CHAPTER 18 PROCESS OF EVOLUTION

Chapter Outline

18.1 Evolution in a Genetic Context

A. What causes variations?
   1. It was not until the 1930s that population geneticists were able to apply genetics to populations to recognize when evolution had occurred.
   2. A **population** is all of the members of a single species occupying a certain area at the same time.
   3. Evolution that occurs within a population is called **microevolution.**

B. Microevolution
   1. **Population genetics** studies the variation in alleles in a gene pool.
   2. The **gene pool** is the total of all the alleles in a population; it is described in terms of gene frequencies.
   3. Neither dominance nor sexual reproduction changes allele frequencies.
   4. **The Hardy-Weinberg Law**
      a. This law states an equilibrium of allele frequencies in a gene pool (using a formula $p^2 + 2pq + q^2$) remains in effect in each succeeding generation of a sexually reproducing population if five conditions are met.
         1) No mutation: no allelic changes occur, or changes in one direction are balanced by changes in the other direction.
         2) No gene flow: migration of alleles into or out of the population does not occur.
         3) Random mating: individuals pair by chance and not according to their genotypes or phenotypes.
         4) No genetic drift: the population is large so changes in allele frequencies due to chance are insignificant.
         5) No selection: no selective force favors one genotype over another.
      b. In real life, conditions of the Hardy-Weinberg law are rarely if ever met, and allele frequencies in the gene pool of a population do change from one generation to the next, resulting in evolution.
      c. Any change of allele frequencies in a gene pool of a population signifies that evolution has occurred.
      d. The Hardy-Weinberg law tells us what factors cause evolution—those that violate the conditions listed.
      e. A *Hardy-Weinberg equilibrium* provides a baseline by which to judge whether evolution has occurred.
      f. Hardy-Weinberg equilibrium is a constancy of gene pool frequencies that remains across generations.
   5. Industrial Melanism
      a. The case of the peppered moths provides a case study in a shift in phenotype frequencies under selection.
      b. Before trees became coated with soot from air pollution, the percentage of dark-colored moths was 10%.
      c. With birds acting as a selective agent, the light colored moths were reduced while dark-colored moths were better adapted to survive on the darkened trees.
      d. The last generation observed has 80% dark-colored moths.

C. Genetic Mutations
  1. Natural populations contain high levels of allele variation.
     a. Analysis of *Drosophila* enzymes indicates they have multiple alleles at least at 30% of their gene loci.
     b. Similar results with other species indicates that allele variation is the rule in natural populations.
  2. Gene mutations provide new alleles, and therefore are the ultimate source of variation.
     a. A **gene mutation** is an alteration in the DNA nucleotide sequence of an allele.
     b. Mutations may not immediately affect the phenotype.
     c. Mutations can be beneficial, neutral, or harmful; a seemingly harmful mutation that requires *Daphnia* to live at higher temperatures becomes advantageous when the environment changes.
     d. Specific recombinations of alleles may be more adaptive than other combinations.

D. Gene Flow
  1. **Gene flow** moves alleles among populations by migration of breeding individuals.
  2. Gene flow can increase variation within a population by introducing novel alleles produced by mutation in another population.
  3. Continued gene flow decreases diversity among populations, causing gene pools to become similar.
  4. Gene flow among populations can prevent speciation from occurring.

E. Nonrandom Mating
  1. **Random mating** involves individuals pairing by chance, not according to genotype or phenotype.
  2. **Nonrandom mating** involves inbreeding and assortative mating.
  3. **Inbreeding** is mating between relatives to a greater extent than by chance.
     a. Inbreeding does not change the allele frequencies.
     b. However, inbreeding decreases the proportion of heterozygotes.
     c. Inbreeding increases the proportions of both homozygotes at all gene loci.
  d. In human populations, inbreeding increases the frequency of recessive abnormalities.
  4. **Assortative mating** occurs when individuals mate with those that have the same phenotype.
  a. Assortative mating divides a population into two phenotypic classes with reduced gene exchange.
  b. Homozygotes for gene loci that control a trait increase, and heterozygotes for these loci decrease.
  5. **Sexual selection** occurs when males compete for the right to reproduce and the female selects males of a particular phenotype.

