CHAPTER 15

Community Interactions 15

Chapter Outline

Key Concepts	Applications
Understand that organisms interact in a variety of ways within a community.	• Describe differences among predation, mutualism, competition, parasitism, and commensalism. • Explain how competition could be both good and bad. • Know the difference between niche and habitat. • Describe an organism's niche, habitat, or community.
Describe the flow of atoms through nutrient cycles.	• Explain why animals must eat. • Describe the importance of bacteria in nutrient cycles. • Explain why carbon and nitrogen must be recycled in ecosystems.
Appreciate that humans alter and interfere with natural ecological processes.	• Describe the impact of introduced species, predator control, and habitat destruction on natural communities. • Describe the impact of persistent organic chemicals on ecosystems. • Relate extinctions to human activities.

15.1 Community, Habitat, and Niche

People approach the study of organism interactions in two major ways. Many people look at interrelationships from the broad ecosystem point of view; others focus on individual organisms and the specific things that affect them in their daily lives. The first approach involves the study of all the organisms that interact with one another—the community—and usually looks at general relationships among them. Chapter 14 described categories of organisms—producers, consumers, and decomposers—that perform different functions in a community.

Another way of looking at interrelationships is to study in detail the ecological relationships of certain species of organisms. Each organism has particular requirements for life and lives where the environment provides what it needs. The environmental requirements of a whale include large expanses of ocean, but with seasonally important feeding areas and protected locations used for giving birth. The kind of place, or part of an ecosystem, occupied by an organism is known as its **habitat.** Habitats are usually described in terms of conspicuous or particularly significant features in the area where the organism lives. For example, the habitat of a prairie dog is usually described as a grassland and the habitat of a tuna is described as the open ocean. The habitat of the fiddler crab is sandy ocean shores and the habitat of various kinds of cacti is the desert. The key thing to keep in mind when you think of habitat is the *place* in which a particular kind of organism lives. In our descriptions of the habitats of organisms, we sometimes use the terminology of the major biomes of the world, such as desert, grassland, or savanna, but it is also possible to describe the habitat of the bacterium *Escherichia coli* as the gut of humans and other mammals, or the habitat of a fungus as a rotting log. Organisms that have very specific places in which they live simply have more restricted habitats.

Each species has particular requirements for life and places specific demands on the habitat in which it lives. The specific functional role of an organism is its **niche.** Its niche is the way it goes about living its life. Just as the word *place* is the key to understanding the concept of habitat, the word *function* is the key to understanding the concept of a niche. To understand the niche of an organism involves a detailed understanding of the impacts an organism has on its biotic and abiotic surroundings as well as all the factors that affect the organism. For example, the niche of an earthworm includes abiotic items such as soil particle size; soil texture; and the moisture, pH, and temperature of the soil. The earthworm's niche also includes biotic impacts such as serving as food for birds, moles, and shrews; as bait for anglers; or as a consumer of dead plant organic matter (figure 15.1). In addition, an earthworm serves as a host for a variety of parasites, transports minerals and nutrients from deeper soil layers to the surface, incorporates organic matter into the soil, and creates burrows that allow air and water to penetrate the soil more easily. And this is only a limited sample of all the aspects of its niche.

Some organisms have rather broad niches; others, with very specialized requirements and limited roles to play, have niches that are quite narrow. The opossum (figure 15.2*a*) is an animal with a very broad niche. It eats a wide variety of plant and animal foods, can adjust to a wide variety of climates, is used as food by many kinds of carnivores (including humans), and produces large numbers of offspring. By contrast, the koala of Australia (figure 15.2*b*) has a very narrow niche. It can live only in areas of Australia with specific species of *Eucalyptus* trees because it eats the leaves of only a few kinds of these trees. Furthermore, it cannot tolerate low temperatures and does not produce large numbers of offspring. As you might guess, the opossum is expanding its range, and the koala is endangered in much of its range.

The complete description of an organism's niche involves a very detailed inventory of influences, activities, and impacts. It involves what the organism does and what is done to the organism. Some of the impacts are abiotic, others are biotic. Because the niche of an organism is a complex set of items, it is often easy to overlook important roles played by some organisms.

For example, when Europeans introduced cattle into Australia—a continent where there had previously been no large, hoofed mammals—they did not think about the impact of cow manure or the significance of a group of beetles called *dung beetles.* These beetles rapidly colonize fresh dung and cause it to be broken down. No such beetles existed in Australia; therefore, in areas where cattle were raised, a significant amount of land became covered with accumulated cow dung. This reduced the area where grass could grow and reduced productivity. The problem was eventually solved by the importation of several species of dung beetles from Africa, where large, hoofed mammals are common. The dung beetles made use of what the cattle did not digest, returning it to a form that plants could more easily recycle into plant biomass.

15.2 Kinds of Organism Interactions

One of the important components of an organism's niche is the other living things with which it interacts. When organisms encounter one another in their habitats, they can influence one another in numerous ways. Some interactions are harmful to one or both of the organisms. Others are beneficial. Ecologists have classified kinds of interactions between organisms into several broad categories, which we will discuss here.

Predation

Predation occurs when one animal captures, kills, and eats another animal. The organism that is killed is called the **prey,** and the one that does the killing is called the **predator.** The predator obviously benefits from the relationship; the prey organism is harmed. Most predators are relatively large compared to their prey and have specific adaptations that aid them in catching prey. Many spiders build webs that serve as nets to catch flying insects. The prey are quickly paralyzed by the spider's bite and wrapped in a tangle of silk threads. Other rapidly moving spiders, like wolf spiders and jumping spiders, have large eyes that help them find prey without using webs. Dragonflies patrol areas where they can capture flying insects. Hawks and owls have excellent eyesight that allows them to find their prey. Many predators, like leopards, lions, and cheetahs, use speed to run down their prey; others such as frogs, toads, and many kinds of lizards blend in with their surroundings and strike quickly when a prey organism happens by (figure 15.3).

Many kinds of predators are useful to us because they control the populations of organisms that do us harm. For example, snakes eat many kinds of rodents that eat stored grain and other agricultural products. Many birds and bats eat insects that are agricultural pests. It is even possible to think of a predator as having a beneficial effect on the prey species. Certainly the *individual* organism that is killed is harmed, but the *population* can benefit. Predators can prevent large populations of prey organisms from destroying their habitat by hindering overpopulation of prey species or they can reduce the likelihood of epidemic disease by eating sick or diseased individuals. Furthermore, predators act as selecting agents. The individuals who fall to them as prey are likely to be less well adapted than the ones that escape predation. Predators usually kill slow, unwary, sick, or injured individuals. Thus the genes that may have contributed to slowness, inattention, illness, or the likelihood of being injured are removed from the gene pool and a better-adapted population remains. Because predators eliminate poorly adapted *individuals*, the *species* benefits. What is bad for the individual can be good for the species.

