ORGANIZATION OF HUMAN BODY : CELL LEVEL

OBJECTIVE

The students will be able to

- Explain the structure of cell and function
- Animal cell structure and function
- Cell physiology including transportation across the membrane.

Notes: B.Sc. Nursing (sem-1st)
Applied physiology (unit-1)
General science- Biology (Unit-3)

CELL

- Smallest fundamental structure of life is called cell
- Discovered cell by Robert hook (1665)-as non living
- Further described by luvin hook as living substance
- It is smallest, structure and functional unit
- Billion cells present in human body
- Largest cell is egg (ovam) and smalless is called sperm
- Neuron cells are longest cells

CELL DEVELOPEMENT

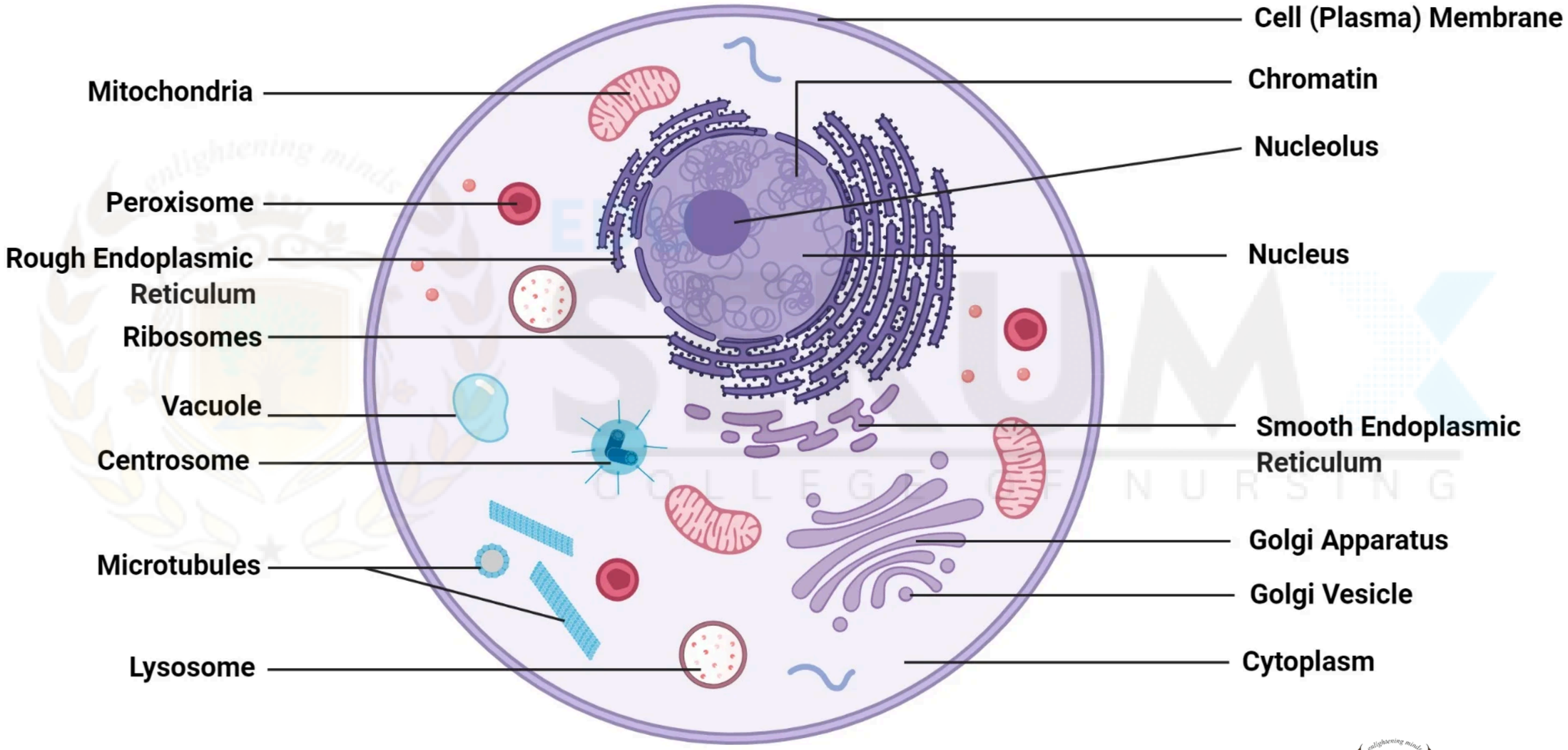
- Development by fusion- ovum and spermatozoa and fuse into zygote- Mitosis/ miosis
- Many cells collectively make tissue- building blocks/bricks
- Many tissues makes organ
- Organ makes organ system e.g.: reproductive sys, urinary system
- Many organ system collectively makes human Body

CELL THEORY

- Developed by microbiologist Schlidon and Scheann (they described about properties of cell) Properties:
- Old theory
- All living body are made up of cells
- old cells are created into new cells (mitosis&miosis)
- Cells are the building blocks
- Modern concept:
- Activity of an organism depends on total activity of and individual cell
- Energy flows occur in cells through breakdown of carbohydrate by respiration
- Cells contain information necessary for the creation of new cells(holding information in DNA- hereditary information)

CELL SRTUCTURE (ANIMAL CELL)

- Cell membrane/ plasma membrane
- Nucleus
- Cytoplasm
- Cell Organelles(small organs)
- 1 - Mitochondria
- 2 - Endoplasmic reticulum (smooth/rough-ribosomes)
- 3 - Golgi apparatus
- 4 - Ribosomes (protin production)
- 5 - lysosomes



CELL ORGAN FUNCTION

- Cell membrane/ plasma membrane- protection. Semi permeable- exchange of substances
- Nucleus- center of cells, nucleolis-menufecture protein components, DNA present, head of cells, no nucleus in RBCS
- Cytoplasm- B/W cell membrane and nuclease wall- thick fluid, organs suspended, (nucleoplasm in nucleus)

- Cell Organelles (small organs)
  - Mitochondria- powerhouse of cell-required for metabolic activity of cell, ATP
  - Endoplasmic reticulum(smooth/rough-ribosomes)RER/SER –protein transport
  - Golgi apparatus- receives proteins, packing and modify and sends to the required part of cells- post office
  - Ribosomes(protein production)
  - Lysosomes- suicidal bag of the cells-engulf cell when cell die

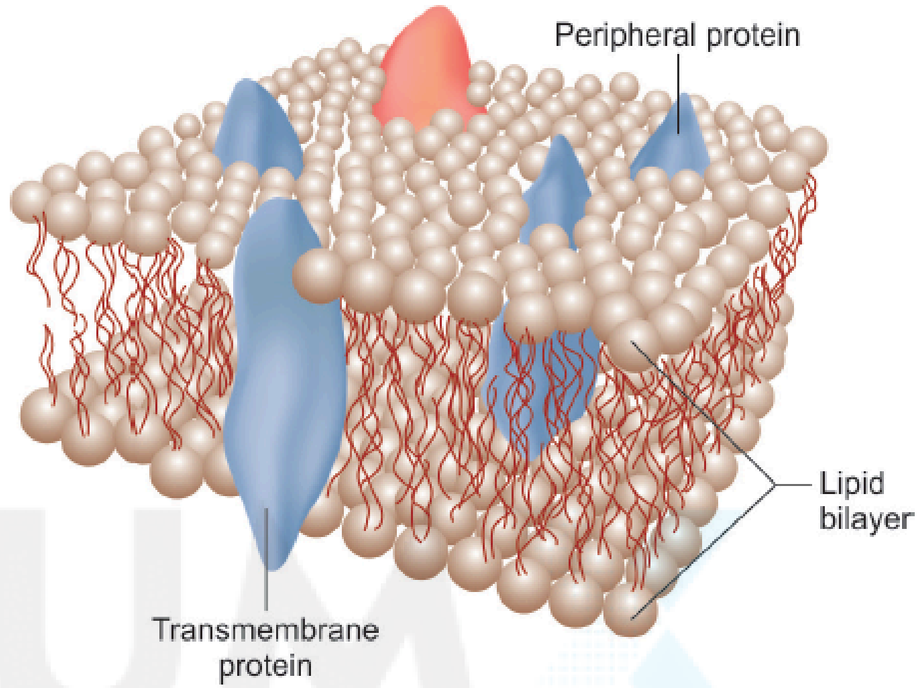
FUNCTION OF CELL

- Facilitate Growth
- Provide support and structure
- Transport of Substances
- Energy production
- Aids In reproduction

CELL MEMBRANE (PLASMA MEMBRANE)

- Definition
- The cell membrane is a thin, flexible, semipermeable boundary that surrounds the cell, separating the intracellular fluid (ICF) from the extracellular fluid (ECF). It controls the movement of substances in and out of the cell.
- Structure of the Cell Membrane
- Thickness: ~7.5 nm (nanometers)
- Appearance: Trilaminar under an electron microscope – two dark layers (protein layers) with a lighter central layer (lipid layer).

