UNIT - I

Genetic, Plant breeding, evolution and boistatistics

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Coimbatore - 18

Gregor Mendel (1822-1884)

Responsible for the Laws governing Inheritance of Traits

1822 - Brunn in Austria, now, Brno (Czecholovakia)

Financial and Health Problem

Unable to continue studies

Joined St.Augustinian Monastery

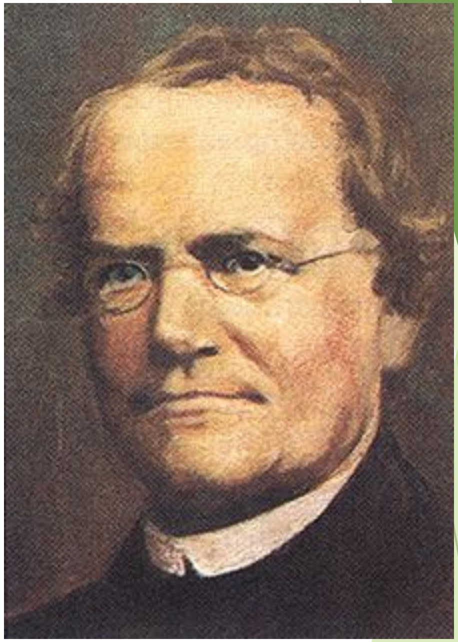
1847 - Priest

1851 - Higher studies at Vienna University

1854- Science teacher

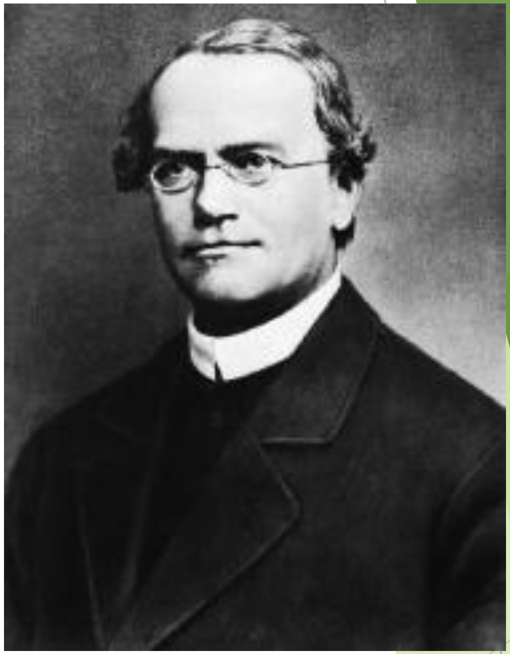
Gregor Johann Mendel

- Between 1856 and 1863, Mendel cultivated and tested some 28,000 pea plants
- He found that the plants' offspring retained traits of the parents



Gregor Johann Mendel

- Austrian monk
- Developed the laws of inheritance
- Presented his findings in the Natural History Society of Brunn - 1865
- Paper entitled, "Experiments in Plant Hybridization" - 1866
- German language.



- Mendel's work was not recognized until the turn of the 20th century
- 1900 - Carl Correns, Hugo deVries, and Erich von Tschermak rediscover and confirm

(a) Gregor Mendel (b) Carl Correns (c) Hugo de Vries (d) Eric von Tschermak

- Called the “Father of Genetics“

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

Particulate Inheritance

- 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 color
- **Dihybrid cross** - cross involving two traits
  e.g. flower color & plant height

Designer "Genes"

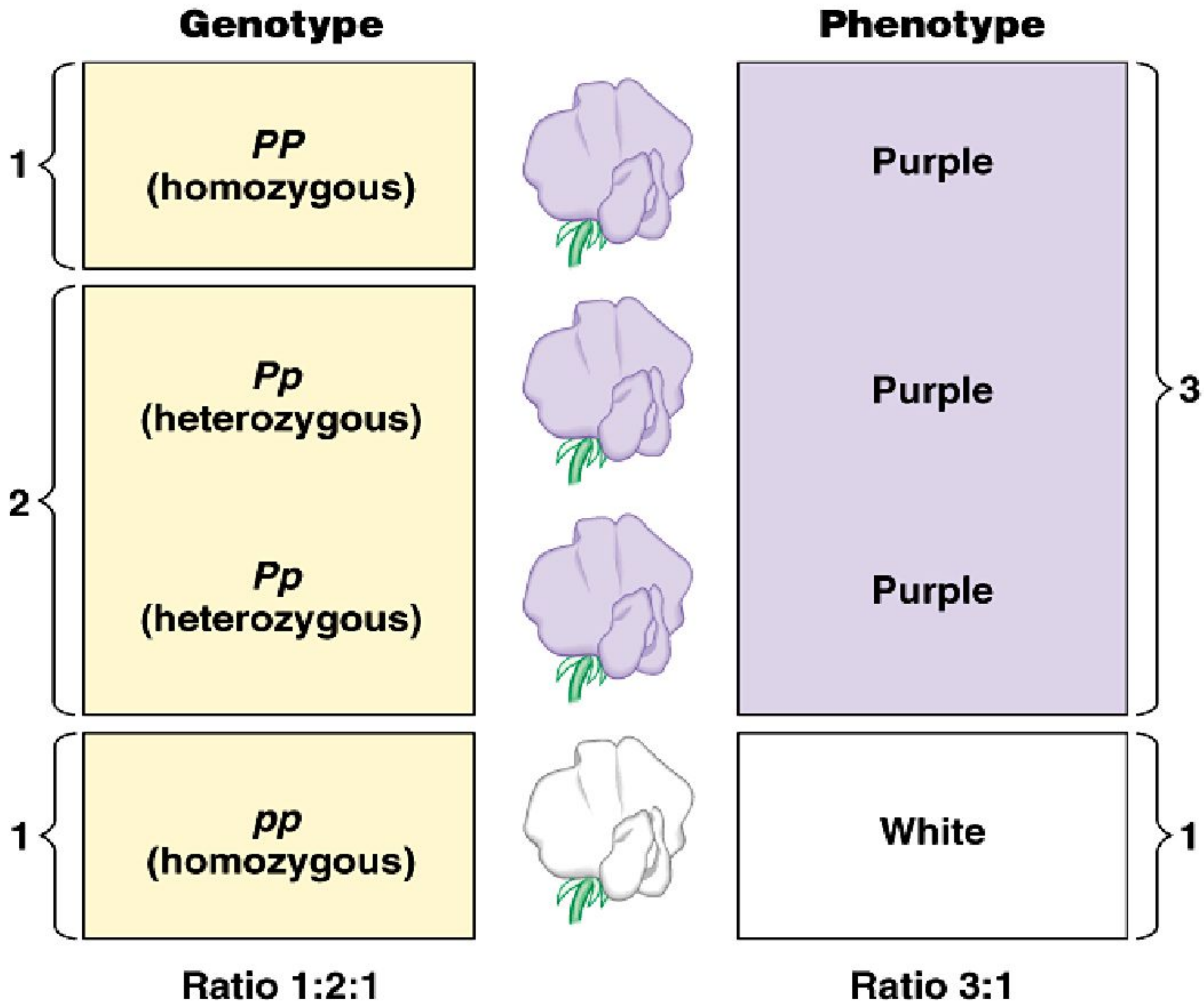
- **Alleles** - two forms of a gene (dominant & recessive)
- **Dominant** - stronger of two genes expressed in the hybrid; represented by a capital letter (R)
- **Recessive** - gene that shows up less often in a cross; represented by a lowercase letter (r)

More Terminology

- **Genotype** - gene combination for a trait (e.g. RR, Rr, rr)
- **Phenotype** - the physical feature resulting from a genotype (e.g. red, white)

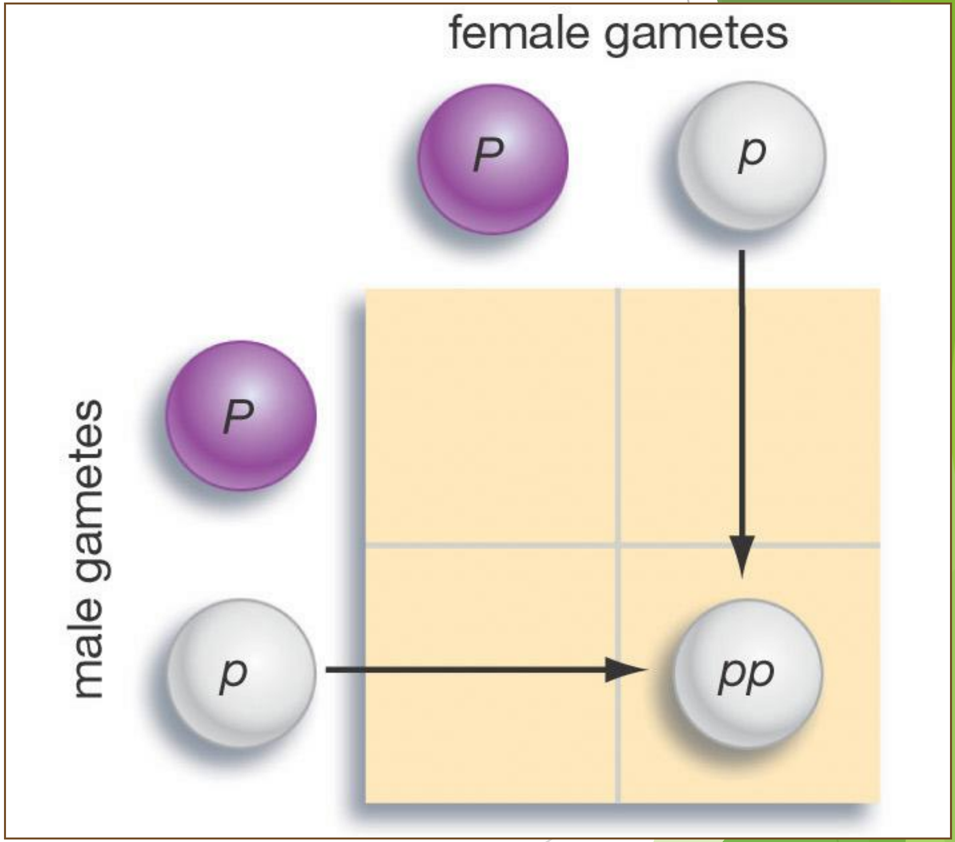
Genotypes

- **Homozygous** genotype - When the two alleles are same (dominant or 2 recessive genes) **e.g. TT or tt;** also called **pure**
- **Heterozygous** genotype - When the 2 alleles are different- one dominant & one recessive allele (**e.g. Tt);** also called **hybrid**


Genotype
Phenotype
1
PP
(homozygous)
Purple
2
Pp
(heterozygous)
Purple
3
Pp
(heterozygous)
Purple
1
pp
(homozygous)
White
1
Ratio 1:2:1
Ratio 3:1

Punnett Square

Used to help solve genetics problems



Mendel's Pea Plant Experiments

Why peas, *Pisum sativum*?

- 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
- Bisexual.
- Many traits known.
- Above all, easy to grow

