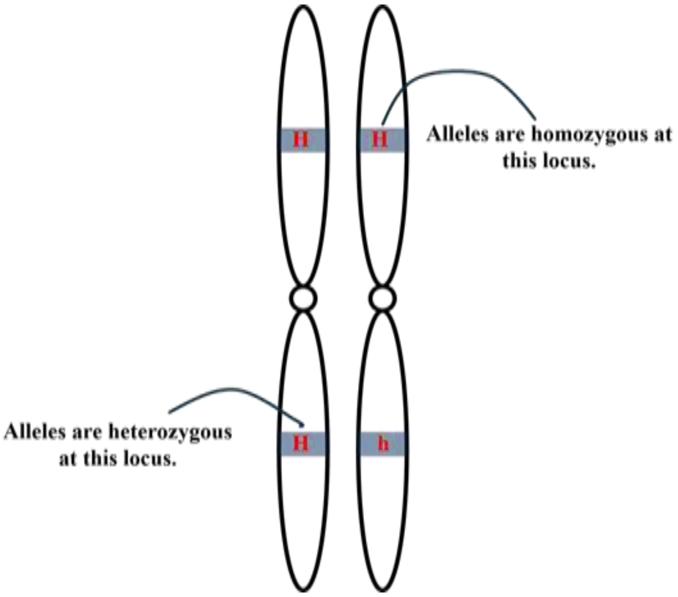
Mendelian Genetics

Trait

- The characteristics of a person are called **traits** or characters. Traits are either hereditary **(eye color, height, etc.)** or not hereditary **(tattoos, scars, etc.)**.

Eye Colour

- Traits are controlled by **genes**.
- The genetic constitution of an individual is called as **genotype** (TT, Tt, tt).
- **Phenotype** is an **observable trait** or **set of traits** (**structural and functional**) of an organism. Traits are produced by the **interaction** between its **genotype** and **the environment**. A phenotype is readily (easily) visible (**eye colour, hair colour, skin colour, height etc**.) or not readily visible but measurable (**blood type, altered protein** or **enzyme**). Genotypes set the range of possible phenotypes, while the environment determines where in that range the phenotype ends up.
- **Dominant allele:** Single copy of the gene able to express itself.
- **Recessive allele:** A recessive allele does not produce a trait at all when only one copy is present.
- **Homozygous:** A diploid organism in which both alleles are the same at a given gene locus is said to homozygous.
- **Heterozygous:** A diploid organism in which both alleles are different at a given gene locus is said to be heterozygous.
- **F1 generation** (the first filial generation): The progeny of mating of individuals of the P generation.
- **F2 generation** (the second filial generation): The progeny resulting from interbreeding F1 generation individuals.



- **Mendel selected seven pairs of traits to study in his breeding experiments**

  1. **Flower** and **seed coat colour**: **grey** versus **white seed coats**, and **purple** versus **white flowers** (*a single gene controls both these colour properties of seed coats and flowers*).
  2. Seed colour: ***yellow*** versus ***green***
  3. Seed shape: ***smooth*** versus ***wrinkled***
  4. Pod colour: ***green*** versus ***yellow***
  5. Pod shape: ***inflated*** versus ***pinched***
  6. Stem height: ***tall*** versus ***short***
  7. Flower position: ***axial*** versus ***terminal***

- **Monohybrid cross:** A cross between individuals that are heterozygous for same pair of alleles is called monohybrid cross.

  A monohybrid cross is represented by the selfing or self-fertilization **(selfing -** the anthers at the ends of the stamen produce pollen which lands on the pistil within the same flower and fertilizes the plant**)** of the **F$_1$** plant, which produces **F$_2$** generation, and **F$_1$** generation is produced by a cross between true breeding plant with contrasting traits.

  For example, if we make a cross between true breeding Tall (**TT**) pea plant and short (**tt**) pea plant, the **F$_1$** will be produced with **Tt** genotype (**Fig 1a)**. While making this cross **Tall** plant will act as **P1** and **short** plant will act as **P2**. From **P1** and **P2** only one type of gamete will be produced. Gamete from **P1** will contain **T** allele and gamete from **P2** will contain **t** allele.

For production of the **F_2** generation the **F_1** offsprings **♀ (Tt)** act as parents and each parent will produce two types of gametes. One gamete will contain **T** allele and the other gamete will contain **t** allele. Each type of gametes from one parent will combine to each type of gametes from other parent. All the possible combinations of gametes will produce **F_2** generation **Fig 1b**. The offsprings of the **F_2** generation in this monohybrid cross will show two different phenotypes i.e**.** ¾ Tall pea plants **(TT, Tt)** and ¼ short pea plants (**tt**).

