

HOLT ENVIRONMENTAL SCIENCE  
CHAPTER 05  
HOW ECOSYSTEMS WORK

I. Energy Flow in Ecosystems

Objectives:

- List two examples of ecological succession.
- Explain how a pioneer species contributes to ecological succession.
- Explain what happens during old-field succession.
- Describe how lichens contribute to primary succession.

A. Life Depends on the Sun

1. Energy from the sun enters an ecosystem when plants use sunlight to make sugar molecules.
  - a. This happens through a process called photosynthesis.
  - b. Photosynthesis is the process by which plants, algae, and some bacteria use sunlight, carbon dioxide, and water to produce carbohydrates and oxygen.
2. Because plants make their own food, they are called *producers*.
  - a. A producer is an organism that can make organic molecules from inorganic molecules.
  - b. Producers are also called autotrophs, or self-feeders.
  - c. Most producers get their energy directly from the sun by absorbing it through their leaves.
3. Organisms that get their energy by eating other organisms are called *consumers*.
  - a. A consumer is an organism that eats other organisms or organic matter instead of producing its own nutrients or obtaining nutrients from inorganic sources.
  - b. Consumers are also called heterotrophs, or other-feeders.
  - c. Consumers get their energy indirectly by eating producers or other consumers.
4. An Exception to the Rule
  - a. Deep-ocean communities of worms, clams, crabs, mussels, and barnacles, exist in total darkness on the ocean floor, where photosynthesis cannot occur.
  - b. The producers in this environment are bacteria that use hydrogen sulfide present in the water.
  - c. Other underwater organisms eat the bacteria or the organisms that eat the bacteria.

B. What Eats What?

1. Organisms can be classified by what they eat.
2. Types of Consumers:
  - a. Herbivores
  - b. Carnivores
  - c. Omnivores
  - d. Decomposers
3. Burning the Fuel
  - a. An organism obtains energy from the food it eats.
  - b. This food must be broken down within its body.

C. Cellular Respiration is the process by which cells produce energy from carbohydrates; atmospheric oxygen combines with glucose to form water and carbon dioxide.

1. Cellular respiration occurs inside the cells of most consumers.
  - a. During cellular respiration, cells absorb oxygen and use it to release energy from food.
  - b. Through cellular respiration, cells use glucose (sugar) and oxygen to produce carbon dioxide, water, and energy.
2. Part of the energy obtained through cellular respiration is used to carry out daily activities.
3. Excess energy is stored as fat or sugar.

#### D. Energy Transfer

1. Each time an organism eats another organism, an energy transfer occurs.
2. This transfer of energy can be traced by studying food chains, food webs, and trophic levels.
3. A food chain is a sequence in which energy is transferred from one organism to the next as each organism eats another organism.
4. Ecosystems, however, almost always contain more than one food chain.
5. A food web shows many feeding relationships that are possible in an ecosystem.
6. Each step in the transfer of energy through a food chain or food web is known as a trophic level.
7. A trophic level is one of the steps in a food chain or food pyramid; examples include producers and primary, secondary, and tertiary consumers.
8. Each time energy is transferred, some of the energy is lost as heat.
9. Therefore, less energy is available to organisms at higher trophic levels.
10. One way to visualize this is with an energy pyramid.
11. Each layer of the pyramid represents one trophic level.
12. Producers form the base of the energy pyramid, and therefore contain the most energy.
13. The pyramid becomes smaller toward the top, where less energy is available.
14. Energy Loss Affects Ecosystems
  - a. Decreasing amounts of energy at each trophic level affects the organization of an ecosystem.
  - b. Energy loss affects the number of organisms at each level.
  - c. Energy loss limits the number of trophic levels in an ecosystem.

