11.3 Mechanisms for Genetic Variation

EXPECTATIONS

- **Explain the role of mutations in micro-evolution.**
- **Analyze evolutionary mechanisms and their effects on biodiversity and extinction.**
- **Explain three ways in which natural selection can affect genetic variation.**

Even though rattlesnakes (such as the one in Figure 11.9) are found throughout much of North America, few humans have close encounters with them. Most rattlesnakes take cover in the underbrush if danger is present or, at least, give warning with their distinctive rattle. Nonetheless, thousands of people are bitten by rattlesnakes each year, although only 0.2 percent of victims will die. In recent decades, however, there have been several reports of unusual reactions to certain rattlesnake venoms. As well, doctors are reporting that they often have to use many more vials of antivenom to treat bites. In some cases, a species whose venom was previously not considered a threat to humans delivered bites that were deadly. In other cases, patients showed symptoms that were not usual for the venom of the snake that bit them. (Rattlesnake venom usually contains either neurotoxins that affect the nerve impulses to muscles and can restrict breathing, or hemotoxins that affect the tissue near the bite.) Victims showed signs of neurotoxin poisoning when they had been bitten by snakes that previously were thought to deliver only hemotoxins. Why do the toxins seem to be changing? Are venoms evolving?

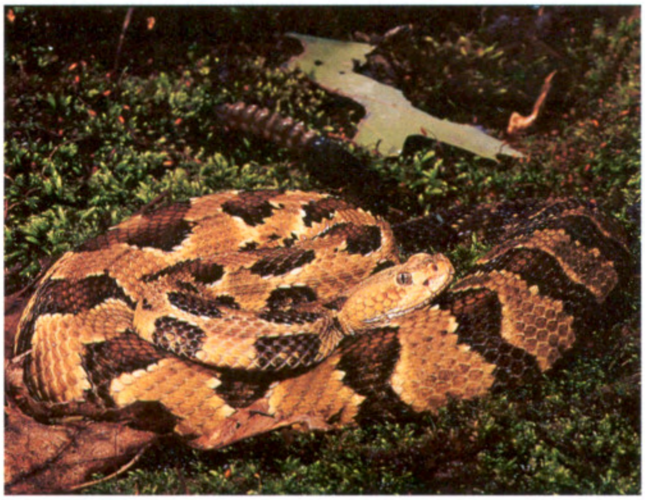

Figure 11.9 What factors might have caused rattlesnake venom to become more potent in recent decades?

Scientists studying this phenomenon have presented several explanations. Some scientists suspect that closely related snakes with differing types and potencies of venom are interbreeding in places where their populations overlap. Others suggest that in some populations, snakes with more potent venoms are being naturally selected because their prey are developing increasingly powerful substances in their blood to block venoms. For example, studies have shown that populations of California ground squirrel that overlap the range of the northern Pacific rattlesnake have a factor in their blood that makes them better able to combat the snake's venom.

A third suggested explanation for the changes in rattlesnake venom relates to the change in age-structure of snake populations. Juvenile rattlesnakes have stronger venom than larger adult snakes. Because humans usually hunt, capture, or even run over larger snakes, the overall age of some snake populations may be shifting to favour young snakes with more potent venom.

All of these possible explanations for the increased toxicity in rattlesnake venom provide scenarios of micro-evolution in action. The gene pools of these populations are changing because of natural selection or because individual snakes are entering or leaving the population. These situations deviate from the Hardy-Weinberg equilibrium. In this section, you will investigate the five conditions that have the potential to result in micro-evolution: mutation, genetic drift, gene flow, non-random mating, and natural selection.

BIO FACT

Of the five causes of micro-evolution, only natural selection always adapts a population to its environment. The other agents of change — gene flow, genetic drift, non-random mating, and mutation — can affect populations in positive, negative, or neutral ways.

WEB LINK

www.mcgrawhill.ca/links/biology12

To learn more about the possible evolution of rattlesnake venom, go to the web site above, and click on **Web Links**. Read through the article and identify specific situations in which the gene pool in the population might be changing. Using resources from the Internet and library, find an example of how the gene pool of a Canadian species is changing.

Mutations

Mutations may provide new alleles in a population and, as a result, may provide the variation required for evolution to occur. (Recall that you learned about mutations in Chapter 9, section 9.1.) When DNA mutates, a cell may die, malfunction, or multiply rapidly into a tumour. Whatever the result, the mutation disappears when the organism dies. If, however, the mutation alters the DNA in a gamete, the mutation may be passed on to subsequent generations. Mutations can have effects that are favourable, unfavourable, or neutral, and the fate of the mutation depends on how it acts in the population.

Mutations alone are not likely to cause evolution. But if a mutation provides a selective advantage (such as the ability of the California ground squirrel to break down rattlesnake poison), it may result in certain individuals producing a disproportionate number of offspring as a result of natural selection. Eventually the favourable mutation will appear with increased frequency in a population.

