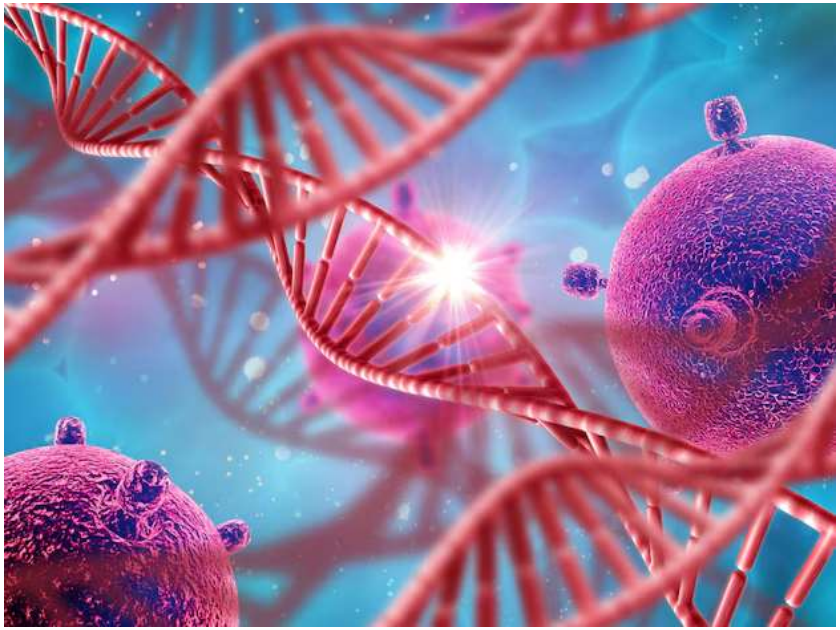
Lecture 11

General Biology & Cytology Course 2301130



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Do all Cells have just one Nucleus?

- Liver cells and muscle fibers are all normal cells that often have more than one nucleus.
- Cancerous cells and those infected with viruses can also have multiple nuclei at times.
- Erythrocytes or Red blood cells. When the RBCs are developing in the red bone marrow, they do have nuclei. However, these nuclei are ejected from the cells when they enter the bloodstream in a process known as enucleation.

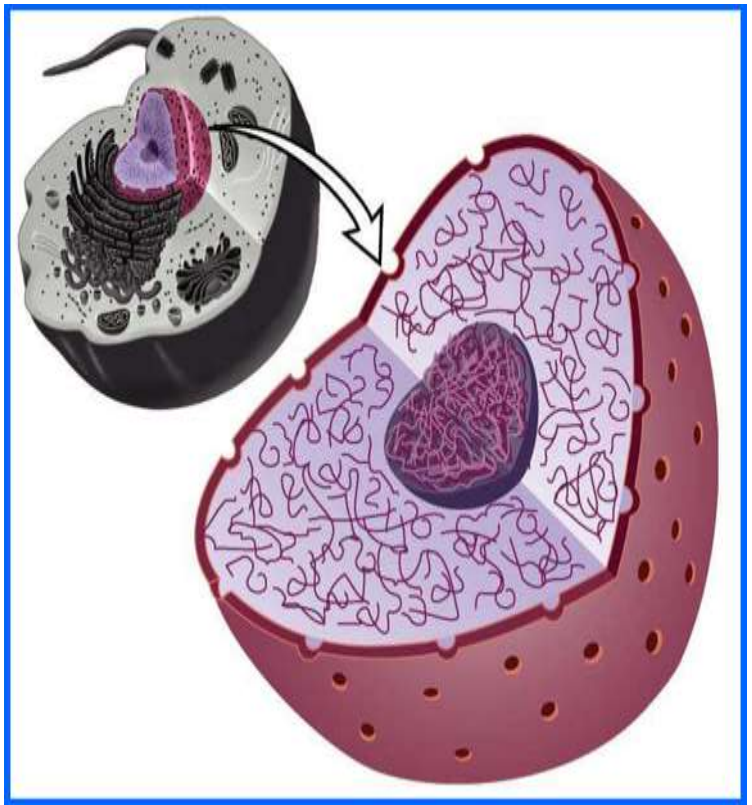
The **nucleus:**

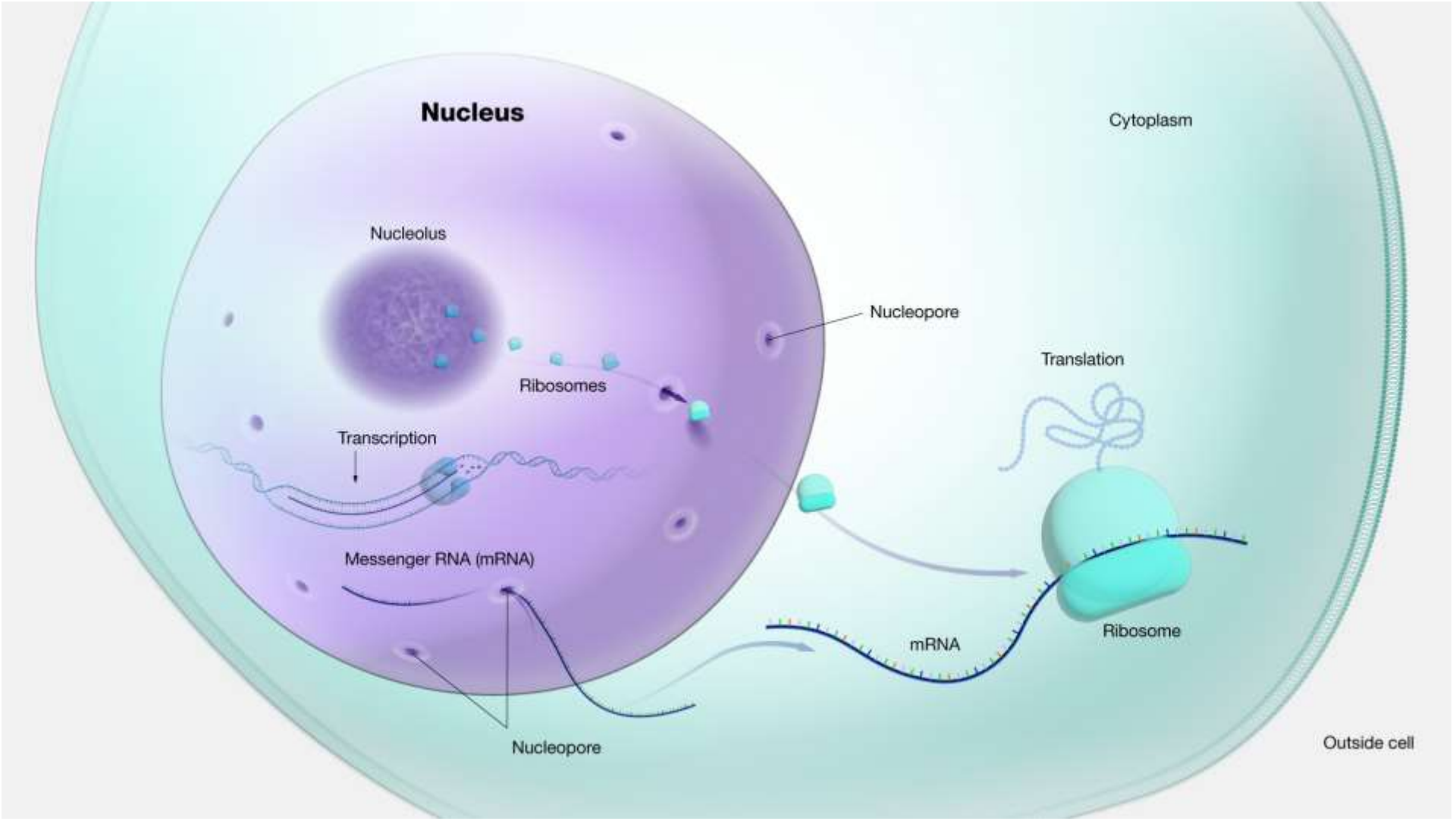
- (plural, **nuclei**) houses the cell's genetic material, or DNA, and is also the site of synthesis for ribosomes, the cellular machines that assemble proteins.
- Inside the nucleus, chromatin (DNA wrapped around proteins) is stored in a gel-like substance called **nucleoplasm**.
- **~ 5 µm in diameter.**
- The nucleus is the **headquarters** (**controls** all cell activity) of the cell.
- It is the most **obvious** organelle.
- The Nucleus is a **membrane-enclosed** organelle which house most of the **genetic** information.
- It is **absent** in mature **erythrocyte**

