfide-oxidizing chemoautotrophic bacteria found in undersea vent communities where no light can reach. Autotrophs are the foundation of every ecosystem on the planet. Autotrophs form the base of food chains and food webs, and the energy they capture from light or chemicals sustains all the other organisms in the community. When we're talking about their role in food chains, we can call autotrophs producers. Think "produce" in the grocery store.

Heterotrophs, also known as other-feeders, can't capture light or chemical energy to make their own food out of carbon dioxide. Humans are heterotrophs. Instead, heterotrophs get organic molecules by eating other organisms or their byproducts. Animals, fungi, and many bacteria are heterotrophs. When we talk about heterotrophs' role in food chains, we can call them consumers. As we'll see shortly, there are many different kinds of consumers with different ecological roles, from plant-eating insects to meat-eating animals to fungi that feed on debris and wastes.

Food chains

A food chain is a linear sequence of organisms through which nutrients and energy pass as one organism eats another. At the bottom are the producers and are most often photosynthetic organisms such as plants, algae, or cyanobacteria. The organisms that eat the primary producers are called primary consumers. Primary consumers are usually herbivores, plant-eaters, though they may be algae eaters or bacteria eaters. The organisms that eat the primary consumers are called secondary consumers. Secondary consumers are generally meat-eaters—carnivores. The organisms that eat the secondary consumers are called tertiary consumers. These are carnivore-eating carnivores, like eagles or big fish. Some food chains have additional levels, such as quaternary consumers—carnivores that eat tertiary consumers. Organisms at the very top of a food chain are called apex consumers.

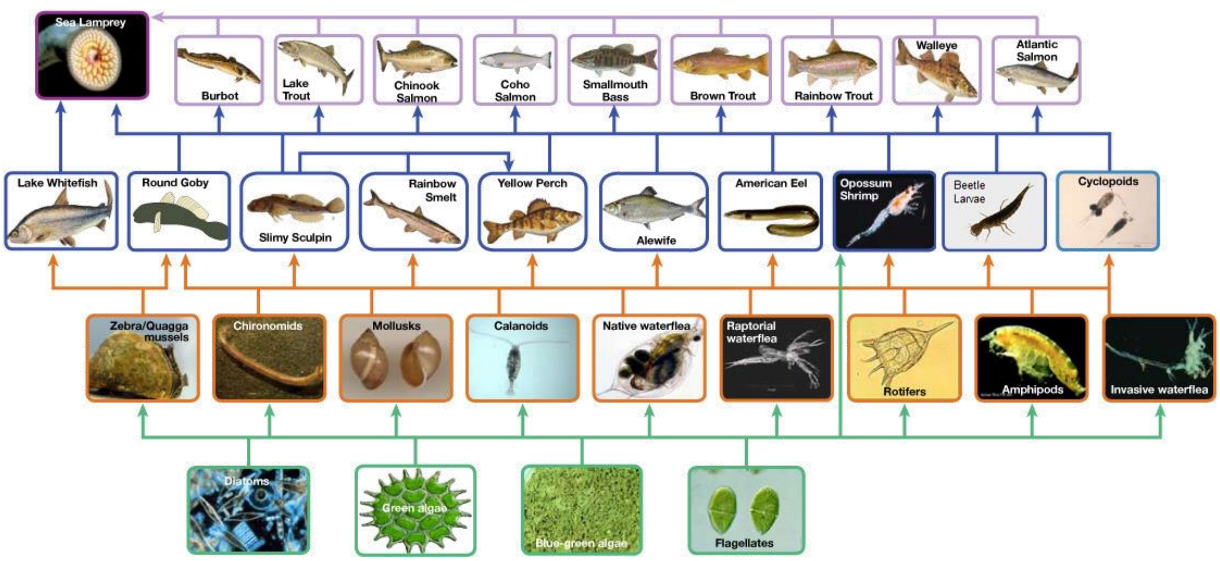
Each of the categories above is called a trophic level, and it reflects how many transfers of energy and nutrients—how many consumption steps—separate an organism from the food chain's original energy source, such as light. As we'll explore further below, assigning organisms to trophic levels isn't always clear-cut. For instance, humans are omnivores that can eat both plants and animals.

