BASUDEV GODABARI DEGREE COLLEGE ,

KESAIBAHAL

BLENDED LEARNING STUDY MATERIAL

UNIT-II

Principal
Basudev Godabari Degree College
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DEPARTMENT OF BOTANY

3rd SEMESTER BOTANY Hons.

PAPER- VII (GENETICS)

SELF STUDY MODULE DETAILS

Class- 3rd sem. (2020-21)

Subject- Botany

Paper Name- Genetics

Paper- VII

UNIT-II

Linkage, Crossing over and chromosome mapping. Linkage and crossing over cytological basis of crossing over, recombination frequency, to factor and three factor crossing, interference and coinciclence, numerical base on gene maping, sex linkage.

Learning Objective

After learning this you should be able to

1. Describe the different types of linkage.
2. Physical basis of Linkage.
3. Describe the molecular mechanism of crossing over.
4. Describe the effect of various factor that effect the frequency of recombination.

5. Exchange of chromatin material between homologous chromosomes.
6. Relationship between chiasma and crossing over.
7. Describe the molecular mechanism of crossing over.
8. Hybrid DNA model of recombination.
9. Sex linkage.
10. Criss – Cross inheritance.
11. X-Chromosomes.
12. Define crossing over.
13. Different theory of crossing over.
14. Details the mechanism of crossing over.
15. Complete Linkage.
16. Incomplete Linkage.

You can used the following video link to:-

https://youtu.be/lyr-GslldGS- Concept of linkage and crossing over.

https://youtu.be/PILzwrQCTfY- Linkage and crossing over.

https://youtu.be/SpfM32F2RPOI- linkage mapping.

https://youtu.be/-USF24HIFspq- Numerical problem based on genetic map.

You can used following books:-

1. Fundamentals of genetic – B.D. Singh - (Kalyani)
2. Genetics – P.K. Gupta- (Rostogi Publisher)

Plan Unit- II

No of period to be taken - 06

Date	Time	Period	Topic Covered	Signature
05.02.21	10.30 to 11.30am	01	Introduction of Linkage, complete and incomplete linkage, crossing over, cytological basis of crossing over, relationship between chiasna and crossing over.	
10.02.21	10.30 to 11.30am	01	Recombination frequency, two factors and three factors crosses	
18.02.21	10.30 to 11.30am	01	Doubt clearing class	
19.02.21	10.30 to 11.30am	01	Interference and coincidence, gene sequence, coefficient of Interference, coefficient of coincidence and Linkage map.	
24.02.21	10.30 to 11.30am	01	Introduction of sex linkage characteristics of sex linked inheritance. Partial sex linkage and the causes of sex linkage.	
12.03.21	10.30 to 11.30am	01	Doubt clearing class.	12/03/21

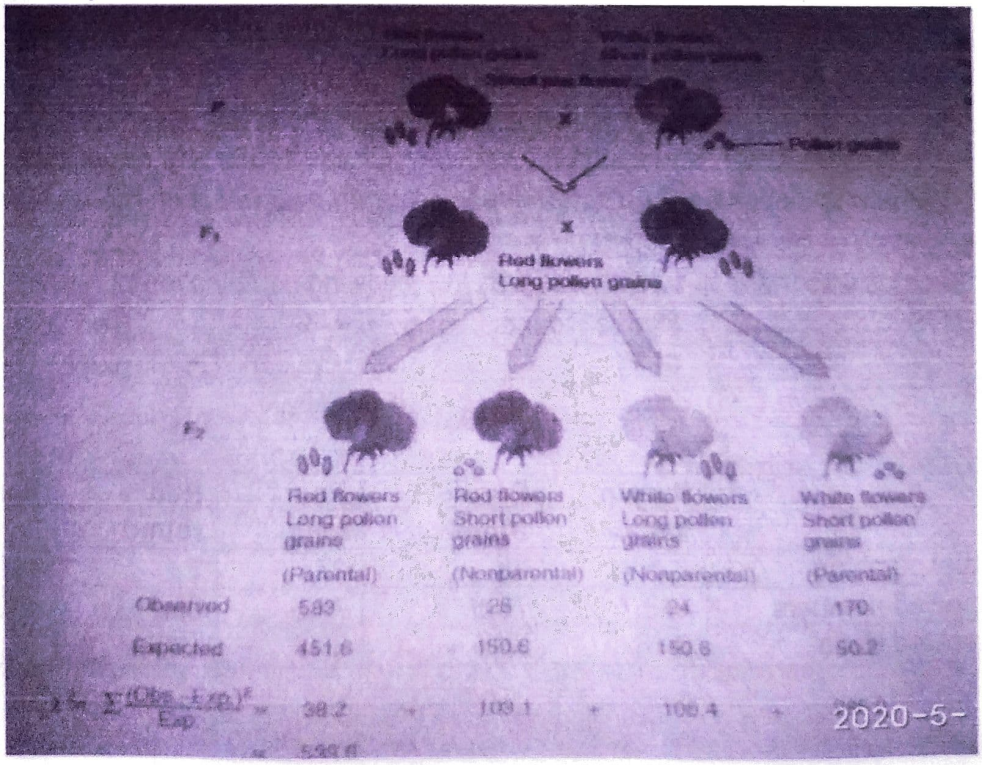
Course: Fundamentals of Genetics
Class: - Ist Year, IInd Semester
Lecture No. XVIII
Title of topic: - Estimation of linkage
Prepared by- Vinod Kumar, Assistant Professor, (PB & G)
College of Agriculture, Powarkheda

Linkage

Sutton and Boveri proposed the chromosome theory of inheritance. According to chromosome theory of inheritance, it is well established that many genes are located in each chromosome in a linear fashion. It may therefore be expected that all genes located in same chromosome would move to same pole during cell division. As a consequence, such genes will fail to show independent segregation and would tend to be inherited together. This tendency of genes to remain together in their original combination during inheritance is called linkage. Mendel's law of independent assortment is applicable only when the genes are located in different chromosomes while linkage refers to the genes located in the same chromosome.

The phenomenon of linkage was first reported by Bateson and Punnet in 1906. They studied flower colour and pollen shape in sweet pea involving two varieties / races.

Plants with red flowers and long pollen grains were crossed to plants with white flowers and short pollen grains. All the F_1 plants had red flowers and long pollen grains, indicating that the alleles for these two phenotypes were dominant. When the F1 plants were self-fertilized, Bateson and Punnett observed a **peculiar distribution** of phenotypes among the offspring. Instead of the 9:3:3:1 ratio expected for two independently assorting genes, they obtained a ratio of **24.3:1.1:1:7.1.** We can see the extent of the disagreement between the observed results and the expected results at the bottom of Figure 7.2. Among the 803 F_2 plants that were examined, the classes that resembled the original parents (called the parental classes) are significantly overrepresented and the two other (non parental) classes are significantly under represented.



The correct explanation for the lack of independent assortment in the data is that the genes for flower color and pollen length are located on the same chromosome—that is, they are linked.

Phases of linkage: In the two races experimented one parent has purple flowers with long pollen grains. The other parent has red flowers and round pollen grains. The character purple (P) is a simple monogenic dominant to red (p); while long (L) pollen is dominant to round (l) pollen, when these two plants were crossed the F_1 (PL/pl) was purple flowered with long pollen. But in F_2, the ratio of four types of plants deviated from the normal di-hybrid ratio of 9:3:3:1 expected on the principle of independent assortment of flower colour and pollen shape.

