INHERITANCE OF ONE GENE

The study of how one specific trait is passed down from parent to child is known as one-gene inheritance. Mendel, a scientist, wanted to learn about this, so he took tall pea plants (6-7 ft.) and short pea plants (0.75-1 ft.) that always produced tall or short offspring. He called these plants P_1 and P_2, which mean parents. Since peas can fertilize themselves, Mendel had to remove the anthers (part of the flower) from the short plants before they matured. This process is called emasculation.

He then took pollen from the tall plants, which were ready to release pollen, and put it on the stigma (part of the female flower) of the emasculated short plants for cross-pollination. After this, he collected the seeds that resulted from this cross and grew them into plants of the first hybrid generation. This generation is also known as F_1, which stands for filial, meaning offspring.

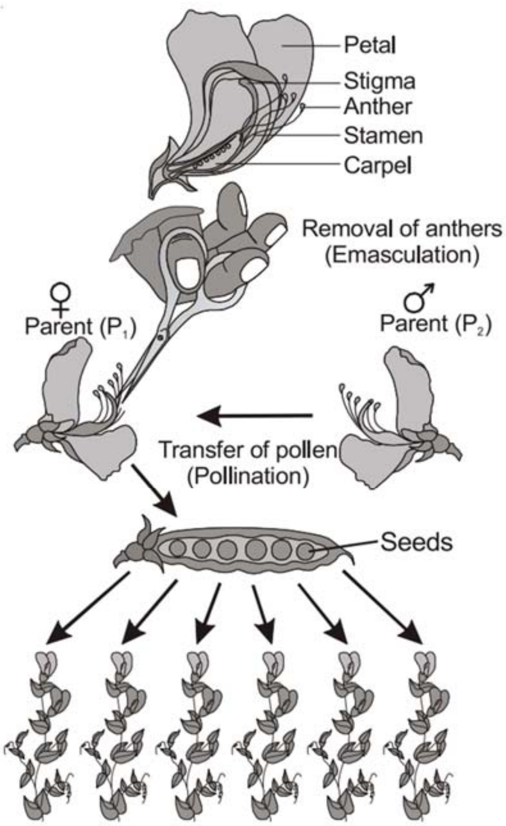


Fig. : Steps in making a cross in pea

Mendel discovered that all the first generation (F_1) plants were tall, just like one of their parents, and none of them were short. He did the same kind of crosses with other pairs of different traits, and every time, the F_1 plants looked exactly like one of the parents.

S.No	Characters	Parents		F_1 Plants
1.	Stem height	Tall	Dwarf	Tall
2.	Flower colour	Violet	White	Violet
3.	Flower position	Axial	Terminal	Axial
4.	Pod shape	Inflated	Constricted	Inflated
5.	Pod colour	Green	Yellow	Green
6.	Seed shape	Round	Wrinkled	Round
7.	Seed colour	Yellow	Green	Yellow

When Mendel let the tall plants from the first generation (F_1) pollinate themselves, he observed a mix of tall and dwarf plants in the second generation (F_2). The offspring resulting from the self-pollination of F_1 are called the second filial or F_2 generation. Among the F_2 plants, three-fourths were tall, and one-fourth were dwarf. Interestingly, the trait of dwarfness, which disappeared in the F_1 generation, showed up again in the F_2 generation.

It's important to highlight that in the F_2 generation, the tall and dwarf plants looked just like their original parents, and there was no blending of traits. All the offspring were either tall or dwarf, with none having a height in between. In this particular example, the cross involved a single pair of contrasting traits, making it a monohybrid cross.