Decomposers

Decomposers are sometimes considered their own trophic level. As a group, they eat dead matter and waste products that come from organisms at various other trophic levels; for instance, they would happily consume decaying plant matter, the body of a half-eaten squirrel, or the remains of a deceased eagle. Fungi and bacteria are the key decomposers in many ecosystems; they use the chemical energy in dead matter and wastes to fuel their metabolic processes. Decomposers as a group play a critical role in keeping ecosystems healthy. When they break down dead material and wastes, they release nutrients that can be recycled and used as building blocks by primary producers.

Food webs

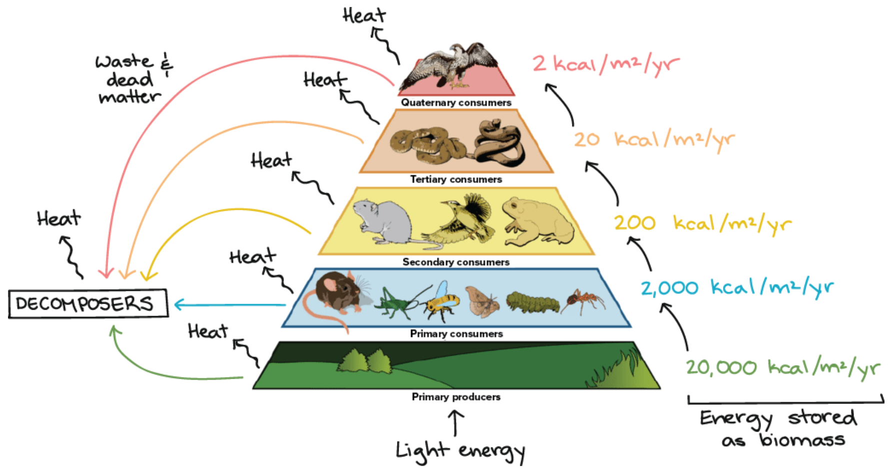
When an organism eats multiple types of prey or can be eaten by multiple predators, including ones at different trophic levels things get confusing. To represent these relationships more accurately, we can use a food web, a graph that shows all the trophic—eating-related—interactions between various species in an ecosystem. The diagram below shows an example of a food web from Lake Ontario. Primary producers are marked in green, primary consumers in orange, secondary consumers in blue, and tertiary consumers in purple.



In food webs, arrows point from an organism that is eaten to the organism that eats it, the direction of energy flow. As the food web above shows, some species can eat organisms from more than one trophic level. For example, opossum shrimp eat both primary producers and primary consumers. Bonus question: This food web above contains the food chain we saw earlier in the article, Can you find it?

green algae → mollusks → slimy sculpin → salmon

Energy transfer efficiency limits food chain lengths



Energy is transferred between trophic levels when one organism eats another and gets the energy-rich molecules from its prey's body. However, these transfers are inefficient, and this inefficiency limits the length of food chains.

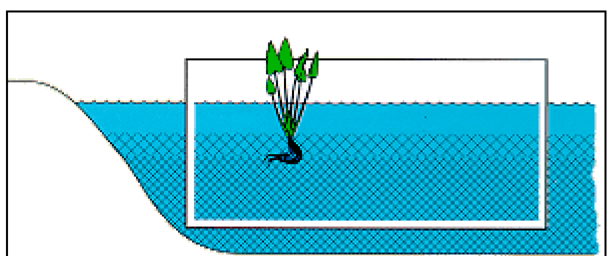
When energy enters a trophic level, some of it is stored as biomass, as part of organisms' bodies. This is the energy that's available to the next trophic level since only energy storied as biomass can get eaten. As a rule of thumb, only about 10% of the energy that's stored as biomass in one trophic level—per unit time—ends up stored as biomass in the next trophic level—per the same unit time. This 10% rule of energy transfer is a good thing to commit to memory.

As an example, let's suppose the primary producers of an ecosystem store 20,000 kcal/m^2/year of energy as biomass. This is also the amount of energy per year that's made available to the primary consumers, which eat the primary producers. The 10% rule would predict that the primary consumers store only 2,000 kcal/m^2/year of energy in their own bodies, making energy available to their predators—secondary consumers—at a lower rate. This limits the length of food chains, to about three to six. Here are a few of the main reasons for inefficient energy transfer: Heat loss and energy of living, indigestible food and some organisms die without being eaten. The feces and uneaten, dead organisms become food for decomposers, who metabolize them and convert their energy to heat through cellular respiration. So, none of the energy actually disappears—it all winds up as heat in the end.

