- For a species to continue to exist it must reproduce.
- Organisms reproduce sexually or asexually.
- Traits are passed from parents to offspring during reproduction.
- Each type of reproduction has advantages and disadvantages.
- Environmental and genetic factors cause variation among individuals in a population.
- Populations produce more offspring than the environment can support.
- In any population, some individuals have a better chance of surviving and reproducing than others.
- Natural selection causes populations to adapt to their environment over time.
- Adaptations help an organism survive in a particular environment.

Reproduction AND ADAPTATION

ometimes called Missouri's mini-deserts, glades are hot, rocky and dry. Organisms that live on glades have an array of special structures and behaviors—called **adaptations**—that help them survive these harsh conditions. For example, prickly pears, a kind of cactus found on Missouri's glades, have dense mats of roots that soak up the tiniest amount of rain. They also have spongelike tissues in their stems that store excess water. You can tell whether it has rained recently on a glade by the shape of the prickly pears you find. After a rain, prickly pears swell up like balloons; during droughts, they deflate and wrinkle.

Water isn't the only resource in short supply on a glade. Food also is hard to find. To catch grasshoppers and other animals, collared lizards can run at speeds up to 25 kilometers per hour. During really fast sprints, these lizards run upright on their hind legs, using their long tails for balance. This allows them to take strides up to three times longer than their body length. Not only is this speed a helpful adaptation for catching prey, it also helps collared lizards avoid becoming prey themselves.

Lichen grasshoppers aren't particularly fast, but they do have a useful adaptation—camouflage—that helps them avoid becoming lizard food. These small grasshoppers are the same color as the lichen-covered rocks on which they live and have light and dark bands that disguise the outline of their bodies. When lichen grasshoppers remain motionless, they are nearly invisible to collared lizards, roadrunners and other predators hoping to eat them.

Whether to gather water, catch food or avoid being eaten, each of these traits can be thought of as a way to survive some environmental challenge. The organisms involved, however, didn't one day decide to grow more roots, run faster or change their color. Each of these traits took time to come about. The purpose of this chapter is to explain how over time, reproduction and natural selection bring about adaptations such as these.

For a species to continue to exist, it must reproduce.

Along with growth and survival, reproduction is one of the primary things that organisms do. **Reproduction** is the process by which new organisms are produced from existing organisms. Each prickly pear, lichen grasshopper and collared lizard—indeed every organism—exists as a result of reproduction.



Getting struck by a car is one of many ways turtles can die. Without reproduction to offset deaths, the turtle population would dwindle away to nothing.

Reproduction is not essential to the survival of individual organisms. Reproduction is essential, however, to the survival of each population and the species as a whole. Why? Because nature is a tough place to live! No matter how well-adapted an organism is to its environment, it eventually gets eaten, starves, catches a disease, succumbs to drought, drowns, freezes, gets struck by lightning, hit by a car, poisoned, or just wears out. Organisms die from many different causes. (Contrary to popular belief, no organism has ever died of boredom in an ecology class.) If individual organisms did not reproduce, the population and the species—would eventually dwindle to nothing. Reproduction is essential for populations and species to continue to exist.



Giving Bobwhite Reproduction a Boost

No animal illustrates the importance of reproduction better than bobwhite quail. This little brown bird leads a tough life. Many animals eat quail or their eggs, including raccoons, skunks, domestic cats, crows, hawks, snakes and even ants. During severe winters, quail are often found frozen to death in snowdrifts or entombed in layers of ice and sleet. Hail storms, heat waves and floods also take their toll.

Quail can perish from food shortages, disease, parasites, hunting, collisions with vehicles and decapitations from mower blades. On average, 90 percent of Missouri's quail die each year.