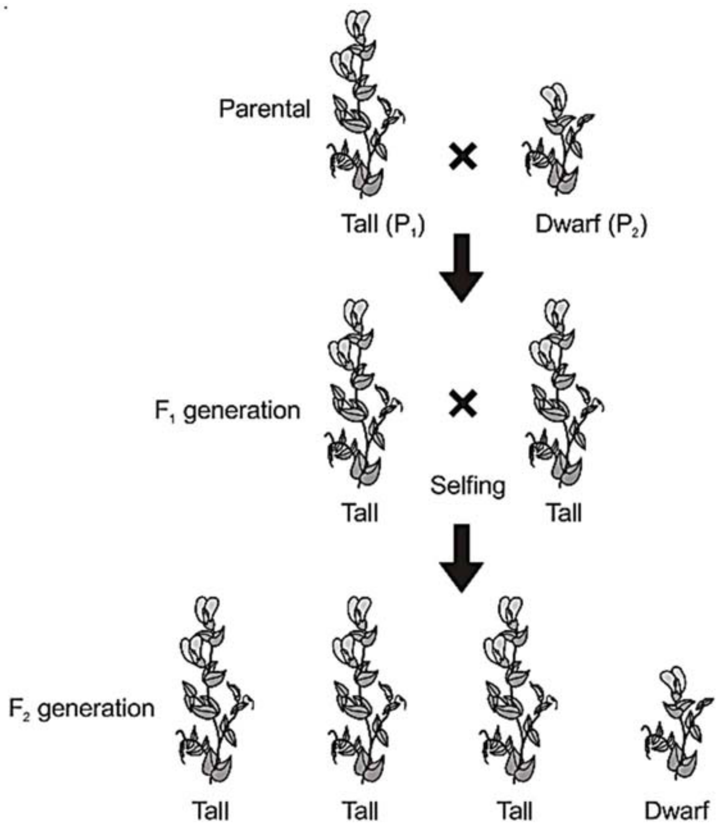


Fig. : Diagrammatic representation of monohybrid cross

Mendel did similar experiments with other pairs of different traits and looked at the second generation (F_2). In the F_2 generation, both traits were present, but in a specific ratio of 3:1.

Now, let's talk about the idea of "factors." Mendel thought that something was consistently passing from parent to child through the gametes and staying the same across many generations. He called these things "factors." Nowadays, we call them "genes." So, a gene is like a tiny unit that carries information from one generation to the next, determining how a particular trait shows up in an organism. Chemically, a gene is a part of DNA that does a specific job, often involving making proteins.

Genes that code for different versions of the same trait are called alleles. It means they are like slightly different forms of the same gene. So, the word "gene" can be used for any factor, but "allele" is used when talking about one version compared to another. We use letters to represent genes. Capital letters stand for the trait expressed in the first generation (F_1), and lowercase letters stand for the other trait. For example, if we use 'T' for 'tall' and 't' for 'dwarf,' then 'T' and 't' are alleles of each other. In plants (which are diploid), the pair of alleles for height could be TT, Tt, or tt.

It's important not to use different letters for the same trait, like 'T' for tall and 'd' for dwarf. That could be confusing when trying to figure out if 'T' and 'd' are alleles of the same character.

Note:

1. 1.Term 'gene' was given by Johannsen while term 'allele' by Bateson,
2. Alleles are the abbreviated form of the term "allelomorphs".

Homozygous and Heterozygous

Mendel suggested that in pea plants with a consistent tall or dwarf trait, the gene pairs for height are either both the same (TT or tt). This was named "homozygous" by Bateson and Saunders. If an individual has two different alleles (Tt), it is called a hybrid, and Bateson and Saunders called this "heterozygous."

Genotype and Phenotype

Genotype is like a genetic recipe for an individual, showing what alleles they have for one or more traits, such as TT, Tt, or tt. On the other hand, phenotype is how someone actually looks, like being tall or dwarf. The combination of alleles determines the phenotype, creating different appearances.

Dominant and Recessive

From studying the first generation (F_1), Mendel figured out that when there are different factors in an individual, only one shows up, and the other doesn't. The one that shows up is called the dominant factor, while the one that doesn't is the recessive factor. In simpler terms, a dominant allele influences how something looks, even if there's another different allele, but a recessive allele only affects appearance when there's another identical allele.

Concept of Segregation

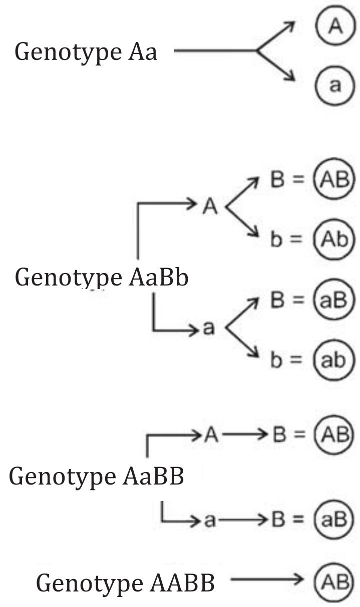
Let's understand the idea of segregation. When we look at the F_2 generation and see that the recessive trait (like dwarfness, tt) shows up without blending, it suggests something interesting. When tall and dwarf plants make reproductive cells (gametes) through a process called meiosis, the gene pairs from the parents separate. Only one gene gets passed on to a gamete.

