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23 YEAR' OF LEGACY

AEP STUDY CIRCLE
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ACCENTS EDUCATIONAL PROMOTERS

Topic-wise

HEREDITY

REVISION MODULE

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Topic-wise

HEREDITY

TOPIC

- Heredity

TOPIC : HEREDITY

The process by which traits and characteristics are reliably inherited is known as **heredity**. Heredity plays an important role in the formation of new species. Hereditary variations refer to the differences in the inherited traits. These involve the change in genotype of the organisms and are passed into subsequent generations. These variations in the progeny are produced by certain genetical events like recombination, crossing over and due to sudden appearance of abnormalities in hereditary make up.

Accumulation of Variation During Reproduction

Reproduction results in the production of new characters in the next generation that includes the character inherited from previous generation as well as newly created differences, *e.g.*, the organisms reproducing asexually have only minor differences between them, which may appear due to small inaccuracies while replicating or copying DNA whereas the organisms reproducing sexually show more variations due to the different genetic make up of parents. Though offspring resemble their parents but their resemblance is never complete.

Sometimes variation provides different kinds of advantages such as survival in extreme conditions, *e.g.*, if the environmental temperature rises up, the variation among the heat resistant character of bacterial colony will favour the survival of few variants which will be able to withstand higher environmental temperature. The selection of variants (produced due to environmental factor) form the basis for evolution.

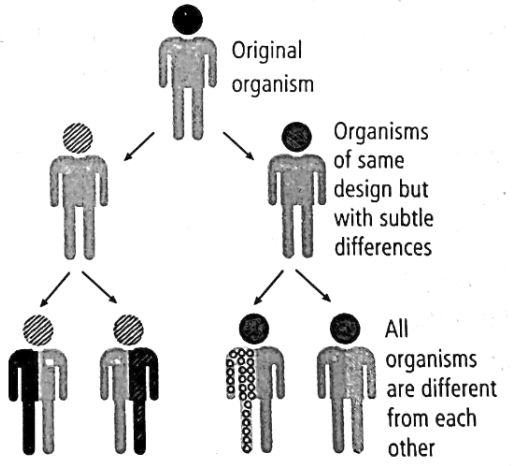


Fig.: Occurrence of diversity over succeeding generations

ILLUSTRATIONS

Q **A trait *A* exists in 30% of a population of a species and a trait *B* exists in 70% of the same population. Which trait is likely to have arisen earlier?**

Ans. During reproduction, variations accumulate. Variations occurring in first generation will be inherited to subsequent generations, thus should be more frequent. Here trait B occurs in more individuals thus it is likely to have arisen earlier.

TRY YOURSELF

1. What are variations?
2. How do variations favour survival of a species?

Mendel's Contribution

If you observe a child, you will observe that he bears all the basic characters of a human being but still he is different from his parents. He could resemble his parents in some characters. The characters that are seen in an individual (*e.g.*, height, facial features, etc.) are called **traits**. The trait inherited from parents are called inherited traits.

The rules for inheritance of such traits are related to the fact that both the parents (mother and father) will equally contribute to the genetic material of child, thus each traits will have two versions in each child.

The Australian monk Gregor Johannes Mendel worked on garden pea plant (*Pisum sativum*) over a period of eight years and contributed in the field of inheritance and expression of such traits. Mendel was first to explain the mechanism of transmission of characters from one generation to other generation. He introduced the concept of gene as a basic unit of heredity and called them **factors**. For his contribution to modern genetic, he is known as **"Father of Genetics".**

Garden pea plant as an experimental plant

Mendel selected garden pea plant as an experimental plant due to its advantages over other plants. The selection criteria was as follows :

(i) Garden pea plant has short life cycle which makes it possible to study several generation in a short time period.

(ii) Garden pea plant shows several well defined contrasting characters such as plant height, flower colour, etc.

(iii) The flowers of garden pea plant are bisexual, *i.e.*, male and female parts are in same flower and also they mature at same time. The flower encloses reproductive parts which ensures self fertilisation. Over many generations, self fertilisation helps in easily obtaining the pure line with constant trait in pea plants.

(iv) Artificial cross pollination, *i.e.*, removal of stamens from one pea plant and dusting the pistil of flower with the pollen grain from desired pea plant, can be easily achieved.

(v) The seven selected traits were readily available in all the pea plants. The pea plants can be raised, maintained and handled conveniently.

(vi) The large number of seed production in each generation ensures in drawing authentic conclusions.

Table : Contrasting characters of *Pisum sativum* that were studied by Mendel

S. No.	Character	Dominant trait	Recessive trait
1.	Seed shape	Round	Wrinkled
2.	Seed colour	Yellow	Green
3.	Flower colour	Violet	White
4.	Pod shape	Full	Constricted
5.	Pod colour	Green	Yellow
6.	Flower position	Axial	Terminal
7.	Stem height	Tall	Dwarf

- An inherited factor that determines a biological character of an organism is called **gene**. This is functional unit of hereditary material.
- Alleles indicate alternative forms of the same gene. Each character has two determiners called **factors**. If the factors represent the extremes or alternatives of the character, they are called alleles or allelomorphic pair.
- An organism, having only one allele or in other words two identical alleles is known as **homozygous**. An individual with two different alleles (Tt) will be called **heterozygous**.
- **Gene locus** is the portion or region on chromosome representing a single gene. The alleles of a gene are present on the same gene locus on the homologous chromosomes.

