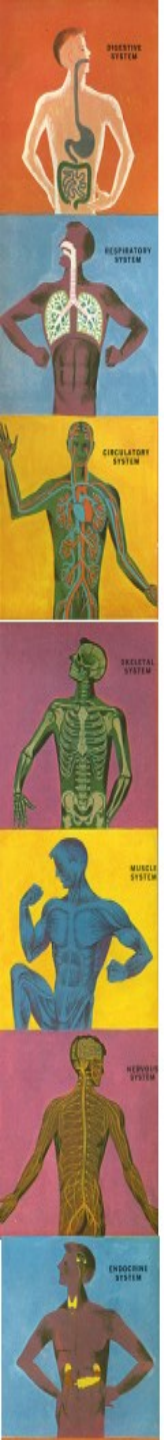
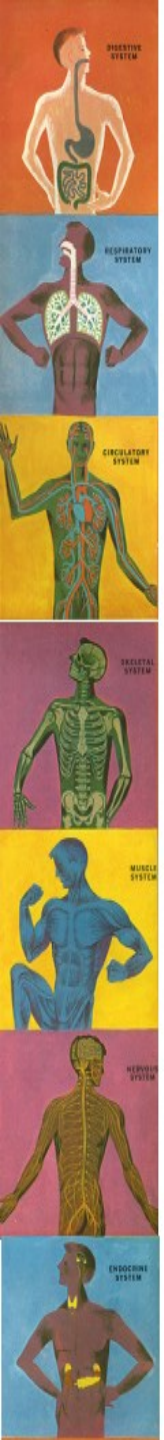


Transport of Substances Through the Cell Membrane

Dr. Maha Saja
Physiology department,
Level 2,
Office 89,
Email: msaja@ksu.edu.sa

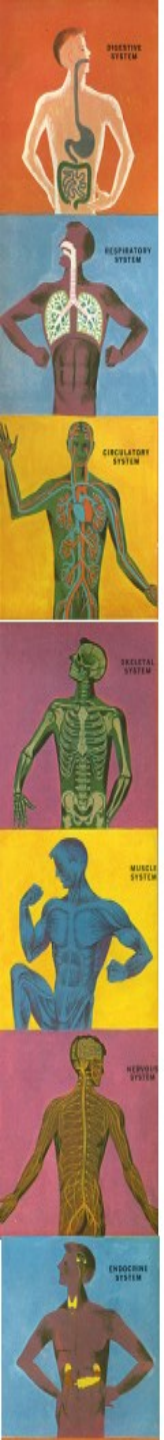


Objectives

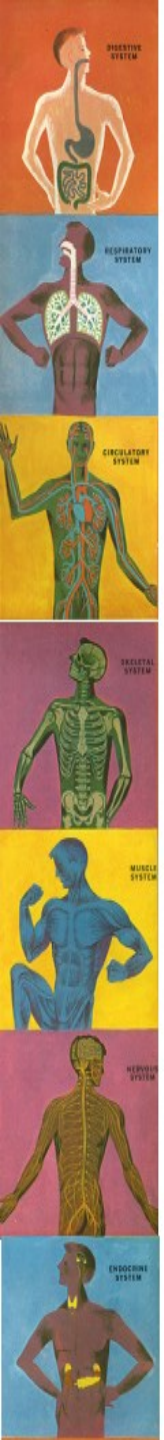
At the end of this session, the students should be able to:

- 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 type.
- Describe the different forms of active transport and state the difference between primary and secondary types giving examples for each in the human body.

Study source for this lecture:
(Guyton & Hall Textbook of Medical Physiology, 13th ed, Chapter 4)



Structure of the Cell Membrane



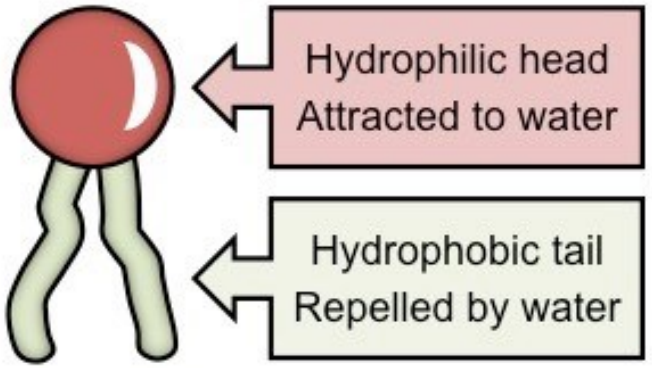
Structure of the Cell Membrane

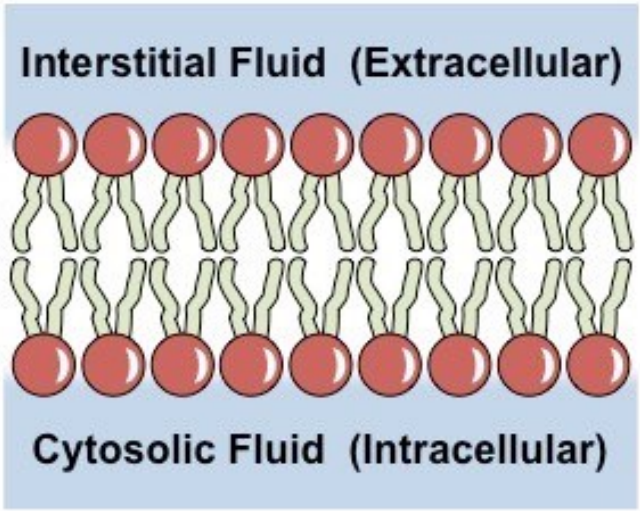
- Cell membrane = plasma membrane.
- Thickness = 7.5-10 nm.
- Composed of:
  - Lipids (42%) → **Phospholipids (25%)**, **Cholesterol (13%)**, **Other lipids (4%)**
  - Proteins (55%)
  - Carbohydrates (3%)

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

Structure of the Cell Membrane

- The cell membrane = a ***lipid bilayer***.
- The most abundant lipid = phospholipids.
- A phospholipid molecule have two ends:
  - ***Hydrophilic*** (phosphate end)
  - ***Hydrophobic*** (fatty acid end)





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

Structure of the Cell Membrane

Membrane proteins

Integral

Span the thickness of the cell membrane.

Function as:

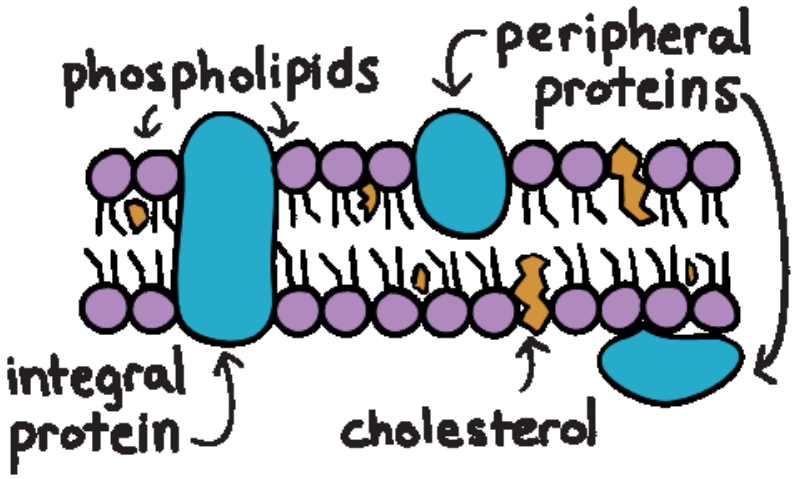
1. Channels (or pores).
2. Carrier proteins.
3. Receptors.

Peripheral

Are attached to one surface of the membrane.

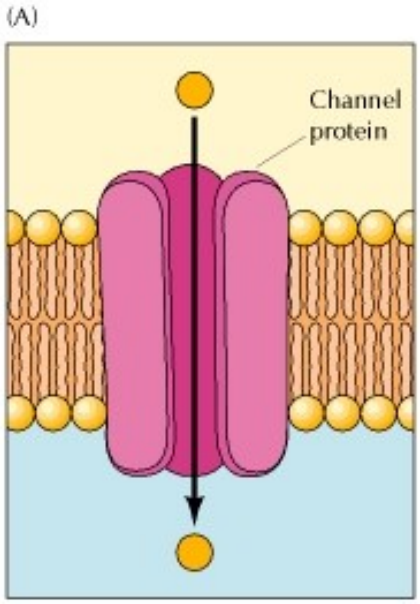
Function as:

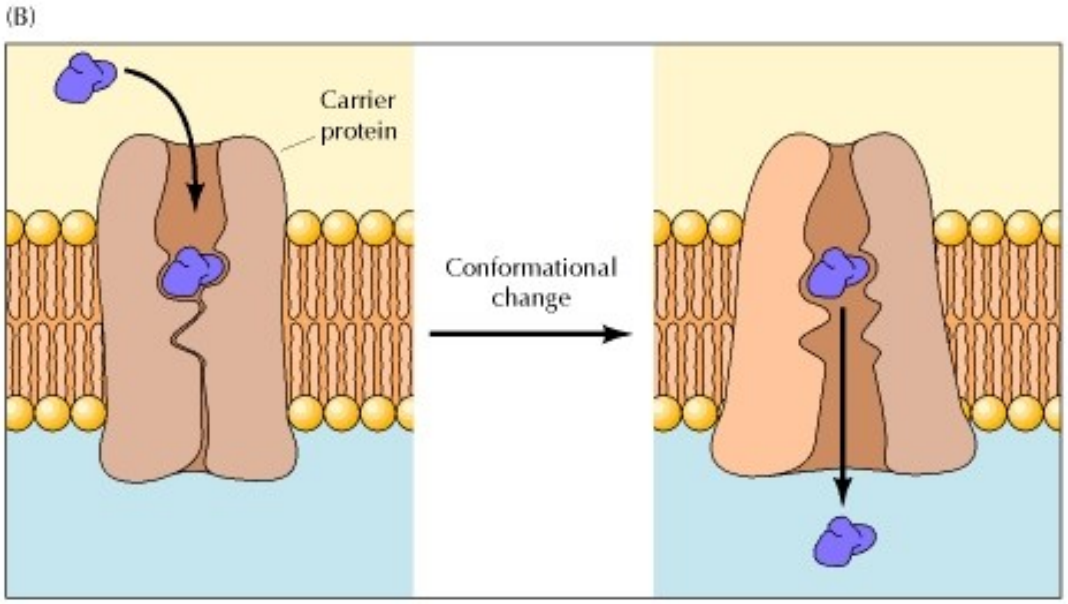
- Enzymes.
- Adhesion molecules.



