Foundation Block

Physiology team 441

3-
Cell membrane structure and transport across cell membrane

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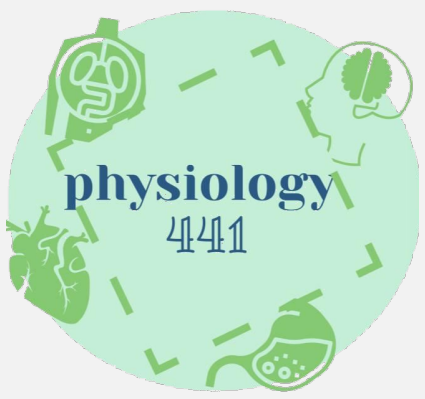
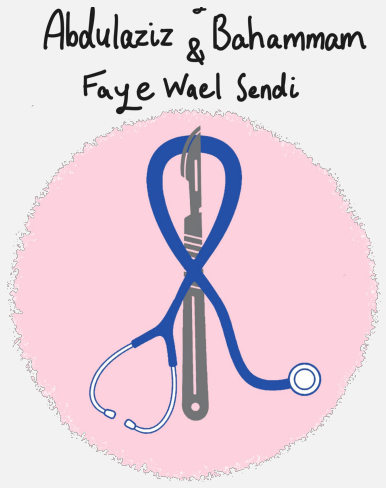
Editing File

Color index

- Main Text
- Important
- Dr's notes
- Female
- Male
- Extra



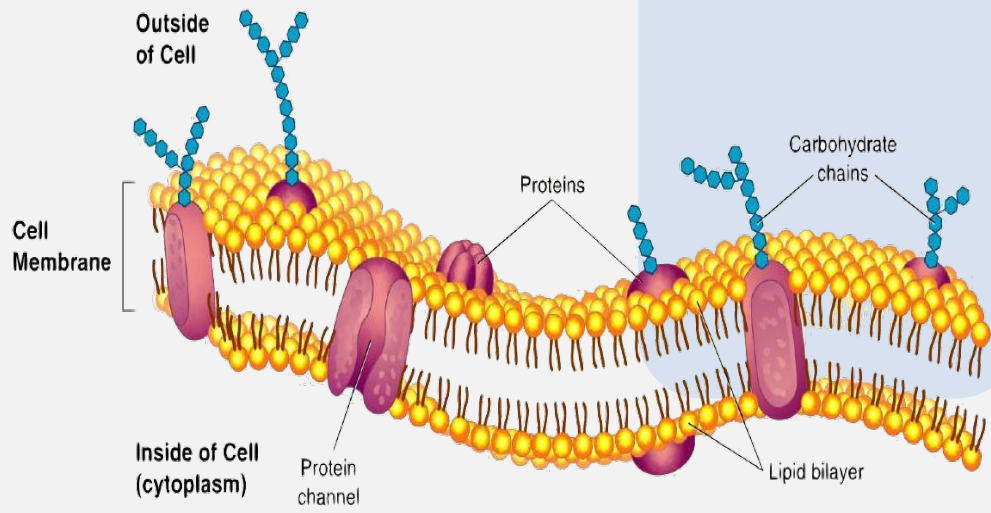


Objectives

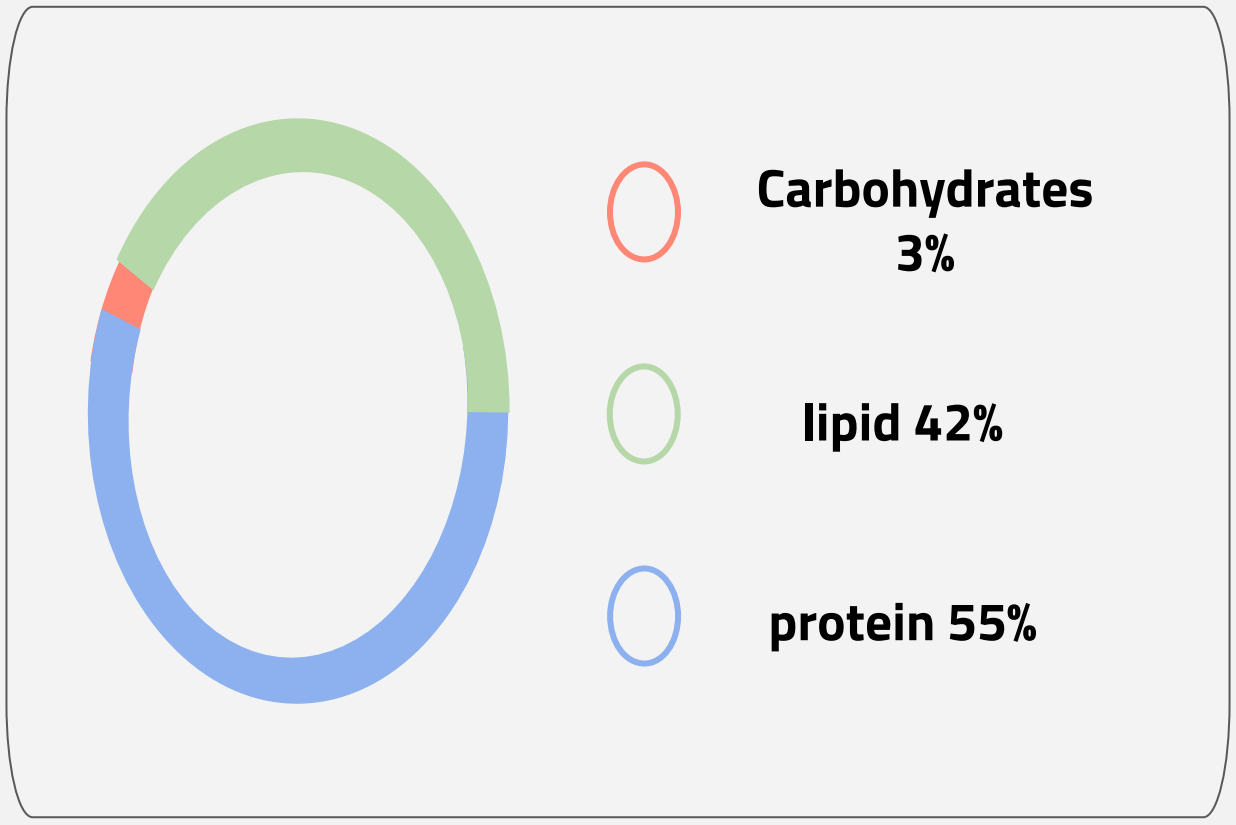
- Describe the fluid mosaic model of membrane structure and function.
- Define permeability and list factors influencing permeability.
- Identify and describe carried-mediated transport processes : Primary active transport, secondary active transport, facilitates diffusion.
- Differentiate between passive and active transport mechanisms and give examples on each.
- Study source for this lecture: (Guyton & Hall Textbook of Medical Physiology, 13th edition) .

★ Characteristics of cell membrane:

- It envelops, **covers** the cell.
- Its thin, pliable and elastic.
- Thickness : 7 - 12 nanometer (very thin).
- Also, known as “plasma membrane, cytoplasmic membrane”.
- It is fluid not solid. It’s fluid (phospholipid bilayer).