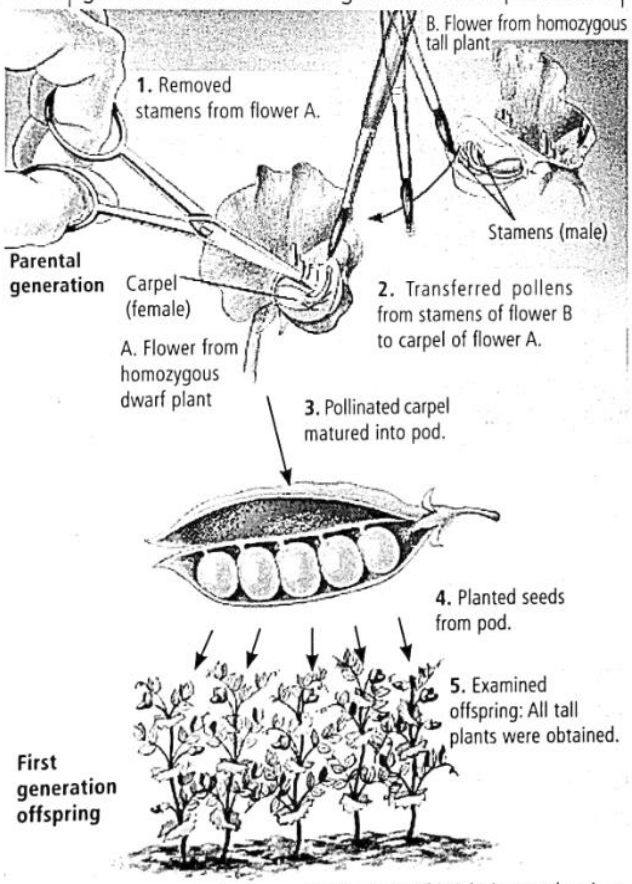
Experimentation

Mendel performed several experiments that includes the crosses involving one contrasting character, two contrasting characters and three contrasting characters. These crosses are called as monohybrid cross, dihybrid cross and trihybrid cross respectively.

Monohybrid cross

The cross that is made to study the inheritance of only one pair of contrasting character is known as monohybrid cross, *e.g.*, Mendel selected two sets of pea plants having different height. One set of pea plant had a height of about 6 feet however other set of pea plant had a height of about 1 foot. Mendel called these plants homozygous tall and homozygous dwarf respectively. These were called pure lines and these plants, *i.e.*, homozygous tall and homozygous dwarf were represented as parent generation (*P* generation).

Mendel performed cross between the two pea plants by taking emasculated flower of dwarf pea plant and dusting of pollen grain from tall pea plants on it and *vice-versa* to ensure that reciprocal crosses would not make any difference in the results. After pollination, the flowers were covered with bags. These plants produced hybrid seeds and the plant produced from these seeds, belonged to the F_1 generation or first filial generation. All plants of F_1 generation were tall.



TT × tt
Tall ↓ Dwarf
Tt (Hybrid tall)
↓ Selfing

♀ \ ♂	T	t
T	TT	Tt
t	Tt	tt

Genotype : TT : Tt : tt
1 : 2 : 1
Phenotype : Tall : Dwarf
3 : 1

Fig.: Inheritance of tall and dwarf height in pea plant in a monohybrid cross

The plants of F_1 generation were self pollinated and the seeds were collected. The plant raised from these seeds belonged to F_2 generation or second filial generation. The plant of F_2 generation were 75% tall and 25% dwarf, *i.e.*, in the ratio of 3 : 1. From these crosses, Mendel concluded that out of two contrasting characters only one is expressed in hybrids. This trait was termed as dominant trait and other was termed as recessive trait. It also showed that dominant trait (*i.e.*, tallness) is expressed in both homo or heterozygous conditions while recessive trait appears only in homozygous conditions.

The cross that includes the inheritance of two pairs of contrasting characters simultaneously is referred as dihybrid cross. Mendel chose pure breeding plants for yellow and green seeds and round and wrinkled shape of seeds. Mendel cross pollinated the plant having yellow round seeds with plant having green wrinkled seeds. All the plants produced in F_1 generation were having, yellow round seeds. The plants raised from these seeds were self pollinated, that resulted in production of plants having four types of seeds, *i.e.*, yellow round seeds, green round seeds, yellow wrinkled seeds and green wrinkled seeds in a ratio of **9 : 3 : 3 : 1**.

On the basis of this experiment, Mendel concluded that:

- The offspring from F_1 generation always exhibit only one of the parental form of traits.
- In F_2 generation, both the traits appeared. The trait hidden in F_1 generation also appeared in F_2 generation.
- Mendel observed a difference in the behaviour of plants raised from F_2 offspring with dominant form of trait. Only one-third of F_2 plants with dominant trait were true breeding, rest two-third of plants were not true breeding and resembled the F_1 hybrid plants in their behaviour.
- Mendel observed that one of the parental forms of the trait was always absent in F_1 hybrid but reappeared unchanged in the F_2 generation. It proved that alternate forms of a trait can retain their identity in the hybrid and can re-emerge unchanged in subsequent generations.
- In dihybrid crosses, Mendel observed four types of plants in F_2 generation. He concluded that the factors of each of the two characters assort independent to each other.

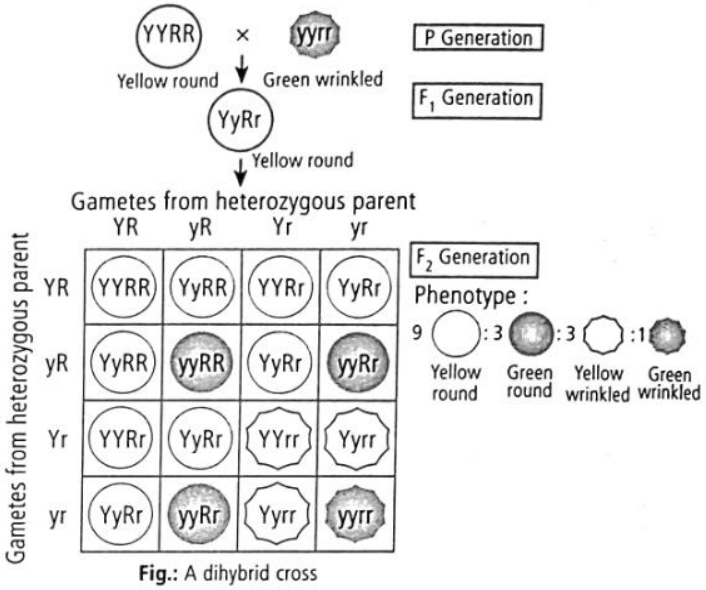


Fig.: A dihybrid cross

- Multiple alleles are three or more alternative forms of a gene that can occupy the same locus but only two of the alleles can be present in a single organism. For example, the ABO system of blood groups is controlled by three alleles I^A, I^B and i only, two of which are present in an individual.
- **Back cross** is a cross which is made between a hybrid and one of its parents. In plant breeding, such crosses are performed to improve the variety of crop plants. For example, a crop plant is crossed with a wild variety (all crop plants are originated from wild varieties) in order to obtain its disease resistance.
- **Reciprocal cross** involves the same trait but sexes are reversed to those in the original cross.
- Cross between an individual of unknown genotype and recessive parent is called **test cross**.

