Organization in the Biosphere

37

It is morning in the tropical valley. Birds call, insects buzz, and raindrops rattle onto huge, shiny leaves and drip to the ground. The crab spider sits on a purple orchid, waiting. Soon, the orchid's sticky stamens attract a fly. The fly begins to feed on the nectar, but its meal is brief. In a flash, the spider pounces. The fly becomes food for the spider. How are the fly, the spider, the orchid, and the rain connected? In this chapter, you will learn how living and nonliving things interact to permit life on our planet.

Guide for Reading

Key words: ecology; population; ecosystem; food chain; food web; nitrogen, carbon, and oxygen cycles; succession; climax community

Questions to think about:

What nonliving factors affect living things?

How are materials cycled between living things and the environment?

37-1 Abiotic Factors in the Environment

Section Objectives:

- *List* the abiotic factors in the environment.
- *Describe* how light, temperature, and precipitation vary with position on the earth's surface.
- *Describe* the process of soil formation.

All types of living organisms have adaptations that allow them to survive in a particular environment. They may show adaptations for food getting and reproduction, as well as for avoiding predators. Living organisms are affected by physical factors in their environment, such as the availability of water, changes in temperature, the amount of light present in the environment, and the composition of the soil. The physical environment is also affected by the organisms that live in it. For example, some organisms help to break rock into soil. The growth of plants contributes to the filling in of ponds. Finally, organisms are affected by other organisms living in the same area. The branch of biology that deals with the interactions among organisms and between organisms and their environment is called **ecology** (ih KAHL uh jee).

In studying the interaction between organisms and their environment, both the living and nonliving factors must be considered. The **biotic** (by AHT ik), or living, **factors** include all the living organisms in the environment and their effects, both direct and

▲ **Figure 37–1**
Environmental Adaptatations. In order to survive in a desert environment, these plants have had to adapt to conditions of little water and large changes in temperature.

indirect, on other living things. The **abiotic** (ay by AHT ik), or nonliving, **factors** include water, oxygen, light, temperature, soil, and inorganic and organic nutrients.

Abiotic factors determine what types of organisms can survive in a particular environment. For example, in deserts there is little water available, and the temperature can change daily from very hot to cold. Only plants that are adapted to these conditions, such as sagebrush and cactus, can survive. Other types of plants, such as corn, oak trees, and orchids, grow in other environments with different abiotic conditions to which they are adapted.

Light

The energy for almost all living things on earth comes directly or indirectly from sunlight. The amount of sunlight striking a given area of the earth's surface changes with the latitude of the area. *Latitude* is the distance north or south of the equator. Both the *intensity,* or strength, of sunlight and the *duration,* or length, of daylight also vary with latitude. As shown in Figure 37–2, areas around the equator receive sunlight of the strongest intensity, while areas around the North and South Poles receive light of the weakest intensity. Areas at the equator receive about 12 hours of daylight throughout the year. At the North and South Poles, the sun does not rise above the horizon for the six winter months of each year. During the summers, the sun never sets. In regions between the equator and the poles, day and night lengths vary with the season. These variations in the amount of sunlight are caused by the daily rotation of the earth, the movement of the earth around the sun, and the tilt of the earth's axis.

The intensity and duration of sunlight affect the growth and flowering of plants. Some plants require high light intensity; others require low light intensity. Some require long days for flowering; others require short days. In many animals, migration, hibernation, and reproduction are influenced by day and night lengths.

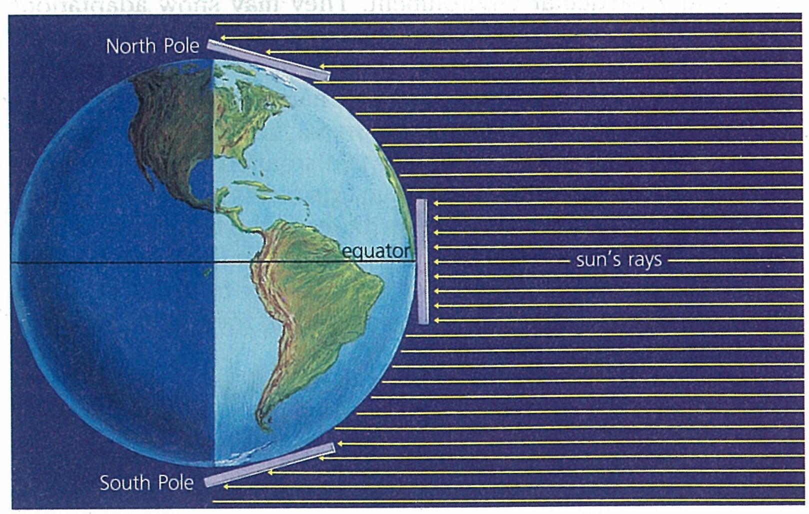


Figure 37–2
Intensity of Sunlight at Different Latitudes. In this diagram, each ray represents the same amount of light. Note that near the equator a larger amount of surface is struck by more rays than is struck near the poles. ▶

Light conditions also vary in aquatic environments. Light is absorbed as it passes through water. Thus, the amount of light present decreases with increasing depth. The layer of water through which light penetrates is called the *photic* (FOH tik) *zone.* About 80 percent of the earth's photosynthesis takes place in this zone. Below the photic zone is the *aphotic* (ay FOH tik) *zone,* where there is no light. Except for a few chemotrophs, organisms in the aphotic zone are heterotrophs that derive their energy from organisms that drift or migrate down from the photic zone.

Temperature

Temperature patterns on the earth's surface vary with latitude and with altitude. *Altitude* is the vertical distance above sea level. The temperature pattern of a region may be affected by the presence of nearby major geographic features, such as a mountain or an ocean. As the altitude rises, the temperature falls. Thus, the tops of mountains may be snow-covered even in warm regions.

The warmest average temperatures on the earth's surface are around the equator. Traveling north or south of the equator, the average temperatures drop. The North and South Poles are the coldest regions on earth.

Water

The release of water from the atmosphere as rain, snow, dew, and fog is called *precipitation.* The annual amount of precipitation varies from one region to another on the earth's surface. Annual precipitation patterns are related to latitude and to altitude. They are also influenced by local features, such as mountains and large bodies of water. Areas around the equator are hot and humid with heavy rainfall throughout the year. Because of the pattern of airflow over the earth's surface, most deserts are found around latitudes 30° north and 30° south of the equator. In these regions, there is a brief rainy season and almost no rain at all during the rest of the year. Still further north and south of the equator are *temperate* regions with hot summers and cold winters. Rainfall is fairly abundant in these regions. The polar regions are cold, and precipitation is in the form of snow.

Soil and Minerals

Soil consists of inorganic and organic materials. The inorganic material is mostly rock particles broken off from larger rocks by the action of water and wind—a process known as *weathering.* Alternate freezing and thawing of water helps to crack the rock and break off pieces. Soluble minerals in the rock dissolve in water, breaking down the rock still further. Lichens and other organisms also help to break down rock. When these organisms die, their remains are mixed with the rock particles, thus adding organic matter to the developing soil. Plants may take root in the soil. When they die, their remains add more organic matter to the soil.

