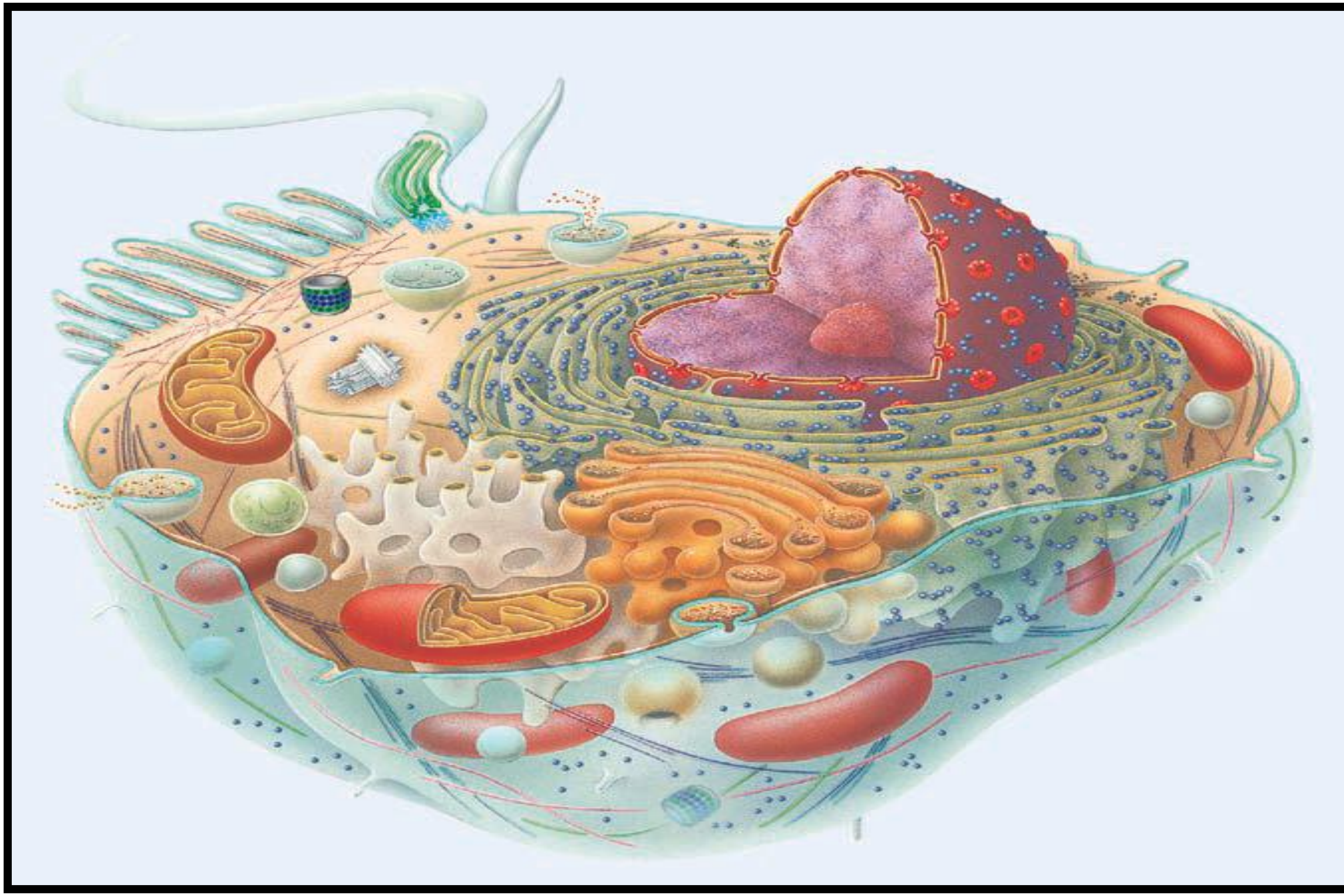
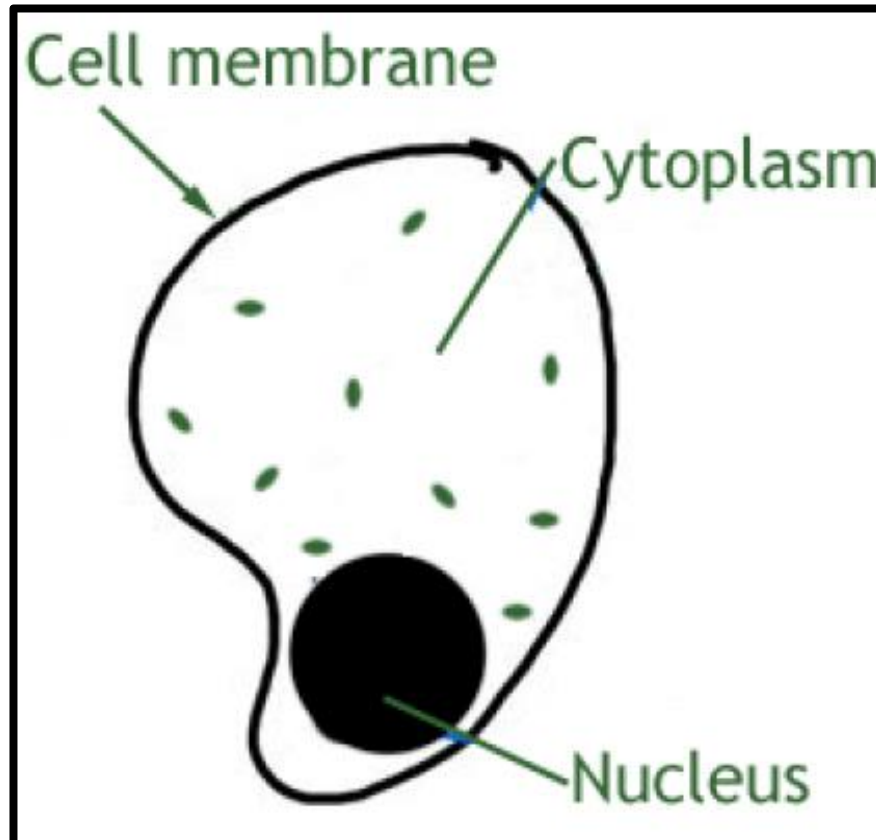
Cell Overview



PARTS OF A CELL

The cell is divided into three main parts:

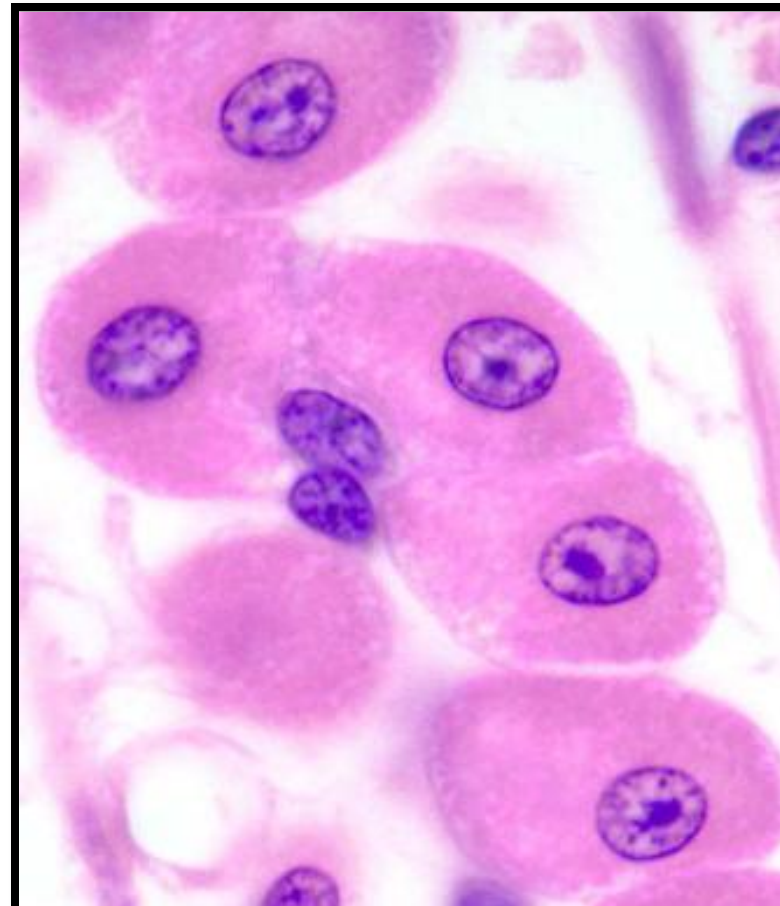
1. Plasma membrane.
2. Cytoplasm.
3. Nucleus.



Cell Overview (Light Microscope)

- The initial information in histology was gained by examining tissue slides with a **light microscope**, its **resolving power** was too limited.

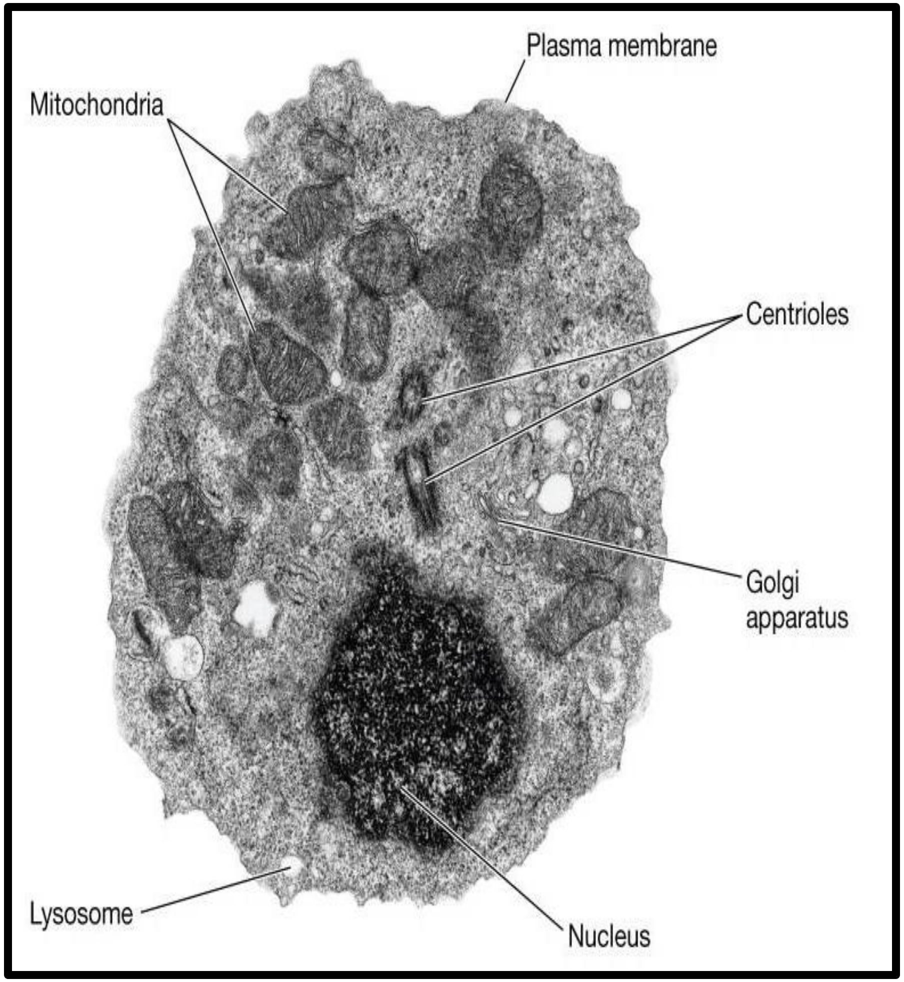
- With the simplest light microscopes, examination of **mammalian cells** showed **a nucleus** and a **cytoplasm**, surrounded by some sort of a **border or cell membrane**.



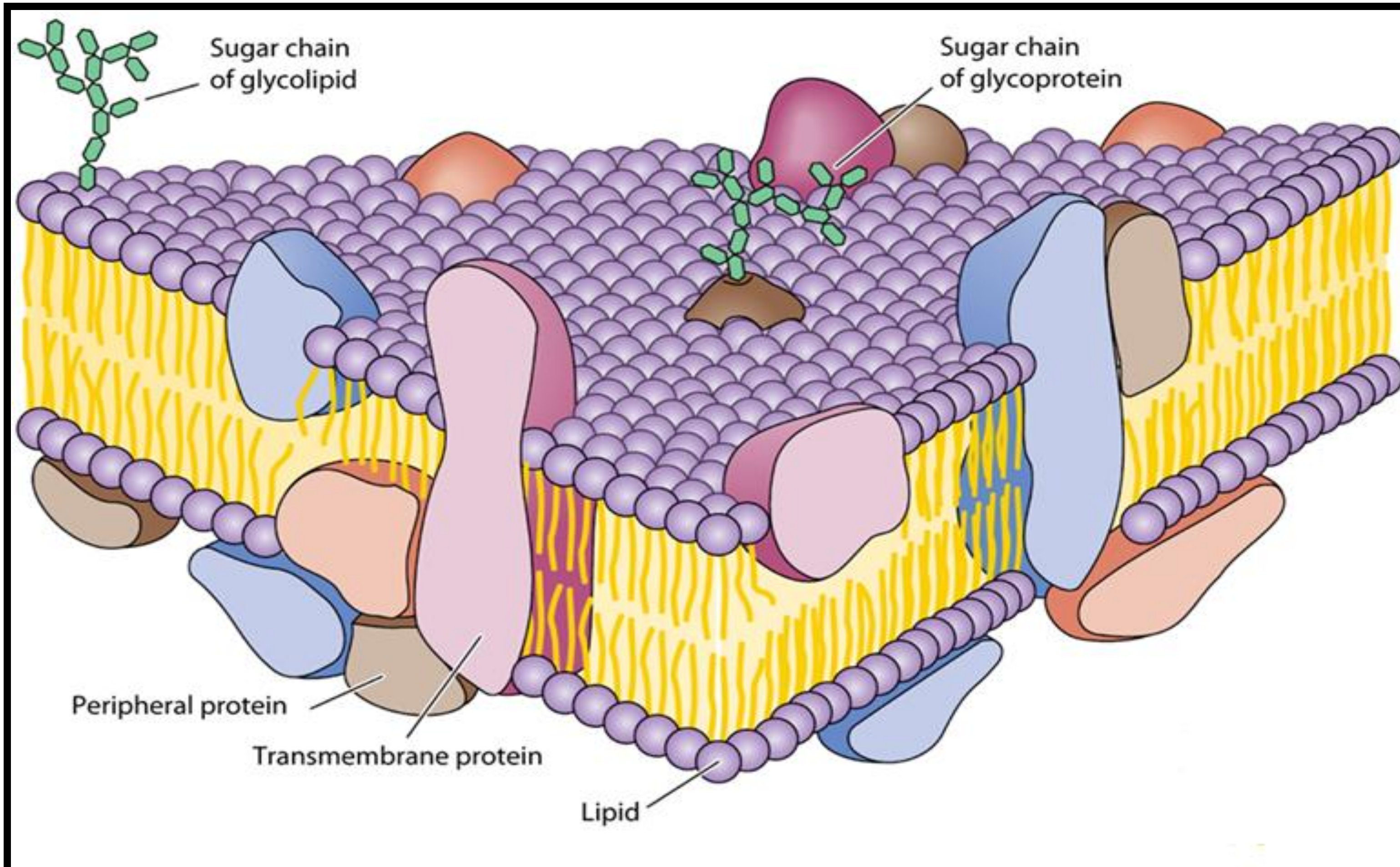
Cell Overview (Electron microscope)

- With the advent **of transmission electron microscopy**, superior **resolution**, and **higher magnification** of cells, the examination of the **contents of the cytoplasm** became **possible**.

- Histologists are now able to describe the **ultrastructure of the cell**, its membrane, and the numerous **organelles** that are present in the cytoplasm of different cells.

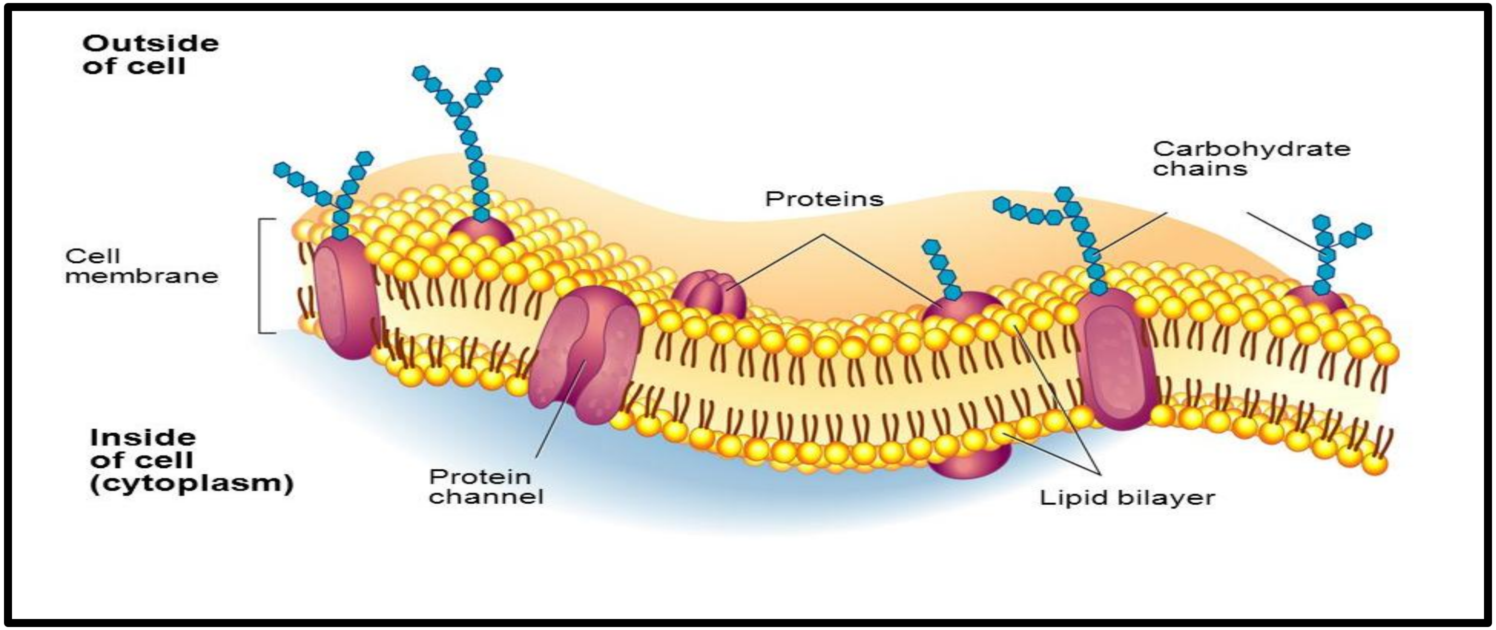


The plasma membrane



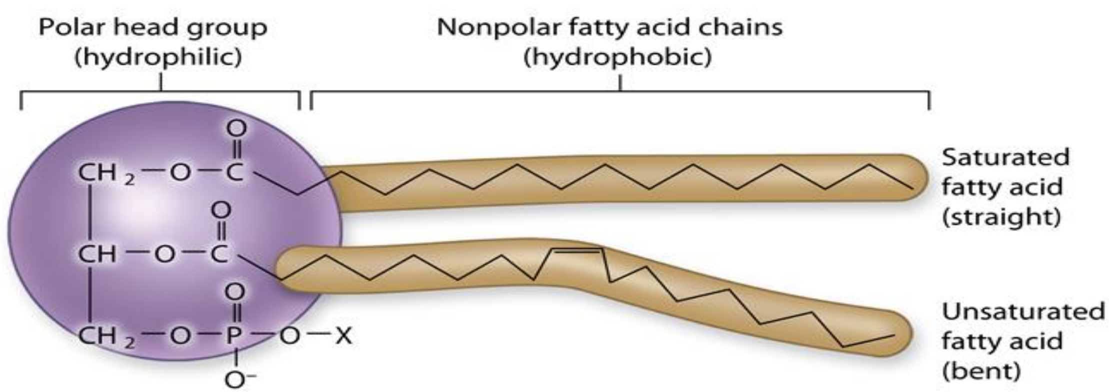
The plasma membrane

- The **plasma membrane,** is a **flexible**, selective **barrier that surrounds** and contains the cytoplasm of a cell.
- Separating the cell's **internal environment** (everything inside the cell) from the **external environment** (everything outside the cell).
- It is best described by using a structural model called the **fluid mosaic model.**



