CHAPTER

4

PRINCIPLES OF INHERITANCE AND VARIATION

CLASS 12TH

NCERT EXERCISE AND SOLUTIONS - BIOLOGY

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

ANSWER:-

Gregor Mendel demonstrated how traits are inherited by offspring from their parents. He chose pea plants for his experiments due to the following reasons:

- **Visible Contrasting Traits:** Pea plants display distinct contrasting characteristics, such as tall/dwarf stature, round/wrinkled seeds, yellow/green pods, and white/purple flowers.
- **Self-Pollination:** Being bisexual, pea plants can easily self-pollinate, allowing them to produce offspring with consistent traits across generations.
- **Ease of Cross-Pollination:** Cross-pollination can be easily conducted through emasculation, where the stamen is carefully removed without disturbing the pistil.
- **Short Life Cycle:** Pea plants have a short life span and produce abundant seeds in a single generation, enabling efficient observation of inheritance patterns.

Q. 2. **Differentiate between the following –**

(a) Dominance and Recessive
(b) Homozygous and Heterozygous
(c) Monohybrid and Dihybrid.

ANSWER:-

(a) Dominance and Recessive

Dominance	Recessive
In the presence or absence of a recessive trait, a dominant factor or allele expresses itself.	A recessive trait expresses itself only in the absence of a dominant trait.
Example: In a pea plant, round seeds and violet flowers are dominant characters.	**Example:** In a pea plant, white flower, dwarf plant, etc., are recessive characters

(b) Homozygous and Heterozygous

Homozygous	Heterozygous
Contains two identical alleles for a specific trait.	Contains two different alleles for a specific trait.
Produces only one type of gamete.	Produces two types of gametes due to the presence of different alleles.
The genotype consists exclusively of either dominant or recessive alleles (e.g., TT or tt).	The genotype includes both dominant and recessive alleles (e.g., Tt).

(c) Monohybrid and Dihybrid.

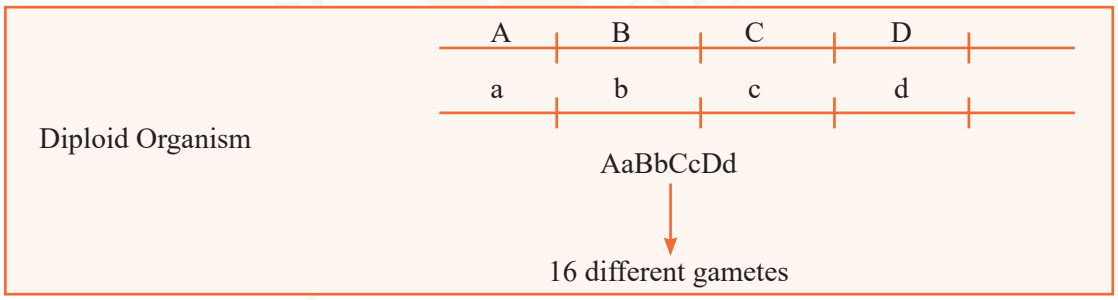
Monohybrid	Dihybrid
A cross involving parents that differ in only one contrasting trait.	A cross involving parents that differ in two contrasting traits.
Example: A cross between a tall pea plant and a dwarf pea plant.	**Example:** A cross between a yellow wrinkled seed and a green round seed.

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

ANSWER:-

A locus is a specific position on a chromosome that is occupied by one or more genes. In an allelic pair, heterozygous individuals possess different alleles. Therefore, a diploid organism that is heterozygous at four loci exhibits four contrasting traits at those loci.

Example: If an organism is heterozygous at four loci (e.g., Aa, Bb, Cc, Dd), during meiosis, these loci assort independently to produce 6 unique gametes.



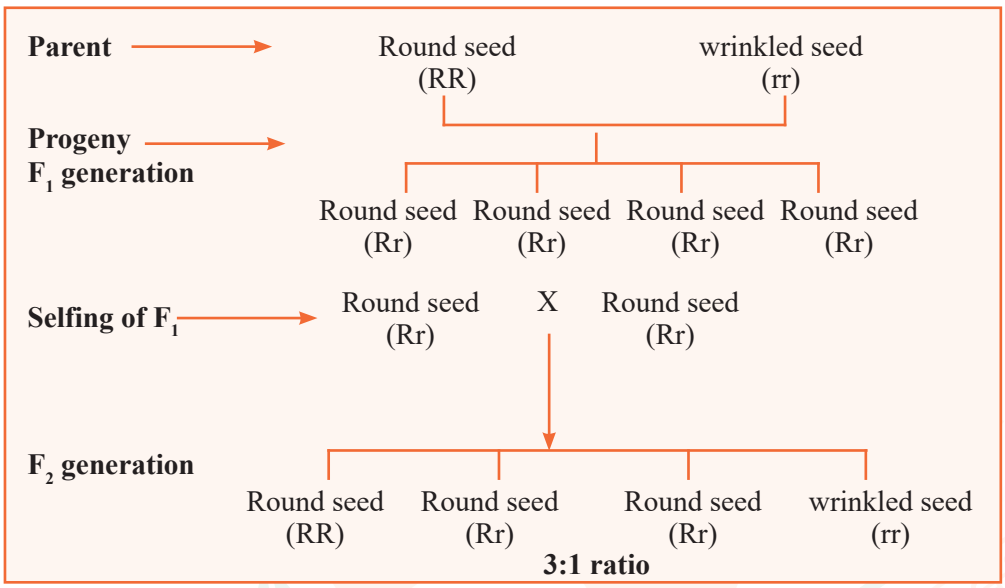
If genes are unlinked, a diploid organism will produce **16 different gametes** due to independent assortment. However, if the genes are linked, the number of gametes produced will decrease. This is because linked genes tend to be inherited together during meiotic division, limiting the combinations formed.

