CHAPTER 9 Evolution and Speciation

Specific Expectations

In this chapter you will learn how to . . .

- C1.2 **evaluate** the possible impact of an environmental change on natural selection and on the vulnerability of species (9.1, 9.2)
- C2.1 **use** appropriate terminology related to evolution (9.1, 9.2)
- C2.2 **use** a research process to **investigate** some of the key factors that affect the evolutionary process (9.2)
- C2.3 **analyze**, on the basis of research, and **report** on the contributions of various scientists to modern theories of evolution (9.2)
- C3.3 **define** the concept of speciation, and **explain** the process by which new species are formed (9.1, 9.2)
- C3.4 **describe** some evolutionary mechanisms, and **explain** how they affect the evolutionary development and extinction of various species (9.1, 9.2)

When Charles Darwin first observed the marine iguana (*Amblyrhynchus cristatus*), he was impressed by its ability to swim. In his journal from the *Beagle* voyage he wrote that the iguana swims "with perfect ease and quickness, by a serpentine movement of its body and flattened tail."

Only on the Galapagos Islands are populations of this single species of swimming iguana found. What evolutionary processes led to this animal's unique appearance and swimming ability? How can geographic isolation, as on an island, lead to the formation of a new species? What other events and mechanisms cause changes in species at the genetic level? These are questions that you will explore in this chapter.

Launch Activity

A Feathery Tale

The greater sage grouse lives on the prairies of Canada and the United States. During mating season, groups of these ground-dwelling birds gather at breeding areas, where the males strut across bare ground in full view of the females. The males display their tail feathers and inflate their yellow air sacs, which are otherwise concealed under white chest feathers. Which males do the females choose? How does the selection of mates affect the next generation?

Materials

- paper silhouette of a greater sage grouse
- paper tail feathers of different lengths
- paper air sacs of different colours
- coloured markers
- stapler or clear tape

Procedure

1. Your teacher will give you a choice of a paper silhouette of a greater sage grouse. You will also choose 5 to 10 paper tail feathers and a pair of paper air sacs. Use a marker to add markings to the tail feathers. Attach the tail feathers and air sacs to the silhouette.
2. Hold up your model bird so the other students can see it. At the same time, observe your classmates' model birds. Notice the variations among the model birds.
3. Your teacher will announce which greater sage grouses will reproduce and pass on their traits to the next generation.

Questions

1. Identify three variations among the tail feathers and air sacs that you observed.
2. In step 3, what determined which male birds will reproduce? Which gender—male or female—influenced this more? What will the next generation of male birds look like?
3. In this activity, the selection of mates was based on two traits. In nature, many traits and other factors influence mate selection. Suggest three traits (not necessarily obvious to the human eye) that female greater sage grouse might use to select a mate.
4. Some of the male birds in this activity did not mate and pass on their genes to the next generation. Explain how that could be both an advantage and a disadvantage to the next generation.

SECTION 9.1

Mechanisms of Evolution and Their Effect on Populations

Key Terms

gene flow
non-random mating
genetic drift
founder effect
bottleneck effect
stabilizing selection
directional selection
disruptive selection
sexual selection

Genetic variation of individuals within a population makes evolution possible. In species that reproduce sexually, each individual inherits a new combination of alleles from that individual's parents. As a result, each new generation is made up of genetically unique individuals. In addition, new mutations occur randomly in each generation, providing the potential for new traits to develop. Although genetic variation in a population occurs randomly, natural selection acts upon that variation in a non-random way. Individuals with genes that help them survive will reproduce, allowing them to pass along those genes to offspring and increase those genes' percentage in the population.

Individual organisms do not evolve. Populations do. Thus, to study the evolutionary process, you must focus on changes that occur within populations. The gene pool of a population consists of all the alleles of all genes of each individual in that population (Section 1.4). The percentage of each allele of any given gene present in the population determines the genetic characteristics of that population. For example, the coat colour of the grey wolf (*Canis lupus*) in many populations has a grey appearance, which accounts for the wolf's common name. However, in far northern populations, alleles that produce a white coat colour predominate ("win out"). Some forest populations of wolves also have a high percentage of alleles that produce a black coat colour.

Factors That Change Allele Frequencies in Populations

Changing percentages, or frequencies, of alleles within populations are the small events that lead to evolution within a population, or microevolution. (Allele frequencies are the number of copies of an allele compared to the total number of alleles in a population.) When the frequency of an allele in a population changes, microevolution has occurred. **Table 9.1** lists the five common factors that lead to such changes. Each of these will be discussed further in this section. Note that the last of these factors, natural selection, is the most significant factor in the formation of new species. This kind of event, called *speciation*, will be discussed in Section 9.2.

Table 9.1 Factors That Cause Evolutionary Change

Factor	Description and Effect
Mutation	**Description:** Mutation randomly introduces new alleles into a population. **Effect:** Mutation changes allele frequencies.
Gene flow (migration)	**Description:** Gene flow occurs between two different interbreeding populations that have different allele frequencies. **Effect:** Gene flow may change allele frequencies in either or both populations through a "flow," or movement, of genes (alleles).
Non-random mating	**Description:** During non-random mating, individuals in a population select mates, often on the basis of their phenotypes. **Effect:** Non-random mating increases the proportion of homozygous individuals in a population, but does not affect the frequencies of alleles.
Genetic drift	**Description:** Genetic drift refers to random change in genetic variation from generation to generation due to chance. **Effect:** Genetic drift changes frequencies of alleles.
Natural selection	**Description:** Natural selection is the result of the environment selecting for individuals in a population with certain traits that make them better suited to survive and reproduce than others in the population. **Effect:** Over many generations, frequencies of alleles of many different genes may change, resulting in significant changes in the characteristics of a population.

Mutations

Recall from your studies of genetics and from Chapter 7 that a mutation is a change that occurs in the DNA of an *individual*, and that a heritable mutation has the potential to affect an entire *gene pool*. The more genetic variation there is in a population, the greater the diversity of the population and the greater the chance of a selective advantage to some individuals in a changing environment.

The poison resistance in the Norway rat is an example of a selective advantage. The compound warfarin has been widely used to control rat populations since the 1950s. Warfarin is a blood thinner, which means that it prevents the blood from clotting. But warfarin can cause internal bleeding. Before warfarin was introduced as a rat poison, it is likely that a few rats already had a mutation that made them resistant to warfarin's effects. These rats survived applications of warfarin, mated, and passed on the mutation for warfarin resistance to their offspring. By the 1960s, there were many warfarin-resistant rat populations in Europe.

Gene Flow

Gene flow, modelled in **Figure 9.1**, describes the net movement of alleles from one population to another as a result of the migration of individuals. For example, grey wolves, such as the one shown in **Figure 9.2**, have large territories. A lone grey wolf may travel over 800 km in search of a new territory or breeding partner. Very often, a grey wolf from one population will mate with a member of a nearby population, bringing new alleles into the gene pool of the nearby population. As a result, genetic diversity in the nearby population may increase. Having greater genetic diversity may help the population survive because such diversity is the raw material on which natural selection acts.

gene flow the net movement of alleles from one population to another due to the migration of individuals

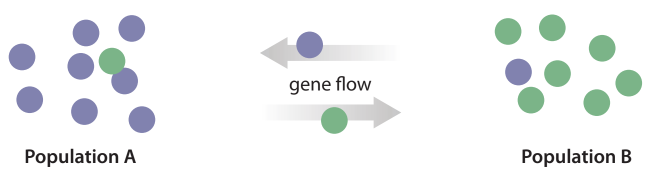

Figure 9.1 Through gene flow, modelled here, genetic information is exchanged between individuals of different populations.

Figure 9.2 Gene flow between grey wolf populations is quite common. Individuals travel long distances and may join or otherwise interact with members of other populations.

Infer *Why might scientists have difficulty defining distinct grey wolf populations in North America?*

Non-random Mating

non-random mating mating among individuals on the basis of mate selection for a particular phenotype or due to inbreeding

Non-random mating is mating among individuals on the basis of mate selection for a particular phenotype or due to inbreeding. In contrast, random mating is much like a draw in which breeding partners are randomly selected by drawing names out of a hat. If mating is random, there is no way to predict which males will mate with which females, or which females will mate with which males. The likelihood of any individual with a specific genotype mating with another individual with a specific genotype depends on the allele distribution in the population.

Non-random Mating: Preferred Phenotypes

In animal populations, individuals may choose mates based on their physical and behavioural traits—their phenotypes. Female greater sage grouse, for example, choose mates based on their phenotypes. In herds of caribou (*Rangifer tarandus*), males compete for mates by using their antlers to spar against other males, chasing one another and fighting, as shown in **Figure 9.3**. This is a form of non-random mating because it prevents individuals with particular phenotypes from breeding. Only the individuals that mate will contribute to the gene pool of the next generation.

Figure 9.3 The male caribou spar with each other to be able to mate with a female in the herd.
Infer *How will non-random mating in caribou cause changes in the gene pool? Explain your answer.*

Learning Check

1. When discussing evolution, explain why it is necessary to keep in mind that populations evolve, not individuals.
2. Explain why mutations may provide a selective advantage to some individuals of a population in a changing environment.
3. Explain what is meant by the term "allele frequency."
4. Why does gene flow increase diversity in one population of a species while at the same time reducing genetic differences among many populations of the same species?
5. Use a labelled diagram to show gene flow between two populations of eastern grey squirrels (*Sciurus carolinensis*).
6. Describe how non-random mating differs from random mating. Use the concept of preferred phenotypes to explain why random mating in nature is uncommon.

Non-random Mating: Inbreeding

Inbreeding occurs when closely related individuals breed together. An extreme example of inbreeding is the self-fertilization of some flowers, such as the one shown in **Figure 9.4**. But close relatives share similar genotypes, so inbreeding increases the frequency of homozygous genotypes. Inbreeding does not directly affect the distribution of alleles. However, as homozygous genotypes become more common, harmful recessive alleles are more likely to be expressed.

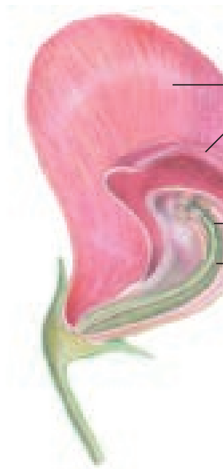

Figure 9.4 Pea flowers include both male and female reproductive structures. The advantage to the pea plant is that self-fertilization takes place if the plant is not able to reproduce sexually via, for example, the action of a pollinating insect.

The negative effects of inbreeding are sometimes seen in purebred farm animals and pets, such as the shar-pei dog shown in **Figure 9.5**. Purebred animals tend to have a higher incidence of deformities and health problems compared with non-purebred animals. For some purebred animals, fertility rates are very low and offspring die at a young age.

Figure 9.5 The shar-pei dog breed originated in China more than 2000 years ago. An inherited genetic mutation—enhanced through inbreeding—increases the production of hyaluronic acid. The overproduction of hyaluronic acid contributes to a skin disorder called mucinosis. The consequence is an excessive build-up of mucin, which accumulates under the skin and produces wrinkles.

Genetic Drift

genetic drift the change in frequencies of alleles due to chance events in a breeding population

In small populations, the frequencies of certain alleles can be changed by chance alone. This is called **genetic drift**. For example, imagine flipping a coin. Each time you flip the coin, you have a 50-50 chance of the coin landing heads or tails. In a large sample size involving 1000 flips, for example, you would expect the number of heads and tails you get to be fairly close. You would not expect widely differing results, such as flipping heads 700 times and tails 300 times. However, in a small sample size, say involving 10 flips of a coin, getting heads 7 times and tails 3 times would not be unusual. The smaller the sample size, the greater the uncertainty of your results.

In nature, sample size can greatly affect the gene pool of a population. The smaller the population, the less likely it is that the parent gene pool will be reflected in the next generation. In a large population, however, there is a better chance that the parent gene pool will be reflected in future generations.

Figure 9.6 shows how genetic drift can occur in a small population, with rapid and significant results. In any population, a few individuals in each generation will not reproduce. This failure to reproduce on the part of a few individuals intensifies the effects of genetic drift. For example, in the first generation of the roses shown in **Figure 9.6**, only four plants produce seeds that give rise to fertile offspring. In such a small population, the allele frequencies shift in the second generation. Allele frequencies change again in the third generation, when only two plants from the second generation give rise to fertile offspring. In this case, genetic drift has reduced variation 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 could produce new variation through the introduction of new alleles.

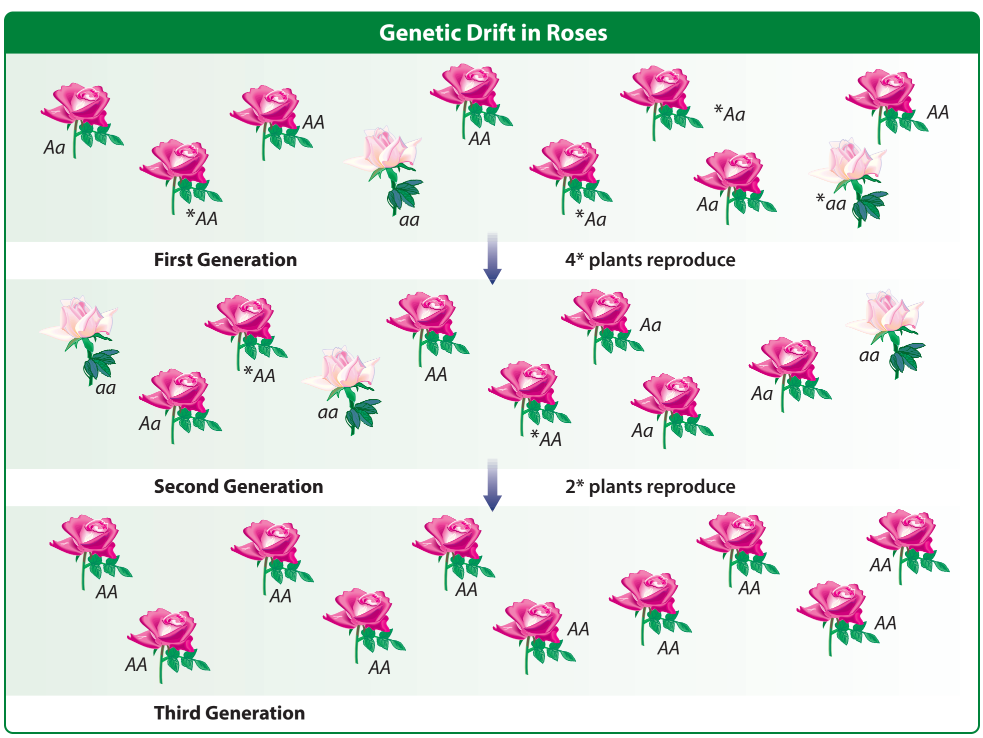

Figure 9.6 In each generation, only some of the plants in this population reproduce. When the light pink (*aa*) and heterozygous roses (*Aa*) in the second generation did not reproduce, the allele for light pink petals was lost from the gene pool.

