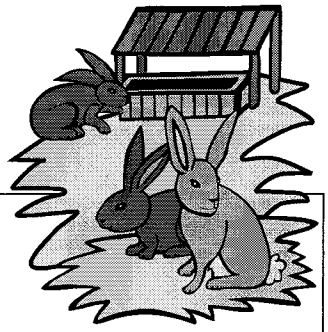
Evidence of Change

Section 14.1
Review of Natural Selection



Pre-View 14.1

- **Natural selection** – a process of nature that favors organisms that are best adapted to their environment
- **Species** – a group of similar organisms that can interbreed and produce fertile offspring
- **Population** – organisms of the same species that live in the same place at the same time and compete for resources such as food and water
- **Mutations** – mistakes in the genetic code
- **Adaptation** – any physical characteristic or behavior that helps an organism to better survive

As you've already seen, the process of **natural selection** describes how organisms that are best adapted to their environment survive and reproduce. It causes populations to change as certain organisms reproduce and pass on their genes to future generations.

Elements of Natural Selection

1. All species have genetic variation.
2. Since organisms generally produce more offspring than can be supported by the environment, individuals within a species frequently compete with each other for survival.
3. The environment itself presents many challenges to an organism's survival.
4. The organisms that can cope best with the environmental challenges usually produce more offspring than organisms that can't cope as well (sometimes called ***survival of the fittest***).
5. The traits of the organisms best suited to a certain habitat tend to become more frequent in a population over time.

When talking about natural selection, we often use the terms *species* and *population*. Be sure you understand what these terms mean.

A **species** is a group of very similar organisms that can interbreed and produce fertile offspring. (You may remember from classification that a species is the smallest taxon.) A thoroughbred and a quarter horse are both in the same species. They can interbreed and produce fertile offspring. A horse and a donkey can interbreed and produce offspring called mules, but they are not the same species since most mules are infertile.

A **population** is made of organisms of the same species that live in the same place at the same time. They may compete with each other for food, shelter, water, and other resources.

Whenever organisms interact, there is a struggle for survival as individuals compete for food, water, shelter, etc. If some individuals are better able to survive because they have a certain trait or characteristic, then they will survive to pass that trait to their offspring. The environment plays a large role in which traits are favored over others. Look at an example.

Example 1: Let's suppose that a wild rabbit population that lives in a densely wooded area has genes that can produce white offspring, brown offspring, or black offspring. How could environmental factors and natural selection affect which trait for fur color occurs most often?

In its environment, a densely wooded area, the brown offspring may be better camouflaged from predators than the black or white offspring. In this case, the brown offspring are more likely to survive, so this is an example of survival of the fittest. Because more brown rabbits survive and reproduce, they will pass on the brown fur color more often to their offspring. The genes for white and black fur will be seen in offspring less and less often, and these genes may eventually disappear.

It is important to remember that the process of natural selection does not cause individuals to *produce* new traits. Natural selection simply favors the traits already present that make an organism better able to survive. Through natural selection, populations of species can change over time.

Because natural selection acts on populations rather than individual organisms, we know that natural selection does not act directly on genes. Instead, it can cause changes in the frequencies of alleles. (Remember that an allele is a different form of a gene. For example, right-handedness and left-handedness are different alleles of the same gene.) Think of the rabbits in the example above. Natural selection caused a change in allele frequencies. In example 1 above, the allele for brown fur color occurs more often than the alleles for black or white fur color.

Natural selection actually affects the distribution of genes in a species in the three ways described below.

- **Stabilizing Selection:** When natural selection favors average individuals in a population, it is called **stabilizing selection**. For example, being average in size is an advantage to many insects. If an insect is larger than average, it is more visible to animals that would capture it for prey. If the insect is too small, it may not be able to capture and eat its prey.
- **Directional Selection:** The second type of natural selection is **directional selection**. It favors organisms with an extreme form of a trait. An example would be found in the Galapagos finches. During a period of drought, food became scarce, and the finches with larger beaks were better suited for survival and reproduction. As a result, the average size of the beaks increased.
- **Disruptive Selection:** The last type of natural selection is **disruptive selection**, which favors organisms with extremes in both directions and eliminates the traits in the middle. If only very large seeds and very small seeds were available to a species of bird, then the birds with large beaks and those with small beaks would be at an advantage. Birds with average-sized beaks would decrease.

Example 1: In humans, infants with a low birth weight or with a high birth weight are less likely to survive. Which type of natural selection is seen in the birth weight of humans?

Birth weight in humans is an example of stabilizing selection. Babies with birth weights in the middle range are more likely to survive.

Practice 1

Consider that a flying beetle has been introduced to a new tropical island. Identify the type of natural selection at work in each example below. In the blank, write A for stabilizing selection, B for directional selection, or C for disruptive selection.

_____ 1. Only the beetles with the darkest bodies thrive in the new environment.

_____ 2. The smallest beetles cannot compete for food. The largest beetles are easy prey for birds.

_____ 3. The beetles with the smallest wings thrive in rotten tree trunks. The beetles with the largest wings thrive along the coastline.

Mutations and Adaptations

Remember, natural selection by itself cannot cause large-scale evolutionary changes. Natural selection only chooses the traits that are already there. Evolutionary scientists believe that random **mutations**, changes in the genetic code, are responsible for creating the variety of life. Although natural selection doesn't produce the new traits, it may explain how mutations of beneficial traits are passed on to offspring.

Example 2: Let's suppose that the wild rabbits living in a heavily wooded area have genes for various shades of brown fur color. If a mutation occurs to produce offspring that are albino (white fur with pink eyes), would the mutation be harmful or beneficial?

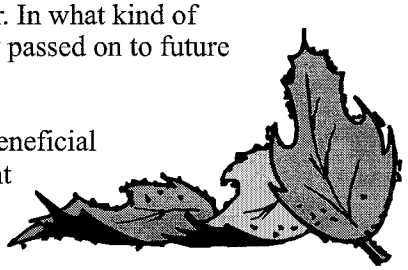
Albino animals rarely live long in a wild environment because they are easily seen by predators. In most cases, an albino animal born in the wild is at a disadvantage and will not survive to pass that mutation on to future offspring.

On the other hand, what if over time the climate in an area changes so that snow covers the ground most of the year. In that case, the white fur color might be beneficial. If the white-colored rabbits thrive because of a change in the environment, this gene mutation would likely be passed to additional generations of rabbits.

If you observe the plants and animals in your surroundings, you will likely notice that they all have specific characteristics that help them survive in their environment. These characteristics are called adaptations. An **adaptation** can be any trait, physical or behavioral, that helps the organism to survive. Cats have claws that help them to catch prey. They have pointed teeth that help them to tear apart their food. These are examples of adaptations, and you will see many examples of adaptations throughout the rest of this book.