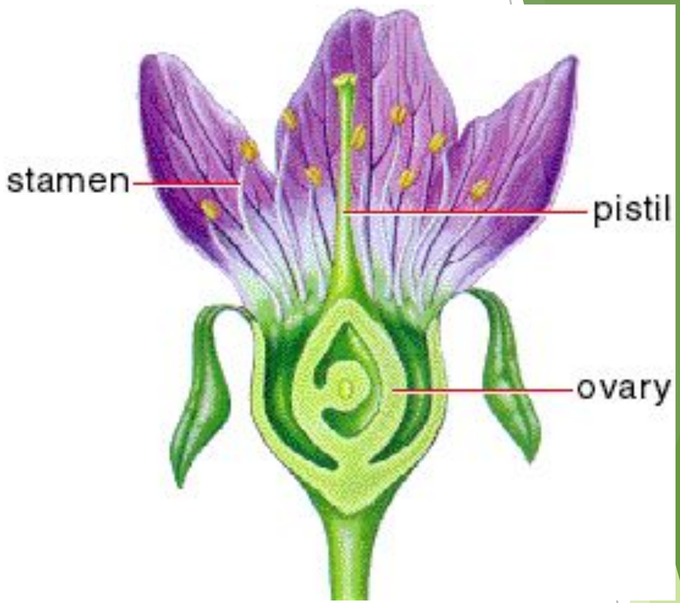
Reproduction in Flowering Plants

Pollen contains sperm

Produced by the stamen

Ovary contains eggs

Found inside the flower



Pollen carries sperm to the eggs for fertilization

Self-fertilization can occur in the same flower

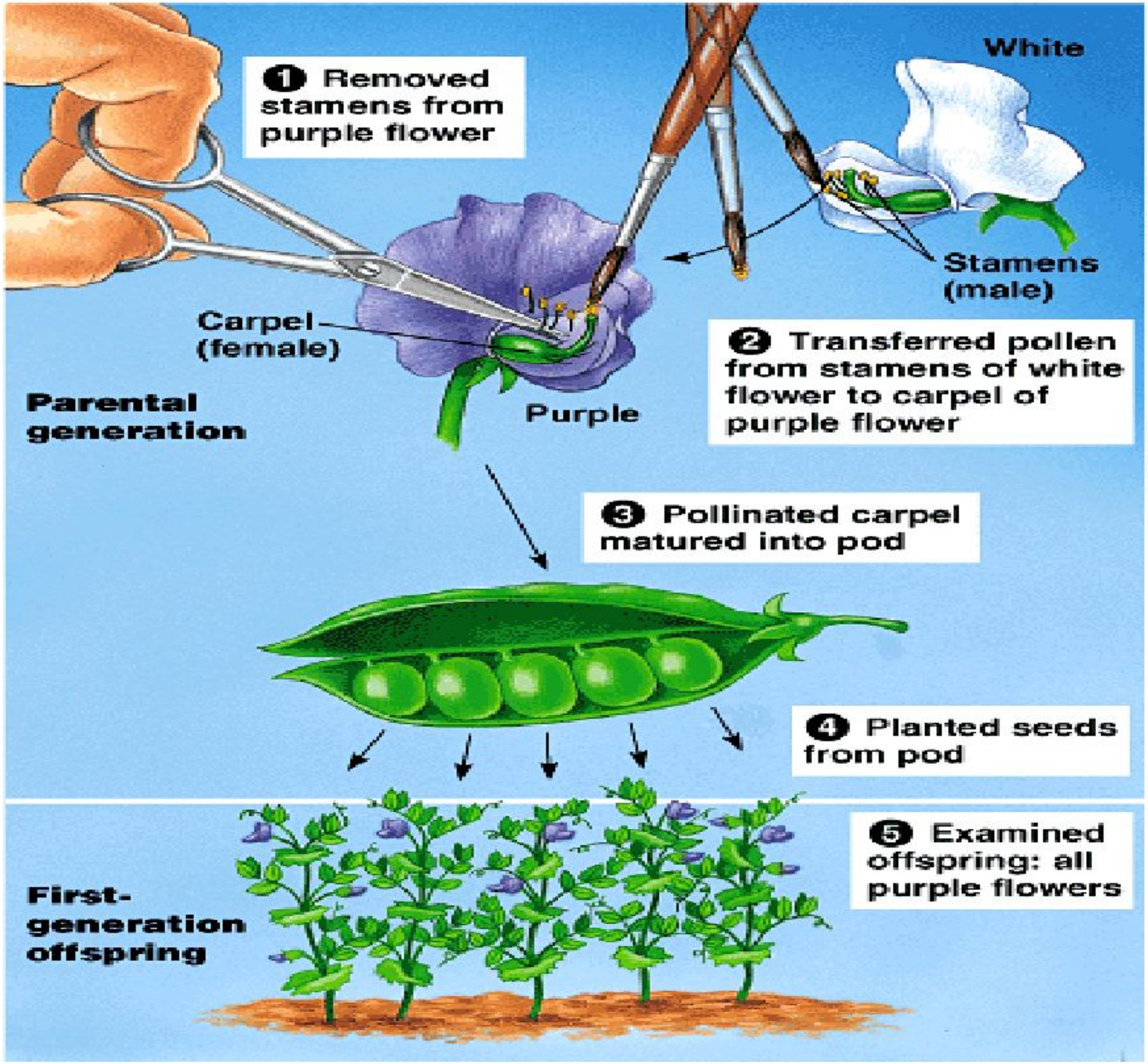
Cross-fertilization can occur between flowers

Mendel's Experimental Methods

Mendel hand-pollinated flowers using a paintbrush

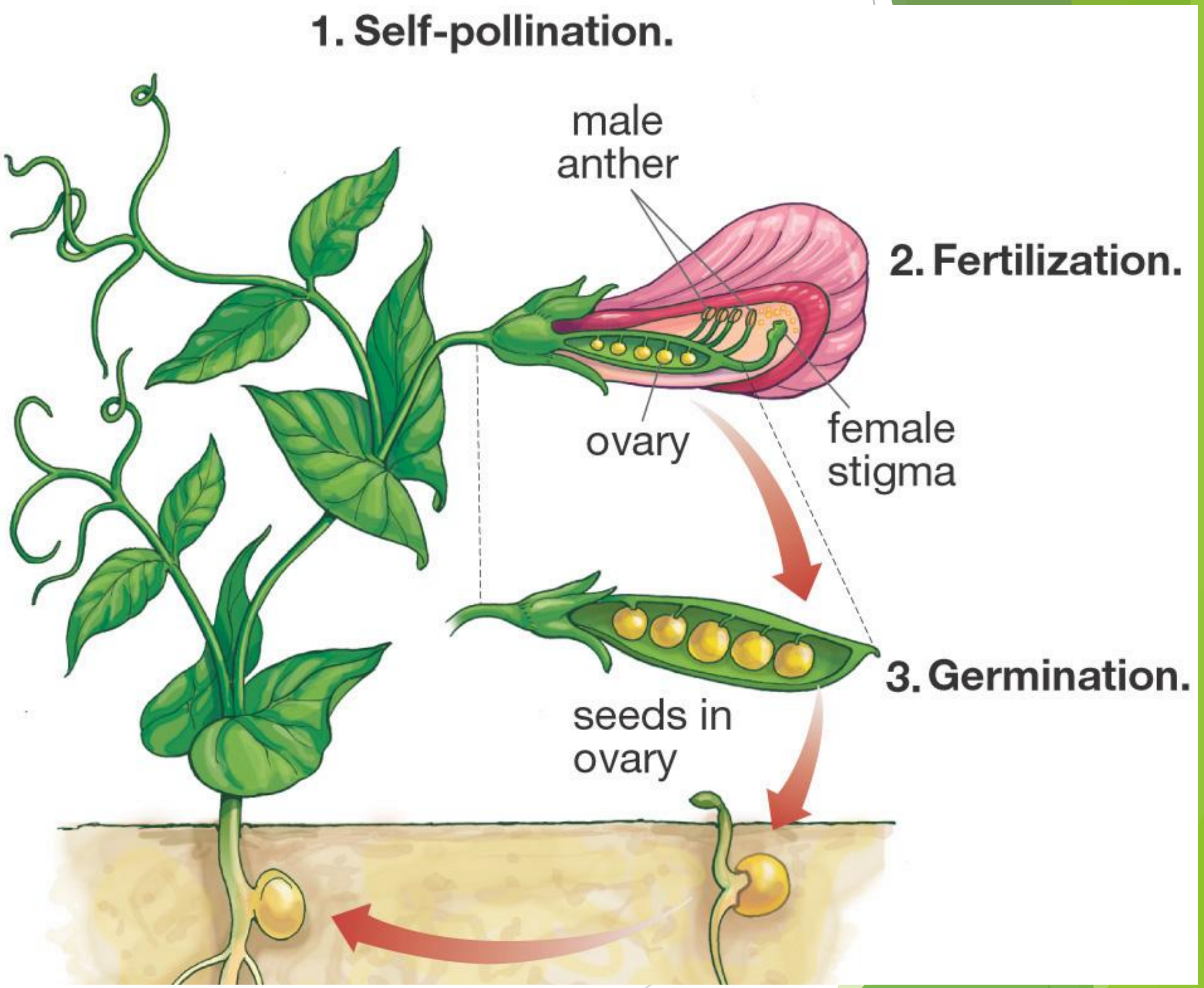
- He could snip (cut) the stamens to prevent self-pollination

He traced traits through the several generations


White
1 Removed stamens from purple flower
Stamens (male)
Carpel (female)
2 Transferred pollen from stamens of white flower to carpel of purple flower
Parental generation
Purple
3 Pollinated carpel matured into pod
4 Planted seeds from pod
5 Examined offspring: all purple flowers
First-generation offspring

How Mendel Began?

Mendel produced pure strains by allowing the plants to self-pollinate for several generations



Reasons for non recognition.

1. *Work was not published properly*

2. *Biologist did not accept*

3. *,factors.- discrete unit - now it called as genes*

4. *Popularity of Darwin during that period*

Reasons for the Success

1. Flowers of pea plants are normally self fertilized

2. Shows number of clear cut contrasting characters

3. Hybrids - perfectly fertile

4. Cross pollination - not difficult

5. Artificial pollination - successful

6. Seven pairs of characters located on seven separate homologous pairs of chromosomes

7. Easy to cultivate

8. Short growth period - short life cycle

9. Studied only one character inheritance at a time - complex become easy

10. Maintained statistical records - helps to derive numerical ratios of significance

Eight Pea Plant Traits

Plant Height --- Tall (T) or Short (t)

Seed shape --- Round (R) or Wrinkled (r)

Seed Color ---- Yellow (Y) or Green (y)

Seed Coat Color ---Gray (G) or White (g)

Pod Shape --- Smooth (S) or wrinkled (s)

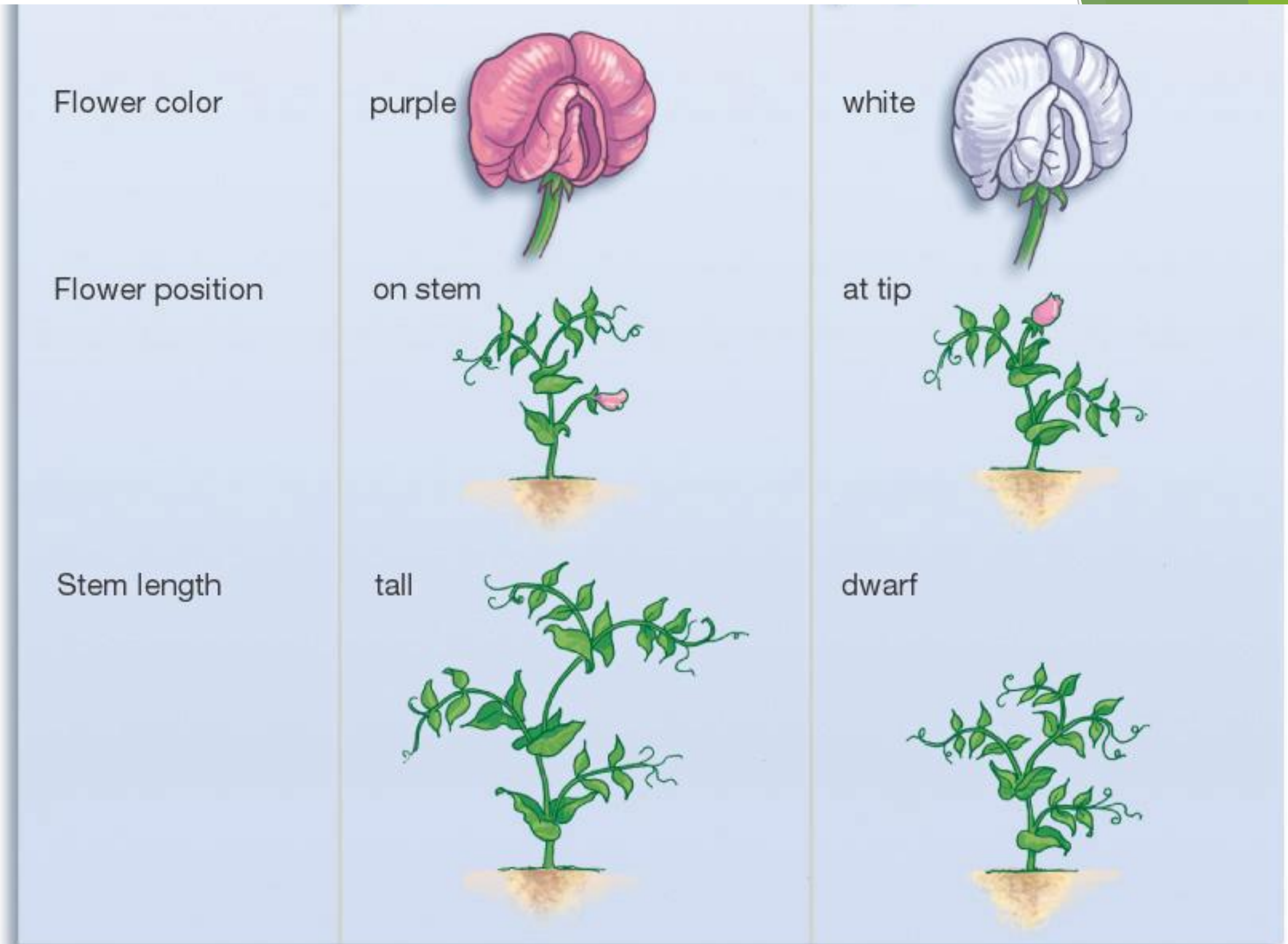
Pod Color --- Green (G) or Yellow (g)

Flower position---Axial (A) or Terminal (a)

Flower color --- Purple (P) or white (p)

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


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

Monohybrid Cross

P_1 Monohybrid Cross

Trait: Plant Height

Alleles: T- Tall   t - Dwarf

Cross: Tall Plants   x   Dwarf Plants

TT   x   tt

	t	t
T	Tr	Tt
T	Tt	Tt

Genotype: Tt

Phenotype: Tall

Genotypic Ratio: All alike

Phenotypic Ratio: All alike

P_1 Monohybrid Cross Review

- Homozygous dominant x Homozygous recessive
- Offspring all Heterozygous (hybrids)
- Offspring called F_1 generation
- Genotypic & Phenotypic ratio is ALL ALIKE

F_1 Monohybrid Cross

Trait: Plant Height

Alleles: T - Tall t - Dwarf

F1 Self Crossed: Tall x Tall

Tt x Tt

	T	t
T	TT	Tt
t	Tt	tt

Genotype: TT, Tt, tt

Phenotype: Tall & Dwarf

G.Ratio: 1:2:1

P.Ratio: 3:1

F_1 Monohybrid Cross Review

- Heterozygous x heterozygous
- Offspring:
  25% Homozygous dominant TT
  50% Heterozygous Tt
  25% Homozygous Recessive tt
- Offspring called F_2 generation
- Genotypic ratio is 1:2:1
- Phenotypic Ratio is 3:1

What Do the Peas Look Like?

