8.2

Theory of Natural Selection

When camouflaged, an animal such as this crocodilefish can be almost impossible to spot.

CAN YOU EXPLAIN IT?

FIGURE 1: The orchid mantis *(Hymenopus coronatus)* resembles a flower in shape, but some scientists think it attracts insects for another reason.

With its brilliant colors and petal-shaped legs, the orchid mantis resembles the flower it is named for. This species' habitat consists of pink and white flowers in bushes and trees. Its diet is made up mainly of flying insects. You might think that the orchid mantis catches its prey by camouflaging itself as a flower. However, researchers have found that when it was placed beside the most common flower in its habitat, the orchid mantis attracted insects more often than the flower.

Predict How do you think the orchid mantis developed the traits that make it so attractive to insects?

Gather Evidence
As you explore the lesson, gather evidence for how natural selection results in species that are adapted to their environment.

Hands-On Activity

Modeling Natural Selection: Owls and Field Mice

We know from molecular, anatomical, and fossil evidence that species have changed over time. This change is called evolution. But how does evolution actually occur in nature? In this lab, you will model one mechanism of evolution called natural selection. You will represent the predator, an owl in search of field mice. Your group will "consume" all the field mice that you can easily see until only 25 percent of the population remains. These surviving field mice will then reproduce. As with the orchid mantises, the mice will pass on an important trait for survival to their offspring. You will continue the process for several generations of mice, with some being consumed and others surviving to pass on the traits that made them successful.

PREDICT

How does a population change as a result of natural selection?

PROCEDURE

1. Spread out the fabric habitat given to you on the tabletop.
2. Count out 20 pieces of paper of each of the five different colors for a total of 100 pieces. This will be your initial population of field mice.
3. One person should spread the pieces out randomly over the entire fabric habitat, making sure that none of the pieces cover the others. The remaining members of the group should not watch this process.
4. The other members of the group are now owls. They should pick up 75 pieces (field mice) as they see them, one by one, until a total of 25 of the field mice remain in the habitat. Be sure to count carefully.
5. Carefully shake off the habitat to remove the surviving mice (a total of 25).
6. Group the survivors by color and record the numbers in your data table. See Figure 3 for an example data table.
7. Next assume that each survivor has three offspring. Place three additional pieces of the same color with each survivor. Record the number of each color in the table. Note that there should again be 100 total pieces.
8. Mix up the new set of pieces and have a different person spread them over the habitat.
9. Repeat the entire process (Steps 3 to 8) two more times, making a total of three generations of field mice being preyed upon.

Analyze Explain how you will model predation in this activity.

FIGURE 2: Barn owls are predators. They feed mostly on small mammals, such as mice, voles, and shrews.

MATERIALS

- construction paper, five colors
- piece of fabric

DATA TABLE

FIGURE 3: Effect of Predation on Field Mice Populations Over Time

	Color 1	Color 2	Color 3	Color 4	Color 5
Number at start	20	20	20	20	20
Number after first predation					
Number after first reproduction					
(Add rows for two more generations.) ⬇					

ANALYSIS

1. Graph your data. What patterns can you identify in the data?
2. Which traits appear to be the most beneficial for survival in this environment? Explain your answer.
3. Explain why the number of some mouse varieties increased over time while others decreased.
4. How do you think the data would have changed if the experiment were continued until a total of five generations of field mice were preyed upon?

FIGURE 4: Mice can reproduce rapidly. The large number of offspring must compete with one another for resources.

Mice can reproduce rapidly. In fact, their population could increase exponentially if given enough resources and few predators. However, the greater the population, the more individuals must compete for resources such as food, water, and mates. In addition, mice must escape predators to survive long enough to pass on their traits. Any traits that help them survive and pass on their genes are considered beneficial in this environment. Natural selection is a mechanism by which individuals that have inherited beneficial adaptations show differential reproductive success.

If the environment were to change, the traits that are beneficial could also change. If the grass in a field were to change colors due to a change in weather, different traits would be "selected for." This does not mean that nature actually "chooses" traits. It simply means that some traits are passed down more often than others because organisms with those traits are better able to survive and reproduce more than others in their population.

Explain Answer these questions about the concepts explored in this activity.

1. Name an animal that uses camouflage to avoid predators. What habitat is it most likely to survive in? What are some other traits that could help an animal survive in the presence of predators?
2. What kinds of resources might field mice compete for? What types of traits would give a field mouse a competitive advantage over other members of its own species?

Developing the Theory of Natural Selection

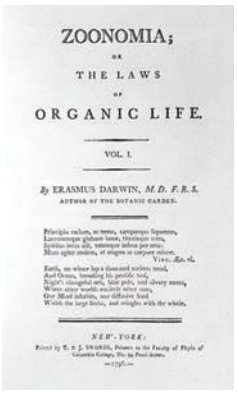
Charles Darwin was one of the most famous people to consider the question of how living things evolve; however, the concept of evolution had been discussed for more than 100 years when Darwin proposed his theory of evolution.

