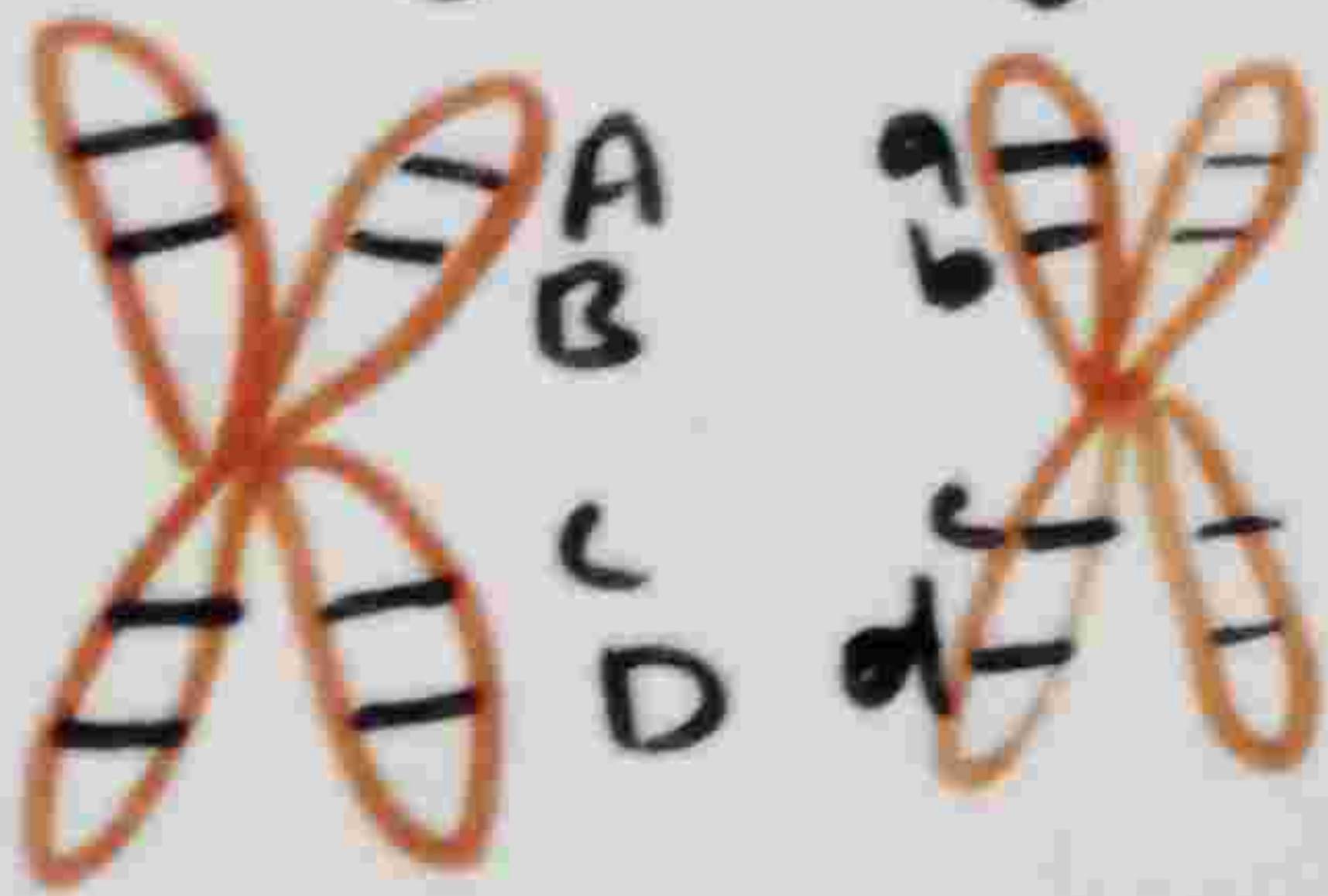


LINKAGE

→ Genes are located on chromosomes in linear manner

→ The tendency of genes present in the same chromosome to stay together is known as

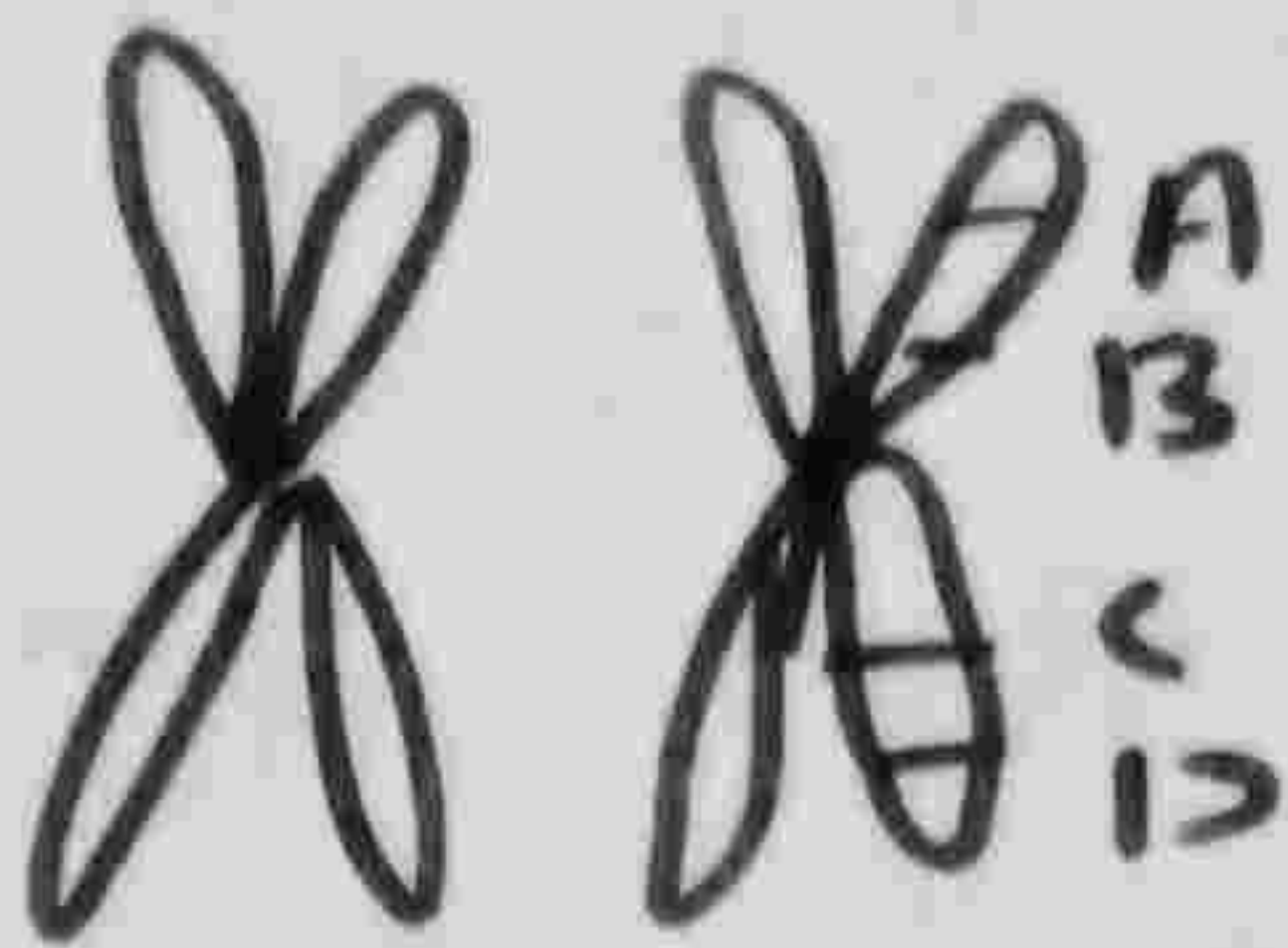
Linkage e.g. Genes present on one chromosome are called linked genes.



