Diffusion of Molecules Across the Cell Membrane

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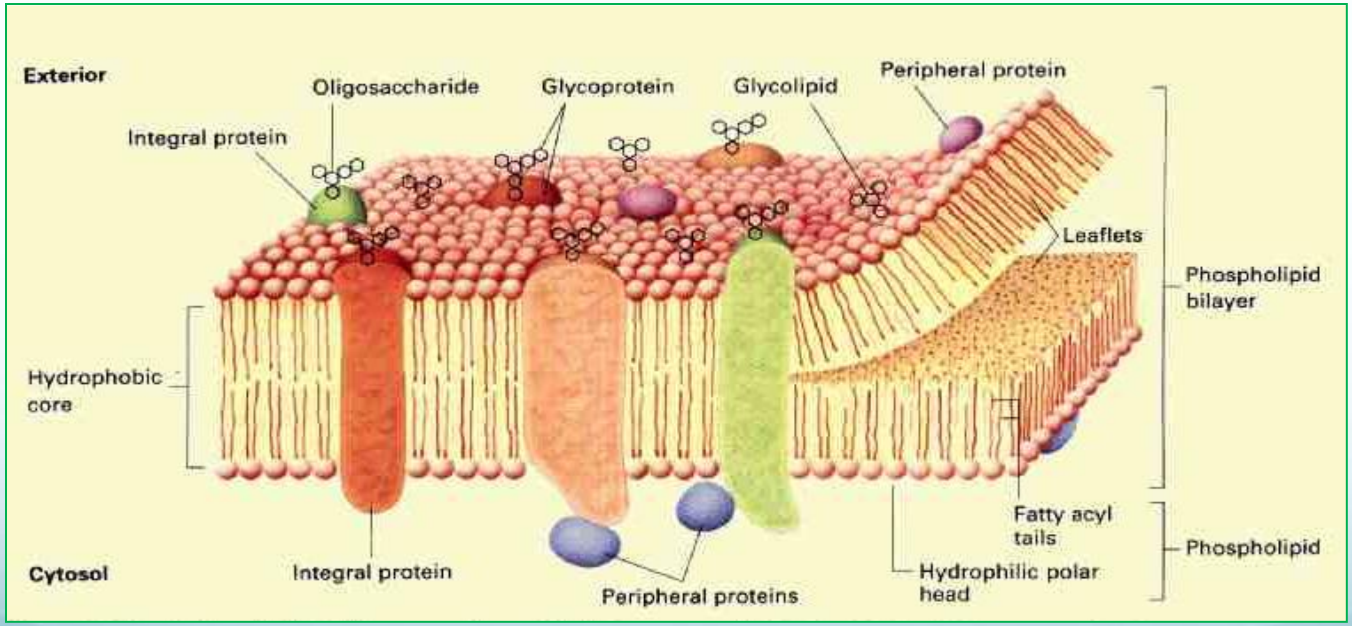
Learning Objectives

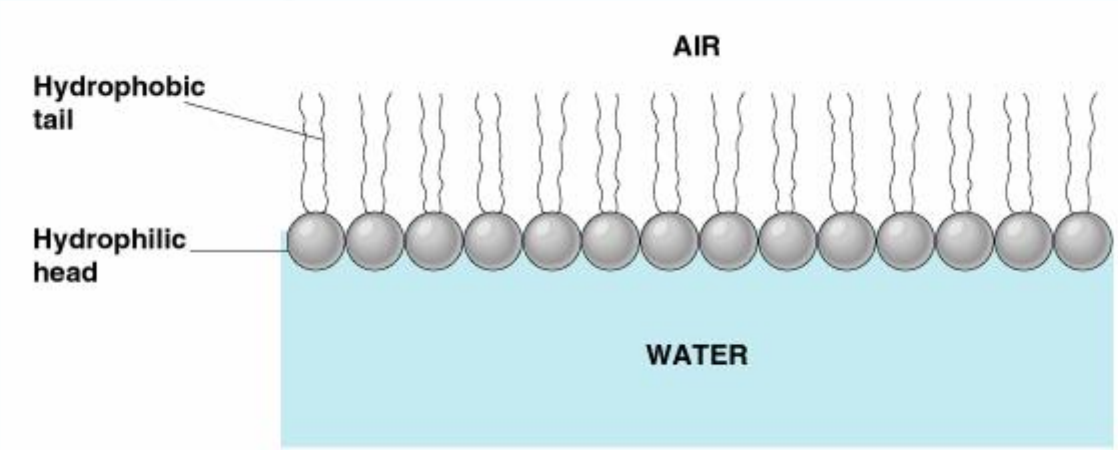
- ***Diffusion***
  - Magnitude and Direction of Diffusion
  - Diffusion Rate versus Distance
  - Diffusion through Membranes
  - Diffusion through Lipid Bilayer
  - Role of Forces on Ion Movement
    - Chemical
    - Electrical
    - Electrochemical
  - Regulation of Diffusion through Ion Channel
- ***Mediated-Transport Systems***
  - Facilitated Diffusion

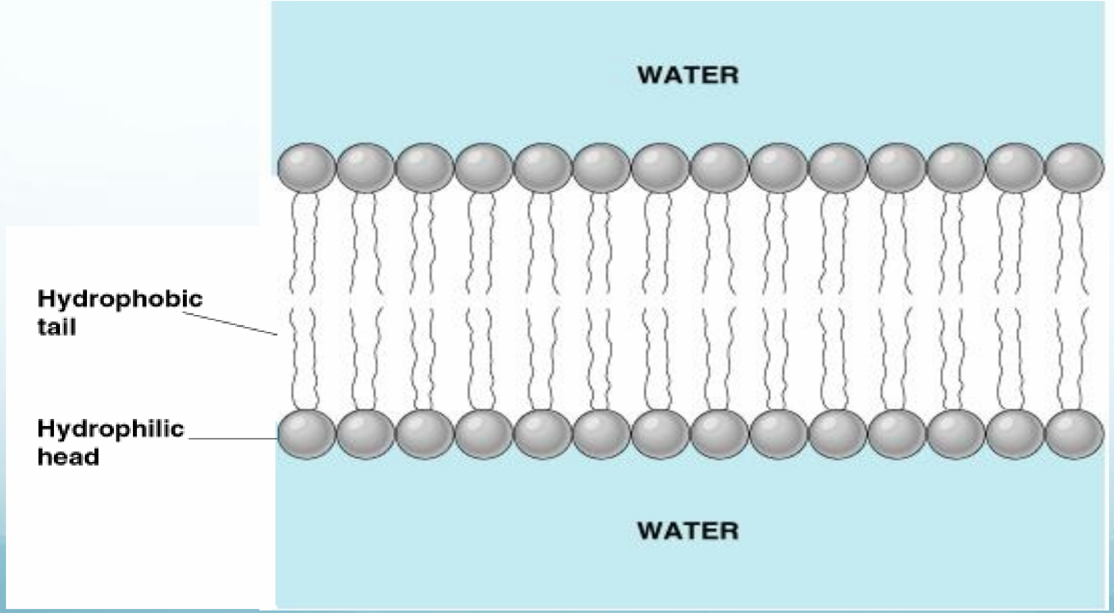
The plasma membrane

The contents of a cell are separated from the surrounding extracellular fluid by a thin layer of lipids and proteins.



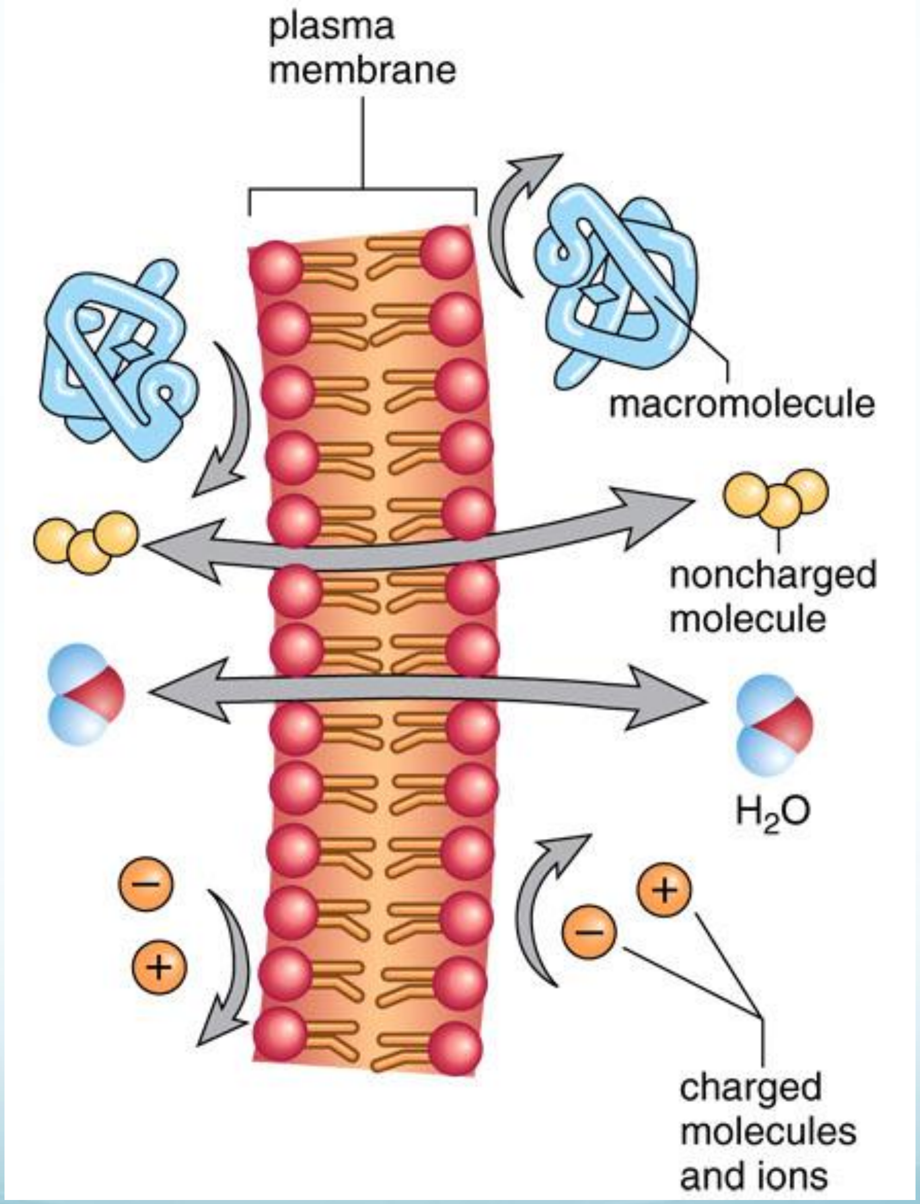
Phospholipid Bilayer





Functions of Membranes

1. Protect cell
2. Control incoming and outgoing substances
3. Maintain ion concentrations of various substances
4. Selectively permeable - allows some molecules in, others are kept out


plasma membrane
macromolecule
noncharged molecule
H_2O
charged molecules and ions

Methods of Transport Across Membranes

1. Diffusion
2. Osmosis
3. Facilitated Diffusion
4. Active Transport

Methods of Transport Across Membranes

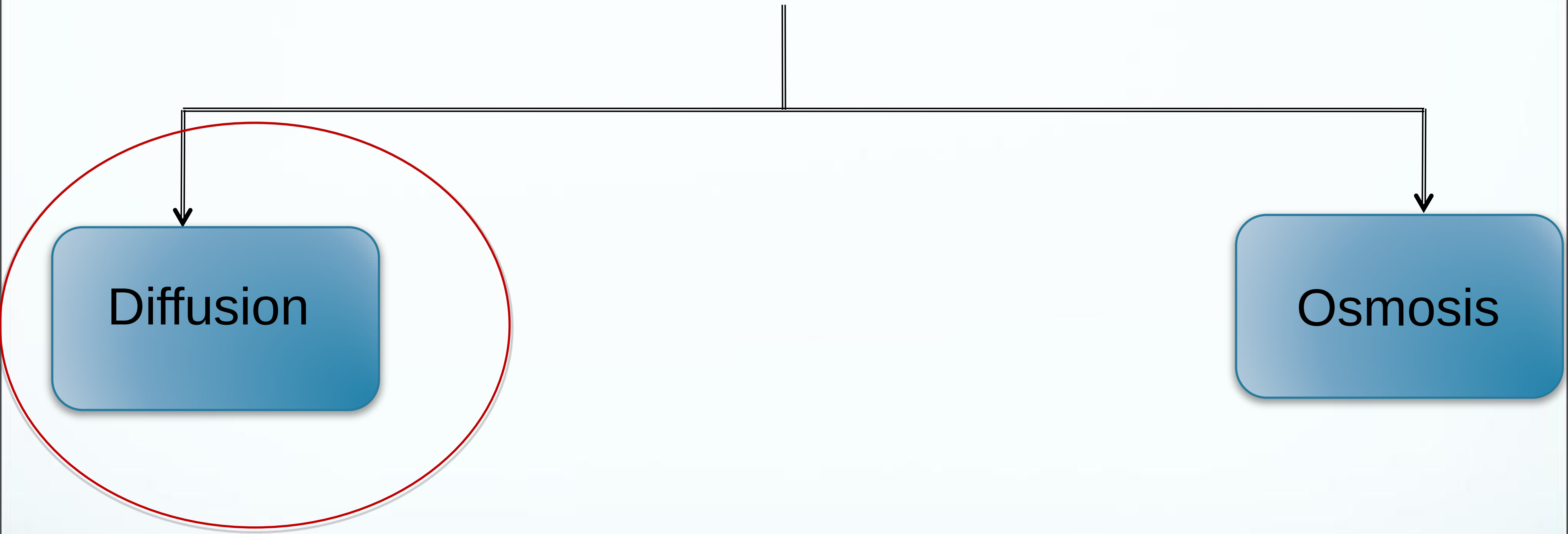
1. Diffusion -passive transport - no energy expended

2. Osmosis - Passive transport of water across membrane

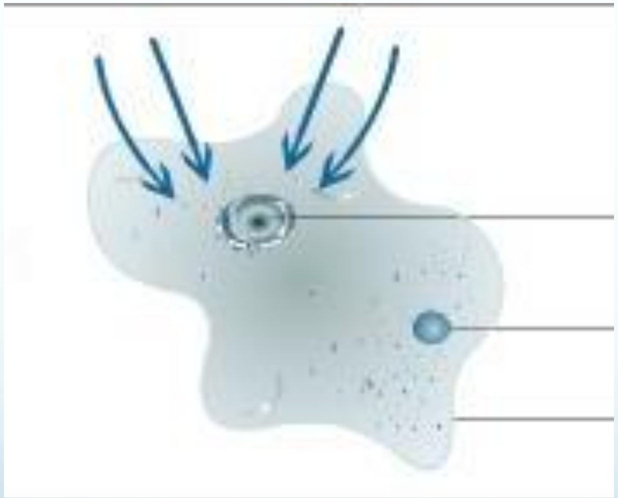
3. Facilitated Diffusion - Use of proteins to carry polar molecules or ions across

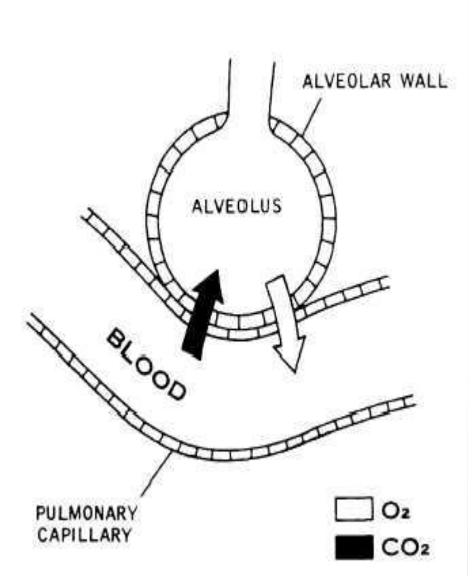
4. Active Transport- requires energy to transport molecules against a concentration gradient –energy is in the form of ATP

Movement of Substances



Diffusion



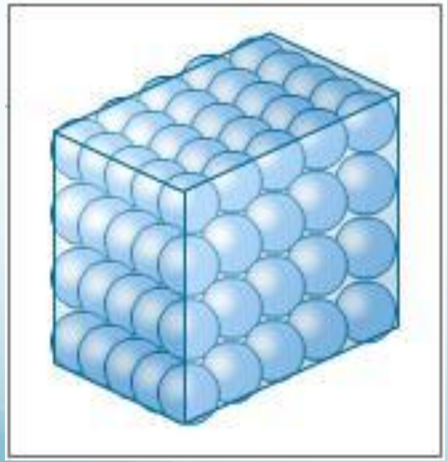


3 particle states of matter

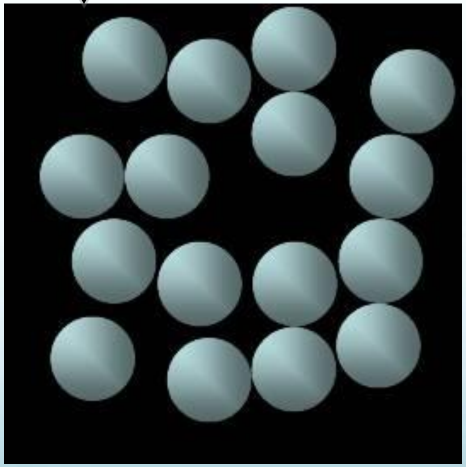
What is the particle arrangement and motion?

