(Foundation Block)

Cell Membrane

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Learning Objectives:

- Describe the model of membrane structure and function
- Define permeability and list factors influencing permeability
- Identify and describe carried-mediated transport processes: Primary active transport, secondary active transport, facilitated diffusion.

Eukaryotic Cell Structure

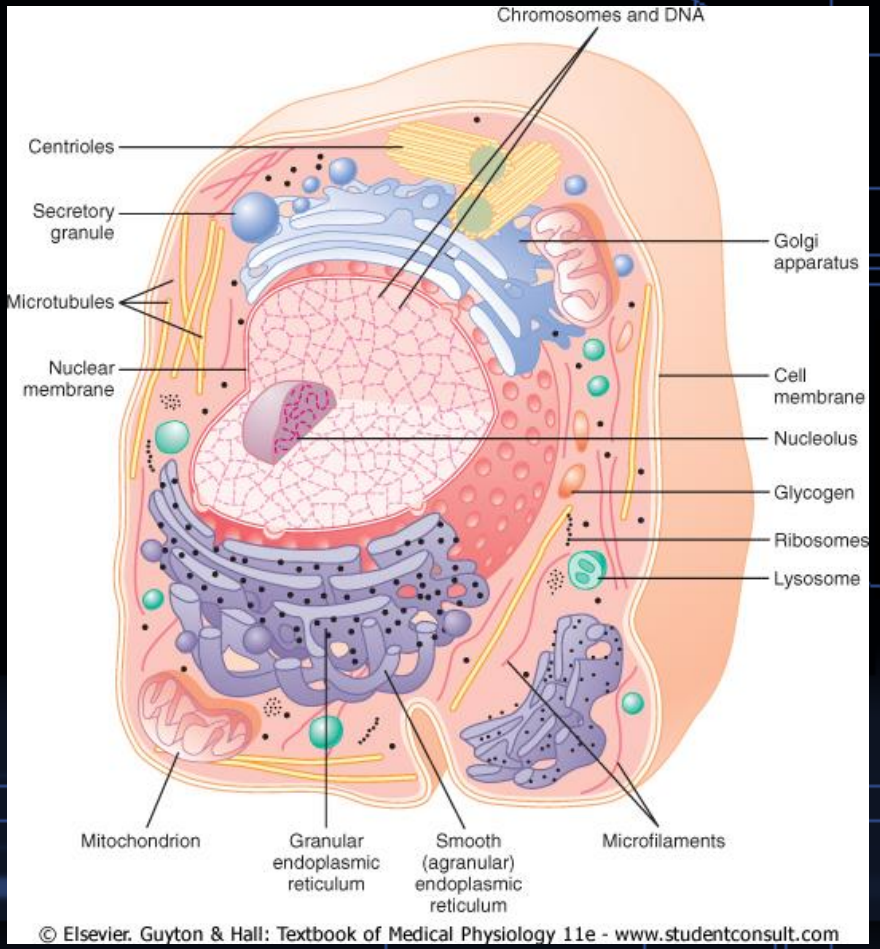
- The cell is basic unit of structure and function within the body (~100 trillion cells in body).

- Comprises three principal parts;

