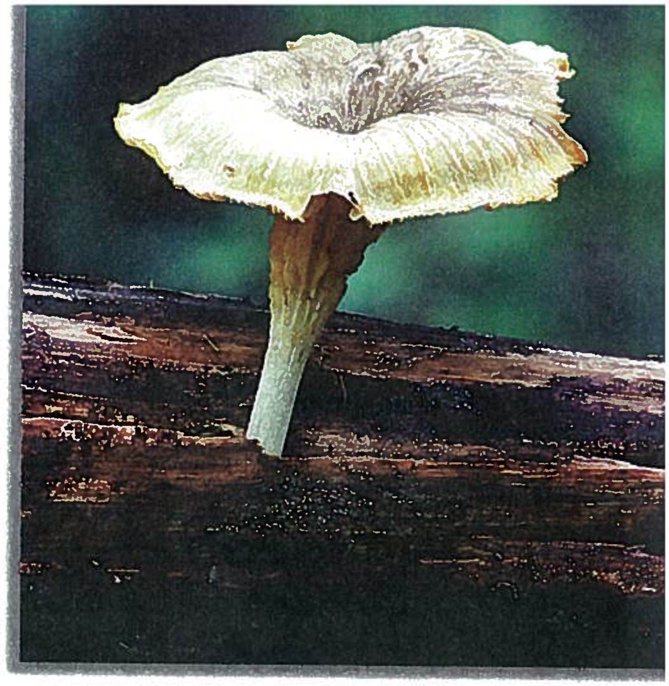
CHAPTER 5

INTERACTIONS: ENVIRONMENTS AND ORGANISMS



There are many kinds of organism interactions. Fungi like this mushroom are decomposers that break down dead organic matter. The mushrooms may, in turn, become food for other organisms.

CHAPTER OUTLINE

OBJECTIVES

After reading this chapter, you should be able to:

- Identify and list abiotic and biotic factors in an ecosystem.
- Define *niche.*
- Describe the process of natural selection as it operates to refine the fit among organism, habitat, and niche.
- Describe predator-prey, parasite-host, competitive, mutualistic, and commensalistic relationships.
- Differentiate between a community and an ecosystem.
- Define the roles of producer, herbivore, carnivore, omnivore, scavenger, parasite, and decomposer.
- Describe energy flow through an ecosystem.
- Relate the concepts of food webs and food chains to trophic levels.
- Explain the cycling of nutrients such as nitrogen, carbon, and phosphorus through an ecosystem.

ECOLOGICAL CONCEPTS

The science of **ecology** is the study of the ways organisms interact with each other and with their nonliving surroundings. Ecology deals with the ways in which organisms are adapted to their surroundings, how they make use of these surroundings, and how an area is altered by the presence and activities of organisms. These interactions involve energy and matter. Living things require a constant flow of energy and matter to assure their survival. If the flow of energy and matter ceases, the organisms die.

All organisms are dependent on other organisms in some way. One organism may eat another and use it for energy and raw materials. One organism may temporarily use another without harming it. One organism may provide a service for another, such as when animals distribute plant seeds or bacteria break down dead organic matter for reuse. The study of ecology can be divided into many specialties and be looked at from several levels of organization. (See figure 5.1.) Before we can explore the field of ecology in greater depth, we must become familiar with some of the standard vocabulary of this field.

ENVIRONMENT

Everything that affects an organism during its lifetime is collectively known as its **environment.** Environment is a very broad concept. For example, during its lifetime, an animal such as a raccoon is likely to interact with millions of other organisms (bacteria, food organisms, parasites, mates, predators), drink copious amounts of water, breathe huge quantities of air, and respond to daily changes in temperature and humidity. This list only begins to describe the various components that make up the raccoon's environment. Because of this complexity, it is useful to subdivide the concept of environment into abiotic (nonliving) and biotic (living) factors.

Abiotic Factors

Abiotic factors are nonliving things that influence an organism. They can be organized into several broad categories: energy, nonliving matter, living space, and processes that involve the interactions of nonliving matter and energy.

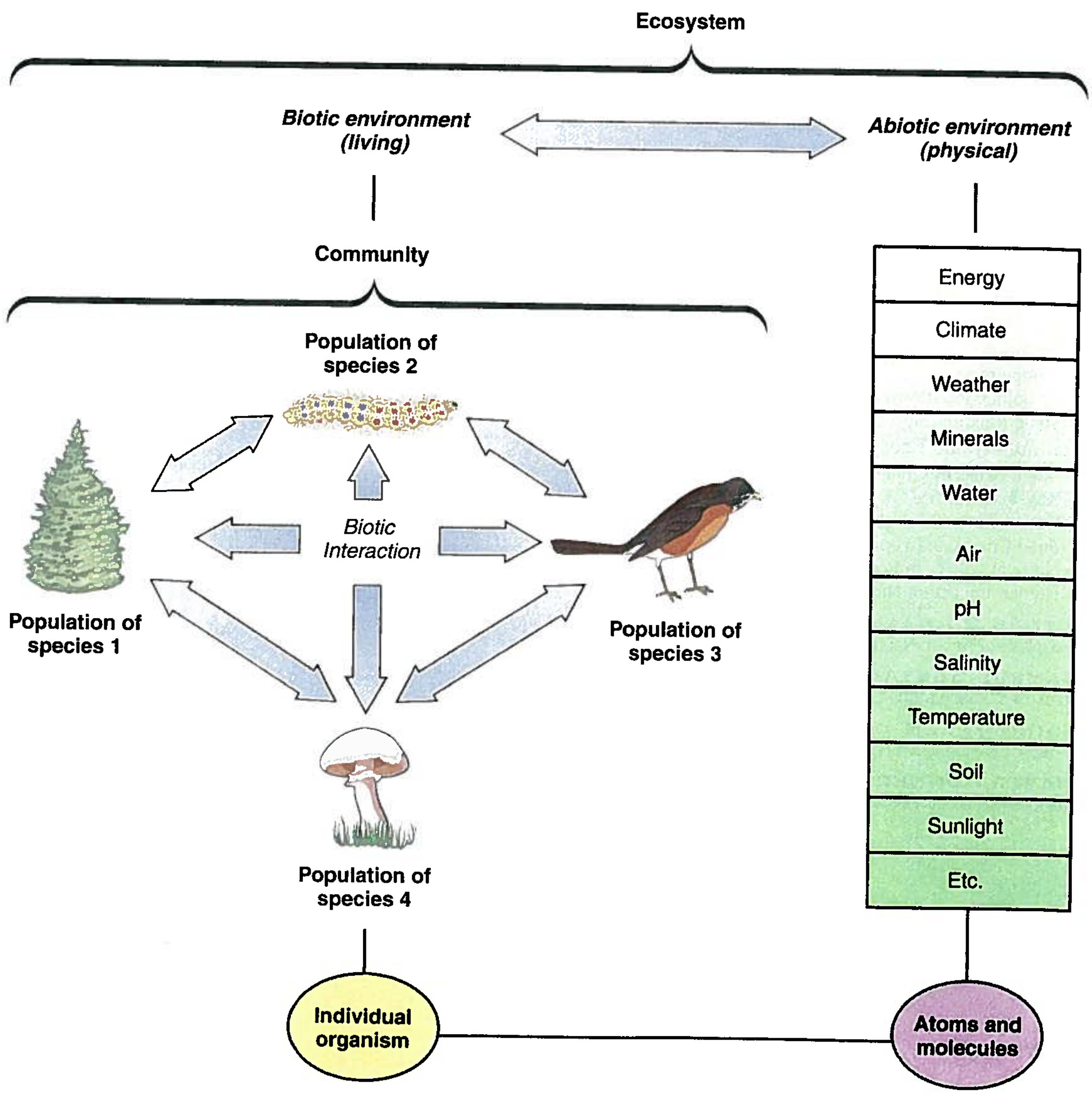


FIGURE 5.1 Levels of Organization in Ecology Ecology is the science that deals with the study of interactions between organisms and their environment. This study can take place at several different levels, from the broad ecosystem level through community interactions to population studies and the study of the niche of individual organisms. Ecology also involves study of the physical environment and the atoms and molecules that make up both the living and nonliving parts of an ecosystem.

