Chapter 5

Evolution

Chapter 5 • Lesson 18

Natural Selection

Key Terms • species • population • inherited trait • biological evolution • natural selection • overproduction of offspring • variation • generation • gene pool • descent with modification • fitness • survival of the fittest • resistance • antibiotic

Getting the Idea

Each organism in a population has slightly different characteristics. Some members of a population survive and reproduce. Others do not. Those members that survive pass on their individual characteristics to future generations. Over time, these differences result in changes to the characteristics of the population.

Biological Evolution and Natural Selection

Recall that a **species** is a group of similar organisms that can breed and produce fertile offspring. A species is made up of one or many populations. A **population** contains all the members of a species that live in an area at the same time.

The organisms in a population have different characteristics, or traits. Many of these are inherited traits. An **inherited trait** is a characteristic that is passed down genetically to offspring. Over generations, certain heritable traits increase in frequency in a population. At the same time, other traits decrease in frequency. **Biological evolution** is a scientific framework that accounts for changes in the distribution of inherited traits in a population over time. Such traits include physical features, behaviors, and the various proteins produced by genes. Biological evolution explains changes in organisms from the earliest living things to the millions of life-forms that exist today.

Large-scale changes in organisms result from many small changes over long periods of time. One mechanism for these small changes is natural selection. **Natural selection** is the process by which organisms with traits that are most favorable in their environment are most likely to survive and pass on their traits to offspring. Such organisms are "selected" by natural events. A population must meet four conditions for natural selection to occur: overproduction of offspring, variation, adaptation, and descent with modification.

Overproduction of Offspring

Most organisms produce more offspring than the resources of their environment can support. This is called **overproduction of offspring**. Many offspring are lost to predators, disease, or other factors. Relatively few survive to reproduce. Overproduction increases the likelihood that some offspring will survive long enough to reproduce. However, overproduction also increases the competition for available resources.

Variation

Variation is the range of possibilities for a trait in a population. Variation in genotypes results in variation in phenotypes, or expressed traits. Resources such as space, food, water, shelter, and oxygen are limited in a given area. Organisms must compete for these resources. Organisms with phenotypes better suited to their environment get more resources and produce more offspring. They pass on their useful inherited traits to their offspring. Organisms with phenotypes that are less well suited get fewer resources. These individuals are less likely to reproduce and pass on their traits. The genes of the next generation will reflect these differences. A **generation** is one step in the line of descent of an organism, from parent to offspring. Each successive round of offspring constitutes a generation.

Adaptation

Recall from Lesson 17 that an adaptation is any feature of an organism that increases the chance of survival and reproduction. Adaptations can be structural (related to an organism's form), functional (related to the way its body works), or behavioral. The word *adaptation* is also used to describe the process that makes helpful traits more common. Over generations, a population's gene pool changes. A **gene pool** is the total genetic information of all members of a population. The individuals in a population share the gene pool because they mate with one another. A population's gene pool includes all alleles carried by its members. Some of these alleles are expressed, while others are not.

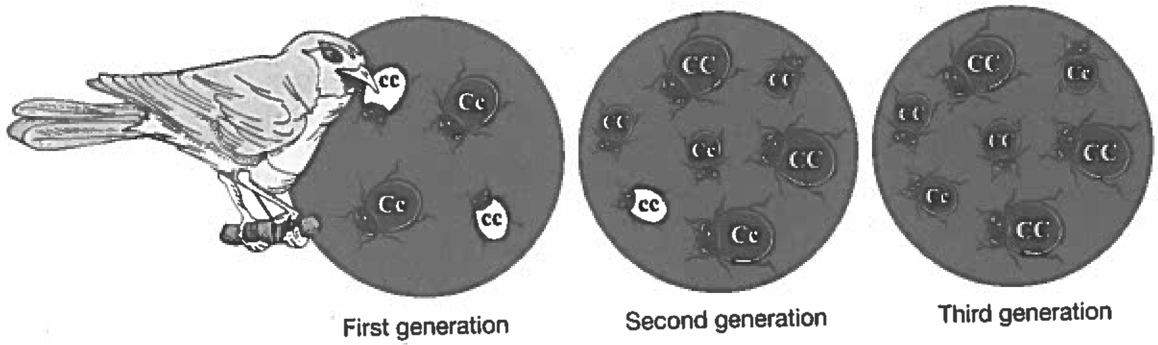
Descent with Modification

All organisms inherit traits from previous generations. If a population's environment stays constant, the same traits will be beneficial generation after generation. These traits tend to increase in frequency in the population. However, environments are prone to change, and different traits are useful in different environments. The phenotypes of a population may change due to natural selection when conditions change. The new traits will be better adaptations to the new conditions. As long as the new traits are useful, the genes for them will spread through the population. Genes for less useful phenotypes will decrease in frequency. This process is referred to as **descent with modification.**

Natural Selection at Work

Fitness is an organism's ability to survive and reproduce. Traits that help an organism meet these goals in a specific environment increase its fitness. Such traits may be physical features, such as thorns on a plant's stem or coloring that helps an animal blend in with its surroundings. Favorable traits may be behaviors, such as a courtship display to a potential mate or a display of strength to a rival. Favorable traits may also be biochemical, such as production of an enzyme that allows an organism to draw nutrients from new sources. Any favorable traits that can be inherited will increase in frequency in a population.