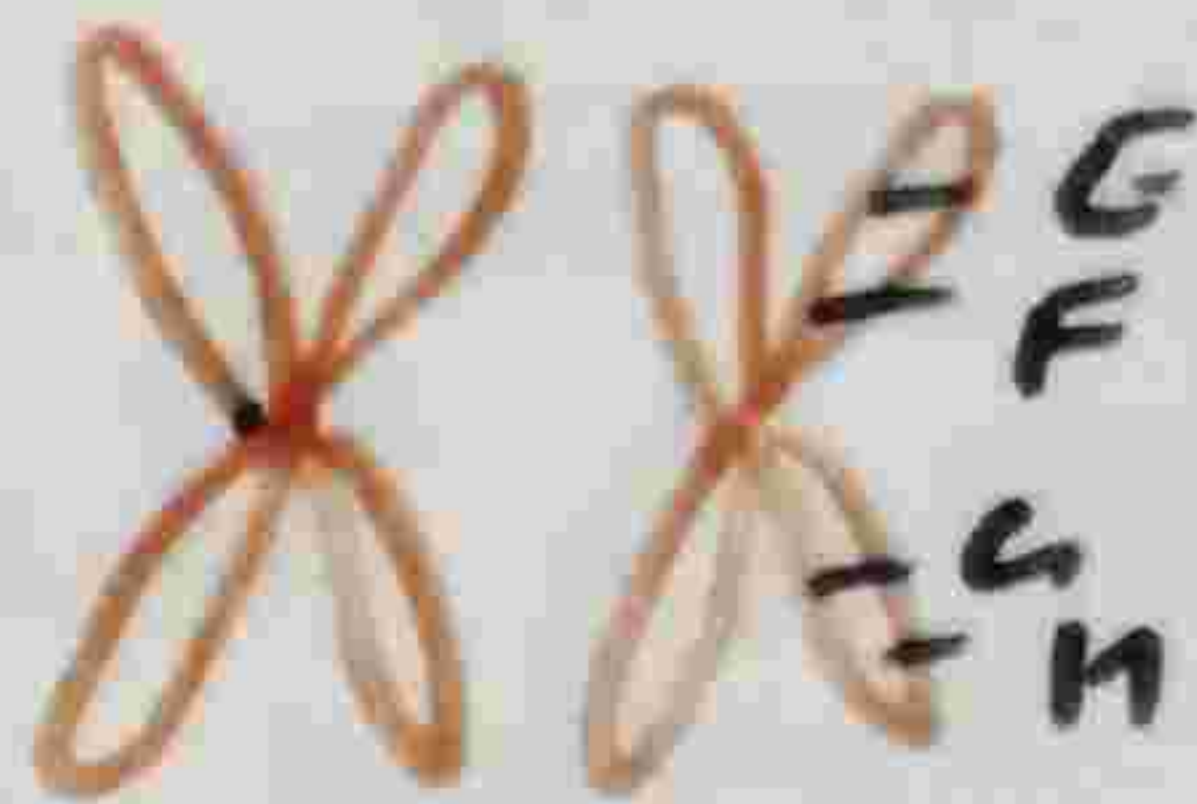
ABCD are linked genes.

→ Linkage is the exception of "Law of Independent Assortment" of Mendel. It is applicable only for those genes which are located distantly or on separate chromosomes.

→ Genes present on Nonhomologous chromosomes are called Unlinked genes.



ABCD are linked



EFGH are linked.

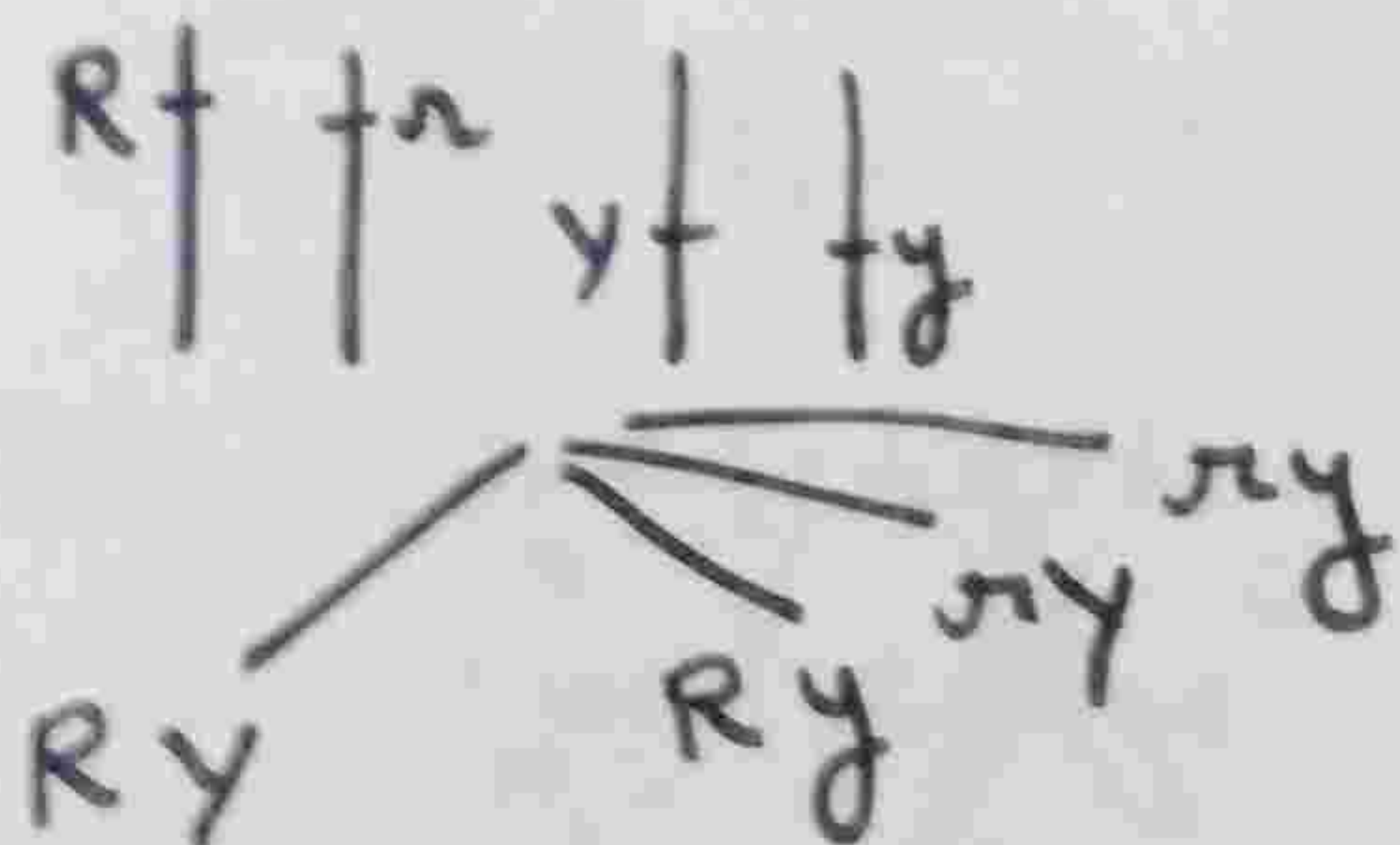
→ If we compare A and E then they are unlinked genes.

e.g In Drosophila Red eye and Grey body occur in same individual

This is because genes of both are located on same chromosome.

