Chapter 23: The Evolution of Populations

23.1 Describe how genetic variation arises and explain why it is a prerequisite for evolution.

23.2 Use allele-frequency data to predict the genotype frequencies of a population in Hardy-Weinberg equilibrium.

23.3 Differentiate between how natural selection, genetic drift, and gene flow affect allele frequencies in a population.

23.4 Explain how natural selection can lead to adaptation.

This chapter begins with the idea that we focused on as we closed the last chapter: Individuals do not evolve! Populations evolve. The Study Tip looks at the work of Peter and Rosemary Grant with Galápagos finches to illustrate this point, and the rest of the chapter examines the change in populations over time. As in the last chapter, first read each concept to get the big picture and then go back to work on the details presented by our questions. Don’t lose sight of the conceptual understanding by getting lost in the details! Remember, change in the genetic makeup of a population over time is evolution. You also need to be able to use the Hardy-Weinberg equation to make predictions about evolving populations, so be sure to do the practice problems.

Study Tip: Always study the figures and pictures and their legends carefully as they have been chosen to illustrate and explain important ideas.

1. What are the three main mechanisms that can cause the evolution of populations?

2. Which of these mechanisms primarily resulted in the evolution of medium ground finches on the island of Daphne Major?

3. What is microevolution?

4. Of the three mechanisms of evolution you cited in your response to question 1, what is the only mechanism that is *adaptive*, or improves the match between organisms and their environment?

Concept 23.1 Genetic variation makes evolution possible

LO 23.1: Describe how genetic variation arises and explain why it is a prerequisite for evolution.

5. Differences among individuals show two common patterns. One type of variation is between "either-or" characters, and the other is when the character varies along a continuum. Explain the underlying genetic differences that contribute to each pattern.

6. Perhaps because we tend to focus on mutations that cause changes in phenotypes, it is easy to think that every mutation will lead to a phenotypic change. Use Figure 23.4 in your text to answer the following.

   a. How many total mutations are shown in the alcohol dehydrogenase gene?

   b. How many mutations occurred in the exon areas? How many of these mutations altered the amino acid sequence of the protein?

   c. Explain how a substitution error in an exon could have no effect on the amino acid sequence.

7. Several sources of genetic variation are available. What is the ultimate source of new alleles?

8. *Mutations* are any change in the nucleotide sequence of an organism's DNA. These mutations provide the raw material from which new traits may arise and be selected. What occurs in a *point mutation*? Do point mutations always result in a change of phenotype?

9. What is neutral variation? Give an example from Figure 23.4 in your text.

10. Chromosomal changes that delete, disrupt, or rearrange many loci at once are usually harmful. How does *gene duplication* occur?

    How might gene duplication play a role in evolution?

11. What are some reasons bacteria and viruses show so much genetic variation and may quickly become resistant to drug treatments?

12. Why have the most effective treatments for HIV been drug "cocktails" rather than single-drug treatments?

13. Much of the genetic variation that makes evolution possible comes through sexual reproduction. What are the three mechanisms by which sexual reproduction shuffles existing alleles?

    1.

    2.

    3.

Concept 23.2 The Hardy-Weinberg equation can be used to test whether a population is evolving

LO 23.2: Use allele-frequency data to predict the genotype frequencies of a population in Hardy-Weinberg equilibrium.

14. What is a *population*?

15. What is a *gene pool*?

16. The greater the number of *fixed* alleles, the lower the species' diversity. What does it mean to say that an allele is *fixed*?

Study Tip: The text offers an explanation for how to reason through the allelic percentages for a specific gene in a population using flower color. Go through this example slowly, checking every calculation. This example is the baseline for understanding the Hardy-Weinberg Equation.

17. In a population that is not evolving, allelic and genotypic frequencies remain constant generation to generation. Such a population is said to be in ________________________.

18. There are five conditions required for a population to remain in Hardy-Weinberg equilibrium. It is very important for you to know these conditions, so enter the conditions on the left side of the chart and a brief explanation of the condition on the right side.

Conditions For Hardy-Weinberg Equilibrium

Conditions for Hardy-Weinberg Equilibrium	Explanation
1.	
2.	
3.	
4.	
5.	

