9.1

Evolution of Populations

These Asian beetles vary in the color of their wings and in the number and color of spots on those wings.

CAN YOU EXPLAIN IT?

Ruffs are birds found mostly in parts of Europe and Asia. They typically make their homes in marshes and mudflats where they feed primarily on insects and seeds. During breeding season, males gather in groups and participate in staged "fights" to attract females. In this courtship ritual, three types of males in the population are involved: the independents, the satellites, and the faeders.

FIGURE 1: Ruffs differ in body size as well as in the size and color of the feathers on their heads and necks.

a An independent male

b A satellite male

c A female. Faeder males greatly resemble females.

About 84 percent of the male ruffs are "independent." These ruffs fight hard and expend a lot of energy to establish a territory and attract female ruffs. They can be easily identified, as they are the largest males and have large black and brown neck feathers. "Satellite" males are smaller and have white neck feathers. They move freely between independents' territories and do not fight. Though independent males may dominate them to attract a female, the satellites are often able to mate with the same females. The smallest males, called "faeders," look similar to females and generally mate with females by sneaking, often when independents and satellites are distracted or fighting.

Gather Evidence As you explore the lesson, make a list of biotic or abiotic factors that may have contributed to the evolution of this population.

Predict How can three types of males evolve in one population?

Genetic Variation

Meerkats are mammals that live in the deserts of Africa. They live together in cooperative groups.

FIGURE 2: Meerkats stand alert to look for predators.

Gather Evidence Record the similarities and differences you see between the meerkats in Figure 2. Why do traits vary between individuals in a population?

Differences in the Gene Pool

As you looked at the physical traits, or phenotypes, of the meerkats, you might have noticed variations in some of their traits. For instance, some are smaller than others. One has a light underside, while most have a darker underside. A few have more white on their faces, and others have more brown.

The phenotypic differences that you observed among the meerkats are due to differences in genes that code for those traits. Certain differences may offer a competitive advantage compared to the rest of the population. A particular phenotype may allow individuals to survive longer and reproduce more efficiently, both of which increase the total number of offspring produced. So, over time the phenotype becomes more prevalent. This gradual favoring of advantageous traits within a population is called natural selection, and it directly affects the population's gene pool. A gene pool is the collection of alleles found in all of the individuals of a population.

The different alleles in a gene pool ultimately result from mutations. When mutations occur during meiosis, the gametes that result may carry these mutations. Genetic variation may also be a result of crossing over and recombination, which occur during meiosis. During this process, chromosomes condense and homologous chromosomes align. Homologous chromosomes have the same genes but could have different alleles. During the alignment, an exchange of genetic material may take place. This exchange could alter the rearrangement of the linked genes in the chromosomes. As a result, the gametes are not genetically identical.

Collaborate Meerkats have a range of fur colors, from very light brown with more silver to a medium brown with less silver. Imagine a plant species with similar colors to the darker brown meerkats starts to grow in their habitat. With a partner, discuss what would happen to the meerkats and why.

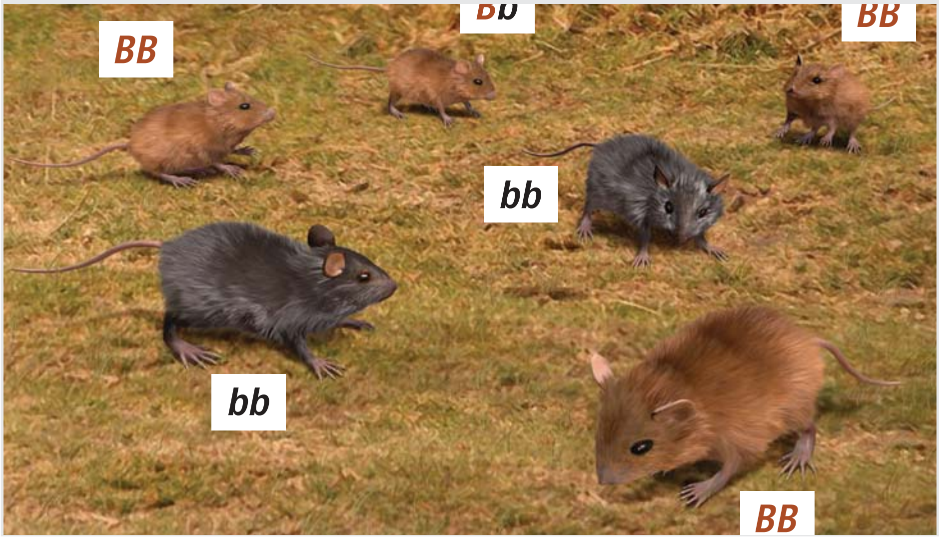
Explain How can mutations in gametes become widespread in the gene pool?

Variation in Alleles

Different combinations of alleles in a gene pool can be formed when organisms mate and have offspring. Alleles are different forms, or versions, of genes. For example, mice with either one or two copies of the dominant *B* allele have brown fur, while mice with two recessive *b* alleles have black fur, shown in Figure 3.