The minerals present in soil depend partly on the type of rock from which the soil was formed and partly on the types of organisms living in the soil. The amount of precipitation determines the extent to which minerals will be retained in, or washed out of, the soil.

As soil development slowly proceeds, three distinct layers form. See Figure 37–3. The uppermost layer, which is called *topsoil,* includes organic matter and various living organisms. Plant "litter," such as fallen leaves and twigs, overlies the topsoil and gradually blends into it. The dark, rich organic matter in the topsoil is called **humus** (HYOO mus). Humus is formed from the decay of dead plants and animals. The living organisms found in the topsoil include plant roots, earthworms, insects, and many other animals and protists. The organisms of decay—bacteria and fungi—are also found in this layer.

Beneath the topsoil is a layer of *subsoil.* The subsoil is made of rock particles mixed with inorganic compounds, including mineral nutrients. Water-soluble materials from the topsoil are carried downward into the subsoil by the downward movement of water. The bottommost layer of the soil is made of bits of rock broken off from the parent bedrock below.

There are many types of soils. They are classified according to their organic content, mineral composition, pH, and size of the rock particles. Sandy soil has the largest particles, silt has particles of intermediate size, and clay is made up of small particles. Water drains too quickly through sand and too slowly through clay for good plant growth. In general, the best soils for plants to grow in consist of a mixture of clay and larger particles. However, different types of plants grow well in different types of soil. Some plants require well-drained, sandy soils, while other plants do best in soils that are clayey. Also, some plants thrive in acid soils, but others need alkaline soils.

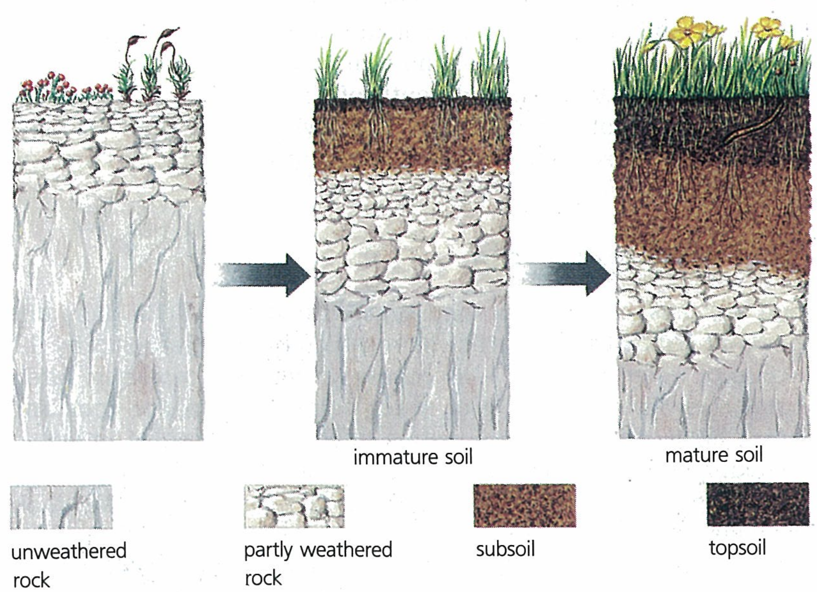


Figure 37–3

Three Stages in the Development of Soil. The forces of weathering and the action of certain small organisms gradually break down bedrock into fine particles. The products and remains of organisms add organic matter to the rock particles, forming soil. ▶

37-1 Section Review

1. What is ecology?
2. List some common abiotic environmental factors.
3. What are some geographic features that influence temperature patterns?
4. Which environmental factors cause the weathering of rock during soil formation?

Critical Thinking

5. First compare and then contrast topsoil with subsoil. (*Comparing and Contrasting*)

37-2 Biotic Relationships in Ecosystems

Section Objectives:

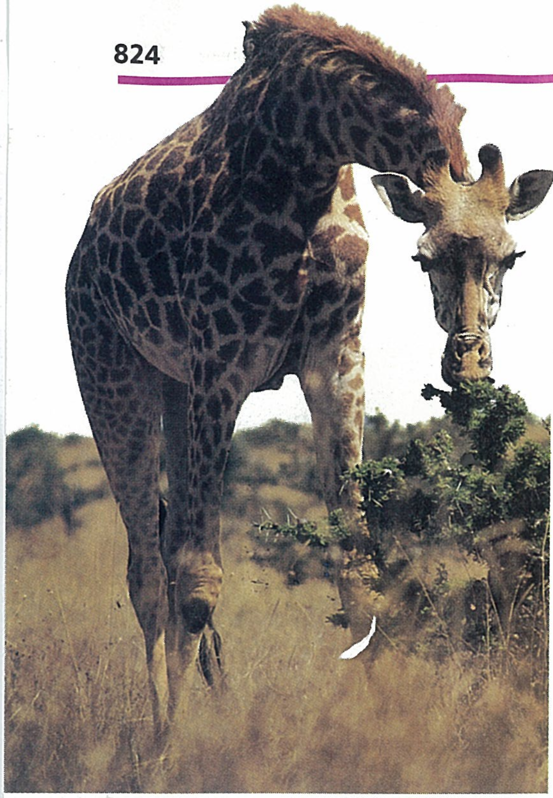
- *Explain* the terms *population, community, ecosystem, biosphere,* and *autotrophic* and *heterotrophic nutrition.*
- *List* the different types of symbiotic relationships and *describe* each of them.
- *Describe* the feeding relationships in an ecosystem in terms of competition, food chains, and food webs.
- *Explain* the flow of energy in an ecosystem using the concepts of pyramids of energy and biomass.

Concept Laboratory: *Gain* an understanding of the interactions that occur within an ecosystem (p. 827).

Populations, Communities, and Ecosystems

In studying organisms in nature, ecologists often look at a particular group of organisms in a particular type of natural setting. The simplest grouping of organisms in nature is a **population.** A population includes all individuals of a particular species within a certain area. All the black oak trees in a forest make up a population. All the bullfrogs in a pond make up a population. Populations can also be considered as parts of larger groups. All the populations of different organisms within a given area make up a **community.** For example, all the frogs, fish, algae, plants, and other living things in and around a pond make up a pond community.

An **ecosystem** includes a community and its physical environment. In an ecosystem, both the biotic and abiotic factors are included. There is an ongoing exchange of materials between the nonliving and living parts of an ecosystem. All the ecosystems of



▲ **Figure 37–4**
Herbivores. Giraffes are just one of many kinds of herbivores that inhabit the African tropical grasslands.

the earth are linked to one another. Organisms move from one ecosystem to another. Water and other inorganic substances pass from one ecosystem to another. Also, organic compounds, with their stored energy, are transferred between ecosystems.