F. Genetic Drift
  1. **Genetic drift** refers to changes in allele frequencies of a gene pool due to chance.
  2. Genetic drift occurs in both large and small populations; large populations suffer less *sampling error*.
  3. Genetic drift causes isolated gene pools to become dissimilar; some alleles are lost and others are *fixed* or are the only allele in the population.
     a. Separate cypress groves in California show patchy variations.
     b. Because there is no apparent adaptive advantage to the many variations, this has been attributed to genetic drift.
  4. Genetic drift occurs when founders start a new population, or after a genetic bottleneck with interbreeding.
     a. The **bottleneck effect** prevents most genotypes from participating in production of the next generation.
        1) The bottleneck effect is caused by a severe reduction in population size due to a natural disaster, predation, or habitat reduction.
        2) The bottleneck effect causes a severe reduction in the total genetic diversity of the original gene pool.
        3) The cheetah bottleneck causes relative infertility because alleles were lost due to intense inbreeding when populations were reduced in earlier times.
     b. The **founder effect** is an example of genetic drift where rare alleles or combinations occur in higher frequency in a population isolated from the general population.
        1) This is due to founding individuals containing a fraction of total genetic diversity of original population.
        2) Which particular alleles are carried by the founders is dictated by chance alone.
        3) As an example, dwarfism is much higher in a Pennsylvania Amish community due to a few German founders.

18.2 Natural Selection

A. Natural selection is the process that results in adaptation of a population to the environment.
   1. Natural selection requires
      a. variation (i.e., the members of a population differ from one another),
      b. inheritance (i.e., many of the differences between individuals in a population are heritable genetic differences),
      c. differential adaptedness (i.e., some differences affect how well an organism is adapted to its environment), and
      d. differential reproduction (i.e., better adapted individuals are more likely to reproduce).
   2. **Fitness** is the extent to which an individual contributes fertile offspring to the next generation.
   3. **Relative fitness** compares the fitness of one phenotype to another.

B. Types of Selection.
   1. **Directional selection** occurs when an extreme phenotype is favored; the distribution curve shifts that direction.
      a. A shift to dark-colored peppered moths from light-colored correlated with increasing pollution.
      b. Drug-resistant strains of bacteria are a serious health threat and represent this type of selection.
      b. Increases in insecticide-resistant mosquitoes and resistance of the malaria protozoan *Plasmodium* to medications are also examples of directional selection.
      c. The gradual increase in the size of the modern horse, *Equus*, correlates with a change in the environment from forest-like conditions to grassland conditions.
   2. **Stabilizing selection** occurs when extreme phenotypes are eliminated and the intermediate phenotype is favored.
      a. The average number of eggs laid by Swiss starlings is four or five.
      b. If the female lays more or less than this number, fewer survive.
      c. Genes determining the physiology of yolk production and behavior are involved in clutch size.
   3. **Disruptive selection** occurs when extreme phenotypes are favored and can lead to more than one distinct form.
      a. British snails (*Cepaea nemoralis*) vary because a wide range causes natural selection to vary.
      b. In forest areas, thrushes feed on snails with light bands.
      c. In low-vegetation areas, thrushes feed on snails with dark shells that lack light bands.

C. Maintenance of Variations
   1. Populations always show some genotypic variation; populations that lack variation may not be able to adapt to new conditions.
   2. How is variation maintained in the face of constant selection pressure?
   3. The following forces promote genetic variation.
      a. Mutation creates new alleles and genetic recombination still combines these alleles.
      b. Gene flow among small populations introduces new alleles.
      c. Natural selection, such as disruptive selection, itself sometimes promotes variation.

