Heredity

Chapter Out Line

- Heredity
- Variations
- Mendelism
- Sex determination

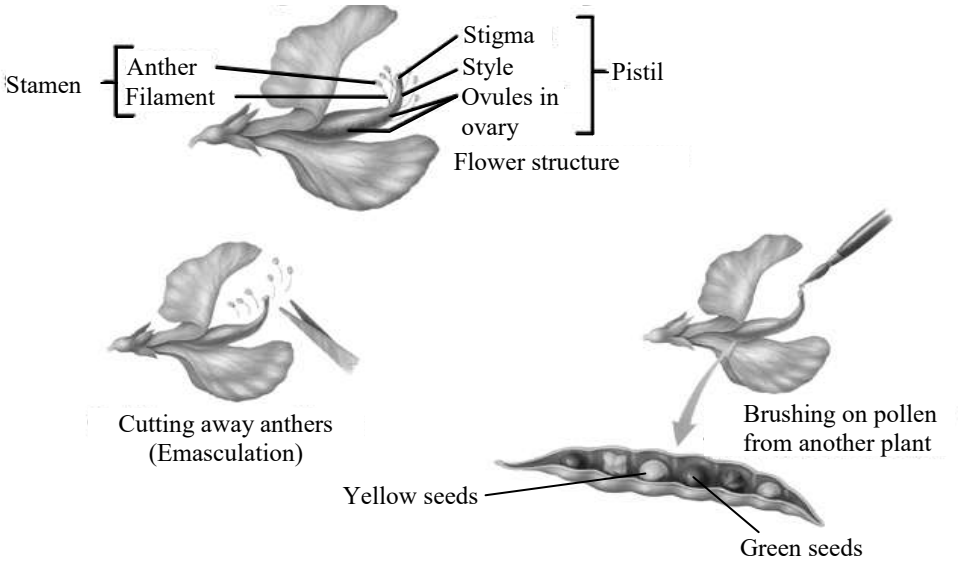


Figure : Experiment of Mendel showing inheritance of colour of seeds

INTRODUCTION

Every organism produces offsprings either through asexual reproduction or through sexual reproduction. The new individuals produced through these reproductive processes are either similar or dissimilar. In asexual reproduction, although the offsprings resemble each other and also to their single parent, yet very minor differences (variations) arise in them. In sexual reproduction, variations are visible among off springs and their parents.

HEREDITY AND VARIATIONS

Heredity : Heredity is the passing of characters from parents to off springs or one generation to next.

Genetics : Study of Heredity and variations is said to be known as genetics. The term genetics was first of all used by W. Bateson in 1905. An Austrian monk namely Gregor Johann Mendel was the first person to study genetics. He was therefore regarded as the **'Father of Genetics'.**

Variation : Variation is the degree of difference found in morphological, physiological & other traits found among individuals belonging to the same family race & species.

Variations could be of two types :

(i) Somatic variation : Somatic variation affects the somatic cells of an organism. It is neither inherited from parents nor transmitted to next generation. It is acquired by individual during it's own life and is lost with it's death. It is therefore also called as acquired variation.

(ii) Germinal variation : It affects the germinal or reproductive cells. These are important source of genetic variation in natural population which lead to evolutionary change . These are passed on to later generations.

Most of the variation are due to mutations (sudden random change in genetic material of a cell) caused by error in DNA replication.

◈ **Accumulation of variations during reproduction**

- Variation appear during reproduction whether organisms are multiplying asexually or sexually. Each generation provides the next generation with a common basic body design and some subtle changes or variations
- The variations accumulate and pass on to more and more individuals with each generation.
- The diversity is small in case of asexually reproducing organism as it is caused by only errors of DNA copying mechanism.

◈ **Significance of variation**

- **Preadaptations :** Some of the variations function as preadaptation to changing environment. For example, heat wave may kill most bacteria except a few which have a pre-adaptation or variation to tolerate high temperature.
- **Evolution :** Variations are raw materials for evolutionary processes. Picking up suitable variants by nature or environment forms the basis of evolution.
- **Struggle for Existence :** Useful variation provide advantage to the individuals in the struggle for existence and hence survival in nature.
- **Individuality :** Variations provide a distinct identity to each and every individual.
- **Artificial Selection :** Picking up of certain variations by breeders have resulted in development of a number of breeds and varieties of domesticated plants and animals.

MENDELISM

- Gregor Johann Mendel (1822- 1884) in silisian (Austria) now a part of Czechoslovakia. He is known as the Father of genetics.
- He conducted his experiments on garden pea *(Pisum sativum).*
- Mendel presented his experiments data conclusions before Brunn Natural Society in 1865 and was published in Annual Proceedings of the Natural History Society in 1866
- His work was recognized in 1900 after his death (1884). Mendel's conclusions (laws) were rediscovered simultaneously by **Hugo de vries** a Dutch biologist, **Carl Correns** a German botanist and **Erich von Tschermak** an Austrian botanist.

