

Nucleic bases are
adenine and guanine
and



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Nucleic acids are macromolecules, composed of many (polymers) small units called nucleotides. Nucleic acid = many nucleotides Each nucleotide consists of phosphoric acid (phosphate), a five carbon sugar and a nitrogenous base.

Nucleotide = phosphoric acid + sugar + nitrogenous base The sugar and base combination (without phosphoric acid) is called nucleoside. Phosphoric acid + sugar + nitrogenous base / Nucleoside /Nucleotide As such

nucleotides are phosphoric esters of nucleosides. I. Phosphoric acid: The acidic nature of nucleic acids is due to the presence of phosphoric acid.

Sugar of the nucleoside combines with phosphoric acid by a phosphodiester bond. II. Sugar: It is a five carbon (pentose) sugar. There are two types of sugars — ribose and deoxyribose sugars.

The nucleic acid containing ribose sugar is called ribose nucleic acid (RNA) and the other with deoxyribose sugar is called deoxyribose nucleic acid (DNA). III. Nitrogenous bases: Each nucleic acid has four nitrogenous bases — two purines and two pyrimidines.

The purine bases are adenine and guanine and the pyrimidine bases are thymine and cytosine. In RNA, uracil (pyrimidine) is present in place of thymine. DNA: Structure: The full form of DNA: Deoxiribose Nucleic Acid. The DNA is a double stranded helix made of many nucleotides. The nucleotides consist of deoxyribose sugar, phosphoric acid, purine bases (adenine and guanine) and pyrimidine bases (cytosine and thymine). The arrangement of these substances in DNA molecule long been a subject of curiosity. It was largely due to X-ray diffraction studies of Wilkins which provided basis for promising double helical structure of DNA.

Watson and Crick (1953) finally described the structure of DNA and were awarded Nobel Prize in 1962 alongwith Wilkins. Following are some of the characteristic features of this model. 1. Each nucleotide consists of sugar, phosphate and a nitrogenous base.

Many such nucleotides are linked to form a polynucleotide chain or strand. 2. The adjacent nucleotides of the same strand are joined with each other by one phosphodiester bond between 5-carbon of sugar of one nucleotide and by another phosphodiester bond with 3-carbon of sugar of the next nucleotide. 3. Nitrogenous base is attached at 1-carbon of sugar. At this place purine is attached by its 9th-position and pyrimidine by its iraf-position. 4. Thus a polynucleotide strand consists of sugar and phosphate forming its long axis. 5.

The two polynucleotide strands are complementary to one another. If one strand has adenine, the other strand would have only thymine opposite to it. Similarly guanine and cytosine form the other complementary base pair. Thus, if the base sequence of one strand is CAT TAG GAC, the base sequence of another strand would be GTA ÀÕÑ CTG. 6. The two strands are joined with one another by hydrogen bonds between their complementary nitrogenous bases. There are tw'o hydrogen bonds between adenine and thymine and three hydrogen bonds between cytosine and guanine.

7. Two polynucleotide strands are helically coiled around a common axis to form a DNA-molecule. The two strands are antiparallel, i. e.

, they run in opposite directions; the sugar molecule in one shows 5—P, 3—OH direction while the (c) other shows 3-OH, 5-P direction. 8. The helical coiling of double strands is right handed. This DNA is called B-DNA. 9.

Double stranded DNA molecule has a diameter of 20 Å, i. e., the distance between two polynucleotide strands is 20 Å. 10. The helix makes one complete turn every 34 Å along its length. RNA: Types and Structure: RNA or Ribose Nucleic Acid is present in all the living cells. It is found in cytoplasm as well as nucleus. I.

Types of RNA: RNA is generally involved in protein synthesis but in some viruses it also serves as a genetic material. The following are the types of RNA. 1. Genetic RNA. H.

Fraenkel-Conrat: (1957) showed that RNA present in TMV (Tobacco Mosaic Virus) acts as a genetic material. Since then it is known to be the genetic material of most of the plant viruses and some bacteriophages. 2. Non-genetic RNA: This type of RNA is present in those cells where DNA is the genetic material.

Non-genetic RNA is synthesized on DNA template. It is of the following three types. (a) Messenger RNA (m RNA): It carries the genetic information present in the DNA. It forms about 5-10% of the total RNA present in the cell. (b) Transfer RNA (t RNA): It is also known as soluble RNA (s RNA).

These are the smallest molecules which carry amino acids to the site of protein synthesis. It forms about 10-15% of the total cell RNA. (c) Ribosomal RNA (r RNA): It is the most stable type of RNA and is found associated with

ribosomes. It forms about 80% of the total cell RNA. RNA is generally single stranded and is made of a chain of polynucleotides. The single strand is folded in such a way that the chain formed by sugar and phosphate is external while the complementary nitrogenous bases are projected inside and joined by hydrogen bonds as in DNA.

