Nuclear envelope

Definition:

The two layered membrane that encases the nucleus of a eukaryotic cell, which separates the nucleus from other cell organelles

Overview:

- The cell nucleus is the organelle of the eukaryotes responsible for maintaining the integrity of DNA and for controlling cellular activities such as metabolism, growth, and reproduction by regulating gene expression.
- It is a double-membraned organelle and this double membrane is referred to as nuclear envelope (also called nuclear membrane, plasmalemma, or karyotheca).
- The nuclear envelope surrounds most of the eukaryotic cell's genetic material as opposed to the genetic material of the prokaryotes that is not membrane bound.

Features:

1. The nuclear envelope is a lipid bilayer.
2. It has nuclear pores that control the movement of molecules between the nucleoplasm and the cytoplasm.
3. It is impermeable to large molecules.
4. It separates the contents of the nucleus from the cellular cytoplasm and allows entry of selected molecules.
5. In between the two membranes of the nucleus is a space called the perinuclear space.
6. The outer membrane is contiguous with the endoplasmic reticulum.
7. The inner membrane is constituted by a network of filaments called nuclear lamina.
8. The lamina attach to chromosomes.
9. It also acts like a shield for the nucleus.
10. The outer and the inner membranes are connected by the nuclear pores.
11. In mammals, the nuclear envelope spectrin repeat proteins are expressed in the outer membrane.
12. These proteins connect the cytoskeletons in the cytoplasm to the nucleoskeleton in the nucleoplasm.

13. This connection aids in the positioning of the nucleus within the cell.

Functions:

1. During cell division, the nuclear envelope undergoes major changes in animal and plant cells. The nuclear envelope disintegrates to allow the spindle fibers to access the chromosomes in the nucleus. An exception to this is the yeast cells whereby the nuclear envelope stays intact during cell division. In animal and plant cells, the nuclear envelope breaks down into pieces during prometaphase of mitosis. Then, during telophase, the nuclear membrane reforms. The reformation process remains unclear how it proceeds. It is postulated to occur via vesicle fusion or probably by reshaping of the endoplasmic reticulum, enclosing the nuclear region with a new nuclear envelope.
2. The presence of the nuclear envelope prevents the easy passage of large molecules (e.g. proteins and RNA) into and out of the nucleus. Although the nuclear envelope is perforated with nuclear pores, large molecules would still need a nuclear transport mechanism in order to enter and exit the nucleus. Small molecules, such as ions, can pass through the

nucleus with ease. However, cargo proteins and RNAs that need to be transported require importins and exportins to enter and exit the nucleus, respectively. On one hand, the cargo(Any protein that is carried within the vesicles of a cell's secretory system (i.e. from the endoplasmic reticulum to the Golgi apparatus to the plasma membrane) binds with the importin in the cytoplasm, and then moved into the nucleus through the nuclear pore. On the other hand, the cargo binds with the exportin inside the nucleus, and then moved outside the nucleus via the nuclear pore. Nuclear transport needs energy to proceed. Thus, GTPases (e.g. Ran enzyme) help by hydrolyzing GTP (guanosine triphosphate) so that energy would be released in the process. The energy released would be used to dissociate the cargo from the importins and to bind the cargo to the exportins.

3. The nuclear envelope compartmentalizes the nucleoplasm, setting boundaries between the nucleus and the cytoplasm. Nevertheless, it is perforated with holes called nuclear pores that regulate the exchange of substances (for example, proteins and RNA) between the nucleus and

the cytoplasm. The nuclear transport of the large molecules like proteins and RNAs occurs via an active transport system carrier proteins while the passage of small molecules and ions occur passively via the nuclear pores.

Nuclear Envelope or Karyotheca:

- The nuclear membrane or karyotheca form an envelope-like structure around the nuclear contents and is commonly known as nuclear envelope.
- The nuclear membrane in higher plant and animal disappears in late prophase during mitosis and re-forms around the daughter chromosomes during telophase.
- In lower eukaryotes, the nuclear envelope remains intact throughout mitosis.
- It separates nucleus from cytoplasm and functions to facilitate and regulate nucleocytoplasmic interaction.
- The light microscope provides little information about the nuclear envelope.
- Under electron microscope the nuclear envelope in the interphase or prophase stage appears to consist of two concentric membranes, viz., inner nuclear membrane and outer nuclear membrane.

Number of nucleus	Organism/cell
True *Nucleus absent*	Prokaryotic organism like bacteria, PPLO, Spirochaeta, blue-green algae
True nucleus present in early stage but absent in mature stage	Plant-sieve tube; Animal—RBC of mammals
Single nucleus (Mononucleate)	Most of the eukaryotic cells or organisms
Two nuclei (Binucleate)	*Paramoecium*, liver cell, cartilage cell
Many nuclei (Polynucleate/multinucleate)	Animal—Cells of bone marrow. Plant—Fungus, *Vaucheria* (algae), endosperm cells

Fig. Number of nucleus/cell in different organism.

