Cell membrane

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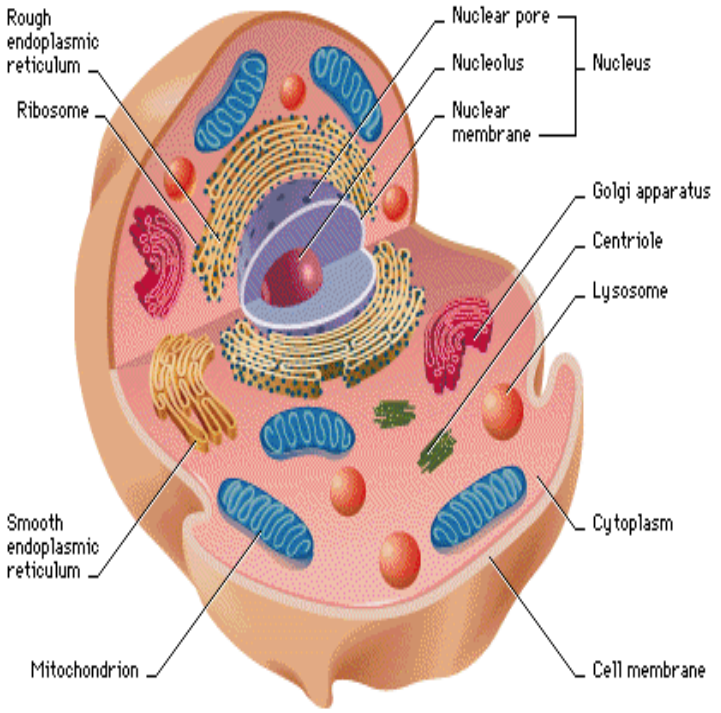
Introduction

•The cell is the structural and functional unit of the organism.

• The cell is limited (bounded) by a **cell membrane** (plasma-membrane or plasmalemma) surrounding the protoplasm.

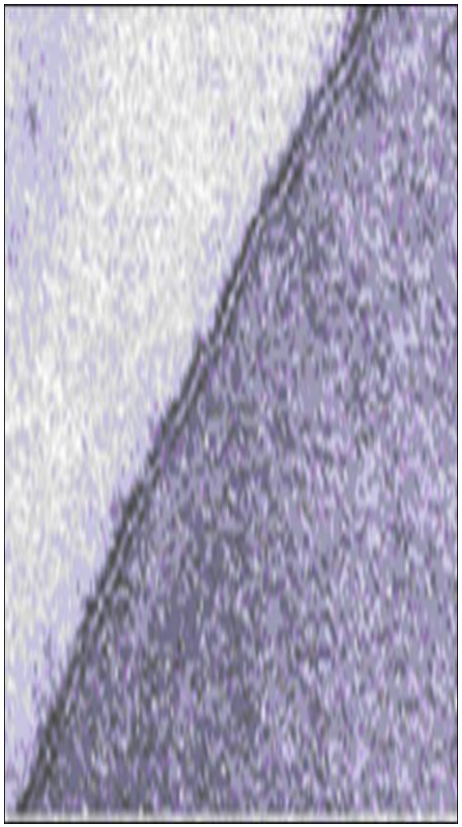
•The protoplasm, is divided into two compartments; the **cytoplasm** and **the nucleus**.

•The Cytoplasm is formed of: Cytosol, Cytoplasmic organelles, Cytoskeleton, Cytoplasmic inclusions.



CELL MEMBRANE

Ultra - thin membrane that surrounds the cell as well as the boundaries of many organelles within the cell. So, it is called a unit membrane.



❑Structure of cell membrane:

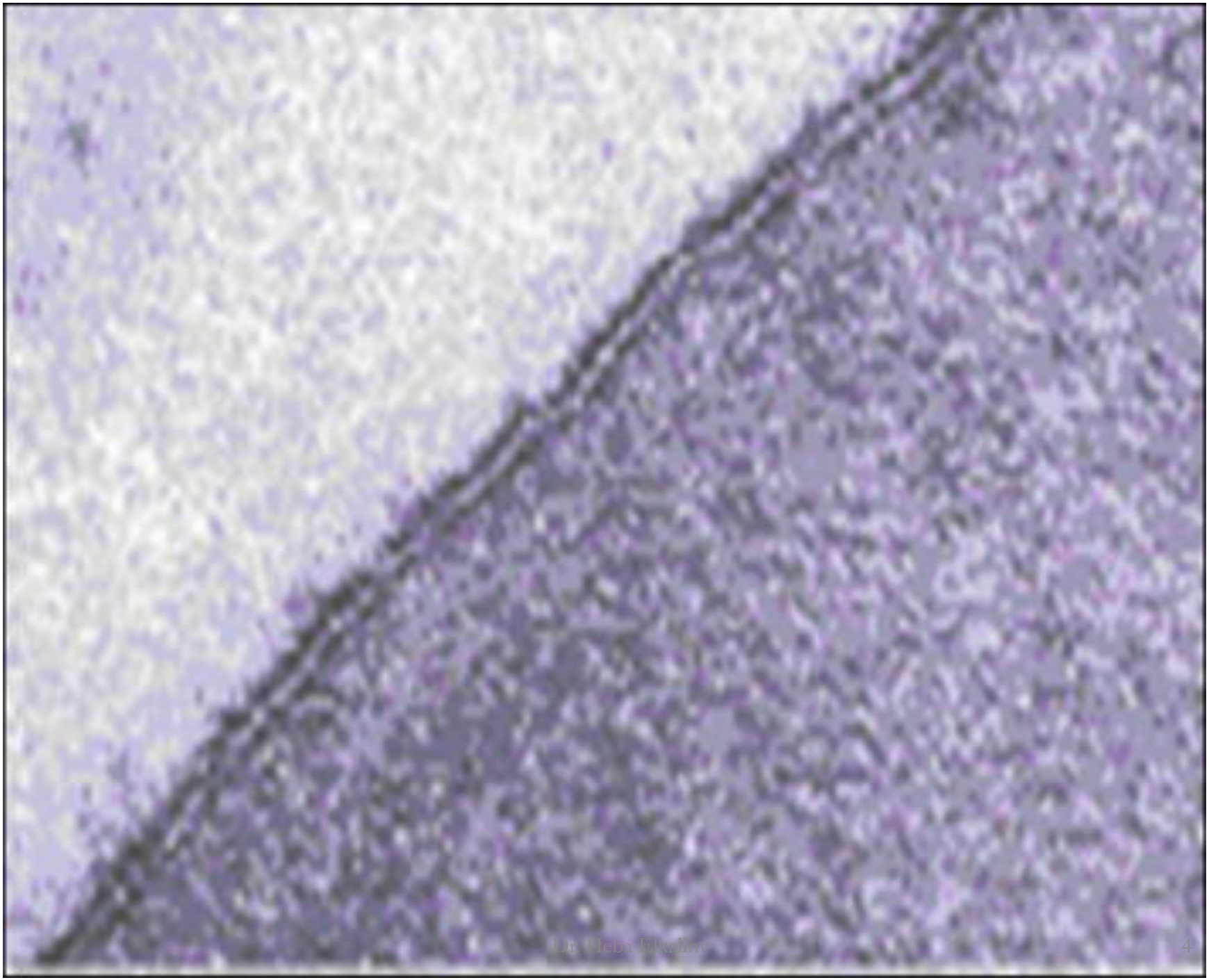
Light microscope (By: L/M):

It can not be seen (not visible) because it is very thin but can be stained by Ag or PAS.