Mendel's principles of inheritance

On the basis of above observations, Mendel formulated three principles / laws of heredity.

Conclusion drawn by Mendel on the basis of monohybrid cross

Law of dominance

According to this law, in a hybrid or heterozygous individual one character is controlled by two dissimilar unit factors. These two factors cannot express together as one factor and only one out of these two is able to express itself and it prevents the expression of the other. The factor which expresses itself is called **dominant factor** or **gene** and the other which remains unexpressed is called **recessive factor** or **gene**. For example, in a hybrid tall (Tt) only a single factor of tallness is expressed. A capital letter is assigned to the dominant factor and small letter is assigned to the recessive factor.

Principle of segregation

According to the law of segregation, the two factors of a character which stay together in an individual do not get mixed up, and keep their distinct identity. During gamete formation, the factors get separated or segregate from each other so that each gamete contains only one factor or gene for each character and is always pure. This postulate is also called **principle of purity of gametes**. For example, the unit factor of tallness (T) and dwarfness (t) separate out from a hybrid tall plant during gamete formation. The two unit factors occur with equal frequency in male and female gametes.

Conclusion drawn by Mendel on the basis of dihybrid cross

Principle of independent assortment

According to the principle of independent assortment, the unit factors of each character are independent of one another in their segregation during gamete formation. If we consider the inheritance of two or more factors at a time, their distribution in the gametes and in progeny of subsequent generation is independent of each other. For example, the dihybrid cross performed by Mendel resulted in the production of four types of offsprings. The two types were similar to parents but the other two had a combination of traits which is only possible if the unit factor of both the characters assorted independent to each other.

Expression of traits

According to Mendel, a pair of factor, which are now called genes, control the inheritance of that character. Later on, these genes were found to occupy specific position on thread like structures called chromosomes. Genes are the segments of DNA which provides information for synthesis of a particular protein. According to Mendalian experiments, both the **parents contribute equal DNA material to progeny** during sexual reproduction.

If progeny plants inherited a single whole gene set from each parent, then independent assortment cannot work, because the two characteristics would then be linked to each other and cannot be independently inherited. This is explained by the fact that each gene set is present, not as a single long thread of DNA, but as separate independent pieces called a **chromosome**. Thus, each cell will have two copies of each chromosome, one each from the male and female parents. Every germ cell will take one chromosome from each chromosome pair and these may be of either maternal or paternal origin. When two germ cells combine, they will restore the normal number of chromosomes in the progeny, ensuring the stability of the DNA of the species.

The paired condition of chromosomes is said to be **diploid**. The chromosome number in somatic cells of higher organisms is diploid and is represented by 2N or 2n. A set of unpaired chromosomes is said to be **haploid** and is represented by N or n. Gametes (sperm and ovum) have haploid set of chromosomes.

A section of DNA carries information for a particular type of protein to be synthesised. The protein may be an enzyme which controls appearance of a particular character.

Let us take the example of inheritance of tallness in plants.

Plants produce growth regulators (hormones) which control the height in plant.

Gene for tallness carries the information for synthesis of more efficient enzyme which in turn produces more amount of hormone which leads to greater height of a plant. On the other hand if plant has both alleles for dwarfness, then less efficient enzymes will be produced which in turn will synthesise less amount of hormone and plant will remain dwarf. In this way genes control characteristics or traits of organisms.

- **E. Strasburger** discovered **chromosomes** in 1875. They appeared as thread- like structures during cell division. These were called chromosomes (*Chroma* = colour) due to their affinity for basic dyes.
- Chromosomes are present in the nuclei of all living cells. Each chromosome consists of two strands called **chromatids** which are joined together at a point called **centromere**.
- **Walter Sutton** and **Theodore Boveri** postulated the **chromosomal theory of inheritance** independently in 1902. They studied the behaviour of chromosome during meiosis and gamete formation. The theory stated that :

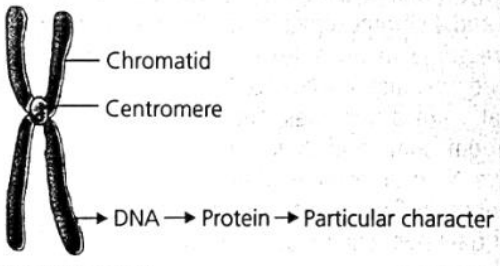


Fig.: Chromosome

(i) Hereditary characters are transmitted from parents to offspring through chromosomes present on nucleus.
(ii) Chromosomes are found in pairs in diploid organisms ; so are the Mendelian factors. Thus a parallelism was found between Mendelian factors and chromosomes found in nucleus of a cell.
(iii) The chromosomes segregate at meiosis. It means that each pair separate and go to different cells. Mendelian factors also segregate at the time of formation of gametes. Homologous chromosomes get segregated at the time of meiosis.
(iv) The union of sperm and egg (fertilisation), each with single set of chromosomes, re-establishes the whole number (two sets) of chromosomes previously seen in body cells of parent organism.

ental plant? *(NCERT Exemplar)*

Ans. Mendel chose garden pea plant as an experimental plant because of the following reasons: (i) It has short life cycle, (ii) It shows well defined, easily detectable contrasting traits, (iii) It has bisexual flower therefore, artificial cross pollination could be easily achieved, (iv) It produces large number of seeds in one generation.

Q Explain the law of purity of gametes.

Ans. Principle of purity of gametes is also known as principle or law of segregation. According to this law, the two unit factors of a character which remains together in an individual do not get mixed up and keep their distinct identity. They separate during gamete formation so that each gamete receives only one factor or gene for each character and is always pure.