Early Ideas About Evolution

Early scientists observed relationships among organisms and how they seemed to be well adapted for specific environments. Darwin built upon the work of these scientists to develop a theory for how evolution occurs. A theory is an explanation based on evidence that has been repeatedly confirmed through experimentation or observation. Today, we have a wide body of evidence that supports Darwin's theory of evolution.

FIGURE 5: Ideas about evolution have developed over time.

1735 *Systema Naturae* Carolus Linnaeus proposed a new system of organization for plants, animals, and minerals based upon their similarities.



1794-1796 *Zoonomia* Darwin's grandfather, Erasmus Darwin, considered how organisms could evolve through mechanisms such as competition.

1809 *Philosophie Zoologique* Jean-Baptiste Lamarck presented evolution as occurring due to environmental change over long periods of time.

1749 *Histoire Naturelle* Georges-Louis Leclerc, Comte de Buffon, discussed important ideas about relationships among organisms, sources of biological variation, and the possibility of evolution.

1798 An Essay on the Principle of Population Thomas Malthus argued that the increasing human population would challenge the world's ability to supply enough food for everyone.

1830 *Principles of Geology* Charles Lyell proposed the theory of uniformitarianism. This theory states that both gradual and catastrophic geological changes have occurred at a constant rate on Earth and are ongoing.

Analyze How does the information in Figure 5 support the idea that theories change and develop over time as new evidence is discovered?

Darwin's Voyage

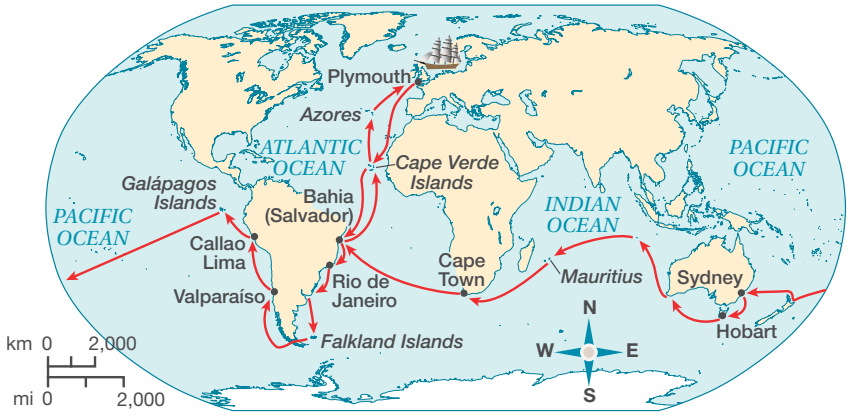
FIGURE 6: Charles Darwin

In 1831, the ship HMS *Beagle* set sail from England on a five-year journey to map the coast of South America and the Pacific islands. The ship captain saw it as an opportunity to collect specimens and study natural history. An invitation was extended to Charles Darwin, a recent graduate from the University of Cambridge. To prepare for the trip, Darwin collected scientific tools, as well as books, one of which was Lyell's *Principles of Geology*, which he read along his travels.

The first stop occurred at the Cape Verde Islands, where Darwin noticed a band of seashells on a cliff high above the shoreline. Darwin was curious about how the shells ended up there. During the following year, the young naturalist explored the rain forest to collect specimens of plants, animals, and rocks. As he worked, Darwin kept a diary, recording each new observation. This approach allowed him to do comparative studies, such as noting the differences between fossils found on a later stop in the Falkland Islands and those found on the coast of South America. Darwin also noted geological phenomena that made him wonder how environments changed.

FIGURE 7: Darwin's Journey on the HMS *Beagle*

Explore Online



Near the end of his journey, the *Beagle* arrived in the Galápagos Islands. At this stop, Darwin would make some of his most widely known observations, which are still studied today. Darwin noted that the species found on one island looked different from those on nearby islands and on the mainland. He was struck by the variation of traits among similar species. Some traits seemed well suited to the animals' environments and diets.

FIGURE 8: Galápagos tortoises (*Geochelone elephantopus*) had variations in their traits that seemed to match their environment.

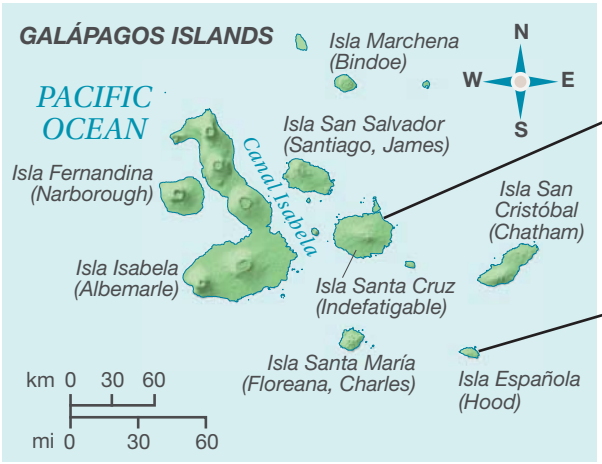
a The high shell edge of saddle-backed tortoises allow them to stretch their long necks.

b Domed tortoises have a short neck and short legs.