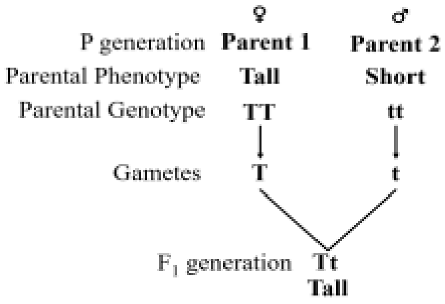


Fig 1a

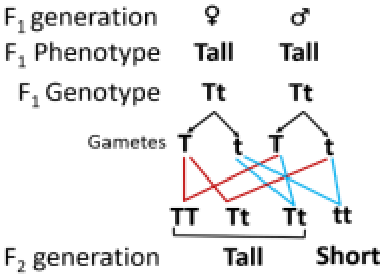


Fig 1b

- **Reciprocal cross**

  Matings that are done in both ways are called reciprocal class. The same results of a reciprocal cross tell that the inheritance of the trait does not depend on sex of strains. If we take a simple trait, height, of pea plant to represent reciprocal cross, then the mating of Tall female [♀ **TT**] and short male [♂ **tt**] **(fig 2a),** and short female [♀ **tt**] and tall male [♂ **TT**] **(fig 2b),** will give same result that is all plants in **F_1** will be **tall** in both the cross.

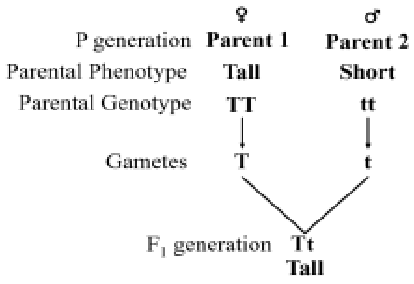


Fig 2a

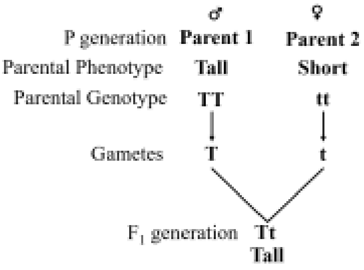


Fig 2b

- **Principle of segregation (Mendel's first law)**

  This law states that the alleles of a gene in a diploid organisms get separated at the time of gametogenesis.

  In a monohybrid cross if a tall pea plant is crossed with a short height pea plant, all the **F_1** plant will be tall. Despite having allele for short height, short height plant is not seen in **F_1**. It happens because the allele for tall phenotype is dominant to recessive allele. In other words, the recessive allele cannot express itself when it is present in a single copy. At the time of gametogenesis, while making **F_1,** each parents of **F_1** produce only one types of gametes. The gametes from both the parents fertilize to give progenies in **F_1** generation with plant which have tall phenotype.

  The law of segregation was followed at the time of gametogenesis in the parents of **F_1**, but they were homozygotes therefore all the gametes from both parent received the same allele, therefore both the parents were able to produce only one type of gamete (**Fig 3a**). The homozygous dominant parent produced gametes containing only one copy of the gene for tall phenotype and the homozygous recessive parent produced gametes containing only one copy of the gene for short height phenotype. Therefore, the union of gametes from both the parents will produce plant with **Tt** genotype in **F_1** generation. Only **T** will be expressed in **F_1** and all the plants will be tall.

  When we will make **F_2** generation, parents of **F_2** generation will produce gametes by gametogenesis. It is important to note that the parents for **F_2** are heterozygous (**fig 3b**) for the gene of interest, therefore one parent will produce two types of gametes. Each gamete type will receive a single copy (***either T or t***) of that gene. Here two types gametes are produced from each parent because of the principle of segregation. The two alleles of a gene for each trait will be segregated in two different gamete type.

  Because of the segregation of the alleles, one type of gamete will contain dominant copy of allele and other gamete type will contain recessive copy of allele. The possible combinations of gametes from one parent with gametes of other parent give **F_2**, where ¾ plants will be tall (**1 TT and 2 Tt**), and ¼ plants will be short (**tt**). The short plants in **F_2** generation are produced because of the segregation of **t** allele from **T** during gametogenesis in parent with **Tt** genotype and union of gametes containing recessive alleles (**t**) from each parent.