In the example shown below, predators (in this case, birds) spot light-colored beetles more easily than they spot dark-colored beetles against a dark background. Beetles with the dark phenotype survive and reproduce in this environment better than beetles with the light phenotype. Therefore, the allele for dark color (*C*) passes to the next generation more often than the allele for light color (*c*).



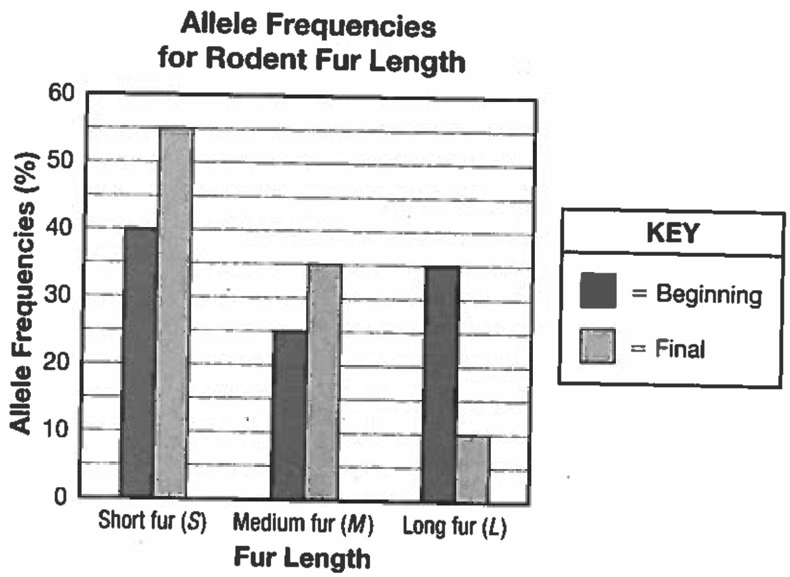
By natural selection, only the organisms that are best adapted to their environment survive and reproduce. (Natural selection is often described as **survival of the fittest**.) In many cases, natural selection occurs when organisms are faced with changing conditions. Because a population shares a gene pool, a successful adaptation will spread through the population over time. Pesticide and antibiotic resistance are examples of natural selection. **Resistance** is an organism's ability to withstand a harmful agent.

The table shows beginning allele frequencies for different fur lengths in one population of rodents.

Allele Frequencies in One Rodent Population

Fur Length	Frequency
Short fur (*S*)	40%
Medium fur (*M*)	25%
Long fur (*L*)	35%

The graph shows the changes in the allele frequencies in this rodent population over time.



In your own words, summarize the information shown in the graph.

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Write a logical explanation describing how changes due to natural selection could have led to the changes in the allele frequencies over time.

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Pesticide Resistance

Insects can cause major harm by destroying crops or spreading disease. People have developed chemicals called pesticides that kill insects. Occasionally, some insects in a population have slight variations that enable them to survive the pesticide. These insects are pesticide resistant. As these organisms survive and reproduce, they may pass on the trait that makes them pesticide resistant to the next generation of insects.

Pesticide-resistant insects can pose serious health problems. For example, the number of cases of malaria around the world has increased dramatically in recent years. Pesticide resistance is a major reason for the increase. Malaria is caused by a parasite that enters a person's blood through the bite of an infected mosquito. Malaria can be prevented by killing the mosquitoes that carry the parasites.

Insecticides, such as DDT, were once widely sprayed in malaria-affected areas. DDT is a colorless insecticide that is harmful to humans and animals. It has been banned in the United States for most uses since 1972. When DDT is first sprayed in an area, the mosquito population quickly declines as many mosquitoes are killed. However, DDT becomes ineffective very quickly because of DDT-resistant mosquitoes. Most mosquito populations contain a few DDT-resistant mosquitoes at all times. When DDT is sprayed, natural selection favors those resistant mosquitoes, allowing them to survive and reproduce. Therefore, the number of pesticide-resistant mosquitoes increases, and DDT becomes less useful.

Keep in mind that resistance to pesticides or other agents does not usually develop in a single generation. Insects from the original population that were not exposed to the pesticide are likely to survive and produce offspring. Nonresistant insects from neighboring ecosystems that were not exposed to the pesticide may move into the sprayed area after the pesticide stops working. In addition, not all the offspring of the pesticide-resistant insects will inherit the trait for resistance. For these reasons, the trait for pesticide resistance is unlikely to appear in all the organisms in a single generation. However, because of natural selection, the number of resistant insects is likely to continue to increase over many generations if people keep using the insecticide.

Hundreds of species of insects have developed resistance to various chemical pesticides. This increase in resistance has made these insects more and more difficult to control.

Antibiotic Resistance

Bacterial infections are often treated with drugs known as antibiotics. An **antibiotic** is a drug that is used to kill bacteria or slow their growth. Some bacteria in a population may have a trait that makes them resistant to an antibiotic. Over time, enough of these bacteria survive and reproduce that the antibiotic becomes ineffective against the infection. Tuberculosis, pneumonia, and childhood ear infections are among the many diseases that have become hard to treat with antibiotics because of antibiotic-resistant bacteria.

The development of antibiotic resistance has been aided by the overuse and misuse of antibiotics. People sometimes ask their doctors for, and receive, antibiotics for the common cold or the flu. These diseases are caused by viruses, which do not respond to antibiotics. The unnecessary use of antibiotics can produce antibiotic resistance in bacteria that happen to be in the patient's body.