Diffusion

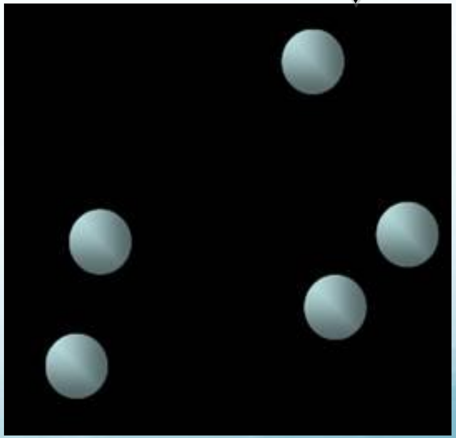
Solid



Liquid



Gas



Diffusion

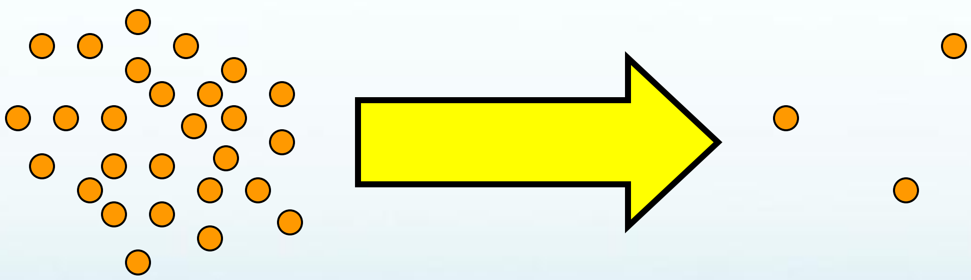
Definition:

1)The **net** movement of particles

2)from a region of **higher concentration**

3)to a region of **lower concentration,**

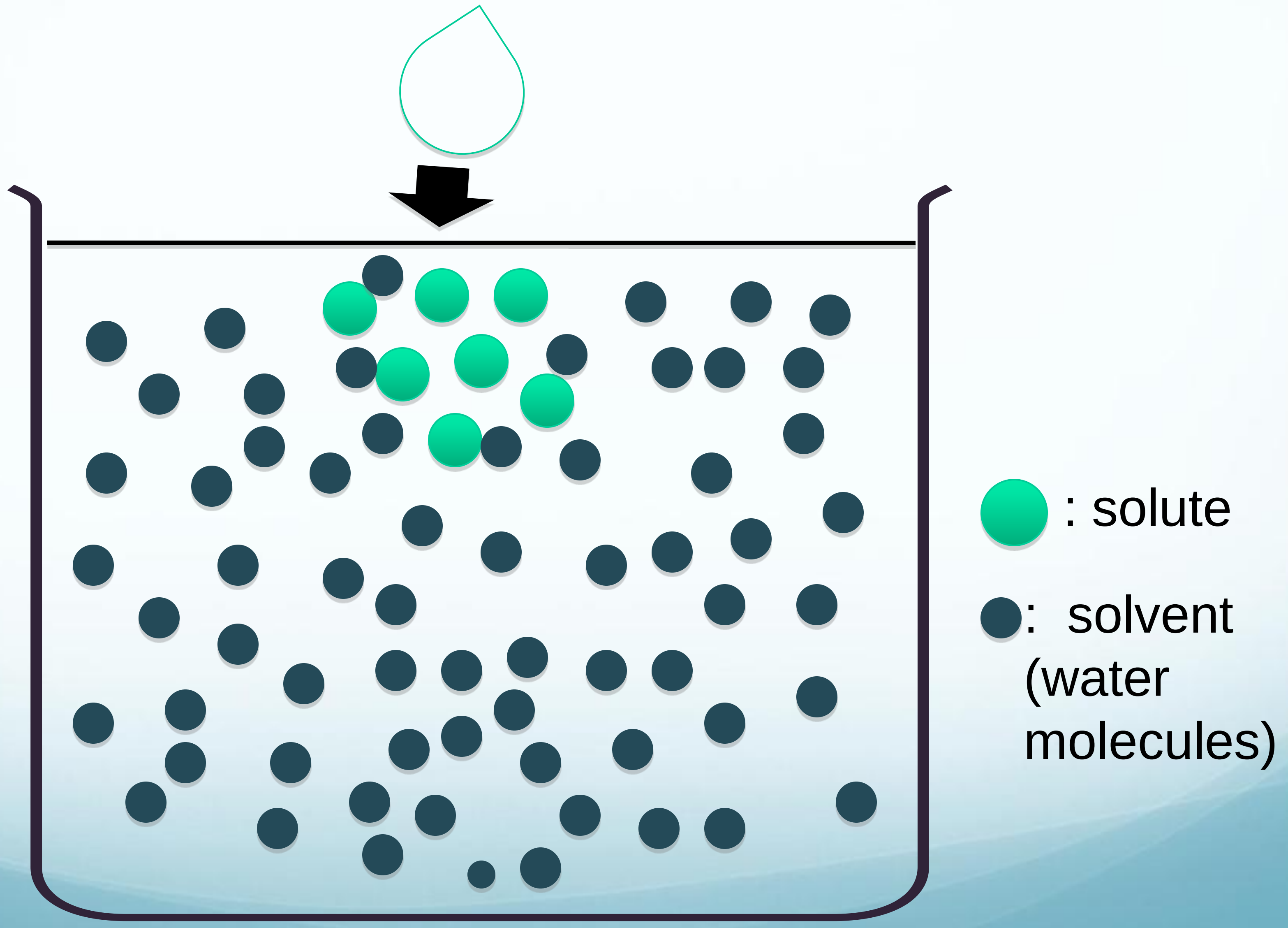
4)**down the concentration gradient.**



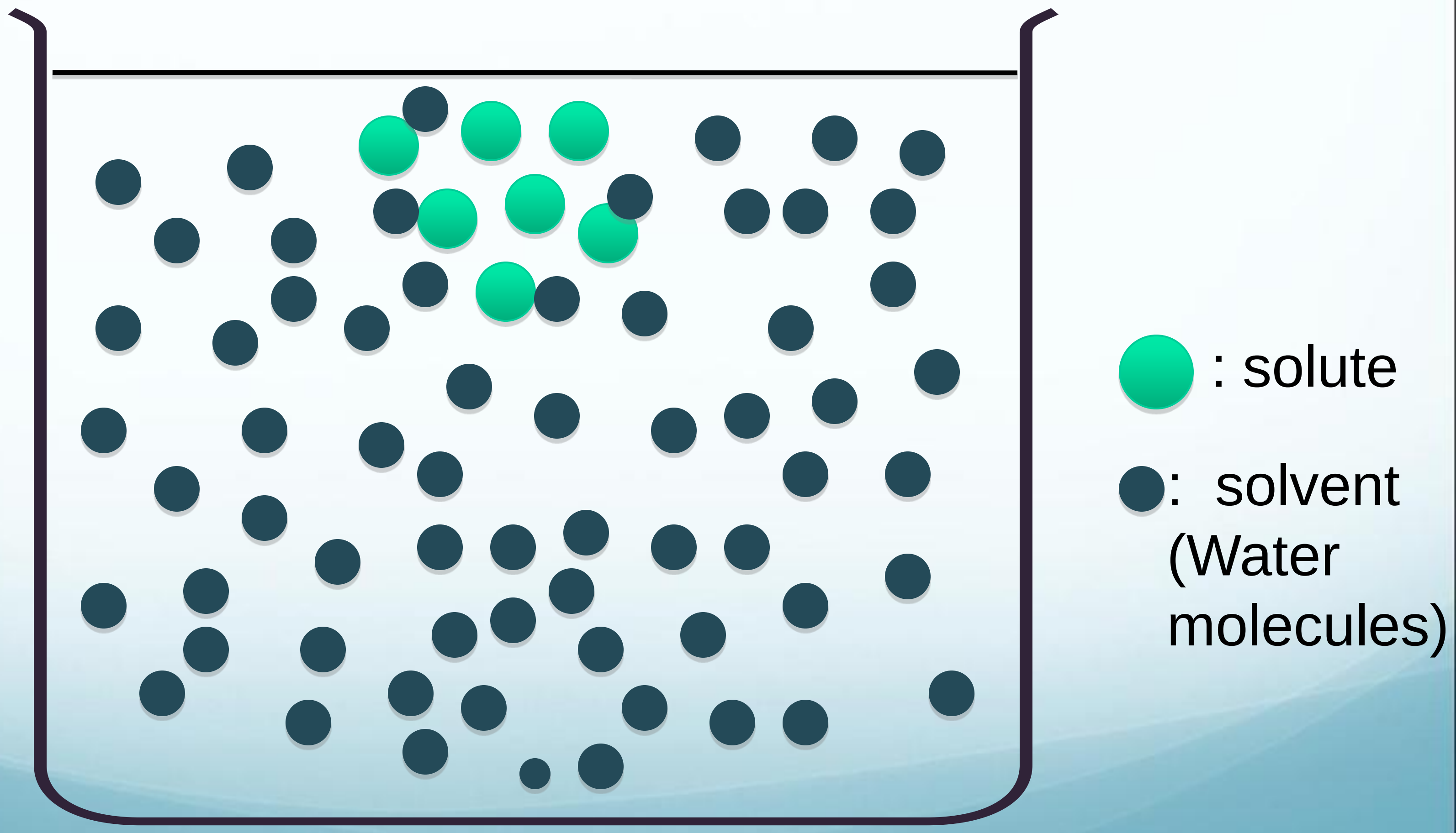
High concentration

Low concentration

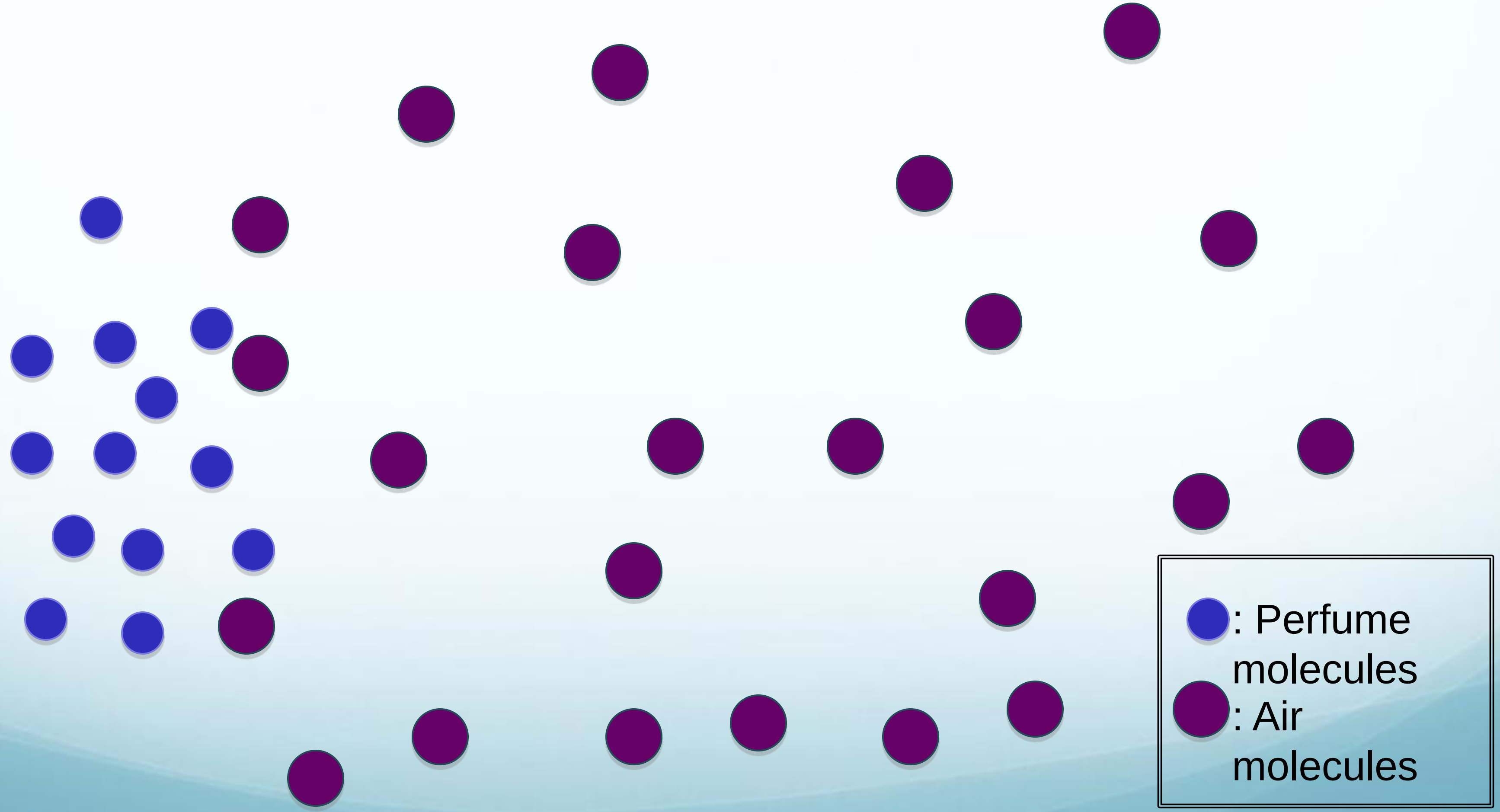
Diffusion in **liquid** state



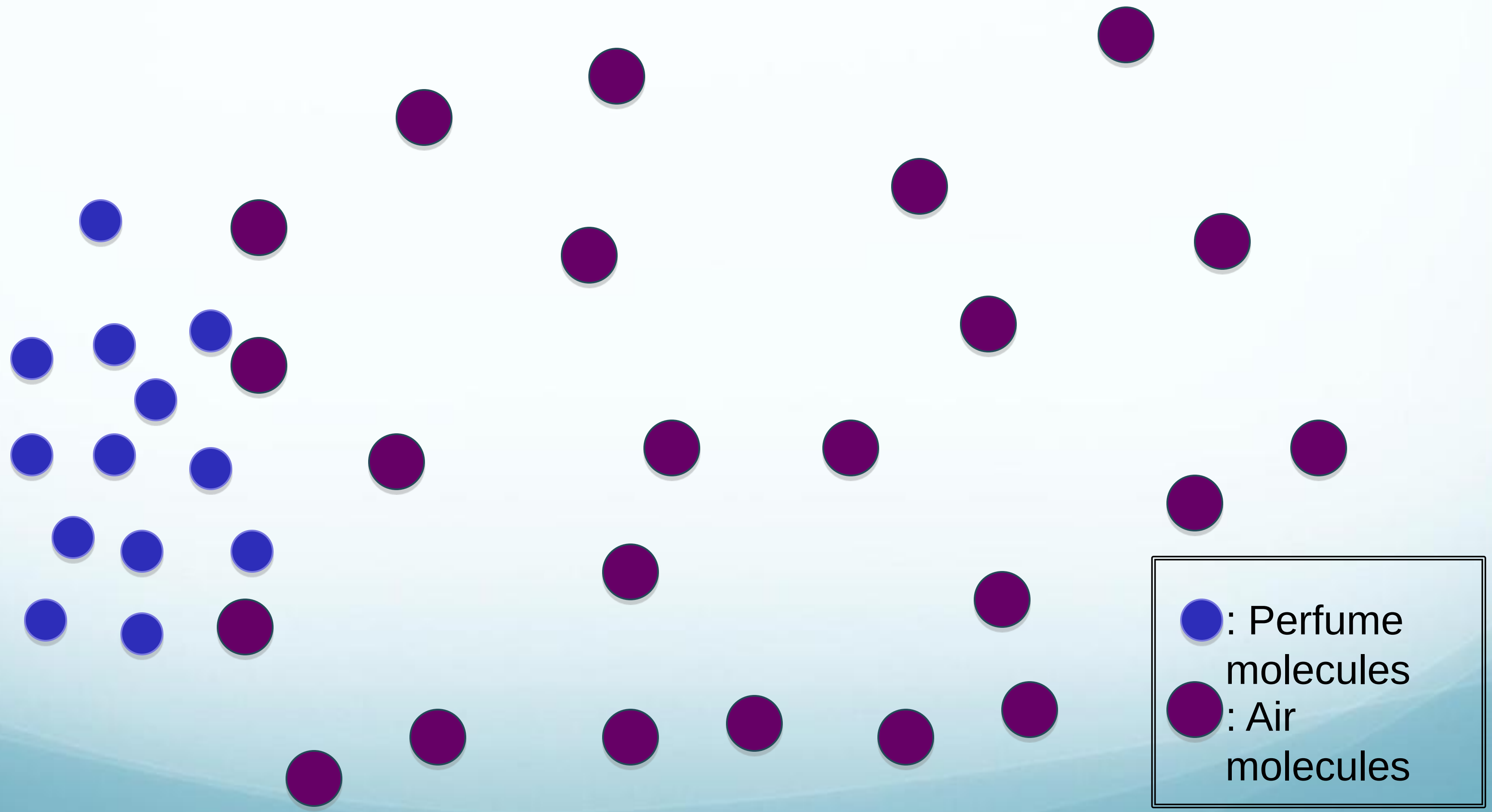
Diffusion in **liquid** state



Diffusion in **gaseous** state



Diffusion in **gaseous** state



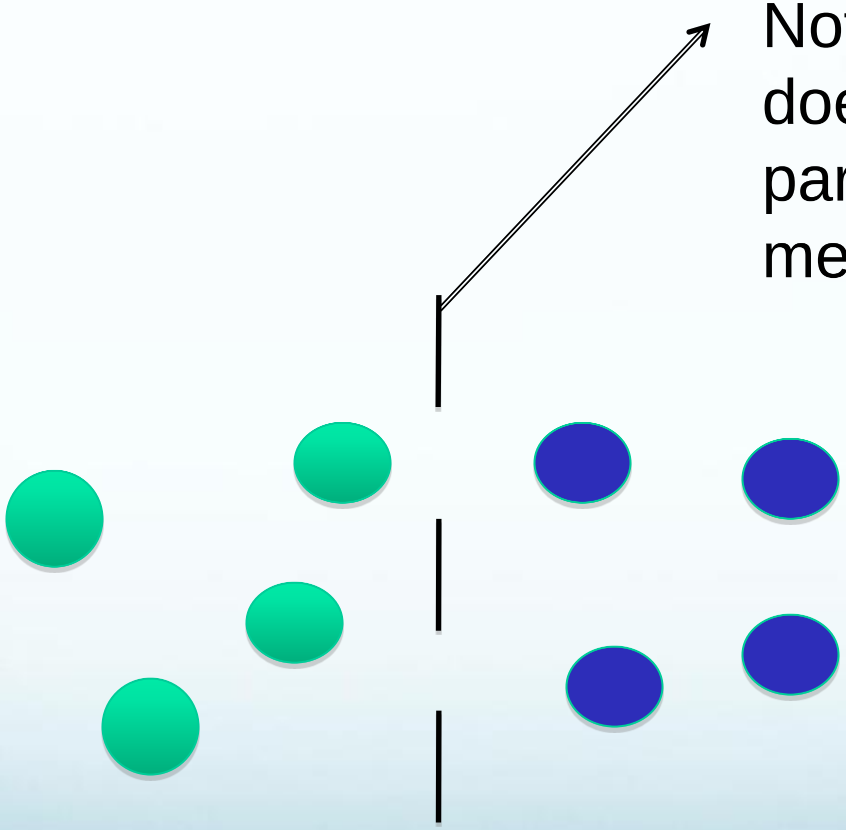
Partially Permeable Membrane

- Allows some substances to pass through but not others.
- Unequal concentration of ions in both sides of the membrane
- Eg: Cell membrane in plant and animal cells.

Permeable Membrane

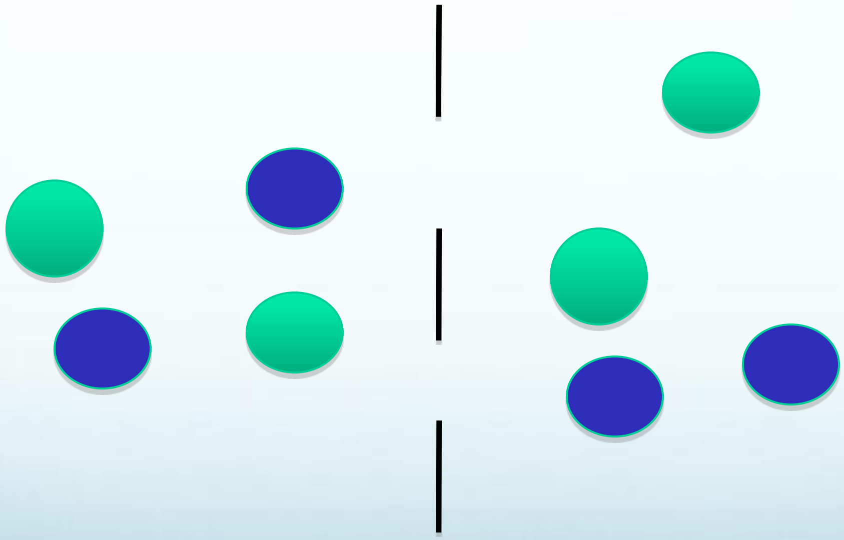
- Allows both the solvent (water) and the solutes (dissolved substances to pass through)
- Equal concentration of all ions in both sides of the membrane.
- Eg: Cell Wall of plant cells

Net Movement



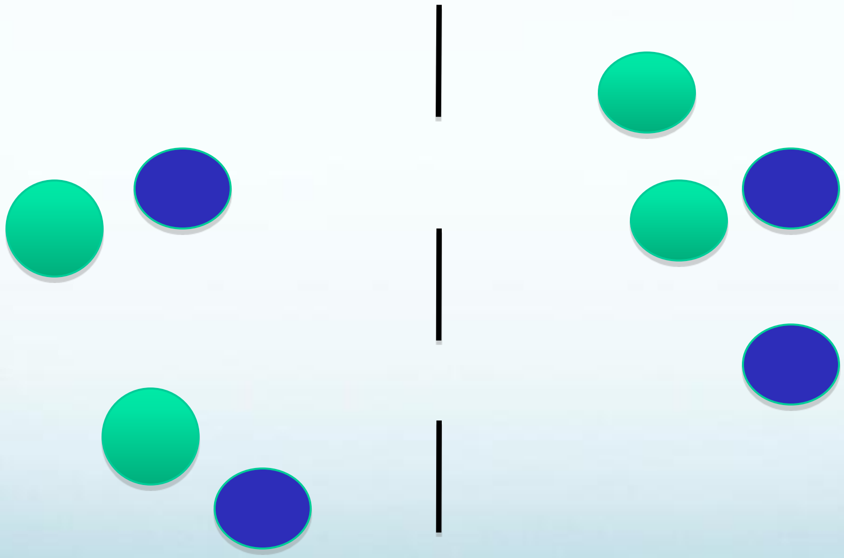
Note: This barrier does not illustrate a partially permeable membrane.

Net Movement



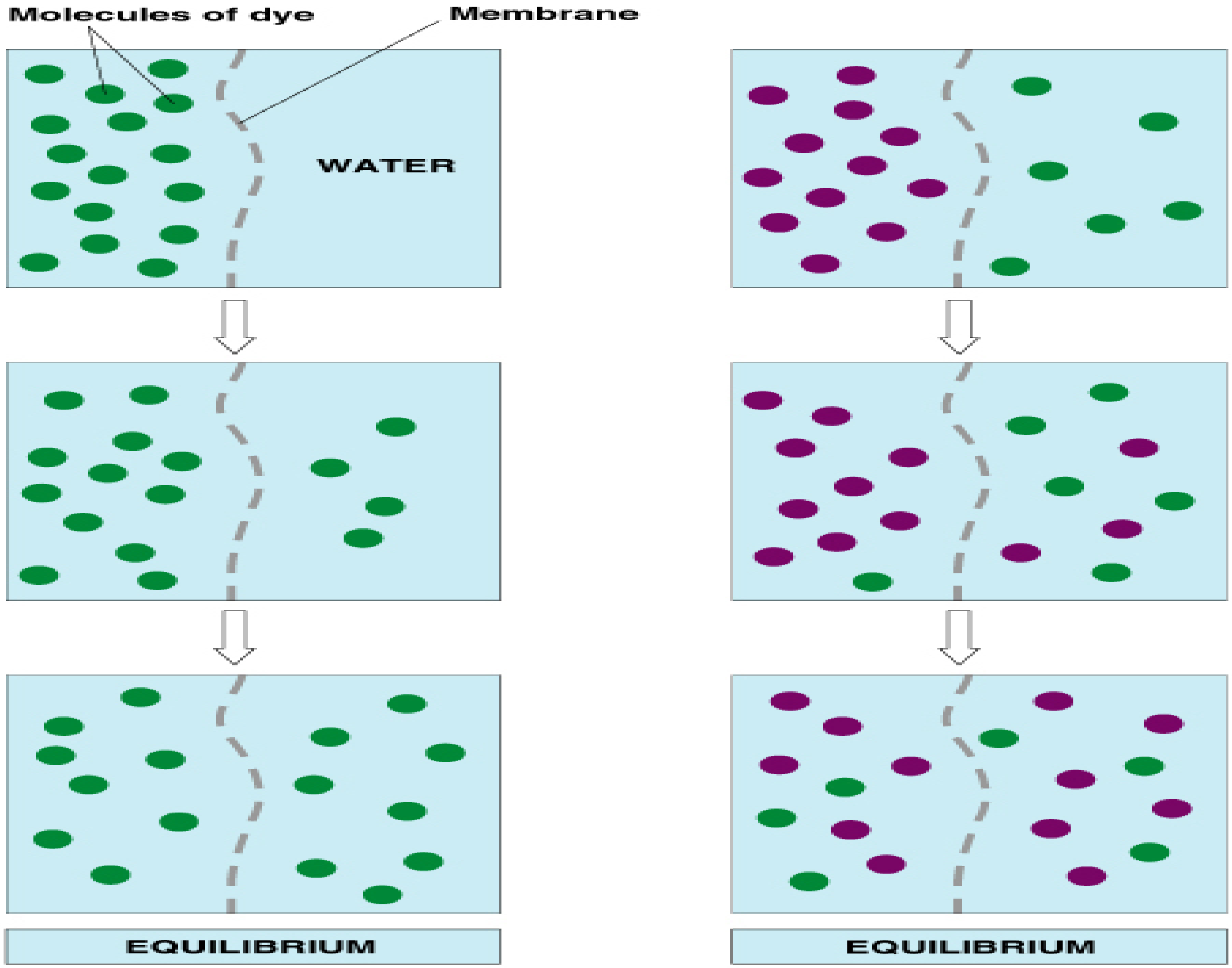
Equilibrium

When particles reaches an equilibrium, does the particles stop moving?



Hint: Particles move in a random and dynamic motion.

Diffusion



(a) Diffusion of one solute

(b) Diffusion of two solutes

Types of Diffusion

- Simple diffusion : no requirement for a carrier
- Rate is determined by the
  - Amount of substance
  - Velocity of the kinetic motion
  - Number of openings in the membrane
- Facilitated diffusion: interaction with a carrier protein
  - Binds chemically and then shuttles
  - Rate is limited to the concentration of carrier

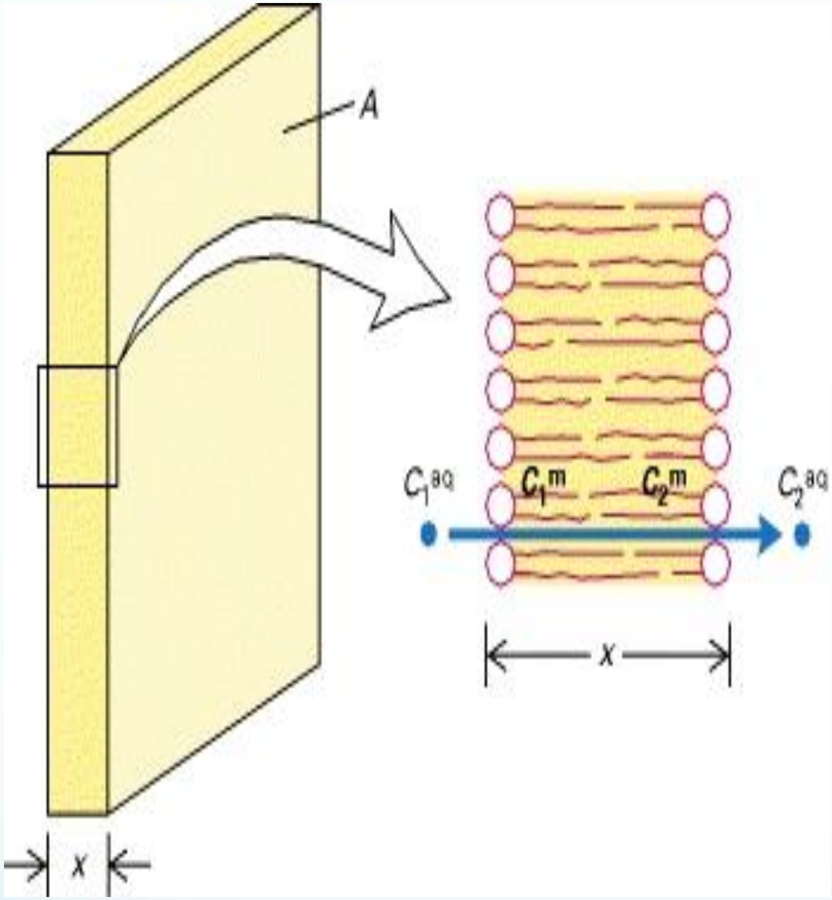
Diffusion through Membranes

- The net flux *F of material across* the membrane is from the region of higher concentration (the extracellular solution) to the region of lower concentration (the intracellular fluid).

- The major factor limiting diffusion across a membrane is the hydrophobic interior of its lipid bilayer.
- Most polar molecules diffuse into cells very slowly or not at all, and have a much lower solubility in the membrane lipids.
- Nonpolar molecules diffuse much more rapidly across plasma membranes— that is, they have large permeability constants.

- The hydrophobicity of a substance is measured by its partition coefficient, K
- K is a measure of equilibrium for its partition between oil & water
- K = $\frac{c_m}{c_{aq}}$
- the higher the K, higher the lipid solubility
- e.g. K for urea: 0.0002; K for diethylurea : 0.01
- Diethylurea is ~ 50 x more hydrophobic

- in hydrophobic core: diffusion rate is slower
- (100-1000 x viscous w.r.t. Water)
- Movement through the hydrophobic core is the rate limiting step



$$\frac{dn}{dt} = PA(C_1^{aq} - C_2^{aq})$$

- For any molecule, the value of *P*, and thus its rate of passive **diffusion**, is proportional to its partition coefficient *K and diffusion coefficient D*:

$$P = \frac{KD}{x}$$

- *The greater the permeability constant*, the larger the net flux across the membrane for any given concentration difference and membrane surface area.
- A membrane acts as a barrier that considerably slows the diffusion of molecules across its surface.

Increasing the lipid solubility of a substance will increase the number of molecules dissolved in the membrane lipids and thus increase its flux across the membrane.

$$F = P \cdot A \cdot (C_o - C_i)$$

The magnitude of the net flux is directly proportional to;

- **the difference in concentration across the membrane,** $(C_o - C_i)$
- ***the surface area of the membrane*** **,** A
- ***the membrane*** **permeability constant,** P

F : The magnitude of the net flux.