#### E. A Case Study

In the 1950s and 1960s, something strange was happening in the estuaries near Long Island Sound, near New York and Connecticut. Birds of prey, such as ospreys and eagles that fed on fish in the estuaries had high concentrations of the pesticide DDT in their bodies. But when the water in the estuary was tested, it had low concentrations of DDT. What accounted for the high levels of DDT in the birds? Poisons that dissolve in fat, such as DDT, can become more concentrated as they move up a food chain in a process called *biological magnification*. When the pesticide enters the water, algae and bacteria take in the poison. When fish eat the algae and bacteria, the poison dissolves into the fat of the fish rather than diffusing back into the water. Each time a bird feeds on a fish, the bird accumulates more DDT in its fatty tissues. In some estuaries on Long Island Sound, DDT concentrations in fatty tissues of organisms were magnified almost 10 million times from the bottom to the top of the food chain. Large concentrations of DDT may kill an organism, weaken its immune system, cause deformities, or impair its ability to reproduce. DDT can also weaken the shells of bird eggs. When eggs break too soon, bird embryos die. Therefore, the effects of these chemicals cause a tremendous drop in the population of carnivorous bird species. The U.S. government recognized DDT as an environmental contaminant and in 1972 banned its sale except in emergencies. The aquatic food chains immediately started to recover, and the populations of ospreys and eagles started to grow. Food chains are still not free of DDT. DDT is still legal in some countries, where it is used in large quantities to eliminate mosquitoes that carry the disease malaria. As a result, migratory birds may be exposed to DDT while wintering in locations outside the United States.

## II. The Cycling of Materials

Objectives:

- List the three stages of the carbon cycle.
- Describe where fossil fuels are located.
- Identify one way that humans are affecting the carbon cycle.
- List the three stages of the nitrogen cycle.
- Describe the role that nitrogen-fixing bacteria play in the nitrogen cycle.
- Explain how the excess use of fertilizer can affect the nitrogen and phosphorus cycles.

## A. The Carbon Cycle

1. The carbon cycle is the movement of carbon from the nonliving environment into living things and back
  - a. Carbon is the essential component of proteins, fats, and carbohydrates, which make up all organisms.
  - b. Carbon exists in air, water, and living organisms.
  - c. Producers convert carbon dioxide in the atmosphere into carbohydrates during photosynthesis.
  - d. Consumers obtain carbon from the carbohydrates in the producers they eat.
  - e. During cellular respiration, some of the carbon is released back into the atmosphere as carbon dioxide.
2. Some carbon is stored in limestone, forming one of the largest “carbon sinks” on Earth.
  - a. Carbon stored in the bodies of organisms as fat, oils, or other molecules, may be released into the soil or air when the organisms dies.
  - b. These molecules may form deposits of coal, oil, or natural gas, which are known as fossil fuels.
  - c. Fossil fuels store carbon left over from bodies of organisms that dies millions of years ago.
3. Humans burn fossil fuels, releasing carbon into the atmosphere.
  - a. The carbon returns to the atmosphere as carbon dioxide.
  - b. Increased levels of carbon dioxide may contribute to global warming.
  - c. Global warming is an increase in the temperature of the Earth.

## B. The Nitrogen Cycle

1. The nitrogen cycle is the process in which nitrogen circulates among the air, soil, water, plants, and animals in an ecosystem.
  - a. All organisms need nitrogen to build proteins, which are used to build new cells.
  - b. Nitrogen makes up 78 percent of the gases in the atmosphere.
2. Nitrogen must be altered, or fixed, before organisms can use it.
  - a. Only a few species of bacteria can fix atmospheric nitrogen into chemical compounds that can be used by other organisms.
  - b. These bacteria are known as “nitrogen-fixing” bacteria.
3. Nitrogen-fixing bacteria are bacteria that convert atmospheric nitrogen into ammonia.
  - a. These bacteria live within the roots of plants called legumes, which include beans, peas, and clover.
  - b. The bacteria use sugar provided by the legumes to produce nitrogen containing compounds such as nitrates.
  - c. Excess nitrogen fixed by the bacteria is released into the soil.
4. Nitrogen stored within the bodies of living things is returned to the nitrogen cycle once those organisms die.
  - a. Decomposers break down decaying plants and animals, as well as plant and animal wastes.
  - b. After decomposers return nitrogen to the soil, bacteria transform a small amount of the nitrogen into nitrogen gas, which then returns to the atmosphere to complete the nitrogen cycle.

