# Chapter 23- The Evolution of Populations

(Key Concepts are <u>Underlined</u>)

## Population Genetics

"Individuals are selected, but populations evolve."

- the advent of population genetics allowed Mendelism (genetic basis of inheritance) and Darwinism (natural selection) to be reconciled in the 1930's

<u>The modern evolutionary synthesis integrated Darwinian selection and Mendelian inheritance</u>

**Population genetics**- emphasizes genetic variation within populations and recognizes the importance of quantitative characters (e.g. polygenic inheritance)

<u>The genetic structure of a population is defined by its allele and genotype frequencies</u>

**Population**- localized group of individuals belonging to the same species (which normally interbreed)

**Species**- a group of populations whose individuals have the potential to interbreed and produce fertile offspring

**Gene pool**- total aggregate of genes in a population at any one time (diploid species have homologous loci which may be heterozygous or homozygous)

*Allelic frequency*- frequency of a particular allele in a population

**Genetic structure-** population's frequency of alleles and genotypes

<u>The Hardy-Weinberg theorem describes a nonevolving population</u>

**Hardy-Weinberg theorem (1908)-** frequencies of alleles and genotypes in a population's gene pool remain constant over the generations unless acted upon by agents other than sexual recombination

**Hardy-Weinberg equilibrium-** population's genetic structure is in a state of equilibrium

**Hardy-Weinberg equation-** enables us to calculate frequencies of alleles in a gene pool if we know frequencies of genotypes, and vice versa

| $p^2$ | + | $2pq$ | + | $q^2$ | $= 1$ |
|---|---|---|---|---|---|
| Frequency of homozygous dominant genotype | | Frequency of heterozygous genotype | | Frequency of homozygous recessive genotype | |

… and $p + q = 1$

Example:

1 in 10,000 babies born w/PKU (homozygous recessive or $q^2$) … so $q^2 = 1/10{,}000 = 0.0001$

$q = \sqrt{0.0001} = 0.01$, so if $p + q = 1$ then …

$p = 1 - q$

$p = 1 - 0.01$

$p = 0.99$

Frequency of carriers = $2pq = 2 \times 0.99 \times 0.01$

$= 0.0198$ (approximately 2%)

Conclusion: About 2% of the U.S. population carries the PKU allele (but them themselves are normal)

## Causes of Microevolution

<u>Microevolution is a generation-to-generation change in a population's allele or genotype frequencies</u>

*Evolution* redefined- generation-to-generation change in a population's frequencies of alleles or genotypes (a change in a population's genetic structure); a.k.a microevolution

Five conditions of Hardy-Weinberg equilibrium:

1) *Very large population size*- reduces genetic drift
2) *Isolation from other populations*- prevents gene flow
3) *No net mutations*- prevents alteration of gene pool
4) *Random mating*- required
5) *No natural selection*- prevents alteration of gene pool

1) **Genetic Drift-** changes in gene pool of a small population due to chance (nonadaptive)

   a) **The Bottleneck Effect-** the resulting genetic make-up of a *small surviving population* will exhibit less variability due to exaggerated genetic drift
   b) **The Founder Effect-** genetic drift in a *new colony* resulting in the overall reduction of genetic variability

2) **Gene Flow-** transfer of alleles between populations due to the movement of individuals or gametes (reduces differences between populations)

3) **Mutations-** Change in organism's DNA; source of genetic variation

4) **Nonrandom Mating-** inbreeding or assortative mating increases the number of homozygotes in a population

5) **Natural Selection-** differential survival and reproductive success alters the gene pool by favoring the transmission of some alleles at the expense of others (adapts populations to their environments by favoring genotypes adapted to changing environmental conditions); the degree of adaptation depends on the realm of the genetic variability present in a population

## Genetic Variation, The Substrate for Natural Selection

Genetic variation occurs within and between populations

- variation provides the raw material for natural selection
- only genotypic variation has evolutionary consequences (not phenotypic variation)

