MENDEL AND MENDELISM

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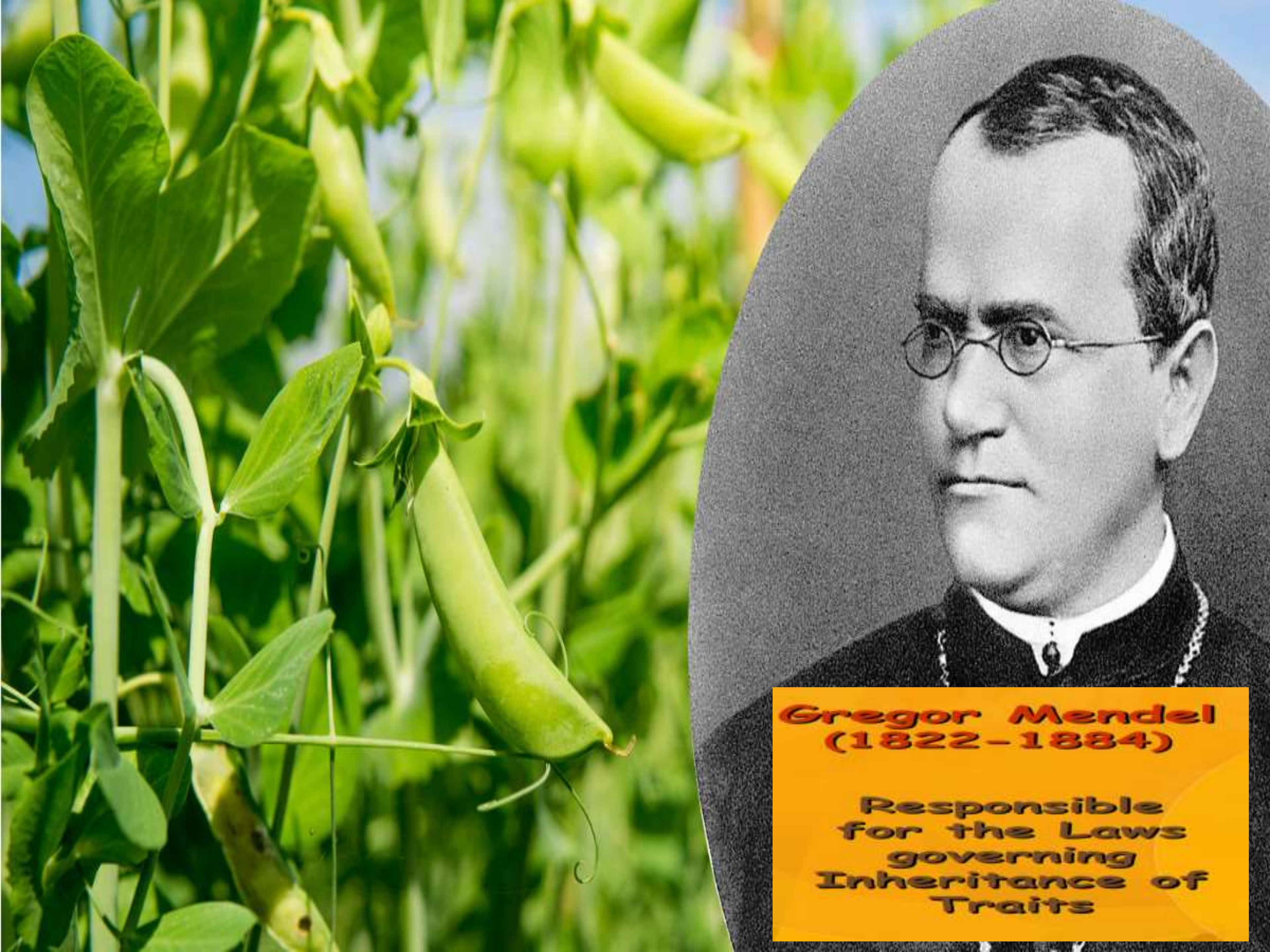
What is heredity?

- The passing on of characteristices from parents to offspring.
- Genetics is the branch of biology that studies heredity
- the characteristics that are inherited are traits.
- Mendel was the first person to success in predicting how traits would be transferred from one generation to the next.

INTRODUCTION

- Mendelism simply put, refers to the laws of inheritance postulated by Gregor Mendel.
- Gregor Mendel was an Austrian Monk who lived between 1822-84.
- He experimented on various plants species and animal
- He was the first to state the universal laws governing inheritance of traits.
- Gregor Mendel is known as father of modern genetics


Gregor Mendel
(1822-1884)
Responsible
for the Laws
governing
Inheritance of
Traits

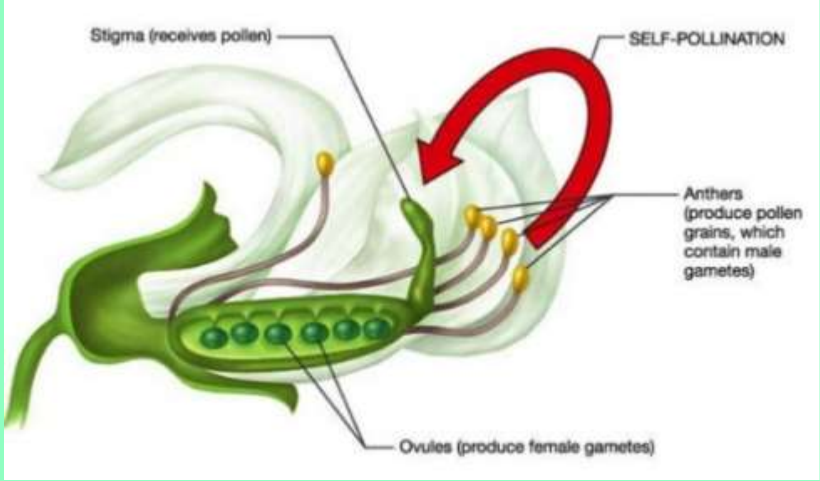
Site of Gregor Mendel's experimental garden in the Czech Republic

- Gregor Mendel experimented with pea plants, by crossing various strains and observing the characteristics of their offspring.
- He also experiment on drosophila, but much success was recorded on pea plants
- Between 1856 and 1863, Mendel cultivated and tested some 28,000 pea plants.
- Mendel stated that physical traits are inherited as “particles”
- Mendel did not know that the “particles” were actually Chromosomes & DNA

- **Genetic Terminology**
- **Trait - any characteristic that can be passed from parent to offspring**
- **Heredity - passing of traits from parent to offspring**
- **Genetics - study of heredity**
- **Types of Genetic Crosses**
- **Monohybrid cross - cross involving a single trait e.g. flower colour**
- **Dihybrid cross - cross involving two traits e.g. flower colour & plant height**

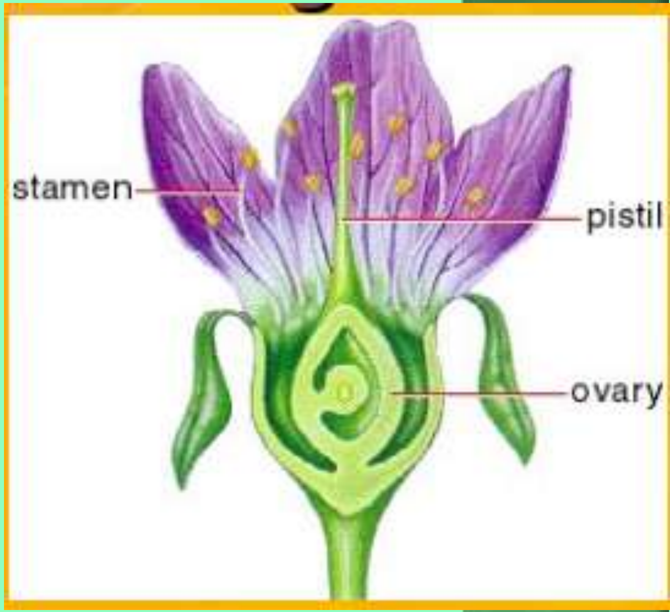
MENDEL'S SELECTION OF MATERIAL

- Garden pea (*Pisum sativum*, Fabaceae)



- The choice of Garden pea (*Pisum sativum*) was due to the following reasons:
- Can be grown in a small area
- Produce lots of offspring
- Produce pure plants when allowed to self pollinate several generations
- Can be artificially cross-pollinated

- One peculiarity of pea reproduction is that the petals of the flower close down tightly, preventing pollen grains from entering or leaving.
- This enforces a system of self fertilization, in which the male and female gametes from the same flower unite with each other to produce seeds.
- As a result, individual pea strains are highly inbred, displaying little if any genetic variation from one generation to the next.
- Because of this uniformity, we say that such strains are true-breeding



MENDEL'S SELECTION OF TRAIT

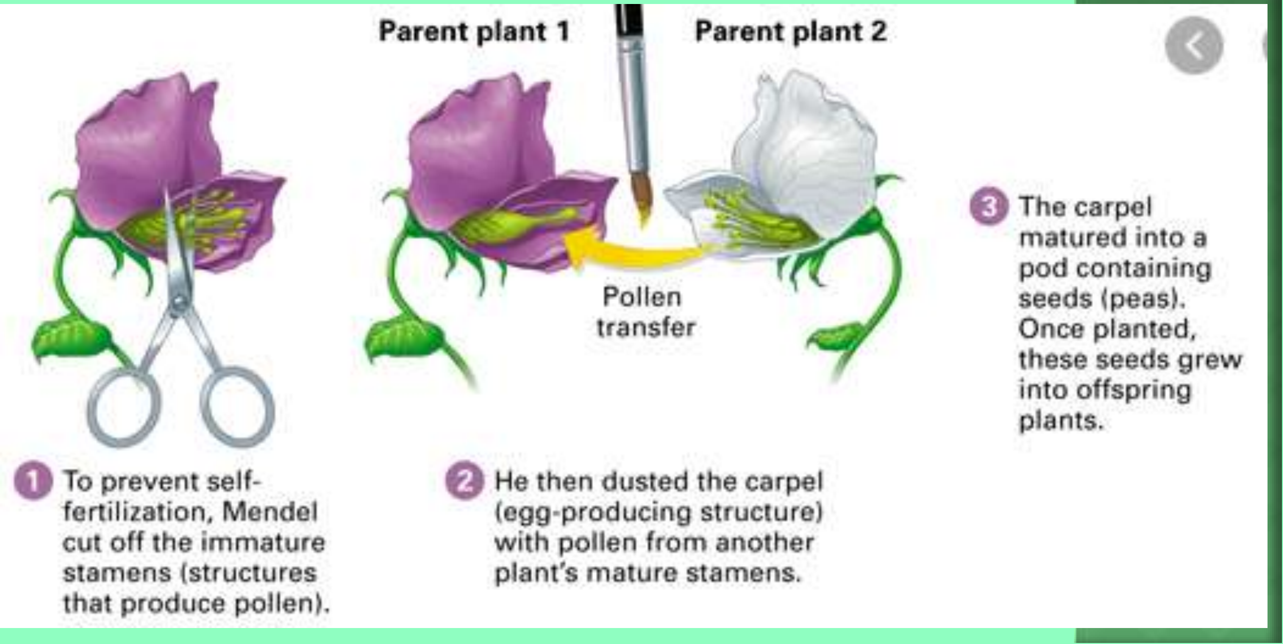
Pea trait	Dominant trait	Recessive trait
Seeds		
Seed shape	Round	Wrinkled
Seed colour	Yellow	Green
Whole plants		
Flower colour	Purple	White
Flower position	Axial	Terminal
Plant height	Tall	Short
Pod shape	Inflated	Constricted
Pod colour	Green	Yellow