Nucleus

Functions

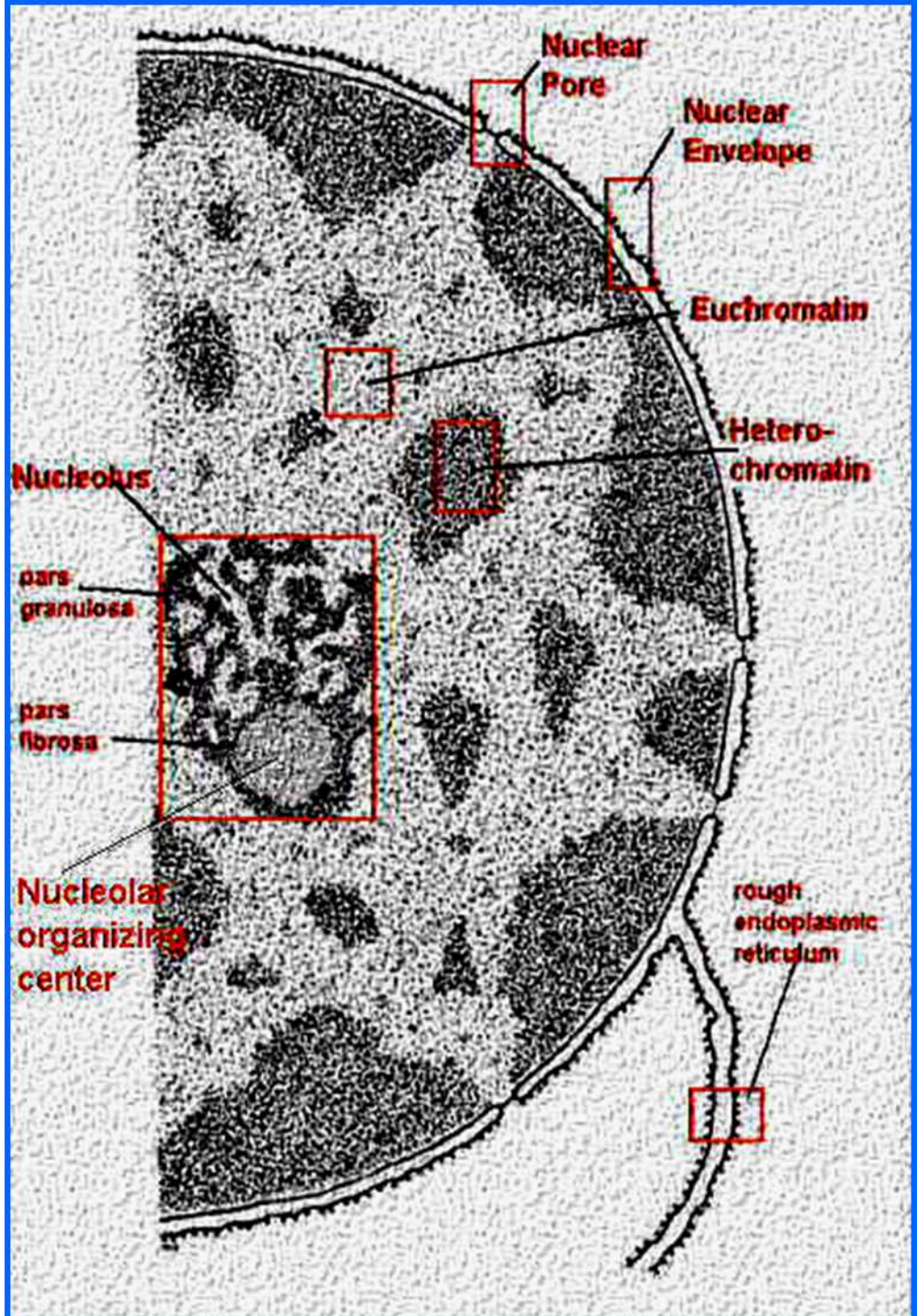
- It stores the cell's hereditary material (DNA)
- Site of DNA replication
- Site of DNA transcription to mRNA
- Ribosomal formation
  - **Nucleolus**: RNA & protein required for ribosomal synthesis
- It controls all the cellular activities including protein synthesis.

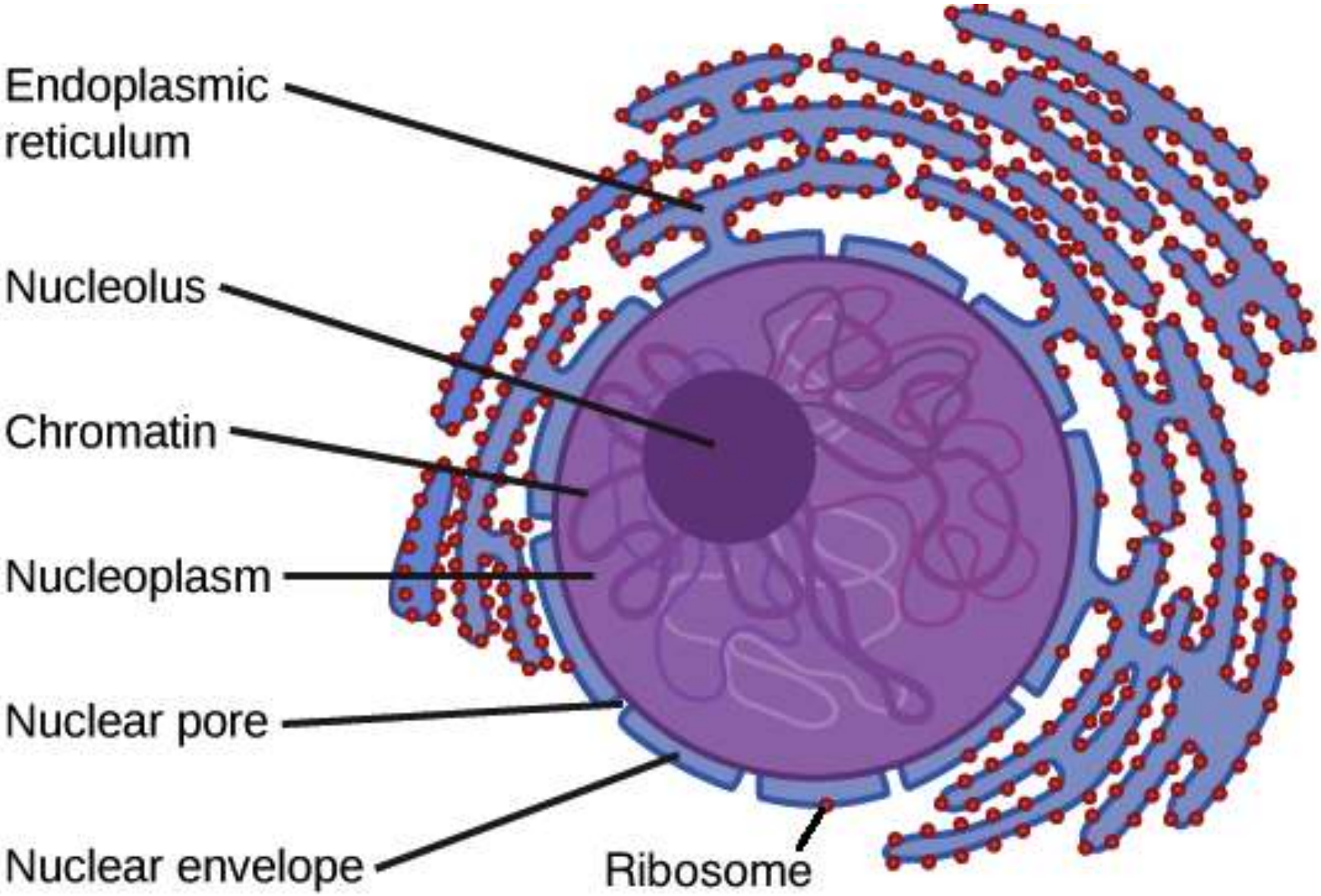



Nucleus
Cytoplasm
Nucleolus
Nucleopore
Translation
Ribosomes
Transcription
Messenger RNA (mRNA)
mRNA
Ribosome
Nucleopore
Outside cell

STRUCTURE and Function

1. **Nuclear envelope, double membrane and nuclear pores**
2. **Nucleoplasm**
3. **Chromatin** Chromatin, Chromosome, DNA and RNA
4. **Nucleolus (concentrated area of chromatin, RNA and proteins)**



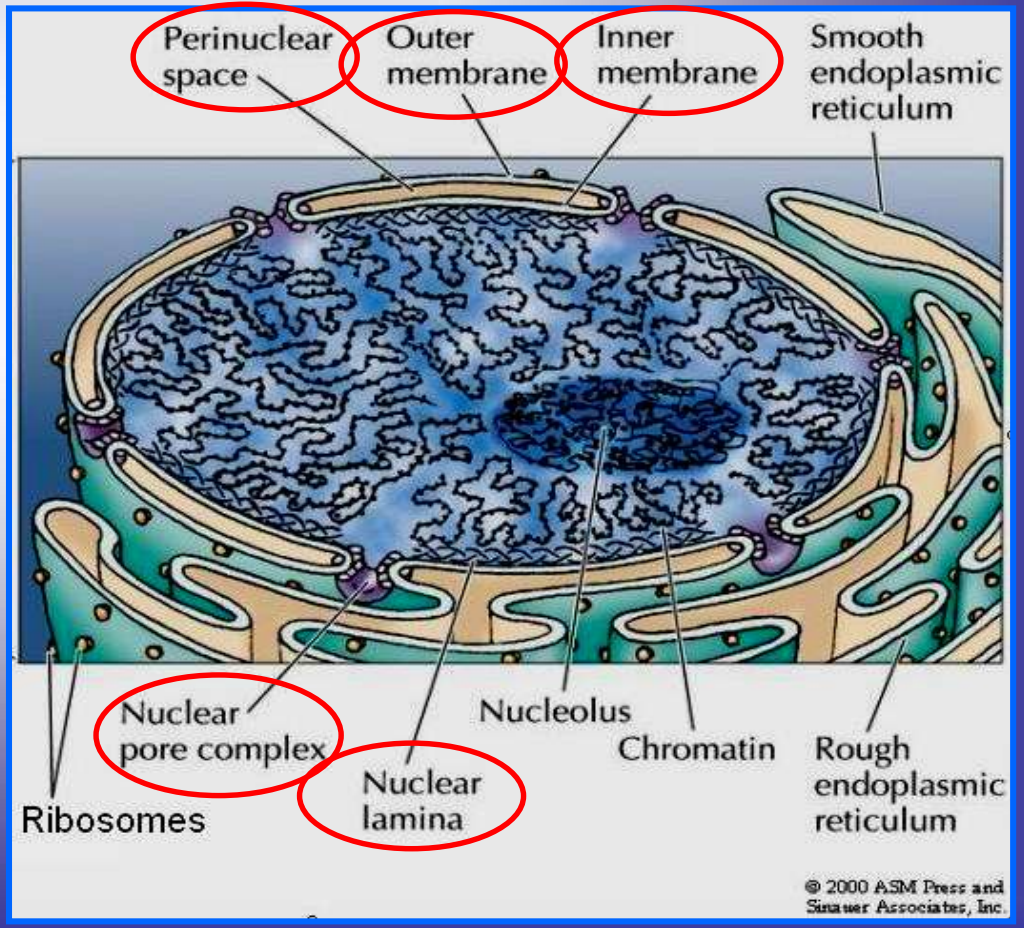

Endoplasmic reticulum
Nucleolus
Chromatin
Nucleoplasm
Nuclear pore
Nuclear envelope
Ribosome

Nuclear envelope (Nucleolemm)

- Separates the enclosed nuclear compartment from cytoplasm
- Maintains the shape of nucleus
- Controls exchanges between nucleus and cytoplasm
- Important role in organization of nucleus content