Most natural populations are large enough that the effects of genetic drift are small. However, two situations can lead to significant genetic drift. These situations involve what is known as "the founder effect," the founding of new colonies by a few individuals, and what is known as a "population bottleneck."

Genetic Drift: The Founder Effect

Often, new populations are formed by only a few individuals, or *founders*. For example, strong winds may carry a single, pregnant fruit fly to a previously unpopulated island, where the fruit fly and her offspring may found a new colony. These founders will carry some, but not all, of the alleles from the original population's gene pool. Therefore, diversity in the new gene pool will be limited. Furthermore, the founders may not be typical of the population they came from, so previously rare alleles may increase in frequency. The gene pool change that occurs when a few individuals start a new, isolated population is called the **founder effect**. The founder effect occurs frequently on islands, and probably occurred when various plants, insects, birds, and reptiles first colonized the Hawaiian and Galapagos Islands.

The founder effect also occurs in human populations, and the lack of genetic diversity in these populations can be a medical concern. Due to the founder effect, the incidence of inherited health conditions in these populations is much higher than average. The Amish population of Philadelphia, Pennsylvania, for example, was founded in the 1700s by only a few families. The current population of Amish in the region has an unusually high frequency of polydactylism, which is the presence of a sixth finger or toe (see **Figure 9.7**).

founder effect a change in a gene pool that occurs when a few individuals start a new isolated population

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Figure 9.7 Polydactylism is a genetic characteristic in which a sixth finger or toe grows.

Genetic Drift: The Bottleneck Effect

Starvation, disease, human activities, and natural disasters such as severe weather can quickly reduce the size of a large population. Since the survivors likely have only a fraction of the alleles that were present before the population declined, the gene pool has lost diversity. Gene pool change that results from a rapid decrease in population size is known as the **bottleneck effect** and is modelled in **Figure 9.8**. An example of the bottleneck effect can be seen in the human population of a small island called Pingelap in the Pacific Ocean. Pingelap is part of Micronesia. In 1775, a typhoon devastated Pingelap. There were fewer than 30 survivors from an original population of about 1600. One of the survivors carried a genetic mutation that causes colour vision deficiency. The current population of the island traces its ancestry back to this person—up to about 10 percent of the current population have colour vision deficiency. In the general population, this condition is relatively rare.

bottleneck effect changes in gene distribution that result from a rapid decrease in population size

Figure 9.8 In this model, the parent population has equal numbers of green and yellow individuals and a few red. A chance catastrophe leaves mostly green survivors with a few yellow and no red. The next generation is mostly green, with a few yellow.

The bottleneck effect is often seen in species driven to the edge of extinction. For example, by the 1890s, overhunting had reduced the number of northern elephant seals (*Mirounga angustirostris*) to as few as 20. Today, there are tens of thousands of these seals. However, due to the bottleneck effect followed by genetic drift, their genetic diversity is very low.

Learning Check

7. Explain why inbreeding is a form of non-random mating.
8. Why are small populations more susceptible to genetic drift than large populations?
9. What is the founder effect?
10. What is the bottleneck effect?
11. Describe the impact of the founder effect on the gene pool of a population.
12. Describe two events that might result in the bottleneck effect.

Natural Selection

Populations have a wide range of phenotypes and genotypes, and some individuals in a population produce more offspring than others. Selective forces such as competition and predation affect populations. As a result, 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 less favourable alleles. There is a greater chance of an individual with the slightly favourable allele surviving, producing, and passing this allele to offspring. Thus, natural selection causes changes in the allele frequencies of a population, which can lead to evolutionary change.

Several types of natural selection affect the frequency of a heritable trait in a population: stabilizing selection, directional selection, and disruptive selection. Refer to **Figure 9.9** as you read about the types of selection in the following paragraphs.

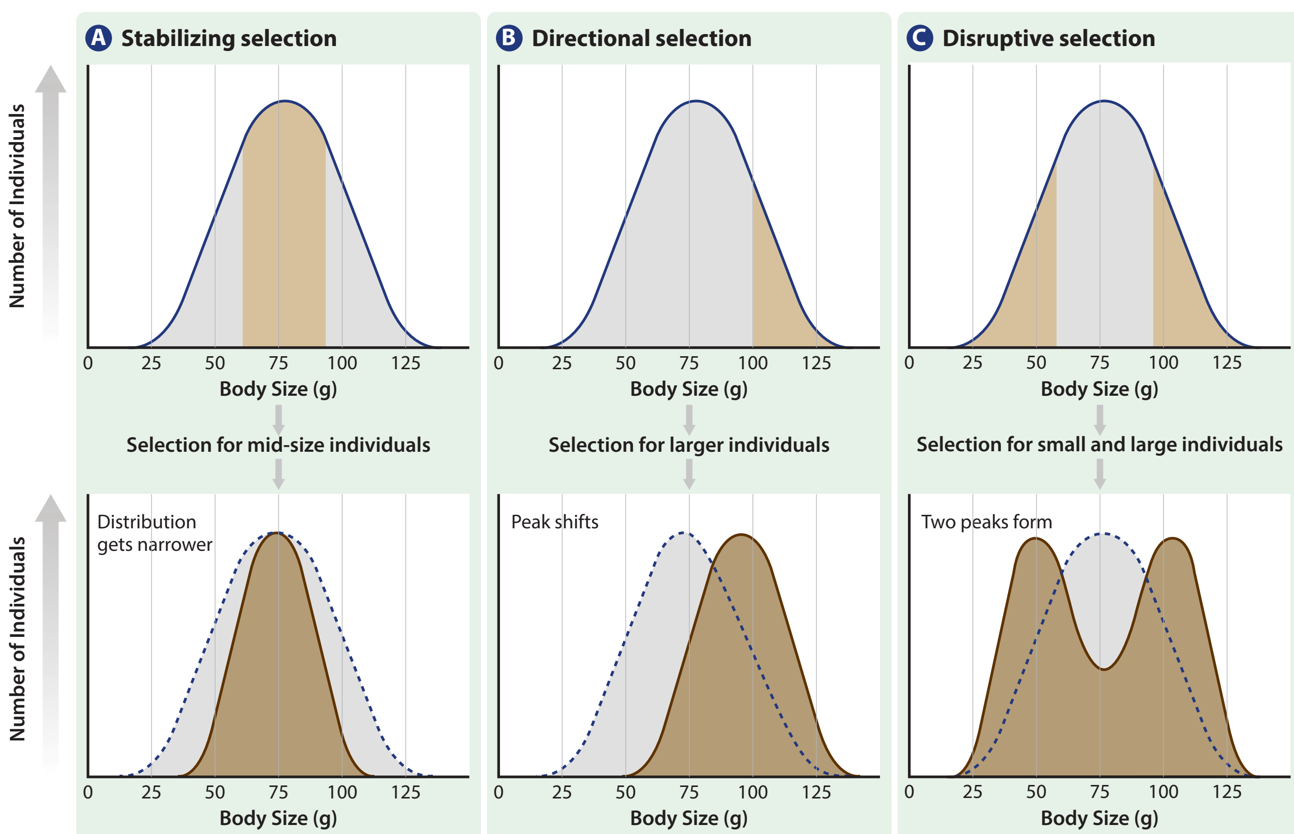


Figure 9.9 These graphs show three types of natural selection. The top panels show the populations before selection has occurred (under the solid blue line). Within the populations, individuals favoured by selection are shown in light brown. The bottom panels show what the populations would look like in the next generation. The blue dashed lines show the original distribution of the population. The dark brown solid lines show the resulting distribution in the next generation.

Stabilizing Selection

Figure 9.9 (A) shows stabilizing selection. **Stabilizing selection** favours an intermediate phenotype and acts against extreme variants of the phenotype. The most common phenotype—the intermediate form—is made more common in the population by removing the extreme forms. This type of selection reduces variation and improves the adaptation of the population to aspects of the environment that remain fairly constant.

stabilizing selection natural selection that favours intermediate phenotypes and acts against extreme variants

directional selection natural selection that favours the phenotypes at one extreme over another, resulting in the distribution curve of phenotypes shifting in the direction of that extreme

disruptive (diversifying) selection natural selection that favours the extremes of a range of phenotypes rather than intermediate phenotypes; this type of selection can result in the elimination of intermediate phenotypes

Directional Selection

Figure 9.9 (B) shows directional selection. **Directional selection** favours the phenotypes at one extreme over the other. 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 and niches to exploit. The changes in the coloration of peppered moths that you read about in Chapter 7 is an example of directional selection. The increase of antibiotic resistance in infection-causing bacteria is another example.

Disruptive Selection

Figure 9.9 (C) shows disruptive selection, also called diversifying selection. **Disruptive selection** takes place when the extremes of a range of phenotypes are favoured over intermediate phenotypes. As a result, intermediate phenotypes can be eliminated from the population. An example of disruptive selection is the extreme size differences in mature male coho salmon (*Oncorhynchus kisutch*). The smaller phenotype of a mature coho salmon averages about 500 g, while the much larger phenotype may be 4500 g or more. This difference in size reflects the means by which each phenotype gains access to females. The smaller salmon are specialized for "sneaking" opportunities to fertilize the eggs of females, while the larger salmon are better equipped for fighting for the same access to the female's eggs.

Sexual Selection

The different phenotypes (forms) of the male coho salmon are also a specific example of natural selection referred to as sexual selection. In general, **sexual selection** involves competition between males through combat (as with the caribou in **Figure 9.3**) or through visual displays (such as the showy feathers and inflated air sacs of the greater sage grouse in the Launch Activity). Sexual selection also involves the choices females make for mates.

sexual selection natural selection for mating based, in general, on competition between males and choices made by females

Males and females of many animal species often have very 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 9.10** shows the striking differences between male and female mallard ducks. These different characteristics, as well as courtship displays and other mating behaviours, are also aspects of sexual selection.

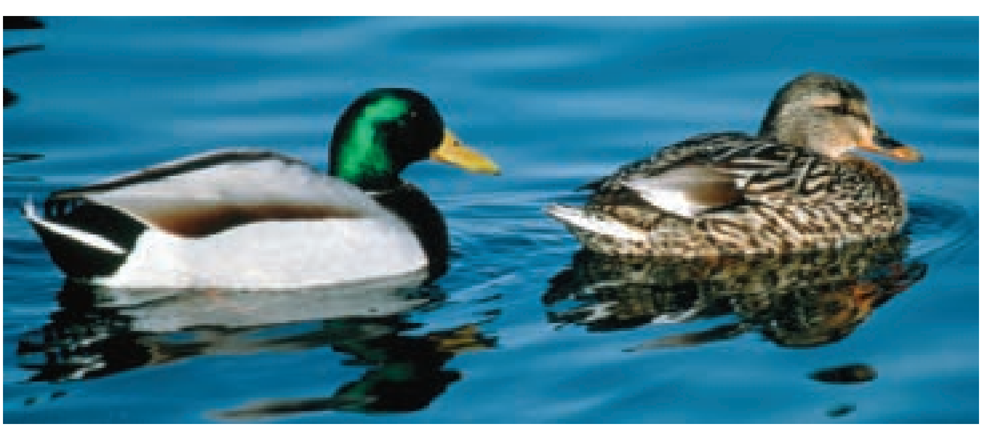


Figure 9.10 Male mallard ducks (*Anas platyrhynchos*) are distinguished from females by their green heads. The coloration of females is brown with white spots.

Identifying Types of Natural Selection

As you have read, different types of natural selection affect the frequency of a heritable trait in a population: stabilizing selection, directional selection, and disruptive selection. Try identifying the type of natural selection described in Activity 9.1 below.

Activity 9.1 Identify the Type of Selection

In this activity, you will interpret visual and graphical information to identify the type of natural selection that is acting on a natural population.

Procedure

1. Read the following information about the growth characteristics of a particular population of a common species of grass.
2. The graphs show a representation of the changes that have occurred in this population of bentgrass over a period of time. Examine these graphs, and use your understanding of the three types of natural selection to identify the type of selection that is acting on this bentgrass population.

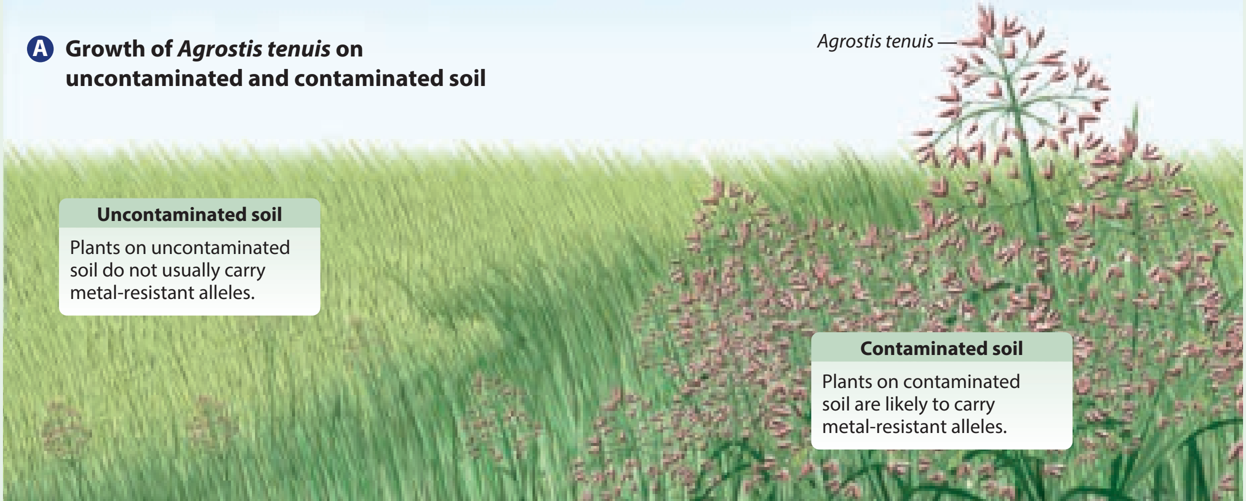
Question

Explain how you decided on the type of selection that you chose.