Unlinked genes	Linked genes
The genes located on different chromosomes assort independently	Genes located on same chromosome do not assort independently

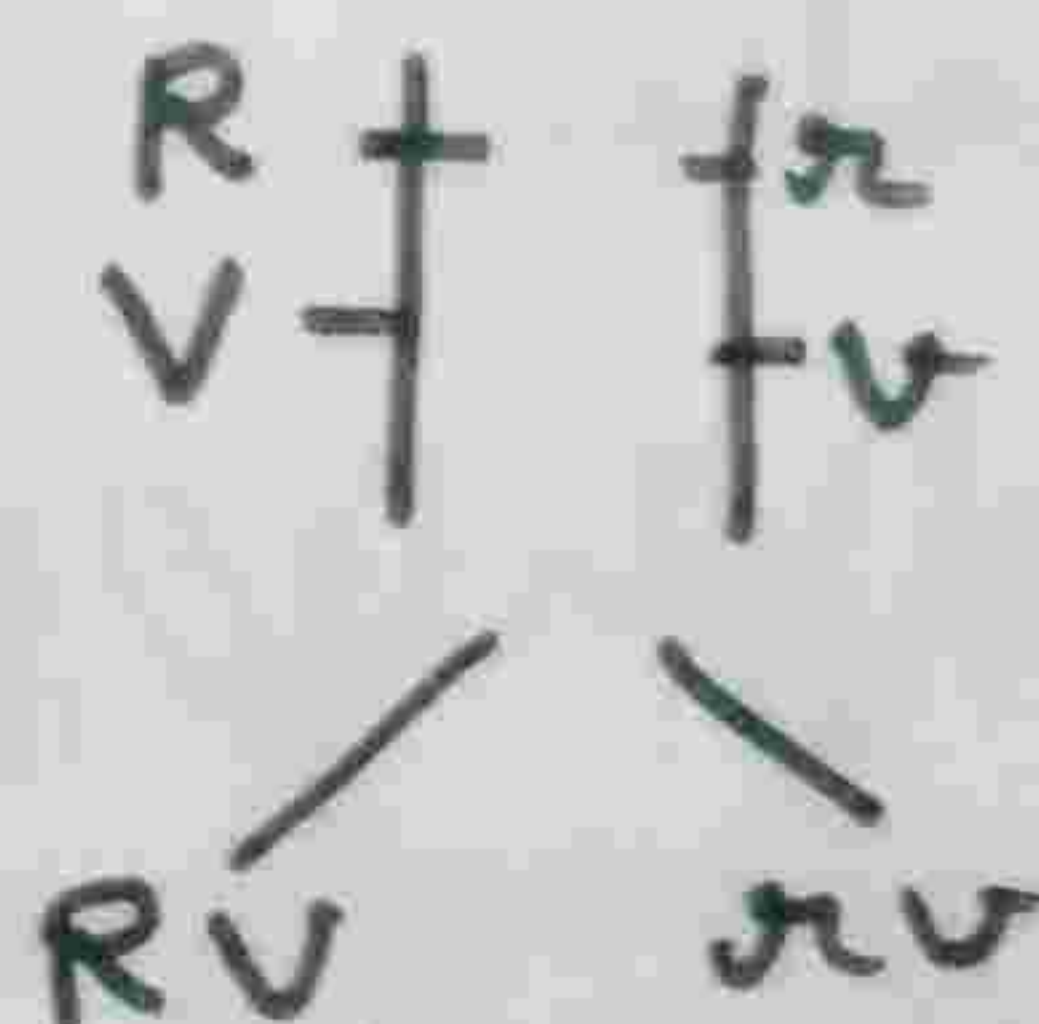
and give dihybrid ratio of 9:3:3:1



→ Test cross ratio is 1:1:1:1

→ 50% recombinants

and give dihybrid ratio of 3:1



→ Test cross ratio is 1:1

No recombinants

→ In 1905 an experiment was done by William Bateson, E.R. Saunders and R.C. Punnett on **Lathyrus odoratus** [Sweet pea]

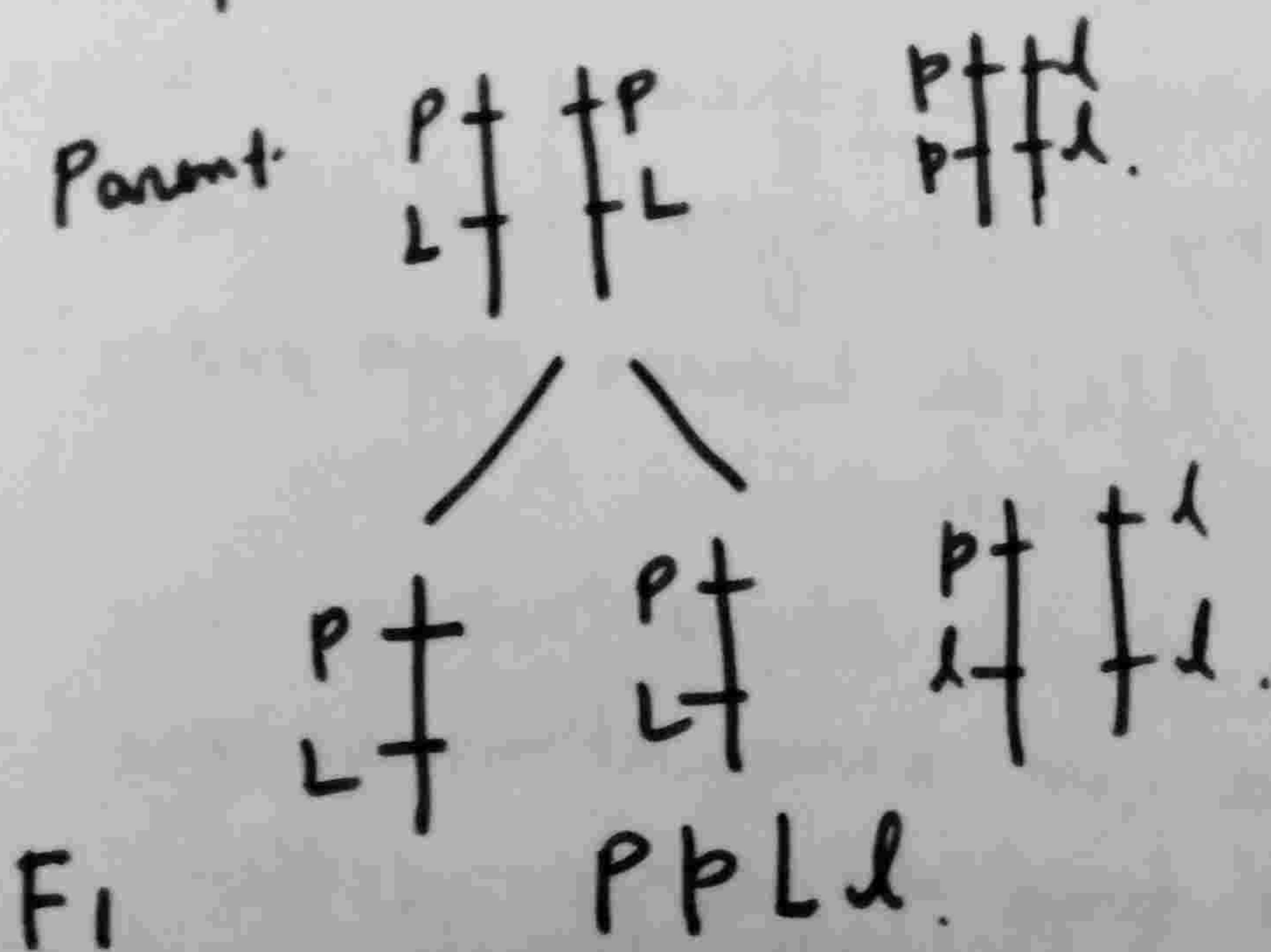
→ They studied two genes i.e. P/p and L/l.

