Heredity
Chapter 3

Mendelian Genetics

3:1 Genetics

You are who you are due to the interaction of HEREDITY and ENVIRONMENT.

ENVIRONMENT: all outside forces that act on an organism.

HEREDITY: traits that are passed from parents to offspring.

INHERITANCE: the passing of traits by heredity

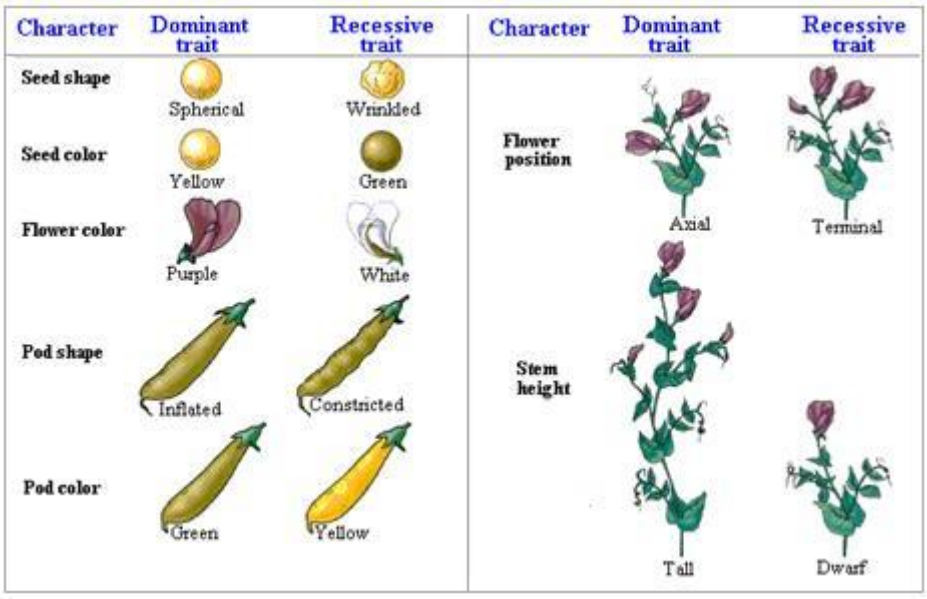
GENETICS: the scientific study of heredity.

GREGOR MENDEL: "Father of Genetics"; Austrian monk and high school teacher who extensively studied heredity.

3:2 What did Mendel do?

MENDEL USED PEA PLANTS TO STUDY HEREDITY FOR TWO REASONS

1. He could easily identify 7 different characteristics and two opposing traits for each characteristic.
   CHARACTERISTIC: a hereditary quality of an organism.
   EX: stem length, seed color
   TRAIT: contrasting or opposing forms of a characteristic.
   EX: Tall stem or short stem
   Yellow seed or green seed



2. He could control the fertilization of pea plants, because each plant has both male and female reproductive organs.
   SELF-POLLINATION: when pollen (sperm) from a plant fertilizes an egg on the same plant.
   CROSS-POLLINATION: when pollen from one plant fertilizes an egg on another plant.

MENDEL WAS SUCCESSFUL BECAUSE:

1. He studied only one characteristic at a time.
2. He kept detailed quantitative records of his work.

3:3 Mendel's Experiments

EXPERIMENT ONE: Mendel observed self pollination in pea plants.

RESULTS: Plants kept the same traits generation after generation.

EX: Tall plants always produce tall offspring when self-pollinating, short always produce short.

EXPERIMENT TWO: Mendel cross-pollinated plants with contrasting traits.

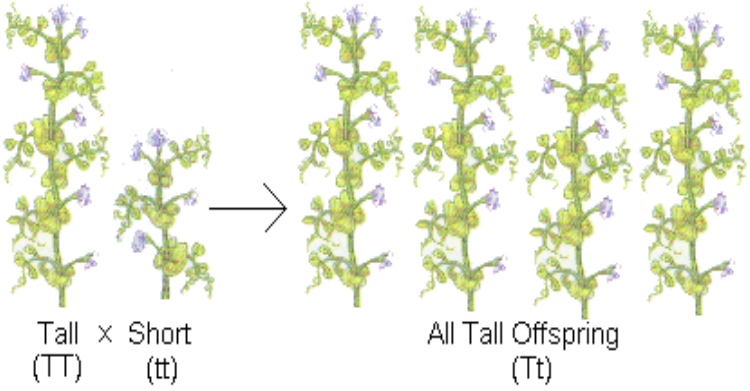
PARENTAL (P_1) GENERATION: parents with two different traits.