Predict Which variety of tortoise (saddle-backed or domed) would most likely live in an environment with mosses and short plants? Which would most likely live in an area with tall plants? Explain your answer.

Among all of Darwin's observations, the most well known are those of the Galápagos finches. These small birds, sometimes known as "Darwin's finches," are closely related, but with significant differences. These observations led Darwin to infer that species must somehow be able to adapt to their surroundings. An adaptation is a feature that allows an organism to survive and reproduce in its environment. It was this analysis that eventually helped shape Darwin's theory about how organisms change over time.

FIGURE 9: Variation in Galapagos Finches



a Large cactus finch *(Geospiza conirostris)*

Species in the genus *Geospiza* have thick beaks and can feed on large, hard seeds that require strength for crushing.

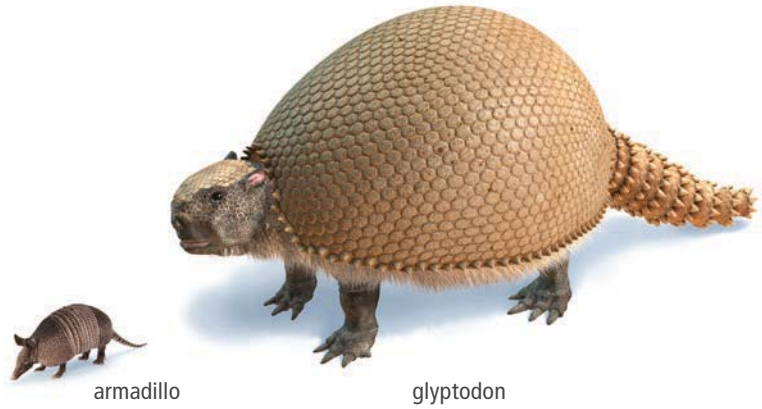
b Small tree finch *(Camarhynchus parvulus)*

Species in the genus *Camarynchus* have biting strength at the tips of their beaks, which is useful for tearing vegetation.

Analyze Use Figure 9 to answer these questions: How do these finches' adaptations help them survive and reproduce in their environment? What type of beak would you expect to see on a finch that eats insects? Explain your answer.

Several years before Darwin landed in the Galápagos, the *Beagle* anchored near Bahia Blanca in Argentina. While there, hunters brought back an armadillo. This was Darwin's introduction to this strange, armored animal. While on a fossil-hunting trip in the area, he found fossils of huge animals, including *Glyptodon*, a giant armadillo. The fact that these fossils looked like the living species suggested that modern animals might have some relationship to fossil forms. These fossils suggested that in order for such changes to occur, Earth must be much older than previously thought.

FIGURE 10: Darwin found fossils of *Glyptodon,* which resembles the modern armadillo.



armadillo glyptodon

Explain How do the *Glyptodon* fossils Darwin found in Argentina show that species have changed over time?

Predict Give three examples of geological processes that could cause fossils of organisms to be found in areas they did not historically inhabit.

During his voyage, Darwin also found fossil shells of marine organisms high up in the Andes Mountains. Darwin later experienced an earthquake during his voyage and observed the effects on the surrounding land. The land that had been underwater was moved above sea level. This experience explained what he saw in the Andes. Darwin's observations on his voyage supported Lyell's theory that daily geologic processes can add up to great change over a long period. Darwin later extended the ideas of an old Earth and slow, gradual change to the evolution of organisms. These observations led to the concept of evolutionary gradualism.

After his voyage, Darwin spent more than 20 years building on his research and knowledge of how evolution occurs. Although he had traveled the world, Darwin also found great insight in his home country of England. One important influence on Darwin's research was the work of farmers and breeders.

Artificial Selection

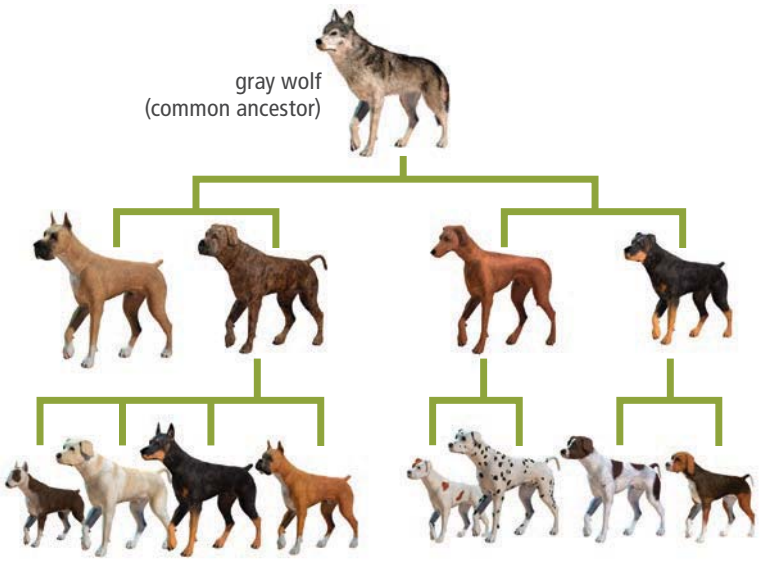
In England, Darwin observed a lot of variation in domesticated plants and animals. Farmers explained to him that, for example, some cows grew big and strong and produced a lot of milk. Others would be smaller and produce far less milk. The farmer would only breed those cows that were larger and that produced more milk. These productive traits were then passed on to the following generations. Through selection of certain traits, breeders could produce a great amount of diversity.

