



# CELL ULTRASTRUCTURE LECTURE



**Curriculum: Phase 1/ Semester2/ TOB/ Session 1,Lecture 2**

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**Degrees: MSc/Ph.D. Histology**

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# SELECTED REFERENCES



- **Histology Textbooks 'Basic Histology', Junqueira, 13 th Edition chapter 1,2,3.pp:1-72**
- **'Colour Atlas of Histology' Gartner and Hiatt 5 th Edition.**



# LECTURE OBJECTIVES



- ❖ define the term “limit of resolution”.
- ❖ explain why electron microscopes are capable of finer resolution than light microscopes
- ❖ draw a simplified diagram of a cell, clearly labelling those ultrastructural components common to eucaryotic animal cells.



❖ ***State how a cell functions by describing the structure and function of the following cell components and organelles:***

- ***membranes (bilipid)***
- ***plasmamembrane***
- ***glycocalyx***
- ***Nucleus***
- ***nucleolu s***
- ***Cytoskeleton***
- ***smooth endoplasmic reticulum***



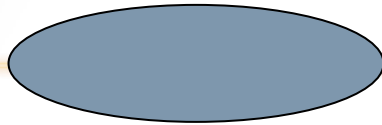
- **Golgi apparatus**
- **Ribosomes**
- **secretory vesicles**
- **Lysosomes**
- **Peroxisomes**
- **Mitochondria**
- **nuclear envelope**
- **rough endoplasmic reticulum**



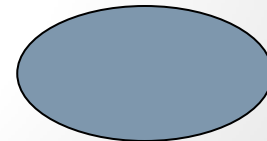
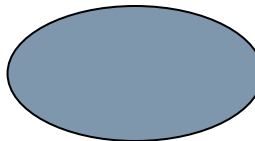
# ***LIMIT OF RESOLUTION***

**Limit of Resolution = the minimum distance at which two objects can be distinguished.**

**Unresolved**



**Resolved (seen as distinct )**





# explain why electron microscopes are capable of finer resolution than light microscopes



Limit of Resolution  $\longrightarrow$  wavelength ( $\lambda$ )

(ie Resolution improves as  $\lambda$  decreases)

☐ Visible light: Violet  $\lambda = 0.4 \mu\text{m}$

Deep red  $\lambda = 0.7 \mu\text{m}$

☐ Electron (at 100,000V acceleration)  $\lambda = 0.004\text{nm}$

☐ Theoretical Limit of Resolution

➤ for light microscope is  $0.2 \mu\text{m}$

➤ for electron microscope is  $0.002 \text{ nm}$

**Electron Scanning  
micrograph of rat  
fibroblasts growing on  
a plastic surface in  
tissue culture.**







**Draw a simplified diagram of a cell, clearly labelling those ultrastructural components common to eukaryotic animal cells.**



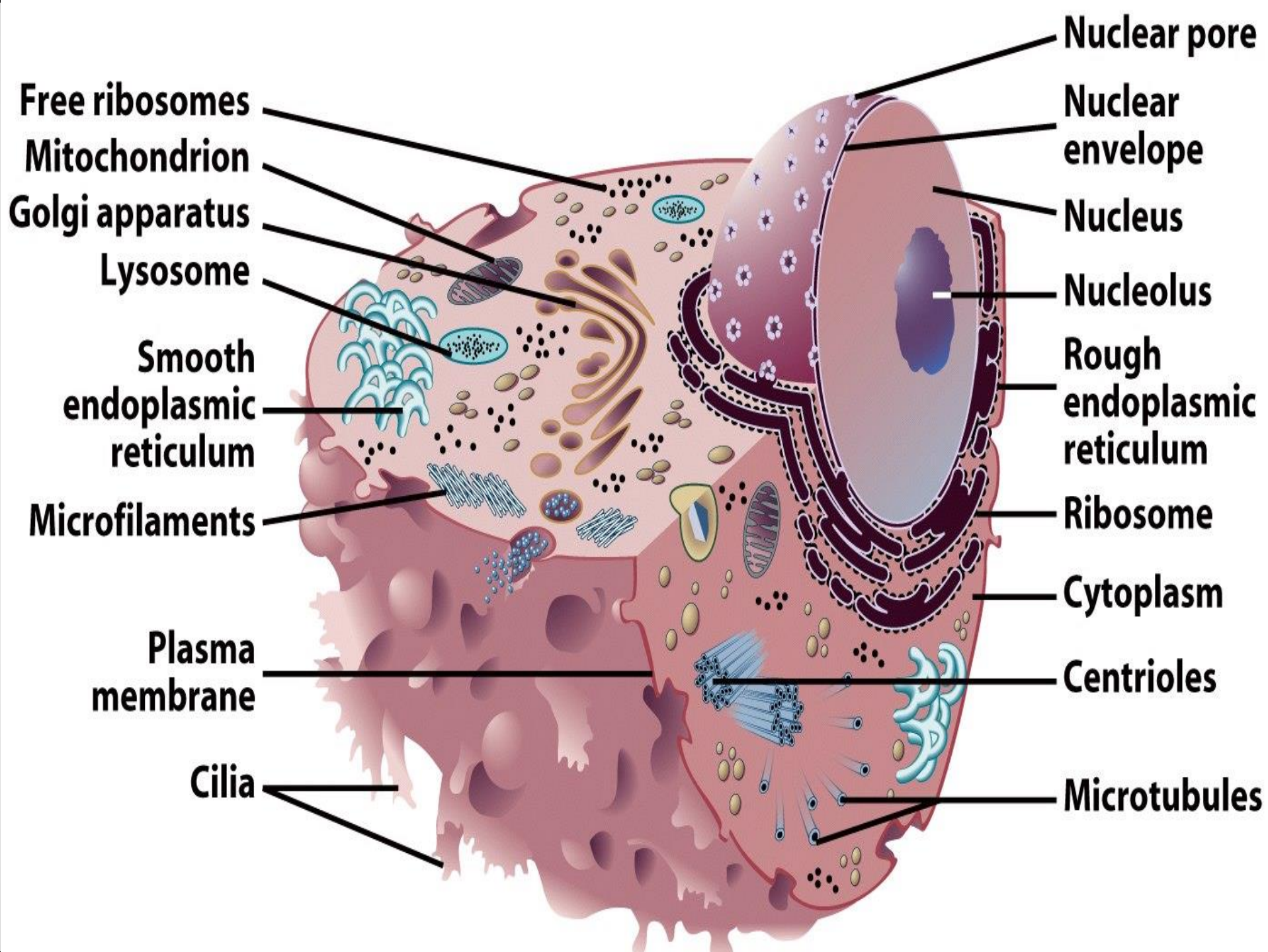
## **Eukaryotic cell**

**Cell interior is divided into functional compartments, including a nucleus that contains the DNA – key here is the nucleus that separates eukaryotes from the prokaryote life forms**

**Usually have organelles and sexual reproduction**

## **Prokaryotic cell**

**Small, simple cells without a nucleus no organelles and asexual reproduction only**





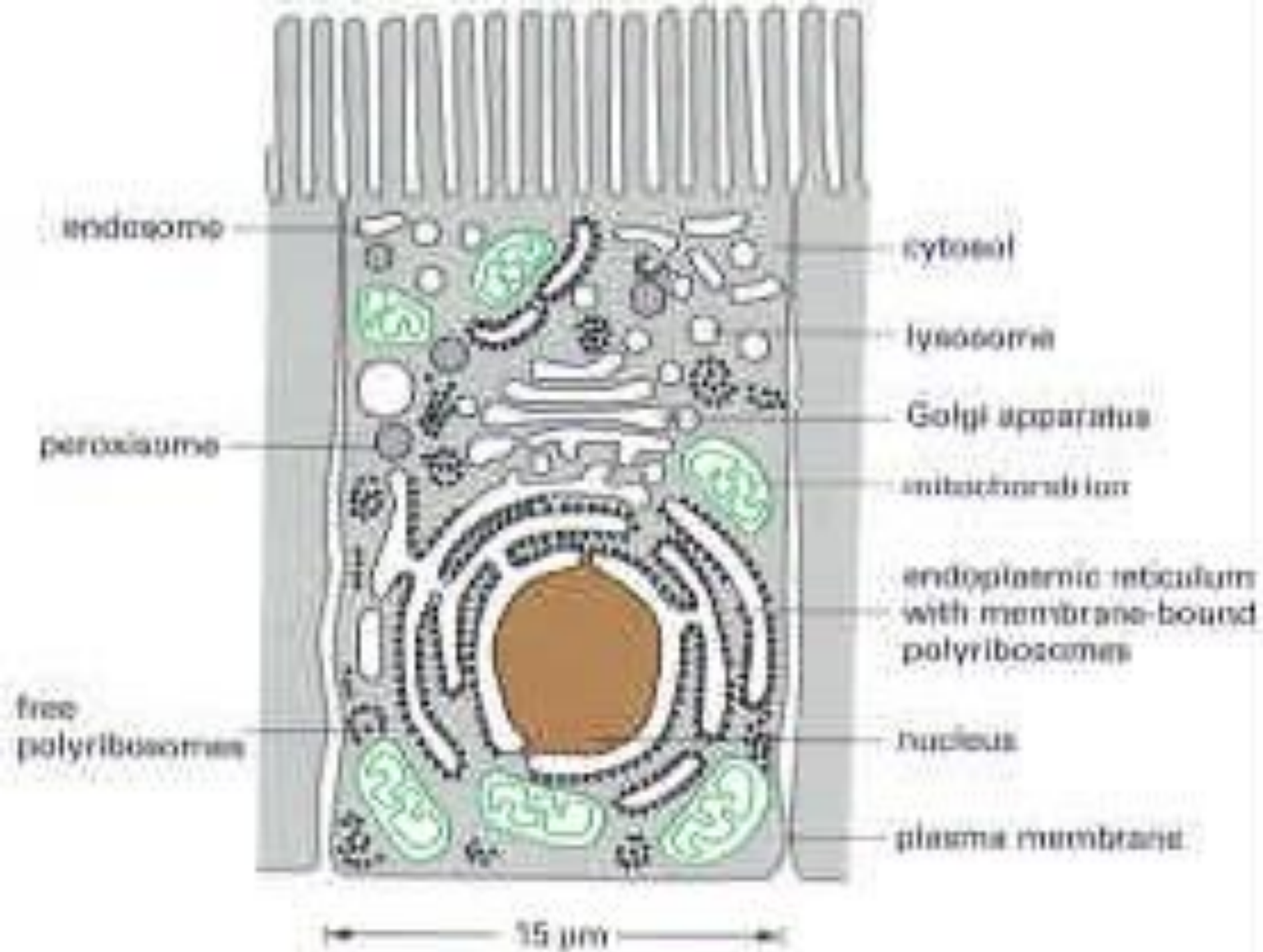
**Prokaryotes, like E. coli (right) have an external membrane**

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**But no internal membranes. All the biochemical processes of the cell occur in the same compartment**

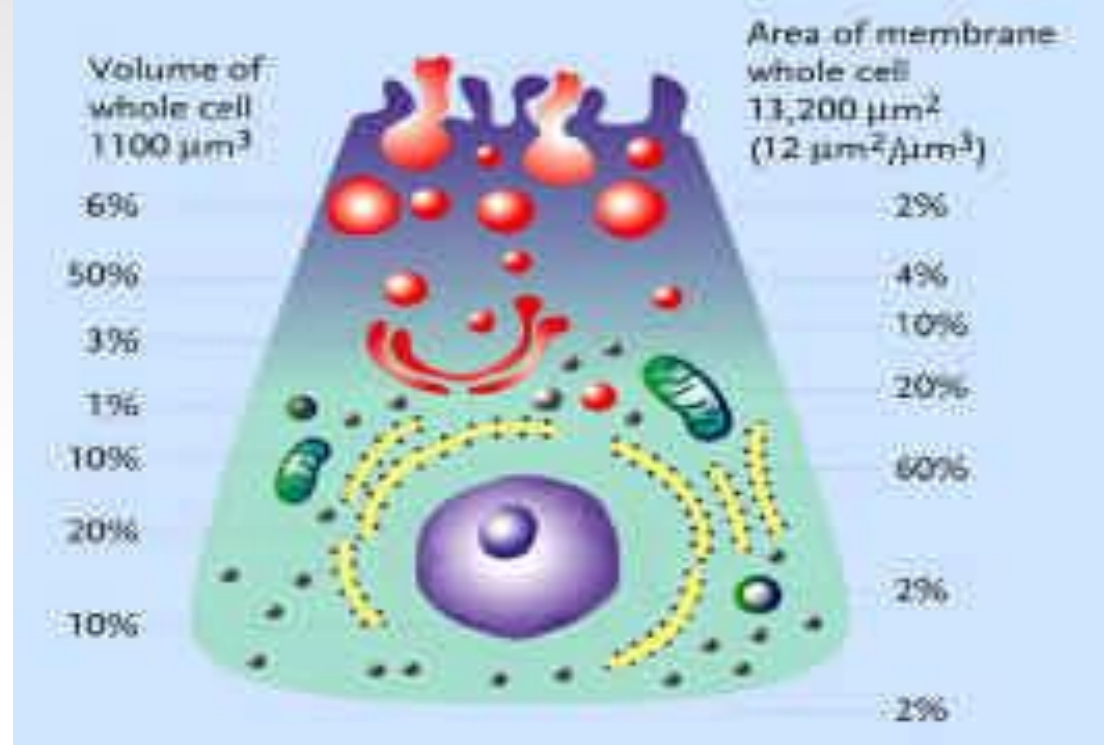






# Cell Size

Surface-to-volume ratio restricts cell size by limiting transport of nutrients and wastes



Diameter (cm)

2

3

6

Surface area ( $\text{cm}^2$ )

12.6

28.2

113

Volume ( $\text{cm}^3$ )

4.2

14.1

113

Surface-to-volume ratio

3:1

2:1

1:1



**state how a cell functions by describing the structure and function of the following cell components and organelles:**

*membranes (bilipid)*

*plasmamembrane*

*glycocalyx*

*Nucleus*

*nucleolu s*

*Cytoskeleton*

*smooth endoplasmic reticulum*

*ribosomes*

*Golgi apparatus*

*secretory vesicles*

*lysosomes*

*peroxisomes*

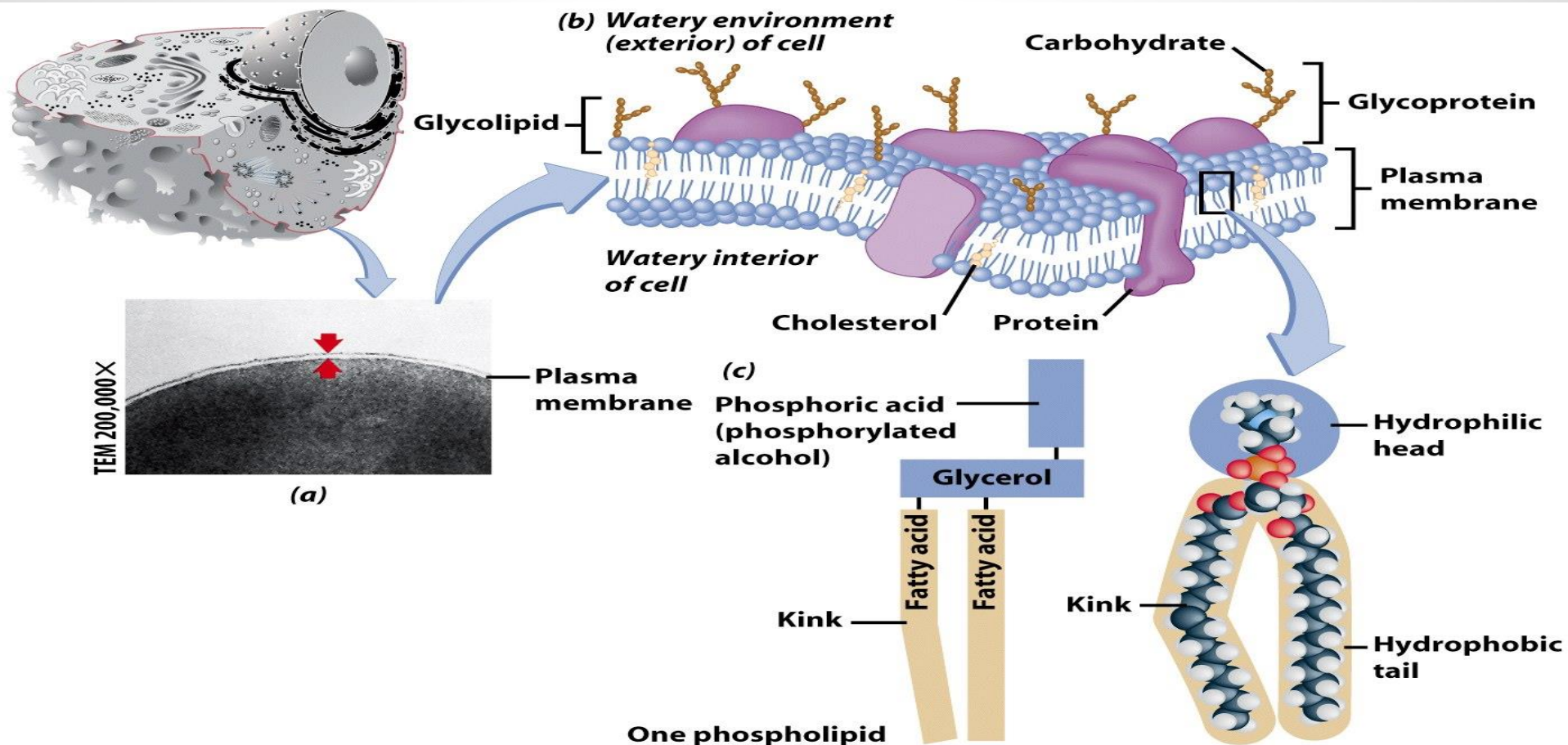
*mitochondria*

*nuclear envelope*

*rough endoplasmic reticulum*

# Basic Structure of Cell(PlasmaMembrane)

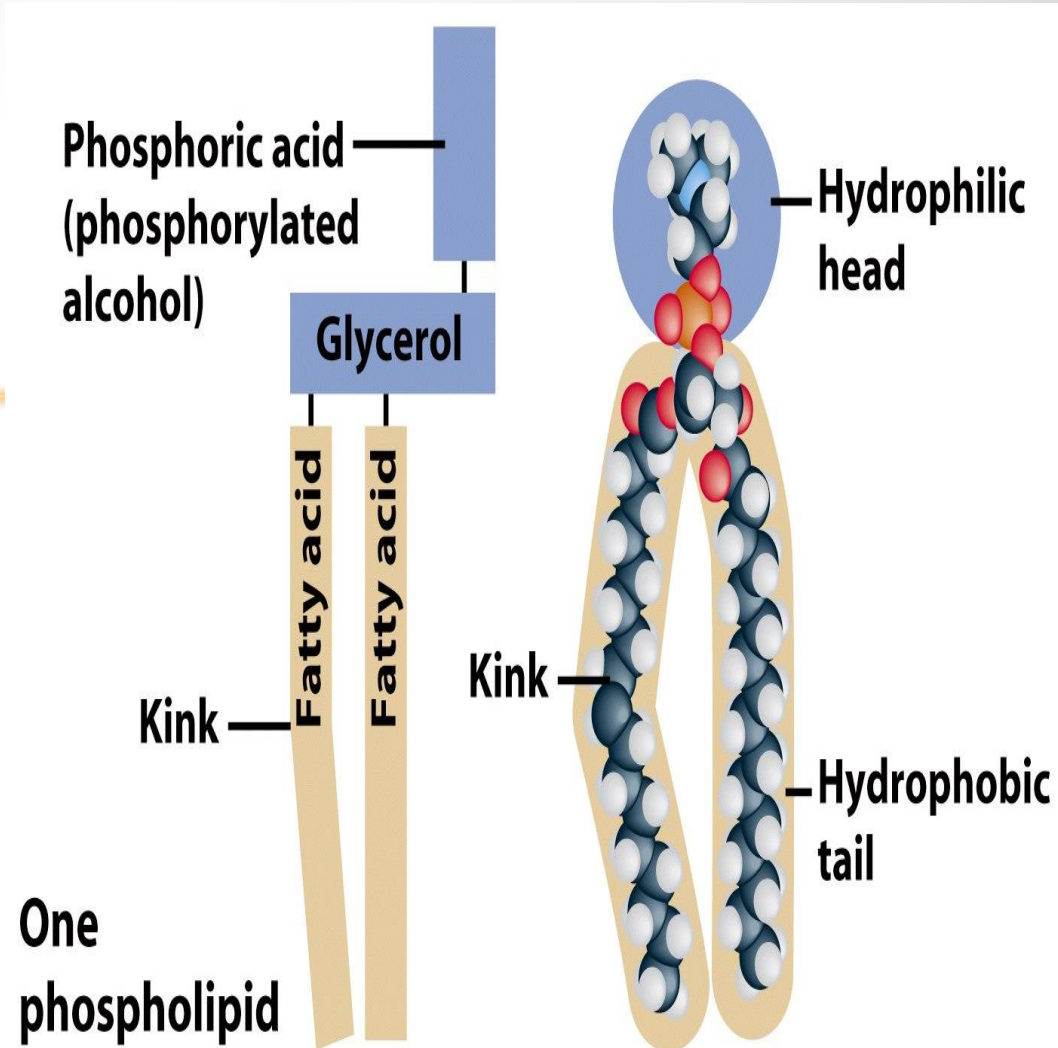
- Contains cell contents
- Double layer of phospholipids & proteins





