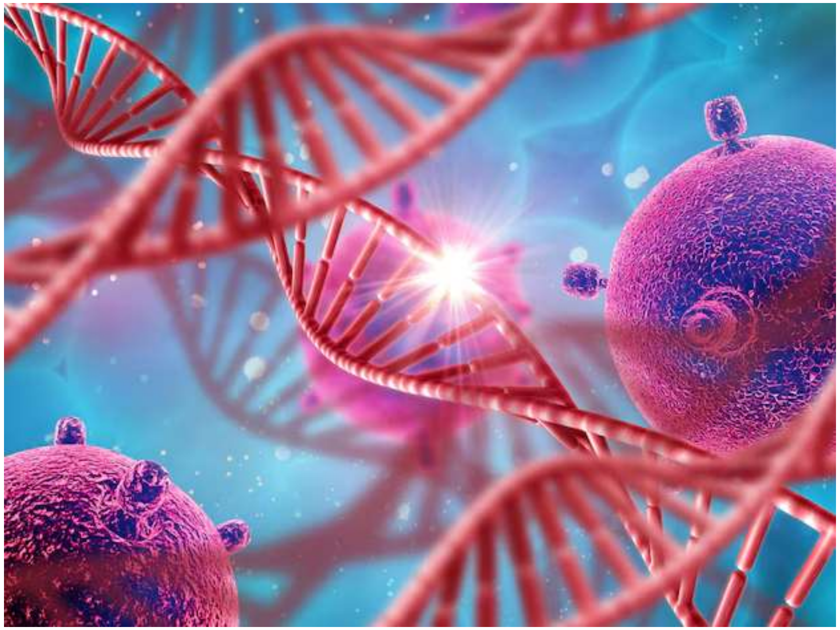
# Lecture 8

# General Biology & Cytology Course 2301130



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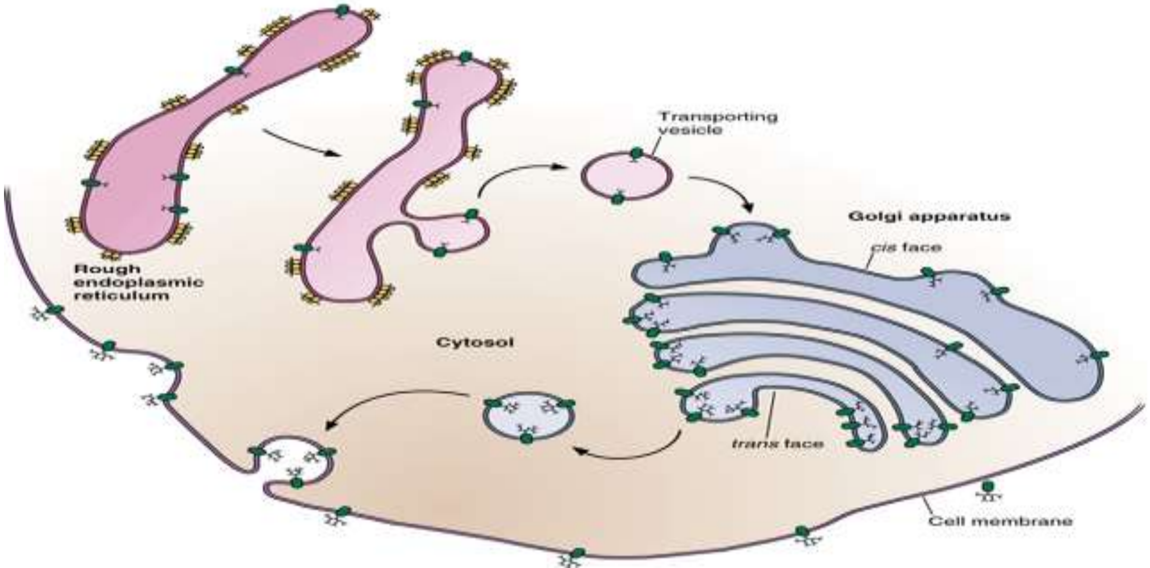
# Membrane Structure and Function

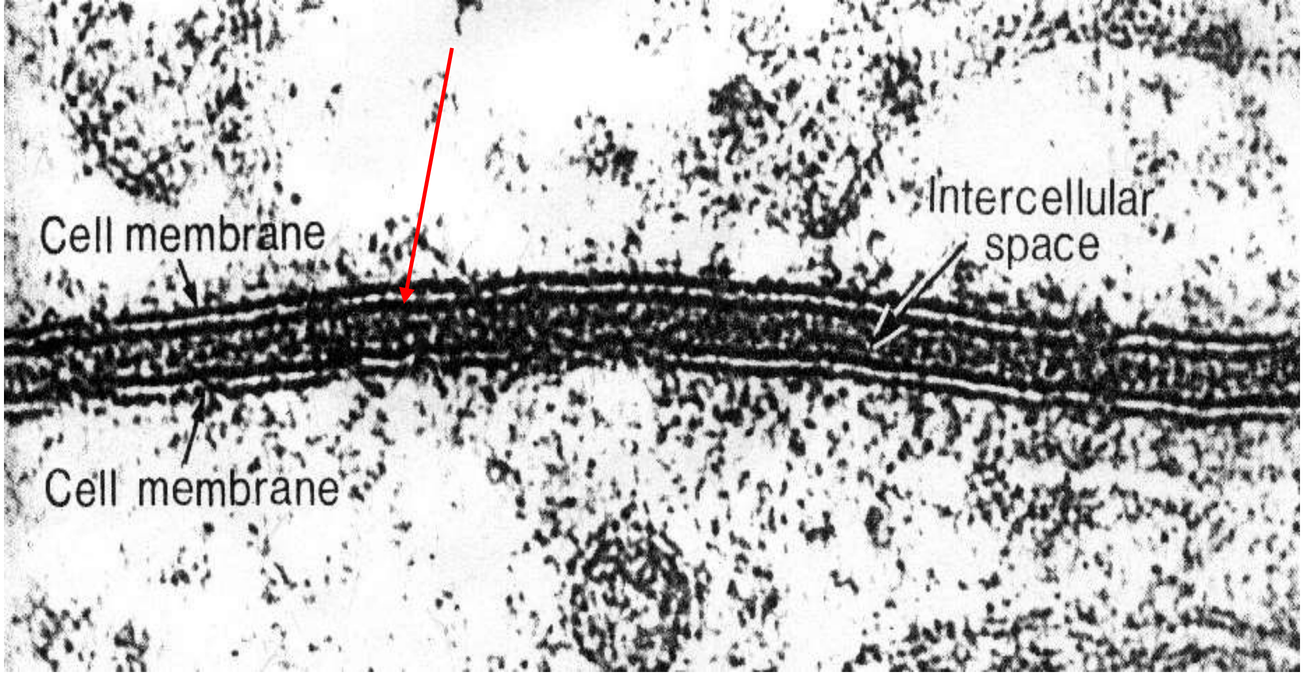
- The plasma membrane is the boundary that separates the living cell from its surroundings
- The plasma membrane exhibits **selective permeability**, allowing some substances to cross it more easily than others.
- Phospholipids are the most abundant lipid in the plasma membrane
- Phospholipids are **amphipathic molecules**, containing hydrophobic and hydrophilic regions
- The **fluid mosaic model** states that a membrane is a fluid structure with a “mosaic” of various proteins embedded in it
- Also called **plasmalemma**

# cell membrane

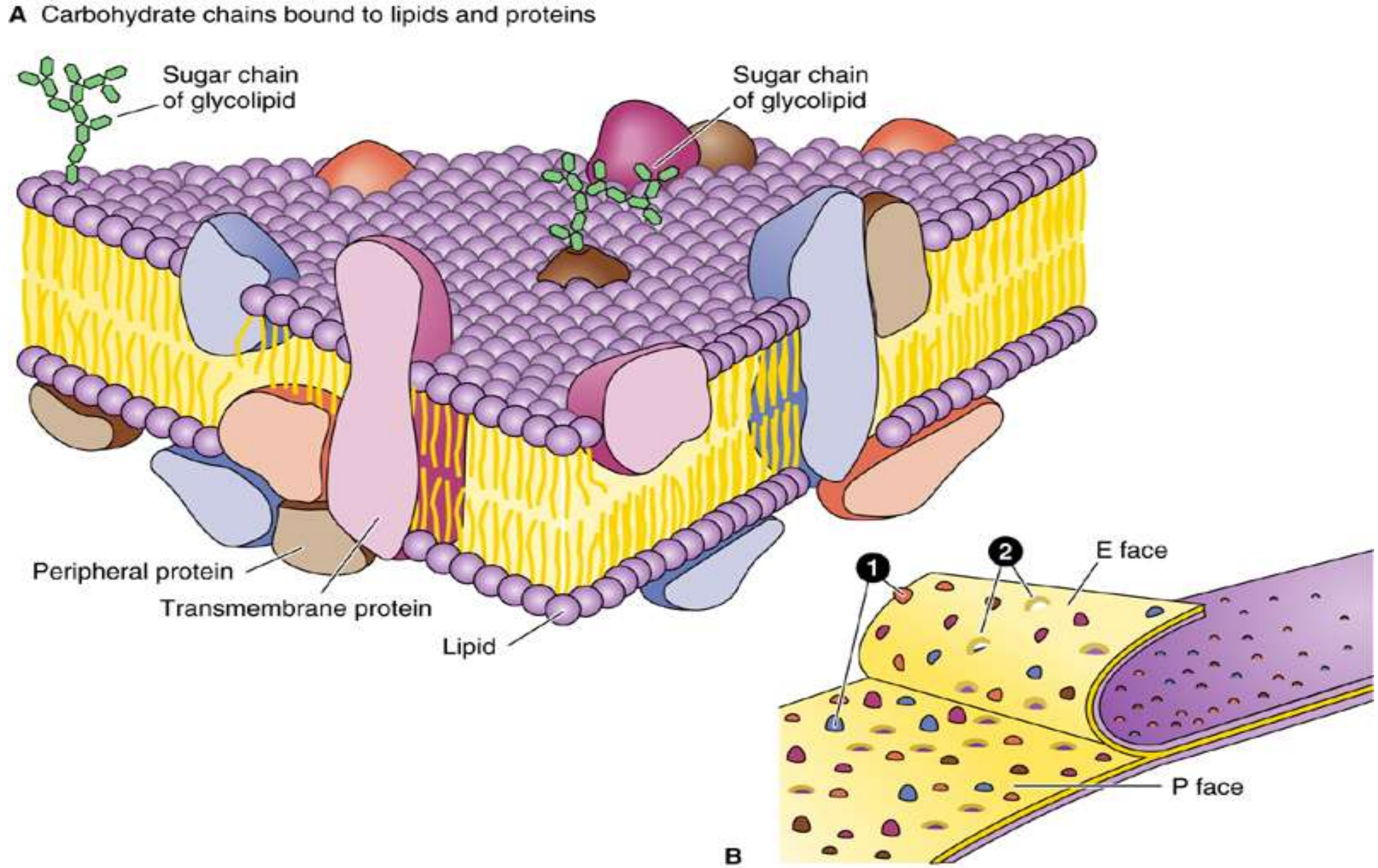
**L.M: It is very thin to be seen (9-10 nm)**

**Needs special stain e.g. PAS** (Periodic acid–Schiff) **& silver**






<u>E.M:</u> appears at high magnification as three parallel Lines; two dark peripheral lines &one light in center It is called trilamellar or <u>unit membrane</u>




Formed of

**Lipids 30%**

**Proteins 60%**

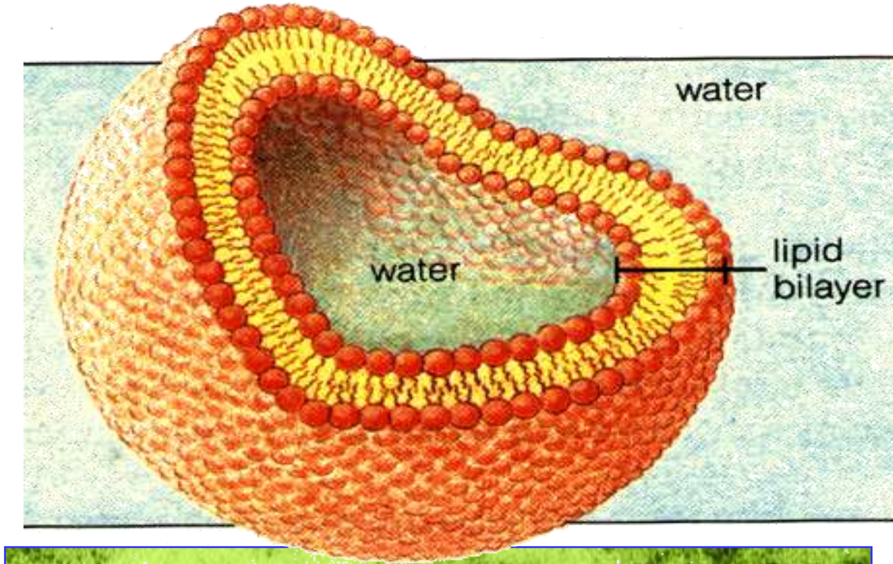
Carbohydrates 10%

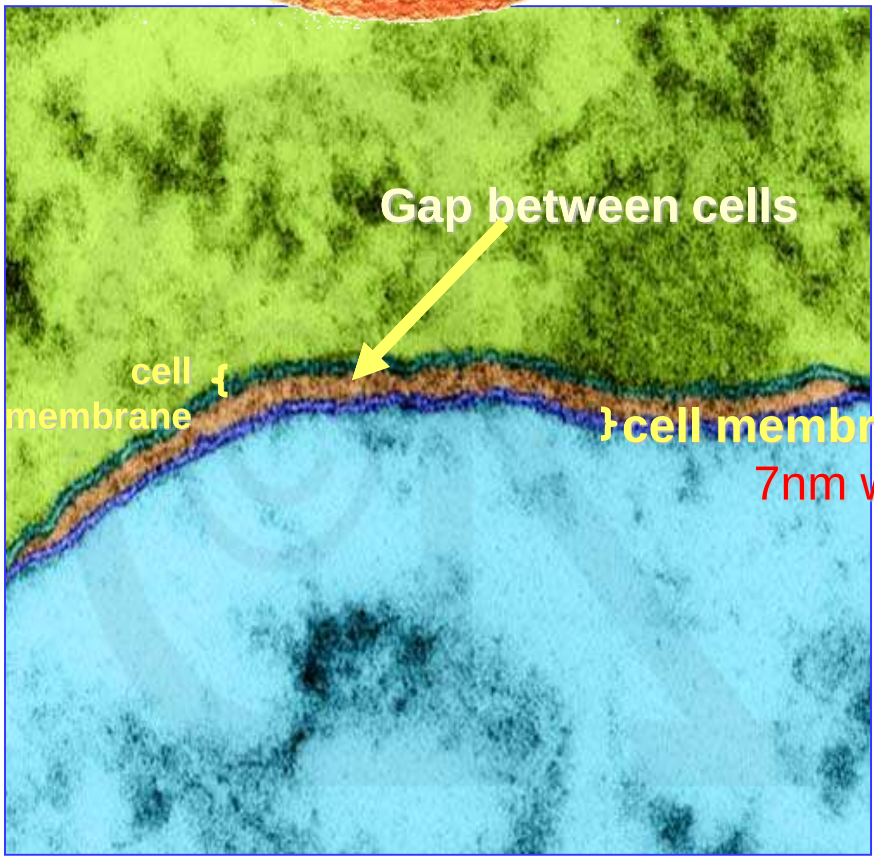
**Cell membrane or plasma membrane**

(Gateway to the cell) **thin barrier = 7nm thick** (5-10nm)

**Cell membrane functions:**

- Physically separate a cell from its environment, provides protection and support for the cell
- Anchor cells to the extracellular matrix
- Maintain an internal balance called **homeostasis**
- Control what goes in and out of the cell (semi-permeable)
- Detect chemical messengers arriving at the surface
- Provide anchoring sites for filaments of cytoskeleton
- Link adjacent cells together by membrane junctions



