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B.Sc Part-III Paper-VII

Topic: Hard-Weinberg law of genetic equilibrium.

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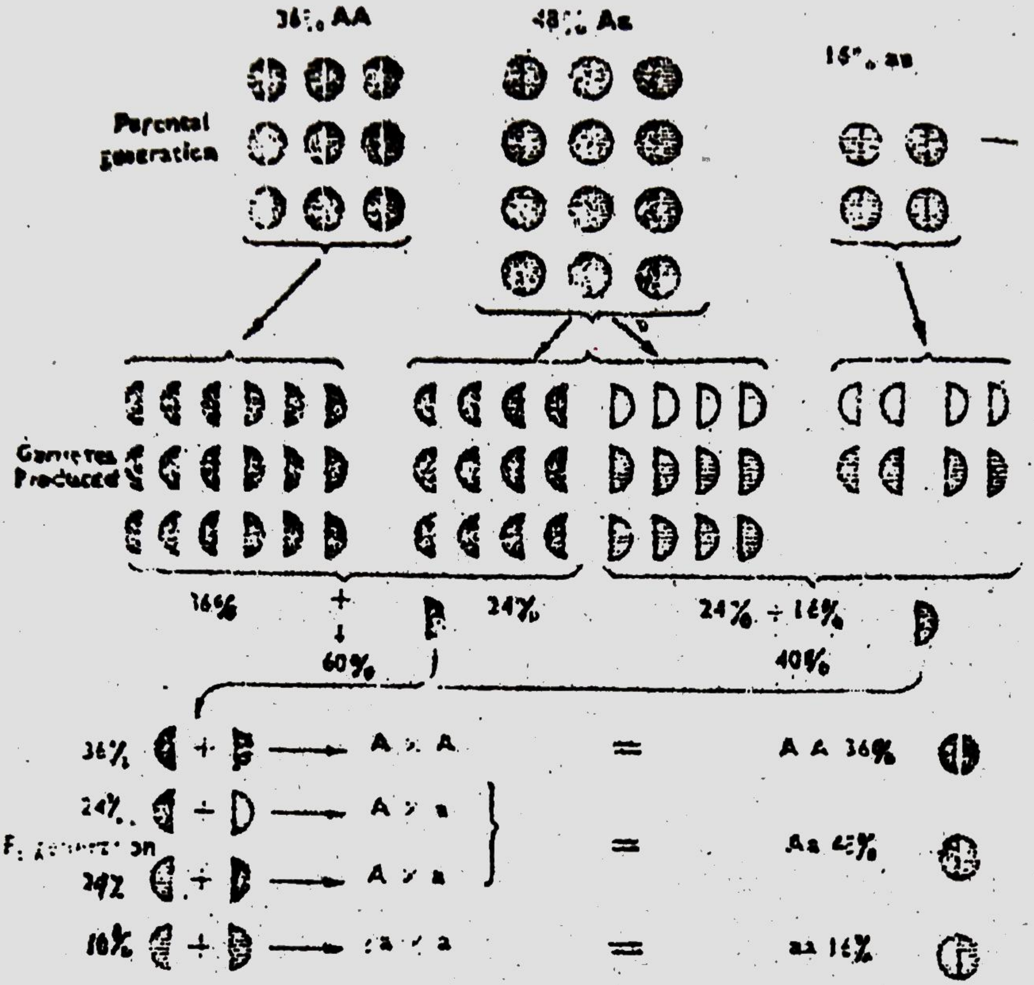
Q. ■. Discuss the Hard-Weinberg law of genetic equilibrium.

Ans. The mathematical treatment of the distribution of ene and genotype frequencies in the population was developed in 1929-30, pirncipally by R.A. Fisher and J.B. haldane in England and Sewall Wright in United States, but the most fundamental idea in population genetics was offered by englishman G.H Hardy and German W. Weinberg simultaneously in the year 1908. It is known as Hardy-weingberg's law. The law is the foundation of population genetics and of modern evolutionary theory.

Definition : That the relative frequencies of various kinds of genes in a large and randomly mating sexual panmictic population tend to remain constant from generation to generation in the absence of mutation, selection and gene flow.



Implications :

Hardy : Weinberg's law describes a theoretical situation in which a population is undergoing no evolutionary change. It explains that if the evolutionary forces are absent. The population is large, its individuals have random mating, each parent produces roughly equal number of gametes and the gametes produced by the mates combine at random and the gene frequency remains constant, then the genetic equilibrium of the genes in question is maintained and the vaiability present in the population is preserved. Suppose there is a panmictic population with gene A will be the same as the frequency of gene A and similarly the frequency of gametes with a will be equal to the frequency of the gene a Let us presume that the numerical proportion of different genes in this population is as follows :

AA	Aa	aa
36%	48%	16%

Since AA individuals make up 36 percent of the total population, they will contribute approximately 36% of all the gametes formed in the population. These gametes will possess gene A. Similarly. aa individuals will produce 16 percent of all the gametes. But the gmetes from Aa individuals will be of two types, i.e. with the gene A and with gene a roughly in equal proportion. Since these constitute 48% of the total population. they will contribute 48% gametes., but out of them 24% will possess gene A and the other 24% will have gene a. Hence, the over all out-put of the gametes will be:

Parents	Gametes	Parents	Gametes
36%AA →	36%A	16%aa	16%a
48%Aa →	24%A	48%Aa	24%a
Total	60%A		40%a

If the gametes unite at random, the total number of different genotypes will be :

Sperm	Ova	Gene Fr equency	Offsprings
A	A	60 × 60	36%AA
A	a	60 × 40	24%Aa
a	A	40 × 60	24%Aa
a	a	40 × 40	16%aa

The above concept can be translated into a simple mathematical expression.

frequency of gene A is represented by -p

frequency of gene a is represented by-q

and there is random union of the gametes with gene A and a at the equilibrium state, the population will contain following frequencies of the genotypes and genes A and a generation after generation :

AA + 2Aa + aa genotype frequency

Or, $P^2 + 2pq + q^2$

Teh above results could be explained by relying on the theory of probability. In a population of large size the probability of receiving (i) the gene A from both his parents will be $p \times p = p^2$, (ii) for gene a will be $q \times q = q^2$ and (iii) the probability of being heterozygote will be $pq+pq=2pq$.

The relationsihip between gene frequency and genotype frequency can be expressed as :

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

Or, $(p + q)^2 = 1$

It is known as Hardy-Weinberg formula or binominal expression. From this binomial expression, proposed by hardy and Weinberg, it is clear that in a large and randomly mating population not only gene frequencies but also the genotype frequencies will remain constant.

Sallent features of Hardy-Weinberg's Law :

In the absence of all evloutionary forces :

1. The gene and genotype frequencies of each allele in a population remain at an equilibrium generation after generation.
2. In a population, the mating is a completely random phenomenon.

3. The equilibrium in the genotype and gene frequencies occurs only in large sized populations. In small populations gene frequencies may be unpredictable.

4. All the genotypes in a population reproduce equally successfully.

5. According to Hardy-Weinberg's law particular alleles will be neither differential added to nor differentially substracted from a population.

Example : In human populations persons with gene T find weak solution of PTC (phenyl-thio-carbamide) to be better in taste, whereas to hommozygous it persons such solutions are tasteless. Moreover, persons are unaware of their reaction to PTC and nobody selects his mate according to whether he or she can or cannot taste this substance. Therefore the marriages take place at random, and population is panmictic with respect to this trait. Suppose, in a particular island or in a town the number of homozygous tasters (TT) and of homozygous nontasters is equal, the possible marriages could occur–

TT × TT or TT× tt or tt × tt

These marriages and their progenies can be represented by the following table :

Father \ Mother	.5TT	.5Tt
.5TT	TT .25	Tt .25
.5tt	Tt .25	tt .25

= .25 TT + 0.5 Tt + .25 tt

Therefore, the genotype frequency in first generation will be TT=25%. and tt = 25% and Tt = 50% but since the homozygous tasters (TT) and heterozygous tasters (Tt) are phenotypically alike, the population will be 75% tasters and 25% nontasters. The same results are obtained if we consider the union of gametes at the time of fertilization.

Sperms \ ova	.5T	.5t
.5T	TT .25	Tt .25
.5t	Tt .25	tt .25

= .25 TT + 0.50 Tt + .25 tt

The proportion or frequency of genes T and t will remain the same. This could be explained as under: Let us once again presume that every individual produces equal number of functional gametes. The homzygous tasters (TT) and homozygous nontasters (tt) will produce all the gametes of only one type, T and t respectively; the heterogygotes Tt will produce gametes with T and t in equal numbers. Therefore, the frequencies of the genes T and t in the gene pool will be:

Gene T .25 from homozygotes

.25 from heterozygotes TT

Total frequency of gene T = .25 + .25 = .50.

Gene t .25 from homozygotes tt

.25 from heterozygoter Tt

Total frequency of gene t = .25 + .25 = .50.

Thus the frequencies of gene T and t among the gametes. giving rise to second generation is the same as in the first generation and will remain the same in nature generations after generation. Similarly the genotype frequencies, according to Hardy Weinber's equation –

$$.25\ TT + .50\ Tt + .25\ tt = 1$$

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

where p is frequency of gene T.

and q is frequency of gene t.

Significancy : The Hardy-weinberg's law is important primarily be cause it describes the situation in which there is no evolution, and thus it provides a theoretical baseline for measuring evolutionary change. The equilibrium tendency tends to conserve gains which have been made in the past and also to avoid too rapie changes.

Factors of Evolution : Hardy-Weinberg's law provides a situation where the genes in the population have reached the equilibrium and the gene pool is constant. In such a case there will be no change and no evolution. But it has been observed in nature that over a long period of time equilibrium is disturbed and changes do occur on account of several forces. In other words those factors which operate to change the genetic equilibrium actually can bring about evolution. These are :

1. Mutations
2. Natural selection
3. Non-random mating
4. Genetic drifts or chance events in small populations
5. Differential migration.