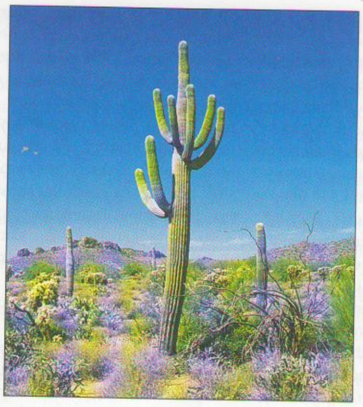

FIGURE 3.3 *Saguaro cacti, symbolic of the Sonoran desert, are an excellent example of distribution controlled by a critical environmental factor. Extremely sensitive to low temperatures, saguaros grow only where minimum temperatures never dip below freezing for more than a few hours at a time.*

Sometimes, the requirements and tolerances of species are useful indicators of specific environmental characteristics. The presence or absence of such species can tell us something about the community and the ecosystem as a whole. Lichens and eastern white pine, for example, are indicators of air pollution because they are extremely sensitive to sulfur dioxide and acid precipitation. Bull thistle is a weed that grows on disturbed soil but is not eaten by cattle; therefore, an abundant population of bull thistle in a pasture is a good indicator of overgrazing. Similarly, anglers know that trout species require clean, well-oxygenated water, so the presence or absence of trout can be an indicator of water quality.

Evolution: Natural Selection and Adaptation

How is it that mussels have developed the ability to endure pounding waves, daily exposure to drying sun and wind, and seasonal threats of extreme cold or hot temperatures? How does the saguaro survive in the harsh temperatures and extreme dryness of the desert? We commonly say that each of these species is "adapted" to its special set of conditions, but what does that mean? **Adaptation,** when species acquire traits that allow them to survive in their environments, is one of the most important concepts in biology.

We use the term *adapt* in two ways. One is a limited range of physiological modifications (called acclimation) available to individual organisms. If you keep houseplants inside all winter, for example, and then put them out in full sunlight in the spring, they get sunburned. If the damage isn't too severe, your plants will probably grow new leaves with a thicker cuticle and denser pigments that protect them from the sun. They can adapt to some degree, but the change isn't permanent. Another winter inside will make them just as sensitive to the sun as before. Furthermore, t changes they acquire are not passed on to their offsprin Although the potential to acclimate is inherited, each generati must develop its own protective epidermis.

Another type of adaptation operates at the population lev and is brought about by inheritance of specific genetic traits th allow a species to live in a particular environment. This process explained by the theory of **evolution**. This theory is mainly attri uted to Charles Darwin (see "Darwin and the Theory of Evol tion" at the beginning of this chapter), but it was also develop independently and simultaneously by Alfred Russel Wallace, wh documented species differentiation in Indonesia. According to th theory, species change gradually through competition for scar resources. **Natural selection** describes the process in which bett competitors survive and reproduce more successfully. Poor competitors are more likely to die or to fail to reproduce. Note th "better competitors" could have any trait that provides individua with some advantage over their peers. Bigger bills, better camou flage, or more attractive plumage or songs each could provic advantages in different circumstances. Individuals carrying advar tageous traits are most likely to reproduce successfully, thus pass ing on those traits.

Natural selection occurs because small, random mutation (changes in genetic material) occur spontaneously in every popu lation. These random differences create genetic diversity (natura variability in traits) in a population. Depending on environmenta conditions, some traits may be more advantageous than others Limited resources or environmental conditions may exert **selec tive pressure** on a population, reducing the chance that less f individuals will reproduce successfully. In such cases, individual with advantageous traits become relatively more abundant in th population.

It is important to remember that mutations can be negativ as well as positive. That is, the characteristics created by a partic ular genetic change can be either harmful or beneficial. Natura selection tends to discard the negative traits and preserve the help ful ones.