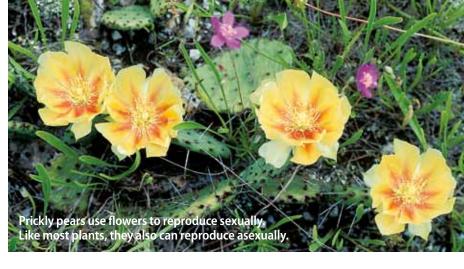
How do quail populations recover from such staggering losses? One word: reproduction. During the breeding season, quail can increase their numbers 160 percent on average and more than 300 percent in some cases. They achieve high reproduction in a variety of ways:

- Hens lay large clutches of 10 to 20 eggs.
- Quail are persistent re-nesters. When their first nest is lost to predators or weather, hens attempt to nest a second or even third time.
- Hens are promiscuous. While their mate incubates the nest, females go away to breed with a second male and lay another clutch of eggs.
- Quail often renest after successfully raising their first clutch of chicks.
- Bobwhite chicks are precocial, which means they can run, feed and take care of themselves shortly after hatching. This allows the parents to abandon their broods after a few weeks and go back to reproducing.

Organisms reproduce sexually or asexually.

Reproduction can occur in two basic ways: asexually or sexually. In **asexual reproduction**, it takes only one parent to produce a new organism. In **sexual reproduction**, it takes two.

Asexual reproduction has many different forms (*Figure 2.1*). For many unicellular organisms, such as



bacteria and protists, asexual reproduction occurs through **binary fission**. During binary fission, a single cell divides into two separate cells, each a separate organism. Other organisms, such as hydras, reproduce asexually by **budding**. Budding occurs when a mass of cells—the bud—begins growing on the parent's body. When the bud has grown large enough, it breaks off of the parent, forming a new organism. Some organisms—including many insects and some fish, amphibians and reptiles—reproduce asexually through **parthenogenesis**. Meaning "virgin birth," parthenogenesis occurs when eggs from a female develop into offspring without being fertilized by a male. **Vegetative reproduction** is the way many plants reproduce asexually. This occurs when some part of the plant, such as its leaves, roots or stem, breaks off and begins growing into a separate organism.

Many multicellular organisms can reproduce both asexually and sexually. For example, most plants are capable of reproducing both asexually and sexually. Prickly pears undergo vegetative reproduction when

A bobwhite's ability to breed its way back from oblivion has important implications for resource managers. Quail are a game bird, harvested by hunters for food and sport. Managers regulate **bag limits** (the number of quail that can be harvested by a single hunter daily), what time of year hunting season occurs and how long hunting season lasts. In setting these regulations, managers take into account how many birds they predict will be shot by hunters and how many will die of natural causes. As



long as hunters leave enough quail to reproduce, the population can recover the following breeding season. Quail numbers have dropped in recent decades not because of hunting but because of habitat loss. Quail survive best in habitat that includes a mixture of shrubs, clumpy grasses, wildflowers, annual weeds and bare soil. This diversity of plants provides everything quail need to escape from predators, find food, build nests and raise their young. To provide this kind of habitat, managers might replant an overgrown pasture to native grasses and wildflowers, disk strips through a shrubby field to create bare ground and encourage the growth of annual weeds, or set a prairie on fire to stall the growth of trees. By creating more habitat and regulating hunting, managers are working to ensure quail can continue to do what quail do best: make more quail.

REPRODUCTION AND ADAPTATION

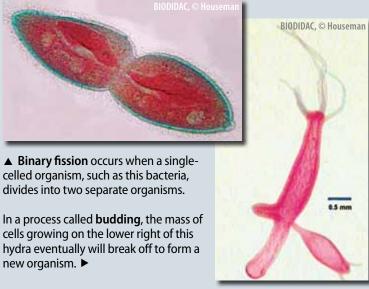
their fleshy stems (called pads) break off, take root and begin growing as a separate cactus. Prickly pears also can reproduce sexually. This occurs when the flower (containing eggs) of one prickly pear is fertilized with pollen (containing sperm) from a different prickly pear. Once fertilized, the flower produces seeds that can grow into new plants. In addition to plants, many insects and some fish, amphibians and reptiles can reproduce both asexually and sexually. With extremely rare exceptions, all birds and mammals reproduce only sexually.