So, during meiosis, the number of chromosomes gets halved, and a gamete ends up with only one chromosome of each type, carrying just one gene for a trait. This separation of genes is a random process, making it a 50-50 chance for a gamete to have either gene. For instance, the gametes of tall plants with TT have the T gene, and those from dwarf plants with tt have the t gene.

Now, when these gametes come together during fertilization, one gene from the pollen (carrying T) joins with one gene from the egg (carrying t), forming a zygote with both T and t genes. This makes a hybrid or heterozygous plant with a mix of genes (2n). So, segregation during meiosis plays a crucial role in creating this mix of traits in the offspring.

Note

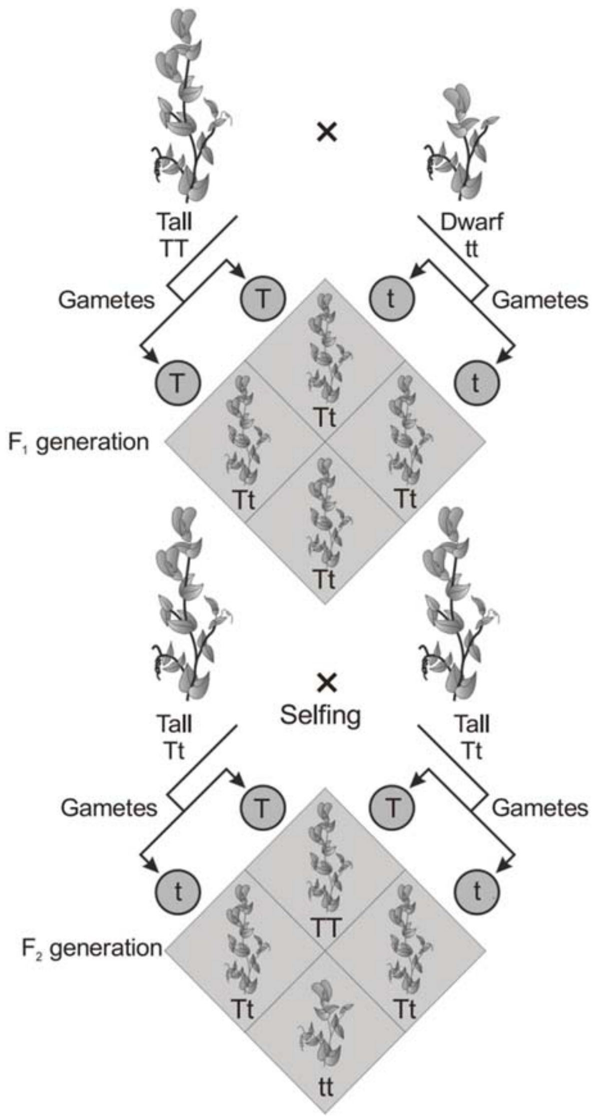
1. Type of gametes produced by a diploid individual can be calculated by using formula, 2^n, here 'n' represents the number of heterozygotes/hybrid.
2. Forked line method to form different types of gametes from the given genotype of an individual.



Punnett Square

Let's talk about something called a Punnett Square. This is like a special diagram that helps us understand how parents make their reproductive cells (gametes), form babies (zygotes), and create the first (F_1) and second (F_2) generations. The idea of Punnett Square was created by a British scientist named Reginald C. Punnett.

This square is like a picture that shows the chances of different traits in the offspring. On one side, we write the possible gametes from the dad (male) in a horizontal row, and on the other side, we write the possible gametes from the mom (female) in a vertical column. When we fill in the boxes below, we can see all the different combinations of traits that could happen. This square helps us figure out the probability of different traits showing up in the babies. It's like a helpful tool for understanding how characteristics are passed from parents to their kids.