Composition



Component	Percentage	Function Summary
Proteins	55%	Receptors, transporters, enzymes, adhesion, cytoskeleton
Lipids	40%	Phospholipids and cholesterol; semipermeable barrier
Carbohydrates	5%	Cell recognition, adhesion, hormone receptors

1. Lipids in Cell Membrane

- A. Phospholipids
- Structure: Head (hydrophilic) + Tail (hydrophobic)
- Arrangement: Bilayer with tails inward and heads facing ECF and cytoplasm.
- Function: Forms the semipermeable barrier; only allows fat-soluble molecules (O_2, CO_2, alcohol) to pass.
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- B. Cholesterol
- Fills spaces between phospholipids.
- Function: Stabilizes membrane fluidity and structural integrity.

LIPIDS IN CELL MEMBRANES

- Phospholipid
- Cholesterol

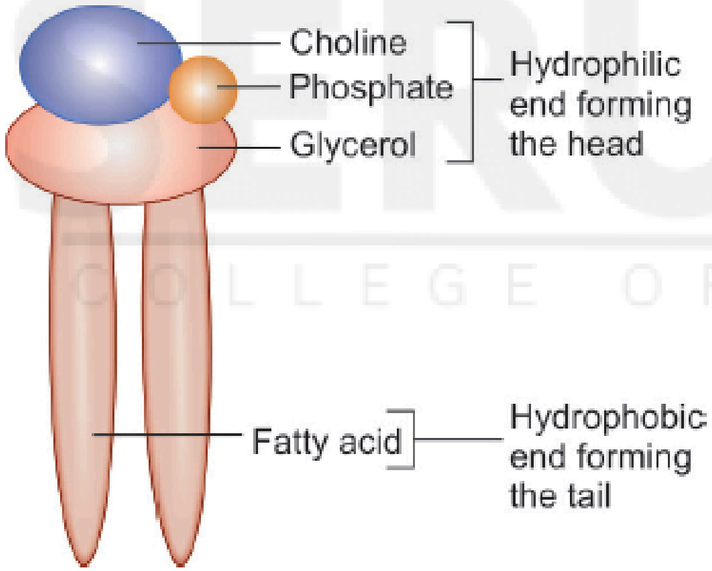


Fig. 3A.2: Phospholipid molecule (schematic representation).

2. Proteins in Cell Membrane

- A. Types
- Integral Proteins (Transmembrane Proteins): Span the entire membrane.
- Peripheral Proteins: Loosely attached on the inner or outer surface.

- B. Functions

Function	Description
Receptors	Bind hormones and initiate intracellular signaling.
Transport Proteins	Form channels/pores for water-soluble substances (ions, glucose).
Carrier Proteins	Facilitate passive/active transport.
Pumps (e.g., Na^+/K^+ ATPase)	Use ATP to move substances against concentration gradients.
Cell Adhesion Molecules	Maintain cell shape, connect to extracellular matrix (e.g., integrins).
Enzymes	Catalyze intracellular reactions.

PROTEIN IN CELL MEMBRANE

- Integral proteins
- Peripheral proteins

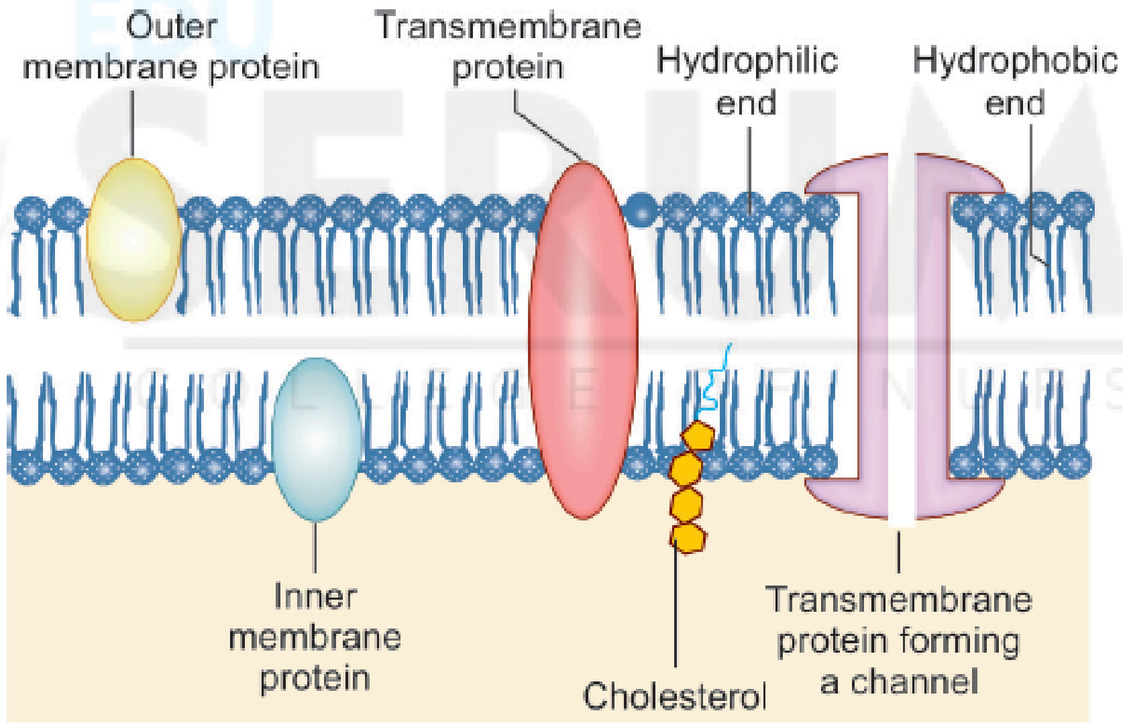


Fig. 3A.3: Arrangement of lipids and proteins in cell membrane (schematic representation).

3. Carbohydrates in Cell Membrane

- A. Location
- Present on the outer surface forming the glycocalyx.
- Attached to proteins (glycoproteins) or lipids (glycolipids).
- B. Functions
- Cell recognition (e.g., immune response).
- Hormone receptor sites.
- Negative charge repels similarly charged particles.
- Cell adhesion – helps bind neighbouring cells together.

CARBOHYDRATES OF THE CELL MEMBRANE

Carbohydrate molecules form a thin loose covering over the entire surface of the cell membrane called glycocalyx.

