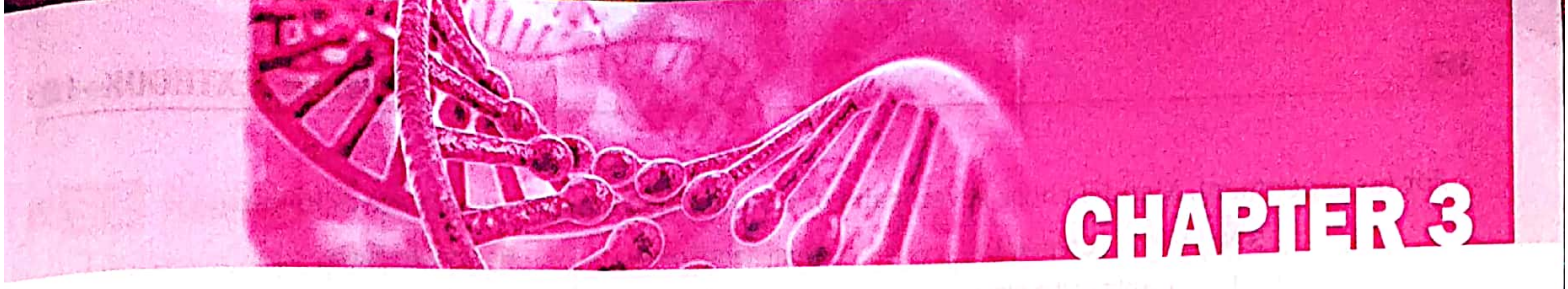


CHAPTER 3

GENETICS

The branch of science which deals with the study of the characteristics of heredity and variations of living beings is called **Genetics.**

Firstly, the word Genetics was used by Bateson in 1905. This word has originated from the Greek word **Gene.**

Transmission of various genetic characteristics is a continuous process which takes place from generation to generation in living organisms through gametes during the process of sexual reproduction.

These characteristics are called **Hereditary characters.**

This transmission of these hereditary characteristics from parental generation to offsprings is called **heredity.**

The term '**Heredity**' was propounded by Spencer in 1863. During sexual reproduction, variations occur due to the crossing over of genes among living organisms of a particulars species.

3.1 Mendelism

Gregor Johann Mendel (1822-1884) is known as the 'Father of Genetics', because he was the first to prpound the laws of heredity in plants.

Mendel was born on 22nd July 1822 in Silision village of Heizendarf province in Austria.

After receiving the degree of philosophy in 1842, he became the father of a church in Brunn city of Austria in the year 1843. In the church garden, Mendel experimented hybridisation on garden pea (*Pisum sativum*) for seven years (1857-1865). The results of these experiments were put in the form of research papers and were presented before Brunn society of Natural History in the year 1865. In the year 1866, these experiments were published in the annual reports of the society under the heading of 'Experiments on plant hybridization'. On the basis of the result of Mendel's experiment on garden pea, '**Laws of inheritance**' was propounded which is also known as **Mendelism**. Mendel died on 6th January, 1884.

Gregor Johann Mendel

3.1.1 Reasons for Mendel's Success

(i) Mendel studied one particular heredity of one particular characteristic at one time.

(ii) Mendel very carefully performed statistical analysis of entire data of his hybridization experiments.

(iii) Mendel made a careful choice of plant for his experiment.

3.1.2 Selection of Pea Plant

Mendel chose the Garden pea plant for his experiments because :

(i) As it was an annual plant, study of different generations could be possibly done in less time.

(ii) Being bisexual flowers. Homozygous or Pure line variety plants can be easily obtained by the process of self-pollination.

(iii) Artificial cross-pollination (hybridization) can be done easily by the process of Emasculation.

(iv) In a pea plant, various pairs of contrasting traits are found.

