TROPHIC LEVELS

Energy and Life

All organisms need energy in order to survive. How an organism acquires its energy defines its role in the ecosystem. But first, what is energy?

Energy is the ability to do work. Living organisms need energy to perform the basic functions of life, such as growth, reproduction, gas exchange, elimination of waste, getting water and nutrients, and responding to the environment. These processes take place in each and every individual cell, whether the cell is a free-living organism (like an amoeba) or one of millions within a multicellular organism. All cells require energy because all cells are constantly working.

Organisms use energy, but they don't make it. Energy must be obtained outside of the organism. Energy is usually obtained from the environment or from another organism that got it from the environment. There are millions of different organisms on Earth, but each obtains energy in one of the following ways, regardless of its size or complexity.

Producers

The Sun is the source of energy for just about all the organisms in every ecosystem on Earth. Some organisms, notably plants, algae, and phytoplankton, capture energy from the Sun using **photosynthesis** (*photo* = light; *synthesis* = putting things together).

Photosynthesis is the chemical process that turns carbon dioxide and water into carbohydrates in the presence of sunlight and chlorophyll (a green pigment found in the cells of plants and other photosynthetic organisms). Oxygen gas is a by-product during this process. Because photosynthetic organisms produce carbohydrate molecules, which have energy in the chemical bonds that hold them together, they are called **producers.** Producers create **biomass** (*bio* = living; *mass* = matter). Biomass is the total organic matter in an ecosystem.

Producers convert light energy into chemical energy. The chemical energy is in the carbohydrate molecules that photosynthesis produces. Carbohydrate is one form of food. Cells use the energy in food to do the various kinds of work they need to do. Because they make their own food, producers are also referred to as **autotrophs,** or self-feeders (*auto* = self; *troph* = food).

Producers on land include plants such as grasses, shrubs, and trees. Aquatic and marine producers include microscopic phytoplankton, water plants, sea grasses, and seaweeds such as giant kelp.

Consumers

Producers transform the Sun's energy into food energy. On land the main producers are plants. They use the food energy to stay alive. Not only plants, however, use the food energy they make. Other organisms eat plants to get the energy they need for life. Organisms that eat other organisms are called **consumers.**

Consumers cannot make their own food, so they must obtain energy by eating other organisms. Organisms that eat other organisms are also referred to as **heterotrophs** (*hetero* = different).

Animals that eat only plants, such as mice, elephants, deer, and caterpillars, are called **herbivores.** They are also known as **primary consumers,** because they are the first level of consumer.

When primary consumers are eaten, they provide food (energy) for other organisms, called **secondary consumers**—organisms that eat the consumers that eat the producers. Secondary consumers are **carnivores,** or meat eaters. They live by eating herbivores. Secondary consumers include wolves, spiders, snakes, and hawks.

Tertiary consumers, animals that feed on the secondary consumers, may be part of the ecosystem. Examples of tertiary (or third-level) consumers include sharks, pelicans, polar bears, barracudas, and orcas (also known as killer whales, the world's largest porpoise).

Some animals, such as brown bears, crows, chimpanzees, and most humans, have a diet of both producers and consumers and are called **omnivores.**