Back Cross and Test Cross

Cross of F1 hybrid with any one of its parent is called Back Cross

Two types

1. Dominant Back Cross (TT x Tt)
2. Recessive Back Cross (tt x Tt)

Recessive back cross is otherwise called as Test Cross - to test the heterozygosity of the F1 plants

Mendel’s Laws

1. Law of Dominance
2. Law of Segregation
3. Law of Independent assortment

Law of Dominance

States that on crossing homozygous organisms for single pair of contrasting characters, only one characters make its appearance in F_1 generation and is name as Dominant character.

Law of Segregation

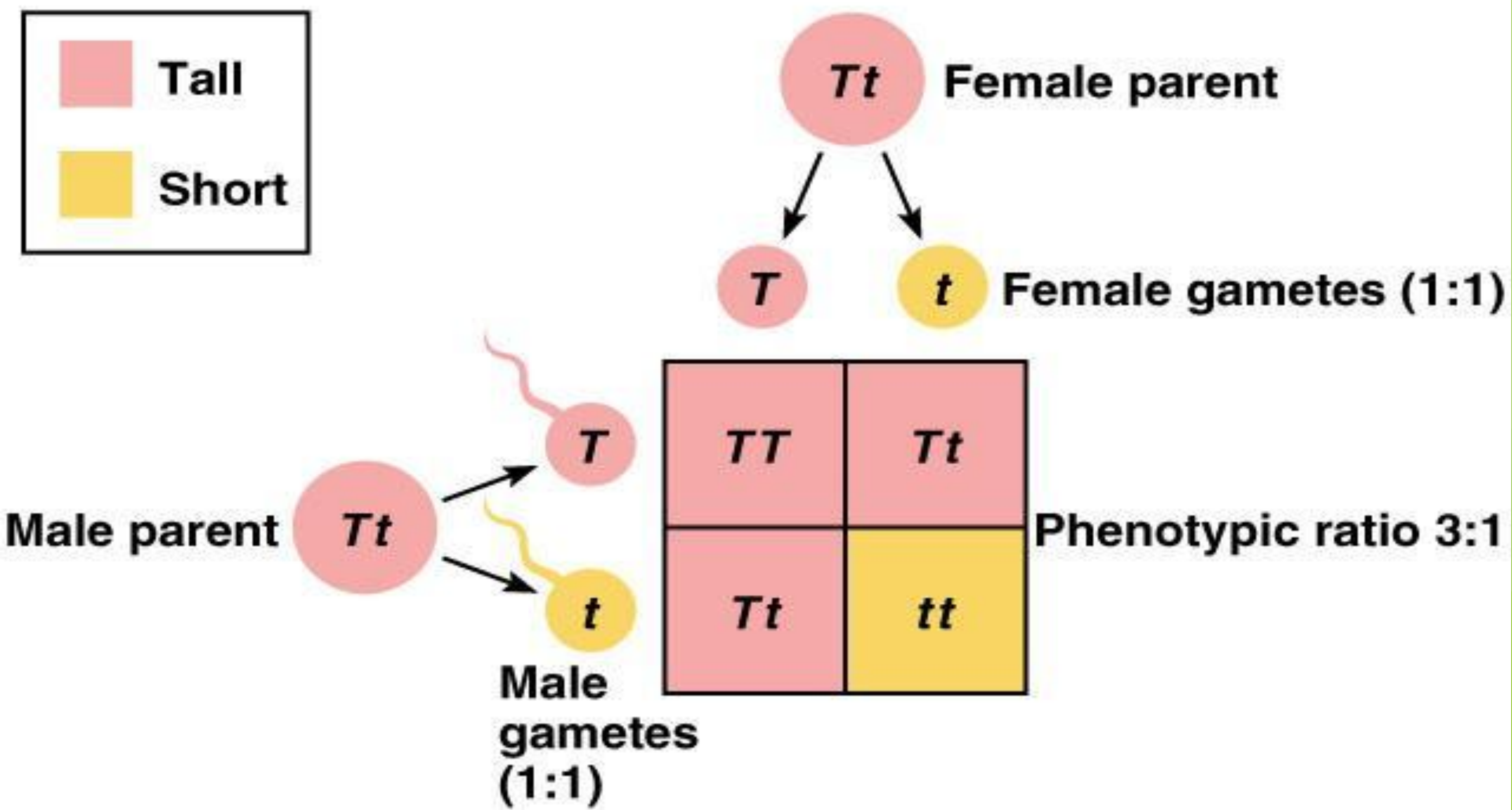
Two allele of a gene remain separate and do not contaminate each other when they are inside the organism. During gamete formation, the paired genes separate and enter into different gametes.

During gamete formation the genes of a particular character separate and enter into different gametes.

During the formation of gametes (eggs or sperm), the two alleles responsible for a trait separate from each other.

Alleles for a trait are then "recombined" at fertilization, producing the genotype for the traits of the offspring.

Applying the Law of Segregation



Law of Independent Assortment

Based on Dihybrid Cross

The genes for each characters separate independently from those of other characters during gamete formation.

During gamete formation the genes for yellow colour assort out independently of the genes for round shape

Dihybrid Cross

Traits: Seed shape & Seed color

Alleles: R-round Y-yellow
r-wrinkled y-green

Round Yellow x Green Wrinkled (P)

RRYY rryy

RY ry (G)

RrYy (F1)

Round Yellow

RrYy x RrYy (Selfing)

Round Yellow x Round Yellow

RY Ry rY ry

RY Ry rY ry

All possible gamete combinations

Dihybrid Cross

	RY	Ry	rY	ry
RY				
Ry				
rY				
ry				

Dihybrid Cross

	RY	Ry	rY	ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

Round/Yellow: 9

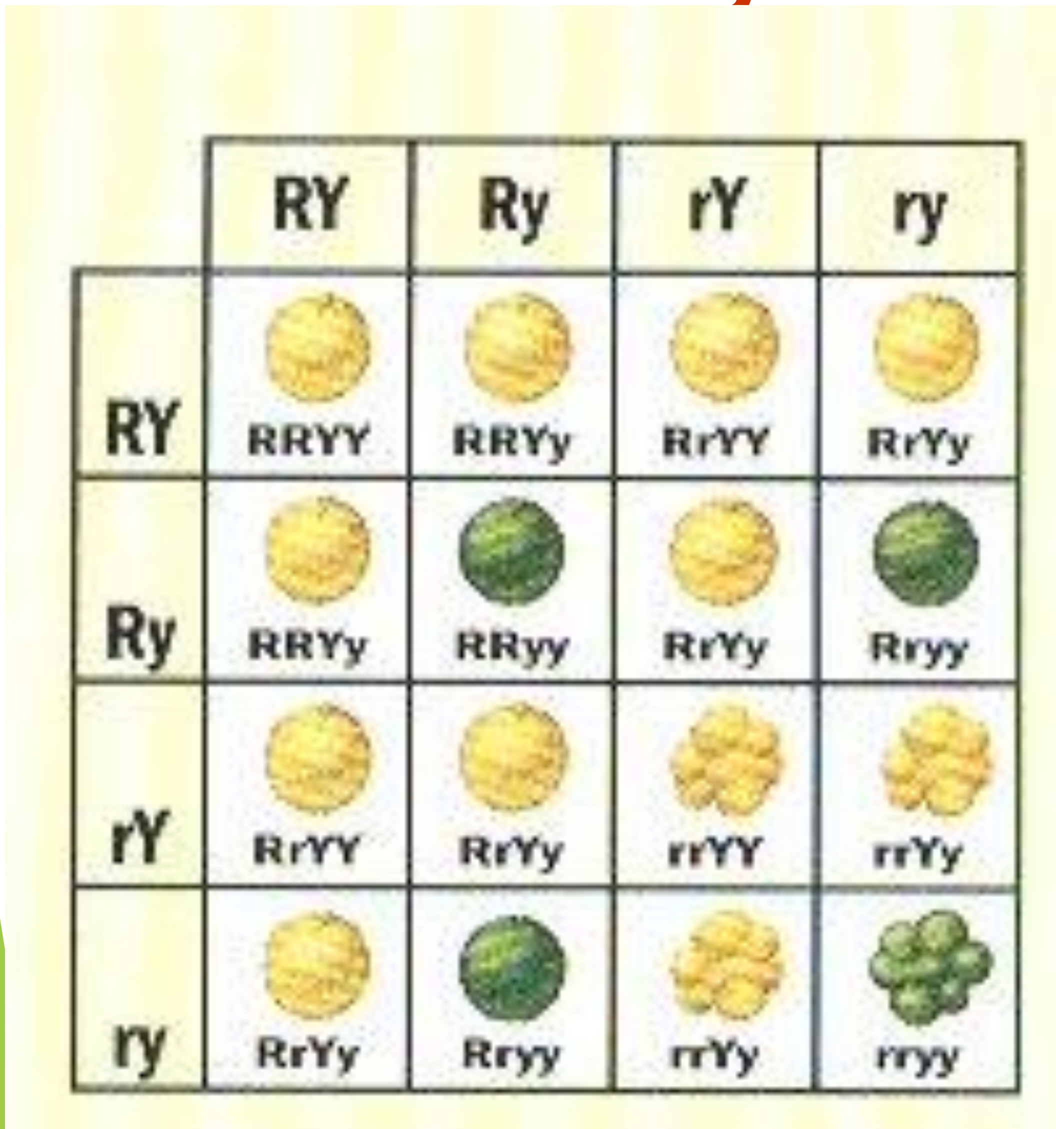
Round/green: 3

wrinkled/Yellow: 3

wrinkled/green: 1

9:3:3:1 phenotypic ratio

Dihybrid Cross



Round/Yellow: 9
Round/green: 3
wrinkled/Yellow: 3
wrinkled/green: 1

9:3:3:1

Question:
How many gametes will be produced for the following allele arrangements?

Remember: 2^n (n = # of heterozygotes)

1. RrYy
2. AaBbCCDd
3. MmNnOoPPQQRrssTtQq

Answer:

1. RrYy: $2^n = 2^2 = 4$ gametes

RY Ry rY ry

2. AaBbCCDd: $2^n = 2^3 = 8$ gametes

ABCD ABCd AbCD AbCd

aBCD aBCd abCD abCD

3. MmNnOoPPQQRrssTtQq: $2^n = 2^6 = 64$ gametes

Gene Interaction

(Non-Mendelian Inheritance)

The expression of a single character by the interaction of more than one pair of genes - Gene Interaction

Proposed by **Bateson & Punnet - factor hypothesis** - some characters are produced by the interaction of two or more pairs of factors (genes) called factor hypothesis.

Two types of gene interaction

1. **Allelic Gene Interaction**

   interaction between the two alleles of a single locus

2. **Non-allelic Gene Interaction**

   interaction between the genes located in different locus of the same chromosome or different chromosome

1. Allelic Interaction

a) Complete Dominance (3:1)

b) Incomplete Dominance (1:2:1)

c) Co-Dominance (1:2:1)

2. Non-allelic Interaction

a) Complementary Genes (9:7)

b) Supplementary Genes (9:3:4)

c) Duplicate Genes (15:1)

d) Epistasis (12:3:1)

e) Lethal Genes (2:1)

Incomplete Dominance and Codominance

Incomplete Dominance

F1 hybrids have an appearance somewhat **in between** the **phenotypes** of the two parental varieties.