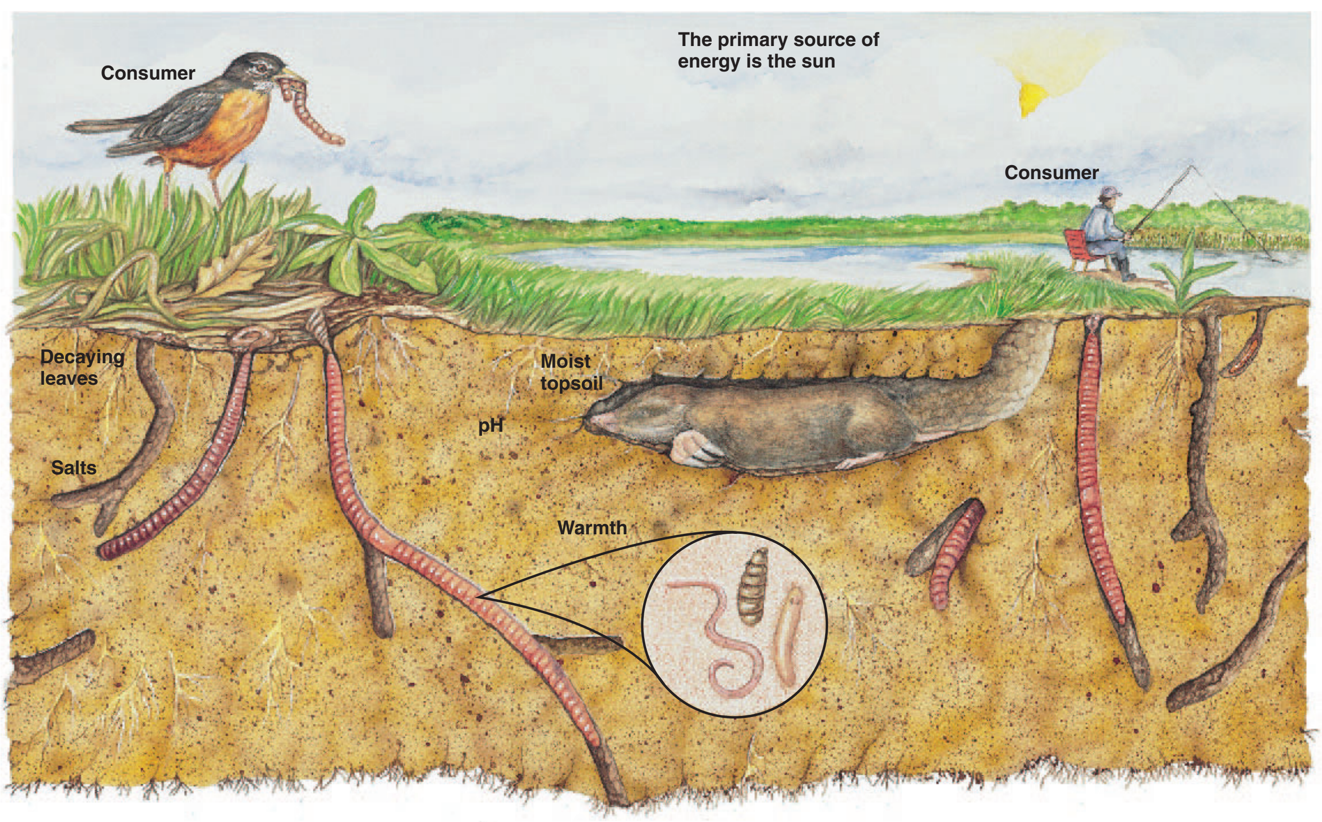


Figure 15.1

The Niche of an Earthworm

The niche of an earthworm involves a great many factors. It includes the fact that the earthworm is a consumer of dead organic matter, a source of food for other animals, a host to parasites, and bait for an angler. Furthermore, that the earthworm loosens the soil by its burrowing and "plows" the soil when it deposits materials on the surface are other factors. Additionally, the pH, texture, and moisture content of the soil have an impact on the earthworm. Keep in mind that this is but a small part of what the niche of the earthworm includes.

Parasitism

Another kind of interaction in which one organism is harmed and the other aided is the relationship of parasitism. In fact, there are more species of parasites in the world than there are nonparasites, making this a very common kind of relationship. **Parasitism** involves one organism living in or on another living organism from which it derives nourishment. The **parasite** derives the benefit and harms the **host**, the organism it lives in or on (figure 15.4). Many kinds of fungi live on trees and other kinds of plants, including those that are commercially valuable. Dutch elm disease is caused by a fungus that infects the living, sap-carrying parts of the tree. Mistletoe is a common plant that is a parasite on other plants. The mistletoe plant invades the tissues of the tree it is living on and derives nourishment from the tree.

Many kinds of worms, protozoa, bacteria, and viruses are important parasites. Parasites that live on the outside of their hosts are called **external parasites.** For example, fleas live on the outside of the bodies of mammals like rats, dogs, cats, and humans, where they suck blood and do harm to their hosts. At the same time, the host could also have a tapeworm in its intestine. Because the tapeworm lives inside the host, it is called an **internal parasite.** Another kind of parasite that may be found in the blood of rats is the bacterium *Yersinia pestis*. It does little harm to the rat but causes a disease known as *plague* or *black death* if it is transmitted to humans. Because fleas can suck the blood of rats and also live on and bite humans they can serve as carriers of bacteria between rats and humans. An organism that can carry a disease from one individual to another is called a **vector.** During the mid-1300s, when living conditions were poor and rats and fleas were common, epidemics of plague killed millions of people. In some countries in western Europe, 50% of the population was killed by this disease. Plague is still a problem today when living conditions are poor and sanitation is lacking. Cases of plague are even found in developed countries like the United States on occasion.

Lyme disease is also a vector-borne disease caused by the bacterium, *Borrelia burgdorferi*, that is spread by certain species of ticks (figure 15.5). Over 90% of the cases are centered in the Northeast (New York, Pennsylvania, Maryland, Delaware, Connecticut, Rhode Island, and New Jersey).

(a) (b)

Figure 15.2

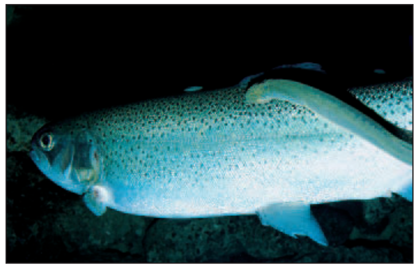
Broad and Narrow Niches
(*a*) The opossum has a very broad niche. It eats a variety of foods, is able to live in a variety of habitats, and has a large reproductive capacity. It is generally extending its range in the United States.
(*b*) The koala has a narrow niche. It feeds on the leaves of only a few species of *Eucalyptus* trees, is restricted to relatively warm, forested areas, and is generally endangered in much of its habitat.

(a) (b)

Figure 15.3

The Predator-Prey Relationship
(*a*) Many predators capture prey by making use of speed. The cheetah can reach estimated speeds of 100 kilometers per hour (about 60 mph) during sprints to capture its prey. (*b*) Other predators, like this veiled chameleon blend in with their surroundings, lie in wait, and ambush their prey. Because strength is needed to kill the prey, the predator is generally larger than the prey. Obviously, predators benefit from the food they obtain to the detriment of the prey organism.

(a)



(b)

(c)

Figure 15.4

The Parasite-Host Relationship
Parasites benefit from the relationship because they obtain nourishment from the host. Tapeworms (*a*) are internal parasites in the guts of their host where they absorb food from the host's gut. The lamprey (*b*) is an external parasite that sucks body fluids from its host. Mistletoe (*c*) is a photosynthesizing plant that also absorbs nutrients from the tissues of its host tree. The host in any of these three situations may not be killed directly by the relationship, but it is often weakened, thus becoming more vulnerable to predators or diseases. There are more species of parasites in the world than species of organisms that are not parasites.

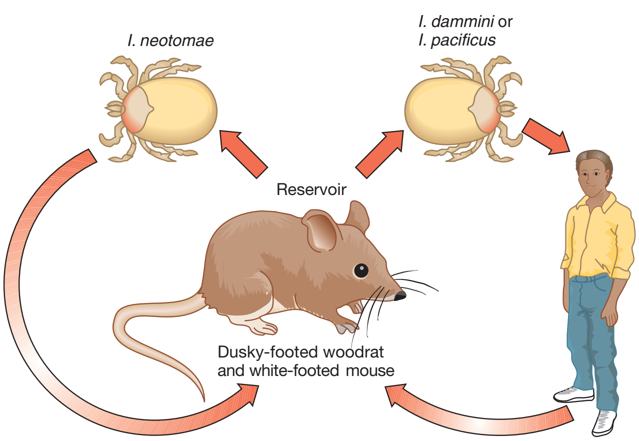


Figure 15.5

Lyme Disease—Hosts, Parasites, and Vectors
Lyme disease is a bacterial disease originally identified in a small number of individuals in the Old Lyme, Connecticut, area. Today it is found throughout the United States and Canada. Once the parasite, *Borrelia burgdorferi*, has been transferred into a suitable susceptible host (e.g., humans, mice, horses, cattle, domestic cats, and dogs), it causes symptoms that have been categorized into three stages. The first-stage symptoms may appear 3 to 32 days after an individual is bitten by an infected tick (various members of the genus *Ixodes*) and include a spreading red rash, headache, nausea, fever, aching joints and muscles, and fatigue. Stage two may not appear for weeks or months after the infection and may affect the heart and nervous system. The third stage may occur months or years later and typically appears as severe arthritis attacks. The main reservoir of the disease is the white-footed mouse and dusky-footed woodrat.

Both predation and parasitism are relationships in which one member of the pair is helped and the other is harmed. But there are many kinds of interactions in which one is harmed and the other aided that don't fit neatly into the categories of interactions dreamed up by scientists. For example, when a cow eats grass, it is certainly harming the grass while deriving benefit from it. We could call cows *grass predators*, but we usually refer to them as *herbivores*. Likewise, such animals as mosquitoes, biting flies, vampire bats, and ticks take blood meals but don't usually live permanently on the host or kill it. Are they temporary parasites or specialized predators? Finally, birds like cowbirds and some species of European cuckoos lay their eggs in the nests of other species of birds, who raise these foster young rather than their own. The adult cowbird and cuckoo often remove eggs from the host nest or their offspring eject the eggs or the young of the host-bird species, so that usually only the cowbird or cuckoo is raised by the foster parents. This kind of relationship has been called *nest parasitism*, because the host parent birds are not killed and aid the cowbird or cuckoo by raising their young.

Commensalism

Both predation and parasitism involve one organism benefiting while the other is harmed. Another common relationship is one in which one organism benefits and the other is not affected. This is known as **commensalism.** For example, sharks often have another fish, the remora, attached to them. The remora has a sucker on the top side of its head that allows it to attach to the shark and get a free ride (figure 15.6*a*). Although the remora benefits from the free ride and

(a) (b)

Figure 15.6

Commensalism

In the relationship called commensalism, one organism benefits and the other is not affected. (*a*) The remora fish shown here hitchhike a ride on the shark. They eat scraps of food left over by the messy eating habits of the shark. The shark does not seem to be hindered in any way. (*b*) The epiphytic plants growing on this tree do not harm the tree but are aided by using the tree surface as a place to grow.

by eating leftovers from the shark's meals, the shark does not appear to be troubled by this uninvited guest, nor does it benefit from the presence of the remora.

Another example of commensalism is the relationship between trees and epiphytic plants. **Epiphytes** are plants that live on the surface of other plants but do not derive nourishment from them (figure 15.6*b*). Many kinds of plants (e.g., orchids, ferns, and mosses) use the surfaces of trees as places to live. These kinds of organisms are particularly common in tropical rainforests. Many epiphytes derive benefit from the relationship because they are able to be located in the tops of the trees, where they receive more sunlight and moisture. The trees derive no benefit from the relationship, nor are they harmed; they simply serve as support surfaces for epiphytes.

