TRANSPORT THROUGH PLASMA MEMBRANE

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Hyman physiology

First Semester

Week 3

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Outline

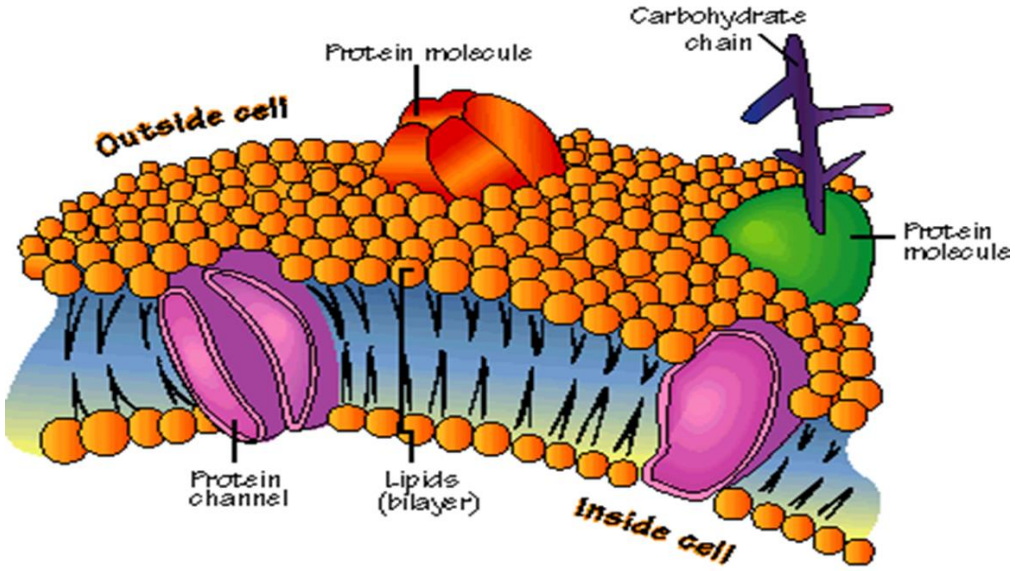
- Plasma membrane structure
- Functions of P.M proteins
- Selective permeability of plasma membrane
- Types of Transport Across Cell Membranes
- Osmolarity and Tonicity

Objectives

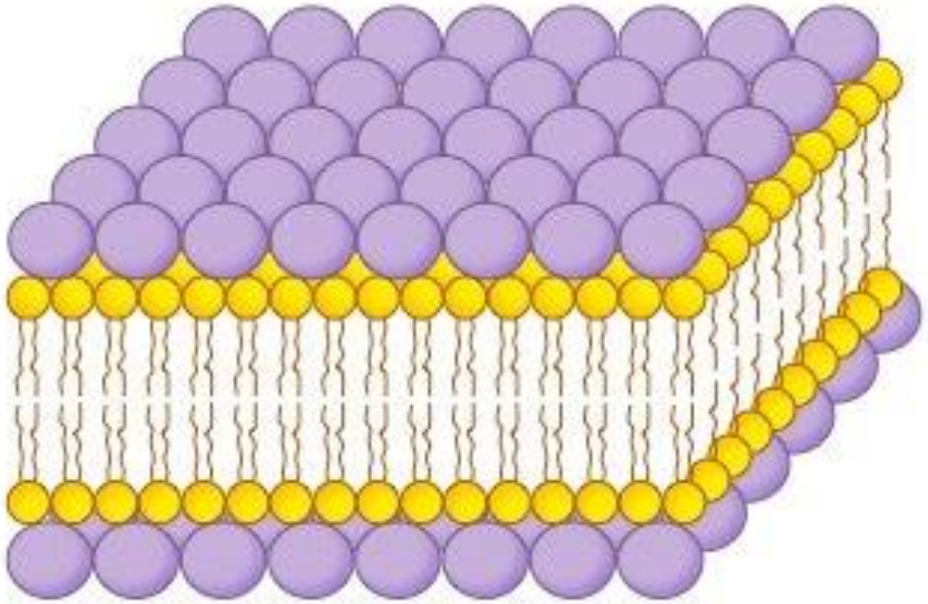
- Understanding the structure of plasma membrane
- Explaining the role of membrane proteins
- Understanding the bases of different type of transport across P.M
- Differentiate between active and passive transport
- Differentiate between simple diffusion and facilitate diffusion
- Understanding Osmolarity and tonicity

Cell membrane structure

- The principal components of the plasma membrane are **lipids** (phospholipids sphingolipids and cholesterol), **proteins**,
- **Carbohydrate** groups are attached to some of the lipids and proteins.

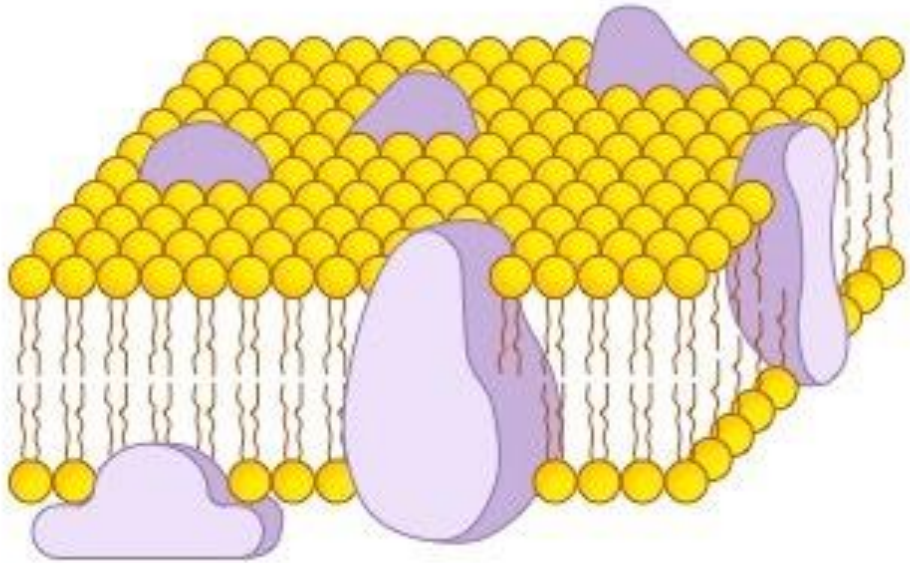


Davson-Danielli Model (1935)



Proteins form distinct layers *(sandwich)*

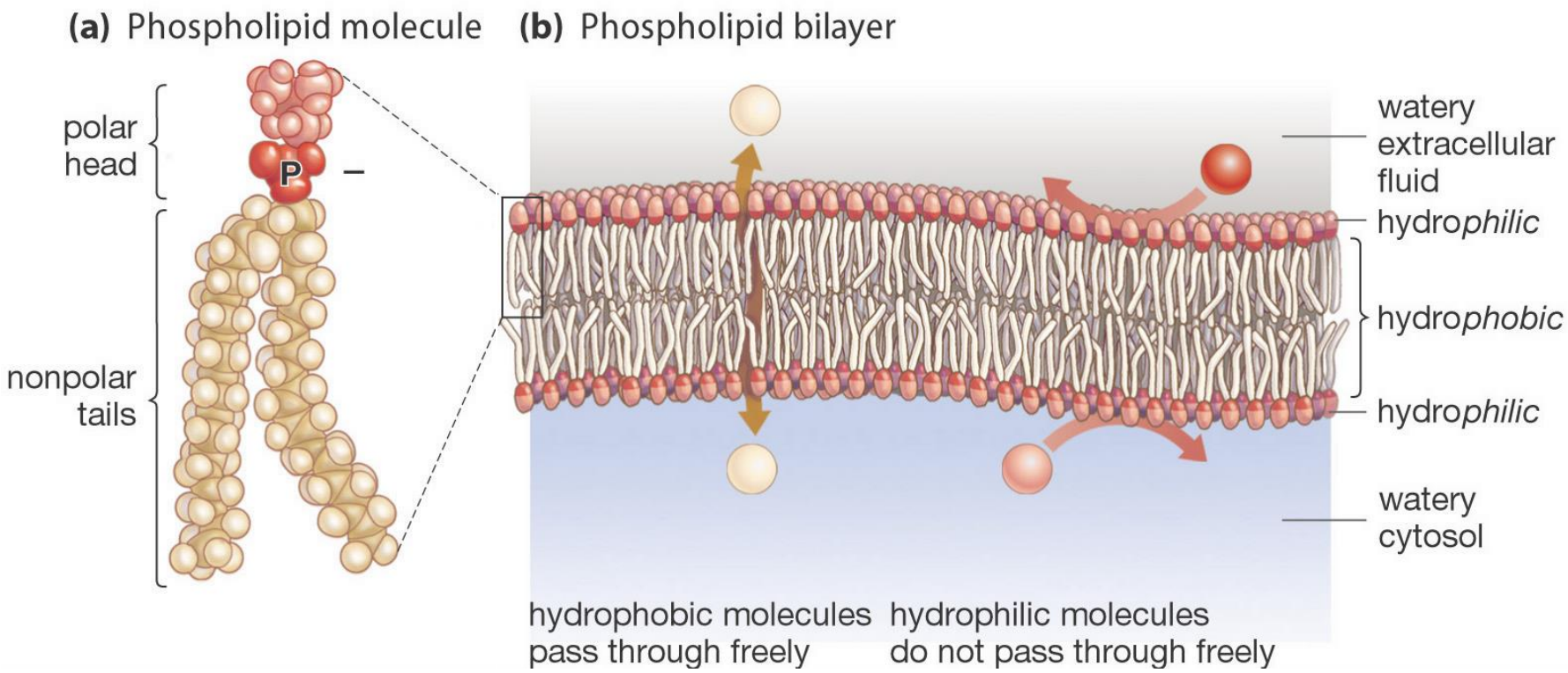
Singer-Nicolson Model (1972)



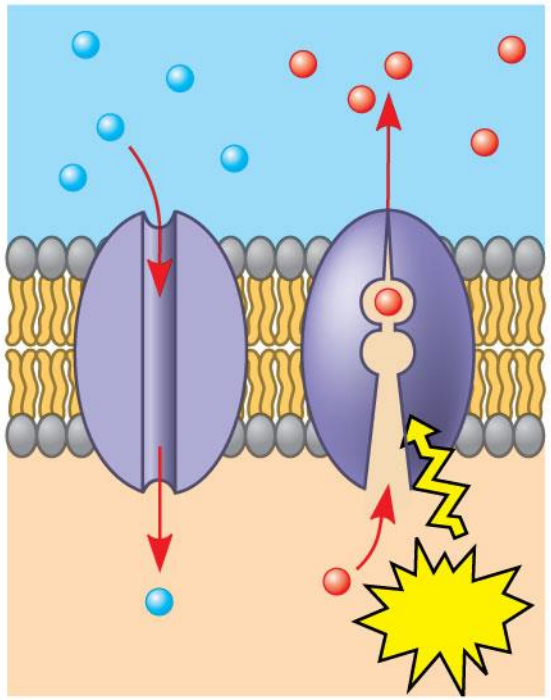
Proteins embedded within bilayer *(fluid-mosaic)*

