Ratna Sagar

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Ratna Sagar
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Revised and Updated

LIVING SCIENCE BIOLOGY

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EDUCATION, OUR MISSION

ICSE
Living Science
Biology

Class 10

Chapter 3 Heredity and Genetics

LEARNING OBJECTIVES

Genetics, Heredity and Variations

- ❖ Some important terms used in genetics
- ❖ Inheritance of traits – Mendel's contributions

Mendel's experiments

- ❖ Monohybrid Cross
- ❖ Dihybrid Cross
- ❖ Interpretation of Mendel's Observations

Mendel's Laws of Inheritance

- ❖ Transmission of traits
- ❖ Sex Determination in Human Beings
- ❖ Sex-linked inheritance
- ❖ Mutation

What do Genetics, Heredity and Variations stand for?

Transmission of genetically-based characteristics from parents to the successive generation is called **heredity** or **inheritance**.

Differences in the genetic characteristics or traits among individuals of a species are called **variations**.

The science which deals with the study of mechanisms responsible for similarities and differences among closely-related species is called **genetics**.

Some important terms used in genetics

❖ **Chromosomes:** Filamentous bodies present in the nucleus of a cell, composed of chromatin material (DNA–protein complex).

❖ **Variation:** Different genetic characteristics or traits produced in individuals of the same species.

❖ **Gene:** It is the basic unit of inheritance. It is a segment of DNA found on the chromosome which controls the expression of a character. It is passed from parents to the offsprings.

❖ **Homologous chromosomes:** A pair of corresponding chromosomes of the same size and shape, one from each parent.

❖ **Alleles:** Alleles are alternating molecular forms of a gene or a pair of matching genes occupying same position on a chromosome, affecting the same characteristic but in two different ways.

❖ **Dominant allele:** A super ruling allele that masks any phenotypic effect of a recessive allele paired with it.

❖ **Recessive allele:** In heterozygous condition, an allele which cannot express fully or partially in presence of other allele.

❖ **Homozygous condition:** A condition in which a pair of homologous chromosomes carries identical (similar) alleles of a gene for a particular character.

❖ **Character:** Any heritable feature is called a character.
❖ **Traits:** The alternative forms of a character are called traits.
❖ **Genotype:** The genetic constitution of an organism.
❖ **Phenotype:** Externally visible expression of a gene, which is an inherited feature in an individual's appearance. For example, free or attached earlobes.
❖ **Mutation:** Sudden change in one or more genes or in the number and structure of chromosomes in the progeny that had not existed in the parents.

Inheritance of traits – Mendel's contribution

Mendel is considered as the Father of Genetics or Modern Genetics. He was the first to introduce the concept of genes as the basic unit of heredity. Mendel called genes as **factors**.

Experimental plant

Mendel conducted his experiments on *Pisum sativum*, the garden pea plant, for the following reasons:
❖ Pea plants **have several distinct varieties**. All the varieties have sharp contrasting characteristics, such as colour and shape of seeds.
❖ **Pea plant bears bisexual flowers** with each flower having both the male and the female parts.

❖ The structure of the flower is such that it completely encloses the reproductive organs until fertilization, which ensures self-pollination.
❖ In pea plants, due to self-fertilization, it is easy to get pure lines for several generations.
❖As it is an annual plant, it is possible to study several generations within a short span of time.
❖ The flowers of pea plants are adequate in size and easy to handle.
❖ Each plant can produce large number of seeds in a single generation.

Mendel's Experiments

Mendel conducted his experiments in three stages.

