NEET- 2020- 45 Days Crash Course

Date :19th August 2020

Chapter Name : PRINCIPLES OF INHERITANCE

Lecture Outline :

MENDALIAN INHERITANCE
LINKAGE
PEDIGREE ANALYSIS
SEX DETERMINATION
MENDALIAN DISORDERS

Genetic Basis of Inheritance

❖ Introduction

- **Genetics** is a branch of biology that deals with the study of heredity and variation.
- **Heredity** involves transmission of characters from parents to offspring.
- **Clone** is product of asexual reproduction. Clones are carbon copies of one another derived from a common ancestor
- **Variations** means the differences (Morphological, Physiological to logical and behavioristic) amongst the individuals of the same species and the offspring of the same parents

❖ Mendelism

- Gregor Johann Mendel is known as 'Father of Genetics'. Mendel proposed that inheritance is controlled by paired germinal units or factor, now called genes.
- Mendel performed hybridization experiment on garden pea (Pisum sativum).
- Mendel took one or two characters at one time for his breeding experiment.

Why Mendel's Selected Pea Plant

- Mendel selected the pea plant for experiment because:

- Pea plant is herbaceous and annual. It can be grown two or three time in a year. So the results obtain very shortly
- Pea's flowers are bisexual and self-pollinated. So Emasculation and cross pollination can be applied in pea flowers.
- It can easily grow in garden.
- Many contrasting characters are found in pea plant. Mendel selected 7 pairs of contrasting characters of pea plant.
- He took care to avoid contamination from foreign pollen grains brought by insects.
- Mendel selected only pure breeding varieties of pea for his experiment and grew in separate row.
- Mendel studied the inheritance of character till F_3 generation.

Reason's For Mendel's Success

Character	Dominant	Recessive	Chromosome
Plant Height	Tall (T) 6-7	Dwarf (t) ¾ - 1 ½	4
Shape of pod	Inflated or Full (F)	Constricted (f)	4
Position of flower/pod	Axillary (A)	Terminal (a)	4
Color of flower/color of seed coat	Violet/Red (V or R)/Grey	White (v or r)/White	1
Cotyledon color	Yellow (Y)	Green (y)	1
Pod color	Green (G)	Yellow (g)	5
Seed shape	Round (R)	Wrinkled (r)	7

Traits	Shape of Seeds	Color of Seeds	Color of Pods	Shape of Pods	Plant Height	Position of Flowers	Flower Color
Dominant trait	Round 	Yellow 	Green 	Full 	Tall 	At leaf junctions 	Purple 
Recessive trait	Wrinkled 	Green 	Yellow 	Flat, constricted 	short 	At tips of branches 	White 

Basic Terminology - 1

- **Gene (Factor):** Mendelian factor (in modern genetics called as “Gene”) is a unit of inheritance, which passes from one generation to the next through the gamete and controls the expression of a character in the organisms. **Gene** can be defined as small functional segments of DNA or chromosomes expressing a particular character.
- **Allele or Allomorph:** Contrasting forms of a gene which are found on the same locus in the two homologous chromosomes & control the expression of a trait are called alleles. Ex: Tallness (T) and dwarfness (t).
- **Phenotype:** It represents the expression of external appearance like colour, shape etc. of an individual. Ex: Red colour, tallness or dwarfness etc.
- **Genotype:** It indicates the genetic constitution of an individual. Ex: The genotype of hybrid tall pea plants is Tt, pure tall TT and dwarf tt. Johannsson (1911) firstly used the term ‘Phenotype ‘and’ Genotype’.
- **Homozygous:** It is an individual which contains identical alleles of a gene or factor of a character on its homologous chromosome Ex: TT and tt.
- **Heterozygous:** It is an individual which contains the two contrasting factor of a character or two different alleles of a gene on its homologous chromosomes. Ex: Tt
- **Hemizygous:** Hemizygous is a condition in which only one copy of a gene or DNA sequence is present in diploid cells. Males are hemizygous for most genes on sex chromosomes, having only one X and one Y chromosome.

Basic Terminology - 2

- **Hybrid:** The organism produced after crossing two genetically different individuals is called hybrids.
- **Hybridization:** The process of obtaining hybrids is called hybridization.
- **Reciprocal cross:** If in one cross individual ‘A’ is used as male and ‘B’ as female and in the next cross ‘B’ is used as male and ‘A’ as female, it is called as reciprocal cross
- **Homologous pair:** Zygotic pair, in which both chromosomes are same in shape and size.
- **Back Cross:** It is a cross between F1 hybrid and one of its parents. Back cross includes test cross.
  - **Test cross:** It is a cross between F_1 hybrid and recessive parent to know whether an individual is homozygous or heterozygous for dominant character.
  - **Out cross:** If cross is performed between F_1 hybrid and dominant parent then it is called ‘Out cross’ All the offspring obtain from this cross have dominant characters.
- **Genome:** A complete set of chromosomes found in each nucleus of given species is called genome. A single genome is present in haploid cell (n).
- **Gene Pool:** Sum of all the genes and their alleles present in an interbreeding population is called gene pool.

Monohybrid Cross

- Cross between two organisms of a species, that are different in a pair of contrasting characters. Ex: height of plant.
- Firstly, Mendel selected long and dwarf plants of garden pea.
- Mendel removed stamens of the flower of tall plants in bud condition called '**Emasculation**'. A Bag tied over the flower for the prevention of cross-pollination. This is called '**Bagging**'.
- Dwarf plant took as male plant and their flower covered through bag.
- On dehiscence or maturity, the pollen grains of dwarf plant sprayed over the stigma of long plant and It again covered through bag.
- Seeds collected through long plant. Afterward Mendel obtained F1 generation through the sowing of former. This process called 'Hybridization' and F1 generation called 'Hybrid'.