Boost your knowledge

Some general terms (Terminology) :

- **Gene :** It is a hereditary unit which carries character from one generation to another generation.
- **Allele :** Alternative forms of a gene which are located on same position (loci) on the homologous chromosome are called alleles.
- **Homozygous traits :** They have similar alleles for specific trait (TT or tt). They produce only one type of gametes.
- **Heterozygous traits :** They have dissimilar alleles for a specific trait (Tt). They produce two types of gametes.
- **Dominant trait :** The trait which appears in F_1 generation is called as dominant trait. It is denoted by capital letter. e.g. TT (tall).
- **Recessive trait :** The traits which does not appear in F_1 generation is called as recessive trait. It is denoted by small letter. e.g. tt (dwarf)
- **Genotype :** It is the genetic representation of a trait. e.g. TT or Tt for a tall plant.
- **Phenotype :** It is the expression(physical appearance) of a trait e.g. Tall pea plant. It can be noted by direct observation of an individual.
- **Monohybrid cross :** It involves the study of inheritance of one pair of contrasting characters. e.g. Inheritance of tall and dwarf characters.
- **Dihybrid Cross :** It is the inheritance of two pairs of contrasting characters.
- **Trihybrid cross:** It is the inheritance of three pairs of contrasting characters.
- **Back cross :** The cross between F_1 generation with any of the parents is known as back cross.
- **Test cross :** The cross between F_1 generation and the recessive parent is called as test cross.
- **Emasculation :** The removal of anther from a flower for the cross pollination
- **Bagging :** It is the process by which hand pollinated flowers are covered with paper bags.

MENDEL'S EXPERIMENT

- **Mendel's experimental plant.** Mendel selected garden pea plant (**Pisum sativum**) for series of hybridization experiments because it had the following special features
  - It was easy to grow.
  - It had a short life cycle and, therefore, it was possible to study number of generations.
  - Garden pea plant had distinct, easily detectable contrasting variants of features. For instance, some plants were tall and some dwarf ; some had violet flowers and some had white flowers : some plants had round seeds and some had wrinkled seeds and so on. Mendel, in fact, noted **seven pairs** of such contrasting characters in garden pea plant
  - All the contrasting traits were existing in every generation because plants had bisexual flowers and normally resorted to self-pollination.
  - In these bisexual plants, artificial cross fertilization could easily be achieved. It was done by removing the stamens (male part) before maturity of the female part of flower and later dusting the pistil (female part) of this flower with the matured pollens from a desired plant.
  - Each pea plant produced many seeds in one generation.
  - The garden pea plants could easily be raised, maintained and handled.
- **Traits chosen by Mendel for his experiment :**

  There are seven traits which Mendel has selected, they are as follows :

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

Table : Characteristic of pea plant and their advantages

- **Mendel performed experiments in three stages :**
  - **(A)** He made sure that, the plant which he had selected must be a true breeding plant, by letting the plant to undergo self – fertilization.
  - **(B)** He performed the process of cross pollination of alternate forms of traits. The resultant generation obtained was termed as hybrid, and these hybrids formed are called as F_1 generation i.e. First filial generation.
  - **(C)** He allowed the hybrid to self pollinate up to five generations and these generations are subsequently termed as F_2, F_3, F_4 and so on.
- **Reasons for Mendel's success :**
  - **(A)** He selected true breeding [pure] pea plant for his experiment.
  - **(B)** He studied single trait at a time.
  - **(C)** He kept an accurate mathematical record of his breeding experiments and noted down the number of each type of offspring produced in each cross.
  - **(D)** He was lucky enough to select the seven traits , as the gene for these traits are located on four different chromosomes.

MONOHYBRID CROSS

It is a cross in which only one character is studied at a time.

In his first monohybrid cross, Mendel crossed a pure breed tall plant (TT) and a pure breed dwarf plant (tt).

And he found that in F1 generation only tall plant were born out of these seeds, no intermediate character or mixing or blending was observed by him. Mendel termed tallness as dominant and dwarfness as a recessive character.

He repeated the same experiment taking other characters too and always found same results.

Mendel's postulates

To explain the experiment he said that each character is controlled by a pair of factor.

During gamete formation, the paired factors got segregated and moved to different gametes.

When these gametes fused together they used to restore paired state again.

In heterozygous conditions out of the two alleles only one allele is able to express its effect it is called dominant allele and other which does not show its effect in heterozygous condition is called recessive allele.

