Mendelian Law of Inheritance

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Gregor Johann Mendel

- Austrian Monk.
- Born in Czech Republic in 20 July 1822.
- Study the inheritance in sweet pea plants (*Pisum sativum*).
- Developed the law of inheritance, which is now called as Mendel's Principles.
- Mendel's work was not recognized until the turn of the 20th century
- He died on 6 January 1884.

Terminology

- **Trait –** It is any characteristic that can be passed from parent to offspring.
- **Heredity –** Passing of traits from parent to offspring.
- **Genetics –** Study of heredity.
- **Genotypes –** Genetic makeup of an organism (Organism's complete set of genes).
- **Phenotypes –** The physical appearance of an organism with respect to a trait, such as yellow seeds.
- **Dominant trait –** A trait expressed preferentially over another trait. It is represented with a capital letter.
- **Recessive trait –** The opposite of dominant. A trait that is preferentially masked. It is represented with the same letter as the respective dominant trait but with lower case.
- **Test cross –** A cross of an individual organism of dominant phenotype but unknown genotype and an organism with a homozygous recessive genotype (and phenotype). It is generally a cross involving a homozygous recessive individual.
- **Reciprocal cross –** Using male and female gametes for two different traits, alternating the source of gametes.

Genes and Related Terms

Genes – A gene is a basic unit of heredity and a sequence of nucleotides in DNA that encodes the synthesis of a gene product, either RNA or protein.

Alleles – two forms of a genes (dominant & recessive)

Dominant genes – Stronger of two genes expressed in the hybrid. It is represented by a capital letter, e.g. for Tall variety, dominant allele will be represented by '**T**'.

Recessive Genes – Genes that shows up less often in a cross. It is represented by a lowercase letter, e.g. for Tall variety, recessive allele will be represented by '**t**'.

Genotype – Gene combination for a trait, e.g. TT, Tt, tt, RR, Rr, rr, etc.

Phenotypes – The physical feature resulting from a genotype, e.g. Tall, Dwarf, Red, White, etc.

Genotypes

Two kinds:

Homozygous genotype: Gene combination involving two dominant or two recessive genes, e.g. TT, RR, tt, rr, etc. It is also called '***pure***'

Heterozygous genotype: Gene combination of one dominant and one recessive genes, e.g. Tt, Rr, etc. It is also called hybrid.

Types of Genetic Crosses

Monohybrid cross – Cross involving a single trait, e.g. flower color, seed shape, eye color, etc.

Dihybrid cross – Cross involving two traits, e.g. flower color and plant height, eye color and abdomen color of the Drosophila melanogaster, eye color and hair color in the human, etc.

Trihybrid cross – Cross involving three traits or alleles belonging to three different genes, e.g. plant size, pod color and seed shape of a Sweet pea plant.

Generation in a Crossing

Parental P_1 Generation – The parental generation in a breeding experiment.

F_1 Generation – The first-generation of offspring in a breeding experiment. It is also called 1^{st} filial generation. It is derived from the breeding male and female of P_1 generation.

F_2 Generation – The second-generation offspring in a breeding experiment. It is also called as 2^{nd} filial generation. It is derived from breeding male and female individual of F_1 generation.

Punnett Square

Punnett Sqaure – A square diagram used to predict the genotypes of a particular cross or breeding experiment.

***It is named after Reginald C. Punnett, who devised the method in 1905*.**

Monohybrid	Paternal gametes		
Maternal gametes		T	t
	T	TT	Tt
	t	Tt	tt

Monohybrid cross between the tall (TT) male and tall (TT) female sweet pea plant

Dihybrid	Paternal gametes			
Maternal gametes	LB	Lb	lB	lb
LB	LLBB	LLBb	LlBB	LlBb
Lb	LLBb	LLbb	LlBb	Llbb
lB	LlBB	LlBb	llBB	llBb
lb	LlBb	Llbb	llBb	llbb

Dihybrid cross between the long-winged (LL) and black-bodied (BB) *Drosophila* and vestigeal-winged (ll) and grwy-bodied (bb) *Drosophila*.