How did a cat acquire its claws and teeth? Again, evolutionary scientists believe that all new structures have been acquired over time through small, random genetic mutations. Once these random mutations result in a useful characteristic, natural selection can then act on that characteristic so that it is passed on to future generations.

Example 3: A mutation occurs in a plant that causes its leaves to taste bitter. In what kind of environment would this mutation be beneficial and more likely passed on to future generations?



If the plant is eaten by insects or other animals, then this mutation could be beneficial to the plant. The bitter taste would then be a beneficial adaptation. If this plant is not a food source for other organisms, the mutation may serve no purpose, and the mutation may *not* be passed on to future generations.

Practice 2

Answer the following questions on natural selection.

Ⓐ Ⓑ Ⓒ Ⓓ 1. A shade-loving plant thrives underneath the trees in a forest. When the seeds of the plant are blown into areas where the plant receives direct sunlight, the plant sprouts but then dies. If a series of mutations occurred in the plant that caused the plant to need more sunlight, when might the mutated plants survive?

A. only if the environment changes so that the forest becomes more dense
B. only if the seeds remain near the parent plant
C. only if the seeds sprout in the forest
D. only if the seeds are blown into areas that receive more sunlight

Ⓐ Ⓑ Ⓒ Ⓓ 2. A hypothetical insect has a range of sizes. A change in climate causes the larger size of the insect to survive more easily than the smaller sizes. Which type of natural selection is at work in this example?

A. stabilizing selection
B. disruptive selection
C. directional selection
D. bilateral selection

Ⓐ Ⓑ Ⓒ Ⓓ 3. Young alligators are eaten by many types of predators: birds, bass, snakes, raccoons, and even other alligators. Once alligators are fully grown, they have very few natural enemies. A mutation can occur in alligators that causes them to be born albino (white skin and pink eyes). Why are adult albino alligators not found in the wild?

A. The young are easily seen and eaten by predators.
B. Their white skin reflects sunlight.
C. They cannot be seen easily.
D. They are too rare to be found.

Ⓐ Ⓑ Ⓒ Ⓓ 4. Which of the following is believed to create new traits in an organism?

A. natural selection
B. mutations
C. selective breeding
D. environmental changes

Ⓐ Ⓑ Ⓒ Ⓓ 5. Arctic hares have many predators: owls, wolves, polar bears, foxes, and weasels. Only the fastest and most alert hares survive. The survival of the fastest and most alert hares is an example of which of the following?

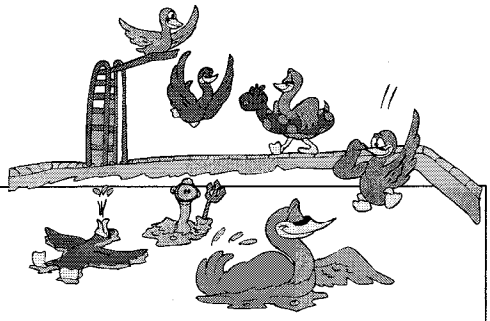
A. a harmful mutation
B. imminent extinction
C. survival of the fittest
D. a beneficial mutation

Ⓐ Ⓑ Ⓒ Ⓓ 6. After a drought, seeds on an island became harder to crack. Which of the following explains why the finch population may favor birds with larger, stronger beaks?

A. natural selection
B. extinction
C. mutations
D. selective breeding

Evidence of Change

Section 14.2
Diversity in Gene Pools



Pre-View 14.2

- **Diversity** – having a variety of traits
- **Genes** – sections of DNA that determine traits
- **Gene pool** – the total number of different genes available to a species
- **Genetic drift** – a process that changes the gene pool just because of chance
- **Founder effect** – the result of a new colony formed by a small population with a limited gene pool

Importance of Diversity

Most species have a variety of traits that might be passed on from generation to generation. This variety of traits is called **diversity**, and diversity makes organisms of the same species different from one another. Remember that traits are passed from generation to generation through **genes**, which are sections of DNA. The total number of genes that account for different traits in a species is called its **gene pool**. Think about humans. We are very diverse. We have different hair color, skin color, and eye color; we have different heights and weights; we have different sizes and shapes of noses, eyes, and ears; and we even have different personalities, intelligence, and talents. The different genes that account for all of these different traits make up the human gene pool.

Species that have a large gene pool have a greater diversity because they have more combinations of genes available to them. Diversity in a species allows a species to adapt to different environments and to overcome disasters like drought, famine, and diseases. The larger the gene pool, the more a species is able to adapt and survive. The plagues of the Middle Ages killed many people across Europe and Asia. Why were some killed when others survived? People who had a higher immunity to the disease survived. Without diversity, all people exposed to the plague would have died.

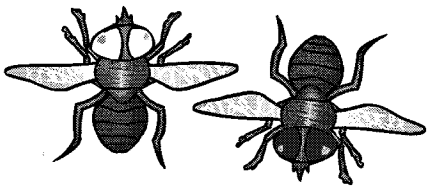
A small gene pool limits a species' diversity. The gene pool of a species can increase due to mutations, or it can decrease when traits die out. As a species becomes more specialized to a specific environment, it loses its ability to adapt to changes. Species can lose traits through natural selection, genetic drift, the threat of extinction, and selective breeding. Let's look at examples of each.

Effect of Natural Selection on the Gene Pool

Natural selection is an important biological concept. Remember that environmental factors often favor some genetic characteristics over others. Through natural selection, specific traits may be favored over others to the point that undesirable traits can no longer be found in the gene pool. Consider the following example.

Example 1: A wild rabbit population has a gene pool that can produce white offspring, brown offspring, or black offspring. If the population lives in a densely wooded area, the brown offspring may be better camouflaged from predators than the black or white offspring. How could this environment affect the gene pool of the rabbits?

If the brown rabbits are better camouflaged against predators, more brown rabbits will survive by natural selection. White and black rabbits will be eaten by predators. Since parents with brown fur are the only ones that survive long enough to reproduce, they will pass the brown fur gene to their offspring. Fewer and fewer white and black rabbits will be born. The genes for white and black fur color may disappear altogether.



Effect of Genetic Drift on the Gene Pool

The process of natural selection gets a lot of attention, but there is another process that also affects the gene pool. This process is called genetic drift. Instead of the environment selecting a trait, sometimes mere chance can cause one trait to occur more frequently and other to occur less frequently. **Genetic drift** is the change in a gene pool generated by chance. To clarify, look at an example.