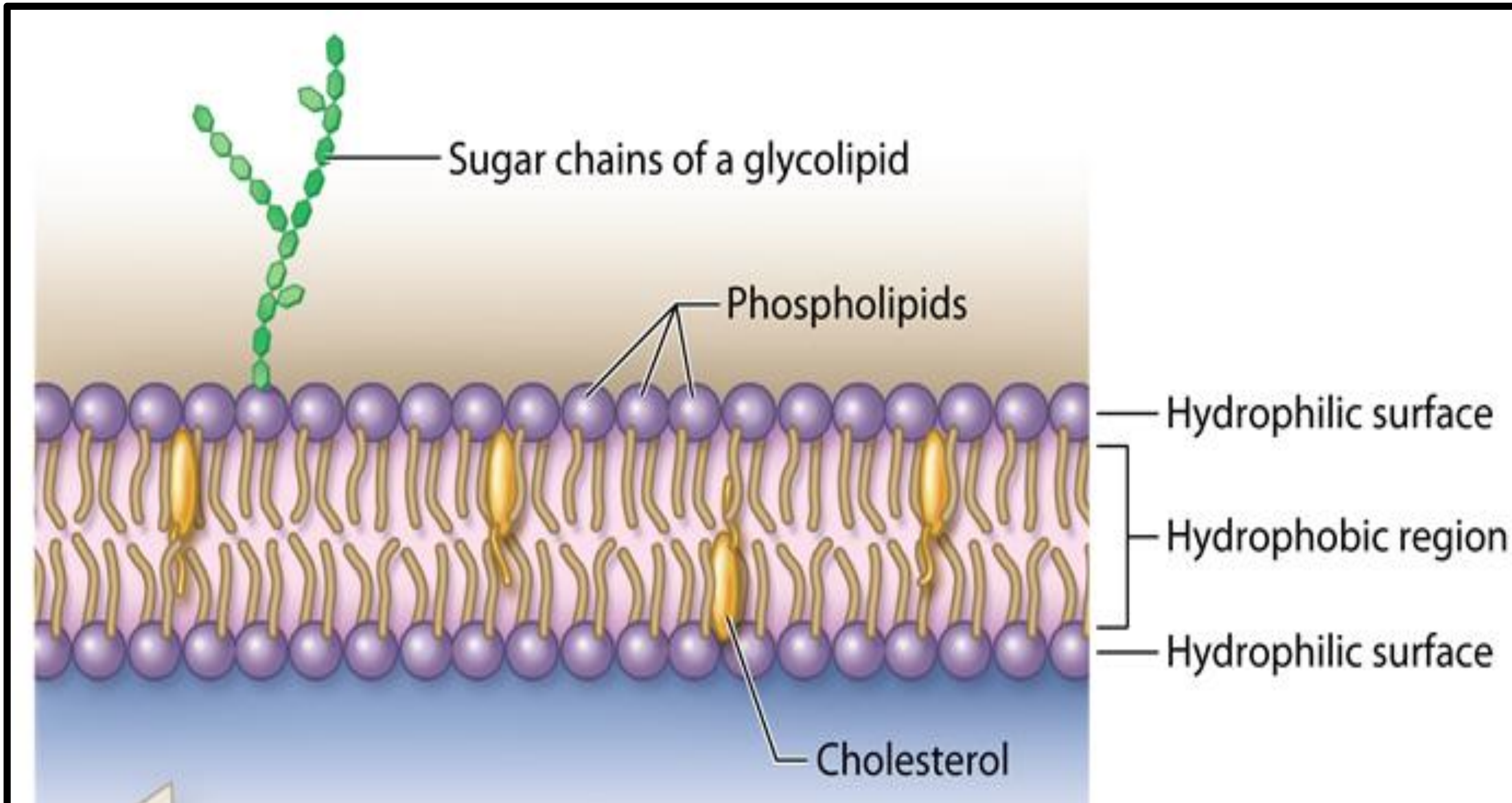
Structure of the Plasma Membrane

- The basic structural framework of the plasma membrane is the **lipid bilayer.**
- The bilayer arrangement occurs because the lipids are **amphipathic** molecules, which means that they have both polar and nonpolar parts.
- In phospholipids the **polar part** is the phosphate-containing **"head"** which is **hydrophilic** *.*
- *The* **nonpolar parts** are the two long fatty acid **"tails"** which are **hydrophobic** hydrocarbon chains.



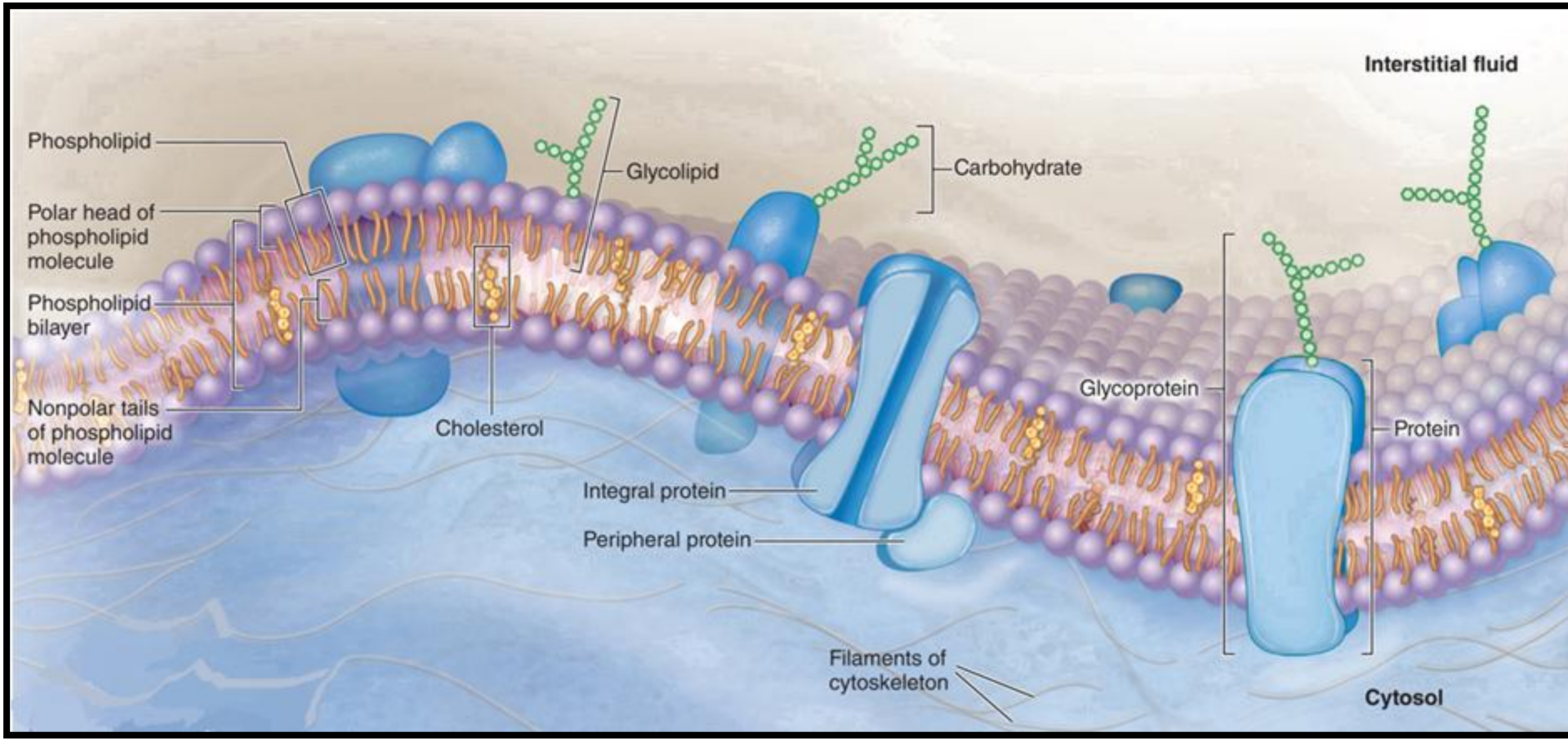
General structure of a phospholipid

Structure of the Plasma Membrane



- Because “like seeks like,” the phospholipid molecules orient themselves in the bilayer with their hydrophilic heads facing outward.
- In this way, the heads face a watery fluid on either side—cytosol on the inside and extracellular fluid on the outside.
- The hydrophobic fatty acid tails in each half of the bilayer point toward one another, forming a nonpolar, hydrophobic region in the membrane’s interior.

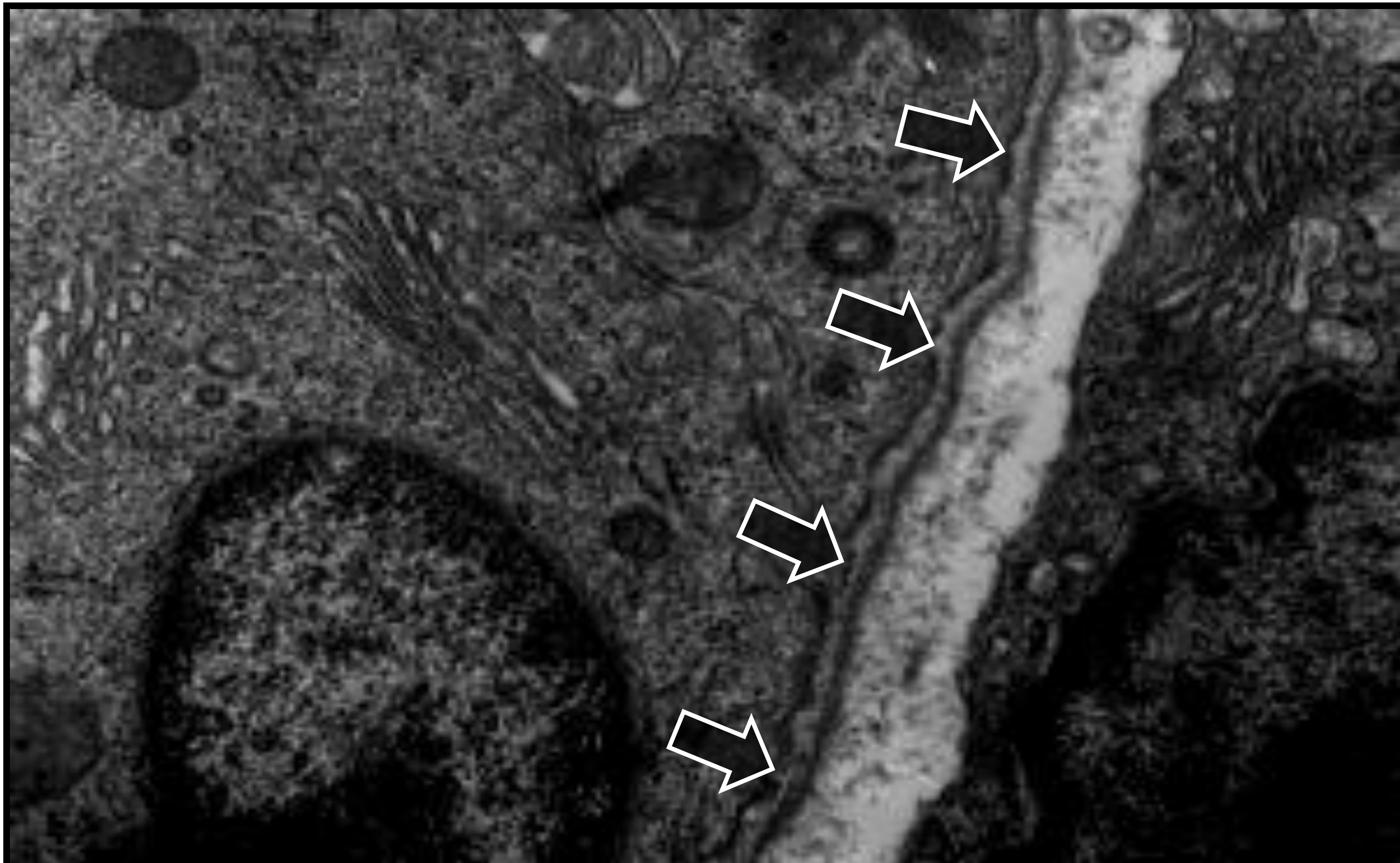
The plasma membrane



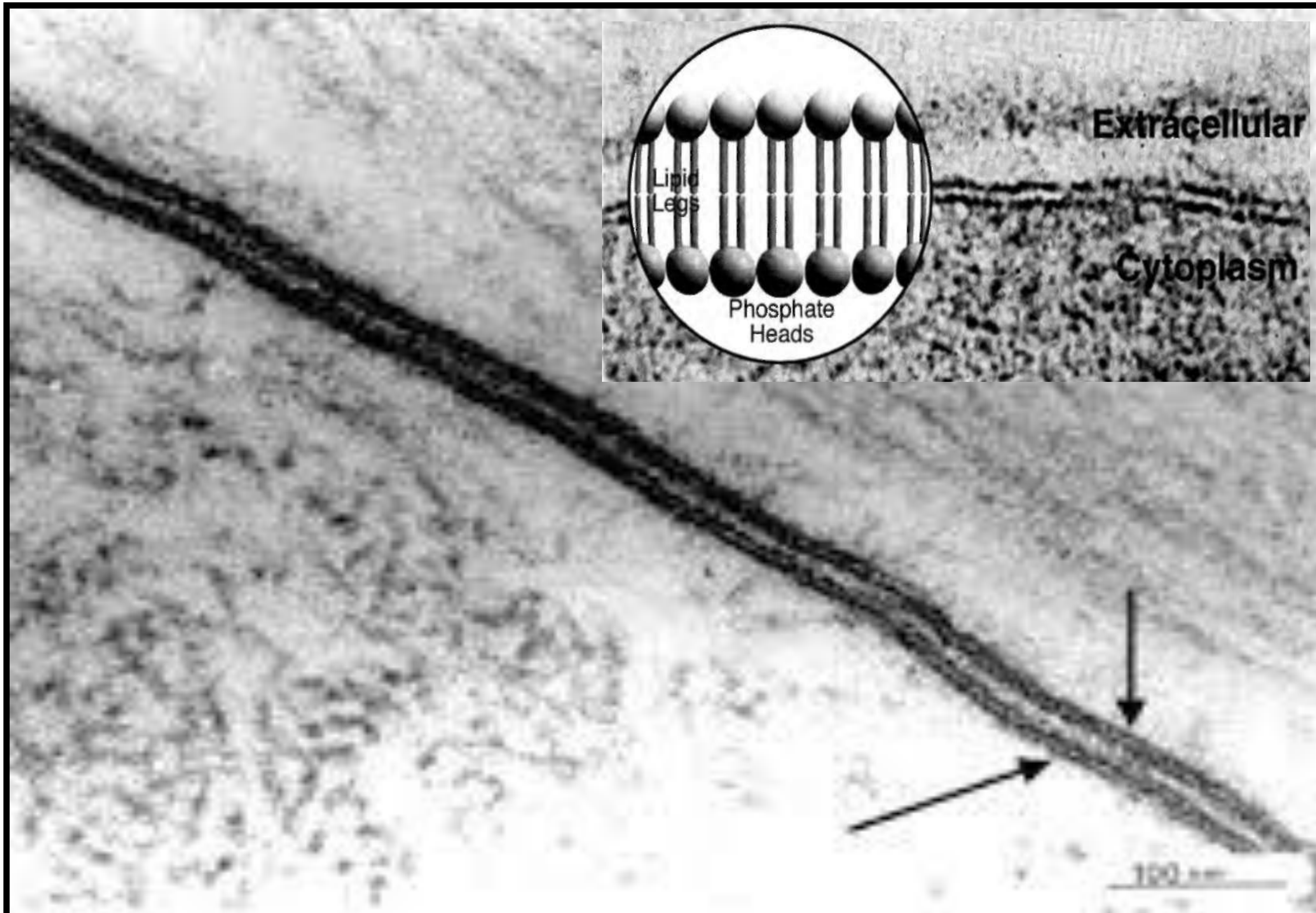
- Images of cell membrane viewed with the transmission electron microscope, appear as **three** distinct layers, consisting of outer and inner electron-dense layers and a less dense or lighter middle layer.

- This discrepancy is due to the osmic acid (osmium tetroxide) that is used to fix and stain tissues for electron microscopy. Osmic acid binds to the polar heads of the lipid molecules in the cell membrane and stains them very densely.
- The nonpolar tails in the middle of the cell membrane remain light and unstained.

Cell membrane



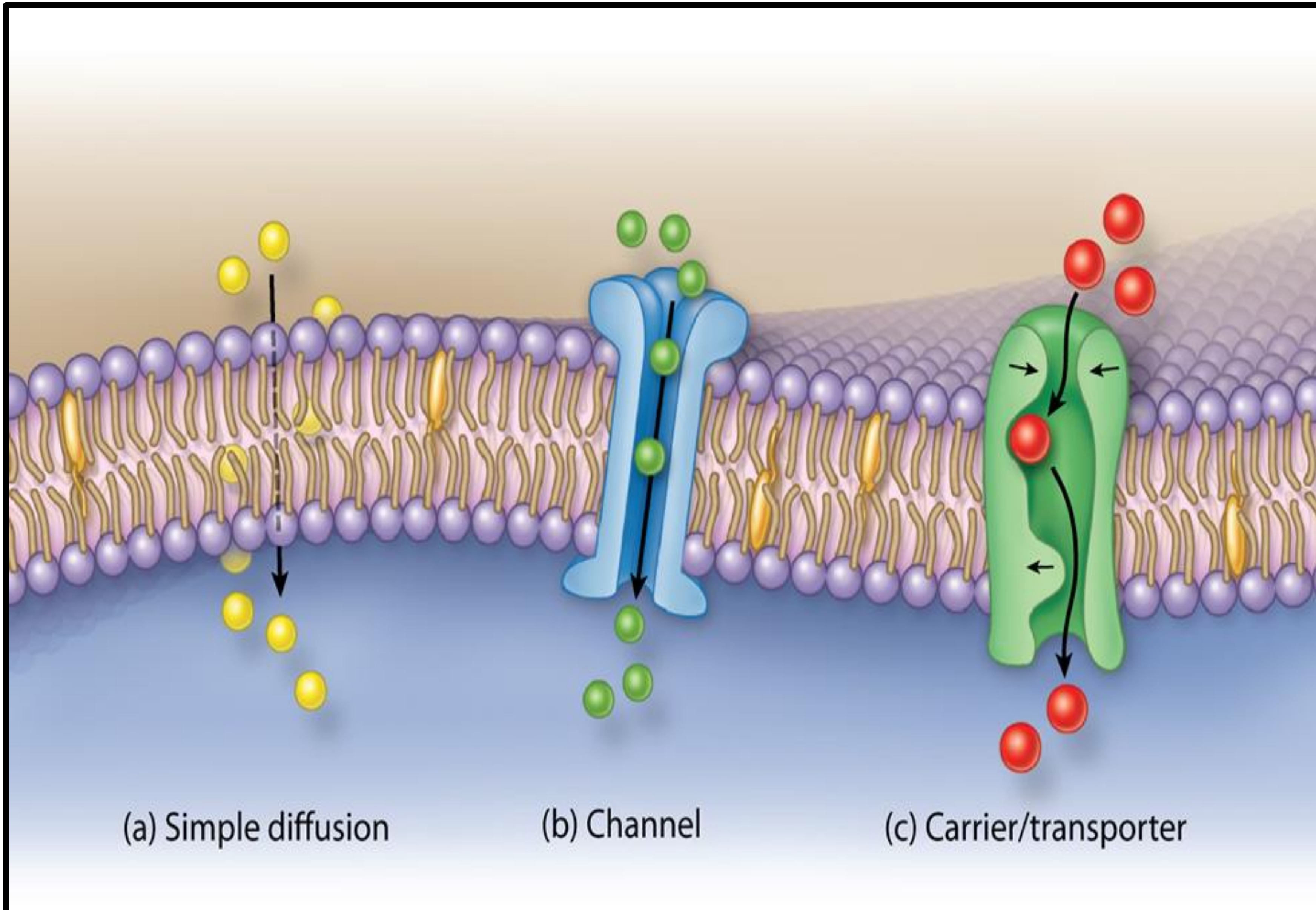
Cell membrane



Cell Membrane Permeability and Membrane Transport

- The phospholipid bilayer of the cell membrane is permeable to certain substances and impermeable to others.
- This property of the cell membrane is called **selective permeability.**
- **Selective** permeability forms an important barrier between the internal and external environments of the cell, which then maintains a constant intracellular environment.

