TOPIC: CHROMOSOMES,CELL CYCLE,CELL DIVISION

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Lampbrush Chromosomes

These are the largest chromosomes which can be seen with naked eyes and are found in yolk rich **oocytic nuclei** of certain vertebrates such as fishes, amphibians, reptiles and birds. They are characterized by the fine lateral loops, arising from the chromomeres, during first prophase of meiosis. Because of these loops they appear like brush; that is why they are called **lampbrush chromosomes** first discovered by **Flemming** in 1882 and were described in shark oocytes by **Ruckert** (1892).

Lampbrush chromosome consists of longitudinal axis formed by a single DNA molecule along which hundreds of bead like chromomeres are distributed. Two symmetrical lateral loops (one for each chromatid) emerge from each chromomere, which are able to expand or contract in response to various environmental conditions. About 5 to 10% of the DNA is in the lateral loops. The axis having compacted DNA and tightly associated proteins is transcriptionally inactive. The loops consist of uncompacted DNA and proteins but have a good amount of RNA and they are transcriptionally active. A chromomere and its associated loop correspond with one gene.

In lampbrush chromosomes the DNA loops are the sites of intensive RNA synthesis. rRNA and mRNA are synthesized in

large amount and the transcription of rRNA causes the enlargement of nucleolus, or formation of numerous additional nucleoli. Due to the synthesis of large amounts of proteins, fats, carbohydrates and other molecules in the cytoplasm needed for further development of the embryo, the oocyte grows in size. Synthesis of proteins occurs near the loops.

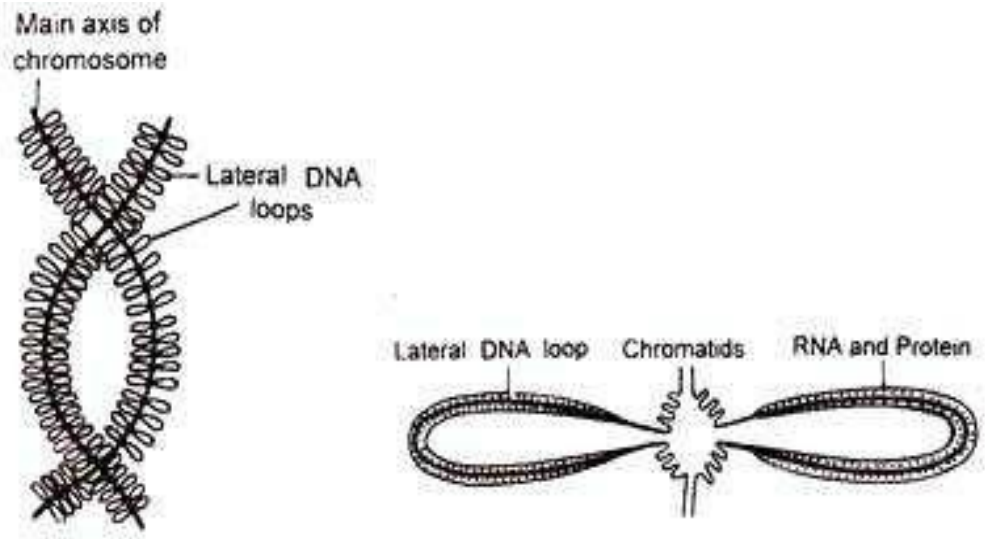

Fig. : Detailed structure of lampbrush chromosome

Functions of Lampbrush Chromosome:-

These chromosomes are involved in the synthesis of RNA and proteins by their loops.

Lampbrush chromosomes probably help in the formation of certain amount of yolk material for the egg.

