24.5: Energy in Ecosystems

Sea Angel

It's easy to see why the aquatic creature in this photo is commonly called a sea angel. It has gossamer-like "wings" that flutter gently and help it swim, and its diaphanous body gives it an otherworldly appearance. Although it appears angelic, this tiny invertebrate is actually a vicious predator. It has a secret weapon in the form of six sharp tentacles hidden in its face. When an unsuspecting prey drifts by, the sea angel turns into a devilish killing machine. It lashes out its tentacles, grabs its prey, and then slowly eats it. Predators like sea angels obtain energy from prey organisms. This is just one of the ways that organisms obtain energy.

Figure 24.1: (CC BY-NC 3.0; Taken by Kevin Raskoff, NOAA via Wikimedia.org)
How Organisms Obtain Energy

There are two basic types of organisms in terms of how they obtain energy: autotrophs and heterotrophs.

**Autotrophs**

Autotrophs are organisms that use energy directly from the sun or from chemical bonds. Commonly called producers, they use the energy and simple inorganic compounds to produce organic molecules. Autotrophs are vital to all ecosystems because all organisms need organic molecules and only autotrophs can produce them from inorganic compounds. There are two basic types of autotrophs: photoautotrophs and chemoautotrophs.

**Photoautotrophs**

Photoautotrophs are autotrophs that use energy from sunlight to make organic compounds by photosynthesis. Photoautotrophs include plants, algae, and many bacteria, as shown in the figure below. They are the primary producers in the vast majority of ecosystems on Earth.

**Chemoautotrophs**

Chemoautotrophs use energy from chemical bonds to make organic compounds by chemosynthesis. Chemoautotrophs include certain bacteria and archaeans. They are the primary producers in ecosystems that form around hydrothermal vents and in hot springs.

**Heterotrophs**

Heterotrophs are organisms that obtain energy from other living things. Like sea angels, they take in organic molecules by consuming other organisms, so they are commonly called consumers. Heterotrophs include all animals and fungi as well as many protists and bacteria. Heterotrophs can be classified by what they usually eat as herbivores, carnivores, omnivores, or decomposers.
Herbivores

Herbivores are heterotrophs that directly consume producers such as plants or algae. They are a necessary link between producers and other heterotrophs such as carnivores. Examples of herbivores include deer, rabbits, sea urchins, grasshoppers, mice, and the larvae of many insects, like the caterpillar pictured below. Herbivorous animals typically have mouthparts or teeth adapted to grasping or grinding the tough materials in plants. Many herbivores have mutualistic intestinal microbes that help them break down hard-to-digest plant matter.

Carnivores

Carnivores are heterotrophs that consume animals; examples of heterotrophs include lions, polar bears, hawks, salmon, and spiders. Obligate carnivores (such as cats) are unable to digest plants so they can only eat animals. Facultative carnivores (such as dogs) can digest plant matter but plants are not an important food source for them. Most carnivores are predators that catch and kill live animals for consumption. Some carnivores, called scavengers, find and eat animals that have already died, such as the prey remnants left behind by predators. Examples of scavengers include vultures, hyenas, and blowflies, like those in Figure \(\PageIndex{4}\).
Omnivores

Omnivores are heterotrophs that consume both plants and animals. They include pigs, brown bears, gulls, crows, and humans. Omnivores actually fall on a continuum between herbivores and carnivores. Some omnivores eat more plants than animals, whereas other omnivores eat more animals than plants. Some organisms are seasonally omnivorous, meaning that they eat plants in some seasons and animals in other seasons. An example is a grizzly bear. When salmon or other fish are plentiful, the bears are primarily carnivorous; but when berries ripen and become plentiful, the bears are mainly herbivorous. Some omnivores eat animals during some life stages and plants during other life stages. For example, most tadpoles are herbivores that eat algae, whereas adult frogs are carnivores that eat insects and other invertebrates.

Decomposers

Figure \(\PageIndex{5}\): Fungi growing on a dead tree secrete enzymes that can break down even tough wood fibers that no other organisms can digest. (CC BY 2.0; Cayce from Malasia via Wikimedia.org).
Decomposers are heterotrophs that break down and feed on the remains of dead organisms and other organic wastes such as feces. In the process, they release simple inorganic molecules back to the environment. Producers can then use the molecules to make new organic compounds. Decomposers are classified by the type of organic matter they break down. Two types are detritivores and saprotrophs.

- Detritivores are decomposers that ingest and digest detritus, which includes dead leaves, animal feces, and other organic debris that collects on the ground or at the bottom of a body of water. Terrestrial detritivores include earthworms and dung beetles. Aquatic detritivores include “bottom feeders” such as sea cucumbers and catfish.
- Saprotrophs are decomposers that feed on dead organic matter by secreting digestive enzymes and digesting it externally, rather than by ingesting the matter and digesting it internally. Saprotrophs include fungi and single-celled protozoa. Fungi, like those in the photo below, are the only organisms can decompose wood.

