

Chapter 23: The Evolution of Populations

This chapter begins with the idea that we focused on as we closed the last chapter: Individuals do not evolve! *Populations* evolve. The Overview 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!

Overview

1. What is *microevolution*?

Microevolution is evolutionary change below the species level; change in the allele frequencies in a population over generations.

2. What are the three main mechanisms that can cause changes in allele frequency?

Natural selection, genetic drift, and gene flow

3. What is the only mechanism that is adaptive, or improves the match between organisms and their environment?

Natural selection

Concept 23.1 Genetic variation makes evolution possible

4. Because Darwin did not know about the work of Gregor Mendel, he could not explain how organisms pass heritable traits to their offspring. In looking at genetic variation, what are *discrete characters*, and what are *quantitative characters*?

Discrete characters can be classified on an either-or basis.

Quantitative characters vary along a continuum within a population.

5. Using the techniques of molecular biology, what are the two ways of measuring genetic variation in a population?

Survey the protein products of genes using gel electrophoresis and compare the DNA sequences of two individuals in a population.

6. *Geographic variation* may be shown in a graded manner along a geographic axis known as a *cline*. What external factors might produce a *cline*? Why does the existence of a cline suggest natural selection?

Some clines are produced by a gradation in an environmental variable, such as temperature. The existence of a cline suggests natural selection because of the close association between the environmental variable and the frequency of the allele.

7. There are several sources of genetic variation. We will look at several. What is the ultimate source of new alleles?

Mutation

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*? Why do not all point mutations result in a change of phenotype?

A point mutation reflects a change in one base in a gene. Not all point mutations result in a change of phenotype because so much of the DNA in eukaryotic genomes does not code for protein products, and because of the redundancy in the genetic code.

9. What is *translocation*? How could it be beneficial?

Translocation is an aberration in chromosome structure resulting from attachment of a chromosomal fragment to a nonhomologous chromosome. Translocation can be beneficial, for example, the translocation of a part of one chromosome to a different chromosome could link DNA segments in a way that results in a positive effect.

10. Chromosomal changes that delete, disrupt, or rearrange many loci at once are usually harmful. How does *gene duplication* occur? How might it play a role in evolution?

Gene duplication can occur due to errors in meiosis, slippage during DNA replication, or the activities of transposable elements. Duplications that do not have severe effects can persist over generations, allowing mutations to accumulate. The result is an expanded genome with new genes that may take on new functions, playing a major role in evolution.

11. 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?

Crossing over, independent assortment of chromosomes, and fertilization

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

12. What is a *population*?

A population is a group of individuals of the same species that live in the same area and interbreed, producing fertile offspring.

13. What is a *gene pool*?

A gene pool consists of all copies of every type of allele at every locus in all members of the population.

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

An allele is said to be fixed if only one allele exists for a particular locus in a population.

15. The *Hardy-Weinberg principle* is used to describe a population that is *not* evolving. What does this principle state?

This principle states that frequencies of alleles and genotypes in a population remain constant from generation to generation, provided that only Mendelian segregation and recombination of alleles are at work.

16. If the frequency of alleles in a population remains constant, the population is at *Hardy-Weinberg equilibrium*. There are five conditions for *Hardy-Weinberg equilibrium*. It is very important for you to know these conditions, so enter them neatly into the box below.

CONDITIONS FOR HARDY-WEINBERG EQUILIBRIUM

Conditions For Hardy-Weinberg Equilibrium	Explanation
1.	No mutations
2.	Random mating
3.	No natural selection
4.	Extremely large population size
5.	No gene flow

It is not very likely that all five of these conditions will occur, is it? Allelic frequencies change. Populations evolve. This data can be tested by applying the *Hardy-Weinberg equation*. Let's look at how to do this.

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,

$$\begin{aligned} p^2 &= AA, \\ q^2 &= aa, \\ 2pq &= Aa \end{aligned}$$

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

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

$$p = 1 - q$$

$$q = 1 - p$$

17. 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 *Reading Guide*.)
18. 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 *Reading Guide*.)

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

19. 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
Natural Selection	Natural selection results in alleles being passed to the next generation in proportions that differ from those in the present generation.
Genetic Drift	The process in which chance events cause allelic frequencies to fluctuate unpredictably from one generation to the next
Gene Flow	The transfer of alleles into or out of a population due to the movement of fertile individuals or their gametes

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

Natural selection is the only mechanism that consistently causes adaptive evolution.

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

Gene flow

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

Natural selection

23. Explain what happens in each of these examples of *genetic drift*:

founder effect: Genetic drift that occurs when a few individuals become isolated from a larger population and form a new population whose gene pool composition is not reflective of that of the original population.

bottleneck effect: Genetic drift that occurs when the size of a population is reduced, as by a natural disaster or human actions. Typically, the surviving population is no longer genetically representative of the original population.

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

24. 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*.

Relative fitness is the contribution an individual makes to the gene pool of the next generation, relative to the contributions of other individuals in the population.

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

Zero

26. Figure 23.13 is important because it helps explain the three modes of selection. Label each type of selection, and fill in the chart to explain what is occurring.

See page 481 of your text for the labeled figure.

Type of Selection	How It Works
Stabilizing	Removes extreme variants from the population and preserves intermediate types
Directional	Shifts the overall makeup of the population by favoring variants that are at one extreme of the distribution
Disruptive	Favors variants at both ends of the distribution

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

Sexual dimorphism: A difference between the two sexes in secondary sexual characteristics

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

Intrasexual selection is selection in which there is direct competition among individuals of one sex for mates of the opposite sex. Possible examples include ring-tailed lemurs and broad-nosed pipefish.

Intersexual selection is selection whereby individuals of one sex (usually females) are choosy in selecting their mates from individuals of the other sex; also called mate choice. Possible examples include peacocks and peahens.

29. Explain two ways in which genetic variation is preserved in a population.

Diploidy: In diploid eukaryotes, a considerable amount of genetic variation is hidden from selection in the form of recessive alleles

Balancing selection: Natural selection that maintains two or more phenotypic forms in a population.

30. Discuss what is meant by *heterozygote advantage*, using sickle-cell anemia as an example.

Heterozygote advantage refers to the greater reproductive success of heterozygous individuals compared with homozygotes; tends to preserve variation in a gene pool. In the case of sickle-cell anemia, the homozygous individuals have a certain recessive allele at the locus that causes sickle-cell disease, resulting in distorted red blood cells in low-oxygen conditions. These sickled cells cause serious damage to vital organs by clumping together. Heterozygous individuals for the sickle-cell allele are protected against the most severe effect of malaria, which destroys the sickled red blood cells without affecting normal cells. This protection gives heterozygous individuals an advantage in selection, especially in regions with high instances of malaria.

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

1. Selection can act only on existing variations.
2. Evolution is limited by historical constraints.
3. Adaptations are often compromises.
4. Change, natural selection, and the environment interact.

Test Your Understanding Answers

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

1. c 2. c 3. e 4. b 5. a 6. d

Solution to Question 17

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. Since $q^2 = 0.25$, $q = 0.5$.
2. Now, $p + q = 1$, so $p = 0.5$.
3. Homozygous dominant individuals are RR or $p^2 = 0.25$, and they will represent $(0.25)(500) = \mathbf{125}$ **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 $(0.5)(500) = \mathbf{250}$ **individuals**.

Solution to Question 18

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. So . . .

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 = 40%**.