**Topic: The Hardy-Weinberg Theorem**

 In 1908, English mathematician Godfrey Hardy and German physician Wilhelm Weinberg independently derived a mathematical model describing what happen to the frequency of alleles in a population over a time. There ideas known as **Hardy**-**Weinberg** **Theorem** which is **stated** **as:**

 ***ʻʻThe frequency of alleles and genotypes in a population gene pool remain constant over the generations unless certain assumptions are met and there is no effect on overall genetic structure of a population due to meiosis and random fertilizationʼʼ.***

**No. of individuals Gene pool Alleles frequency Genotype frequency**

 *Frequency of dominent There are two types of*

 *a*lleles (T) **=***p* alleles T and t .

  ***p =*** $\frac{6}{10}$ ***= 0.6* Tt × Tt**

*Fr Frequency of recessive T t*

 *alleles (t)* = ***q T TT Tt***

 ***q =*** $\frac{4}{10}$ ***= 0.4 t Tt tt***

 ***Punnet Squar***

 p + q = 1 $p^{2}+ 2pq+q^{2}$**=1**

 *The sum of all the 0.6 + 0.4 = 1 Homozygous dominent*

 alleles for all traits in (TT) = *pp* =$p^{2 }$

  *population individuals* *Homozygous recessive*

 *called gene pool.* (tt) = qq = $q^{2}$

 *Heterozygous dominent*

 *(Tt)(Tt)=2(p*q)

 = 2 *p*q

 $ $

  According to this theorem, there is no chance of evolution when there is constant frequency of alleles.Hardy and Weinberg used a mathematical equation to describe the frequency of alleles and genotype frequncies.

 **p + q = 1 , p^2+ 2pq+ q^2**

 They described that frequency of alleles in gene pool is constant and is equal to unity (1).

 So, as we know that a single gene controls a single character and it has two alleles at same loci for controlling expressions of genes. Let suppose study a character of height in individuals of population in order to describe the frequency of alleles in population gene pool.

**Proof by uning mathematical form and examples:**

 The gene for height having two alleles T and t . T represents that individuals having large height and t represents that individuals having small height but T is dominent allele in this case.

 **Example : If there are 168 dominent alleles for height out of 200 . So, answer the questions given below:**

1. **What is the frequency of heterozygous ?**
2. **What is the frequency of dominent homozygous ?**
3. **What is the frequency of recessive homozygous ?**
4. **What is the percentage frequency of heterozygous ?**

**Solution :**

$p^{2}+ 2pq+q^{2}$**= 1**

As we know that we have given dominent homozygous = $p^{2}$ + 2*pq* = $\frac{168}{200}$= 0.84

 Put it in this equation $p^{2}+ 2pq+q^{2}$**= 1**

 0.84 + $q^{2}$ = 1 $q^{2}$= 1 ̶ 0.84 = 0.16 $q^{2 }$= 0.16

 **p** = 0.6 **;** **q** = 0.4

 **a) Frequency of heterozygous : b) Frequency of homozygous dominent :**

 $p^{2}+ 2pq+q^{2}$**= 1** $p^{2}+ 2pq+q^{2}$**= 1**

Frequency of heterozygous **=** 2pq Frequency of homozygous dominent **=** $p^{2}$

 **=** 2 × 0.6 **×** 0.4 **=** 0.48 **=** ($0.6)^{2}$ **=** 0.36

 **c)**  **Frequency of recessive homozygous :** **d) % of frequency of heterozygous** :

 $p^{2}+ 2pq+q^{2}$**= 1** $p^{2}+ 2pq+q^{2}$**= 1**

Frequency of recessive homozygous **=**$q^{2}$Frequency of heterozygous **=** 2pq

**=** ($0.4)^{2}$ **=** 0.16 **=** 2 × 0.6 **×** 0.4 **=** 0.48

 % of frequency of heterozygous **=** 100 × 0.48**=** 48 %

**MUST EVOLUTION HAPPEN ?**

 Evolution is central to biology, but is evolution always occuring in a particular population? Sometimes the rate of evolution is slow and sometimes it is rapid. But are there time when evolution does not occur at all? The answer to this question lies in the theories of population genetics, the study of genetic events in gene pool. So we get some evidances how evolution occure and what are the assumptions which make difficulty in occurance of evolution in individuals of population. So, we discuss Hardy-Weinberg Theorem to know that assumptions .

