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B.Sc HONS Part-III Paper -VI
Topic - Structure and Function of Chromosomes.
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Q. Give an account of structure and function of Chromosomes.

Introduction :

Chromosomes are self reproducing thread like structures located inside the nucleus. They are called chromosomes (chromo = colour, soma = body) because they are easily stained with dyes. They are the vehicles of heredity.

Chromosomes were first observed by HOFMEISTER in 1848 in the nuclei of pollen mother cells of tradescantia. However, they were named chromosomes in 1888 by WALDEYER.

Shape : The shape of a chromosome is largely determined by the position of its centromere. On this basis, chromosomes are classified into four types. They are the following :

1. Telocentric : The centromere is located at the end of the chromosome. Such chromosomes are rare. It exists normally in certain species of protozoa.

2. Acrocentric : These are rod like chromosomes having a very small arm and a very long arm. This is characteristic of locusts.

3. Submetacentric : These chromosomes are L-shaped having unequal arms.

4. Metacentric : These chromosomes are V-shaped. They have arms equal in length. They are characteristic of amphibia.

Size : The size of the chromosome ranges from 0.1 micron to 30 micron. The diameter varies from 0.2 micron to 2 micron. In general, plants have larger chromosomes than animals. The plant trillium has chromosomes with the length of 32 micron at metaphase.

The length of the human chromosomes varies from 4 micron to 6 micron. But there are also giant chromosome which vary in length and diameter. The lamp brush chromosomes in oocytes of amphibia may reach upto 800 microns long.

Structure : A typical somatic chromosome has an elongated cylindrical body with two arms. It consists of a pellicle, matrix, chromonema, chromomeres, centromere or primary construction, secondary construction satellite bodies and telomeres.

Pellicle : It is the outermost covering of the chromosome. It is thin and formed of a chromatic or non-genetic material.

Matrix : The pellicle encloses a mass of homogenous non-genetic material called the matrix. It forms the main bulk of the chromosome. It helps in keeping the chromonemata within the bounds.

Chromonemata : Internally, the chromosome contains two identical, spirally coiled filaments. They are called chromonemata. The nature and the degree of coiling of chromonemata is variable in meiotic and mitotic chromosomes. In meiotic chromosomes two distinct coils are observed. One is called the major coil, which consists of 10 to 30 gyres. The other is called the minor coil, which has more number of gyres. In mitotic chromosomes, a kind of coil similar to the major coil is described. It is called the somatic or standard coil. The coiling may be either plectonemic where are coiling can be easily separated or paranemic where the coiling cannot be easily separated.

Euchromatin and Heterochromatin : During interphase such region or the chromatin stain darker with Feulgen. Such regions are called heterochromatin. The other regions are called euchromatin. This Phenomenon is known as heteropycnosis or differential staining. Hetrochromatin is in close contact with nucleoids. During mitosis, the heterochoromatic regions may stain more strongly or more weakly than euchromatic regions.

Chromomere : In the meiotic and the mitotic prophase, the chromonemeta shows alternating thick and thin regions. The thick region are bead-like structures and are called chromomeres. The regions in between them are called inter chromomeres. It is presumed that genes are located on chromomeres. But some thought that the genes may be located on inter chromomeres, but it has not been well established.

Centromere : There is a lighter staining narrow region in the chromosome called centromere. This narrow region is in the form of a constriction. Hence it is also called primary constriction. The parts of the chromosome which lie on either side of the chromosome are called arms. The shape of the chromosomes is determined by the location of the centromere. The centromere has five zones namely an inner zone, two middle zones and two outer zones. The middle region is formed of one or more chromomeres. The centromere has three functions :

1. Spindle fibres are attached to centromere.
2. It helps the formation of spindle fibres.
3. It gives shape to the chromosome.

Secondary Constriction :

Occasionally, additional constrictions are seen other than the primary constriction. These are called secondary constriction. These are constant in position. These are differ from the primary constrictions by the absence of marked angular deviation of the chromosomal segments. These constrictions are often associated with the formation of nucleous. So these are referred to as nucleolar organizers. The chromosomes with these structures are known as the nucleolar chromosomes.

Satellites : The secondary constriction is subterminal in position. The small piece of chromosome located beyond the secondary constriction is called satellite. It is a round, elongate body and its diameter may be the same as that of the other parts of the chromosome. Chromosomes with satellite are called SAT chromosomes. The satellites are usually single. Butin rare cases there may be two or more.

Telomere : The lips of chromosomes are called telomeres. They determine the polarity of chromosomes. They prevent other chromosomes to join with each other.