FIRST FILIAL (F_1) GENERATION: offspring of the P_1 parents, have only one of the two parental traits.

RESULTS: All of the F_1 offspring exhibited the same trait, they looked like only one of the parents.

EX: P_1 Tall X short

F_1 ALL Tall



EXPERIMENT THREE: Mendel allowed the F_1 generation to self-pollinate.

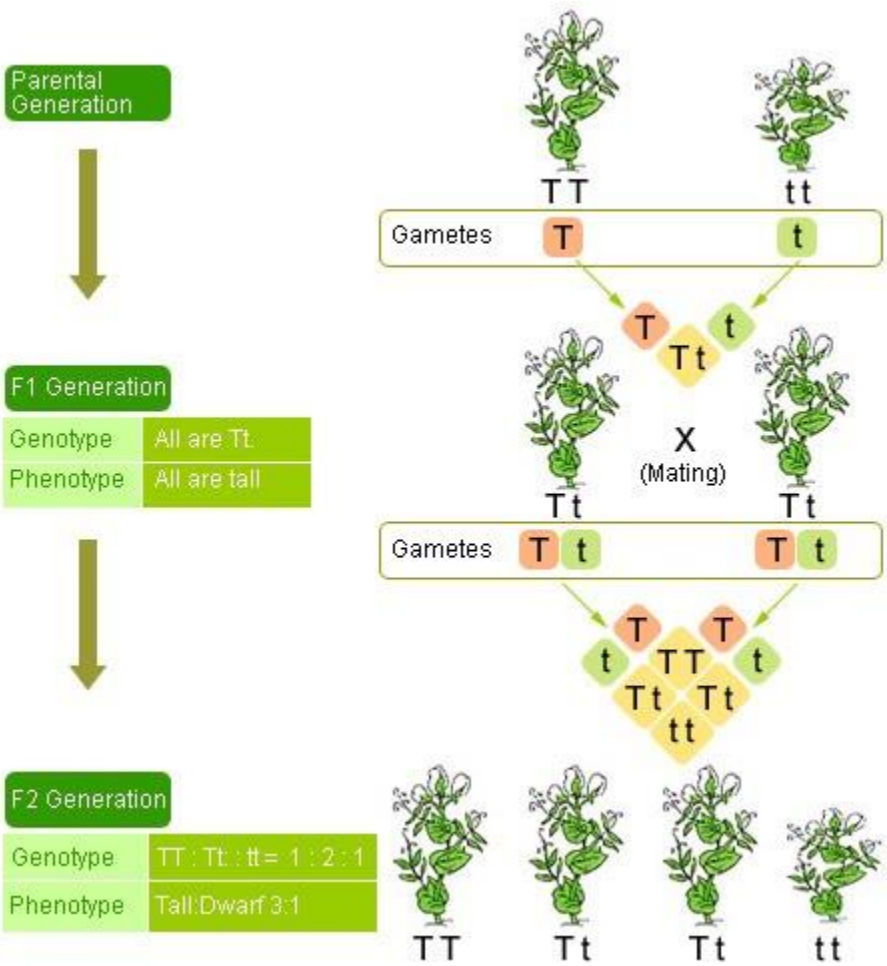
SECOND FILIAL (F_2): offspring of the F_1 generation.

RESULTS: In the F_2 generation ¾ had one trait, ¼ had the contrasting trait.