Antibiotic resistance can also develop when healthy farm animals are given antibiotics in their feed. Farmers use the antibiotics to reduce diseases from occurring and to make the animals grow faster. Antibiotics have been used, and overused, this way for many years. Some of these antibiotics are important in treating diseases in human beings. The overuse of antibiotics in livestock contributes to antibiotic resistance in disease-causing bacteria.

You might think the solution is simply to develop new antibiotics. However, developing new antibiotics is difficult. Finding, testing, and getting government approval for a new antibiotic takes years. Drug companies are developing new classes of antibiotics. However, bacterial resistance is developing faster than these companies can develop new antibiotics. People need to work to prevent and reduce antibiotic resistance. Otherwise, doctors will be unable to cure some diseases that we are used to thinking of as treatable.

Changes in the traits of bacteria occur, in part, due to chance. Models are helpful tools that can be used to explain how natural selection plays a role in antibiotic resistance.

Begin with a population of 10 bacterial cells. Flip a coin to determine if each cell is resistant to an antibiotic. Heads = resistant, and tails = not resistant. Record the results of your coin flips in the table below. This will establish your initial population.

Coin Flip	Resistant (Heads)	Nonresistant (Tails)	Coin Flip	Resistant (Heads)	Nonresistant (Tails)
1			6		
2			7		
3			8		
4			9		
5			10		

Model the application of an antibiotic to this population. Assume that the resistant bacteria are able to survive the antibiotic and pass on the trait for resistance to the next generation. Assume that 10 percent of nonresistant bacteria survive the antibiotic. Write your results in the space below.

Using your model, explain what will happen to the proportion of nonresistant bacteria when compared to the beginning population. Then explain what will happen in future generations.

Viruses

Like bacteria, viruses evolve in response to changes in their environment. Recall that a virus is a particle made up of a nucleic acid in a protein coating. Many viruses cause disease in humans and other organisms.

Although viruses are not considered to be living, they do have the ability to make new viruses through a process called replication when they are inside a living cell. When a virus replicates, it injects some of its genetic material into the host cell. Sometimes, two different strains of viruses happen to infect the same cell. The genes from the two viruses can recombine to produce a new virus that has traits that are different from either of the previous strains.

Viral replication can produce large numbers of viruses quickly. Viruses, like organisms, are susceptible to mutations that change their traits. Some viruses do not mutate very often. Others, such as the flu virus, mutate very quickly. When a virus mutates, an organism that was previously immune to the virus because of a vaccine or prior infection may no longer be protected. The ability of viruses to mutate quickly is one of the factors that make viral diseases difficult to treat.

Lesson Review

1. What makes up a population's gene pool?

   A. all the alleles carried by members of the population

   B. all the alleles expressed in members of the population

   C. all the favorable alleles carried by members of the population

   D. all the dominant alleles carried by members of the population

2. Which of these is required for natural selection?

   A. All individuals of a population must be identical.

   B. There must be a small number of individuals in a population.

   C. There must be variation among the members of a population.

   D. A population of individuals must be forced out of their natural habitat.

3. A certain mammal population contains two alleles for claw length. Some members of the population have long claws that enable them to climb trees, while most members do not. When a new predator that feeds on these mammals is introduced into this environment, some long-clawed mammals climb up trees to escape.

   Which statement describes the **most likely** impact of natural selection on the population over the coming generations?

   A. The alleles for long claws will increase in the population.

   B. The alleles for long claws will decrease in the population.

   C. The alleles for short claws will increase in the population.

   D. The alleles for short claws will disappear from the population.

4. Why do some strains of bacteria become resistant to antibiotics?

   A. The bacteria grow in habitats protected from antibiotics.

   B. The bacteria develop a method of surviving without energy.

   C. Some bacteria that live in host organisms are not affected by antibiotics.

   D. Some bacteria develop an adaptation that enables them to survive in the presence of antibiotics.

Standards:
SB6.b, d

Mechanisms for Evolutionary Change

Key Terms • genetic variability • gene flow • genetic drift • nonrandom mating • genetic equilibrium • Hardy-Weinberg principle • speciation

Getting the Idea

Genetic variation and pressures from the environment together bring about changes in populations and species. Over time, these factors can cause some species to die out and new species to form.

Factors Affecting Genetic Variability

Variations in traits result from random changes in genetic material. New genotypes and phenotypes appear in each generation of a population. **Genetic variability** is the range of genetic differences within a population or species. Various factors can cause such genetic differences to increase or decrease. These factors include gene flow, genetic drift, nonrandom mating, mutations, and natural selection.

Gene flow is the introduction of genes from one population into the gene pool of another population. Recall that a gene pool contains all the alleles of all the members of a population. The movement of genes into a gene pool increases a population's genetic variation. Several factors affect gene flow. The most significant factor is mobility, or the movement of individuals between populations. For example, animals are more mobile than plants. Therefore, animals have a higher rate of gene flow. Gene flow can also describe the loss of genes from a population. This type of gene flow reduces variation.

Chance can also affect gene pools. Due to chance events, some individuals in a population may have more offspring than other individuals. A series of such chance events can cause certain alleles to become more common. A change in the allele frequencies of a population as a result of chance events is called **genetic drift**. A natural disaster can also cause genetic drift by removing individuals and their alleles from a population.

