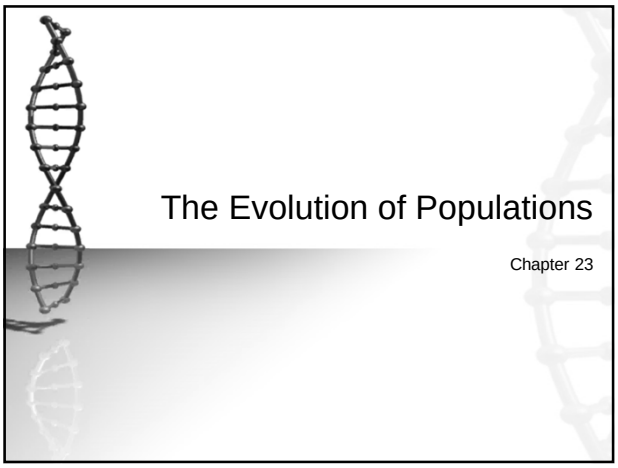

The Evolution of Populations

Chapter 23

- Objectives
  - Explain why the majority of point mutations are harmless.
  - Explain how sexual recombination generates genetic variability.
  - Define the terms population, species, gene pool, relative fitness, and neutral variation.
  - List the five conditions that must be met for a population to remain in Hardy-Weinberg equilibrium.
  - Apply the Hardy-Weinberg equation to a population genetics problem.

2

- Explain why natural selection is the only mechanism that consistently produces adaptive change.
- Explain the role of population size in genetic drift.
- Distinguish among the following sets of terms: directional, disruptive, and stabilizing selection; intrasexual and intersexual selection.
- List four reasons why natural selection cannot produce perfect organisms.

3

The Smallest Unit of Evolution

- One common misconception about evolution is that individual organisms evolve, in the Darwinian sense, during their lifetimes
- Natural selection acts on individuals, but populations evolve
- Genetic variations in populations contribute to evolution

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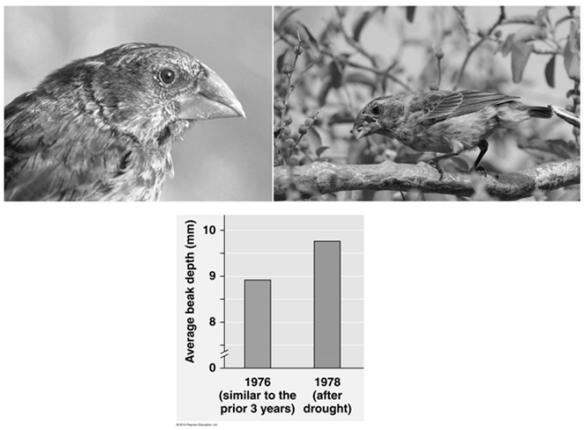

Population Genetics and The Modern Synthesis

- Microevolution is change in the genetic makeup of a population from generation to generation
- Population genetics provides a foundation for studying evolution
  - Population genetics is the study of how populations change genetically over time
    - Reconciled Darwin's and Mendel's ideas

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- The modern synthesis integrates Mendelian genetics with the Darwinian theory of evolution by natural selection
  - Focuses on populations as units of evolution

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Gene Pools and Allele Frequencies

- A population is a localized group of individuals that are capable of interbreeding and producing fertile offspring
- The gene pool is the total aggregate of genes in a population at any one time
  - Consists of all gene loci in all individuals of the population

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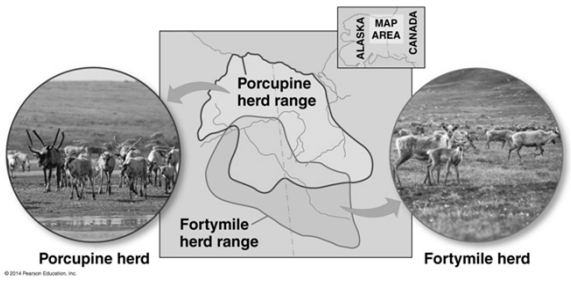

