

## Chapter 16 Evolution of Populations

## Summary

### 16-1 Genes and Variation

Darwin's original ideas can now be understood in genetic terms. Beginning with variation, we now know that traits are controlled by genes and that many genes have at least two forms, or alleles. We also know that individuals of all species are heterozygous for many genes.

To understand evolution, genetic variation is studied in populations. A population is defined as a group of individuals of the same species that interbreed. Members of a population share a common group of genes, called a gene pool. A gene pool consists of all the genes, including all the different alleles, that are present in the population. In genetic terms, evolution is any change in the relative frequency of alleles in a population. The relative frequency of an allele is the number of times the allele occurs in a gene pool, compared with the number of times other alleles for the same gene occur.

The two main sources of genetic variation are mutations and gene shuffling. A mutation is any change in a sequence of DNA. Gene shuffling occurs during the production of gametes in sexual reproduction. It can result in millions of different combinations of genes. Mutation and gene shuffling do not change relative allele frequencies. However, they increase genetic variation by increasing the number of different genotypes.

The number of different phenotypes for a given trait depends on how many genes control the trait. A single-gene trait is controlled by one gene. If there are two alleles for the gene, two or three different genotypes are possible. An example in humans is the presence or absence of widow's peak. A polygenic trait is controlled by two or more genes, and each gene may have more than one allele. An example of a human polygenic trait is height.

Polygenic traits such as height produce many different phenotypes. Variation in a polygenic trait in a population often produces a bell-shaped curve, with most people falling near the middle of the curve.

### 16-2 Evolution as Genetic Change

Natural selection acts on individuals. Evolution acts on populations. Natural selection acting on individuals leads to the evolution of populations.

Natural selection on a trait controlled by a single gene with two alleles can cause one allele to increase and the other allele to decrease. Natural selection on polygenic traits is more complicated. Natural selection on polygenic traits can occur as directional selection, stabilizing selection, or disruptive selection.

Directional selection takes place when individuals at one end of the bell-shaped curve have higher fitness than individuals near the middle or at the other end of the curve. The result of directional selection is a shift in the curve toward the higher fitness end.

Stabilizing selection takes place when individuals near the middle of the curve have higher fitness than individuals at either end. The result of stabilizing selection is a narrowing of the curve around the middle.

Disruptive selection takes place when individuals at the upper and lower ends of the curve have higher fitness than individuals near the middle. As a result of disruptive selection, the curve develops a peak at each end and a low point in the middle.

Natural selection is not the only source of evolutionary change. In small populations, alleles can become more or less common simply by chance. This kind of change in allele frequency is called genetic drift. It occurs when individuals with a particular allele leave more descendants than other individuals, just by chance. Over time, this can cause an allele to become more or less common in a population.

Genetic drift also may occur when a small group of individuals colonizes a new habitat. By chance, the small group may have different relative allele frequencies than the original population. When this happens, it is called the founder effect.

To understand how evolution occurs, scientists first had to answer the question: Under what conditions does evolution not occur? The answer to this question is called the Hardy-Weinberg principle. The principle states that allele frequencies in a population will remain constant unless one or more factors cause those frequencies to change. The situation in which allele frequencies remain constant is called genetic equilibrium. For a population to be in genetic equilibrium, five conditions are required: random mating, very large population size, no migrations, no mutations, and no natural selection. Random mating assures that each individual has an equal chance of reproducing. Very large population size prevents genetic drift from occurring. If all five conditions are met, relative allele frequencies will not change and evolution will not occur.

### **16-3 The Process of Speciation**

Speciation means the formation of new species. For one species to evolve into two new species, the gene pools of two populations must become separated, or reproductively isolated. Reproductive isolation occurs when members of two populations cannot interbreed and produce fertile offspring. Reproductive isolation can involve behavioral, geographic, or temporal isolation.

Behavioral isolation occurs when populations have different courtship rituals or other behaviors involved in reproduction. Geographic isolation occurs when populations are separated by geographic barriers, such as mountains or rivers. Temporal isolation occurs when populations reproduce at different times.

