BHARATHIDASAN UNIVERSITY

Tiruchirappalli- 620024,
Tamil Nadu, India

Programme: M.Sc., Marine Biotechnology

Course Title: Cell and Developmental Biology

Course Code: 21CC3

Unit-I

Cell membrane and Transport

Dr. S. Rajakumar
Associate Professor

What does Selective Permeability mean?

•The membrane allows some substances to cross it but not others.

A. Through proteins:Water-soluble substances (Glucose, ions)
B. Directly through the bilayer: Fat-soluble substances (O2, CO2, OH)

•This controls the type & amount of substances entering and leaving the cell.

• It arises from the membrane structure.

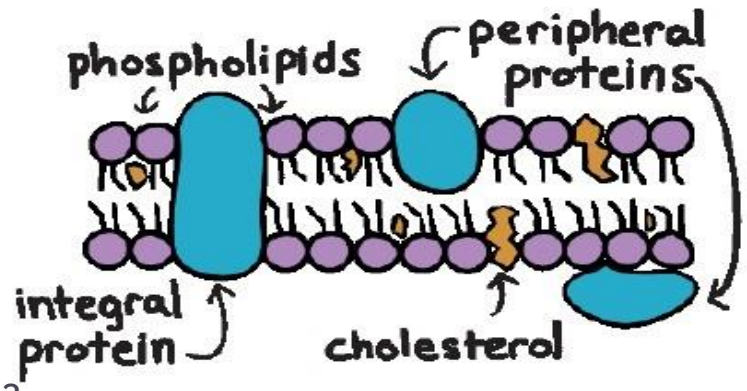
Membrane Proteins (Two categories)

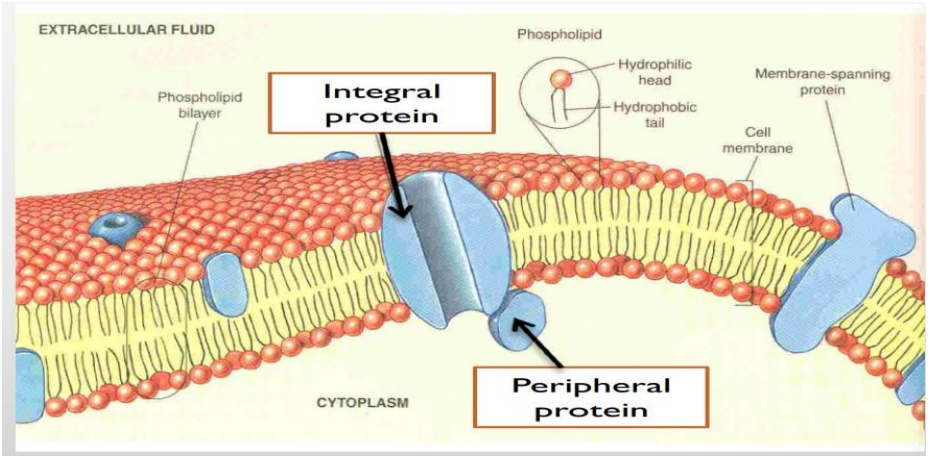
Integral

- Span the thickness of the membrane
- Function:
1. Channels (or pores)
2. Carrier proteins
3. Receptors

Peripheral

- Only attach to the surface of the membrane (or attached to integral proteins)
- Function: Hormone receptors and Enzymes





Transport across cell membrane

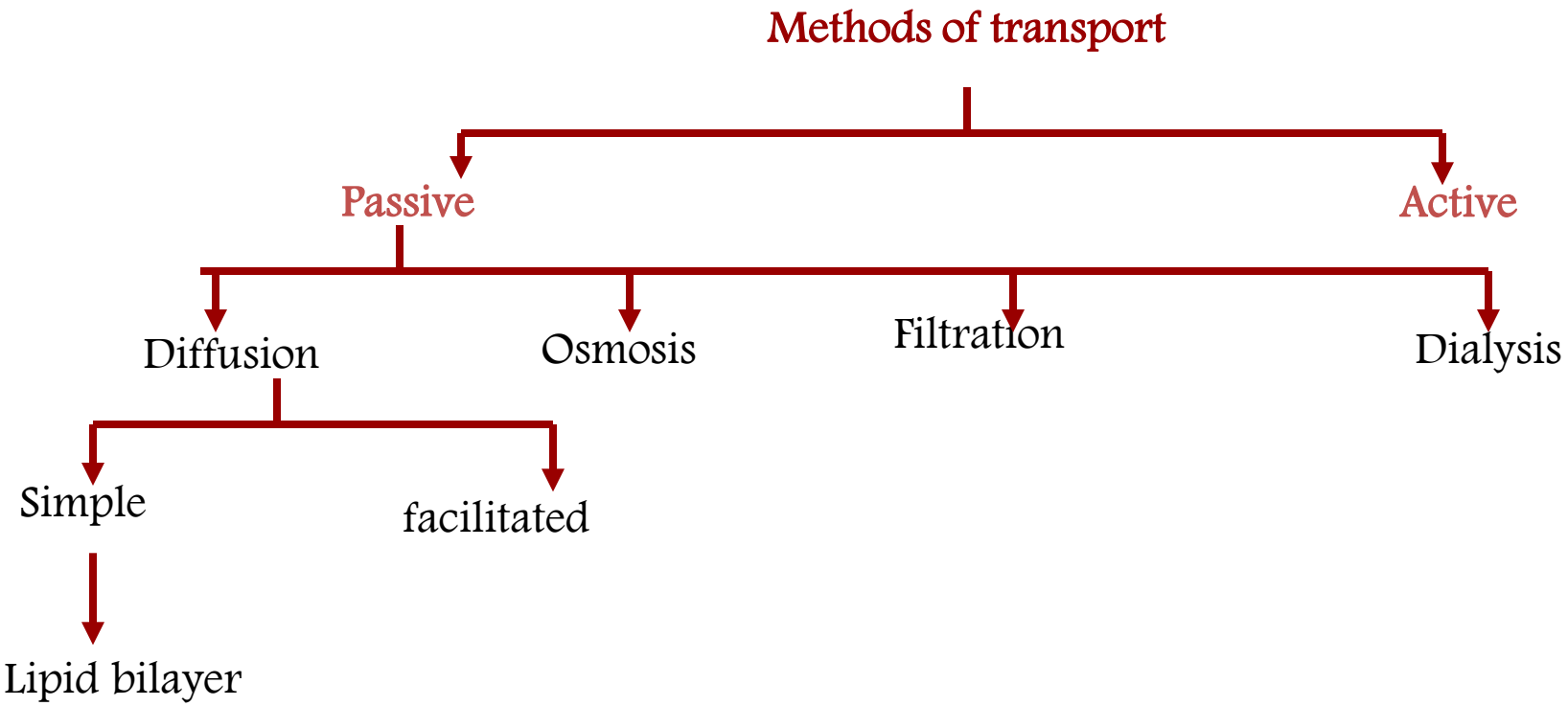
Transport Mechanisms

Passive

- Simple diffusion
- Facilitated diffusion
- Filtration
- Osmosis
- dialysis

Active

- Primary active transport
- Secondary active transport
- Endo/Exocytosis

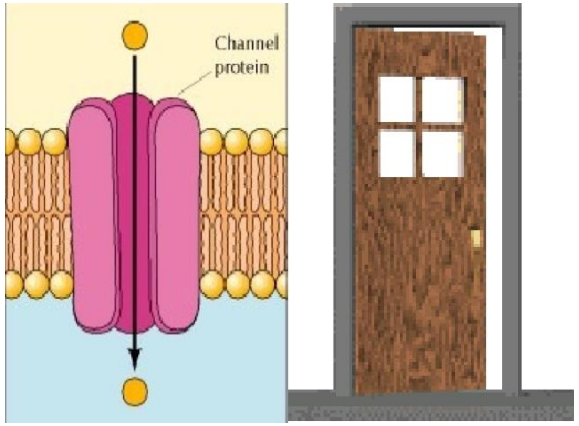


- Protein channels
  - Leaky channels
  - Gated channels
    - voltage gated
    - Ligand gated

Channel vs. Carrier Proteins

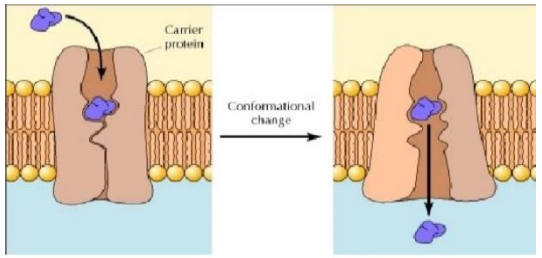
Channel proteins

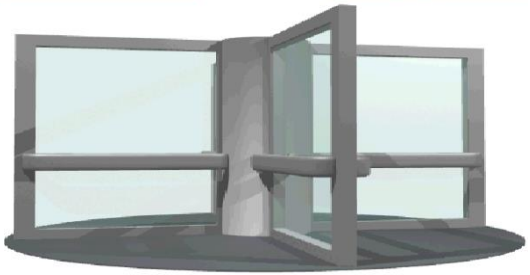
- Form open pores that allow molecules of the appropriate size (e.g. Ions) to pass the membrane.
- Similar to a normal door.



