RAMA UNIVERSITY

www.ramauniversity.ac.in

FACULTY OF AGRICULTURAL SCIENCES

AND ALLIED INDUSTRIES

MUTATION

In the broad sense, the term 'mutation' refers to all the heritable changes in the genome, excluding those resulting from incorporation of genetic material from other organisms. A mutation is an abrupt qualitative or quantitative change in the genetic material of an organism.

Types of mutations:

- Intragenic or intergenic. Intragenic mutations or point mutations include alterations in the structure of the DNA molecule within a gene. In a point mutation there is a change in the normal base sequence of the DNA molecule. This change results in a modification of the structural characteristics or enzymatic capacities of the individual. The unit of gene mutation is the muton. This may consist of one or many nucleotide pairs. Intergenic mutations, of which chromosomal changes in structure are examples, involve long regions of DNA, i.e. many genes. These include deletion or addition of segments of chromosomes, resulting in deficiency and duplication, respectively. In large deletions a base sequence corresponding to an entire polypeptide chain is sometimes lost. Such mutations are very useful in genetic mapping.
- Germinal and Somatic Mutations Eukaryotic organisms have two primary cell types - germ and somatic. Mutations can occur in either cell type. If a gene is altered in a germ cell, the mutation is termed a germinal mutation. Because germ cells give rise to gametes, some gametes will carry the mutation and it will be passed on to the next generation when the individual successfully mates. Typically germinal mutations are not expressed in the individual containing the mutation. Somatic cells give rise to all non-germline tissues. Mutations in somatic cells are called somatic mutations. Because they do not occur in cells that give rise to gametes, the mutation is not passed along to the next generation by sexual means. To maintain this mutation, the individual containing the mutation must be cloned. Two example of somatic clones are navel oranges and red delicious apples.
- Spontaneous and Induced Mutations In general, the appearance of a new mutation is a rare event. Most mutations that were originally studied occurred spontaneously. This class of mutation is termed spontaneous mutations. But these mutations clearly represent only a small number of all possible mutations. To genetically dissect a biological system further, new mutations were created by scientists by treating an organism with a mutagenizing agent. These mutations are called induced mutations. The spontaneous mutation rate varies.

Large gene provides a large target and tends to mutate more frequently. A study of the five coat color loci in mice showed that the rate of mutation ranged from 2 x 10-6 to 40 x 10-6 mutations per gamete per gene. Data from several studies on eukaryotic organisms shows that in general the spontaneous mutation rate is 2-12 x 10-6 mutations per gamete per gene.

Mutations can be induced by several methods:

Three general approaches used to generate mutations are radiation, chemical and transposon insertion. The first induced mutations were created by treating Drosophila with X-rays. In addition to X-rays, other types of radiation treatments that have proven useful include gamma rays and fast neutron bombardment. These treatments can induce point mutations (changes in a single nucleotide) or deletions (loss of a chromosomal segment).

Other Types of mutations: Morphological mutants affect the outward appearance of an individual. Plant height mutations could changes a tall plant to a short one, or from having smooth to round seeds. Biochemical mutations have a lesion in one specific step of an enzymatic pathway.

For bacteria, biochemical mutants need to be grown on a media supplemented with a specific nutrient. Such mutants are called auxotrophs. Often though, morphological mutants are the direct result of a mutation in a biochemical pathway.

In humans, albinism is the result of a mutation in the pathway which converts the amino acid tyrosine to the skin pigment melanin. Similarly, cretinism results when the tyrosine to thyroxine pathway is mutated.

For some mutations to be expressed, the individual needs to be placed in a specific environment. This is called the restrictive condition. But if the individual grow in any other environment (permissive condition), the wild type phenotype is expressed. These are called conditional mutations. Mutations that only expressed at a specific temperature (temperature sensitive mutants), usually elevated, can be considered to be conditional mutations. Lethal mutations are also possible. As the term implies, the mutations lead to the death of the individual. Death does not have to occur immediately, it may take several months or even years. But if the expected longevity of an individual is significantly reduced, the mutation is considered a lethal mutation. If a mutation occurs in that allele, the function for which it encodes is also lost. The general term for these mutations is loss-of-function mutations. The degree to which the function is lost can

vary. If the function is entirely lost, the mutation is called a null mutation. If is also possible that some function may remain, but not at the level of the wild type allele. These are called leaky mutations.