Mutualism

So far in our examples, only one species has benefited from the association of two species. There are also many situations in which two species live in close association with one another, and both benefit. This is called **mutualism.** One interesting example of mutualism involves digestion in rabbits. Rabbits eat plant material that is high in cellulose even though they do not produce the enzymes capable of breaking down cellulose molecules into simple sugars. They manage to get energy out of these cellulose molecules with the help of special bacteria living in their digestive tracts. The bacteria produce cellulose-digesting enzymes, called *cellulases,* that break down cellulose into smaller carbohydrate molecules that the rabbit's digestive enzymes can break down into smaller glucose molecules. The bacteria benefit because the gut of the rabbit provides them with a moist, warm, nourishing environment in which to live. The rabbit benefits because the bacteria provide them with a source of food. Termites, cattle, buffalo, and antelope also have collections of bacteria and protozoa living in their digestive tracts that help them digest cellulose.

Another kind of mutualistic relationship exists between flowering plants and bees. Undoubtedly you have observed bees and other insects visiting flowers to obtain nectar from the blossoms (figure 15.7). Usually the flowers are constructed in such a manner that the bees pick up pollen (sperm-containing packages) on their hairy bodies, which they transfer to the female part of the next flower they visit. Because bees normally visit many individual flowers of the same species for several minutes and ignore other species of flowers, they can serve as pollen carriers between two flowers of the same species. Plants pollinated in this manner produce less pollen than do plants that rely on the wind to transfer pollen. This saves the plant energy because it doesn't need to produce huge quantities of pollen. It does, however, need to transfer some of its energy savings into the production of showy

Figure 15.7

Mutualism
Mutualism is an interaction between two organisms in which both benefit. The plant benefits because cross-fertilization (exchange of gametes from a different plant) is more probable; the butterfly benefits by acquiring nectar for food.

Figure 15.8

Competition
Whenever a needed resource is in limited supply, organisms compete for it. This competition may be between members of the same species (*intraspecific*), illustrated by the vultures shown in the photograph, or may involve different species (*interspecific*).

flowers and nectar to attract the bees. The bees benefit from both the nectar and pollen; they use both for food.

Lichens and corals exhibit a more intimate kind of mutualism. In both cases the organisms consist of the cells of two different organisms intermingled with one another. Lichens consist of fungal cells and algal cells in a partnership; corals consist of the cells of the coral organism intermingled with algal cells. In both cases, the algae carry on photosynthesis and provide nutrients and the fungus or coral provides a moist, fixed structure for the algae to live in.

One other term that relates to parasitism, commensalism, and mutualism is *symbiosis*. **Symbiosis** literally means "living together." Unfortunately, this word is used in several ways, none of which is very precise. It is often used as a synonym for mutualism, but it is also often used to refer to commensal relationships and parasitism. The emphasis, however, is on interactions that involve a close physical relationship between the two kinds of organisms.

Competition

So far in our discussion of organism interactions we have left out the most common one. It is reasonable to envision every organism on the face of the Earth being involved in competitive interactions. **Competition** is a kind of interaction between organisms in which both organisms are harmed to some extent. Competition occurs whenever two organisms need a vital resource that is in short supply (figure 15.8). The vital resource could be food, shelter, nesting sites, water, mates, or space. It can be a snarling tug-of-war between two dogs over a scrap of food, or it can be a silent struggle between plants for access to available light. If you have ever started tomato seeds (or other garden plants) in a garden and failed to eliminate the weeds, you have witnessed competition. If the weeds are not removed, they compete with the garden plants for available sunlight, water, and nutrients, resulting in poor growth of both the garden plants and the weeds.

The more similar the requirements of two species of organisms, the more intense the competition. According to the **competitive exclusion principle,** no two species of organisms can occupy the same niche at the same time. If two species of organisms do occupy the same niche, the competition will be so intense that one or more of the following will occur: one will become extinct, one will be forced to migrate to a different area, or the two species may evolve into slightly different niches so that they do not compete.

It is important to recognize that although competition results in harm to both organisms there can still be winners and losers. The two organisms may not be harmed to the same extent with the result that one will have greater access to the limited resource. Furthermore, even the loser can continue to survive if it migrates to an area where competition is less intense or evolves to exploit a different niche. Thus competition provides a major mechanism for natural selection. With the development of slight differences between niches the intensity of competition is reduced. For example, many birds catch flying insects as food. However, they do not compete directly with each other because some feed at night, some feed high in the air, some feed only near the ground, and still others perch on branches and wait for insects to fly past. The insect-eating niche can be further subdivided by specialization on particular sizes or kinds of insects.

Many of the relationships just described involve the transfer of nutrients from one organism to another (predation, parasitism, mutualism). Another important way scientists look at ecosystems is to look at how materials are cycled from organism to organism.

15.3 The Cycling of Materials in Ecosystems

Although some new atoms are being added to the Earth from cosmic dust and meteorites, this amount is not significant in relation to the entire biomass of the Earth. Therefore, the Earth can be considered to be a closed ecosystem as far as matter is concerned. Only sunlight energy comes to the Earth in a continuous stream, and even this is ultimately returned to space as heat energy. However, it is this flow of energy that drives all biological processes. Living systems have evolved ways of using this energy to continue life through growth and reproduction and the continual reuse of existing atoms. In this recycling process, inorganic molecules are combined to form the organic compounds of living things. If there were no way of recycling this organic matter back into its inorganic forms, organic material would build up as the bodies of dead organisms. This is thought to have occurred millions of years ago when the present deposits of coal, oil, and natural gas were formed. Under most conditions decomposers are available to break down organic material to inorganic material that can then be reused by other organisms to rebuild organic material. One way to get an appreciation of how various kinds of organisms interact to cycle materials is to look at a specific kind of atom and follow its progress through an ecosystem.

The Carbon Cycle

Living systems contain many kinds of atoms, but some are more common than others. Carbon, nitrogen, oxygen, hydrogen, and phosphorus are found in all living things and must be recycled when an organism dies. Let's look at some examples of this recycling process. Carbon and oxygen atoms combine to form the molecule carbon dioxide (CO_2), which is a gas found in small quantities in the atmosphere. During photosynthesis, carbon dioxide (CO_2) combines with water (H_2O) to form complex organic molecules like sugar ($C_6H_{12}O_6$). At the same time, oxygen molecules (O_2) are released into the atmosphere (Outlooks 15.1).

The organic matter in the bodies of plants may be used by herbivores as food. When an herbivore eats a plant, it breaks down the complex organic molecules into more simple molecules, like simple sugars, amino acids, glycerol, and fatty acids. These can be used as building blocks in the construction of its own body. Thus the atoms in the body of the herbivore can be traced back to the plants that were eaten. Similarly, when herbivores are eaten by carnivores, these same atoms are transferred to them. Finally, the waste products of plants and animals and the remains of dead organisms are used by decomposer organisms as sources of carbon and other atoms they need for survival. In addition, all the organisms in this cycle—plants, herbivores, carnivores, and decomposers—obtain energy (ATP [adenosine triphosphate]) from the process of respiration, in which oxygen (O_2) is used to break down organic compounds into carbon dioxide (CO_2) and water (H_2O). Thus the carbon atoms that started out as components of carbon dioxide (CO_2) molecules have passed through the bodies of living organisms as parts of organic molecules and returned to the atmosphere as carbon dioxide, ready to be cycled again. Similarly, the oxygen atoms (O) released as oxygen molecules (O_2) during photosynthesis have been used during the process of respiration (figure 15.9).

The Hydrologic Cycle

Water molecules are the most common molecules in living things and are essential for life. Water molecules are used as raw materials in the process of photosynthesis. The hydrogen atoms (H) from water (H_2O) molecules are added to carbon atoms to make carbohydrates and other organic molecules. Furthermore, the oxygen atoms in water molecules are released during photosynthesis as oxygen molecules (O_2). In addition, all the metabolic reactions that occur in organisms take place in a watery environment. We can trace the movement and reuse of water molecules by picturing a hydrologic cycle (figure 15.10).

Most of the forces that cause water to be cycled do not involve organisms, but are the result of normal physical processes. Because of the kinetic energy possessed by water molecules, at normal Earth temperatures liquid water evaporates into the atmosphere as water vapor. This can occur wherever water is present; it evaporates from lakes, rivers, soil, or the surfaces of organisms. Because the oceans contain most of the world's water, an extremely large amount of water enters the atmosphere from the oceans. In addition, **transpiration** in plants involves the transport of water from the soil to leaves, where it evaporates. The movement of water carries nutrients to the leaves and the evaporation of the water assists in the movement of water upward in the stem.

