TOPIC: CHROMOSOMES

LECTURE NO:11
B.SC PART-II(SUB.)-GROUP A
DATE: 8TH APRIL 2020
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Objectives:-

Reading of the unit will let the readers to:

Define chromosomes

Describe various types of chromosomes Mention the functions of chromosomes Explain Giant chromosomes

Describe with structure polytene and lampbrush chromosomes

Introduction:-

The word chromosome has been derived from two Greek words **"Chroma"** meaning colour and **"Soma"** meaning body. They are the unique cell organelles made up of chromatin material which is the most important and permanent constituent of the cell nucleus. They are capable of self-reproduction. They control cell's structure and metabolism, and play an important role in the differentiation, heredity, mutation and evolution.

Chromosomes:-

General History of Chromosomes

W. Hofmeister in 1848, discovered nuclear filaments in the nuclei of pollen mother cells of ***Tradescantia***. First accurate count of chromosomes was made by W. Flemming in 1882, in the nucleus of a cell. In 1884**, W. Flemming, Evan Beneden and E. Strasburger** demonstrated that the chromosomes double in number by longitudinal division during mitosis. Beneden in 1887 found that the number of chromosomes for each species was constant. The term **"Chromosomes"** was coined in 1888 by **W. Waldeyer** for the nuclear filaments. **W.S. Sutton and T. Boveri** suggested the role of chromosomes in heredity in 1902, which was confirmed by **Morgan** in 1933.

The structure of chromosomes varies in viruses, prokaryotes and eukaryotes.

Viral chromosome- In viruses there is a single chromosome bearing a single nucleic acid molecule **(DNA or RNA)** surrounded by a protein coat called **Capsid**. It may be linear or circular. The viruses having DNA as genetic material are called **DNA viruses** and those having RNA as genetic material are known as **RNA viruses**. A limited amount of genetic information is present in the viral chromosome which codes for little more than the production of more virus particles of the same kind in the host cell. In RNA viruses, often the RNA directs the synthesis of DNA complementary to itself by reverse transcription in the host. The RNA is then transcribed by the DNA for the formation of new virus particles. Such ribovirus is called **retrovirus**. The AIDS causing virus is a retrovirus.

Prokaryotic chromosomes- Prokaryotic chromosome (e.g., bacteria) has a **single and circular two-stranded DNA molecule** which is not enveloped by any membrane. It lacks proteins and is in direct contact with the cytoplasm. The bacterial chromosome is packed into the nucleoid by some RNA that appears to form a core. It is attached to plasma membrane permanently at least at one point. In addition to the main chromosome some **extra-chromosomal DNA** molecules may also be present in most of the bacterial cells they are also double stranded and circular, but are much smaller in size. They are known as **plasmids**. The plasmid may occur independently in the cytoplasm of calls or may also be found in association of main chromosomal DNA and called as **episome.**

Eukaryotic chromosomes- The eukaryotic chromosomes are present in **nucleus** and in certain other organelles, like

mitochondria and plastids. These chromosomes are called nuclear and extra nuclear chromosomes respectively.

Nuclear chromosomes are **double stranded long DNA** molecules of linear form. Proteins are associated with them. They are surrounded by nuclear envelope. More DNA is involved in coding far more proteins than the prokaryotic chromosomes.

Extra nuclear chromosomes are present in mitochondria and plastids. They are double stranded short DNA molecules of circular form. They lack protein association. Less genetic information is available for the synthesis of only some particles of proteins for the organelles containing them. Other proteins are received from the cytoplasm where they are synthesized under the direction of nuclear chromosomes.

Morphology of Chromosomes

During the interphase stage, the eukaryotic chromosomes are extended into long and thin chromatin fibers where they lie criss-cross to form the **chromatin reticulum**. They replicate in the S-phase and become double. At this stage they consist of two chromatids that are held together at one point called **centromere**. At the time of cell division, the chromosomes condense and tightly coil up and become distinct at metaphase stage. The eukaryotic chromosomes vary in number, size, shape and position but they have remarkably uniform structure.

Number- Eukaryotic chromosomes vary in number from two to a few hundred in different species. In a species all the individuals have same number of chromosomes in all of their cells, except the gametes. Since **the chromosome number is constant for a species,** it is helpful in determining the phylogeny and taxonomic position of the species.

Size- In a **species all the chromosomes are not of the same size.** Their size also varies from species to species. The particular chromosome of a species however has more or less a constant size. The organisms having fewer chromosomes have large sized chromosomes than those having many.