↓
Colour
P - purple
p - red

↓
Shape of Pollen grain
L - Long
l - round

This was actually showing Linkage but term used was Coupling when two alleles P and L come from same parent $[PPLL \times ppll]$ then they will enter the same gamete.
 → When the allele P and L comes from different parent it was called repulsion
 $PPll \times ppLL$.

→ Thomas Hunt Morgan found coupling and repulsion are two aspects of same phenomenon i.e. Linkage.



→ concept of Linkage was experimentally proved by T H Morgan
He is known as "Father of
"Experimental Genetics".

→ Experimental Material
Drosophila Melanogaster.

→ Morgan found results very different from Mendel's Laws of Independent Assortment.

when two autosomal gene
one for eye colour [P_r (purple)
 P_r^+ (red)]
other for wing length [vg (vestigial)
 vg^+ (Normal)]

Chromosomal theory of Linkage

Given by Morgan and Castle.

→ a) Genes lie in Linear order of Chromosome

b) Gene which show linkage are located on same chromosome

c) Genes tend to stay together and show Parental combination

except for crossing over

→ Distance between linked genes in a chromosome determines strength of linkage.

→ Genes located closer to each other show stronger linkage.

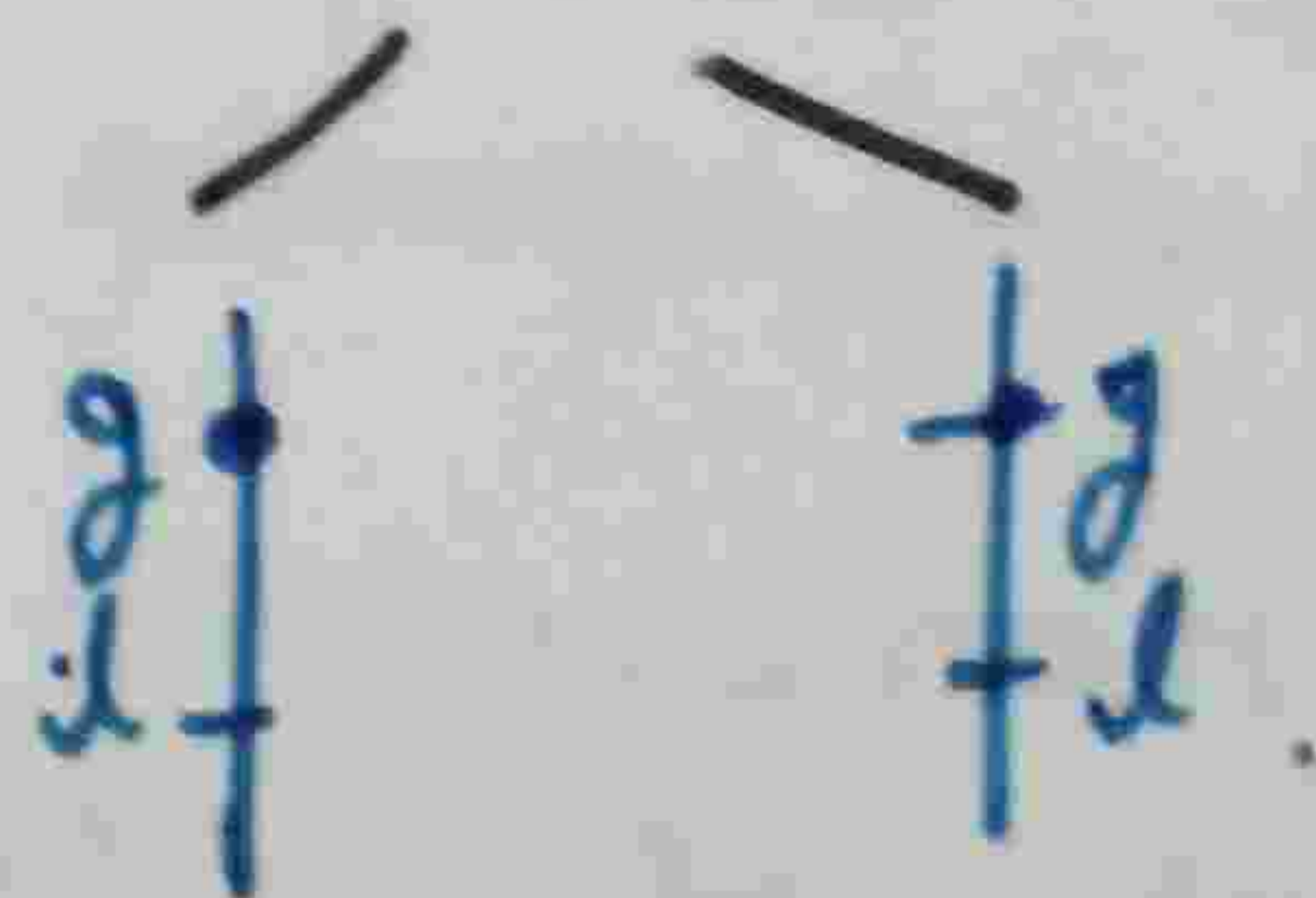
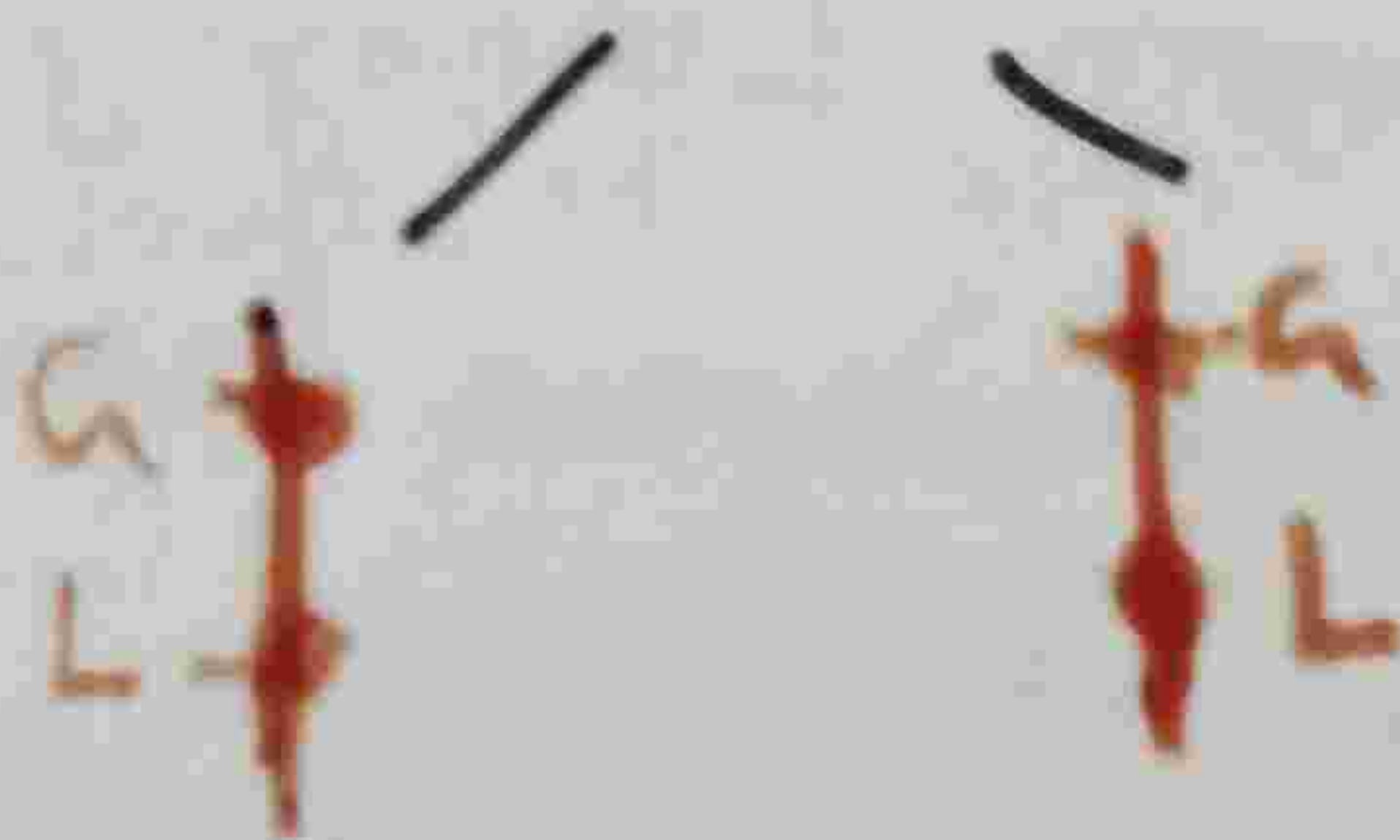
Parents