The fate of particular mutations may also change. Neutral, or perhaps even harmful, mutations can be a source of variation that ultimately helps a population survive given the right circumstances, such as when environments change. For example, the water flea *Daphnia* (shown in Figure 11.10) normally lives in water that is around 20°C and cannot survive in water 27°C or warmer. However, there is a mutation that enables *Daphnia* to survive in temperatures between 25°C and 30°C. This mutation is only advantageous — and thus only perpetuated in the population — when water temperatures are so warm that the other *Daphnia* die off.

In situations in which the environment is changing extremely rapidly, mutant alleles that were previously insignificant in the population may, by chance, fit the new environmental conditions better. As a result, the organisms containing the mutant allele survive and the mutant allele is perpetuated because it provides a selective advantage. The once neutral, or even negative, mutation can in some cases mean the survival of a population. For instance, there are many examples of insects, bacteria, and viruses quickly becoming adapted to new environments because of mutations that prove to be beneficial. Populations of mosquitoes have rapidly developed resistance to certain ingredients in insecticides because of a mutation that resulted in alleles that could break down and withstand the chemical poisons. When the mosquitoes were first sprayed by the insecticide, most died. However, those with the mutant allele that withstood the chemicals were naturally selected for and thus were more likely to survive and reproduce. This scenario is repeated generation after generation until there is a mosquito population resistant to the insecticide. Another scenario is being played out today as strains of bacteria become increasingly resistant to once-effective antibiotics.

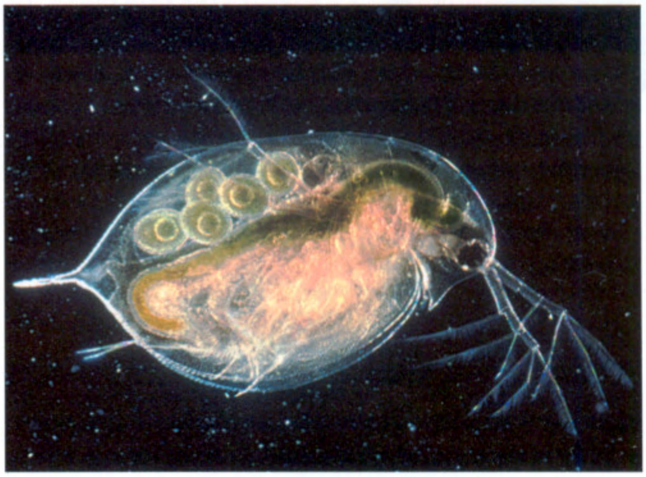

Figure 11.10 Populations of *Daphnia* can have a mutation that allows them to survive at higher-than-normal water temperatures.

Bacteria and other micro-organisms reproduce quickly, and mutations that affect the population's genetic variation can have a significant impact in a short period of time. Bacteria can reproduce asexually by dividing as frequently as every 20 minutes. This could result in a single cell having close to a billion descendants in about 10 hours. Because of these astounding reproductive rates, any new mutation that proves beneficial can increase its frequency in the population quickly. This phenomenally rapid asexual cloning of individuals resistant to the new environment (the "poison" of an antibiotic, for example) makes the development of new antibiotics increasingly challenging for biochemists.

COURSE CHALLENGE

You may choose to examine an example of micro-evolution in a particular species as your Biology Course Challenge topic. Start making notes on the links that this topic has with metabolic processes, homeostasis, and molecular genetics. In the next unit, think about how the population dynamics of this species are related to its predator or prey species.

Genetic Drift

In small populations, the frequencies of particular alleles can be changed drastically by chance alone. This is called **genetic drift**. As an example, imagine flipping a coin 1000 times. Every time you flip a coin you have a 50–50 chance of having an outcome of heads or of tails. In a large sample size (for example, 1000 flips), you would logically expect the number of outcomes of heads and tails to be fairly close. If, however, you flipped heads 700 times and tails 300 times, you might start to wonder about your coin. On the other hand, in a small sample size (for example, 10 flips), it would not be too unusual to flip heads seven times and tails three. The smaller the sample size, the greater the chance of sampling error. In population genetics, the sample size can greatly affect the gene pool of a population; the smaller the population, the less likely that the parent gene pool will be reflected in the next generation. In a large population, there is a better chance that the parent gene pool will be reflected in subsequent generations.

Figure 11.11 on the following page illustrates how genetic drift can happen in a small population and how these changes can be rapid and significant. In any population, not all of the individuals in each generation will necessarily reproduce. This further amplifies the effect of genetic drift. For example, in the first generation of flowers in Figure 11.11, only four plants produce seeds that give rise to fertile offspring. In such a small population size, the allele frequencies shift in the second generation. Allele frequencies again change in the third generation when only two of the plants in the second generation leave fertile offspring. In this example, genetic drift reduced variability because one allele was lost (it "drifted" out of the population) and the other allele became fixed in the population. By the third generation, only mutation or migration of new individuals into the population could re-introduce the lost allele.

THINKING LAB

An Evolving Disease: Tuberculosis

Background

Tuberculosis is an infectious lung disease caused by the bacterium *Mycobacterium tuberculosis*. Tuberculosis is a contagious disease that can be spread by the inhalation of the bacteria. Although anyone can get tuberculosis, people who are already in poor health and who live in crowded conditions are particularly susceptible. Tuberculosis was once fairly easy to treat — an antibiotic discovered about 60 years ago treated the disease effectively. At one time it was thought that tuberculosis could one day be eradicated. Today, however, new drug-resistant strains of tuberculosis are causing great concern to medical researchers.