Structure

- External (outer) nuclear membrane
- Internal (inner) nuclear membrane
- Perinuclear space
- Lamina densa (nuclear lamina)
- Nuclear pores



External nuclear membrane

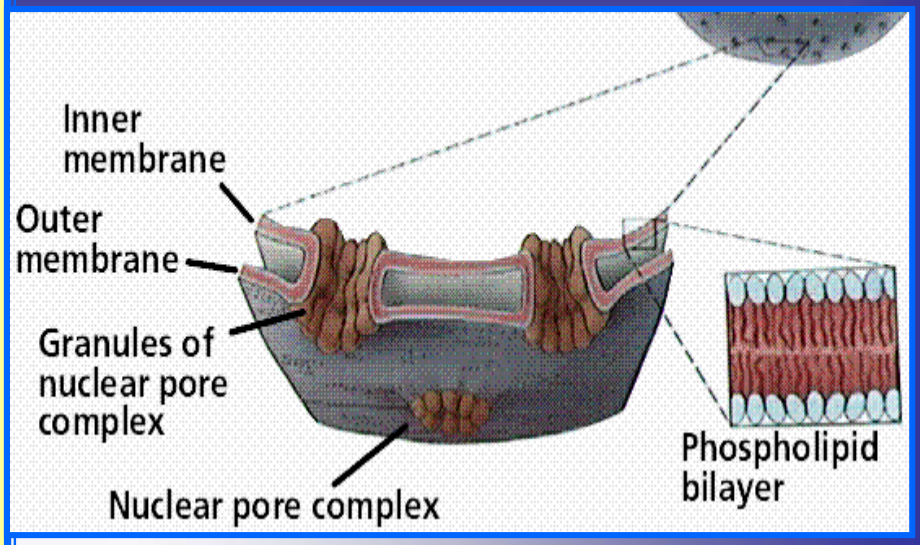
•Fluid mosaic (**lipid bilayer** of ~ 7 nm thick with **70% proteins**). Eg. Nesprin proteins.
•Visible only by electron microscopy
•Ribosome attached on external face
•It **continues** with RER membrane

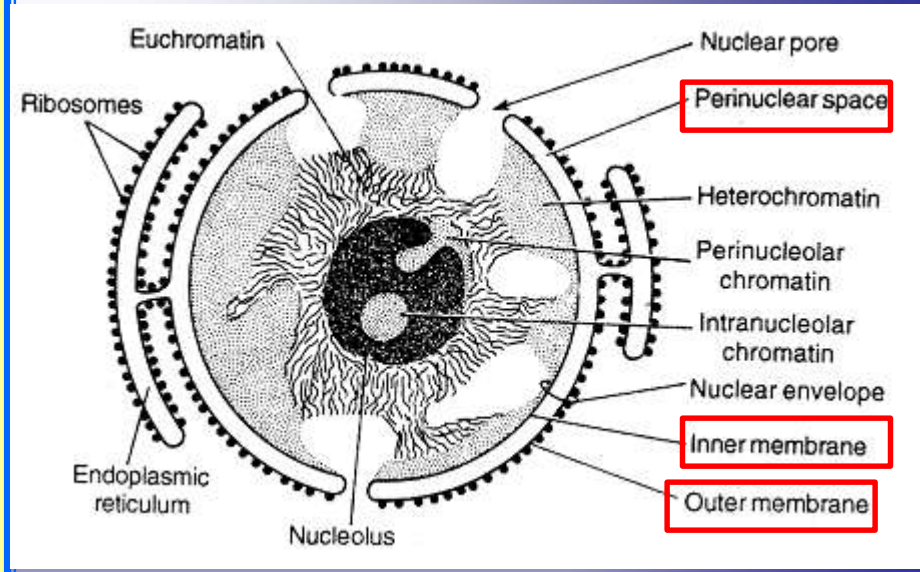
The perinuclear space

•10-40 nm
•It **communicates** with the RER internal space
•Contains the same molecules as RER
•Contains **Ca2**+

Internal nuclear membrane

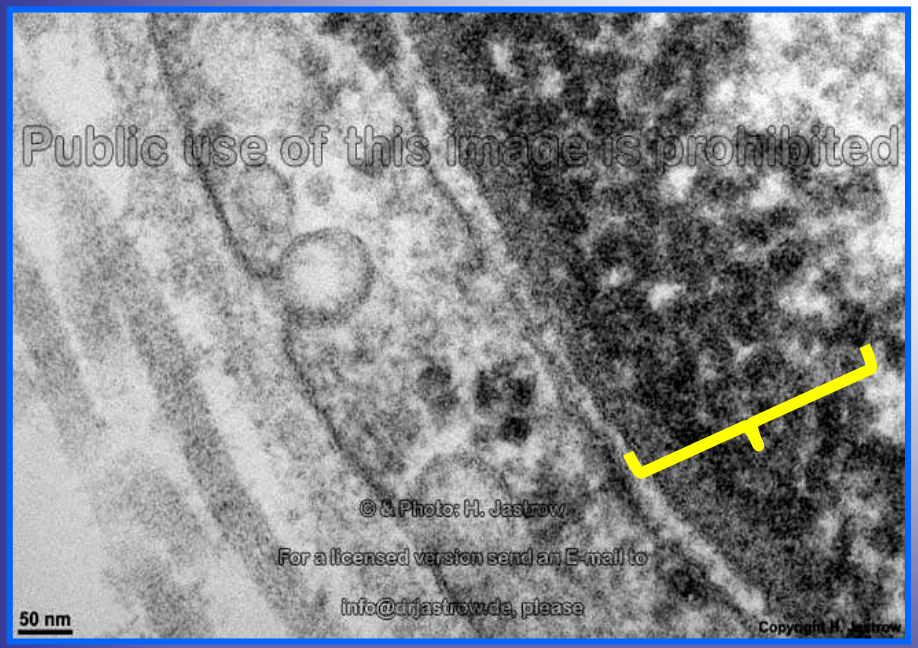
•Fluid mosaic (**lipid bilayer**)
•Visible only by electron microscopy;
•The inner surface of the nuclear envelop is bound to a thin filamentous network (*lamins polypeptides*) called the **nuclear lamina.**

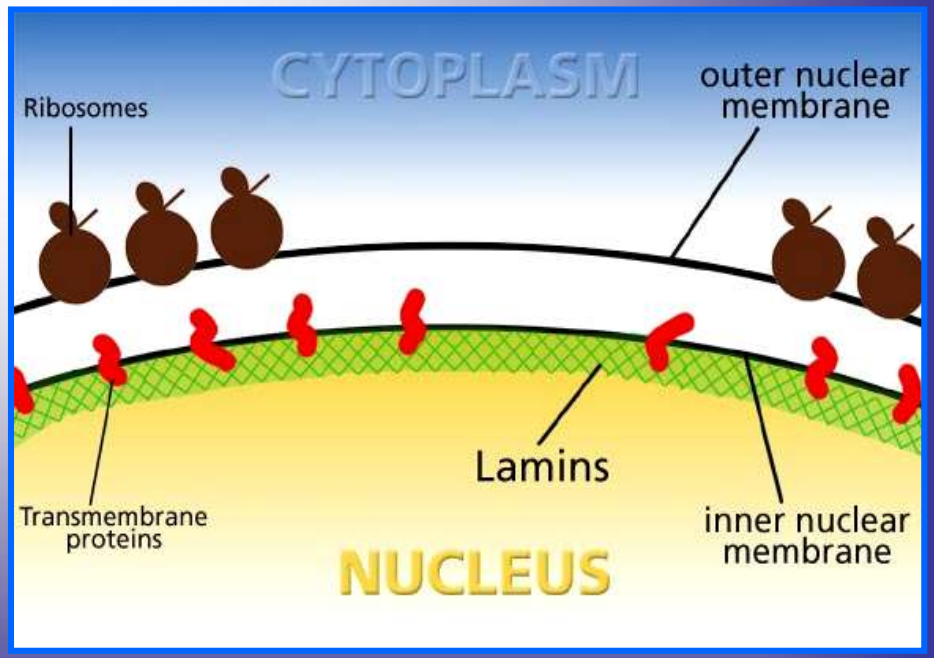




Nuclear lamina

- a network of **intermediate filaments** composed of various **lamins**
- The lamina acts as a site of **attachmen**t for chromosomes and provides structural **stability** to the nucleus.
- The lamins have been associated with **various genetic** disorders collectively termed **laminopathies (**e.g. a rare form of muscular dystrophy).

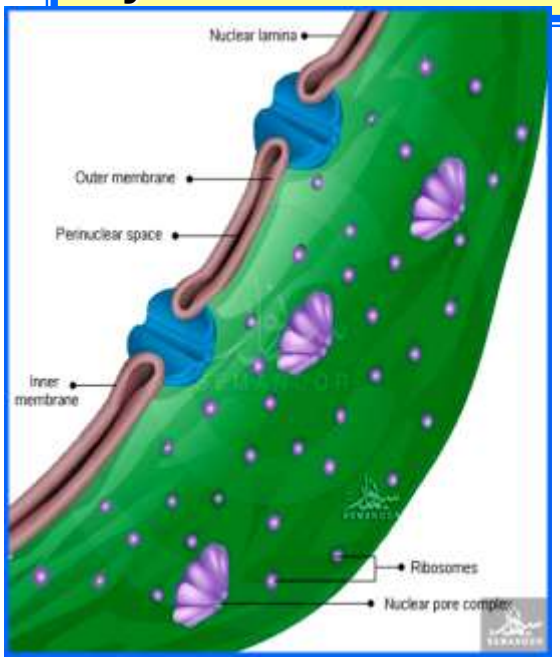




THE NUCLEAR PORE

- Small channels that span the nuclear envelope, let substances enter and exit the nucleus.
- Each pore is lined by a set of proteins, called the nuclear pore complex, that control what molecules can go in or out.
- Openings in the nuclear envelope, diameter about **10nm**

•Area where the nuclear envelope is **interrupted**
•Regulates **exchanges** between nucleus and cytoplasm
•Ensures the selective **transport** for big molecules
•There are 3000-4000 nuclear pores (10 pores/μm2)
•**Dynamic** structures – their number grows if it's necessary