D. Diploidy and the Heterozygote
   1. Only alleles that cause phenotypic differences are subject to natural selection.
   2. In diploid organisms, a heterozygote shelters rare recessive alleles that would otherwise be selected out.
   3. Even when selection reduces the recessive allele frequency from 0.9 to 0.1, the frequency in the heterozygote remains the same and remains a resource for natural selection in a new environment.

E. Sickle-Cell Disease
   1. In sickle-cell disease, heterozygotes are more fit in malaria areas because the sickle-cell trait does not express unless the oxygen content of the environment is low; but the malaria agent causes red blood cells to die when it infects them (loss of potassium).
   2. Some homozygous dominants are maintained in the population but they die at an early age from sickle-cell disease.
   3. Some homozygotes are maintained in the population for normal red blood cells, but they are vulnerable to malaria.

18.3 Speciation

A. **Speciation** is the splitting of one species into two or more species or the transformation of one species into a new species over time; speciation is the final result of changes in gene pool allele and genotypic frequencies.

B. What is a Species?
   1. Linnaeus separated species based on morphology; simply, their traits differed..
   2. A **biological species** is a category whose members are *reproductively isolated* from all other such groups.
   3. **Gene flow** occurs between populations of one species but not between populations of different species.
   4. Biochemical genetics uses DNA hybridization techniques to determine relatedness of organisms; the **phylogenetic species concept** uses DNA/DNA comparisons.

C. Reproductive Isolating Mechanisms
   1. For two species to be separate, gene flow must not occur between them.
   2. A **reproductive isolating mechanism** is any structural, functional, or behavioral characteristic that prevents successful reproduction from occurring.
   3. **Prezygotic isolating mechanisms** are anatomical or behavioral differences between the members of two species that prevent mating or make it unlikely fertilization will take place if mating occurs.
      a. **Habitat isolation** occurs when two species occupy different habitats, even within the same geographic range, so that they are less likely to meet and to attempt to reproduce.
      b. **Temporal isolation** occurs when two species live in the same location, but each reproduces at a different time of year, and so they do not attempt to mate.
      c. **Behavioral isolation** results from differences in mating behavior between two species.
      d. **Mechanical isolation** is the result of differences between two species in reproductive structures or other body parts, so that mating is prevented.
      e. **Gamete isolation** includes incompatibility of gametes of two different species so they cannot fuse to form a zygote; an egg may have receptors only for the sperm of its own species or a plant stigma prevents completion of pollination.
   4. **Postzygotic isolating mechanisms** prevent development of a hybrid after mating has taken place.
      a. **Zygote mortality** is when **hybrids** (offspring of parents of two different species) do not live to reproduce.
      b. **Hybrid sterility** occurs when the hybrid offspring are sterile (e.g., mules).
      c. In **F_2 fitness**, the offspring are fertile but the F_2 generation is sterile.

D. Modes of Speciation
   1. **Allopatric speciation** occurs when new species result from populations being separated by a geographical barrier that prevents their members from reproducing with each other.
      a. First proposed by Ernst Mayr of Harvard University.
      b. While geographically isolated, variations accumulate until the populations are reproductively isolated.
      c. First postzygotic isolation occurs, then prezygotic reproductive isolation occurs.
   2. **Sympatric speciation** would occur when members of a single population develop a genetic difference (e.g., chromosome number) that prevents them from reproducing with the parent type.
      a. The main example of sympatric speciation is in plants.
      b. Failure to reduce chromosome number produces polyploid plants that reproduce successfully only with polyploids.
      c. Backcrosses with diploids are sterile.

E. Adaptive Radiation
   1. **Adaptive radiation** is a rapid development from a single ancestral species of many new species.
   2. The case of Darwin's finches illustrates the adaptive radiation of 13 species from one founder mainland finch.
   3. On the Hawaiian Islands, a wide variety of honeycreepers descended from one goldfinchlike ancestor.
   4. Hawaii is also the home of the silversword plants that radiated from ancestral tarweeds.