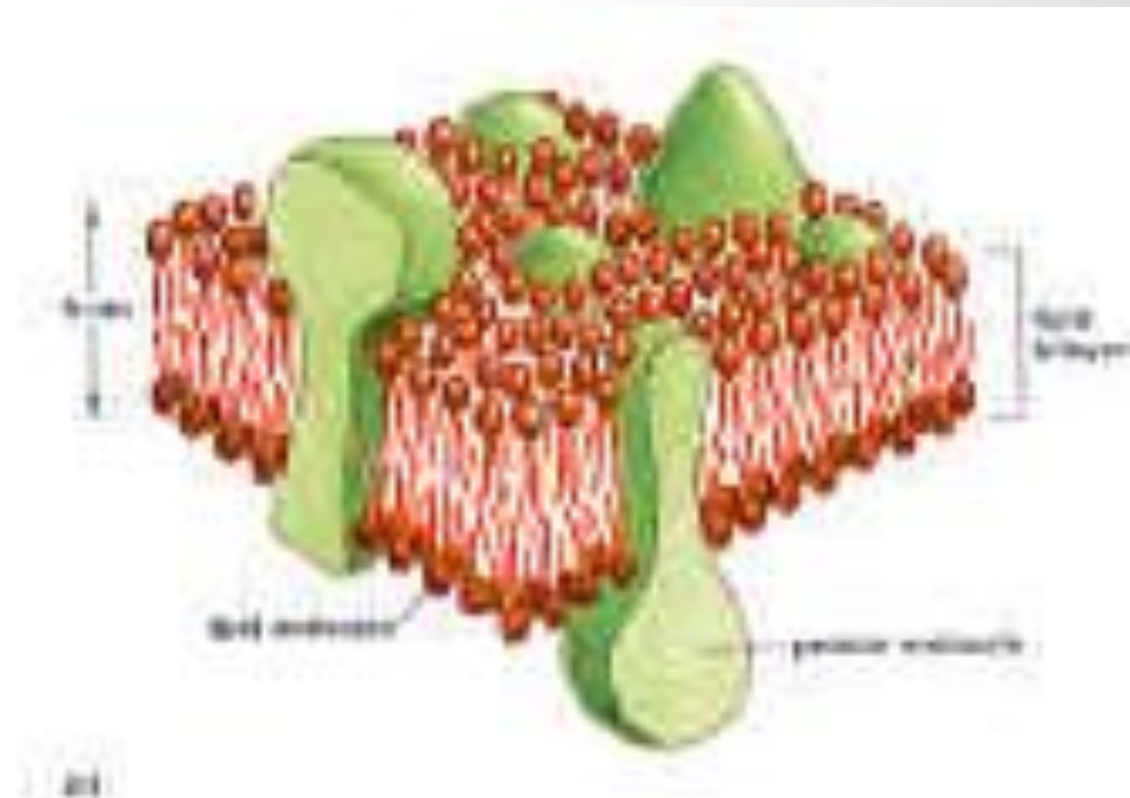
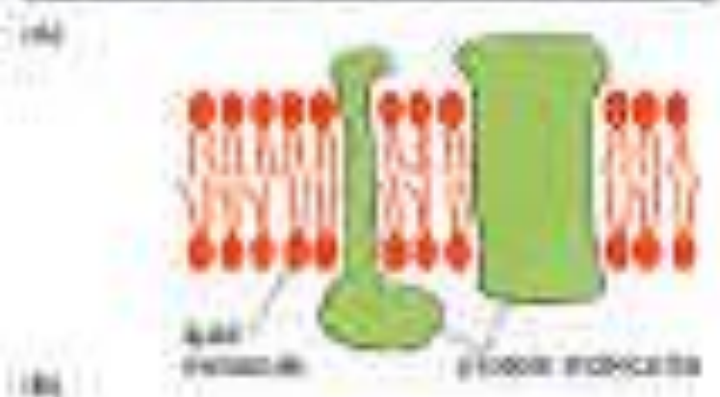
# Phospholipids

- **Polar**
  - Hydrophilic head
  - Hydrophobic tail
- 
- **Interacts with water**

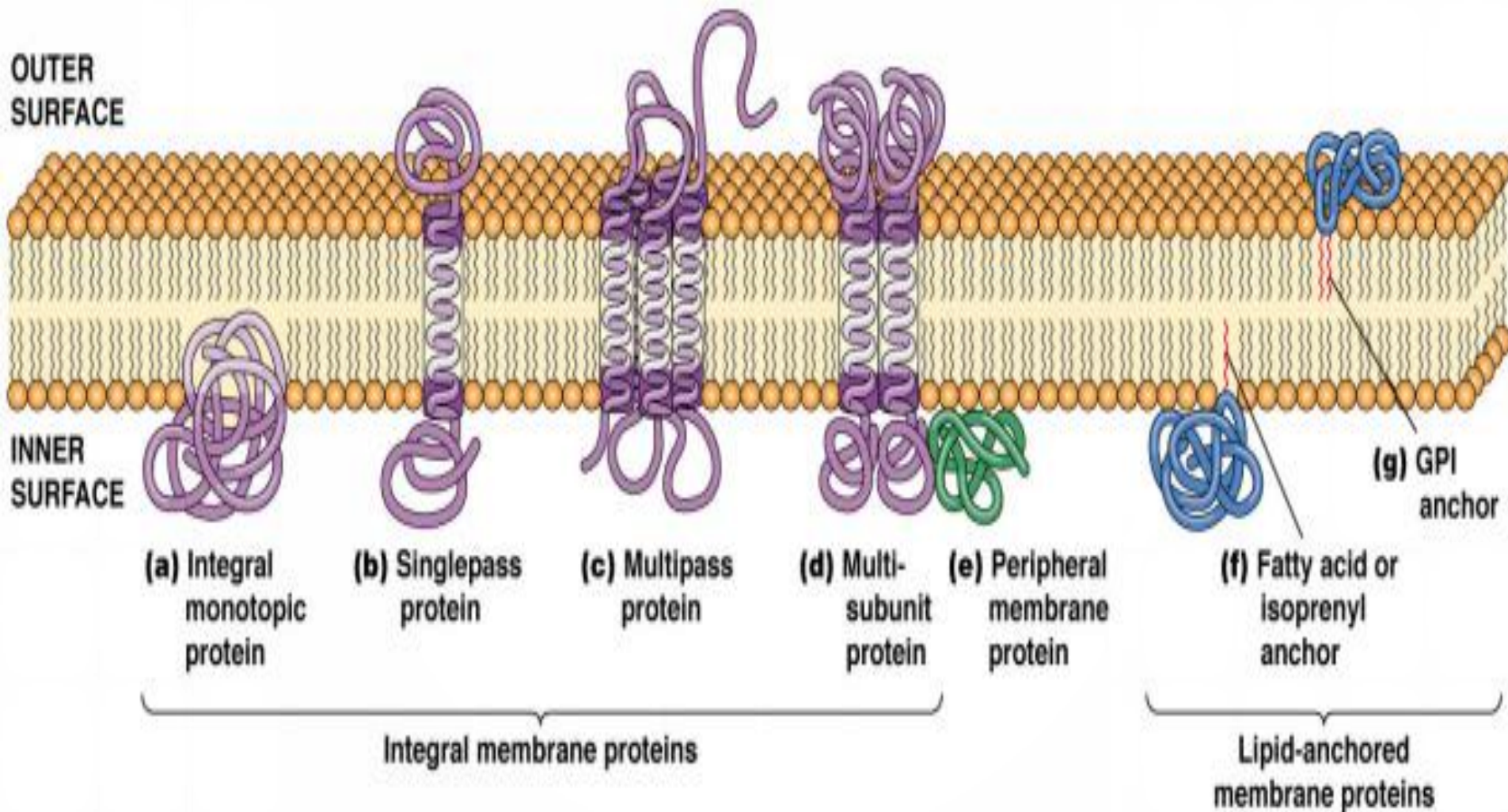




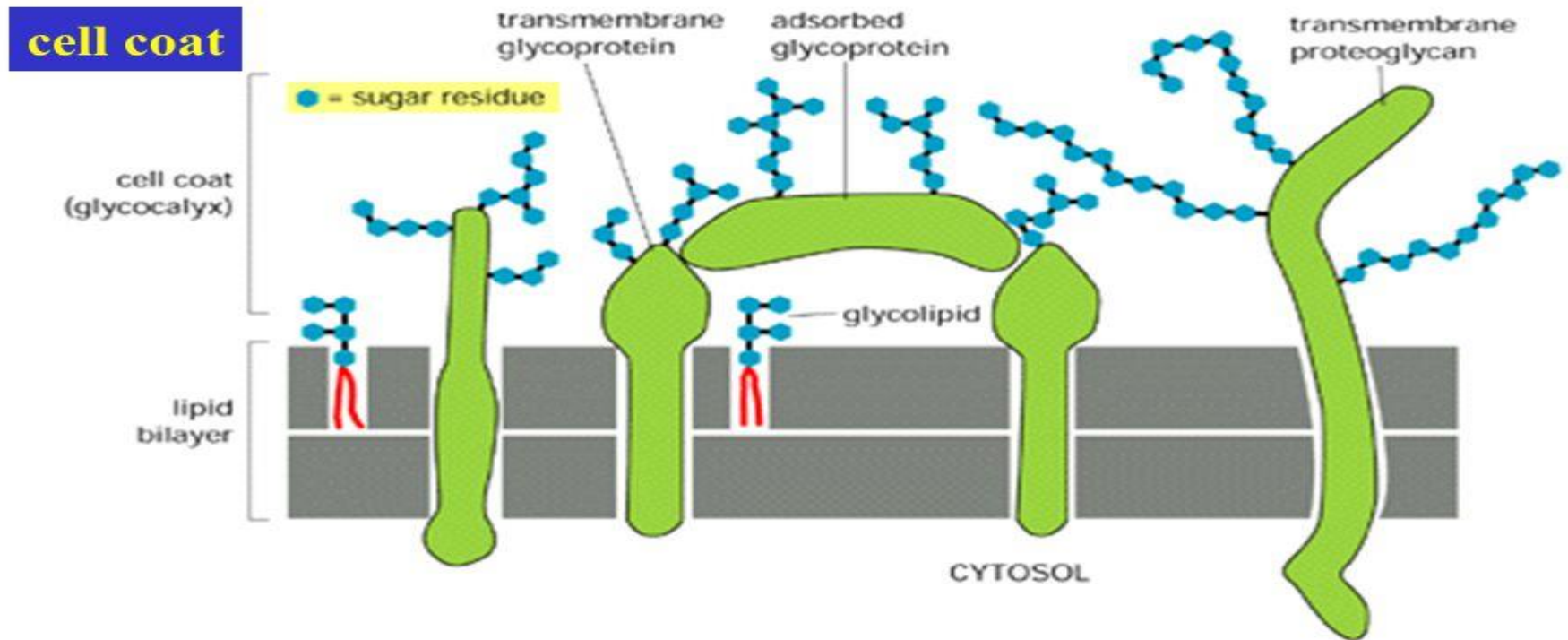
The phospholipid bilayer (membrane) forms a relatively impermeable barrier to most water-soluble molecules. The protein molecules, “dissolved” in the lipid bilayer mediate most of the other functions of the membrane.



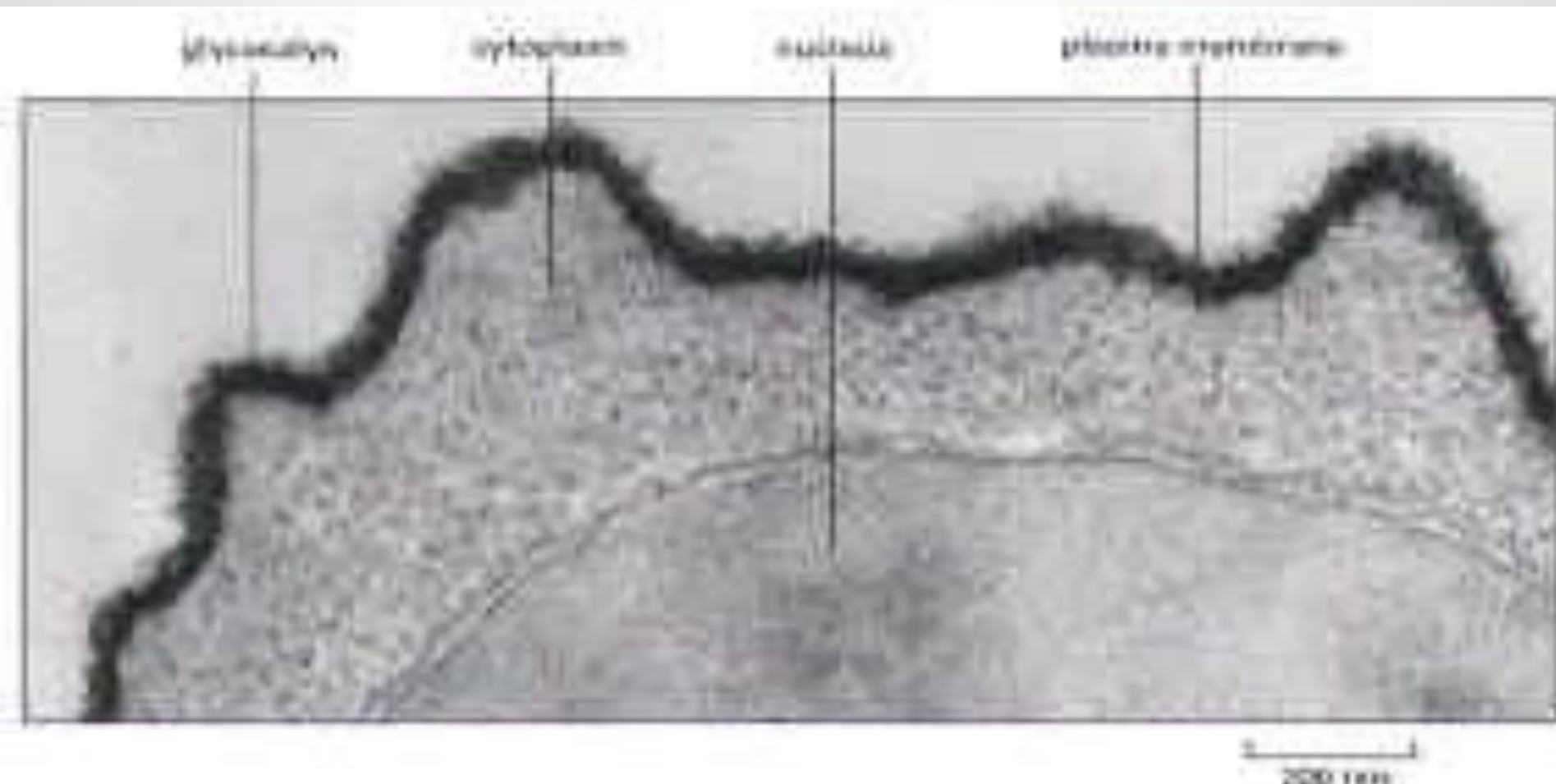
**Membrane proteins can be associated with the lipid bilayer in different ways.**







**Figure 10-41. Simplified diagram of the cell coat (glycocalyx).** The cell coat is made up of the oligosaccharide side chains of glycolipids and integral membrane glycoproteins and the polysaccharide chains on integral membrane proteoglycans. In addition, adsorbed glycoproteins and adsorbed proteoglycans (not shown) contribute to the glycocalyx in many cells. Note that all of the carbohydrate is on the noncytoplasmic surface of the membrane.