Gather Evidence Use the image to determine how many total alleles, dominant alleles (*B*), and recessive alleles (*b*), are in the gene pool of this mouse population.

FIGURE 3: Differences in fur color in mice are due to differences in allele combinations.



You can use the total number of alleles, the number of dominant alleles, and the number of recessive alleles to find the allele frequency in a population. Allele frequency is the proportion of one allele, compared with all the alleles for that trait, in the gene pool. To find the frequency of a particular allele, divide the number of times the allele is present by the total number of alleles in the population.

$$\text{Allele Frequency} = \frac{\text{Number of particular allele}}{\text{Total number of alleles}}$$

Allele frequency can also be expressed as a percentage by multiplying the frequency by 100. The frequencies of all the different alleles in a population should equal 1.0, or 100 percent.

Allele frequency is used to track genetic variation in populations and detect changes in alleles. Imagine that periodic fires blacken the ground in the field mice habitat in Figure 3. The black mice may be better camouflaged, providing more protection against predators. If they survive and reproduce more effectively than brown mice, the frequency of the *b* allele may increase over time relative to the *B* allele frequency.

Math Connection

Use Figure 3 and the allele frequency equation to answer the following questions:

1. What is the allele frequency of the dominant allele *B*? Express your answer as a decimal rounded to the thousandths place and as a percentage.
2. What is the allele frequency of the recessive allele *b*? Express your answer as a decimal rounded to the thousandths place and as a percentage.

Analyzing Population Evolution

Some chickens, ducks, and other birds can lay eggs that have either white or blue shells. Blue eggshells are dominant and are coded for by allele *O*. White eggshells are recessive and are coded for by allele *o*. The outcome of a heterozygous-heterozygous cross for eggshell color can be determined by creating a Punnett square. We can create a Punnett square to represent any dominant or recessive allele in a population for this type of cross. In this generic Punnett square, *p* represents any dominant allele and *q* represents any recessive allele. The Punnett square that gives the possible genotypes of the offspring of heterozygous parents for eggshell color is shown in Figure 4.

The Punnett square shows that the genotypic frequency of *OO* is represented as p^2, *Oo* is represented as $2pq$, and *oo* is represented as q^2. The frequency of all possible genotypes in a population must equal 1. If allele frequency can be found using the equation $p + q = 1$, then $p^2 + 2pq + q^2 = 1$. Scientists use these equations to predict the genotypic frequencies in a population. Then, they compare the predicted frequencies to the actual frequencies in a population.

Predict What could a scientist conclude if the genotypic frequencies in a population are different from the predicted values?

FIGURE 4: In this Punnett square, *p* represents any dominant allele and *q* represents any recessive allele.

	O (*p*)	*o* (*q*)
O (*p*)	*OO* (p^2)	*Oo* (*pq*)
o (*q*)	*Oo* (*pq*)	*oo* (q^2)

Data Analysis

In a population of 1,000 chickens, 840 hens lay blue eggs and 160 hens lay white eggs. Use the equation $p^2 + 2pq + q^2 = 1$ to determine the predicted genotypic frequencies for this population. Then compare those values with the actual genotypic frequencies in the population.

STEP 1 Solve for q^2 by dividing the number of *oo* chickens by 1,000.

$$q^2 = \frac{160}{1000} = 0.16$$

STEP 2 Solve for *q* by taking the square root of each side of the equation.

$$q = \sqrt{0.16} = 0.4$$

STEP 3 Determine *p* by substituting the value of *q* in the equation $p + q = 1$:

$$p + 0.4 = 1$$

$$p = 1 - 0.4 = 0.6$$

These are the predicted allele frequencies: $p = 0.6$ and $q = 0.4$.

STEP 4 Calculate the predicted genotypic frequencies from the predicted allele frequencies:

$$p^2 = (0.6)^2 = 0.36$$

$$2pq = 2\,(0.6)(0.4) = 0.48$$

$$q^2 = (0.4)^2 = 0.16$$

Analyze Answer the following questions in your Evidence Notebook:

1. What percentage of this population is expected to be *OO*, *Oo*, and *oo*? What do these values mean?
2. Through genetic analysis, scientists discovered the actual genotypic frequencies for the above population to be *OO* = 0.60, *Oo* = 0.14, and *oo* = 0.26. What can you infer by comparing these data to the values predicted above?

VARIABLES

p = frequency of *O* (dominant allele, blue shell)

q = frequency of *o* (recessive allele, white shell)

p^2 = frequency of chickens with *OO* (homozygous dominant genotype)

$2pq$ = frequency of chickens *Oo* (heterozygous genotype)

q^2 = frequency of chickens with *oo* (homozygous recessive genotype)

The equation $p^2 + 2pq + q^2 = 1$ is known as the Hardy-Weinberg equation. A Hardy-Weinberg population is in equilibrium, meaning it is stable and not evolving. Five conditions must be met for a population to be in equilibrium: no mutations, very large population, no natural selection, no new genetic material is introduced, and individuals are equally likely to mate with any other individual in the population.