TRY YOURSELF

3. What is monohybrid cross?
4. State law of dominance with example.
5. Mendel crossed homozygous round and yellow seeded pea plant with homozygous wrinkled and green seeded pea plants for two generations. Name this cross and identify the Mendel's postulate that is proved by this cross.

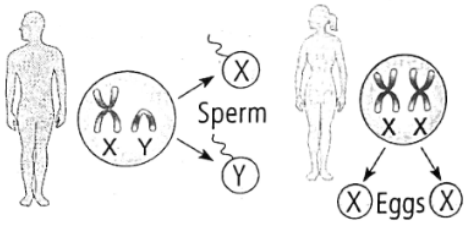
Sex Determination

Sex is the hereditary difference between two individuals of same species. The sex of an individual is determined at the time of fertilisation when the male and female gametes fuse together.

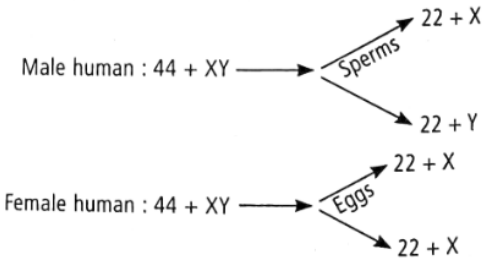
Different organisms use different strategies for sex determination which may be chromosomal, environmental or temperature. Even some animals like snails can change sex.

By 1900, when microscope techniques had become quite well developed and chromosome behaviour was understood, it was noticed that there was one pair of chromosomes that differ from others. In females, members of this pair were similar, but differ in appearance in other sex (males). The chromosome which was present in pair in female and single in male was identified as X chromosome and in male the other chromosome was called as Y chromosome.

In 1905, **Wilson** and **Stevens** first identified X chromosome. Females were found to contain two X chromosomes. It was pointed out that the presence of Y chromosomes determine maleness and its absence determines femaleness. X and Y chromosomes are called **sex chromosomes** and rest of them, which are same in both sexes are called **autosomes**. There are four pairs of chromosomes in each cell of *Drosophila melanogaster*, out of which three pairs are autosomes. The fourth pair in males possess one X and one Y chromosome and thus produces two types of sperms while females possess two X chromosomes, therefore producing eggs, each with X chromosome. Hence, in *Drosophila*, females are **homogametic** as they produce same type of gametes while males are **heterogametic** as they produce different type of gametes.



X X Female	X X Female
X Y Male	X Y Male



In a similar manner, human beings have 22 pairs of autosomes and one pair of sex chromosomes. Women bear XX type of sex chromosomes (homomorphic) and men are with XY type of sex chromosomes (heteromorphic). Thus men are with 44 + XY combination and women are with 44 + XX combination of chromosomes.

The type of system discussed above is called **XX-XY system**.

In human beings, the sex of baby is determined by the type of sperm that fuses with ovum. During fertilisation, there are equal chances that an ovum is fertilised by either a sperm having X chromosome or a sperm having Y chromosome. When a sperm carrying X chromosome fertilises an egg, the zygote develops into a female (XX condition). When a sperm carrying Y chromosome fertilises an egg, the zygote develops into a male (XY condition). As human male produces two types of sperms in equal proportion, so there are 50% chances of male baby and 50% chances of a female baby.

Birds have ZW - ZZ type of sex determination mechanism. In this type, the male has two homomorphic sex chromosomes (ZZ) and is homogametic, while the female has two heteromorphic sex chromosomes (ZW) and is heterogametic. There are, thus, two types of eggs: one with Z chromosome and other with W and only one type of sperms, *i.e.*, each with Z chromosome. Fertilisation of an egg with Z chromosome by a sperm with Z chromosome gives a zygote with ZZ chromosomes (male). Fertilisation of an egg with W chromosome by a sperm with Z chromosome yields a zygote with ZW chromosomes (female).

ILLUSTRATIONS

Q How sex is determined in human beings?

Ans. The human female have two X chromosomes as sex chromosome and males have XY sex chromosome. Female produces only one type of eggs while male produces two types of sperm. When a sperm carrying X chromosome fertilises the egg, the zygote develops into a female (XX condition) and when a sperm carrying Y chromosome fertilises the egg, the zygote develops into a male (XY condition). So the sex of the baby is determined at the time of fertilisation.

Q How many chromosomes are present in a human female?

Ans. All human beings contain 23 pairs of chromosomes in each cell. Out of 23 pairs, 22 pairs of chromosome carry gene that control somatic traits. The 23rd pair of chromosome are sex chromosome. Human females have XX chromosome while males have XY chromosome. So human females have 22 pair of autosomes and one pair of sex chromosome XX.

TRY YOURSELF

6. How many types of gametes will be produced by the human male?
7. What are the chances of having a male child in humans?

NCERT FOCUS

1. A Mendelian experiment consists of breeding tall pea plants bearing violet flowers with short pea plants bearing white flowers. The progeny all bore violet flowers, but almost half of them were short. This suggests that the genetic make-up of the tall parent can be depicted as
(a) TTWW (b) TTww
(c) TtWW (d) TtWw.
2. A study found that children with light–coloured eyes are likely to have parents with light coloured eyes. On this basis, can we say anything about whether the light eye colour trait is dominant or recessive? Why or why not?
3. Outline a project which aims to find the dominant coat colour in dogs.
4. How is the equal genetic contribution of male and female parents ensured in the progeny?

CBSE FOCUS

Objective Type Questions

MCQs and VSA Type Questions (1 Mark)

1. All the variations in a species do not have equal chances of survival. Why?
2. What is genetics?
3. **Assertion (A) :** In humans, if gene (B) is responsible for black eyes and gene (b) responsible for brown eyes, then the colour of eyes of the progeny having gene combination Bb, bb or BB will be black only.
Reason (R) : The black colour of the eyes is a dominant trait.