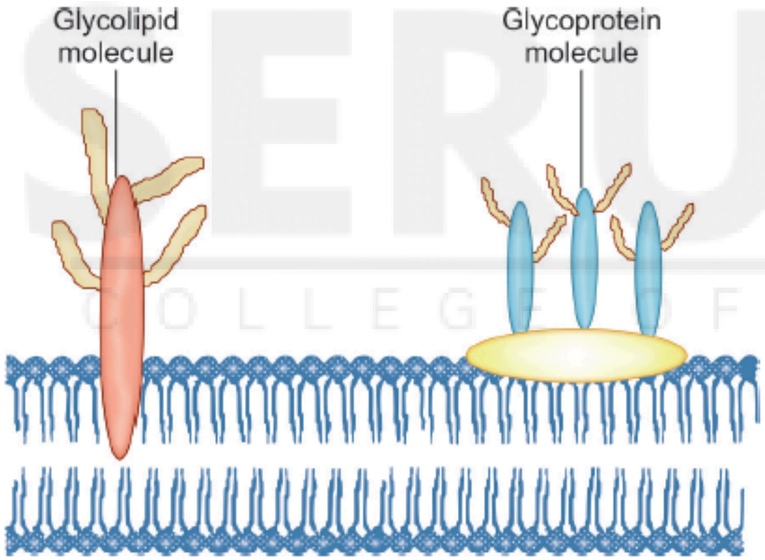


Fig. 3A.4: Glycolipid and glycoprotein molecules attached to outer aspect of cell membrane (schematic representation)

Functional Summary of Cell Membrane

Carbohydrate molecules form a thin loose covering over the entire surface of the cell membrane called glycocalyx.

Function	Description
Protective	Encloses and protects cell contents.
Selective Permeability	Allows selective entry/exit of substances.
Absorptive	Facilitates nutrient uptake.
Excretory	Removes waste products.
Gas Exchange	Oxygen enters; carbon dioxide exits.
Shape Maintenance	Maintains size and shape of the cell.

Transport Across the Cell Membrane

Transport across the cell membrane is essential for maintaining homeostasis, allowing cells to obtain nutrients, expel waste, and communicate with their environment. It occurs in the following major ways:

1. Passive Transport
2. Active Transport
3. Bulk Transport (Vesicular Transport)

1. Passive Transport

Movement of substances across the membrane without using cellular energy (ATP).

A. Simple Diffusion

- Definition: Movement of molecules from an area of high concentration to low concentration until equilibrium is reached.
- Examples: Oxygen (O_2), Carbon dioxide (CO_2), alcohol, and fat-soluble vitamins.
- Mechanism: Moves directly through the phospholipid bilayer.

B. Facilitated Diffusion

- Definition: Diffusion of water-soluble or charged molecules via specific carrier proteins or channel proteins in the membrane.
- Examples: Glucose, amino acids, ions (Na^+, K^+, Cl^-).
- Key Feature: No ATP required, but uses membrane proteins for assistance.

C. Osmosis

- Definition: Movement of water molecules from an area of low solute concentration to high solute concentration through a selectively permeable membrane.
- Key Term: Water moves toward hypertonic (higher solute) regions.
- Example: Water absorption in intestinal cells or kidney tubules.

Example

- Oxygen Diffusion:
  In lungs, O_2 diffuses from alveoli (high concentration) into blood (low concentration).
- Dehydration and Osmosis:
  When a person is severely dehydrated, water moves out of cells into the bloodstream, causing cell shrinkage (crenation).

2. Active Transport

- Movement of substances against the concentration gradient (low to high), requiring ATP.
- Features:
- Requires specific carrier proteins (pumps).
- Uses energy from ATP to function.
- Helps maintain concentration differences essential for cell function.
- Example: Sodium-Potassium Pump (Na^+/K^+ ATPase)
- Pumps 3 Na^+ ions out and 2 K^+ ions in against their concentration gradients.
- Maintains electrochemical gradient necessary for nerve impulse transmission and muscle contraction.

Example

- Active Transport:
- Sodium-Potassium Pump in Neurons:
- Essential for generating action potentials.
- Clinical link: Nerve paralysis can occur if ATP production is impaired (e.g., in hypoxia).

3. Bulk Transport (Vesicular Transport)

- Transport of large molecules or particles via vesicles.
- A. Endocytosis
- B. Exocytosis

A. Endocytosis

- Process by which the cell engulfs material from the external environment by folding the membrane inward.
- i. Pinocytosis ("Cell Drinking")
- Definition: Ingestion of fluid and dissolved solutes into small vesicles.
- Example: Absorption of nutrients in cells lining the small intestine.
- ii. Phagocytosis ("Cell Eating")
- Definition: Engulfment of large solid particles like microbes, debris, or other cells.
- Example: White blood cells (macrophages and neutrophils) engulf bacteria.
- iii. Receptor-Mediated Endocytosis
- Definition: Highly specific; cells use receptor proteins to bind and internalize specific substances (e.g., hormones, cholesterol).
- Example: LDL (Low-Density Lipoprotein) cholesterol uptake by liver cells.

B. Exocytosis

- Process by which cells expel materials in vesicles that fuse with the plasma membrane.
- Used to release hormones, neurotransmitters, digestive enzymes.

Example:

- Neurons release neurotransmitters at synapses.
- Pancreatic cells release insulin into the bloodstream.
- Goblet cells release mucus in the intestine.