Cause and Effect

FIGURE 5: Peppered Moths

Selection on Peppered Moth Populations

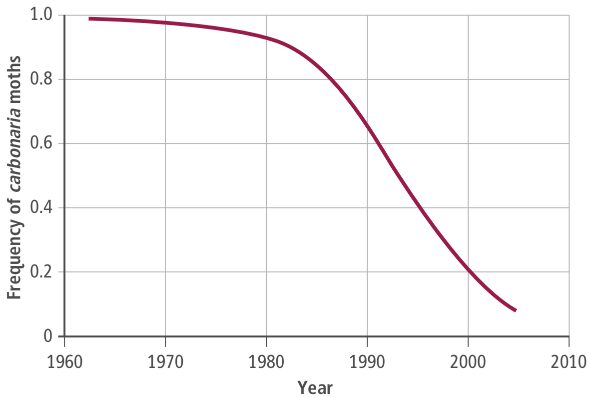
The peppered moth *Biston betularia* found in the English countryside, ranges in color from light (*Biston betularia typica*) to dark (*Biston betularia carbonaria*). Before the Industrial Revolution, light moths were more prevalent than dark moths. During the Industrial Revolution, trees became covered in dark soot from coal burned in factories. Over time, scientists observed that the number of dark moths increased relative to light moths. More recently, clean air laws returned the trees to their lighter coloring, and the dark colored moths decreased in frequency (Figure 6).

Recent studies found bird predation was one possible driving force behind the population shift. When trees were covered with soot, birds preyed on light moths. When the soot faded, birds preyed on dark moths (Figure 7). Other factors, such as migration, may have also influenced the population and require further study.

Analyze Create a graph of the shift observed in the peppered moth population. Place the color range on the *x*-axis and frequency of the trait on the *y*-axis.

Frequency of dark moths around Leeds, England, from 1970-2000

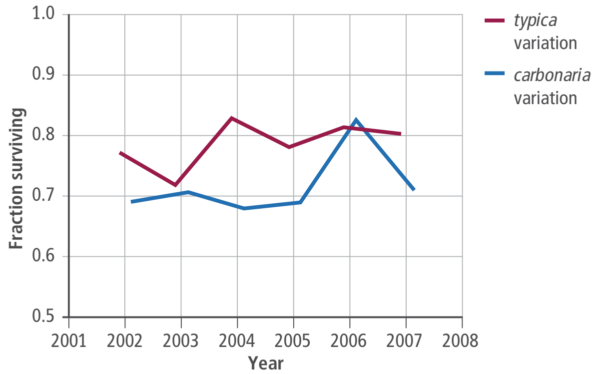
FIGURE 6: Frequency of Dark Moths



Source: John N. Thompson, *Relentless Evolution* (2013): 57, quoted in http://phenomena.nationalgeographic.com/2013/10/09/evolution-in-color-from-peppered-moths-to-walking-sticks/

Effect of bird predation on the population of light and dark moths

FIGURE 7: Effect of Bird Predation



Source: Cook, L. M., B. S. Grant, and I. J. Saccheri, J. Mallet. "Selective bird predation on the peppered moth: the last experiment of Michael Majerus." *Biol. Lett.* 2012. Published 8 February 2012. doi: 10.1098/rsbi.2011.1136.

Explain How does the Hardy-Weinberg equilibrium equation use genetic variation and allele frequencies in a population to describe whether a population is evolving?

Selection on Populations

Though king penguins look similar, members of the population differ in some of their physical traits. Some penguins may be larger and some smaller. Some individuals may have long beaks, and some may have short beaks. The majority of penguins have characteristics somewhere between these two extremes.

Normal Distribution

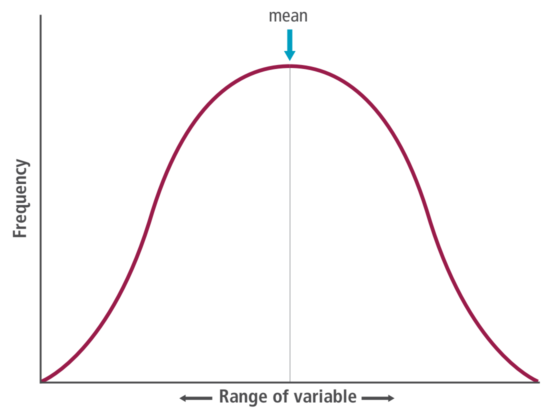
If penguin beak lengths and their frequencies are graphed, the result is a bell-shaped curve, shown in Figure 8. The shape of the curve shows that the beak length of the majority of the individuals is close to the mean length. Mean (also called average) beak length is determined by adding the beak lengths of all the individuals and then dividing the sum by the number of individuals. The graph also shows that there are not many individuals with extreme traits (very short or very long beaks).

Analyze Why do few individuals have very extreme phenotypes, such as very long or very short beaks, and more individuals show a trait somewhere in between?

A normal distribution shows an arrangement of data in which most of the values fall in the middle of the data set, represented by the mean. The curve that results is bell-shaped and symmetrical. The frequency is highest near the mean value and decreases toward each extreme end of the range. This means that for a population showing normal distribution, the alleles for the mean phenotype are more advantageous than the alleles associated with either extreme phenotype.