### Models of Energy Flow

Energy enters all ecosystems from the sun or from inorganic chemicals. The energy then flows through ecosystems from producers, who can use inorganic forms of energy, to consumers, who can obtain energy only from organic compounds in other living things. Ecologists commonly represent this flow of energy through the organisms of an ecosystem with models such as food chains and food webs. These models represent feeding relationships, showing who eats whom. Although the models are generally oversimplifications of reality, they have proven useful for testing hypotheses about ecosystems and identifying common patterns that many ecosystems share.
A food chain is an ecological model that represents a single pathway through which energy flows in an ecosystem. Food chains are virtually always simpler than what really happens in nature because most organisms consume — and are consumed by — more than one species. Two examples of food chains, one terrestrial and one aquatic, are shown in Figure 6. In both food chains, the organisms at the bottom are producers. In the terrestrial food chain, the producers are grasses, and in the aquatic food chain, the producers are tiny plants called phytoplankton. The producers in each food chain are consumed by herbivores. The herbivores, in turn, are consumed by carnivores, which are themselves the prey of other carnivores. The top organism in each food chain is a predator — called an apex predator — that is not preyed upon by any other species.

Many food chains, including those pictured above, do not include decomposers. However, decomposers are a significant component of energy flow in every ecosystem. Decomposers break down any remaining organic matter (whether from producers or consumers), using some of the energy it contains and releasing excess nutrients back into the environment.
Food Webs

A food web is an ecological model that represents multiple pathways through which energy flows in an ecosystem. It generally includes many intersecting food chains. Although food webs, like food chains, are usually simplifications of reality, they do demonstrate that most organisms eat, and are eaten by, more than one species. Two examples of food webs, one terrestrial and one aquatic, are shown in the figure below. Consider the grasshopper in the terrestrial food web as an example. It is an herbivore that consumes only plants, but the grasshopper is consumed by multiple other consumers, including spiders, mice, birds, and frogs.

![Terrestrial and aquatic food webs](https://bio.libretexts.org/Bookshelves/Human_Biology/Book%3A_Human_Biology_(Wakim_and_Grewal)/24%3A_Ecology/24.02%3A_Foodwebs)

Figure 7: A terrestrial food web (top) and an aquatic food web (bottom) represent multiple feeding relationships in ecosystems. (CC BY-NC 3.0; By LadyofHats via Wikimedia.org).

Trophic Levels

Table: Trophic Levels in Food Chains and Food Webs

<table>
<thead>
<tr>
<th>Trophic Level</th>
<th>How It Obtains Energy</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(^{st}) trophic level: producers</td>
<td>photosynthesis or chemosynthesis</td>
<td>grass</td>
</tr>
<tr>
<td>2(^{nd}) trophic level: primary consumers</td>
<td>consumes producers</td>
<td>rabbit</td>
</tr>
<tr>
<td>3(^{rd}) trophic level: secondary consumers</td>
<td>consumes primary consumers</td>
<td>snake</td>
</tr>
<tr>
<td>4(^{th}) trophic level: tertiary consumers</td>
<td>consumes secondary consumers</td>
<td>hawk</td>
</tr>
</tbody>
</table>

The different feeding positions in a food chain or food web are called trophic levels. The main trophic levels are defined in the table below. All food chains and food webs have at least two or three trophic levels, one of which must be
producers (1\textsuperscript{st} trophic level). Generally, there are a maximum of four trophic levels, and only rarely are there five or more trophic levels. Most consumers actually feed at more than one trophic level. Humans, for example, are primary consumers when they eat plants such as vegetables. They are secondary consumers when they eat meat from herbivores such as cattle. They are tertiary consumers when they eat secondary consumers such as salmon, which eat smaller fish.

**Trophic Levels and Energy**

Energy is passed up a food chain or food web from lower to higher trophic levels. However, as shown in the energy pyramid in Figure \(\PageIndex{8}\), only about 10 percent of the energy at one trophic level is actually passed up to the next higher trophic level. The other 90 percent of energy at each trophic level is used by organisms at that level for metabolism, growth, and repair. Metabolism generates heat (thermal energy), which is energy that is lost to the environment. Some energy is also lost as incompletely digested food that is excreted. The decline in energy from one trophic level to the next explains why there are rarely more than four trophic levels in a food chain or food web. There is generally inadequate energy remaining above four trophic levels to support organisms at additional trophic levels.