Genetic drift has a much greater effect on small populations than on large ones. Consider two populations of the same species, one population with 1,000 members and the other population with 10 members. Each member of the larger group contributes one-thousandth of the alleles in the gene pool. Each member of the smaller group contributes one-tenth of the alleles. The loss of one individual from the smaller group has a much greater effect on allele frequencies. Changes in phenotypes are far more easily observed in the smaller group. Genetic drift over generations causes rare alleles to decrease in frequency until they disappear. The frequencies of more common alleles, though, increase until they stabilize.

Genetic variation can also change because of nonrandom mating. **Nonrandom mating** occurs when individuals within a population select mates based on the phenotypes of those mates. This means that some individuals have more opportunity to mate and produce offspring than others. The alleles for phenotypes of individuals that have less chance to mate are not expressed as frequently over time. As a result, these phenotypes become less common in the population. Nonrandom mating is common in animals because many animals choose their mates.

Mutations can also lead to greater variation. Recall that a mutation is a change in a DNA sequence. Most mutations are caused by errors during DNA replication or by damage to DNA from environmental factors, such as radiation. These changes may turn one allele in an organism into another allele already present in the population. Mutations may also introduce new alleles into a population. To influence evolution, mutations must be passed from one generation to the next. In organisms that reproduce sexually, only mutations in gametes can be passed to offspring.

Recall that natural selection is the process by which organisms with favorable traits are most likely to survive and reproduce. Also recall that the theory of natural selection is based on several core concepts.

- Organisms produce more offspring than can survive and reproduce.
- Populations have varied traits. Some of these phenotypes are more useful for survival than others.
- Organisms whose phenotypes are best suited for their environments are most likely to survive, produce offspring, and pass on their traits to future generations.

Genetic Equilibrium

The state in which the frequency of alleles in a population stays constant is called **genetic equilibrium**. The **Hardy-Weinberg principle** states that genetic equilibrium will be reached when certain conditions are met. For this state to be reached, the population must be very large and have no genetic drift. There must be no heritable mutations. Natural selection must not occur. There must be no nonrandom mating. Finally, organisms must not move into or out of the population. The conditions required by the Hardy-Weinberg principle are only theoretical. They do not exist in nature.

In nature, genetic equilibrium does not exist because gene pools are constantly changing. Scientists use two equations to predict how allele frequencies can change over time. You will use one of these equations to model how allele frequencies change once a condition required by the Hardy-Weinberg principle is violated.

Begin by modeling a gene pool that is 50 percent dominant (A) and 50 percent recessive (a) alleles. Your teacher will provide you with a bowl containing 100 beads, 50 of one color and 50 of another color. Use the bowl of beads to represent the gene pool.

We represent this gene pool with the equation $p + q = 1$. In this equation, p is the frequency of the dominant allele (A), and q is the frequency of the recessive allele (a). Because there are only two alleles, their frequencies ($0.5 + 0.5$) must add up to 1.

Determine the genotype of an offspring by closing your eyes and randomly drawing 2 beads. On a separate sheet of paper, record the individual's genotype, and then return the beads to the gene pool. Repeat until you have chosen 50 offspring. Record the number of each genotype in the table below.

Homozygous dominant (*AA*)	
Heterozygous (*Aa*)	
Homozygous recessive (aa)	

Determine the values of p and q in this new generation. How do they compare to the values of p and q in the original population?

In the founder effect, a small group of individuals from one population moves to a new area and starts a new population. Use your beads to model the founder effect. Close your eyes, and select 10 individuals (2 beads each) from the bowl. Record the number of each genotype.

Homozygous dominant (*AA*)	
Heterozygous (*Aa*)	
Homozygous recessive (aa)	

Determine the new p and q for these individuals that represent the founder effect. Record your results below.

Recall that you started with 50 beads of one color and 50 of another color. Now you will change the number of beads of each color in the bowl of 100 beads so that the number of each color reflects the new *p* and *q*. Draw 50 individuals from the bowl as you did earlier.

Use the bowl of beads to represent the gene pool.

Homozygous dominant (*AA*)	
Heterozygous (*Aa*)	
Homozygous recessive (*aa*)	

How do the values of *p* and *q* in this population compare to the values in your original generation of 50 offspring? Use your model to explain how genetic drift can lead to changes in the gene pool.

Speciation

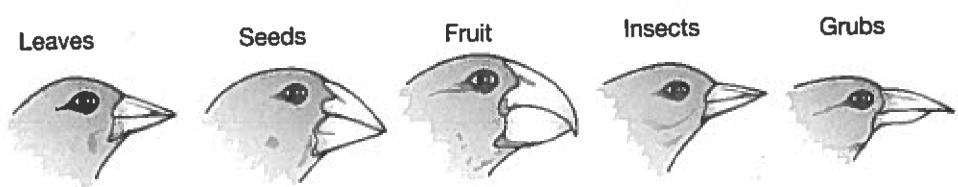
Recall that a species is a group of organisms with similar characteristics that can produce fertile offspring. All the members of a species that live in the same area at the same time make up a population. Over time, genetic variations in a population due to natural selection can have two major outcomes: speciation or extinction.

Speciation is the formation of one or more new species from an existing species. The process begins when a group of organisms becomes isolated, or separated, from the rest of a population. The new population cannot mate with the original one, so the two gene pools do not blend. Over generations, different variations appear in each population. Natural selection favors different traits in the two groups, which may live in different environments. Over time, genetic and phenotypic differences between the populations may become so great that they can no longer interbreed. At that point, the populations have become separate species.