REASONS FOR THE SUCCESS OF MENDEL:

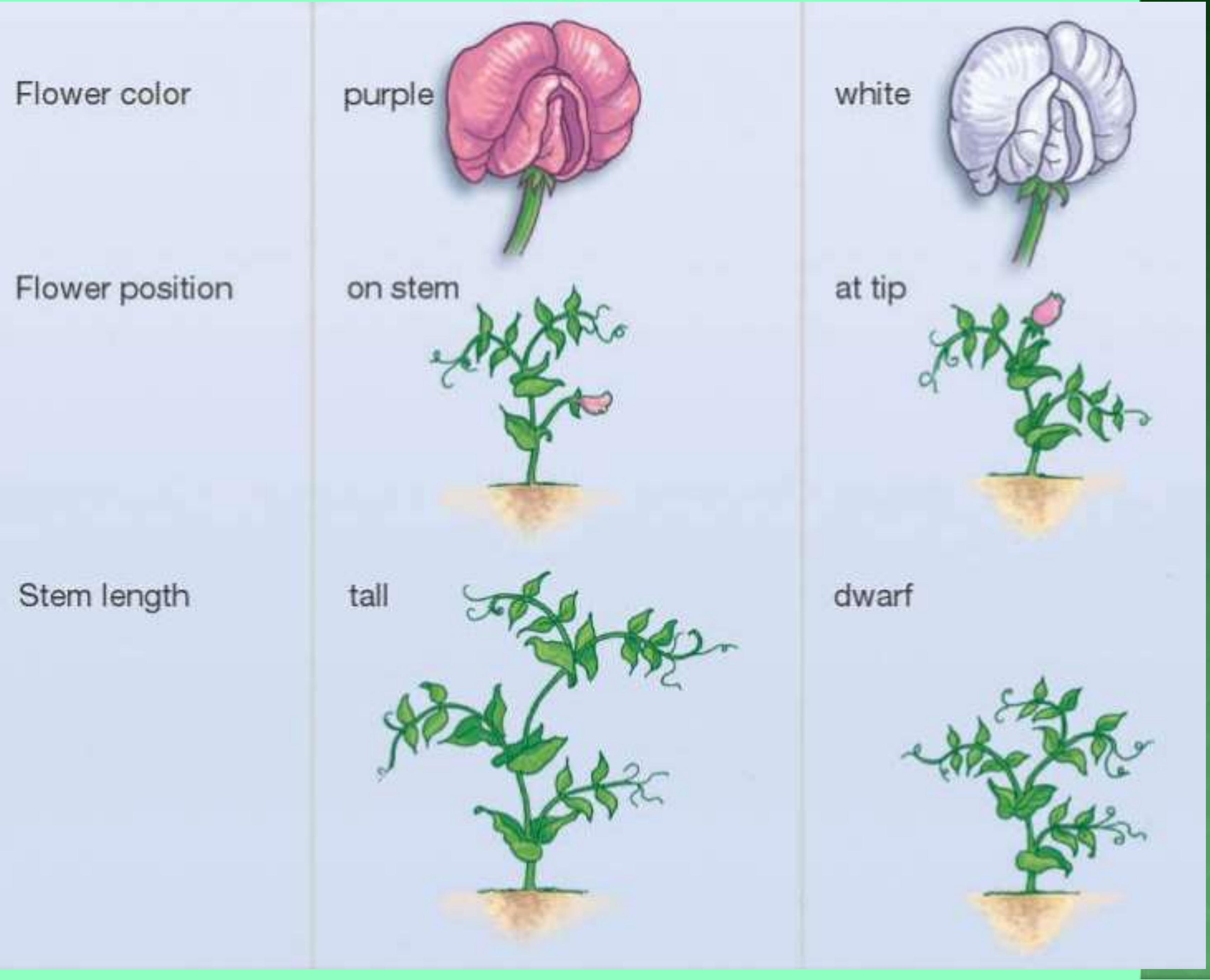
1. Systematic maintenance of correct statistical records
2. Study of only one individual character at a time
3. Ideal choice of material
4. Proper choice of apt characters
5. Absence of interaction between the selected characters
6. Maintenance of genetic purity
7. Mathematical background
8. Knowledge of the shortfalls of earlier workers

MENDEL'S EXPERIMENTS

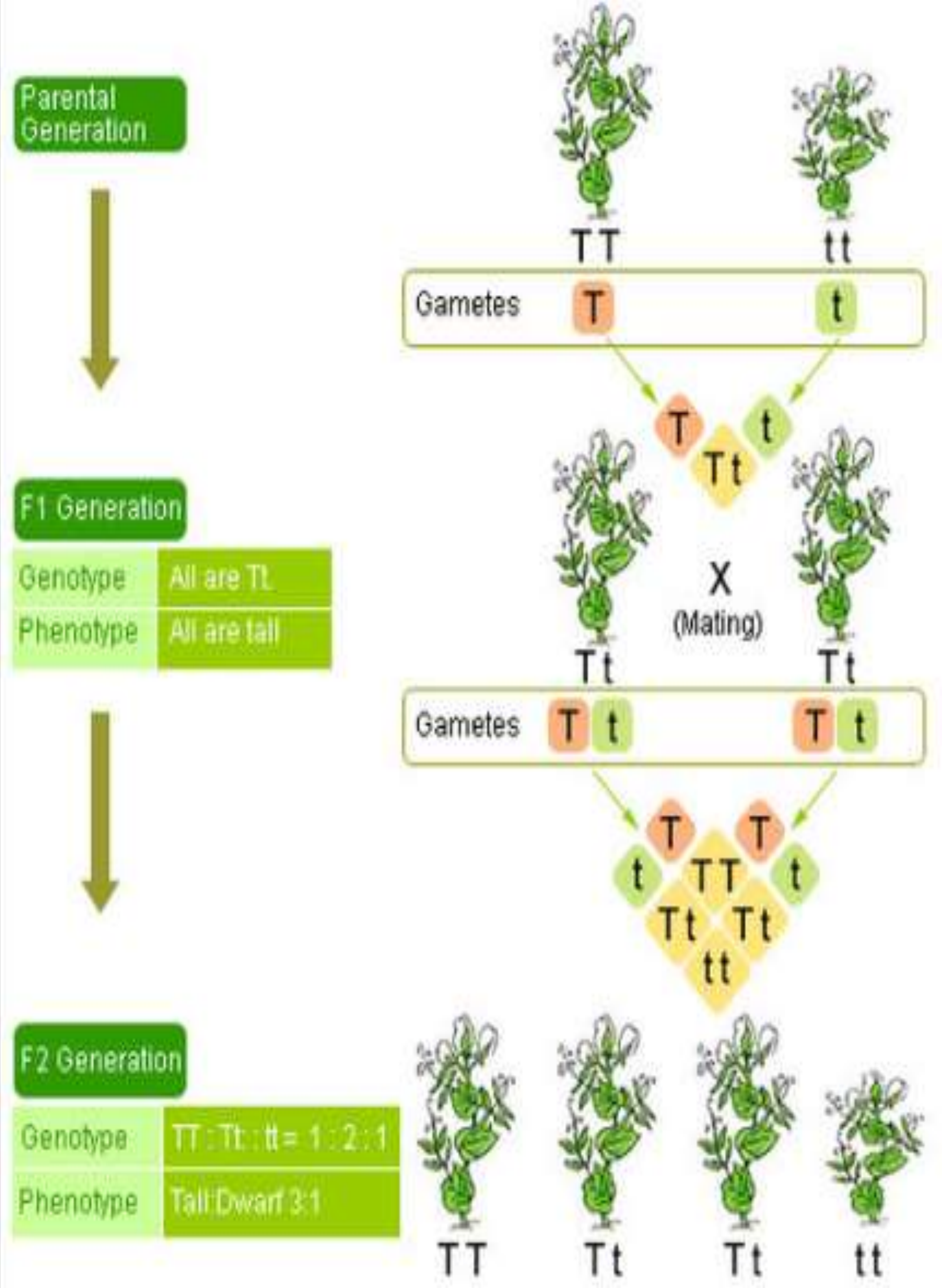
- Mendel produced pure strains by allowing the plants to self pollinate for several generations
- Mendel hand-pollinated flowers using a paintbrush He could snip the stamens to prevent self-pollination. Covered each flower with a cloth bag He traced traits through the several generations