PARENTS Purple Long PL/PL x Red Round pl/pl

F_1 Purple Long PL/pl

F_2	Purple long	Purple round	Red long	Red round	Total
Actual numbers	4831	390	393	1338	6952
Expected numbers	3910.5	1303.5	1303.5	434.5	6952
Expected Ratio	9/16	3/16	3/16	1/16	

The plants with the character combination as in the original parents are known as parental forms or parental combinations, i.e., (i) Plants with purple flowers and long pollen and (ii) Plants with red flowers and round pollen. Plants possessing one character from one parent and another character from the second parent are known as recombined types or recombinations or new combinations or cross-overs, i.e. (i) plants with red flowers and long pollen and (ii) plants with purple flowers and round pollen.

From the above table the following features can be noted that in F_2, there are both parental forms and recombinations. The chief peculiarity of the results in the above table was that parental forms are in far excess of the expected number while the recombinations were fewer. This deviation from the expected ratio is due to linkage of the character pairs, viz., 1. Purple flowers (P) and long pollen (L) are linked because both the genes are located on the same chromosome.

Similarly red flowers (p) and round pollen (l) are linked together because the genes are located in the same chromosome (which is the homologue of the previous one). The recombinations are obtained due to crossing over between the two concerned genes in some of the spore mother cells.

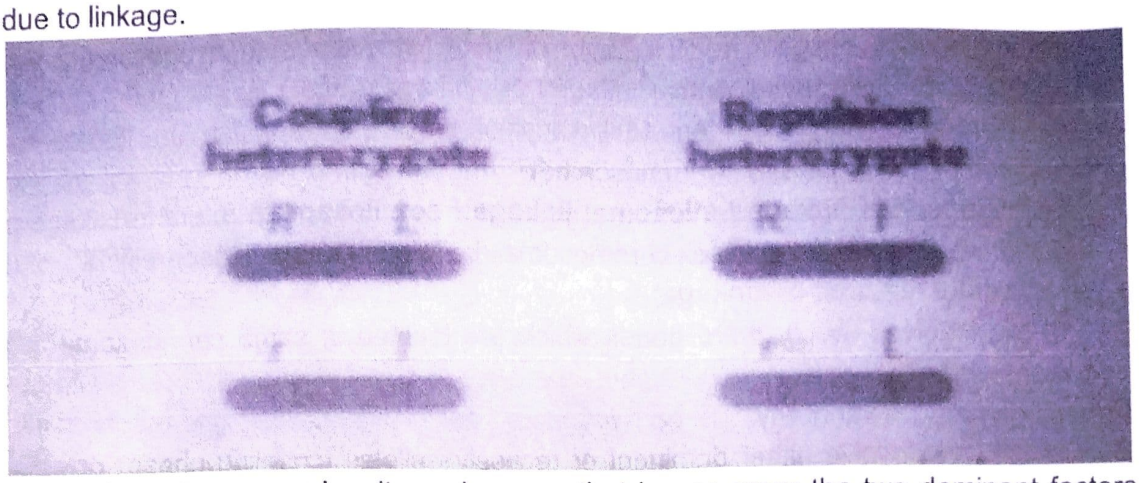
Another cross was made in sweet peas with the following combinations:

PARENTS Purple Round Pl/Pl x Red Long pL/pL

Purple Long Pl/pL

F_2	Purple long	Purple round	Red long	Red round	Total
Actual numbers	225	95	97	2	419
Expected numbers	235.7	78.5	78.5	26.2	419
Expected Ratio	9/16	3/16	3/16	1/16	

Here again the parental types are more while the recombinant types are less than expected on the basis of independent assortment, viz., 9:3:3:1. This deviation is also due to linkage.



In the above two examples, it can be seen that in one cross the two dominant factors (PL) are linked in one parent and two recessive factors (pl) are linked in the other. Linkage in such crosses is said to be in coupling phase. In the second cross, dominant allele of one character pair (P) and the recessive allele of another character pair (l) are linked together in one parent, while in the second parent the other recessive (p) and dominant alleles (L) are linked. Linkage in such crosses is said to be in repulsion phase. Later, T H Morgan put forth the theory of linkage and concluded that coupling and repulsion were two phases of single phenomenon, linkage.

Types of Linkage: Linkage is generally classified on the basis of three criteria viz., (i) Crossing over, (ii) Genes involved and (iii) Chromosomes involved

(i) Based on crossing over: Linkage may be classified into (a) complete and (b) incomplete / partial depending up on absence or presence of recombinant phenotypes in test cross progeny.

(a) Complete linkage: It is known in case of males of *Drosophila* and females of silkworms, where there is complete absence of recombinant types due to absence of crossing over.

(b) Incomplete / partial linkage: If some frequency of crossing over also occurs between the linked genes, it is known as incomplete / partial linkage. Recombinant types are also observed besides parental combinations in the test cross progeny. Incomplete linkage has been observed in maize, p ea, *Drosophila* female and several other organisms.

(ii) Based on genes involved : Depending on whether all dominant or some dominant and some recessive alleles are linked together, linkage can be categorized into (a) Coupling phase and (b) Repulsion phase

(a) Coupling phase: All dominant alleles are present on the same chromosome or all recessive alleles are present on same chromosome.

TR tr

----- --- Coupling phase

TR tr

(b) Repulsion phase: Dominant alleles of some genes are linked with recessive alleles of other genes on same chromosome.

Tr tR

----- --- Repulsion phase

Tr tR

(iii) **Based on chromosomes involved:** Based on the location of genes on the chromosomes, linkage can be categorized into (a) autosomal linkage and (b) X-chromosomal linkage / allosomal linkage / sex linkage

(a) **Autosomal linkage:** It refers to linkage of those genes which are located in autosomes (other than sex chromosomes).

(b) **X-chromosomal linkage / allosomal linkage / sex linkage**: It refers to linkage of genes which are located in sex chromosomes i.e. either 'X' or 'Y' (generally 'X')

Characteristic features of Linkage:

1. Linkage involves two or more genes which are located in same chromosome in a linear fashion.
2. Linkage reduces variability.
3. Linkage may involve either dominant or recessive alleles (coupling phase) or some dominant and some recessive alleles (repulsion phase).
4. It may involve either all desirable traits or all undesirable traits or some desirable and some undesirable traits.
5. It is observed for oligo-genic traits as well as polygenic traits.
6. Linkage usually involves those genes which are located close to each other.
7. The strength of linkage depends on the distance between the linked genes. Lesser the distance, higher the strength and vice versa.
8. Presence of linkage leads to higher frequency of parental types than recombinants in test cross. When two genes are linked the segregation ratio of dihybrid test cross progeny deviates significantly from 1:1:1:1 ratio.
9. Linkage can be determined from test cross progeny data.
10. If crossing over does not occur, all genes located on one chromosome are expected to be inherited together. Thus the maximum number of linkage groups possible in an organism is equal to the haploid chromosome number.

Eg. Onion 2n = 16 n = 8 maximum linkage groups possible = 8 Maize 2n = 20 n = 10 maximum linkage groups possible = 10

11. Linkage can be broken by repeated intermating of randomly selected plants in segregating population for several generations or by mutagenic treatment.
12. Besides pleiotropy, linkage is an important cause of genetic correlation between various plant characters.

Linkage and pleiotropy: A close association between two or more characters may result either due to linkage or pleiotropy or both. Pleiotropy refers to the control of two or more characters by a single gene. A tight linkage between two loci can be often confused with pleiotropy. The only way to distinguish between linkage and pleiotropy is to find out a crossover product between linked characters. Intermating in segregating populations may break a tight linkage, but a huge population has to be raised to find out the crossover product. If a cross over product is not found in spite of repeated intermatings, there seems to be the case of pleiotropy rather than linkage.