i) Plasma (cell) membrane

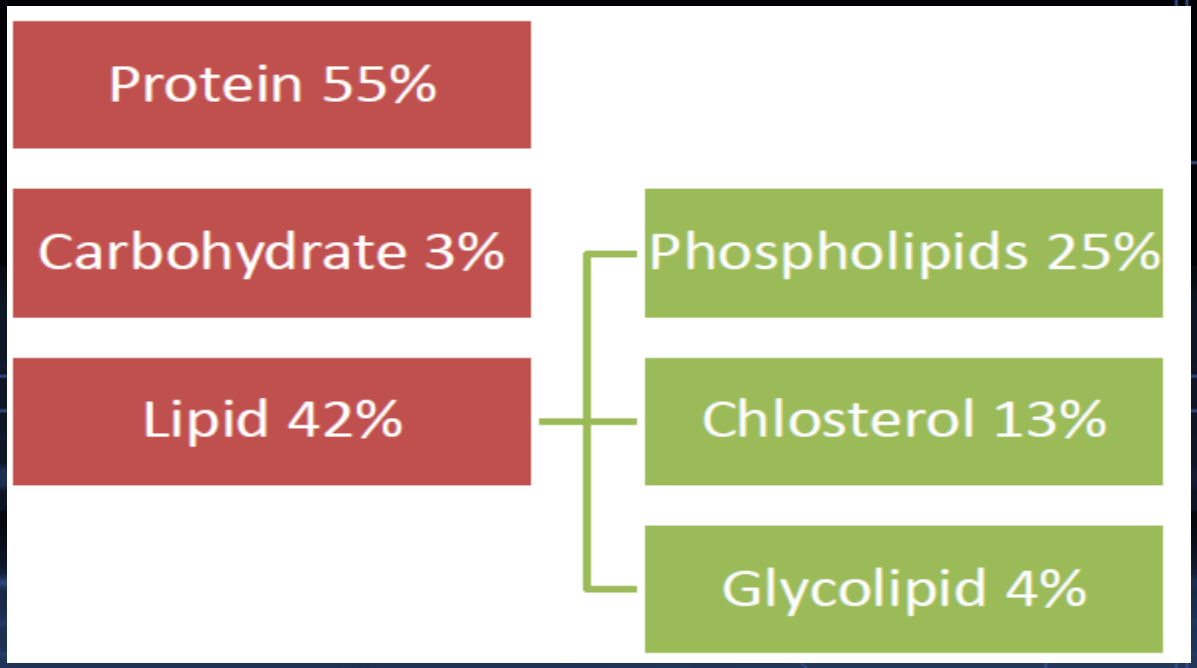
ii) Cytoplasm & organelles

iii) Nucleus



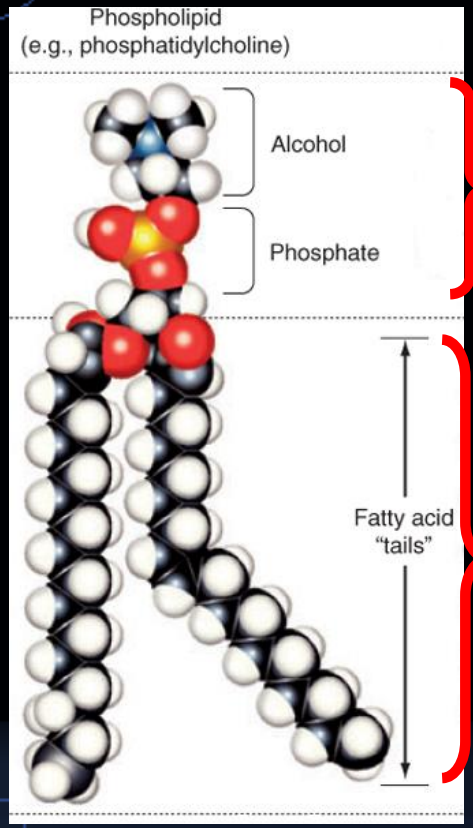
Cell membrane

- It covers the cell.
- It is a fluid and not solid.
- It is 7-10 nanometer thick.
- It is also referred to as the plasma membrane.
- **Composition**



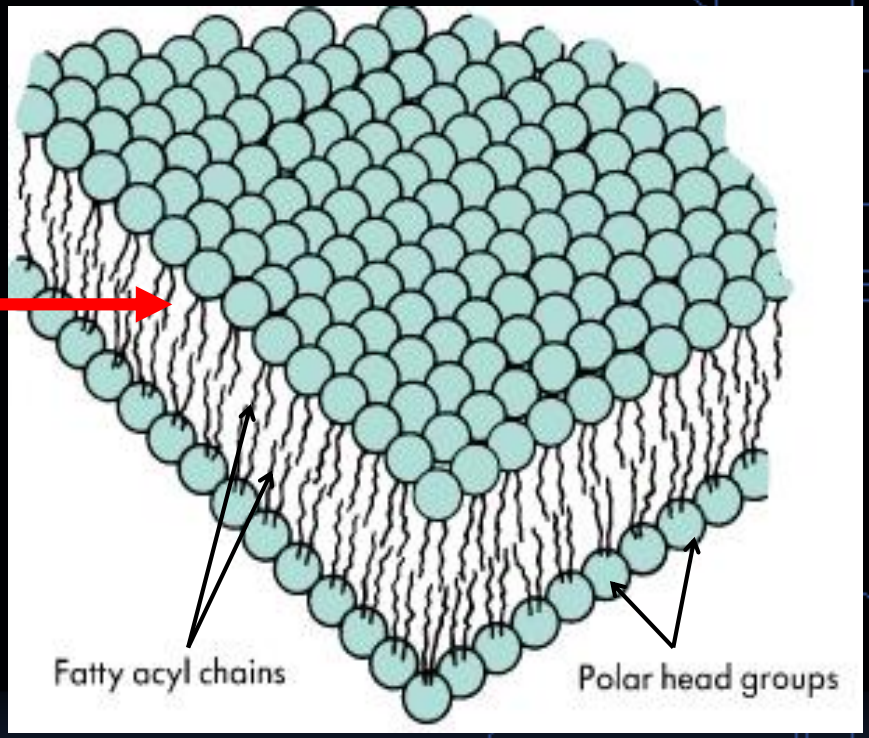
The Plasma Membrane

- Main constituents of plasma membrane are **PHOSPHOLIPIDS.**



Hydrophilic
(polar)

Hydrophobic
(non-polar)



Cell membrane structure

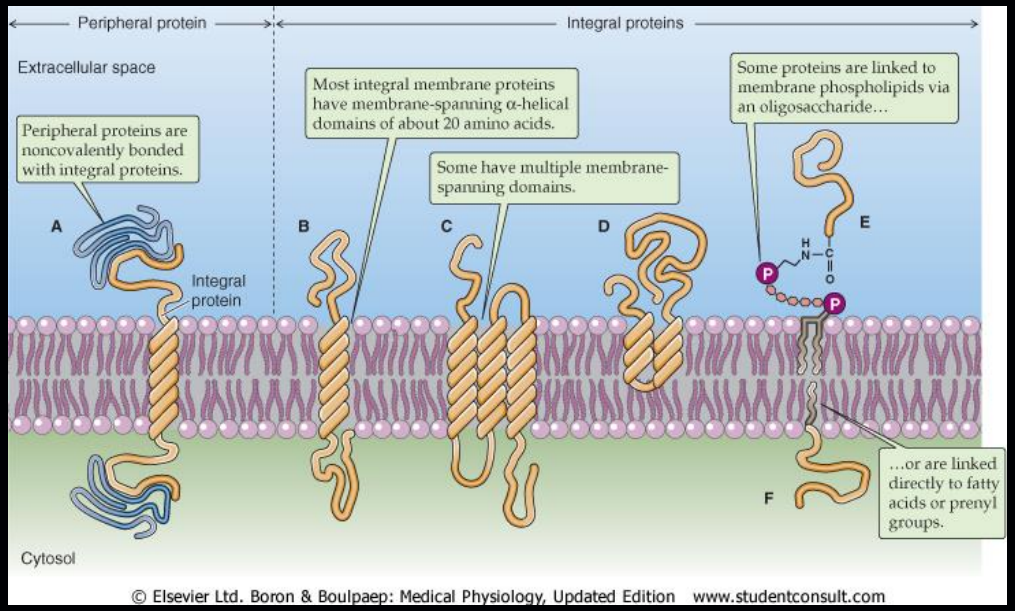
Organized in a bilayer of **phospholipid** molecules

1. **Glycerol head** (hydrophilic).
2. **Two fatty acid** ‘’tails’’ (hydrophobic).