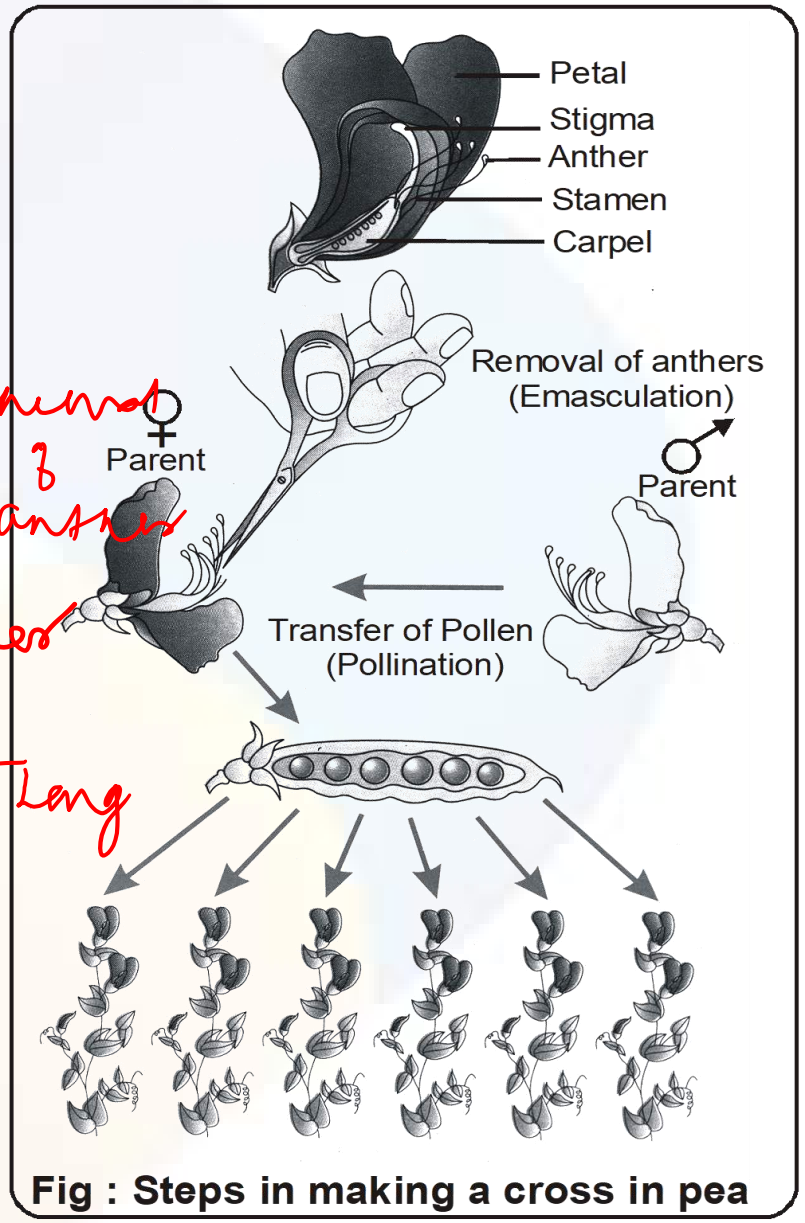


Fig : Steps in making a cross in pea

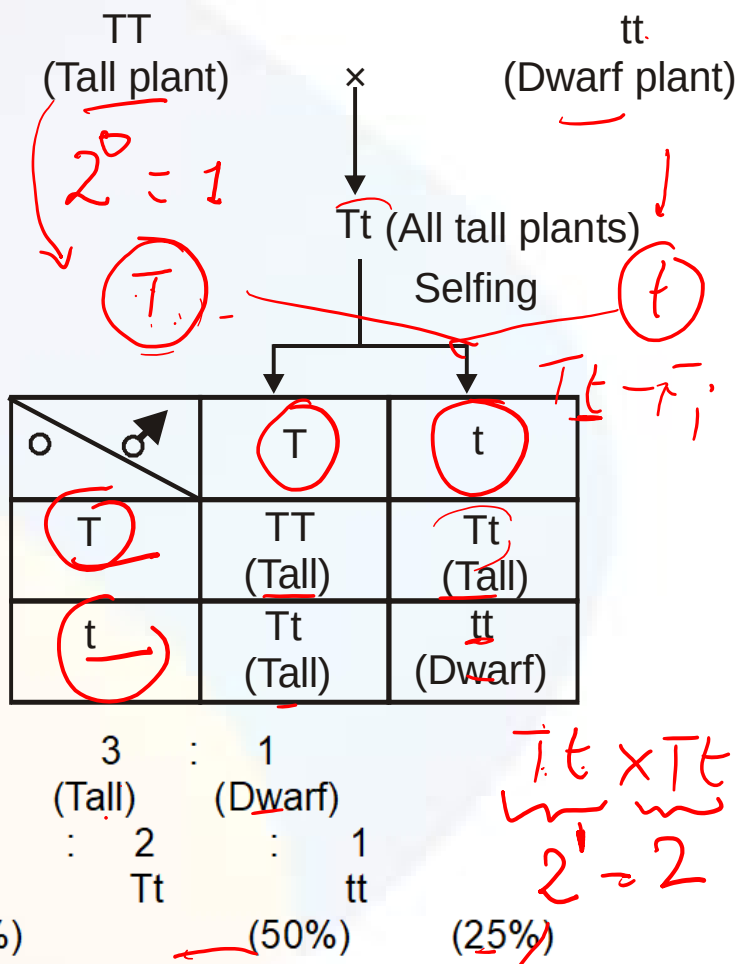
Monohybrid Cross – Punnett Square

- Mendel obtained only tall plants in F_1 generation.

- After this process, Mendel obtained F_2 generation through the sowing of those seeds which obtained from self-pollination of F_1 plants.

- In F_2 generation, Tall and dwarf plants obtained in 3: 1 ratio. It is proved that the character of tallness in the plants of F_1 generation does not pure.

- The phenotypic ratio of F_2 generation in Monohybrid cross is 3: 1 and genotypic ratio is 1: 2: 1



"Law of segregation" stating that during the production of gametes the two copies of each hereditary factor **segregate** so that offspring acquire one factor from each parent.

Conclusion of Monohybrid Cross

- **Principle of paired Factors:** A plant possesses two factors of each character. Each trait is controlled by a unit factor.

- **Principle of Dominance:** Out of the two factors or alleles representing the alternate form of a trait, one is dominant and expresses itself in the hybrid of F_1 generation. The other factor or allele is recessive and does not show its effect. It is called the '**Mendel's law of dominance**'.

The factor of dominant character is denoted by capital letter and the factor of recessive character is denoted by small letter

Parents	TT (Tall plant)	×	tt (Dwarf plant)
F_1 generation	Tt (All tall plants)		

Dihybrid Cross

- It is a cross between two organisms of a species that are different in two pairs of contrasting characters.

- Mendel selected the following two character for this purpose.
  - Color of seed - Yellow and green
  - Shape of seed - Round and wrinkled

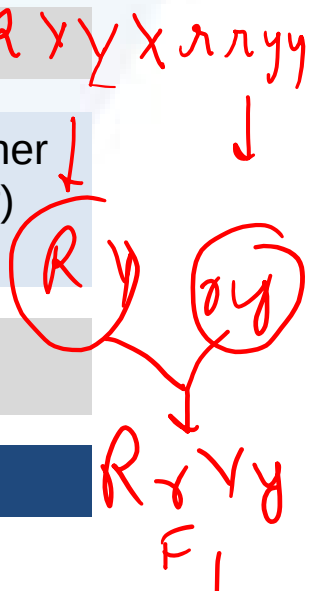
- In which Yellow and Round traits are respectively dominant over green and wrinkle traits.

- Mendel performed cross between pure breeding pea plants having **yellow round seeds (YYRR)** and pure breeding Pea plants having **green wrinkled seeds (yyrr)**

- All the plants of the **F_1 generation** were yellow and round seeds **(YyRr).**

- The factors of both characters will have independently segregated to each other during gamete formation. Thus total four types of gametes(YR), (yR), (Yr), (yr) form in F_1 generation.

- On selfing of F_1 the resultant F_2 generation show four types of plants
  - Yellow Round, Yellow wrinkled, Green Round, Green wrinkled



Dihybrid Cross – Punnett Square

❖ Conclusion of dihybrid cross

- Number of genotype in any cross is = 3n.
- Number of genotypes in dihybrid cross = $3^2 = 9$

Yellow round and green wrinkled plants show parental combinations (9+1) while green round and yellow wrinkled show new combinations (3 + 3 = 6). The ratio between parental combination and new combination is 5: 3. So 62.5%Parental combination and 37.5% new combination are obtained.

Parents: YYRR (Yellow Round) × yyrr (Green wrinkled)

(gamete) YR | yr (gamete)

F_1 generation: YyRr (All Yellow Round)

Selfing

F_2 generation

♀ \ ♂	YR	yR	Yr	yr
YR	YYRR (Yellow Round)	YyRR (Yellow Round)	YYRr (Yellow Round)	YyRr (Yellow Round)
yR	YyRR (Yellow Round)	yyRR (Green Round)	YyRr (Yellow Round)	yyRr (Green Round)
Yr	YYRr (Yellow Round)	YyRr (Yellow Round)	YYrr (Yellow wrinkled)	Yyrr (Yellow wrinkled)
yr	YyRr (Yellow Round)	yyRr (Green Round)	Yyrr (Yellow wrinkled)	yyrr (Green wrinkled)

phenotypic ratio 9 : 3 : 3 : 1

Yellow Round : Yellow wrinkled : Green Round : Green wrinkled

Genotypic ratio 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1

YYRR : YYRr : YyRR : YyRr : YYrr : Yyrr : yyRR : yyRr : yyrr

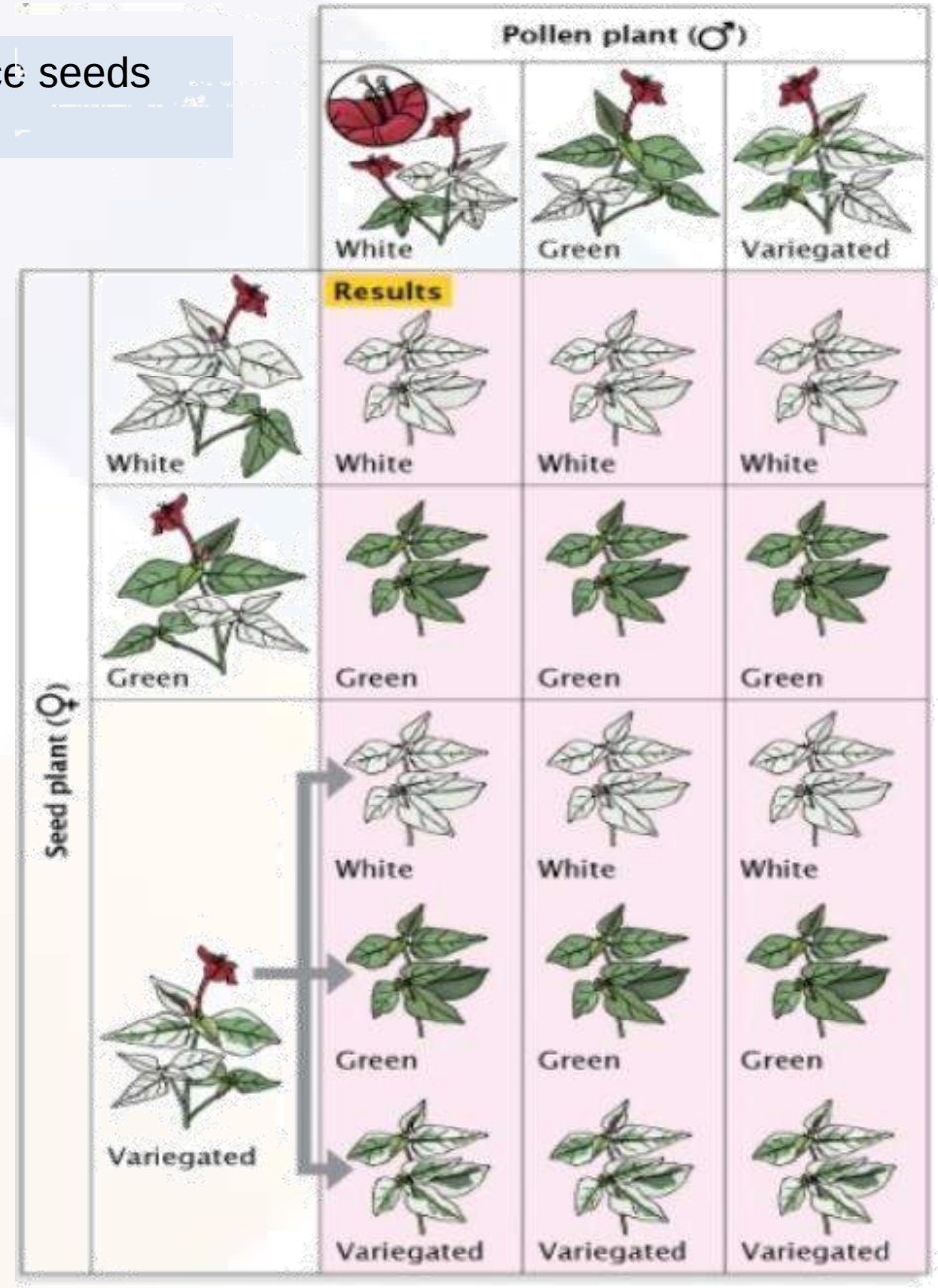
Dihybrid Cross

- Flowers on wholly green branches produce seeds that grow into normal plants.

- Flowers on variegated branches yield offspring of three kinds – green, white and variegated in variable proportions.