- Since P = K D / x:
- $\frac{dn}{dt}\frac{1}{A}$ = K.D. $\frac{\Delta C}{\Delta x}$

Thickness is around 2.5-3 nm, D is similar for most molecules, then it largely depends on K

Gases and small, uncharged molecules like ethanol, urea, oxygen, nitrogen, carbondioxide and alcohols: easily diffuse

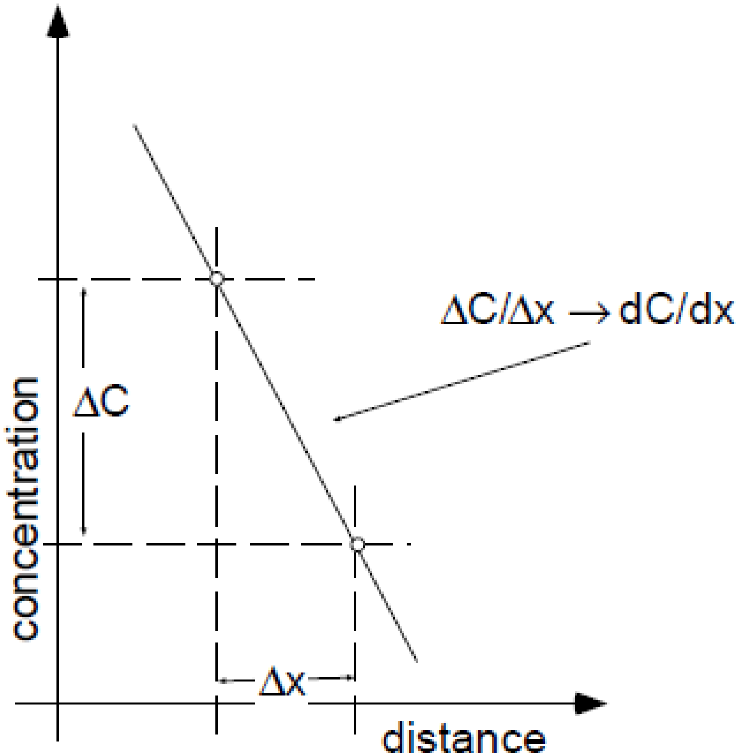
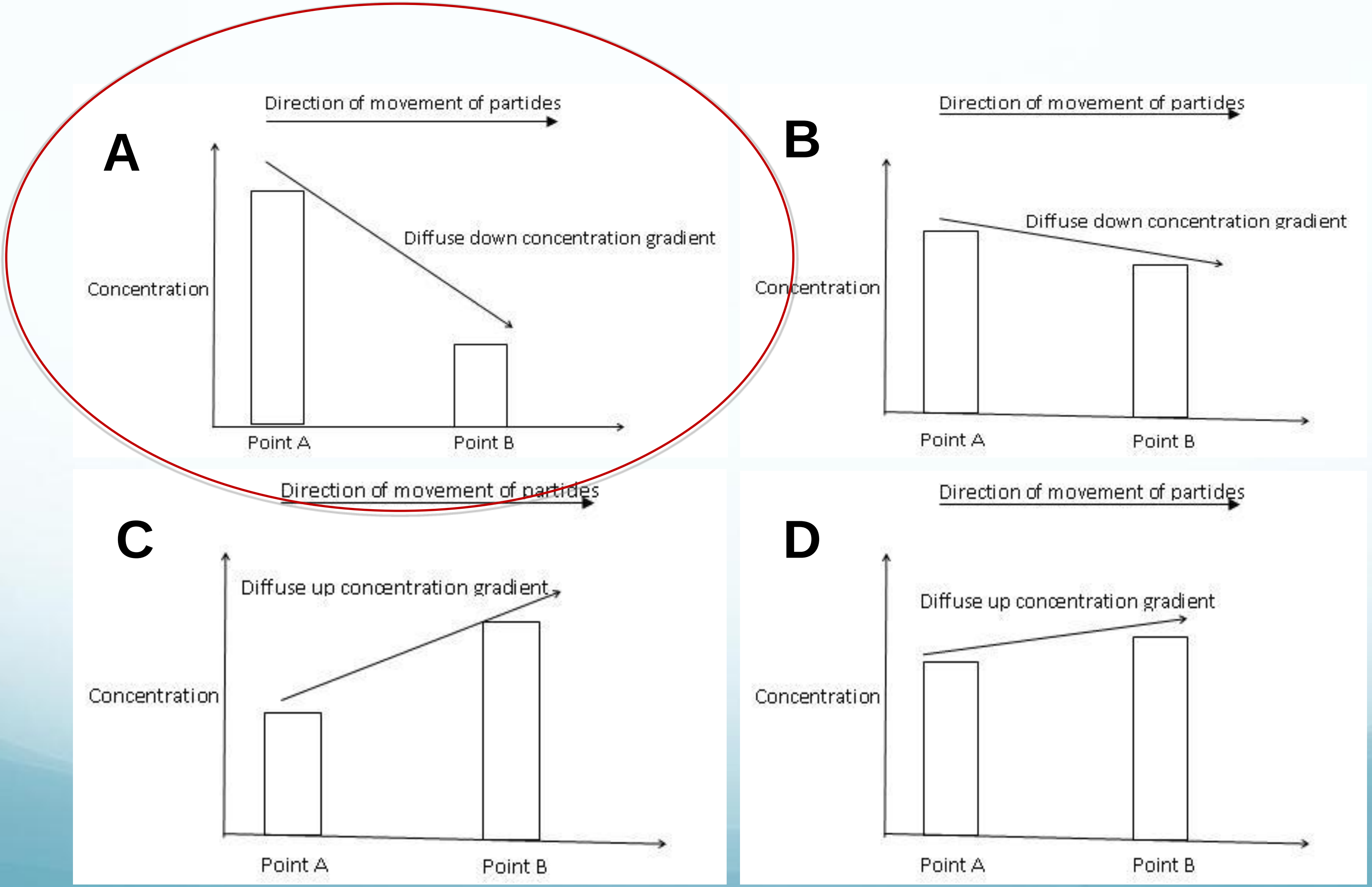
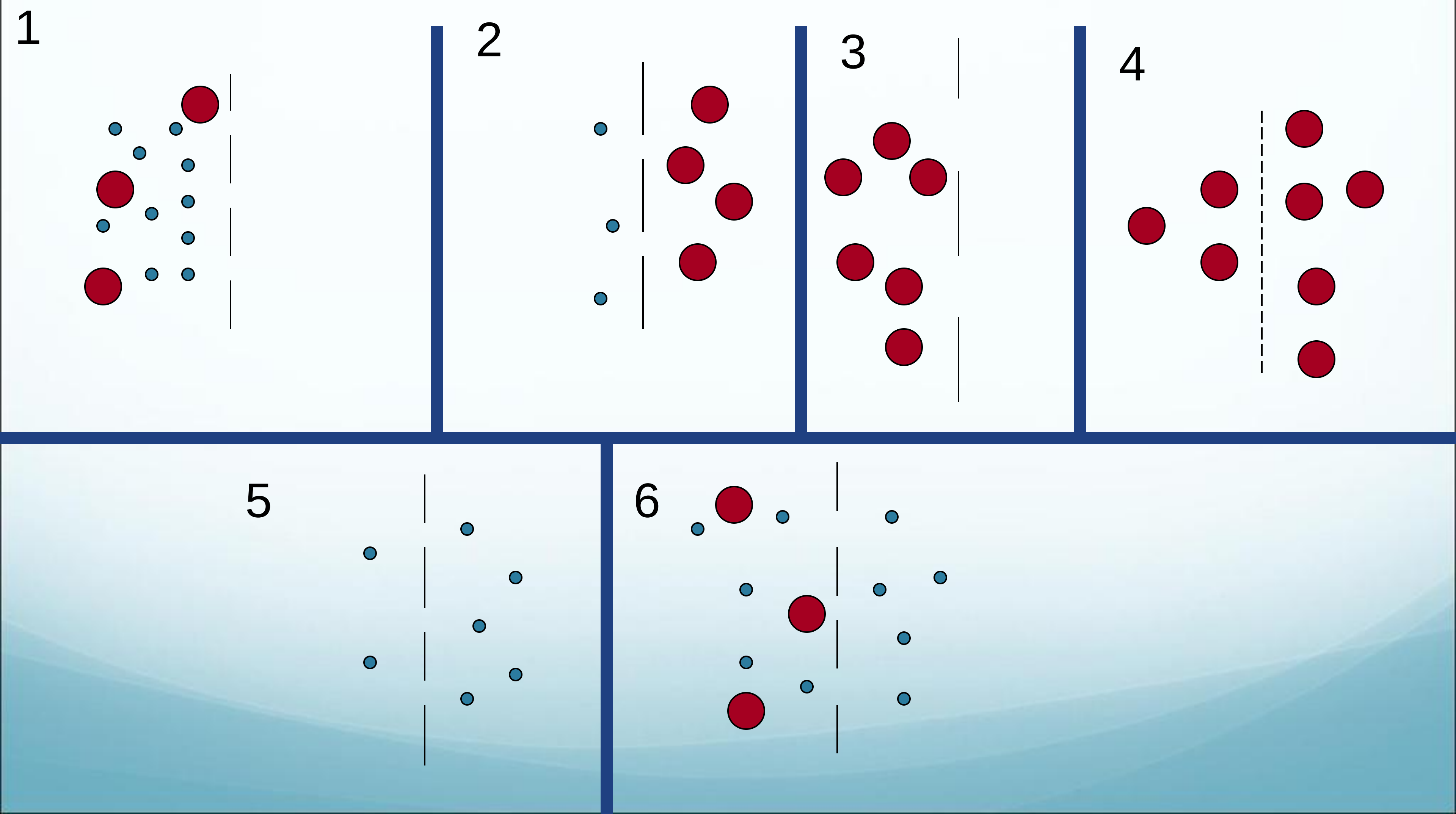


Figure 2 Concentration gradient (constant) in the x direction

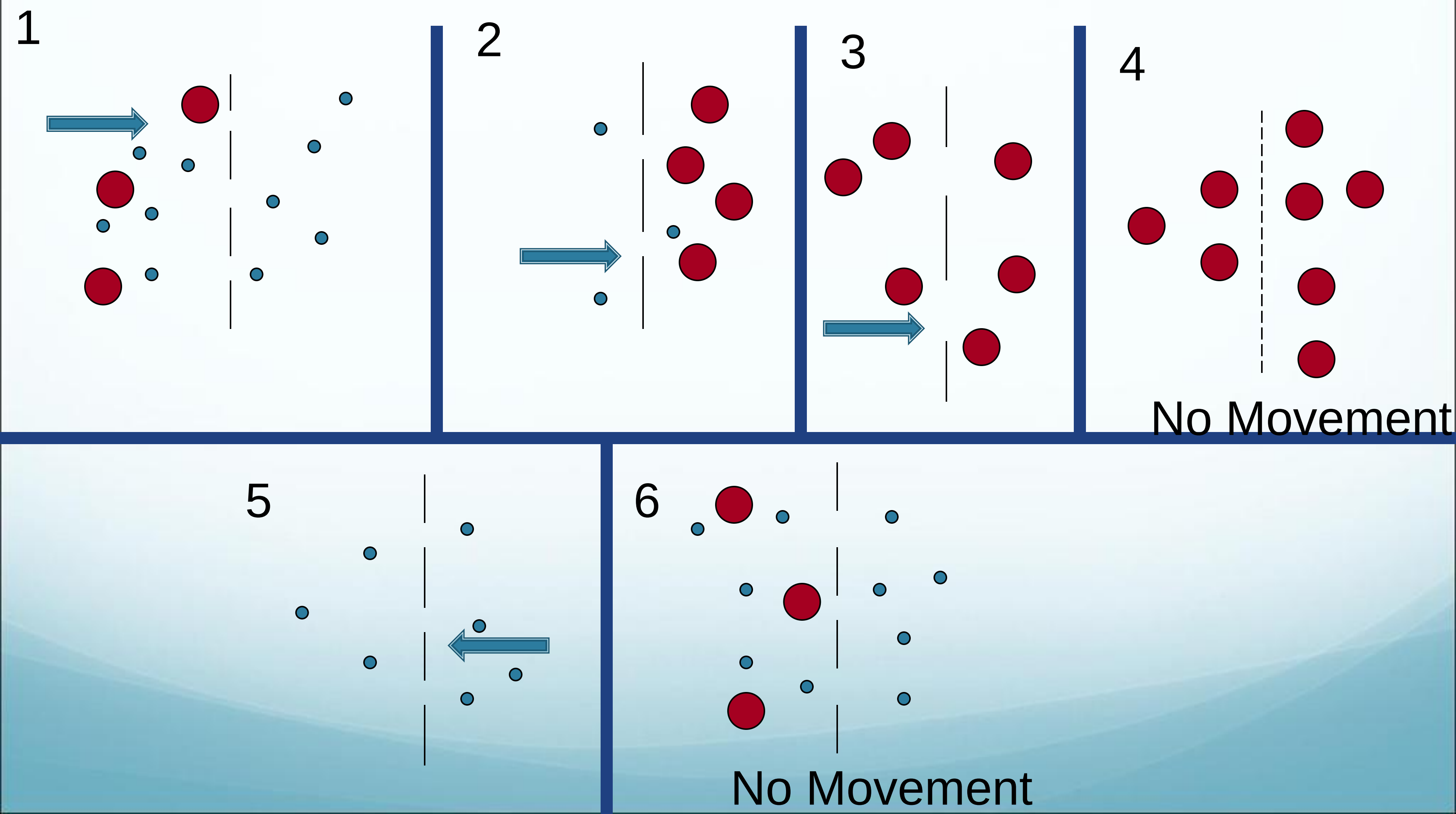
Which graph will result in the fastest rate of diffusion?



Which molecules will diffuse in each of the figures below?



ANSWERS



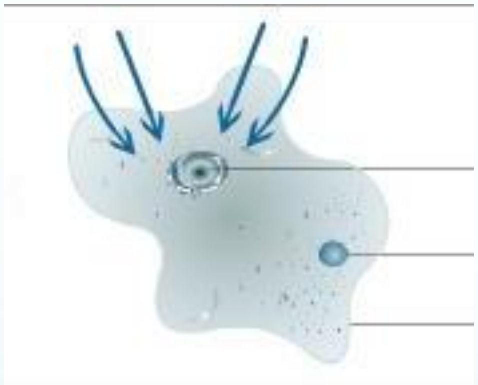
Many processes in living organisms are closely associated with diffusion.

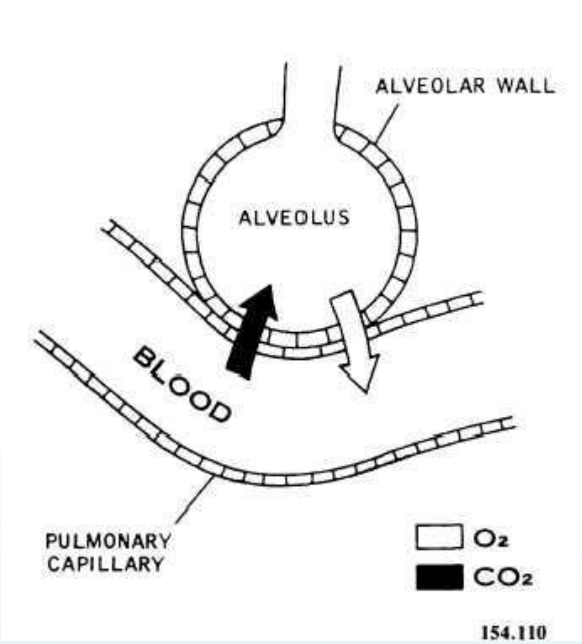
<u>For example,</u>

- Oxygen, nutrients, and other molecules enter and leave the smallest blood vessels (capillaries) by diffusion
- The movement of many substances across plasma membranes and organelle membranes occurs by diffusion.

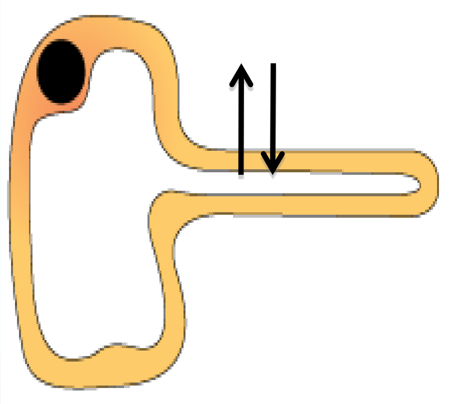
Examples

Movement of substances in and out of **amoeba cells**





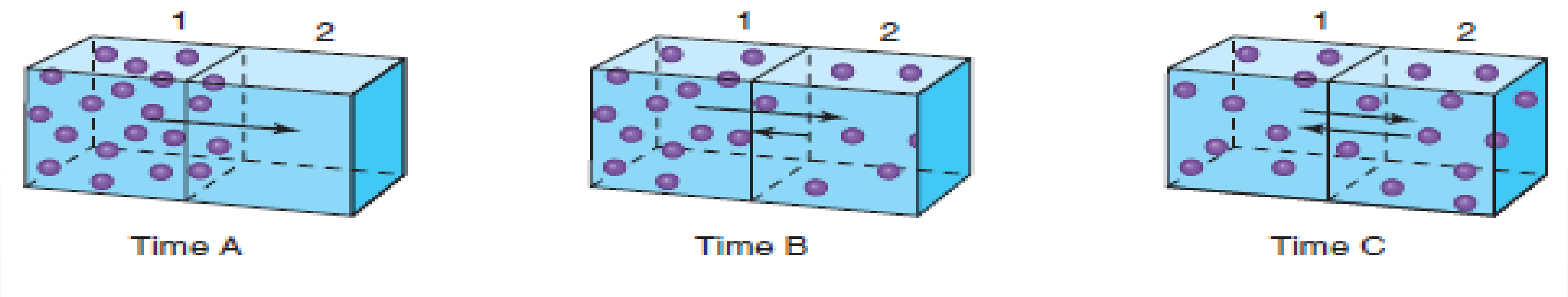
Movement of CO_2 and O_2 in and out of **lung cells**

