CHROMOSOMAL BASIS OF INHERITANCE

- **Chromosome Theory of Inheritance was proposed by Walter Sutton and Theodor Boveri in 1902.**
- **Sutton and Boveri made a correlation between Mendel's conclusions about genes and the behaviour of chromosomes during mitosis and meiosis.**
- **Chromosome theory of inheritance described that**
  - **Chromosomes are in pairs and genes or their alleles are located on chromosomes.**
  - **Homologous chromosomes separate during meiosis so that alleles are segregated.**
  - **Meiotic products have one of each homologous chromosomes but not both.**
  - **Fertilization restores the pairs of chromosomes.**
- **Mendel considered that each character is controlled by single gene. But at present we know that a character may be controlled by two or more than two genes. In such a situation , two or more than two genes may interact to give rise to a particular phenotype.**

- If A and B are two gene, both dominant over their respective recessive alleles a and b ,then the interaction will depend upon.
  - The presence of both dominant alleles A and B
  - The absence of A
  - The absence of B
  - The absence of both A and B

- Interaction of genes resulted into abbreviated genotypic ratio which is the genotypic ratio other than expected 9:3:3:1.
- **EPISTASIS**
  - When a gene at one locus 'masks' or inhibits the expression of a gene at a distinct locus, such an interaction is called epistasis.
  - Epistatic interaction means that one gene masks or changes the effect of another gene.
  - Epistasis is the interaction between different genes whereas dominance is the interaction between different alleles of the same gene.

- Dominance works at interallelic but intragenic level, whereas epistasis works at intergenic level.
- In epistasis out of two independent genes one express itself called epistatic , while other is masked called hypostatic. Such interactions give modified F_2 ratio as 12:3:1.

- **COMPLEMETARY GENES**
  - W Bateson and R.C. Punnett observed complementary gene interaction in sweet pea. In such type of interaction, two separate pairs of genes interact to produce the phenotype in such a way that neither of the dominant genes is expressive unless the other one is present.
  - Complementary gene interaction is found in sweet pea (*Lathyrus odoratus*) and shows 9:7 in F_2 generation.

- **SUPPLEMETARY GENES**
  - In supplementary gene interaction, two non-allelic gene pairs control the phenotypic expression of a trait, but the dominant gene of one pair expresses itself only when the dominant gene of the other pair is present, whereas the dominant gene of the other pair is expressed even in absence of the dominant gene of the first pair.
  - Interaction of supplementary gene is found in flower colour of Snapdragon (*Antirrhinum majus*) which shows 9:3:4 ratio in F_2 generation.
- **DUPLICATE GENE**
  - When two pairs of genes are involved and both of them are able to produce the same effect singly as well as in combustion, these are called duplicate genes.
  - G.S.Shull reported interaction of duplicate genes in *Capsella brusa pastonis* (Shepherd's purse) , which shows triangular and top shaped capsule in 15:1 in F_2 generation.

- **MULTIPLE ALLELISM**
  - Some traits have genes with more than two alleles. These are called multiple alleles, but any one individual can still have only two alleles .
  - The human blood group gene provides an example of this, as well as an interesting dominance relationship. There are three A, B, O blood group alleles, usually given the symbols I^A ,I^B and I^i. I^A and I^B are codominant to each other , but are both dominant to I^i. Since any individual only has two alleles , there are four possible blood group phenotypes but nine possible genotypes.
  - Some other examples of multiple allelism are- Colour loci in corn; Skin colour in rodents; Eye colour in *Drosophila;* Self incompatiblility genes in some plants
  - The characteristic features of multiple alleles are that they are usually located on the same locus and hence there is absence of crossing over between them.
  - Multiple alleles can be found only in population and in any diploid individual only two alleles can be found.

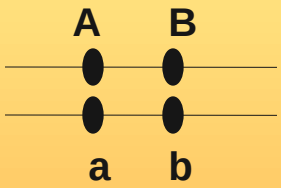
- **POLYGENIC INHERITANCE**
  - Genes that are acting individually have a small effect but that collectively produce a significant phenotypic expression are called polygene, Example gene for height or weight.
  - Polygene show polygenic inheritance or quantitative inheritance. As genes are present on different chromosomes, they will segregate independently during meiosis. Polygenic inheritance then becomes a genetic problem for dihybrid cross and possibly much more , if more than two genes are involved.
  - The resulting variety of possible genotypes can give a large number of phenotypes and when the influence of the environment is also considered, it is hardly surprising that almost every possible variety of phenotype can be observed in a large population. This is termed as continuous variation.
  - Inheritance of kernel colour in wheat [H Nilsson-Ehle ; 1909] and human skin colour [Davenport; 1910] are important examples of polygenic inheritance.