Mutagens:

A variety of agents increase the frequency of mutation. Such agents are called mutagens. They include chemical mutagens, and radiations like X-rays, γ-rays and UV-light. Chemical Mutagens.

The first chemical mutagen discovered was mustard 'gas'. In the 1950s chemical mutagens with more or less specific action were developed. Chemical mutagens can be classified according to the way in which they bring about mutations: (1) Base analogues which are incorporated into DNA instead of normal bases (2) Agents modifying purines and pyridines and agents labilizing bases, and (3) agents producing distortions in DNA.

The agents in categories (1) and (3) require replication for their action, while agents in category (2) can modify even non replicating DNA. Chemical mutagens work mostly by inducing point mutations.

Two major classes of chemical mutagens are routinely used. These are alkylating agents and base analogs. Each has a specific effect on DNA. Alkylating agents [such as ethyl methane sulphonate (EMS), ethyl ethane sulphonate (EES) and musta rd gas] can mutate both replicating and nonreplicating DNA. By contrast, a base analog (5-bromouracil and 2- aminopurine) only mutate DNA when the analog is incorporated into replicating DNA. Each class of chemical mutagen has specific effects that can lead to transitions, transversions or deletions.

CIB Technique for detection of mutation:

This method was discovered by Muller. In this method, females containing one normal X-chromosome and another X-chromosome (CIB) containing extra 3 genes are used for the analysis. Out of the 3 extra genes, one gene suppresses crossover (c), the other is a recessive lethal (L) in heterozygous condition, and the last gene is semi dominant marker, Bar (B) gene. Females containing CIB chromosome are called as CIB stock drosophila. The normal males are exposed to mutagenic source for a fixed period and then mated to the CIB stock drosophila. Males containing CIB chromosome will die due to the effect of lethal genes, whereas norm ill males and females both normal and with CIB will survive. Females with CIB chromosomes and identified by barred phenotype are selected and crossed to normal males. In this next generation 50% of males (which have received the CIB gene) will die. If mutation has occurred in normal X chromosome then even the normal male (without CIB gene) will die. If no mutation has occurred all the other 50% of males will survive. The frequency of lethal mutations can be

accurately scored in large samples. This technique is simple, rapid and there is little chance of an error in scoring. However, it is suitable for the scoring of sex linked recessive lethal only.

POLY PLOIDS

Individual with one set of chromosomes – haploid or Monoploids.

Individual with two sets of chromosomes – True diploid

Most plants and animals posses two sets of chromosomes.

Individuals with more than two sets of chromosomes are called ‘ polyploid’. (poly = many; ploid – fold). Poly ploid in otherwise called as ‘Euploidy’.

HAPLOID (Monoploid)

Haploidy in flowering plants was first recorded by Blakeslee (1937) in *Datura stramonium* . One in very 1000 seedlings of maize was found to be a haploid, developed from the unfertilized egg (i.e by female parthenogenesis).

Polyembryony in plants in a possible source of haploids, due to the occurrence of more than one embryosac within a ovule. Out of the four haploid megaspores derived by meiotic divisions from a single megaspore mother cell, more than one may develop into embryo sacs.

Production of embryos from synergids without fertilization is more common than production of embryos from antipodal. For instance, out of about 30,000 seeds of G. Girsutum, 20 were found to give rise to twin embryos of which from were haploids.

Haploids can be obtained by anther and pollenculture using tissue culture techniques and also by wide species crosses.

Characteristics of haploids

Generally smaller in size than diploids. Their guard cells are also smaller than those of diploids. They are highly sterile because none of chromosomes of true haploid has a homologue.

Classification of haploids : 1. Mono-haploid. 2. Poly haploids.