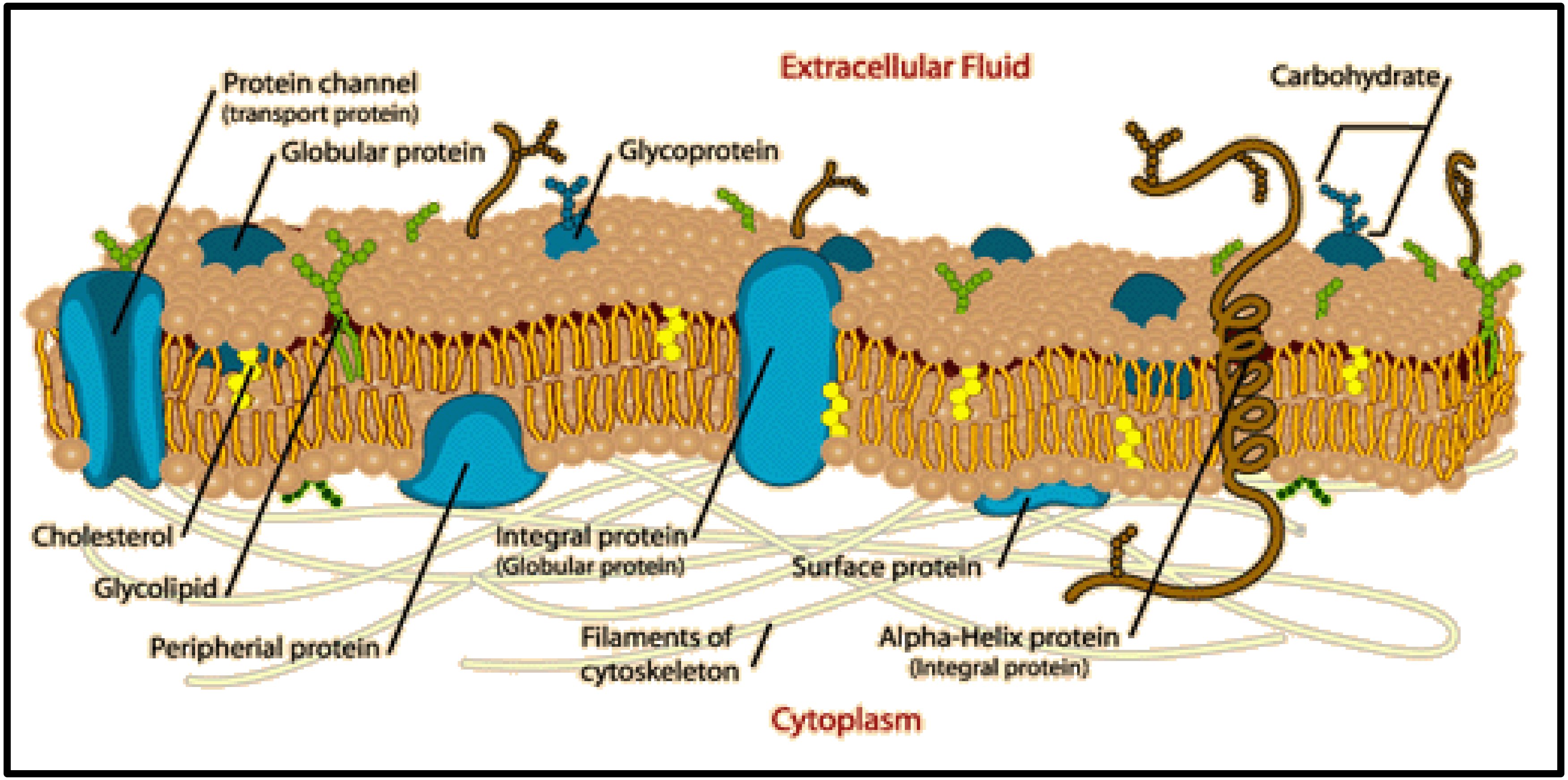
- The phospholipid bilayer is **permeable** to such molecules as oxygen, carbon dioxide, water, steroids, and other lipid-soluble chemicals.
- Other substances, such as glucose, ions, and proteins, cannot pass through the cell membrane and cross it only by specific **transport mechanisms.**
- Some of these substances are transported through the integral membrane proteins using pump molecules or through protein channels that allow the passage of specific molecules.


(a) Simple diffusion
(b) Channel
(c) Carrier/transporter

Arrangement of Membrane Proteins

- Membrane proteins are classified as integral or peripheral according to whether they are firmly embedded in the membrane.
- **Integral proteins** extend into or through the lipid bilayer among the fatty acid tails and are firmly embedded in it.
- Most integral proteins are **transmembrane proteins,** which means that they span the entire lipid bilayer and protrude into both the cytosol and extracellular fluid.

- **peripheral proteins are** not as firmly embedded in the membrane. They are attached to the polar heads of membrane lipids or to integral proteins at the inner or outer surface of the membrane.



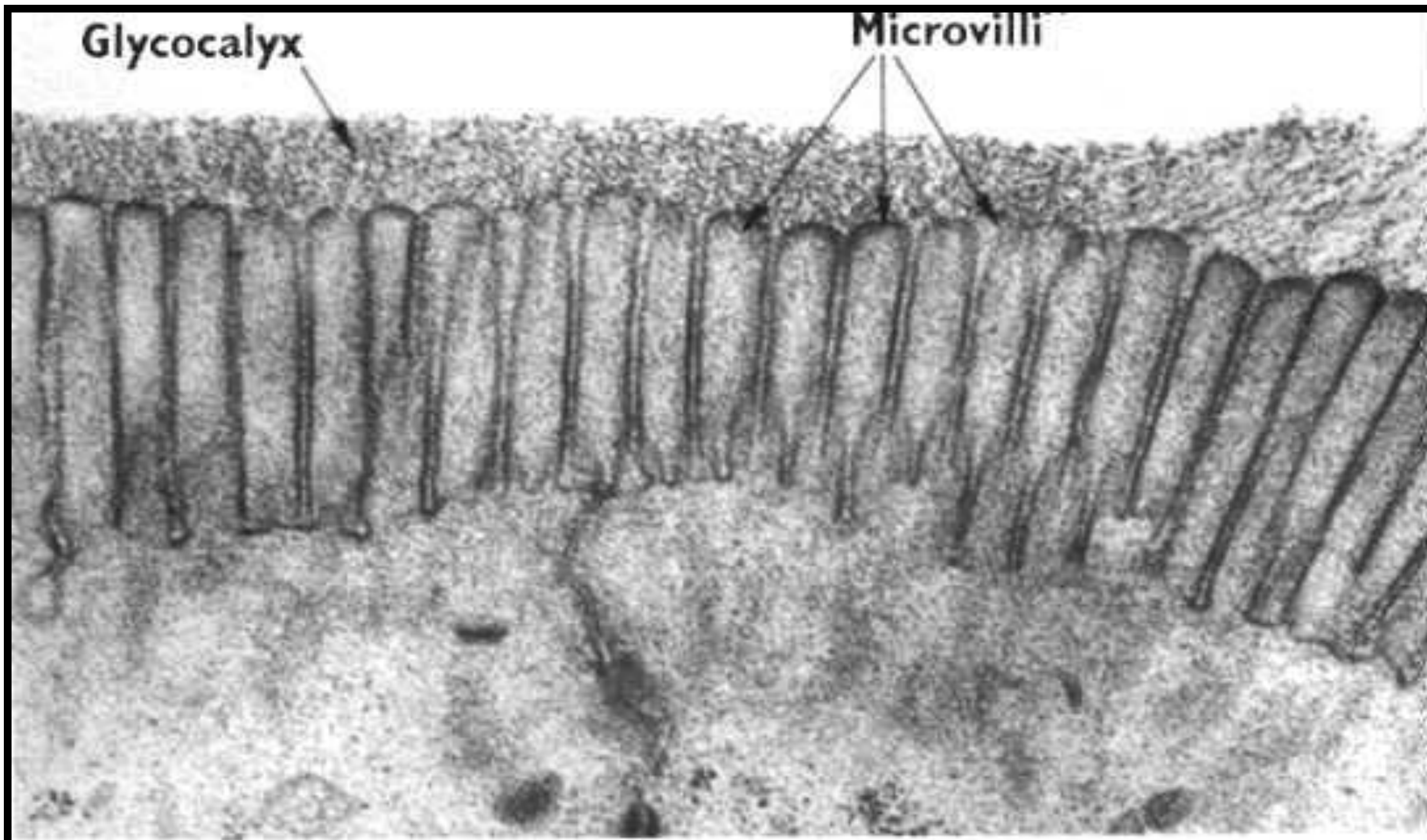
Extracellular Fluid
Protein channel
(transport protein)
Globular protein
Glycoprotein
Carbohydrate
Cholesterol
Glycolipid
Peripherial protein
Integral protein
(Globular protein)
Surface protein
Filaments of
cytoskeleton
Alpha-Helix protein
(Integral protein)
Cytoplasm

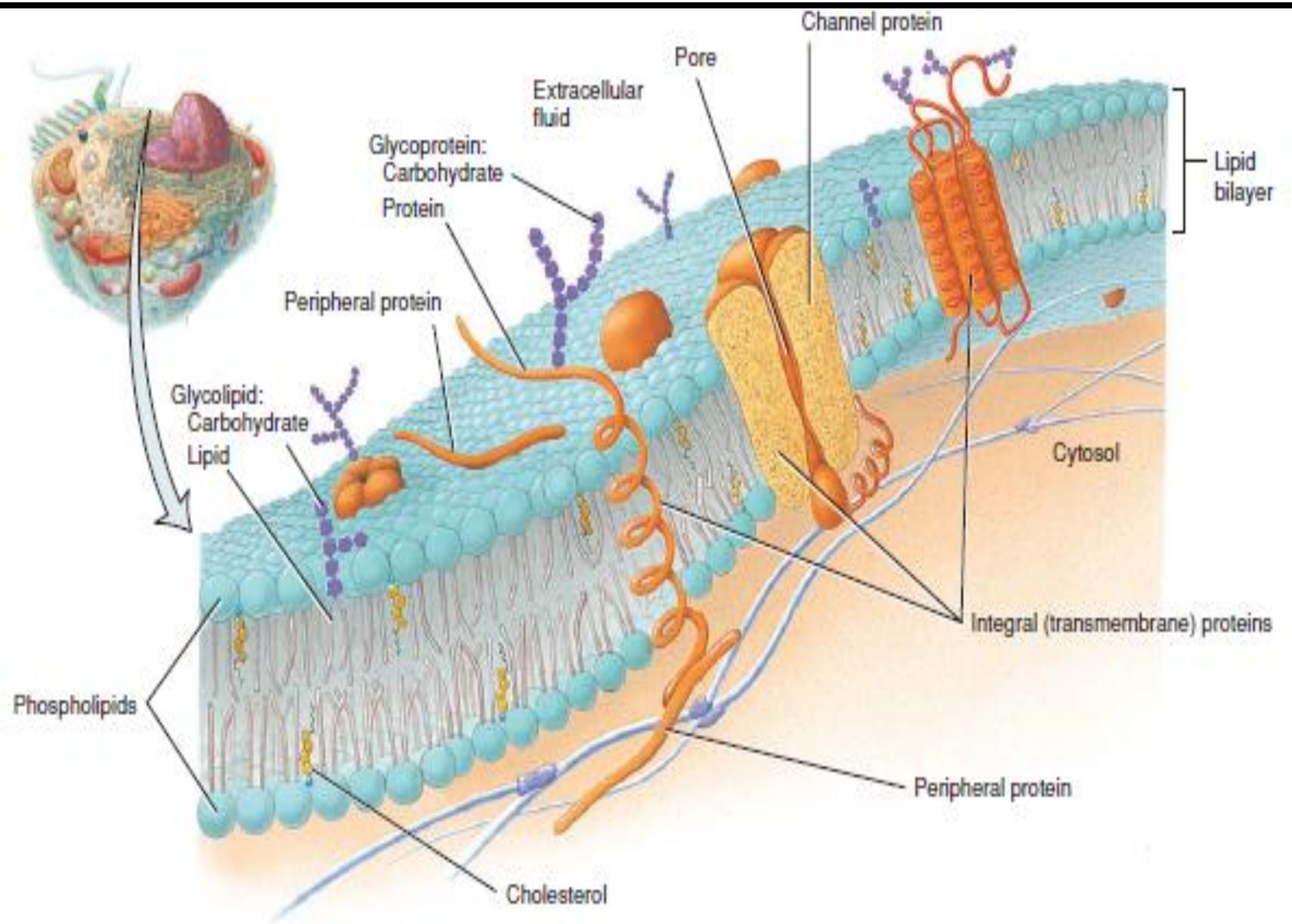
- The peripheral proteins do not protrude into the phospholipid bilayer membrane on both its extracellular (outer) and intracellular (inner) surfaces.

- Some of the peripheral proteins are anchored to the network of tiny **microfilaments** of the cytoskeleton of the cell and are held firmly in place.

- **Cholesterol** stabilizes the cell membrane, makes it more rigid, and regulates the fluidity of the phospholipid bilayer.

- Many integral proteins are **glycoproteins, proteins with carbohydrate** groups attached to the ends that protrude into the extracellular fluid.
- The carbohydrate portions of glycolipids and glycoproteins form an extensive sugary coat called the **glycocalyx.**



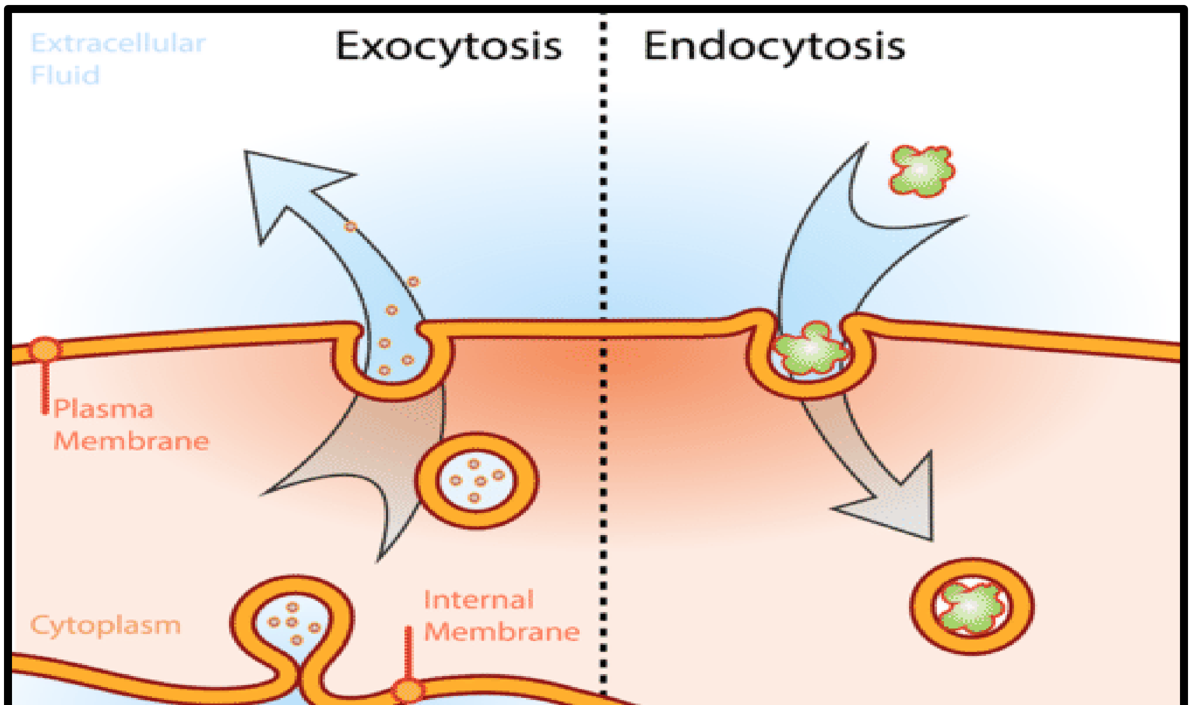


Channel protein
Pore
Extracellular fluid
Glycoprotein:
Carbohydrate
Protein
Lipid bilayer
Peripheral protein
Glycolipid:
Carbohydrate
Lipid
Cytosol
Integral (transmembrane) proteins
Phospholipids
Peripheral protein
Cholesterol

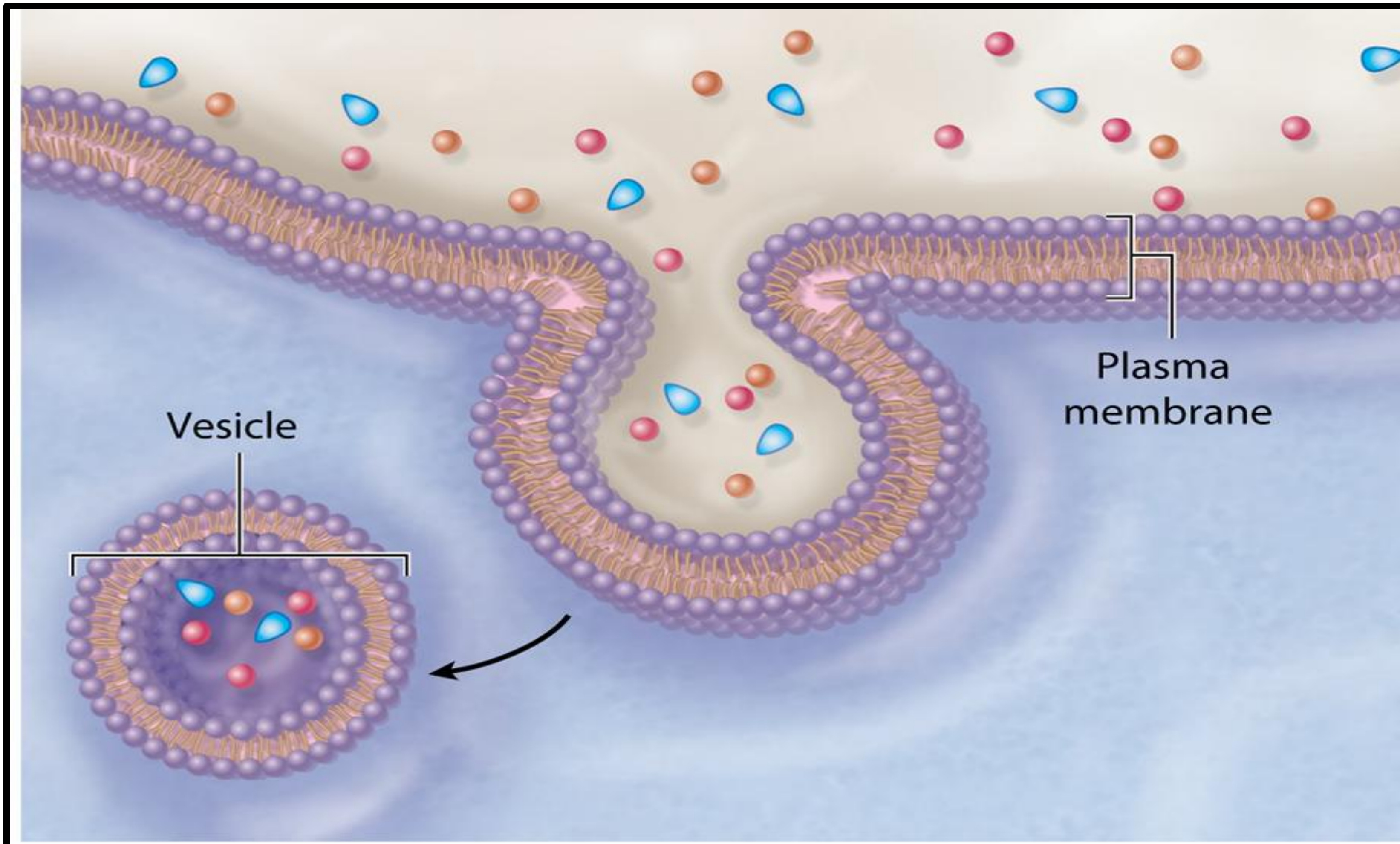
- The glycocalyx acts like a molecular “signature” that enables **cells to recognize one another**.
- For example, a white blood cell’s ability to detect a “foreign” glycocalyx is one basis of **the immune response** that helps us destroy invading organisms.
- The glycocalyx **enables cells to adhere to one another** in some tissues and **protects cells from being digested** by enzymes in the extracellular fluid.
- The hydrophilic properties of the glycocalyx attract a film of fluid to the surface of many cells.
- This **action makes red blood cells slippery** as they flow through narrow blood vessels and protects cells that line the airways and the gastrointestinal tract from drying out.