The farmers and breeders were not causing one cow to be more productive than another. Rather, they were controlling which cows would be used to breed offspring. The process of changing a species by breeding it for certain traits is called artificial selection. In this process, humans make use of the genetic variation in plants and animals by acting as the selective agent. Humans determine which traits are favorable and then breed individuals that show those traits.

Humans have been using artificial selection to select for desirable traits in plants and animals for thousands of years. Virtually all of the fruits and vegetables we eat have been greatly altered from their wild forms through the process of artificial selection.

Collaborate Discuss this question with a partner: How is artificial selection different than genetic engineering?

FIGURE 11: Domesticated dogs evolved through artificial selection. The common ancestor for domesticated dogs was the gray wolf.



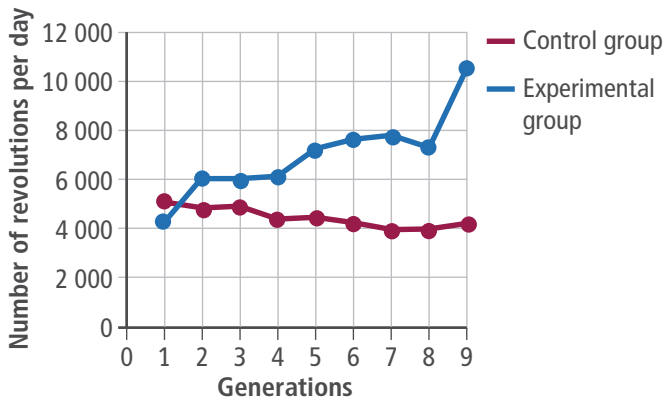
Although Darwin had no knowledge of genetics, he observed that, with human intervention, certain individuals could be selected to produce offspring with desirable traits. When selected and allowed to breed, these individuals would pass their traits onto their offspring. In order for artificial selection to occur, the trait must be heritable. Heritability is the ability of a trait to be passed down from one generation to the next.

Darwin related what he learned about breeding to his ideas on adaptation. In artificial selection, individuals with desired traits are bred over generations, but only if the traits are advantageous to breeders. However, breeders also might select against features that are not desirable or "useful." During artificial selection, humans act as the selective agent. In nature, however, the environment generates the selective pressure that determines if a trait is passed on or not.

Cause and Effect

Selection of Exercise Ability

FIGURE 12: In artificial selection, humans can make use of genetic variation by acting as the selective agent.



Source: Swallow et.al, *Behavior Genetics*, 28:3.

Scientists used mice to study whether exercise ability can improve in animals over several generations. In this experiment, mice were artificially selected for increased wheel-running behavior. The mice that were able to do the most wheel running were selected to breed the next generation. The control group represents generations of mice that were allowed to breed randomly.

Analyze Answer these questions about the data in the graph:

1. What is the difference in results between the mice in the control group and the mice in the experimental group?
2. Use the trend in the data to make a prediction about the number of revolutions on the wheel per day for mice in Generation 10 of the experimental group.

Darwin applied this thinking to develop his theory of evolution by natural selection. In nature, the environment is the selective agent. Similar to artificial selection, in natural selection the characteristics are selected only if they give an advantage to individuals in the environment as it is right now. Furthermore, Darwin realized that desirable traits would only emerge gradually in a population. He knew that it sometimes took many generations for breeders to produce the varieties he had observed.

Explain Make a graphic organizer to summarize Darwin's findings and illustrate how each observation relates to the processes that lead to changes in species.

Principles of Natural Selection

Charles Darwin was not the only person to develop a theory to explain how evolution may take place. An English naturalist named Alfred Russel Wallace independently developed a theory very similar to Darwin's. Both Darwin and Wallace had studied the huge diversity of plants and animals in the tropics, and both had studied the fossil record. They also were both influenced by the work of Thomas Malthus and his principles of economics.

Malthus had published a book in 1798 in which he discussed how increasing human populations would challenge the world's ability to produce enough food for everyone. Both Darwin and Wallace applied Malthus's ideas to the pressures experienced by plants and animals as populations increased. They noted that no species dominated the world, because some resource limited their ability to reproduce and survive. In an environment where resources are limited, individuals must compete for them. Those organisms that compete successfully go on to reproduce and pass on their traits.