Electron microscope (By: E/M):

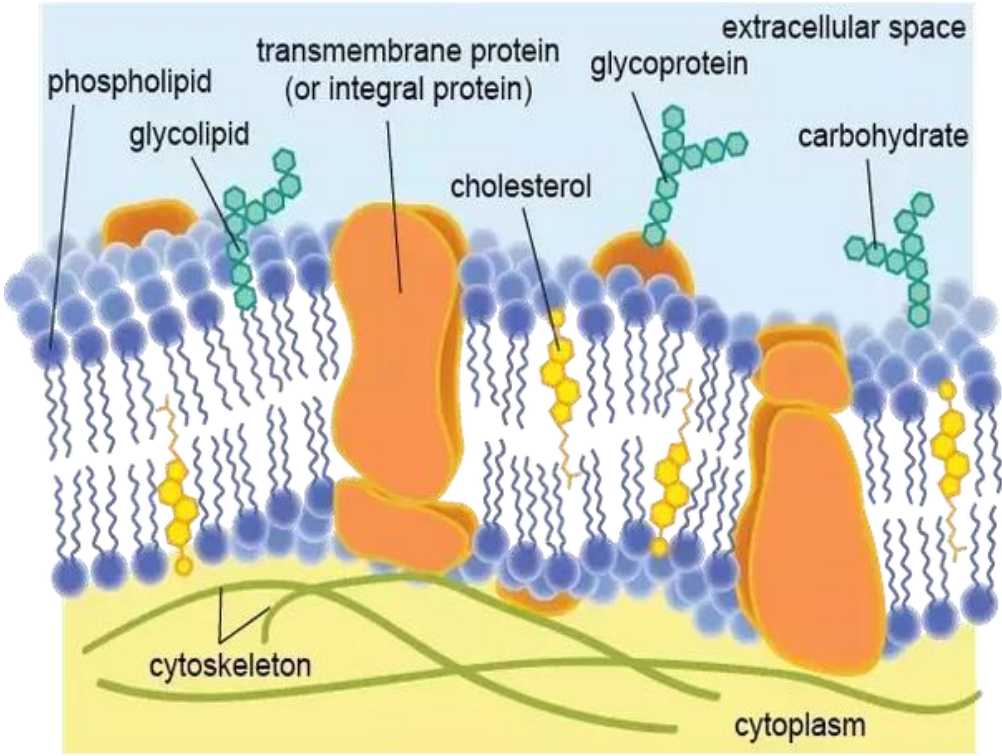
1- **Low magnification:** it appears as a **single** electron-dense (dark) line(8-10 nm) .

2- **High magnification:** it appears as two electron-dense(dark) lines separated by an electron-lucent (pale) intermediate zone. Therefore it has a characteristic **trilaminar** appearance



❑Molecular structure of the cell membrane (The fluid-mosaic model by Singer and Nicolson)

The cell membrane is composed of **lipids** (phospholipids bilayer and cholesterol), **proteins** (integral and peripheral), and **carbohydrates** (glycoprotein and glycolipid).



1- Lipids components of the cell membrane allow passage of fat-soluble substances through it. Lipids are of two types:

I) Phospholipid bilayer:

- It is the backbone of the cell membrane.

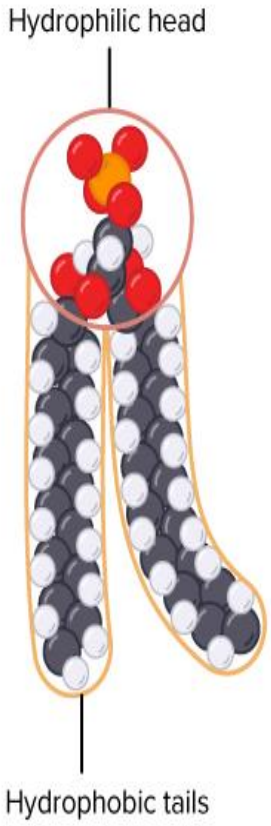
- It is formed of a double layer of phospholipid molecules.

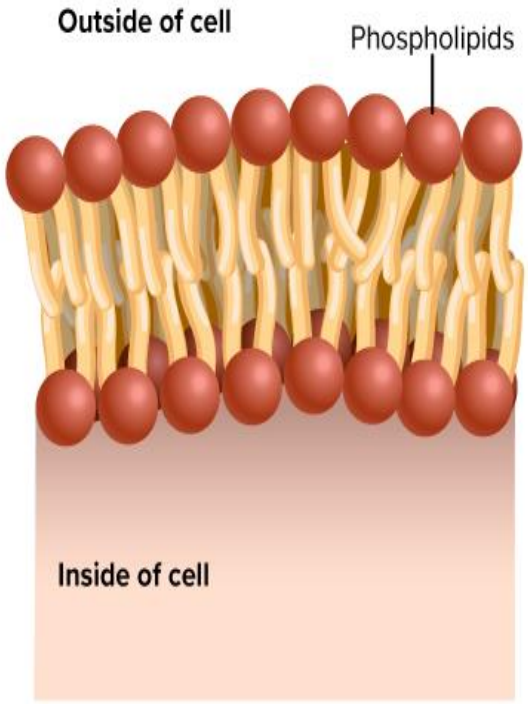
The phospholipids molecules have:

•**Outer phosphate heads:** polar and hydrophilic (water-attracting).

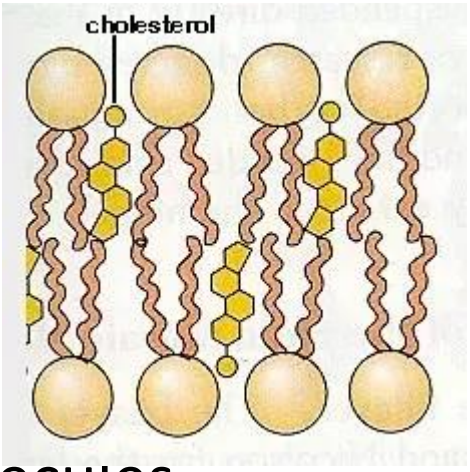
•**Inner two long fatty acid chain tails:** non-polar and hydrophobic (water-repelling).

•The weak intermolecular forces between the bilayer allow phospholipid molecules to move freely.





II) Cholesterol molecules:



- They are present in the lipid bilayer.

-They have one to one ratio with phospholipids.

-They fill the gaps between the fatty acid tails restricting their movement.

-They regulate the passage of water-soluble molecules.

N.B: Fluidity of the lipid bilayer is essential in exocytosis, endocytosis, membrane trafficking, and membrane biogenesis.

Factors affecting the fluidity of the cell membrane :

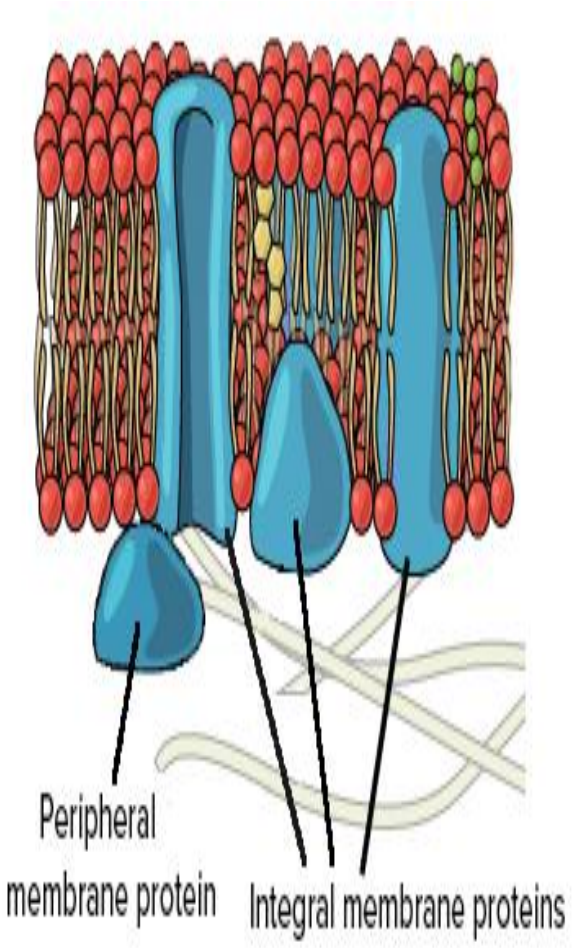
a. Fluidity decreases with an increase in the membrane's cholesterol content.

b. Fluidity increases with increased body temperature.