EX: P_1 Tall X short

F_1 All Tall

F_2 ¾ Tall and ¼ short

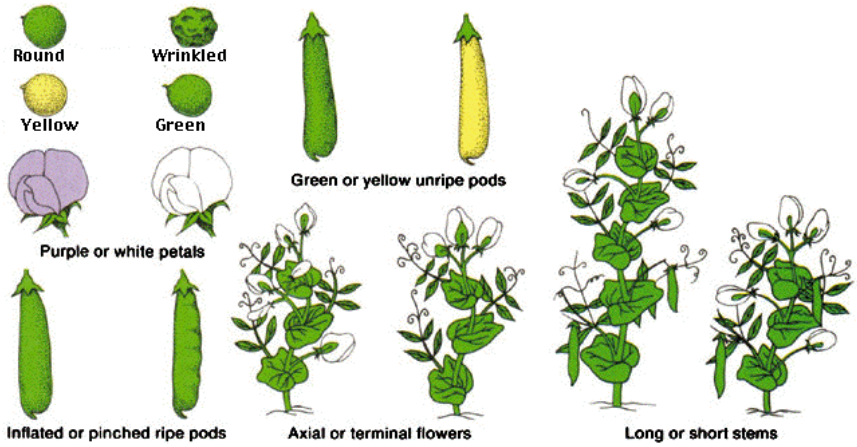


Experiment 2

Experiment 3

Mendel's Peas ~ Characteristics and Traits ~ Crosses and Results

The trait on the left is dominant and the trait on the right is recessive



Results of Mendel's Monohybrid Crosses

Characteristics	P_1 Contrasting Traits	F_1 Results	F_2 Results	F_2 Ratio
Seed Shape	Round X wrinkled seed	Round	5474 Round 1850 wrinkled	2.96:1
Seed Color	Yellow X green seed	Yellow	6022 Yellow 2001 green	3.02:1
Flower Color	Purple X white flower	Purple	705 Purple 224 white	3.15:1
Pod Shape	Inflated X constricted pod	Inflated	882 Inflated 299 constricted	2.95:1
Pod Color	Green X yellow pod color	Green	428 Green 152 yellow	2:82:1
Flower Position	Axial X terminal flower	Axial	651 Axial 207 terminal	3.14:1
Stem Height	Tall X short	Tall	787 Tall 277 short	2.84:1

Conclusion of the result in the above table:

- The heterozygous F_1 generation expresses the dominant trait.
- In the F_2 generation, offspring may express either the dominant or the recessive trait.
- In the F_2 generation, the dominant to recessive ratio is 3:1 (75% dominant, 25% recessive).

3:4 Mendel's Hypothesis

1. FIRST HYPOTHESIS: Inherited characteristics (traits) are determined by genes, genes consist of two alleles (1 gene = 2 alleles).

   GENE: unit of heredity that determines the trait expressed for a characteristic, enough DNA to code for one protein.
   ALLELE: one half of a gene, comes from either the mother or the father.

ALLELE from mom + ALLELE from dad = GENE of offspring

Alleles may be symbolized by using capital or lower case letters.

T → allele for tall stem trait
t → allele for short stem trait

2. SECOND HYPOTHESIS: One allele of the pair of a gene may mask the other allele, preventing it from expressing its effect.
   AKA Principle of Dominance and Recessiveness.

   DOMINANT ALLELE: allele whose trait is expressed
   RECESSIVE ALLELE: allele whose trait is not expressed because it is overruled by the dominant allele

EX: Tall allele is dominant T
short allele is recessive t

GENE		TRAIT
TT	pure Tall	Tall
tt	pure short	short
Tt	hybrid Tall	Tall

HYBRID: an organism that expresses the dominant trait, but carries both the dominant and recessive allele.

3. THIRD HYPOTHESIS: The alleles in the pair of a gene are separated during formation of gametes (egg or sperm).
AKA Principle of Segregation

GAMETES: haploid reproductive sex cells, have only one allele of each gene.