For his experiment, Mendel chose seven pairs of contrasting characters which are as follows :

S.No.	Characters	Dominant Traits	Recessive Traits
1.	Height of the plant	Tall	Dwarf
2.	Position of flower	Axial	Terminal
3.	Shape of matured pea	Inflated	Constricted
4.	Colour of immatured pea	Green	Yellow
5.	Colour of the flower	Violet	White
6.	Shape of the seed	Rounded	Wrinkled
7.	Colour of the seed	Yellow	Green

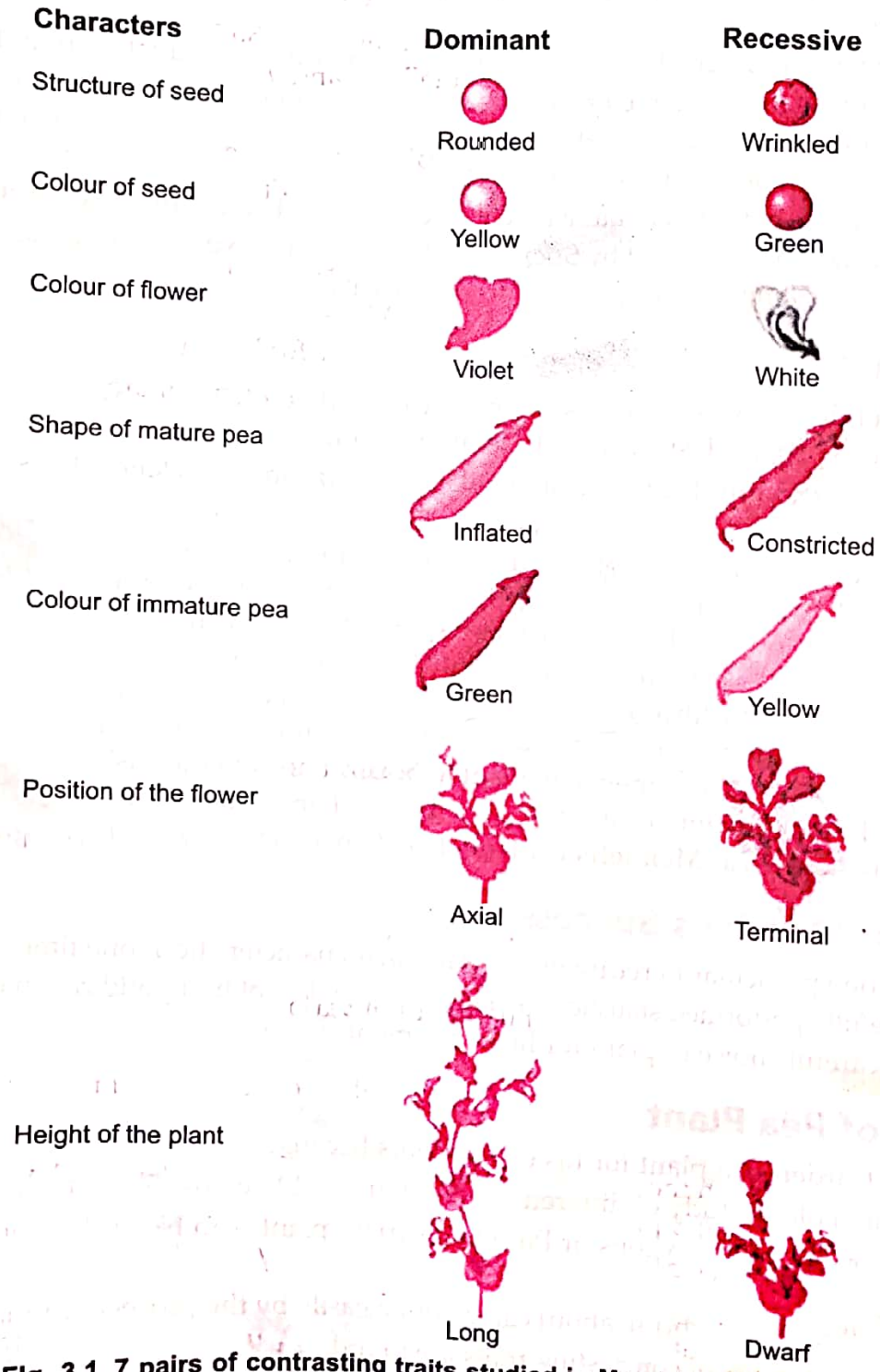


Fig. 3.1 7 pairs of contrasting traits studied in Mendel's experiments

3.2 Rediscovery of Mendelism

The laws of inheritance (1865) propounded by Mendel were not appreciated for 35 years by contemporary biologists.

Hugo de Vries of Holland, carl Correns of Germany and Erich Von Tschermak of Austria conducted individual experiments and rediscovered the laws of Mendel in 1900.

3.3 Genetics Terminology

To understand Mendel's laws of inheritance, it is necessary to go through the following terms :

1. **Gene :** The factor which controls any one character is called **gene.** The word 'factor' was used by Mendel for a gene. The term 'gene' was later on given by Johannsen.
2. **Allelomorph or Allele :** The term Allelomorph allele was used for the factors representing the two alternate forms of a gene. For example, the genes T and t for tallness and dwarfness are alleles for height in garden pea.
3. **Homozygous :** An individual who contains identical alleles of a gene or factors of a character on his homologous chromosome is called homozygous. For example, TT allele pair is homozygous for height in pea plant. TT or tt is another example.
4. **Heterozygous :** An individual who contains two contrasting factors of a character or two different alleles of a gene on his homologous chromosome is called heterozygous.

   For example- The pea plant with Tt allele pair is heterozygous for height.
5. **Phenotype :** External appearance and functional traits of a living organism produced due to the interaction of genes and environment is called phenotype.

   For example- Tall plants can be homozygous (TT) or heterozygous (Tt). Here, tallness is the phenotype.