2- Protein Components: There are two types:

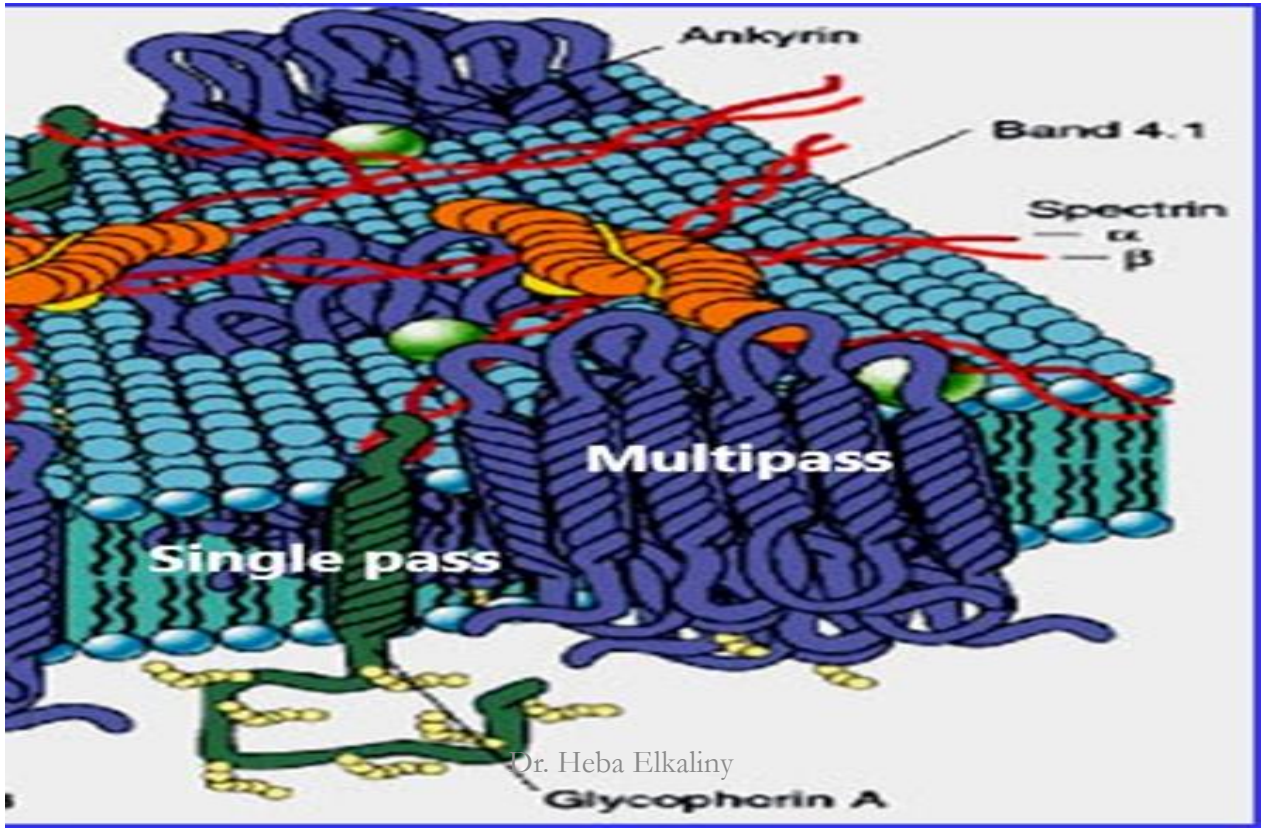
I) Integral (intrinsic) proteins:

- They are present among lipid molecules.
- Some are partially embedded in a lipid bilayer.
- Other proteins extend across lipid bilayer and protrude from both membrane surfaces. They are known as transmembrane proteins forming channels for the passage of water-soluble molecules (e. g., ions).



- Integral membrane proteins can move within the lipid bilayer.

- When Proteins inserted once through the membrane called "single-pass transmembrane proteins." and if crosses the membrane many times, it is called multipass protein.



- **II) Peripheral (extrinsic) Proteins:**

▪They are bound to one of the membrane surfaces of the bilayer.

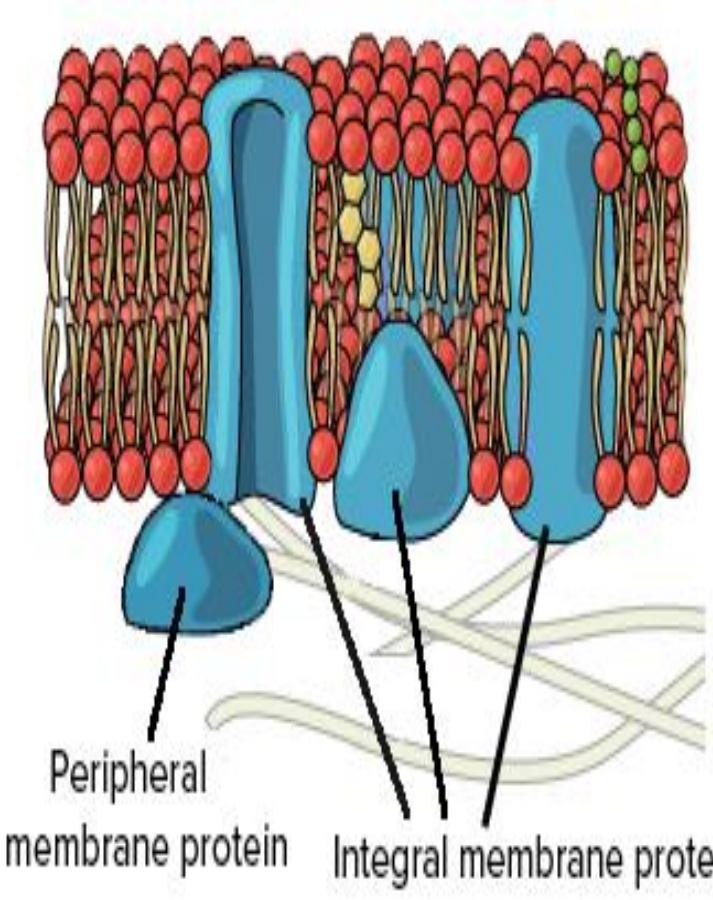
▪They are loosely attached to the membrane surfaces.

- Membrane proteins have different functions:

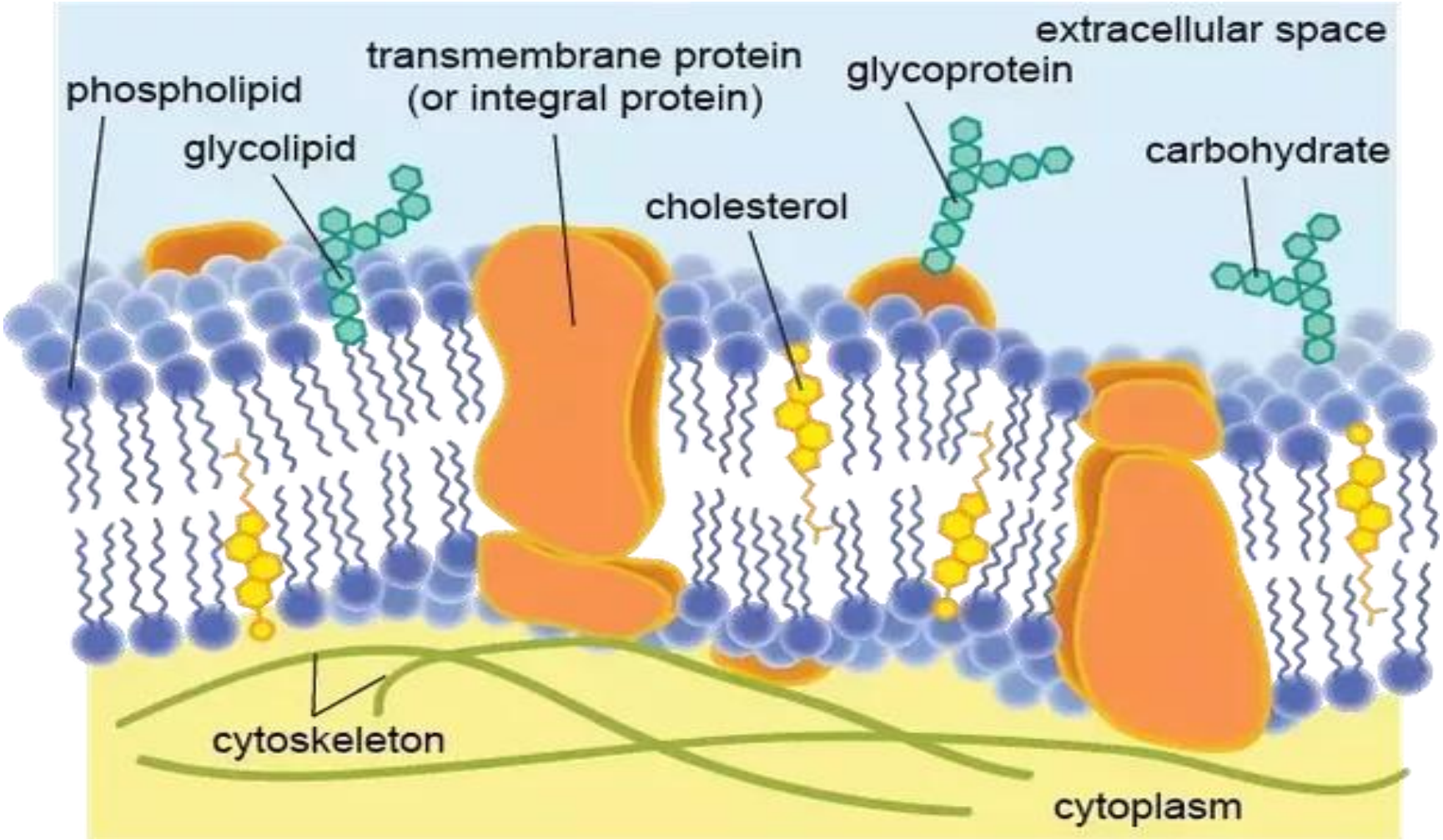
i) They can act as enzymes to speed up chemical reactions.

