

# **GPAT Online Class for B Pharm students**

## **Human Anatomy and Physiology part -1**

**(Cell, Cell junctions and transport mechanisms)**

**By**

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- **Anatomy** – the study of the structure of the human body
- **Physiology** – the study of the function of the human body

“The complementarity of structure and function.”



# Levels of Organization

**Subatomic Particles** – electrons, protons, and neutrons

**Atom** – hydrogen atom, lithium atom, etc.

**Molecule** – water molecule, glucose molecule, etc.

**Macromolecule** – protein molecule, DNA molecule, etc.

**Organelle** – mitochondrion, Golgi apparatus, nucleus, etc.

**Cell** – muscle cell, nerve cell, etc.

**Tissue** – epithelia, connective, muscle and nerve etc.

**Organ** – skin, femur, heart, kidney, etc.

**Organ System** – skeletal system, digestive system, etc.

**Organism** – the human



# Characteristics of Life

**Movement** – change in position; motion

**Responsiveness** – reaction to a change

**Growth** – increase in body size; no change in shape

**Reproduction** – production of new organisms and new cells

**Respiration** – obtaining oxygen; removing carbon dioxide; releasing energy from foods

**Digestion** – breakdown of food substances into simpler forms



**Absorption** – passage of substances through membranes and into body fluids

**Circulation** – movement of substances in body fluids

**Assimilation** – changing of absorbed substances into chemically different forms

**Excretion** – removal of wastes produced by metabolic reactions



# Maintenance of Life

Life depends on five (5) environmental factors

Water, Food, Oxygen, Heat, Pressure

- **Water**

- most abundant substance in body
- required for metabolic processes
- required for transport of substances
- regulates body temperature



- **Food**
  - provides necessary nutrients
  - supplies energy
  - supplies raw materials
- **Oxygen (gas)**
  - one-fifth of air
  - used to release energy from nutrients
- **Heat**
  - form of energy
  - partly controls rate of metabolic reactions





- **Pressure**
  - application of force on an object
  - atmospheric pressure – important for breathing
  - hydrostatic pressure – keeps blood flowing



# Cell

Cell is the fundamental, structural and functional unit of all living organisms.

All cells arise from pre existing cells through the process of cell division.

Unicellular organisms – Organisms with single cell, capable of independent existence and carries all functions like digestion, excretion, respiration, growth & reproduction (Acellular). Examples, Amoeba, Euglena.

**Multicellular organisms** – Organisms with more than one cell

Cells in multicellular organisms vary in size & shape depending on function

**SHAPE:** Parenchyma - Polyhedral cells performs storage.

Sclerenchyma - spindle shaped cells & provides mechanical support

Nerve cells- long and branched cells conducting nerve impulses RBC -Biconcave & helps in carrying oxygen



Muscle cells- cylindrical or spindle shaped concerned with the movement of body parts.



- Different substances that make a cell are collectively called

## **Protoplasm.**

- Protoplasm is composed of
- Water - **70-80% Water** is present in cell.
- Carbohydrates
- Lipids
- Proteins
- Electrolyte - Sodium ( $\text{Na}^+$ ), Potassium ( $\text{K}^+$ ), Magnesium ( $\text{Mg}^{2+}$ ), Calcium ( $\text{Ca}^{2+}$ ), Phosphate, Chloride ( $\text{Cl}^-$ ), and Bicarbonate ( $\text{HCO}_3^-$ ).