Normal Distribution

FIGURE 8: Most individuals in this population have traits that fall between two extreme phenotypes.



Changing Populations

King penguins live and breed on islands around Antarctica. Like other penguin species that live in cold areas, king penguins have features that allow them to live in this type of environment. They have layers of feathers as well as thick layers of fat to help keep them warm. Suppose the climate in this area warms up and continues to warm up. How might this continuing change in temperature affect the population?

Collaborate Suppose as a result of increasing temperatures, the trait for having a thick layer of fat was selected against and the thinner layer of fat was selected for. With a partner, discuss how the normal distribution graph will be affected.

FIGURE 9: King Penguins

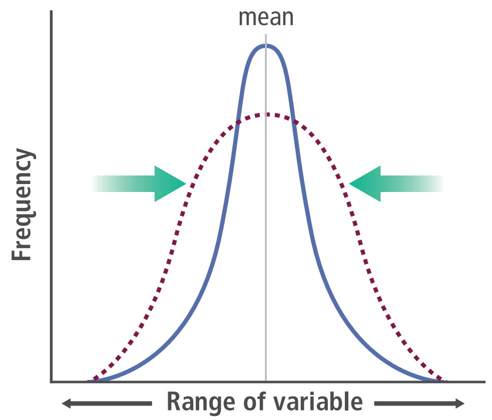
In populations, natural selection favors phenotypes that allow individuals in the population to adapt to their environment and selects against phenotypes that make individuals less able to adapt to their environment. This “favoring” and “selecting against” result in observable changes in the allele frequencies in a population. Microevolution is the observable change in the allele frequencies of a population over time. Microevolution occurs on a small scale—within a single population.

Stabilizing Selection

In humans, very low or very high birth weight can cause complications that affect a baby’s health. Many infants with very low or very high birth weights do not survive to adulthood. Over many generations, these two phenotypes were selected against. More average birth weights, which had fewer weight-related complications, were selected for. Today, the frequency of individuals with an average birth weight is higher than those with extremely low or extremely high birth weights.

Stabilizing Selection Explore Online

FIGURE 10: In stabilizing selection, intermediate phenotypes are selected over phenotypes at both extremes.



This type of selection is called stabilizing selection. This is the type of natural selection in which intermediate phenotypes are selected over phenotypes at both extremes. In the example of birth weight in humans, individuals with average birth weights were more successful than those with very low or very high birth weights.

In stabilizing selection, extreme phenotypes are selected against. Over time, the survival rate of the individuals with these phenotypes decreases, so the frequency of these traits in the population also decreases. Phenotypes near the mean are selected for, so individuals that express these traits survive and reproduce more effectively than individuals without these traits. This results in an increase in the frequency of these phenotypes in the population.

Directional Selection

Another type of selection can be seen in the case of the peppered moth. Recall that before the Industrial Revolution, there were more sightings of light-colored (*typica*) moths and few sightings of dark-colored (*carbonaria*) moths. As factories were built during the Industrial Revolution, pollution increased. At this time, scientists observed that the number of *typica* moths decreased, while the number of the *carbonaria* moths increased and became more abundant in the population than the *typica* variety.

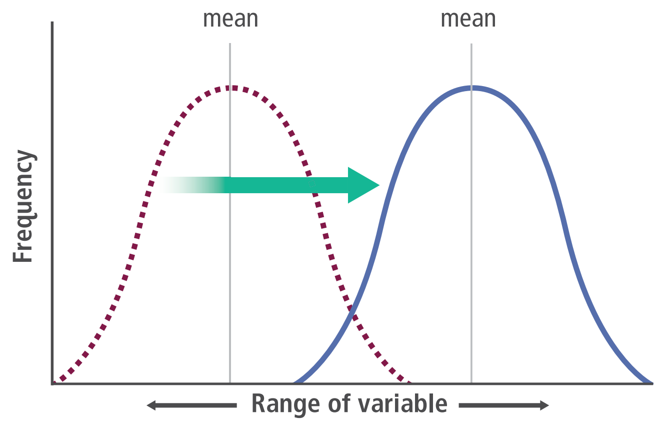
Model In your Evidence Notebook, draw a normal distribution graph for peppered moth coloration before the Industrial Revolution. Then, show how the frequencies of the phenotypes changed during the Industrial Revolution.

The type of selection observed in peppered moths is called directional selection. This is the type of natural selection in which one extreme phenotype is selected over the other extreme phenotype, shifting the mean toward one of the extremes. In the case of the peppered moths, the dark phenotype was selected over the light phenotype during the Industrial Revolution.

Directional Selection

Explore Online

FIGURE 11: After directional selection occurs, an extreme phenotype becomes the more abundant phenotype.



In directional selection, one extreme phenotype becomes more advantageous in the environment. Over time, individuals with this trait are more successful than individuals without the trait. Directional selection shifts the phenotypic frequencies, favoring individuals with genotypes that code for the extreme phenotype. The mean value of the trait shifts in the direction of the more advantageous phenotype.