ii) They can act as receptors for specific molecules.

iii) They transport materials across the cell membrane through channels.



3- Carbohydrate component:



- **3- Carbohydrate component:**
- It is associated with the external (outer) surface of the cell membrane forming the cell coat or the glycocalyx.
- **Chemically:** It consists of oligosaccharides conjugated mainly with membrane proteins to form **glycoprotein** and with some membrane lipids to form **glycolipids.**
- **Structure by E/M**, it appears as a fine filamentous material of varying thickness.
- It is important for cell recognition, protection, and intercellular adhesions.

FUNCTIONS OF CELL MEMBRANE:

1.Physical barrier: Establishes a flexible boundary, protects cellular contents, supports cell structure and separates substances inside and outside the cell

2. Selective permeability: Regulates entry and exit of ions, nutrients, and waste molecules through the membrane

3. Electrochemical gradients: Establishes and maintains an electrical charge difference across the plasma membrane

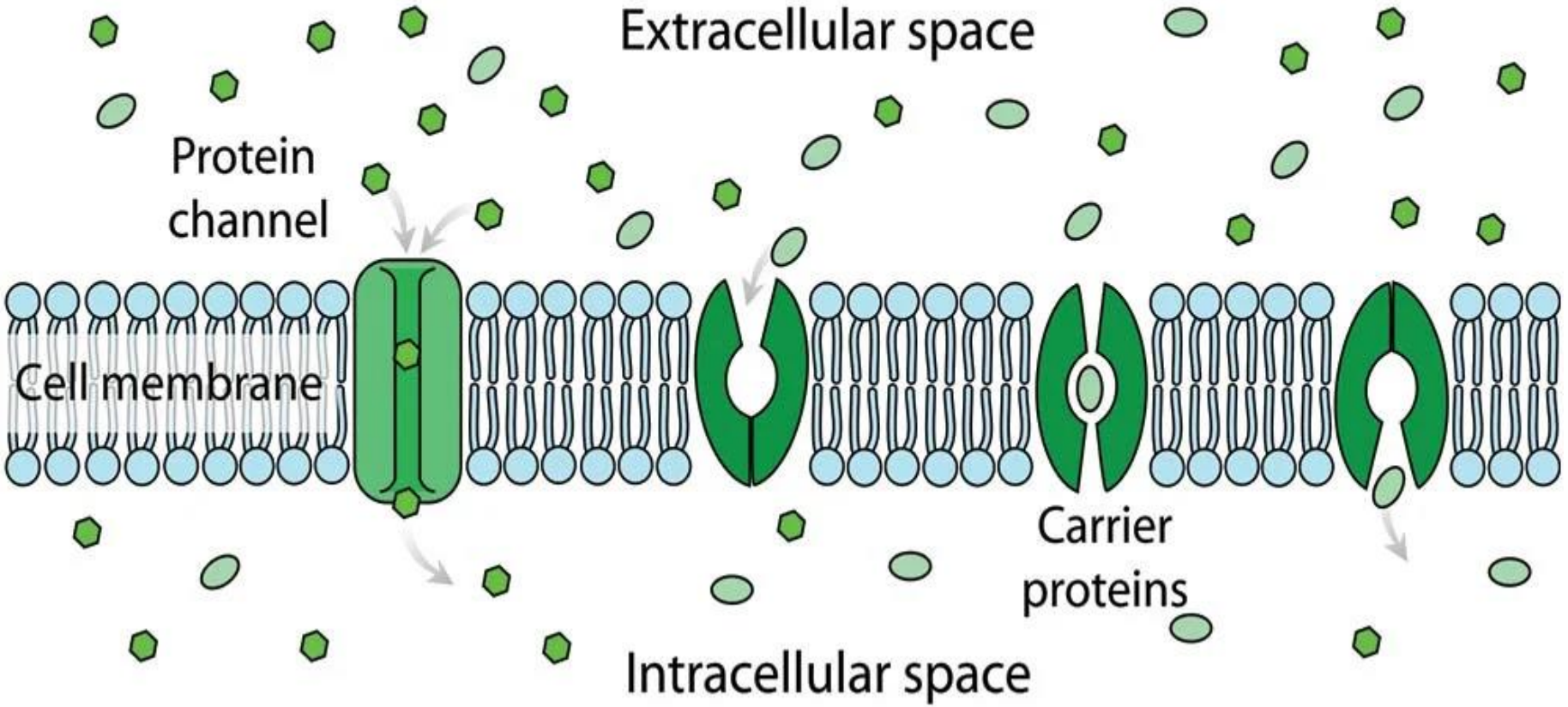
4. Communication: Contains receptors that recognize and respond to molecular signals

Mechanisms of transport across the plasma membrane.

PASSIVE PROCESSES: Movement of substances down a concentration gradient across a selectively permeable membrane until equilibrium is reached; no energy is required.

	Type of Movement	Example
Simple diffusion	Unassisted net movement of small, nonpolar substances down their concentration gradient	Exchange of oxygen and carbon dioxide between blood and body tissues
Facilitated diffusion	Assisted movement of ions and small, polar molecules down their concentration gradient by a transport protein.	• Na+ moves through Na+ channel • Transport of glucose by glucose carrier
Osmosis	Diffusion of water across a selectively permeable membrane; direction is determined by relative solute concentrations; continues until equilibrium is reached.	

Facilitated diffusion in cell membrane, showing ion channels and carrier proteins



ACTIVE PROCESSES: Movement of substances requires expenditure of cellular energy. •**Active transport** • **Vesicular transport**

Active transport: Transport of ions or small molecules across the membrane against a concentration gradient by transmembrane protein pumps.

	Type of Movement	Example
Primary	Movement of substance up its concentration gradient; powered directly by ATP	Ca2+ pumps: transport Ca2+ out of the cell
Secondary	Movement of a substance up its concentration gradient is powered by harnessing the movement of a second substance (eg, Na+) down its concentration gradient	• Na+/glucose transport (Symport) • Na+/H+ transport (Antiport)

Vesicular transport may be one of two processes:

1. Endocytosis: In which substances enter the cell.

If the substance that enters the cell is solid the process is called phagocytosis. The entrance of fluid is called pinocytosis.