Recently, Peter and Rosemary Grant proved that natural selection is still causing evolution of finches on the Galápagos Islands. The Grants showed that there was enough heritable variation in finch beaks to provide raw material for natural selection. They also showed that differences in beaks produced differences in fitness. These differences in fitness caused directional selection to occur.

Darwin thought that different finch species evolved on the Galápagos Islands from a single species of founding birds. We now know how this could have happened. A few finches may have traveled from mainland South America to one of the islands to found a new population. There, they survived and reproduced. Some birds crossed to a second island, and the two populations became geographically isolated. They no longer shared a gene pool. Seed sizes on the second island favored birds with larger beaks. The population on the second island evolved into a population with larger beaks. Eventually, the large-beaked birds on the second island became reproductively isolated and evolved into a new species.

Evolution continues today. For example, bacteria are evolving to have resistance to drugs. Evolutionary theory can help us understand these changes.

**Chapter 16 Evolution of Populations**

**Section 16–1 Genes and Variation (pages 393–396)**

 **Key Concepts**

- What are the main sources of heritable variation in a population?
- How is evolution defined in genetic terms?
- What determines the numbers of phenotypes for a given trait?

**Introduction (page 393)**

1. Is the following sentence true or false? Mendel’s work on inheritance was published after Darwin’s lifetime. \_\_\_\_\_
2. Which two important factors was Darwin unable to explain without an understanding of heredity? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**How Common Is Genetic Variation? (page 393)**

3. All organisms have additional \_\_\_\_\_ that is “invisible” because it involves small differences in biochemical processes.

**Variation and Gene Pools (page 394)**

4. A group of individuals of the same species that interbreed is a(an) \_\_\_\_\_.
5. All of the genes in a population are called a(an) \_\_\_\_\_.
6. Is the following sentence true or false? A gene pool typically contains just one allele for each inheritable trait. \_\_\_\_\_
7. The number of times that an allele occurs in a gene pool compared with the number of times other alleles for the same gene occur is called the \_\_\_\_\_ of the allele.

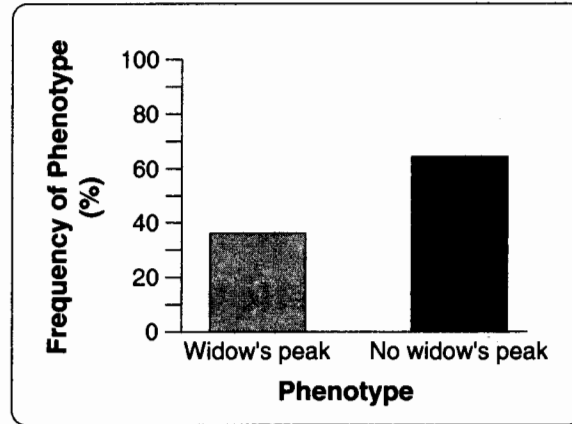
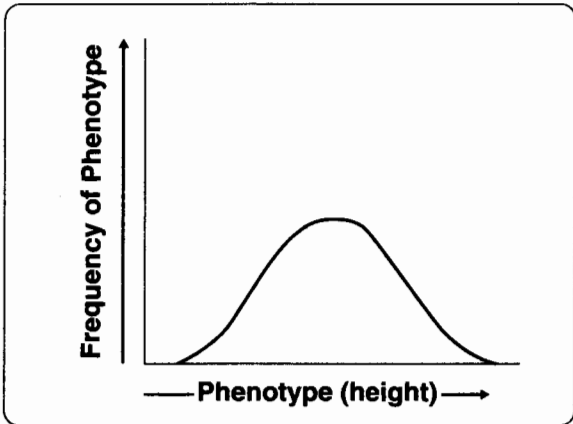
**Sources of Genetic Variation (pages 394–395)**

8. What is a mutation? \_\_\_\_\_  
\_\_\_\_\_
9. Why do mutations occur? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

10. Circle the letter of each choice that is true about mutations.
- They do not always change an amino acid.
  - They always affect lengthy segments of a chromosome.
  - They always affect an organism's phenotype.
  - They always affect an organism's fitness.
11. Is the following sentence true or false? Most heritable differences are due to gene shuffling that occurs during the production of gametes. \_\_\_\_\_
12. Circle the letter of each choice that is true about sexual reproduction.
- It is a major source of variation in many populations.
  - It can produce many different phenotypes.
  - It can produce many different genetic combinations.
  - It can change the relative frequency of alleles in a population.