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

Channel vs. Carrier Proteins



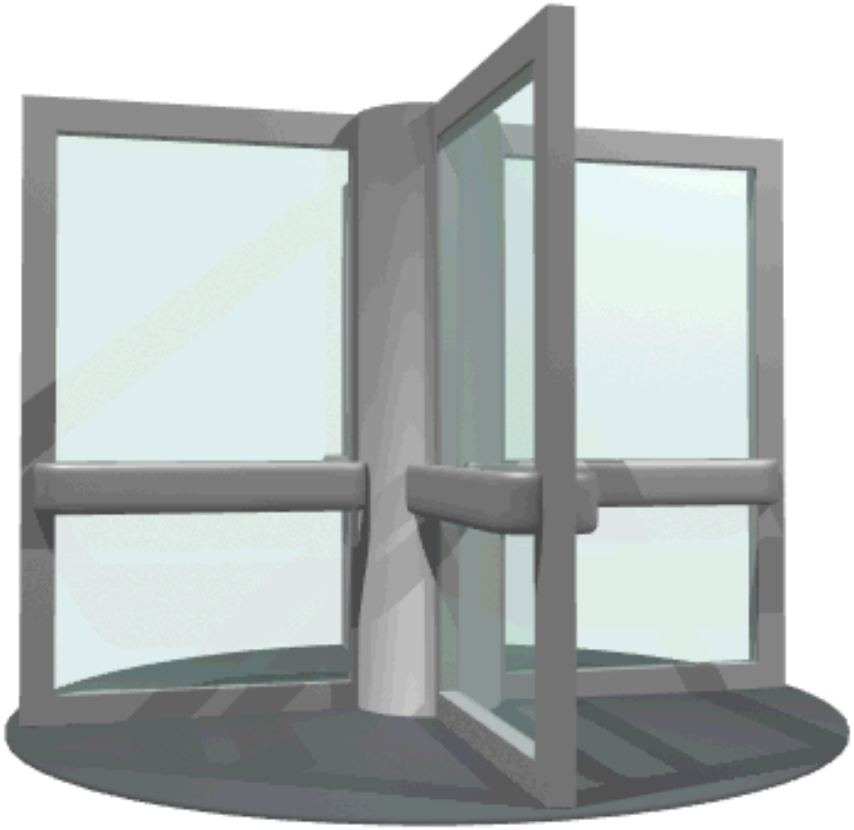


Channel proteins form open pores through which molecules of the appropriate size (e.g., ions) can cross the membrane.

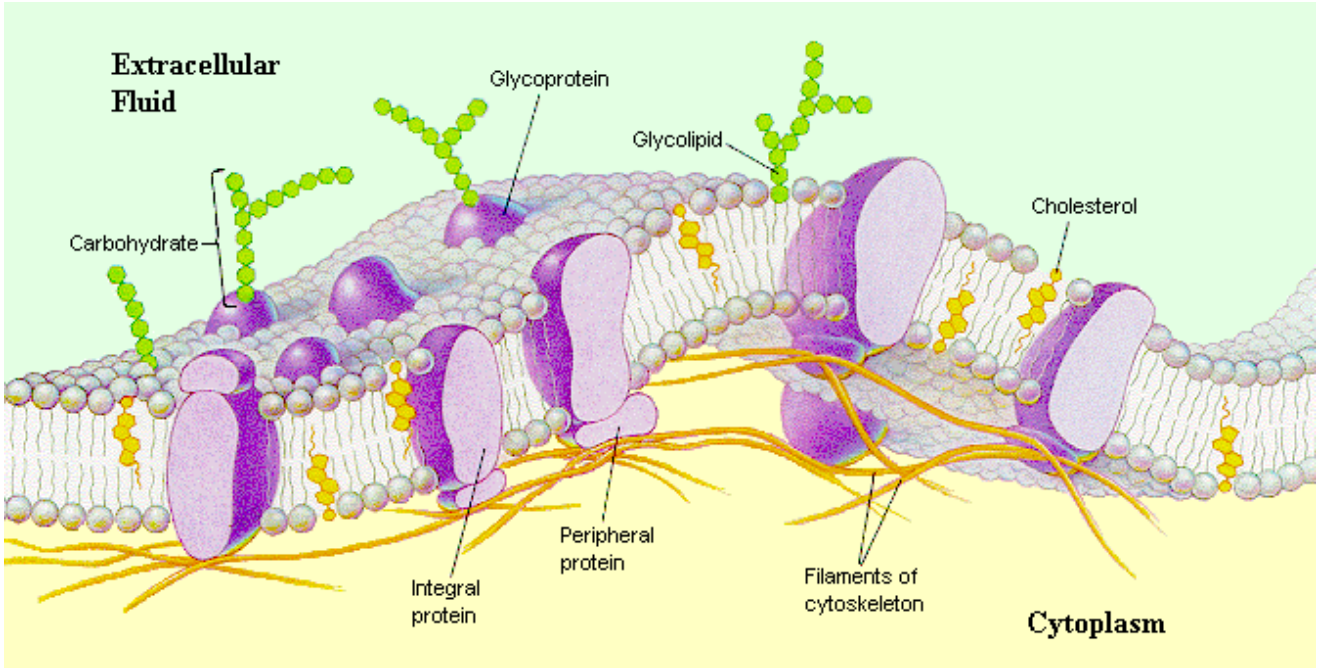
Carrier proteins selectively bind the small molecule to be transported and then undergo a conformational change to release the molecule on the other side of the membrane.

Channel

Carrier



Structure of the Cell Membrane

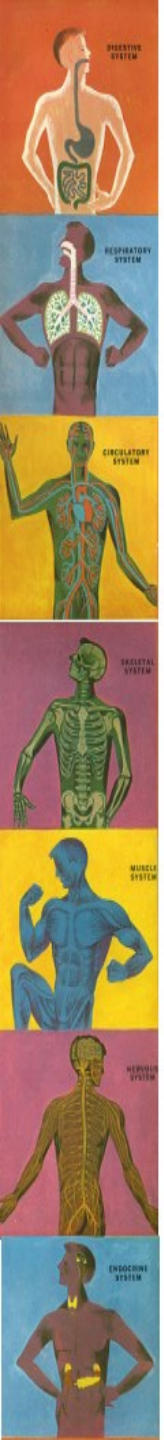


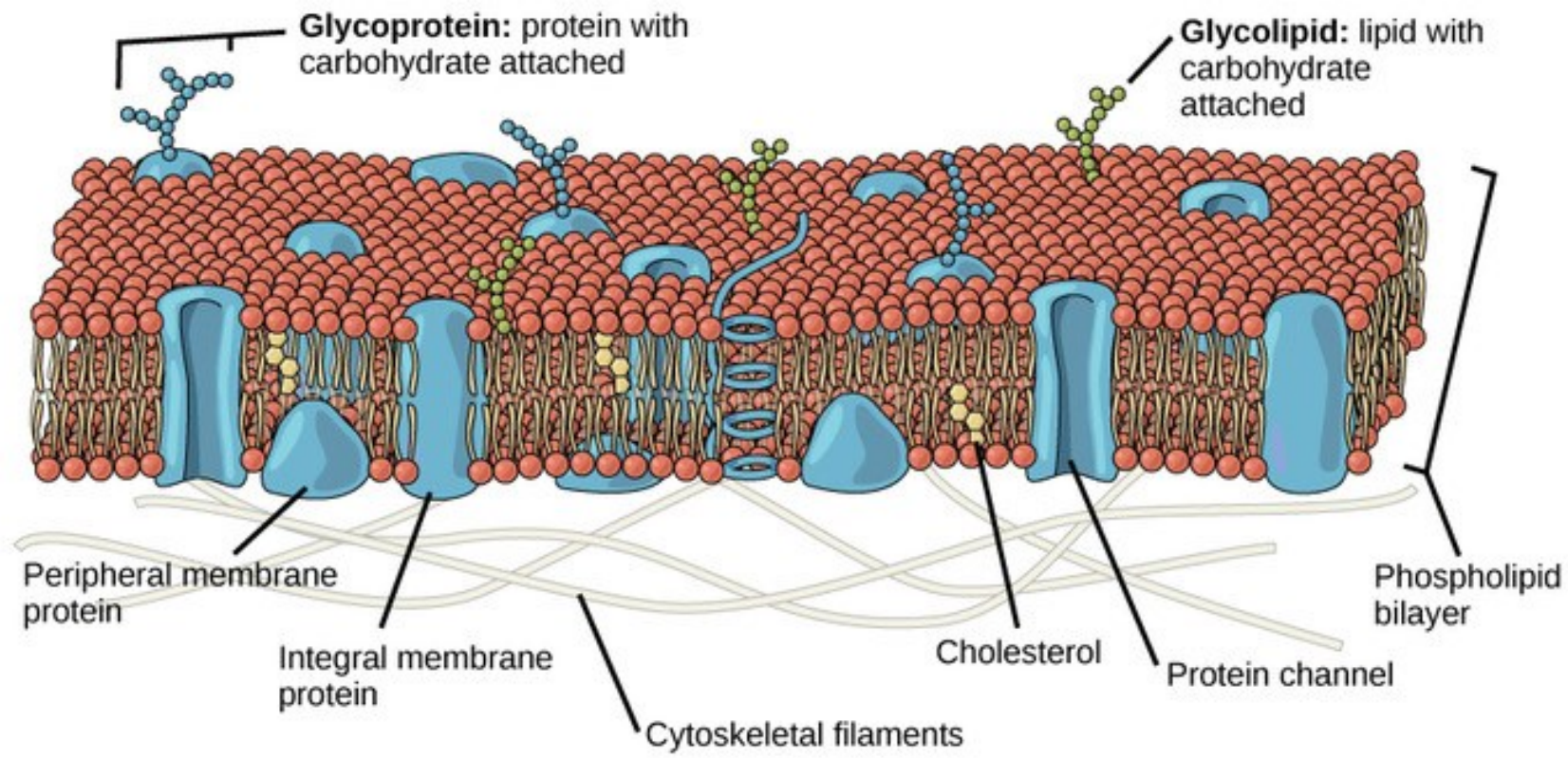
Function of CHOs:

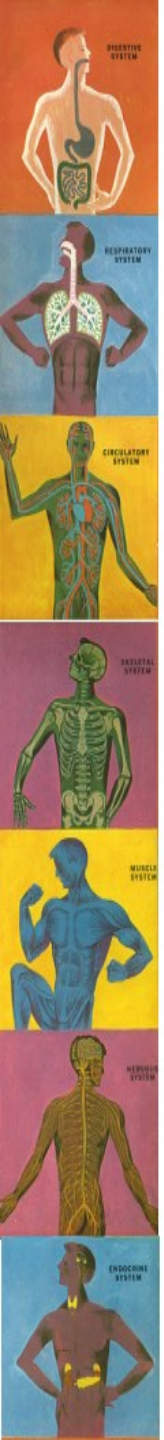
- Receptors.
- Cell-to-cell interaction.
- Immune reactions.