Summary:-

Chromosomes are made up of chromatin material and are capable of self-reproduction. They control cell's structure and metabolism and play an important role in the differentiation, heredity, mutation and evolution. Their structure varies in

viruses, prokaryotes and eukaryotes. In viruses there is a single chromosome bearing a single nucleic acid molecule i.e. DNA or RNA, surrounded by a protein coat, which may be linear or circular, while prokaryotic chromosomes have a single and circular two stranded DNA molecule which is not enveloped by any membrane. The eukaryotic chromosomes are present in nucleus and are called nuclear chromosomes which are double stranded long DNA molecules of linear forms. When they are present in certain other organelles like mitochondria and plastids, then they are called extra nuclear chromosomes, which are double stranded short DNA molecules of circular forms. The eukaryotic chromosomes vary in number, size, shape and position, but they have remarkably uniform structures. The ends of chromosomes are known as “telomeres”. A chromatin contain very fine chromonema which is single, long, double stranded DNA molecule wrapped around histones to form nucleosomes. Chemically a chromosome consists of DNA, proteins, RNA, some metal ions and some enzymes. Chromosomes on the basis of position and number of centromeres can be classified as metacentric, Submetacentric, Acrocentric, Telocentric and Acentric, Monocentric and Dicentric respectively. Giant chromosomes are special enormously enlarged chromosomes about 100 times thicker than the ordinary mitotic chromosomes. They are of two types- Polytene chromosomes (Balbiani, 1881). These occur in the larval salivary glands,
midgut, epithelium, rectum and malphigian tubules of various genera of dipterans. They carry genes which control physiology of an organism and they also help in protein synthesis indirectly. Second type is Lampbrush chromosomes (Flemming, 1882) found in yolk rich Oocytic nuclei of certain vertebrates. They bear fine lateral loops arising from the chromosomes during first prophase of meiosis.

Glossary:-

Chromatin fiber: A complex of macromolecules found in cells consisting of DNA, RNA and proteins.

Nucleic acid: The biopolymers, which include DNA (deoxyribonucleic acid) and RNA (ribonucleic acid), made from nucleotides are known as nucleic acids.

Ribovirus: Any of a group of viruses whose nucleic acid core is composed of RNA, including the retroviruses and picornaviruses is known as ribovirus.

Nucleoid: The nucleoid is an irregularly shaped region within the cell of a prokaryote that contains all or most of the genetic material and it is not surrounded by a nuclear membrane.

Extra nuclear Chromosomes: Extra chromosomal DNA is any DNA that is found outside of the nucleus of a cell like in mitochondria and plastids.

Centrosome: The centrosome is an organelle that is the main place where cell microtubules get organized.

Kinetochore: A kinetochore is a protein structure that forms on a chromatid during cell division and allows it to attach to a spindle fiber on a chromosome.

Sat-chromosome: A satellite chromosome or SAT chromosome has a chromosome segment that is separated from the main body of the chromosome by a secondary constriction.

Nuclear organizer: A nucleolar organizer is a chromosomal region around which the nucleolus forms.

Telomere: At each end of a chromosome there is a region of repetitive nucleotide sequences which protects the end of the

chromosome from deterioration or from fusion with neighboring chromosomes. This region is known as telomere.

Malpighian tubule: The Malpighian tubule system is a type of excretory and osmoregulatory system found in some insects, myriapods, arachnids, and tardigrades. It consists of branching tubules extending from the alimentary canal that absorbs solutes, water, and wastes from the surrounding haemolymph.

Chromomere: A chromomere is one of the serially aligned beads or granules of a eukaryotic chromosome, resulting from local coiling of a continuous DNA thread.

CELL DIVISION

Objectives

After reading this unit the readers will be able to:

- Define mitosis and meiosis. Elucidate stages of cell cycle. Explain cytokinesis.
- Describe reproductive cycle stages and synaptonemal complex. Discuss recombination nodules.
- Compare between mitosis and meiosis.

Introduction:-

A multicellular organism starts its life as a single cell and it undergoes repeated division, thus, the growth and development of every living organism depends on the growth and multiplication of its cells. The cell increase in size due to growth and it is the characteristic feature of all the living organisms. After the cell attains maximum growth, it begins to divide. The vegetative growth of an organism takes place by an increase in the number of cells through cell divisions which follows the geometrical progression. The cell division is a continuous and dynamic process and it involves the following three stages:

DNA or genome replication

Nuclear division or karyokinesis

Cytoplasmic division or cytokinesis

The cell division is of two types on the basis of number of genomes present in the daughter cells in comparison to the dividing parent cell — **mitosis** and **meiosis**.