CAMPUS SUSTAINABILITY INITIATIVE

Creek Restoration at the University of Arkansas–Little Rock

A partnership that involves the University of Arkansas–Little Rock, the City of Little Rock, and the Audubon Society of Arkansas is turning a 5-acre urban concrete and asphalt part of the campus into a creek shoreline of native trees and grasses. The site is located in a floodplain of Coleman Creek.

The first part of the project includes the removal of concrete pilings, asphalt, and five unusable buildings. When the demolition is completed, landscaping will begin. The landscaping will include planting of native grasses and trees. Foot paths will be constructed that will create a "circle of life" in which historical markers will be placed to identify the creek as a stop-over along the old Southwest Trail. The old Southwest Trail was part of the "Trail of Tears" over which members of the Chickasaw and Choctaw tribes were forced to migrate to reservations farther west.

This project is the first step in a 47-acre greenway reaching the full length of the campus that will include plantings, the construction of bicycle and walking trails, and other structures like benches and bridges. The restoration project also will provide an outdoor laboratory for biologists, Earth scientists, and hydrologists for teaching and research activities. The reclamation of the area is also part of the strategic plan for the University District aimed at improving life and business in the neighborhood surrounding the campus and will connect to other open space in the area.

Energy is required by all organisms to maintain themselves. The ultimate source of energy for almost all organisms is the sun; in the case of plants, the sun directly supplies the energy necessary for them to maintain themselves. Animals obtain their energy by eating plants or other animals that eat plants. Ultimately, the amount of living material that can exist in an area is determined by the amount of energy plants, algae, and bacteria can trap.

Matter in the form of atoms such as carbon, nitrogen, and phosphorus and molecules such as water provides the structural framework of organisms. Organisms constantly obtain these materials from their environment. The atoms become part of an organism's body structure for a short time, and eventually all of them are returned to the environment through respiration, excretion, or death and decay.

The *space* organisms inhabit has a particular structure and location that is also an important abiotic aspect of their environment. Some organisms live in the ocean; others live on land at sea level; still others live on mountaintops or fly through the air. Some spaces are homogeneous and flat; others are a jumble of rocks of different sizes. Some are close to the equator; others are near the poles.

Ecological processes involve interactions between matter and energy. The climate (average weather patterns over a number of years) of an area involves energy in the form of solar radiation interacting with the matter that makes up the Earth. The kind of climate present is determined by many different factors, including the amount of solar radiation, proximity to the equator, prevailing wind patterns, and closeness to water. The intensity and duration of sunlight in an area cause daily and seasonal changes in temperature. Differences in temperature generate wind. Solar radiation is also responsible for generating ocean currents and the evaporation of water into the atmosphere that subsequently falls as precipitation. Depending on the climate, precipitation may be of several forms: rain, snow, hail, or fog. Furthermore, there may be seasonal precipitation patterns.

Soil-building processes are influenced by prevailing weather patterns, local topography, and the geologic history of the region. These factors interact to produce a variety of soils that range from those that are coarse, sandy, dry, and infertile to fertile soils composed of fine particles that hold moisture.

Biotic Factors

The **biotic factors** of an organism's environment include all forms of life with which it interacts. Some broad categories are: plants that carry on photosynthesis; animals that eat other organisms; bacteria and fungi that cause decay; bacteria, viruses, and other parasitic organisms that cause disease; and other individuals of the same species.

Limiting Factors

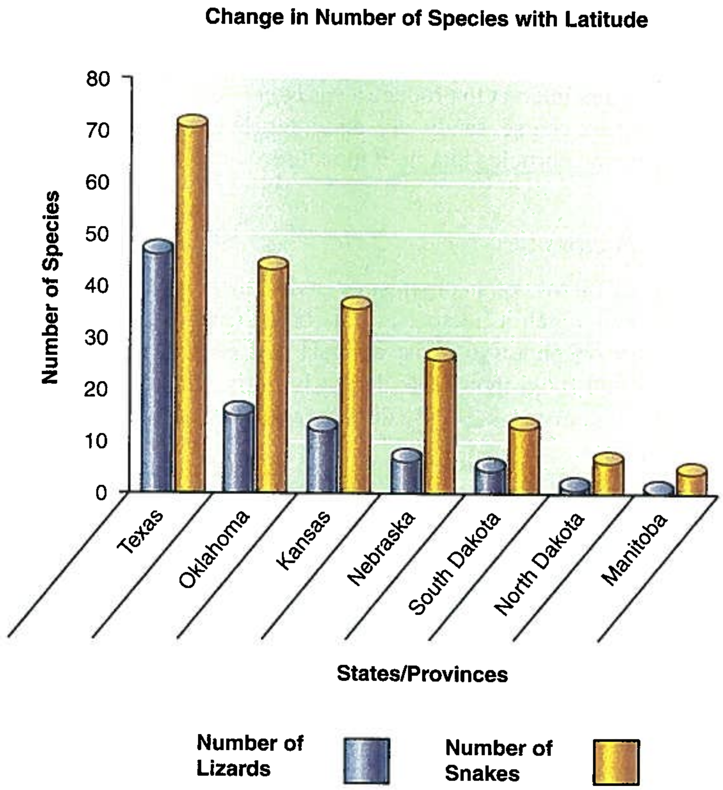
Although organisms interact with their surroundings in many ways, certain factors may be critical to a particular species' success. A shortage or absence of a factor can restrict the success of the species; thus, it is known as a **limiting factor.** Limiting factors may be either abiotic or biotic and can be quite different from one species to another. Many plants are limited by scarcity of water, light, or specific soil nutrients such as nitrogen or phosphorus. Monarch butterflies are limited by the number of available milkweed plants, since their developing caterpillars use this plant as their only food source. (See figure 5.2.)

Climatic factors such as temperature range, humidity, periods of drought, or length of winter are often limiting factors.

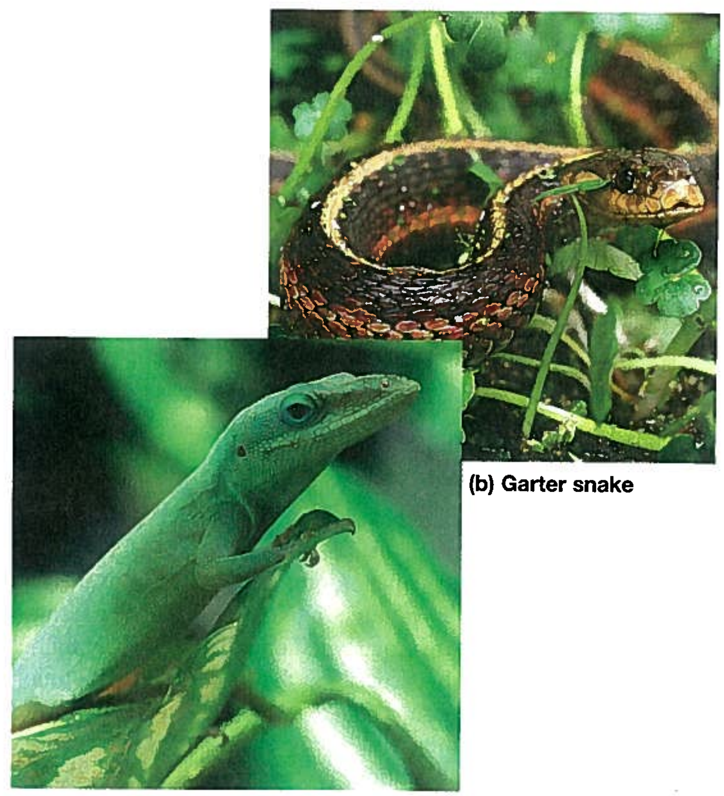
Adult monarch on milkweed **Caterpillar feeding on milkweed**

FIGURE 5.2 Milkweed Is a Limiting Factor for Monarch Butterflies Monarch butterflies lay their eggs on various kinds of milkweed plants. The larvae eat the leaves of the milkweed plant. Thus, monarchs are limited by the number of milkweeds in the area.