Carrier proteins

- Selectively bind the small molecule to be transported and then undergo a conformational change to release the molecule on the other side of the membrane.
- Similar to electronic door.





Transport Mechanisms:

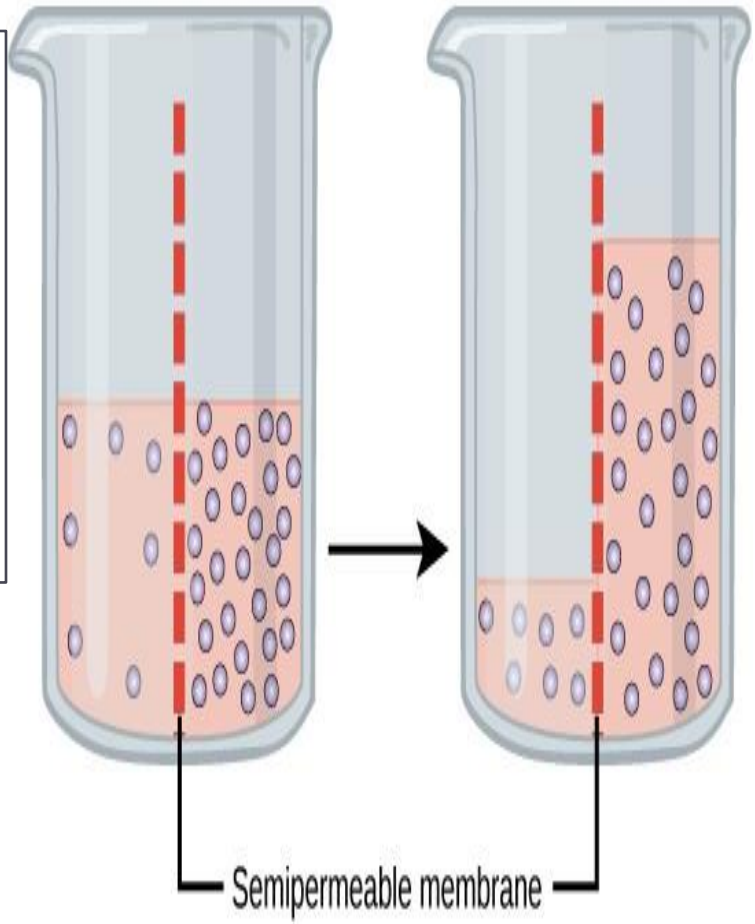
The transport of material between body or cellular compartments can be divided into:

- **Passive Transport**
  - Molecules move down or along their energy gradient.
  - Does not require energy.
- **Active Transport**
  - Molecules move against their energy gradient.
  - require energy.

Passive Transport (Osmosis)

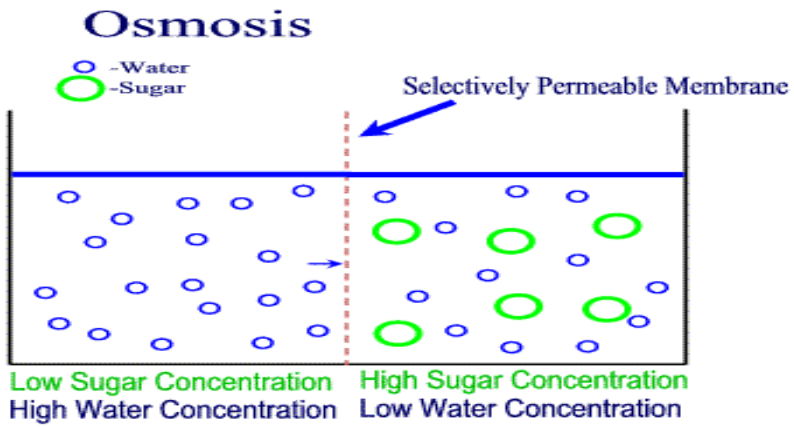
Osmosis :

Movement of water from an area of low solute concentration (hypotonic) to an area of high solute concentration(hypertonic)



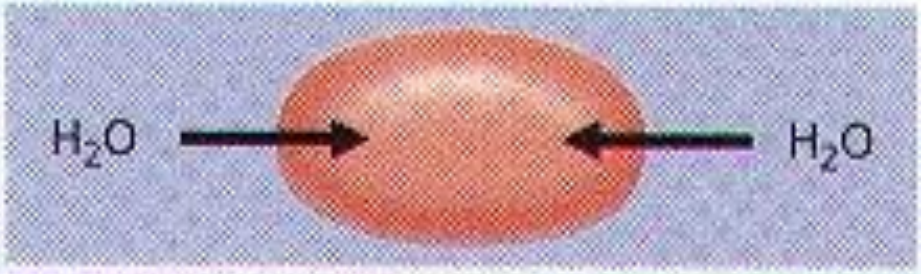
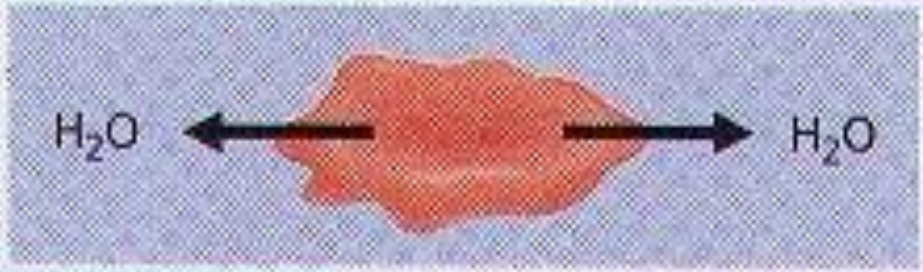
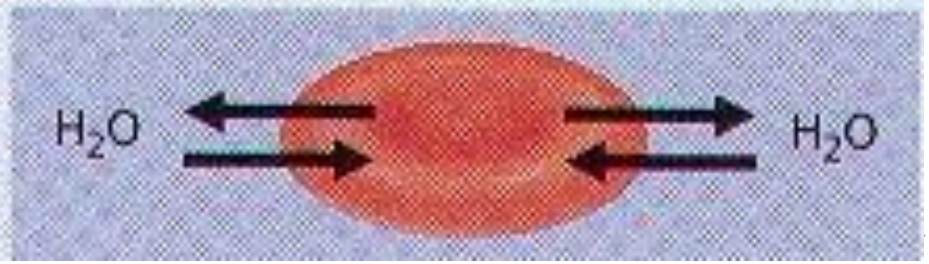
Osmosis

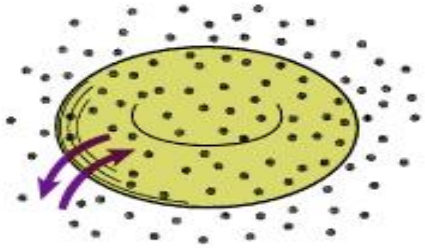
- Each compound obeys the law of diffusion
- diffusion of water from HIGH concentration of water to LOW concentration of water
- across a semi-permeable membrane
- However, some compounds are unable to cross the cell membrane (glucose, electrolytes…)
- Water can cross, will enter or exit the cell depending its concentration gradient.