Disruptive Selection

Lazuli buntings are birds found in the western part of the United States. The male birds have feathers with colors that range from brown to bright blue. The dominant adult males have the brightest blue feathers. They are the most successful in winning mates and have the best territories. For young buntings, the brightest blue and the dullest brown males are more likely to win mates than males with bluish-brown feathers.

Analyze In your Evidence Notebook, compare and contrast stabilizing, directional, and disruptive selection.

Research suggests that dominant adult males are aggressive toward young buntings they see as threats, 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.

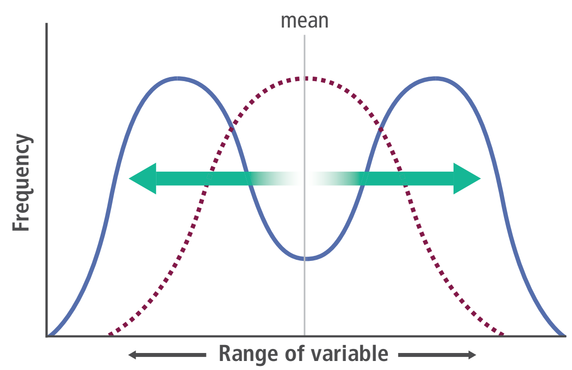
The type of selection observed in male lazuli bunting birds is called disruptive selection. This is the type of natural selection in which both extreme phenotypes (brown and bright blue feathers) are favored, while individuals with the intermediate phenotype (in between brown and blue) are selected against.

In disruptive selection, both extreme phenotypes are favored, while intermediate forms are selected against. The middle of the distribution graph is disrupted: individuals with genotypes that code for intermediate phenotypes are less successful that those with genotypes that code for extreme phenotypes. By favoring both extreme phenotypes, disruptive selection can lead to the formation of new species.

Disruptive Selection

Explore Online

FIGURE 12: In disruptive selection, the extreme phenotypes are selected over the intermediate phenotypes.



Explain Using evidence from this lesson, explain why populations, and not individuals, evolve.

Effects of Gene Flow

Predict Explain how the difference in gene flow between populations could cause them to evolve in different or similar ways.

Roses can grow in the wild or be cultivated. A bee may transport pollen from a farm that cultivates roses of different colors to a nearby area where wild red roses grow. The pollen can fertilize a wild rose flower, introducing new genetic material into the wild population. This is an example of gene flow, which is the movement of alleles from one population to another. Gene flow can cause a population to evolve.

Genetic Drift

Small populations are more likely to be affected by chance than large populations. Let's look at how a chance event can affect the alleles that code for a lizard's tail shape.

Hands-On Activity

Modeling Population Changes

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

Predict How can random chance affect the allele frequencies in a population?

MATERIALS
- deck of cards

PROCEDURE

1. Shuffle the cards. Holding the deck face down, turn over 40 cards. These cards represent the alleles of 20 offspring produced by random mating of the individuals in the initial population.
2. Separate the 40 cards by suit and then find the allele frequencies for the offspring by calculating the percentage of each suit. Record these values in your Evidence Notebook.
3. Suppose a storm isolates a few lizards on another island where they start a new population. Reshuffle the deck and draw 10 cards to represent the alleles of five offspring produced in this smaller isolated population.
4. Repeat Step 2 to calculate the resulting allele frequencies. Record the results in your Evidence Notebook.

ANALYZE

Answer the following questions in your Evidence Notebook:

1. Compare the original allele frequencies to those calculated in Steps 2 and 4. How did they change?
2. Does this activity demonstrate evolution? Why or why not? Does it demonstrate natural selection? Why or why not?

What you observed in the activity is called genetic drift, which is a change in allele frequencies due to chance. For example, chance events such as natural disasters or birds dropping seeds on an island can change allele frequencies in a population. This phenomenon of genetic drift is typically observed in small populations because small populations are more likely to be affected by chance alone than large populations. The chance event causes some alleles to decrease in frequency, which may cause them to eventually disappear from the population all together. It causes other alleles to increase in frequency and possibly become fixed in the population.

Scientists have identified two processes that can cause population sizes to decrease enough for genetic drift to occur. Each of these processes results in a population with different allele frequencies than those that existed in the original population.

Bottleneck Effect

In the late 1800s, northern elephant seals were severely overhunted for their blubber, which was used in lamp oil. It is estimated that by 1890, there were fewer than 100 individuals left. After hunting ended, the population rebounded, and now there are more than 100,000 individuals.

FIGURE 13: The hunting of northern elephant seals greatly depleted the species' numbers and genetic diversity.

Analyze Use the model in Figure 13 to explain the change in genetic variation between the initial elephant seal population and the population after it rebounded.

The northern elephant seal suffered from the bottleneck effect. This is genetic drift resulting from an event that drastically reduces the size of a population. Through genetic drift, some alleles can be completely lost from the gene pool and others can be fixed in the population, resulting in lower genetic diversity.