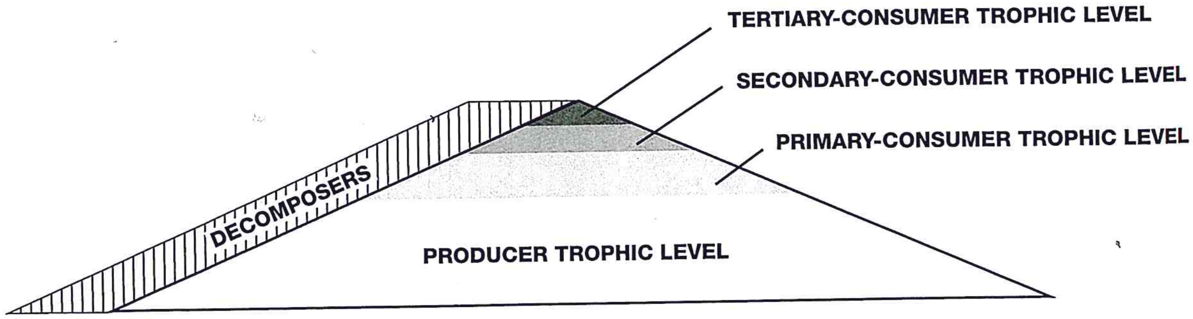
Decomposers

Many producers and consumers die without being eaten by other organisms. Their biomass falls to the ground or bottom of the ocean or lake and is available for other organisms to eat. Organisms such as bacteria, mushrooms, and other fungi are called **decomposers,** because they eat the remains of dead organisms.

When something rots or decays, it is actually being consumed by decomposers. This process of decay transfers every last bit of energy from the dead organism to the decomposers. When the decomposers are through, all that remains is a few simple chemicals, which return to the soil or water. These simple chemicals are minerals, which can be used once again by the producers to begin the cycle. Without decomposers, the ecosystem's recycling crew, Earth would be buried under mountains of wastes and dead organisms!

Bacteria and fungi are the most important decomposer organisms, and their action in the ecosystem clearly satisfies the description of decomposer discussed earlier. But what about organisms like worms, maggots, termites, and even vultures and coyotes, which consume dead organic matter for the energy they need? Are they decomposers or are they herbivores and carnivores? Ecologists are still defining the roles played by the less glamorous, but critically important, organisms that clean up the dead and discarded bits of life. A thriving community of organisms works on the film of dead organic matter that covers much of the surface of Earth at the interface between land and air or land and water. This organic matter, known as **detritus,** is the home of the **detritivores,** organisms that eat dead material. Not all detritivores reduce the matter to simple chemicals. Worms and beetle larvae, for instance, miss a significant amount of matter, and produce feces, which have energy that can be used by more thorough decomposers.

In this course we cast the bacteria and fungi in the role of decomposer, because they are the organisms that extract the last iota of energy from the matter they exploit. Macroscopic "decomposers," such as earthworms and other scavengers, are considered detritivores or consumers.



Organizing the Ecosystem Based on Feeding Relationships

Organisms in an ecosystem can be grouped by how they get food. The groups are called **trophic levels.** Trophic levels are feeding levels. The trophic level at the base of the ecosystem is the producers. The producer trophic level always has the largest amount of biomass. The next largest amount of biomass is in the trophic level made up of primary consumers. The primary consumers are followed by the secondary consumers, and so on.

When the groups are placed in order from producers to primary consumer to secondary consumers, and so on, the result is a layered representation of the ecosystem. It is often represented as a pyramid, because each level has less biomass than the one below it.

It's difficult to place the decomposers in the pyramid model of trophic levels because they affect every trophic level. They are often placed along the side to suggest that they interact with all the other trophic levels.

If you were organizing the organisms in an ecosystem into trophic levels, what would you do with the raccoons and crayfish? They both eat plant material, so they go in the primary-consumer trophic level. But they both eat insects and other animals, too. That would place them in the secondary-consumer or, possibly, the third-level-consumer trophic level. Where do you place them?

Animals that are generalists, that is, those that feed at several trophic levels, should probably be represented in each trophic level where they play a role. Thus, the crayfish might appear in three levels because it eats plants, insects, and fish.

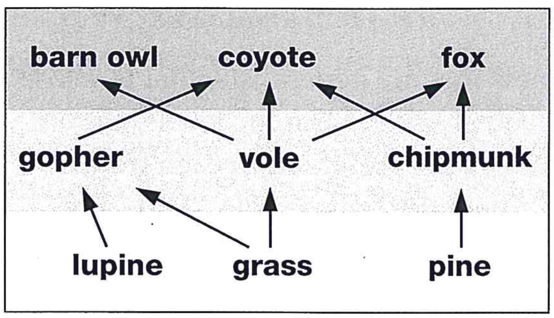
Food Webs

In a typical ecosystem, the producers, consumers, and decomposers transfer food energy from organism to organism to form what is known as a **food web.** A food web is an informative way to represent energy flow through an ecosystem because it shows all the feeding relationships. For instance, grass, lupines, and pine trees are producers. Voles, pocket gophers, and chipmunks are primary consumers. Foxes, coyotes, and barn owls are secondary consumers in an ecosystem.