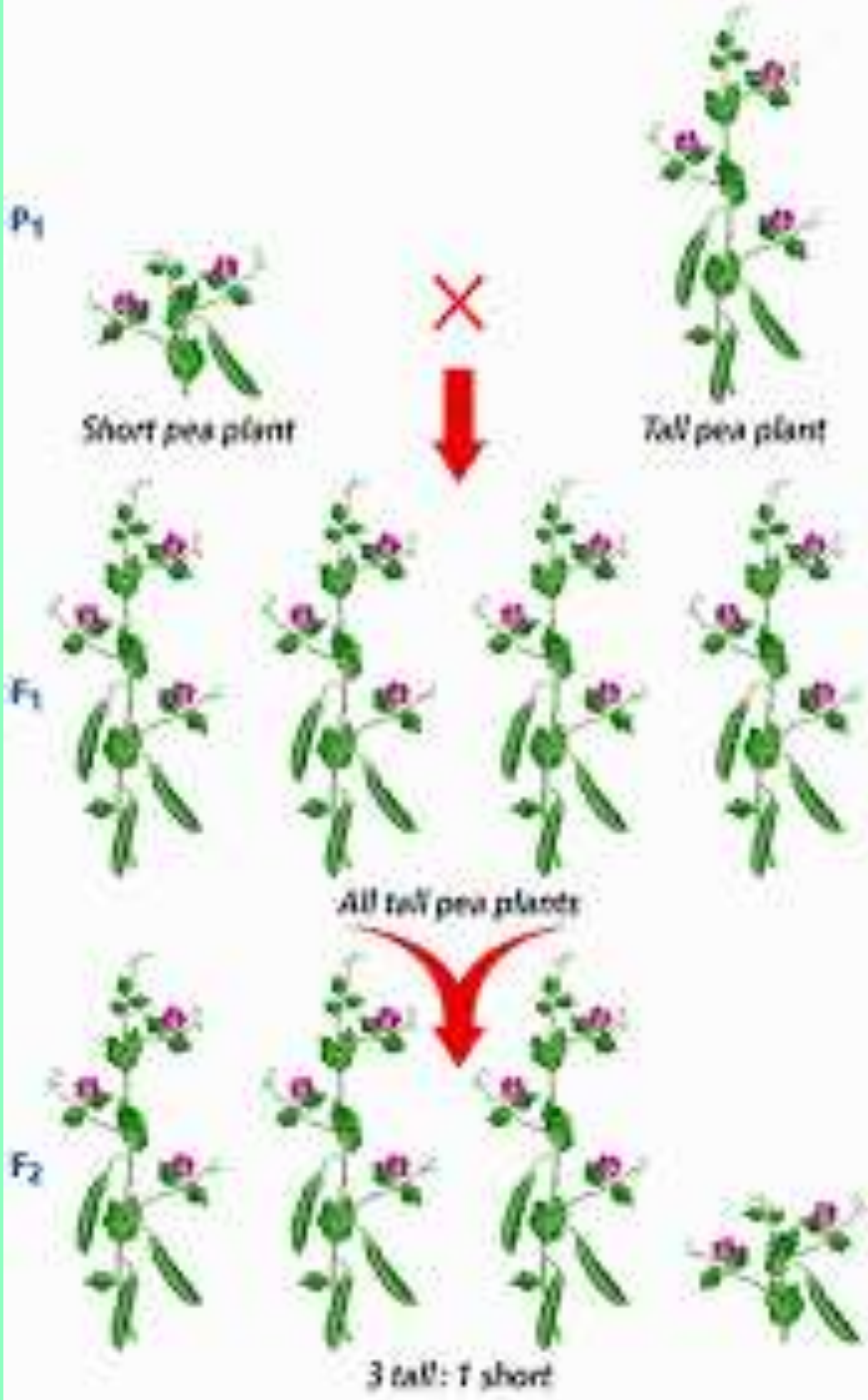
Character studied	Dominant trait	Recessive trait
Seed shape	smooth 	wrinkled 
Seed color	yellow 	green 
Pod shape	inflated 	wrinkled 
Pod color	green 	yellow 


Flower color
purple
white
Flower position
on stem
at tip
Stem length
tall
dwarf

- Parental Generation
- F1 generation -the first-generation offspring in a breeding experiment (1st filial generation)
- From breeding individuals from the F1 generation F2 generation = the second-generation offspring in a breeding experiment. (2nd filial generation)



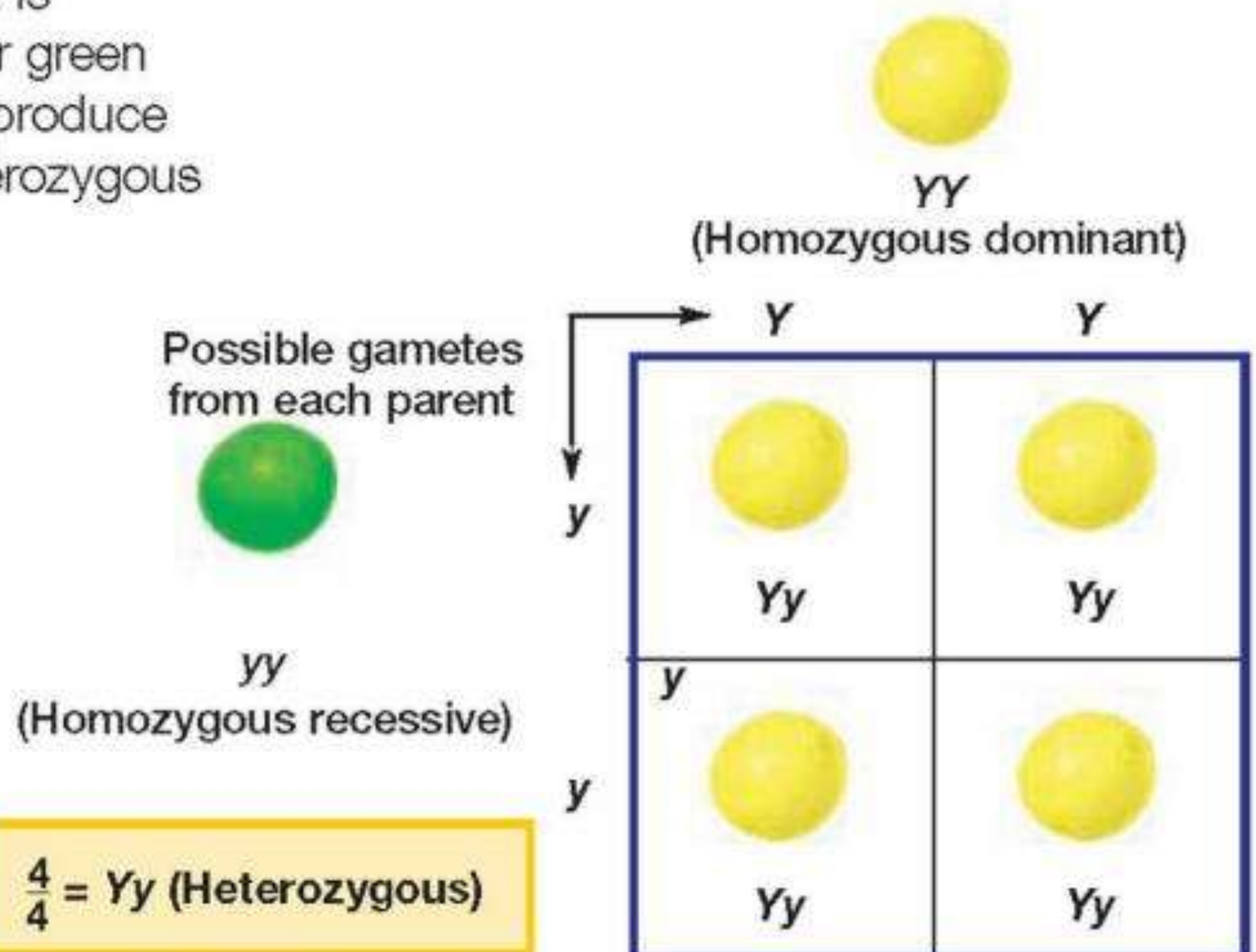
- Mendel focused on the study of inheritance of one trait at a time.
- In an experiment, Mendel crossed tall and dwarf pea plants to investigate how height was inherited.
- This type of crossing between parents differing in only one trait or in which only one trait is being considered is termed **monohybrid cross.**



- All the offspring from the cross (First filial generation- F1) were all tall
- Mendel noted that the dwarf characteristic seemed to have disappeared in the progeny of the cross.
- Mendel decided to cross the F1 generation with each other to see if the dwarf trait would reappear in the next generation.
- When he examined the progeny (F2 generation), he found that they consisted of both tall and dwarf plants in a ratio of approximately **3:1.**
- Mendel inferred that these hybrids carried a latent genetic factor for dwarfness, one that was masked by the expression of another factor for tallness.
- He said that the latent factor was recessive and that the expressed factor was dominant.

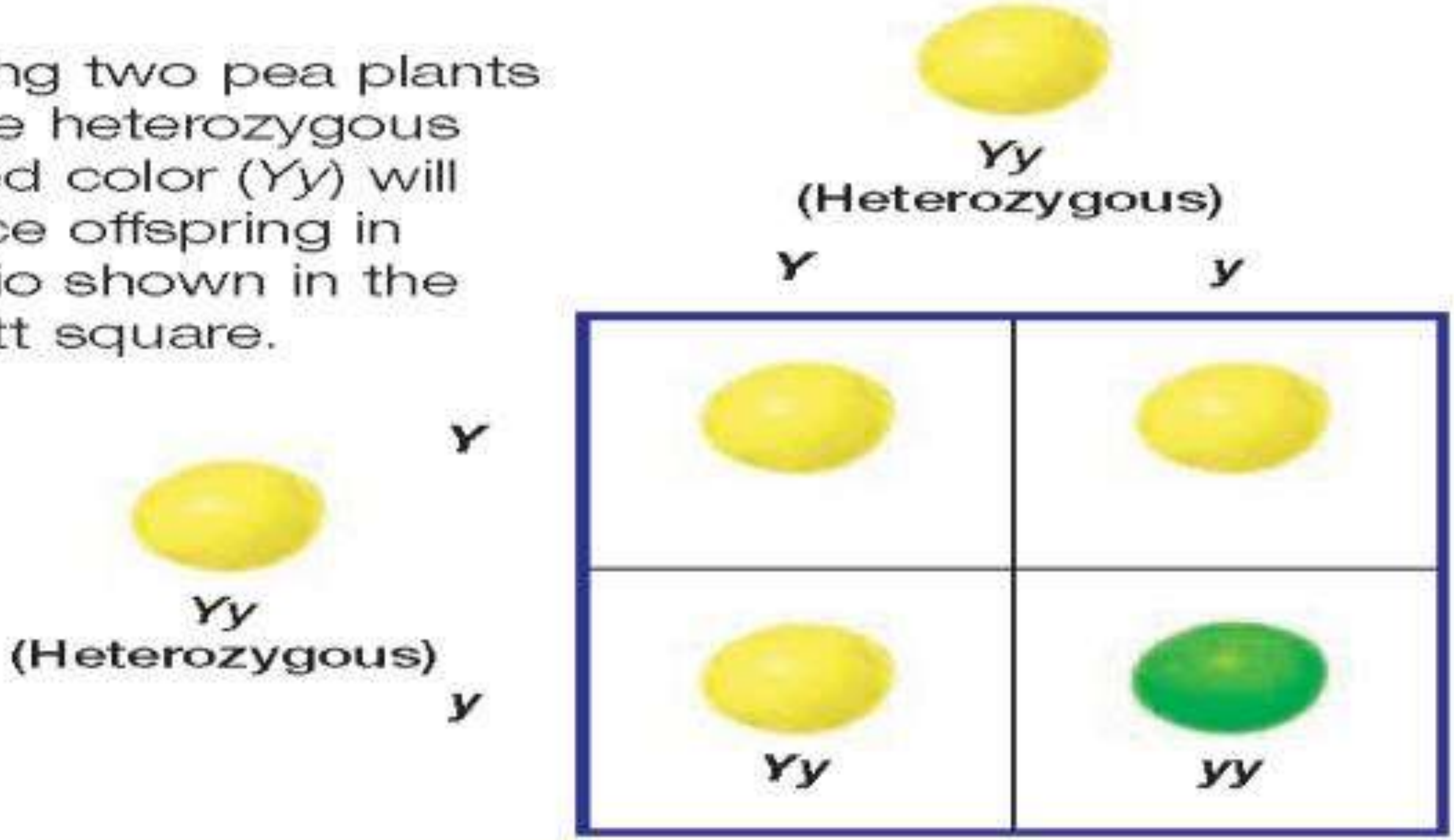
Monohybrid Cross

A cross between a pea plant that is homozygous for yellow seeds (*YY*) and a pea plant that is homozygous for green seeds (*yy*) will produce only yellow heterozygous offspring (*Yy*).