When F1 plants are grown and allowed to self pollinate he got many seeds and when they were grown he found that the ratio of tall plants and dwarf plants was 3:1 respectively.

The dwarfness which was not visible in F_1 generation reappeared in F_2 generation.

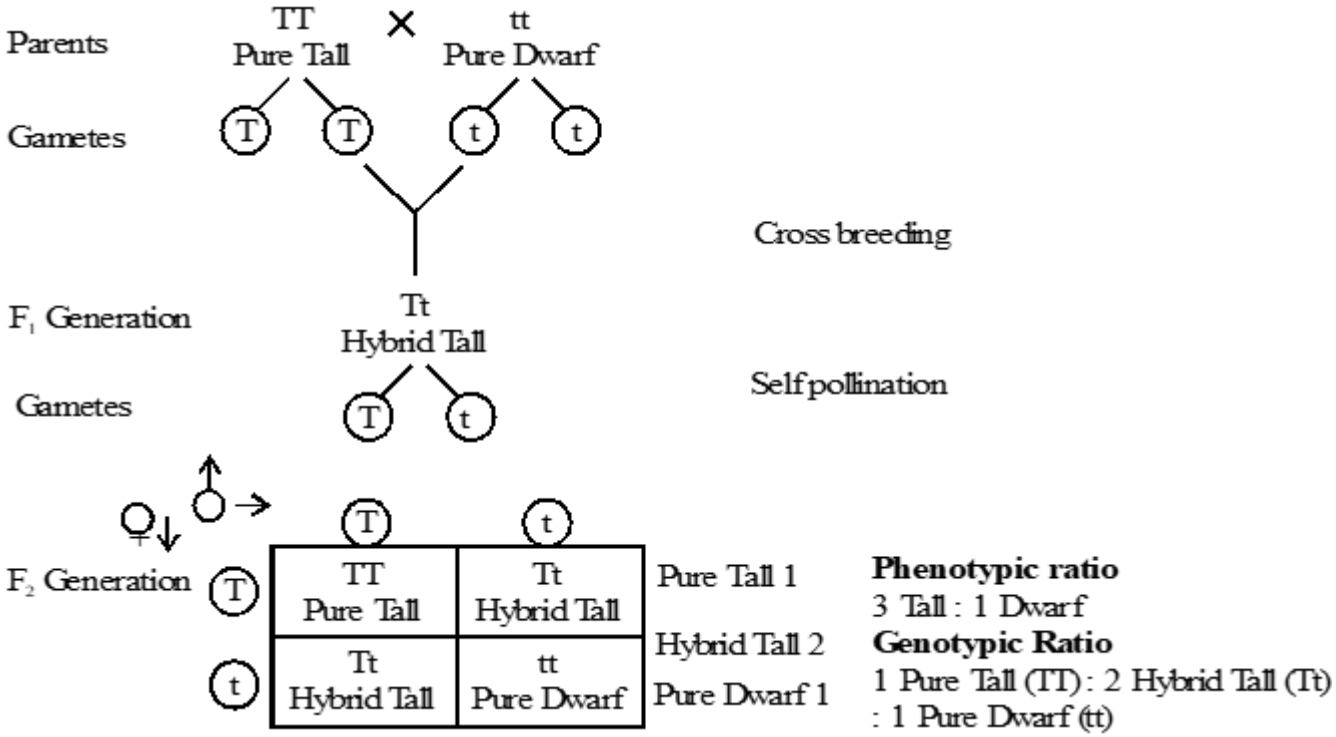


Fig. Monohybrid Cross

DIHYBRID CROSS

It is a cross in which 2 characters are simultaneously studied.

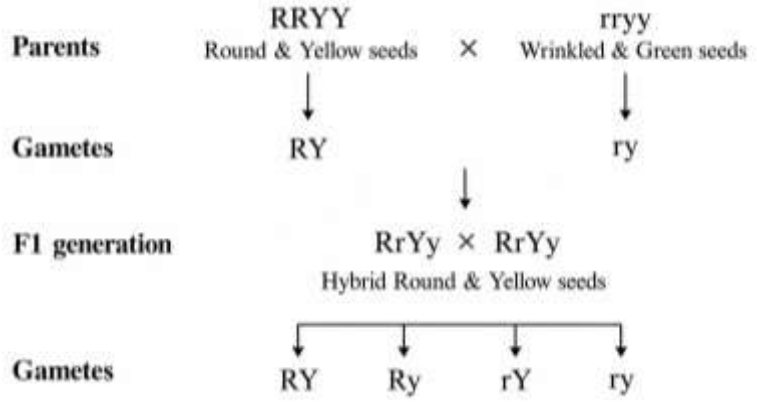
In Mendel's first dihybrid cross, he crossed a pure breed plant with yellow and round (YYRR) seeds with another pure breed plant having green and wrinkled (yyrr) seeds.

