01 Genetic Basis of Inheritance

Subtopics
1.0 Introduction
1.1 Mendelian Inheritance
1.2 Deviations from Mendelian ratios

1.0 Introduction

Note:
“Like begets like”.
i. Living organisms produce young ones similar to them.
ii. A dog gives puppies and a mango tree gives mango seeds.
iii. This basic principle of life giving rise to life of its own kind is called “Like begets like”.
iv. Reproduction, a fundamental characteristic of life, becomes possible due to replication of DNA (genetic material) and its transmission to next generation.

Q.1. Define the terms:
i. Heredity ii. Variation iii. Genetics
Ans: i. Heredity: The transmission of characters from one generation to the next or from parents to offsprings is called heredity.

ii. Variation: The differences between parents and offsprings or among the offsprings of the same parents and among individuals of the same species is called variation.

iii. Genetics: It is a branch of biology which deals with the study of heredity and variations. The term ‘genetics’ was coined by William Bateson in 1906.

Q.2. Who is called as the Father of genetics?
Ans: Gregor Johann Mendel is called as the Father of Genetics.

1.1 Mendelian Inheritance

Q.3. Define or explain the following terms:
i. Clone *ii. Factor
iii. Gene *iv. Alleles or Alleomorphs
v. Homozygous vi. Heterozygous
*vi. Genotype *vii. Phenotype
*x. Dihybrid cross
xi. Monohybrid *xii. Monohybrid ratio
xiii. Dihybrid ratio *xiv. Dihybrid
*xv. F1 generation xvi. F2 generation
xvii. Dominant xviii. Recessive
xix. Offsprings  xx. Progeny
xxi. Trait  xxii. Character
xxiii. Hybrid  xxiv. Homologous chromosomes or Homologues
*xxv. Emasculation  xxvi. Genome
xxvii. Pure line

Ans: i. **Clone**: Organisms produced by asexual reproduction or plants produced by vegetative propagation which are identical to their parents are called clones.

ii. **Factor**: Particles present in an organism which is responsible for the inheritance and expression of the characters is called as Factor.

iii. **Gene**: (coined by Johannsen)

Specific segment of DNA which determines a particular character of an organism.

**OR**

It is a particular segment of DNA which is responsible for the inheritance and expression of that character.

iv. **Alleles or Allelomorphs**: (coined by Bateson)

Two or more alternative forms of a gene present at the same loci of homologous chromosomes and controlling the same character are called as alleles or allelomorphs.

v. **Homozygous**: An individual having identical alleles for a particular character is homozygous for that character. It is pure or true breeding. e.g. TT, tt.

vi. **Heterozygous**: An individual having dissimilar alleles for a particular character is heterozygous for that character. It is a hybrid. e.g. Tt

vii. **Genotype**: It is the genetic constitution of an individual with respect to a single character or a set of characters. e.g. Tall (TT or Tt), Dwarf (tt).

viii. **Phenotype**: The external appearance of an individual for a given trait. e.g. tallness, dwarfness.

ix. **Monohybrid cross**: A cross between two pure (homozygous) parents differing in a single pair of contrasting character is called monohybrid cross. The ratio for this cross is 3 : 1.

x. **Dihybrid cross**: A cross between two pure parents differing in two pairs of contrasting characters is called dihybrid cross. The ratio for such cross is $9 : 3 : 3 : 1$.

xi. **Monohybrid**: It is heterozygous for one trait and produced by crossing two pure parents differing in a single pair of contrasting characters. e.g. Cross between pure tall (TT) and dwarf (tt) parent gives rise to hybrid tall (Tt).

xii. **Monohybrid ratio**: The phenotypic ratio of different types of offsprings (dominant and recessive) obtained in $F_2$ generation of a monohybrid cross is called Monohybrid ratio.

In all Mendelian crosses, the monohybrid ratio is $3 : 1$.

xiii. **Dihybrid ratio**: The phenotypic ratio of different types of offsprings (having different combinations) obtained in $F_2$ generation of dihybrid cross is called Dihybrid ratio.

In all Mendelian crosses, the dihybrid ratio is $9 : 3 : 3 : 1$.

xiv. **Dihybrid**: It is heterozygous for two traits and produced in a cross between two parents differing in two pairs of contrasting characters.

xv. **$F_1$ generation**: The hybrid individuals obtained by a cross between two pure parents with contrasting characters is called $F_1$ generation or first filial generation.

xvi. **$F_2$ generation**: The generation of offsprings obtained by selfing of $F_1$ individuals is called $F_2$ generation or second filial generation.

xvii. **Dominant**: The character expressed in $F_1$ generation is called dominant character.
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OR
It is an allele that expresses even in presence of an alternative allele.

xviii. Recessive:
The character which is not expressed in F₁ generation is called recessive character.

OR
It is an allele which is not expressed in presence of an alternative allele.

xix. Offsprings:
The individuals produced by sexual reproduction are called offsprings.

xx. Progeny:
All offsprings produced by the parents are called progeny.

xxi. Hybrid:
Heterozygous individual produced by parents having contrasting characters. e.g. Tt.

xxii. Character:
A visible feature is a character. e.g. height, seed colour.

xxiii. Trait:
One form of the visible feature. e.g. tallness or dwarfness, yellow or green.

xxiv. Homologous chromosomes or Homologues:
Morphologically, physiologically and genetically similar chromosomes present in a diploid cell are called homologues or homologous chromosomes. In each pair of homologous chromosomes, one chromosome is maternal and the other is paternal.

xxv. Emasculation:
Removal of stamens well before anthesis is called emasculation. It is done in bud condition to prevent self-pollination.

xxvi. Genome:
Entire genetic constitution of an organism is called genome.

xxvii. Pure line:
An individual or a group of individuals (population) that is homozygous or true breeding for one or more traits.

Q.4. Which term did Mendel use for gene?
Ans: Mendel used the term ‘factor’ for the unit of heredity which is now called as gene.

Q.5. What is Punnett square/Checker Board?
Ans: Punnett square is a graphical representation to calculate the probability of all possible genotypes and phenotypes of offsprings in a genetic cross. It was developed by Reginald C. Punnett.

Q.6. Distinguish between:
  #*i. Homozygous and Heterozygous

<table>
<thead>
<tr>
<th>No.</th>
<th>Homozygous</th>
<th>Heterozygous</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>Organisms having identical alleles for a character are homozygous.</td>
<td>Organisms having dissimilar alleles for a character are heterozygous.</td>
</tr>
<tr>
<td>b.</td>
<td>It is pure or true breeding.</td>
<td>It is hybrid.</td>
</tr>
<tr>
<td>c.</td>
<td>They form only one type of gamete.</td>
<td>They form more than one type of gametes.</td>
</tr>
<tr>
<td>d.</td>
<td>e.g. Tall (TT), Dwarf (tt).</td>
<td>e.g. Tt.</td>
</tr>
</tbody>
</table>

  #ii. Dominant and Recessive character

<table>
<thead>
<tr>
<th>No.</th>
<th>Dominant character</th>
<th>Recessive character</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>The characters that are expressed in F₁ generation are dominant.</td>
<td>The characters that are not expressed in F₁ generation are recessive.</td>
</tr>
<tr>
<td>b.</td>
<td>It is expressed in presence of dominant as well as recessive allele. e.g. Tt, TT = tall.</td>
<td>It is expressed only when both the recessive alleles of a gene are present. e.g. tt = dwarf.</td>
</tr>
<tr>
<td>c.</td>
<td>In pea plant, tallness and red flowers are dominant characters.</td>
<td>In pea plant, dwarfness and white flowers are recessive characters.</td>
</tr>
<tr>
<td>d.</td>
<td>Dominant character can express in both homozygous as well as heterozygous condition.</td>
<td>Recessive character can be expressed only in homozygous condition.</td>
</tr>
</tbody>
</table>
**iii. Phenotype and Genotype**

**Ans:**

<table>
<thead>
<tr>
<th>No.</th>
<th>Phenotype</th>
<th>Genotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>It is the physical appearance of an organism.</td>
<td>It is the genetic constitution of an organism.</td>
</tr>
<tr>
<td>b.</td>
<td>It can be directly seen.</td>
<td>It is determined by inheritance pattern.</td>
</tr>
<tr>
<td>c.</td>
<td>Phenotype can be determined from genotype.</td>
<td>Genotype cannot be determined from phenotype e.g.</td>
</tr>
<tr>
<td></td>
<td>e.g. Tt = tall</td>
<td>Tt, Tt, tt.</td>
</tr>
<tr>
<td>d.</td>
<td>e.g. Tallness, dwarfness.</td>
<td></td>
</tr>
</tbody>
</table>

*Q.7. Why did Mendel select garden pea for his experiments? Explain the characteristics of pea.*

**Ans:** Mendel selected garden pea plant (*Pisum sativum*) for his experiments because of the following characteristics:

i. The pea plant (*Pisum sativum*) is an annual plant with short life cycle.
ii. The flowers are bisexual and naturally self-pollinating.
iii. They can be artificially cross-pollinated.
iv. The offspring produced after cross-pollination are fertile.
v. Pea plant has several pairs of contrasting characters.
vi. Flowers of pea plant are large enough for easy emasculation.
vii. It is a small herbaceous plant, so he could grow a large number of plants.

*Q.8. Enlist seven traits in pea selected by Mendel.*

**Ans:**

<table>
<thead>
<tr>
<th>No.</th>
<th>Character</th>
<th>Contrasting form / traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>i.</td>
<td>Height of stem</td>
<td>Tall (TT)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dwarf (tt)</td>
</tr>
<tr>
<td>ii.</td>
<td>Colour of flower</td>
<td>Colored (CC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>White (cc)</td>
</tr>
<tr>
<td>iii.</td>
<td>Position of flower</td>
<td>Axial (AA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Terminal (aa)</td>
</tr>
<tr>
<td>iv.</td>
<td>Pod shape</td>
<td>Inflated (II)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Constricted (ii)</td>
</tr>
<tr>
<td>v.</td>
<td>Pod colour</td>
<td>Green (GG)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yellow (gg)</td>
</tr>
<tr>
<td>vi.</td>
<td>Seed shape</td>
<td>Round (RR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wrinkled (rr)</td>
</tr>
<tr>
<td>vii.</td>
<td>Seed colour (cotyledon)</td>
<td>Yellow (YY)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Green (yy)</td>
</tr>
</tbody>
</table>

*Q.9. What are the reasons for Mendel’s success?*

**Ans:** The reasons for Mendel’s success are:

i. Mendel chose garden pea plant for his experiments which was an annual, naturally self-pollinating plant with several pairs of contrasting characters.
ii. Mendel concentrated only on one character at a time.
iii. He kept accurate records (both qualitative and quantitative).
iv. He used statistical methods for analyzing the results.
v. The characters selected by Mendel were present on different chromosomes.
vi. All the seven pairs of contrasting traits selected by him showed complete dominance.