What environmental factors cause selective pressure anc influence fertility or survivorship in nature? Some important fac tors include (1) physiological stress due to inappropriate levels o some critical environmental factor, such as moisture, light, temperature, pH, or specific nutrients; (2) predation, including parasitism and disease; (3) competition; and (4) luck. In some cases the organisms that survive environmental catastrophes or find their way to a new habitat where they start a new population may simply be lucky rather than more fit or better suited to subsequent environmental conditions than their less fortunate contemporaries.

Speciation

Given enough time, many small changes (mutations) may collectively allow a species to become better suited to new environmental conditions. Sometimes, evolution creates entirely new species, physically distinct from their ancestors. The development of new species is known as speciation. Speciation can result from the

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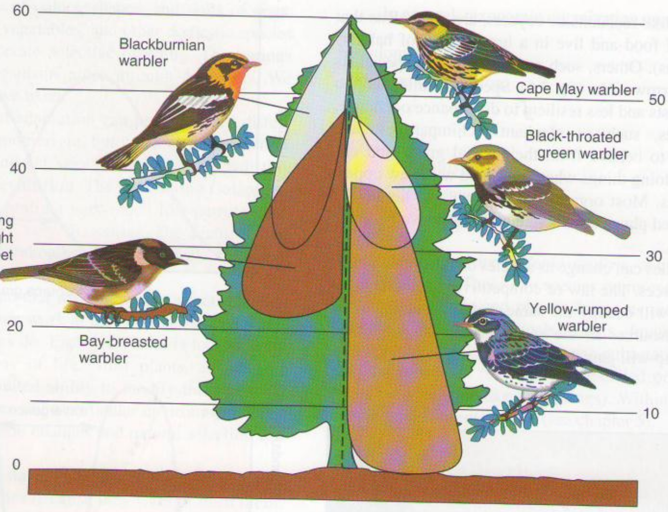

FIGURE 3.8 *Several species of wood warblers use different strata of the same forest, thereby demonstrating resource partitioning and the concept of the ecological niche. This is a classic example of the principle of competitive exclusion.*
Source: Original observation by R. H. MacArthur.

seeds long distances (fig. 3.9). Many weeds are generalist species, able to tolerate a wide variety of environmental conditions (hot, cold, sunny, shady, dry, wet) and to endure environmental change. Ecologically, these attributes make such species excellent competitors in the environmental conditions of your yard. Weeds are also frequently *pioneer species,* able to quickly colonize open, disturbed, or bare ground. Such species can play important ecological roles, covering bare soil and reducing erosion, for example. If they have no natural predators, they can also quickly overwhelm other vegetation, causing significant environmental change.

Many animals can be considered "weedy" species as well. Generalist, opportunistic species, such as starlings and English sparrows, raccoons, and rats, all spread readily and can tolerate a wide range of climate and environmental conditions. Ecologically, these traits are advantageous to these species. Their aggressiveness can quickly alter environments in which they arrive, however.

SPECIES INTERACTIONS

Predation and competition for scarce resources are major factors in evolution and adaptation. Not all biological interactions are competitive, however. Organisms also cooperate with, or at least tolerate, members of their own species as well as individuals of other species in order to survive and reproduce. In some cases, different organisms depend on each other to help acquire resources. In this section, we will look more closely at the different interactions within and between species that shape biological communities.

FIGURE 3.9 *Dandelions and other opportunistic species generally produce many highly mobile offspring.*

Predation

All organisms need food to live. Producers make their own food, and consumers eat organic matter created by other organisms. In most communities, as we saw in chapter 2, photosynthetic plants

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and algae are the producers. Consumers include herbivores, carnivores, omnivores, scavengers, detritivores, and decomposers. With which of these categories do you associate the term predator? Ecologically, a **predator** is any organism that feeds directly upon another living organism, whether or not it kills its prey to do so (fig. 3.10). By this definition, herbivores, carnivores, and omnivores that feed on live prey are predators, but scavengers, detritivores, and decomposers that feed on dead things are not. In this broad sense, parasites (organisms that feed on a host organism or steal resources from it without necessarily killing it) and even pathogens (disease-causing organisms) might also be considered predator organisms.