 **This theorem is stayed only when these conditions are satisfied :**

**Conditions :**

1. **Big population** : The population size must be large. Large size ensures that gene frequency will not change by chance alone. So, if there is small lost of alleles in large population then there will be no big change in gene pool and no chance of evolution.
2. **Random mating** : Mating with in population must be random. Every individual must have equal chance of mating with any other individual in the population. If this condition is not fulfilled, then some individuals are more likely to reproduce than others, and natural selection may occur.
3. **No migration** : There should be no migration either **immigration(**add new genes from outside or individuals move from another place into that population**)** or **emigration(**Remove genes or individuals migrate out of population**)**. So , migration may introduce new genes into the gene pool or add or delete copies of existing genes.

 **Gene Flow**

“Changes in relative allelic frequency from the migration of individuals are called gene flow”.

* There should be migration either immigration(add new genes from outside or individuals move from another place into that population) or emigration(Remove genes or individuals migrate out of population). So , migration may introduce new genes into the gene pool or add or delete copies of existing genes. So, by this change can be occurred and more chance of evolution.
* The effects of gene flow can differ, depending on the circumstances. The exchange of alleles between an island population and neighbouring population. If gene flow continues in both directions, the both population become more similar.
* **Example :** Evidence suggests that the African elephants should be divided into two species. The elephants intropical forest of Africa are smaller, have straighter and thinner tusks and have distictive skull morphology as compared to savannah elephants. Molecular studies reveal marked genetic difference between these two groups. A lack of gene flow between these groups has helped to maintain the uniqueallelic frequencies with in the group.
1. **No mutation** : Mutation must not occur. As we know that if mutation is occurred than variety must ensure and chance of evolution increases.

 **“ Mutations are the changes in the structure of genes and chromosomes.”**

* **Mutation** plays a key role and increases the chance of evolution. When mutation is occurred somewhere so at this place evolution should be occurred. The effects of mutations are enormously.
* Neutral mutation are neither harmful nor helpful to the organism. Neutral mutations may occur in regions of DNA that donot code for proteins. Other neutral mutations may change a protein structure, but some proteins tolerate minor changes in structure without effecting the function of protein.
* Mutations in DNA that is incorporated into a gamete have the potential to affect the function of every cell in an individual in the next generation. These mutations are likely to influence the evolution of a group of organism.
* Mutation pressure : “It is a measure of tendency for gene frequency to change through mutation”.
1. **No natural selection** : In natural selection, the most fittest genes adapt themselves in changing environment and then only these genes may survive in new environment than others. So, this may result evolution. To obey this theorem, there will be no chance ofevolution.

 **This theorem is effected by certain factors :**

**Factors :**

1. **Mutation** : Mutation plays a key role in process of evolution. This may be slow or fast process. This factor also effects the stability of Hardy-Weinberg Theorem.
2. **Gene migration** : There should be migration either **immigration(**add new genes from outside or individuals move from another place into that population**)** or **emigration(**Remove genes or individuals migrate out of population**)**. So , migration may introduce new genes into the gene pool or add or delete copies of existing genes. So, by this change can be occurred and more chance of evolution.
3. **Recombination** : This is another important factor in which there are more chance of change in gene pool of individuals of population and hence evolution may occur. In this case, fussion of gametes may occur and varieties of gene there.
4. **Natural selection** : In natural selection, the most fittest genes adapt themselves in changing environment and then only these genes may survive in new environment than others. So, this may result evolution. To obey this theorem, there will be no chance ofevolution. So, this is another important factor for evolution.
5. **Genetic drift** : The loss of genes by chance or natural disasters. In this case, if more genes are lost so there will be more chance of evolution due to change in gene pool of entire population.
* Because gene frequencies are changing independently of natural selection, and genetic drift is often called neutral evolution.
* In this case, if more genes are lost so there will be more chance of evolution due to change in gene pool of entire population.