For example, many species of snakes and lizards are limited to the warmer parts of the world because they have difficulty maintaining their body temperature in cold climates and cannot survive long periods of cold. If we look at the number of species of snakes and lizards, we see that the number of species declines as one moves from warmer to colder climates. While this is a general trend, there is much variation among species. The **range of tolerance** of a species is the degree to which it is able to withstand environmental variation. Some species have a broad range of tolerance, whereas others have a narrow range of tolerance. The common garter snake (*Thamnophis sirtalis*) consists of several subspecies and is found throughout the United States and Southern Canada and has scattered populations in Mexico. Thus, it is able to tolerate a wide variety of climates. Conversely, the green anole (*Anolis carolinensis*) has a much narrower range of tolerance and is found only in the southeastern part of the United States where temperatures are mild. (See figure 5.3.)



(a)



(b) Garter snake

(c) Green anole

FIGURE 5.3 Temperature Is a Limiting Factor Cold temperature is a limiting factor for many kinds of reptiles. Snakes and lizards are less common in cold regions than in warm regions. (a) The graph shows the number of species of snakes and lizards in regions of central North America. Note that the number of species declines as one proceeds from south to north. (b) Some species, like the common garter snake (*Thamnophis sirtalis*), have a broad range of tolerance and are not limited by cold temperature. It is found throughout the United States and several Canadian provinces. (c) However, the green anole (*Anolis carolinensis*) has a very narrow range of tolerance and is found only in the warm, humid southeastern states.

Habitat and Niche

As we have just seen, it is impossible to understand an organism apart from its environment. The environment influences the organism, and organisms affect the environment. To focus attention on specific elements of this interaction, ecologists have developed two concepts that need to be clearly understood: habitat and niche.

Habitat—Place

The **habitat** of an organism is the space that the organism inhabits, the place where it lives (its address). We tend to characterize an organism's habitat by highlighting some prominent physical or biological feature of its environment such as soil type, availability of water, climatic conditions, or predominant plant species that exist in the area. For example, mosses are small plants that must be covered by a thin film of water in order to reproduce. In addition, many kinds dry out and die if they are exposed to sunlight, wind, and drought. Therefore, the typical habitat of moss is likely to be cool, moist, and shady. (See figure 5.4.) Likewise, a rapidly flowing, cool, well-oxygenated stream with many bottom-dwelling insects is good trout habitat, while open prairie with lots of grass is preferred by bison, prairie dogs, and many kinds of hawks and falcons. The particular biological requirements of an organism determine the kind of habitat in which it is likely to be found.

FIGURE 5.4 Moss Habitat The habitat of mosses is typically cool, moist, and shady, since many mosses die if they are subjected to drying. In addition, mosses must have a thin layer of water present in order to reproduce sexually.

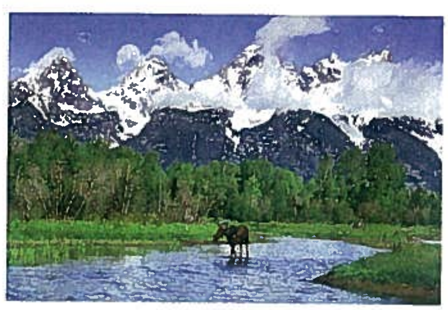
Niche—Role

The **niche** of an organism is the functional role it has in its surroundings (its profession). A description of an organism's niche includes all the ways it affects the organisms with which it interacts as well as how it modifies its physical surroundings. In addition, the description of a niche includes all of the things that happen to the organism. For example, beavers frequently flood areas by building dams of mud and sticks across streams. (See figure 5.5.) The flooding has several effects. It provides beavers with a larger area of deep water, which they need for protection; it

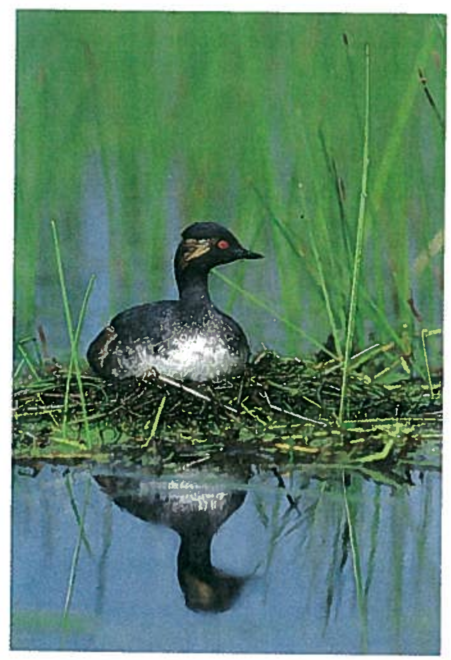
Beavers eat woody plants

Beaver dam

Beaver gnawing



Beaver ponds provide habitat



Beaver ponds provide habitat

FIGURE 5.5 The Ecological Niche of a Beaver The ecological niche of an organism is a complex set of interactions between an organism and its surroundings, which includes all of the ways an organism influences its surroundings as well as all of the ways the organism is affected by its environment. A beaver's ecological niche includes building dams and flooding forested areas, killing trees, providing habitat for waterbirds and other animals, serving as food for predators, and many other effects.

FIGURE 5.6 **The Niche of a Dandelion** A dandelion is a familiar plant that commonly invades disturbed sites because it produces many seeds that are blown easily to new areas. It serves as food for various herbivores, supplies nectar to bees, and can regrow quickly from its root if its leaves are removed.

provides a pond habitat for many other species of animals such as ducks and fish; and it kills trees that cannot live with their roots under water. The animals that are attracted to the pond and the beavers often become food for predators. After the beavers have eaten all the suitable food, such as aspen, they abandon the pond, migrate to other areas along the stream, and begin the whole process over again.

In this recitation of beaver characteristics, we have listed several effects that the animal has on its local environment. It changes the physical environment by flooding, it kills trees, it enhances the environment for other animals, and it is a food source for predators. This is only a superficial glimpse of the many aspects of the beaver's interaction with its environment. A complete catalog of all aspects of its niche would make up a separate book.

Another familiar organism is the dandelion. (See figure 5.6.) Its niche includes the fact that it is an opportunistic plant that rapidly becomes established in sunny, disturbed sites. It can produce thousands of parachutelike seeds that are easily carried by the wind over long distances. (You have probably helped this process by blowing on the fluffy, white collections of seeds of a mature dandelion fruit.) Furthermore, it often produces several sets of flowers per year. Since there are so many seeds and they are so easily distributed, the plant can easily establish itself in any sunny, disturbed site, including lawns. Since it is a plant, one major aspect of its niche is the ability to carry on photosynthesis and grow. It uses water and nutrients from the soil to produce new plant parts. Since dandelions need direct sunlight to grow successfully, mowing lawns helps provide just the right conditions for dandelions because the vegetation is never allowed to get so tall that dandelions are shaded. Many kinds of animals, including some humans, use the plant for food. The young leaves may be eaten in a salad, and the blossoms can be used to make dandelion wine. Bees visit the flowers regularly to obtain nectar and pollen.

THE ROLE OF NATURAL SELECTION AND EVOLUTION

Since organisms generally are well adapted to their surroundings and fill a particular niche, it is important that we develop an understanding of the processes that lead to this high degree of adaptation. Furthermore, since the mechanisms that result in adaptation occur within a species, we need to understand the nature of a species.