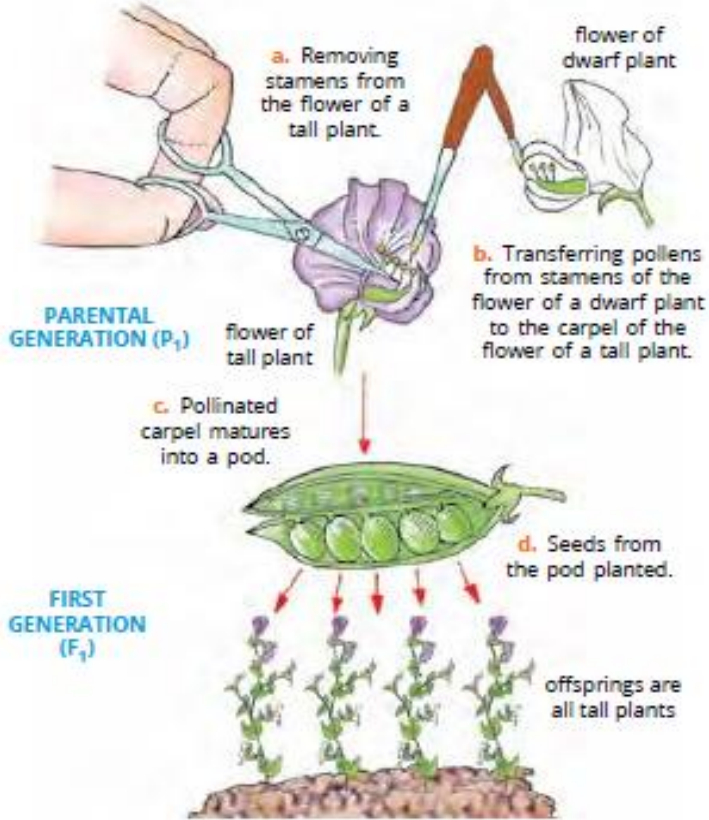
Stage I

Mendel selected seven pairs of contrasting characters. He self-pollinated the pea plant for several generations. He observed that seeds from tall plants produce only tall plants, and those from plants with purple flowers produce plants which always have purple flowers.

Stage II

He conducted reciprocal crosses (contrasting features), for example, he crossed a true-breeding tall stem variety plant (which he called tall plant) with a true-breeding short stem variety plant (dwarf plant).

Such a cross between two parents representing contrasting forms of a single character was called **monohybrid cross** and the offspring was called a **hybrid**. In other crosses, he took two or more traits into consideration for his experiments. Thus, **the crosses in which two traits were taken into consideration were designated as dihybrid crosses**. He performed the experiment by transferring pollen grains from the anther of the tall plant to the stigma of the dwarf plant. **The plants of parental generation were designated as P1.** The seeds from the dwarf plant were collected and sown.



He allowed these plants to self fertilize. He found that all plants which grew from these seeds were tall plants. The plants in this generation were called **F1 generation or first filial generation.**

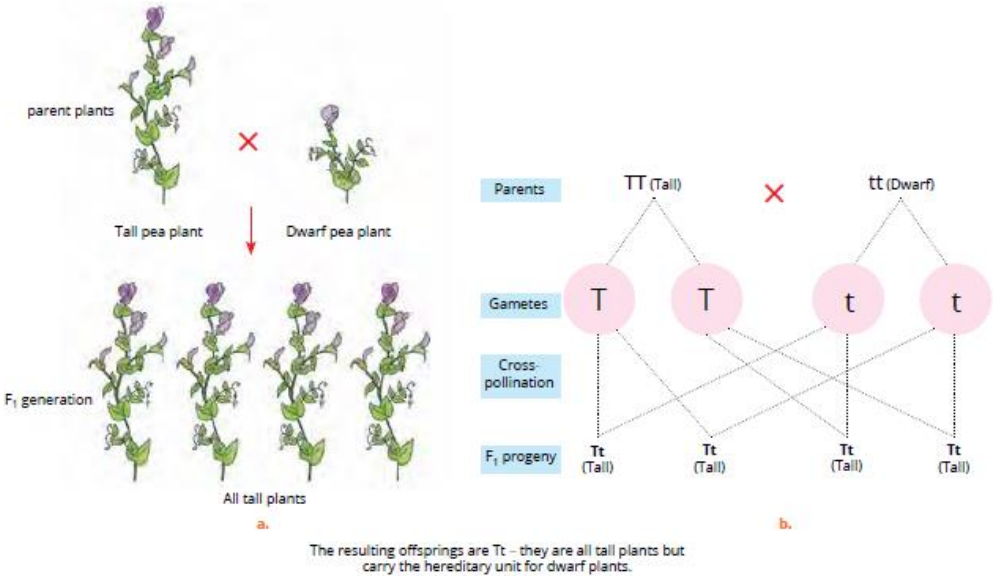
Steps involved in cross-pollination of plants

Stage III

The plants of F1 generation were allowed to selfpollinate and the seeds were collected. When these seeds were sown, few plants were tall and few were dwarf, in the ratio of 3 : 1. These plants were called **second filial generation (or F2 generation)**.

Monohybrid Cross

A cross between two parents representing contrasting forms of a single trait or feature is called monohybrid cross.