In one recent study, researchers have been working with officials from the Russian prison system to help stave off the rapid evolution of drug-resistant forms of tuberculosis. Prisons in Russia are very crowded and it is thought that up to 100 000 prisoners carry strains of tuberculosis resistant to at least one antibiotic. Tuberculosis is readily spread in the prisons and bacteria move quickly from host to host. *Myobacterium* can be destroyed with a long course of antibiotics. However, since few prisoners get the full course of antibiotics (either because it cannot be provided or because patients are discharged before the treatment is completed), resistant bacteria spread easily through their bodies. When prisoners are released and left untreated, they can spread a new drug-resistant version of the bacteria to the general public. The tuberculosis rate increased five-fold in Russia between 1990 and 1996, and it is now one of the leading causes of death of young Russian men. Health officials who monitor tuberculosis are beginning to see drug-resistant strains of *Myobacterium* in places such as North America, where tuberculosis is relatively uncommon. As well, *Myobacterium* is just one of the many bacteria that are becoming resistant to antibiotics.

You Try It

1. Create a model showing how a population of *Myobacterium* could become resistant to antibiotics.
2. Is poorly supervised or incomplete treatment of antibiotics better than no treatment? Discuss this statement with a partner.
3. Using the Internet or library resources, investigate how researchers are treating drug-resistant tuberculosis or another disease that can be treated by antibiotics. Also, find out how they are trying to limit the spread of the disease.

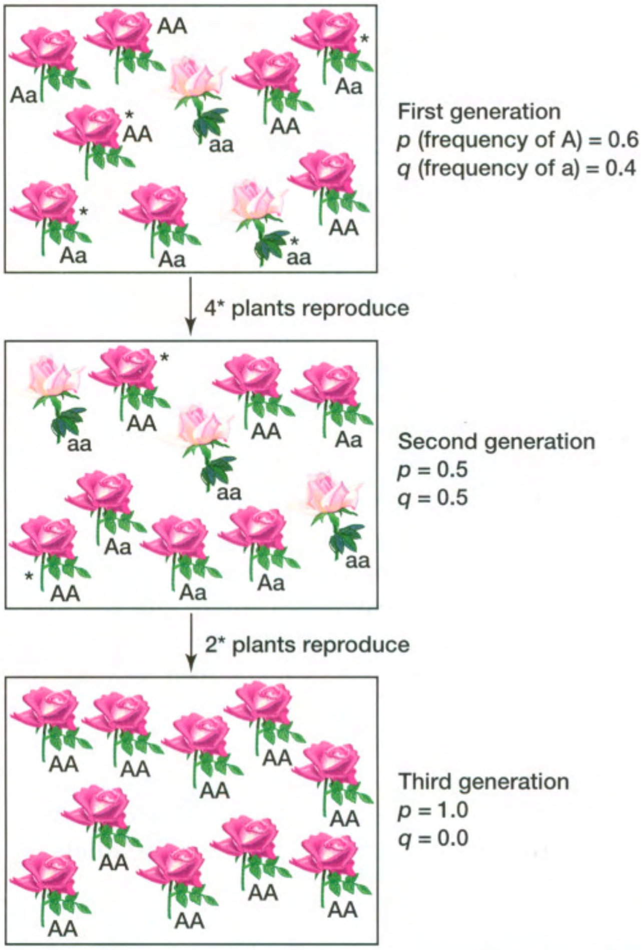

Figure 11.11 The frequency of alleles changes in this population over three generations because of genetic drift.

Most natural populations are large enough that the effects of genetic drift are negligible. However, two situations — population bottlenecks and the founding of new colonies by a few individuals (the founder effect) — lead to genetic drift.

The Bottleneck Effect

Populations can be subject to near extinction as a result of natural disasters such as earthquakes, floods, or fires, or of human interferences such as overhunting or habitat destruction. The surviving population is unlikely to represent the gene pool of the original population. The **bottleneck effect** is a situation in which, as a result of chance, certain alleles are overrepresented and others are underrepresented (or even absent) in the reduced population. Genetic drift then follows and the genetic variation in the surviving population is reduced.

The population of northern elephant seals (see Figure 11.12) passed through a bottleneck in the 1890s when overhunting reduced the population to, possibly, as few as 20 individuals. Since the species became protected, the population has increased to over 30 000 individuals. Biologists have studied 24 gene loci of several of the 30 000 individuals and have found no genetic variation; electrophoresis showed that at each of the 24 loci there is only one kind of allele. This is markedly different from what is found in populations of southern elephant seals that were not subject to the bottleneck effect, in which there is a high degree of genetic variation.

Whooping cranes, which breed in Wood Buffalo National Park in the Northwest Territories, also went through a genetic bottleneck. In 2001, the population at Wood Buffalo National Park was 177 whooping cranes. According to the data, scientists hypothesized that these birds were descendants of at most 12 (and more likely six or eight) founding birds. In addition to these 177 birds, another 86 whooping cranes are found in flocks that scientists are trying to establish in the Rocky Mountains (two individuals) and in Florida (84 individuals.) Biologists are working on strategies to limit loss of diversity due to genetic drift.