★ Composition of cell membrane



protein 55%

1- Integral proteins
2- Peripheral proteins

lipid 42%

1- Phospholipids 25%
(Amphipathic)
2- Cholesterol 13%
3- Glycolipid 4%

Carbohydrates 3%

Composition of cell membrane [protein 55%-Lipid 42%]

ICF = intracellular fluid
ECF = extracellular fluid

[protein 55%]

★ Integral proteins:

- Span the membrane.
- Provides structural channel or pores.

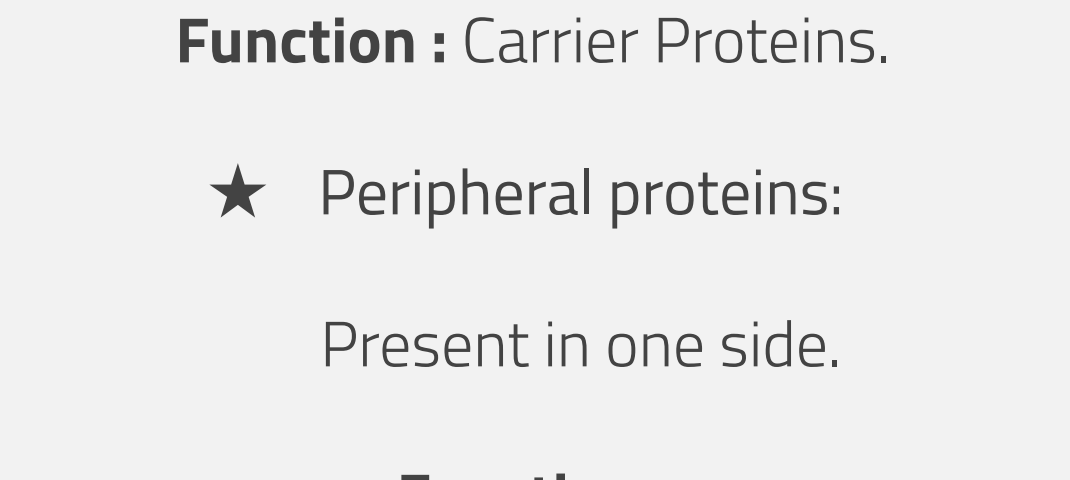
Function : Carrier Proteins.

★ Peripheral proteins:

Present in one side.

Function :

- Hormone receptors.
- **Cell surface antigens.**



▪ Cell membrane is **PERMEABLE** to:

1▪ Non-polar molecules (O^2).
2▪ Lipid soluble molecules (steroids).
3▪ Small polar covalent bonds (CO^2).
4▪ H_2O (small size, lack charge).

▪ Cell membrane **IMPERMEABLE** to:

1 ▪ Large polar molecules (glucose).
2 ▪ Charged inorganic ions (Na^+).

[Lipid 42%]

★ 25% Phospholipids **(Amphipathic)**
Consist Of :

1. Glycerol head: **(Hydrophilic):**

(glycerol molecule is attached to a phosphate group) facing ICF, ECF and tails.

2. Two fatty Acid "tails: **(hydrophobic):**

(long chains of hydrogen and carbon molecules) face each other in the interior of the bilayer.

3. Amphipathic.

★ 13% Cholesterol:

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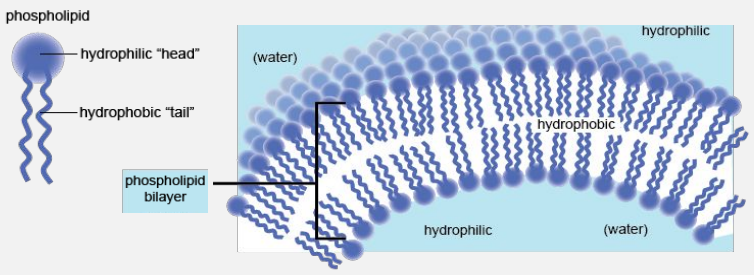
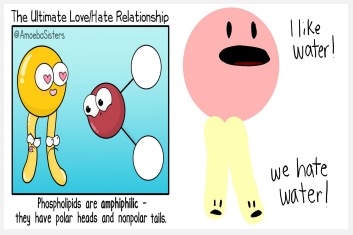
- Present in membrane in varying amounts.
- Controls much of the fluidity of the membrane.
- Function : increases membrane flexibility and stability.

★ 4% Glycolipid



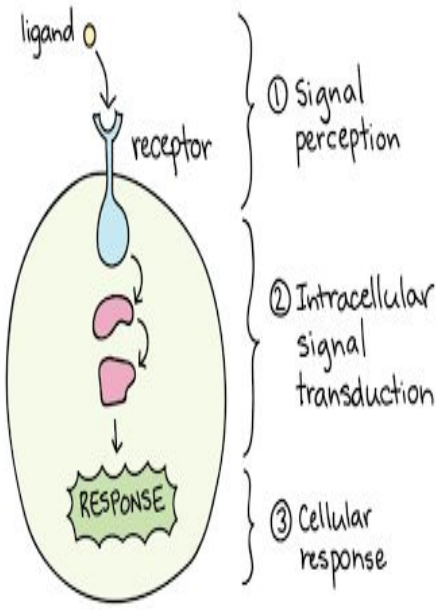


★ Composition of cell membrane cont.

[Carbohydrates 3%]

- Carbohydrates function:

1. **Attaches** cell to each others.
2. Act as **receptors** substances [help legend to recognize its receptor].
3. Some enter to **immune reactions**.
4. Give most of cells overall **-ve surface.**



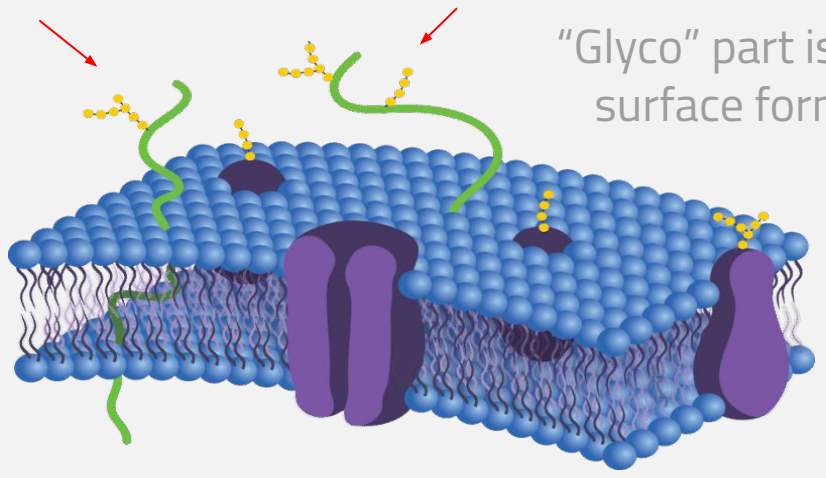
★ Structure:

Glycoproteins	Carbohydrates + Proteins (Mainly protein bound to carbohydrates).
Glycolipids	Carbohydrates (glucose) + Lipids
Proteoglycans	Mainly carbohydrate bound together by protein
Glycocalyx	Loose coat of carbohydrates

★ Percentage:

Most of the membrane carbohydrates

10%=[1/10]

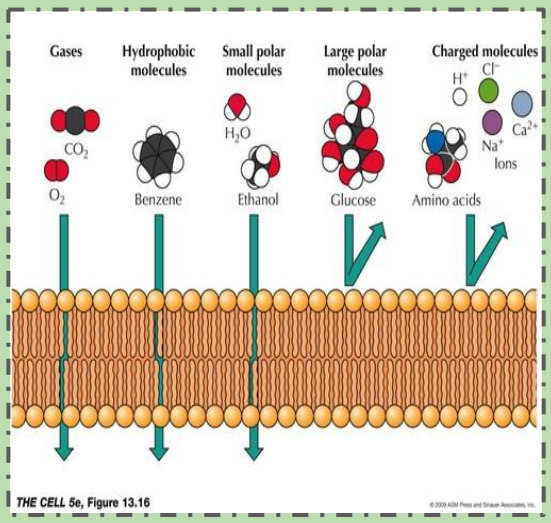


"Glyco" part is in the surface forming.

★ Transport through the cell membrane

Cell membrane is
selectively permeable (semi-permeable) to some molecules and ions.

Not permeable (impermeable) to proteins, nucleic acids, and other molecules.

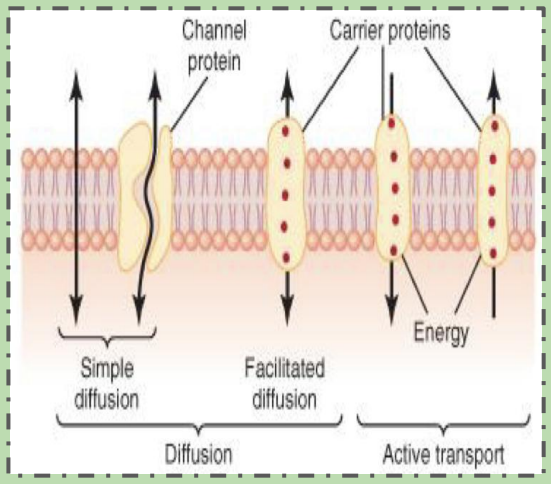


1. Through the proteins

Water-soluble (hydrophilic) substances that **can't** pass directly through lipid bilayer. They must pass through carrier proteins.

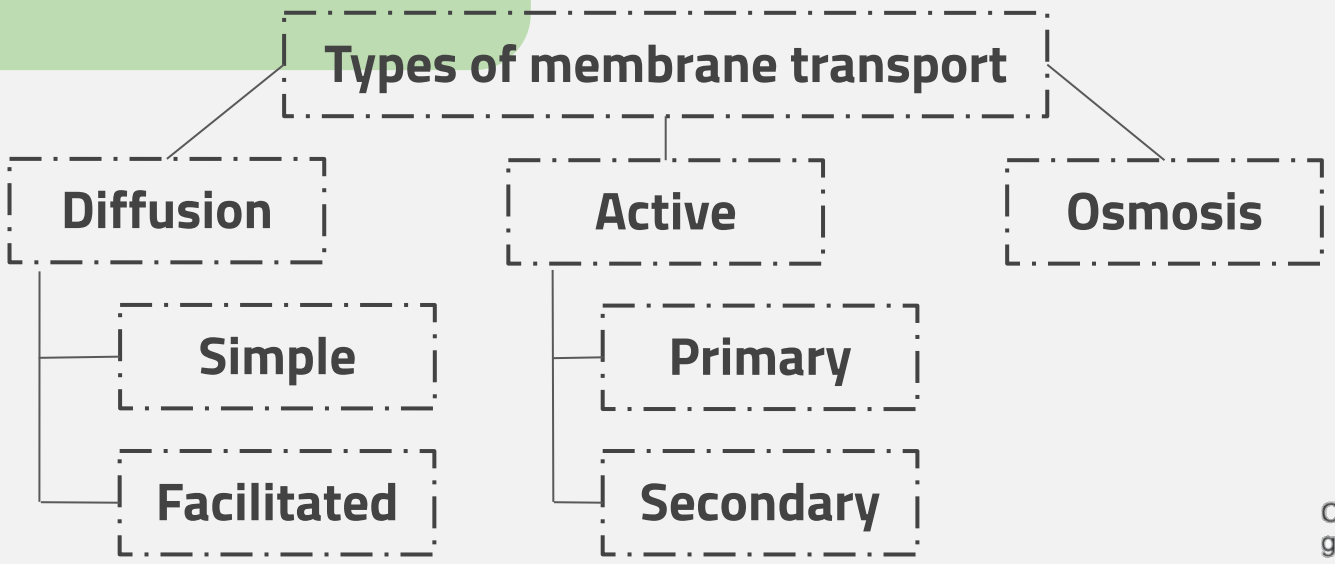
E.g. ions, glucose..

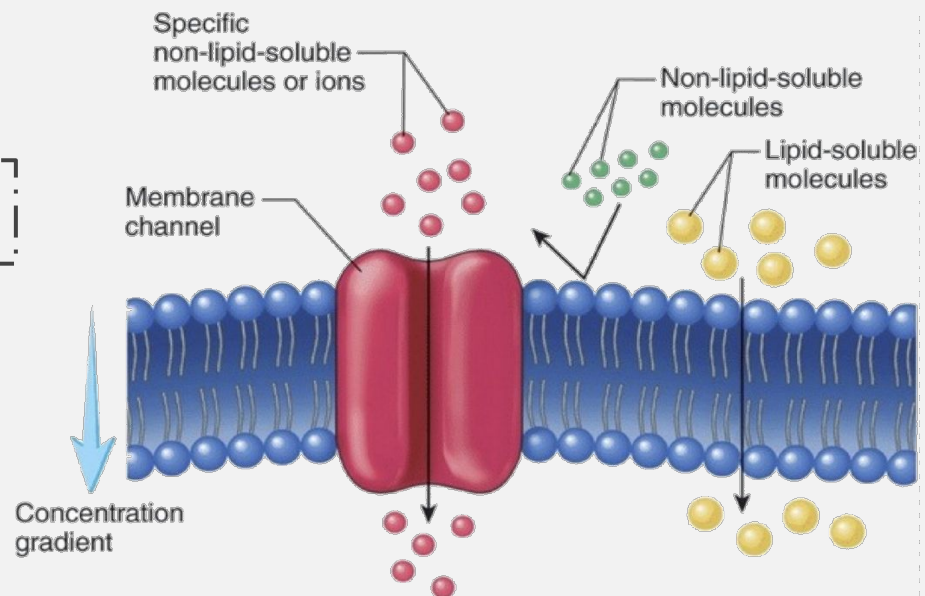
2. Directly through the lipid bilayer



Fat-soluble (hydrophobic) substances that **can** pass directly through lipid bilayer.