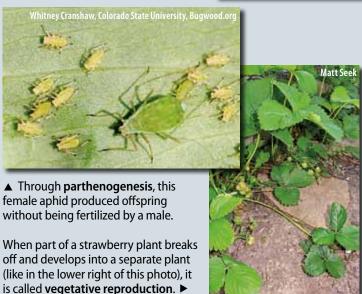
Traits are passed from parents to offspring during reproduction.

Before either type of reproduction occurs, parent organisms make a copy of their DNA. Think of DNA as the blueprint used to build a new organism. Within this blueprint are sections of DNA called **genes** that give instructions to create specific traits. Every organism has many genes for many different traits. For example, you have genes for the number of eyes you have, your hair color, blood type and whether or not you have a widow's peak. Where did you get these genes? From your parents, of course. They were passed on to you as a result of reproduction.

In asexual reproduction, a single parent passes on an exact copy of its genes to its offspring. Unless a mistake is made when the DNA is copied, the offspring are identical copies—clones—of their parents. A prickly pear made from asexual reproduction will have the exact same genetic blueprint as its parent.

Figure 2.1—Types of asexual reproduction





If every environmental factor—amount of sunlight, water and nutrients—is the same for both parent and offspring, the two also will have the same set of traits and look identical.

Offspring created by sexual reproduction have two versions of every gene: one from the mother and one from the father. How the two versions of each gene interact with each other determines the offspring's traits. Sometimes one version of a gene masks the properties of the other. When this happens, we say that one gene is dominant and the other is recessive. If your mom gives you the gene for a widow's peak, you'll have one, even if your dad gives you the gene for a straight hairline. The widow's peak gene is dominant over the straight hairline gene. In other cases, the two versions of each gene or a combination of several different genes will influence a particular trait. The color of your eyes is influenced by several different genes. Regardless of whether you are blue-eyed and widow-peaked or brown-eyed and straight-hairlined, these genetic traits were passed on to you from your parents.

Some traits, however, didn't come from your parents. Your ability to sink a three-pointer, speak pig-Latin or drive a car weren't inherited from your parents. Although you may have been genetically predisposed to be

a great basketball player, your ability to make a jump-shot is something you learned on your own. Only traits with a genetic basis can be passed from parents to offspring. This is true of all organisms.

Each type of reproduction has advantages and disadvantages.

Sexual reproduction is complicated and risky, but ecologists believe it has a big payoff that compensates for its many disadvantages. Table 2.1 compares asexual and sexual reproduction.

One disadvantage with sexual reproduction is that males are needed. Males use resources like food, water and space that could be used by females and their offspring. Males can't produce offspring—all they produce is sperm. To produce sperm and eggs most organisms must form and maintain reproductive organs, which takes energy and resources away from other things, such as growth and survival. For sperm and egg to meet, males and females have to find each other, a pollinator has to help or the organisms involved must rely on wind or water to bring their sex cells together—none of which are foolproof systems. For many organisms, mating is a major production involving elaborate courtship rituals, brightly colored flowers or plumage, or fighting between males (and sometimes females) for mates. These displays and conflicts expose organisms to predators, injury and other risks.

Since asexual reproduction involves only one parent, asexual organisms avoid these costs. Because it requires considerably less energy, asexual reproduction can occur quickly. Bacteria can reproduce every couple of hours, enabling a few bacteria to multiply to millions literally overnight. (Remember this next time you eat a