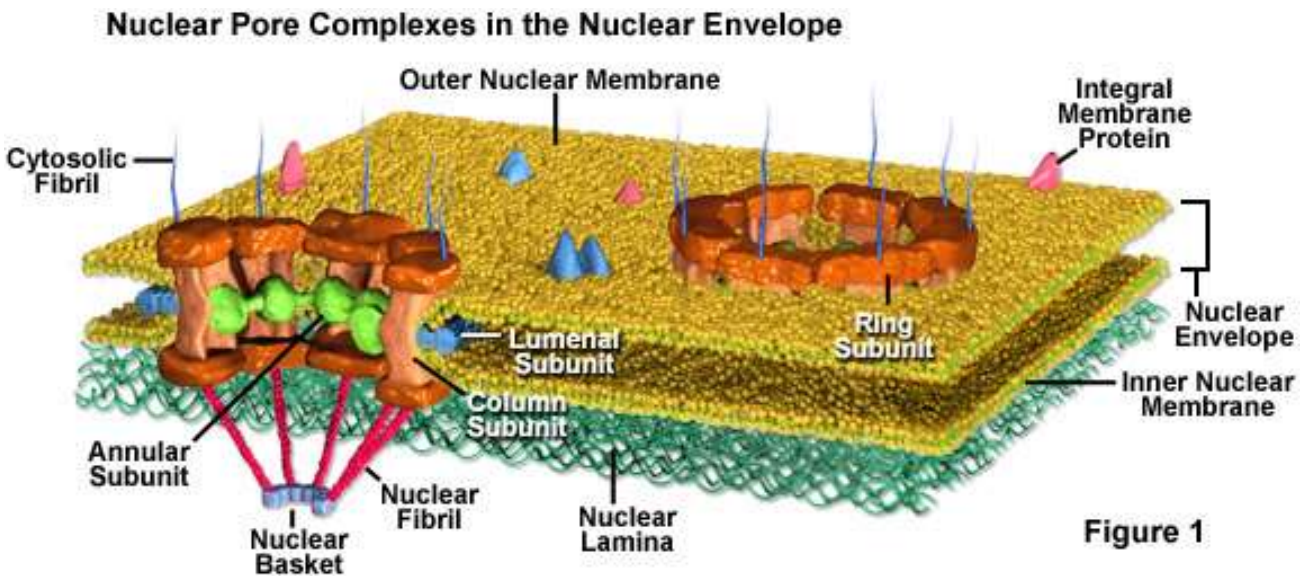
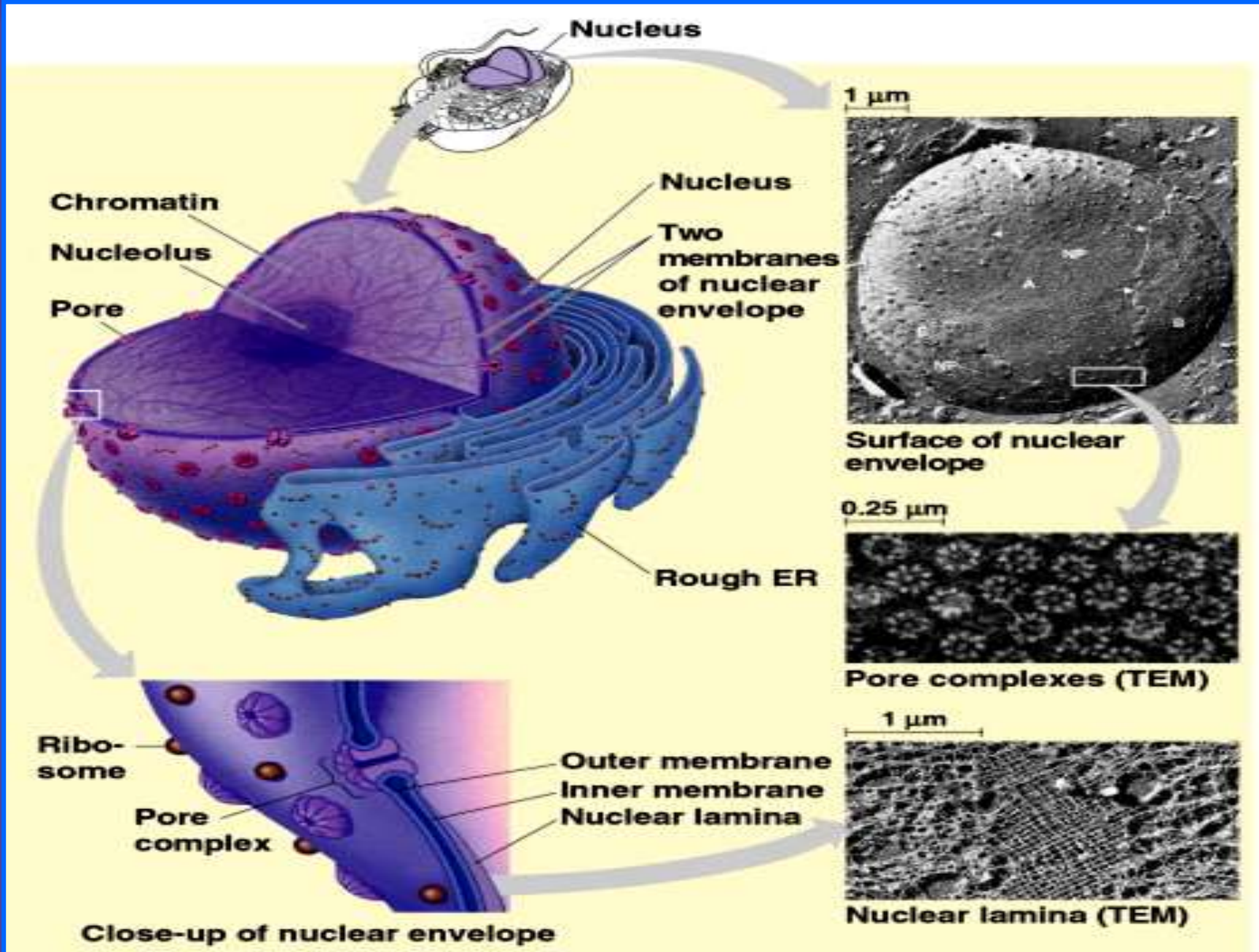


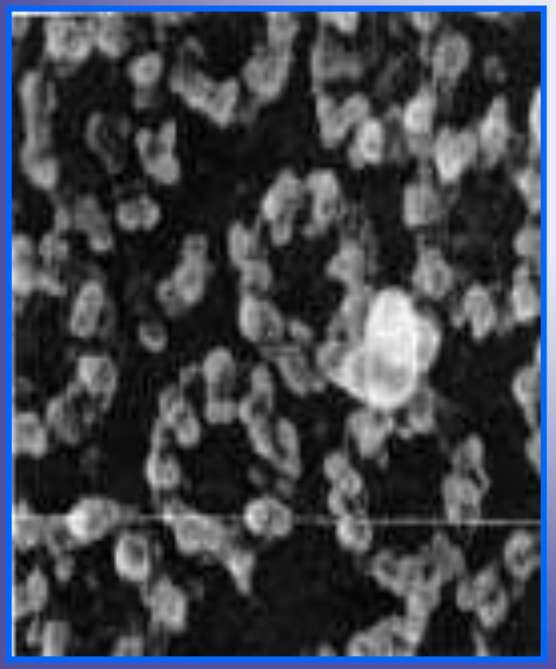
Figure 1


Nucleus
Chromatin
Nucleolus
Pore
Nucleus
Two membranes of nuclear envelope
Rough ER
1 µm
Surface of nuclear envelope
0.25 µm
Pore complexes (TEM)
Ribo-some
Pore complex
Outer membrane
Inner membrane
Nuclear lamina
Close-up of nuclear envelope
1 µm
Nuclear lamina (TEM)

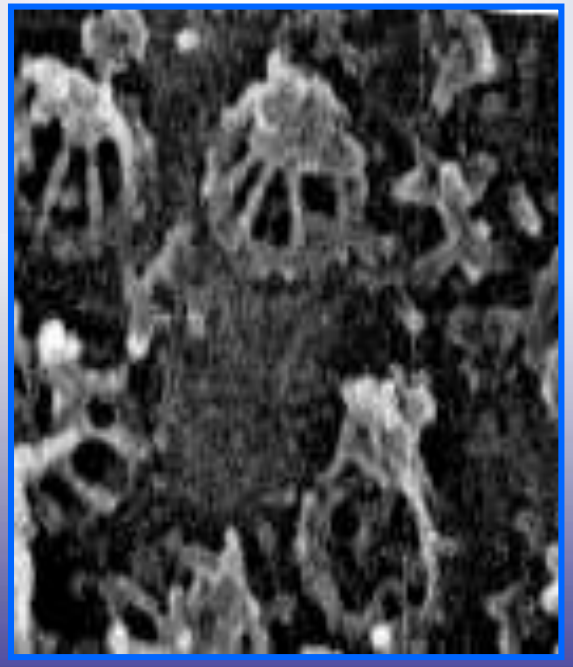
•The nuclear pores are the gateways across which movement of **RNAs** and **proteins** takes place between the nucleus and cytoplasm in both direction.

