
MED437
KING SAUD UNIVERSITY


# PHYSIOLOGY

- Females & Males Slides
- Only Found in Males' slides
- Only Found in Females' slides
- Vary Important Notes
- Notes
- Extra Information

# Transport of Substances Through the Cell Membrane

# Objectives

**At the end of this session, the students should be able to:**

- Describe the fluid mosaic model of membrane structure and function.
- Define permeability and list factors influencing permeability.
- Differentiate between passive and active transport mechanisms and give examples on each.
- Describe the different forms of passive transport and state the differences between them and the molecules transported by each.
- Describe the different forms of active transport and state the difference between primary and secondary types giving examples for each in the human body.
- Identify and describe carried-mediated transport processes:
  Primary active transport, secondary active transport, facilitated, diffusion.

***Study source for this lecture***:

(Guyton & Hall Textbook of Medical Physiology, 13th ed, Chapter 4)

# Eukaryotic Cell Structure

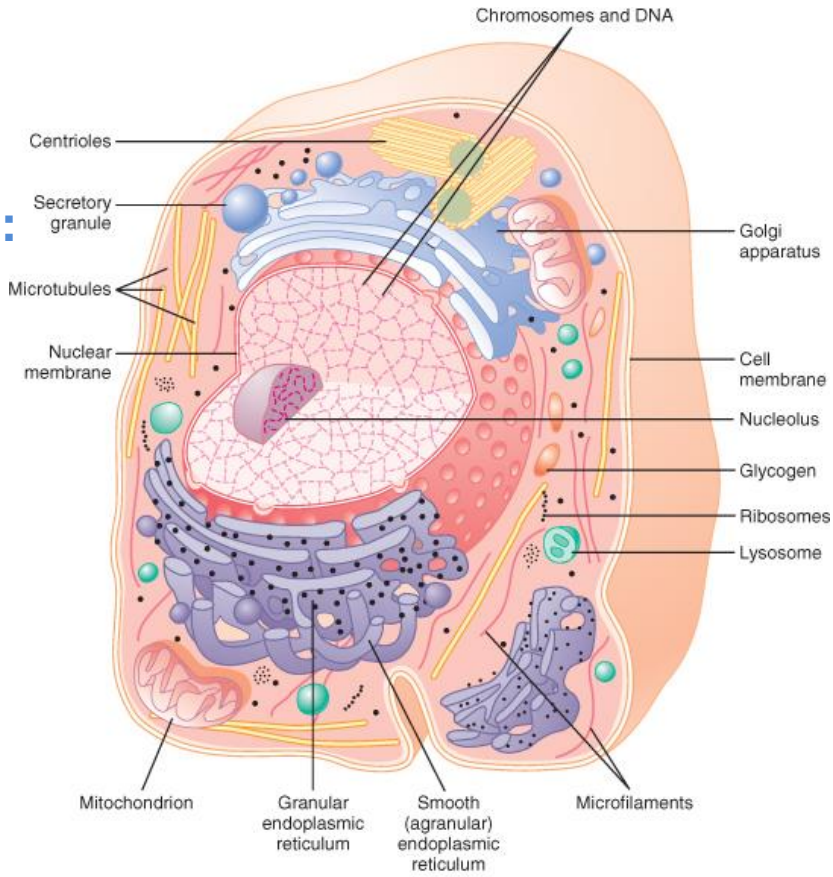
The cell is basic unit of structure and function within the body (~100 trillion cells in body).

**Comprises three principal parts:**

**i) Plasma (cell membrane)**

**ii) Cytoplasm & organelles**

**iii) Nucleus**



# Structure of the Cell Membrane

It covers the cell.

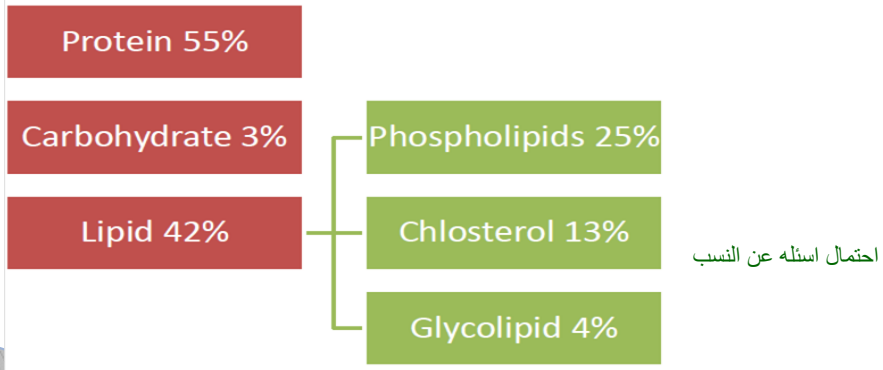
It is a fluid and not solid.

Cell membrane = plasma membrane = a *lipid bilayer*.

Thickness = 7.5-10 nm.

عند الأولاد مكتوب 7-10 nm ما يفرق

## Composition




احتمال اسئله عن النسب

# The Plasma Membrane

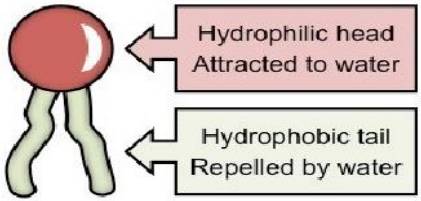
- Main constituents of plasma membrane are **phospholipids**.

Because it covers the inner and outer sides of cell membrane

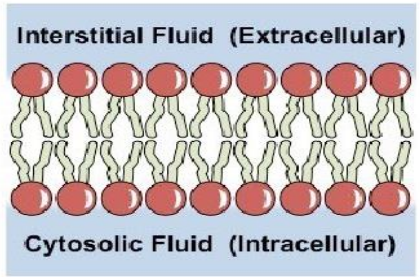
- A phospholipid molecule have two ends:

➢ ***Hydrophilic*** (phosphate end)

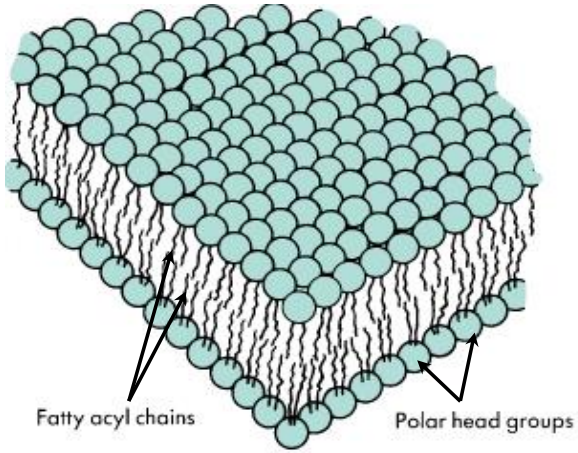
➢ ***Hydrophobic*** (fatty acid end)




**Glycerol Heads**
(hydrophilic)
facing ICF and ECF

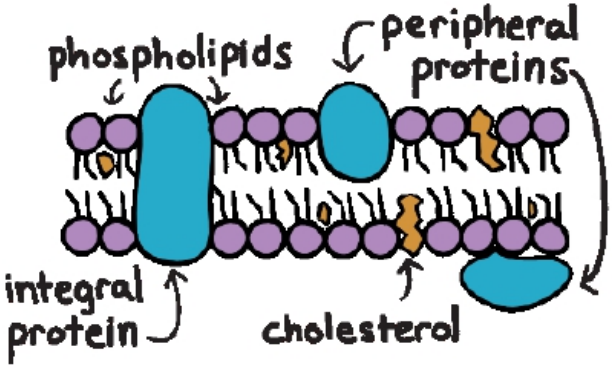



**Tow fatty acid tails**
(hydrophobic)
face each other in the interior of the bilayer **(**Amphipathic**)**




الرسمة بسلايدات الأولاد ..

# Structure of the Cell Membrane




## Membrane proteins

### Integral

Span the thickness of the cell membrane

***Function as:***

1. Channels (or pores).
2. Carrier proteins
3. Receptors.

### Peripheral

Are attached to one surface of the membrane.