A population can become isolated geographically by a physical barrier. Physical barriers can result from natural changes to the land, such as earthquakes or flooding, or from changes caused by humans, such as building a highway through an area. Over time, the isolated population may form a new species that breeds only in its particular habitat.

Populations can also become isolated by differences in reproductive timing or behavior. For example, frogs breed at a certain time each year. If some members of a frog population start breeding earlier than usual, they may no longer breed with the rest of the population. Eventually, the early breeders may form a new species. Alternatively, an insect species may breed and lay eggs on a certain tree species. If some of the insects begin to breed on a different species of tree, they will form a distinct breeding population that may become a new species over time.

A famous example of speciation due to geographic isolation occurred in the Galápagos Islands. This group of islands is located in the Pacific Ocean 1000 kilometers from the coast of South America. On a voyage to the islands in the 1830s, naturalist Charles Darwin observed the finch species shown in the diagram below. Each species lived on a different island and had different sources of food. Darwin concluded that the all the finch species had developed from a single species that came to the islands from South America. Isolated on separate islands, the finches developed different beak shapes suited to their food sources. Over time, each group became a separate species. Darwin's observations of the finches led him to develop his theory of natural selection.



Beak shapes in Galápagos Islands finches vary according to the type of food the finches eat.

A species of ground squirrels lives on a volcanic island. The habitat in which the squirrels live is sandy and rocky. The table shows some of the physical traits of this population as well as the frequency of those traits in the population.

Trait	Frequency	Trait	Frequency
Light-gray fur	80%	Short claws	75%
Dark-gray fur	20%	Long claws	25%

The volcano erupts and causes part of the island to become covered with dark, hard, volcanic rock. The squirrel population that lives on that part of the island becomes isolated from the main population.

The following table shows some of the physical traits of the isolated population after several generations. Scientists have noted that the squirrels in the isolated population can no longer breed with the original population.

Trait	Frequency	Trait	Frequency
Light-gray fur	40%	Short claws	22%
Dark-gray fur	60%	Long claws	78%

Interpret the information provided to explain whether or not the isolated population is a new species.

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Analyze the data provided in the tables. Explain why the frequencies for each trait have changed.

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Lesson Review

1. Which factor is required for genetic equilibrium?

   A. nonrandom mating

   B. small population size

   C. absence of genetic drift

   D. presence of heritable mutations

2. Two closely related forms of the fruit fly *Drosophila* mate at different times of day. One type mates only in the morning, while the other mates only in the afternoon. Which statement **most likely** describes the two forms of *Drosophila*?

   A. They share the same gene pool.

   B. They belong to the same species.

   C. They make up two separate species.

   D. They are part of populations in genetic equilibrium.

3. A population of 50 land mammals has a small number of alleles for one trait. After being attacked by a pack of predators, only one-half of the population remains. Which term **best** describes the change in allele frequencies for this trait in the population?

   A. gene flow

   B. genetic drift

   C. mutation

   D. nonrandom mating

4. A single population of lizards living on an island in the Pacific Ocean becomes separated into two populations due to volcanic activity. Which statement describes the **most** likely outcome of this event after several generations?

   A. One population will become extinct.

   B. Different traits will appear in each population.

   C. Each population will begin to breed at a different time.

   D. The two populations will maintain the same genotypes.

Standards:
SB6.a, c

Evidence of Evolution

Key Terms • fossil • relative dating • radioisotope dating • homologous structures • analogous structures • embryology • embryo

Getting the Idea

The history of life on Earth shows that as species evolve, they develop new traits and lose other traits. Scientists use many kinds of data to uncover the evolutionary histories of organisms. This information helps scientists learn how and why adaptations arise, how new species develop, and why some species become extinct.

Types of Evidence

Although scientists lack the ability to observe evolution directly, multiple lines of evidence support the scientific community's understanding of evolutionary theory. Charles Darwin theorized that new species evolve from an existing species and that adaptations can occur because of changes in a population's environment. This revolutionized the way that scientists understand the natural world. Darwin's work, along with the work of scientists such as Gregor Mendel, continues to provide the foundation for questions that arise today.

Combining evidence from the study of fossils, anatomy, embryology, genetics, and biochemistry helps explain how new species can arise from existing species. New discoveries are constantly being made about Earth's history, evolution, and how traits are inherited. These new discoveries will continue to shape our understanding of life on Earth.

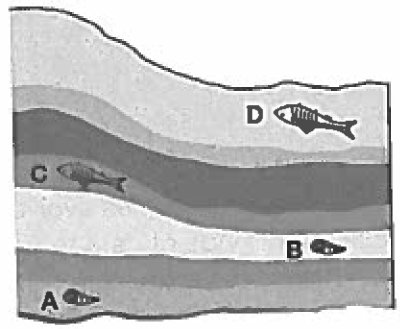
Evidence from Fossils

Fossils are the remains or traces of organisms that lived in past ages. The structures most likely to become fossils are the shells, bones, and teeth of animals as well as plant structures that have thick cell walls, such as wood. Soft structures, such as skin or internal organs, are less likely to fossilize. In addition, a specific set of physical conditions is required for fossils to form.

Much evidence about past life-forms comes from fossils. Fossils also provide clues about when different species lived. Scientists can use either relative dating or radioisotope dating to estimate the age of a fossil.

Relative dating is a means of identifying the age of a fossil or a rock by comparing it to other fossils or rocks. Relative dating begins when scientists find fossils in specific rock layers. Scientists can match the age of the rock layers with the fossils they contain to determine the approximate age of the fossil.