Predict Why were Darwin and Wallace's ideas presented to other scientists before they were published?

In 1858, the ideas of Darwin and Wallace were presented to an important group of scientists in London. The next year, Darwin published his ideas in the book *On the Origin of Species by Means of Natural Selection*. The theory of natural selection explains how evolution can occur. Natural selection is a mechanism by which individuals that have inherited beneficial adaptations show differential reproductive success. This theory is built on the premise that more individuals are produced in each generation than can survive in any environment where resources are not infinite.

Genetic Variation

Darwin's theory of evolution by natural selection was based on observed patterns among plants and animals he and others studied. What he did not understand was how these changes occurred. About six years after the publication of *The Origin of Species*, a little-known monk named Gregor Mendel published his research on genetics and the basic principles of heredity.

FIGURE 14: Variation in coat color can be seen in jaguars and their offspring.

Mendel's work showed that traits are passed down from parents to offspring and that traits are inherited independently of one another. We now know that traits are coded for by genes and that alleles are different variations of the same gene. Variation in the alleles between individual organisms within a population is called genetic variation. Genetic variation is the basis for natural selection.

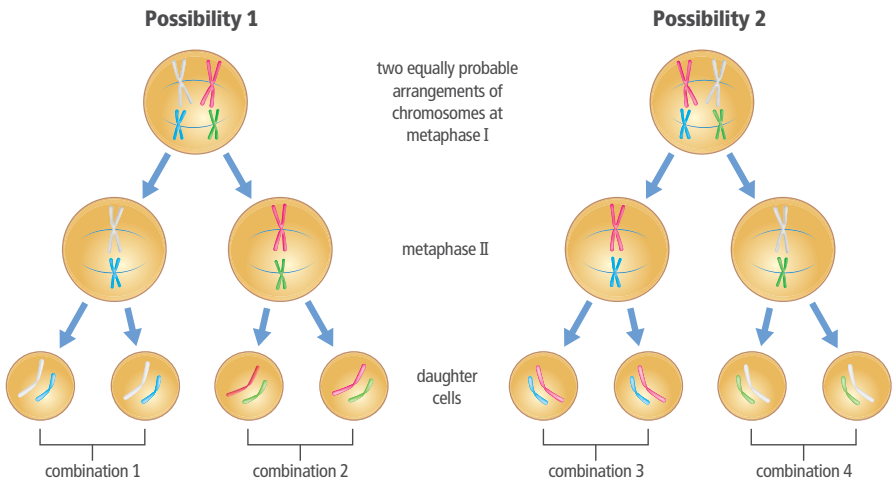
For example, the jaguar cub in Figure 14 inherited a combination of alleles that resulted in it having a different color than its mother. Therefore, there is variation in coat color in the jaguar population, and some variations may prove more beneficial than others in a given environment.

Collaborate In the owl and field mouse simulation, how did you model both variation in traits and parents passing down traits to offspring? Write your answer and discuss it with a partner.

Genetic variation is increased by sexual reproduction and meiosis. In sexual reproduction, the offspring receives two forms of each gene, one from each parent. Genes are segregated during the formation of gametes. If the genes are not linked, they will segregate separately, or undergo independent assortment. As genes are lined up and shuffled in different ways during meiosis, various combinations of genetic material are generated. As a result, sexually reproducing organisms exhibit variety in their traits. For example, Figure 15 shows the variation that can be seen in color patterns on Asian beetles. It is this type of variation that natural selection acts on. Crossing over during meiosis also allows for new combinations of genetic material. This generates an even higher number of possible combinations of genes.

FIGURE 15: Sexual reproduction increases genetic variation.

FIGURE 16: Chromosomes separate independently during meiosis. As a result, gametes have many different combinations of genes.



Heritable mutations also increase genetic variation. Damage to DNA is often caught at checkpoints in the cell cycle. The cell cannot proceed through the cell cycle until the damage is repaired or the cell self-destructs. However, sometimes the checkpoint fails, and cells with mutations proceed with replications. If a mutation is heritable, or passed on to an organism's offspring, it can increase genetic diversity within a population.

Model Explain how you could have modeled a new trait arising from a mutation in the owl and mouse simulation.

Keep in mind that natural selection acts on phenotypes, or physical traits, rather than on the genetic material itself. New alleles are not made by natural selection—they occur by genetic mutation. In addition, these mutations must be heritable, or passed down to offspring. Only mutations that occur in sex cells are passed on to offspring.

Overproduction

It was the work of Thomas Malthus that inspired many of Darwin's ideas about modification by natural selection. In his work, Malthus pointed out the potential of human populations to grow exponentially if there was a constant birth rate and ideal conditions. Such conditions would include unlimited resources and an absence of predators or disease. However, populations do not grow in an unchecked way. As Malthus pointed out, human populations are limited by many factors, such as disease, war, and limited resources.