- Heads (hydrophilic) facing ICF and ECF and tails (hydrophobic) face each other in the interior of the bilayer **(Amphipathic)**

Cell Membrane Proteins

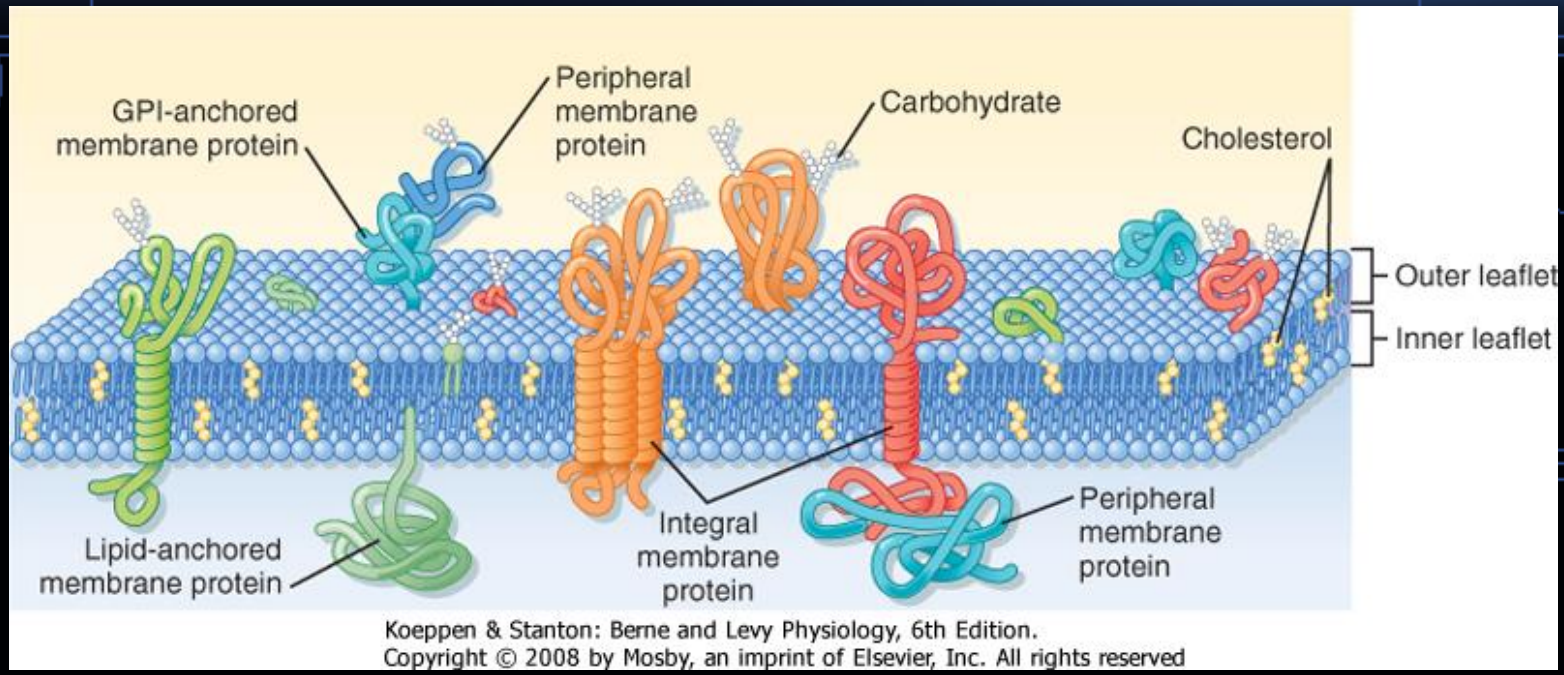
- Proteins integrated into phospholipid bilayer separated into 2 groups;
  i) **Peripheral**
  ii) **Integral** (intimately attached to PM)



1. **INTEGRAL** proteins span the membrane (Proteins provide structural channels or pores)

2. **PERIPHERAL** proteins (carrier) can participate in intracellular signalling, present in one side, work as cell membrane receptor and cell surface antigens.

The cell membrane carbohydrates



- **Glycoproteins** (most of it)
- **Glycolipids** (1/10)
- **Proteoglycans** (mainly carbohydrate substance bound together by protein)
- **Glycocalyx** (loose coat of carbohydrates)