Carl Correns Crossed **4'O Clock Plant (flower)**

red (RR) x white (rr)

RR = red flower

=

	R	R
r		
r		

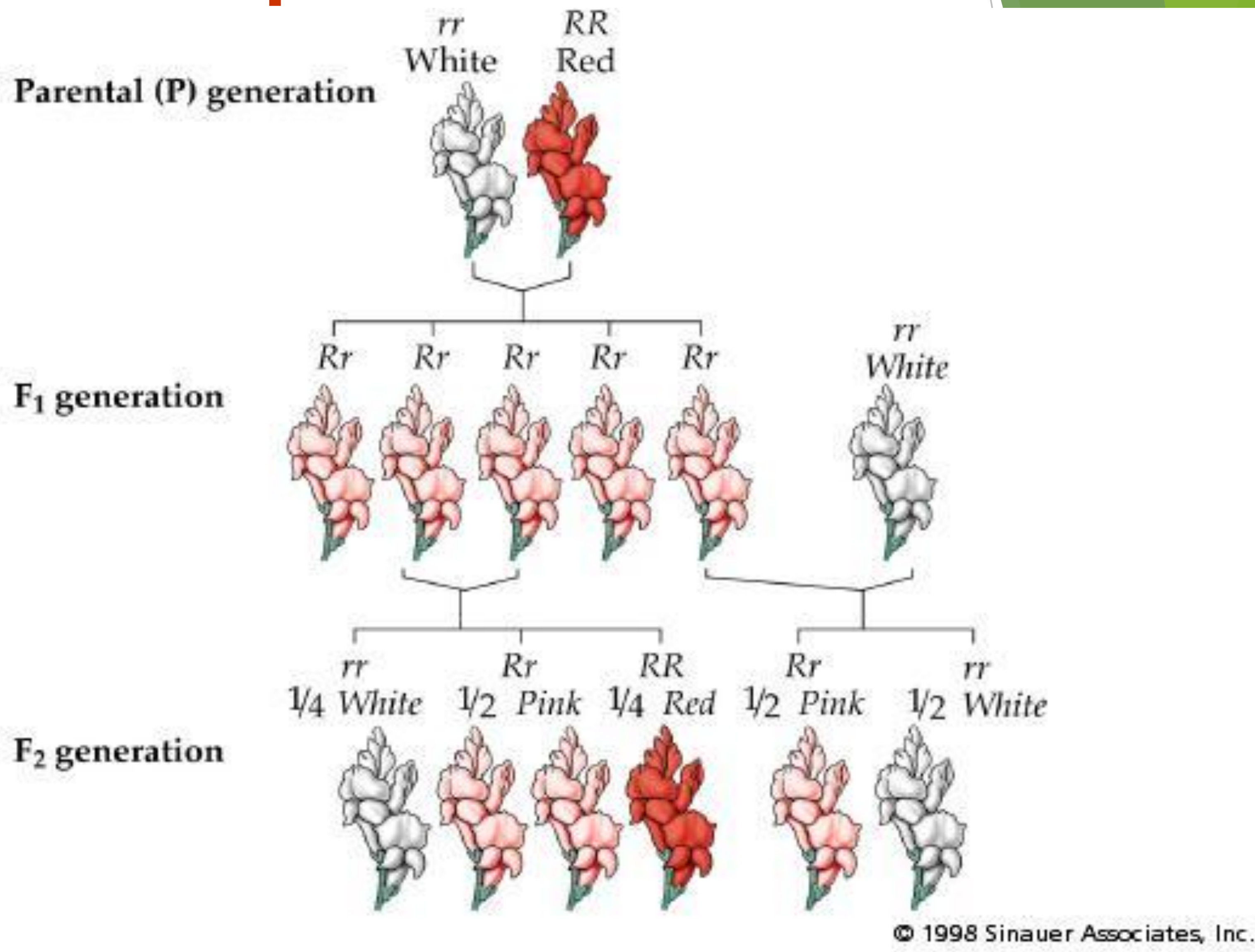
Incomplete Dominance

	R	R
	Rr	Rr
	Rr	Rr

produces the F_1 generation

All Rr = pink
(heterozygous pink)

Incomplete Dominance



Another Example

Codominance

Both the alleles can be expressed

Eg. Red cows crossed with white will generate Roan cows.

Might seem to support blending theory.

But F_2 generation demonstrate Mendalian genetics (1:2:1)

Codominance

Two alleles are expressed in **heterozygous individuals**.

Example: **blood type**

1. type A = $I^A I^A$ or $I^A i$
2. type B = $I^B I^B$ or $I^B i$
3. type AB = $I^A I^B$
4. type O = ii

In humans, there are four blood types: A,B,AB and O

Blood type is controlled by three alleles: A,B,O

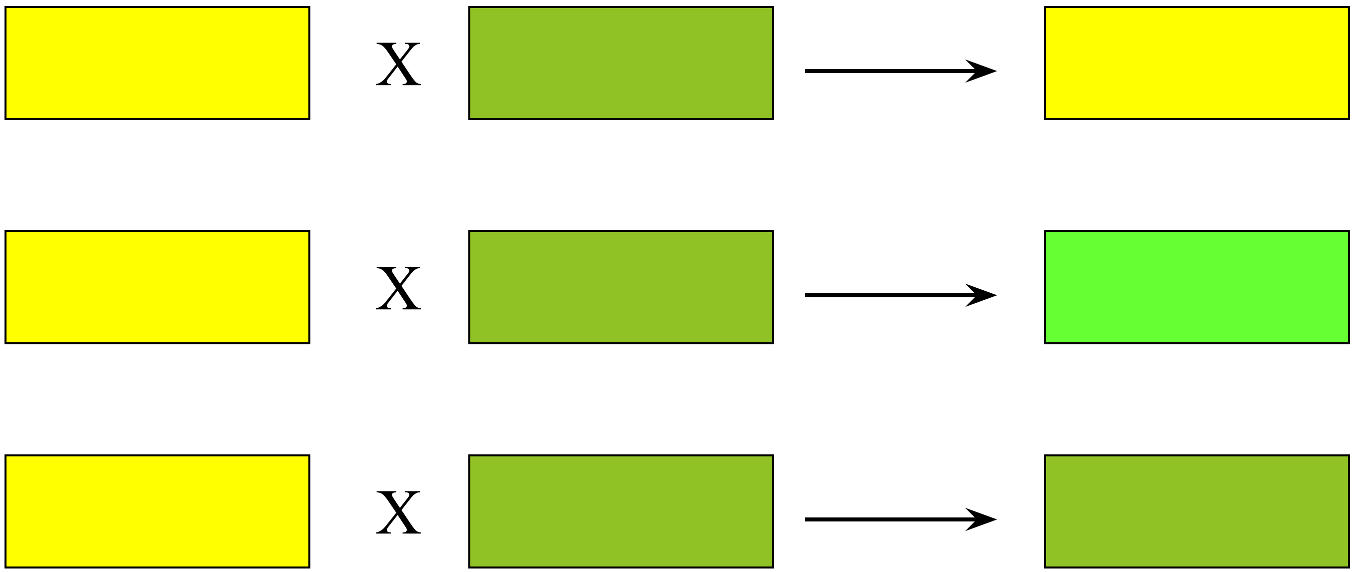
O is recessive, two O alleles must be present for the person to have type O blood

A and B are Codominant. If a person receives an A allele and B allele, their blood type is AB type

Crosses involving blood type often use an *I* to denote the alleles

Summary of Dominance Relationships

Dominance



complete

incomplete

codominance

Non - Allelic Gene Interaction

a). Complementary Genes

Two or more non-allelic dominant genes interact with one another to produce a character – but one gene alone cannot produce that character ie. in the absence of the other gene.

Example: Flower Colour in Sweet Pea (*Lathyrus odaratus*)

Studied by Bateson & Punnet

Two varieties of pea plants - red flower & White flower

Gene C → Enzyme A

Gene A → Enzyme B

Substrate —(Enzyme A)→ Chromogen —(Enzyme B)→ Anthocyanin

Chromogen (Colourless / White)

Anthocyanin (Red Colour)

The anthocyanin is produced from a colourless substance called chromogen. For the conversion of Chromogen into anthocyanin an enzyme (B) is necessary.

Similarly the chromogen has to be produced from a substrate by the action of an another enzyme (A).

Thus, for the production of red colour, the action of both the enzymes (A & B) is necessary.

If enzyme A is absent – no chromogen – no anthocyanin

If enzyme A is present but B is absent – Chromogen is formed but it will not be converted into anthocyanin due to absence of enzyme B.

A dominant gene C is responsible for the production of chromogen (enzyme A). If it is recessive (c) the chromogen cannot be produced (enzyme A not produced)

An another dominant gene A is responsible for the production enzyme B, which converts the chromogen into anthocyanin. If it is recessive (aa) the chromogen cannot be converted into anthocyanin (no enzyme B)

Parents:

CCaa X ccAA

(White) (White)

Gametes:

Ca cA

F_1 → CcAa

(Red)

F1 plants are selfed Red X Red

CcAa CcAa

Gametes : CA; Ca: cA; ca CA; Ca: cA; ca

	CA	Ca	cA	ca
CA	CCAA Red	CCAa Red	CcAA Red	CcAa Red
Ca	CCAA Red	CCaa	CcAa Red	Ccaa
cA	CcAA Red	CcAa Red	ccAA	ccAa
ca	CcAa Red	Ccaa	ccAa	ccaa

9 : 7

b).Supplementary Genes

In this gene interaction, the dominant allele of one gene (B) produces a phenotypic effect.

The dominant allele of the other gene (A) does not produce any phenotypic effect on its own;

But when it is present with the dominant allele of the first gene (B&A), it modifies the phenotypic effect produced by the first gene.

Example: Coat colour in Mice

Studied by : Castle

Three different varieties of Mice

1. Agouti (Grey) - dominant to both black & Albino
2. Black - dominant to albino but recessive to agouti
3. Albino (White) - recessive to both agouti & black

Dominant gene A & B ⟶ Agouti

Dominant gene B alone ⟶ Black

Dominant gene A alone ⟶ No effect (Albino)

Castle crossed a homozygous black mice (BBaa) with a homozygous albino (bbAA)

Phenotypic ratio: 9 : 3 : 4

Agouti : Black : Albino

Parents:

BBaa X bbAA

(Black) (Albino)

Gametes:

Ba bA

F_1 → BbAa

(Agouti)

F1 are self crossed: BbAa (Agouti) X BbAa (Agouti)

Gametes: BA; Ba; bA; ba   BA; Ba; bA; ba

	BA	Ba	bA	ba
BA	BBAA Agouti	BBAa Agouti	BbAA Agouti	BbAa Agouti
Ba	BBAa Agouti	Bbaa Black	BbAa Agouti	Bbaa Black
bA	BbAA Agouti	BbAa Agouti	bbAA Albino	BbAa Albino
ba	BbAa Agouti	Bbaa Black	bbAa Albino	bbaa Albino

9 : 3 : 4

- Modified ratio
- Still 1/16ths

9:Agouti (B&A)
3: Black (B alone)
4: Albino (A alone)

c).Duplicate Genes

In this gene interaction, a single character is controlled by two or more (duplicate) pairs of non-allelic genes independently.

Example: Seed shape in Shepherd purse (common weed)

Studied by: George H. Shull (1914) - two types of seed case - Triangular and Oval

Dominant gene T alone → Triangular

Dominant gene D alone → Triangular

Dominant gene T&D → Triangular

Both are recessive td → Oval

These two types of plants are crossed

Here, the presence of a single dominant allele of any of the two genes governing the trait produces the dominant phenotype (triangular).

The recessive genotype (Oval) is produced only when the genes are in the homozygous recessive state.

The genes that show duplicate interaction is called Duplicate gene action.

Parents : Triangular x Oval

TTDD x ttdd

Gametes : (TD) (td)

F_1 : TtDd

Triangular

F_1 plants are selfed : Triangular x Triangular

TtDd x TtDd

Gametes : (TD) (Td) (tD) (td) (TD) (Td) (tD) (td)

Gametes	TD	Td	tD	td
TD	TTDD Triangular	TTDd Triangular	TtDD Triangular	TtDd Triangular
Td	TTDd Triangular	TTdd Triangular	TtDd Triangular	Ttdd Triangular
tD	TtDD Triangular	TtDd Triangular	ttDD Triangular	ttDd Triangular
td	TtDd Triangular	Ttdd Triangular	ttDd Triangular	ttdd Oval

F_2 Generation: Triangular 15: Oval 1.

d). Epistasis

Mendel was lucky that in his studies each character was governed by a single gene

Typical Dihybrid ratio: 9:3:3:1

The phenomenon of two or more genes governing the development of single character is known as Gene interaction.

When one gene affects in anyway the expression of another gene, the phenomenon is called Epistasis.

The prevention of the expression of one gene by another non-allelic gene is called Epistasis.

Inhibiting gene - Epistatic gene

Inhibited gene - Hypostatic gene

Epistatis is of two types

1. Dominant Epistasis –
   prevention of expression of a gene by a dominant non-allelic gene
2. Recessive Epistasis
   prevention of expression of a gene by a recessive non-allelic gene

Dominant Epistasis

Example: Inheritance of Fruit colour in Cucurbita

Summer squash (*Cucurbita pepo*)

Yellow – Dominant gene Y

White – Dominant gene W

Green – Both recessive (wwyy)

The gene W is epistatic over Y – mask the expression of yellow colour.