## Functions of plasma membrane (plasmalemma)

- Selective permeability
- Transport of materials along cell surface
- Endocytosis
- Exocytosis
- Intercellular adhesion
- Intercellular recognition
- Signal transduction



# MOVEMENT ACROSS THE PLASMA MEMBRANE



A few molecules move freely:

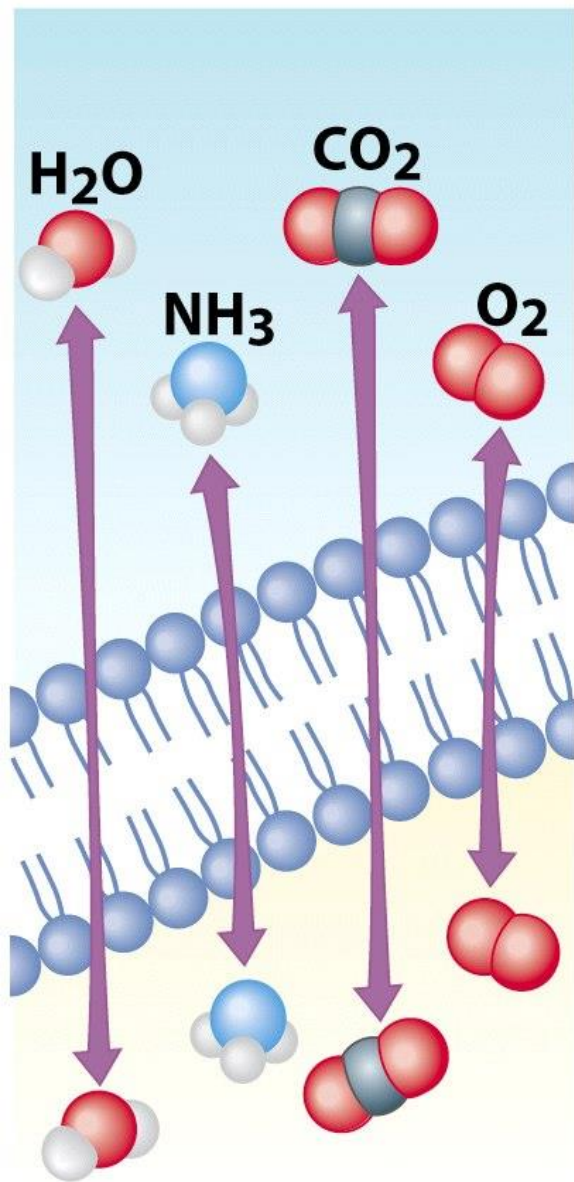
- Water, Carbon dioxide, Ammonia, Oxygen

Carrier proteins transport some molecules:

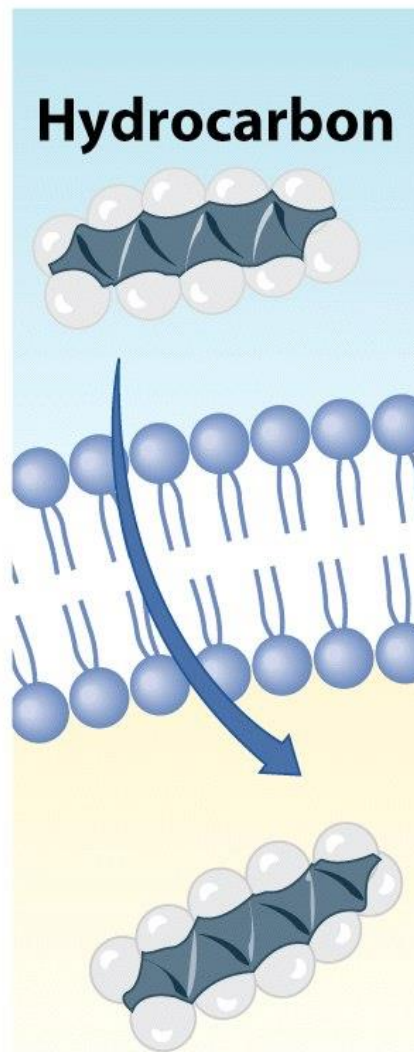
- Proteins embedded in lipid bilayer
- Fluid mosaic model – describes fluid nature of a lipid bilayer with proteins



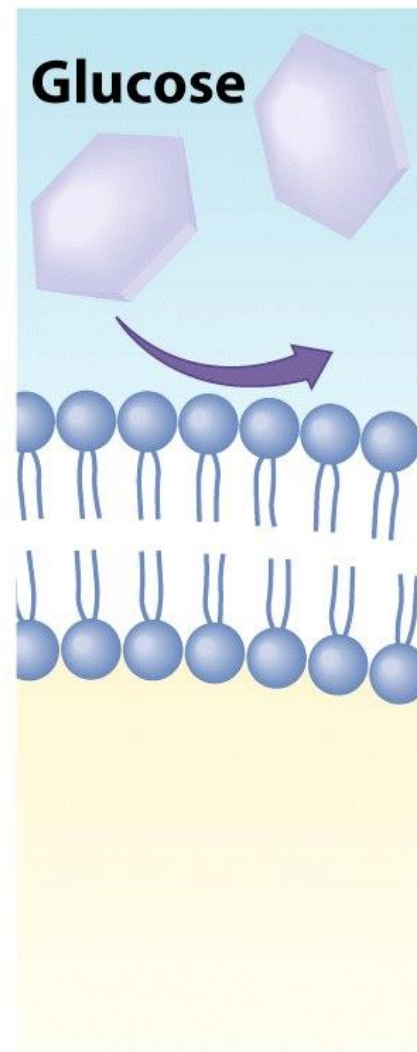
**(a)**  
**Small uncharged molecules**



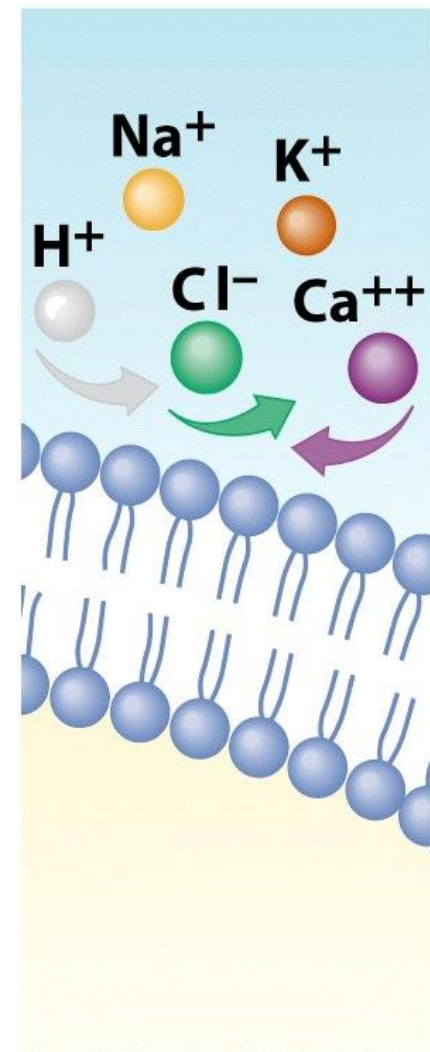
**(b)**  
**Lipid-soluble substances**



**(c)**  
**Water-soluble substances**

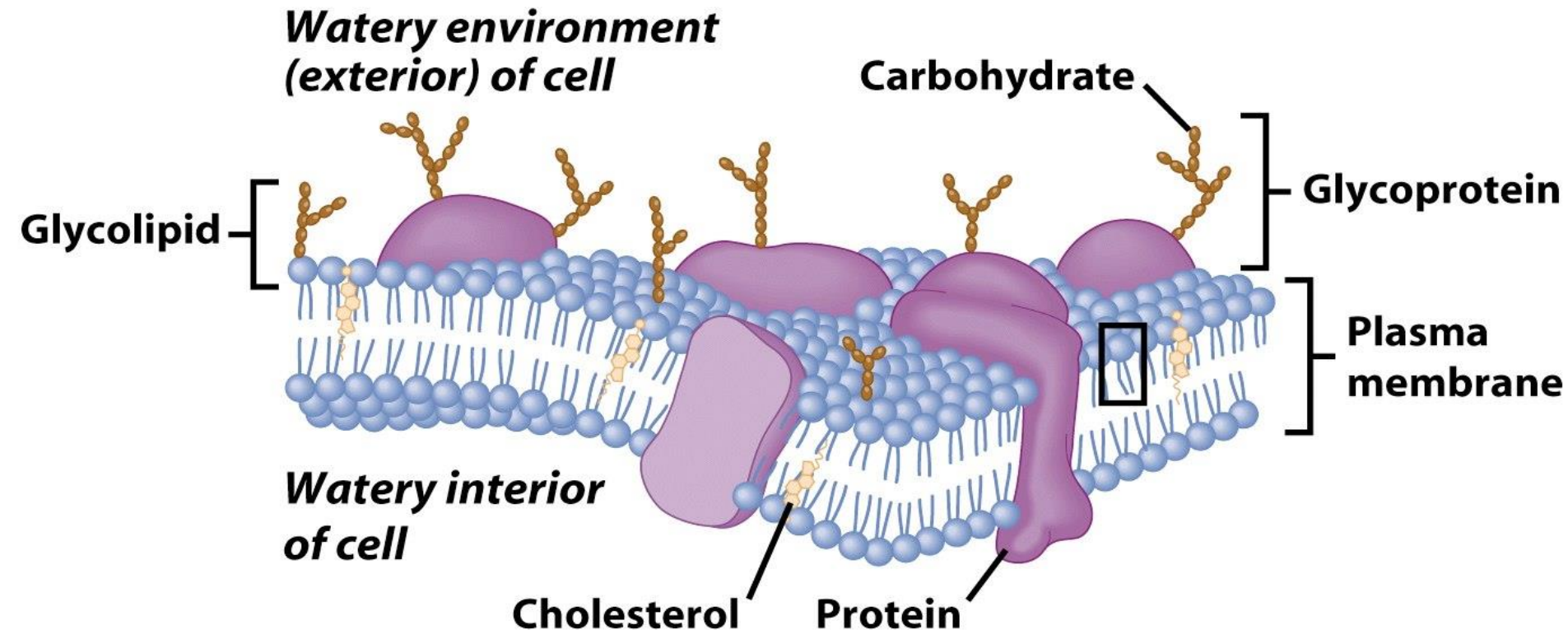


**(d)**  
**Ions**



# Membrane Proteins

1. Channels or transporters (Move molecules in one direction)
2. Receptors (Recognize certain chemicals)
3. Glycoproteins (Identify cell type)
4. Enzymes (Catalyze production of substances)



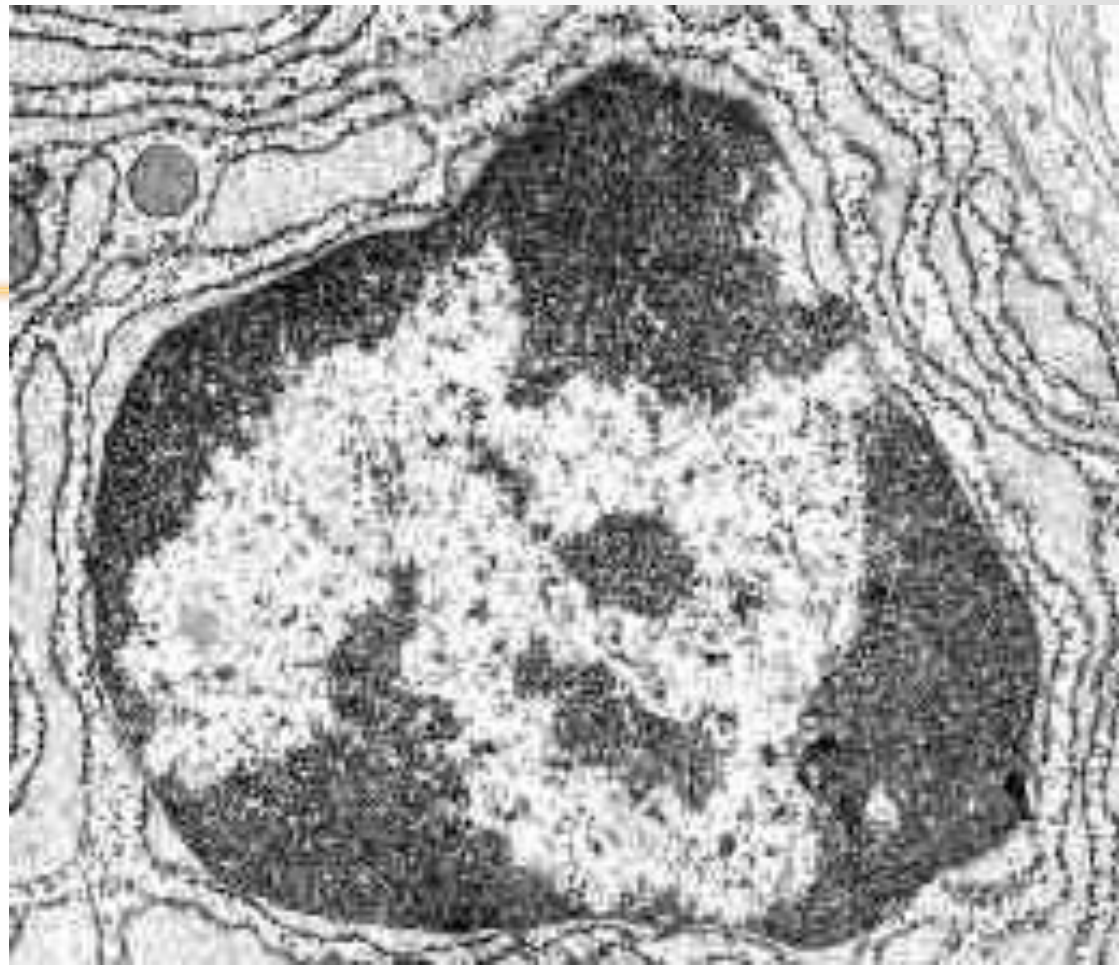




# Nucleus (TEM)



- Control center of cell separates nucleus from rest of cell
- Double membrane has pores
- Contains
  - Chromosomes
  - Nucleolus





# DNA – Chromatin, Chromosomes, genes



## ❑ Chromatin

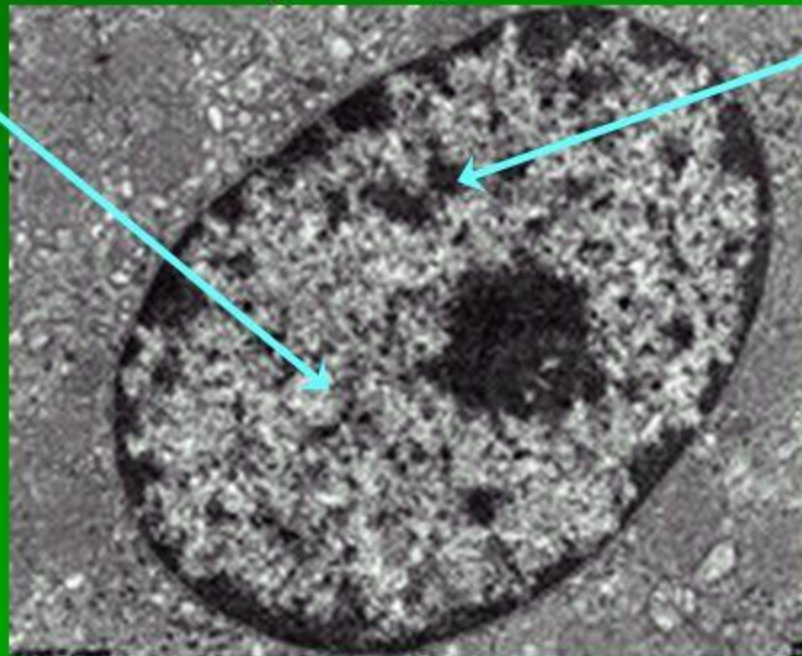
- The DNA and associated proteins in the nucleus
- Name used when DNA is not condensed

## ❑ Chromosome

- A single DNA molecule with its attached proteins
- During cell division, chromosomes condense and become visible in micrographs
- Human have 46 chromosomes (23 sets of 2)
- Name used when DNA is condensed
- Genes are identified stretches of DNA that carry the heritable information for a trait

## II.1.4.2. Chromatin

The chromatin is composed of deoxyribonucleic acids and proteins. In interphase they are arranged in a relatively loose, „network” form. EM shows that there are two different forms of the chromatin, one appearing as a light element (euchromatin), the other one being dark (heterochromatin).



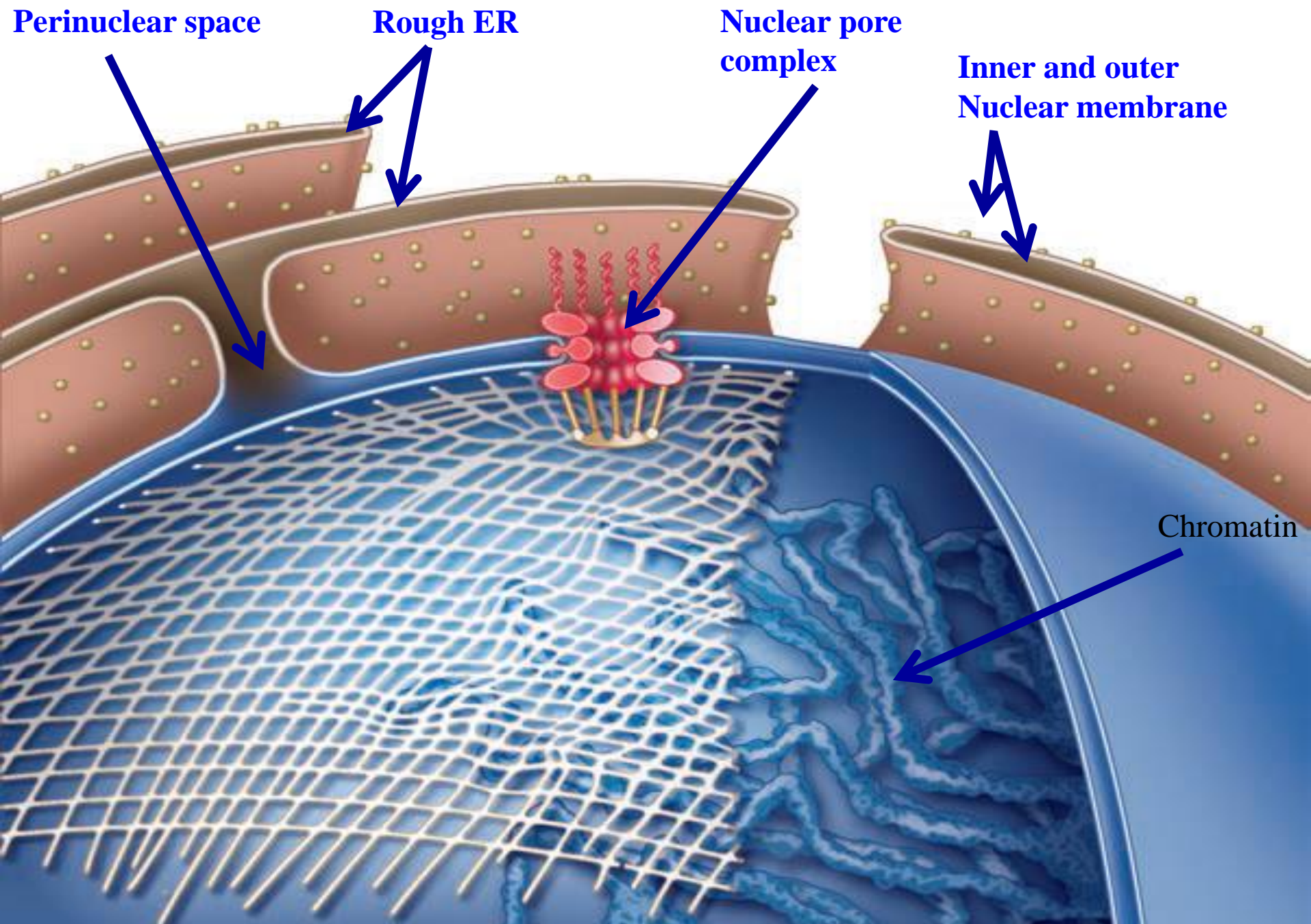
### Euchromatin:

Here the chromatin is loosely arranged. The DNA double helices are partially split to single strands by RNA polymerases.