E.g. O_2, CO_2, N_2, Alcohol..

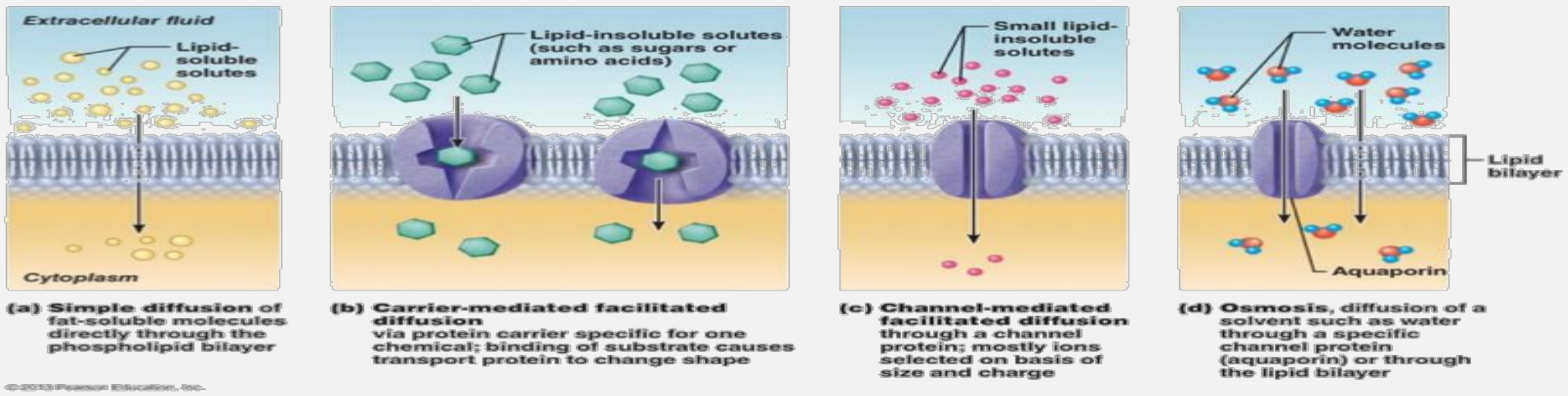




I. Passive Transport: (Diffusion):

Definition: a random movement of substance either through the membrane directly or combination with carrier protein **down** an electrochemical gradient.(downhill). (constant state).

Physical process occur whenever there is a concentration difference across the membrane and the membrane is permeable to the diffusing substance.



(a) Simple diffusion of fat-soluble molecules directly through the phospholipid bilayer

(b) Carrier-mediated facilitated diffusion via protein carrier specific for one chemical; binding of substrate causes transport protein to change shape

(c) Channel-mediated facilitated diffusion through a channel protein; mostly ions selected on basis of size and charge

(d) Osmosis, diffusion of a solvent such as water through a specific channel protein (aquaporin) or through the lipid bilayer

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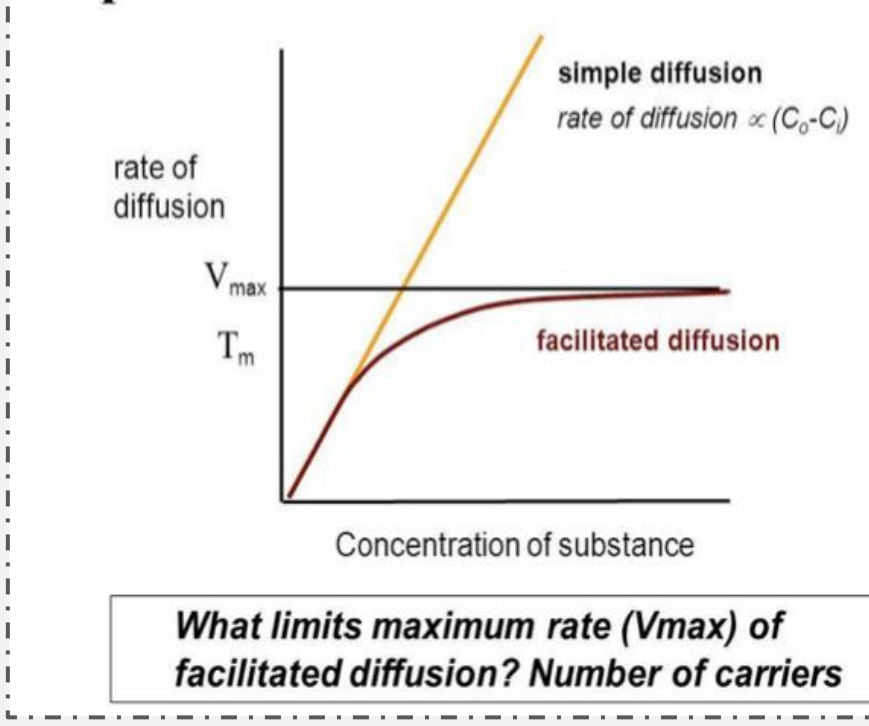
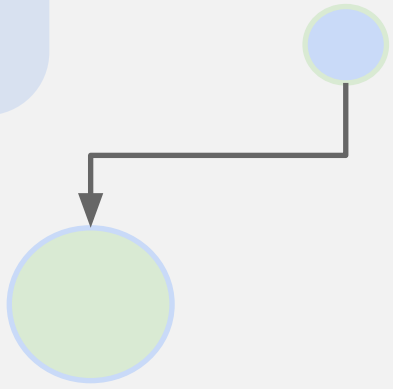
Simple diffusion	Facilitated diffusion
• Non carrier mediated transport. • The rate of diffusion increases proportionately with the concentration of the diffusing substance.	• The rate of diffusion increases proportionately with the concentration of the diffusing substance **until it reaches a transport maximum (T_{max}).** • At T_{max}, an increase in the concentration of the diffusing substance **does not** increase the rate of diffusion.

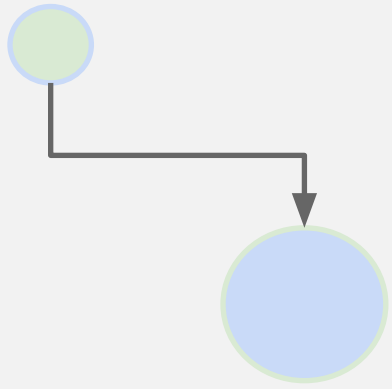


T_m = transport maximum = the transport rate at which saturation occurs.

when does the facilitated diffusion reach (V_{max}) ?
The rate of diffusion reaches a maximum (V_{max}) when all the carriers are functioning as rapidly as possible.