The differences between DNA and RNA are given in the table 1. DNA and RNA: A Comparison of their Structure, Reactions and Role in the Cell:

DNARNA1. LocalizationPrimarily in nucleus also in mitochondria & chloroplastsIn cytoplasm, nucleolus and chromosomes2. Pyrimidine basesCytosine, ThymineCytosine, Uracil3.

Purine basesAdenine. GuanineAdenine, Guanine4. Pentose sugarDeoxyriboseRibose5. StrandsMostly double strandedMostly single stranded6. Cytochemical reactioFeulgenBasophilic dyes with Ribonuclease treatment7.

Hydrolysing enzymeDeoxyribonuclease (DNase)Ribonuclease (RNase)8. Role in cellAlways genetic informationSynthesis of proteins, sometimes genetic9. Replicationself replicatingFormed from DNA.

Self repli cation only in some viruses

Alleles and Genes:

Allele: Alternative form of a gene is known as allele. Main feature of Allele —
1. Govern same characters of an individuals. 2. A haploid cell has single copy of an allele, diploid two and polyploid more than two for a character. 3. All individual may have identical alleles.

4. They may be dominant and recessive type. Test for Allelism: 1.

Recombination test 2. Complementation test. Multiple Allele: 1. Always belong to the same locus.

2. Control same characters. 3. No crossing over in the multiple allelism.

4. Wild type is always dominant. 5. Don't show complementation. Example for multiple Allele — 1. Fur colour in rabbits. 2.

Wing type in drosophilla 3. Eye colour in drosophila 4. ABO blood group in man.

Pseudoalleles: Closely linked and functionally related genes. Characters: 1. Govern different expression of the same characters.

2. Pseudo alleles occupy different position on the same locus. 3. Low frequency of Recombination by crossing over. 4. They exhibit cis-trans position effect. Isoalleles: An allele which is similar in its phenotypic expression to that of other independently occurring allele is known as isoallele.

Types of Isoallele: 1. Mutant Isoalleles. 2.

Normal Isoalleles. Genes: Smallest and Individually functional part of genetic material. Properties of Gene: 1. Form (alternative form allele). 2. Location (chromosome, linear, locus) 3. Status (several unit).

4. Number (each Diploid) 5. Sequence (specific sequence) 6.

Expression - incomplete, complete. 7. Change in form - mutation. 8.

Exchange of Gene - Translocation. 9. Composition - DNA Bacteriophage

Function 1. Control the expression of a specific character in an organism.

2. Based on gene control over characters. Oligogenic traits, polygenic traits and pleiotropic.

3. Gene interaction (when two or more gene govern a characters). 4.

Linkage > two or more genes are inherited together. Modern Concept of

Gene: Genetical View: 1. Mendel Idea: i. Factor for gene > responsible for transmission of characters from parents to their offspring. ii. Sutton and Boveri hypothesis > chromosomal theory of inheritance.

iii. Morgan > linkage studies given that idea of genes are located on the chromosome in linear fashion. 2. Modern Concepts: (a) Gene is divisible it was believed that gene is basic unit of structure which is indivisible by crossing over now observed that gene is divisible based on studies on Intragenic recombination like bar eye gene of drosophila. (b) Part of a gene can function: 1. Reton > Region between recombination. 2. Muton > Elements of gene rise to mutant.

3. Cistron > Unit of function of gene. Biochemical View: (a) Earlier Concept: Gene is sequence of nucleotides in DNA which control a single polypeptide chain.

(b) Mordern Concept: (i) fine structure of gene (Benzer) (ii) Split Genes. The sequence of nucleotides were interrupted by intervening sequences such genes with interrupted sequence of nucleotides are referred as split genes or

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interrupted genes. It have two types of sequences (i) Normal sequences (ii) Interrupted sequences.

(c) Jumping Genes: A gene keeps on changing its position within the chromosome and also between the chromosomes of the same gene. Such genes are known as jumping genes or transposons or transposable elements. The transposable elements are of two types – (i) Insertion sequence (ii) Transposons (d) Overlapping Genes: Some nucleotide sequences (genes) can code for two or more proteins.

The genes which code for more than one protein are known as overlapping genes. (e) Pseudo Genes: There are some DNA sequences, especially in eukaryotes, which are non functional and defective copies of normal genes. Such DNA sequences of genes are known as pseudogenes.

Application of Genetics: 1. Taxonomy: To study evolution, classification and identification. 2.

Agriculture: Improvement of crop plants Yield, resistance to insects, disease, salinity, drought, frost, lodging and adaptability. 3. In Medicine: (i) Detection of Hereditary Disease (ii) Production of Antibiotics. 4. Evolution: Natural and Artificial selection have been responsible for evolution of various crop plants. (i) Polyploidy (ii) Mutation.

Genetic Material:

1.