- **PLEIOTROPIC GENES**
  - When a gene affects many aspects of phenotype or controls several phenotypic characters, is called pleiotropic gene and this phenomenon is called pleiotropy.
  - Some examples of pleiotropy are-
    - ❖ 'Vestigial wing' mutation of Drosophila not only controls the size and shape of the wings but also affects several other features including reduced fecundity.
    - ❖ Gene for phenylketonuria in human beings also interferes with synthesis of Melanin pigment.
    - ❖ Sickle cell anaemia.
    - ❖Pleiotropic genes alongwith their main effect may also act as modifiers for different genes and thus have more than one effect.
- **LINKAGE**
  - Linkage was discovered by W Bateson , E.R. Saunders and R.C. Punnett (1905) , when they were working with sweet pea (Lathyrus odoratus). They found test cross ratio 7:1:1:7 instead of 1:1:1:1 and described it as coupling and repulsion.

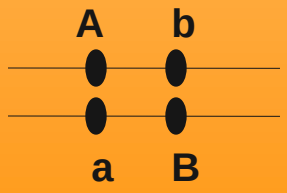
- Linkage is the tendency for alleles of different genes to be passed together from one generation to next. If the chromosomes in a gamete producing cell are not rearranged during meiosis, it would be expected that all the genes on a particular chromosome would be transferred together into whichever gamete gets that particular chromosome. That is , the genes are linked together on their chromosomes.
- Linkage is an exception to the law of independent assortment. It is inversely proportional to the distance between the genus on chromosomes.
- T. H. Morgan (1910) reported linkage in Drosophila and gave the term 'Linkage' to this phenomenon. He also reported that coupling and repulsion are two aspects of the linkage.
- A linkage group is a linearly arranged group of linked gene, which means all the linked genes of a chromosome from a linkage group. The number of linkage group corresponds to the haploid number of chromosomes.

- **Number of linkage groups in prokaryotes such as bacteria cyanobacteria or blue-green algae, Mycoplasma etc. is one.**
- **When only parental combinations are produced linkage is called complete linkage. It is exhibited when the genes for a particular character are present very close to one another. It is rarely found in nature. Crossing over remains absent in this case. Example -Male *Drosophila* , female silk worm (*Bombyx mori*).**
- **When some recombinations are also produced alongwith parental combinations, linkage is called incomplete linkage.**

- **Cis and Trans-arrangements of Genes**
  - **When dominant alleles of two linked genes are present on the same chromosome and their recessive alleles are present on the homologous chromosomes, the arrangement of genes is called cis-arrangement.**



  - **When one dominant gene and other recessive gene are present on the same chromosome and their alleles type on the homologous chromosome , the arrangement of genes is called trans-arrangement.**



- **CROSSING OVER**
  - Crossing over is a process occurring in the prophase-I of meiosis, in which exchange of non-sister chromatids and genetic recombination takes place.
  - The term 'crossing over' was introduced by Morgan and Cattell for separation of linked genes.
  - The location of a gene on a chromosome is called a locus (loci).
  - The loci of the genes on a chromosome are arranged in a linear sequence.
  - The two alleles of a gene in a heterozygote occupy corresponding positions in the homologous chromosomes, that is allele A occupies same position in homolog 1 that allele 'a' occupies in homolog 2.
  - Crossing over occurs involves the breakage of each of two homologous chromosomes and the exchange of parts.

- Crossing over occurs at pachytene sub-stage of prophase-I of meiosis but visible at diplotene sub stage.
- Chiasmata are the points where crossing over takes place.
- Crossing over occurs at pachytene stage after the synapsis of the homologous chromosomes has occurred in prophase-I of meiosis.
- Since chromosome replication occurs during S-phase, meiotic crossing over occurs in the post-replication tetrad stage. That is after each chromosome has doubled such that four chromatids are present for each pair of homologous chromosomes.
- Each pair of synapsed homolog is called a tetrad ,because it consists of four chromatids.
- Crossing over takes place between any two non-sister chromatids of a homologous pair of chromosomes.