•Proteins synthesized in the cytoplasm cross the nuclear envelop to initiate replication and transcription of genetic material. Similarly, mRNA, tRNA and ribosomal subunits built in the nucleus cross through the nuclear pores to the cytoplasm**.**

The Nuclear Pore Complex



Cytoplasmic face



Nuclear face

Nuclear transport

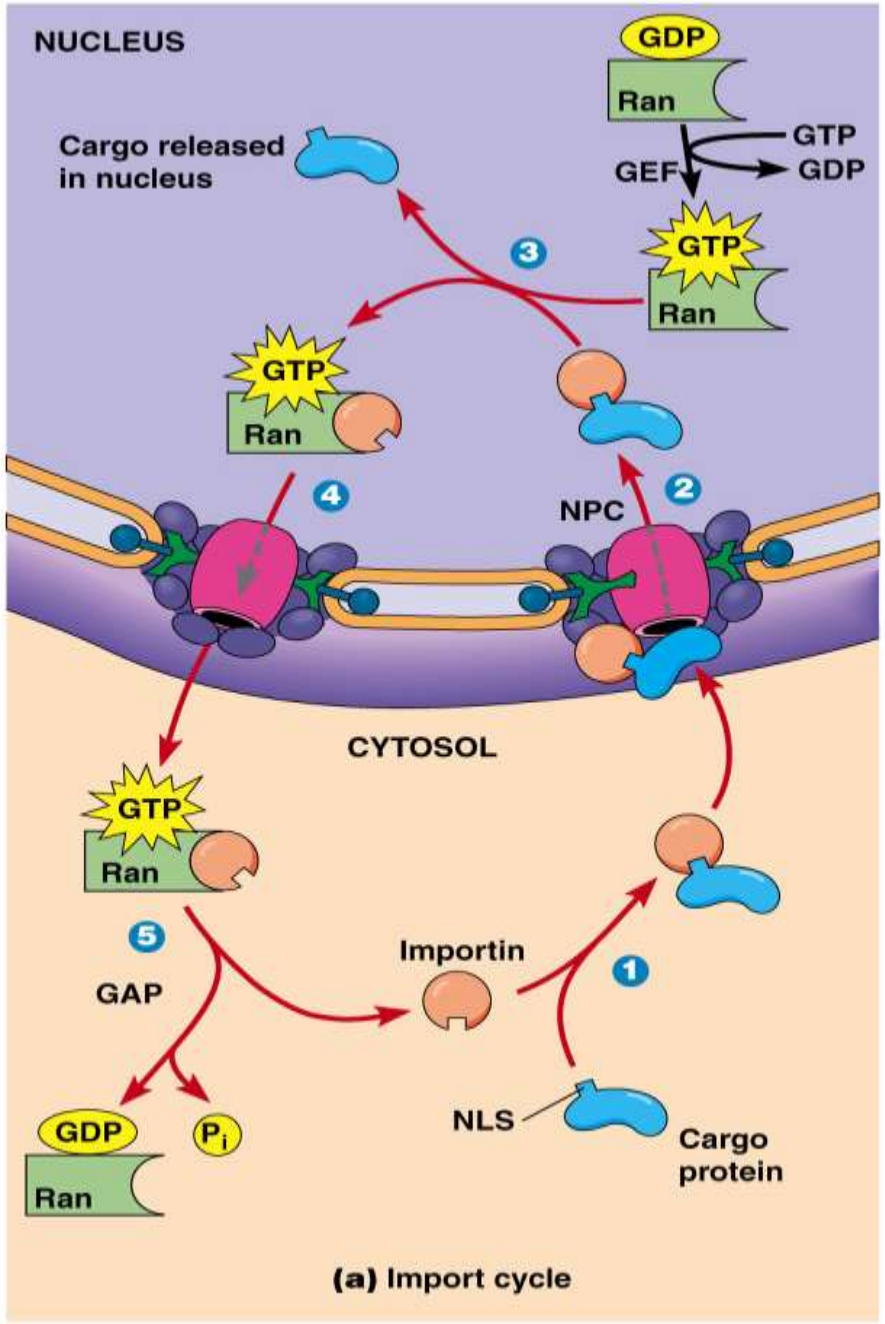
- The entry and exit of **large** molecules from the cell nucleus is **tightly controlled** by the nuclear pore complexes (NPCs).
- Although **small molecules** can enter the nucleus **without** regulation.
- Macromolecules such as RNA and proteins require association with **importins** proteins to enter the nucleus and **exportins** to exit

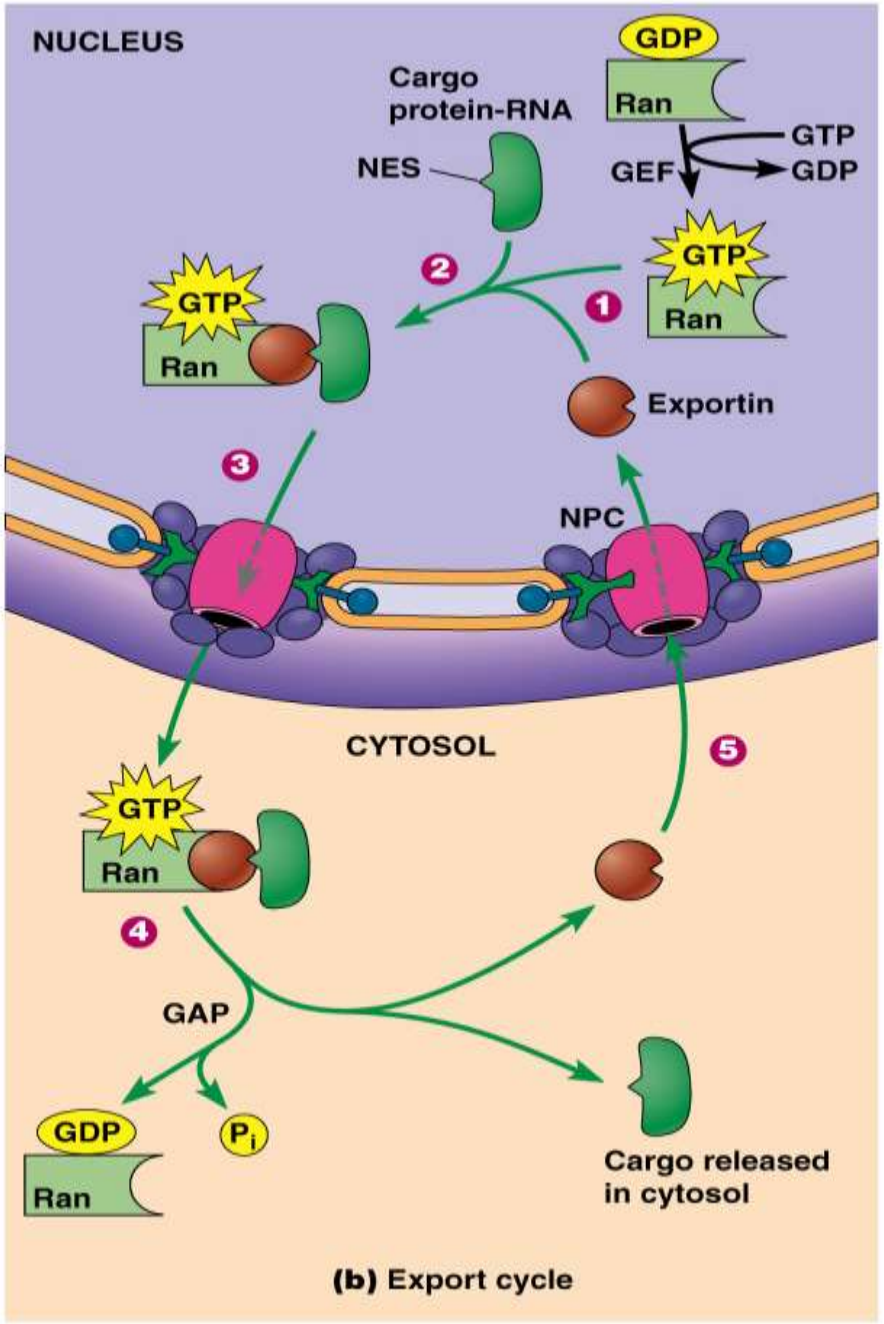
Nuclear Import

To get materials into the nucleus there is amino acid tag (zip code) called **nuclear localization signals** (NLS) added onto molecules and are assisted with transport factors known as nuclear transport receptors, like karyopherins called **importins**

Nuclear Export

Nuclear export roughly **reverses** the import process; in the nucleus, the **exportin** carry **nuclear export signals** (NES) or the zip code bound by **exportins**.



