11.1 Genetic Variation Within Populations

KEY CONCEPT A population shares a common gene pool.

MAIN IDEAS

- Genetic variation in a population increases the chance that some individuals will survive.
- Genetic variation comes from several sources.

VOCABULARY

gene pool, p. 328
allele frequency, p. 328

Review
phenotype, gene, allele, meiosis, gamete

CALIFORNIA STANDARDS

7.c ***Students know*** **new mutations are constantly being generated in a gene pool.**

7.d ***Students know*** **variation within a species increases the likelihood that at least some members of a species will survive under changed environmental conditions.**

Review Life Science
7.3.a *Students know* both genetic variation and environmental factors are causes of evolution and diversity of organisms.

Connect You may think that if you've seen one penguin, you've seen them all. However, penguins can differ in body size, feather patterns, and many other traits. Just like humans, penguins are genetically different from one another. What is the nature of genetic variation in populations? And how is this variation measured by biologists?

MAIN IDEA

Genetic variation in a population increases the chance that some individuals will survive.

Body size and feather patterns in penguins are each examples of phenotypes. A phenotype is a trait produced by one or more genes. In a population, there may be a wide range of phenotypes. For example, some penguins may be short and rounded. Others could be tall and slim.

Natural selection acts on different phenotypes in a population. However, in order to have different phenotypes, a population must have genetic variation. A population with a lot of genetic variation likely has a wide range of phenotypes. The greater the variation in phenotypes, the more likely it is that some individuals can survive in a changing environment. For example, if an unusually cold winter occurs, short, rounded penguins might be able to stay warm more easily. But if there is a shortage of food, tall, slim penguins might be better divers, allowing them to catch more fish.

Genetic variation is stored in a population's **gene pool**—the combined alleles of all of the individuals in a population. Different combinations of alleles in a gene pool can be formed when organisms mate and have offspring. Each allele exists at a certain rate, or frequency. An **allele frequency** is a measure of how common a certain allele is in the population. As shown in **FIGURE 11.1**, you can calculate allele frequencies. First count the number of times an allele occurs in a gene pool. Then divide by the total number of alleles for that gene in the gene pool.

Analyze **What is the relationship between allele frequencies and a gene pool?**

TAKING NOTES

Use mind maps to show relationships among related terms and concepts.

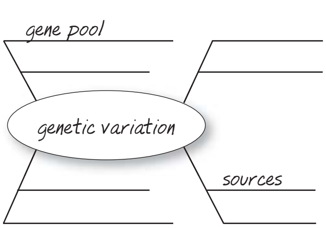
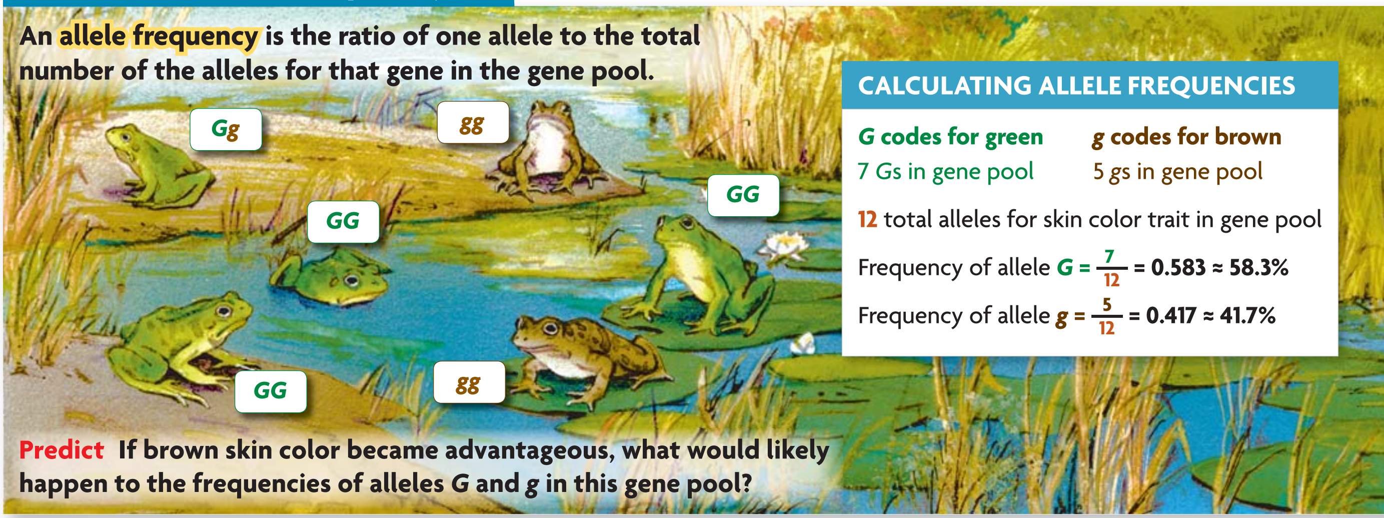


FIGURE 11.1 Allele Frequency

An allele frequency is the ratio of one allele to the total number of the alleles for that gene in the gene pool.