- Flowers from branches wholly white produce seeds that grow into white plants that is without chlorophyll.

CONCLUSION: The phenotype of the progeny is determined by the phenotype of the branch from which the seed originated. Not from the branch on which the pollen originated. Stem and leaf color exhibits cytoplasmic inheritance.



Law of Independent Assortment

Mendel concluded that the two factors of a character assort or separate independent of the factors of other characters at the time of gamete formation and get randomly rearranged in the offspring's. It is called the '**Law of Independent assortment**'.

- This law is applicable to only those factors or genes which are either situated distantly on the same chromosome or occur on different chromosomes.

→ Should not be linked

F_2 generation of dihybrid cross shows that the inheritance of cotyledon color assorts independent to the inheritance of seed shape unless green round and yellow wrinkled seeds do not obtain.

F_1 generation

Tt (Tall Heterozygous) × TT (Tall Homozygous) (Dominant parent)

Gametes (T) (t) — (T) (T) Gametes

♀ \ ♂	T	T
T	TT (Tall)	TT (Tall)
t	Tt (Tall)	Tt (Tall)

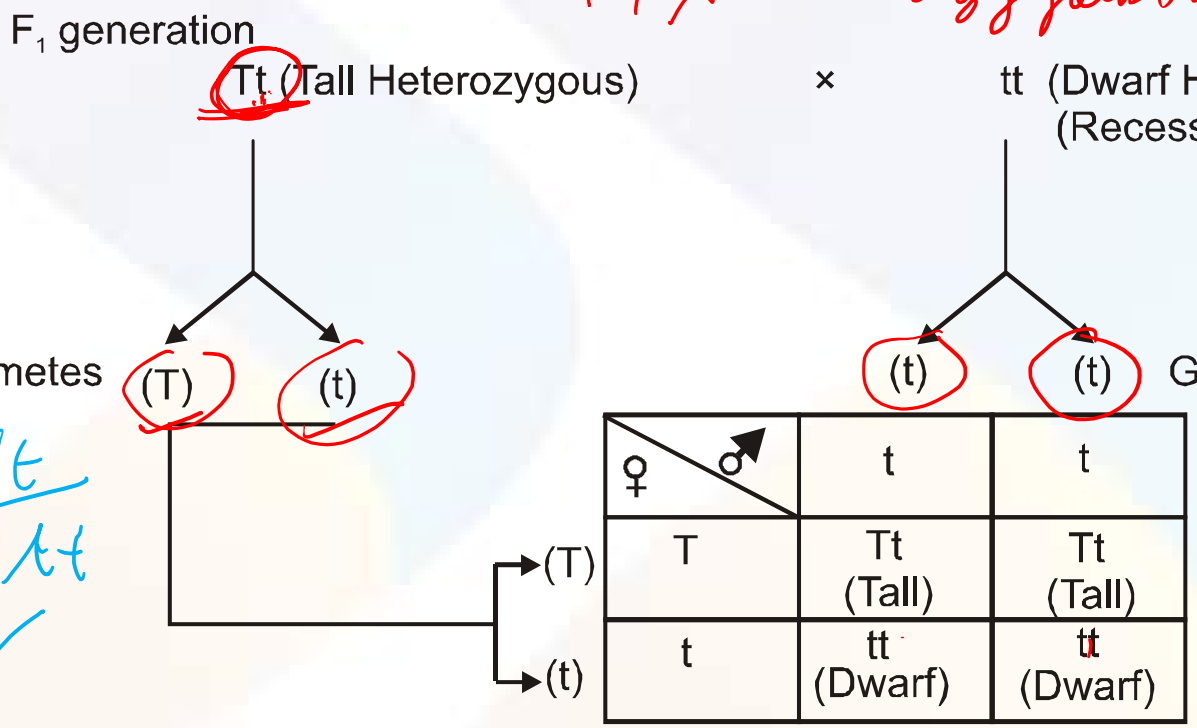
(i) Phenotypic ratio = 100% (Tall plants)

(ii) Genotypic ratio = 1 : 1

TT (Homozygous Tall) Tt (Heterozygous Tall)

Monohybrid Test Cross

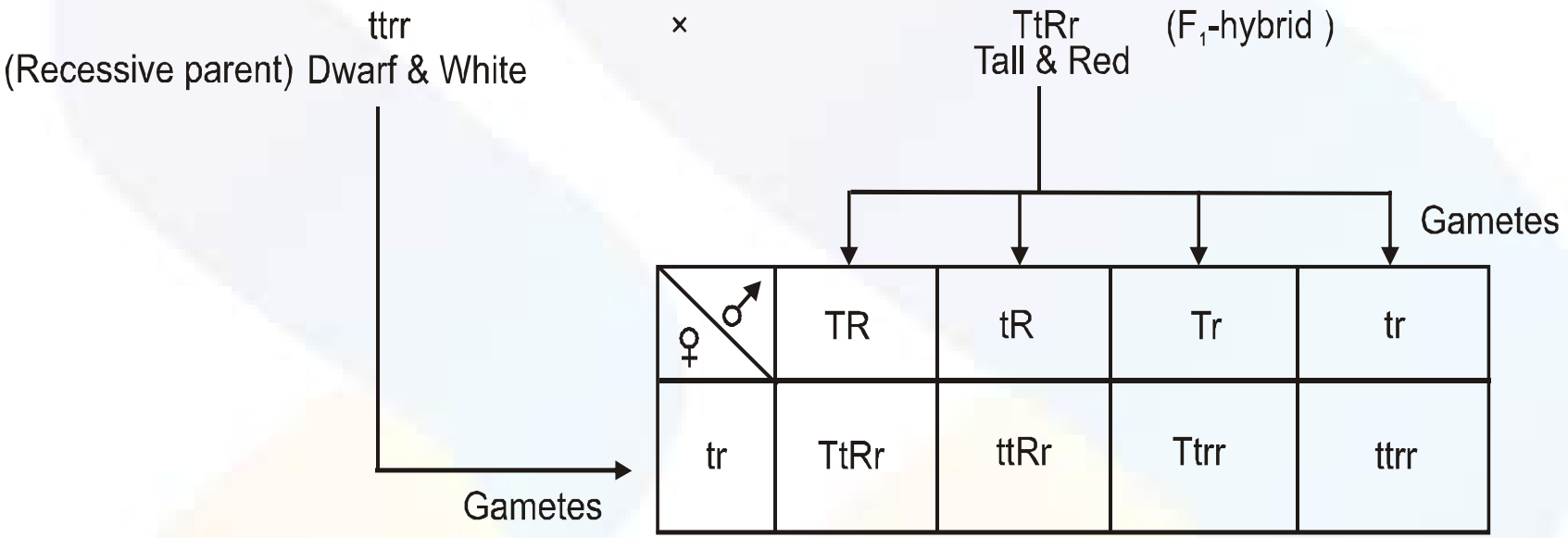
- Cross is performed between F_1 hybrid and recessive parent. It is a cross to know whether an individual is homozygous or heterozygous for dominant character.



(i)	Phenotypic ratio	1 : 1 (Tall : Dwarf)
(ii)	Genotypic ratio	1 : 1 (Tt : tt)

Dihybrid Test Cross

❖ **Dihybrid test cross**



(i) Phenotypic ratio 1 Tall & Red : 1 Dwarf &Red : 1 Tall & White : 1 Dwarf & White

(ii) Genotypic ratio 1 TtRr : 1 ttRr : 1 Ttrr : 1 ttrr

Importance of Mendelism

- It is useful in the field of plant breeding. Advanced features can be used in the development of improved varieties of offspring through the hybridization method.
- The knowledge of dominant and recessive characters is possible through Mendelism.
- Development of high productive varieties and disease resistance varieties is possible.
- It is also useful for the development of improved varieties in animals.

Back cross - Improve the breed

F_1 x either parent

Tt x Tt →

	T	t
T	TT	Tt
t	Tt	tt

Exceptions of Principle of Dominance – Incomplete Dominance

❖ Incomplete dominance

- Incomplete dominance is the phenomenon where recessive allele can't be completely masked by dominant allele . Heterozygous Offspring in F_1 generation express intermediate character (partial or mosaic). **Mirabilis Jalapa** (Gulbans) show incomplete dominance.

- In Mirabilis Jalapa, Red and White flower containing homozygous plants are crossed. The hybrid of F_1 generation have pink flower. If the latter are selfed, the plants of F_2 generation are of three types- Red, Pink and White flowered in the ratio of 1: 2: I

- The phenotypic and genotypic ratio is similar (1: 2: 1) due to incomplete dominance in F_2 generation.

❖ Analysis

- It is cleared that factors of Red and White color are found in F_1 generation of Mirabilis but the factor of Red color does not completely express itself in the presence of factor of white color. Thus the pink color apparently appears due to mixing of Red and White color in Heterozygous F_1 generation.

Incomplete Dominance – Punnett Square

German botanist **Carl Correns** (1864–1933) was credited with the actual discovery incomplete dominance. **Correns** observed a blend of colours in flower petals.

