Lecture Outline: The Evolution Of Populations

I. **Evolution and Populations (Microevolution)**

A. Defining Evolution and Individuals/Populations

1. Individuals do not evolve; they change (grow, develop) during their lifetimes, but this is not evolution.
2. Evolution occurs between generations and requires reproduction.
3. Only populations evolve.

B. Definition of a Population

1. A population is a group of individuals of the same species.
2. They occur in some defined area.
3. There must be reproduction within the population.
4. Distinct populations of the same species can overlap geographically but remain separate if they choose not to interbreed.

C. Definition of Evolution

1. Evolution, at the population level, is defined as a change in allele frequencies over time (over generations).
2. Evolution at the population level is also called **microevolution**.

D. Allele Frequencies

1. An allele frequency is the fraction of the total number of alleles in the population that is a specific type.
2. Allele frequency is measured for the entire populationâ€™s allele pool.
3. If the frequency of the dominant allele (P) or the recessive allele (Q) changes from one generation to the next, evolution has occurred.

E. Example of Evolution in Finches

1. Evolution can happen in a single generation.
2. A drought caused the birds to rely on older, tougher seeds.
3. Individuals with larger bills (a broader bill) were favored (selected for) because they could crack the tougher seeds.
4. This survival advantage led to the passing on of the larger bill trait, causing a measurable increase in bill depth for the population within two generations.

II. **Genetic Variation and Inheritance**

A. Phenotypic Variation

1. A phenotype is the actual trait in words (e.g., blue-eyed).

2. Phenotypic variation exists among individuals within any real population.

B. Types of Inheritance Patterns
   1. Simple Mendelian cases involve two alleles and distinct traits.
   2. Some characteristics (like coat color in horses or human skin color) show traits that occur on a continuum (a continuous range).
   3. Continuous variation is usually an indication of **polygenic inheritance** (multiple different genes are involved, each contributing to the overall phenotype).

C. Heritable Variation
   1. Evolution only operates on **heritable variation** (variation that is passed on to the next generation via reproduction).
   2. Changes during a lifetime that are not defined by genes (e.g., a bodybuilder physique) are not heritable and do not affect evolution.

D. DNA and Phenotype
   1. DNA is the substance physically inherited from parent to offspring; it indirectly codes for traits.
   2. Proteins directly determine the traits (phenotype).
   3. Protein synthesis involves two major steps starting with DNA:
      1. Transcription (DNA code transferred to RNA).
      2. Translation (ribosome reads messenger RNA (mRNA) to assemble the polypeptide/protein).

III. **Sources of Genetic Variation (Mutation)**

A. Mutation is the original source of all genetic variation.

B. Mutations are accidental (random) changes in the DNA sequence (nucleotide sequence).

C. Mutations do not happen in a certain direction toward better or worse fitness.

D. Reasons a Mutation May Not Change Phenotype
   1. It occurs in non-coding regions: Only about 1% of overall DNA sequences are genes (coding regions); the vast majority are non-coding regions between genes.
   2. It occurs in an intron: In eukaryotes, transcription produces pre-mRNA which contains introns and exons.
      1. Introns (intervening sequences) are cut out during post-transcriptional modification (splicing) and do not affect the final mRNA sequence used in translation.
   3. It results in a **silent mutation** due to the redundancy of the genetic code.
      1. In translation, a sequence of three mRNA nucleotides (a **codon**) specifies one amino acid.
      2. Since there are 64 possible codons but only 20 amino acids used, the code is **redundant** (multiple codons specify the same amino acid).

3. If a mutation changes a codon into a different codon that still specifies the same amino acid, the protein remains unchanged, and the phenotype is unaffected.

E. Effects of Mutations that Change the Protein
   1. A single amino acid change in a protein may be neutral or drastically affect protein function.
   2. Mutations leading to beneficial proteins are favored by natural selection, improving population adaptation over time.

IV. **Phenotypic Variation: Environmental Influence**
   A. Not all phenotypic variation is genetic (DNA).
   B. The popular phrase **nature versus nurture** addresses the two components of variation:
      1. Nature refers to heritable DNA.
      2. Nurture refers to the environmental component (e.g., diet or exposure).
   C. The environmental component of phenotypic variation cannot be operated on by natural selection.