CALCULATING ALLELE FREQUENCIES

G **codes for green**
7 *G*s in gene pool

g **codes for brown**
5 *g*s in gene pool

12 total alleles for skin color trait in gene pool

Frequency of allele $G = \frac{7}{12}$ = **0.583 ≈ 58.3%**

Frequency of allele $g = \frac{5}{12}$ = **0.417 ≈ 41.7%**

Predict **If brown skin color became advantageous, what would likely happen to the frequencies of alleles *G* and *g* in this gene pool?**

MAIN IDEA

Genetic variation comes from several sources.

Genetic variation comes from two main sources: mutation and recombination.

- **Mutation** A mutation is a random change in the DNA of a gene. This change can form a new allele. Mutations in reproductive cells can be passed on to offspring. This increases the genetic variation in the gene pool. Because there are many genes in each individual and many individuals in a population, new mutations form frequently in gene pools.
- **Recombination** New allele combinations form in offspring through a process called recombination. Most recombination occurs during meiosis—the type of cell division needed for sexual reproduction. When gametes are made, each parent's alleles are arranged in new ways. This shuffling of alleles results in many different genetic combinations.

Some biologists are studying hybridization as another source of genetic variation. Hybridization is the crossing of two different species that share common genes. Research suggests that this process occurs within many groups of animals, including birds and mammals, when similar species live in the same area and individuals cannot easily find mates of their own species.

Infer **Why aren't mutations in nonreproductive cells sources of genetic variation?**

Connecting CONCEPTS

Genetics Recall from **Chapter 8** that mutations on noncoding regions of DNA do not affect phenotypes. Only mutations on coding regions of DNA can affect an organism's phenotype.

11.1 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. Why does genetic variation increase the chance that some individuals in a population will survive? **7.d, 7.3.a**
2. Describe two main sources of genetic variation. **7.c**

CRITICAL THINKING

3. **Analyze** In what way is a **gene pool** representative of a population?
4. **Apply** If a certain trait's **allele frequency** is 100 percent, describe the genetic variation for that trait in the population.

Connecting CONCEPTS

5. **Genetics** How does crossing over during meiosis provide a source of genetic variation? Draw a diagram to show this process.

11.2 Natural Selection in Populations

KEY CONCEPT Populations, not individuals, evolve.

MAIN IDEAS

- Natural selection acts on distributions of traits.
- Natural selection can change the distribution of a trait in one of three ways.

VOCABULARY

normal distribution, p. 330
microevolution, p. 331
directional selection, p. 331
stabilizing selection, p. 332
disruptive selection, p. 333

Review
natural selection

CALIFORNIA STANDARDS

8.a ***Students know*** **how natural selection determines the differential survival of groups of organisms.**

Review Life Science
7.3.a *Students know* both genetic variation and environmental factors are causes of evolution and diversity of organisms.

Connect How do you describe a person's appearance? Perhaps you use height, hair color, and eye color. These traits are often used in descriptions because these traits vary widely among humans. In this section you will learn about how natural selection can act upon such variation.

MAIN IDEA

Natural selection acts on distributions of traits.

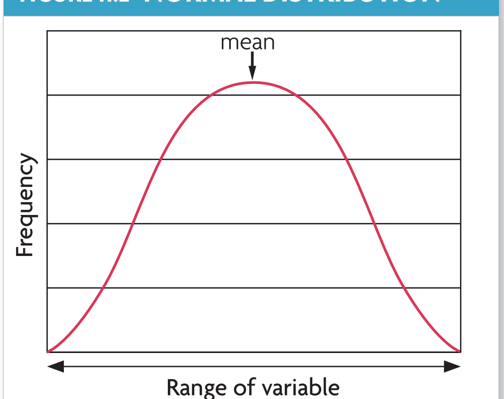
Any time you stand in a large crowd of people, you are likely to observe a wide range of heights. Imagine organizing this crowd across a football field according to each individual's height, with very short people at one end, people of average height in the middle, and very tall people at the other end. You would soon notice a pattern in the distribution for the human height trait. Relatively few people would be at each extreme height, very short or very tall. A majority of people would be in the middle due to their medium height.

This type of distribution, in which the frequency is highest near the mean value and decreases toward each extreme end of the range, is called a **normal distribution.** When these frequency values are graphed, the result is a bell-shaped curve like the one you see in **FIGURE 11.2**.

***Connecting* CONCEPTS**

Genetics As you learned in **Chapter 7**, single-gene traits are expressed in either one distinct form or another. However, the range of phenotypes common for most traits is the result of polygenic traits, which are controlled by multiple genes.

FIGURE 11.2 NORMAL DISTRIBUTION



For some traits, all phenotypes provide an equal chance of survival. The distribution for these traits generally shows a normal distribution. Phenotypes near the middle of the range tend to be most common, while the extremes are less common. However, environmental conditions can change and a certain phenotype may become an advantage. Nature favors individuals with this phenotype. These individuals are able to survive and reproduce at higher rates than individuals with less favorable phenotypes. Therefore, alleles associated with favorable phenotypes increase in frequency.

Synthesize **What other types of data might follow a normal distribution?**

MAIN IDEA

Natural selection can change the distribution of a trait in one of three ways.