**Quantitative characters-** usually indicates polygenic inheritance

**Discrete characters-** usually coded by a single locus producing distinct phenotypes (either-or basis)

**Polymorphism-** when 2 or more forms of a *discrete character* represented in a population (contrasting forms called morphs)

- genetic variation in populations are commonly measured by the *percentage of gene loci represented by two or more alleles* and the *average percentage of heterozygous loci*

**Geographical variation-** differences in genetic structure between populations due to location (e.g. **cline-** a graded change in some trait along a geographic axis; e.g. altitude or latitude)

Mutation and sexual recombination generate genetic variation

- new alleles originate only by mutations, but only heritable mutations are passed on to offspring

*Point mutations*- probably relatively harmless in DNA due to the redundancy in the genetic code and many non-coding segments, though they are usually more harmful than beneficial when the protein is altered

*Chromosomal mutations* (or breakages)- rearrangements and duplications are rarely beneficial

- new genes may arise from the shuffling of exons within the genome

- mutations in microorganisms have a noticeable effect on a population's variation due to their short generation spans
- sexually reproducing populations genetically vary **primarily** due to the unique combinations resulting from the vast number of possible gamete pairings (as opposed to mutations)

<u>Diploidy and balanced polymorphism preserve variation</u>
*Diploidy*- recessive alleles being less favorable than their dominant counterparts can persist in a population via their propagation of heterozygotes
**Balanced polymorphism**- the ability of natural selection to maintain diversity in a population

1) **Heterozygote advantage-** when heterozygotes have a greater survivorship and reproductive success than homozygotes, 2 or more alleles will be maintained at that locus by natural selection (e.g. sickle-cell hets and hybrid vigor)
   **Hybrid vigor-** often times hybrids are more vigorous; probably due to segregation of harmful recessives and the heterozygote advantage at many of their loci
2) **Frequency-dependent selection**- reproductive success of any one morph declines if it becomes too common in the population (e.g. African swallowtail butterfly mimics- females mimic different noxious species of butterflies, as opposed to just one)

**Neutral variation**- genetic variation in populations which are seemingly trivial in their reproductive success (i.e. not affected by natural selection since they have no adaptive qualities); e.g. fingerprints, protein variation

## Natural Selection as the Mechanism of Adaptive Evolution

Evolutionary fitness is the relative contribution an individual makes to the gene pool of the next generation (a.k.a. **Darwinian fitness**)

**Relative fitness-** contribution of a genotype to the next generation compared to the contributions of alternative genotypes for the same locus

- survival and fertility determine an individual's evolutionary fitness
- natural selection acts on phenotypes, and genotypes indirectly
- the whole organism is subject to natural selection (the integrated composite of phenotypes), not its individual parts

The effect of selection on a varying characteristic can be stabilizing, directional, or diversifying

***** Most meaningful for quantitative traits (many gene loci)

**Stabilizing selection-** acts against extreme phenotypes and favors the more common intermediate variants

**Directional selection-** shifts the frequency curve for variations in some phenotypic character in one direction or the other (most common during environmental change)

**Diversifying selection-** favors individuals on both extremes of a phenotypic range over intermediate phenotypes (e.g. balanced polymorphism)

Sexual selection may lead to pronounced secondary differences between the sexes

**Sexual dimorphism-** distinction between the secondary sex characteristics of males and females (as opposed to reproductive organs)

**Sexual selection**- over generations, females shape the appearance of males and may play an active role in favoring genotypes contributing to healthy offspring

Natural selection cannot fashion perfect organisms

1) *Organisms are locked into historical constraints*- each species has a legacy of descent with modification from a long line of ancestral forms (e.g. our skeleton and musculature are not fully compatible with upright posture, as evidenced by frequent and chronic back pain)
2) *Adaptations are often compromises*- each organism must do many different things (e.g. in humans, structural reinforcement of limbs has been compromised for agility)
3) *Not all evolution is adaptive*- chance probably affects the genetic structure of populations (*genetic drift*) greater than we believe (i.e. the alleles within the gene pool of a small founding population may not be better suited to the environment)
4) *Selection can only edit variations that exist*- favors the fittest variations available at the time (may not be ideal)