Mono-haploids: are haploids which arise from time diploids and whose chromosomes are therefore non-homologous to one another. Eg. haploids of maize.

Polyhaploids: Haploids arise from polyploids eg; Haploid of triticum aestivum with one representative of each chromosomes of A. B and D genome.

GENOME

The complete set of chromosome found in the gamete of a true diploid is called a genome. e.g. p. glaucm, 14 chromosome 2 sets n=7, 2n=14.

A gamete contains one set of seven chromosomes (I, II, III, IV, V, VI, VII) is called a genome and if this is represented as ‘ A’ the genomic constitution of the plant in ‘ AA’.

BASIC NUMBER

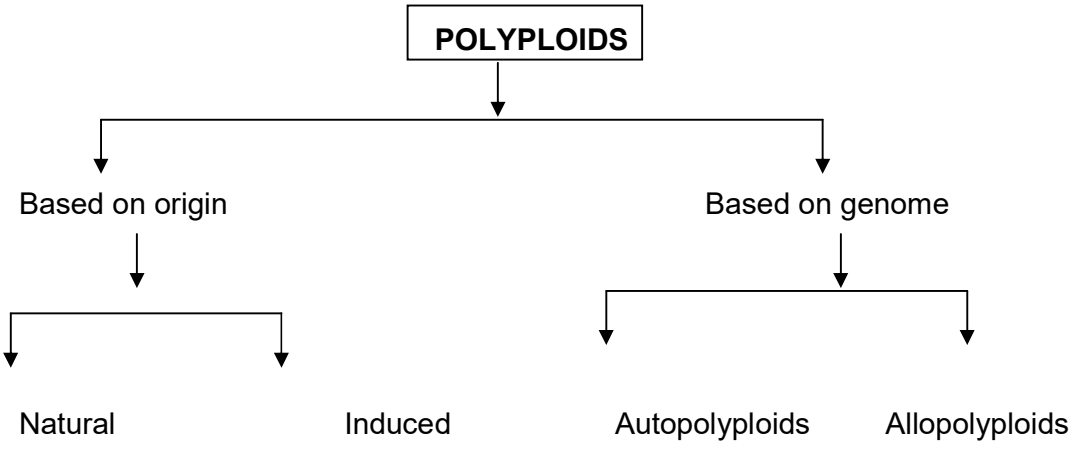
The number of chromosomes constituting a genome is called the basic number. It is the number of chromosomes found in the gamete of a true diploid.

POLYPLOID

Species of solanum which have a chromosome number of 24 are true diploid and species which have somatic no higher than 24, but which are multiples of 12, are called polyploids.

Somatic No. (2n)	Multiples of Basic No.(x-12)	Level of ploidy
24	2x	Diploid
36	3x	Triploid
48	4x	Tetraploid
60	5x	Pentaploid
72	6x	Hexaploid

CLASSIFICATION



Natural polyploids: Polyploids arise in nature by failure of meiosis that result in formation of unreduced gametes. They may also be formed from somatic cells in which a failure of mitosis has resulted in doubling of the chromosome complement. The cultivated banana and tobacco are examples of natural polyploids.