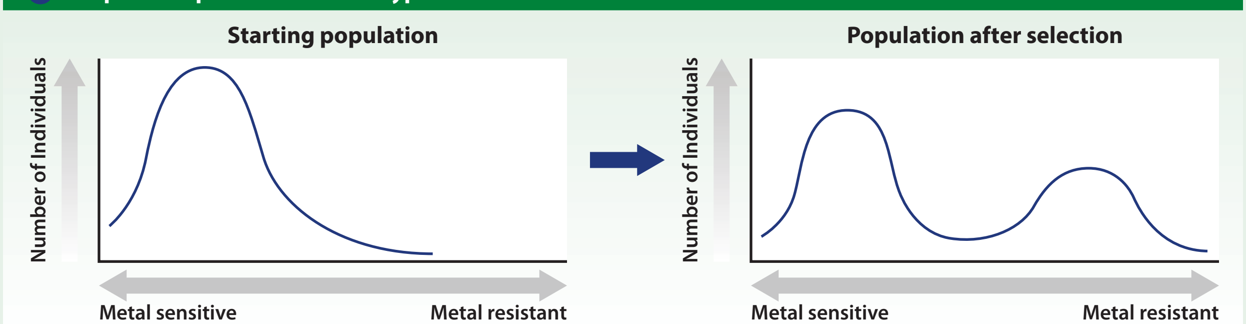
Colonial bentgrass (*Agrostis tenuis*) belongs to a genus of grasses that number about 200 known species worldwide. In some places, this species grows in soil that has been contaminated from mining activities. High concentrations of copper, nickel, lead, and other heavy metals are present in the soil.

In a population of bentgrass growing on contaminated soil in South Wales in the United Kingdom, random mutations have produced alleles that are metal-resistant. As a result, some members of the population show tolerance for the heavy metals and are able to grow on the contaminated soil. However, these same alleles tend to inhibit growth on uncontaminated soil. Sites with varying amounts of metal concentration support bentgrass populations of both types. Therefore, there are sites where metal-resistant bentgrass growing on contaminated soil is visible growing near non-metal-resistant bentgrass growing on uncontaminated soil. The illustration summarizes this situation.

A Growth of *Agrostis tenuis* on uncontaminated and contaminated soil



B Graphical representation of a type of selection



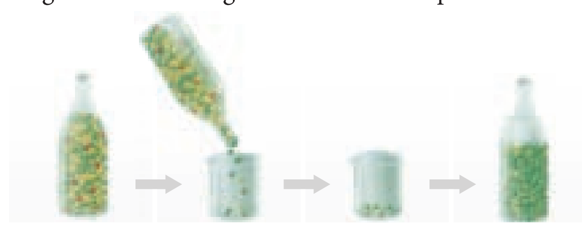
Section 9.1 REVIEW

Section Summary

- Gene flow is the movement, or flow, of alleles between populations.
- The sources of genetic variation in a population are mutations that are acted on by gene flow, non-random mating, genetic drift, and, most importantly, natural selection. When these mechanisms alter gene frequencies, evolution has occurred.
- Gene flow due to migration of individuals can increase the genetic diversity of a population, but gene flow can also decrease the genetic diversity among populations of the same species.
- Non-random mating increases the number of certain alleles because the phenotype produced by those alleles is more attractive to the opposite sex.
- Genetic drift occurs more rapidly in small populations. It can result in the loss of alleles from a population and an increase in the frequency of previously rare alleles. The founder and bottleneck effects are two examples.
- Natural selection is the process that produces adaptive changes within populations.
- When stabilizing selection occurs, an intermediate phenotype has an advantage. When directional selection occurs, an extreme phenotype increases in frequency in a population. When disruptive selection occurs, extreme phenotypes survive in the population at the expense of intermediate forms.
- Sexual selection, which is a type of natural selection, involves characteristics or behaviours that make it more likely for individuals to choose a mate.

Review Questions

1. K/U How do mutations affect genetic variation?
2. K/U Explain why microevolution applies to populations but not to individual organisms.
3. K/U Describe one effect of non-random mating in sexually reproducing plants and one effect in animals.
4. C Use a graphic organizer such as a flowchart to compare stabilizing, directional, and disruptive selection.
5. C Use a graphic organizer to compare and contrast the founder effect with the bottleneck effect.
6. A DNA analysis of cheetahs (*Acinonyx jubatus*) shows little or no genetic variation among individuals. This evidence suggests that their populations declined sharply in the past, and that all the cheetahs alive today are descendants of the survivors.
   - **a.** Explain why skin that is transplanted from one cheetah to another is rejected only about 50 percent of the time. (Normally, skin that is transplanted from one individual of a species to another individual of the same species is rejected 100 percent of the time, unless the two individuals are identical twins.)
   - **b.** Which of the mechanisms that change allele frequencies in populations likely applies to cheetahs? (More than one mechanism may apply.) Explain your answer.
   - **c.** In what ways might the lack of genetic diversity in cheetahs put their populations at risk? Suggest a human action that could be taken to increase the genetic diversity of cheetahs.
7. C Explain what agent of evolutionary change the diagram is modelling. Describe an example.



8. A A population of deer is isolated in a park, and the deer cannot mix with other populations. If this park were connected to another park and the deer were able to mix, what would happen to the gene pools of the two populations? Use a diagram to support your answer.
9. T/I Predict what might happen to the diversity of a gene pool if individuals with rare alleles migrate from the population.
10. K/U Describe the role of mutation in evolutionary changes within a population.
11. T/I An imaginary population of mouse-like "meeps" lives in tunnels under a vegetable garden, which is the source of their food. About 80 percent of the meeps have green fur, and the rest have grey fur. One summer, a dust storm covers the garden with a coating of grey-brown soil. The people who tend the garden can now easily see the green meeps and are better able to trap and remove them humanely to protect their crops. Predict at least one outcome of this situation on the microevolution of this population of meeps as time passes. (Assume that similar dust storms happen every few years.)

SECTION 9.2 Speciation: How Species Form

Key Terms

- speciation
- pre-zygotic isolating mechanism
- post-zygotic isolating mechanism
- sympatric speciation
- allopatric speciation
- ecological niche
- adaptive radiation
- divergent evolution
- convergent evolution
- gradualism
- punctuated equilibrium

speciation the formation of new species from existing species

The two zebras in **Figure 9.11** look very similar, but they are different species. How is a species defined? Historically, biologists defined species in terms of their physical form. Physical similarity, however, does not necessarily mean that organisms are the same species. Biologists now consider physiology, biochemistry, behaviour, and genetics when distinguishing one species from another.

Recall from Section 1.1 that a biological species is a population or group of populations in nature whose individual members can interbreed to produce viable, fertile offspring—offspring that also can interbreed. In Section 9.1, you learned that various factors cause changes within populations—that is, microevolution. When some members of a sexually reproducing population change so much that they are no longer able to produce viable, fertile offspring with members of the original population, speciation has occurred. **Speciation** is the formation of new species from existing species. The formation of new species is also sometimes called macroevolution.

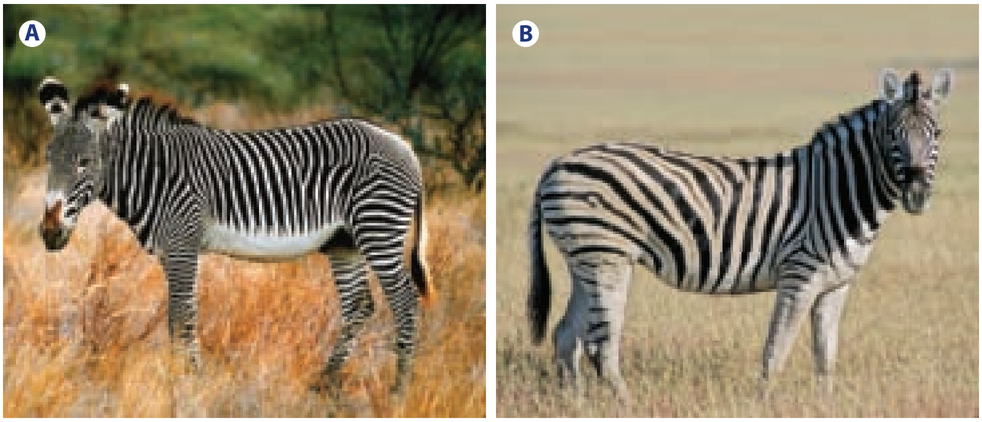


Figure 9.11 The Grevy's zebra (*Equus grevyi*) in **(A)** is classified as an endangered species, whereas the plains zebra (*Equus quagga*) in **(B)** is widespread in Africa.

Explain *If a Grevy's zebra mated with a plains zebra, could the offspring be viable?*

Two populations may become *reproductively isolated* over time (that is, become two species) if there is little or no gene flow between them. Two types of reproductive isolating mechanisms prevent gene flow between populations. As summarized in **Figure 9.12**, these reproductive isolating mechanisms may be pre-zygotic or post-zygotic.

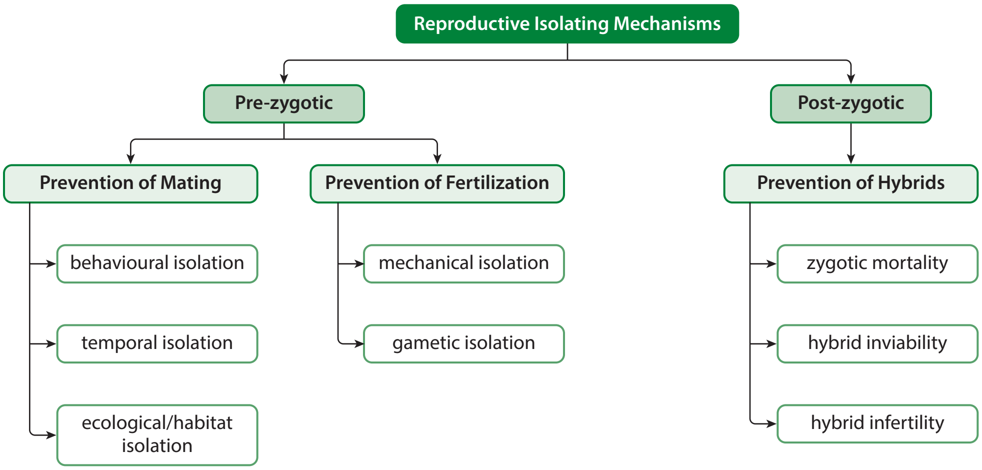


Figure 9.12 The types of reproductive isolating mechanisms are subdivided further, as shown here.

Pre-zygotic Isolating Mechanisms

Pre-zygotic isolating mechanisms (also called pre-fertilization barriers) either impede mating between species or prevent fertilization of the eggs if individuals from different species attempt to mate. There are five kinds of pre-zygotic isolating mechanisms, described below.

pre-zygotic isolating mechanism a barrier that either impedes mating between species or prevents fertilization of the eggs if individuals from different species attempt to mate; also called pre-fertilization barrier

Behavioural Isolating Mechanisms

The songs of birds, the courtship rituals of elk, and the chemical signals (pheromones) of insects are examples of behavioural isolation. Any special signals or behaviours that are species specific prevent interbreeding with closely related species. Another example is the eastern meadowlark (*Sturnella magna*) and the western meadowlark (*Sturnella neglecta*). These species are nearly identical in shape, coloration, and habitat, and their habitat ranges overlap, as shown in **Figure 9.13**. In the area where the ranges overlap, very little mating takes place between the two species, largely due to the differences in their songs. The eastern meadowlark's song is a simple series of whistles, typically about four or five notes. The western meadowlark's song is a longer series of flute-like gurgling notes that go down the scale.

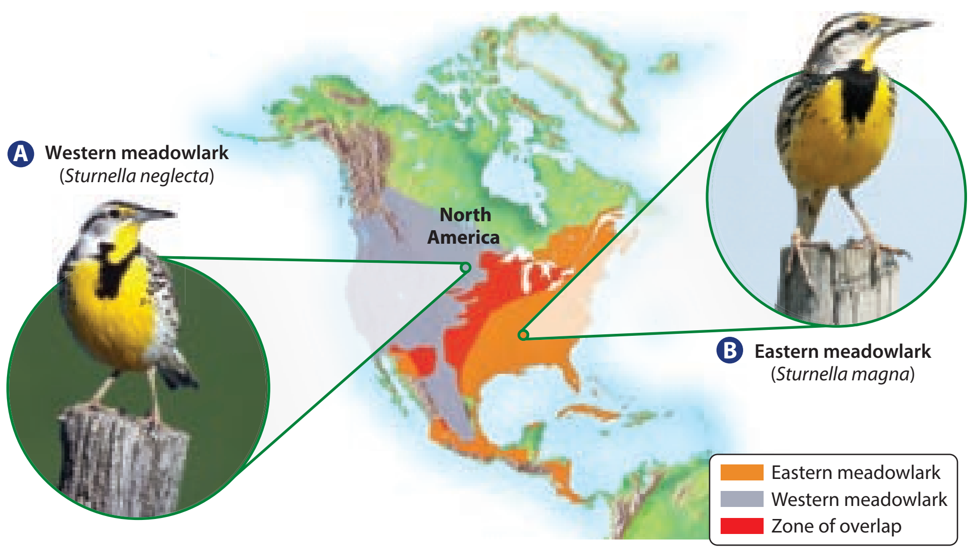


Figure 9.13 **(A)** The western meadowlark and **(B)** the eastern meadowlark are very similar in appearance. The red regions in this map show where the two species' ranges overlap. However, very little interspecies mating takes place because of the differences in their songs.

Habitat Isolating Mechanisms

Two species may live in the same general region but in different habitats, so they may encounter each other rarely, if at all. This mechanism is called habitat isolation. For example, two species of North American garter snakes—the common garter snake (*Thamnophis sirtalis*) and the northwest garter snake (*Thamnophis ordinoides*)—live in the same area. However, the northwest garter snake prefers open areas such as meadows and rarely enters water. The common garter snake, on the other hand, is commonly found near water.