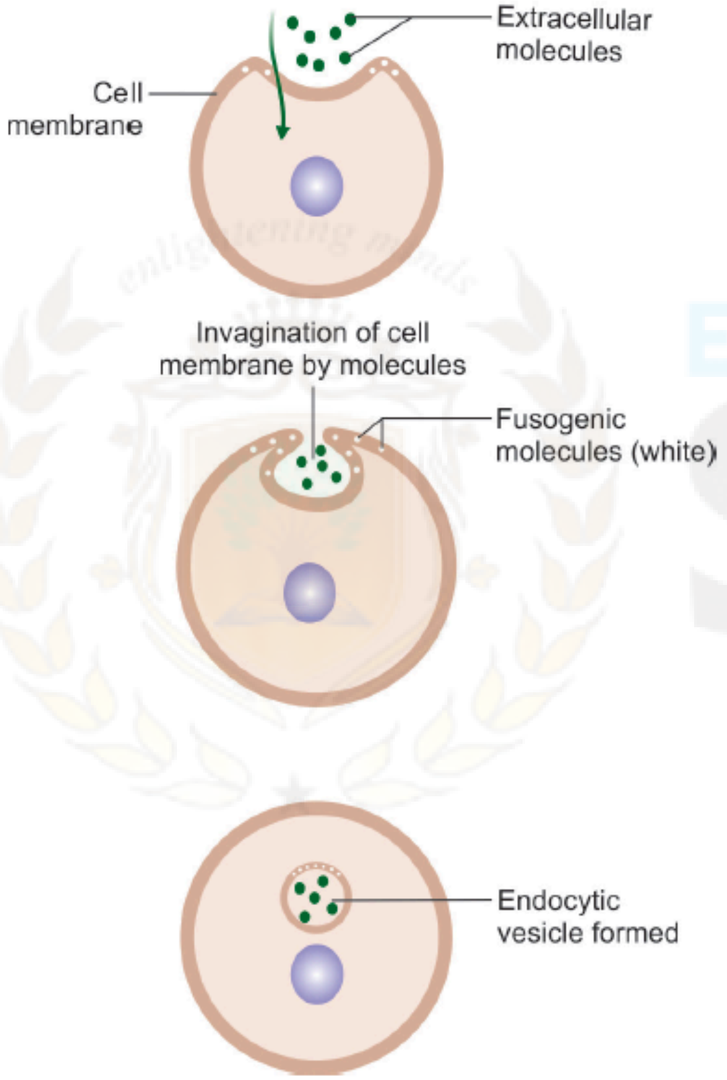


Fig. 3A.5: Three stages in the absorption of extracellular molecules

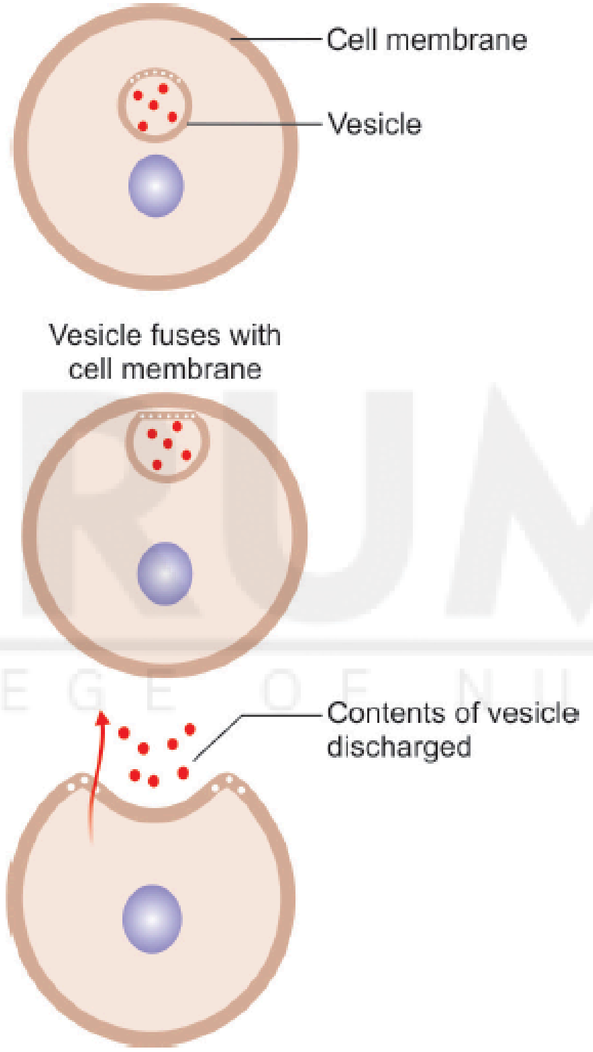


Fig. 3A.6: Three stages in exocytosis (schematic representation).

Example

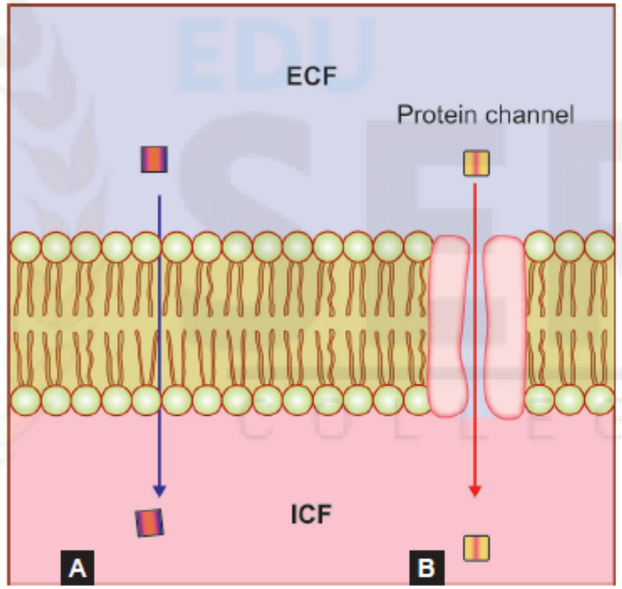
- 3. Endocytosis:
- Phagocytosis in Immunity:
- Macrophages and neutrophils engulf bacteria through phagocytosis.
- Clinical link: Infections persist in patients with phagocytic defects (e.g., Chronic Granulomatous Disease).
- Pinocytosis in Nutrient Absorption:
- Intestinal epithelial cells absorb fluids and small molecules from digested food via pinocytosis.
- 4. Exocytosis:
- Neurotransmitter Release:
- Neurons release acetylcholine at the neuromuscular junction via exocytosis.
- Clinical link: In Botulism, the exocytosis of acetylcholine is blocked, causing muscle paralysis.
- Insulin Secretion:
- Pancreatic β-cells release insulin into the bloodstream via exocytosis.
- Clinical link: Impaired exocytosis of insulin can contribute to Type 2 Diabetes.

Comparison Chart

Type	Energy Required	Direction	Example Substances	Mechanism
Simple Diffusion	❌ No	High → Low	O_2, CO_2, alcohol	Through phospholipid bilayer
Facilitated Diffusion	❌ No	High → Low	Glucose, Na^+, Cl^-	Via carrier/channel proteins
Osmosis	❌ No	Low → High (water)	Water	Through aquaporins
Active Transport	✅ Yes (ATP)	Low → High	Na^+, K^+, Ca^{2+}, glucose (in kidneys)	Via membrane pumps
Endocytosis	✅ Yes	Into cell	Fluids, bacteria, LDL	Membrane engulfs material
Exocytosis	✅ Yes	Out of cell	Hormones, enzymes, neurotransmitters	Vesicle fuses with membrane

PASSIVE TRANSPORT

- Simple diffusion
- Facilitated diffusion



Figs. 3.15A and B: Simple diffusion through the cell membrane
A. Diffusion through lipid layer; B. Diffusion through protein channe
(schematic representation).

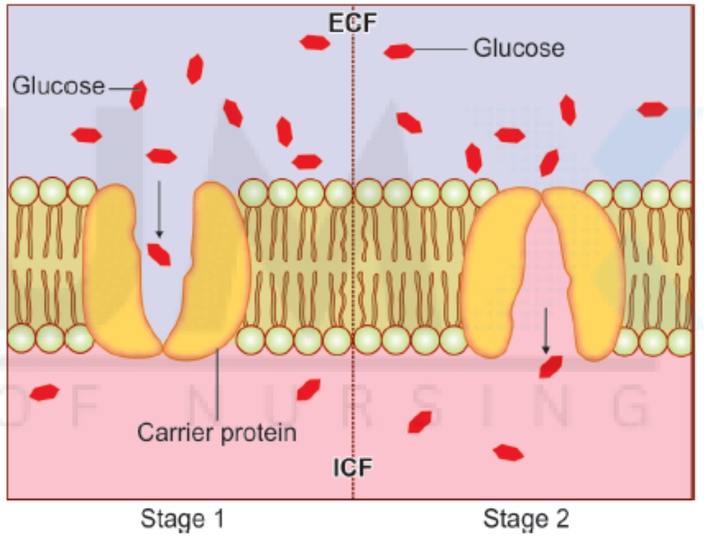


Fig. 3A.16: Facilitated diffusion from higher concentration (ECF
lower concentration (ICF). Stage 1: Glucose binds with carrier prot
Stage 2: Conformational change occurs in the carrier protein
glucose is released into ICF (schematic representation).

ACTIVE TRANSPORT

- Movement of substances against the chemical or electrical or electrochemical gradient is called active transport.

Types of Active Transport

- Primary active transport
- Secondary active transport

Table 3A.5: Examples of primary and secondary active tr

Types of active transport	*Examples*
Primary active transport	Na^+-K^+ ATPase pump, H^+– K^+ AT pump, Ca^{2+} pump, Na^+– H^+ ATPa
Secondary active transport	SGLT in kidney and intestine, N antiporter in kidney

OSMOSIS

- OSMOSIS
- Osmosis is the special type of diffusion. It is the movement of water or any other solvent from an area of lower concentration to an area of higher concentration through a semipermeable membrane.

TYPES

- Endosmosis by which water
- moves into the cell.
- Exosmosis by which water
- moves outside the cell.

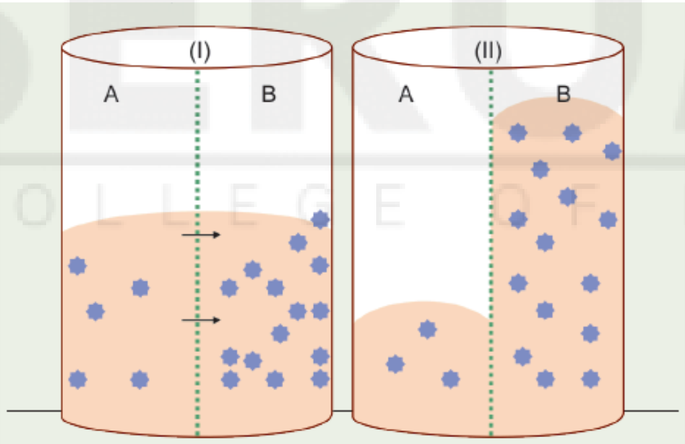


Fig. 3A.17: Osmosis. Blue objects = solute. Peach shade = water. Green dotted line = semipermeable membrane. In (I), concentration of solute is high in the compartment B and low in compartment A. So, water moves from A to B through semipermeable membrane. In (II), entrance of water into B exerts osmotic pressure (schematic representation)

NA+– K+ ATPase PUMP

- This pump for primary active transport is present on almost all cells of our body.
- It consists of two subunits—alpha (α) and beta (β).