Q.10. What is the genotype of a “true breeding tall” and “true breeding dwarf” pea plant?

**Ans:** The genotype of a “true breeding tall” pea plant is “TT” and that of a “true breeding dwarf” pea plant is “tt”.

*Q.11. Describe the steps or procedure of Mendel’s experiment with suitable example.*

**Ans:** The steps or procedure of Mendel’s experiments are as under:

i. **Selection of material:**
   Mendel selected garden pea (*Pisum sativum*) as the experimental material for his experiments.

ii. **Selection of characters:**
   Mendel selected seven pairs of contrasting characters in garden pea which are listed in the table given below.
### Chapter 01: Genetic Basis of Inheritance

#### No. Character | Dominant trait | Recessive trait
--- | --- | ---
1. Stem height | Tall (T) | Dwarf (t)  
2. Seed colour | Yellow (Y) | Green (y)  
3. Seed shape | Round (R) | Wrinkled (r)  
4. Pod colour | Green (G) | Yellow (g)  
5. Pod shape | Inflated (I) | Constricted (i)  
6. Flower position | Axial (A) | Terminal (a)  
7. Flower colour | Coloured (C) | White (c)

#### Procedure of Experiments:
- Mendel was very methodical in carrying out his experiments.
- First, he studied only one trait at a time, unlike others who had considered the organism as a whole.
- Then, he studied two traits and three traits at a time by performing monohybrid, dihybrid and trihybrid crosses.
- He started his experiments with true breeding (pure line) plants and maintained a complete record of the actual number of each type of offsprings.
- He conducted several crosses to eliminate chance factor.

**Mendel conducted experiments in the following three steps:**

**Step 1 - Selection of parents and obtaining pure lines.**
Mendel started with pure lines that were available. He also ensured that the selected male and female parent plants are breeding true for the selected trait/trait by selfing them for three generations. (Breeding true or ‘true breeding’ means they produce offsprings with the same selected trait/trait only).

**Step 2 - Artificial cross of the selected parents to raise F1 generation.**
Mendel first emasculated the flowers of the plant which he had selected as a female parent. Then, pollens from the flower of selected male parent were dusted on the stigma of the emasculated flower, i.e. artificial cross.
Mendel crossed many flowers, collected seeds and raised the hybrids that represent first filial generation or F1 generation.

**Step 3 - Selfing of F1 hybrids to raise F2 generation.**
Mendel allowed the natural self-pollination in each F1 hybrid; collected seeds separately and raised F2 generation, i.e. second filial generation. (F2 generation was obtained by selfing of F1 hybrids.)

**Q.12. Explain monohybrid cross with an example.**

**Ans:** Monohybrid cross: The cross between two pure parents differing in a single pair of contrasting character is called monohybrid cross. The ratio for the cross is 3 : 1.

**e.g.** Monohybrid cross between pure tall pea plant and pure dwarf pea plant.

<table>
<thead>
<tr>
<th>Phenotype of parents</th>
<th>Pure Tall</th>
<th>Pure Dwarf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotype</td>
<td>TT</td>
<td>tt</td>
</tr>
<tr>
<td>Gametes</td>
<td>T</td>
<td>t</td>
</tr>
</tbody>
</table>

**F1 generation**

<table>
<thead>
<tr>
<th>Tt</th>
<th>Hybrid tall</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>Tt</td>
</tr>
<tr>
<td>t</td>
<td>Tt</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gametes</th>
<th>Tt</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>t</td>
</tr>
<tr>
<td>t</td>
<td>T</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>F2 generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
</tr>
<tr>
<td>Tt</td>
</tr>
<tr>
<td>t</td>
</tr>
</tbody>
</table>

**Phenotypic ratio → 3 : 1 (3 tall : 1 dwarf)**

**Genotypic ratio → 1 : 2 : 1 (1 pure tall : 2 hybrid tall : 1 pure dwarf)**
Q.13. State Mendel’s first law of inheritance or law of dominance.
Ans: Law of dominance states that “in a cross between two homozygous organisms differing in a single pair of contrasting character, the character which is expressed in the F₁ generation is called dominant character and the character which is not expressed is the recessive character”.

Q.14. State Mendel’s second law of inheritance or law of segregation or law of purity of gametes.
Ans: Law of segregation states that “when the two alleles for a contrasting character are brought together in a hybrid, they do not mix or contaminate but segregate or separate out from each other during gamete formation”. Law of segregation is also known as law of purity of gametes, as gametes have only one allele.

Q.15. State Mendel’s third law of inheritance or law of independent assortment.
Ans: The law of independent assortment states that “when two homozygous parents differing from each other in two or more pairs of contrasting characters are crossed, then the inheritance of one pair of characters is independent of the other pair of characters”.

#Q.16. Explain law of dominance using a monohybrid cross.
Ans: Law of dominance states that “in a cross between two homozygous organisms differing in a single pair of contrasting character, the character which is expressed in the F₁ generation is called dominant character and the character which is not expressed is the recessive character”.

\[ \text{Tallness in pea plant is a dominant character, while dwarfness is a recessive character.} \]

\[
\begin{array}{c|c|c}
\text{Phenotype of parents} & \text{Pure tall} & \times \text{Pure dwarf} \\
\text{Genotype} & TT & tt \\
\text{Gametes} & T & t \\
\text{F₁ generation} & Tt & \\
\text{Explanation:} & & \\
\text{i.} & \text{In a cross between pure tall and pure dwarf pea plant, only tall character is expressed in all the individuals of F₁ generation.} \\
\text{ii.} & \text{Hence, it can be inferred that in pea plants, tallness is the dominant character, while dwarfness is a recessive character.} \\
\text{iii.} & \text{Tallness in F₁ hybrid is determined by genotype Tt in which the dominant allele ‘T’ suppresses the recessive allele ‘t’, thereby suppressing its expression in the phenotype.} \\
\end{array}
\]

Q.17. A pea plant pure for yellow seed colour is crossed with a pea plant pure for green seed colour. In F₁ generation, all pea plants were with yellow seed. Which law of Mendel is applicable? [Mar 15]
Ans: Mendel’s law of dominance is applicable. [1 mark]

Q.18. Explain why law of segregation is also called law of purity of gametes.
Ans: i. In F₁ hybrid (Tt), the two alleles Tall (T) and dwarf (t) present would segregate during gamete formation.
ii. Due to segregation, the two types of gametes produced, i.e. T and t would be pure for the trait they carry.
iii. Example:
\[
\begin{array}{c|c|c}
\text{F₁ hybrid} & \rightarrow & Tt \\
\text{Gametes} & \rightarrow & T \quad t \\
\end{array}
\]

Thus, law of segregation is also called law of purity of gametes.

Q.19. State and explain Mendel’s second law of inheritance.
Ans: Law of segregation states that “when the two alleles for a contrasting character are brought together in a hybrid union, they do not mix or contaminate but segregate or separate out from each other during gamete formation”. Explanation:

\[ \text{i. Each organism contains two factors for each trait in its diploid cells and the factors segregate during the formation of gametes.} \]
i. Each gamete then contains only one factor from each pair of factors.

ii. When fertilization occurs, the new organism has two factors for each trait, one from each parent.

iii. When Mendel crossed a homozygous tall plant (TT) with a homozygous dwarf plant (tt), the offspring was found to be a hybrid tall (Tt).

iv. The hybrid tall thus produced has two alleles, viz. ‘T’ (tallness) and ‘t’ (dwarfness). During gamete formation, the two alleles, viz. ‘T’ and ‘t’ segregate as shown below:

<table>
<thead>
<tr>
<th>Phenotype of parents</th>
<th>Pure Tall × Pure Dwarf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotype</td>
<td>TT</td>
</tr>
<tr>
<td></td>
<td>tt</td>
</tr>
<tr>
<td>Gametes</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>t</td>
</tr>
<tr>
<td>F1 generation</td>
<td>(Hybrid Tall)</td>
</tr>
<tr>
<td>Selfing of F1 generation</td>
<td>Tt × Tt</td>
</tr>
<tr>
<td>Gametes</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>t</td>
</tr>
<tr>
<td></td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>t</td>
</tr>
</tbody>
</table>

The two alleles (contrasting characters) do not mix, alter or dilute each other and the gametes formed are ‘pure’ for the characters which they carry. Hence, this law is also called the law of purity of gametes.

Q.20. A pea plant with purple flowers was crossed with white flowers producing 50 plants with only purple flowers. On selfing, these plants produced 482 plants with purple flowers and 162 with white flowers. What genetic mechanism accounts for these results? Explain.

Ans: In pea plant: Purple colour of flower is dominant and white is recessive trait.

<table>
<thead>
<tr>
<th>Phenotype of parents</th>
<th>Purple flower × White flower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotype</td>
<td>pp</td>
</tr>
<tr>
<td></td>
<td>pp</td>
</tr>
<tr>
<td>Gametes</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>p</td>
</tr>
<tr>
<td>F1 generation</td>
<td>Purple flower</td>
</tr>
<tr>
<td>Selfing of F1 generation</td>
<td>Pp × Pp</td>
</tr>
<tr>
<td>Gametes</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>p</td>
</tr>
<tr>
<td></td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>p</td>
</tr>
<tr>
<td>F2 generation</td>
<td></td>
</tr>
</tbody>
</table>

| Phenotypic ratio → 3:1 (482 purple flowers : 162 white flowers) |
| Genotypic ratio → 1:2:1 (1PP: 2Pp: 1pp) |

In F2 generation, the ratio comes to 3 : 1 between purple and white flowers. It is a monohybrid cross involving one pair of contrasting character. It explains law of dominance and law of segregation. The characters are controlled by factors that occur in pairs. Only the dominant factor expresses in F1 generation.

#Q.21. Using a Punnett square, workout the distribution of phenotypic features in the first filial generation after a cross between a homozygous female and heterozygous male for a single locus.

Ans: Female can be represented as TT (homozygous tall) and male can be represented as Tt (heterozygous tall). Thus, using Punnett square, their cross can be given as follows:
Thus, in the first filial generation, all offsprings will be phenotypically dominant, i.e. tall, whereas genotypically 50% will be homozygous tall and 50% will be heterozygous tall.