Once the water molecules are in the atmosphere, they are moved by prevailing wind patterns. If warm, moist air encounters cooler temperatures, which often happens over landmasses, the water vapor condenses into droplets and falls as rain or snow. When the precipitation falls on land, some of it runs off the surface, some of it evaporates, and some penetrates into the soil. The water in the soil may be taken up by plants and transpired into the atmosphere, or it may become groundwater. Much of the groundwater also

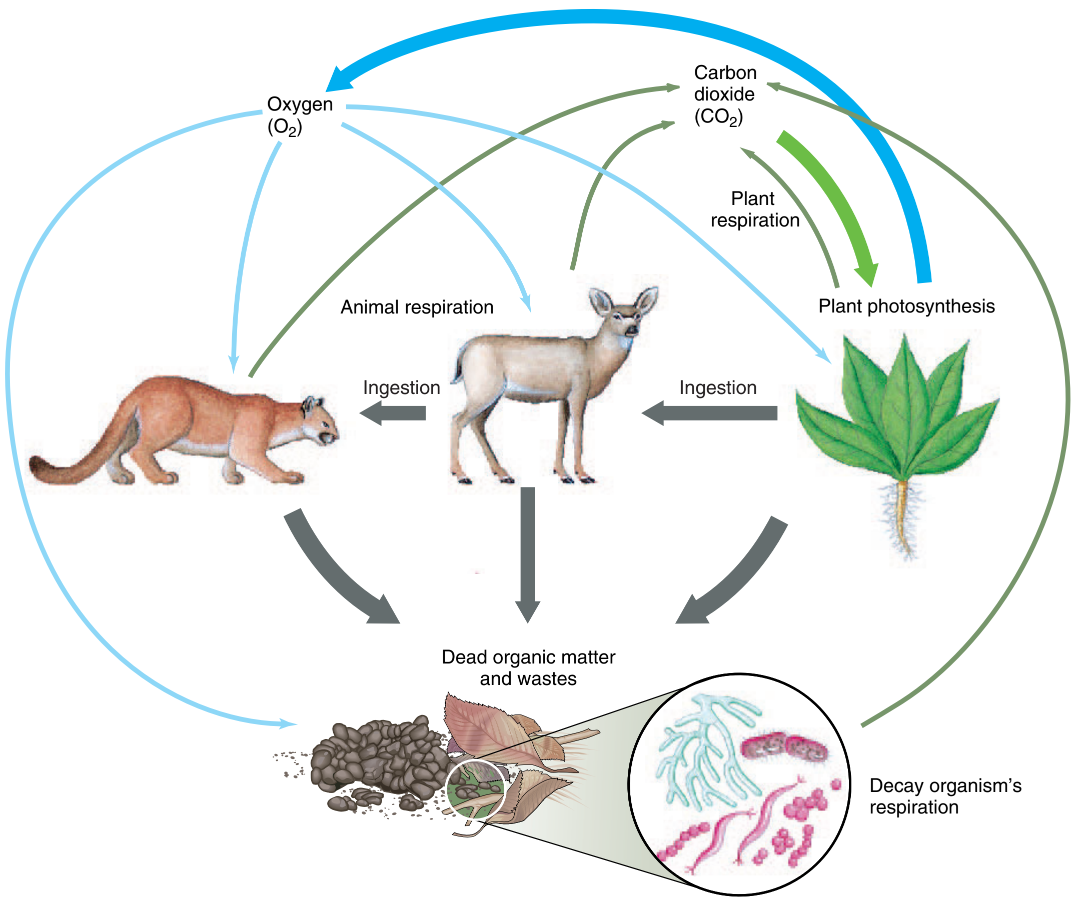


Figure 15.9

The Carbon Cycle
Carbon atoms are cycled through ecosystems. Carbon dioxide (green arrows) produced by respiration is the source of carbon that plants incorporate into organic molecules when they carry on photosynthesis. These carbon-containing organic molecules (black arrows) are passed to animals when they eat plants and other animals. Organic molecules in waste or dead organisms are consumed by decay organisms in the soil when they break down organic molecules into inorganic molecules. All organisms (plants, animals, and decomposers) return carbon atoms to the atmosphere as carbon dioxide when they carry on cellular respiration. Oxygen (blue arrows) is being cycled at the same time that carbon is. The oxygen is released to the atmosphere and into the water during photosynthesis and taken up during cellular respiration.

eventually makes its way into lakes and streams and ultimately arrives at the ocean from which it originated.

The Nitrogen Cycle

Another important element for living things is nitrogen (N). Nitrogen is essential in the formation of amino acids, which are needed to form proteins, and in the formation of nitrogenous bases, which are a part of ATP and the nucleic acids DNA and RNA. Nitrogen (N) is found as molecules of nitrogen gas (N_2) in the atmosphere. Although nitrogen gas (N_2) makes up approximately 80% of the Earth's atmosphere, only a few kinds of bacteria are able to convert it into nitrogen compounds that other organisms can use. Therefore, in most terrestrial ecosystems, the amount of nitrogen available limits the amount of plant biomass that can be produced. (Most aquatic ecosystems are limited by the amount of phosphorus rather than the amount of nitrogen.) Plants utilize several different nitrogen-containing compounds to obtain the nitrogen atoms they need to make amino acids and other compounds (figure 15.11).

Symbiotic nitrogen-fixing bacteria live in the roots of certain kinds of plants, where they convert nitrogen gas molecules into compounds that the plants can use to make amino acids and nucleic acids. The most common plants that enter into this mutualistic relationship with bacteria are legumes such as beans, clover, peas, alfalfa, and locust trees. Some other organisms, such as alder trees and even a kind of

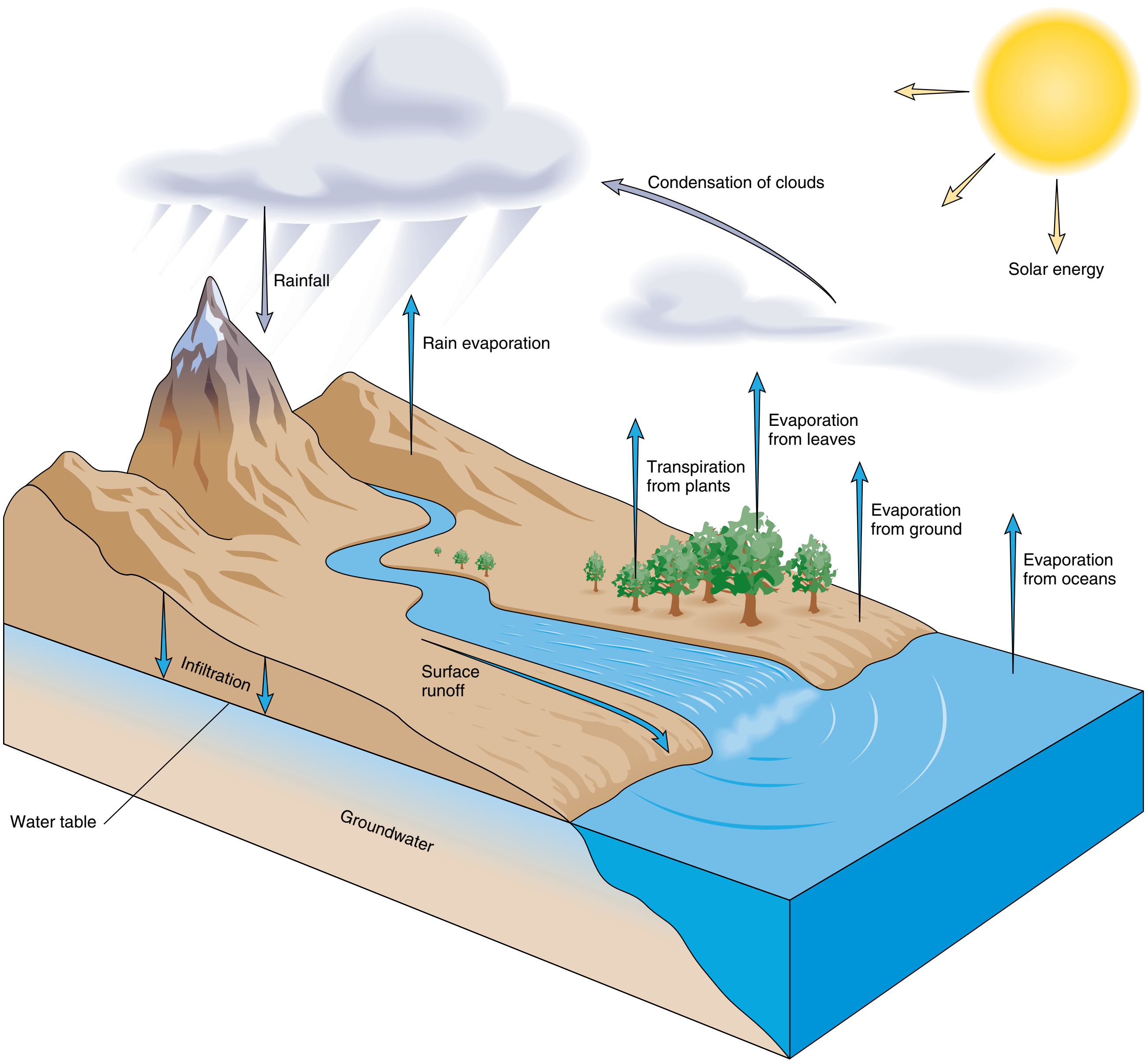


Figure 15.10

The Hydrologic Cycle
The cycling of water through the environment follows a simple pattern. Moisture in the atmosphere condenses into droplets that fall to the Earth as rain or snow. Organisms use some of the water, but much of it flows over the Earth as surface water or through the soil as groundwater. It eventually returns to the oceans, where it evaporates back into the atmosphere to begin the cycle again.

aquatic fern can also participate in this relationship. There are also **free-living nitrogen-fixing bacteria** in the soil that provide nitrogen compounds that can be taken up through the roots, but the bacteria do not live in a close physical union with plants.

Another way plants get usable nitrogen compounds involves a series of different bacteria. Decomposer bacteria convert organic nitrogen-containing compounds into ammonia (NH_3). **Nitrifying bacteria** can convert ammonia (NH_3) into nitrite-containing (NO_2^-) compounds, which in turn can be converted into nitrate-containing (NO_3^-) compounds. Many kinds of plants can use either ammonia (NH_3) or nitrate (NO_3^-) from the soil as building blocks for amino acids and nucleic acids.