Cellular membranes are fluid mosaics of lipids and proteins

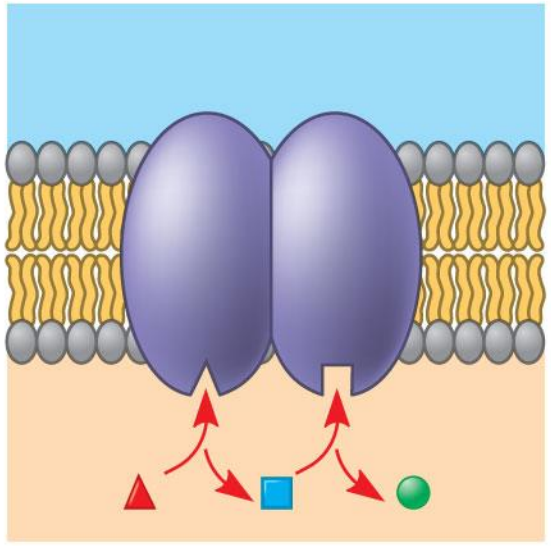
- **Phospholipids** are the most abundant lipid in the plasma membrane
- Phospholipids are **amphipathic molecules**, containing hydrophobic and hydrophilic regions
- Biological membranes usually consist of two layers of phospholipids with their tails pointing inward, an arrangement called a **phospholipid bilayer.**


(a) Phospholipid molecule
(b) Phospholipid bilayer
polar head
nonpolar tails
P
–
watery extracellular fluid
hydrophilic
hydrophobic
hydrophilic
watery cytosol
hydrophobic molecules pass through freely
hydrophilic molecules do not pass through freely

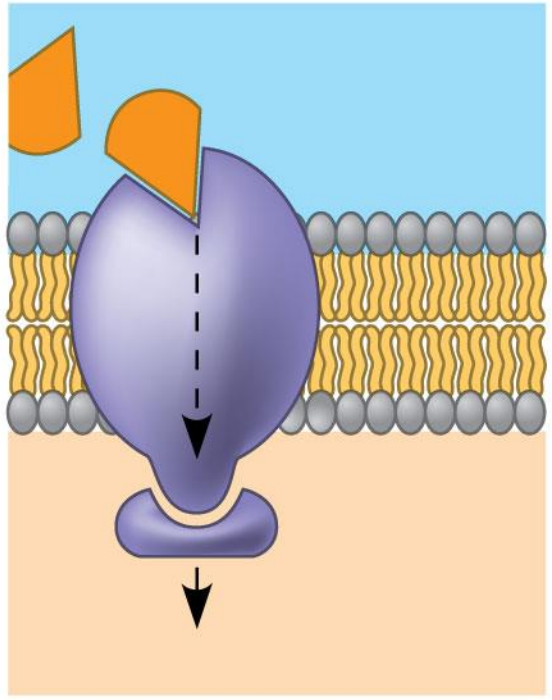
- **Six major functions of membrane proteins**
  1. Transport
  2. Enzymatic activity
  3. Signal transduction
  4. Cell-cell recognition
  5. Intercellular joining
  6. Attachment to the cytoskeleton and extracellular matrix (ECM)



(a) Transport

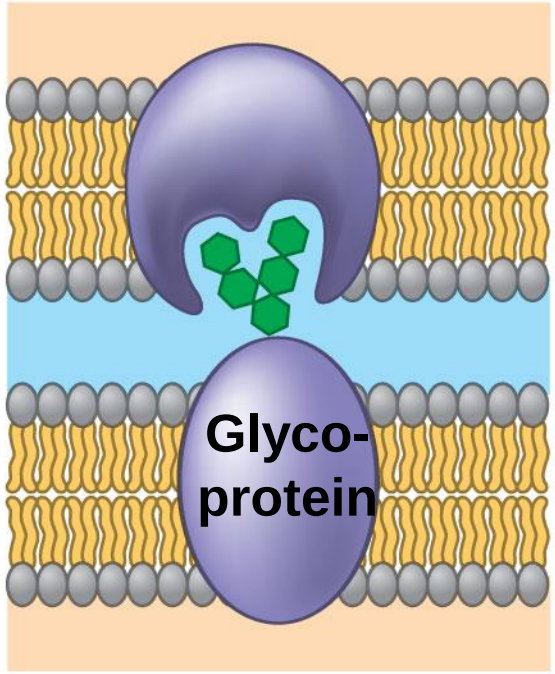


(b) Enzymatic activity

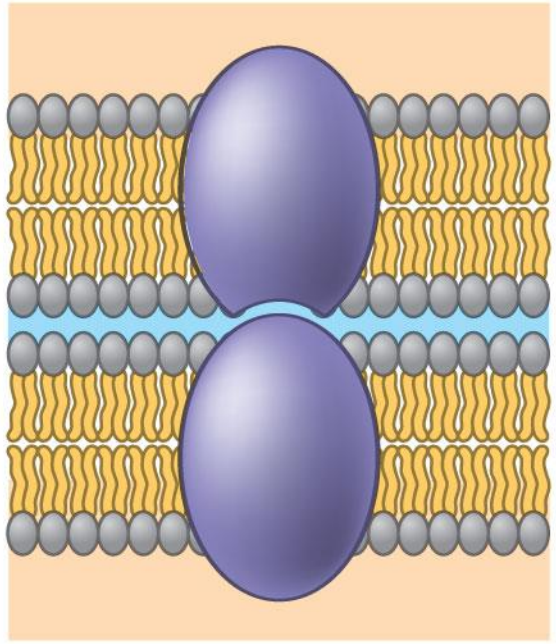


(c) Signal transduction

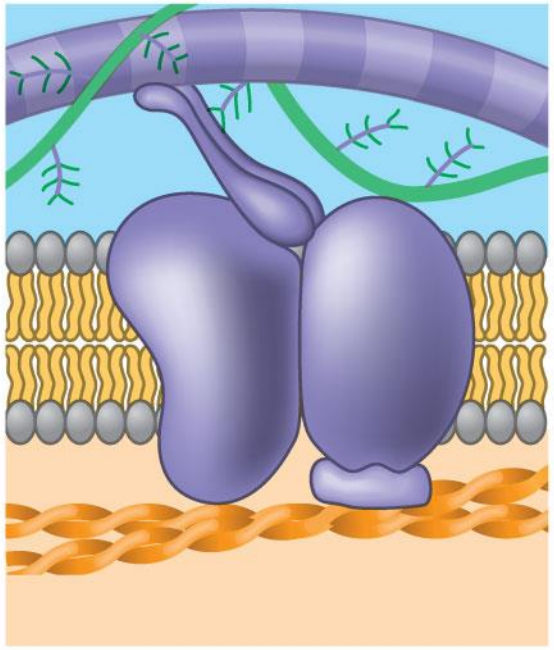
Figure 7.10b



(d) Cell-cell recognition



(e) Intercellular joining



(f) Attachment to the cytoskeleton and extracellular matrix (ECM)

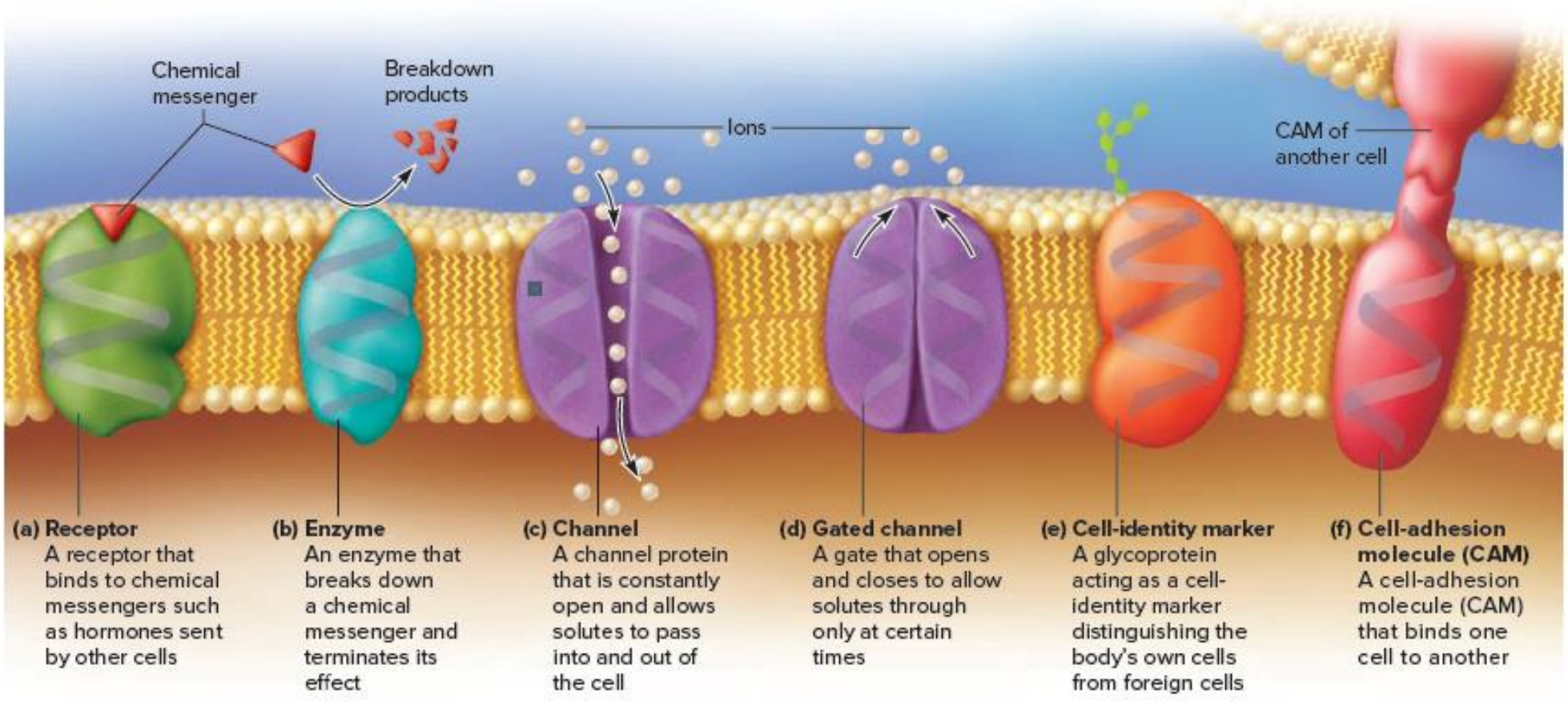


FIGURE 3.7 Some Functions of Membrane Proteins.

