TOPIC: MICROTUBULES AND INTRODUCTION TO NUCLEUS

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B.SC PART-II(SUB.)-GROUP A
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Microtubules

General History of Microtubule:-

The cytologists like **Freud** (1882), **Ballowitz** (1890) and **Meves** (1910) observed filamentous components of the cytoplasm and referred these as fibrils. Later, with the improved microscopic techniques along with advancement made in the field of sectioning and staining, the ultra structure of these components was revealed. These were found to be tubular in nature (Burgos and Fawcett, 1955; Palay, 1960; Harris, 1962). **De Robertis** and **Franchi** (1953) reported the presence of microtubules in the axons of medullated nerve fibers and called them neurotubules. Slautterback in 1963 describes them to be associated with the developing nematocysts of Hydra and he proposed the name microtubules to these components.

Structure of Microtubule:-

The microtubules are hollow, unbranched cylinders, generally about 200 to 270 Å thick and several micrometers long. They may occur singly or in bundles, and radiate from the centriole to the periphery of the cell. The microtubule is composed of 13 parallel proto-filaments that run its entire length and enclose a central lumen about 150 Å wide (Fig. 5). Each proto-filament is made up of a row of globular subunits that have a diameter of about 40 to 50 Å. There may be cross bridges between adjacent microtubules.

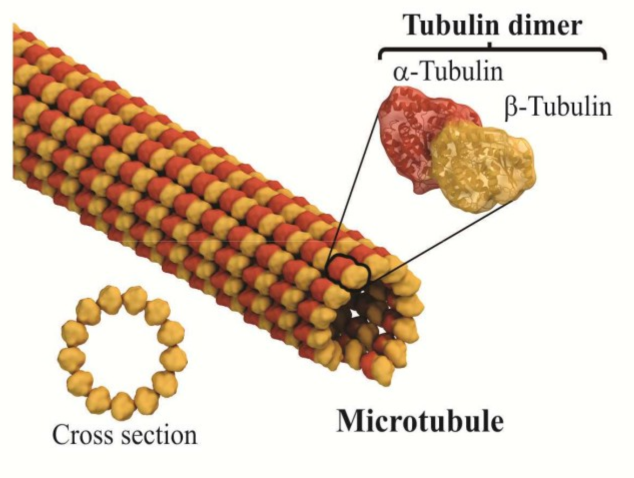

Fig. : A microtubule in surface view and in cross section

Chemical Composition:-

The microtubules are formed of a protein called **tubulin**. A tubulin subunit contains one α-tubulin molecule and one β-tubulin molecule. This αβ dimer is 80-100 Å long. The α-and β-tubulin molecules are arranged alternately in a helical manner. Many other proteins, called MAPs (microtubule associated proteins), form some 5 to 10 percent of the proteins of microtubules. These proteins promote tubulin polymerization. A tubulin dimer has two GTP molecules bounded to it. One GTP is hydrolyzed to GDP when a tubulin dimer is incorporated into a microtubule. The α-β-α-β arrangement of the tubulin subunits gives polarity to the microtubule.

Functions of Microtubules:-

Form and support- The microtubules form a part of cytoskeleton which (a) maintains the shape of the cell and (b) provides mechanical support to the cell. This role of microtubules is especially evident in cells having long processes such as the axopodia of certain protozoans and axons of nerve cells. Red blood corpuscles of non-mammalian vertebrates are kept flat by peripheral band microtubules.

Movement- The microtubules form the motile elements of cilia and flagella. These bring about locomotion in protists and cause currents in the environment of animals.

Components of centriole and basal bodies- The microtubules are components of centriole and basal bodies. The centriole give rise to the mitotic spindle and the basal bodies produce cilia and flagella.

Formation of mitotic spindle- The microtubules forms the spindle and astral rays in cell division.

Chromosome movement- The chromosome fibers of spindle bring about movement of the chromosomes to the opposite poles of the cell in the anaphase.