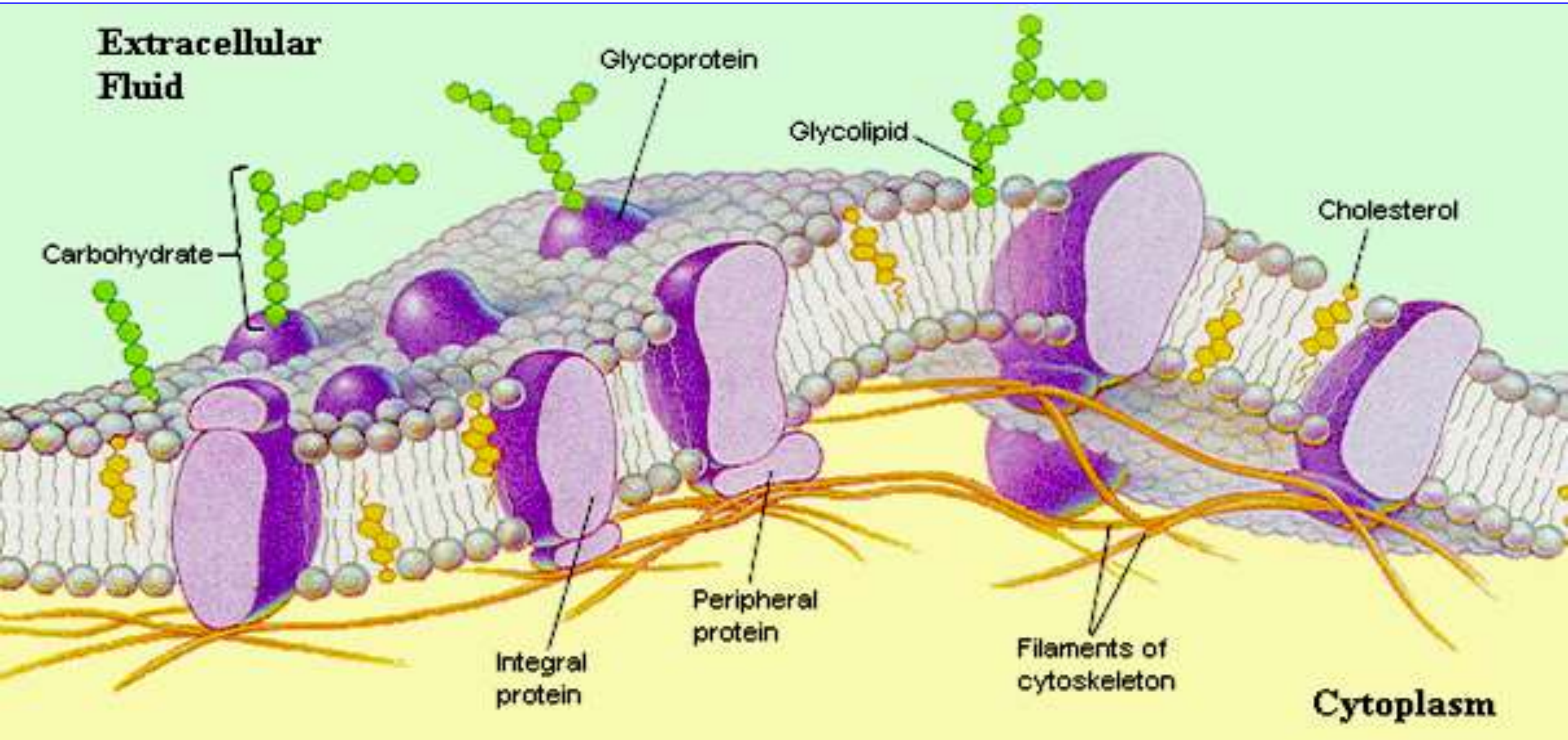



# Biochemical components of plasma membrane

In 1972, S. Singer and G. Nicolson proposed the **Fluid Mosaic Model** of membrane structure

**FLUID-** because individual phospholipids and proteins can move around freely within the layer, like it's a liquid.

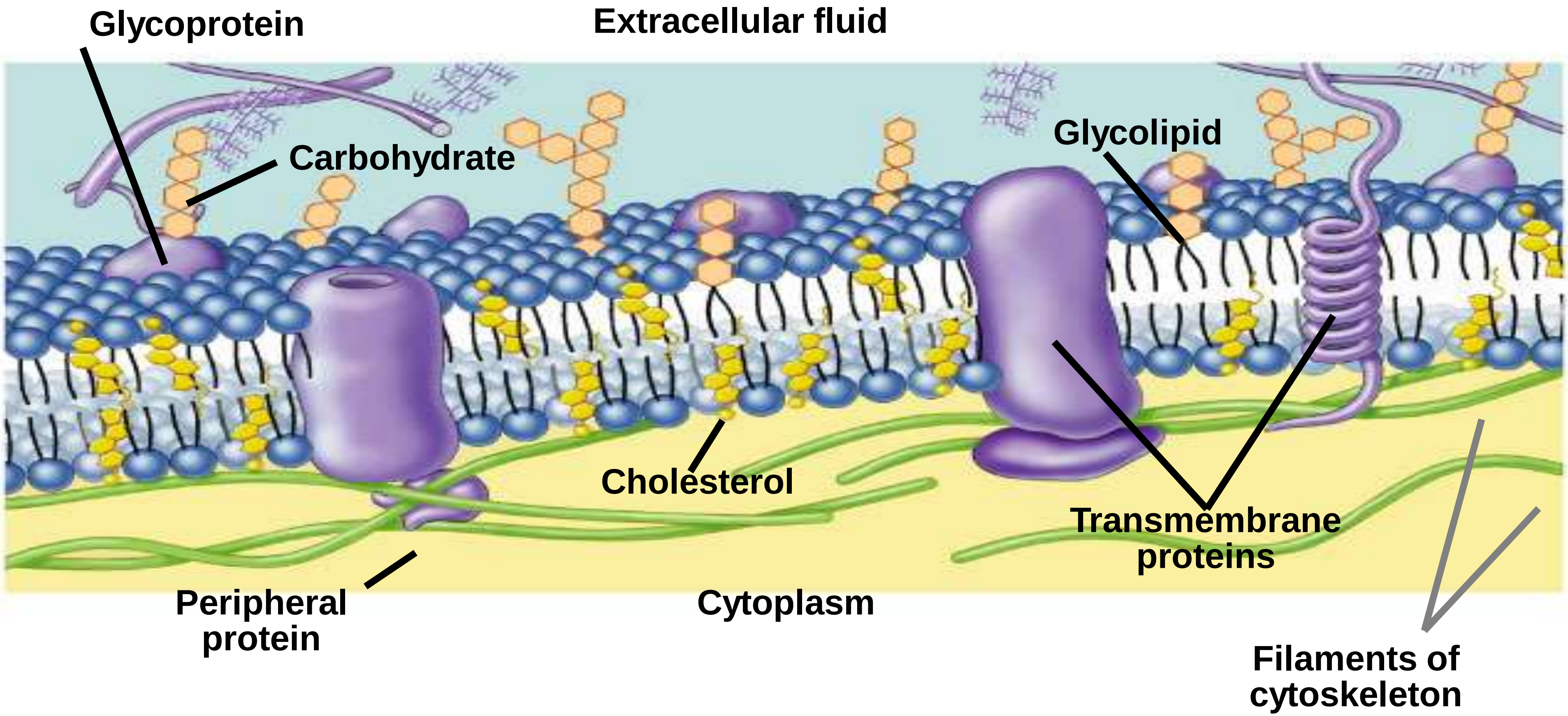
**MOSAIC**- because of the pattern produced by the scattered protein molecules when the membrane is viewed from above.



•Cell membranes are composed of a **lipid bilayer** with **globular proteins** embedded in the bilayer.

•On the external surface, **carbohydrate** groups join with lipids to form **glycolipids**, and with proteins to form **glycoproteins**. These function as cell identity markers.

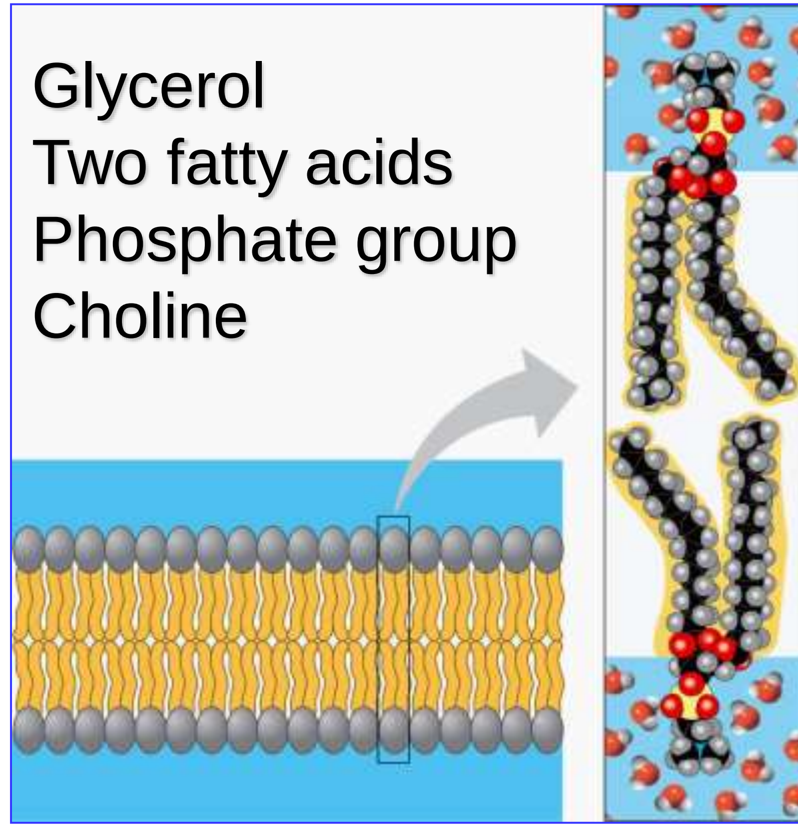
•It is composed of **-lipids** **-proteins** **-carbohydrates**



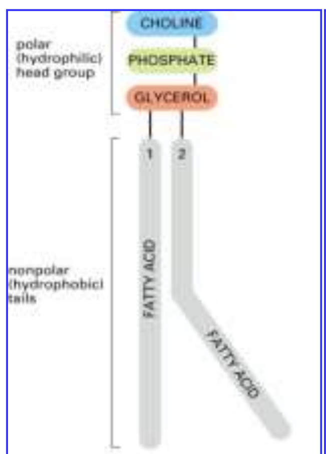
# Lipids

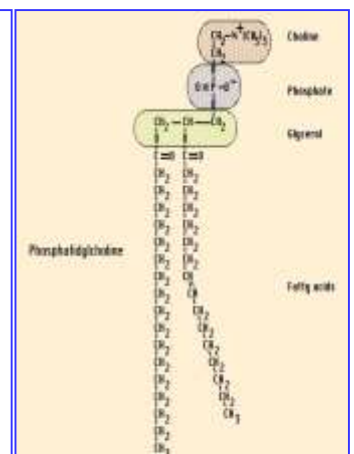
**1.PHOSPHOLIPID BILAYER** the basic structural composition

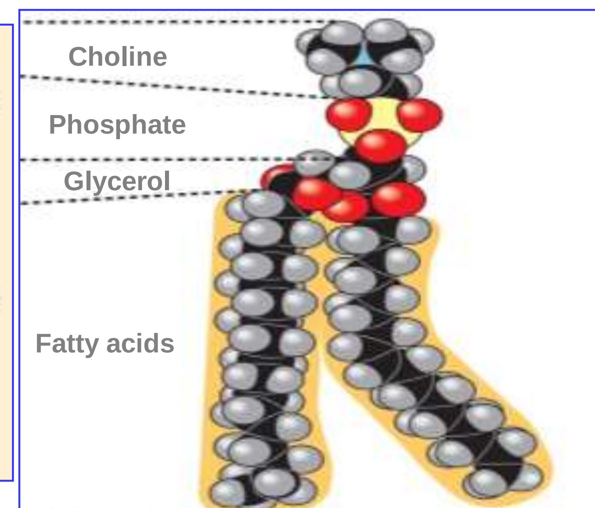
- Phospholipids are **amphiphilic** (**amphipathic**) molecules: have HYDROPHOBIC (**non-polar**/ water fearing) **tails** and HYDROPHILIC (**polar**/ water liking) **heads**.
- It's a pair of fatty acid chains and a phosphate group attached to a glycerol backbone.
- Mainly 2 layers of phospholipids; the non-polar tails point inward and the polar heads are on the surface.




- Phospholipids form the bilayer, act as barrier to most water soluble substances





Membranes are **dynamic**

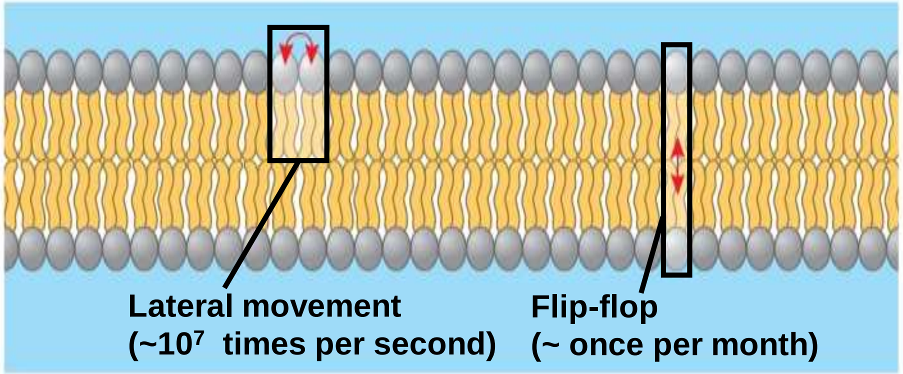
•They can **move**.

•Their components are **continuously** synthesized and degraded.

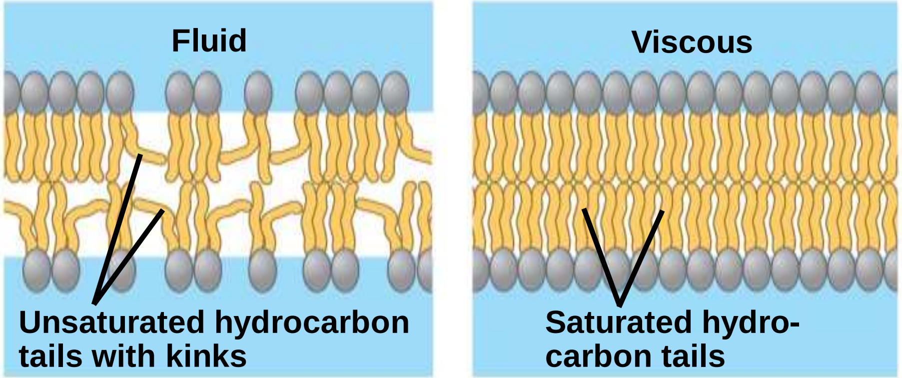
•damage to the cell membrane leads to **cell death** (*e.g.* myocardial infarction)

**Lateral diffusion** refers to the **lateral** movement of **lipids** and **proteins** found in the membrane. Membrane lipids and proteins are generally free to move laterally if they are not restricted by certain interactions. Lateral diffusion is a fairly **quick** and **spontaneous** process.

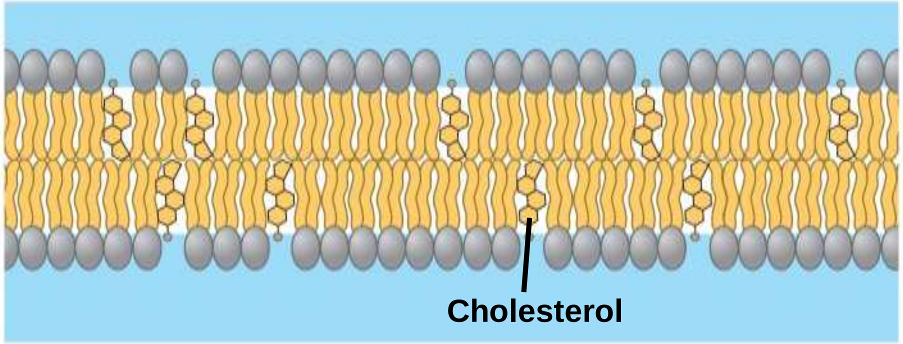
**Transverse diffusion** or **flip-flop** involves the movement of a **lipid** or **protein** from one membrane surface to the other. Unlike lateral diffusion, transverse diffusion is a fairly **slow** process due to the fact that a relatively significant amount of **energy** is required for flip-flopping to occur.