The Hardy-Weinberg Theorem

- The Hardy-Weinberg theorem describes a population that is not evolving
  - States that the frequencies of alleles and genotypes in a population's gene pool remain constant from generation to generation provided that only Mendelian segregation and recombination of alleles are at work
    - Mendelian inheritance preserves genetic variation in a population
      - In a given population where gametes contribute to the next generation randomly, allele frequencies will not change

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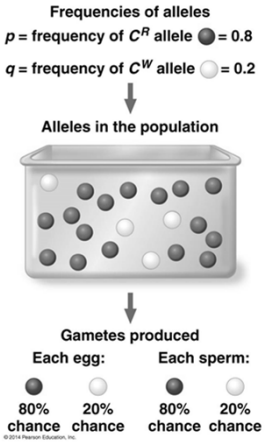

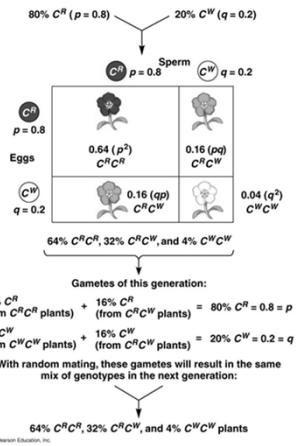

Hardy-Weinberg Equilibrium

- Hardy-Weinberg equilibrium:
  - Describes a population in which random mating occurs
  - Describes a population where allele frequencies do not change

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- If p and q represent the relative frequencies of the only two possible alleles in a population at a particular locus, then:
  - $p + q = 1$, and
  - $p^2 + 2pq + q^2 = 1$
    - p^2 and q^2 represent the frequencies of the homozygous genotypes and 2pq represents the frequency of the heterozygous genotype

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Conditions for Hardy-Weinberg Equilibrium

- The Hardy-Weinberg theorem describes a hypothetical population
  - Five conditions for non-evolving populations
    - Extremely large population size
      - infinitely large
    - No gene flow
      - no migration
    - No mutations
      - do not alter gene pool
    - Random mating
      - mates randomly selected
    - No natural selection
      - equal reproductive success

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- In real populations allele and genotype frequencies do change over time

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Population Genetics and Human Health

- We can use the Hardy-Weinberg equation to estimate the percentage of the human population carrying the allele for an inherited disease
  - example:
    - PKU occurs in 1 in 10000 babies (q^2=0.0001), then q=0.01, p=0.99 and 2pq=0.0198

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The Origin of Variation

- Two processes, mutation and sexual recombination, produce the variation in gene pools that contributes to differences among individuals

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Mutation

- Mutations are changes in the nucleotide sequence of DNA
  - Cause new genes and alleles to arise
- A point mutation is a change in one base in a gene
  - Can have a significant impact on phenotype
    - Is usually harmless, but may have an adaptive impact

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- Genetic variation can be measured as gene variability or nucleotide variability
  - For gene variability, average heterozygosity measures the average percent of loci that are heterozygous in a population
- Nucleotide variability is measured by comparing the DNA sequences of pairs of individuals
  - Nucleotide variation rarely results in phenotypic variation

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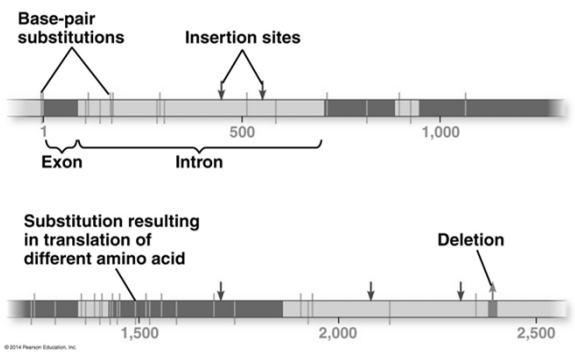

Mutations That Alter Gene Number or Sequence

- Chromosomal mutations that affect many loci are almost certain to be harmful
  - May be neutral and even beneficial
- Gene duplication duplicates chromosome segments

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Mutation Rates

- Mutation rates tend to be low in animals and plants
  - Average about one mutation in every 100,000 genes per generation
  - Are more rapid in microorganisms

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Sexual Recombination

- In sexually reproducing populations, sexual recombination is far more important than mutation in producing the genetic differences that make adaptation possible