Cell differentiation- The microtubules play a role in cell differentiation and determination of polarity.

Intracellular transport- Vesicles and protein molecules in the cell move along the "tracks" of microtubules. The movement is brought about by motor proteins kinesin and MAPIC (cytoplasmic dynin) powered by ATP.

Importance of Microtubules:-

Microtubules are very important for the cells as they provide internal framework serving as cytoskeleton to determine and maintain the cell form. They also define pathway along which the particles move in cell. The mitotic apparatus consisting of spindle fibers and astral rays is in fact bundles of microtubules. The generation of bending movements in cilia and flagella is attributed to a sliding microtubule mechanism.

Summary:-

Lysosomes which are also known as suicidal bags are the secretary pathway in the cells. They are rounded tiny bags consisting of two parts, one part made of single limiting membrane composed of lipoproteins and the other part is inner dense mass. Various types of lysosomes are present in a cell which is characterized according to their functions. Primary lysosomes act as storage granules, secondary lysosomes functions

as digestive vacuoles or heterophagosome. Third type of vacuole is residual bodies which is formed in case of digestion is incomplete and the fourth type is autophagic vacuole which digest a part of cell itself like a portion of ER or mitochondria. Thus lysosomes store the hydrolysisng enzymes of the cell and they digest the incoming food materials and remove the foreign bodies and the cell organelles which are no longer required by the cell. Malfunctioning of lysosomes may lead to certain diseases. The centrioles occur in pairs as hollow cylinder and lie at right angles to each other. It is composed of nine sets of microtubule triplets and in the centre the microtubule is absent giving rise to the pattern as "9+0". Microtubules are hollow unbranched cylinders having length of several micrometers which may occur single or in bundles. These are composed of a protein tubulin and some lipids having high concentration of ATPase enzymes. They perform various functions like they help in organizing spindle fibers and astral rays during mitosis and meiosis. They also provide basal bodies for the emergence of cilia and flagella. The wall of microtubule is composed of 13 parallel protofilaments which is made up of a row of globular subunits. Microtubules form a part of cytoskeleton which maintains the shape of the cell. They define pathway along which particles move. They play vital role in cell differentiation and determination of polarity.

Glossary:-

Lysosome: an organelle in the cytoplasm of eukaryotic cells containing degrading or hydrolysing enzymes enclosed in a membrane.

Matrix: matrix is the material in animal or plant cells, in which more specialized structures are embedded. A specific part of the mitochondrion that is the site of oxidation of organic molecules is also called matrix.

Plasmalemma: Plasmalemma is the cell membrane that surrounds the cytoplasm of living cells, physically separating the intracellular components from the extracellular environment.

Centriole: It is a cylindrical cell structure composed mainly of a protein called tubulin.

Phagocytosis: Phagocytosis is the process by which a cell engulfs a solid particle to form an internal vesicle known as a phagosome.

Pinocytosis: The ingestion of liquid into a cell by the budding of small vesicles from the cell membrane.

Autophagosome: Autophagy allows the orderly degradation and recycling of cellular components. During this process, targeted cytoplasmic constituents are isolated from the rest of the cell within a double-membrane vesicle known as an autophagosome.

Leucocytes: White blood cells are also called leucocytes. These are the cells of the immune system that are involved in protecting the body against both infectious diseases and foreign invaders.

Macrophages: Macrophages are the type of white blood cells that engulf and digest cellular debris, foreign substances, microbes, cancer cells, and anything else that does not have the types of proteins specific of healthy body cells on its surface.

Metamorphosis: Metamorphosis is a biological process by which an animal physically develops after birth or hatching, involving a conspicuous and relatively abrupt change in the animal's body structure through cell growth and differentiation.

Kinetosome: Kinetosome forms the base of the flagellum, consisting of a circular arrangement of microtubules.

Dimer: A dimer is a chemical structure formed from two similar subunits.

