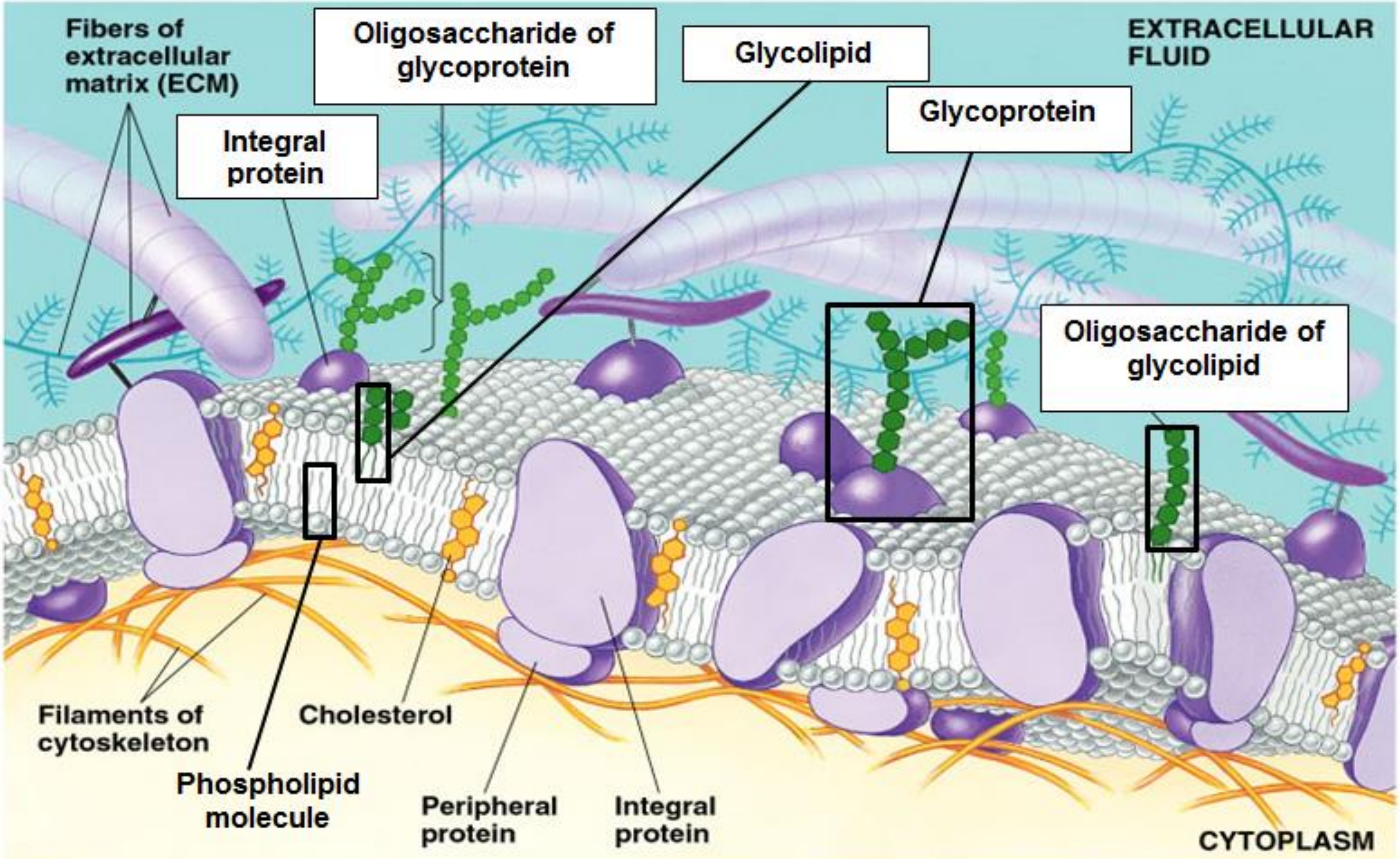
MEMBRANES


Fibers of extracellular matrix (ECM)
Oligosaccharide of glycoprotein
Glycolipid
EXTRACELLULAR FLUID
Glycoprotein
Integral protein
Oligosaccharide of glycolipid
Filaments of cytoskeleton
Cholesterol
Phospholipid molecule
Peripheral protein
Integral protein
CYTOPLASM

Recall: SDL notes on "Organelles"

Membrane(s)

Single membrane **Double-membrane (2 membranes)**

rough and smooth ER

Golgi body

mitochondria & chloroplasts

ribosomes ✘

lysosomes

centrioles ✘

nucleus

nucleolus ✘

Learning Objectives

1(b) **Interpret** and **recognize** drawings, photomicrographs and electronmicrographs of the following **membrane** systems and organelles :

- rough and smooth endoplasmic reticulum,
- Golgi body,
- mitochondria,
- ribosomes,
- lysosomes,
- chloroplasts,
- **cell surface membrane,**
- nuclear envelope,
- centrioles,
- nucleus and
- nucleolus.

Learning Outcomes

1 b) Interpret and recognize drawings, photomicrographs and electronmicrographs of the following membrane systems and organelles : RER and SER, Golgi body, mitochondria, ribosomes, lysosomes, chloroplasts, **cell surface membrane**, nuclear envelope, centrioles, nucleus and nucleolus.

1 c) Outline the **functions of the membrane systems** and organelles listed in LO1(b).

1 h) Explain the **fluid mosaic model** and the **roles of the constituent biomolecules** (including phospholipids, proteins, glycolipids, glycoproteins and cholesterol) in the cell membranes.

1 i) Outline the **functions of membranes** at the surface of cell and membranes within the cell.

1 j) Explain how and why different substances move across membranes through **simple diffusion, osmosis, facilitated diffusion, active transport, endocytosis** and **exocytosis**.

Introduction : Membranes

- Found on **cell surface** or around **organelles**.

cell surface membrane

cell membrane

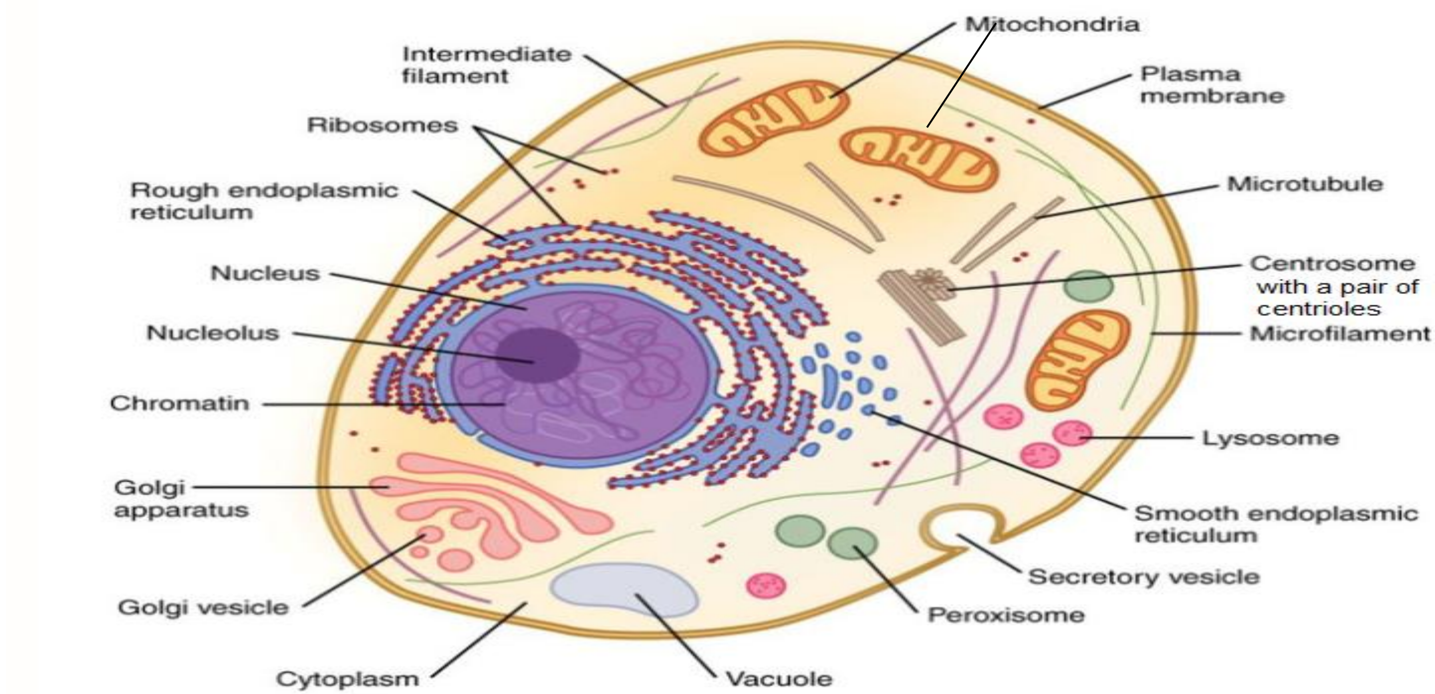
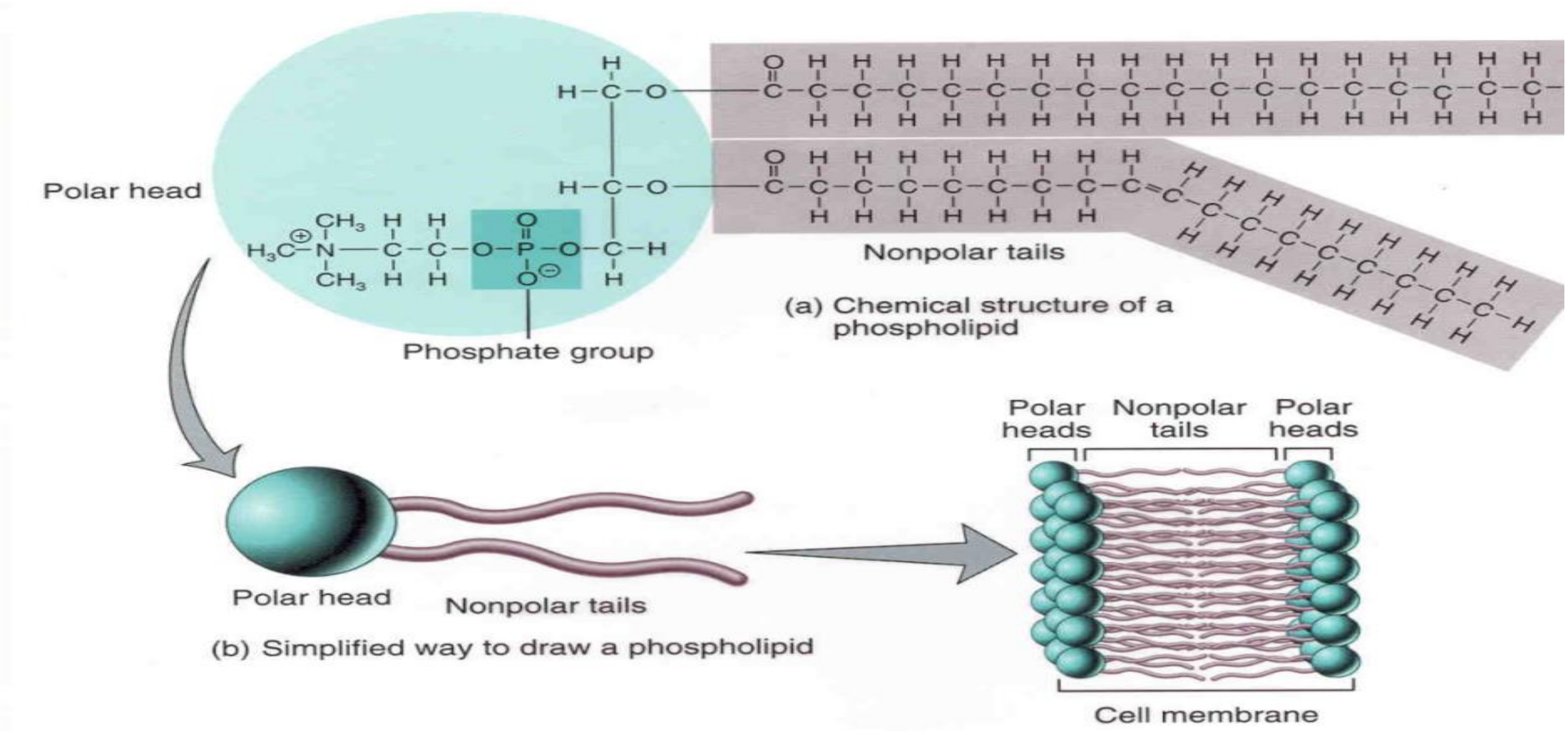


Diagram of an animal cell

Membranes

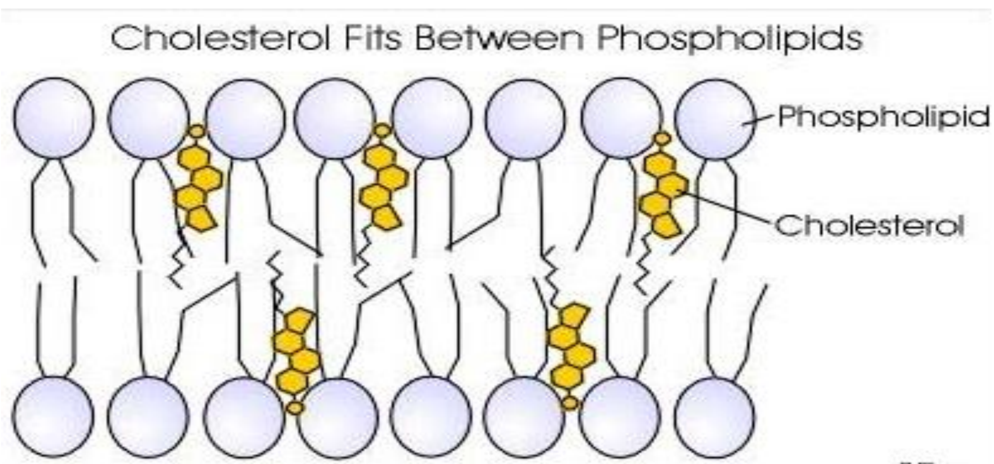
- Composed of mainly **lipids** and **proteins**.

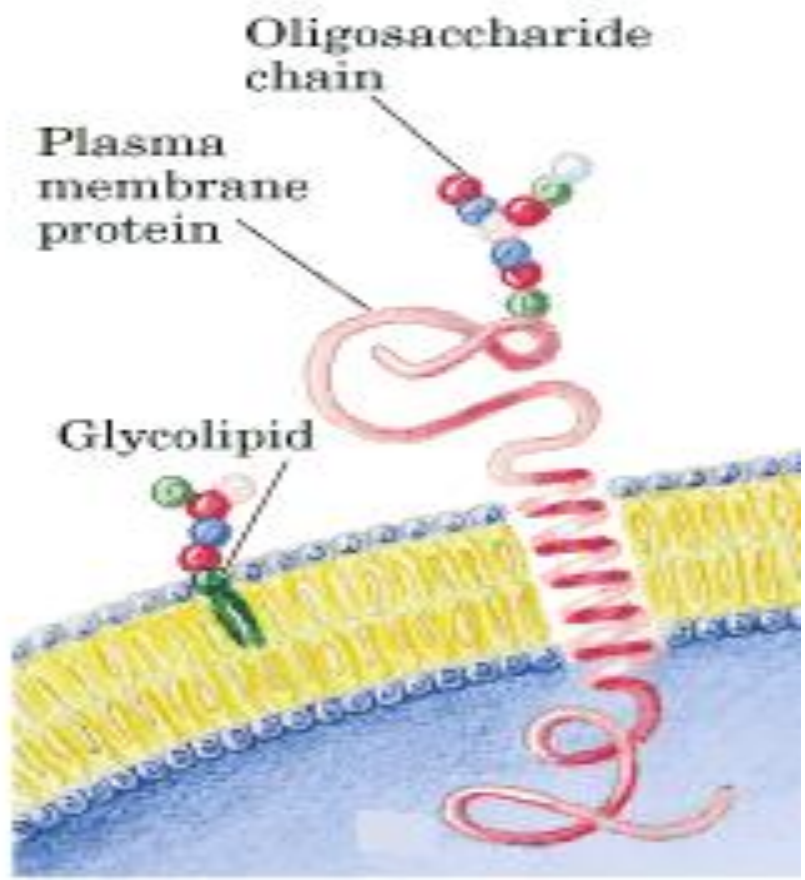
Recall "Lipids" lecture => "phospholipid"



Membranes

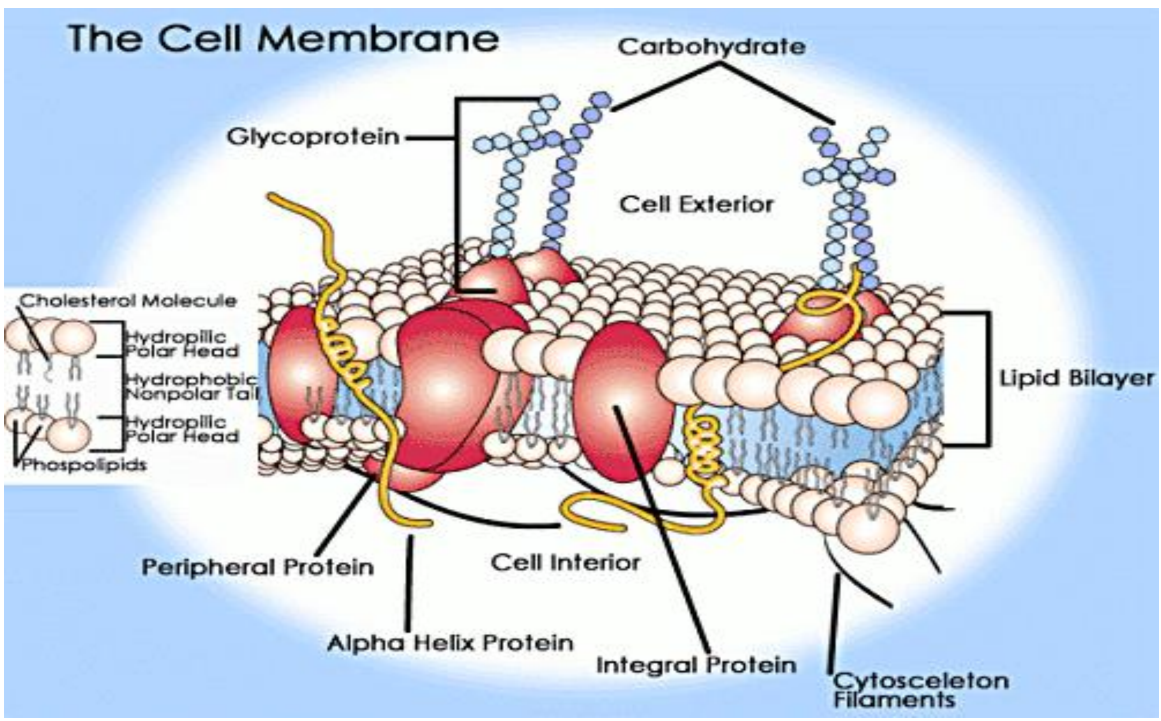
- Composed of mainly **lipids** and **proteins**.
- **Lipids** include:
  - –phospholipid
  - –glycolipid
  - –cholesterol

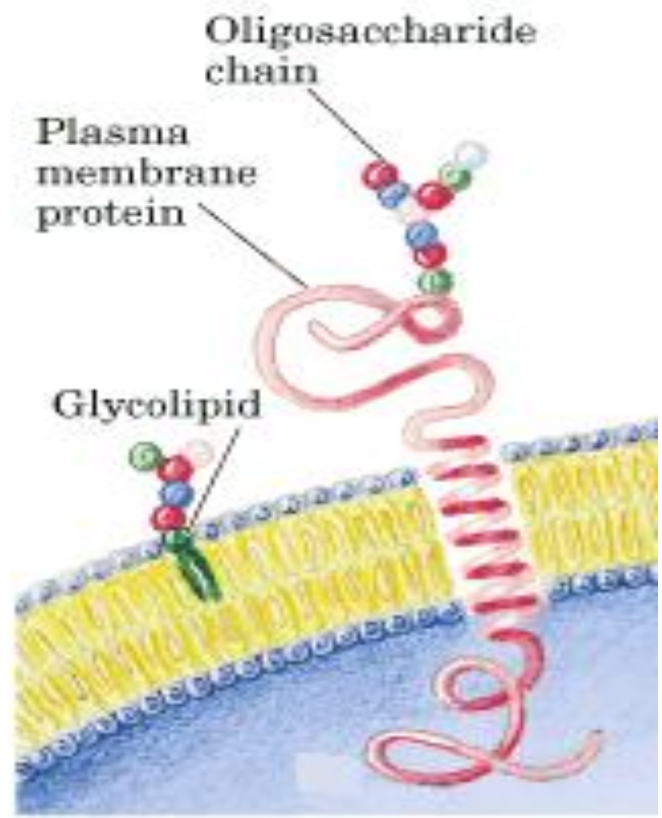




Membranes

- Composed of mainly **lipids** and **proteins**.
- Proteins (peripheral & integral) include:
  - i.e. Glycoprotein

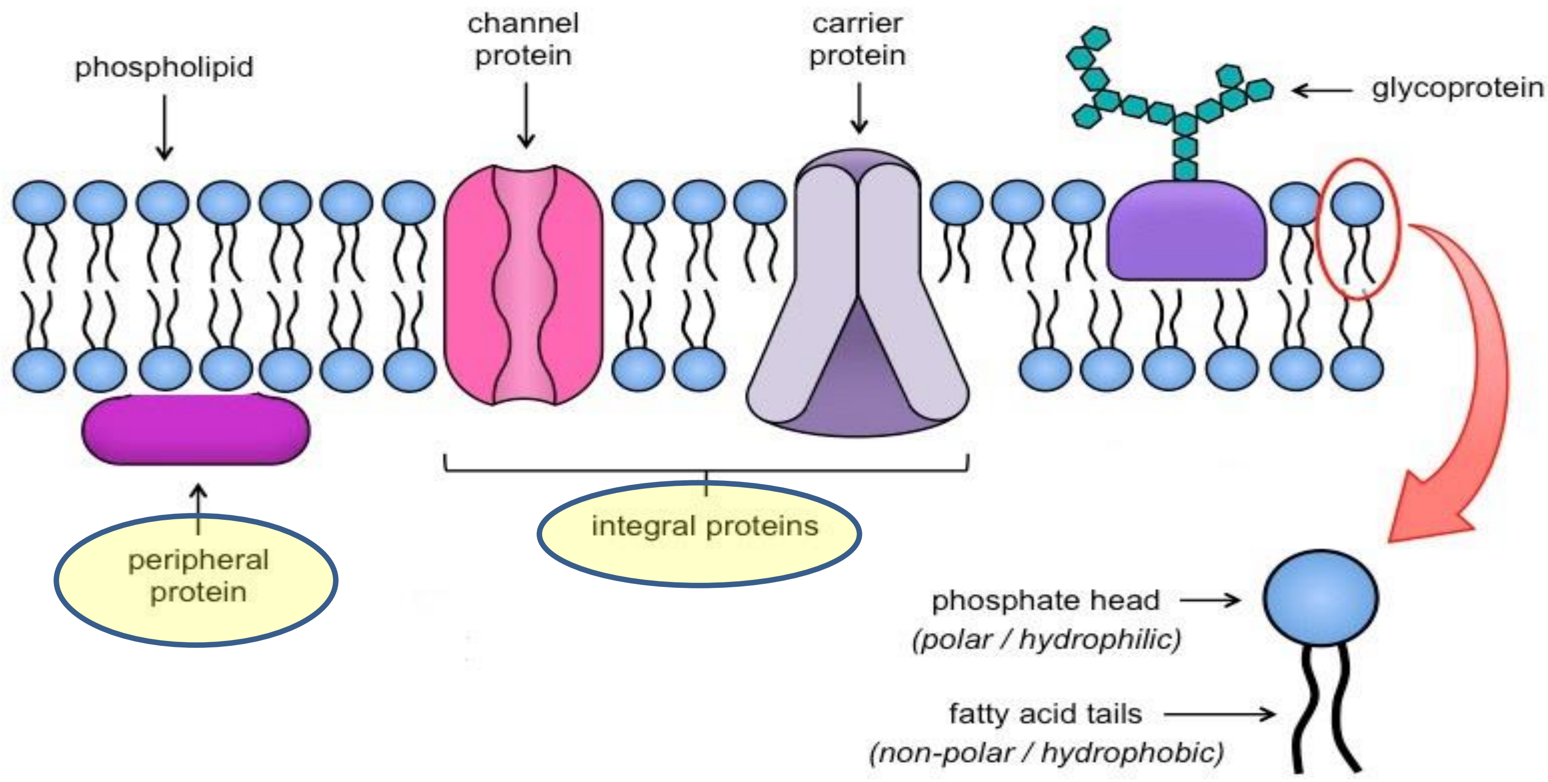




Regardless of locations

- All biological membranes have **similar structures**.

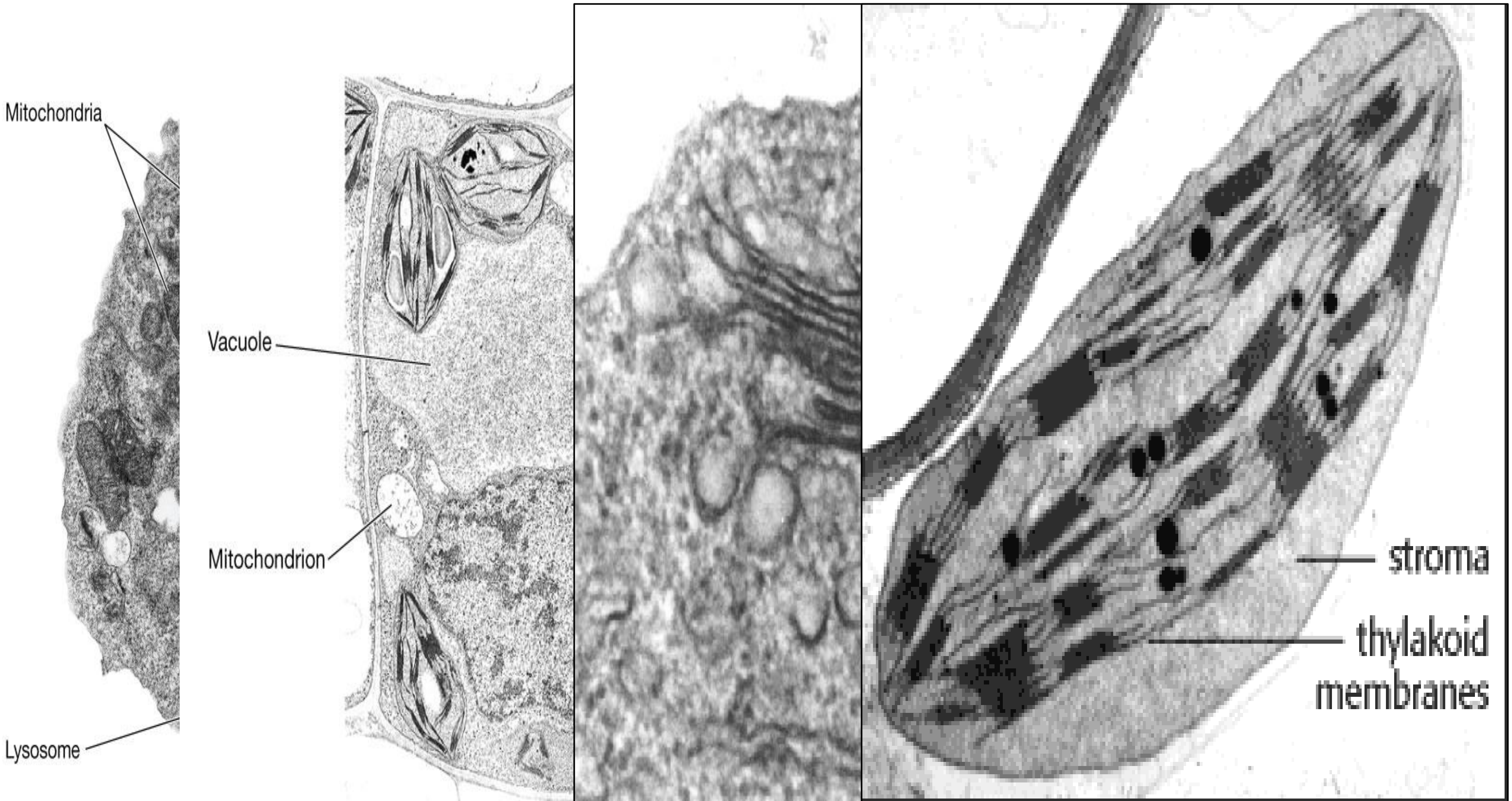
proteins + phospholipid bilayer



Regardless of locations

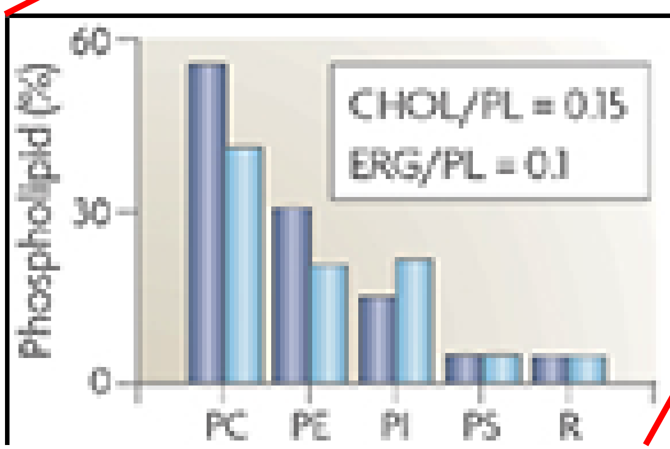
- All biological membranes have **similar structures**.