## Components of Cell

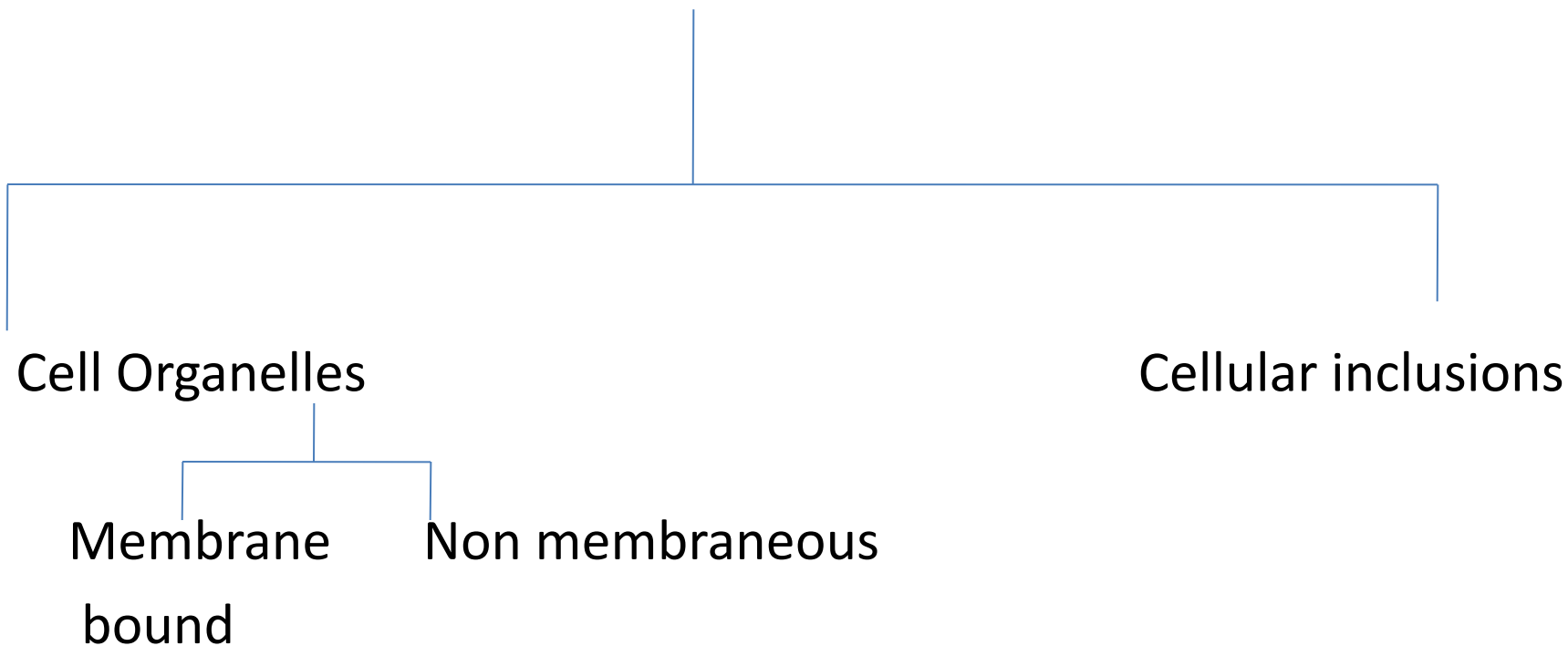
Cell membrane

Cytoplasm

Nucleus



## Cytoplasm



## Cellular organelles

### Membrane bound

- Mitochondria
- Endoplasmic reticulum
- Golgi apparatus
- Lysosomes

### Non membraneous

Ribosomes  
Cytoskeleton  
Centrioles





## Cell Inclusions

### Storage Products

Starch, Fats and Oils, Proteins

### Secretory Products

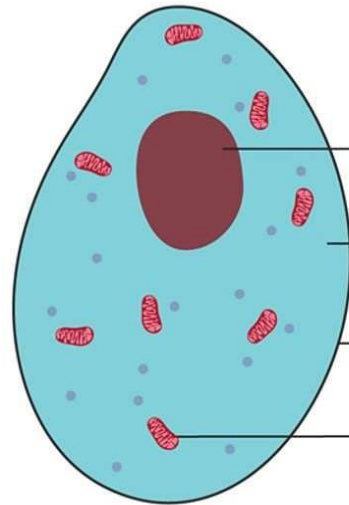
Enzymes, hormones

### Excretory products

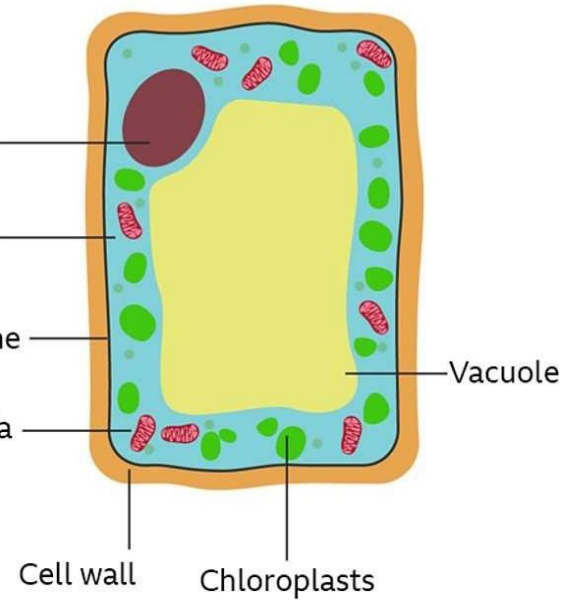
Carbon dioxide, water



Animal cell



Plant cell



Nucleus

Cytoplasm

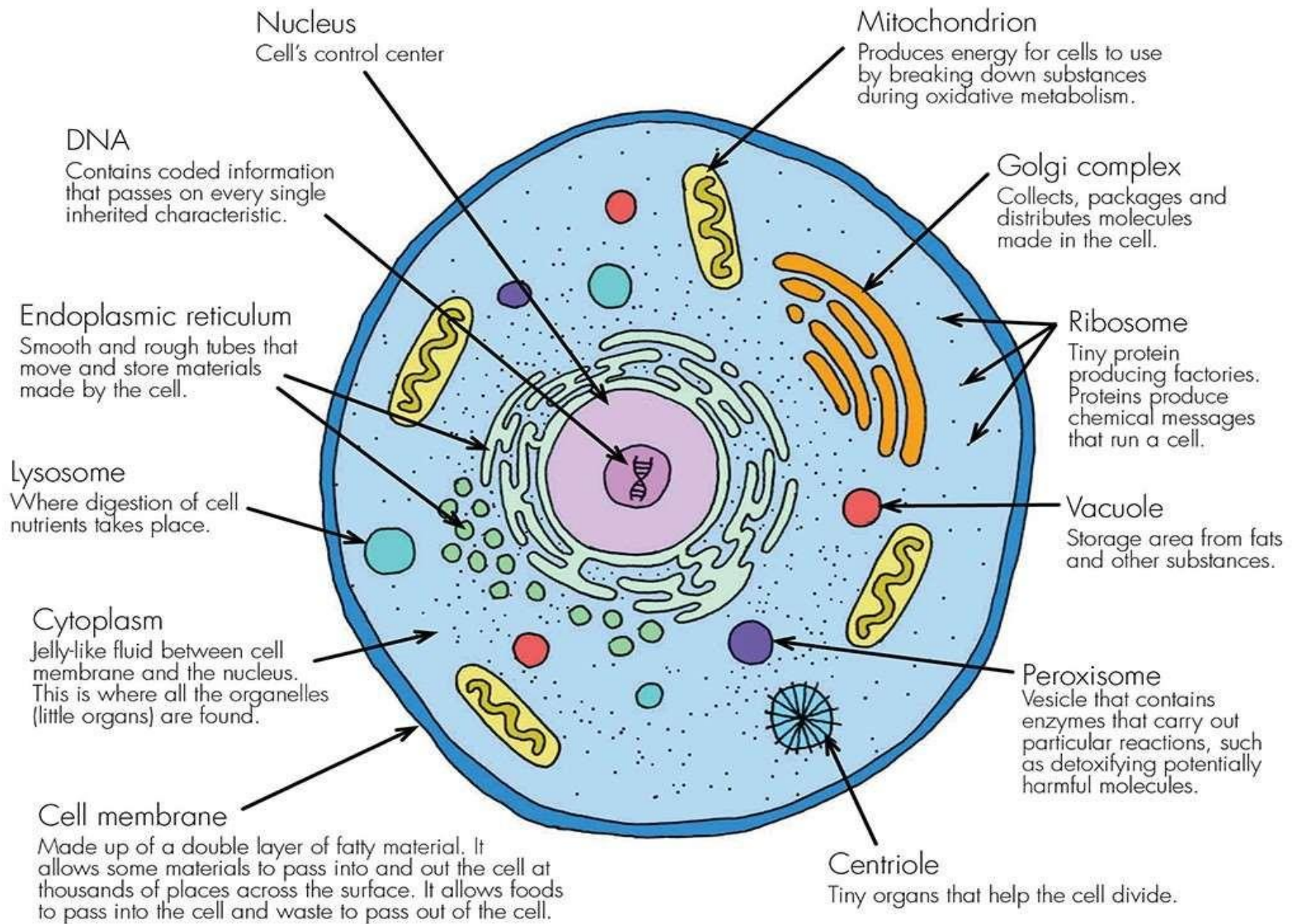
Cell membrane

Mitochondria

Cell wall

Chloroplasts

Vacuole



## Cell wall

- Outermost layer, non living ,rigid
- Found in bacterial cells, fungal cells and plant cells.
- Permeable
- Made up of cellulose (in bacteria- peptidoglycans,
- in fungus- Chitin)
- FUNCTION :
- Rigidity, mechanical support and protection



## Cell membrane

- Present in all cells, just below the cell wall in plant cells,
- outermost membrane in animal cells
- Semi-permeable
- Made up of phospholipids, proteins, carbohydrates and
- Cholesterol
- FUNCTION : It allows outward and inward movement
- of molecules across it like diffusion, osmosis,
- active transport, phagocytosis and pinocytosis



Links adjacent cells together by junctional complexes to form tissues.

**Insulating Properties**:- It acts as **dielectric material** of a charged condenser, thus cell membrane have very high insulating value



## CYTOPLASM

- Semi fluid matrix present between cell membrane and nuclear membrane
- It has various living cell inclusions called cell organelles and non living substances called Ergastic substances

## Cytosol

- **The cytosol**, the aqueous part of the cytoplasm outside all of the organelles, also contains its own distinctive proteins.
- It accounts for almost 70% of the total cell volume.
- **Gelatinous substance** consisting mainly of cytoskeleton filaments, organic molecules, salt and water.





# CYTOSKELETON

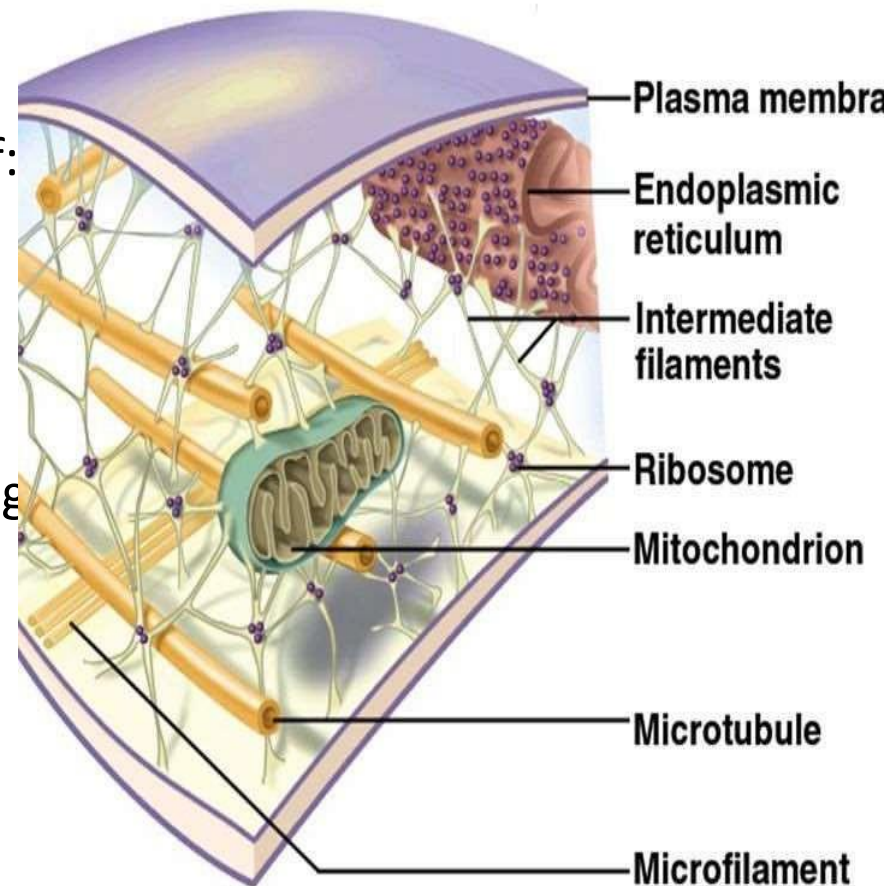
- System of fibers that not only maintains the structure of the cell but also permit it to change shape and move.

- The cytoskeleton is made up primarily of:

ii) Intermediate Filaments

iii) Microfilaments

along with protein that anchor tie them together





- **Microtubules**- These are long hollow structures approx. 25nm in diameter. Determine shape of the cell, role in the contraction of the spindle and movement of chromosomes and centrioles as well as in ciliary and flagellar motion.
- **Intermediate Filaments**- They are 8-14nm in diameter and are made up of various subunits. They form a flexible scaffolding or cell and help it resist external pressure.

In their absence cell ruptures more easily and when they are abnormal in human, blistering is common.

- The proteins that make up intermediate filament are cell type specific and are thus frequently used as cellular markers.
- **Microfilaments**- They are long solid fibers 4-6 nm in diameter. They comprise the contractile protein actin and are responsible for the cell motion.