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Temporal Isolating Mechanisms

Many species are kept separate by temporal (timing) barriers. For example, two species may occupy the same habitat but mate or flower at different times of day, in different seasons, or in different years. For example, three tropical orchid species in the genus *Dendrobium* bloom for a single day, with the flowers opening at dawn and withering in the evening. Flowering in all three species occurs in response to various stimuli in the weather. However, the lapse between the stimulus and flowering is 8 days in one species, 9 in another, and 10 in the third. Thus, the three species remain reproductively isolated, even though they live in the same habitat.

Mechanical Isolating Mechanisms

Species that are closely related may attempt to mate but fail to achieve fertilization because they are anatomically incompatible. For example, the genitals of some insects operate in a kind of lock-and-key system. If a male and female of different species attempt to breed, their genitals will not fit together. Genital anatomy is so distinctive in many organisms (especially insects) that it is often used to classify species based on morphology.

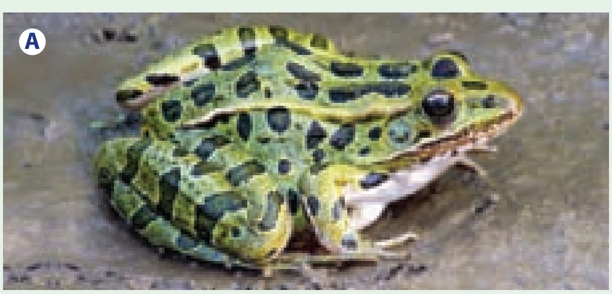
In plants, variations in flower structure may impede pollination if the flower and the pollinator are incompatible. In two species of sage, for example, the flowers have different arrangements of male and female reproductive structures. One species is pollinated by bees that carry pollen on their backs, and the other species is pollinated by bees that carry pollen on their wings. If the "wrong" pollinator visits a flower, pollination cannot occur because the pollen does not come into contact with the male structure of the other species.

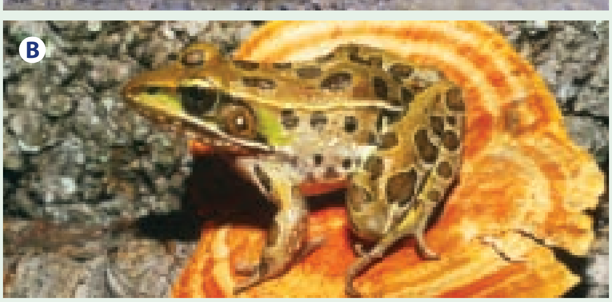
Gametic Isolating Mechanisms

If gametes (egg and sperm) from different species do meet, gametic isolation ensures they will rarely fuse to form a zygote. The methods of gametic isolation vary among species. For example, in species in which the eggs are fertilized within the female reproductive tract, the sperm of one species may not be able to survive in the environment of the female reproductive tract of another species. In plants, pollen grains of one species typically fail to germinate on the stigma of another species, so fertilization is prevented.

Activity 9.2 Leopard Frogs—One Species or Eight?

Leopard frogs were once believed to be a single, extremely variable species (*Rana pipiens*) that ranged across North America. Analyzing frog calls provided one of the clues that led biologists to realize that there was more than one species of leopard frog. Today, scientists know that what they thought of as the leopard frog is actually at least eight different but related species. In this activity, you will explore a biological barrier by listening to frog calls.





The **(A)** northern leopard frog (*Rana pipiens*) and **(B)** Florida leopard frog (*Rana sphenocephala*) are different species.

Materials

- computer with Internet access
- print resources

Procedure

1. Listen to the calls of two different species of leopard frogs supplied by your teacher. What type of biological barrier is a mating call? Explain how this type of biological barrier keeps species separate.
2. Leopard frogs in North America include the northern, southern, Rio Grande, plains, relict, Florida, Ramsey Canyon, and lowland leopard frogs. Research two of these species using Internet or print resources. Describe, in point form, the differences that result in the two species being regarded as a closely related but separate species. (They are called sibling species.)
3. Populations of amphibians, including frogs, are declining in North America, and scientists are tracking population numbers to try to determine the cause of the decline. When it comes to conservation and monitoring of species, why is it important to know that there are eight species of leopard frog rather than a single wide-ranging species?

Question

Populations of amphibians, including frogs, are declining in North America, and scientists are tracking population numbers to try to determine the cause of the decline. When it comes to conservation and monitoring of species, why is it important to know that there are eight species of leopard frog rather than a single wide-ranging species?

Post-zygotic Isolating Mechanisms

In rare cases in nature, the sperm of one species successfully fertilizes an egg of another species and a zygote is produced. There are several **post-zygotic isolating mechanisms** (post-fertilization barriers) that prevent these hybrid zygotes from developing into viable, fertile individuals.

post-zygotic isolating mechanism a barrier that prevents hybrid zygotes from developing into viable, fertile individuals; also called post-fertilization barrier

Hybrid Inviability

Genetic incompatibility of the interbred species may stop development of the hybrid zygote during its development. For example, hybrid embryos between sheep and goats die in early development before birth. Hybrid inviability is usually due to genetic incompatibility, which prevents normal mitosis after fusion of the nuclei in the gametes.

Hybrid Sterility

Sometimes, two species can mate and produce hybrid offspring. A familiar example, shown in **Figure 9.14**, is a mule, which is the offspring of a horse and a donkey. However, a reproductive barrier still exists between the two species if the hybrid offspring is sterile, as in the case of a mule. If meiosis fails to produce normal gametes in the hybrid (because the chromosomes of the two parent species differ in number or structure), this barrier may come into effect.

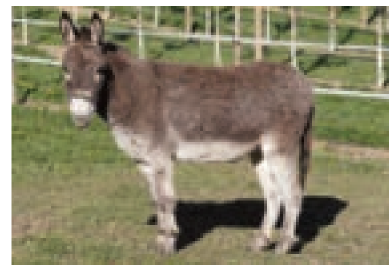


Figure 9.14 A mule is the offspring of a female horse and a male donkey.

Hybrid Breakdown

In some cases, the first-generation hybrids of crossed species are viable and fertile. However, when these hybrids mate with each other or with an individual from either parent species, offspring of the next generation are either sterile or weak. For example, different species of cotton plants can produce fertile hybrids, but the offspring of the hybrids die as seeds or early in development.

Types of Speciation

Recall from Chapter 1 that a biological species is only one of several species concepts that include the morphological and phylogenetic species concepts. Regardless of how species are defined, the process of speciation requires populations of organisms to become, and largely to remain, genetically isolated from one another.

There are two types of speciation, called sympatric and allopatric speciation, and they are based on how gene flow is disrupted within a population. Sympatric speciation enables populations that live in the same habitat to diverge genetically. Allopatric speciation occurs when populations are separated by a geographical barrier and then diverge genetically. These ideas are discussed starting on the next page.

Learning Check

13. Explain the meaning of the term *biological species*.

14. In a Venn diagram, compare the two types of reproductive isolating mechanisms.

15. If two species produce a hybrid offspring that is infertile, is reproductive isolation between the two species still maintained? Explain your answer.

16. Two species of grass plants flower at different times of year, but they live in the same habitat. What type of reproductive isolating mechanism is this?

17. If the two zebra species shown in **Figure 9.11** were found to mate in zoos but not in nature, would they still be considered different species? Explain your answer.

18. Two species of birds overlap in range, but one lives in open woods and farmland, and the other lives in swampy areas. What type of reproductive isolating mechanism is this?

sympatric speciation speciation in which populations within the same geographical areas diverge and become reproductively isolated

Sympatric Speciation

When populations live in the same geographical area and become reproductively isolated, **sympatric speciation** occurs. In sympatric speciation, factors such as chromosomal changes (in plants) and non-random mating (in animals) alter gene flow. This type of speciation is far more common in plants than in animals.

Given the right set of conditions, a new species can be generated in a single generation if a genetic change results in a reproductive barrier between the offspring and the parent population. For example, errors in cell division that result in extra sets of chromosomes (a mutant condition called *polyploidy*) can lead to speciation. A polyploidy organism has three or more sets of chromosomes in the nucleus of each of its cells. Most animals are diploid, with one set of chromosomes inherited from each parent. It is rare for animals to be polyploid, but among plants—especially flowering plants—it is quite common because many species are able to self-pollinate.

Recall that during meiosis, a sequence of events must occur for organisms to reproduce successfully. As shown in **Figure 9.15**, if errors occur during meiosis and chromosomes do not separate, the gametes produced have two sets of chromosomes (diploid, $2n$) instead of one set (haploid, $1n$). Then, if two diploid gametes fuse, the offspring have four of each chromosome (tetraploid, $4n$). If tetraploid offspring survive, they could undergo normal meiosis and produce diploid gametes. The plant can now self-pollinate or reproduce with other tetraploids. However, it cannot produce viable seeds when crossed with diploid plants from the original population, since any offspring from this mating would be triploid ($3n$) and therefore sterile. In just one generation, a reproductive barrier has been established in a population because gene flow is interrupted between a small population (as small as one individual) of tetraploids and the parent population.

In another model of sympatric speciation, two species can interbreed to produce a sterile offspring. Although the offspring is infertile, it can reproduce asexually, resulting in the formation of a separate population. Through mechanisms such as errors in meiosis, the sterile hybrids can be transformed into fertile polyploids in subsequent generations, thus forming a new, fertile species. This situation is responsible for the evolution of wheat. Chromosome analysis has shown that wheat is the result of two hybridizations of wheat with wild grasses, and two instances of meiotic error. As a result, a new species—the wheat that has been used to make bread for 8000 years—arose. Many other species grown for agriculture, including cotton, oats, and potatoes, are also polyploids.

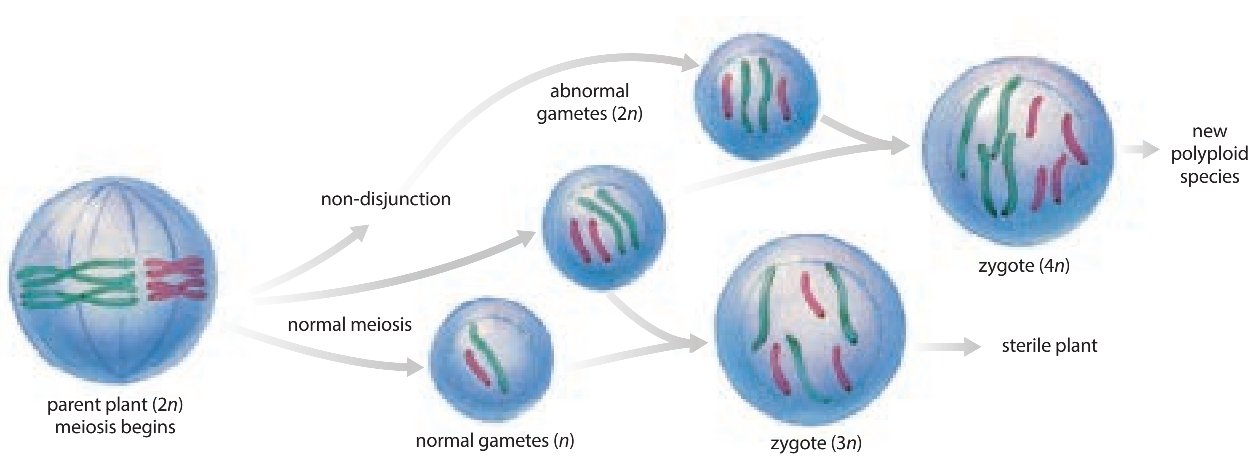


Figure 9.15 Polyploidy can lead to the formation of new species through sympatric speciation.

Allopatric Speciation

As shown in **Figure 9.16**, **allopatric speciation** occurs when a population is split into two or more isolated groups by a geographical barrier. (Allopatric speciation is also called geographical speciation.) Eventually, the gene pool of the split population becomes so distinct that the two groups are unable to interbreed even if they are brought back together. Examples of geographical barriers that lead to allopatric speciation include a glacier or lava flow that isolates populations, fluctuations in ocean levels that turn a peninsula into an island, and a few colonizers reaching a geographically separate habitat. Once populations are reproductively isolated, allele frequencies in the two populations can begin to diverge due to natural selection, mutation, genetic drift, and/or gene flow. This geographical isolation of a population does not have to be maintained forever for speciation to occur. However, it must be maintained long enough for the populations to become reproductively incompatible before they are rejoined.

allopatric speciation speciation in which a population is split into two or more isolated groups by a geographical barrier; also called geographical speciation

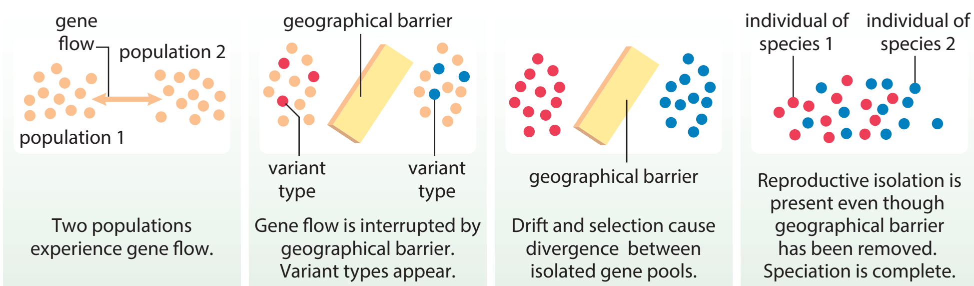


Figure 9.16 Allopatric speciation occurs after a geographical barrier prevents gene flow between populations that originally were part of a single species.

Generally, small populations that become isolated from the parent population are more likely to change enough to become a new species. Part of the reason for this is that populations usually become geographically isolated at the periphery, or edges, of their range. It has been shown that groups of individuals at the periphery of a population already have a slightly different gene pool than that of the parent population. As a result, if this population splinters off, it is subject to the founder effect, since it already has a gene pool not representative of the parent population. In addition, until the peripheral population becomes large, it is subject to the effects of genetic drift. Because of the smaller population size, new mutations or new combinations of alleles may become fixed in the population simply by chance. This fixing of alleles would cause the genotype and phenotype to diverge from those of the parent population.

In addition, because the isolated population may inhabit an environment that is slightly different from that of the parent population, natural selection through selective pressure may change the population in a different way. Note that isolated groups within populations will not automatically survive and thrive when separated into a new population. Many isolated populations do not last long enough or change enough to become new species.

Learning Check

19. What is necessary in a population for the process of speciation to occur?

20. Explain the main differences between sympatric and allopatric speciation.

21. Explain why sympatric speciation is more common in plants than in animals.

22. The Grand Canyon is about 6 km wide, 450 km long, and over 1.5 km deep. The same bird species have been observed living on either side of the Grand Canyon, while different squirrel species live on opposite sides. In what way are the squirrels an example of allopatric speciation?