Microevolution is the observable change in the allele frequencies of a population over time. Microevolution occurs on a small scale—within a single population. One process that can lead to microevolution is natural selection. Natural selection can change the distribution of a trait along one of three paths: directional, stabilizing, or disruptive selection. Such changes can have major effects on how a population looks and behaves.

Directional Selection

A type of selection that favors phenotypes at one extreme of a trait's range is called **directional selection.** Directional selection causes a shift in a population's phenotypic distribution. An extreme phenotype that was once rare in a population becomes more common. As shown in **FIGURE 11.3**, during directional selection, the mean value of a trait shifts in the direction of the more advantageous phenotype.

The rise of drug-resistant bacteria provides a classic example of this type of selection. Before antibiotics were developed in the 1940s, a trait for varying levels of drug resistance existed among bacteria. At the time, there was no advantage to having drug resistance. But once antibiotics came into use, the resistant bacteria had a great advantage.

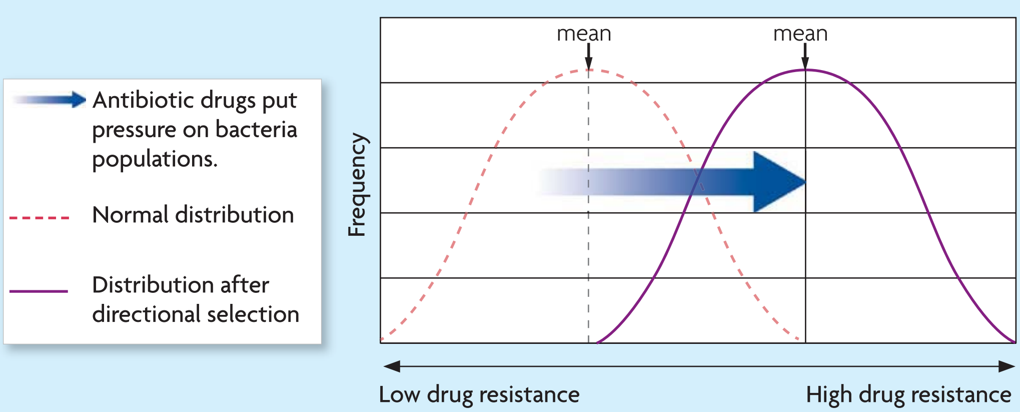
The early success of antibiotics in controlling infectious diseases led to overuse of these drugs. This overuse favored even more resistant phenotypes. New drugs were then developed to fight the resistant bacteria. This resulted in the evolution of "superbugs" that are highly resistant to many drugs. Today, over 200 types of bacteria show some degree of antibiotic resistance.

Connecting CONCEPTS

Bacteria Although many bacteria are helpful to other organisms, some do cause disease. You will learn more about how bacteria can evolve and become resistant to antibiotics in **Chapter 18.**

FIGURE 11.3 Directional Selection

Directional selection occurs when one extreme phenotype is favored by natural selection.



Today, scientists continue to research new drugs developed to treat infection-causing bacteria such as *Enterococcus faecalis*, which is resistant to many antibiotics.

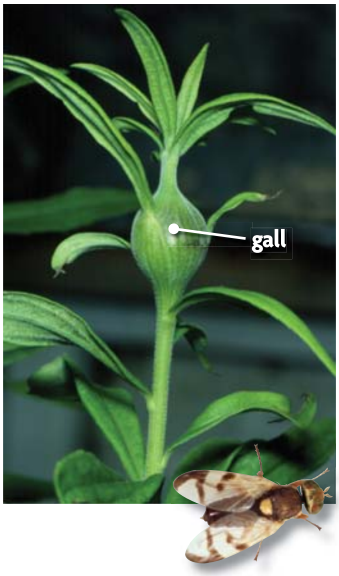


FIGURE 11.4 The gall fly and the goldenrod have a parasitic relationship. The fly benefits by receiving shelter and food during its larval stage, while the goldenrod is harmed, growing more slowly than a gall-free goldenrod.

Stabilizing Selection

The gall fly and its predators provide an excellent example of stabilizing selection. During **stabilizing selection,** the intermediate phenotype is favored and becomes more common in the population. That is, the distribution becomes stable at the intermediate phenotype rather than shifting toward one of the extremes. In the case of gall flies, something in nature selects against phenotypes at both extremes of the trait's range.

Gall flies lay their eggs in developing shoots of the tall goldenrod. The fly larvae produce a chemical that causes the plant tissue to swell around them. **FIGURE 11.4** shows the resulting mass of plant tissue, called a gall. The gall serves as a home where the larvae can develop. There is a range of phenotypes for body size in gall-fly larvae. Each body size causes a certain size gall to form, and each of the two main predators of gall flies specializes on a specific gall size.