The Biosphere

The portion of the earth in which living things exist is known as the **biosphere.** Compared to the diameter of the earth, the biosphere is a thin zone. It is about 20 kilometers in thickness, extending from the ocean floor to the highest point in the atmosphere where life is found. The biosphere includes portions of the *lithosphere* (the solid part of the earth's surface), the *hydrosphere* (the water on and under the earth's surface as well as the water vapor of the air), and the *atmosphere* (the mass of air surrounding the earth).

Autotrophic and Heterotrophic Nutrition

An ecosystem includes all kinds of organisms—microorganisms, plants, and animals. These organisms interact in many ways, but their nutritional and energy relationships are among the most important.

Autotrophs are organisms that can make their own food using carbon dioxide. Most autotrophs carry on photosynthesis. A few, however, carry on chemosynthesis. Directly or indirectly, autotrophs provide the food for heterotrophs—those organisms that cannot synthesize their own food.

Heterotrophs are divided into several groups according to what they eat and how they obtain their food. Heterotrophs include herbivores, carnivores, omnivores, and saprobes. **Herbivores** (HER buh vorz) are animals that feed only on plants. Rabbits, cattle, horses, sheep, and deer are herbivores. **Carnivores** (KAR nuh vorz) are animals that feed on other animals. Some carnivores are predators, and some are scavengers. **Predators** (PRED uh terz), such as lions, hawks, and wolves, attack and kill their prey and feed on their bodies. **Scavengers** (SKAV en jerz) feed on dead animals they find. Vultures and hyenas are scavengers. **Omnivores** (AHM nih vorz) are animals that feed on both plants and animals. Humans and bears are omnivores. **Saprobes** are organisms that obtain nutrients by breaking down the remains of dead plants and animals. Many bacteria and fungi function as saprobes.

Symbiotic Relationships

Symbiotic relationships are relationships in which two different organisms live in close association with each other to the benefit of at least one of them. There are three types of symbiotic relationships: mutualism, commensalism, and parasitism.

In **mutualism** (MYOOCH uh wuh liz um), both organisms benefit from their association. For example, termites have cellulose-digesting microorganisms living in their digestive tracts. Without they are provided with nutrients and an environment in which to grow and reproduce. However, the host is harmed by the presence of the tapeworms. The loss of nutrients and tissue damage caused by the worm can cause serious illness. There are also parasitic plants that grow on other plants. Two examples of plant parasites are mistletoe and Indian pipe.

Symbiotic relationships, particularly those involving mutualism or commensalism, are not always permanent. Also, it is not always possible to say whether an organism is helped or harmed by such a relationship. For example, in many environments the algal cells of a lichen can survive well without the fungal cells. The fungal cells, on the other hand, may not be able to survive alone.

Competition in Ecosystems

Each type of organism within an ecosystem has a particular part of the environment in which it lives. This is its **habitat.** For example, the habitat of a slime mold is the damp floor of a forest. Because of the complex interactions that occur within an ecosystem, each species also plays a particular role in an ecosystem. The role of a species in an ecosystem is its **niche.** An organism's habitat is part of its niche, but only part. Also included are how, when, and where it obtains nutrients, its reproductive behavior, and its direct and indirect effects on the environment and on other species within the ecosystem.

In a balanced ecosystem, each species occupies its own niche. It occupies a particular territory (its habitat) and obtains nutrients in a particular way. Competition arises when the niches of two species overlap. The greater the overlap—the more requirements the two species have in common—the more intense the competition. Competition between two different species is called **interspecific competition.** As the resources being competed for become

Figure 37–7
Habitat of a Slime Mold. This white slime mold has grown around a small twig on the forest floor. Slime molds are found in cool, shady, moist places in the woods. ▶

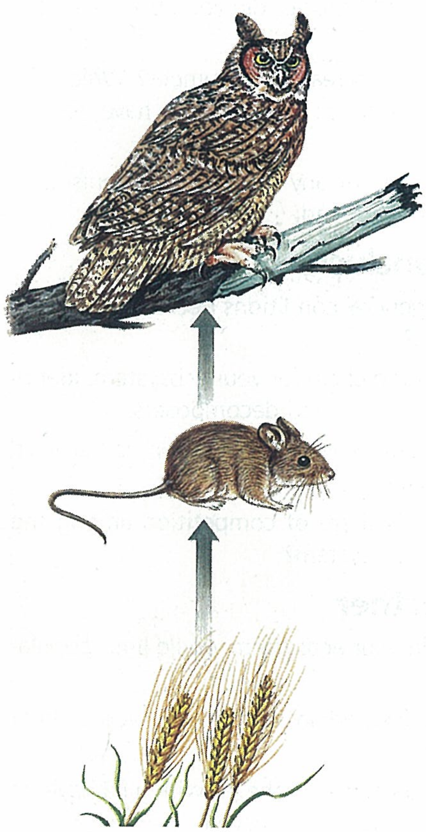
more scarce, the competition becomes more intense. Eventually, one of the species is eliminated from the ecosystem, leaving the more successful species to occupy the niche.

Competition also occurs between members of the same species. This is called **intraspecific competition.** The intensity of the competition between members of the same species is affected by population density and the availability of resources. If conditions become harsh, those individuals with the most helpful adaptations will survive. The less-well-adapted individuals will not.

Producers, Consumers, and Decomposers

In all but a few small ecosystems, the autotrophs are plants and other photosynthetic organisms. They trap energy from sunlight and use it for the synthesis of sugars and starch. These substances can be changed to other organic compounds that are needed by the plant, or they can be broken down for energy. Heterotrophs can only use the chemical energy stored in organic compounds for their life processes. These organic nutrients must be obtained from the bodies of other organisms—either plants or animals. Because autotrophs are the only organisms in an ecosystem that can produce organic compounds (food) from inorganic compounds, they are called **producers.** Since heterotrophs must obtain nutrients from other organisms, they are called **consumers.**

Saprobes play an important role in an ecosystem. They function as *organisms of decay,* or **decomposers.** They break down the remains of dead plants and animals, releasing substances that can be reused by other members of the ecosystem. In this way, many important substances are recycled in an ecosystem.