23. Why are smaller populations more likely to undergo speciation compared with larger populations?

24. Will all isolated populations become new species? Why or why not?

ecological niche the ecological role and physical distribution of a species in its environment

Darwin's Finches: An Example of Allopatric Speciation

The population of finches being studied in the Galapagos is an example of speciation "in action." At some time in the past, members of the ancestral species reached one of the islands in the Galapagos, possibly as a result of being blown off course during a tropical storm. With no other land birds on this island, the ancestral finch species had many unoccupied **ecological niches** to move into and adopt. During the time that this occurred, individual finches were subjected to different types of selective pressures, and some may have flown to nearby islands with still more unoccupied niches to adopt. As a result, over time, the ancestral species divided into different populations, and some of these evolved into new species—the species that now populate the many islands of the Galapagos.

By observing the finches now present on the islands, measuring features such as beak length, and analyzing the DNA of the birds, scientists have been able to develop an evolutionary (phylogenetic) tree showing the descent of 14 species from one common ancestor. The phylogenetic tree in **Figure 9.17** shows some of these species. The length of each branch of the tree reflects how much the DNA of the various species has mutated from the group's common ancestor. The phylogenetic tree shows how the ancestral population initially gave rise to several groups of finches. DNA evidence suggests that the warbler finches were an early offshoot, and ground finches and tree finches diverged later. Over time, populations within each group specialized to use the resources in their particular island habitats, and some of these populations eventually diverged to form species with distinctive lifestyles. For instance, some specialized in catching insects on the ground, and others specialized in catching insects in trees.

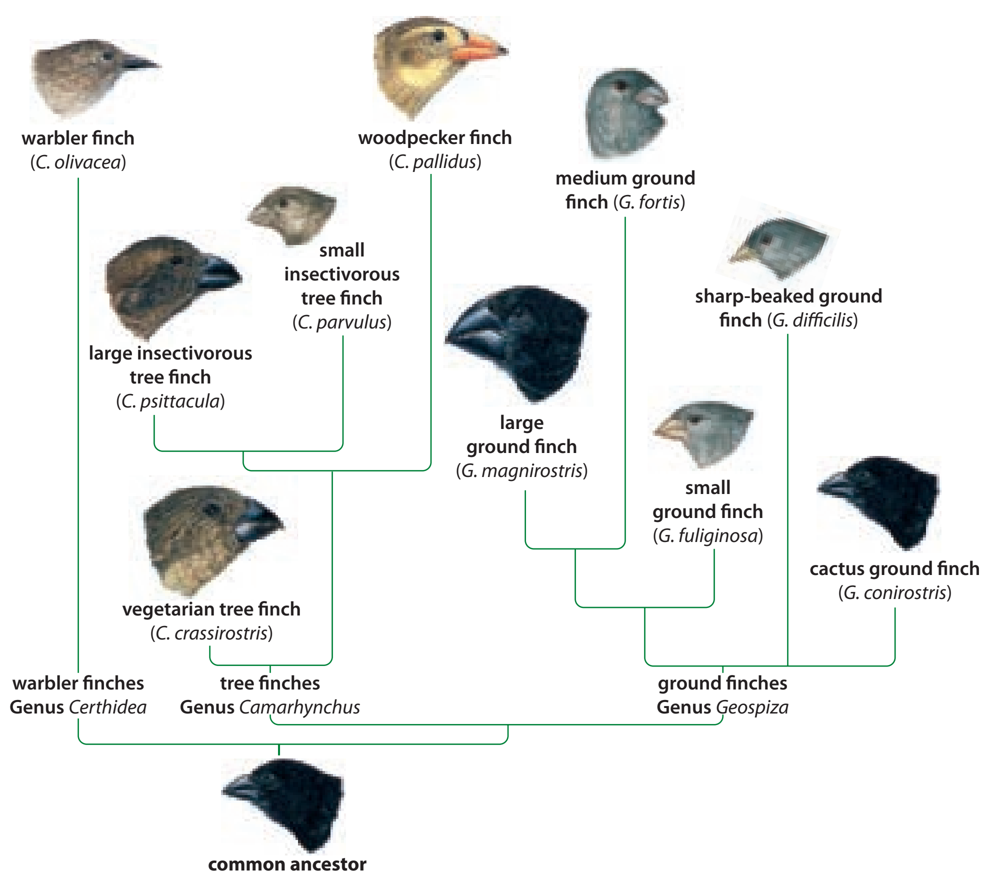


Figure 9.17 The common ancestor initially gave rise to several groups of finches. As time passed, populations within different groups became geographically and reproductively isolated from one another.

Adaptive Radiation

The speciation of finches throughout the Galapagos Islands is an example of adaptive radiation. **Adaptive radiation**, a form of allopatric speciation, is the diversification of a common ancestral species into a variety of differently adapted species. Islands are excellent places to study speciation, and biologists sometimes refer to them as living laboratories. Islands give organisms that have dispersed from a parent population the opportunity to change in response to new environmental conditions in relative isolation.

adaptive radiation the diversification of a common ancestral species into a variety of differently adapted species

The volcanic Hawaiian Islands are one of the best places in the world to study evolution. The group of islands, or archipelago [ahr-ke-PEL-agoh], is about 3500 km from the nearest continent, and the islands vary in age. When the islands first formed, they had no life. Over time, they were gradually populated by species travelling by ocean currents or by winds. Each island has different physical characteristics with many exploitable niches, so adaptive radiation has resulted in great biodiversity. Most of the thousands of species of animals and plants that live in the Hawaiian Islands are found nowhere else in the world. For example, Hawaiian honeycreepers, members of the finch family, are found only in Hawaii. About 28 species of honeycreepers are believed to have evolved from ancestors that crossed the ocean from the American mainland about five million years ago.

Adaptive radiation does not occur just on islands. In 1991, two biologists at the University of British Columbia, Anna Lindholm and Craig Benkman, studied a particular type of finch, called a red crossbill, to demonstrate speciation. The twisted beak of the crossbill, shown in **Figure 9.18**, allows it to pry open closed conifer cones. Different-sized birds open different-sized cones. Small-beaked crossbills feed mostly on softer larch cones; birds with a medium-sized bill feed on harder spruce cones; and heavy-beaked crossbills feed on tightly closed, very hard pine cones.

Suggested Investigation

Inquiry Investigation 9-A, Islands and Species

The beaks of seven birds, which specialize in eating the tightly closed cones of western hemlock, were "uncrossed" by trimming them with nail clippers—a painless procedure. The scientists observed that birds with clipped bills were as effective as those with crossed bills at getting seeds from open cones. However, birds with clipped bills could not open closed cones. As their bills grew back and began to cross again, the birds gradually became better at opening the closed cones again.

The development of the crossed bill did not arise all at once. The crossed bill changed gradually by selective pressure, one generation after the next, until the birds were expert at opening tightly closed cones. The novelty of a crossed bill gave the birds an advantage over others in the same habitat because it allowed them to eat food no other bird could. Individuals with this variation were then able to radiate into other habitats and niches, since they had perfected a feeding technique for which they had no competitors.

Major episodes of adaptive radiation often occur after the evolution of a novel characteristic. For example, the evolution of limbs in vertebrates and wings in insects opened up new possibilities for habitat and food supplies. Insect wings resulted in the evolution of hundreds of thousands of variations on the basic insect body plan, making this group the most successful and widespread type of animal on Earth.

Figure 9.18 The crossed bill of the red crossbill (*Loxia curvirostra*) enables it to extract seeds from even the most tightly closed of conifer cones.

Activity 9.3 Lake Victoria Cichlid Speciation

Lake Victoria, in the heart of equatorial Africa, is the largest tropical lake in the world. The lake is home to hundreds of species of small, closely related fishes called cichlids [SI-kleds]. Each species has features that make it unique from other cichlid species in the lake, and none of these species is found anywhere else on Earth. What accounts for their incredible diversity?

Materials

- computer with Internet access
- print resources

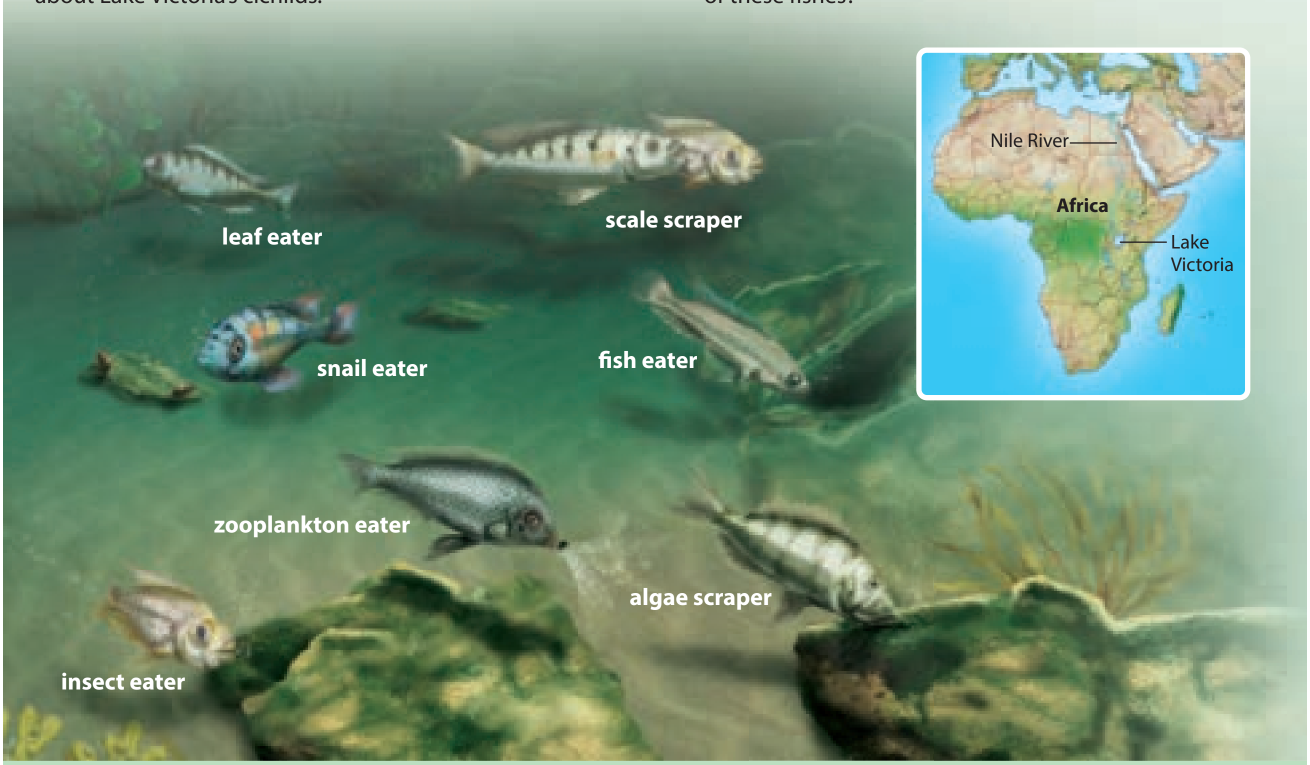
Procedure

Do research to find out the following information about Lake Victoria's cichlids.

- When and by what means do scientists think cichlids first entered Lake Victoria, and why do they think so?
- In what ways have food-related adaptations enabled cichlids to occupy so many different niches?
- How have selective pressures affected cichlids since the 1950s?

Questions

1. Which method of speciation, sympatric or allopatric, likely accounts for cichlid diversity in this lake? What is the evidence?
2. What has been the effect of human activity on cichlid diversity in Lake Victoria, and what is the current status of these fishes?



divergent evolution a pattern of evolution in which species that were once similar to an ancestral species diverge, or become increasingly distinct

convergent evolution a pattern of evolution in which similar traits arise because different species have independently adapted to similar environmental conditions

Divergent and Convergent Evolution

The patterns of speciation discussed in the previous pages are examples of **divergent evolution**, a pattern of evolution in which species that were once similar to an ancestral species diverge, or become increasingly distinct. Divergent evolution occurs when populations change as they adapt to different environmental conditions. The populations become less and less alike as they adapt, eventually resulting in two different species.

In contrast, in some instances two unrelated species share similar traits. For example, both birds and bees have wings, yet they have different ancestors. In **convergent evolution**, similar traits arise because each species has independently adapted to similar environmental conditions, not because they share a common ancestor. Birds and bats evolved independently and at different times, yet natural selection favoured variations suitable for the same environment: air. Since they do not share a common ancestor, however, birds and bats evolved quite different wings.

The Speed of Evolutionary Change

Figure 9.19 shows two models that attempt to explain the speed at which evolution occurs. Since Darwin's time, evolutionary biologists have supported the model of **gradualism**, which views evolutionary change as slow and steady, before and after a divergence. According to this model, big changes occur by the accumulation of many small changes. The fossil record, however, rarely reveals fossils that show this gradual transition. Instead, paleontologists most often find species appearing suddenly in the fossil record, and then disappearing from the record equally as suddenly.

In 1972, Niles Eldredge of the American Museum of Natural History and Stephen Jay Gould of Harvard University suggested an alternative model, which they called **punctuated equilibrium**. According to this model, evolutionary history consists of long periods of stasis, or equilibrium, that are "punctuated," or interrupted, by periods of divergence. Most species undergo much of their morphological change when they first diverge from the parent species. After that, they change relatively little, even as they give rise to other species. Given this model, the fossil record should consist mostly of fossils from the long periods of time when little or no change occurred, with only a few fossils from periods of rapid change.