Phenotypic ratio : tall : dwarf
3 : 1
Genotypic ratio : TT : Tt : tt
1 : 2 : 1

Fig.: A Punnett square used to understand a typical monohybrid cross conducted by Mendel between true-breeding tall plants and true-breeding dwarf plants

The special chart we call a Punnett Square helps us see how traits are passed down. In the square above, we have tall dad (TT) and short mom (tt) plants. The square shows what happens when they make reproductive cells (gametes) and create the first generation (F_1) plant with the genotype Tt.
When this F_1 plant, which has both tall and short traits, makes its own reproductive cells, it produces equal amounts of T and t gametes. Now, when these gametes come together during fertilization, there's a 50% chance for T pollen to join with both T and t eggs, and the same goes for t pollen. This randomness leads to zygotes with genotypes TT, Tt, or tt.
The Punnett Square helps us see that 1/4 of the combinations result in TT, 1/2 in Tt, and 1/4 in tt. Because the tall trait dominates over the short one, all the F_1 plants are tall (even though they have both tall and short genes). In the second generation (F_2), 3/4 of the plants are tall (even though

genetically 1/2 are Tt and 1/4 are TT). So, the visible traits show a ratio of 3 tall to 1 short, but the genetic makeup is in a ratio of 1 : 2 : 1.

In mathematical terms, this ratio of TT, Tt, tt can be written like the expression $(ax + by)^2$, where the genes T and t appear equally often.

The expression is expanded as given below:

$$(\frac{1}{2}T + \frac{1}{2}t)^2 = (\frac{1}{2}T + \frac{1}{2}t) \times (\frac{1}{2}T + \frac{1}{2}t) = \frac{1}{2}TT + \frac{1}{2}Tt + \frac{1}{2}tt$$

Mendel self-pollinated the F_2 plants and found that dwarf F, plants continued to generate dwarf plants in F_3 and F_1 generations. He concluded that the genotype of the dwarfs was homozygous le., tt.

Test Cross

From what we've discussed earlier, figuring out the genetic makeup (genotype) just by looking at how a trait looks (phenotype) isn't always possible. Even though we can use math to calculate the chances, like whether a tall plant has TT or Tt genes, it's not something we can just tell by looking at it.

To solve this mystery, Mendel came up with something called a test cross. Imagine we have a tall plant, and we want to know if it's TT or Tt. Mendel crossed this tall plant with a short (dwarf) plant. This special cross is called a test cross. Normally, we'd expect the tall plant to self-pollinate, but in a test cross, it partners up with the short one.

Here's an example: Let's say we have a purple-flowered pea plant (the one we're testing), and we're not sure if it's PP or Pp. To find out, we cross it with a white-flowered pea plant instead of letting it self-pollinate.

By looking at the babies (progenies) from this cross, we can easily figure out the genetic makeup of the plant we're testing. This way, we can solve the mystery of whether it's homozygous (PP) or heterozygous (Pp). So, a test cross is like a genetic detective tool Mendel used to uncover the hidden genetic code in plants.