- Carbohydrates (CHOs) in the cell membrane are invariably attached to:
  - Proteins → Glycoproteins
  - Lipids → Glycolipids
- Carbohydrate molecules protrude to the outside of the cell forming a loose carbohydrate coat = "***glycocalyx***"

The Fluid Mosaic Model of Plasma Membrane







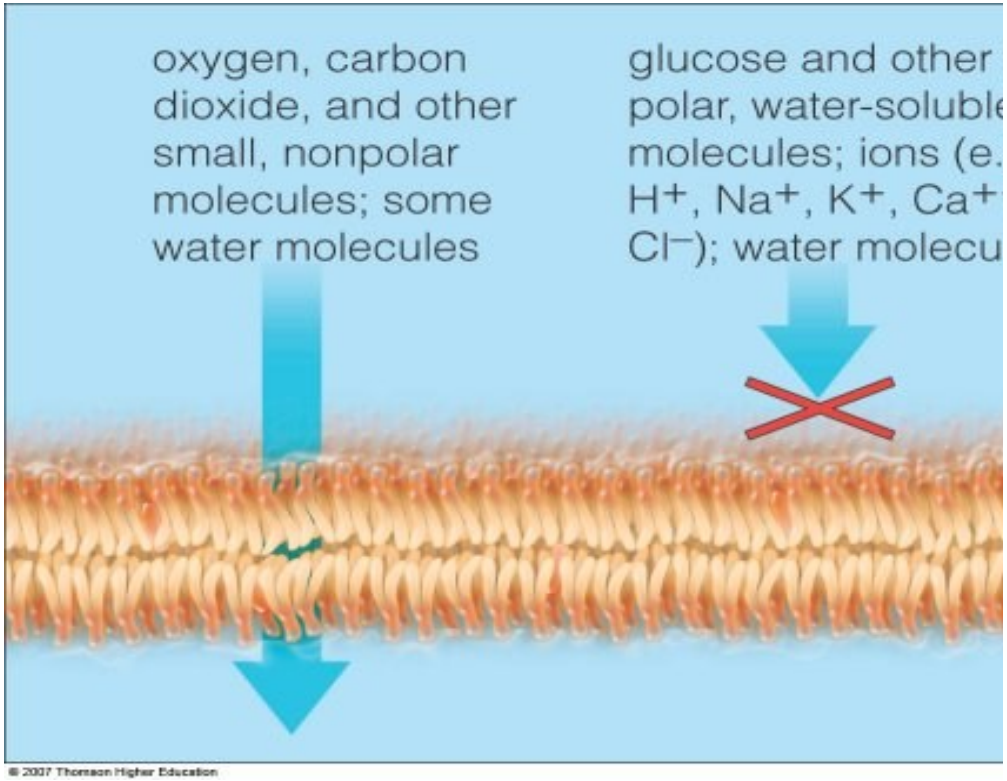
Movement (Transport) of Substances Across the Cell Membrane

Substances that can Across the Cell Membrane

Oil and water do not mix

Lipid soluble substances

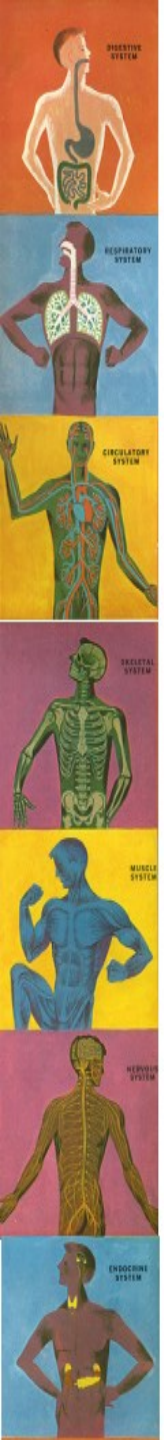
Water soluble substances



Alternative route

Cross freely by diffusion

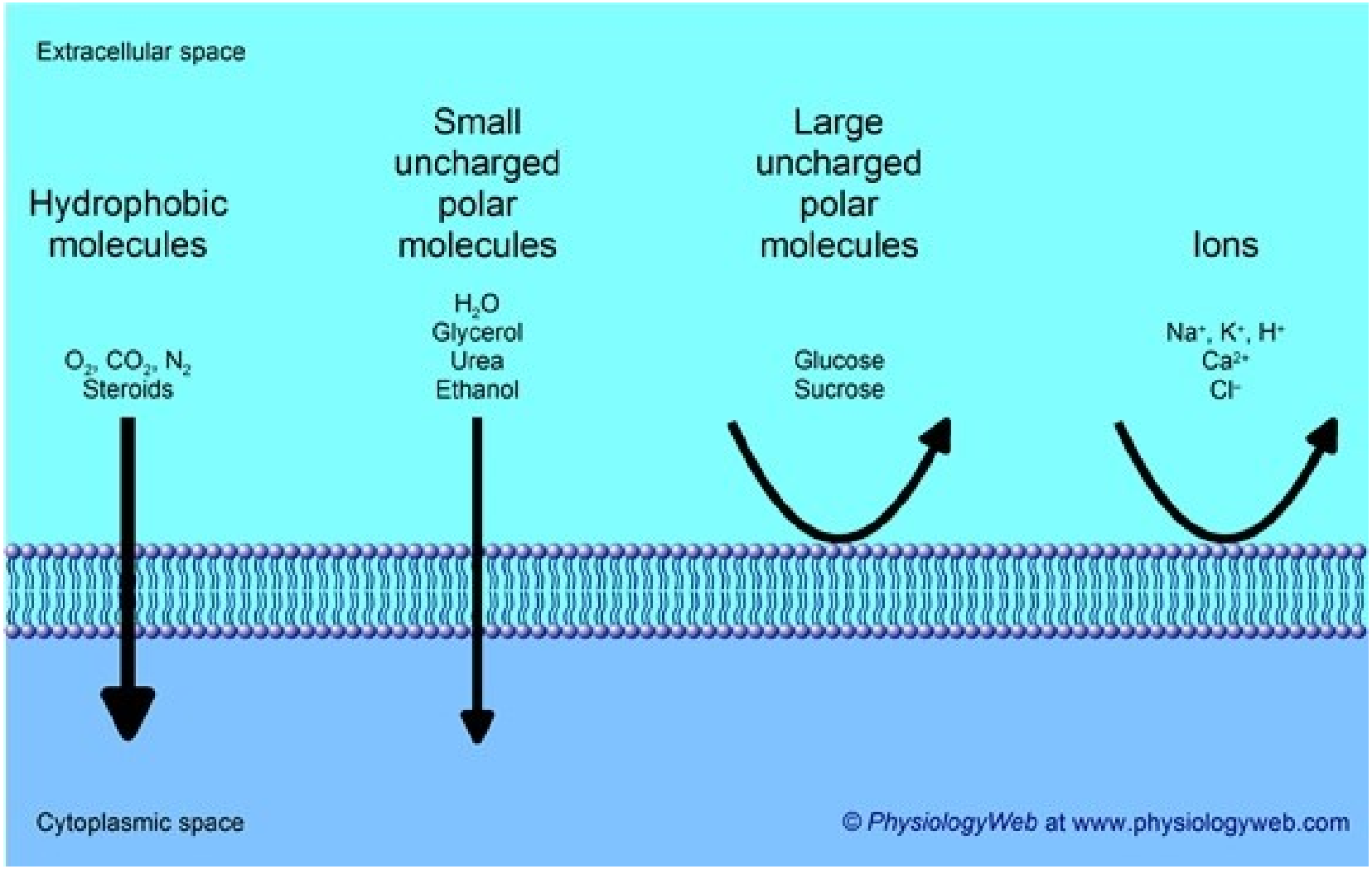
Through memb proteins



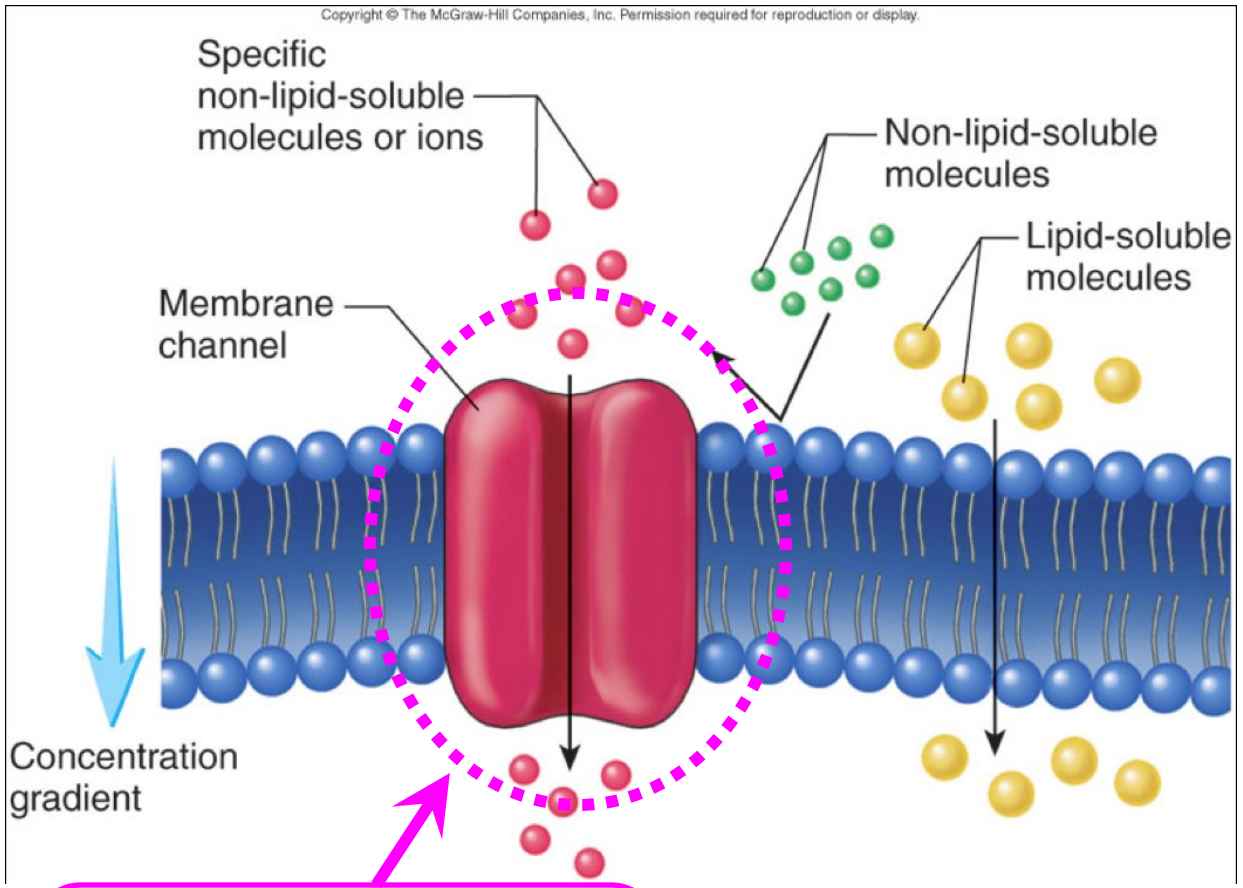
"Selective Permeability"