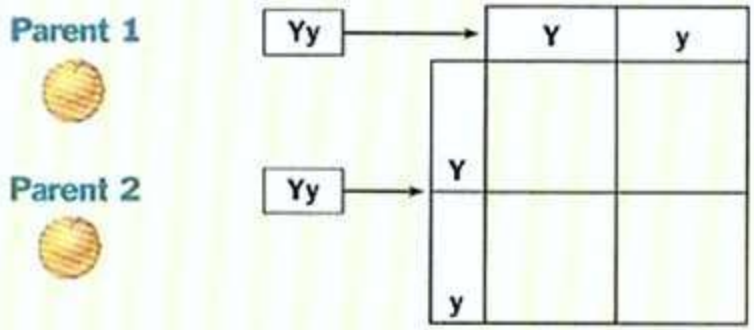
Punnett Square

How to Make a Punnett Square

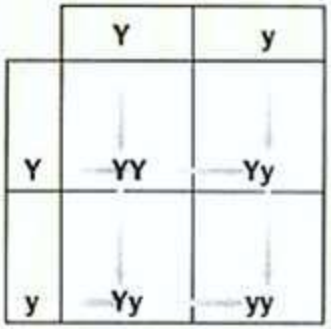
Punnett squares allow geneticists to predict the possible genotypes and phenotypes of offspring.

In this example, both parents are heterozygous for yellow-pea allele (*Yy*).

1 Make the grid
Place the alleles of the gametes of one parent along the top of a grid and those of the other parent along the left-hand side.

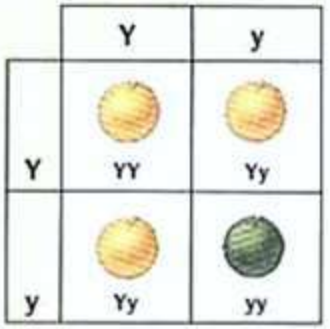


2 Fill in the grid
Combine the parent alleles inside the boxes. The letters show the genotypes of the offspring.



The genotype ratio is 1:2:1, meaning 1 *YY*, 2 *Yy*, 1 *yy*.

3 Fill in the offspring
Use the Law of Dominance to determine the phenotypes and phenotype ratio of the offspring.



The phenotype ratio is 3:1, meaning 3 yellow peas to 1 green pea.

Why Mendel selected Sweet Pea?

Because,

→ It can be grown in a small area.

→ It produces lots of offspring.

→ It produces pure plants when allowed to self-pollinate several generations.

→ It can be artificially crossed.

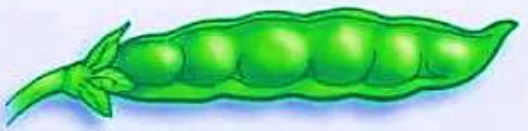
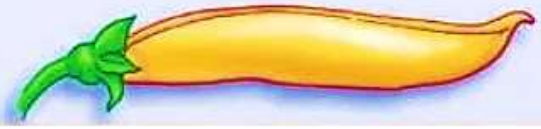
Mendel's Selection of Traits

Mendel selected seven pairs of contrasting characters of pea plants for his experiments which are as follows:

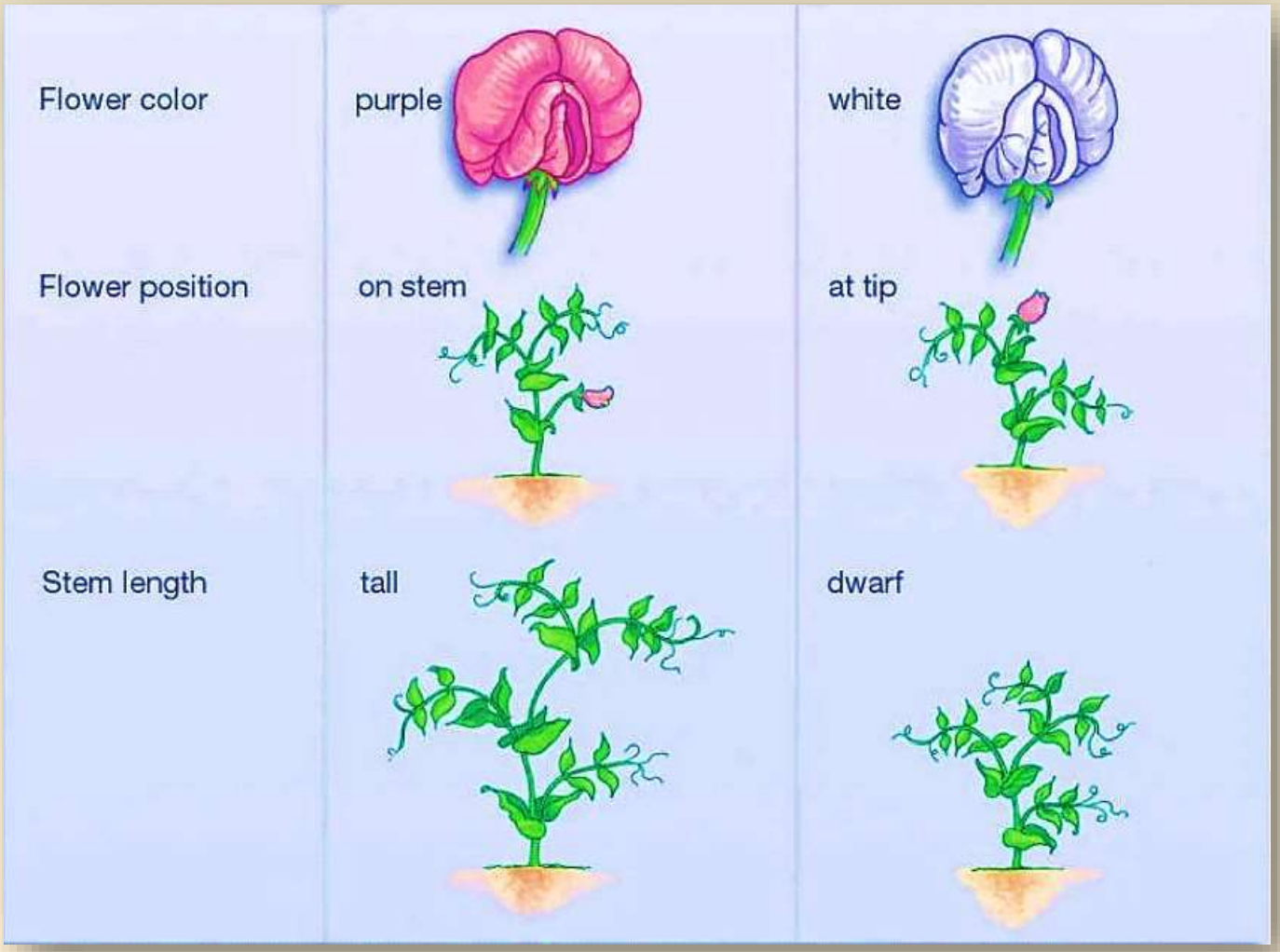
Phenotype	Dominant trait	Recessive trait
Plant height	Tall (T)	Dwarf (t)
Flower color	Purple (P)	White (p)
Flower position	Axial (A)	Terminal (a)
Pod shape	Smooth (S)	Wrinkled (s)
Pod color	Green (G)	Yellow (g)
Seed shape	Round (R)	Wrinkled (r)
Seed color	Yellow (Y)	Green (y)

Mendel's Selection of Traits

Table 11.1 Pea-Plant Characters Studied by Mendel

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

Mendel's Selection of Traits



Results of Mendel's Experiments

The Results of Mendel's Garden Pea Hybridizations

Characteristic	Contrasting P_0 Traits	F_1 Offspring Traits	F_2 Offspring Traits	F_2 Trait Ratios
Flower color	Violet vs. white	100 percent violet	705 violet 224 white	3.15:1
Flower position	Axial vs. terminal	100 percent axial	651 axial 207 terminal	3.14:1
Plant height	Tall vs. dwarf	100 percent tall	787 tall 277 dwarf	2.84:1
Seed texture	Round vs. wrinkled	100 percent round	5,474 round 1,850 wrinkled	2.96:1
Seed color	Yellow vs. green	100 percent yellow	6,022 yellow 2,001 green	3.01:1
Pea pod texture	Inflated vs. constricted	100 percent inflated	882 inflated 299 constricted	2.95:1
Pea pod color	Green vs. yellow	100 percent green	428 green 152 yellow	2.82:1