Parents: RR (Red) × rr (White)

Gamete (R) — (r) Gamete

F_1 generation: Rr (Pink)

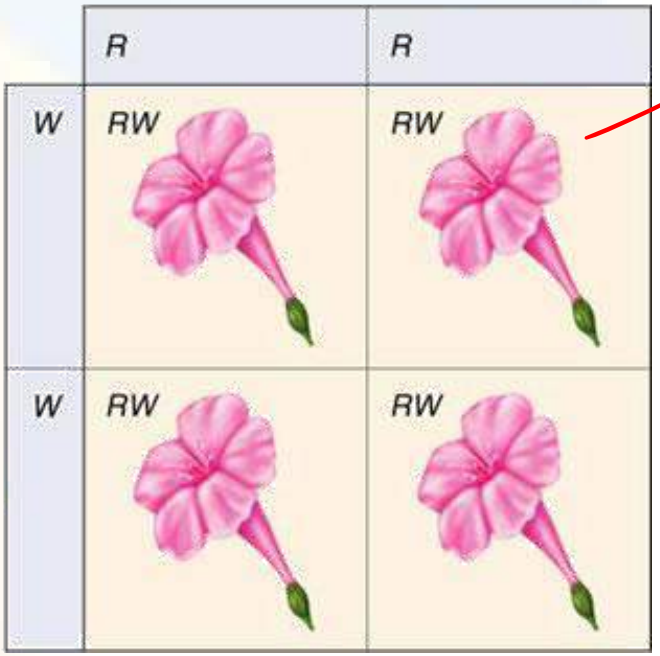
Selfing

♀ \ ♂	R	r
R	RR (Red)	Rr (Pink)
r	Rr (Pink)	rr (White)

F_2 generation

Phenotypic ratio 1 Red : 2 Pink : 1 White

Genotypic ratio 1 RR (25%) : 2 Rr (50%) : 1 rr (25%)



Exceptions of Principle of Dominance - Co-dominance

In codominance both the alleles are fully expressed and the offspring with a phenotype of neither recessive nor dominant. Ex: **Skin color in Short Horned cattle's, ABO blood group, Camellia flower etc.**

Parents: RR (Red) × WW (White)

Gamete (R) (W) Gamete

F_1 generation: RW (Roan heterozygous)

Sib mating cross

F_2 generation

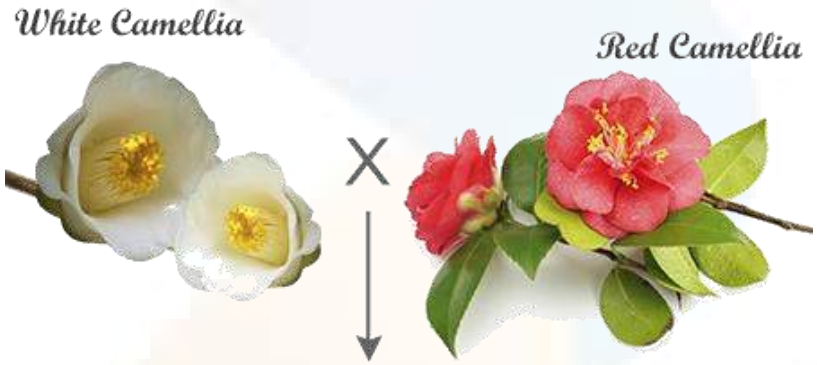
♀ \ ♂	R	W
R	RR (Red)	RW (Roan)
W	RW (Roan)	WW (White)

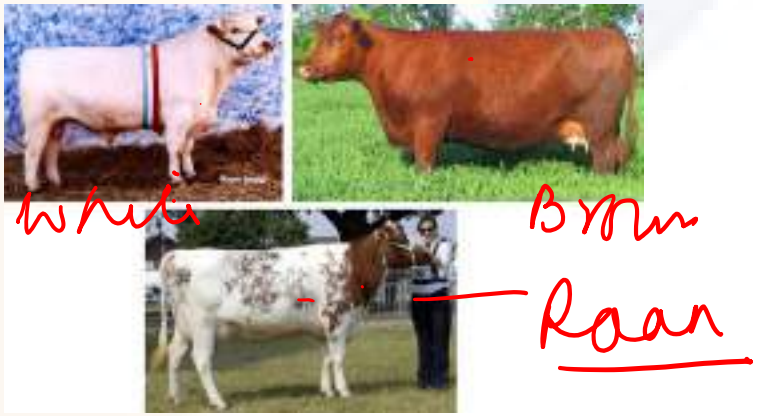
Phenotypic ratio 1 : 2 : 1

Red Roan White

Genotypic ratio 1 : 2 : 1

RR RW WW

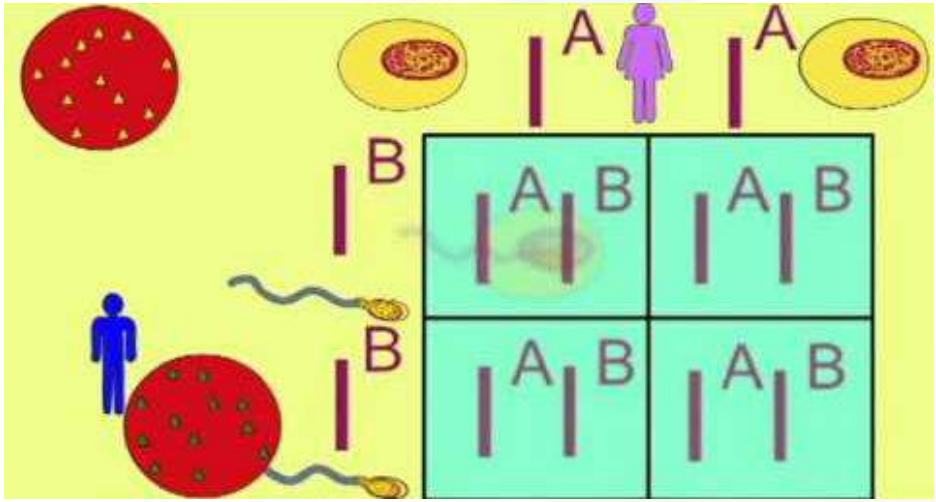




Multiple Allele and Codominance in ABO Blood group

- More than 2 alternative forms of a gene are called **as multiple allele** located on same locus of homologous chromosome. Ex: Human Blood group - 3 alleles (I^A, I^B, I^o).

Blood Group	Antigen on surface of RBC	Antibody in Plasma	Genotype (Alleles)	Can donate Blood to	Can Receive Blood from
A	A	B	$I^A I^A$, $I^A I^o$	A and AB	A and O
B	B	a	$I^B I^B$, $I^B I^o$	B and AB	B and O
AB	A, B both	Nill	I^A, I^B	AB	A, B and O
O	Nill	a, b both	I^o, I^o	A, B, AB, O	O



I^A = dominant

I^B= dominant

I° = recessive

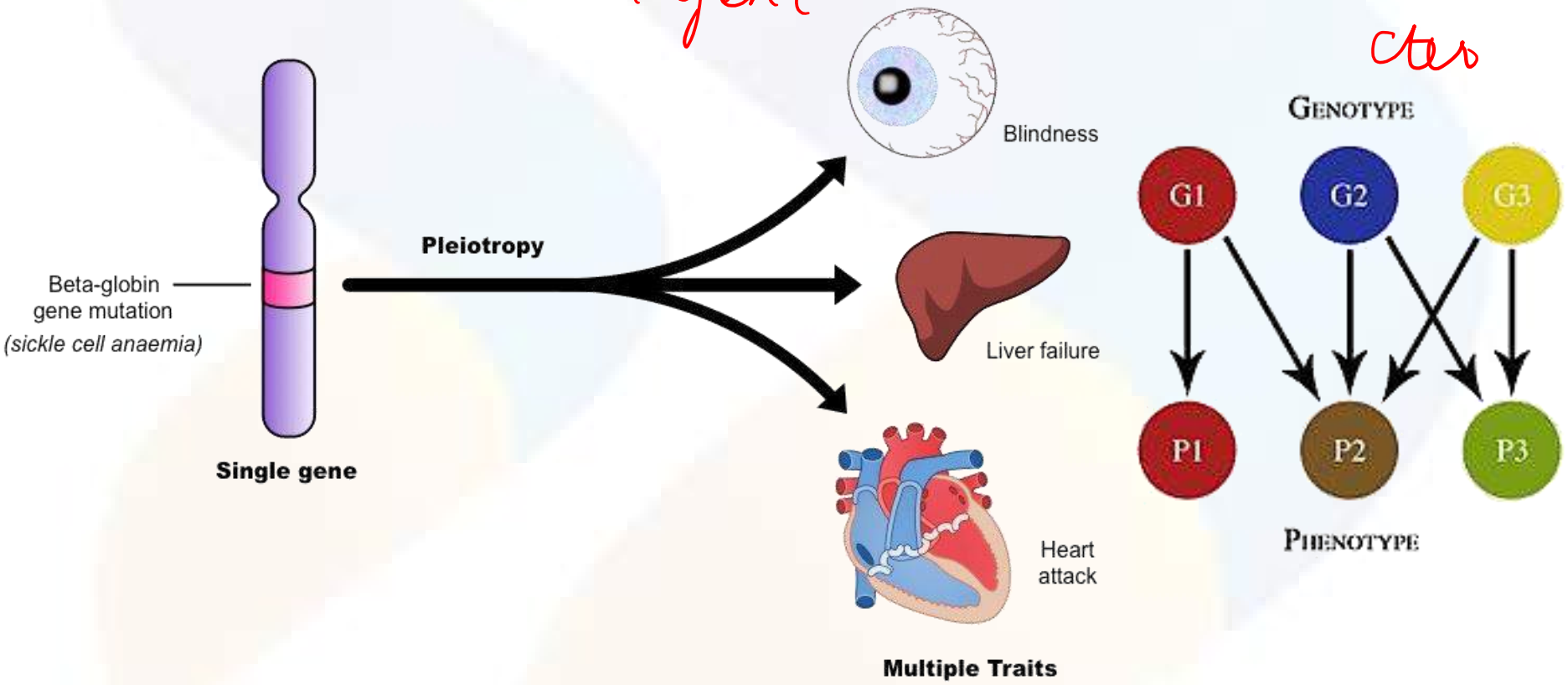
I^A & I^B = codominant

Universal Donor: Person with blood group O.
Universal acceptor: person with blood group AB

Exceptions of Principle of Dominance - Pleiotropy

❖ Pleiotropy

- Pleiotropy occurs when one gene regulates more then one unrelated phenotypic trait.
  Ex: **sickle cell anemia**.