Generally, **plant chromosomes are larger than animal chromosomes** and among plants the **monocots have larger chromosomes than the dicots.**

Shape- The chromosomes at metaphase stage look like slender rods that may be straight or curved to form an arc or a letter S. In anaphase stage they may assume J or V shapes, depending upon the position of the centromere.

Position- In a nucleus each chromosome is independent of all the other chromosomes in its location. Thus, they may occupy any region of the nucleus.

Structure- At **metaphase stage**, since the chromosome is **a highly condensed nucleoprotein filament, it contains two greatly coiled sister chromatids.** These chromatids that lie side by side along their length, are held together at a point called centromere, an area of the narrow region also called **primary constriction** of the metaphase chromosome. At the centromere each chromatid has a darkly staining, disc like, fibrous structure, called **kinetochore**, to which spindle microtubules attach during cell division. Kinetochores are the sites where force is exerted to pull the chromatids towards the poles. One or more chromosomes may have additional narrow regions called the **secondary constrictions**. The part of the chromosome separated by secondary constrictions is termed as **satellite**. A chromosome with a satellite is called **sat chromosome**. The size and the shape of the satellite remain constant for a species. Secondary constrictions are associated with the nucleoli, and are known as the **nucleolar organizers**. The chromosomes which have nucleolar organizing regions are known as the **nucleolar chromosomes** (Fig. 7.1).

Ends- The ends of chromosomes are called **telomeres**. The function of telomere varies from the rest of the chromosome. On exposure to X-rays a chromosome may break and its pieces may rejoin, but no segment connects to the telomere, showing that the telomere has a polarity, and it, somehow "seals" the end (Fig. 7.1).

Ultra structure- A chromatid contains a very fine filament called chromonema which is a single, long, double stranded DNA molecule. It is wrapped around histones to form **nucleosomes**. The nucleosome and non-histone proteins together form the chromatin fiber. The chromatin fiber has reactive groups, probably H1 histone molecules, which act as "folders" and crosslink the chromatin fiber changing it into a great coiled, compact metaphase chromatid.

Chemical composition- The chromatin in the eukaryotic chromosome consists chemically of DNA, about 60% proteins, about 5% RNA, some metal ions about 35% and certain enzymes.

Types of chromosomes- On the basis of the position and number of centromeres, the chromosomes are classified as below (Fig. 7.2):

Metacentric- In metacentric chromosomes the centromere is at the middle of the chromosome, and the arms are equal. In anaphase the chromosome appears V-shaped. For example: human chromosome no. 3.