Table 2.1—A comparison of asexual and sexual reproduction

	ASEXUAL	SEXUAL
Number of parents needed	1	2
Forms	Binary fission Budding Parthenogenesis Vegetative reproduction	Sex
Organisms that use this type of reproduction	Single-celled organisms such as bacteria and protists Most plants and fungi Many simple animals such as hydras, corals and bryozoans Some insects, fish, amphibians and reptiles	Most plants and fungi Most fish, amphibians and reptiles Birds and mammals
Are offspring genetically different from their parents?	Rarely	Always
Cause of genetic variation	Mutation	Recombination of genes during meiosis Mixing of genes from two parents during fertilization Mutation
Advantages	Requires less energy Can produce offspring at a fast rate Offspring can colonize new habitats quickly Offspring can take advantage of temporary resources	Offspring are genetically different than their parents Genetic variation helps some offspring survive when environmental conditions change
Disadvantages	Offspring are identical to their parents Many offspring die when environmental conditions change	Must have males Eggs and sperm must meet Forming reproductive organs uses energy Courtship uses energy and exposes organisms to injury and predators



Mead's Milkweed

A scorching sun beats down on a line of biologists trudging slowly across
Paintbrush Prairie near Sedalia. The biologists keep their eyes on the ground,
searching amidst the vegetation for Mead's milkweed, one of Missouri's rarest plants.
Trying to find the little green plant with green flowers in a field of green grass is like
trying to find a needle in a haystack. To better the odds, the biologists are tied

together, 2 meters apart along a 30-meter rope. This keeps the researchers evenly spaced in a line and helps them track how much area they have surveyed.

Mead's milkweed provides a good example of the importance of sexual reproduction to the long-term survival of a species. Like several other milkweed species, Mead's is **self-incompatible**, which means it produces seeds only when pollen from one plant reaches the flowers of a different plant. For managers hoping to increase its numbers, this finicky reproductive habit poses a challenge.



Mead's milkweed once flourished throughout Missouri's tallgrass prairies. Today, with 99 percent of our prairies gone, it hangs on in just a few small and isolated populations scattered across the state. Many populations grow on prairies grazed by cattle or mowed for hay in mid-summer, right about the time Mead's milkweed begins producing flowers. Without flowers to make pollen, sexual reproduction has stopped in many populations. In a 2005 survey, biologists found 212 Mead's milkweed stems across the state, but only five seed pods. Without seeds, Mead's milkweed spreads by sprouting new stems from a long underground rhizome. Although they look like different plants, each of these stems is actually part of the same plant, and, therefore, genetically identical.

This loss of genetic diversity worries resource managers. With few seeds to colonize new prairies, Mead's milkweed populations have little chance of expanding beyond their current locations. With less genetic diversity, adaptation has a harder time keeping up with drastic environmental changes, and small, isolated Mead's milkweed populations are prone to being wiped out. To prevent this, resource managers are trying a number of approaches, including:

- Encouraging landowners with Mead's milkweed to delay grazing and haying until mid-September, after Mead's milkweed has dispersed its seeds
- Asking landowners to avoid spraying pesticides, which kill bees, a primary pollinator of Mead's milkweed
- Reducing herbicide use in areas where Mead's milkweed occurs
- Using prescribed fire to stimulate the growth of Mead's milkweed.

In addition, at Wah'Kon-Tah Prairie in southwestern Missouri, managers have planted over 150 Mead's milkweed plants obtained from botanical gardens. The managers hope the new plants will cross-pollinate with the prairie's naturally growing population and produce seed that can be used to start additional, genetically diverse populations.

Will these actions be enough to prevent Mead's milkweed from vanishing from Missouri's prairies? Back at Paintbrush Prairie, the biologists have finished their survey. After searching all day, they found 61 Mead's milkweed plants. Only three had flowers. Three, however, is better than none.

doughnut dropped on the floor. The five-second rule doesn't work!) Reproducing at a faster rate allows asexual organisms to take advantage of temporary resources and colonize new habitats. A big disadvantage of asexual reproduction is that offspring are usually identical to their parents. This makes it tough for asexual organisms to adapt to changing environments.