Q.22. Explain dihybrid cross with suitable example. [Oct 13]

Ans: Dihybrid cross:

A cross between two pure (homozygous) parents in which the inheritance pattern of two pairs of contrasting characters is considered simultaneously is called Dihybrid cross. [1 mark]

The phenotypic ratio of different types of offsprings (with different combinations) obtained in F\textsubscript{2} generation of dihybrid cross is called dihybrid ratio. It is 9:3:3:1.

For example, when we cross a yellow round seed pea plant with a green wrinkled seed pea plant, we get 9 yellow round, 3 yellow wrinkled, 3 green round and 1 green wrinkled plants in the F\textsubscript{2} generation. [1 mark]

<table>
<thead>
<tr>
<th>Phenotype of parents</th>
<th>TT</th>
<th>Tt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotype</td>
<td>F\textsubscript{1} generation</td>
<td></td>
</tr>
<tr>
<td>Gametes</td>
<td>T</td>
<td>t</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>Tt</td>
</tr>
<tr>
<td></td>
<td>Tall</td>
<td>Tall</td>
</tr>
</tbody>
</table>

Thus, in the first filial generation, all offsprings will be phenotypically dominant, i.e. tall, whereas genotypically 50% will be homozygous tall and 50% will be heterozygous tall.

Phenotypic ratio: Yellow round = 9; Yellow wrinkled = 3; Green round = 3; Green wrinkled = 1

Dihybrid ratio → 9 : 3 : 3 : 1
Q.23. State and explain the ‘Law of Independent Assortment’ with a suitable example.  

**Ans:** The law of independent assortment states that “when two parents differing from each other in two or more pairs of contrasting characters are crossed, then the inheritance of one pair of character is independent of the other pair of character.”

For example, when we cross a pure tall, red flowered pea plant with a pure dwarf white flowered pea plant, we get 9 tall red, 3 tall white, 3 dwarf red and 1 dwarf white plants in the F₂ generation. A cross between two homozygous individuals differing in two pairs of contrasting characters is called dihybrid cross.

<table>
<thead>
<tr>
<th>Phenotype of parents</th>
<th>Tall Red</th>
<th>Dwarf White</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotype</td>
<td>TTRR</td>
<td>ttr</td>
</tr>
<tr>
<td>Gametes</td>
<td>TR</td>
<td>tr</td>
</tr>
<tr>
<td>F₁ generation</td>
<td>TtRr (Tall Red)</td>
<td></td>
</tr>
<tr>
<td>Selfing of F₁ generation</td>
<td>TtRr  × TtRr</td>
<td></td>
</tr>
<tr>
<td>Gametes</td>
<td>TR Tr tR tr</td>
<td></td>
</tr>
<tr>
<td>F₂ generation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Result:** Tall red = 9; Tall white = 3; Dwarf red = 3; Dwarf white = 1

Phenotypic ratio → 9 : 3 : 3 : 1

Genotypic ratio → 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1

TTRR TTRr TtRR TtRr ttRR ttRr TTRr Tttr

From the above results, it is obvious that the inheritance of character of tallness in no way linked with the red colour of the flower. Similarly, the character of dwarfness is not linked with the white colour of the flower. This is due to the fact that in the above cross, the two pairs of characters segregate independently. In other words, there is independent assortment of characters during inheritance.

**[Explanation – 3 marks, Diagrammatic representation – 3 marks]**

Q.24. Describe the cross between a homozygous tall, round-seeded pea plant and a dwarf, wrinkled-seeded pea plant.

What will be the types of progeny in the F₂ generation of this cross and in what proportion will it be?

Name and state the law which is explained by this example.  

**Ans:** Let the gene for tall habit of pea plant be represented by ‘T’ and dwarf habit be represented by ‘t’.

Let the gene for round-seed be represented by ‘R’ and that of wrinkled seed be represented by gene ‘r’.

Then, the genotypes of the parents would be:

i. Homozygous tall, round-seeded – TTRR

ii. Homozygous dwarf, wrinkled seeded – ttrr
Offspring in F<sub>2</sub> generation:
Tall round = 9, Tall wrinkled = 3
Dwarf round = 3, Dwarf wrinkled = 1
Phenotypic ratio → 9 : 3 : 3 : 1
Genotypic ratio → 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1

The above example of a dihybrid cross between homozygous tall, round-seeded pea plant and dwarf, wrinkled-seeded pea plant explains the 'Law of Independent Assortment'.

Q.25. Why law of independent assortment is not universally applicable?
Ans

i. When the two homozygous parents differing in two pairs of contrasting traits are crossed, the inheritance of one pair is independent of the other. In other words, when a dihybrid forms gametes, assortment (distribution) of alleles of different traits is independent of their original combinations in the parents.

ii. Many genes are located on one chromosome, i.e. they are linked. Therefore, they pass through gametes in the form of a linkage group. However, recombinations are due to the crossing over that takes place during meiosis.

iii. Therefore, the law of independent assortment is applicable only for the traits which are located on different chromosomes. Thus, law of independent assortment is not universally applicable.
Q.26. A true breeding pea plant homozygous for axial violet flowers (AAVV) is crossed with terminal white flowers (aavv).

i. What would be the phenotype and genotype of F₁ and F₂ generations?

ii. Give the phenotypic ratio of F₂ generation.

iii. List Mendel’s generalisation that can be derived from the above cross.

Ans:

i. Phenotype of parents → Axial violet × Terminal white

Genotype → AAVV × aavv

Gametes → AV AV av av

F₁ generation →

<table>
<thead>
<tr>
<th>Parent</th>
<th>F₁ Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV AV</td>
<td>AaVv</td>
</tr>
<tr>
<td>av av</td>
<td>AaVv</td>
</tr>
</tbody>
</table>

Phenotype of F₁ generation – All Axial Violet
Genotype of F₁ generation – AaVv

ii. Selfing of F₁

Gametes → AV Av aV av × AV Av aV av

F₂ generation →

<table>
<thead>
<tr>
<th>Parent</th>
<th>F₂ Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV AV</td>
<td>AAVV, AaVv</td>
</tr>
<tr>
<td>av av</td>
<td>AaVv</td>
</tr>
</tbody>
</table>

F₂ phenotypic ratio → 9 Axial Violet; 3 Axial White; 3 Terminal Violet; 1 Terminal White.

iii. Mendel proposed “The law of independent assortment” from the above cross.

In a dihybrid cross, the segregation of one pair of traits is independent of the other.

#Q.27. When a cross is made between tall plant with yellow seeds (TtYy) and tall plant with green seeds (Ttyy), what proportions of phenotype in the offspring could be expected to be:

i. Tall and green

ii. Dwarf and green

Ans:

i. Tall and green

Phenotype of parents → Tall plant with yellow seeds × Tall plant with green seeds

Genotype → TtYy × Ttyy

Gametes → Ty Ty Ty ty × Ty Ty ty ty

F₁ Generation →

<table>
<thead>
<tr>
<th>Parent</th>
<th>F₁ Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ty Ty</td>
<td>TTYy, TyYy</td>
</tr>
<tr>
<td>Ty Ty</td>
<td>TTYy, TyYy</td>
</tr>
<tr>
<td>ty ty</td>
<td>TtYy, tYy</td>
</tr>
<tr>
<td>Ty Ty</td>
<td>TTTYy, TyYy</td>
</tr>
<tr>
<td>Ty Ty</td>
<td>TTTYy, TyYy</td>
</tr>
<tr>
<td>ty ty</td>
<td>TtYy, tYy</td>
</tr>
<tr>
<td>Ty Ty</td>
<td>TtYy, tYy</td>
</tr>
<tr>
<td>Ty Ty</td>
<td>TtYy, tYy</td>
</tr>
<tr>
<td>ty ty</td>
<td>TtYy, tYy</td>
</tr>
</tbody>
</table>

In a dihybrid cross, the segregation of one pair of traits is independent of the other.
Thus,

i. Offsprings with phenotype tall and green are 3.

ii. Offspring with phenotype dwarf and green is 1.

#Q.28. Distinguish between Monohybrid cross and Dihybrid cross.

Ans:

<table>
<thead>
<tr>
<th>No.</th>
<th>Monohybrid cross</th>
<th>Dihybrid cross</th>
</tr>
</thead>
<tbody>
<tr>
<td>i.</td>
<td>The cross between two pure parents differing in a single pair of contrasting character is called Monohybrid cross.</td>
<td>The cross between two pure parents differing in two pairs of contrasting characters is called dihybrid cross.</td>
</tr>
<tr>
<td>iv.</td>
<td>The law of segregation is explained by this cross.</td>
<td>The law of independent assortment is explained by this cross.</td>
</tr>
</tbody>
</table>

Q.29. Answer the following:

i. What is a back cross?

Ans: The cross between F₁ hybrid and any one of the parents is called back cross.

*ii. Define the term Test cross.

Ans: The cross between F₁ hybrid and the recessive parent is called test cross.

iii. When is back cross not a test cross?

Ans: A back cross with dominant parent is not a test cross.

*Q.30. Explain the statements.

i. Test cross is a back cross but back cross is not necessarily a test cross.

ii. Law of dominance is not universally applicable.

iii. Law of segregation is universally applicable.

Ans: i. Test cross is a back cross but back cross is not necessarily a test cross.

It is because; in back cross F₁ generation can be crossed with either dominant or recessive parent.

But in test cross, F₁ generation is crossed with recessive parent only. Thus, test cross is a back cross but back cross is not necessarily a test cross.

ii. Law of dominance is not universally applicable.

In a cross between two organisms pure for any pair (or pairs) of contrasting characters, the character that appears in F₁ generation is called dominant and the one which is suppressed is called recessive.

In many cases, the dominance is not complete or absent. Phenomenon of dominance is significant as the harmful recessive traits are masked, i.e. not expressed in the presence of its normal dominant allele.

e.g. In humans a form of idiocy, diabetes and haemophilia are recessive characters.

Thus, law of dominance is significant and true, but it is not universally applicable.

iii. Law of segregation is universally applicable.

Member of allelic pair in a hybrid remain together without mixing with each other and separate or segregate during gamete formation. Thus gametes receive only one of the two factors and are pure for a given trait. Therefore, this is also known as law of segregation.

All sexually reproducing higher organisms are diploid (2n), i.e. with two sets of chromosomes and gametes are haploid (n), i.e. with one set of chromosome. Therefore, law of segregation is universally applicable.

Q.31. Explain briefly the back cross and test cross.