(a) Movement of phospholipids



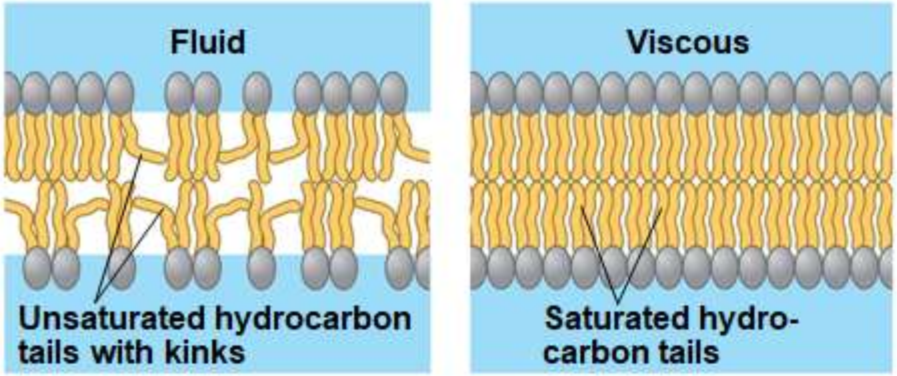

(b) Membrane fluidity




(c) Cholesterol within the animal cell membrane

- As temperatures cool, membranes switch from a fluid state to a solid state
- The temperature at which a membrane solidifies depends on the types of lipids
- Membranes rich in unsaturated fatty acids are more fluid that those rich in saturated fatty acids
- Membranes must be fluid to work properly; they are usually about as fluid as salad oil

Fig. 7-5b




(b) Membrane fluidity

## 2. Glycolipids

least common of the membrane lipids (**2~5%)**

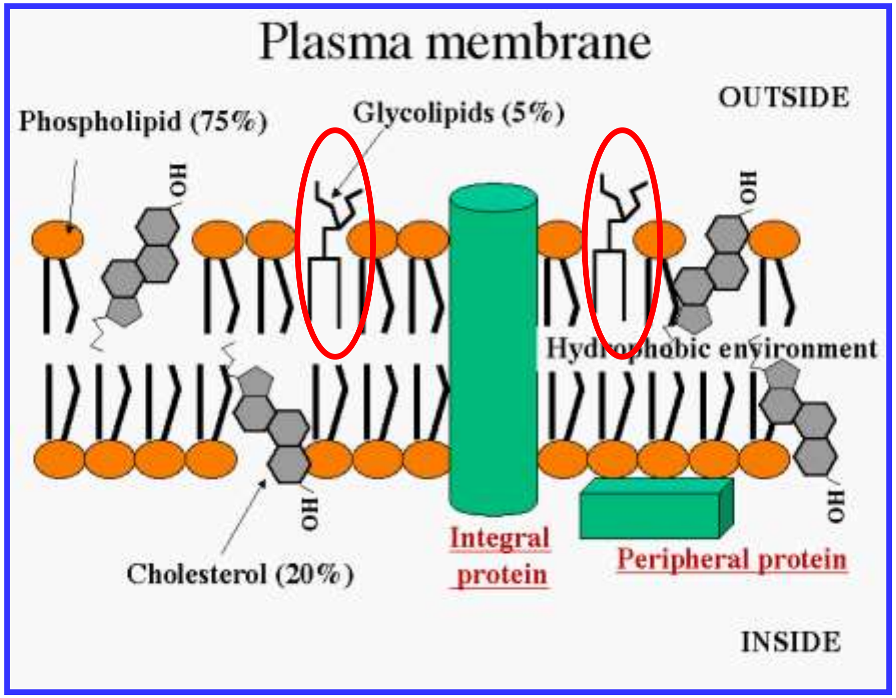
always found in **outer** leaflet of plasma membrane

which have their **hydrophobic tails** embedded in the hydrophobic region of the membrane and their heads exposed outside the cell.

**Function**

Glycolipids and glycoproteins are thought to function in the **recognition**.

help to **stabilize** membrane structure, some act as **receptor molecules, protective**, and **insulators**



## 3. Cholesterol

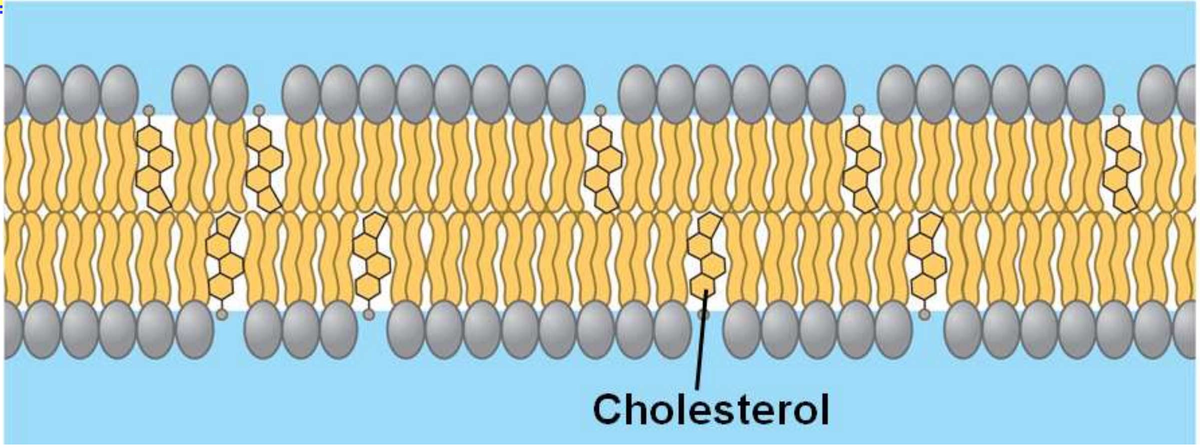
**steroid; lipid soluble; found in both leaflets of lipid bilayer ~20%**

**Wedged between phospholipid molecules with the same orientation as the phospholipid molecules (the polar head of the cholesterol is aligned with the polar head of the phospholipids).**

**Function**

- **Cholesterol regulates the fluidity of the membrane, gives mechanical stability and help to prevent ions from passing through the membrane.**
- **At warm temperatures (such as 37°C), cholesterol restrains the movement of phospholipids and reduces fluidity.**
- **At cool temperatures, it maintains fluidity by preventing tight packing.**

**Thus, cholesterol acts as a "temperature buffer" for the membrane, resisting changes in membrane fluidity as temperature changes**



# 4.Carbohydrates

found on the **outer surface** of all eukaryotic cell membranes, and are linked **covalently** to the membrane proteins (**glycoproteins)** or sometimes to the phospholipids (**glycolipids)**

- Membrane carbohydrates are usually branched **oligosaccharides** < 10 sugar units

**Functions:**

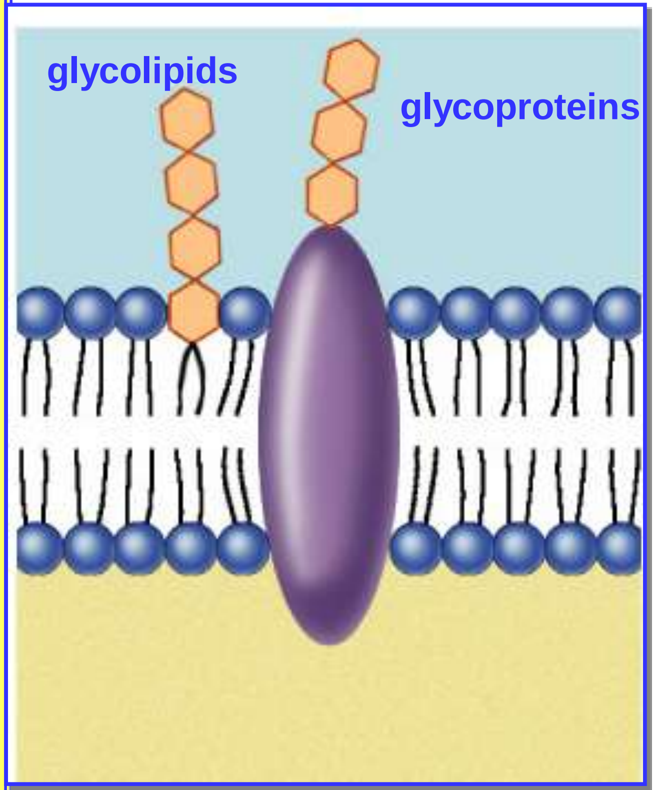
**1-** They form **hydrogen bonds** with the water molecules surrounding the cell and thus help to **stabilize** membrane structure

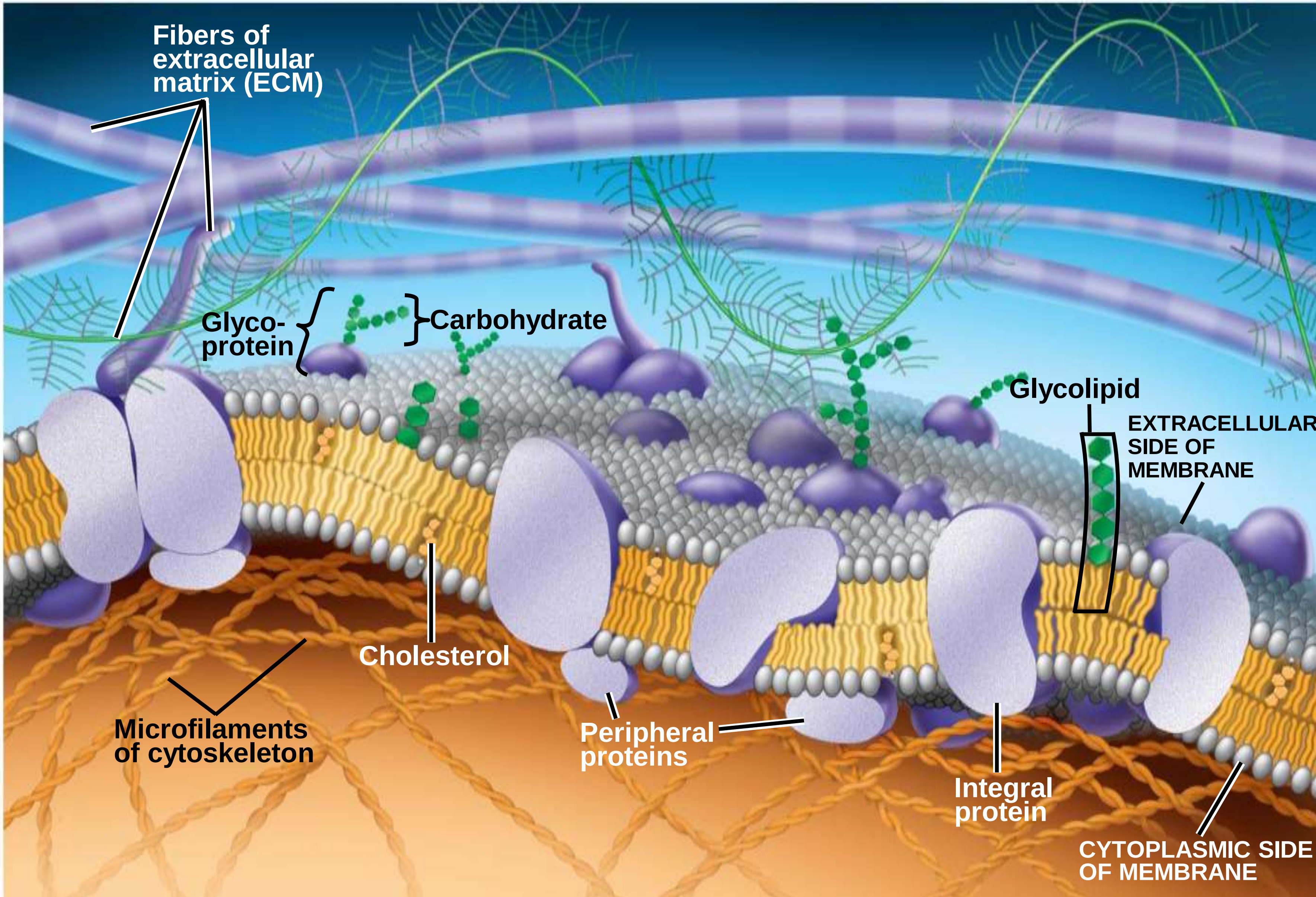
**2**- Used for **cell to cell recognition**(glycolipids and glycoproteins), the ability of a cell to distinguish one type of neighboring cell from another– **antigens** (glycoprotein)

**3**- Basis of immune response. **e.g.** WBC and T-cell response **basis for rejection of foreign cells by immune system**

**4**- **Receptors:** binding with hormones or neurotransmitters

- vary from species to species, individual to individual, and even from cell type to cell type within the same individual. **e.g. ABO group/ blood typing** (glycolipids)



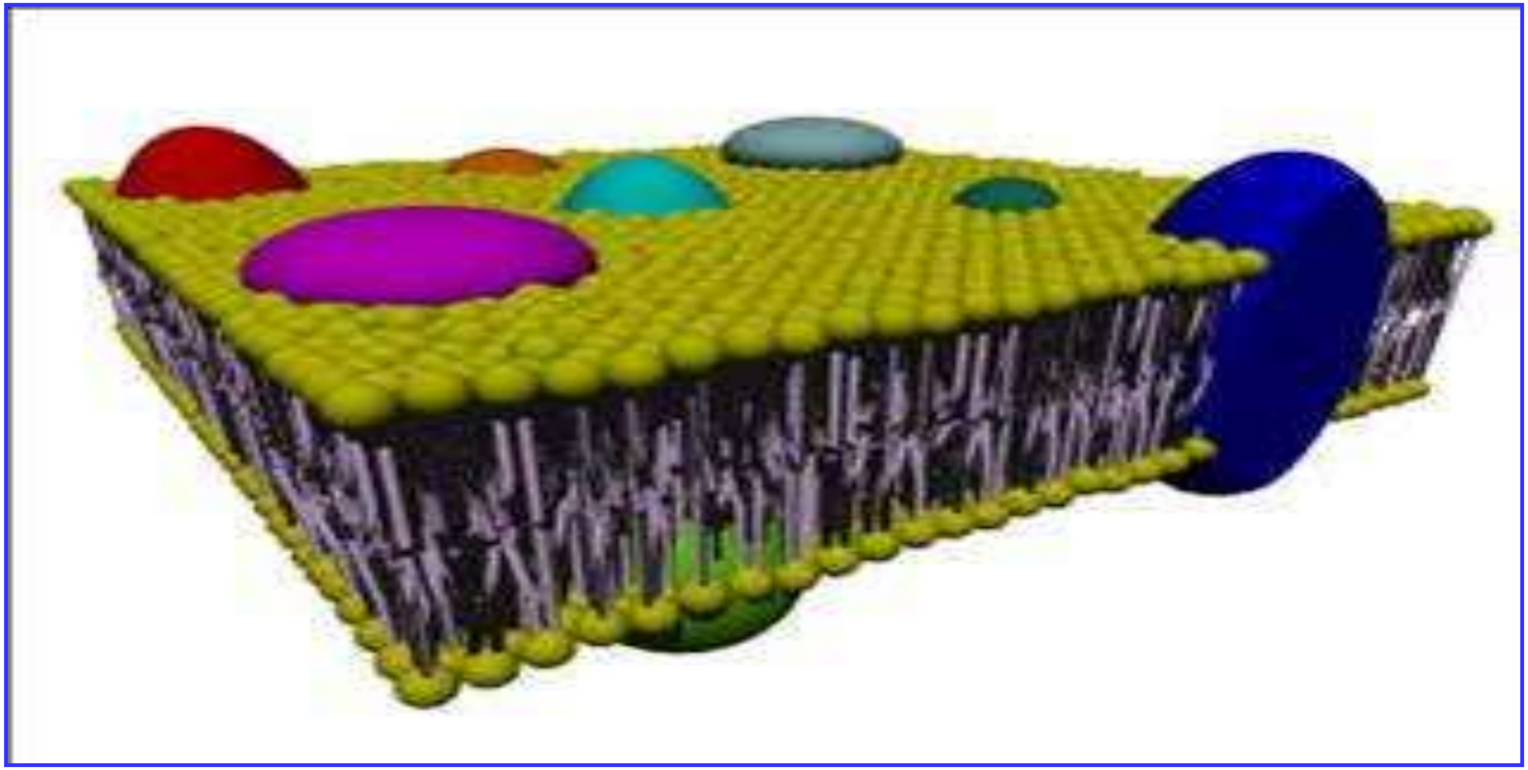

Fibers of extracellular matrix (ECM)
Glyco-protein
Carbohydrate
Glycolipid
EXTRACELLULAR SIDE OF MEMBRANE
Cholesterol
Microfilaments of cytoskeleton
Peripheral proteins
Integral protein
CYTOPLASMIC SIDE OF MEMBRANE