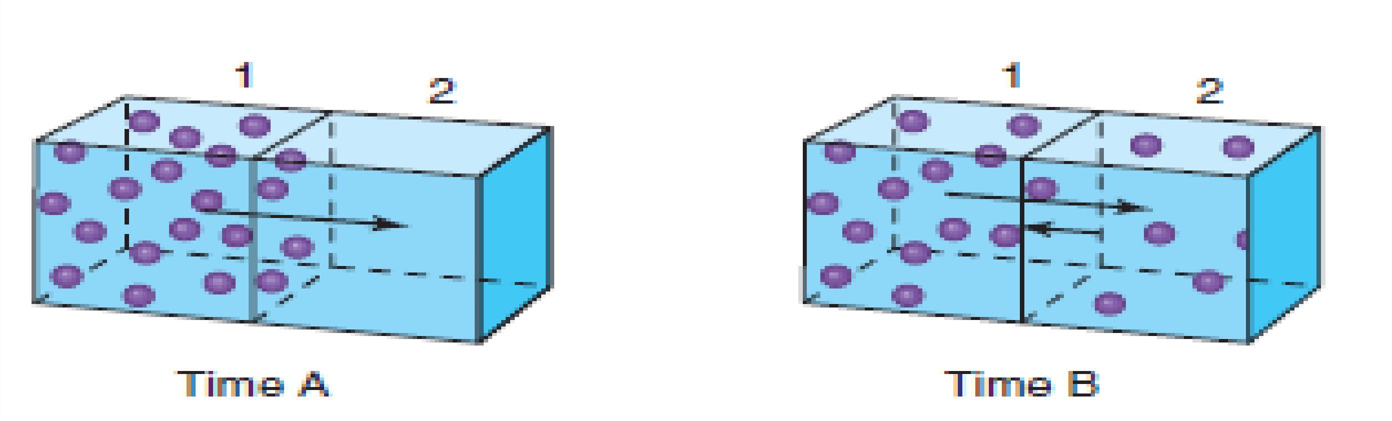


Movement of nitrates in and out of **root hair cells**

Magnitude and Direction of Diffusion

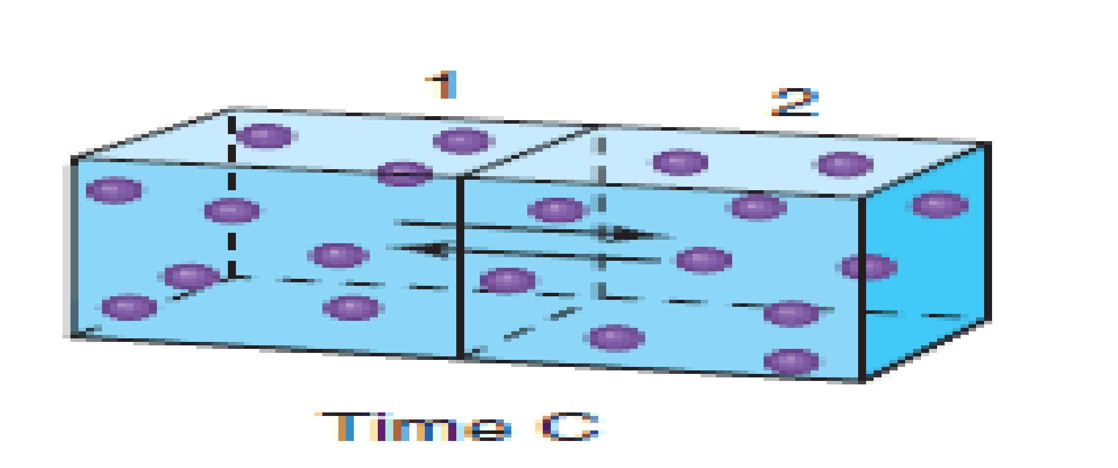
The diffusion of glucose between two compartments of equal volume separated by a barrier permeable to glucose.





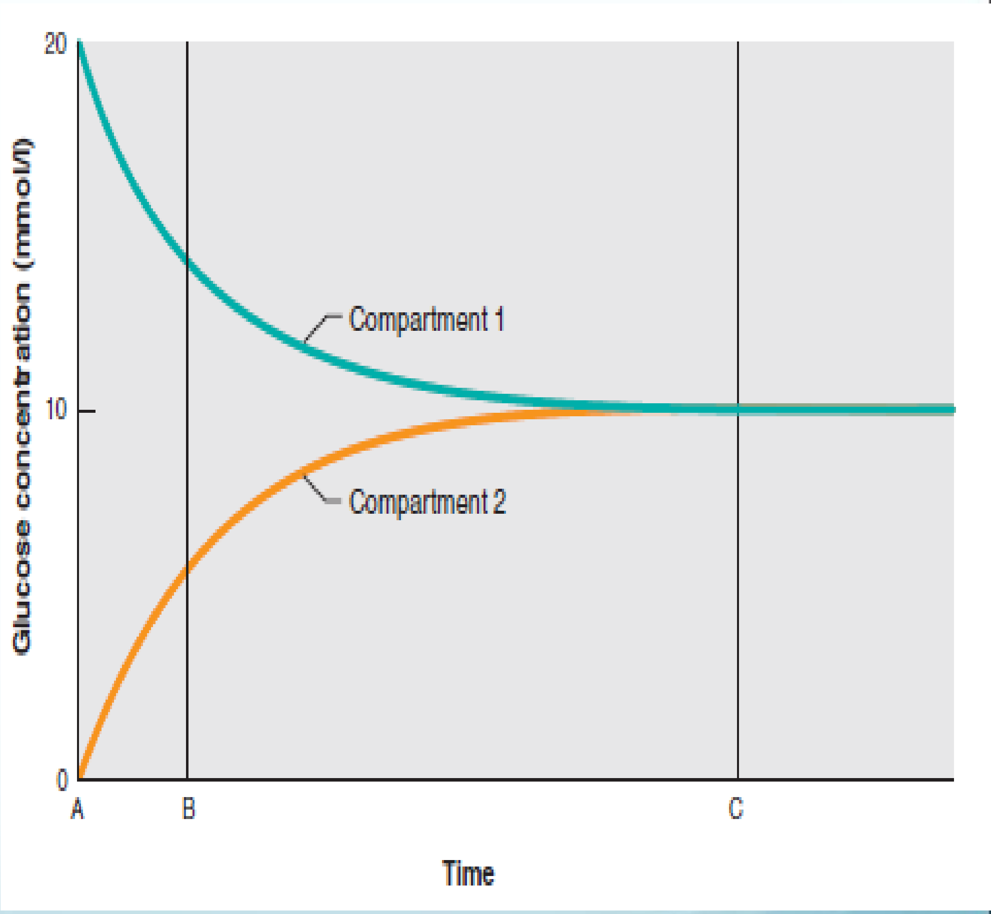
- At time A,
  - *compartment 1* contains glucose at a concentration of 20 mmol/L,
  - no glucose is present in *compartment 2*.
- At time B,
  - some glucose molecules have moved into *compartment 2*,
  - some of these are moving back into *compartment 1*.

P.S: The length of the arrows represents the magnitudes of the one-way movements



- At time C,
  - diffusion equilibrium has been reached, the concentrations of glucose are equal in the two compartments (10mmol/l).
    - The *net movement is zero at* equilibrium.

- The green line represents glucose concentration in compartment_1.
- The orange line represents glucose concentration in compartment _2.
- At time C, glucose concentration is 10 mmol/L in both compartments.

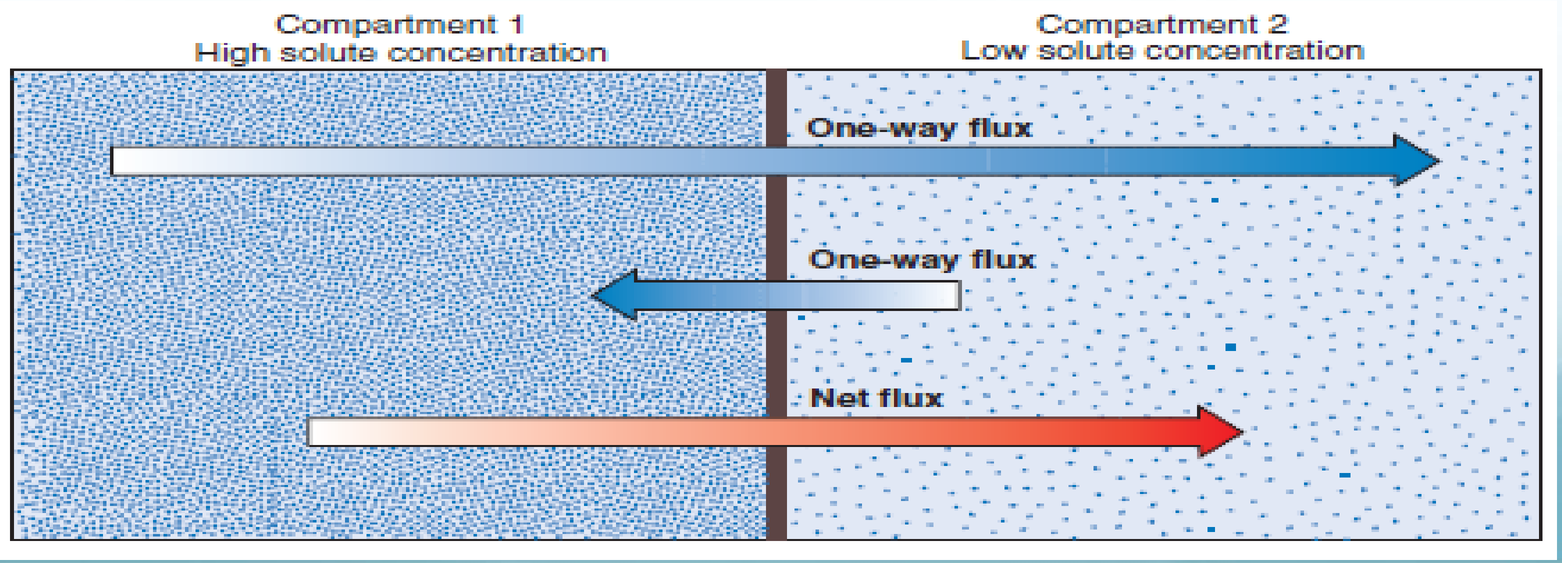


This one-way flux of glucose from compartment_1 to compartment_2 depends on the concentration of glucose in compartment_1.

P.S: The amount of material crossing a surface in a unit of time is known as a **flux.**

Three fluxes can be identified at any surface:

- Two one-way fluxes
  - occurring in opposite directions from one compartment to the other
- The net flux,
  - which is the difference between them.

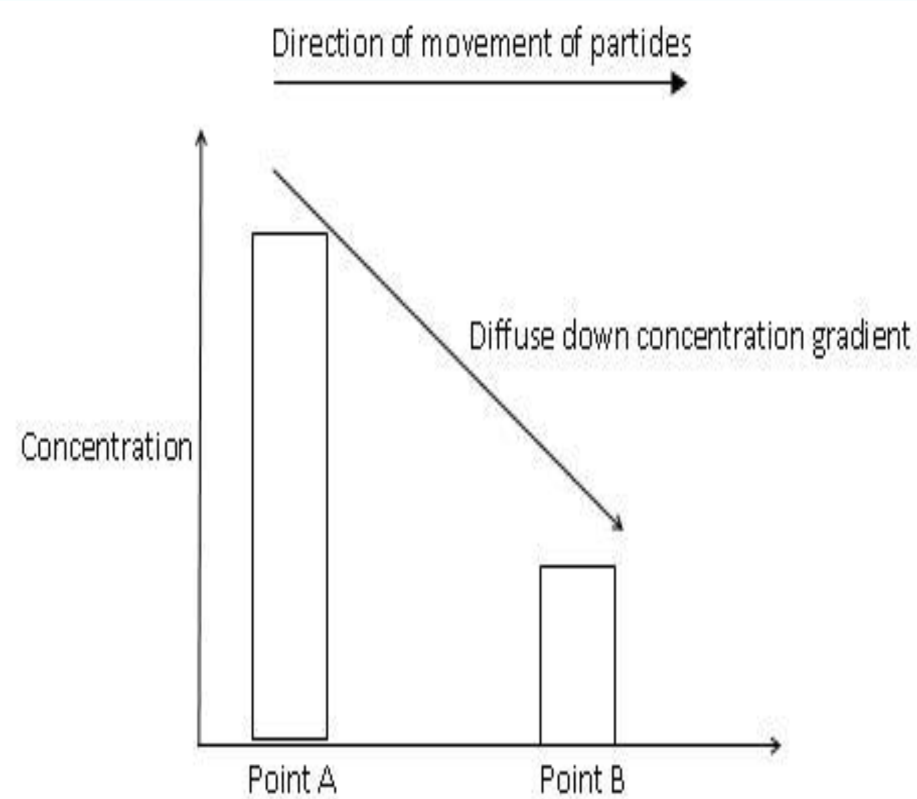


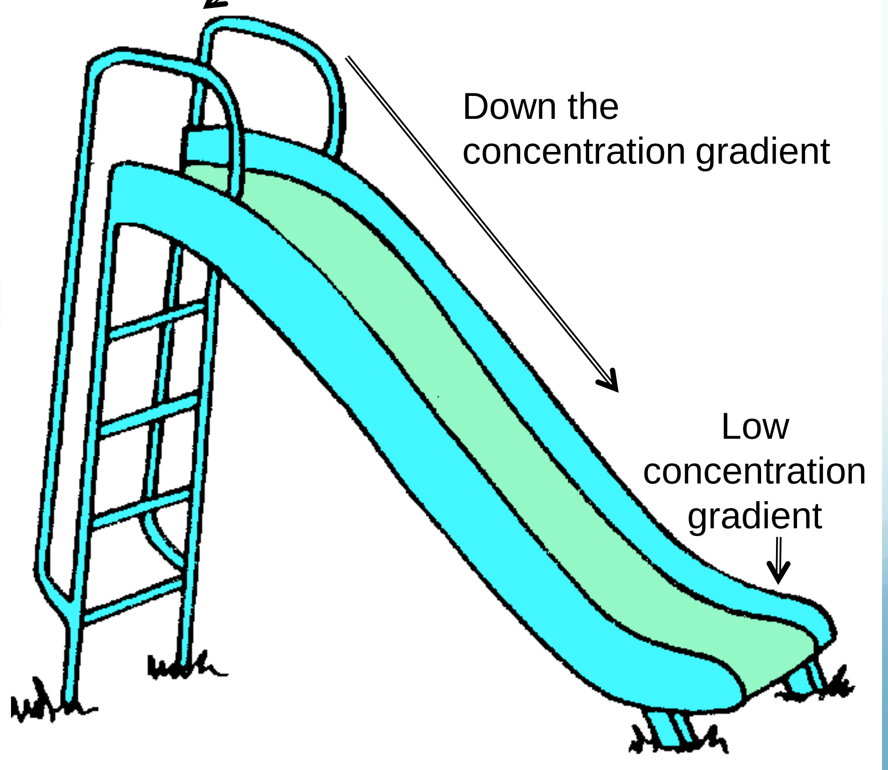
The movement of individual molecules is random, the net flux always proceeds from regions of higher concentration to regions of lower concentration. *For* this reason, we often say that substances move *"down hill"* by diffusion.

Both the direction and the magnitude of the net flux are determined by the concentration difference.

Concentration Gradient

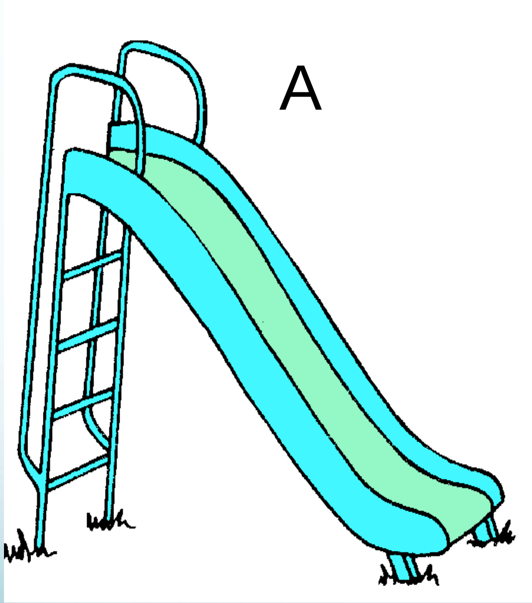
The concentration **difference** between regions of high concentration and low concentration.

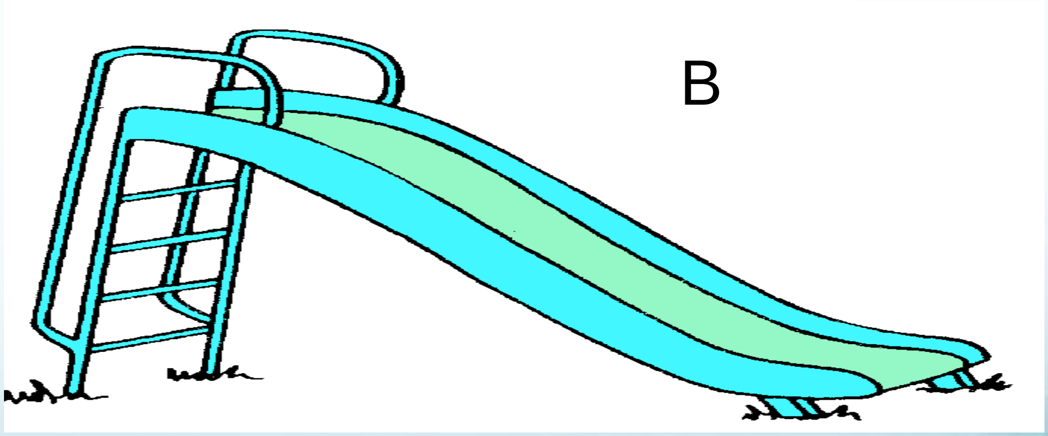




Concentration Gradient

Which slide will allow you to go down faster?