- The cell membrane is "***selectively permeable***"… ***what does this mean?***
- 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.

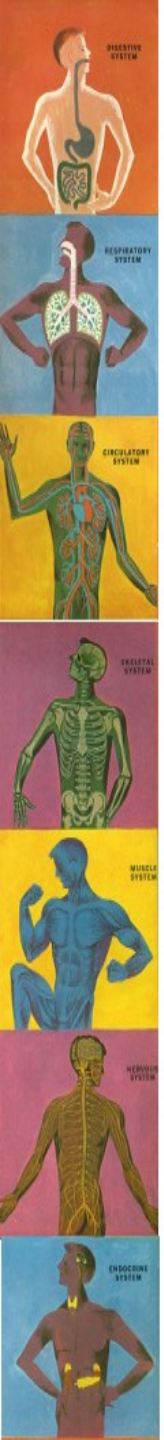
Substances That Can Move Across the Cell Membrane



Substances that Cannot Cross the Cell Membrane



Will enter the cell through a trans-membrane protein carrier/transporter/channel

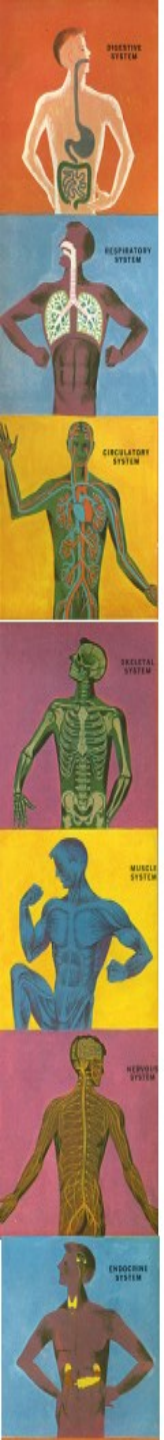


Transport Mechanisms

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

1. ***Passive Transport*** = *does not* require energy.

2. ***Active Transport*** = *requires* energy.



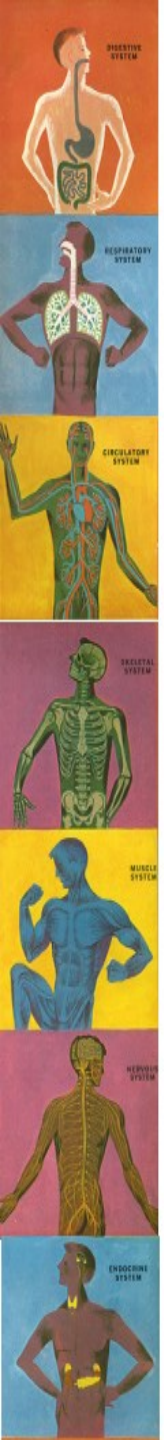
Transport Mechanisms

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.



Passive Transport Mechanisms

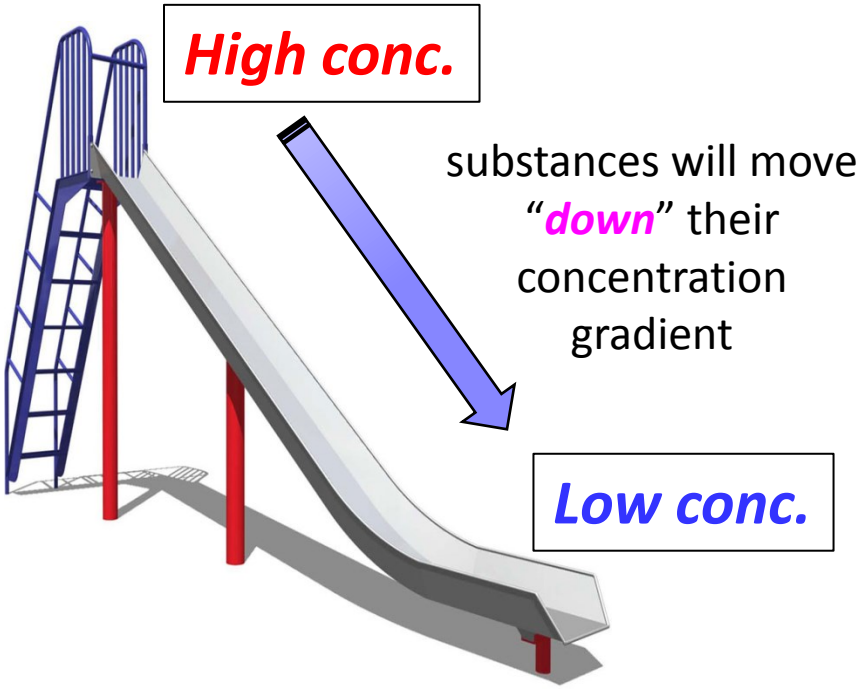
- Passive Transport
  - Diffusion
    - Simple
    - Facilitated
  - Osmosis

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

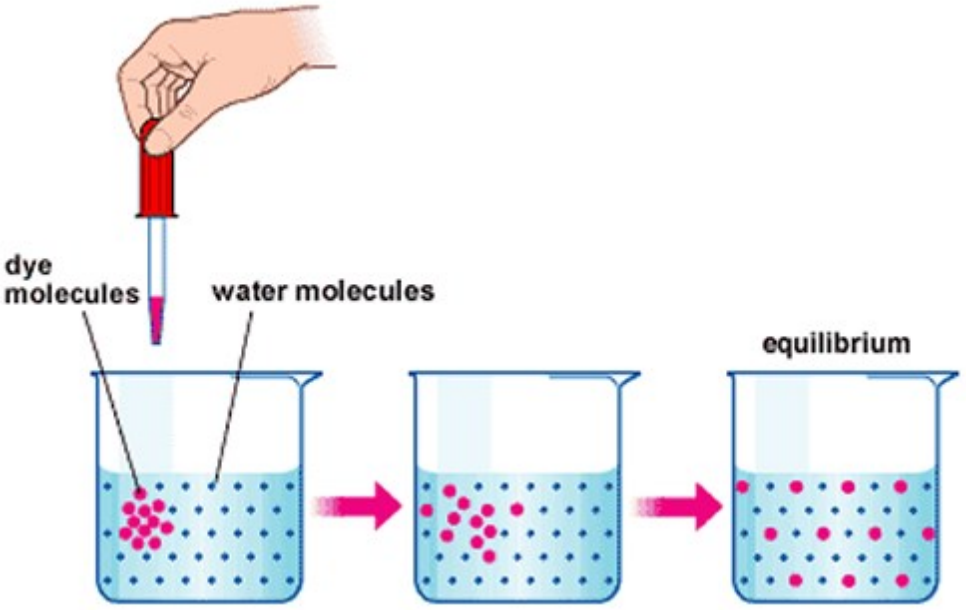
Diffusion

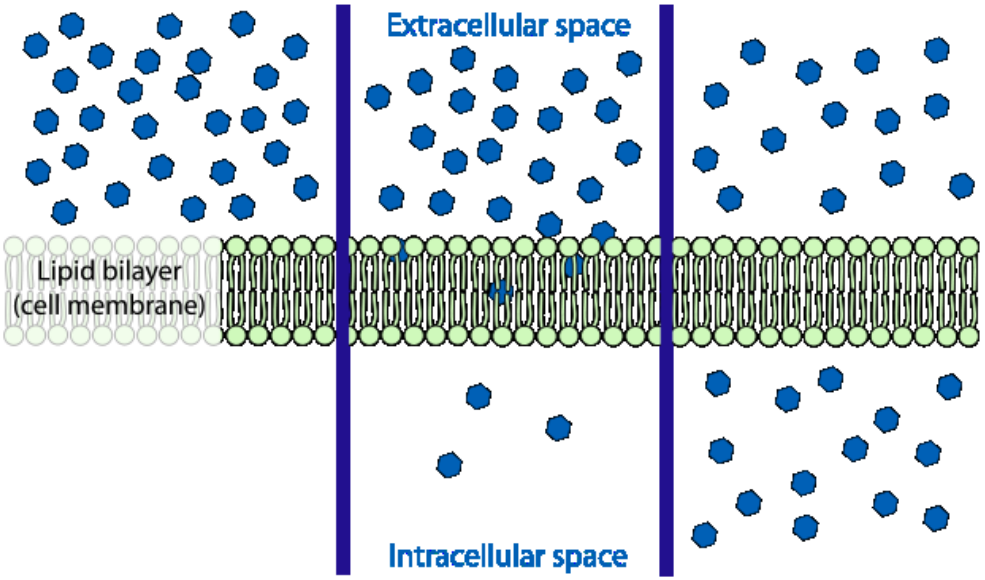
- ***Diffusion*** = the random movement of substances down an energy gradient.

- This gradient can be:
  - Concentration gr.
  - Electrical gr.
  - Pressure gr.