Chemical Nature: Properties of the Genetic Material — 1. The Genetic material must be replicated with high fidelity. 2. Genetic material must be able to express itself.

3. Genetic material must be able to store the highly variable information. 4.

The distribution of Genetic material must allow errors in a low frequency for the origin of new genetic variation. Experiments of Griffith (1928): His studies on *Diplococcus pneumoniae* Different strains of *Diplococcus* from two types of colonies 1. Smooth 2. Rough. Smooth colonies are enclosed in a polysaccharide capsule the strain are able to produce pneumonia, the virulent Rough colonies lack the polysaccharide capsule such strains are avirulent they can't produce pneumonia. Virulent strains are classified into several types eg.

II, III etc. on the basis of antigenic properties of the polysaccharides present in their capsule. (a) Live HIS (virulent) cells injected died (due to pneumonia). (b) III S heat killed cells (virulent) > A live indicating that all the cells were killed by the heat treatment. (d) Mix of heat killed 11 IS and live HR > died (pneumonia) since all the cells of heat killed 11IS culture were dead it was postulated that some of the cells HR had changed into the 11IS type due to influence of dead 11IS cells present in the mixture.

This phenomenon was called transformation and the component of HIS cells which induced the conversion of HR cells to 11IS was named transforming principle. Griffith demonstrated transformation but they did not hint at the identity of the transforming principle. It is now known that transformation is essentially a special type of recombination in which a segment from the

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transforming DNA replaces the homologous segment of the bacterial chromosome. Experiments of Avery, Macleod and McCarty- 1944: Avery and associates carried out experiments of Griffith in vitro (in test tubes). A culture of live HR cells: Rough colonies heat killed IIS cells or DNA isolated from IIS cells no colony.

Live HR + Heat killed HIS + Antibody HR > HIS colonies. Live HR + IIS DNA + Anti HR > IIS colonies. Anti HR was used for inactivating HR cells.

These findings show that DNA is the transforming principle. In order to establish beyond any doubt that DNA is the transforming principle. They treated IIS DNA with RNA (the enzyme which digest RNA) or proteases (enzymes which dgrade proteins) before it was mixed with HR cells. In both the experiments some IIS type colonies were obtained. This shown RNA and proteins present as impurities in IIS DNA preparations were not responsible for transformation. Then next they treated IIS DNA with DNA (enzyme digests DNA) before it was mixed with HR cells.

There is no colony. They established beyond any doubt that DNA is the transforming principle. Experiments of Hershey and Chase (1952): This led to the universal acceptance of DNA as the genetic material. They studied the life cycle of T2 phage of E. coli. They showed that only the DNA component of T, particle is transmitted to the progeny. T2 has a hexagonal head and a contractile tail. Head coat and tail are made up of protein, while the DNA is packed inside the head coat.

Infection begins when the tail plate of a T2 particle comes in contact with the cell wall of an E. coli cell. They labelled T2 DNA and protein in two separate

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experiments. DNA contains P but no S. Protein - S but no P. They labelled T2 DNA > ^{32}P or ^{35}S labelled phage particles E. coli cells were grown for several generations on a culture medium containing ^{32}P or ^{35}S . The progeny phage particles thus obtained were labelled with either ^{32}P or ^{35}S .

In one experiment they mixed ^{32}P labelled T2 particles with E-coli cells. The cells were than agitated in a blender to separate the empty phase particles (called ghosts) remaining outside the bacterial cells after infection. Most of the ^{32}P labelled form was present in the infected E-coli cells.

The progeny phage particles obtained after types of these E. coli cells also contained the ^{32}P labelled from this we come to know that DNA is transmitted from one generation to the next. In the other experiment they used ^{32}S labelled T7 particles obtained through lysis of the infected E.

coli cells was almost negligible. From this we come to know that proteins are not transmitted from one generation to the next. RNA as Genetic Material (1957): In TMV DNA is absent but these viruses are composed of RNA and protein. The proteins and RNA of TMV can be separated when they are remixed they reassociate to produce TMV. In one experiment either RNA or proteins isolated from TMV were used for the infection of tobacco leaves.

Mosaic symptoms developed only when RNA was used for infection and not the proteins were used. They constructed two types of hybrid virus particles by mixing (1) RNA from strains A and proteins from strain (2) Proteins from strain A and RNA from strain B. When tobacco leaves were infected with hybrid TMV or the first type the disease symptoms of strain A developed the proteins also identical with those of strain A. Similarly when hybrid protein of

the second type were used for infection of tobacco leaves symptoms of strain B. It is evident from these findings RNA (and not the protein) of TMV has the capacity to produce the disease and that the type of proteins present in the virus particle is determined by the RNA.

Chromosome Structure:

The darkly stained, rod shaped bodies visible under light microscope in a cell during metaphase stage of mitosis are referred as chromosomes. Main features of eukaryotic chromosomes: i. Chromosomes are not visible during interphase under light microscope.

ii. Transmission of characters from generation to generation. iii. It vary in shape, size and number in different species of plants and animals. iv.