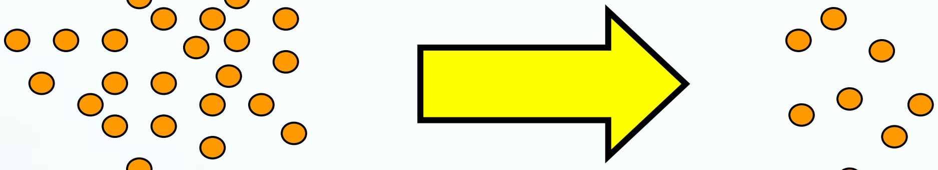


Answer: A

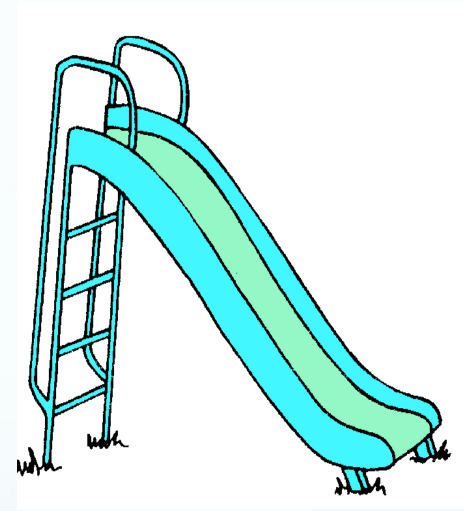
Concentration Gradient

The **steeper** the concentration gradient, the **faster** diffusion takes place

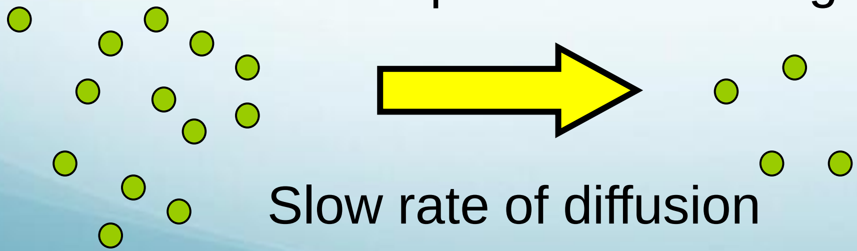
Steeper concentration gradient



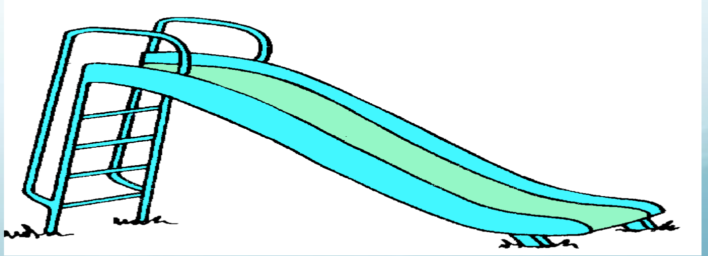
Fast rate of diffusion



Less steep concentration gradient



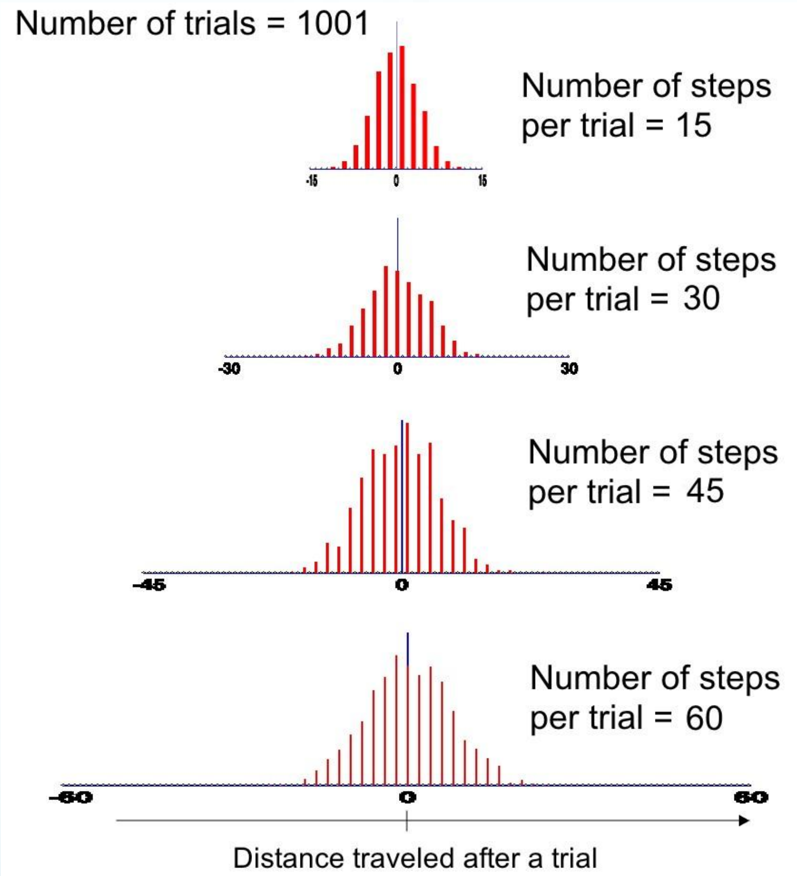
Slow rate of diffusion



Diffusion coefficient

- A molecule moving inside a liquid with velocity v will experience some friction given by :
- F = - f . V, where f is the friction coefficient
- F depends on the size and shape of the molecule & viscosity of the liquid.
- e.g. For a spherical molecule with radius r :
- $f = 6 \pi \eta \; r$

- Diffusion is similar to random walk:
- 1.Each particle steps to the right or to the left every ΔT seconds, moving at a velocity v for a distance v.ΔT.
- 2.The probability of going to the right at each step is 1/2, and the probability of going to the left at each step is 1/2. Successive steps are statistically independent (that is, what they do does not depend on what has gone before).
- 3.Each particle moves independently of all the other particles. The particles do not interact with one another. (This is because we are focusing on will be true to a good approximation in practice provided that the suspension of particles is sufficiently dilute.)



Average path will be zero, but $\overline{x^2}$ will be an increasing value.

If we use our probability function to calculate the average value of x^2

$$\langle x^2 \rangle = 2Dt$$

or

$$\text{distance distribution has spread} = \sqrt{\langle x^2 \rangle} = \sqrt{2Dt}$$

in 3-D:

$$\langle r^2 \rangle = 6Dt$$

where

$$r^2 = x^2 + y^2 + z^2$$

- After a time, there will be a gaussian distribution where 2/3 of the particles stayed in short path, 1/3 take long distance, and most probable is to return to the original position

- As the steps increase distribution curve becomes wider.

- Molecules in solution are not independent!
- According to the kinetic theory, for ideal gases and liquids, average kinetic energy of particles in temperature T is 1/2kT in 1-D, 3/2kT in 3-D
- Where k is the Boltzmann constant, 1.3×10^{-23} J/K

Stoke-Einstein Law

Boltzmann constant, $k = R/N$

R = gas constant ($8.314\ JK^{-1}mol^{-1}$)

N = Avogadro number ($6.022 \times 10^{23}\ mol^{-1}$)

From Einstein:

$$D = kT/f$$

- $D = kT/\ 6\pi\eta r$ or
- $D = RT/6N\pi\eta r$

- MW = N . ρ V, for a global molecule V = 4/3πr^3
- If we take r from this equation and insert it to the equation in the previous slide:
- D = $\frac{k\,T}{6\,\pi\,\eta}\sqrt[3]{\frac{4\,\pi\,\rho\,N}{3\,MW}}$ we can find the MW if we know D
- molecules generally hydrated...
- so above equation is just an approximation !!

Factors affecting Diffusion

Fick's First Law: **$dm/dt = -DA(dc/dx)$,**

Stoke-Einstein Law: **$D = RT/6N\pi\eta r$**

1) Area (A)

- As surface area /cross-sectional area of pores increases,amount of solutes diffused, dM or M,increases.
  - E.g. amount absorbed in small intestine is higher than in stomach.

2) Concentration gradient (dc/dx)

- As the concentration gradient (difference) increases, dM or M increases

3) Time (t)

- As duration increases, dM or M increases,until saturation is obtained.

4) Distance or thickness (x or L)

- As distance/thickness increases, dM or M decreases.
- E.g. transdermal drug delivery depends on location due to varying thickness of the skin: thigh, arm, chest, back, sole, palm, back of ear.

5) Temperature (T)

- As temperature increases,
  diffusion coefficient, D,increases, dM or M increases

Continue Factors affecting Diffusion

6) Frictional coeffiecient (f)

- As f increases, D decreases, dM or M decreases.

7) Viscosity (h)

- f α h and D α 1/h, as h increases, dM or M decreases.

8) Particle size (r)

- f α r and D α 1/r, as r increases, dM or M decreases.

9) Pore size or porosity

- As porosity increases, dM or M increases.

At any concentration difference, however, the magnitude of the net flux depends on several additional factors:

- Temperature
  - The higher the temperature, the greater the speed of molecular movement and the greater the net flux;
- Mass of the molecule
  - large molecules (e.g. proteins) have a greater mass and lower speed than smaller molecules (e.g. glucose) and thus have a smaller net flux;
- Surface area
  - the greater the surface area between two regions; the greater the space available for diffusion and thus the greater the net flux;

Diffusion Rate versus Distance

- Diffusion times increase in proportion to the **square of the distance** *over* which the molecules diffuse.

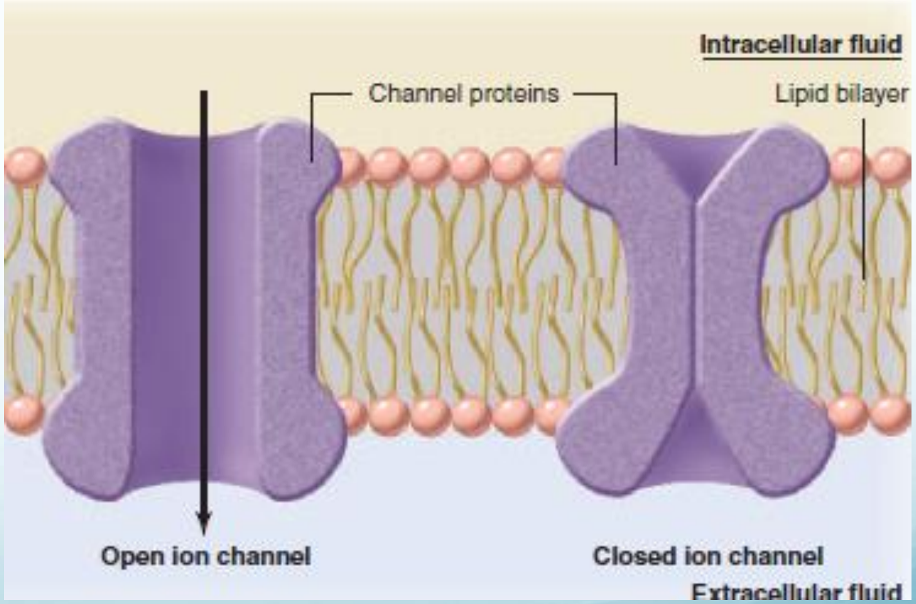
Role of Forces on Ion Movement

- Molecules will move from an area of higher energy to a lower energy.
- The forces that create this energy may be
  - chemical,
  - electrical,
  - electrochemical.

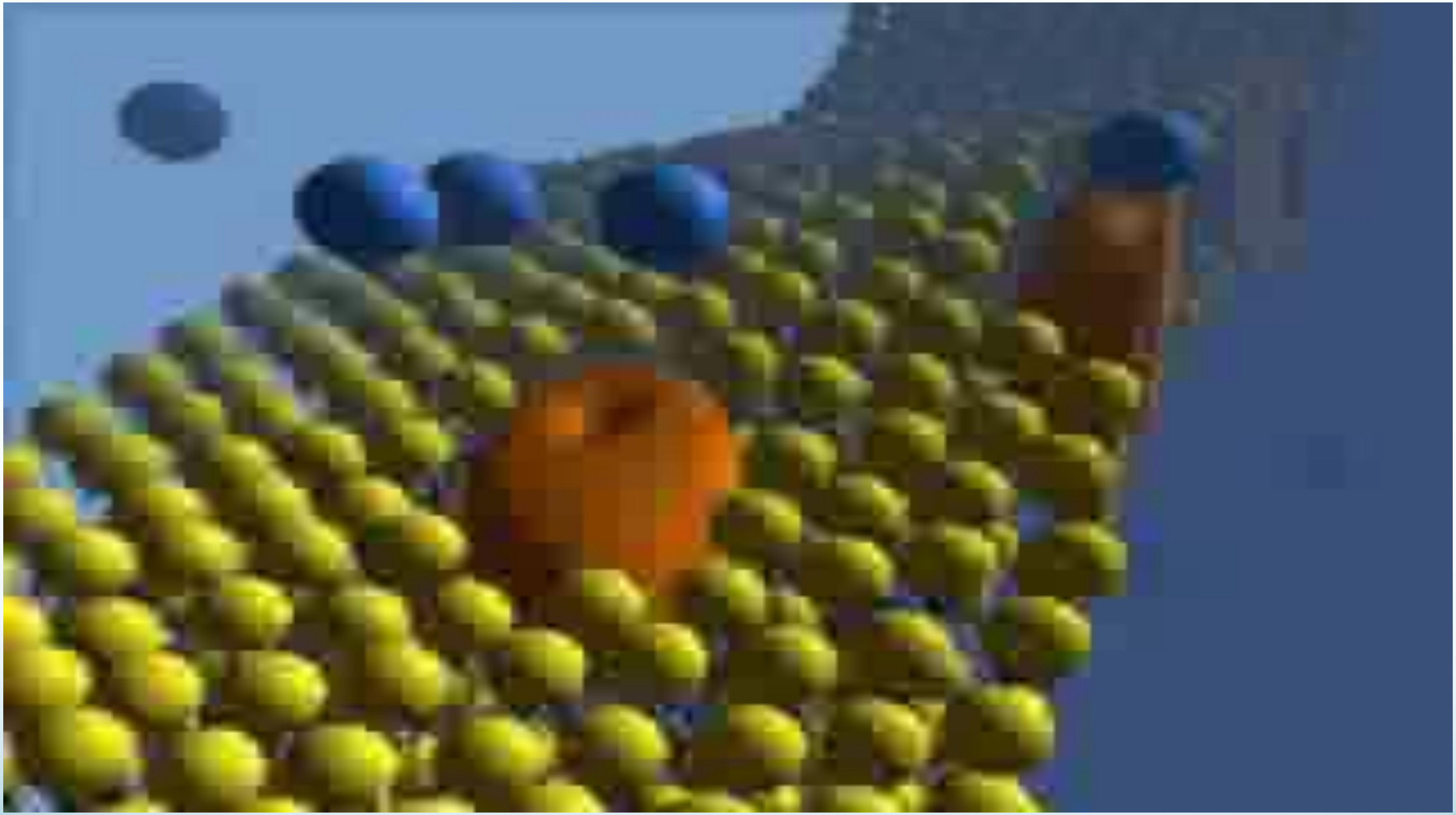
Regulation of Diffusion through Ion Channels

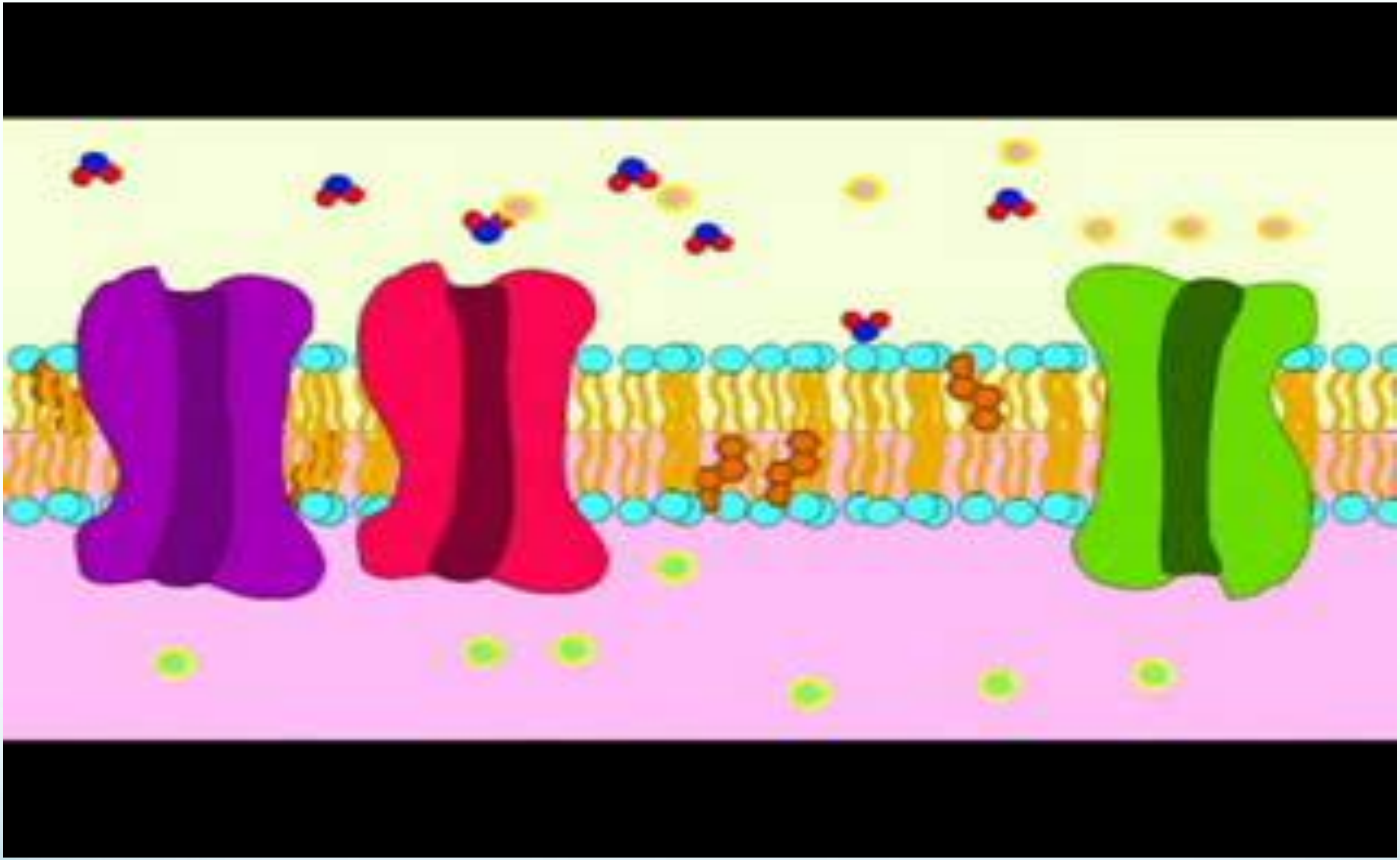
- Ion channels can exist in an open or closed state, and changes in a membrane's permeability to ions can occur rapidly as a result of the opening or closing of these channels.