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Changing Allele Frequencies

- Three major factors alter allele frequencies and bring about most evolutionary change
  - Natural selection
  - Genetic drift
  - Gene flow

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Natural Selection

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

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Genetic Drift

- Statistically, the smaller a sample the greater the chance of deviation from a predicted result
- Genetic drift describes how allele frequencies can fluctuate unpredictably from one generation to the next
  - Tends to reduce genetic variation

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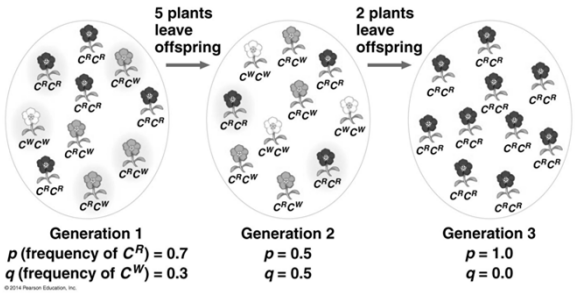

The Bottleneck Effect

- In the bottleneck effect a sudden change in the environment may drastically reduce the size of a population
  - The gene pool may no longer be reflective of the original population's gene pool
- Understanding the bottleneck effect can increase understanding of how human activity affects other species

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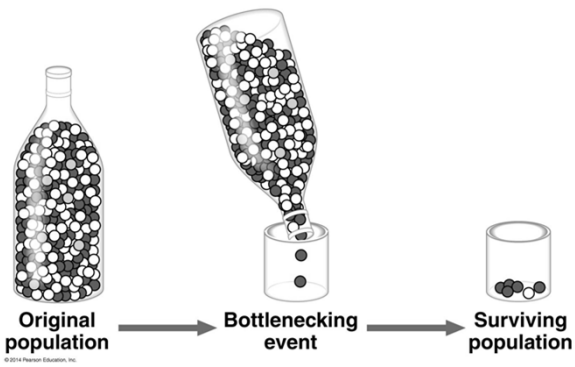

Greater prairie chicken

Range of greater prairie chicken

Pre-bottleneck (Illinois, 1820) Post-bottleneck (Illinois, 1993)

(a)

Location	Population size	Number of alleles per locus	Percentage of eggs hatched
Illinois			
1930–1960s	1,000–25,000	5.2	93
1993	<50	3.7	<50
Kansas, 1998 (no bottleneck)	750,000	5.8	99
Nebraska, 1998 (no bottleneck)	75,000–200,000	5.8	96

(b)

The Founder Effect

- The founder effect occurs when a few individuals become isolated from a larger population
  - Can affect allele frequencies in a population

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Gene Flow

- Gene flow causes a population to gain or lose alleles
  - Results from the movement of fertile individuals or gametes
  - Tends to reduce differences between populations over time

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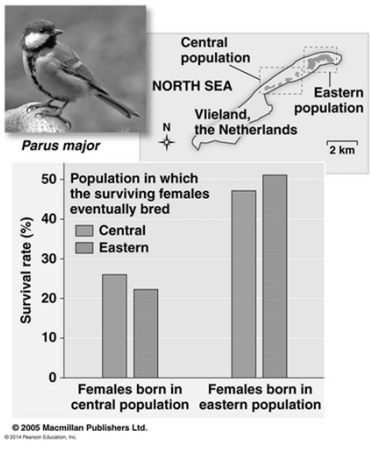

Natural Selection

- Natural selection is the primary mechanism of adaptive evolution
  - Natural selection accumulates and maintains favorable genotypes in a population

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Genetic Variation

- Genetic variation occurs in individuals in populations of all species
  - Is not always heritable

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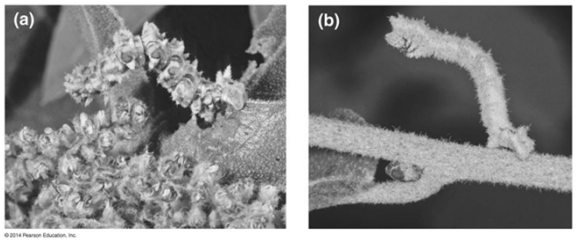

Variation Within a Population

- Both discrete and quantitative characters contribute to variation within a population
  - Discrete characters can be classified on an either-or basis
  - Quantitative characters vary along a continuum within a population