(a) Both (A) and (R) are true and (R) is the correct explanation of (A).
(b) Both (A) and (R) are true and (R) is not the correct explanation of (A).
(c) (A) is true but (R) is false.
(d) (A) is false but (R) is true. *(CBSE 2023)*

4. Consider the following two statements:
(i) The trait that expresses itself in F_1 generation.
(ii) The trait that keeps on passing from one generation to another.
The appropriate terms for the statements (i) and (ii) respectively are
(a) Recessive trait ; Dominant trait
(b) Dominant trait ; Recessive trait
(c) Dominant trait ; Inherited trait
(d) Recessive trait ; Inherited trait
(CBSE 2023)

5. How does the creation of variations in a species promote survival? *(NCERT)*

6. What is a gene?

7. A cross between pea plant with white flowers (vv) and pea plant with violet flowers (VV) resulted in F_2 progeny in which ratio of violet (VV) and white (vv) flowers will be
(a) 1 : 1 (b) 2 : 1
(c) 3 : 1 (d) 1 : 3 *(CBSE 2023)*

8. Which among the following is a dominant trait studied by Mendel in a pea plant?
(a) White flower (b) Terminal flower
(c) Green pod colour (d) Green seed colour

9. Human males are
(a) homomorphic (b) homogametic
(c) heterologous (d) heteromorphic.

10. Why is the progeny always tall when a tall pea plant is crossed with a short pea plant?

Case Based Questions [4 × 1 Mark]

11. Read the following and answer any four questions from 11(i) to 11(v).
Sex determination is the method by which distinction between males and females is established in a species. The sex of an individual is determined by specific chromosomes. These chromosomes are called sex chromosomes or allosomes. X and Y chromosomes are called sex chromosomes. The normal chromosomes other than the sex chromosomes of an individual are known as autosomes.

(i) In XX-XO type of sex determination
(a) females produce two different types of gametes
(b) males produce two different types of gametes
(c) females produce gametes with Y chromosome
(d) males produce gametes with Y chromosome.

(ii) A couple has six daughters. What is the possibility of their having a girl next time?
(a) 10% (b) 50% (c) 90% (d) 100%

(iii) Number of autosomes present in liver cells of a human female is
(a) 22 autosomes (b) 22 pairs
(c) 23 autosomes (d) 23 pairs.

(iv) XX-XO type of sex determination and XX-XY type of sex determination are the examples of
(a) male heterogamety (b) female heterogamety
(c) male homogamety (d) both (b) and (c).

(v) Select the incorrect statement.
(a) In male grasshoppers, 50% of sperms have no sex chromosome.
(b) Female fruitfly is heterogametic.
(c) Human male produces two types of sperms 50% having X chromosome and 50% having Y chromosomes.
(d) In turtle, sex determination is regulated by environmental factors.

12. Read the following and answer any four questions from 12(i) to 12(v).
Gregor Mendel conducted hybridisation experiments on garden peas for seven years and proposed the laws of inheritance in living organisms. He investigated characters in the garden pea plant that were manifested as two opposing traits, *e.g.*, tall or dwarf plants, yellow and green seeds, etc.

(i) Among the seven pairs of contrasting traits in pea plant as studied by Mendel, the number of traits related to flower, pod and seed respectively were
(a) 2, 2, 2 (b) 2, 2, 1 (c) 1, 2, 2 (d) 1, 1, 2.

(ii) The colour based contrasting traits in seven contrasting pairs, studied by Mendel in pea plant were
(a) 1 (b) 2 (c) 3 (d) 4.

(iii) Refer to the given table of contrasting traits in pea plants studied by Mendel.

Character	Dominant trait	Recessive trait
(i) Seed colour	 Yellow	 Green
(ii) Flower colour	 Violet	 White

(iii) Pod shape


Full


Constricted

(iv) Flower position


Axial


Terminal

Which of the given traits is correctly placed?
(a) (i), (ii) and (iii) only (b) (ii), (iii) and (iv) only
(c) (ii) and (iii) only (d) (i), (ii), (iii) and (iv)

(iv) Some of the dominant traits studied by Mendel were
(a) round seed shape, green seed colour and axial flower position
(b) terminal flower position, green pod colour and inflated pod shape
(c) violet flower colour, green pod colour and round seed shape
(d) wrinkled seed shape, yellow pod colour and axial flower position.

(v) Which of the following characters was not chosen by Mendel?
(a) Pod shape (b) Pod colour
(c) Position of flower (d) Position of pod

Short Answer Type Questions

SA Type Questions (2/3 Marks)

13. Which type of organisms will have more variations – sexually or asexually reproducing organisms? Justify.

14. How is the sex of newborn determined in humans? *(NCERT Exemplar)*

15. In pea plant, round seed is dominant over the wrinkled one. If a cross is carried out between a homozygous round seed plant and a homozygous wrinkled seed plant, give answer to the following questions.
(i) Mention the genes for the traits of parents.
(ii) State the trait of F_1 hybrid.
(iii) Write the ratio of F_2 progeny obtained from this cross. What is the name of the cross?

16. Define the following terms :
(i) Inheritance (ii) Heredity
(iii) Trait (iv) Variations

17. "It is a matter of chance whether a couple will have a male or a female child." Justify this statement by drawing a flow chart.

18. Do genetic combination of mothers play a significant role in determining the sex of a new born? *(NCERT Exemplar)*

19. An individual inherits different traits from his parents. On what basis classification of traits as dominant and recessive is done?

20. In pea plants, axial position of flowers is considered as dominant trait and terminal position of flower is considered as recessive trait. Heterozygous plant with terminal flower is not possible. Why?

