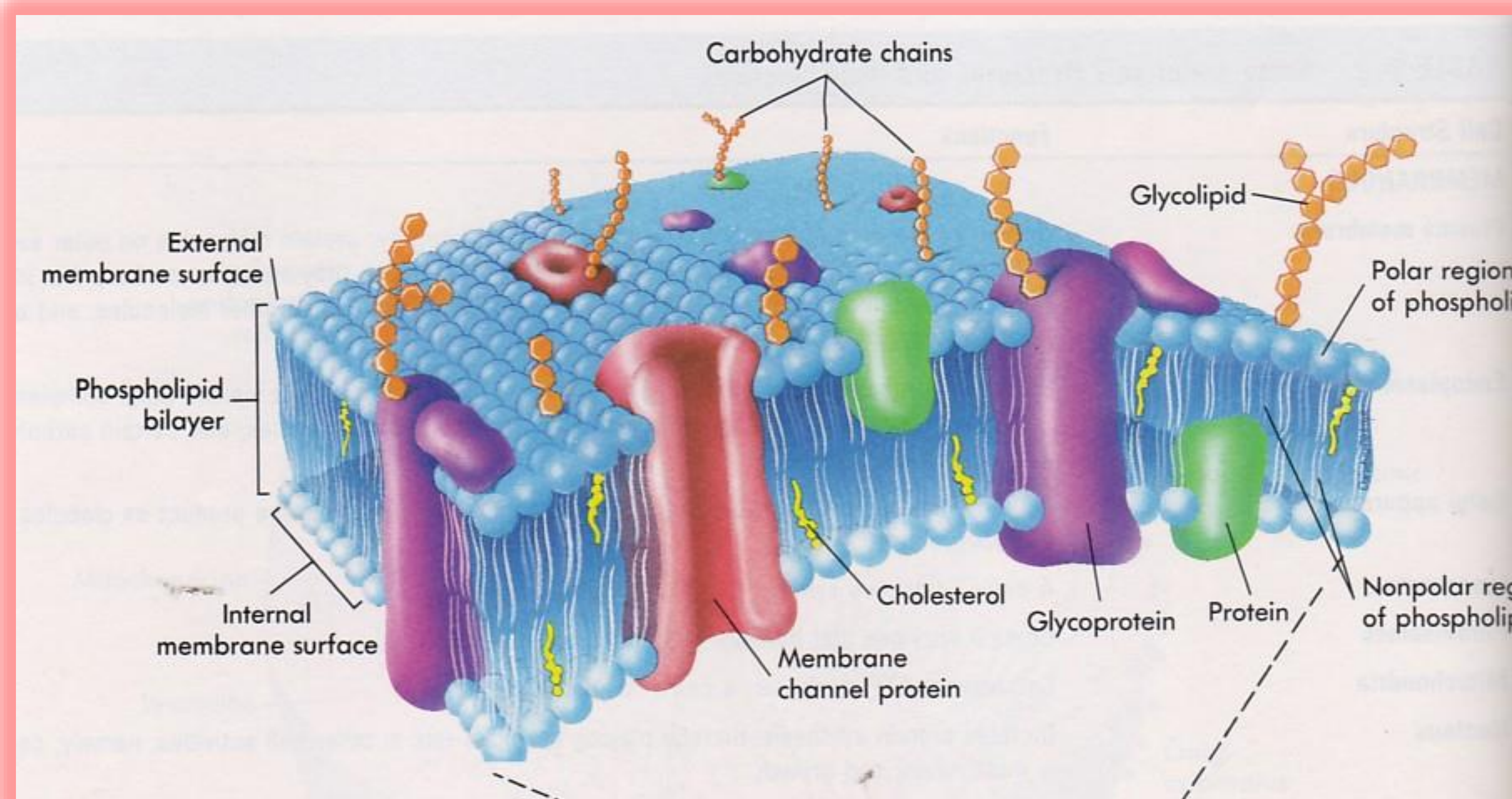
CELL MEMBRANE & CELLULAR MEMBRANE TRANSPORT



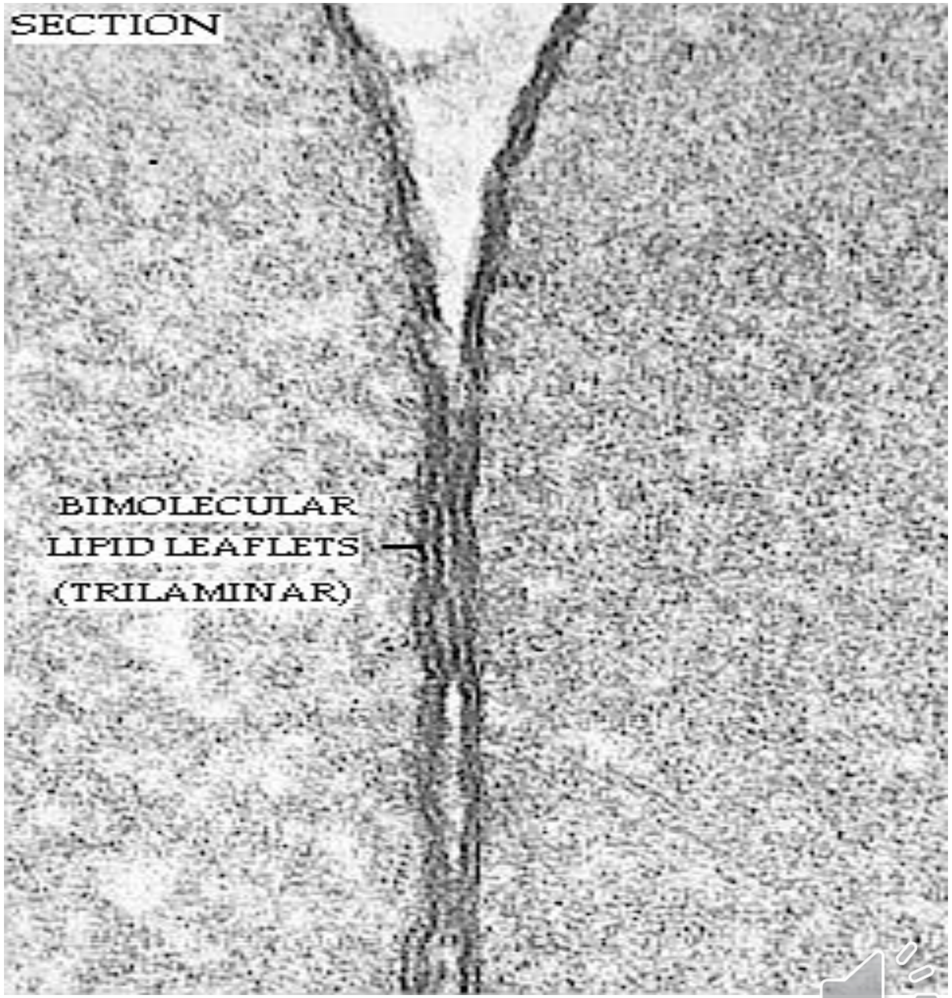
Learning Objectives:

- 1)Chemical composition of membrane-Lipids & its types
- 2)Proteins present in cell mem. & types
- 3)Nature of carbohydrates present
- 4)Fluid Mosaic Model-
- 5)Ion channels:Ionophores, water channels, gap junctions
- 6) Transport mech.:Passive T,Active T & diffusion
- 7)Mech. of transport of macromolecules including
- Exocytosis & Endocytosis(Phagocytosis ,Pinocytosis)

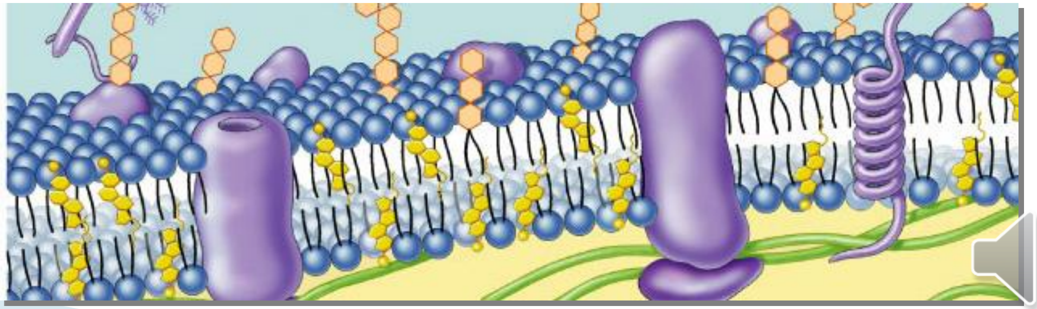
Cell membrane:

Gate way to the cell.
Cell membrane separates living cell from each other and surroundings
- thin barrier = 8nm thick

Controls traffic in & out of the cell
- selectively permeable allows some substances to cross more easily than others



- Cell membrane separates living cell from each other and surroundings
- Controls traffic in & out of the cell
  - selectively permeable
  - allows some substances to cross more easily than others
- Made of phospholipids, proteins & other macromolecules

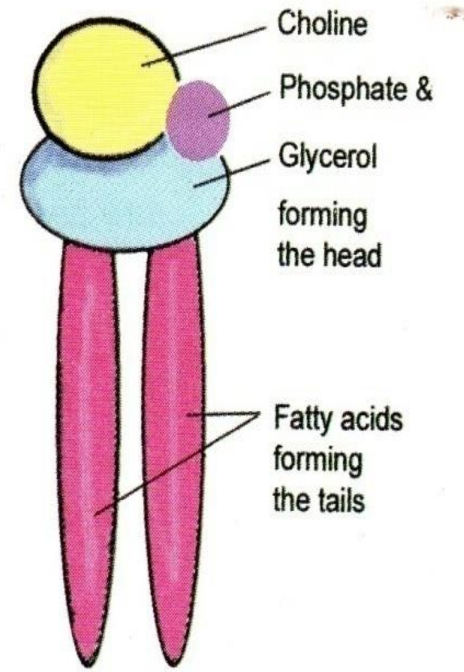


Function of the Cell Membrane

- Controls traffic into and out of the cell.
- Protective barrier
- It is selectively permeable to diff. ions & molecules
- Allow cell recognition
- Provide anchoring sites for filaments of cytoskeleton
- Provide a binding site for enzymes
- Interlocking surfaces bind cells together (junctions)
- Contains the cytoplasm (fluid in cell)

Major constituents of cell membrane are:

- lipids
- proteins
- carbohydrates



LIPIDS :

1. Fatty acids
2. Glycero phospholipids
3. Cholesterol
4. sphingolipids

Composition of cell membrane

Table 2.1: Composition of different membranes: Content of lipid, protein and carbohydrates as percentage of dry weight