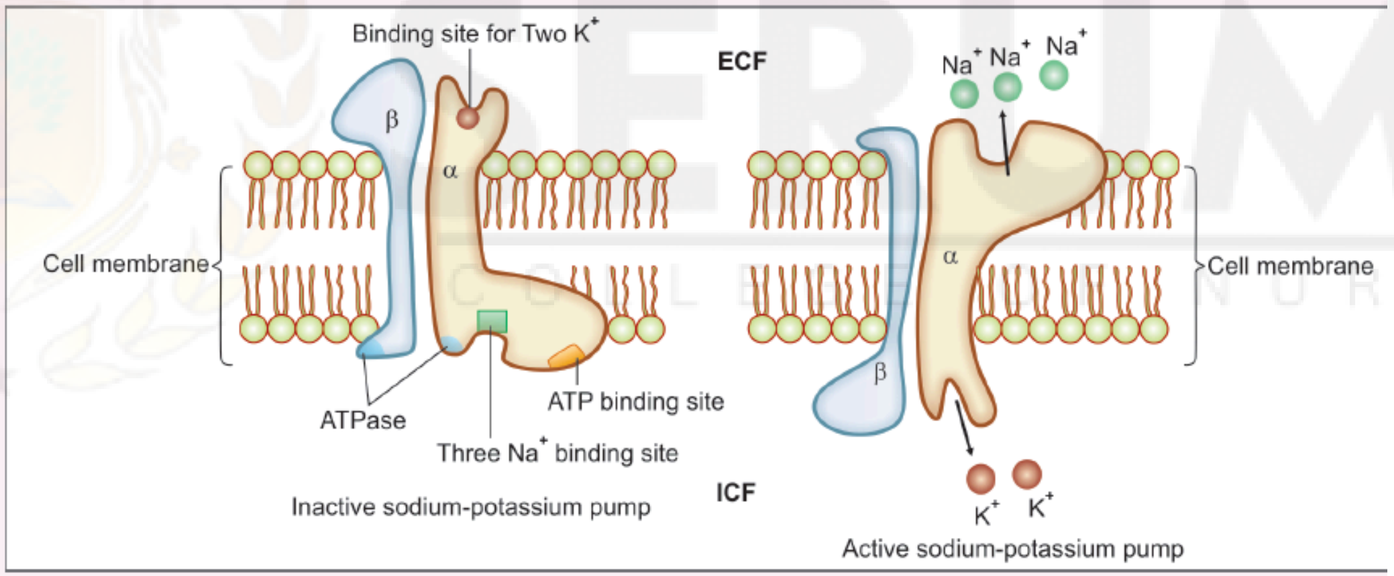


Fig. 3A.18: Mechanism of operation of Na^+K^+ ATPase pump (schematic representation).
(ECF: extracellular fluid; ICF: intracellular fluid)

CYTOPLASM

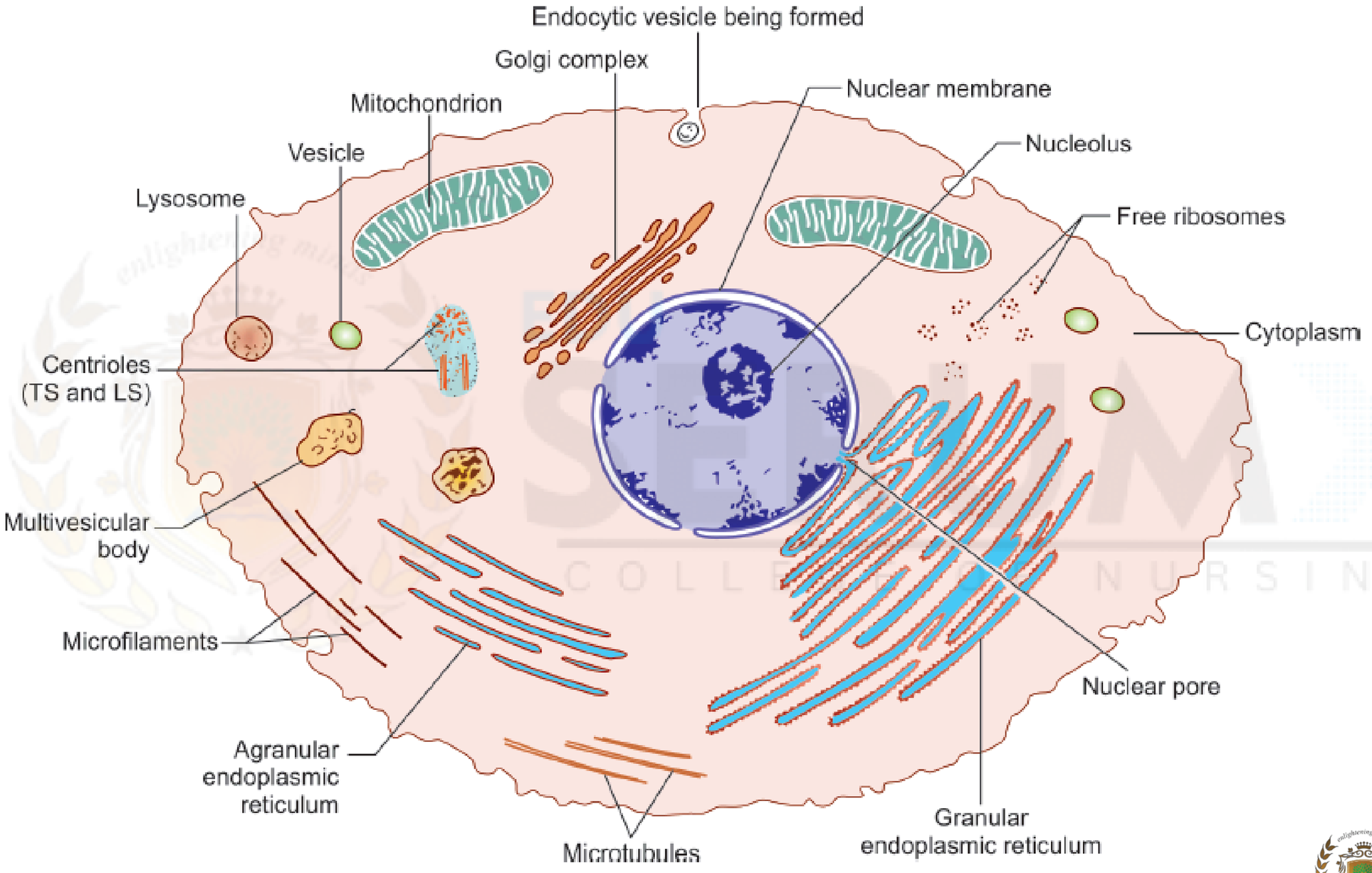
- The cytoplasm is the fluid present inside the cell.
- It contains a clear liquid portion called cytosol.
- The cytoplasm is distributed as peripheral ectoplasm just beneath the cell membrane and inner endoplasm between the ectoplasm and the nucleus.

CELL ORGANELLES

- Endoplasmic reticulum (ER)
- Ribosomes
- Mitochondria
- The Golgi complex
- Various types of vesicles

Table 3A.2: Cell organelles.