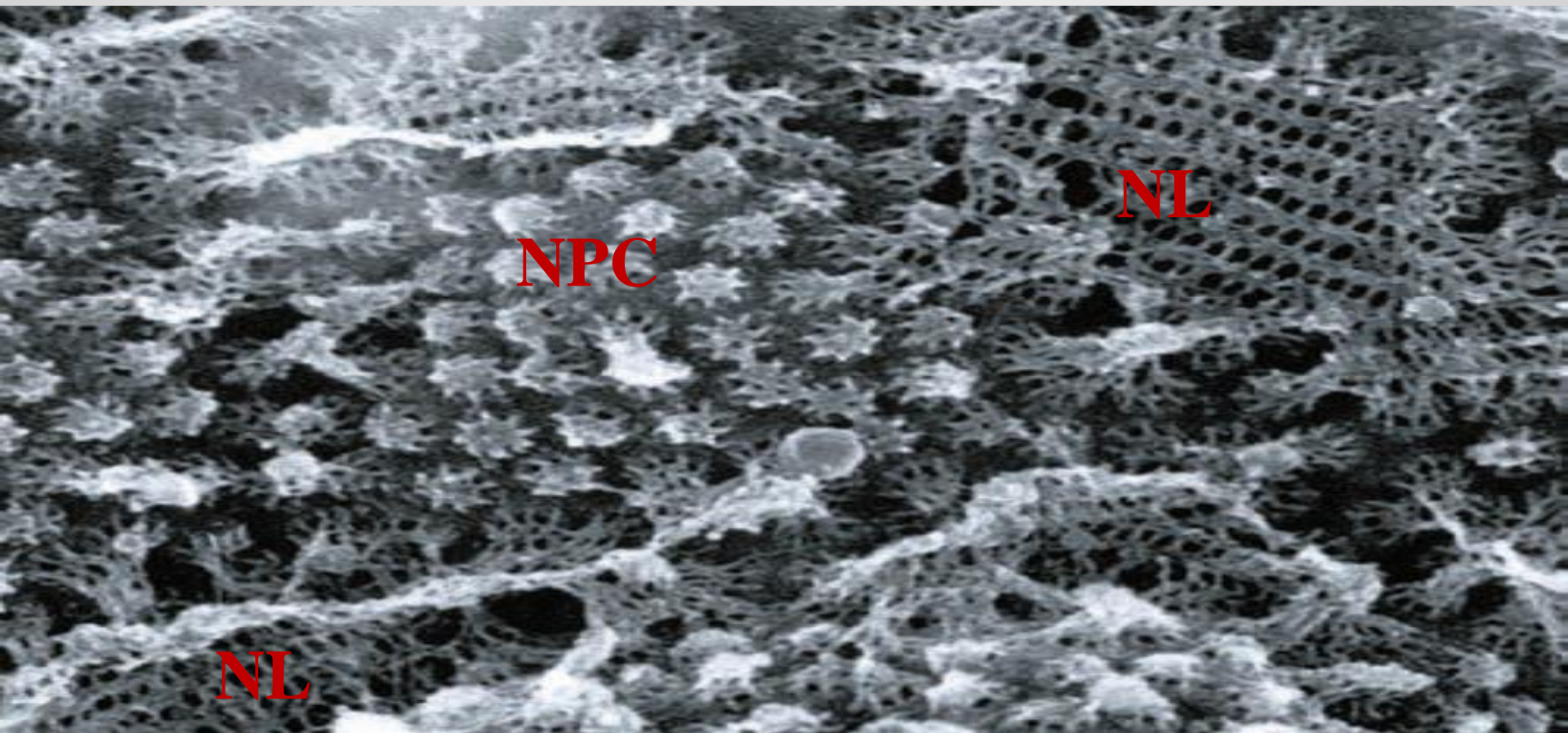
### Heterochromatin:

Closely packed chromatin. The DNA is organized by histone and non-histone proteins.



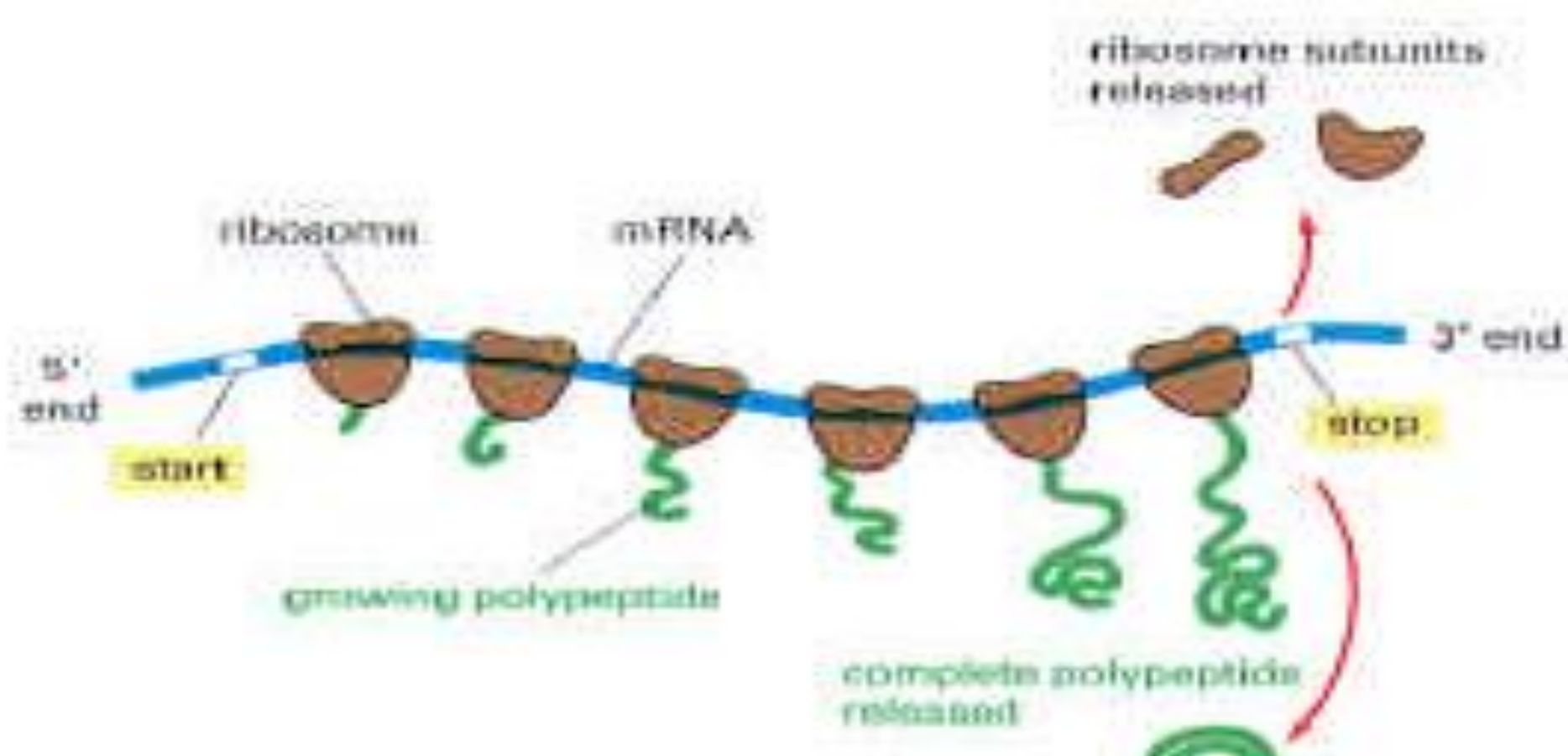






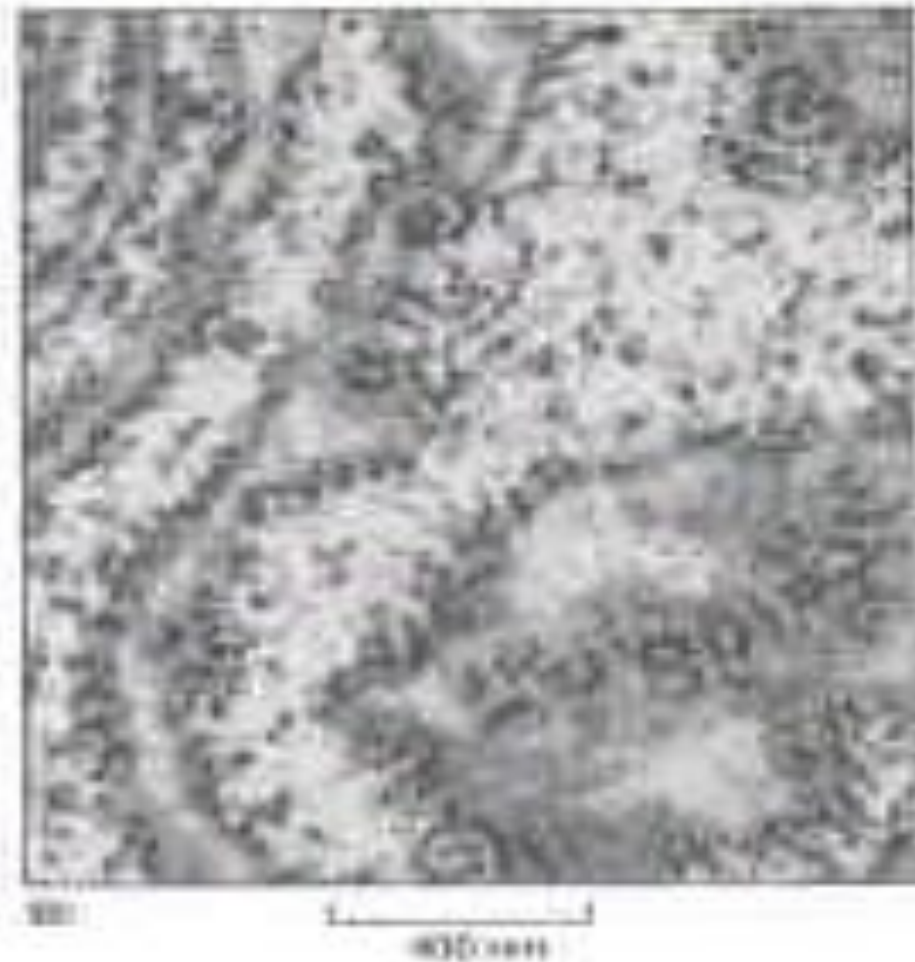
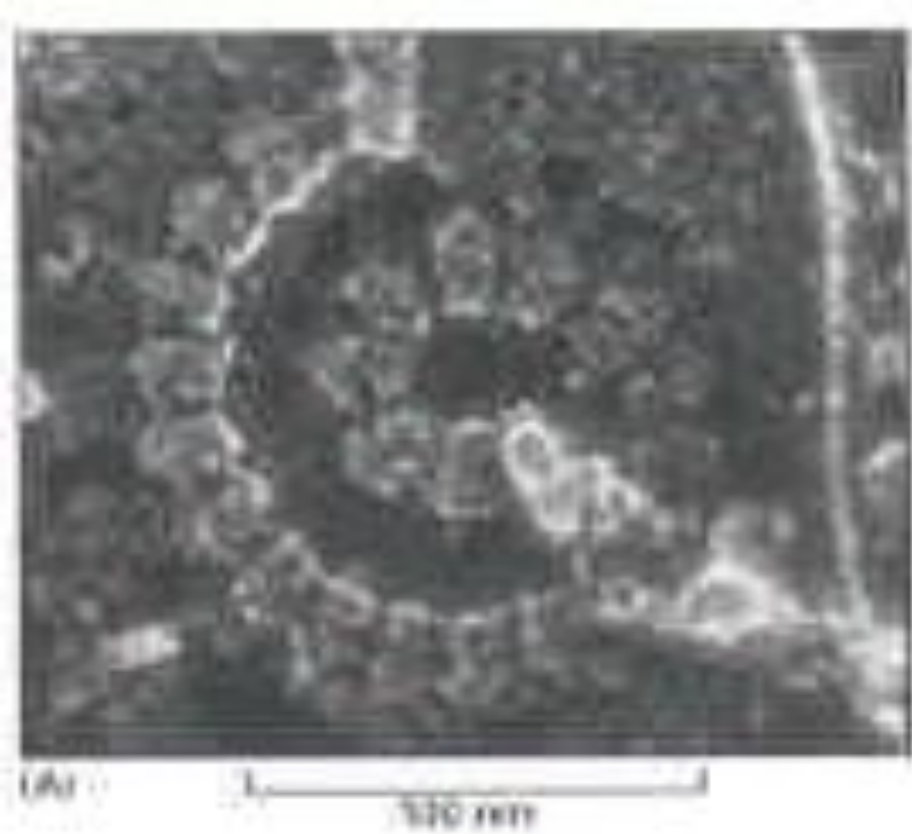
Scanning EM of the inner nuclear membrane (nucleoplasmic face) showing portions of the nuclear lamina (**NL**) meshwork with many embedded nuclear pore complexes (**NPC**). The preparation is from an actively growing amphibian oocyte. Nuclei of these very large cells can be isolated manually, facilitating ultrastructural studies of the nucleaenvelope.X100,000

**Ribosomes are sites of translation.**  
**Ribosomes are the “machinery” for protein synthesis.**





## Polyribosomes in the cell cytoplasm during protein synthesis.





# The Endoplasmic Reticulum

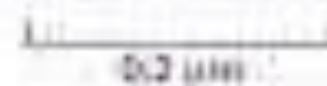
## Endoplasmic reticulum (ER)

An extension of the nuclear envelope that forms a continuous, folded compartment

### Two kinds of endoplasmic reticulum

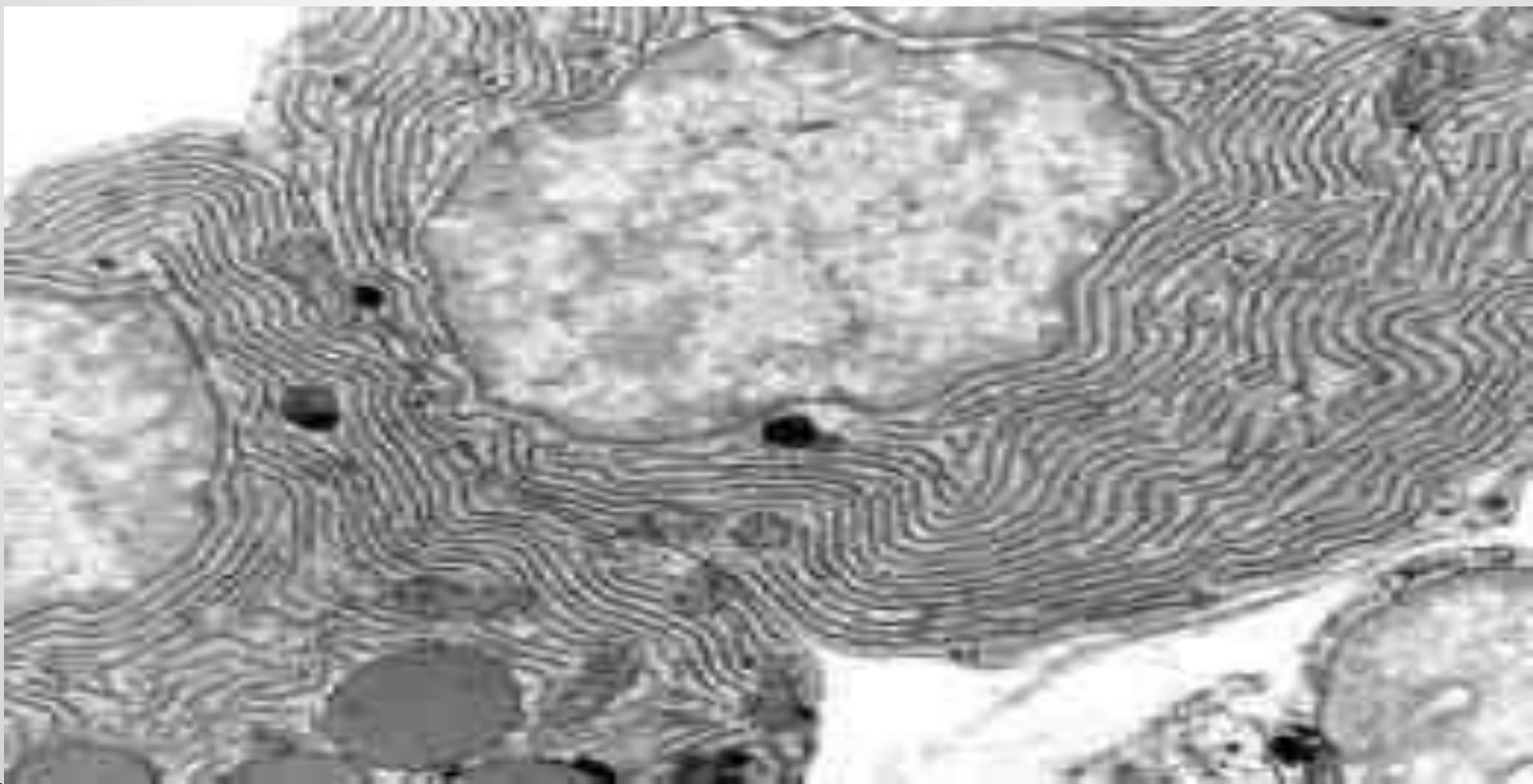
- Rough ER (with ribosomes) makes proteins, folds polypeptides into their tertiary form
- Smooth ER (no ribosomes) makes lipids, breaks down carbohydrates and lipids, detoxifies poisons