POLYPLOIDY: Mutations which alter the chromosome structure, size or gene arrangement are chromosomal mutations. Chromosomal mutations are widely called as chromosomal aberrations. These are grouped into two broad classes based open whether they alter the structure or number of chromosomes. Chromosome Mutations - gross changes in chromosomes. Changes in the number of chromosomes. 1. Euploidy - variation in the number of sets of chromosomes. a. Haploidy (Monoploidy) - one set of chromosomes (n) : ABC b. Polyploidy-three or more sets of chromosomes. c. Triploidy-3 sets of chromosomes (3n) : ABC, ABC, ABC. d. Tetraploidy-4 sets of chromosomes (4n): ABC, ABC, ABC, ABC. e. Pentaploidy-5 sets of chromosomes (5n) : ABC, ABC, ABC, ABC, ABC. f. Hexaploidy (6n), Septaploidy (7n), Octoploidy (8n), etc 2. Aneuploidy - variation in the number of chromosomes of a set. (Reduction in the normal number of chromosomes.) a. Monosomics - Loss of one chromosome (2n-1) : ABC, AB. b. Double monosomics - Loss of 2 different chromosomes (2n-1-1): ABC, A. b - loss of a pair of homologous chromosomes (2n-2) : AB, AB: b. Increase in the number of chromosomes (polysomies). Trisomies - presence of 1 extra chromosome (2n+ 1) : ABC, ABC, A. Double trisomics - 2 different extra chromosomes (2n + 1 + 1) : ABC, ABC, AB. Tetrasomics - an extra pair of homologous chromosomes (2n+2): ABC, ABC, AA. pentasomics (2n+3), Hexasomics (2n+4), Sepiasomics (2n+5), etc. Euploidy The term euploidy (Gr., eu-true or even; ploid-unit) designates genomes containing whole sets of chromosomes. The euploids are those organisms which contain balanced set or sets of chremosomes or genomes in any number, in their body cells. The euploidy is of following types: The number of chromosomes in a basic set is called the monoploid number (x). Organisms with multiples of the monoploid number of chromosomes are called euploid. Eukaryotes normally carry either one chromosome set (haploids) or two sets (diploids). Haploids and diploids, then, are both cases of normal euploidy. Euploid types that have more than two sets of chromosomes are called polyploid. Polyploidy Humans are diploid creatures, meaning for every chromosome in our body, there is another one to match it. • Haploid creatures have one of each chromosome • Diploid creatures have two of each chromosome • Triploid creatures have three of each chromosome • Polyploid creatures have three or more of each chromosome They can be represented by n where n equals haploid, 2n equals diploid and so on. It is

possible for a species, particularly plant species, to produce offspring that contains more chromosomes than its parent. This can be a result of nondisjunction, where normally a diploid parent would produce diploid offspring, but in the case of non-disjunction in one of the parents, produces a polyploid. In the case of triploids, although the creation of particular triploids in species is possible, they cannot reproduce themselves because of the inability to pair homologous chromosomes at meiosis, therefore preventing the formation of gametes. Polyploidy is responsible for the creation of thousands of species in today's planet, and will continue to do so. It is also responsible for increasing genetic diversity and producing species showing an increase in size, vigour and an increased resistance to disease. The polyploid types are named triploid (3x), tetraploid (4x), pentaploid (5x), hexaploid (6x), and so forth. Polyploids arise naturally as spontaneous chromosomal mutations. However, many species of plants and animals have clearly arisen through polyploidy, so evidently evolution can take advantage of polyploidy when it arises. It is worth noting that organisms with one chromosome set sometimes arise as variants of diploids; such variants are called monoploid (1x). In some species, monoploid stages are part of the regular life cycle, but other monoploids are spontaneous aberrations. The haploid number (n), which we have already used extensively, refers strictly to the number of chromosomes in gametes. In most animals and many plants with which we are familiar, the haploid number and monoploid number are the same. Hence, n or x (or 2n or 2x) can be used interchangeably. However, in certain plants, such as modern wheat, n and x are different. Wheat has 42 chromosomes, but careful study reveals that it is hexaploid, with six rather similar but not identical sets of seven chromosomes. Hence, 6x=42 and x=7. However, the gametes of wheat contain 21 chromosomes, so n=21 and 2n=42. Monoploids In monoploidy, the monoploid organisms have one genome (n) in their body cells. When monoploidy occurs in gametes (sperms and eggs) it is termed as haploidy. Most micro-organisms (e.g., bacteria. fungi and algae); gametophytic generation of plants (e.g., bryophytes and other plants); sporophytic generation of some higher angiospermic plants (e.g., Sorghum, Triticum, Hordeum, Datura, etc.) and certain hymenopteran male insects (e.g., wasps, bees, etc.) have one genome in their body cells, hence are monoploids. Monoploids are usually smaller and less vigorous than their diploid prototypes. Characteristically, monoploid plants are