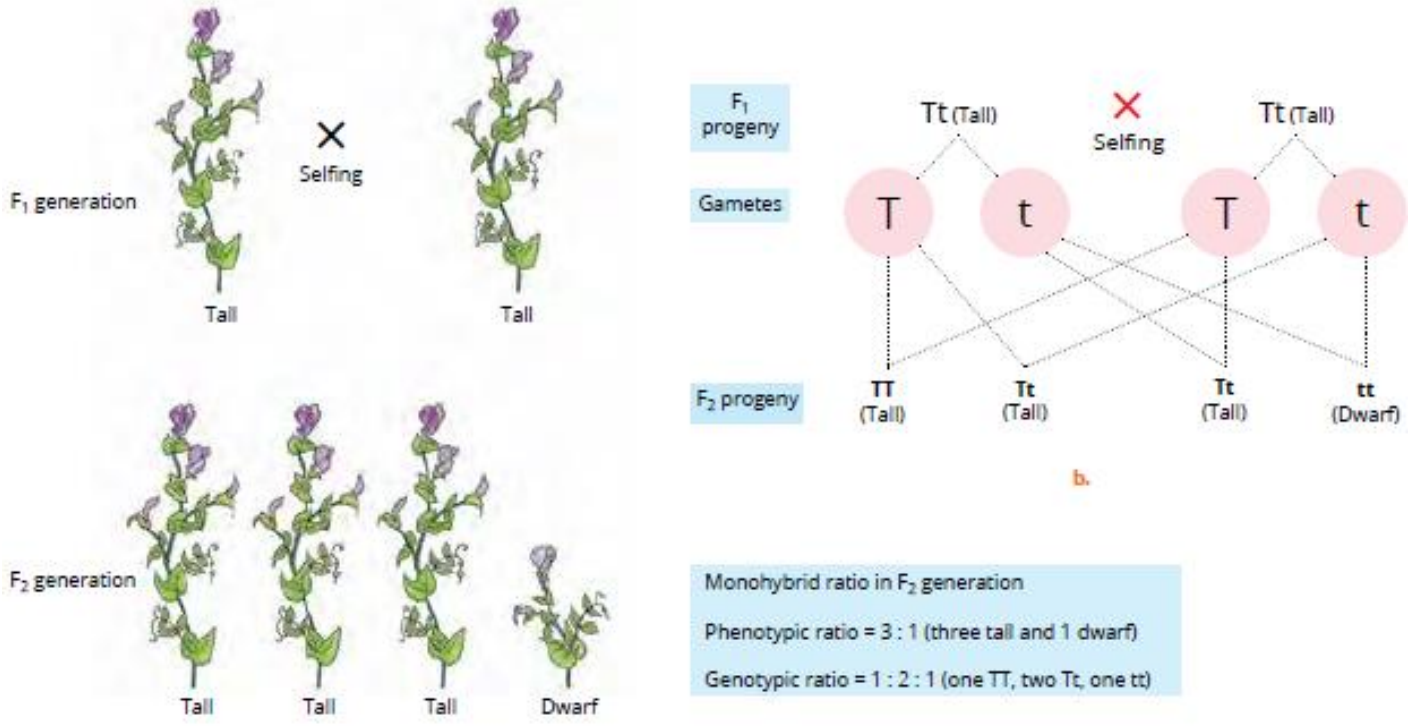
Monohybrid cross, step 1: Cross-pollination between tall and dwarf plants

Step 1. Cross-pollination between tall and dwarf plants

For a monohybrid cross between tall and dwarf plant, Mendel performed the experiment by transferring pollen grains from the flower (anther) of a dwarf plant (tt) to the stigma of the previously emasculated flower of a tall plant (TT). Mendel observed that all the plants of F1 generation were tall.

Step 2. Self-pollination of F1 generation plants

Mendel further planted the F1 seeds and flowers were again allowed to self-pollinate to produce the F2 generation plants. In the F2 generation, it was found that tall plants and short plants were obtained in the ratio of 3 : 1 (3 tall : 1 dwarf). So, 3 : 1 is the phenotypic ratio of the monohybrid cross. Mendel called the expressed trait of tallness as the **dominant trait** and repressed trait of dwarfness as **recessive trait.**



Monohybrid cross, step 2: Self-pollination of F1 generation plants

Meiosis – the reduction division

Meiosis takes place in the reproductive cells that produce gametes, sperms and ova. Meiosis is a modified mitosis in which **chromosomes divide once and the nucleus divides twice**. As a result of which **the number of chromosomes is reduced to half**. Thus, the four cells resulting from a meiotic division have a haploid number of chromosomes. It means that the **number of chromosomes becomes half in each sex cell**. This is because when the male and female gametes fuse during fertilization, the **diploid** (double) number of chromosome pairs is restored. **Meiosis is a reductional division.**

Meiosis has two nuclear divisions.