This diagram shows fossils in undisturbed layers of sedimentary rock. Scientists would use relative dating to look at these layers and conclude that the fossil in Layer B is older than the rocks and fossils in the shallower rock layers (Layers C and D) and is younger than the rocks and fossils below it (Layer A).



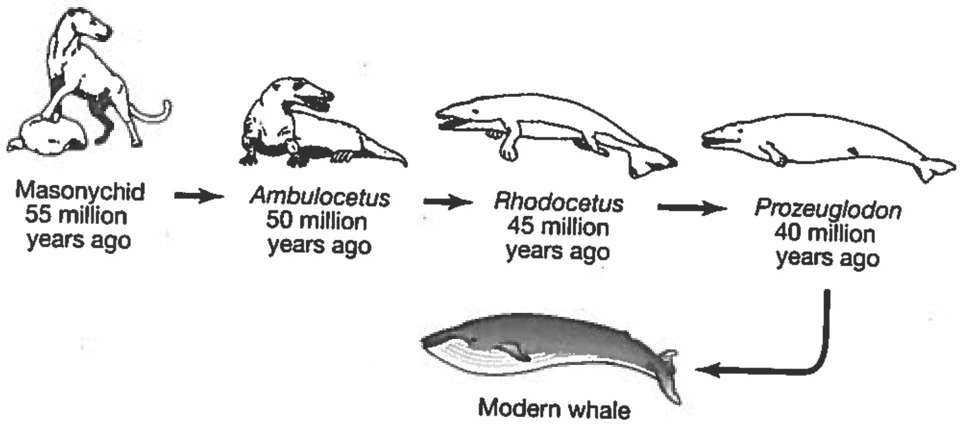
Relative dating gives scientists an approximate idea of when a fossil formed. To determine the age of a fossil more accurately, scientists often use radioisotope dating. **Radioisotope dating** measures the age of a material by comparing the amount of a radioactive form of an element contained in the material with the amount of that element's decay product. Carbon-14 (C-14) is the radioactive isotope used to date objects and fossils that are less than about 50,000 years old. When an organism dies, it contains a certain amount of C-14. The C-14 slowly breaks down at a predictable rate to become N-14. Scientists can use this information to determine how long ago the organism lived.

Organizing similar fossils by age helps scientists study and describe how species change over time. However, the fossil record is incomplete. Scientists have found fossils of only a small number of the many organisms that have lived on Earth. Despite these gaps in the fossil record, scientists have found some *transition fossils*, which are fossils that show a transition from one species to another.

One group of organisms for which transition fossils are known is whales. The history of the modern whale goes back to a group of hoofed mammals that lived on land. Fossil evidence indicates that those animals walked on land and could also swim. Later fossils suggest that over time, the hind limbs of the whales' ancestors shrank. Their forelimbs became modified into flippers, and their hind limbs disappeared. They developed a powerful tail with two lobes, called flukes. The illustration on the next page shows one possible sequence of events by which modern whales evolved.

Scientists have discovered relatively few transition fossils. One reason that the discovery of transition fossils is rare is that the discovery of fossils in general is rare. Many organisms, especially those lacking hard body parts such as teeth and bones, do not readily form fossils. In addition, the intermediate forms of organisms, which could form transitional fossils, do not appear to exist for very long.

Follow the arrows to trace one possible sequence of events by which modern whales evolved.



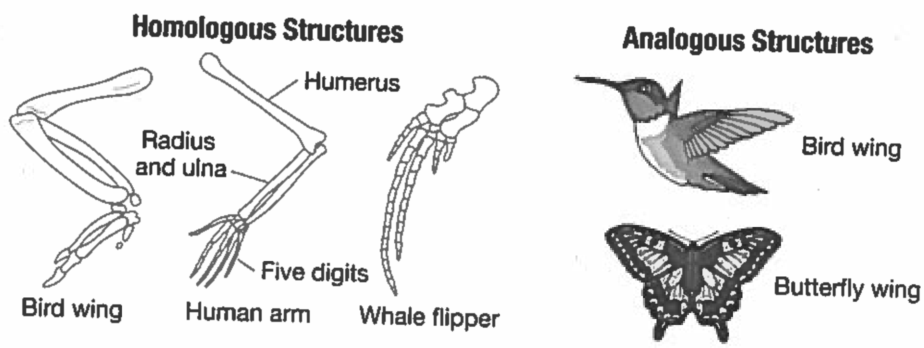
Evidence from Anatomy

Many species of organisms have similar structures. For example, both turkeys and blue jays have feathers. The feathers suggest that both species are descended from an animal with feathers. Turkeys and blue jays are more closely related to each other than to animals without feathers. Scientists often study the anatomical structures of organisms to try to discover how the organisms are related.

Homologous structures are body parts of different organisms that have a similar structure but may have different functions. For example, the human arm, the wing of a bird, and the flipper of a whale are homologous structures. Although these appendages are used in different ways, they are composed of similar bones. Homologous structures indicate that organisms share an ancestor that had a similar structure.

Analogous structures are body parts that have a similar function but do not have a similar structure. For example, the wings of a bird and a butterfly have a similar function. However, their structures are quite different. Analogous structures do not indicate shared ancestry.