6. **Genotype :** Genetic constitution of any living organism is called its genotype.

   For example : Pure or homozygous tall (TT) or Impure or heterozygous tall (Tt).
7. **Dominant Characters :** The allele which always expresses itself in F_1 generation is called dominant character.
8. **Recessive Character :** The allele which fails to express itself in the presence of its contrasting dominant allele in F_1 generation is called recessive character.
9. **Monohybrid Cross :** It is a cross made to study the inheritance of a single pair of alleles or factors of a character and is called monohybrid cross.
10. **Dihybrid Cross :** It is a cross made to study the inheritance of two pairs of factors or alleles of two genes and is called dihybrid cross.
11. **Trihybrid Cross :** A cross in which the inheritance of three pairs of alleles or factors are studied is called trihybrid cross.
12. **Polyhybrid Cross :** The cross in which the inheritance of various pairs of alleles or factors are studied, is called polyhybrid cross.
13. **Test Cross :** The cross in which F_1 generation is crossed with the recessive homozygous parent is called test cross.
14. **Back Cross :** The cross in which the F_1 generation is crossed with one of its parents is called back cross.
15. **Reciprocal Cross :** The cross (the hybridization) in which plant 'A' (TT) is used as the male parent while plant 'B' (tt) is used as the female parent. In second case, plant 'A' (TT) is used as the female parent and plant 'B' (tt) is used as the male parent which is called reciprocal cross.
16. **Parental Generation :** The plants which are crossed to get new hybrid offsprings are called parental generation.

17. **F_1 (first filial) generation :** The first generation produced by the cross hybridization between genetically different individuals or parents.
18. **F_2 (second filial) generation :** The hybrids produced by the cross between F_1 generation.
19. **Monohybrid ratio :** It is the ratio obtained by monohybrid cross.
20. **Dihybrid ratio :** It is the ratio obtained by dihybrid cross.