Grey body
Long wing



Black body
vestigial wings



F₁



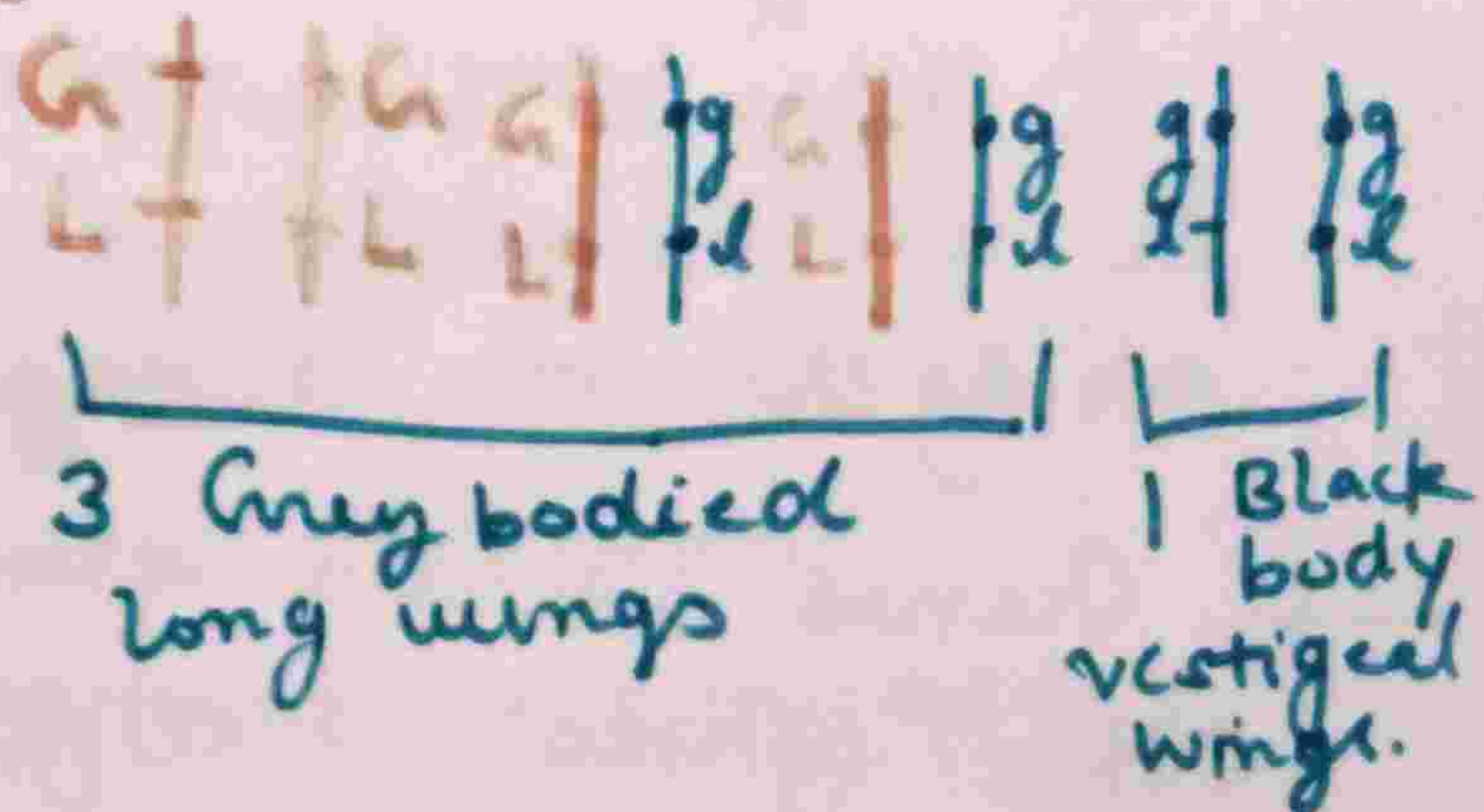
Grey body
long wings
(Heterozygous)



Grey body, Long wing
(Heterozygous)