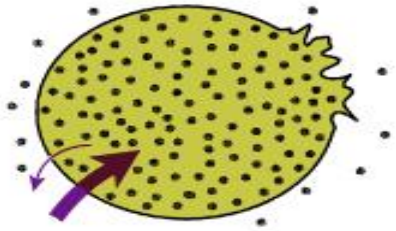


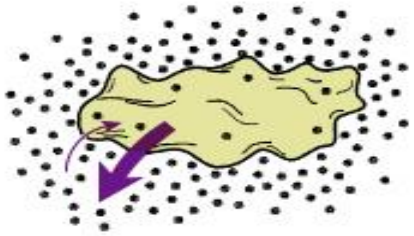
Cells in Solutions

TABLE 5-1 Direction of Osmosis

Condition	Net movement of water	
External solution is hypotonic to cytosol	into the cell	
External solution is hypertonic to cytosol	out of the cell	
External solution is isotonic to cytosol	none	







Isotonic Solution

NO NET MOVEMENT OF H_2O (equal amounts entering & leaving

Hypotonic Solution

CYTOLYSIS

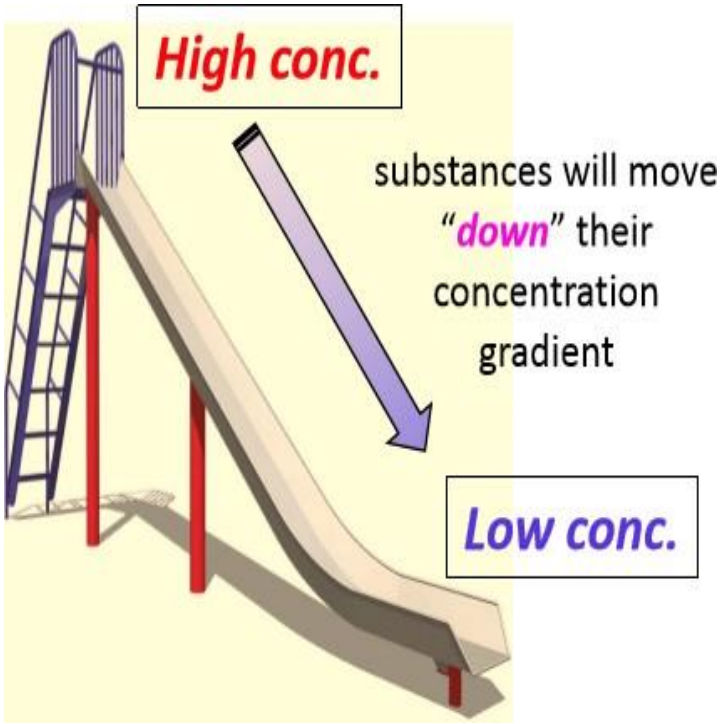
Hypertonic Solution

PLASMOLYSIS

Passive Transport (Diffusion)

- Diffusion: Random movement of substance either through the membrane directly or in combination with carrier protein **down** concentration gradient.

- This gradient can be:
  - Concentration.
  - Electrochemical.
  - Pressure.



Passive Transport (Types of Diffusion)

Simple diffusion

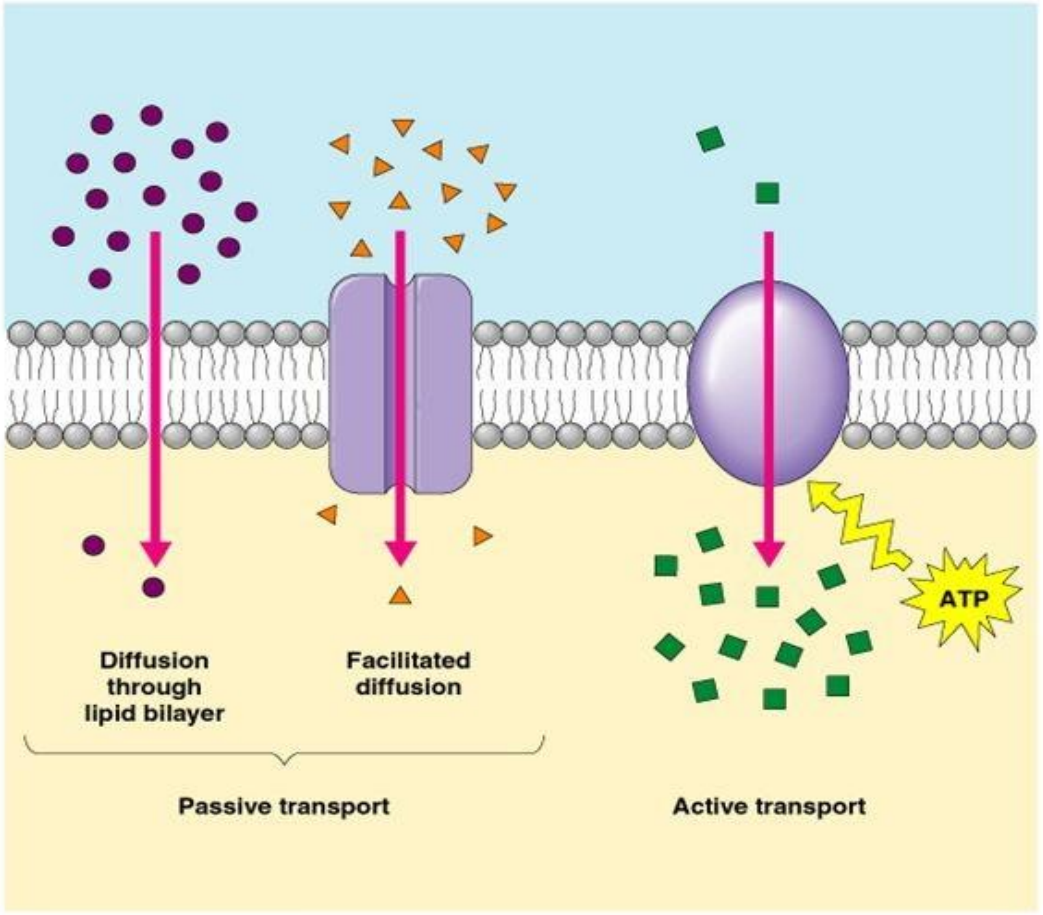
The movement of molecules through the intermolecular spaces **or** membrane openings (channels) **without** the necessity of binding **to a carrier protein** on the membrane.

Facilitated diffusion

The transported molecule binds to a **carrier protein** which then undergoes a conformational change allowing the molecule to pass through to the other side of the cell membrane.

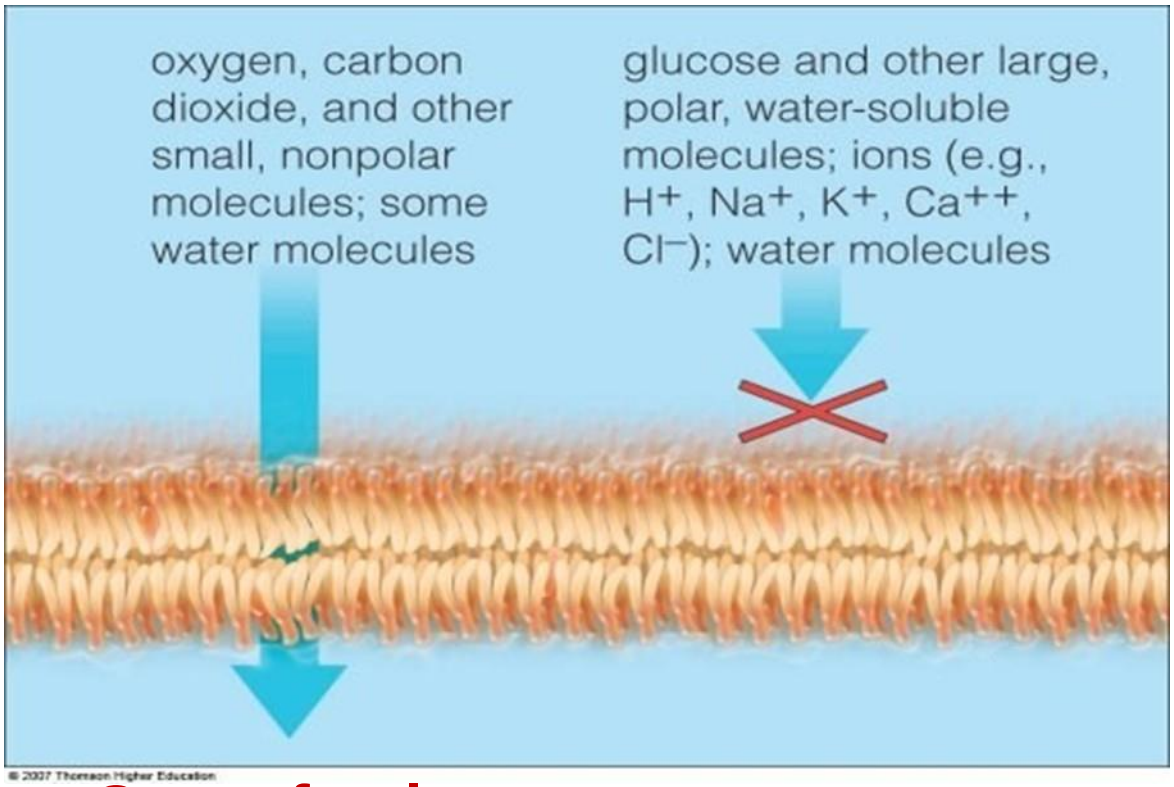
The carrier **facilitates** passage of the molecule through the CM.