sterile. The reason of sterility is that the chromosomes have no regular pairing partners (homologous chromosomes) during meiosis, and meiotic products are deficient in one or more chromosomes. For instance, a haploid in maize (2n=20) will have 10 chromosomes and the number of chromosomes in a gamete can range from 0-10. Consequently, considerable sterility will be found in a monoploid maize. Male bees, wasps, and ants are monoploid. In the normal life cycles of these insects, males develop parthenogenetically—that is, they develop from unfertilized eggs. However, in most species, monoploid individuals are abnormal, arising in natural populations as rare aberrations. The germ cells of a monoploid cannot proceed through meiosis normally, because the chromosomes have no pairing partners. Thus, monoploids are characteristically sterile. Monoploids play an important role in modern approaches to plant breeding. Diploidy is an inherent nuisance when breeders want to induce and select new gene mutations that are favorable and to find new combinations of favorable alleles at different loci. New recessive mutations must be made homozygous before they can be expressed, and favorable allelic combinations in heterozygotes are broken up by meiosis. Monoploids provide a way around some of these problems. In some plant species, monoploids can be artificially derived from the products of meiosis in a plant's anthers. A cell destined to become a pollen grain can instead be induced by cold treatment to grow into an embryoid, a small dividing mass of cells. The embryoid can be grown on agar to form a monoploid plantlet, which can then be planted in soil.

Plant monoploids can be exploited in several ways. In one, they are first examined for favorable traits or allelic combinations, which may arise from heterozygosity already present in the parent or induced in the parent by mutagens. The monoploid can then be subjected to chromosome doubling to achieve a completely homozygous diploid with a normal meiosis, capable of providing seed. It is achieved by the application of a compound called colchicine to meristematic tissue. Colchicine—an alkaloid drug extracted from the autumn crocus - inhibits the formation of the mitotic spindle, so cells with two chromosome sets are produced. These cells may proliferate to form a sector of diploid tissue that can be identified cytologically.

The anther technique for producing monoploids does not work in all organisms or in all genotypes of an organism. Another useful technique has been developed in barley, an important crop plant. Diploid barley, Hordeum vulgare, can be fertilized by pollen from a diploid wild relative called Hordeum bulbosum. This fertilization results in zygotes with one chromosome set from each parental species. In the ensuing somatic cell divisions, however, the chromosomes of H. bulbosum are eliminated from the zygote, whereas all the chromosomes of H. vulgare are retained, resulting in a haploid embryo. (The haploidization appears to be caused by a genetic incompatibility between the chromosomes of the different species.) The chromosomes of the resulting haploids can be doubled with colchicine. This approach has led to the rapid production and widespread planting of several new barley varieties, and it is being used successfully in other species too. Diploidy The diploidy is characterized by two genomes (2n) in each somatic cell of the diploid organisms. Most animals and plants are diploids. The diploidy is related with fertility, balanced growth, great vigorosity, adapatability and survivality of the diploid organisms Polyploids The organisms with more than two genomes are called polyploids. Among plants and animals, the polyploidy occurs in a multiple series of 3, 4, 5, 6, 7, 8, etc., of the basic chromosome or genome number and thus is causing triploidy, tetraploidy, pentaploidy, hexaploidy, heptaploidy, octaploidy, respectively. Ploidy levels higher than tetraploid are not commonly encountered in natural populations, but our most important crops and ornamental flowers are polyploid, e.g., wheat (hexaploid, 6n), strawberries (octaploid, 8n), many commercial fruit and ornamental plants, liver cells of man, etc. Other examples of polyploidy among plants and animals are following: A: Examples of polyploidy in plants The polyploidy is most common among angiosperms and some of economically important polyploid angiospermic plants are peanuts (Arachis),oats (Avena), coffee (Coffea), strawberry (Fragaria), cotton (Gossypium), barely (Hordeum), sweet potato (Ipomoea), apple (Malus), alfa-alfa (Medicago), banana (Musa), tobacco (Nicolina), plum (Prunus), sugar cane (Saccharum), potato (Solanum), sorghum (Sorghum), clover (Trifolium), and wheat (Triticum). A continuous polyploid series has been reported in rose plant. Aeuploid series of basic number of 7 (monoploid) including diploids (2n= 14), triploids (21), tetraploids (28), pentaploids (35), hexapolid (42), and octaploid (56) has been reported in different species of Rosa. Likewise, the genus