There are two types of diffusion transport which are:

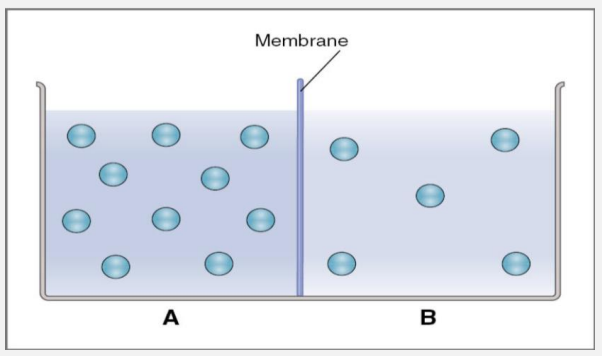


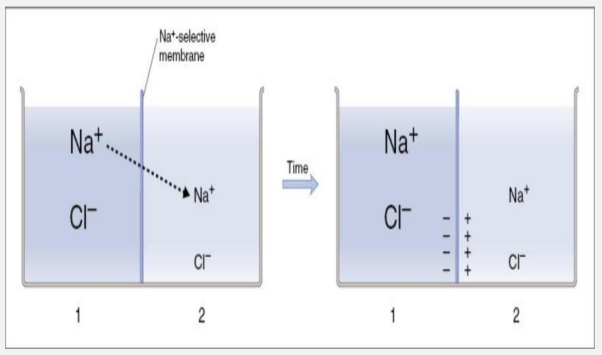


A. Simple diffusion

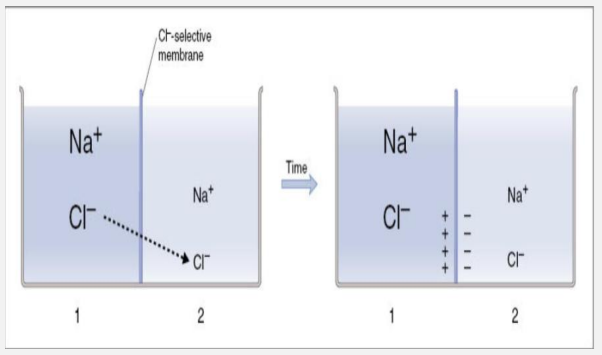
➔ Non-carrier mediated transport down an electrochemical gradient.from high concentration to low concentration.

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





➔ Diffusion of electrolytes (charged) depend on both chemical, as will as electrical potential.



B. Facilitated diffusion

➔ Carrier mediated transports down an electrochemical gradient.

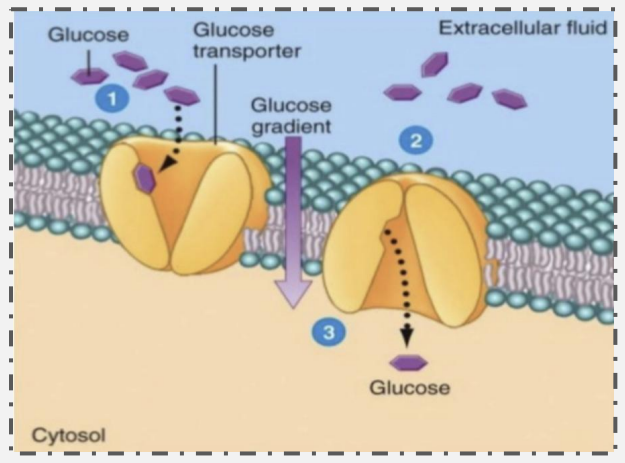
➔ The process that allows selective movement in and out of the cell membrane.

E.g. Transport glucose and most of amino acids (due to their big size).

(Simple and facilitated diffusion Do NOT require input of energy (ATP).)

★ Net Rate of Simple Diffusion Depends on:

1. **Amount of substance available.**
2. **The number of opening in the cell membrane for the substance (pores)selective gating system.**
3. **Electrical potential difference.**
4. **Molecular size of the substance.**
5. **Lipid solubility.**
6. **Temperature.**
7. **Presence of Protein Channels.**
8. **Pressure, Concentration Difference between the substances.**
9. **Chemical concentration difference.**
   Net diffusion= P x A (Co-Ci)



NOTE:

Neuronal plasma membrane is 20 x more permeable to K+ than Na+

★ Rate of Diffusion= P x A (C1-C2):

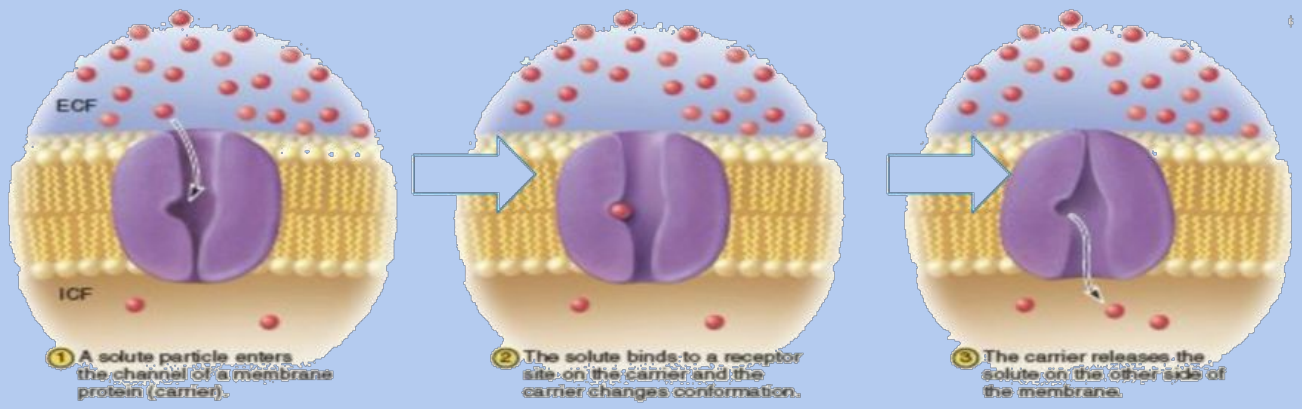
1. P = Permeability coefficient
   a. Temperature.
   *كل مازادت الحرارة الطاقة الحركية تزيد.
   b. Size of molecule.
   c. Solubility in the lipids.
   d. Thickness of membrane
2. A = Surface area.
3. C1-C2 = Gradient Difference:
   a. Concentration difference.
   b. Electrical difference.
   c. Pressure difference.

