Evolutionary Mechanisms
• One misconception is that organisms evolve, in the Darwinian sense, during their lifetimes

• Natural selection acts on individuals, but only populations evolve

• Genetic variations in populations contribute to evolution
Concept 23.1: Mutation and sexual reproduction produce the genetic variation that makes evolution possible

- Two processes, mutation and sexual reproduction, produce the variation in gene pools that contributes to differences among individuals.
Genetic Variation

- Variation in individual genotype leads to variation in individual phenotype
- Not all phenotypic variation is heritable
- Natural selection can only act on variation with a genetic component
Mutation

- **Mutations** are changes in the nucleotide sequence of DNA
- Mutations cause new genes and alleles to arise
- Only mutations in cells that produce gametes can be passed to offspring
Sexual Reproduction

• Sexual reproduction can shuffle existing alleles into new combinations

• In organisms that reproduce sexually, recombination of alleles is more important than mutation in producing the genetic differences that make adaptation possible
Concept 23.2: The Hardy-Weinberg equation can be used to test whether a population is evolving

- The first step in testing whether evolution is occurring in a population is to clarify what we mean by a population
Gene Pools and Allele Frequencies

- A **population** is a localized group of individuals capable of interbreeding and producing fertile offspring.

- A **gene pool** consists of all the alleles for all loci in a population.
The frequency of an allele in a population can be calculated

- For diploid organisms, the total number of alleles at a locus is the total number of individuals x 2

- The total number of dominant alleles at a locus is 2 alleles for each homozygous dominant individual plus 1 allele for each heterozygous individual; the same logic applies for recessive alleles
• By convention, if there are 2 alleles at a locus, \( p \) and \( q \) are used to represent their frequencies.

• The frequency of all alleles in a population will add up to 1.
  
  – For example, \( p + q = 1 \)
The Hardy-Weinberg Principle

- The Hardy-Weinberg principle describes a population that is not evolving.
- If a population does not meet the criteria of the Hardy-Weinberg principle, it can be concluded that the population is evolving.
Hardy-Weinberg Equilibrium

- The **Hardy-Weinberg principle** states that frequencies of alleles and genotypes in a population remain constant from generation to generation.

- In a given population where gametes contribute to the next generation randomly, allele frequencies will not change.
Conditions for Hardy-Weinberg Equilibrium

• The Hardy-Weinberg theorem describes a hypothetical population

• In real populations, allele and genotype frequencies do change over time
• The five conditions for nonevolving populations are rarely met in nature:
  – No mutations
  – Random mating
  – No natural selection
  – Extremely large population size
  – No gene flow
Natural Selection

- Differential success in reproduction results in certain alleles being passed to the next generation in greater proportions.
Genetic Drift

- The smaller a sample, the greater the chance of deviation from a predicted result
- **Genetic drift** describes how allele frequencies fluctuate unpredictably from one generation to the next
Gene Flow

- **Gene flow** consists of the movement of alleles among populations

- Alleles can be transferred through the movement of fertile individuals or gametes (for example, pollen)

- Gene flow tends to reduce differences between populations over time

- Gene flow is more likely than mutation to alter allele frequencies directly
• Gene flow can decrease the fitness of a population

• In bent grass, alleles for copper tolerance are beneficial in populations near copper mines, but harmful to populations in other soils

• Windblown pollen moves these alleles between populations

• The movement of unfavorable alleles into a population results in a decrease in fit between organism and environment
Concept 23.4: Natural selection is the only mechanism that consistently causes adaptive evolution

• Only natural selection consistently results in adaptive evolution
A Closer Look at Natural Selection

- Natural selection brings about adaptive evolution by acting on an organism’s phenotype
Relative Fitness

• The phrases “struggle for existence” and “survival of the fittest” are misleading as they imply direct competition among individuals

• Reproductive success is generally more subtle and depends on many factors
• **Relative fitness** is the contribution an individual makes to the gene pool of the next generation, relative to the contributions of other individuals.

• Selection favors certain genotypes by acting on the phenotypes of certain organisms.
The Key Role of Natural Selection in Adaptive Evolution

- Natural selection increases the frequencies of alleles that enhance survival and reproduction

- Adaptive evolution occurs as the match between an organism and its environment increases
• Because the environment can change, adaptive evolution is a continuous process

• Genetic drift and gene flow do not consistently lead to adaptive evolution as they can increase or decrease the match between an organism and its environment
Sexual Selection

• **Sexual selection** is natural selection for mating success

• It can result in **sexual dimorphism**, marked differences between the sexes in secondary sexual characteristics