***Function as:***

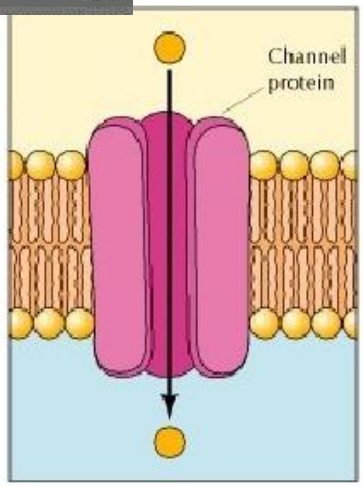
1. Enzymes.
2. Adhesion molecules.

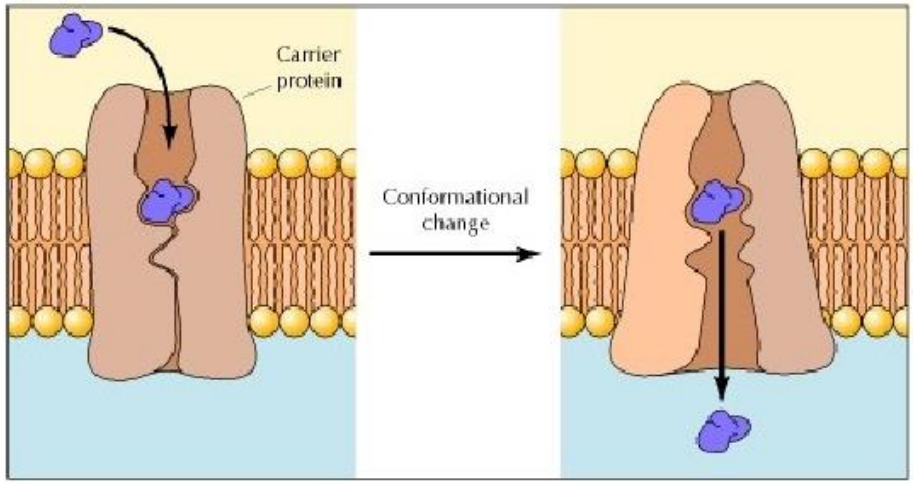
proteins (carrier) can participate in intracellular signalling, present in one side, work as cell membrane receptor and cell surface antigens.

-The % of proteins is higher than phospholipids because proteins are condensed

(Guyton ad Hall Textbook of Physiology. 13th ed. Chapter-2)

# Channel vs. Carrier Proteins



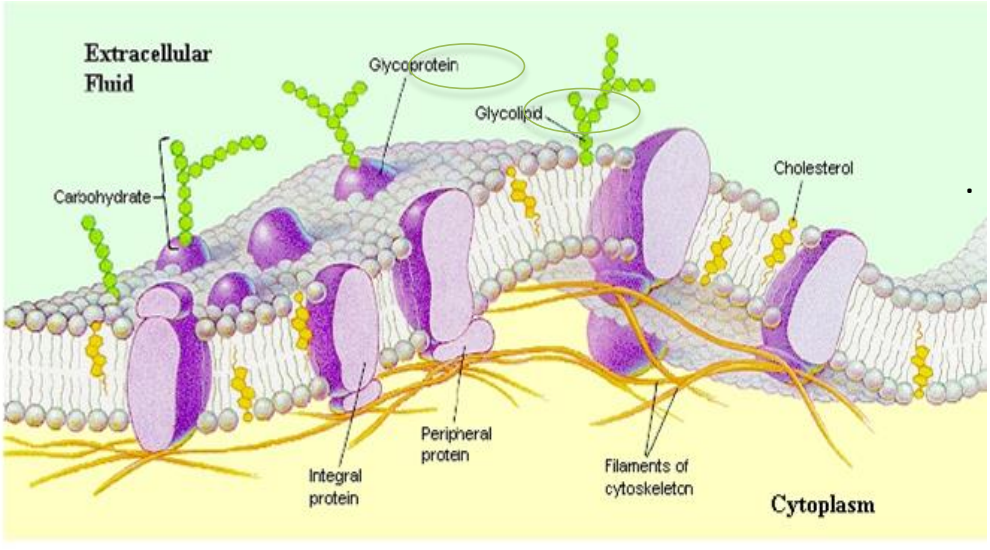




Channel proteins form open pores through which molecules of the appropriate size (e.g., ions) can cross the membrane.

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.

* They are small that's why they pass

# Structure of the Cell Membrane




***Function of CHOs (carbohydrates) :***

- Receptors.
- Cell-to-cell interaction.
- Immune reactions.
- Give most of cells overall –ve surface.

- **Carbohydrates** (CHOs) in the cell membrane are invariably **attached** to:

– **Proteins** → Glycoproteins (most of it) carbohydrates + proteins

– **Lipids** → Glycolipids (1/10) carbohydrates + lipids

**Proteoglycans** (mainly **carbohydrate** substance **bound** together by **protein**)

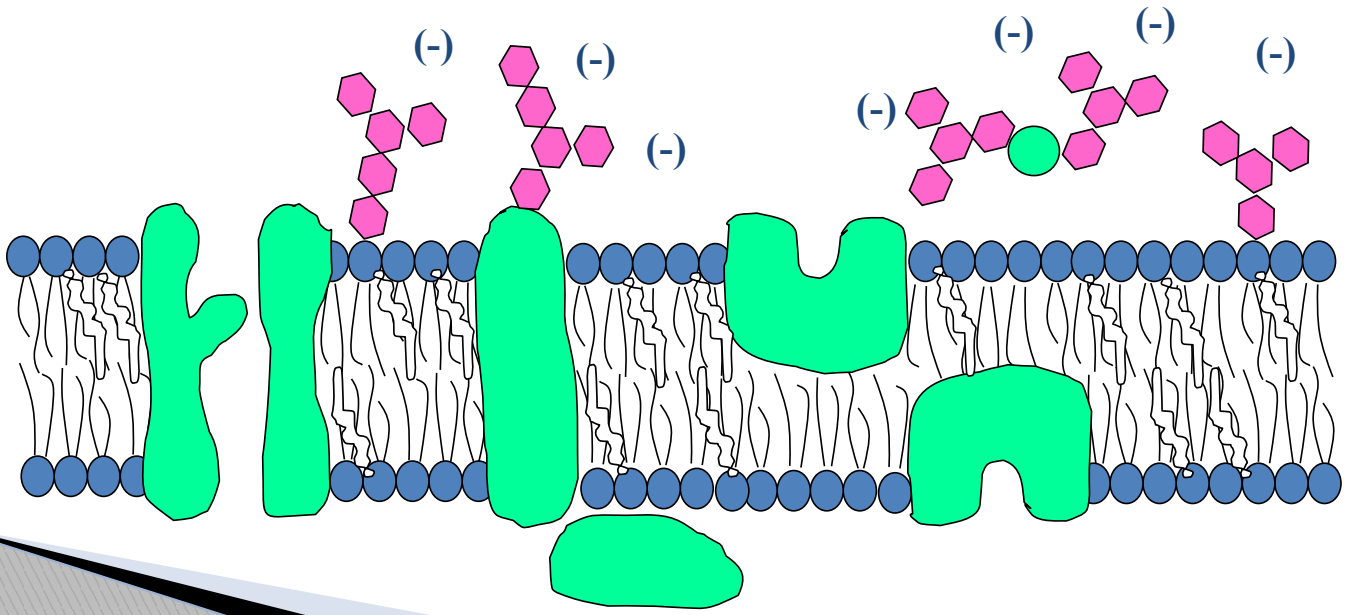
- Carbohydrate molecules protrude to the outside of the cell forming a loose carbohydrate coat = "***glycocalyx***"