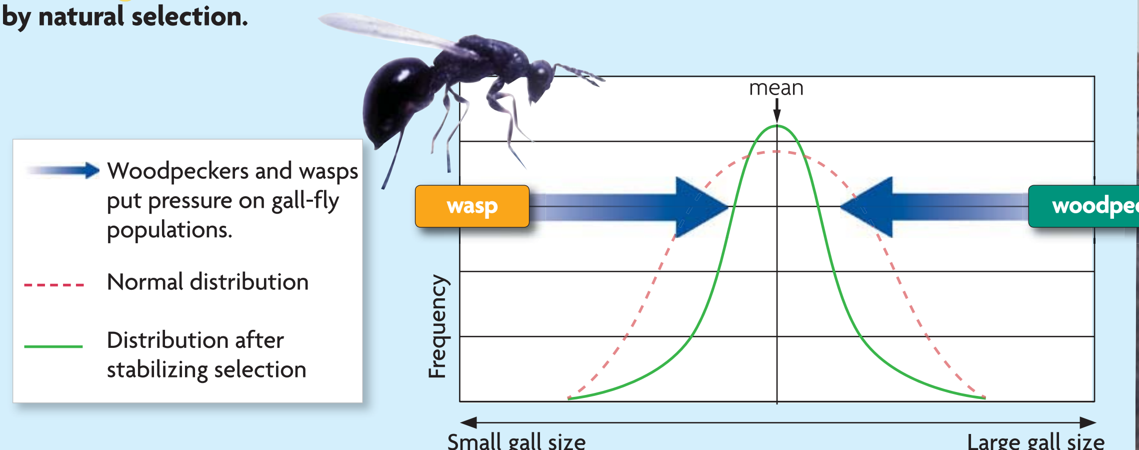
- Downy woodpeckers attack larger galls and feed on the larvae inside.
- The parasitic wasp lays its own eggs inside small galls. After the wasp larvae emerge from the eggs, they eat the gall-fly larvae.

In this situation, selective pressure from predators works against fly phenotypes that produce galls at both extremes, large and small. As a result, flies that produce middle-sized galls become more common. As you can see in **FIGURE 11.5,** over time, stabilizing selection results in a higher frequency of flies that produce middle-sized galls.

Stabilizing selection increases the number of individuals with intermediate phenotypes. Notice, however, that selection against both extremes decreases the genetic diversity of the gall fly population. Flies that produce small and large galls become less common. In some populations, these extreme phenotypes may be lost altogether.

FIGURE 11.5 Stabilizing Selection

Stabilizing selection occurs when intermediate phenotypes are favored by natural selection.



Disruptive Selection

Disruptive selection occurs when both extreme phenotypes are favored, while individuals with intermediate phenotypes are selected against by something in nature. As you can see in **FIGURE 11.6**, the middle of the distribution is disrupted. One example of this type of selection involves feather color in male lazuli buntings, a bird species native to North America.

Young male lazuli buntings vary widely in the brightness of their feathers, ranging from dull brown to bright blue. Dominant adult males are those with the brightest blue feathers on their heads and backs. These birds have their pick of the best territories. They also are most successful at attracting females. However, for young buntings, the brightest blue and dullest brown males are more likely to win mates than males with bluish brown feathers are.

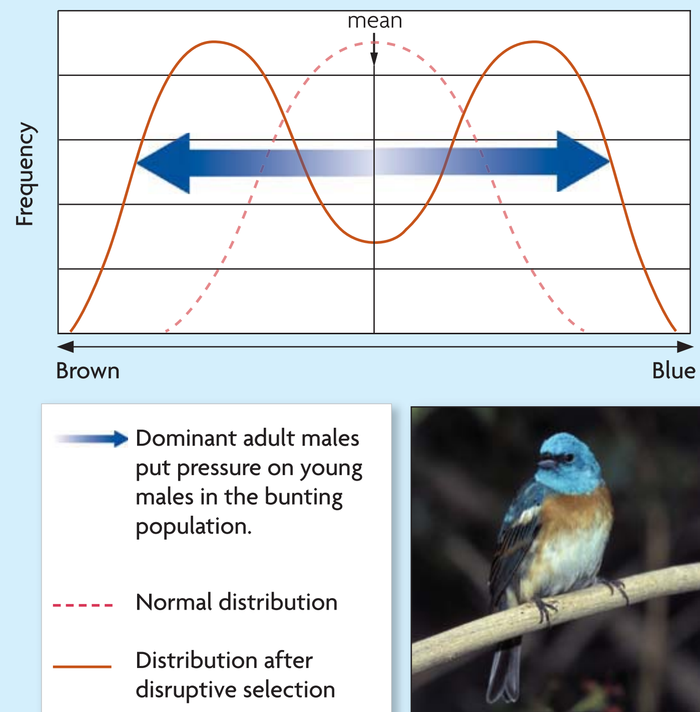
Research suggests that dominant adult males are aggressive toward young buntings that they see as a threat, including bright blue and bluish brown males. The dullest brown birds can therefore win a mate because the adult males leave them alone. Meanwhile, the bright blue birds attract mates simply because of their color.

Both extreme phenotypes are favored in this situation, while intermediate forms are selected against. The bluish brown males are not as well adapted to compete for mates because they are too blue to be left alone by adult males, but not blue enough to win a mate based on color alone. By favoring both extreme phenotypes, disruptive selection can lead to the formation of new species.

Apply If bluish brown coloring became advantageous for young males, what type of selection would likely occur in a lazuli bunting population?

FIGURE 11.6 Disruptive Selection

Disruptive selection occurs when both extreme phenotypes are favored by selection.