FIGURE 17: Malthus predicted that population growth would outpace food production, causing a "Malthusian catastrophe."

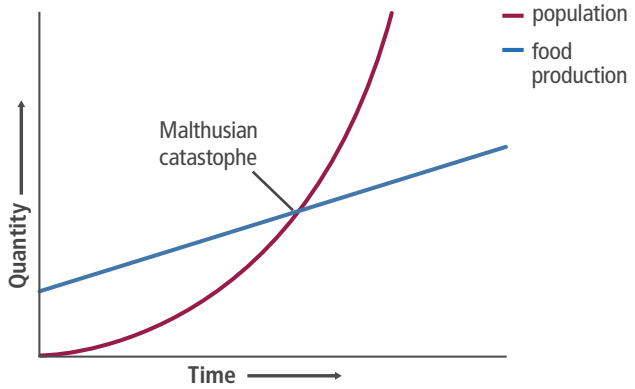


FIGURE 18: Individuals compete for resources such as food.

Predict The birds in Figure 18 are competing for a piece of food. What are some traits that might allow a bird to outcompete other birds for food?

Competition

Darwin noted that more offspring are born than can survive and that, without limits, any one species might overrun Earth. However, environments place limits on population growth, where some individuals are more successful at survival than others. Those individuals that survive better and produce more offspring will have their traits passed on to subsequent generations.

Building on Malthus's ideas that there were limits to human population growth, Darwin reasoned that a similar struggle for resources took place in nature. The challenge is for each individual to be better at obtaining available resources, such as food, water, and shelter.

Adaptation

Sometimes, a certain variation allows an individual to survive better than other individuals it competes against in its environment. More successful individuals are "naturally selected" to live longer and to produce more offspring that share those adaptations. Over time, natural selection will result in species with adaptations that are well suited for survival and reproduction in an environment. More individuals will have the trait in every following generation, as long as the environmental conditions continue to remain beneficial for that trait.

A well-studied example of natural selection in jaguars is shown in Figure 19. About 11,000 years ago, many species faced extinction. Large cats, including jaguars, faced a shortage of food due to the changing climate of that time. Fewer mammals were available to eat, so the jaguars had to eat other animals, such as reptiles. The jaguar population showed variations of jaw and tooth size that became important for survival.

FIGURE 19: Natural selection has led to changes in the jaguar species over time.

a Like many other species, jaguars can produce more offspring than can be supported by the environment. Some jaguars may be born with slightly larger jaws and teeth (skull 1) due to natural variation in the population.

b Jaguars with large jaws and teeth are able to eat armored animals, such as shelled reptiles. These jaguars are more likely to survive and to have more offspring than jaguars that can eat only mammals.

Explain Why did larger jaws and teeth become more common in the jaguar species over time? How do the four principles of natural selection explain these changes?

In biology, the term fitness is a measure of the ability of an organism to survive and produce more offspring relative to other members of the population in a given environment. An individual with high fitness is well adapted to its environment. After the change in climate, jaguars that had larger teeth and jaws had a higher fitness than other jaguars in the population. Jaguars that ate less did not necessarily all die or stop producing altogether; they just reproduced a little less.

It is important to note that fitness does not simply mean being the biggest and strongest individual. For example, being small is beneficial for some types of male spiders. Their lower body weight makes it easier for these males to cast a strand of silk into the air and be carried by the wind to a new location. As a result, these males have more opportunities to find mates and pass on their genes.

Understanding Natural Selection

In order to fully understand the theory of natural selection, it is important to consider how changes in the environment can influence fitness. It also is useful to examine some of the common misconceptions about how natural selection occurs.

Changing Environments

As an environment changes, different traits will become beneficial. Ecologists Peter and Rosemary Grant observed an example of natural selection acting on existing traits within a population of medium ground finches on one of the Galápagos Islands. A drought in 1977 reduced the number of the small, soft seeds that the finches preferred. However, there were still plenty of large, tough-shelled seeds.

The two graphs in Figure 20 represent the number of birds with each size of beak. In 1976, a total of 751 birds were measured. The distribution of beak size is shown in the histogram on the left. After the drought, the Grants again measured the beak sizes of the 1978 survivors. There were 90 birds measured to construct the histogram on the right. The Grants noticed that the distribution of beak sizes changed after the drought affected the types of available food in the environment.

Cause and Effect

Natural selection causes populations to adapt over time. The main principles of natural selection are:

Genetic Variation There is natural variation in the population.