EX: pure tall plant (TT)→ all gametes have Tall allele (T)
pure short plant (tt)→ all gametes have short allele (t)
hybrid tall plant (Tt)→ ½ gametes have Tall allele (T)
½ gametes have short allele (t)

4. FOURTH HYPOTHESIS: The allele pair of one gene is separated and distributed to gametes (egg & sperm) independently of all other genes.
AKA Principle of Independent Assortment

EX: alleles for height gene have no connection with alleles for the seed color gene

Parent gene → TtYy
Possible gametes → TY, Ty, tY, ty

3:5 Modern Uses of Mendel's Work

GENOTYPE: symbols representing the alleles present in a gene in the cells of an organism.

EX: TT, Tt, tt

PHENOTYPE: the trait caused by a gene; what you can see.

EX: Tall plant, short plant

HOMOZYGOUS: genotype in which both alleles of a gene are the same.

EX: TT → homozygous dominant
tt → homozygous recessive

HETEROZYGOUS: genotype in which the two alleles of a gene are different; hybrid.

EX: Tt → heterozygous

PROBABILITY: the likelihood that a specific event will occur.

$$\text{Probability} = \frac{\#\text{ of one kind of event}}{\#\text{ of all events}}$$

EX: In F_2: dominant seed color (Yellow) = 6022
recessive seed color (green) = 2001
total = 8023

$$\text{probability (Yellow)} = \frac{6022}{8023} = 0.75 \text{ or } 75\%$$

$$\text{probability (green)} = \frac{2001}{8023} = 0.25 \text{ or } 25\%$$

Ratio of dominant to recessive = 3:1

In genetics and other systems based on probability the expected ratios occur only when there are many trials.

PUNNETT SQUARE: grid used to show all possible offspring resulting from a cross between two parents.

TO MAKE A PUNNETT SQUARE

1. Draw square and select a trait to study.
2. List alleles for all possible male gametes across top of the square.
3. List alleles for all possible female gametes down the side of the square.
4. Fill in the square by placing one female gamete and one male gamete in each square.

Punnett's Squares

These show the 2 alleles of each parent plant crossed with each other and the resulting 4 possible offspring with T = tall, t = short.

TT = dominant tall, tt = recessive short, Tt = mixed hybrid

TT = dominant tall (genotype tall, phenotype tall)
Tt = mixed hybrid (genotype hybrid, phenotype tall)
tt = recessive short (genotype short, phenotype short)

Using the Punnett's Squares below, name the offspring of all possible parent combinations.

	T	T
T		
T		

Both parents are dominant tall, name the 4 possible offspring.

1. _____ 2. _____

3. _____ 4. _____

	T	t
T		
t		

Both parents are mixed hybrids, name the 4 possible offspring and the expected ratio.

1. _____ 2. _____

3. _____ 4. _____

	T	T
T		
t		

One parents is dominant tall, one is mixed hybrid, name the 4 possible offspring.

1. _____ 2. _____

3. _____ 4. _____

	t	t
t		
t		

Both parents are recessive short, name the 4 possible offspring.

1. _____ 2. _____

3. _____ 4. _____

3:6 Monohybrid Crosses

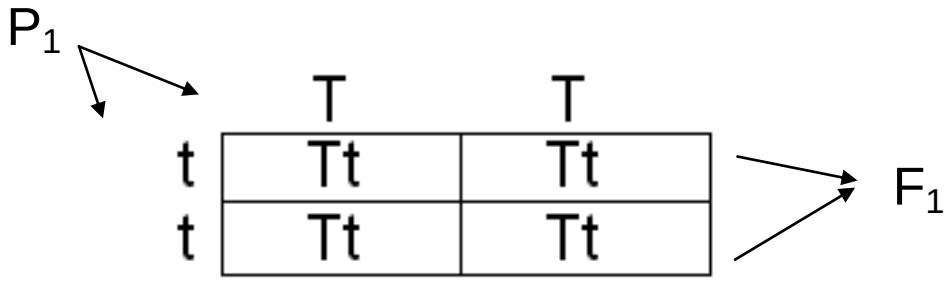
MONOHYBRID CROSS: a cross that involves one gene, one characteristic, or one pair of contrasting traits.

EX: show a Punnett square to represent Mendel's experiments.

Experiment Two

- Cross a homozygous Tall male with a homozygous short female.