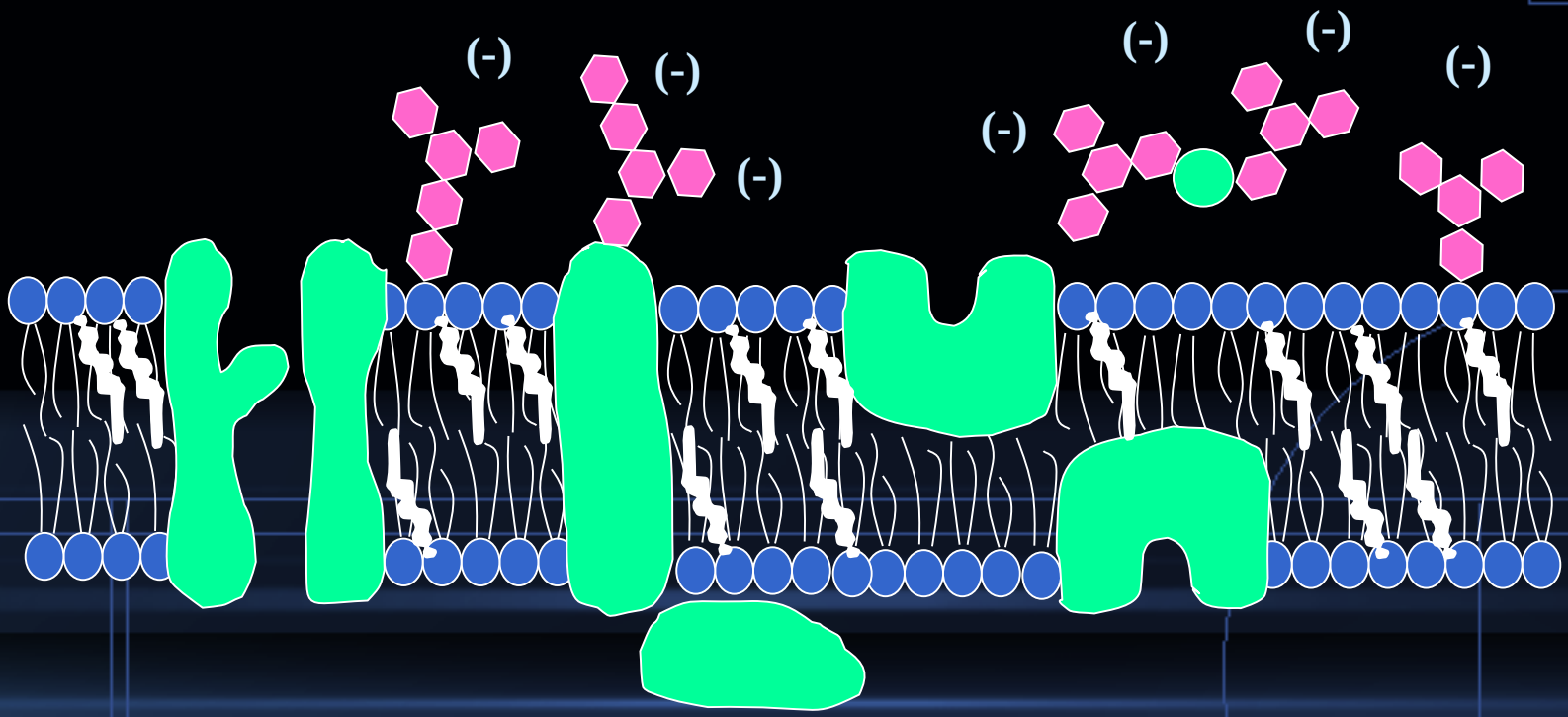
The cell membrane carbohydrates

- **Function of carbohydrates:**

- Attaches cell to each others.
- Act as receptors substances (help ligand to recognize its receptor)
- Some enter into immune reactions.
- Give most of cells overall –ve surface.

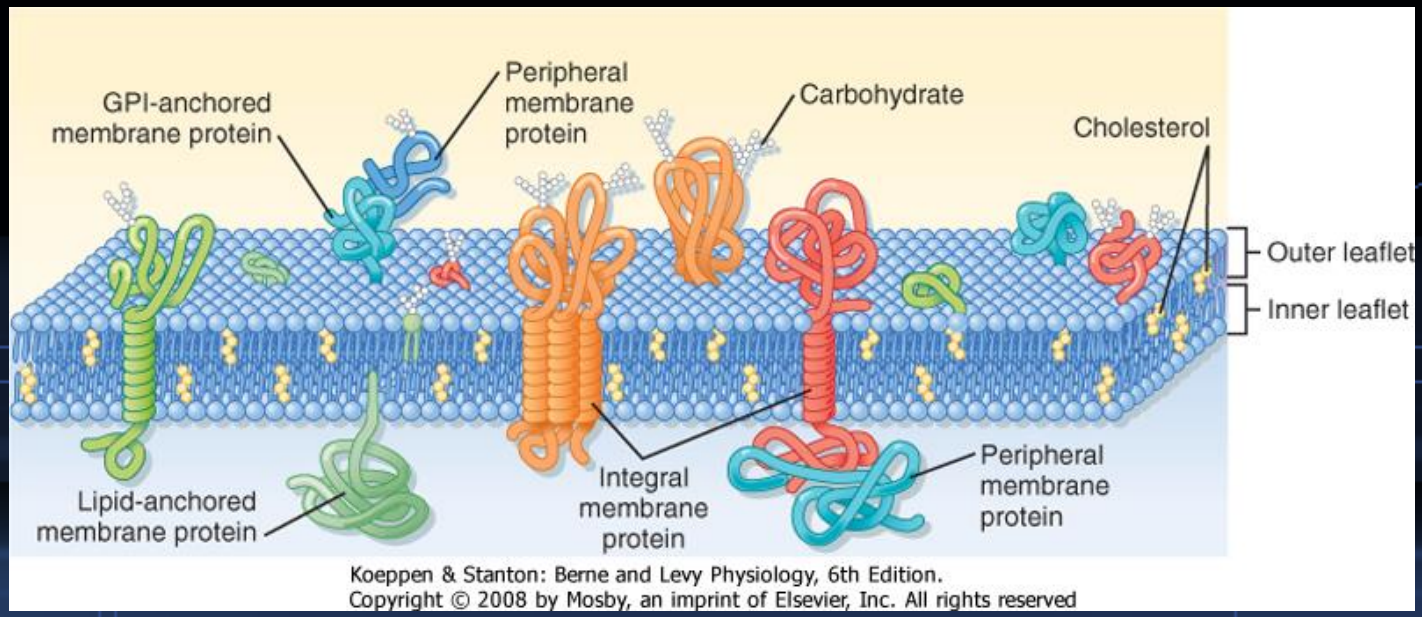
Cholesterol

- present in membranes in varying amounts
- controls much of the fluidity of the membrane
- increases membrane **FLEXIBILITY** and **STABILITY**



Transport through the cell membrane

- **Cell membrane is selectively permeable.**
- Through the proteins.
  - water –soluble substances e.g. ions, glucose
- Directly through the lipid bilayer.
  - fat – soluble substance (O2, CO2, alcohol)



Solute Movement Across Plasma Membrane

- For cell viability, nutrients must continually enter the cell and waste products must exit.

- Four principal mechanisms:

i) Simple Diffusion

ii) Facilitated Diffusion (+ Osmosis)

