5. Principles of Inheritance and Variation

Question 1. Mention the advantages of selecting pea plant for experiment by Mendel.

Answer: The advantages of selecting garden pea (Pisum sativum) for experiments by Mendel were –
1. Pea has many visibly distinct contrasting characters.
2. The life span of the pea plant is short and they produce many seeds in one generation.
3. Pea flowers are bisexual and show self-pollination, reproductive whorls being enclosed by corolla.
4. It is easy to artificially cross-pollinate the pea flowers. The hybrids thus produced were fertile.

Question 2. Differentiate between the following –

(a) Dominance and Recessive

(b) Homozygous and Heterozygous

(c) Monohybrid and Dihybrid.

Answer: **(a) Dominance and Recessive**

Dominance	Recessive
A dominant factor or allele expresses itself in the presence or absence of a recessive factor.	A recessive trait is able to express itself only in the absence of a dominant factor.
For example, tall plant, round seed, violet flower, etc. are dominant traits in a pea plant.	For example, dwarf plant, wrinkled seed, white flower, etc. are recessive traits in a pea plant.

(b) Homozygous and Heterozygous

Homozygous	Heterozygous
It contains two similar alleles for a particular trait.	It contains two different alleles for a particular trait.

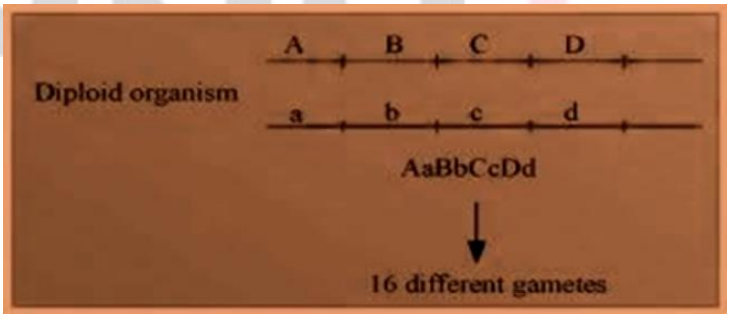
Genotype for homozygous possess either dominant or recessive, but never both the alleles. For example, RR or rr	Genotype for heterozygous possess both dominant and recessive alleles. For example, Rr
It produces only one type of gamete.	It produces two different kinds of gametes.

(c) Monohybrid and Dihybrid

Monohybrid Cross	Dihybrid Cross
Monohybrid Cross involves cross between parents, which differs in only one pair of contrasting characters.	Dihybrid Cross involves cross between parents, which differs in two pairs of contrasting characters.
For example, the cross between tall and dwarf pea plant is a monohybrid cross.	For example, the cross between pea plants having yellow wrinkled seed with those having green round seeds is a dihybrid cross.

Question 3. A diploid organism is heterozygous for 4 loci, how many types of gametes can be produced?

Answer: Locus is a fixed position on a chromosome, which is occupied by a single or more genes. Heterozygous organisms contain different alleles for an allelic pair. Hence, a diploid organism, which is heterozygous at four loci, will have four different contrasting characters at four different loci. For example, if an organism is heterozygous at four loci with four characters, say Aa, Bb, Cc, Dd, then during meiosis, it will segregate to form 8 separate gametes.