GENES, POPULATIONS, AND SPECIES

We can look at an organism from several points of view. We can consider an individual, groups of individuals of the same kind, or groups that are distinct from other groups. This leads us to discuss three interrelated concepts.

Genes are distinct pieces of DNA that determine the characteristics an individual displays. There are genes for structures such as leaf shape or feather color, behaviors such as cricket chirps or migratory activity, and physiological processes such as photosynthesis or muscular contractions. Each individual has a particular set of genes.

A **population** is considered to be all the organisms of the same kind found within a specific geographic region. (See figure 5.7.) The individuals of a population will have very similar sets of genes, although there will be some individual variation. Because some genetic difference exists among individuals

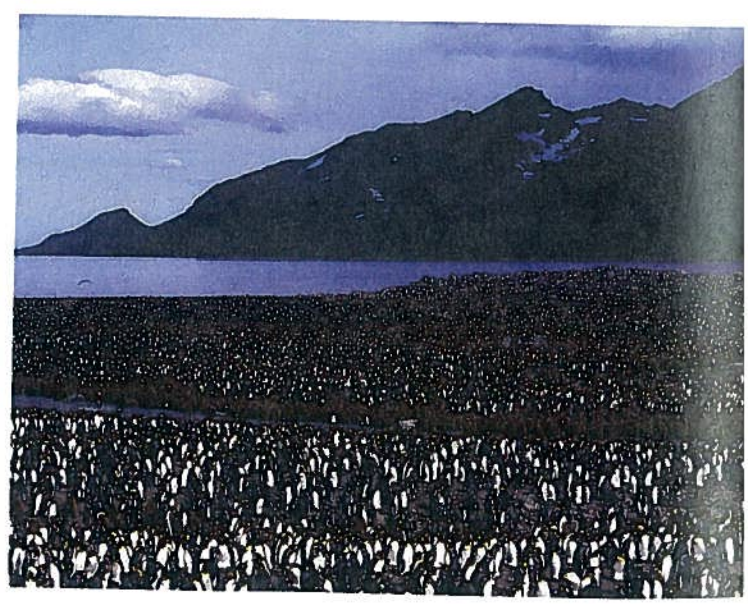


FIGURE 5.7 **A Penguin Population** This population of King penguins is from South Georgia Island near Antarctica.

in a population, a population contains more kinds of genes than any individual within the population. Reproduction also takes place among individuals in a population so that genes are passed from one generation to the next. The concept of a species is an extension of this thinking about genes, groups, and reproduction.

A **species** is a population of all the organisms potentially capable of reproducing naturally among themselves and having offspring that also reproduce. Therefore, the concept of a species is a population concept. *An individual organism is not a species but a member of a species.* It is also a genetic concept, since individuals that are of different species are not capable of exchanging genes through reproduction. (See figure 5.8.)

Some species are easy to recognize. We easily recognize humans as a distinct species. Most people recognize a dandelion when they see it and do not confuse it with other kinds of plants that have yellow flowers. Other species are not as easy to recognize. Most of us cannot tell one species of mosquito from another or identify different species of grasses. Because of this, we tend to lump organisms into large categories and do not recognize the many subtle niche differences that exist among the similar-appearing species. However, species of mosquitoes are quite distinct from one another genetically and occupy different niches. Only certain species of mosquitoes carry and transmit the human disease malaria. Other species transmit the dog heartworm parasite. Each mosquito species is active during certain portions of the day or night. And each species requires specific conditions to reproduce.

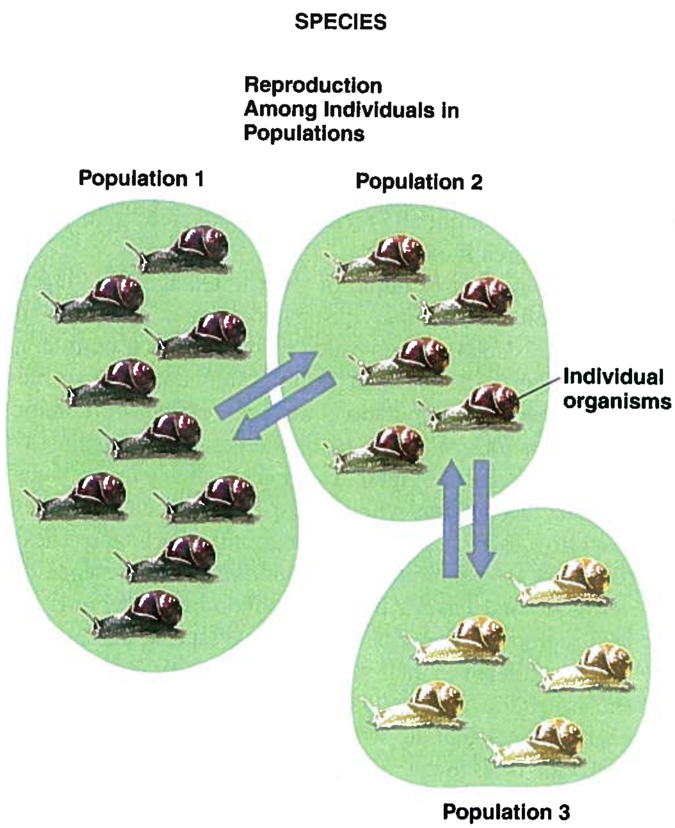


FIGURE 5.8 **The Species Concept** A species is all the organisms of a particular kind capable of interbreeding and producing fertile offspring. Often species consist of many distinct populations that show genetic differences from one another.

Natural Selection

As we have seen, each species of organism is specifically adapted to a particular habitat in which it has a very specific role (niche). But how is it that each species of plant, animal, fungus, or bacterium fits into its environment in such a precise way? Since most of the structural, physiological, and behavioral characteristics organisms display are determined by the genes they possess, these characteristics are passed from one generation to the next when individuals reproduce. The process that leads to this close fit between the characteristics organisms display and the demands of their environment is known as natural selection.

Charles Darwin is generally credited with developing the concept of natural selection. Although he did not understand the gene concept, he understood that characteristics were passed from parent to offspring. He also observed the highly adaptive nature of the relationship between organisms and their environment and developed the concept of natural selection to explain how this adaptation came about. (See figure 5.9.)

Natural selection is the process that determines which individuals within a species will reproduce and pass their genes to the next generation. The changes that we see in the genes and the characteristics displayed by successive generations of a population of organisms over time is known as **evolution.** Thus, natural

FIGURE 5.9 **Charles Darwin** Charles Darwin observed that each organism fit into its surroundings. He developed the theory of natural selection to explain how adaptation came about.

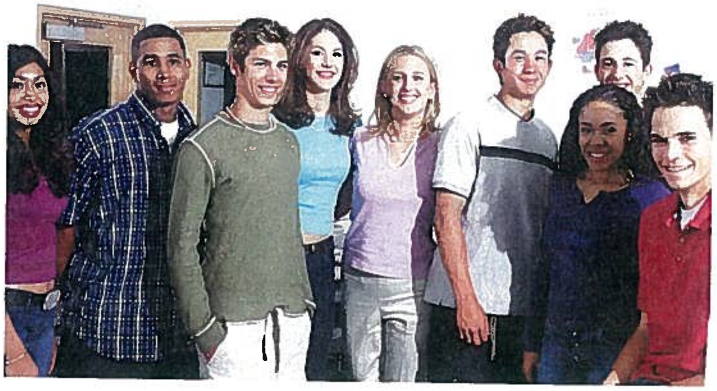


FIGURE 5.10 **Genetic Variation** Since genes are responsible for many facial characteristics, the differences in facial characteristics shown in this photograph are a good visual illustration of genetic variation. This population of students also differs in genes for height, susceptibility to disease, and many other characteristics.

selection is the mechanism that causes evolution to occur. Several conditions and steps are involved in the process of natural selection.