# Cholesterol

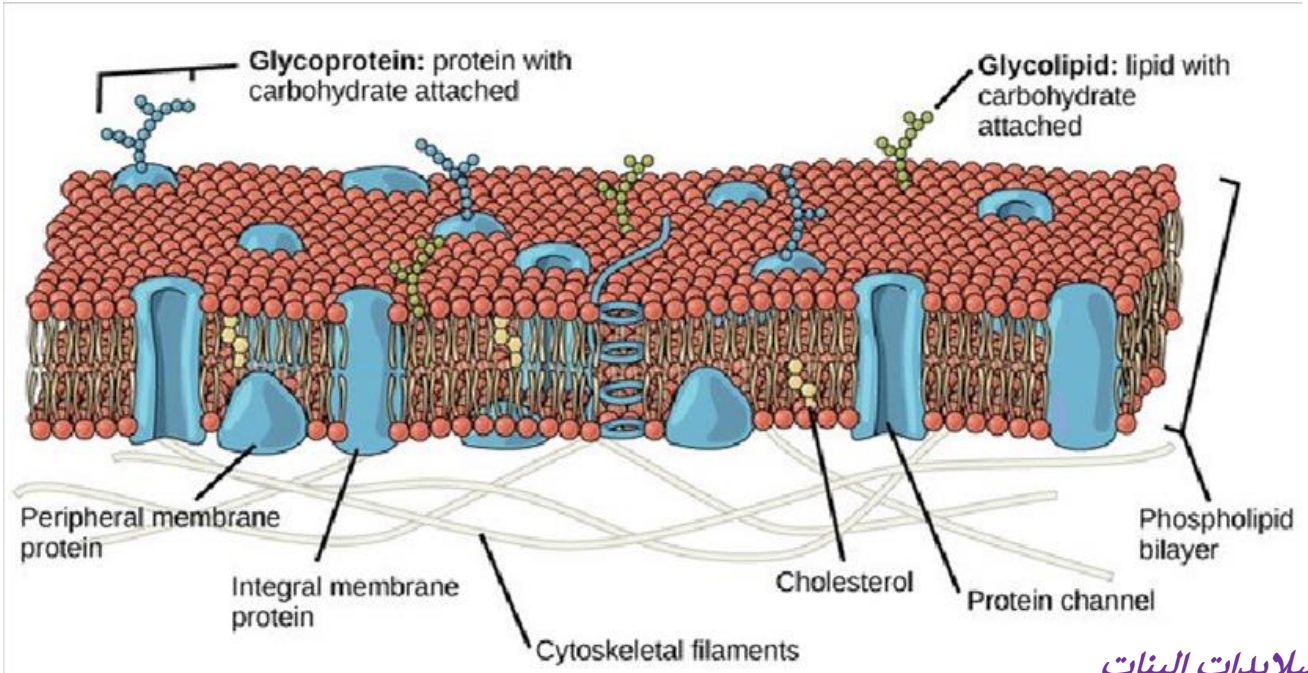
- present in membranes in varying amounts
- controls much of the fluidity of the membrane

function

- increases membrane **FLEXIBILITY** and **STABILITY**



# The Fluid Mosaic Model of Plasma Membrane

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# Transport through the cell membrane

The cell membrane is "***selectively permeable***"…

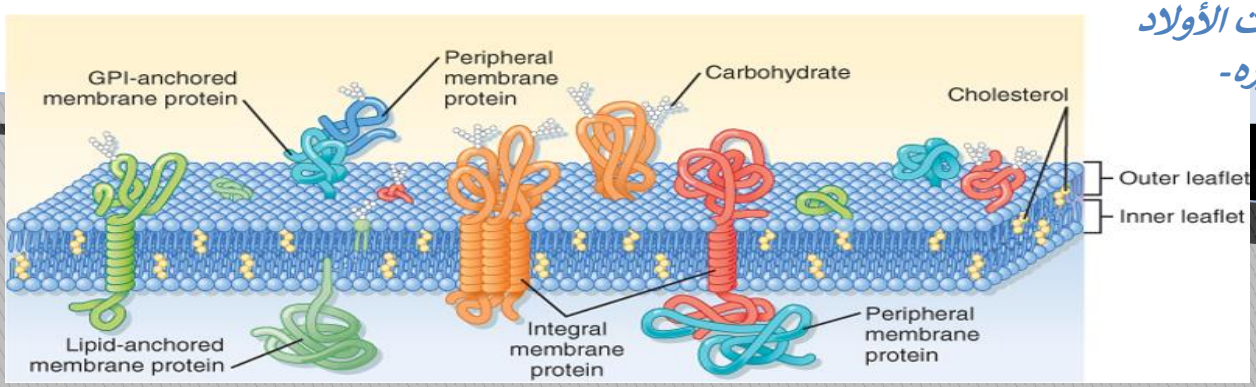
The membrane allows some substances to cross it but not others.

It arises from the membrane's structure.

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

Through the **proteins**. - water –soluble substances e.g. ions, glucose

Directly through the **lipid bilayer**. - fat – soluble substance (O2, CO2, alcohol)



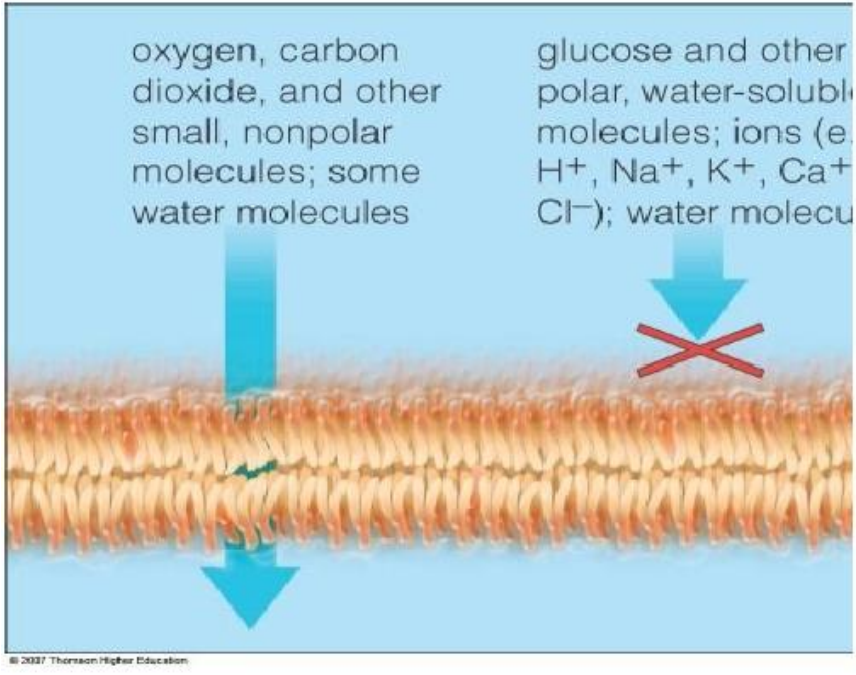

الرسمة بسلايدات الأولاد
– معلومات مكرره-

# Substances that can Across the Cell Membrane

*Oil and water do not mix*

***Lipid soluble substances***

***Water soluble substances***




**Cross freely by diffusion**

**Through membrane proteins**

الرسمة بسلايدات البنات

# Substances That Can Move Across the Cell Membrane

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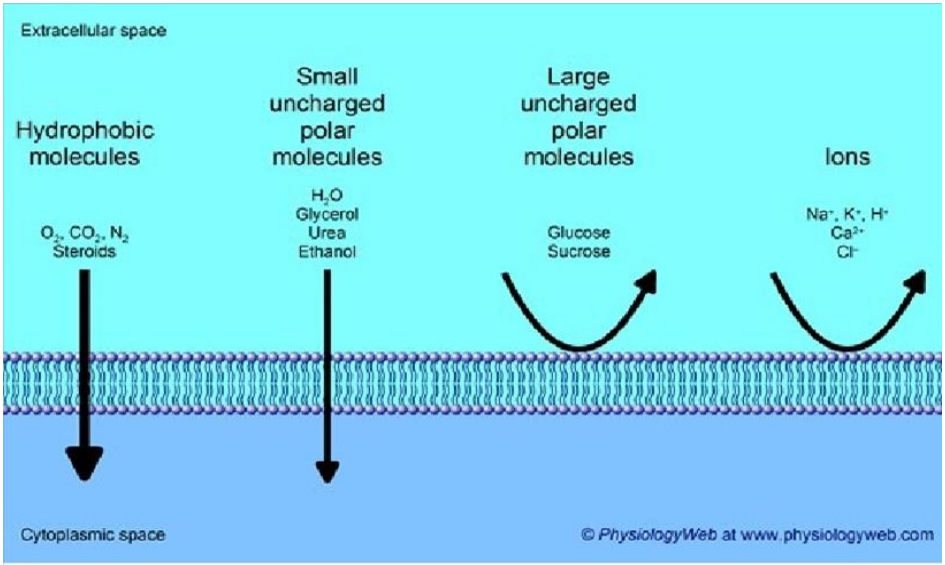