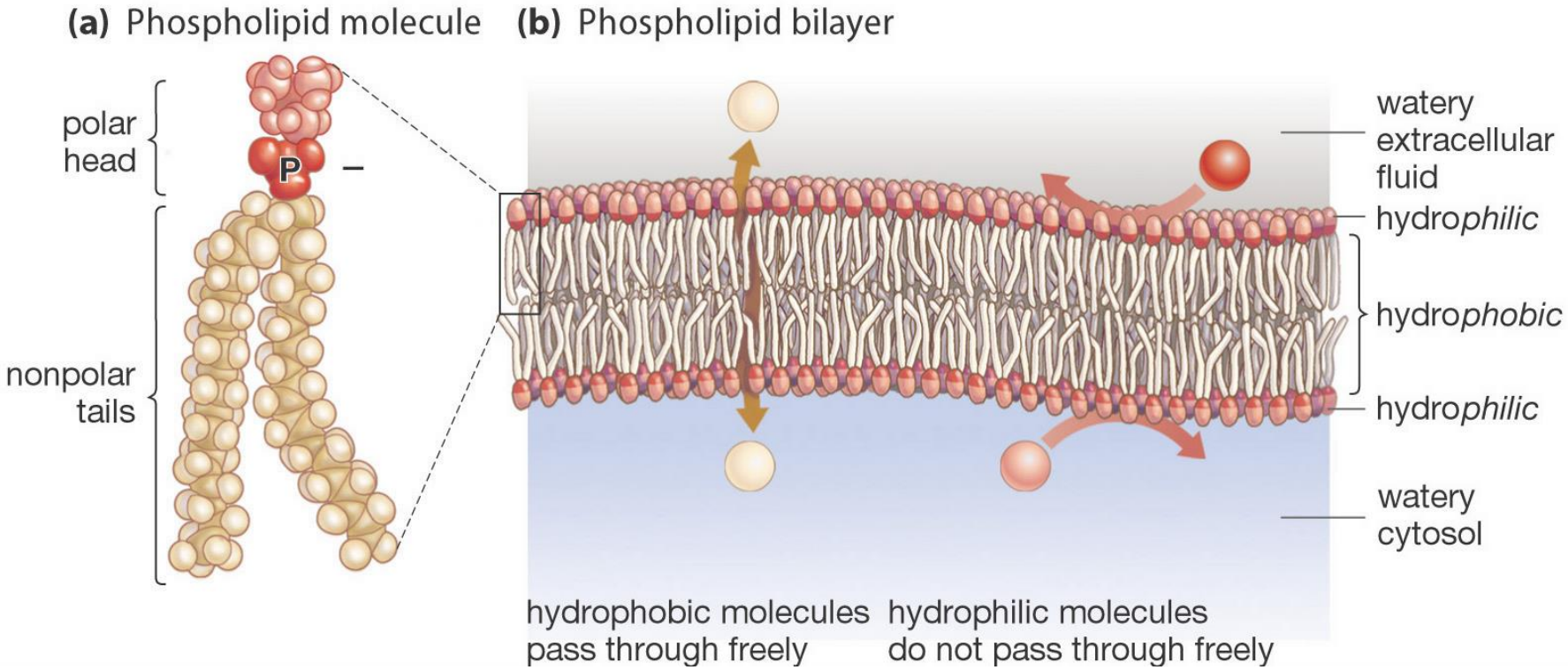
Membrane structure results in selective permeability

- A cell must exchange materials with its surroundings, a process controlled by the plasma membrane
- Plasma membranes are **selectively permeable,** regulating the cell's molecular traffic
- **Selectively permeable means allows certain substances to pass through while restricting the passage of others. The selectivity of the membrane is based on the size, charge, and solubility of the molecules or ions trying to pass through it.**

The Permeability of the Lipid Bilayer

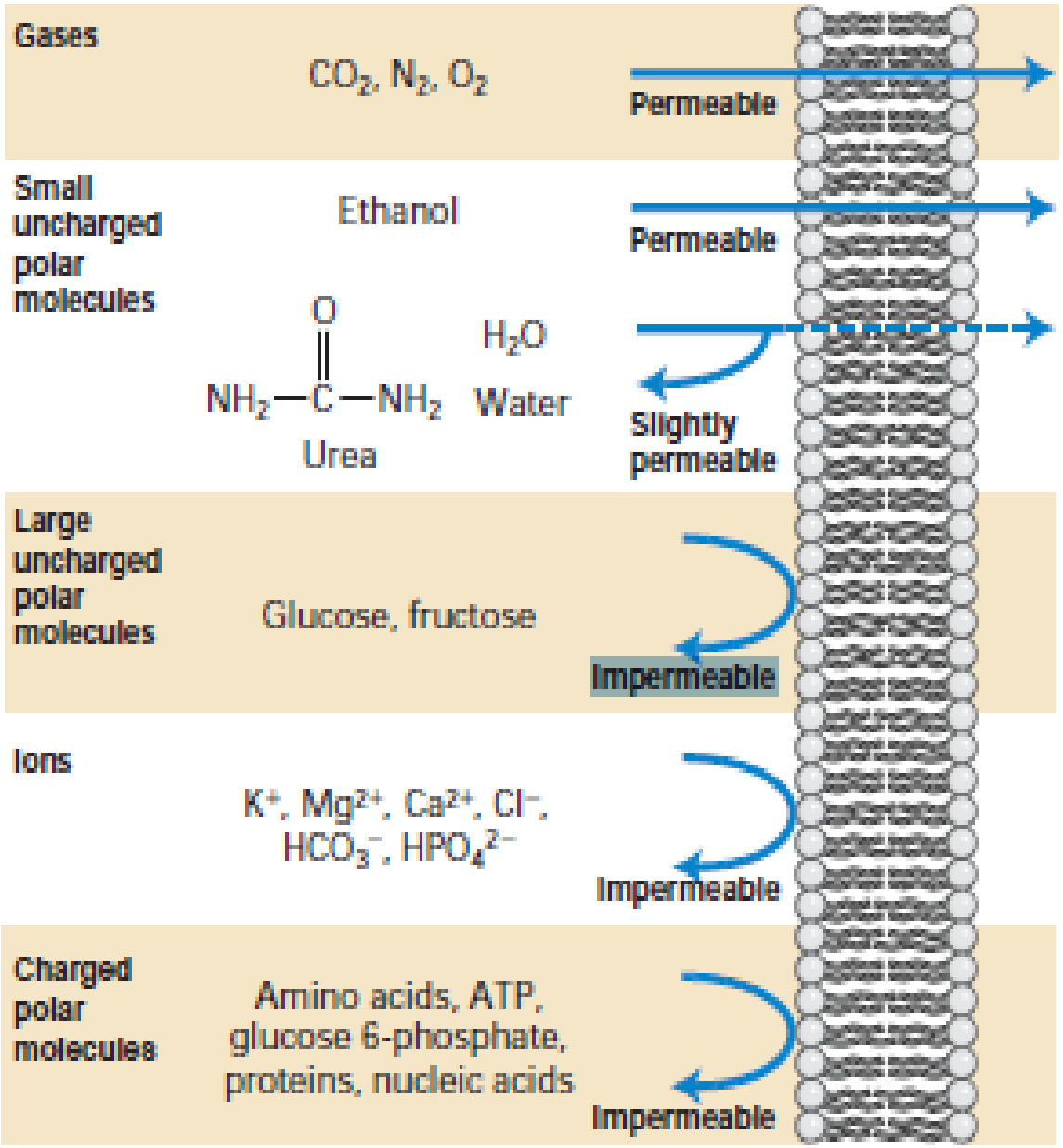
- Hydrophobic (nonpolar) molecules, such as hydrocarbons, carbon dioxide, and oxygen , can dissolve in the lipid bilayer and pass through the membrane rapidly
- However, the hydrophobic interior of the membrane impedes the direct passage of ions and **polar molecules**, which are **hydrophilic**, through the membrane
- **Polar molecules, ions, sugars and proteins** do not cross the membrane easily, thy can be transported through **membrane portions**

Semipermeable Membrane

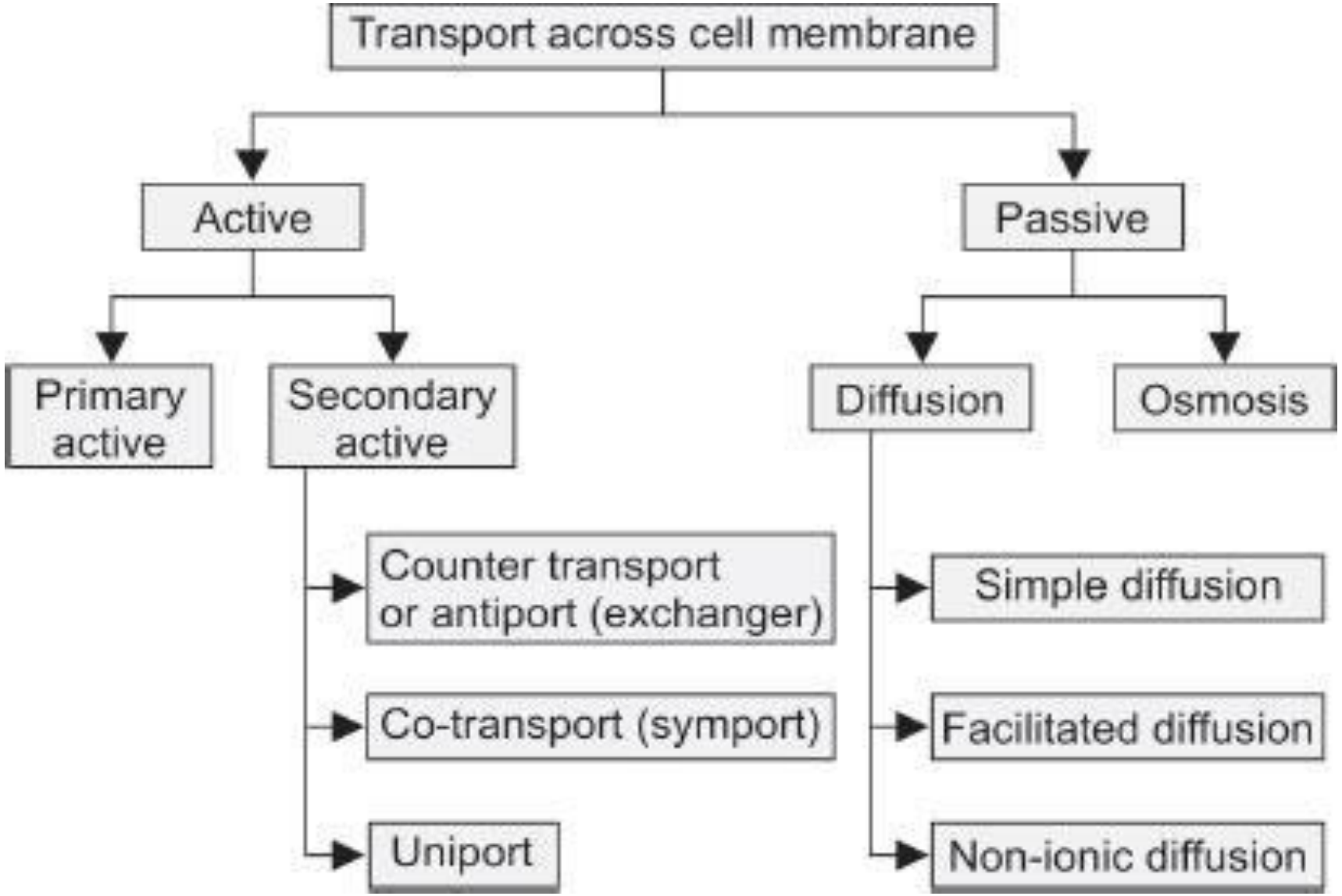


Small non-charged molecules move through easily.