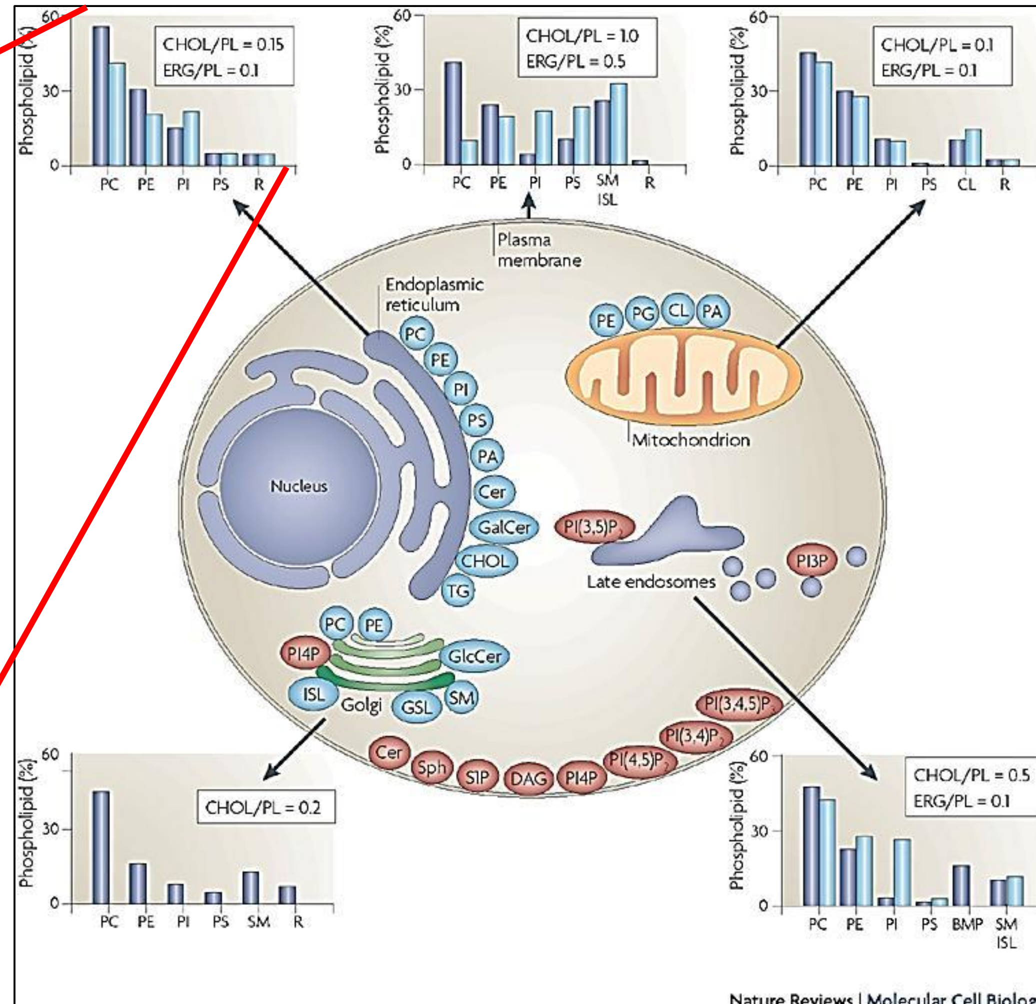
Phospholipid bilayer



Membranes

- Only difference is that the **amount of lipids and proteins** may **vary** according to
  - function
  - location
  - type of membrane





Membranes

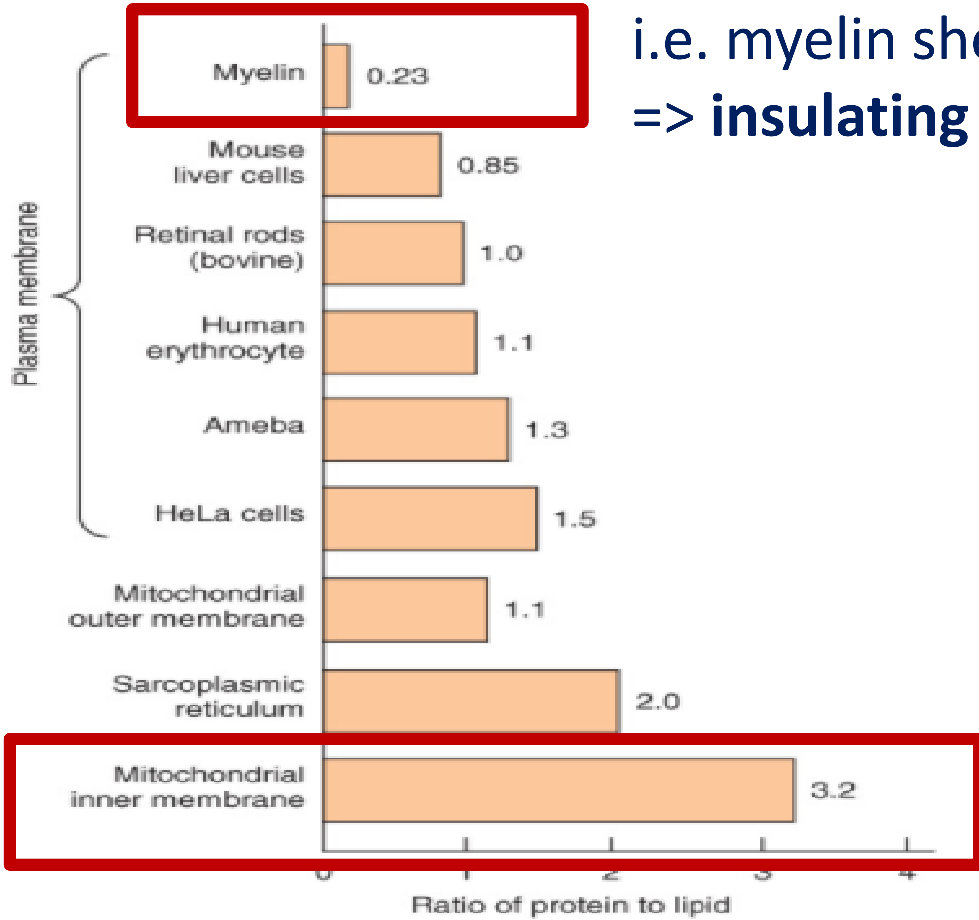


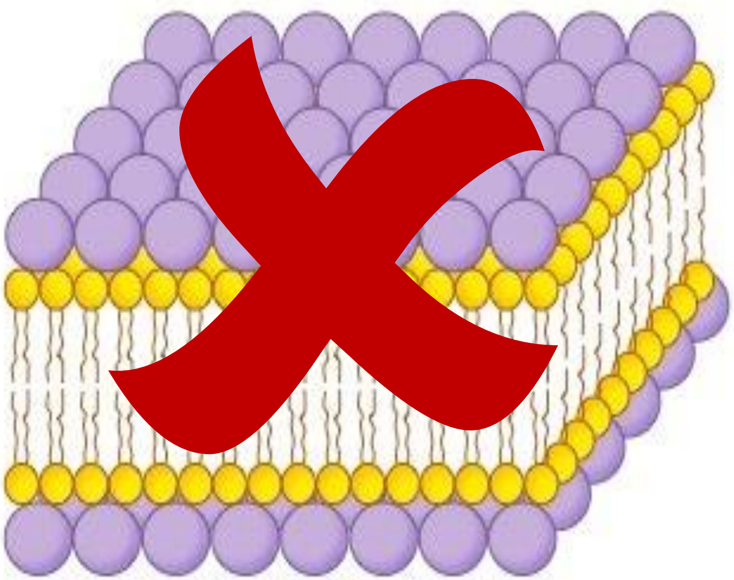
FIGURE 40–1 Ratio of protein to lipid in different membranes. Proteins equal or exceed the quantity of lipid in nearly all membranes. The outstanding exception is myelin, an electrical insulator found on many nerve fibers.

i.e. myelin sheath in neurons
=> **insulating layer wrapped around axon**

Inner membrane has enzymes, protein pumps etc embedded for oxidative phosphorylation
=> higher ratio of protein:lipid

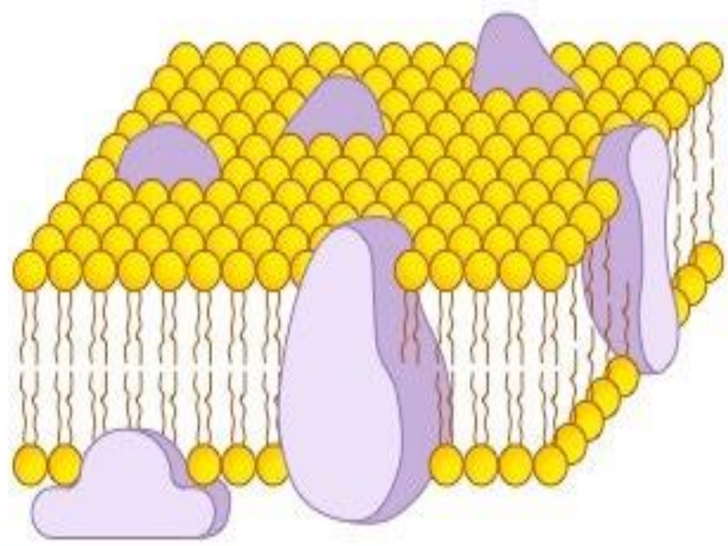
Membrane Models

Davson-Danielli Model (1935)



Proteins form distinct layers *(sandwich)*

Singer-Nicolson Model (1972)



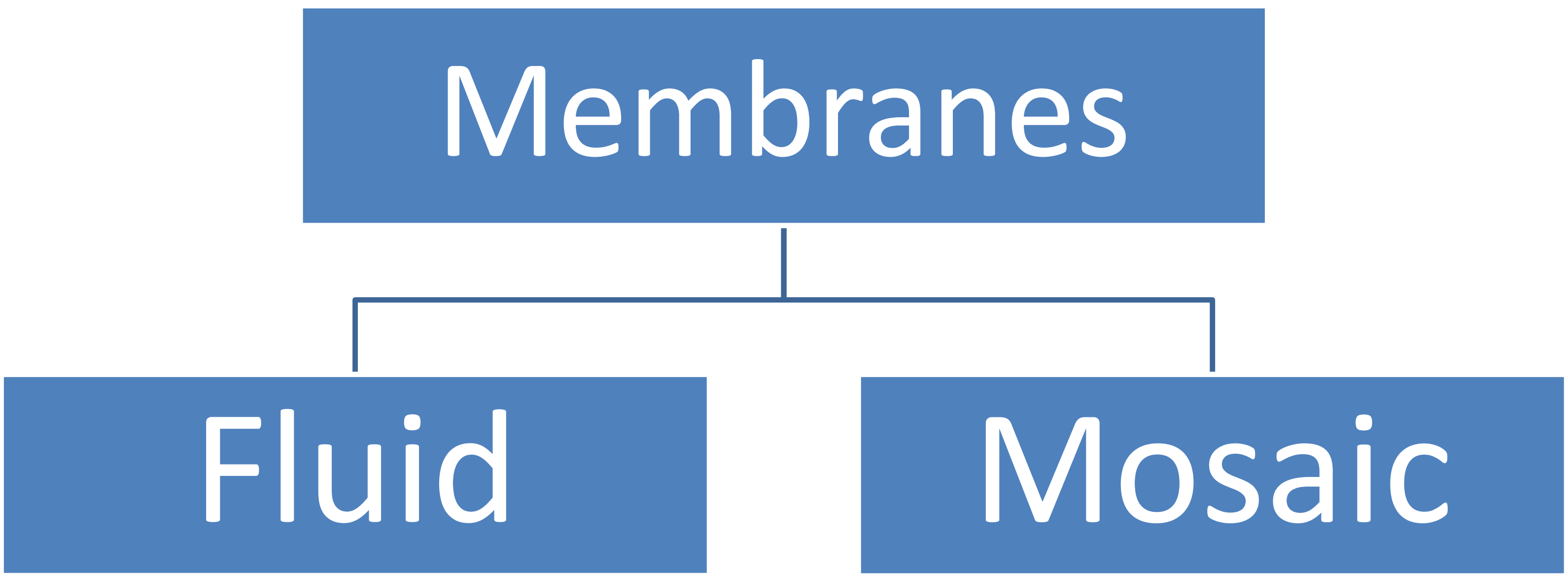
Proteins embedded within bilayer *(fluid-mosaic)*

Learning Objectives

1(h) Explain the **fluid mosaic model** and the **roles** of the constituent biomolecules (including **phospholipids, proteins, glycolipids, glycoproteins and cholesterol**) in the cell membranes.

Fluid Mosaic Model

- describes the nature of biological membranes;
- Membrane is a **mosaic** of protein molecules moving in a **fluid** bilayer of phospholipids =>"**fluid mosaic model**"

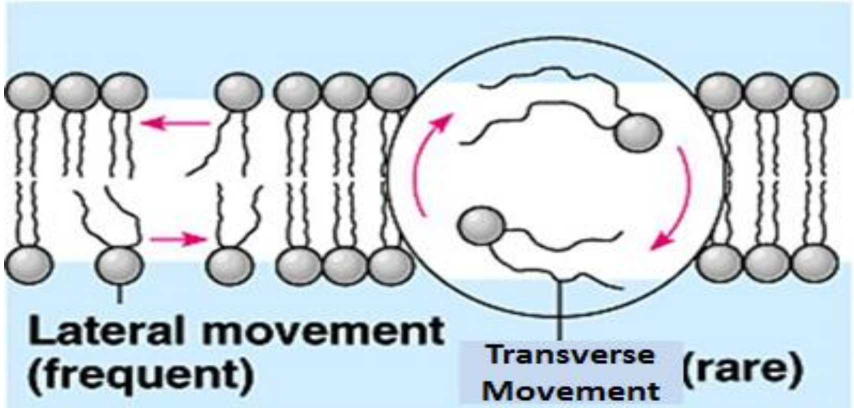


2007 A-Level Qn

Fluid Mosaic Model

FLUID

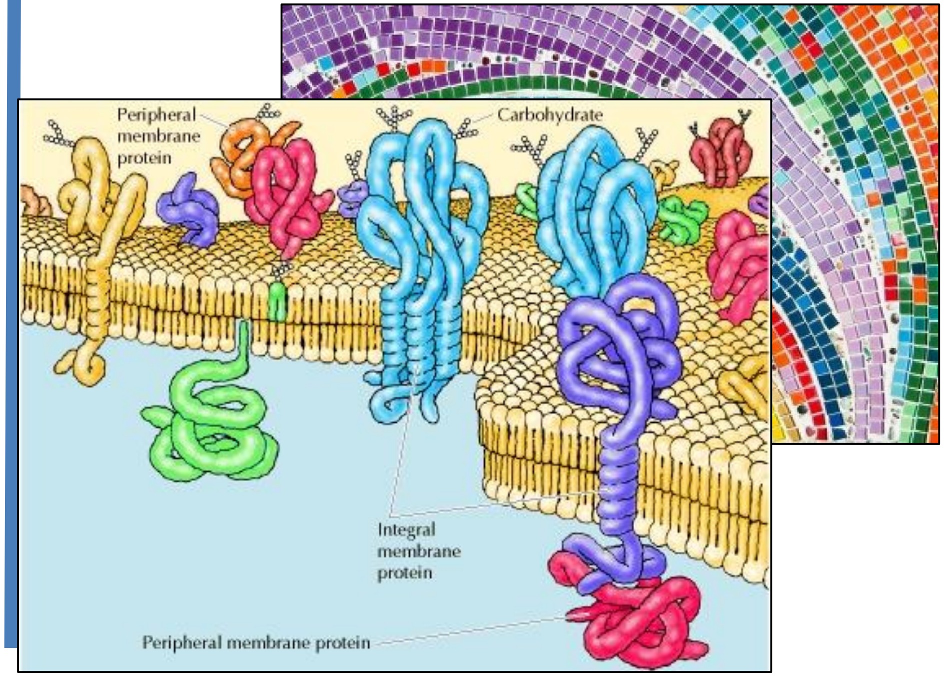
- **Phospholipids** and **proteins** free to move within membrane **laterally**
- **Phospholipids** can also move **transversely**



(a) Movement of phospholipids

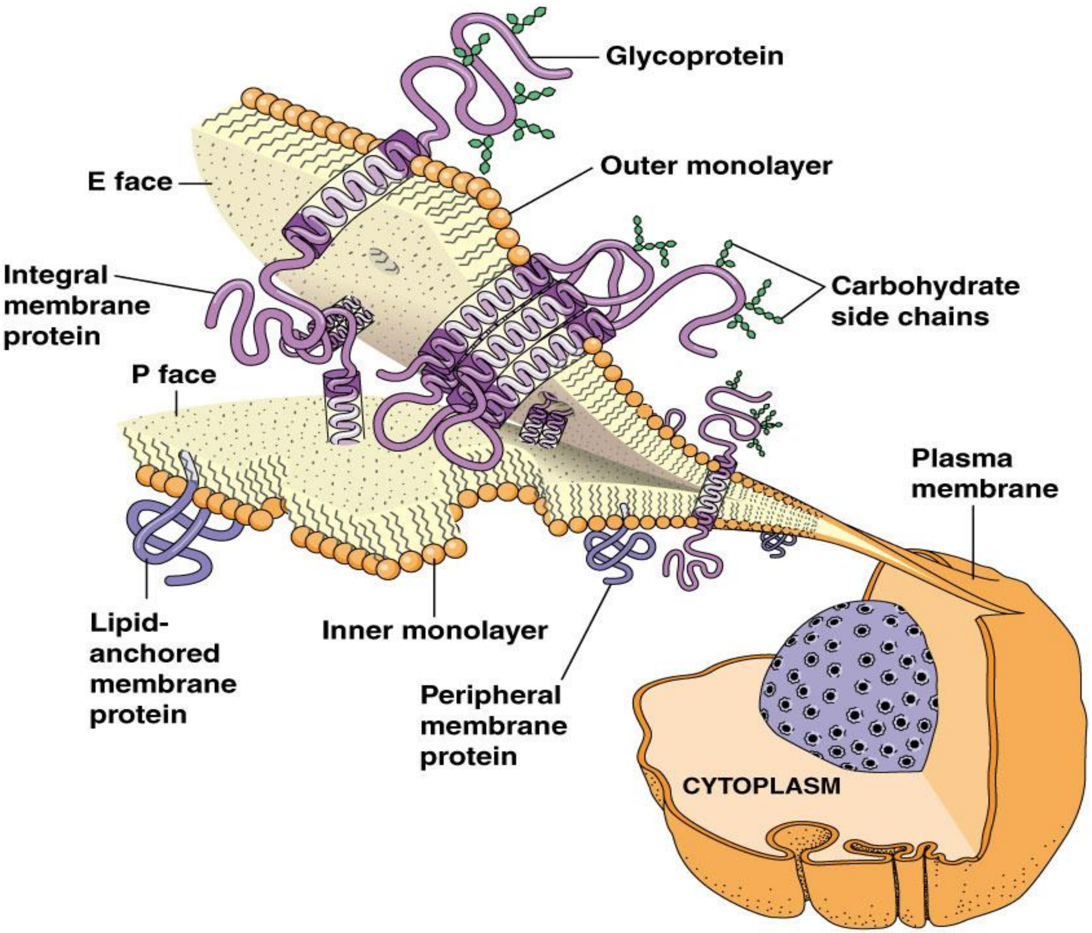
MOSAIC

- **Proteins embedded** in the phospholipid bilayer in a **scattered or random** arrangement

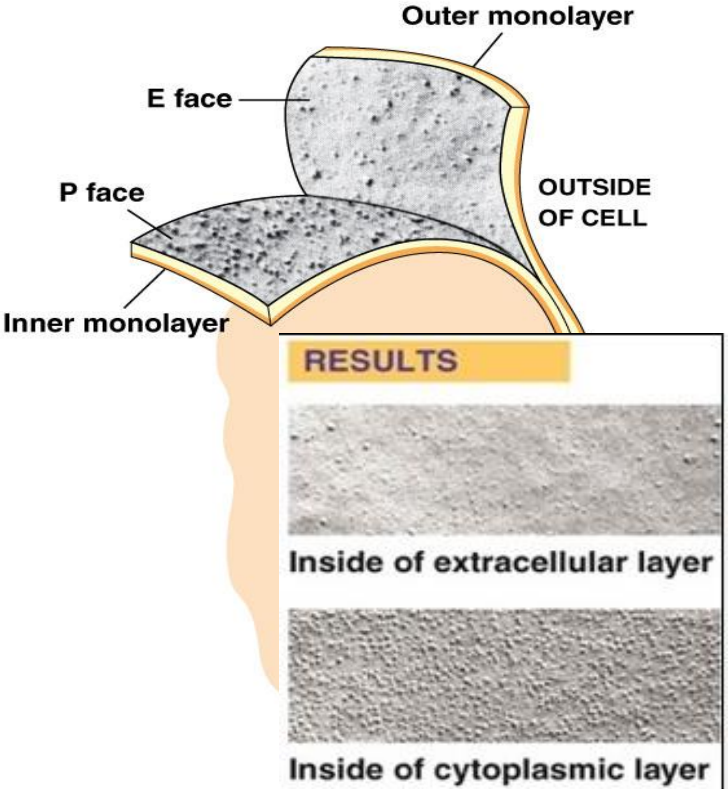


Evidence – freeze-fracture technique

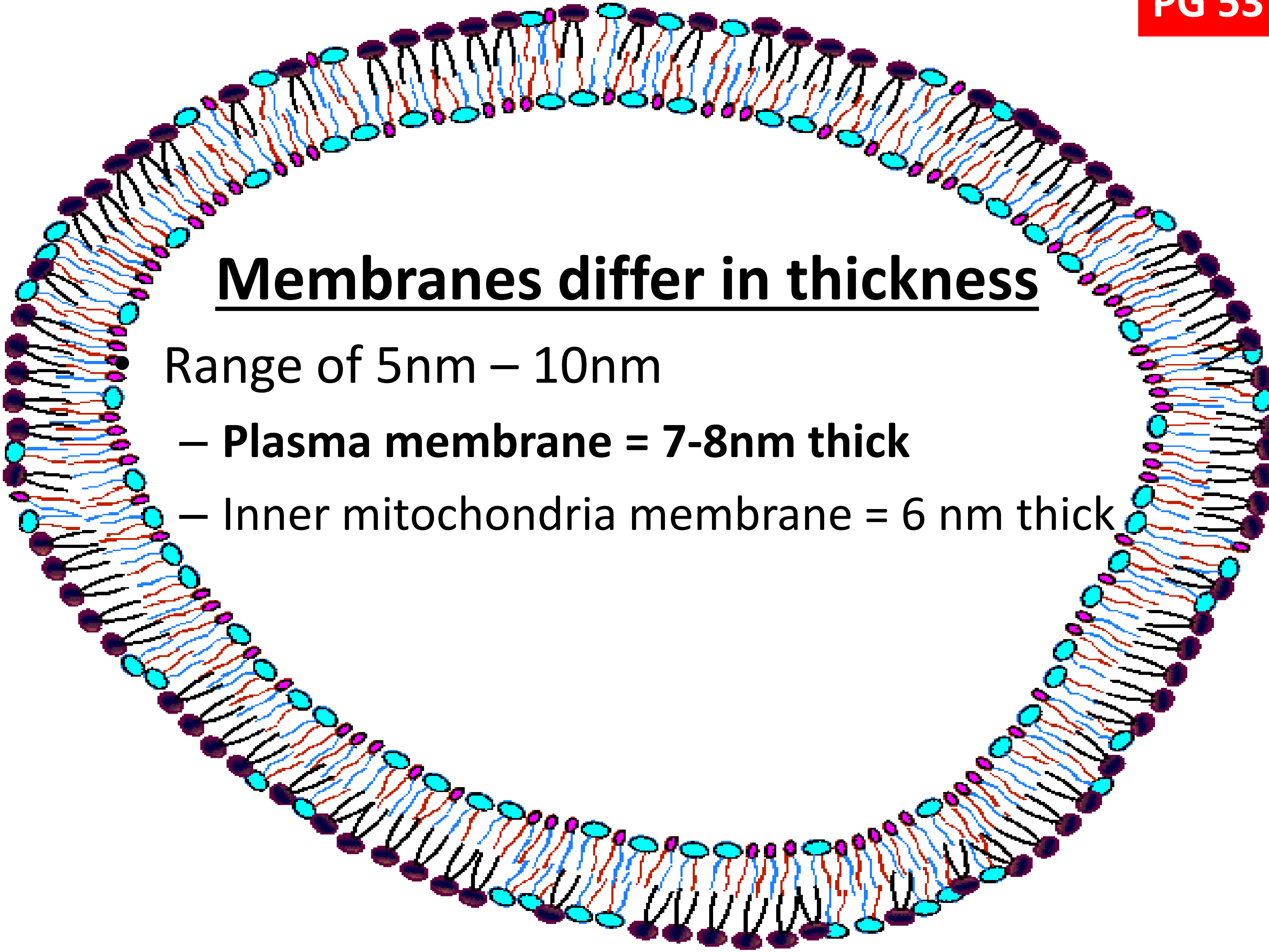
(a) Separation of membrane monolayers. Notice how the fracture plane has passed through the hydrophobic interior of the membrane, revealing the inner surfaces of the two monolayers. Integral membrane proteins that remain with the outer monolayer are seen on the E (exoplasmic) face, whereas those that remain with the inner monolayer are seen on the P (protoplasmic) face.



(b) Surface view of monolayers. This sketch of a freeze-fractured membrane shows electron micrographs of the E and P faces from the plasma membrane of a mouse kidney tubule cell. Individual proteins imbedded in either face show up as small particles (TEMs).



Membranes differ in thickness

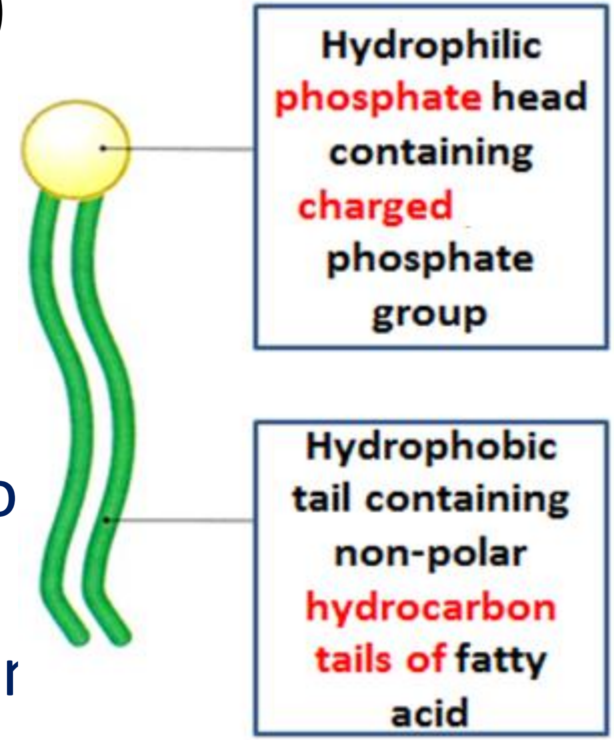


- Range of 5nm – 10nm
  - **Plasma membrane = 7-8nm thick**
  - Inner mitochondria membrane = 6 nm thick

Phospholipids

- **Main** lipid found in membranes (cell surface membranes & cell membranes)
- **Form a <u>bilayer</u>**
- **Is an <u>amphipathic</u> molecule**
  - has both hydrophilic and hydrophobic ends

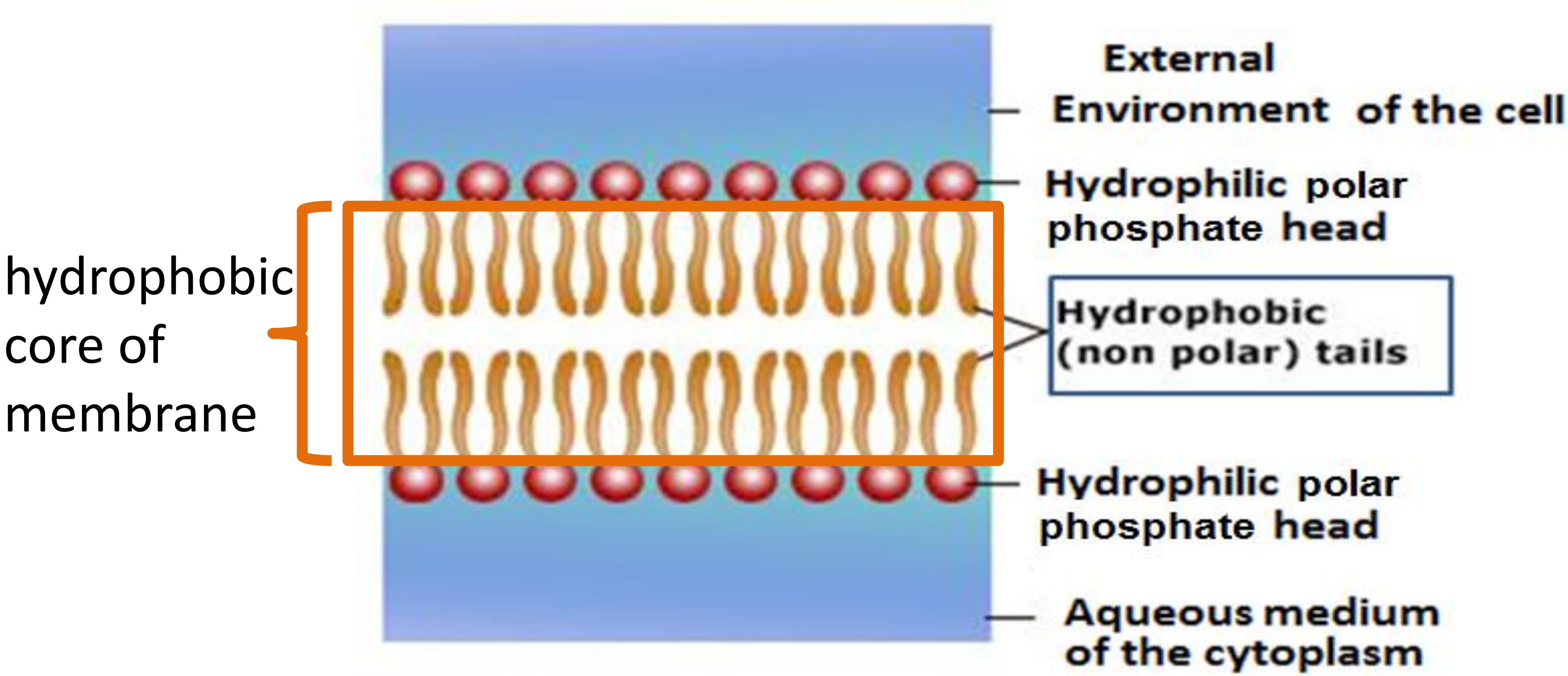
reason fo
bilayer
formatior



<u>amphipathic</u> vs amphoteric?