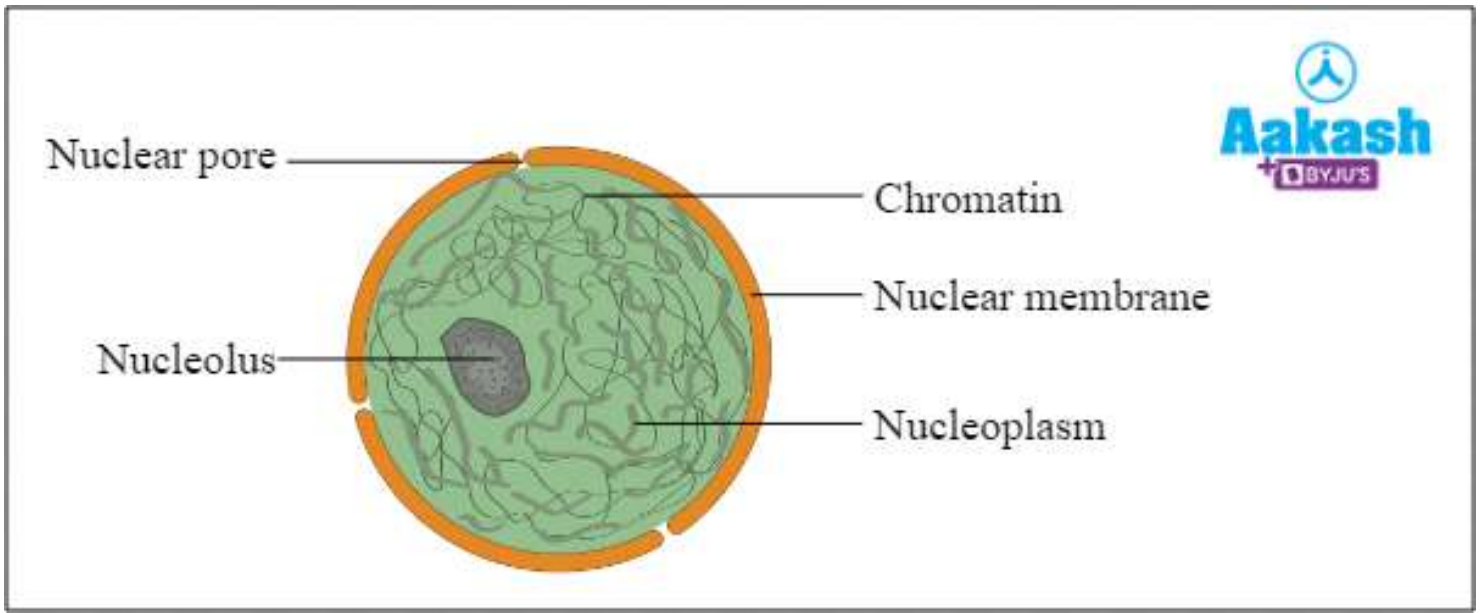


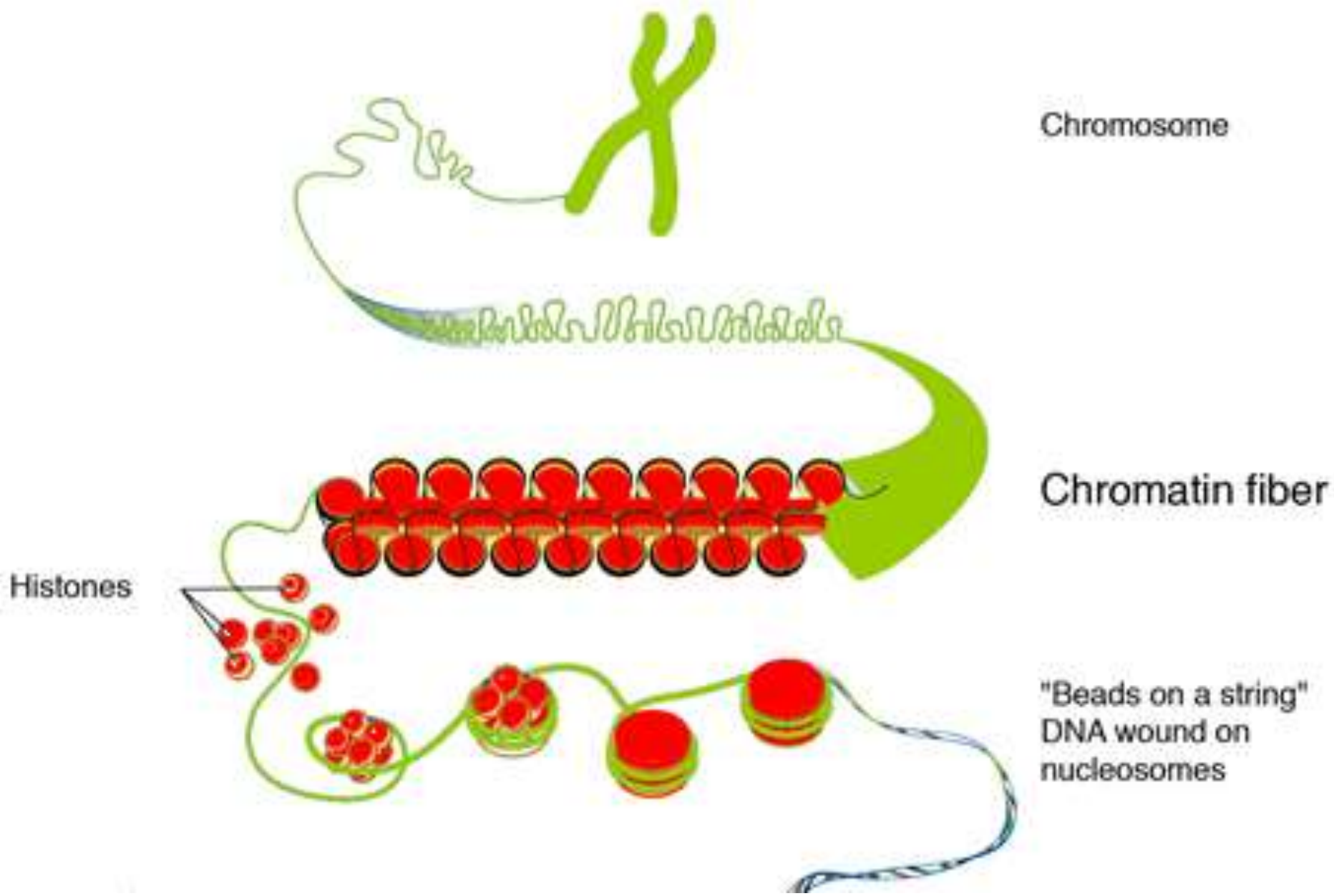
Nucleoplasm (nucleus sap) or karyoplasm

- **Analogy** with cytoplasm, Also called karyoplasm.
- is the gelatinous substance within the nuclear envelope, highly **viscous** liquid that surrounds the chromosomes and nucleolus.
- Composed mainly of water with dissolved salts, enzymes, and organic molecules suspended within such as **nucleotides** and **enzymes** are dissolved in the nucleoplasm
- A network of **fibers** known as the **nuclear matrix** can also found in the nucleoplasm.
- The nucleolus and chromosomes are surrounded by nucleoplasm, which functions to cushion and protect the contents of the nucleus.
- Nucleoplasm also supports the nucleus by helping to maintain its shape.
- Nucleoplasm provides a medium by which materials, such as enzymes and nucleotides (DNA and RNA subunits), can be transported throughout the nucleus.
- Substances are exchanged between the cytoplasm and nucleoplasm through nuclear pores.

Chromatin reticulum

- A stained thread like fibres seen in the nucleoplasm of stained cells and these are called **chromatin fibres**.
- It appears in the form of fine overlapping and coiled fibres which appears to produce a network called chromatin network or nuclear reticulum.
- If the cell is living, but unstained, the chromatin fibres can not be observed.
- During cell division (mitosis or meiosis) **dispersed** in the **interphase** and condensed to form chromosomes.




Chromosome
Chromatin fiber
Histones
"Beads on a string"
DNA wound on
nucleosomes

Chemical composition of chromatin

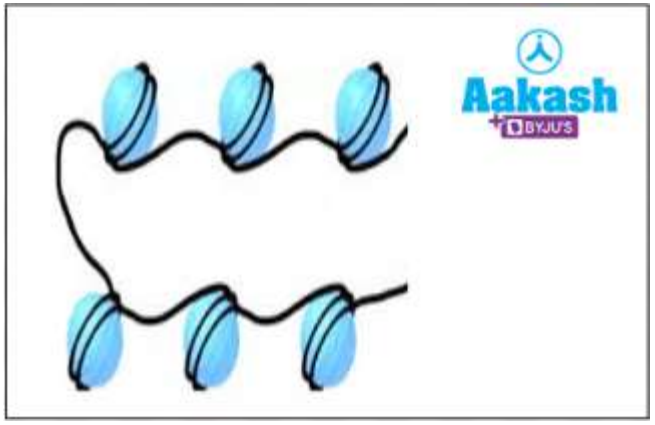
- Chromatin consists of a continuous linear DNA duplex strand.
- Associated basic histones proteins, or protamines are present in the chromatin.
- Acidic non-histone proteins.
- Ratio 1:1 DNA: Proteins.
- A small amount of RNA is also present.
- It also possesses inorganic components such as salts.
- Enzymes like DNA-polymerase and RNA polymerase can also be observed in the chromatin fibres.
- It also possesses some phosphorus containing organic components.

CHROMATIN

Functions

- Package DNA into a smaller volume to fit in the cell
- prevent DNA damage
- Regulate gene expression (transcription)
  and DNA replication

Types (During **interphase** // **no** cell division)

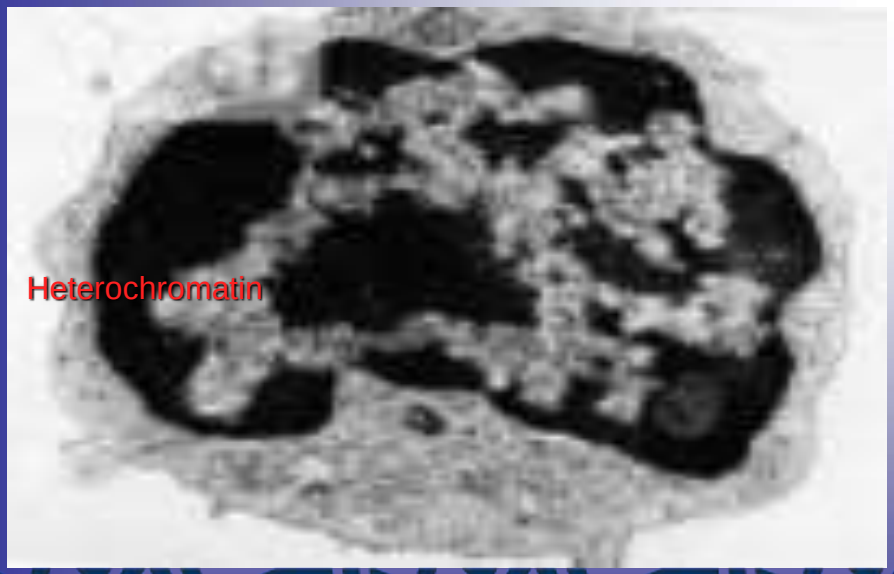


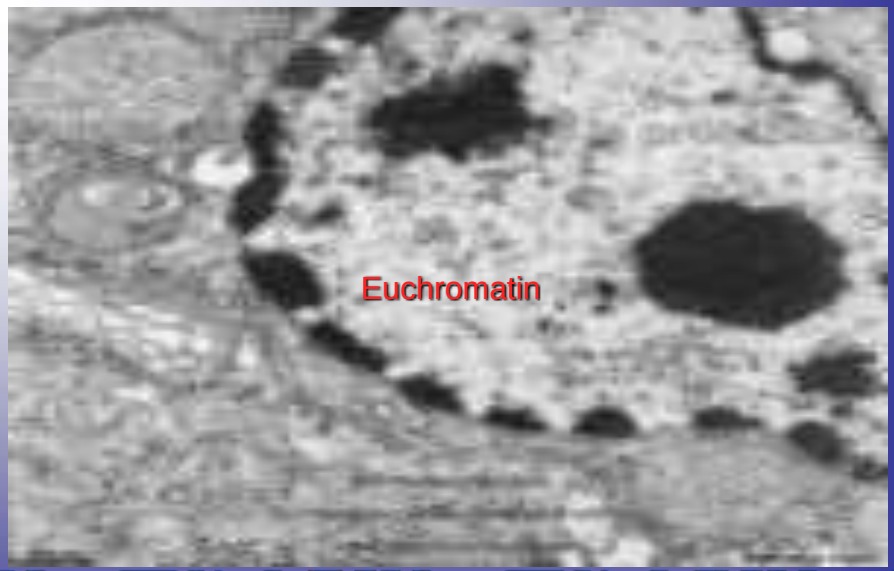
1- **Euchromatin**

2- **Hetrochromatin**

Chromatin has two forms:

- **1- Euchromatin** (extended)which is the **active form** (i.e. it control protein synthesis).
- **2- Heterochromatin** (condensed)which is the **inactive f**orm(i.e. it does not control protein synthesis).