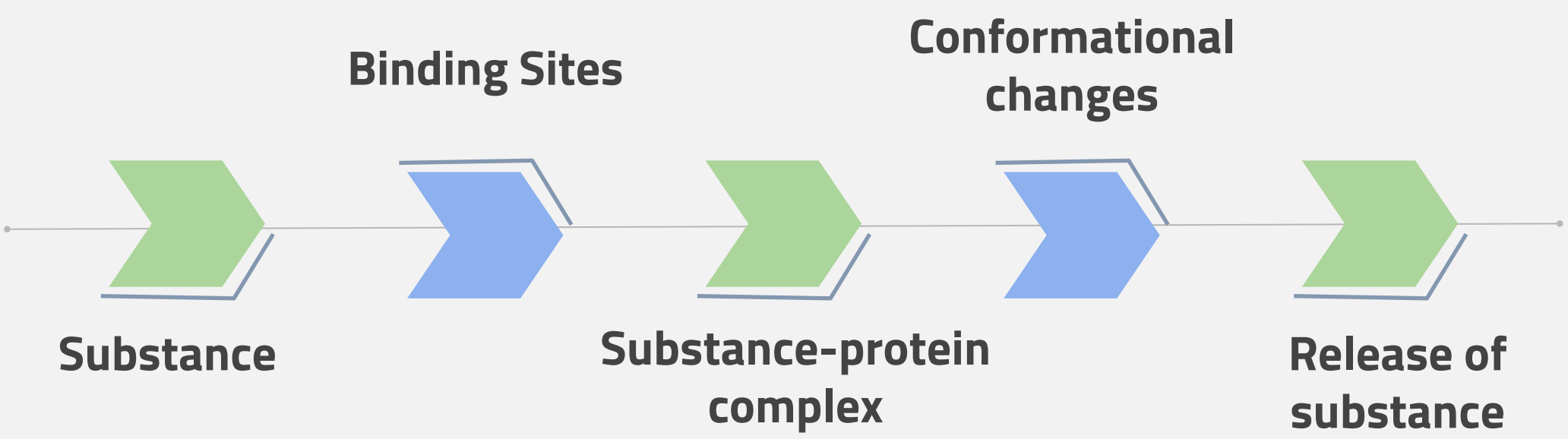
★ Features Of Carrier-mediated Transport (Facilitated diffusion]:

1. **Saturation:** Increase in concentration = increase binding of protein, if all protein is occupied we achieve full saturation.
   i.e. The rate of diffusion reaches a maximum (Vmax)
   when all the carriers are functioning as rapidly as possible.
2. **Stereospecificity:** The binding Site recognize a specific substances.
   D-glucose but not L-glucose.
3. **Competition:** Chemically similar substances can compete for the same binding site.
   Ex: D-galactose and D-glucose.

General Steps For Any Carrier-Mediated Transport:

1. Solute at one side of the membrane (substance-protein complex).
2. Change in carrier conformation (shape), allowing solute to pass through.
3. Release of solute on the opposite side of membrane.





2. Active transport:

A helpful video

A helpful video

A helpful video

Definition :

Transport (uphill) against electrochemical gradient, required energy (direct or indirect), require carrier protein.

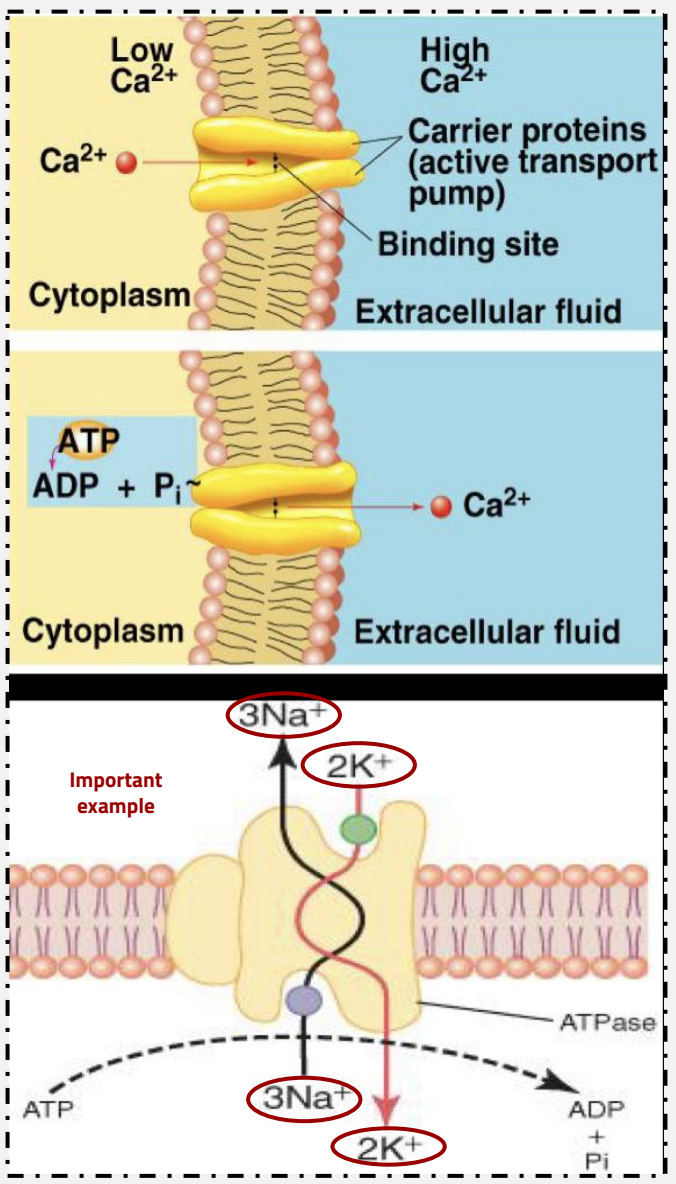
- Hydrolysis of ATP directly required for the function of the pump.
- Molecule or ion binds to “recognition site” on one side of pump.
- Binding stimulates phosphorylation(breakdown of ATP) of carrier protein.
- Carrier protein undergoesconformational change.
- Hinge-like motion releases transported molecules to opposite side of membrane.

Examples:

A. Sodium-Potassium Pump.

B. Calcium ATPase (Ca^2+ ATPase).

C. Hydrogen Ions H+-K ATPase.



A. Primary active transport

Energy is supplied directly from ATP.

ATP ⟶ ADP + P + Energy.

★ **Sodium Potassium pump (Na^+ - K^+ pump)**

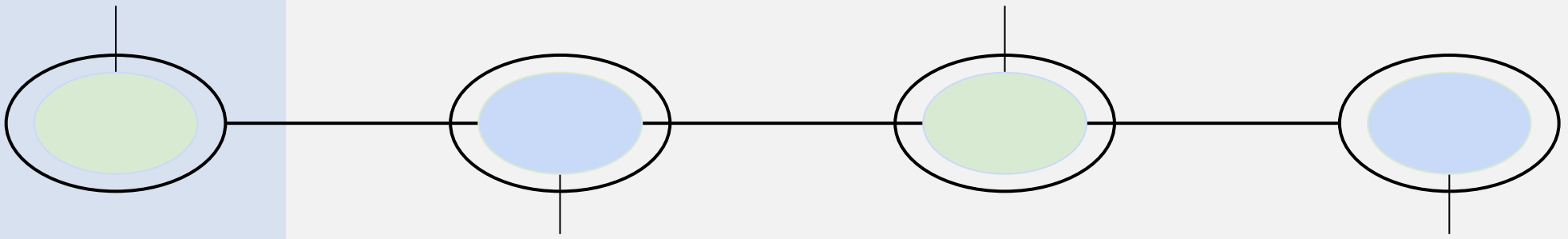
- 3 Na^+ in ⟶ Out. - 2 K^+ out ⟶ In.

All cell membranes

❖ Function :

Maintaining Na^+ and K^+ concentration difference.

It's the basis of nerve signal transmission.



Maintaining –ve potential inside the cell.

Maintains a normal cell volume.

❖ Characteristics of the pump :

01 ➢ Carrier protein is formed from α and β subunits.

02 ➢ It has ATPase activity.