It have property of self duplication, segregation and mutation. v. It composed of DNA, RNA and histones. Chromosome Shape: It is usually observed during anaphase.

It have three different shapes viz rod shape, S shape and V shape.

Chromosome Number: (i) Haploid: It refers to half of the somatic chromosome number of a species and is denoted by n . (ii) Diploid: It refers to somatic chromosome number of a species and is denoted by $2n$. (iii) Basic Number: The genetic chromosome number of a true diploid species is called basic number.

Chromosome Morphology: i. Centromere: The region of chromosome with which spindle fibres are attached during metaphase is known as centromere.

ii. Chromatid: One of the two distinct longitudinal subunits of a chromosome is called chromatid.

iii. Secondary constriction: The constricted or narrow region other than that of centromere is called secondary constriction. iv. Telomere: The terminal region of chromosome on either side is known as telomere. v. Chromomeres: The linearly arranged bead like structures found on the chromosomes are known as chromomeres. vi.

Matrix: A mass of acromatic material in which chromonemta are embeded is called matrix. Karyotype: Karyotype is a phenotypic appearance of chromosomes of a particular species. It is represented by a diagram which is known as idiogram.

Karyotype is of two types viz symmetrical and asymmetrical. Special Types of Chromosomes: Lampbrush Chromosome: These are special types of chromosomes in which large number of loops are projected out from the chromatin axis giving a lampbrush appearance. They are formed in oocyte nuclei of both vertibrates and invertibrates and spermatocyte nuclei of drosophila during diplotene stage.

1. Extra ordinary length 2. Large number of loops 3. Lamp-brush appearance.

Polytene or Giant Chromosomes: The multiple replicates of the same chromosome holding together in a parallel fashion resulting in very thick chromosome are known as polytene chromosomes.

These chromosomes have three main features: 1. Bands: The strips which are found in these chromosomes are known as bands. 2.

Puffs: The smaller regions are known as chromosome puffs. These are the regions of genetic activity. 3. Giant Size. B-Chromosomes:— Some species possess extra chromosomes which are not members of normal chromosome complements. These are called as chromosomes. Classification — on the basis of stability: i.

Stable ii. Unstable on the basis of size iii. Standard type iv. Small type v.

Very small type vi. Large type Behaviour at Mitosis and Meiosis: The meiotic behaviour of chromosomes is studied during pachytene stage. 1. They do not pair with a chromosomes. 2. Lower degree of pairing is observed among chromosomes. 3.

When single chromosome is present, it remains univalent during pachytene.

Chromosome Models: Chromatin fibres are the basic units of chromosome structure. 1. Folded Fibre Model: Chromatin fibres are basic units of chromosome which are about 230 A in diameters. A single chromatin fibre is found in each chromatid which consists of a single coiled double DNA helix. The folding of chromatin fibre in different ways results in the development of chromatin structure which is observed at metaphase.

Two copies of chromatin fibre are formed from a single chromatin as a result of DNA replication during interphase. The replication of chromatin in the centromere region takes place wheie two chromatins have to separate out. Extensive folding of chromatin fibres leads to significant reduction in their length and increase in thickness and stainability. 2. Nucleosome - Solenoid Model: Chromatin is composed of DNA, RNA, histories and other proteins. Chromatin fibres are 300 A in diameter.

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The nucleosomes are sub units of chromatin and have bead like appearance. Each nucleosome is composed of a histone octamer and 146 bp of DNA. Each nucleosome consists of (1) a core particle and (2) linker or spacer DNA. The core particle has two copies each of H2A, H2B, H3 and H4 histone molecules. The core particle is about 110 Å in diameter and 60 Å in height one molecule of histone H1 is connected with linker DNA. The super coiled nucleosome fibre is known as solenoid.

Chromosomal Aberration – Structural Changes:

Any change which alters the normal structure of a chromosome is known as structural chromosomal aberration. Types: Alter gene number in chromosomes > (i) Deletion (ii) Duplication. Alter the sequence of genes in the Chromosome > (i) Translocation (ii) Inversion. Deletion (Deficiency): Loss of a portion of segment from a chromosome.

Observed > Drosophila, maize, tomato, wheat. Depending upon location deletion two types. 1. Terminal Deletion: Loss of either terminal segment of a chromosome two types. (i) Heterozygous Deletion > Deletion occurs only in one chromosome of a homologous pair. (ii) Homozygous Deletion > Deletion occurs in both the chromosome of a pair.

2. Interstitial Deletion: Loss of a segment of chromosome from the intermediate portion or between telomere and centromere. The interstitial deletion generally does not involve centromere. In such deletion the break occurs at two places.

Detection: Cytological Method — (i) Meiotic pairing (ii) Chromosome length.