## Function

- They are involved in the
  - Movement of the chromosomes
  - Cell movement
  - Processes that move secretion granules in the cell
  - Movement of proteins within the cell membrane



# Nucleus

## STRUCTURE

- Largest cell organelle present in eukaryotic cells
- It is usually spherical
- It has double layer nuclear membrane with nuclear pores
- It has transparent granular matrix called nucleoplasm,
- chromatin network composed of DNA and histone proteins
- It also has a spherical body called Nucleolus



FUNCTION: It is the control centre of the cell

It contains genetic material DNA which regulates all metabolic activities of the body



# MITOCHONDRIA

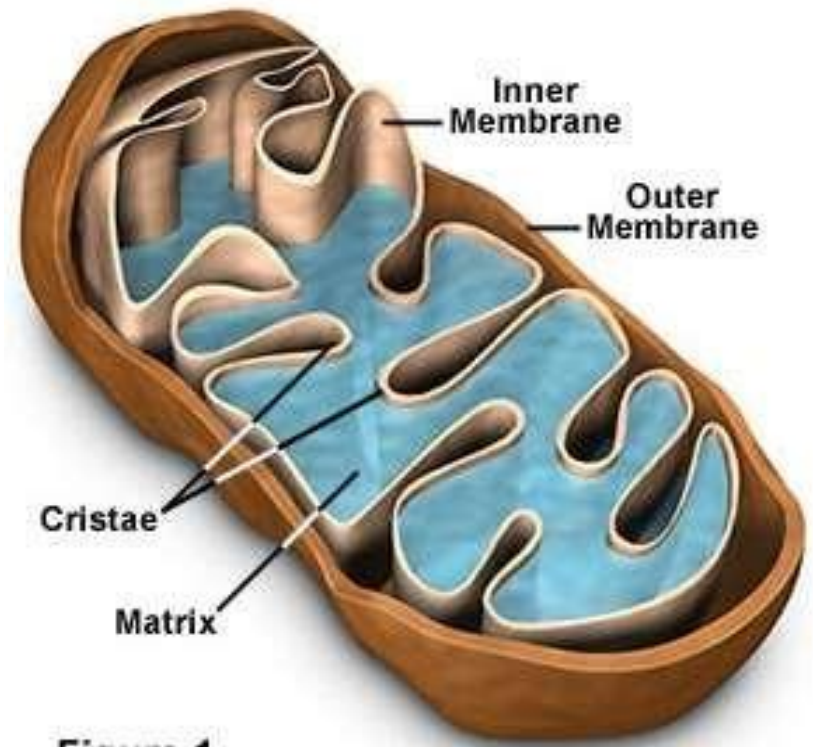
- The mitochondria were first observed by **Kolliker** in **1850** as granular structures in the striated muscles.
- Mitochondria are called **the 'powerhouse of the cell'**.

## STRUCTURE-

- **Length-** 5-12 $\mu\text{m}$

**Diameter-** 0.5-1 $\mu\text{m}$

- Filamentous or globular in shape.



- Components of Mitochondria are

**Outer Membrane, Inner Membrane**

**Intermediate Space-** space between outer and inner membranes

**Cristae** - In foldings of inner membrane

**Matrix-** The space enclosed by inner membrane

The membranes are made up of phospholipids and proteins



## Outermost Membrane-

a) It contains large numbers of integral membrane proteins called **Porins**.

These porins form channels that allow molecules of 5000 daltons or less to pass.

b) Studded with enzymes concerned with biological oxidation .



**Interior (Matrix)** of the Mitochondria contains enzymes concerned with '*citric acid cycle*' and '*respiratory chain*

Major metabolic pathways involved in oxidation of carbohydrates, lipids and amino acids and part of special biosynthetic pathways involving urea and heme synthesis are located in inner matrix.





## Inner Membrane

- It contains ATPase and other enzymes concerned with synthesis and metabolism of ATP.
- Contains enzymes of Electron Transport Chain.

The ultimate purpose of these mechanisms is *oxidative phosphorylation* and *synthesis of ATP*.

Mitochondria has some protein synthesised by Mitochondrial DNA.



## Functions

Power generating units of the cells.

Important to maintain proper concentration of calcium ions within the various compartments of the cell.

Energy transduction through respiration.

Responsible for thermogenesis.



# Endoplasmic Reticulum

Network of **tubular and flat vesicular structures** in the cytoplasm. An extensive network of closed, flattened membrane-bounded sacs called **cisternae** .

Space inside the tubules is filled with Endoplasmic Matrix.



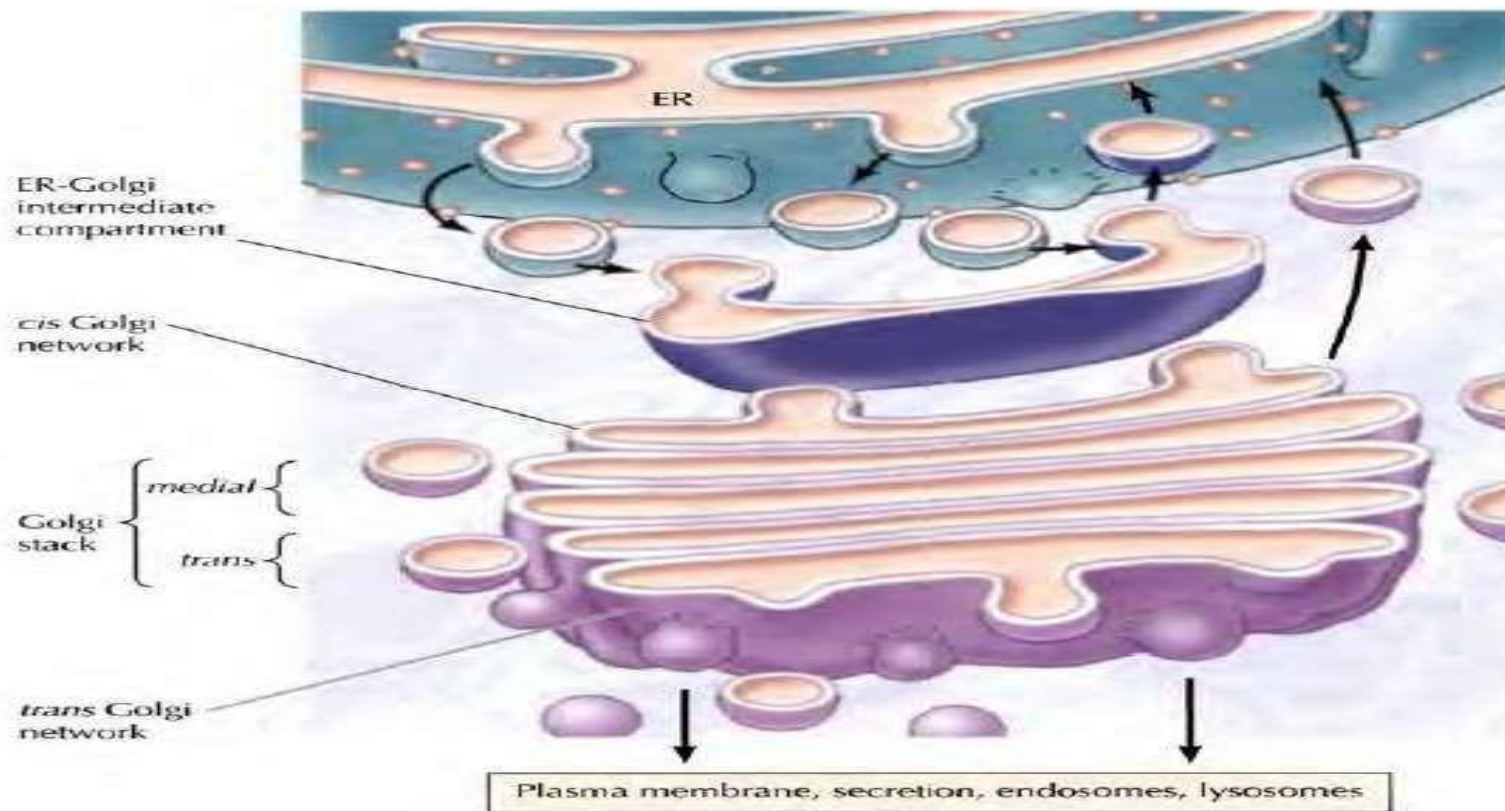
## ○ TWO TYPES-

Smooth Endoplasmic Reticulum	Rough Endoplasmic Reticulum
<ul style="list-style-type: none"><li>▪ Ribosomes absent</li><li>▪ Site of synthesis of lipid and steroid hormones.</li><li>▪ Mainly present in lipid forming cells such as adipocytes, interstitial cells of testis, glycogen storing cells of liver, adrenal cortex cells, muscle cells, leucocytes etc.</li></ul>	<ul style="list-style-type: none"><li>▪ Contains ribosomes</li><li>▪ Site of protein synthesis, processing and packaging.</li><li>▪ Mainly present in protein forming cells such as pancreatic acinar cells, Goblet cells, antibody producing plasma cells, Nissl's granules of nerve cells etc.</li></ul>

## Golgi Bodies

- Golgi Bodies is a collection of membrane enclosed sacs composed of four or more stacked layers of thin, flat enclosed vessels lying near the side of the nucleus.
- Consist of multiple discrete compartments.
- Consist of four functionally distinct regions:





## The cis Golgi network

- i) Golgi stack –which is divided into
  - a) The medial and
  - b) Trans sub compartments
- iii) The trans Golgi network.