Ans: i. When the F₁ hybrid is crossed back with any one of the parents, it is called a back cross. Cross of F₁ hybrid with homozygous recessive parent is test cross.

ii. A back cross can be a test cross, but all test crosses need not be back crosses. A back cross with dominant parent is not a test cross.

iii. Back cross can be a dominant or recessive back cross.
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iv. In dominant back cross, \( F_1 \) individual is crossed with dominant parent and all progeny shows dominant character.

v. \( F_1 \) hybrid tall plant (\( Tt \)) is crossed with dominant parent (\( TT \)), progeny will be \( TT \) or \( Tt \). Genotypically and phenotypically all offsprings would be tall.

vi. In recessive back cross, \( F_1 \) individual is crossed with recessive parent (\( tt \)).

vii. If progeny is \( Tt \) or \( tt \) genotypically and 50 % tall and 50 % dwarf phenotypically, then one can infer that \( F_1 \) generation is heterozygous, i.e. \( Tt \).

viii. If progeny is \( TT \) genotypically, i.e. all tall phenotypically, then one can infer that \( F_1 \) generation is homozygous, i.e. \( TT \).

Back cross:

\[ F_1 \text{ generation} \times \text{Dominant parent} \]

\[ \begin{array}{c|c|c}
   T & t \\
\hline
   T & TT & Tt \\
   T & TT & Tt \\
\end{array} \]

All offsprings are tall.

Thus, in back cross with dominant parent, all the progeny obtained show dominant character.

Recessive back cross (Test cross):

\[ F_1 \text{ generation} \times \text{Recessive parent} \]

\[ \begin{array}{c|c|c}
   T & t \\
\hline
   t & Tt & tt \\
   t & Tt & tt \\
\end{array} \]

50% offsprings are tall and 50% dwarf.

Thus, test cross produced progeny with both dominant and recessive characters in equal proportion.

Q.32. A heterozygous tall plant of pea is crossed with a dwarf plant of pea. Calculate the phenotypic ratio of the progeny. [Oct 13]

Ans: When a heterozygous tall plant of pea (\( Tt \)) is crossed with a dwarf plant of pea (\( tt \)), it can be represented as follows:

\[ \text{Phenotype of Parents} \rightarrow \text{Heterozygous Tall} \times \text{Dwarf} \]

\[ \text{Genotype} \rightarrow \text{Tt} \times \text{tt} \]

\[ \text{Gametes} \rightarrow \text{\( T \) and \( t \)} \times \text{\( t \)} \]

\[ \text{\( F_1 \) generation} \rightarrow \text{\( Tt \) and \( tt \)} \]

In this cross, 50% offsprings are tall and 50% are dwarf.

Thus, phenotypic ratio of the progeny = 1 (Tall) : 1 (Dwarf) [1 mark]
Q.33. What is the ratio of dihybrid test cross? Give a graphical representation with the help of Punnett square.

**Ans:** The ratio of dihybrid cross can be explained with the help of a cross between tall pea plant with red flowers and dwarf pea plant with white flowers.

<table>
<thead>
<tr>
<th>Phenotype of parents</th>
<th>Gametes</th>
<th>F₁ generation</th>
<th>Test cross</th>
<th>F₂ generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure tall with Red flowers</td>
<td>TR × tr</td>
<td>Hybrid tall with Red flower</td>
<td>TtRr × ttr</td>
<td>Test cross ratio: 1 : 1 : 1 : 1</td>
</tr>
<tr>
<td>Pure dwarf with white flowers</td>
<td>TTRR × trrr</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thus, in the F₂ generation of a test cross, 50% are heterozygous tall plants (Tt) and 50% are homozygous dwarf plants (tt).

**Significance of test cross:**

i. It helps to determine whether individuals exhibiting dominant character are genotypically homozygous or heterozygous.

ii. Purity of the parents can be determined.

iii. It helps to determine the genotype of the individual.

iv. It has wide application in plant breeding experiments.
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Q.35. Give the significance of back cross.
Ans: Significance of back cross:
   i. It is a rapid method of improving crop variety.
   ii. It helps to verify laws of inheritance.
   iii. Back cross with dominant parent always produce dominant characters.
   iv. Continuous back cross never produce recessive trait, hence recessive trait can be eliminated from progeny.

Q.36. Distinguish between Test cross and Back cross.
Ans:

<table>
<thead>
<tr>
<th>No.</th>
<th>Test cross</th>
<th>Back cross</th>
</tr>
</thead>
<tbody>
<tr>
<td>i.</td>
<td>The cross between F₁ hybrid and its recessive parent is called test cross.</td>
<td>The cross between F₁ hybrid and any one of its parents (either dominant or recessive) is called back cross.</td>
</tr>
<tr>
<td>ii.</td>
<td>A test cross is always a back cross.</td>
<td>A back cross is not always a test cross.</td>
</tr>
<tr>
<td>iii.</td>
<td>Test cross determines the genetic constitution of an organism.</td>
<td>Back cross helps in improving and obtaining desirable characters.</td>
</tr>
<tr>
<td>iv.</td>
<td>Test cross produces both dominant and recessive characters in equal proportion.</td>
<td>Back cross with dominant parent produces all dominant character.</td>
</tr>
</tbody>
</table>

1.2 Deviations from Mendelian ratios

Incomplete Dominance

#Q.37. Explain incomplete dominance with an example. [July 16]
Ans: Incomplete dominance:
   i. Incomplete dominance can be defined as a phenomenon in which neither of the alleles of a gene is completely dominant over the other and hybrid is intermediate between the two parents.
   ii. Incomplete dominance is a deviation of Mendel’s law of dominance which states that out of two contrasting allelomorphic factors, only one expresses itself in an individual in F₁ generation called as dominant, while other which has not shown its effect is called as recessive, however this recessive hidden character reappeared, unchanged in F₂ generation.
   iii. Thus, according to incomplete dominance, F₁ phenotype is intermediate between the parental traits. Incomplete dominance is demonstrated in Mirabilis jalapa (four o’clock plant) as given below:

   Phenotype of Parents → Red flower White flower
   Genotype → RR RR × rr rr
   Gametes → R R × r r
   F₁ generation → Pink flower
   Seling of F₁ generation → Rr Pink flower Rr Pink flower
   Gametes → R R × r r
   F₂ generation

<table>
<thead>
<tr>
<th></th>
<th>R</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>RR</td>
<td>Rr</td>
</tr>
<tr>
<td>r</td>
<td>Rr</td>
<td>rr</td>
</tr>
</tbody>
</table>

   Diagrammatic representation - 1 mark

Phenotypic ratio → 1:2:1 (1 Red : 2 Pink : 1 White) [½ mark]
Genotypic ratio → 1:2:1 (1 RR : 2 Rr : 1 rr) [½ mark]
This indicates the following facts:

i. Pink is the phenotype of the heterozygous genotype (Rr).

ii. This pattern of inheritance is due to non-blending of the characters, because one-fourth of the F₂ progeny are red-flowered and another one-fourth are white-flowered, which are the parental combinations.

iii. The phenotypic and genotypic ratios are the same.

iv. This type of observation has resulted from incomplete dominance of the alleles.

Q.38. Name two plants showing incomplete dominance.
Ans: Snapdragon (Antirrhinum majus) and Four o’clock plant (Mirabilis jalapa) show incomplete dominance.

Co-dominance

Q.39. Explain co-dominance with suitable examples.
Ans: Co-dominance is a condition in which both alleles of a gene pair in heterozygous condition are fully expressed, with neither one being dominant or recessive to the other. Thus, in co-dominance, we get a blending of dominant and recessive traits resulting in different phenotype.

Example 1:
Blood group ‘AB’ in humans is an example of co-dominance.

i. Blood group character is controlled by gene I, that exists in three allelic forms Iᴬ, Iᴮ and Iᴼ.

ii. In Iᴬ and Iᴮ, superscripts A and B stand for glycoproteins (sugar polymers) that are found projecting from the surface of RBCs.

iii. The allele Iᴬ produces glycoprotein A, while Iᴮ produces glycoprotein B, allele Iᴼ does not produce any of them.

iv. The allele Iᴬ is dominant over Iᴼ, Iᴮ is also dominant over Iᴼ. Allele Iᴬ and Iᴮ are co-dominant and express themselves when present together. Such RBCs have both the types of glycoproteins and blood group will be AB.

Example 2:
Roan coat colour in Cattle.

i. There are two types, one with red coat (skin with red colour hair) and the other with white coat (with white hair).

ii. When red cattle (RR) is crossed with white cattle (WW), F₁ hybrids (RW) have roan colour. Roans have the mixture of red and white colour hair.

iii. Thus, both the traits are expressed equally. In F₂ generation (produced by interbreeding of roans), red (RR), roans (RW) and white (WW) are produced in the ratio 1:2:1.

iv. Thus, in co-dominance also, genotypic and phenotypic ratios are identical.

Q.40. Distinguish between the following:

i. Complete dominance and Incomplete dominance. ii. Dominance and Co-dominance.

*iii. Incomplete dominance and Co-dominance.

Ans: i. Complete dominance and Incomplete dominance.

<table>
<thead>
<tr>
<th>No.</th>
<th>Complete Dominance</th>
<th>Incomplete Dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>Dominant trait always dominates recessive trait or character.</td>
<td>Neither of the traits/characters is completely dominant over the other.</td>
</tr>
<tr>
<td>b.</td>
<td>When we cross two homozygous parents for one or more pairs of contrasting characters, the hybrid of F₁ is always dominant. It is termed as complete dominance.</td>
<td>When a cross is made between two homozygous parents for one or more pairs of traits, the hybrid of F₁ is intermediate. It is called incomplete dominance, when dominance is not complete.</td>
</tr>
<tr>
<td>c.</td>
<td>Dominant allele is stronger than the recessive allele in it.</td>
<td>Both alleles of one contrasting pair have equal strength. They express themselves incompletely in it.</td>
</tr>
<tr>
<td>d.</td>
<td>Example: Height of Pea plant. P₁ → Tall Plant × Dwarf plant TT × tt F₁ → Tt Tall plant</td>
<td>Example: Flower colour in M. jalapa P₁ → Red flower × White flower RR × rr F₁ → Rr Pink Flower</td>
</tr>
</tbody>
</table>
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ii. **Dominance and Co-dominance.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Dominance</th>
<th>Co-dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>In a pair of genes with contrasting characters, only one of the traits (dominant) is expressed in hybrid.</td>
<td>In a pair of genes with contrasting characters, both traits are expressed in hybrid.</td>
</tr>
<tr>
<td>b.</td>
<td>Dominant allele is stronger than recessive allele.</td>
<td>Both alleles possess equal strength.</td>
</tr>
<tr>
<td>c.</td>
<td>Only the product of dominant allele is observed in phenotype.</td>
<td>Product of both alleles are observed in phenotype.</td>
</tr>
<tr>
<td>d.</td>
<td>Example: Hybrid tall pea plant (Tt).</td>
<td>Example: AB blood group in humans.</td>
</tr>
</tbody>
</table>

*iii. Incomplete dominance and Co-dominance.