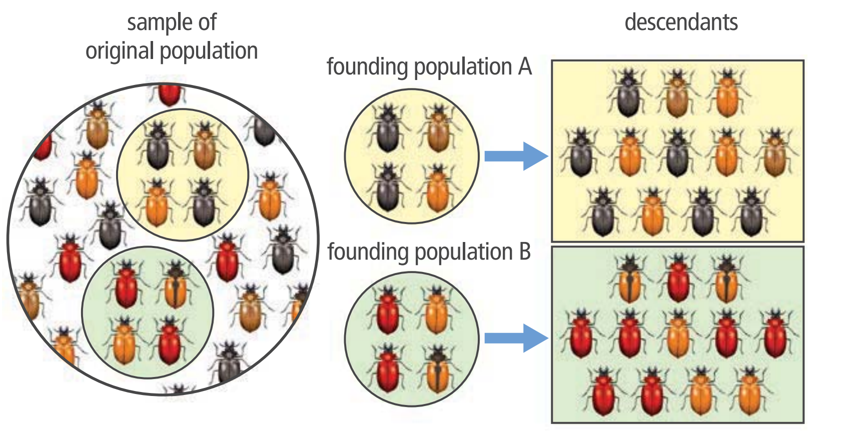
Founder Effect

The Old Order Amish communities were founded in North America by small numbers of migrants from Europe. The gene pools of these smaller populations are very different from those of the larger populations. 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.

Consider what would happen to a population of beetles that were nearly wiped out due to a natural disaster, such as the population shown in Figure 14. The original population had high levels of genetic diversity. After the disaster, two smaller populations of beetles survived, but there was no gene flow between the populations. The descendants of founding population A would have a different gene pool from the descendants of population B. For example, founding population A had beetles with genes coding for black exoskeletons. The descendants of these individuals also had black exoskeletons. Founding population B, however, had no individuals with genes for a black exoskeleton, so this gene was lost in population B.

Gather Evidence How does the genetic variation of the new population compare to that of the old population? Use evidence to support your answer.

FIGURE 14: Genetic variation decreases when a small number of individuals colonize new areas.



The founder effect is genetic drift that occurs when a small number of individuals become isolated from the original population and colonize a new area. Figure 14 demonstrates genetic drift due to the founder effect in a beetle population. The founding populations each represent a distinct gene pool observed in the founding population. As a result, allele frequencies within the founding populations change from the original population reducing genetic variation.

Sexual Selection

Male peacocks have elaborate tails made of long, colorful feathers. These tail feathers not only make male peacocks easy targets for predators, they also make flying away from predators harder. Female peacocks, though, are a muted, brown color and do not possess long tail feathers like the males. These flashy colors and ornamental traits seem to be in contrast with what should have evolved from natural selection, so how did they evolve?

FIGURE 15: The winner of a fight increases his chances of mating with a female.

In general, mating is less costly to a male than a female. Males produce many sperm, so they can invest in mating without much cost. Females, on the other hand, produce a limited number of offspring. They tend to select males that will give their offspring the best chance of survival. This difference in reproductive costs can make females choosier than males about mates. Sexual selection occurs when certain traits increase reproductive success.

Prior to the mating season, male animals like deer, elk, and moose fight other males. The winner in this competition establishes his dominance over other males and his fitness to mate with the females in the population. This type of competition among male members for the right to mate is known as intrasexual selection.

The superb bird of paradise, like other species of birds of paradise, engages in courtship behavior that increases mating success by attracting females. Superb males have feathers on their backs that are not used for flying. During courtship, the male birds use the back and chest feathers to form a funnel-like structure around their heads. This posture highlights their bright-colored breast feathers. They also flick their feathers and dance. Other birds of paradise have bright colors, large plumes, and long tail feathers and perform dances to attract the attention of females.

FIGURE 16: The male superb bird of paradise has bright feathers and large plumes to attract females.

Intersexual selection is a form of sexual selection in which males display certain traits that attract females. Males involved in intersexual selection are often more brightly colored, have larger features, or have other characteristics to attract females.

In birds of paradise, long feathers, bright plumes, and courtship behavior are due to intersexual selection. These traits are costly to develop, so males who possess them are usually healthy and strong. Scientific data show that, in some species, bright colors indicate parasite resistance. Sick males may have muted coloring and likely do not possess characteristics attractive to females. Females are able to pick the males in the best condition or that have better genes for mating.

Collaborate With a partner, discuss what a female might learn about a male through his color, size, and ornamental features, like bright tail feathers.

Stability and Change

A population is stable and in genetic equilibrium when its genetic makeup does not change over time. Because the conditions that lead to this genetic stability are rare in the natural world, evolution occurs.

There are five mechanisms that can lead to evolution:

- Mutation can lead to the formation of new alleles. Mutations produce genetic variation.
- Natural selection affects populations, acting on traits that increase an individual's ability to survive and reproduce.
- Sexual selection selects for traits that give members of a population a competitive advantage in mating and reproducing.
- Genetic drift affects small populations and is caused by random events that affect the population.
- Gene flow occurs when individuals move in and out of populations. This movement introduces and removes alleles from the gene pool.