## Function

Wrapping and Packaging department of the cell.

- Produces secretion granules i.e. membrane enclosed complexes, which store hormones and enzymes in the protein secreting cells, it packages proteins.



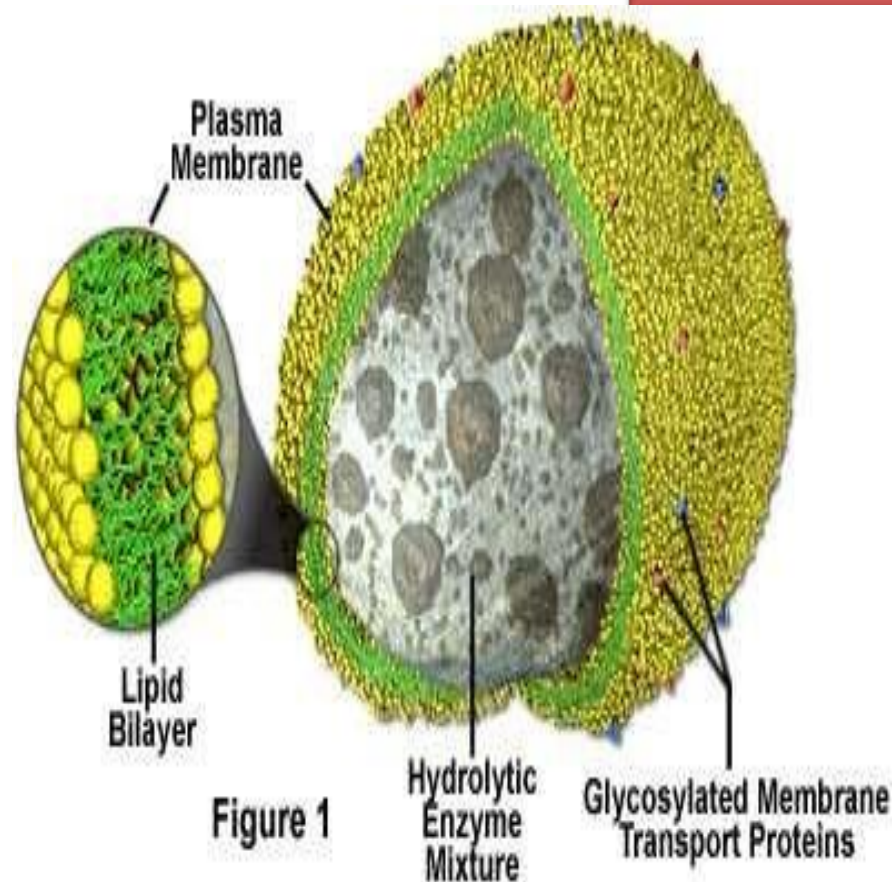
- Site of formation of lysosomes i.e. large irregular structures surrounded by membrane which are present in the cytoplasm.
- It adds certain carbohydrates to form glycoproteins, which play an important role in the association of the cells to form tissues





## Lysosomes

These are the irregular  
Structures surrounded by the  
Unit membrane  
More acidic than rest of the  
Cytoplasm and external  
bacteria as well as worn out  
Cell components are digested  
in them



- The interior is kept acidic(near pH 5.0) by the action of proton pump
- Lysosomes are cell hydrolases and they function best at the acidic pH.

## Functions

Acts as a form of digestive (lytic ) system or the cell, because enzymes present in it can digest essentially all macromolecules.

Engulf worn out components of the cells in which they are located.

When a cell dies, lysosomal enzymes causes autolysis of the remanant . Thats why lysosomes are called as ***Suicidal Bags***.



## Peroxisomes

A lipid bilayer membrane surrounds which regulates what enters or exits the peroxisomes.

Urate oxidase crystalline core.

Structure is similar to that of the lysosomes but with a different composition.

Peroxisomes can be formed by the budding of ER, or by division.

Contains oxidases that produces  $H_2O_2$ .



Catalases degrades hydrogen peroxide to yield water and oxygen

Proteins are directed to the Peroxisomes by a unique signal sequence with the help of protein chaperones, **Peroxisins**.

## Function

H<sub>2</sub>O<sub>2</sub> metabolism and detoxification

Helps in Photorespiration in plants

Biosynthesis of lipids

Cholesterol and dolichol are synthesized in animals

Synthesis of bile acids in liver

Synthesis of plasmalogens (myelin sheath)



# SUMMARY

## COMPARTMENTS

- Plasma Membrane
- Cytosol
- Mitochondria
- Endoplasmic Reticulum
- Golgi apparatus
- Lysosomes
- Peroxisomes
- Cytoskeleton
- Nucleus

## MAJOR FUNCTIONS

- Transport of ions and molecules
- Metab. of carbohydrate, lipids and amino acids
- Energy production
- Synthesis of proteins and lipids
- Modification and sorting of proteins
- Cellular digestion
- Utilization of  $H_2O_2$
- Cell Morphology and cell motility
- DNA synthesis and Repair

## Cell Junctions

- Intercellular space in closely packed tissue is about 20nm. The cells are bound together by the specific adhesive glycoprotein.
- Modified cell membranes contributing in cohesion and communication are called *Cell junctions*.



## Types of cell junctions

There are three types of Cell Junctions

1. Occluding Junctions
2. Adhering Junctions
3. Communicating Junctions

### Occluding Junctions

Found in epithelial tissues

Also known as ***“Tight Junctions”***



- Do not allow passage of small molecules form impermeable membrane.

## Types

Zonula Occludens

Fascia Occludens

## Zonula occludens

- Encircles the entire cell perimeter
- Occludes the intercellular space



## Series of focal fusions

The adjacent cell membranes approach each other, outer leaflets fuse, diverge again then fuse again.

At fusions sites specific trans membranous proteins named **Occludins and Claudins** perform the binding function.

Occludins and claudins come out of cell membrane and interact with each other and seal the surface of two adjacent cells.



- These two proteins are attached to three proteins called ZO1, ZO2, ZO3.
- These three proteins help in holding occludens and claudins properly in their positions.
- This type of junction is present at apical region.

## Location

Blood–Brain Barrier, Intestines, Nephrons  
Skin.



Cell membrane

Cell membrane

Integral  
membrane  
protein



ZONULA OCCLUDENS

## Fascia occludens

- A strip like tight junction of limited extent.
- Found between the endothelial cells of the blood vessels.

## Adhering Junctions

- Anchoring junctions
- Provide cell-cell or cell to basal lamina adherence



## Types

*Zonula adherence*

*Fascia adherence*

*Macula adherence (Desmosomes)*

*Hemidesmosomes*

*Zonula adherence*

This is like a sticky belt present around the cell.

E. cadherins are the proteins helping in sticking the cells together in the presence of calcium.

E-cadherin links to adherent proteins in cytoplasm which are Catenin, Vinculin.



## Fascia adherence

Structurally it is similar to Zonula adherence

But its cell junction is strip-like and (not ring-like or belt-like) i.e. Cardiac muscle cells.