- Gametes are always pure for a character hence it is also called '**law of purity of gametes**'. (by Bateson)

PLEIOTROPY

Single gene

Influences

More than one phenotypic trait

Gene expression

Example

Cystic fibrosis

Sickle-cell disease

Phenylketonuria (PKU)

imp

NEET *

Metabolism of Phenylalanine

In a person without PKU :

Phenylalanine → (**Phenylalanine hydroxylase**) → **Tyrosine**

In a person with PKU :

Phenylalanine

Phenylalanine

Phenylalanine

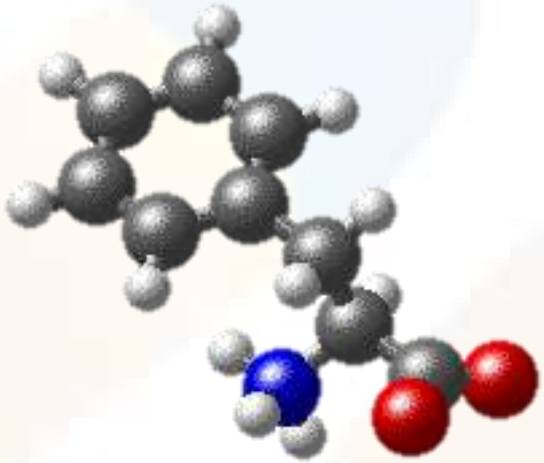
No phenylalanine hydroxylase → **X**

~~**Phenylpyruvate**~~

Build–up phenylalanine to toxic levels

PHENYLKETONURIA

PKU is a very rare condition in which a baby is born and does not have the ability to break down the amino acid called phenylalanine.



PKU is an autosomal recessive trait.

simple Pedigree analysis

Pleiotropy (Sickle Cell Anemia)

Shape of haemoglobin molecule is controlled by two alleles.

- Normal haemoglobin allele (Hb^N)
- Sickle cell haemoglobin allele (Hb^S)

Genotype	Phenotype
Hb^NHb^N	Normal Hemoglobin
Hb^NHb^S	Sickle cell trait
Hb^SHb^S	Sickle cell anaemia

Phenotypes	Sickle cell trait	x	Sickle cell trait
Genotypes	Hb^NHb^S		Hb^NHb^S
Gametes	Hb^N Hb^S		Hb^N Hb^S

	Hb^N	Hb^S
Hb^N	Hb^NHb^N	Hb^NHb^S
Hb^S	Hb^NHb^S	Hb^SHb^S

Offspring	Normal	Sickle cell trait	Sickle cell anaemia
Proportion	25%	50%	25%

Hb
$2\alpha + 2\beta$
$1\beta \rightarrow$ point mutation
Sickle cell anaemia
Str of Hb changes
change in shape of RBC

Epistasis

Bateson describe this epistasis effect in 1909.

An interaction between a pair of loci in which the phenotype effect of one locus depends on the genotype at the second locus.

Epistasis is the phenomenon of the effect of one gene (locus) being dependent on the presence of one or more "modifier genes".

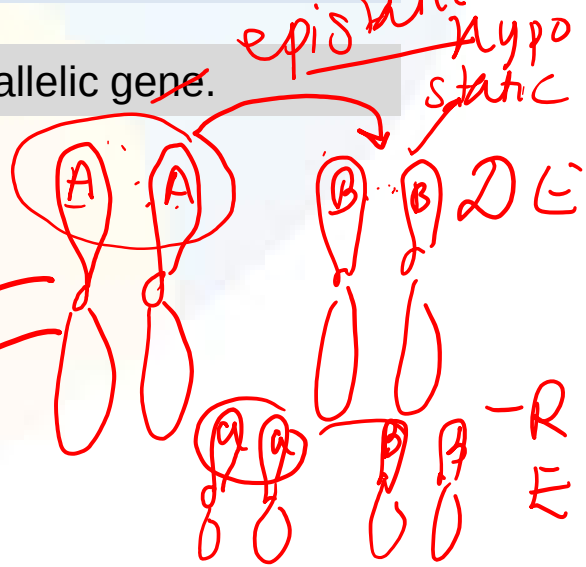
Epistatic Gene: a gene is said to be epistatic when its presence suppress the effect of gene at another locus.

The gene whose effect is suppresses by epistatic gene are known as **hypostatic**.

Dominance involve intra allelic gene while epistasis involve interallelic gene.

Phenotypic ration in various types of epistasis

1. **Dominant epistasis** (12:3:1)
2. **Recessive epistasis** (9:3:4) supplementary interaction
3. **Duplicate recessive genes** (9:7) complementary genes
4. **Duplicate dominant genes** (15:1) Pseudo alleles
5. **Duplicate genes with cumulative effect** (9:6:1)
6. **Dominant Recessive interaction** (13:3)



Various types of Genes

Complementary genes are the genes which are present on different genetic loci but interact with each other to express a single character in combination.

Supplementary genes are the genes which include two pairs of non-allelic genes. Both of them are involved in affecting the same character. Out of the non-allelic genes, one gene is dominant and can express by itself. Second gene is also dominant but expresses only when it is supported by the presence of the first gene.

Duplicate genes: Two identical **genes** showing the same phenotypic action but localized in different regions of a chromosome or on different chromosomes.

Pleiotropy occurs when one **gene** influences two or more seemingly unrelated phenotypic traits.

An example of pleiotropy is phenylketonuria, an inherited disorder that affects the level of phenylalanine in the human body. This disease can also cause mental retardation, reduced hair and skin pigmentation.

Gene interactions: the **collaborative** efforts of two or more **genes** in. specifying the phenotype for a specific trait.

"**Jumping genes** or **transposons"**, are sequences of DNA that move (or jump) from one location in the genome to another.

SpeedLabs
Practice with experts

Dominant Epistasis

eg flower colour in Summer squash
(cucurbita pepo)

epi - W, hy - Y → 12 : 3 : 1

W Y green

Supplementary Gene

One gene express, other gene - no expression

Both → Third character → B - Black
A - Albino
AB - Agouti
ab - Albino

eg coat colour in Mice

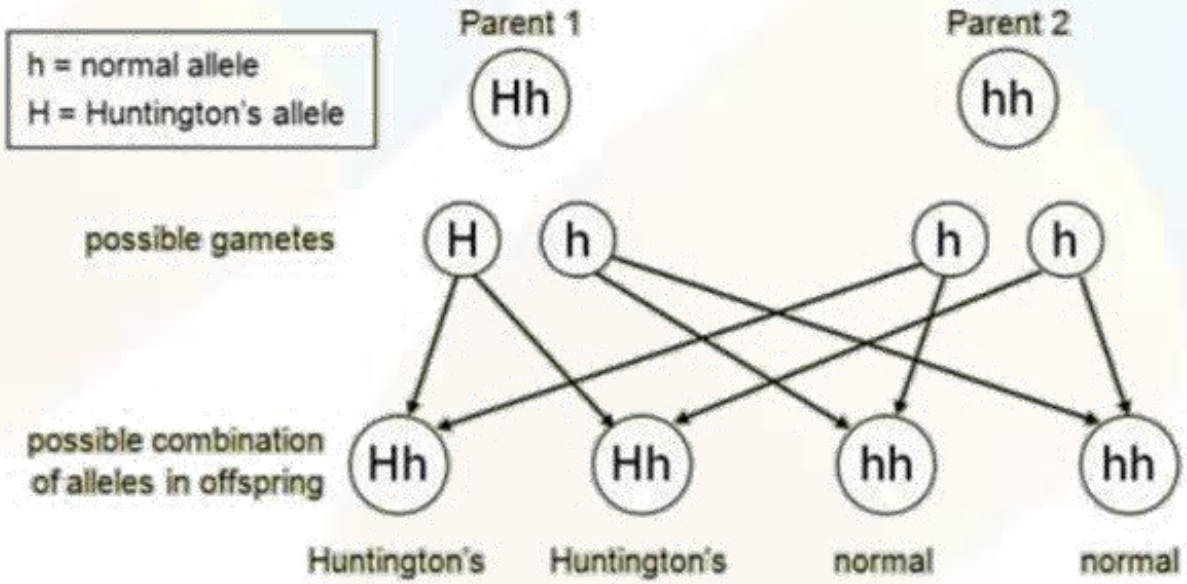
9 : 3 : 4
↓ ↓ ↓
Agouti Black Albino

Lethal Gene Effect

Lethal genes cause the death of the organism that carries them. They are usually a result of mutations in **genes** that are essential to growth or development.

Some lethal genes cause the death of the zygote or early embryonic stage while some express their effect in later stage of development.

Lethal alleles are dominant or recessive. Fully dominant lethal allele kills the organism in both homozygous and heterozygous condition.



Trihybrid Cross

3 characters at a time

Each gamete must have ONE COPY OF EACH GENE.

Genes segregate randomly and according to law of Independent assortment.

Genotype of gametes produced by each parent is according to 2^n.

Breakdown multi-hybrid crosses into a series of monohybrid crosses.

Multiply the individual ratios to get final ratio.