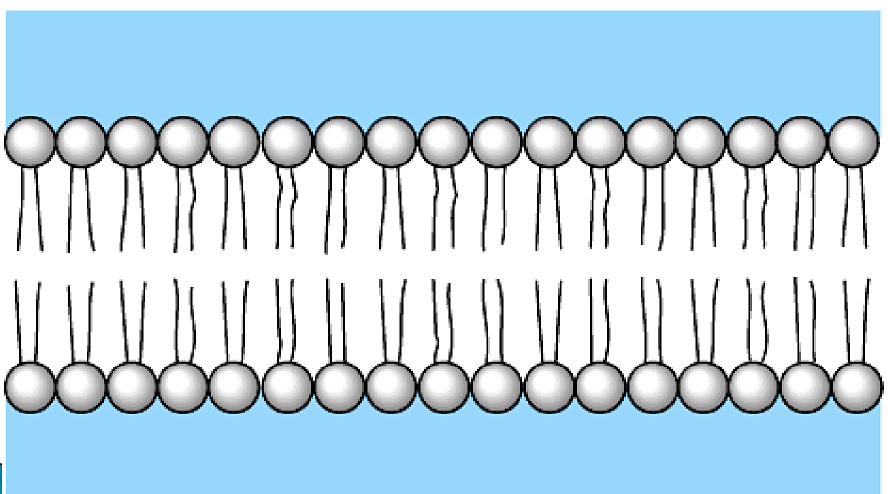
Type of membranes	Lipid	Protein	Carbohydrate
Plasma membrane (mammals)	43	49	8
Nuclear membrane	35	59	3
Outer mitochondrial membrane	48	52	Trace
Inner mitochondrial membrane	24	76	Trace
Endoplasmic reticulum	44	54	2
Myelin	75	22	3

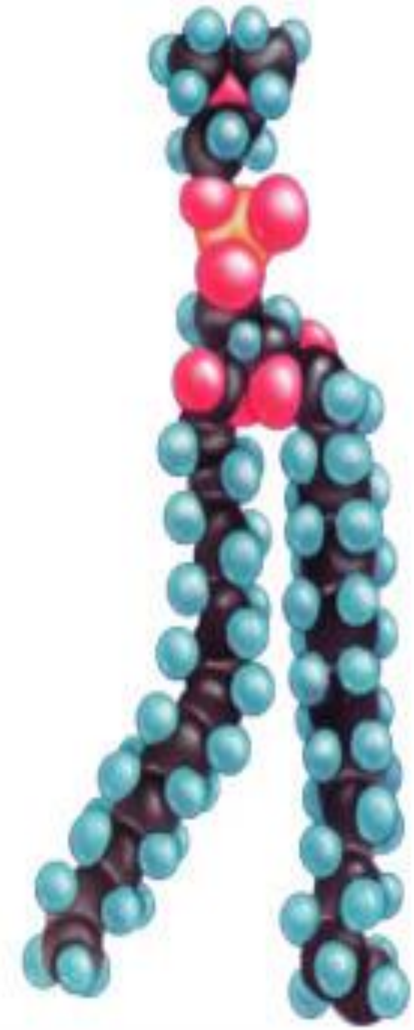
Membrane Lipids:

- The Fluid Part of the Model
- Membrane lipids are amphipathic.
- Phospholipids have a polar head containing a negatively charged phosphate group and two non polar (electrically neutral) fatty-acid chain tails.
- The polar end is **hydrophilic (“water loving**”) because it can interact with water molecules, which are also polar, the non polar end is **hydrophobic (“water fearing”)** and will not mix with water.

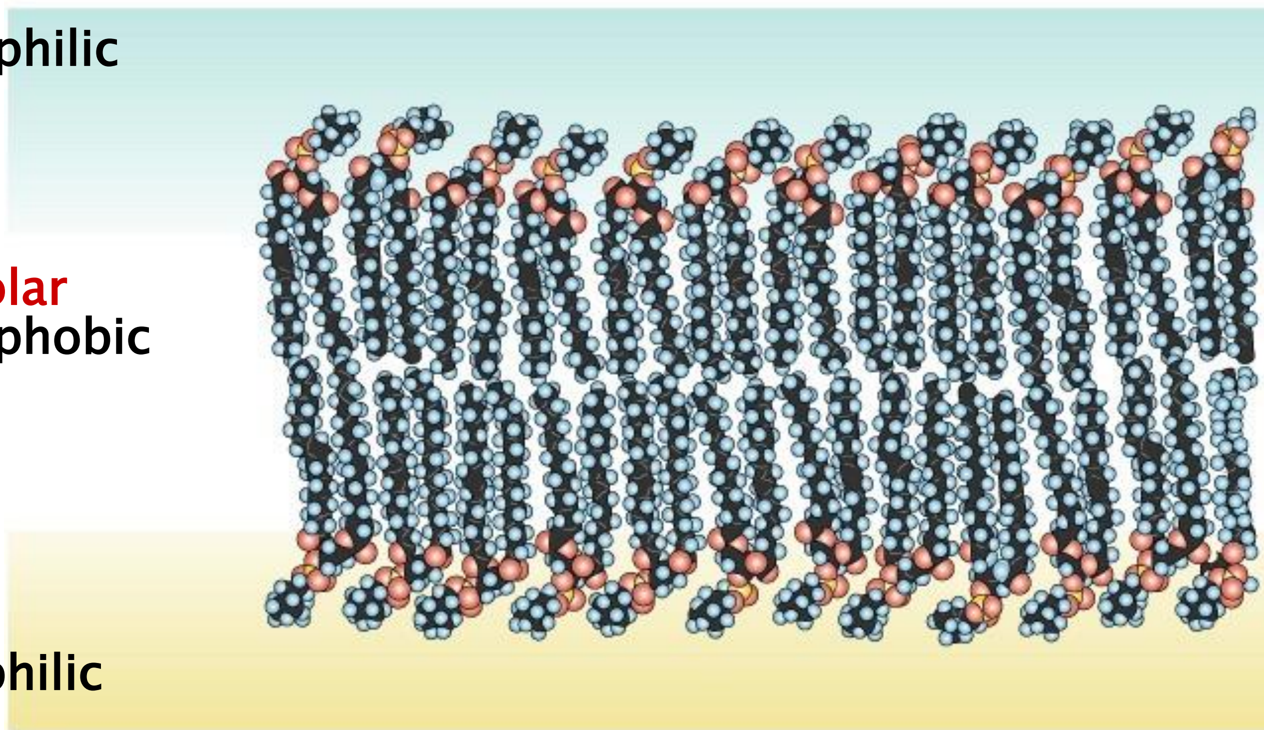
Phospholipids

- <u>Phosphate</u> group head
  - <u>Hydrophilic</u>
- <u>Fatty acid</u> tails
  - <u>hydrophobic</u>
- Arranged as a <u>bilayer</u>





Phospholipid bilayer



Types of Lipids in cell membrane:

- **1) Fatty acids**:
- 50% saturated with 16-18 carbon atoms, rest contains one or more double bonds
- Oleic acid is the most abundant F.A in animal cell mem.
- The degree of unsatuartion determines the fluidity of cell mem.
- **2)Glycerophospholipids:**
- **Cephalins,Lecithins & phosphatidyl serine**

Types of lipids in cell mem.

- **3)Sphingolipids:**
- Esp. in the nervous tissue
- Sphingomyelin, cerebrosides & gangliosides

- **4)Cholesterol:**
- Common in animal cell but not in plants
- It helps to regulate the fluidity of cell mem.

Types of lipids in cell mem.

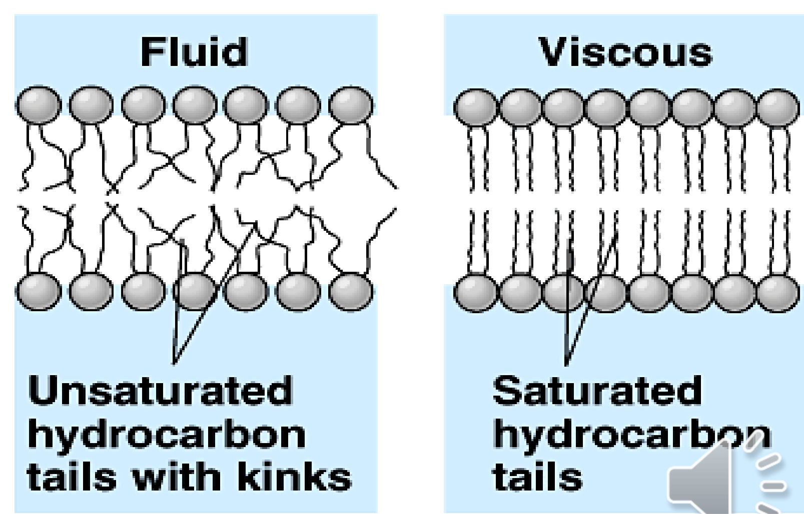
Table 2.2: Composition of different membranes:

Content of various lipids as percentage of total lipids

Type of membranes	Various types of lipids					
	Cholesterol	Lecithin	Cephalin	Phosphatidyl-serine	Sphingo-myelin	Glycolipid
• Plasma membrane (mammals)	20	19	12	7	12	10
• Nuclear membrane	3	45	20	3	2	0
• Outer mitochondrial membrane	8	45	20	2	4	0
• Inner mitochondrial membrane	0	35	25	0	3	0
• Endoplasmic reticulum	5	48	19	4	5	0
• Myelin	28	11	17	6	7	29

Membrane Lipids

- Membrane fluidity is influenced by **temperature** and by its **constituents.**
- As temperatures decreases, membranes switch from a fluid state to a solid state as the phospholipids are more closely packed.
- Membranes rich in **unsaturated fatty acids** are more fluid that those dominated by saturated fatty acids because the kinks in the unsaturated fatty acid tails prevent tight packing.



