THE MODERN SYNTHESIS: DARWINISM MEETS GENETICS

- The **modern synthesis** is the fusion of
  - genetics with
  - evolutionary biology.

Populations as the Units of Evolution

- A population is
  - a group of individuals of the same species, living in the same place at the same time and
  - the smallest biological unit that can evolve.
- The total collection of alleles in a population at any one time is the **gene pool**.
- When the relative frequency of alleles changes over a number of generations, evolution is occurring on its smallest scale.

Genetic Variation in Populations

- Individual variation abounds in all species.
  - Not all variation in a population is heritable.
  - Only the genetic component of variation is relevant to natural selection.
- Variable traits in a population may be
  - polygenic, resulting from the combined effects of several genes, or
  - determined by a single gene.
- Polygenic traits tend to produce phenotypes that vary more or less continuously.
- Single-gene traits tend to produce only a few distinct phenotypes.

Sources of Genetic Variation

- Genetic variation results from processes that both involve randomness:
  - mutations, changes in the nucleotide sequence of DNA, and
  - sexual recombination, the shuffling of alleles during meiosis.

Sources of Genetic Variation

- For any given gene locus, mutation alone has little effect on a large population in a single generation.
- Organisms with very short generation spans, such as bacteria, can evolve rapidly with mutation as the only source of genetic variation.

Analyzing Gene Pools

- A gene pool
  - consists of all the alleles in a population at any one time and
  - is a reservoir from which the next generation draws its alleles.
- Alleles in a gene pool occur in certain frequencies.
- Alleles can be symbolized by
  - p for the relative frequency of the dominant allele in the population,
  - q for the frequency of the recessive allele in the population, and

  - $p + q = 1$.
- Note that if we know the frequency of either allele in the gene pool, we can subtract it from 1 to calculate the frequency of the other allele.
- Genotype frequencies can be calculated from allele frequencies (if the gene pool is stable = not evolving).
- The Hardy-Weinberg formula
  - $p^2 + 2pq + q^2 = 1$
  - can be used to calculate the frequencies of genotypes in a gene pool from the frequencies of alleles.

Population Genetics and Health Science

- The Hardy-Weinberg formula can be used to calculate the percentage of a human population that carries the allele for a particular inherited disease.

Population Genetics and Health Science

- PKU
  - is a recessive allele that prevents the breakdown of the amino acid phenylalanine and
  - occurs in about one out of every 10,000 babies born in the United States.
- People with PKU must strictly regulate their dietary intake of the amino acid phenylalanine.

Microevolution as Change in a Gene Pool

- How can we tell if a population is evolving?
- A non-evolving population is in genetic equilibrium, also known as **Hardy-Weinberg equilibrium**, meaning the population's gene pool is constant over time.
- From a genetic perspective, evolution can be defined as a generation-to-generation change in a population's frequencies of alleles, sometimes called **microevolution**.

MECHANISMS OF EVOLUTION

- The main causes of evolutionary change are
  - genetic drift,
  - gene flow, and
  - natural selection.
- Natural selection is the most important, because it is the only process that promotes adaptation.

Genetic Drift

- **Genetic drift** is a change in the gene pool of a small population due to chance.

The Bottleneck Effect

- The **bottleneck effect**

  - is an example of genetic drift and
  - results from a drastic reduction in population size.
- Passing through a "bottleneck," a severe reduction in population size,
  - decreases the overall genetic variability in a population because at least some alleles are lost from the gene pool, and
  - results in a loss of individual variation and hence adaptability.

- Cheetahs appear to have experienced at least two genetic bottlenecks:
  - during the last ice age, about 10,000 years ago, and
  - during the 1800s, when farmers hunted the animals to near extinction.
- With so little variability, cheetahs today have a reduced capacity to adapt to environmental challenges.

The Founder Effect

- The **founder effect** is likely when a few individuals colonize an isolated habitat.
- This represents genetic drift in a new colony.
- The founder effect explains the relatively high frequency of certain inherited disorders in some small human populations.

Gene Flow

- **Gene flow**
  - is another source of evolutionary change,
  - is separate from genetic drift,
  - is genetic exchange with another population,
  - may result in the gain or loss of alleles, and
  - tends to reduce genetic differences between populations.

Natural Selection: A Closer Look

- Of all causes of microevolution, only natural selection promotes adaptation.
- Evolutionary adaptation results from
  - chance, in the random generation of genetic variability, and
  - sorting, in the unequal reproductive success among the varying individuals.

Evolutionary Fitness

- **Relative fitness** is
  - the contribution an individual makes to the gene pool of the next generation
  - relative to the contributions of other individuals.

Three General Outcomes of Natural Selection

- If we graph the coat color of a population of mice, we get a bell-shaped curve.
- If natural selection favors certain fur-color phenotypes,

  - the populations of mice will change over the generations and
  - three general outcomes are possible.
- **Directional selection shifts the overall makeup of a population by selecting in favor of <u>one</u> extreme phenotype.**
- **Disruptive selection can lead to a balance between two or more contrasting phenotypic forms in a population by shifting the overall makeup of a population towards <u>both</u> extremes.**
- **Stabilizing selection favors intermediate phenotypes, occurs in relatively stable environments, and is the most common, and shifts the overall makeup of a population by selecting in favor of the <u>most central</u> phenotypic form.**

Sexual Selection

- **Sexual selection** is a form of natural selection in which individuals with certain traits are more likely than other individuals to obtain mates.
- **Sexual dimorphism** is a distinction in appearance between males and females not directly associated with reproduction or survival.