Linkage groups: Linkage group refers to a group of genes which are present in one chromosome. In other words, all those genes which are located in one chromosome constitute one linkage group. The number of linkage groups is limited in each individual. The maximum number of linka ge groups is equal to the haploid chromosome number of

an organism. For example there are ten linkage groups in corn (2n = 20), seven in garden pea (2n = 14), seven in barley (2n = 14), four in *Drosophila melanogaster* (2n = 8) and 23 in man (2n = 46).

Detection of linkage: Test cross is the most common method of detecting the linkage. In this method, the F, heterozygous at two loci (AB/ab) is crossed to a double recessive parent (ab/ab) and the phenotypic ratio of test cross progeny is examined. If the phenotypic ratio of test cross progeny shows 1:1:1:1 ratio of parental and recombinant genotypes, it indicates absence of linkage. If the frequency of parental types and recombinant types deviate significantly from the normal dihybrid test cross ratio of 1:1:1:1, it reveals presence of linkage between two genes under study.

Another way to detect the presence or absence of linkage is to self pollinate the individual heterozygous at two loci. If there is complete dominance at each locus and no epistasis, the segregation ratio of the progeny will be 9:3:3:1. Presence of linkage either in coupling or repulsion phase will lead to significant deviation from 9:3:3:1 ratio. The deviation of observed values from the expected ratio is tested with the help of x_2 test.

Significance of Linkage in Plant Breeding :

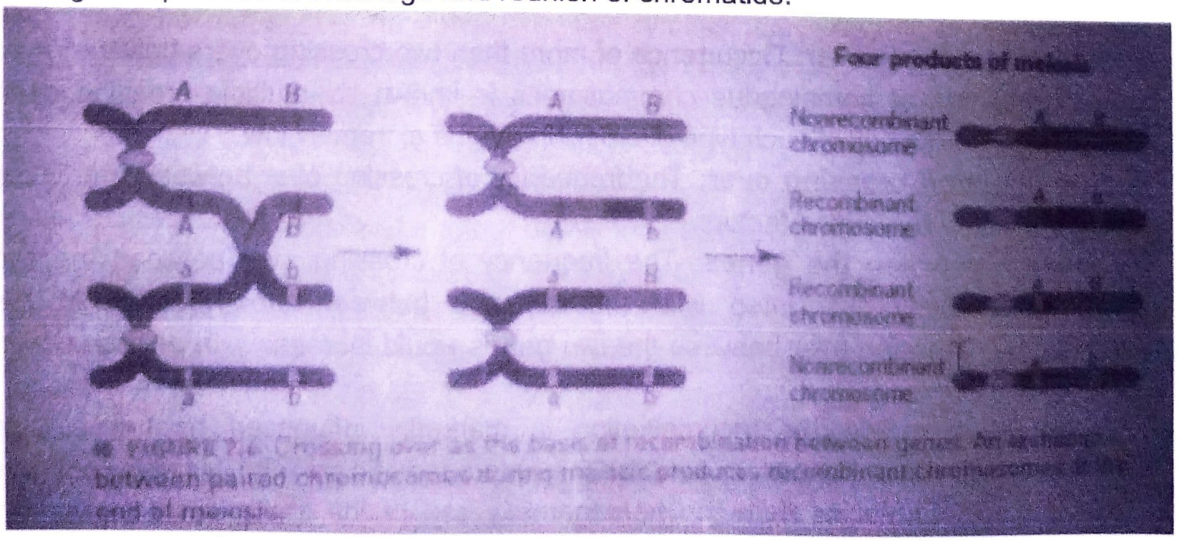
1. Linkage limits the variability among the individuals.
2. Linkage between two or more loci controlling different desirable characters is advantageous for a plant breeder. A linkage between genes controlling two different desirable characters will help in simultaneous improvement of both the characters.
3. Linkage is undesirable when desirable and undesirable genes are linked together.
4. The estimates of genetic variances for quantitative characters are greatly influenced by the presence of linkage.

Lecture No.: XIX

Crossing Over

The term crossing over was first used by Morgan and Cattell in 1912. "The exchange of precisely homologous segments between non-sister chromatids of homologous chromosomes is called crossing over."

Mechanism of crossing over: It is responsible for recombination between linked genes and takes place during pachytene stage of meiosis i.e. after the homologous chromosomes have undergone pairing and before they begin to separate. It occurs through the process of breakage and reunion of chromatids.



During pachytene, each chromosome of a bivalent (chromosome pair) has two chromatids so that each bivalent has four chromatids or strands (four-strand stage). Generally one chromatid from each of the two homologues of a bivalent is involved in crossing over. In this process, a segment of one of the chromatids becomes attached in place of the homologous segment of the non sister chromatid and vice-versa. It is assumed that breaks occur at precisely homologous points in the two non sister chromatids involved in crossing over; this is followed by reunion of the acentric segments. This produces a cross (x) like figure at the point of exchange of the chromatid segments. This figure is called chiasma (which is seen in diplotene stage of meiosis) (plural-chiasmata).

Obviously, each event of crossing over produces two recombinant chromatids (involved in the crossing over) called cross over chromatids and two original chromatids (not involved in crossing over) referred to as non crossover chromatids. The crossover chromatids will have new combinations of the linked genes, i.e. will be recombinant; gametes carrying them will produce the recombinant phenotypes in test-crosses, which are called crossover types.

Similarly, the noncrossover chromatids will contain the parental gene combinations and the gametes carrying them will give rise to the parental phenotypes or noncrossover types. Therefore the frequency of crossing over between two genes can be estimated as the frequency of recombinant progeny from a test-cross for these genes. This frequency is usually expressed as percent.

Thus, the frequency of crossing over (%) can be calculated using the formula;

$$\text{Frequency of crossing over(\%)} = \frac{\text{No. of recombinant progeny from a test cross}}{\text{Total number of progeny}} \times 100$$

Types of crossing over: Depending upon the number of chiasmata involved, crossing over is of three types.

1. Single crossing over: It refers to the formation of single chiasma between non-sister chromatids of homologous chromosomes. It involves two linked genes (Two point test cross).

2. Double crossing over: It refers to the formation of two chiasmata between non-sister chromatids of homologous chromosomes. It involves three linked genes (Three point test cross).

3. Multiple crossing over: Occurrence of more than two crossing overs between non-sister chromatids of homologous chromosomes is known as multiple crossing over. However, the frequency of such type of crossing over is extremely low.

Factors affecting crossing over: The frequency of crossing over between the linked genes is affected by several factors.

1. Distance between the genes: The frequency of crossing over between the two genes is positively associated with the distance between their location in the chromosome. Crossing over between the two genes would increase with an increase in distance between them.

2. Sex: The frequency of recombination is markedly influenced by the sex of heterozygotes for linked genes. In general, the heterogametic sex shows relatively lower recombination frequencies than the homogametic sex of the same species. Eg: No

crossing over occurs between linked genes in *Drosophila* males and females of silkworm.

3. Age of female: The frequency of crossing over shows a progressive decline with the advancing age of *Drosophila* females.

4. Temperature: In *Drosophila*, the lowest frequency of crossing over is observed when females are cultured at 22_0C. The frequency of recombination tends to increase both at the lower and higher temperatures than 22_0C.

5. Nutrition: The frequency of crossing over in *Drosophila* is affected by the presence of metallic ions Eg: Ca^{+2} and Mg^{+2} in its food. Higher the amount, lower will be the crossing over frequenc y and vice-versa.

6. Chemicals: Treatment of *Drosophila* females with certain antibiotics like mitomycin D and actinomycin D and certain alkylating agents such as ethylmethane sulphonate promotes crossing over.