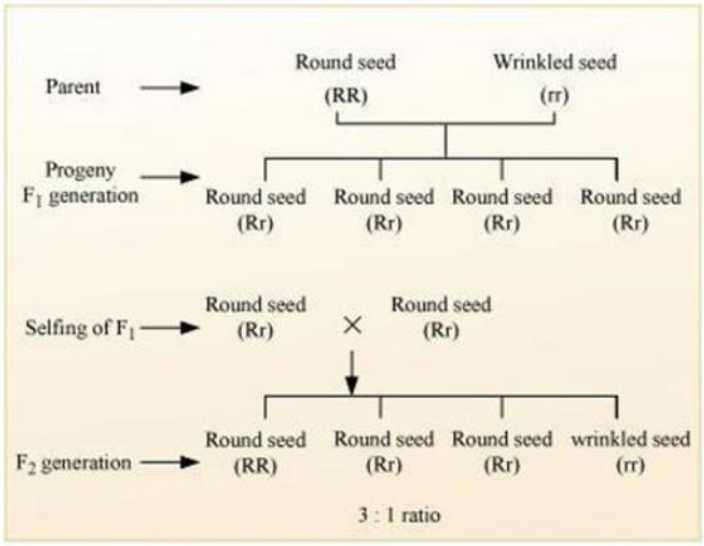


Types of gametes produced by organism= 2^n wherein n= number of loci for which the organism is heterozygous. The given diploid organism is heterozygous for 4 loci, types of gametes produced = 2^4= 16.

Question 4. Explain the Law of Dominance using a monohybrid cross.

Answer: Mendels law of dominance states that a dominant allele expresses itself in a monohybrid cross and suppresses the expression of recessive allele. However, this recessive allele for a character is not lost and remains hidden or masked in the progenies of F1generation and reappears in the next generation.

For example, when pea plants with round seeds (RR) are crossed with plants with wrinkled seeds (rr), all seeds in F1 generation were found to be round (Rr). When these round seeds were self-fertilized, both the round and wrinkled seeds appeared in F2 generation in 3: 1 ratio. Hence, in F1 generation, the dominant character (round seeds) appeared and the recessive character (wrinkled seeds) got suppressed, which reappeared in F2 generation.



A monohybrid cross between round and wrinkled pea seeds

Question 5. Define and design a test-cross.

Answer: Test cross is a cross between an organism with unknown genotype and a recessive parent. It is used to determine whether an individual is homozygous or heterozygous for a trait.

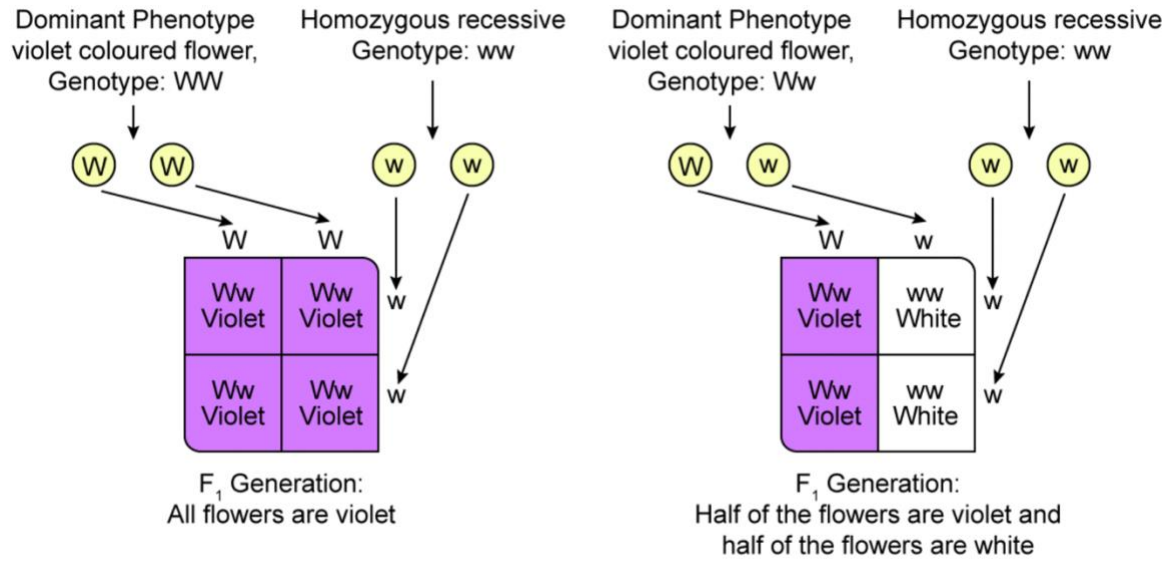
Example:

Suppose you have a violet and white flower and violet color (P) is dominant to white (p). The white flower must be homozygous for the recessive allele, but the genotype of the violet flower is unknown. It could be either PP or Pp.

