Chapter 23: Evolution of Populations

1. What is microevolution?

Microevolution is a 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 (chance events that alter allele frequencies), and gene flow (the transfer of alleles between populations) have distinctive effects on the genetic composition of populations.

3. Which is the only mechanism that is adaptive?

Natural selection is the only mechanism that consistently improves the match between organisms and their environment.

4. What are discrete characters and quantitative characters?

Discrete characters can be classified on an either-or basis. Many discrete characters are determined by a single gene locus with different alleles that produce distinct phenotypes. However, most heritable variation involves quantitative characters, which vary along a continuum within a population. Heritable quantitative variation usually results from the I nfluence of two or more genes on a single phenotypic character.

5. What are the two ways of measuring genetic variation in a population?

Genetic variation can be measured at the whole-gene level (gene variability) and at the molecular level of DNA (nucleotide variability). Gene variability can be quantified as the average heterozygosity, the average percentage of heterozygous loci.

6. What external factors might produce a cline?

A cline is a graded change in a character along a geographic axis. Some clines are produced by a gradation in an environmental variable, as illustrated by the impact of temperature on the frequency of a cold-adaptive allele in mummichog fish. Clines probably result from natural selection – otherwise there would be no reason to expect a close association between the environmental variable and the frequency of the allele. But selection can only operate if multiple alleles exist for a given locus.

7. What is the ultimate source of new alleles?

New alleles can arise by mutation, a change in the nucleotide sequence of an organism's DNA.

8. What occurs in a point mutation?

A point mutation is a change of as little as one base in a gene. This can have a significant impact on phenotype.

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

Chromosomal changes that delete, disrupt, or rearrange many loci at once are usually harmful. However, when such large-scale changes leave genes intact, their effects on organisms may be neutral, or even beneficial. For example, the translocation of part of one chromosome to a different chromosome could link DNA segments in a way that results in a positive effect.

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

Genes may be duplicated due to errors in meiosis (such as unequal crossing over), slippage during DNA replication, or the activities of transposable elements. Duplications of large chromosome segments, like other chromosomal aberrations, are often harmful, but the duplication of smaller pieces of DNA may not be. Gene 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. Such beneficial increases in gene number appear to have played a major role in evolution.

11. What are the three mechanisms by which sexual reproduction shuffles existing alleles?

Crossing over, independent assortment of chromosomes, and fertilization contribute to the shuffling of existing alleles.

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. Populations need not have sharp boundaries. Members of a population typically breed with one another and thus on average are more closely related to each other than to members of other populations.

13. What is a gene pool?

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

14. What is a fixed allele?

If only one allele exists for a particular locus in a population, that allele is said to be fixed in the gene pool, and all individuals are homozygous for that allele. But if there are two or more alleles for a particular locus in a population, individuals may be either homozygous or heterozygous.

15. What does the Hardy-Weinberg principle state?

The gene pool of a population that is not evolving can be described by the Hardy-Weinberg principle, which states that the frequencies of alleles and genotypes in a population will remain constant from generation to generation, provided that only Mendelian segregation and recombination of alleles are at work.

16. List the five conditions for Hardy-Weinberg equilibrium.

1. No mutations: The gene pool is modified if mutations alter alleles or if entire genes are deleted or duplicated.
2. Random mating: If individuals mate preferentially within a subset of the population, such as their close relatives, random mixing of gametes does not occur.
3. No natural selection: Differences in the survival and reproductive success of individuals carrying different genotypes can alter allele frequencies.
4. Extremely large population size: The smaller the population, the more likely it is that allele frequencies will fluctuate by chance from one generation to the next.
5. No gene flow: By moving alleles into or out of populations, gene flow can alter allele frequencies.

17. In a plant population, red (R) flowers are dominant to white (r) flowers. 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?

If p = frequency of the dominant allele (R) and q = frequency of the recessive allele (r), q^2 = frequency of the homozygous recessive genotype = 25%, so q = 50%. Since $p + q = 1$, p = 50%. Homozygous dominant (RR) individuals = p^2 = 25% of the population = (500)(0.25) = 125 individuals. The heterozygous individuals = $2pq$ = 2(0.5)0.5 = 50% of the population = (500)(0.5) = 250 individuals.

18. In a plant population, 64% exhibit the dominant flower color, and 36% have white flowers. What is the frequency of the dominant allele?

If p = frequency of the dominant allele (R) and q = frequency of the recessive allele (r), q^2 = frequency of the homozygous recessive genotype = 36%, so q = 60%. Since $p + q = 1$, p, the frequency of the dominant allele, = 40%.