It is not very likely that all five of these conditions will occur simultaneously in a population. Therefore, allelic frequencies often change in a population, thus the population evolves. Allelic frequency data can be tested by applying the Hardy-Weinberg equation.

Equation for Hardy-Weinberg Equilibrium

$$p^2 + 2pq + q^2 = 1$$

where p^2 is equal to the frequency of the homozygous dominant in the population, $2pq$ is equal to the frequency of all the heterozygotes in the population, and q^2 is equal to the frequency of the homozygous recessive in the population.

Consider a gene locus that exists in two allelic forms, *A* and *a*, in a population.

Let p = the frequency of *A*, the dominant allele

and q = the frequency of *a*, the recessive allele.

So, $p^2 = AA$,
$q^2 = aa$,
$2pq = Aa$

If we know the frequency of one of the alleles, we can calculate the frequency of the other allele:

$$p + q = 1, \text{ so}$$
$$p = 1 - q$$
$$q = 1 - p$$

19. In a plant population, suppose that red flowers *(R)* are dominant to white flowers *(r)*. In a population of 500 individuals, 25% show the recessive phenotype. How many individuals would you expect to be homozygous dominant and heterozygous for this trait? (A complete solution for this problem is at the end of this *Active Reading Guide* chapter.)

20. In a population of plants, 64% exhibit the dominant flower color (red), and 36% of the plants have white flowers. What is the frequency of the dominant allele? (There are a couple of twists in this problem, so read and think carefully. A complete solution for this problem is at the end of this *Active Reading Guide* chapter.)

Evolution occurs when allelic frequencies change over time. The Hardy-Weinberg equation allows the scientist to determine a baseline for allelic frequencies at the beginning of a research project, then test again in the future to determine if the allelic frequencies have changed. If frequencies have changed, at least one of the conditions for Hardy-Weinberg Equilibrium has not been met. Which one? That is the researcher's next question.

Study Tip: According to our students, the Scientific Skills Exercise on p. 493 will really help you to understand the Hardy-Weinberg Equation.

Concept 23.3 Natural selection, genetic drift, and gene flow can alter allele frequencies in a population

LO 23.3: Differentiate between how natural selection, genetic drift, and gene flow affect allele frequencies in a population.

21. First, let's try to summarize the big idea from this section. Scan through the entire concept to pull out this information. Three major factors alter allelic frequency and bring about evolutionary change. List each factor and give an explanation.

Factor	Explanation

22. Which of the factors results in a random, nonadaptive change in allelic frequencies?

23. Which of the factors tends to reduce the genetic differences between populations and make populations more similar?

24. Of the three factors you previously listed, only one results in individuals that are better suited to their environment. Which is it?

25. Explain the fundamental concepts on which natural selection is based.

26. Describe what happens in each of these special types of *genetic drift*:

    founder effect

    bottleneck effect

27. Summarize the four effects genetic drift can have on a population.

    1.

    2.

    3.

    4.

Each of the effects you described above are more likely when the population size is small.

Concept 23.4 Natural selection is the only mechanism that consistently causes adaptive evolution

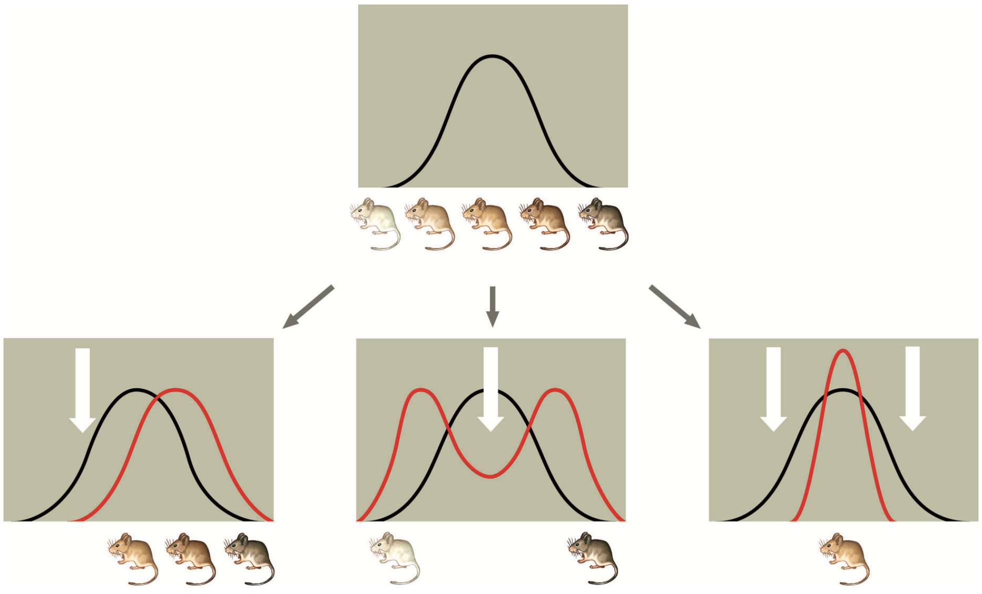
LO 23.4: Explain how natural selection can lead to adaptation.