21. What do you mean by a true breeding plant?

22. Name the plant Mendel used for his experiment. What type of progeny was obtained by Mendel in F_1 and F_2 generations when he crossed the tall and short plants? Write the ratio he obtained in F_2 generation plants. *(Delhi 2019)*

23. Why do all the gametes formed in human females have an X chromosome? *(NCERT Exemplar)*

24. How did Mendel's experiments show that different traits are inherited independently? Explain. *(NCERT, Delhi 2017)*

25. How did Mendel explain that it is possible that a trait is inherited but not expressed in an organism? *(AI 2017)*

26. In human beings, the statistical probability of getting either a male or female child is 50 : 50. Justify.

27. (a) Why did Mendel carry out an experiment to study inheritance of two traits in garden pea?
(b) What were his findings with respect to inheritance of traits in F_1 and F_2 generation?
(c) State the ratio obtained in the F_2 generation in the above mentioned experiment. *(CBSE 2020)*

Long Answer Type Questions

LA Type Questions (4/5 Marks)

28. How do Mendel's experiments show that :
(i) traits may be dominant or recessive
(ii) inheritance of two traits is independent of each other? *(Delhi 2017)*

29. A blue colour flower plant denoted by BB is cross-bred with that of white colour flower plant denoted by bb.
(i) State the colour of flower you would expect in their F_1 generation plants.
(ii) What must be the percentage of white flower plants in F_2 generation if flowers of F_1 plants are self-pollinated?
(iii) State the expected ratio of the genotypes BB and Bb in the F_2 progeny.

30. In some families, either rural or urban, females are tortured for giving birth to a female child. They do not seem to understand the scientific reason behind the birth of a boy or a girl. Infact the mother is not responsible for the sex of the child and it has been genetically proved that the sex of a newborn is determined by what the child inherits from the father.
(a) State the basis on which the sex of a newborn baby is determined in humans.

(b) Why is the pair of sex chromosomes called a mismatched pair in males?

(c) How is the original number of chromosomes present in the parents restored in the progeny?

OR

(c) Explain by giving two examples of the organisms in which the sex is not genetically determined. *(CBSE 2023)*

31. (a) Work out a cross upto F_2 generation between two pure breed pea plants, one bearing violet flowers and the other white flowers.

(b) (i) Name this type of cross.

(ii) State the different laws of Mendel that can be derived from such a cross.

32. (a) Why did Mendel chose garden pea for his experiments ? Write two reasons.

(b) List two contrasting visible characters of garden pea Mendel used for his experiment.

(c) Explain in brief how Mendel interpreted his results to show that the traits may be dominant or recessive.

ANSWERS

1. All the variations do not have equal chances of survival in the environment in which they live. Depending on the nature of variations, different individuals would have different kinds of advantages. The organisms which are most adapted to the environment will survive.

2. Genetics is the branch of biology that deals with the study of heredity and variations. The term `genetics' was coined by William Bateson in 1906.

3. (d) :

Parents : BB (Black) × bb (Brown)

Gametes : B × b

F_1 : Bb (black)

F_2 :

♀ / ♂	B	b
B	BB (Black)	Bb (Black)
b	Bb (Black)	bb (Brown)

Genotypic Ratio : BB (Black) : Bb (Black) : bb (Brown) = 1 : 2 : 1

Phenotypic Ratio : Black : Brown = 3 : 1

4. (c)

5. Creation of variation may be suitable for a population to fight against some new change in environment while those which do not have this variation will not be able to fight with such changing conditions and will die.

6. A gene is a unit of DNA on a chromosome which governs the synthesis of particular protein that controls specific characteristics (or traits) of an organism.

7. (a)

8. (c) : Green pod colour is a dominant trait studied by Mendel in a pea plant.

9. (d) : Human males have XY sex chromosomes, where X chromosome is morphologically distinct from Y chromosome. Y chromosome is smaller than X chromosome. Hence, they are dissimilar or heteromorphic.

10. When a tall pea plant is crossed with a short pea plant, the resultant progeny is always tall because tallness is a dominant trait while shortness is a recessive trait. Hence, dominant trait expresses itself in the progeny.

11. (i) (b) : In XX-XO type and XX-XY type of sex determining mechanisms, males produce two different types of gametes, either with or without X-chromosome (XO type), or some gametes with X-chromosome and some with Y-chromosome (XY type). Such type of sex determination mechanism is designated to be the example of male heterogamety. In both, females are homogametic and produce X type of gametes in both the cases and have XX genotype.

(ii) (b) : The possibility of having a girl or boy child is equal *i.e.*, 50%, as 50% male gametes are Y type and 50% are X type. Fusion of egg with X type sperm will produce a girl child.

(iii) (b) : In humans, number of autosomes are 2n = 44 or 22 pairs regardless of the sex.

(iv) (a) : *Refer to answer 11 (i).*

(v) (b) : Male fruitfly is heterogametic whereas female fruitfly is homogametic.

12. (i) (a) : Characters studied by Mendel are as follows:

	Trait studied	Dominant	Recessive
1.	Plant height	Tall (T)	Dwarf (t)
2.	Flower position	Axial (A)	Terminal (a)
3.	Flower colour	Violet (V) or (W)	White (v) or (w)
4.	Pod shape	Full or Inflated (I) or (C)	Constricted (i) or (c)
5.	Pod colour	Green (G) or (Y)	Yellow (g) or (y)
6.	Seed shape	Round (R) or (W)	Wrinkled (r) or (w)
7.	Seed colour	Yellow (Y) or (G)	Green (y) or (g)

(ii) (c) : *Refer to answer 12 (i).*

(iii) (d) : *Refer to answer 12 (i).*

(iv) (c) : *Refer to answer 12 (i).*

(v) (d) : *Refer to answer 12 (i).*

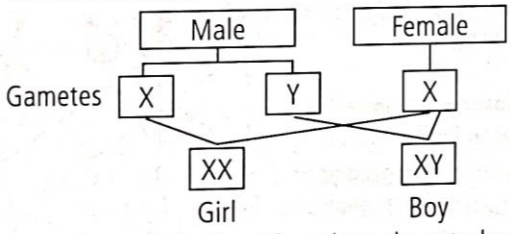
13. Sexually reproducing organisms will show more variations as genetic material is exchanged between homologous pair of chromosomes during cross over. However, during asexual reproduction, mutations are the only means of variations during DNA replication which are not very common and thus may lead to very little variation.

14. In human, sex of a baby is determined at the time of fertilisation. When the sperm carrying X chromosome fertilises an egg, the zygote develops into female (XX condition) and when a sperm carrying Y chromosome fertilises an egg, the zygote develops into male (XY condition).

15. (i) RR (Homozygous round) and rr (Homozygous wrinkled)
(ii) Rr (hybrid)—Round seed plant
(iii) 3:1 (phenotypic ratio), 1:2:1 (genotypic ratio)
Since only a single trait is involved in this cross, thus cross is known as monohybrid cross.