The big payoff for sexual reproduction is that mixing genes from two parents produces offspring with unique genetic blueprints. Unique genetic blueprints leads to offspring with unique traits. Populations with individuals having unique traits are more likely to survive if environmental conditions change. If all the members of the population had similar genes and traits, the population would be less likely to survive a disease outbreak or a change to its habitat. **Genetic homogeneity**—when all the members of a population have similar genetic blueprints—can cause extinction. Variation among members in a population is key to survival.



Environmental and genetic factors cause variation among individuals in a population.

For nearly any trait we can measure, some variation exists among the individuals making up a population. For example, if we were to catch all the 12-month-old collared lizards in a glade and measure their lengths from their snouts to the tips of their tails, we would find that some lizards are shorter and some longer than others. Likewise, if we measured the heights of prickly pears in a glade—or even the heights of all the students in your class—we would find a range of sizes. What causes this variation?

Some variation is caused by environmental factors. Some of the collared lizards we are studying may live where food is more abundant. With more to eat, these lizards might grow longer than their cousins who live where food is scarce. Some prickly pears may be bigger because they live in a sunnier or wetter location than other prickly pears.

Some of this variation is caused by genetic factors. The genetic blueprint used to build you is different from the blueprint used to build your best friend. In fact, none of the blueprints for anyone in your class is exactly alike. Each individual's DNA is unique. Two things cause this: mutations and the recombination of genes during sexual reproduction.

Every cell in an organism's body contains its complete genetic blueprint. Each time a cell divides, the parent cell makes a copy of its DNA to pass on to the new cell. A **mutation** occurs when a mistake is made during the copying, resulting in a genetic blueprint different from the original. Sometimes mutations cause the new cell to die. Sometimes mutations don't affect the new cell at all. And, sometimes mutations cause the new cell to have traits different from its parent. In unicellular organisms, like bacteria, cell division is a form of reproduction. For bacteria and other asexually reproducing organisms, mutations are the principal cause of genetic variation for the population. Mutations also can cause variation in sexually reproducing populations if the mutation occurs during the formation of sex cells. When an egg or sperm with a mutation combines with its counterpart, the mutation can affect the traits of the offspring.

Another cause of genetic variation occurs only in sexually reproducing populations. **Recombination** occurs during the formation of eggs and sperm when homologous chromosomes trade genetic information with each other. This causes the eggs or sperm to have a genetic blueprint different from the genetic blueprint

of the parent. Genes are mixed and shuffled a second time when a sperm fertilizes an egg to form a new organism. This twofold shuffling and mixing of genetic information creates variation in sexually reproducing populations.

Populations produce more offspring than the environment can support.

With abundant resources, populations can grow at startling rates. For example, imagine we have a population of 10 collared lizards—five males and five females. If we made sure that everything our lizards needed was in plentiful supply, within five years the population would increase to 2,500 lizards. Somewhere between years seven and eight the population would climb above 100,000 lizards. And, after just a decade of lizard-farming, our population would contain 2.5 million individuals! Left unchecked, our collared lizards would quickly overrun the earth, end civilization as we know it and generate a series of low-budget horror movies on the science fiction channel.

Of course this could not happen. Many factors would keep our lizard population—or any population—in check. Resources are rarely abundant, predators are often hungry, and the environment is harsh and unforgiving. Although populations produce many offspring, the environment usually can't support them all. Individuals with traits that help them compete for resources, avoid predators and survive harsh conditions are more likely to live long enough to reproduce.



Because their camouflage helps them avoid predators, lichen-colored grasshoppers have a better chance to survive and reproduce than pink-colored grasshoppers in the same environment.

In any population, some individuals have a better chance of surviving and reproducing than others.

Environmental factors, such as food shortages

and predators, keep

collared lizards

from overrunning the Earth.

Imagine a population of lichen grasshoppers. Some of the individuals in the population are lichen colored and other individuals are hot pink. The lichen-colored grasshoppers are more likely to avoid predators because they blend in with their environment. Because they are better at avoiding predators, more lichen-colored grasshoppers than hot-pink grasshoppers will likely survive to reproduce. When some individuals survive and reproduce at a higher rate than others in the same population, **differential reproduction** is occurring.