Theoretical or expected ratio is 3:1, while Mendel's observed ratio was 2.96:1

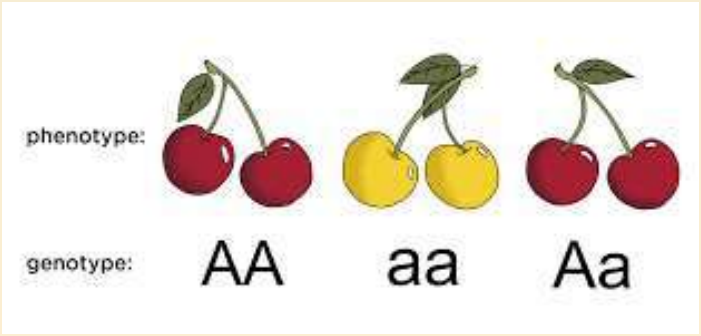
Mendel's Law

There are three main drawings of Mendel's experiments:

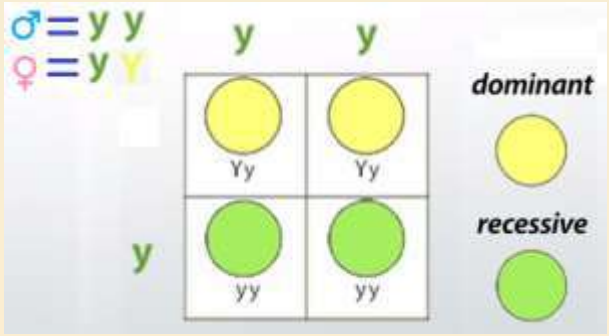
1. **Law of Dominance:** This is the Mendel's first law of inheritance. According to this law, Hybrid offspring inherit only the dominant trait in the phenotype. The allele that are suppressed are called the recessive traits, while the alleles that determine the traits are called as the dominant traits.

2. **Law of Independent Assortment:** This is the Mendel's second law of inheritance. It states that a pair of traits segregates independently of another pair during gamete formation. It ensures equal opportunity of different traits to occur together.

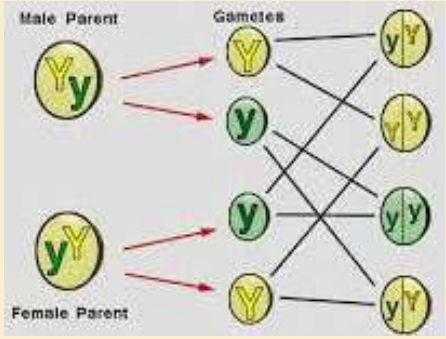
3. **Law of Segregation:** This is the Mendel's third law of inheritance. It states that two copies of hereditary factors segregate during the production of gametes so that offspring acquire one factor from each parent. In other words, allele pairs segregate during the formation of gamete and reunite randomly during fertilization.



Law of Dominance



Law of Independent Assortment



Law of Segregation

Monohybrid Cross

Law of Dominance

P_1 Monohybrid cross

For seed shape, a pure monohybrid cross can be understand as follows:

Trait: Seed shape

Alleles: R – Round r – Wrinkled

Cross: Round seeds X Wrinkled seeds

RR X rr

♀ \ ♂	R	R
r	Rr	Rr
r	Rr	Rr

Offspring (F1 Generation)

Genotype: ***Rr (Heterozygous)***

Phenotype: ***Round***

Genotypic ratio: ***All alike***

Phenotypic ratio: ***All alike***

Monohybrid Cross

F_1 Monohybrid cross

For seed shape, a F_1 monohybrid cross can be understand as follows:

Trait: Seed shape

Alleles: R – Round r – Wrinkled

Cross: Round seeds X Wrinkled seeds

Rr X Rr

♀ \ ♂	R	r
R	RR	Rr
r	Rr	rr

Offspring (F2 Generation)

Genotype: ***RR, Rr, rr***

Phenotype: ***Round & Wrinkled***

Genotypic ratio: ***1:2:1***

Phenotypic ratio: ***3:1***

Monohybrid Cross

F_2 Monohybrid cross or Test Cross (Pure X Hybrid)