It is now accepted that both models of evolutionary change are at work. While many species have evolved rapidly during periods of Earth's history, the fossil record also shows very gradual change for some species over extended periods of time.

gradualism a model of evolution that views evolutionary change as slow and steady, before and after a divergence

punctuated equilibrium a model of evolution that views evolutionary history as long periods of stasis, or equilibrium, that are interrupted by periods of divergence

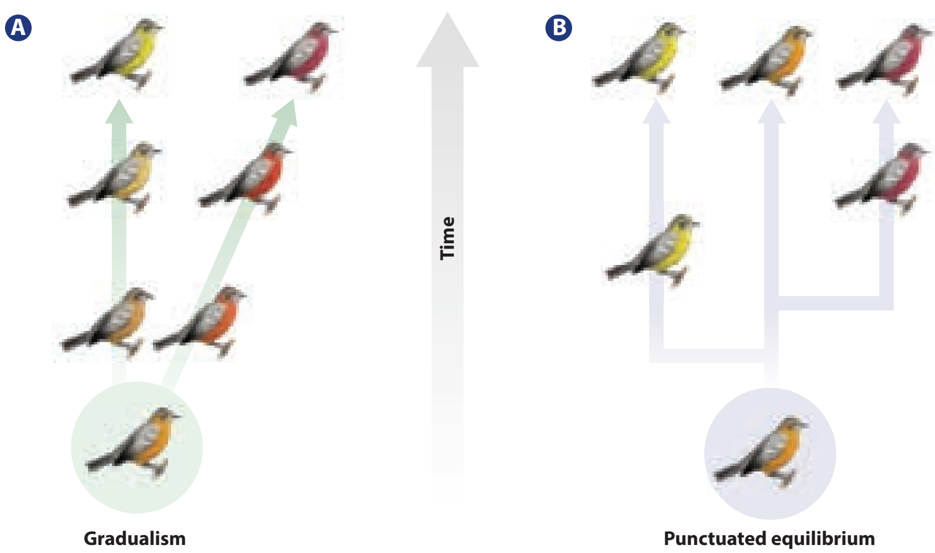


Figure 9.19 Two models have been proposed to explain the speed of evolution: **(A)** gradualism and **(B)** punctuated equilibrium.

Activity 9.4 Shaping the Theory

In Activity 8.1 in Chapter 8, you researched scientists who influenced Charles Darwin's theory of evolution by natural selection. In this activity, you will consider several scientists since Darwin whose ideas have further shaped this theory.

Materials

- computer with Internet access
- print resources

Procedure

1. Research how the following people have affected the modern theory of evolution: George G. Simpson, Theodosius Dobzhansky, Ernst Mayr, Niles Eldredge, and Stephen J. Gould.
2. Search further to find at least two more scientists who have also made important contributions to the theory.
3. Summarize your results with a timeline or graphic organizer.

Question

Which contributor do you consider the most valuable in helping you understand the modern theory of evolution? Why?

Learning Check

25. What is an ecological niche?

26. Explain why it would have been possible for an ancestral finch species, having arrived on one of the Galapagos Islands, to have diversified and evolved into other species over time.

27. Why is the evolution of finches on the Galapagos Islands an example of allopatric speciation?

28. What is adaptive radiation?

29. Use a Venn diagram to compare and contrast divergent evolution and convergent evolution.

30. Explain how the two models, gradualism and punctuated equilibrium, are different from each other and yet both can be used to explain evolution by natural selection.

Consequences of Human Activities on Speciation

Human activities can affect the genetic diversity of populations in various ways. Habitats may become fragmented when people conduct activities such as the following:

- convert large stretches of wilderness into croplands
- develop wilderness areas for recreation or tourism
- build roads
- build urban subdivisions
- flood large areas of land to build dams for hydroelectric power generation

As with the geographic barriers that may lead to natural allopatric speciation events, these human-made barriers may prevent gene flow between the split populations. Over time, the isolated populations may undergo adaptive radiation if their environments are very different. On the other hand, severely fragmented populations may eventually die out if there is insufficient genetic diversity to permit adaptation to particularly challenging environmental changes.

The giant panda, seen in **Figure 9.20**, is a large black and white bear that lives in the bamboo forests of China. The giant panda eats only bamboo that grows at altitudes between 500 m and 3100 m. But this habitat is being reduced through human activities, such as agriculture, collecting medicinal herbs, harvesting bamboo, and the development of roads and hydroelectric stations. Pandas are also being hunted illegally. As a result, the remaining panda populations are in danger of going extinct.

A pair of breeding pandas needs a range of around 30 km^2 to support them. However, many populations of pandas are now isolated in small belts of bamboo forests as narrow as 1.2 km wide. Panda populations are dependent on conservation efforts to avoid extinction. Significant work has been done. According to a survey, there were over 2000 pandas in the wild in 2006, which is about 75 percent more than were thought to exist. In addition, panda habitat conservation areas are increasing in size and number, offering hope for natural populations.

Figure 9.20 Giant panda populations are under extreme pressure from habitat loss. With their low reproductive rates and their total dependence on bamboo for food, the giant panda has hovered on the brink of extinction for several decades. Populations are recovering and habitat is being preserved and protected, but the future of the panda is still uncertain.

Human Activities and Population Decline

Unregulated hunting, habitat removal, and other human activities that cause populations to decline abruptly can cause a bottleneck effect followed by genetic drift. The sudden large-scale loss of genetic diversity results in inbreeding, which may cause fertility rates to decline. Populations that lack genetic diversity are more susceptible to new diseases and other environmental changes, too. For example, during the last century, the chestnut blight fungus, an introduced species, destroyed populations of the American chestnut tree. As a result, the current populations of American chestnut trees have little genetic variation. Conservation and wildlife management programs must take into account the processes affecting gene pools in order to ensure that wild populations remain large enough and have sufficient genetic diversity to survive.

Speciation and Mass Extinctions

Go to **scienceontario** to find out more

You have learned how species form, but how do species end, apart from the influence of human activities? The environment is a strong influence on both speciation and extinction. Environmental influences create selective pressure, and these influences can be both positive and negative. In some cases, new species will arise. In other cases, though, existing species go extinct.

Overall, biological diversity has increased since the Cambrian period, about 500 million years ago. While the general trend has been an increase in the number of species, there have also been several sharp declines in the number of species. These are known as mass extinction events. Five major mass extinctions have been identified, as shown in **Figure 9.21**. The most severe one occurred at the end of the Permian period, about 250 million years ago. At that time, more than 50 percent of all families, representing about 96 percent of all species, are thought to have gone extinct.

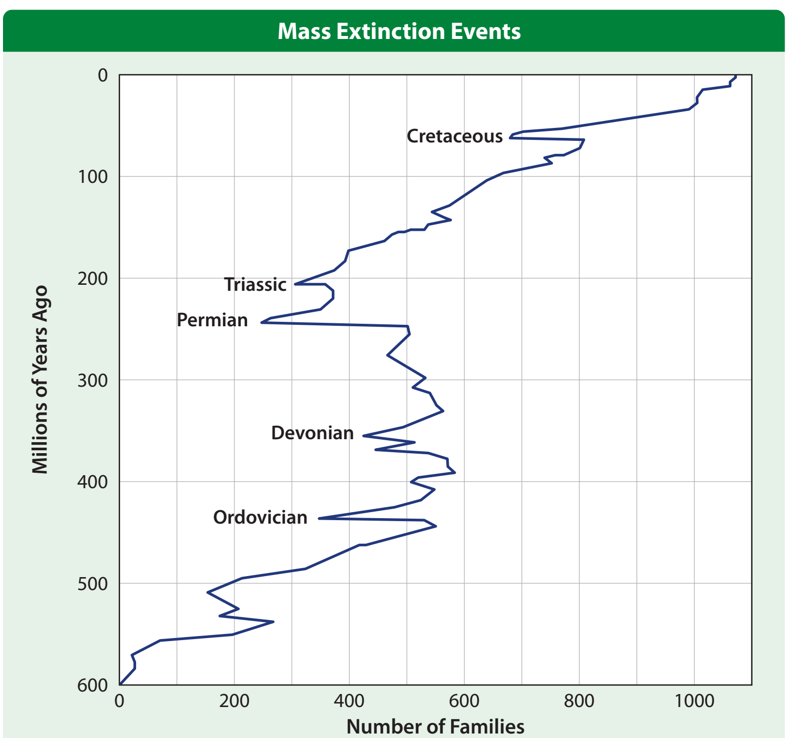


Figure 9.21 The five major mass extinction events are labelled here. The vertical axis of the graph begins about 600 million years ago to mark the approximate start of the Cambrian period. The graph shows families of organisms, rather than individual species, because many species that have been identified and named by scientists are known from only one discovered specimen.

Mass Extinction and Adaptive Radiation of Mammals

The Cretaceous extinction of 65 million years ago (**Figure 9.21**) marks the boundary between the Mesozoic and Cenozoic eras. Recent scientific research supports the hypothesis that this extinction event was triggered by the impact of a large asteroid. This may have caused massive forest fires. As a result, huge amounts of particles may have been thrown into the air, blocking the Sun for months. During this mass extinction, more than half the existing marine species and many families of terrestrial plants and animals, including the dinosaurs, were exterminated. The climate cooled and the sea levels changed. While this event ended the age of the dinosaurs, it was a catalyst for the adaptive radiation of mammals, which, until that time, were probably not much larger than mice.

Although species diversity does come back after mass extinctions, it is not a rapid recovery. Scientists estimate that it takes about 10 million years for species diversity to reach its former levels.

Speciation: A Summary

Go to **scienceontario** to find out more

One way to summarize how a new species can form is to take an example and hypothesize its speciation using the concepts presented in this chapter. For example, the tortoises on the individual islands in the Galapagos are all different. In fact, when Charles Darwin visited the islands in 1835, the vice-governor of the islands told him that he could identify what island any tortoise was from simply by looking at it. **Figure 9.22** shows the conditions that may have resulted in the speciation of the various tortoises in the Galapagos Islands.

Example of How a New Species Can Form

- Individuals from a species of South American tortoise found their way to the Galapagos Islands, and some survived in their new environment.
- As these tortoises foraged on the islands, their ability to survive the environmental conditions of their surroundings resulted in some individuals surviving and reproducing. (Mutations ensure that the genetic make-up of each individual in a species is slightly varied.)
- Those producing offspring passed on the characteristics that enabled them to survive in the new environment.
- Through natural selection, the descendants of the ancestral tortoise population began to change. Over time, new species arose.
- The tortoises also moved to different islands, so the populations changed further through adaptive radiation.

Figure 9.22 This figure illustrates how the various mechanisms of speciation interact to form a new species.

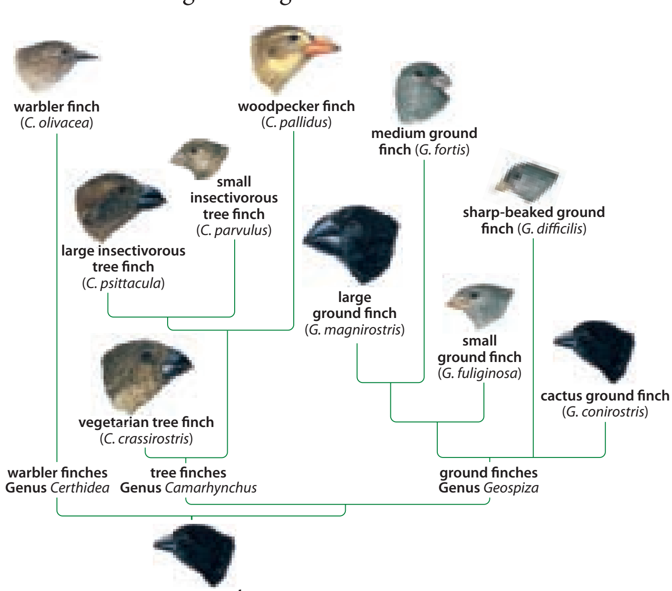
Section 9.2 REVIEW

Section Summary

- A species consists of a reproductively compatible population, and speciation is the formation of new species from previously existing species.
- Pre-zygotic isolating mechanisms either impede mating between species or prevent fertilization of the egg. These mechanisms include behavioural, habitat, temporal, mechanical, and gametic barriers.
- Post-zygotic isolating mechanisms prevent hybrid zygotes from developing into viable, fertile individuals.
- In sympatric speciation, populations become reproductively isolated without geographical isolation. In allopatric speciation, populations are geographically isolated and thus become reproductively isolated.
- Adaptive radiation, a form of allopatric speciation, occurs when there is diversification from a common ancestor into a variety of species.
- In convergent evolution, similar traits arise because each species is independently adapted to similar environmental conditions. In divergent evolution, a species that was once similar to an ancestral species diverges or becomes increasingly distinct.
- Gradualism proposes that evolution occurs slowly and steadily over time. Punctuated equilibrium proposes that evolution consists of long periods of equilibrium, interrupted by periods of speciation.

Review Questions

1. K/U What does *reproductive isolation* mean?
2. K/U Two species produce a hybrid offspring that is infertile. Is reproductive isolation between the two species still maintained? Explain.
3. T/I Severe flooding results in a river changing course. Would you expect that a species of mouse that now lives on both sides of the river might eventually become two different species? What about a species of bird that now lives on both sides of the river? Explain.
4. A One frog species lives only in tree holes, and another lives only in streams. Both live in the same area. Identify the reproductive barrier in this example.
5. T/I Interpret the speciation of four of the Galapagos finches using this diagram.



6. C Use the following table to compare the different isolating mechanisms. Give your table a descriptive title.

Type of Isolating Mechanism	Description	Example

7. A Hedgehogs are porcupine-like rodents that are native to Europe, Asia, and Africa. Echidnas are anteaters native to Australia. Both have spiny skins. Is this an example of divergent evolution? Explain.
8. K/U List two ways that human activity can affect species and speciation, and explain how.
9. C In a graphic organizer, distinguish between the two models that describe the speed of evolution.
10. K/U What is a mass extinction?
11. A The Greater Antilles are a group of islands in the Caribbean, which include Cuba, Dominican Republic, Haiti, Jamaica, and Puerto Rico. Each island is home to many lizard species that look very similar. DNA analysis shows that the similar-looking lizards from different islands are not alike genetically. Explain this.
12. A Before they became extinct about 10 000 years ago, populations of a small horse (*Equus conversidens*) roamed North America. Suggest two hypotheses—one due to natural activity and one due to human activity—that could account for the extinction of this species.
13. K/U How does adaptive radiation explain the speciation of the red crossbill?

Inquiry INVESTIGATION

9-A

Skill Check

- Initiating and Planning
- ✓ Performing and Recording
- ✓ Analyzing and Interpreting
- ✓ Communicating

Materials

- paper
- computer with Internet access
- print resources
- coloured pencils

Go to ***Developing Research Skills*** in ***Appendix A*** for help with conducting research.

Islands and Species

Suppose there is a small group of islands, off the west coast of South America, just below the equator. They are volcanic in origin and have existed for over five million years. Five hundred thousand years ago, a single pair of rats, one male and one female (that looked exactly like present-day rats), was washed off the main coast of South America. Clinging to a large tangle of logs, the rats drifted out to sea and came ashore on one of the volcanic islands. Over thousands of years, the offspring of those rats colonized all the islands in the group. In this investigation, you will design a rat that has adapted to one of the islands.