Figure 11.12 The reduced genetic variation in populations of northern elephant seals is the result of the bottleneck effect and genetic drift.

WEB LINK

www.mcgrawhill.ca/links/biology12

To learn what biologists in Canada and the United States are doing to help preserve genetic diversity in whooping cranes, go to the web site above, and click on **Web Links**. Read the essays on the web sites and summarize some of the problems associated with the small population size of whooping cranes. What strategies are being used to help preserve the species?

The Founder Effect

When a small number of individuals colonize a new area, chances are high that they do not contain all the genes represented in the parent population. The change in allele frequencies that result in this new population is called the **founder effect**. The particular alleles carried by these founders are dictated by chance only. As well, since the new population is in a new environment, its members will experience different selective pressures than the members of the parent population do. In practice, it is difficult to tell how much of the genetic difference between two populations is because of the founder effect and how much is a result of natural selection and the different selective pressures working on the populations. The ancestral population of Hawaiian honeycreepers shown in Figure 11.13 was thought to have migrated from North America about five million years ago. Individuals from the population became isolated on different islands and evolved into different species. Each population started with a small assortment of genes (founder effect), which were subjected to different selective pressures depending on the local environmental conditions.

While the founder effect is important on islands and other isolated habitats, other populations that have limited input of new genetic material also show the effects of a limited gene pool. Isolated human populations occasionally have high frequencies of inherited genetic disorders. An example of the founder effect is found in a small village in Venezuela, where the incidence of Huntington's disease is remarkably high. Huntington's disease is a debilitating, degenerative disease of the nervous system. It is caused by a lethal dominant allele that is not manifested in any particular phenotype. Because of this, individuals show no symptoms of the condition until they are about 30 years old (or older), when the deterioration of their nervous system begins. The presence of this condition in this particular village can be traced back to one woman who carried the dominant allele. Since the symptoms of the disease do not appear until later in life, carriers can reproduce (thereby potentially passing on the allele for this disease) before it is clear whether they carry the dominant allele or not.

In another example, in 1814 a population of 15 people founded a British colony on the Tristan da Cunha, a small group of islands in the Atlantic

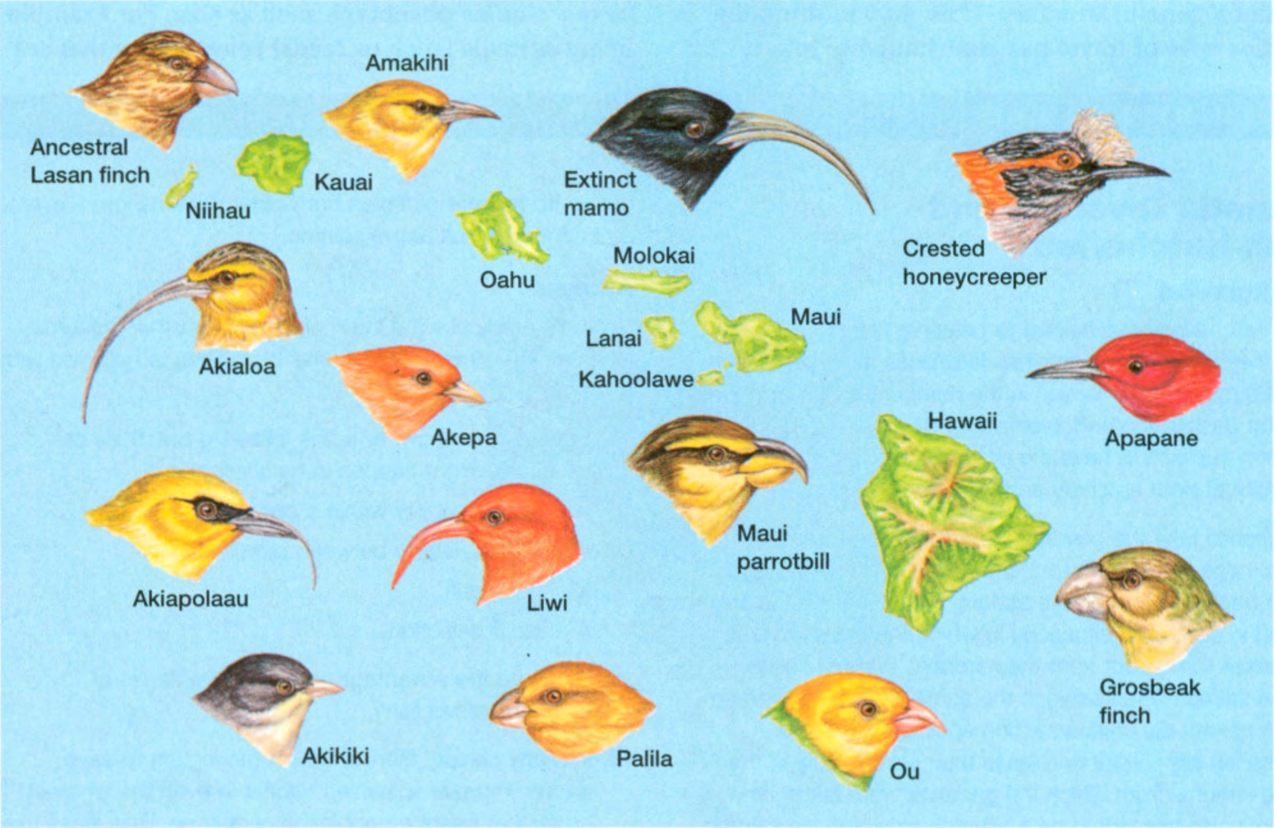

Figure 11.13 Hawaiian honeycreepers evolved into different species from a common ancestral population as a result of the founder effect and selective pressures.