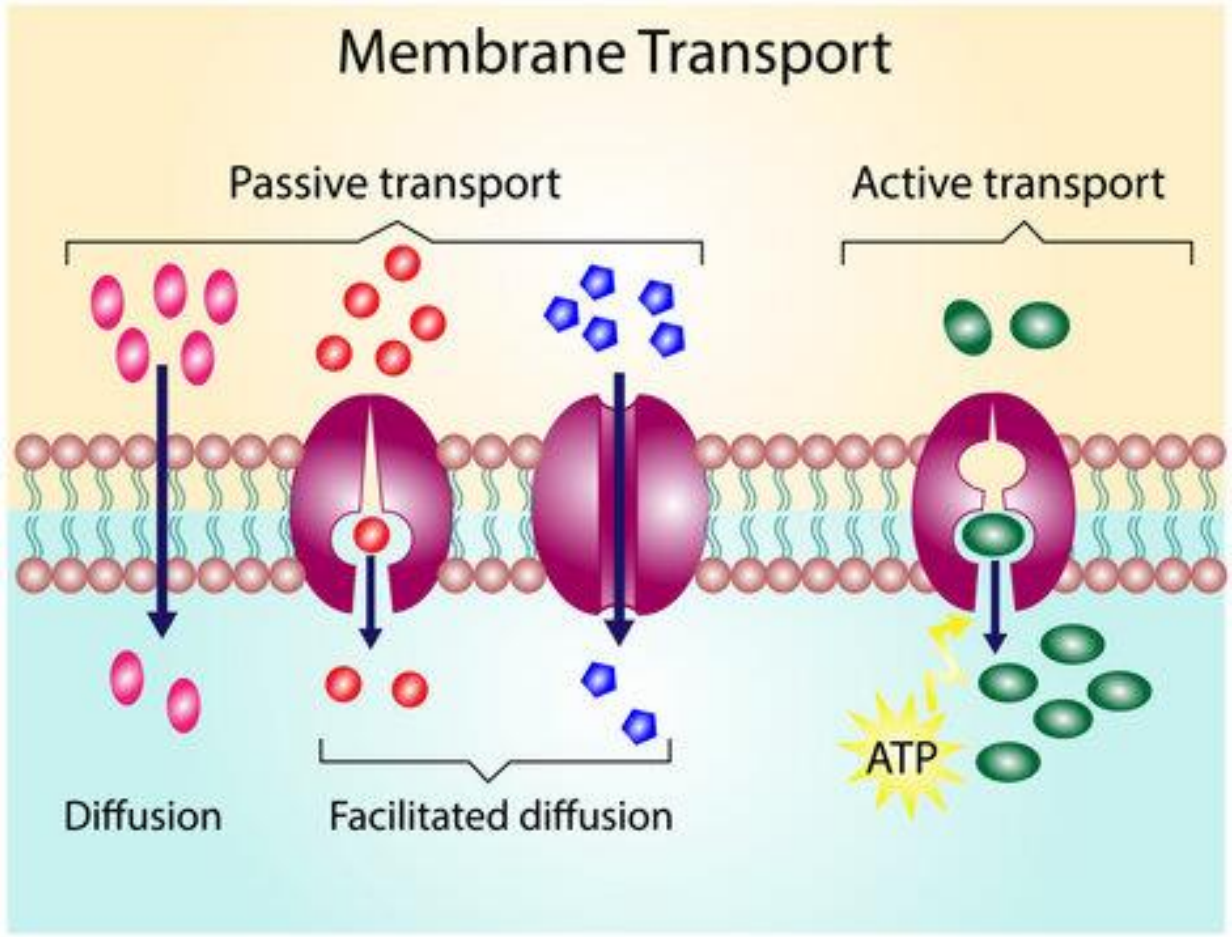
Examples: O_2, and CO_2


Gases
CO_2, N_2, O_2
Permeable
Small uncharged polar molecules
Ethanol
Permeable
O
NH_2—C—NH_2
Urea
H_2O
Water
Slightly permeable
Large uncharged polar molecules
Glucose, fructose
Impermeable
Ions
K^+, Mg^{2+}, Ca^{2+}, Cl^-, HCO_3^-, HPO_4^{2-}
Impermeable
Charged polar molecules
Amino acids, ATP, glucose 6-phosphate, proteins, nucleic acids
Impermeable

Types of Transport Across Cell Membranes



Types of Transport Across Cell Membranes

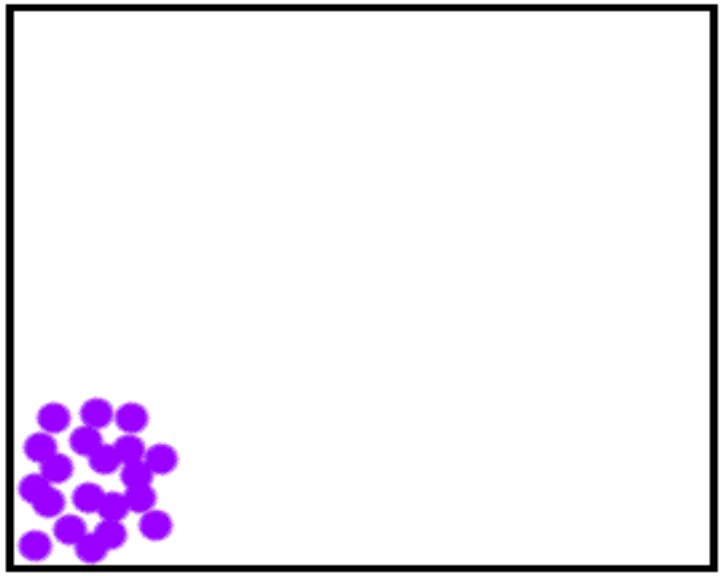


DIFFUSION

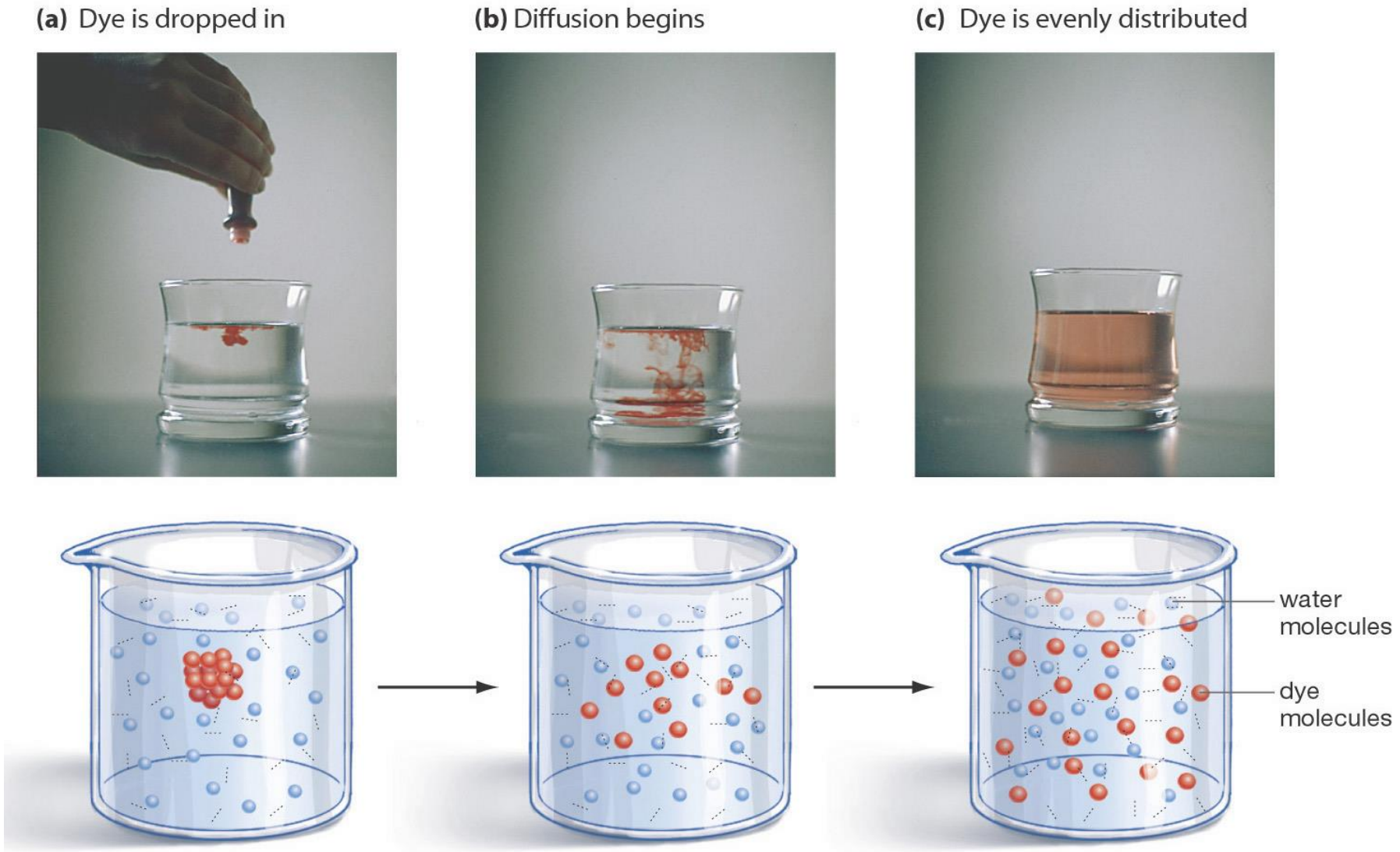
The movement of molecules of any substance so that they spread out evenly into the available space