Endocytosis & Exocytosis

- **Endocytosis :** is the process which performs by the uptake and transfer of molecules and solids across the cell membrane into the cell interior.
- **Exocytosis: is** the process of releasing material from the cell cytoplasm across the cell membrane to the exterior.



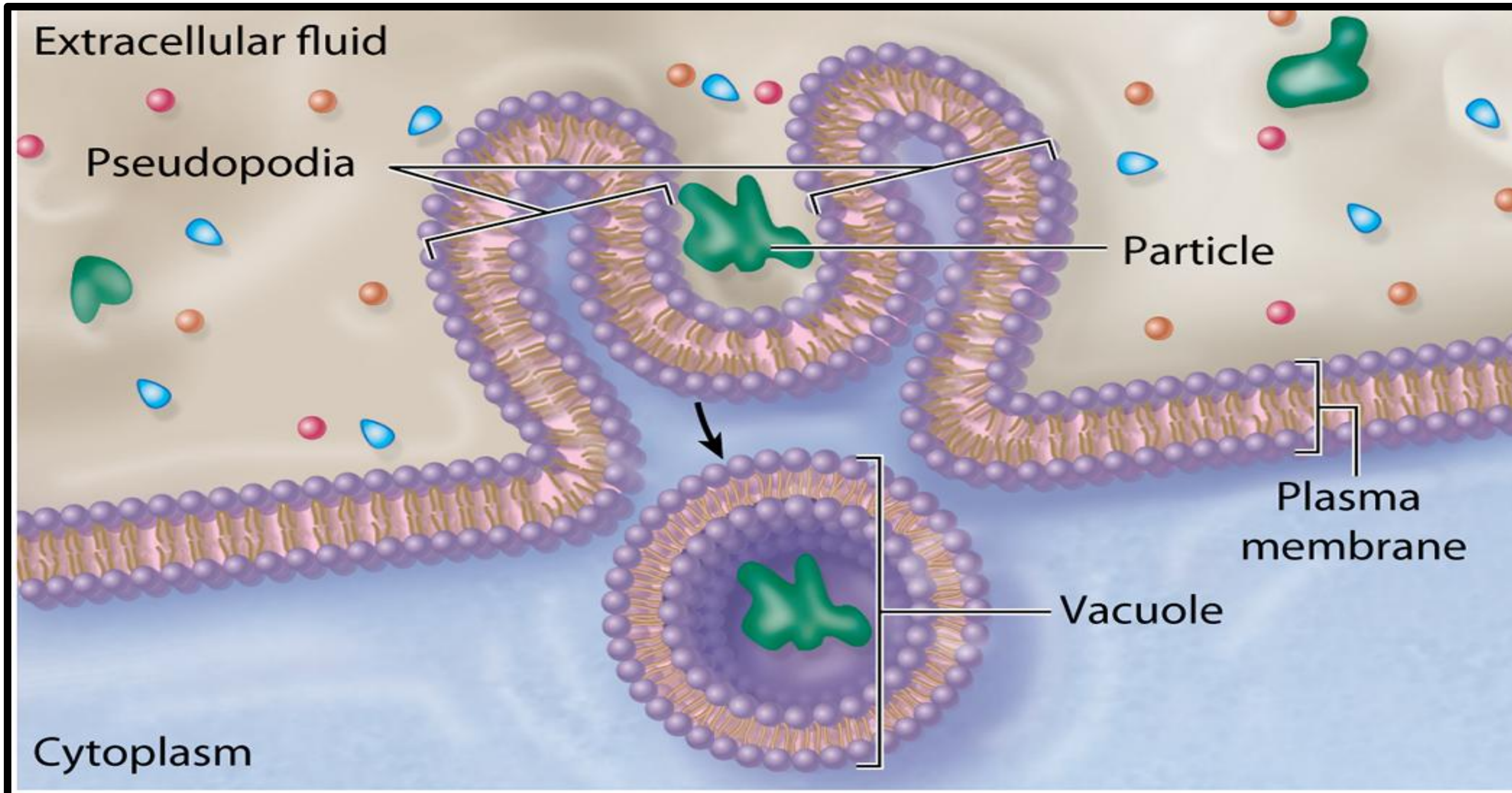
- **Pinocytosis** is the process by which cells ingest small molecules of extracellular fluids or liquids.



b Pinocytosis

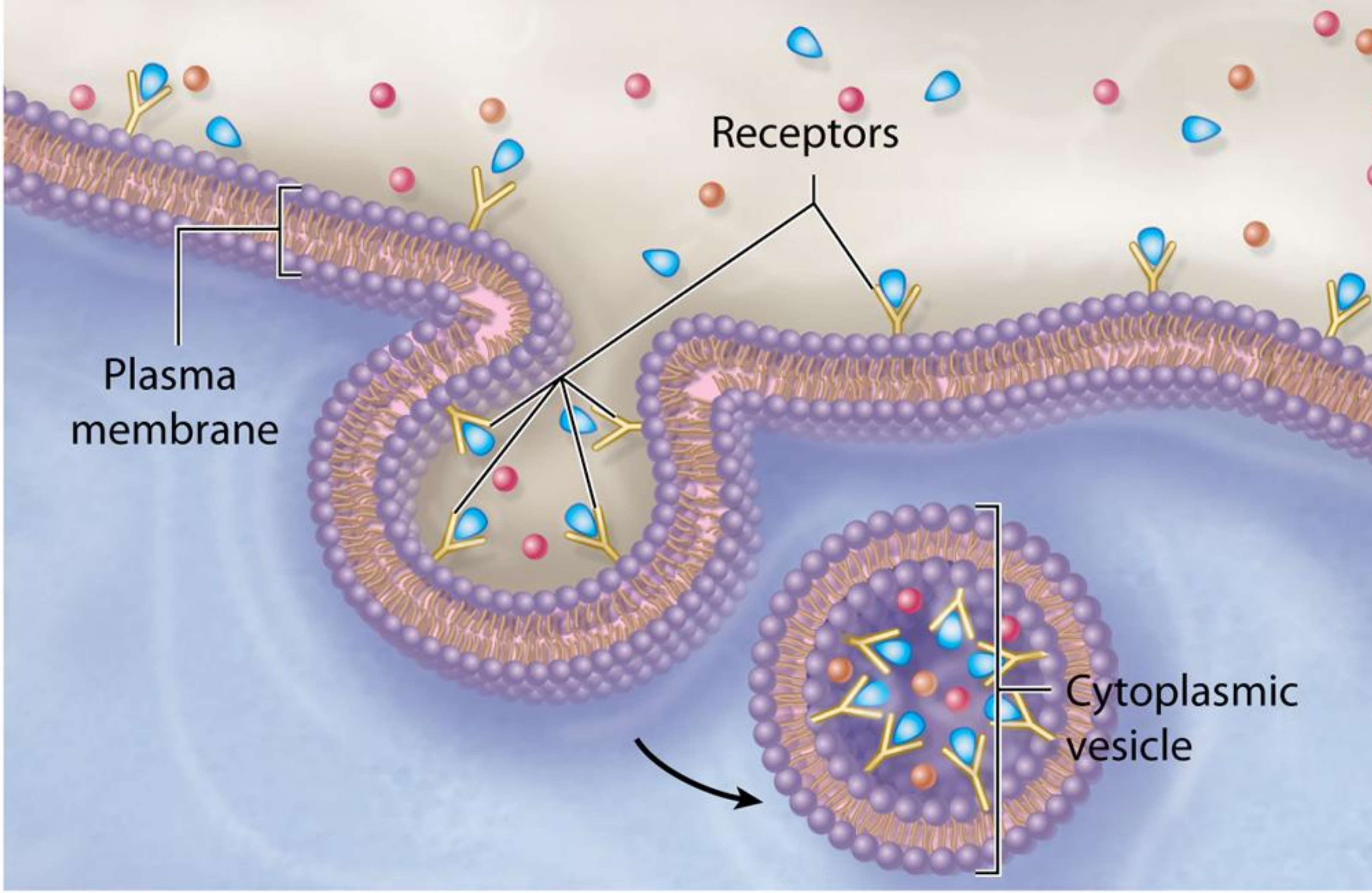
Phagocytosis refers to the ingestion or intake of large solid particles, such as bacteria, worn-out cells, or cellular debris, by specialized cells.

Neutrophils in the blood and macrophages or monocytes in the extracellular connective tissues.



a Phagocytosis

- **Receptor-mediated endocytosis :** is a highly selective form of pinocytosis, or phagocytosis.
- **In this process,** specific molecules in the extracellular fluid bind to receptors on the cell membrane and are then taken into the cell cytoplasm.
- Examples of receptor-mediated endocytosis include uptake of low-density lipoproteins and insulin from the blood.



c Receptor-mediated endocytosis

The **cytoplasm**

- Consists of all the cellular contents between the plasma membrane and the nucleus.
- This compartment has two components:

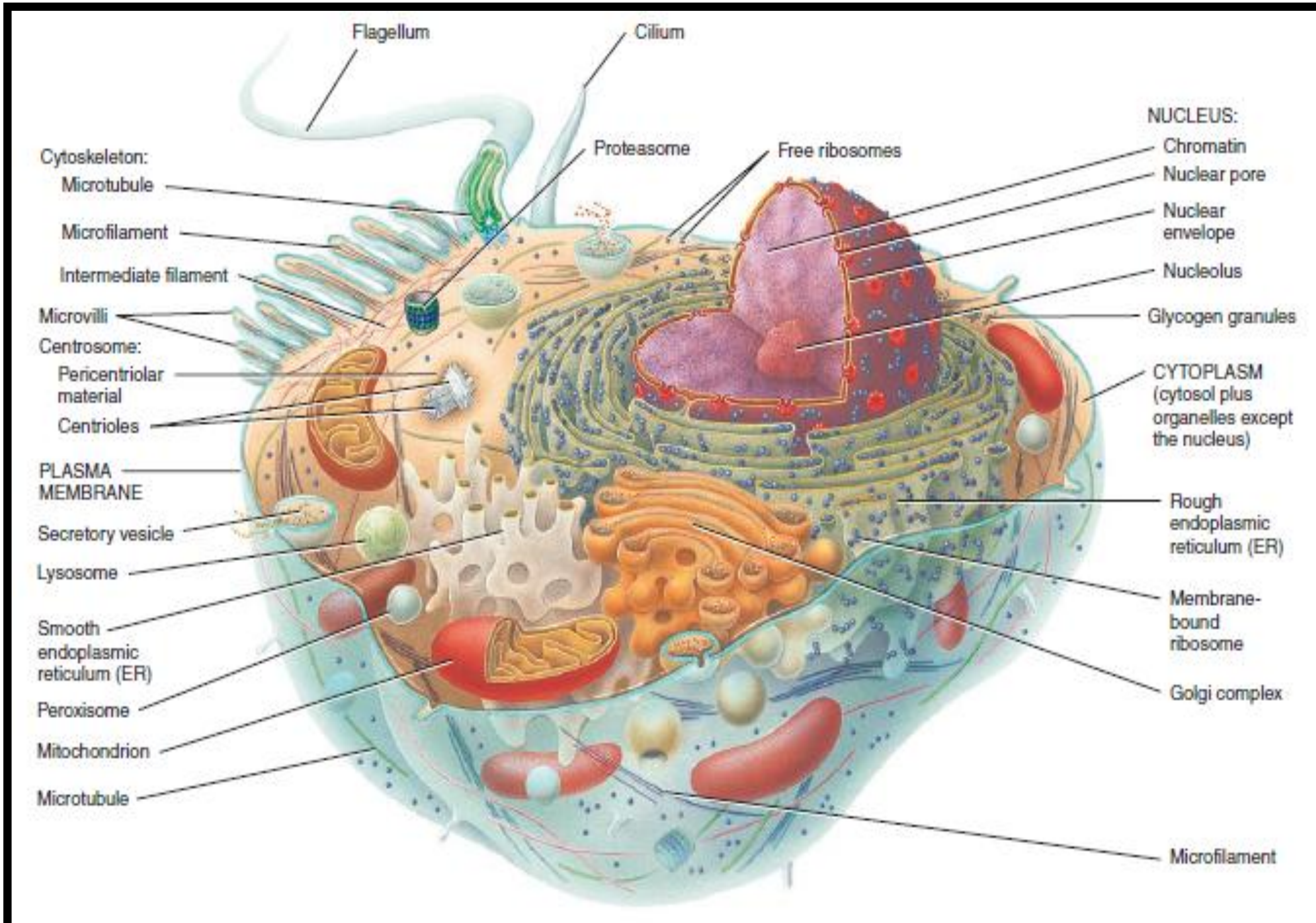
1. **Cytosol:**

   The fluid portion of cytoplasm, contains water, dissolved solutes, and suspended particles.

2. **Organelles**.

   Are several different types, **each type of organelle** has a characteristic shape and specific functions.

- Examples include:
- The cytoskeleton, ribosomes, endoplasmic reticulum, Golgi complex, lysosomes and mitochondria.

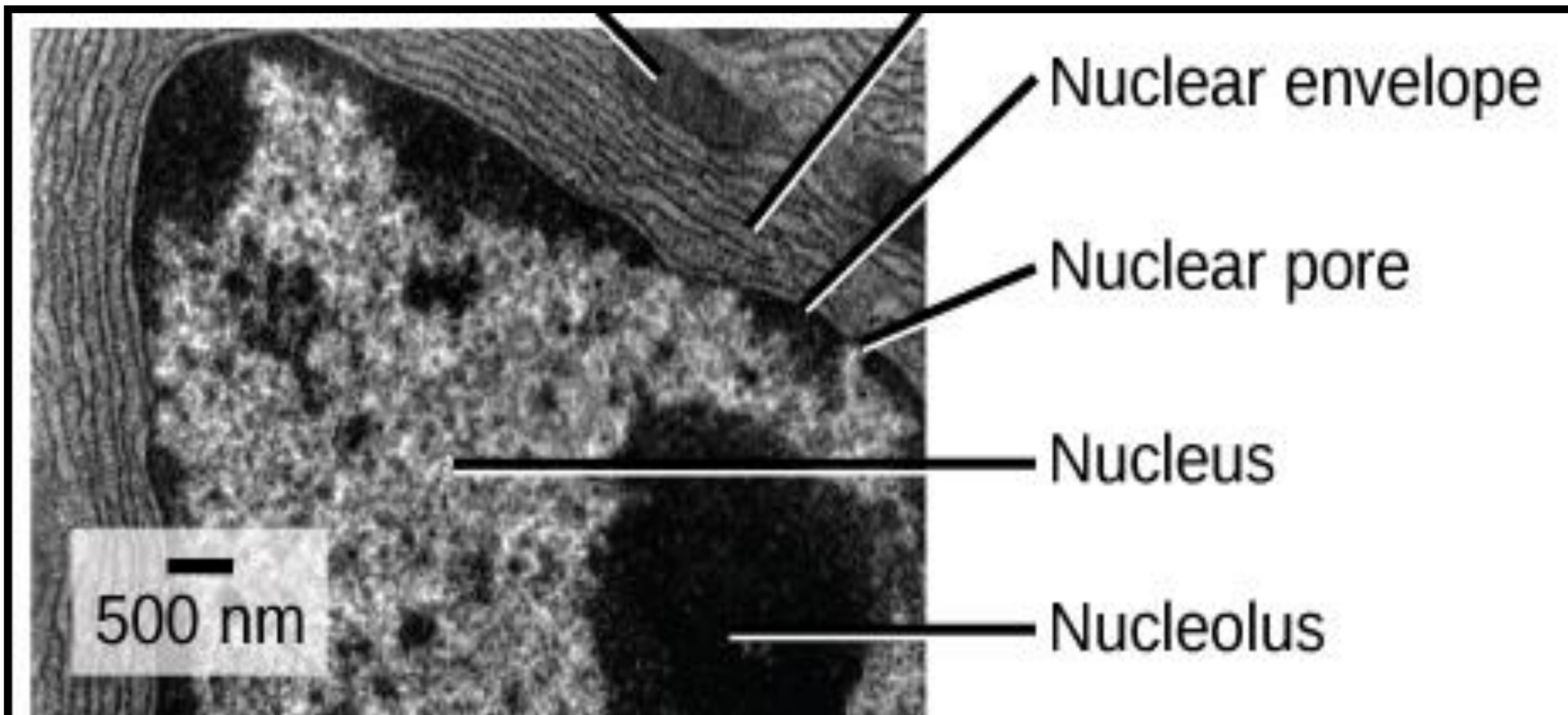

Flagellum
Cilium
NUCLEUS:
Chromatin
Nuclear pore
Nuclear envelope
Nucleolus
Glycogen granules
CYTOPLASM (cytosol plus organelles except the nucleus)
Rough endoplasmic reticulum (ER)
Membrane-bound ribosome
Golgi complex
Microfilament
Proteasome
Free ribosomes
Cytoskeleton:
Microtubule
Microfilament
Intermediate filament
Microvilli
Centrosome:
Pericentriolar material
Centrioles
PLASMA MEMBRANE
Secretory vesicle
Lysosome
Smooth endoplasmic reticulum (ER)
Peroxisome
Mitochondrion
Microtubule