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

ANSWER:-

Mendel's **Law of Dominance** states that in a monohybrid cross, the dominant allele masks the expression of the recessive allele. While the recessive allele remains unexpressed in the F1 generation, it does not disappear; instead, it is hidden and reappears in the subsequent generation.

Example: In a monohybrid cross between two pea plants with round seeds (RR) and wrinkled seeds (rr), all the seeds in the F1 generation are round (Rr) due to the dominance of the round allele. When these F1 plants are self-fertilized, the F2 generation exhibits both traits—round and wrinkled seeds—in a **3:1 ratio**. Thus, in the F1 generation, the dominant trait (round seeds) is expressed, while the recessive trait (wrinkled seeds) remains suppressed but resurfaces in the F2 generation.



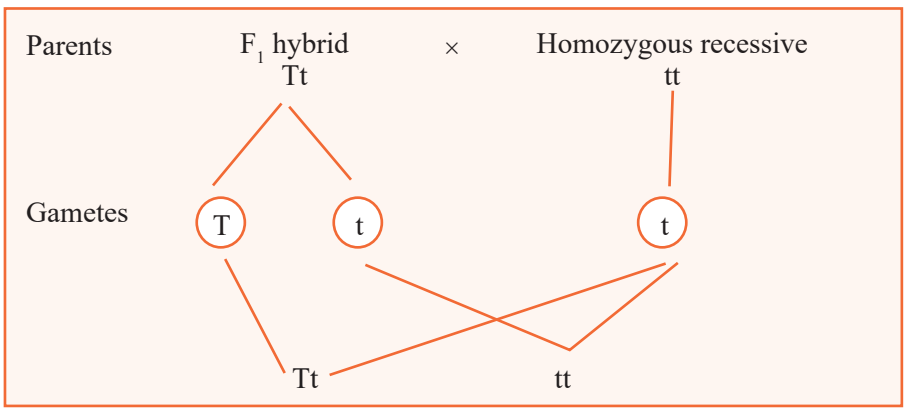
Q. 5. Define and design a test-cross.

ANSWER:-

A test cross is performed by crossing an F1 individual with a dominant phenotype to its homozygous recessive parent. This helps determine whether the individual exhibiting the dominant trait is homozygous or heterozygous.

Example:-

1. A tall plant with genotype TT is crossed with a dwarf plant tt.
2. The F1 generation produces tall plants with genotype Tt.
3. This tall plant (Tt) is then test-crossed with a homozygous recessive dwarf plant (tt) to analyse the results.

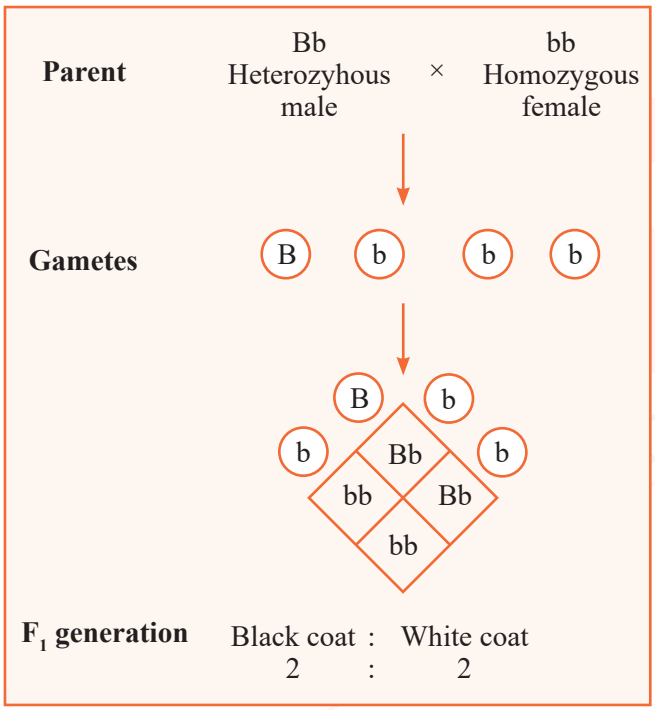


As demonstrated above, a test cross between a tall heterozygous F1 hybrid and a dwarf homozygous recessive parent produces tall and dwarf plants in equal proportions. This outcome confirms that the F1 hybrid is heterozygous.