28. In evolutionary terms, *fitness* refers only to the ability to leave offspring and contribute to the gene pool of the next generation. It may have nothing to do with being big, or strong, or aggressive. Define *relative fitness*.

29. Does natural selection act on the genotype or phenotype or both? Explain.

30. What is the *relative fitness* of a sterile mule? ____________

31. Figure 23 13 in your text is important because it helps explain the three modes of selection. Label each type of selection and fill in the chart that follows to explain what is occurring.



Type of Selection	How It Works
Stabilizing	
Directional	
Disruptive	

32. What is often the result of *sexual selection*?

33. What is the difference between *intrasexual selection* and *intersexual selection*? Give an example of each type of selection.

34. Natural selection can act to maintain genetic variability due to balancing selection. Explain and give an example of the two mechanisms of balancing selection.

    1. Frequency-dependent selection

    2. Heterozygote advantage

35. Give four reasons why natural selection cannot produce perfect organisms.

Figure 23.18 Make Connections: The Sickle- Cell Allele

36. Sickle-cell allele is often used as an example of *heterozygote advantage*. Refer to Figure 23.18, Figure 14.17, and Figure 5.19 in your text to study the sickle-cell allele at the molecular, cellular, and organismal levels. Explain the phenotypic consequences of each genotype for a person living in a region of the world where malaria is common:

    a. homozygous for the wild-type allele for hemoglobin (normal hemoglobin)

    b. homozygous for the sickle-cell allele (sickle-cell disease)

    c. heterozygous for these two alleles (sickle-cell trait)

37. Professional football players with sickle-cell trait are sometimes <u>advised</u> to not play at Mile-High Stadium in Denver. Why?

Test Your Understanding, p. 505

Now you should be ready to test your knowledge. Place your answers here:

1. ____________ 2. _____________ 3. ______________ 4. ______________ 5. ____________

Solution to Question 19

Let p = frequency of the dominant allele *(R)* and q = frequency of the recessive allele *(r)*.

1. q^2 = frequency of the homozygous recessive = 25% = 0.25. Because $q^2 = 0.25$, $q = 0.5$.
2. Now, $p + q = 1$, so $p = 0.5$.

3. Homozygous dominant individuals are *RR* or $p^2 = 0.25$, and they will represent (0.25)(500) = **125 individuals**.

4. The heterozygous individuals are calculated from $2pq = (2)(0.5)(0.5) = 0.5$, and in a population of 500 individuals will be (0.5)(500) = **250 individuals**.

Solution to Question 20

This problem requires you to recognize that individuals with the dominant trait can be either homozygous or heterozygous. Therefore, you cannot simply take the square root of 0.64 to get p. For problems of this type, you must begin with the homozygous recessive group.

Let p = frequency of the dominant allele *(R)* and q = frequency of the recessive allele *(r)*.

1. q^2 = frequency of the homozygous recessive = 36% = 0.36. Because $q^2 = 0.36$, $q = 0.6$.

2. Now, $p + q = 1$, so $p = 0.4$.

3. Notice that this problem asks for the *frequency of the dominant allele (p)*, not the frequency of the homozygous dominant individuals *(p^2)*. So, you are done . . . **the frequency of the dominant allele = 0.4 or 40%.**