A testcross will determine the organism's genotype. The unknown genotype can be determined by observing the phenotypes of the resulting offspring.

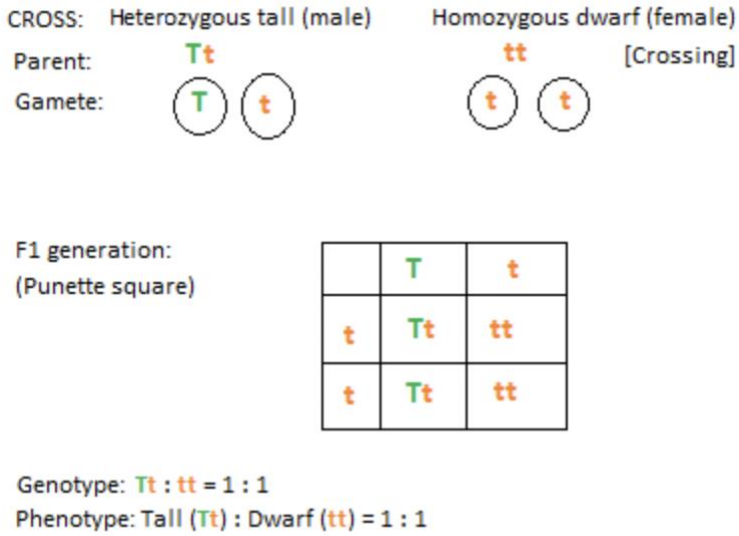
If crossing the unknown dominant phenotype (PP or Pp genotype) individual with the recessive phenotype individual produces only dominant phenotypes (no recessive), then the unknown individual is homozygous dominant.

If any recessive phenotypic individuals result from the cross, then the unknown individual must carry the recessive allele, and have the heterozygous genotype.



Question 6. Using a Punnett Square, workout the distribution of phenotypic features in the first filial generation after a cross between a homozygous female and a heterozygous male for a single locus.

Answer: The phenotypic features in the first filial generation after a cross between a homozygous female and a heterozygous male for a single locus, say height, is as follows:



Question 7. When a cross in made between tall plant with yellow seeds (TtYy) and tall plant with green seed (Ttyy), what proportions of phenotype in the offspring could be expected to be

(a) tall and green.

(b) dwarf and green.

Answer: As given phenotype of TtYy parent, tallness is dominant over dwarfism and yellow seed is dominant over green seeds. Genotype of tall and green progeny will be Ttyy and TTyy, and that of dwarf and green progeny will be ttyy. Proportion of tall and green progeny= 3

Proportion of dwarf and green progeny= 1

	Ty	ty
TY	TT Yy Tall yellow	Tt Yy Tall yellow
Ty	TT yy Tall green	Tt yy Tall green
ty	Tt yy Tall green	tt yy Dwarf green
tY	Tt Yy Tall yellow	tt Yy Dwarf yellow

Question 8. Two heterozygous parents are crossed. If the two loci are linked what would be the distribution of phenotypic features in F_1 generation for a dihybrid cross?

Answer: In this case, the distribution of phenotypic feature would follow the same pattern as in dihybrid cross done by Mendel. It is important to recall the Law of Independent Assortment while answering this question. This law says that different traits segregate independent of each other; during gamete formation.

Question 9. Briefly mention the contribution of T.H. Morgan in genetics.