Membrane-bound cell organelles	*Nonmembranous cell organelles*
Endoplasmic reticulum (ER) Golgi complex Mitochondria Membrane-bound vesicles including: • Phagosomes • Lysosomes • Peroxisomes • Exocytic vesicles	Cytoskeleton including: • Microfilaments • Microtubules • Intermediate filaments • Ribosomes



ENDOPLASMIC RETICULUM

- Endoplasmic reticulum is made up of tubules and microsomal vesicles.
- These structures form an interconnected network which acts as the link between the organelles and cell membrane.
- Types of Endoplasmic Reticulum
- Rough endoplasmic reticulum
- Smooth endoplasmic reticulum

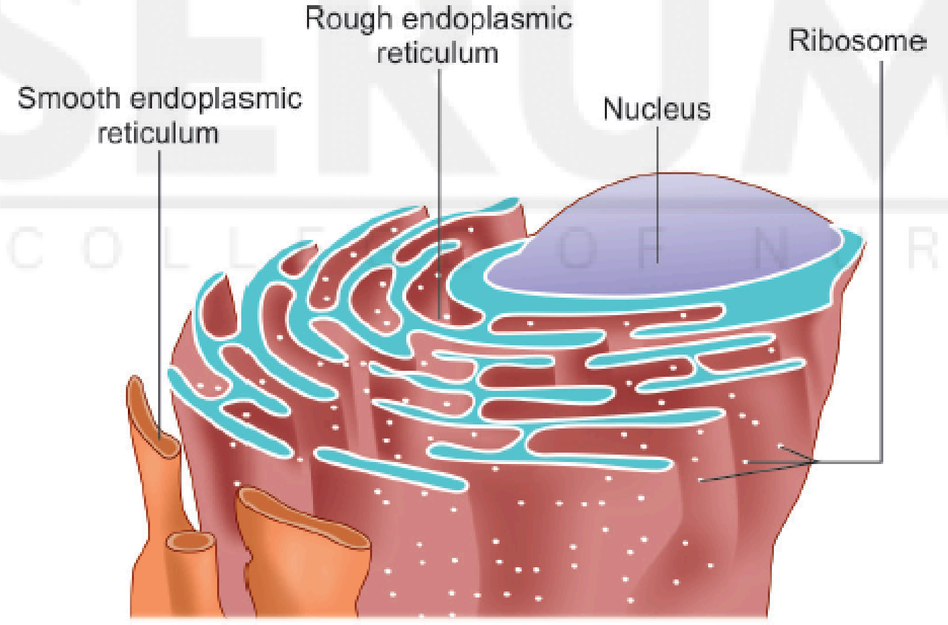


Fig. 3A.8: Endoplasmic reticulum (schematic representation).

GOLGI APPARATUS

- Golgi apparatus (Golgi body or Golgi complex) is present in all the cells except RBCs. It consists of 5–8 flattened membranous sacs called cisternae.

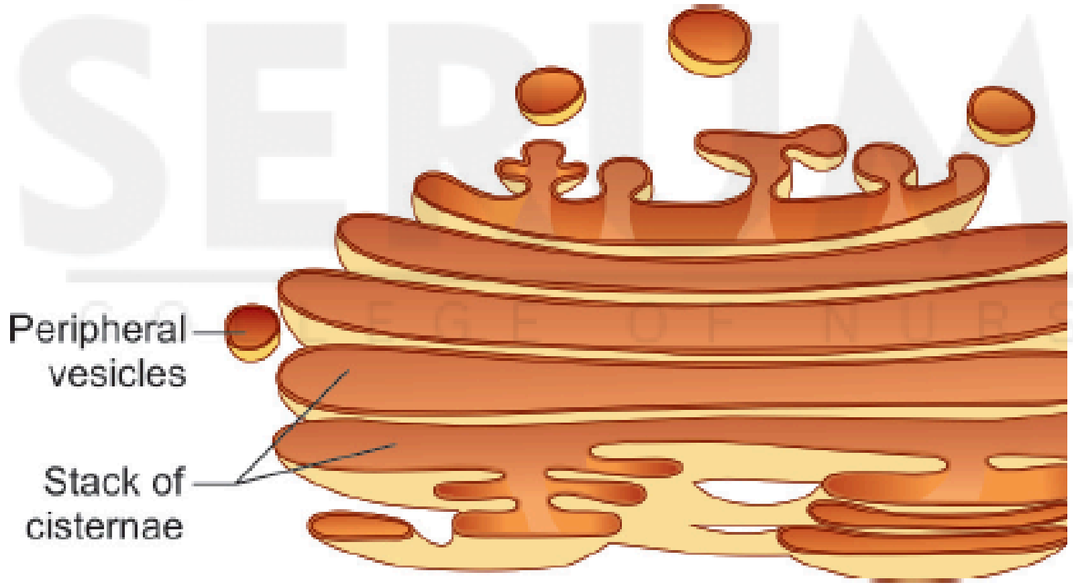


Fig. 3A.9: Structure of the Golgi complex (schematic represe

MEMBRANE-BOUND VESICLES

- The cytoplasm of a cell may contain several types of vesicles.
- Phagosomes
- Pinocytotic Vesicles
- Exocytic Vesicles
- Lysosomes
- Peroxisomes
- Centrosome

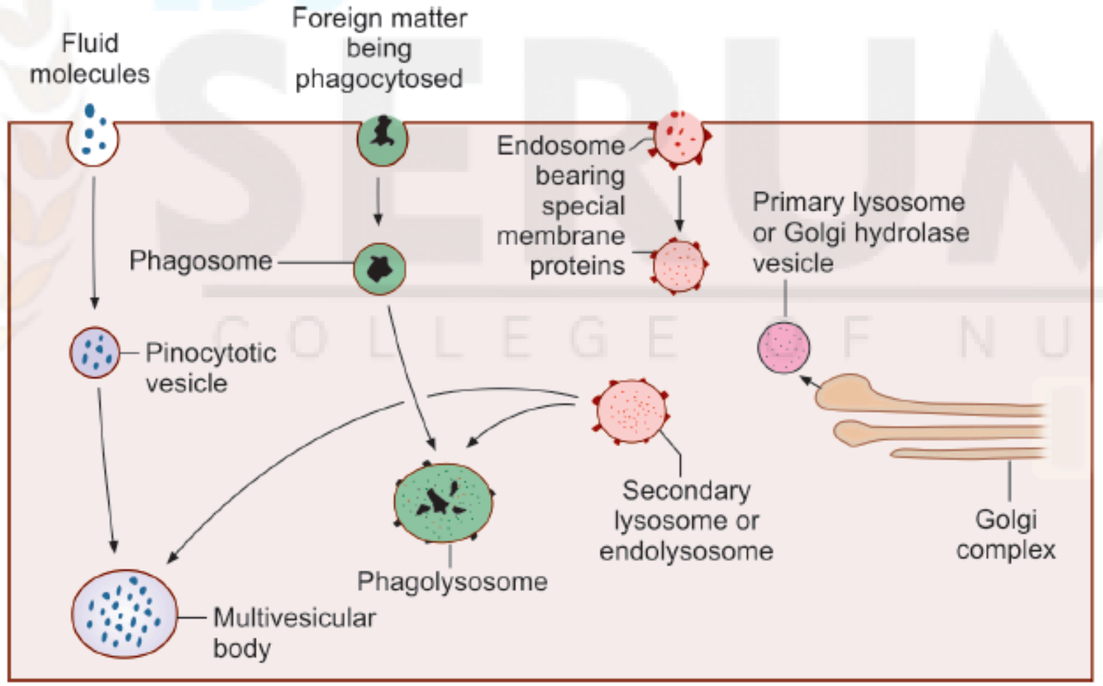


Fig. 3A.10: Scheme to show how lysosomes, phagolysosomes, and multivesicular bodies are formed.

MITOCHONDRIA

- Mitochondria are membrane-bound organelles and are called the ***power-generating units of the cell.***
-
- ***FUNCTIONS***
- Chief site of tricarboxylic acid
- cycle (TCA) cycle,
- Electron transport chain, and fatty
- acid metabolism.
- Release of energy from ATP and
- guanosine triphosphate (GTP)
- It concentrates Ca2.