The **Nucleus**

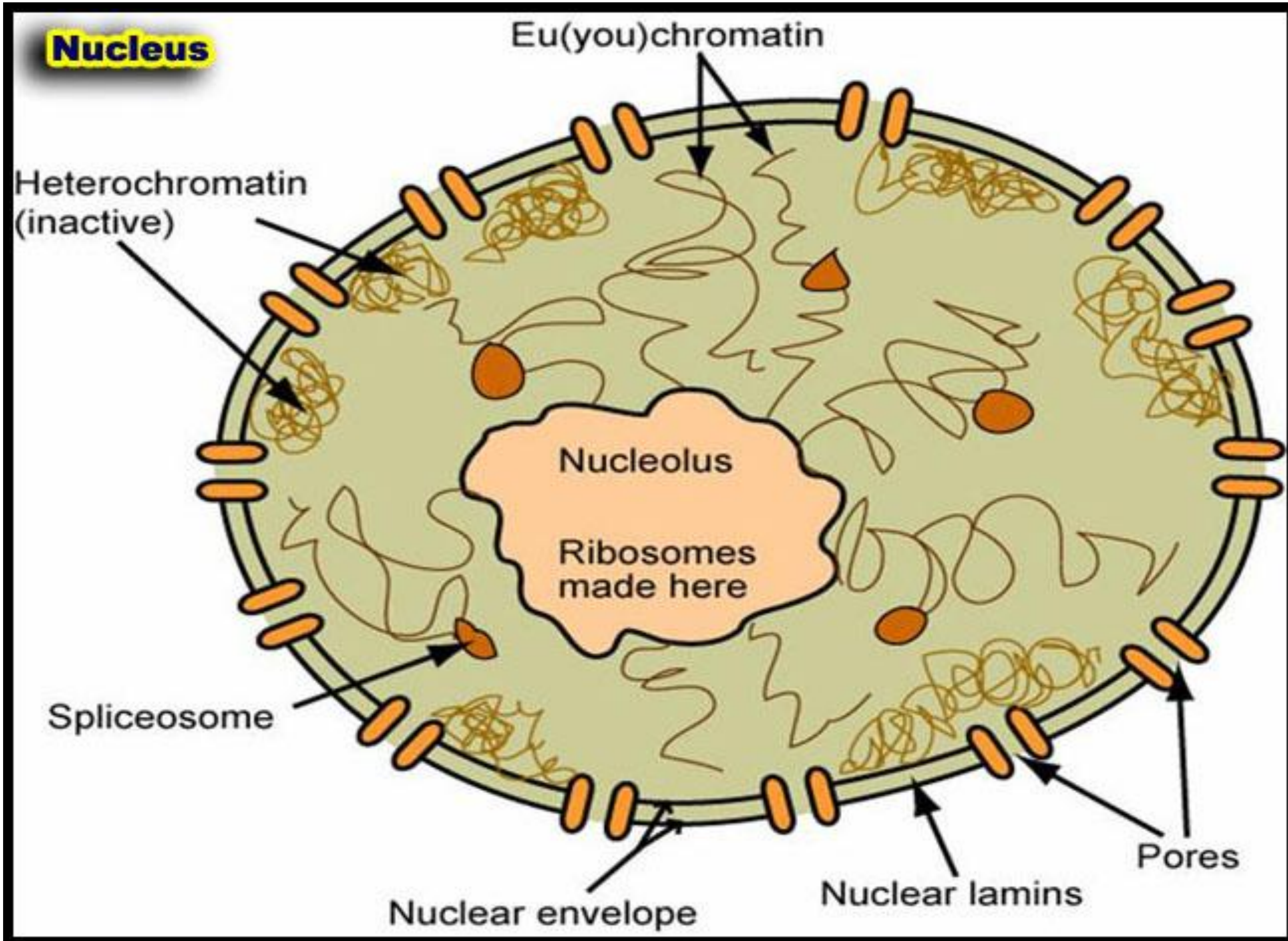
- Is a spherical or oval-shaped structure that usually is the most prominent feature of a cell.
- Most cells have a single nucleus.
- Some, such as **mature red blood cells**, have none.
- **Skeletal muscle cells** and a few other types of cells have multiple nuclei.
- Is a large organelle.
- The nucleus consists of **chromatin,** one or more **nucleoli** and **nuclear matrix.**

The **Nucleus**

- Nuclear envelope
- Nuclear pores
- **Heterochromatin** : Condensed chromatin
- **Euchromatin:** Dispensed or extended chromatin.
- Nucleolus



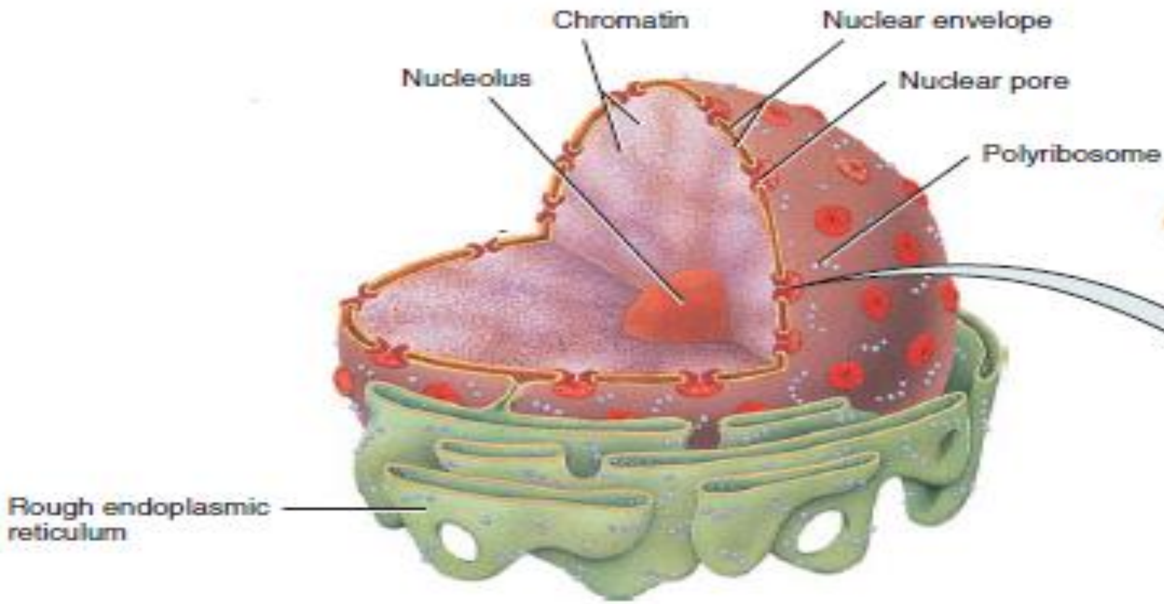
- A double membrane called the **nuclear envelope** surrounds the nucleus.
- Both the inner and outer layers of the nuclear envelope have a structure similar to that of the lipid bilayer of the cell membrane.
- At intervals around the periphery of the nucleus, the outer and inner membranes of the nuclear envelope **fuse** to form numerous **nuclear pores.**
- These pores **function** in controlling the movement of metabolites, macromolecules, and ribosomal subunits between the nucleus and the cytoplasm.
- For example, proteins needed for nuclear functions move from the cytosol into the nucleus; newly formed RNA molecules move from the nucleus into the cytosol.


Nucleus
Eu(you)chromatin
Heterochromatin
(inactive)
Nucleolus
Ribosomes
made here
Spliceosome
Pores
Nuclear lamins
Nuclear envelope

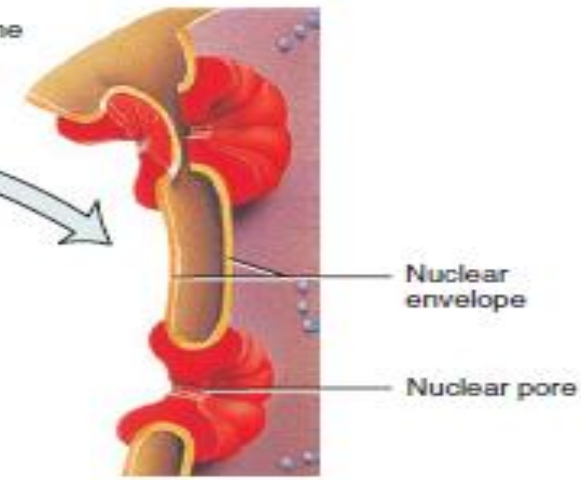
- The nucleus contains the **cellular genetic material deoxyribonucleic acid (DNA)** that associated with several proteins, contains thousands of hereditary units called **genes that control most** aspects of cellular structure and function.
- The complex of DNA, proteins, and some RNA is called **chromatin**
- **The total genetic information** carried in a cell or an organism is its **genome.**

The Nucleolus

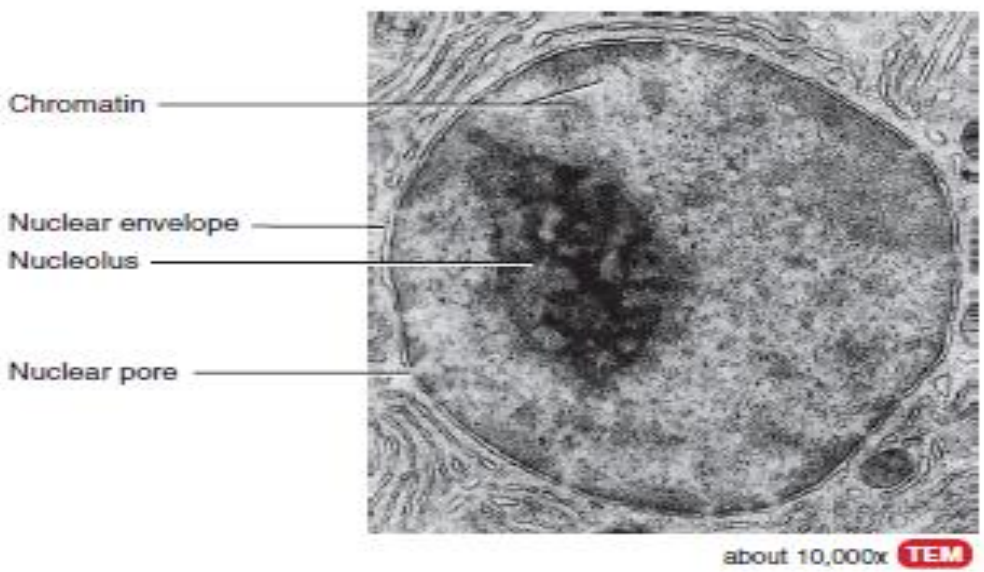
- Inside the nucleus are one or more spherical bodies called **nucleoli (singular is *nucleolus*)** .
- Each nucleolus is simply a cluster of protein, DNA, and RNA.
- It is not enclosed by a membrane.
- Nucleoli are the sites of synthesis of rRNA and assembly of rRNA and proteins into ribosomal subunits.
- Nucleoli are **quite prominent** in cells that synthesize large amounts of protein, such as muscle and liver cells.
- Nucleoli disperse and disappear during cell division.



(a) Details of the nucleus



(b) Details of the nuclear envelope



Organelles

- **Organelles are specialized structures within the** cell that have characteristic shapes, and they perform specific functions in cellular growth, maintenance, and reproduction.

- The numbers and types of organelles vary in different cells, depending on the cell's function.

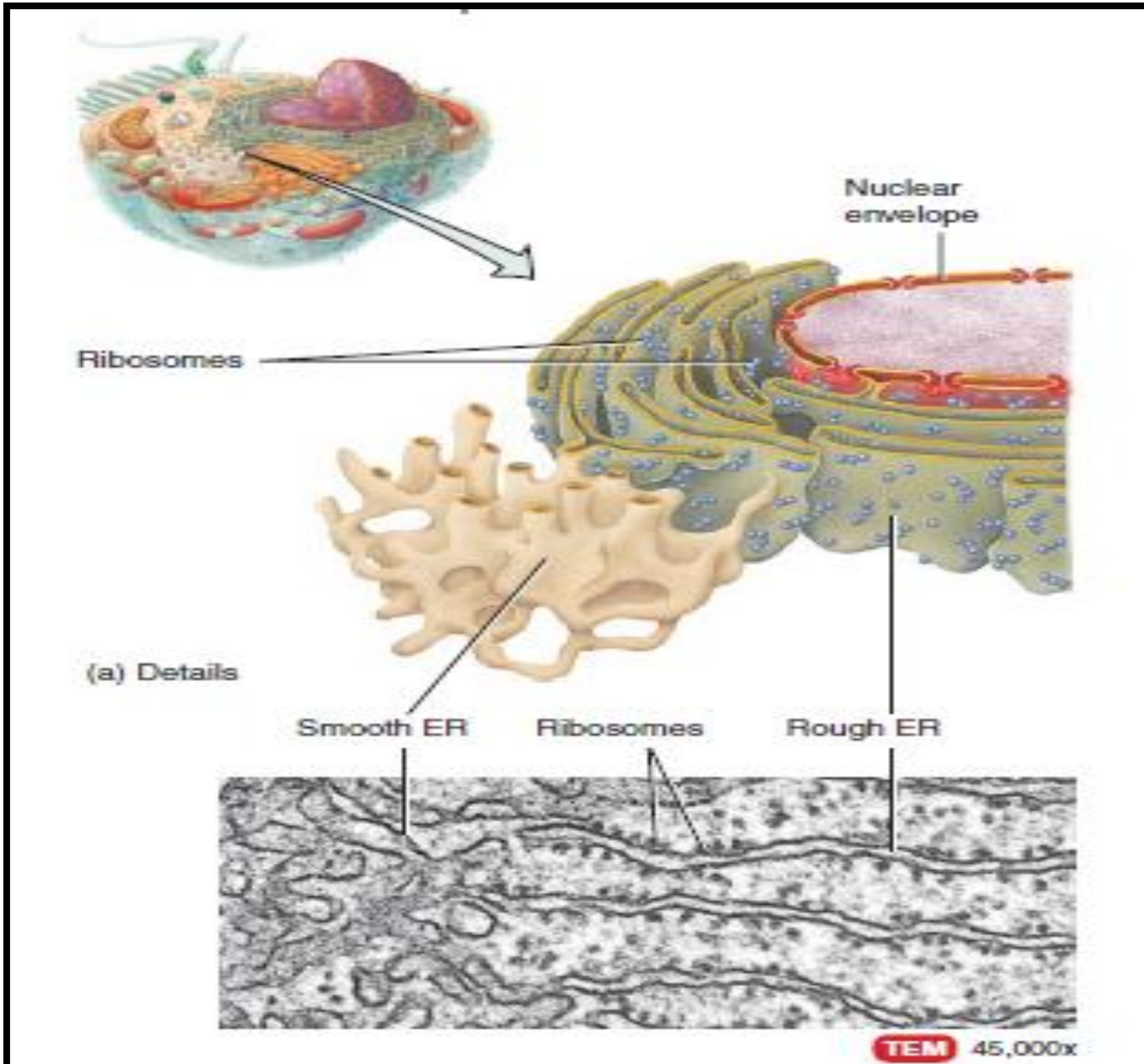
- A membrane similar to the cell membrane **surrounds** such cytoplasmic organelles as nuclei, mitochondria, endoplasmic reticulum, Golgi complexes, lysosomes.

- Organelles that **are not surrounded** by membranes include ribosomes, basal bodies, centrioles, and centrosomes.

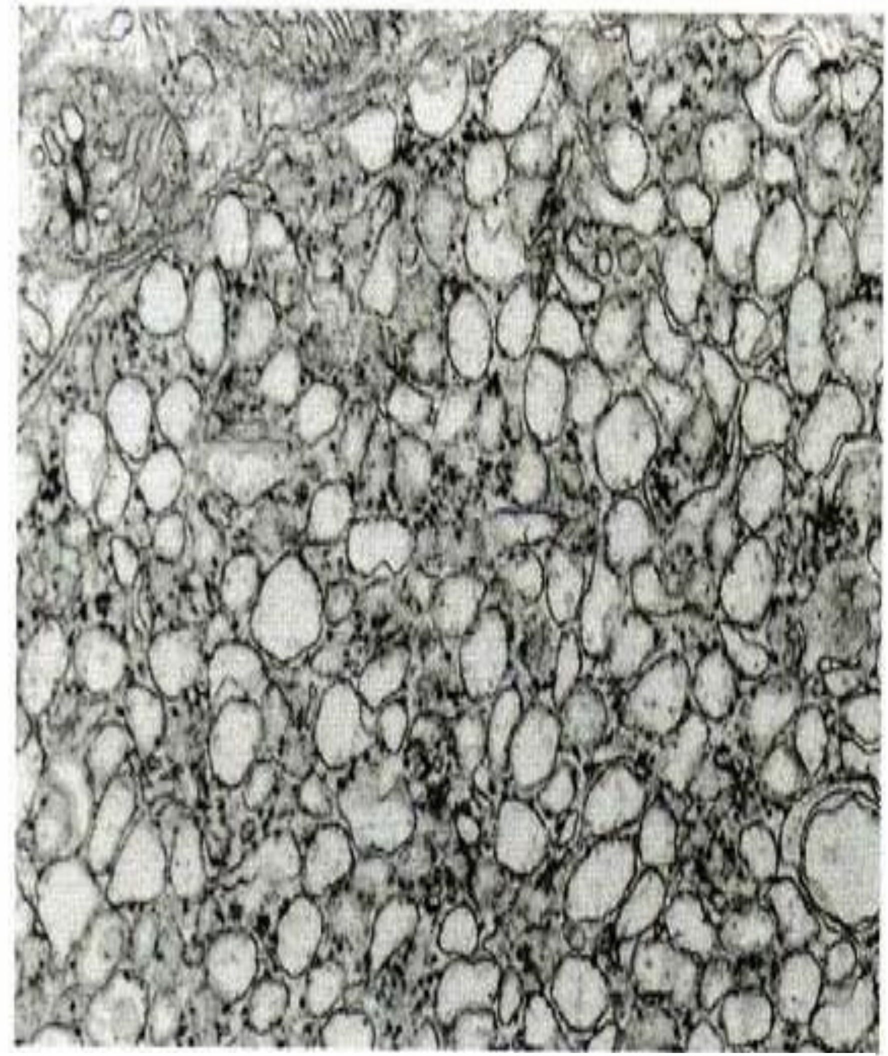
Endoplasmic Reticulum

- The **endoplasmic reticulum** or **ER** is a network of membranes in the form of flattened sacs or tubules.
- The ER extends from the nuclear envelope, to which it is connected, throughout the cytoplasm.
- Cells contain two distinct forms of ER, which differ in structure and function:

1. **Rough endoplasmic reticulum (rER).**
2. **Smooth endoplasmic reticulum (sER).**


Nuclear envelope
Ribosomes
(a) Details
Smooth ER
Ribosomes
Rough ER
TEM 45,000x

Rough endoplasmic reticulum



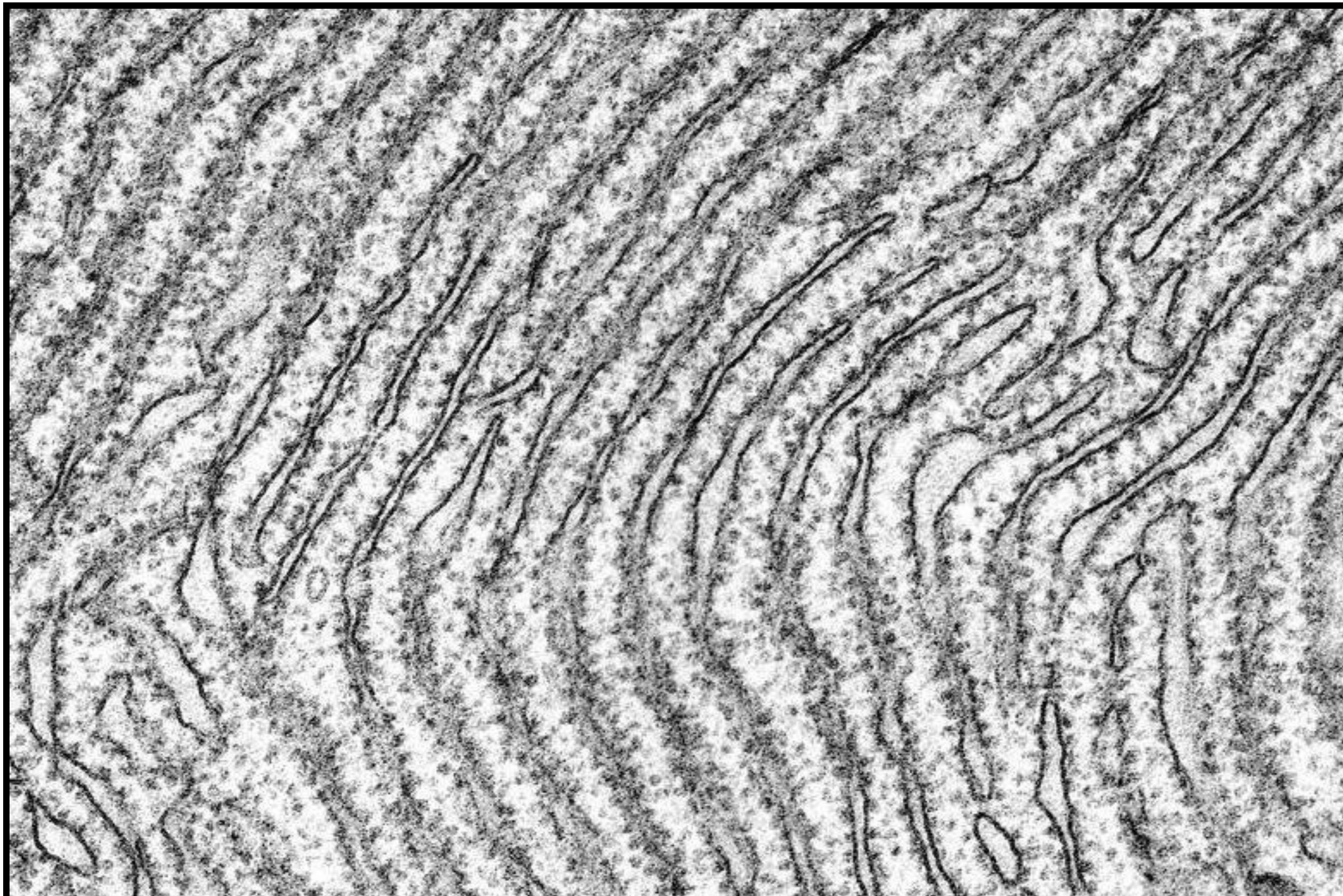
Smooth endoplasmic reticulum

Rough endoplasmic reticulum (rER)

- Is continuous with the nuclear membrane and usually is folded into a series of flattened sacs.
- The outer surface of rough ER is studded with ribosomes, the sites of protein synthesis.
- Proteins synthesized by ribosomes enter spaces within the ER for processing and sorting.
- Thus rough ER produces secretory proteins, membrane proteins, and many organellar proteins.