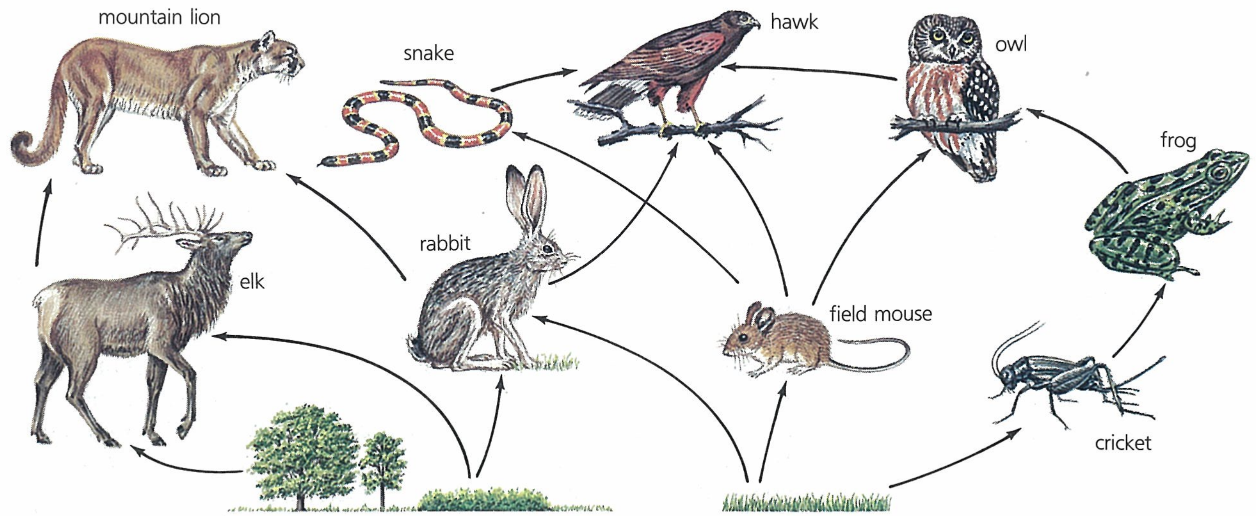
▲ **Figure 37–8**

A Simple Food Chain. The grass is a producer, the field mouse is a first-order consumer, and the owl is a second-order consumer. The arrows show the flow of energy in the food chain.

Food Chains and Food Webs

Within an ecosystem, there is a pathway of energy flow that always begins with the producers. Energy stored in organic nutrients synthesized by the producers is transferred to consumers when the plants are eaten. Herbivores are the primary consumers, or *first-order consumers.* The carnivores that feed on the plant-eating animals are secondary consumers, or *second-order consumers.* For example, mice feed on plants and are first-level consumers. The snake that eats the mice is a second-level consumer, while the hawk that eats the snake is a third-level consumer. Since many consumers have a varied diet, they may be second-, third-, or higher-level consumers, depending on their prey. Each of these feeding relationships forms a **food chain,** a series of organisms through which food energy is passed. A simple food chain is shown in Figure 37–8.

Feeding relationships in an ecosystem are never just simple food chains. There are many types of organisms at each feeding level, and there are always many food chains in an ecosystem. These food chains are connected at different points, forming a **food web.** One of these is shown in Figure 37–9.



▲ **Figure 37–9**
A Simple Food Web. Usually, each organism is part of several different food chains.

At every level in an ecosystem, there are organisms that act as decomposers. The decomposers make use of the wastes and remains of all organisms in the system. They use the energy they find in these materials for their own metabolism. At the same time, they break down organic compounds into inorganic compounds and make substances available for reuse. The decomposers are the final consumers in every food chain and food web.

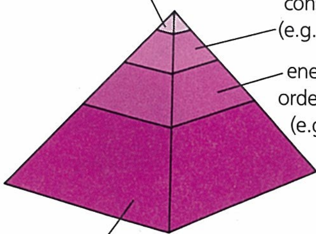
Critical Thinking in Biology

Predicting

When you say, "The Birds will win the pennant this year," you are making a prediction. Predicting is determining the probable outcome of an event before it occurs.

Consider the ecosystem inhabited by the organisms in the food web shown in Figure 37–9. Suppose a disease caused most of the rabbits in the ecosystem to die.

1. Predict what effects this would have on (a) the hawk population; (b) the amount of grass available, and (c) the field mouse population. Explain the basis for your prediction.
2. Which, if any, of these effects is certain to occur? Explain.
3. Why do predictions about changes in ecosystems contain a high degree of uncertainty?
4. Given the uncertainty of ecological predictions, what advice would you give to scientists working on acid rain, global warming, and other environmental problems?
5. Think About It Describe your thought process as you answered question 1.



▲ **Figure 37–10**
The Pyramid of Energy in an Ecosystem. At each level in an ecosystem, the energy available is only about 10 percent of the energy at the level below it.

Pyramids of Energy and Biomass

The amount of energy available in a food web decreases with each higher feeding level. This happens because only a small fraction of the energy taken in as food becomes stored as new tissue. Much of the food eaten is not digested and absorbed. Furthermore, a large part of the energy in the food is used for respiration and maintenance. This energy is lost as heat. As a result, only about 10 percent of the energy taken in at any feeding level is passed to the next feeding level.

The amount of energy available in an ecosystem is commonly shown in the form of a **pyramid of energy.** The greatest amount of energy is present in the producers—the base of the pyramid—and the least energy is present at the top of the pyramid—the highest-level consumers. Because the amount of available energy decreases so steeply, there are usually no more than four or five feeding levels in an ecosystem.

Figure 37–10 is an example of a pyramid of energy. In a field, green plants are the producers, trapping the sun's energy for photosynthesis. For every 1000 calories of energy absorbed by the plants, only 100 are stored. Thus, 100 calories are available to a first-order consumer, such as a cricket, that feeds on the plants as they grow. As a second-order consumer, a toad that eats the cricket receives only 10 of the original 100 calories consumed by the cricket. At the top of the energy pyramid, a snake that eats the toad receives only 1 calorie of the 10 calories received by the toad. This amount is only 0.001 percent of the energy originally absorbed by the plants at the base of the pyramid.

Since the total amount of energy available decreases with each higher feeding level, the total mass of living organisms that can be supported at each level decreases, too. This relationship can also be represented by a pyramid. The relationship, known as the **pyramid of biomass,** shows the relative mass of the organisms—the *biomass*—at each feeding level. The greatest amount of biomass is in the lowest level, the producers. The least is found in the highest level of consumers.

37-2 Section Review

1. What is a population?
2. List three types of symbiotic relationships.
3. Which kind of organisms are always found at the base of a food chain?
4. Which level of an energy pyramid contains the most energy?

Critical Thinking

5. Can two species occupy the same habitat? Can they occupy the same niche? Explain. (*Reasoning Conditionally*)

37-3 Cycles of Materials

Section Objectives:

- *Describe* each of the following biogeochemical cycles: the nitrogen cycle, the carbon and oxygen cycles, and the water cycle.
- **Laboratory Investigation:** *Observe* nitrogen-fixing nodules in legumes (p. 840).

In all ecosystems, materials revolve between living things and the environment. Organisms incorporate certain substances from the environment into their bodies. When these organisms die, their bodies are broken down by decomposers, and the substances returned to the environment. If these substances were not returned to the environment, their supply would eventually become exhausted. The cycles of materials between living things and the environment are called *biogeochemical cycles.* Nitrogen, carbon, oxygen, and water are among the substances involved in such cycles.