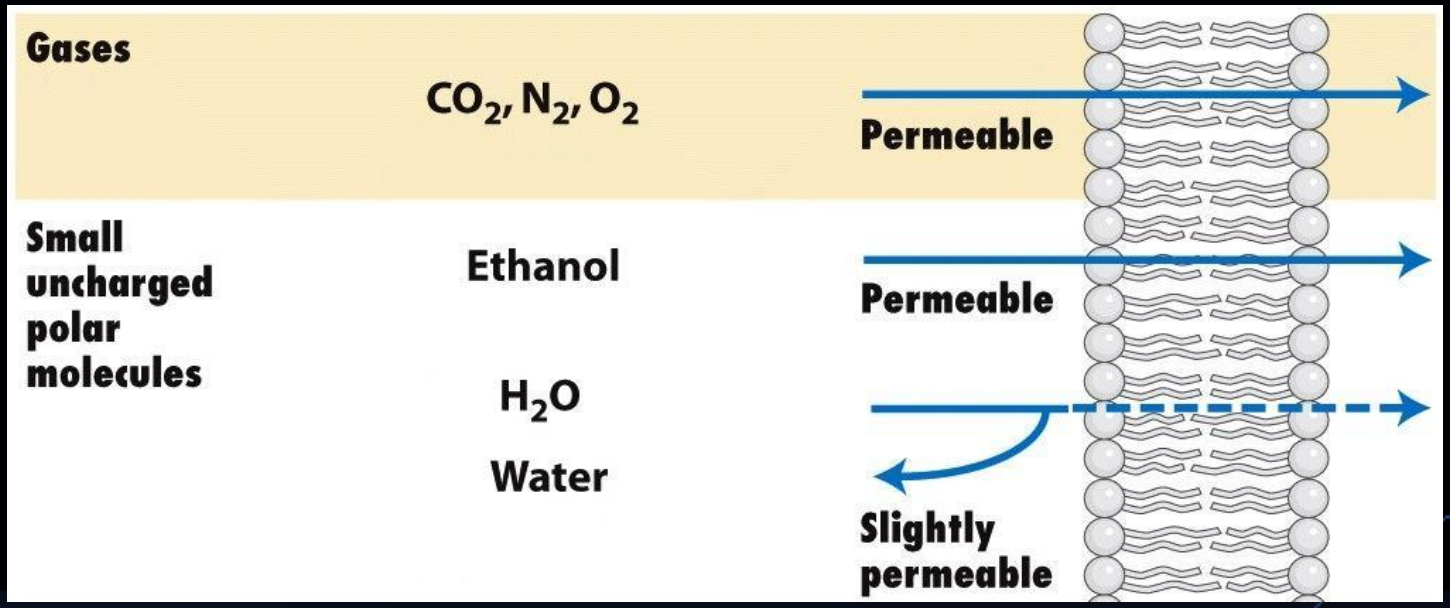
} Movement <u>with</u> a **concentration gradient**, *e.g.* high to low concentration, <u>no metabolic energy</u> required

iii) Active Transport } Movement <u>against</u> a concentration gradient, *e.g.* low to high concentration, <u>requires</u> metabolic energy (ATP)

iv) Bulk (Vesicular) Transport } Large quantity transport of molecules

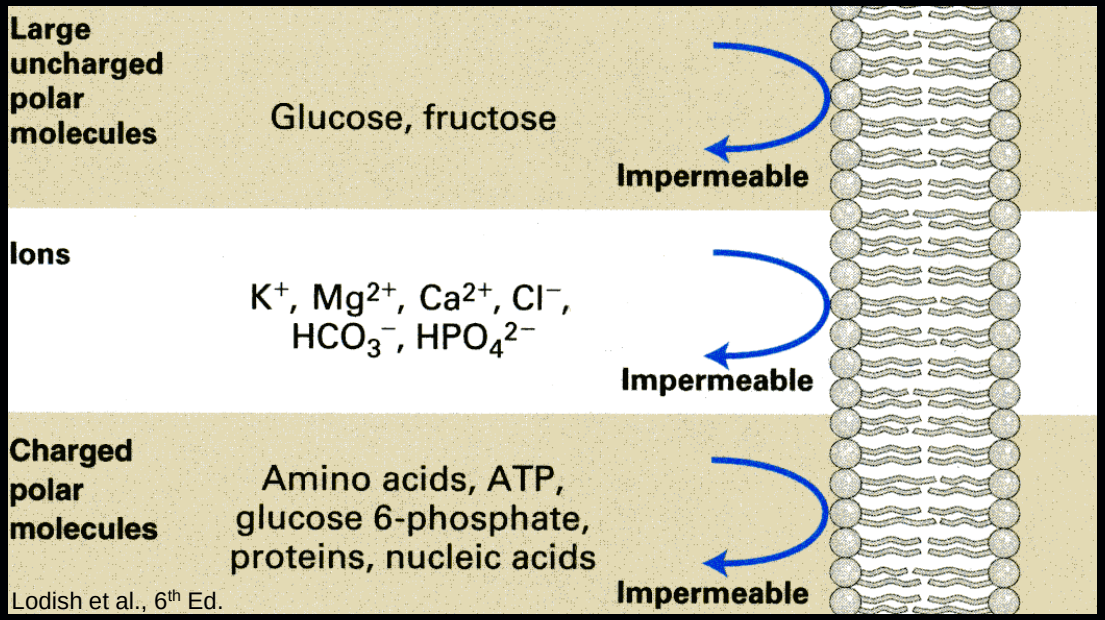
Simple Diffusion

- Small, uncharged substances cross the membrane by **SIMPLE DIFFUSION** (by dissolving in PM).
  e.g. gases, alcohol, steroids and general anaesthetics



- Non carrier mediated transport down an electrochemical gradient

- **QUESTION**: How do larger and / or lipid-insoluble substances (charged molecules, ions) cross the lipid bilayer?



- They require transport (carrier) proteins - these are all **INTEGRAL (TRANSMEMBRANE) PROTEINS**
- Responsible for allowing transport of the majority of molecules (and all ions) across biomembranes (in & out).
- Rate of diffusion far higher than simple diffusion.

Rate of simple diffusion depends on:

1- Amount of substance available

2- The number and sizes of opening in the membrane for the substance (selective gating system)

3- Chemical concentration difference

4- Electrical potential difference

5- Molecular size of the substance

6- Lipid solubility

7- Temperature

Protein-Mediated Transport

- Two types of protein-mediated transport;
  i) **Facilitated Diffusion** &
  ii) **Active Transport**

Facilitated Diffusion

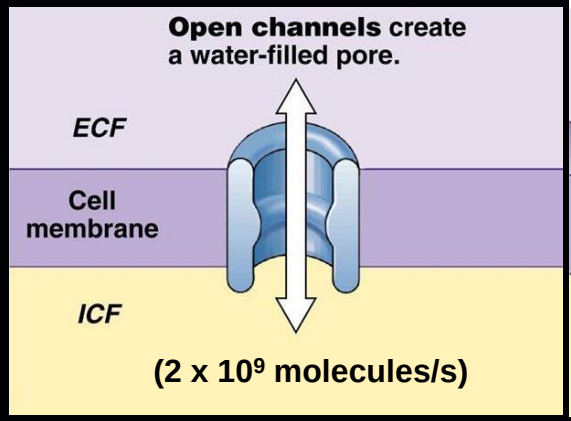
- Facilitated diffusion is a **PASSIVE** process *i.e.,* movement is **DOWN** a concentration gradient and does **NOT** require ATP.
- There are two principal types of membrane proteins that mediate facilitated diffusion;