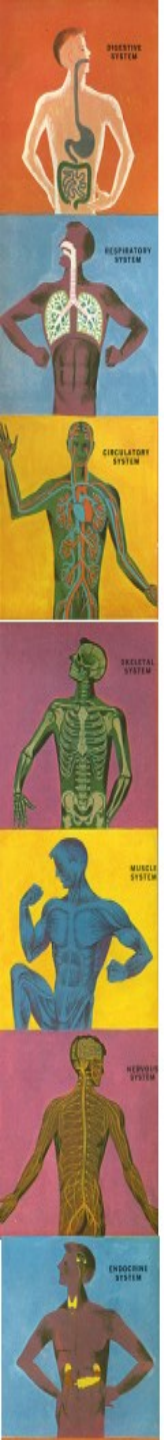


Diffusion





TIME



Types of Diffusion

Diffusion

Simple Diffusion

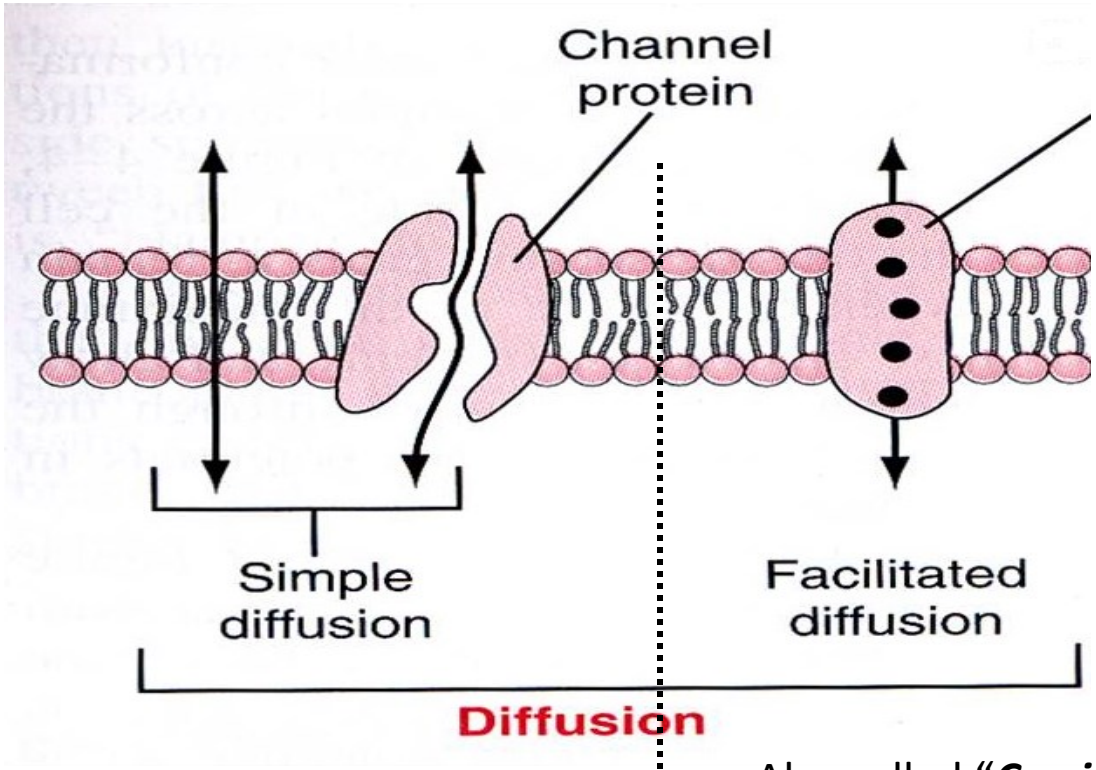
The movement of molecules through the intermolecular spaces or membrane openings (channels) ***without*** the necessity of ***binding to a carrier protein*** on the membrane.

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

Types of Diffusion

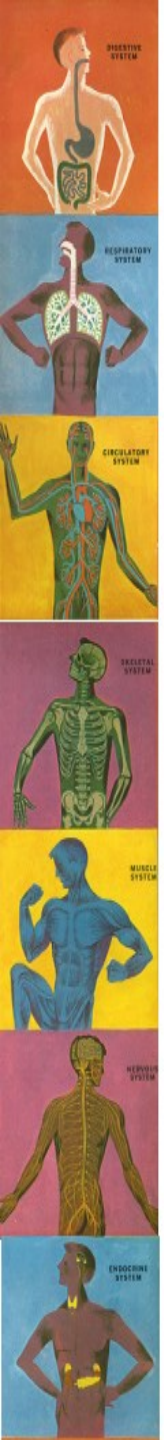


1. ***Lipid-soluble substances*** (e.g. O2, CO2, and alcohol)→ Pass through the interstices of the lipid bilayer.
2. ***Water-soluble substances*** (water, ions) → pass through channels that penetrate all the way through the CM.

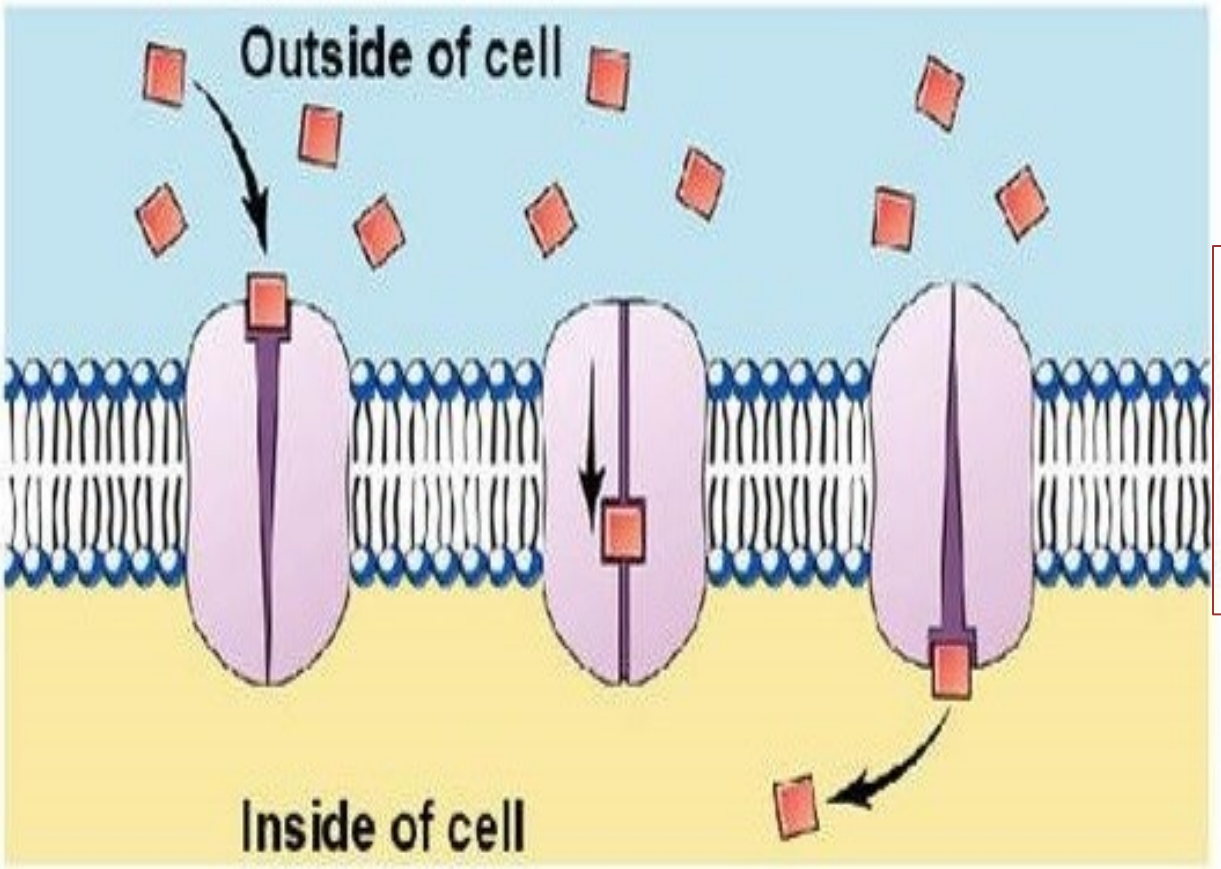
- Also called "***Carrier-mediated diffusion***".
- Diffusion of a substance is "***facilitated***" by the use of a specific carrier protein.
- Examples (glucose, amino acids).

General Steps for Facilitated Diffusion

(Or any carrier-mediated transport)

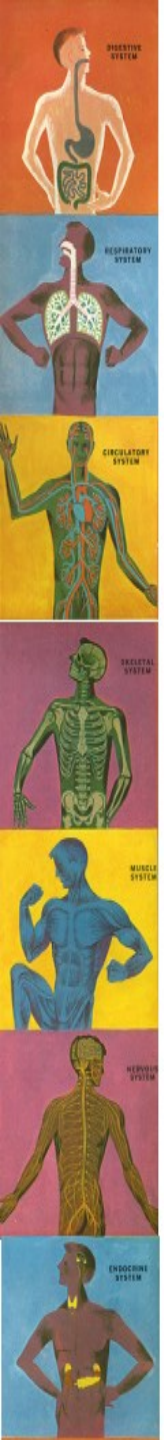


1. Solute-binding step



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

2. Change in carrier conformation allowing solute to pass through



What is the difference between simple and facilitated diffusion?