A substance will diffuse from where it is more concentrated to where it is less concentrated. Any substance will diffuse down its **concentration Gradient**

- **Molecules move from area of HIGH to LOW concentration**
- **Requires NO energy**



DIFFUSION


(a) Dye is dropped in
(b) Diffusion begins
(c) Dye is evenly distributed
water molecules
dye molecules

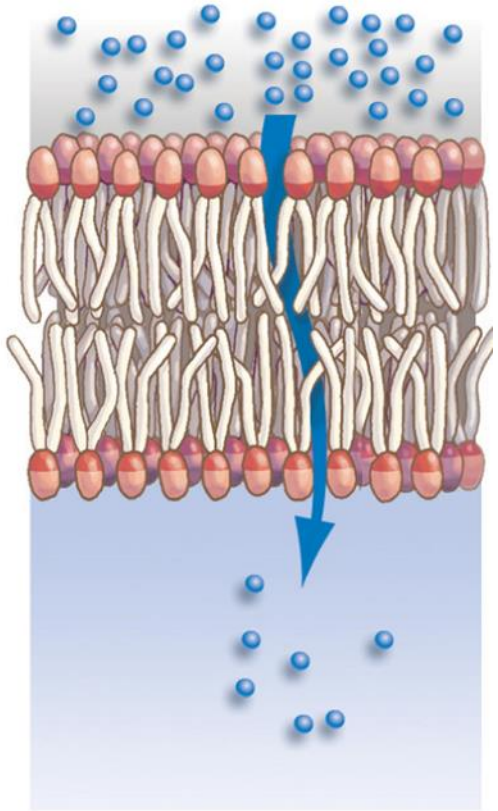
Types of Transport Across Cell Membranes

Passive Transport

❖ Simple Diffusion

- ❖ Doesn't require energy
- ❖ Moves high to low concentration through lipid layers of plasms membrane
- ❖ Example: Oxygen diffusing in or carbon dioxide diffusing out

simple diffusion



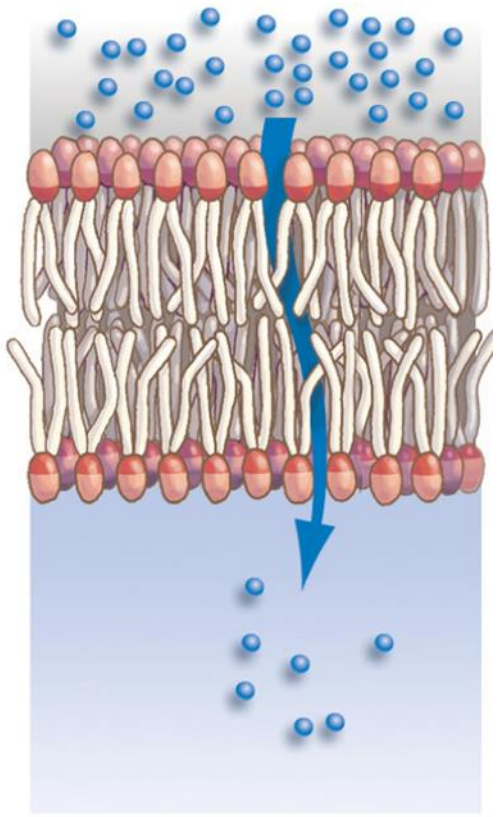
Materials move down their concentration gradient through the phospholipid bilayer.

DIFFUSION

1- Simple diffusion means that kinetic movement of **molecules** or **ions** occurs from a place of high concentration to a place of lower concentration(*down their concentration gradient)* because of their constant, spontaneous motion.

- Diffusion occurs either through readily in air or water or it occurs though a membrane opening or through intermolecular spaces.
- Substances diffuse without interaction with **membrane proteins** in the membrane

simple diffusion



Materials move down their concentration gradient through the phospholipid bilayer.

- Nonpolar, **hydrophobic**, lipid soluble substances such as **oxygen**, **CO2 nitric oxide**, **alcohol**, and **steroids** diffuse through the phospholipid regions of a plasma membrane.

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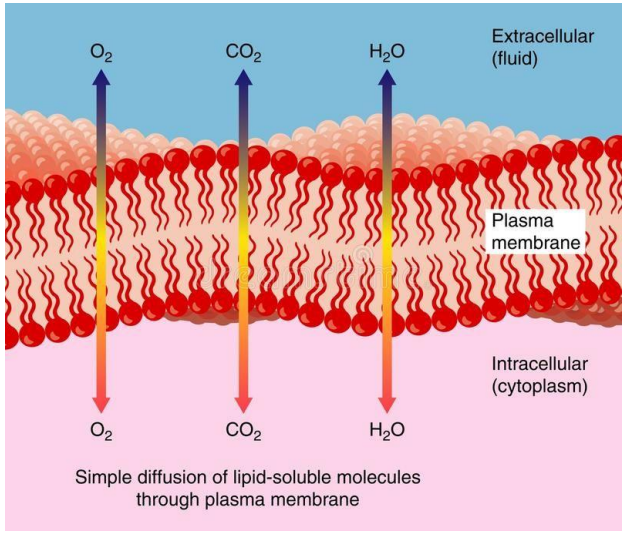
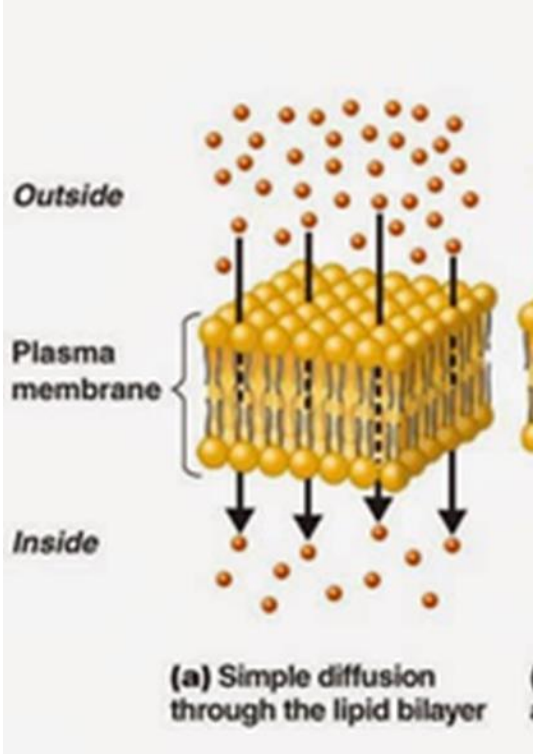
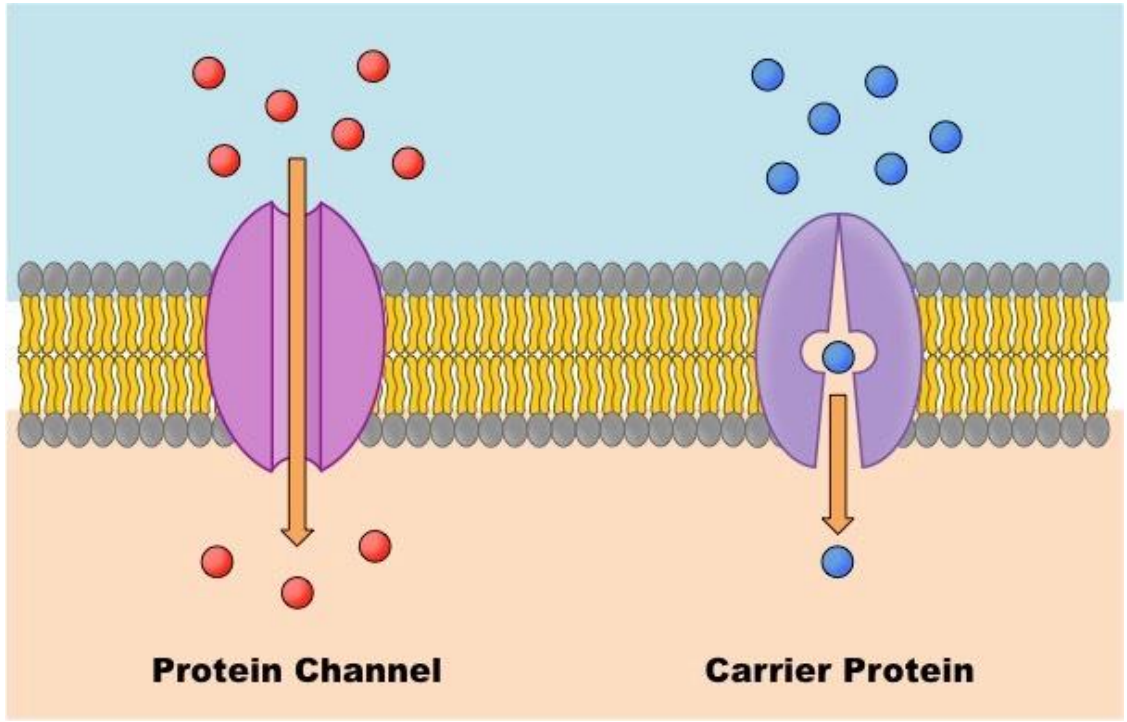