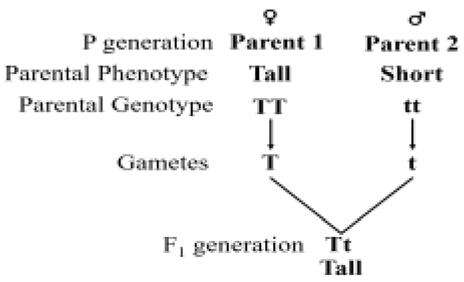


Fig 3a

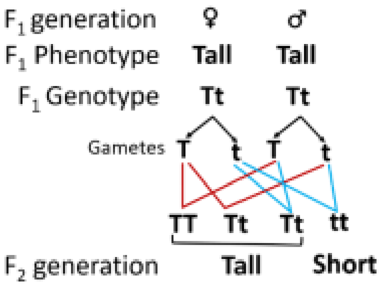


Fig 3b

- **Test Cross**

  The **TT** and **Tt** plants have different genotypes but the same dominant phenotype in the ***Fig 3b***. Although the self-fertilization test of the **F_2** progeny can be used to determine whether a plant with the dominant phenotype is homozygous (**TT**) or heterozygous (**Tt**). However, a more common method is test cross to find a plant with dominant phenotype is homozygous (**TT**) or heterozygous (**Tt**). A cross of an individual expressing the dominant phenotype with a homozygous recessive individual to determine its genotype is called **test cross**.

- **Dihybrid cross**

  A cross between individuals **heterozygous** at two genetic locus of interest is called **dihybrid cross**. When Mendel made crosses between true-breeding smooth, yellow plants (**SS YY**) and wrinkled, green plants (**ss yy**), he got the result as given in the **fig 4a**. All the **F_1** seeds from this cross were smooth and yellow. The given figure shows, the smooth, yellow parent produces only **S Y** gametes, which give rise to **Ss Yy** zygotes upon fusion with the **s y** gametes from the wrinkled, green parent. Because of the dominance of the smooth and yellow alleles, all **F_1** seeds are smooth and yellow. To obtain **F_2** generation Mendel made cross between two **F_1** plants. This step of crossing between two **F_1** plant is called **dihybrid cross** because plants in **F_1** generation are **dihybrids** (*heterozygous at two different gene loci*). In a dihybrid cross, there are **4** possible gamete types. The result is **9** different genotypes but, because of dominance, only four phenotypes are obtained (**Fig 4b)**.

1 SS YY, 2 Ss YY, 2 SS Yy, 4 Ss Yy = 9 **Smooth, Yellow**

1 SS yy, 2 Ss yy = 3 **Smooth, Green**

1 ss YY, 2 ss Yy = 3 **Wrinkled, Yellow**

1 ss yy = 1 **Wrinkled, Green**

Here a dihybrid cross (F_1 X F_1 cross) has given a 9:3:3:1 ratio of the four possible phenotypic classes

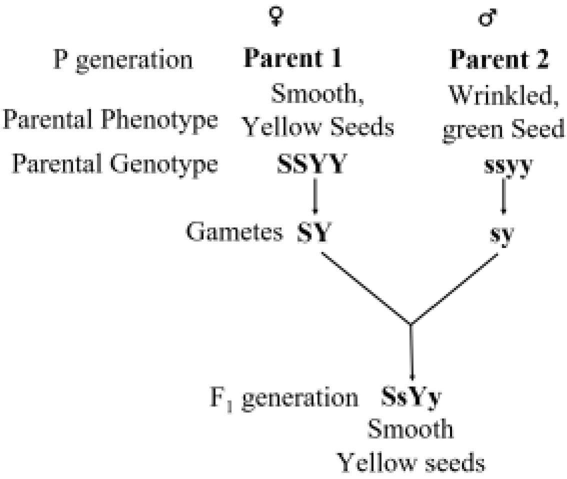


Fig 4a

	SY	Sy	sY	sy
SY	SSYY	SSYy	SsYY	SsYy
Sy	SSYy	SSyy	SsYy	Ssyy
sY	SsYY	SsYy	ssYY	ssYy
sy	SsYy	Ssyy	ssYy	ssyy

Fig 4b

Principle of Independent Assortment (Mendel's second Law)

Principle of independent assortment states that *the factors for different pairs of traits assort independently of one another*. In modern terms, this means that *pairs of alleles for genes on different chromosomes segregate independently in the formation of gametes*.

Example of Independent assortment

Mendel stated the law of independent assortment with the help of dihybrid cross. The example of dihybrid cross is given above, where **P1** and **P2** will produce only one type of gamete containing **SY Allele** (From P1) and **sy Allele** (From P2) alleles respectively. Union of these gametes produce **F_1** with **Ss Ys** genotype (**fig 4a)**. All the **F_1** plants will be smooth and yellow because smooth and yellow are dominant to wrinkled and green. If we want to produce **F_2** generation, we have to make selfing between **F_1**. During gametogenesis there are to possible outcomes of gamete formation in **F_1** plants. there two ways in which **F_1** plants will produce gamete. In one way each **F_1** (**Ss Yy**) can produce two types of gametes (**Fig 5a**), one type of gamete will contain **SY** alleles, and the other type of gamete will have **sy** allele. The alleles determining **seed shape** and **seed color** in the original parents would be transmitted together to the progeny. In this case, a phenotypic ratio would be **3:1 smooth, yellow: wrinkled, green (Fig 5a)**.

