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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*?

   Change in 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. Which is the only mechanism that is adaptive, or improves the match between organisms and their environment?

   Natural selection

Concept 23.1 Mutation and sexual reproduction produce the genetic variation that 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 are classified on an either-or basis (blue OR brown eyes) and quantitative characters include variation 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?

   Genetic variation can be measured by gene variability or nucleotide variability (gel electrophoresis, PCR, fragment analysis)

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?

   Temperature may produce a cline (graded change in a character along geographic axis). The cline's existence suggests natural selection because there would be no reason to ~~think~~ expect association between temperature (environmental factor) and allele frequency otherwise.

7. 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*?

A point mutation changes one base in a gene.
Usually this does not prove to be beneficial.

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

Translocation is the movement of genes or segments of genes, which may link DNA segments for a positive effect.

10. How does *gene duplication* occur? How might it play a role in evolution?

Gene duplication occurs because of errors and meiosis (like unequal crossing over, slippage during replication ...) and could allow mutations to accumulate, resulting in new genes.

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)
Fertilization

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

12. What is a *population*?

A group of individuals of the same species living in the same area

13. What is a *gene pool*?

All alleles at every locus in all members of a 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 fixed if there is only one allele for a particular locus in a population (all are homozygous)

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

Frequencies of alleles and genotypes in a population will remain constant over generations if 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

1.	No mutations
2.	Random mating
3.	No natural selection
4.	Very 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,
$p^2 = AA$,
$q^2 = aa$,
$2pq = Aa$

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

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

$$p = 1 - q$$

$$q = 1 - p$$

17. So, here is a problem to try. Suppose in a plant population 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*.)

$25/100 = x/500$
$x = 125$ individuals
$q^2 = 0.25$ $\sqrt{}$
$q = 0.5$

$p + q = 1$
$p = 0.5$
$p^2 = 0.25$
$2pq = 0.5$

homo. dom. = 125
hetero. = 250
homo. rec. = 125

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*.)

$p^2 + 2pq = 64\%$ (0.64)
$q^2 = 0.36$ $\sqrt{}$
$q = 0.6$
$p = 0.4$

$p^2 = 0.16$
$2pq = 0.48$

Frequency of dominant allele: (0.16 + 0.24 = 0.40) (40%)
just $p = 0.4$

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	Individuals with beneficial traits leave more offspring (w/same traits) which changes frequency
Genetic drift	chance events that cause unpredictable change in allele frequencies from one gen. to next (esp. small pop.)
Gene flow	Transfer of alleles into or out of pop. due to movement of individuals, altering allele frequency

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

✓ Genetic drift

(maybe gene flow too? It is random...)

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 — individuals of a pop. isolate and can establish new population with new gene pool

bottleneck effect — a sudden environmental change that can drastically reduce size of a population

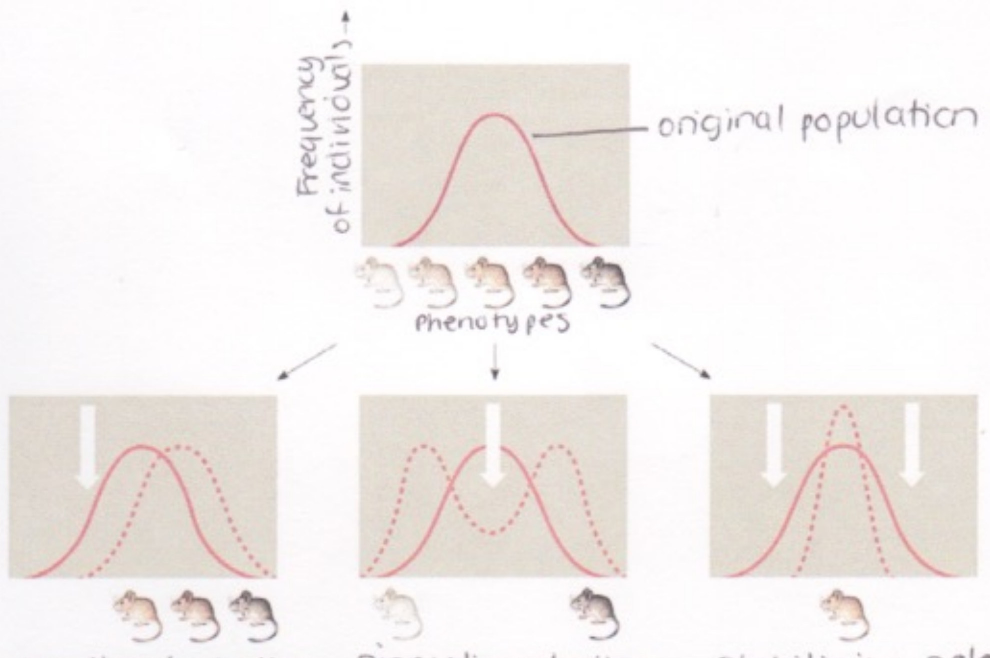
Concept 23.4 Natural selection is the only mechanism that consistently causes adaptive evolution

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 can make to the gene pool of the next generation relative to contributions of other individuals.

25. What is the *relative fitness* of a sterile mule? Nothing (poor mule is unfit)

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.



Directional selection — favors one extreme

Disruptive selection — favors both extremes

Stabilizing selection — favors intermediate variants

Type of Selection	How It Works
Stabilizing	acts against both extremes and favors intermediate variants (reduces variation)
Directional	conditions favor individuals at one extreme of a phenotypic character
Disruptive	favors individuals at both extremes of a range over intermediates

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

sexual dimorphism
→ 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 occurs within the same sex (individuals of one sex compete for opposite sex, like peacocks), while intersexual selection occurs when an individual of one sex is choosy about a mate (girl frog picks boy frog).

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

Genetic variation in a population is preserved by heterozygotes (carrying both alleles) and ~~diploid eukaryotes (recessive~~ balancing selection, which maintains two or more forms in a population.

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

Heterozygote advantage means that heterozygotes for a particular gene exhibit greater fitness than the homozygotes. Heterozygotes for sickle-cell don't have the actual disease and are protected from malaria better than homozygotes.

31. Finally, give four reasons why natural selection cannot produce perfect organisms.

1. Selection acts only on existent variations.
2. Evolution only alters/adapts what already exists.
3. Adaptations are often compromises. (good + bad)
4. Chance, natural selection, & environment interact.

Testing Your Knowledge: Self-Quiz Answers

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

1. ________ 2. ________ 3. ________ 4. ________ 5. ________

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) = **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 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%**.