SYNTHETIC THEORY OF EVOLUTION or **NEODARWINISM**

- Darwin failed to explain the mechanism by which these variations could appear.
- Weismann's continuity of germplasm and Mendel's postulates of inheritance helped to a large extent understanding the inheritance of variations.
- De Vries' mutational theory accounts for the origin of variations. Neo-Darwinists like **T. H. Huxley, A. Weismann, E. Haeckel and G.G. Simpson** supported the natural selection. Later **J.B.S. Haldane, R.A. Fisher, Sewall Wright, H.J. Muller, Ernst Mayr and G.L. Stebbins** are responsible for the understanding of modern synthesis neo-Darwinism.

I. Hardy - Weinberg equilibrium :

- To understand the Hardy-Weinberg equilibrium gene pool, allelic frequency and genotypic frequencies are to be known.
- 1. **Gene pool** : It is the sum of all genes present in a sexually reproducing population during a given generation or a period.
- 2. **Allelic frequency :** It is the frequency of any allele in the total alleles of that population.
- 3. **Genotypic frequency :** It is the frequency of any genotype in the population.
- Hardy-Weinberg is concerned with the frequency of genes in a population of sexually reproducing diploid individuals.
- The frequency of dominant and recessive alleles in a population will remain constant from generation to generation provided certain conditions exist. These are:
  1. The population is large.
  2. Mating is random *(panmictic).*
  3. No change in allelic frequency due to mutations or large scale migrations.
  4. All genotypes are equally fertile so that no selection occurs.
  5. Generations do not overlap.
- Any change in one or more of these conditions will result in a change in allelic and genotypic frequencies.
- Changes in gene frequencies are significant in producing variations, which are the basis of evolution.
- **The basic principles of Hardy Weinberg equilibrium :**

1. Equilibrium of allelic frequency:

In a diploid population the frequency of alleles at an autosomal locus will not change from generation to generation. Ratio of dominant and recessive allelic frequencies will remain constant.

2. Genotypic frequencies: in a population genotypic frequencies are determined by allelic frequencies in a predictable way.

3. The equilibrium is neutral: If the equilibrium is disturbed, it will be re-established within one generation of random mating at the new frequencies.

- A mathematical model was developed independently by **Godfrey H. Hardy** of U.K. and **Wilhelni Weinberg** of Germany to explain the genetic equilibrium in a population.
- In a stable population for a gene with two alleles where 'A' is a dominant allele and 'a' is a recessive allele, three possible genotypes are AA, Aa and aa.
- If the frequency of occurrence of'A' is 'p^r and 'a' is 'q', then the frequency of occurence of AA, Aa and aa can be expressed by equation $p^2+2pq+q^2 = 1$ or $(p+q)^2 = 1$.
- Its major application is the calculation of dominant allelic frequency 'p' and the recessive allelic frequency 'q'

In mathematical terms p + q = I .

Therefore $(p + q)^{:} = 1$.

$p^2 + 2pq + q^2 = 1$ is the binomial expansion of that equation i.e. $(p + q)^2 = 1$

p = dominant allelic frequency

q = recessive allelic frequency

p^2 = homozygous dominant genotype frequency

2pq = heterozygous dominant genotype frequency

q^2 = recessive genotype frequency

Calculation of allelic frequencies :

The examples are given for better clarity of the Hardy weiberg equilibrium.

Example 1 :

Assume in the population of 1600, 256 individuals are recessive.

The recessive genotypic frequency = q^2

$= \frac{\text{no.of recessive individuals}}{\text{total no.of individuals in the population}}$

$= \frac{256}{1600} = 0.16$

There fore $q = \sqrt{q^2} = \sqrt{0.16} = 0.4$

Then $p = (1 - q) = (1 - 0.4) = 0.6$

The heterozygous genotypic frequency = $2pq = 2 \times 0.6 \times 0.4 = 0.48$

The heterozygous individuals in the population $= 0.48 \times 1600 = 768$

The homozygous dominant genotypic frequency=$p^2 = 0.6 \times 0.6 = 0.36$

Then homozygous dominant individuals in the population = $0.36 \times 1600 = 576$.

II. Forces of evolution :

A. Forces responsible for changes in allelic frequencies and genotypic frequencies :

- The following factors are responsible for changes in allelic frequencies and genotypic frequencies in populations.

Natural Selection :

- Organisms which are physically, physiologically and behaviourally better adapted to the environment are selected. They survive and reproduce.
- The organisms which are not so well adapted either fail to reproduce or die. Selection is an operative process.
- They that occurs in a population whenever there is differential reproductive success of individuals. A measure of the reproductive success is the **fitness or adaptive value** of a genotype.
- A genotype that leaves more fertile offspring has higher fitness when compared to others. Selections are three types.

a. Stabilising selection (centripetal selection):

- This selection operates in a stable environment. in this process extreme individuals from the two ends of the phenotypic distribution are eliminated.
- The organisms which are in the average of the phenotypic distribution are preserved. Stabilising selection does not promote evolutionary change that leads to speciation, but tends to maintain phenotypic stability within the population over generations.
- Hence, over a time the same average value of the phenotypic distribution in the population is maintained.
- It removes deleterious genotypes from the population, for which reproductive success is zero.
- Eg. In England, weights of babies I a large sample were taken. It was found that greater mortality in the babies was when the weight was greater or lesser than the average weight 8 lbs.

b. Directional selection: This selection operates in response to gradual changes in environmental conditions.

- **Directional selection works by constantly removing individuals from one end of the phenotypic distribution.**
- Therefore mean value of fitness is constantly shifting towards the other end of the phenotypic distribution. In the case of the long-necked giraffes the mean value of the neck is shifting towards the long-neck.
- Once the mean value of phenotype coincides with the new optimum environmental conditions, stabilising selection will take over.