Adult male lazuli bunting

11.2 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. In terms of phenotypes, describe what is meant by the phrase "distribution of traits." **8.a**
2. What are the three ways in which natural selection can change a distribution of traits? **8.a**

CRITICAL THINKING

3. **Predict** How might the extinction of downy woodpeckers affect the phenotypic distribution of gall flies? **7.3.a**
4. **Predict** How might overfishing of large pink salmon select for smaller body size in subsequent generations? **8.a**

Connecting CONCEPTS

5. **Genetics** For polygenic traits, a smooth curve results when the range of phenotypes is plotted against frequency. If you were to plot the frequencies of two phenotypes of a single-gene trait, you would end up with a double bar graph. Explain why.

11.3 Other Mechanisms of Evolution

KEY CONCEPT Natural selection is not the only mechanism through which populations evolve.

MAIN IDEAS

- Gene flow is the movement of alleles between populations.
- Genetic drift is a change in allele frequencies due to chance.
- Sexual selection occurs when certain traits increase mating success.

VOCABULARY

gene flow, p. 335
genetic drift, p. 336
bottleneck effect, p. 336
founder effect, p. 336
sexual selection, p. 338

Review
homozygous, heterozygous

CALIFORNIA STANDARDS

8.c ***Students know*** **the effects of genetic drift on the diversity of organisms in a population.**

7.b *Students know* why alleles that are lethal in a homozygous individual may be carried in a heterozygote and thus maintained in a gene pool.

Connect Have you ever wondered why many male birds, such as cardinals, are brightly colored while females of the same species are dull brown? Such bright coloring may not make sense in terms of natural selection, since the male birds are more likely to be seen by predators. However, natural selection is not the whole story. There are other factors that can lead to the evolution of populations.

MAIN IDEA

Gene flow is the movement of alleles between populations.

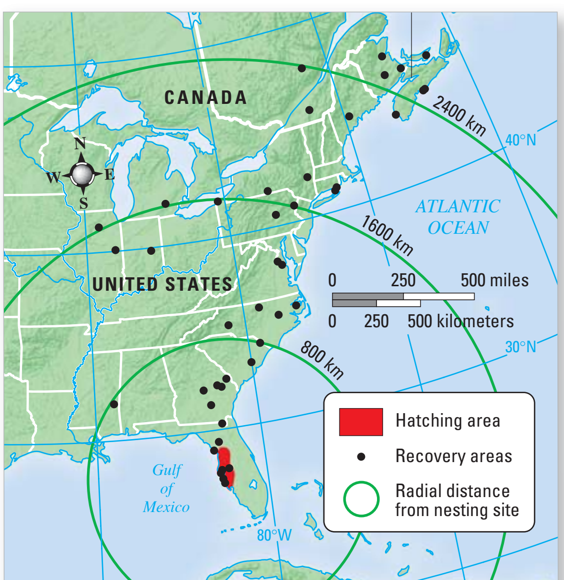


FIGURE 11.7 This map shows the locations where young banded eagles were found during the first summer after hatching.

Bird-banding studies have shown that certain birds leave their nesting areas once they are able to fly. As shown in **FIGURE 11.7,** bald eagles banded as nestlings have been tracked during the same summer more than 2500 kilometers away. These eagles have possibly joined a new population.

When an organism joins a new population and reproduces, its alleles become part of that population's gene pool. At the same time, these alleles are removed from the gene pool of its former population. The movement of alleles from one population to another is called **gene flow.** For many animals, gene flow occurs when individuals move between populations. Gene flow can occur in fungi and plant populations when spores or seeds are spread to new areas.

Gene flow increases the genetic variation of the receiving population. Gene flow between neighboring populations keeps their gene pools similar. However, the less gene flow that occurs between two populations, the more genetically different the two populations can become. A lack of gene flow also increases the chance that the two populations will evolve into different species.

Predict **How does gene flow affect neighboring populations?**

MAIN IDEA

Genetic drift is a change in allele frequencies due to chance.

Imagine a patch of 100 flowers growing in a field. Fifty are white and fifty are purple. If you randomly pick flowers from this patch to create a bouquet, you would expect about half white and half purple flowers. The more flowers you randomly pick, the more likely you are to get these proportions. However, the fewer flowers you pick, the more likely you are to have a bouquet that is not representative of the patch. It might even be all one color.

VOCABULARY

Fixed means "not subject to change." If an allele increases to a frequency of 1.0 (100%), it is said to be fixed in the population.

A similar situation can occur in small populations. Small populations, like small sample sizes, are more likely to be affected by chance. Due to chance alone, some alleles will likely decrease in frequency and become eliminated. Other alleles will likely increase in frequency and become fixed. These changes in allele frequencies that are due to chance are called **genetic drift.** Genetic drift causes a loss of genetic diversity in a population.

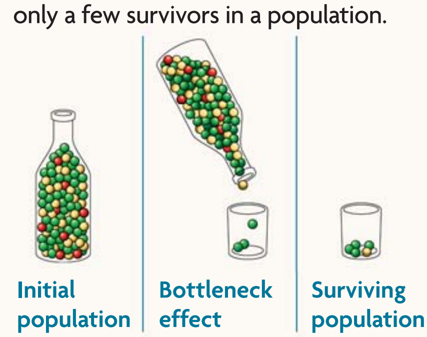
Two processes commonly cause populations to become small enough for genetic drift to occur. Each of these processes results in a population with different allele frequencies than the original population.