When the white fruit (Wwyy) is crossed with yellow fruit variety (wwYY)

Parents : White fruit x Yellow fruit

WWyy **wwYY**

Gametes: (Wy) (wY)

F$_1$: **WwYy**

White fruit

Gametes: (WY) (Wy) (wY) (wy) (WY) (Wy) (wY) (wy)

♀ \ ♂	WY	Wy	wY	wy
WY	WWYY White	WWYy White	WwYY White	WwYy White
Wy	WWYy White	WWyy White	WwYy White	Wwyy White
wY	WwYY White	WwYy White	wwYY Yellow	wwYy Yellow
wy	WwYy White	Wwyy White	wwYy Yellow	wwyy Green

White 12 : Yellow 3: Green 1

Recessive Epistasis

prevention of expression of a gene by a recessive non-allelic gene

Example: Inheritance of Coat colour in Mice

Agouti (grey) – Interaction of two Dominant genes – M and A

Black - Dominant gene M

Albino – by the epistatic recessive gene mm

The recessive gene mm is epistatic over A – mask the expression of dominant gene A and gives Albino.

When a black mouse (Mmaa) is crossed with an albino mouse (mmAA).

Key points:

M-A- : Agouti

M-aa : Black

mm-- : Albino

Recessive Epistatis

The prevention of the expression of a gene by a recessive non-allelic gene is called ***recessive epistasis.*** Eg. *Coat colour in mice.*

1. Inheritance of Coat Colour in Mice

Inheritance of ***coat colour in mice*** is an example of ***recessive epistasis.***

Parents : Black male **MMaa** x Albino female **mmAA**

Gametes : Ma, A

F_1 generation : **MmAa** Agouti

F_1 individuals crossed : Agouti male **MmAa** x Agouti female **MmAa**

Gametes: MA, Ma, mA, ma; MA, Ma, mA, ma

Gametes	MA	Ma	mA	ma
MA	**MMAA** Agouti	**MMAa** Agouti	**MmAA** Agouti	**MmAa** Agouti
Ma	**MMAa** Agouti	**MMaa** Black	**MmAa** Agouti	**Mmaa** Black
mA	**MmAA** Agouti	**MmAa** Agouti	**mmAA** Albino	**mmAa** Albino
ma	**MmAa** Agouti	**Mmaa** Black	**mmAa** Albino	**mmaa** Albino

F_2 Generation : Agouti 9: Black 3: Albino 4.

Fig. 3.9: Inheritance of coat colour in mice.

LETHAL GENE

A lethal gene causes death of individual in the appropriate genotype before they reach adulthood.

Lethal are generally recessive, resulting in the death of the recessive homozygote.

- Some lethals are dominant.

In 1904 French geneticist Lucien Cuenot, discovered a recessive lethal affecting coat colour in mice.

LETHAL GENE

He observed that yellow colour is dominant;

But while crossing 2 yellow mice, he got only 2:1 ratio.

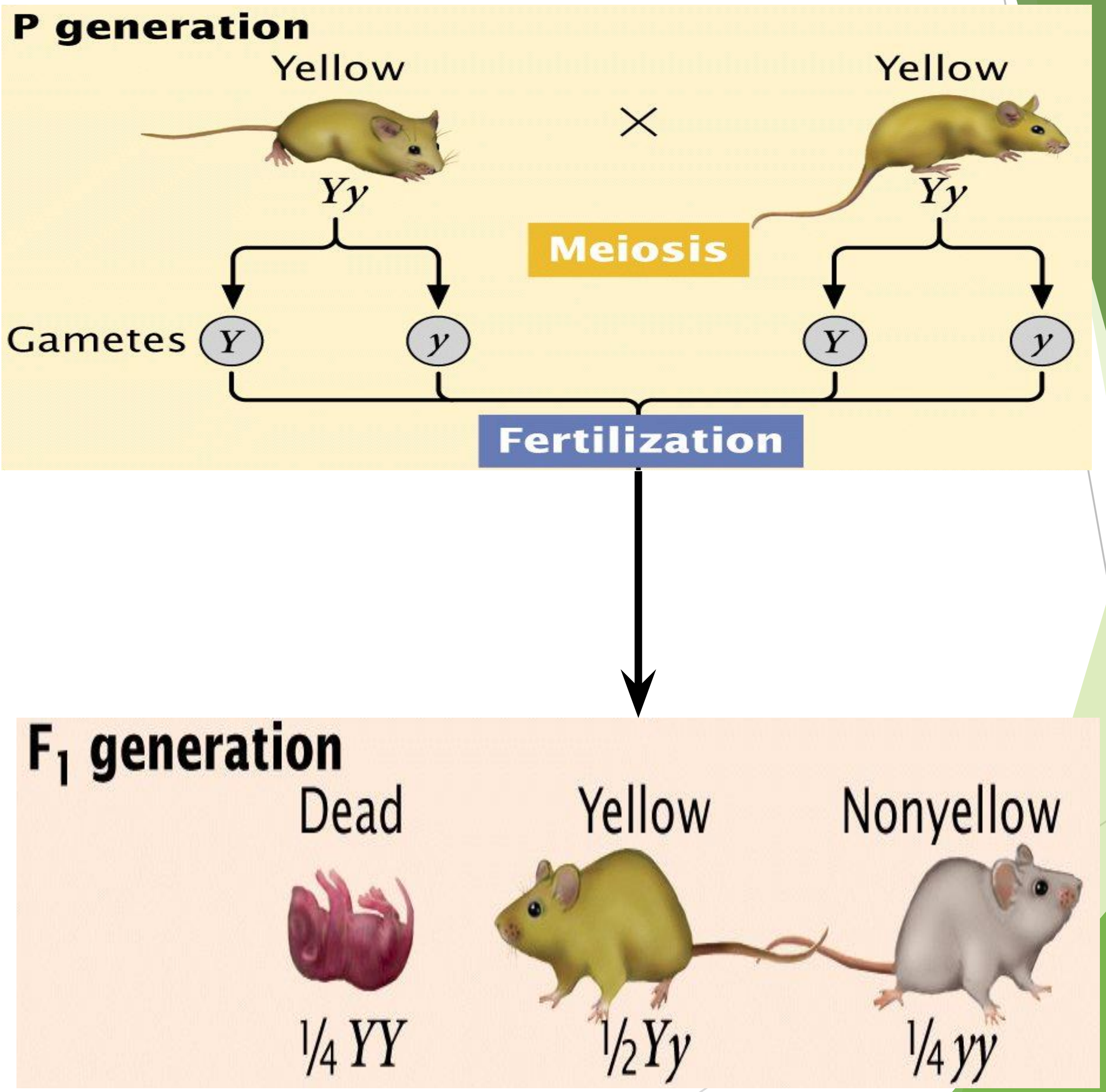
While he crossed yellow with recessive wild type (grey) found that all are yellow.

Concluded all yellow mice were heterozygotes.

LETHAL GENE

Later it was suggested that homozygosity for yellow is lethal, and that these individuals died in utero, a fact observed by histological studies.

Recessive Lethal Alleles



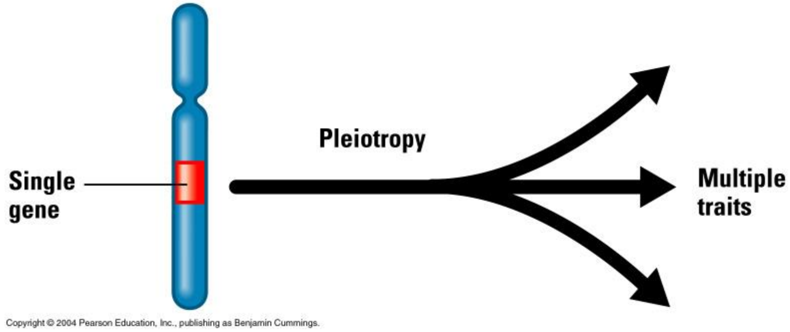
PLEIOTROPY

- Impact of a single gene on more than one characteristic
- Sickle-cell disease
  - Most common inherited illness among black people
  - RBCs are sickle-shaped

Can cause many problems

RBCs: Sickle-cell disease

Normal RBCs

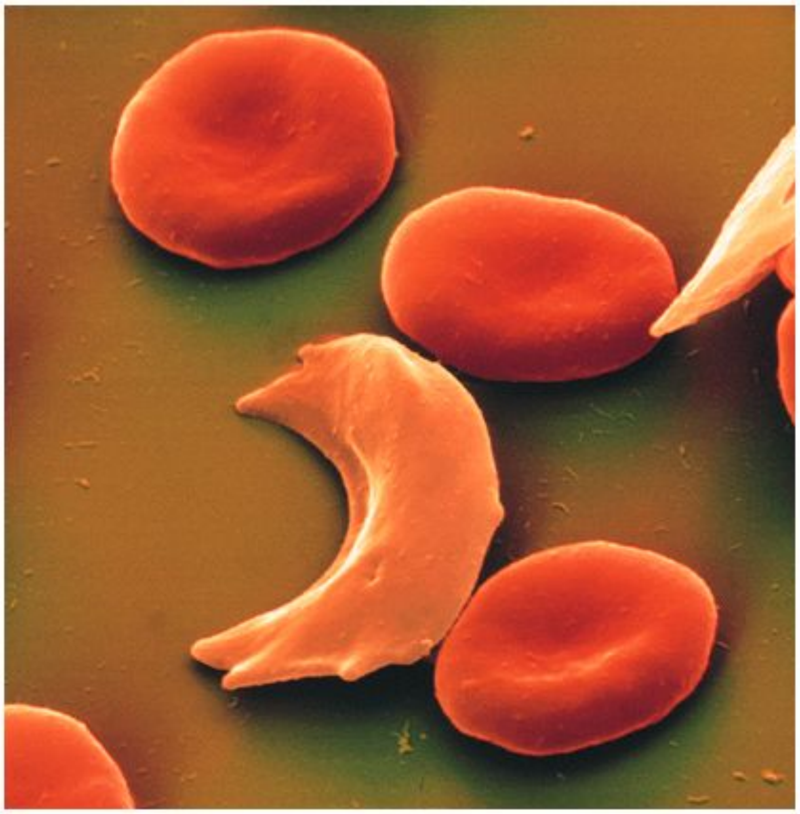


Sickle Cell Anemia

Under conditions of low oxygen tension, hemoglobin S will precipitate, causing cells to sickle

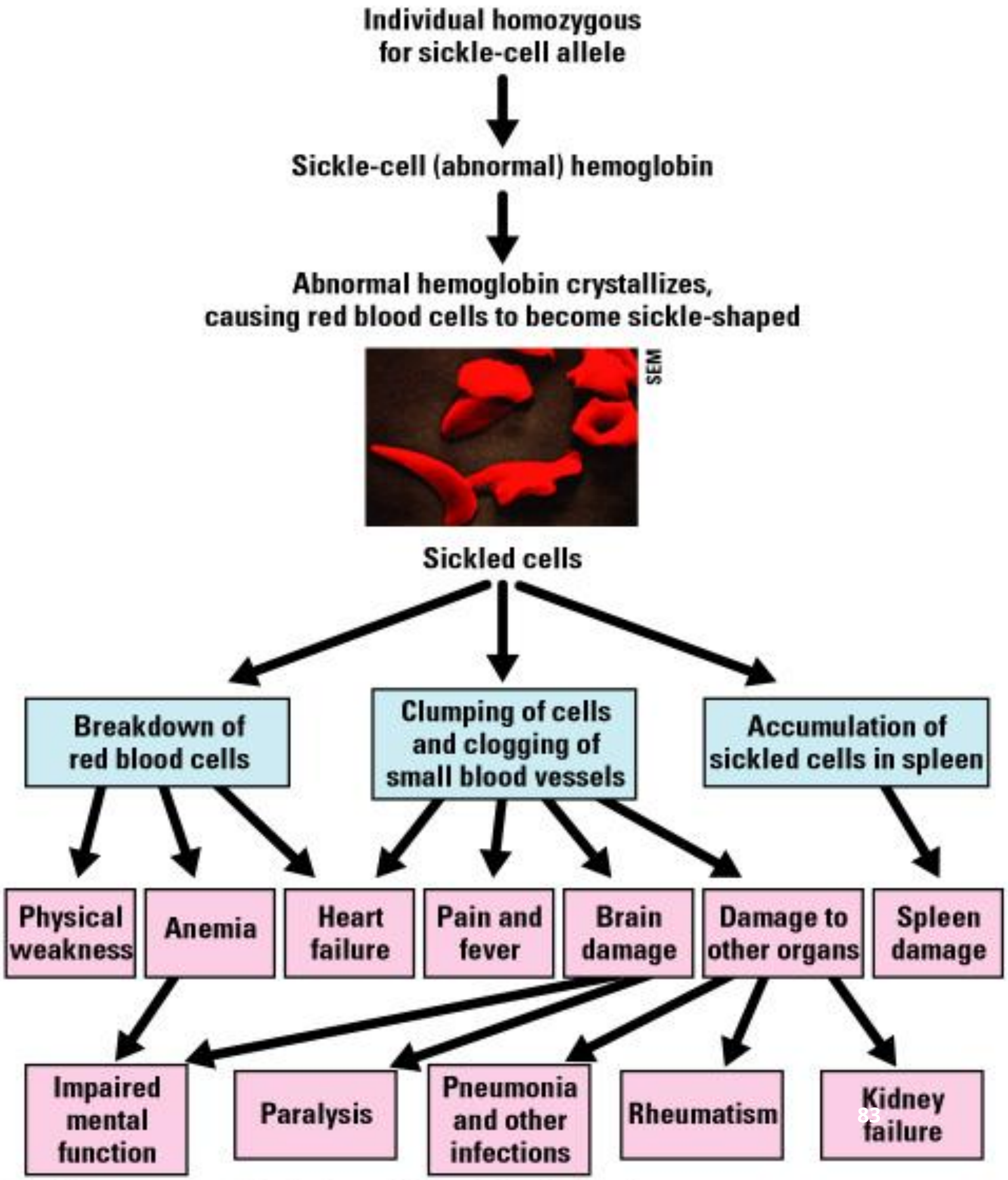
Mutations in same amino acid

Some individuals die in childhood;
Some individuals have mild symptoms



HbA: V – H – L – T- P – G –G

HbS: V – H – L – T- P – V–G


Individual homozygous for sickle-cell allele
Sickle-cell (abnormal) hemoglobin
Abnormal hemoglobin crystallizes, causing red blood cells to become sickle-shaped
SEM
Sickled cells
Breakdown of red blood cells
Clumping of cells and clogging of small blood vessels
Accumulation of sickled cells in spleen
Physical weakness
Anemia
Heart failure
Pain and fever
Brain damage
Damage to other organs
Spleen damage
Impaired mental function
Paralysis
Pneumonia and other infections
Rheumatism
Kidney failure

Genetic linkage

- Genetic linkage is the tendency of alleles that are located close together on a chromosome to be inherited together during meiosis.