The Nitrogen Cycle

Nitrogen is an important element in living things. It is a basic component of amino acids, which form proteins, and of nucleotides, which form nucleic acids. Nitrogen gas (N_2) makes up almost 80 percent of the earth's atmosphere. However, most organisms cannot use N_2 directly. They must use nitrogen compounds. Most plants can use nitrogen only in two inorganic forms, ammonia (NH_3) and nitrate (NO_3^-). Usually, nitrate is the major source of nitrogen for plants. From nitrate and ammonia, plants can make proteins and nucleic acids. Animals lack this ability. They can use nitrogen only in an organic form. Thus, animals must ingest plants or other animals to meet their nitrogen needs.

Nitrogen in the wastes and in the remains of organisms must be made available to living plants for reuse. This is accomplished through the activity of decomposers that break down the complex organic compounds in plant and animal remains. During decomposition, most of the nitrogen in organic compounds is released as ammonia. Some of this may be taken up directly by plants, but most is converted by **nitrifying bacteria** to nitrite (NO_2^-) and finally to nitrate. The nitrate then is available for uptake again by plants.

Not all nitrate in the soil and in water remains as nitrate until taken up by plants. **Denitrifying bacteria** get energy for their life processes by converting nitrite and nitrate to nitrogen gas (N_2). This form of nitrogen, which is released into the atmosphere, cannot be used by plants and animals. However, nitrogen gas can be changed to a form available to plants. A few kinds of bacteria, including blue-green bacteria, convert nitrogen gas directly to ammonia through a process called **nitrogen fixation.** Some of these **nitrogen fixers** are free-living. The ammonia they produce is used to synthesize their own nitrogen-containing compounds. Other nitrogen-fixers are symbiotic. They fix nitrogen only when living in close association with a host plant. Figure 37–11 shows the

Figure 37–11
Root Nodules of a Legume. The nodules on this legume root contain nitrogen-fixing bacteria that provide the plant with usable forms of nitrogen. ▼

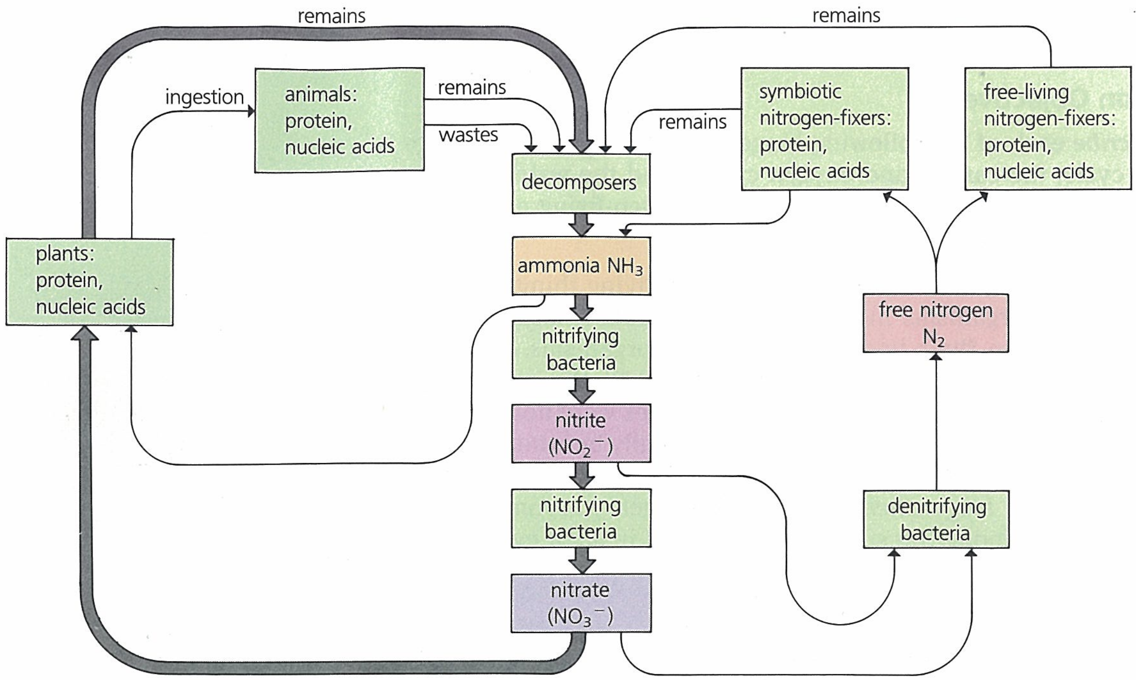


Figure 37–12

The Nitrogen Cycle. The nitrogen cycle is a complex pathway by which nitrogen moves through an ecosystem. Most nitrogen enters living organisms through nitrogen-fixing bacteria that oxidize it to nitrites and nitrates. Nitrogen is returned to the soil through animal waste products and the decay of organisms.

bacteria-containing nodules on the roots of one of the legume plants. In these symbiotic associations, the nitrogen fixers utilize the ammonia themselves. They also supply some ammonia directly to the host plant. When the nitrogen fixers die, their nitrogen is recycled through decomposition.

Figure 37–12 shows the various pathways of the nitrogen cycle. The nitrogen cycle keeps the level of usable nitrogen in the soil fairly constant. The nitrogen cycle also occurs in lakes, streams, and oceans. Most of the nitrogen being cycled remains in compound form. Only a small fraction is cycled through the atmosphere.

The Carbon and Oxygen Cycles

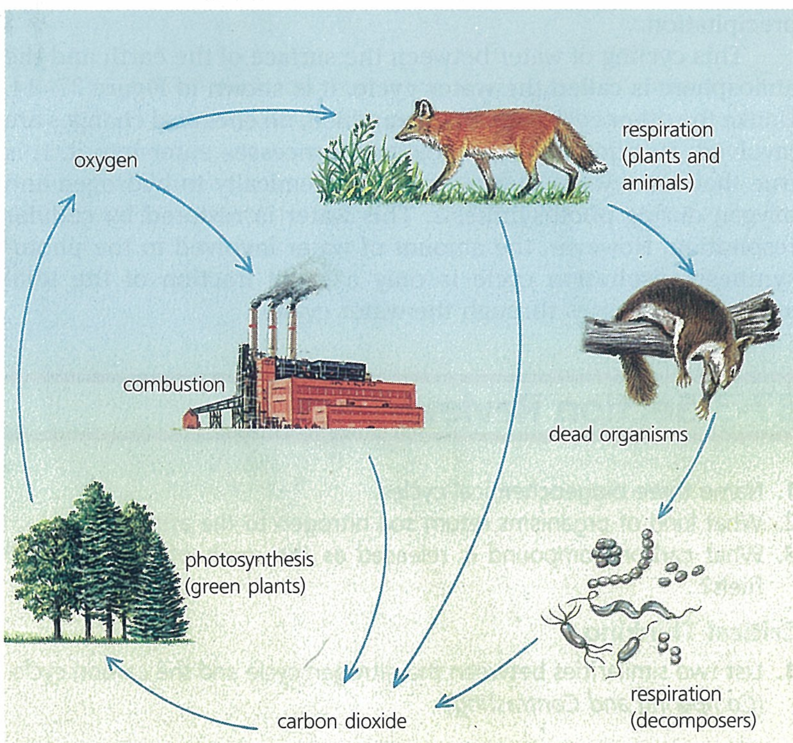
Carbon, in the form of carbon dioxide, makes up about 0.03 percent of the atmosphere. Carbon dioxide is also found dissolved in the waters of the earth. In the course of photosynthesis, carbon dioxide from the atmosphere is incorporated into organic compounds, a process known as *carbon fixation.* Some of these organic compounds are broken down during cellular respiration by photosynthetic organisms. This releases carbon dioxide into the atmosphere. If the plants or other photosynthetic organisms are eaten by animals, the carbon compounds pass through a food web. At each level, some are broken down by cellular respiration, releasing carbon dioxide into the atmosphere. Finally, the remains of dead plants and animals and animal wastes are broken down by decomposers, which also releases carbon dioxide.