<table>
<thead>
<tr>
<th>No.</th>
<th>Incomplete dominance</th>
<th>Co-dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>It is the phenomenon in which neither of the alleles of a gene is completely dominant over the other.</td>
<td>It is the phenomenon in which two alleles of a gene are equally dominant and express themselves in the presence of the other, when they are together.</td>
</tr>
<tr>
<td>b.</td>
<td>In case of incomplete dominance, the phenotype of hybrids is intermediate between phenotypes of parents.</td>
<td>In codominance, both the genes are expressed equally.</td>
</tr>
<tr>
<td>c.</td>
<td>e.g. Pink colour flower of <em>Mirabilis jalapa</em>.</td>
<td>e.g. Roan coat colour in cattle.</td>
</tr>
</tbody>
</table>

Q.41. ‘In incomplete dominance and co-dominance, genotypic and phenotypic ratios are identical.’ Explain how co-dominance differs from incomplete dominance in phenotypic nature of their hybrids. [Mar 13]

**Ans:**

i. **Co-dominance** is a condition in which both alleles of a gene pair in heterozygous condition are fully expressed, with neither one being dominant or recessive to the other.

- Genotypic ratio of Co-dominance → 1:2:1
- Phenotypic ratio of Co-dominance → 1:2:1 [1 mark]

ii. **Incomplete dominance** can be defined as a phenomenon in which neither of the alleles of a gene is completely dominant over the other and hybrid is intermediate between the two parents.

- Genotypic ratio of Incomplete dominance → 1:2:1
- Phenotypic ratio of Incomplete dominance → 1:2:1 [1 mark]

iii. In incomplete dominance, the phenotype of hybrid is intermediate between the phenotypes of parents, whereas in co-dominance, there is no intermediate expression as both the alleles express themselves independently. [1 mark]

### Multiple Alleles and Inheritance of blood groups

Q.42. What is multiple allelism? Explain with example of ABO blood group system in humans.

**Ans:** Multiple Allelism:

i. More than two alternative forms (alleles) of gene in a population occupying the same locus on a chromosome or its homologue are known as multiple alleles.

ii. ABO blood group system in humans is an example of multiple allelism, because gene I exists in three allelic forms $I^A$, $I^B$ and $I^O$.

iii. Here, allele $I^A$ codes for type A blood, allele $I^B$ codes for type B blood and allele $I^O$ codes for type O blood.

iv. Allele $I^O$ is recessive to the alleles $I^A$ and $I^B$.

v. Thus, with these three alleles, we can have 6 different genotypes and 4 different phenotypes for blood groups.

<table>
<thead>
<tr>
<th>No.</th>
<th>Genotype</th>
<th>Phenotype (Blood group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i.</td>
<td>$I^A I^A$ or $I^A I^O$</td>
<td>Type A</td>
</tr>
<tr>
<td>ii.</td>
<td>$I^B I^B$ or $I^B I^O$</td>
<td>Type B</td>
</tr>
<tr>
<td>iii.</td>
<td>$I^A I^B$</td>
<td>Type AB</td>
</tr>
<tr>
<td>iv.</td>
<td>$I^O I^O$</td>
<td>Type O</td>
</tr>
</tbody>
</table>
Q.43. A child has blood group O. If the father has blood group A and mother has blood group B. Work out the genotypes of the parents and the possible genotypes of the other offsprings.

Ans: Possible genotype of father = $I^A I^A$ or $I^A I^O$
Possible genotype of mother = $I^B I^B$ or $I^B I^O$

The blood group of child is ‘O’. So, its genotype must be $I^O I^O$ because it has recessive alleles of a gene.
Since the genotype of child $I^O I^O$, so the genotype of father and mother should be $I^A I^O$ and $I^B I^O$ respectively because both parents are contributing their recessive allele ($I^O$) to the child.

Phenotype of parents  Male  ×  Female
Gametes  $I^A I^O$  $I^B I^O$
F$_1$ generation  

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>Genotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal wings</td>
<td>$V_g^+$</td>
</tr>
<tr>
<td>Nicked wings</td>
<td>$v_g^{ni}$</td>
</tr>
<tr>
<td>Notched wings</td>
<td>$v_g^{no}$</td>
</tr>
<tr>
<td>Strap wings</td>
<td>$v_g^{st}$</td>
</tr>
<tr>
<td>Vestigial wings</td>
<td>$v_g$</td>
</tr>
</tbody>
</table>

Q.44. Give multiple alleles of the different wings in Drosophila.
Ans:

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>Genotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal wings</td>
<td>$V_g^+$</td>
</tr>
<tr>
<td>Nicked wings</td>
<td>$v_g^{ni}$</td>
</tr>
<tr>
<td>Notched wings</td>
<td>$v_g^{no}$</td>
</tr>
<tr>
<td>Strap wings</td>
<td>$v_g^{st}$</td>
</tr>
<tr>
<td>Vestigial wings</td>
<td>$v_g$</td>
</tr>
</tbody>
</table>

Pleiotropy

*Q.45. Write a note on pleiotropy.
Ans: Pleiotropy:

i. When a single gene controls two (or more) different traits, it is called pleiotropic gene and this phenomenon is called pleiotropy or pleiotropism.

The ratio is 2:1 instead of 3:1.

ii. According to Mendel’s principle of unit character, one gene (factor) controls one character (trait), but sometimes single gene produces two related or unrelated phenotypic expressions.

iii. For example, the disease, sickle cell anaemia is caused by a gene $Hb^S$. Normal or healthy gene is $Hb^A$ and is dominant.

iv. The carriers (heterozygotes – $Hb^A/Hb^S$) show signs of mild anaemia as their RBCs become sickle-shaped (half-moon shaped) in oxygen deficiency. They are said to have sickle-cell trait and are normal in normal conditions.

v. The homozygotes with recessive gene $Hb^S$ however, die of fatal anaemia.

vi. Thus, the gene for sickle-cell anaemia is lethal in homozygous condition and produces sickle cell trait in heterozygous carrier.

vii. Two different expressions are produced by a single gene.

Q.46. Why is marriage between sickle cell anaemic carriers discouraged? Explain with graphical representation.
Ans: A marriage between two carriers will produce normal, carriers and sickle-cell anaemic children in 1:2:1 ratio. But, sickle-cell anaemics who are homozygous for gene $Hb^S$ will die, as $Hb^S$ is a lethal gene causing death of the bearer.

Thus, marriage between two heterozygotes can be discouraged to avoid birth of children with fatal sickle-cell anaemia.
**Q.47. Why the ratio in pleiotropy is 2:1? Explain it with example.**

**Ans:**

i. When a single gene controls two (or more) different traits, it is called pleiotropic gene and this phenomenon is called pleiotropy or pleiotropism. [½ mark]

a. The ratio is 2:1 instead of 3:1.

b. According to Mendel’s principle of unit character, one gene (factor) controls one character (trait), but sometimes single gene produces two related or unrelated phenotypic expressions.

c. For example, the disease, sickle cell anaemia is caused by a gene \( Hb^S \). Normal or healthy gene is \( Hb^A \) and is dominant.

d. The carriers (heterozygotes – \( Hb^A/Hb^S \)) show signs of mild anaemia as their RBCs become sickle-shaped (half-moon shaped) in oxygen deficiency. They are said to have sickle-cell trait and are normal in normal conditions.

e. The homozygotes with recessive gene \( Hb^S \) however, die of fatal anaemia.

f. Thus, the gene for sickle-cell anaemia is lethal in homozygous condition and produces sickle cell trait in heterozygous carrier.

g. Two different expressions are produced by a single gene.

h. A marriage between two carriers will produce normal, carriers and sickle-cell anaemic children in 1:2:1 ratio. But, sickle-cell anaemics who are homozygous for gene \( Hb^S \) will die, as \( Hb^S \) is a lethal gene causing death of the bearer.

Thus the sickle cell anaemics die leaving carriers and normals in the ratio 2:1. [½ mark]

**Polygenic (Quantitative) inheritance**

*Q.48. What are polygenes? Explain with suitable example.*

**Ans:** Polygenes:

Characters are determined by two or more gene pairs, and they have additive or cumulative effect. Such genes are called cumulative genes or polygenes or multiple factors.
Example 1:

Human skin colour

i. Population derived from marriage between negro and white show intermediate skin colour and are called mulattoes.

ii. When such individuals marry each other, all shades of colour are observed in the population in the ratio, 1:6:15:20:15:6:1.

From this, it can be concluded that skin colour in humans is controlled by three pairs of genes, Aa, Bb, and Cc.

iii. The presence of melanin pigment in the skin determines the skin colour. Each dominant gene is responsible for the synthesis of fixed amount of melanin.

iv. The effect of all the genes is additive and the amount of melanin synthesized is always proportional to the number of dominant genes.

v. Genotype of negro parent is AABBCC, and that of albino (pure white, melanin is not produced at all) is aabbcc.

vi. Genotype of their offspring (mulatto) is AaBbCc.

vii. Mulattoes (F₁ offspring) produce eight different types of gametes, and total sixty four combinations are possible in the population of next generation (F₂), but there are seven different phenotypes due to the cumulative effect of each dominant gene as follows.

<table>
<thead>
<tr>
<th>i.</th>
<th>Pure black (negro)</th>
<th>6 dominant genes</th>
<th>1/64</th>
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</thead>
<tbody>
<tr>
<td>ii.</td>
<td>Black (less dark than negro parent)</td>
<td>5 dominant genes</td>
<td>6/64</td>
</tr>
<tr>
<td>iii.</td>
<td>Lesser black or brown</td>
<td>4 dominant genes</td>
<td>15/64</td>
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<tr>
<td>iv.</td>
<td>Mulatto (intermediate-'sanwla')</td>
<td>3 dominant genes</td>
<td>20/64</td>
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<tr>
<td>v.</td>
<td>Fair</td>
<td>2 dominant genes</td>
<td>15/64</td>
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<tr>
<td>vi.</td>
<td>Very fair</td>
<td>1 dominant gene</td>
<td>6/64</td>
</tr>
<tr>
<td>vii.</td>
<td>Pure white (albino)</td>
<td>No dominant gene</td>
<td>1/64</td>
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</tbody>
</table>

Example 2:

Kernel colour in Wheat

i. A variety of wheat with red kernel was crossed with wheat having white kernel.

ii. The F₁ generation plants had red kernel, but of a shade intermediate between the red and white of the parental generation.

iii. When F₁ plants were self-pollinated, the F₂ individuals produced were of five different phenotypes, in the ratio of 1:4:6:4:1.

iv. 1/16 of the individuals of the progeny were darkest red (as red as a parent plant) resembled one of the parents and another 1/16 individuals were white (as white as a parent plant).

v. 4/16 of the individuals were medium red (less than parent but more than F₁ hybrids), 6/16 of the individuals were intermediate red (as F₁ hybrids) and 4/16 of the individuals were light red (less than F₁ hybrids).

vi. It was concluded that the kernel colour is under control of two pairs of alleles.