- Genes whose loci are nearer to each other are less likely to be separated on to different chromatids during chromosomal crossover, and are therefore said to be genetically ***linked***.

- In other words, the nearer two genes are on a chromosome, the lower is the chance of a swap occurring between them, and the more likely they are to be inherited together.

The discovery of genetic linkage

- ***William Bateson*** and ***Reginald Punnett*** completed a study in **1905** that determined the movement of alleles found on the same chromosome.

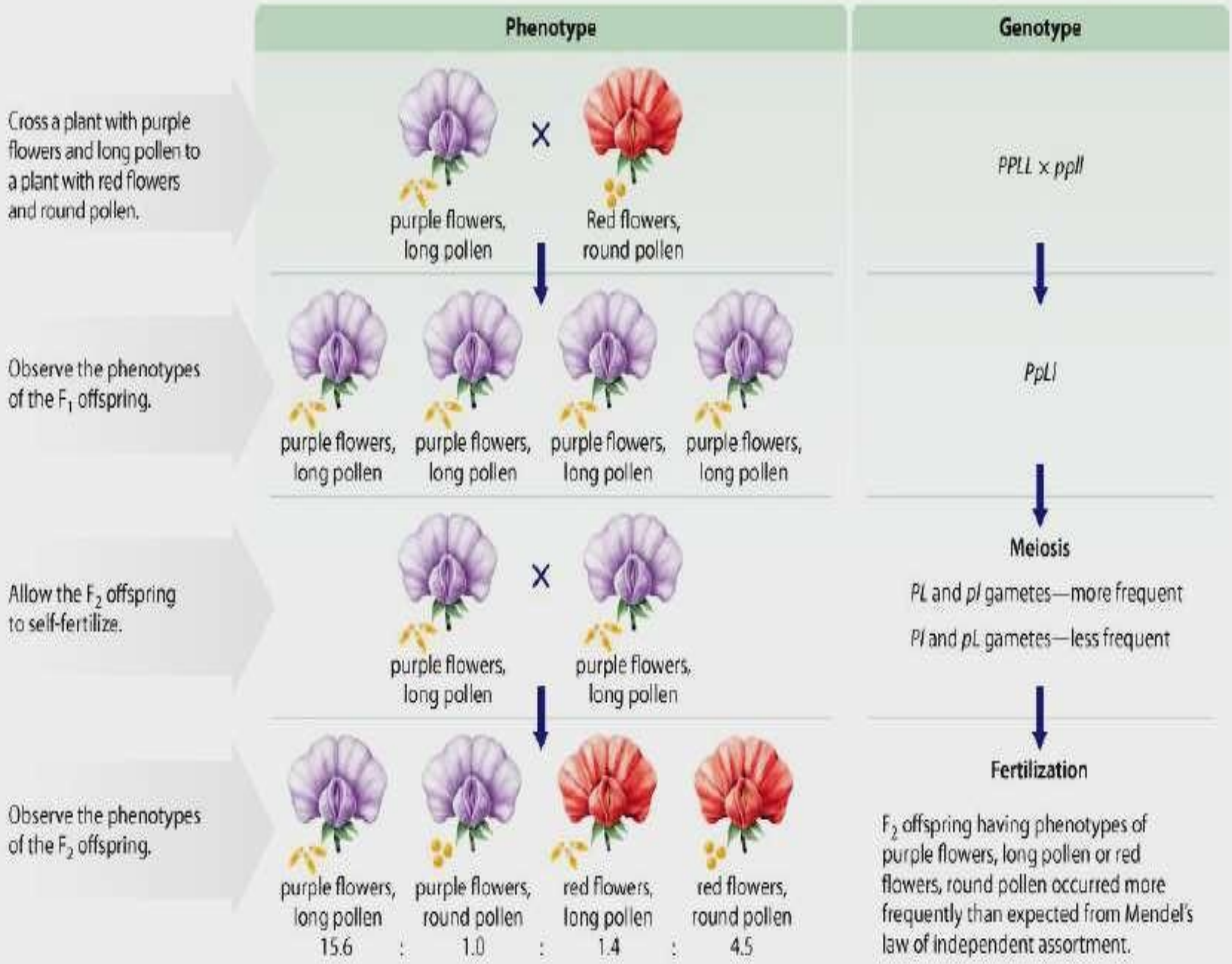
- The study used sweet peas, particularly flower colour and pollen shape, they followe
pattern.


Reginald Punnett (left) joined William Bateson (right) in 1903

- For flower colour, purple is dominant over red, and for pollen shape long is dominant over round.
- A cross was performed using a true breeding purple/long and red/round.
- The **F1** generation was 100% purple/long.

- Crossing two individuals from the **F1** generation resulted in a **F2** generation with four different phenotypes. (***purple/long, purple/round, red/long and red/round***).

- The alleles that created these combinations did not follow the 9:3:3:1 pattern, but supported the idea that these alleles did not assort independently and therefore must be ***linked***.


Phenotype
Genotype
Cross a plant with purple flowers and long pollen to a plant with red flowers and round pollen.
purple flowers, long pollen
×
Red flowers, round pollen
PPLL × ppll
Observe the phenotypes of the F_1 offspring.
purple flowers, long pollen
purple flowers, long pollen
purple flowers, long pollen
purple flowers, long pollen
PpLl
Allow the F_2 offspring to self-fertilize.
purple flowers, long pollen
×
purple flowers, long pollen
Meiosis
PL and pl gametes—more frequent
Pl and pL gametes—less frequent
Observe the phenotypes of the F_2 offspring.
purple flowers, long pollen
purple flowers, round pollen
red flowers, long pollen
red flowers, round pollen
15.6 : 1.0 : 1.4 : 4.5
Fertilization
F_2 offspring having phenotypes of purple flowers, long pollen or red flowers, round pollen occurred more frequently than expected from Mendel's law of independent assortment.

Why Linkage

- Linkage refers to packaging genes onto chromosomes.

- Chromosomes (and therefore linkage) are for organizing genes for their safe coordinated transmission from cell to cell(parent to offspring).

Types of Linkage

Depending upon the presence or absence of new combinations or non-parental combinations, linkage can be of two types:

(i) Complete Linkage:

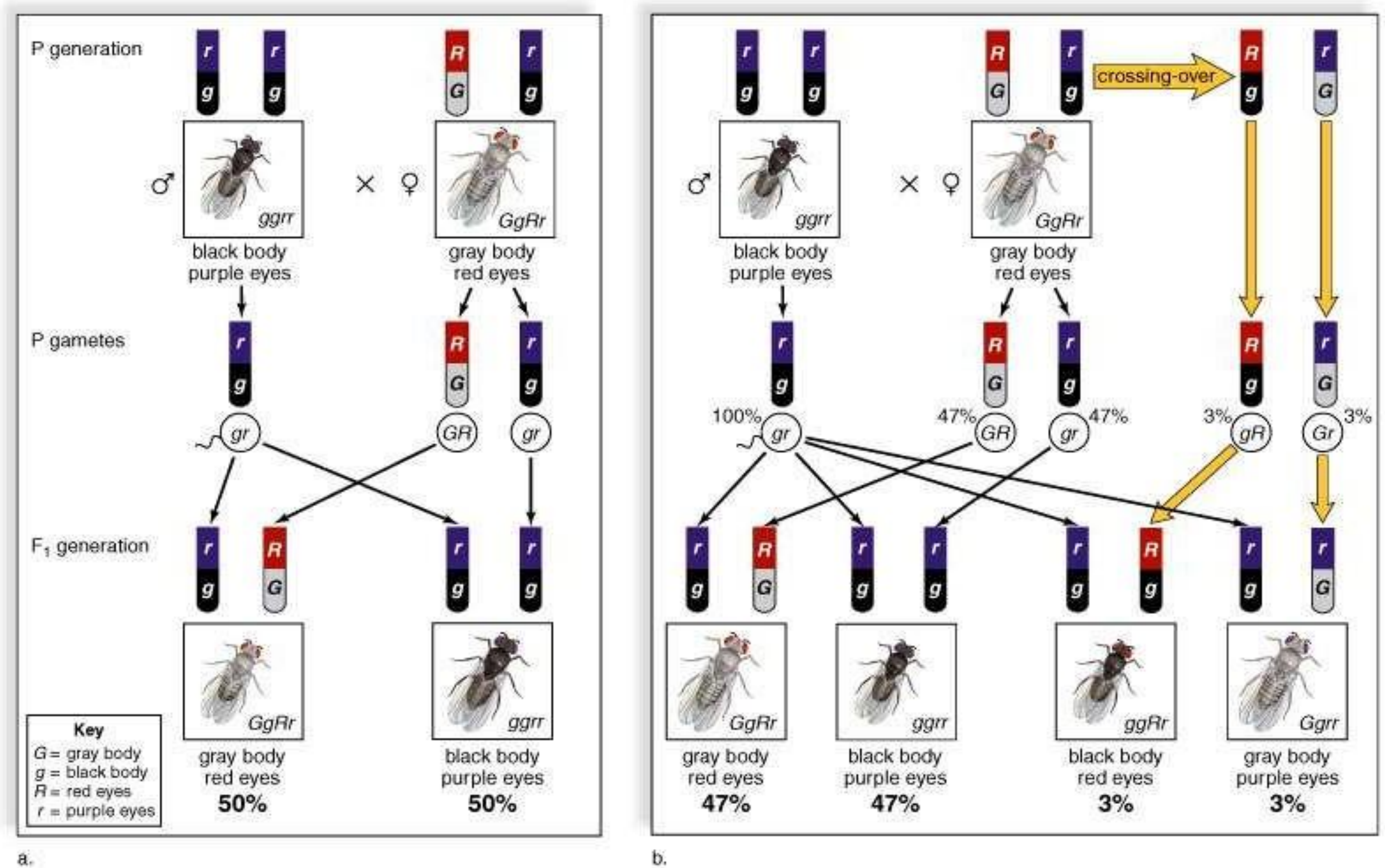
If two or more characters are inherited together and consistently appear in two or more generations in their original or parental combinations, it is called complete linkage. These genes do not produce non-parental combinations.

Genes showing complete linkage are closely located in the same chromosome.

(ii) Incomplete Linkage:

Incomplete linkage is exhibited by those genes which produce some percentage of non-parental combinations. Such genes are located distantly on the chromosome. It is due to accidental or occasional breakage of chromosomal segments during crossing over.

Complete vs. Incomplete



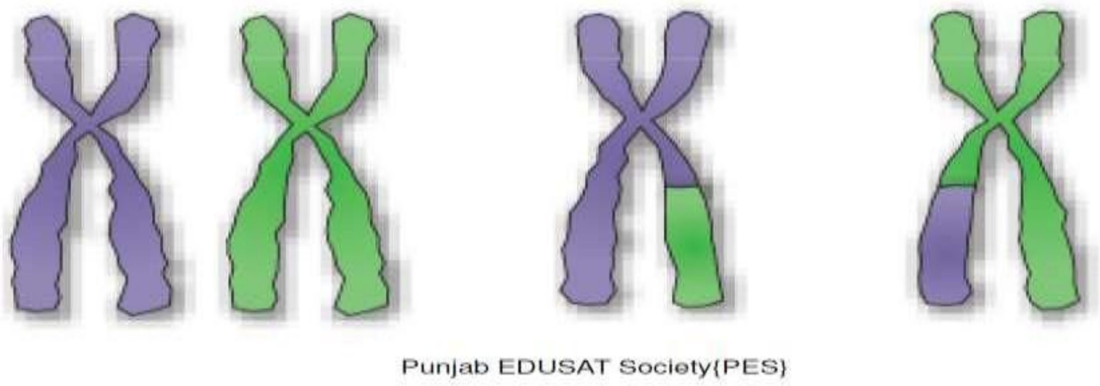
Significance of Linkage

1. Linkage does not permit the breeders to bring the desirable characters in one variety. For this reason plant and animal breeders find it difficult to combine various characters.