Pre-Lab Questions

1. Define *allopatric speciation.*
2. Explain the process of adaptive radiation.
3. How are reproductive barriers important to speciation?

Question

What are the characteristics of the rat species living on your island, and how do those characteristics reflect natural selection and adaptation?

Island A

The island is fairly flat, with an occasional hill. The ground is soft dirt, and several species of shrubs grow toward the centre of the island. There is no animal life on land, but the water is teeming with fish. The island is surrounded by a coral reef, which keeps the predators out. The shore is sandy with no algal growth. Fresh water is available.

Island B

The island has a rocky shoreline. Numerous tidal pools dot the island along the shore where the wave action is somewhat sheltered by rock outcrops. The tidal pools host barnacles, chitons (primitive molluscs), abalone, sea urchins, and crabs. Algae grow all around the island, but algal growth is quite sparse in the tidal pools where the various land and aquatic animals feed. The current is quite strong along the rocky outcrops where the algae grow best. Fresh water is available.

Island C

The island is somewhat barren. A few species of cactus thrive on the bare rocks. A species of large cactus-eating tortoises inhabits the island. A species of very large birds nests on the island annually. They build their nests on the rocks, and protect their eggs from the Sun by standing over the nests with outspread wings. The nests are always on the windy side of the island, which is cooled by offshore breezes.

Island D

The island is an extinct volcano. Vegetation on the island changes, depending on the altitude. Grasses grow at the base. On the lower slope of the volcano, the grasses give way to low shrubs. Halfway up, the island becomes quite lush—tropical plants and trees dominate the landscape. At this altitude, the island experiences frequent rain showers. There are two species of birds that inhabit the island. One is a raptor that preys on the smaller birds. The other bird species fishes the waters approximately half a kilometre offshore. Both nest in trees.

Procedure

1. Research print and Internet sources to learn specific characteristics of rats, including their size, coloration, living and feeding habits, and predators. List the characteristics of a modern rat as your ancestor rat.

This photograph shows a modern-day brown rat.

2. Consider the characteristics of the island that your teacher has assigned you. List what types of food are available, what types of predators exist, and so on. Draw a sketch of your island, showing the geography and any other characteristics you can add.
3. Think about the types of adaptations a rat would need to survive on your island. Draw your rat.
4. Present your rat and your island to the class along with your answers to the Analyze and Interpret questions.

Analyze and Interpret

1. How many adaptations did your rat have, compared with the ancestral rat?
2. List the adaptations of your rat. Explain how each adaptation helps the rat survive the environment.
3. Choose one adaptation, and describe a possible path for natural selection.
4. Imagine your rat was washed away by the tide and landed on one of the other islands.
   a. Would it have a good chance of survival? Explain your answer.
   b. Could this rat's alleles be added to the already existing gene pool? Explain why or why not.

Conclude and Communicate

5. Compare and contrast your rat with the rat of another group. Explain the differences and similarities.

Extend Further

6. **INQUIRY** Design a rat that is adapted to one of the other islands.
7. **RESEARCH** There are many small island chains in the world, for example, the Cook Islands, the Canary Islands, and the Maldive Islands. Research one of these island chains, or another of your choosing, and describe some of the species that live on the islands. Are there obvious differences in species between islands?

STSE

Case Study

What's Good About Forest Fires?

Assessing the Impact of Forest Fires on the Boreal Forest Ecosystem

Scenario

A family friend from northern Ontario works as a volunteer firefighter. Your friend is concerned about the effects of forest fires on the woodland caribou. You decide to research the matter and post a blog to open discussion on this issue.

my blog spot

new posts old posts

DAY 10 – 2:30 P.M.

Facts About Forest Fires

Some plant species in Canada's boreal (northern) forests have evolved to take advantage of environmental disturbances caused by forest fires. In fact, the boreal forest is dependent on forest fires for its health.

After a forest fire, a sequence of ecological responses quickly begins. After any leaves and twigs on the ground burn, the soil below becomes more exposed and then covered with a nutrient-rich ash. After older and dying trees burn, the forest canopy opens up so that sunlight can reach the ground. This provides ideal growing conditions for grasses and weeds, which are soon followed by shrubs and bushes and different types of trees. It can take decades or even hundreds of years for a forest to fully regenerate after a fire.

After a fire new plants grow, either from seeds or from sprouts emerging from unburned roots.

The boreal forest is composed mostly of coniferous trees, such as spruce, fir, tamarack, and pine. Some boreal tree species, such as the jack pine and tamarack, have evolved to be fire-dependent—they need fire to survive. The cones of these trees are sealed with resin, and the extreme heat of a fire is needed to melt the resin and open the seed pods. When fire kills these conifers, thousands of live seeds are released from their cones. The seeds then scatter and germinate, and new trees begin to grow. Some animal species are also dependent on fires. A number of beetle species feed on recently burned wood and are found in abundance in forests after a fire. Black-backed woodpeckers rely on the larvae of these beetles for food.

Over the past several hundred years, human activities have altered natural fire patterns. In many areas, park managers have been intentionally preventing forest fires for almost a century. While the boreal forest still experiences a natural pattern of forest fires, human intervention has made the forest older than it would be naturally. Today, the preferred approach to forest management is to reproduce the natural patterns of forest fires, to maintain the natural forest structure and conserve forest biodiversity. Prescribed burns, which are deliberately set and carefully controlled fires, are now often used to maintain or restore ecosystems.

In Canada each year, an average of 9000 fires burn an average of 25 000 km^2 of forest. Human carelessness causes most forest fires, but fires caused by lightning account for most of the forest area burned. Forest fires are most common in the boreal forest. The thin needles of coniferous trees burn more readily than the leaves of deciduous trees. When a fire starts in a boreal forest, it is more likely to take hold and spread. In addition, fires in remote areas are often left to burn as part of the natural ecological cycle. Most fires remain small, but a few occur under conditions that allow them to spread rapidly. This small proportion of large, lightning-caused fires has the most influence on the area burned and the fire cycle.

Forest fires generally kill and injure only a small proportion of animal populations. Most animals can run or fly away, or burrow underground until the fire has passed. Changes to habitats caused by a fire affect wildlife populations much more than the fire itself. Some populations recover rapidly; others may not return for many years. Most birds and mammals can migrate in response to changes in food supplies, and can readily move into or out of burned areas. After a fire, habitats improve for species such as moose, which prefer open spaces. Species that require dense cover, such as the caribou, decline significantly or disappear for a number of years.

my blog spot

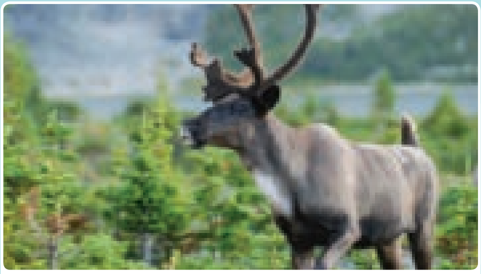
DAY 12 – 4:00 P.M.

Risks to Woodland Caribou

Woodland caribou are a threatened species in Ontario and are protected under Ontario's Endangered Species Act. (A threatened species is vulnerable to extinction in the near future. An endangered species is currently at risk of extinction.) This Act calls for the creation of recovery strategies for endangered and threatened species. Ontario's woodland caribou require large areas of mature, coniferous forest, particularly stands (growths of similar trees) of jack pine and spruce. These types of trees contain mature populations of slow-growing lichens, the caribou's main food source in the winter. Lichens are also an important food and nesting material for many birds and small mammals.

Mature forests also provide protection for the caribou from timber wolves, the caribou's main predator. Wolves prefer less dense areas. The reason for this preference is that wolves prey on moose as well as caribou, and moose prefer forests at an earlier stage of development. Young forests contain many smaller plants for foraging and browsing, and more open space to allow moose to spot wolves. Caribou cannot survive high levels of predation. Female caribou have a relatively high pregnancy rate, but they always give birth to single calves, whereas moose and deer often give birth to twins. Therefore, the number of calves born to caribou each year is much lower than for other types of deer. When forest habitats change to favour the moose, such as after a forest fire, wolf populations increase and caribou populations decline.

Should the Ontario Ministry of Natural Resources control fires in the boreal forest to protect woodland caribou populations? Or should the Ministry allow forest fires (including prescribed burns) to burn to protect the overall health of the boreal forest ecosystem?



Woodland caribou were once found as far south as Algonquin Park in Ontario. Roads, land clearing, and logging have encroached into their former range and disturbed their habitat, as have forest fires. Woodland caribou are now found in Ontario north of Lake Nipigon.

Research and Analyze

1. The boreal forest is home to a wide variety of animals and is a resting ground for many species of migrating birds. Research boreal species and identify one or more North American organisms whose habitat and chances of success are improved by forest fires (for example, Canada lynx), and one or more organisms whose habitat and chances of success are harmed by forest fires (for example, common juniper). Explain how each species is benefited or harmed.

2. Fire management that preserves older forest habitat is one way to support woodland caribou populations. Research the potential long-term effects of fire management on the health of the boreal forest and its wildlife. Organize your findings in a table with the following headings: Biotic Impact, Abiotic Impact, Impact on Food Chain, and Impact on Species.

3. Analyze how forest fires, including fires started by lightning, fires started accidentally, and prescribed burns, affect woodland caribou populations. In your analysis, use concepts you learned in this unit, such as natural selection and adaptation. Then form an opinion—should some forest fires be managed to protect the woodland caribou population, or should forest fires be allowed to burn to maintain the overall health of the boreal forest ecosystem? To help organize your data and show your opinion, display your analysis in a cycle chart or other graphic organizer.

Take Action

4. **Plan** Share and discuss your research and analysis with other students. Decide which information you will post in your blog. Complete your blog.

5. **Take Action** Contact the Ontario Ministry of Natural Resources and advocate your opinion. Include a link to your blog in your e-mail or letter.

Chapter 9 SUMMARY

Section 9.1 Mechanisms of Evolution and Their Effect on Populations

KEY TERMS

bottleneck effect
directional selection
disruptive selection
founder effect
gene flow
genetic drift
non-random mating
sexual selection
stabilizing selection

KEY CONCEPTS

- Gene flow is the movement, or flow, of alleles between populations.
- The sources of genetic variation in a population are mutations that are acted on by gene flow, non-random mating, genetic drift, and, most importantly, natural selection. When these mechanisms alter gene frequencies, evolution has occurred.
- Gene flow due to migration of individuals can increase the genetic diversity of a population, but gene flow can also decrease the genetic diversity among populations of the same species.
- Non-random mating increases the number of certain alleles because the phenotype produced by those alleles is more attractive to the opposite sex.
- Genetic drift occurs more rapidly in small populations. It can result in the loss of alleles from a population and an increase in the frequency of previously rare alleles. The founder and bottleneck effects are two examples.
- Natural selection is the process that produces adaptive changes within populations.
- When stabilizing selection occurs, an intermediate phenotype has an advantage. When directional selection occurs, an extreme phenotype increases in frequency in a population. When disruptive selection occurs, extreme phenotypes survive in the population at the expense of intermediate forms.
- Sexual selection, which is a type of natural selection, involves characteristics or behaviours that make it more likely for individuals to choose a mate.

Section 9.2 Speciation: How Species Form

KEY TERMS

adaptive radiation
allopatric speciation
convergent evolution
divergent evolution
ecological niche
gradualism
post-zygotic isolating mechanism
pre-zygotic isolating mechanism
punctuated equilibrium
speciation
sympatric speciation

KEY CONCEPTS

- A species consists of a reproductively compatible population, and speciation is the formation of new species from previously existing species.
- Pre-zygotic isolating mechanisms either impede mating between species or prevent fertilization of the egg. These mechanisms include behavioural, habitat, temporal, mechanical, and gametic barriers.
- Post-zygotic isolating mechanisms prevent hybrid zygotes from developing into viable, fertile individuals.
- In sympatric speciation, populations become reproductively isolated without geographical isolation. In allopatric speciation, populations are geographically isolated and thus become reproductively isolated.
- Adaptive radiation, a form of allopatric speciation, occurs when there is diversification from a common ancestor into a variety of species.
- In convergent evolution, similar traits arise because each species is independently adapted to similar environmental conditions. In divergent evolution, a species that was once similar to an ancestral species diverges or becomes increasingly distinct.
- Gradualism proposes that evolution occurs slowly and steadily over time. Punctuated equilibrium proposes that evolution consists of long periods of equilibrium, interrupted by periods of speciation.

Chapter 9 REVIEW

Knowledge and Understanding

Select the letter of the best answer below.

1. Which of the following is the best example of the founder effect?
   a. A population explosion of mosquitoes occurs after a storm.
   b. A moth carries pollen from one plant population to another and cross-fertilization occurs.
   c. An earthquake forms a canyon that splits apart a population of toads, and this leads to speciation.
   d. Ten birds of the same species colonize a newly formed volcanic island, and this leads to a new species of bird.
   e. Ten male and seven female seagulls of an original population of 500 survive a devastating tornado. This leads to changes in the population.
2. What aspect of a population is most critical for determining a species?
   a. similar appearance or morphology
   b. the ability to mate in captivity
   c. the ability to eat the same food in the same ecological niche
   d. similar behaviours
   e. the ability to interbreed in nature
3. Which of the following is an example of a post-zygotic isolating mechanism?
   a. Species use different mating songs.
   b. Hybrids of two species are sterile.
   c. Species feed at different times of the day.
   d. Species have different breeding times.
   e. Specific pheromones are used by species to communicate.
4. A human population has an unusually high percentage of individuals with a particular genetic disease. The most likely explanation for this is
   a. gene flow
   b. gradualism
   c. natural selection
   d. genetic drift
   e. punctuated equilibrium
5. How does inbreeding affect genetic variation within a population?
   a. variation decreases
   b. variation increases
   c. variation does not change
   d. variation increases, and then decreases
   e. variation decreases, and then increases
6. Allopatric speciation, but not sympatric speciation, requires which of the following?
   a. reproductive isolation
   b. geographical isolation
   c. spontaneous differences in males and females
   d. prior hybridization
   e. rapid rate of mutation
7. What is gene flow?
   a. reproductive success
   b. the colonization of an area by a few individuals of a population that can lead to new species
   c. when individuals preferentially mate with individuals of a particular genotype
   d. the movement of alleles between populations
   e. a severe reduction of a population that can lead to changes in populations
8. What is the term that means rapid evolution of many species from an ancestral species, such as what happened with the Galapagos finches?
   a. gene flow
   b. mutation
   c. adaptive equilibrium
   d. gradualism
   e. adaptive radiation

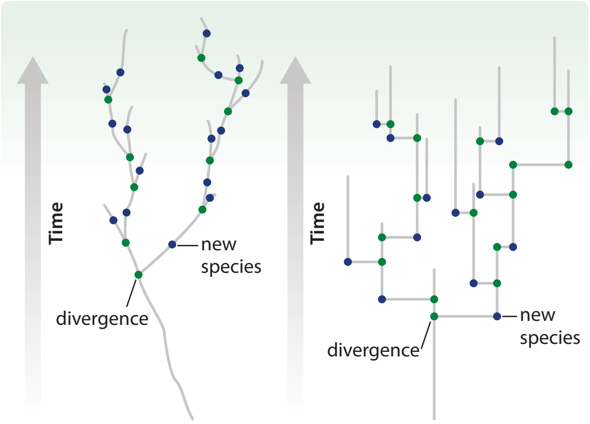
Answer the questions below.