Predation is a potent and complex influence on the population balance of communities involving (1) all stages of the life cycles of predator and prey species, (2) many specialized food-obtaining mechanisms, and (3) specific prey-predator adaptations that either resist or encourage predation.

Predatory relationships can change dramatically with life stages. In marine intertidal ecosystems, many crustaceans, mollusks, and worms release eggs directly into the water, and the eggs and free-living larval and juvenile stages are part of the floating community, or plankton (fig. 3.11). Planktonic animals feed upon each other and are food for successively larger carnivores, including small fish. As prey species mature, their predators change. Barnacle larvae are planktonic and are eaten by fish. Adult barnacles, on the other hand, build hard shells that protect them from fish but can be crushed by limpets and other mollusks. Predators also may change their feeding targets. Adult frogs, for instance, are carnivores, but the tadpoles of most species are grazing herbivores. Sorting out the trophic levels in these communities can be very difficult.

Predation can be an important factor in controlling populations of both prey organisms and their consumers. The cyclamen mite (*Tarsonemus sp.*), for example, is a pest of strawberry crops in California. It is kept in check by a predatory mite in the genus *Typhlodromus*. When predators are removed, cyclamen mite populations explode and can severely damage a crop. If predators are re-introduced, they quickly reduce the cyclamen mite populations and bring them under control.

FIGURE 3.10 *Insect herbivores are predators as much as lions and tigers are. In fact, insects consume the vast majority of biomass in the world. Complex patterns of predation and defense have often evolved between insect predators and their plant prey.*

FIGURE 3.11 *Microscopic plants and animals form the basic levels of many aquatic food chains and account for a large percentage of total world biomass. Many oceanic plankton are larval forms that have very different habitats and feeding relationships than their adult forms.*

Given enough time, these trophic relationships can exert selective pressure that favors evolutionary adaptation. The predator becomes more efficient at finding and feeding, and the prey becomes more effective at escape or avoidance. In plants, predator avoidance is often accomplished with thick bark, spines, thorns, or chemical defenses. Animal prey may become very adept at hiding, fleeing, or fighting back against predators. Predators, in turn, evolve mechanisms to overcome the defenses of their prey. This process in which species exert selective pressure on each other is called **coevolution**. Coevolution can also be mutually beneficial: many plants and pollinators have evolved together, each aiding the other.

Competition

Competition is another kind of antagonistic relationship within a community. For what do organisms compete? To answer this question, think again about what all organisms need to survive: energy and matter in usable forms, space, and specific sites for life activities. Plants compete for growing space for root and shoot systems so they can absorb and process sunlight, water, and nutrients. Animals compete for living, nesting, and feeding sites, as well as for food, water, and mates. Competition among members of the same species is called intraspecific competition, whereas competition between members of different species is called interspecific competition.