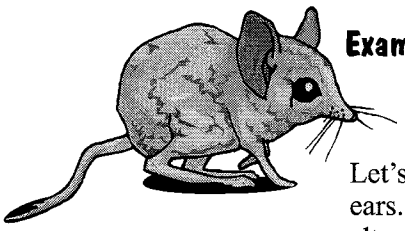
Example 2: A species of insect can have white eyes or brown eyes. Both eye colors are equally beneficial and equally found in a population. Just because of chance, more insects are born with brown eyes than with white eyes during one season. Because more of the population has brown eyes, the next generation is more likely to have brown eyes as well. Over time, the population drifts towards having more brown eyes than white eyes, and the gene for white eyes may eventually be lost.

Genetic drift is more likely to occur in small populations than in large ones. In a small population, any random event can have large consequences on future generations.

The Effect of the Threat of Extinction on the Gene Pool

When a species is threatened with extinction, very few organisms are available for mating. Only the genes of the few living organisms are in the gene pool. If the species recovers, only the genes in that limited gene pool will get passed on to the offspring, so the diversity of the species is diminished.

Even if a population size is reduced for just one generation, the gene pool can be greatly affected. Look at the example below.



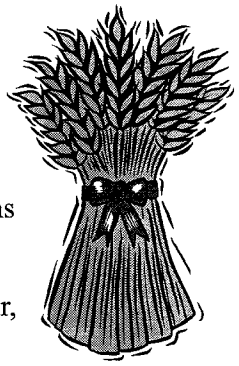
Example 3: A mouse species lives on a small island. A hurricane kills 80% of all life on the island including the mouse population. How might this decrease in the population affect the gene pool?

Let's say that in the original mouse population, 10% of the mice were born with larger ears. If none of the mice that survived have the gene for larger ears, this trait may be lost altogether. By chance, some of the genes that were present in the 80% that died will be lost. Only the genes present in the 20% that survived will remain in the gene pool.

The threat of extinction or any drastic decrease in population size often accelerates genetic drift. The remaining organisms have a more limited gene pool. This new gene pool may favor a different trait than was seen in the original population. When a small population repopulates, it results in what is called the **founder effect**.

Example 4: Let's consider again the mouse population in example 3. Let's say that the 20% of mice that survived belonged mostly to one closely related family that happened to live on higher ground and was protected by surrounding rocks. In this family of mice, many have a genetic defect that causes them to be born with stumpy tails instead of long ones. How will the new mouse population be affected?

In the original mouse population, most mice had long tails. In the new mouse population, stumpy tails will probably be more common because of the founder effect. The gene pool now contains a larger percentage of this genetic defect, so this trait will become more common in the new population than it was in the original one.



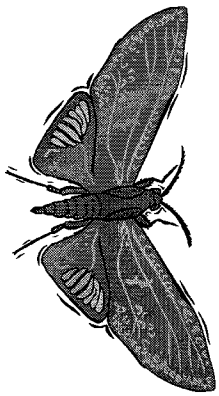
Effect of Selective Breeding on the Gene Pool

Nature uses natural selection and genetic drift for determining genes that are passed on, but humans can use artificial selection through selective breeding. For example, wheat is a crop that has been harvested for many thousands of years. Wheat used to grow wild in many different types of climates. It had a large gene pool, which led to diversity in wheat plants. In modern times, however, farmers began selectively breeding wheat so that the wheat has only the traits that make it more profitable and more easily harvested. Through selective breeding, farmers have bred out certain "undesirable" wild traits, and the gene pool for wheat decreased. Today, wheat is almost genetically uniform with little variation. If the earth's climate changes, what will happen to the wheat? Will it be able to survive? Since wheat lacks diversity, it may not be able to grow in a different climate. This lack of variation also makes wheat susceptible to evolving diseases and pests.

The Effect of Mutations on the Gene Pool

When organisms cannot adapt to an environment, they die. You've seen that through natural selection, genetic drift, and selective breeding, organisms can lose genetic variation. This loss of genetic variation can cause them to be less able to adapt to a changing environment, but they may thrive in a stable, unchanging environment.

Mutations, on the other hand, can add genetic variation. In a stable environment, mutations may have little or no benefit, or they are likely to be harmful. However, in a changing environment, a mutation may allow an organism to adapt. Consider another example.



Example 5: In a population of moths, dark wing color is best adapted to its environment because the moths are well camouflaged against the tree trunks where they usually rest. If a mutation occurs so that a moth is born with light-colored wings, how might it be beneficial?

As long as the environment stays the same, the dark-colored wings will be selected over the light-colored wings. For example, the light-colored moths may be more easily seen by predators and therefore quickly eaten as prey. On the other hand, what if trees in the area change over time so that the bark of the trees is lighter in color? In that case, the moths with light-colored wings may be better camouflaged against predators, so the light color might now be beneficial. If the light-colored moths thrive because of a change in the environment, this gene mutation would likely be passed to additional generations of moths.

Antibiotic and Pesticide Resistance

People have a habit of using chemicals to kill undesirable organisms. We use antibiotics to kill disease-causing bacteria, we use pesticides to kill insects that eat crops, and we use herbicides to kill unwanted weeds. Unfortunately, we may make the problem worse. Consider how mutations and natural selection enable organisms to survive.

Organisms with a high rate of mutations have a better chance of survival in a changing environment. Bacteria, for example, seem to mutate easily. As a result, bacteria can acquire antibiotic resistance in only a few generations. Insects and plants also have the ability to mutate. Insects and plants have mutated in order to acquire a resistance to man-made pesticides and herbicides. For example, some mosquitos have acquired a resistance to the pesticide DDT. Once an organism acquires a mutation that allows it to survive against a harmful substance, natural selection can quickly take over and allow that organism to pass on the beneficial mutation to its offspring.

Example 6: A bacteria culture is started from a single bacterium. After treating the culture with an antibiotic, only 2% of the culture survives. If the culture is left to repopulate, how will it likely respond to future antibiotic treatment?

The 2% of bacteria that survive are resistant to the antibiotic. It is likely that they have acquired a mutated gene that allows them to survive against the antibiotic. If the bacteria culture repopulates, the resulting population will be less affected by the antibiotic and more resistant to it. These bacteria cells will be more difficult to kill.

Practice

Answer the following questions on diversity.

Ⓐ Ⓑ Ⓒ Ⓓ 1. Farmers selectively breed cows so that only the cows that produce the most milk are born. What is the effect of selective breeding on diversity.

A. It increases the number of traits passed on from one generation to another.
B. It has no affect on the gene pool.
C. It decreases genetic diversity.
D. It allows natural selection to determine traits.

Ⓐ Ⓑ Ⓒ Ⓓ 2. Compared to a species population with a small gene pool, a population with a large gene pool is more likely to do which of the following?