9. In the Hawaiian Islands, there are thousands of species of plants and animals that are found nowhere else on Earth. How would you explain this phenomenon, and what is the name of this process?
10. In order for species to remain distinct, they must remain reproductively isolated. Describe a pre-zygotic and a post-zygotic isolating mechanism.
11. Explain how the following situations are isolating mechanisms that keep species separate.
    a. Species of fireflies use distinctive patterns of flashes.
    b. Two species of grasses flower at different times of year, yet they live in the same environment.
    c. The crossing of two species of flies produces a fertile hybrid offspring. The offspring of that fertile hybrid is weak and infertile.
    d. Two species of flycatcher birds overlap in range, but one lives in open woods and farmland and the other lives in swampy areas.
12. Explain the role of the environment in the speed of evolutionary change.

13. It is more likely for small populations that have become isolated from a parent population to become a new species than it is for a large population to become a new species. Explain why this is.
14. Why do geographical barriers, such as a river, prevent gene flow in some species but not in others?
15. How can 1000 species of fruit flies on remote volcanic islands have the same ancestor?
16. How can a bird's call be a barrier to speciation? What type of isolating mechanism is this?

Thinking and Investigation

17. Identify each model shown in the diagram, and explain how each is used to describe evolution.



18. You are asked to catalogue the species of birds living in a remote area that has never been visited by biologists. What criteria could you use to determine whether the individual birds you study are of the same species?
19. If mass extinction events eliminate most of the species alive at a given time in Earth's history, how can biodiversity increase, over time, after such events?
20. Adaptive radiation often occurs on islands. Would you expect to find more adaptive radiation on islands that are remote from the mainland, like small Pacific islands, or islands that are close to the mainland, like Vancouver Island? Explain your answer.
21. Male bighorn sheep battle for females by running at each other and butting their heads together. In some cases, the bighorn sheep can be hurt badly enough that they do not survive. Hypothesize how this behaviour may have evolved, even though it means that some individual males may not live as long as they could.
22. Draw a cause-and-effect chart to show how scientists hypothesize that the dinosaurs became extinct.
23. Why is it difficult to classify species that do not reproduce sexually? What criteria could you use to classify asexual species?
24. What are some limitations to the biological species definition, that is, a population that can interbreed and produce a group of viable offspring in nature?
25. *Geospiza fuliginosa* and *Geospiza fortis* are closely related finches that are found separately on several of the Galapagos Islands and together on at least one island. Given the hypothesis that competition for food played a large role in the adaptive radiation of the Galapagos finches, answer the following questions.
    a. How morphologically similar would you expect these two species to be, and why?
    b. For any pair of finch species that are more distantly related, in what ways (if any) would your expectations of morphology be different? Explain.

Communication

26. Use software to create a flowchart or other type of presentation showing how geographical barriers lead to speciation.
27. BIG IDEAS Evolution is the process of biological change over time based on the relationships between species and their environments. Write a short essay that outlines how genetic variation is involved in natural selection and evolutionary change.
28. Sea stars eat clams by pulling apart the two halves of a clam's shell. Create a sequence of drawings to show how this could result in selection of muscle size in clams.
29. Use a flowchart or a cause-and-effect diagram to explain why natural selection can lead to the evolution of pre-zygotic isolating mechanisms but not to post-zygotic isolating mechanisms.
30. Use a graphic organizer to compare and contrast the advantages and disadvantages of the biological species concept. Refer to Using Graphic Organizers in Appendix A to help you decide which graphic organizer to use.
31. In a graphic organizer of your choice, compare and contrast the ideas of gradualism and punctuated equilibrium. Refer to Using Graphic Organizers in Appendix A to help you decide which graphic organizer to use.
32. Create a labelled diagram that explains how genetic drift can shift the distribution of alleles in a population in just a few generations.

33. Summarize your learning in this chapter using a graphic organizer. To help you, the Chapter 9 Summary lists the Key Terms and Key Concepts. Refer to Using Graphic Organizers in Appendix A to help you decide which graphic organizer to use.

Application

34. Innate behaviours—also known as instinctive behaviours—are behaviours that an organism is born with. Innate behaviours are inherited from parents, and they occur in all members of the species. These behaviours involve two steps: the presence of a sign stimulus, which prompts a fixed action pattern (behaviour in response to a stimulus). Using print or Internet resources, research innate behaviour using one of the examples below. Produce a visual that outlines the behaviour.
   - taxis: a movement toward (positive) or away from (negative) a directional stimulus
   - migration patterns

35. Identify each of the following as one of the five mechanisms that cause evolution in populations. Mechanisms can be used more than once.
   a. Organisms become adapted to their environment.
   b. The lack of genetic variability among cheetahs has been attributed to this.
   c. This often results in two adjacent populations having similar genetic variation due to immigration and emigration.
   d. The movement of humans all over the world can influence this.
   e. The original finches that were blown over to the Galapagos Islands from South America are an example of this.

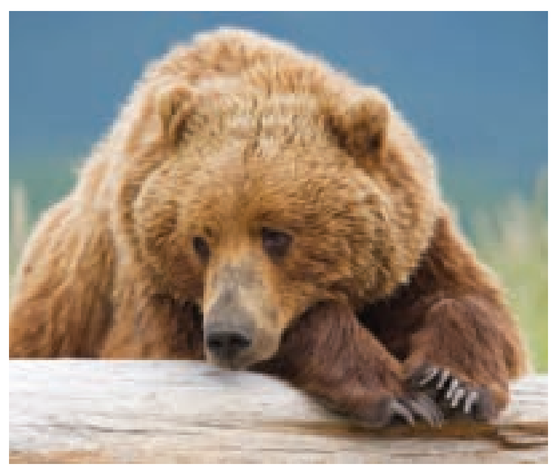
36. Some people are concerned that too many species are going extinct, and that Earth will never achieve such biodiversity again. How would you respond to these concerns?

37. Identify each of the following as pre-zygotic or post-zygotic isolating mechanisms:
   a. preferred times during the day for mating
   b. species-specific mating dances
   c. unsuccessful offspring
   d. habitat isolation
   e. adult birds with unique mating songs that they learn as young birds

38. Monarch butterfly larvae, such as the one shown below, feed on milkweed. Research monarch butterflies and the decline in the milkweed population, and answer the following questions.

   a. What are two different causes of the declining milkweed population?
   b. How has the declining milkweed population affected the migration of monarch butterflies?

39. In Canada, individual grizzly bears and populations of grizzly bears are being isolated as human populations expand their use of land that was previously used by the bears.



   a. If the grizzly bear were to become extinct, what might some of the economic, political, and social implications be for Canada?
   b. How might wildlife corridors help the situation? (Wildlife corridors are routes designed to help animals cross busy highways safely in Canada's mountain parks.)

40. Today, individual giant pandas and populations of giant pandas are being isolated in many small reserves in China. What are the genetic implications of having so many small reserves rather than one large reserve?

Chapter 9 SELF-ASSESSMENT

Select the letter of the best answer below.

1. K/U What prevents one species from successfully interbreeding with another species?
   a. transformational speciation
   b. reproductive isolating mechanisms
   c. gradualism
   d. punctuated equilibrium
   e. microevolution
2. K/U Two animal species mate at different times of the year. Which type of reproductive isolating mechanism is this?
   a. habitat
   b. mechanical
   c. temporal
   d. gametic
   e. hybrid breakdown
3. K/U Which is likely to be a pre-zygotic isolating mechanism in grasshoppers?
   a. number of wings
   b. mating call
   c. thorax length
   d. size of forewings
   e. head shape
4. K/U You study two very similar rabbit populations, one from northeast Canada and one from northwest Canada. How could you start the process to determine whether the populations belong to the same species?
   a. Show that the ranges of the two rabbits are exclusive.
   b. Show that there are colour similarities between the two rabbit populations.
   c. Demonstrate that the two types of rabbits have the same diet.
   d. Show that the rabbits will mate and produce viable offspring.
   e. Show that the rabbits live in different habitats.
5. K/U What is adaptive radiation?
   a. the slow change in organisms over time
   b. a mechanism of evolution that causes adaptive changes in organisms
   c. the evolution of many species from a single ancestral species
   d. the formation of a new behaviour or structure within a species
   e. a reproductive isolating mechanism that keeps species apart
6. K/U In a population of birds, the survival rate for large-beaked and small-beaked birds is greater than it is for birds with intermediate beaks. Which type of selection is this?
   a. stabilizing selection
   b. intermediate selection
   c. disruptive selection
   d. direction selection
   e. dissertational selection
7. K/U The various species of Galapagos finches are each adapted to eating different foods. This is an example of
   a. gene flow
   b. adaptive radiation
   c. sympatric radiation
   d. Only b and c are correct.
   e. All of these are correct.
8. K/U Which of the following is an example of the founder effect?
   a. an adaptation in a grass species that keeps herbivores from eating the grass
   b. the evolution of a long neck in giraffes
   c. the presence of unique characters in island plants
   d. the appearance of a few South American birds in the Galapagos Islands
   e. birds that attract more mates due to brightly coloured tail feathers
9. K/U Which of the following is true about the effect of a mutation in a gene pool?
   a. It leads to competition between males for females.
   b. It can add genetic variation to a population.
   c. It can increase or decrease genetic variation in a population.
   d. It decreases genetic variation in a population.
   e. It can prevent individuals with particular phenotypes from breeding.
10. K/U Which of the following best describes natural selection?
   a. Natural selection causes inbreeding.
   b. Individuals with adaptive traits survive and reproduce better.
   c. Natural selection is the ultimate source of genetic variation.
   d. Natural selection is the random fluctuation in allele frequencies in a large population.
   e. Gametes move from one population to another.

Use sentences and diagrams as appropriate to answer the questions below.

11. T/I Suppose there are two iguana populations in two different locations. The iguanas differ only in the colour of their skin.

a. Suggest data that would help you decide whether both populations belong to the same species of iguana.

b. Assume that the two populations are different species. Suggest data that would help you decide how closely related these two species are.

12. C In a graphic organizer, show the relationships between the following terms: reproductive isolation, pre-zygotic isolating mechanisms, post-zygotic isolating mechanisms, and species. Refer to Using Graphic Organizers in Appendix A to help you decide which graphic organizer to use.

13. A Explain how the following situations are reproductive barriers that keep species separate.

a. Species of fire ants use unique chemical signals emitted from their antennae.

b. Two species of moths mate at different times of the day, yet they live in the same environment.

c. The crossing of two species of beetle produces offspring that do not survive.

14. K/U Describe allopatric speciation and give an example.

15. T/I How could the rise and fall of the water level of a lake over thousands of years result in the speciation of a population of fish?

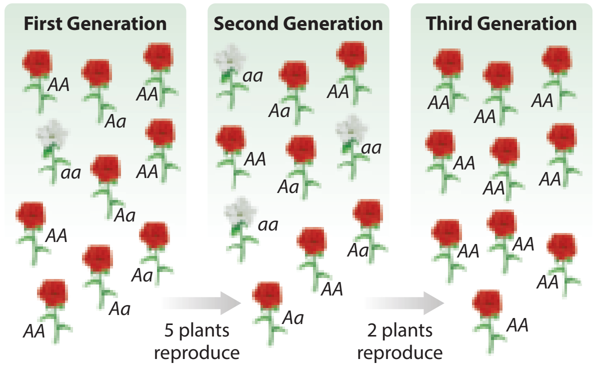
16. C Using a Venn diagram, compare and contrast the founder effect and the bottleneck effect.

17. A The females of a species of toad commonly select mates that are similar in size to themselves. How might this behaviour affect microevolution?

18. K/U Describe two models for the speed of evolutionary change.

19. C Create a flowchart that shows how non-random mating can increase the frequency of homozygous individuals in a population. Go to Using Graphic Organizers in Appendix A for help making a flowchart.

20. T/I You are raising a plant with two variations in flower colour—red and white. White is recessive. Explain what is happening in this plant population based on three generations of data containing genotypes and phenotypes for flower colour as shown in the diagram.



21. A You test the probability of getting heads or tails by flipping a coin. You know you have a 50-50 chance of heads or tails, but you do not get this ratio when you flip the coin 10 times. You do get close to the ratio of 50 percent heads and 50 percent tails when you flip the coin 50 times. How do these results support the idea of genetic drift of allele frequencies in populations if each coin flip represents a mating event in a population? Assume that a head is one allele and a tail is the other allele for one gene.

22. K/U What is an ecological niche, and how is it related to the evolution of a species?

23. C Make a spider map, with natural selection in the middle. Use the spider map to describe directional selection, stabilizing selection, disruptive selection, and sexual selection. Go to Using Graphic Organizers in Appendix A for help making a spider map.

24. K/U Every autumn in Ontario, the leaves on deciduous trees change—they turn different colours and fall. Is this an example of evolution? Explain your answer.

25. T/I Think about how insect pollinators can contribute to gene flow between plant populations. Suggest another mechanism of gene flow using an animal as an example.

Self-Check

If you missed question...	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Review section(s)...	9.2	9.1	9.2	9.1	9.2	9.1	9.1	9.1	9.1	9.1	9.2	9.2	9.2	9.2	9.2	9.1	9.1	9.2	9.1	9.1	9.1	9.1	9.2	9.1	9.1