1. First meiotic division (reduction division)

2. Second meiotic division (mitotic division/ equational division)

Thus, in meiotic cell division, all the stages, i.e. prophase, metaphase, anaphase and telophase are repeated twice.

During meiosis, the diploid cells are reduced to haploid cells (number of chromosomes is halved).

Diploid → Haploid
(2n) (n)

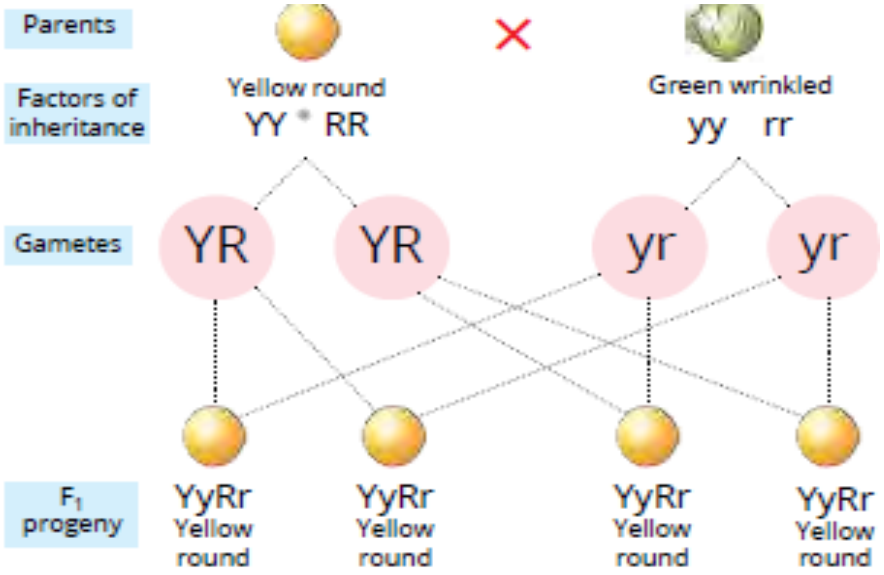
In absence of meiosis, the number of chromosomes will double and the offspring will not be able to survive.

Dihybrid Cross

A dihybrid cross is one in which two varieties of pea plants having two contrasting characters are crossed to study inheritance of two pairs of traits simultaneously.

Step 1. Cross between yellow round and green wrinkled pea plant

Mendel selected a pure line variety of peas for yellowround seeds and another for green wrinkled seeds. He crossed these plants and observed that all F1 generation seeds had the features of only one type (yellow coloured and round shape seeds).



a. Dihybrid cross, step 1: Cross-pollination between yellow round and green wrinkled pea plant.

Dihybrid cross, step 1: Cross-pollination between yellow round and green wrinkled pea plant.

This showed that:

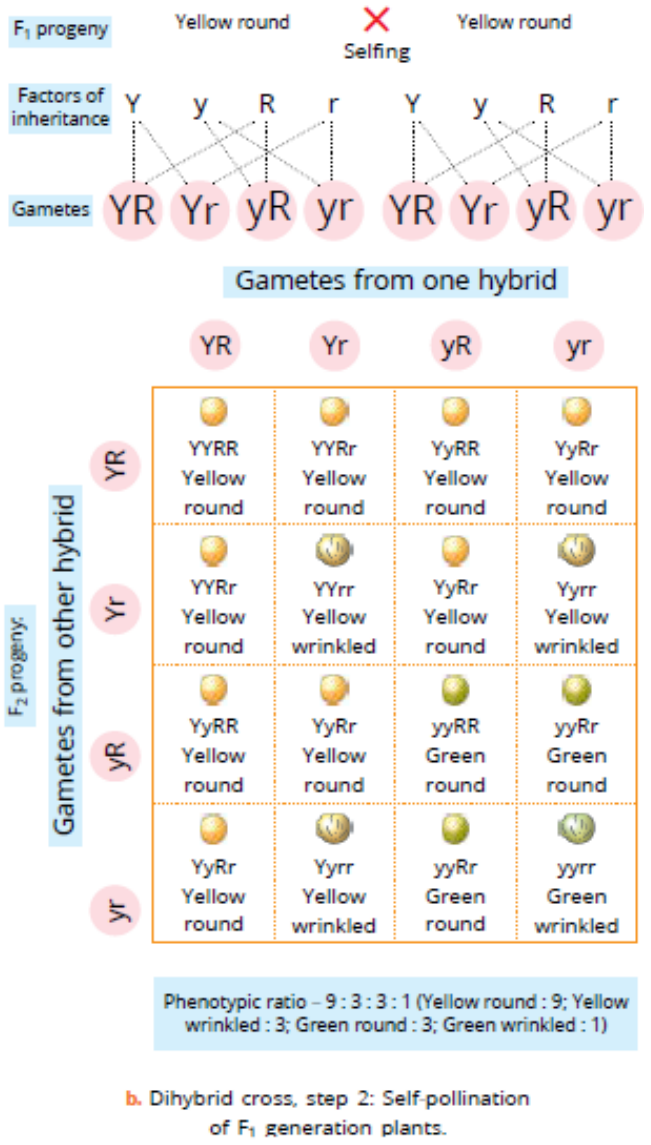
- Yellow colour was dominant over green which is a recessive trait.
- Round shape was dominant over wrinkled shape.

Step 2. Self-pollination of F1 generation plants

In the next step, Mendel self-pollinated these hybrids obtained in the F1 generation. When these F1 generation seeds were cross-bred to raise the F2 generation, the F2 progeny showed four different kinds of phenotypes of seeds. It was observed that not only both the parental types (round seeds of yellow colour and wrinkled seeds of green colour) were present, but two new combination of traits (round seeds of green colour and wrinkled seeds of yellow colour) also appeared.

Thus, there were yellow round, yellow wrinkled, green round and green wrinkled seeds in the ratio of 9 : 3 : 3 : 1, respectively. Of these, two are of the parental P1 types and two are new combinations or recombinants. **The dihybrid ratio is, therefore, 9 : 3 : 3 : 1.**

Ratio 9 : 3 : 3 : 1 is known as the phenotypic dihybrid ratio.



b. Dihybrid cross, step 2: Self-pollination of F_1 generation plants.

Interpretation Of Mendel's Observations

On the basis of analysis of results of the monohybrid and dihybrid crosses, following conclusions can be drawn:

1. In a monohybrid cross, when a cross is made between the contrasting pair of a trait, only one of the traits appears in the F1 generation.

2. The trait, which was not present in the offspring of a particular cross in F1 generation, again reappears in the F2 generation.

3. In a dihybrid cross, when combination of contrasting pairs of two traits were taken together, only one variety of each trait appears in the F1 generation.

4. The other variety of each trait reappears in the F2 generation on the same lines of the dihybrid cross.

5. However, the presence of two new combinations of the two contrasting pairs of traits in the F2 generation also occurs.

Mendel's Laws of Inheritance

Mendel postulated three laws of inheritance on the basis of his monohybrid and dihybrid experiments.

Law I: Law of dominance

It states that when two homozygous individuals with one or more sets of contrasting characteristics are crossed, the characteristics which appear in the F1 hybrids are dominant and those which do not appear in F1 generation are recessive.

Law II: Law of segregation

It states that when a pair of allele is brought together in a hybrid, the members of the allelic pair remain together without mixing and separate or segregate from each other when the hybrid forms gametes. Since each gamete is pure for a characteristic, the law is also known as law of purity of gametes.

Law III: Law of independent assortment

It states that, when a dihybrid organism forms gametes,

- each gamete receives one allele from each allelic pair (or each characteristic), and
- the assortment of alleles of different characteristics during gamete formation is independent of their parental combinations.

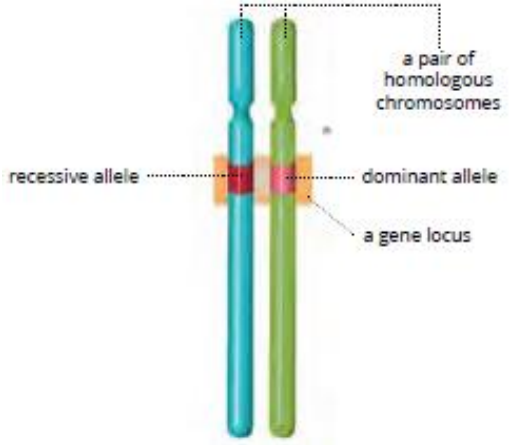
Transmission of Traits

All living organisms produce their own kind. So, there must be some common thing that makes an offspring similar to its parents.