Metabolic pathway: A sequence of chemical reactions undergone by a compound or class of compounds in a living organism.

Electron microscope: A microscope that uses a beam of accelerated electrons as a source of illumination is known as electron microscope. As the wavelength of an electron can be up to 100,000 times shorter than that of visible light photons, the electron microscope has a higher resolving power than a light microscope and can reveal the structure of smaller objects.

Pericentriolar satellite: Pericentriolar satellites are electron-dense granules that are concentrated around the centrosome. They are involved in the recruitment of centrosomal proteins and microtubule organization the interphase stage of the cells.

NUCLEUS

Objectives

After reading this unit the readers will be able to:

Define nucleus

Explain the structure of nucleus Mention the functions of nucleus Describe the importance of nucleus

Introduction:-

Nucleus is usually the most conspicuous organelle of eukaryotic cell. However, well defined nucleus is absent in prokaryotic cells. Nucleus is the repository of genome and the source of informational macromolecules that govern the synthetic activities of the cytoplasm. It is surrounded by a bilaminary nuclear envelop having pore complexes that permit the nuclear-cytoplasm transport of materials. In the animal cells, it generally lies in the centre, surrounded on all sides by the cytoplasm. However, in plant cells it is often pushed to one side of the cell due to the presence of large central sap vacuole.

The shape of nucleus is variable according to cell type. It is generally spheroid but ellipsoid or flattened nuclei may also occur in certain cells. In certain WBC (white blood cells) the nucleus is dumbbell shaped. In human neutrophil it is trilobed.

Most cells contain a single nucleus, known as **mono or uninucleate** cells. Cells with two nuclei are known as **binucleate cells e.g. Paramecium**. Sometimes more than two nuclei are present in a single cell. Such cells are called **polynucleate or multinucleated cells**. Such cells in animals are called **syncytial cells (e.g. osteoblast**) and such plants are termed **coenocytes (e.g. siphonal algae).** Cells having distinct nucleus are called eukaryotic cells, whereas cells without definite nucleus are called prokaryotic cells (e.g. bacteria). The latter possess scattered chromatin material (DNA) in the cytoplasm called nucleoid. The mature mammalian erythrocytes also do not possess any nucleus.

Size of nucleus is not constant and is generally correlated with DNA content. The nuclear size is variable depending upon the number of chromosomes (DNA content).

Nucleus:-

General History of Nucleus:-

Nucleus was observed by a Dutch Microscopist, **Antonie van Leeuwenhoek in 1710**, as a centrally placed clear area in the blood cells of amphibians and birds. **Fontana** (1781) recorded an ovoid structure in each of the isolated epidermal cells of eel's skin. However, **Robert Brown (1831)** was the first to use the term nucleus for a prominent body present in the orchid cell. He stated that nucleus was the regular feature of the cells and initiated the concept of nucleated cells.

Structure of Nucleus:-

The nucleus consists of various parts. It is bounded by a thin but clearly defined covering, the nuclear envelop or karyotheca. Within the envelope is a clear fluid substance called nucleoplasm or nuclear sap or karyolymph is present in which the solutes of the nucleus are dissolved. Suspended in the nucleoplasm are network of protein-containing fibrils called nuclear matrix; fine intermingled nucleoprotein filaments collectively referred to as the chromatin; and one or more spherical bodies known as nucleoli (singular, nucleolus). There are no membranes or microtubules inside the nucleus. Protozoans that form a mitotic spindle within the nuclear envelop, however, have microtubules in their nuclei (Fig. 1).