F1 Cross

Crossing two pea plants that are heterozygous for seed color (*Yy*) will produce offspring in the ratio shown in the Punnett square.



$\frac{1}{4}$ = ***YY*** **(Homozygous dominant)**

$\frac{2}{4}$ = ***Yy*** **(Heterozygous)**

$\frac{1}{4}$ = ***yy*** **(Homozygous recessive)**

LET US FAMILIARISE SOME TERMS….

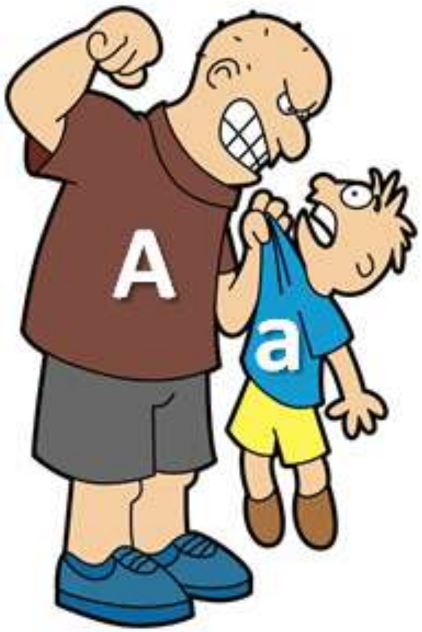
- Parental generation
- F1 Generation
- F2 Generation
- Monohybrid Cross
- Dominant
- Recessive
- Phenotype
- Genotype
- Homozygous
- Heterozygous
- Test Cross
- Back Cross

- Dominant and Recessive:
- When two unlike alleles responsible for a single character are present in a single individual, one allele can mask the expression of another allele.
- That is, one allele is dominant to the other. The latter is said to be recessive.

- have two copies of each gene – one on each chromosome – and these are called alleles. One allele is from your mother and one from your father, and these genes can be slightly different. In some cases, the gene is **dominant**, which means that the variant of the trait that it is responsible for will take over – this would be represented by the dominant character.
- Other genes are considered recessive – or the submissive. Only when the dominant person isn't around does the submissive get to do what it wants.

A = dominant

a = recessive

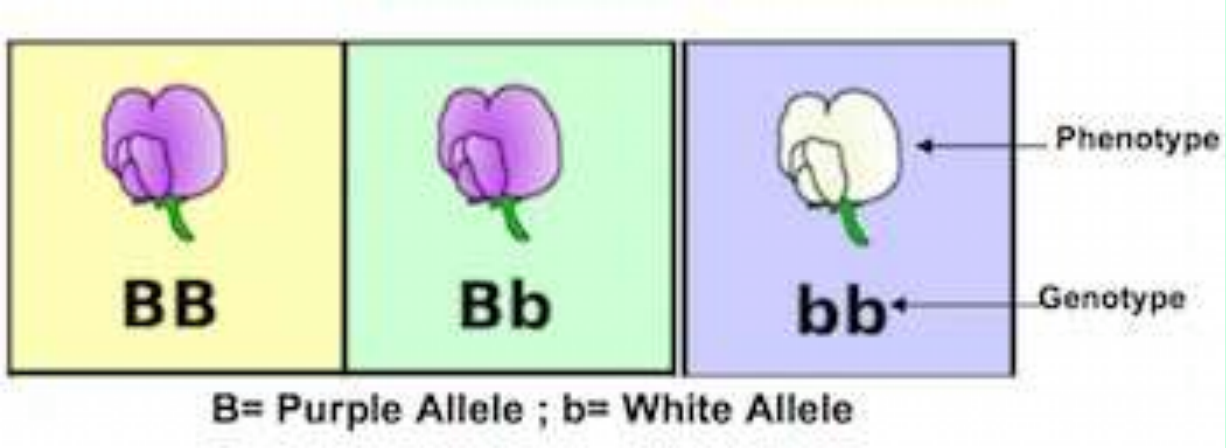


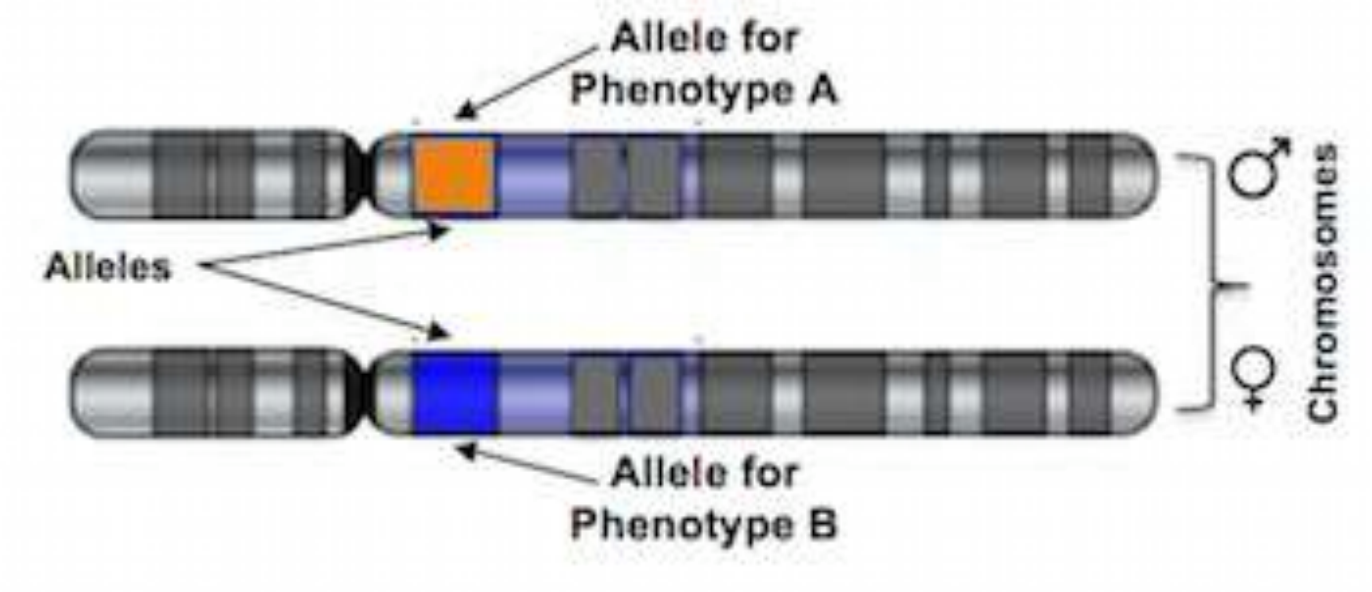
Gene A — brown eyes

Gene a — blue eyes

♂ \ ♀	A	a
A	AA	Aa
a	Aa	aa

- The term, **genotype**, refers to the genetic expression of a particular trait. Not to be confused with **phenotype**, which refers to the physical manifestation of the trait

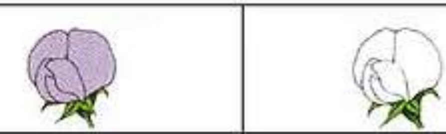




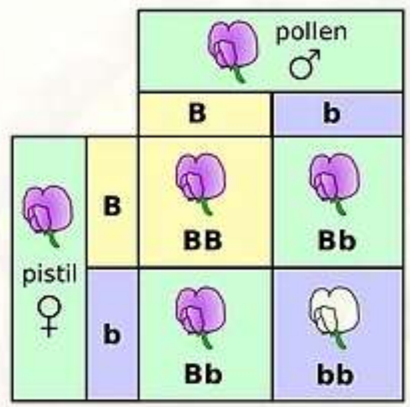
Genotypes and Phenotypes

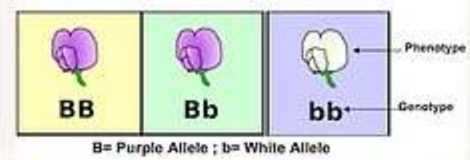
A **Genotype** is " the genetic construction of an individual" (Merriam-Webster). On the other hand, **Phenotypes** are the "observable properties of an organism that are produced by the interaction of the genotype and the environment" (Merriam-Webster).

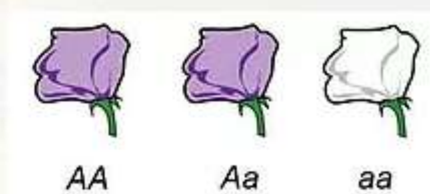
Genotype and Phenotype



Phenotype:	purple flower	white flower
Genotype: (partial)	AA or Aa	aa







- if you have two dominant alleles, known as **homozygous dominant**, each coding for purple flowers (BB) than the phenotype would be purple. Conversely, if you have two recessive alleles, known as **homozygous recessive**, each coding for white flowers (bb) than the phenotype would be white. But, if you have one dominant and one recessive allele, known as **heterozygous** (Bb), than the phenotype would express the dominant trait, which, in this case, is purple. Now, with that being said, you can see that by looking at the genotype you can always determine the phenotype; however, due to the heterozygote, you cannot accurately determine the genotype from merely looking at the phenotype.