It is called trait or character that is passed from parents to the offspring during sexual reproduction. These traits are transferred through genes located on their chromosomes.

What are genes?

A segment of DNA on a chromosome which codes for synthesis of a specific protein is called gene. Genes are the units of heredity. They are located in a linear fashion on chromosomes. Thus, chromosomes are the carriers of genes.



Alternative forms of the gene occupying the same position on the chromosomes.

These are located within the cell nucleus. In normal condition, each gene has two alternative forms of a character producing different effects. These alternative forms are called **alleles** .

Dominant and recessive alleles

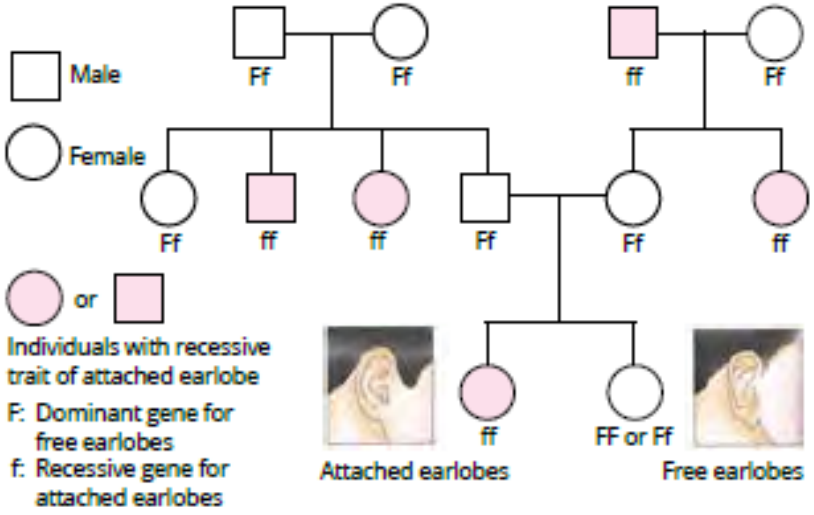
Out of the two alleles of a gene, the allele which masks any phenotypic effect of any recessive allele is called **dominant allele**. While the allele that is masked is called **recessive allele**.

Genotype and phenotype

The genetic constitution of an organism in which the genes are present in various combinations is called **genotype**. On the other hand, the externally visible expression of genes, which is an inherited feature in an individual's appearance is called **phenotype**. For every phenotype, there may be two conditions, homozygous and heterozygous.

Homozygous condition: A condition in which a pair of a homologous chromosomes carries identical alleles on a gene locus for a specific trait.

Heterozygous condition: A condition in which a pair of homologous chromosomes carries non-identical alleles on a gene for a specific trait.



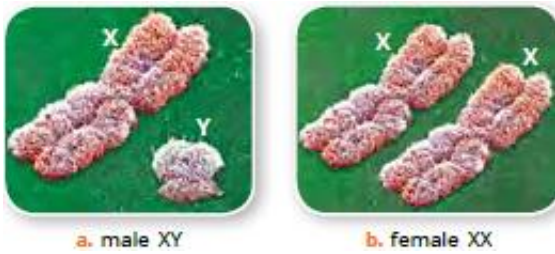
Pedigree analysis – From parents to children

A pedigree is a family tree or chart describing the inheritance of a particular character across generations.

Pedigree analysis

Sex Determination in human beings

Determining the sex of an individual at prenatal (before birth or during pregnancy) stage is called sex determination.