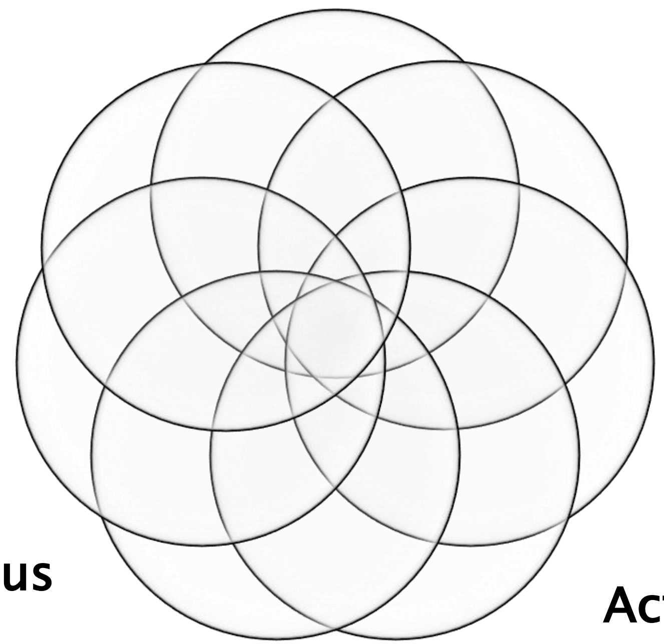
(b) Membrane fluidity

FUNCTIONS OF PLASMA MEMBRANE:

It maintains the shape of cell

Helps in exchange of gases

Helps in absorption of nutrients



Helps in adhesion between cells

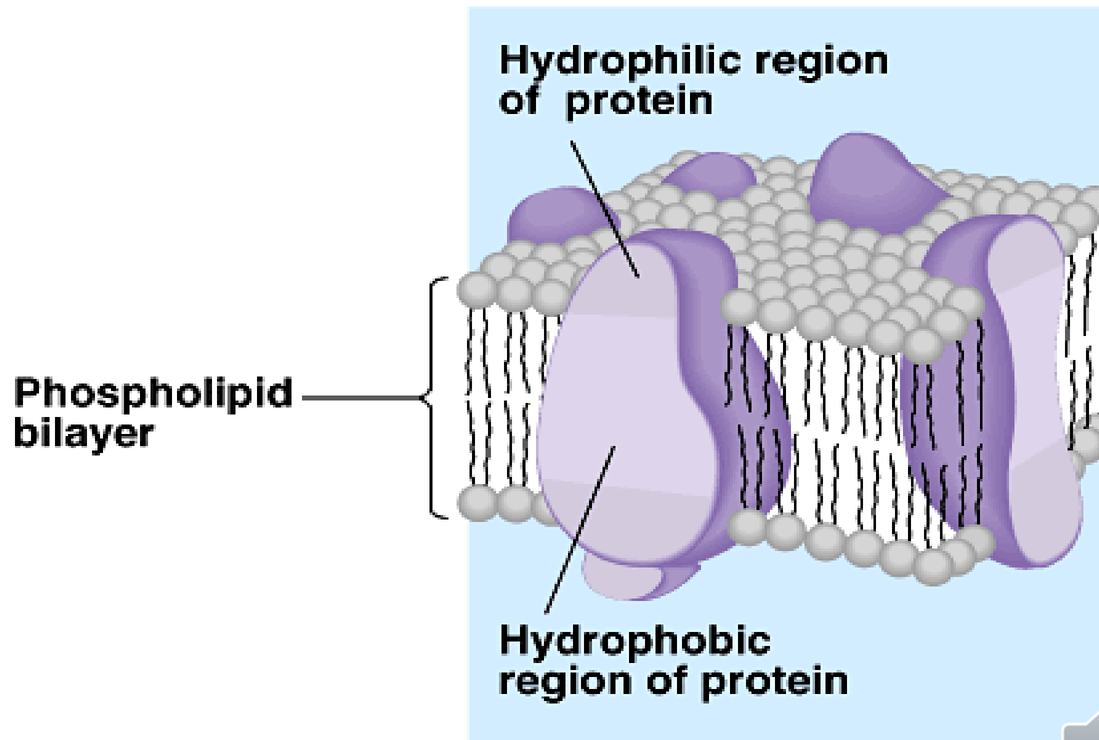
Acts as Semipermeable membrane

Regulates various metabolic reactions

Acts as Receptors for hormones & enzymes

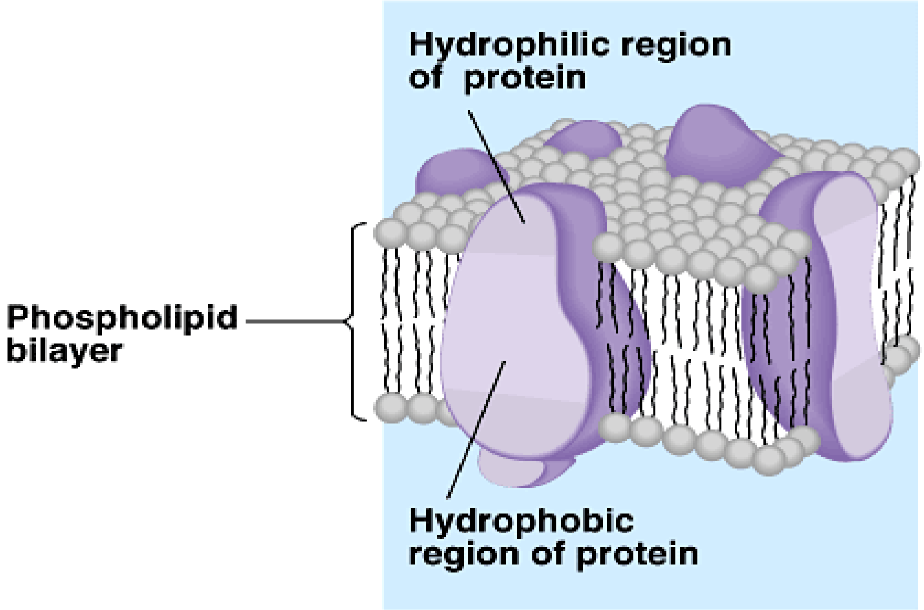
PROTEINS:

- In 1972, S.J. Singer & G. Nicolson proposed that membrane proteins are inserted into the phospho lipid bilayer



MEMBRANE STRUCTURE (fluid mosaic model)

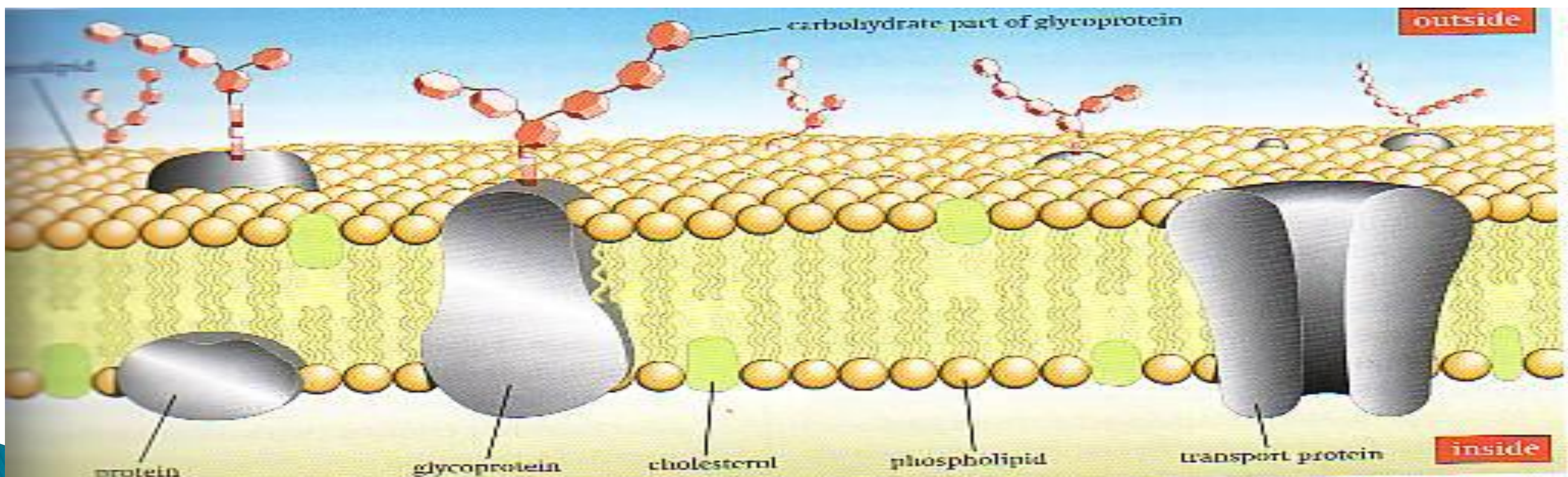
- In 1972, S.J. Singer and G. Nicolson presented a revised model that proposed that the membrane proteins are dispersed and individually inserted into the phospholipid bilayer. In this fluid mosaic model, the hydrophilic regions of proteins and phospholipids are in maximum contact with water and the hydrophobic regions are in a non aqueous environment



(b) Current fluid mosaic model

Fluid Mosaic Model

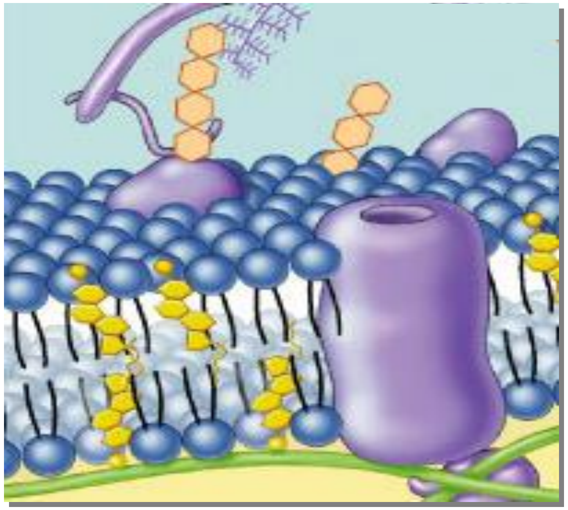
FLUID- because individual phospholipids and proteins can move
side-to-side within the layer, like it's a liquid.
MOSAIC- because of the pattern produced by the scattered protein molecules when the membrane is viewed from above.



Membrane Proteins

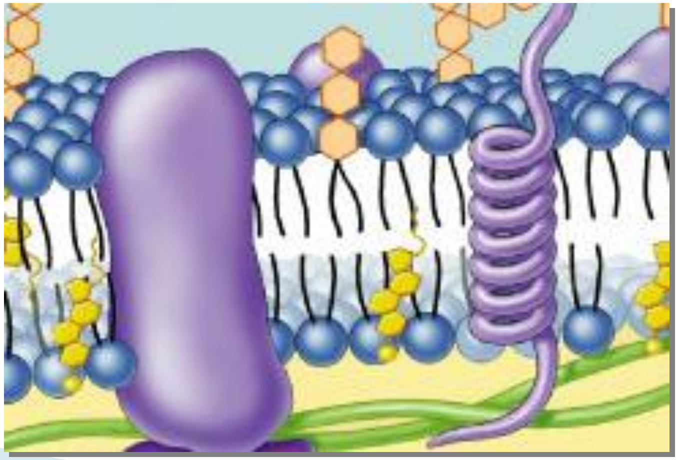
They are mainly of three types:

1) Peripheral protein

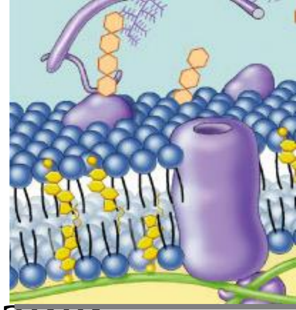


2)Integral proteins ,

3)transmembrane proteins



MEMBRANE PROTEINS:



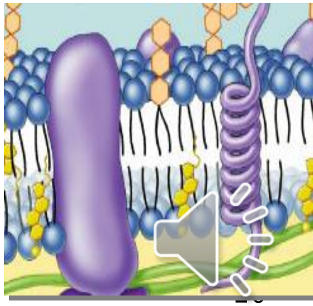
1)Integral proteins: which are inserted into the membrane: Their hydrophobic regions are surrounded by hydrophobic portions of phospholipids**.**

