Faculty Science

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B.Sc II Paper-II(Cytology, Genetics, Evolution& Ecology)

Unit-I Topic- The Nucleus

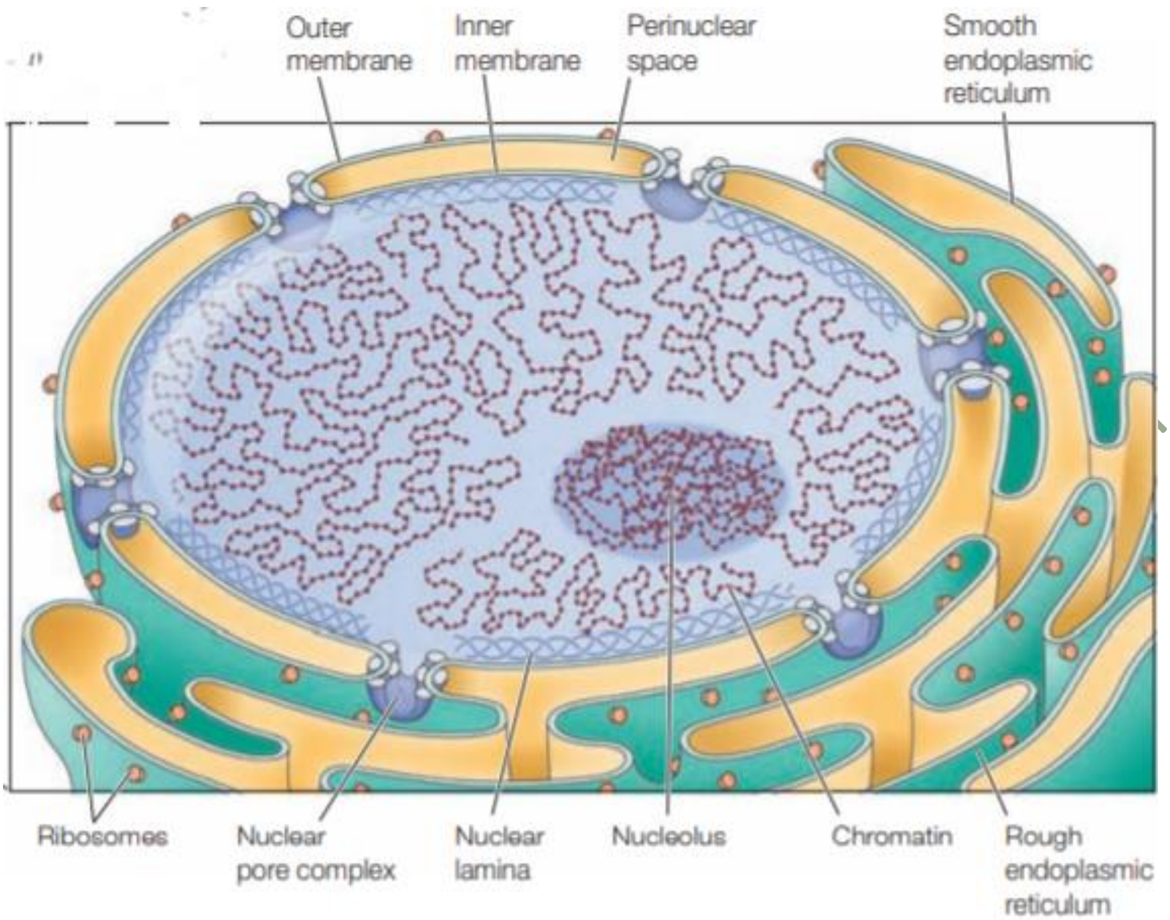
The nucleus was discovered by Robert Brown in 1831. It is the control centre of the cell. The nuclear information contributes toward growth, differentiation, and the other activities of the complex eukaryotic cell. The nucleus also stores hereditary information, which is passed from cell to cell as new cells are formed. Typical nucleus occupies about 10% of a eukaryotic cell's volume. The nucleus mainly contains all the genes, collectively called as nuclear genome.

Number, shape and size - Usually the cells contain single nucleus known as mononucleate cells. Most plant and animal cells are mononucleated. The cells which contain two nuclei are known as binucleate cells (e.g Paramecium). Certain fungi and algae have numerous nuclei within a single cell or coenocytic condition (as in Mucor fungi and in Vaucheria algae). The nucleus is not found in mature sieve tube cell of higher plants and in mature mammalian RBCs. Usually the nucleus is found in the centre of the cell but it may be present to one side of the cell. The shape of the nucleus may be spherical to ellipsoidal or sometime may be irregular. They can vary greatly in size. They are generally from 2 to 15micron meters or larger in diameter.