Three Types of Cellular Transport



Amazing video summarizing cellular transport: https://m.youtube.com/watch?v=UgN76naeA1Q

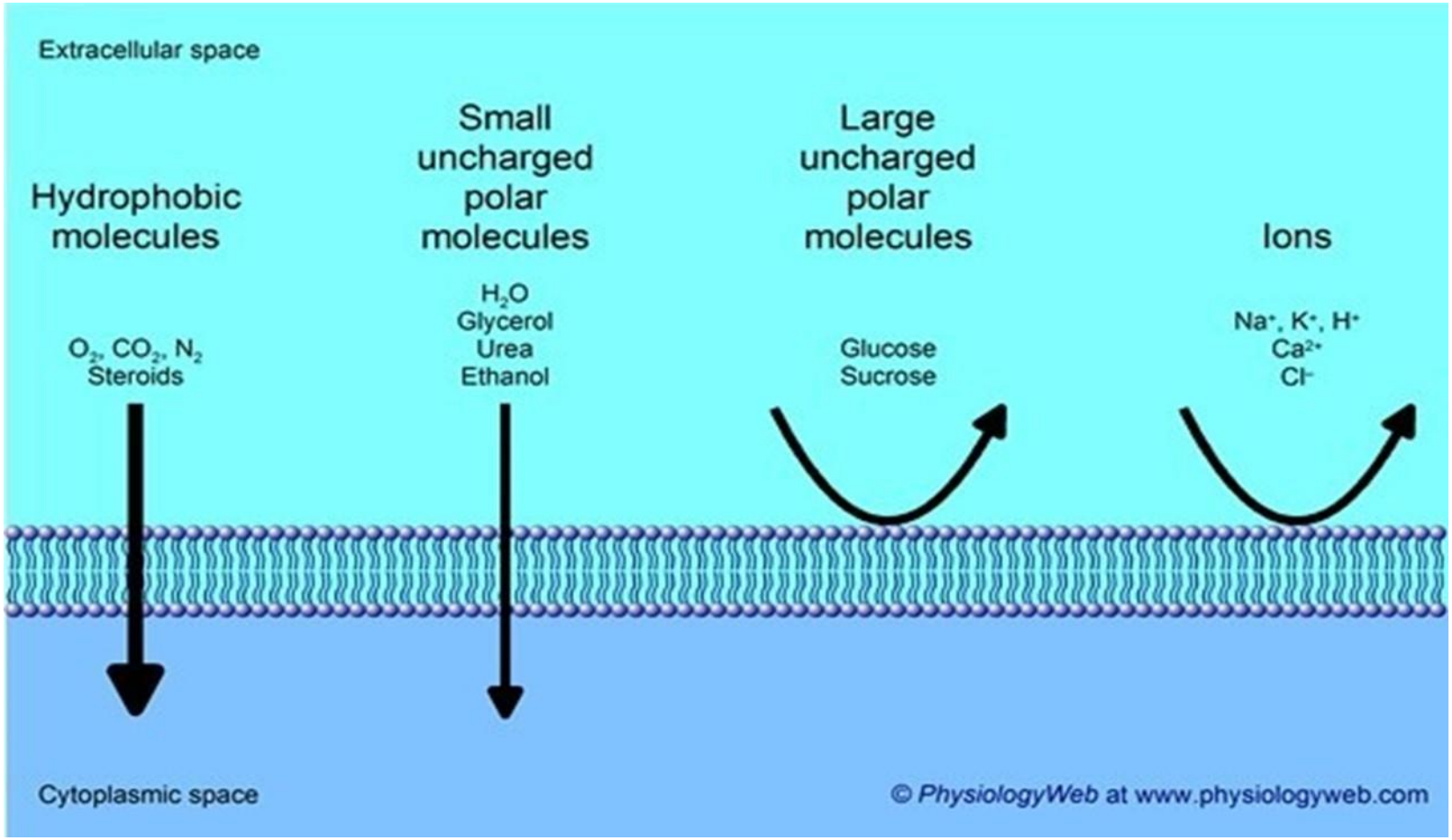
Substances that can cross the Cell Membrane



Cross freely by diffusion

Cross through membrane proteins

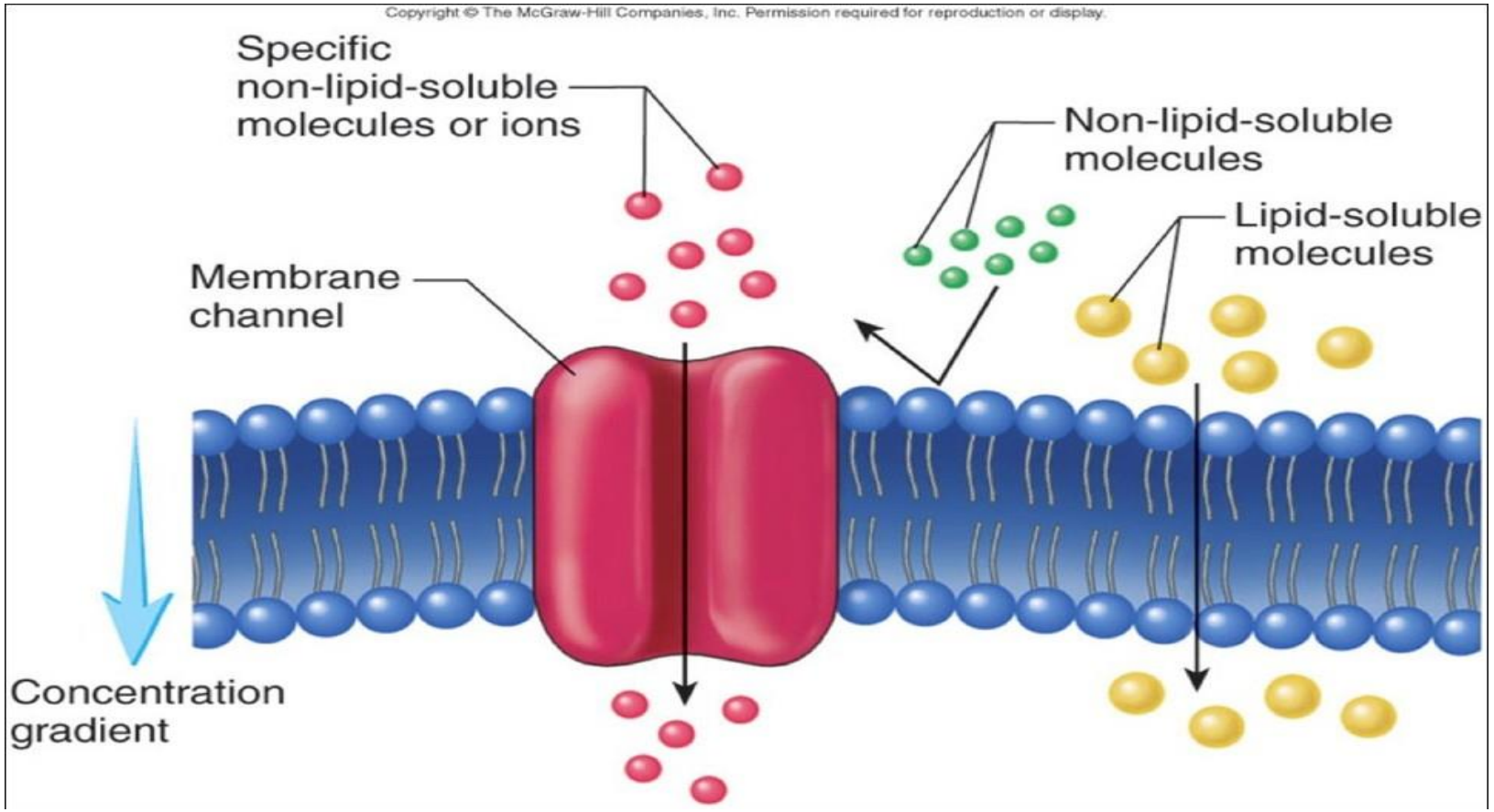
Substances that can cross the Cell Membrane