In heterozygous Deletion: The pairing occurs between homologous segments. In terminal Deletion: Normal chromosome remains unpaired at one end. Interstitial Deletion: A loop is formed in the normal chromosome in the region of deletion.

The loop confirms the presence of deletion. Genetic Effects: 1. Fertility: The pollen fertility is reduced in the presence of deletion. The pollens with deficient chromosomes are non functional. 2. Viability: A large deletion is lethal. 3.

Crossing over: The crossing over is suppressed in the region of deficiency due to lack of corresponding segment in the area of deletion. 4. Phenotype: Deletion affects the phenotype. In the absence of dominant gene in the deletion region the recessive gene express. This results in the change in phenotype.

5. Change in Karyotype: The chromosomes with deletion can never revert to a normal condition. The gene number as well as the keryotype of the individual is changed. Significance: It plays an important role in species formation and releasing variety through mutations. Important cytological tools for mapping genes.

Deletion mapping has been widely used in drosophila to locate various genes in polytene chromosomes. Translocation: One way or reciprocal transfer of segments between non homologous chromosome is known as translocation.

Origin: Translocation originate through breakage and exchange of parts between non homologous chromosomes. When only one chromosome from

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each pair of two homologous is involved, it gives rise to translocation heterozygotes and when both chromosomes from each pair are involved it produces translocation homozygotes. Detection: Translocation can be detected by cytological and genetic methods.

Cytological methods includes study of pachytene configurations and metaphase configurations. Table 2. Differences between translocation and crossing over: Translocation: 1.

It involves in non-homologous chromosomes. 2. Change the linkage map.

3. Breakage and reunion 4. Pollen and ovule sterility Crossing Over: 1. It involves in non-sister chromatids of homologous chromosome.

2. Does not change the linkage map. 3. Chiasma formation.

4. No sterility. At Anaphase the chromosome disjoin (segregate) in three different ways — 1. Alternate Disjunction: When two normal chromosome (N1 and N2) move towards one pole and two translocated chromosome (T1 and T2) to another pole, is known as alternate disjunction segregation. In such segregation all gametes receive full complement of genes and will give rise to viable individual. 2. Adjacent one Segregation: The segregation of one normal chromosome with one translocated is called adjacent segregation. Such segregation occurs in open ring configuration.

Here the chromosomes which go to one pole are non homologous (T1 + N2 and T2 + N1). 3. Adjacent two Segregation: Sometimes in open ring configuration, two homologous chromosome (T1 N1) i. e.

one normal one translocated move to one pole and other homologous (T2 N2) move to another pole. Such disjunction is known as adjacent 2 segregation. Both adjacent types of segregation will produce gametes with duplication and deficiencies which may cause some sterility. Translocation can be detected by genetic methods based on pollen sterility, gene segregation and linkage studies.

Genetic Effects: 1. Sterility: Translocations lead to duplication and deletion of genes. Thus translocations result in pollen sterility and ovule sterility. If there is a ring of four chromosomes 50% sterility. If there is a ring of six chromosome > 75% sterility. 2. Crossing over: Crossing over is generally suppressed due to competition in pairing.

3. Karyotype: Changes in chromosome number and karyotype. They may alter the size of chromosome as well as position of centromere. Phenotype: In human down syndrome (Mangolism) can arise in the progeny of an individual heterozygous for a translocation involving chromosome number 21.

Significance: Translocation alter the chromosome size, chromosome number and karyotype and thus play an important role in the formation of species. Translocation are useful in locating the position of genes, centromere and other genetic markers on the chromosomes. They are useful tools in breeding programmes for transfer of desirable characters from one species to another. Inversion: It refers to structural change in a chromosome in which a segment is oriented in a reverse order. (i) Paracentric Inversion: The inversion in which centromere is not involved is called Paracentric Inversion.

In this type both breaks occur in one arm of the chromosome. Only one chromosome of a homologous pair has inversion it is called inversion heterozygote. When both the members of a homologous pair have similar type of inversion it is called inversion homozygote. Meiosis is normal in inversion homozygotes. Crossing over within the inversion loop in a paracentric inversion heterozygote results in the formation of dicentric bridge and an acentric fragment after exchange. The other two chromosome remain normal. The dicentric chromosome leads to formation of bridge at anaphase. The bridge is later on broken due to pull from both the poles, thus a centric segment is lost due to lack of movement.

Thus out of four two are normal and two are deficient for some genes. (ii)

Pericentric Inversion: When centromere is involved in the inversion it is known as pericentric inversion. When a break occurs in each of the two arms of a chromosome the centromere is included in the detached segment resulting in s pericentric inversion.