V. **Hardy-Weinberg Principle Review**
   A. The mathematical model can be used to test whether a population is evolving for a specific gene.
   B. Allele Frequency Equation: $$ P + Q = 1 $$
      1. P represents the allele frequency for the dominant allele.
      2. Q represents the allele frequency for the recessive allele.
   C. Genotype Frequency Equation: $$ P^2 + 2PQ + Q^2 = 1 $$
      1. P^2 is the frequency of homozygous dominant individuals.
      2. Q^2 is the frequency of homozygous recessive individuals.
      3. $2PQ$ is the frequency of heterozygous individuals.
         1. The 2 factor exists because there are two ways to inherit the heterozygous genotype.
   D. If P and Q values remain the same from one generation to the next, the population is in **Hardy-Weinberg equilibrium** (not evolving for that characteristic).

VI. **Three Mechanisms of Evolution**
   A. The three major mechanisms that cause evolution are:
      1. Natural Selection
      2. Genetic Drift
      3. Gene Flow
   B. Genetic Drift
      1. Genetic drift is a random occurrence where an event causes the elimination of some alleles from the allele pool.
      2. The elimination is random and has nothing to do with the fitness or adaptiveness of the

eliminated individuals.

3. It causes evolution by changing allele frequencies but does not reliably lead to better adaptation.
4. Genetic drift tends to reduce genetic variability in the population.
5. Subcategories of Genetic Drift:
    1. The **Founder Effect**: A small number of individuals are separated from the original population and become the founders of a new population.
    2. The **Bottleneck Effect**: A drastic random event leaves only a small number of survivors, whose traits determine the future population characteristics.

C. Gene Flow

1. Gene flow refers to the movement of alleles into or out of a population (e.g., migration).
2. It causes evolution because adding or subtracting alleles changes the overall allele pool frequencies.
3. Gene flow does not reliably increase overall fitness.

D. Comparison of Mechanisms

1. Natural selection is the **only** mechanism that reliably increases the adaptation of the population as a whole from generation to generation.
2. Gene flow can counteract natural selection, especially if the flow of maladaptive alleles into a population is frequent.

VII. **Natural Selection Subcategories and Related Concepts**

A. Three Ways Natural Selection Operates (Defined by their effect on phenotypic distribution in a bell curve):

1. **Directional Selection**: Favors one extreme phenotype, shifting the population distribution in that direction.
2. **Disruptive Selection**: Disfavors the intermediate phenotype and favors both extremes, leading to a bimodal (two-humped) distribution.
3. **Stabilizing Selection**: Reinforces the advantage of the intermediate phenotype, increasing its frequency and reducing the frequency of the extremes.

B. Sexual Selection

1. Sexual selection is a specialized form of natural selection based on mate choice.
2. It can favor traits that are otherwise **maladaptive** in terms of survival (e.g., a large peacock tail that makes the animal visible to predators).
3. These traits are favored because they increase the chance of successful reproduction, which is required for evolution.

C. Heterozygote Advantage

1. The **heterozygote advantage** occurs when heterozygous individuals have a greater fitness

than either homozygous type under specific conditions.

2. Example: Sickle Cell Disease (caused by the homozygous recessive genotype) in areas with high malaria risk.
    1. Heterozygous individuals are protected from the severe symptoms of sickle cell disease.
    2. The presence of the abnormal hemoglobin (from the mutant allele) makes heterozygotes less susceptible to malarial infection.
    3. This maintains the otherwise maladaptive mutant allele in the population because heterozygotes have the highest overall survivability.

D. Frequency Dependent Selection
    1. The fitness of a particular phenotype depends on how common it is in the population.
    2. Example: Side-mouthed predator fish.
        1. Prey fish learn to anticipate attacks from the majority mouth direction (left or right).
        2. The minority mouth type is then favored because it catches the prey off guard.
        3. This process leads to the favored trait alternating between generations (oscillating frequencies).

VIII. **Constraints on Natural Selection**

A. Evolution is not a clean process; there are conflicting forces at play (e.g., trade-offs between traits that enhance survival and traits that enhance reproduction).

B. Natural selection never leads to a perfectly adapted population for two main reasons:
    1. Environments constantly change, disrupting adaptation.
    2. Natural selection can only operate on what variation is already present; it cannot design an organism from scratch.