Phospholipid Bilayer formation

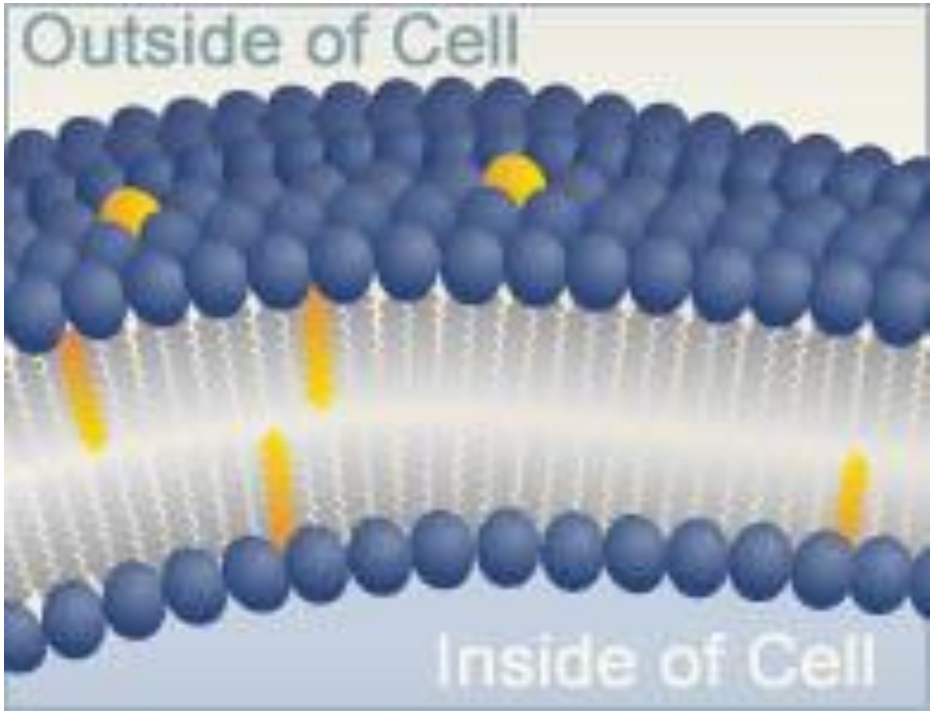
- Hydrocarbon chains of fatty acids in phospholipid
  - face each other in the interior of the bilayer
  - forming the interior of the cell membrane



Phospholipids in Plasma Membrane

What is/are the kind of bonds formed when the hydrophobic fatty acid tails interact with each other?

Non-polar hydrocarbon tails interact with other hydrophobic tails via **hydrophobic interactions**



Phospholipids in Plasma Membrane

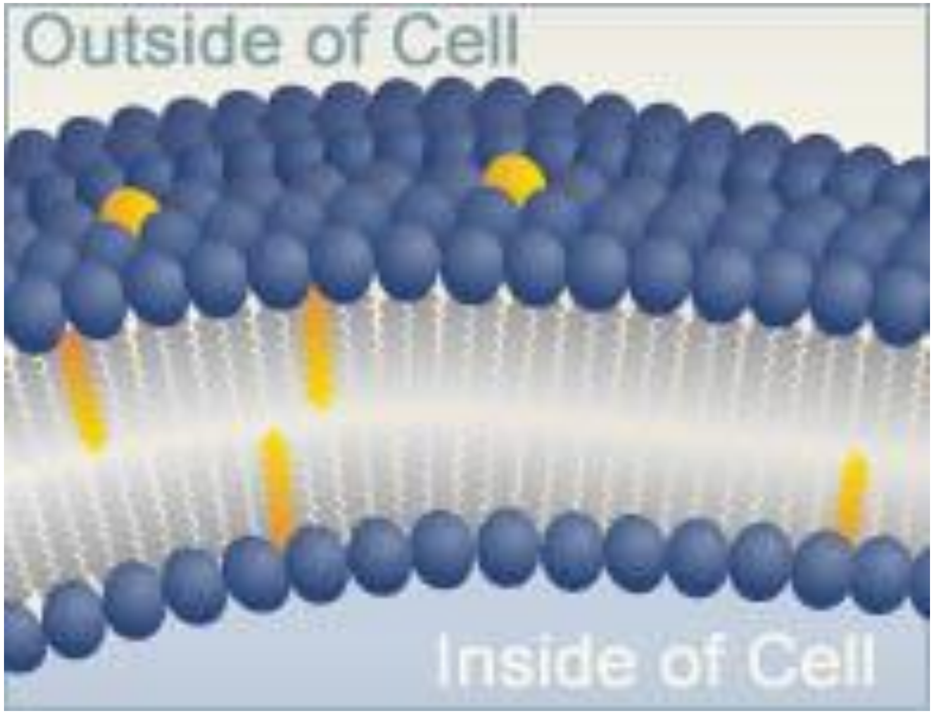
In cell surface membrane,

- Hydrophilic polar phosphate head of phospholipid molecules faces **outwards** (of the bilayer) and interacts with aqueous medium of

Phosphate heads interact with **external environment**

Hydrophobic core

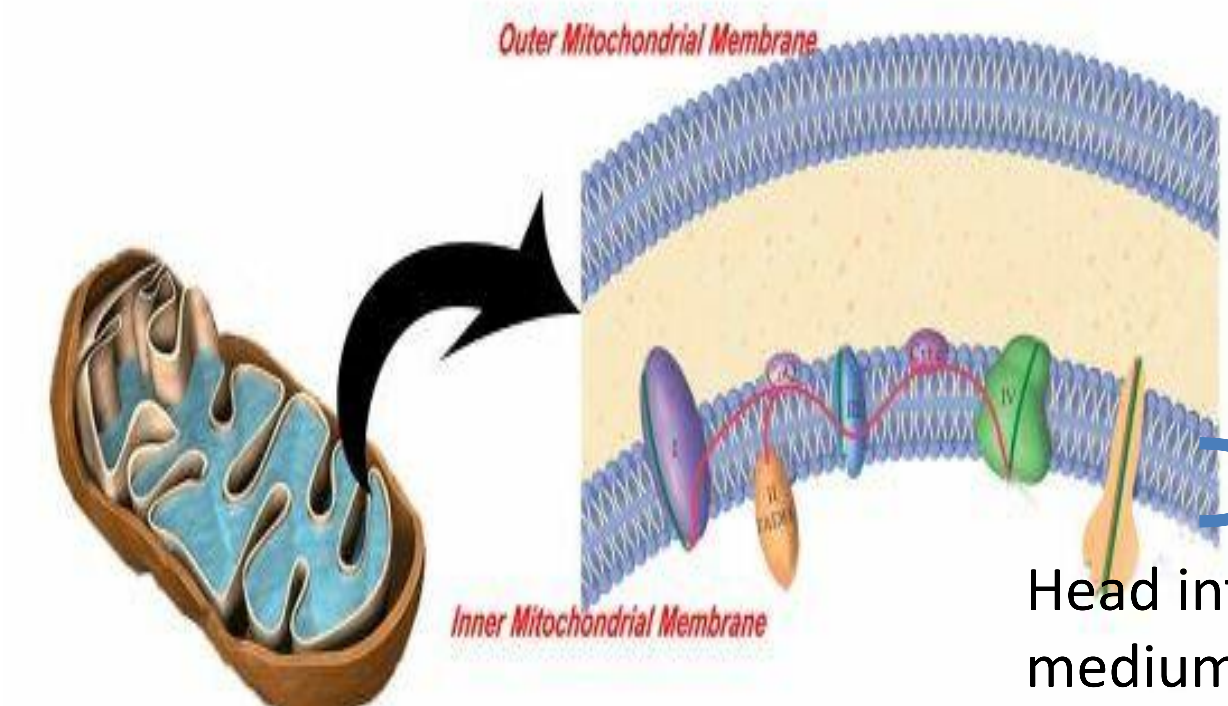
Phosphate heads interact with aqueous medium of **cytoplasm**



Phospholipids in Cell Membrane

In cell membranes,

- Hydrophilic polar phosphate heads of phospholipid molecules face **outwards** (of the bilayer) and interacts with the aqueous ~~cytoplasm~~ **medium** of the cytoplasm on either side of the cell membrane.



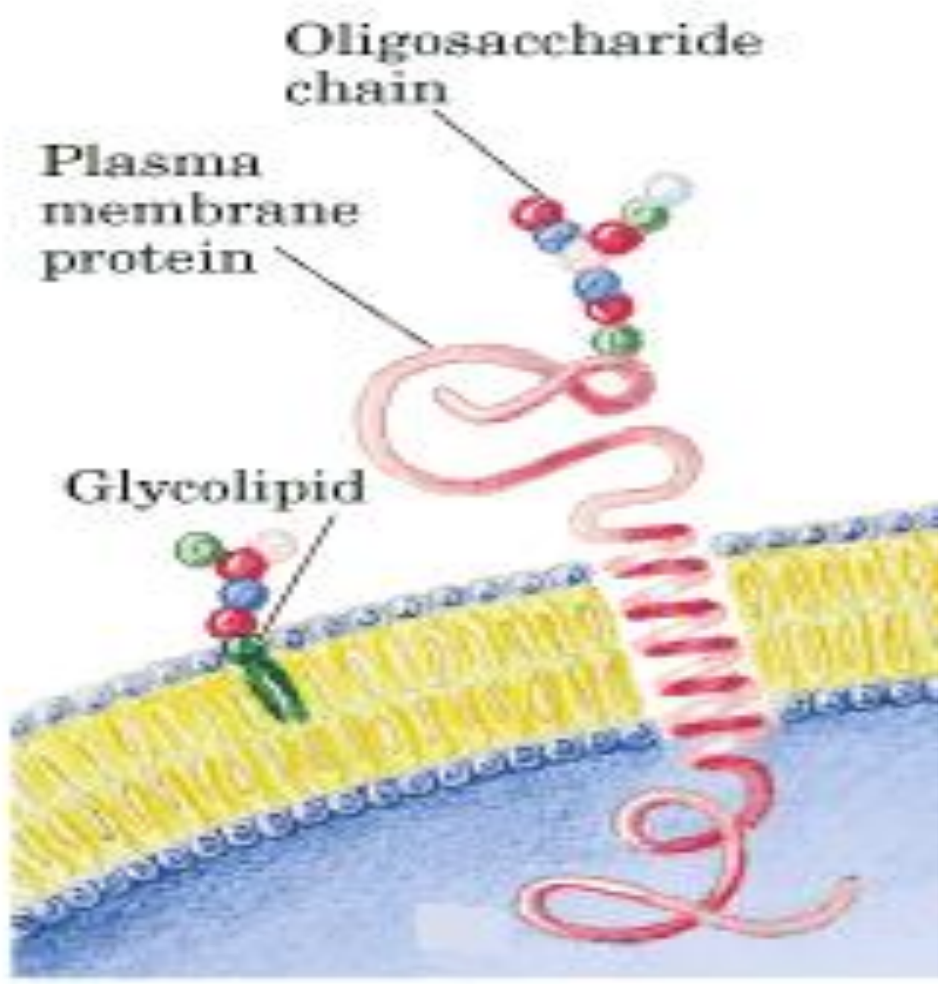
Head interacts with aqueous medium in intermembrane space

Hydrophobic core

Head interacts with aqueous medium in mitochondrial matrix

Recall: Glycolipid

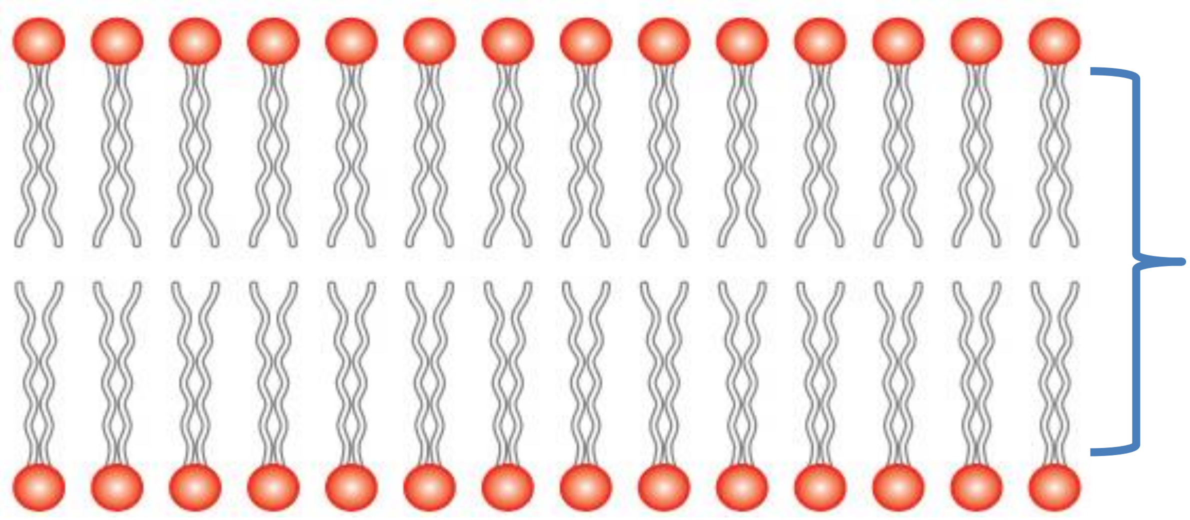
Serve as **recognition sites for cell-cell interaction**



Learning Objectives

1(l) **Explain** how and why different substances move across membranes through **simple diffusion**, **osmosis**, **facilitated diffusion**, **active transport**, **endocytosis** and **exocytosis**.

Selective permeability of membranes



Hydrophobic core makes up a large part of the membrane

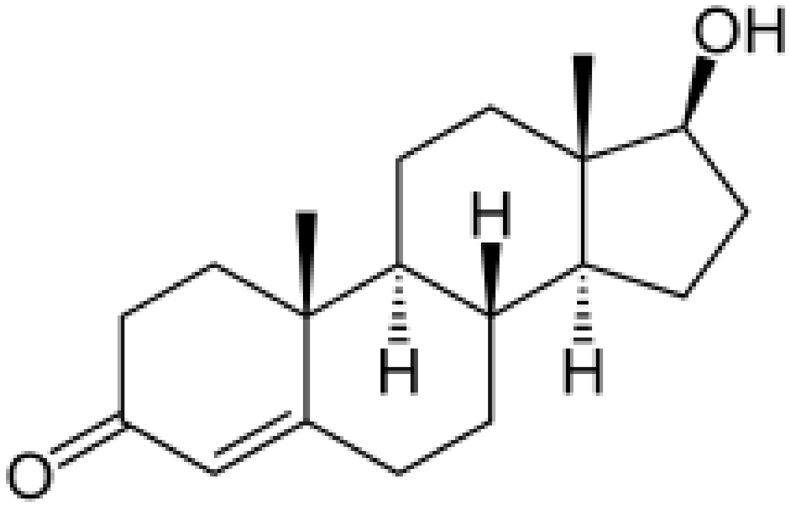
Important in determining the selective permeability!!

Selective permeability of membranes

- To be able to diffuse across a membrane, generally, the molecule needs to be:
  - **Non-polar**
  - **Uncharged**
  - **Small**

(Non-polar and Uncharged: hydrophobic)

Is this polar, non-polar, charged or uncharged?



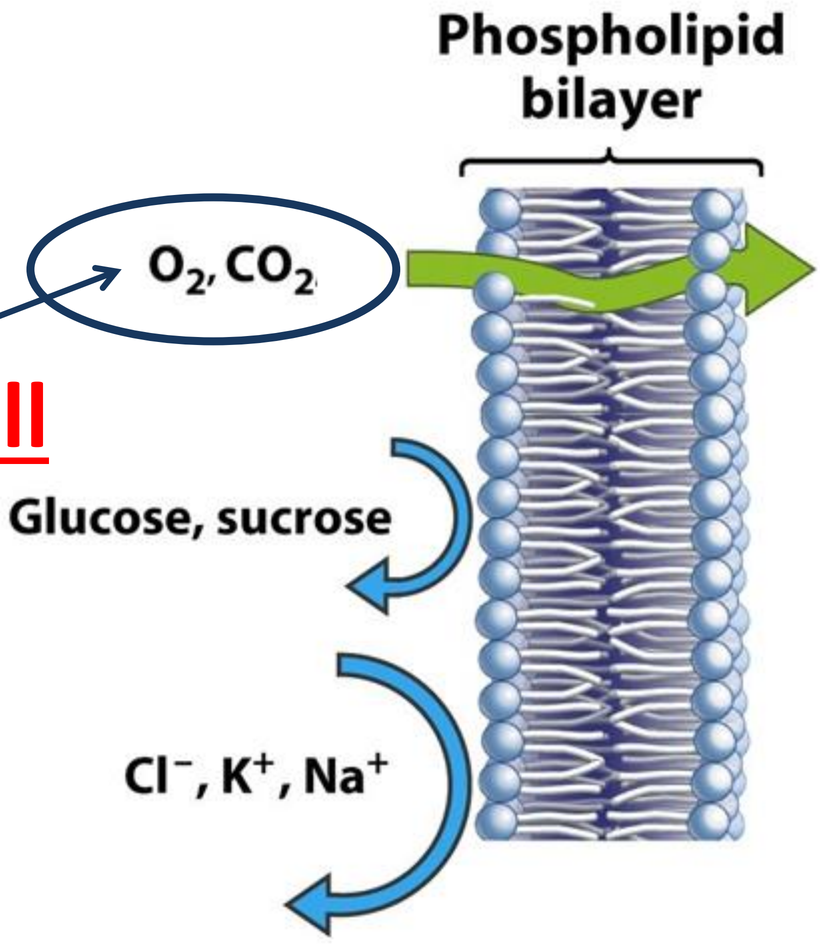
testosterone

Non-polar!

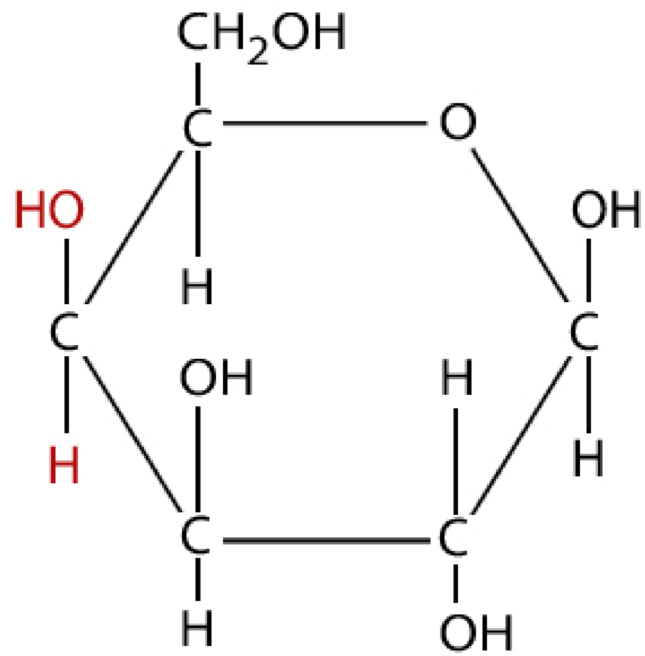
Main Features of Membranes

Selective permeability

- **Non-polar (hydrophobic)** and **small uncharged molecules** dissolve in the membrane and diffuse across the membrane.



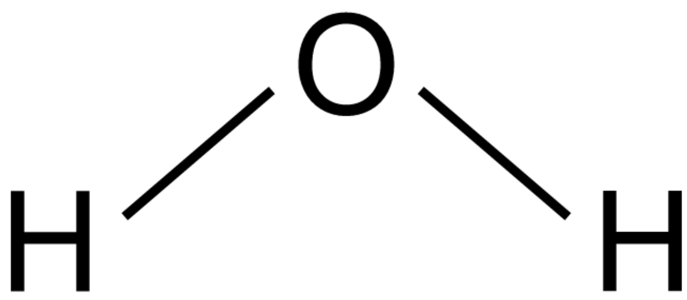
Is this polar, non-polar, charged or uncharged?



Galactose

Polar!

Is this polar, non-polar, charged or uncharged?



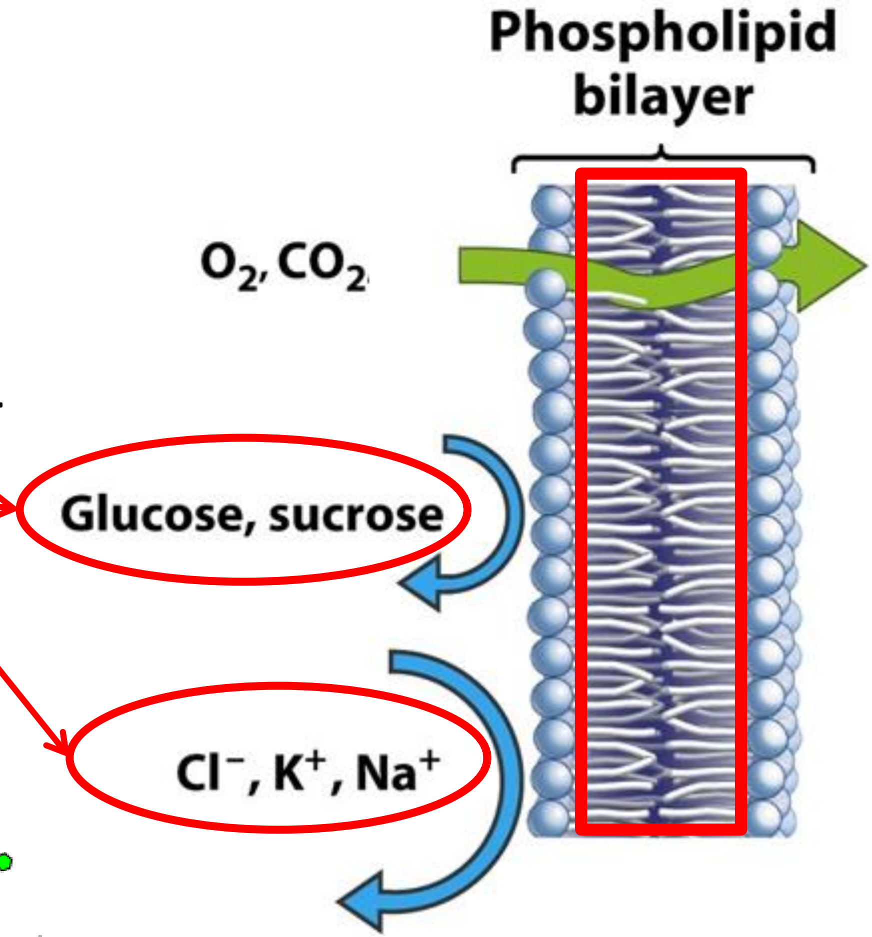
Water

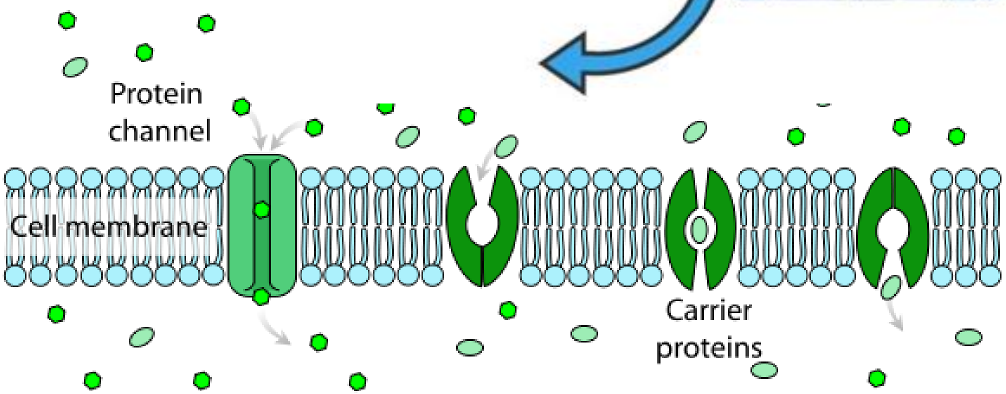
Polar!

Main Features of Membranes

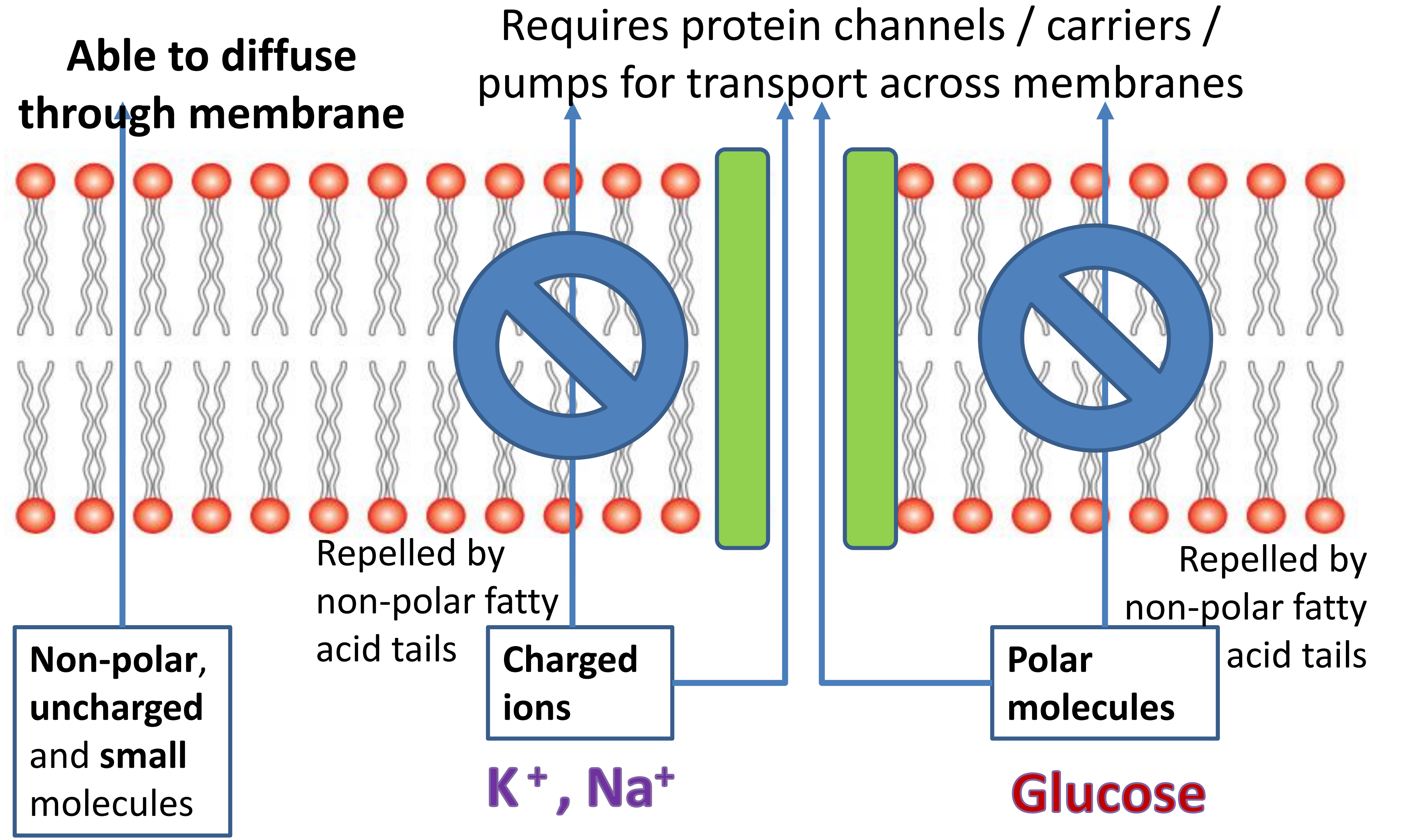
Selective permeability

- Hydrophobic core of phospholipid bilayer restricts movement of **charged ions** & (generally **large**) **polar** molecules
- They enter cell via selective transmembrane **protein channels / carriers / pumps**.