Ocean. Apparently, one of these individuals carried the recessive allele for a type of blindness called retinitis pigmentosa. Studies have shown that the frequency of this allele in the current population on Tristan da Cunha is much higher than in populations from which the original founders came.

Gene Flow

To maintain genetic equilibrium, the gene pool of a population must be completely isolated. In practice, this is rarely the case. A windstorm or tornado can deliver new seeds or pollen to a population. This movement of new alleles into a gene pool, and the movement of genes out of a gene pool, is called **gene flow**.

Gene flow can reduce the genetic differences between populations that may have arisen because of natural selection or genetic drift. Previously isolated populations, including human populations, can accumulate differences over generations because of selective pressure or as a result of having a closed gene pool (no new alleles entering or leaving) in a small population. If the gene flow is extensive enough between two neighbouring populations, they can eventually become amalgamated into a single population with a common genetic structure. How do you think the relative ease of travel has contributed to microevolutionary change in human populations? What factors have limited the extent to which microevolutionary change can take place even with the accessibility of travel?

Non-random Mating

Genetic equilibrium can be maintained in a population only if that population mates on a random basis. However, not all organisms mate in such a way. Individuals will usually mate more often with neighbours than with more distant members of the population. **Inbreeding** (mating between closely related partners) is a type of **non-random mating** that causes frequencies of certain genotypes to change in the population. Inbreeding does not change allele frequencies; it results in a population with more homozygous individuals. Self-fertilization is particularly common in plants and is the most extreme case of inbreeding. Pea flowers, for example (as shown in Figure 11.14), include both the male and female reproductive structures. This ensures that self-fertilization will take place unless the flower is disturbed by an insect or other means.

Assortative mating is another type of non-random mating, in which individuals choose partners that have a similar phenotype such as size. For example, many animals (such as toads) select mates that are

THINKING LAB

Genetic Diversity and Fish Hatcheries

Background

Fish hatcheries have helped to preserve fish stocks for commercial and sport fishers. Hatcheries have stepped in to help make up for losses in the numbers of fish due to habitat destruction and overfishing. However, several genetic risk factors have the potential to affect the genetic diversity of both hatchery and wild stocks.

Hatcheries take the gametes from wild salmon, fertilize them, raise the salmon to a small size, and then release them back into their native stream. Fish in hatcheries are raised in controlled situations in which the objective is to maximize the output from the hatchery. In most cases, native salmon also spawn in the same areas. Each stream has a genetically unique salmon species. Therefore, hatcheries are careful to release their salmon only in the same streams from which the gametes were taken. The exception to this would be a situation in which the salmon that run in a river are extinct — hatcheries may release fish grown from gametes taken from other streams into a river that no longer has native salmon.

Analyze

Note: You may use the Internet, library, or other resources (such as interviews with fisheries biologists) to help you with this activity.

1. Speculate on how, or if, the following practices or situations might happen in hatcheries:
   - loss of variability within a population
   - loss of variability between populations
   - genetic drift
   - artificial selection
2. What are the advantages and disadvantages of hatchery-raised fish?
3. In many places, there is now a movement to save and/or improve spawning habitat in even the smallest creek that bears a population of salmon. How does this trend support improving the genetic diversity of wild salmon populations?

similar sized. Assortative mating is the basis of artificial selection, in which animals such as dogs are bred for particular characteristics. This inbreeding has led to a decrease in the genetic diversity in breeds of dogs and the perpetuation of certain diseases and conditions (such as hip dysplasia) in some breeds.

Natural Selection

The Hardy-Weinberg equilibrium says that all individuals are equal in their ability to survive and reproduce. In actual situations, however, this condition can rarely, if ever, be met. Populations have a range of phenotypes and genotypes, and some individuals in the population will leave more offspring than others. As you learned in Chapter 10, natural selection is the mechanism that results in this differential reproductive success. Selective forces such as predation and competition work on populations, and consequently some individuals are more likely to survive and reproduce than others. If having a single allele gives even a slight yet consistent selective advantage, the frequency of the allele in the population will increase from one generation to the next at the expense of the less favourable allele. There is a greater chance of the organisms with the slightly favourable allele living and reproducing and then passing this slightly favourable allele to their offspring. Therefore, selection causes changes in a population's gene frequencies that shift the population away from Hardy-Weinberg equilibrium.

There are three ways in which natural selection can affect the frequency of a heritable trait in a population: stabilizing selection, directional selection, and disruptive selection.