All animals obtain their nitrogen from the food they eat. The ingested proteins are broken down into their component

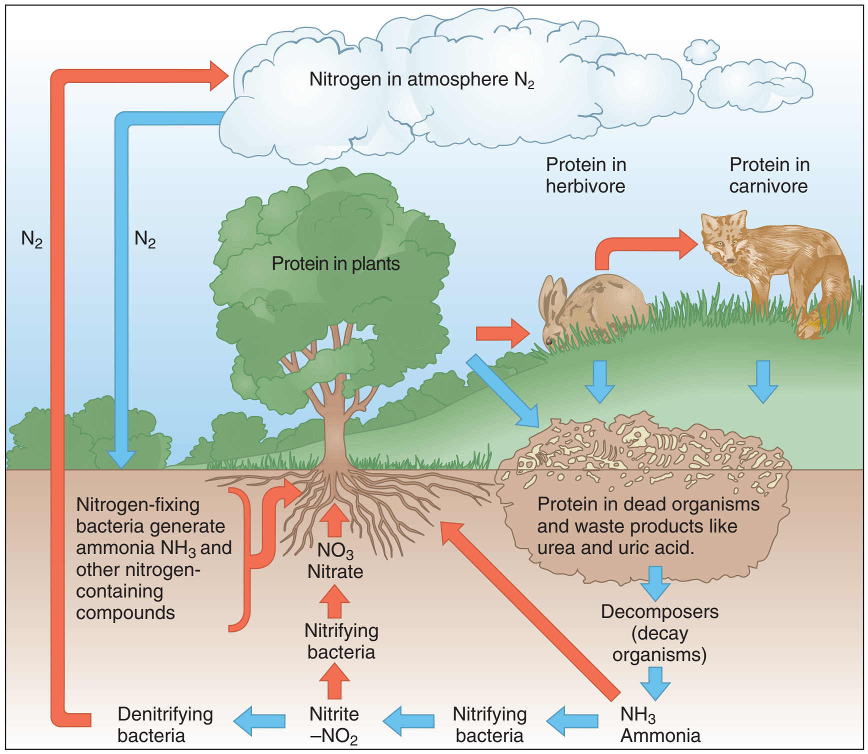


Figure 15.11

The Nitrogen Cycle
Nitrogen atoms are cycled through ecosystems. Atmospheric nitrogen is converted by nitrogen-fixing bacteria to nitrogen-containing compounds that plants can use to make proteins and other compounds. Proteins are passed to other organisms when one organism is eaten by another. Dead organisms and their waste products are acted upon by decay organisms to form ammonia, which may be reused by plants and converted to other nitrogen compounds by nitrifying bacteria. Denitrifying bacteria return nitrogen as a gas to the atmosphere.

amino acids during digestion. These amino acids can then be reassembled into new proteins characteristic of the animal. All dead organic matter and waste products of plants and animals are acted upon by decomposer organisms, and the nitrogen is released as ammonia (NH_3), which can be taken up by plants or acted upon by nitrifying bacteria to make nitrate (NO_3^-).

Finally, other kinds of bacteria called **denitrifying bacteria** are capable of converting nitrite (NO_2^-) to nitrogen gas (N_2), which is released into the atmosphere. Thus, in the nitrogen cycle, nitrogen from the atmosphere is passed through a series of organisms, many of which are bacteria, and ultimately returns to the atmosphere to be cycled again. However, there is also a secondary cycle in which nitrogen compounds are recycled without returning to the atmosphere.

Because nitrogen is in short supply in most ecosystems, farmers usually find it necessary to supplement the natural nitrogen sources in the soil to obtain maximum plant growth. This can be done in a number of ways. Alternating nitrogen-producing crops with nitrogen-demanding crops helps maintain high levels of usable nitrogen in the soil. One year a crop such as beans or clover that has symbiotic nitrogen-fixing bacteria in its roots can be planted. The following year the farmer can plant a nitrogen-demanding crop such as corn. The use of manure is another way of improving nitrogen levels. The waste products of animals are broken down by decomposer bacteria and nitrifying bacteria, resulting in enhanced levels of ammonia and nitrate. Finally, the farmer can use industrially produced fertilizers containing ammonia or nitrate. These compounds can be used directly by plants or converted into other useful forms by nitrifying bacteria.

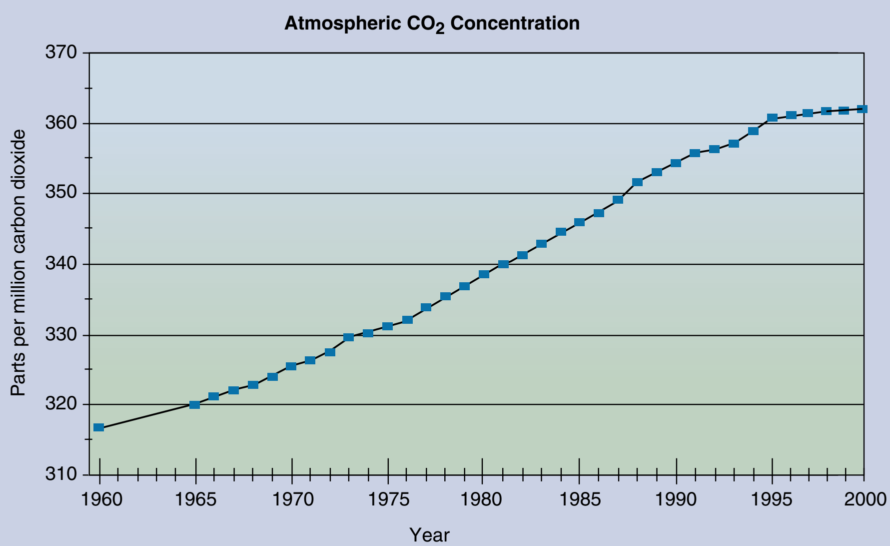
The Phosphorus Cycle

Phosphorus is another kind of atom common in the structure of living things. It is present in many important biological molecules such as DNA and in the membrane structure of cells. In addition, the bones and teeth of animals contain significant quantities of phosphorus. The ultimate source of phosphorus atoms is rock. In nature, new phosphorus compounds are released by the erosion of rock and dissolving in water. Plants use the dissolved phosphorus compounds to construct the molecules they need. Animals obtain the phosphorus they need when they consume plants or other animals. When an organism dies or excretes waste products, decomposer organisms recycle the phosphorus compounds back into the soil. Phosphorus compounds that are dissolved in water are ultimately precipitated as deposits. Geologic processes elevate these deposits and expose them to erosion, thus making these deposits available to organisms. Waste products of animals often have significant amounts of phosphorus. In places where large numbers of seabirds or bats congregate for hundreds of years, the thickness of their droppings (called guano) can be a significant source of phosphorus for fertilizer

OUTLOOKS 15.1

Carbon Dioxide and Global Warming

Humans have significantly altered the carbon cycle. As we burn fossil fuels, the amount of carbon dioxide in the atmosphere continually increases. Carbon dioxide allows light to enter the atmosphere but does not allow heat to exit. Because this is similar to what happens in a greenhouse, carbon dioxide and other gases that have similar effects are called greenhouse gases. Therefore, increased amounts of carbon dioxide in the atmosphere could lead to a warming of the Earth. Many are concerned that increased carbon dioxide levels will lead to a warming of the planet and, thus, cause major changes in weather and climate, leading to the flooding of coastal cities and major changes in agricultural production. The Intergovernmental Panel on Climate Change (IPCC), established by the United Nations, concluded that there has been an increase in the average temperature of the Earth and humans are the cause because of the burning of fossil fuels and the destruction of forests. There is no doubt that the amount of carbon dioxide in the atmosphere has been increasing. Despite this fact and the conclusions of the IPCC, there is still controversy about this topic and some doubt that warming is occurring. At a meeting in Koyoto, Japan, in 1998 many countries agreed to reduce the amount of carbon dioxide and other greenhouse gases they release into the atmosphere. However, emissions of carbon dioxide are directly related to economic activity and the energy usage that fuels it. Therefore, it remains to be seen if countries will meet their goals or will succumb to economic pressures to allow continued use of large amounts of fossil fuels. However, some countries have sought to control the change in the amount of carbon dioxide in the atmosphere by planting millions of trees or preventing the destruction of forests. The thought is that the trees carry on photosynthesis, grow, and store carbon in their bodies, leading to reduced carbon dioxide levels. At the same time people in other parts of the world continue to destroy forests at a rapid rate. Tree planting does not offset deforestation. In addition, the trees that have been planted will ultimately die and decompose, releasing carbon dioxide back into the atmosphere, so it is not clear that this is an effective means of reducing atmospheric carbon dioxide over the long term.



Source: Data from Carbon Dioxide Information Analysis Center, 2000, Oak Ridge, Tenn.

(figure 15.12). In many soils, phosphorus is in short supply and must be provided to crop plants to get maximum yields. Phosphorus is also in short supply in aquatic ecosystems.