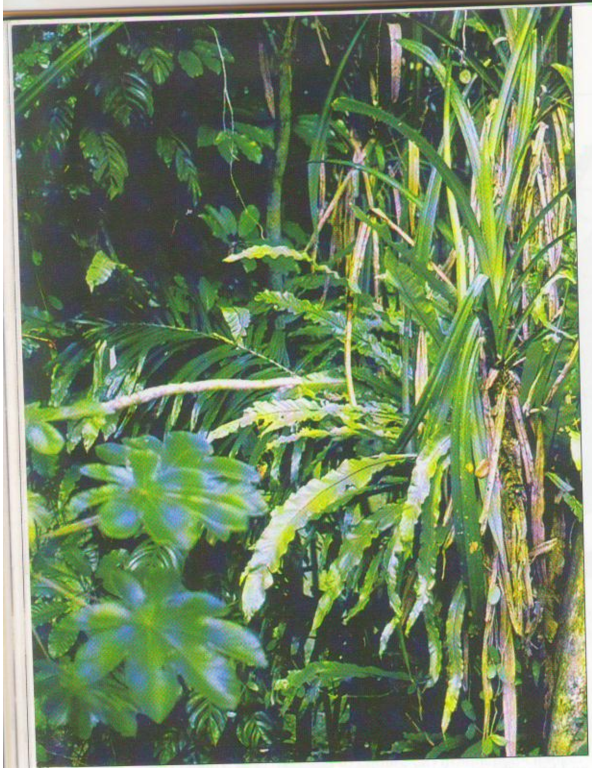

FIGURE 3.12 *Plants compete for light and growing space in this Indonesian rainforest. Epiphytes, such as the ferns and bromeliads shown here, find a place to grow in the forest canopy by perching on the limbs of large trees. This may be a commensal relationship if the epiphytes don't hurt their hosts. Sometimes, however, the weight of the epiphytes breaks off branches and even topples whole trees.*

If you look closely at a patch of weeds growing on good soil early in the summer, you likely will see several types of interspecific competition. First of all, many weedy species attempt to crowd out their rivals by producing prodigious numbers of seeds. After the seeds germinate, the plants race to grow the tallest, cover the most ground, and get the most sun. You may observe several strategies to do this. For example, vines don't build heavy stems of their own; they simply climb up over their neighbors to get to the light.

We often think of competition among animals as a bloody battle for resources, "nature red in tooth and claw." In fact, many animals tend to avoid fighting if possible. It's not worth getting injured. Most confrontations are more noise and show than actual fighting. Often competition is a matter of getting to food or habitat first or being able to use it more efficiently. As we discussed earlier, each species has a tolerance range for abiotic factors. Repeated studies have shown that when two species compete, the one closest to its optimum range of abiotic conditions will have an advantage and, more often than not, will prevail.

Intraspecific competition (within species) can be just as intense as interspecific competition (between species). Members of the same species have the same space and nutritional requirements; therefore, they compete directly for these environmental resources. How do organisms cope with intraspecific competition? One way is by dispersing: plants use wind, water, and passing animals to disperse seeds away from the parent plant. Young animals are forced to leave the parents' territory as soon as they are independent. Territoriality, vigorously defending territory, is a way of minimizing competition within a species. From grizzly bears to song birds, many species vigorously defend territories—and food and water sources—from others of their own kind. Another way to reduce intraspecific competition is resource partitioning. Often the young of a species use resources differently than mature individuals. A leaf-munching caterpillar uses different food sources than a nectar-sipping adult butterfly. Crabs start out as floating planktonic larvae, which do not compete with bottom-crawling adult forms. In these examples, the adults and juveniles of each species do not compete because they occupy different ecological niches.

Symbiosis

In contrast to predation and competition, symbiotic interaction between organisms can be nonantagonistic. **Symbiosis** is the inti mate living together of members of two or more species. Symb otic relationships often enhance the survival of one or bot partners. **Commensalism** is a type of symbiosis in which or member clearly benefits and the other apparently is neither bene fited nor harmed. Cattle, for example, are often accompanied b cattle egrets and cowbirds, both of which catch insects kicked u as the cattle graze through a field. The birds benefit, while the ca tle seem indifferent. Many of the mosses, bromeliads, and oth plants growing on trees in the moist tropics are also considered be commensals (fig. 3.12). These epiphytes get water from ra and nutrients from leaf litter and dust fall, and often neither he nor hurt the trees on which they grow. In a way, the robins a sparrows that inhabit suburban yards are commensals wi humans.

Lichens are a combination of a fungus and a photosynthe partner, either an alga or a cyanobacteria. Their association is type of symbiosis called **mutualism**, in which both members the partnership benefit (fig. 3.13). Some ecologists believe t cooperative, mutualistic relationships may be more important evolution than we have commonly thought. Aggressive intera tions often are dangerous and destructive, while cooperation a compromise may have advantages that we tend to overlook. S vival of the fittest often may mean survival of those organisms t can live best with one another.

Parasitism, described earlier as a form of predation, a could be considered a type of symbiosis, where one species be fits and the other is harmed. All of these relationships have a be ing on such ecological issues as resource utilization, ni specialization, diversity, predation, and competition.