F₂ generation

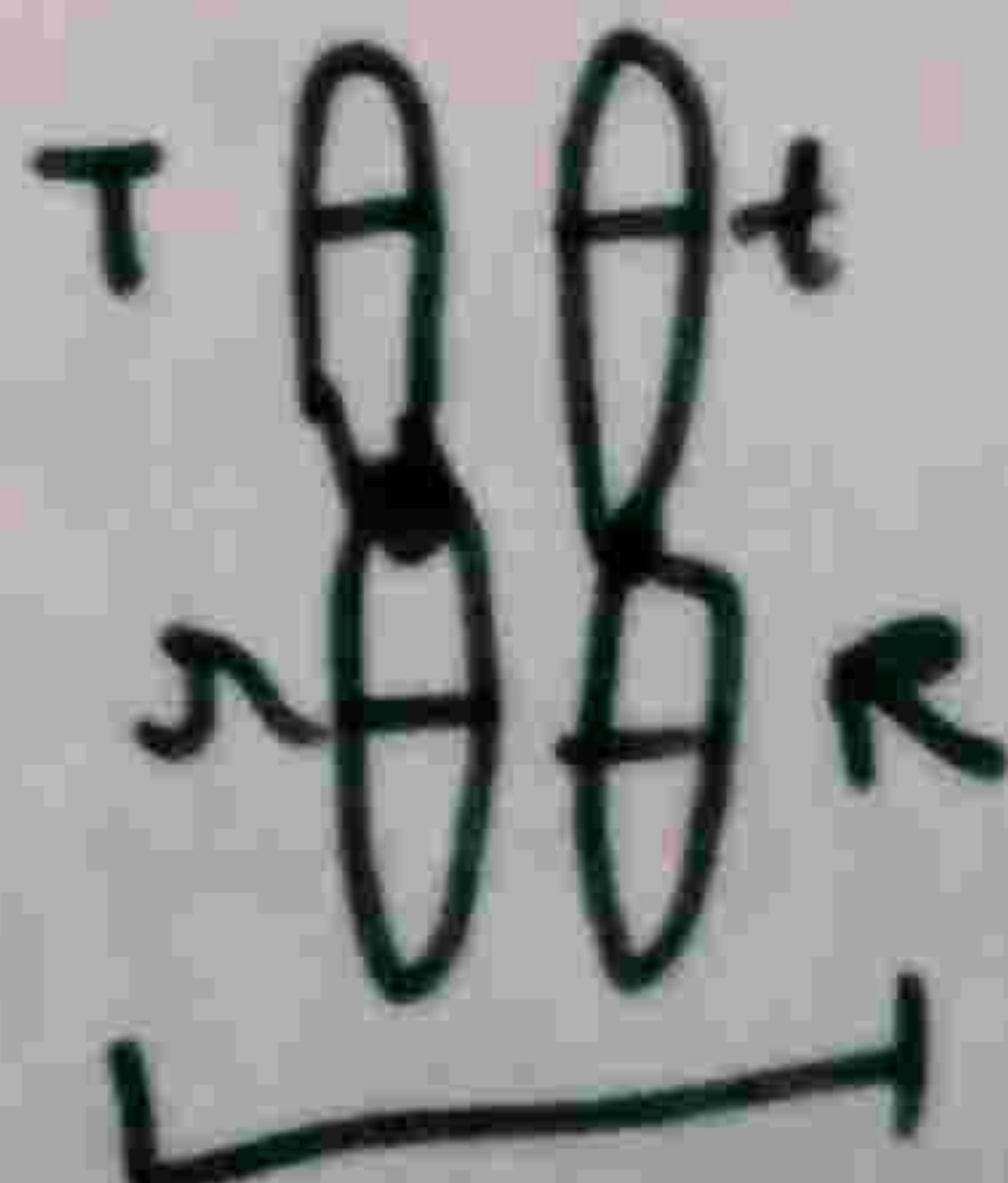


Cross showing Dihybrid ratio
3:1 in Linked genes

LINKAGE GROUP

→ All the genes located on one chromosome form Linkage group.

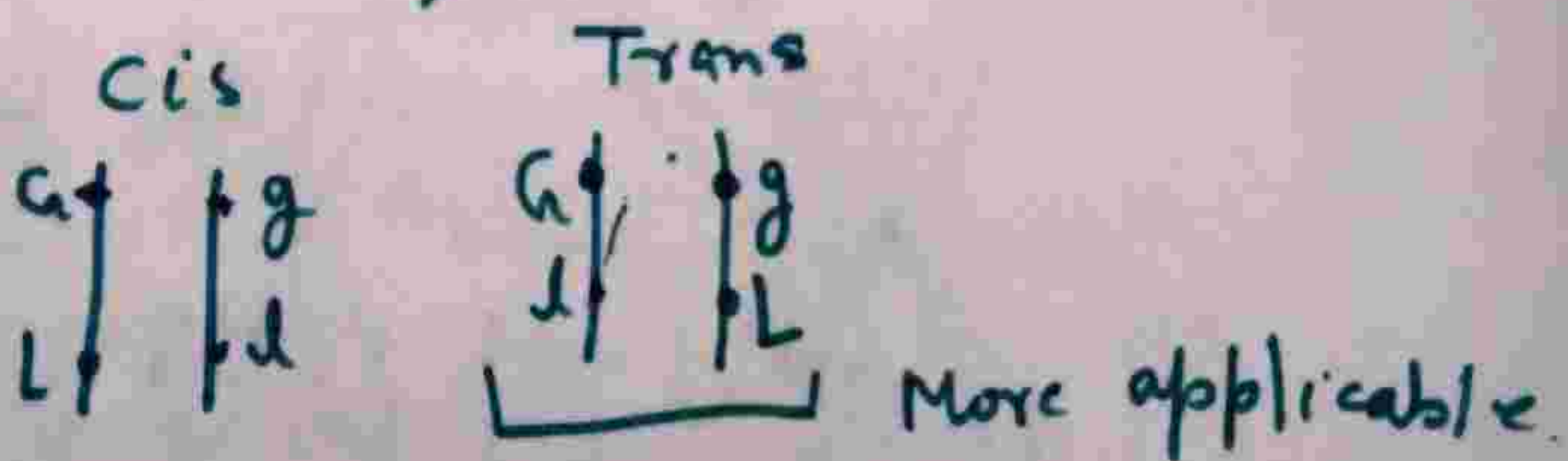
→ Homologous chromosome carry same type of genes so they are said to be form one linkage group



one linkage group

- In a species no. of Haploid chromosome = Linkage group
- In Human male Genes of Y chromosome are different so males have 24 linkage group
- Females have 23 linkage group
- In Drosophila 4 linkage groups are present [3 Large, 1 small]
- Garden Pea 7 linkage group.
- Maize 10 linkage group.