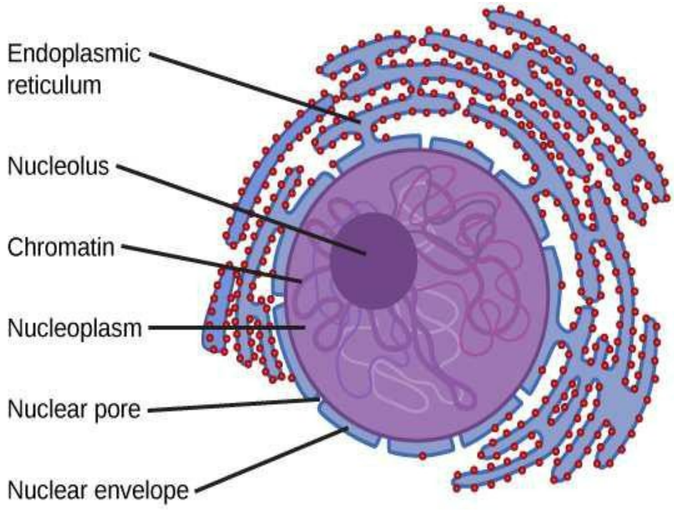

Fig. 6.1: Structure of nucleus

Chemical Composition: The nucleus is composed of about 9-12% DNA, 5% RNA, 3% lipids, 15% simple basic proteins such as histone or protamines, about 65% complex acid or neutral proteins, including enzymes such as polymerases for the synthesis of DNA and RNA, organic phosphates and inorganic salts or ions such as Mg^{++}, Ca^{++} and Fe^{++}.

Functions: The nucleus acts as a control center of the cell. It serves the following main functions:

- It maintains the cell by directing the synthesis of structural proteins.
- It regulates cell metabolism by directing the synthesis of enzymatic proteins.
- It contains genetic information for reproduction, development and behavior of the organism besides for structure and metabolism.
- It brings about cell replication when needed.
- It is the site for the formation of ribosome subunits.
- It brings about cell differentiation by keeping only certain genes operational.
- It develops genetic variations that result in evolution.

Nuclear Envelope:-

The nuclear envelop separates the nucleoplasm from the cytoplasm. It consists of two unit membranes: outer and inner. Each unit membrane is about 75Å thick, and is a trilaminar lipoprotein like the plasma membrane. The two unit membranes are separated by a space called the inter membrane or perinuclear space. It is about 250Å wide. The outer or cytoplasmic surface of the outer membrane is studded with ribosomes and polysomes and is rough. These ribosomes carry on protein synthesis. The outer membrane is continuous with RER at certain places. Thus, the perinuclear space is continuous with the channels of the RER. The inner membrane of the nuclear envelope is free of ribosomes, but has a dense layer, the nuclear lamina, closely associated with its inner or nucleoplasmic surface. The nuclear lamina is a 30 to 100 nm thick network of filaments composed of proteins named lamina A, B and C. The nuclear lamina supports the inner membrane and gives shape to it. It connects chromatin to the inner membrane, keeping most of the chromosomes in the periphery of the nucleus. It also plays a role in the breakdown and reformation of nuclear envelope during mitosis (Fig. 2).

Nuclear Pores: The nuclear envelope is generally perforated by minute apertures, the nuclear pores that control the passage of some molecules and particles. The pores are formed by fusion of the inner and outer membranes of the nuclear envelope. There may be 1000 to 10,000 pores per nucleus.

Each nuclear pore is fitted with an apparatus called the **pore complex** which fills considerable part of the pore. The pore complex is nearly cylindrical, projects into both cytoplasm and nucleoplasm, and projects beyond the rim of the pore over the nuclear envelope. The pore complex consists of two rings, the annuli, one located at the cytoplasmic rim of the pore and the other at the nucleoplasmic rim. Each annulus comprises eight symmetrically arranged subunits, and sends a spoke into the pore. The spoke encloses a channel about 100 to 200 Å wide. Ions and small molecules of the size of monosaccharide, disaccharides or amino acids pass freely between the nucleus and cytoplasm. The pore complexes do control the passage of larger molecules, such as RNA and proteins, and of ribosomal subunits. The pore complexes also act as a barrier to some molecules such as DNA of chromosomes.