AABBCC x aabbcc

AaBbCc	ABC	ABc	AbC	aBC	Abc	aBc	abC	abc
ABC	AABBCC	AABBCc	AABbCC	AaBBCC	AABbCc	AaBBCc	AaBbCC	AaBbCc
ABc	AABBCc	AABBcc	AABbCc	AaBBCc	AaBbcc	AaBBcc	AaBbCc	AaBbcc
AbC	AABbCC	AABbCc	AAbbCC	AaBbCC	AAbbCc	AaBbCc	AabbCC	AabbCc
aBC	AaBBCC	AaBBCc	AaBbCC	aaBBCC	AaBbCc	aaBBCc	aaBbCC	aaBbCc
Abc	AABbCc	AABbcc	AAbbCc	AaBbCc	AAbbcc	AaBbcc	AabbCc	Aabbcc
aBc	AaBBCc	AaBBcc	AaBbCc	aaBBCc	AaBbcc	aaBBcc	aaBbCc	aaBbcc
abC	AaBbCC	AaBbCc	AabbCC	aaBbCC	AabbCc	aaBbCc	aabbCC	aabbCc
abc	AaBbCc	AaBbcc	AabbCc	aaBbCc	Aabbcc	aaBbcc	aabbCc	aabbcc

Generation of F_2 trihybrid phenotypes

A or a	B or b	C or c	Combined proportion
3/4 A	3/4 B	3/4 C	(3/4)(3/4)(3/4) ABC = 27/64 ABC
		1/4 c	(3/4)(3/4)(1/4) ABc = 9/64 ABc
	1/4 b	3/4 C	(3/4)(1/4)(3/4) AbC = 9/64 AbC
		1/4 c	(3/4)(1/4)(1/4) Abc = 3/64 Abc
1/4 a	3/4 B	3/4 C	(1/4)(3/4)(3/4) aBC = 9/64 aBC
		1/4 c	(1/4)(3/4)(1/4) aBc = 3/64 aBc
	1/4 b	3/4 C	(1/4)(1/4)(3/4) abC = 3/64 abC
		1/4 c	(1/4)(1/4)(1/4) abc = 1/64 abc

ABC

AbC

No of Genoty

$3^n = 9$

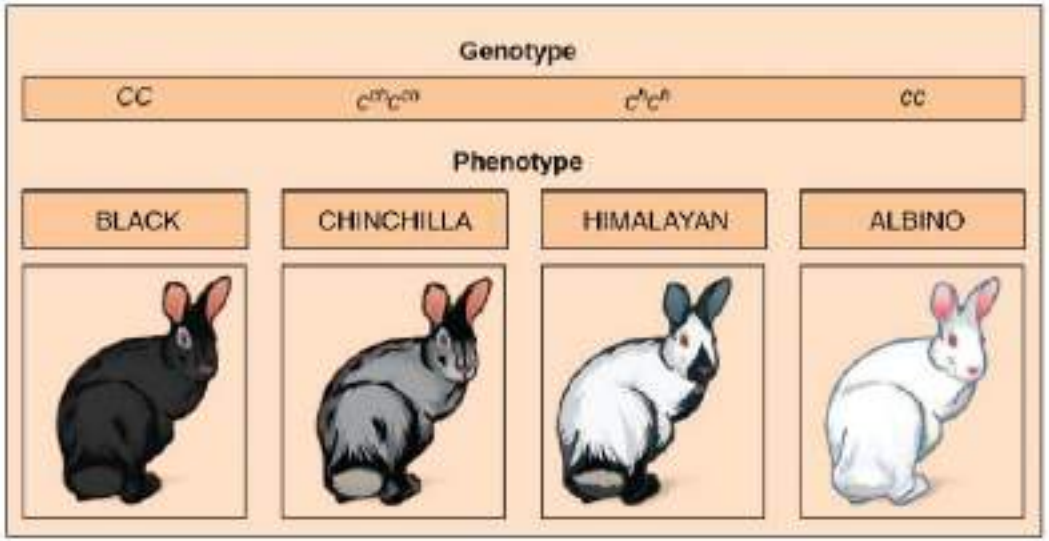
AaBbCc

2 : 8

Multiple Alleles

Coat color in rabbits, called the C gene. The C gene comes in four common alleles: C, c^{ch}, c^{h}, c.

A CC rabbit has black or brown fur
A c^{ch} c^{ch} rabbit has chinchilla coloration (grayish fur).
A c^{h} c^{h} rabbit has Himalayan (color-point) patterning, with a white body and dark ears, face, feet, and tail
A cc rabbit is albino, with a pure white coat.



	I^A	I^B	i
I^A	I^AI^A A	I^AI^B AB	I^Ai A
I^B	I^BI^A AB	I^BI^B B	I^Bi B
i	$i\,I^A$ A	$i\,I^B$ B	$i\,i$ O

Inheritance of ABO blood group system

Multiple Alleles: ABO Blood Groups

Blood Group (Phenotype)	Genotypes	Antibodies Present in Blood	Reaction When Blood from Groups Below Is Mixed with Antibodies from Groups at Left			
			O	A	B	AB
O	ii	Anti-A Anti-B				
A	$I^A I^A$ or $I^A i$	Anti-B				
B	$I^B I^B$ or $I^B i$	Anti-A				
AB	$I^A I^B$	—				

Inheritance of Kernel Colour in Wheat

Cross made by Nilsson-Ehle postulated three pair of genes controlling grain color in wheat.

Genes for red (ABC) dominates over genes of white (abc).

- Each of the three gene pairs when considered singly in crosses segregated in the expected Mendelian fashion producing F_2 progeny of 3 red and 1 white.
- When the genes were considered two at a time, F_2 segregated in the ratio 15 red to 1 white.
- All the three genes considered together produced an F_2 ratio of 63 red to 1 white, and segregated in a manner typical for a Mendelian tri-hybrid cross.

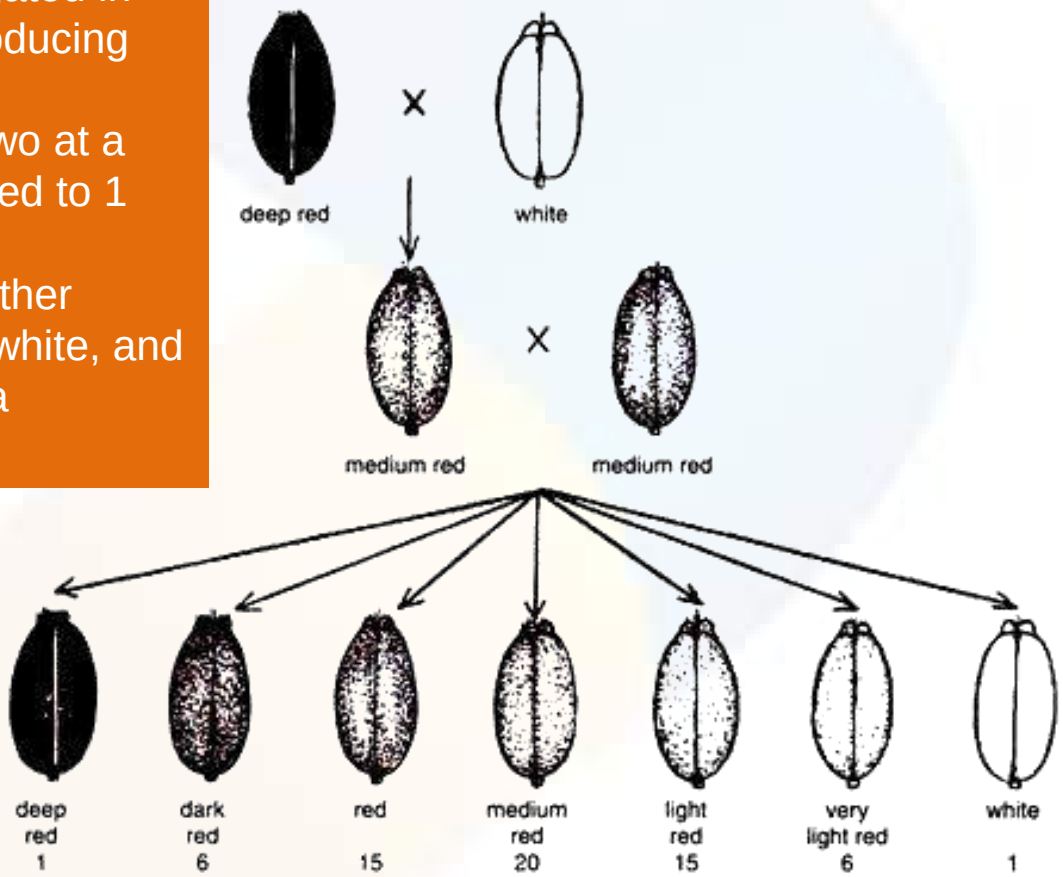


Fig. 4.1 Cross made by Nilsson-Ehle between red and white varieties of wheat.

Importance of Mendelism

- The inheritance of some characters is governed by mitochondrial DNA. The examples of mitochondrial inheritance include cytoplasmic male sterility in plants, pokiness in Neurospora, petite in yeast, etc.
- There are three types of male sterility in crop plants, viz, genetic (controlled by nuclear genes), cytoplasmic (controlled by plasma genes) and cytoplasmic genetic (controlled by both nuclear and plasma genes). The cytoplasmic male sterility is controlled by plasma genes associated with mtDNA or cpDNA .
- In other words, in maize cytoplasmic sterility is governed by mitochondrial DNA. Cytoplasmic sterility is found in several other crop plants, viz., pearl millet, Sorghum, cotton, etc.
- In certain other cases, although male sterility is wholly controlled by cytoplasm, but a restorer gene, if gene if present in the nucleus will restore fertility.
- For instance, if female parent is male sterile, then genotype (nucleus) of male parent will determine the phenotype of F_1 progeny.
- The male sterile female parent will have the recessive genotype (rr) with respect to restorer gene. If male parent is RR, F_1 progeny would be fertile (Rr).
- On the other hand, if male parent is rr, the progeny would be male sterile.
- If F_1 individual (Rr) is testcrossed , 50% fertile and 50% male sterile progeny would be obtained

Polygenic inheritance

- When one phenotypic character is controlled by more than one gene, it is called **polygenic inheritance**
- **Kolerenter** is known as father of polygenic inheritance
- It is also called **Quantitative inheritance**
- The quantity of inheritance depends on dominant alleles
- Dominant alleles have **cumulative effect** each expressing part of trait
- Gene involved in quantitative inheritance is known as **polygenes**
- Polygenic inheritance don't follow the **mendelian ratio**
- Eg; **skin color of man, wheat kernel colour**
- when 2 polygene are considered - **1:4:6:4:1**
- when 3 polygene are considered- **1:6:15:20:15:6:**
- It was first studied by **Devenport** (1913) in case of Negro- Europeian intermarriage.