1. *Individuals within a species show genetically determined variation; some of the variations are useful and others are not.* (See figure 5.10.) For example, individual animals that are part of the same species show variation in color, size, or susceptibility to disease. Some combinations of genes are more valuable to the success of the individual than others.
2. *Organisms within a species typically produce many more offspring than are needed to replace the parents when they die. Most of the offspring die.* One blueberry bush may produce hundreds of berries with several seeds in each berry, or a pair of rabbits may have three to four litters of offspring each summer, with several young in each litter. Few of the seeds or baby rabbits become reproducing adults. (See figure 5.11.)

FIGURE 5.11 **Excessive Reproduction** One blueberry bush produces thousands of seeds (offspring). Only a few will actually germinate and only a few of the seedlings will become mature plants.

3. *The excess number of individuals results in a shortage of specific resources.* Individuals within a species must compete with each other for food, space, mates, or other requirements that are in limited supply. If you plant 100 bean seeds in a pot, many of them will begin to grow, but eventually, some will become taller and get the majority of the sunlight while the remaining plants are shaded and die. Great horned owls typically produce two young at a time, but if food is in short supply, the larger of the two young will get the majority of the food.
4. *Because of variation among individuals, some have a greater chance of obtaining needed resources and, therefore, have a greater likelihood of surviving and reproducing than others.* Individuals that have genes that allow them to obtain needed resources and avoid threats to their survival will be more likely to survive and reproduce. Even if less well-adapted individuals survive, they may mature more slowly and not be able to reproduce as many times as the more well-adapted members of the species.

   The degree to which organisms are adapted to their environment influences their reproductive success and is referred to as fitness. It is important to recognize that fitness does not necessarily mean the condition of being strong or vigorous. In this context, it means how well the organism fits in with all the aspects of its surroundings so that it successfully passes its genes to the next generation. For example, in a lodgepole pine forest, many lodgepole pine seedlings become established following a fire. Some grow more rapidly and obtain more sunlight and nutrients. Those that grow more rapidly are more likely to survive. These are also likely to reproduce for longer periods and pass more genes to future generations than those that die or grow more slowly.
5. *As time passes and each generation is subjected to the same process of natural selection, the percentage of individuals showing favorable variations will increase and those having unfavorable variations will decrease.* Those that reproduce more successfully pass on to the next generation the genes for the characteristics that made them successful in their environment, and the genes that made them successful become more common in future generations. Thus, each species of organism is continually refined to be adapted to the environment in which it exists.

One modern example of genetic change resulting from natural selection involves the development of pest populations that are resistant to the pesticides previously used to control them. Figure 5.12 shows a graph of the number of species of weeds that have populations that are resistant to commonly used herbicides. When an herbicide is first used against weed pests, it kills most of them. However, in many cases, some individual weed plants within the species happen to have genes that allow them to resist the effects of the herbicide. These individuals are better adapted to survive in the presence of the herbicide and have a higher likelihood of surviving. When they reproduce, they pass on to their offspring the same genes that contributed to their survival. After several generations of such selection, a majority of the individuals in the species will contain genes that allow them to resist the herbicide, and the herbicide is no longer effective against the weed.

Evolutionary Patterns

When we look at the effects of natural selection over time, we can see considerable change in the characteristics of a species and kinds of species present. Some changes take thousands or millions of years

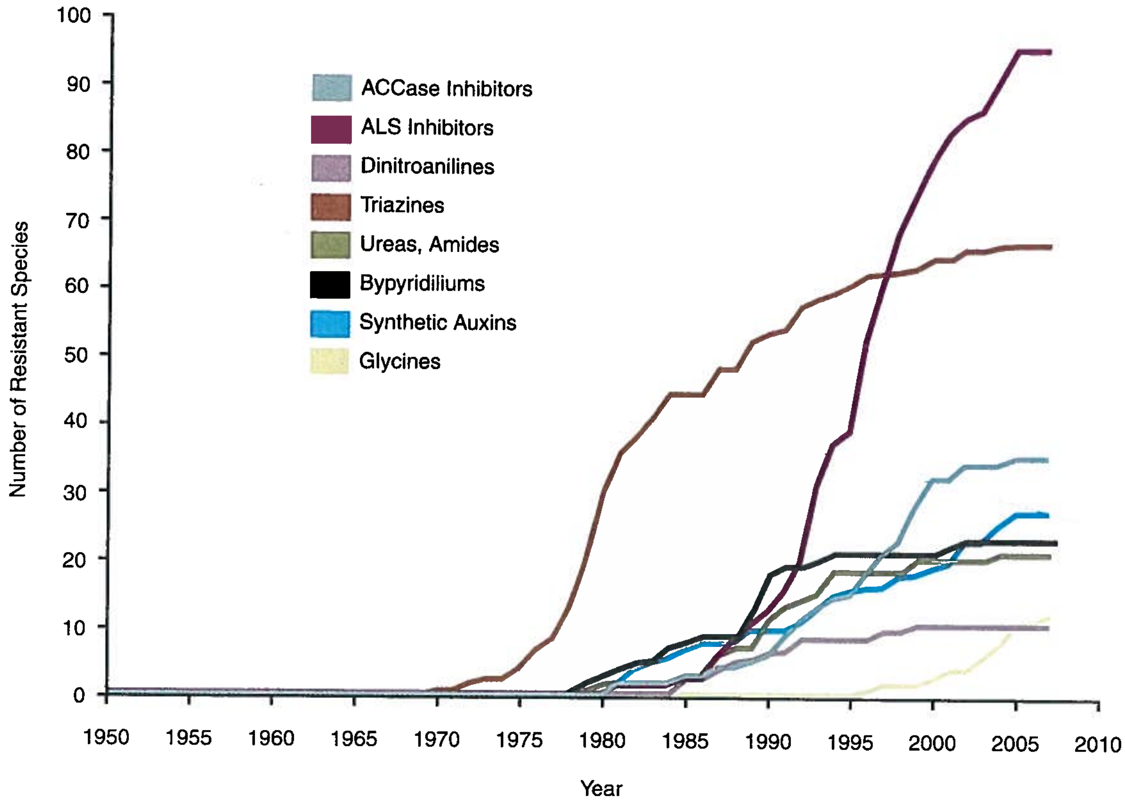


FIGURE 5.12 **Change Resulting from Natural Selection** Populations of weed plants that have been subjected repeatedly to herbicides often develop resistant populations. Those individual weed plants that were able to resist the effects of the herbicide lived to reproduce and pass on their genes for resistance to their offspring; thus, resistant populations of weeds develop. This graph shows the number of weeds with resistance to commonly used herbicides.

Source: Data from Ian Heap, "The International Survey of Herbicide Resistant Weeds," [cited 2 April 2008], Internet.

to occur. Others, such as resistance to pesticides, can occur in a few years. (See figure 5.12.) Natural selection involves the processes that bring about change in species, and the end result of the natural selection process observable in organisms is called evolution.

Scientists have continuously shown that this theory of natural selection can explain the development of most aspects of the structure, function, and behavior of organisms. It is the central idea that helps explain how species adapt to their surroundings. When we discuss environmental problems, it is helpful to understand that species change and that as the environment is changed, either naturally or by human action, some species will adapt to the new conditions while others will not.

There are many examples that demonstrate the validity of the process of natural selection and the evolutionary changes that result from natural selection. In recent times, we have become aware that many species of insects, weeds, and bacteria have become resistant to the insecticides, herbicides, and antibiotics that formerly were effective against them.

When we look at the evolutionary history of organisms in the fossil record over long time periods, it becomes obvious that new species come into being while other species disappear.