Cross freely by diffusion

Cross through membrane proteins

Substances that can cross the Cell Membrane



Achieved through a trans-membrane protein: carrier/transporter/channel

Passive Transport (Simple Diffusion):

1-Simple Diffusion:

1-directly through the lipid bilayer

- Pass through the interstices of the lipid bilayer

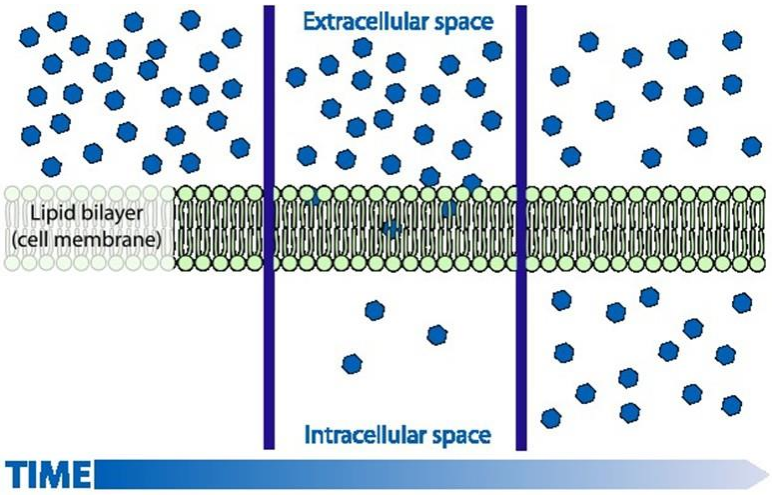
EX :small lipid-soluble substances (uncharged substances, O2,CO2, alcohol, steroid and general anesthetic).

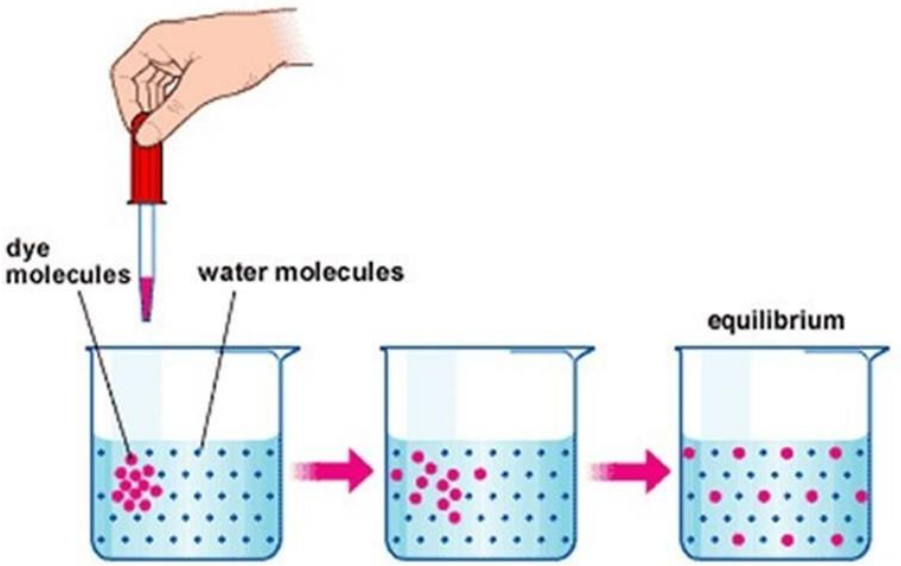
2- through the channel protein

- Its require transport protein (channel protein).
- EX: **1- Large and lipid-insoluble substances** (charged molecule).

2-Water-soluble substances (water,ions) pass through channels that penetrate through the cell membrane.

Passive Transport (Simple Diffusion):



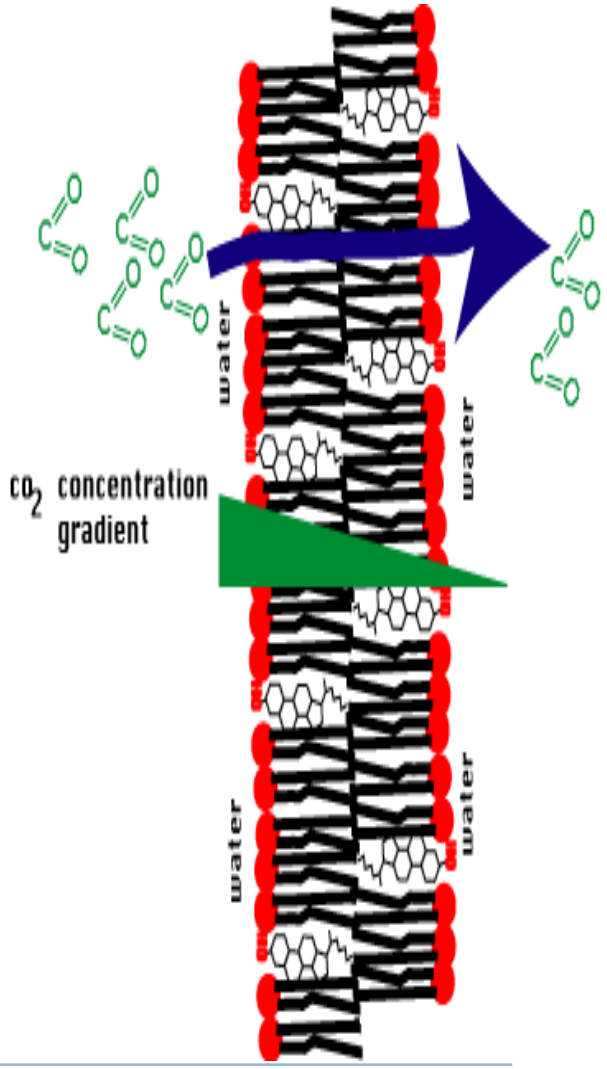


Passive Transport (Simple Diffusion)

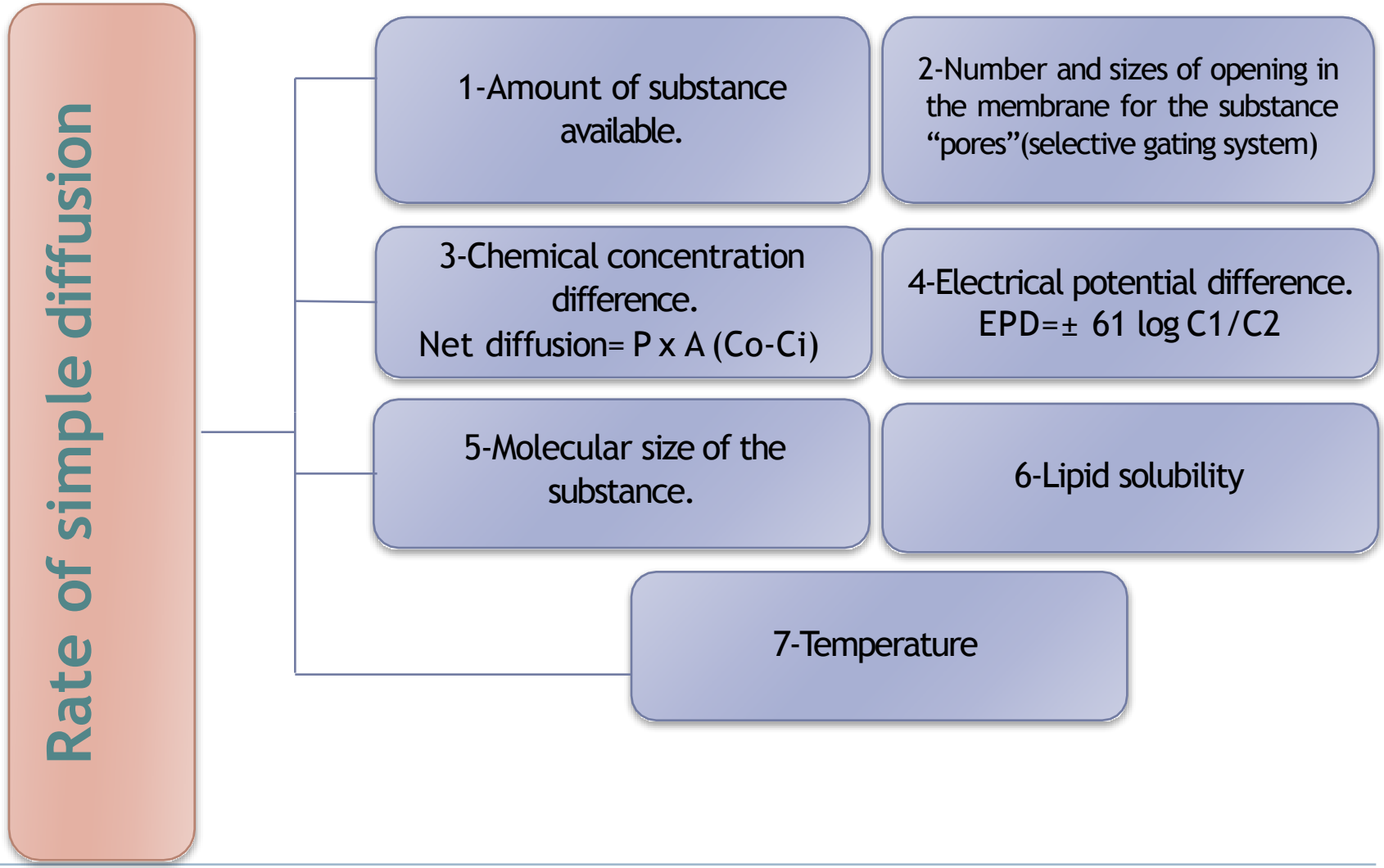
- **Non-carrier:** mediated transport down an electrochemical gradient.