7. Radiations: An increase in frequency of crossing over is observed when *Drosophila* females are irradiated with x-rays and g-rays.

8. Plasmagenes: In some species, plasma genes reduce the frequency of crossing over. Eg: The Tifton male sterile cytoplasm reduces the frequency of crossing over in bajra.

9. Genotype: Many genes are known to affect the occurrence as well as the rate of crossing over. For example C_3G gene of *Drosophila* located in chromosome 3 prevents crossing over when present in homozygous state while it promotes crossing over in the heterozygous state.

10.Chromosomal aberrations: In *Drosophila*, some chromosomal aberrations Eg: paracentric inversions, reduce recombination between the genes located within the inverted segment.

11.Distance from centromere: Centromere tends to suppress recombination. Therefore genes located in the vicinity of centromeres show a relatively lower frequency of crossing over than those located away from them.

Significance of crossing over in Plant Breeding:

1. It increases variability
2. It helps to break linkages
3. It makes possible to construct chromosome maps

Cytological proof of crossing over: The first cytological evidence in support of genetic crossing over was provided by Curt stern in 1931 on the basis of his experiments with *Drosophila* by using cytological markers. He used a *Drosophila* female fly in which one X-chromosome was broken into two segments and out of these two segments, one behaved as X-chromosome. This chromosome had one recessive mutant allele *car* (carnation) for eye colour and another dominant allele *B* (Bar) for eye shape. The other X-chromosome had small portion of Y chromosome attached to its one end. This chromosome had the dominant allele + (wild type allele of *car*) producing dull red eye colour and a recessive allele + (wild type allele of *B*) producing normal ovate eye shape. Thus the phenotype of female is barred (since *B* is dominant to +) with normal eye colour (since *car* is recessive to +) and both the X-chromosomes in the female had distinct morphology and could be easily identified under microscope. Such females were crossed with male flies having recessive alleles for both genes (*car* +). As a result of crossing over female flies produce four types of gametes *viz.*, two parental types or non

crossover types (*car B* and + +) and two recombinant types or cross over types (*car* + and + *B*). The male flies produce only two types of gametes (car + and Y), because crossing over does not occur in *Drosophila* male. A random union of two types of male gametes with four types of female gametes will produce males and females in equal number of four each.

Stern cytologically examined the chromosomes of recombinant types i. e. carnation with normal eye shape and barred with normal eye colour. It was found that carnation flies did not have any fragmented X-chromosome but rather had normal X-chromosome. On the other hand barred flies had a fragmented X-chromosome with a segment of Y-chromosome attached to one of the two fragments of X-chromosome. Such chromosome combination in barred is possible only through exchange of segments between non-sister chromatids of homologous chromosomes. This has proved that genetic crossing over was accompanied with an actual exchange of chromosome segments.

Similar proof of cytological crossing over was provided by Creighton and McClintock in maize.

Coincidence: It refers to the occurrence of two or more distinct crossing overs at the same time in the same region of a pair of homologous chromosomes and as a result, a double cross over product is obtained. Coefficient of coincidence is estimated b y using the formula:

$$\text{Coefficient of coincidence} = \frac{\text{Observed frequency of double cross over}}{\text{Expected frequency of double cross over}}$$

(The ratio between the observed and the expected frequencies of double crossovers is called coefficient of coincidence)

Interference: The occurrence of crossing over in one region of a chromosome interferes with its occurrence in the neighbouring segment. This is known as interference. The term interference was coined by Muller. It may also be defined as the tendency of one crossing over to prevent another crossing over from occurring in its vicinity. This is called positive interference. Sometimes, one crossing over enhances the chance of another crossing over in the adjacent region. This is termed as negative interference. Eg: *Aspergillus*, bacteriophages.

The effect of interference reduces as the distance from the first crossing over increases. The intensity of interference may be estimated as coefficient of interference.

Coefficient of interference = 1 - coefficient of coincidence

Differences between crossing over and linkage

Crossing over	**Linkage**
1. It leads to separation of linked genes	1. It keeps the genes together
2. It involves exchange of segments between non-sister chromatids of homologous chromosomes	2. It involves individual chromosomes
3. The frequency of crossing over can	3. The number of linkage groups can never exceed 50 % never be more than haploid chromosome number
4. It increases variability by forming new gene combinations	4. It reduces variability

5. It provides equal frequency of parental and recombinant types in test cross progeny	5. It produces higher frequency of parental types than recombinant types in test cross progeny

Chromosome Maps

Chromosome maps can be prepared by genetical or cytological methods

1. Genetical method: This is the general method and is based upon cross over data. The resulting map is the linkage map. Linkage map (cross over map or genetical map) map be defined as a line on which the relative positions of genes proportional to the amount of crossing over between them is represented.

A rule widely followed in plotting genes is that if genes A and B are known to be linked and if a particular gene is found by experiment to be linked with gene A it must also be linked with gene B. This principle follows from the fact that two linked genes are on the same chromosome. The genes, which are linked together on the same chromosomes are called syntenic genes.

Genetic mapping of chromosomes is based on the following assumptions:

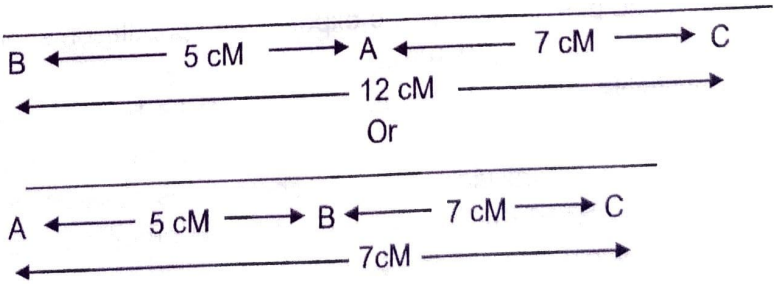
a) The genes are arranged in a linear order.

b) Crossing over is due to breaks in the chromatids

c) Crossing over occurs by chance and is at random

d) The percentage of crossing over between the genes is an index of their distance apart.

Map distance: Recombination frequencies between the linked genes are determined from appropriate testcrosses. These percent frequencies are used as map units for preparing linkage maps. A map unit is that distance in a chromosome, which permits one percent recombination (crossing over) between two linked genes. A map unit is also called a centri-Morgan, after the name of the scientist Morgan, who first constructed the linkage map in *Drosophila*. Thus 5 % crossing over between genes A and B is taken to mean that they are situated 5 map units of distance apart on the same chromosome. If a third gene C with 7 % crossing over between A and C is included the relationship of linkage between the three genes A, B and C is indicated as below:



To choose the correct one between these two alternatives, one more information i.e. either the order of arrangement of the three genes or the cross over value between B and C is required. Eg: If the crossover value between B and C is found to be 2 % by actual experiments, the second arrangement is the correct one. Therefore, for preparing a chromosome map of three genes either the map distances (cross over frequencies) between all three gene pairs must be known or the cross over frequencies between any two gene pairs plus the order or sequence of these three genes in the chromosome must be known. In obtaining cross over value care should be taken about the

occurrence of double crossing over between the concerned genes. If two genes A and B are rather far apart in a chromosome and if two crossing overs (i.e. double cross over) occur between A and B, the chromatids involved do not show recombination of marker genes. If double crossing over occurs frequently, the recombination value will be less and gives a false impression that the distance between the concerned two genes is less. To overcome this difficulty, data for chromosome mapping should be taken from linked gene pairs that are quite close together. Usually double crossing over does not occur within distances less than 5 map units or for certain chromosome segments within distances upto 15 or 20 map units.