# **Rough endoplasmic reticulum in pancreatic exocrine cells**



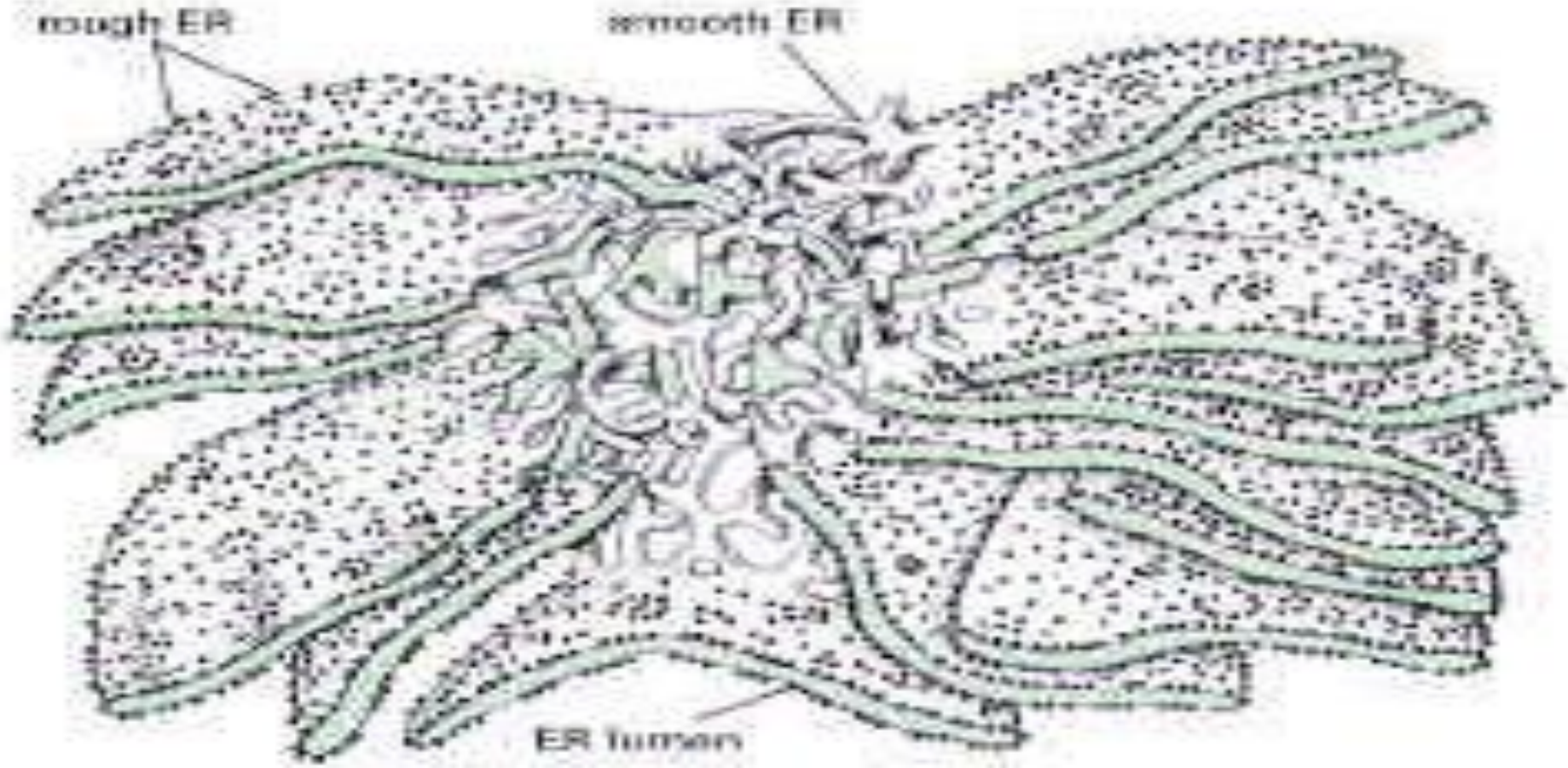


# **Rough endoplasmic reticulum (rer) – note ribosomes**

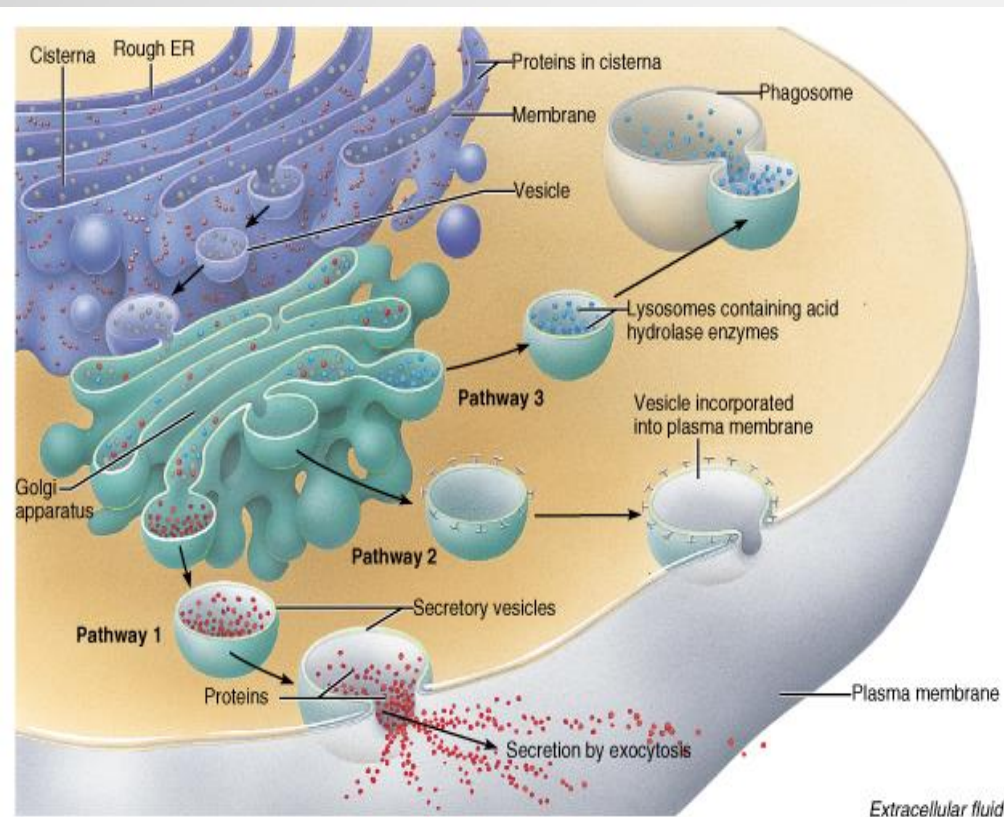




**It is thought that the endoplasmic reticulum membrane is continuous and encloses a single lumen.**



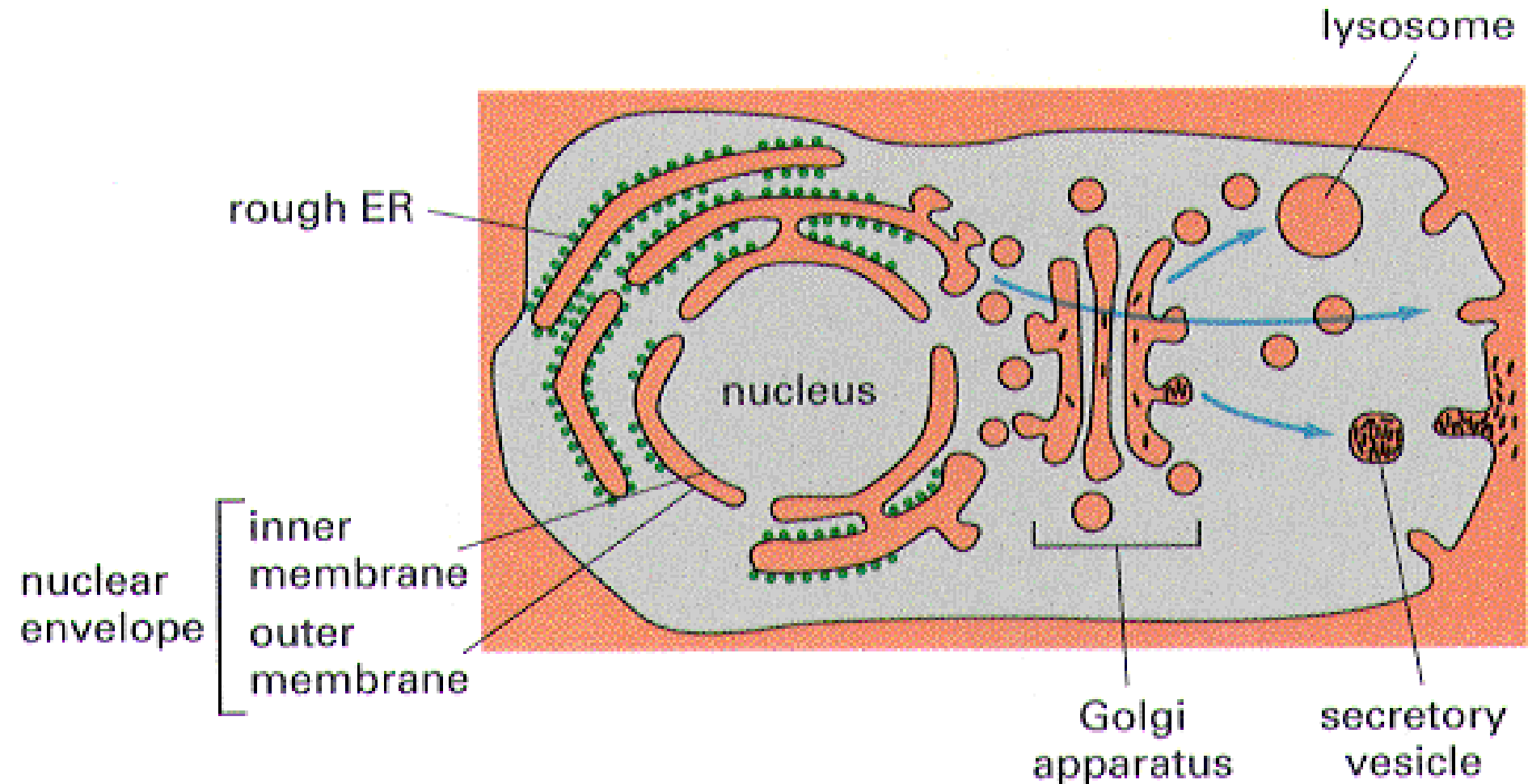
## Golgi Apparatus: Sorting, modifications and concentration in protein synthesis



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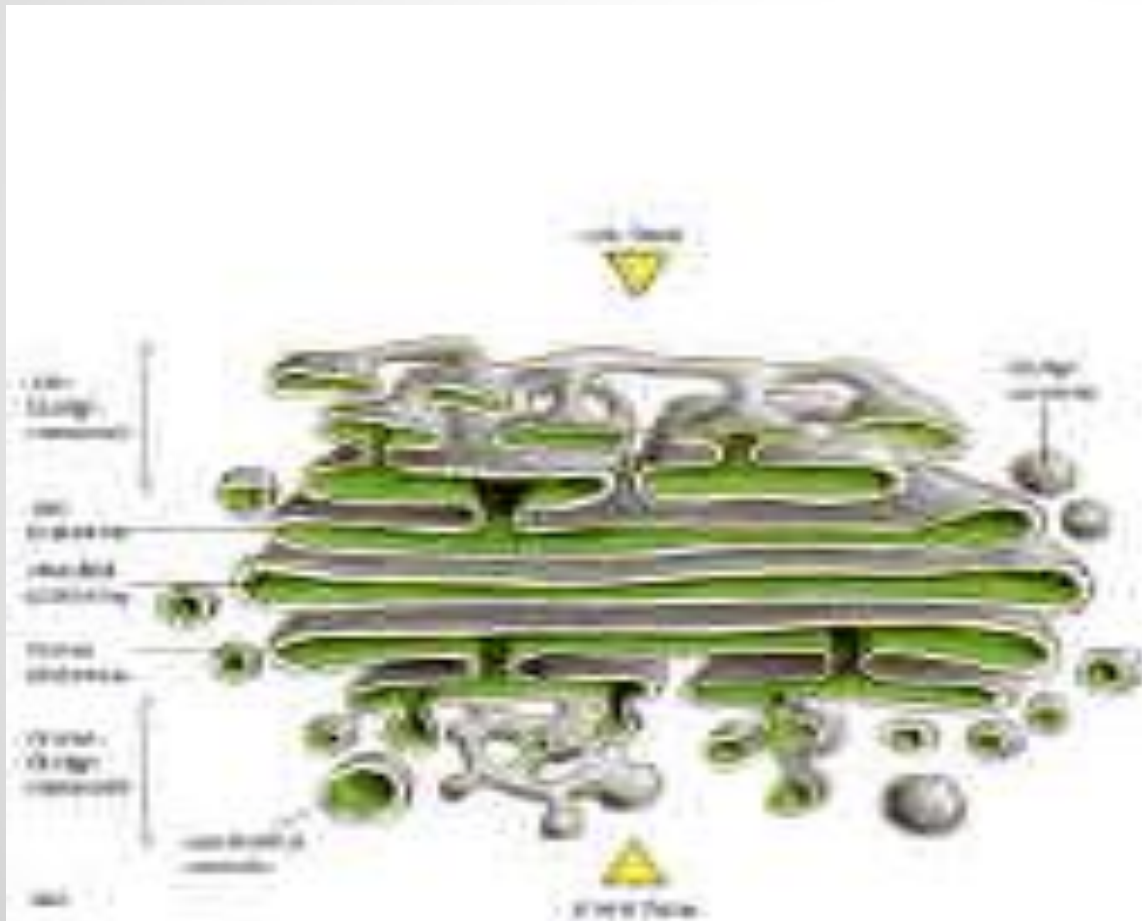
**rER → Golgi complex → secretory → vesicle (organelle) membrane proteins → vesicle with membrane proteins → plasma membrane proteins → lysosomes (incl. Enzymes)**

# Protein synthesis and secretion





# The Golgi apparatus

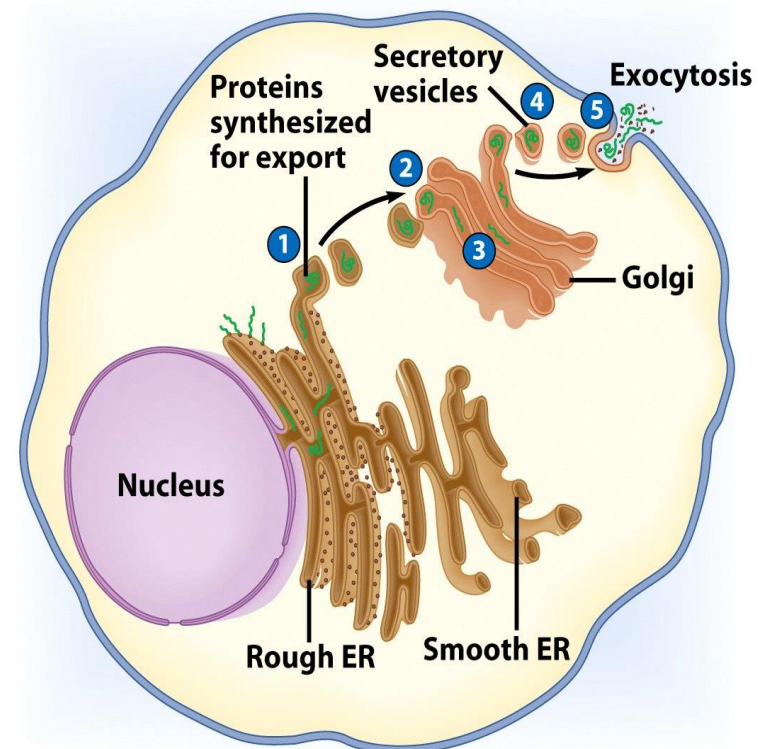




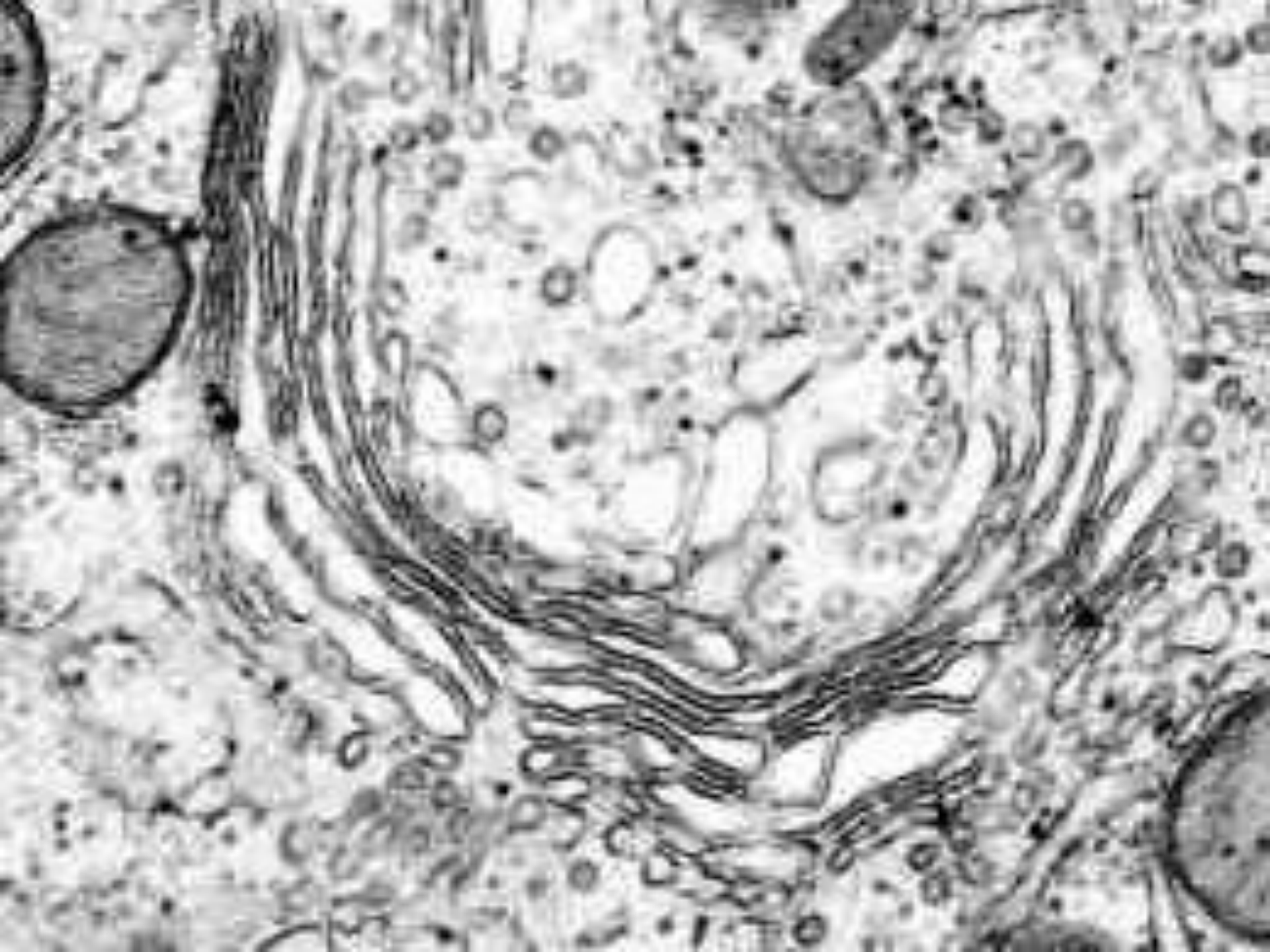
# Golgi Apparatus Function



1. Molecules come in vesicles
2. Vesicles fuse with Golgi membrane
3. Molecules may be modified by Golgi
4. Molecules pinched-off in separate vesicle
5. Vesicle leaves Golgi apparatus
6. Vesicles may combine with plasma membrane to secrete contents