Differential reproduction occurs in most populations. Sometimes individuals reproduce

at a higher rate because, like the lichen-colored grasshoppers, they are better able to survive in their environment. Other times, individuals reproduce at a higher rate because they are able to attract more mates. Greater prairie-chickens live on Missouri grasslands. Male prairie-chickens fight with each other and do a courtship dance to attract females. Although fighting exposes males to injury and dancing exposes them to predators, the winning fighters and best dancers attract the most mates.



Greater Prairie-Chicken Translocation

Starlight shines down on a team of Missouri biologists creeping through a prairie in Kansas. One of the biologists swings an antenna from side to side, trying to home in on a sleeping prairie-chicken. Three months earlier, several of the stocky, foot-tall hens were trapped, fitted with tiny radio transmitters and released to go about the business of mating and nesting. Now, with their chicks hatched and partially grown,

the biologists have returned to catch them.

Tonight, the biologists are lucky. The antenna man points to a nearby clump of grass, and another biologist sneaks slowly forward. Suddenly, he swings a huge net down, capturing a hen and two of her chicks. They flap and struggle to get free.

In the 1860s, prairies covered nearly a third of Missouri and prairie-chickens were so abundant they were shot by the wagonload and shipped to game markets in St. Louis, Chicago and New York. Over the next half century, overharvest and loss of prairie habitat caused prairie-chicken populations to plummet. By the 1990s, 99 percent of Missouri's prairies had been plowed under and less than 500 prairie-chickens remained, scattered in small, isolated populations in the northwest and southwest corners of the state.

With such a substantial drop in numbers, Missouri's prairie-chicken population has lost genetic diversity. The potential for a **genetic bottleneck** worries conservationists. With less genetic variation to work with, adaptation cannot keep up with drastic environmental changes, and small populations are prone to extinction. In addition, breeding between closely related individuals, called **inbreeding**, often results in a decrease in reproductive fertility. For prairie-chickens, this means fewer eggs hatch. In Illinois, a prairie-chicken population of just 50 birds saw its hatching rate drop from 93 percent in the 1930s to 38 percent by 1990. Over the same period, the same population lost about one-third of its genetic diversity. Researchers think the loss of diversity and drop in hatching are connected. Surveys show that many of Missouri's prairie-chicken populations have dropped to critically low levels. Biologists in Missouri don't want the same thing to happen here.

In 2008, the Conservation Department began a prairie-chicken translocation project. **Translocation** involves taking individuals from thriving populations and releasing them into struggling populations. Over

a 5-year period, managers plan to relocate up to 500 prairie-chickens from Kansas to a healthy prairie in southwest Missouri. They hope this will establish a viable flock and allow biologists to study how well the translocated birds survive and which habitats they use. If the translocation is a success, the information gained could help stop the downward spiral of prairie-chicken populations elsewhere in Missouri.

Back in Kansas, the captured prairiechickens are untangled, loaded into a pickup, and transported to Wah'Kon-Tah Prairie near El Dorado Springs, Missouri. There, the birds are placed inside a release box, and the box is deposited on a hillside covered with auburn grass and yellow wildflowers. Hiding in a blind, a biologist pulls on a rope, and the



door to the box swings open. Cautiously, the hen pokes her head out. Clear blue sky stretches from horizon to horizon. Satisfied with the new surroundings, she shuffles off across the prairie, her two chicks follow, and the future of prairie-chickens in Missouri becomes three birds brighter than before.

REPRODUCTION AND ADAPTATION

Natural selection causes populations to adapt to their environment over time.