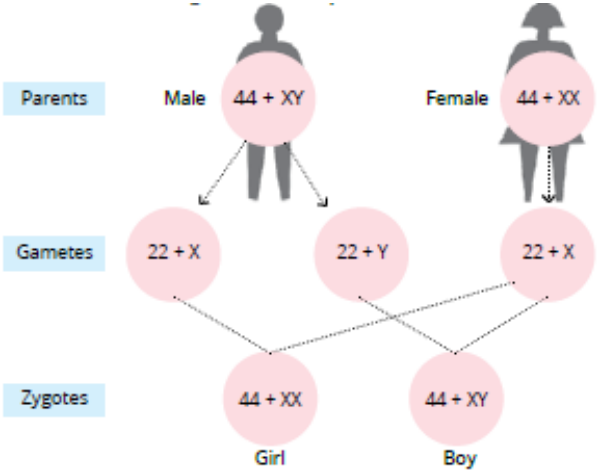
Sex chromosomes

In a number of organisms, one specific pair of chromosome plays a significant role in the determination of sex of the organisms. These chromosomes are named as **sex chromosomes**. In human beings, there are 23 pairs of chromosomes, out of which one pair is sex Chromosome.

How is it determined if the child would be male or female?

❖ The sex of the offspring will be determined by the type of chromosome (X or Y) inherited from father.

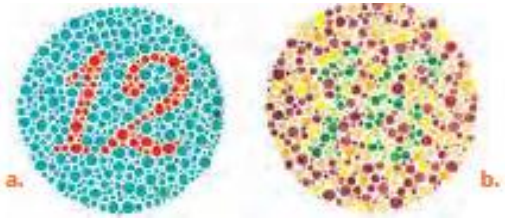
❖ At the time of fertilization, when the sperm and the egg unite to form a zygote, each individual inherits one of the two possible combinations of sex chromosomes .



❖ A zygote (XX) with two X chromosomes (one from father and one from mother) develops into a girl while a zygote, (XY) with one X chromosome (from mother) and one Y chromosome (from father) develops into a boy.

X-linked inheritance

X-linked genes are present on that portion of the X chromosome for which there is no homologous region on the Y chromosome. Examples of inheritance of traits determined by X-linked genes include colour blindness and haemophilia.



Plates to test for colour blindness

These diseases are caused by recessive alleles located on the X chromosome. Mostly males suffer from this disorder and females are rarely affected. A person suffering from colour blindness is unable to distinguish between red and green colours.

Haemophilia is a sex linked recessive disorder that slows down the process of blood clotting in an affected individual. It results in prolonged bleeding following an injury. It is rare to have haemophilia in females but they act as the carrier and may transfer the mutated gene to their sons.

From the given crosses, it can be concluded that,

❖ an X-linked recessive gene affects more males than females because males need only one copy of the defective allele to express the characteristic.

❖ an X-linked recessive characteristic can skip generations because males can receive an X-linked recessive only from their mothers.

Y-linked gene

The gene for hairy pinna is an example of Y-linked inheritance. Y chromosome is present singly in the male genotype. Will females be carriers of this gene? The obvious answer is no as the human female genotype does not have a Y chromosome. The characteristics of a Y-linked trait are as follows.

- ❖ They are expressed only in males.
- ❖ They are always passed from father to son.

Mutation

A sudden change in the amount, arrangement or structure of the DNA or chromosomes of an organism is called mutation. A mutation resulting from a change in the amount or arrangement of DNA is known as **chromosomal mutation**. A mutation resulting from a change in the structure of gene in DNA is known as **gene mutation**.

Genetic engineering: A technique in which the genetic constitution of an organism can be altered by introducing new genes or replacing existing genes into its chromosomes is known as genetic engineering.

Genetic counselling: This is a counselling of the parents/newly married couples in which they are advised to get them screened for any genetic diseases such as haemophilia,thalassemia, Down syndrome, etc.

SUMMARY...

- The science which deals with the mechanisms responsible for similarities and differences among closely related members of the species is called genetics.
- Gregor Mendel is the father of genetics. He postulated three laws of heredity on the basis of his experiments on the sweet pea plant.
- Mendel's first law of inheritance: It states that when two homozygous individuals with one or more sets of contrasting characteristics are crossed, the characteristics which appear in F1 hybrids are dominant.
- Mendel's second law of inheritance: It states that when a pair of alleles is brought together in a hybrid, the members of the allelic pair remain together without mixing and separate from each other when the hybrid forms gametes.
- Mendel's third law of inheritance: It states that when a dihybrid organism forms gametes, each gamete receives one allele from each allelic pair, and the assortment of alleles of different characteristics during gamete formation is independent of their parental combinations.
- Pedigree is a family tree or chart describing the inheritance of a particular characteristic across generations.
- Sex determination in humans is based on combination of sex chromosomes.
- Inheritance of non-sexual characteristics through sex chromosomes is called sex-linked inheritance.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