Q. 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:-

In guinea pigs, a cross is conducted between a heterozygous, black-coated male (**Bb**) and a white-coated female (**bb**). The male produces two types of gametes (**B** and **b**), while the female produces only one type of gamete (**b**). As a result, the F1 progeny shows a genotype and phenotype ratio of **1:1**, with half having a black coat (**Bb**) and half having a white coat (**bb**).



Q. 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:-

When a cross is conducted between a tall plant with yellow seeds and a tall plant with green seeds, the resulting offspring exhibit the following phenotypes:

- Three tall green plants
- One dwarf green plant

This phenotypic ratio suggests that the tall and dwarf traits are determined by a monohybrid cross, with tall being dominant over dwarf. The green seed trait appears consistently, indicating either dominance of the green allele or homozygosity in both parents for the green seed allele.

Parent	Tall yellow seed plant TtYy	×	Tall green seed plant Ttyy
Gametes	TY, Ty, ty, tY		Ty, ty

	Ty	ty
TY	TTYy Tall yellow	TtYy Tall yellow
Ty	TTyy Tall green	Ttyy Tall green
ty	Ttyy Tall green	ttyy Dwarf green
tY	TtYy Tall yellow	ttYy Dwarf yellow

Q. 8. Two heterozygous parents are crossed. If the two loci are linked what would be the distribution of phenotypic features in F1 generation for a dihybrid cross?

ANSWER:-

Linkage refers to the co-existence of two or more genes on the same chromosome. When these genes are located close to each other, they tend to be inherited together and are called **linked genes**.

For example, when two heterozygous parents with the genotype BbLl x BbLl exhibit linkage, the resulting F1 generation will most likely show the parental phenotypes, such as blue long. If the genes are completely linked, the offspring will predominantly display the parental phenotype. However, in the case of incomplete linkage, the parental combinations will still be more common, though new combinations will appear in smaller numbers.

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

ANSWER:-

- T. H. Morgan made several key contributions to the field of genetics:
- He proposed and demonstrated that genes are located on chromosomes.
- He identified the role of sexual reproduction in generating variations.
- He introduced the concept of linkage, distinguishing between linked and unlinked genes.
- He formulated the chromosomal theory of linkage.
- He conducted research on sex-linked inheritance.
- Morgan proposed the chiasma hypothesis, showing that crossing over occurs at chiasmata.
- He observed that the frequency of recombination between two linked genes is proportional to the distance between them.
- He proposed a theory of inheritance.
- He developed a methodology for chromosome mapping.
- He studied mutations.

Q. 10. What is pedigree analysis? Suggest how such an analysis, can be useful.

ANSWER:-

A pedigree is a chart that records the inheritance of a specific genetic trait across two or more generations, typically presented as a diagram or family tree. Pedigree analysis involves studying several generations within a family, often applied to humans and domesticated animals.

Benefits of Pedigree Analysis:

- It is an effective tool for tracing the inheritance of traits, diseases, or abnormalities.
- It aids genetic counsellors in advising couples about the likelihood of having children with genetic conditions such as color blindness, haemophilia, thalassemia, or sickle cell anaemia.
- Pedigree analysis helps trace the origin of a trait and its transmission through generations.
- It demonstrates how Mendel's principles can be adapted to human genetics, including concepts like quantitative inheritance, sex-linked traits, and genetic characters.
- It provides insight into why marriages between close relatives can be harmful.
- It plays a significant role in advancing research in medical science.

Q. 11. How is sex determined in human beings?

ANSWER:-

The chromosomal mechanism of sex determination in humans follows the XX-XY genotype system. Each cell's nucleus contains 23 pairs of chromosomes, or 46 chromosomes in total, with 22 pairs being autosomes and the 23rd pair being the sex chromosomes. Females have two identical sex chromosomes (XX), making them homomorphic, while males have two different sex chromosomes (XY), making them heteromorphic. Females are homogametic, producing only one type of egg (22+X), whereas males are heterogametic, producing two types of sperm – (22+X) and (22+Y).

During fertilization, if a sperm with an X chromosome fertilizes the egg, the offspring will be female (XX). If a sperm with a Y chromosome fertilizes the egg, the offspring will be male (XY). As a result, the sex ratio in the offspring is 1:1. Heterogamety, the chromosomal mechanism of sex determination, can be either male heterogamety or female heterogamety.