## Macula adherence (Desmosomes)

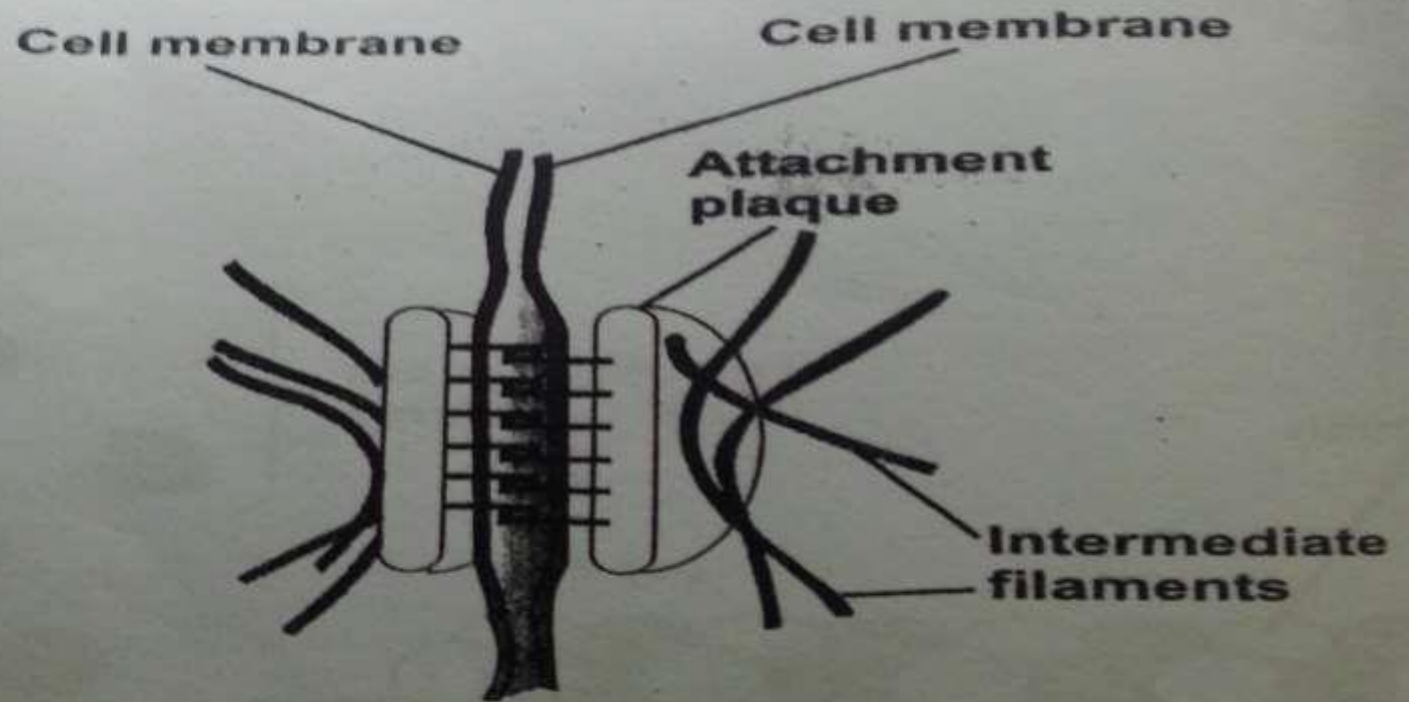
Macula means a spot like.

This is also helpful for sticking the cells together but in only some places.

These are not as strong as zona adherens.



# ZONULA OCCLUDENS



DESMOSOME

The proteins which are helpful for adhering here are Desmocollins and Desmogleins.

Inside the cell, there is a special disc present which is made up of desmoplachins and plakoglobins.

The cytoskeletal filaments attatched to this disc are intermediate fillaments and tonofillaments( keratin).

Present in simple epithelium, Stratified epithelium and also in cardiac muscle cells.





## Hemidesmosomes

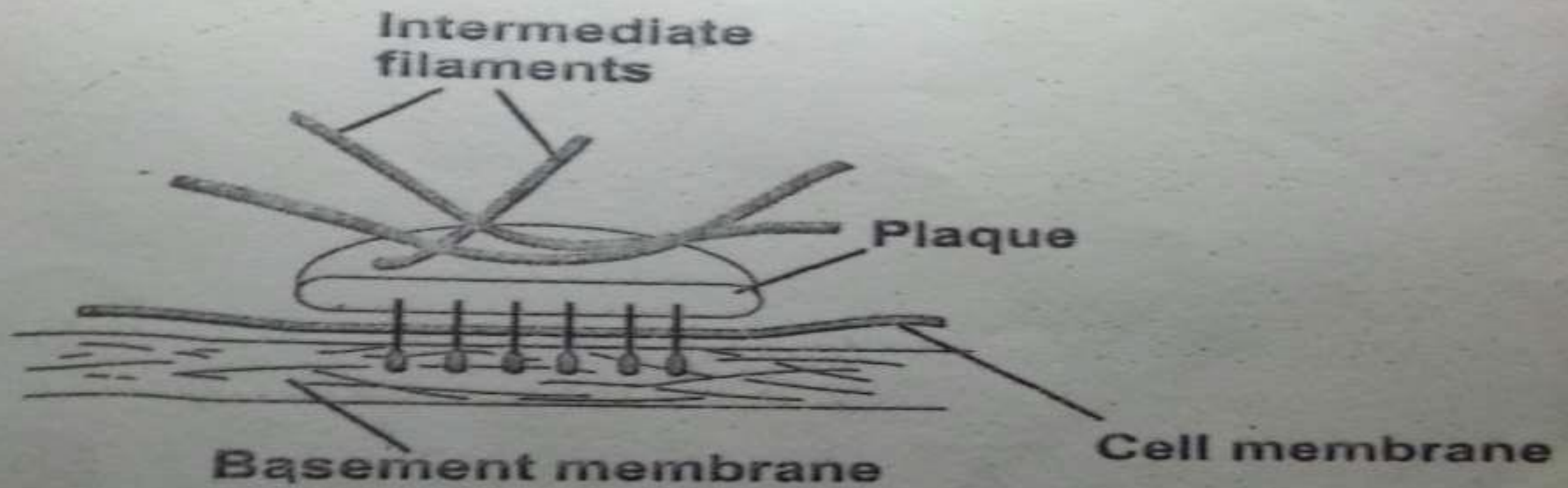
These junctions serve to anchor the epithelial cells to the basal lamina.

A hemidesmosome is a spot like adhering junction which gives appearance of a half desmosome.

In hemidesmosome transmembrane linker proteins are integrins.

The cytoplasmic intermediate filaments of keratin are inserted in to the attachment plaque.





**HEMIDESMOSOME**

# Communicating Junctions ( Gap Junctions)

- These are the window like structures present on the lateral surface of each epithelial cells for the sake of communication between the cells.
- It is made up of 6 types of proteins made up of connexins, so these 6 connexins combine to form a protein channel called connexon.



- Characterized by presence of minute tubular passage ways
- Provide direct cell to cell communication
- Tubular passages allow movement of ions and other small molecules between adjacent cells
- These can be opened or closed when necessary
- In cardiac and smooth muscles the gap junction provides electrical coupling of the adjacent cells
- Gap junctions are frequently found in embryonic cells