Selective permeability of membranes



Type of transport processes

Simple transport

for small molecules e.g CO_2, glucose

- Simple diffusion
- Osmosis
- Facilitated diffusion
- Active transport

Bulk transport

for large molecules e.g large protein (insulin), particles eg viruses, macromolecules

- exocytosis
- endocytosis
  - pinocytosis
  - phagocytosis
  - receptor-mediated endocytosis

Overview:

Transport across membranes can occur via

- Simple diffusion
- Osmosis
- Facilitated diffusion
- Active transport
- Bulk transport

Do not involve expenditure of ATP

Require transport proteins

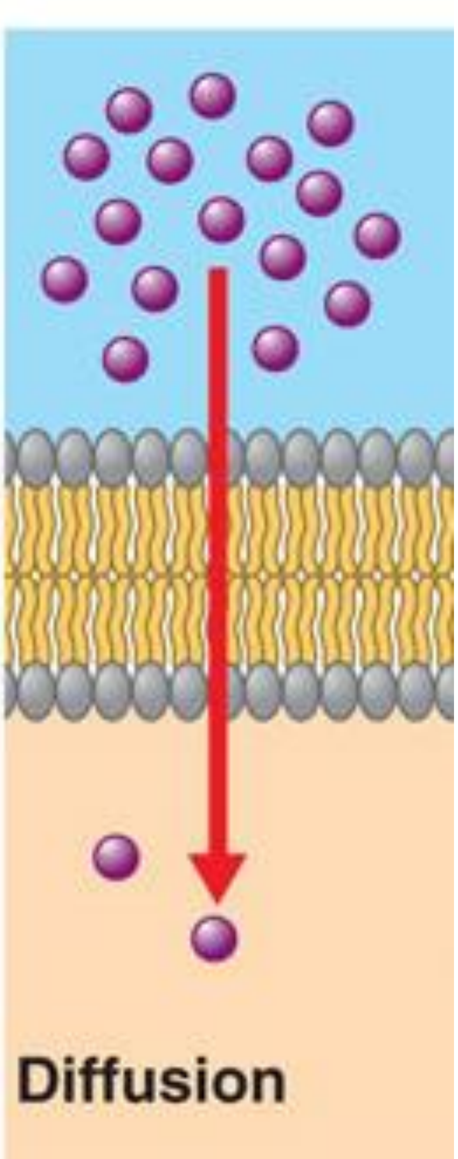
Involve expenditure of ATP

Transport processes that <u>do not require proteins</u>

(1) diffusion (2) osmosis

(1) Diffusion

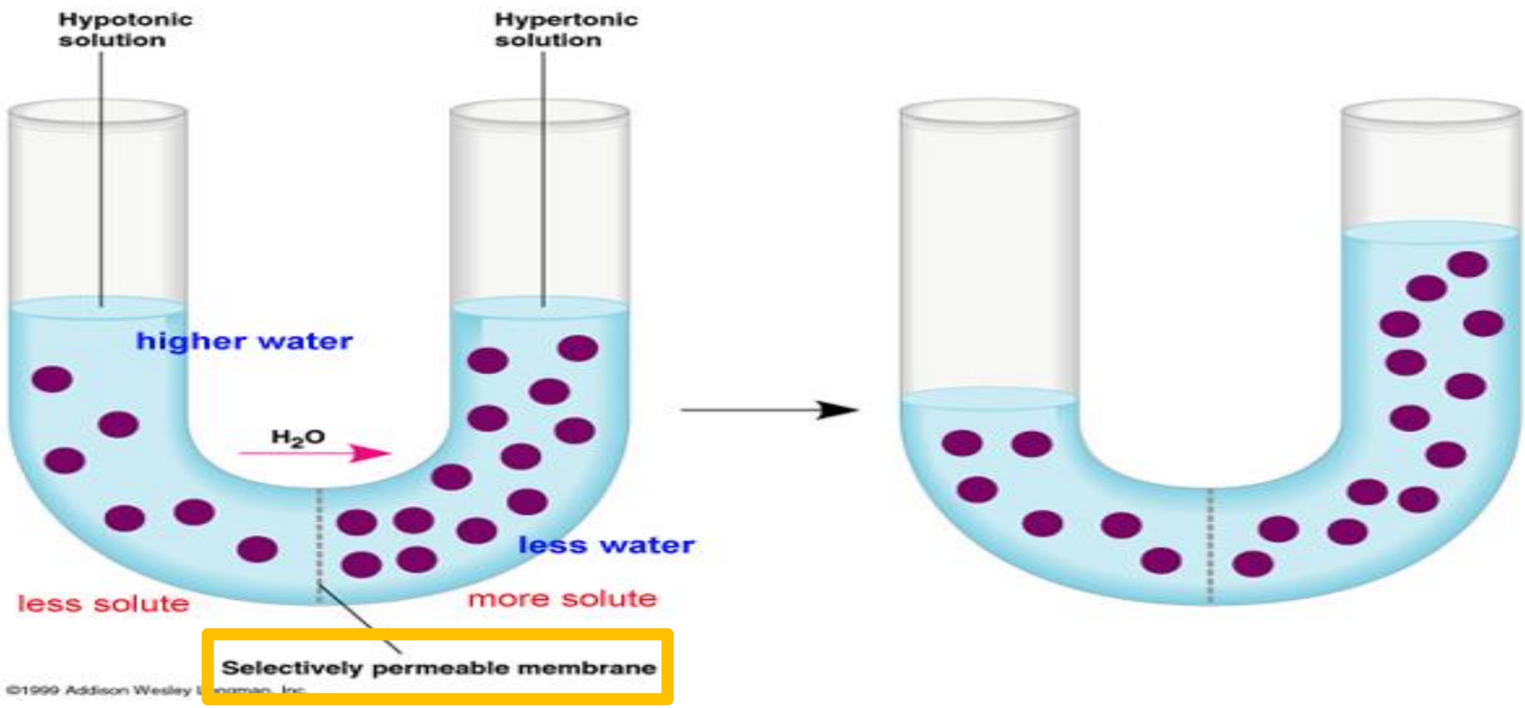
- [no hydrolysis of ATP for energy]
  - **Passive transport**
  - Usually **small** molecules (e.g. O_2, CO_2) or **non-polar** ones (e.g. testosterone)



Transport processes that **do not require proteins**

(2) Osmosis

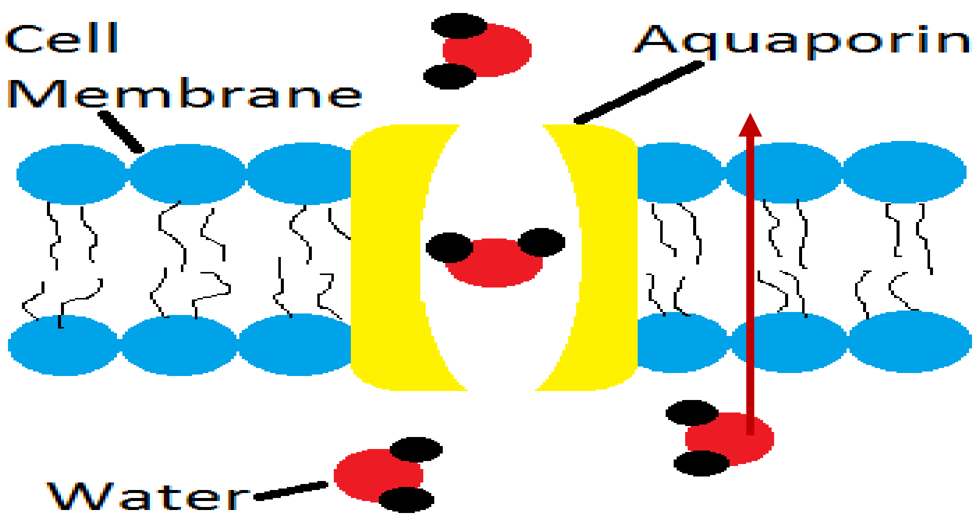
- [no hydrolysis of ATP for energy]
  - **Passive transport**
  - Only for H_2O molecules



Movement of water through a membrane

Small, polar molecule

- 2 ways that water could move across membrane:
  1) Directly across lipid bilayer
  2) Via **aquaporins**: transport proteins that provide hydophillic channels for H_2O to pass through



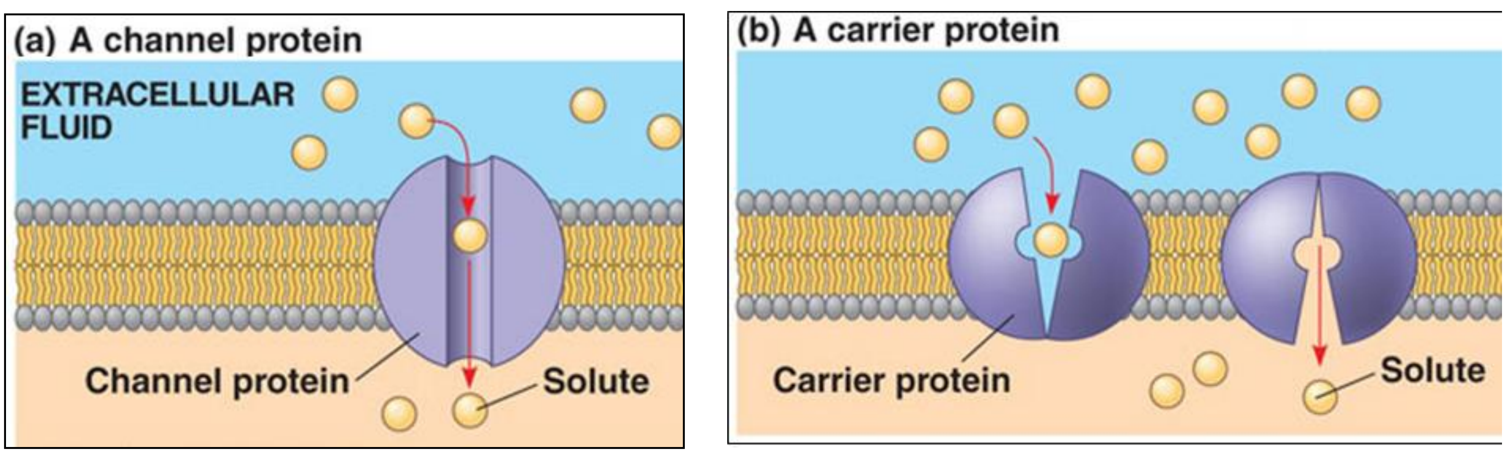
Channel protein!

Transport processes that require proteins

(1) facilitated diffusion (2) active transport

(1) Facilitated transport

- [no hydrolysis of ATP for energy needed]
  - **Passive transport**
- Transport proteins (**channel** proteins, **carrier** proteins)
  - Allow transport of **charged ions & polar molecules**

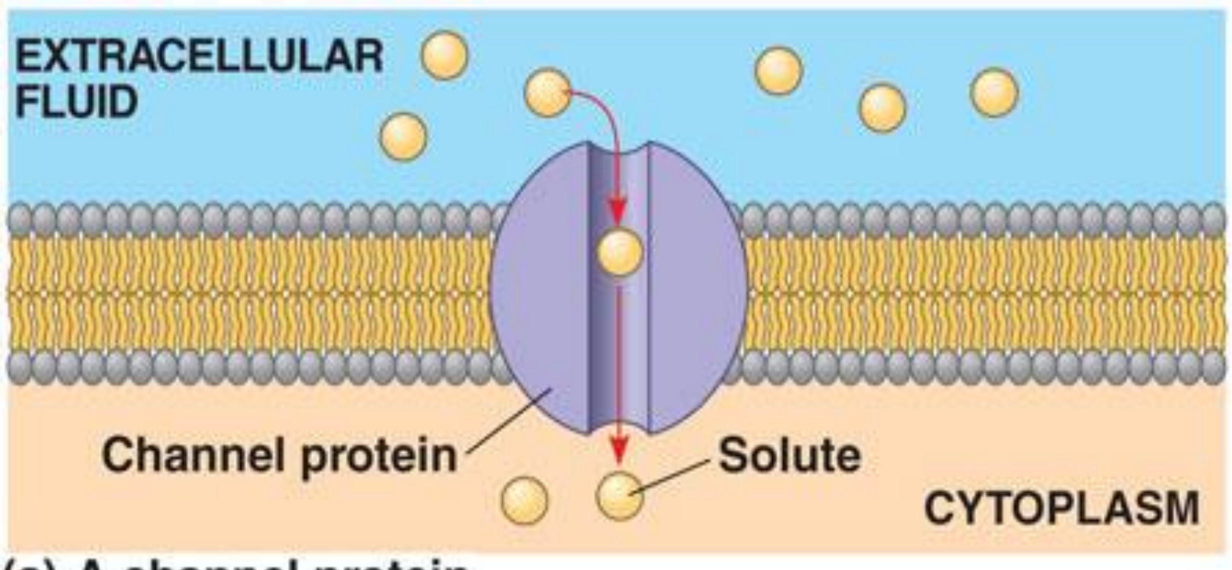


Transport processes that <u>require proteins</u>

(1) Facilitated transport

- Some proteins span the cell surface membrane and forms a hydrophilic channel which allows polar molecules to pass through

➔ **channel** proteins



(a) A channel protein

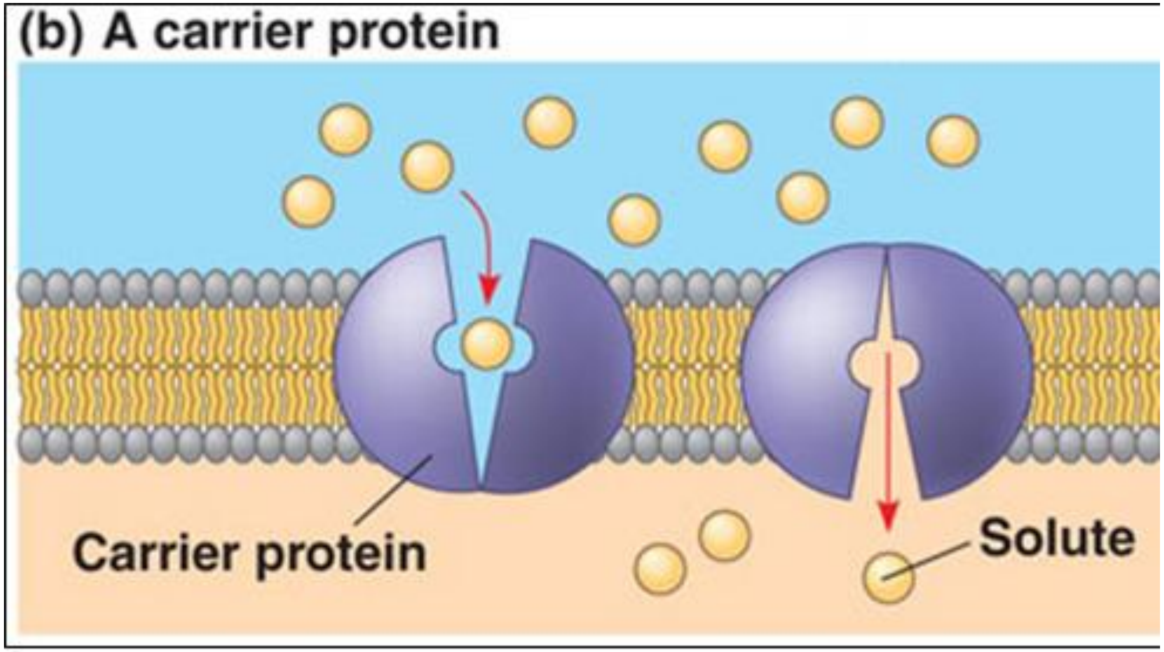
Transport processes that **require proteins**

(1) Facilitated transport

- Other proteins are **carriers** specific for a particular molecule

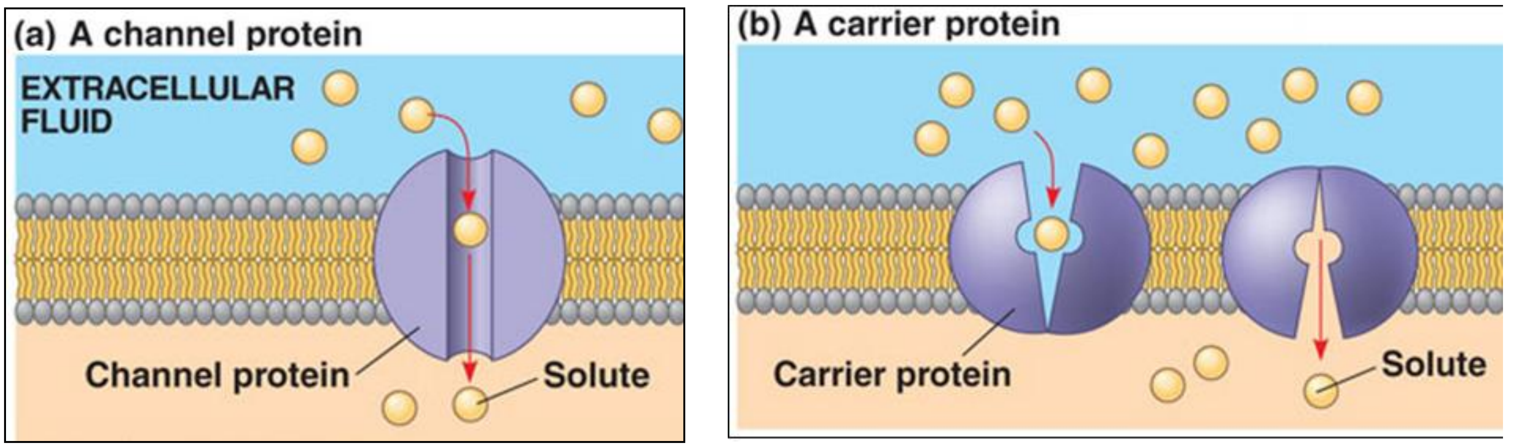
→ **carrier** proteins

Complementary binding site to the specific molecule



Facilitated diffusion is EXACTLY like diffusion except that:

- It is via a **protein** (transport, carrier, channel)
- Allows transport of charged ions or polar molecules

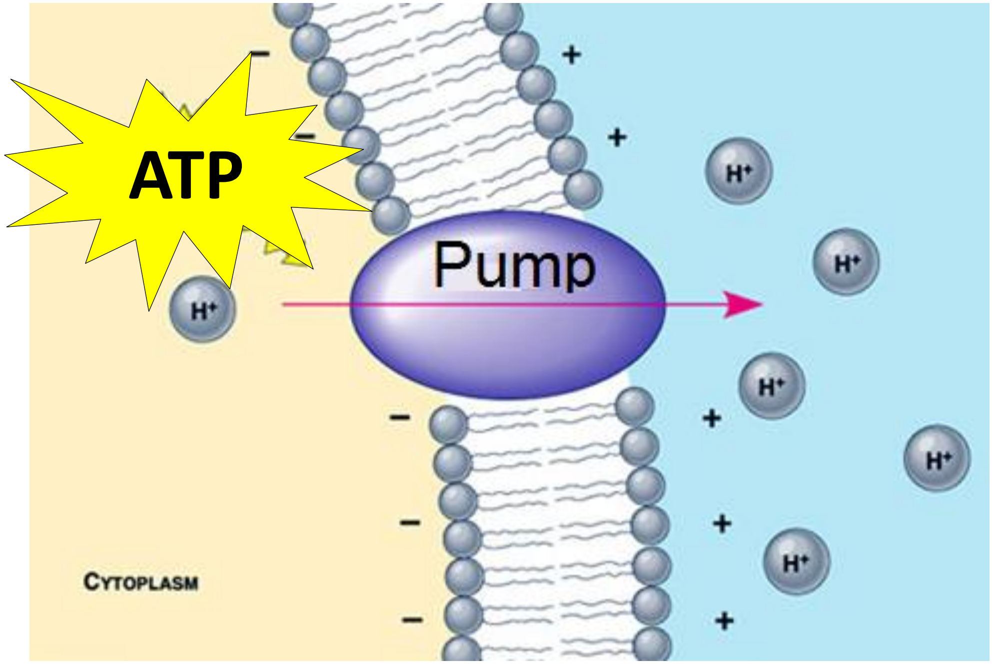


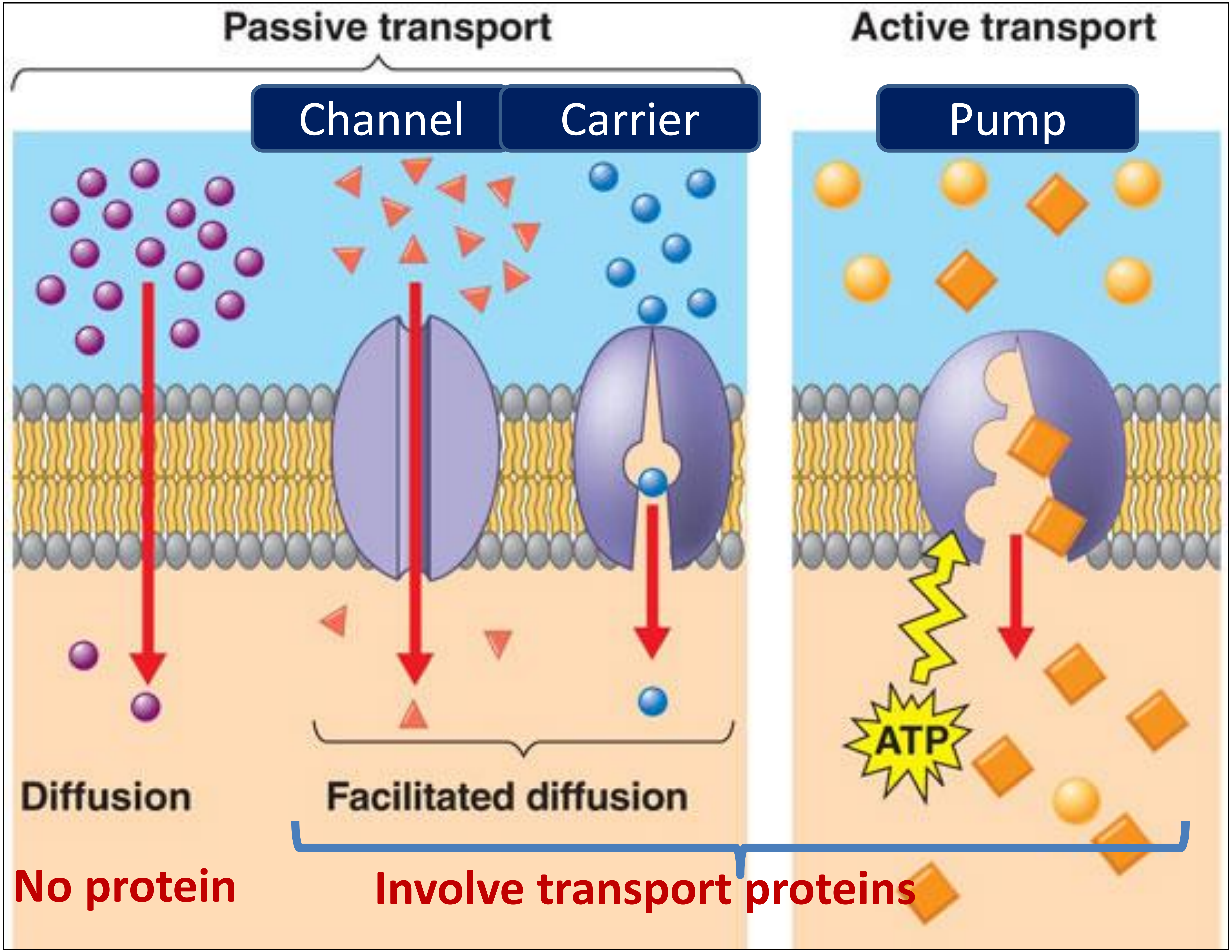
Transport processes that **require proteins**

(2) Active transport

- Requires **protein pumps** (a type of carrier protein)
- Protein pump **hydrolyses ATP** as an energy source required to **pump** substances across the cell membrane

NB: ATP is synthesized within the cell during cellular respiration




Passive transport
Active transport
Channel
Carrier
Pump
ATP
Diffusion
Facilitated diffusion
No protein
Involve transport proteins

Bulk Transport across Cell Surface Membrane

Definition

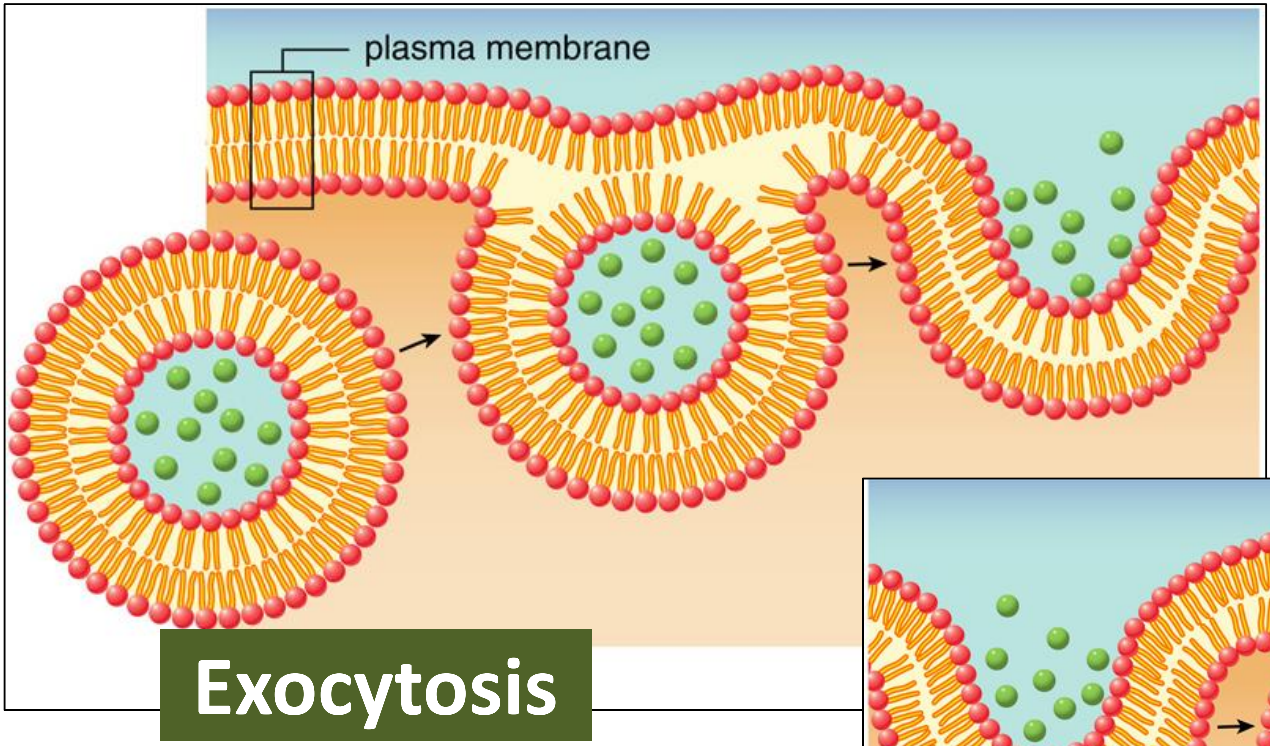
- Movement of **large-sized** materials into cells (**endocytosis**) or out of cells (**exocytosis**).
- Example: Large molecules such as **proteins**
- This process **requires energy** (from hydrolysis of ATP) for movement of vesicles along microtubules

Bulk Transport across Cell Surface Membrane

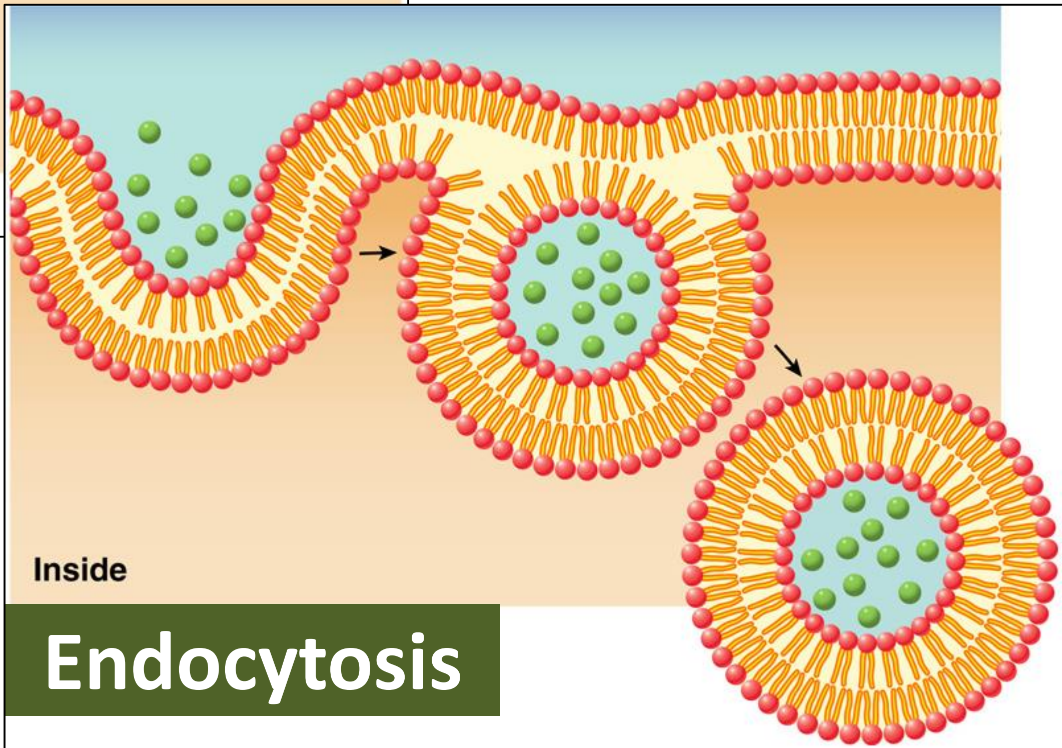
Bulk transport vs **Active transport**

- No concentration gradient involved in bulk transport.