Mitosis- The term mitosis was coined by **W. Flemming** in 1882. The multiplication of a body cell into two daughter cells of

equal size and containing the same number of chromosomes as in the parent cell is called mitosis or **somatic division**.

***Meiosis*-** The term meiosis was first coined by **J. B. Farmer (1905) with J. E. Moore.** Meiosis occurs only in gonads (in germ mother cells) during the formation of gametes like sperm and ovum. Meiosis is a process by means of which double number or 2N or diploid chromosomes is reduced to its half number or N or haploid. It is also called **reduction process.**

Cell Cycle Stages, Mitosis & Cytokinesis

Cell Cycle

Every cell having the capacity to divide passes through a regular cycle of changes known as cell cycle. A cell starts its cycle in diploid condition.

Phases of cell cycle:-

Cell cycle consists of two stages: A long un-dividing stage called **interphase or I-phase** and a short dividing stage called **mitotic or M-phase.**

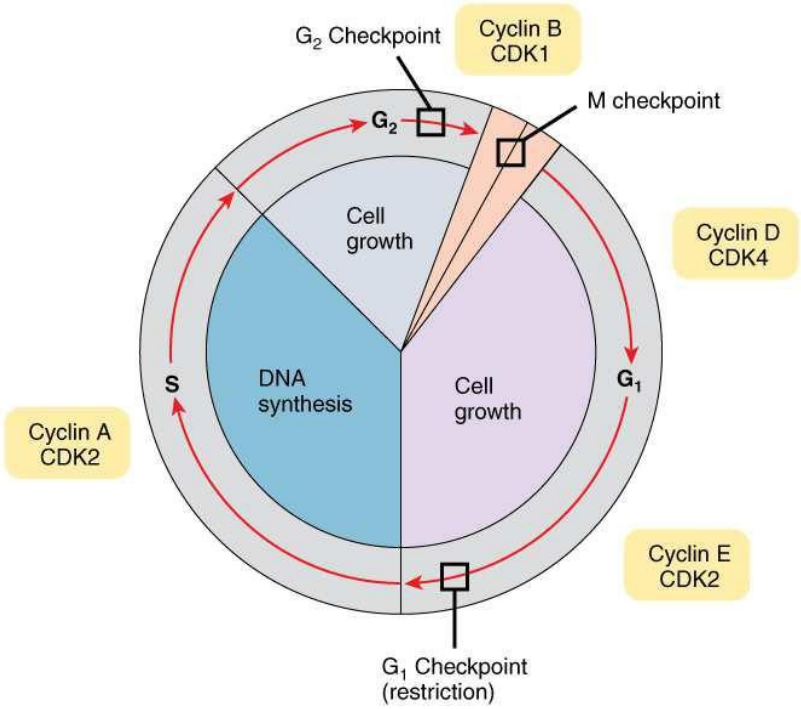

Fig. : Cell Cycle checkpoints

Interphase- The time between the end of telophase and the beginning of the next M-phase is called the interphase. It is a long stage that lasts for 10 to 30 hours. During this phase the cell grows by synthesizing biological molecules such as lipids, proteins, carbohydrates, nucleic acids.

Interphase is further divided into three sub phases or periods: first gap or G1 phase, synthetic or S phase and second gap or G2 phase.

G_1 phase- The **gap between previous mitosis and beginning of DNA synthesis** is represented by G_1 phase. In this stage initial growth of a newly formed cell takes place. Various biological molecules (carbohydrates, proteins, lipids, including some non-histones, RNAs) are synthesized in this phase. Normal metabolism is carried out for the preparation for DNA replication that is to take place next to it. DNA synthesis does not occur in this phase.

S Phase- During this **phase duplication of each chromosome** take place by replication of new DNA molecule on the template of the existing DNA. Synthesis of histone proteins and their mRNA, some non-histone proteins and formation of new nucleosome also occur in S-phase only. In most of the eukaryotes the S-phase lasts for 6 to 8 hours.