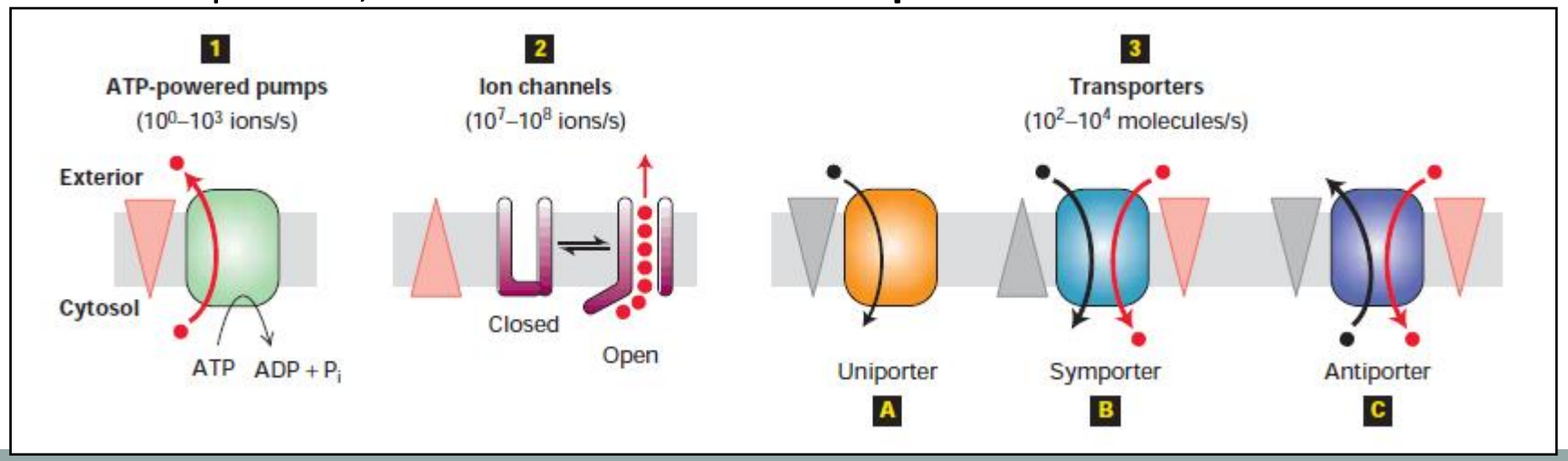
Facilitated Diffusion: Passive Transport Aided by Proteins

In facilitated diffusion, transport proteins speed the passive movement(high con--→low) of molecules across the plasma membrane



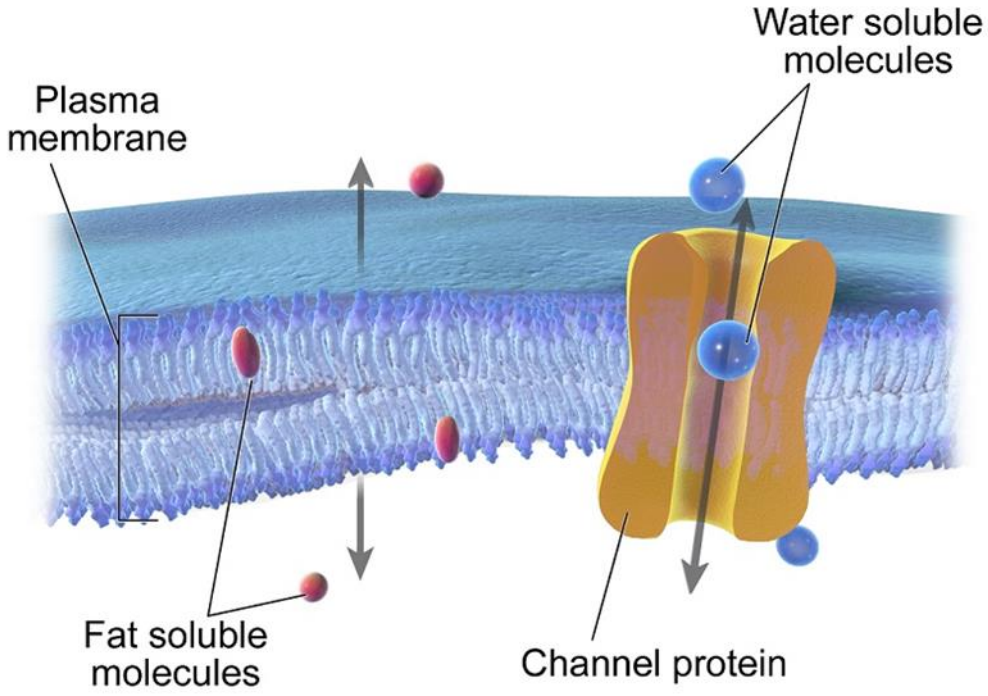
Transport proteins include:

1. **Channel proteins** transport water or specific types of ions and hydrophilic small molecules down their concentration or electric potential gradients. **Such protein-assisted transport sometimes is referred to as facilitated diffusion**
2. **Transporters (also called carriers)** move a wide variety of ions and molecules across cell membranes
3. **ATP-powered pumps (or simply pumps) are ATPases** that use the energy of ATP hydrolysis to move ions or small molecules across a membrane against a chemical concentration gradient or electric potential or both. This process, referred to as **active transport**



1- Facilitated Diffusion: Passive Transport Aided channel proteins

- **Water** and small charged, **hydrophilic** solutes such as electrolytes(ions) don't mix with lipids but diffuse primarily through **channel proteins** in the membrane. Cells can adjust their permeability to such a substance by adding **channel proteins** to the membrane, by taking them away, or by opening and closing membrane gates.

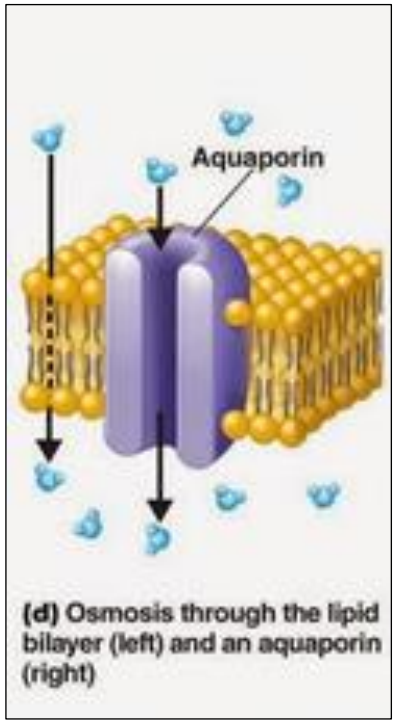


Some factors that affect the rate of diffusion through a membrane are as follows:

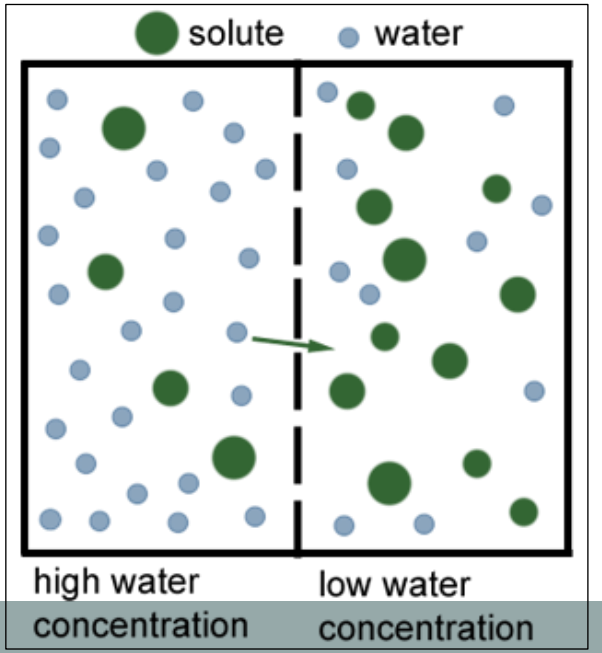
- **Temperature.** Diffusion is driven by the kinetic energy of the particles, and temperature is a measure of that kinetic energy. The warmer a substance is, the more rapidly its particles diffuse. This is why sugar diffuses more quickly through hot tea than through iced tea.
- **Molecular weight.** Heavy molecules such as proteins move more sluggishly and diffuse more slowly than light particles such as electrolytes and gases. Small molecules also pass-through membrane pores more easily than large ones.
- **"Steepness" of the concentration gradient.** The steepness of a gradient refers to the concentration difference between two points. Particles diffuse more rapidly if there is a greater concentration difference.
- **Membrane surface area.** As noted earlier, the apical surface of cells specialized for absorption (for example, in the small intestine) is often extensively folded into microvilli. This makes more membrane available for particles to diffuse through.
- **Membrane permeability.** Diffusion through a membrane depends on how permeable it is to the particles. For example, potassium ions diffuse more rapidly than sodium ions through a plasma membrane

Osmosis NET DIFFUSION" OF WATER

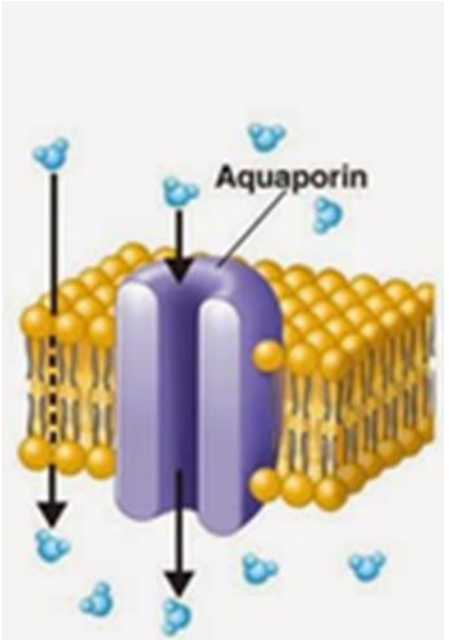
- **Osmosis:** is the net flow of water from one side of a selectively permeable membrane to the other.
- The usual direction of net movement is from the **waterier side**, with a lower concentration of dissolved matter, to the **less watery side, with a greater concentration of solute**
- Imbalances in osmosis underlie such problems as diarrhea, constipation, hypertension, and edema (tissue swelling); osmosis also is a vital consideration in intravenous (I.V.) fluid therapy.



(d) Osmosis through the lipid bilayer (left) and an aquaporin (right)

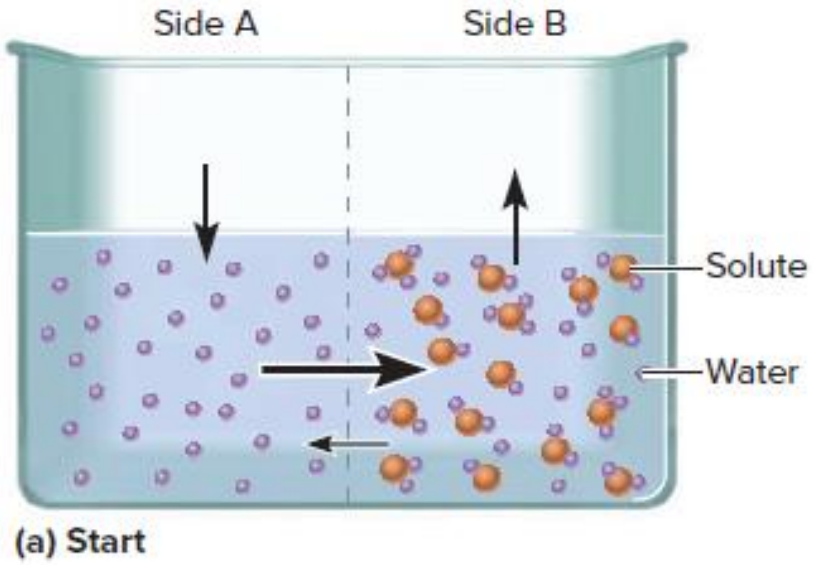


- Significant amounts of water pass even through the hydrophobic, phospholipid regions of a plasma membrane, but water passes more easily through channel proteins called **aquaporins,** specialized for water.
- Cells can increase the rate of osmosis by installing more aquaporins in the membrane or decrease the rate by removing them.
- Certain cells of the kidney, for example, regulate the rate of urinary water loss by adding or removing aquaporins
- If the kidneys did not perform this function, you would excrete about 180 L of urine per day—and have to drink an equal volume of water!
- Channel proteins that transport ions are called ion channels.