16. (i) Inheritance : The transmission of characters and variations along the forthcoming generations.
(ii) Heredity : The inheritance of characters from the parents to the offspring is called heredity.
(iii) Trait : The character or feature that is carried by a gene is called a trait, *e.g.*, height of plant.
(iv) Variations : The differences existing among the individuals of a species and also among the offspring of the same parents are called variations.

17. Sex is determined at the time of fertilisation when male and female gametes fuse to form zygote. Male produces two types of gametes, *i.e.*, having X or Y chromosome and female produces one type of gametes all containing X chromosomes. If a sperm (male gamete) carrying X chromosome fertilises an egg or ovum (female gamete) carrying X chromosome, then the offspring will be a girl (female). This is because the offspring will have XX combination of sex chromosomes.
Therefore, there are 50% chance of a male child and 50% chance of a female child.



18. No, genetic combination of mothers do not play role in determining the sex of new born. Mothers (human female) are homogametic, *i.e.*, they have a pair of X chromosomes. All children will inherit an X chromosome from their mother regardless of whether they are boys or girls.

19. A trait which is able to express itself both in homozygous as well as heterozygous conditions is called a dominant trait, *e.g.*, tallness is a dominant trait in pea plant. A trait which expresses itself only in homozygous condition, but remains suppressed in heterozygous condition is called recessive trait, *e.g.*, dwarfness is the recessive trait in a pea plant.

20. Heterozygous condition represents the presence of one gene for axial position and one gene for terminal position. Since axial position of flower is a dominant trait, the gene for terminal position of flower is not expressed out. Therefore, heterozygous recessive condition does not exist for terminal flower trait.

21. A true breeding plant is the one that when self-fertilised, produces offspring with the same traits. They will be either homozygous dominant or homozygous recessive.

22. Mendel selected garden pea (*Pisum sativum*) for his series of hybridisation experiments.
He first selected two pureline plants (tall plant having gene TT and short plant having gene tt) and then crossed such plants having contrasting characters. In the F_1 generation, he observed that only one of the two contrasting characters appeared, he called this character as dominant and the one which does not get expressed in F_1 was called recessive. He later selfed the F_1 plants and observed that both the traits appear in next generation but in a definite proportion. This can be explained by the following cross :

Parents (pureline) : TT (Tall plant) × tt (Dwarf plant)
Gametes : T, t
F_1 generation : Tt (Tall)
Selfing
T t

	T	t
T	TT	Tt
t	Tt	tt

F_2 generation : Tall : Dwarf
Phenotype : 3 : 1
Genotype : 1 : 2 : 1 :: TT : Tt : tt

So, the plants of F_1 generation will be all tall plants and after selfing the ratio of tall and dwarf plants that Mendel obtained in F_2 generation plants is 3 : 1.

23. Genotype of human female is 44 + XX. Human female is homogametic. During meiosis, at the time of gamete formation, only one X chromosome enters in each gamete. Hence, all female gametes have genotype (22 + X).

24. In a dihybrid cross given by Mendel, it was observed that when two pairs of traits or characters were considered, each trait expressed independent of the other. Thus, Mendel was able to propose the Law of Independent Assortment which says that pair of genes separate independently of each other during gamete formation. This could be explained clearly from the given cross:

P generation: RRYY (Round yellow) × rryy (Wrinkled green)
Gametes: RY, ry
F_1 generation: RrYy
Round yellow
Selfing

	RY	Ry	rY	ry
RY	RRYY Round yellow	RRYy Round yellow	RrYY Round yellow	RrYy Round yellow
Ry	RRYy Round yellow	RRyy Round green	RrYy Round yellow	Rryy Round green
rY	RrYY Round yellow	RrYy Round yellow	rrYY Wrinkled yellow	rrYy Wrinkled yellow
ry	RrYy Round yellow	Rryy Round green	rrYy Wrinkled yellow	rryy Wrinkled green

F_2 generation ratio : 9 Round-yellow : 3 Round-green : 3 Wrinkled-yellow : 1 Wrinkled-green

25. Mendel first selected two pureline plants having contrasting characters. He then crossed such plants. In the F_1 generation, he observed that only one of the two contrasting characters appeared, he called it dominant and the one which does not get expressed in F_1 was recessive. He later selfed the F_1 plants and observed that both the traits appear but in a definite proportion. It can be explained by the following cross :

Parents (pureline) : TT (Tall plant) × tt (Dwarf plant)

Gametes : T, t

F_1 generation : Tt (Tall)

↓ Selfing

T t

	T	t
T	TT	Tt
t	Tt	tt

F_2 generation : Tall : Dwarf

3 : 1

This is how Mendel explained that a trait may be inherited but not expressed in the plant.

26. Human females are homogametic (44 + XX), that is they produce only one type of ova (22 + X). Human males are heterogametic. They produce two types of sperms : (22 + X) and (22 + Y) in equal proportion that is 50 : 50 ratio. The chance of getting male or female child is also 50 : 50, as there is equal chance of androsperm (22 + Y) or gynosperm (22 + X) fertilising an ovum.

27. (a) Mendel carried out crosses with two traits to see the interaction and basis of inheritance between them. In a dihybrid cross given by Mendel, it was observed that when two pairs of characters were considered each trait expressed independent of the other.

(b) For example, a cross between round yellow and wrinkled green parents.

P generation: RRYY (Round yellow) × rryy (Wrinkled green)

RY ry

F_1 generation: RrYy

Round yellow

↓ Selfing

	RY	Ry	rY	ry
RY	RRYY Round yellow	RRYy Round yellow	RrYY Round yellow	RrYy Round yellow
Ry	RRYy Round yellow	RRyy Round green	RrYy Round yellow	Rryy Round green
rY	RrYY Round yellow	RrYy Round yellow	rrYY Wrinkled yellow	rrYy Wrinkled yellow
ry	RrYy Round yellow	Rryy Round green	rrYy Wrinkled yellow	rryy Wrinkled green

In F_1 generation, all plants are with round yellow seeds. But in F_2 generation, we find all types of plants : Round yellow, Round green, Wrinkled yellow, Wrinkled green.