Fine Structure of the chromosome : The chromonemata are twisted around one another. Each chromonemata is formed of about 8 microfibrils having 60 to 100Å thickness. Each microfibril is formed to two double helic as of DNA. DNA strand is about 20Å thick. The next largest unit of the chromosome is the half chromatid which is formed of 4 microfibrils. Each is 100Å thick. Thus a half chromatid is about 400Å thick and is formed of 8 DNA helics. Two half chromatids join together to form a chromatid and two chromatid form a chromosome. A chromosome is formed of 32 DNA helices.

Types of chromosomes : In vertebrates, the chromosomes can be grouped under two groups. They are autosomes and allosomes. The male of the most species is characterized by XY chromosome and the female by XX chromosomes.

Generally only one X chromosome is functionally active in a interphase Cell. If the Cell contains more than one X-chromosome, only one X-chromosome becomes functional. All other X-chromosomes become inactivated. This inactivated X-chromosome is called Sex-chromatin or Barr Body (MURRAY BARR, 1940)

Idiogram : The diagramatic representation of the chromosome complex or karyotypes showing all the morphological features of the chromosomes of a organism is termed ideogram.

Chemical Composition–Chemically, the chromosomes are formed of nucleic acids and proteins. About 90% are deoxyribonucleo proteins.

The remaining 10% constitute the residual chromosome. The DNA proteins are formed of 45% DNA and 55% basic proteins the histone. The residual chromosome is the substance of the chromosome remaining after the removal of DNA and histones. The residual chromosome contains RNA, DNA and residual protein. The residual protein is acidic in nature which forms the structural integrity of the chromosome. If the residual protein is removed, the structural integrity of the chromosome is lost. Removal of DNA and histone does not affect the structural integrity. There is another special types of protein called chromosomin formed of high tryptophan. The linkage between the DNA and protein is of ionic nature and is called salt linkage. Specific divalent ions, namely Ca^{++}, Mg^{++} and Fe^{++} present in cells form additional linkages in the chromosomes between DNA and protein or between DNA groups.

Functions :

1. They control the heredity.
2. The chromosomes control the metabolism of an organism.
3. The heterochromatin help in the formation of nucleolus.
4. Chromosomes control the differentiation of different characteristics of an organism.
5. Changes in the position, number and the structure of chromosome lead to the formation of new species.

Special types of Chromosomes :

In addition to the normal types of chromosomes, special types of chromosomes with different structure size, shape and functions have been found in varied group of animals and plants. These are very useful in cytogenetic studies. The most important are giant chromosomes and super numerary chromosomes.

Giant Chromosomes : These are exceptionally larger chromosomes. They are described as unusual chromosomes by A. M. WINCHBETER. There are two types of giant chromosomes, namely polytene chromosomes and lamp brush chromosomes.

Polytene Chromosomes : Polytene chromosomes have the following salient features :

1. It was discovered by BALBIANI 1881.
2. It is found in the salivary gland cell of chromosomes larva. Hence it is also called salivary gland chromosome.
3. It is larger in size. For example in drosophillia melagaster it is 1000 times larger than somatic chromosomes.
4. The larger size of the chromosome is due to the presence of many longitudinal strands called chromonemata. Hence they are also called polytene chromosomes (many stranded).
5. The many strands of the giant chromosome are due to repeated division of the chromosome without the cytoplasmic division. This type of division is called endomitosis.

6. The polytene chromosome contains two types of transverse bands namely dark bands and inter bands. The dark bands are darkly stained and the inter bands are lightly stained with nuclear stains. The dark bands contain more DNA and less RNA. The inter bands contain more RNA and less DNA.

7. The bands of polytene chromosomes become enlarged at certain times to form swelling called puffs or Balbiani rings. The formation of puffs is called puffing. In the regions of puffs the chromonemata uncoil and open out to form many loops. Thus puffing is caused by the uncoiling of individual chromomeres in a band. The puffs indicated the site of active genes when rRNA synthesis takes place.

Lamp brush chromosomes :

1. It was discovered by RUCKERT in 1892.

2. It contains lateral loops and appears like a brush. Hence the name lamp brush chromosome.

3. It is found in the oocytes of Sagitta, Sepla, Echinaster insects, Sarks, amphibians, reptiles and birds.

4. It is a larger in size. Hence it is called a giant chromosomes.

5. Each lamp brush chromosome consists of a main axis and many lateral loops.

6. The main axis of each chromosome is formed of 4 chromatids.

7. The main axis contains a series of thickenings called chromomeres.

8. From each chromomere a pair of lateral loop arise one on each side.

9. Each loop has a axial fibre. The axial fibre is the continuation of the chromonemata of the main axis. Hence it contains DNA.

10. The axial fibre of loop is surrounded by a matrix. The matrix is formed of RNA and proteins. The matrix gives a fuzzy appearance.