19. List three major factors that alter allelic frequency and bring about evolutionary change.

Factor	*Explanation*
Natural selection	individuals with traits better suited to their environment tend to produce more offspring; can cause adaptive evolution
Genetic drift	chance events can cause allele frequencies to fluctuate unpredictably from one generation to the next, especially in small populations
Gene flow	transfer of alleles into or out of a population due to the movement of fertile individuals

	or their gametes

20. Which of the factors in #19 results in a random, nonadaptive change in allelic frequencies?

Unlike natural selection, which in a given environment consistently favors some alleles over others, genetic drift causes allele frequencies to change at random over time.

21. Which of the factors in #19 tends to reduce the genetic differences between populations and make populations more similar?

Because alleles are exchanged between populations, gene flow tends to reduce the genetic differences between populations. If it is extensive enough, gene flow can result in two populations combining into a single population with a common gene pool.

22. Which of the factors in #19 results in individuals that are better suited to their environment.

By consistently favoring some alleles over others, natural selection can cause adaptive evolution, which results in a better match between organisms and their environment.

23. Explain the founder effect and the bottleneck effect.

The founder effect occurs when a few individuals become isolated from a larger population and establish a new population whose gene pool differs from the source population. A severe drop in population size, typically due to some disastrous event, can cause the bottleneck effect, whereby certain alleles may be overrepresented among the survivors, others may be underrepresented, and some may be absent altogether by chance alone.

24. 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.

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

Since the mule is sterile, it is unable to pass on its genes, so its relative fitness is zero.

26. Explain the three modes of selection.

Directional selection occurs when conditions favor individuals exhibiting one extreme of a phenotype, thereby shifting a population's frequency curve for the phenotypic character in one direction or the other. Directional selection is common when a population's environment changes or when members of a population migrate to a new (and different) habitat. Disruptive selection occurs when conditions favor individuals at both extremes of a phenotypic range over individuals with intermediate phenotypes. Stabilizing selection acts against both extreme phenotypes and favors intermediate variants. This mode of selection reduces variation and tends to maintain the status quo for a particular phenotypic character.

27. What is often the result of sexual selection?

In sexual selection, individuals with certain inherited characteristics are more likely than other individuals to obtain mates. Sexual selection can result in sexual dimorphism, a difference between the two sexes in secondary sexual characteristics.

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

In intrasexual selection, individuals of one sex compete directly for mates of the opposite sex. In intersexual selection, also called mate choice, individuals of one sex are choosy in selecting their mates from the other sex.

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

The tendency for directional and stabilizing selection to reduce variation is countered by mechanisms that preserve or restore it. In diploid eukaryotes, a considerable amount of genetic variation is hidden from selection in the form of recessive alleles. Recessive alleles that are less favorable than their dominant counterparts, or even harmful in the current environment, can persist by propagation in heterozygous individuals. Heterozygote protection maintains a huge pool of alleles that might not be favored under present conditions, but which could bring new benefits if the environment changes. In balancing selection, two or more forms in a population are maintained. This type of selection includes heterozygote advantage and frequency-dependent selection, in which the fitness of a phenotype depends on how common it is in the population.

30. Discuss what is meant by heterozygote advantage.

If individuals who are heterozygous at a particular locus have greater fitness than do both kinds of homozygotes, they exhibit heterozygote advantage, wherein natural selection tends to maintain two or more alleles at that locus. Since heterozygote advantage is defined by genotype, not phenotype, whether it represents stabilizing or directional selection depends on the relationship between genotype and phenotype. For example, if the phenotype of a heterozygote is intermediate to the phenotypes of both homozygotes, heterozygote advantage is a form of stabilizing selection.

Heterozygotes for the sickle-cell allele are protected against the most severe effects of malaria. In regions where malaria is a major killer, selection favors heterozygotes over homozygous dominant individuals, who are more vulnerable to the effects of malaria, and also over homozygous recessive individuals, who develop sickle-cell disease. The frequency of the sickle-cell allele in Africa is generally highest in areas where the malaria parasite is most common.

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

First, selection can act only on existing variations. Natural selection favors only the fittest phenotypes among those currently in the population, which may not be the ideal traits. New advantageous alleles do not arise on demand. Second, evolution is limited by historical constraints. Each species has a legacy of descent with modification from ancestral forms. Evolution does not scrap the ancestral anatomy and build each new complex structure from scratch; rather, evolution co-opts existing structures and adapts them to new situations. Third, adaptations are often compromises. Each organism must do many different things. Fourth, chance, natural selection, and the environment interact. Chance events can affect the subsequent evolutionary history of populations. In addition, the environment at a particular location may change unpredictably from year to year, again limiting the extent to which adaptive evolution results in a close match between the organism and current environmental conditions.