2)Transmembrane proteins : Their hydrophilic ends are

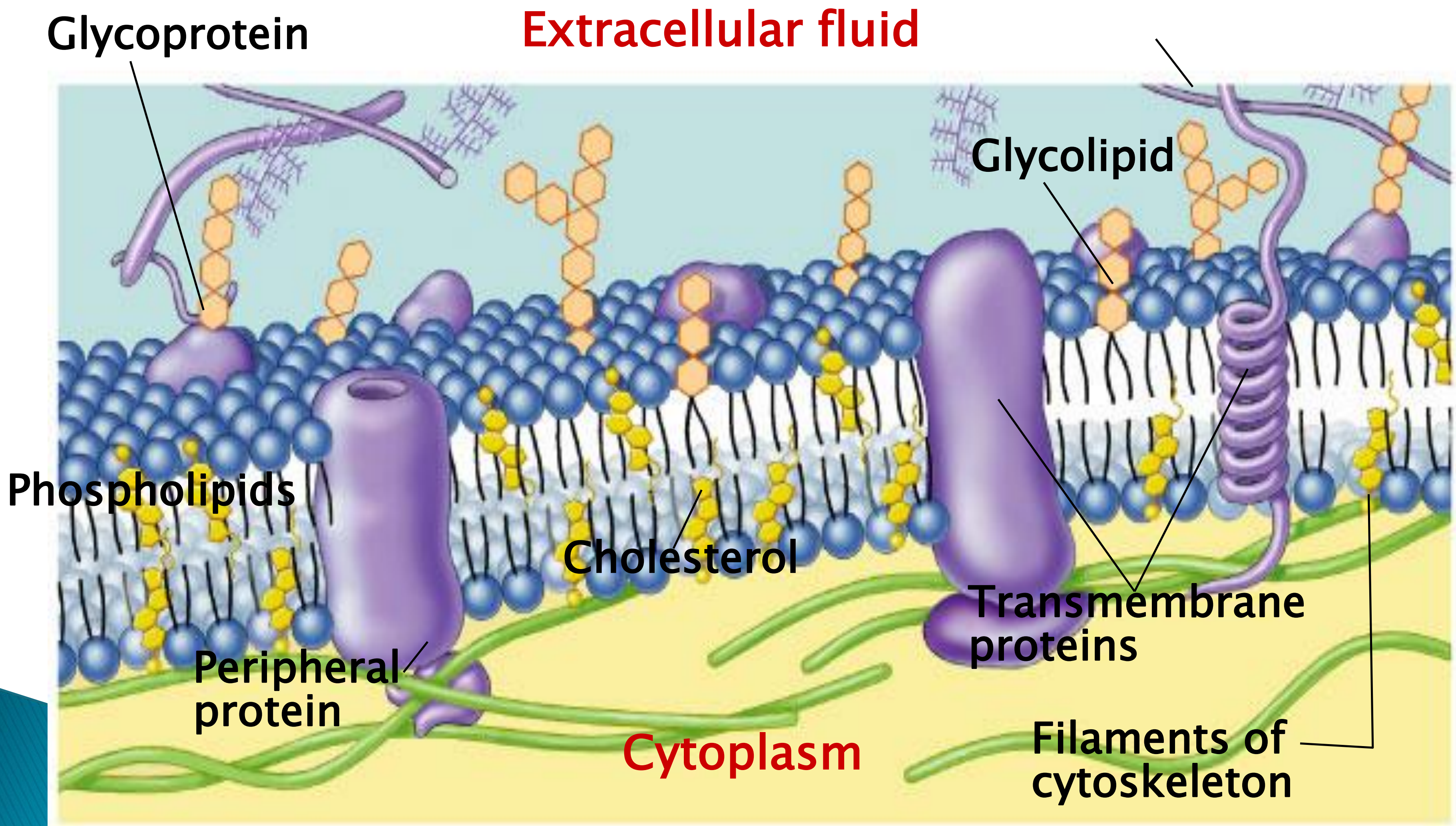
exposed on both sides of the membrane.e.g;receptors,NT,TSA,GF etc.

3)Peripheral proteins: which are not embedded in the lipid bilayer but attached to the membrane surface:

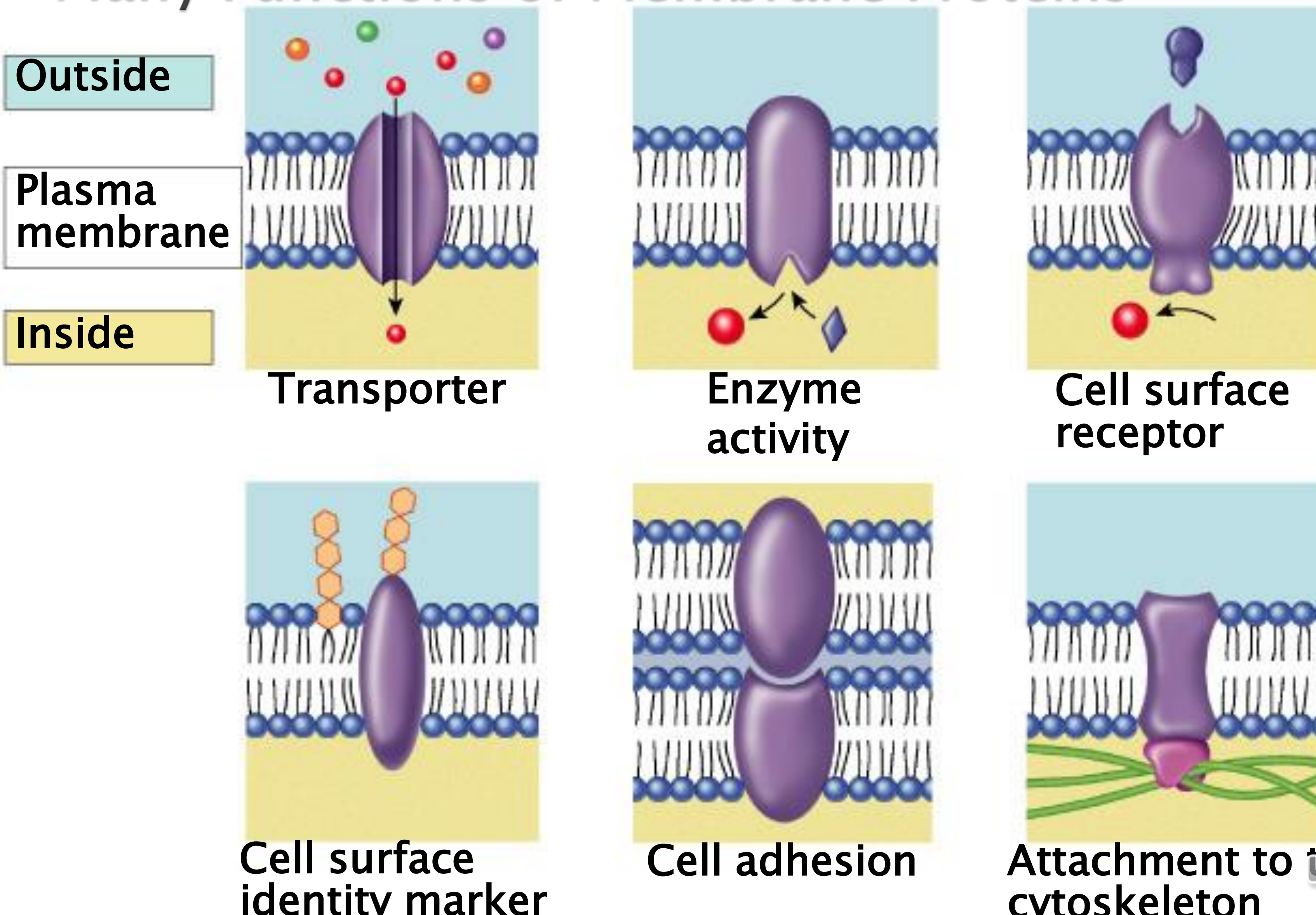
- May be attached to integral proteins or held by fibers of the extracellular matrix.
- On the cytoplasmic side, may be held by filaments of cytoskeleton



Membrane is a complex structure of proteins & other molecules embedded in the fluid matrix of the lipid bilayer



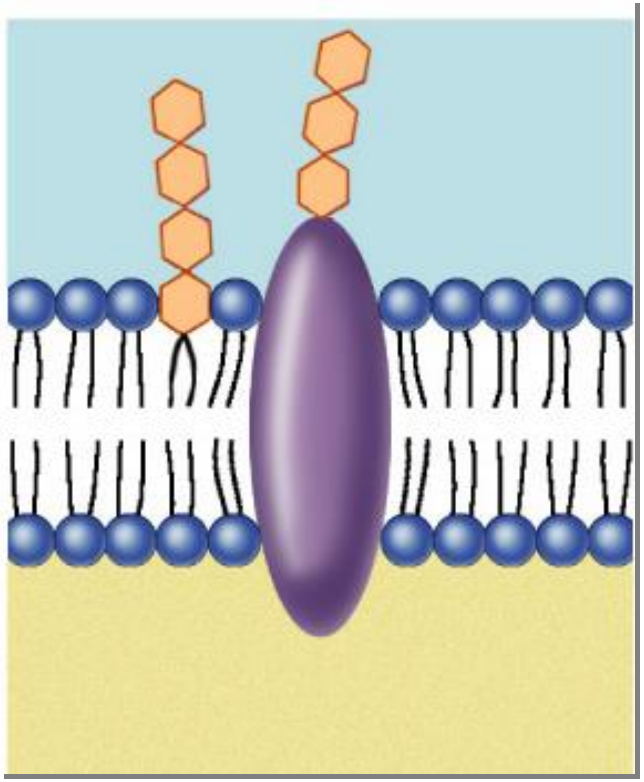
Many Functions of Membrane Proteins



Membrane carbohydrates

- Play a key role in cell-cell recognition
  - ability of a cell to distinguish one cell from another
    - antigens
  - important in organ & tissue development

  (Micro heterogeneity)
  - basis for rejection of foreign cells by immune system



Membrane Carbohydrates (The Glycocalyx)

- Membrane carbohydrates are important for cell-cell recognition
- Cell-cell recognition is crucial in the functioning of an organism. It is the basis for:
  - Sorting of cells into tissues and organs in an animal embryo’s cell.
  - Rejection of foreign cells by the immune system.
- The way cells recognize other cells is probably by keying on surface molecules (markers)

- **Markers:** Surface molecules found on the external surface of the plasma membrane that distinguish one cell from another.