2. Cytological maps: By cytological studies of chromosomal aberrations and by their behaviour in genetical experiments, it is possible to construct map of chromosomes showing the actual physical location of gene in a chromosome. Such maps are called cytological maps of chromosomes. The work on cytological maps also confirm the theory of linear arrangement of genes in chromosomes.

Comparison between linkage maps and cytological maps: The relative distances between the genes on linkage map and cytological map do not always correspond. The discrepancies are greatest in the vicinity of the centromere where one cross over unit corresponds to a relatively much greater physical distance on the chromosome than in other regions of the same chromosome. These discrepancies may be explained on the basis that different chromosomes and various regions in the same chromosome may also show variations in frequency of crossing over. Eg: In *Drosophila,* frequency of crossing over seems to be affected by temperature of the mother flies and by environmental factors.

Importance of linkage and chromosome maps in plant breeding:

1. They give an idea whether particular genes are linked or segregate independently.
2. Linkage intensities can be known and the probability of obtaining a given combination of genes can be assessed. If linkage between two genes is close, it is difficult to obtain recombination. In such cases, linkage can be broken artificially by irradiating with x-rays etc. and the desired combinations may be obtained. However, close linkage is useful to preserve desirable gene combinations.
3. Help the geneticist to plan how large the experimental population should be to obtain plants with the desired gene combination.
4. If an easily identifiable qualitative character is found to be linked with the quantitative character, the qualitative character can be used to easily identify the recombinants. This means that when a particular qualitative character is observed in a recombinant plant, it can be understood that the associated linked quantitative character is also present. Eg: Anthocyanin pigment and yield in rice
5. Linkage limits the variability among the individuals.

TYPES OF CYTOPLASMIC INHERITANCE

cytoplasmic inheritance are off three type is

→ cytoplasmic inheritance involving essential organelle like chloroplast and mitochondria called organellar inheritance

(Chloroplast and mitochondria show maternal inheritance

→ Maternal effect depending indirectly on nuclear genes and involving no known cytoplasmic hereditary unit ~~and involving~~ called as predetermination. In this maternal effect is determined before fertilisation

eg - shell coiling in snail (Limnae peregra)

→ cytoplasmic inheritance involving dispensable and infective heriditary particle in cytoplasm which may or may not depend on nuclear gene called as Dauer modification

eg - Sigma particle in drosophilla, kappa particle in paramecium

Linkage

→ It is phenomenon of certin (2 or more) genes staying togather during inheritance through generation with out changes or separations as they are present on same chromosome

→ It is first discovered by Bateson & Punnet (1905) sweet pea (Lathyrus odoratus)

→ They give coupling and repulsion phenomenon

→ Linkage can be thought of exception of independent assortment

→ Morgan defined linkage as follows

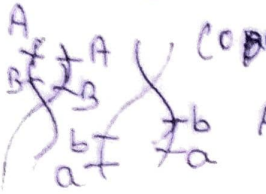
All the genes present on a chromosome have the tendency to maintain original combination and to enter one and the same gamete

→ The tendency of two alleles to stay together is called coupling

→ The tendency of two alleles to avoid one another is called Repulsion.

* If the two alleles, such as A and B come from the same parent they tend to enter the same gamete & transmit together (Coupling phase)

* If the same alleles come from different parent they tend to enter in to diff^{n} gamete. (Repulsion phase)



Coupling phase

AABB × aabb

Cis

Repulsion phase

AAbb × aa BB

Trans

SUTTON DUE of Linkage

→ Sutton in 1903 predicated that each chromosome contains a gene during meosis chromosome move in to gamete as unit.

→ Hence all the gene which are situated in the same chromosome will be linked together as a result each species would have a specific number of group corresponds with the number of chromosome

* Sc Batson and punnet

coupling and Repulsion hypothesis

→ B.P while working on sweet pea observe that flower colour and pollen shape tend to remain together & do not asort independently

Blue flower long pollen. × Red flower Round pollen

Blue long	Blue Round	Red long	Red Round
7	1	1	7

→ Bateson and punnett observed that parents tends to same gamete ... to be inherited together

→ This phenomenon is called coupling ... gene comes from 2 diff^n parent tends to enter gamets and to be inherited separately & independently this phenomenon is known as Repulsion

CHROMOSOMAL THEORY of LINKAGE

Proposed by Morgan and castel (1911)
According to this theory

- Gene thats show in linkage are situated on same chromosome. (in parental combination except for crossing over)
- Linkage gene are arranged in linier order
- The distance bet^n the linked genes in the chromosome determines the strength of the linkage.
- The closely located genes show greater linkage then the distant genes.
- Linkage genes depend on the original combination during inheritance.
- The linked genes show two types of arrangement Cis and Trans.

Cis - arrangement - Dominant alleles of both the gene are present on the chromosome while their recessive alleles are present over its homologous chromosome

Trans - arrangement - presence of dominant alleles of one gene and recessive allele of the other gene on one chromosome (reverse arrangement of this genes present over its homologous

TYPES OF LINKAGE

There are two types of linkage

(1) Complete linkage

(2) Incomplete linkage

COMPLETE LINKAGE

→ Linkage in which gene always show parental combination. It never forms new combination

→ Crossing over is absent in it because gene are also located very closely on chromosome. (Reason

* When the two or more genes remain together closely for a number of generations. the linkage is said to be complete

* It produce only parental combination

* It is very rare and found in only male Drosophila & female silkworm moth

ex-

→ A Red eyes normal wings (RRWW) female Drosophila is crossed with male drosophilla have purple eye and vestigial wings (rrww)

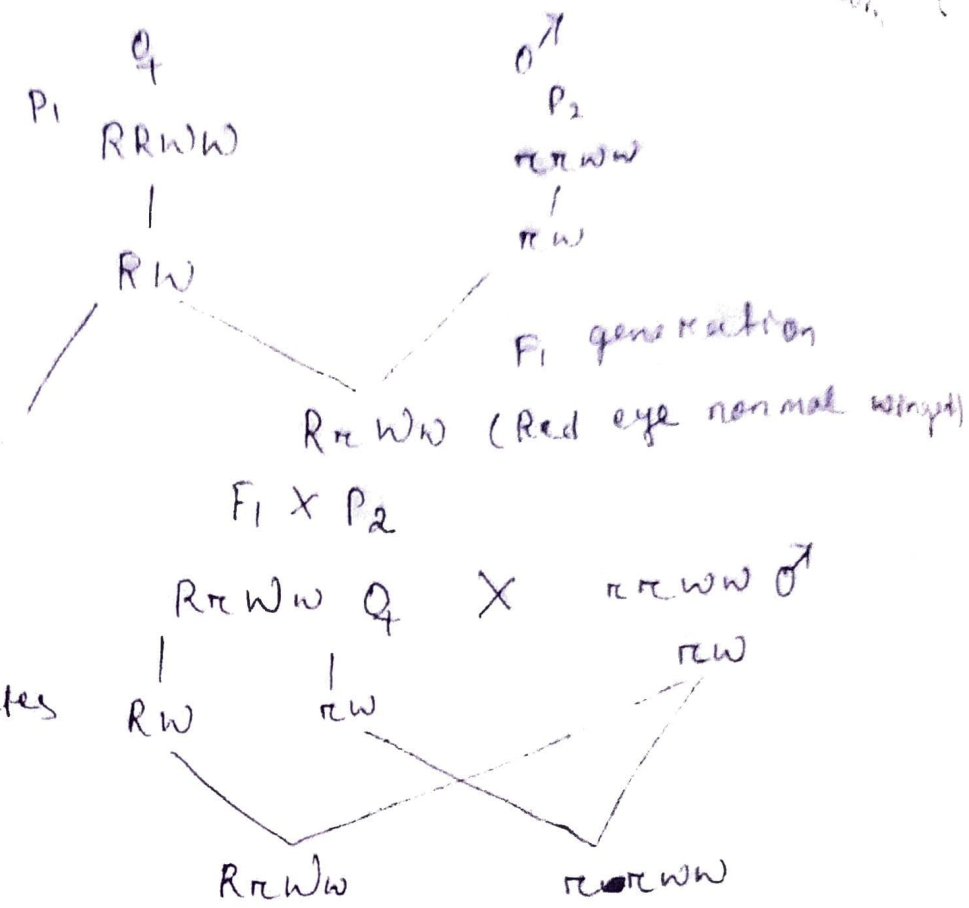
→ In F_1 generation ofspring are (RrWw) Heterozygous Red eyed & normal winged.