2. Linkage reduces the chance of recombination of genes and thus helps to hold parental characteristics together. It thus helps organism to maintain its parental, racial and other characters.

- **Linked genes are not inherited together every time**

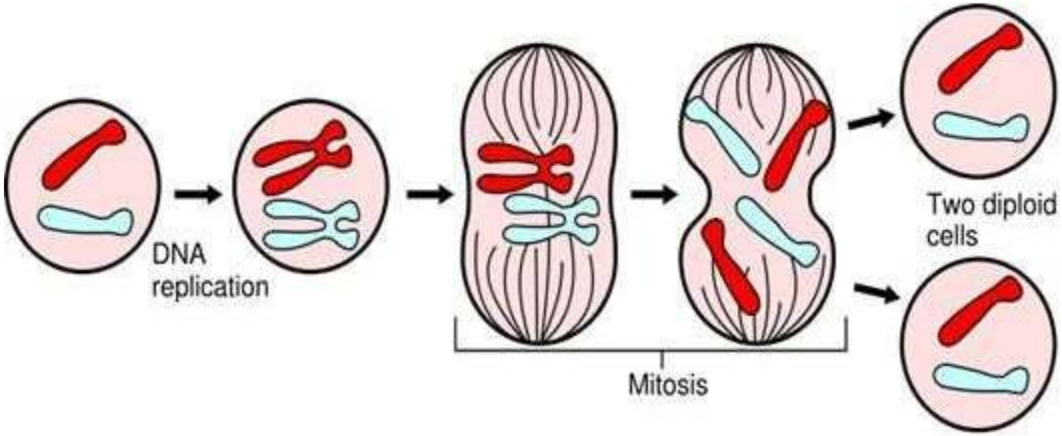
Chromosomes exchange homologous genes during meiosis.



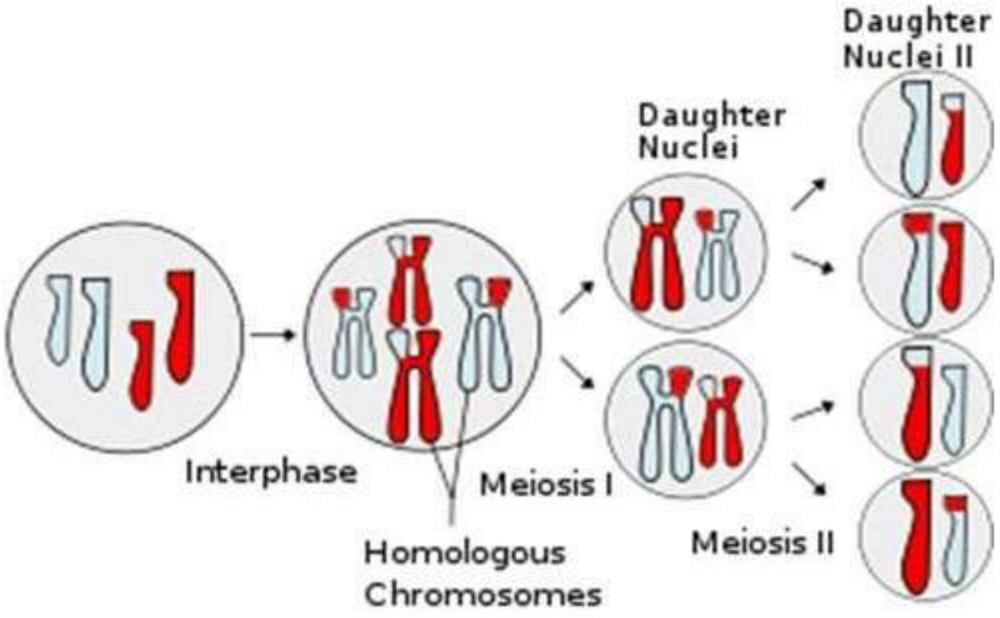
Crossing Over and the Inheritance of Linked Genes

- Linked genes don't always stay linked.

- These linkage groups can be separated by crossing over during ***prophase I*** of meiosis.



No crossing over – daughter cells are **identical** to parent cells

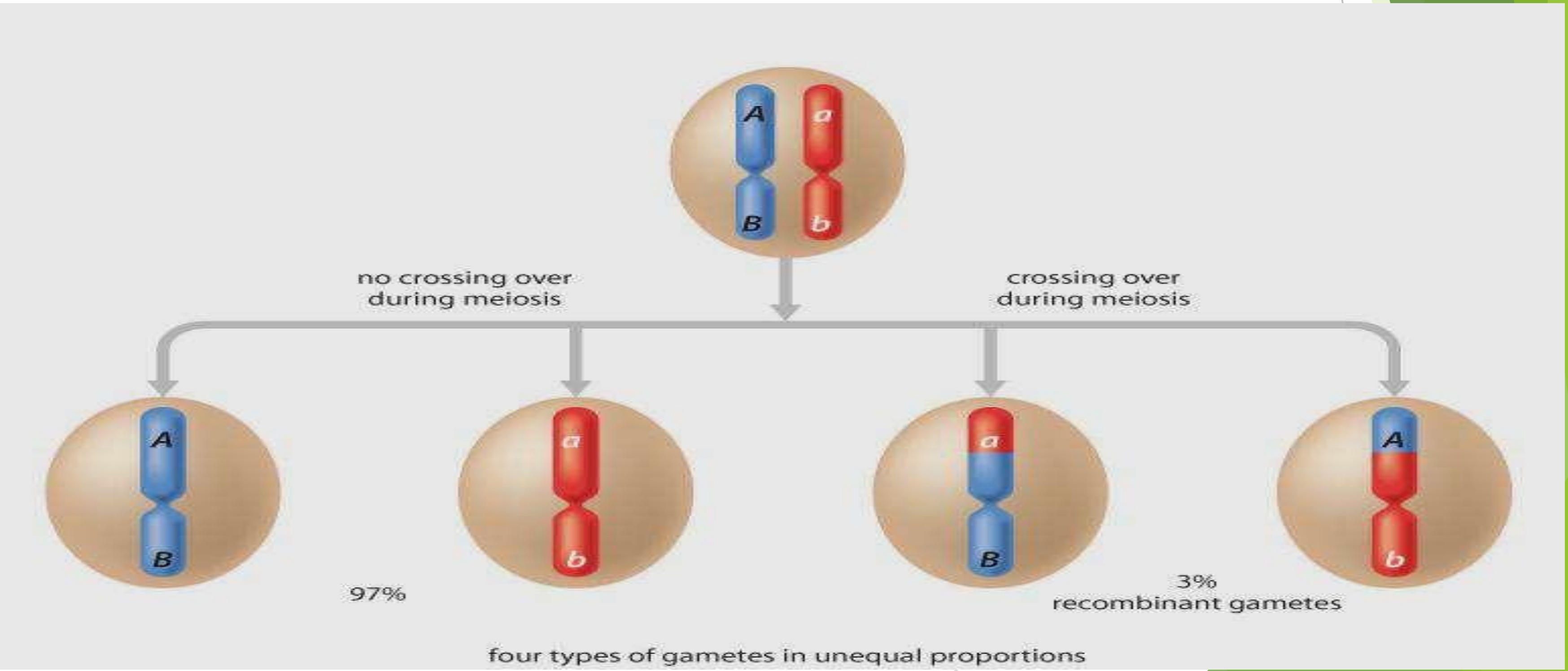


Crossing over occurs –causes **genetic variation**

(Daughter cells are NOT identical to parent cell)

- When crossing over occurs, the genes that were previously linked become unlinked, creating four different types of chromosomes (***gametes***).

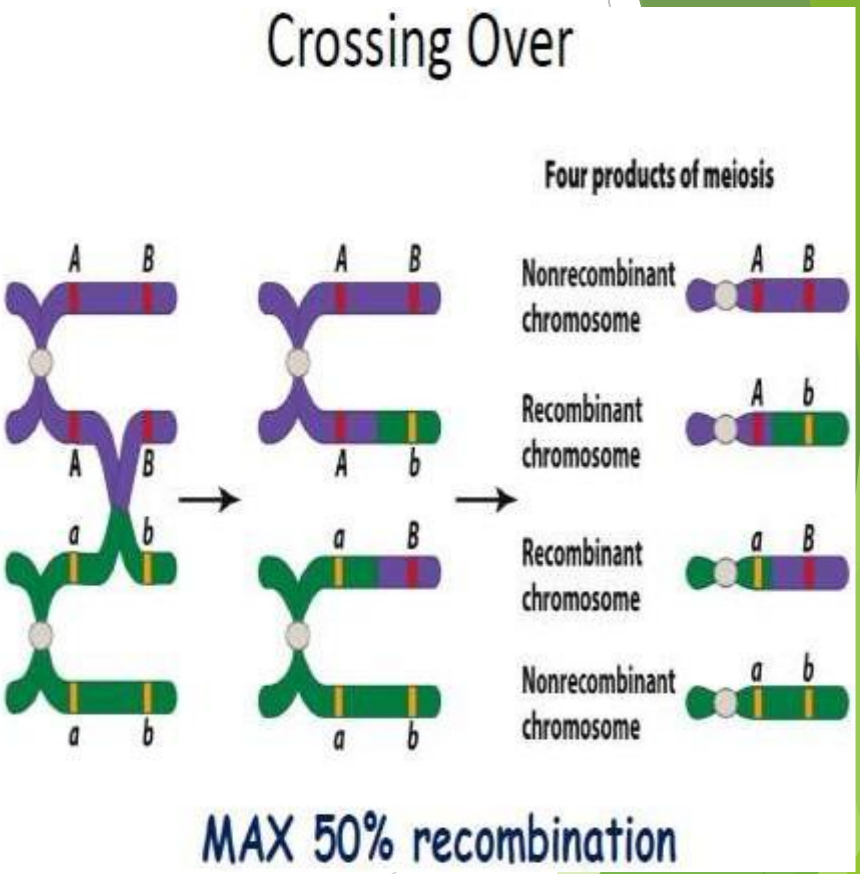
- The proportions are not equal because crossing over does not occur in every cell during meiosis.



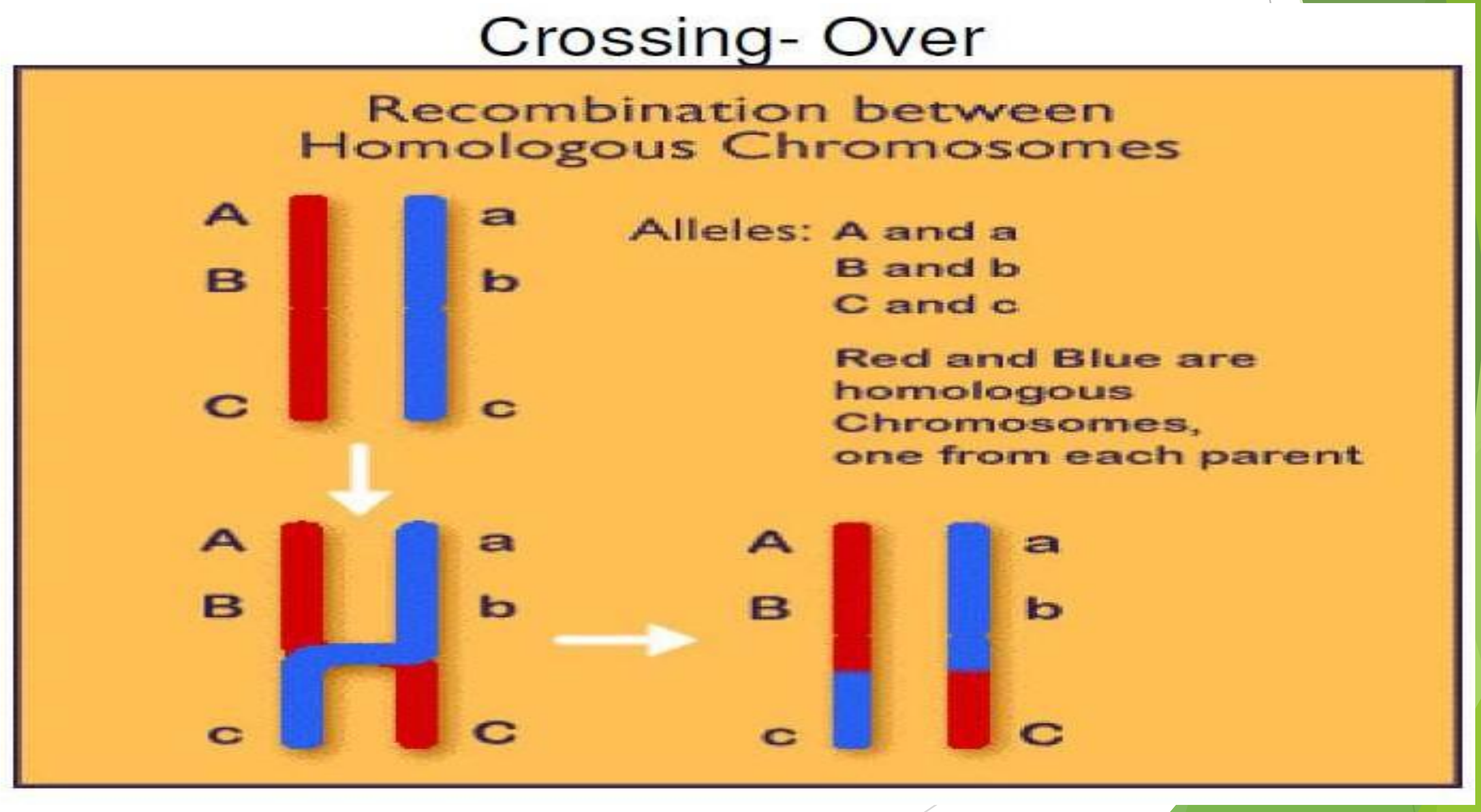
Crossing Over

- A random exchange of DNA between two non-sister chromatids of homologous chromosomes.