Bulk transport across cell surface membrane



Exo – Out of the cell

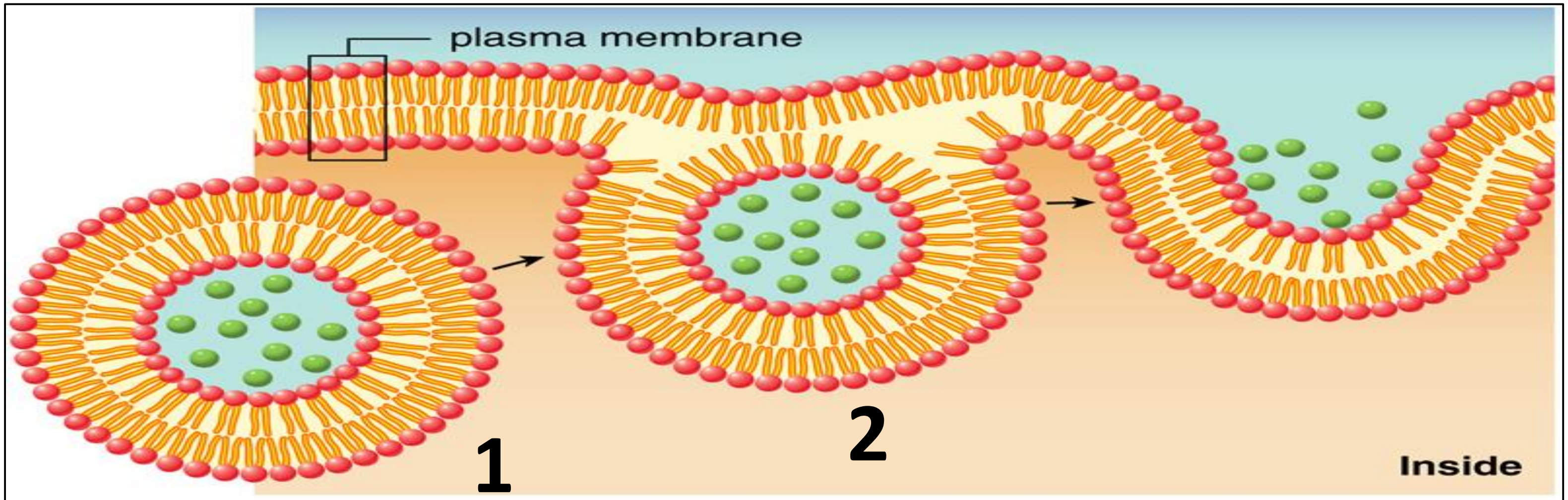


Endo – into the cell

Exocytosis

For proteins synthesized in the cell that are to be secreted out of the cell:

1. Secretory vesicles **migrate** or move towards the plasma membrane (cell surface membrane)
2. Membrane of the vesicle **fuses** with the plasma membrane

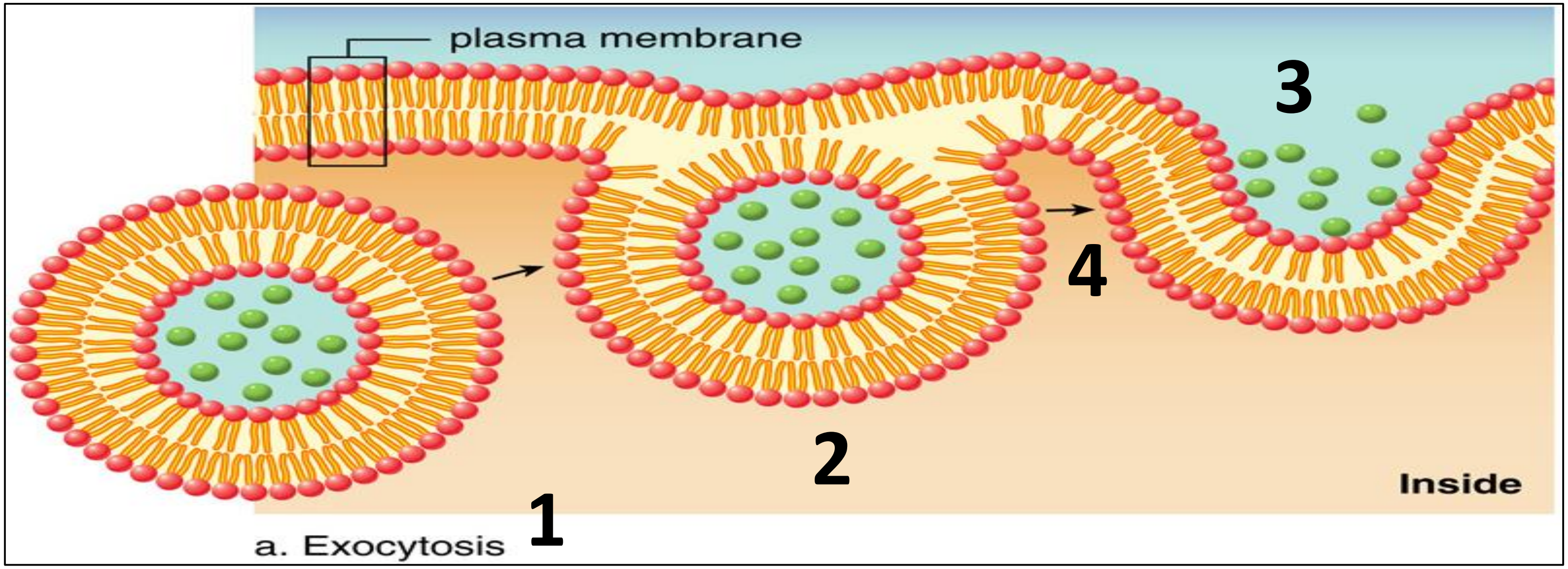


a. Exocytosis

Exocytosis

For proteins synthesized in the cell that are to be secreted out of the cell:

3. Vesicle membrane becomes part of the **plasma membrane**
4. Contents of vesicles are **released** to the outside of cell **via exocytosis**

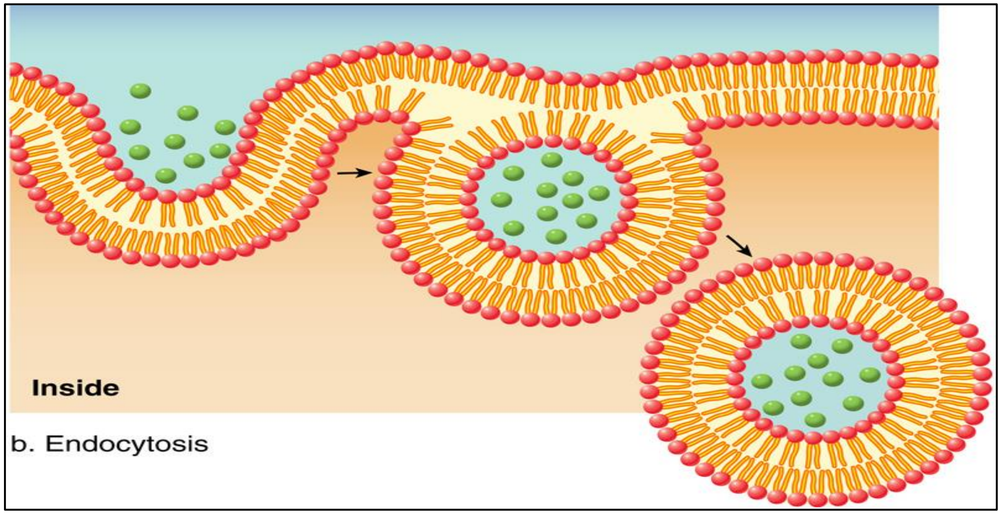


Endocytosis

- Molecules enter cells when cell surface membrane pinch inwards (invaginates) enclosing the molecules within vesicles

3 types of endocytosis:

- **1) phagocytosis**,
- **2) pinocytosis** &
- **3) receptor-mediated endocytosis**



Animation on endocytosis & exocytosis

https://youtu.be/XCqwYRjKWOc

Type of transport processes

Simple transport

for small molecules e.g CO_2, glucose

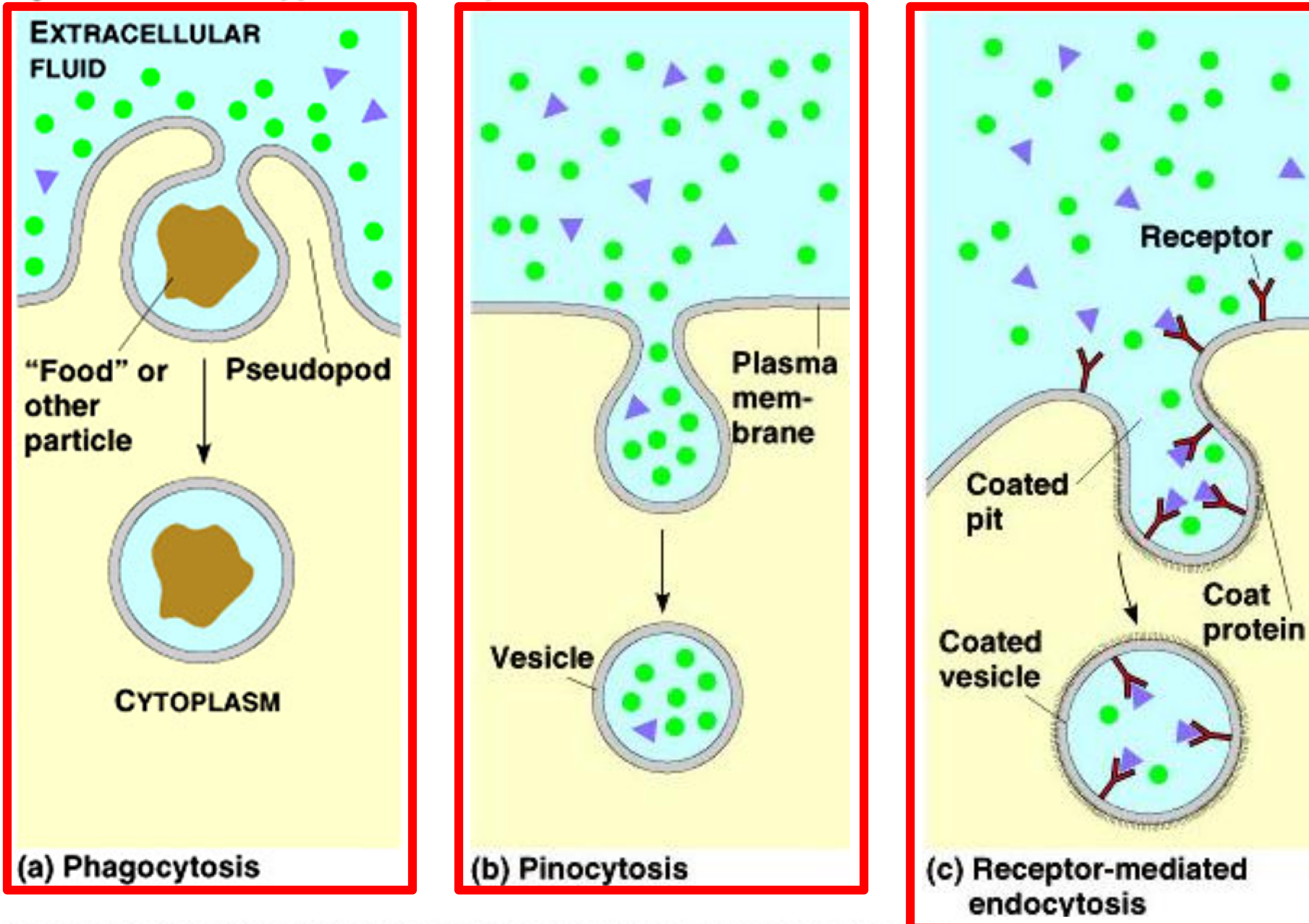
- Simple diffusion
- Osmosis
- Facilitated diffusion
- Active transport

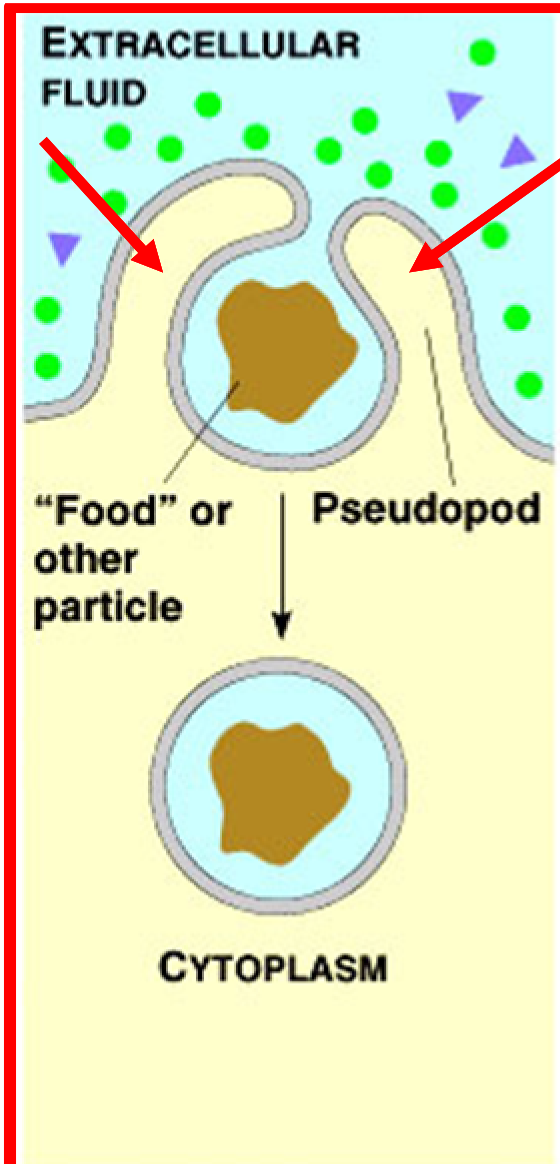
Bulk transport

for large molecules e.g large protein (insulin), particles eg viruses, macromolecules

- exocytosis
- endocytosis
  - pinocytosis
  - phagocytosis
  - receptor-mediated endocytosis

Figure 8.17 Three types of endocytosis in animal cells

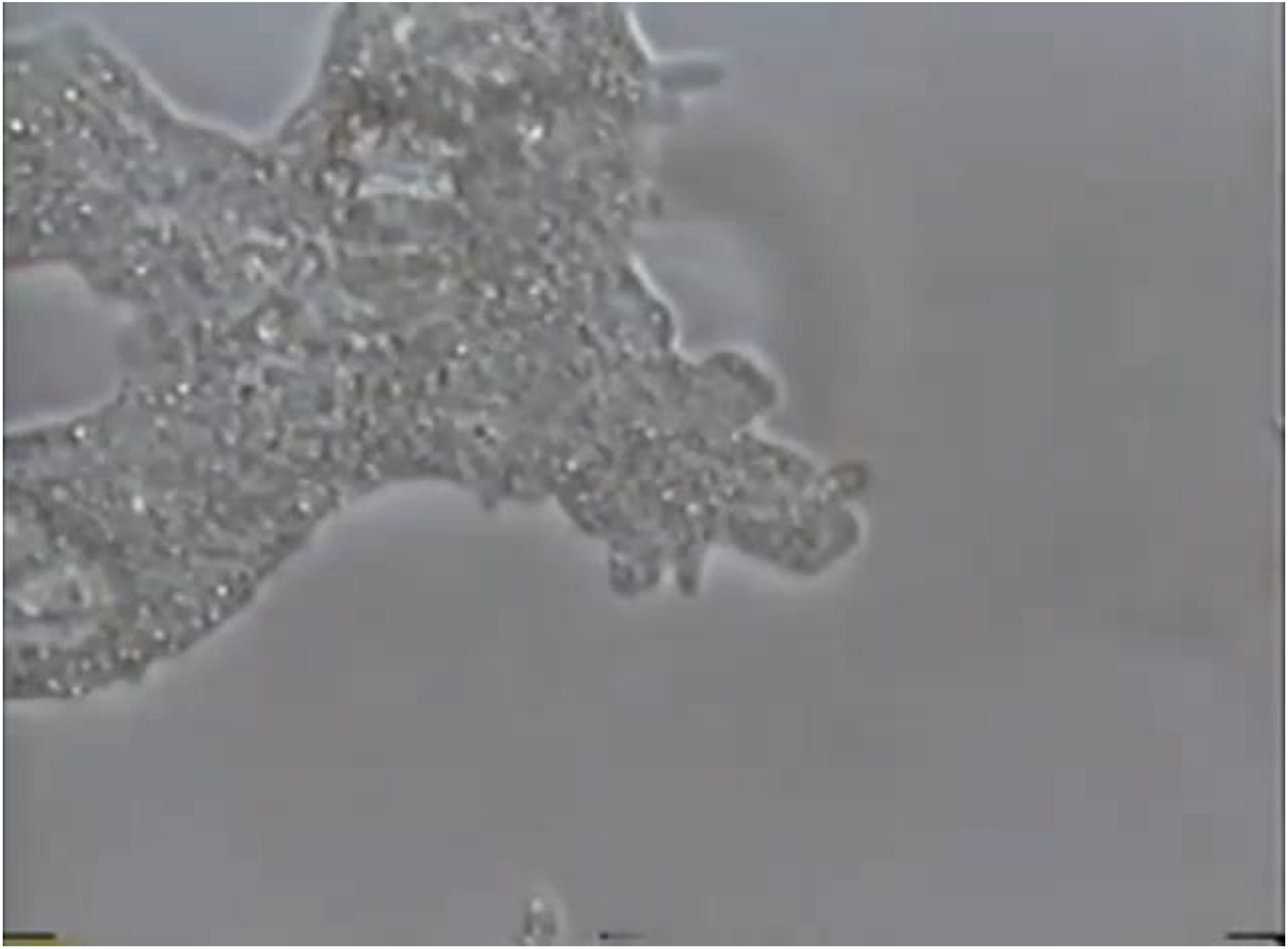




(a) Phagocytosis

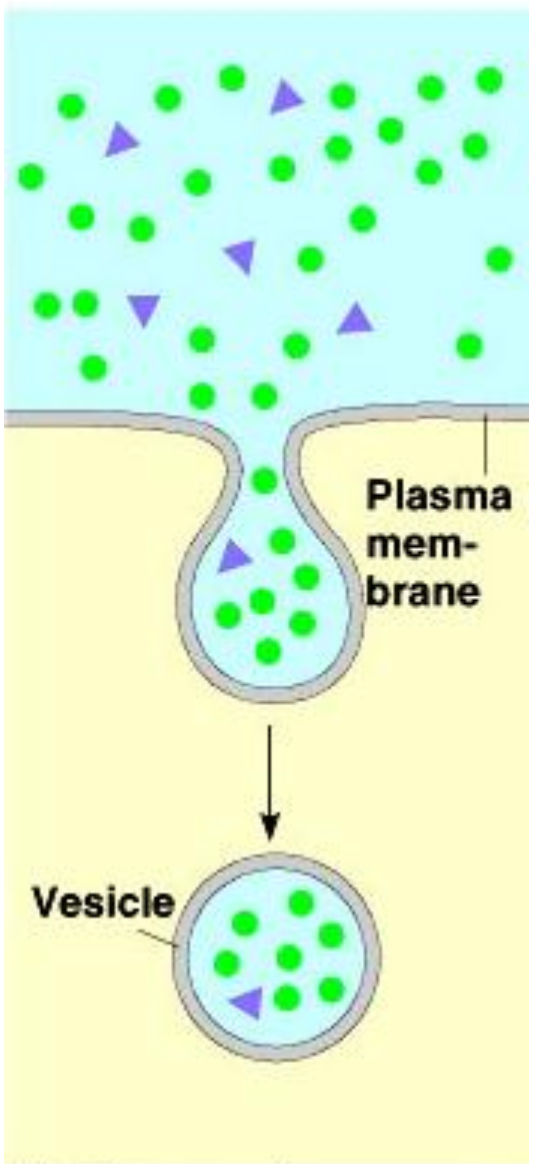
Phagocytosis

- "Cell eating"
- **Large particles** such as microorganisms, cell debris are taken into large vesicles
- Specialised phagocytic cells carry out phagocytosis eg. immune cells



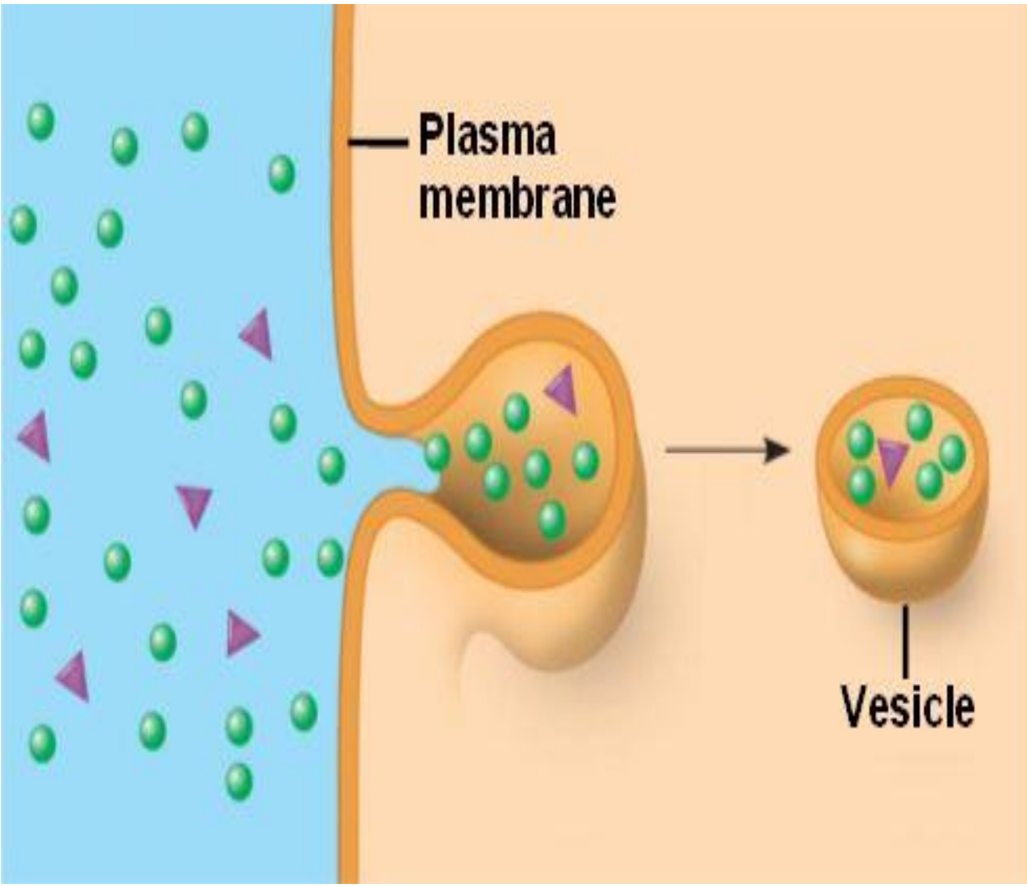
Pinocytosis

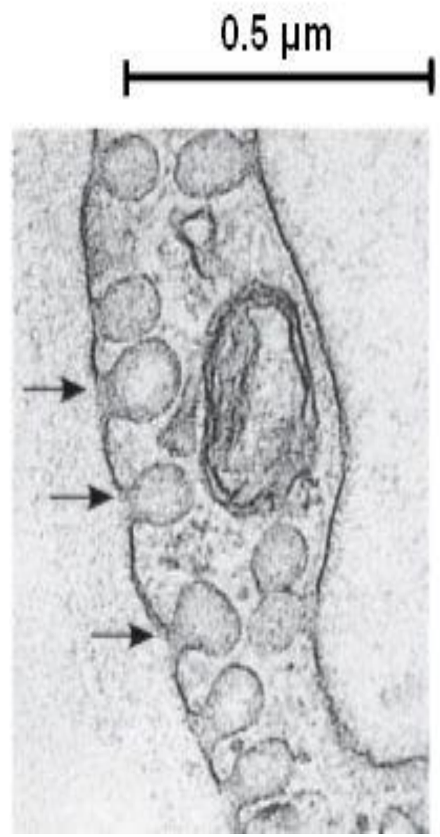
- “Cell drinking”
- **Fluid / Solutes** brought into the cell
- Most cells carry out pinocytosis



(b) Pinocytosis

Endocytosis – Pinocytosis



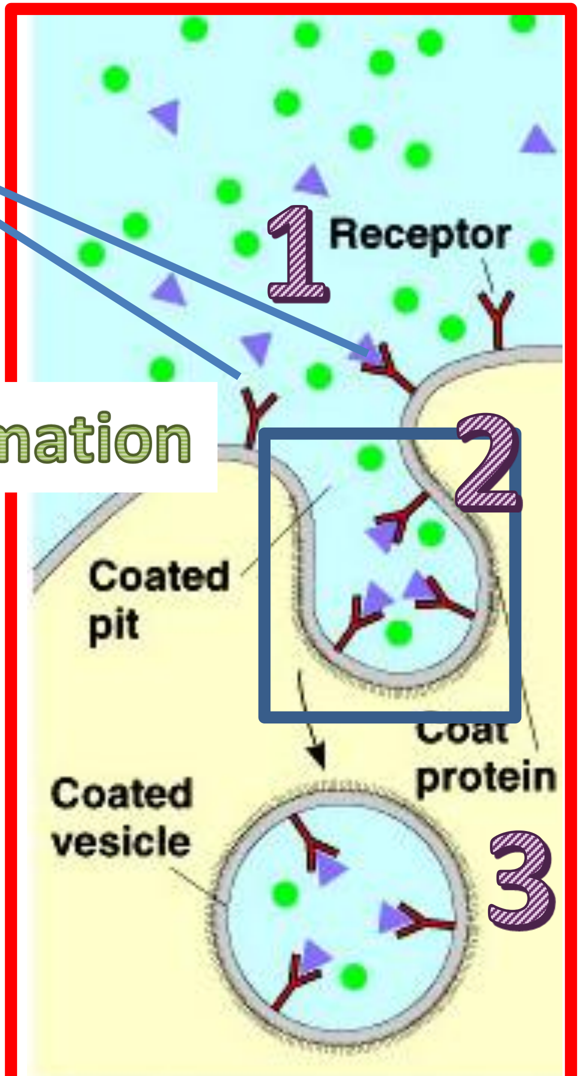


Pinocytosis vesicles forming (arrows) in a cell lining a small blood vessel (TEM)

Receptor-mediated endocytosis

ligands

1. Specific macromolecules (the **ligand**) bind to specific recognition sites on cell surface protein receptors complementary conformation
2. Plasma membrane region containing receptor-ligand complex undergoes endocytosis
3. ~~Transport~~ **Vesicle** is formed
    - Receptor-ligand complexes selectively incorporated into ~~transport~~ **vesicle**