Explain Why is genetic drift more likely in small populations than in large populations? Consider the male ruffs from the beginning of this lesson. How could genetic drift or sexual selection explain the different types of males in the population? Use evidence from the lesson to support your claims.

Data Analysis

Antibiotic-Resistant Bacteria

Antibiotics are medicines used to kill disease-causing bacteria. Studies have shown that certain species of disease-causing bacteria evolved to be resistant to antibiotics. The Centers for Disease Control and Prevention (CDC) found that doctors were prescribing antibiotics when they weren't necessary. Additionally, patients were not taking their full antibiotic doses. Both practices have led to bacteria developing resistance against various antibiotics.

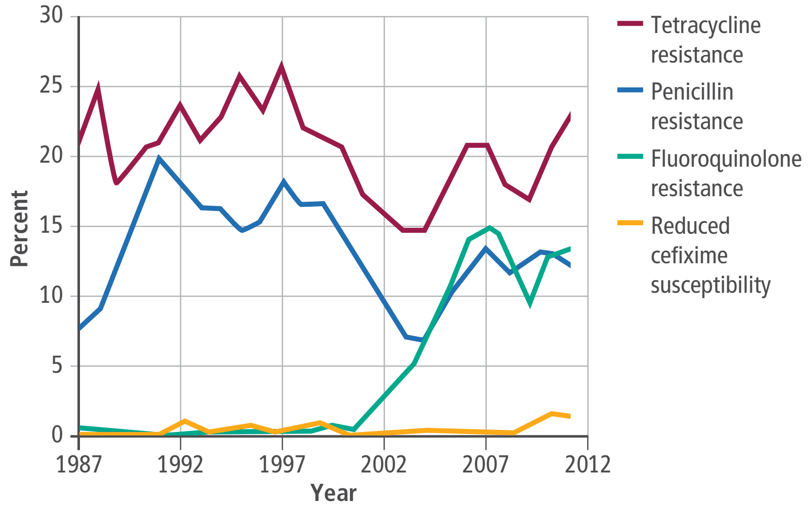
Consider a population of bacteria. In the population, most bacteria have genes that make them susceptible to antibiotics, but a very small percentage of the population do not have these genes. These bacteria are antibiotic resistant. When exposed to antibiotics, the bacteria population experiences the bottleneck effect. The bacteria in the population that are susceptible to antibiotics are killed. The remaining resistant individuals reproduce, passing on the resistance genes to their offspring. Eventually, the population consists of more antibiotic-resistant bacteria.

The bacterium *N. gonorrhoeae* causes the disease gonorrhea. This disease affects organs of the reproductive system, as well as parts of the urinary tract. If not treated, an affected person may lose the ability to produce offspring. The bacteria are transferred from one person to another through sexual activity.

N. gonorrhoeae has now developed varying levels of resistance to most antibiotics, including penicillin.

N. gonorrhoeae Resistance, United States, 1987-2011

FIGURE 17: *N. gonorrhoeae* shows some level of resistance to many types of antibiotics.



Source: The Gonococcal Isolate Surveillance Project (GISP), quoted in "Antibiotic Resistance Threats in the United States, 2013" (CDC)

N. gonorrhoeae is also developing resistance to the drug cefixime. It is recommended that cefixime be used with other antibiotics, or not at all, so the bacteria do not become fully resistant to it.

Figure 17 shows resistance patterns of *N. gonorrhoeae*. This graph shows an increased resistance to fluoroquinolones around 2000. This can be attributed to the increased use of this antibiotic during this time. It also shows that the bacteria has been resistant to penicillin since the 1980s and continues to be resistant. For this reason, scientists need to continuously develop new antibiotics to treat gonorrhea. However, new antibiotics can lead to new resistances.

Data Analysis

Answer the following questions in your Evidence Notebook:

1. What happened to penicillin resistance from 1987 to 1990?
2. What type of natural selection is observed in antibiotic-resistant bacteria?
3. Make a model to show the changes in the population of bacteria over time as they are were exposed to antibiotics.

EXAMINING SELECTION | NATURAL SELECTION IN AFRICAN SWALLOWTAILS | RUNAWAY SELECTION | Go online to choose one of these other paths.

Lesson Self-Check

CAN YOU EXPLAIN IT?

FIGURE 18: There are three types of male ruffs, and all can occur in a single population.

a An independent male

b A satellite male

c A female. Faeder males greatly resemble females.

Recall that there are three types of males in the ruff population. The dominant “independent” males are territorial and fight other independent males to attract females. The smaller “satellite” males do not fight. Satellites freely move between independents’ territories and are able to mate with some females. The “faeder” males look like female ruffs. They generally mate with females sneakily while the other males are distracted or fighting.

Explain Refer to the notes in your Evidence Notebook to explain how three very different types of males evolved in a single population.

Scientists think that the independent males expend a lot of energy and incur the risk of being injured in a fight when establishing a territory to attract females. The independents (84 percent of the population) attract females by showing dominance.