Membrane Carbohydrates

- The cell markers of membrane are carbohydrates:
- Usually branched oligosaccharides (<15 monomers)
- Some are covalently bonded to lipids, forming glycolipids
- Most covalently bonded to proteins, forming glycoproteins.
- **i)Glycophorin;** Vary from species to species, between individuals of the same species and among cells within the same individual.
  - This variation marks each cell type as distinct.
  - The four human blood groups (A, B, AB, and O) differ in the external carbohydrates on red blood cells.

Membrane Carbohydrates

- Glycocalyx
  - Composed of sugars protruding from lipids and proteins
  - Eg;ii) **apoprotein B** of plasma lipoproteins.
  - Functions
    - Binding sites for proteins
    - Lubricate cells.
    - Sites for attachment of viruses

Transport Systems:

A. 1. Ion Channels

Ion channels are transmembrane channels, ***pore like structures composed of proteins.*** Specific channels for Na^+, K^+, Ca^{++}, and Cl^- have been identified.

Cation conductive channels are negatively charged within the channel and have an average diameter of about 5 to 8 nm.

All ion channels are basically made up of transmembrane subunits that come together to form a central pore through which ions pass selectively.

All channels have *gates*, and are controlled by opening and closing.

Types of Gates

Two types of gated channels. They are:

a. Ligand gated channels: In this a specific molecule binds to a receptor and opens the channel.

b. Voltage gated channels: These channels open or close in response to changes in membrane potential.

2. Ionophores

Certain microorganisms can synthesise small organic molecules, called **ionophores**, which function as shuttles for the movement of ions across the membrane.

Structure: These ionophores contain hydrophilic centres that bind specific ions and are surrounded by peripheral hydrophobic regions.

Types: Two types:

(a) Mobile ion carriers: Like valinomycin (Refer uncouplers of oxidative phosphorylation).

(b) Channel formers: Like gramicidin.

3. Water Channels (Aquaporins)

In certain cells, e.g. in red blood cells, and cells of the collecting ductules of the kidney, the movement of water by simple diffusion is enhanced by movements of water through **water channels**, composed of tetrameric transmembrane proteins called **aquaporins**. About five distinct types of aquaporins have been recognised.

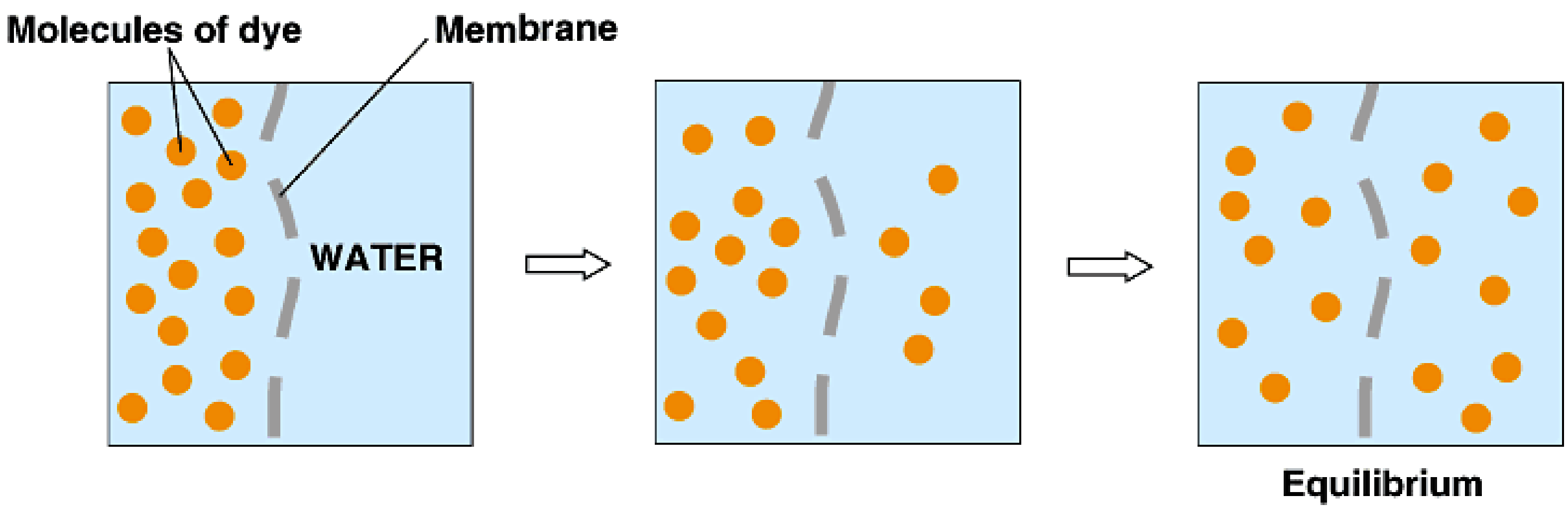
Molecules move through plasma membrane by:

- Passive Transport
  - Simple diffusion
    - diffusion of nonpolar, hydrophobic molecules
    - lipids
    - high → low concentration gradient
  - Facilitated transport
    - diffusion of polar, hydrophilic molecules
    - through a Carrier protein
    - high → low concentration gradient
- Active transport
  - diffusion *against* concentration & electrical gradient
    - low → high
  - uses a protein pump
  - requires ATP

ATP

Diffusion

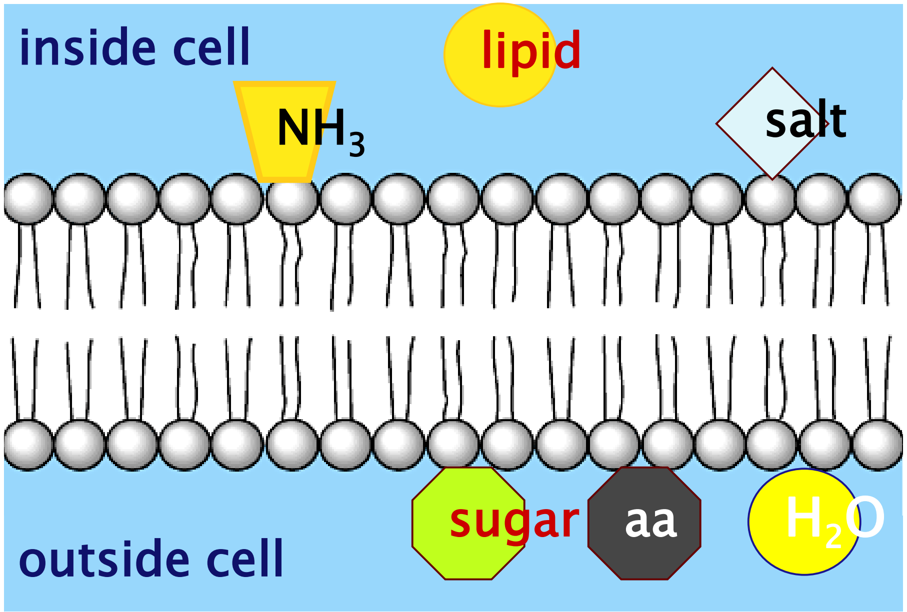
- Diffusion
  - movement from high → low concentration
  - No energy needed.



- **Simple migration of molecules from high concentration to low concentration**

Diffusion through phospholipid bilayer

molecules that can get directly through the membrane are fats & other lipids



- molecules can NOT get through the membrane are
  - polar molecules
    - H_2O
  - Ions
    - salts, ammonia
  - large molecules
    - starches, proteins

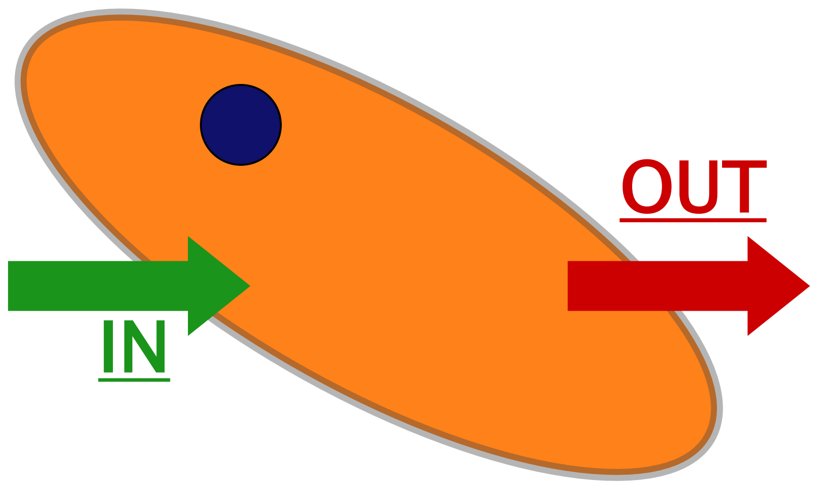
Diffusion across cell membrane

- Cell membrane is the boundary between inside & outside…
  - separates cell from its environment

It is semi permeable boundary for the
Cell needs materials in & products or waste out