Structure:

1. Each membrane is about 75 to 90 A thick and lipoproteinous in nature.
2. The outer and inner membranes are separated by perinuclear space of 1000-1700 nm.(100-170 A).
3. The inter-membrane space is known as perinuclear cisternae (Fig.2).
4. The inner membrane defines the content of nucleus itself and it contains specific proteins that act as binding sites for the nuclear lamina.

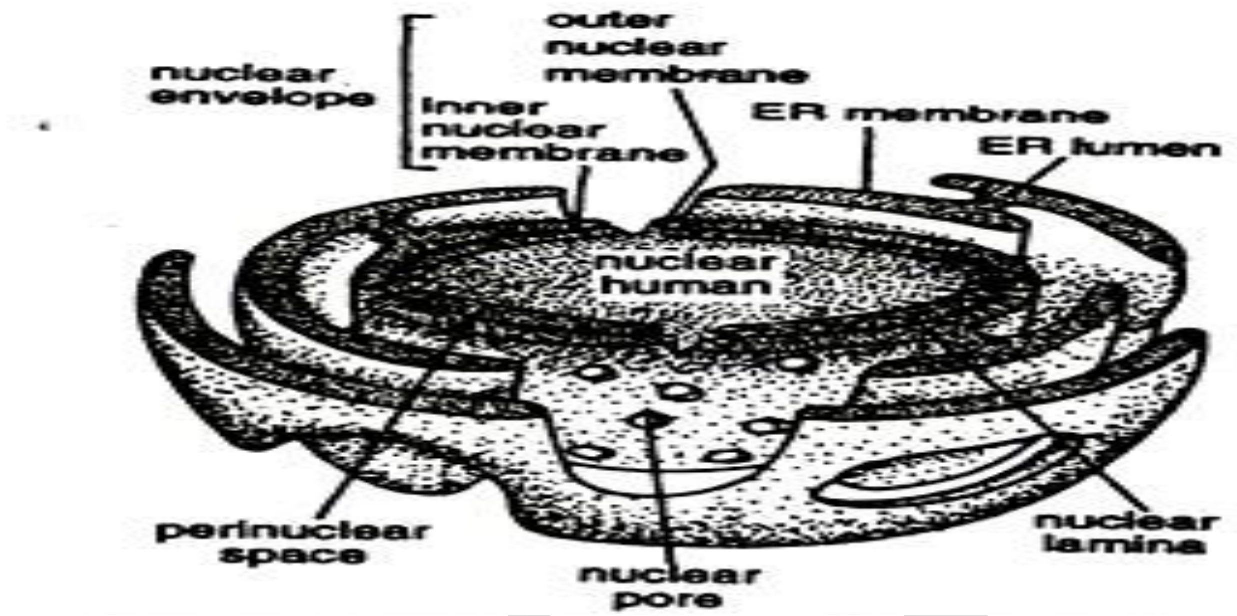

Fig.2 3D structure of double membrane envelope that surrounds the nucleus. The nuclear envelop is penetrated by nucleopore and is continuous with the ER.

5. The outer membrane is rough due to presence of ribosomes (25 nm in diameter) attached with it.
6. The ribosomes are engaged in protein synthesis.
7. The proteins made on these ribosomes are transported into the space between the inner and outer nuclear membrane.
8. In many cells, the outer nuclear membrane is continuous with rough endoplasmic reticulum.
9. The space between the inner and outer nuclear membrane is continuous with the lumen or inner cavity of the rough endoplasmic reticulum.

Electron Microscopic Structure of Nuclear Envelope:

1. Under the electron microscope the nuclear envelope appears to consist of two membranes, the outer and the inner nuclear membranes, separated by a peri-nuclear space of 20 nm(200 A) (Fig.3).
2. Each of the two membranes of the nuclear envelope appears to have trilaminar unit membrane structure of 7 – 10 nm thickness.
3. The outer nuclear membrane communicates with endoplasmic reticulum at several points and has ribosomes on the outer side.

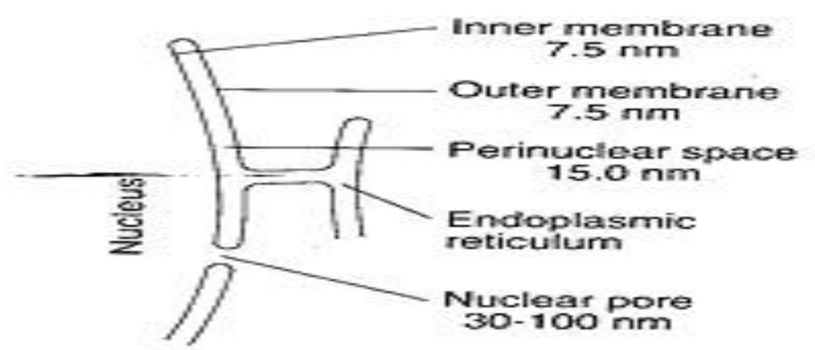

Fig.3 Nuclear membrane showing double membrane structure.