(c) Receptor-mediated endocytosis

Receptor Mediated Endocytosis

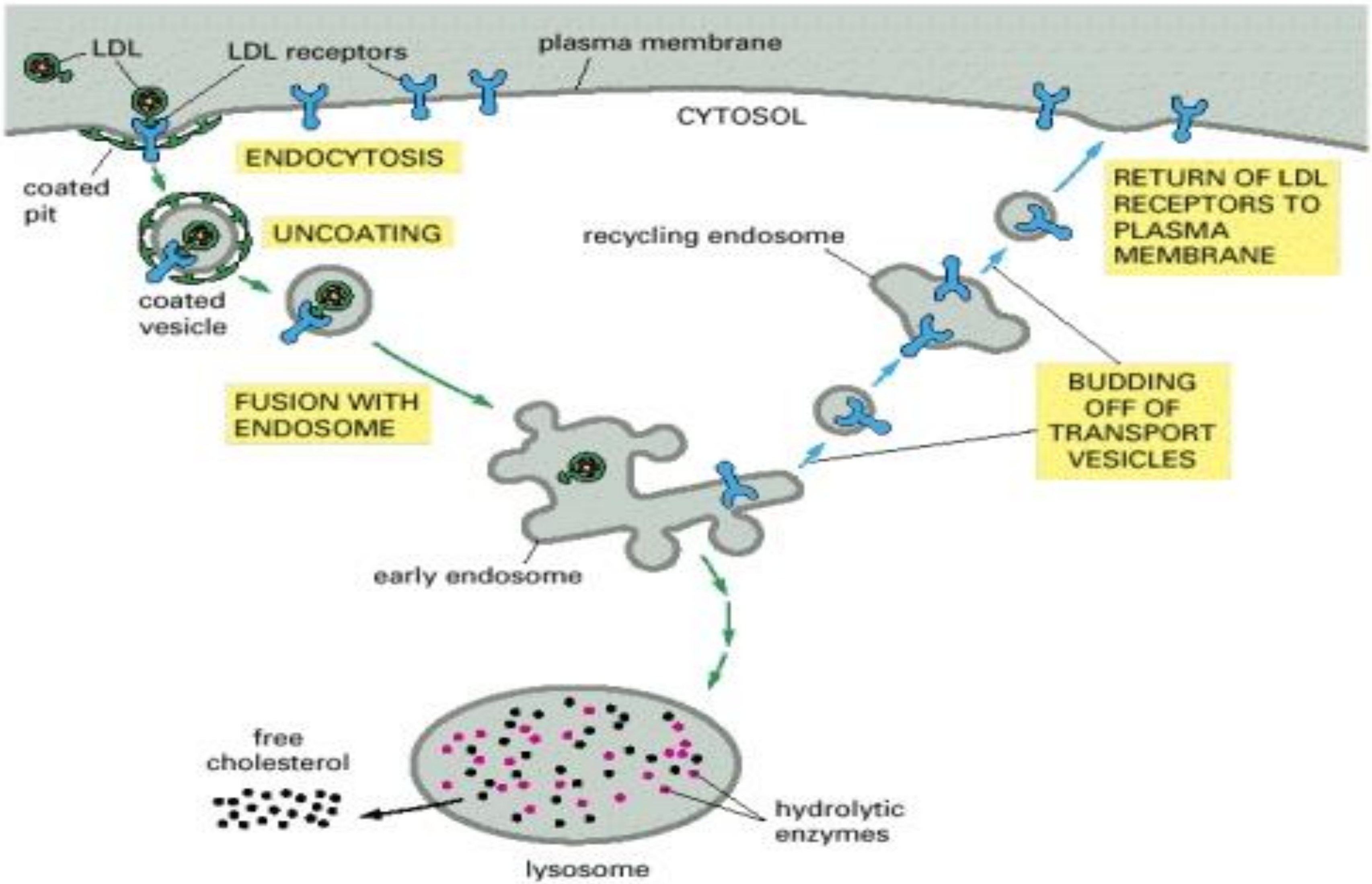
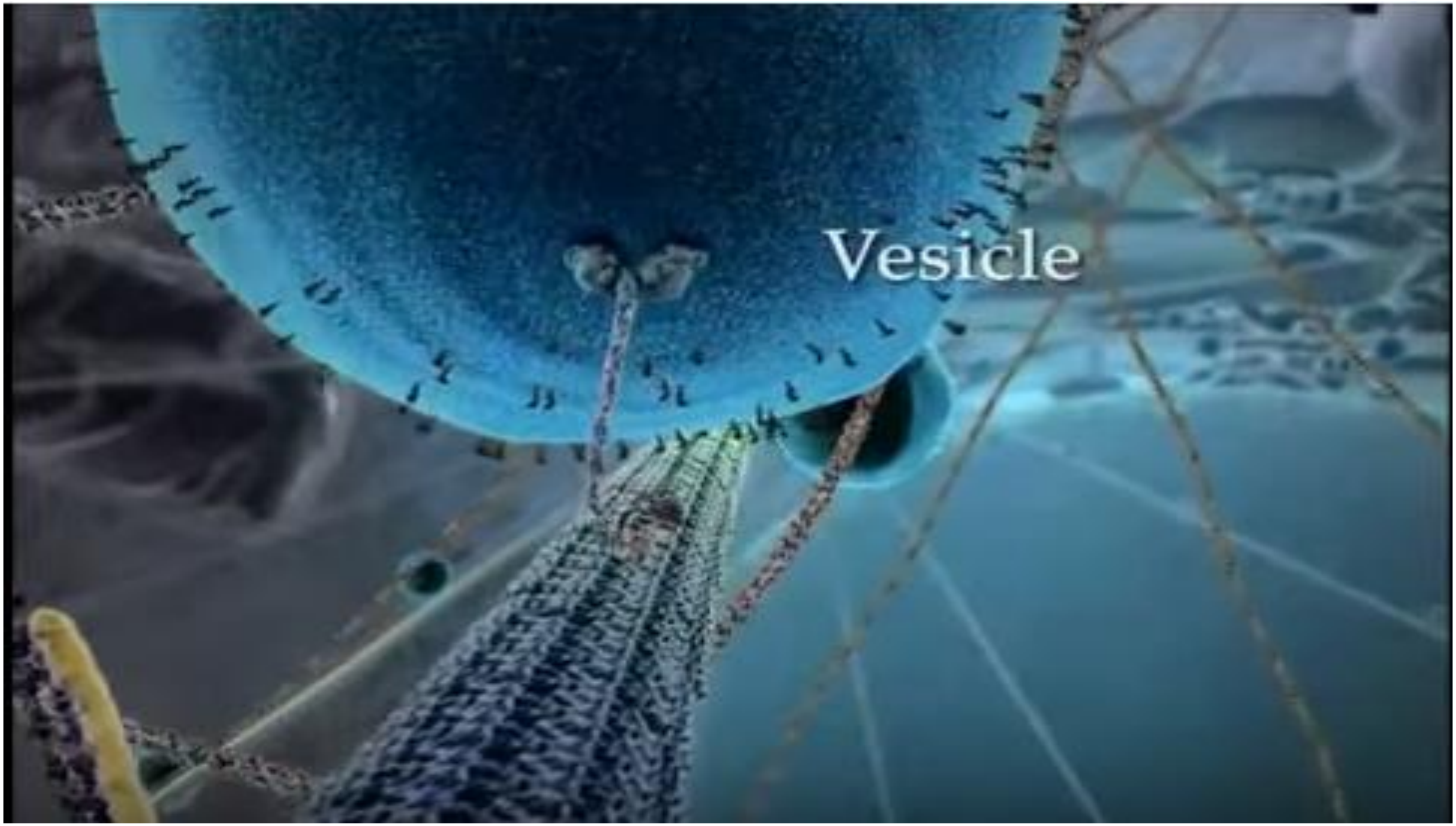
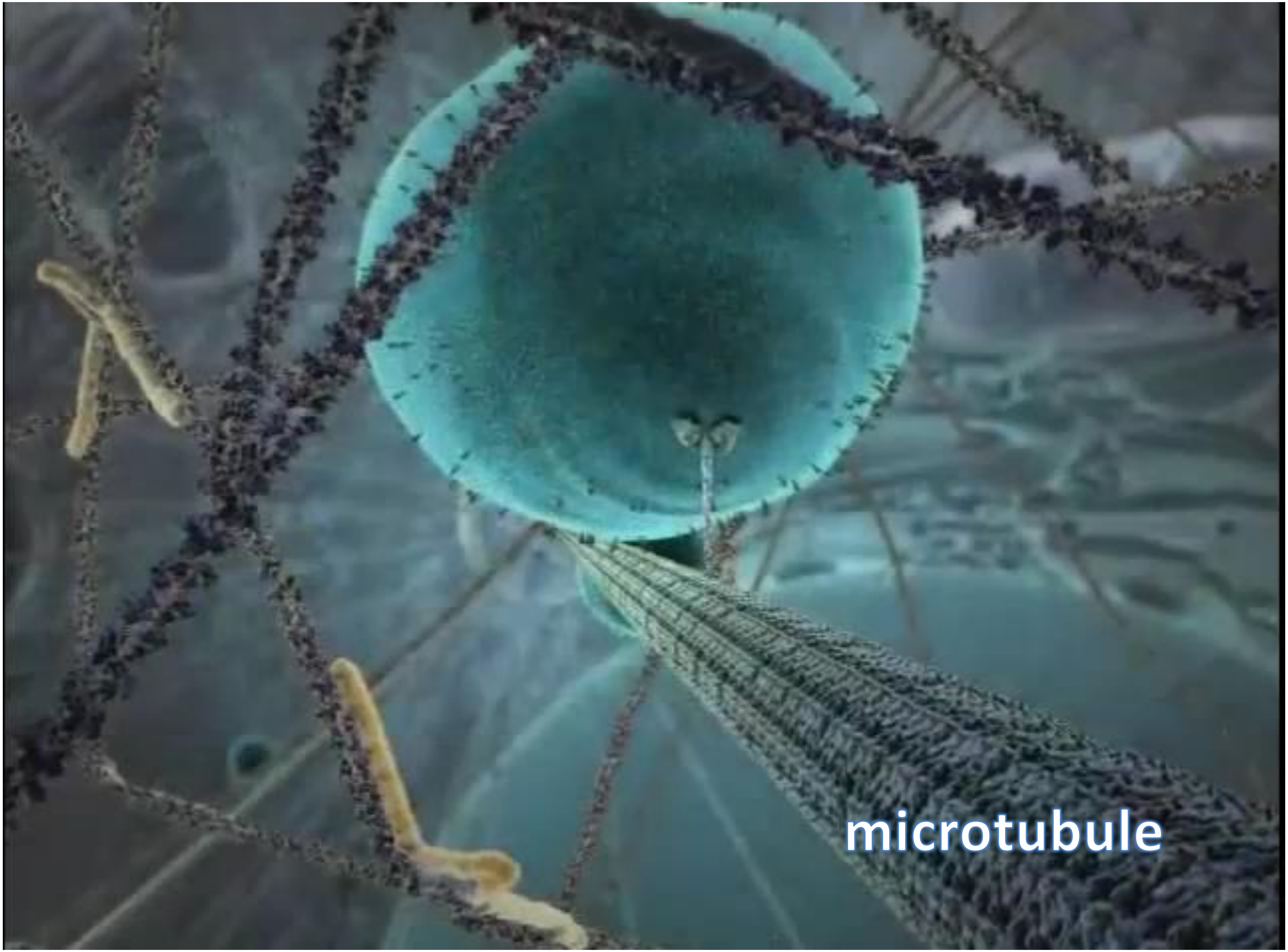


Figure 13-46 The receptor-mediated endocytosis of LDL

Vesicles move along filaments & microtubules using ATP

https://www.youtube.com/watch?v=y-uuk4Pr2i8

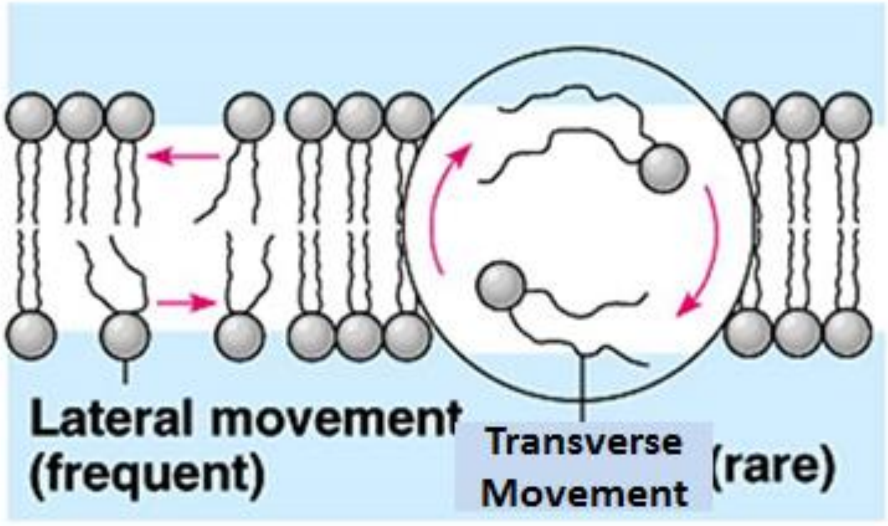



microtubule

Main Features of Membranes

Fluidity of membranes

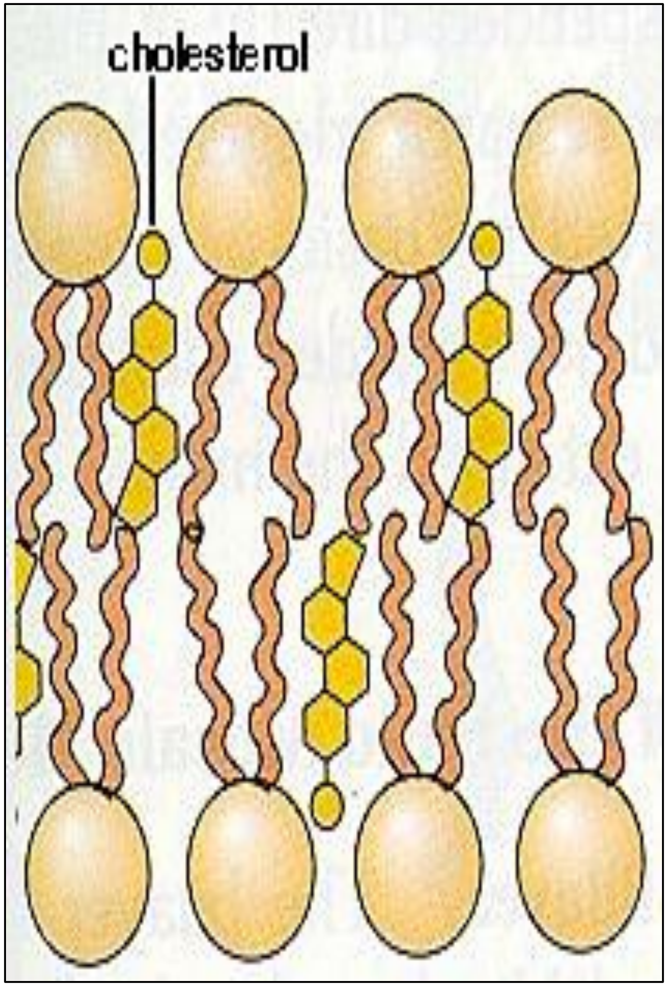
- Lipids move **laterally** in a membrane, but **transverse movement** across the membrane is rare



(a) Movement of phospholipids

Fluidity of membrane depends on

1. Proportion of **unsaturated hydrocarbon tails** in phospholipids
2. Amount of **cholesterol**
3. **Length of hydrocarbon chains** of fatty acid



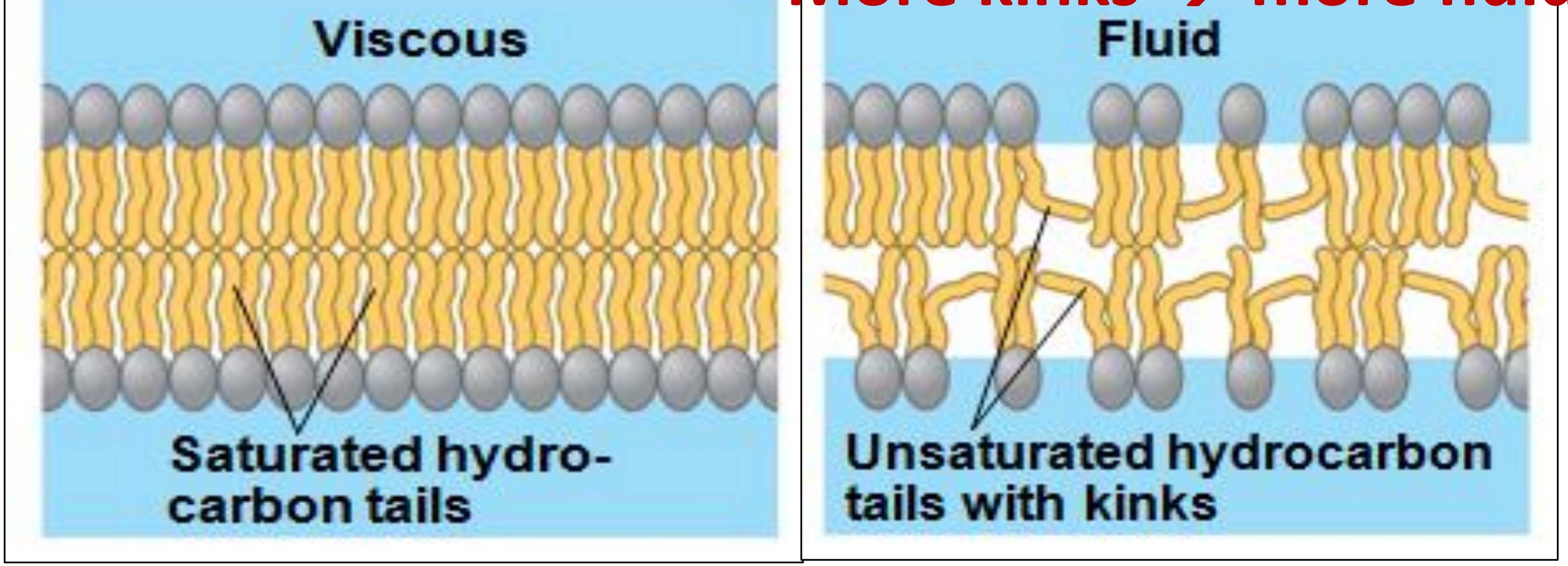
Main features of Membranes

Fluidity of membranes

1. **Unsaturated** hydrocarbon tails of phospholipids have **kinks** (due to C=C)

=> Prevent phospholipids from packing close together, enhancing membrane fluidity.

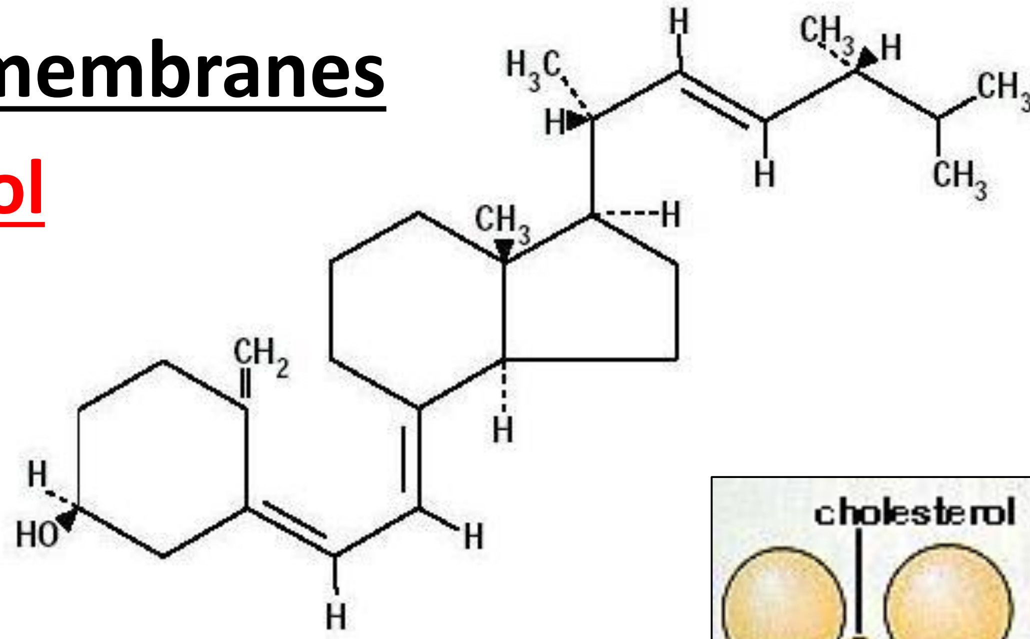
More kinks → more fluid



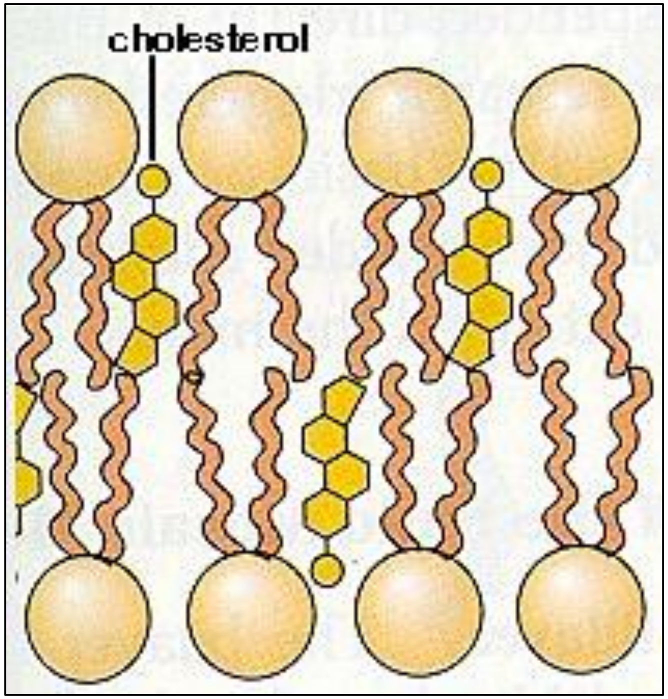
Main features of Membranes

Fluidity of membranes

2. Cholesterol



How is cholesterol being held in the membrane?

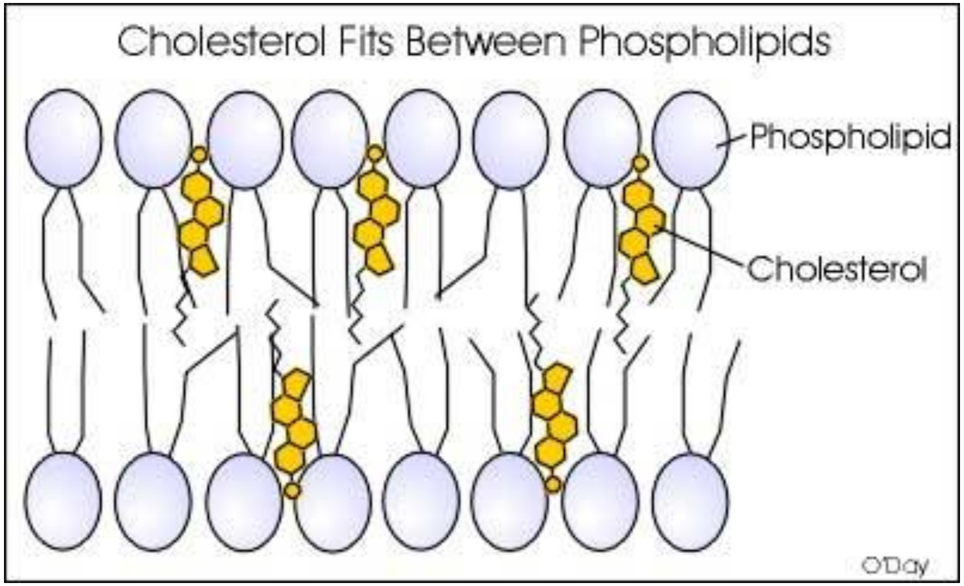


Why is cholesterol described as a "temperature buffer" for the membrane?

Regulates fluidity of membrane when temp changes

At relatively <u>warm temperatures</u> (37^0C),

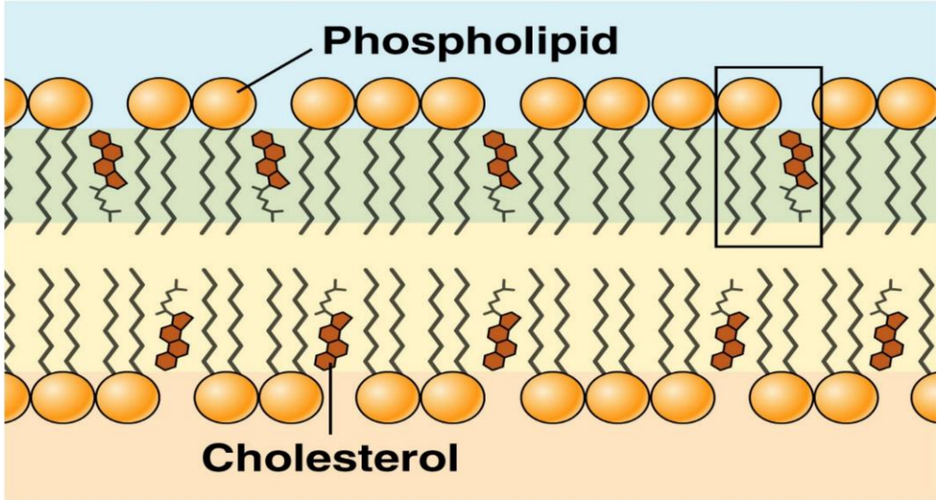
- cholesterol makes the membrane **less fluid** by reducing/restraining movement of phospholipids



Why is cholesterol described as a "temperature buffer" for the membrane?