Ultrastructure

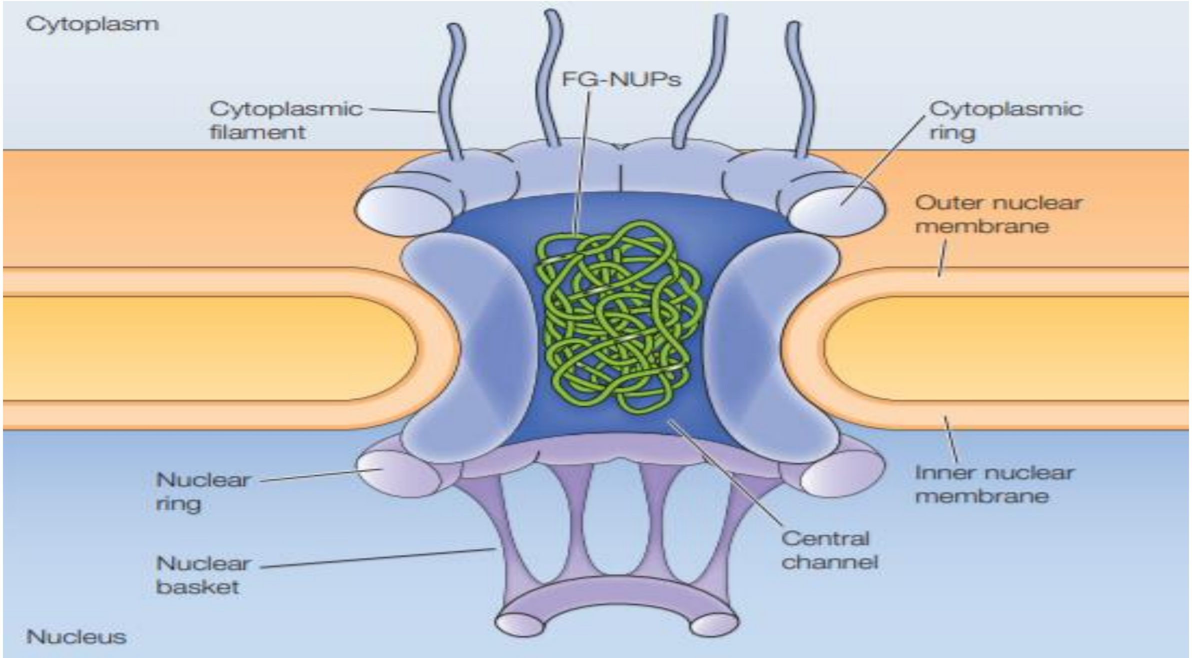
The nucleus has the following parts:

1. Nuclear envelope- Each nucleus is bounded by two membranes, which together constitute the nuclear envelope. The space between two membrane is known as perinuclear space. The inner nuclear membrane contains specific proteins that act as binding sites for the nuclear lamina. The outer nuclear membrane is continuous with rough endoplasmic reticulum. Although the nuclear envelope separates nucleoplasm from cytoplasm, nucleus is not isolated from rest of the cell.



Ultrastructure of The Nucleus

Nuclear pore complexes-The NPCs provide channels for molecular exchange between nucleus and cytoplasm. Outer and inner nuclear membranes are fused at nuclear pores, so the membranes are considered to be continuous with one another. The outer membrane is also continuous with the membrane of endoplasmic reticulum, so both outer and inner nuclear membranes can exchange materials with endoplasmic reticulum. Pore density varies according to cell type and also according to species. Highest pore density is observed in highly active and differentiated cells. The nuclear pore complex is an elaborate structure of about 120 nm diameter which spans in both cytoplasm and nucleus. These are made up of about 30 different proteins known as **nucleoporins**. Nuclear pore complex is lined by eight spoke proteins which connect the cytoplasmic and nuclear ring. The spoke ring assembly surrounds a central channel which is composed of unstructured meshwork of nucleoporins. Rod like fibrils extending from the cytoplasmic ring into the cytoplasm are called as cytoplasmic filaments. Fibrils extending from the nuclear ring form nuclear basket. The filaments extending from the nuclear basket link neighbouring NPCs together. The central core of the NPC is composed of unstructured meshwork of nucleoporins. This meshwork of nucleoporins acts as a supra molecular sieve for transport of proteins.



Structure of The Nuclear Pore Complex

2. Nuclear matrix and nuclear lamina- The shape of the nucleus is maintained by nuclear matrix or nuclear skeleton. The nuclear matrix may also provide the anchoring site to chromatin at the time of DNA or RNA synthesis. The network of intermediate filaments present on the nuclear side of the inner nuclear membrane is called nuclear lamina. This is made up of intermediate filament protein called **lamins**. The lamins bind to specific proteins present in the inner nuclear envelope, such as **emerin** and **lamin B receptors**. The lamins provide skeletal support to nuclear envelope. These also provide the site for attachment to chromatin fibres. Lamins also help in dissolution of nuclear envelope at the time of cell division and its reorganization after the cell division over.