4. The nuclear envelope is perforated by many circular apertures called nuclear pores.
5. Each nuclear pore shows the presence of an electron-dense ring or cylinder called the annulus.

6. The actual opening of the nuclear pore is thus confined to the cavity of the annulus.
7. The annulus extends both into the cytoplasm and the nucleoplasm.
8. The annulus typically consists of eight subunits arranged in radial symmetry around the periphery of the pore.
9. The subunits have been variously interpreted as micro-cylinders, filaments, spheres or ovoid's.
10. A central ribonucleoprotein granule of 10-15 nm size may be present in some pore complexes and may be absent in adjacent ones.
11. On the inner side of the nuclear envelope of many cell types is present fibrous material which has been called the fibrous lamina which extends into the nucleoplasm.

Nuclear lamina:

- The inner nuclear membrane is lined on the inner surface by the nuclear lamina, which is a protein fibrous network of 30-100 nm thick that connects the inner nuclear membrane with chromatin.
- It is composed of three principal extrinsic membrane proteins — lamins A, B and C.

- The lamins are made up of two parts — one is rod like tail of 52 nm long and the other is two globular heads at one end.
- Lamins are highly similar in sequence and structure with the cytoplasmic intermediate filament.
- Inner nuclear membrane contains lamin B receptors that binds to lamin B; and lamin A and C bind with lamin B and with interactions between the lamina and chromatin (Fig.4).

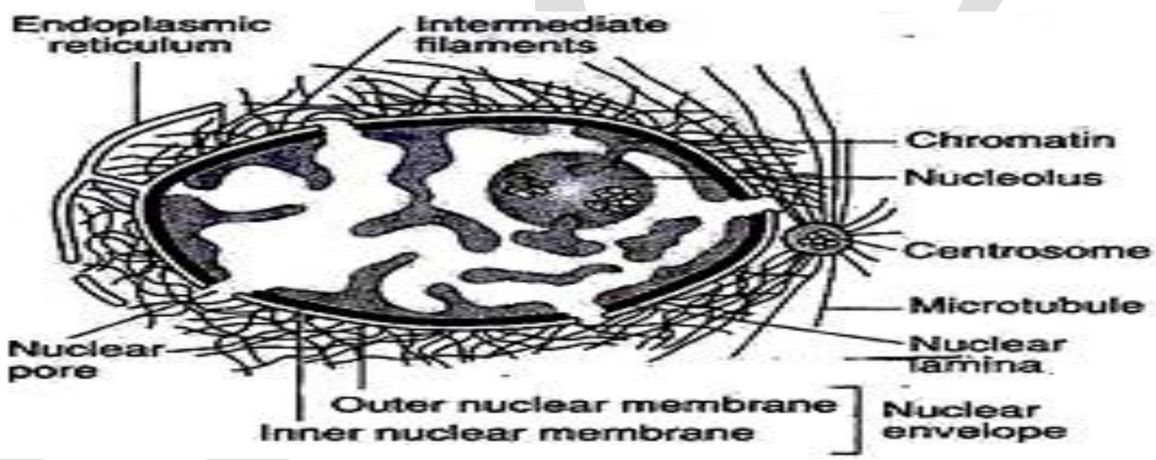

Fig.4 Structure of nuclear envelop.

The nuclear lamina and its polypeptide carry out the following functions:

(a) Regulating assembly and disassembly of the nuclear membrane during cell division. De-polymerization of lamina due to phosphorylation at late prophase causes the nuclear envelope to disassemble into a number of small vesicles. At telophase de-phosphorylation and polymerisation of lamins into fibrous network along with fusion of small nuclear vesicles causes reassembly of nuclear envelope.

(b) Attachment of chromatin to the nuclear envelope.

(c) Helps to form micronuclei when the cells are left for a long time in colchicine.

Function of Nuclear Envelope:

1. The nuclear envelope is an interface between nucleus and the cytoplasm.
2. It serves to separate the genetic component of the cell (the chromosomes) from the protein-synthesis machinery (ribosome and ER).
3. It thus provides protection to DNA against the mutagenic effects of cytoplasmic enzymes.
4. It is concerned with nucelocytoplasmic exchange, attachment of structural elements to the cytoplasm, attachment of nuclear components, contribution to other cell membranes and electron transport activity.