P_1 → male : TT X female : tt



F_1 → genotype ratio - 0 TT:4 Tt:0 tt
phenotype ratio - 4 Tall:0 short

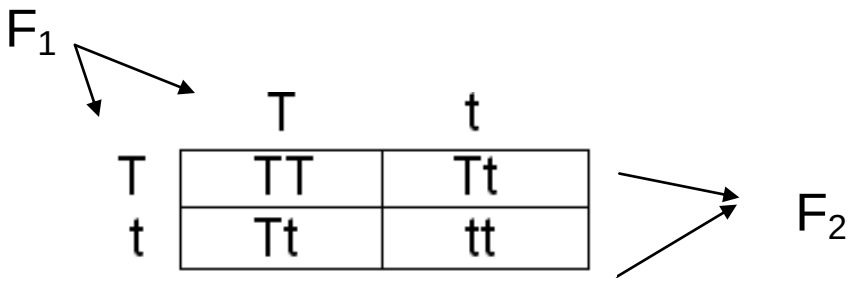
All offspring of the P_1 parents (F_1 generation) are HETEROZYGOUS (Tt) and would be TALL.

F_1 → genotype - Tt (heterozygous)
phenotype - TALL

Experiment Three

- Cross two of the F_1 (heterozygous) offspring.

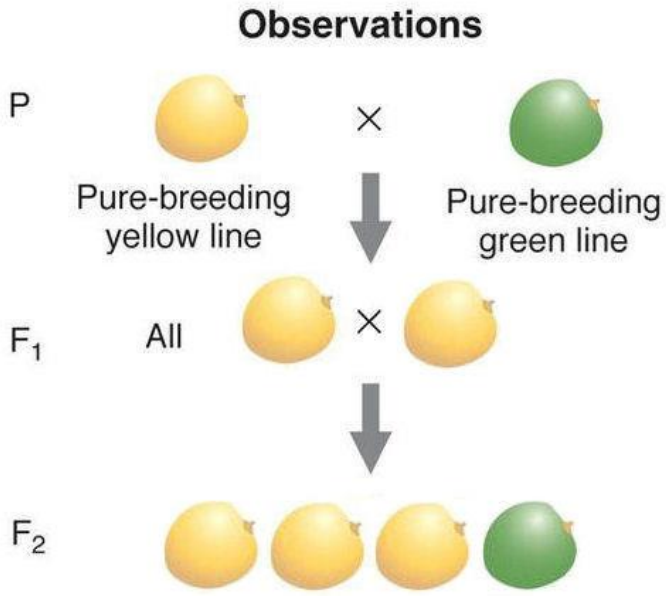
F_1 → male : Tt X female : Tt



F_2 → genotype - 1 TT:2 Tt:1 tt
phenotype - 3 Tall:1 short

The offspring of the F_1 parents (F_2 generation) are ¾ tall and ¼ short.

F_2 → genotype:1 TT phenotype: 3 Tall
2 Tt 1 short
1 tt



3:7 Testcross

TESTCROSS: procedure in which an individual with dominant phenotype but unknown genotype is crossed with a homozygous recessive individual in order to determine the unknown genotype.

Cats: Siamese (AA or Aa) x albino (aa)


Cross 1 genotypes – AA x aa

	A	A
a	Aa	Aa
a	Aa	Aa

Offspring → phenotypes = 100% Siamese
genotypes = 100% Aa

If all offspring from testcross are dominant phenotype, unknown genotype of parent is homozygous dominant.

Cross 2 genotypes – Aa x aa

	A	a
a	Aa	aa
a	Aa	aa

Offspring → phenotypes = 50% Siamese
50% albino
genotypes = 50% Aa, 50% aa

If any offspring from testcross are recessive phenotype, unknown genotype of parent is heterozygous.

The Test Cross

Gametes from parent of unknown genotype

Y ?

Gametes from recessive parent

y

y

Yy	Yy
Yy	Yy

A test cross resulting in all dominant offspring indicates that the parent is homozygous dominant.

Gametes from parent of unknown genotype

Y ?