Bottleneck Effect

The **bottleneck effect** is genetic drift that occurs after an event greatly reduces the size of a population. One example of the bottleneck effect is the overhunting of northern elephant seals during the 1800s. By the 1890s, the population was reduced to about 20 individuals. These 20 seals did not represent the genetic diversity of the original population. Since hunting has ended, the population has grown to over 100,000 individuals. However, it has very little genetic variation. Through genetic drift, certain alleles have become fixed while others have been lost completely from the gene pool.

VISUAL VOCAB

The **bottleneck effect** describes the effect of a destructive event that leaves only a few survivors in a population.

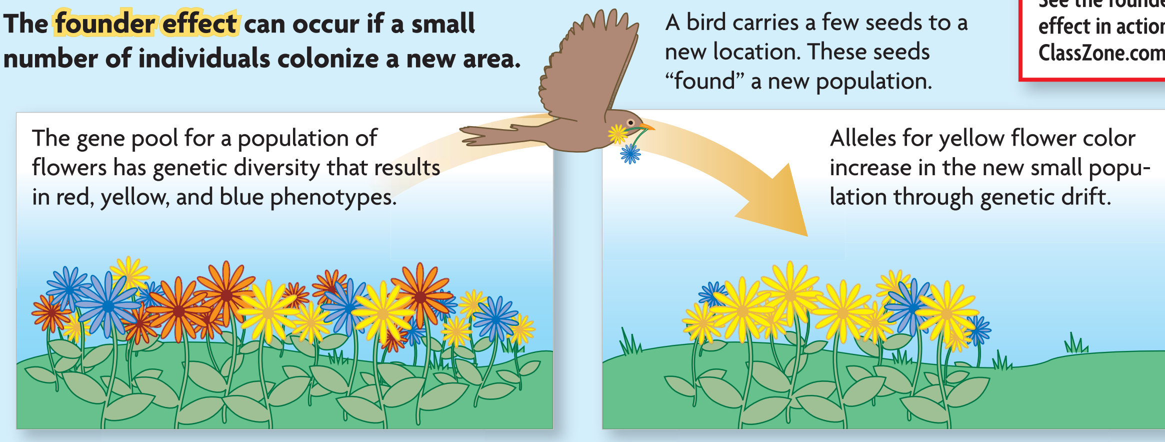


Founder Effect

As shown in **FIGURE 11.8**, the **founder effect** is genetic drift that occurs after a small number of individuals colonize a new area. The gene pools of these populations are often very different from those of the larger populations. The founder effect can be studied in human populations such as Old Order Amish communities. These communities were founded in North America by small numbers of migrants from Europe. For example, the Amish of Lancaster County, Pennsylvania, have a high rate of Ellis–van Creveld syndrome. Although this form of dwarfism is rare in other human populations, it has become common in this Amish population through genetic drift. Geneticists have traced this syndrome back to one of the community's founding couples.

FIGURE 11.8 The Founder Effect

The founder effect can occur if a small number of individuals colonize a new area.



Animated BIOLOGY See the founder effect in action at ClassZone.com.

Effects of Genetic Drift

Genetic drift can cause several problems for populations. One problem is that the population loses genetic variation. With little genetic variation, a population is less likely to have some individuals that will be able to adapt to a changing environment. Another problem is that alleles that are lethal in homozygous individuals may be carried by heterozygous individuals, and become more common in the gene pool due to chance alone.

Apply Why is genetic drift more likely to occur in smaller populations?

QUICK LAB **MODELING**

Genetic Drift

Use a deck of cards to represent a population of island birds. The four suits represent different alleles for tail shape. The allele frequencies in the original population are 25% spade, 25% heart, 25% club, and 25% diamond tail shapes.

PROBLEM How does genetic drift occur?

MATERIALS
- deck of cards

PROCEDURE

1. Shuffle the cards and hold the deck face down. Turn over 40 cards to represent the alleles of 20 offspring produced by random matings in the initial population.
2. Separate the 40 cards by suit. Find the allele frequencies for the offspring by calculating the percentage of each suit.
3. Suppose a storm blows a few birds to another island. They are isolated on this island and start a new population. Reshuffle the deck and draw 10 cards to represent the alleles of five offspring produced in the smaller population.
4. Repeat step 2 to calculate the resulting allele frequencies.

ANALYZE AND CONCLUDE

1. **Analyze** Compare the original allele frequencies to those calculated in steps 2 and 4. How did they change?
2. **Analyze** Did step 1 or 3 demonstrate genetic drift?
3. **Evaluate** Does this activity demonstrate evolution? Why or why not? Does it demonstrate natural selection? Explain.

CALIFORNIA STANDARDS

8.c *Students know* the effects of genetic drift on the diversity of organisms in a population.
IE.1.d Formulate explanations by using logic and evidence.

FIGURE 11.9 Male frigate birds inflate an air sac in their chest to attract females. This trait has evolved through sexual selection.