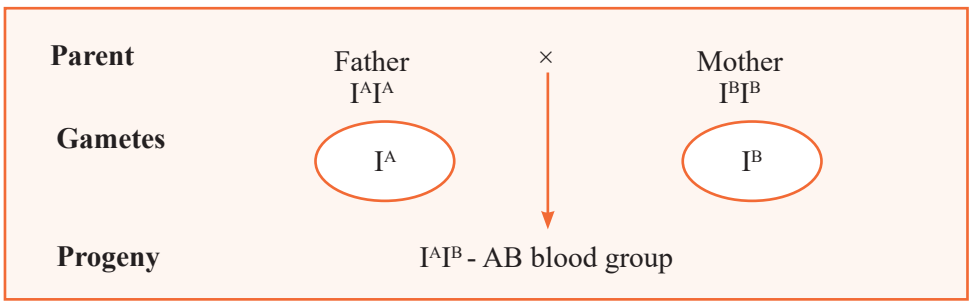
Q. 12. A child has blood group O. If the father has blood group A and mother blood group B, work out the genotypes of the parents and the possible genotypes of the other offsprings.

ANSWER:-

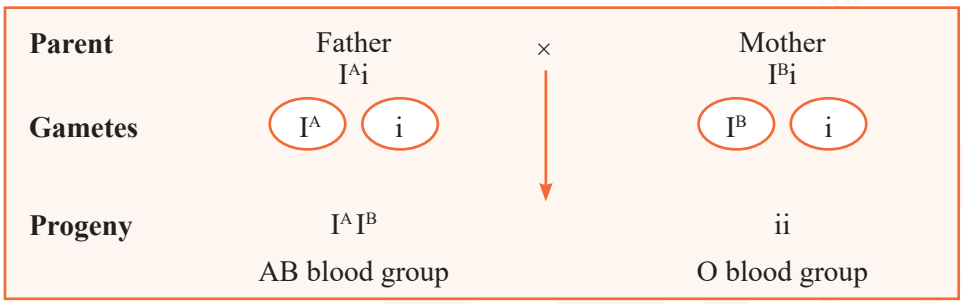
In humans, blood group characteristics are controlled by a set of three alleles: I^A, I^B, and i. The alleles I^A and I^B are equally dominant, while allele i is recessive to both I^A and I^B. The table below illustrates the genotypes and corresponding blood groups.

Genotype	Corresponding blood group
I^AI^A, I^Ai	A
I^BI^B, I^Bi	B
I^AI^B	AB
ii	O

If the father has blood group A and the mother has blood group B, their genotypes could be heterozygous (I^Ai and I^Bi).



A cross between these heterozygous parents can produce offspring with the following possible blood groups: AB (I^AI^B) and O (ii).



Q. 13. Explain the following terms with example

(a) Co-dominance

(b) Incomplete dominance

ANSWER:-

(a) Co-dominance refers to a situation where alleles express themselves independently when present together in a heterozygote. These alleles are known as co-dominant alleles.

(b) Incomplete dominance is a form of inheritance where neither of the contrasting traits in a pair is dominant. In this case, the F1 hybrid displays a blend of both traits. For example, in *Mirabilis jalapa*, a hybrid cross between red and white flowers results in pink flowers.

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

ANSWER:-

An abrupt change in the gene structure occurs when a single-base pair of DNA undergoes inversion or substitution, without affecting the reading of the subsequent bases. An example of this is sickle cell anaemia.

In sickle cell anaemia, a substitution of a single nitrogen base—from guanine to adenine—at the sixth codon of the β-globin chain in haemoglobin causes a change in the shape of red blood cells (RBCs). Normal RBCs are biconcave, flexible discs that can easily pass through both large and small blood vessels to transport oxygen. In contrast, sickle-shaped RBCs are elongated, rigid, and

non-flexible, causing them to stick to blood vessel walls. This results in blockages that slow or stop blood flow, leading to sickle cell anaemia.

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

ANSWER:-

In 1902, Theodore Boveri and Walter Sutton independently proposed the chromosomal theory of inheritance.

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

ANSWER:-

These disorders are caused by defects in genes located on the autosomes. Some examples of autosomal genetic disorders include Down's syndrome, sickle cell anemia, Patau syndrome and phenylketonuria.

1. **Down's Syndrome**

Symptoms:

- Flat hands and short neck
- Broad forehead
- Partially open mouth with a furrowed tongue
- Mongolian-type eyelid fold and stubby fingers
- Delayed psychomotor, physical, and mental development
- Heart defects and deformities in other organs
- Underdeveloped genitalia and gonads

2. **Sickle Cell Anaemia**

Symptoms:

- The shape of RBCs changes from elongated to sickle-shaped (curved) under low oxygen conditions.
- Sickle-shaped RBCs are destroyed more rapidly than normal ones, leading to anaemia.