3.4 Mendel's Laws of Inheritance

Mendel conducted breeding experiments on garden pea (*Pisum sativum*) and formulated some important principles called Mendel's laws of heredity or laws of inheritance. These laws are as follows :

1. Law of dominance.
2. Law of segregation or law of purity of gametes.
3. Law of independent assortment.

3.4.1 Law of Dominance

This law of Mendel is based on the results of a monohybrid cross. According to this law, out of two contrasting allelomorphic factors, only one expresses itself in an individual. The factor that expresses itself is called dominant, while the other which is not expressed is called *recessive*.

Example : If a pure or homozygous tall (TT) pea plant is crossed with homozygous dwarf plant (tt), the plants appeared in F_1 generation are all (100%) tall (Tt).

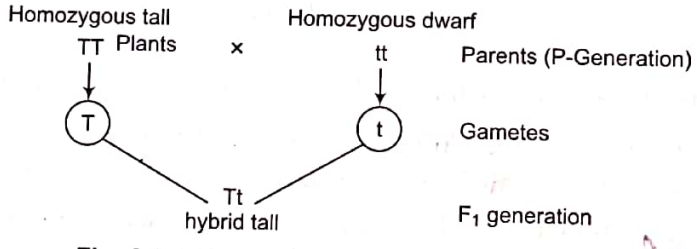


Fig. 3.2 Interpretation of Law of Dominance

3.4.2 Law of Segregation or Law of Purity of Gametes

This law of Mendel is also based on the monohybrid cross. According to this law, during gamete formation, the alleles for each gene segregate from each other, so that each gamete carries only one allele for each gene. In hybrid of F_1, both contrasting characters remain in pair. These characters are separated in F_2 generation. Since, each gamete possesses one allele for each character, they are always pure, therefore, it is also called **law of purity of gametes.**

Example : If homozygous tall (TT) and homozygous dwarf (Tt) pea plants are crossed, then all the hybrids in F_1 generation will be heterozygous tall (Tt). In heterozygous, although both the alleles remain with each other, yet they do not contaminate. During the gamete formation, both the alleles from the pair separate and form individual gamete. Because of this, dwarf character (Tt) reappears in F_2 generation.

The phenotypic ratio of F_2 generation is 3 : 1 and the genotypic ratio is 1 : 2 : 1.

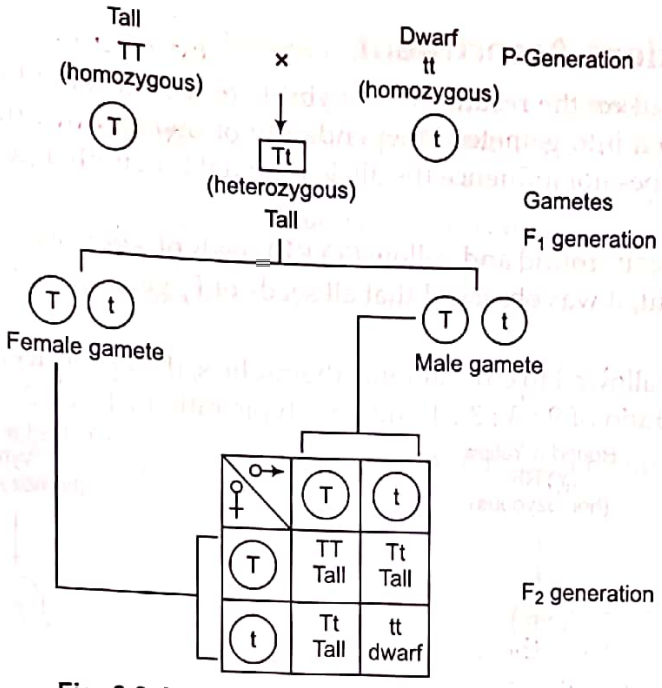


Fig. 3.3 Interpretation of Law of Segregation

Phenotypic ratio – 3 tall : 1 dwarf

Genotypic ratio – 1 homozygous tall : 2 heterozygous tall : 1 homozygous dwarf

1 (TT) : 2 (Tt) : 1 (tt)

3.4.2.1 Back Cross

It is a cross which is performed between hybrid and one of its parents.