# 5. Proteins

the cell membrane also contains a number of proteins

While the lipid bilayer provides the **structure** for the cell membrane, membrane proteins allow for many of the **interactions** that occur between cells

**Most** membrane proteins are **free** to move within the lipid bilayer as a result of its **fluidity**, some can  be **confined** to certain areas of the bilayer



**classifications**

**1. Integral Proteins**

-Usually about **70 to 80%** of membrane proteins are ***spanning*** the membrane in some manner

-integral proteins are usually **transmembrane** proteins, extending through the lipid bilayer. **Transmembrane proteins** are amphipathic, in that they have hydrophobic and hydrophilic regions

**Within membrane**

**nonpolar amino acids**

**hydrophobic**

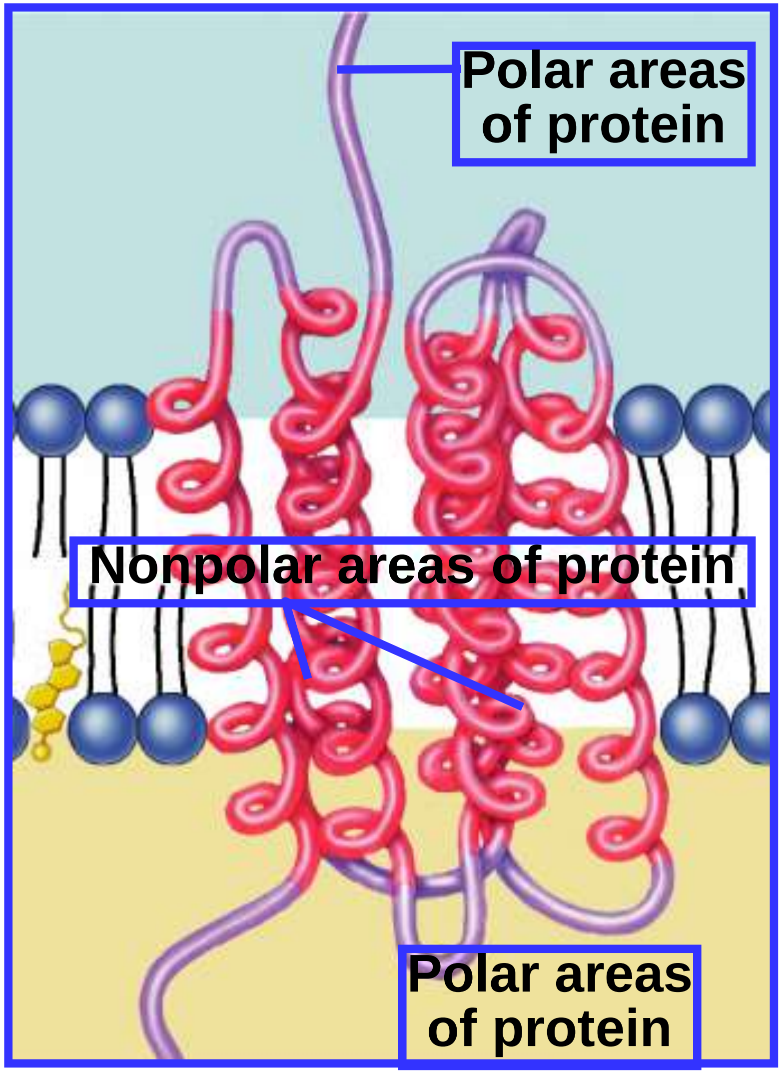
**anchors protein into membrane**

**On outer surfaces of membrane**

**polar amino acids**

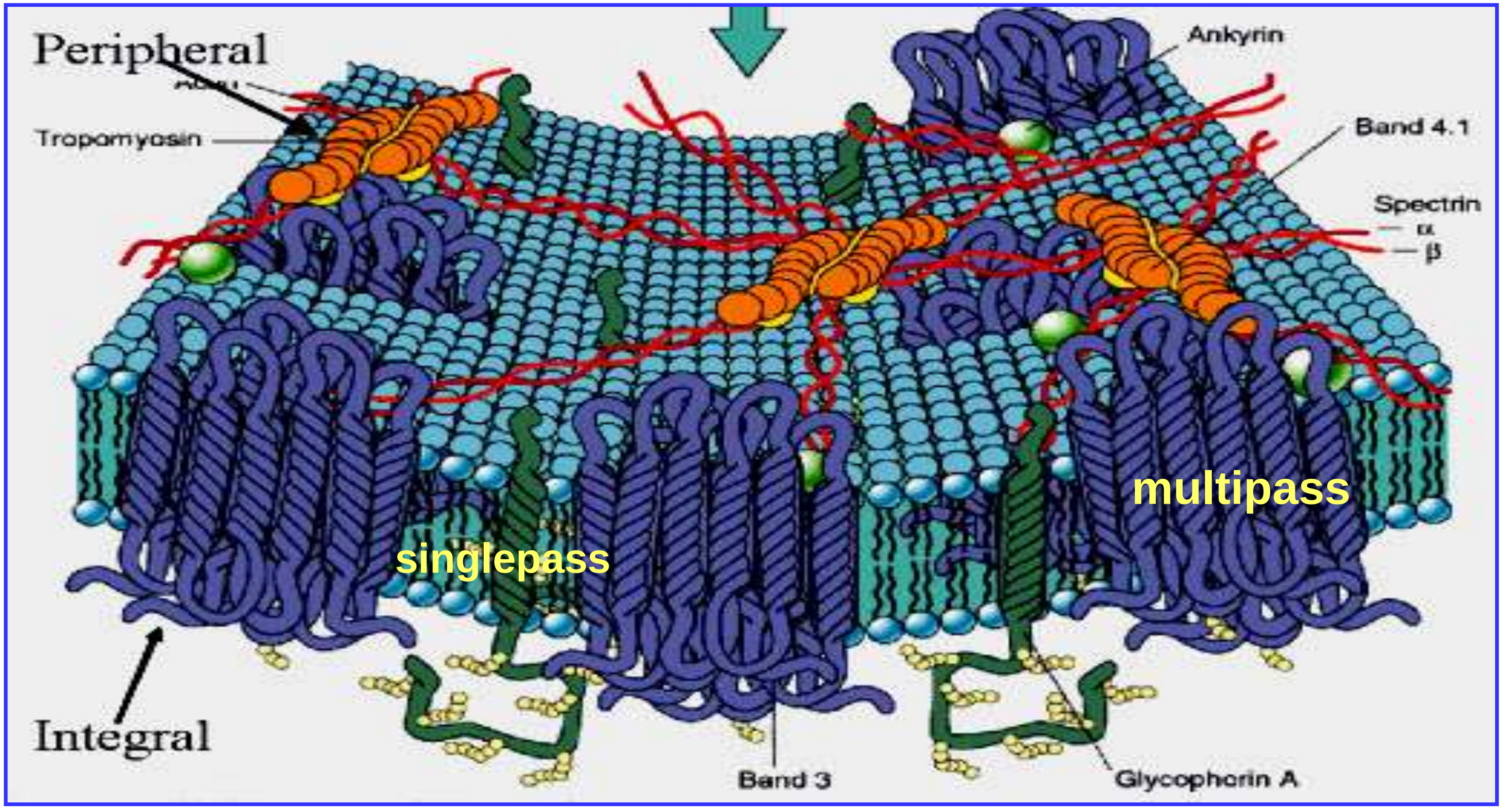
**hydrophilic**

**extend into extracellular fluid & into cytosol**



Transmembrane proteins are the only class of proteins that can perform **functions** both **inside** and **outside** of the cell.

Proteins inserted once through the membrane are called "**single-pass transmembrane proteins**." Those that pass through several times are called "**multipass transmembrane proteins**" , they form loops outside the membrane

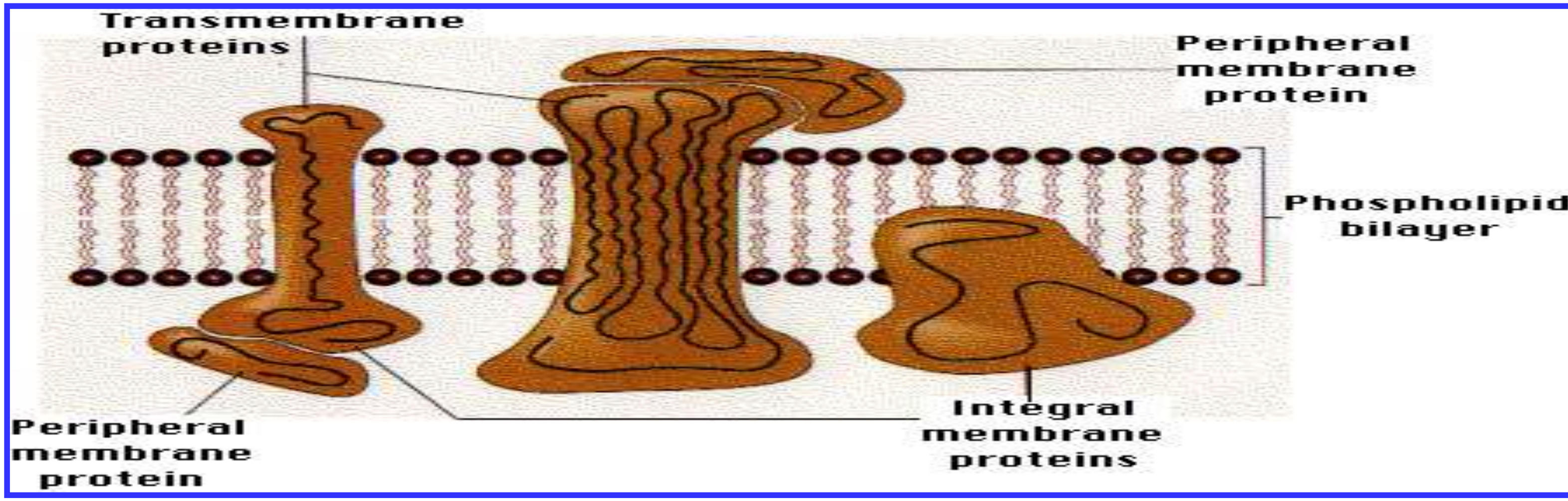


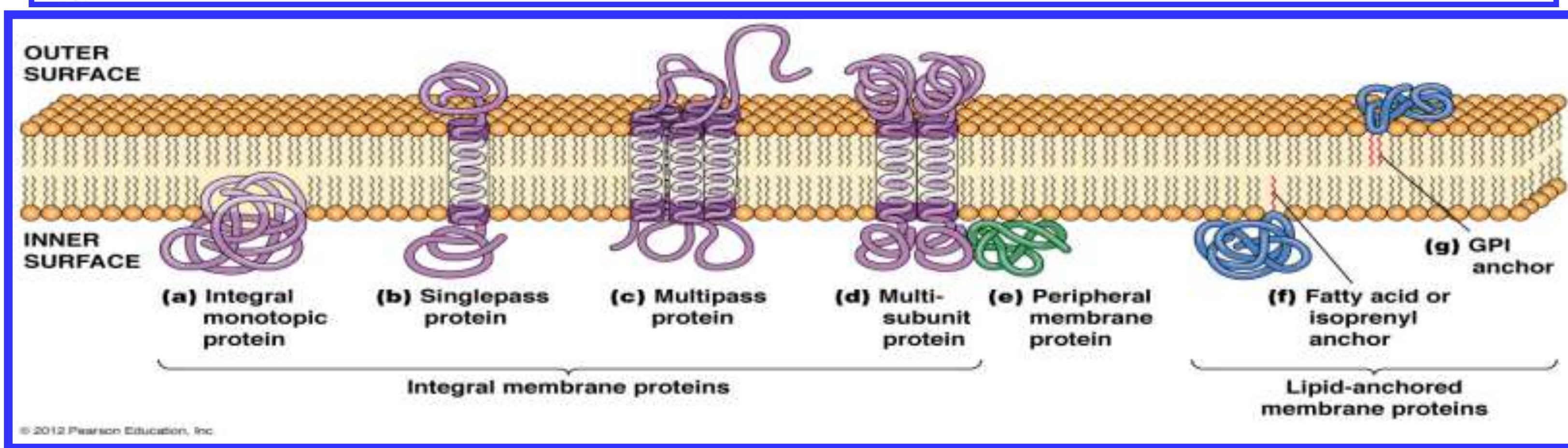
**2. Peripheral Proteins**

Peripheral proteins are attached to the **exterior** of the lipid bilayer**.** easily **separable** from the lipid bilayer **20 to 30%**

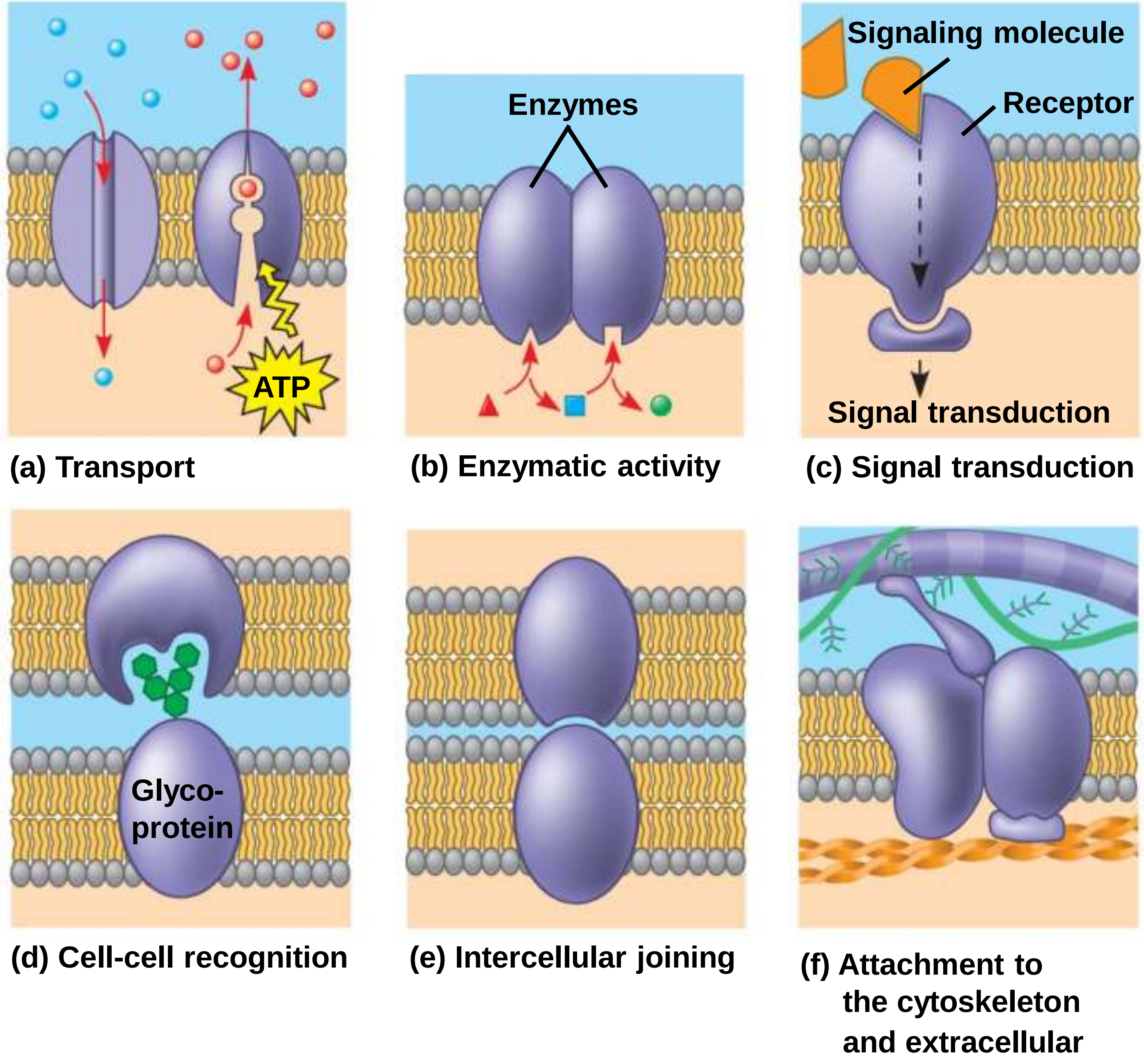
are those that **do *not*** span the membrane but instead are **bound** either to lipids-based molecules or attached **noncovalently** to proteins that span the membrane