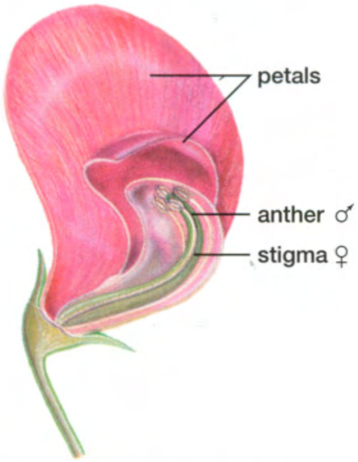

Figure 11.14 Pea flowers are designed so that self-fertilization is ensured if the flower is not disturbed.

Stabilizing selection favours an intermediate phenotype and acts against extreme variants. This type of selection reduces variation and improves the adaptation of the population to aspects of the environment that remain relatively constant. Figure 11.15 shows how stabilizing selection keeps the majority of baby weights between 3 and 4 kg. Infant mortality is greater for babies who are smaller or larger than this size.

Directional selection favours the phenotypes at one extreme over the other, and results in the distribution curve of phenotypes shifting in that direction. This type of selection is common during times of environmental change or when a population migrates to a new habitat that has different environmental conditions. Figure 11.16 on page 384 shows the directional selection shift that took place as horses evolved from an ancestral form that was adapted to a forest habitat to the modern form, which is adapted to a grassland habitat. This shift took place in response to a changing environment. *Hyracotherium* was about the size of a dog and was well-adapted to the forest environment present during the Eocene epoch. During the Miocene and Pliocene epochs, however, grasslands began to replace the forests and the ancestral horses were selected for larger size, more durable teeth suitable for grinding grasses, and longer legs for increased speed in the more open habitats.

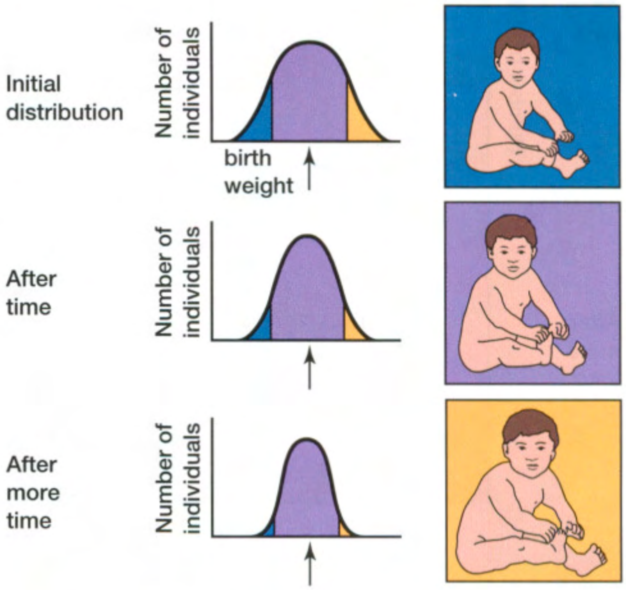

Figure 11.15 Natural selection favours the intermediate phenotype (for example, human baby weight) in stabilizing selection. Now, most babies are of intermediate weight.

Global climate change may also cause directional selection in some populations. Imagine that a hypothetical population of penguins lives near Pacific islands where the water temperatures have been moderate until recently. Global climate change has resulted in a shift in ocean currents such that the water is now consistently much colder. In the changing environment, birds with less body fat are less successful because they need to use more energy (food) to keep themselves warm. Birds with more body fat stay warmer in the water and can afford to use more energy for reproduction. As a result, the fatter penguins have more success raising young, so there is an overall increase in the number of alleles for increased body fat in the penguin population.

The shift in the population of peppered moths you learned about in Chapter 10 is an example of directional selection. The resistance of insects and bacteria to pesticides and antibiotics, respectively, are also examples of directional selection.

Disruptive (diversifying) selection takes place when the extremes of a phenotypic range are favoured relative to intermediate phenotypes (as shown in Figure 11.17). As a result, intermediate phenotypes can be eliminated from the population. In several salmon species (including coho salmon) there are two male phenotypes that are extremely different. When small "jack" males mature, they weigh about 500 g and are approximately 30 cm in length. In comparison, the "normal-sized" males average about 4.5 kg (and can be as large as 8.5 kg) when they are mature.