03 ➢ Binding site for Na inside the cell.

04 ➢ Binding site for K outside the cell.

05 ➢ 3 Na out.
(طلع برا يسوق **وصدم** بالعمود)
صدم: كلمة من ٣ حروف يعني ٣ صوديوم بيطلعون.

06 ➢ 2 K in.
(يحب **البيت** ويدخل جوا)
الباء: تكررت مرتين بالجملة يعني ٢ بوتاسيوم بيدخلون .

- **Primary active transport of calcium (Ca^2 + ATPase)**

❖ Function:

➢ Maintaining a low Ca^2 + concentration inside the cell.

❖ Found in:

Mitochondria | some cell membranes | Sarcoplasmic reticulum (SR)

- **Primary active transport of hydrogen ions H - K ATPase:**

Found in:

Kidneys | Stomach | Pump to the lumen | H^+-K ATPase inhibitors (treat ulcer disease). (omeprazol)
(تساعد على توقف نقل الهيدروجين وتقلل حمضية المعدة الزائدة)

2. Active transport

A helpful video

B. Secondary Active transport:

- Energy is supplied indirectly from primary transport.
- It is transport of one or more solutes against an electrochemical gradient ,coupled to transport of another solute down an electrochemical gradient.

➢ " downhill " solute is Na. (Na in secondary active transport is usually down the electrochemical gradient).

➢ " uphill " solute is Glucose. (against the electrochemical gradient).

Type of secondary Active Transport:

1- Co-Transport.

2- Countertransport.

BULK TRANSPORT:

- Movement of many large molecules, that cannot be transported by carriers, at the same time.

▪ Exocytosis:

- Fusion of the membrane-bound vesicles that contains cellular products with the plasma membrane.

▪ Endocytosis:

- Exocytosis in reverse.
- Specific molecules can be taken into the cell because of the interaction of the molecule and protein receptor.

- Countertransport (antiport):

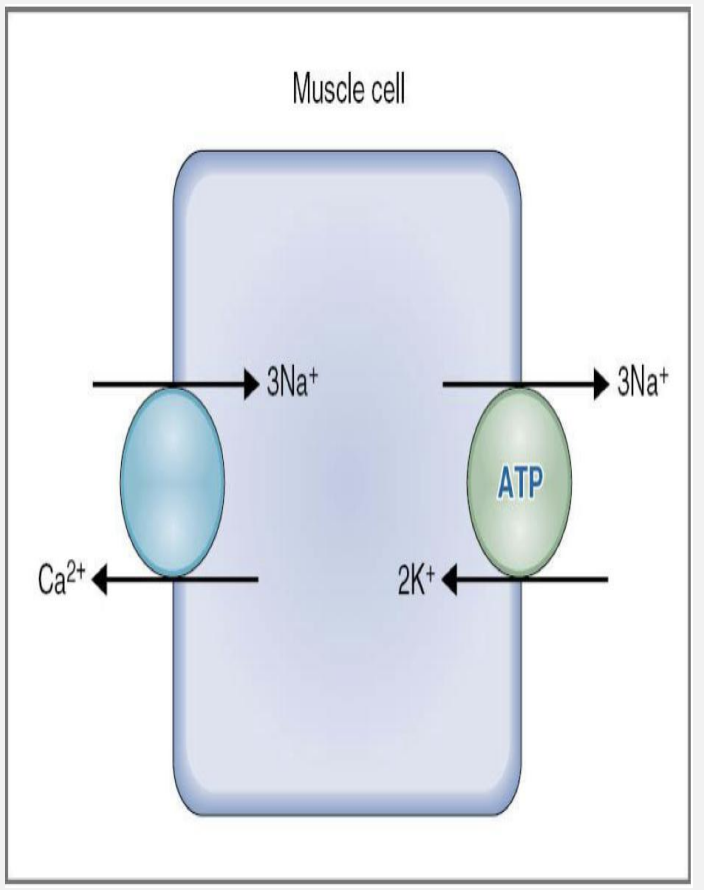
❖ Na is moving to the interior causing other substance to move out.

❖ e.g.

➢ Ca^{2} + - Na exchange. (present in many cell membranes).

➢ Na - H exchange in the kidney.

Countertransport



- Co-transport (symport):

❖ All solutes move in the same direction "inside cell".

❖ e.g.

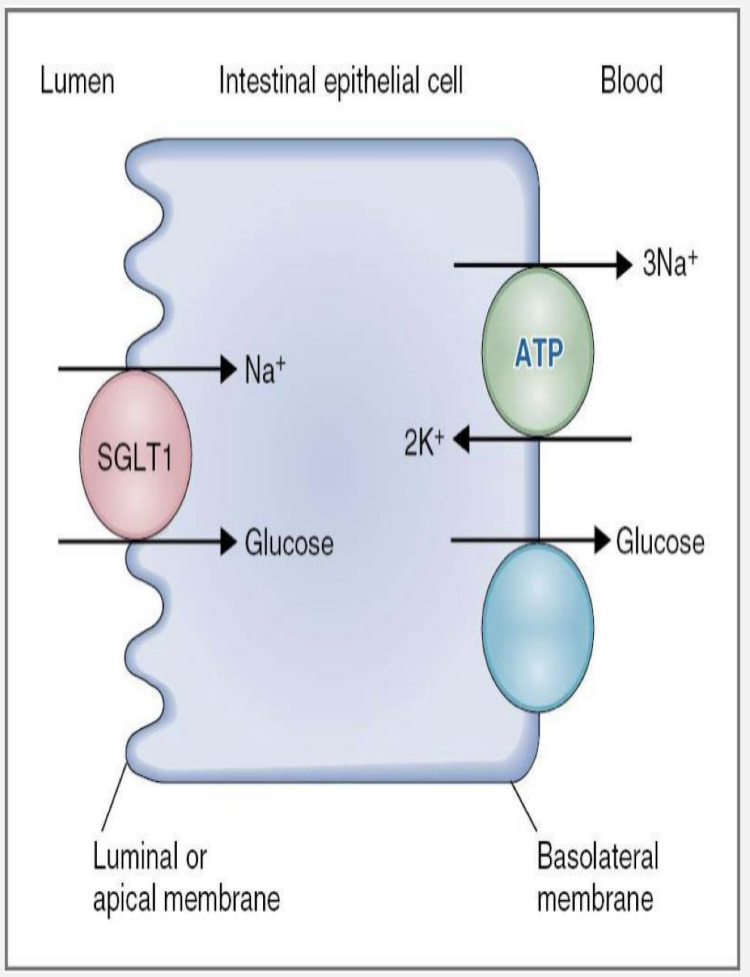
➢ Na - glucose Co-transport.