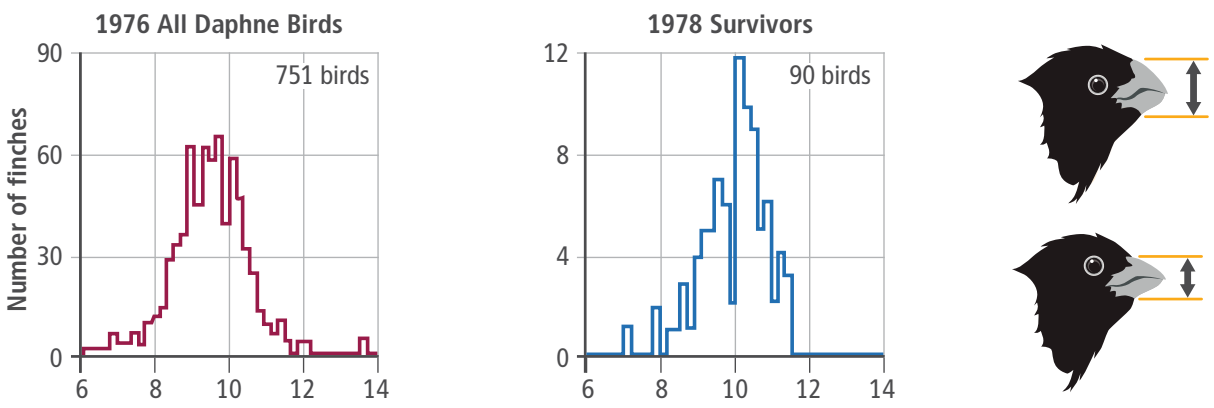
Overproduction More offspring are produced than can survive.

Competition Individuals must compete for resources, and some will outcompete others.

Adaptation Over time, beneficial traits become more common in the population, as individuals with those traits survive better and reproduce more often.

Analyze How did the distribution of beak sizes change after the 1977 drought? Explain how changes in the environment and the process of natural selection resulted in these changes.

FIGURE 20: The data in these graphs shows finch beak size before and after a drought.



The numbers of large-beaked finches on this Galápagos island kept rising until 1984, when the supply of large seeds went down after an unusually wet period. These conditions favored production of small, soft seeds, and small-beaked birds were now better adapted for the environment. With evolution, a trait that is an advantage today may be a disadvantage in the future.

Misconceptions About Natural Selection

It is tempting to assume that any feature on an organism must be the ideal trait for that organism's environment. However, not all traits are adaptations. For example, humans have a tail bone, but this anatomical feature is not the result of natural selection in humans. A feature such as this may have resulted from natural selection for a previous function, but it now serves no specific function. This trait is heritable, so it is passed down from person to person, but it no longer serves its original purpose.

FIGURE 21: This cartoon depicts a misconception about natural selection.

Explain The cartoon in Figure 21 depicts a cat who has developed a can opener for a hand. How does this cartoon demonstrate a misunderstanding of the theory of natural selection?

It also is important to keep in mind that natural selection does not produce individuals which are perfectly suited to their environment. This is partly because organisms have combinations of traits that result from complex sets of tradeoffs. For example, having large horns may help an organism fight successfully for mates, but they may make it difficult for the animal to escape predators as effectively as it could with lighter horns. Therefore, it would be difficult for selective pressures to produce "ideal" traits, because a trait that is ideal for one purpose may be less than ideal in other contexts.

Another reason natural selection does not produce ideal traits is that natural selection acts only on traits that already exist. Genetic variation within a population is what allows for the environment to "select" for certain traits. New alleles are not made by natural selection—they occur by genetic mutations.

Many mutations have harmful results and therefore are not likely to produce a trait that is beneficial in a given environment. However, some mutations lead to traits that might be advantageous to certain individuals. A mutation could change an organism's DNA in a way that leads to the production of a new type of protein. If this results in a trait that increases an organism's fitness, this trait would be selected for. Therefore, new traits can occur, but they are not created through natural selection.

Analyze You may have heard someone use the phrase "We'll have to adapt" to describe the way people adjust to their surroundings. Explain why this phrase could lead to misconceptions about natural selection.

Another common misconception about natural selection is that individuals can adapt to their environment. Natural selection leads to changes in populations, not in individual organisms. Evolution is a change in the proportion of alleles in a population over many generations. Therefore, individuals do not adapt to their environment over the course of one lifetime. Adaptations occur in populations, and those adaptations evolve over time through the process of natural selection. This process may take millions of years, or it may occur very quickly, as it does in single-celled organisms, such as bacteria.

Model Think back to the owls and field mice simulation. Were the four main principles of natural selection modeled accurately? How could you improve this model to reflect the principles of natural selection more effectively?

Guided Research

Natural Selection Today

The battle is on against bedbugs—those nasty little critters that invade your home and can give you painful, itchy bites. These pests were nearly vanquished from Earth in the 1940s by the use of the pesticide DDT, but now they are back. And those that survived the onslaught of DDT have developed a resistance to pesticides.

The DNA of bedbugs tells an interesting story about change and adaptations for survival. At one time, bedbugs fed on bats as much as they fed on humans. Although bats and humans live completely different lifestyles, that was not always the case.

Bedbugs started out as cave dwellers, feeding on bats. Early humans made homes in caves and became a new food source for the bedbugs. But technology changed everything, and soon humans were building houses. Humans also sleep at night, and bats nod off during the day. So, bedbugs that fed on bats and bedbugs that fed on humans began to diversify.