Speciation

Speciation is the production of new species from previously existing species. It is thought to occur as a result of a species dividing into two isolated subpopulations. If the two subpopulations contain some genetic differences and their environments are somewhat different, natural selection will work on the two groups differently and they will begin to diverge from each other. Eventually, the differences may become so great that the two subpopulations are no longer able to interbreed. At this point, they are two different species. This process has resulted in millions of different species. Figure 5.13 shows a collection of a few of the thousands of species of beetles.

Among plants, another common mechanism known as polyploidy results in new species. **Polyploidy** is a condition in which the number of sets of chromosomes in the cells of the plant is increased. Many organisms are diploid; that is, they have two sets of chromosomes. They got a set from each parent, one set in the egg and one set in the sperm. Polyploid organisms may have several sets of chromosomes. The details of how polyploidy comes about are not important for this discussion. It is sufficient to recognize that many species of plants appear to have extra sets of chromosomes, and they are not able to reproduce with closely related species that have a different number of sets of chromosomes.

Extinction

Extinction is the loss of an entire species and is a common feature of the evolution of organisms. The environment in which

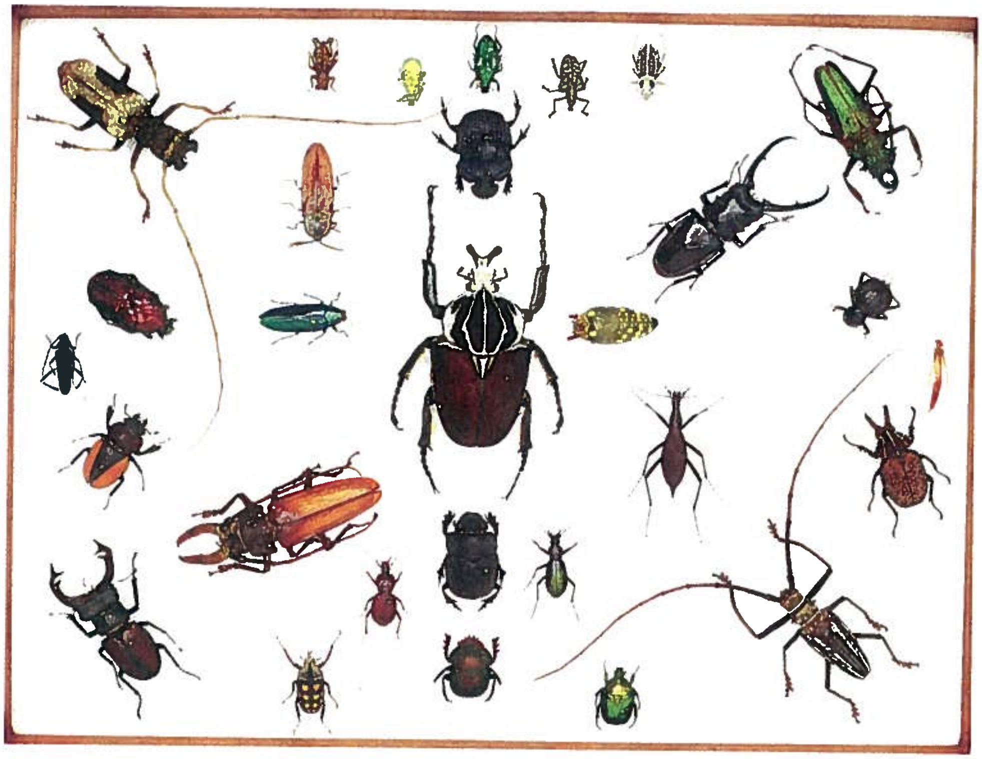


FIGURE 5.13 **Speciation** This photo shows a few of the many different species of beetles.

Natural selection is constantly at work shaping organisms to fit a changing environment. It is clear that humans have had a significant impact on the extinction of many kinds of species. Wherever humans have modified the environment for their purposes (farming, forestry, cities, hunting, and introducing exotic organisms), species are typically displaced from the area. If large areas are modified, entire species may be displaced. Ultimately, humans are also subject to evolution and the possibility of extinction as well.

Although extinction is a common event, there have been several instances of past mass extinctions in which major portions of the living world went extinct in a relatively short time. The background rate of extinction is estimated to be about 10 species per year. However, the current rate is much higher than that, leading many people to suggest that we may be in the middle of a mass extinction caused by human influences on the Earth. See chapter 11 on biodiversity for a more complete discussion.

organisms exist does not remain constant over long time periods. Those species that lack the genetic resources to cope with a changing environment go extinct. Of the estimated 500 million species of organisms that are believed to have ever existed on Earth since life began, perhaps only 5 million to 10 million are currently in existence. This represents an extinction rate of 98 to 99 percent. Obviously, these numbers are estimates, but the fact remains that extinction has been the fate of most species of organisms. In fact, studies of recent fossils and other geologic features show that only thousands of years ago, huge glaciers covered much of Europe and the northern parts of North America. Humans coexisted with mammoths, saber-toothed tigers, and giant cave bears. As the climate became warmer and the glaciers receded, and humans continued to prey on these animals, new pressures affected the organisms in the area. Some, including the mammoths, saber-toothed tigers, and giant cave bears, did not adapt and became extinct. (See figure 5.14.) Others, such as humans, horses, and many kinds of plants, adapted to the new conditions and so survive to the present.

It is also possible to have the local extinction of specific populations of a species. Most species consist of many different populations that may differ from one another in significant ways. Often some of these populations have small local populations that can easily be driven to extinction. While these local extinctions are not the same as the extinction of an entire species, local extinctions often result in the loss of specific gene combinations. Many of the organisms listed on the endangered species list are really local populations of a more widely distributed species.

Coevolution

Coevolution is the concept that two or more species of organisms can reciprocally influence the evolutionary direction of the other. In other words, organisms affect the evolution of other organisms. Since all organisms are influenced by other organisms, this is a common pattern.

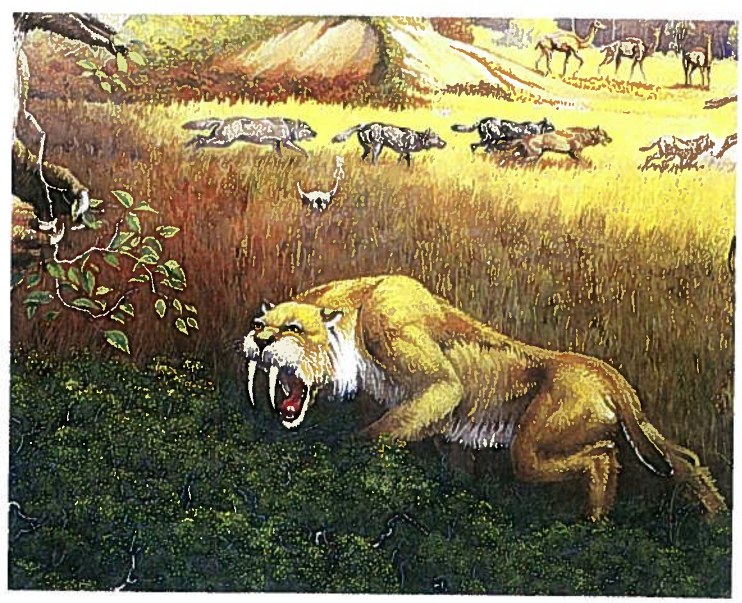


FIGURE 5.14 **Extinction** This figure shows a scene that would have been typical at the end of the last ice age. Nearly all of these large mammals are extinct.

For example, grazing animals and the grasses they consume have coevolved. Grasses that are eaten by grazing animals grow from the base of the plant near the ground rather than from the tips of the branches as many plants do. Furthermore, grasses have hard materials in their cell walls that make it difficult for animals to crush the cell walls and digest them. Grazing animals have different kinds of adaptations that overcome these deterrents. Many grazers have teeth that are very long or grow continuously to compensate for the wear associated with grinding hard cell walls. Others, such as cattle, have complicated digestive tracts that allow microorganisms to do most of the work of digestion.