3. Nucleoplasm- Nucleoplasm is the interior space of nucleus other than the nucleolus. When nucleus is observed over the period of time during interphase and the cell division stage, changes in the appearance of chromosomes are observed. At the time of interphase chromosomes remain dispersed but during cell division chromosomes become visible again. The appearance and disappearance of chromosomes are due to the manner in which DNA condensed and decondensed. Chromosome are present in the nucleus in organized manner. Each chromosome occupies the specific area in the nucleus known as **chromosome territories**. In the cells of the same organism, position of these territories varies from cell to cell. The nucleus also contains nucleolus and other nuclear bodies such as **cajal bodies** (site of snRNPs assembly) and **nuclear speckles** (storage sites of splicing components).

4. Nucleolus- The nucleoli are globular structures present within the nucleus. They are not surrounded by any membranes. A nucleolus consists of three distinguishable regions the fibrillar center, dense fibrillar component and granular component. The pre-r RNA is synthesized in the fibrillar center and processed in the dense fibrillar component. The assembly of ribosomal subunits takes place in the granular component. Following each cell division, nucleoli become associated with the chromosomal regions that contain r RNA genes. These regions of certain chromosomes are known as nucleolar organizing regions (NOR) and the chromosomes are known as NOR-chromosomes. The size of nucleolus depends on the metabolic activity of the cell, with large nucleoli found in the cells that are actively engaged in protein synthesis. Number of nucleolus in a cell also varies. There is minimum of one nucleolus per cell. In certain case number of nucleoli present may be hundred or even thousands.

The 5.8S, 18Sand 28S r RNAs are transcribed into a single unit 45S ribosomal precursor RNA in the nucleolus by RNA polymerase I. The 45S pre-r RNA is processed to 18S r RNA of 40S ribosomal subunit and to 5.8S and 28S r RNAs of 60S ribosomal subunit. The transcription of 5S r RNA of 60S ribosomal subunit takes place outside the nucleolus by RNA polymerase III. The DNA segment carrying the information for ribosomal RNA is present in multiple copies (in tandem repeats), so that more ribosomal RNA can be synthesized simultaneously, resulting in the synthesis of more ribosomes and the requirement of ribosomes in actively metabolizing cell could be met. The DNA segment present in between the gene for ribosomal RNA is not transcribed and is called spacer DNA. Ribosomes consist of ribosomal RNA and ribonucleoproteins. The ribonucleoproteins are synthesized in cytoplasm and are imported from the cytoplasm to nucleus through the nuclear pore. Once inside the nucleus, these proteins get associated with the r RNAs to form ribosomes. The granules, observed in the granular region of nucleolus, are the ribosomes. These ribosomes, then move to the cytoplasm through the nuclear pore

5. Chromatin In eukaryotic cell DNA is present complexed with proteins. The DNA protein complex is called chromatin. During interphase, the chromosomes remain extended and these are not visible with the light microscope. The chromosomes are decondensed during that time, so that DNA replication and DNA transcription can take place (the chromatin becomes accessible by the proteins involved in transcription and translation). However, some of the DNA remains condensed during interphase. In 1928, E. Heitz called this highly condensed and darkly staining DNA as **heterochromatin**. The chromatin which is lightly stained and which remains extended during interphase was called **euchromatin**. In a typical mammalian cell 10% of the genome is packaged in the form of heterochromatin. If a gene, which is normally expressed in euchromatic region, is relocated in heterochromatin region it does not express and vice a versa. This effect on gene expression is called position effect. The expression of a gene is controlled by its proximity to heterochromatin region. Heterochromatin represents the inactive form of chromatin i.e., genes of this area are not transcribed. The DNA of heterochromatin is last to be replicated. Heterochromatin can either be constitutive heterochromatin or facultative. Constitutive heterochromatin is permanently condensed. This is also called junk DNA. Distribution of constitutive heterochromatin is similar in all the cell of an individual and in all individuals of a species. In electron micrograph, a dark irregular layer appears around the nuclear periphery. This represents constitutive heterochromatin, which is the part of chromatin bound to inner surface of nuclear envelope that remains compacted. Besides that, constitutive heterochromatin is also distributed in centromeric and telomeric regions of chromosomes. DNA of constitutive heterochromatin consists of short sequences that repeat tandemly. These are not transcribed. In many cases, these are telomeres of the chromosomes which are attached to nuclear envelope during interphase. On the contrary, facultative heterochromatin is the one which differs from cell to cell of an organism or in different organisms of a species, e.g. in cells of mammalian females one of the X is heterochromatic, while at the time of meiosis, both of the X chromosomes becomes euchromatic in egg mother cells.

References

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2. Cooper G M, Hausman R E (2019) in "The cell a molecular approach", 8th edition, ASM Press, USA.