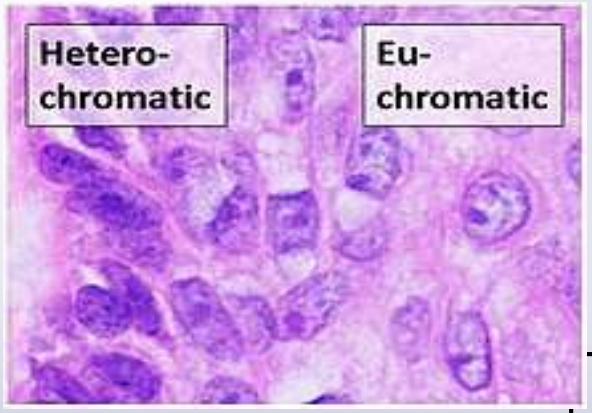
Euchromatin:

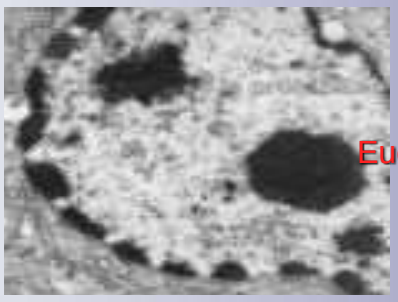
- Less condensed and can be transcribed.
- Genetically active type of chromatin involved in transcribing RNA to produce proteins used in cell function and growth.
- The predominant type of chromatin found in cells during interphase.
- More diffuse than the other kind of chromatin, which is termed heterochromatin.

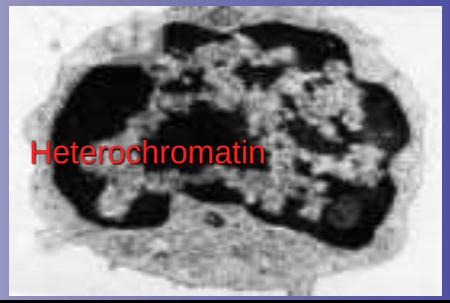
Heterochromatin:

- Highly condensed and cannot typically be transcribed. Involve various proteins in addition to the histones.
- DNA it contains is thought to be genetically inactive.
- Tends to be most concentrated along chromosomes at certain regions of the structures, such as the **centromeres** and **telomeres**.
- Genes typically located in euchromatin can be experimentally silenced (not expressed) by relocating them to a heterochromatin position.

Comparison between Euchromatin and Heterochromatin







	Euchromatin	Heterochromatin
1- L/M	-Pale nucleus -Can not be seen.	- Visible as blue basophilic granules
2- E/M	- Very fine threads in-between the condensed parts of chromatin.	- appears as (black) electron dense granules distributed throughout the nucleus.

The Nucleolus

- The **nucleolus** (plural **nucleoli**) is a **non-membrane** bound structure composed of **proteins** and **nucleic acids** found within the nucleus/ **1-2 µm**
- It is the **most dense** (prominent) structure of the cell, and frequently is located in central area of nucleus
- A single nucleus can house one to several nucleoli, depending on the organism and cell type. E.g. Liver cells and muscle fibers.

Function, site of **rRNA synthesis,** initial ribosomal **assembly**

Structure:

-fibrillar centers, filaments of chromatin

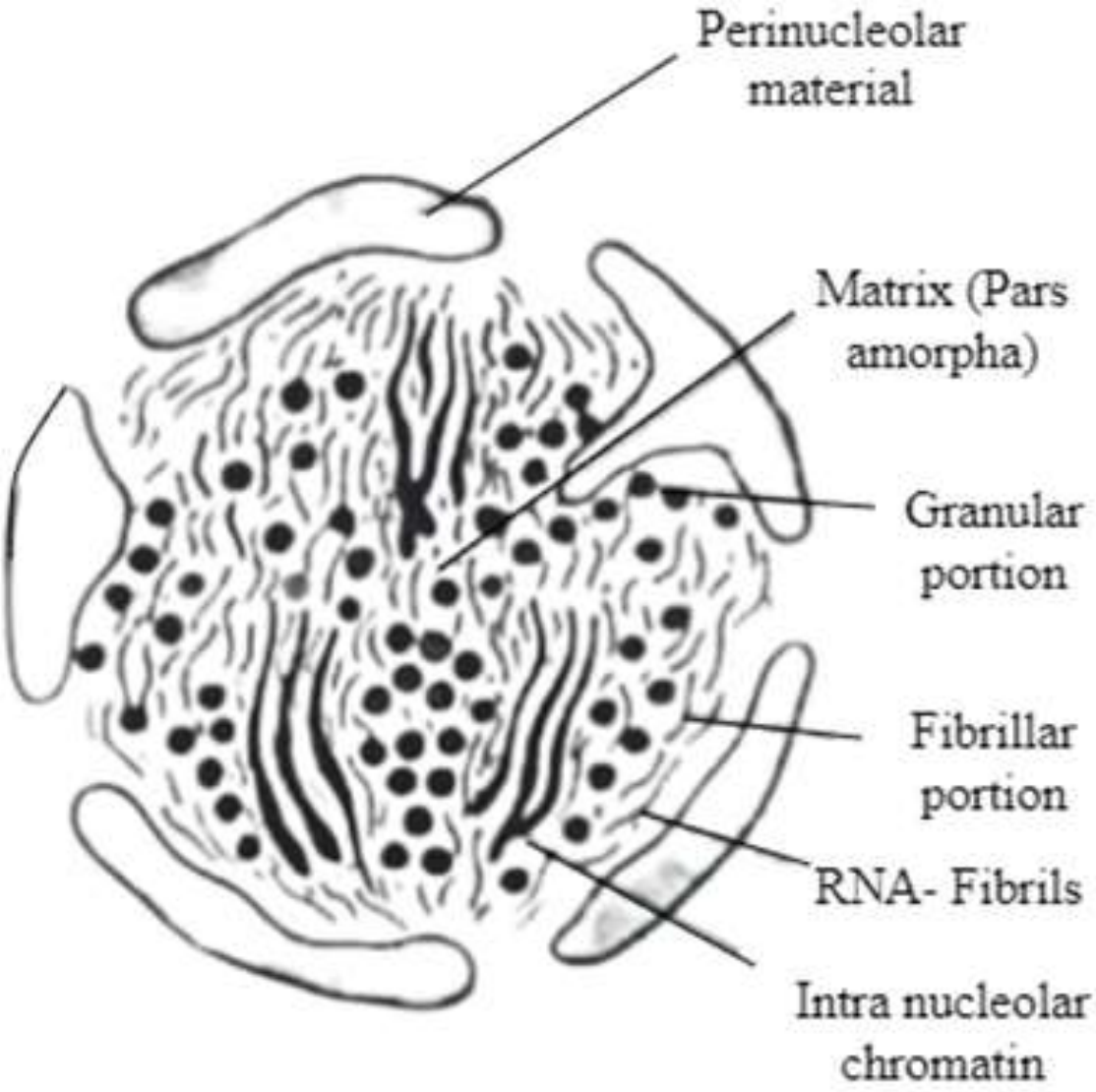
-pars fibrosa, newly transcribed rRNA

-pars granulosa, rRNA bound to ribosomal proteins that are beginning to **assemble** into ribosomes