Similarly, the red color and production of nectar by many kinds of flowers is attractive to hummingbirds, which pollinate the flowers at the same time as they consume nectar from the flower. In addition to the red color that is common for many flowers that are pollinated by hummingbirds, many such flowers are long and tubular. The long bill of the hummingbird is a matching adaptation to the shape of the flower. (See figure 5.15.)

The "Kinds of Organism Interactions" section will explore in more detail the ways that organisms interact and the results of long periods of coevolution.

FIGURE 5.15 **Coevolution** The red tubular flowers and the nectar they produce are attractive to hummingbirds. The long bill of the hummingbird allows it to reach the nectar at the base of the flower. The two kinds of organisms have coevolved.

KINDS OF ORGANISM INTERACTIONS

Ecologists look at organisms and how they interact with their surroundings. Perhaps the most important interactions occur between organisms. Ecologists have identified several general types of organism-to-organism interactions that are common in all ecosystems. When we closely examine how organisms interact, we see that each organism has specific characteristics that make it well suited to its role. An understanding of the concept of natural selection allows us to see how interactions between different species of organisms can result in species that are finely tuned to a specific role.

As you read this section, notice how each species has special characteristics that equip it for its specific role (niche). Because these interactions involve two kinds of organisms interacting, we should expect to see examples of coevolution. If the interaction between two species is the result of a long period of interaction, we should expect to see that each species has characteristics that specifically adapt it to be successful in its role.

PREDATION

One common kind of interaction called **predation** occurs when one organism, known as a **predator,** kills and eats another, known as the **prey.** (See figure 5.16.) The predator benefits from killing and eating the prey and the prey is harmed. Some examples of predator-prey relationships are lions and zebras, robins and earthworms, wolves and moose, and toads and beetles. Even a few plants show predatory behavior. The Venus flytrap has specially modified leaves that can quickly fold together and trap insects that are then digested.

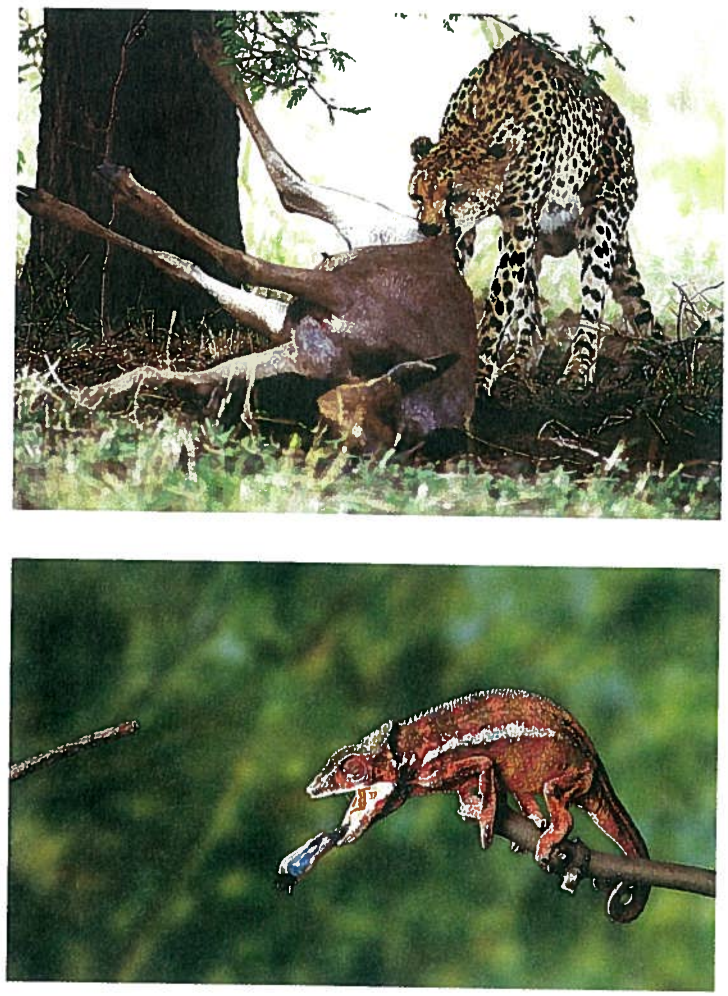


FIGURE 5.16 **Predator-Prey Relationship** Cheetahs are predators of impalas. Cheetahs can run extremely fast to catch the equally fast impalas. Impalas have excellent eyesight, which helps them see predators. The chameleon hunts by remaining immobile and ambushing prey. The long, sticky tongue is its primary means of capturing unsuspecting insects as they fly past.

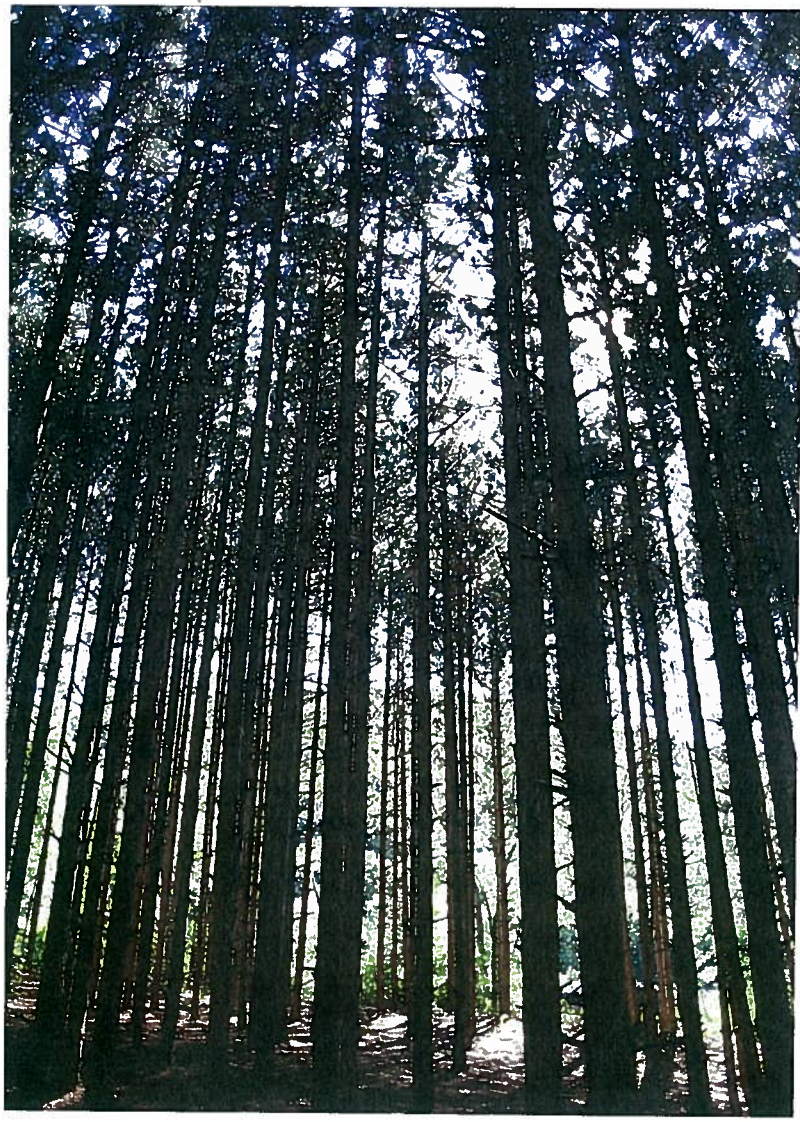


FIGURE 5.17 **Intraspecific Competition** Whenever a needed resource is in limited supply, organisms compete for it. Intraspecific competition for sunlight among these pine trees has resulted in the tall, straight trunks. Those trees that did not grow fast enough died.

