CELL BIOLOGY

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Lecture 7: The Nucleus and Nucleolus 15/11/2021

The nucleus

- Nucleus was the first organelle to be discovered. It also known as the control center of the cell.
- The nucleus is the largest cellular organelle in animal cells.
- Nucleus is a membrane enclosed organelle found in eukaryotic cells.
- It contains most of the cell's genetic material.
- The main structures making up the nucleus is the **nuclear envelope** a double membrane that encloses the entire organelle.
- In mammalian cells, the average diameter of the nucleus is approximately 6 micrometres (μm), which occupies about 10% of the total cell volume.
- It appears as a dense, roughly spherical or irregular organelle.
- The composition by dry weight of the nucleus is approximately: DNA 9%, RNA 1%, Histone Protein 11%, Residual Protein 14%, Acidic Proteins 65%
- The nucleus is a highly specialized organelle that serves as the information processing and administrative center of the cell.
- This organelle has two major functions:
  1- It stores the cell's hereditary material, or DNA.
  2- It coordinates the cell's activities, which include growth, intermediary metabolism, protein synthesis, and reproduction (cell division).

Eukaryotes usually have a single nucleus, but a few cell types, such as mammalian red blood cells, have no nuclei, and a few others have many. Human skeletal muscle cells have more than one nucleus

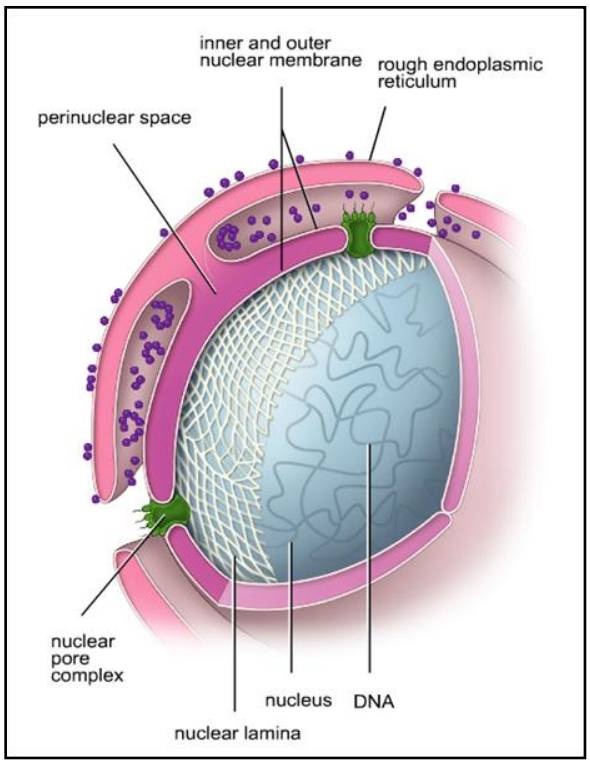
Nucleoplasm

Nucleoplasm is the gelatinous substance within the nuclear envelope. Also called karyoplasm, this semi-aqueous material is similar to cytoplasm in that it is composed mainly of water with dissolved salts, enzymes, and organic molecules suspended within.

The nucleolus and chromosomes are surrounded by nucleoplasm, which cushions and protects nuclear contents.

Nuclear lamina

- In animal cells, the nuclear lamina forms an organized meshwork on the internal face of the envelope, while less organized support is provided on the cytosolic face of the envelope. Both systems provide structural support for the nuclear envelope and anchoring sites for chromosomes and nuclear pores
- The nuclear lamina is composed mostly of lamin proteins. Like all proteins, lamins are synthesized in the cytoplasm and later transported to the nucleus.
- Lamins found on the cytosolic face of the membrane, such as emerin and nesprin, bind to the cytoskeleton to provide structural support. Lamins are also found inside the nucleoplasm where they form another regular structure, known as the *nucleoplasmic veil*.

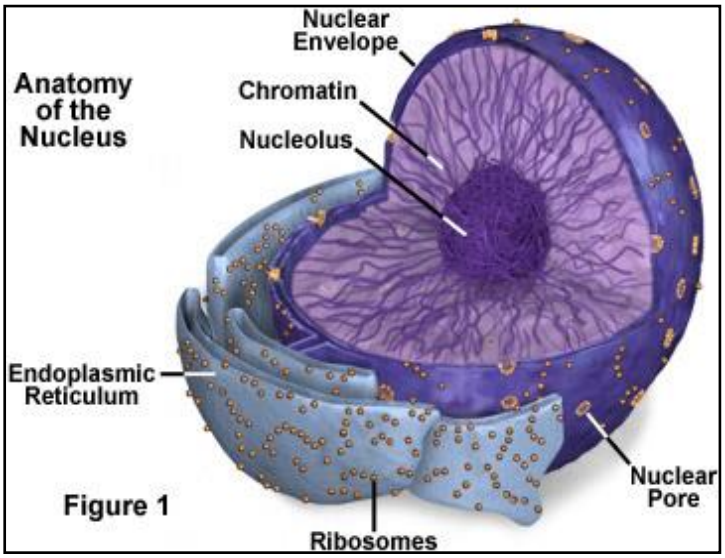


Nuclear envelope

* The nuclear envelope, otherwise known as nuclear membrane, consists of two cellular membranes, an inner and an outer membrane, arranged parallel to one another and separated by 10 to 50 nanometres (nm).

* The nuclear envelope completely encloses the nucleus and separates the cell's genetic material from the surrounding cytoplasm, serving as a barrier to prevent macromolecules from diffusing freely between the nucleoplasm and the cytoplasm.