Simple diffusion

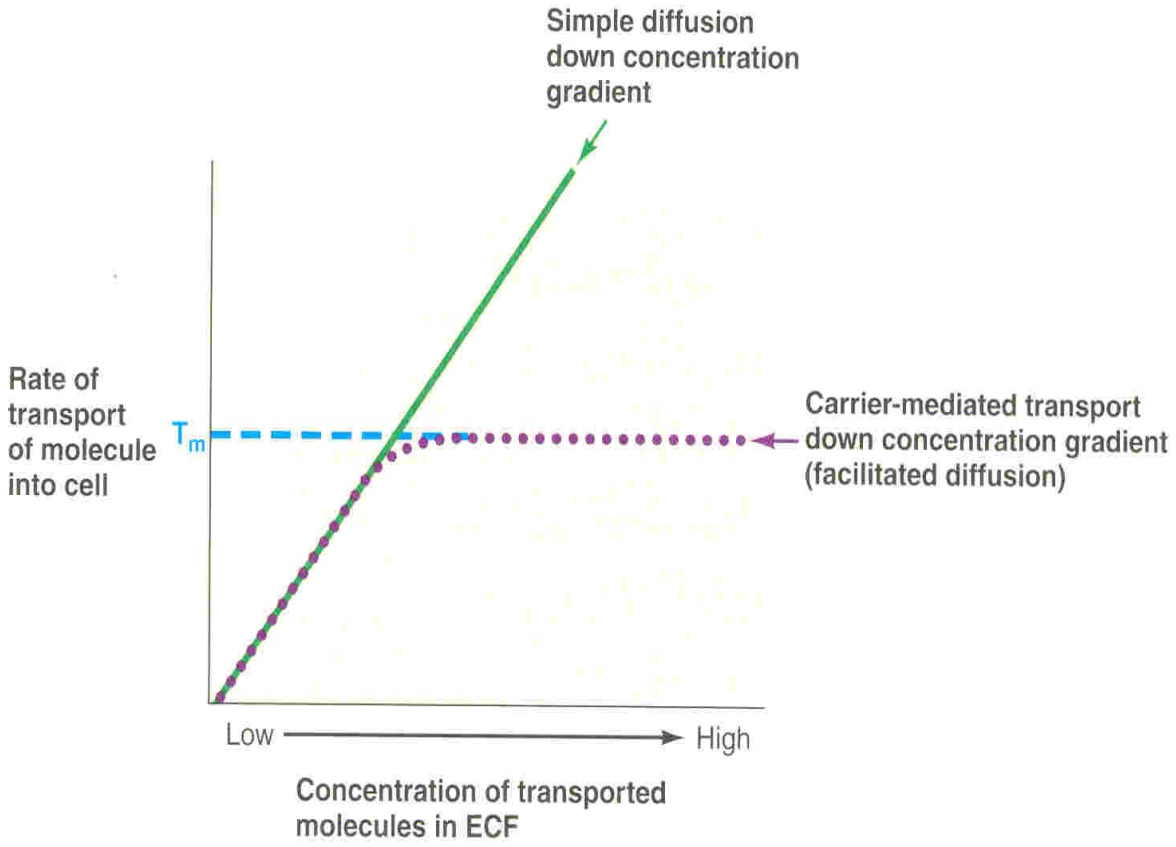
The rate of diffusion increases proportionately with the concentration of the diffusing substance.

Facilitated diffusion

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

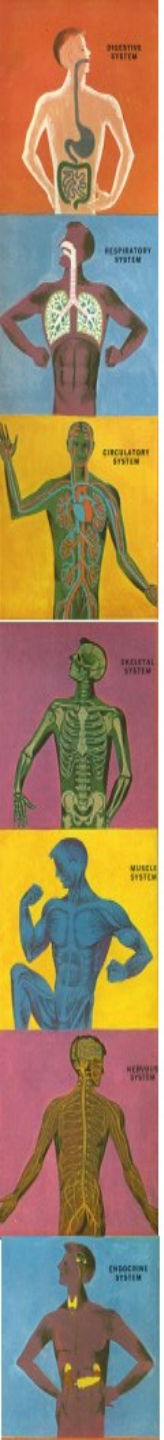
Why?

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



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

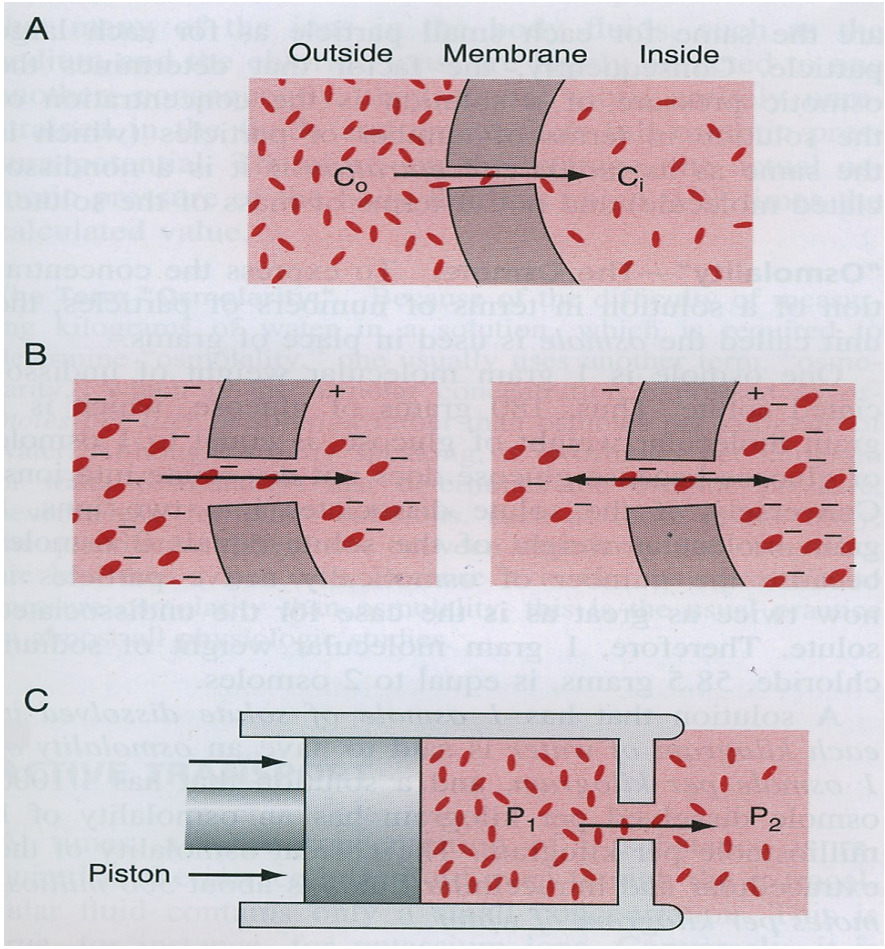
1. ***The number of solute-binding sites on the carrier.***
2. ***The rate at which the carrier protein molecule can undergo conformational change* back and forth between its bound and unbound state.**

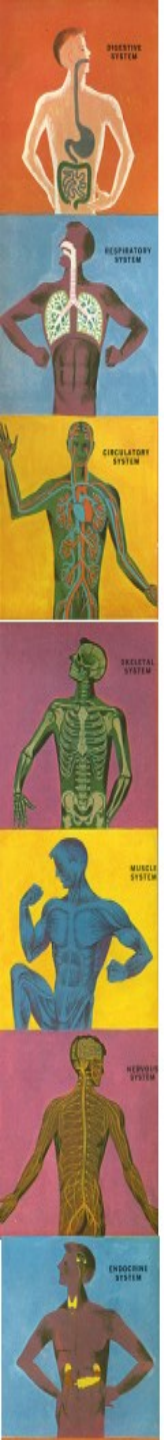


Factors Affecting Rate of Diffusion

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

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.



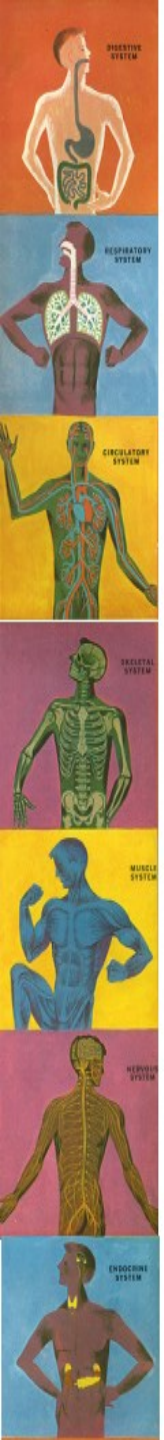


Active Transport

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

- ***Examples include***:
  - Ions like: sodium, potassium, calcium, iron, iodine, hydrogen ions.
  - Amino acids, glucose and other sugars.

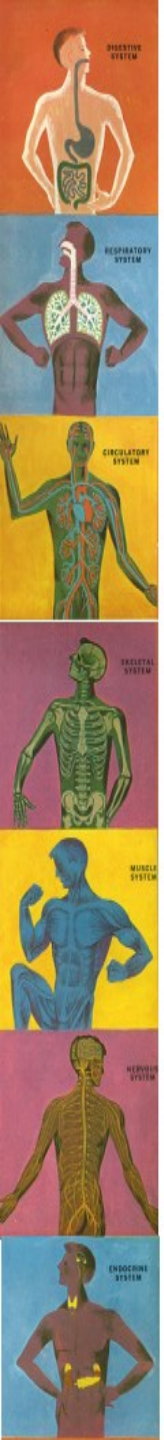
- Requires ***energy*** and a ***carrier protein***.



Active Transport

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

- **Active Transport**
  - **Primary Active Transport**
    - Direct source of energy
  - **Secondary Active Transport**
    - Indirect source of energy
    - **Co-transport**
    - **Counter-transport**