Gametes from recessive parent

y

y

Yy	yy
Yy	yy

A test cross resulting in a 1:1 ratio of yellow to green offspring indicates that the parent is heterozygous.

3:8 Incomplete Dominance and Codominance

INCOMPLETE DOMINANCE: when neither allele of a gene is dominant and both affect the phenotype.

EX: Four-o-clock flowers

Characteristic – flower color

R=allele for red color

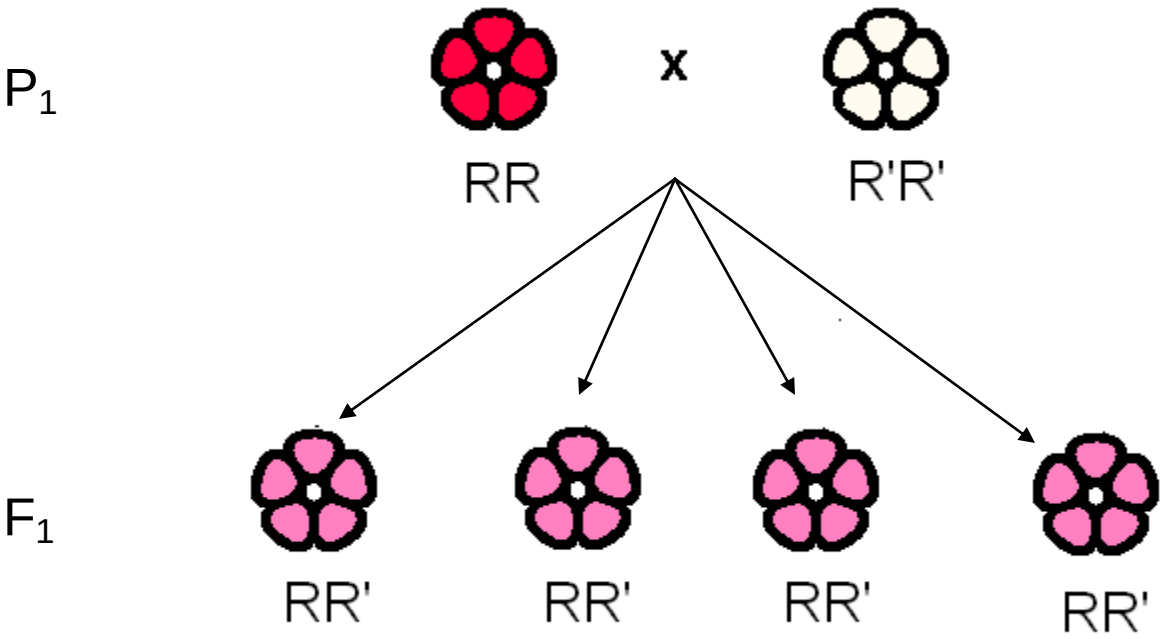
R′=allele for white color

Genotypes	Phenotypes
RR	Red
RR′	Pink
R′R′	White

➢ Cross a red flower plant with a white flower plant.

	R′	R′
R	RR′	RR′
R	RR′	RR′

All offspring are heterozygous (RR′) and have the PINK flower color trait.



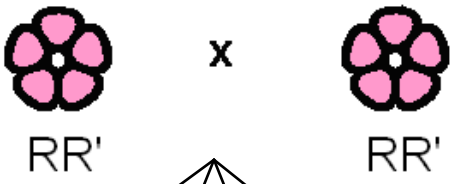
➢ Cross two of the heterozygous pink.