→ Now Heterozygous female fly (RrWw) is test crossed with a (rrww) Drosphilla male (Having P.E and V.W)

→ In f_2 generation red eye, normal wings (50%.) and vestigial weings, purple eye (50%.) in the ratio of 1:1

→ No recombinant types are formed because linkage is complete. & no crossing over occurs.

parents. Red eyed, normal weight × purple eye, wrinkled wing



Due to complete linkage, instead of four gametes only two gametes are formed.

Test cross progeny	(R.E, N.W)	(P.E, V.W)
Ratio	1	1
Recombinants	Nill	

→ How ever, test cross in F1 blue and long (BBLL) and double recessive (bbll) give blue long (e.g. (Hybrid) (F1 generation)

Red round (+ 3 1%)

Blue round (6.3%)

Red long (6.3%)

→ The parental combination are 81.4% due to linkage in genes on two homologous chromosome.

→ While increase of new combinations (12.6%) the genes get separated due to breaking of chromosome at the time of crossing over in prophase-I of Meiosis

→ New combination due to incomplete linkage

IMPORTANCE OF LINKAGE

- Linkage plays an important role in determining the patterns of crop of hybridization and selection programmes
- It holds the parental characters together and restricts the appearance of new recombinants
- It helps in maintaining the valuable traits of newly developed variety
- It allows the plant and animal breeding to combine all the desirable traits in a single unit.

CROSSING OVER

- Crossing over is the exchange of chromosomal part between non-sister chromatids of a homologous pair resulting in recombination of gene
- The non-sister chromatids in which exchang of segments takes place are known as cross overs or recombinants while other chromatids not involved in exchange of segments are called non crossover or parental type
- The terem crossing over was first introduced by T. H Morgan and Castell (1911) & defined it as the separation of linked gene.
- The chiasma were first observed by Janssens (1909)
- The no of chisma is variable, min^m one chisma bivalent is the rule The highest number of chismata in long chromosomes of Vicia faba has been observed to be 12 / bivalent

There are two types of crossing over depending on the cell types

a) meiotic crossing over / gametic crossover

b) mitotic crossing over / somatic cross over

(i) [illegible] / gametic crossing over

→ It occurs in all sexually reproducing [illegible] when they undergo meiosis during gametogenesis.

→ It is primarily responsible for variation among the individuals of a species.

(ii) Mitotic / somatic crossing over

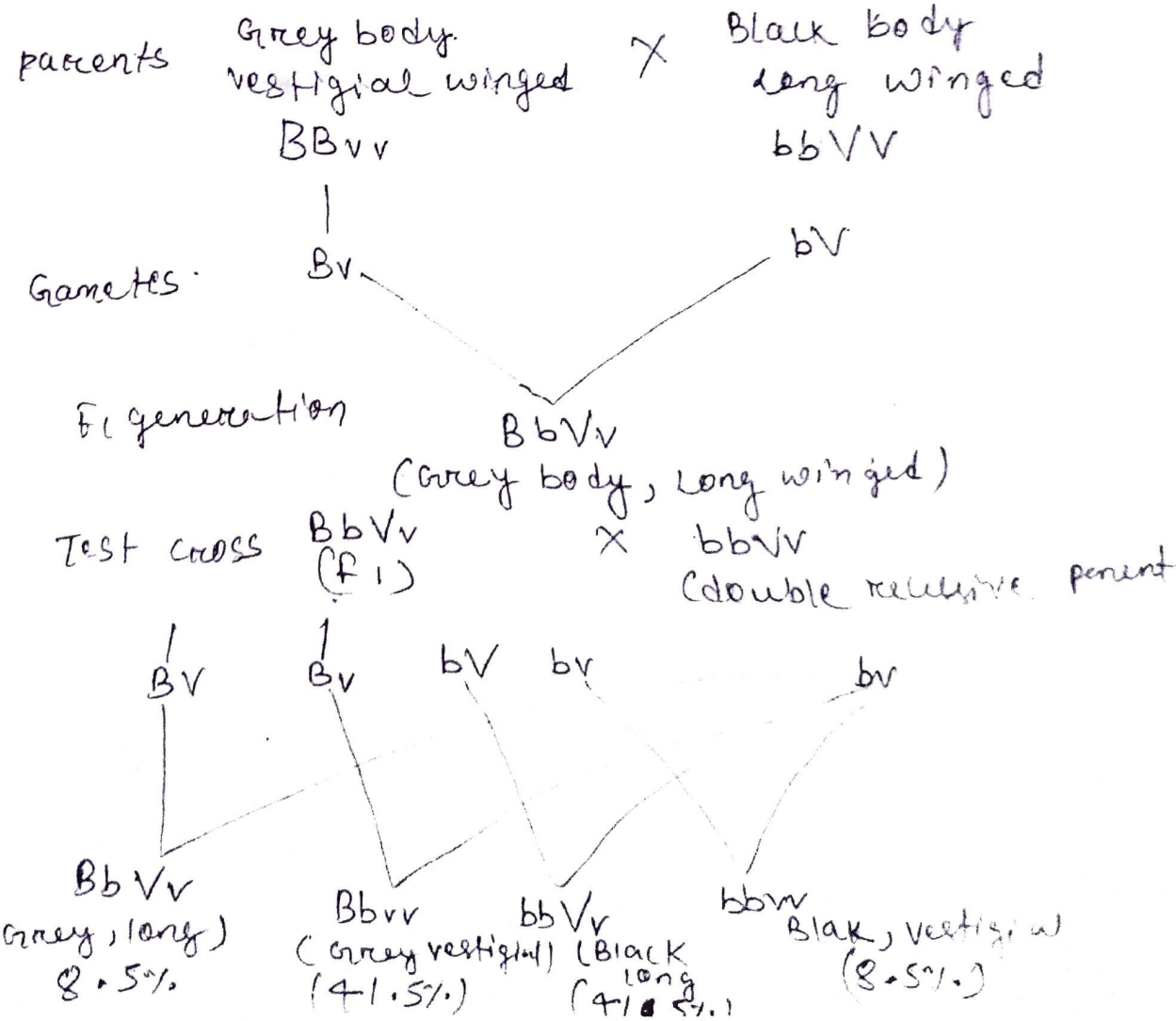
→ It is rare occurance in somatic cell during mitotic cell division.

→ It has no significance from the point of view of inheritance.

→ It is observed in Drosophilla and Aspergillus nedulence.