Arrangement^{ment} of Linked genes

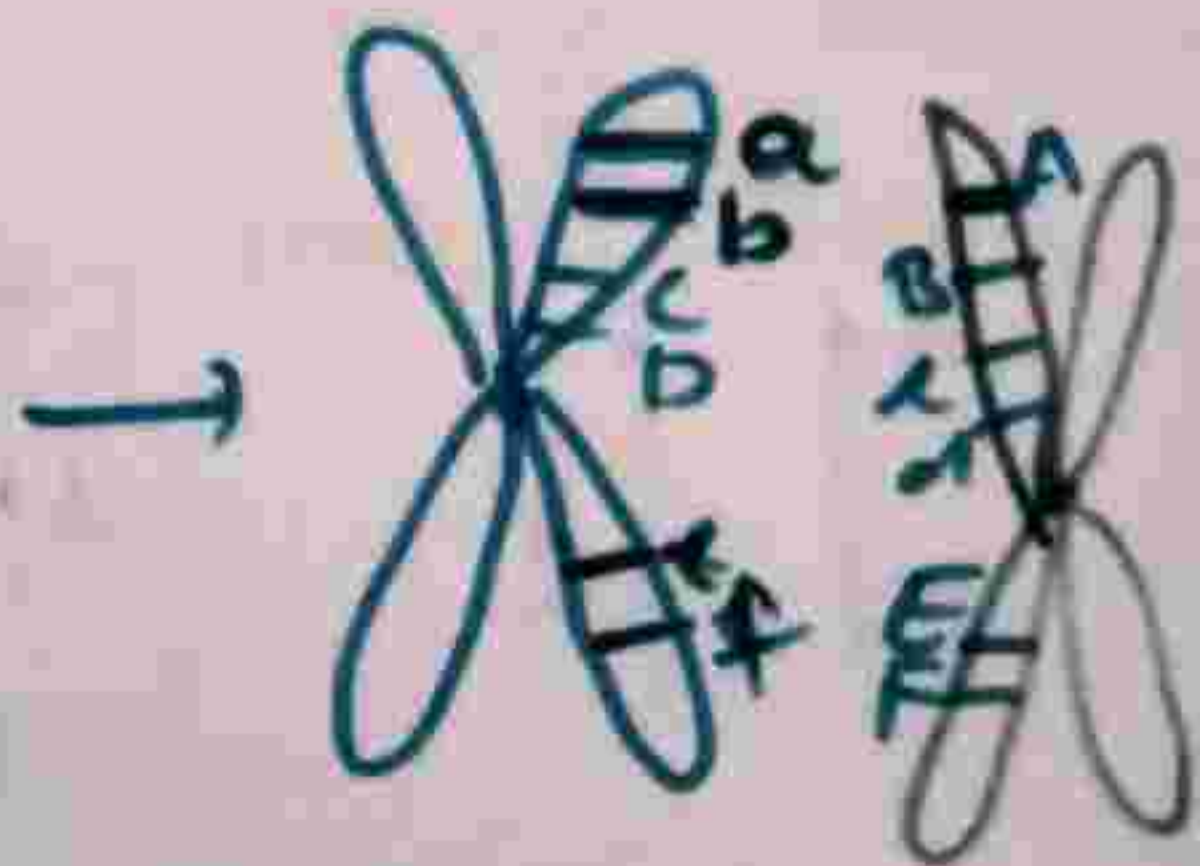
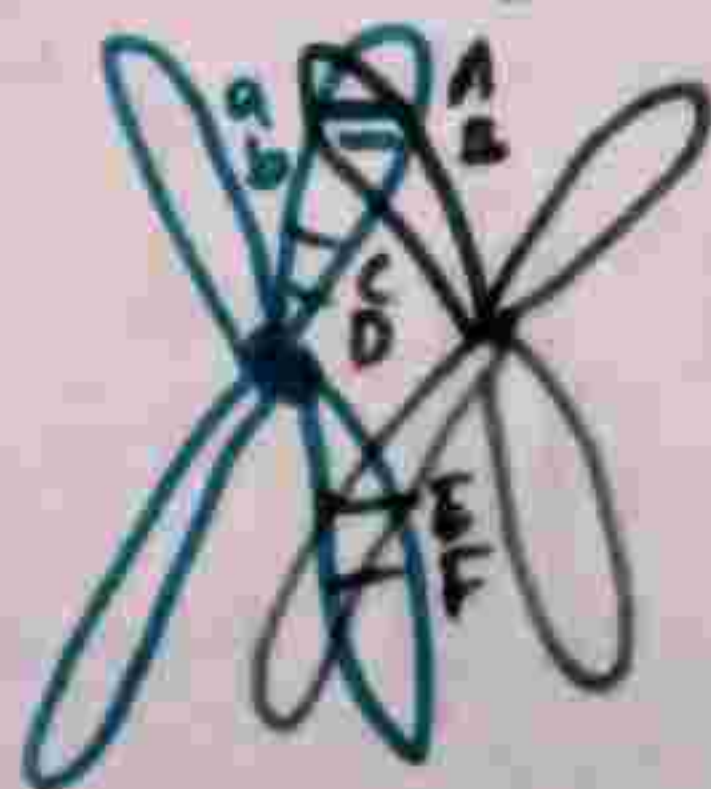
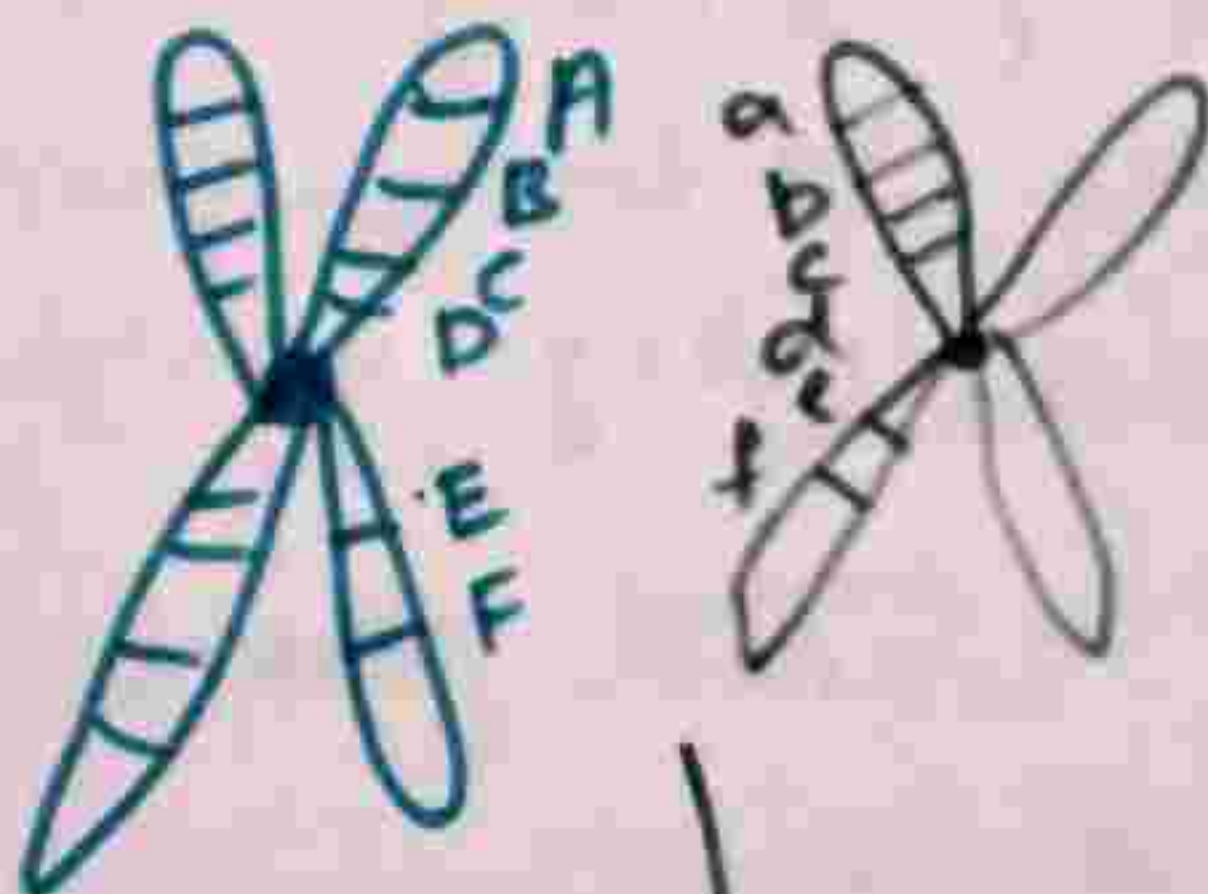
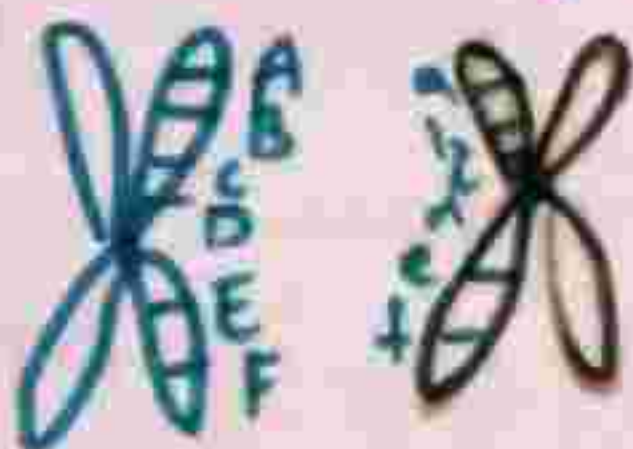