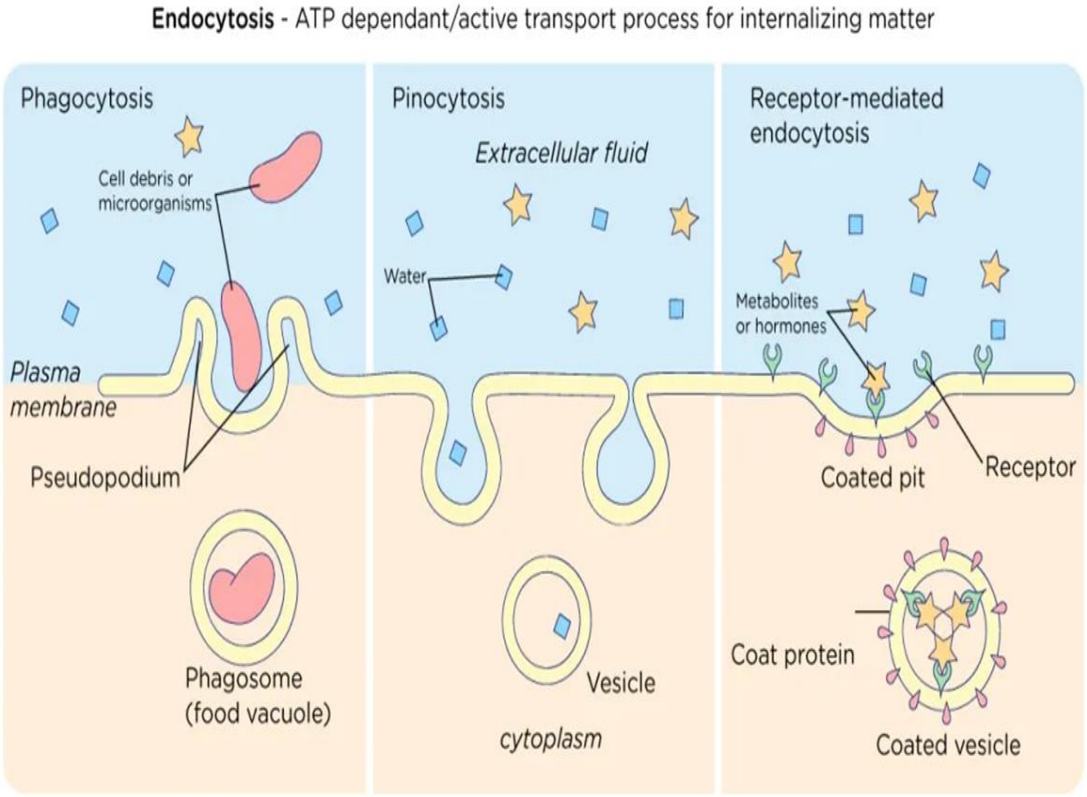
2. Exocytosis: In which substances leave the cell to outside.

1- Endocytosis:

A) Phagocytosis

B) Fluid phase pinocytosis

C) Receptor-mediated endocytosis.

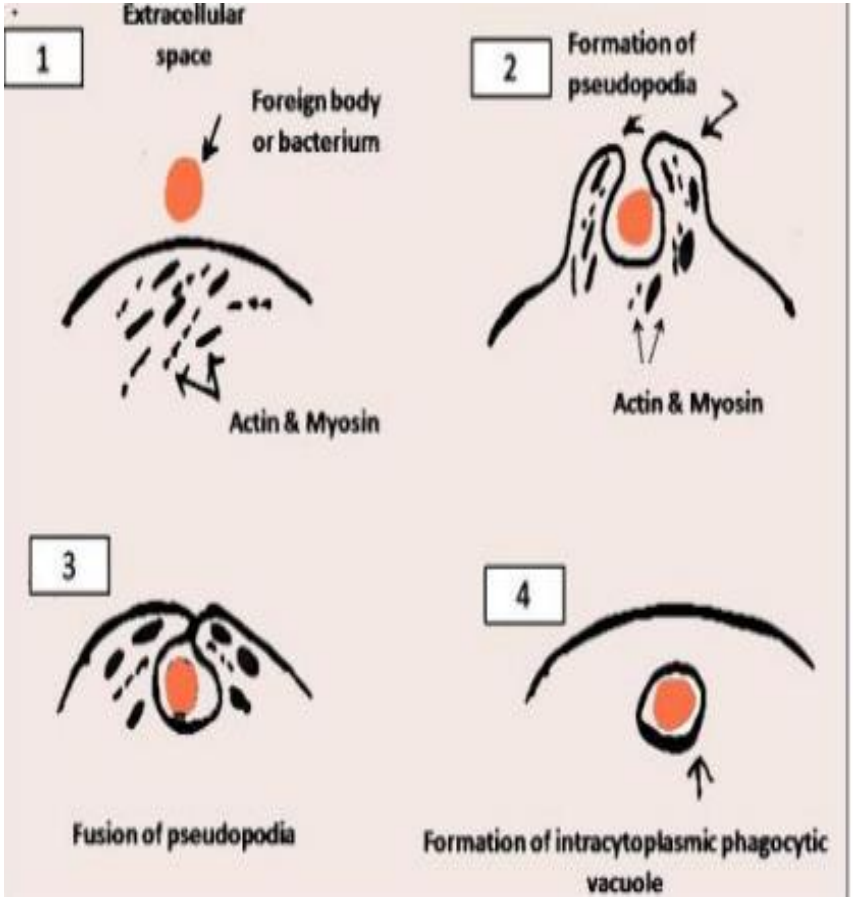


Jack Westin

A) Phagocytosis (Cell eating):

Definition: It is the process of engulfing large particles by the cell or into the cell e.g., bacteria, microorganisms, cell fragments, and dead cells.

Sites: It is performed by specialized cells known as phagocytes; as neutrophils and macrophages.



Steps of phagocytosis : The process runs through the following steps:

1. Binding of a solid particle as a bacterium to the cell surface.
2. Formation of cell processes (pseudopodia) by mobilization of actin and myosin in the cytoplasm.
3. Fusion of the cell processes to engulf the bacterium in an intracellular phagocytic vacuole.
4. Digestion of this vacuole by lysosomes to destroy the bacteria.

Clinical correlation:

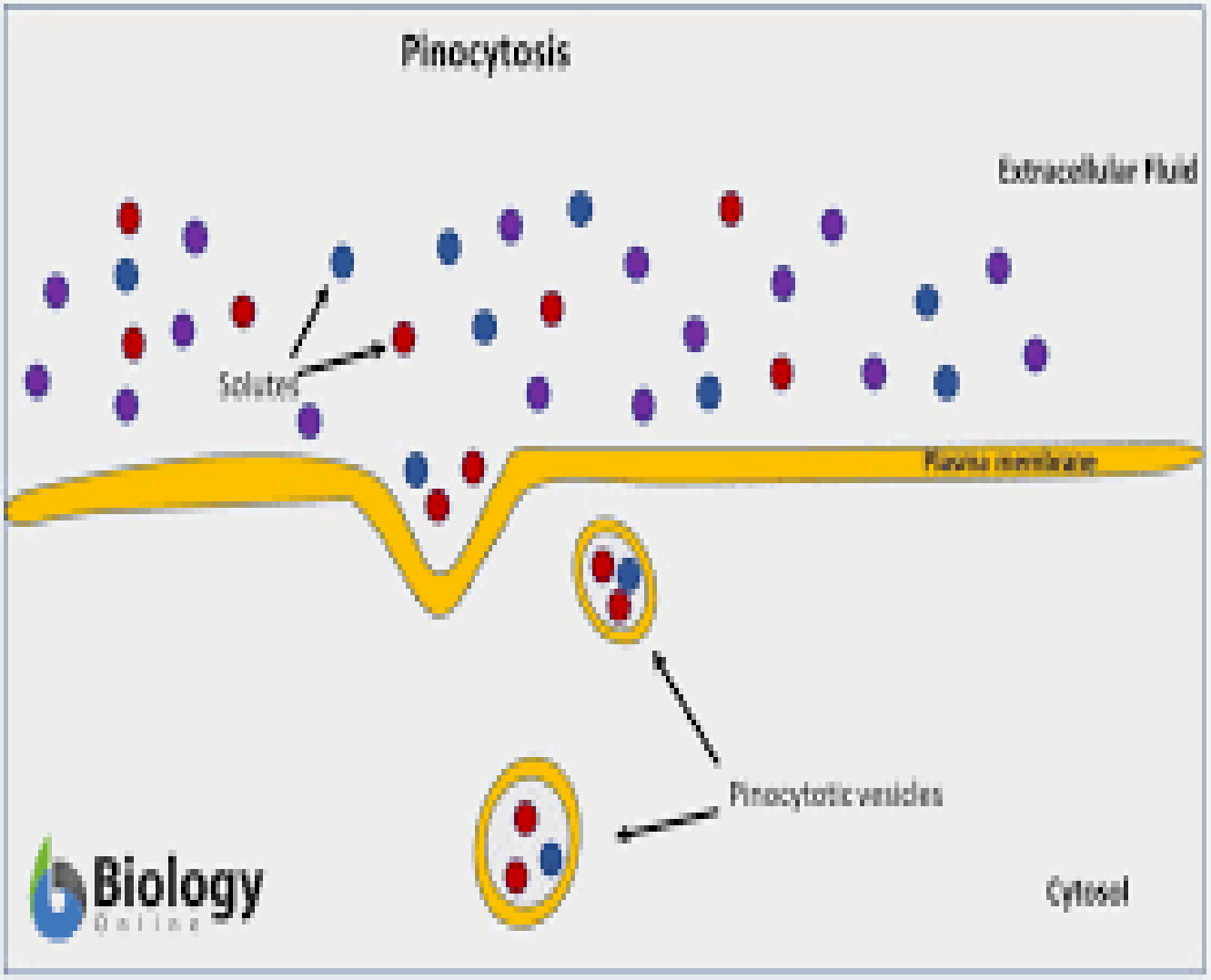
Familial hypercholesterolemia: is a disorder that is passed down through families. It causes LDL (bad) cholesterol levels to be very high. The condition begins at birth and can cause heart attacks at an early age. This disease is due to a genetic defect in the synthesis of LDL receptors or Defective receptors unable to bind to LDLs.