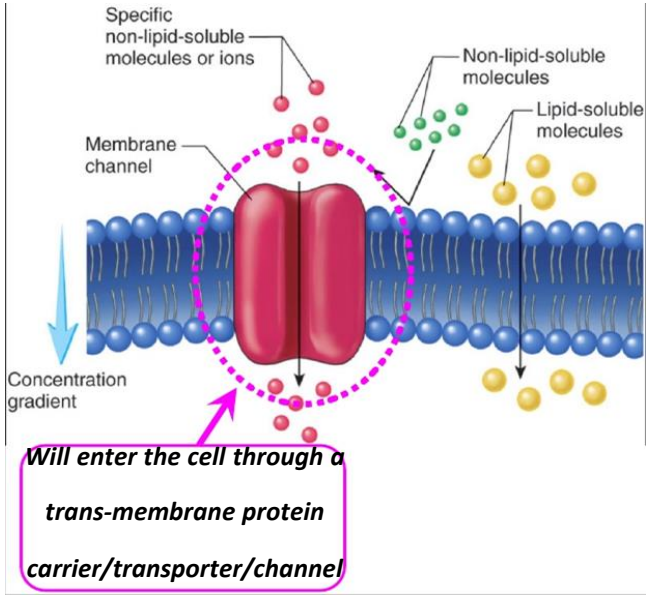

# Transport Mechanisms

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

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

## Passive Transport

- Molecules move along their energy gradient.
- ***Does not require energy***.
- Types:
  - Simple Diffusion.
  - -Facilitated Diffusion.
  - Osmosis.

## Active Transport

- Molecules move against their energy gradient.
- ***Requires energy.***
- Types:
  - Primary Active Transport.
  - Secondary Active Transport.

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

# Passive Transport Mechanisms

- **Simple Diffusion**
- **Facilitated**
- **Osmosis**

Movement of from an water area of ***low*** to an area of ***high solute concentration***.

Explanation:

Passive transport is the movement from high to low concentrations, so why in osmosis shows the opposite? First, we have to know that there is a semipermeable membrane that is trying to prevent- some of the solutes pass to the other side. Therefore, the water has the priority to move from a place which contains (high volume of water-low *solute concentration) to a place contains* (low volume of water-high *solute concentration).*

# Diffusion

• ***Diffusion*** = the random movement of substances down an energy gradient.

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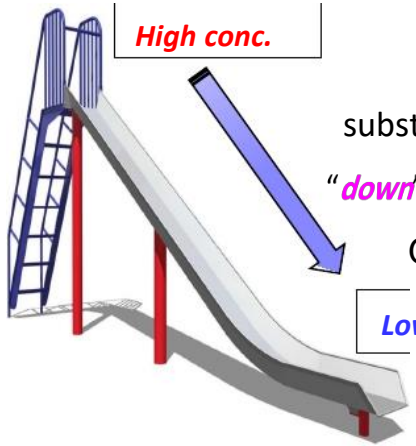
• This gradient can be:

– Concentration gr.

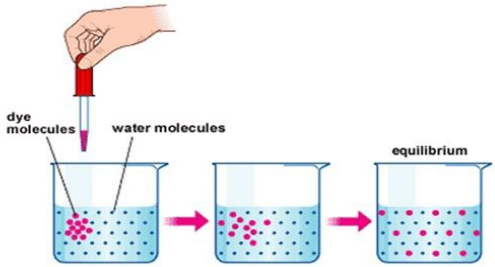
– Electrical gr.

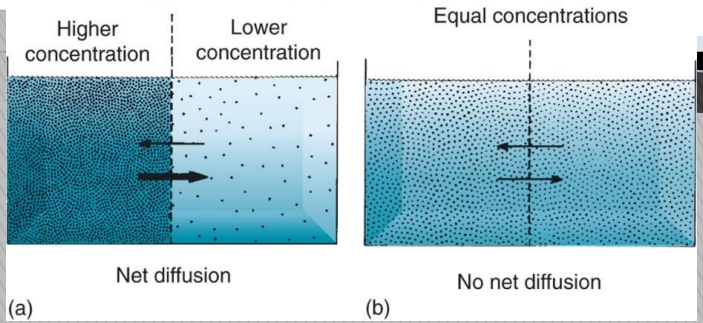
– Pressure gr.

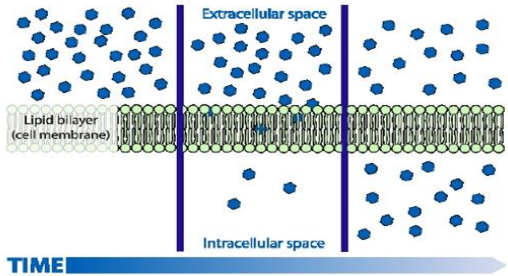



substances will move "*down*" their concentration Gradient

## Diffusion



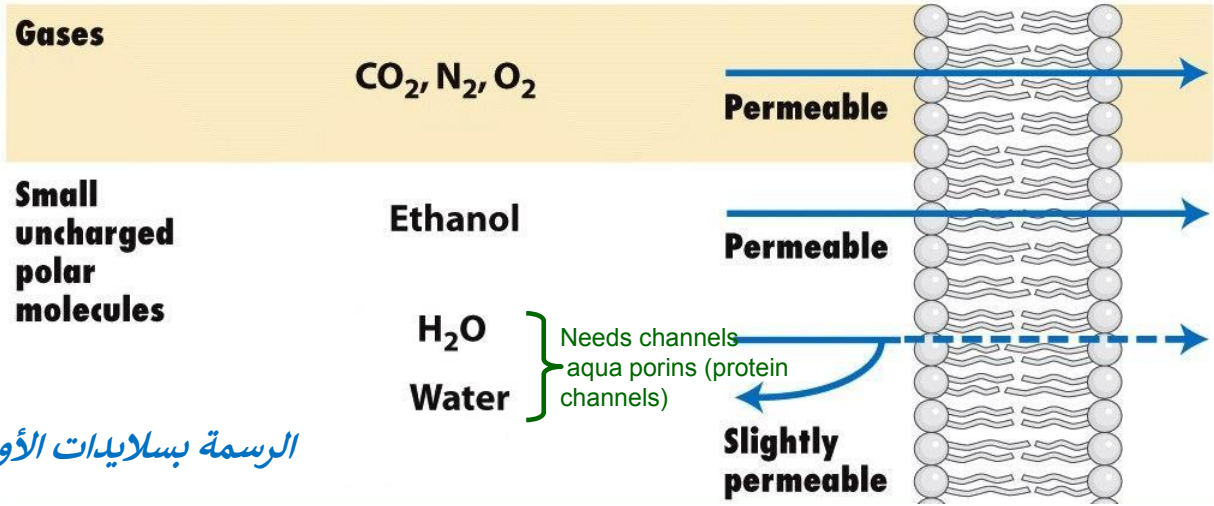



# Simple Diffusion

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

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




الرسمة بسلايدات الأولاد

- Non carrier mediated transport down an electrochemical gradient

# Factors affecting rate of diffusion

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

Net Diffusion= P x A (C2 – C1 )