A. bear offspring with similar traits
B. become extinct
C. die out due to disease
D. survive environmental changes

Ⓐ Ⓑ Ⓒ Ⓓ 3. Bald eagles once thrived in North America, but as human population increased, the eagle population decreased. In the 1960s, the bald eagle was declared an endangered species as it faced near extinction. By the mid 1990s, the eagle population had recovered significantly and is now considered a threatened species but no longer endangered. Which of the following is a TRUE statement about the bald eagle population?

A. The current bald eagle population has been altered by genetic engineering.
B. The current bald eagle population has less genetic diversity than it did before it became endangered.
C. Beneficial genetic mutations allowed the bald eagle population to recover.
D. The bald eagle population has a greater gene pool now than it did before it became endangered.

Ⓐ Ⓑ Ⓒ Ⓓ 4. Which of the following is MOST susceptible to disease?

A. a small population of organisms that have been favored due to natural selection
B. a small population of genetically diverse organisms
C. a large population of organisms that are spread out over a large area
D. a large population of genetically diverse organisms

Ⓐ Ⓑ Ⓒ Ⓓ 5. In which of the following situations would natural selection be most likely to lead to extinction?

A. A species is in an environment that never changes.
B. A species has many mutations that lead to a change in the environment.
C. A species cannot adapt to a change in its environment.
D. A species is able to interbreed in a large population.

Ⓐ Ⓑ Ⓒ Ⓓ 6. Which of the following is MOST likely true of an organism that experiences a high rate of mutations?

A. It will survive in a rapidly changing environment.
B. It will become extinct in a rapidly changing environment.
C. It will thrive in a stable environment that changes very little.
D. It will survive equally well in any environment.

Ⓐ Ⓑ Ⓒ Ⓓ 7. Which of the following is an example of genetic drift?

A. A volcano destroys all the vegetation on a small island. All plants become extinct.
B. A bacterium is exposed to an antibiotic. Instead of being killed by the antibiotic, the bacterium mutates and survives.
C. A lizard population has a variety of tongue lengths. A change in the environment favors lizards with longer tongues.
D. A bird population normally has either light or dark feathers. By chance, one generation produces more birds with light feathers.

Ⓐ Ⓑ Ⓒ Ⓓ 8. A certain species of bird migrates south for the winter. A hurricane relocates a small number of the birds to an unpopulated island. The birds make the island their new home and no longer have contact with the original population. The birds on the island have longer tail feathers than the birds in the original population even though longer tail feathers give the birds no survival advantage. Which of the following explains the longer tail feathers?

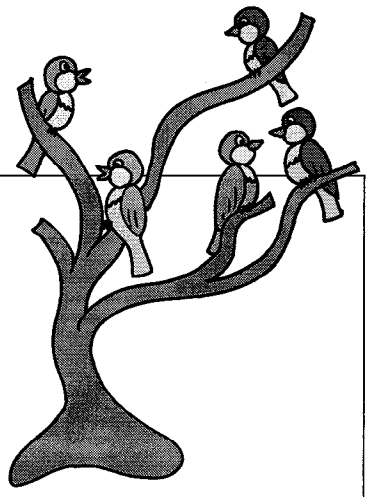
A. a genetic mutation due to environmental pressure
B. natural selection
C. an increase in the gene pool
D. the founder effect

Ⓐ Ⓑ Ⓒ Ⓓ 9. A commercial farmer sprays his crops with an insecticide to kill whiteflies. Most of the whiteflies are killed, but a few survive. Which of the following is likely to occur the following year if the farmer uses the same insecticide again?

A. The insecticide will kill the remaining whiteflies.
B. The remaining whiteflies will migrate to another field that is not treated with the insecticide.
C. The insecticide will be less effective in killing the surviving whiteflies and their offspring.
D. The insecticide will become more toxic not only to whiteflies but also to other species of insects.

Evidence of Change

Section 14.3
Speciation



Pre-View 14.3

- **Speciation** – the formation of a new species
- **Geographic isolation** – a separation of a population due to a physical barrier
- **Temporal isolation** – a type of isolation that occurs when a species develops different reproductive cycles
- **Behavioral isolation** – a type of isolation between populations due to differences in courtship or other mating behaviors

You've already seen that natural selection, genetic drift, the threat of extinction, selective breeding, and mutations can change the gene pool of a population over time. Natural selection will always favor specific traits that allow an organism to better survive. As the gene pool shifts, speciation can occur. **Speciation** is the beginning of a new species and occurs when members of populations no longer interbreed. Speciation can be caused by different types of isolation. Let's look at the three main types.

Geographic Isolation

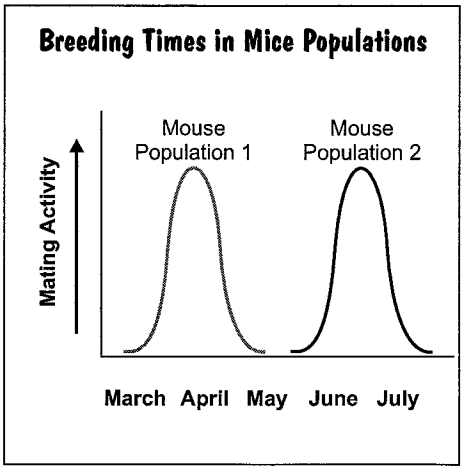
Geographic isolation occurs when an event creates a physical barrier that divides a population into two or more separate groups. Such an event could be a force of nature like a volcanic eruption or the separation of a land mass into several isolated islands. If the populations cannot interbreed, the new, smaller populations may adapt in different ways through natural selection. In time, each new population could become so different that they would become different species.

Geographic isolation may be the cause of the speciation seen in the Galapagos finches. Remember, the finches on the Galapagos Islands were different from finches found on the mainland. Darwin and others believe that finches from the mainland may have originally populated the islands, but over time, these finches were geographically isolated from the finches on the mainland. These finches eventually became new species.

Temporal Isolation

Sometimes populations will not interbreed because of **temporal isolation**, which occurs when a species develops different reproductive cycles (like a spring cycle or a fall cycle). Members of the spring cycle will not interbreed with members of the fall cycle. Eventually the two groups may become so different that they can no longer interbreed, and they would be considered two distinct species.

The graph on the right shows the hypothetical breeding times for two different populations of mice. The mice live in the same geographic location, but they do not interbreed. Scientists determine that the two populations of mice can interbreed when they are held in captivity at the local zoo. These populations are an example of temporal isolation. Over time, these two populations may become two species that are no longer able to interbreed, even in captivity.