Crossing over within the inversion loop results in the formation of chromatids with duplication and deficiency. Out of four chromatids two are cross over products and two are normal. One of the non cross over have original gene sequence and the other has inverted gene sequence. **Origin:** Inversion result when there are two breaks in a chromosome and the detached segment is reunited to the same chromosome in the reverse order. **Detection:** Three cytological criteria (i) pachytene configuration (ii) anaphase configuration (iii) position of centromere are used for detection of inversion.

Inversions can be detected in the meiotic nuclei by the presence of an inversion loop in the paired homologous during pachytene. Genetic Effects:

1. Fertility: The crossing over in the inversion loop leads to formation of chromosomes with duplication and deficiencies. Gametes with such chromosome are inviable and lead to 50% sterility. 2. Crossing over: Inversion heterozygotes often have pairing problems in the area of inversion. Thus competition for pairing reduces crossing over in the area of inversion.

3 Gene order: The Gene order is changed in the inverted segment of a chromosome. Inversion heterozygotes exhibit a linkage map with different gene order. In inverted chromosome there is no loss of genetic material provided crossing does not occur in the inversion loop. 4. Karyotype: Pericentric inversion sometimes results in change of karyotype by shifting the position of centromere in the inversion loop may lead to shift in the position of centromere. Duplication: Occurance of a segment twice in the same chromosome. It results in addition of one or more genes to a chromosome.

First reported in drosophila by Bridges in 1919. Now it has been reported in maize and wheat. Four types of duplication: 1. Tandom Duplication: Sequence of genes in the duplicated segment is similar to the sequence of genes in the original segment of a chromosome.

a b ñ [b c] d e f 2. Reverse Tandom duplication: The sequence of genes in the duplicated is reverse to the sequence of genes in the original segment of a chromosome. a b ñ [c b] d e f 3. Displaced Duplication: When the

duplication is found away from the original segment but on the same arm of the chromosome
a b ñ d e f i j k Normal a [d e] b c d e f g h l j k Displaced 4.

Reverse displaced duplication: Duplication is also away from the original segment but found on the other arm of a chromosome. These two types (3 & 4) are known as non- adjacent duplication because they are away from the segment which shows duplication. Origin: Duplication originate due to unequal crossing over during meiosis. The homologous chromosome usually pair in such a way that all the identical loci match with each other in their positions. This facilitates equal crossing over between non-sister chromatids. Sometimes homologous chromosome pair in such a misaligned manner that the corresponding identical loci do not fall opposite to each other.

Such situation leads to unequal crossing over between non sister- chromatids. This gives rise to two types of chromatids viz one with duplication other with deletion. When a gamete with duplication unites with normal ovule, it leads to formation of zygote with duplicate genes in a particular segment of a chromosome. Detection: a b ñ/b c/d e f g h i j

Duplication loop can be observed during pachytene stage when homologous chromosome pair, chromosome having duplicate segment are longer than normal chromosome. If a duplicate segment includes centromere it may be present as a small extra chromosome added to a normal chromosome complement duplication can also be detected by suppression of recessive characters.

A single dominant gene in the duplicate region is enough to suppress the expression of two recessive alleles. Significance: Duplications are less

harmful than deletions. They do not reduce the viability of an individual.

Duplications lead to addition of some genes in population.

Changes in Chromosome Number:

Introduction: A basic or monoploid set of chromosomes of an individual is called genome. In a genome, each type of chromosome is represented only once. Most of the sexually reproducing plant species are diploid, i. e., have two sets of chromosomes. Any change in the chromosome number from the diploid state is referred to as heteroploidy and the individuals having chromosome number other than diploid are called heteroploids. The heteroploidy is of two types viz., I.

euploidy and II. aneuploidy. 1. Euploidy: The change in chromosome number which involves entire set is called euploidy. Euploidy includes, monoploids, diploids and polyploids. Monoploids and Haploids Monoploids contain a single chromosome set and are characteristically sterile. In a true diploid species, both monoploid and haploid chromosome number is the same ($n = x$). Thus a monoploid can be a haploid but all haploids cannot be monoploids.

Types of Haploids: Depending upon the origin, haploids are of two types viz., euhaploids and aneuhaploids. Euhaploids develop from a euploid species and have complete chromosome set.