barn owl	coyote	fox
gopher	vole	chipmunk
lupine	grass	pine

The same organisms can be organized into a food web. A food web uses arrows to connect organisms that eat one another. The arrow points from an organism to the organism that eats it. Another way to think of it is that the arrows point in the direction that the energy in the food goes. For instance, when a spider eats a fly, the food energy in the fly goes into the spider. The arrow points from the fly to the spider.

This is how our little community of organisms can be organized into a food web.



If the organisms are grouped by trophic level before arrows are drawn, a picture of community interactions is easier to see. Another important fact can be seen: some organisms must die to maintain the lives of others.

Energy Transfer

What becomes of the food made or eaten by an organism? Much of the chemical energy available in the food made by a producer or eaten by a consumer is used to maintain life functions. A portion of the energy is stored in the body of organisms in the form of biomass, but most is used to do work and then passes to the environment in the form of heat. So the energy needed to run, think, digest, pump blood, and perform all other life activities passes through the organism and into the environment.

The energy that passes through the ecosystem (from the Sun to the environment) is often referred to as "lost" because it is not stored as biomass to be used as food at the next trophic level. Only a small percentage (an average of about 10%) of the food consumed at a trophic level is converted to biomass. As a result, consumers must eat a lot just to maintain their body mass and functions.

What does the 10% rule tell us about the distribution of organisms in the various trophic levels in a typical ecosystem? Will there be more producers? More primary consumers? More secondary consumers? The 10% rule tells us that the biomass of producers will be much larger than the biomass of primary consumers. Using the 10% rule again, the biomass of primary consumers will be much larger than the biomass of secondary consumers.

Food Pyramids

At each trophic level, the amount of energy transferred to new biomass through growth and reproduction is only about 10% of what the organism eats. In other words, there are usually fewer predators than prey. In the same way, because so much energy is lost as primary consumers eat producers, there are generally fewer herbivores than plants. This is why trophic-level diagrams are often pyramids. Each layer is smaller as you go up the trophic levels, so the ecosystem diagram tapers to a point on top.

It is extremely rare for an ecosystem to have fourth-level consumers that eat third-level consumers because the amount of energy lost in each transfer is so great. Most examples of fourth-level (and higher) consumers live in freshwater aquatic or marine ecosystems. An orca is an example of a very high-level consumer. An orca might eat a sea lion, which eats a salmon, which eats an anchovy, which eats zooplankton, which eats a single-celled alga. The orca is a fifth-level consumer. And when the great white shark eats the orca...you get the idea.

Summary

Living organisms are complex. Their bodies are made of atoms. That is the biomass of life. The functions of living organisms are driven by energy. The energy for life comes from the Sun, captured in energy-rich molecules. The energy-rich molecules are called food.

Every organism needs a constant supply of atoms and energy. Autotrophs (producers) get atoms and energy from raw materials in the environment. Heterotrophs (consumers) get atoms and energy by eating other organisms. Atoms and energy move up through the trophic levels in an ecosystem by feeding relationships.

Dead organic matter still has valuable atoms and energy. Decomposers get the last bit of energy out of organic matter and reduce the atoms to simple chemicals. The energy that entered the ecosystem as sunlight leaves the ecosystem as heat. The atoms that entered the ecosystem as food made by producers return to the environment to be used by living organisms again.

Energy passes through the ecosystem only once. Matter recycles again and again and again. The simple chemicals from which life is constructed—water, carbon dioxide, minerals—can enter and reenter the life process time and time again. Matter recycles.

Energy, on the other hand, comes from the Sun, passes from organism to organism for various periods of time, and then is gone. Energy passes through once and is lost to the life process. Energy transfers but does not recycle. The fate of virtually all energy that passes through the trophic system is to be radiated into the environment as heat. Once released to the environment, it is gone.