At colder temperatures,

- cholesterol hinders solidification of membrane by disrupting regular (close) packing of phospholipids.
- Lowers temperature required for membrane to solidify
- Membrane remains fluid at <u>**colder temperatures**</u>

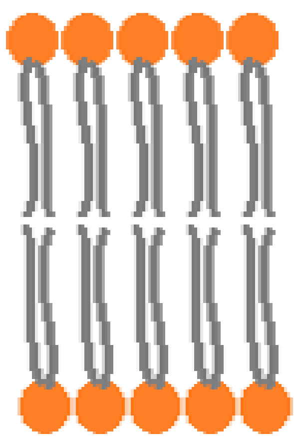


Main features of Membranes

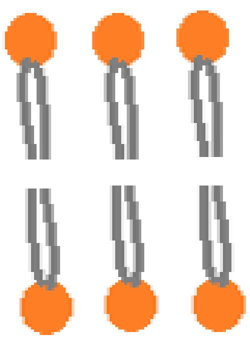
Fluidity of membranes

3. Length of hydrocarbon chains in fatty acids

- Longer length of hydrocarbon chains
  → Phospholipids are more closely packed
  → less fluid membrane



Membrane with long hydrocarbon chains in fatty acids

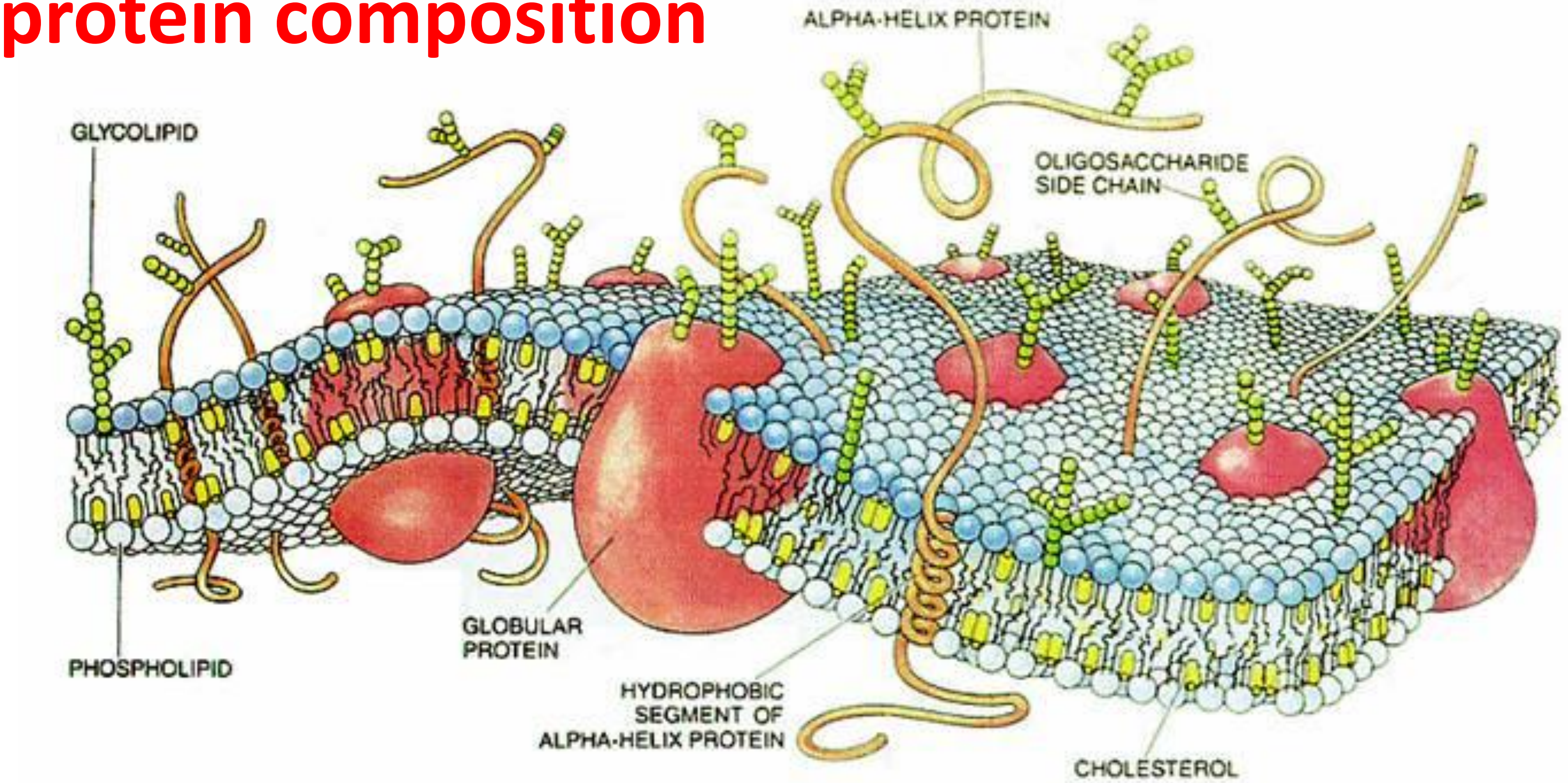


Membrane with short hydrocarbon chains in fatty acids

Main features of Membranes

Cell membrane are asymmetric

- Two halves of membrane (facing inside and outside of the cell) have **different lipid & protein composition**

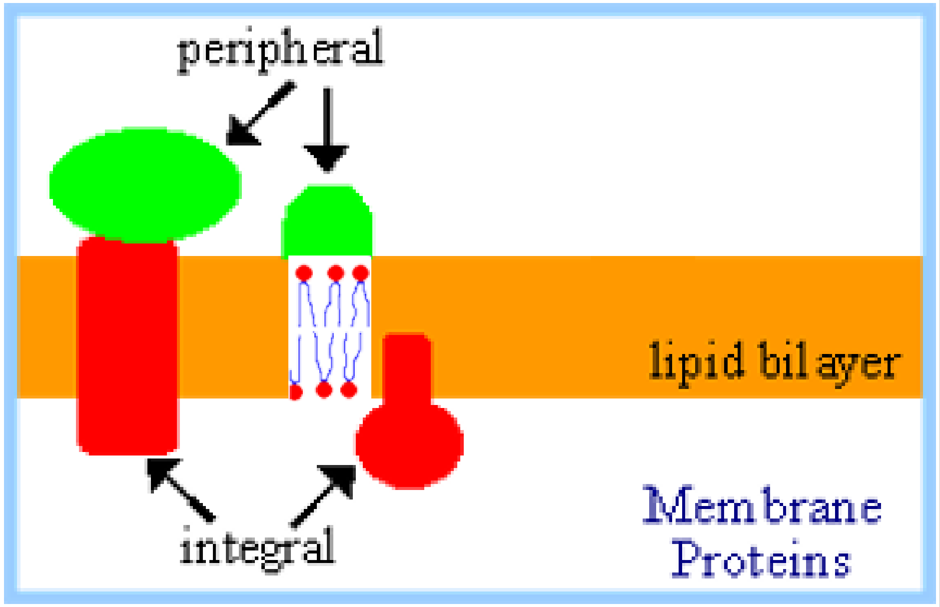


Main features of plasma membrane

Peripheral proteins (extrinsic proteins)

- Occurs on **surface** of the phospholipid bilayer (on either sides)
- Bound to membrane by **hydrogen bonds and ionic bonds**

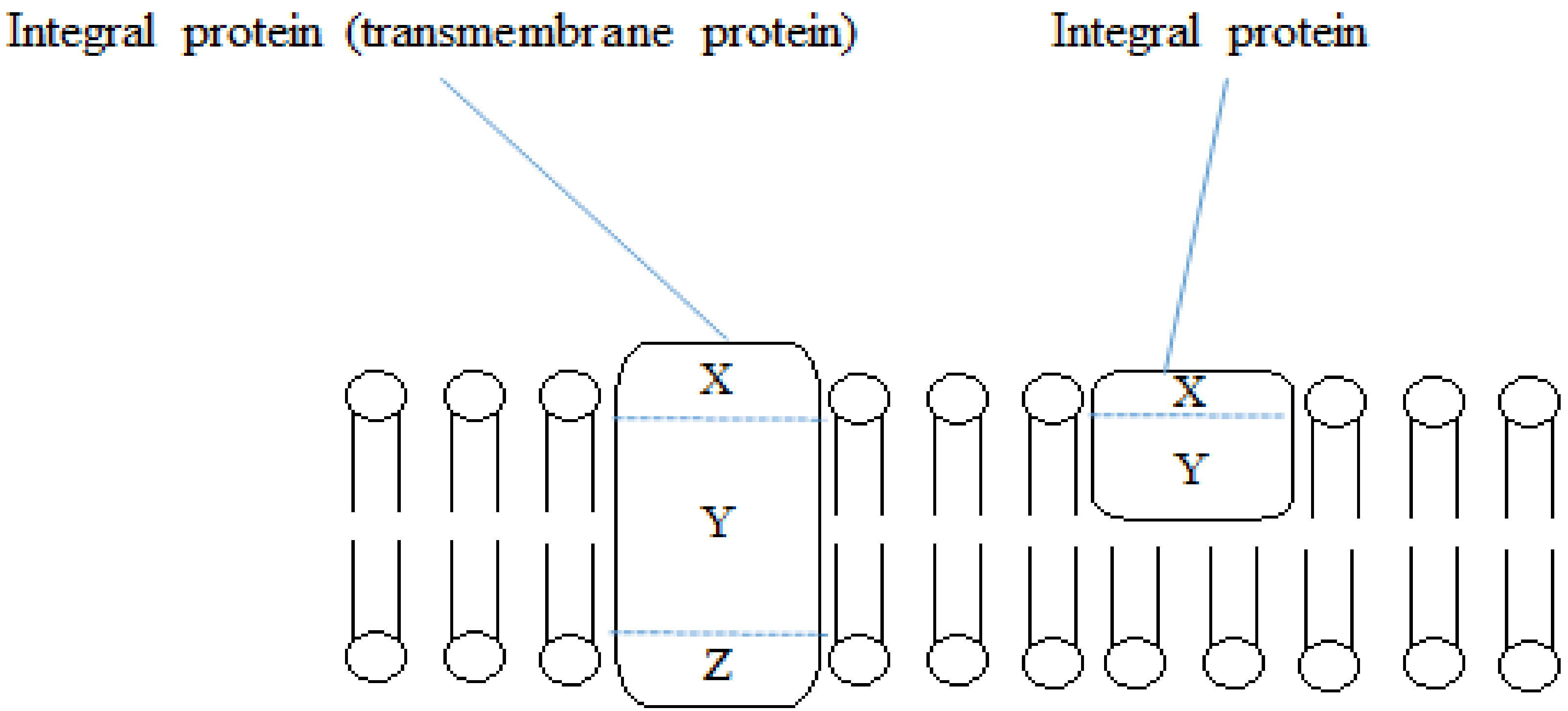
How are these bonds formed?



Main features of plasma membrane

Integral proteins (intrinsic proteins)

– Either **penetrate/span** part or whole of phospholipid bilayer

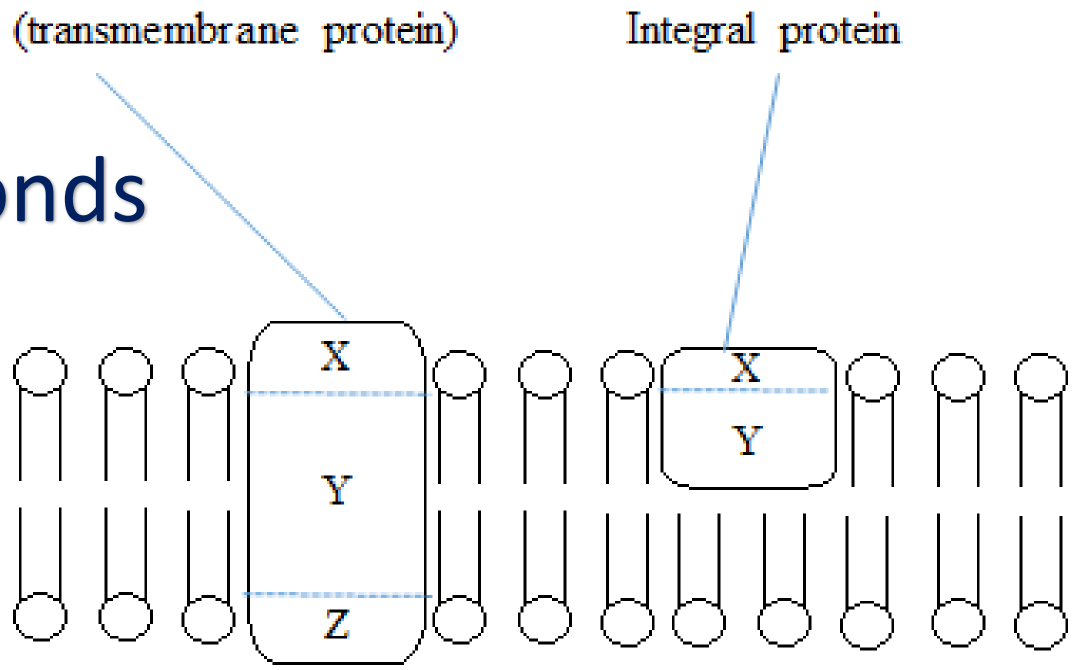


Main features of plasma membrane

<u>Integral proteins</u> (intrinsic proteins)

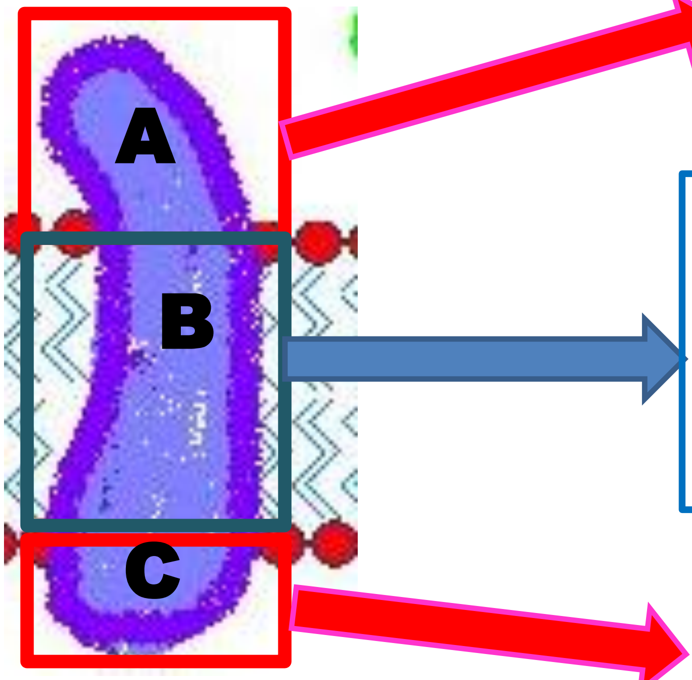
- Bound to hydrophobic core of membrane via **<u>hydrophobic interactions</u>** and to membrane by **<u>ionic and hydrogen bonds</u>**

How are these bonds formed?



Main features of plasma membrane

How are proteins stabilized within membranes?



Charged and polar R groups of amino acids (on surface of the protein) interact with the charged and polar phosphate head (of the phospholipid in the membrane) via ionic and hydrogen bonds

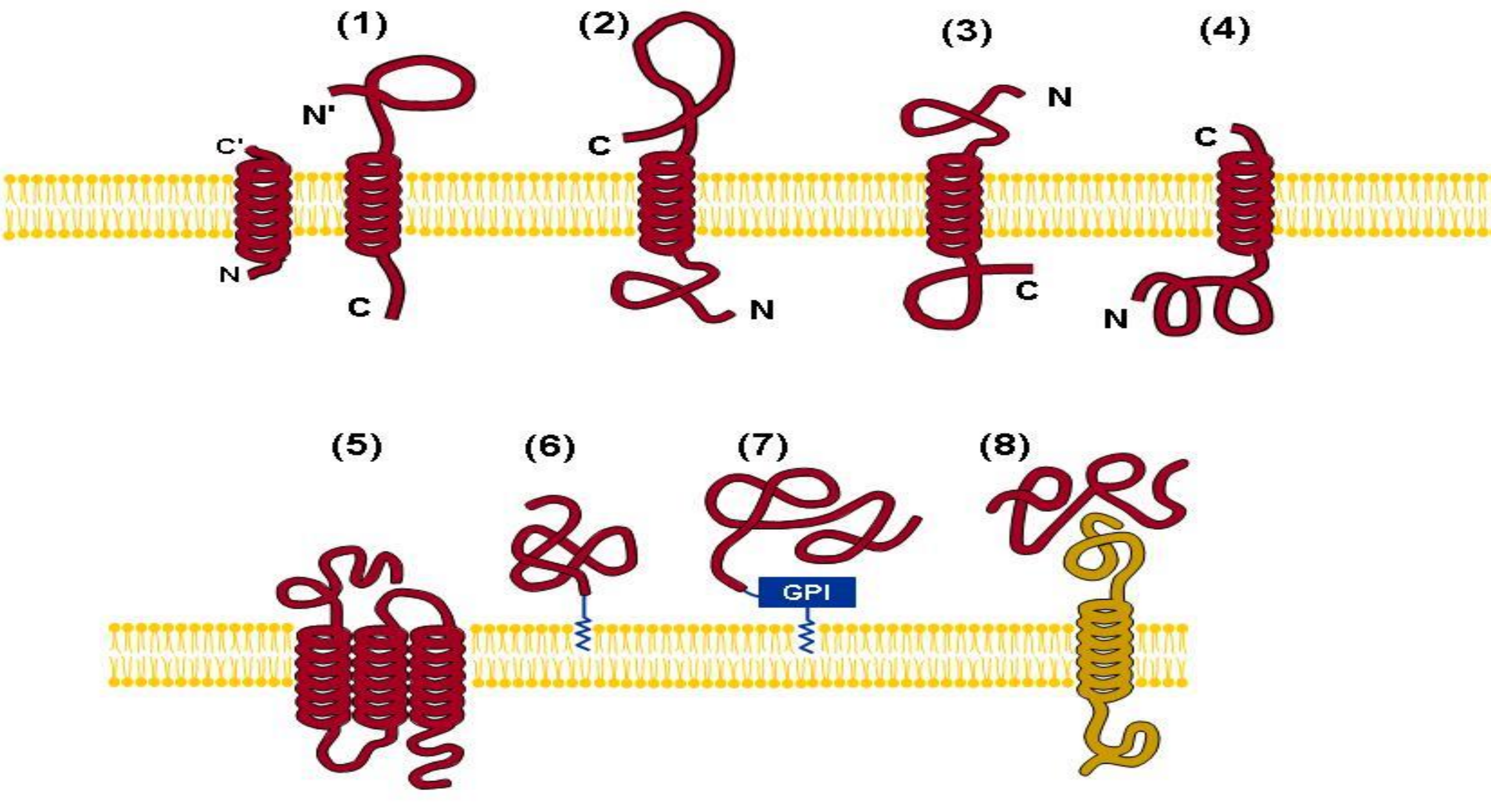
Non-polar R groups of amino acids (on the surface of the protein) interact with the non-polar hydrocarbon tails of the phospholipid in the membrane via hydrophobic interactions

Ref to explanation for A

Main features of plasma membrane

Integral proteins

Examples: Receptors, Transport Proteins such as channels, carriers and pumps

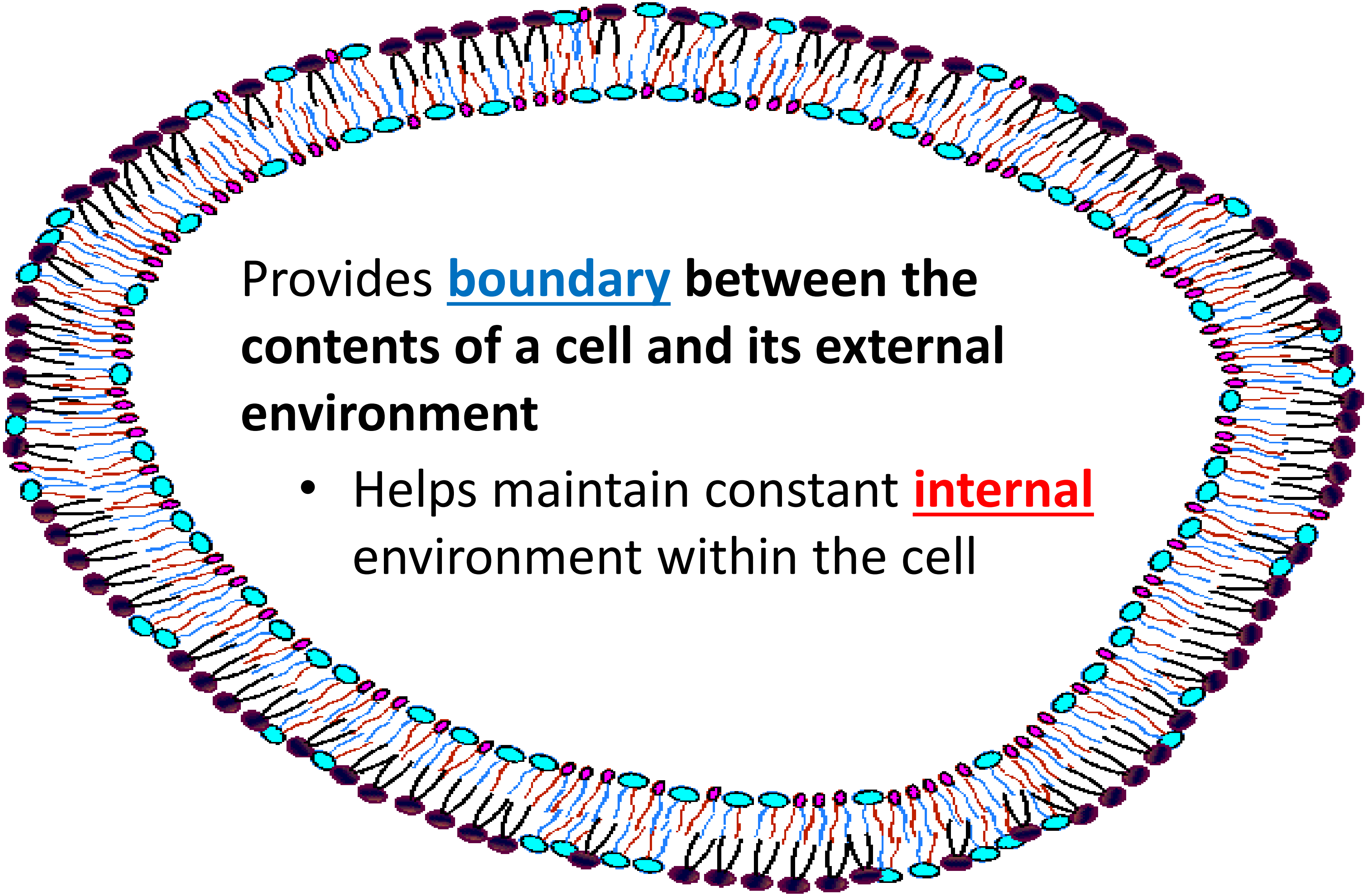


General Functions of Cell Membranes

Learning Objectives

1(k) **Outline** the functions of membranes at the surface of cell and membranes within the cell.

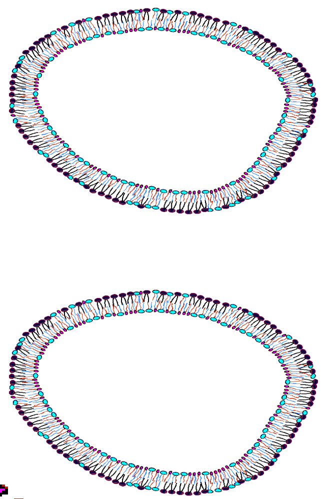
General functions of cell surface membranes



Provides **boundary between the contents of a cell and its external environment**

- Helps maintain constant **internal** environment within the cell

General functions of cell membranes within the cell (i.e. surrounding organelles)



1) Provides **boundary** between cytoplasm and specific contents within membrane-bound organelles so that **separate compartments** can be formed within a cell

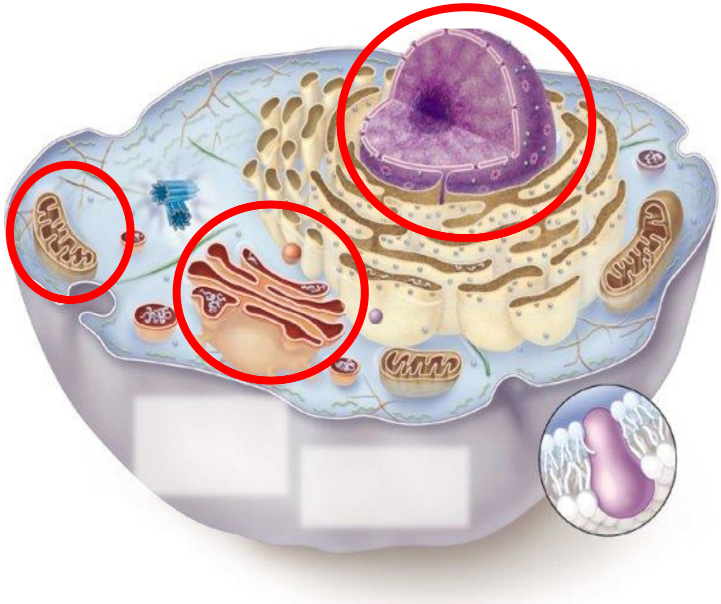
2) **Increase surface area** for reaction to occur

Compartmentalization!

General functions of cell membranes within the cell (i.e. surrounding organelles)

Advantages of compartmentalization:

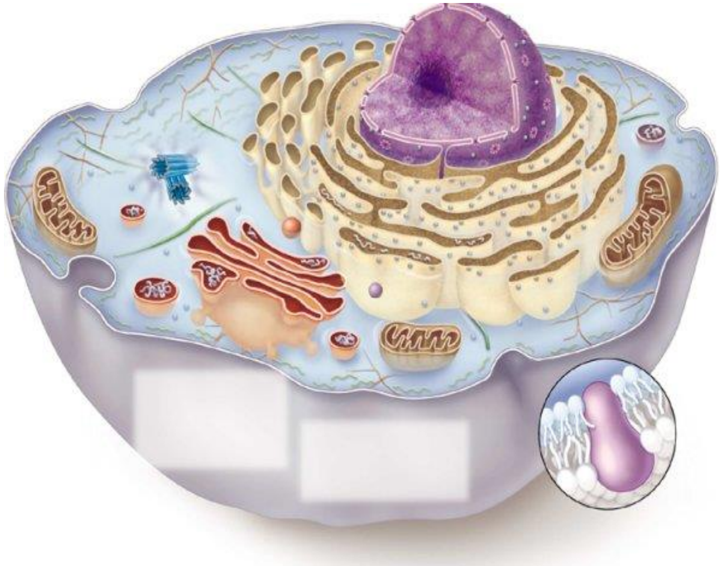
1. Allows maintenance of a constant internal environment within each organelle
2. Maintains high concentrations of reactants at specific site
3. Prevents intermediates of one pathway from mixing with those of another. A → B → C → D → E



General functions of cell membranes within the cell (i.e. surrounding organelles)

Advantages of compartmentalization:

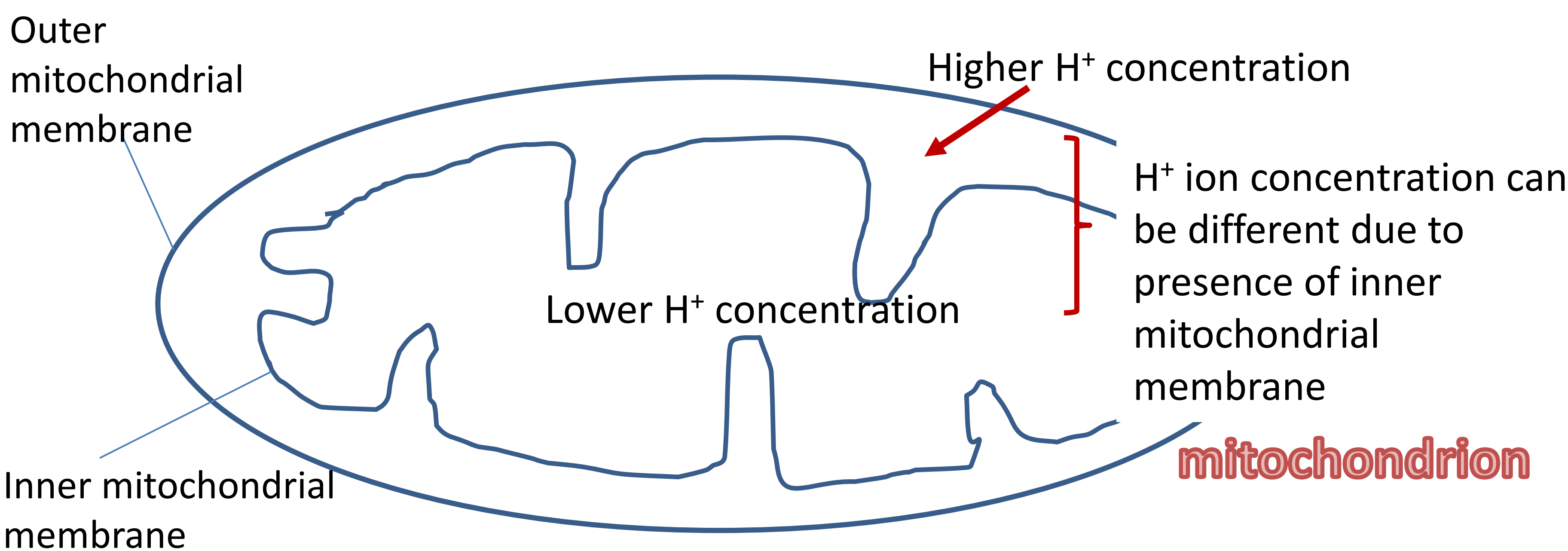
4. Provides many different **local environments** that facilitate biochemical pathways.
   - E.g. pH within lysosome or mitochondrion can be maintained at a value which would otherwise be detrimental to processes occurring in other parts of the cell.