* Crossing over is absent in female silk worm and male Drosophila during sperm formation.

ex- Crossing over was reported in Drosophila by T. H. Morgan



Parental combination bbVv
(Grey, vestigial) Black, long
(±1.5%)

Recombinant combination BbVv bbvv
(Grey, long) Black, vestigial
(8.5%) (8.5%)

→ no. of recombinant progeny in the test cross
Total no. of progeny in the test cross

OR

(%) = no. R. progeny in t.c / Total no R.P in t.c × 100

MECHANISMS OF CROSSING OVER

Crossing over occurs during meiosis of gametogenesis

1. Synapsis
2. Duplication Chromosome
3. Exchange of chromosomal part
4. Recombinalisation

Synapsis (meiosis)

> During the zygotene stage of prophase - I the homologous chromosome pairs formed the ... and come to present side by side (longitudinally). This pairing of homologous chromosome is synapsis
> The paired chromosomes are called bivalent
> In some organisms, a network of filamentous structure appears between two chromosome during the process of pairing called synaptonemal complex help in the synapsis

DUPLICATION of CHROMOSOME

→The bivalent undergoes duplication during pro
pachytene stage.

→Each two homologous chromosoms splits longitudi
in to chromatids.
Hence 4 chromatids are produce & called tetrad
stag

→The two chromatids of a chromosome are attachi
to a single centromere so called sister chromati

Exchange of chromosomal part / crossing over

→The non-sister chromatids of a (homologous) chromosome
intercross to each other at certain point called
as chiasmata (~~centromere~~)

→At the chiasma, the chromatids break by
endonuclease enzyme.

→The broken segregate of non-sister chromatid
are exchanged and fused with the other
chromatids in presence of an enzyme ligase.

→The exchange of chromosomal segment between
non-sister chromatids is called crossing over

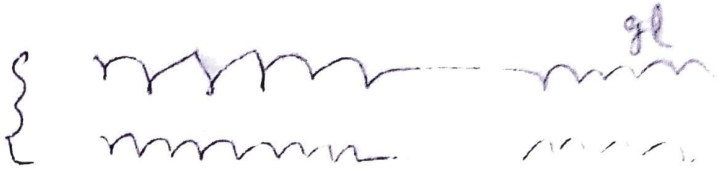
TERMINALISATION

-> After the exchange of the chromosomal segment the non-sister chromatids repel each other

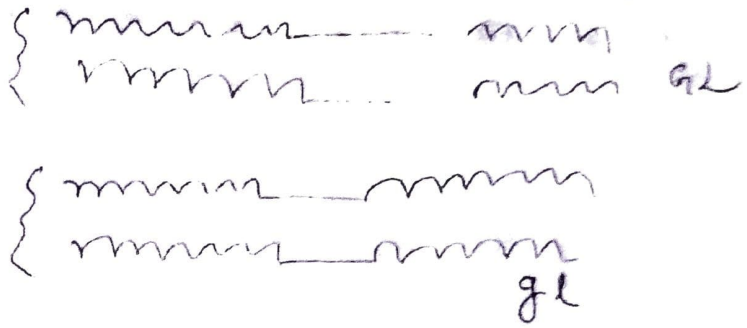
-> The separation begins from the centromere and moves towards the end of chromosome

-> During separation of chromosome, the chiasmata move towards end of the chromosome. This process is called terminalisation.

1) One bivalent



2) One Tetrad



Significance of crossing over

→ Crossing over provides direct proof for the linear arrangement of gene.

→ The segment of homologous chromosome are interchanged through crossing-over. Hence crossing over provides origin of new character and genetic variation.

→ Crossing over leads to construction of linkage Map and genetic maping of chromosome.

→ Crossing over plays an important role in the field of breeding to improved the varities of animals and plants.

characterestic of sex-linked inheritance

→ Individual showing a recessive sex-linked treat is noticeable Higher in heterogametic sex (male Drosophila & human & female birds) the homogametic sex (female Drosophila & humans & male birds)

→ In male Human & Drosophila the sex linked traits are not transmited directly male parents to their male progeny.

→ In male human or Drosophila transmits its sex linked genes to all its daughters. These daughter transmitted this gene to half of their male progeny

→ Hence a sex-linked gene passes from male to female then back to male. This inheritance pattern is known as criss-cross inheritance

Cassese

→ The inheritance is cause by mainly two reson.
a) The location of a gene in the X chromosome
b) The absence of its allele in the Y chromosome

partical sex linkage

The human X and Y chromosome are morphologically distinct But they pair during meiosis in male cell the pairing occures in the 2 telomeric region, which are called psedoautosomal regions (PAR).

There are 2 types
① PAR1
② PAR 2

→ The genes located in Y and X are also present in the X chromosome. But these genes do not show the typical inheritance patterns for sex-linkage
Because these genes have alleles in the Y chromosome as well.
→ As a result inheritance process responsible that of autosomal genes. These phenomenon is called partial sex-linkage and the chromosome region involved in it are referred to as pseudoautosomal regions

Factor influenced crossing over

① sex - in drosophilla crossing over is completely supressed in male but very high in female. There is a tendency of reduction of crossing over in male mammals
2- Mutation- Gower first discovered that mutation reduced crossing over in all the chromosomes of drosophila
3- Inversion- crossing over is suppressed due to inversion
4- Temperature - plough shown that when a drosophilla is subjected to high & low temperature variation, The percentage of crossing over in certain parts of the chromosome is increased
5- X-ray effect - muller demonstrated that X-ray radiation increases crossing over near centromere.
6- Age- Bridges demonstrated when the female drosophilla becomes older, the rate of crossing-over increases
7- Nutrition- High calcium diet in young drosophilla decrease crossing over but diet deficient in calcium increase crossing over
8- Heterochromatin- It decreases crossing over.
(Dark/Deep colour of chromosome strands)

Chromosome map(s)

The phenomenon of linkage and crossing over has established following facts (chromosome)
① The genes are arranged in a linear order in a
② The linkage group in an organism are equivalent to the number of chromosome pairs.
③ Frequency of crossing over or recombination between genes depends upon the distance between of crossing over are more than 2 distantly placed genes similarly the change of crossing over is less between 2 closely placed genes.

→The strength of linkage is inversely proportional to the distance betn linked gene

→The position of gene is very definite in chromatids Basing the following observation strutevast in 1913 developed the idea the frequency of crossing over can be caused as a title for determination of relative distance betn the genes in a linkage group.

Chromosome maps

→The chromosome map is the graphic representation of the relative distance betn the linked genes expressed in the percentage of recombination among the genes in a linkage group.

construction of chromosome maps (linkage maps):- process

The construction of chromosome map includes following

① Determination of linkage group:-

The exact no. of chromosome of a given species determined. The total no. of genes are determined by hybridisation experiment in betn wild & mutant strain.

→The no. of phenotypic trait which remain always linked is determined. The different linkage group of that species are found out.

② % Determination of map distance:-

The distance betn genes is determined by a unit called "morgan unit" or "map unit"

1 morgan unit represent 100% crossing over

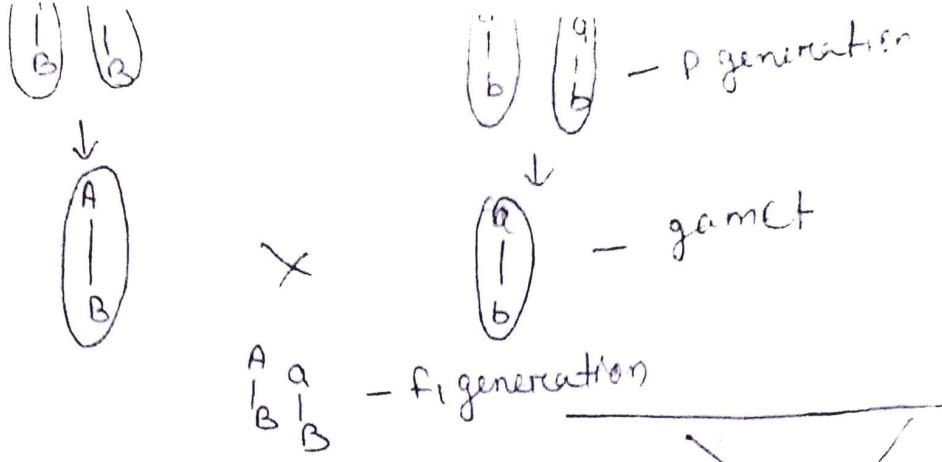
1 crossing over is expressed in 1 centimorgan or 1 map unit.