**(Bounded Proteins**, lipid bound and carbohydrate bound)



Six major functions of membrane proteins:



# Permeability across cell membrane

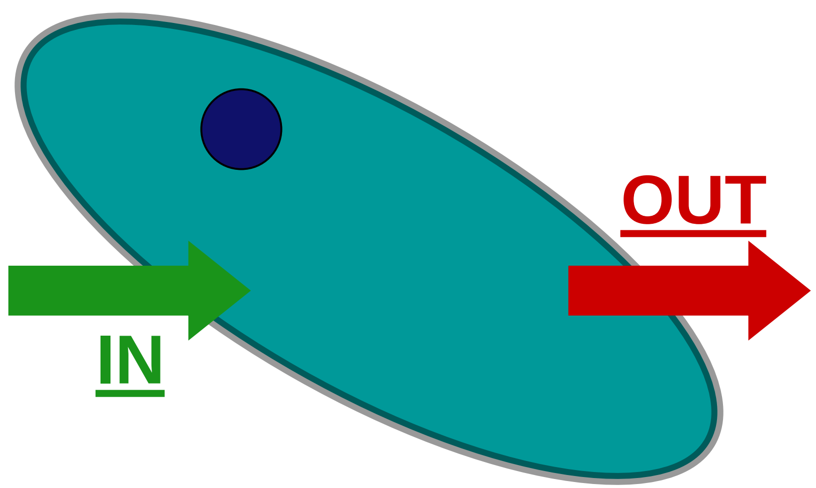
- Cell membrane is the boundary between inside & outside…
  - separates cell from its environment

**Can it be an impenetrable boundary?** **NO!**

**IN**

**food**

**carbohydrates**
**sugars, proteins**
**amino acids**
**lipids**
**salts, $O_2$, $H_2O$**




**OUT**

**waste**

**ammonia**
**salts**
**$CO_2$**
**$H_2O$**
**products**

**cell needs materials in & products or waste out**

## Permeability Factors

- Lipid solubility
- Size of molecules
- Charge and polar molecules
- Temperature increases
- Presence of channels and transporters
- pH

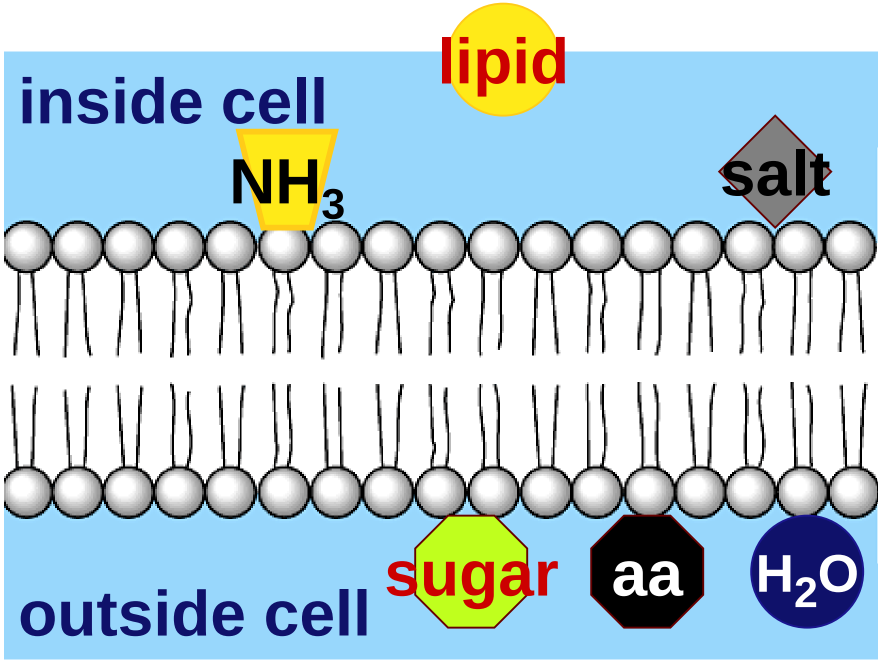
-**Hydrophobic molecules** are lipid soluble and can **pass** through the membrane rapidly

-**Polar molecules** do **not** cross the membrane rapidly

-**Transport proteins** allow passage of **hydrophilic** substances across the membrane

# Diffusion through phospholipid bilayer

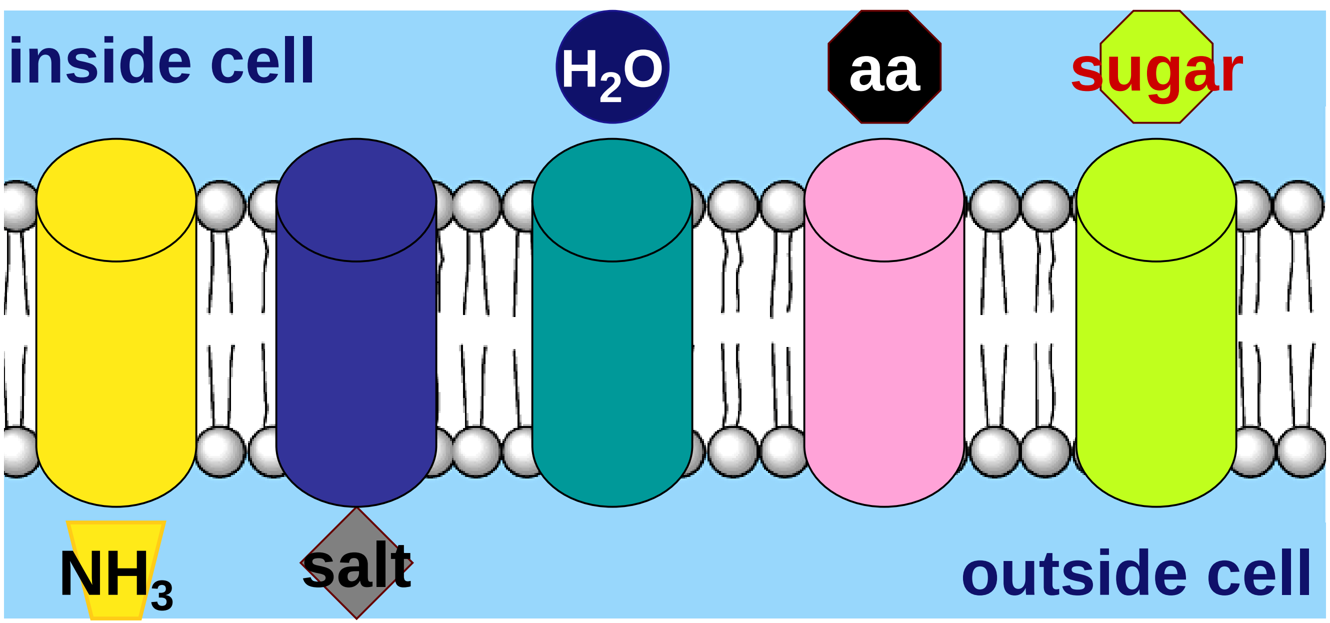
- What molecules can get through directly?
  - fats & other lipids

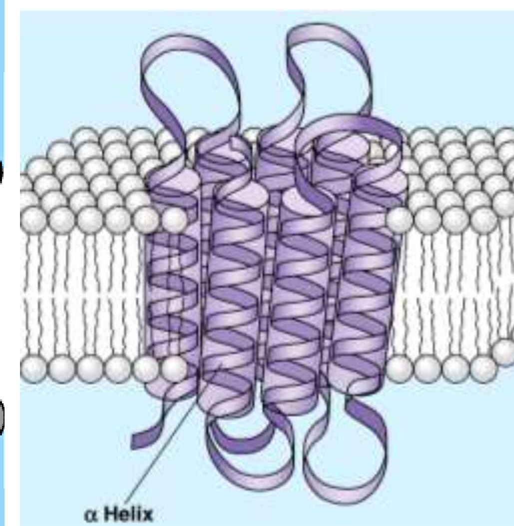



- What molecules can NOT get through directly?
  - polar molecules
    - $H_2O$
  - ions
    - salts, ammonia
  - large molecules
    - starches, proteins

# Channels through cell membrane

- Membrane becomes <u>semi-permeable</u> with protein channels
  - specific channels allow specific material across cell membrane



## Membrane permeability

The plasma membrane is **selectively permeable**, it allows some substances to cross it more easily than others

Types of Cellular Transport

**Passive Transport**

cell **does not** use energy

molecules move randomly, molecules spread out from an area of **high** concentration to an area of **low** concentration

- Diffusion
- Facilitated Diffusion
- Osmosis

**Active Transport**

cell does **use energy**

- Protein Pumps
- Endocytosis
- Exocytosis

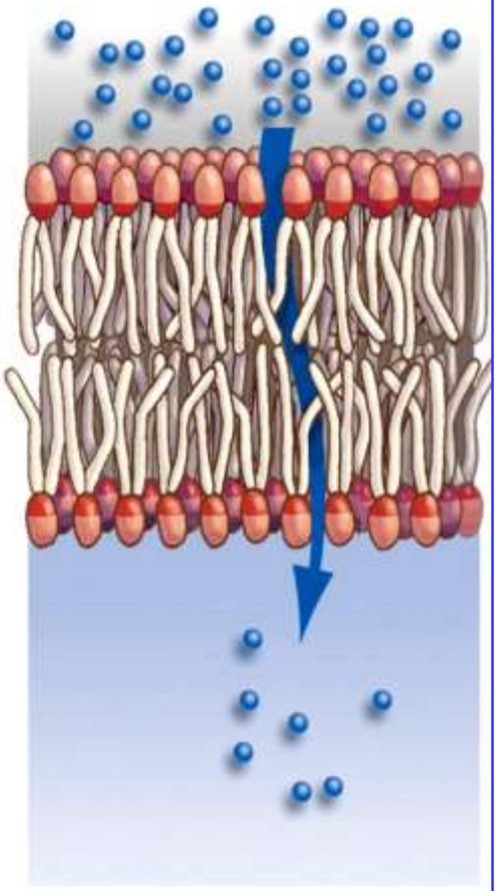
# Passive Transport

**Diffusion**: random passive movement of particles from an area of **high concentration** to an area of **low concentration** until ***equilibrium*** is reached. (***High to Low***)

**diffusion of nonpolar, hydrophobic molecules**

Example: **lipid** and **gases**, oxygen diffusing into a cell and carbon dioxide diffusing out.

simple diffusion



Materials move down their concentration gradient through the phospholipid bilayer.

## Facilitative Diffusion

diffusion of specific particles (**high** to **low** concentration)

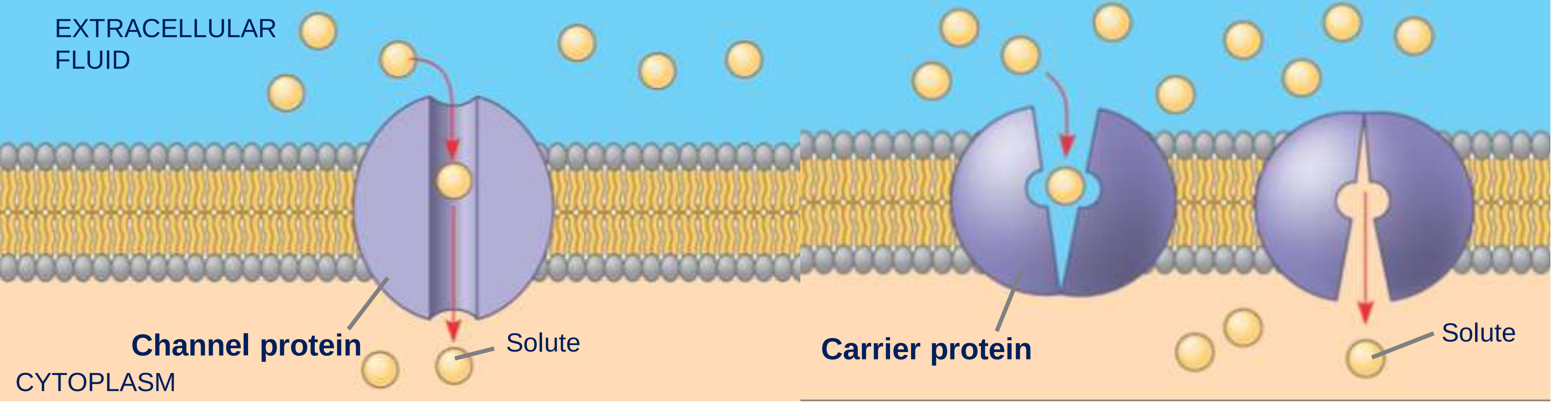
- **Diffusion through protein channels**
- **no energy** needed

**diffusion of polar, hydrophilic molecules**

**Two types** of transport proteins can help ions and large polar molecules diffuse through cell membranes:

- **Channel proteins** – provide a narrow channel for the substance to pass through.
- **Carrier proteins** – physically bind to the substance on one side of membrane and release it on the other.
- Some diseases are caused by malfunctions in specific transport systems, for example the kidney disease cystinuria

Examples: **Glucose** or **amino acids** moving from blood into a cell.