B) Fluid-phase pinocytosis (cell drinking):

Definition: It is non-specific ingestion of fluids via small vesicles. It occurs in all types of cells.

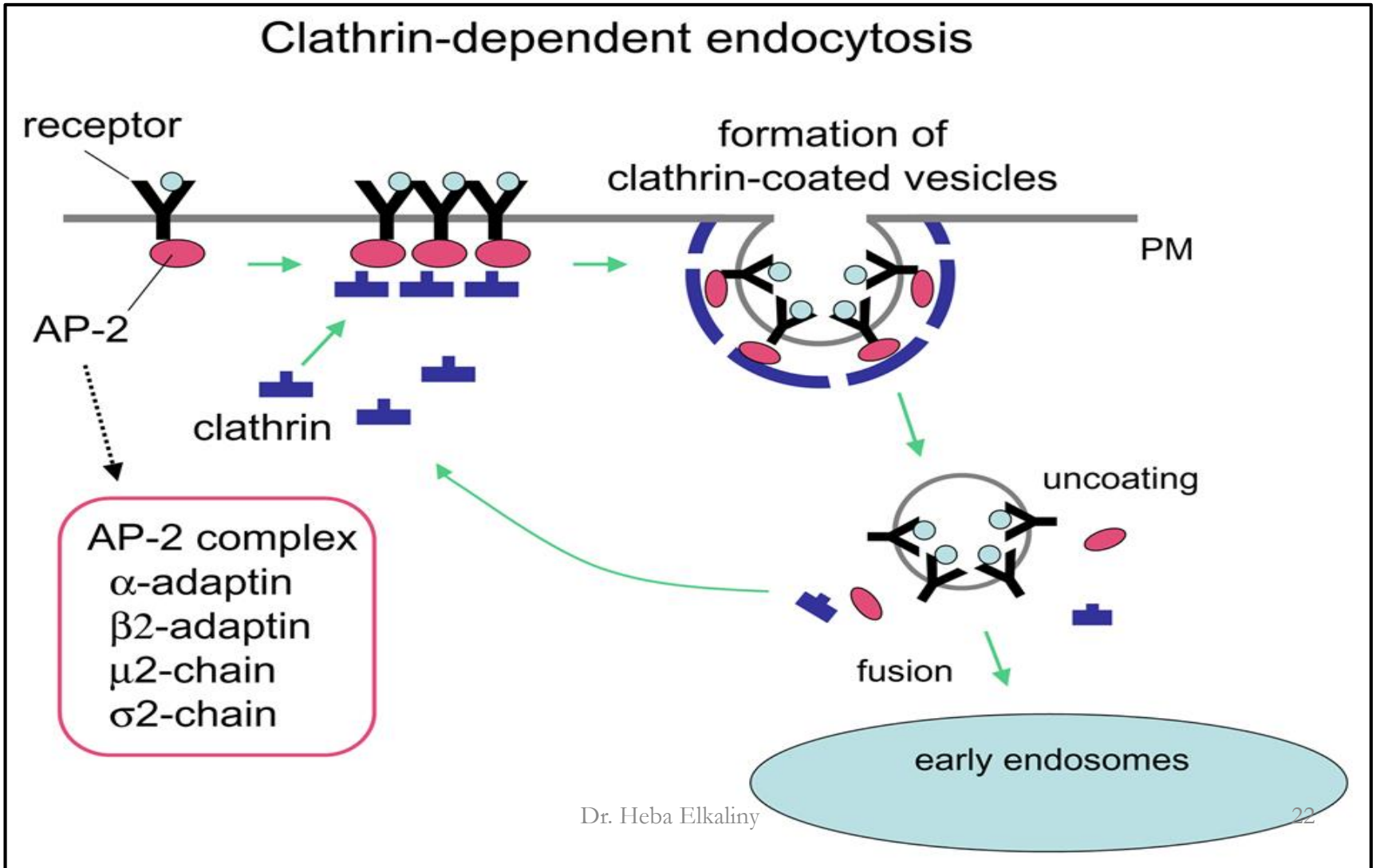
Steps:

1. It involves small invagination of the cell membrane when fuses and entraps extracellular fluid.
2. This forms a pinocytotic vesicle.
3. Pinocytotic vesicles will fuse with lysosomes. If the pinocytic vesicle moves and fuses to the plasma membrane of the other side of the cell to release the content out, it is a process called **transcytosis**, as in blood vessels.


Pinocytosis
Extracellular Fluid
Solutes
Plasma membrane
Pinocytotic vesicles
Cytosol
Biology
Online

C) Receptor-mediated endocytosis:

Definition: It is a highly selective process requiring the presence of receptors and their ligands.



Steps:

1. This process starts by binding the ligands (e.g., proteins or hormones) to their specific receptors located at the cell surface to form a ligand-receptor complex.

2. Ligand-receptor complex aggregates in shallow invagination of the cell membrane called the coated pit.

3. The cytoplasmic surface of the pit is coated with a spiny fibrous cytoplasmic protein called Clathrin.

4. Coated pits continue to go deep into the cytoplasm until they separate from the cell membrane forming coated vesicles.

5. Coated vesicles soon lose their Clathrin coat.

6. Then, they fuse with early endosomes and go deeper into the cytoplasm. The acidic interior of the endosome dissociates the ligand from its receptor.

7. Receptors move back to the cell membrane to be used again (recycling).

8. Ligands may have different fates within the endosomes:

a) Receptors and ligands may be carried to late endosomes and then to lysosomes for degradation.

b) Ligands may be released internally, and the receptors are recycled to the cell surface.

c) Vesicles may move to and fuse with another cell surface, where the ligands are released again outside the cell (transcytosis).