Fertilizers usually contain nitrogen, phosphorus, and potassium compounds. The numbers on a fertilizer bag indicate the percentage of each in the fertilizer. For example, a 6-24-24 fertilizer has 6% nitrogen, 24% phosphorus, and 24% potassium compounds. In addition to carbon, nitrogen, and phosphorus, potassium and other elements are cycled within ecosystems. In an agriculture ecosystem, these elements are removed when the crop is harvested. Therefore farmers must not only return the nitrogen, phosphorus, and potassium, but they must also analyze for other less prominent elements and add them to their fertilizer mixture as well. Aquatic ecosystems are also sensitive to nutrient levels. High levels of nitrates or phosphorus compounds often result in rapid growth of aquatic producers. In aquaculture, such as that used to raise catfish, fertilizer is added to the body of water to stimulate the production of algae which is the base of many aquatic food chains.

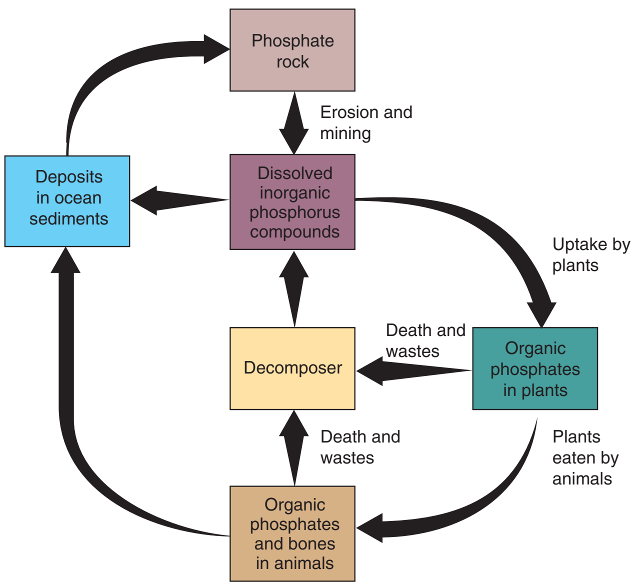


Figure 15.12

Phosphorus Cycle
The source of phosphorus is rock which, when dissolved, provides a source of phosphorus used by plants and animals.

15.4 The Impact of Human Actions on Communities

As you can see from this discussion and from the discussion of food webs in chapter 14, all organisms are associated in a complex network of relationships. A community consists of all these sets of interrelations. Therefore, before one decides to change a community, it is wise to analyze how the organisms are interrelated. This is not always an easy task because there is much we still do not know about how organisms interact and how they utilize molecules from their environment. Several lessons can be learned from studying the effects of human activity on communities.

Introduced Species

One of the most far-reaching effects humans have had on natural ecosystems involves the introduction of foreign species. Most of these introductions have been conscious decisions. Nearly all of our domesticated plants and animals are introductions from elsewhere. Cattle, horses, pigs, goats, and many introduced grasses have significantly altered the original ecosystems present in the Americas. Nearly all of our agriculturally important plants and animals are not native to North America. (Corn, beans, sunflowers, squash, and the turkey are exceptions.) Cattle have replaced the original grazers on grasslands. Pigs have become a major problem in Hawaii and many other places in the world where they destroy the natural ecosystem by digging up roots and preventing the reproduction of native plants. The introduction of grasses as food for cattle has resulted in the decline of many native species of grasses and other plants that were originally part of grassland ecosystems. In Australia the introduction of domesticated plants and animals, and wild animals such as rabbits and foxes, has severely reduced the populations of many native marsupial mammals.

Accidental introductions have also significantly altered ecosystems. Chestnut blight essentially eliminated the American chestnut from the forests of eastern North America. Similarly a fungal disease (Dutch elm disease) has severely reduced the number of elms in forests.

Predator Control

During the formative years of wildlife management, it was thought that populations of game species could be increased if the populations of their predators were reduced. Consequently, many states passed laws that encouraged the killing of foxes, eagles, hawks, owls, coyotes, cougars, and other predators that use game animals as a source of food. Often bounties were paid to people who killed these predators. In South Dakota it was decided to increase the pheasant population by reducing the numbers of foxes and coyotes. However, when the supposed predator populations were significantly reduced, there was no increase in the pheasant population. There was rapid increase in the rabbit and mouse populations, however, and they became serious pests. Evidently the foxes and coyotes were major factors in keeping rabbit and mouse populations under control but had only a minor impact on pheasants.

The absence of predators can lead to many kinds of problems with prey species. In many metropolitan areas deer have become pests. This is due to several reasons, including the fact that there are no predators, and hunting (predation by humans) is either not allowed or is impractical because of the highly urbanized nature of the area. Some municipalities have instituted programs of chemical birth control for their deer populations. In parts of Florida increased numbers of alligators present a danger; particularly to pets and children. Hunting is now allowed in an effort to control the numbers of alligators because humans are the only effective predators of large alligators. Only a few years ago the alligator was on the endangered species list and all hunting was suspended. Similarly, in Yellowstone National Park, elk, bison, and moose populations have become very large because hunting is not allowed and predators are in low numbers. In 1995 wolves were reintroduced to the park in the hope that they would help bring the elk and moose populations under control. This was a controversial decision because ranchers in the vicinity do not want a return of large predators that might prey on their livestock. They are also opposed to having bison, many of which carry a disease that can affect cattle, stray onto their land. The wolf populations have increased significantly in Yellowstone and are having an effect on the populations of bison, elk, and moose. Regardless of the politics involved in the decision, Yellowstone is in a more natural condition today with wolves present than it was prior to 1995.

By contrast, the state of Alaska instituted a project to kill wolves because they believe the wolves are reducing caribou populations below optimal levels. Caribou hunting is an important source of food for Alaskan natives, and hunters who visit the state provide a significant source of income. Many groups oppose the killing of wolves in Alaska. They consider the policy misguided and believe it will not have a positive effect on the caribou population. They also object to the killing of wolves on ethical grounds.

Habitat Destruction

Some communities are fragile and easily destroyed by human activity, whereas others seem able to resist human interference. Communities with a wide variety of organisms that show a high level of interaction are more resistant than those with few organisms and little interaction. In general, the more complex an ecosystem is, the more likely it is to recover after being disturbed. The tundra biome is an example of a community with relatively few organisms and interactions. It is not very resistant to change, and because of its slow rate of repair, damage caused by human activity may persist for hundreds of years.

Some species are more resistant to human activity than others. Rabbits, starlings, skunks, and many kinds of insects and plants are able to maintain high populations despite human activity. Indeed, some may even be encouraged by human activity. By contrast, whales, condors, eagles, and many plant and insect species are not able to resist human interference very well. For most of these endangered species it is not humans acting directly with the organisms that cause their endangerment. Very few organisms have been driven to extinction by hunting or direct exploitation. Usually the cause of extinction or endangerment is an indirect effect of habitat destruction as humans exploit natural ecosystems. As humans convert land to farming, grazing, commercial forestry, development, and special wildlife management areas, the natural ecosystems are disrupted, and plants and animals with narrow niches tend to be eliminated because they lose critical resources in their environment. Table 15.1 lists several endangered species and the probable causes of their difficulties.

Table 15.1

ENDANGERED AND THREATENED SPECIES

Species	Reason for Endangerment
Hawaiian crow *Corvis hawaiinsis*	Predation by cat and mongoose; disease; habitat destruction
Sonora chub *Gila ditaenia*	Competition with introduced species
Black-footed ferret *Mustela nigripes*	Poisoning of prairie dogs (their primary food)
Snail kite *Rostrhamus sociabilis*	Specialized eating habits (only eat apple snails); draining of marshes
Grizzly bear *Ursus arctos*	Loss of wilderness areas
California condor *Gymnogyps californianus*	Slow breeding; lead poisoning
Ringed sawback turtle *Graptemys oculifera*	Modification of habitat by construction of reservoir that reduced their primary food source
Scrub mint *Dicerandra frutescens*	Conversion of habitat to citrus groves and housing

Pesticide Use

Humans have developed a variety of chemicals to control specific pest organisms. One of the first that was used widely was the insecticide DDT. DDT is an abbreviation for the chemical name dichlorodiphenyltrichloroethane. DDT is one of a group of organic compounds called *chlorinated hydrocarbons.* Because DDT is a poison that was used to kill a variety of insects, it was called an **insecticide.** Another term that is sometimes used is **pesticide,** which implies that the poison is effective against pests. Although it is no longer used in the United States (its use was banned in the early 1970s), DDT is still manufactured and used in many parts of the world, including Mexico.

DDT was a valuable insecticide for the U.S. Armed Forces during World War II. It was sprayed on clothing and dusted on the bodies of soldiers, refugees, and prisoners to kill body lice and other insects. Lice, besides being a nuisance, carry the bacteria that can cause a disease known as *typhus fever.* When bitten by a louse, a person can develop typhus fever. Because body lice could be transferred from one person to another by contact or by wearing infested clothing, DDT was important in maintaining the health of millions of people. Because DDT was so useful in controlling these insects, people envisioned the end of pesky mosquitoes and flies, as well as the elimination of many disease-carrying insects.

Although DDT was originally very effective, many species of insects developed a resistance to it. The genetic diversity present in all species is related to their ability to respond to many environmental factors, including manufactured ones such as DDT. When DDT or any pesticide is applied to a population of insects, susceptible individuals die, and those with some degree of resistance have a greater chance of living. Now the reproducing population consists of many individuals that have resistant genes, which are passed on to the offspring. When this happens repeatedly over a long time, a resistant population develops, and the insecticide is no longer useful.