G_2 Phase- G_2 phase is the gap between DNA synthesis and nuclear division. RNA transcription and protein synthesis continues during this phase. Further growth of the cell and preparation for its division also takes place in this stage. During this stage the cytoplasmic organelles such as centrioles, mitochondria

and Golgi apparatus are doubled, proteins for spindle and asters are synthesized and active metabolism stores energy for the next mitosis. The G_2 phase in most cells lasts for 2 to 5 hours.

Mitotic Phase- Interphase is followed by mitotic phase. During mitotic phase the already **duplicated chromosomes are equally distributed to the daughter cells** which contain exactly the same hereditary information as the parent cell. Though, the other cell components (organelles and molecules) are also divided approximately

equally between the daughter cells, but not as precisely as the DNA. After the mitosis is over, the daughter cells enter the G_1 phase of the next cell cycle.

During mitosis many structural and physiological changes take place in the cell, as the chromatin of the nucleus is packed into visible chromosomes, which are set free by breakdown of nuclear envelope. An extensive reorganization of the membranous components and cytoskeletal elements takes place. Endoplasmic reticulum and Golgi apparatus

break down into small vesicles and stops the protein movement. Microtubules dissociate into tubulin dimers and are assembled into the spindle which occupies most of the cell and helps in the distribution of chromosomes into the daughter cells. Actin filaments get reorganized and form a contractile ring for the cytoplasmic division.

Control of Cell Cycle:-

Nucleo-cytoplasmic Ratio- In 1910, **Hertwig** proposed that the **cell division starts**

when the ratio between the volume of the nucleus and the volume of the cytoplasm is upset. As the cell grows, the synthesis of proteins, nucleic acids, lipids and other cellular components takes place. During synthesis of these molecules, the back and forth movements of materials through the nuclear and the cell membranes occurs. With the growth of the cell, its volume increases more than the surface of the nucleus and the cell, and at a critical point, the surface of the nucleus become inadequate for the exchange of materials between the nucleus and the cytoplasm required for further growth. The cell divides at this stage and regains the optimum and

efficient nucleo-cytoplasmic ratio that allows the growth. Although the cell division usually occurs after a cell has grown to a certain size, there are important exceptions to this pattern.

Surface-Volume Ratio- With the growth of the cell size, its volume increases more than its surface area. All the materials of the cell required for its maintenance and growth are drawn through its surface. A stage will reach when the surface area is insufficient to supply the large volume of the cell. It is thought that there is a critical point at

which the cell division starts and the division of the cell greatly increases the surface without increasing the volume. This theory fails in case of starved cells, which may divide without doubling their size and form smaller daughter cells.

Nucleolus- Damage to nucleolus at a certain critical time (telophase or mid prophase) stops cell division.

Cyclic Nucleotides- Concentration of cAMP and cGMP vary regularly during the cell division. Concentration of cAMP is high during G_1 phase, but it falls as the cell enters the S phase and mitosis. However the concentration of cGMP often varies in the reverse pattern. Thus, addition or removal of any of these nucleotides can start or stop entry of many cells into S phase and the subsequent M phase. The concentration of these cyclic nucleotides remains constant throughout the cell cycle in many cells.

Also, plant cells do not have cyclic nucleotides. On the basis of these facts, cyclic AMP and GMP are no longer thought to regulate the cell cycle.

Phosphorylation- During cell cycle the phosphate groups are added to the histone groups particularly to H_1 as the cell enters S phase, increases during M phase, and are removed on the completion of mitosis before G_1 starts. Phosphate groups are also added and removed to non-histone proteins during cell cycle. Thus, it is believed that the changes in the histones and non-histones may have a role in the control of cell cycle because these proteins have been found to regulate the activity of genes in RNA transcription during interphase.

Cyclin*:* The concentration of the protein called cyclin appears to control mitosis as it builds up during interphase and is degraded during mitosis.

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