Inheritance of Skin colour in man - 1

- Skin colour is due to pigment melanin. **More pigment, darker is the colour.**
- There are **three genes (polygene)** controlling the production of melanin,
- But, for convenience we consider only **two pair of genes.**
- For **Negro** :AABB (maximum melanin)
- For **Albino** :aabb (minimum melanin)

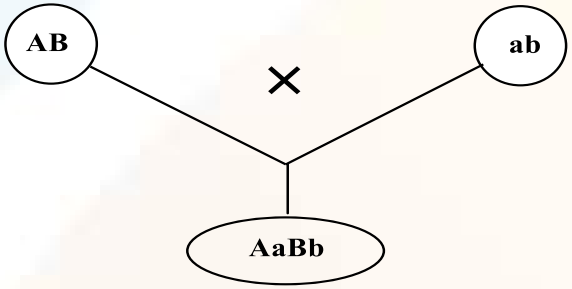
A, B, C control Skin colour

Negro (high melanin)
AABB

- **Parents-**

Albino (no melanin)
aabb

- **Gametes-**



- **F_1--**

Inheritance of Skin colour in man - 2

F2-

Gametes- AB Ab aB ab

♀ \ ♂	AB	Ab	aB	ab
AB	AA BB (Negro)	AA Bb (Dark)	Aa BB (Dark)	Aa Bb (Mulleto)
Ab	AA Bb (Dark)	Aa bb (Mulleto)	Aa Bb (Mulleto)	Aa bb (Fair)
aB	Aa BB (Dark)	Aa Bb (Mulleto)	aa BB (Mulleto)	aa Bb (Fair)
ab	Aa Bb (Mulleto)	Aa bb (Fair)	aa Bb (Fair)	aa bb (Albino)

Albino

aabb

Fair

aaBb, Aabb

Mulleto

Aabb, AaBb, aaBB

Dark

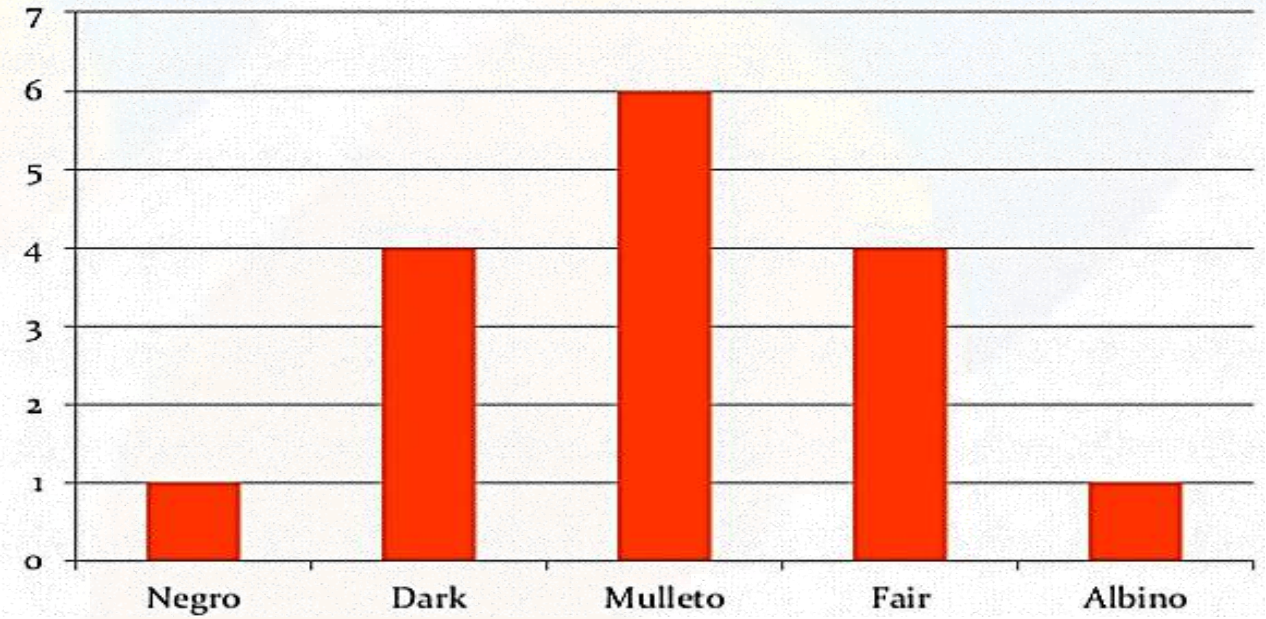
AaBB, AABB

Negro

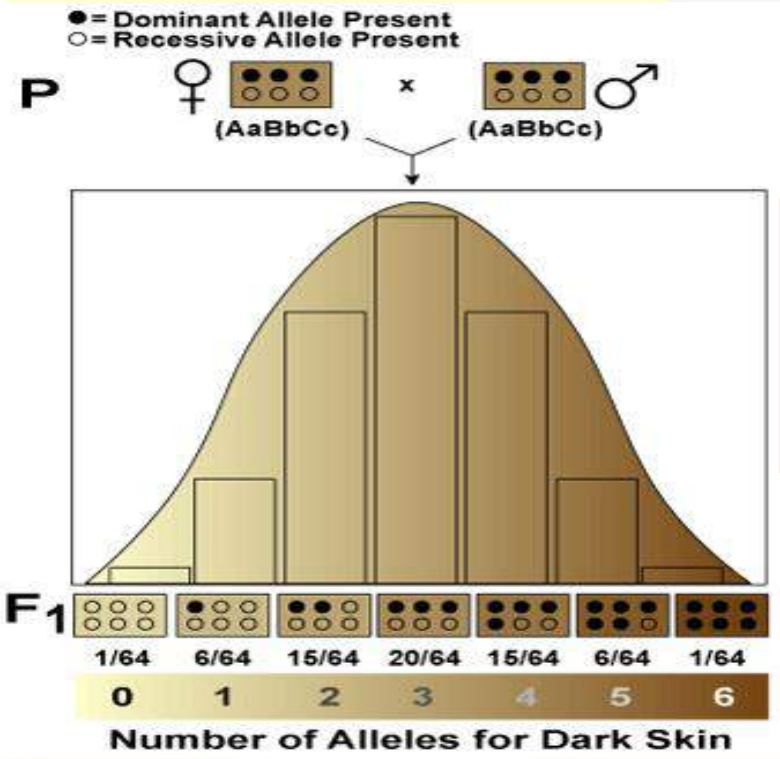
AABB

F_2 Ratio- 1:4:6:4:1 (Skin color)

Number of Dominant all	Phenotype	Ratio
No of dominant alleles	Albino	1/16
One dominant alleles	Fair	4/16
Two dominant alleles	Mulleto	6/16
Three dominant alleles	Dark	4/16
Four dominant alleles	Negro	1/1



SKIN COLOUR IN MAN



In this manner the number of each type of alleles in the genotype would determine the degree of darkness or lightness of the skin in an individual.

Polygenic (Quantitative Inheritance)

No melanin ← Medium melanin → Black (max melanin)

Phenotypic ratio :
1:6:15:20:15:6:1

6D – Black
5D – V. Dark
4D – Dark
3D – Intermediate
2D – Fair
1D – Very fair
0D – Albino

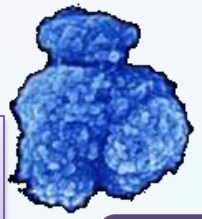
sperm

Gametes	ABC	ABC	AbC	Abc	aBC	aBc	abC	abc
F2 generation ABC	6	5	5	4	5	4	4	3
ABC	5	4	4	3	4	3	3	2
AbC	5	4	4	3	4	3	3	2
eggs Abc	4	3	3	2	3	2	2	1
aBC	5	4	4	3	4	3	3	2
aBC	4	3	3	2	3	2	2	1
abC	4	3	3	2	3	2	2	1
abc	3	2	2	1	2	1	1	0

SEX LINKED GENES

X – linked genes

Genes located on the X-chromosome



Genes located on the Y-chromosome

Y–linked genes

These alleles are absent on the X-chromosome

Completely sex–linked genes

These alleles are ab c

X –linked and Y –linked genes do not undergo pairing or crossing over during meiosis.

→ ANEUT

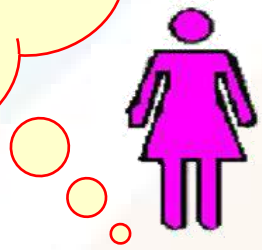
SEX LINKED GENES

X – linked genes

Females have homozygous or heterozygous alleles.

Y–linked genes

Males have hemizygous alleles.



Female

Male

XY-LINKED GENES

These genes are located on the homologous segments of the X and Y-chromosomes.

The regions undergo pairing and crossing over.

pseudo autosomal regions

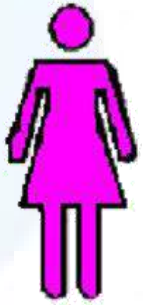
Incompletely sex–linked genes

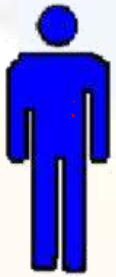
X-LINKED RECESSIVE INHERITANCE

Is a mode of inheritance in which a mutation in a gene on the X-chromosome causes the phenotype to be expressed in males and females.