IN

food
carbohydrates
sugars, proteins
amino acids
lipids
salts, O_2, H_2O

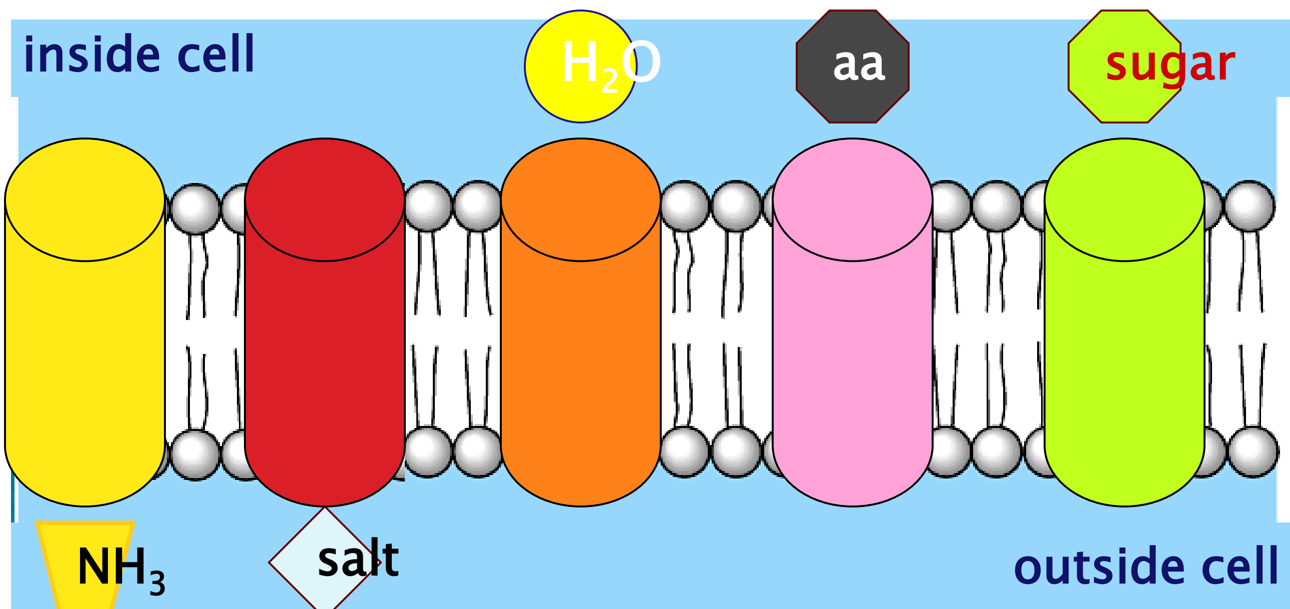


OUT

waste
ammonia
salts
CO_2
H_2O
products

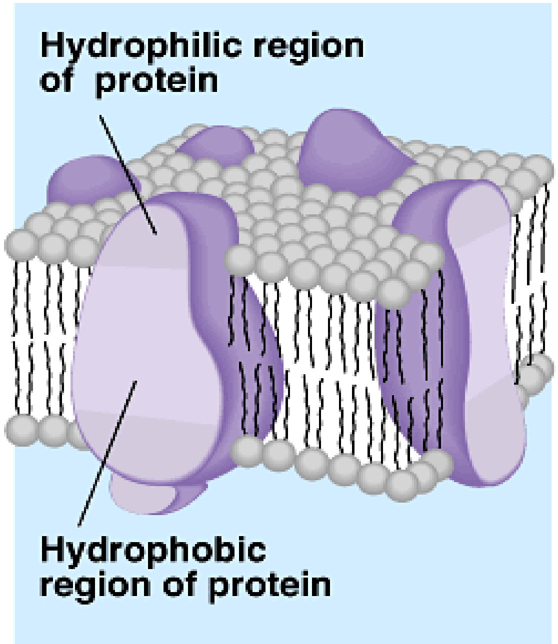
Channels through cell membrane

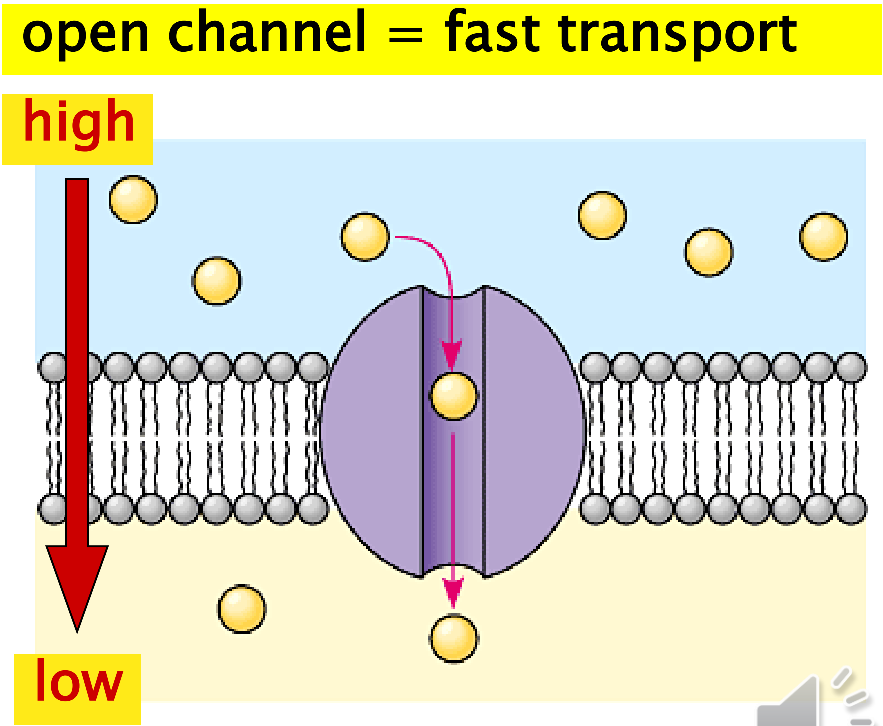
- Membrane becomes semi-permeable with protein channels.
- specific channels allow specific material across cell membrane.



Facilitated Diffusion

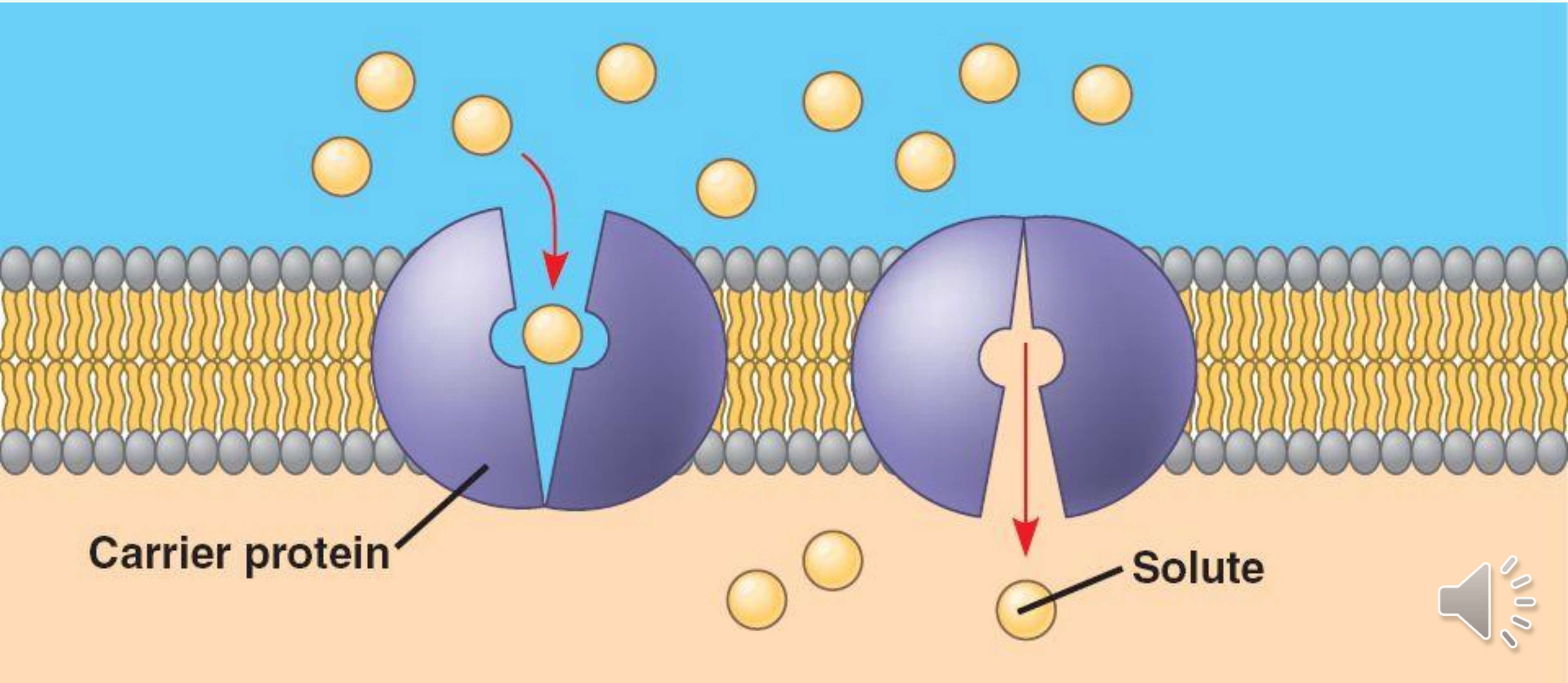
- Diffusion with the aid of protein channels or carrier proteins.
- No energy is needed.





CARRIER PROTEINS:

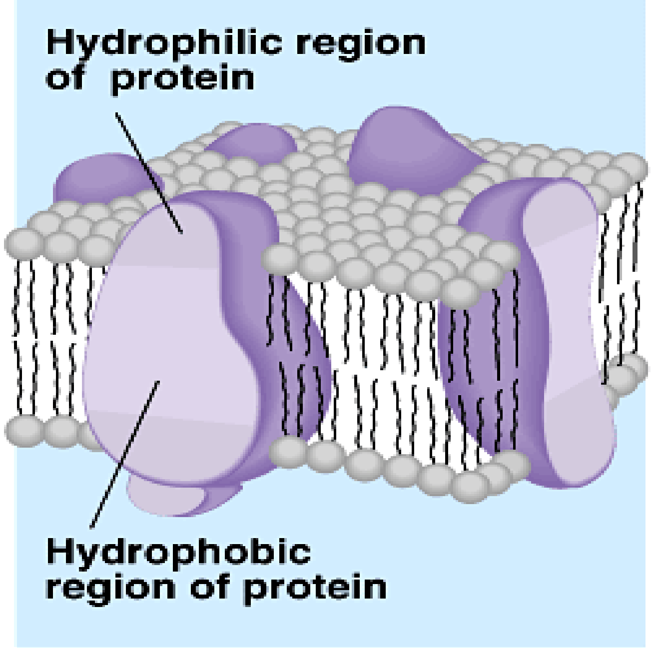
The proteins move specific type of molecules through the membrane from one side to other side of membrane.