**Single-Gene and Polygenic Traits (pages 395–396)**

13. Is the following sentence true or false? The number of phenotypes produced for a given trait depends on how many genes control the trait. \_\_\_\_\_
14. Is the following sentence true or false? Most traits are controlled by a single gene. \_\_\_\_\_
15. Label the two graphs to show which one represents a single-gene trait and which one represents a polygenic trait.



## Section 16–2 Evolution as Genetic Change

(pages 397–402)



### Key Concepts

- How does natural selection affect single-gene and polygenic traits?
- What is genetic drift?
- What is the Hardy-Weinberg principle?

### Natural Selection on Single-Gene Traits (pages 397–398)

1. Is the following sentence true or false? Natural selection on single-gene traits cannot lead to changes in allele frequencies. \_\_\_\_\_
2. If a trait made an organism less likely to survive and reproduce, what would happen to the allele for that trait? \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_
3. If a trait had no effect on an organism’s fitness, what would happen to the allele for that trait? \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

### Natural Selection on Polygenic Traits (pages 398–399)

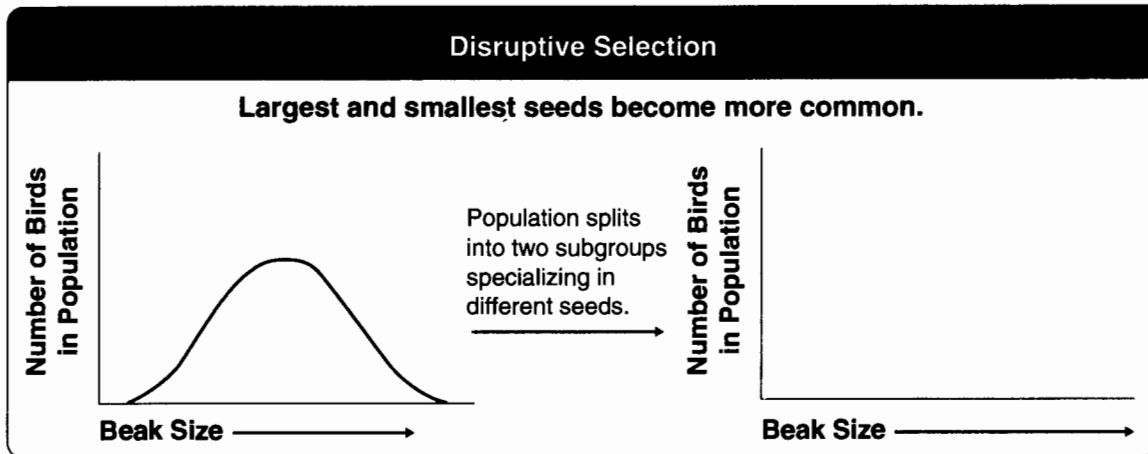
4. List the three ways that natural selection can affect the distributions of phenotypes.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_

Match the type of selection with the situation in which it occurs.

Type of Selection	Situation
_____ 5. Directional	a. Individuals at the upper and lower ends of the curve have higher fitness than individuals near the middle.
_____ 6. Stabilizing	b. Individuals at one end of the curve have higher fitness than individuals in the middle or at the other end.
_____ 7. Disruptive	c. Individuals near the center of the curve have higher fitness than individuals at either end.