## Osmosis

Osmosis is the **diffusion of water** across a semi-permeable membrane from a hypotonic solution to a hypertonic solution

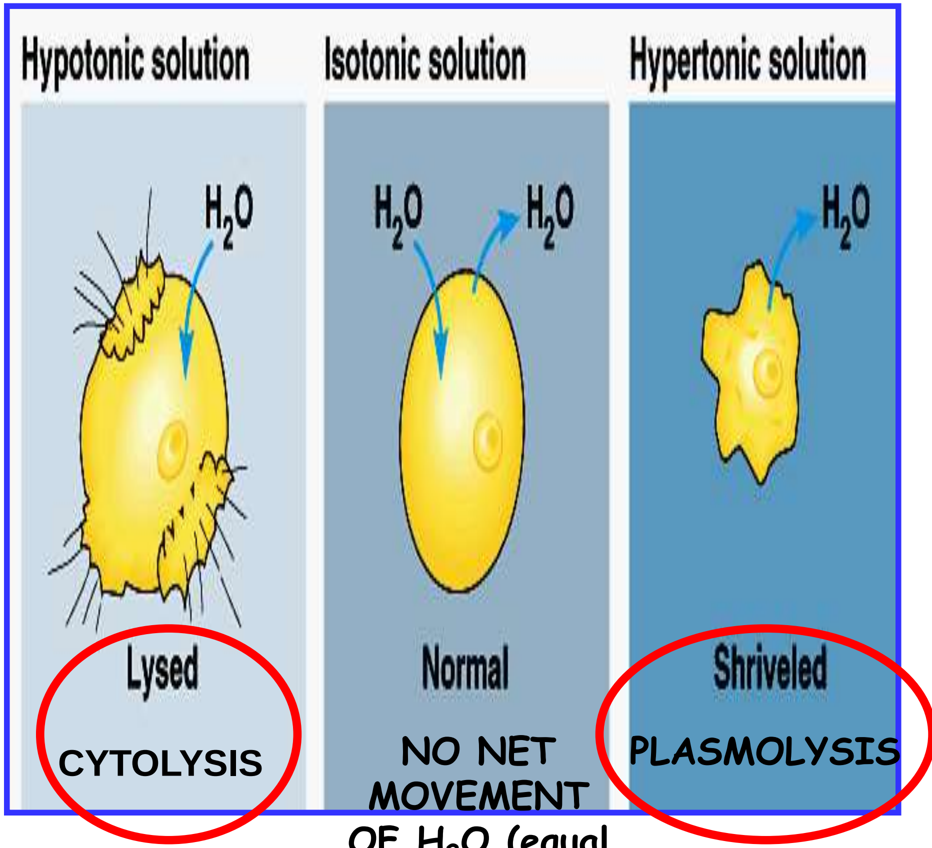
**Direction of osmosis is determined by comparing total solute concentrations (Tonicity)**

- **Hypertonic - more solute, less water**
- **Hypotonic - less solute, more water**
- **Isotonic - equal solute, equal water**

**Water can diffuse across plasma membrane--- Moves from HIGH water potential (low solute concentration) to LOW water potential (high solute concentration)**

**Aquaporins (water channels)** are proteins embedded in the cell membrane that regulate the flow of water only.

**Homeostasis (equilibrium)**




NO NET MOVEMENT OF $H_2O$ (equal amounts entering & leaving) e.g. Normal saline 0.9%NaCl

# *Water Balance of Cells Without Walls*

- **Tonicity** is the ability of a solution to cause a cell to gain or lose water
- **Isotonic** solution: Solute concentration is the same as that inside the cell; no net water movement across the plasma membrane
- **Hypertonic** solution: Solute concentration is greater than that inside the cell; cell loses water
- **Hypotonic** solution: Solute concentration is less than that inside the cell; cell gains water

**-Active Transport**

**// Protein Pumps** -transport proteins that require **energy** to do work (**low to high** concentration) **AGAINST concentration gradient**

2 types:

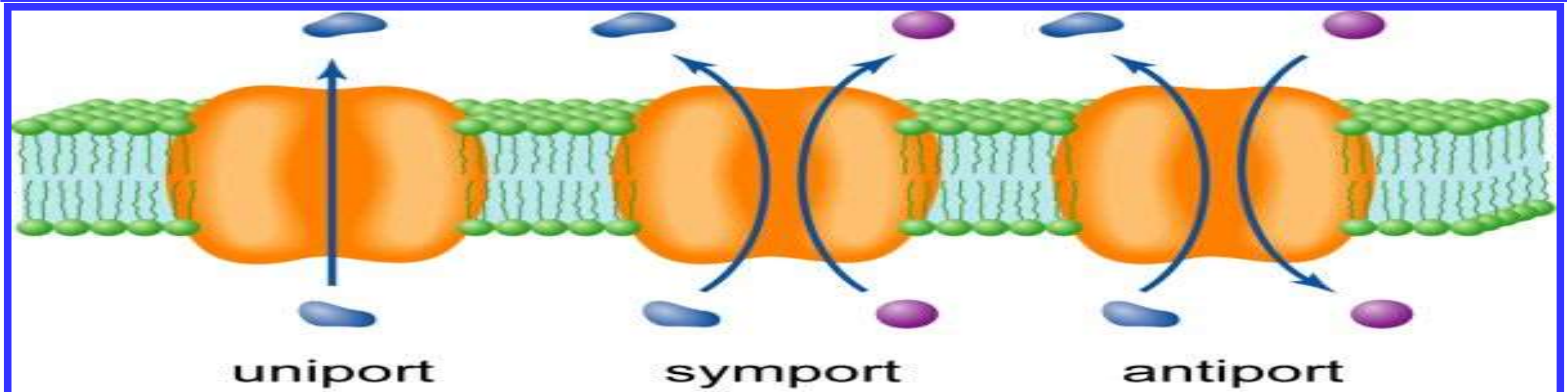
- **Primary active transport (** directly uses metabolic energy/ energy is derived directly from the breakdown of ATP)**: Membrane pump** (protein-mediated active transport) example **Na+/K+ Pump (Shown in figure)**

- **Secondary active transport**: (electrochemical potential difference created by pumping/ energy is derived secondarily from energy that has been stored in the form of ionic concentration differences between the two sides of a membrane.)

  **Coupled transport (cotransport)**

  -**symport** transport two substances simultaneously in the same direction example **glucose symporter** (glucose and sodium)

  **-antiport** transport two substances in opposite directions example **sodium-calcium exchanger** or **antiporter**



# How Ion Pumps Maintain Membrane Potential

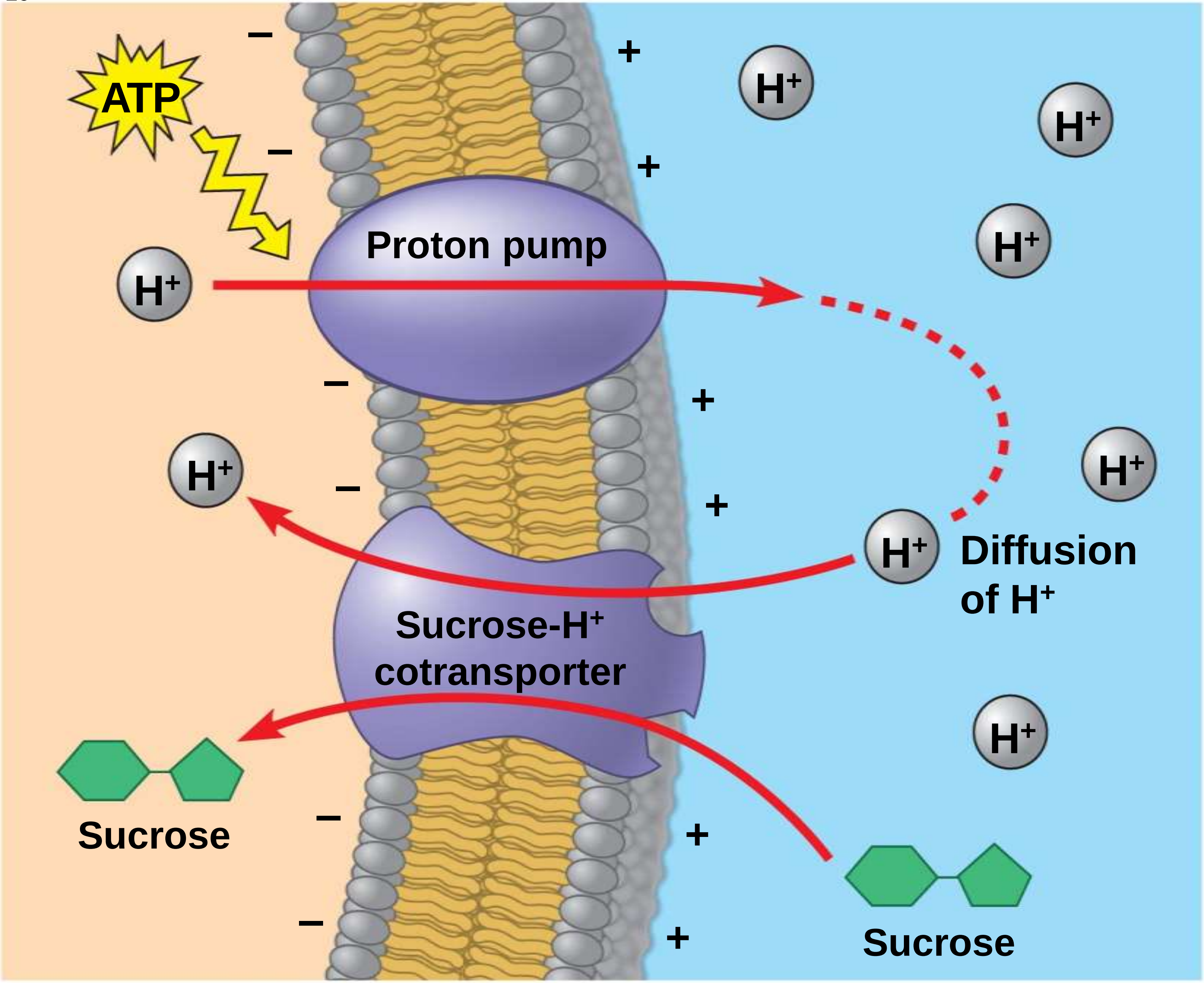
- **Membrane potential** is the voltage difference across a membrane

- Voltage is created by differences in the distribution of positive and negative ions

- Two combined forces, collectively called the **electrochemical gradient**, drive the diffusion of ions across a membrane:
  - A chemical force (the ion’s concentration gradient)
  - An electrical force (the effect of the membrane potential on the ion’s movement)

- An **electrogenic pump** is a transport protein that generates voltage across a membrane
- The **sodium-potassium pump** is the major electrogenic pump of animal cells
- The main electrogenic pump of plants, fungi, and bacteria is a **proton pump.**
- **Cotransport** occurs when active transport of a solute indirectly drives transport of another solute

Fig. 7-19


ATP
Proton pump
H+
Diffusion of H+
Sucrose-H+ cotransporter
Sucrose
Sucrose

# The Sodium-potassium Pump

1. Cytoplasmic $Na^+$ binds to the sodium-potassium pump.

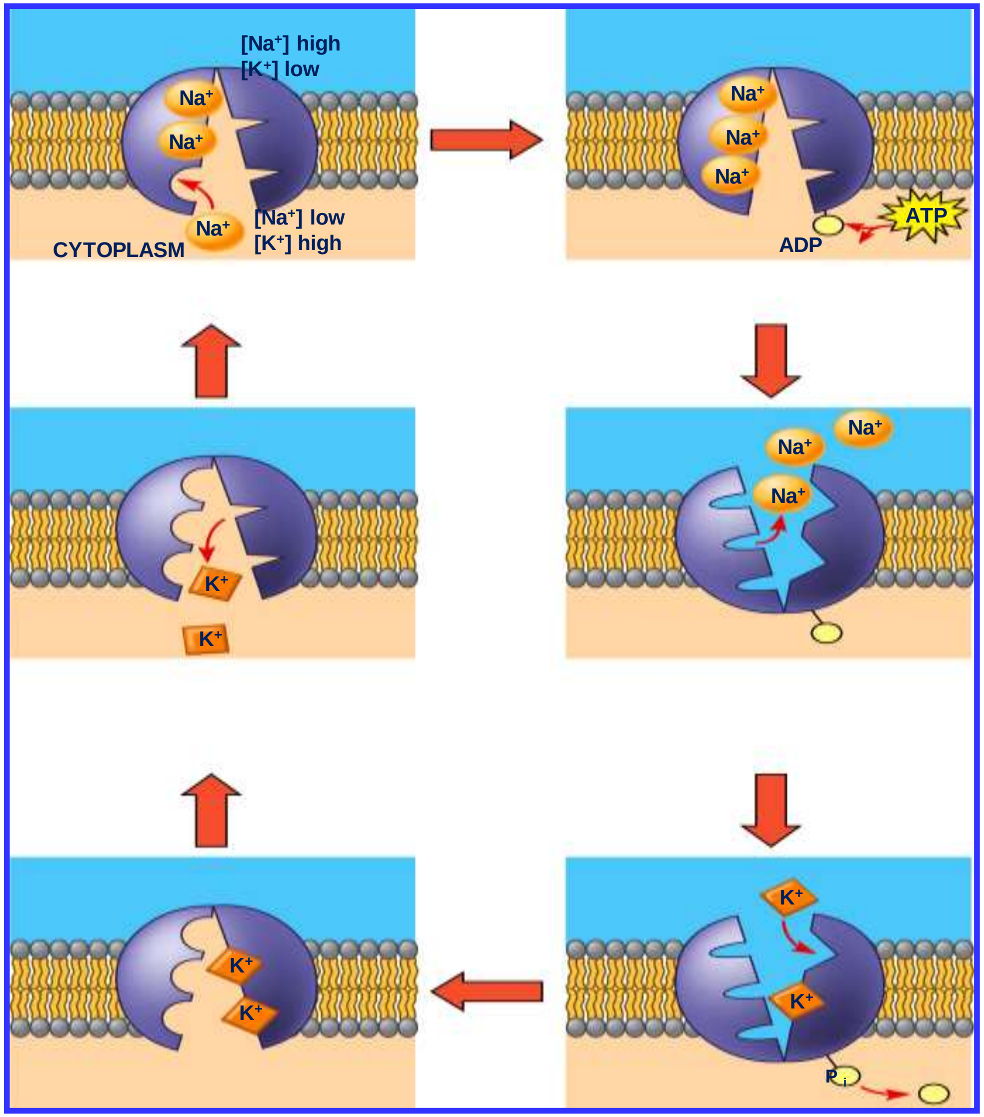
2. Na+ binding stimulates phosphorylation by ATP.

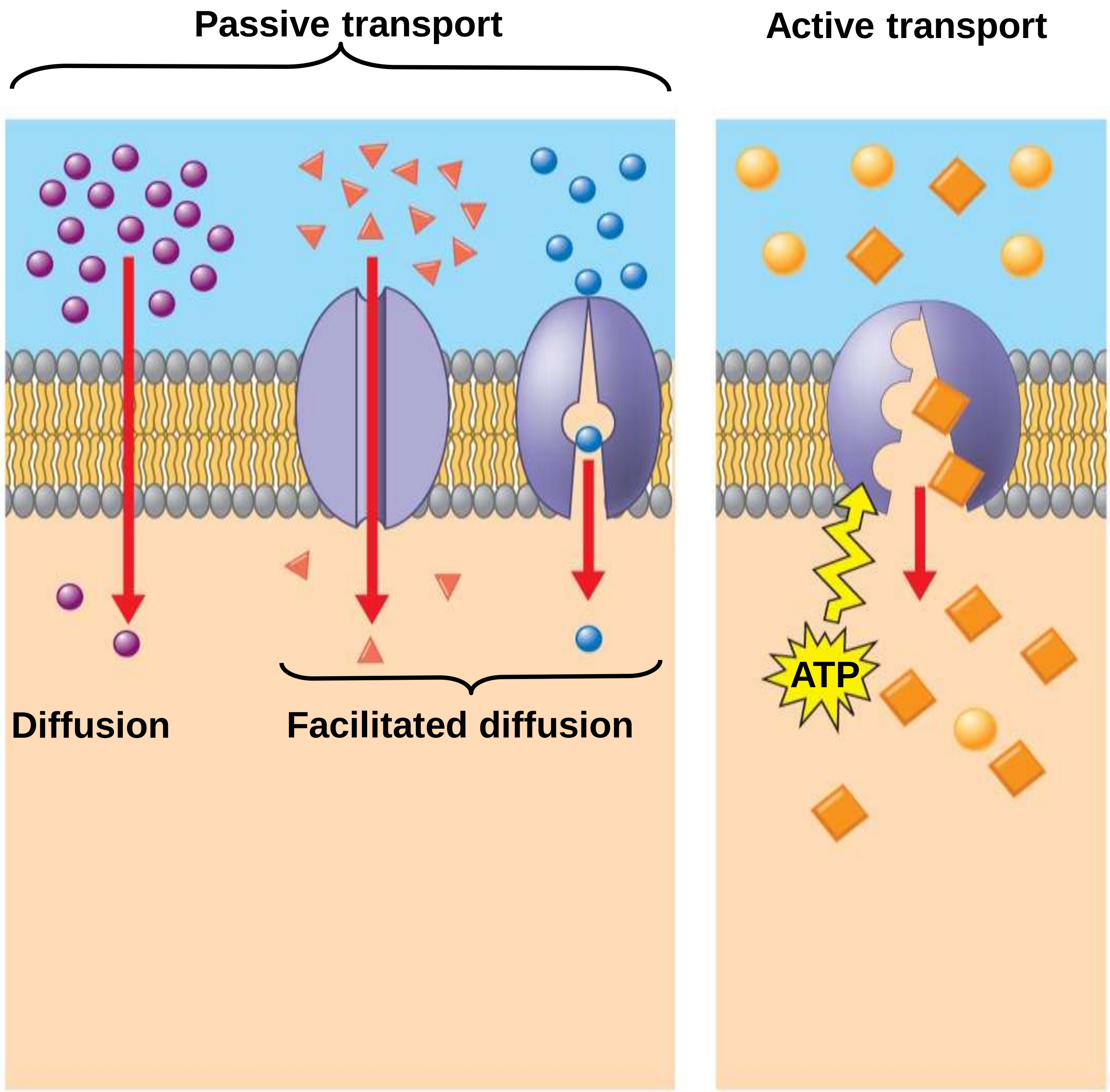
3. Phosphorylation causes the protein to change its conformation, expelling $Na^+$ to the outside.