4- Electrical potential difference

5- Molecular size of the substance

6- Lipid solubility

7- Temperature

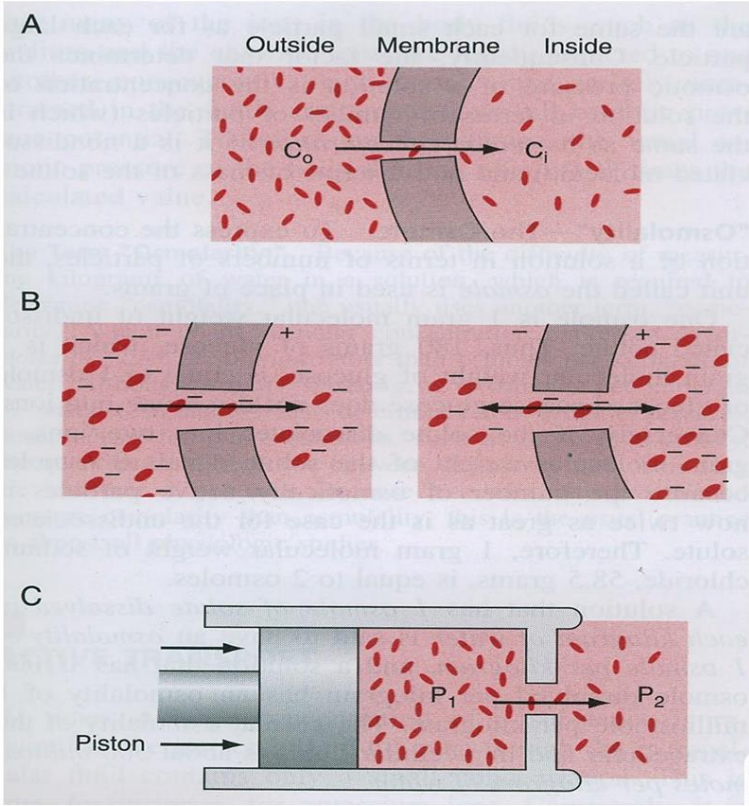
سلايد كاملة من الأولاد

د .مها السجا تقول هذي وحقت البنات (السلايد اللي بعدها)زي بعض

# Factors affecting rate of diffusion

$$Rate\ of\ diffusion = P\ X\ A\ (C1 - C2)$$

1. **P = Permeability coefficient.**
   a. Temperature.
   b. Size of molecule.
   c. Solubility in lipids.
   d. Thickness of membrane.
2. **A = surface area.**
3. **C1-C2 = gradient difference:**
   a. Concentration difference
   b. Electrical difference.
   c. Pressure difference.




سلايد كاملة من البنات
د .مها السجا تقول هذي وحقت الأولاد (السلايد اللي قبلها)زي بعض

# Facilitated diffusion Down con. No ATP

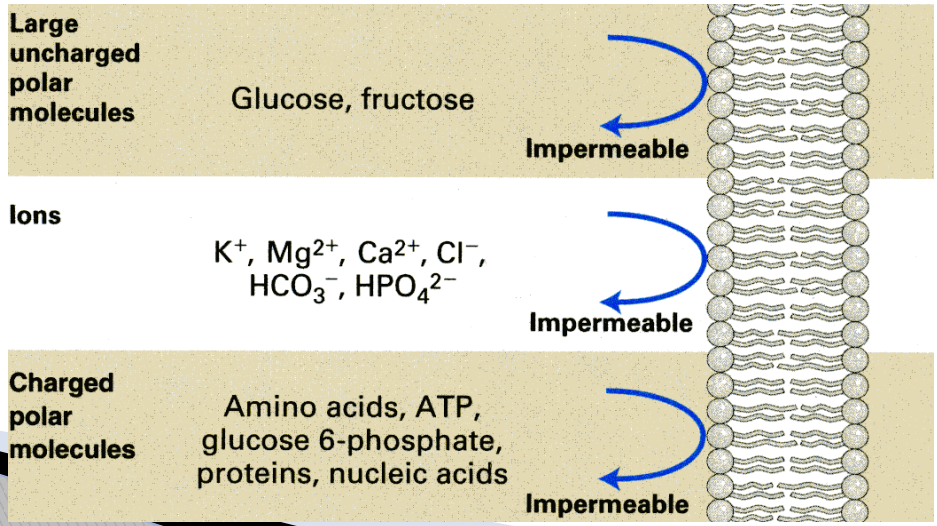
**QUESTION**: How do larger and / or lipid-insoluble substances (charged molecules, ions) cross the lipid bilayer?

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

- They require transport (carrier) proteins - these are all INTEGRAL (TRANSMEMBRANE) PROTEINS
- Allow larger and / or lipid-insoluble substances (charged molecules, ions) cross the lipid bilayer
- Responsible for allowing transport of the majority of molecules (and all ions) across bio membranes (in & out).
- Rate of diffusion far higher than simple diffusion.
- Diffusion continues until equilibrium is reached
- Processes are SPECIFIC, SATURABLE and COMPETITIVE

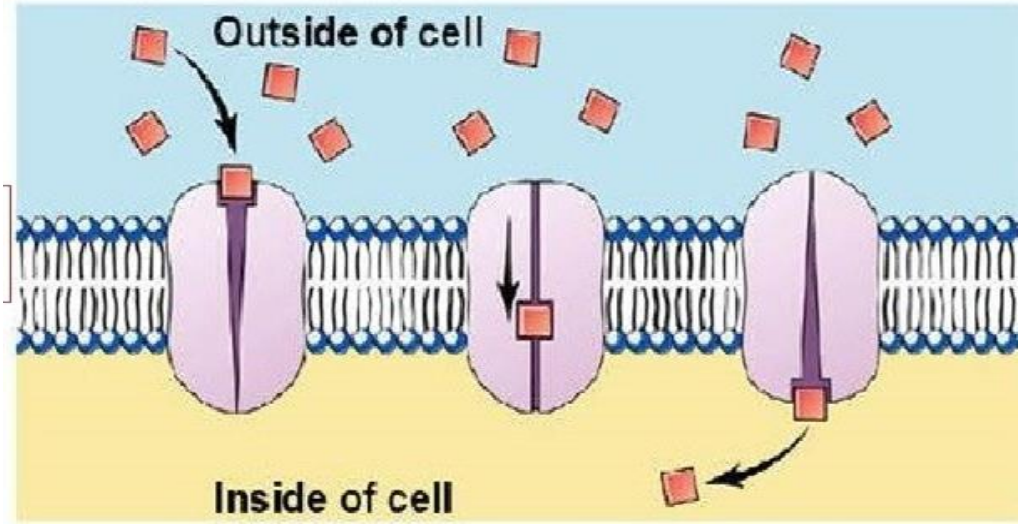
الرسمة بسلايدات الأولاد



# General Steps for Facilitated Diffusion

(Or any carrier-mediated transport)

1. Solute-binding step



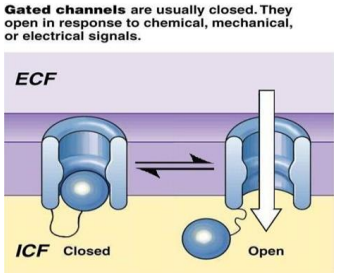

2. Change in carrier conformation allowing solute to pass through

3. Release of solute on the opposite side of the membrane

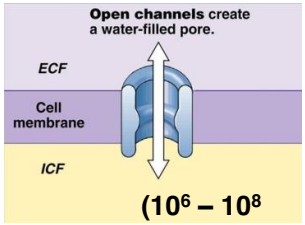
# There are two principal types of membrane proteins that mediate facilitated diffusion:

**1) Channel Proteins**

**GATED CHANNELS**
(are usually closed. They open in response to chemical , mechanical , electrical signals)
Ion channels (*e.g.*, $Na^+$, $K^+$, $Cl^-$ & $Ca^{2+}$)



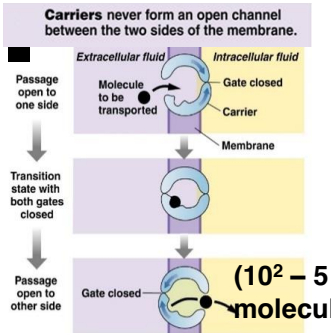

**OPEN CHANNELS**
( create a water-filled pore)
Aquaporins (water & small solutes)




**($10^6$ – $10^8$ ions/s)**

**2) Carrier Proteins**
(never form an open channel between two sides of the membrane)

**UNIPORTERS**
Glucose & amino acids




**($10^2$ – 5 x$10^4$ molecules/s)**

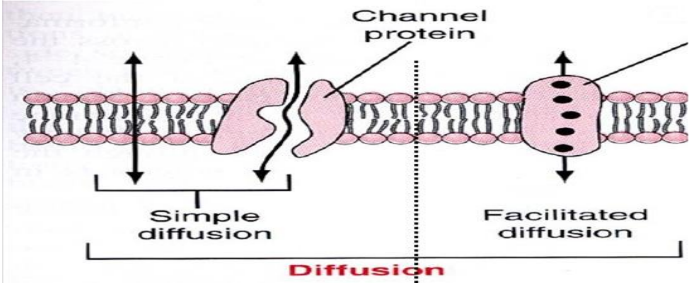
Don't get confused. Water can be both =)

Water can move through the cell membrane directly through the membrane (simple diffusion ) or through protein channels called aquaporins.