8. An increase in the average size of beaks in Galápagos finches is an example of \_\_\_\_\_ selection.
9. Is the following sentence true or false? The weight of human infants at birth is under the influence of disruptive selection. \_\_\_\_\_

10. Draw the missing graph to show how disruptive selection affects beak size.



**Genetic Drift (page 400)**

11. Is the following sentence true or false? Natural selection is the only source of evolutionary change. \_\_\_\_\_
12. Random change in allele frequencies in small populations is called \_\_\_\_\_.
13. A situation in which allele frequencies change as a result of the migration of a small subgroup of a population is known as the \_\_\_\_\_.
14. What is an example of the founder effect? \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

**Evolution Versus Genetic Equilibrium (pages 401–402)**

15. What does the Hardy-Weinberg principle state? \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_
16. The situation in which allele frequencies remain constant is called \_\_\_\_\_.
17. List and describe the five conditions required to maintain genetic equilibrium.
  - a. \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_
  - b. \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

- c. \_\_\_\_\_  
\_\_\_\_\_
- d. \_\_\_\_\_  
\_\_\_\_\_
- e. \_\_\_\_\_  
\_\_\_\_\_

18. Is it common for a population to remain in genetic equilibrium? Explain your answer.

\_\_\_\_\_

19. If you are studying a population and 92% exhibits the dominant phenotype, what percentage exhibits the recessive phenotype? \_\_\_\_\_

20. What are three resulting phenotypes of a cross of two heterozygous (Aa) parents? Show your answer using a Punnett square. \_\_\_\_\_

**Reading Skill Practice**

When you read about related concepts, making a graphic organizer such as a Venn diagram can help you focus on their similarities and differences. Make a Venn diagram comparing and contrasting single-gene and polygenic traits. For more information on Venn diagrams, see Appendix A of your textbook. Do your work on a separate sheet of paper.

## Section 16–3 The Process of Speciation

(pages 404–410)

### Key Concepts

- What factors are involved in the formation of new species?
- Describe the process of speciation in the Galápagos finches.

### Introduction (page 404)

1. What is speciation? \_\_\_\_\_

### Isolating Mechanisms (pages 404–405)

2. Is the following sentence true or false? Individuals in different species can have the same gene pool. \_\_\_\_\_
3. What does it mean for two species to be reproductively isolated from each other?  
\_\_\_\_\_  
\_\_\_\_\_
4. What must happen in order for new species to evolve? \_\_\_\_\_  
\_\_\_\_\_
5. List three ways that reproductive isolation occurs.
- a. \_\_\_\_\_ c. \_\_\_\_\_
- b. \_\_\_\_\_
6. When does behavioral isolation occur? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
7. Is the following sentence true or false? Eastern and Western meadowlarks are an example of behavioral isolation. \_\_\_\_\_
8. When does geographic isolation occur? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
9. Abert and Kaibab squirrels in the Southwest are an example of \_\_\_\_\_ isolation.
10. Is the following sentence true or false? Geographic barriers guarantee the formation of new species. \_\_\_\_\_
11. What is an example of temporal isolation? \_\_\_\_\_  
\_\_\_\_\_

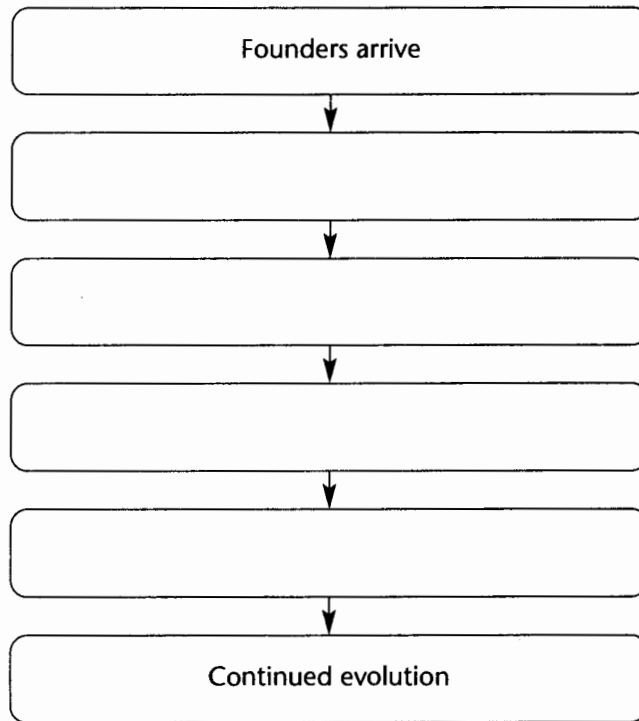
### Testing Natural Selection in Nature (pages 406–407)