Chrysanthemum has basic chromosome number 9 and has a euploidic series of diploid (2n = 18), tetraploids (4n=36), hexaploids (6n=54), octaploids (8n=72) and decaploids (10n=90) in its different species. The genus Solanum has basic chromosome number 12 and has a euploidic series of diploids (2n=24), triploids (3n=36), tetraploids (4n=48), pentaploids (5n=60), hexaploids (6n=72), octaploids (8n=96), and decaploids (10n = 120) in its different species. Origin of Polyploidy Different degrees of ploidy are originated by different means. However, two basic irregular processes have been discovered by which polyploids may evolve from diploid plants and become established in nature: (1) Somatic doubling-cells sometimes undergo irregularities at mitosis and give rise to meristematic cells that perpetuate these irregularities in new generations of plants. (2) Reproductive cells may have an irregular reduction or equation division in which the sets of chromosomes fail to separate completely to the poles at anaphase. Both sets thus become incorporated in the same nucleus resulting in the doubling of chromosome number in the gamete (see Gardner, 1912). Thus, a triploid originates by the fusion of a haploid gamete (n) with a diploid gamete (2n), the later of which may be originated by irregularities during meiosis. Likewise, a tetraploid may be originated by the somatic doubling of the chromosome number or by union of unreduced diploid gametes. The somatic doubling of genome is accomplished either spontaneously or it can be induced in high frequency by exposure to chemicals such as colchicine, etc., or heat or cold. Other levels of polyploidy are also originated by same methods.

Induction of Polyploidy The polyploidy can be induced in common diploid organisms by following methods: 1. Cell generation - In certain bryophytes such as mosses, the polyploidy has been induced by cutting their diploid sporophytes and keeping the sporophytes in moist conditions. The cells of the cut ends regenerated threads which were true protonema and produced diploid gametophytic generation instead of monoploidic generation. 2. Physical agents - Following kinds of physical conditions induce polyploidy in plants: (i) Temperature shocks - Extreme temperature changes some. times result in a higher frequency of polyploid cells. (ii) Centrifugation - The centrifugation of seedlings of plants causes polyploidy in their cells. In Nicotiana, polyploidy has been induced by this method. (iii) X-rays - The radioactive substances such as radium and X-rays have

been found to induce polyploidy in normal diploid plant cells. 3. Chemical agents - Some chemicals such as colchicine, chloral hydrate, acenaphthene, veratrine, sulfanil amide, ethyl, mercury chloride. hexachlorocyclohexane have been reported to induce polyploidy in plants. These chemical substances when used to dividing diploid cells, they disturb the mitotic spindle and cause non-segregation of already duplicated chromosomes and thus, convert the diploid cells into tetraploid cells. The tetraploid cells, likewise, are converted into different levels of polyploidy Kinds of Polyploidy In the realm of polyploids, we must distinguish between autopolyploids, which are composed of multiple sets from within one species, and allopolyploids, which are composed of sets from different species. Allopolyploids form only between closely related species; however, the different chromosome sets are homeologous (only partly homologous)—not fully homologous, as they are in autopolyploids. Allopolyploidy- The prefix "allo" indicates that nonnhomologous sets of chromosomes are involved. P1: Species X X Species Y (AA) ↓ (BB) (Diploid) (Diploid) F1: AB Diploid sterile hybrid ↓ Colchicine AABB Fertile amphidiploid tetraploid The union of unreduced or diploid or polyploid gametes from different diploid or polyploid species could produce in one step, an amphipolyploid or allopolyploid; which appears and behaves like a new species. Let A represent a set of genome in species X, and let B represent another genome in a species Y. The F 1 hybrids of these species than would have one A genome and another B genome. The F1 diploid but sterile hybrids can be converted into fertile allotetraploids by treating them by colchicine.