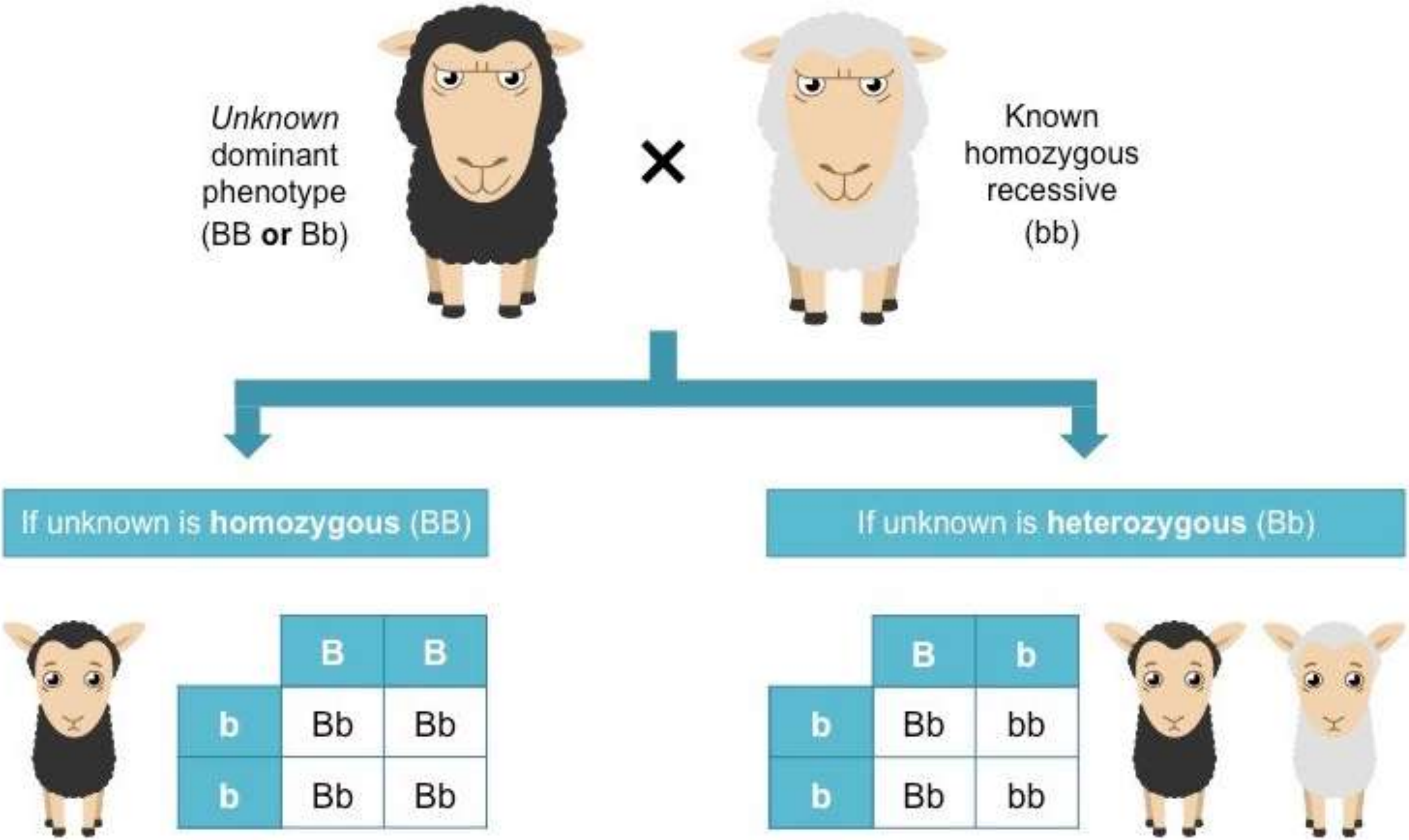
- Mendel noticed two different expressions of a trait – Example: Tall and dwarf.
- Traits are expressed in different ways due to the fact that a gene can exist in alternate forms (versions) for the same trait is called **alleles.**
- If an individual has two identical alleles of a gene, it is called as **homozygous(TT)**.
- An individual with two different alleles is called **heterozygous (Tt)**.
- Mendels non-true breeding plants are heterozygous, called as **hybrids**.

- When the gene has two alleles the dominant allele is symbolized with capital letter and the recessive with small letter. When both alleles are recessive the individual is called **homozygous recessive** (tt) dwarf pea plants. An individual with two dominant alleles is called **homozygous dominant** (TT) tall pea plants. One dominant allele and one recessive allele (Tt) denotes non-true breeding tall pea plants **heterozygous tall.**

Types of genetic crosses

- Reciprocal
  - Sex of parents with a specific trait is switched
- Test
  - Cross of unknown dominant with recessive
- Back
  - Cross of individual with a parent

WHY TEST CROSS ?

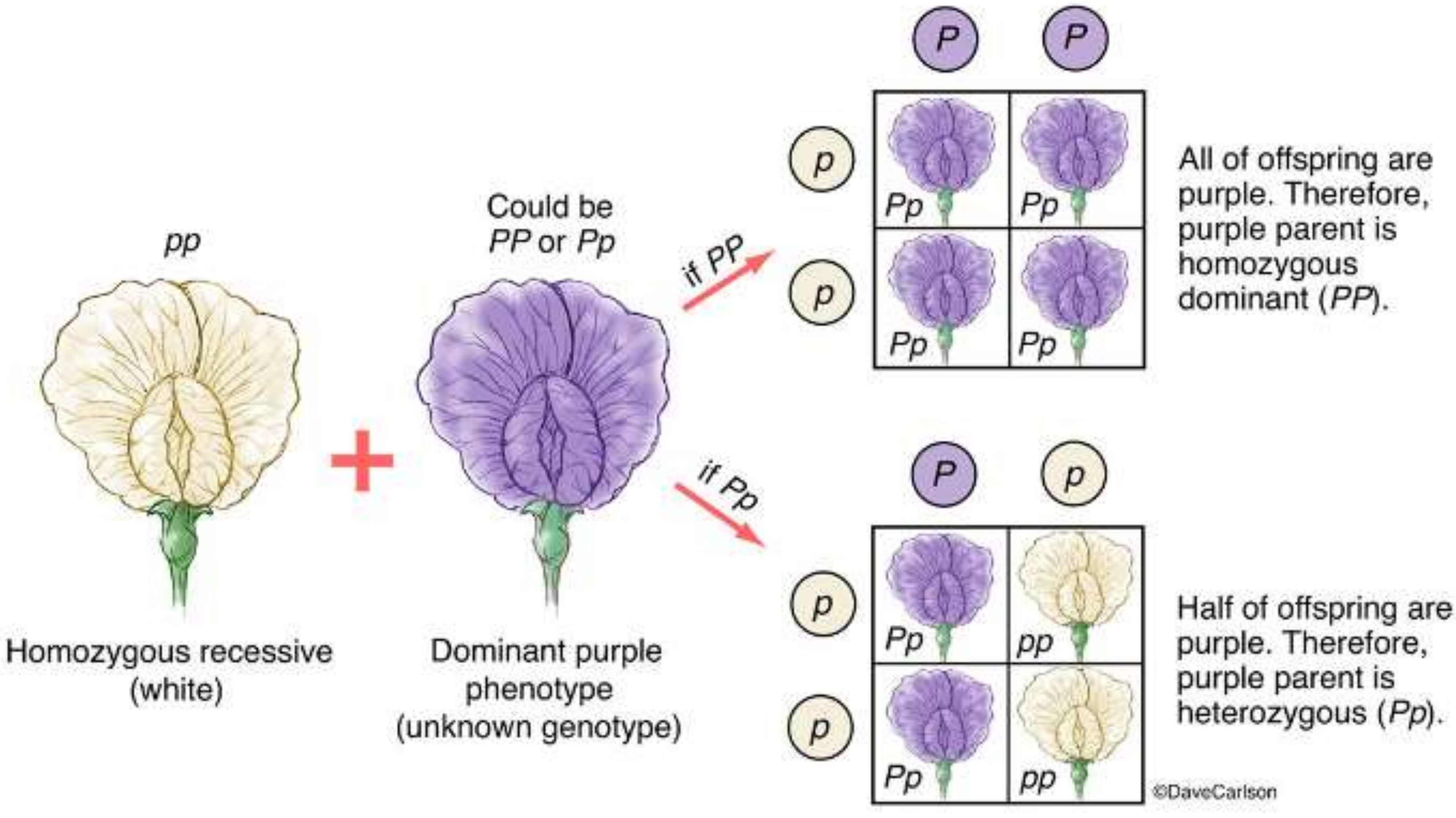


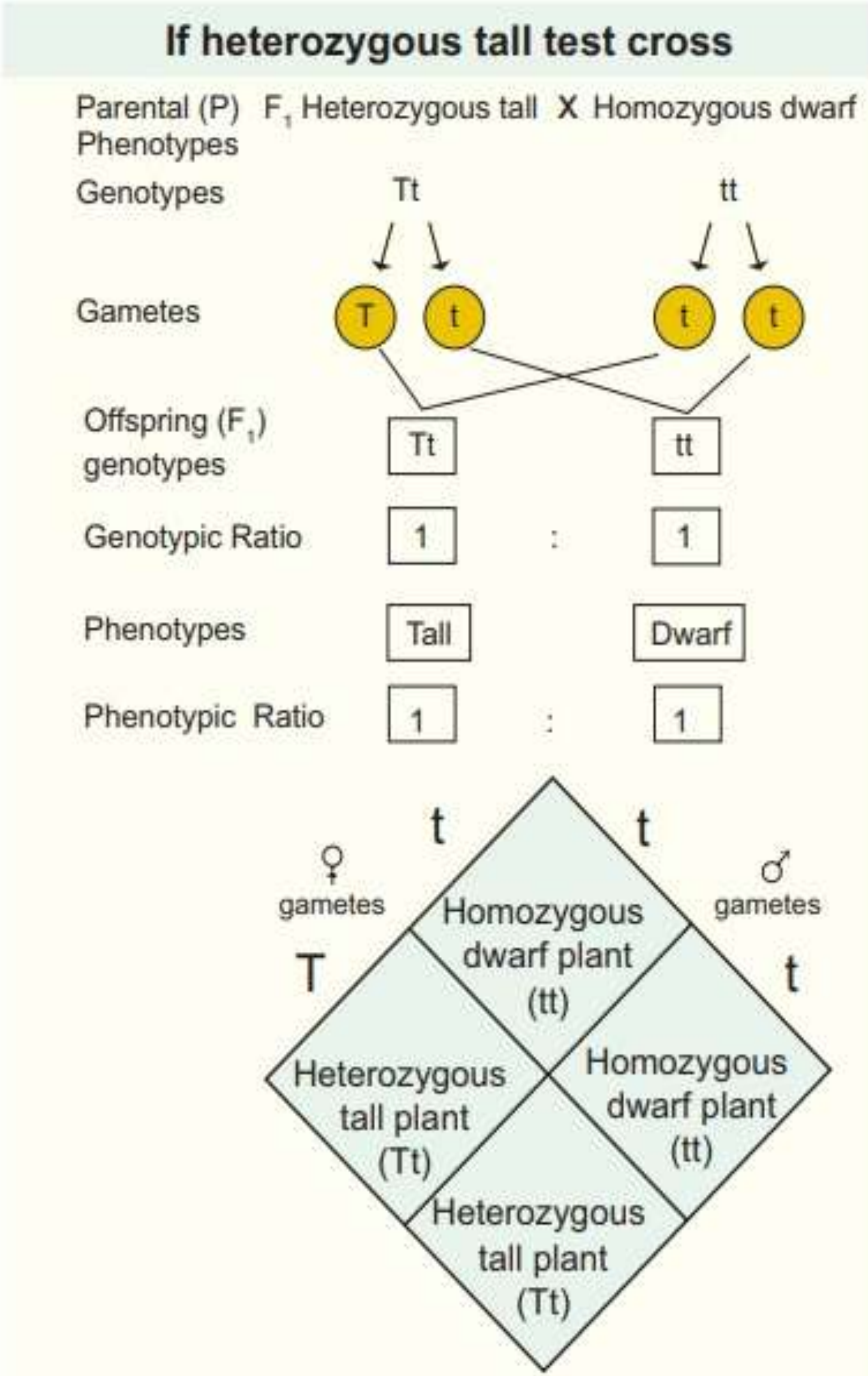
	B	B
b	Bb	Bb
b	Bb	Bb

Phenotypic Ratio: 100% Black

	B	b
b	Bb	bb
b	Bb	bb

Phenotypic Ratio: 50% Black ; 50% White


pp
Could be
PP or Pp
if PP
if Pp
P
P
p
p
Pp
Pp
Pp
Pp
All of offspring are purple. Therefore, purple parent is homozygous dominant (PP).
P
p
p
p
Pp
pp
Pp
pp
Half of offspring are purple. Therefore, purple parent is heterozygous (Pp).
Homozygous recessive (white)
Dominant purple phenotype (unknown genotype)
©DaveCarlson