ملاحظة: هذه السلايد كاملة من الأولاد

# The difference between simple and facilitated diffusion?

ملاحظة: سلايد كاملة من البنات




## Simple diffusion

1. ***Lipid-soluble substances***

(e.g. O2,CO2, and alcohol)→
Pass through the interstices of the lipid bilayer.

***Water-soluble substances***

(water, ions) → pass through channels that penetrate all the way through the CM

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

## Facilitated diffusion

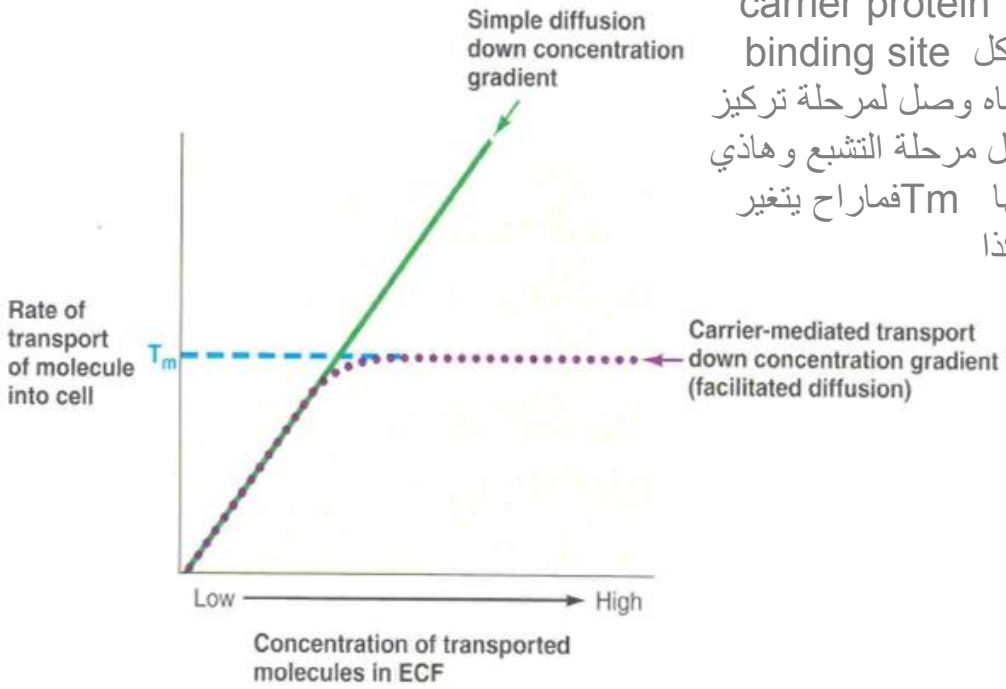
1. Also called "***Carrier-mediated diffusion***".
2. Diffusion of a substance is "***facilitated***" by the use of a specific carrier protein.
3. Examples (glucose, amino acids).
4. The rate of diffusion increases proportionately with the concentration of the diffusing substance ***until it reaches a transport maximum (Tmax)***.

At Tmax, an increase in the concentration of the diffusing substance ***does not*** increase the rate of diffusion.

# Why?

لما يوصل carrier protein لمرحلة أن كل binding site مشغولة معناه وصل لمرحلة تركيز عالي ووصل مرحلة التشبع وهاذي النقطة اسمها Tm فماراح يتغير rate بعد كذا

***Tm*** = ***transport maximum*** = the transport rate at which saturation occurs.




**The rate at which molecules can be transported by facilitated diffusion**

**Depend on:**

1-the number of solute-binding sites on the carrier.

2- the rate at which the carrier protein molecule can undergo conformational change back and forth between its bound and unbound state.

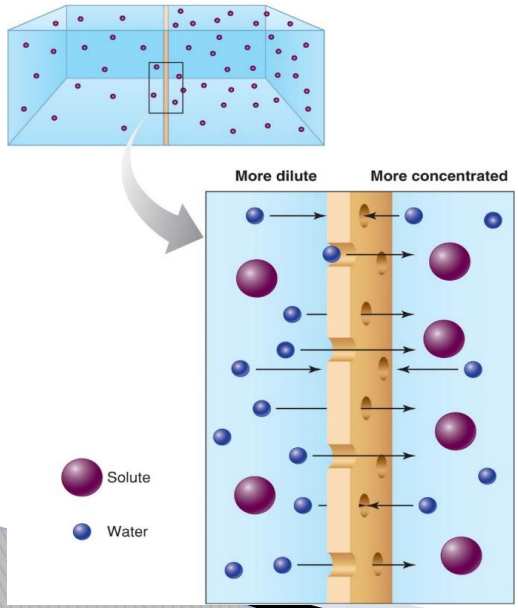
ملاحظة :سلايد كاملة من البنات

# osmosis

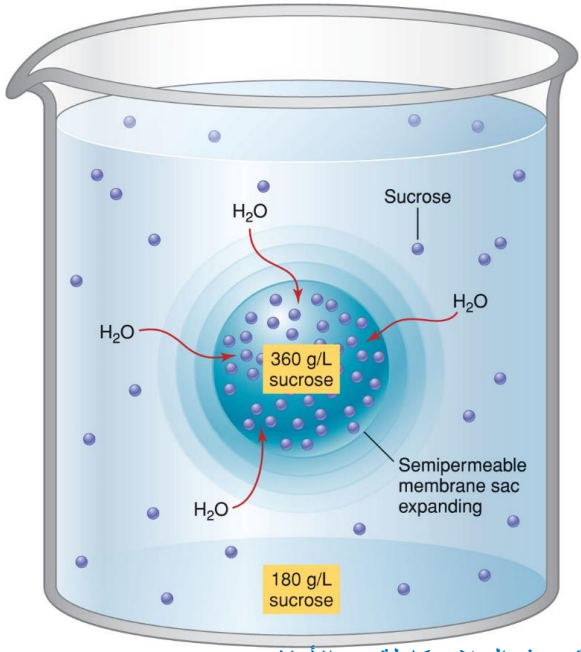
Because water molecules do not carry a charge, they can pass through the plasma membrane slowly. Because this is the diffusion of solute instead of solvent, it is unique. Aided by channels in membrane called **aquaporin** in some tissues

