

section 15 Shaping Evolutionary Theory

MAIN Idea

The theory of evolution is being refined as scientists learn new information.

What You'll Learn

- factors that influence how new species originate
- about gradualism with punctuated equilibrium

Study Coach

Make Flash Cards Write the underlined words on one side of a flash card. Write the definition on the other side of the card.

Reading Check

- 1. Explain** What happens when a population is in genetic equilibrium?

Before You Read

In this section, you will learn how our understanding of evolution has changed in the last 150 years. Other aspects of science have also changed. On the lines below, name several other scientific advances that have happened since the mid-1800s.

Read to Learn

Mechanisms of Evolution

Natural selection helps explain how one or two ancestors became today's diversity. Natural selection is one way that species evolve, but it is not the only way.

In the 150 years since Darwin published his findings on natural selection, scientists have learned much about evolution. They have uncovered other ways that species can change. To understand the other mechanisms for evolution, it is important first to learn about population genetics.

What is the Hardy-Weinberg principle?

In 1908, English mathematician Godfrey Hardy and German physician Wilhelm Weinberg each arrived at the same conclusion about how the laws of inheritance work in a population. The Hardy-Weinberg principle states that the frequency of alleles in populations does not change unless the frequencies are acted on by some factor that causes change. When the frequency of alleles remains the same, the population is in genetic equilibrium. A population in genetic equilibrium does not evolve.

How does the Hardy-Weinberg principle work?

The Hardy-Weinberg principle helps us understand when evolution can occur. Evolution occurs only when a population is not in genetic equilibrium.

Genetic equilibrium occurs when five conditions, listed in the table below, are met. When one or more of the conditions is violated, the population can change or evolve.

Populations can meet some of these requirements for long periods of time. Many populations are large enough to maintain genetic equilibrium. Other conditions do not often occur in nature. For example, one condition is that mating must be random across an entire population. But mating is rarely random. It usually occurs between closest neighbors. Because all five conditions do not usually occur in nature, most populations are able to evolve.

Conditions for Genetic Equilibrium		
Condition	Violation	Consequence
The population is large.	Many populations are small.	Chance events can change population traits.
There is no immigration or emigration.	Organisms move in and out of the population.	The population can lose or gain traits with movement of organisms.
Mating is random.	Mating is not random.	New traits do not pass as quickly to the rest of the population.
Mutations do not occur.	Mutations occur.	New variations appear in the population with each new generation.
Natural selection does not occur.	Natural selection occurs.	Traits in a population change from one generation to the next.

How does genetic drift lead to evolution?

Genetic drift is the random change in the frequency of alleles in a population. Genetic drift usually affects small populations. Genetic drift occurs because chromosomes are sorted randomly during meiosis. The one of a parent's two alleles that passes to the offspring is determined by chance. Genetic drift is another way that a population can evolve.

Unlike natural selection, the adaptations that result from genetic drift are not always the best ones for the environment. Sometimes, important adaptations can be lost by genetic drift.

Picture This

2. Explain White rabbits blend in with the snow. Brown rabbits are more likely to be eaten by predators. Is the population of rabbits in genetic equilibrium? Explain your answer.

Think it Over

3. Draw Conclusions

What population would be most likely to experience genetic drift? (Circle your answer.)


- 4000 mice living in a meadow
- 30 rabbits living on a mountaintop
- five million people living in a city

What is the founder effect?

The **founder effect** can occur when a few individuals are separated from the rest of the population. The few individuals carry a random subset of the genes in the original population. The frequency of alleles in the subset might be different from the frequency of alleles in the original population. The founder effect is a random way that species can evolve. Unlike natural selection, the traits that result might or might not be the best available for the environment.

The founder effect often occurs on islands. New species can result from a few founders of the original population. The founder effect also occurs in people. Amish and Mennonite people live in the United States but do not usually marry outside their communities. They have many unique genes.

What happens in a genetic bottleneck?

When a large population declines in number then rebounds to a large number again, a **bottleneck** occurs. Bottlenecks reduce the total alleles in a population. The genes of the resulting population can be unusually similar. 

Cheetahs in Africa might have gone through a bottleneck a few thousand years ago. Cheetahs are genetically similar and appear to be inbred. Inbreeding reduces fertility and can eventually cause extinction.

What is gene flow?

A population in genetic equilibrium experiences no gene flow. No new genes enter the population and no genes leave the population. However, few populations are isolated. Gene flow occurs when individuals move among populations. This movement increases the variations in genes and reduces the differences among populations.

With whom do organisms mate?

Mating in a population is usually nonrandom. Individuals tend to mate with other individuals that live near them. This promotes inbreeding. Nonrandom mating might favor individuals that are homozygous for particular traits.

How do mutations affect genetic equilibrium?