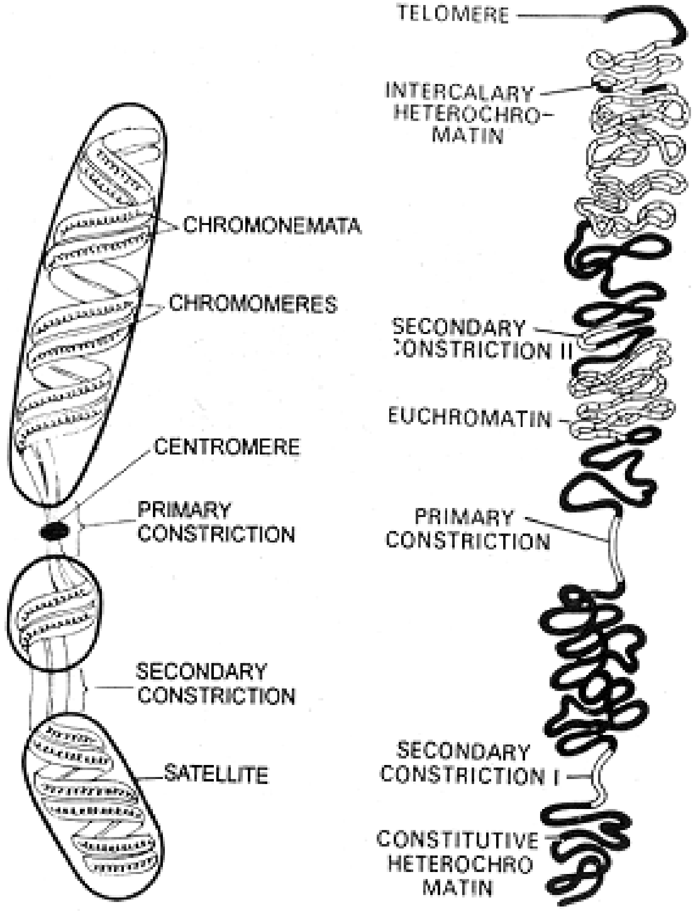

Fig. : Detailed schematic structure of chromosomes

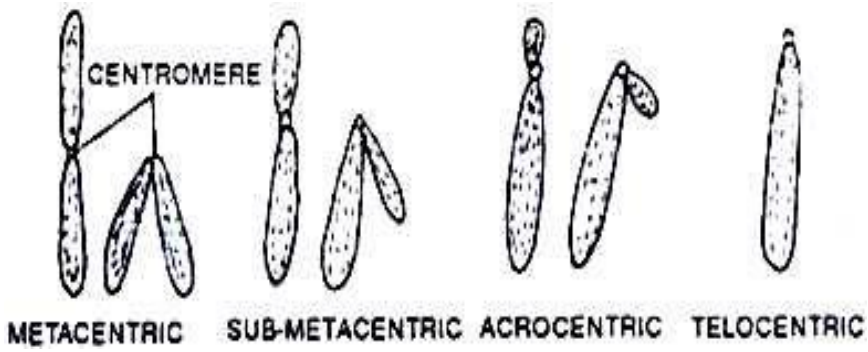

Fig. : Ty pes of chromosomes based on centromere position

Submetacentric-. In such chromosome, the centromere is near the centre of the chromoso me, and the arms are slightly unequal and in anaphase the chromosome appears J or L shaped. For example: Human chromosome No. 1.

Acrocentric- In this type the centromere is near one end o f the chromosome, and the arms a re very unequal. For example: Human chromosome No. 4 & 5.

Telocentric- The centromere is at one end in such chromosomes, and the arms are on one side only. The chromosome remains rod shaped in anaphase also.

Depending upon the number of centromeres there are three types of chromosomes:

Acentric- The chromosome is without a centromere, which is formed by breakage of the chromosome. It does not attach to spindle microtubules so it is lost in the cell division.

Monocentric- It is the chromosome with a single centromere and it is the most common type.

Dicentric- It is the chromosome with two centromeres and is formed by the fusion of two chromosome segments each having a centromere. It is unstable and may break when the two centromeres are pulled to opposite poles in mitosis.

Functions of Chromosomes:-

Chromosomes carry hereditary characters from parents to offspring.

They direct the synthesis of structural proteins and thus, help the cell grow, divide and maintain itself.

By directing the formation of necessary enzymes, they control metabolism.

They guide cell differentiation during development.

They form nucleoli at nucleolar organizer sites in daughter cells.

They produce variations through changes in their genes and contribute to the evolution of the organisms.

They play role in sex determination.

They maintain the continuity of life by replication.

Giant Chromosomes:-

Giant chromosomes are special, enormously enlarged chromosomes about 100 times thicker than the ordinary mitotic chromosomes. These are seen in certain tissues of varied groups of animals and plants. They are easily visible under light microscope. The giant chromosomes are of two types: polytene and lampbrush.

Polytene Chromosomes:-

Polytene chromosomes were first observed by **Balbiani (**1881) in **Chironomus** (a dipteran larva). Because of their large size showing numerous strands these are named as polytene chromosomes by **Kollar**. These banded chromosomes occur in the larval salivary glands, midgut epithelium, and rectum and Malpighian tubules of various genera of dipterans. These are also known as **salivary gland chromosomes** because they have been best studied in the salivary gland cells of fly larvae