Answer: The contributions of T.H. Morgan are:
i. Morgan was the first to provide experimental verification for the chromosomal theory of inheritance by his work on Drosophila melanogaster.

ii. He defined linkage between two genes located close together which are always inherited together.

iii. The identified linkage to be of two types tightly linked genes, where both the genes are passed onto the next generation and loosely linked genes in which recombination may take place due to a large distance present within the two genes.

iv. He also defined the term recombination of non – parental gene recombination.

v. His findings of linked genes pavemented the path for genome mapping that is done today.

vi. He also contributed to the understanding of sex – linked inheritance vii. He has also worked on mutations.

Question 10. How is sex determined in human beings?

Answer: Sex determination in human beings
In humans, out of 23 pairs of chromosomes, 22 pairs are exactly the same in male and female called autosomes. However, a pair of the X chromosome is present in female and XY in male. During spermatogenesis, male produce two types of gametes (sperms), 50% carries Y chromosome and remaining 50% contain X chromosome. On the other hand, female produces only one kind of gamete (ovum) having X chromosomes only. When sperm having Y chromosome fertilises the ovum the sex of the baby is male and when sperm carrying X chromosome fertilises the egg, the sex of the baby is female.

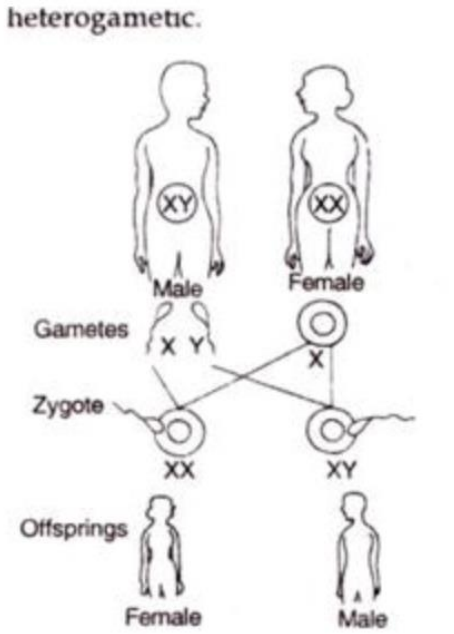


Fig. Human sex-determination mechanism.

Question 11. What is pedigree analysis? Suggest how such an analysis, can be useful.

Answer: Pedigree analysis is the study of transmission of particular traits over the generations for finding out the possibility of their occurrence in the future generations.
Importance of pedigree analysis is as follows:
(i) It is used to know the possibility of expressive or recessive allele, which may cause genetic disorders.

(ii) It shows the origin of trait and inheritance pattern of that trait in a family.

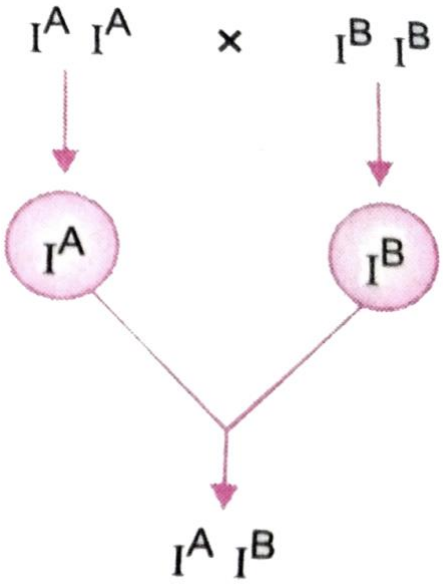
(iii) It predicts the harmful effects of marriage between close relatives. .

(iv) It is extensively used in medical research.