Functions:

- It maintains the shape of the nucleus.
- It keeps the nuclear contents in place and distinct from cytoplasm.
- It regulates the flow of materials into and out of the nucleus by active transport and out pocketing.
- Its pores allow the exit of ribosomal subunits formed in the nucleolus and tRNA and mRNA synthesized on the chromosomes.

Nucleoplasm:-

Nucleoplasm is a transparent fluid material in the nucleus. The chromatin fibers and nucleoli are suspended in it. It contains raw materials (nucleotides), enzymes (polymerases) and metal ions (Mn^{++}, Mg^{++}) for the synthesis of DNA and RNA. It also contains proteins and lipids. The proteins include basic histones and acidic or neutral non-histones that associate with the DNA molecules. There are proteins for the formation of ribosomal subunits also. The RNAs (rRNAs, tRNAs, mRNAs) and ribosomal subunits synthesized in the nucleoplasm pass into the cytoplasm via nuclear pores (Fig. 2).

Functions:

It is the seat for the synthesis of DNA, RNAs, ribosomal subunits, ATP and NAD. It supports the nuclear matrix, chromatin material and nucleoli.

It provides turgidity to the nucleus.

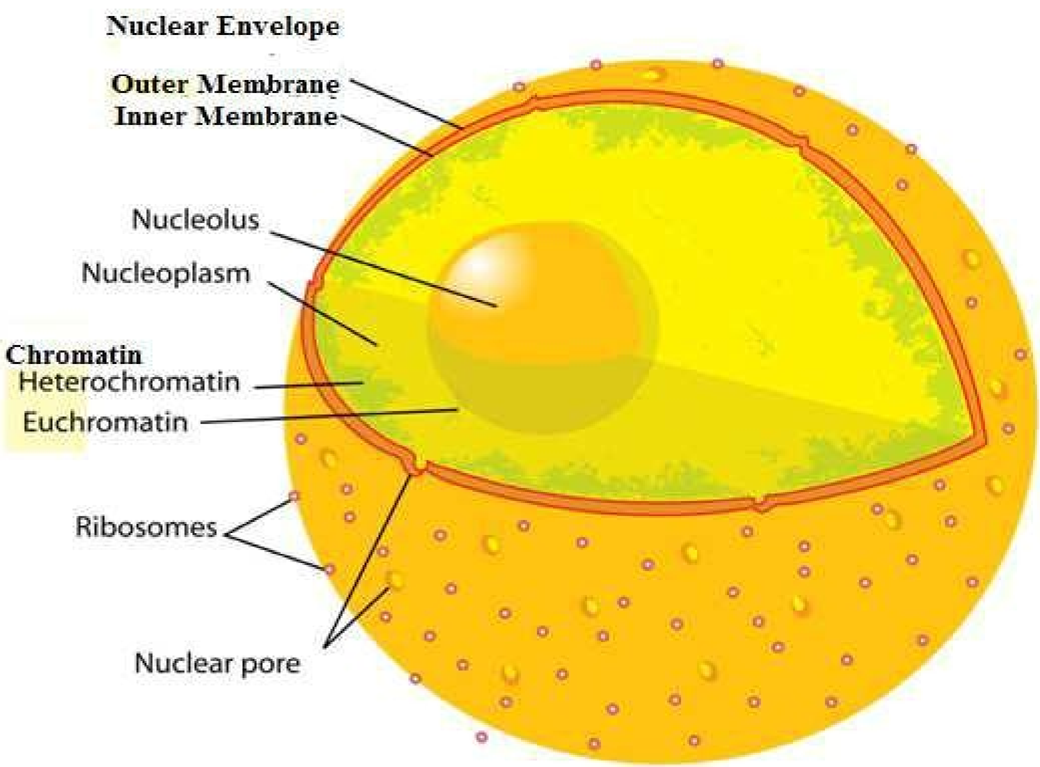

Fig. 6.2: Ultra structure of nucleus