Clinical Correlation:

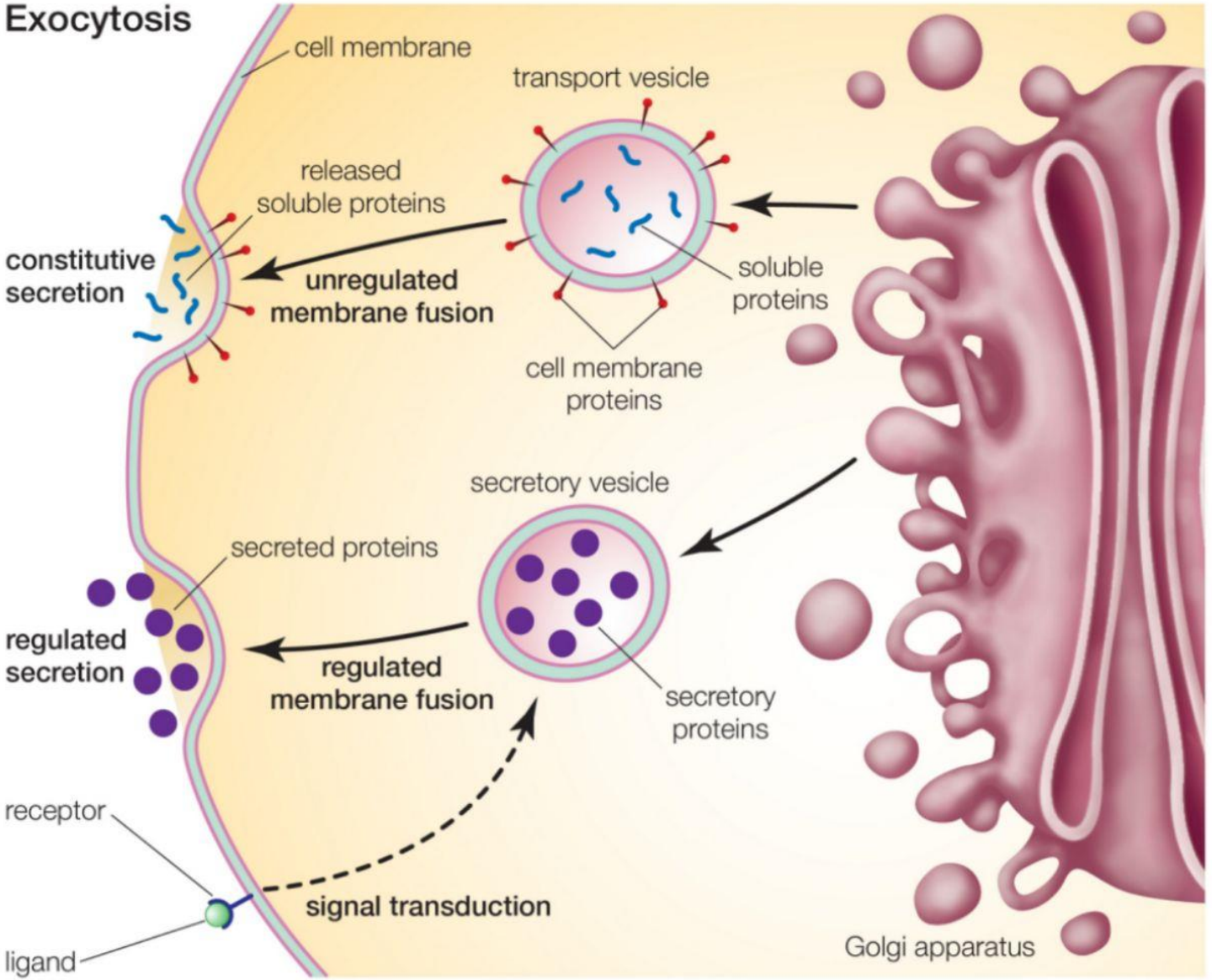
Several diseases are due to defective receptors. For example, a type of dwarfism is due to nonfunctioning growth hormone receptors. In this condition, the gland produces the respective hormone, but the target cells do not respond, because they lack normal receptors.

2-Exocytosis:

- **Definition:** It is a process that is used to transport materials from inside the cell to outside the cell (the extracellular compartment) using energy.

- Therefore, it is a type of active transport mechanism, and it is the opposite of endocytosis.

- In this process, a special vesicle containing the cellular product fuses with the cell membrane allowing the outflow of its contents.

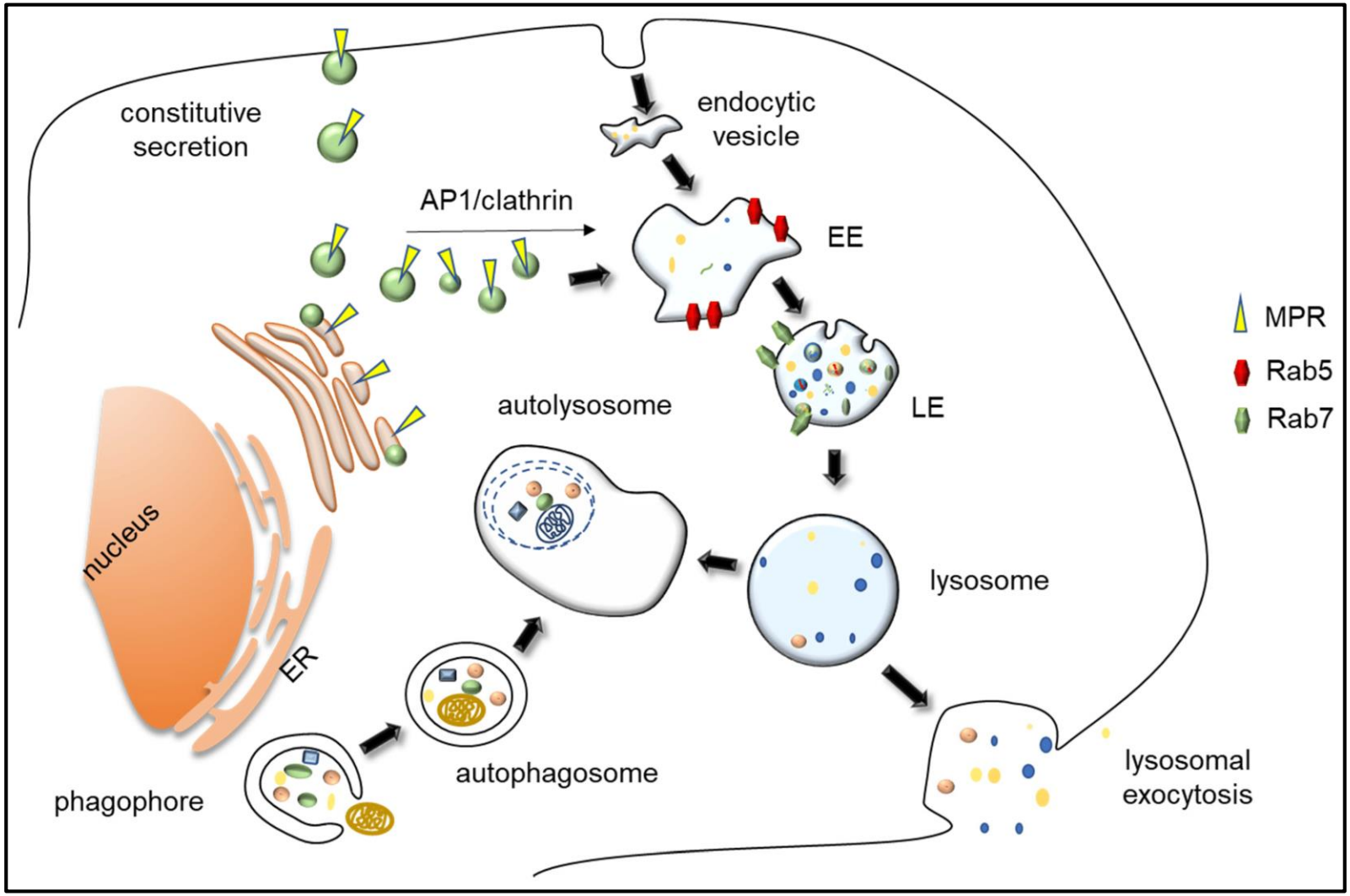

Exocytosis
cell membrane
transport vesicle
released
soluble proteins
constitutive
secretion
unregulated
membrane fusion
soluble
proteins
cell membrane
proteins
secretory vesicle
secreted proteins
regulated
secretion
regulated
membrane fusion
secretory
proteins
receptor
signal transduction
ligand
Golgi apparatus

- There are three pathways involved in the exocytotic process.

a- Constitutive (continous) pathway: This is the most common pathway that is performed by all body cells. The product is secreted immediately after synthesis, e.g., immunoglobulin by plasma cells.