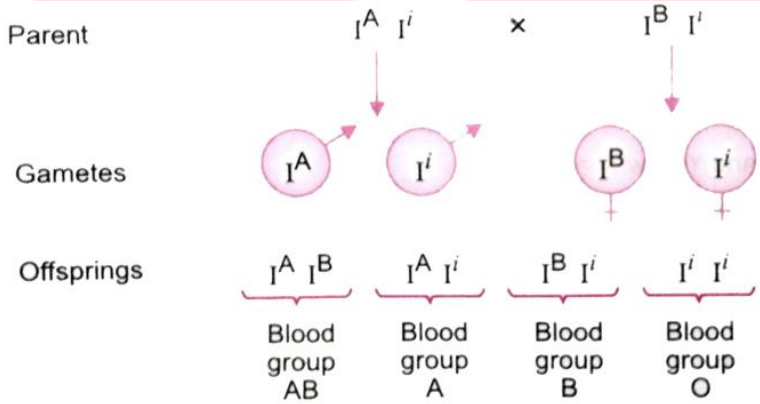
Question 12. A child has blood group O. If the father has blood group A and mother blood group B, work out the genotypes of the parents and the possible genotypes of the other offsprings.

Answer: If the father has blood group A, the genotype may be IAIA (homozygous) or IAIi(heterozygous). Similarly, if mother has blood group B, the genotype maby be IBIB (homozygous) or IBIi (heteroxygous). In case a homozygous IAIA father and IBIB mother,

then the offspring will have blood group AB, as follows :



If parents are heterozygous i.e., father IAIi and mother IBIi then offspring will be
Thus, the genotype of parents of a child having blood group, 'O' will be IAIi(male) and IBIi (female).
The possible genotypes of the other offsprings will be A,B and AB.



Question 13. Explain the following terms with example

(a) Co-dominance

(b) Incomplete dominance

Answer: Co-dominance: When both recessive and dominant traits are expressed in a heterozygous genotype. This means that none of the factors is recessive but both can express themselves irrespective of their presence in homozygous or heterozygous condition. For example, IA and IB alleles of I gene of ABO blood group.
Incomplete dominance: When none of the factors of a gene is dominant, the phenotype of a heterozygous dominant individual is a blend of dominant and recessive traits. For example, flower colour in *Mirabilis jalapa.*

Question 14. What is point mutation? Give one example.

Answer: Point mutation is a change in a single base pair of DNA by substitution, deletion, or insertion of a single nitrogenous base. An example of point mutation is sickle cell anaemia. It involves mutation in a single base pair in the beta-globin chain of haemoglobin pigment of the blood. Glutamic acid in short arm of chromosome II gets replaced with valine at the sixth position.

Question 15. Who had proposed the chromosomal theory of the inheritance?

Answer: The chromosomal theory of inheritance was independently proposed by Walter Sutton and Theodore Boveri in 1903 and 1902 respectively. The experimental verification of this theory was put forth by Thomas Hunt Morgan in 1915 by his work on *Drosophila melanogaster*.

Question 16. Mention any two autosomal genetic disorders with their symptoms.

Answer:
Sickle cell anaemia: This is an autosomal linked recessive trait that can be transmitted from parents to offsprings only when both the parents are the carrier for the gene governing the trait. Thus only homozygous recessive individuals show the diseased phenotype. This defect is caused by the substitution of the amino acid Glutamic acid by Valine at the sixth position of the β globin chain of the haemoglobin molecule.
Symptoms: The different symptoms of sickle cell anaemia are- rapid heart rate, breathlessness, weakness, excessive thirst, chest pain, prone to diseases such as jaundice, delayed growth and puberty and decreased fertility.

Down's Syndrome: It was first discovered and published in 1866 by a British physician John Langdon Brown. This is a trisomic condition of chromosome 21 where an extra copy of chromosome 21 is

found. It is the result of asymmetrical division in meiosis of the parents.

Symptoms: They are characteristically short; have protruding, furrowed tongue; short and broad hands with fingers showing characteristic palm and fingerprint patterns. Physical psychomotor and mental development is retarded and poor muscle tone is characteristic. Children affected by Down's syndrome are prone to respiratory diseases and heart malfunctions and they show incidence of leukemia approximately 20 times higher than the normal population. Its estimated occurrence is approximately 1 in every 800 live births.