Types of Active Transport

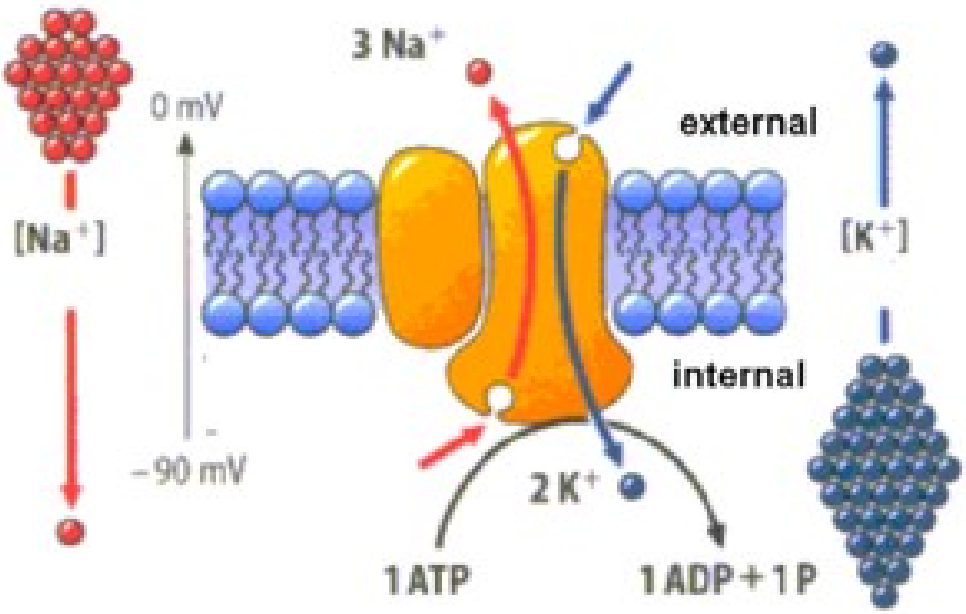
Primary Active

- 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.**

Primary Active Transport

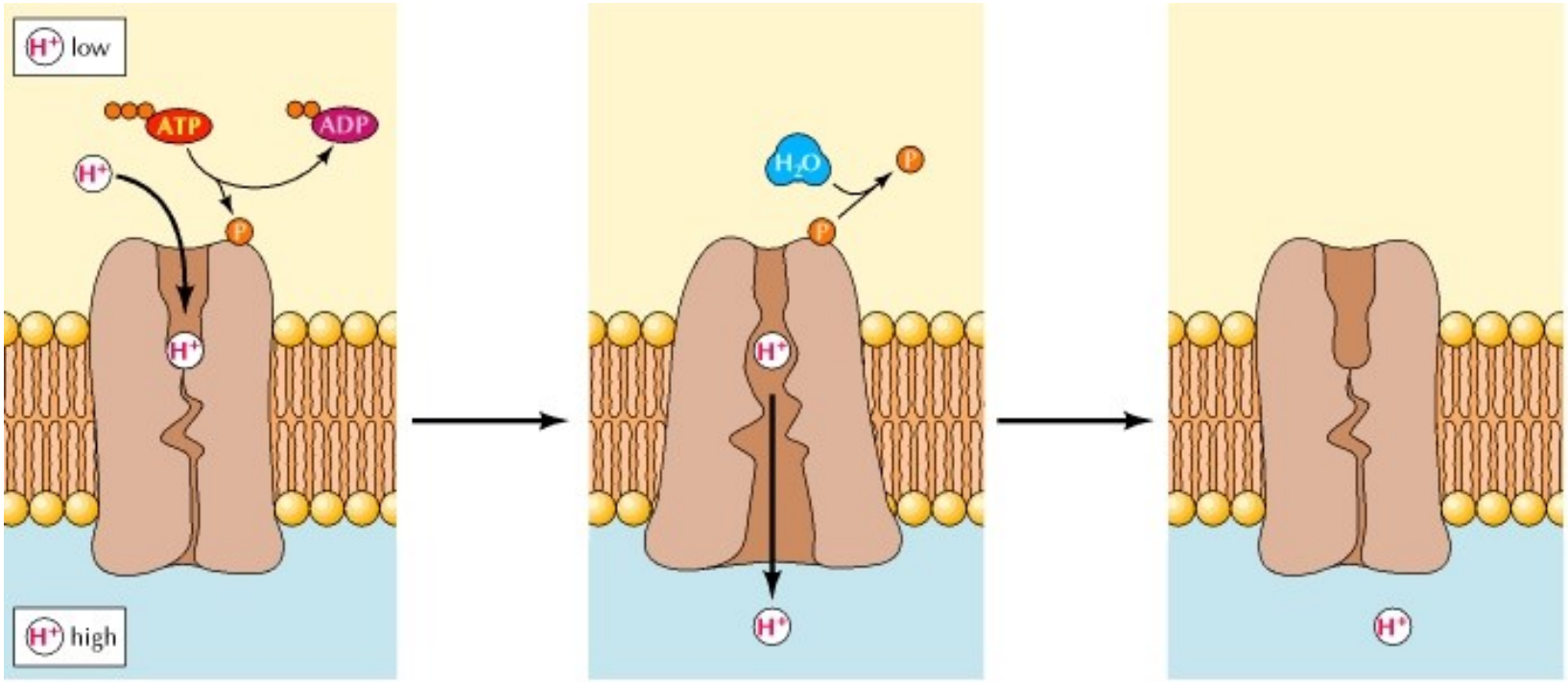


This pump functions by moving ***3 molecules*** of **sodium** **OUT** and ***2 molecules*** of **potassium** **INTO** the cell both against their concentration gradients.

The importance of this pump:

- Maintaining Na^+ and K^+ concentration differences across the cell membrane.
- Establishes a negative electrical voltage inside the cell.
- Is the basis for nerve signal transmission.

Primary Active Transport

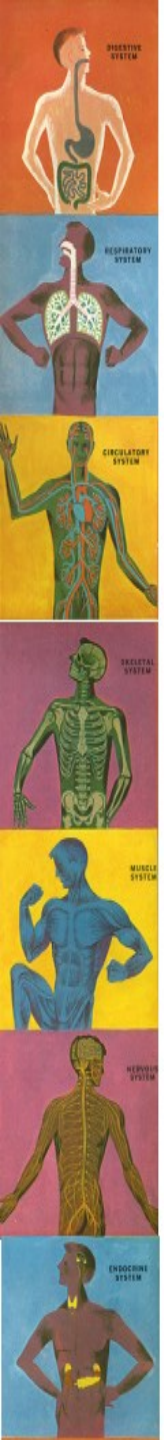


H^+-ATPase Pump

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.



Primary Active Transport

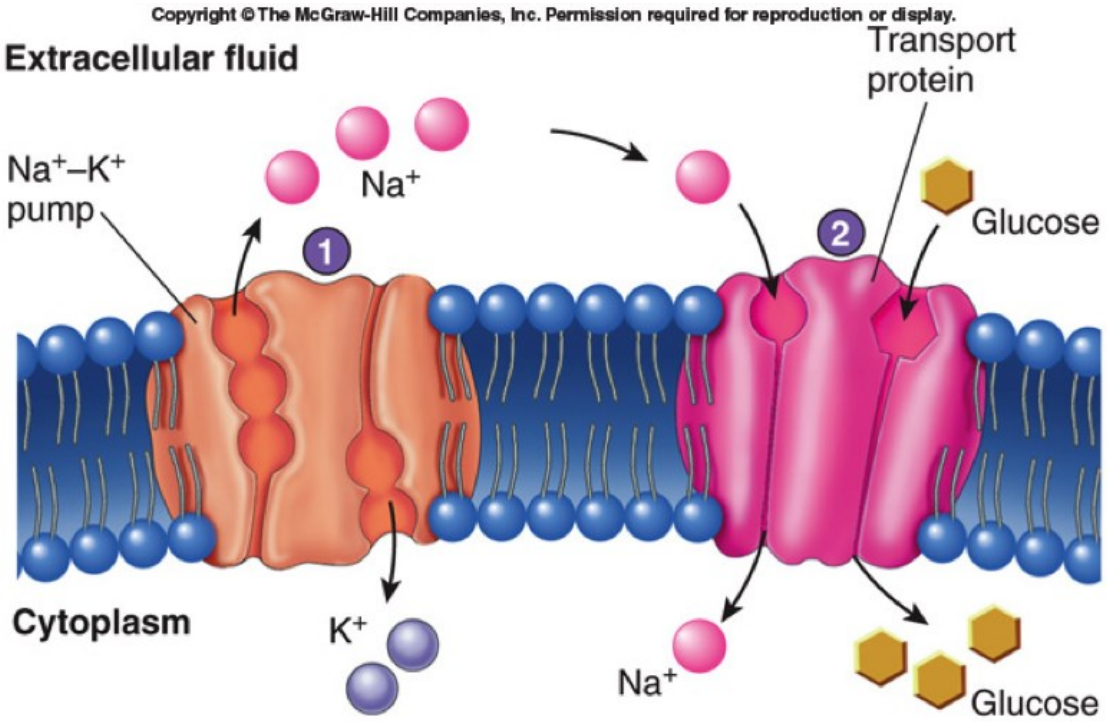
Ca^{+2} ATPase Pump

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

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

Secondary Active Transport
(Co-transport)

Derives energy indirectly… How?

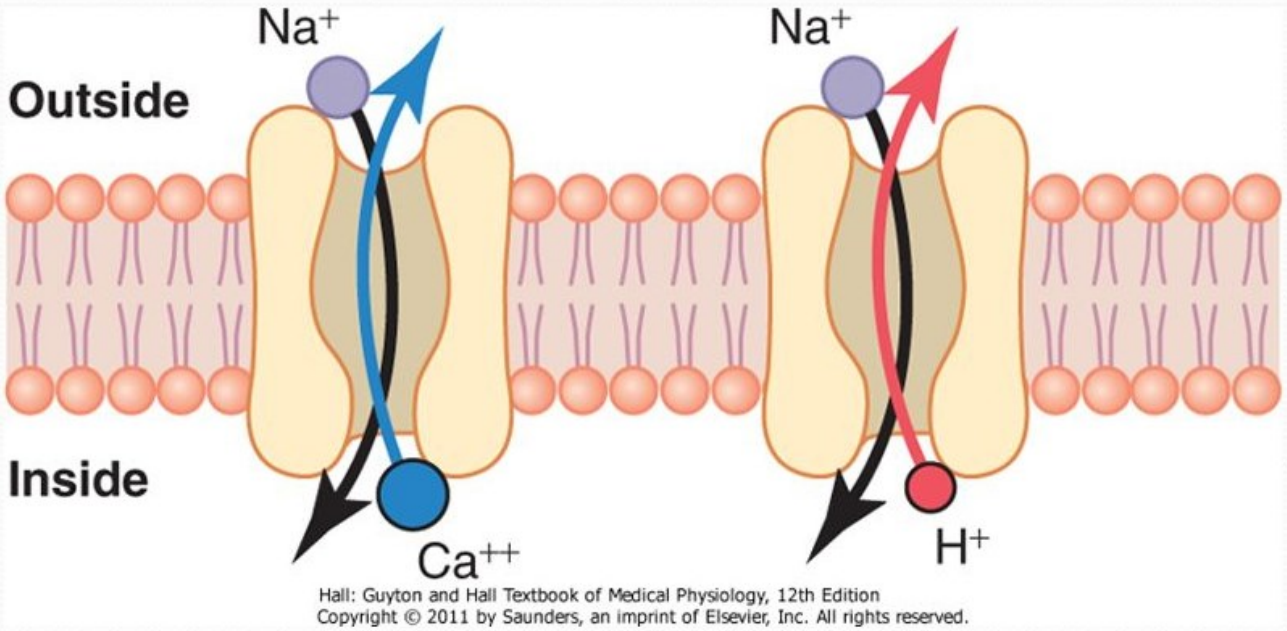


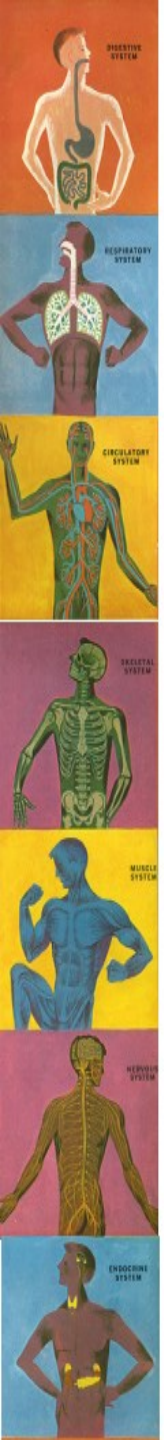
1. A Na^+–K^+ pump maintains a concentration of Na^+ that is higher outside the cell than inside.