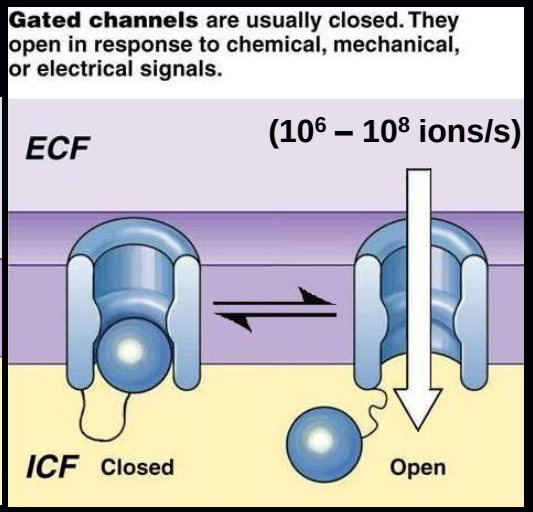
1) Channel Proteins →
   - GATED CHANNELS
     Ion channels (*e.g.*, Na^+, K^+, Cl^- & Ca^{2+})
   - OPEN CHANNELS
     Aquaporins (water & small solutes)

2) Carrier Proteins → UNIPORTERS
   Glucose & amino acids

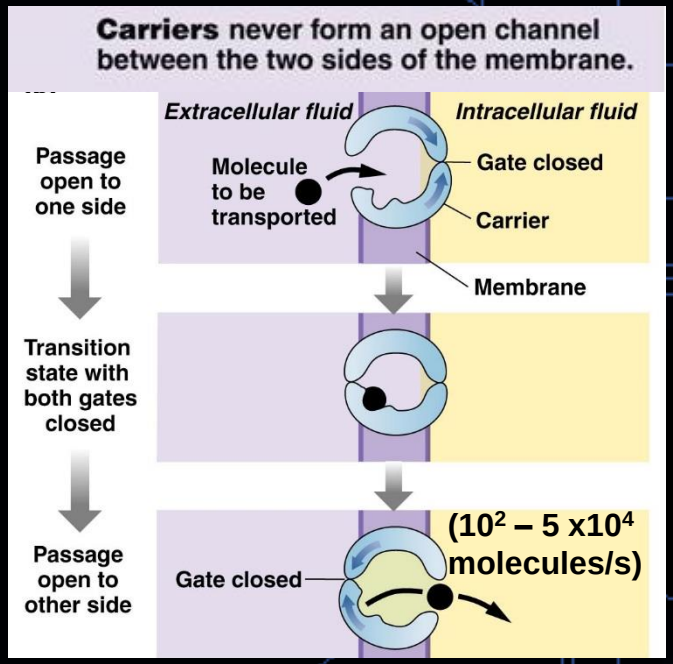
Facilitated Diffusion

Channels





Carriers



Adapted from Silverthorn, 4th Ed.

- Diffusion continues until <u>equilibrium is reached</u> *(or otherwise terminated)*
- Processes are ***SPECIFIC***, ***SATURABLE*** and ***COMPETITIVE***.

- **QUESTION**: How do larger and / or lipid-insoluble substances (charged molecules, ions) cross the lipid bilayer **AGAINST** their concentration gradient?

Primary Active Transport

- Primary active transport enables net transport of a solute **AGAINST** its concentration gradient that **REQUIRES** hydrolysis of **ATP** as energy source.

  - ATP-powered pumps. "ATPases".

  - Primary examples are;
    Ca^{2+} / H^+ ATPase
    H^+ / K^+ ATPase
    Na^+ / K^+ ATPase

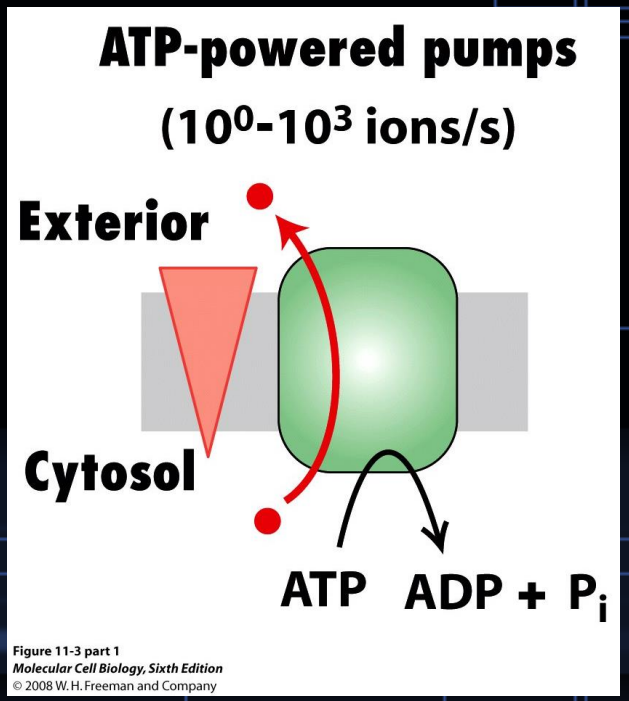


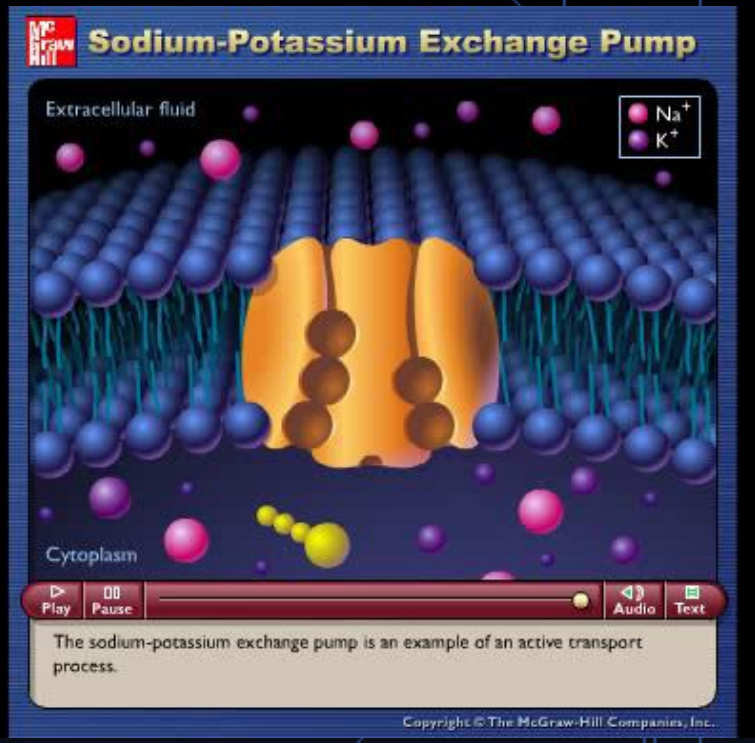
Figure 11-3 part 1
Molecular Cell Biology, Sixth Edition