In the **carbon cycle,** carbon dioxide is removed from the atmosphere by photosynthesis, and it is returned to the atmosphere by cellular respiration. The carbon cycle is shown in Figure 37–13. These two processes are normally in balance, maintaining a relatively constant level of carbon dioxide in the atmosphere. However, the burning of fossil fuels (oil, coal, and natural gas) also releases carbon dioxide. Because of the increasing use of these fuels, there has been a gradual increase in the carbon dioxide content of the atmosphere since the mid-1800s. The long-term effects of this change are not known. However, some scientists think that it will result in an increase in temperature on the earth's surface. This would occur because the atmospheric carbon dioxide absorbs heat from the earth that would otherwise be radiated away into space. This phenomenon is known as the "greenhouse effect."

Oxygen makes up about 20 percent of the earth's atmosphere. During photosynthesis, water molecules are split into hydrogen and oxygen. The hydrogen is used in the formation of carbohydrates, and the oxygen is released into the atmosphere. Animals, plants, and many protists use oxygen in cellular respiration and release carbon dioxide. Thus, in the **oxygen cycle,** oxygen is released into the atmosphere by the process of photosynthesis and removed from the atmosphere by cellular respiration.

Figure 37–13

The Oxygen and Carbon Cycles. The cycling of carbon and oxygen in an ecosystem results from photosynthesis and respiration. ▼



Science, Technology and Society

Issue: Greenhouse Effect

For years, scientists have been worried about the greenhouse effect. Many human activities, especially the burning of fossil fuels, release carbon dioxide into the air. Carbon dioxide traps the sun's heat, which is reflected back to the earth. This is causing the average temperature of the earth to rise gradually.

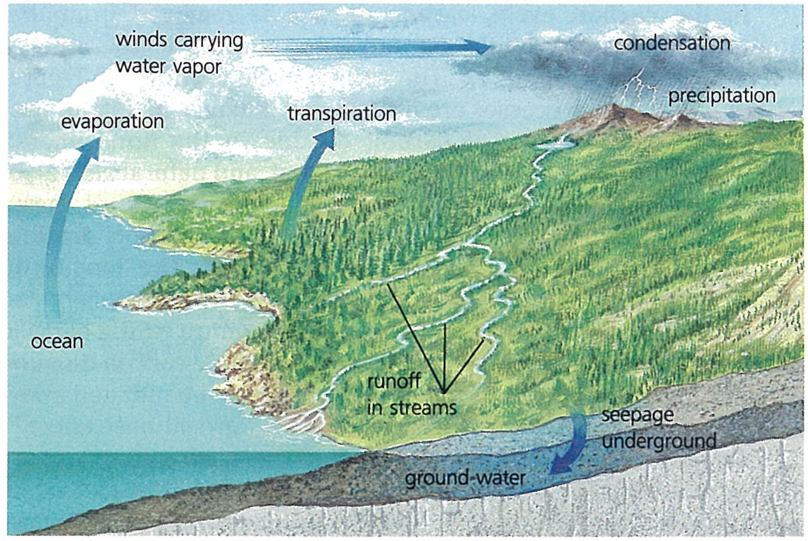
Some scientists fear that global warming may lead to drought and famine. As the earth warms, the melting of icecaps may cause floods in major coastal cities. If we do not prevent the greenhouse effect soon, they claim, it will be too late. Thus, they want to look for solutions and explore alternatives to fossil fuels now.

Other scientists claim that the greenhouse effect may have been blown out of proportion. Scientific data is somewhat contradictory and does not explain all the factors affecting climate. They argue that global warming is a gradual process and no quick decisions should be made. Time and money should be spent on research now and not on taking action.

- ***Should we take immediate action against the greenhouse effect? Why or why not?***

Figure 37–14

The Water Cycle. Water from the earth's surface enters the atmosphere in the form of water vapor through the processes of evaporation and transpiration. It returns to the surface through condensation and precipitation. ▶



The Water Cycle

The cycling of water on the earth is almost entirely a physical process. Wherever water is exposed to the air, it evaporates—escapes into the air in the form of water vapor. Plants contribute to this loss of water to the air by the process of transpiration. However, there is a limit to the amount of water vapor the air can hold. Through various physical processes, excess water vapor condenses to form clouds and falls back to the earth's surface as precipitation.

This cycling of water between the surface of the earth and the atmosphere is called the **water cycle.** It is shown in Figure 37–14. Unlike the other cycles we have examined, no chemical changes are involved. Nor do any truly biological processes enter into it. It is true that some water is broken down chemically to hydrogen and oxygen during photosynthesis. This water is restored by cellular respiration. However, the amount of water involved in the photosynthesis-respiration cycle is only a small fraction of the total amount that passes through the water cycle.

37-3 Section Review

1. Name three biogeochemical cycles.
2. What kind of organisms return soil nitrogen to the atmosphere?
3. What carbon compound is released as the result of burning fossil fuels?

Critical Thinking

4. List two similarities between the nitrogen cycle and the carbon cycle. (*Comparing and Contrasting*)

37-4 Maintenance and Change in Ecosystems

Section Objectives:

- *Describe* the conditions necessary for a stable, self-sustaining ecosystem.
- *Explain* the terms ecological succession, dominant species, climax community, primary succession, and secondary succession.
- *Compare* succession on land, which leads to development of a forest community, with succession in lakes and ponds.