- **Diffusion of non-electrolytes:** (uncharged) from high concentration to low concentration.

- **Diffusion of electrolytes:** (charged) depends on both chemical as will as electrical potential difference.



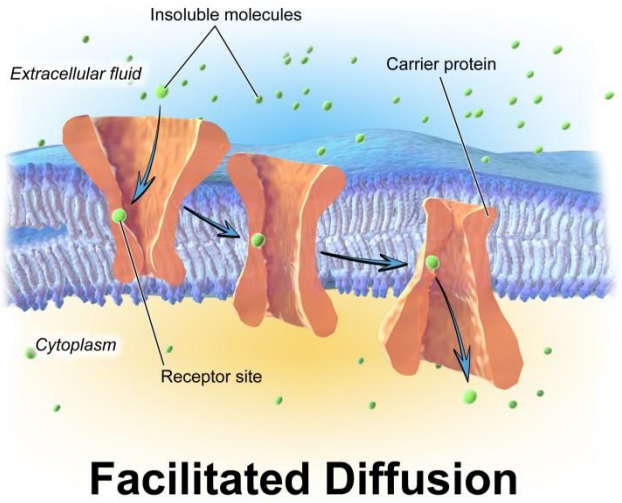
Passive Transport (Simple Diffusion)



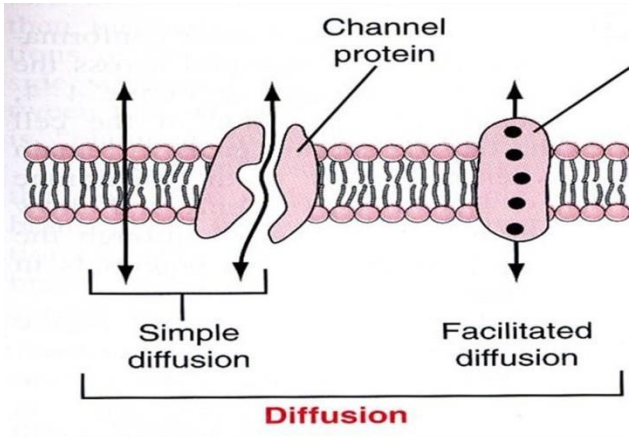
Passive Transport (Facilitated Diffusion)

2- Facilitated diffusion: also called (Carrier mediated diffusion)

- Diffusion of a substance is "facilitated" by the use of a specific carrier protein.
- Diffusion continues until equilibrium is reached or terminated.
- Examples: Glucose, amino acids.



Facilitated Diffusion

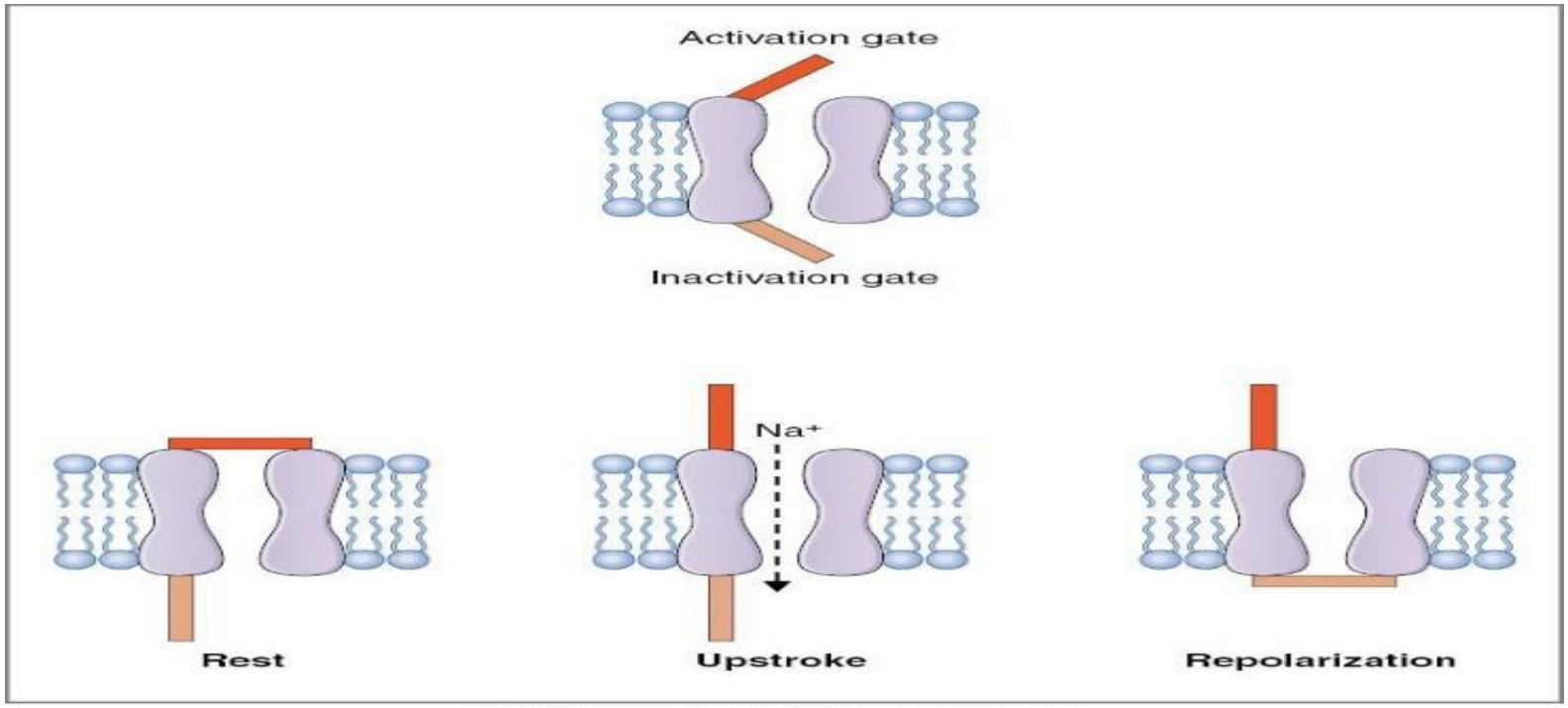


Passive Transport (Facilitated Diffusion)

Features of Carrier Mediated Transport: (Facilitated diffusion)

- **Saturation :** ↑ → ↑ full saturation.
- **Stereospecificity :** The binding site recognizes a specific substance D-glucose but not L-glucose.
- **Competition :** Chemically similar substances can compete for the same binding site D-galactose / D-glucose.

Passive Transport (Facilitated Diffusion)



- Substance → binding site → substance protein complex → conformational changes → release of substance.

Passive Transport “rate of diffusion” (Simple Vs. Facilitated)

Simple diffusion

The rate of diffusion increases proportionately with the concentration of the diffusing substance.