- Crossing over refers to the exchange of segments of chromosomes whereas recombination implies the formation of new combinations of genes.
- Thus crossing over occurs in completely homozygous organisms but new combinations can be formed only in organisms that are heterozygous at two or more loci.
- The most accepted theory of crossing over is percosity theory or stain theory, given by C. D. Darlington by which ,as a result of twisting of homologous chromosomes a strain develops which causes breakage of chromatids at the point of contact. The broken segments unite with other segments to bring about crossing over.
- The significance of crossing over are-
  - ❖ It provides proof for linear arrangement of genes on chromosomes.

- ❖ It is the basis for linkage maps or genetic maps construction.
- ❖ Recombination or new gene combinations are produced due to crossing over, which is a source of variations.

- **LINKAGE MAPS**
  - The graphical representation of relative distances between linked genes of a chromosome is called linkage map or genetic map. As recombination frequencies or cross over frequencies are directly proportional to distances between genes, hence these values are used in formation of linkage maps.
  - In linkage map, one map unit is equal to 1% recombination. It is also called Centi Morgan after the name of Thomas H Morgan.

- **Linear order of genes on chromosome can be estimated by determining the cross-over percentage between genes.**

Frequency of crossing over= $\frac{\text{Total no. of recombinants}}{\text{Total Progeny}} \times 100$

- **The first chromosome maps were prepared by Sturtevent in 1911.**

- Dominant lethal gene is one which kills the organisms.
- Two genes R and Y are located very close on the chromosomal linkage map of maize plant. When RRYY and rryy genotypes are hybridized ,then F_1 segregation will show higher number of parental types.
- A common test to find the genotype of a hybrid is by crossing of one F_1 progeny with male parent.
- Genotypic ratio of a dihybrid cross is 1:2:2:4:1:2:1:2:1.
- Number of gamete types formed by AaBbCc individual is 8.
- Rh-Factor is a dominant trait.
- The father has blood group AB and mother O. The child is supposed to have A or B blood group.
- Drosophila flies with XXY genotypes are females but human beings with such genotypes are abnormal males. It shows that Y-chromosome is male determining in human beings.
- AB,Ab,aB,ab gametes are produced by individual of genotype AaBb.

- **There will be no independent assortment in presence of linkage.**
- **Crossing over is the exchange of parts of chromatids. Crossing over in diploid organism is responsible for recombination of linked genes.**
- **When normal and mutant alleles are present on opposite chromosomes of homologous pair, the heterozygotes are called as trans heterozygote.**
- **The number of linkage groups in *Drosophila*, Pisum, corn and mice are 4, 7, 10 and 19 respectively.**
- **In a chromosome map, B and C give crossing over 3% and A and B 8%. The percentage cross over between A and C will be 11%.**
- **Crossing over occurs between non-sister chromatids.**
- **Crossing over that results in genetic recombination in higher organism occurs between non-sister chromatids of a bivalent.**

- In polytene chromosomes , dark bands are visible. These bands are formed by the aposition of chromomeres on chromonemata.
- The complete linkage is found in male Drosophila.
- Individuals with patches of other sex are called Gynandromorph.
- At a particular locus ,frequency of 'A' allele is 0.6 and that of 'a' is 0.4. The frequency of heterozygotes in a random mating population at equilibrium will be 0.48 .
- If the sequence of genes on a chromosome is changed from ABCDEFG to ABCDFEG, then it is inversion.
- Genes located on Y-chromosomes are called holandric genes.
- Barr body represents one of the two X-Chromosomes in somatic cells of female.
- Haemophilia is more commonly seen in human males than in human females because this disease is due to an X-linked recessive mutation.

- Recessive mutations are expressed in homozygous condition.
- The two eukaryotic organelles responsible for cytoplasmic inheritance are mitochondria and chloroplasts.
- In a dihybrid cross, two recessive genes showed 10% recombinants. The distance between two genes is 10 map units.
- Two genes situated very close on the chromosomes show hardly any crossing over.
- Primary source of allelic variation is recombination.
- In a mutational event, when adenine is replaced by guanine , it is case of transition.
- Lack of independent assortment of two genes A and B in fruitfly Drosophila is due to linkage.
- Extra nuclear inheritance is a consequence of presence of genes in mitochondria and chloroplasts.
- The recessive genes located on X-chromosome in humans are always expressed in males.

- Crossing over that results in genetic recombination in higher organism occurs between non-sister chromatids of a bivalent.
- The duplicated genes are also called pseudoalleles.
- Duplicate genes although present on different locus but have the ability to produce same or almost same trait of a character.
- Gene flow increases genetic variations.
- The random introduction of new alleles into recipient population affects allele frequency.
- The genetic compliment of an organism is called genotype.

Thanks…