4. Extracellular $K^+$ binds to the protein, triggering release of the Phosphate group.

5. Loss of the phosphate restores the protein's original conformation.

6. $K^+$ is released and $Na^+$ sites are receptive again;
the cycle repeats.





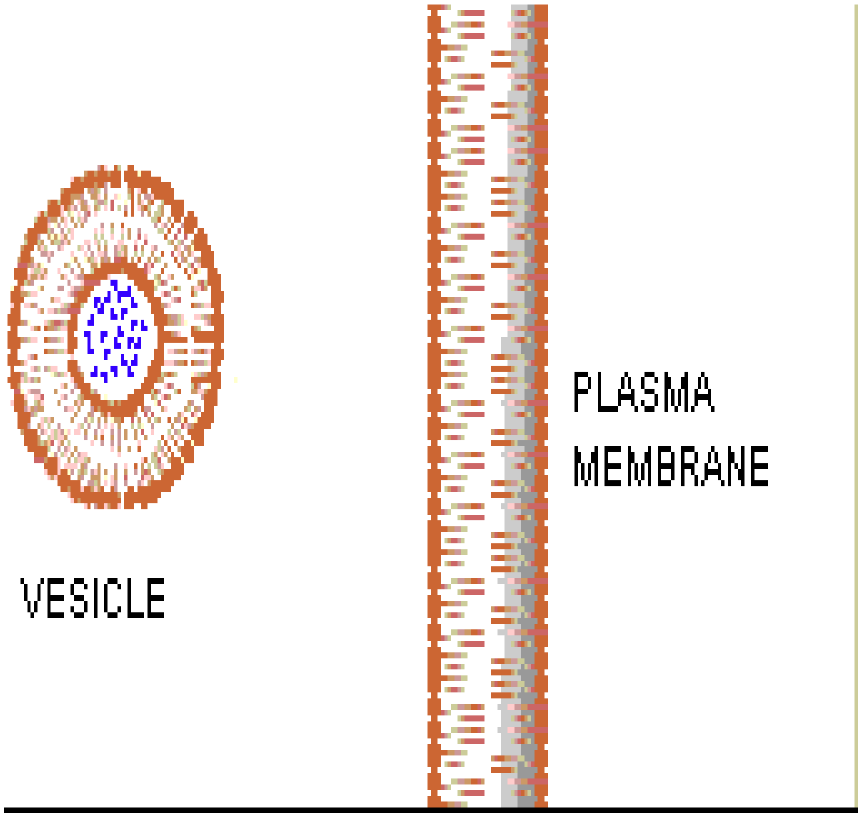
Passive transport
Active transport
Diffusion
Facilitated diffusion
ATP

# Bulk Transport

Allows small particles, or groups of molecules to enter or leave a cell without actually passing through the membrane.
2 mechanisms of bulk transport:
**endocytosis** and **exocytosis**
Both endocytosis and exocytosis involve motor proteins and **require energy**

## Endocytosis

- **Phagocytosis** large particles
- **Pinocytosis** fluids and small particles
- **Receptor-Mediated Endocytosis**

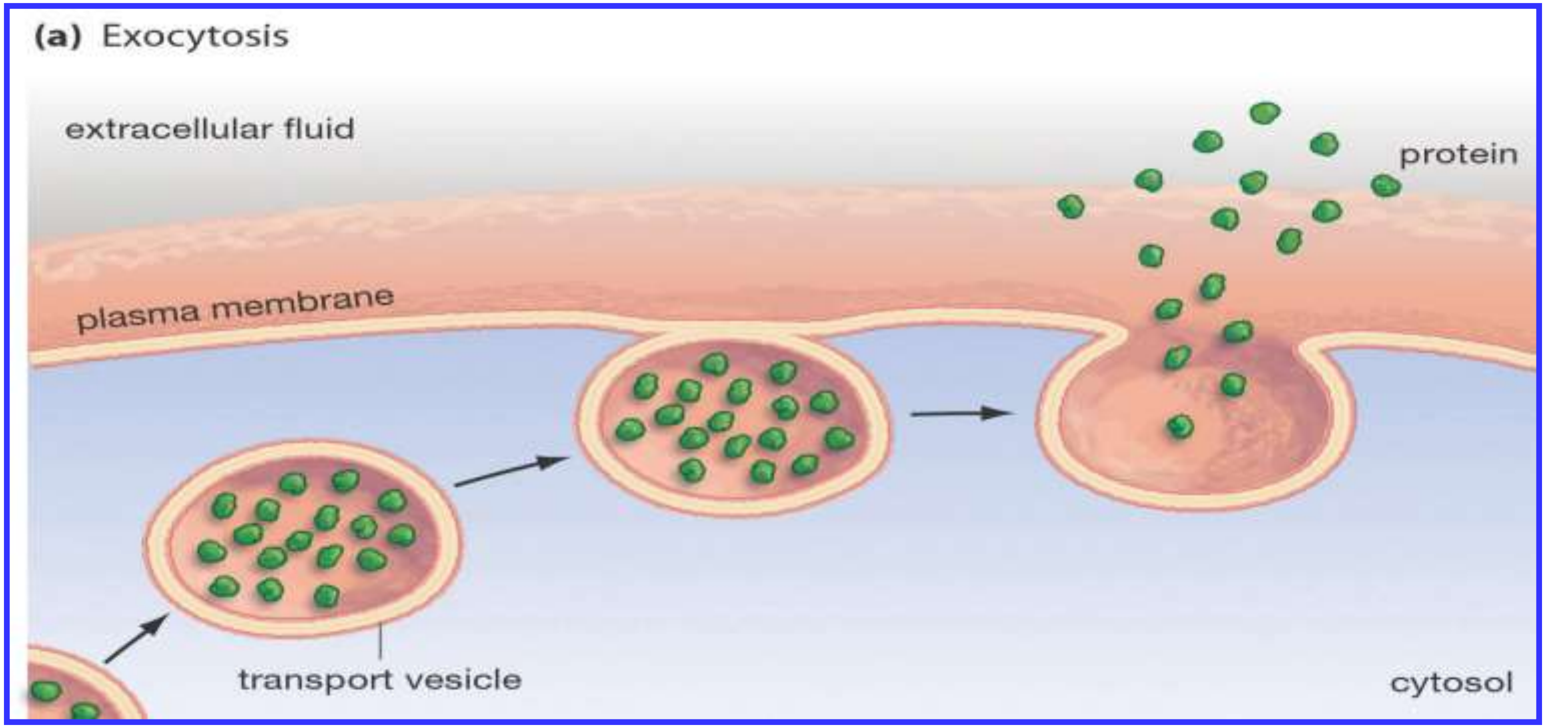


**Exocytosis**

**moving things out**

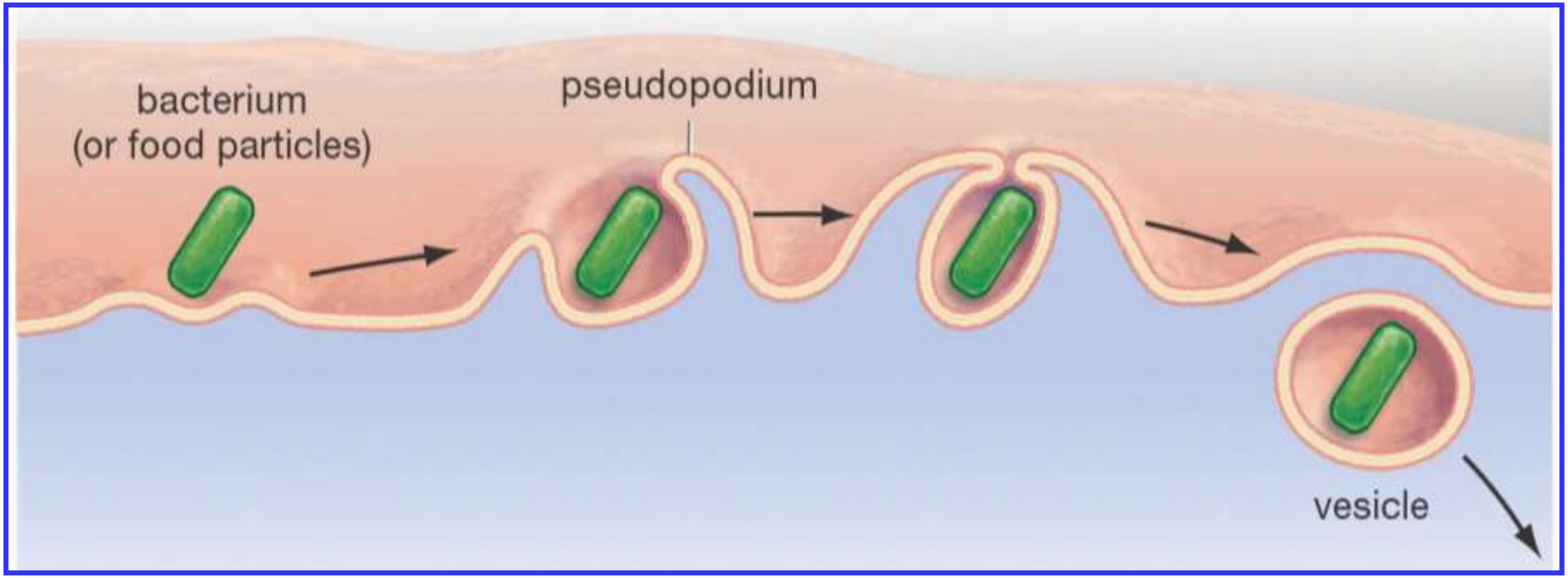
Molecules are moved out of the cell by **vesicles** that fuse with the plasma membrane, **waste** and **secretory products**

This is how many **hormones** are secreted and how nerve cells communicate with one another (**neurotransmitters**)



## Endocytosis

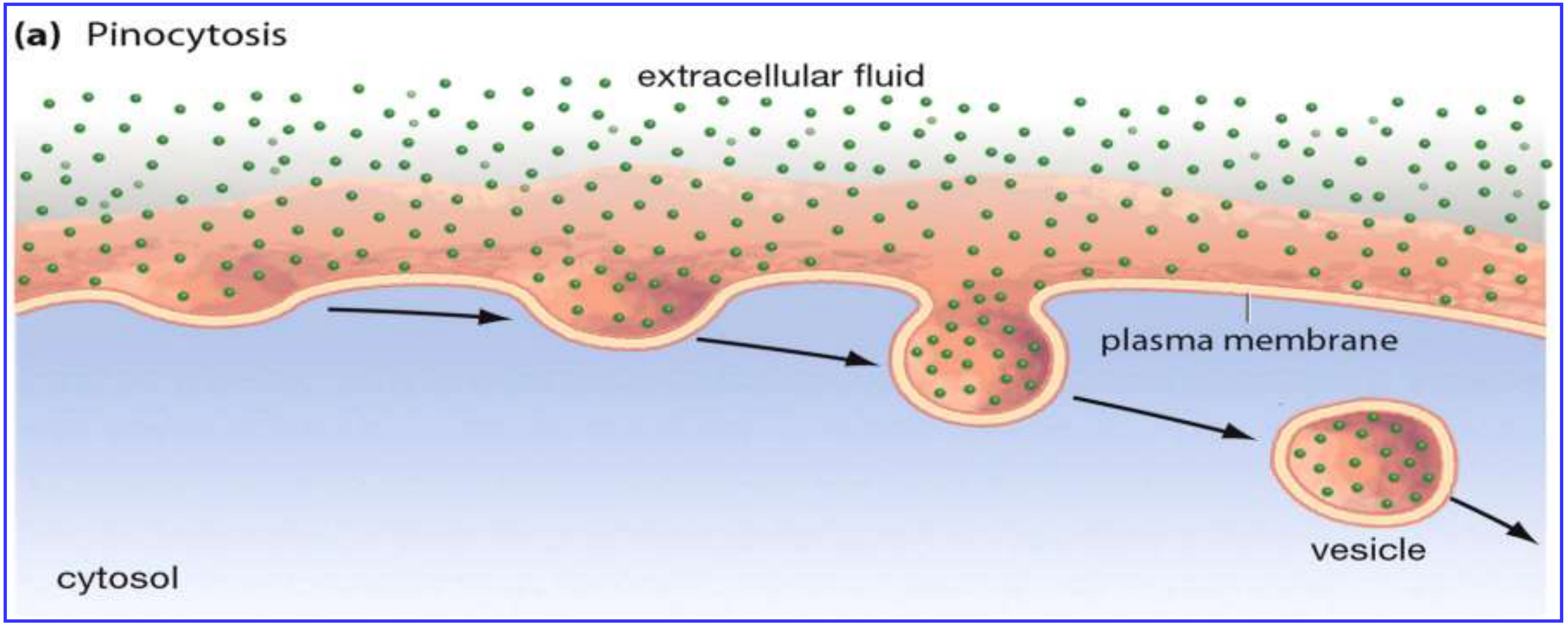
**Phagocytosis** Transports large particles**,** a cell engulfs a particle by **wrapping pseudopodia** around it and packaging it within a membrane-enclosed sac as a vesicle or vacuole. The particle is digested after the vacuole fuses with a lysosome containing hydrolytic enzymes.



## Pinocytosis

Transport **fluids** and **small** particles **(Cell Drinking)**

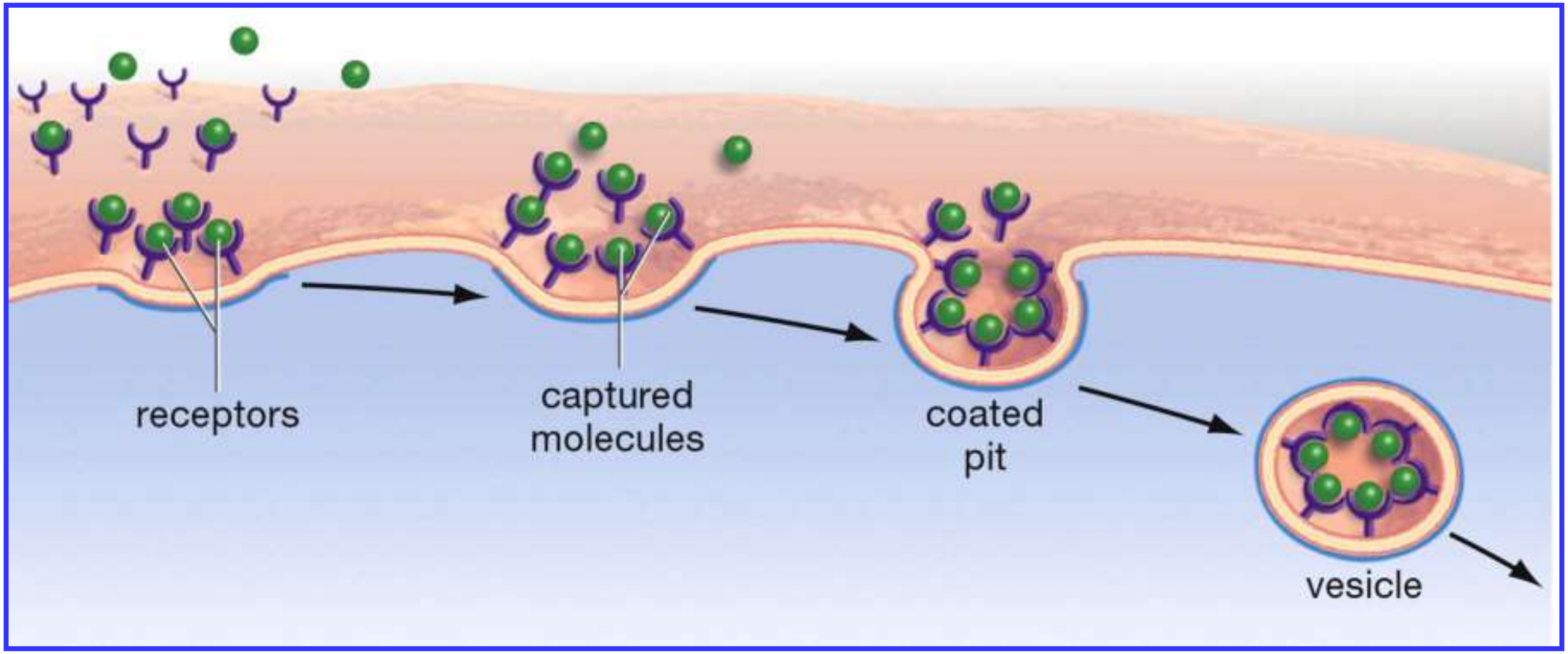
This is the **most common** form of endocytosis
In **pinocytosis,** the cell "gulps" droplets of extracellular fluid into tiny **vesicles**. It is not the fluid itself that is needed by the cell, but the **molecules dissolved** in the droplet. Pinocytosis is **nonspecific** in the substances it transports