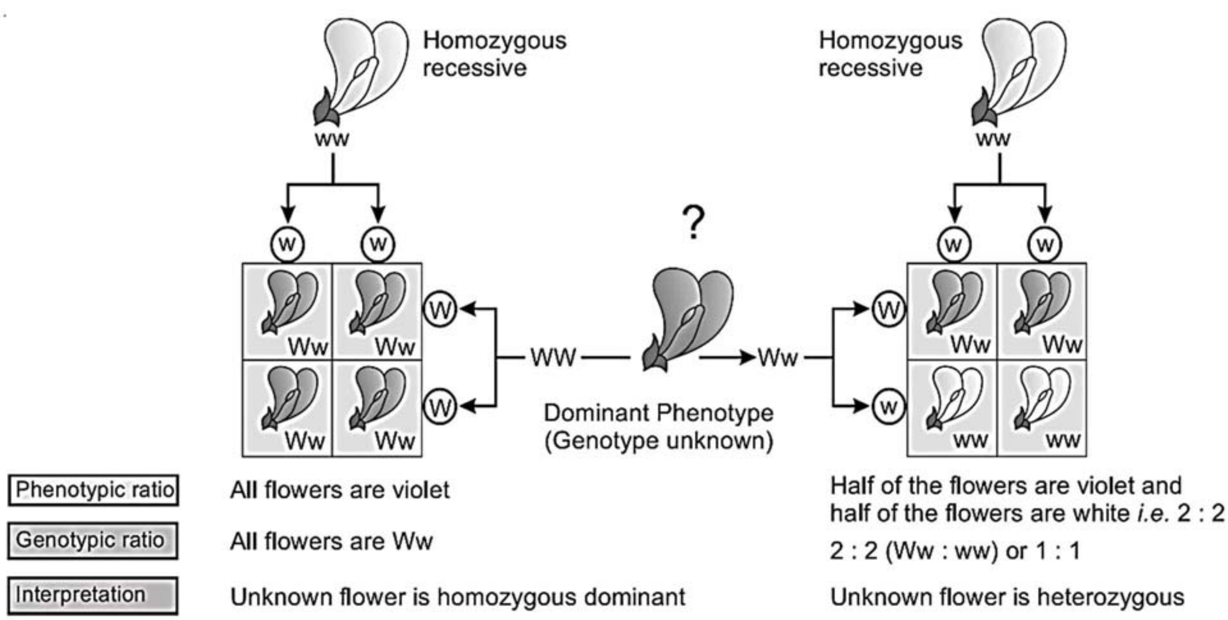


Fig.: Results of monohybrid cross in the plant Snapdragon

Mendel's Laws of Inheritance

Mendel, after studying how traits pass down, came up with two important rules known as the Laws of Inheritance.

Law of Dominance

Mendel worked with pea plants and figured out a few things:

- Traits are controlled by tiny units called factors.
- These factors come in pairs.
- When there's a pair with different traits (like Tt), only one shows its effect, and it's called the dominant factor. The other one, not showing an effect, is the recessive factor.

This law helps us understand why, in the first generation (F_1) after a cross, we see only one parent's trait, and in the second generation (F_2), we see both traits. It also explains the 3:1 ratio of traits in the second generation, but remember, this law doesn't work for every situation.

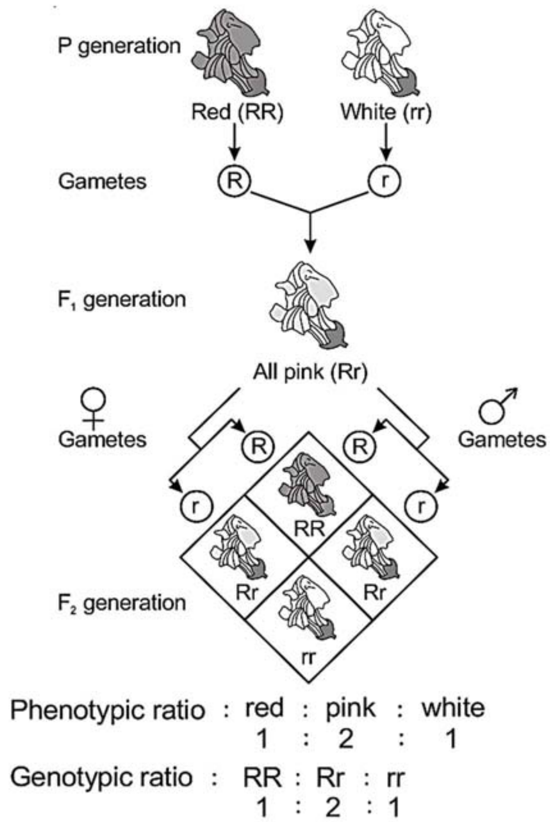
Law of Segregation

This rule is built on the notion that when it comes to a person's traits, the two factors involved don't blend together. Although both traits exist, only one is noticeable in the first generation (F_1). When the reproductive cells (gametes) are being formed, these factors split up, making sure each gamete has only one factor. This ensures that the gametes remain pure. If a parent has two identical factors (homozygous), all the gametes will be identical. On the other hand, if there are different factors (heterozygous), two kinds of gametes are produced, each carrying one factor.

Exceptions to Mendelian Principles:

1. **Incomplete Dominance:**

   After Mendel's discoveries, exceptions were found. In some cases, the offspring's appearance in the first generation (F_1) is a mix between the dominant and recessive traits, not looking exactly like either parent. This is called incomplete dominance. An example is seen in Snapdragon flowers. When a pure red-flowered plant (RR) is crossed with a pure white-flowered plant (rr), the F_1 plants (Rr) have pink flowers. Here, one gene is incompletely dominant over the other, resulting in a blend of traits.



If these pink F_1 plants are allowed to self-pollinate, the next generation (F_2) has a mix of red (RR), pink (Rr), and white (rr) flowers in a ratio of 1:2:1. In the case of heterozygous plants (Rr), the effect of one gene is more noticeable than the other, creating a combination of both colors and forming the pink hue.