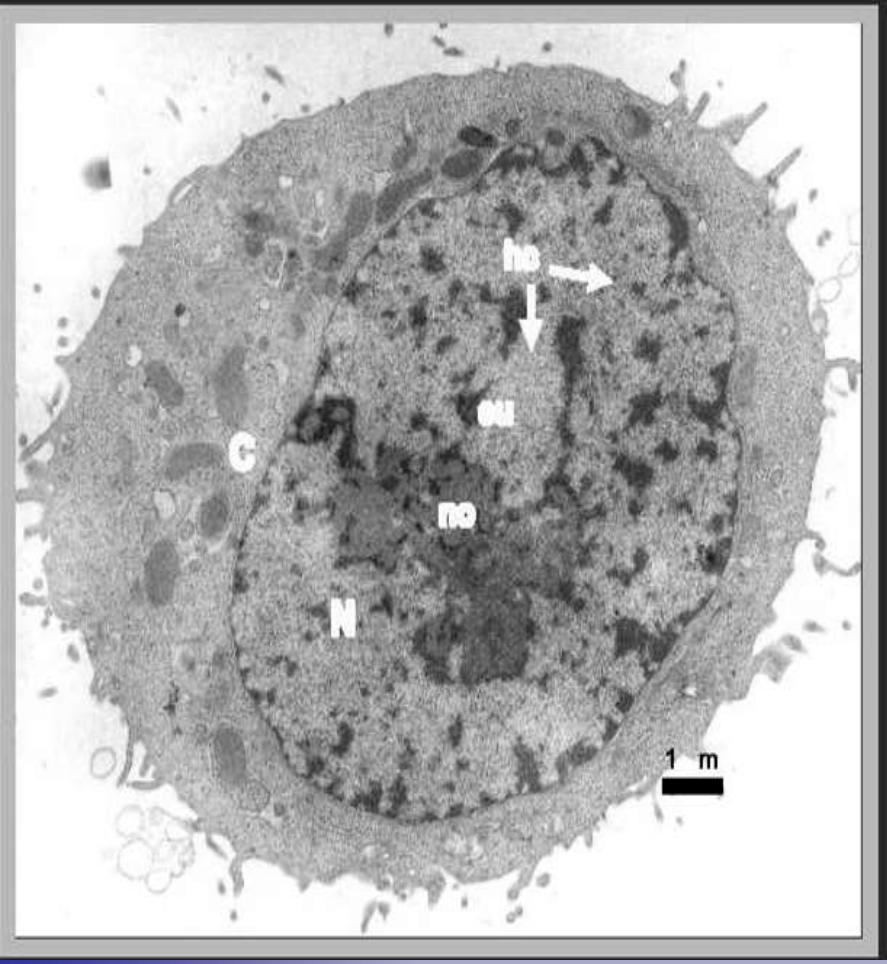
Structural of nucleolus

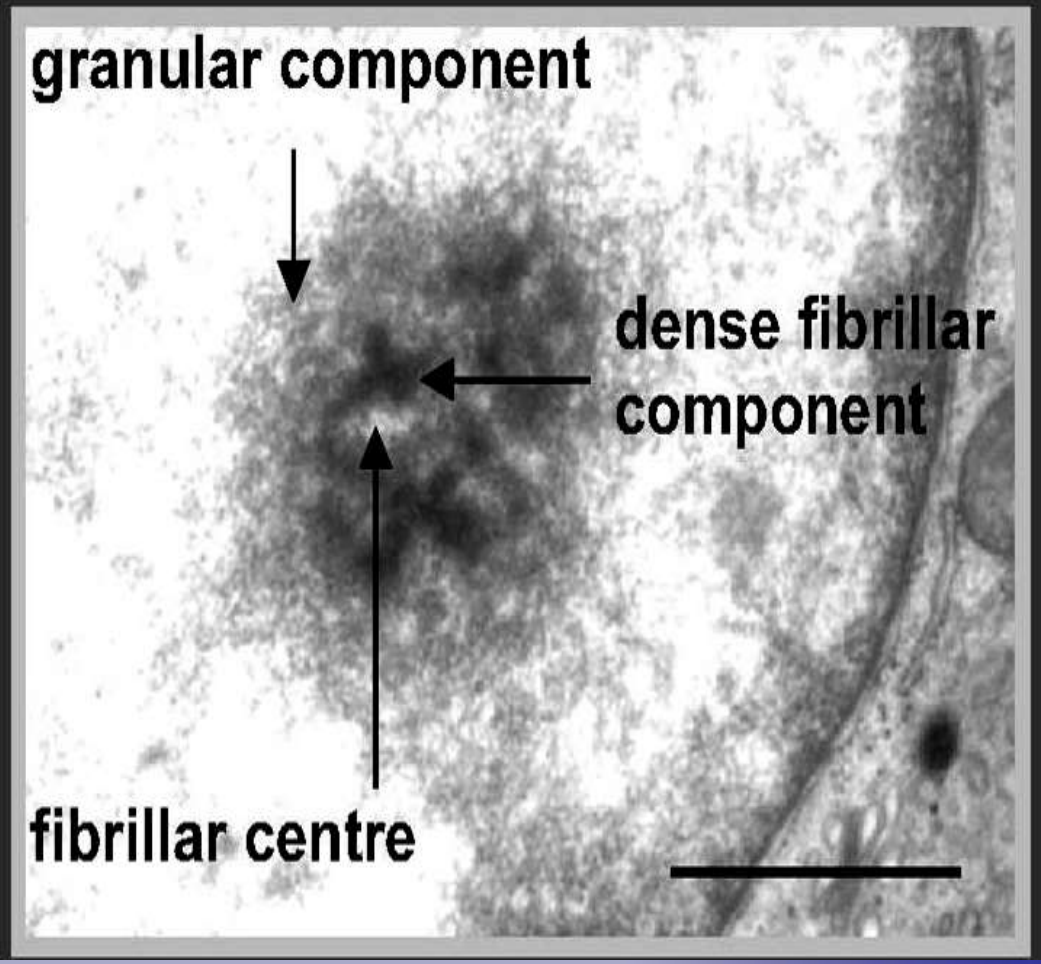
It has four components and they are as follows:

1. Amorphous matrix
2. Granular region, components of granules are proteins and RNA in the ratio 2:1 and these are thought to be the precursors of ribosomes.
3. Fibrillar region. The central region, the components of fibrils are ribosomal RNA or and proteins and they are believed to be the precursors of granules.
4. Chromatin part. Nucleolar chromatin contains DNA which contains genes for rRNAs and tRNAs.



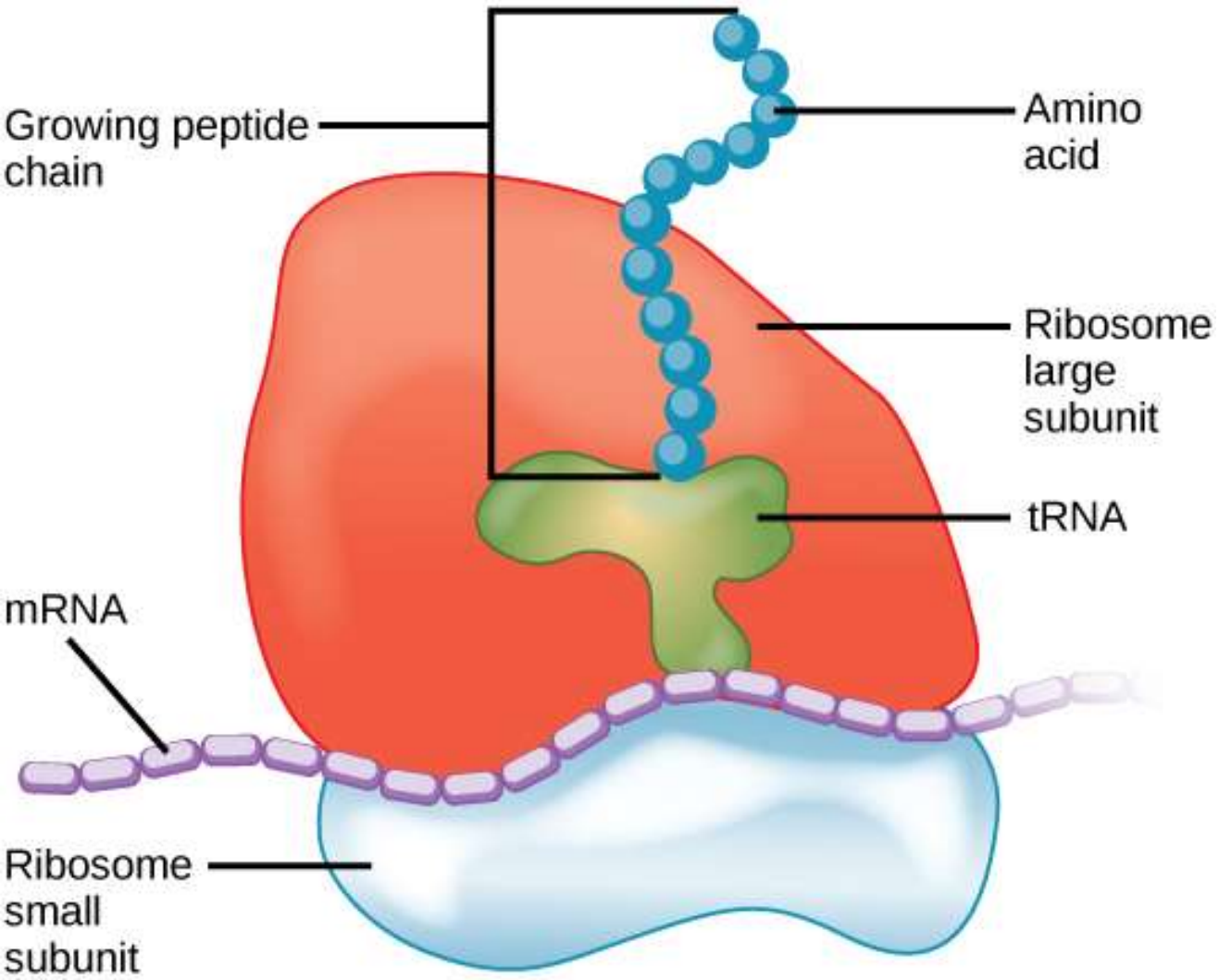
Ultrastructure of the nucleolus





Ribosomes - The Protein Builders of a Cell

- ✓ Ribosomes are cell organelles that function in protein synthesis.
- ✓ Ribosomes in plant and animals cells are larger than those found in bacteria.
- ✓ Ribosomes are composed of RNA and proteins that form ribosome subunits: a **large** ribosome subunit and **small** subunit.
- ✓ These two subunits are produced in the nucleus and unite in the cytoplasm during protein synthesis.
- ✓ Free ribosomes are found suspended in the cytosol, while bound ribosomes are attached to the endoplasmic reticulum.
- ✓ Mitochondria and chloroplasts are capable of producing their own ribosomes.


Growing peptide chain
Amino acid
Ribosome large subunit
tRNA
mRNA
Ribosome small subunit

- ✓ Eukarotic ribosomes (80S) consist of 60S+40S, such as those in plant and animal cells, are larger than

- ✓ Prokaryotic ribosomes (70S) consist of 50S+ 30S, such as those in bacteria.

- ✓ Ribosomal subunits are synthesized in the nucleolus and cross over the nuclear membrane to the cytoplasm through nuclear pores.
- ✓ **Mitochondria and chloroplasts** in eukaryotic organisms have their own ribosomes.
- ✓ Ribosomes in these organelles are more like ribosomes found in bacteria with regard to size.

❖ Location in the Cell

There are **two places** where ribosomes commonly exist within a eukaryotic cell:

1. Suspended in the cytosol (free ribosomes)
2. Bound to the endoplasmic reticulum.

❖ **Free ribosomes function**

- Make proteins that will function in the cytosol (fluid component of the cytoplasm).

❖ **Bound ribosomes function**

- Make proteins that are exported from the cell or included in the cell's membranes.
- Interestingly enough, free ribosomes and bound ribosomes are interchangeable and the cell can change their numbers according to metabolic needs.

❖ S in 80S and 70S referring to their sedimentation coefficients in **Svedberg units**, because they sediment faster than the prokaryotic (70S) ribosomes.

Nucleus Worksheet