Facilitated diffusion

- The rate of diffusion increases proportionately with the concentration of the diffusing substance **until it reaches a maximum Vmax.**
- At Vmax, an increase in the concentration of the diffusing substance **does not increase the rate.**

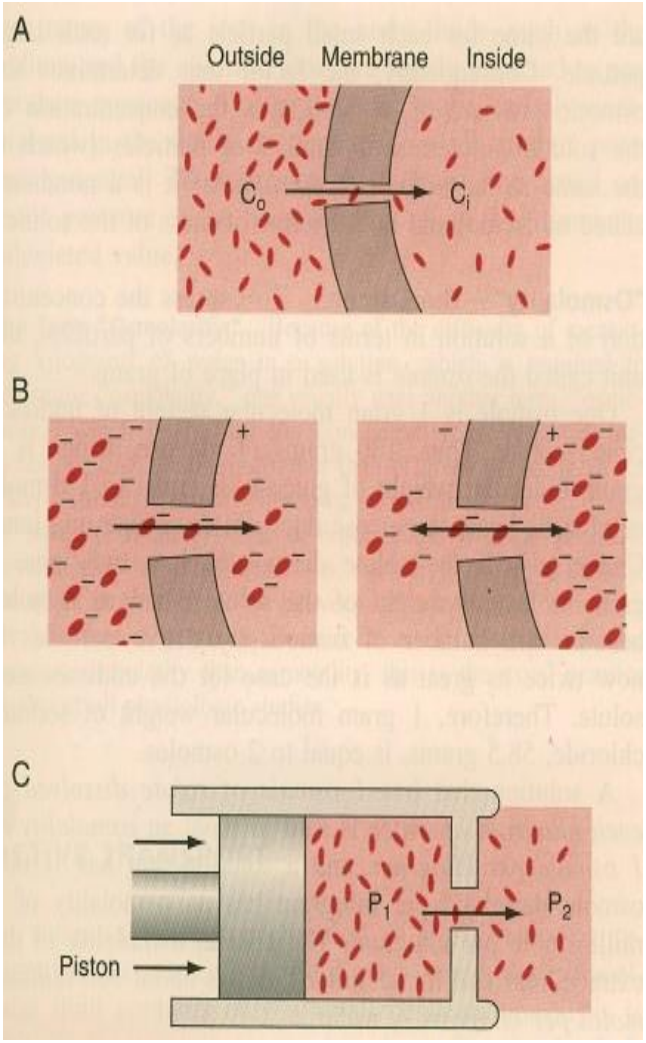
Factors Affecting Net Rate of Diffusion:

- Size.
- Temperature.
- Steepness of the gradient: 1- Concentration difference.

2 Membrane electrical difference.

3 Pressure difference.

- Charge.
- Pressure.



Filtration

Filtration is a process in which fluid along with solutes passes through a membrane due to difference in pressures on both sides.

e.g. Filtration at capillary

Capillary hydrostatic pressure – 28mm Hg

Interstitial fluid hydrostatic pressure - -2mm Hg

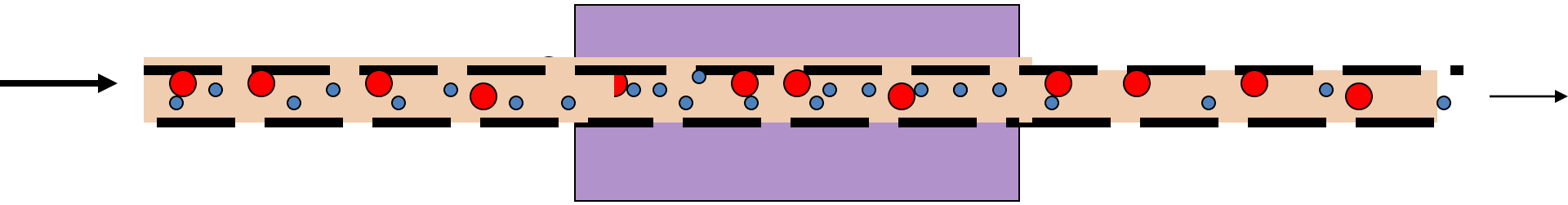
Colloidal osmotic pressure - 25mm Hg

Net Filtration pressure = 28 - (- 2 + 25) = 5 mm Hg

Dialysis

Separation of larger dissolved particles from smaller particles

It is used for elimination of waste products in the blood in case of renal failure.



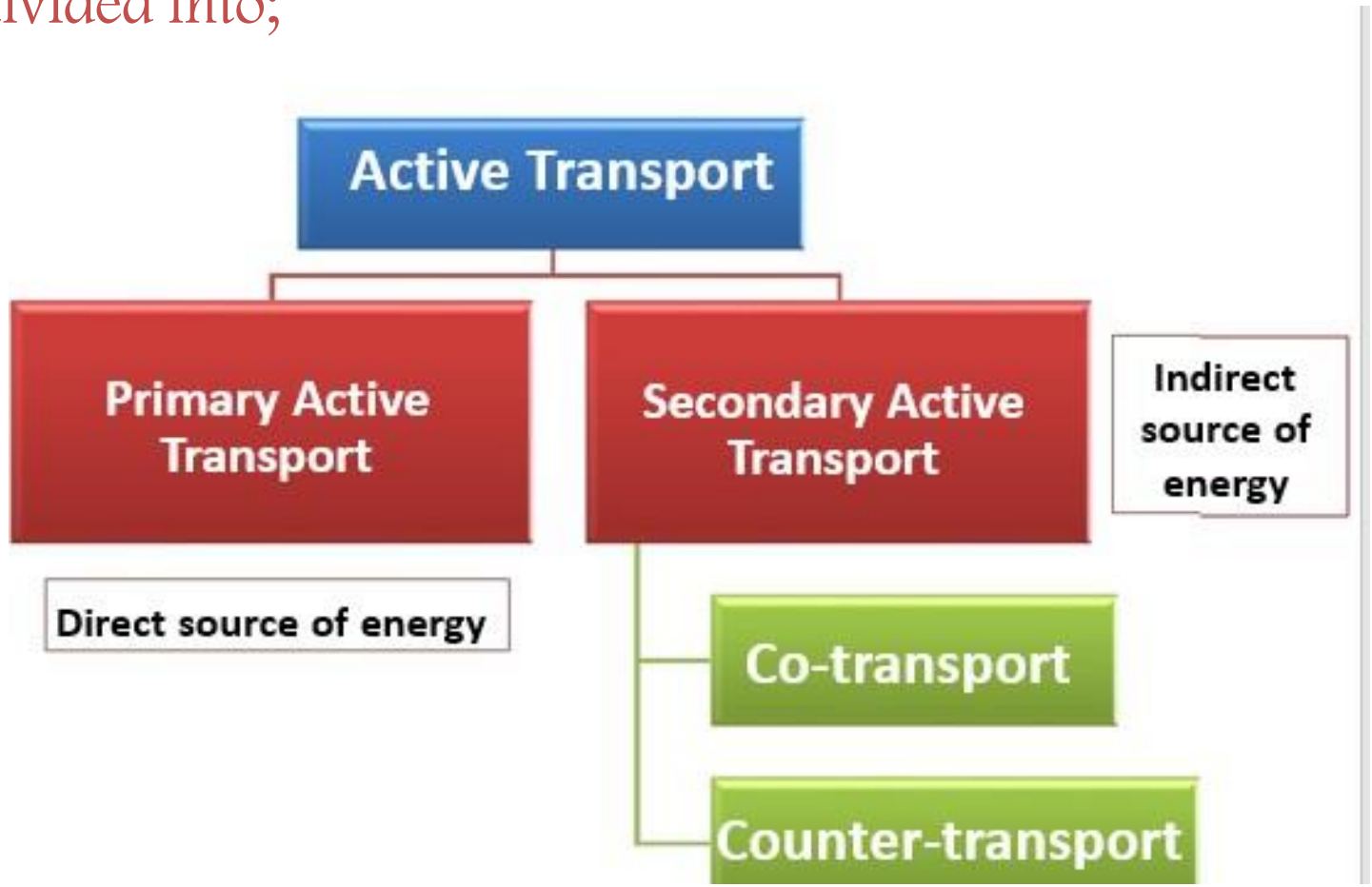
Active transport

Occurs when a cell membrane moves molecules or ions **"up-hill" against** a concentration gradient (or "up-hill" against an electrical or pressure gradient).

Examples include:

- Ions like: sodium, potassium, calcium, iron, iodine, hydrogen ions.
- Amino acids, glucose and other sugars. Requires **energy** and a **carrier protein**

According to the source of energy used to facilitate transport, it can be divided into;



Primary Active

- The energy is derived directly from breakdown of (ATP) to (ADP) this breakdown will release energy.