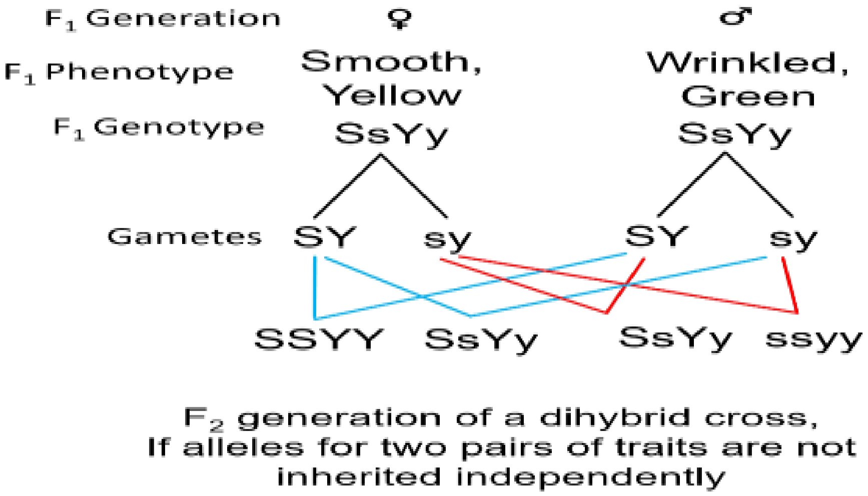
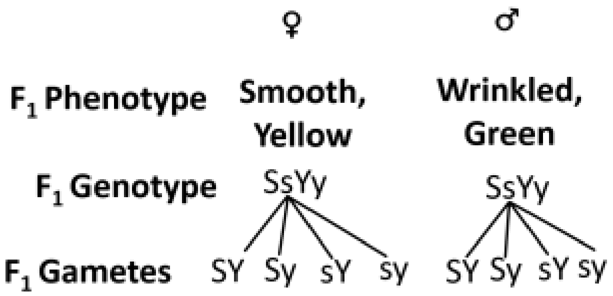


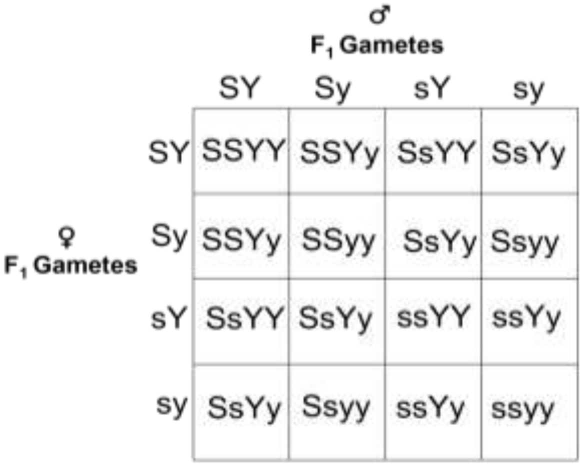
Fig 5a

In other possible way the alleles determining **seed shape** and **seed colour** would be inherited independently that is allele **S** (shape determining allele) is separated from allele **Y** (seed color determining allele) **(Fig 5b)**. Separation of **s** and **y** allele also occur in the same way. By this way each **F_1** plant (**Ss Yy**) is able to produce four types of gametes: **SY**, **Sy**, **sY**, and **sy** (**Fig 5b**). This outcome is different from the previous one because the shape determining allele and seed color determining allele got separated independently of each other, that is both **S** and **s** allele can go with both the **Y** and **y** allele during gametogenesis in a **F_1** parent (**Ss Yy**). In **F_1XF_1** crosses, the four types of gametes would be expected to fuse randomly in all possible combinations to give rise **F_2**. All the possible gametic fusions are represented in the Punnett square in **Figure 6. In the given example the alleles for two pair of traits assorted independently during the gametogenesis.** Therefore, the phenotypic ratio of **F_2** generation will be **9 Smooth, Yellow: 3 Smooth, Green: 3 Wrinkled, Yellow: 1 Wrinkled, Green (Fig 6)**.



Gametes produced by F_1 generation,
if alleles of two pair of traits are inherited independently

Fig 5b



	SY	Sy	sY	sy
SY	SSYY	SSYy	SsYY	SsYy
Sy	SSYy	SSyy	SsYy	Ssyy
sY	SsYY	SsYy	ssYY	ssYy
sy	SsYy	Ssyy	ssYy	ssyy

**F_2 generation of a dihybrid cross,
If alleles for two pairs of traits are
inherited independently**

Fig 6