The cumulative effect of mutations might change the allelic frequencies in a population and violate genetic equilibrium. Occasionally, a mutation provides an advantage for an organism. The mutation will become more common in future generations. Mutations are the raw material in which natural selection works.

Reading Check

4. Define What happens in a bottleneck?

Think it Over

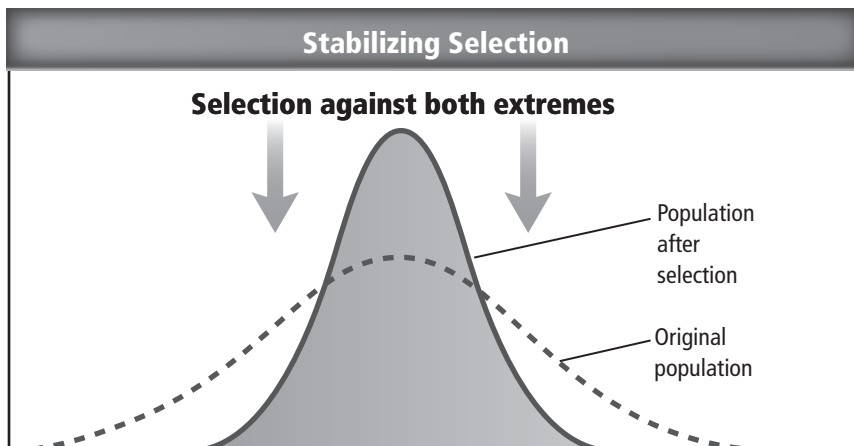
5. Evaluate What is a problem with inbreeding?

What are the different types of natural selection?

Recall that natural selection changes organisms to better fit their environment. There are three different ways (stabilizing, directional, and disruptive selection) that natural selection can change populations.

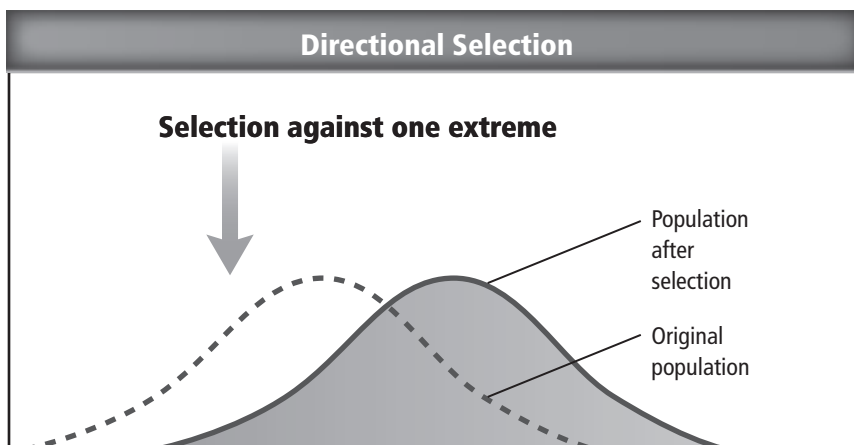
Stabilizing selection removes organisms with extreme forms of a trait. It is the most common form of selection. Stabilizing selection favors the average value of a trait, as shown in the figure below.

For example, human babies born with below-normal or above-normal birth weights are less likely to survive than babies born at average weights. Therefore, the average birth weight in humans remains about the same.



What is favored in directional selection?

Directional selection favors the extreme form of a trait. When an extreme form of a trait results in higher fitness, **directional selection** shifts the populations toward the beneficial trait. Directional selection is shown in the graph below.



Picture This

6. Highlight the curve representing the population in which the extreme forms of a trait have been removed.

Picture This

7. Highlight the curve representing a population before it has undergone directional selection.

✓ Reading Check

8. Evaluate In this example, what causes directional selection to occur?

✓ Reading Check

9. Identify What are two types of isolating mechanisms?

What is an example of directional selection?

American biologists, Peter and Rosemary Grant have observed directional selection in Galápagos finches. In years with little water, food supplies decrease. The remaining foods are hard seeds. Birds with small beaks starve because they are unable to crack the seeds. Birds with larger beak sizes can more easily crack the seeds and survive. In years with little water, average beak size increases. When rain returns, average beak size decreases because smaller beak size is a better fit for the environment. ✓

What is disruptive selection?

Disruptive selection removes individuals with the average form of a trait. It creates two populations with extreme forms of a trait. Disruptive selection occurs in water snakes on the shores of Lake Erie. Mainland snakes live in grass habitats and have brown skin. Island snakes live on rocky shores and have gray skin. The color of both snakes helps them blend in with their habitat. Snakes that have an intermediate color would be obvious to predators.

What is sexual selection?