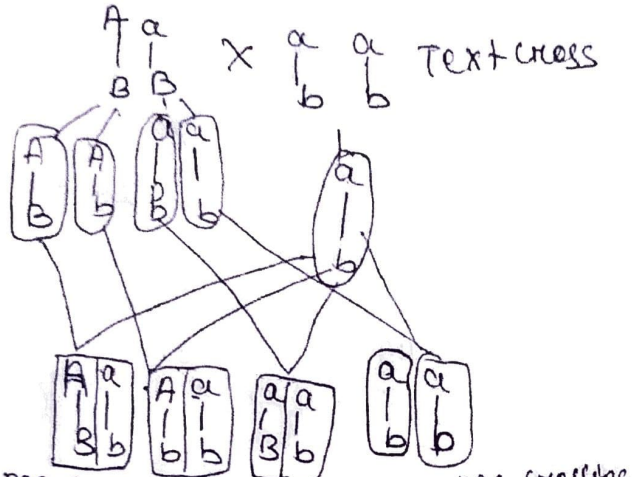
Expt

-suppose the percentage of crossing over betn gene A & B is 26%. then the distance betn A & B is 26 cm or map unit.

③ 2 point of test cross:-

The percentage of crossing over betn linked gene is capa by test cross





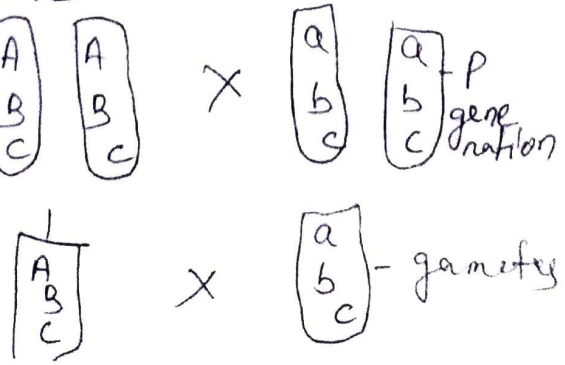
Total single cross betn A & B
= 13% + 13%
= 26%.

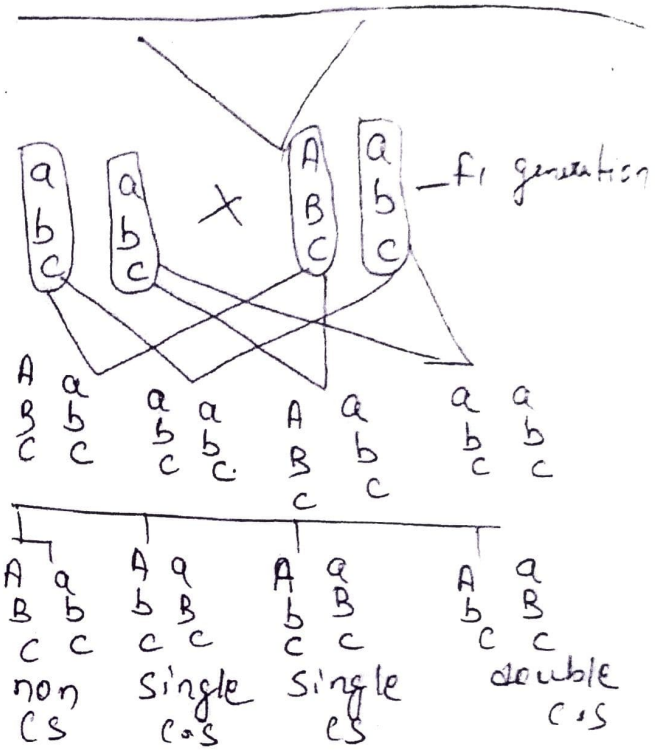
These distance betn A & B
= 36

Double crossing over don't occur betn the genes in which the distance 5cm & less

4) Three point test cross

A Three point of test cross- ~~tag over~~ (involving 8 genes) gives the accurate information about the distance betn the gene





36%	36%	9%	9%	4%	4%	2%	2%

Non-crossing over (C.O) = 72%.
Total single C.O betn A & B = 18%.
Total single C.O betn B & C = 8%.
Total double C.O betn B & C = 2%.
Distance betn A & B =
Total single C.O +
Total double C.O betn A & B
= 18% + 2% = 20%
Distance betn B & C =
Total single C.O +
Total double C.O betn B & C
= 8% + 2% = 10%.
10 cm or map unit

Genetics

unit-11

No-1 (1×10-10)

1- The Linkage was first discovered by _____ and _____

2- Linkage is exception of _____ principle.

3- Crossing over is absent _____ type of linkg.

4- Crossing over is exchang of _____ part

5- The genes are arcranged in linear orderc in a _____

6- The strength of linkage is inversely properctional to the distance between _____.

7- The distance betn genes is determined by a unit called _____.

8- Who is the father of Linkage _____.

9- New combination is occurs in _____ type of Linkage

10- The x and y chromosome are pair during _____ Divisio

No-2 Short note (3×5-15)

1- Crossing over

2- Coincidance

3- Interference

4- Chromosome

5- Cis and Trans- arcrangement of gene.

No-3 Long question (8×5-40)

1- Briefly describe the linkage & its significance.

2- Explaination of complete & incomplete linkage.

3- What is the chromosomal Theory of linkage

4- Describe the two factor & 3 factor crosses.

5- Cromosome maps

6- Describe the characteresttc of sex-linked inheritance.

Determination of gene order

Distance bet^n A & C: Single C.O + single C.O between 2 bet^n A & B + double crossing over

= 20% + 10% − 2 (2%)

= 30% − 4% = 26%

= 26 or map unit

Determination of gene order

After knowing the relative distance bet^n the genes of linkage group, it becomes easy to place in there proper linear order

Suppose the distance bet^n the genes

A − B = 12 Cm

B − C = 7 Cm

A − C = 5 Cm

Case-I Let gene A is in the middle (B-A-C)

B 12 A | A 5 C | = 17 = 7

B 7 C | The distance B-C are not equivable

Case-II Let gene 'B' is in the middle (A-B-C)

A 12 B | B 7 C |

A 5 C |

The distance A-C are not equivble

Case III

A 5 C | C 7 B |

A 12 B |

The distance bet^n A-B are equivable Therefore (C) must be in middle.

Combine map segment

Firally the different segments of a complete genetic map.

A 5 C 7 B

D 4 E 8 F

A 20 C

Interferance

The Tendency of one crossing over (C.O) to interference with the C.O is called Interferance

→ Because one chismata form reduced production adjacent chismata

→ The strength of interferance is expressed in the form of co-efficient of co-incident

Co-efficient of coincidance = % actual double C.O / % expected double C.O

EXP-

Suppose expected double C.O are 2% or 0.2% & observed is 1%.

The co-efficient of coincidence = 1% / 0.02% = 0.5% or 50%

co-efficient of interferances = 1.0