12. Is the following sentence true or false? The basic mechanisms of evolutionary change cannot be observed in nature. \_\_\_\_\_

13. Circle the letter of each hypothesis about the evolution of Galápagos finches that was tested by the Grants.
- a. The finches' beak size and shape has enough inheritable variation to provide raw material for natural selection.
  - b. The different finch species are the descendants of a common mainland ancestor.
  - c. Differences in the finches' beak size and shape produce differences in fitness that cause natural selection to occur.
  - d. The evolution of the finches is proceeding slowly and gradually.

**Speciation in Darwin's Finches (pages 408–409)**

14. Complete the flowchart to show how speciation probably occurred in the Galápagos finches.



15. How could differences in beak size lead to reproductive isolation? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

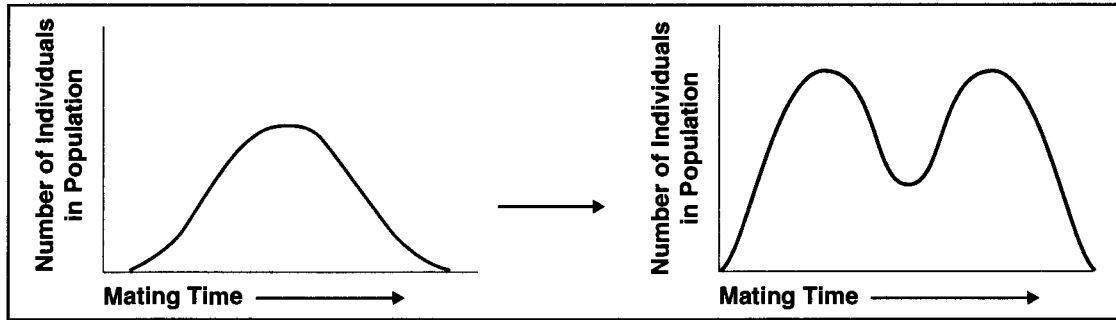
**Studying Evolution Since Darwin (page 410)**

16. Why is the study of evolution important? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Chapter 16 Evolution of Populations**

**Vocabulary Review**

**Interpreting Diagrams** The diagrams show the distribution curves for time of mating in a population of insects. The diagram on the left represents the starting population. The diagram on the right represents the population several generations later. Study the diagrams and answer the questions below.



1. What type of natural selection has occurred? \_\_\_\_\_  
\_\_\_\_\_
2. Which phenotypes are selected against? \_\_\_\_\_  
\_\_\_\_\_
3. Which phenotypes have higher fitness? \_\_\_\_\_  
\_\_\_\_\_
4. If natural selection continues in this way, what may eventually happen to the population?  
\_\_\_\_\_  
\_\_\_\_\_

**Completion** Fill in the blanks with terms from Chapter 16.

5. Any change in the relative frequency of alleles in a population is called \_\_\_\_\_.
6. A gene pool consists of all the genes in a(an) \_\_\_\_\_.
7. The two main sources of genetic variation are gene shuffling and \_\_\_\_\_.
8. A random change in allele frequency is called \_\_\_\_\_.
9. When birds cannot interbreed because they have different mating songs, they are characterized by \_\_\_\_\_ isolation.
10. A situation in which allele frequencies change as a result of the migration of a small subgroup of a population is known as the \_\_\_\_\_.
11. Research on Galápagos finches by Peter and Rosemary Grant showed that a type of natural selection called \_\_\_\_\_ selection was occurring.
12. Two related species that live in the same area but mate during different seasons are separated by \_\_\_\_\_ isolation.