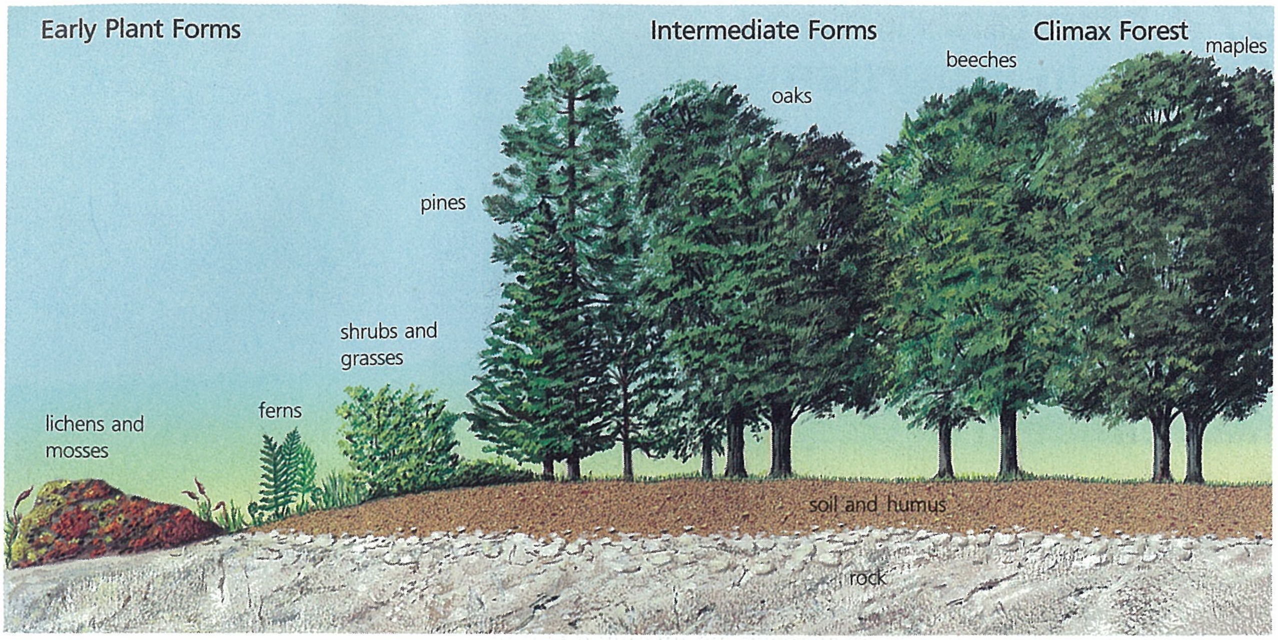
Maintenance in an Ecosystem

For an ecosystem to be stable and self-sustaining, certain conditions must exist. First, there must be a constant source of energy. For almost all ecosystems on earth, the source of energy is light from the sun. Only a few ecosystems are based on chemosynthesis. In these ecosystems, the producers derive energy for the synthesis of organic compounds from chemical reactions involving various inorganic compounds. Second, there must be organisms within the ecosystem that can use incoming energy (light) for the synthesis of organic compounds. This role is filled by green plants and algae, which are the producers of the ecosystem. Third, there must be a cycle of materials between living organisms in the ecosystem and the environment. The producers incorporate inorganic compounds from the environment into organic compounds, which may then pass through a food chain or food web. Eventually, however, the decomposers break down the remains of dead organisms, releasing the inorganic substances back into the environment for reuse.

Ecological Succession

Although ecosystems appear stable, they do undergo change. Change occurs because the living organisms present in the ecosystem alter the environment. Some of the changes tend to make the environment more suitable for new types of organisms and less suitable for the existing organisms. Thus, the original organisms in an ecosystem are slowly replaced by other types. A new community replaces the original community in the ecosystem. Over time, this community is gradually replaced by still another community. The process by which an existing community is slowly replaced by another community is called **ecological succession.** In land environments, ecological succession usually depends upon the types of plants that are present at any given time. Plants determine the type of community that develops because plants are the producers. The types of animals that can survive in the community depend, directly or indirectly, on the types of plants.

During each stage of ecological succession, only a few species have a great effect on the environment and on other members of the



▲ **Figure 37–15**

Stages of Primary Succession. The sequence of stages is shown from left to right. In an actual succession, only one stage is present at any given time.

community. These species are called the **dominant species.** The conditions imposed on the environment by the dominant species determine the types of other species that can survive in each successive community.

Succession of one community by another goes on until a mature, stable community develops. Such a community is called a **climax community.** In an ecosystem with a climax community, the conditions continue to be suitable for all the members of the community. The climax community remains until it is upset by a catastrophic event, such as a fire, flood, or volcanic eruption. After the destruction of a climax community, succession begins again and continues until a new climax community develops. Such catastrophic events are not necessarily bad. For example, some conifer species require a fire in order to release their seeds.

When succession occurs in an area that has no existing life, for example, on a bare rock, it is called **primary succession.** Succession that occurs in an area in which an existing community has been partially destroyed and its balance upset is called **secondary succession.**

Succession on Land Primary succession occurs on land in areas that are nearly lifeless. The process is shown in Figure 37–15. Such conditions exist on rocky cliffs, sand dunes, newly formed volcanic islands, and newly exposed land areas. Primary succession is a slow process because it must begin with the formation of soil.

Soil forms slowly over thousands of years. By the process of weathering, large rocks are gradually broken into smaller and smaller pieces. Eventually, some of the rock is broken down into small particles. The first organisms to inhabit an area are called *pioneer organisms.* These organisms include bacteria, fungi, and lichens. They break down the rock still further and add organic matter to the developing soil. Lichens are adapted to exposed conditions. They become attached to irregularities in the surface of the rock by rootlike rhizoids. They secrete acids that dissolve the rock. Some lichens die, and their remains are added to the soil. Mosses appear in areas where a little soil has accumulated. The mosses may shade the lichens, causing them to die and thus adding more organic material to the still primitive soil.

Eventually, grasses and annual plants grow in the areas where organic material has accumulated. When these plants die, the soil becomes richer. Small shrubs begin to grow, and their roots break rocks apart. The shrubs may shade the grasses, killing them. Tree seedlings may take root. The trees eventually shade out the shrubs. The seedlings that grew among the shrubs may have required a fair

Careers in Action

Forestry Technician

Under the direction of a forester, a forestry technician helps manage forest lands and resources. Because forests are used in many ways, forestry technicians perform a variety of activities.

Forestry technicians estimate timber yields and supervise some logging and tree replanting operations. They also help maintain the lands for campers, hikers, and others. By checking trees for disease and insect damage and by pruning and clearing unwanted growth, technicians maintain the health of forests.

An important part of the forestry technician's job is to prevent fires. When fires do occur, technicians help to supervise fire-fighting crews. Forestry technicians may also assist in research, work to prevent damage from floods and erosion, maintain and repair tools, and prepare educational programs for the public.