To succeed, predators employ several strategies. Some strong and speedy predators (cheetahs, lions, sharks) chase and overpower their prey; other species lie in wait and quickly strike prey that happen to come near them (many lizards and hawks); and some (spiders) use snares to help them catch prey. At the same time, prey species have many characteristics that help them avoid predation. Many have keen senses that allow them to detect predators, others are camouflaged so they are not conspicuous, and many can avoid detection by remaining motionless when predators are in the area.

An adaptation common to many prey species is a high reproductive rate compared to predators. For example, field mice may have 10 to 20 offspring per year, while hawks typically have two to three. Because of this high reproductive rate, prey species can endure a high mortality rate and still maintain a viable population. Certainly, the *individual* organism that is killed and eaten is harmed, but the prey *species* is not, since the prey individuals that die are likely to be the old, the slow, the sick, and the less well-adapted members of the population. The healthier, quicker, and better-adapted individuals are more likely to survive. When these survivors reproduce, their offspring are more likely to have characteristics that help them survive; they are better adapted to their environment.

At the same time, a similar process is taking place in the predator population. Since poorly adapted individuals are less likely to capture prey, they are less likely to survive and reproduce. The predator and prey species are both participants in the natural selection process. This dynamic relationship between predator and prey species is a complex one that continues to intrigue ecologists.

Competition

A second type of interaction between species is **competition,** in which two organisms strive to obtain the same limited resource. Ecologists distinguish two different kinds of competition. **Intraspecific competition** is competition between members of the same species. **Interspecific competition** is competition between members of different species. In either case organisms are harmed to some extent. However, this does not mean that there is no winner or loser. If two organisms are harmed to different extents, the one that is harmed less is the winner in the competition, and the one that is harmed more is the loser.

Examples of Intraspecific Competition

Lodgepole pine trees release their seeds following a fire. Thus, a large number of lodgepole pine seedlings begin growing close to one another and compete for water, minerals, and sunlight. None of the trees grows as rapidly as it could because its access to resources is restricted by the presence of the other trees. Eventually, because of differences in genetics or specific location, some of the pines will grow faster and will get a greater share of the resources. The taller trees will get more sunlight and the shorter trees will receive less. In time, some of the smaller trees die. They lost the competition. (See figure 5.17.)

Similarly, when two robins are competing for the same worm, only one gets it. Both organisms were harmed because they had to expend energy in fighting for the worm, but one got some food and was harmed less than the one that fought and got nothing. Other examples of intraspecific competition include corn plants in a field competing for water and nutrients, male elk competing with one another for the right to mate with the females, and wood ducks competing for the holes in dead trees to use for nesting sites.

Examples of Interspecific Competition

Many species of predators (hawks, owls, foxes, coyotes) may use the same prey species (mice, rabbits) as a food source. If the supply of food is inadequate, intense competition for food will occur and certain predator species may be more successful than others. (See figure 5.18.)

In grasslands, the same kind of competition for limited resources occurs. Rapidly growing, taller grasses get more of the water, minerals, and sunlight, while shorter species are less successful.

FIGURE 5.18 **Interspecific Competition** The lion and vultures are involved in interspecific competition for the carcass of the zebra. At this point, the lion is winning in the competition.

Often the shorter species are found to be more abundant when the taller species are removed by grazers, fire, or other activities.

Competition and Natural Selection

Competition among members of the same species is a major force in shaping the evolution of a species. When resources are limited, less well-adapted individuals are more likely to die or be denied mating privileges. Because the most successful organisms are likely to have larger numbers of offspring, each succeeding generation will contain more of the genetic characteristics that are favorable for survival of the species in that particular environment. Since individuals of the same species have similar needs, competition among them is usually very intense. A slight advantage on the part of one individual may mean the difference between survival and death.

As with intraspecific competition, one of the effects of interspecific competition is that the species that has the larger number of successful individuals emerges from the interaction better adapted to its environment than its less successful rivals.

The **competitive exclusion principle** is the concept that no two species can occupy the same ecological niche in the same place at the same time. The more similar two species are, the more intense will be the competition between them. If one of the two competing species is better adapted to live in the area than the other, the less-fit species must evolve into a slightly different niche, migrate to a different geographic area, or become extinct.

When the niche requirements of two similar species are examined closely, we usually find significant differences between the niches of the two species. The difference in niche requirements reduces the intensity of the competition between the two species. For example, many small forest birds eat insects. However, they may obtain them in different ways; a flycatcher sits on a branch and makes short flights to snatch insects from the air, a woodpecker excavates openings to obtain insects in rotting wood, and many warblers flit about in the foliage capturing insects.

Even among these categories there are specialists. Different species of warblers look in different parts of trees for their insect food. Because of this niche specialization, they do not directly compete with one another. (See figure 5.19).

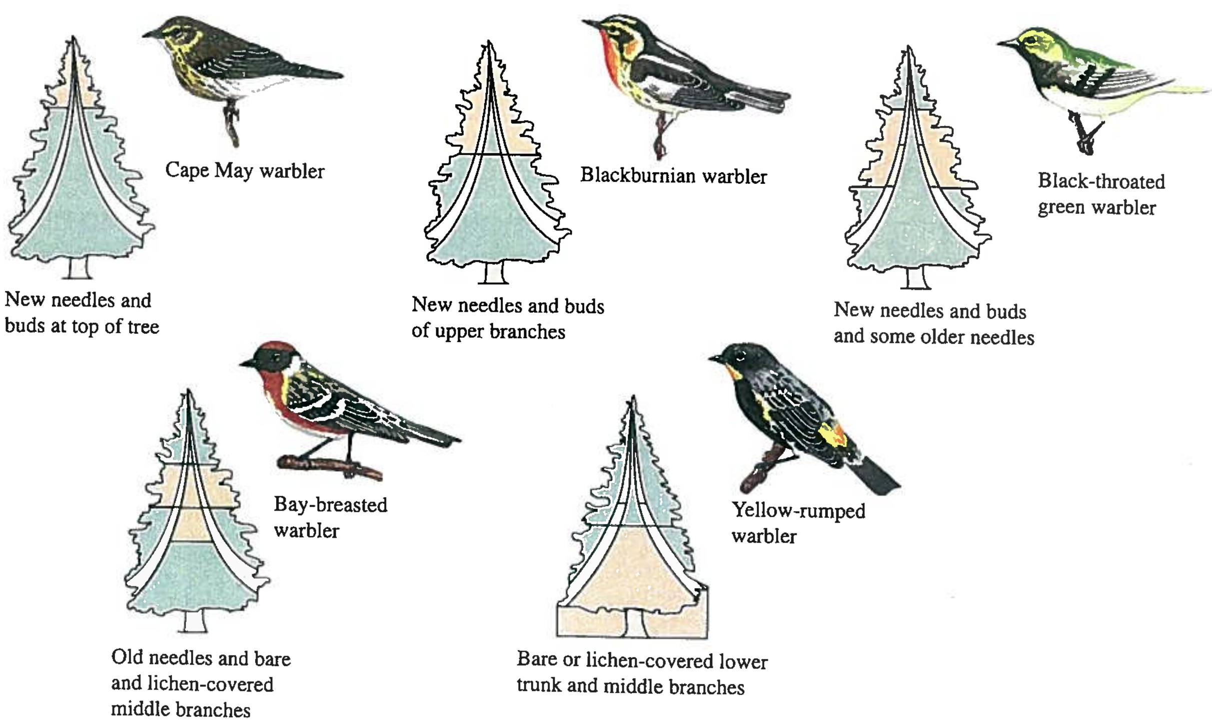


FIGURE 5.19 **Niche Specialization** Although all of these warblers have similar feeding habits, the intensity of competition is reduced because they search for insects on different parts of the tree.