-Water is the solute so water diffuses to more concentrated parts








ملاحظة: هذه السلايد كاملة من الأولاد

# Active transport

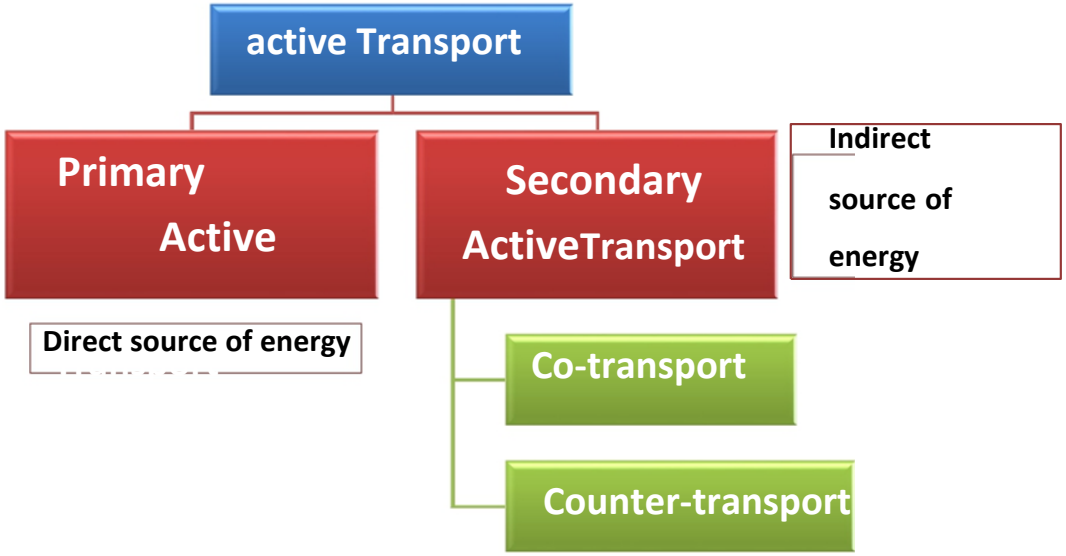
Occurs when a cell membrane moves molecules or ions ***"uphill"*** **against** a concentration gradient (or an electrical or pressure gradient). It requires ***energy*** and a ***carrier protein***.

Examples:

Ions like: sodium, potassium, calcium, iron, iodine, hydrogen ions

Amino acids, glucose and other sugars.

***According to the source of energy used to fuel transport, it can be divided into:***



# Types of Active Transport

## Primary Active

- The energy is derived ***directly*** from breakdown of adenosine triphosphate *(ATP)* or some other high-energy phosphate compound.
- ***3 main examples***:

➢ Sodium-potassium ATPase pump.

➢ Calcium ATPase pump

➢ Hydrogen ATPase pump.

## Secondary Active

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

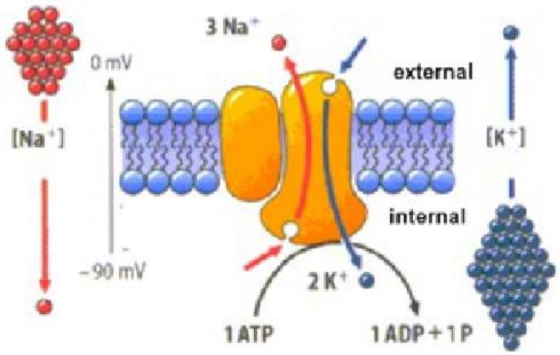
# $Na^+$ / $K^+$ ATPase

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

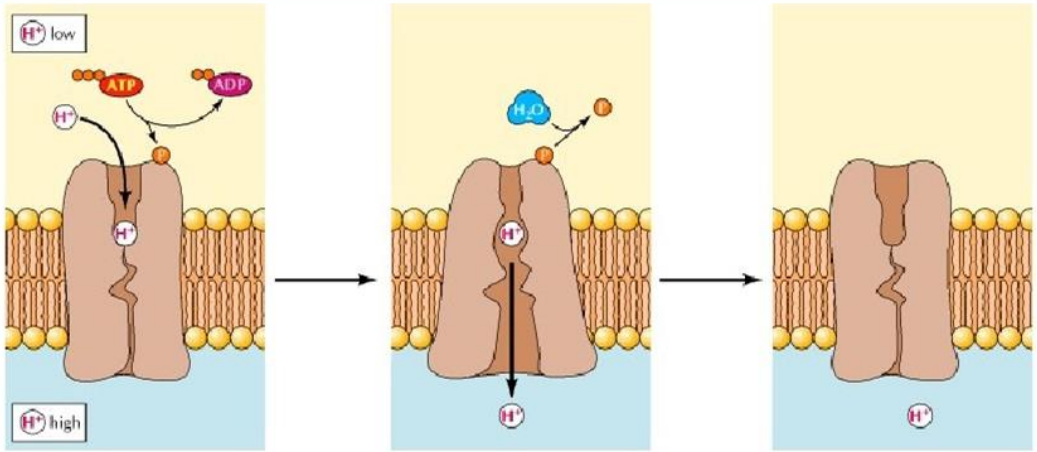
- This pump functions by moving ***3 molecules*** of **sodium OUT** and ***2 molecules*** of **potassium INTO** the cell both against their concentration gradients. ('electrogenic pump'.)
- **Na-K pump act as** Carrier protein and binding site for Na inside the cell also binding site for K outside the cell

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

**Importance:**
1. Maintaining Na and K concentration differences.
2. It's the basis for nerve signal transmission.
3. Establishes a negative electrical voltage inside the cell. (–Ve)



# H+-ATPase Pump




**Present in:**

- **Parietal cells of stomach → secretion of HCl in the stomach.**
- **Intercalated cells of distal renal tubules → excretion of acids from the body.**
- **Pumps $H^+$ out of the cell and into the lumen.**
- kidneys
- H+-K ATPase inhibitors (treat ulcer disease). (omeprazol)

# $Ca^{+2}$ ATPase Pump

- Present in:
  - Sarcoplasmic reticulum in muscle cells
  - Mitochondria
  - Some cell membranes.

- **Function:**

  Maintains low $Ca^{+2}$ concentration inside the cell.

# 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 which is Na.(usually Na is the downhill solute)

Energy is supplied indirectly form primary transport

***PCT = proximal convoluted tubules* in the kidney**

| co-transport (symporter) | counter transport (anti-porter) |
|---|---|
| All solutes move in the same direction 'inside cell'' (transported together and in the same direction) | When one substance is transported in the opposite direction to the other substance. |
| ***Examples***:<br>– Na - glucose Co transporter (PCT).<br>– Na – amino acid Co transporter (PCT) | ***Examples:***<br>– $Na_{+}$-$H_{+}$ counter-transporter (PCT) exchanger in the kidney<br>– $Na_{+}$-$Ca_{+2}$ counter-transporter (present in many cell membrane) |

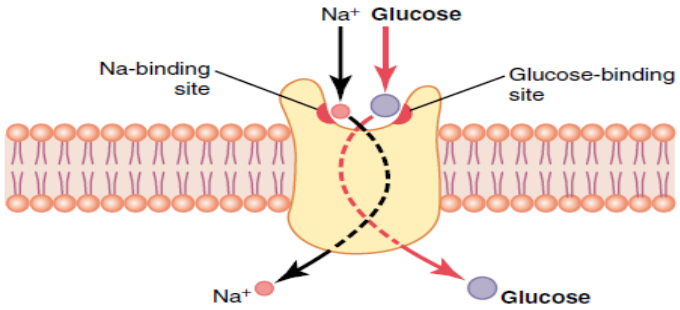



**Figure 4-13** Postulated mechanism for sodium co-transport of glucose.

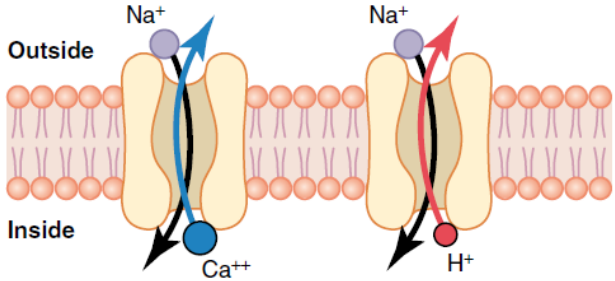
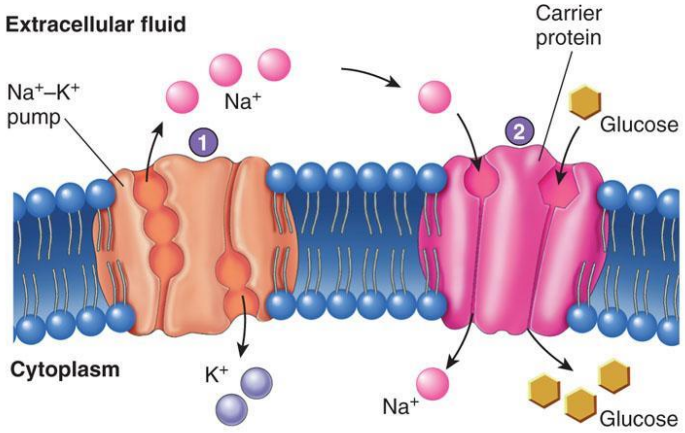