Na^+ / K^+ ATPase

- Na^+ / K^+ ATPases most prevalent example of primary active transporters (vital for cell volume maintenance & neuronal cellular excitability).

- In some cells (*e.g.*, neurones), energy needed to move these ions uses 70% of all ATP production of the cell.

- Carries three Na^+ ions out of cell in exchange for two inward K^+ ions – '**ELECTROGENIC PUMP**'.



Na-K pump act as Carrier protein and binding site for Na inside the cell also binding site for K outside the cell

Function

1. Maintaining Na and K concentration difference
2. It's the basis of nerve signal transmition
3. Maintaining –Ve potential inside the cell

Active transport

Primary active transport of calcium (Ca $^{2+}$ ATPase)

- sarcoplasmic reticulum (SR)
- mitochondria
- in some cell membranes

- **Function:** Maintaining a low Ca^{2+} concentration inside the cell

Primary active transport of hydrogen ions (H+-K ATPase)

- stomach
- kidneys
- pumps to the lumen
- H+-K ATPase inhibitors (treat ulcer disease). (omeprazol)

Secondary active transport

- Transport of one or more solutes against an electrochemical gradient, coupled to the transport of another solute down an electrochemical gradient
- ‘’downhill’’ solute is Na.
- Energy is supplied indirectly form primary transport.

➢ **Co transport:**

- All solutes move in the same direction ‘’ inside cell’’. e.g.
- Na - glucose Co transport.
- Na – amino acid Co transport in the intestinal tract kidney.

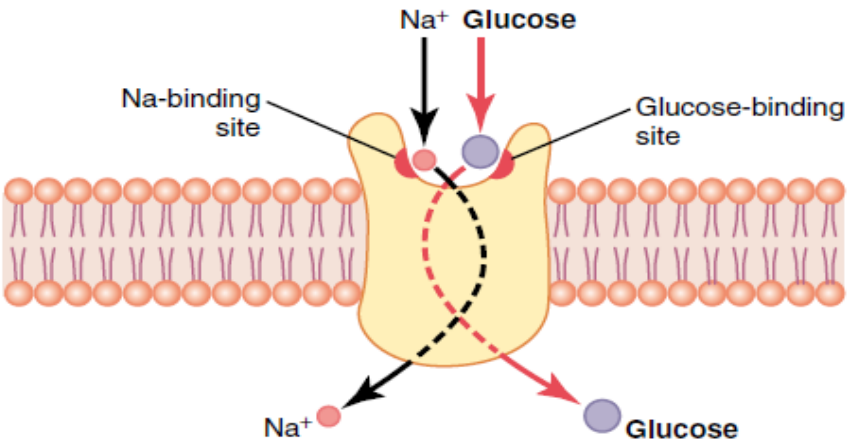
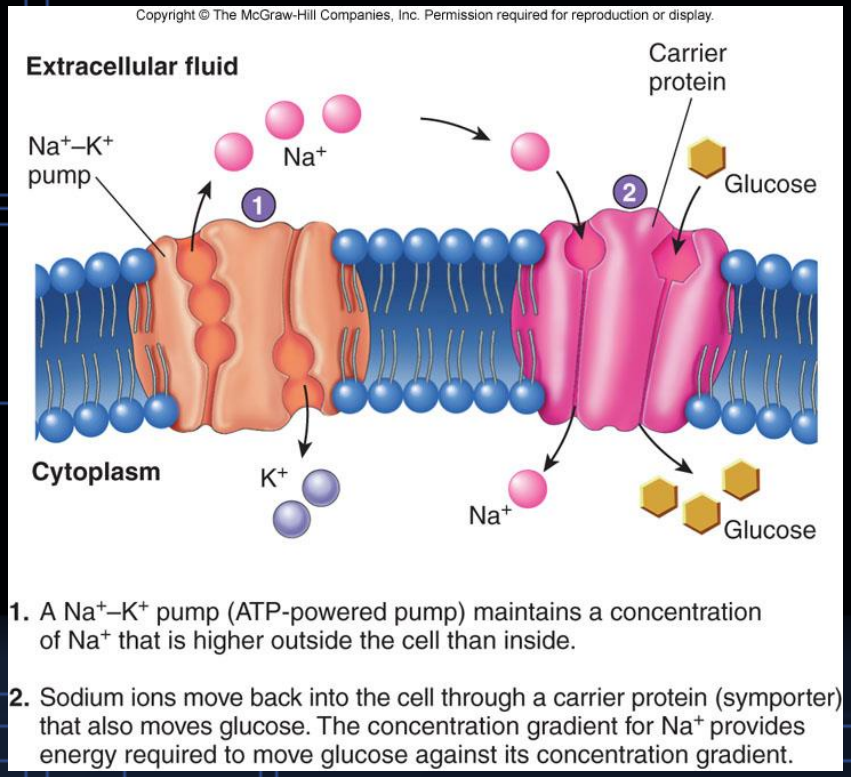
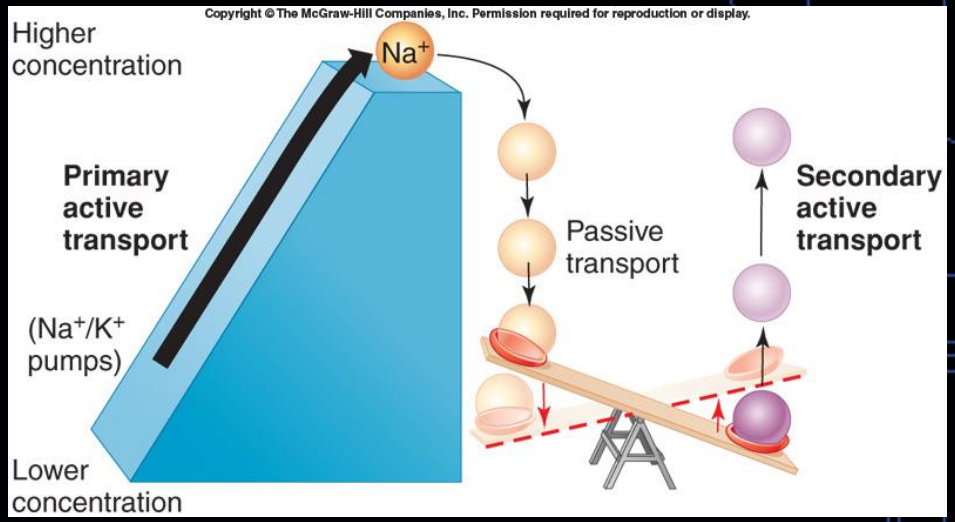