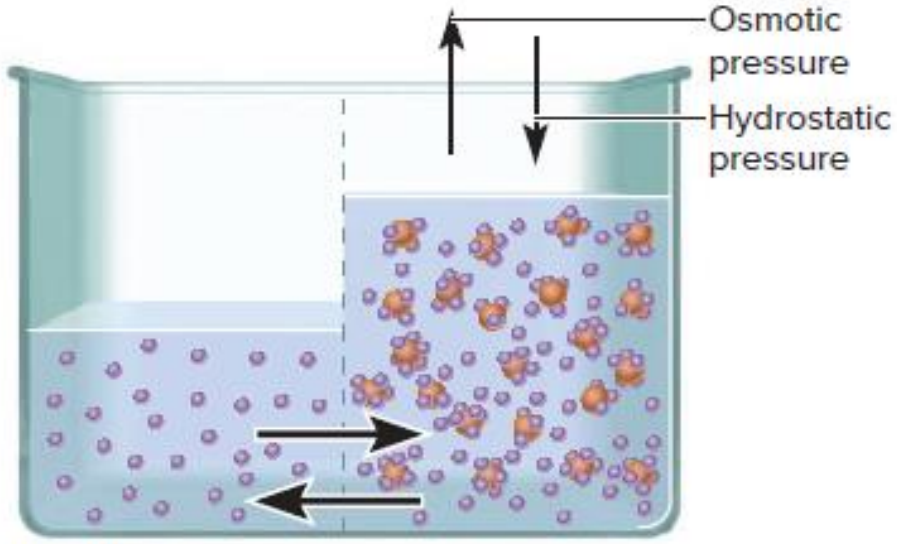


(d) Osmosis through the lipid bilayer (left) and an aquaporin (right)

Osmosis model



(a) Start



(b) 30 minutes later

- **Osmotic pressure ?**
- Hydrostatic pressure ?

Osmolarity and Tonicity

The **osmolarity**, or **osmotic concentration**, of body fluids has such a great effect on cellular function that it is important to understand the units in which it is measured. Physiologists and clinicians usually express this in terms of **milliosmoles per liter (mOsm/L),** a unit of measure that expresses the quantity of nonpermeating particles per liter of solution. Blood plasma, tissue fluid, and intracellular fluids measure about 300 mOsm/L.

Tonicity

- **Tonicity** is the ability of a solution to affect the fluid volume and pressure in a cell. If a solute cannot pass through a plasma membrane but remains more concentrated on one side of the membrane than on the other, it causes osmosis
- **Hypotonic** solution has a lower concentration of nonpermeating solutes than the intracellular fluid (ICF). Cells in a hypotonic solution absorb water, swell, and may burst *(lyse)* .
- A **hypertonic** solution is one with a higher concentration of nonpermeating solutes than the ICF. It causes cells to lose water and shrivel *(crenate)* **.** Such cells may die of torn membranes and cytoplasmic loss.
- In **isotonic** solutions, the total concentration of nonpermeating solutes is the same as in the ICF—hence, isotonic solutions cause no change in cell volume or shape
- https://www.youtube.com/watch?app=desktop&v=A8cI6FkcG4c
- **It is important to note that osmolarity and tonicity are not the same.**

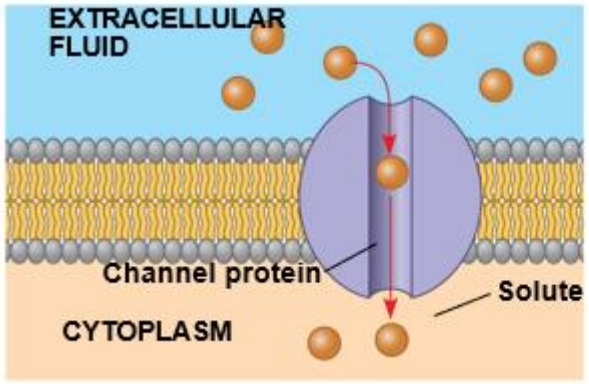
Diffusion of Water and Other Lipid-Insoluble Molecules Through Protein Channels

Channel proteins form a hydrophilic passageway across the membrane through which multiple water molecules or ions move simultaneously, single file at a very rapid rate

Channel proteins include

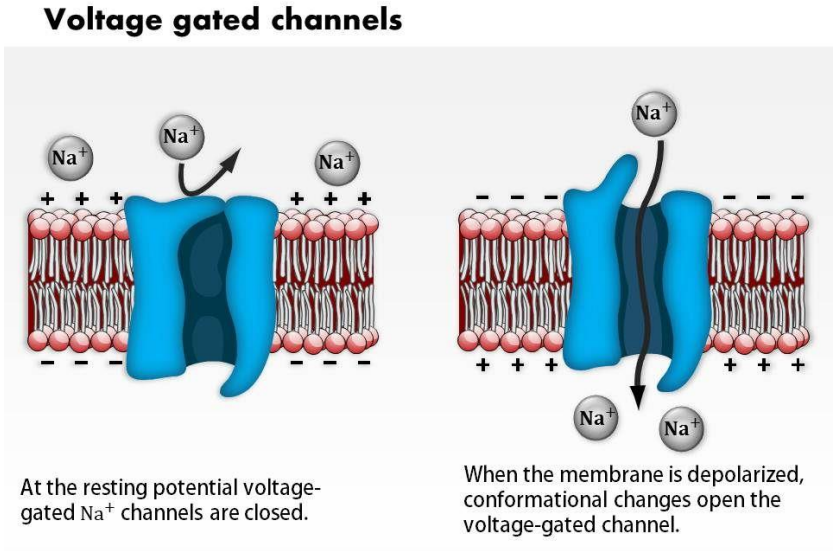
Aquaporins, for facilitated diffusion of water

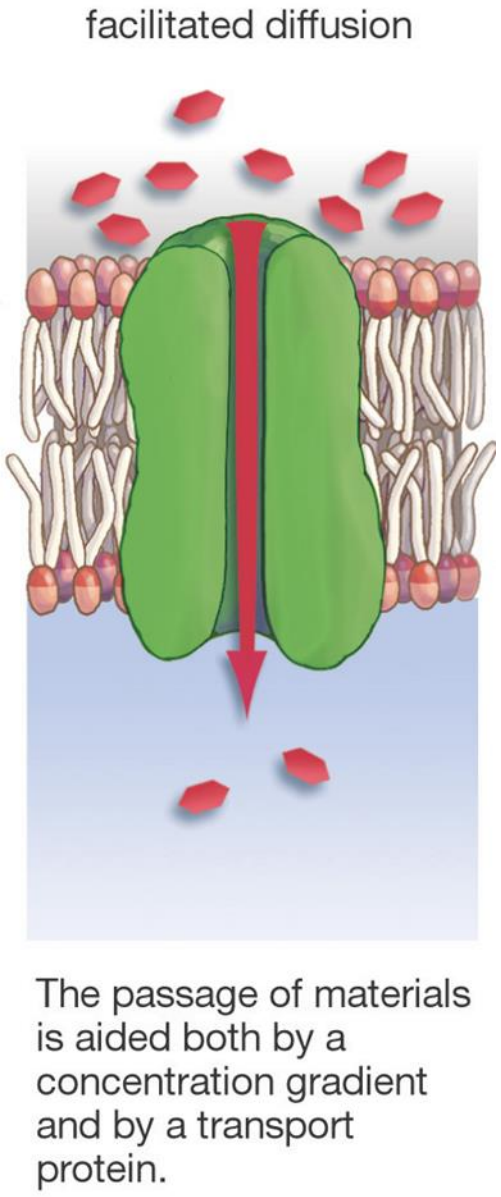
Ion channels transport ions (K, Na, Cl, and Ca_2



(a) A channel protein

- Some **ion channels** are open much of the time; these are referred to as ***non-gated*** channels. Most ion channels, however, open only in response to specific chemical or electrical signals; these are referred to as ***gated channels***..
- For example, potassium channel opens in response to an electrical stimulus, allowing potassium ions to leave the cell.