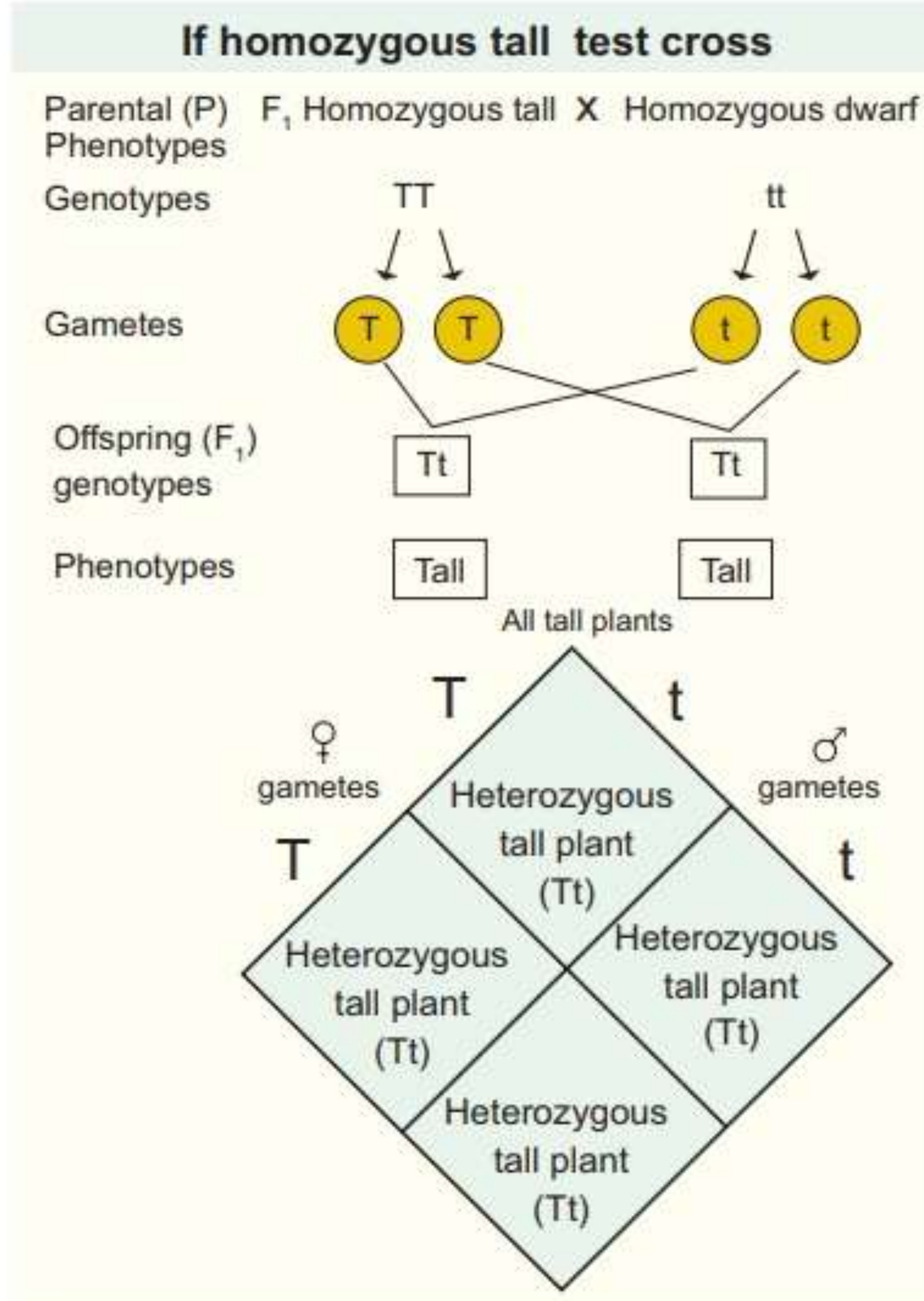
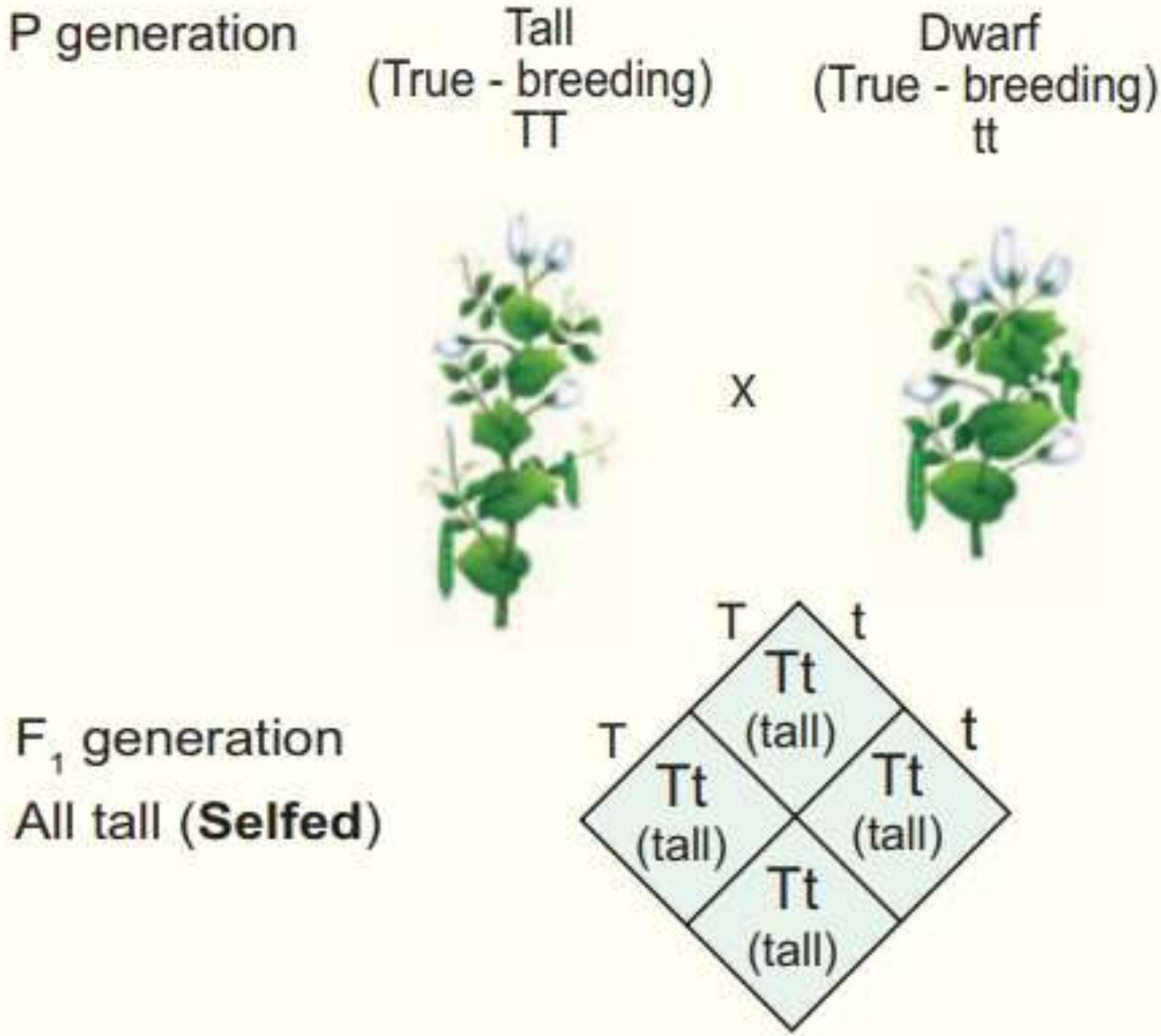


Figure 2.7: Test cross

BACK CROSS

- Crossing of F1 with one of its parents or with an individual genetically identical to one of the parents.
- Dominant back cross
- Recessive backcross

- **Reciprocal cross** – In one experiment, the tall pea plants were pollinated with the pollens from a true-breeding dwarf plants, the result was all tall plants. When the parental types were reversed, the pollen from a tall plant was used to pollinate a dwarf pea plant which gave only tall plants. The result was the same - All tall plants.
- Tall x Dwarf and Tall x Dwarf matings are done in both ways which are called reciprocal crosses.


P generation
Tall
(True - breeding)
TT
Dwarf
(True - breeding)
tt
X
F1 generation
All tall (Selfed)
T
t
T
t
Tt (tall)
Tt (tall)
Tt (tall)
Tt (tall)