Eg. In the case of giraffe the long-neck is stabilised due to stabilizing selection. The development of

- resistance to DDT by mosquitoes is another example for the directional selection.

c. Disruptive selection: (centrifugal selection):
It is the rarest form of selection, but very important in bringing about evolutionary change.

- Fluctuating conditions within an environment (heterogenous environment) increases the competition. As a result of increased competition, selection pressure acting within the population may push the phenotypes away from the population mean towards the ends of the population.
- This can split the population into two or more subpopulations, called **species populations.** If the gene flow between the populations is prevented, each population may give rise to a new species. It is also called **adaptive radiation.**

- **Eg.** In California the sunflower population was divided into two subpopulations. One subpopulation was adapted to dry area and the other was adapted to wet area over a period of 12 years.

ii. Gene flow :

- Gene flow is the movement of alleles from one population to another because of the interbreeding between members of the two populations.
- The random introduction of alleles into the recipient population and their removal from donor population affect the allelic frequencies of both populations.

iii. Genetic load :

- **The existence of deleterious genes within the populations is called genetic load.** e.g. A single pair of alleles is involved in the highly fatal sickle cell disease. Those homozygous for sickle cell usually die early due to anaemia.
- Those heterozygous to these alleles live reasonably healthy but perpectuate the disadvantageous gene.
- This heterozygous condition, some times, is found beneficial, i.e. If malaria is endemic in the areas where this deleterious gene is prevalent in the population, only normal individuals suffer from the disease.
- The heterozygous individual with sickle celled RBC exhibit resistance to malaria. Recessive mutations which are disadvantageous also lead to genetic load.

iv. Genetic drift :

- The variations that occur by **chance** in a small population can also cause deviations from Hardy- Weinberg equilibrium. Any deviation due to chance variations is called **random genetic drift** or **Sewall Wright effect**. Chance plays an important role in genetic drift.
- Suppose in a population only one individual is phenotypically recessive. If accidental death (chance event) occurs to that organism prior to reproduction, it results in the elimination of that allele from the population.
- Suppose, for a gene there are two alleles and the allelic frequency of a particular type is 1% (q = 0.01). In one million alleles of a population ten thousand alleles are of that type.
- In 100, only one allele is of that type. So, the probability of losing that allele from a small population by chance is more.
- The end result is either **fixation** (p or q = 1) or **loss** (p or q = 0) of an allele.
- The probability of reaching the end point (fixation for loss) depends on the size of the population.
- **Founder effect** is one form of genetic drift. **It is the derivation of a new population from a small isolated group of individuals (founders) that is genetically different from the parent population.**
- The allelic frequencies of the new population are similar to the founders rather than to the ancestral parent population.
- Eg. Human populations founded on pitcarian island is a good example of founder effect.
- Pitcarian island population is resulted from the small numbers of founders of Caucasian and Polynesian individuals.
- The gene frequencies in the population of Pitcairn island is neither similar to the Caucasian parent population nor the Polynesian parent population, but similar to the founders of Pitcairn islands.
- **Bottleneck effect** is another form of genetic drift. Bottlenecks are the natural calamities like earthquakes, volcanic eruptions, floods etc.
- After the bottlenecks the parents of the next generation have been reduced to a small number and may be genetically different from the original population.
- A genetically different population, from the parent population, may arise from these individuals that are left after bottlenecks.
- Eg. Polydactylic dwarf individuals are more in Old Order Amish population of Lancaster in USA. This phenotype is a recessive type.
- Both homozygous (recessive) and heterozygous (carriers) genotypes are non-adaptive.
- The only reason for the increased frequency of this phenotype in this population is founding bottleneck.
- Genetic drift tends to *"reduce"* the amount of genetic variation with in the population mainly by removing the alleles, which have low frequency.

v. Change in mutation rate :

- Many evolutionary changes occur due to the appearance of new alleles and the source of this is the **mutation.**

- Mutations occur at random. **Mutation rate is expressed as the number of new mutant alleles per given number of gametes.**
- However new alleles produced by mutations have negligible influence, in the absence of other forces like Natural selection.

B. Factors responsible for changes in genotypic frequencies without change in allelic frequencies :

i. Sexual recombination :

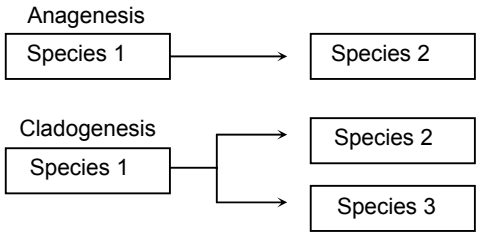
- Crossing-over or independent segregation during meiosis followed by random fertilization are referred to as **sexual recombination** and they account for **gene reshuffling.**

ii. Assortative mating or Nonrandom mating Assortative mating is the nonrandom or preferential mating between males and females of a species.

- Deviation from random mating alters genotypic frequencies, but not the allelic frequencies.

SPECIATION :

- Speciation is a process in which one species evolves into a different species, which is called anagenesis or **phyletic evolution.**
- On the other hand if one species diverges to become two or more species, it is called **cladogenesis.**



- **Allopatric speciation** is characterised by the occurrence of spatial separation by geographical barriers. Geographical barriers such as mountain ranges, seas, rivers etc. many produce a barrier to interbreeding of populations leading to reproductive isolation and the evolution of new species

- **Sympatric** speciation is the process of speciation in which organisms live in the same habitat, theoritically capable of interbreeding, do not interbread because of differences in behavioural, structural, physiological reproductive mechanisms. Reproductive isolating mechanisms evolve within the range and habitat of the parent species.