Crosses of homozygous dominant with hybrid offspring

Trait: Seed shape

Alleles: R – Round r – Wrinkled

Cross: Round seeds X Wrinkled seeds

RR X Rr

♀ \ ♂	R	R
R	RR	RR
r	Rr	Rr

Offspring (F2 Generation)

Genotype: ***RR, Rr***

Phenotype: ***Round***

Genotypic ratio: ***1:1***

Phenotypic ratio: ***All alike***

Monohybrid Cross

F_2 Monohybrid cross or Test Cross (Pure X Hybrid)

Crosses of homozygous recessive with hybrid offspring

Trait: Seed shape

Alleles: R – Round r – Wrinkled

Cross: Round seeds X Wrinkled seeds

rr X Rr

♀ \ ♂	r	r
R	Rr	Rr
r	rr	rr

Offspring (F2 Generation)

Genotype: ***RR, rr***

Phenotype: ***Round & Wrinkled***

Genotypic ratio: ***1:1***

Phenotypic ratio: ***1:1***

Monohybrid Cross

Problems:

Make a Punnett square and derive genotypic and phenotypic ratio of following crosses:

a. Tall (TT) and dwarf (tt) variety of Sweet Pea

b. Tall (Tt) and tall (Tt) variety of Sweet Pea

c. Long winged (LL) and long winged (Ll) of *Drosophila melanogaster*

d. Vestigeal winged (ll) and long winged (Ll) of *D. melanogaster*

Dihybrid Cross

✓ **Crosses with two contrasting traits**

Trait: Seed shape & Seed color

Alleles: R – Round r – Wrinkled

Y – Yellow y – green

Cross: Round seeds X Wrinkled seeds

Heterozygous RrYy X RrYy

Gametogenesis (Segregation)

RY Ry rY ry

RY Ry rY ry

Number of gametes is equal to 2^n, where n is number of heterozygotes.

Dihybrid Cross

♀ \ ♂	RY	Ry	rY	ry
RY	RYRY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

Offspring

Round/Yellow = 9

Round/green = 3

wrinkled/Yellow = 3

wrinkled/green = 1

Phenotypic ratio = 9:3:3:1

Dihybrid Cross

Problems:

1. How many gametes will be produced for the following allele arrangements?
    a. RrYy
    b. TtRRYyAa
    c. AaBbCCDd
    d. AaBbCcDdJJLlPpvv
2. Make a Punnett square and predict phenotypic ratio of following crosses:
    a. RRYY X RrYy
    b. RrYy X RrYy

Incomplete Dominance

Incomplete dominance is a type of relationship between alleles in which both alleles of a gene at a locus are partially expressed, often resulting in an intermediate or different phenotype.

F1 hybrids will have an appearance in between the two parental varieties, such as appearance of flower color in Snapdragon flower.

Crosses in Snapdragon flower: Red (RR) X White (rr)

♀ \ ♂	R	R
r	Rr	Rr
r	Rr	Rr

Offspring (F1 Generation):

All Rr = *Pink*

Genotypes: *All alike (Heterozygous)*

Phenotypes: *All alike*

Codominance

It refers to a type of inheritance in which two versions (alleles) of the same gene are expressed separately to yield different traits in an individual.

Two alleles are expressed (multiple alleles too) in heterozygous individuals, such as blood type.

Genotype of blood types:

i. Type A = I^AI^A or I^ai

ii. Type B = I^BI^B or I^bi

iii. Type C = I^AI^B

iv. Type O = ii

Cross

Type B male (I^BI^B) X Type A female (I^Ai)

♀ \ ♂	I^B	I^B
I^A	I^AI^B	I^Bi
i	I^AI^B	I^Bi

Offspring

50% I^AI^B (Type C) & 50% I^Bi (Type B)

Codominance

Problems:

1. What will be the genotypes and phenotypes if a male Type O (ii) crossed with female Type AB (I^AI^B)?

2. If a boy has a blood type O and his sister has blood type AB. What are the genotypes and phenotypes of their parents?

There is no substitute for hard work.