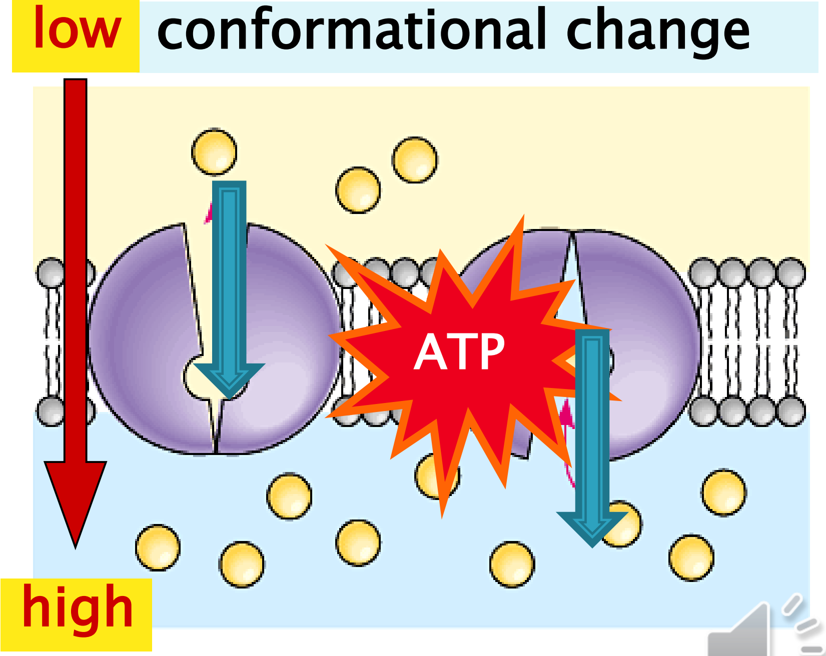


Active Transport

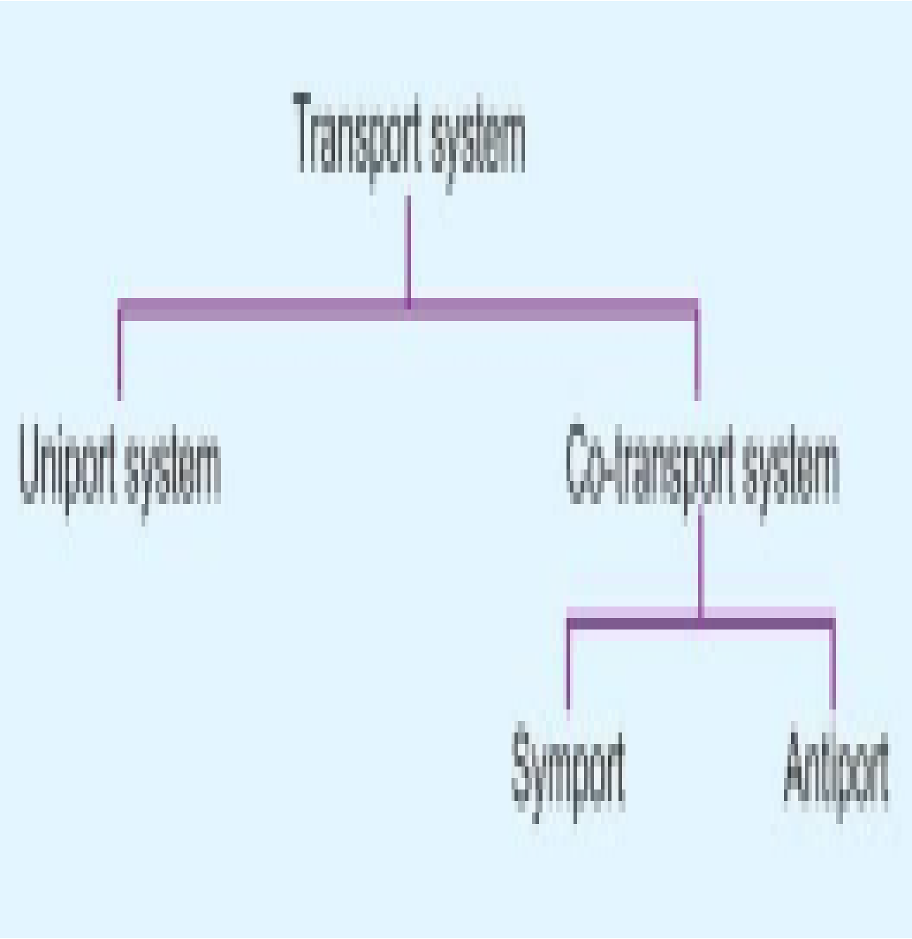
Cells may need to move molecules ***against*** concentration gradient.

- Protein "pump"
- "costs" energy = ATP



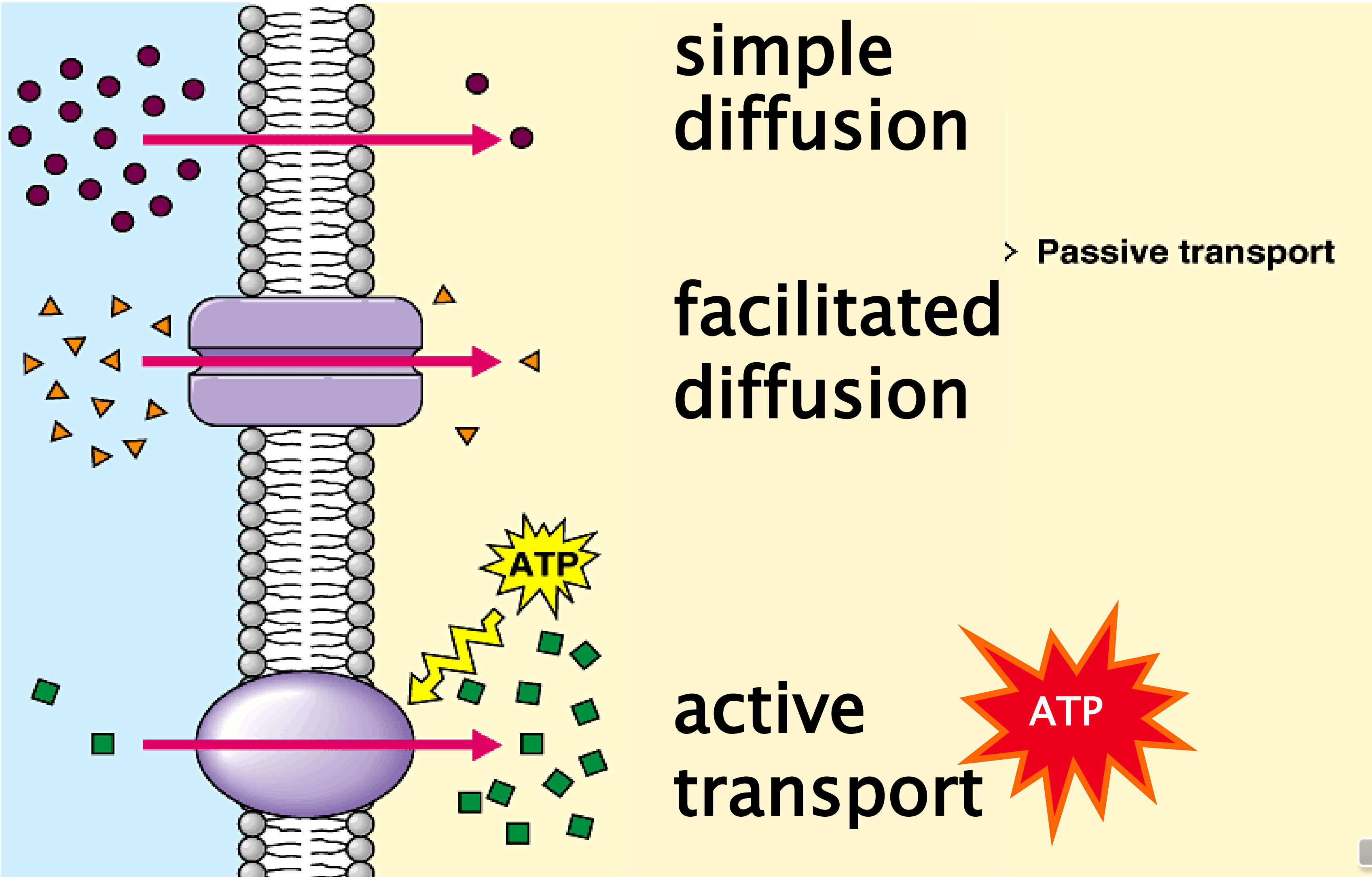


Transport system:



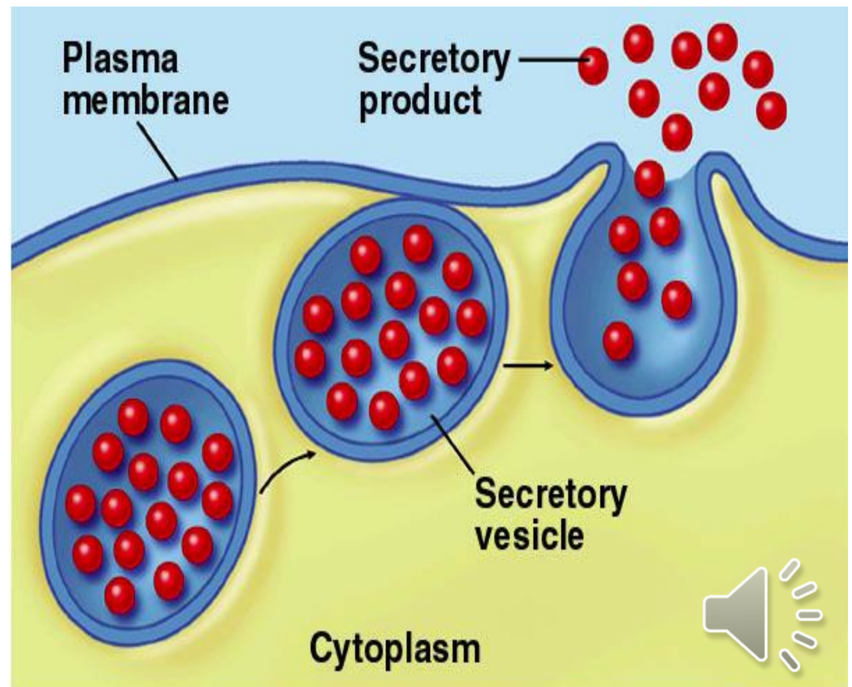
1. *Uniport system:* This system involves the transport of a single solute molecule through the membrane. *Example:* Glucose transporters in various cells.
2. *Co-transport system:* D-Glucose, D-Galactose and L-amino acids are transported into the cells by Na^+ -dependant co-transport system. Na^+ is not allowed to accumulate in the cells and it is pumped out by "sodium pump".
   - (i) *Symport system (Fig. 2.7):* It is a co-transport system in which the transporter carries the two solutes in the same direction across the membrane.
   - (ii) *Antiport system (Fig. 2.8):* It is a type of co-transport system in which two solutes or ions are transported simultaneously in opposite directions. *Example:* Chloride and bicarbonate ion exchange in lungs in red blood cells.

Transport summary



How about large molecules?