	R′	R
R′	R′R′	R′R
R	R′R	RR

Genotype: 1 RR
2 R′R
1 R′R′

Phenotype: 1 Red
2 Pink
1 White

F_1

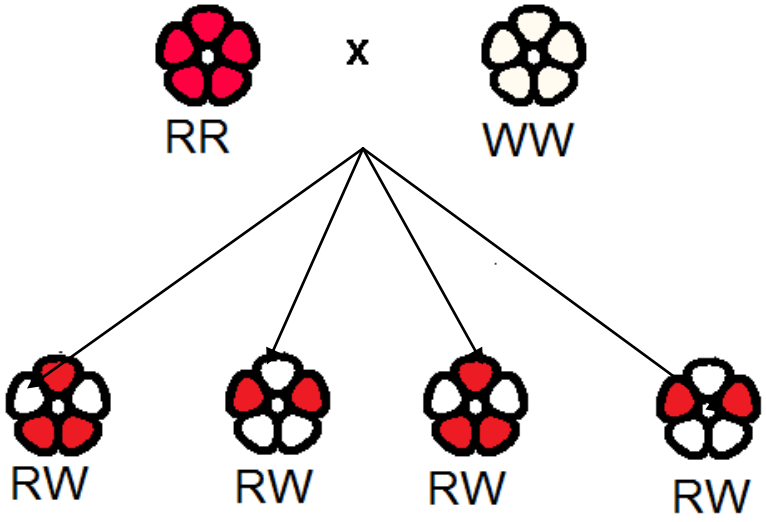


F_2

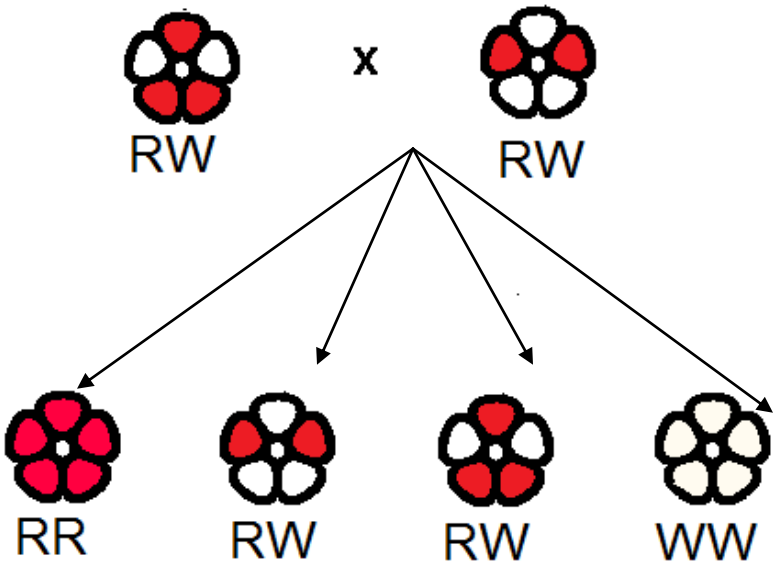
CO-DOMINANCE: occurs when both alleles for a gene are expressed in a heterozygous offspring

Co-Dominance in Flowers

P_1



F_1



3:9 Multiple Alleles

MULTIPLE ALLELES: three or more contrasting alleles that may control a single trait.