- Cells that synthesize large amounts of protein for export, such as **pancreatic acinar cells** or **salivary gland cells**, exhibit a highly developed and extensive rough endoplasmic reticulum.

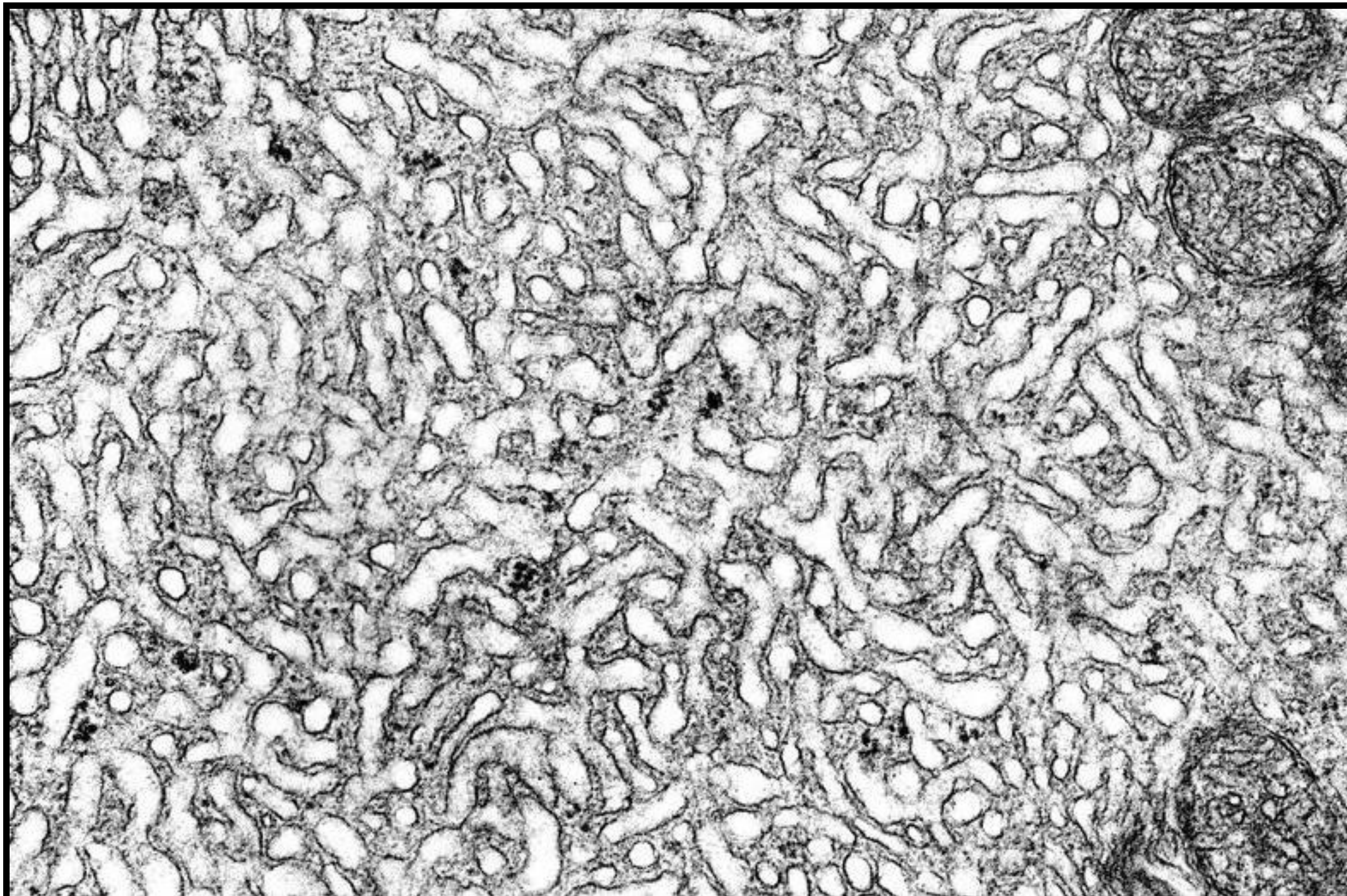
Rough endoplasmic reticulum



Smooth endoplasmic reticulum (sER).

- Extends from the rough ER to form a network of membrane tubules .
- Smooth ER does not have ribosomes on the outer surfaces of its membrane.
- Smooth ER contains unique enzymes.
- Because it lacks ribosomes smooth ER does not synthesize proteins.
- SER is found in abundance in cells that synthesize **phospholipids** that constitute all cell membranes**, cholesterol,** and **steroid hormones,** such as estrogens, testosterone, and corticosteroids.
-

Smooth endoplasmic reticulum



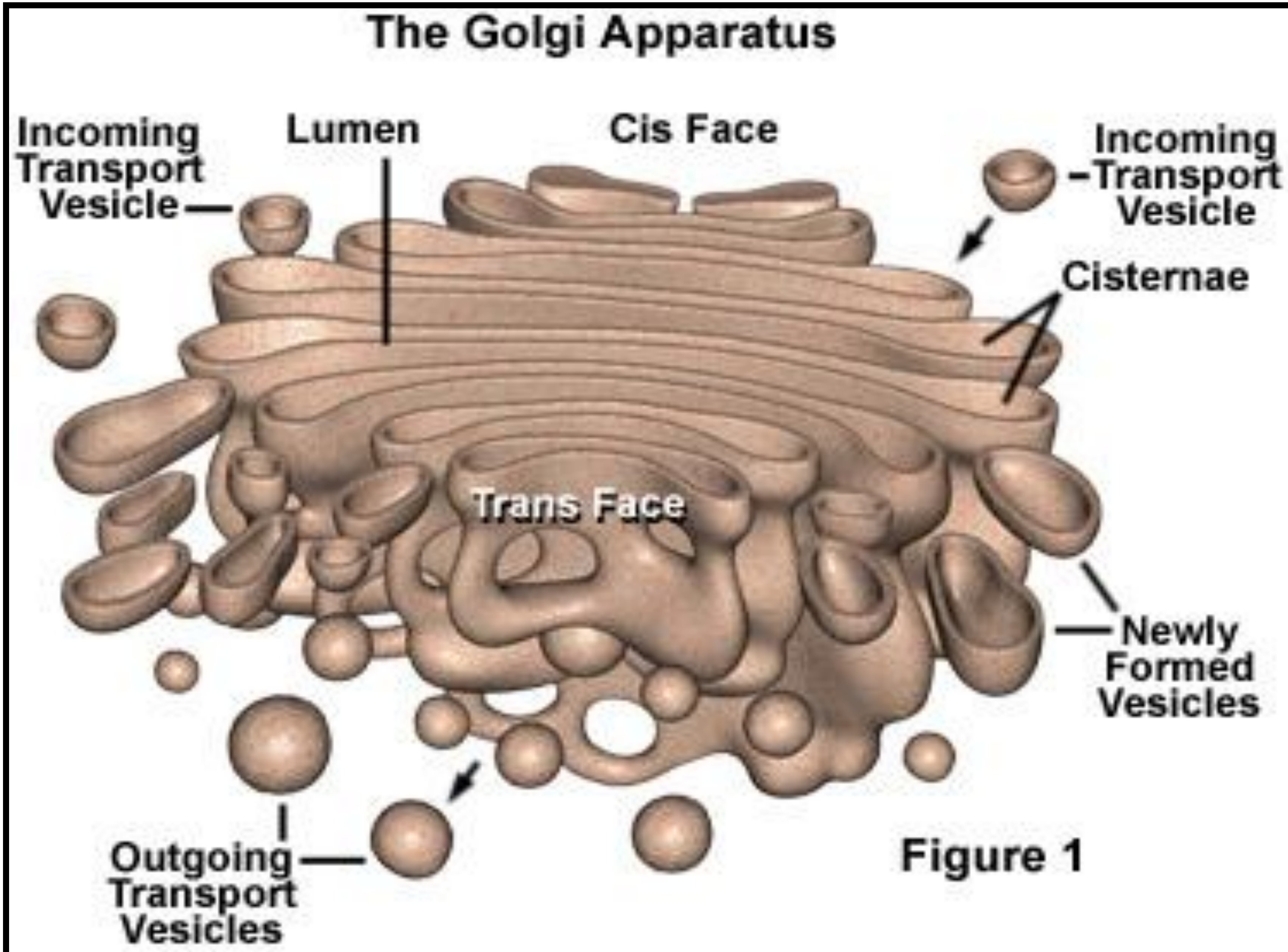
- In liver cells, enzymes of the smooth ER help **release glucose** into the bloodstream **and inactivate or detoxify** lipid-soluble drugs or potentially harmful substances, such as alcohol, pesticides, and *carcinogens (cancer-causing agents).*

- **When liver cells** (hepatocytes) are exposed to potentially harmful drugs and chemicals, SER proliferates and inactivates or **detoxifies the chemicals.**

- In muscle cells, the calcium ions (Ca^{+2}) that trigger contraction are released from the sarcoplasmic reticulum, a form of smooth ER.

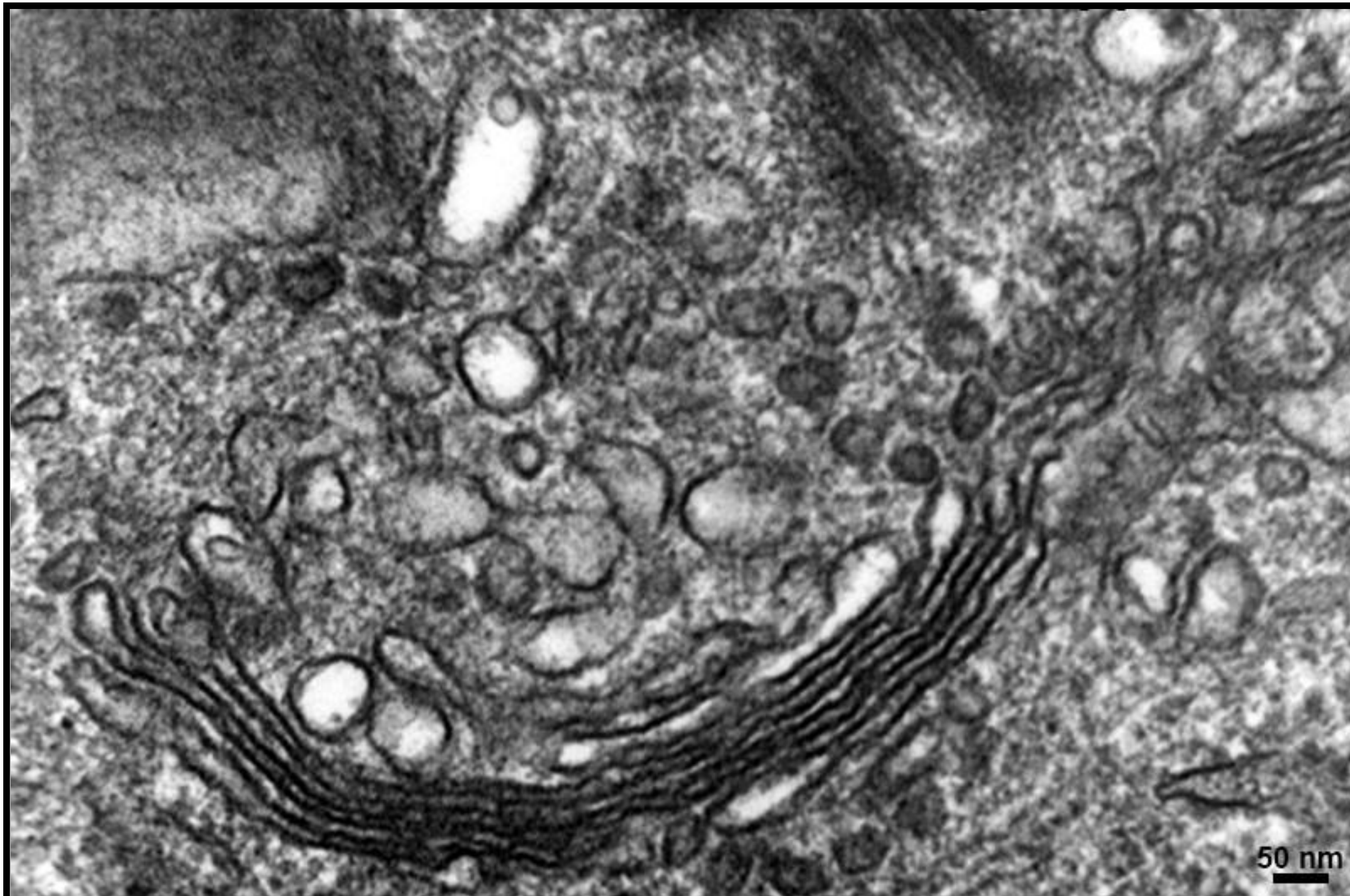
Golgi Complex

- It consists of 3 to **20 cisternae** (cavities), small flattened membranous sacs, are curved with bulging edges that resemble a stack of pita bread or a cuplike shape.
- It is most highly developed in **secretory cells.**
- The cisternae at the opposite ends of a Golgi complex differ from each other in size, shape, and enzymatic activity.
- The convex **entry or *cis face*** is a cisterna that faces the rough ER.
- The concave **exit or *trans face*** is a cisterna that faces the plasma membrane.
- Sacs between the entry and exit faces are called **medial cisternae.**
- **Transport vesicles from** the ER merge to form the entry face. From the entry face, the cisternae are thought to mature, in turn becoming medial and then exit cisternae.


The Golgi Apparatus
Incoming Transport Vesicle
Lumen
Cis Face
Incoming Transport Vesicle
Cisternae
Trans Face
Newly Formed Vesicles
Outgoing Transport Vesicles
Figure 1

- Most of the new proteins synthesized by the cisternae of the RER are transported in the cell cytoplasm as **transfer vesicles to the *cis face of the Golgi apparatus, which*** faces the RER.
- Within the Golgi cisternae are different types of enzymes that modify, sort, and package proteins for different destinations in the cell.
- As the protein molecules move through the different Golgi cisternae, sugars are added to the proteins and lipids to form **glycoproteins and glycolipids.**
- **Proteins are added to lipids to form lipoproteins.**
- **As the secretory molecules near the exit or *trans face of the Golgi cisternae,*** they are further modified, sorted, and packaged as membrane-bound vesicles, which then separate from the Golgi cisternae.

Golgi Complex

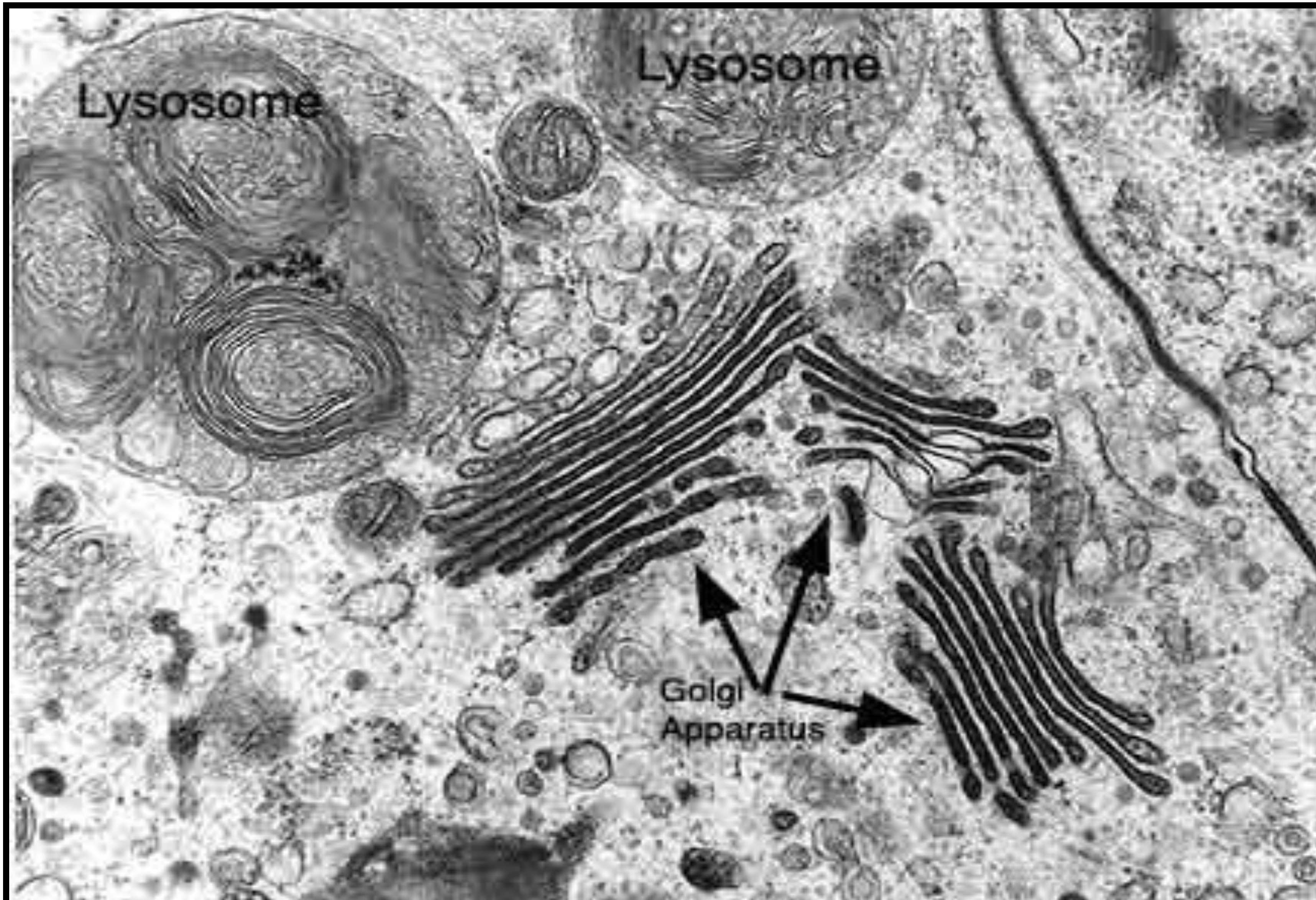


- Different enzymes in the entry, medial, and exit cisternae permit each of these areas to **modify, sort, and package proteins** into vesicles for transport to different destinations.
- The entry face receives and modifies proteins produced by the rough ER.
- The proteins move from the entry face into one or more medial cisternae.
- Enzymes in the medial cisternae modify the proteins to form **glycoproteins**, **glycolipids**, and **lipoproteins**.
- The exit face modifies the molecules further and then sorts and packages them for transport to their destinations.