VOCABULARY

Intra is Latin for "within." Intrasexual selection occurs within one sex.

Inter is Latin for "between." Intersexual selection occurs between both sexes.

MAIN IDEA

Sexual selection occurs when certain traits increase mating success.

Mating can have an important effect on the evolution of populations. Both sexes benefit from having offspring that survive. However, the cost of reproduction often differs for males and females.

- Males produce many sperm continuously, making the value of each sperm relatively small. They can make many investments at little cost.
- Females are much more limited in the number of offspring they can produce in each reproductive cycle. Each investment they make is more valuable, and they want a good return.

In many species, this difference in reproductive cost makes females choosy about mates. **Sexual selection** occurs when certain traits increase mating success. There are two types of sexual selection:

- Intrasexual selection involves competition among males, such as the head-butting of bighorn sheep. Whoever wins the competition wins the female.
- Intersexual selection occurs when males display certain traits that attract the female, such as peacocks fanning out their tails.

Traits that increase mating success are not always adaptive for the survival of the individual. As shown in **FIGURE 11.9**, bright red air sacs likely make male frigate birds very easy to spot by predators. How could such an exaggerated trait evolve?

Research has shown that some showy traits may be linked with genes for good health and fertility. Other traits are present in males that can offer better care for offspring or defense from predators. Therefore, females may use showy traits as signs of quality and health in males. These traits, such as the red air sacs of male frigate birds, can become very exaggerated over time through sexual selection.

Apply **Male Irish elks, which are now extinct, had 12-foot-wide antlers. Describe how sexual selection could have caused such an exaggerated trait to evolve.**

11.3 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. How does **gene flow** affect neighboring populations?
2. Name two processes through which **genetic drift** can occur. **8.c**
3. How does **sexual selection** occur?

CRITICAL THINKING

4. **Analyze** Would a population of 10 individuals or 100 individuals be more vulnerable to genetic drift? Why? **8.c**
5. **Infer** What impact can the **bottleneck effect** have on populations that have rebounded after near extinction? **8.c**

Connecting CONCEPTS

6. **Genetics** Ellis–van Creveld syndrome is a recessive trait. Explain why it has become common in the Amish of Lancaster County while remaining very rare in other human populations. **7.b, 8.c**

11.5 Speciation Through Isolation

KEY CONCEPT New species can arise when populations are isolated.

MAIN IDEAS

- The isolation of populations can lead to speciation.
- Populations can become isolated in several ways.

VOCABULARY

reproductive isolation, p. 344
speciation, p. 344
behavioral isolation, p. 345
geographic isolation, p. 346
temporal isolation, p. 346

CALIFORNIA STANDARDS

8.d ***Students know*** **reproductive or geographic isolation affects speciation.**

Connect You have learned that gene flow helps to keep neighboring populations similar. The more gene flow that exists between populations, the more similar the populations will be. However, the less gene flow there is between two populations, the more likely the two populations are to become different. What happens if no gene flow occurs between two populations? This is one way that new species can arise.

MAIN IDEA

The isolation of populations can lead to speciation.

If gene flow between two populations stops for any reason, the populations are said to be isolated. As these populations adapt to their environments, their gene pools may change. Random processes like mutation and genetic drift can also change gene pools. All of these changes add up over many generations. With time, isolated populations become more and more genetically different. Members of the two populations may also begin to look and behave differently from one another.

Reproductive isolation occurs when members of different populations can no longer mate successfully with one another. Sometimes members of the two populations are not physically able to mate with each other. In other cases, they cannot produce offspring that survive and reproduce. Reproductive isolation between populations is the final step of becoming separate species. The rise of two or more species from one existing species is called **speciation.**

FIGURE 11.12 illustrates a recent experiment that shows how one mutation can result in reproductive isolation. Scientists studied the *ds2* gene of fruit flies. This gene affects how well fruit flies can deal with cold temperatures. Fruit flies living in tropical areas, where competition for food is high, have a tropical allele. Fruit flies living in cooler regions, where competition for food is less, have a temperate allele. The *ds2* gene also affects chemical scents called pheromones. Fruit flies use these scents to attracts mates of their own species.

***Connecting* CONCEPTS**

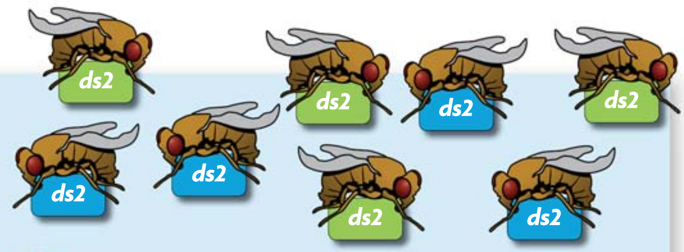
Genetics Fruit flies (*Drosophila melanogaster*) are very common in genetic research, as you may recall from **Unit 3.** Their popularity is based on several factors: they are easy to breed, they are common, and they have well understood genetic structures.

FIGURE 11.12 Reproductive Isolation

Reproductive isolation occurs when members of isolated populations are no longer able to mate with each other successfully.

Tropical fruit flies have a tropical *ds2* allele.