2. Sodium ions move back into the cell through a transport protein that also moves glucose. The concentration gradient for Na^+ provides energy required to move glucose against its concentration gradient.

Secondary Active Transport
(Counter-transport)

- Sodium Counter-transport of Calcium and Hydrogen Ions





Types of Secondary Active Transport

Co-Transport

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

- ***Examples;***
  - **Na^+-glucose co-transporter (PCT)**
  - **Na^+-amino acid co-transporter (PCT)**

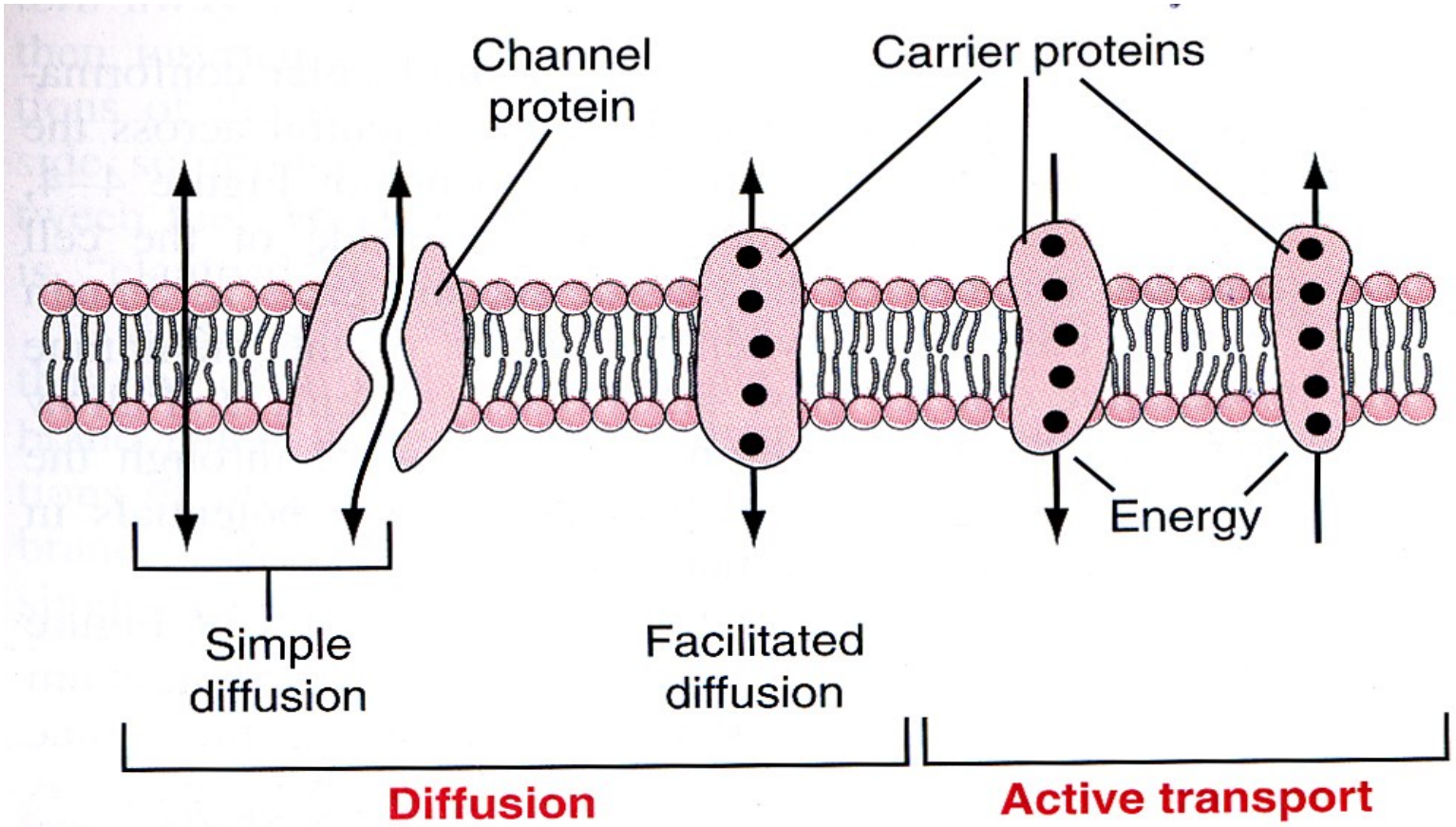
Counter-Transport

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

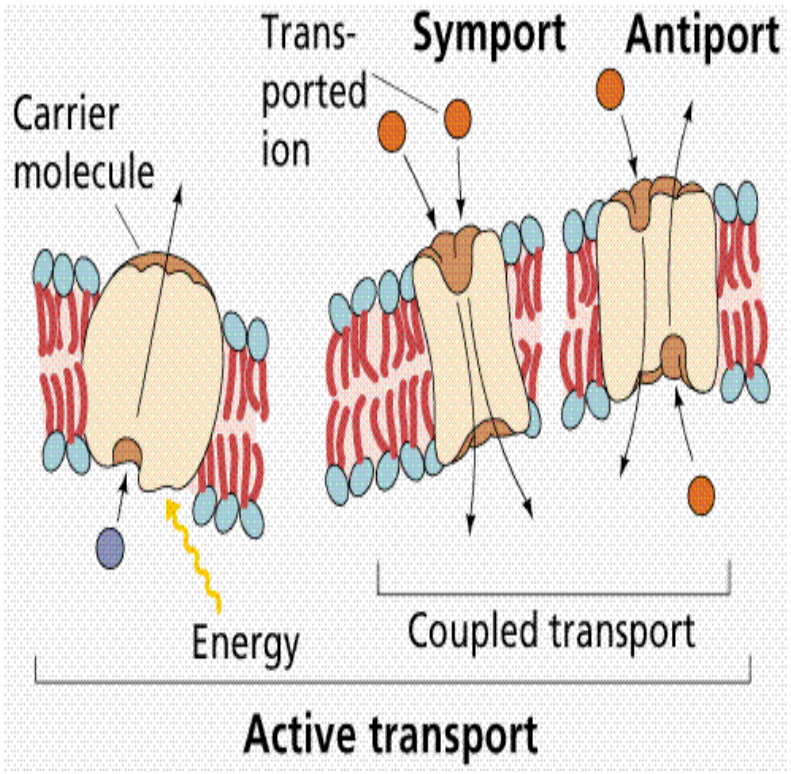
- ***Examples;***
  - **Na^+-H^+ counter-transporter (PCT)**
  - **Na^+-Ca^{+2} counter-transporter**

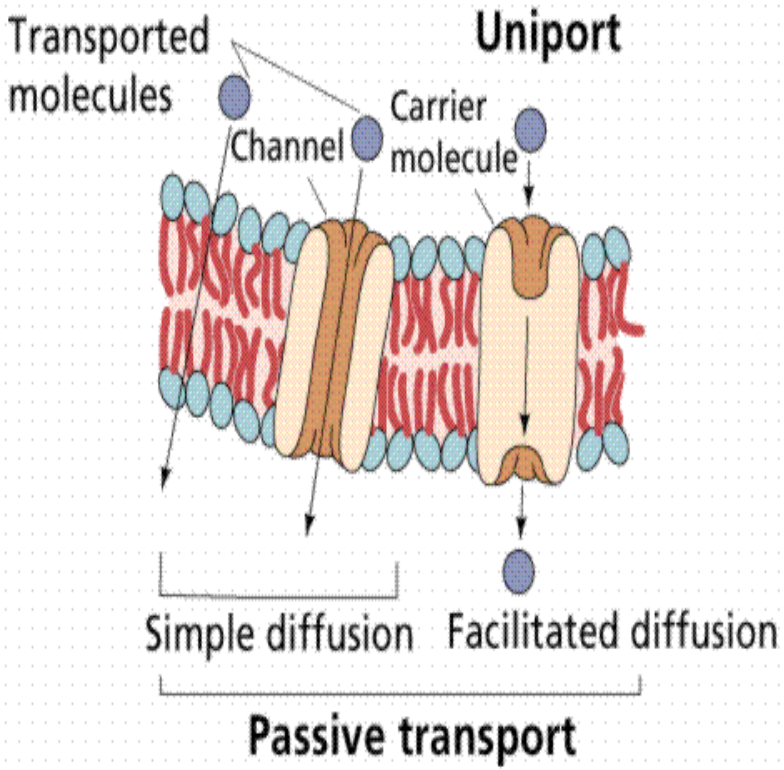
N.B. ***PCT = proximal convoluted tubules*** in the kidney

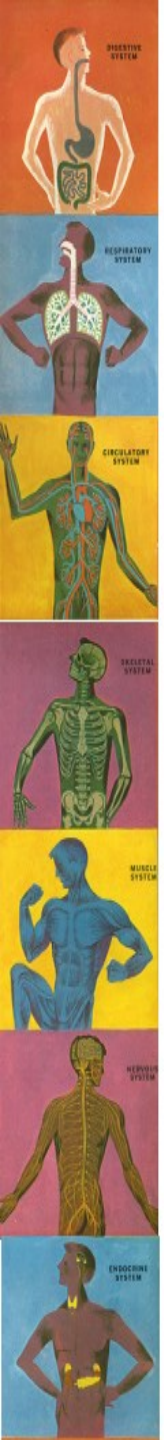
Revision!


Channel protein
Carrier proteins
Energy
Simple diffusion
Facilitated diffusion
Diffusion
Active transport

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


DIGESTIVE SYSTEM
RESPIRATORY SYSTEM
CIRCULATORY SYSTEM
SKELETAL SYSTEM
MUSCLE SYSTEM
NERVOUS SYSTEM
ENDOCRINE SYSTEM

Thank you