Types that pay fewer of these costs also have evolved within the population. The satellites (14 percent of the population) mate with the females in the independent males’ territories. Though independent ruffs may mate with more females, they are at risk of being injured in territorial fights and are more susceptible to predators because of their elaborate plumage and larger size. The faeders (1 percent of the population) are able to reproduce by sneaking into an independent male’s territory and quickly mating with a female.

Interestingly, scientists have discovered that the behavior and physical traits that differentiate the three types are controlled at a single genetic location, a “supergene.” Studies indicate that the faeders are a result of a chromosome inversion that occurred 3.8 million years ago. The satellite type was a result of a chromosomal rearrangement between the original sequence and the inverted sequence that happened about 0.5 million years ago. The differences in traits and behavior among these types allow them all to be successful and persist in the population.

CHECKPOINTS

Check Your Understanding

Use the following information to answer Questions 1-4.

In a population of 900 pea plants, 530 are homozygous purple, 250 are heterozygous purple, and 120 are homozygous white. Purple color (*P*) is dominant and white color (*p*) is recessive.

1. Determine the genotypic frequency in the population for *PP*, *Pp*, and *pp* individuals.

2. What is the total number of alleles in this gene pool?

3. What is the allele frequency of *P*? Express the frequency as a decimal rounded to the nearest hundredth.

4. What is the allele frequency of *p*? Express the frequency as a decimal rounded to the nearest hundredth.

Use the information in the table below to answer Question 5.

Color Variation	Frequency in Original Population (%)	Frequency in New Population (%)
Gray	15	45
Gray and white	60	20
White	25	35

5. The frequencies of a color trait among rabbits living in a mountainous area have changed over time. What type of selection most likely occurred?
   - **a.** directional
   - **b.** disruptive
   - **c.** stabilizing
   - **d.** sexual

6. Scientists observed a population of monkeys on an island. The monkeys were observed to have different finger lengths. Some monkeys had long fingers, some had short fingers, but the majority of them had finger lengths that were closer to the short finger length. Explain how this trait in the population of monkeys would evolve over time if tree branches on the island grew thicker. Would this be an example of stabilizing, directional, or disruptive selection?

7. Widowbirds are members of a bird species found in the southeastern part of Africa. The females have dull brown feathers and the males have black feathers, including tail feathers that measure an average of 41 centimeters long. Studies have shown that females prefer and choose to mate with males that have longer tails. Which outcome can be expected to occur in this scenario?
   - **a.** Over time, there will be more males with 41 centimeters tails.
   - **b.** Over time, there will be more males with tails longer than 41 centimeters.
   - **c.** Over time, there will be more males with tails shorter than 41 centimeters.
   - **d.** Over time, there will be more males with no tails.

8. Model how the bottleneck effect can lead to evolution by putting the following events in order.
   - **a.** Many of the individuals die in the population.
   - **b.** Population increases with less variation.
   - **c.** A random event acts on a population.
   - **d.** Surviving individuals reproduce.

9. Determine if the scenarios will likely result in an increase or a decrease in genetic variation over time. Copy and then complete the table below in your notebook by writing “increase” or “decrease” in the second column.

Scenarios	Genetic Variation within Individual Population
Mosquitos become resistant to pesticides.	
Arabian horses mate with wild horses.	
A population becomes lactose intolerant through mutation.	
A smaller body is selected for in cheetahs.	

10. The Florida panther is a type of mountain lion. About a hundred years ago, Florida panthers scattered and mated with other subspecies of mountain lions in nearby populations.

  a. Explain how the gene flow in this population would be affected by the introduction of the Florida panthers.

  b. Would genetic variation increase or decrease in the mountain lion population?

11. Give an example of the way sexual selection can cause extreme phenotypes in a population.

Use the information in the table below to answer Question 12.

Trait	Frequency of Trait (%)	
Color Variation	Predicted Frequencies Using the Hardy-Weinberg Equation	Observed Frequencies after Three Generations
Large flowers	75	44
Medium flowers	10	22
Small flowers	15	34

12. Study the table to compare predicted and actual frequencies of flower size in a flower population. What conclusion is best supported by the data in the table?

  a. The population is evolving.

  b. The population's gene pool remained the same.

  c. The population is in equilibrium.

  d. The population selected for an intermediate trait.

13. Why must allele frequencies in a gene pool always add up to 100 percent?

14. Explain how the process of genetic drift occurs completely by chance.

15. What are the differences and similarities between natural selection and sexual selection?

MAKE YOUR OWN STUDY GUIDE

In your Evidence Notebook, design a study guide that supports the main ideas from this lesson:

Changing allele frequencies can be an indication of the evolution of a population.

Selective pressures, such as competition and predation, can shift the distribution of traits in a population.

Small populations are more susceptible to genetic drift because large populations are able to lessen the impact of random events.

Remember to include the following information in your study guide:

- Use examples that model main ideas.
- Record explanations for the phenomena you investigated.
- Use evidence to support your explanations. Your support can include drawings, data, graphs, laboratory conclusions, and other evidence recorded throughout the lesson.

Consider how the evolution of populations relates to the assumption that natural laws operate today as they did in the past and will continue to do so in the future.