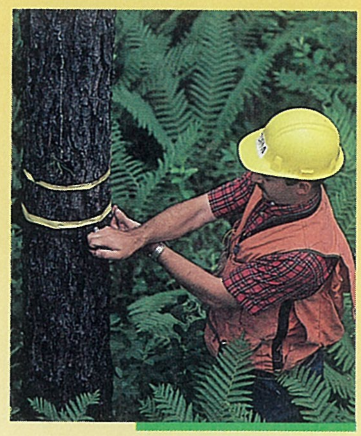
Problem Solving In 1988, a huge fire raged in Yellowstone National Park. Suppose you were a forestry technician at the park. The head forester has decided to let the fire burn in certain climax areas. The people in a nearby town are worried that the areas will be charred forever. The forester asks you to discuss these concerns with the townspeople.

1. Are the townspeople right? Why or why not?

2. Prepare an explanation of what is likely to happen to the burned areas in the future.

3. The people are concerned about erosion in burned areas and possible flooding in the town from heavy rains. What reasons would they have for these concerns?

4. The townspeople are worried that the animals living in the forests will escape the fire and become pests in the town. Do you think this is likely? Explain your answer in terms of habitats.



Help Wanted:
Forestry technician. High-school diploma required; one- or two-year college forestry course recommended. Contact: The American Forestry Association, 1319 18th St., N.W., Washington, D.C. 20036.

amount of sunlight. Thus, when they become mature trees, there may not be enough sun on the forest floor for seedlings of the same type to survive. However, seedlings of other trees may grow well in the shade. In this way, one community of trees will be succeeded by another community with different trees. After thousands of years, a climax community will develop. Climax communities are usually described in terms of their dominant plant forms.

The dominant plants of a climax community are determined by the physical factors of the environment. Where there is adequate rainfall and suitable soil, the climax community is likely to be a forest. If there is not enough water for a forest, the climax community can consist of grasses or some other type of plant.

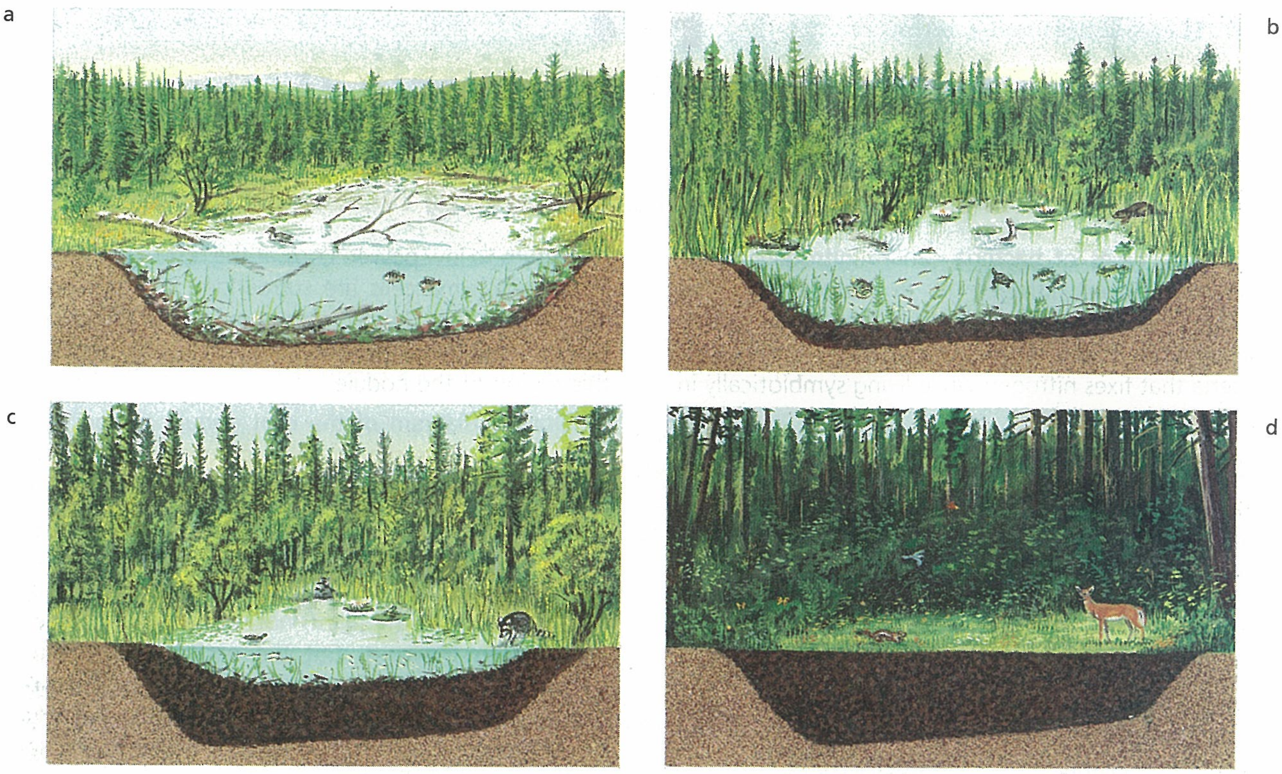
Animal life changes with the plant communities. For example, as a succession proceeds toward a forest community, animals that live among grasses and shrubs will be replaced by animals that live on the forest floor and at varying levels in the trees.

Secondary succession occurs in areas in which the climax community has been destroyed. For example, a forest may be cut down in order to clear the land for farming. If, after being farmed for awhile, the land is left untended, a new succession will begin. Eventually, it, too, will end in another forest climax community. In secondary succession, the area already has existing soil. Since the sequence does not begin with soil formation, the process is faster than primary succession. A climax community may become reestablished after a few hundreds of years, rather than the thousands originally needed for the primary succession. After the forest fires in 1988, the process of succession has begun to occur in Yellowstone National Park.

Succession in Lakes and Ponds Lakes and ponds may also pass through stages of ecological succession, eventually developing into a forest climax community as shown in Figure 37–17. The

Figure 37–16

Secondary Succession. In 1988, forest fires swept through Yellowstone National Park in Wyoming, destroying much of the vegetation. As seen in this recent photo, the process of secondary succession has already begun. ▶



process begins when sediment, fallen leaves, and other debris gradually accumulate on the lake bottom, decreasing its depth. Around the edges of the lake, sphagnum moss and many of the rooted plants, such as cattails, reeds, and rushes, grow out into the shallower water. They gradually extend the banks inward, decreasing the size of the lake. As the lake fills in, it becomes rich in nutrients that can support a large population of organisms. The increased number of plants and animals contribute organic material to the sediment, which hastens the filling-in process. As succession continues, the lake becomes a marsh. Still later, the marsh fills in, forming dry land. Land communities replace aquatic forms. Over time, the filled area becomes part of the surrounding community.

▲ **Figure 37–17**
Ecological Succession in a Pond. A pond may gradually change to dry land that supports a forest community.

37-4 Section Review

1. By what process do ecosystems change?
2. What is any group of organisms that is the first to inhabit an area?
3. How does secondary succession differ from primary succession?

Critical Thinking

4. A fire has wiped out an old maple forest near your home. Predict the dominant plants that will inhabit the area 400 years after the fire. (*Predicting*)