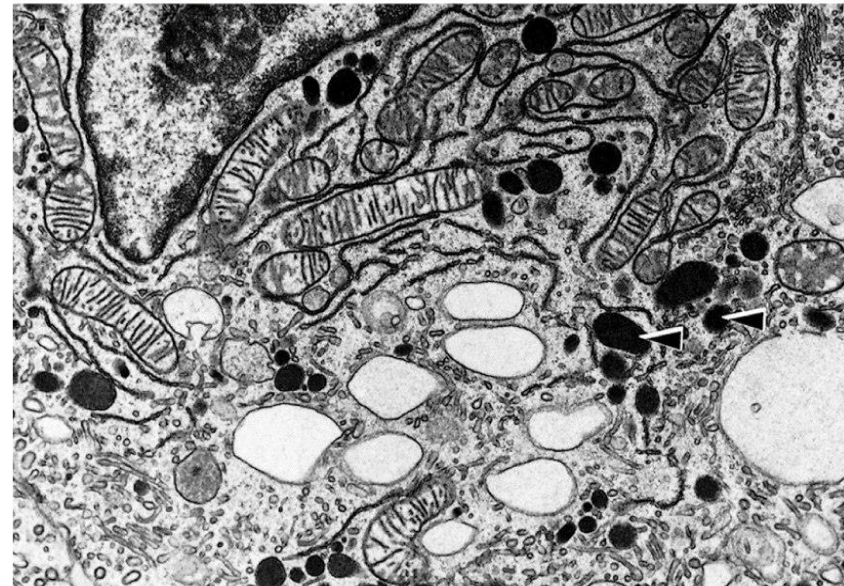
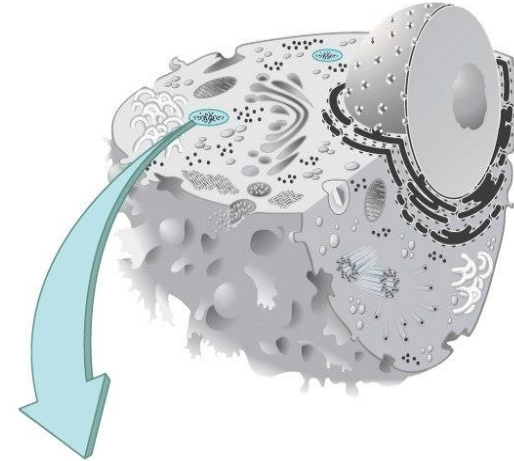
**The Golgi apparatus/body/complex functions to modify, sort, concentrate and package proteins synthesised on the rough endoplasmic reticulum.**

# Lysosomes

Contain digestive enzymes

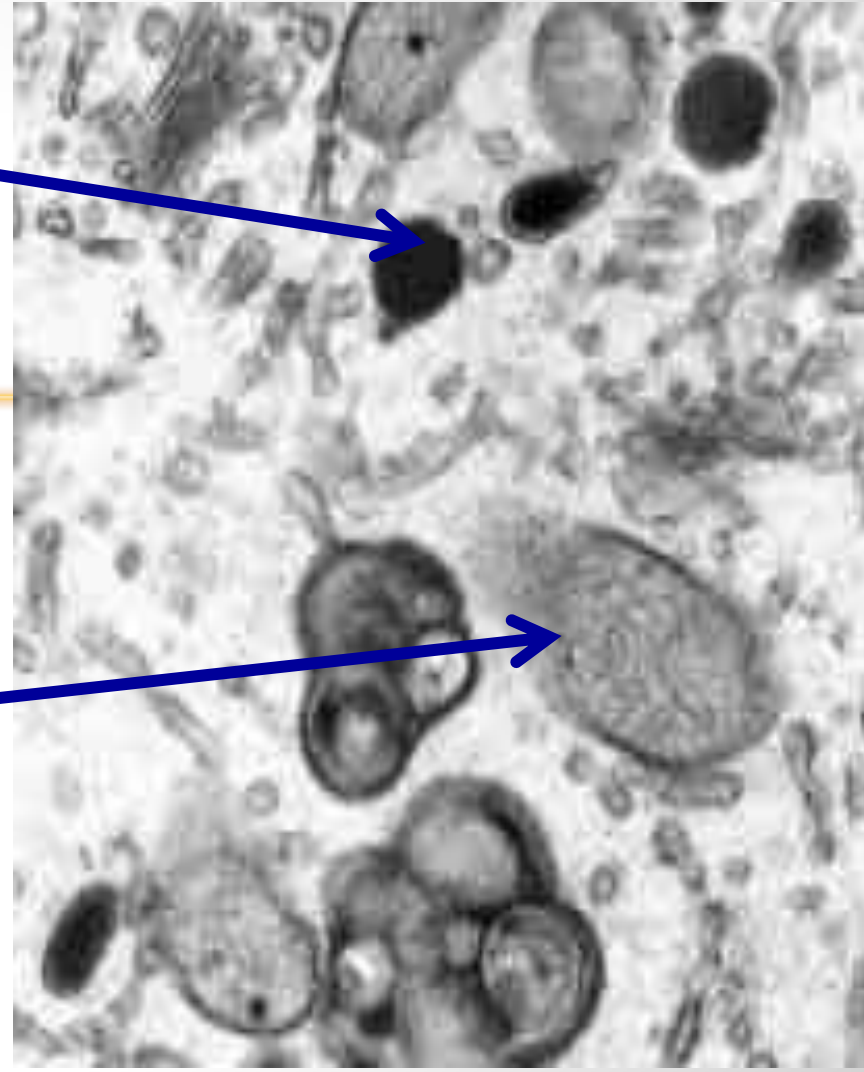
## Functions

- Aid in cell renewal
- Break down old cell parts
- Digests invaders



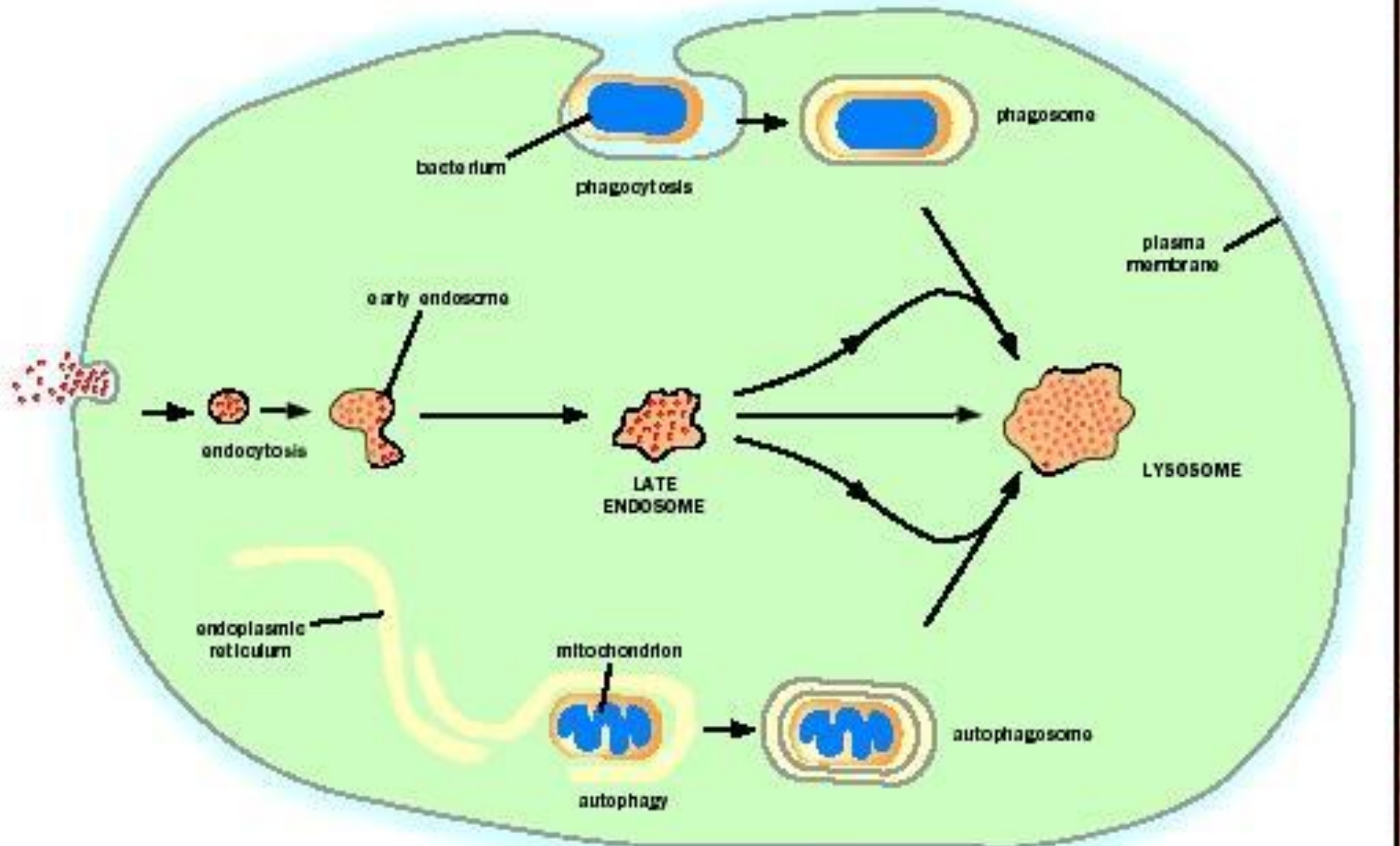
**Primary lysosome**

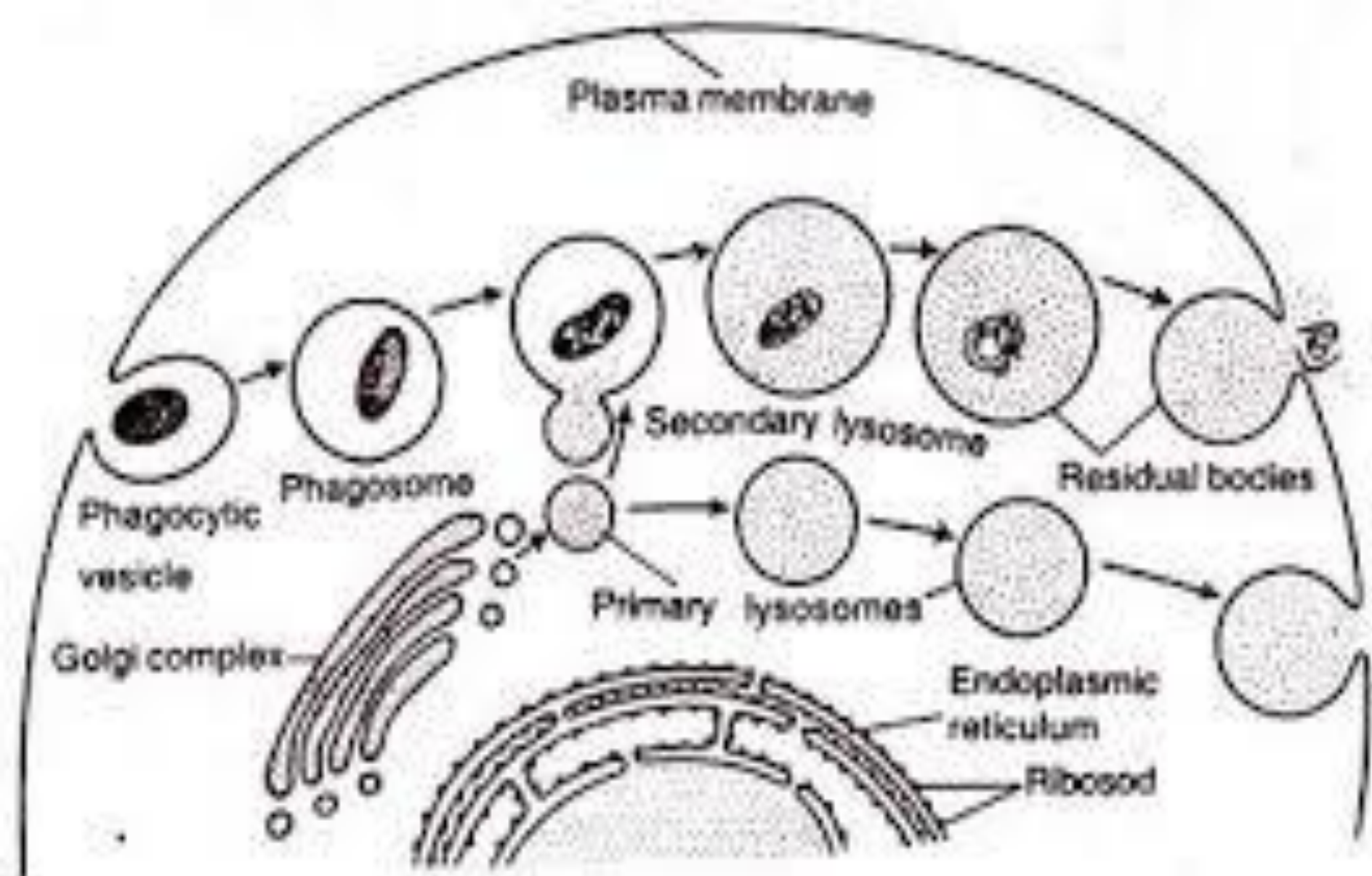
**Secondary lysosome**





# Lysosomes fuse with material requiring digestion





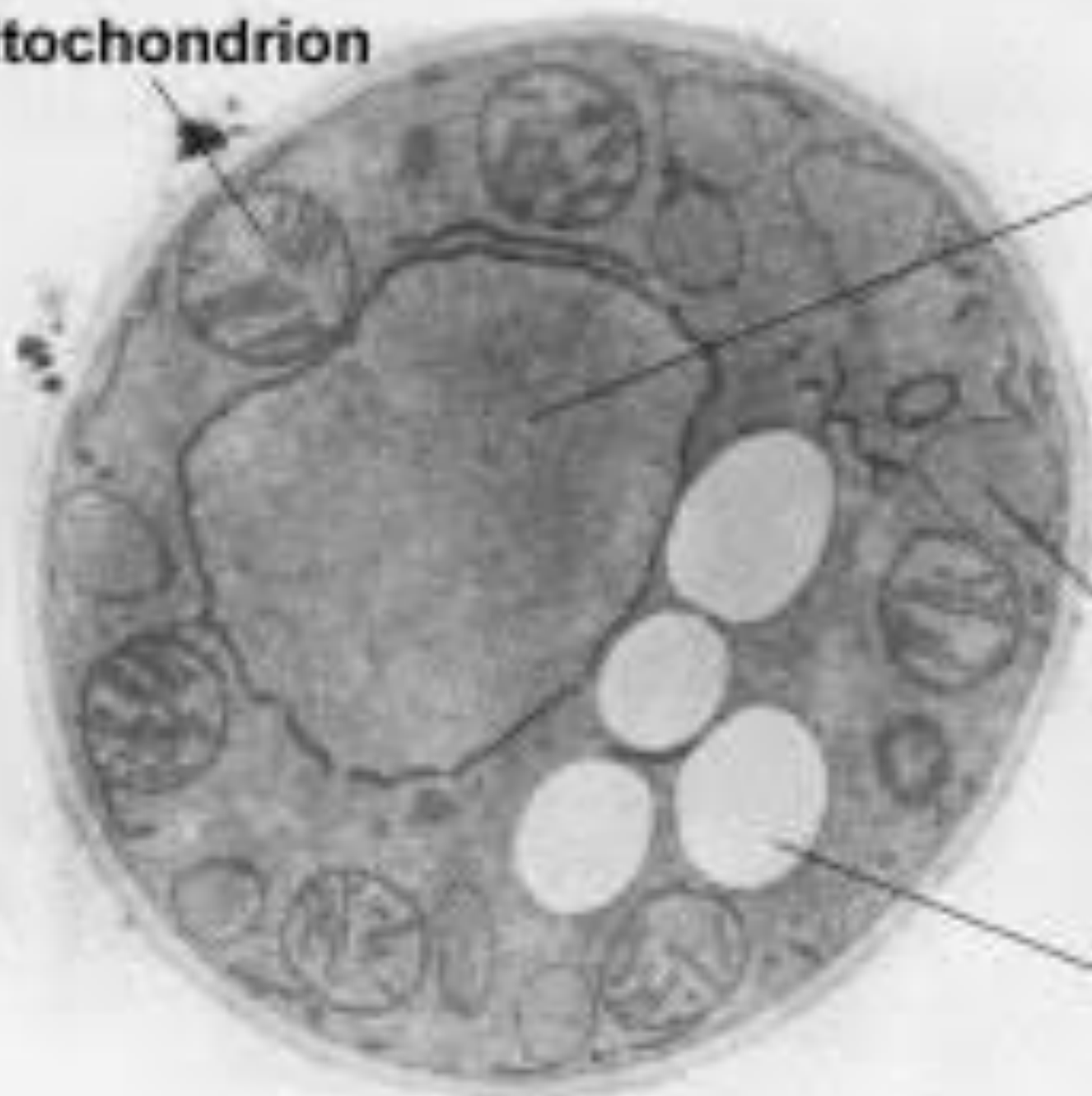
**Fig. 7.3** Formation of Primary Lysosomes from Golgi Vesicle and their fusion with digestive vacuole.

**mitochondrion**

**nucleus**

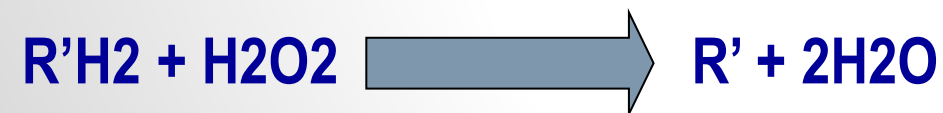
**peroxisome**

**vacuole**

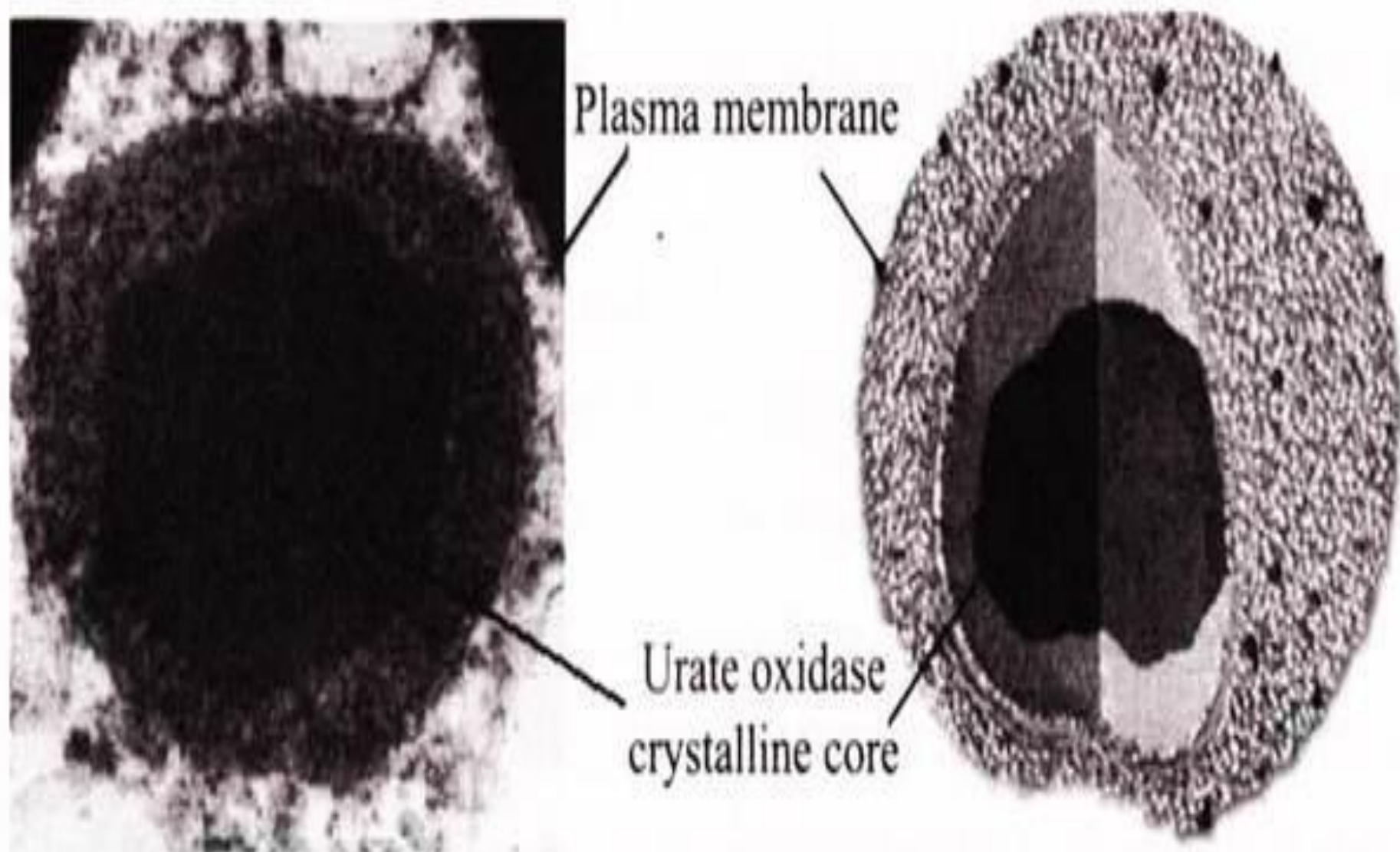


## Three peroxisomes in a rat liver cell.

Peroxisomes in liver and kidney cells detoxify (oxidise) a number of molecules including alcohol, phenols, formic acid and formaldehyde.