* The outer nuclear membrane is continuous with the membrane of the rough endoplasmic reticulum(RER), the space between the membranes is called the perinuclear space and is continuous with the RER lumen



Nuclear pores

Nuclear pores, which provide aqueous channels through the envelope, are composed of multiple proteins, collectively referred to as nucleoporins.

This size selectively allows the passage of small water-soluble molecules while preventing larger molecules, such as nucleic acids and larger proteins, from inappropriately entering or exiting the nucleus. These large molecules must be actively transported into the nucleus instead.

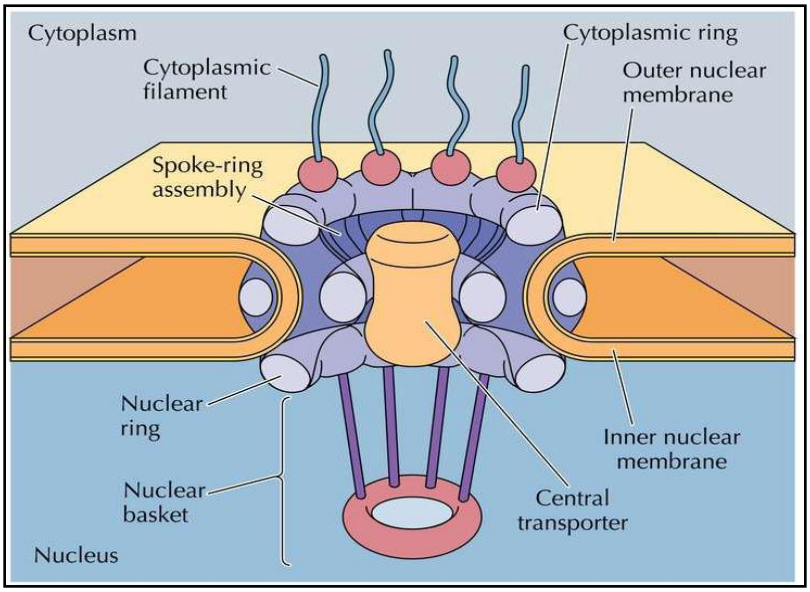
- The nucleus of a typical mammalian cell will have about 3000 to 4000 pores throughout its envelope.
- The pores are 100 nm in total diameter; however, the gap through which molecules freely diffuse is only about 9 nm wide, due to the presence of regulatory systems within the center of the pore.

The Nuclear Pore Complex (NPC)

- Each pore contains an **eight** fold-symmetric ring-shaped structure at a position where the inner and outer membranes fuse.
- Attached to the ring is a structure called the **nuclear basket** that extends into the nucleoplasm, and a series of filamentous extensions that reach into the cytoplasm. Both structures serve to mediate binding to nuclear transport proteins.
- Most proteins, ribosomal subunits, and some DNAs are transported through the

pore complexes in a process mediated by a family of transport factors known as **karyopherins.** Those karyopherins that mediate movement into the nucleus are also called importins, whereas those that mediate movement out of the nucleus are called exportins.

- Proteins larger than ~50kDa are too large to passively diffuse from the cytoplasm to the nucleus and must be actively transported across the NPC. These proteins must contain a nuclear localization sequence/signal (NLS) in order to be recognized by the alpha subunit of importin. When the cargo protein binds to alpha importin, alpha importin binds to beta importin, and beta importin is recognized by the FG repeat domains on the cytoplasmic filaments of the NPC.



- Most karyopherins interact directly with their cargo, although some use adaptor proteins. Steroid hormones such as cortisol and aldosterone, as well as other small lipid-soluble molecules involved in intercellular signaling, can diffuse through the cell membrane and into the cytoplasm, where they bind nuclear receptor proteins that are trafficked into the nucleus.
- Large numbers of proteins synthesized in cytoplasm and transported into the nucleus, RNAs manufactured in nucleus transported to cytoplasm

Large molecules are actively transported between the nucleus and cytoplasm

- Uncharged molecules smaller than 100 daltons can pass through the membranes of the nuclear envelope.
- Molecules and macromolecules larger than 100 daltons cross the nuclear envelope

by moving through NPCs.

- Particles up to 9 nm in diameter (corresponding to globular proteins up to 40 kDa) can pass through NPCs by passive diffusion.
- Larger macromolecules are actively transported through NPCs and must contain specific information in order to be transported.

Anucleated cells

- An anucleated cell contains no nucleus and is, therefore, incapable of dividing to produce daughter cells. The best-known anucleated cell is the mammalian red blood cell, or erythrocyte, which also lacks other organelles such as mitochondria, and serves primarily as a transport vessel to ferryoxygen from the lungs to the body's tissues. Erythrocytes mature through erythropoiesis in the bone marrow, where they lose their nuclei, organelles, and ribosomes. The nucleus is expelled during the process of differentiation from an erythroblast to a reticulocyte, which is the immediate precursor of the mature erythrocyte. The presence of mutagens may induce the release of some immature "micronucleated" erythrocytes into the bloodstream. Anucleated cells can also arise from flawed cell division in which one daughter lacks a nucleus and the other has two nuclei.

Multinucleated cells

- In humans, skeletal muscle cells, called myocytes become multinucleated during development; the resulting arrangement of nuclei near the periphery of the cells allows maximal intracellular space for myofibrils. Multinucleated and binucleated cells can also be abnormal in humans; for example, cells arising from the fusion of monocytes and macrophages, known as giant multinucleated cells, sometimes accompany inflammation and are also implicated in tumor formation.