**Now we can discuss special cases of genetic drift which have influenced the genetic makeup of some population :**

* **Founder Effect :** “The newly emerged small population having far less variation in genetic makeup than their parental genetic makeup by migration among generations.”
* When a few individuals from a parent population colonize new habitats, they not often carry alleles in the same frequency as the alleles in the gene pool from which they came. The new colony that emerges from the founding individuals is likely to have a distinctive genetic makeup with less variation than the larger population. This form of genetic drift is the founder effect.
* **Example :** The founder effect concerns the genetic makeup of the Dunkers of eastern Pennsylvania. They emigrated from Germany to the United States early in the eighteenth century, and for religious reason, have not married out side their sect. Examination of same traits(e.g ABO blood type) in their population reveals very different gene frequencies are attributed to the chance absence of certain genes in the individuals who founded the origin Pennsylvania Dunker population.
* **Bottleneck Effect :** “The effect in which numbers of individuals are reduced and in which the fittest genes only passed over generations and other genes are reduced or depleted.”
* In this case, the genes having more power to adapt themselves when change occurs in the environment. Only these genes are passed among generations and the other should be reduced or depleted. So, there are also more chances of evolution in this case. Eve if the population size recovers, genetic diversity has been significantly reduced.
* **Example :** The northen elephant seal (Mirounga angustirostis) lives along the western coast of Northen America from Alaska to Baja, California. It gets its name from very large proboscis of the male. Males average 1800 kg and females average 650kg. So, there is competition among males during breeding, and a single male may win the right to mate with up 50 males. The northen elephant seal was over hunted in the late 1800s. Even though its numbers are now increasing, its genetic diversity is very low.

**Conclusion :** The result is that evolution only occurs when gene pool is not constant and not equal to unity. This theorem help us in order to describe the chance of evolution with related it with gene pool by using mathematical equation. If gene pool is constant than there is no chance of evolution.

* So, we have concluded that this theorem will saty in situation wgere no chance of evolution. If there changes become occur in populations, so, evolution will occur and frequency of entire genetic makeup of population should be changed. We have already discussed those conditions which caused the evolution.
* There should be migration either immigration(add new genes from outside or individuals move from another place into that population) or emigration(Remove genes or individuals migrate out of population). So , migration may introduce new genes into the gene pool or add or delete copies of existing genes. So, by this change can be occurred and more chance of evolution.

**Questions:**

1. **This condition is essential for a population to be in the Hardy-Weinberg Equilibrium:**
2. Random mating
3. No mutation
4. Large population
5. All of these (Answer)
6. **Immigration means:**
7. Add new genes from outside (Answer)
8. Move gene from inside
9. Both a and b
10. None of above
11. **This mechanism occurs when individuals migrate between populations:**
12. Extinction
13. Gene Flow (Answer)
14. Genetic Drift
15. None of these
16. **All of the genetic information found in a population:**
17. Population
18. Genetic Drift
19. Gene Pool (Answer)
20. All of these
21. **Gene flow tends to ------- genetic variation:**
22. Increase (Answer)
23. Decrease
24. Stabilize
25. None of these
26. **What do we called change over time?**
27. Evolution (Answer)
28. Natural Selection
29. Speciation
30. None of these
31. **The frequency of heterozygous represented by:**
32. 2pq (Answer)
33. P
34. q
35. None of these
36. **Frequency of homozygous dominant alleles represented by:**
37. $p^{2}$ (Answer)
38. $pq$
39. Q
40. None of these
41. **Evolution occurs when:**
42. Genetic Drift
43. Gene mutation
44. Migration
45. All of these (Answer)
46. **What is basic principle of Hardy Weinberg Theorem?**
47. No evolution (Answer)
48. Evolution
49. Both a and b
50. None of these

…END…