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Polymorphism

- Phenotypic polymorphism describes a population in which two or more distinct morphs for a character are each represented in high enough frequencies to be readily noticeable
- Genetic polymorphisms are the heritable components of characters that occur along a continuum in a population

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Measuring Genetic Variation

- Population geneticists measure the number of polymorphisms in a population by determining the amount of heterozygosity at the gene level and the molecular level
- Average heterozygosity measures the average percent of loci that are heterozygous in a population

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Variation Between Populations

- Most species exhibit geographic variation differences between gene pools of separate populations or population subgroups

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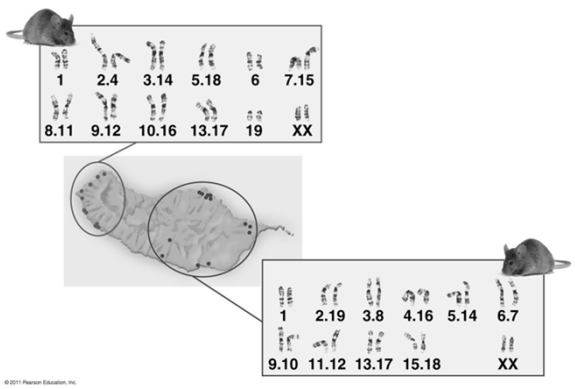

- Some examples of geographic variation occur as a cline, which is a graded change in a trait along a geographic axis

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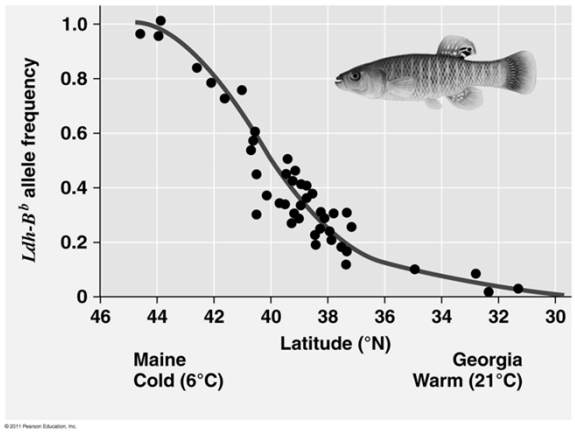

A Closer Look at Natural Selection

- From the range of variations available in a population natural selection increases the frequencies of certain genotypes, fitting organisms to their environment over generations

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Evolutionary Fitness

- The phrases “struggle for existence” and “survival of the fittest” are commonly used to describe natural selection
  - Can be misleading
- Reproductive success is generally more subtle and depends on many factors

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- Relative fitness is the contribution an individual makes to the gene pool of the next generation, relative to the contributions of other individuals
  - Relative fitness measures, indirectly, the contribution of a genotype to the next generation as compared to the contributions of alternative genotypes for the same locus

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Directional, Disruptive, and Stabilizing Selection

- Selection favors certain genotypes by acting on the phenotypes of certain organisms
- Three modes of selection are:
  - Directional
  - Disruptive
  - Stabilizing

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- Directional selection favors individuals at one end of the phenotypic range
- Disruptive selection favors individuals at both extremes of the phenotypic range
- Stabilizing selection favors intermediate variants and acts against extreme phenotypes

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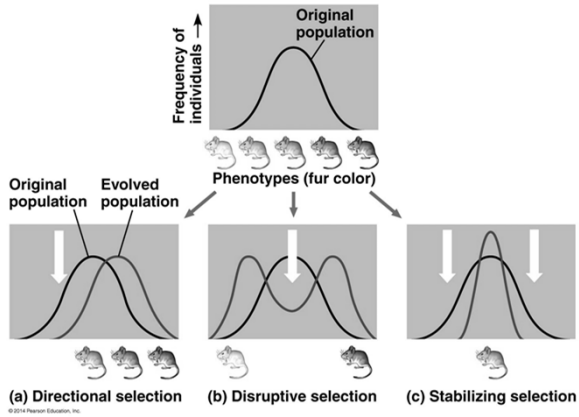

The Preservation of Genetic Variation

- Various mechanisms help to preserve genetic variation in a population including:
  - Diploidy
  - Balancing selection
  - Neutral variation