  - The channel may be open, allowing ions to diffuse across the membrane, or may be closed.

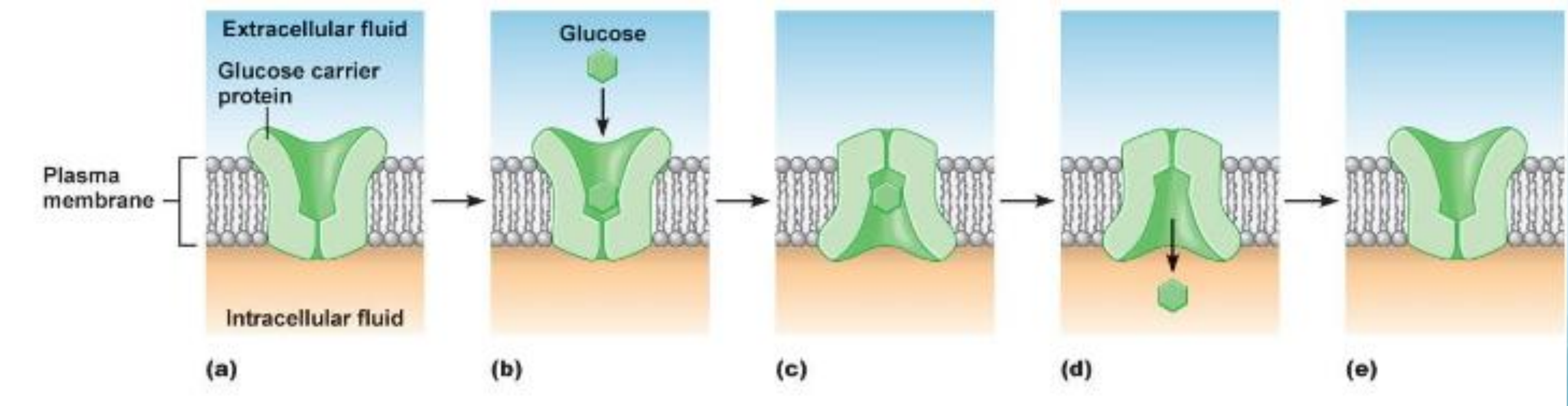


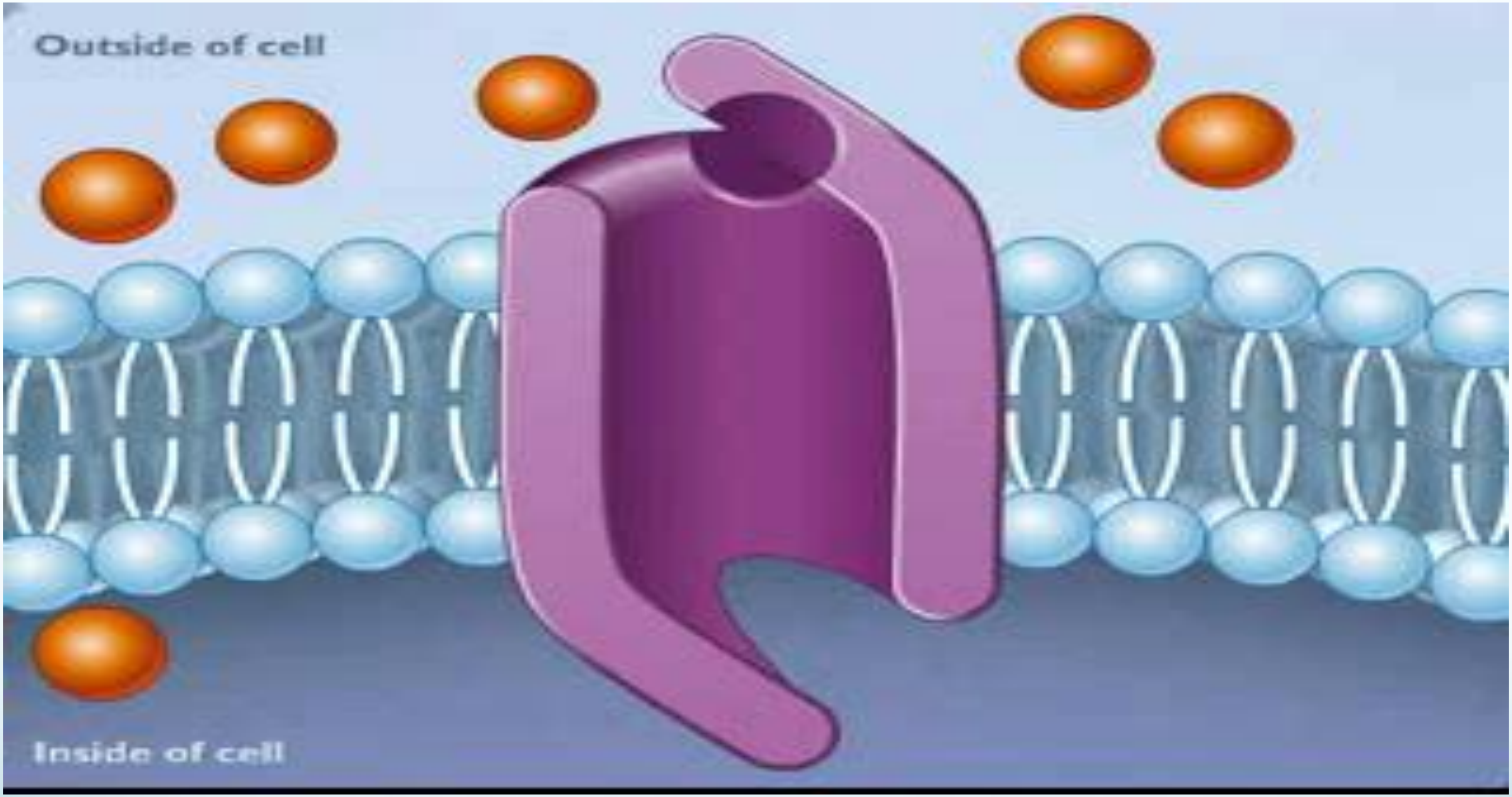
- The process of opening and closing ion channels is known as channel gating.
- A single ion channel may open and close many times each second.





- A carrier is transmembrane protein that binds specific molecules or classes of molecules and transports them to the other side by changing their shape (conformation).




Outside of cell
Inside of cell

Mediated Transport Systems

The passage of ions and the nondiffusional movements of ions are mediated by integral membrane proteins known as transporters.

Facilitated Diffusion

- In facilitated diffusion the net flux of a molecule across a membrane always proceeds from higher to lower concentration and continues until the concentrations on the two sides of the membrane become equal.
- Neither diffusion nor facilitated diffusion is coupled to energy (ATP) derived from metabolism.

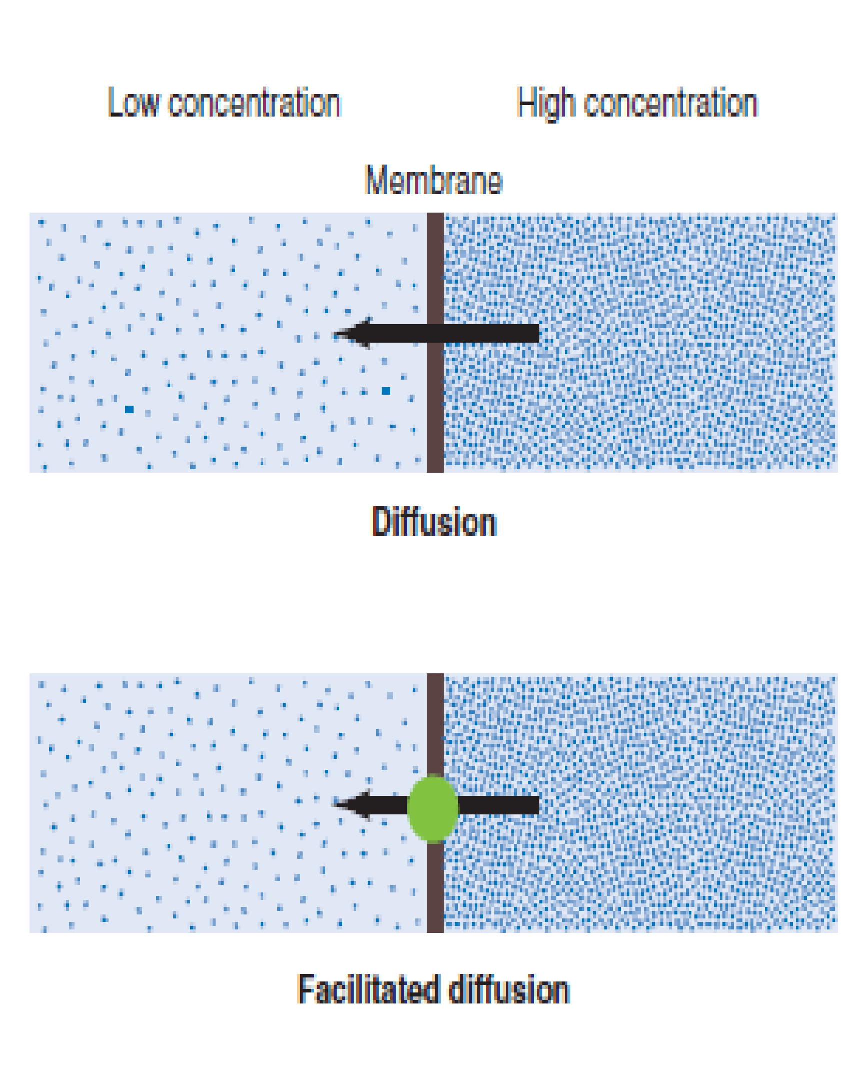
- **If the transport of molecules across the membrane is mediated by a transmembrane protein, but the force driving transport is either a concentration gradient (chemical force) or an electrochemical gradient, the process is facilitated diffusion.**

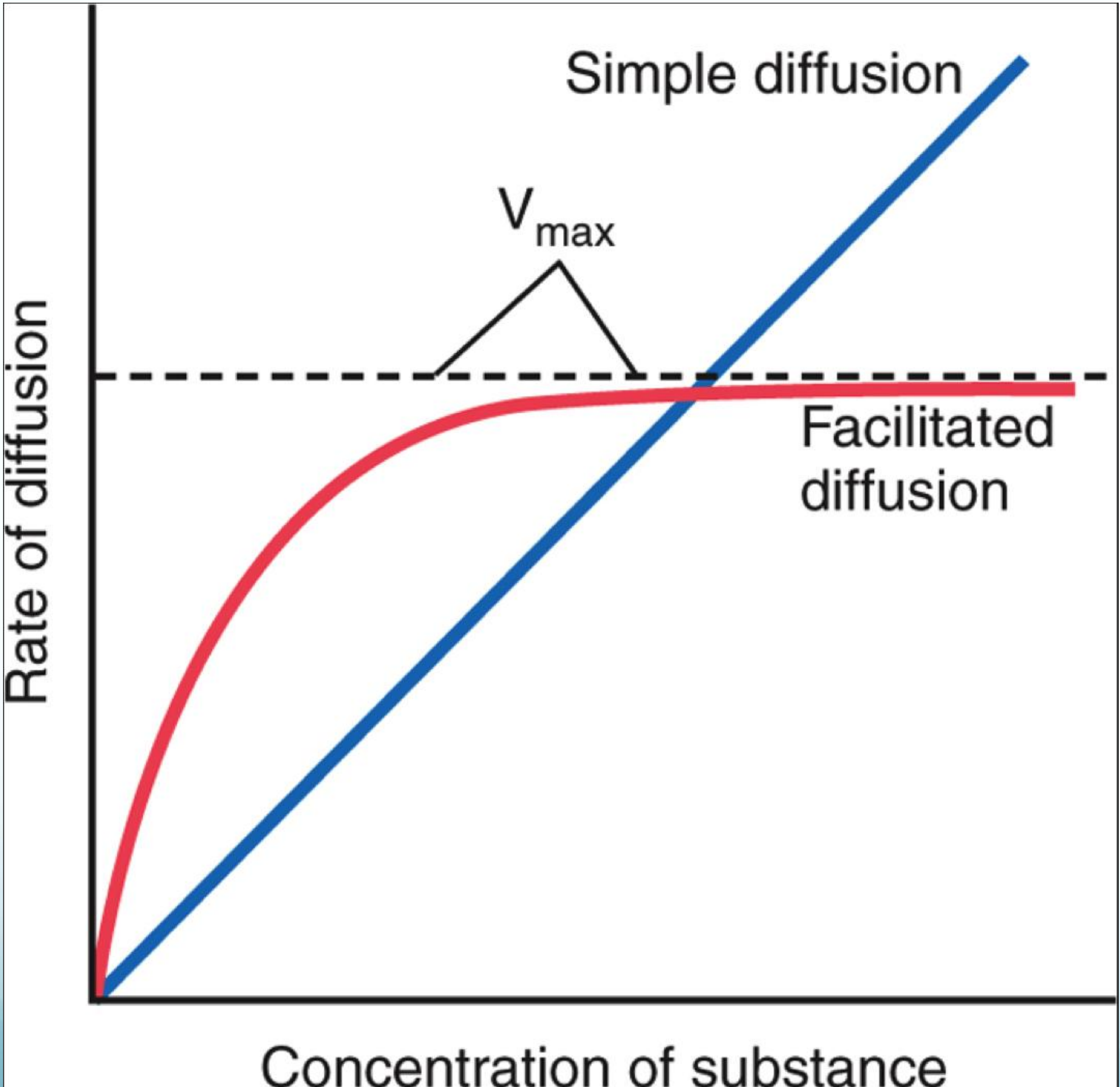
Direction of net solute flux crossing a membrane by:

diffusion (high to low concentration),

facilitated diffusion (high to low concentration).

P.S: The colored circles represent transporter molecules.