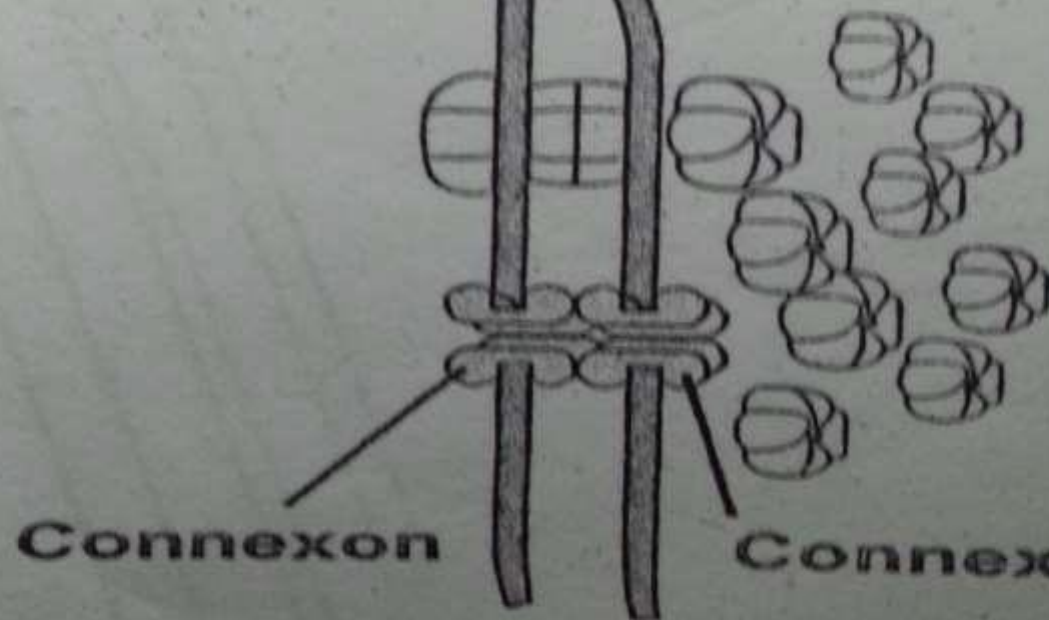
Cell membrane

Cell membrane

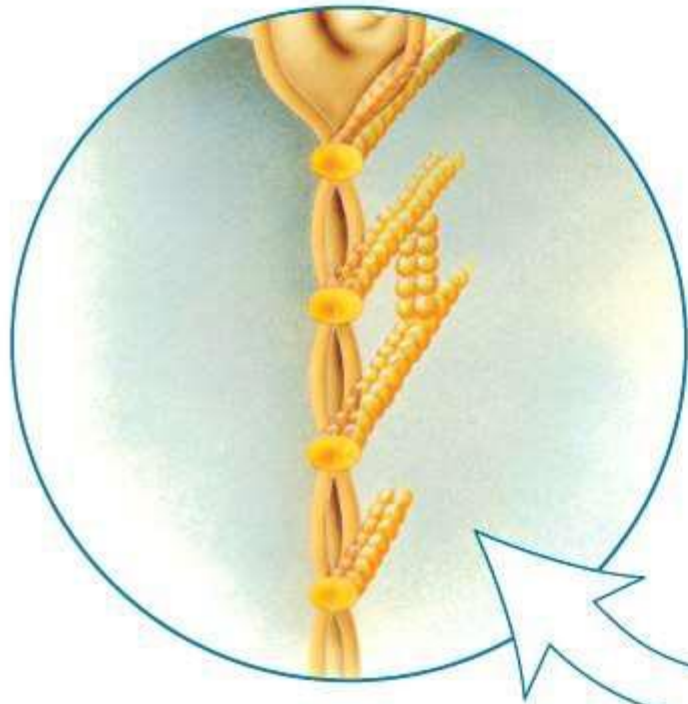
Connexon

Connexon

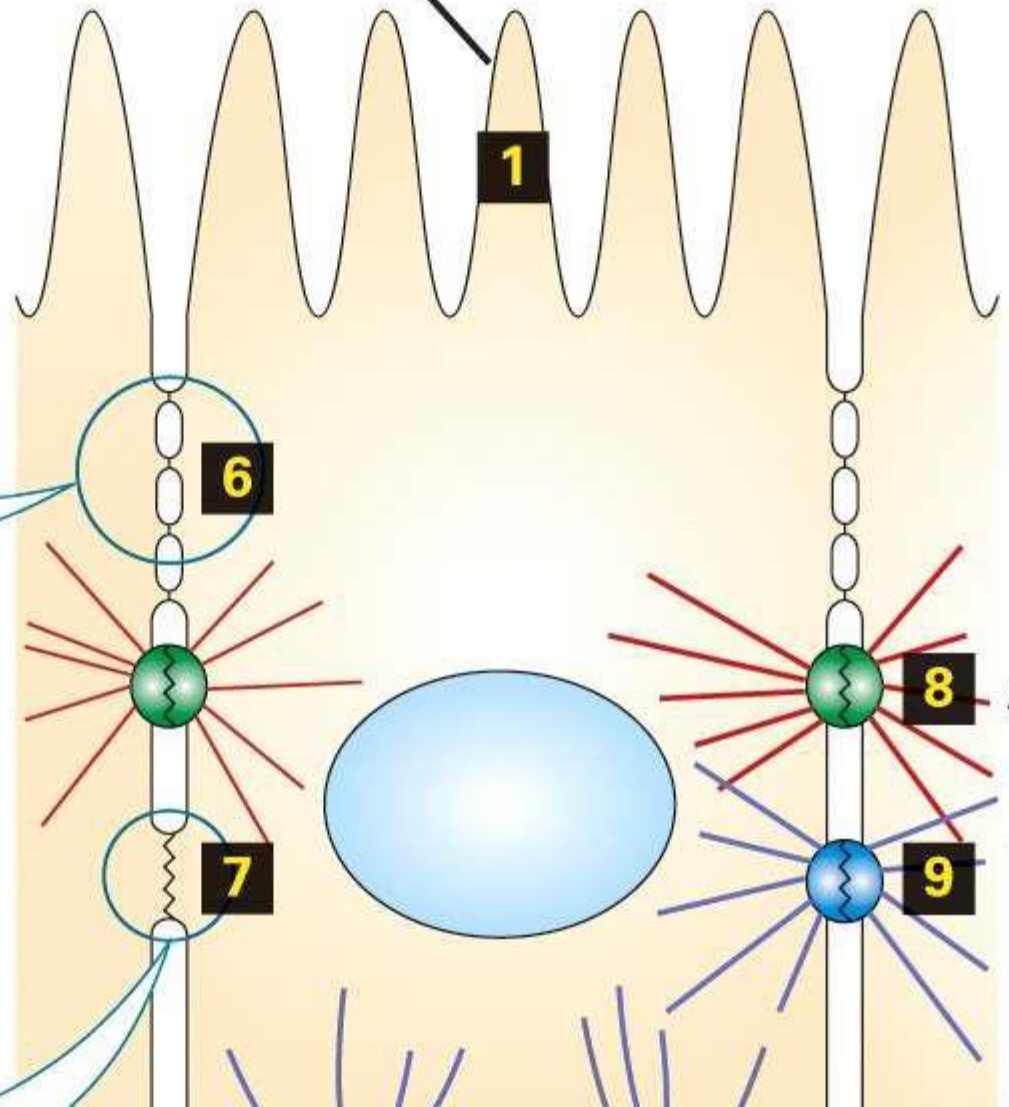
GAP JUNCTION



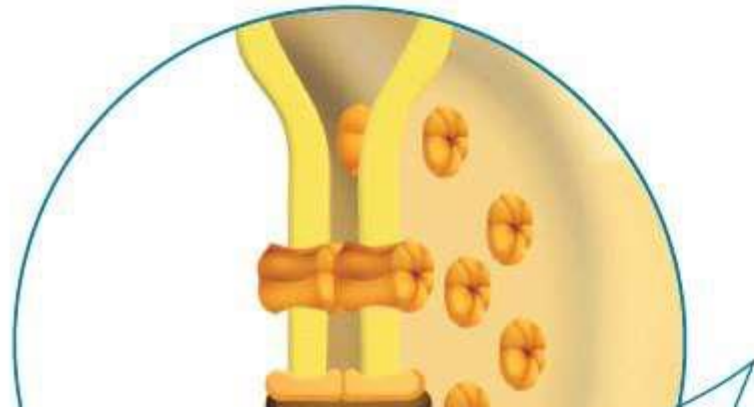
## Tight junction



Apical surface



## Gap junction





## Transport mechanisms

- Transport of substances across the cell membrane is necessary to maintain the normal functioning of the cells in our body.
- Lipid soluble substances, water & urea can easily pass through the lipid bilayer of the cell membrane.
- The lipid bilayer of the cell membrane is impermeable to lipid insoluble substances such as ions & charged or polar molecules like glucose



- These substances pass through specialized protein channels, carrier proteins & active pump mechanisms.
- Large macromolecules are transported through vesicles.





# Types

- Passive transport
  - Diffusion – simple, facilitated
  - Osmosis
- Active transport
  - Primary
  - Secondary
- Vesicular transport
  - Endocytosis
  - Exocytosis
  - Transcytosis



## Diffusion-simple

- It is the movement of ions or molecules from a region of their high concentration to a region of their low concentration, without the expenditure of energy
- Movement is towards the concentration gradient until an equilibrium is achieved.

## Diffusion through lipid matrix

- Lipophilic/hydrophobic/nonpolar/uncharged substances such as O<sub>2</sub>, CO<sub>2</sub>, N<sub>2</sub>, fatty acids, alcohol, steroid hormones, etc.



- Water as it is a small molecule with high kinetic energy
- Urea

### Ionic diffusion – through channel proteins

- Ions diffuse through the ion channels gated channels open when stimulus is given
  - Voltage gated
  - Ligand gated
  - Mechano sensitive gated



**They are either open or gated**  
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**Open/leak channels – ex: K<sup>+</sup> channels**

## Facilitated diffusion

- Facilitated diffusion is the movement of specific
- molecules (or ions) across the plasma membrane
- assisted by a carrier protein
- The direction of movement is down the concentration gradient of the molecules concerned
- No energy required



## Difference between carrier proteins & channel proteins

- **Carrier proteins bind to larger molecules, and** change their shape so molecules can diffuse through.
- **Channel proteins provide water filled pores** for charged ions to pass through