- Moving large molecules into & out of cell
  - through vesicles & vacuoles
  - exocytosis
  - endocytosis
    - phagocytosis = "cellular eating"
    - pinocytosis = "cellular drinking"

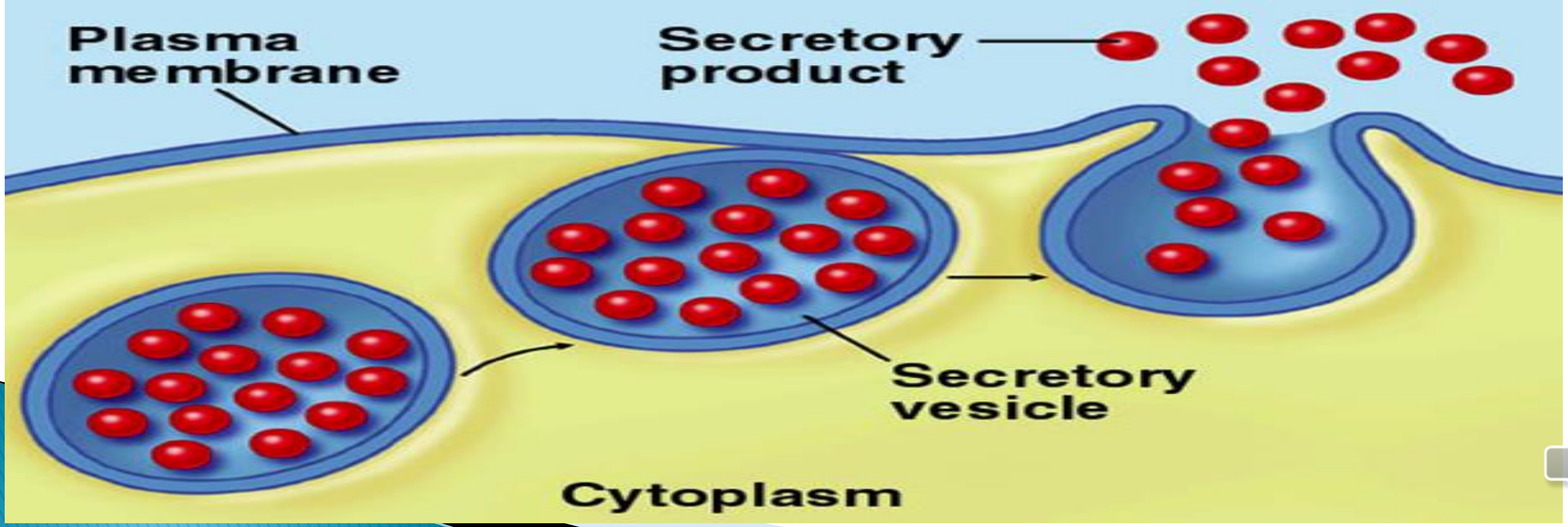


exocytosis

EXOCYTOSIS

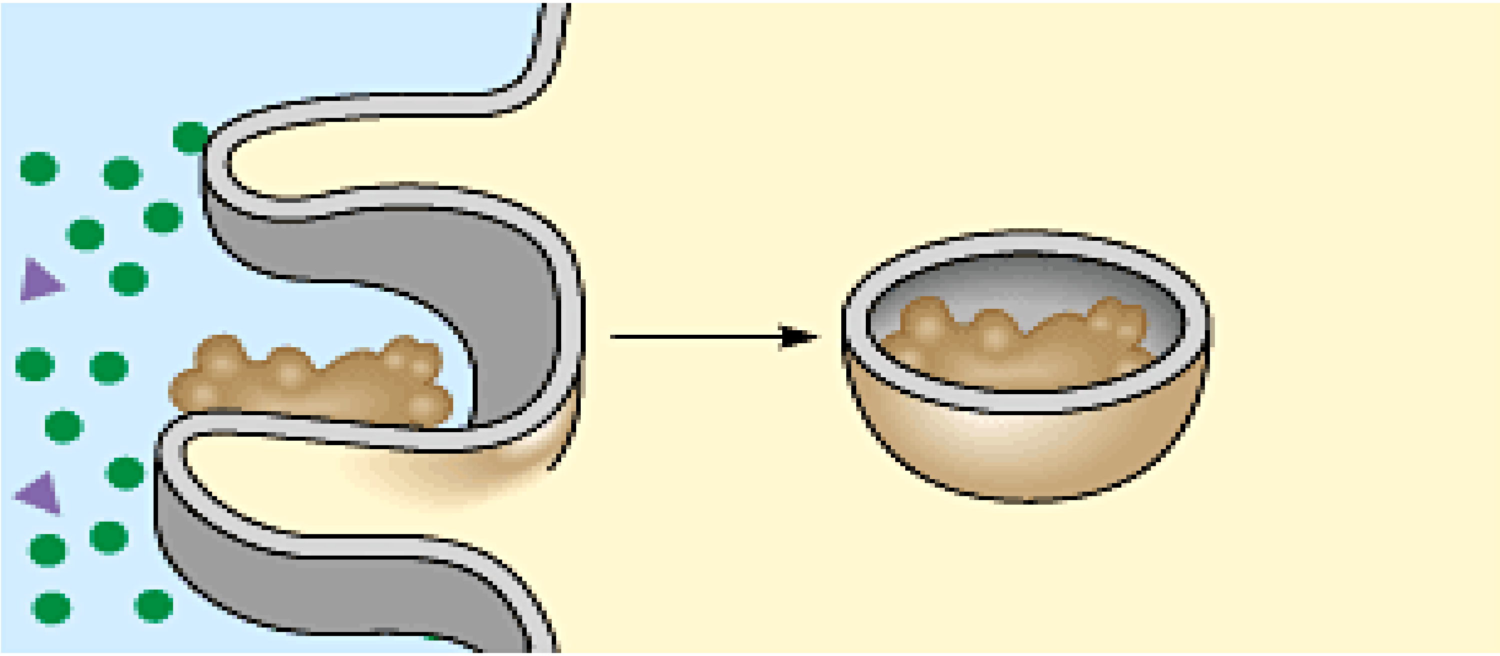
It is the process by which a vesicle moves from cytoplasm to the plasma membrane where it discharges its contents to the extracellular space.

e.g; release of insulin by beta cells & acetyl choline by the pre synaptic cholinergic nerves.



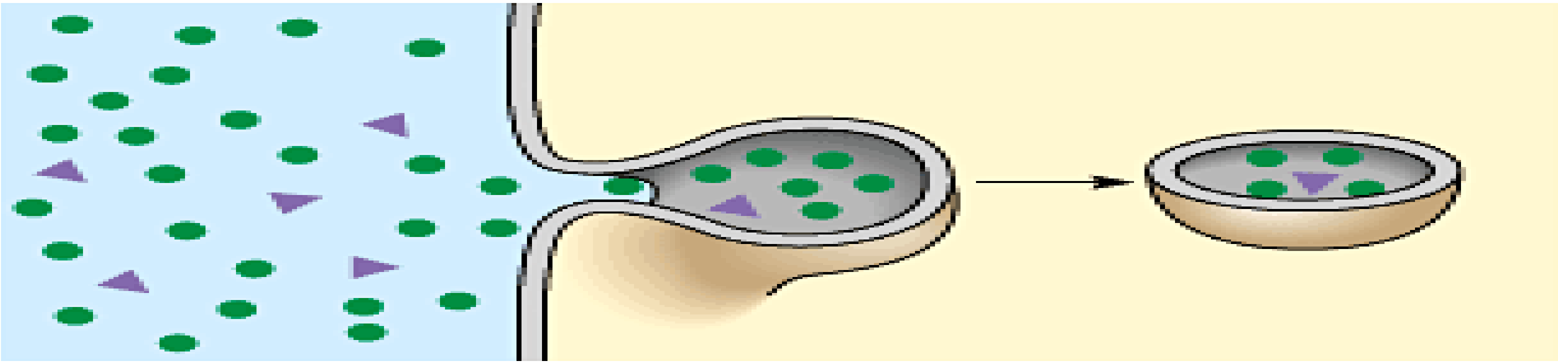
Phagocytosis:

Derived from greek word ‘phagein’ meaning ‘to eat’. It is engulfment of large particles such as bacteria by Macrophages & Granulocytes.

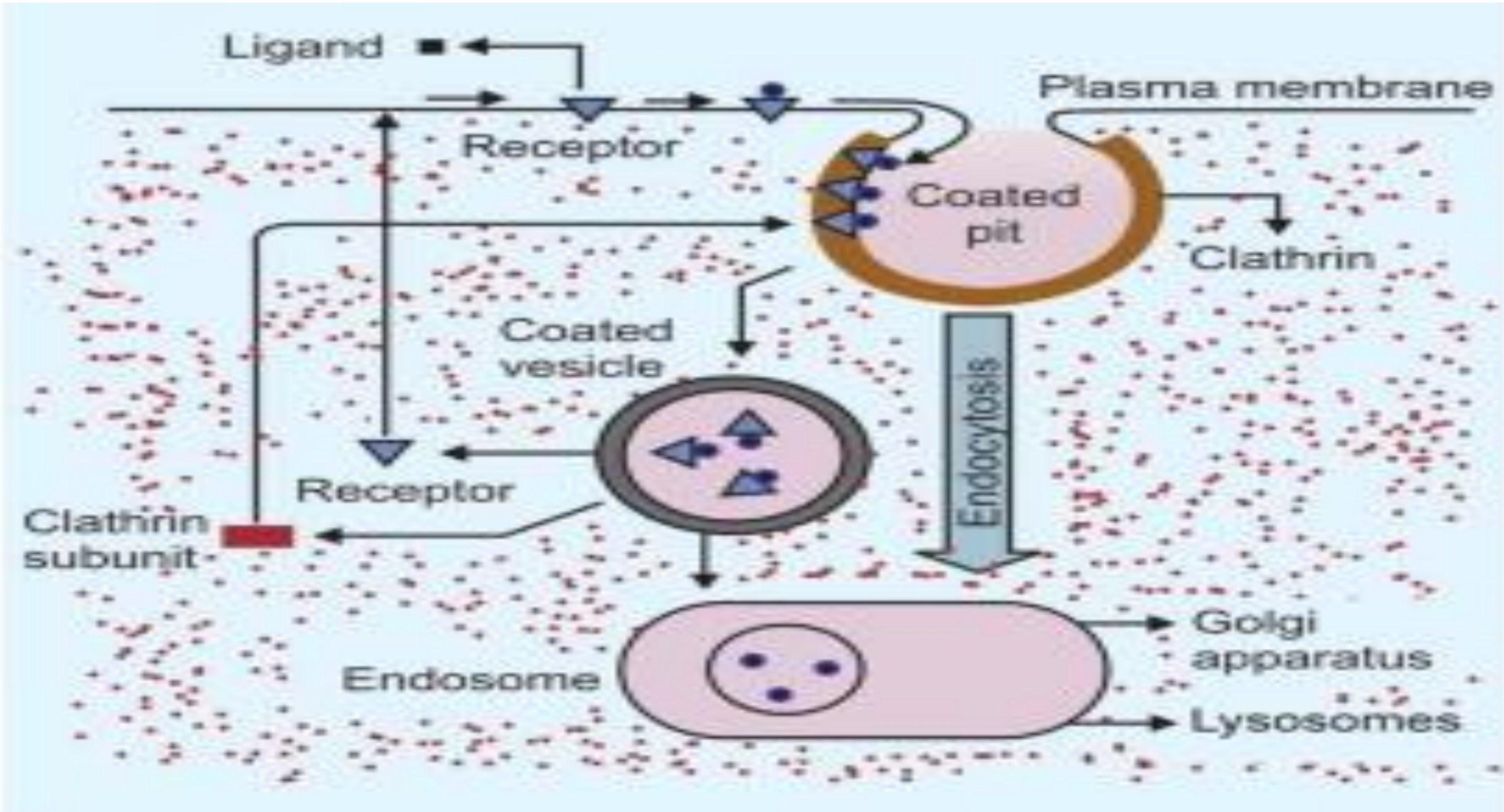


Pinocytosis

- ‘drinking by a cell’
- **Two types: Fluid phase pinocytosis & recepter mediated pinocytosis**
- **The ‘selective or absorptive pinocytosis’ is receptive mediated.e.g; LDL binding to LDL-recepter & the complex is then internalised.**
- **clathrin dependent endocytosis.**



Receptor mediated absorptive pinocytosis:

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