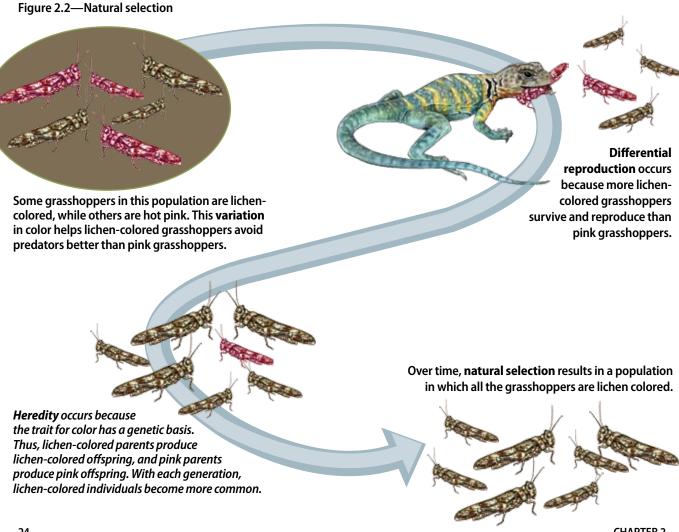
Let's return to our lichen grasshopper population. Because the trait for body color has a genetic basis, lichencolored parents produce lichen-colored offspring more often than pink-colored offspring. Therefore, with each generation of grasshoppers, the trait of being lichen colored becomes more common in the population. If this process of differential reproduction and passing of traits continues over a long period of time, eventually all the grasshoppers in the population will be lichen colored (Figure 2.2).

We've just described **natural selection**, the process by which populations become adapted to their environment over time. An easy way to remember how natural selection works is with an equation:

Variation + Heredity + Differential Reproduction = Natural Selection

When some individuals in a population have different traits, variation exists. If the trait has a genetic basis, it can be passed from parent to offspring, which is called **heredity**. When individuals possessing the trait survive and reproduce at a higher rate than other individuals in the population, differential reproduction is occurring. And, if all three of these things happen, natural selection will occur.

Natural selection is not a conscious process in which organisms strive to develop new traits to help them survive. A hot-pink grasshopper would probably prefer to be lichen colored, but unless he inherited the ability to change color, he's stuck being pink. Eventually, sunlight might fade the color of a hot-pink grasshopper. However, because the change was due to environmental factors and not genetics, the faded color could not be passed on to the grasshopper's offspring, and natural selection would not occur.



Natural selection is not a random process. Individuals with favorable traits tend to survive more often than individuals with unfavorable traits. There's nothing random about that! If natural selection were random, hot-pink grasshoppers would have just as much chance of surviving as lichen-colored ones.

Natural selection does not lead to organisms that are perfectly adapted to their environment. If that were the case, all collared lizards would be fast enough to catch enough to eat and all lichen grasshoppers would be camouflaged well enough to avoid being eaten. Of course, this isn't the case. Natural selection works because some traits are *more* favorable than others. If an organism's traits give it an advantage—or if the organism is just lucky—it will survive to reproduce and pass its traits to the next generation.

Adaptations help an organism survive in a particular environment.

Over time, natural selection produces **adaptations**. Every organism has adaptations. The gills of fish, the venom of rattlesnakes, the bitter taste of some plants—all of these are adaptations. For a trait to be an adaptation, it must help an organism survive in a particular environment. It must also be genetically based, so that the trait can be passed from parent to offspring.

Adaptations aren't just anatomical structures. Behaviors and physiological processes also can be adaptations. For example, when predators get too close to a killdeer's nest, one of the parents will act as if it has a broken wing to lure the predator away. While this behavior may seem risky for the parent, it does contribute to the survival of the population as a whole. Because of this, a killdeer's broken-wing behavior is an adaptation. During cold winters, spadefoot toads produce a compound that acts like antifreeze in their blood. This physiological adaptation helps him survive freezing temperatures.

It's important to remember that adaptations are suited to a specific environment. The same adaptation that helps an organism survive in one environment might be unfavorable to survival in a different environment. The gills of fish help them use oxygen dissolved in water, but not from air. Lichen grasshoppers blend in on a glade, but they would stick out in an environment of hot-pink rocks. ▲