Euhaploids are of two types, viz., monohaploid – which develop from a normal diploid species, and polyhaploids – which develop from autopolyploid species. When a haploid develops from a tetraploid species, it is called dihaploid. Aneuhaploids develop from aneuploid species and have either one additional or missing chromosome. Aneuhaploids include disomic haploids (n
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+ 1), nullisomic haploids ($n - 1$), substitution haploids ($n - 1 + 1$), misdivision haploids etc. Mis-division haploids have an isochromosome which is produced by vertical division of centromere. Generally centromere divides longitudinally. Aneuhaploids are generally inviable. Production: Now various methods are known by which haploids can be produced. These methods include (1) Pollination with foreign pollen, (2) delayed pollination, (3) use of X-ray irradiated pollen for pollination, (4) temperature shock, (5) treatment with chemicals like colchicine, (6) interspecific and intergeneric crosses, and (7) anther and pollen culture. Uses of Haploids: Haploids have several applications in plant breeding. They are used for (1) development of pure lines, (2) disease resistance, (3) development of inbred lines, and (4) production of aneuploids. These aspects are briefly described below. Diploids Normal diploids are known as disomies. They have regular bivalent pairing during meiosis. Diploids also have disomic genetics with two alleles at each locus. Pure line or inbred lines of diploids have homozygosity at each locus. Polyploids which behave like diploids are known as disomic polyploids like wheat, cotton, etc. Polyploids: An organism or individual having more than two basic or monoploid sets of chromosomes is called polyploid and such condition is known as polyploidy. Polyploidy is of two types, viz, (1) autopolyploidy, and (2) allopolyploidy. 1. Autopolyploidy: Polyploids which originate by multiplication of the chromosome of a single species are known as autopolyploids or autopoloids and such situation is referred to as autopolyploidy. Autopoloids include triploids (3x), tetraploids (4x), pentaploids (5x), hexaploids (6x), heptaploids (7x), octaploids (8x), and so on. Autopoloids are also known as simple polyploids or single species polyploids.

Autotriploids: They have three sets of chromosomes of the same species.

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They can occur naturally or can be produced artificially by crossing between autotetraploid and diploid species. Triploids are generally highly sterile due to defective gamete formation. Triploids are useful only in those plant species which propagate asexually like banana, sugarcane, apple, etc.

Autoteraploids: They have four copies of the genome of same species. They may arise spontaneously or can be induced artificially by doubling the chromosomes of a diploid species with colchicine treatment. Tetraploids are usually very stable and fertile because pairing partners are available during meiosis. In such individuals diploid gametes ($2n$) are formed. Autotetraploids are usually larger and more vigorous than the diploid species. Rye, grapes, alfalfa, groundnut, potato and coffee are well known examples of autotetraploids.

2. Allopolyploidy: A polyploid organism which originates by combining complete chromosome sets from two or more species is known as allopolyploid or allopolyploid and such condition is referred to as allopolyploidy.

Allopolyploids are also known as hybrid polyploids or bispecies or multispecies polyploids. An allopolyploid which arises by combining genomes of two diploid species is termed as allotetraploid or amphidiploid. Allopolyploidy can be developed by interspecific crosses and fertility is restored by chromosome doubling with colchicine treatment. Allopolyploids has played greater role in crop evolution than autopolyploidy, because allopolyploidy is found in about 50% of crop plants. **Natural Allopolyploids:** Some important natural allopolyploid crops are wheat, cotton, tobacco, mustard, oats, etc.

Interspecific crossing followed by chromosome doubling in nature have resulted in the origin of allopolyploids. **Induction of Polyploidy:** Polyploidy is mainly induced by treatment with a chemical known as colchicine. This is an alkaloid which is obtained from the seeds of a plant known as *Colchicum*

autumnale, which belongs to the family Liliaceae. The colchicine induced polyploidy is known as colchipoity. In plants, colchicine is applied to growingtips, meristematic cells, seeds and axillary buds in aqueous solution. Colchicine induces polyploidy by inhibiting formation of spindle fibres. The chromosomes do not line up on the equatorial plate and divide without moving to the poles due to lack of spindle fibres. The nuclear membrane is formed around them and the cell enters interphase. Thus nucleus has double the chromosome number. Effects of Polyploidy: 1. Stems are thicker and stouter. 2. Leaves are fleshy, thicker, larger and darker green in colour. 3. Roots are stronger and longer. 4. Flowers, pollens and seeds are larger than diploids. 5. Maturity duration is longer and growth rate is slower than diploids. 6. Water content is higher than diploids, etc. Applications in Crop Improvement: Polyploidy plays an important role in crop improvement. Both autoploidy and allopolyploidy are useful in several ways. However, allopolyploidy has wider applications than autoploidy. Applications of autoploidy and allopolyploidy in crop improvement are briefly presented below: Autoploidy: Both triploids and tetraploids have been used in crop improvement. However, their applications have been limited to few species only. Autotriploids have been developed in sugarbeets and water melon only. The triploid sugarbeets have larger roots and higher sugar content than diploids. The triploid water melons are seedless or have rudimentary and soft seeds like cucumber. Allopolyploidy: Allopolyploidy is useful in four principal ways, viz., (1) In tracing the origin of natural allopolyploids, (2) In creating new species, (3) in interspecific gene transfer, (4) as a bridging species.

Limitations of Polyploidy: Polyploidy has several limitations. Some important limitations of polyploidy in crop improvement are briefly presented below: 1.