X-LINKED RECESSIVE INHERITANCE

XX XY

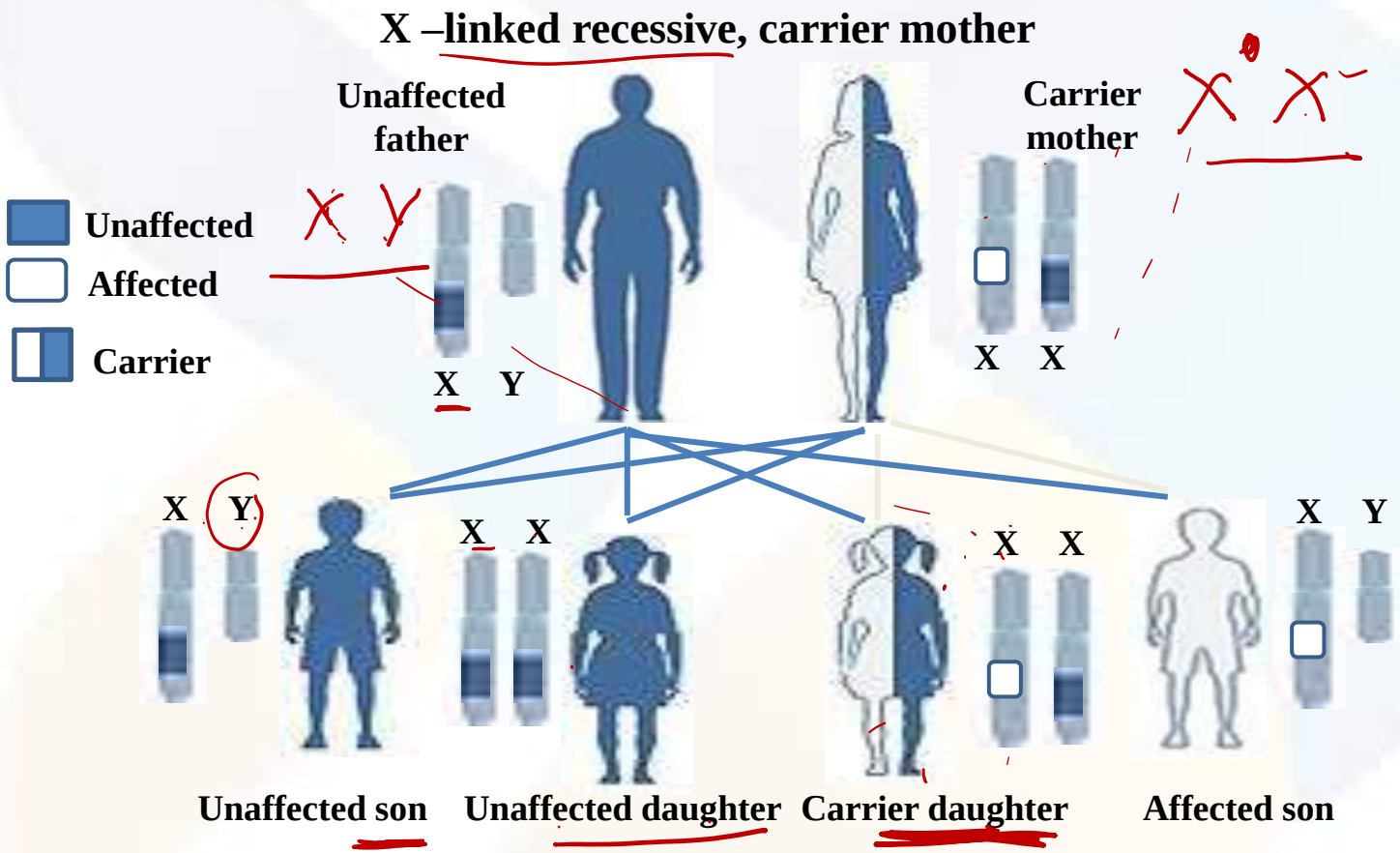




Affected male gets the allele from their mother.

X-LINKED RECESSIVE INHERITANCE

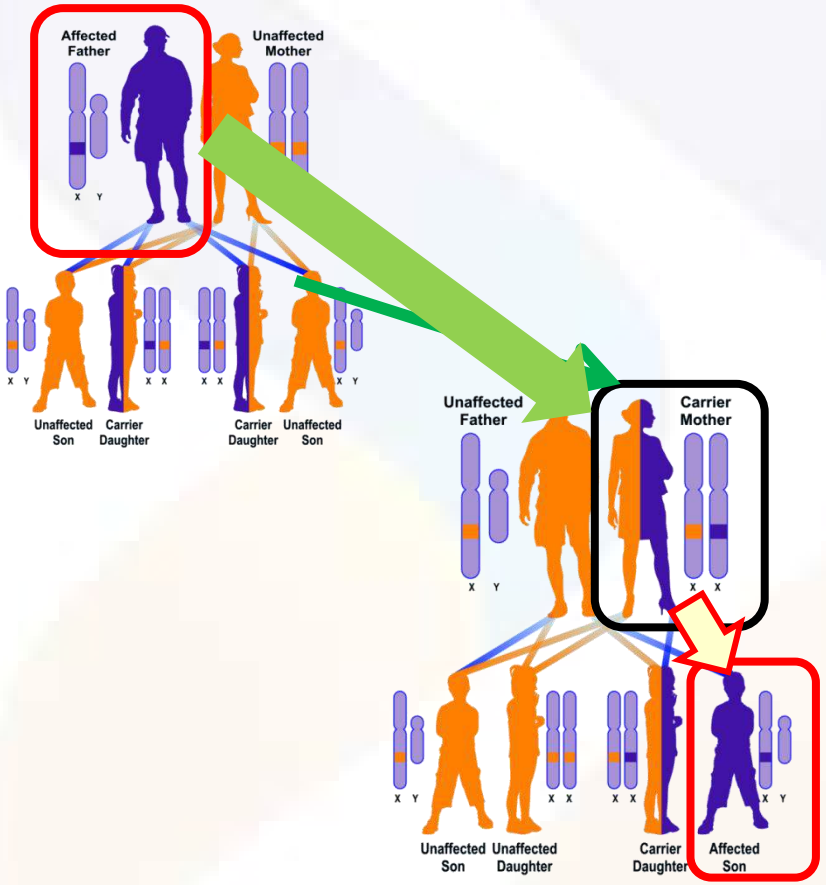
- If a female is homozygous affected, all her sons are affected.
- All affected females have an affected father and a carrier or affected mother.
- X-linked recessive traits are typically passed on from an affected father to 50 percent of his grandsons through carrier daughter.


X –linked recessive, carrier mother
Unaffected father
Carrier mother
Unaffected
Affected
Carrier
X Y
X X
X Y
X X
X X
X Y
Unaffected son
Unaffected daughter
Carrier daughter
Affected son

Sex-Linked Traits

- Sex-linked traits are caused by genes found on the X chromosome.
- Sex-linked traits are recessive.
- Fewer females are afflicted with these traits because they have two X chromosomes and the other is usually normal.
- Males only have one X chromosome, so when they inherit the sex-linked gene, they display the trait.
- Examples: color-blindness, haemophilia

XX	XX-	X-X-	XY	X-Y
Normal female	Carrier female	Afflicted female	Normal male	Afflicted male



P ♂ → F1 ♀ → F2 ♂

P ♀ → F1 ♂ → F2 ♀

Criss cross inheritance

Color blind father

Transmits disease

Daughter

Grandson

Carrier daughters

Haemophilia & colour blindness follow criss cross inheri-

X linked Recessive

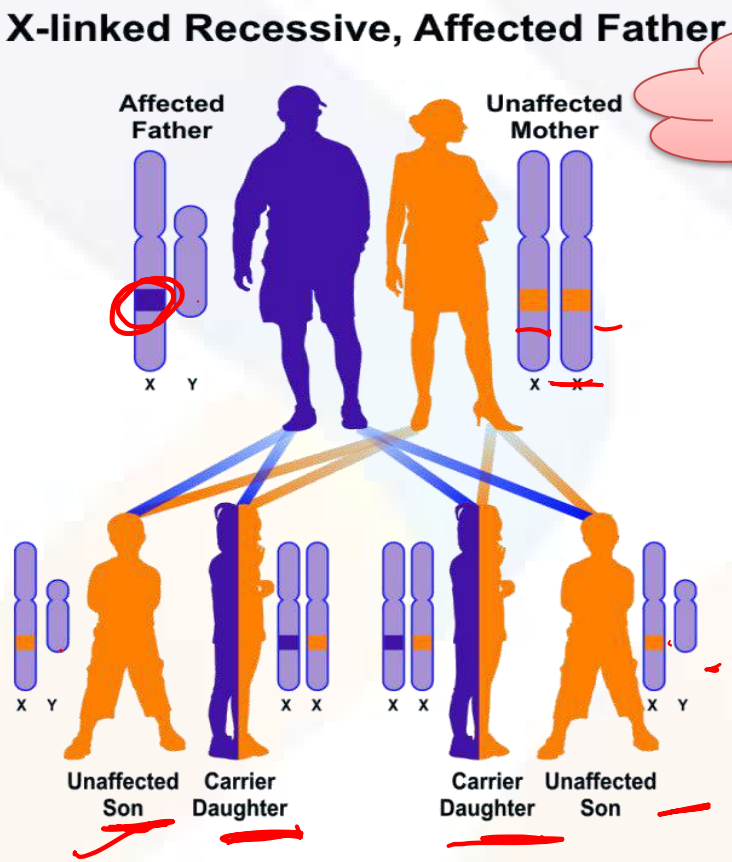
Colour blindness

When a woman with normal vision marries a colour-blind man, all the sons and daughters are normal, but all daughters are carriers.

Homozygous

If a carrier woman marries a man with normal vision, all the daughters and half of the sons have normal vision and another half of the sons are colour-blind.

Heterozygous



All offspring with normal vision

100%

Normal males

100%

Carrier females