If a pure tall plant (TT) is crossed with pure dwarf plant (tt), then hybrid plants (Tt) are produced in F_1 generation. When F_1 hybrid is crossed with any one parent (whether TT or tt) then this cross is called back cross. In this type of cross, offsprings will always be 50% pure breed tall TT and 50% hybrid type Heterozygous tall (Tt) plant.

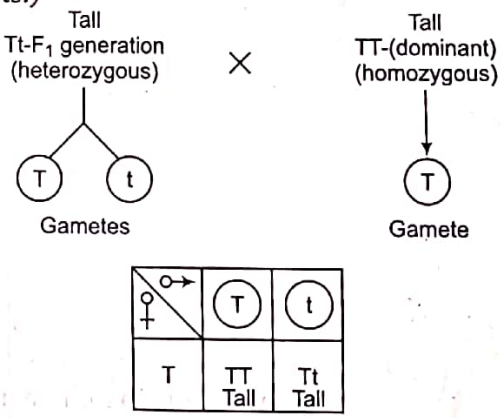


Fig. 3.4 Interpretation of Back Cross

Phenotypic ratio - 100% tall plant

Genotypic ratio - 1 : 1

50% TT : 50% Tt

(homozygous) (heterozygous)

3.4.2.2 Test Cross

A cross between an organism of F_1 generation and a homozygous recessive parent is a test cross. The offsprings obtained from this cross show the same genotype and phenotype ratio, *i.e.*, 1 : 1. The ratio will be 50% (heterozygous tall, Tt) dominant and 50% (homozygous dwarf, tt) recessive.

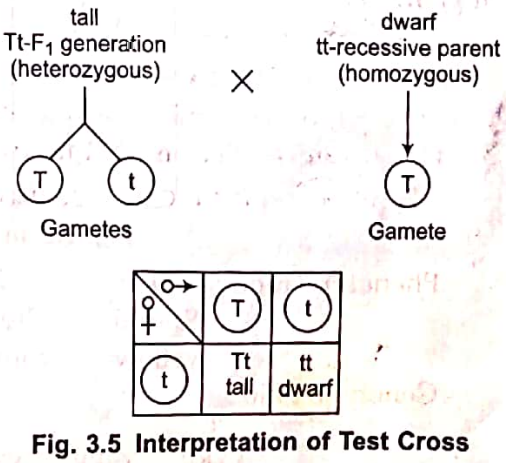


Fig. 3.5 Interpretation of Test Cross

Phenotypic ratio - 50% tall : 50% dwarf

Genotypic ratio -

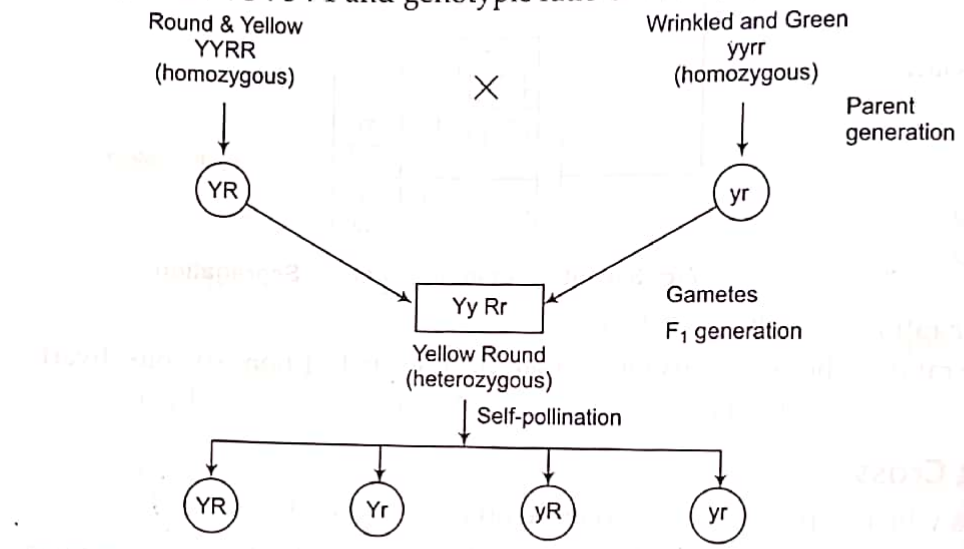
50 % heterozygous tall (Tt) : 50% homozygous dwarf (tt)