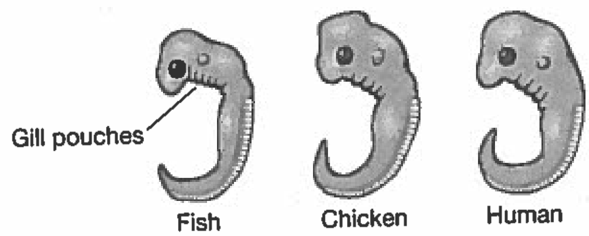
Examples of homologous and analogous structures are shown in the diagram.



Evidence from Embryology

Embryology is the study of embryos. An **embryo** is an early stage in the development of an organism. Scientists have discovered that the embryos of related organisms develop in similar ways.

The diagram below shows that the embryos of fish, chickens, and humans look similar. They all have folds, called gill pouches, in the neck region. In fish, these folds develop into gills. Although adult chickens and humans do not have gills, the similarities in their embryos suggest that the organisms are at least distantly related.



Evidence from Genetics and Biochemistry

Biochemistry is the study of the chemical processes that occur in organisms. The biochemical substances in organisms are also clues about common ancestry. All organisms have DNA. DNA directs the production of proteins, which are made up of amino acids. The similarity of all DNA and the resulting proteins suggests that biodiversity on Earth is due to changes in the genetic code of organisms.

Scientists called molecular biologists study both DNA and proteins to compare organisms. As new technologies develop, evolutionary biologists use these powerful tools to gain a better understanding of how evolution might have occurred. Using technology to compare DNA and the amino acid sequences in some proteins helps show how closely organisms are related. The DNA sequences and proteins in closely related organisms are more similar than those in organisms that are less closely related.

Consider hemoglobin, a protein in red blood cells. The table shows the number of differences in a certain amino acid chain in the hemoglobin of humans and other organisms. The hemoglobin protein in humans is almost identical to that in gorillas; the sequences differ by only one amino acid. In contrast, the human sequence differs by 67 amino acids from the sequence in frogs. The more similar the amino acid sequences, the more recently the organisms shared a common ancestor. The data in the table show that humans and gorillas share a common ancestor more recently than do humans and frogs.

Comparisons of Human Hemoglobin to Hemoglobin of Other Organisms

Organism	Amino Acid Differences	Organism	Amino Acid Differences
Human beta chain	0	Mouse	27
Gorilla	1	Kangaroo	38
Rhesus monkey	8	Chicken	45
Dog	15	Frog	67
Cow	25	Soybean	124

Advances in technology consistently influence our understanding of the world around us. Identify one specific advance in technology that has helped or changed scientists' ability to understand evolution. Research this advance, being sure to use valid and reliable sources. Then write a blog post about the technology. Include an explanation of how the technology has increased our understanding of biology and evolution. Make your notes on a separate piece of paper. Write your blog in the space below.

This lesson has showed that multiple lines of evidence support the theory that all living organisms are related by way of common descent. Researchers continue to gather evidence supporting the ways in which evolution has occurred.

Do further research on examples of lines of evidence for a group of organisms of your choice, using valid and reliable sources. Then complete the graphic organizer on this page. Label each box with the name of a line of evidence.

Evidence:

Evidence:

Claim: Fossil evidence, comparative anatomy, embryology, and biochemical evidence support the theory that all organisms are related by way of common descent.

Evidence:

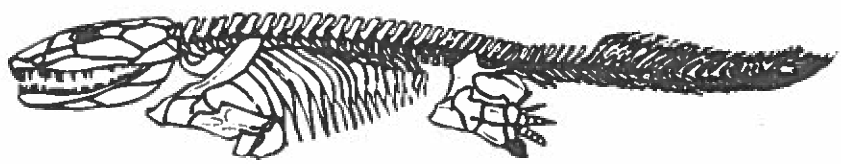
Evidence:

Use the evidence you found to write a short argument that supports the central claim.

Lesson Review

1. Which term describes parts of organisms that have a similar structure but a different function?
   - A. analogous structures
   - B. embryological structures
   - C. homologous structures
   - D. fossilized structures

2. Fossils of an animal called *Ichthyostega* show that it had lungs and legs. It also had gills and teeth and a tail similar to that of a fish. *Ichthyostega* is considered to be one of the first amphibians. Other fossils show that amphibians lost these fishlike features.



   How might scientists interpret the fossil of *Ichthyostega*?
   - A. It was an early type of primitive fish.
   - B. It was the last example of an amphibian with lungs.
   - C. It might be an animal that could live on land and in the water.
   - D. It might be a connection to birds that were also efficient swimmers.

3. Which of these lines of evidence would **not** be used by a biologist to determine the relationship between two organisms?
   - A. bone structure
   - B. fossil age
   - C. genetic traits
   - D. population size

4. The flipper-like wings of a penguin and the fins of a fish help both animals survive in an aquatic environment, but the structures develop differently. Which inference might a scientist make by comparing penguin wings and fish fins?
   - A. The two animals have many similar structures.
   - B. The two animals have similar embryonic structures.
   - C. The two animals do not share a recent common ancestor.
   - D. The two animals developed from a recent common ancestor.

Chapter 5 Review

1. Some insect species are resistant to pesticides. Which statement BEST explains this phenomenon?

   ⓐ Natural selection resulted in an unfavorable variation for the insects.

   ⓑ Random variation in the population led to a population with a favorable adaptation.

   ⓒ Some of the insects became instantly immune when the poisons were introduced into their environment.