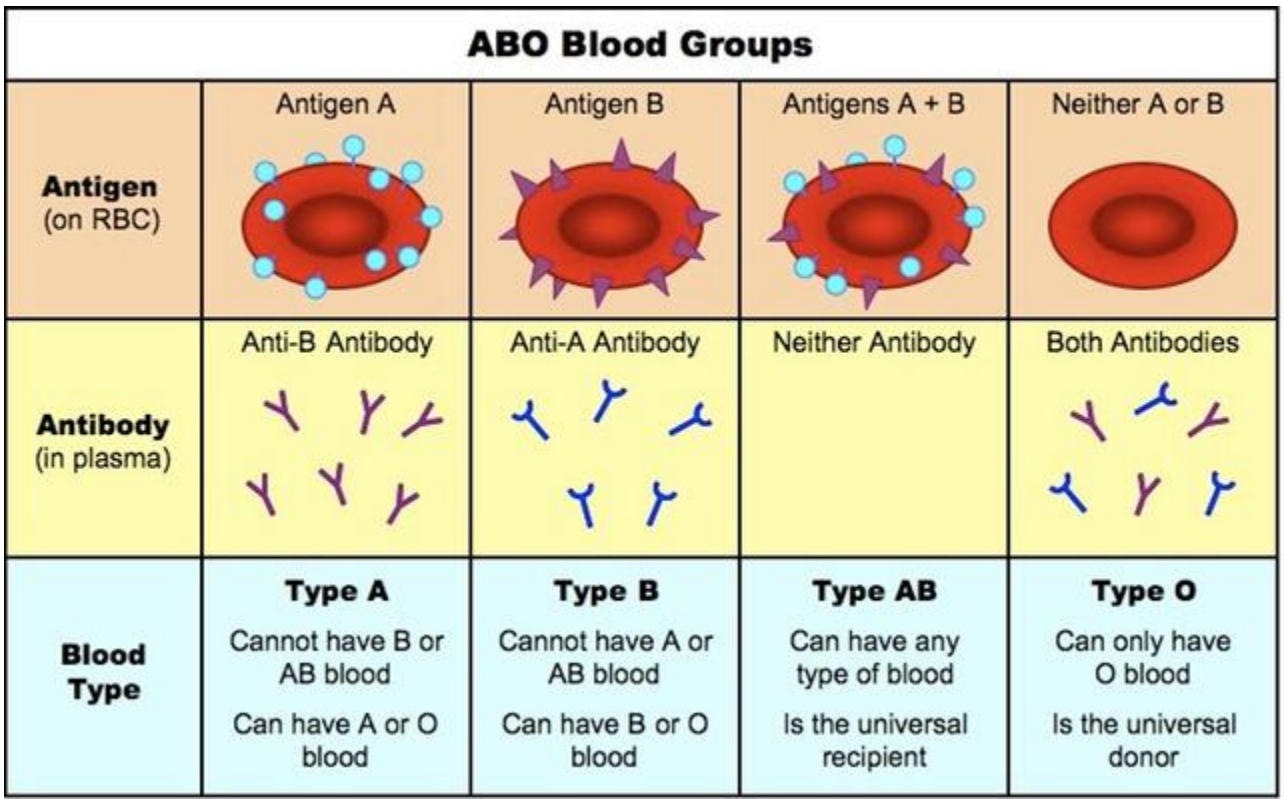
EX: Characteristic - human blood type

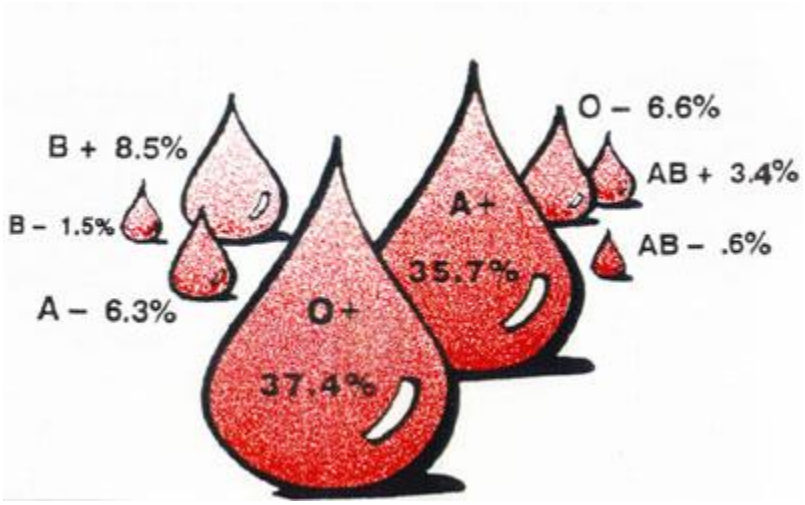
Traits – type A, type B, type AB, type O

Alleles – I^A, I^B, i^O

Genotype	causes	Phenotype
I^AI^A		type A
I^Ai^O		type A
I^AI^B		type AB
I^BI^B		type B
I^Bi^O		type B
i^Oi^O		type O

Both allele I^A and I^B are dominant so the heterozygous genotype (I^AI^B) allows both alleles to be expressed. In this example, both I^A and I^B dominate i^O.




O – 6.6%
B + 8.5%
AB + 3.4%
A+
35.7%
B – 1.5%
AB – .6%
A – 6.3%
O+
37.4%