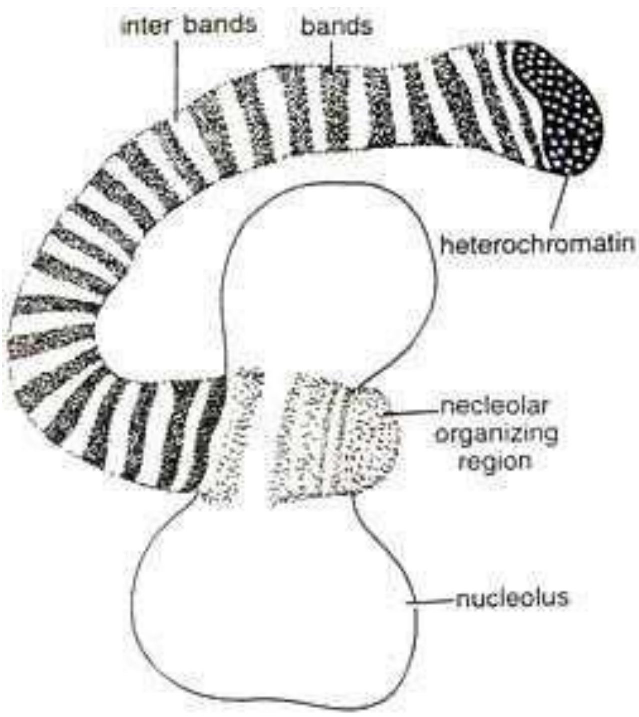

Fig. : Structure of polytene chromosome showing nucleolar part

These chromosomes are about 100-200 times larger than those of somatic chromosomes. They are roughly cylindrical and exhibit a distinct pattern of transverse striated structures consisting of alternate **darkly staining band** and **light staining interbands**. Dark bands are rich in DNA along with a small amount of RNA and basic proteins. They are genetically active. The inter-bands contain less of DNA but more acidic proteins and hence they are less active. The polytene chromosomes are formed by repeated replication of DNA without division of chromosome into daughter chromosomes. This amplification without separation is called **polytenization**. As a result, a thick bundle of parallel DNA molecules all having the same banding pattern across them is produced. Thus, there can be as many as several thousands of chromonemata in a giant chromosome.

During the initial stages of development the bands or inter-bands of chromosomes exhibit swellings or puffs. During development the **puffs** appear and disappear in definite patterns in response to the needs of developing larvae for the RNAs. The puffs are genetic sites active in RNA synthesis. In some regions of polytene chromosomes the chromonemata may give out a number of loops at certain places. Such loops are known as the **Balbiani rings**. These rings are formed by the lateral stretching of loops. They are rich in mRNA like the chromosomal puffs (Fig. 7.4).

Functions of the Giant Polytene Chromosomes

Polytene chromosomes carry genes which ultimately control physiology of an organism. These genes are formed of DNA molecules.

These chromosomes also help in protein synthesis indirectly. The RNA present in the nucleolus serves as a means of transmission of genetic information to the cytoplasm, leading to the formation of specific protein.

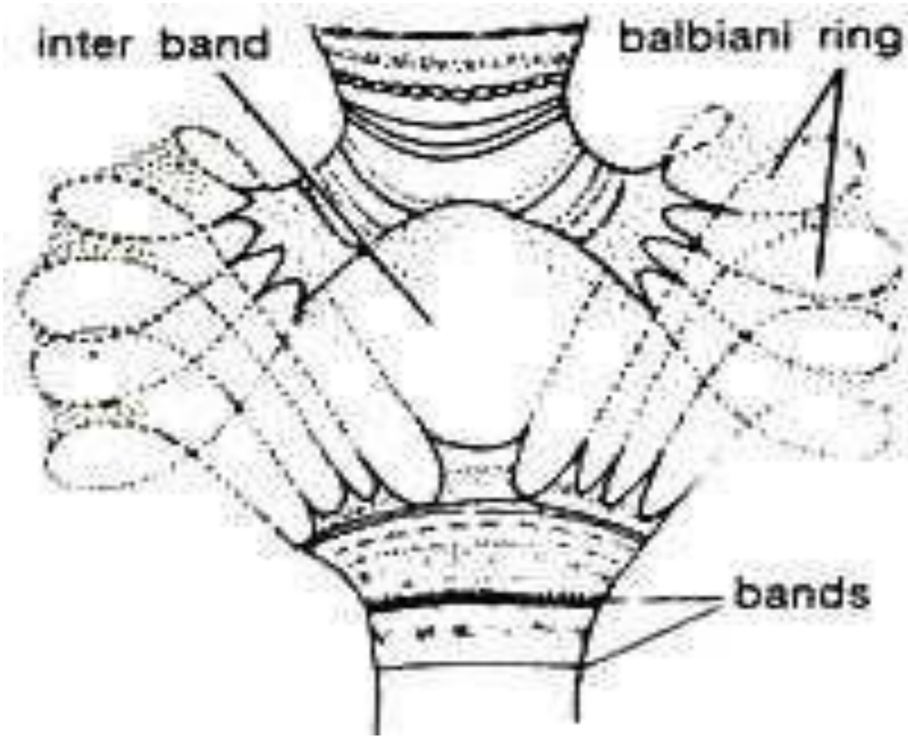

Fig. 7.4: Structure of Balbiani ring of polytene chromosome

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