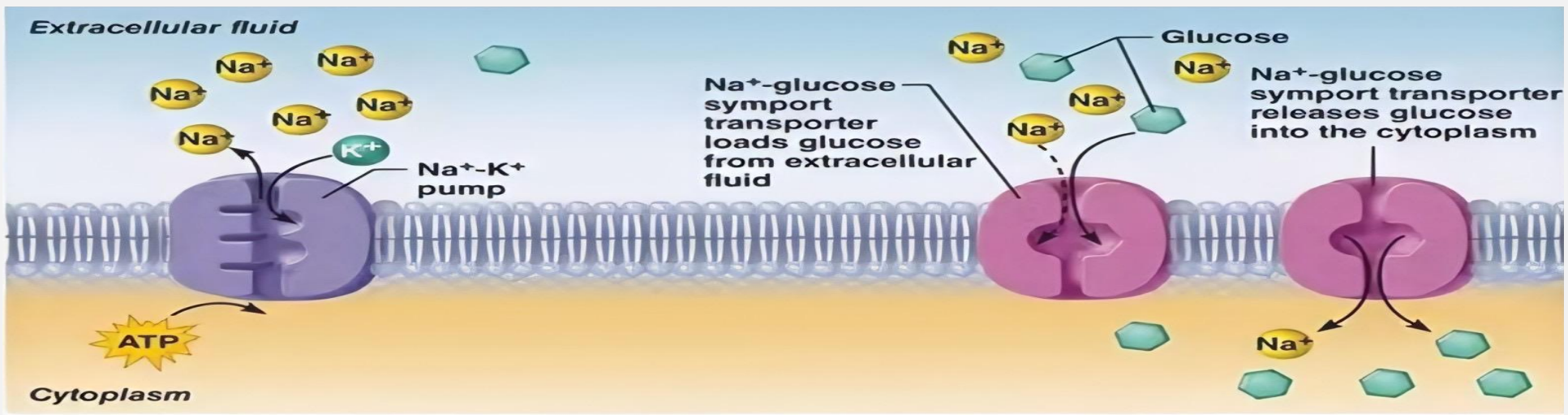
➢ Na - amino acid Co-transport.

❖ Found in:

➢ in the intestinal tract, kidney.

Co-transport





① **Primary active transport**
The ATP-driven Na^{+}-K^{+} pump stores energy by creating a steep concentration gradient for Na^{+} entry into the cell.

② **Secondary active transport**
As Na^{+} diffuses back across the membrane through a membrane cotransporter protein, it drives glucose against its concentration gradient into the cell.

Summary:

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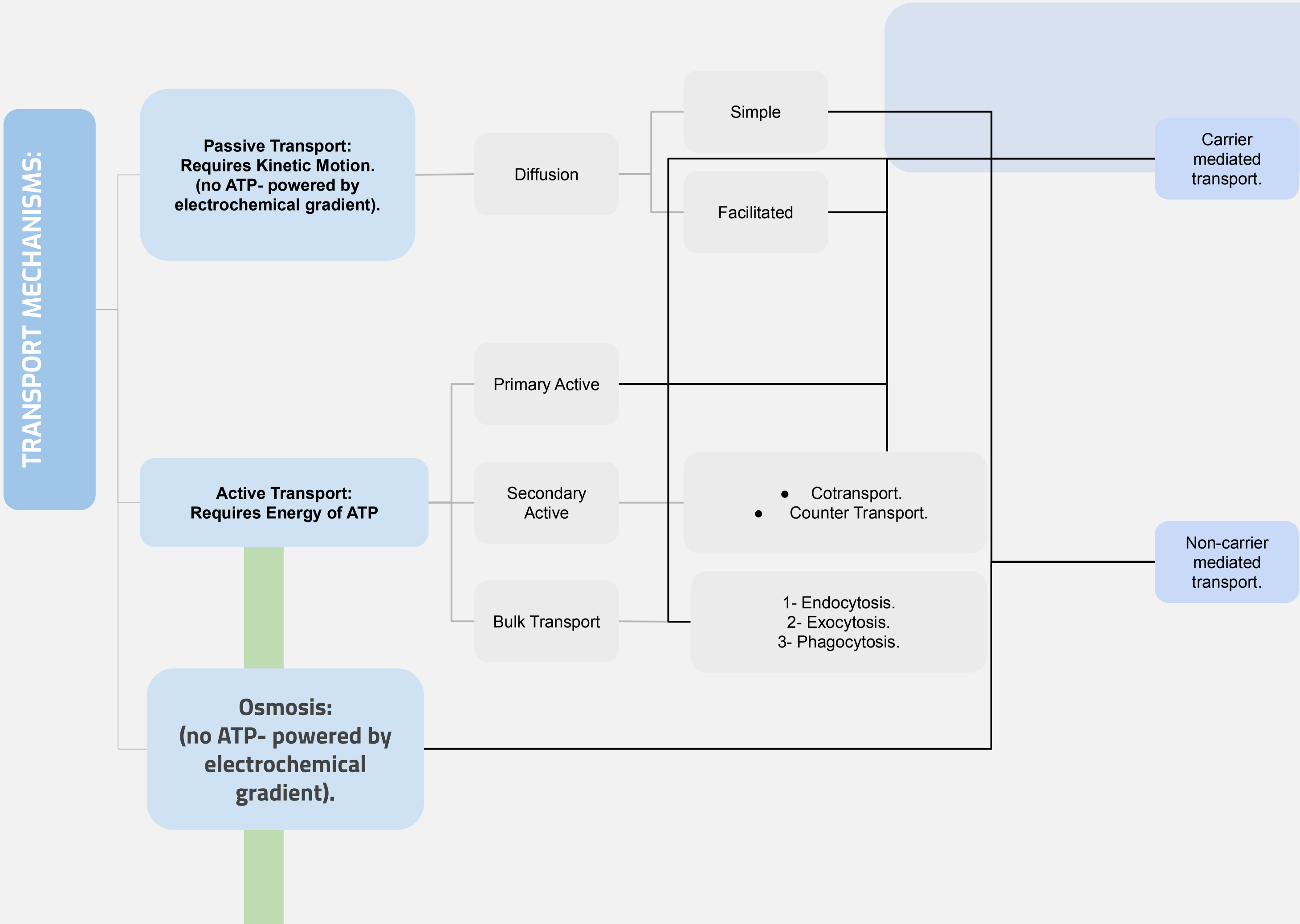

Test yourself

★ MCQs

Q1: The uncharged molecules cross the cell membrane via			
A- osmosis	B-facilitated diffusion	C-simple diffusion	D-active transport
Q2: In Na+/K+-pump, the binding site for Na+ is …… the cell			
A- doesn't exist	B-between	C-outside	D-inside
Q3: Which of the following is not a factor affecting the rate of simple diffusion?			
A- Surface area	B-Saturation	C-Temperature	D-Electrical difference
Q4: Protein about …… of cell membrane composition			
A- 25%	B-30%	C-55%	D-75%
Q5:Where can we find H-K ATPase pump?			
A- Stomach	B-Sarcoplasmic reticulum	C-Mitochondria	D-some cells membane

1-C 2-D 3-B 4-C 5-A

★ SAQ

Q1:List an example of both Co-transport and countertransport pumpsCo-transport:

Co-transport:
Na+- glucose
Na +- amino acid
countertransport:
Ca^{2}+ - Na + exchange
Na+-H+ exchange

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physiology 441

Foundation Block

Physiology team 441

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