General functions of cell membranes within the cell (i.e. surrounding organelles)

Advantages of compartmentalization:

5. Allows for establishment of concentration gradient of materials to facilitate sequential reactions to occur
   - E.g. proton gradient in intermembrane space between inner and outer mitochondrial membrane

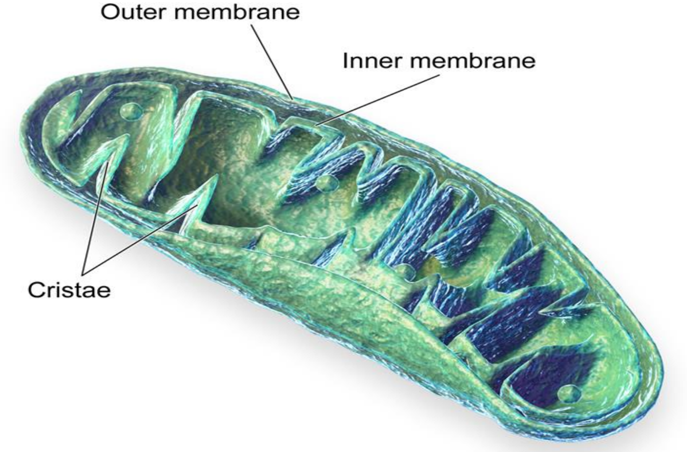


General functions of cell membranes within the cell (i.e. surrounding organelles)

2) Increase surface area for reaction to occur

E.g. Folding of inner mitochondrial membrane results in greater surface area

for the attachment of more proteins and enzymes of the electron transport chain and ATP synthase for higher rates of ATP synthesis

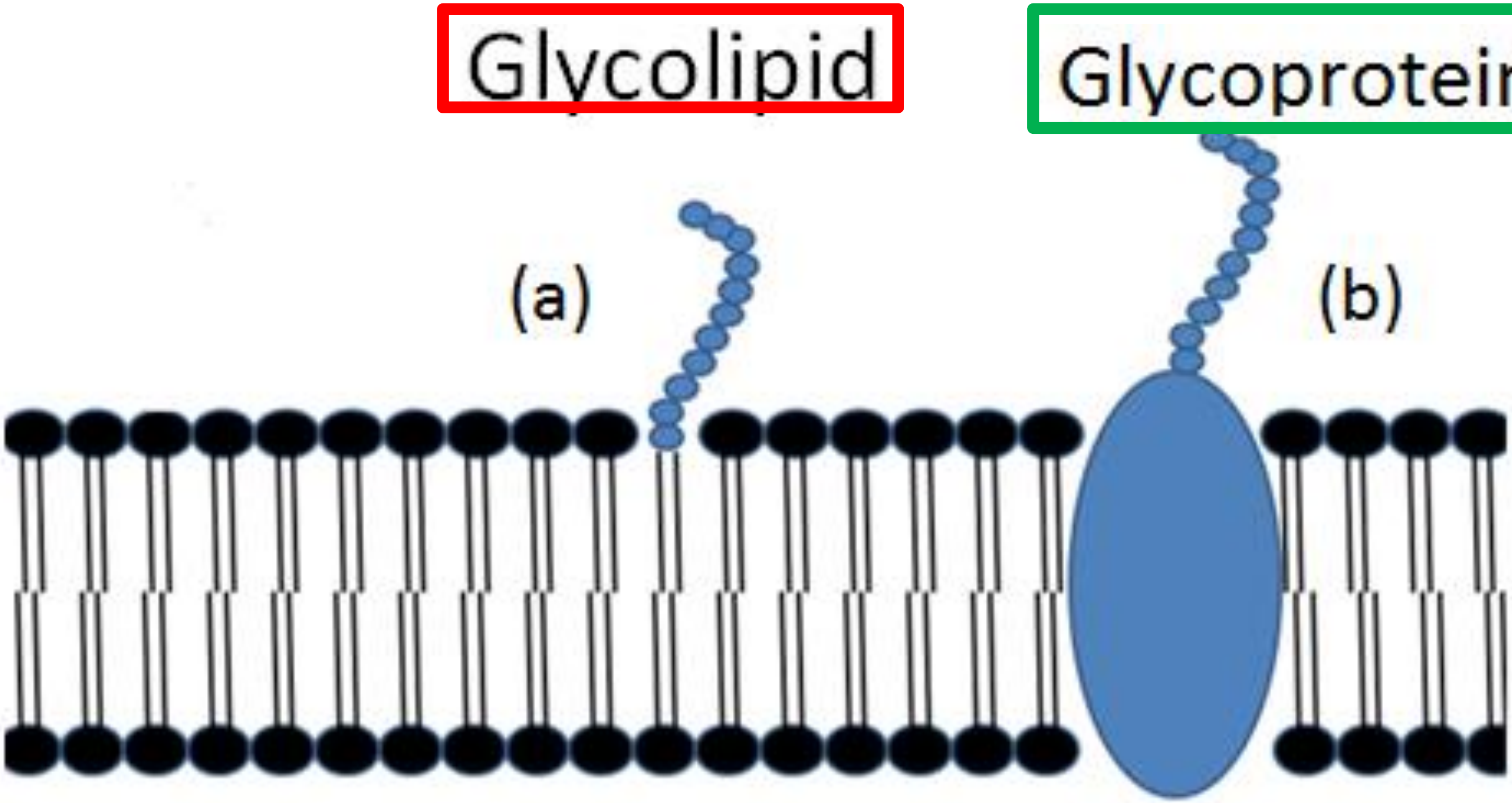


Mitochondria

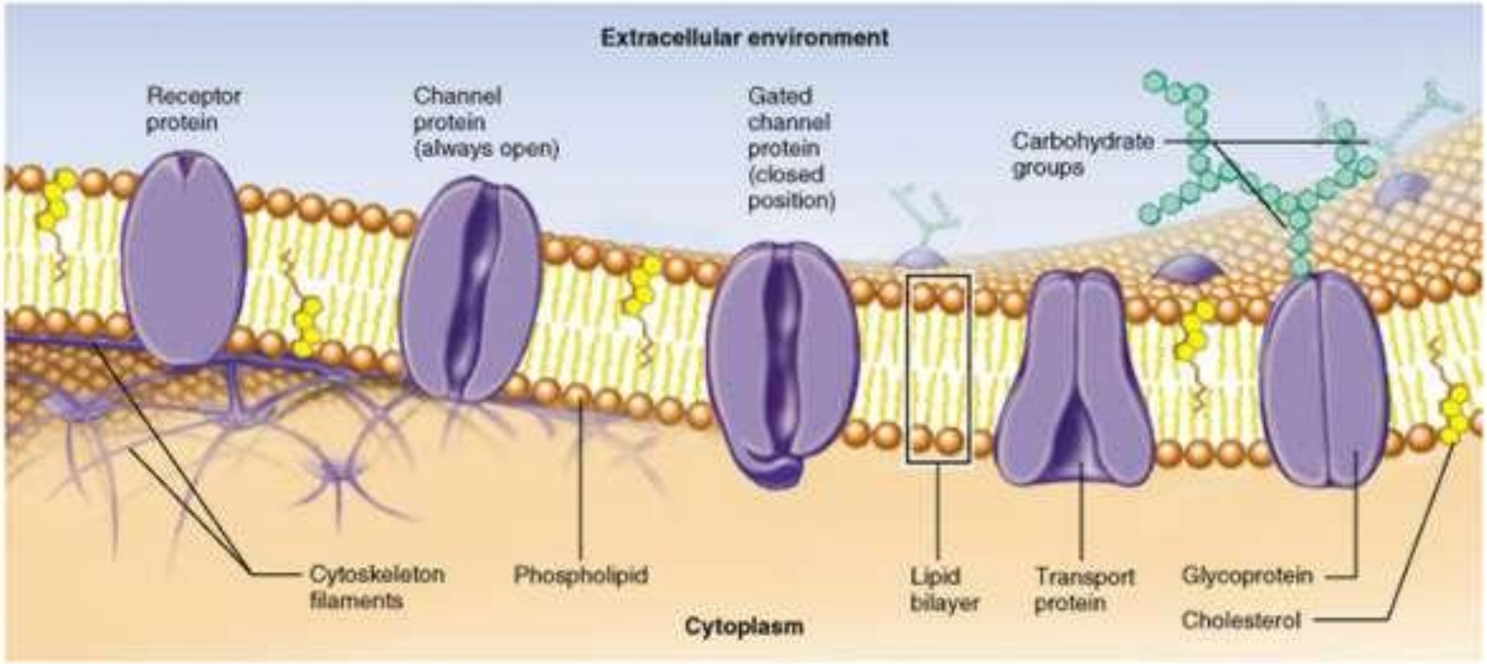
Learning Objectives

1(j) Explain the **fluid mosaic model** and the **roles** of the constituent biomolecules (including **phospholipids, proteins, glycolipids, glycoproteins and cholesterol**) in the cell membranes.

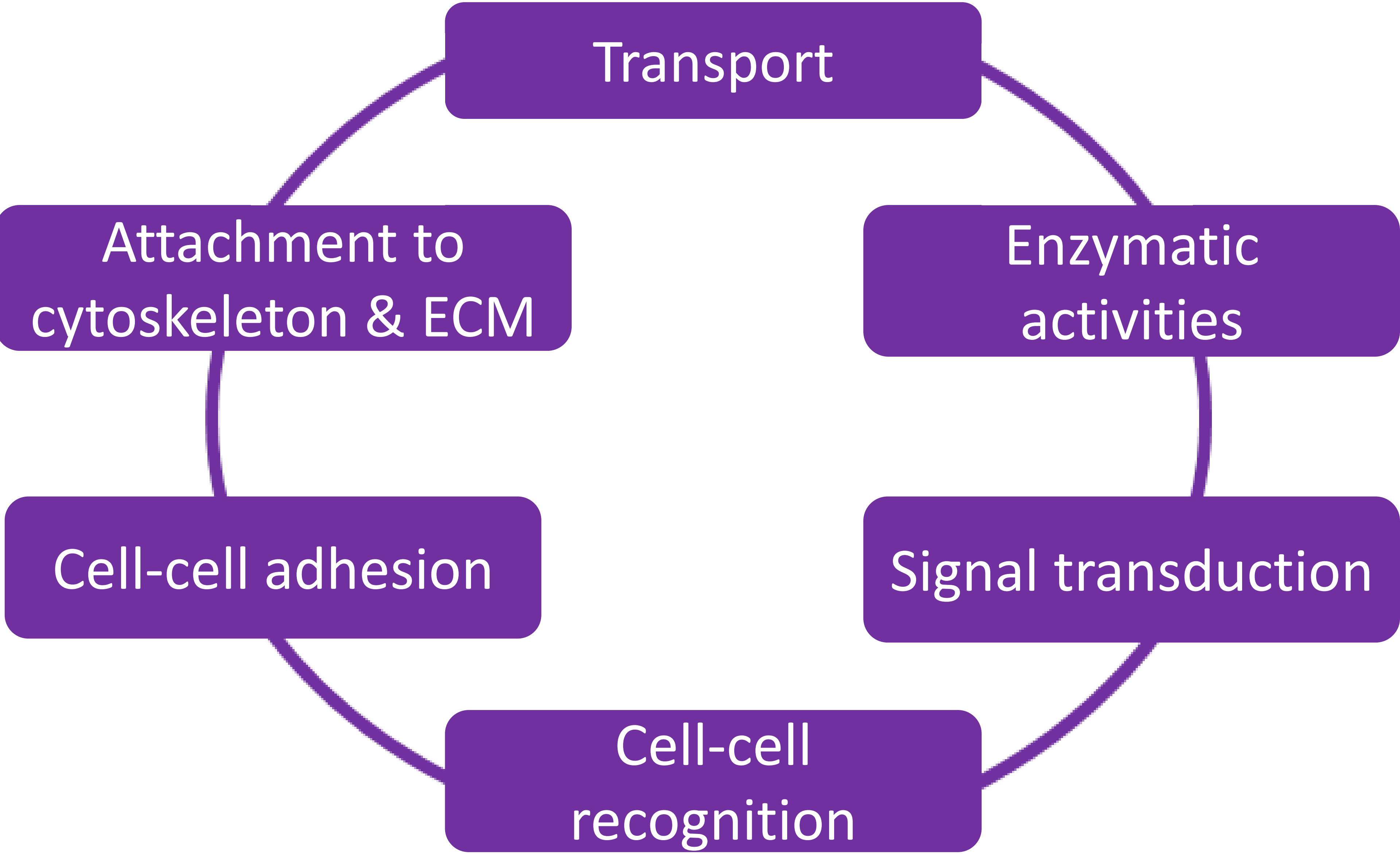
Glycoprotein & Glycolipid

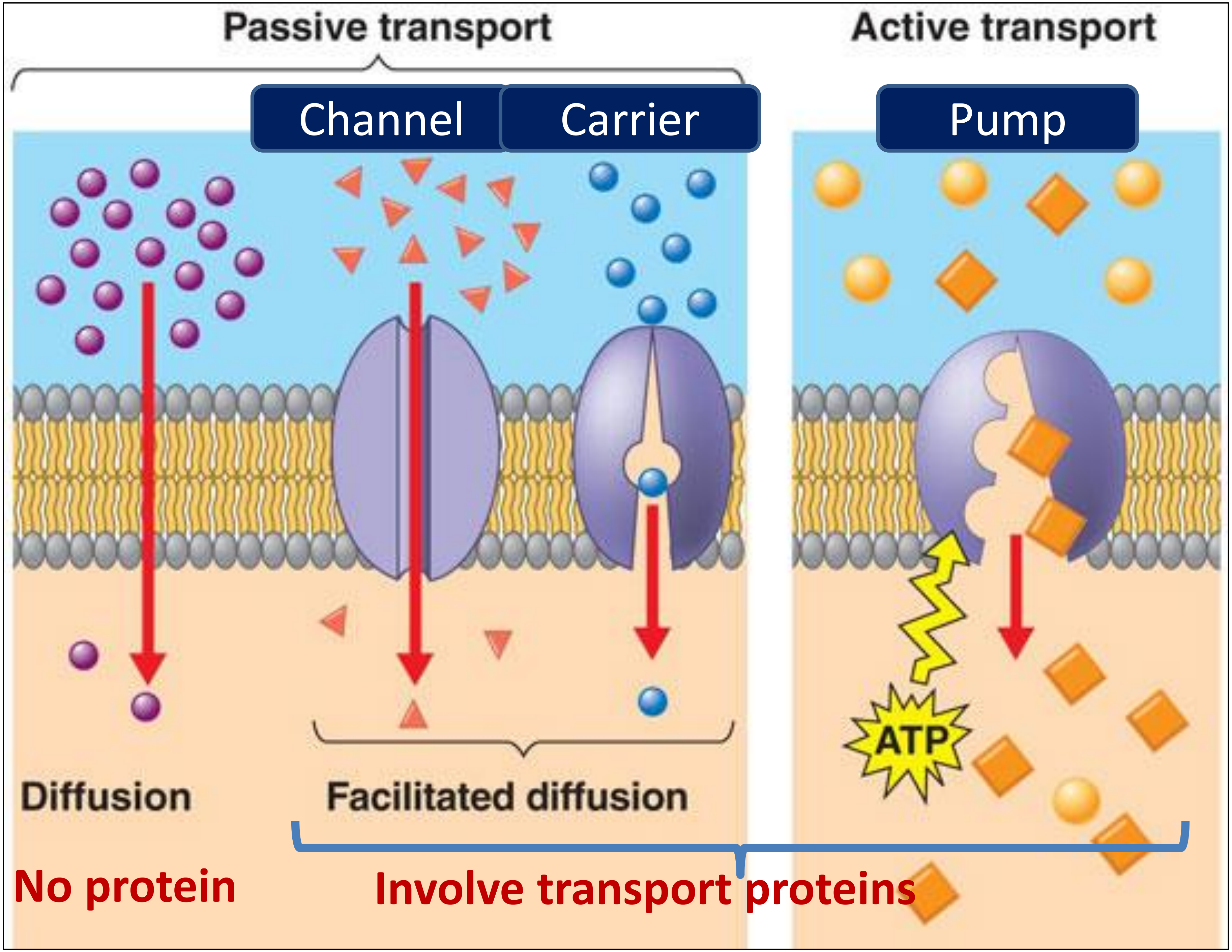


(Specific) Functions of Membrane Proteins /Glycoproteins



Functions of membrane proteins/glycoproteins

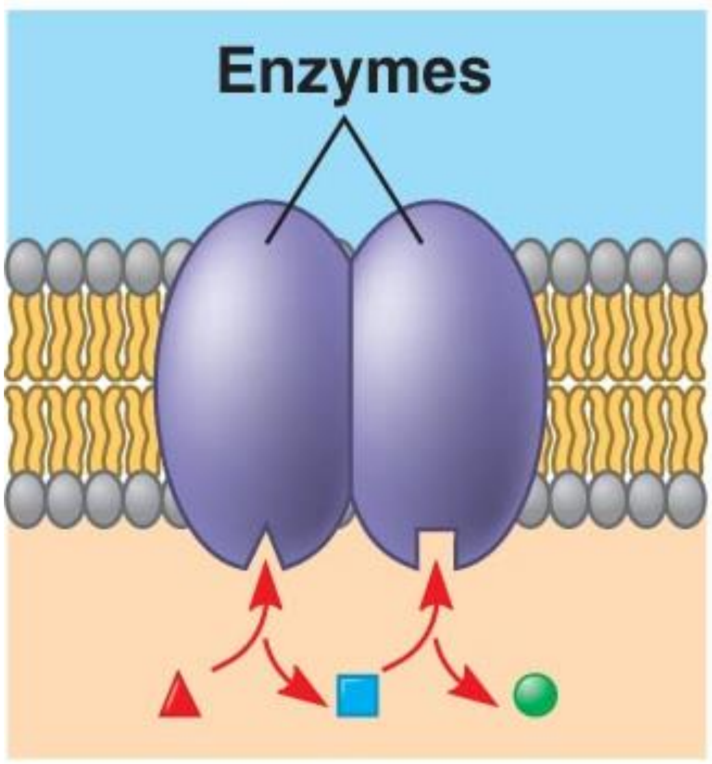



Passive transport
Active transport
Channel
Carrier
Pump
ATP
Diffusion
Facilitated diffusion
No protein
Involve transport proteins

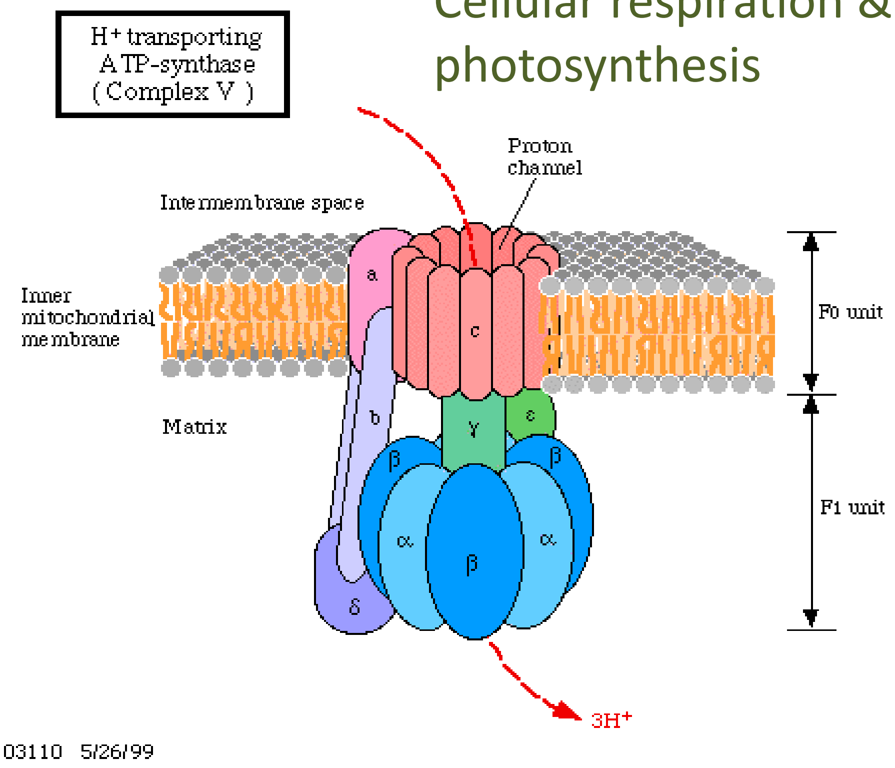
Functions of membrane proteins / glycoproteins

(2) Enzymatic activities

- Membrane proteins may function as **enzymes**



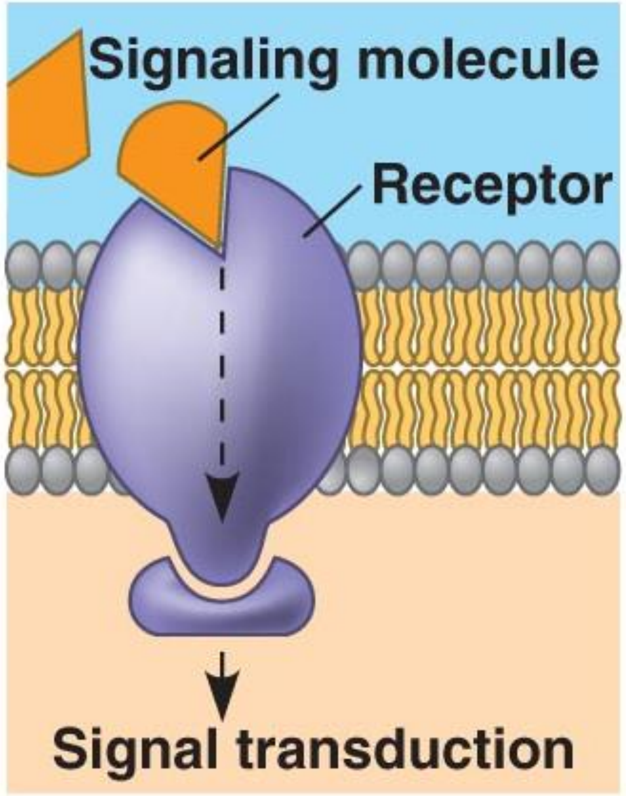
Cellular respiration & photosynthesis



Functions of membrane proteins / glycoproteins

(3) Signal transduction

- Function as **receptor sites**
- Receptor protein has a **binding site** with a specific shape that fits the shape of a chemical messenger
- E.g. insulin hormone

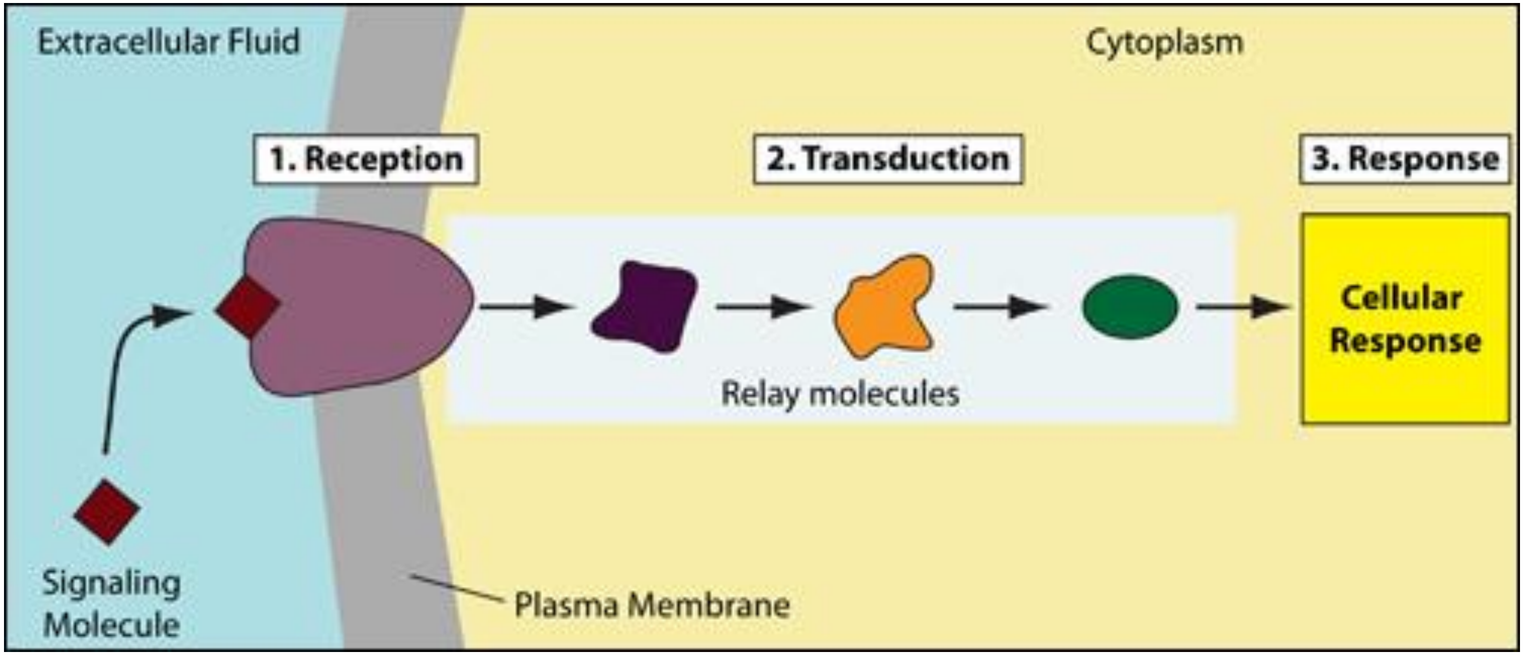


Cell signalling

Functions of membrane proteins / glycoproteins

(3) Signal transduction

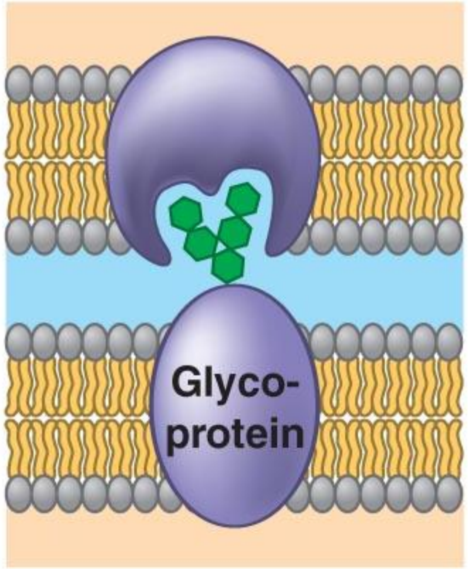
- External messenger (signal) may cause a **conformational change** in the protein (receptor) that relays the message to the inside of the cell



Functions of membrane proteins / glycoproteins

(4) Cell-cell recognition

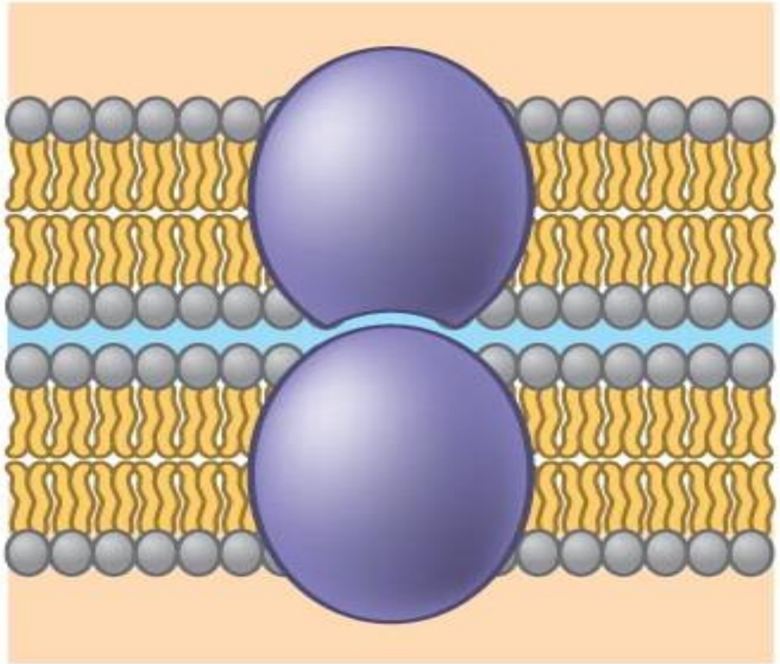
- The carbohydrate chain of **glycoproteins** extend from the exterior surfaces of cell membrane
- Serve as **recognition tags** that are specifically recognised by receptors on other cells



Functions of membrane proteins / glycoproteins

(5) Cell-cell adhesion (intercellular joining)

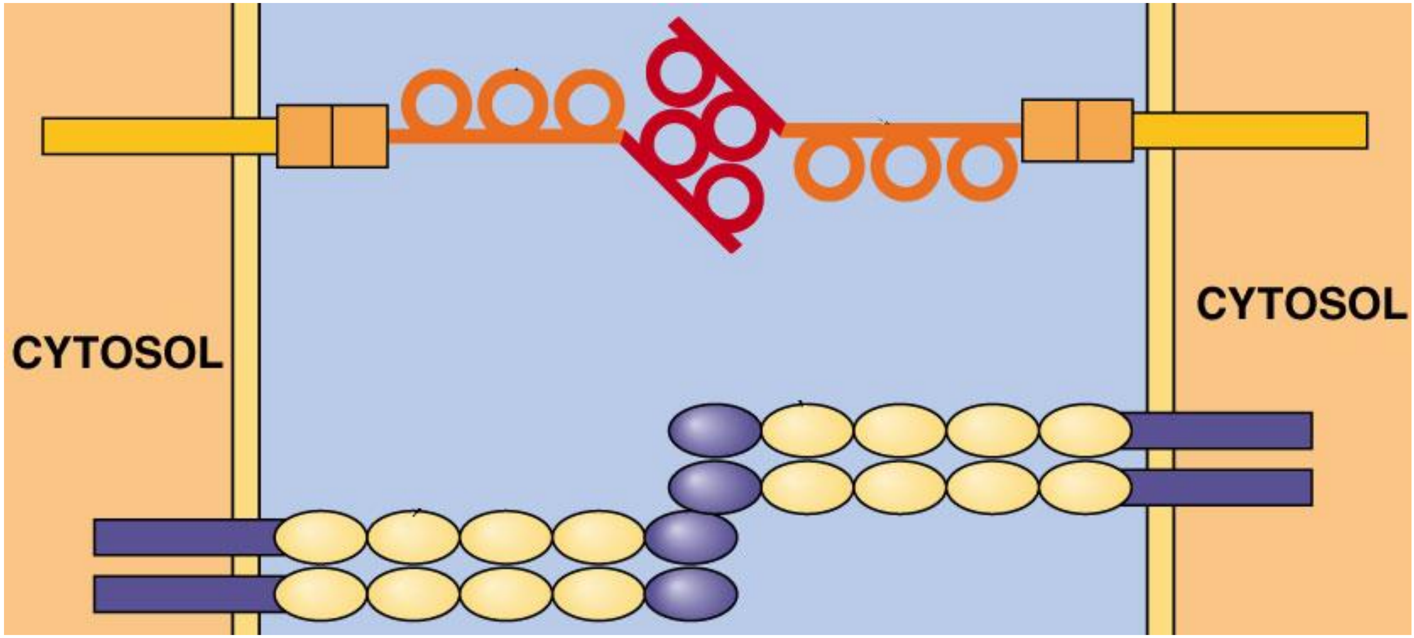
- Needed for cells to orientate and form **tissues**
- Membrane proteins of adjacent cells may bind with each other



Functions of membrane proteins / glycoproteins

(5) Cell-cell adhesion (intercellular joining)

- The carbohydrate chains of **glycoproteins** on adjacent cells may also bind with each other



Functions of membrane proteins / glycoproteins

(6) Attachment to the cytoskeleton and extracellular matrix (ECM)

- Microfilaments or other elements of the cytoskeleton may be bonded to membrane proteins

- To maintain **cell shape** and stabilise the **location** of certain membrane proteins