**Figure 4-14** Sodium counter-transport of calcium and hydrogen ions.

# The $Na^+$ / glucose symporter

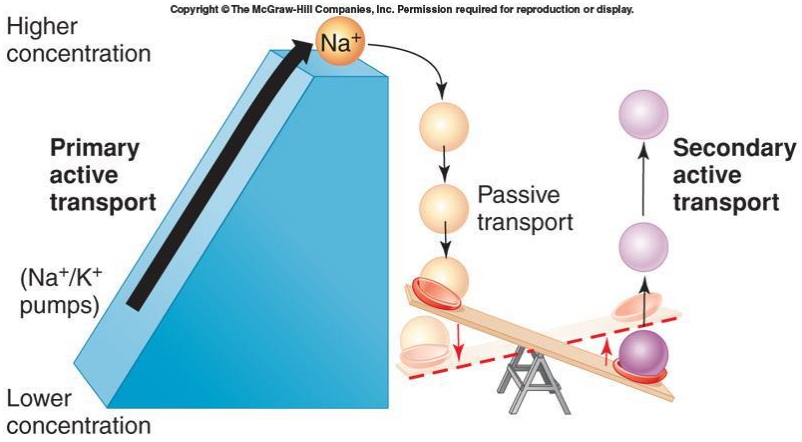
## (Secondary Active co-transport )






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.





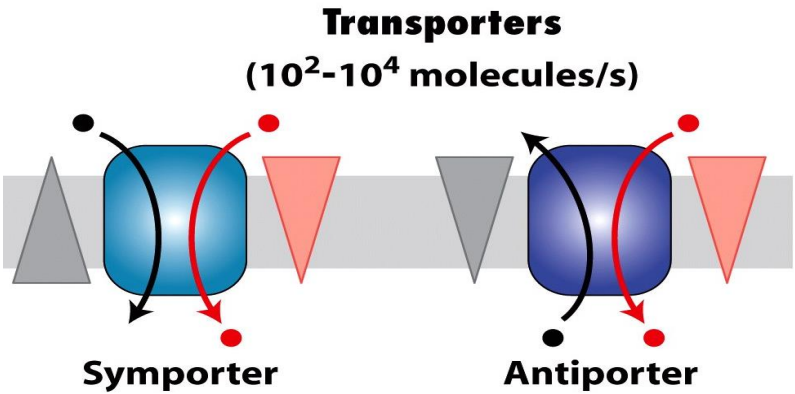
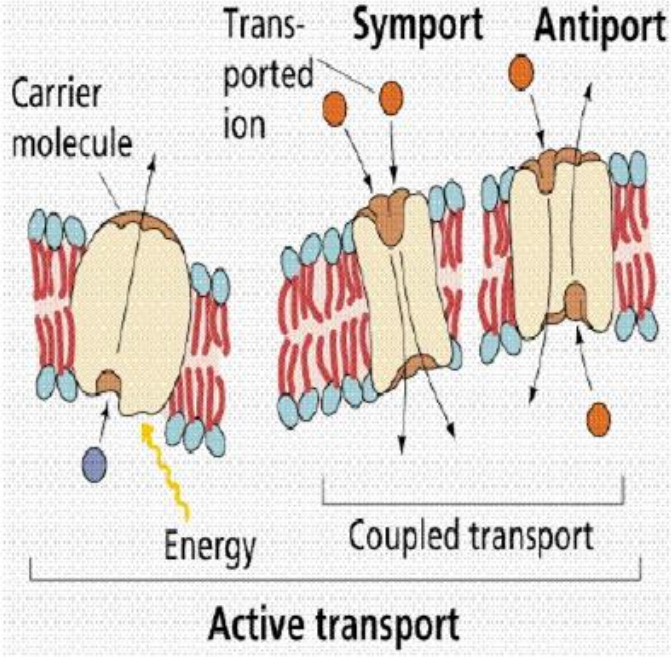
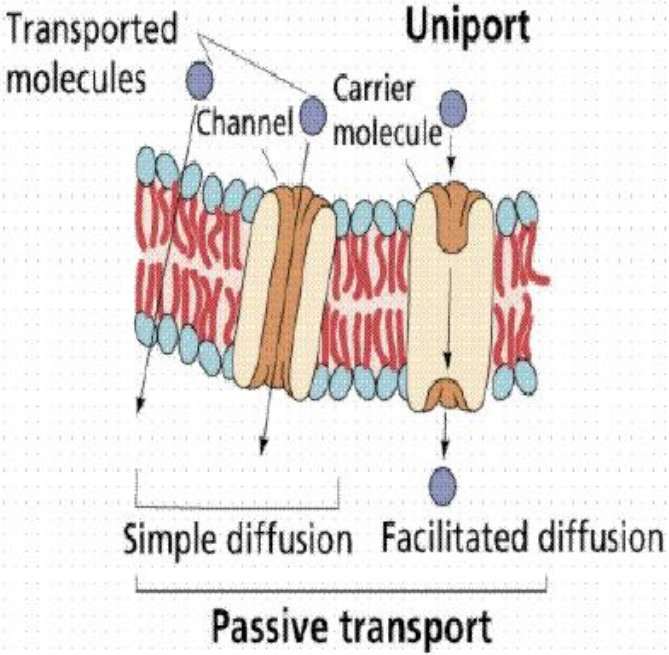




Figure 11-3 part 3
*Molecular Cell Biology, Sixth Edition*

# Revision


Trans-
ported
ion
Symport
Antiport
Carrier
molecule
Energy
Coupled transport
Active transport


Transported
molecules
Uniport
Channel
Carrier
molecule
Simple diffusion
Facilitated diffusion
Passive transport

# Quiz

**1.The cell membrane is composed of?**

a)Lipids, proteins, carbohydrates
b)Proteins, ribosomes, carbohydrates
c)Lipids, carbohydrates, enzymes, proteins
d)Phosphate end, carbohydrates, integral protein
**Ans: a**

**2.Carrier proteins....**

a)Carrier proteins are open pores through which molecules such as ions can cross the membrane
b)Carrier proteins selectively bind to a small molecule and undergo a conformational change to release the molecule on the other side of the membrane
c)are attached to one surface of the membrane
d)function as enzymes and adhesion molecules
**Ans: b**

**3.What are examples of the two types of secondary active transport?**

**Ans**: Na - glucose (co-transport) and Na+ -Ca+2 counter-transporter (counter transport)

# Quiz

**4.What is the difference between primary active transport and secondary active transport?**

**Ans:** Primary active transport uses direct energy source while secondary active transport uses indirect energy source

**5.All of the following are factors that affect the rate of diffusion except…**

a)temperature
b)surface area
c)the number of organelles inside the cell
d)electrical difference

**Ans: c**

# Thank you & good luck

## Boys team members:

- هشام الشايع
- سعود الاحمري
- عبدالرحمن آل الشيخ
- فايز الدرسوني
- محمد الحسن
- محمد الصويغ
- محمد المنجومي
- معاذ الحمود
- منصور العبرة
- احمد الصبي
- خالد العقيلي
- عبدالجبار اليماني
- عمر الفوزان

## Girls team members:

- مها العمري
- هديل عورتاني
- ريما العنزي
- روتانا خطيب
- لجين عزيز الرحمن
- العنود المفرج
- ريم القرني
- عهد القرين
- العنود المنصور
- مها النهدي
- بلقيس الراجحي
- سارة البليهد
- ميعاد النفيعي
- نورة البسام
- عبير العبدالجبار
- وجدان الشامري
- الجوهرة الشنيفي


## Team Leaders:

-مها بركة -طارق العميم