Types of Linkage

Complete Linkage Incomplete Linkage

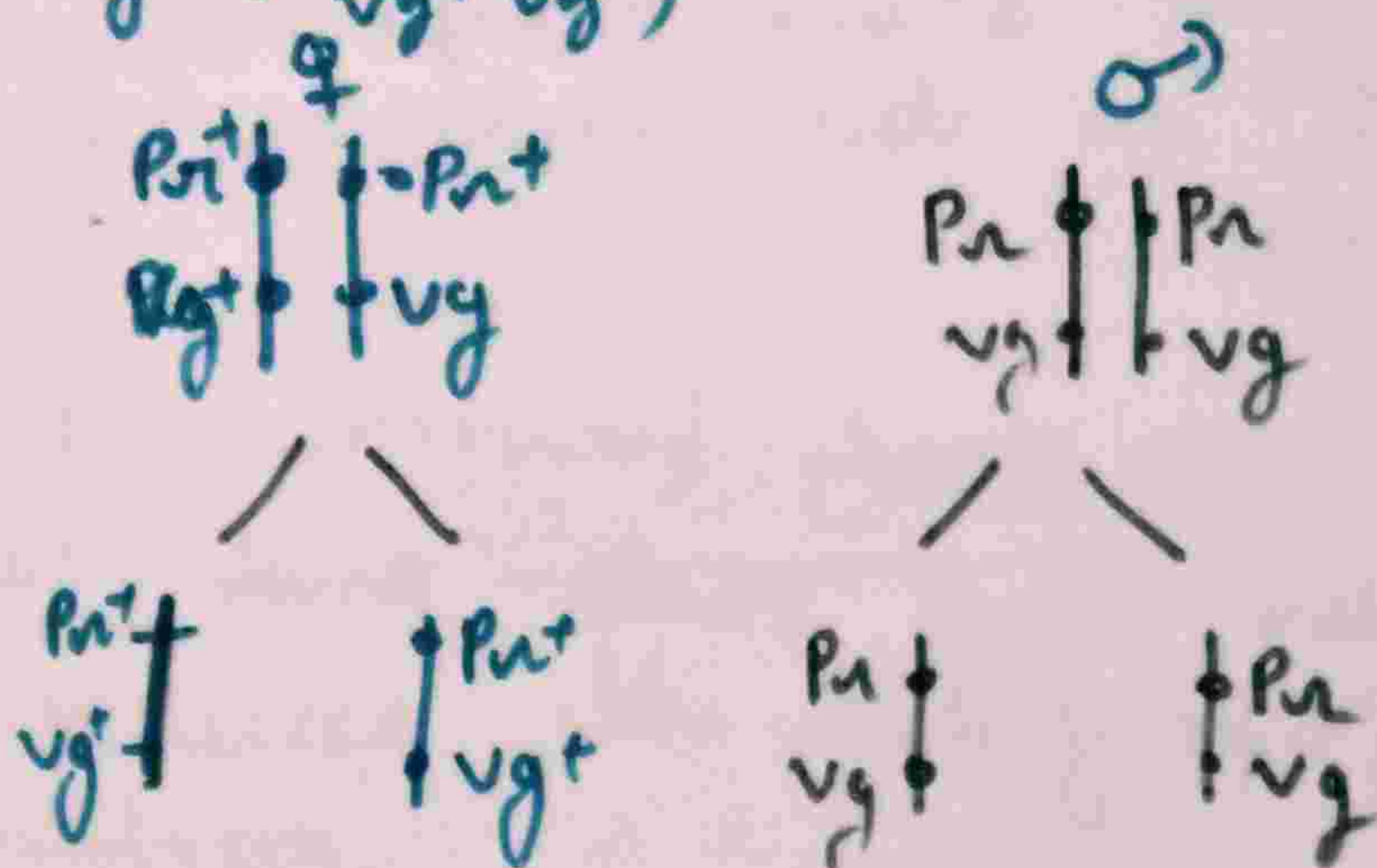
~~Complete~~ complete Linkage

→ When genes present on one chromosome - some remain together through many generations i.e. they do not get separated during crossing over. Complete linkage are rare in nature.



Genes AB and EF are showing complete linkage.

e.g. crossed is made between a female *Drosophila* with Red eye and Long wing ($P_{rt}^{+} vg^{+} / P_{rt}^{+} vg^{+}$) and Male with Purple eye and vestigial wings (P_{r} / P_{r} vg / vg)



F₁

$P_{rt}^{+} \quad P_{r}$
 $vg^{+} \quad vg$

Normal
 i.e. Long winged
 Red eyed.

Test cross

Complete Linkage $P_{rt}^{+} \quad P_{r}$
 $vg^{+} \quad vg$ × $P_{r} \quad P_{r}$
 $vg \quad vg$

$P_{rt}^{+} \quad P_{r}$
 $vg^{+} \quad vg$

Normal

$P_{r} \quad P_{r}$
 $vg \quad vg$

Purple vestigial.

Incomplete linkage

In incomplete linkage two linked genes get separated during crossing over

→ Partially show independent assortment as the genes are distantly located.

→ cross is made between white eyed Miniature wing Male and Normal wild type female

W^+m^+
 w^+m^+ ♀

x

Wm
male

↓

Wm female
 W^+m^+

W^+m^+
wild

Wm

white miniature

62.4% Parental

W^+m

miniature

37.6% Recombinant

wmt
white

Factors affecting linkage.

- 1) Distance
- 2) Age
- 3) Sex
- 4) Radiation
- 5) Chemicals

Significance

- a) Reduces the chances of recombination
- b) Helps in keeping racial and Parental traits
- c) Help in maintaining valuable traits
- d) Evidence for location of genes on chromosome.