Behavioral Isolation

Many animals have elaborate courtship rituals and behaviors. Each species of bird will sing a distinct song to attract a mate. Other animals also have specific mating calls. Some animals perform dances. These rituals and behaviors help an individual to identify a suitable mate of the same species. If the song isn't correct or the dance steps aren't in the right order, mating is unlikely to occur.

Behavioral isolation occurs when two populations do not interbreed because of differences in courtship behaviors. For example, two similar species of birds may overlap in their territories and may be capable of producing fertile offspring, but because they sing slightly different mating songs, they will not interbreed in the wild.

Practice

Answer the following questions on speciation.

Ⓐ Ⓑ Ⓒ Ⓓ 1. What term is used to describe the formation of a new species?

A. temporal isolation B. speciation C. a community D. a niche

Ⓐ Ⓑ Ⓒ Ⓓ 2. A group of organisms that can interbreed and produce fertile offspring is defined as what?

A. a community B. a niche C. a kingdom D. a species

Ⓐ Ⓑ Ⓒ Ⓓ 3. By which process does a population change as organisms reproduce and pass on genes that make them better able to survive?

A. natural selection B. behavioral isolation C. speciation D. interbreeding

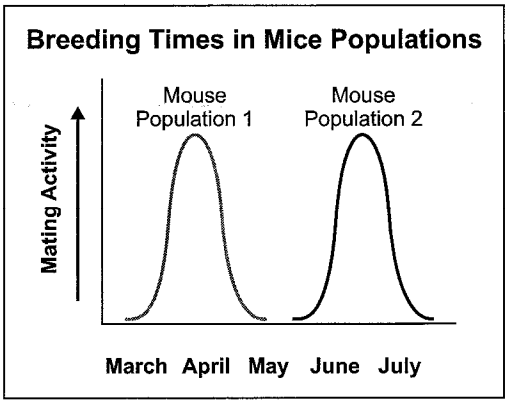
Ⓐ Ⓑ Ⓒ Ⓓ 4. Which of the following could NOT cause a population to develop into two distinct species?

A. behavioral isolation
B. interbreeding
C. geographic isolation
D. temporal isolation

Ⓐ Ⓑ Ⓒ Ⓓ 5. Which of the following pairs of organisms would be considered different species?

A. a poodle (dog) and a German Shepard (dog)
B. a brown hamster and a white hamster
C. a donkey and a horse
D. a male tiger and a female tiger

Use the graph on the right to answer questions 6 and 7.



Ⓐ Ⓑ Ⓒ Ⓓ 6. According to the graph, when is peak mating season for mouse population 1?

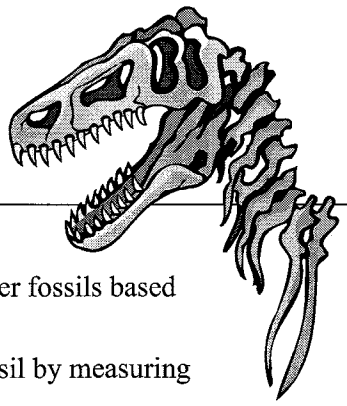
A. March
B. April
C. May
D. June

Ⓐ Ⓑ Ⓒ Ⓓ 7. If the two mouse populations shown in the graph do not interbreed but are found in the same area, they may form different species due to which process?

A. geographic isolation
B. extinction community
C. species divergence
D. temporal isolation

Evidence of Change

Section 14.4
Evidences of Evolution



Pre-View 14.4

- **Relative dating** – a technique that ages a fossil as older or younger than other fossils based on its location in sedimentary rock layers
- **Radiometric dating** – a technique for approximating the actual age of a fossil by measuring the amounts of radioactive isotopes present
- **Punctuated equilibrium** – the idea that evolution is not always gradual but that changes in a species may occur rapidly for short periods of time
- **Homologous structures** – structures in different species that have similar internal structure even though they may function differently
- **Analogous structures** – structures that have similar functions but are structurally different
- **Vestigial organs** – structures that have no useful purpose
- **Biogeography** – the study of how plants and animals are distributed around the world

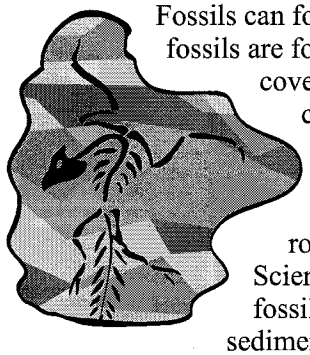
How many different species of organisms do you think inhabit the earth? If you're thinking that you don't know, then you're on the right track. In less than 250 years, scientists have identified and named almost 1.5 million different species, and over 750,000 of those are insects. And we're still counting.

Most scientists estimate that there are between 20 billion and 100 billion species existing today, and they believe about 99% of all species that ever lived are now extinct. How do we know anything about what existed on our planet in the past? What evidence shows that species have changed over time?

The theory of evolution requires millions, or even billions, of years for organisms to make noticeable changes. Scientists have not yet made much progress in artificially producing large-scale evolutionary changes in a laboratory setting. Indeed, it may not be possible to do so. Instead, scientists rely on things like the fossil record, comparative anatomy, and biogeography, to show evidence of evolution. Let's look at each of these.

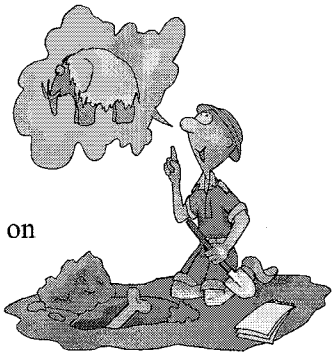
Fossil Record

Much of what we know about life on the earth long ago comes from indirect knowledge based on the fossil record.



Fossils can form in various ways, but they provide us with valuable information about the past. Most fossils are found in sedimentary rock. In order for fossils to form, organisms have to be completely covered in mud or clay shortly after death. Once covered, the clay or mud particles get compressed more and more, layer by layer, until sedimentary rock forms. Minerals replace the wood, shells, and bone, and the organisms petrify or fossilize.

Relative Dating: As a general rule, the lower the layer of sedimentary rock, the older the rock. Fossils found in lower layers, therefore, are older than fossils found in upper layers. Scientists use this principle to date fossils as they relate to other fossils. **Relative dating** of fossils tells which fossils are older than other fossils based on where they are found in sedimentary rock layers.



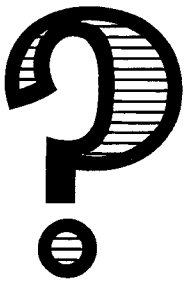
Radiometric Dating: Scientists can also determine the approximate age of a fossil by using **radiometric dating**. Radiometric dating techniques measure the amount of radioactive isotopes found in the fossil. The approximate age can then be calculated based on the half-lives of the radioactive isotopes. (A half-life is the amount of time that it takes for half of a radioactive material to decay into a different material.)