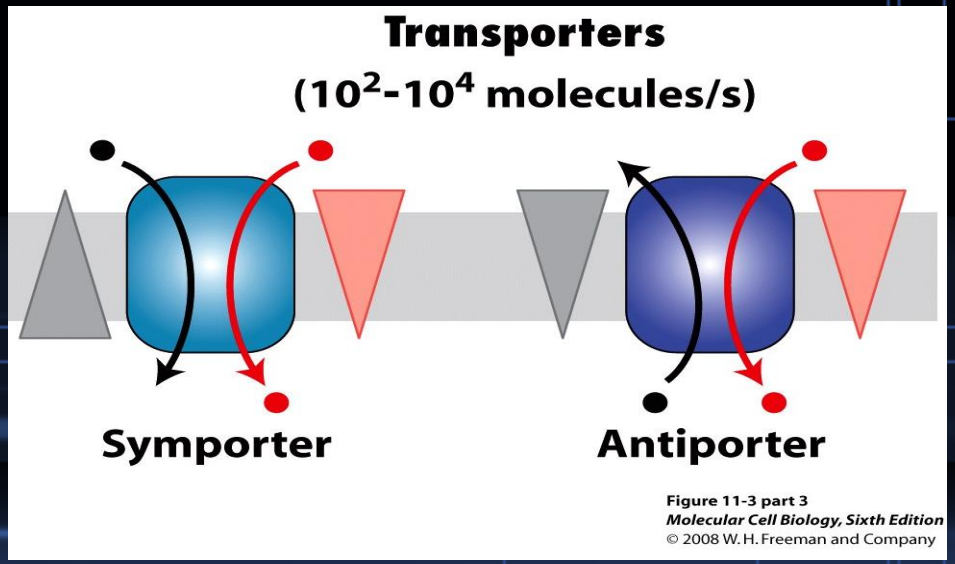
Figure 4-13 Postulated mechanism for sodium co-transport of glucose.

The Na^+ / glucose symporter
(Secondary Active Transport)



1. A Na^+–K^+ pump (ATP-powered pump) maintains a concentration of Na^+ that is higher outside the cell than inside.
2. Sodium ions move back into the cell through a carrier protein (symporter) that also moves glucose. The concentration gradient for Na^+ provides energy required to move glucose against its concentration gradient.





Active transport

- **Counter transport:**
- Na is moving to the interior causing other substance to move out.
- Ca^{2+} - Na^{+} exchanger (present in many cell membranes)
- Na –H^{+} exchanger in the kidney.

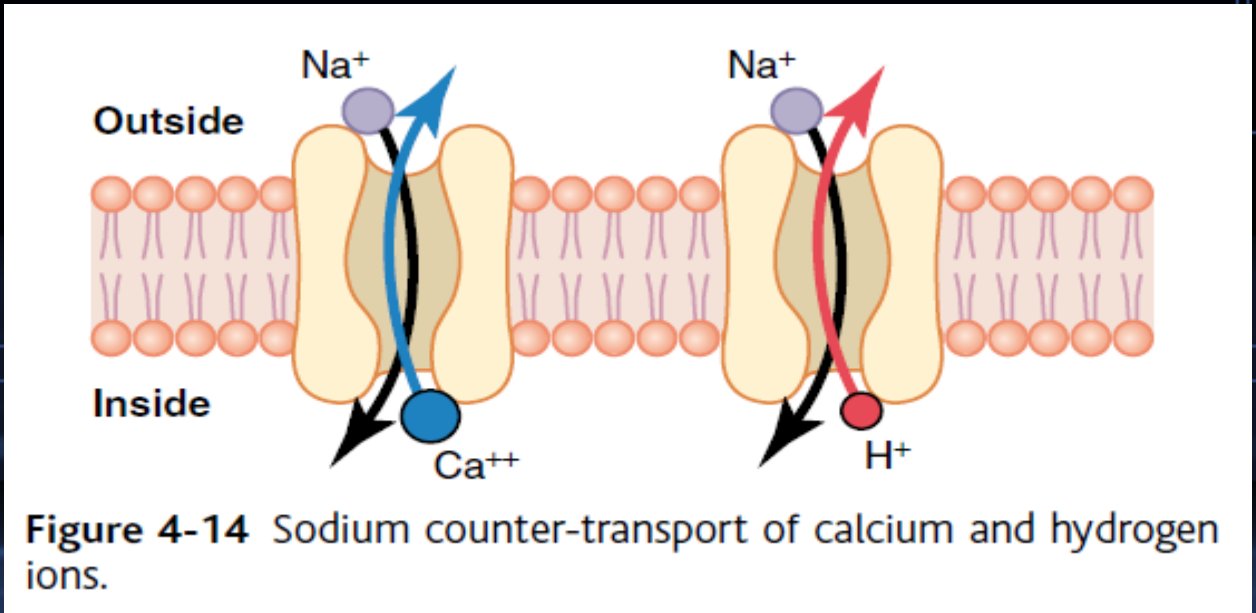


Figure 4-14 Sodium counter-transport of calcium and hydrogen ions.


Thanks