- Results in recombination of genetic material



- Prevalence of recombination is dependent on the distance between linked genes



FACTORS AFFECTING CROSS OVER

1. **Sex:**

   there is a tendency of reduction of crossing over in male mammals.

2. **Mutation:**

   mutation reduces crossing over

3. **Temperature:**

   high and low temperature variations increase the percentage of crossing over in certain parts of the chromosome.

4. **X-ray Effect:**

   X-ray irradiations increase crossing over near centromere.

5. **Age:**

   older age increases the rate of crossing over.

Significance of Crossing-over

1. Produces new combinations of traits.

2. Through crossing over segments of homologous chromosomes are interchanged and hence provide origin of new characters and genetic variations.

3. Crossing over plays a very important role in the field of breeding to improve the varieties of plants and animals.

Theories of Crossing Over

(i) Contact First Theory :

According to this theory the inner two chromatids of the homologous chromosomes undergoing crossing over, first touch each other and then cross over. At the point of contact breakage occurs. The broken segments again unite to form new combinations.

(ii) The Breakage-First Theory :

According to this theory the chromatids under-going crossing over, first of all break into two without any crossing over and after that the broken segments reunite to form the new combinations.

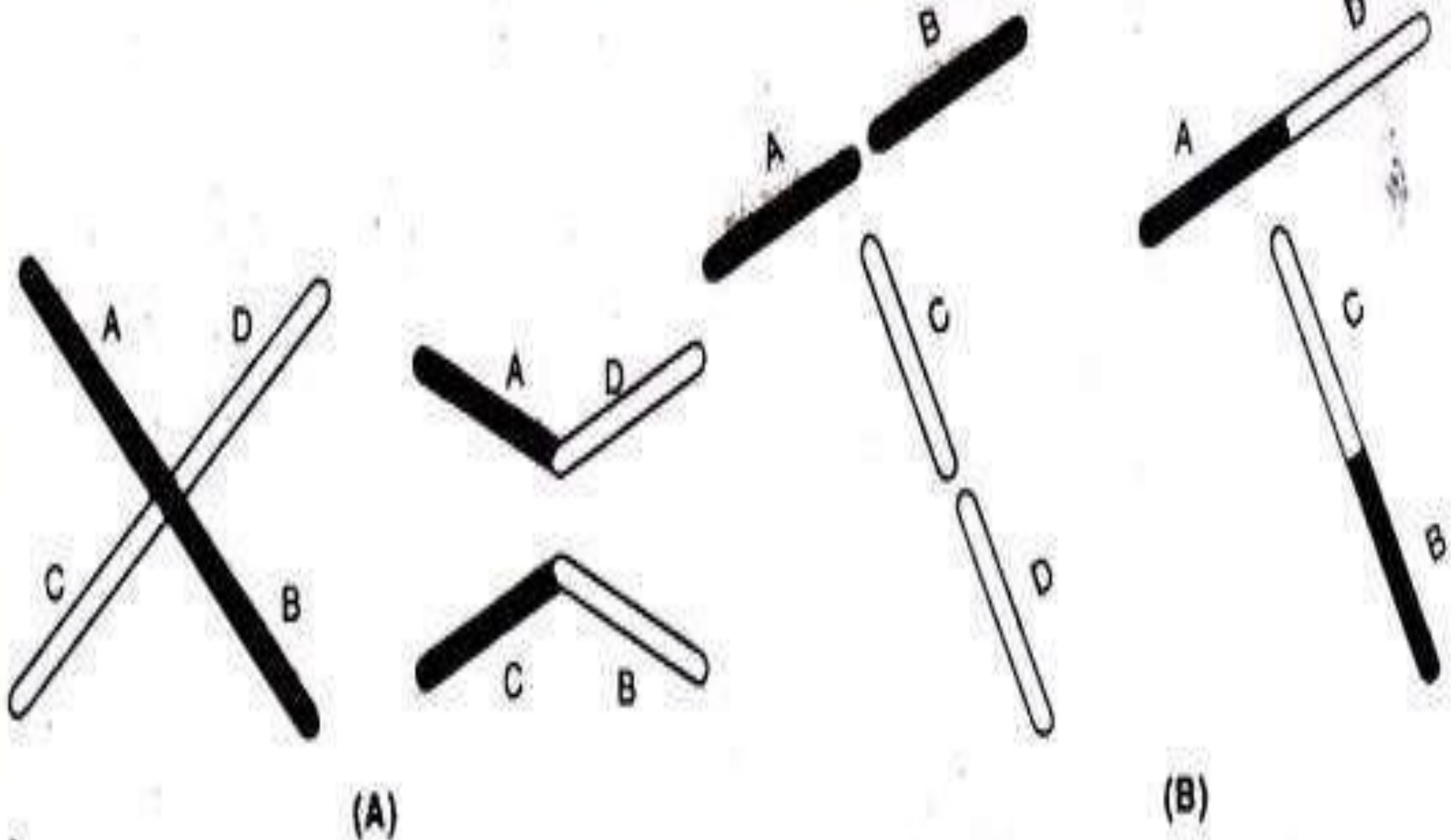


Fig. 5.11 Diagrams showing
A : contact-first theory of crossing over. B : Breakage-first theory of crossing over.

Types of Crossing Over

(i) Single Crossing Over:

In this type of crossing over only one chiasma is formed (a **chiasma** is the point where two homologous non-sister chromatids exchange genetic material during chromosomal crossover in meiosis) all along the length of a chromosome pair. Gametes formed by this type of crossing over are called single cross over gametes .

Types of Crossing Over

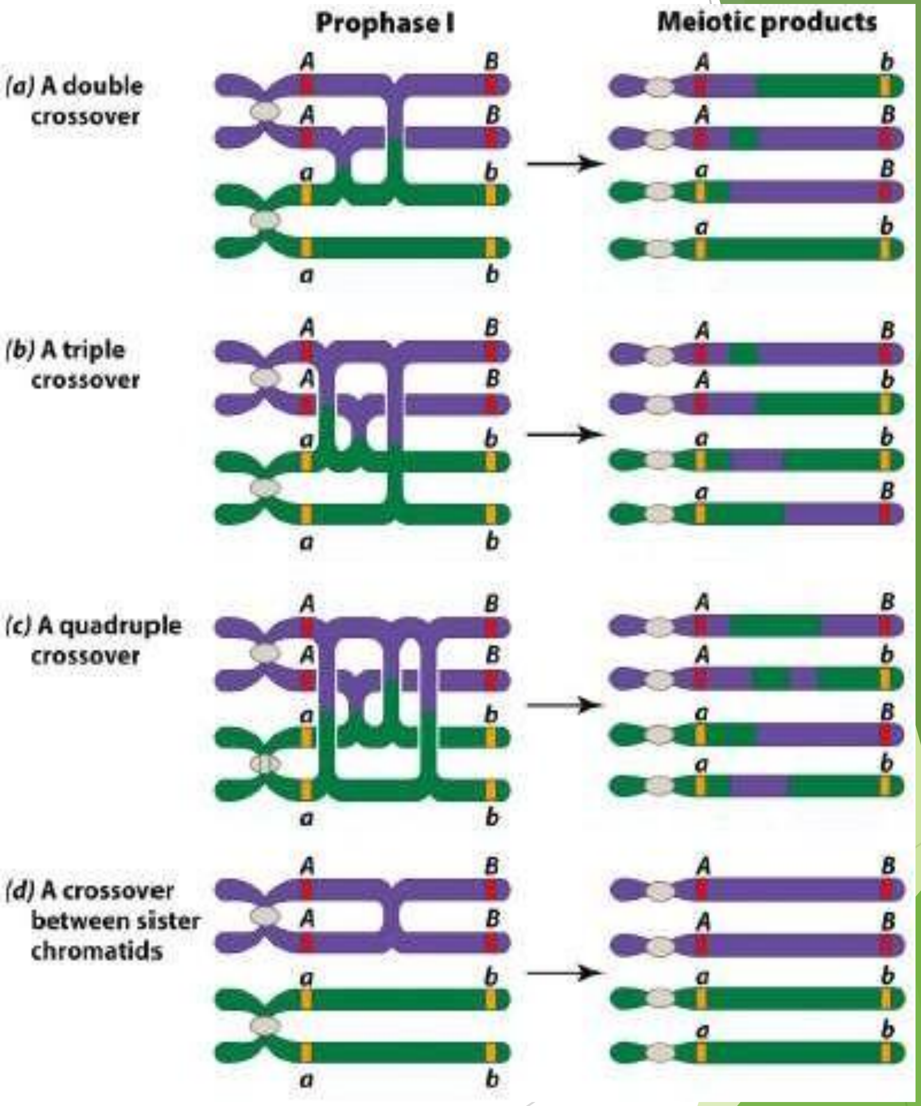
(ii) Double Crossing Over:

In this type two chiasmata are formed along the entire length of the chromosome leading to breakage and rejoin of chromatids at two points. The gametes produced are called double cross over gametes.

(iii) Multiple Crossing Over:

In this type more than two chiasmata are formed and thus crossing over occurs at more than two points on the same chromosome pair. It is a rare phenomenon.

Multiple Crossovers



Genetic map

Graphical representation of relative distances between linked genes of a chromosome is called genetic map, also known as gene map or chromosome map or cross over map.

Purpose and uses of Genetic mapping

- ✔The purpose of genetic mapping is to determine the linear order and distance of separation among genes that are linked to each other along the same chromosome.
- ✔The chromosome maps display the exact location, arrangement and combination of genes in a linkage group of chromosomes.
- ✔They are useful in predicting results of dihybrid and trihybrid crosses.
- ✔It allows geneticists to understand the overall complexity and genetic organization of a particular species.

Purpose and uses of Genetic mapping

- The genetic map of a species portrays the underlying basis for the inherited traits that an organism displays.
- In some cases, the known locus of a gene within a genetic map can help molecular geneticists to clone that gene and thereby obtain greater information about its molecular features.
- In addition, genetic maps are useful from an evolutionary point of view. A comparison of the genetic maps for different species can improve our understanding of the evolutionary relationships among those species.

Purpose and uses of Genetic mappin

- ✔Along with these scientific uses, genetic maps have many practical benefits. For example, many human genes that play a role in human disease have been genetically mapped. This information can be used to diagnose and perhaps someday treat inherited human diseases. It can also help genetic counselors predict the likelihood that a couple will produce children with certain inherited diseases.
- ✔In addition, genetic maps are gaining increasing importance in agriculture.
- ✔A genetic map can provide plant and animal breeders with helpful information for improving agriculturally important strains through selective breeding programs.

Construction of a Linkage Map

or Genetic Mapping

The method of construction maps of different chromosomes is called **genetic mapping.**

The genetic mapping includes following processes:

1. **Determination of Linkage Groups(No. of Chromosomes)**

   Before starting the genetic mapping of chromosomes of a species,

   - To know the exact number of chromosomes of that species.
   - To determine the total number of genes of that species by undergoing hybridization experiments in between wild and mutant strains.

2. Determination of Map Distance

- ## Map unit

Genetics use an arbitrary unit to measure the intergene distance on the chromosomes that is **map unit** which describe distances between linked genes.

A map unit is equal to 1 per cent of crossovers (recombinants); that is, it represents the linear distance along the chromosome for which a recombination frequency of 1 per cent is observed.

- ## Morgan units

These distances can also be expressed in **morgan units;** one morgan unit represents 100 per cent crossing over. Thus 1 per cent crossing over can also be expressed as **1 centimorgan (1cM).**

1. Two point test cross

The percentage of crossing over between two linked genes is calculated by test crosses in which a F1 dihybrid is crossed with a double recessive parent. Such crosses because involved crossing over at two points, so called two point test

2. Three point test cross(Trihybrid cross)

Double cross over usually don't occur between genes less than 5 centimorgans apart, so for genes further apart, the three point test crosses are used. A three point test cross or trihybrid test cross (involving three genes) gives us information regarding relative distances between these genes, and also shows us the linear order in which these genes should be present on chromosome. Such a three point test cross may be carried out if three points or gene loci on a chromosome pair can be identified by marker genes.