The bats that followed humans from caves to houses had to change their sleep schedule. Even as bats began to move into barns and bat houses, they brought their own brand of bedbug with them, and evidence suggests that the populations of bedbugs never mixed.

Evidence further suggests that the two groups continue to diverge. For example, the bedbugs that maintained their feeding relationship with humans now carry a genetic variation that makes them resistant to pesticides. This is not the case for the bat-feeding bedbugs.

Researchers are now studying bedbugs to learn how they develop resistance to pesticides. Several genes have been identified that may be related to this phenomenon. Many of these genes give rise to proteins in the insect's exoskeleton. This makes sense, because bedbugs are exposed to pesticides through contact with their exoskeleton.

For now, humans will have to rely on bedbug-sniffing dogs and a variety of pesticides, many of which lose their effectiveness as these pests continue to adapt by developing resistances to them.

FIGURE 22: Bedbugs show evidence of recent evolution. New traits include a thick, waxy exoskeleton that repels pesticides and a more efficient process for making its natural chemical defenses.

Language Arts Connection

Research another species whose evolution interests scientists. Gather evidence to explain how this species' traits have changed, why these traits are beneficial, and how this species might continue to change in the future. Be sure to cite specific textual evidence to support your claims. Finally, present your findings in the form of an essay, slideshow, or poster. Include a list of sources in the format specified by your instructor.

Evidence is anything that helps in forming a conclusion or judgment. When drawing evidence from informational texts, ask yourself these questions:

- Are the facts verifiable—that is, can they be proven true?
- Are the opinions from an expert or experts on the topic?
- Is the evidence relevant to the topic?
- Is there enough evidence to answer all reasonable questions?

GENETIC DIVERSITY IN FLORIDA PANTHERS | MODELING NATURAL SELECTION | BIOMECHANICS OF STAG BEETLE JAWS

Go online to choose one of these other paths.

Lesson Self-Check

CAN YOU EXPLAIN IT?

FIGURE 23: The orchid mantis *(Hymenopus coronatus)* resembles a flower in shape. But it attracts flies for another reason. Its color appears to be more important than its shape.

Recall the orchid mantis, the insect that resembles the flower after which it is named. It is easy to assume that the insect has high fitness because it looks like a flower. In fact, researchers have found that when placed beside the most common flower in its habitat, the orchid mantis attracts insects more often than the flower.

Why would insects be more attracted to the mantis than a flower? Apparently, it has more to do with the mantis's bright color than its flowerlike shape. Many insects have brains that are more attuned to color than to complex shapes. If an insect sees a color it thinks is a nectar-bearing flower, it flies in to investigate. That is when the orchid mantis makes its move—it captures the insect with lightning-fast speed.

Explain Refer to the notes in your Evidence Notebook and use what you have learned about natural selection to make a claim for how this trait could have evolved over time. Include a discussion of each of the principles of natural selection and how they led to the adaptations we see in modern-day orchid mantises.

1. State your claim.
2. Use evidence to support your claim.
3. Explain how the evidence you cited supports the claim you are making.

CHECKPOINTS

Check Your Understanding

1. Which two processes that occur during the formation of gametes contribute to increasing diversity within a population's gene pool?
   - **a.** independent assortment
   - **b.** cell signaling
   - **c.** transformation
   - **d.** crossing over
   - **e.** segregation of alleles

2. If the climate were to change in an environment, it is more likely that some individuals within a population will survive if _____
   - **a.** the individuals reproduce sexually.
   - **b.** the individuals are genetically identical.
   - **c.** there is genetic variation within the population.
   - **d.** the individuals reproduce asexually.

3. The work of _____ most helped Charles Darwin understand how bands of seashells could be found in rock strata high above sea level.
   - **a.** Malthus
   - **b.** Lyell
   - **c.** Mendel
   - **d.** Leclerc

4. Which of the following are key elements of Darwin's theory of evolution by natural selection? Select all correct answers.
   - **a.** genetic variation
   - **b.** genetic engineering
   - **c.** fitness
   - **d.** adaptation
   - **e.** overproduction

5. Explain how mutations lead to genetic variation.

6. Construct an explanation as to how natural selection might produce an effect of the giraffe's neck length changing over time.

7. How did the work of farmers and breeders in England influence the work of Charles Darwin? Use examples to support your explanation.

8. What effect did Darwin's travels to the Galápagos Islands have on the development of his theory of natural selection?

9. Draw a timeline of events that influenced Darwin's work and the people whose work he built upon.

10. Develop a model that can be used to illustrate natural selection. Explain how your model demonstrates the four main principles of natural selection.

MAKE YOUR OWN STUDY GUIDE

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

Many scientists had made observations and developed ideas about evolution, but it was Charles Darwin who developed the theory of evolution by natural selection.

Natural selection is a process in which overproduction, variation, and competition lead to the adaptation of populations over time.

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 models you observed demonstrate the four main principles of natural selection.