DDT and other pesticides act as selecting agents, killing the normal insects but allowing the resistant individuals to live. This happened in the orange groves of California, where many populations of pests became DDT-resistant. Similarly, throughout the world, DDT was used (and in many areas is still used) to control malaria-carrying mosquitoes. Many of these populations have become resistant to DDT and other kinds of insecticides. The people who anticipated the elimination of insect pests did not reckon with the genetic diversity of the gene pools of these insects.

Another problem associated with pesticide use is the effects of pesticides on valuable nontarget organisms. Because many of the insects we consider pests are herbivores, you can expect that carnivores in the community use the pest species as prey, and parasites use the pest as a host. These predators and parasites have important roles in controlling the numbers of a pest species.

Generally, predators and parasites reproduce more slowly than their prey or host species. Because of this, the use of a nonspecific pesticide may indirectly make controlling a pest more difficult. If such a pesticide is applied to an area, the pest is killed but so are its predators and parasites. Because the herbivore pest reproduces faster than its predators and parasites, the pest population rebounds quickly, unchecked by natural predation and parasitism. This may necessitate more frequent and more concentrated applications of pesticides. This has actually happened in many cases of pesticide use; the pesticides made the problem worse, and the chemicals became increasingly costly to apply. Today, a more enlightened approach to pest control involves *integrated pest management,* which uses a variety of approaches to reduce pest populations. Integrated pest management may involve the use of pesticides as part of a pest control program, but it will also include strategies such as encouraging the natural enemies of pests, changing farming practices to discourage pests, changing the mix of crops grown, and accepting low levels of crop damage as an alternative to costly pesticide applications.

Biomagnification

Another problem associated with the use of persistent chemicals involves their effect on the food chain. DDT was a very effective insecticide because it is extremely toxic to insects but not very toxic to birds and mammals. It is also a very stable compound, which means that once it is applied it remains effective for a long time. It sounds like an ideal insecticide. What went wrong? Why was its use banned?

When DDT was sprayed over an area, it fell on the insects and on the plants that the insects used for food. Eventually the DDT entered the insect either directly through the body wall or through its food. When ingested with food, DDT interferes with the normal metabolism of the insect. If small quantities are taken in, the insect can digest and break down the DDT just like any other large organic molecule. Because DDT is soluble in fat or oil, the DDT or its breakdown products are stored in the fat deposits of the insect.

Some insects can break down and store all the DDT they encounter and, therefore, they survive. If an area has been lightly sprayed with DDT, some insects die, some are able to tolerate the DDT, and others break down and store nonlethal quantities of DDT. As much as one part DDT per 1 million parts of insect tissue can be stored in this manner. This is not much DDT! It is equivalent to one drop of DDT in 100 railroad tank cars. However, when an aquatic area is sprayed with a small concentration of DDT, many kinds of organisms in the area can accumulate tiny quantities in their bodies. Even algae and protozoa found in aquatic ecosystems accumulate persistent pesticides. They may accumulate concentrations in their cells that are 250 times more concentrated than the amount sprayed on the ecosystem. The algae and protozoa are eaten by insects, which in turn are eaten by frogs, fish, or other carnivores.

The concentration in frogs and fish may be 2,000 times what was sprayed. The birds that feed on the frogs and fish may accumulate concentrations that are as much as 80,000 times the original amount. Because DDT is relatively stable and is stored in the fat deposits of the organisms that take it in, what was originally a dilute concentration becomes more concentrated as it moves up the food chain.

Before DDT was banned, many animals at higher trophic levels died as a result of lethal concentrations of pesticide accumulated from the food they ate. Each step in the food chain accumulated some DDT and, therefore, higher trophic levels had higher concentrations. This process is called **biomagnification** (figure 15.13). Even if they were not killed directly by DDT, many birds at higher trophic levels, such as eagles, pelicans, and osprey, suffered reduced populations because the DDT interfered with the female birds' ability to produce eggshells. Thin eggshells are easily broken, and thus no live young hatched. Both the bald eagle and the brown pelican were placed on the endangered species list because their populations dropped dramatically as a result of DDT poisoning. The ban on DDT use in the United States and Canada has resulted in an increase in the populations of both kinds of birds; the status of the bald eagle has been upgraded from endangered to threatened.

Another widely used group of synthetic compounds of environmental concern are polychlorinated biphenyls (PCBs). PCBs are highly stable compounds that resist changes from heat, acids, bases, and oxidation. These characteristics made PCBs desirable for industrial use, but also made them persistent pollutants when released into the envi-

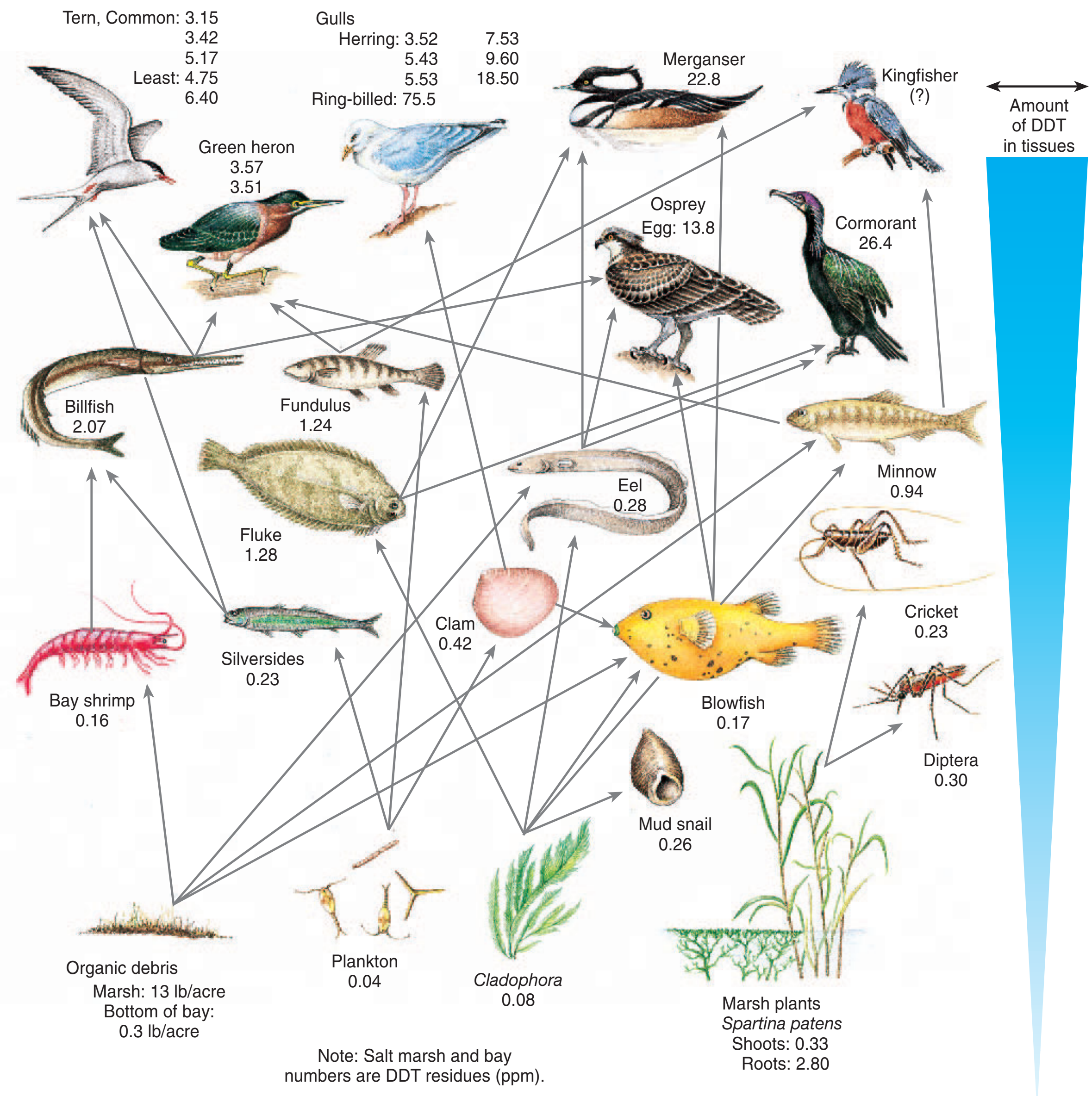


Figure 15.13

The Biomagnification of DDT
All the numbers shown are in parts per million (ppm). A concentration of one part per million means that in a million equal parts of the organism, one of the parts would be DDT. Notice how the amount of DDT in the bodies of the organisms increases as we go from producers to herbivores to carnivores. Because DDT is persistent, it builds up in the top trophic levels of the food chain.

ronment. About half the PCBs were used in transformers and electrical capacitors. Other uses included inks, plastics, tapes, paints, glues, waxes, and polishes. PCBs are harmful to fish and other aquatic forms of life because they interfere with reproduction. In humans, PCBs produce liver ailments and skin lesions. In high concentrations, they can damage the nervous system and are suspected carcinogens. In 1970, PCB production was limited to cases where satisfactory substitutes were not available. Today, substitutes have been found for nearly all the former uses of PCBs (How Science Works 15.1).