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Limited Use: The single species polyploidy has limited applications. It is generally useful in those crop species which propagate asexually like banana, potato, sugarcane, grapes, etc. 2. Difficulty in Maintenance: The maintenance of monoploids and triploids is not possible in case of sexually propagating crop species. 3. Undesirable Characters: In bispecies or multispecies polyploids characters are contributed by each of the parental species. These characters may be sometimes undesirable as in case of Raphanobrassica. 4. Some other Defects: Induced polyploids have several defects such as low fertility, genetic instability, slow growth rate, late maturity, etc. 5. Chances of developing new species through allopolyploidy are extremely low. II. Aneuploidy: Aneuploids are of three types, viz., (1) monosomies, (2) nullisomics, and (3) polysomics. These are described below:

(1) Monosomies: An individual lacking one chromosome from a diploid set ($2n-1$) is called monosomic and such condition is known as monosomy. Monosomies may originate in three main ways, viz., (i) from diploids, (ii) from nullisomics, and (iii) from trisomics as described below. (i) From Diploids: Monosomies may originate spontaneously from diploids. Sometimes nondisjunction during meiosis gives rise to $n-1$ gamete. If this gamete is fertilized by a normal (n) gamete, a monosomic zygote ($2n-1$) is produced. (ii) From Nullisomics: Nullisomics produce $n-1$ gametes. Union of such gamete with normal gamete gives rise to monosomies as shown below: Nullisomic Gametes Union with normal gamete Result $2n-2$ $n-1$ $n-1+n$ $2n-1$ (iii) From Trisomics: Trisomics ($2n+1$) also give rise to monosomies. Sometimes non disjunction of three homologous chromosomes in a trisomic during meiosis gives rise to $n-1$ gametes. Union of such gametes with normal one results in the development of monosomic zygote. Trisomics Gametes Union with

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normal Result $2n+1$ $n - 1/n-1$ $n -1 + n$ $2n-1$ (2) Nullisomics: An individual lacking one pair of chromosomes from a diploid set ($2n-2$) is called nullisomic and such situation is referred to as nullisomy. (3) Polysomics: An individual having either single or one pair of extra chromosome in the diploid complement is known as polysomic and such condition is referred to as polysomy. Applications in Crop Improvement: Aneuploids are useful in crop improvement in various ways. Some of the uses of aneuploids in plant breeding are briefly presented below: 1. Locating Genes. Aneuploids are useful tools for locating genes on a specific chromosome. Monosomies and nullisomics are used for this purpose. 2. Interspecific Gene Transfer. Monosomies are also used in transferring chromosomes with desirable genes from one species to another. 3. Aneuploids are used for developing alien addition and alien substitution lines in various crops. 4. Primary trisomics are useful in identification of chromosomes involved in translocations.

DNA Replication:

The process by which a DNA molecule makes its identical copies is known as DNA replication. Three possible modes of DNA replication. 1. Dispersive Replication 2. Conservative Replication 3. Semi conservative Replication. Semi Conservative Replication: Main features — 1. Separation of two strands of parental DNA. 2. Complementary base pairing of the bases located in the single stranded regions. 3. Formation of phosphodiester linkages between the neighbouring deoxyribonucleotides. 4. This ensures that the base pairs of the new strands are complementary to the old strands. 5. The base sequence of a newly synthesized strand is dictated by the base sequence of old strand. Evidence for Semi Conservative Replication: 1. Meselson and

Stahl 1958: They grew *E. coli* in ^{15}N for 14 cell generations till nitrogen in the bacterial DNA was only ^{15}N . This heavy DNA had more density than DNA with ^{14}N . Then the bacteria were transferred to culture medium ^{14}N . They observed that such DNA was half dense indicating the presence of DNA hybrid (one ^{15}N strand + one ^{14}N strand). After second round of replication there would be 4 DNA molecules of these, two molecules would be hybrid ($^{14}\text{N} - ^{15}\text{N}$).

Methods of DNA Replication:

1. Initiation of Replication: Replication begins at a replication origin.
2. Unwinding of Helix: Unwinding is brought by enzyme ' helicase.' This unwinding may result in formation of supercoils which are removed by enzyme DNA Gyrase (topoisomerase). Formation of replication fork (y shaped structure). Single strands are stabilised by a single strand binding protein (SSB).
3. Formation of Primer Strand: An enzyme primase initiates transcription of $3' \rightarrow 5'$ strands. This generates long primer RNA in $5' \rightarrow 3'$ direction. The free $3'-\text{OH}$ of this primer RNA provides the initiation point for DNA polymerase for the sequential addition of deoxyribo nucleotides. DNA polymerase III catalyse DNA replication.
4. Elongation of New Strand: Synthesis of new strand occurs continuously along the upper strand known as leading daughter strand - Synthesis of another daughter strand along lower parental strand takes place in the form of short pieces lagging daughter strand. Short pieces of DNA is called okazaki fragments. Discontinuous pieces of the lagging strand are joined together by the enzyme DNA ligase.