By using processes like radiometric dating and relative dating, scientists are able to determine the time period in which an organism lived. Although the fossil record is not complete, they can then compare modern species with species believed to exist millions of years ago. This comparison helps to determine what changes have occurred and why some species no longer exist. They can also see when new species split off from older ones along an evolutionary time line.

Scientists have also learned to extract DNA from fossils. They use the DNA to compare the amino acid and nucleotide sequences to those in living species. A lot of similarities indicate that the organisms are closely related. Scientists can also use this information to help determine if certain gene mutations could play a role in the formation of a new species.

Punctuated Equilibrium

Does the fossil record give strong evidence that slow, gradual change has occurred? You may be surprised to know that Charles Darwin didn't think so. Read the following passage taken from Chapter 6 of *On the Origin of Species*:



On the absence or rarity of transitional varieties. As natural selection acts solely by the preservation of profitable modifications, each new form will tend in a fully-stocked country to take the place of, and finally to exterminate, its own less improved parent or other less-favoured forms with which it comes into competition. Thus extinction and natural selection will, as we have seen, go hand in hand. Hence, if we look at each species as descended from some other unknown form, both the parent and all the transitional varieties will generally have been exterminated by the very process of formation and perfection of the new form.

But, as by this theory innumerable transitional forms must have existed, why do we not find them embedded in countless numbers in the crust of the earth?

In other words, Darwin believed that as an organism evolved, there must have been many intermediate forms. He was puzzled, however, that the fossil record doesn't show these many transitional forms. Darwin later answers his own question by reasoning that the fossil record is incomplete. He believed transitional forms would eventually be found.

Was Darwin correct? Have transitional fossils been found? Paleontologists continually find new fossils, and some extinct organisms have been discovered that scientists believe are transitional forms. For example, archaeopteryx is believed to be a transitional species that links reptiles to birds. However, there isn't a smooth, continuous fossil record that shows the transition of one species to another. This is not to suggest that gaps will not be filled in as new fossils are discovered. They may be, but it is still considered unusual that even today large gaps are still present.

The lack of transitional forms and the sudden appearance of some fully-formed species in the fossil record have caused some scientists to reconsider how species evolve. In the 1970s, two scientists Niles Eldredge and Stephen Jay Gould suggested that sometimes evolution moves very slowly, but at other times, it occurs quickly. This new idea is called **punctuated equilibrium**, and it suggests that long intervals in which little or no change occurs are suddenly interrupted by short bursts of quick, radical transitions. Many scientists now believe that a combination of gradual evolution and punctuated equilibrium have occurred over time.

Comparative Anatomy

Another way that scientists look for evidence of change in species is by looking at similarities in living organisms.

Homologous and Analogous structures: Homologous structures develop from the same tissues as embryos and have similar internal structures. They may look different on the outside, and they may have different functions. For example, if you looked at the forelimb of a bat, a human, a crocodile, and a bird, you would see that they all have the same skeletal structures — humerus, ulna, carpals, and radius — although they have different functions. See figure 14-1. These similarities suggest that they may have had a common ancestor long ago.

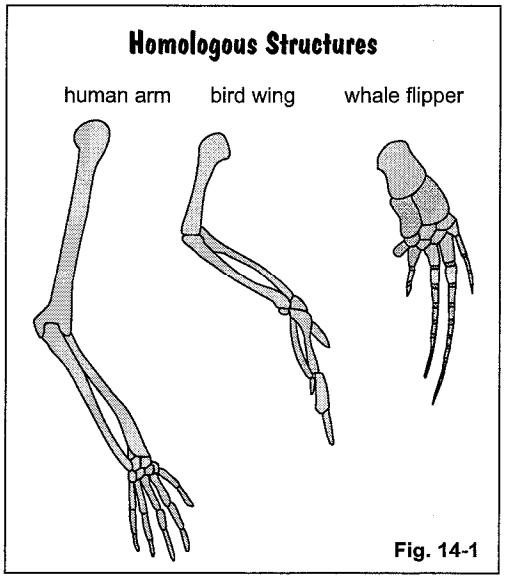


Fig. 14-1

Homologous structures should not be confused with **analogous structures**, structures that have similar functions but are not believed to have evolved from a common ancestor. A bird's wing and a butterfly's wing are analogous structures. Both have the same function, to enable flight, but these two types of wings are structurally very different.

Vestigial structures: Sometimes an animal has structures that seem to have no useful purpose now although they resemble structures that are useful in other species. These structures are called **vestigial structures**. The flightless wings of the ostrich, the sightless eyes of the cave salamander, and the pelvis bone found in some whales are considered examples of vestigial structures.

Embryology: Embryos of many vertebrates look very similar, especially in the earliest stages of development. These physical similarities suggest that the organisms have genetic similarities as well. By looking at the similarities in embryological development, scientists can determine if two very different species might have had a common ancestor.

Biogeography

Plate tectonics theory explains that the surface or "crust" of the earth is divided into large plates that float on a semi-molten layer underneath the earth's surface. According to this theory, these plates continually move, and this movement explains earthquake and volcanic activity as well as continental drift. Continental drift is the movement of continents. Scientists believe that all land mass was once consolidated together in a single continent called *Pangaea*. Over time, the different continents have been formed as the plates of the earth drifted apart.

Biogeography is the study of how plants and animals are distributed around the world. This distribution depends on the migration ability of a particular species and how plants and animals have been separated from one another over time by continental drift.

Scientists use this distribution of organisms to figure out how and when species may have evolved. For example, some species are isolated to specific continents. Apes, including all fossils of apes, are found only in Africa and Asia. Marsupials, mammals with pouches, are found only in Australia. These species must have been separated from a common ancestor early in their history and then evolved differently. In other cases, species on a nearby island are similar but not exactly the same as those on the nearest mainland. Darwin made many of these observations about species on the Galapagos Islands. The explanation of how these different species may have evolved differently is explained by speciation, which you saw in Section 14.3.

Practice

Answer the following questions on the evidences of evolution.

Ⓐ Ⓑ Ⓒ Ⓓ 1. A paleontologist uncovers a fossil of an ancient plant classified as an angiosperm. Then, in several layers of rock below the angiosperm fossil, she finds a fossil of another plant classified as a type of ginkgo. What do the positions of these fossils indicate about them?

A. The ginkgo fossil and the angiosperm fossil are probably about the same age.
B. The ginkgo plant is closely related to the angiosperm plant.
C. The ginkgo fossil is probably older than the angiosperm fossil.
D. The ginkgo plant probably evolved into the angiosperm plant.