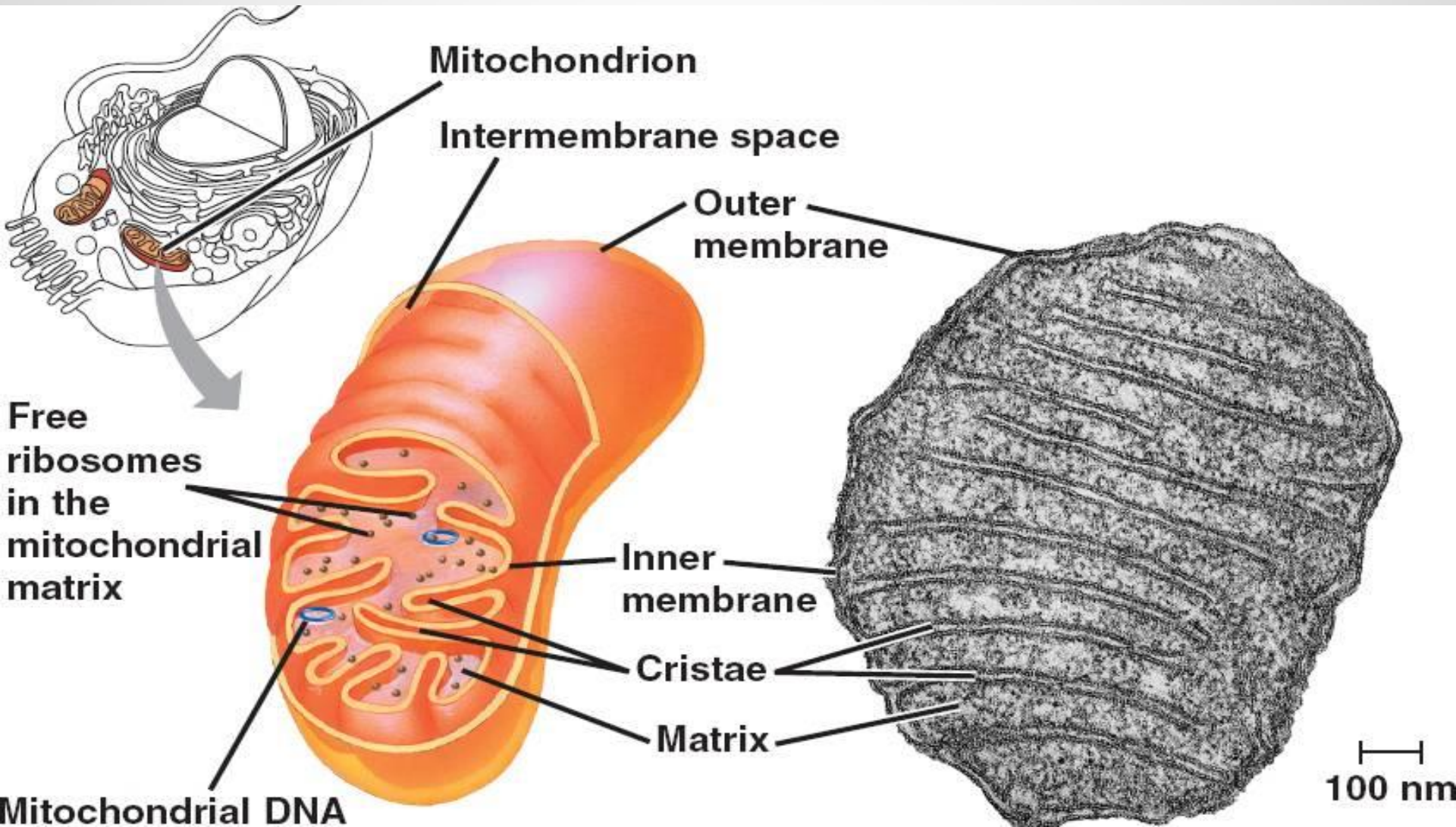






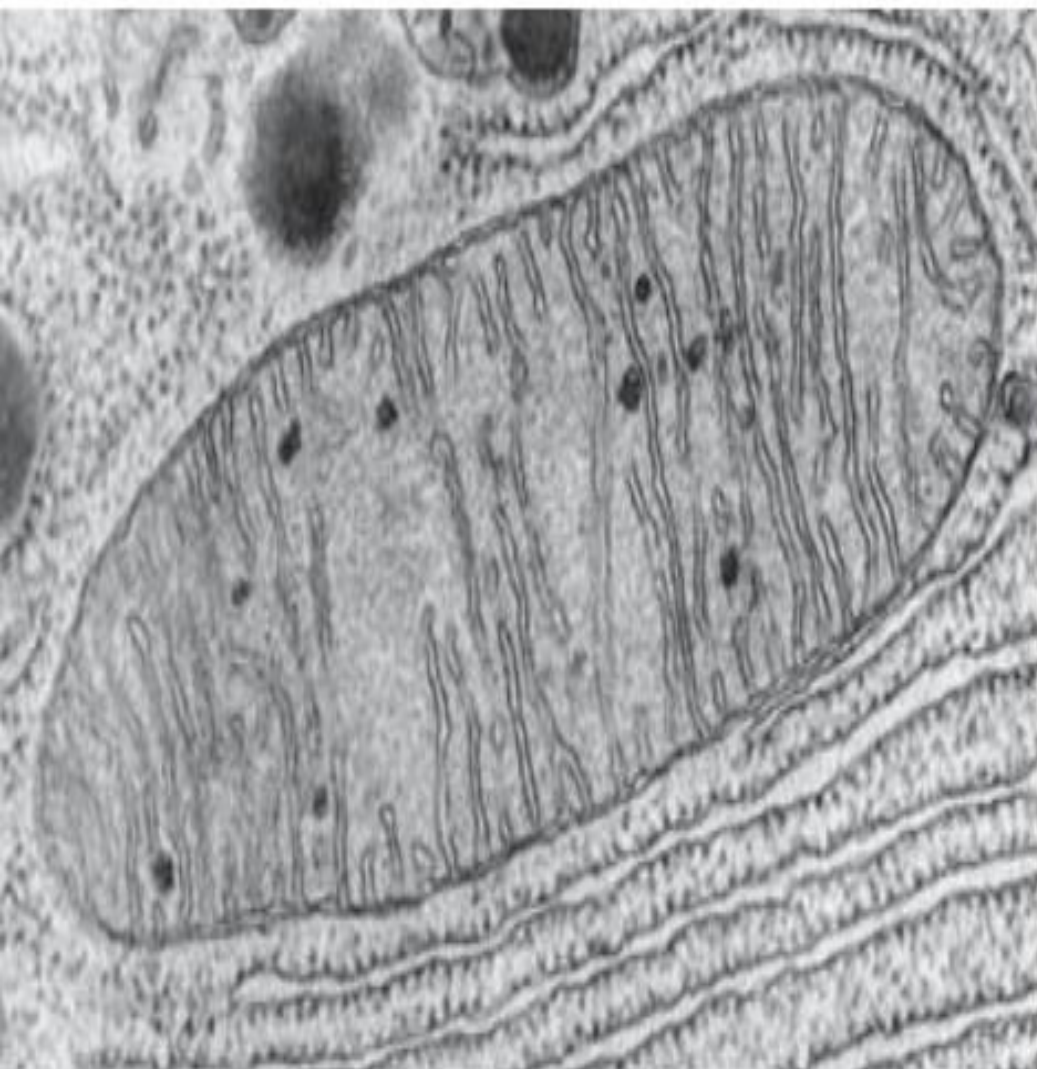
**Figure 4.59:** Transmission electron micrograph of a peroxisome

# Mitochondria



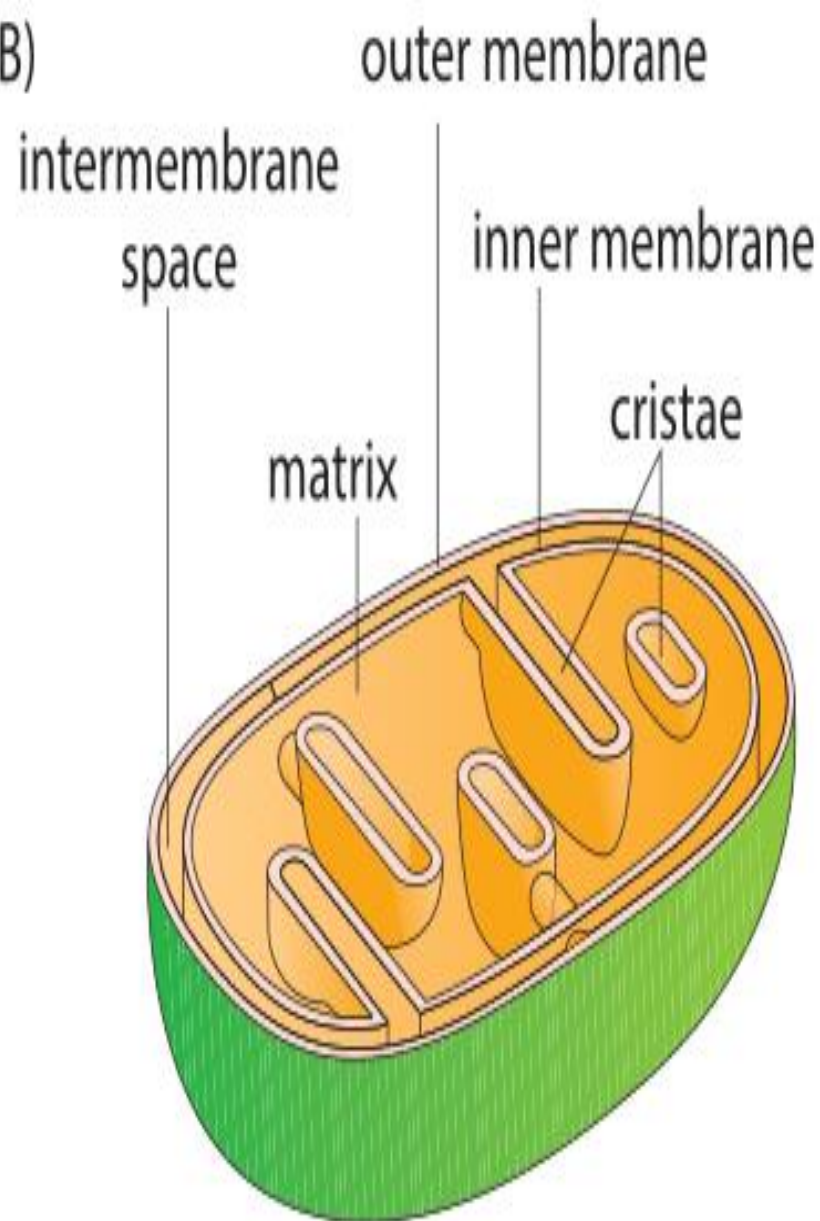


(A)



0.5  $\mu\text{m}$

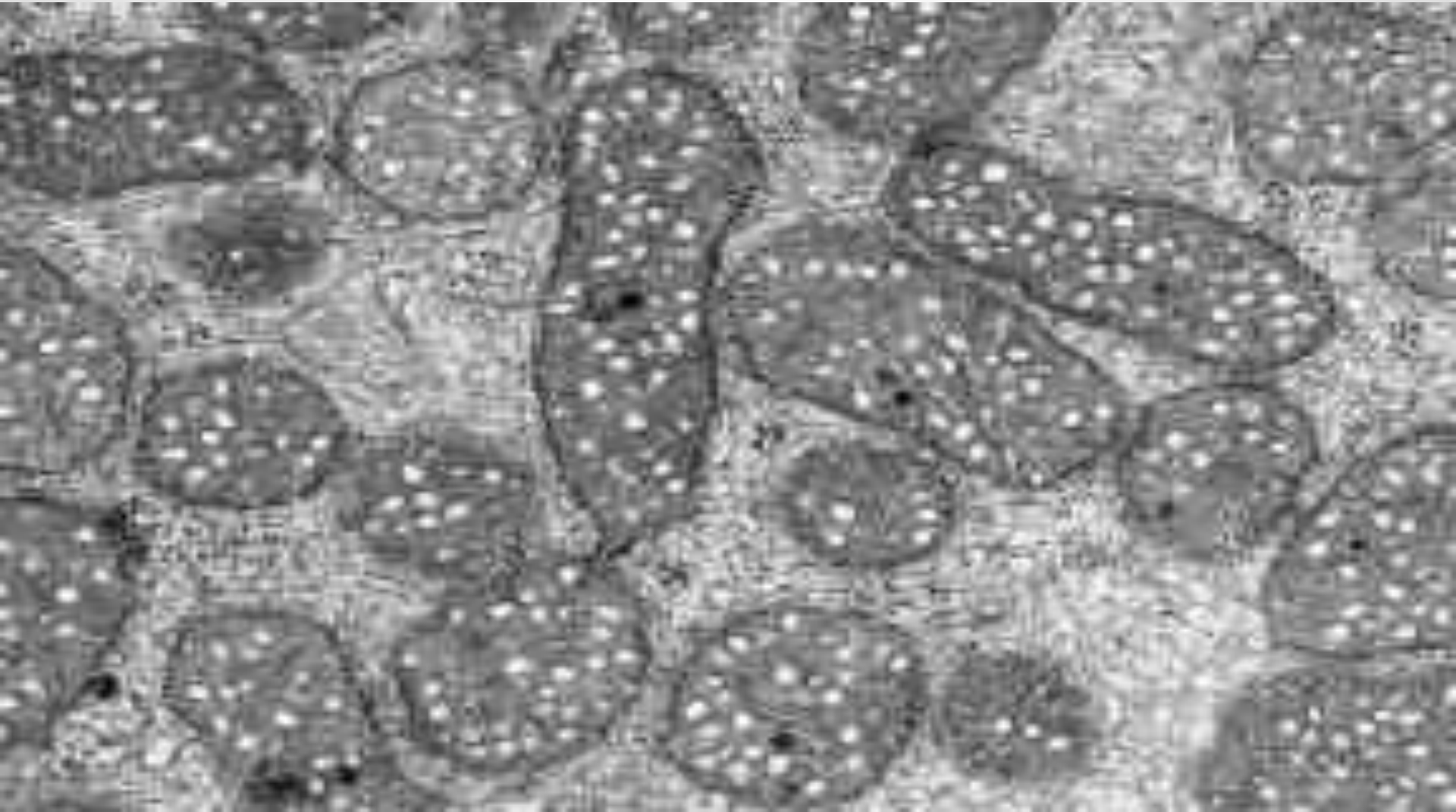
(B)