Biogeochemical Cycles

The basic elements that occur in living organisms move through the environment in a series of naturally occurring physical, chemical and biological processes known as biogeochemical cycles. The cycle generally describes the physical state, chemical form, and biogeochemical processes affecting the substance at each point in the cycle in an undisturbed ecosystem. Many of these processes are influenced by microbial populations that are naturally adapted to life in either aerobic, oxygenated, or anaerobic, oxygen free, conditions.

The bulk of nitrogen is stored as nitrogen gas in the atmosphere. In wetlands both aerobic and anaerobic conditions can cause cycling of nitrogen. In the form of ammonium (NH_4) is released from decaying plant and animal matter under both aerobic and anaerobic conditions in a process known as ammonification. The ammonium then moves to the aerobic layer where it is converted to nitrate ($N0_3$). Nitrate not taken up by plants or immobilized by adsorption onto soil particles can leach downward with percolating water to reach the groundwater supply or move with surface and subsurface flow. Nitrate can also be converted to nitrogen gas by denitrification by bacteria and returned to the atmosphere.

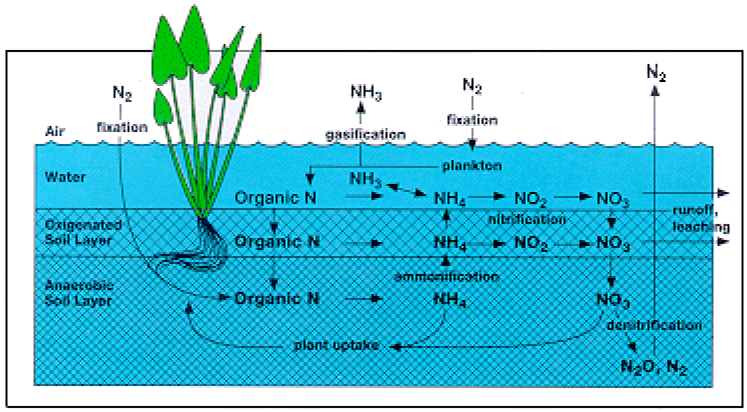


Nitrogen cycling in wetlands progresses more rapidly where there is a thin oxygenated soil layer present.

If both aerobic and anaerobic conditions were not available, some of the cycle processes would cease and pollutants could accumulate. In wetlands, anaerobic condition are amply provided by flooding and by saturated soils. However, the oxygen requiring processes take place in a thin oxidized zone usually existing at the soil surface. This layer may be only a fraction of an inch thick and is present even when the wetland is submerged. In many wetlands the water table fluctuates 12 to 18 inches each year with the summer level averaging between 4 and 18 inches below the surface of the soil. This zone of aeration is often called the active layer.

Phosphorus, sulfur, iron, manganese and carbon also move through the wetland ecosystem in complex cycles. Sulfur and carbon, like nitrogen, have gaseous cycles. As a result of the biogeochemical cycle processes, sulfides and methane are released into the atmosphere attended by the smell of rotten eggs and swamp gas respectively. Phosphorus, however, has a sediment cycle with excess phosphorus being tied up in sediments, peat in organic wetlands and clay particles in mineral wetlands. However, although phosphorus retention is an important attribute of wetlands, sediment attached phosphorus is subject to resuspension and movement with water when sediments are disturbed.

The cycles are similar in that they provide storage for excess elements and require a certain amount of time to complete the chemical processes. The cycle processes also require the varying environments provided by aerobic and anaerobic conditions. In closed systems, the processes take place within the wetland. In open systems, like riparian wetlands, many elements can be imported from or exported to adjacent systems with surface and groundwater flows or flooding.



Nitrogen cycling in wetlands progresses more rapidly where there is a thin oxygenated soil layer present.

After Mitsch & Gosselink 1993

To avoid changing the natural biogeochemical function, it is important that the hydrology of the wetland, the inflow, outflow and residence time of the water, remain relatively undisturbed. It is also necessary to minimize disturbance to the aerobic zone of saturated soils. However, even with minimal disturbance, wetlands will continue to function as net receptors (sinks) or net exporters (sources) of various elements primarily due to seasonal and other natural fluctuations in the biogeochemical cycle processes.