Lysosomes

- **Lysosomes** (dissolving bodies):
- Are membrane-enclosed vesicles that form from the Golgi complex.
- They can contain as many as 60 kinds of powerful digestive and hydrolytic enzymes that can break down a wide variety of molecules .
- The lysosomal interior has a pH of 5, which is 100 times more acidic than the pH of the cytosol (pH 7).
- The main function of lysosomes is the **intracellular digestion or phagocytosis** of substances taken into the cells.
- Lysosomes digest phagocytosed microorganisms, cell debris, cells, and damaged, worn-out, or excessive cell organelles, such as RER or mitochondria.

Lysosomes

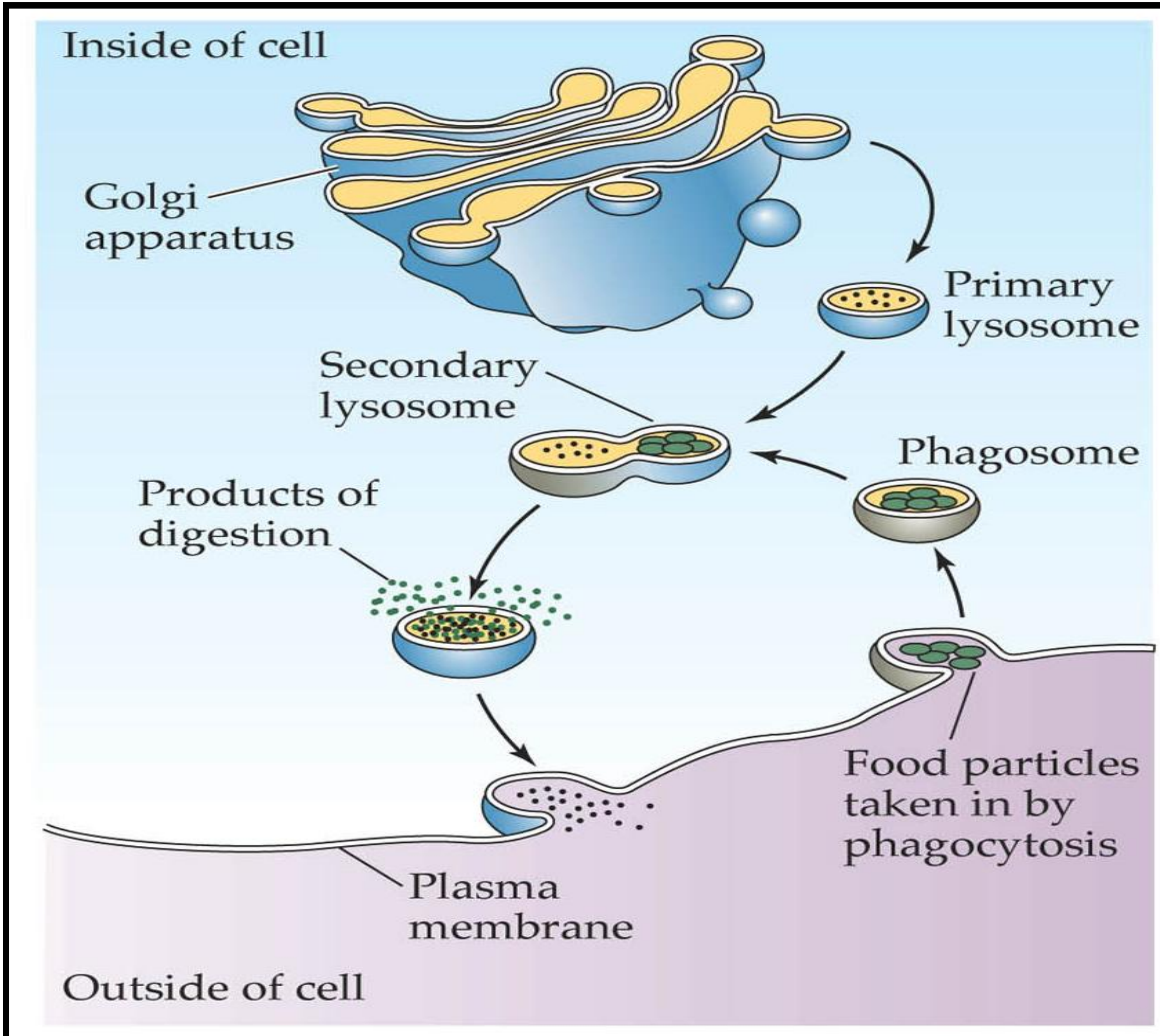


- Lysosomal enzymes also help recycle worn-out cell structures.
- A lysosome can engulf another organelle, digest it, and return the digested components to the cytosol for reuse.

- The process by which entire worn-out organelles are digested is called **autophagy** (self eating).

- Lysosomal enzymes may also destroy the entire cell that contains them, a process known as **autolysis.**
- Autolysis occurs in some pathological conditions and also is responsible for the tissue deterioration that occurs immediately after death.
- Most lysosomal enzymes act within a cell. Some operate in extracellular digestion.
- One example: occurs during fertilization. The **head of a sperm** cell releases lysosomal enzymes that aid its penetration of the **oocyte** by dissolving its **protective coating** in a process called the **acrosomal reaction.**

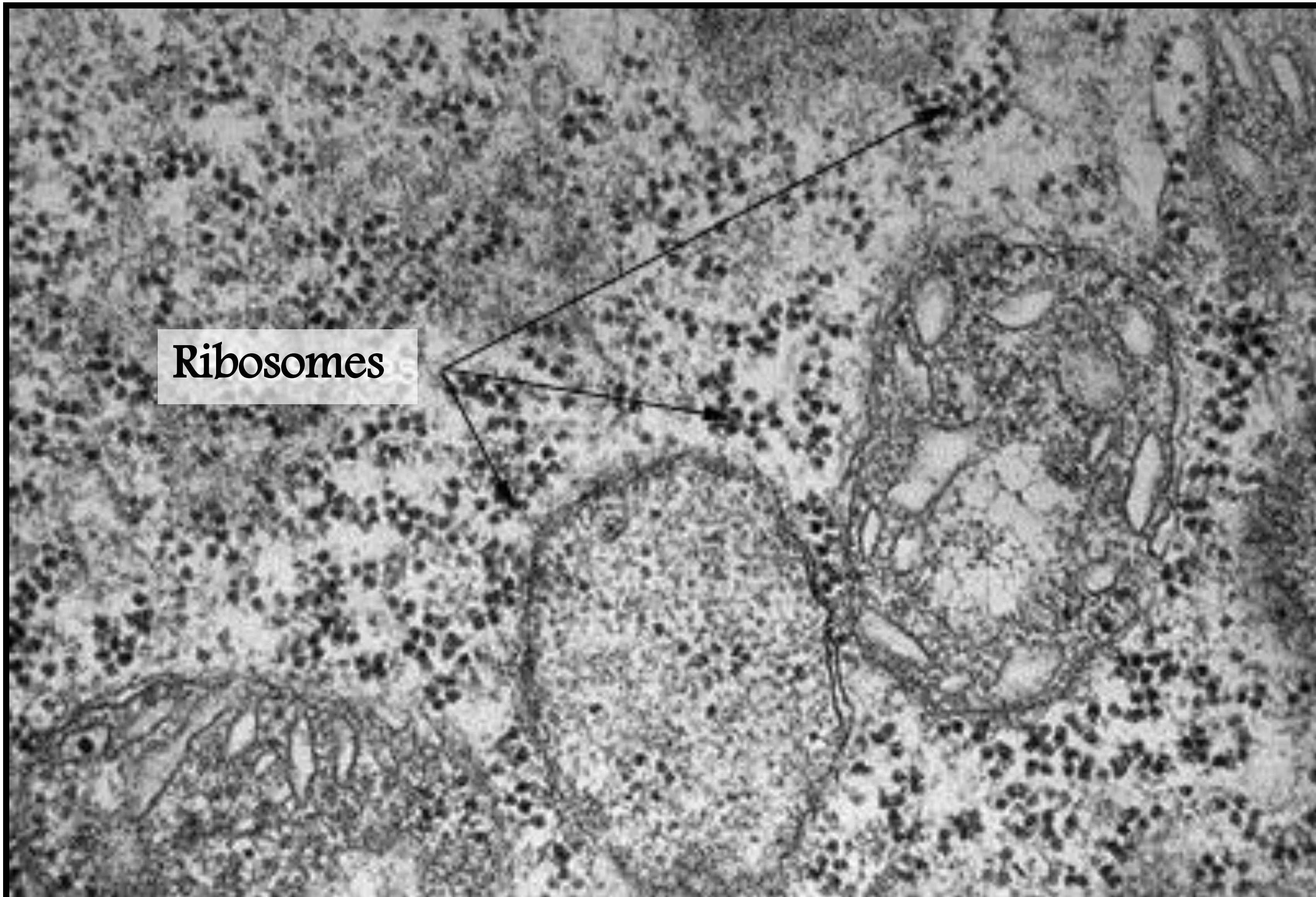
- During intracellular digestion, a membrane surrounds the material to be digested.
- The membrane of the lysosome then fuses with the ingested material, and their hydrolytic enzymes are emptied into the formed vacuole.
- After digestion of the lysosomal contents, the **indigestible debris** in the cytoplasm is retained in large membrane-bound vesicles called **residual bodies.**
- **Lysosomes** are very **abundan**t in such **phagocytic cells** as tissue macrophages and specific white blood cells (leukocytes) such as neutrophils.


Inside of cell
Golgi apparatus
Primary lysosome
Secondary lysosome
Phagosome
Products of digestion
Food particles taken in by phagocytosis
Plasma membrane
Outside of cell

Ribosomes

- The **ribosomes** are small, electron-dense granules found in the cytoplasm of the cell; a membrane does not surround ribosomes.
- In a given cell, there are both **free ribosomes and attached ribosomes,** as seen on the endoplasmic reticulum cisternae.
- Ribosomes have an important role in **protein synthesis** and are most **abundant** in the cytoplasm of **protein-secreting cells.**
- **Ribosomes** perform an essential role in decoding or translating the **coded genetic messages** from the nucleus for the amino acid sequence of proteins that are then synthesized by the cell.

Ribosome


Ribosomes

- The unattached or **free ribosomes** synthesize proteins for use **within the cell cytoplasm**.
- In contrast, ribosomes that are attached to the membranes of the **endoplasmic reticulum** synthesize proteins that are **packaged and stored in the cell** as lysosomes or are released from the cell as secretory products.

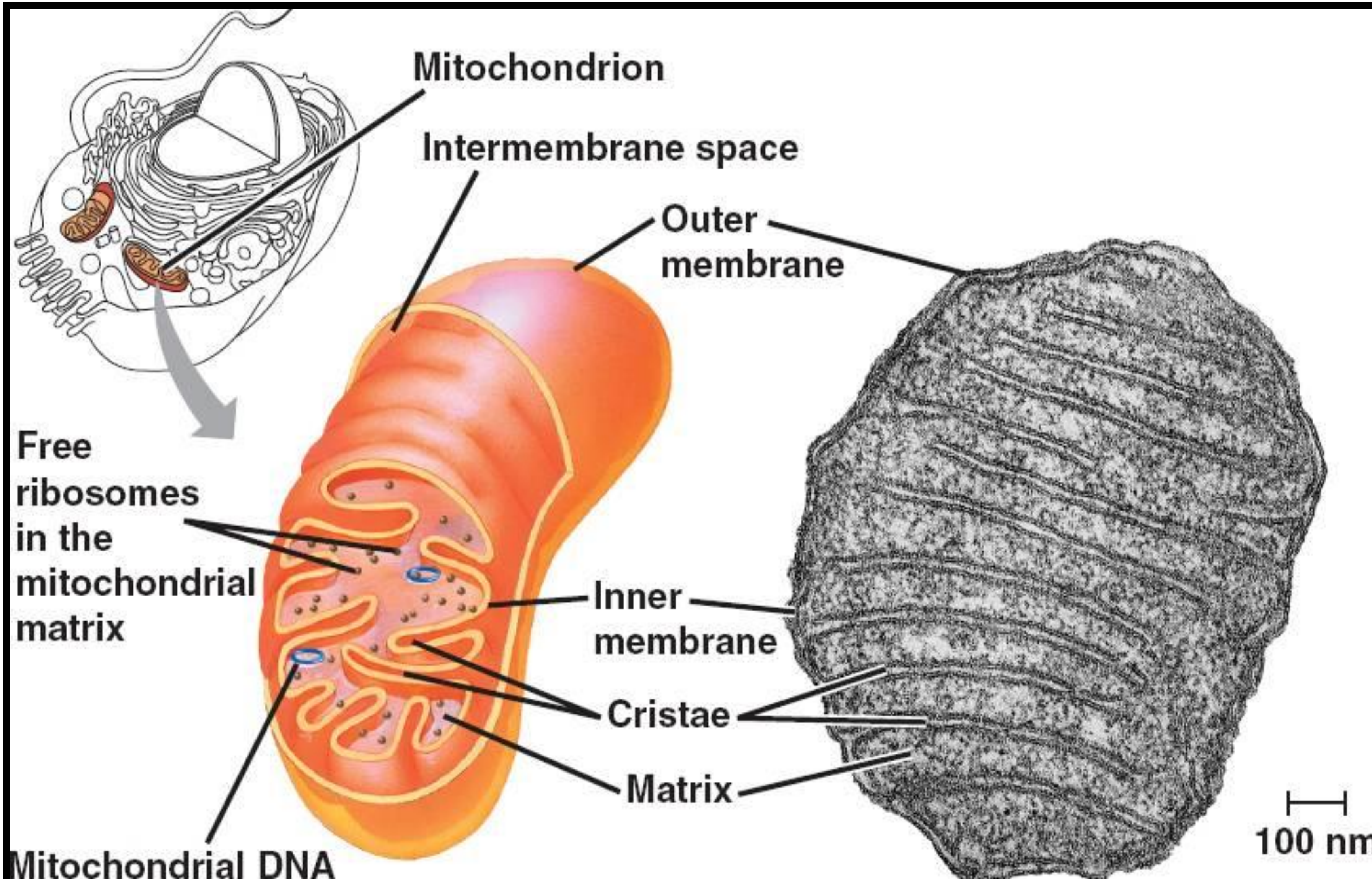
- Ribosomal subunits and associated proteins are first synthesized in the nucleolus and then transported to the cytoplasm via the nuclear pores.

Mitochondria

- **Mitochondria are round, oval, or elongated structures** whose variability and number depend on cell function.
- *Are* referred to as the **"powerhouses"** of the cell. Because they generate most of the ATP through aerobic respiration.
- A cell may have as few as a hundred or as many as several thousand mitochondria, depending on its activity.

- Active cells, such as those found in the muscles, liver, and kidneys, which use ATP at a high rate, have a large number of mitochondria.
- For example, **regular exercise** can lead to **an increase** in the number of mitochondria in **muscle cells**, and this allows muscle cells to function more efficiently.

Mitochondria



- A mitochondrion consists of an **outer mitochondrial membrane** and an **inner mitochondrial membrane** with a small fluid-filled space between them.
- The inner mitochondrial membrane contains a series of folds called **mitochondrial cristae .**

The central fluid-filled cavity of a mitochondrion, enclosed

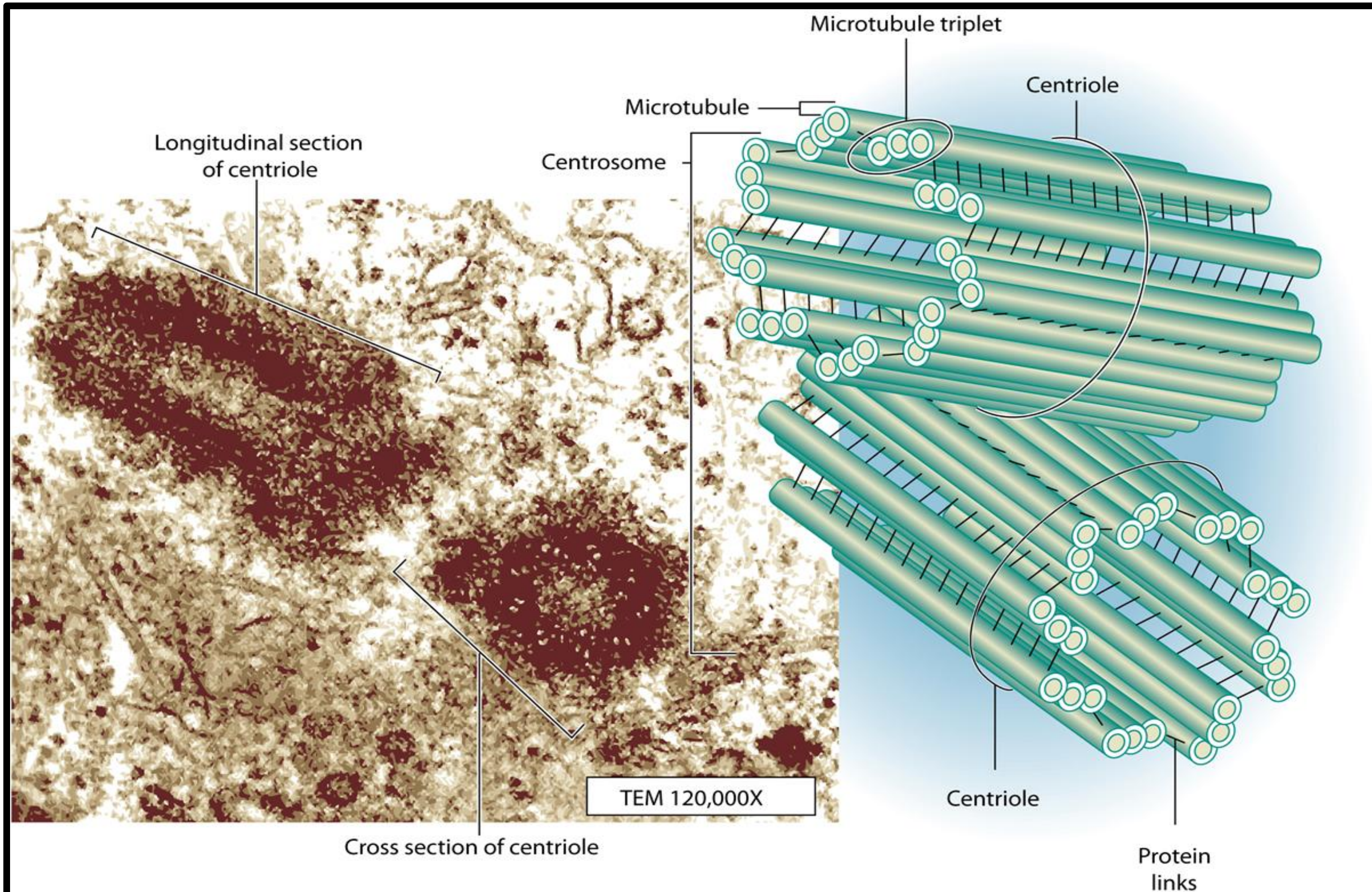
- by the inner mitochondrial membrane, is the **mitochondrial matrix.**

- **The elaborate folds of the cristae provide an enormous surface** area for the chemical reactions.
- The enzymes that catalyze these reactions are located on the cristae and in the matrix of the mitochondria.

