## HARDY - WEINBERG PRINCIPLE

In a given population, one can assess the frequency of alleles for a specific gene or locus. This frequency is assumed to remain consistent and unchanged across generations.

This principle asserts that allele frequencies within a randomly interbreeding population remain stable and consistent over time. The gene pool, comprising all genes and their alleles within a population, remains constant. This state is termed genetic equilibrium, where the sum total of allelic frequencies equals 1.

The equation representing this equilibrium is: $p + q = 1$

Where:

- p represents the frequency of the dominant allele (A)
- q represents the frequency of the recessive allele (a)

The binomial expansion of this equation is as follows:

$$p^2 + 2pq + q^2 = 1$$

Where:

- $p^2$ indicates the frequency of individuals with the genotype AA
- $q^2$ indicates the frequency of individuals with the genotype aa
- 2pq indicates the frequency of individuals with the genotype Aa

When the measured frequency differs from the expected values, the variance (direction) indicates the degree of evolutionary change. Any disturbance in the genetic equilibrium of the Hardy-Weinberg equilibrium, characterized by changes in allele frequencies within a population, may be interpreted as resulting in evolution.

Five factors are recognized to influence the Hardy-Weinberg equilibrium:

1) Gene migration or gene flow
2) Genetic drift
3) Mutation
4) Genetic recombination
5) Natural selection

### (1) Migration

Migration, in genetic terms, refers to the movement of individuals from one population to another, which can significantly impact the genetic stability of natural populations. The process of alleles moving from one population to another is termed gene migration. This can happen through:

(a) Migration of a portion of the population from one geographical area to another.

(b) Interbreeding between members of two distinct populations, leading to the exchange of alleles. If the traits of the newcomers differ from those already present, the genetic makeup of the receiving population may change, provided the newcomers can adapt to the new environment and successfully reproduce.

**Gene Pool:** The complete collection of all genes and their alleles present within a population is known as the gene pool. Therefore, the gene pool encompasses all possible genotypes, representing the genetic diversity of the organisms within the population.

**Gene Flow:** When genes are exchanged between two different populations of the same species on multiple occasions, resulting in a more uniform or homogeneous population, it is referred to as gene flow.

### (2) Genetic Drift / Sewall Wright Effect / Non-directional Factor

Natural selection is not the sole force driving changes in gene frequencies; chance, or Genetic Drift, also plays a significant role.

Genetic Drift leads to changes in gene frequency by chance within small populations. In a small population, individual alleles of a gene are represented by only a few individuals. If these individuals fail to reproduce, the alleles they carry may be lost, causing allele frequencies to appear to change randomly. This phenomenon, akin to the drifting of frequencies, is termed Genetic Drift. A series of small, isolated populations may diverge significantly as a result of Genetic Drift.

Genetic Drift manifests in two key forms:

(a) Bottleneck Effect:

This refers to the reduction in genetic variability within a population. For instance, the cheetah population in Africa has dwindled due to hunting, leading to decreased genetic diversity among cheetahs. Consequently, the current cheetah population is vulnerable to various deadly diseases. Should any of these diseases strike, the path towards cheetah extinction may become irreversible.

(b) Founder's Effect:

When one or a few individuals disperse and establish a new, isolated population some distance from their original habitat, the alleles they carry assume special significance. Even if these alleles are rare in the source population, they become a significant portion of the new population's genetic makeup. This phenomenon, wherein rare alleles and allele combinations may be amplified in new populations, is termed the founder's effect. This effect holds particular importance in the evolution of organisms on islands, such as the Galapagos Islands visited by Darwin. Many species found in such regions likely originated from one or a few initial founders.

### Fixation of New Mutations

Genetic drift plays a crucial role in the fixation of new alleles, which are genes that emerge through mutation, within a population. Over time, genetic drift can lead to the elimination of the original gene variants, thereby altering the genetic composition of small populations.

### (3) Mutation

(i) Mutations occur randomly and are not influenced by the adaptive needs of organisms.

(ii) The majority of mutations are either harmful or have a neutral effect on the organism.

(iii) Mutation rates are typically slow, leading to gradual changes in genetic makeup over time.

(iv) The Replica Plate experiment conducted by Lederberg and Lederberg demonstrated that mutations exist beforehand and are not necessarily a response to environmental pressures.

### (4) Genetic Recombination

During the formation of gametes (sperm or ovum), alleles from parental chromosomes separate and recombine to form new combinations. This process, known as genetic recombination, occurs primarily through crossing over during meiosis. The resulting offspring display novel combinations of traits and are referred to as recombinants.

### (5) Natural Selection

Natural selection favors heritable variations that enhance an organism's survival and reproductive success. This process leads to changes in allelic frequencies within populations. However, natural selection can have various effects on traits, including stabilizing, directional, or disruptive effects, depending on the environmental pressures and selective forces acting on the population.