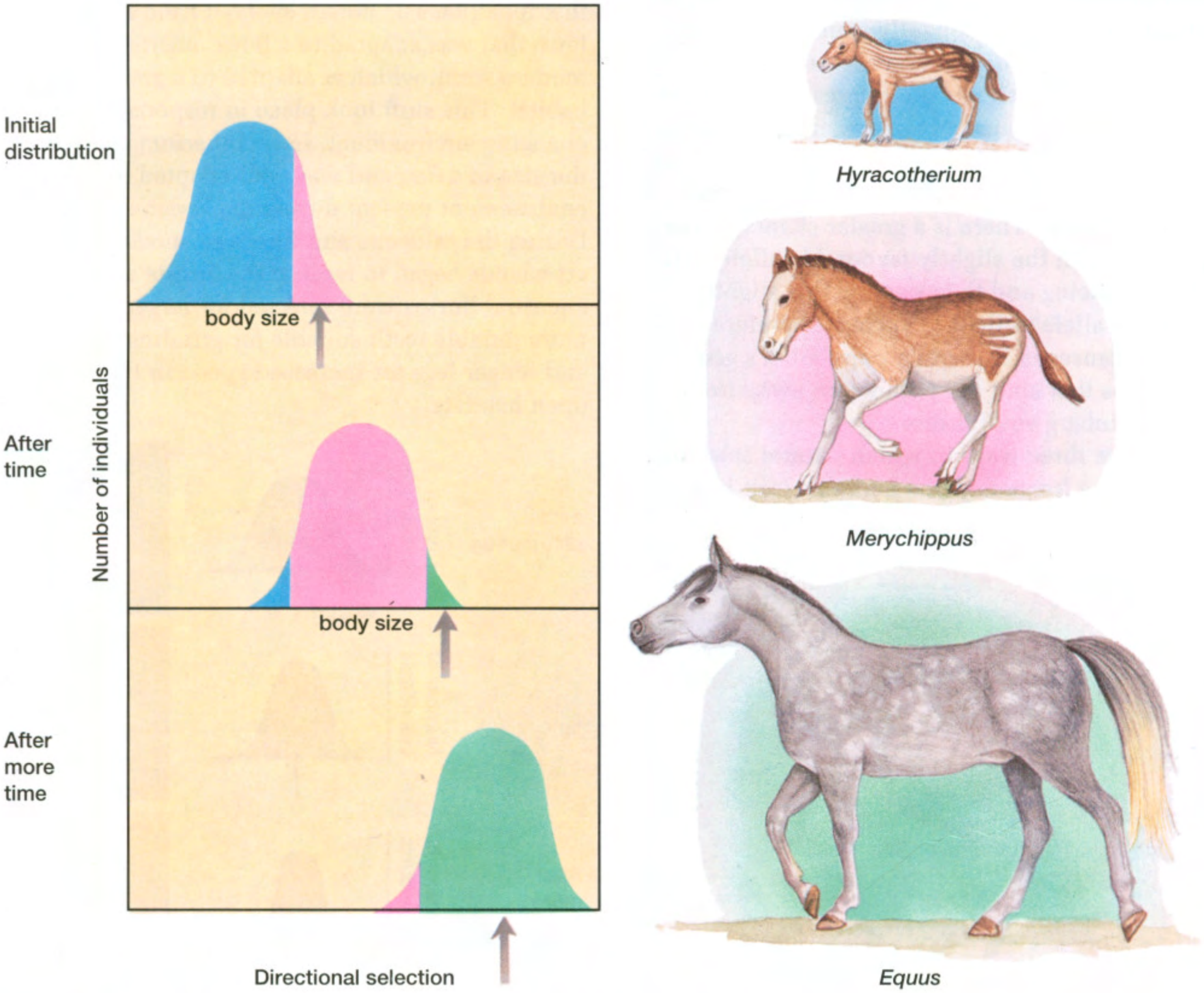

Figure 11.16 The modern horse, which is adapted to a grassland habitat, evolved from an ancestral horse that was adapted to a forest habitat. This shift in phenotype is called directional selection.

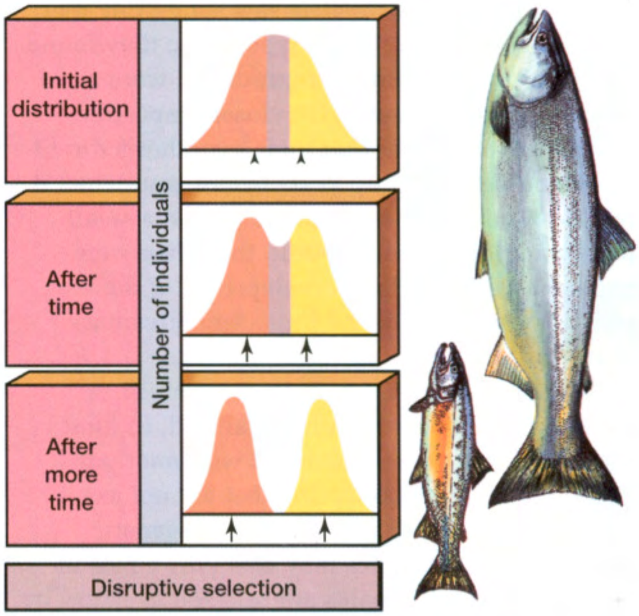

Figure 11.17 In disruptive selection, two extreme phenotypes are favoured over the intermediate form. Shown are two phenotypes of male coho salmon — the smaller "jack" salmon and the noticeably larger, regular-sized male.

Sexual Selection

Sexual reproduction has evolved independently several times throughout the course of evolutionary history. Remarkably, most forms of sexual reproduction share similar characteristics: the ova are large and immobile, while the sperm are small swimmers. Instead of both gametes wandering around searching for each other, it is more practical for one (the ova) to stay in place while the other searches for it. Two things occur to increase the probability of the gametes meeting — the ova releases powerful pheromones and males release millions of sperm.