   ⓓ Because their survival depended on it, the insects developed variations that made them resistant to poisons.

2. The DNA of nearly all living organisms codes for the same amino acids using the same three-base sets. What does this suggest?

   ⓐ All living organisms use the same proteins for the same purposes.

   ⓑ All living organisms use the same amino acids to build the same proteins.

   ⓒ All living organisms converged from ancestors with different genetic codes.

   ⓓ All living organisms share a common ancestor that used the same genetic code.

3. A disorder causes members of a mammal species to die soon after birth. The disorder is caused by inheriting two matching alleles for the disorder. What will MOST LIKELY happen to the frequency of this allele in the population over time?

   ⓐ It will disappear from the population because it decreases fitness.

   ⓑ It will decrease in the population because natural selection cannot act on it.

   ⓒ It will increase in the population because it allows parents to have more offspring.

   ⓓ It will remain in the population because heterozygous individuals are not affected.

4. A student is preparing for a presentation on evolution. She plans to show that multiple lines of evidence support evolutionary theory. She finds a study that compared a particular nucleotide sequence in four species. The data in the table show the number of differences in nucleotides among the species. For example, species A and B have five different nucleotides.

Species	A	B	C	D
A	–	5	25	90
B	5	–	35	89
C	25	35	–	92
D	90	89	92	–

Part A

Which statement is supported by the data in the table?

ⓐ Species A and B share a recent common ancestor.

ⓑ Species C is not related to any other species.

ⓒ Species D is most closely related to species A.

ⓓ Species A and D have DNA sequences that are most similar.

Part B

The student wants to include an explanation of how scientists have strengthened their understanding of Darwin's theory of evolution. Which statement about the data in the table can she BEST use in her explanation?

ⓐ The data show that all organisms have DNA.

ⓑ The data show that some organisms are not influenced by natural selection.

ⓒ The data show that all the organisms developed in similar ways.

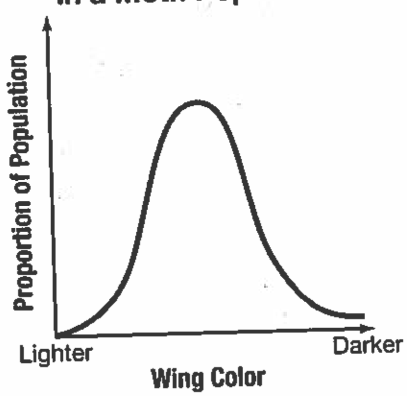
ⓓ The data show that genetics can be used to show relationships among organisms.

5. A student is hiking and discovers an outcrop of sedimentary rock. The rock has three distinct layers that appear to be undisturbed. When the student examines the layers more closely, she observes fossils in the bottom and middle layers. Which conclusion can she make about these fossils based on her observations?

- ⓐ The fossils in the middle layer are older than those in the bottom layer.
- ⓑ The rock in the surface layer is younger than the fossils in the middle layer.
- ⓒ The fossils in the bottom layer are younger than the rock in the surface layer.
- ⓓ The rock in the surface layer formed before the rock in any of the fossils layers.

6. A factory is built near the woods where a population of moths lives. The color of the moth wings ranges from light gray to dark gray. Because both the light and dark moths are most easily seen and eaten by birds, most of the current population of moths has medium-gray wings. The model shows the distribution of wing color in the population.

Distribution of Wing Color in a Moth Population



The factory releases smoke and ash into the woods. The smoke and ash settle on the bark of the trees, turning the bark dark gray. How will the model MOST LIKELY change after several generations of moths?

- ⓐ The curve will shift to the left.
- ⓑ The curve will shift to the right.
- ⓒ The curve will increase in height.
- ⓓ The curve will become a line with a positive slope.

7. Suppose an earthquake changes the course of a river, splitting a population of field mice into two groups. Half the mice now live east of the river, and the other half live west of the river. After 500 years, the climate changes, and the river dries up. The two populations of mice mix together again but are not able to interbreed. Which term describes what has occurred?

   ⓐ equilibrium
   ⓑ migration
   ⓒ resistance
   ⓓ speciation

8. Ticks are parasitic insects that feed on blood. Consider a single population of ticks that divides into two populations. One population feeds on the blood of mammals that live only in trees. The other population feeds on the blood of mammals that live only on the ground. Which observation supports the idea that speciation has occurred?

   ⓐ The tree population and the ground population of ticks cannot mate and have offspring.

   ⓑ The tree population of ticks feeds more frequently than does the ground population.

   ⓒ The genes in both the tree population and the ground population of ticks combine to form a single, large gene pool.

   ⓓ The ground population of ticks gets eaten less frequently by birds than the tree population.

9. The legs of a crocodile and the legs of a mouse have similar bone structures and develop in a similar way. Which inference might a scientist make based on these similarities?

   ⓐ The bone structures are homologous, suggesting that the two animals do not share a common ancestor.

   ⓑ The bone structures are analogous, suggesting that the two animals shared a similar environment.

   ⓒ The bone structures are analogous, suggesting that the animals are closely related.

   ⓓ The bone structures are homologous, suggesting that the two animals developed from a common ancestor.

10. Many insects have become resistant to pesticides. In which population of insects would you MOST LIKELY expect pesticide resistance to develop?

   ⓐ a population that reproduces quickly
   ⓑ a population that reproduces very slowly
   ⓒ a population that is never exposed to a pesticide
   ⓓ a population that is completely killed off by a pesticide