Centrosome

- The **centrosome** located near the nucleus**,** consists of two components: a pair of centrioles and pericentriolar material
- The two **centrioles** are cylindrical structures, each composed of nine clusters of three microtubules (triplets) arranged in a circular pattern.
- The long axis of one centriole is at a right angle to the long axis of the other.
- Surrounding the centrioles is **pericentriolar material** which contains hundreds of ring-shaped complexes composed of the **protein tubulin.**
- *These* tubulin complexes are the organizing centers for growth of the **mitotic spindle**, which plays a critical role in **cell division, and for microtubule** formation in **nondividing cells.**
-

Centrosome


Microtubule triplet
Centriole
Microtubule
Longitudinal section
of centriole
Centrosome
TEM 120,000X
Centriole
Cross section of centriole
Protein
links

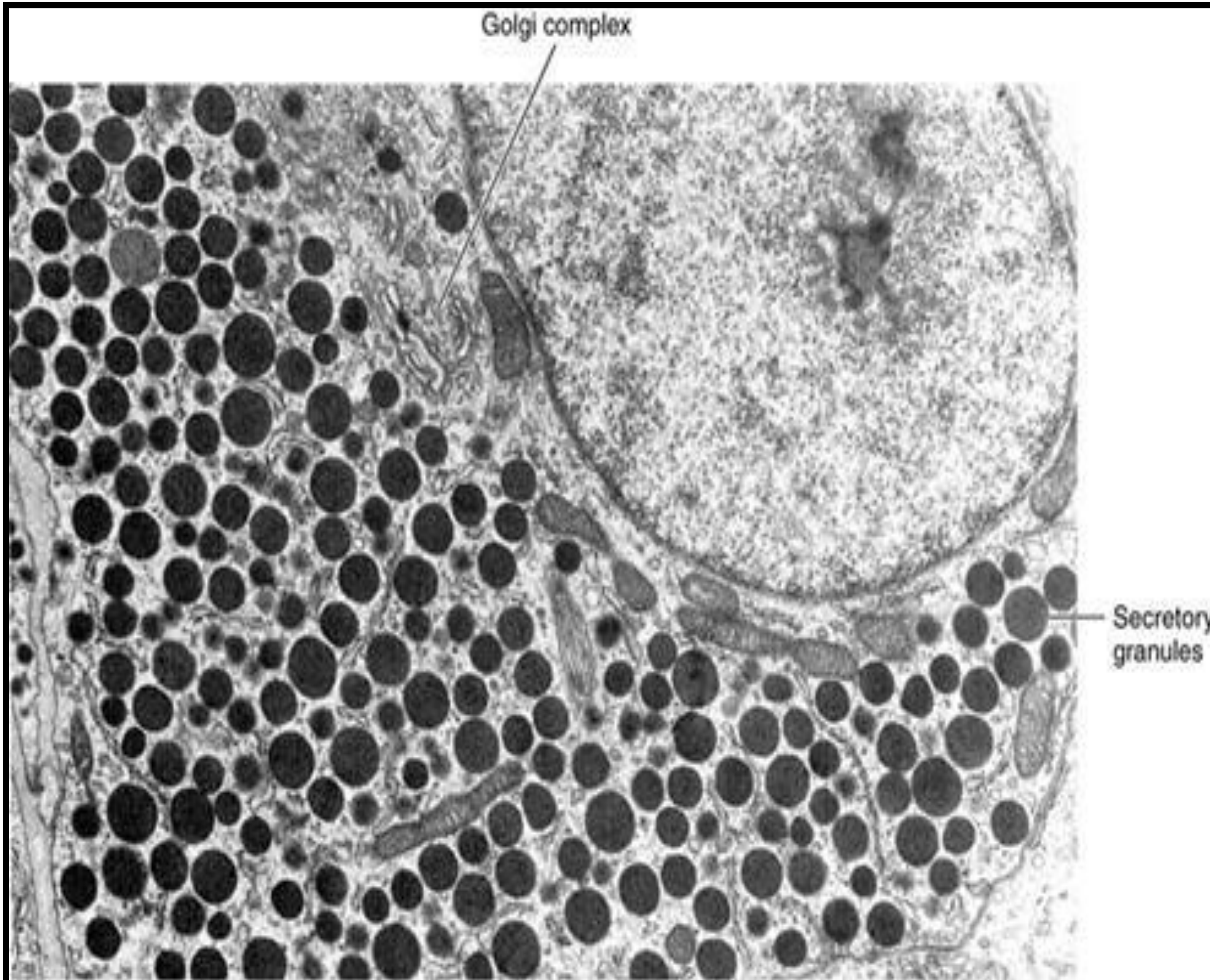
- During cell division, centrosomes replicate so that succeeding generations of cells have the capacity for cell division.

- Beneath the cell membrane, the centrioles induce the formation of **basal bodies** and organize the development of the microtubules in **cilia and flagella.**

Secretory vesicles

- Some secretory vesicles become lysosomes and remain in the cytoplasm. Other proteins migrate to the cell membrane and are incorporated into the cell membrane itself, thus contributing proteins and phospholipids to the membrane.

- Still other secretory granules become vesicles filled with a secretory product destined for **exocytosis (export) to the outside of the cell.**

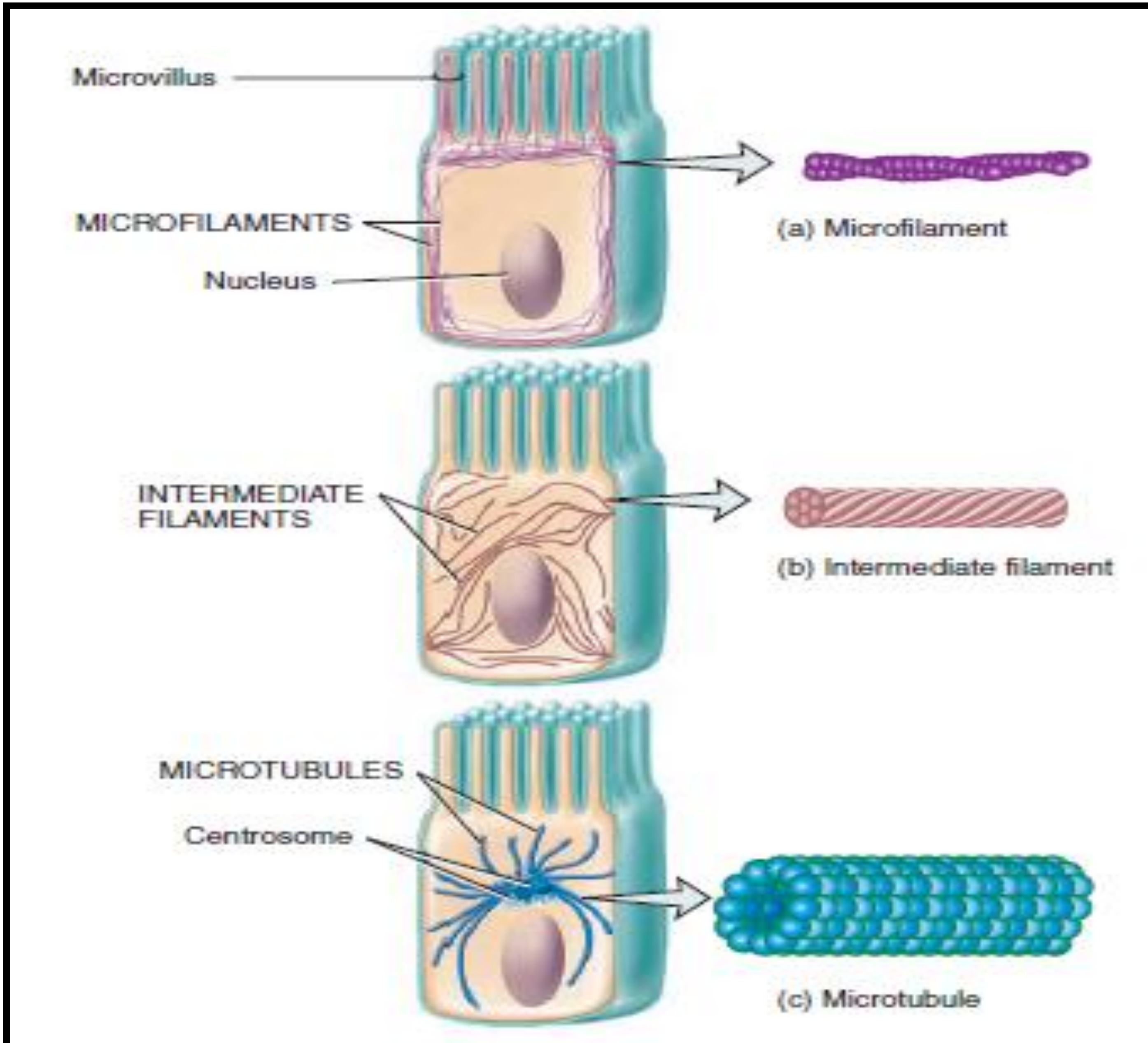

Golgi complex
Secretory granules

The Cytoskeleton of the Cell

- The **cytoskeleton of a cell consists of a network of tiny protein filaments and tubules that extend** throughout the cytoplasm.
- It serves as the cell's structural framework.

Three types of filamentous proteins form the cytoskeleton of a cell:

1. Microfilaments.
2. Intermediate filaments.
3. Microtubules.

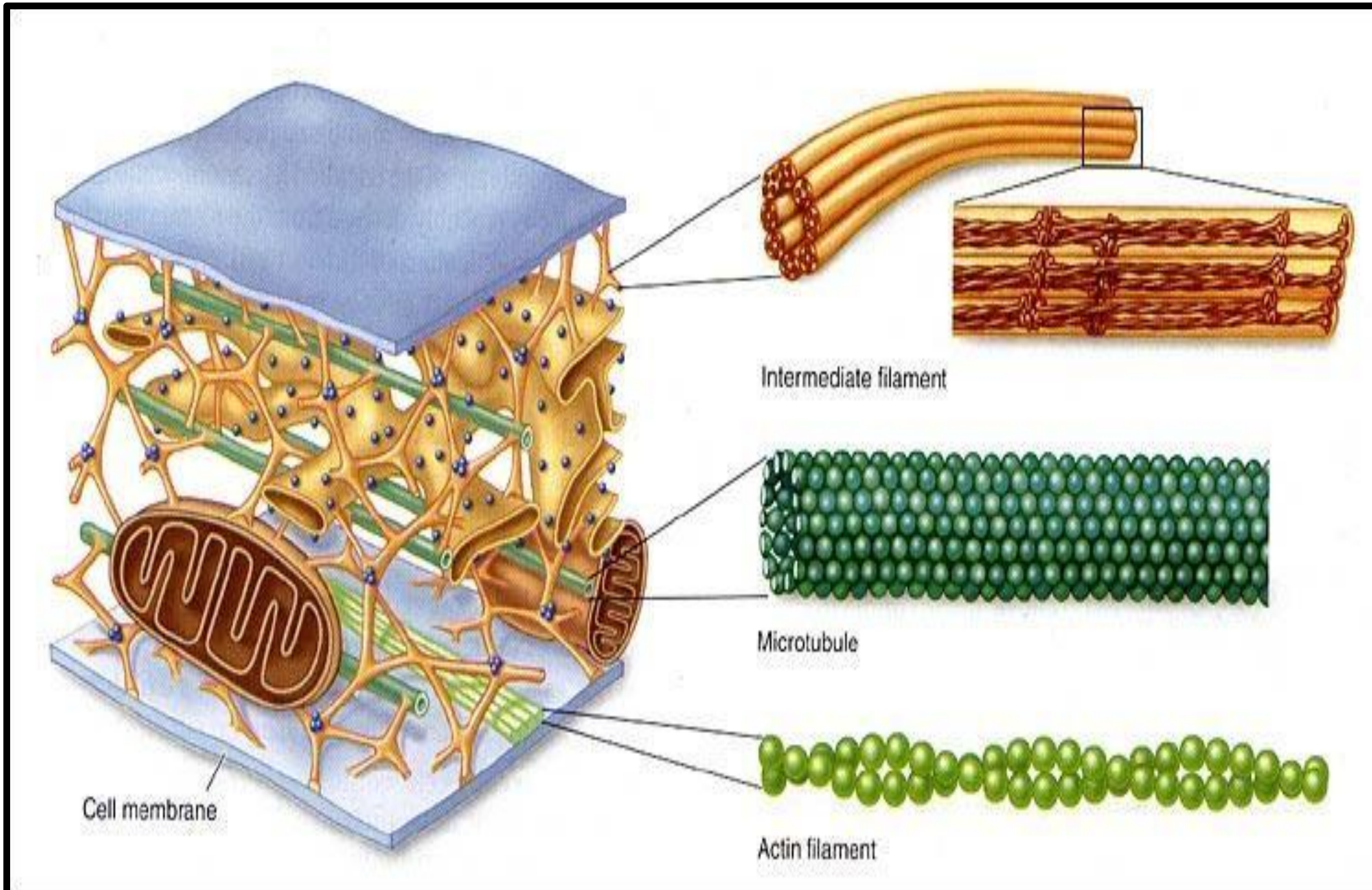

Microvillus
MICROFILAMENTS
Nucleus
(a) Microfilament
INTERMEDIATE FILAMENTS
(b) Intermediate filament
MICROTUBULES
Centrosome
(c) Microtubule

Microfilaments

- Microfilaments are the thinnest structures of the cytoskeleton.
- They are composed of the protein actin and are most prevalent on the peripheral regions of the cell membrane.
- These structural proteins shape the cells and contribute to cell movement and movement of the cytoplasmic organelles.

- The microfilaments are distributed throughout the cells and are used as anchors at cell junctions.
- The actin microfilaments also form the structural core of microvilli and the terminal web just inferior to the plasma membrane.
- In muscle tissues, the actin filaments fill the cells and are associated with myosin proteins to induce muscle contractions.

The Cytoskeleton of the Cell



The **intermediate filaments**

- The **intermediate filaments are thicker than microfilaments and are** more stable.
- Several cytoskeletal proteins that form the intermediate filaments have been identified and localized.
- The intermediate filaments vary among cell types and have specific distribution
- in different cell types.
- Epithelial cells contain the intermediate filaments **keratin.**
- **In skin cells,** these filaments terminate at cell junctions, **desmosomes and hemidesmosomes, where they stabilize** the shape of the cell and their attachments to adjacent cells.
- **Vimentin filaments are found in** many mesenchymal cells.
- **Desmin filaments are found in both smooth and striated muscles.**


IF
IF
J
J

Microtubules

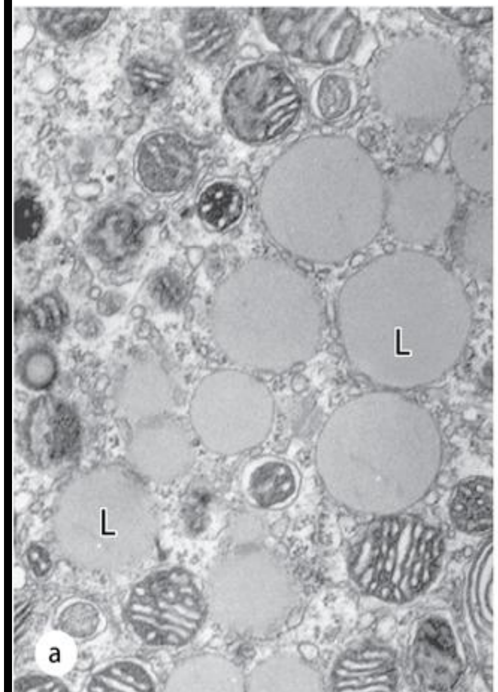
- **Microtubules are found in almost all cell types except red blood cells.**
- **They are the largest** elements of the cytoskeleton.
- Microtubules are hollow, unbranched cylindrical structures composed of two protein subunits, **a and b tubulin.**
- **All microtubules originate from the microtubule organizing** center, the **centrosome in the cytoplasm, which contains a pair of centrioles.**

- **In the** centrosome, the tubulin subunits polymerize and radiate from the centrioles in a star like pattern from the center.
- Microtubules determine cell shape and function in the intracellular movement of organelles and secretory.
- Microtubules are essential in cell mitosis, where they form spindles that separate the duplicated chromosomes and remodel the cell during mitosis.
- These tubules are most visible and are predominant in **cilia**
- and **flagella, where they are responsible for their beating movements.**
- **Microtubules also form the** basis of the centrioles and basal bodies of the cilia.

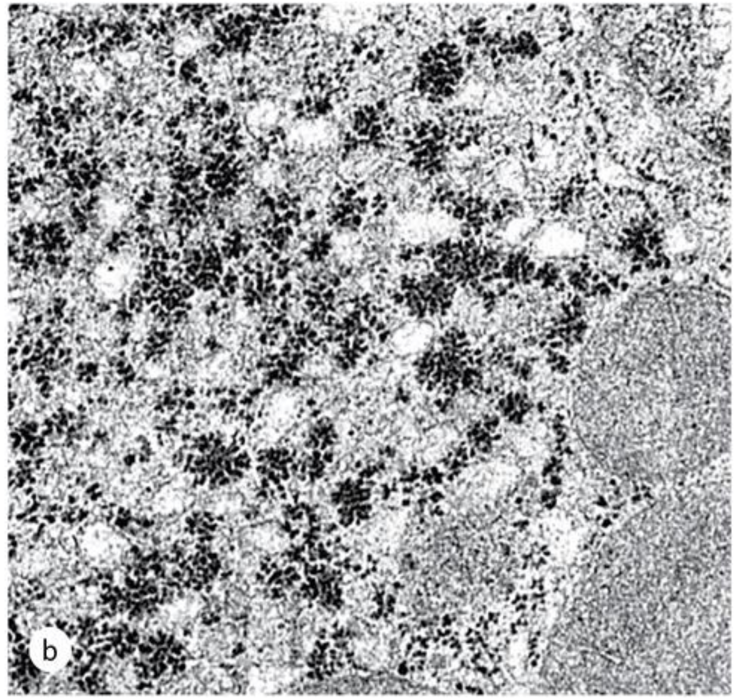
Cytoplasmic Inclusions

- The cytoplasmic inclusions are temporary structures that accumulate in the cytoplasm of certain cells.
- Lipids, glycogen, crystals, pigment, or byproducts of metabolism are inclusions and represent the nonliving parts of the cell.

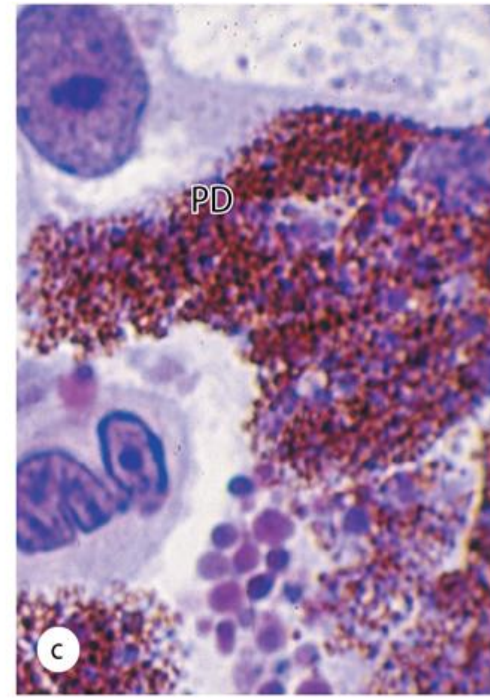
Cytoplasmic Inclusions



Lipid droplets



Glycogen granules



Pigment deposits