Temperate fruit flies have a temperate *ds2* allele.



1 Scientists used lab fruit flies that are genetically similar. They developed a technique that allowed them to replace the *ds2* gene in each lab fruit fly with either the tropical or temperate allele.

2 Laboratory males that received the tropical allele were attracted to females that received the tropical allele. Males that received the temperate allele were attracted to females that received the temperate allele.

Synthesize **Explain why fruit flies with a specific *ds2* allele prefer to mate with fruit flies with the same allele.**

This experiment shows how speciation may have occurred in natural fruit fly populations. Fruit flies migrating north from Africa to areas where there is less competition for food faced colder temperatures. A mutation in the *ds2* gene may have produced the temperate allele. This allele allows fruit flies to survive in cooler climates. Because the *ds2* gene also affects pheromones, mating behaviors changed. Fruit flies with the temperate allele and fruit flies with the tropical allele mated together less and less often. Eventually, these populations became reproductively isolated.

Summarize **Why is reproductive isolation considered to be the final stage in speciation?**

MAIN IDEA

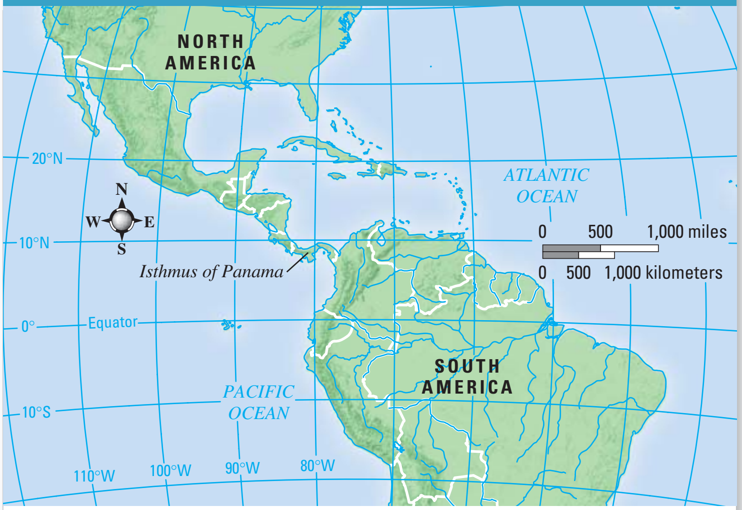
Populations can become isolated in several ways.

Several kinds of barriers can prevent mating between populations, leading to reproductive isolation. These include behavioral, geographic, and temporal barriers.

Behavioral Barriers

Chemical scents, courtship dances of birds, and courtship songs of frogs are sexual signals used to attract mates. Changes in these signals can prevent mating between populations. **Behavioral isolation** is isolation caused by differences in courtship or mating behaviors. Over 2000 species of fireflies are isolated in this way. Male and female fireflies produce patterns of flashes that attract mates of their own species. For example, *Photuris frontalis* emits one flash every second, *P. hebes* emits one flash every 2 seconds, and *P. fairchildi* produces a double flash every 5.5 seconds.

FIGURE 11.13 GEOGRAPHIC BARRIER



Although snapping shrimp in the Atlantic and Pacific oceans look similar, they are distinct species that have evolved through geographic isolation.

Geographic Barriers

The most commonly studied type of isolation is geographic isolation. **Geographic isolation** involves physical barriers that divide a population into two or more groups. These barriers can include rivers, mountains, and dried lakebeds. As shown in **FIGURE 11.13**, the formation of the Isthmus of Panama created a barrier for many marine species. Marine organisms could no longer easily cross between the Atlantic and Pacific oceans. Over time, the isolated populations became genetically different. Several species of snapping shrimp have evolved through geographic isolation. These species appear almost identical to one another. However, when males and females from opposite sides of the isthmus are placed together, they snap at each other instead of courting. Because they will no longer mate, these shrimp are classified as different species.

VOCABULARY

Temporal comes from the Latin word *tempus*, meaning "time."

Temporal Barriers

Barriers can also involve timing. **Temporal isolation** exists when timing prevents reproduction between populations. Some members of a population may show signs of courtship at different times if there is a lot of competition for mates. Reproductive periods may change to a different time of the year or a different part of the day. These differences in timing can lead to speciation. For example, two tree species that grow on the Monterey peninsula in California are very closely related. However, they have different pollination periods. The Monterey pine sheds its pollen in February, while the Bishop pine sheds its pollen in April. These pine species have likely evolved through temporal isolation.

Compare and Contrast What are the differences and similarities between behavioral isolation and temporal isolation?

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To learn more about speciation, visit scilinks.org.
Keycode: MLB011

11.5 ASSESSMENT

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REVIEWING MAIN IDEAS

1. How can **reproductive isolation** lead to **speciation**? **8.d**
2. What are three types of barriers that can lead to reproductive isolation? **8.d**

CRITICAL THINKING

3. **Apply** Why are the flash patterns of fireflies considered to be **behavioral isolation**?
4. **Synthesize** How did **geographic isolation** affect the diversity Darwin observed in Galápagos finches? **8.d**

Connecting CONCEPTS

5. **Scientific Process** What could have been used as a control group in the fruit fly experiment described on page 345?