3.4.3 Law of Independent Assortment

This law of Mendel is based on the results of a dihybrid cross. According to this law, the alleles of two (or more) different genes get sorted into gametes independently of one another. In other words, the allele that a gamete receives for one gene does not influence the allele received for another gene. Therefore, it is called law of independent assortment.

Example : When heterozygous round and yellow (YYRR) seeds of a pea plant was crossed with wrinkled and green (yyrr) seeds of a pea plant, it was observed that all seeds of F_1 generation were of round and yellow seeds (YyRr).

When the F_1 hybrids were allowed to cross among themselves, they produced four types of seeds producing plants in F_2 generation in the ratio of 9 : 3 : 3 : 1 and genotypic ratio of 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1.



♀ \ ♂	YR	Yr	yR	yr
YR	YYRR Yellow round	YYRr Yellow round	YyRR Yellow round	YyRr Yellow round
Yr	YYrR Yellow round	YYrr Yellow wrinkled	YyrR Yellow round	Yyrr Yellow wrinkled
yR	YyRR Yellow round	YyRr Yellow round	yyRR Green round	yyRr Green round
yr	YyRr Yellow round	Yyrr Yellow wrinkled	yyRr Green round	yyrr Green wrinkled

Fig. 3.6 Interpretation of Law of Independent Assortments

Phenotype ratio : 9 : 3 : 3 : 1

Round yellow : Green round : Yellow wrinkled : Green wrinkled

Genotype ratio : 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1

YYRR : YyRR : YYRr : YyRr : yyRR : yyRr : YYrr : Yyrr : yyrr

Importance of Mendel's Laws of Inheritance

1. It is extremely important that dominant characters are found in living organisms because various harmful and lethal genes, being recessive, cannot express themselves in the presence of dominant genes.
2. Gene concept is proved by the Mendel 'Law of segregation or law of purity of gametes'.
3. According to the law of segregation, one gene has two alleles and it controls two contrasting traits.
4. New characters (traits) in cross hybrids can be better understood by Mendel's laws.
5. By the process of crossing over, useless traits can be removed, while useful traits can be brought in a specific generation.
6. By the use of Mendel's laws, disease disinfectant and improved varieties of plants can be developed and obtained.
7. The branch of science which deals with the development of human beings is eugenics and it is based on Mendel's laws of inheritance.