3-D view of mitochondrion

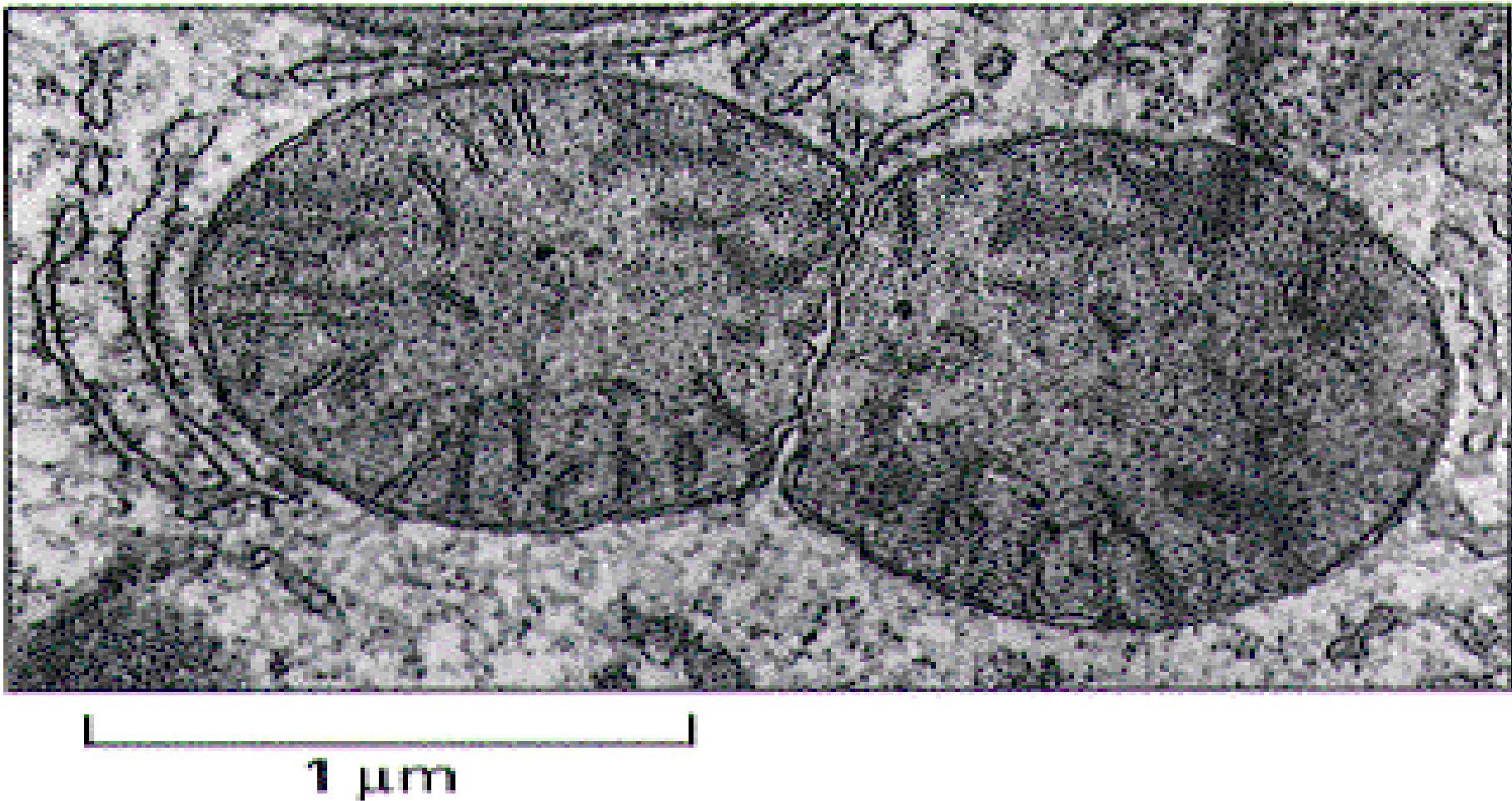


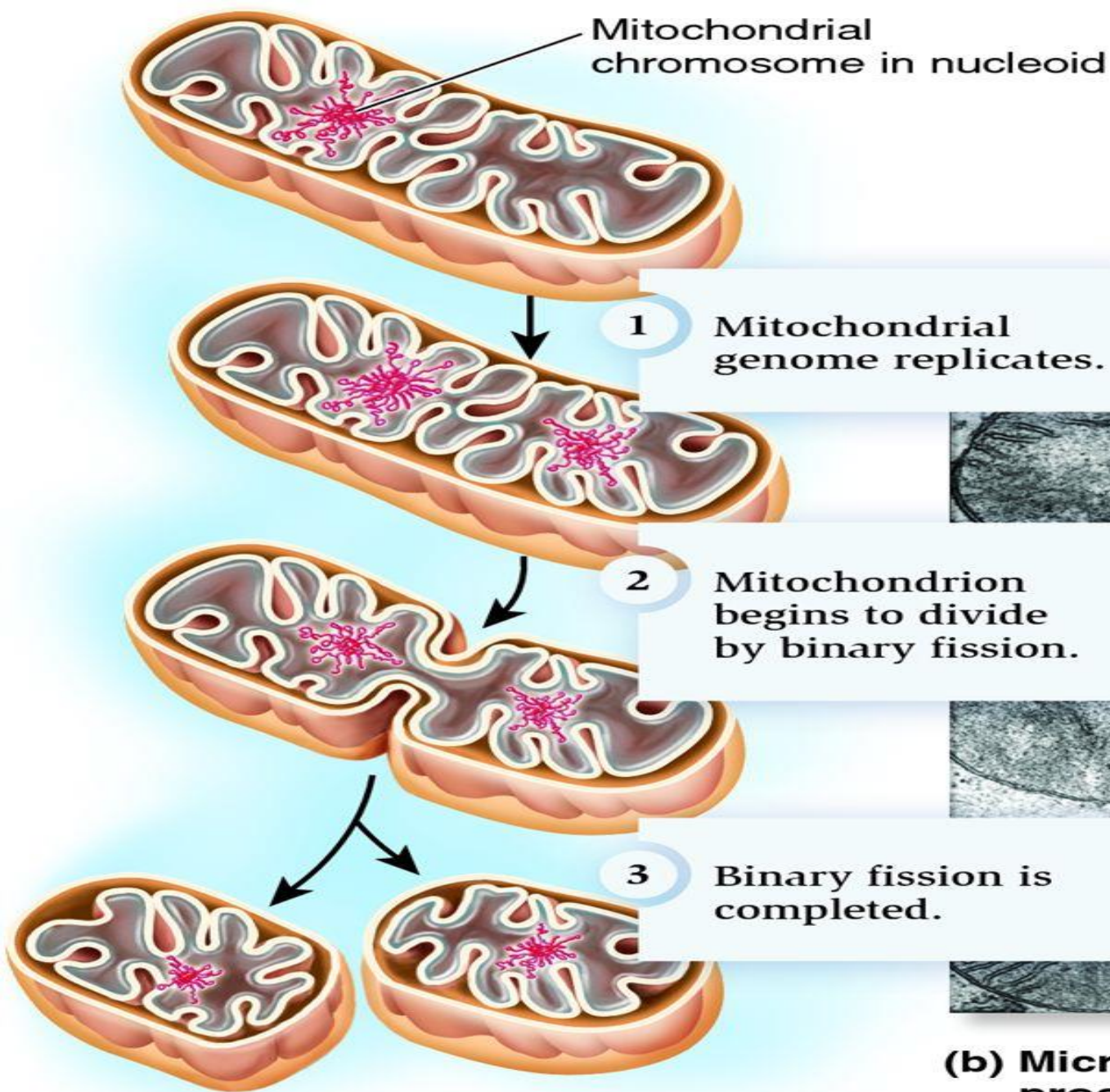
**In steroidogenic cells the mitochondrial cristae are typically tubular (or finger- like)**



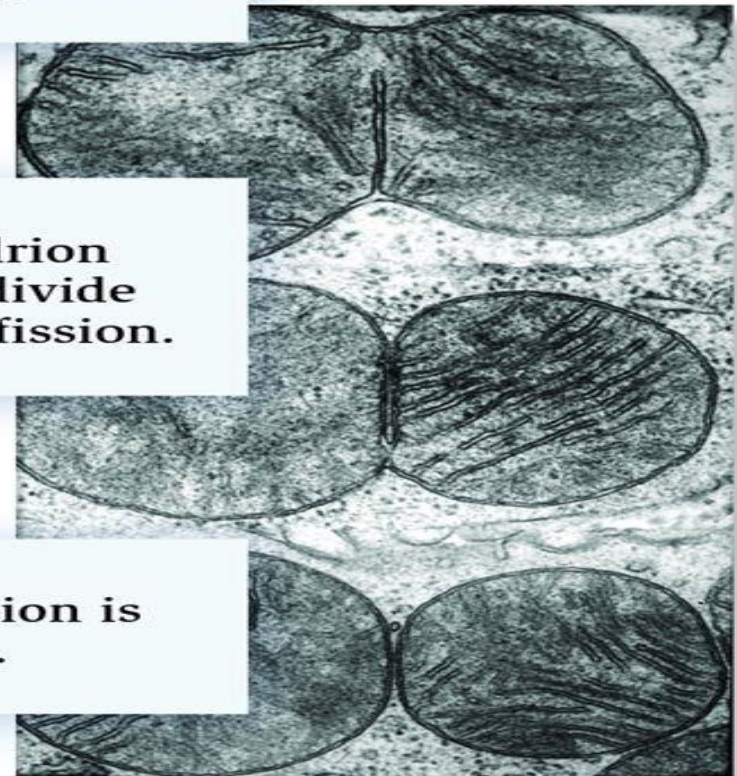


## Dividing of mitochondria





**(a) Binary fission of mitochondria**



**(b) Micrographs of the process**



# Cytoskeleton

## Filaments & fibers

### Made of 3 fiber types

Microfilaments

Microtubules

Intermediate filaments

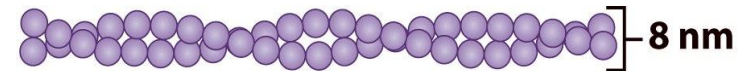
### 3 functions:

mechanical support

anchor organelles

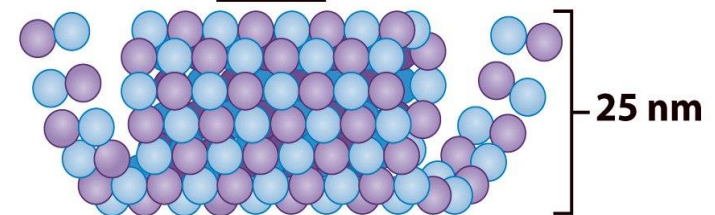
help move substances

#### (a) Microfilament



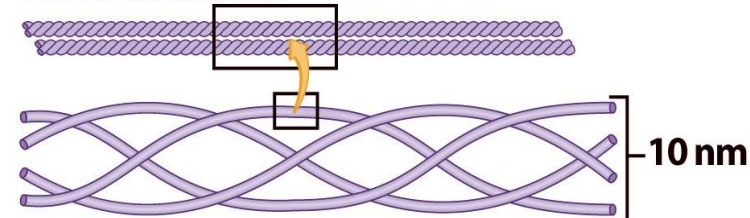
#### (b) Microtubule

Protein subunit



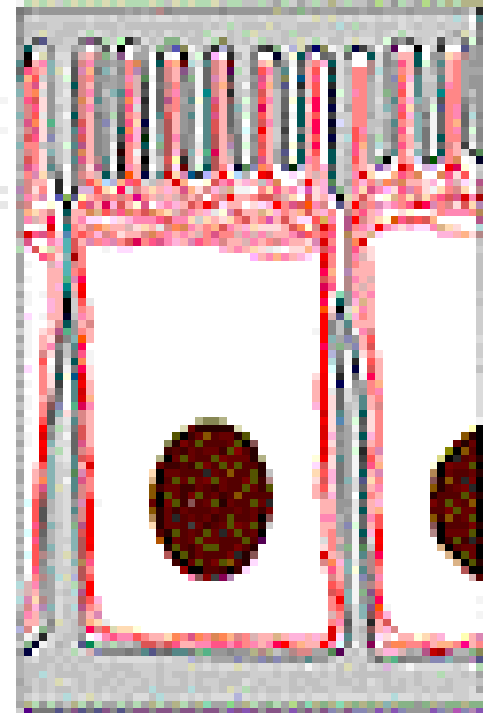
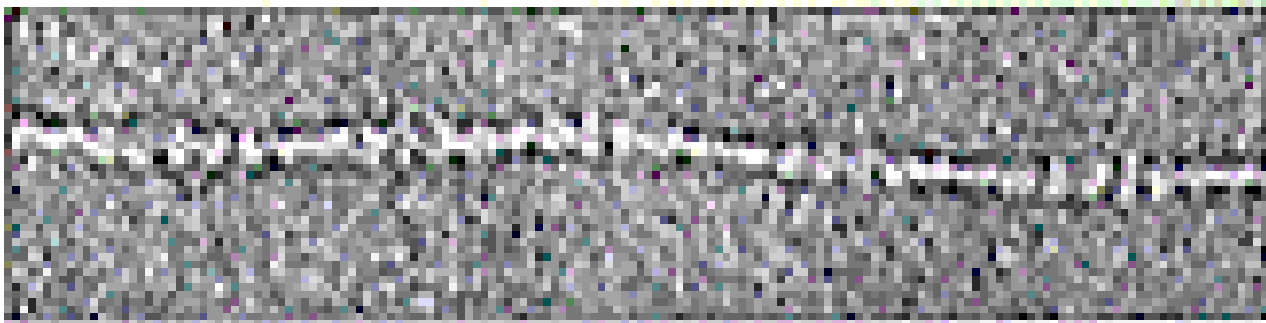
#### (c) Intermediate filament

Threadlike unit





**Actin filaments (microfilaments) – 5-9nm diameter, mainly cortical in distribution.**



25 μm





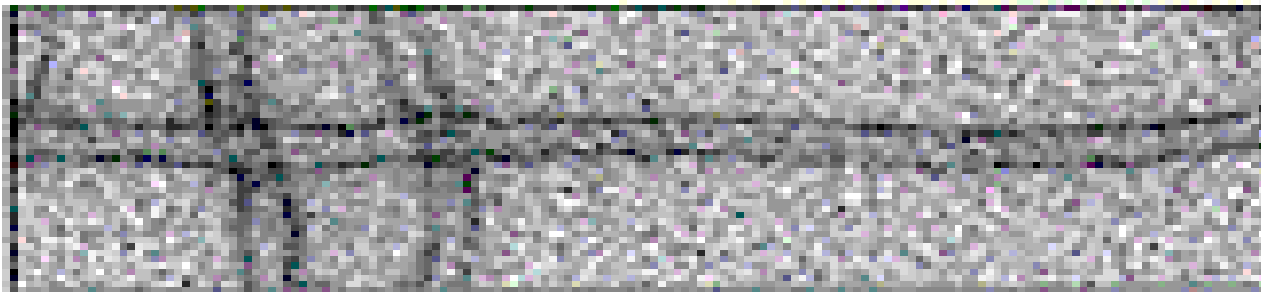
**A network of actin filaments underlying the plasma membrane of an animal cell as seen in a scanning electron micrograph**



Scanning electron micrograph  
1003.1411

**Intermediate filaments have a diameter of about 10nm. Several different proteins belong to this family. Common in epithelial cells. Form tough supporting meshwork in cytoplasm. Also found just beneath inner nuclear membrane forming the nuclear lamina.**

### INTERMEDIATE FILAMENTS



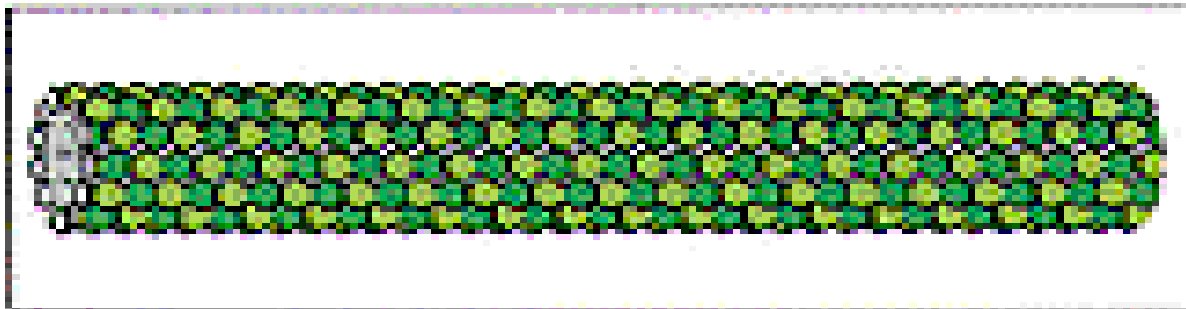
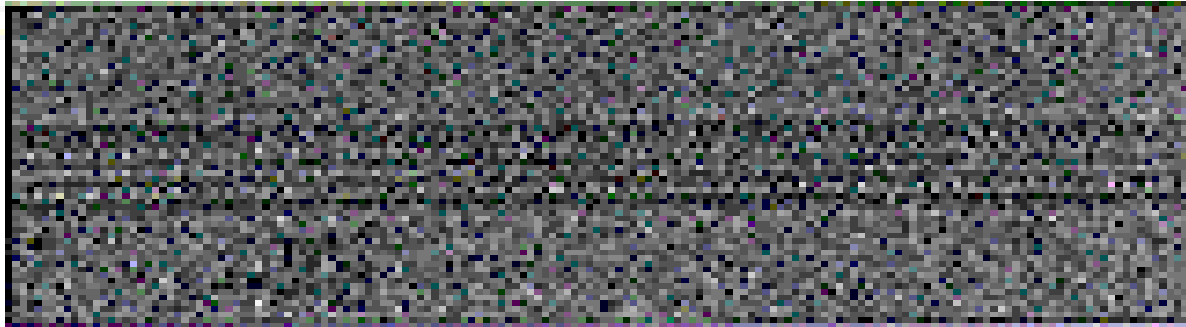
25 nm



25 μm

**Microtubules are long hollow cylinders made of the protein tubulin. Found at sites where structures are moved (i.e. in nerve fibres, the mitotic spindle, cilia and flagella).**

### MICROTUBULES



25 nm

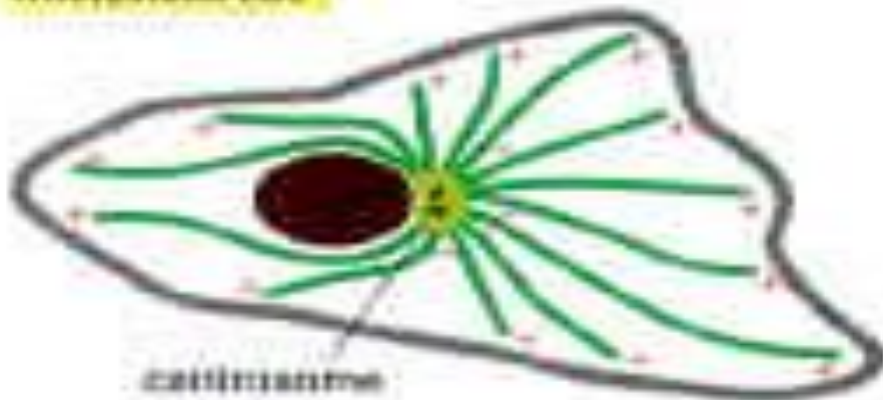


25  $\mu$ m

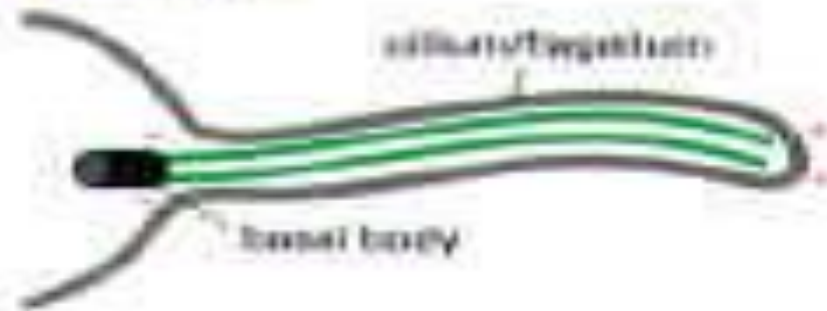


# MICROTUBULE ORIENTATION IN CELLS

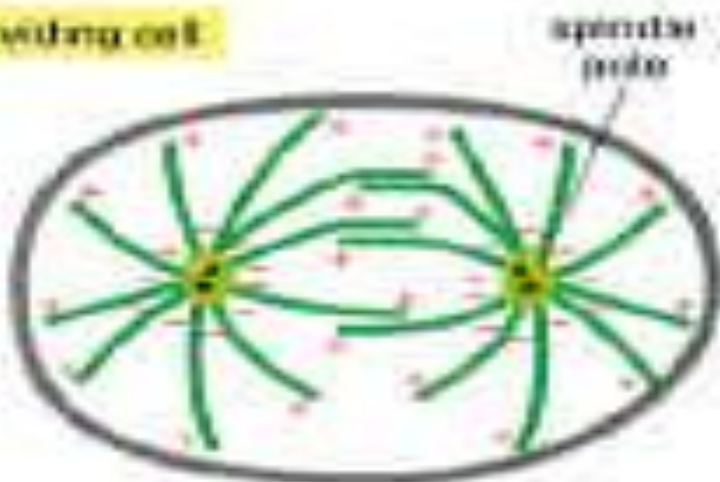
Interphase cell



ellipsoid cell



dividing cell



rathe cell