Evolution has favoured mutations that make a species' sperm smaller and eggs larger. If sperm's only function is to carry genes (and not to carry the energy required for cell division), a species can have more, smaller-sized sperm. To complement this strategy, fewer, larger eggs that have the stored energy needed for cell division are required. This trend towards females with large eggs and males with more than enough sperm to fertilize the entire population of their species has produced a very competitive situation for sexually reproducing species. While one male may be able to fertilize all of his species, virtually every other male is in the same position. This has led to the evolution of a wide array of sexual behaviours and sexual attractants, such as plumage or scents, as males compete for the chance to mate with a female.

Males and females of many animal species often have markedly different physical characteristics, such as colourful plumage in male birds and antlers in male deer. This difference between males and females is called **sexual dimorphism**. Figure 11.18 shows the striking difference between male and female orioles. These obvious characteristics, as well as courtship displays and other mating rituals, result in another type of selection — **sexual selection**. Although the selection of mates has many facets, in general, competition between males (through actual combat or visual displays) and the choices made by females result in sexual selection and enhanced reproductive success.

Characteristics used in sexual selection may not be adaptive in the sense that they help an individual survive in the environment in any way. The larger mane of a lion or the antlers of a moose, for example, do not help these animals better withstand environmental conditions. However, if such characteristics give them the advantage of being chosen by a female, then their alleles can be perpetuated in the population and sexual selection has occurred.

Many organisms, including bacteria and many protozoa, reproduce without sex. Even some plants and animals can reproduce asexually. Sexual reproduction can be costly — it takes vast amounts of energy to grow new plumage, or a large rack of antlers. In many ways, sex seems to make no sense. A very well-adapted individual that could create clones of itself would create offspring that were equally well-adapted, so why has sexual reproduction evolved at all? Recently, scientists proposed a surprising idea: sex is a way of fighting off parasites and disease because sexual reproduction enhances genetic variability within the species.

Figure 11.18 Many birds, such as Baltimore orioles, show a high degree of sexual dimorphism.

Since sexual reproduction mixes the genes from both parents, any ability to fight off parasites or disease can be passed on to offspring. While a population may be perfectly adapted to the current environment, a population of clones will have little genetic variation to work with to survive changing conditions. Biologists tested their hypothesis by studying a type of fish — called topminnows — that live in Mexican ponds and streams. These fish sometimes mate with a closely related species, producing hybrids that are only female and that always reproduce by cloning rather than by mating. Curiously, in order to activate their eggs to grow, these hybrid females get sperm from male fish but they do not incorporate DNA from the sperm into their eggs.

In one pond the scientists studied, they found that the clones, rather than the sexually reproducing fish, were infected by parasitic cysts. Because the clones were exact replicas of one another, this strain of fish was an easy target for the parasites. Once the parasites became established in the population, they began to reproduce quickly.

In a second pond, where there were two different strains of clones, the researchers found that the more common strain of clone was subject to more infections. This also fit their hypothesis, which said that parasites able to attack the most common fish will thrive and spread throughout the population. (Meanwhile, the numbers of the other strain of fish remained low — at least temporarily — since they had less habitat available to them.) Eventually, however, the parasites became so successful that they killed their hosts and the more common strain of clone died out. This gave more habitat for the other strain of fish and their population rose. Of course, this also provided more opportunities for *another* parasite to infect *this* strain, and the cycle began all over again.

In a third pond, scientists saw something that seemed to contradict their hypothesis: they found that the fish that sexually reproduced were more infested than the clones. On closer inspection, however, it was clear that their hypothesis did fit. The pond had dried up years before, and when it refilled it had been recolonized by just a small population of fish. As a result, these fish were highly inbred and therefore deprived of the genetic variety that is the important advantage of sexual reproduction.

So, in many ways, sex is a compromise. A perfectly well-adapted individual will, in most cases, still mix genetic material with another individual to create offspring that are not exact clones. The questions is, who to mix genetic material with? Parasites may also play a role in determining which males are selected as mates by females. The displays demonstrate the fitness (because it takes energy and resources to produce the displays) and genetic potential of the males. Scientists speculate that a strong display — whether a loud song or a particularly bright display of feathers — shows that the male is healthy, strong, and not weakened by parasites or disease.

WEB LINK

www.mcgrawhill.ca/links/biology12

Our understanding of evolution grows daily as new ideas are presented and new information is gathered. To learn more about recent ideas and discoveries, go to the web site above, and click on **Web Links**. Investigate one new discovery or scientific study that advances our understanding of evolution. Create a short summary of this new information and post it on a bulletin board in your classroom.

SECTION REVIEW

1. MC Hunters often seek "trophy" animals — those that have large sets of antlers or horns. You are a wildlife biologist who recommends stopping trophy hunting in a certain area. Justify your reasoning and explain how this hunting behaviour might affect a population.
2. C Create a diagram that explains how genetic drift can shift the allele frequency in a population in just a few generations.
3. K/U Explain the difference between how natural selection changes phenotypes observed in populations and how the other four agents of micro-evolutionary change (genetic drift, gene flow, etc.) act on populations.
4. K/U Can the role of a particular mutation present in a population change over time? Explain your answer.
5. K/U Compare and contrast the founder effect and the bottleneck effect.