Sexual selection occurs when certain traits are inherited because they increase the chance of attracting a mate. This type of selection is often found in populations where males and females look different. Notice that in natural selection, traits best for survival in the environment are selected. In sexual selection, the traits selected are not necessarily those that are best for survival in the environment.

Reproductive Isolation

Genetic drift, gene flow, nonrandom mating, mutation, and natural selection are mechanisms of evolution. All these mechanisms violate the Hardy-Weinberg principle. Scientists disagree about the extent to which each of these mechanisms contributes to the evolution of new species.

Speciation can be defined as the process by which some members of a sexually reproducing population change so much that they can no longer produce fertile offspring that can mate with the original population. Gene flow can be prevented by two types of reproductive isolating mechanisms. **Prezygotic isolating mechanisms** take place before fertilization occurs. **Postzygotic isolating mechanisms** take place after fertilization has occurred. The organism that results from a postzygotic isolating mechanism is infertile. ✓

How do prezygotic isolating mechanisms work?

Prezygotic isolating mechanisms prevent genotypes from entering a population's gene pool. The isolation might occur geographically, ecologically, or behaviorally. The eastern meadowlark and western meadowlark exhibit a form of behavioral isolation. They have a similar appearance and live in overlapping areas. However, the two species use different mating songs and do not interbreed.

Time is another factor that can be a reproductive barrier. For example, closely related species of fireflies mate at different times of night. Different species of trout live in the same stream. Because they mate at different times of the year, they do not interbreed.

Does postzygotic isolation occur?

Postzygotic isolating mechanisms prevent offspring from surviving or reproducing. Lions and tigers are considered separate species, but they do sometimes mate. The offspring of such a mating—the liger—is sterile and cannot reproduce.

Speciation

Speciation occurs when a population reproduces in isolation. Most scientists believe that allopatric speciation is the most common form of speciation. In **allopatric speciation**, a physical barrier divides one population into two or more populations. After a long period of time, the two populations will contain organisms that can no longer successfully breed with one another. Physical barriers can include mountain ranges, wide rivers, and lava flows.

Sympatric speciation occurs when a species evolves into a new species without a physical barrier. The ancestor species and the new species live in the same habitat during the speciation process. Scientists think that sympatric speciation happens fairly often in plants. Polyploidy, a mutation that increases the number of chromosomes in an organism, might cause sympatric speciation in plants. A plant that results from polyploidy is no longer able to interbreed with the main population.

Patterns of Evolution

Many details of speciation are not yet known. Speciation is a long process. Observations of speciation are rare. However, evidence of speciation is visible in most patterns of evolution.



Think it Over

- 10. Apply** Two closely related birds live on separate islands and do not interbreed. What type of isolation is occurring?
-



Think it Over

- 11. Explain** Kaibab squirrels live on the north rim of the Grand Canyon, and Albert squirrels live on the south rim. Which form of speciation is more likely taking place? (Circle your answer.)
- allopatric speciation
 - sympatric speciation

 **Reading Check**


12. Define What happens in adaptive radiation?

 **Think it Over**

13. Compare Which statement describes two organisms that emerged by convergent evolution? (Circle your answer.)

- a. They have similar morphology.
- b. They are closely related.

When does adaptive radiation occur?

Adaptive radiation occurs when one species evolves in a short period of time into a number of new species. Adaptive radiation can occur when a species evolves a new, useful trait or when a species arrives in a new habitat. Adaptive radiation, also called divergent evolution, can occur on a large scale. Recall that the Cretaceous period ended with a mass extinction. Soon afterward, mammals became more diverse. This example of adaptive radiation on a large scale likely produced the wide variety of mammals on Earth today. 

How do species coevolve?

Two species can evolve together, or coevolve. Coevolution sometimes benefits both species. For example, flowers have markings that guide bees to nectar. While the bees gather nectar, they pollinate the flower. The flowers and bees have coevolved in a way that benefits both species.

What is convergent evolution?

Places far apart on Earth can have similar environments. Deserts in North America are similar to deserts in Africa. Similar environments can cause similar organisms to evolve by natural selection. In convergent evolution, unrelated organisms in different places evolve to resemble one another. Convergent evolution produces organisms with similar morphology, physiology, and behavior, even though the organisms are unrelated.

How quickly do species evolve?

Early in the study of evolution, scientists thought evolution was gradual. **Gradualism** is the idea that evolution occurs in small steps over millions of years. Much evidence favors this theory.

Punctuated equilibrium is the idea that speciation occurs in sudden bursts followed by long periods of stability. Stability does not mean an organism is not changing. The organism's genes might still be changing, but the changes are not reflected in fossils of the organism.

Scientists continue to research the tempo of evolution. Some scientists think the fossil record shows that most change occurs in short bursts. Some scientists think that evolution occurs in a combination of gradual and punctuated changes. Many areas of science will contribute evidence to resolve the question of the pace of evolution.