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Diploidy

- Diploidy maintains genetic variation in the form of hidden recessive alleles

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Balancing Selection

- Balancing selection occurs when natural selection maintains stable frequencies of two or more phenotypic forms in a population
  - Leads to a state called balanced polymorphism

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Heterozygote Advantage

- Some individuals who are heterozygous at a particular locus have greater fitness than homozygotes
  - Natural selection will tend to maintain two or more alleles at that locus
- The sickle-cell allele causes mutations in hemoglobin but also confers malaria resistance
  - Exemplifies the heterozygote advantage

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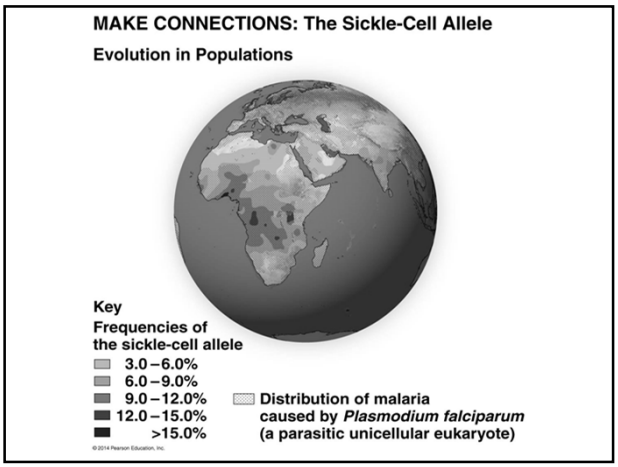

Frequency-Dependent Selection

- In frequency-dependent selection the fitness of any morph declines if it becomes too common in the population

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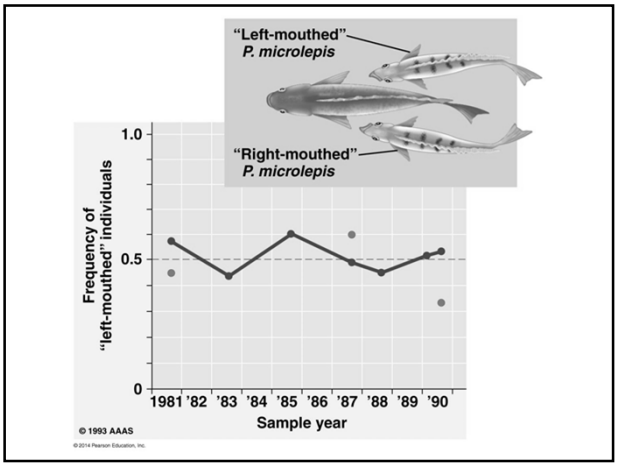

Neutral Variation

- Neutral variation is genetic variation that appears to confer no selective advantage

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Sexual Selection

- Sexual selection is natural selection for mating success
  - Can result in sexual dimorphism, marked differences between the sexes in secondary sexual characteristics
- Intrasexual selection is a direct competition among individuals of one sex for mates of the opposite sex

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- Intersexual selection occurs when individuals of one sex (usually females) are choosy in selecting their mates from individuals of the other sex
  - May depend on the showiness of the male's appearance

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The Evolutionary Enigma of Sexual Reproduction

- Sexual reproduction produces fewer reproductive offspring than asexual reproduction, a so-called reproductive handicap
- If sexual reproduction is a handicap, why has it persisted?
  - It produces genetic variation that may aid in disease resistance

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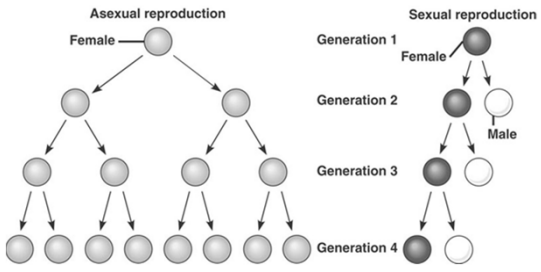

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Why Natural Selection Cannot Fashion Perfect Organisms

- Selection can only edit existing variations
- Evolution is limited by historical constraints
- Adaptations are often compromises
- Chance and natural selection interact

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