Ecological Succession

Ecological succession is the predictable and orderly set of changes that happen in the composition or structure of ecological community. The time scale can be decades or even millions of years.

3 Types of Ecological Succession

Succession may be initiated either by formation of new habitat (landslide or lava flow) or disturbance of already existing habitat (fires, land clearance). There are three recognized stages to ecological succession.

1. Primary – This is when an ecological community first enters into a new form of habitat that it has not been present in before.
2. Secondary – The secondary succession stage occurs after a habitat has been established, but it is then disturbed or changed in some fashion and a new community moves in.
3. Climax – the climax stage is the last stage of an ecosystem. It is when the ecosystem has become balanced and there is little risk of an interfering event or change to mutate the environment.

4 Stages of Ecological Succession

When talking about the types of ecological succession it is important to remember that the “types” occur within the stages, but they may not necessarily be unique to that stage. What determines the stage that an ecosystem is in is dependent on its energy balance – which is discussed in the next section. There are four main types of ecological succession:

- Pioneer – pioneer types are the new lifeforms that enter into a primary succession and begin to take hold.
- Establishing –Establishing is the process in which lifeforms identify elements in an ecosystem that can sustain their basic needs – such as food, water and safe habitat.
- Sustaining – Sustaining type means that life in the ecosystem has begun to enter into a pattern that allows for a cycle of life to continue.
- Producing –This is when lifeforms are breeding and growing, but there is migration because what is produced is also not capable of being supported within the ecosystem.

Pioneer species are the ones that thrive the new habitat at the beginning of ecological succession. Pioneer species fast growing and well-dispersed. Early succession is therefore dominated by ‘r-selected’ species. As succession continues, more species enter the community and begin to alter the environment. These are called ‘k-selected’ species. They are more competitive and fight for resources and space. The species that are better suited for the modified habitat then begin to succeed the other species. These are superseded by newer set of species. This goes on till the stage of climax or equilibrium is achieved.

When succession reaches a climax, where community is dominated by stable and small number of prominent species and no other species can be admitted, that is called the state of equilibrium or the climax community.

Ecological Succession and Energy Balance

The climax stage of ecological succession is defined by the energy balance that is achieved. This means that within this very stable ecological system, there is a balance between the life that is produced, and the life that is consumed. For example, there are enough animals to eat the extra seeds to prevent overgrowth that could choke out plants, but not enough to prevent some of the seeds from growing and continuing their cycle of life. The climax stage is stable, but not static. During the other stages, the balance of energy is not in place and there may be crises that develop as a result which will prolong the secondary stage.

How Long Does Each Stage of Ecological Succession Take?

Each stage of ecological succession can take 100s to 1,000s of years – if not more. That is true, but only in a forensic sense. The assumption of ecological succession is that it is a forward moving, and linear path. As more of humankind encroaches on the natural world, the linear progression of this methodology is changing itself. That someone seems fitting for a theory that talks about the inevitability of change.

How is Mankind Changing Ecological Succession?

Let us suppose that a granite wall was quarried by man, and then abandoned once they had what they needed. This allows for a primary stage to begin. Left alone by man, it could quickly pass into a secondary stage within a hundred years or so. Another few centuries after that, the old quarry is slowly entering its stable climax stage – except – now man has returned to build a road. One thing that ecological succession recognizes is the death of an ecosystem. That is what occurs when a climax stage ecosystem like the rain forest is destroyed by logging. When a climax stage ecosystem is interrupted, it is not yet understood whether it returns to the secondary stage, or would still be considered at its climax of ecological succession.

Sources:

- https://www.boundless.com/biology/textbooks/boundless-biology-textbook/the-study-of-life-1/themes-and-concepts-of-biology-49/levels-of-organization-of-living-things-269-11402/
- https://www.khanacademy.org/science/biology/ecology/intro-to-ecosystems/a/food-chains-food-webs
- https://www.na.fs.fed.us/spfo/pubs/n_resource/wetlands/wetlands7_biogeochemical%20cycles.htm
- http://www.conserve-energy-future.com/types-and-stages-of-ecological-succession.php