Ⓐ Ⓑ Ⓒ Ⓓ 2. Some people might argue that gaps in the fossil record are evidence that organisms have not changed gradually over time. Which of the following ideas explains these gaps?

A. biogeography
B. vestigial structures
C. radiometric dating
D. punctuated equilibrium

Ⓐ Ⓑ Ⓒ Ⓓ 3. Why do scientists compare embryonic development of different organisms?

A. to determine if they may have a common ancestor
B. to determine if they could develop differently
C. to determine how long it takes for some organisms to become extinct
D. to determine why some organisms develop more quickly than other organisms

Ⓐ Ⓑ Ⓒ Ⓓ 4. If two organisms have homologous structures, what might those structures indicate?

A. The organisms have nothing in common.
B. The organisms have a common ancestor.
C. The organisms have the same parents.
D. The organisms have the same genes.

Ⓐ Ⓑ Ⓒ Ⓓ 5. Which of the following pairs of structures would be considered analogous?

A. a bat's wing and an insect's wing
B. a person's arm and an ape's arm
C. a bird's wing and a bat's wing
D. a bird's wing and a whale's flipper

Ⓐ Ⓑ Ⓒ Ⓓ 6. Which of the following is NOT used by scientists to determine a common ancestor of organisms?

A. nucleotide and amino acid sequences
B. structural similarities
C. hair, fur, scales, or feather color
D. embryotic development

Ⓐ Ⓑ Ⓒ Ⓓ 7. Which of the following would MOST clearly indicate that two organisms are closely related?

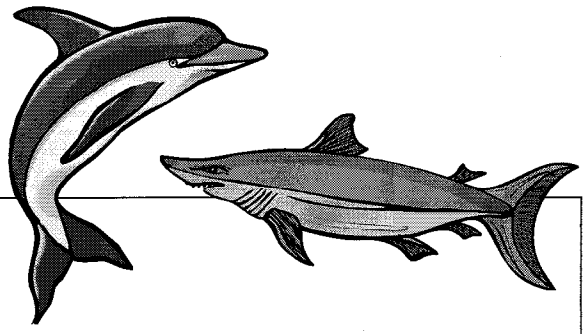
A. Both have the same number of chromosomes, and the DNA sequences are similar.
B. Both organisms are found in the same habitat and live in heavily wooded areas.
C. Both organisms live in similar environments but on different continents.
D. Both organisms have longer hind legs than forelegs and hop on their hind legs.

Ⓐ Ⓑ Ⓒ Ⓓ 8. A certain scientist studies the distribution of mammals around the world. This type of study is called what?

A. comparative anatomy
B. punctuated equilibrium
C. embryology
D. biogeography

Evidence of Change

Section 14.5
Patterns of Evolution



Pre-View 14.5

- **Divergent evolution** – the pattern of evolution that shows new species being formed from a common ancestor
- **Adaptive radiation** – a type of divergent evolution in which one species splits into many different related species
- **Convergent evolution** – the pattern of evolution that shows unrelated species evolving similar characteristics
- **Coevolution** – the pattern of evolution that shows two species evolving together

As natural selection works on different populations over time, scientists believe it can be observed as different patterns of evolution. Let's look at three types of patterns: divergent evolution, convergent evolution, and coevolution.

Divergent Evolution

Remember that speciation is the creation of a new species, and it is believed to occur when part of a population becomes isolated from the rest of the population. This process of forming new species results in **divergent evolution**. In divergent evolution, new species "diverge" or split from a common ancestor. For example, evolutionary biologists believe that apes and humans diverged from a common ancestor. Homologous structures as you saw in Section 14.4 are seen as evidence of divergent evolution.

Adaptive radiation is a specific kind of divergent evolution in which one ancestoral species splits into many related species. When Charles Darwin visited the Galapagos Islands, he noticed many different species of finches. These finches were not only different from one another, but they were also different from the finches found on the nearest mainland. Each species of finch was specifically adapted to its environment. Scientists believe that all the Galapagos finches had one common ancestor and that the many different species are a result of adaptive radiation. Through natural selection, these finches adapted to specific environments. Adaptive radiation is commonly seen in island populations of both plants and animals.

Convergent Evolution

Evolutionary scientists believe that through natural selection, organisms in similar environments acquire similar characteristics. Organisms that have similar characteristics but are not considered closely related show the pattern of **convergent evolution**. Sharks and porpoises, for example, have many similar characteristics, but sharks are classified as fish and porpoises are classified as mammals. They are not considered closely related even though they look alike. Analogous structures as you saw in Section 14.4 are seen as evidence of convergent evolution. The fins of sharks and the flippers of porpoises are analogous structures.

Coevolution

When two organisms are dependent on one another for survival, coevolution is suspected. Coevolution is a pattern of evolution in which two species must have evolved, or changed, together. Flowering plants and the specific insects that pollinate them are believed to be examples of coevolution. For example, the yucca plant has small flowers that are pollinated by yucca moths. Scientists believe that the plant and the moths must have evolved together.

Practice 1

Determine which type of evolution is indicated for each situation described below.

A. divergent evolution

B. convergent evolution

C. coevolution

_____ 1. Fungi and algae live together in such a close symbiotic relationship that they are classified together as a lichen.

_____ 2. The marsupial mouse found only in Australia and New Guinea is very similar in appearance to placental mice found elsewhere around the world, but their similarities are thought to be analogous and not homologous.

_____ 3. The bumblebee has hairs on its legs that collect pollen. The flowers that are pollinated by the bumblebee have nectar for the bees to eat.

_____ 4. The wings of birds and bats look similar but are thought to have evolved separately.

_____ 5. A group of birds found on the Hawaiian Islands are known as Hawaiian Honeycreepers. These birds represent several different species of birds that are believed to have evolved from a common ancestor.

Practice 2

Answer the following questions on the patterns of evolution.

Ⓐ Ⓑ Ⓒ Ⓓ 1. The Galapagos finches observed by Charles Darwin are an example of adaptive radiation. Adaptive radiation is an example of which type of evolution?

A. divergent evolution
B. convergent evolution
C. coevolution
D. macroevolution

Ⓐ Ⓑ Ⓒ Ⓓ 2. Predator-prey relationships, such as the relationship between wolves and rabbits, are dependent on one another. Which type of evolution is indicated between two organisms that evolve together?

A. divergent evolution
B. convergent evolution
C. coevolution
D. macroevolution

Ⓐ Ⓑ Ⓒ Ⓓ 3. Many different types of plants have leaves, but according to evolutionary theory, plant leaves evolved independently for the different types of plants. Which type of evolution is indicated by plant leaves?