Important Points

- Genetics word was first used by Bateson.
- In living organisms, transmission of inherited characters from their parents to the offsprings is called heredity.
- The study of heredity and variations is called inheritance.
- Gregor Johann Mendel is known as the Father of Genetics.
- Mendel used (*Pisum sativum*) garden pea for his experiments of crossing over in plants. On the basis of the results of these experiments, Mendel propounded the laws of inheritance called Mendelism.
- Hugo de Vries, Carl Correns and Ericis Von Tschermak rediscovered the Mendel's laws of segregation.
- Mendel studied the heredity of one character of a heredity at one time.
- When two alleles of a gene are the same then it is called homozygous and when they are different then it is called heterozygous.
- The generation obtained by the crossing over of parents is F_1 generation and the generation obtained by the crossing over of F_1 generation is F_2 generation.
- The character which expresses its identity in F_1 generation is called dominant trait, while the character which does not express its identity F_1 generation is called recessive trait.
- When F_1 generation is crossed with recessive parent then it is called test cross.
- When F_1 generation is crossed with any one of the parents then it is called back cross.
- According to the Mendel's law of seggregation or law of purity of gametes, during gamete formation, alleles get separated and each gamete possess one allele of each gene.
- According to the Mendel's law of independent assortment, alleles of two (or more) different genes behave independently.
- According to Mendel's monohybrid cross of F_2 generation has :
  Phenotypic ratio - 3 : 1 ; Genotypic ratio - 1 : 2 : 1
- The dihybrid cross of F_2 generation has
  Phenotypic ratio - 9 : 3 : 3 : 1 ; Genotypic ratio - 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1
- Through crossing over, different good characters of different class (family) can be brought into one individual (progeny) of choice.
- By using Mendel laws, disease disinfectants and high yield of crops can be obtained.
- Mendel's laws proved the theory of 'Gene concept' .
- Eugenics is the branch of science which deals with the study of development or improvement of human life and it is based on Mendel's laws.

Text Book EXERCISE

Multiple Choice Questions

1. Who propounded the word 'Genetics'?
(a) Mendel (b) Bateson (c) Morgan (d) Punnet

2. On which of the following, Mendel performed his experiments :
(a) sweet pea (b) wild pea (c) garden pea (d) All these

3. The branch of science which deals with the study of heredity and variations of characters in livi organisms is called :
(a) Genetics (b) Geology
(c) foresting (d) None of these

4. The green colour of the pea bean is a —trait :
(a) Dominant (b) Recessive
(c) Incomplete dominance (d) Codominance

5. Generally, how many alleles are there in a gene?
(a) Four (b) Three (c) Two (d) One

6. How many pairs of contrasting traits did Mendel chose for his experiment?
(a) 34 (b) 7 (c) 12 (d) 7

7. When F_1 generation is crossed with any one parent then it is called as :
(a) Back cross (b) Test cross
(c) Reciprocal cross (d) All these

8. The ratio of the hybrids formed from the cross Tt × tt will be :
(a) 3 : 1 (b) 1 : 1 (c) 1 : 2 : 1 (d) 2 : 1

9. Which contrasting trait did Mendel not choose for his experiment :
(a) colour of the root (b) colour of the flower
(c) colour of the seed (d) colour of the fruit

10. In F_2 generation of monohybrid cross, how many types of genotype are formed?
(a) 2 (b) 3 (c) 4 (d) 9

Very Short Answer Type Questions

11. Who is known as the Father of Genetics ? Sir Gregor John Mendal
12. On which plant did Mendel perform his experiments ? Pea plant
13. What is dominant character?
14. What do you call the transmission of hereditary characters from one generation to another generation? heredity
15. Who rediscovered the laws of Mendel ? Hugo de vries, carl correns and Erich von Tshermak
16. Write down the complete name of Mendel. Sir Gregor John Mendal
17. Write the names of the laws formulated by Mendel.
18. What is Test cross?
19. What do you understand by Back cross?
20. Which law of Mendel cannot be understood by monohybrid cross? Law of independent assortment

Short Answer Type Questions

21. Differentiate between phenotype and genotype. (Definition)
22. Explain dihybrid cross.
23. Mention the reasons for Mendel's success.
24. Why did Mendel choose pea plant for his experiments?
25. Write a brief introduction of Mendel's life.
26. Explain Mendel's law of dominance. f_1 generation
27. Explain the importance of Mendel's laws of inheritance.

Long Answer Type Questions

28. Describe Mendel's law of segregation with example.
29. What is Mendelism? Describe the law of independent assortment.
30. Briefly explain Mendel's laws of inheritance.

Answers

1. (b)	2. (c)	3. (a)	4. (a)	5. (c)	6. (d)	7. (c)
8. (b)	9. (a)	10. (b)				