The two pairs of alleles segregate independently of each other as in Mendel’s dihybrid crosses. The two genes contribute in the production of pigment and a graded phenotype is produced.
**Chapter 01: Genetic Basis of Inheritance**

**Phenotype of parents** → Red kernel × White kernel  
**Genotype** → AABB  
**Gametes** → AB, ab  
**F₁ generation** → Intermediate red  
**Selfing of F₁ generation** → AaBb × AaBb  
**Gametes** → AB, Ab, aB, ab, Ab, Ab, aB, ab  
**F₂ generation** →  
<table>
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<tr>
<th>Phenotypic ratio →</th>
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</thead>
<tbody>
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<td>Dark red</td>
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<td>4</td>
<td>6</td>
<td>4</td>
<td>1</td>
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<td>Medium red</td>
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<td>White</td>
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**Additional Theory Questions**

#Q.1. Mention the advantages of selecting pea plant for his experiment by Mendel. Refer Q.7.

[Any four points - ½ mark each]


Q.5. What was Mendel’s experimental procedure? Refer Q.11.


Q.7. State and explain Mendel’s first law or law of dominance. Refer Q.16.

*Q.8. State and explain the Law of dominance with suitable example. Refer Q.16.

Q.9. State and explain Mendel’s second law of inheritance or law of segregation or law of purity of gametes. Refer Q.19.


Q.13. State Mendel’s third law of inheritance or law of independent assortment and explain it with a dihybrid cross. Refer Q.23.


[Definition of multiple alleles – 1 mark, Any four points of explanation – 2 marks]

Quick Review

- 7 Pairs of contrasting characters studied by Mendel in pea plant:

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<tr>
<th>No.</th>
<th>Character</th>
<th>Dominant</th>
<th>Recessive</th>
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<tbody>
<tr>
<td>i.</td>
<td>Height of stem</td>
<td>Tall (TT)</td>
<td>Dwarf (tt)</td>
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<td>ii.</td>
<td>Colour of flower</td>
<td>Coloured (CC)</td>
<td>White (cc)</td>
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<tr>
<td>iii.</td>
<td>Position of flower</td>
<td>Axial (AA)</td>
<td>Terminal (aa)</td>
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<td>iv.</td>
<td>Pod shape</td>
<td>Inflated (II)</td>
<td>Constricted (ii)</td>
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<tr>
<td>v.</td>
<td>Pod colour</td>
<td>Green (GG)</td>
<td>Yellow (gg)</td>
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<tr>
<td>vi.</td>
<td>Seed shape</td>
<td>Round (RR)</td>
<td>Wrinkled (rr)</td>
</tr>
<tr>
<td>vii.</td>
<td>Seed colour (cotyledon)</td>
<td>Yellow (YY)</td>
<td>Green (yy)</td>
</tr>
</tbody>
</table>

Cross:

- Monohybrid (Involves only one pair of contrasting character)
- Dihybrid (Involves two pairs of contrasting characters)

Result of monohybrid cross experiments:

<table>
<thead>
<tr>
<th>No.</th>
<th>Cross</th>
<th>F₁</th>
<th>F₂</th>
<th>Ratio</th>
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<tbody>
<tr>
<td>i.</td>
<td>Tall × dwarf</td>
<td>Tall</td>
<td>Tall, 277 dwarf</td>
<td>2.84:1</td>
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<td>ii.</td>
<td>Yellow × green seeds</td>
<td>Yellow seed</td>
<td>Yellow, 2001 green</td>
<td>3.01:1</td>
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<td>iii.</td>
<td>Round × wrinkled seeds</td>
<td>Round seed</td>
<td>Round, 1850 wrinkled</td>
<td>2.96:1</td>
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<td>iv.</td>
<td>Green × yellow pods</td>
<td>Green pods</td>
<td>Green, 152 yellow</td>
<td>2.82:1</td>
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<td>v.</td>
<td>Inflated × constricted pods</td>
<td>Inflated pods</td>
<td>Inflated, 299 constricted</td>
<td>2.95:1</td>
</tr>
<tr>
<td>vi.</td>
<td>Axial × terminal flower</td>
<td>Axial flower</td>
<td>Axile, 207 terminal</td>
<td>3.14:1</td>
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<td>vii.</td>
<td>Violet × white flower</td>
<td>Violet flower</td>
<td>Violet, 224 white</td>
<td>3.15:1</td>
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<tr>
<td>viii.</td>
<td>Grey × white seed coat</td>
<td>Grey seed coat</td>
<td>Grey, 224 white</td>
<td>3.15:1</td>
</tr>
</tbody>
</table>

* Monohybrid Phenotypic ratio = 3 : 1
* Monohybrid Genotypic ratio = 1 : 2 : 1
* Dihybrid Phenotypic ratio = 9 : 3 : 3 : 1
* Dihybrid Genotypic ratio = 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1
* Back cross : F₁ hybrid × parent (Dominant /Recessive)
* Test cross : F₁ hybrid × parent (Recessive)
* Deviation from Mendelian ratio: a. Incomplete dominance
  b. Co-dominance
  c. Multiple alleles

Mendel’s Laws

- Law of dominance (First law of inheritance)
- Law of Segregation (Second Law of inheritance or Law of purity of gametes)
- Law of Independent assortment (Third law of inheritance)

Gene interactions

- Intragenic (Interallelic)
  eg. Incomplete dominance
  Co-dominance
  Multiple alleles
- Intergeneric (Non-allelic)
  eg. Pleiotropy
  Polygenes
  Epistasis
### Blood group and its inheritance:

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### Scientists and their contribution:

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<th>No.</th>
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<th>Contribution</th>
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<tbody>
<tr>
<td>i.</td>
<td>Mendel</td>
<td>Father of genetics</td>
<td>1908</td>
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<td>ii.</td>
<td>William Bateson</td>
<td>Coined the word genetics</td>
<td>1908</td>
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<td>iii.</td>
<td>Hugo De Vries (Holland)</td>
<td>Rediscovered Mendel’s findings</td>
<td>1901</td>
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<td>Karl Correns (Germany)</td>
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<td>Erich Tschermark (Austria)</td>
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<td>Johannsen</td>
<td>Coined the word gene</td>
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<td>iv.</td>
<td>Bateson</td>
<td>Coined the word Allele or Allelomorphs</td>
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<td>v.</td>
<td>Reginald C. Punnett</td>
<td>Devised Punnett square</td>
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<td>vi.</td>
<td>H. Nilsson-Ehle</td>
<td>Discovered Polygenic inheritance</td>
<td>1908</td>
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<td>vii.</td>
<td>Davenport and Davenport</td>
<td>Studied the inheritance of skin colour in Negroes and albinos</td>
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### Concept Builder

**Q.1.** Consider the following dihybrid cross between Yellow Round (YYRR) seed pea plant and Green Wrinkled (yrr) seed pea plant. With reference to the Punnett’s square, answer the questions given below:

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<td>YYRr</td>
<td>YyRr</td>
<td>Yyrr</td>
</tr>
<tr>
<td>YyRr</td>
<td>YYRr</td>
<td>YyRr</td>
<td>Yyrr</td>
</tr>
<tr>
<td>YYRr</td>
<td>YyRr</td>
<td>YYRr</td>
<td>YYRr</td>
</tr>
<tr>
<td>YyRr</td>
<td>YyRr</td>
<td>YyRr</td>
<td>Yyrr</td>
</tr>
</tbody>
</table>
i. Number of offsprings having dominant trait.
   Ans: 15 (YYRR, YYRr, YyRR, YYRr, YYrr, YyRR, YyRr, YYRr, YYrr, YYrr, YyRR, YyRr, Yyrr, YYRR, YYRr, YYrr)

ii. Number of offsprings showing recessive trait.
   Ans: 7 (YYtt, YYrr, yyRR, YYRr, YYtt, yyRr, yytt)

iii. Number of offsprings showing single dominant trait.
   Ans: 6 (YYtt, YYrr, yyRR, YYRr, YYtt, yyRr)

iv. Number of offsprings which are double dominant.
   Ans: 9 (YYRR, YYRr, YyRR, YYRr, YYRr, YYRr, YyRR, YyRr, YyRr)

v. Number of offsprings that are single recessive.
   Ans: 6 (YYrr, Yyrr, yyRR, yyRr, YYrr, yyRr)

vi. Number of offsprings that are double recessive.
   Ans: 1 (yyrr)

vii. Number of offsprings that are double homozygous.
   Ans: 4 (YYRR, YYrr, yyRR, yyrr)

viii. Number of offsprings that are double heterozygous.
   Ans: 4 (YyRr, YyRr, YyRr, YyRr)

ix. Number of offsprings which are single homozygous.
   Ans: 8 (YYRr, YyRR, YYRr, Yyrr, YyRR, yyRr, Yyrr, yyRr)

x. Number of offsprings which are single heterozygous.
   Ans: 8 (YYRr, YyRR, YYRr, Yyrr, YyRR, yyRr, Yyrr, yyRr)

xi. Number of offsprings that are phenotypically similar to the parents.
   Ans: 10 (YYRR, YYRr, YyRR, YYRr, YYRr, YyRR, YyRr, YyRr, YYRr, yyrr)

xii. Number of offsprings that are genotypically similar to the parents.
    Ans: 2 (YYRR, yyrr)

Q.2. With reference to the table, answer the questions given below:

<table>
<thead>
<tr>
<th></th>
<th>Phenotypic ratio</th>
<th>Genotypic ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monohybrid cross</td>
<td>3 : 1</td>
<td>1 : 2 : 1</td>
</tr>
<tr>
<td>Dihybrid cross</td>
<td>9 : 3 : 3 : 1</td>
<td>1 : 2 : 4 : 1 : 2 : 1 : 2 : 1</td>
</tr>
<tr>
<td>Test cross (Monohybrid)</td>
<td>1 : 1</td>
<td>1 : 1</td>
</tr>
<tr>
<td>Test cross (Dihybrid)</td>
<td>1 : 1 : 1 : 1</td>
<td>1 : 1 : 1 : 1</td>
</tr>
<tr>
<td>Incomplete dominance</td>
<td>1 : 2 : 1</td>
<td>1 : 2 : 1</td>
</tr>
<tr>
<td>Co-dominance</td>
<td>1 : 2 : 1</td>
<td>1 : 2 : 1</td>
</tr>
<tr>
<td>Pleiotropy</td>
<td>2 : 1</td>
<td>2 : 1</td>
</tr>
<tr>
<td>Trihybrid cross</td>
<td>27 : 9 : 9 : 3 : 3 : 3 : 1</td>
<td>–</td>
</tr>
</tbody>
</table>

i. Same phenotypic ratio is seen in:
   Ans: Incomplete dominance and Co-dominance (1 : 2 : 1)

ii. Same genotypic ratio is seen in:
    Ans: Incomplete dominance and Co-dominance (1 : 2 : 1)
         Dihybrid cross and Polygenes (1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1)
iii. Identical phenotypic and genotypic ratio is seen in:
Ans: Monohybrid test cross  →  1 : 1
                                Dihybrid test cross  →  1 : 1 : 1 : 1
                                Incomplete dominance  →  1 : 2 : 1
                                Co-dominance         →  1 : 2 : 1
                                Pleiotropy            →  2 : 1

➤ Shortcuts to remembering ratio’s
• Phenotypic ratio of Dihybrid cross
  \[ \frac{3}{3} : \frac{1}{3} \leftarrow \text{Monohybrid} \]
  \[ \times \frac{3}{1} \leftarrow \text{Monohybrid} \]
  \[ 9 : 3 : 3 : 1 \]
• Genotypic ratio of Dihybrid cross
  \[ 1 : 2 : 1 \leftarrow \text{Monohybrid} \]
  \[ \times 1 : 2 : 1 \leftarrow \text{Monohybrid} \]
  \[ 1 : 2 : 1 : 2 : 4 : 2 : 1 : 2 : 1 \]
• Phenotypic ratio of Trihybrid cross
  Dihybrid  →  9 : 3 : 3 : 1
  Monohybrid  ×  3 : 1

Q.3. If T-Tall (dominant), t-Dwarf (recessive) and R-Violet (dominant), r-white (recessive), then what percentage of plants would be tall with violet flowers in the following crosses:

i. $TTRR \times ttrr$
Ans:

Gametes: $\begin{array}{c} TTRR \times ttrr \\ TR \quad tr \end{array}$

$F_1$ generation:

$\begin{array}{c} TtRr \end{array}$

$= 100 \%$

ii. $TtRR \times ttrr$
Ans:

Gametes: $\begin{array}{c} TtRR \times ttrr \\ TR \quad tR \quad tr \end{array}$

$F_1$ generation:

$\begin{array}{c} TtRr \quad ttRr \\ TR \quad tr \quad TtRr \quad tr \\ tr \quad tr \end{array}$

$= 50 \%$

iii. $TTRr \times ttrr$
Ans:

Gametes: $\begin{array}{c} TTRr \times ttrr \\ TR \quad Tr \quad tr \end{array}$

$F_1$ generation:

$\begin{array}{c} TtRr \quad Ttrr \\ tr \quad TtRr \quad TtRr \quad tr \\ tr \quad tr \end{array}$

$= 50 \%$
iv. $TtRr \times ttrr$

**Ans:**

Gametes: $TR, Tr, tR, tr, ttrr$

$F_1$ generation

- $TR, Tr, tR, tr, ttrr$
- $TR, TTRr, Ttr, ttRr, ttrr$

$= 25\%$

v. $TtRr \times TTRR$

**Ans:**

Gametes: $TR, Tr, tR, tr, TTR, TTRr, TtRR, TtRr$

$F_1$ generation

- $TR, TTRr, TTRr, ttRr, TtRr$
- $TR, TTRR, TTRr, TtRR, TtRr$

$= 100\%$

vi. $TtRr \times TtRR$

**Ans:**

Gametes: $TR, Tr, tR, tr, TtR, TtRR, TtRr, ttRR$

$F_1$ generation

- $TR, TTRr, TTRr, ttRr, TtRr$
- $TR, TTRR, TTRr, TtRR, TtRr$

$= 75\%$

vii. $TtRr \times TTRr$

**Ans:**

Gametes: $TR, Tr, tR, tr, TtR, TTRr, TtRr, ttRr$

$F_1$ generation

- $TR, TTRr, TTRr, ttRr, TtRr$
- $TR, TTRR, TTRr, TtRR, TtRr$

$= 75\%$

viii. $TtRr \times TTrr$

**Ans:**

Gametes: $TR, Tr, tR, tr, TT, Tr, TtR, TtRr$

$F_1$ generation

- $Tr, TTRr, TTrr, TtRr$
- $Tr, TTRr, TTrr, TtRr$

$= 50\%$
Chapter 01: Genetic Basis of Inheritance

ix. \( \text{TtRr} \times \text{ttRR} \)
\[ \text{Ans:} \]
\[ \begin{array}{c}
\text{Gametes:} \\
\text{F}_1 \text{ generation} \rightarrow \\
\text{TR} & \text{Tr} & \text{tR} & \text{tr} \\
\text{tR} & \text{TtRR} & \text{TtRr} & \text{ttRR} & \text{ttRr} \\
\end{array} \]
\[ = 50\% \]

x. \( \text{TTrr} \times \text{ttRR} \)
\[ \text{Ans:} \]
\[ \begin{array}{c}
\text{Gametes:} \\
\text{F}_1 \text{ generation} \rightarrow \\
\text{TR} & \text{tr} \\
\text{TtRr} \\
\end{array} \]
\[ = 100\% \]

xi. \( \text{TtRr} \times \text{TtRr} \)
\[ \text{Ans:} \]
\[ \begin{array}{c}
\text{Gametes:} \\
\text{F}_1 \text{ generation} \rightarrow \\
\text{TR} & \text{Tr} & \text{tR} & \text{tr} \\
\text{tR} & \text{TTRR} & \text{TtRr} & \text{ttRR} & \text{ttRr} \\
\text{tR} & \text{TtRR} & \text{TtRr} & \text{ttRR} & \text{ttRr} \\
\text{tR} & \text{TtRr} & \text{ttRr} & \text{ttRr} & \text{ttrr} \\
\end{array} \]
\[ = 56.25\% \]

Q.4. How many types of gametes can be produced by the following type of genotypes?

i. \( \text{TT} \)
\[ \text{Ans:} \ 1 \ (T) \]

ii. \( \text{TTRR} \)
\[ \text{Ans:} \ 1 \ (TR) \]

iii. \( \text{TTRr} \)
\[ \text{Ans:} \ 2 \ (TR, Tr) \]

iv. \( \text{Tt} \)
\[ \text{Ans:} \ 2 \ (T, t) \]

v. \( \text{TtRRbb} \)
\[ \text{Ans:} \ 2 \ (TRb, tRb) \]

vi. \( \text{TtRr} \)
\[ \text{Ans:} \ 4 \ (TR, Tr, tR, tr) \]

vii. \( \text{TtRRBBaaDd} \)
\[ \text{Ans:} \ 4 \ (TRBaD, TRBaD, tRbaD, tRbad) \]

viii. \( \text{TtRrAa} \)
\[ \text{Ans:} \ 8 \ (TRA, TRa, TrA, Tra, tRA, tRa, trA, tra) \]
ix. \( \text{TTRrAABB} \)
Ans: 2 (TRAB, TrAB)

x. \( \text{TtAaBbRRCC} \)
Ans: 8 (TABRC, TAbRC, TaBRC, TabRC, tABRC, tAbRC, taBRC, tabRC)

xi. \( \text{TTaabbCCDDrreeyy} \)
Ans: 1 (TabCDrey)

**Important Note**

Types of gametes may be calculated by the following formula:
Number of gametes = \( 2^n \), where \( n \) is the number of heterozygous alleles.

---

**Multiple Choice Questions**

1. The functional unit of heredity is
   (A) chromosome  (B) protein
   (C) nucleus  (D) gene

2. The factors which represent the contrasting pairs of characters are called
   (A) dominant and recessive
   (B) alleles
   (C) homologous pairs
   (D) determinants

3. The first work on genetics was done by
   (A) Lamarck  (B) Hugo de Vries
   (C) Mendel  (D) Darwin

4. Mendel’s laws were rediscovered by
   (A) Lamarck, de Vries and Correns
   (B) Hugo De Vries, Correns and Tschermak
   (C) Morgan, Beadle and Tatum
   (D) Hugo de Vries, Morgan and Correns

5. Mendel’s principles are related to
   (A) evolution
   (B) reproduction
   (C) variations
   (D) heredity

6. Mendel performed experiments on
   (A) Pigeon Pea  (B) Cow Pea
   (C) Garden Pea  (D) Chick Pea

7. Emasculation is
   (A) removing pollen grains.
   (B) removing stamens before anthesis.
   (C) removing stamens after anthesis.
   (D) removing stamens from male parent.

8. The term ‘genetics’ was coined by
   (A) Mendel  (B) Bateson
   (C) Muller  (D) Morgan

9. The character which appears in \( F_1 \) generation in a hybrid cross is called
   (A) recessive  (B) dominant
   (C) co-dominant  (D) fillial

10. Which of the following pair does not represent a contrasting character?
    (A) Tall and Dwarf stem
    (B) Axial and Terminal flower
    (C) Green and Yellow seed colour
    (D) Round and Light seed

11. The offspring of a cross between two individuals differing in at least one set of characters is called
    (A) polyploid  (B) mutant
    (C) hybrid  (D) variant

12. Mendel selected pea plant as material for his experiments because
    (A) it is an annual plant with short life cycle.
    (B) the flowers are naturally self-pollinated.
    (C) flowers can be artificially cross pollinated.
    (D) all of these.