A. divergent evolution
B. convergent evolution
C. coevolution
D. macroevolution

Ⓐ Ⓑ Ⓒ Ⓓ 4. A fly that ate hawthorn berries began to eat apples instead. Over time, a new species of fly evolved that ate only apples. What type of evolution has occurred in these flies?

A. divergent evolution
B. convergent evolution
C. coevolution
D. macroevolution

Evidence of Change

Section 14 Review

Answer the following questions on evidence of change.

1. According to natural selection, organisms who survive are the ones best adapted for their environment. Why do they survive?

- **A** They have adaptations developed through use.
- **B** They do not have competition within the species.
- **C** They have inherited adaptations that maximize fitness.
- **D** They grow larger than others in their population.

Ⓐ Ⓑ Ⓒ Ⓓ

2. What does the theory of natural selection say about members of a population that live long enough to reproduce?

- **F** They will pass down characteristics acquired by use and disuse to their offspring.
- **G** They will produce fewer offspring than others in the population.
- **H** They will be best adapted to survive in their environment.
- **J** They will pass down unfavorable changes to their offspring.

Ⓕ Ⓖ Ⓗ Ⓙ

3. Which of the following allows natural selection to have the GREATEST effect?

- **A** a stable environment and a large gene pool
- **B** a changing environment and a large gene pool
- **C** a stable environment and a small gene pool
- **D** a changing environment and a small gene pool

Ⓐ Ⓑ Ⓒ Ⓓ

4. After an earthquake, a small number of tree frogs gets geographically separated from a much larger population of tree frogs. Which of the following is likely to occur in the small group of tree frogs?

- **F** It is more likely to undergo speciation because of its small gene pool.
- **G** It is more likely to produce a greater number of offspring.
- **H** It is more likely to have greater diversity since its population has decreased.
- **J** It is more likely to breed with other species of frogs.

Ⓕ Ⓖ Ⓗ Ⓙ

5. Quinine is often used to treat malaria, a disease caused by a parasite that is transmitted by a mosquito bite. After years of quinine treatment, the malaria-causing parasite has become resistant in some areas so that quinine no longer kills it. Which of the following is the likely cause of quinine resistance in the parasite?

- **A** less potent quinine doses
- **B** a genetic mutation in the parasite
- **C** stronger immunity in infected humans
- **D** a larger mosquito population

Ⓐ Ⓑ Ⓒ Ⓓ

6. Where are most fossils found?

- **F** in salt water
- **G** in volcanic rock
- **H** in sedimentary rock
- **J** in the sap of trees

Ⓕ Ⓖ Ⓗ Ⓙ

7. Separation of a population by a barrier, such as a river, a mountain, or a body of water, results in which of the following?

A temporal isolation
B geographic isolation
C behavioral isolation
D genetic drift

Ⓐ Ⓑ Ⓒ Ⓓ

8. Which of the following is the result of geographic isolation of a species?

F It prevents interbreeding within each separated population.
G It prevents interbreeding between the two separated populations.
H It causes temporal isolation of the two separated populations.
J It increases differences in courtship behavior.

Ⓕ Ⓖ Ⓗ Ⓙ

9. A chicken farmer breeds his chickens for the fastest growth and for the most breast meat. Over several generations, almost all of the chickens that are born on his farm have large pectorals muscles, small legs, and small heads. Now, he would like to breed his chickens for larger legs. Why might this not be possible if he breeds only his existing chickens?

A The trait for larger legs may have been eliminated from the gene pool.
B The trait for larger legs may be recessive and not expressed in the chickens.
C The trait for larger legs can only be gained through a mutation.
D The chickens will lose their ability to breed.

Ⓐ Ⓑ Ⓒ Ⓓ

10. Some flowers in a population of plants open before noon. Other plants in the same population have flowers that open late in the day. This difference is an example of which of the following?

F behavioral isolation
G geographic isolation
H temporal isolation
J genetic equilibrium

Ⓕ Ⓖ Ⓗ Ⓙ

11. Which of the following is an example of natural selection?

A A baby finch learns to fly from its nest.
B A mother finch protects her nest against predators.
C Finches with stronger beaks better survive on an island that has harder seeds.
D A male and a female finch will form a mating pair that will stay together for life.

Ⓐ Ⓑ Ⓒ Ⓓ

12. A species of beetle is introduced on an island. The beetles have wings, which in its original habitat are beneficial because they allow the beetles to fly away from predators. On the island, the beetles don't have the same predators. When the beetles attempt to fly, large numbers of them die because they are blown into the ocean. A fraction of the beetles manage to survive on the island. Which of the following would be a beneficial mutation to this species of beetle on this island?

F a mutation that causes them to grow larger wings
G a mutation that prevents them from flying
H a mutation that changes their wing color
J a mutation that allows them to eat a different type of food

Ⓕ Ⓖ Ⓗ Ⓙ

13. Which of the following is an example of directional selection?

A Average-sized deer offspring are more likely to survive.

B A chicken population with members having different colors of feathers are equally likely to survive.

C Butterflies having either small wings or large wings have a reproductive advantage.

D Only the fastest rabbits are able to escape predators.

Ⓐ Ⓑ Ⓒ Ⓓ

14. The characteristics of a plant species on an isolated island have changed over time in response to environmental changes. Which idea explains these changes?

F evolution due to genetic drift

G evolution by natural selection

H punctuated equilibrium

J convergent evolution

Ⓕ Ⓖ Ⓗ Ⓙ

15. The wing of a bird and the arm of a human being are considered homologous structures. Which pattern of evolution explains these structures?

A coevolution

B divergent evolution

C convergent evolution

D adaptive radiation

Ⓐ Ⓑ Ⓒ Ⓓ

16. The North American kangaroo rat, the Australian hopping mouse, and the North African jerboa have similar appearances and behaviors that are convergent adaptations. In other words, each species evolved separately. Which of the following would you expect to be the same for these three species?

F the genetic code of their DNA

G a closely-related common ancestor

H their embryo development

J the environments in which they evolved

Ⓕ Ⓖ Ⓗ Ⓙ

17. A paleontologist uses relative dating techniques to determine that fossil A is older than fossil B. Based on this dating method, which of the following is most likely true?

A Fossil A was found in a sedimentary rock layer below fossil B.

B Fossil A and fossil B were found in the same layer of sedimentary rock.

C Fossil A was found preserved in tree sap, but fossil B was found in sedimentary rock.

D Fossil A has more radioactive isotopes than fossil B.

Ⓐ Ⓑ Ⓒ Ⓓ

18. Which of the following increases variation in a gene pool?

F natural selection

G extinction

H mutations

J genetic drift

Ⓕ Ⓖ Ⓗ Ⓙ