b- Regulated secretory pathway: The product in this type is concentrated and stored in secretory granules, e.g., zymogen granules of the exocrine pancreas. The secretion of these products must be triggered by extracellular signals to release its content onto the outer part of the cell.

c- Lysosome-mediated pathway:

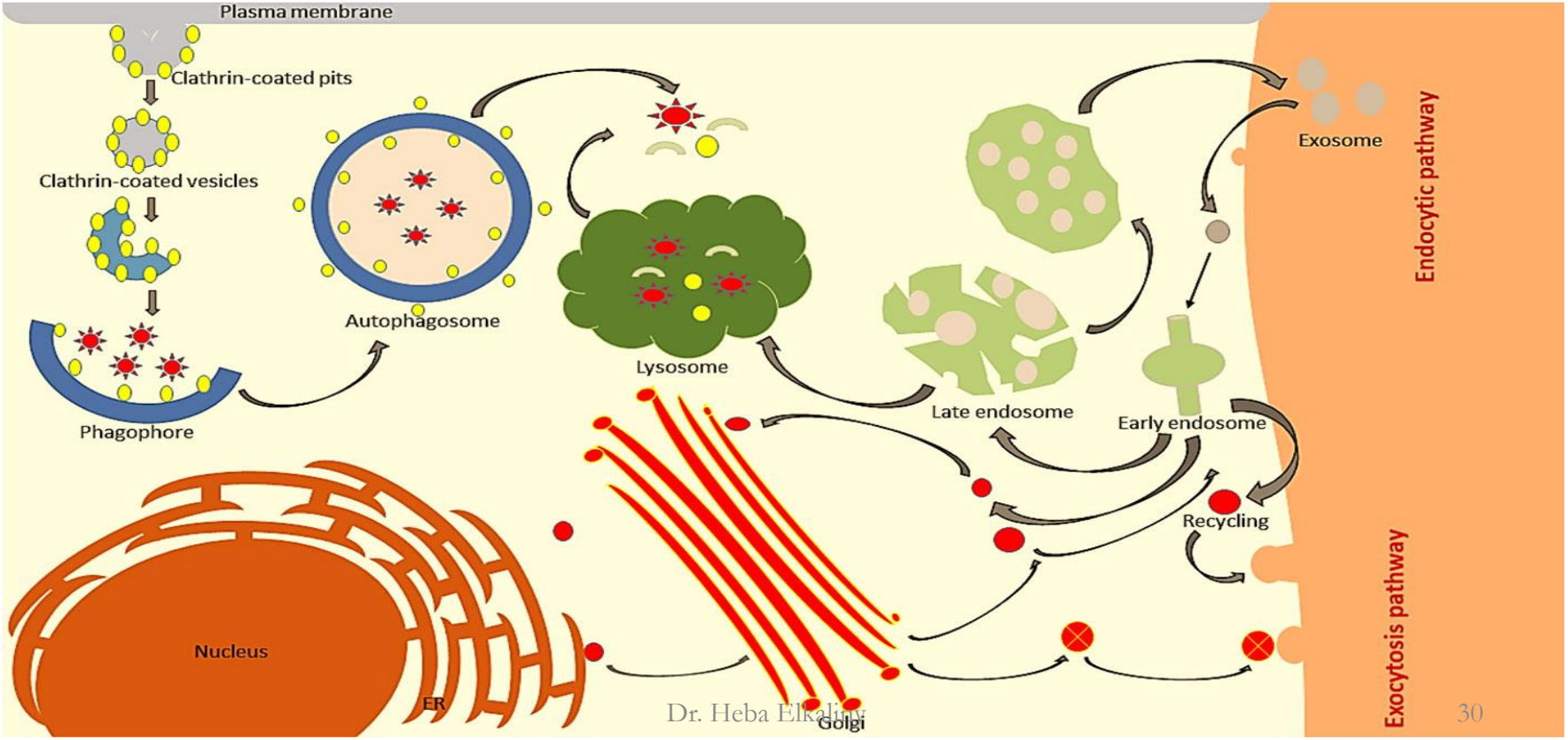


c- Lysosome-mediated pathway:

This process involves the fusion of cell vesicles with the cell lysosomes. Lysosomes contain hydrolase enzymes whose function involves the breakdown of cellular waste materials, microorganisms, and debris. The lysosome carries the elements that have been broken down onto the cell membrane where it fuses with the cell membrane releasing its elements into the extracellular cell matrix.

Membrane trafficking

It means repeated recycling of the cell membrane. During endocytosis, portions of the cell membrane are used as endocytic vesicles, while during exocytosis the lost portions are compensated by other membranes.



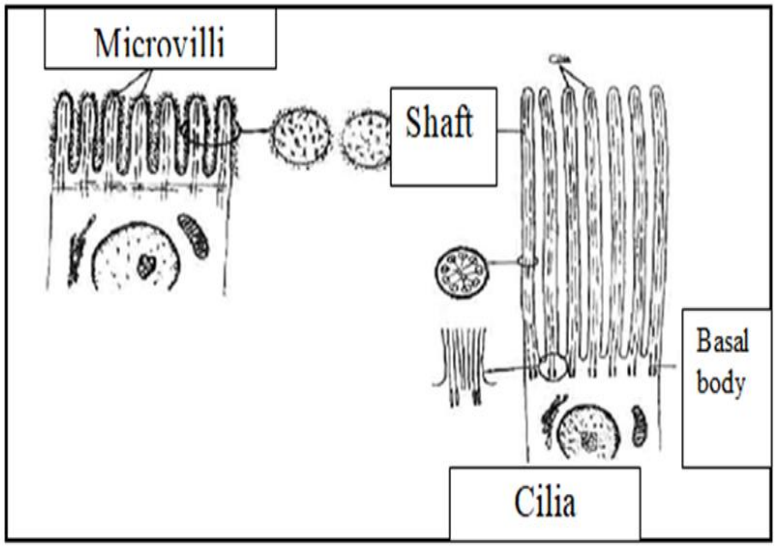
Specializations of cell membrane

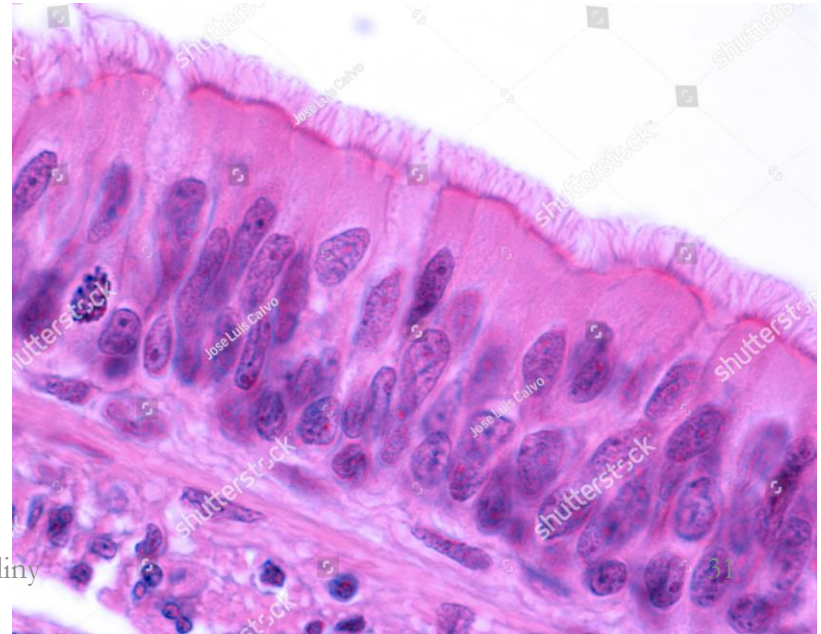
1-Microvilli: which are long finger-like projections on the surface of certain cells e.g. absorptive cells of small intestine to increase the surface area of these cells.

2- Cilia: these are hair-like processes on the free surface of certain cells e.g. epithelial cells of some parts of respiratory tract. They move in one direction and push away mucus and harmful materials.

3- Flagella: they resemble cilia in general structure but are longer and present only in spermatozoa.

4- Cell junctions: they connect adjacent cells together





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