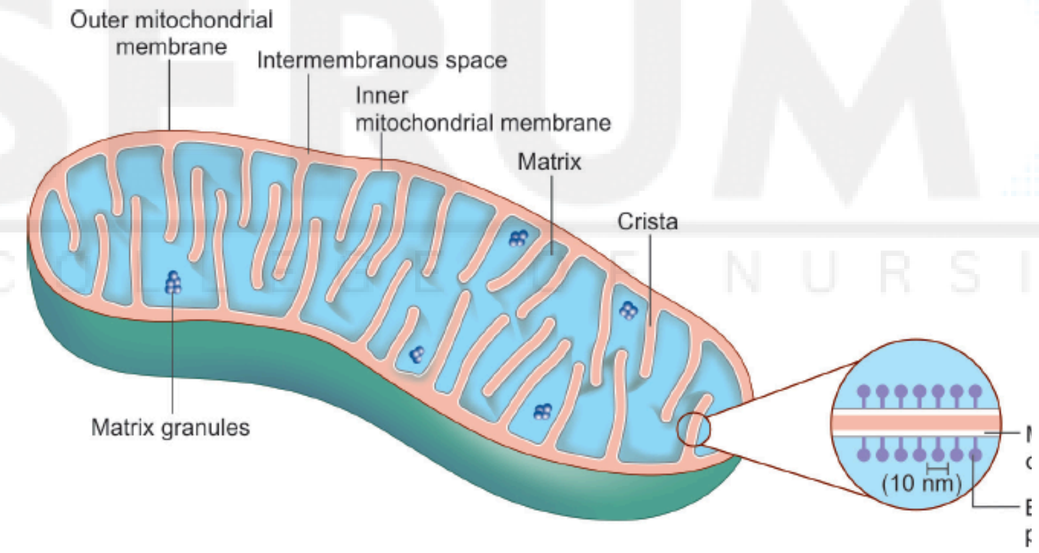


Fig. 3A.11: Structure of a mitochondrion (schematic representation).

Different cell organelles and their functions

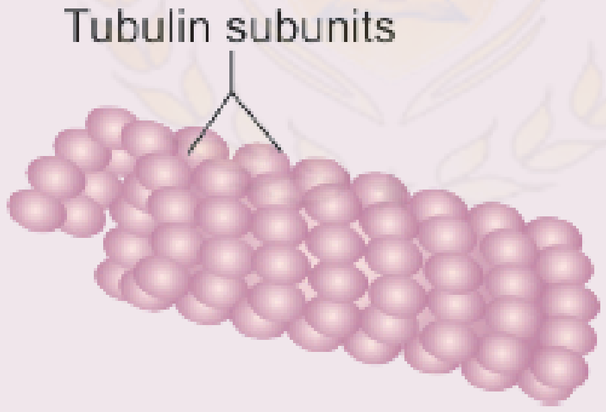
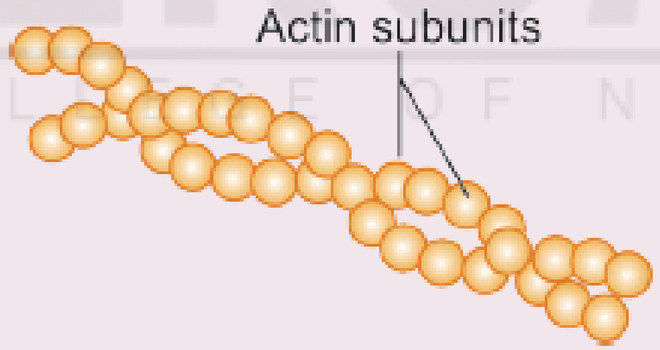
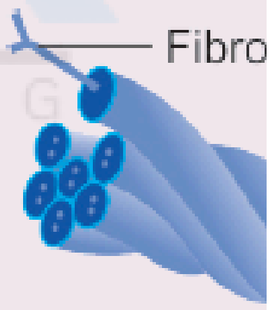
Table 3A.3: Different cell organelles and their functions.

Cell organelle	*Functions*
Endoplasmic reticulum	Synthesis of proteins (rough endoplasmic reticulum), synthesis of lipids, steroids, cholesterol, and carbohydrates (smooth endoplasmic reticulum, detoxification, storage and release of Ca^{2+} to initiate muscle contraction
Golgi apparatus	Processing and packaging of substances into the secretory granules, secretory vesicles, and lysosomes for transporting them inside and

CYTOSKELETON

- The cytoskeleton of the cell is a complex network that gives shape, support and stability to the cell.
- The cytoskeleton consists of three major protein components viz.:
- Microtubules
- Intermediate filaments
- Microfilaments

Table 3A.4: Cytoskeleton of cell.

Microtubules	*Microfilaments*	*Intermediat*
Large contractile protein fibers	Smallest protein fibers	Thicker than
Made up of tubulin (α-tubulin and β-tubulin subunits)	Made up of two actin strands coiled on each other	Made of fibr
• Involved in movement of: – Organelles within the cell – Chromosomes during cell division – Cell extensions (see next page for detail)	• Provide structural support • Maintains shape of cell • Helps in muscle contraction	• Help mair • Stabilize t as nucleu
		

NUCLEUS

- Nucleus is present in those cells which divide and produce enzymes.
- The cells with nucleus are called eukaryotes and those without nucleus are known as prokaryotes (e.g., RBCs).
- Prokaryotes do not divide or synthesize the enzymes.

- **Nuclear Components**
- Nuclear membrane
- Nucleoplasm
- Nucleolus

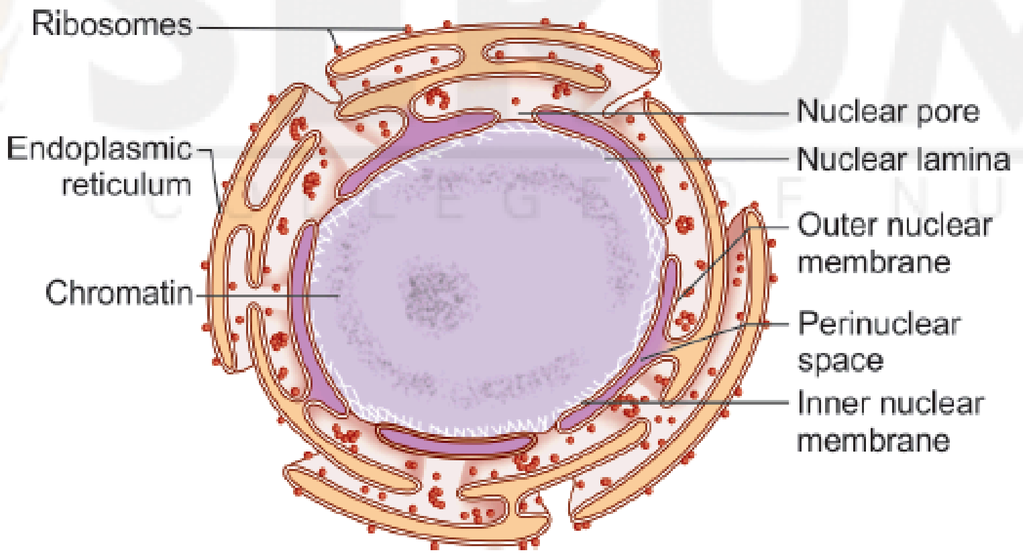


Fig. 3A.12: Nuclear envelope (schematic representation).

CELL EXTENSIONS

- Many cells show projection from the cell surface. The various types of projections are described below:
- Cilia
- Flagella
- Microvilli

FLAGELLA

- These are somewhat larger processes having the same basic structure as cilia.
- In the human body the best example of a flagellum is the tail of the spermatozoon.
- The movements of flagella are different from those of cilia.
- In a flagellum, movement starts at its base.