F1 generation had plants with yellow and round seeds.

It means yellow and round seed characters are dominant over green and wrinkled seeds.

He allowed these plant produced in F1 generation to self pollinate and he expected same 3 : 1 in F2 generation. But to his surprise the ratio was all new 9 : 3 : 3 : 1 in which beside 2 parental varieties, 2 new varieties were also produced. So, the ratio was 9 yellow and round ; 3 yellow and wrinkled ; 3 green and round ; 1 green and wrinkled.

This could be explained only when beside the parental combination of factors (YR) and (yr) two new combinations of factors are also produced as



♀ \ ♂	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

Fig. Dihybrid Cross

Phenotypic ratio :

9 round and yellow : 3 round and green : 3 wrinkled and yellow : 1 wrinkled and green.

The occurence of four types of plants in the F2 generation of dihybrid cross shows that during gamete formation in F2 generation, the two factors of a character are independently assorted and get randomly rearranged in the offspring. So four types of gametes are formed as YR, Yr, yR, yr from each parent. When they are randomly fused they resulted following combinations. So this is how the 9 : 3 : 3 : 1 ratio could be understood.

MENDEL'S LAWS

The Principle of Paired Factors : Each character in an individual is governed by two factors called as gene. The alternative form of gene is called as alleles or allelomorphs. If an individual consists of similar types of alleles, they are called as homozygous e.g. TT, tt while those having different types of alleles are called as heterozygous e.g. Tt etc.

The principles of Mendel formulated into 3 laws -

(i) Mendel's Law of Dominance : When two homozygous individuals with one or more sets of contrasting characters are crossed then the characters that appear in the F_1 hybrids are dominant characters and those which do not appear in F_1 are recessive characters .

(ii) Mendel's Law of Segregation : [Law of purity of gametes] The law of segregation states that when a pair of contrasting factors or genes or alleles are brought together in a heterozygous condition, the two remains together without being contaminated but when gametes are formed from them the two separate out from each other. This is also known as Mendel's first law of heredity.

(iii) Mendel's Law of Independent Assortment : If the inheritance of more than one pair of characters are studied simultaneously, the factors or genes for each pair of characters assort out independently. It is called as Mendel's second law of heredity.

HOW A TRAIT IS EXPRESSED ?

A function is controlled by formation of a specific enzyme, this enzyme then leads to a specific chemical reaction to express its character.

If we consider the hybrid condition obtained by Mendel in F1 generation, it has both "T" and "t", yet it shows tallness not dwarfness. There are two possible reasons for it as follows-

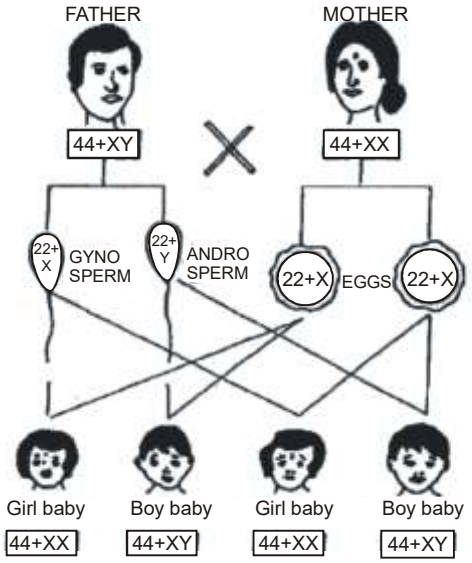
(a) Allele t may not be able to make its enzyme, so its character is not expressed.

(b) Its enzymes are not in enough quantity to show its expression in presence of enzyme of "T".

SEX DETERMINATION

It is a process by which the sex of a person is determined. Genetics is involved in the determination of the sex of a person, which is explained as follows :

- A male has one X chromosome and one Y chromosome, i.e., half of the male gamete or sperms will have X chromosome and the other half will have Y chromosome.
- A female has two X chromosomes, i.e., all the female gametes or ova will have only X chromosomes.
- Sex of a child depends on what happens at fertilisation.
- If a sperm carrying **X** chromosome fertilises an ovum which carries **X** chromosome, then the **child born** will be a **girl**.
- If a sperm carrying **Y** chromosome fertilises an ovum which carries **X** chromosome, then the **child born** will be a **boy**.
- Thus, the sperm determines the sex of the child.
- Sex determination is also controlled by the environmental factors in some animals.
- For example, in some reptiles like **turtle**, high incubation temperature leads to the development of female offsprings, while in case of **lizard**. high incubation temperature results in male offsprings.



Sex determination in humans and birth of a boy or girl baby

Can you think why ?

- Why females should not be blamed for giving birth to a girl child ?