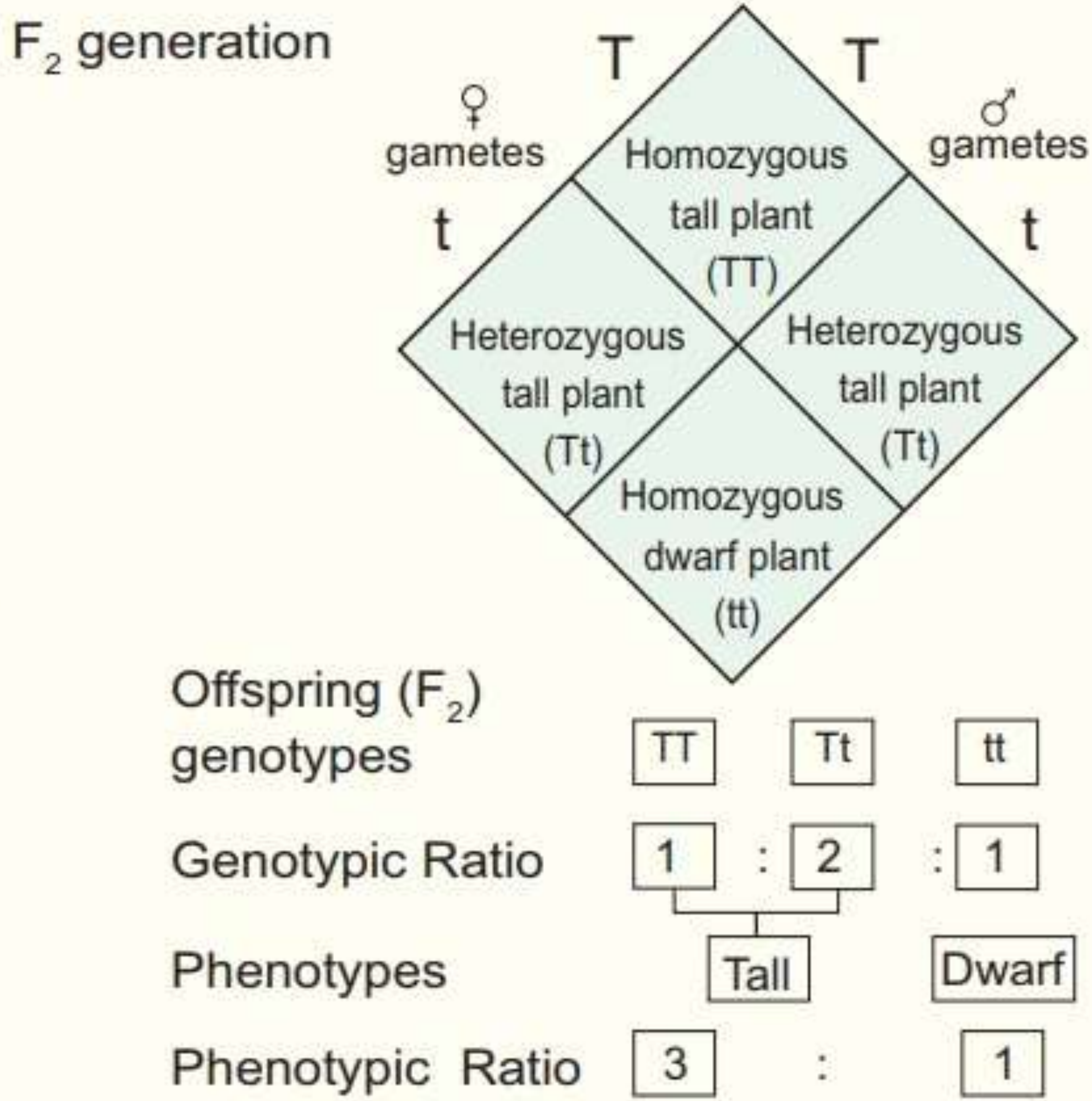
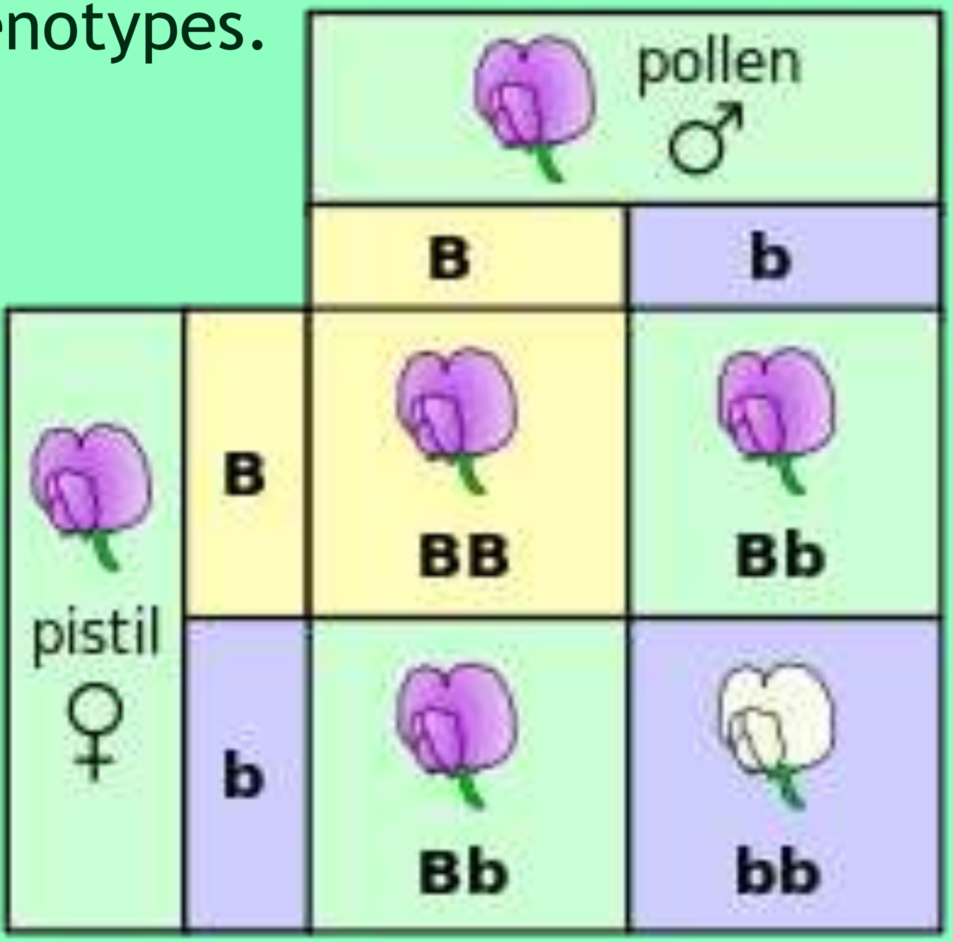


Figure 2.6: Monohybrid Cross

- How do scientists figure out what possible genotypes can arise from two crossbred parents? Well, they use something called a Punnett square. A **Punnett square** is a tool for determining the genotype, and therefore phenotype, possibilities from two parental genotypes.



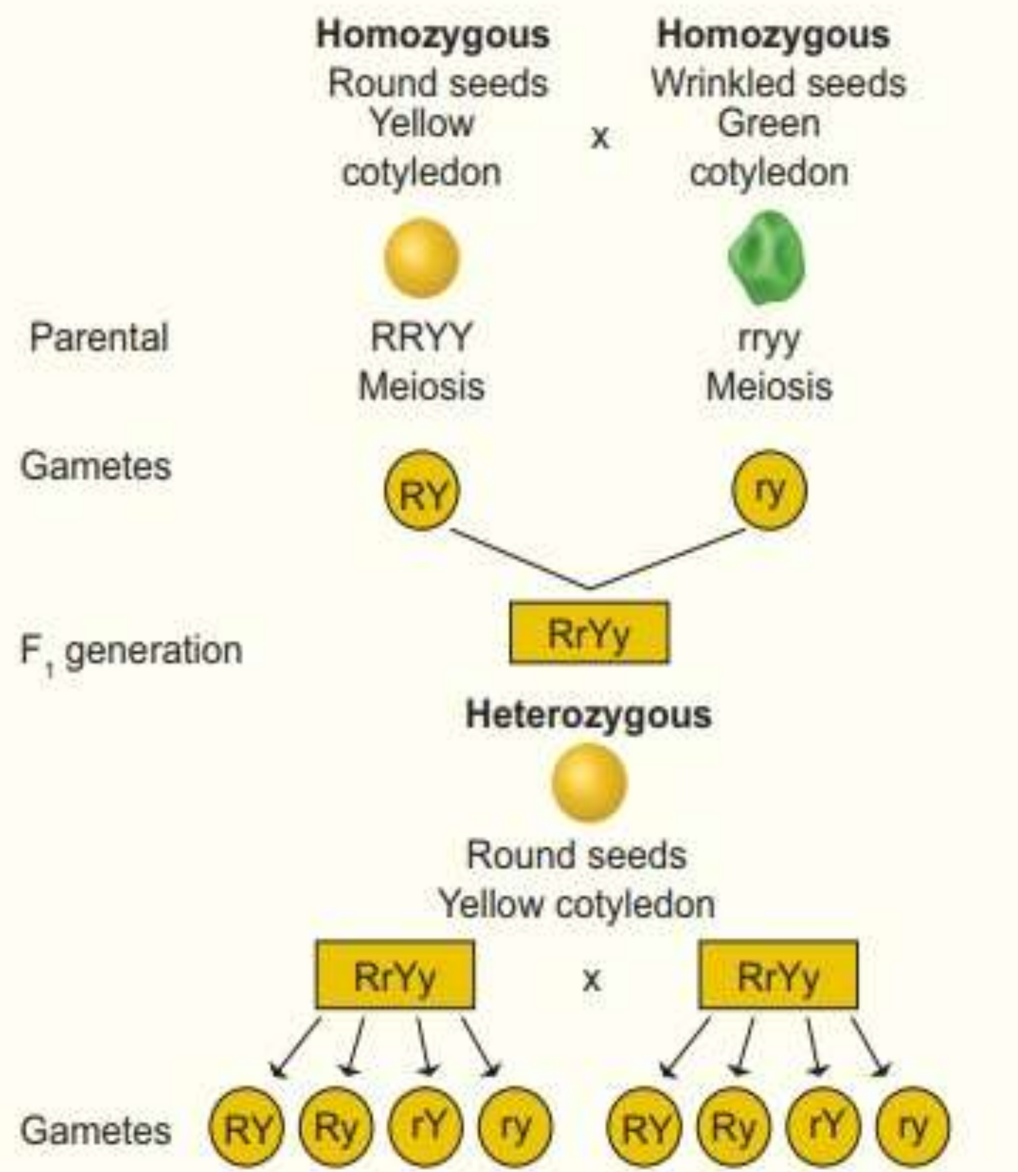
- **Mendelian inheritance - Mendel’s Laws of Heredity:**
- Mendel proposed two rules based on his observations on monohybrid cross, today these rules are called laws of inheritance The first law is The Law of Dominance and the second law is The Law of Segregation. These scientific laws play an important role in the history of evolution.

- **The Law of Dominance**: The characters are controlled by discrete units called factors which occur in pairs.
- In a dissimilar pair of factors one member of the pair is dominant and the other is recessive.
- This law gives an explanation to the monohybrid cross (a) the expression of only one of the parental characters in F_1 generation and (b) the expression of both in the F_2 generation.
- It also explains the proportion of 3:1 obtained at the F_2

- **The Law of Segregation (Law of Purity of gametes):**
- Alleles do not show any blending, both characters are seen as such in the F_2 generation although one of the characters is not seen in the F_1 generation.
- During the formation of gametes, the factors or alleles of a pair separate and segregate from each other such that each gamete receives only one of the two factors.
- A homozygous parent produces similar gametes and a heterozygous parent produces two kinds of gametes each having one allele with equal proportion.
- **Gametes are never hybrid.**

DIHYBRID CROSS

It is a genetic cross which involves individuals differing in two characters. Dihybrid inheritance is the inheritance of two separate genes each with two alleles



Selfed – Genes are present on separate chromosomes and random assortment takes place. So four different types of gametes in equal proportions are formed. Law of Independent Assortment.