Gossypium hirsutum, the New world cotton plant, is another interesting example of allopoly ploidy. Old world cotton, Gossypium herbaceum, has 13 pairs of chromosomes, while American or "upland cotton" also contains 13 pairs of chromosomes. J. O. Beasley crossed the old world and American cottons and doubled the chromosome number in the F) hybrids. The allopolyploids thus produced resembled the cultivated New world cotton and when crossed with it gave fertile F1 hybrids These results, thus, suggested that tetraploid Gossypium hirsutum originated from two diploid species, namely G. herbaceum (20=26) and G. raimondii (2n=26).

Aneuploidy Aneuploidy is the second major category of chromosome mutations in which chromosome number is abnormal. An aneuploid is an individual organism

whose chromosome number differs from the wild type by part of a chromosome set. Generally, the aneuploid chromosome set differs from wild type by only one or a small number of chromosomes. Aneuploids can have a chromosome number either greater or smaller than that of the wild type. Aneuploid nomenclature is based on the number of copies of the specific chromosome in the aneuploid state.

- For example, the aneuploid condition 2n−1 is called monosomic (meaning “one chromosome”) because only one copy of some specific chromosome is present instead of the usual two found in its diploid progenitor.
- The aneuploid 2n+1 is called trisomic,
- 2n−2 is nullisomic, although nullisomy is a lethal condition in diploids, an organism such as bread wheat, which behaves meiotically like a diploid although it is a hexaploid, can tolerate nullisomy.

Note: Non-disjunction in mitosis or meiosis is the cause of most aneuploids. Disjunction is the normal separation of homologous chromosomes or chromatids to opposite poles at nuclear division. Non-disjunction is a failure of this disjoining process, and two chromosomes (or chromatids) go to one pole and none to the other. Nondisjunction occurs spontaneously; it is another example of a chance failure of a basic cellular process. Monosomics show the deleterious effects of genome inbalance, as well as unexpected expression of recessive alleles carried on the monosomic chromosome.

- Trisomics: A diploid cell with an extra chromosome. Basically a diploid with an extra chromosome of one type, producing a chromosome number of the form 2n + l. The diploid organisms which have one extra chromosome are called trisomics. They have the chromosomal formula 2n+1. In a trisomic, one of the pairs of chromosomes has an extra member, therefore, forms a trivalent structure during meiosis.During anaphase of meiosis, two chromosomes go to one pole and one chromosome to another pole and thus, two types of gametes n + 1 and n are resulted. The trisomy has variable effects on the phenotype of the organism and in man trisomy of autosome 21 cause mongolism. In plants, first case of trisomy was investigated in Datura stromonium. Stramonium normally has 12 pairs of chromosomes in the somatic cells, but in a individual they discovered 25

chromosomes (2n + 1). The size, shape and spine characteristic of seed capsule of this trisomic plant had difference with seed capsule of the wild type. species. Theoretically, because the complement was composed of 12 chromosome pairs differing in the genes they carried, 12 distinguishable trisomics were possible in Jimson weed. Through experimental breeding, Blakeslee and his associates succecceded in producing all 12 possible trisomies. These were grown in Blakeslee's garden and each was found to have a distinguishable phenotype that was attributed to an extra set of the genes contained in one of the 12 chromosomes.

- Tetrasomy: When one chromosome of an otherwise diploid organism is present in quadruplicate, the tetrasomy is resulted. The tetrasomics have the .chromosomal formula 20+2. During meiosis a quadrivalent is formed by extra chromosomes and segregation of chromosomes occurs like autotetraploids. Double Trisomy In a diploid organism when two different chromosomes are represented in triplicate, the, double, trisomy is resulted. A double trisomic has the chromosomal formula 2n+1+1.

IMPORTANT QUESTIONS:

1. Explain multiple factor hypothesis with example.
2. Define transgressive segregation.
3. Differentiate between quantitative and qualitative inheritance.
4. Define cytoplasmic inheritance with help of suitable examples.
5. What is structural aberrations? Explain its types and roles.

6. What is numerical aberrations? Describe its types and importance.
7. Write down the use of haploids.