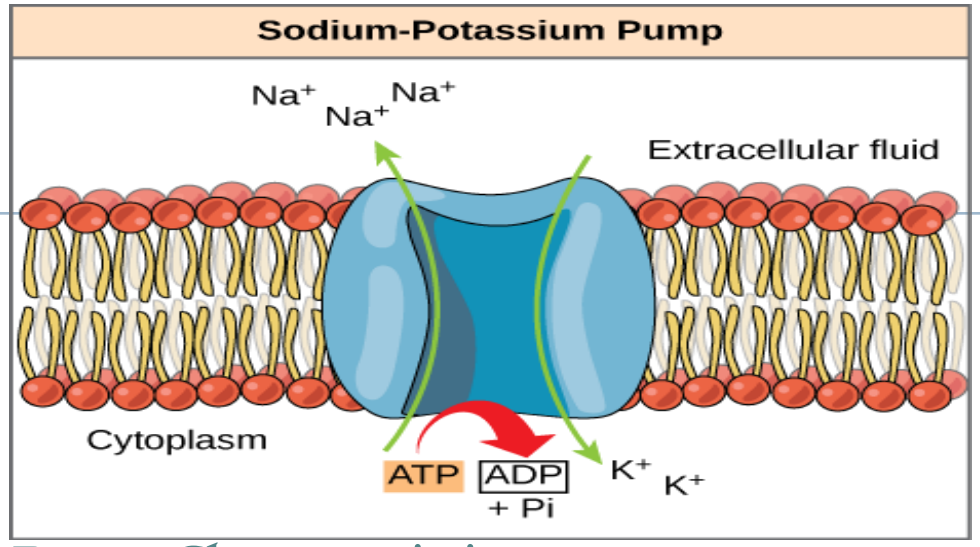
Examples include:

Sodium–Potassium

ATPase pump Calcium

ATPase pump.

Hydrogen ATPase pump.



Functions:

- Maintaining Na+ and K+ concentration difference.
- Establishes –ve potential inside the cell.
- Maintains a normal cell volume.
- It is the basis of nerve signal transmission.

Pump Characteristics:

1- Carrier protein is made of alpha and beta subunits. 2- Na binding site is inside, K binding site is outside. 3- It has ATPase activity

In the first body fluid lecture we decided that the intercellular fluid has more K and less Na, also extracellular fluid has more Na and less K. If the cell have more Na inside and more K outside that the cell will burst, therefore, this pump functions by moving 3 molecules of sodium out and 2 molecules of potassium into the cell both against their concentration gradients to maintain the body fluid balance.

Na-K pump is one of the major energy using process in the body & accounts for a large part of basal metabolism.

Regulators of Na-K pump –

- Incraesed amount of cellular Na conc.
- Thyroid hormones increase pump activity by more # of Na-K ATPase mol
- Aldosterone also increases # of pumps
- Dopamine inhibits pump
- Insulin increases pump activity
- Oubain or Digitalis inhibits ATPase (used when weakness of cardiac muscle –maintains Ca conc. In ICF of cardiac muscle

More examples:

1- Ca+2 ATPase Pump

- Present in:

A) Sarcoplasmic reticulum in muscle cells

B) Mitochondria

C) Some cell membranes.

Function:

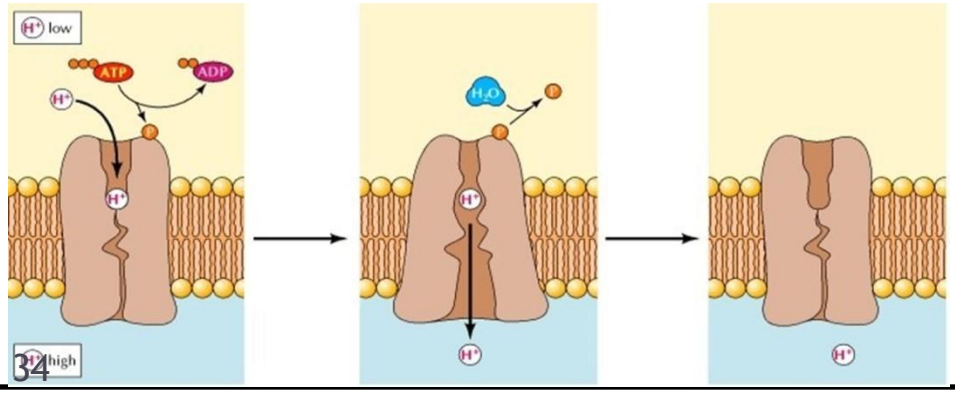
Maintains low Ca+2 concentrations in the cell

2- H+ ATPase (OR H+-K) Pump

Present in:

A) Parietal stomach cells

B) Intercalated cells of distal renal tubule



Function:

A) Secretes HCL in stomach

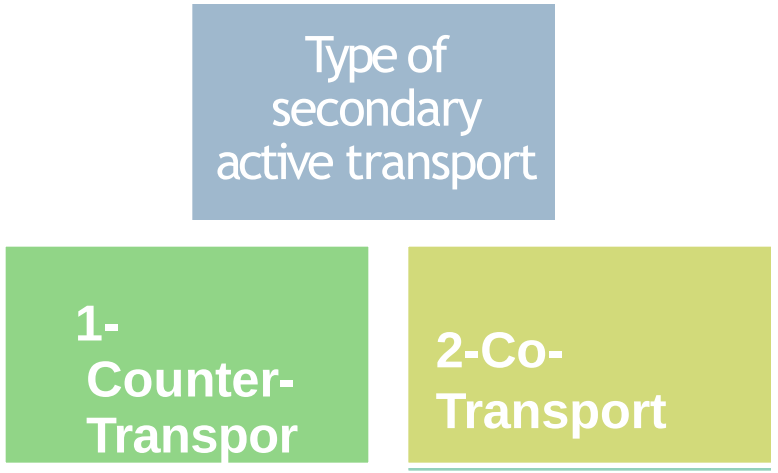
B)Excretes acids from the body

Generally: Pumps H outof the cell into lumen

H+-KATPase inhibitors treat ulcer disease (omeprazol)

Secondary Active Transport

The energy is derived indirectly by using the concentration or electrochemical gradient generated by a primary active transporter.



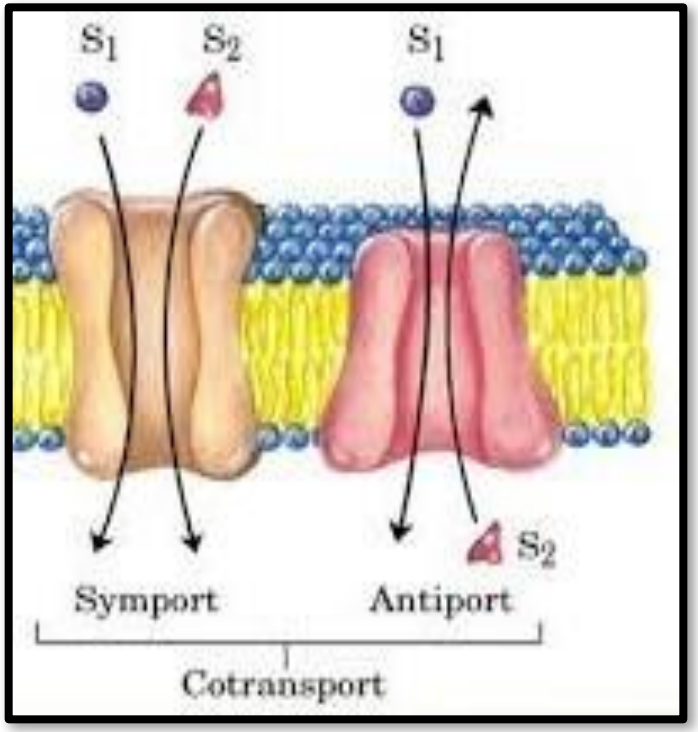
More Explanation (Co Transport) :

In primary NA-K pump, the concentration of sodium is more outside the cell, therefore the sodium will move into the cell with it's gradient, and goes back outside to maintain body fluid balance. When Na moves inside, the cell will use energy from the concentration gradient using a carrier, but the carrier has place for another molecule (glucose, against its gradient) to pass with Na, sodium can not move alone.

Co-Transport

- When both substances are transported together in the same direction.

Examples: 1- Na+-Glucose 2- Na +-amino acid, 3- In the Kidney



Counter-Transport

- When one substance is transported in the opposite direction to the other substance.

Examples: 1- Na+-H+ (Kidney)
2- Na+-Ca+2 (Many cell membranes)