**Trophic Levels and Biomass**

With less energy at higher trophic levels, it is generally the case that fewer organisms can be supported at higher levels. Although individual organisms tend to be larger in size at higher trophic levels, their smaller numbers result in less biomass at higher levels. Biomass is the amount of organic matter present in an individual organism or in all the organisms at a given trophic level. The decrease in numbers and biomass of organisms from lower to higher trophic levels is represented by the ecological pyramid below.

![Ecological Pyramid](https://bio.libretexts.org/Bookshelves/Human_Biology/Book%3A_Human_Biology_(Wakim_and_Grewal)/24%3A_Ecology/24.6%3A_Energy%20and%20Biomass/4.6.8%3A_Ecological_Pyramid#/media/File:Ecological_Pyramid.png) Figure \(\PageIndex{8}\): This ecological pyramid model shows the decrease in numbers and biomass of organisms from lower to higher trophic levels. (CC BY-NC 3.0; Mariana Ruiz Villarreal via CK12.org).
Bioaccumulation of Pollutants

One way nonbiodegradable pollutants can accumulate in the environment is through bioaccumulation, also called biomagnification. Nonbiodegradable pollutants that are consumed by organisms pass up food chains from one trophic level to the next. At each higher trophic level, they become much more concentrated. For example, the heavy metal mercury pollutes aquatic ecosystems and becomes increasingly concentrated at higher trophic levels in food webs, like the one below for Lake Huron. Bioaccumulation of mercury and other nonbiodegradable pollutants makes it more dangerous for people to eat higher-level consumers such as trout than to eat lower-level consumers such as perch.

Summary

- All organisms need energy. There are two basic types of organisms in terms of how they obtain energy: autotrophs and heterotrophs.
- Autotrophs (producers) use energy directly from the sun or from chemicals to produce organic molecules. Photoautotrophs such as plants use energy from sunlight to make organic compounds by photosynthesis. Chemoautotrophs such as certain bacteria use energy from chemicals to make organic compounds by chemosynthesis.
- Heterotrophs (consumers) obtain energy by consuming other organisms. Heterotrophs include all animals and fungi as well as many protists and bacteria. They can be classified on the basis of what they consume as carnivores, which eat animals; herbivores, which eat plants; omnivores, which eat both animals and plants; and decomposers, which consume organic wastes and dead organisms.
- The flow of energy in an ecosystem can be represented with a food chain or food web. A food chain represents a
single pathway through which energy flows in an ecosystem. A food web represents multiple pathways through which energy flows in an ecosystem.

• Feeding positions in a food chain or food web are called trophic levels. The first trophic level is producers; the second trophic level is consumers that eat producers; third and higher trophic levels are consumers that eat organisms from the trophic level below them. There are rarely more than four trophic levels. Most consumers actually feed at more than one trophic level.
• Only about 10 percent of the energy at one trophic level actually passes on to the next higher trophic level. The rest of the energy is used up at the lower trophic level or lost to the environment as heat or incompletely digested food. Generally, there are fewer organisms and less biomass at higher trophic levels.
• Nonbiodegradable pollutants do not break down in the environment, so they accumulate over time and become more damaging. They may pass from lower to higher trophic levels in food chains and become increasingly concentrated.

Review

1. What are autotrophs? Name three types of organisms that are autotrophs.
2. Compare and contrast photoautotrophs and chemoautotrophs.
3. Define heterotroph.
4. What types of organisms are heterotrophs?
5. How are heterotrophs classified on the basis of what they consume?
6. What are food chains and food webs?
7. What are trophic levels? Identify the different trophic levels in a food chain or food web.
8. Why are there rarely more than four trophic levels in an ecosystem?
9. How do the numbers and biomass of organisms usually change from lower to higher trophic levels?
10. Explain the phenomenon of bioaccumulation.
11. Herbivores are at the ______ trophic level.
   A. \(1^{st}\)
   B. \(2^{nd}\)
   C. \(3^{rd}\)
   D. \(4^{th}\)
12. True or False. In some food chains, chemoautotrophs are the type of organism at the 1\textsuperscript{st} trophic level.
13. True or False. Apex predators are at the trophic level that contains the most energy.
14. Which of the following is not a heterotroph?
   A. An apple tree
   B. A mushroom
15. Which of the following terms apply to humans?

autotroph; heterotroph; carnivore; omnivore; herbivore; producer; primary consumer; tertiary consumer

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https://bio.libretexts.org/link?17818#Explore_More

Watch this video to learn more about food webs and energy pyramids.
https://youtu.be/0oCtfA1f14c

Watch this video to learn more about pollution
https://youtu.be/kdDSRRCKMiI?list=PL8dPuualjXtNdTKZkV_GiYXpV9w4WxbX
Media, iframe, embed and object tags are not supported inside of a PDF.