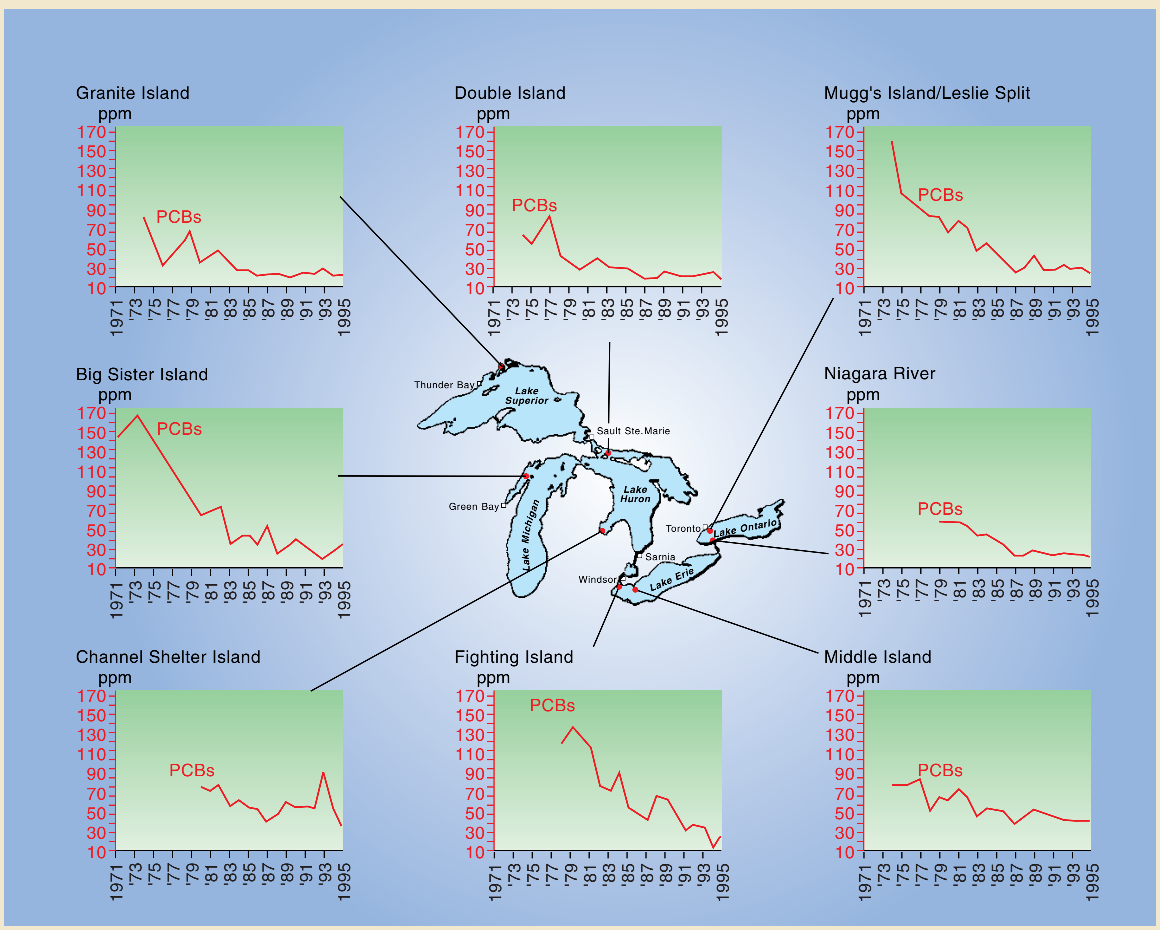
HOW SCIENCE WORKS 15.1

Herring Gulls as Indicators of Contamination in the Great Lakes

Herring gulls nest on islands and other protected sites throughout the Great Lakes region. Because they feed primarily on fish, they are near the top of the aquatic food chains and tend to accumulate toxic materials from the food they eat. Eggs taken from nests can be analyzed for a variety of contaminants.

Since the early 1970s, the Canadian Wildlife Service has operated a herring gull monitoring program to assess trends in the levels of various contaminants in the eggs of herring gulls. In general, the levels of contaminants have declined as both the Canadian and U.S. governments have taken action to stop new contaminants from entering the Great Lakes. The figure shows the trends for PCBs. PCBs are a group of organic compounds, some of which are much more toxic than others. They were used as fire retardants, lubricants, insulation fluids in electrical transformers, and in some printing inks. Both Canada and the United States have eliminated most uses of PCBs.

The data collected show a downward trend in the amount of PCBs present in the eggs of herring gulls. Long-term studies like this one are very important in showing slow, steady responses to changes in the environment. Without such long-term studies we would be less sure of the impact of environmental clean-up activities.



Source: The Canada Centre for Inland Waters, World Wide Web servers operated by Computing and Programming Services, National Water Research Institute, Environment Canada. http://www.cciw.ca/green-lane/wildlife/gl-factsheet/herring

SUMMARY

Each organism in a community occupies a specific space known as its habitat and has a specific functional role to play, known as its niche. An organism's habitat is usually described in terms of some conspicuous element of its surroundings. The niche is difficult to describe because it involves so many interactions with the physical environment and other living things.

Interactions between organisms fit into several categories. Predation is one organism benefiting (predator) at the expense of the organism killed and eaten (prey). Parasitism is one organism benefiting (parasite) by living in or on another organism (host) and deriving nourishment from it. Organisms that carry parasites from one host to another are called vectors. Commensal relationships exist when one organism is helped but the other is not affected. Mutualistic relationships benefit both organisms. Symbiosis is any interaction in which two organisms live together in a close physical relationship. Competition causes harm to both of the organisms involved, although one may be harmed more than the other and may become extinct, evolve into a different niche, or be forced to migrate.

Many atoms are cycled through ecosystems. The carbon atoms of living things are trapped by photosynthesis, passed from organism to organism as food, and released to the atmosphere by respiration. Water is necessary as a raw material for photosynthesis and as the medium in which all metabolic reactions take place. Water is cycled by the physical processes of evaporation and condensation. Nitrogen originates in the atmosphere, is trapped by nitrogen-fixing bacteria, passes through a series of organisms, and is ultimately released to the atmosphere by denitrifying bacteria. Phosphorus compounds are found in rocky deposits. Erosion of rock and dissolving of phosphorus compounds make phosphorus available to plants. Animals obtain phosphorus in the food they eat. Phosphorus in waste products may be recycled or be deposited in sediments, which may be subjected to erosion at some future date.

Organisms within a community are interrelated in sensitive ways; thus, changing one part of a community can lead to unexpected consequences. Introduction of foreign species, predator-control practices, habitat destruction, pesticide use, and biomagnification of persistent toxic chemicals all have caused unanticipated changes in communities.

THINKING CRITICALLY

This is a thought puzzle. Place the following items on a sheet of paper so that they show levels of interaction. Which is the most important item? Which items are dependent on others? Here are the pieces:

- People are starving.
- Commercial fertilizer production requires temperatures of 900°C.
- Geneticists have developed plants that grow very rapidly and require high amounts of nitrogen to germinate during the normal growing season.
- Fossil fuels are stored organic matter.
- The rate of the nitrogen cycle depends on the activity of bacteria.
- The Sun is expected to last for several million years.
- Crop rotation is becoming a thing of the past.
- The clearing of forests for agriculture changes the weather in the area.

CONCEPT MAP TERMINOLOGY

Construct a concept map to show relationships among the following concepts.

competition
epiphytes
host
mutualism
niche
nitrogen cycle
parasite
predator
prey
producers
symbiotic nitrogen-fixing bacteria

KEY TERMS

biomagnification
commensalism
competition
competitive exclusion principle
denitrifying bacteria
epiphyte
external parasite
free-living nitrogen-fixing bacteria
habitat
host
insecticide
internal parasite
mutualism
niche
nitrifying bacteria
parasite
parasitism
pesticide
predation
predator
prey
symbiosis
symbiotic nitrogen-fixing bacteria
transpiration
vector

e—LEARNING CONNECTIONS *www.mhhe.com/enger10*

Topics	Questions	Media Resources
15.1 Community, Habitat, and Niche	1. Describe your niche. 2. What is the difference between habitat and niche?	**Quick Overview** • The home address and job **Key Points** • Community, habitat, and niche
15.2 Kinds of Organism Interactions	3. What do parasites, commensal organisms, and mutualistic organisms have in common? How are they different? 4. Describe two situations in which competition may involve combat and two that do not involve combat.	**Quick Overview** • Relationships between neighbors **Key Points** • Kinds of organism interactions **Animations** • Species interactions • Concept quiz **Interactive Concept Maps** • Interactions **Experience This!** • Observing organism interactions
15.3 The Cycling of Materials in Ecosystems	5. Trace the flow of carbon atoms through a community that contains plants, herbivores, decomposers, and parasites. 6. Describe four different roles played by bacteria in the nitrogen cycle. 7. Describe the flow of water through the hydrologic cycle. 8. List three ways the carbon and nitrogen cycles are similar and three ways they differ.	**Quick Overview** • A different way to look at a food chain **Key Points** • The cycling of materials in ecosystems **Animations and Review** • Nutrient cycles • Concept quiz **Interactive Concept Maps** • Text concept map • Carbon cycle • Nitrogen cycle • Hydrologic cycle **Case Study** • Averting disaster in biosphere 2
15.4 The Impact of Human Actions on Communities	9. Describe the impact of DDT on communities. 10. How have past practices of predator control and habitat destruction negatively altered biological communities?	**Quick Overview** • Are you always a good neighbor? **Key Points** • The impact of human actions on communities **Animations and Review** • Pesticides • Biomagnification alternatives • Concept quiz **Case Study** • Columbia River tragedy **Food for Thought** • Killer seaweed begins U.S. invasion • The wolf in Yellowstone National Park