MICROVILLI

- Microvilli are finger-like projections from the cell surface that can be seen by EM.
- Each microvillus consists of an outer covering of plasma membrane and a cytoplasmic core.
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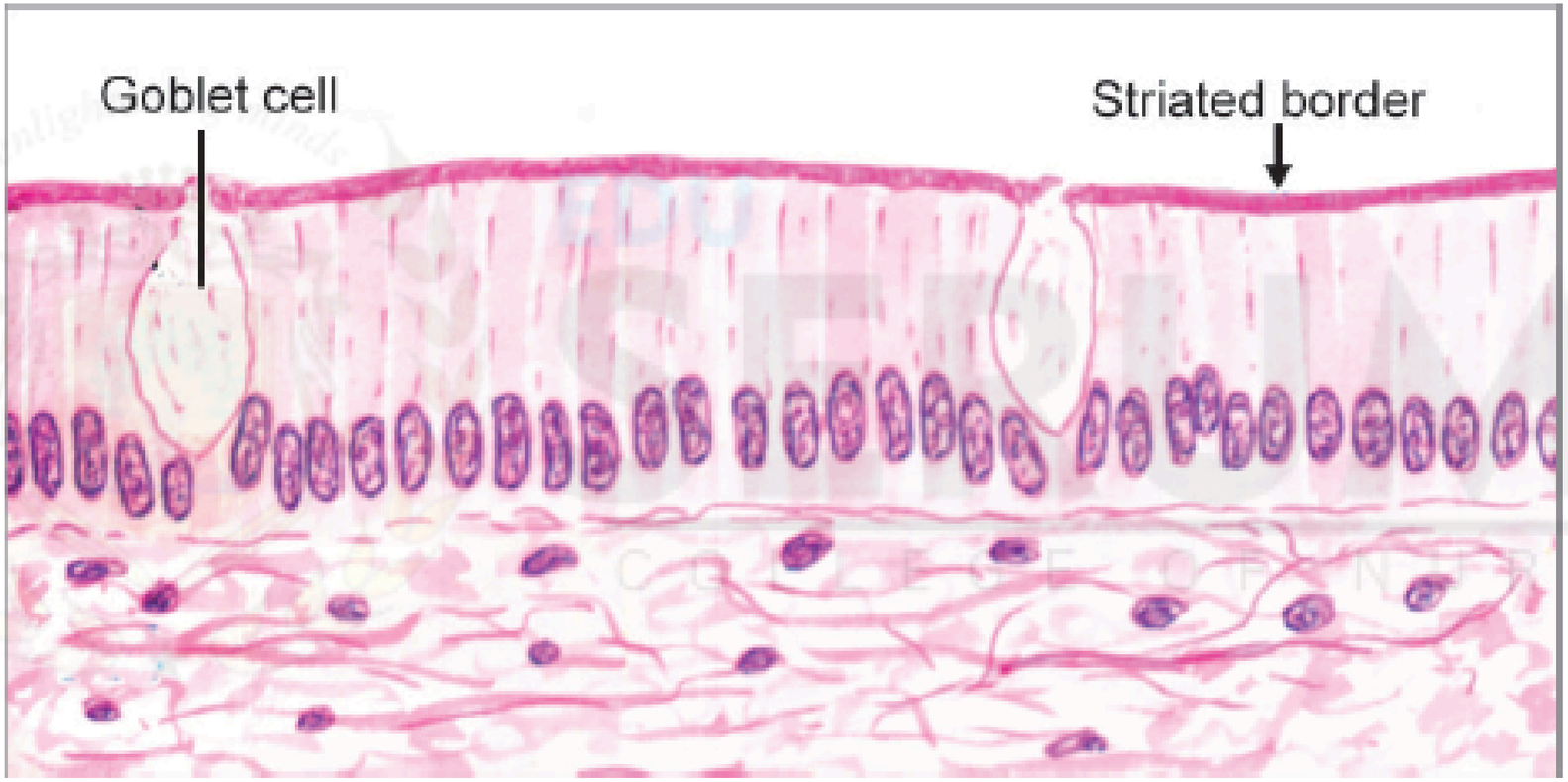
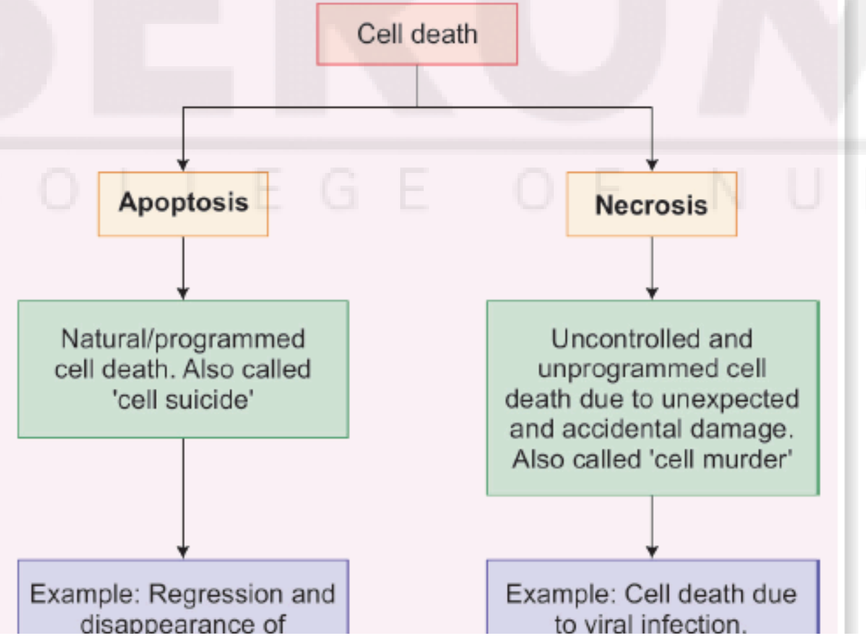
- Depending on the arrangement of microvilli on the epithelium, two types of appearances can be seen:
- Striated border
- Brush border


Goblet cell
Striated border

CELL DEATH

CELL DEATH (FLOWCHART 3A.2)
Cell death occurs by two distinct processes:
1. Necrosis
2. Apoptosis

Flowchart 3A.2: Process of cell death.

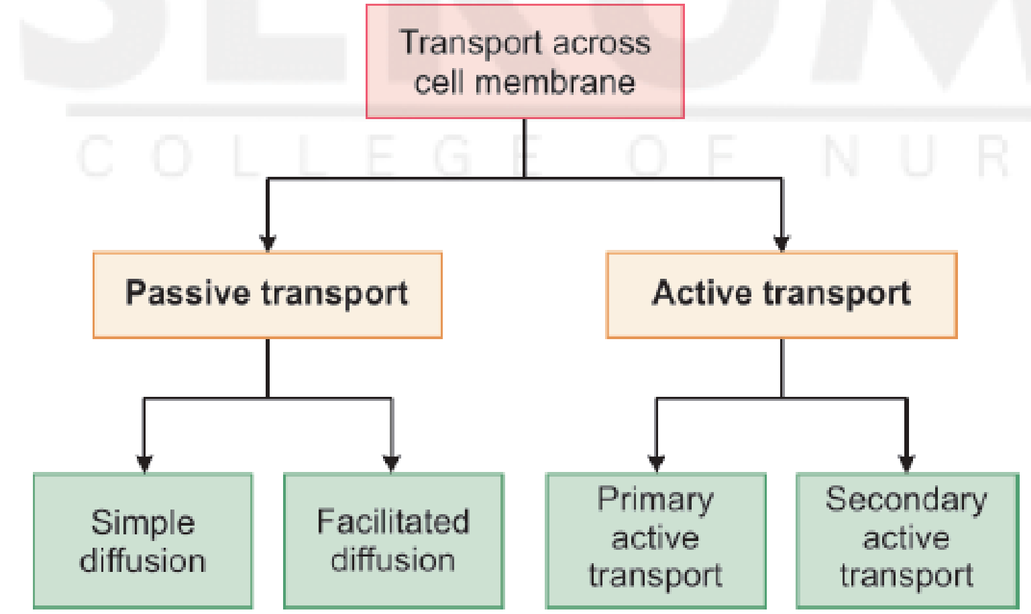


TRANSPORT ACROSS CELL MEMBRANE

BASIC MECHANISM OF TRANSPORT

- Two basic mechanisms for the transport of substances across the cell membrane are:
- Passive mechanism
- Active mechanism

Flowchart 3A.3: Mechanism of transport across cell membrane.




Thank
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