## C. The Phosphorus Cycle

1. Phosphorus is an element that is part of many molecules that make up the cells of living organisms.
  - a. Plants get the phosphorus they need from soil and water, while animals get their phosphorus by eating plants or other animals that have eaten plants.
  - b. The phosphorus cycle is the cyclic movement of phosphorus in different chemical forms from the environment to organisms and then back to the environment.
2. Phosphorus may enter soil and water when rocks erode.
  - a. Small amounts of phosphorus dissolve as phosphate, which moves into the soil.
  - b. Plants absorb phosphates in the soil through their roots.
  - c. Some phosphorus washes off the land and ends up in the ocean.

- d. Because many phosphate salts are not soluble in water, they sink to the bottom and accumulate as sediment.
3. Fertilizers, which people use to stimulate and maximize plant growth, contain both nitrogen and phosphorus.
  - a. Excessive amounts of fertilizer can enter terrestrial and aquatic ecosystems through runoff.
  - b. Excess nitrogen and phosphorus can cause rapid growth of algae.
4. Excess algae can deplete an aquatic ecosystem of important nutrients such as oxygen, on which fish and other aquatic organisms depend.
5. When fuel is burned, large amounts of nitric oxide is release into the atmosphere.
  - a. In the air, nitric oxide can combine with oxygen and water vapor to form nitric acid.
  - b. Dissolved in rain or snow, the nitric acid falls as acid precipitation.

### III. How Ecosystems Change

#### Objectives:

- List two examples of ecological succession.
- Explain how a pioneer species contributes to ecological succession.
- Explain what happens during old-field succession.
- Describe how lichens contribute to primary succession.

#### A. Ecological Succession

1. Ecosystems are constantly changing.
2. Ecological succession is a gradual process of change and replacement of the types of species in a community.
3. Each new community that arises often makes it harder for the previous community to survive.

#### B. Primary succession is a type of succession that occurs on a surface where no ecosystem existed before.

1. It begins in an area that previously did not support life.
2. Primary succession can occur on rocks, cliffs, or sand dunes.
3. Primary succession can occur
  - a. on new islands created by volcanic eruptions
  - b. in areas exposed when a glacier retreats
  - c. any other surface that has not previously supported life
4. Primary succession is much slower than secondary succession because it begins where there is no soil.
5. The first pioneer species to colonize bare rock will probably be bacteria and lichens, which can live without soil.
6. The growth of lichens breaks down the rock, which with the action of water, begins to form soil.

#### C. Secondary succession occurs on a surface where an ecosystem has previously existed.

1. It is the process by which one community replaces another community that has been partially or totally destroyed.
2. Secondary succession can occur in ecosystems that have been disturbed or disrupted by humans, animals, or by natural process such as storms, floods, earthquakes, or volcanic eruptions.
3. A pioneer species is a species that colonizes an uninhabited area and that starts an ecological cycle in which many other species become established.
4. Over time, a pioneer species will make the new area habitable for other species.

#### D. A climax community is the final, stable community in equilibrium with the environment.

1. Even though a climax community may change in small ways, this type of community may remain the same through time if it is not disturbed.
2. Natural fires caused by lightning are a necessary part of secondary succession in some communities.

3. Minor forest fires remove accumulations of brush and deadwood that would otherwise contribute to major fires that burn out of control.
  4. Some animal species also depend on occasional fires because they feed on the vegetation that sprouts after a fire has cleared the land.
- E. Old-field succession is a type of secondary succession that occurs when farmland is abandoned.
1. When a farmer stops cultivating a field, grasses and weeds quickly grow and cover the abandoned land.
  2. Over time, taller plants, such as perennial grasses, shrubs, and trees take over the area.