General Biology: The Evolution Of Populations

AI-Generated Study Guide

(Based on lectures delivered by Dr. Ty C.M. Hoffman)

I. Defining Evolution and Populations
Evolution at the Population Level Evolution is defined as a change**Study Guide: The Evolution Of Populations**
I. Defining Evolution and Populations
Evolution at the Population Level Evolution is defined as a change in allele frequencies over time, across generations, from one generation to the next.
• **Individuals vs. Populations:** No individual evolves; individuals grow and develop during their lifetimes, but this is not evolution. Evolution is a process that occurs only within populations and requires reproduction. Evolution studied at this level is called **microevolution**.
Population Definition A population is a group of individuals of the same species in a specific, defined area, and there must be reproduction occurring within that group.
Allele Frequencies and Hardy-Weinberg An allele frequency is the fraction or percentage of the total number of alleles in the population that is a specific type (e.g., dominant or recessive).
• **Hardy-Weinberg Equilibrium:** If the allele frequencies (P and Q values) for a characteristic remain the same from one generation to the next, the population is in Hardy-Weinberg equilibrium and is not evolving for that characteristic.
• **Hardy-Weinberg Equations (for two alleles):**
1. **Allele Frequencies:** P+Q=1. P is the frequency of the dominant allele, and Q is the frequency of the recessive allele.
2. **Individual (Genotype) Frequencies:** P2+2PQ+Q2=1. P2 is the frequency of homozygous dominant individuals, Q2 is the frequency of homozygous recessive individuals, and 2PQ is the frequency of heterozygous individuals. The 2 in 2PQ accounts for the two ways an individual can become heterozygous (dominant from the mother/recessive from the father, or vice versa).

II. Variation and its Sources
Phenotypic Variation Phenotype is the actual trait (e.g., green-eyed), while genotype is the specific DNA version. Phenotypic variation exists among individuals in a population.
• **Polygenic Inheritance:** Characteristics that display traits along a **continuum** (a continuous range) are often caused by **polygenic inheritance**, meaning multiple different genes are involved, each contributing to the overall phenotype (e.g., horse coat color or human skin color).
Heritable vs. Non-Heritable Variation Evolution operates only on **heritable variation**—variation that gets inherited and passed on to the next generation via reproduction.

• **Environmental Influence (Nurture):** Not all phenotypic variation is determined by genetics (nature); environmental factors (nurture) can cause variation (e.g., a person becoming a bodybuilder, or caterpillars changing appearance based on diet). Environmental components of phenotypic variation cannot be selected for or against by natural selection.

The Source of New Alleles (Mutation) The original source of all genetic variation is **mutation**, which involves accidental changes in the DNA sequence.

• Mutations are random; they do not occur toward better or worse fitness.

• **DNA to Trait Process:** DNA indirectly codes for traits. The sequence is **transcribed** into RNA, and the messenger RNA (mRNA) is **translated** by ribosomes into a polypeptide, which folds into the **protein** that directly determines the trait.

Reasons Mutations Might Not Affect Phenotype A mutation (a change in DNA) does not necessarily lead to a change in phenotype (trait) or protein function for several reasons:

1. **Non-Coding Regions:** The vast majority of DNA (about 99% in humans) lies between genes and does not code for RNA. A random mutation is likely to occur in these non-coding regions, having no effect on gene expression.
2. **Introns:** In eukaryotes, genes contain **introns** (intervening sequences) and **exons** (expressed regions). Introns are cut out of the pre-mRNA during post-transcriptional modification. A mutation in an intron will not affect the final mRNA sequence that is translated into protein.
3. **Redundancy of the Genetic Code (Silent Mutation):** The genetic code uses sequences of three mRNA nucleotides (**codons**) to specify the 20 types of amino acids. Because 64 possible codons exist (more than the 20 needed), the code is **redundant** (multiple codons can specify the same amino acid). A mutation that changes a codon but still results in the same amino acid being used is a **silent mutation** and does not change the resulting protein or phenotype.
4. **Neutral Effects:** Even if a mutation changes a single amino acid, the overall function of the protein might remain largely unchanged, making the mutation neutral.

III. Mechanisms of Evolution

Evolution (a change in allele frequencies) is caused by three major mechanisms.

A. Natural Selection (NS)

Natural selection is the mechanism that scientifically explains how evolution occurs. Natural selection reliably leads to the **increase in adaptation** of a population across generations because it favors traits that work well in a given environment (the selection pressures).

Modes of Natural Selection Natural selection can occur in three distinct modes:

1. **Directional Selection:** Favors one extreme phenotype, causing the phenotypic average to shift in that direction (e.g., favoring darker coats).
2. **Disruptive Selection:** Disfavors the intermediate phenotype, leading to an increase in the frequency of **both** extreme phenotypes, making the population's trait distribution bimodal (two humps).
3. **Stabilizing Selection:** Reinforces and favors the intermediate phenotype, leading to an even higher frequency of the average trait and lower frequencies of the extreme traits.

Special Cases of Natural Selection

• **Sexual Selection:** A form of natural selection driven by **mate choice**. Because successful reproduction is required for evolution, traits preferred by mates—even if they are **maladaptive** for survival (e.g., a massive peacock tail or a loud frog call)—can be favored and passed on.
• **Heterozygote Advantage:** Occurs when the heterozygous genotype is more fit or better adapted than both the homozygous dominant and homozygous recessive genotypes. The classic example is the sickle cell allele, where heterozygotes do not have the disease but gain resistance to malaria in malaria-prone regions.
• **Frequency Dependent Selection:** The fitness of a trait depends on how common (frequent) it is in the population. In the example of sidemouthed fish, prey learn to avoid attacks from the side most commonly used by the majority of predators, favoring the rare (minority) predator phenotype, leading to a constant cycle where the majority and minority phenotypes swap advantages.

B. Genetic Drift (GD)

Genetic drift is a random occurrence where an environmental event eliminates individuals and their alleles from the gene pool.
• Genetic drift causes evolution (changes allele frequencies) but is random and has **nothing to do with fitness or adaptation**; therefore, it does not reliably lead to better adaptation.

Subtypes of Genetic Drift:

1. **Founder Effect:** A small number of individuals separate from the original population (e.g., being blown off course during migration) and become the sole founders of a new population. The new population's genetic makeup is determined entirely by the random traits of these few founders.
2. **Bottleneck Effect:** A drastic random event (e.g., earthquake, human activity) kills most of the population, leaving only a small number of survivors (the bottleneck). The traits of the survivors determine the traits of future generations, often reducing genetic variability in the population.

C. Gene Flow (GF)

Gene flow refers to the movement of alleles **into or out of** a population, typically through the migration of individuals between populations of the same species.
• Gene flow causes evolution by adding or subtracting alleles, changing P and Q values.
• Like genetic drift, gene flow **does not reliably increase** overall fitness, as migrating individuals may introduce traits that are maladaptive in the new environment. Gene flow can sometimes counteract the adaptive progress caused by natural selection.

IV. Constraints on Natural Selection

Natural selection leads to increased adaptation but does not result in perfection for several reasons:

1. **Environmental Change:** Natural selection only reliably increases adaptation if the environment (living conditions) stays the same. Since real environments constantly change, what was favorable one generation might become unfavorable in the next, disrupting the drive toward perfection.
2. **Tradeoffs and Conflicting Forces:** Natural selection involves tradeoffs; for example, traits that increase reproductive success (like a loud mating call) may decrease survivability.

3. **Operating on Existing Variation:** Natural selection does not design an optimal organism from scratch; it only operates by making small changes to the heritable traits already present in the population from the previous generation.