(c) F_2 generation ratio : 9 Round-yellow : 3 Round-green : 3 Wrinkled-yellow : 1 Wrinkled-green

28. (i) Mendel first crossed pure-bred tall pea plants with pure-bred dwarf pea plants and found that only tall pea plants were produced in the first generation (F_1). He then self crossed the tall pea plants of the F_1 generation and found that tall plants and dwarf plants were obtained in the second generation or (F_2) in the ratio of 3:1. Mendel said that the trait of dwarfness of one of the parent pea plant had not been lost, it was merely concealed or suppressed in the first generation to re-emerge in the second generation. He called the suppressed trait of 'dwarfness' as 'recessive trait' and the expressed trait of 'tallness' as the 'dominant trait'. In this way, Mendel's experiments with tall and dwarf pea plants showed that the traits may be dominant or recessive. It can also be explained by the given cross :

Parental generation : Tall plant (TT) × Dwarf plant (tt)

Gametes : T, T, t, t

Crossing of gametes during fertilisation :

F_1 generation genotype : Tt Tt Tt Tt

F_1 generation phenotype : Tall Tall Tall Tall

(All tall plants)

F_1 selfing : Tall plant (Tt) × Tall plant (Tt)

Gametes : T, t, T, t

Crossing of gametes during fertilisation

F_2 generation genotype : TT Tt Tt tt

F_2 generation phenotype : Tall Tall Tall Dwarf

(3 tall : 1 dwarf plant)

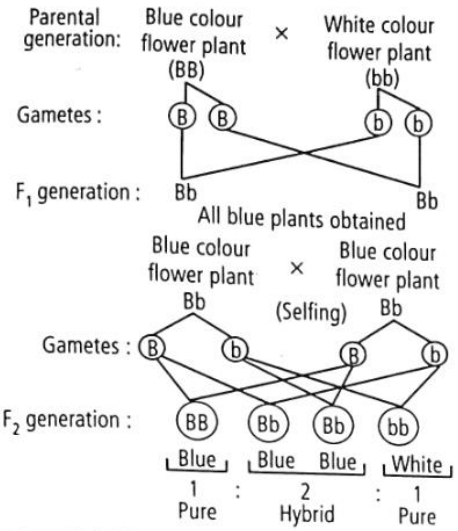
(ii) *Refer to answer 24.*

29. (i) The colour of the flower in F_1 generation will be blue with Bb genotype.

(ii) If the flowers of F_1 generations are self pollinated, then the percentage of white flowers in F_2 generation must be 25%.

(iii) The expected ratio of the genotypes BB and Bb in the F_2 progeny is 1 : 2.

The above results could be depicted by the given cross:



30. (a) Sex of child is determined by what it inherits from the father. A child who inherits X chromosome from her father will be a girl and one who inherits a Y chromosome from father will be a boy.

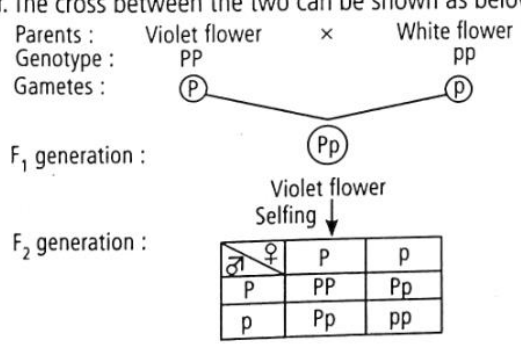
(b) Human beings have 22 pairs of autosomes and one pair of sex chromosomes. The females possess two homomorphic sex chromosomes, named XX while males contain two heteromorphic sex chromosomes, i.e., XY. The Y chromosome is shorter than X chromosome. Therefore a pair of sex chromosomes in human beings is called mismatched pair in terms of type and size.

(c) Gametes contain half the number of chromosomes of parent. But, when the two gametes (male and female) fuse to form the zygote, the normal diploid condition is restored. Hence, the formation of gametes by meiosis and fusion of male and female gamete help to maintain the number of chromosomes in organism.

OR

(c) Two animals in which sex is not determined genetically are turtle and crocodile. The type of sex in them is determined by environmental factors. In turtles, the temperature of egg incubation has a significant effect on the sex of developing embryos. Males are predominant below 28°C, females above 33°C and equal number of the two sexes between 28-33°C. In crocodiles, high temperature induces maleness and low temperature femaleness.

31. (a) In pea plant, violet colour is dominant over the white colour. The cross between the two can be shown as below :



Violet flower : White flower
3 : 1

(b) (i) Cross involving only 1 pair of contrasting factors is called monohybrid cross.

(ii) Mendel's law of dominance and law of segregation can be derived from this cross. Law of dominance states that when individuals differing in a pair of contrasting characters are crossed, the character that appears in the F_1 hybrid is dominant over the alternate form that remain hidden. Principle of segregation states that, "when a pair of contrasting factor or gene are brought together in a hybrid; these factors do not blend or mix up but simply associate themselves and remain together and separate at the time of gamete formation", *i.e,* allele pairs segregate during gamete formation and the paired condition is restored by random fusion of gametes during fertilisation.

32. (a) Mendel chose garden pea for his experiments because:

(i) It was easy to grow and shows several well defined contrasting traits.

(ii) Pea plants are self pollinating and many generation of pea plants can be produced in comparatively less time.

(b) The contrasting characters of garden pea plant studied by Mendel are:

	Character	Plant	
		Dominant	Recessive
(i)	Plant height	Tall	Dwarf
(ii)	Colour of the seed	Yellow	Green

(c) Mendel crossed the pea plant for two contrasting characters under consideration. The trait that expressed itself in F_1 generation was dominant and the one not expressed in F_1 generation was recessive. He later selfed the plants of F_1 generation and recovered both parental traits in a definite proportion in F_2 generation. Mendel interpreted his results as, the trait that expressed itself in F_1 was dominant and the one that reappeared in F_2 generation was recessive. It can be demonstrated by the following cross :