13. First generation after a cross is called
    (A) first filial generation
    (B) \( F_1 \) hybrid
    (C) second filial generation
    (D) both (A) and (B)

14. \( F_2 \) generation is produced as result of
    (A) crossing \( F_1 \) individual with dominant individuals.
    (B) crossing \( F_1 \) individual with recessive individuals.
    (C) crossing \( F_1 \) individuals amongst themselves.
    (D) crossing \( F_1 \) individuals with their dominant parents.
15. In *Pisum sativum*, which of the following traits is dominant?
(A) White flowers  (B) Green seeds
(C) Yellow pods  (D) Inflated pods

16. Which one of the following is an incorrect pair in Mendelian characters?

<table>
<thead>
<tr>
<th>Character</th>
<th>Dominant</th>
<th>Recessive</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Pod colour</td>
<td>Green</td>
<td>Yellow</td>
</tr>
<tr>
<td>(B) Seed shape</td>
<td>Round</td>
<td>Wrinkled</td>
</tr>
<tr>
<td>(C) Flower position</td>
<td>Terminal</td>
<td>Tall</td>
</tr>
<tr>
<td>(D) Shape of pod</td>
<td>Inflated</td>
<td>Constricted</td>
</tr>
</tbody>
</table>

17. A pure tall pea plant was crossed with a pure dwarf pea plant. All the plants of F₁ were found to be tall. This is due to
(A) dominance.  
(B) disappearance of factor for dwarfness in F₁ generation.  
(C) segregation of factors.  
(D) incomplete dominance.

18. A monohybrid cross is the one in which
(A) only a single plant is involved for the experiment.  
(B) a single pair of contrasting characters is considered for the cross.  
(C) a hybrid is crossed to a homozygous plant.  
(D) F₁ hybrid is crossed back with recessive parent.

19. In *Mirabilis jalapa*, when two F₁ pink flowered plants were crossed with each other, the F₂ generation produced 40 red, 80 pink and 40 white flowering plants. This is a case of
(A) duplicate genes  
(B) lethal genes  
(C) incomplete dominance  
(D) epistasis.

20. For a given character, a gamete is always
(A) homozygous  
(B) pure  
(C) hybrid  
(D) heterozygous.

21. How would you test a pea plant whether it is a pure or hybrid for tallness?
(A) Crossing it with another tall pea plant of unknown genotype.  
(B) Crossing it with a pure tall pea plant.  
(C) Crossing with a homozygous dwarf pea.  
(D) Crossing it with any pea plant.

22. A cross between F₁ hybrid and its parent is
(A) back cross  
(B) reciprocal cross  
(C) monohybrid cross  
(D) dihybrid cross.

23. Test cross is a cross between
(A) hybrid × dominant parent (Tt × TT)  
(B) hybrid × recessive parent (Tt × tt)  
(C) hybrid × hybrid (Tt × Tt)  
(D) hybrid × unknown parent.

24. A cross between an individual with unknown genotype for a trait with recessive plant for that trait is
(A) Back cross  
(B) Reciprocal cross  
(C) Test cross  
(D) Monohybrid cross.

25. A cross used to verify the unknown genotype of F₁ hybrid is a _______ cross. [Mar 15]
(A) test  
(B) back  
(C) dihybrid  
(D) monohybrid.

26. Genetically identical progeny is produced when individuals
(A) perform cross fertilization.  
(B) produce identical gametes.  
(C) inbreed without meiosis.  
(D) exhibit sexual reproduction.

27. Tall plant with round seeds is crossed with dwarf plant having wrinkled seeds. This type of cross is
(A) dihybrid  
(B) monohybrid  
(C) test cross  
(D) back cross.

28. Genes do not occur in pairs in
(A) zygote  
(B) somatic cell  
(C) brain cells  
(D) gametes.

29. *Pisum sativum* is
(A) strictly a self fertilizing plant.  
(B) naturally self fertilizing but cross fertilizable plant.  
(C) naturally cross fertilizing but self fertilizable plant.  
(D) strictly cross fertilizing plant.

30. The phenotypic ratio of incomplete dominance is [Mar 16]
(A) 2 : 1  
(B) 1 : 2 : 1  
(C) 1 : 1 : 1  
(D) 1 : 1 : 2.

31. In a dihybrid cross, F₂ generation offsprings show four different phenotypes, while the genotypes are
(A) Six  
(B) Nine  
(C) Eight  
(D) Sixteen.

32. Pea plant with double hybrid yellow round seeds (YyRr) is crossed with pea plant having single hybrid green round seeds (yyRr). The progeny shall be
(A) 3 : 3 : 1 : 1  
(B) 1 : 1 : 1 : 1  
(C) 9 : 3 : 3 : 1  
(D) 3 : 1 : 3 : 1.
33. The ratio of phenotypes in F<sub>2</sub> generation of a monohybrid cross is
(A) 3 : 1  (B) 1 : 2 : 1  (C) 9 : 3 : 3 : 1  (D) 2 : 1

34. Heterozygous tall plant is selfed. It produced both tall and dwarf plants. This confirmed Mendel’s law of
(A) dominance  (B) segregation  (C) independent assortment  (D) incomplete dominance

35. ‘R’ is dominant red flower trait, while ‘r’ is recessive white flower trait. Heterozygous Rr (red) is crossed with homozygous red (RR) flowered plant. In all, 64 offsprings are produced. Number of white flowered plants is
(A) 64  (B) 32  (C) 16  (D) 0

36. Heterozygous tall (Tt) is crossed with homozygous tall (TT). Percentage of heterozygous tall in the progeny would be
(A) 25%  (B) 50%  (C) 75%  (D) 100%

37. Hybrid pea plant with yellow round seeds (YyRr) is self pollinated. Phenotypic ratio of next generation would be
(A) 13 : 3  (B) 9 : 7  (C) 1 : 4 : 6 : 4 : 1  (D) 9 : 3 : 3 : 1

38. In a cross between heterozygous tall (Tt) and homozygous tall (TT), there is a progeny of 12. How many of them would be tall?
(A) 8  (B) 10  (C) 6  (D) 12

39. In red–white flowered cross of Mirabilis jalapa, F<sub>2</sub> generation has red, pink and white flowered plants in the ratio of
(A) 1 : 2 : 1  (B) 1 : 0 : 1  (C) 2 : 1 : 1  (D) 1 : 1 : 2

40. The gene which controls many characters is called
(A) Codominant gene  (B) Polygene  (C) Pleiotropic gene  (D) Multiple gene

41. In an experiment on pea plant, pure plants with yellow round seeds (YYRR) were crossed with plants producing green wrinkled seeds (yyrr). What will be the phenotypic ratio of F<sub>1</sub> progeny?
(A) 9 yellow round : 3 round green : 3 wrinkled yellow : 1 green wrinkled  (B) All yellow round
(C) 1 round yellow : 1 round green : 1 wrinkled yellow : 1 wrinkled green  (D) All wrinkled green

42. A pea plant with yellow and round seeds is crossed with another pea plant with green and wrinkled seeds produced 51 yellow round seeds and 49 yellow wrinkled seeds. Genotype of plant with yellow round seeds must be
(A) YYRr  (B) YyRr  (C) YyRR  (D) YYRR

43. In a cross, 45 tall and 14 dwarf plants were obtained. Genotype of parents was
(A) TT × TT  (B) TT × Tt  (C) Tt × Tt  (D) TT × tt

44. Tallness (T) is dominant over dwarfness (t), while red flower colour (R) is dominant over white colour (r). A plant with genotype TtRr is crossed with plant of genotype ttrr. Percentage of progeny having tall plants with red flower is
(A) 25%  (B) 50%  (C) 75%  (D) 100%

45. “Gametes are never hybrid”. It is a statement of law of
(A) dominance  (B) segregation  (C) independent assortment  (D) unit character

46. Appearance of new combinations in F<sub>2</sub> generation in a dihybrid cross proves the law of __________.  [Mar 15]
(A) dominance  (B) segregation  (C) independent assortment  (D) purity of gametes

47. Inheritance of skin colour in humans is an example of
(A) Point mutation  (B) Polygenic inheritance  (C) Co-dominance  (D) Chromosomal aberration

48. Blood grouping in humans is controlled by
(A) 4 alleles in which A is dominant.  (B) 3 alleles in which AB is co-dominant.
(C) 3 alleles in which none is dominant.  (D) 3 alleles in which A is dominant.
49. Genes located on same locus but show more than two different phenotypes are called
   (A) polygenes  (B) multiple alleles
   (C) co-dominants  (D) pleiotropic genes

50. Which one of the following is an example of multiple alleles?
   [Oct 13]
   (A) Height in pea plant
   (B) Hair colour in cattle
   (C) Petal colour in four o’clock plant
   (D) Wing-size in Drosophila

51. Genotype of blood group ‘A’ will be
   (A)  I^A I^A  (B)  I^A I^B
   (C)  I^A or  I^O  (D)  I^O

52. Genotype of human blood group ‘O’ will be
   [July 16]
   (A)  I^A I^A  (B)  I^A I^B
   (C)  ii  (D)  I^A i

53. When phenotypic and genotypic ratio is the same, then it is an example of
   (A) Incomplete dominance
   (B) Cytoplasmic inheritance
   (C) Quantitative inheritance
   (D) Incomplete or Co-dominance

54. Which one of the following is true pleiotropic gene?
   [Oct 14]
   (A) Hb^A  (B) Hb^S
   (C) Hb^D  (D) Hb^P

55. When two genes control single character and have cumulative effect, the ratio is
   (A) 1:1:1:1
   (B) 1:4:6:4:1
   (C) 1:2:1
   (D) 1:6:15:20:15:6:1

56. If cattle with black coat is crossed with white coat, the F1 hybrids possess roan coat. This is an example of
   (A) epistasis
   (B) co-dominance
   (C) incomplete dominance
   (D) law of segregation

57. When single gene produces two effects and one of it is lethal, then ratio is
   (A) 2:1  (B) 1:1
   (C) 1:2:1  (D) 1:1:1:1

\[\text{Answers to Multiple Choice Questions}\]

1. (D)  2. (B)  3. (C)  4. (B)
5. (D)  6. (C)  7. (B)  8. (B)
9. (B)  10. (D)  11. (C)  12. (D)
13. (D)  14. (C)  15. (D)  16. (C)
17. (A)  18. (B)  19. (C)  20. (B)
21. (C)  22. (A)  23. (B)  24. (C)
25 (A)  26. (B)  27. (A)  28. (D)
29. (B)  30. (B)  31. (B)  32. (D)
33. (A)  34. (B)  35. (D)  36. (B)
37. (D)  38. (D)  39. (A)  40. (C)
41. (B)  42. (B)  43. (C)  44. (A)
45. (B)  46 (C)  47. (B)  48. (B)
49. (B)  50. (D)  51. (C)  52. (C)
53. (D)  54. (B)  55. (B)  56. (B)
57. (A)