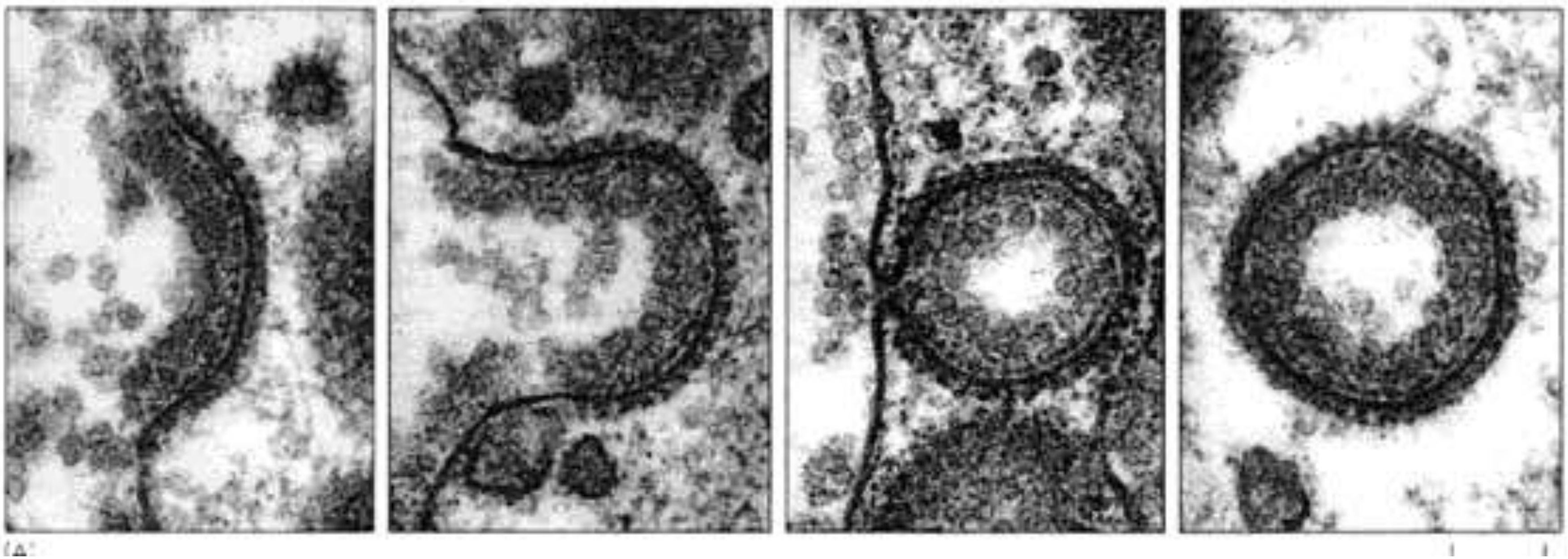
## Receptor-Mediated Endocytosis

**triggered by molecular signal** Receptor proteins make this a highly **specific** form of transport

**Cholesterol** is taken-up this way.



# Formation of Clathrin-Coated Vesicles

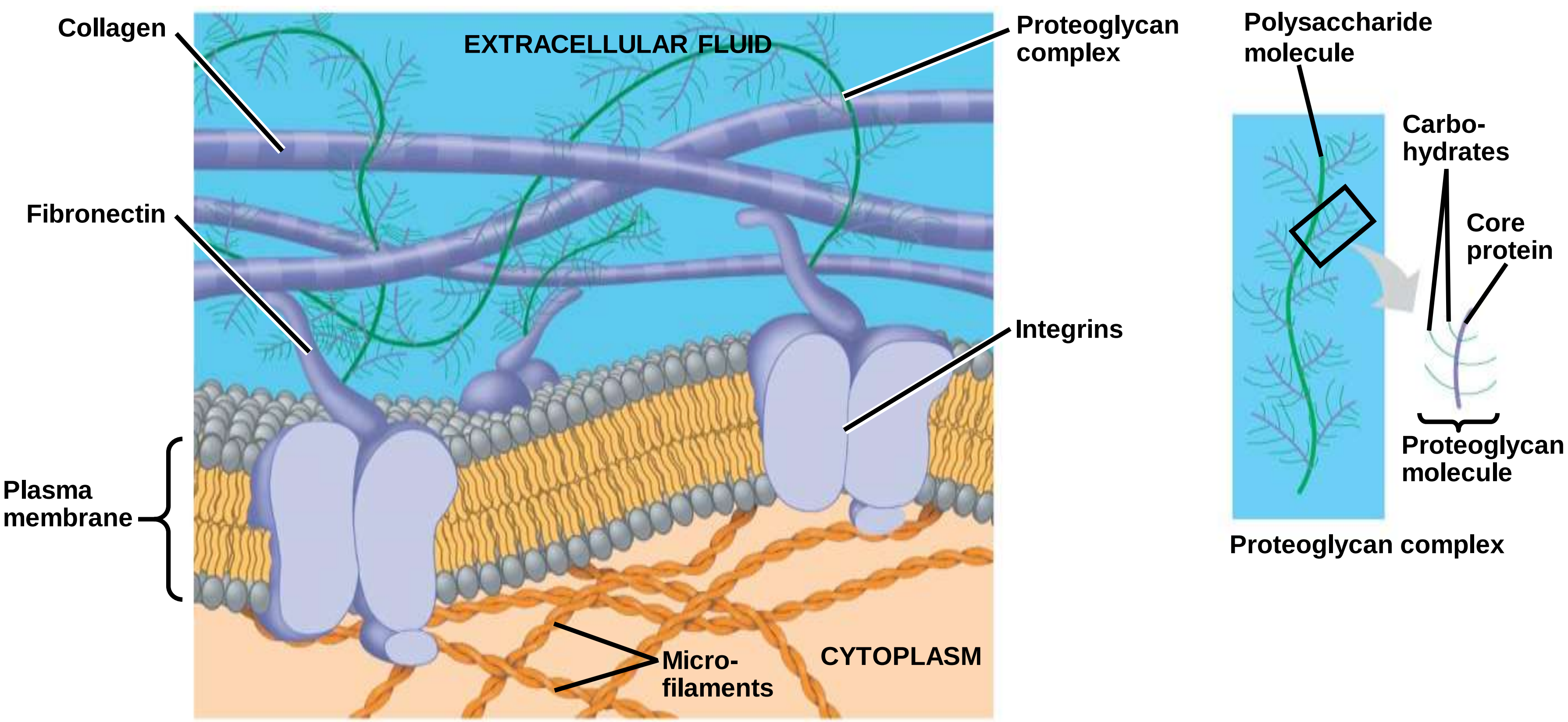


# Extracellular components and connections between cells help coordinate cellular activities

- Most cells synthesize and secrete materials that are external to the plasma membrane
- These extracellular structures include:
  - Cell walls of plants
  - The  extracellular matrix (ECM) of animal cells
  - Intercellular junctions

# The Extracellular Matrix (ECM) of Animal Cells

- Animal cells lack cell walls but are covered by an elaborate **extracellular matrix (ECM)**
- The ECM is made up of glycoproteins such as **collagen**, **proteoglycans**, and **fibronectin**
- ECM proteins bind to receptor proteins in the plasma membrane called **integrins.**
- Functions of the ECM:
  - Support
  - Adhesion
  - Movement
  - Regulation



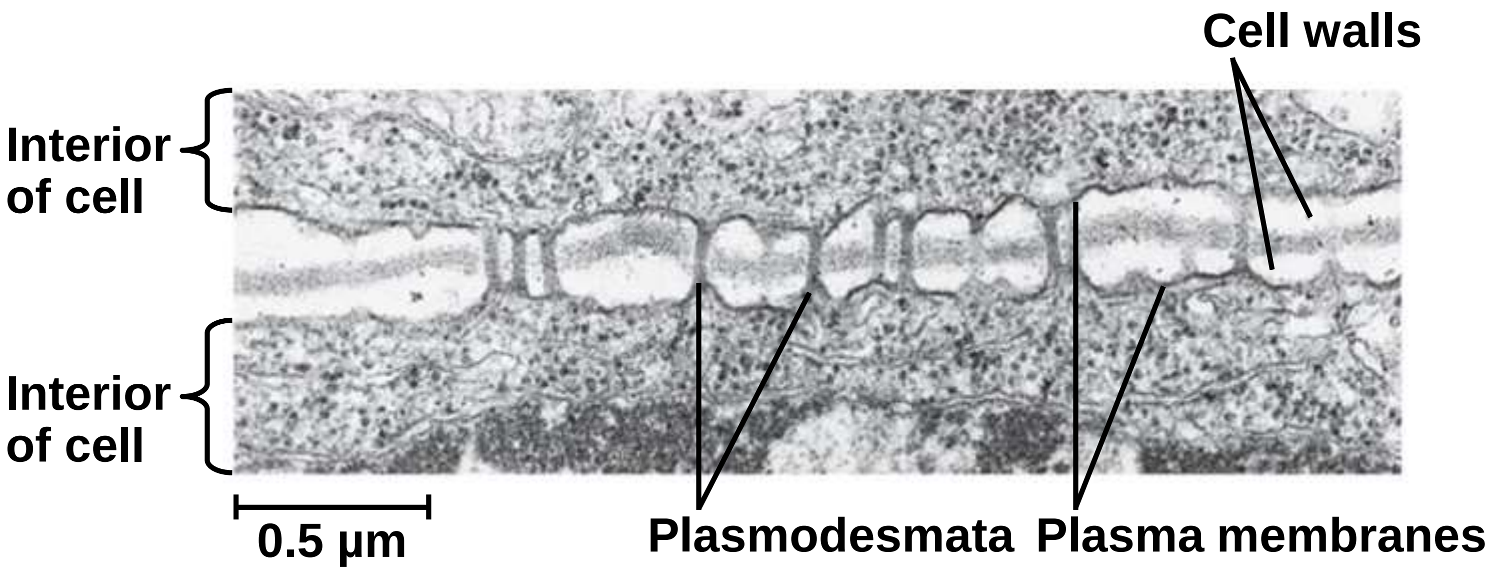
Collagen
EXTRACELLULAR FLUID
Proteoglycan complex
Polysaccharide molecule
Carbo-hydrates
Core protein
Fibronectin
Integrins
Plasma membrane
Proteoglycan molecule
Proteoglycan complex
Micro-filaments
CYTOPLASM

# Intercellular Junctions

- Neighboring cells in tissues, organs, or organ systems often adhere, interact, and communicate through direct physical contact
- Intercellular junctions facilitate this contact
- There are several types of intercellular junctions
  - Plasmodesmata
  - Tight junctions
  - Desmosomes
  - Gap junctions

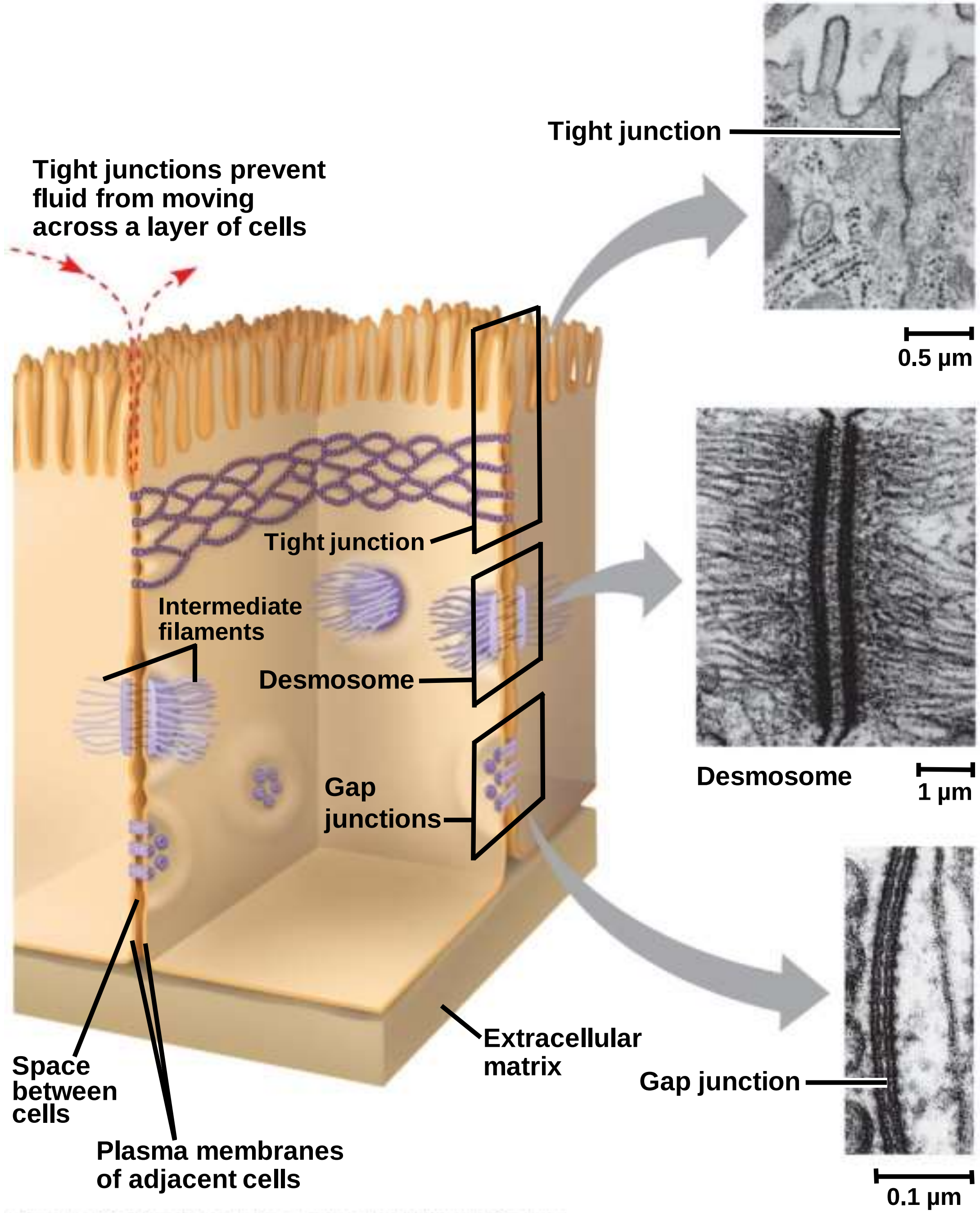
# *Plasmodesmata in Plant Cells*

- **Plasmodesmata** are channels that perforate plant cell walls
- Through plasmodesmata, water and small solutes (and sometimes proteins and RNA) can pass from cell to cell


Cell walls
Interior of cell
Interior of cell
0.5 µm
Plasmodesmata
Plasma membranes

# *Tight Junctions, Desmosomes, and Gap Junctions in Animal Cells*

- At **tight junctions**, membranes of neighboring cells are pressed together, preventing leakage of extracellular fluid
- **Desmosomes** (anchoring junctions) fasten cells together into strong sheets
- **Gap junctions** (communicating junctions) provide cytoplasmic channels between adjacent cells


Tight junctions prevent fluid from moving across a layer of cells
Tight junction
Intermediate filaments
Desmosome
Gap junctions
Space between cells
Plasma membranes of adjacent cells
Extracellular matrix
Tight junction
0.5 µm
Desmosome
1 µm
Gap junction
0.1 µm