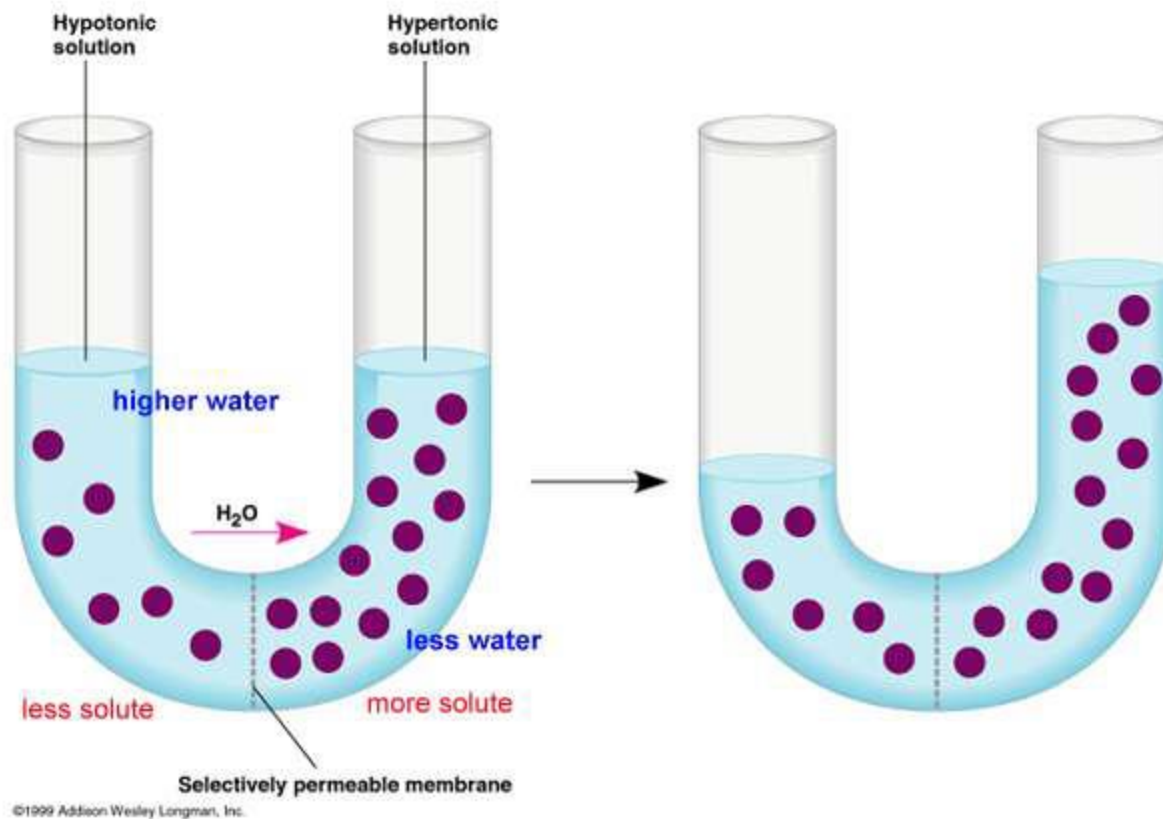


## Osmosis

Osmosis is the movement of water molecules (solvent) through a selectively permeable membrane/semi permeable membrane.

Water diffuses across a membrane from an area of high concentration to an area of low concentration, Semi-permeable membrane is permeable to water, but not to the solute i.e. sugar.





## Active Transport

- Molecules move **against the** concentration gradient (low to high)
- Energy must be provided
- Exhibit saturation kinetics

Active transport is divided into two types according to the source of the energy used to cause the transport:

1. Primary active transport
2. Secondary active transport





## Primary active transport

- They use the energy directly from the hydrolysis of ATP
- Sodium potassium Pump
- Calcium pump
- Hydrogen Potassium pump

## Secondary active transport

- Energy utilised in the transport of one substance helps in the movement of the other substance.



- Energy is derived secondarily, from energy that has been stored in the form of ionic concentration differences of secondary molecular or ionic substances between the two sides of a cell membrane, created originally by primary active transport.



## Vesicular transport

Endocytosis, Exocytosis, Transcytosis

### Endocytosis/Exocytosis

- For substances the cell needs to take in (endo = in) or expel (exo = out), that are too large for passive or active transport.

### Endocytosis

- The material makes contact with the cell membrane then invaginates, Invagination is then pinched off leaving the cell membrane intact.



## Types of Endocytosis

1. Receptor mediated endocytosis
2. Phagocytosis (solids)
3. Pinocytosis (liquids)

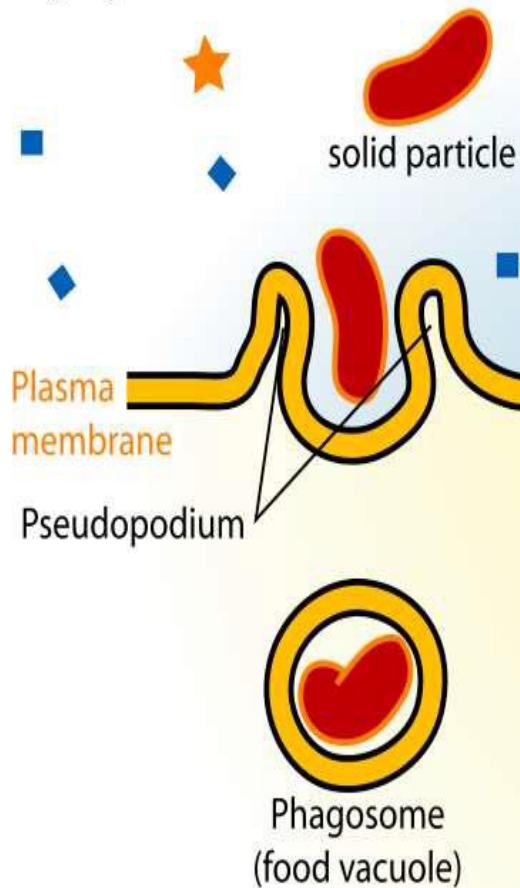
Ex: White Blood Cells surround and engulf bacteria by **Phagocytosis.**

- **Pinocytosis – amino acids, fatty acids**
- **Receptor mediated endocytosis – LDL, Nerve growth factor, vitamins, hormones, HIV virus entering the T cell etc.,**