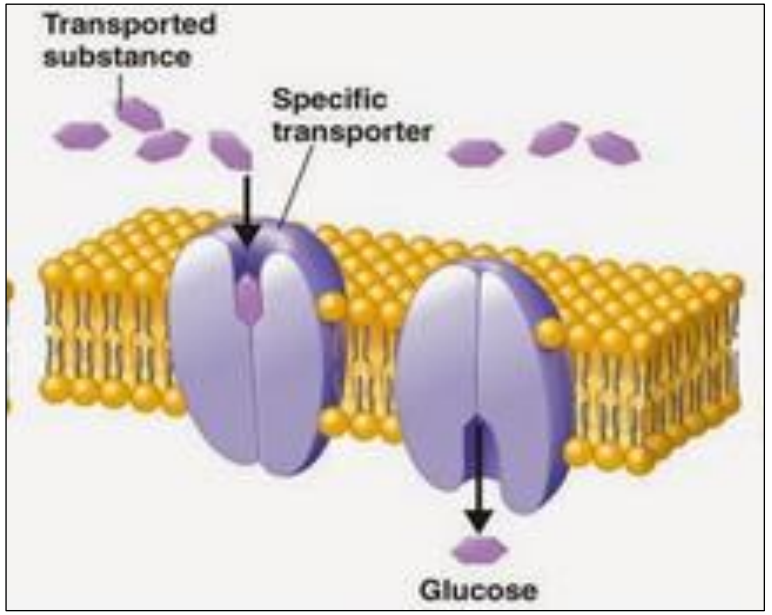


Types of ion channels

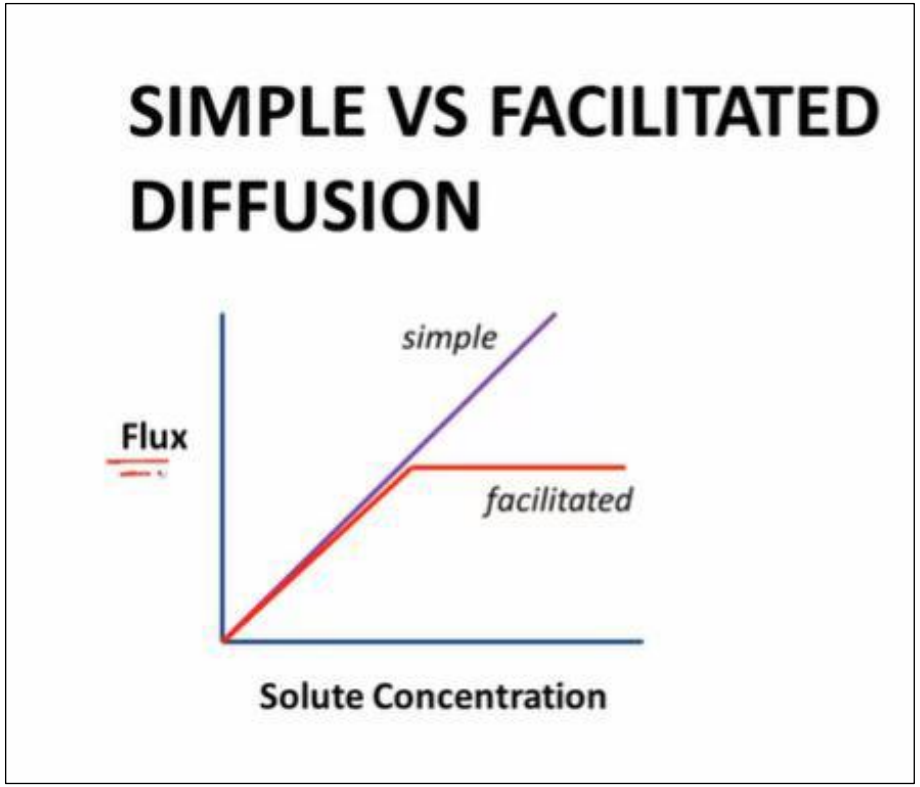
1. Ligand-gated channels:
2. Voltage-gated channels:
3. Mechanically-gated channels:

2- Facilitated Diffusion: Passive Transport Aided by carriers Proteins

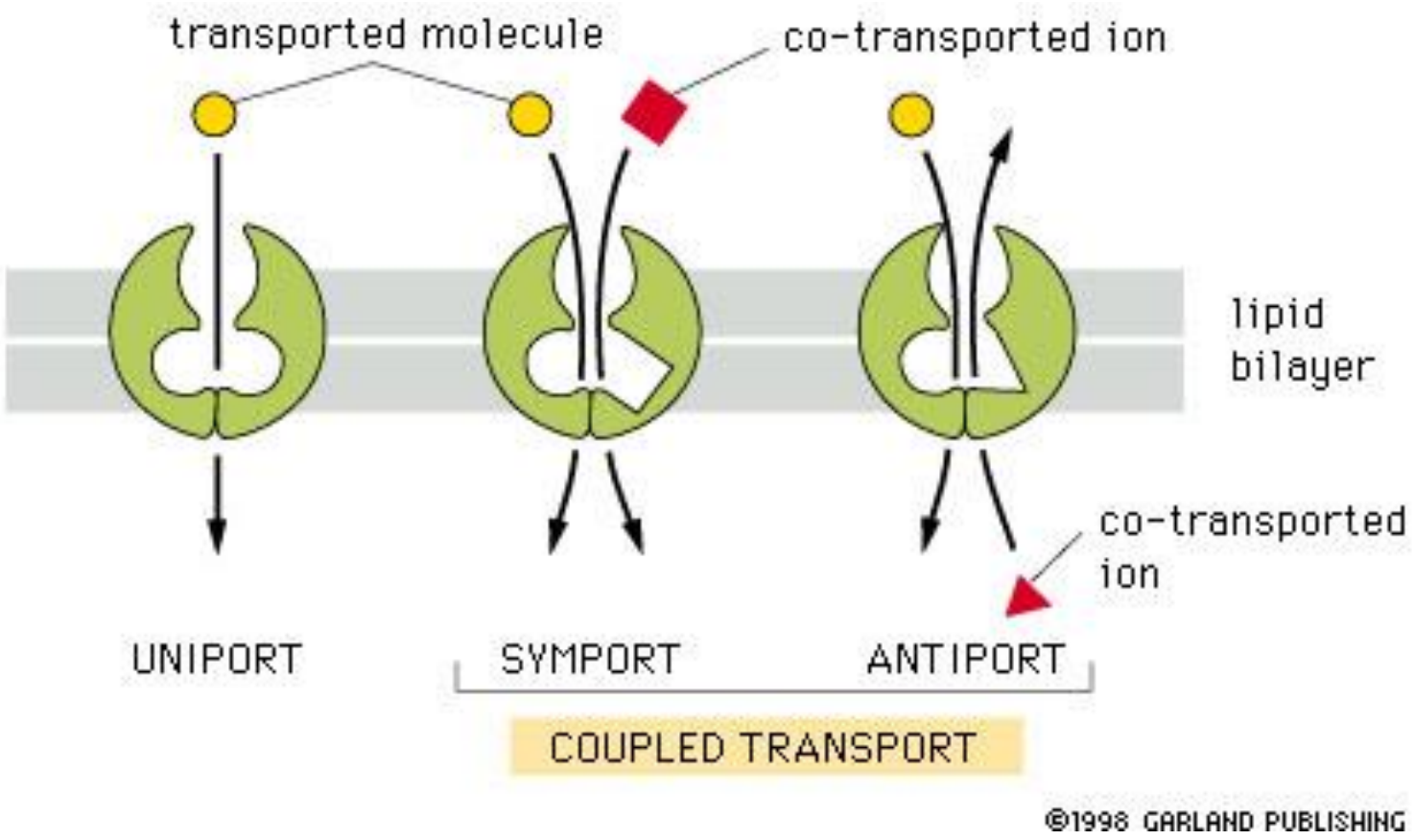
- In **facilitated diffusion**, transport proteins which are called **carriers** perform the passive movement of molecules across the plasma membrane, simply they pick them up on one side of the membrane and release them, unchanged, on the other side.
- A solute binds to a carrier in the plasma membrane, which then changes shape and releases the solute to the other side. Carriers can move substances into or out of a cell, and into or out of organelles within the cell.
- The process is very rapid; for example, one carrier can transport 1,000 glucose molecules per second across the membrane.



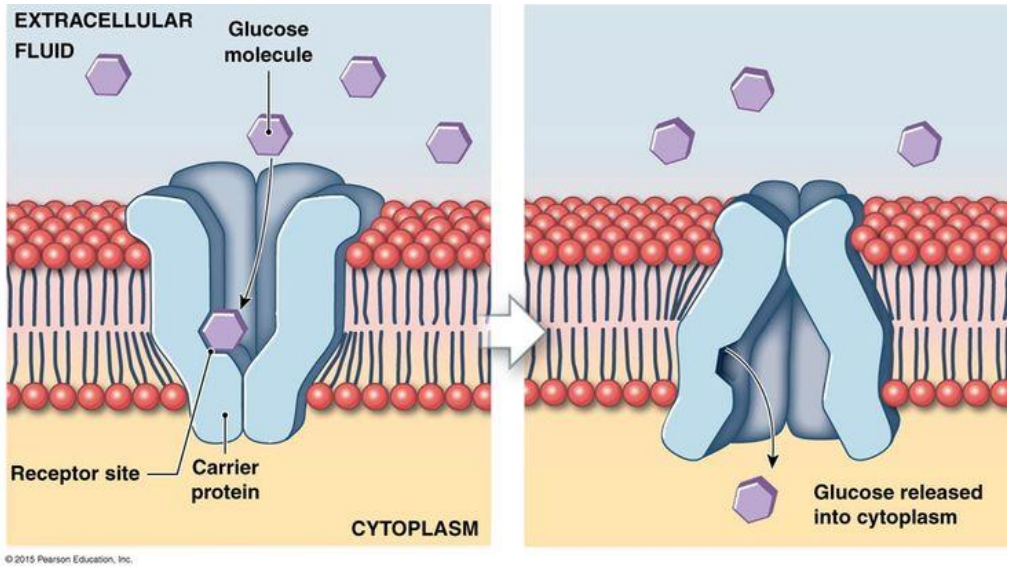
- **Like ion channels**, carrier proteins involved in facilitated diffusion result **in the net movement of a substance down its concentration gradient. No energy input is thus required: This is passive transport**.
  - Carriers also exhibit saturation; as the solute concentration rises, its rate of transport increases, but only up to a point. When every carrier is occupied, adding more solute can't make the process go any faster. The carriers are saturated—no more are available to handle the increased demand

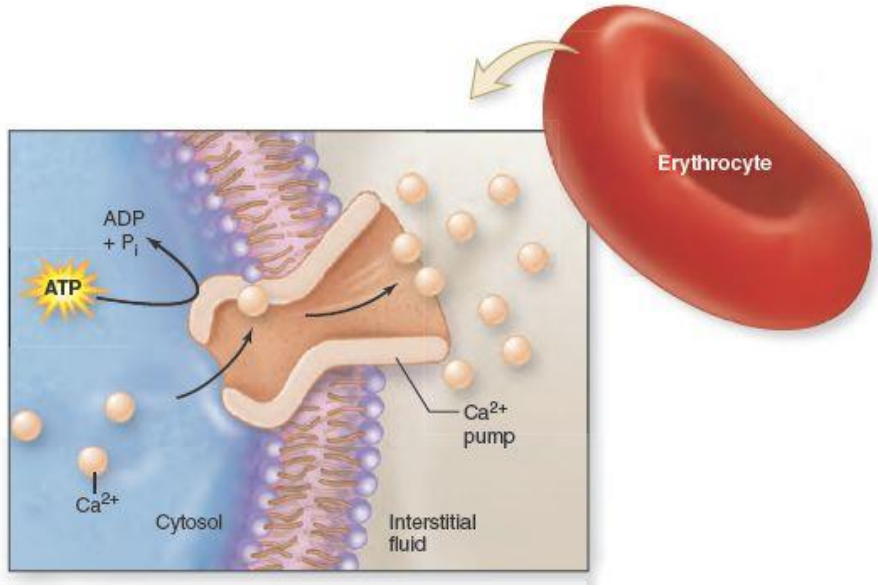


There are three kinds of carriers: uniports, symports, and antiports.



1. **Uniporters** transport a single type of molecule down its concentration gradient via facilitated diffusion glucose carrier. Or against its concentration gradient by using energy(ATP)





2. **Symport carrier** move two or more solutes through a membrane simultaneously in the same direction; this process is called **cotransport**
3. **Antiport carrier proteins** that move two or more solutes in opposite directions; this process is called **countertransport**