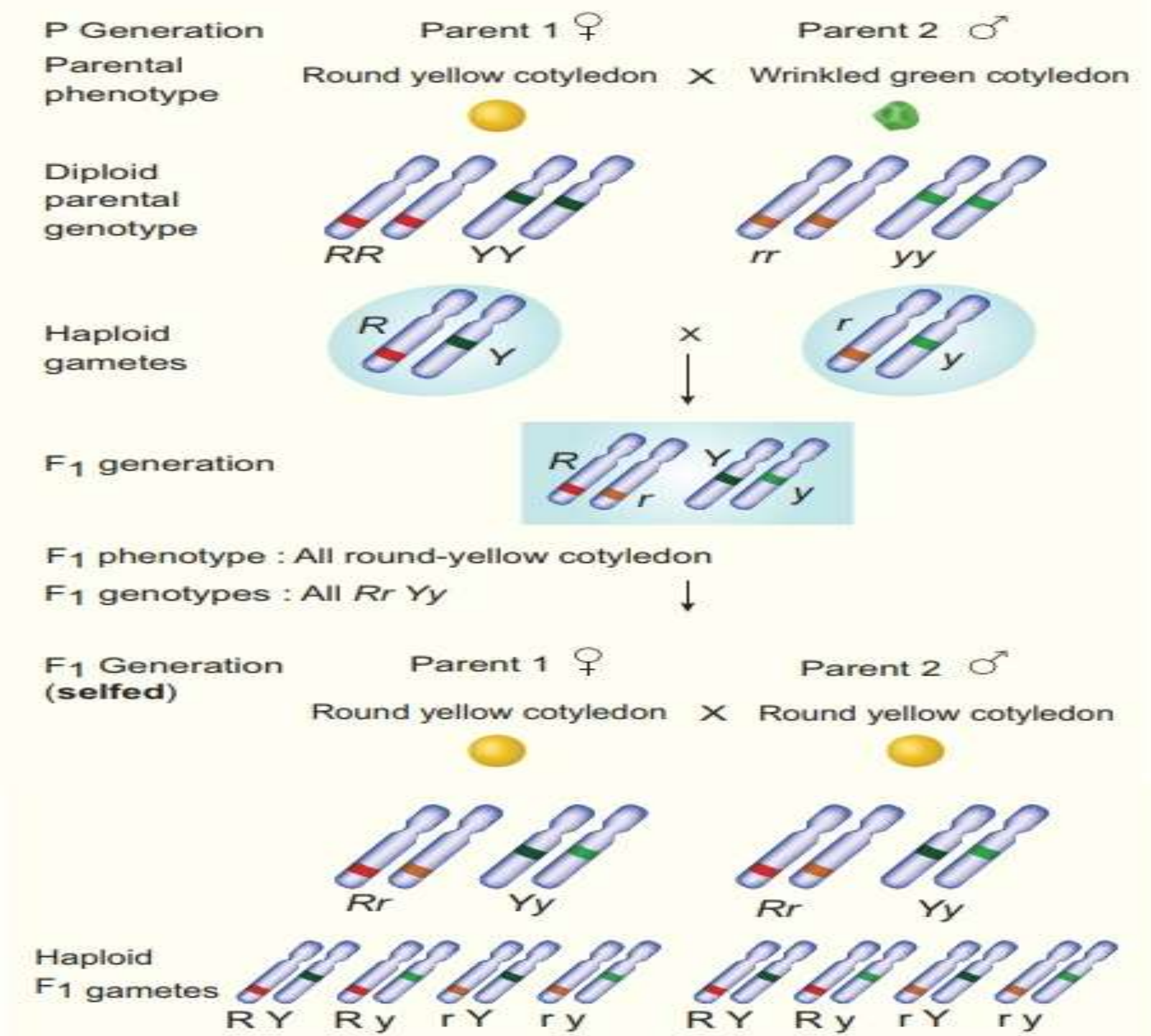
- **Law of Independent Assortment** – When two pairs of traits are combined in a hybrid, segregation of one pair of characters is independent to the other pair of characters. Genes that are located in different chromosomes assort independently during meiosis. Many possible combinations of factors can occur in the gametes.
- Independent assortment leads to genetic diversity. If an individual produces genetically dissimilar gametes it is the consequence of independent assortment. Through independent assortment, the maternal and paternal members of all pairs were distributed to gametes, so all possible chromosomal combinations were produced leading to genetic variation.
- In sexually reproducing plants / organisms, due to independent assortment, genetic variation takes place which is important in the process of evolution. The Law of Segregation is concerned with alleles of one gene but the Law of Independent Assortment deals with the relationship between genes.

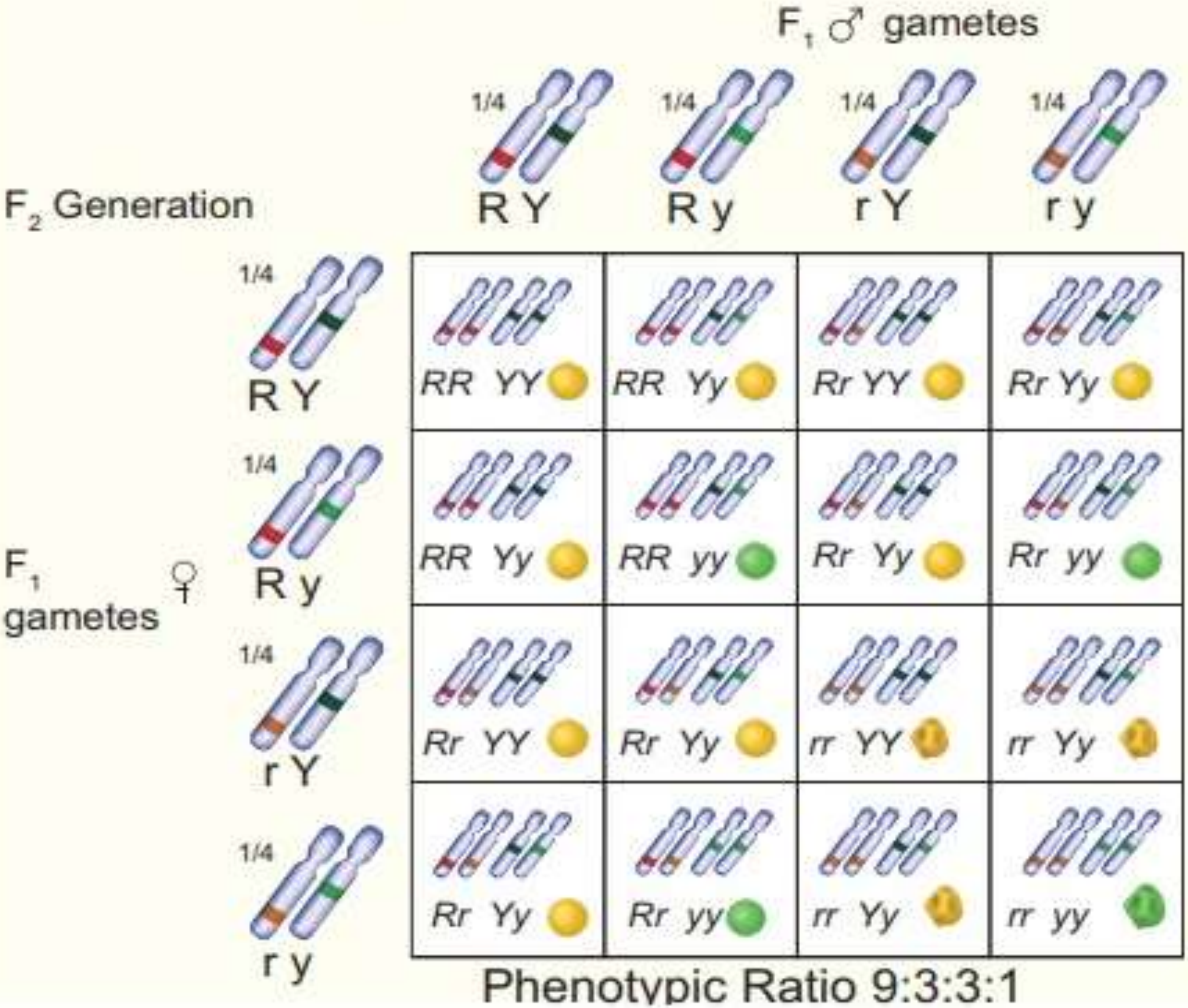
- The crossing of two plants differing in two pairs of contrasting traits is called dihybrid cross. In dihybrid cross, two characters (colour and shape) are considered at a time. Mendel considered the seed shape (round and wrinkled) and cotyledon colour (yellow & green) as the two characters. In seed shape round (R) is dominant over wrinkled (r) ; in cotyledon colour yellow (Y) is dominant over green (y).
- Hence the pure breeding round yellow parent is represented by the genotype RRYY and the pure breeding green wrinkled parent is represented by the genotype rryy. During gamete formation the paired genes of a character assort out independently of the other pair. During the F_1 x F_1 fertilization each zygote with an equal probability receives one of the four combinations from each parent.

- The resultant gametes thus will be genetically different and they are of the following four types:
- 1) Yellow round (YR) - 9/16
- 2) Yellow wrinkled (Yr) - 3/16
- 3) Green round (yR) - 3/16
- 4) Green wrinkled (yr) - 1/16

- 9:3:3:1

- These four types of gametes of F_1 dihybrids unite randomly in the process of fertilization and produce sixteen types of individuals in F_2 in the ratio of 9:3:3:1 as shown in the figure. Mendel’s 9:3:3:1 dihybrid ratio is an ideal ratio based on the probability including segregation, independent assortment and random fertilization. In sexually reproducing organism plants from the garden peas to human beings, Mendel’s findings laid the foundation for understanding inheritance and revolutionized the field of biology. The dihybrid cross and its result led Mendel to propose a second set of generalisations that we called Mendel's Law of independent assortment.


P Generation
Parent 1 ♀
Parent 2 ♂
Parental phenotype
Round yellow cotyledon
×
Wrinkled green cotyledon
Diploid parental genotype
RR
YY
rr
yy
Haploid gametes
R
Y
r
y
×
F1 generation
R
r
Y
y
F1 phenotype : All round-yellow cotyledon
F1 genotypes : All Rr Yy
F1 Generation (selfed)
Parent 1 ♀
Parent 2 ♂
Round yellow cotyledon
×
Round yellow cotyledon
Rr
Yy
Rr
Yy
Haploid F1 gametes
R Y
R y
r Y
r y
R Y
R y
r Y
r y


F$_1$ ♂ gametes
1/4 R Y
1/4 R y
1/4 r Y
1/4 r y
F$_2$ Generation
F$_1$ ♀ gametes
RR YY
RR Yy
Rr YY
Rr Yy
RR Yy
RR yy
Rr Yy
Rr yy
Rr YY
Rr Yy
rr YY
rr Yy
Rr Yy
Rr yy
rr Yy
rr yy
Phenotypic Ratio 9:3:3:1

TRIHYBRID CROSS

- The trihybrid cross demonstrates that Mendel's laws are applicable to the inheritance of multiple traits. Mendel Laws of segregation and independent assortment are also applicable to three pairs of contrasting characteristic traits called trihybrid cross.

- A cross between homozygous parents that differ in three gene pairs (i.e. producing trihybrids) is called trihybrid cross. A self fertilizing trihybrid plant forms 8 different gametes and 64 different zygotes. In this a combination of three single pair crosses operating together. The three contrasting characters of a trihybrid cross are

Tall, Yellow, Round x Dwarf, Green, Wrinkled

TTYYRR ↓ ttyyrr

F_1 Tall, Yellow, Round (Selfed)

TtYyRr

F_2 Phenotypic ratio - 27 : 9 : 9 : 9 : 3 : 3 : 3 : 1

RELEVANCE OF MENDELISM

- Traits are the results of complex interaction between genes
- Incomplete dominance-mendelian concepts of inheritance
- Linkage and independent assortment

Thank You