# Endocytosis

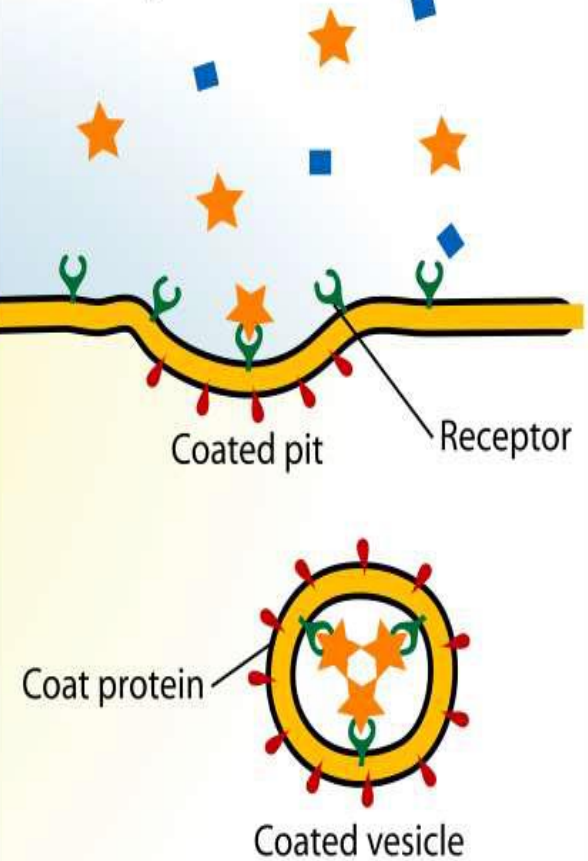
## Phagocytosis



## Pinocytosis



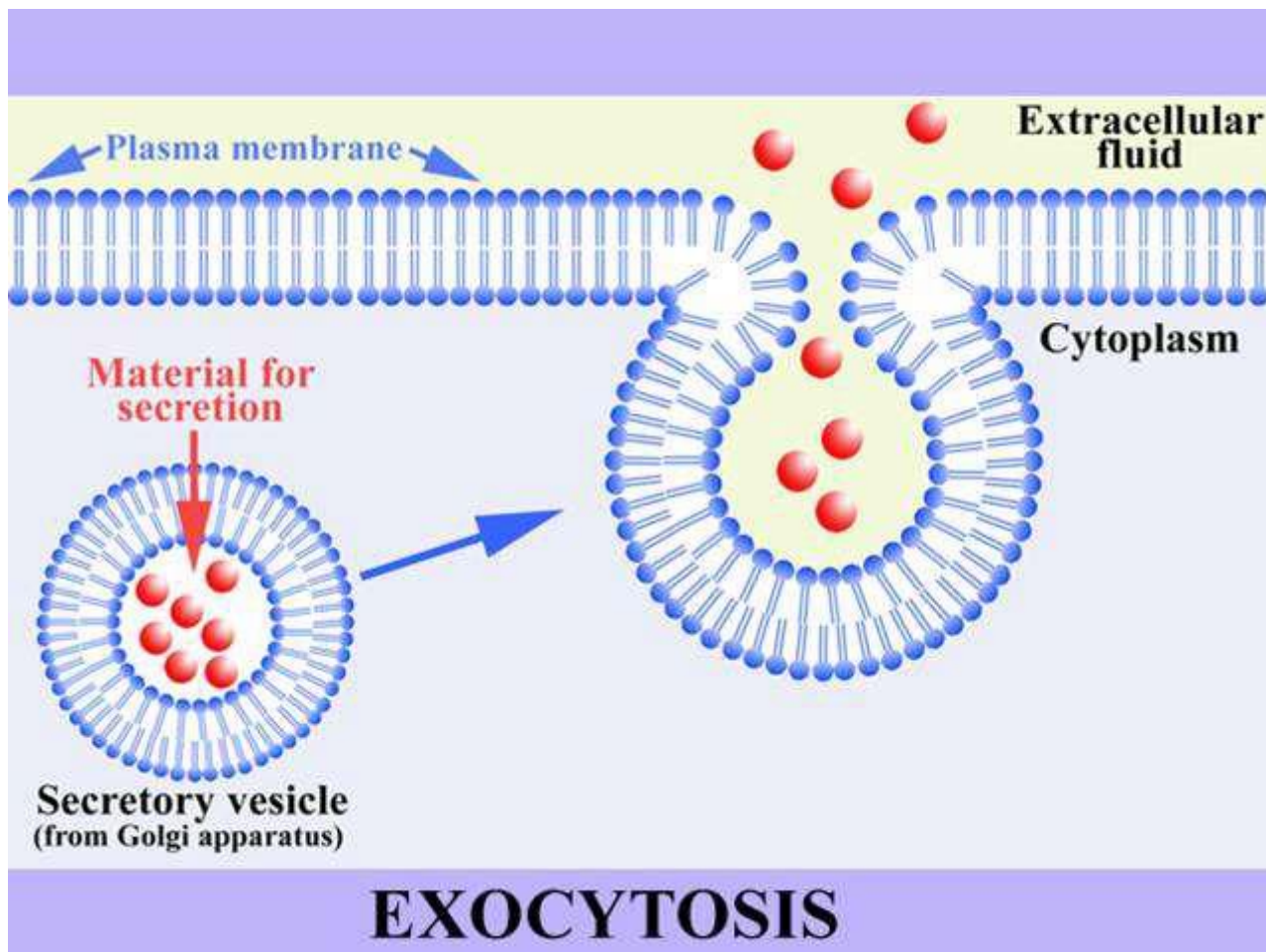
## Receptor-mediated endocytosis



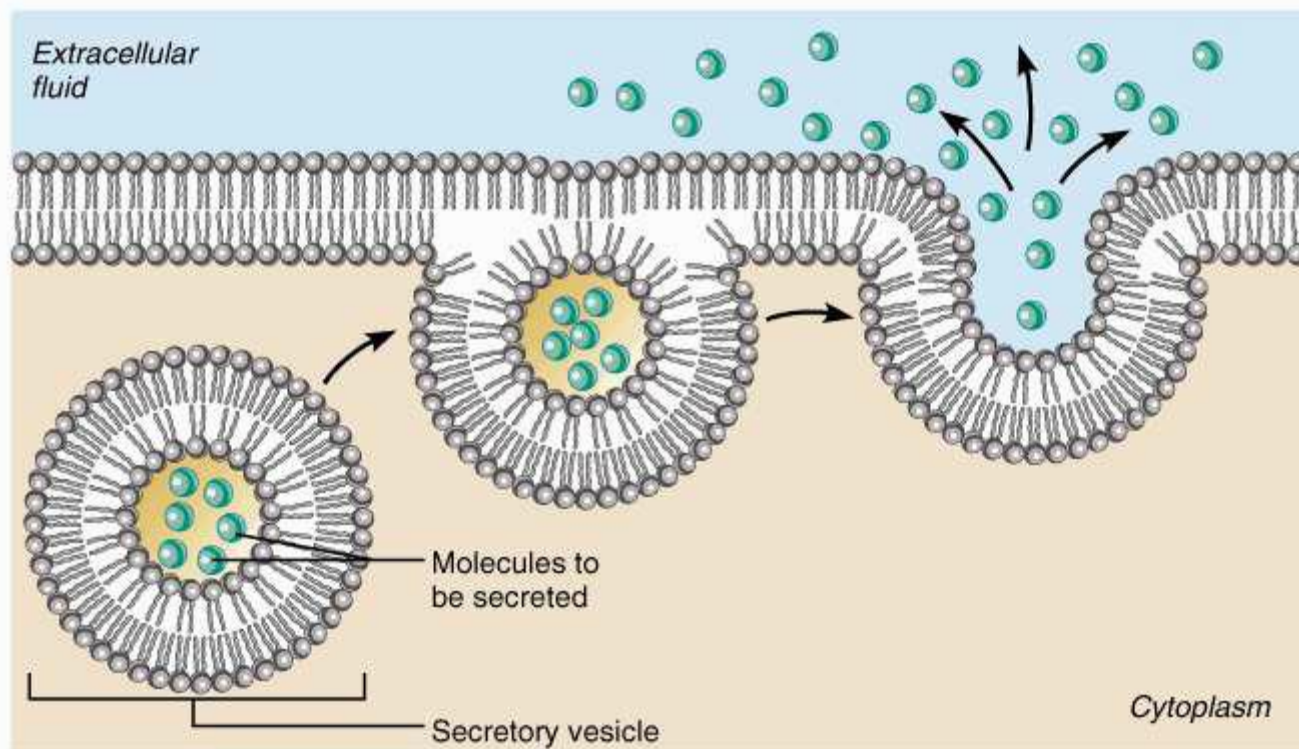
## Exocytosis

- The process of release of macromolecules from the cells to the exterior.
- Vesicles containing material to be exposed, bind to the cell membrane
- Area of fusion breaks down leaving the contents of the vesicle outside & the cell membrane intact
- Reverse pinocytosis or emeiocytosis
- Requires calcium & energy
- Secretory granules, hormones









(a)

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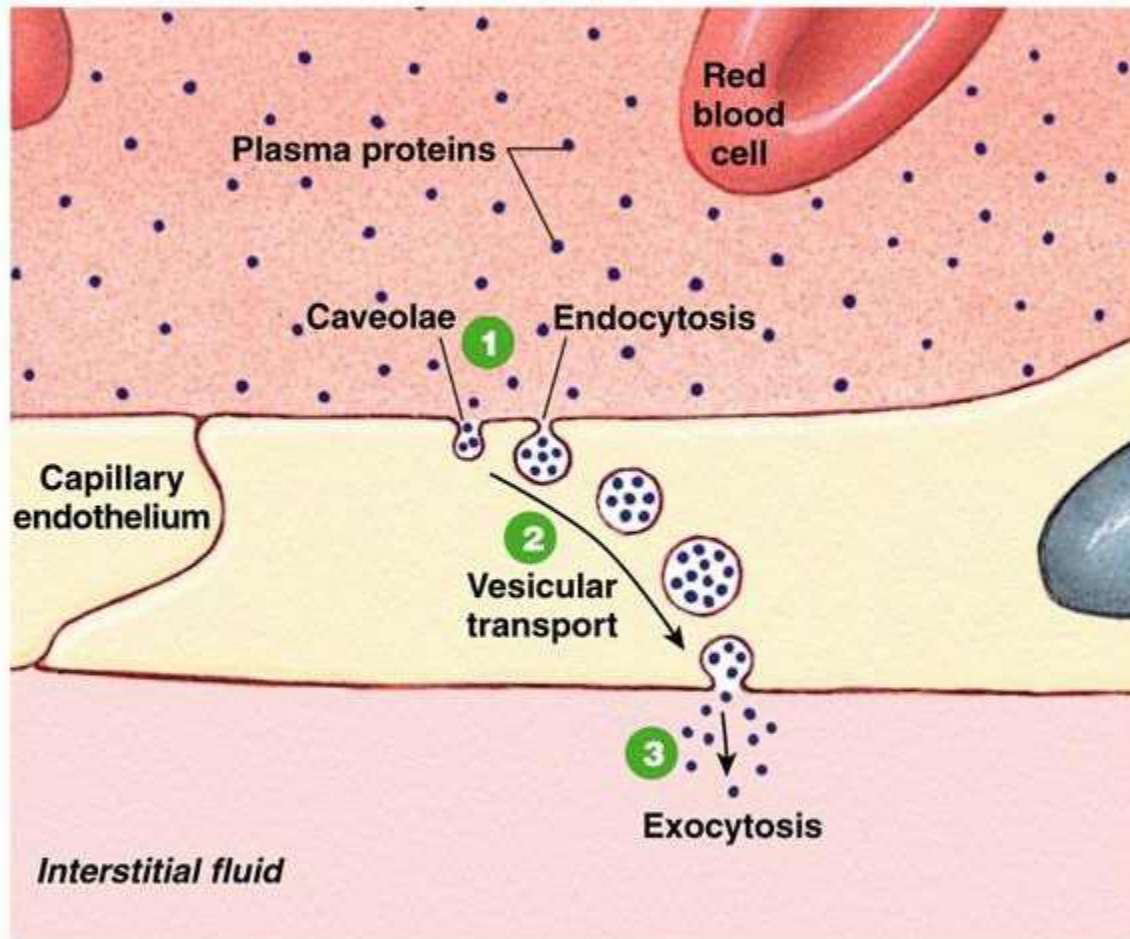


## Transcytosis

- Vesicles endocytosed on one side of the cell; exocytosed on the opposite side.
- Caveolin mediated (Rafts & Caveolae)
- Also known as cytopempsis
- Transport of substances across the endothelial cells of blood vessels to interstitial fluid



# Transcytosis across the Capillary Endothelium



**1** Plasma proteins are concentrated in caveolae, which then undergo endocytosis and form vesicles.

**2** Vesicles cross the cell with help from the cytoskeleton.

**3** Vesicle contents are released into interstitial fluid by exocytosis.

THANK YOU EVERY ONE



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