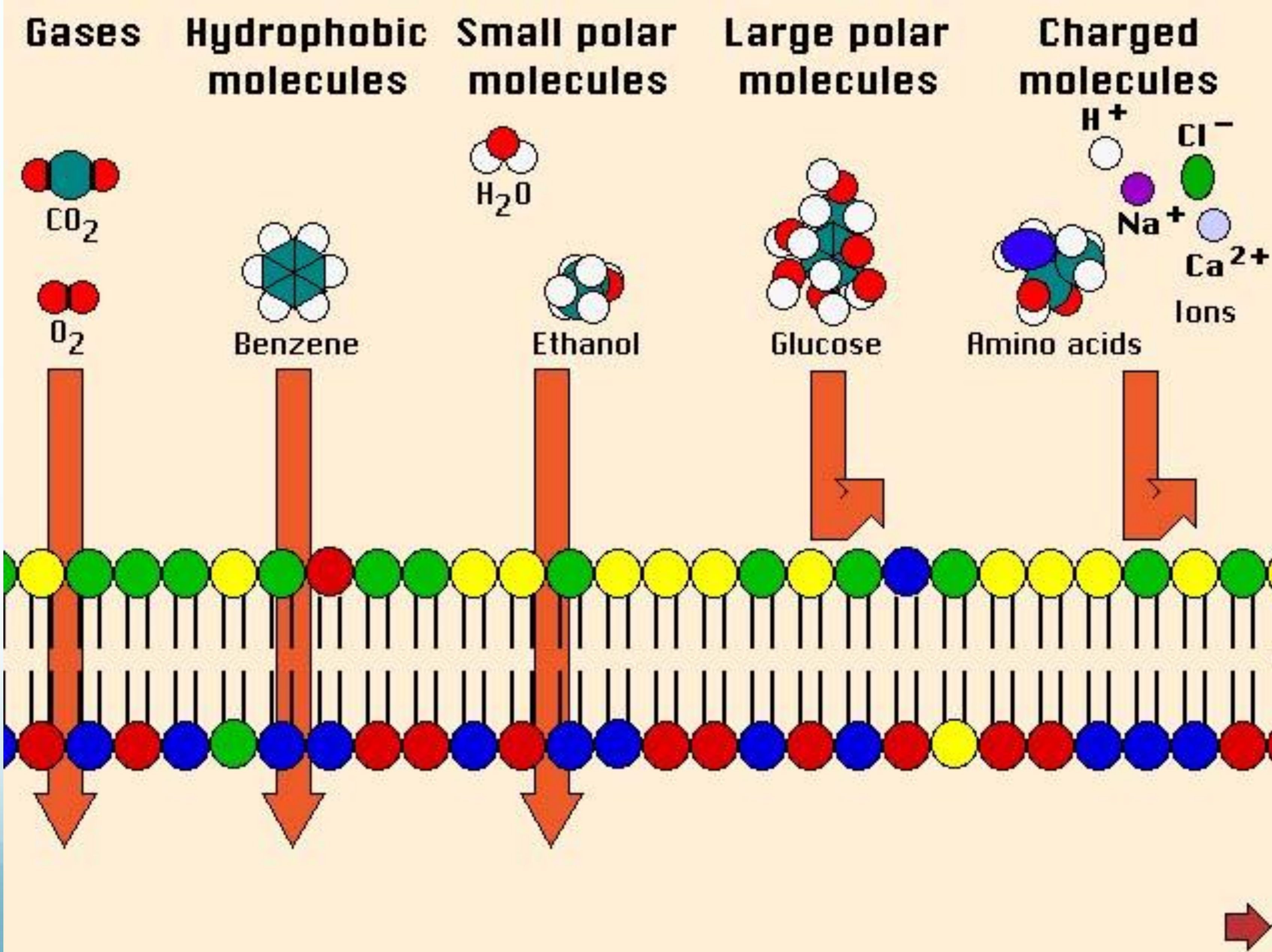


Hall: Guyton and Hall Textbook of Medical Physiology, 12th Edition

Major Characteristics of Pathways by which Substances Cross Membranes

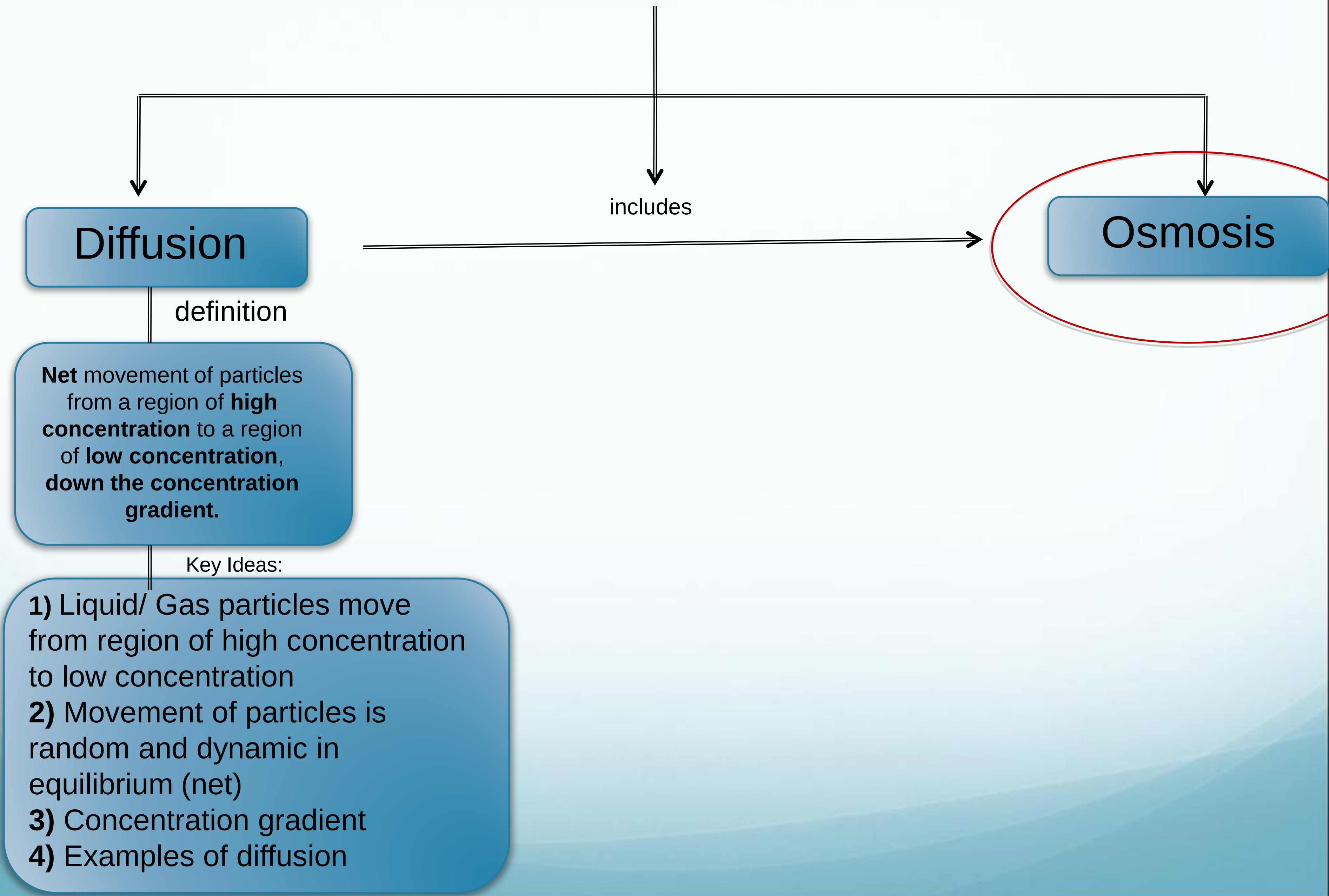
	Diffusion		
	THROUGH LIPID BILAYER	THROUGH PROTEIN CHANNEL	FACILITATED DIFFUSION
Direction of net flux	High to low concentration	High to low concentration	High to low concentration
Typical molecules using pathway	Nonpolar: O_2, CO_2, fatty acids	Ions: Na^+, K^+, Ca^{2+}	Polar: glucose

*In the presence of a membrane potential, the intracellular and extracellular ion concentrations will not be equal at equilibrium.

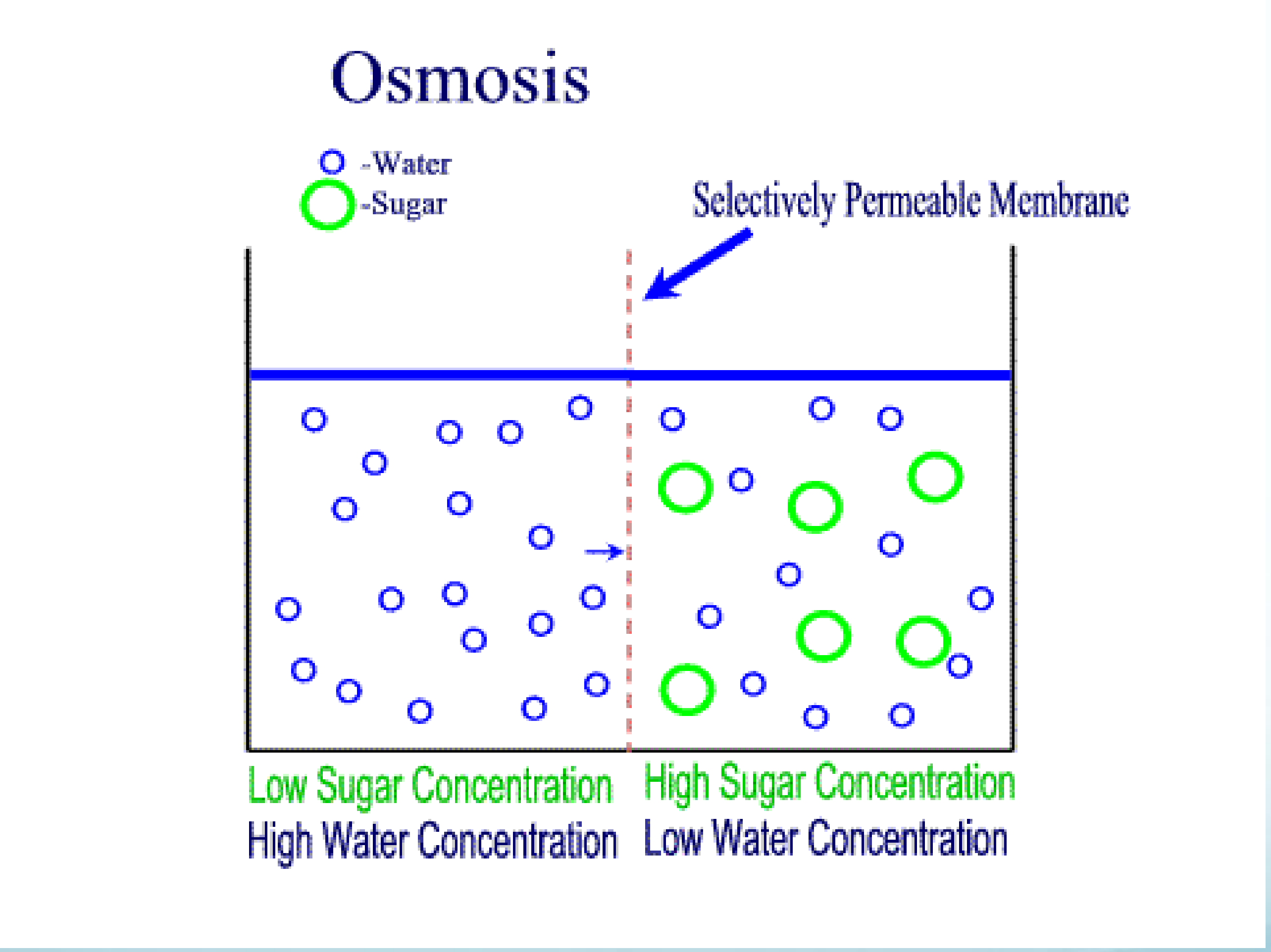


Gases
Hydrophobic molecules
Small polar molecules
Large polar molecules
Charged molecules
CO_2
O_2
Benzene
H_2O
Ethanol
Glucose
Amino acids
H^+
Cl^-
Na^+
Ca^{2+}
Ions

Movement of Substances



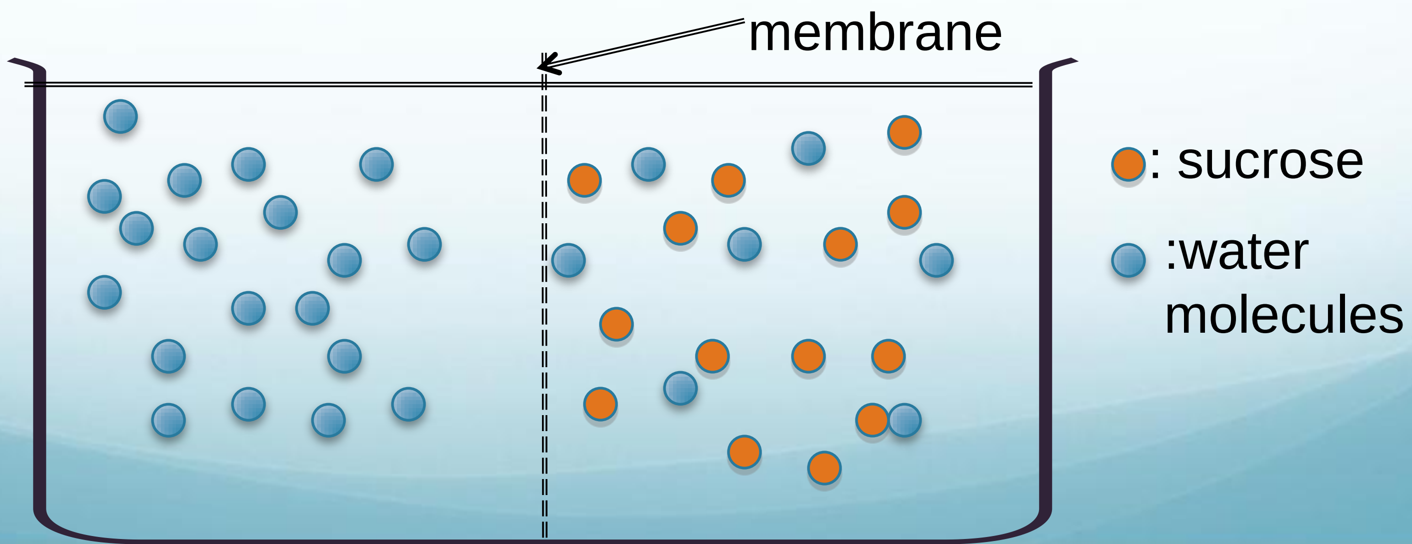
Osmosis


Osmosis
-Water
-Sugar
Selectively Permeable Membrane
Low Sugar Concentration
High Water Concentration
High Sugar Concentration
Low Water Concentration

Osmosis

Definition:

The movement of **water molecules** through a **partially permeable membrane** from a solution of **high water potential,** to a solution of **lower water potential.**



OSMOSIS

- Water is a polar molecule that diffuses across most cell membranes very rapidly.
- Because of its polar structure, water would not penetrate the nonpolar lipid regions of membranes.
- The reason why water diffuses through cell membranes so readily is that a group of membrane proteins known as aquaporins form channels through which water can diffuse.

- The greater the solute concentration, the lower the water concentration.

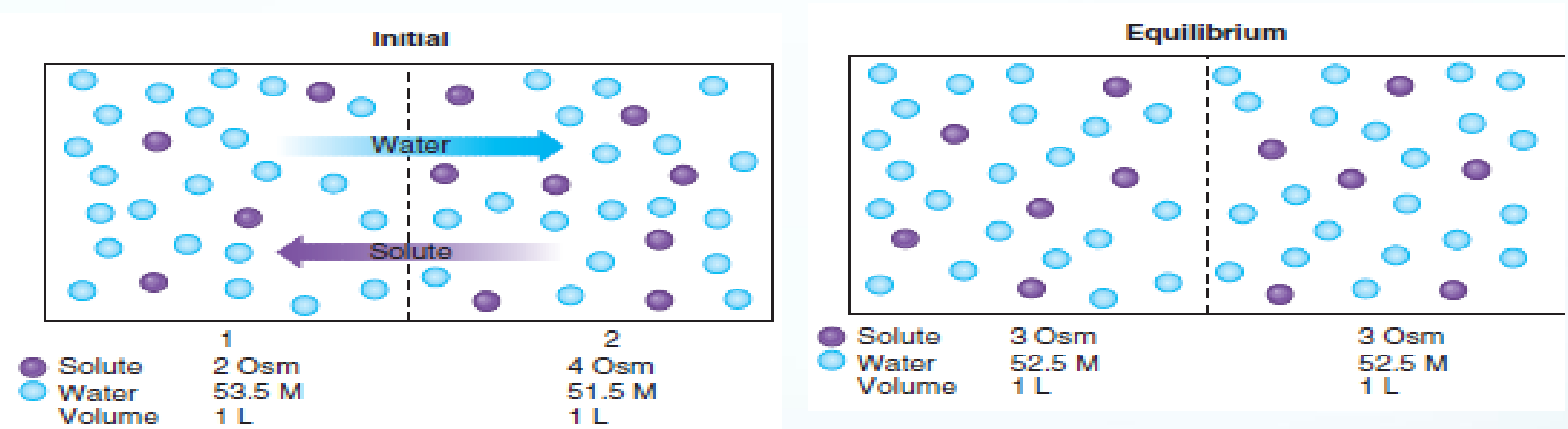
- **It is essential to recognize that the degree to which the water concentration is decreased by the addition of solute depends upon the number of particles (molecules or ions) of solute in solution (the solute concentration) and not upon the chemical nature of the solute.**

- The total solute concentration of a solution is known as its **osmolarity**.

- **One osmol is equal to 1 mol of solute particles.**
  - a 1 M solution of glucose has a concentration of 1 Osm (1 osmol per liter)
  - a 1 M solution of sodium chloride contains 2 osmol of solute per liter of solution.

- **Although osmolarity refers to the concentration of solute particles, it is essential to realize that it also determines the water concentration in the solution since the higher the osmolarity, the lower the water concentration.**

Apply these principles governing water concentration to the diffusion of water across membranes:



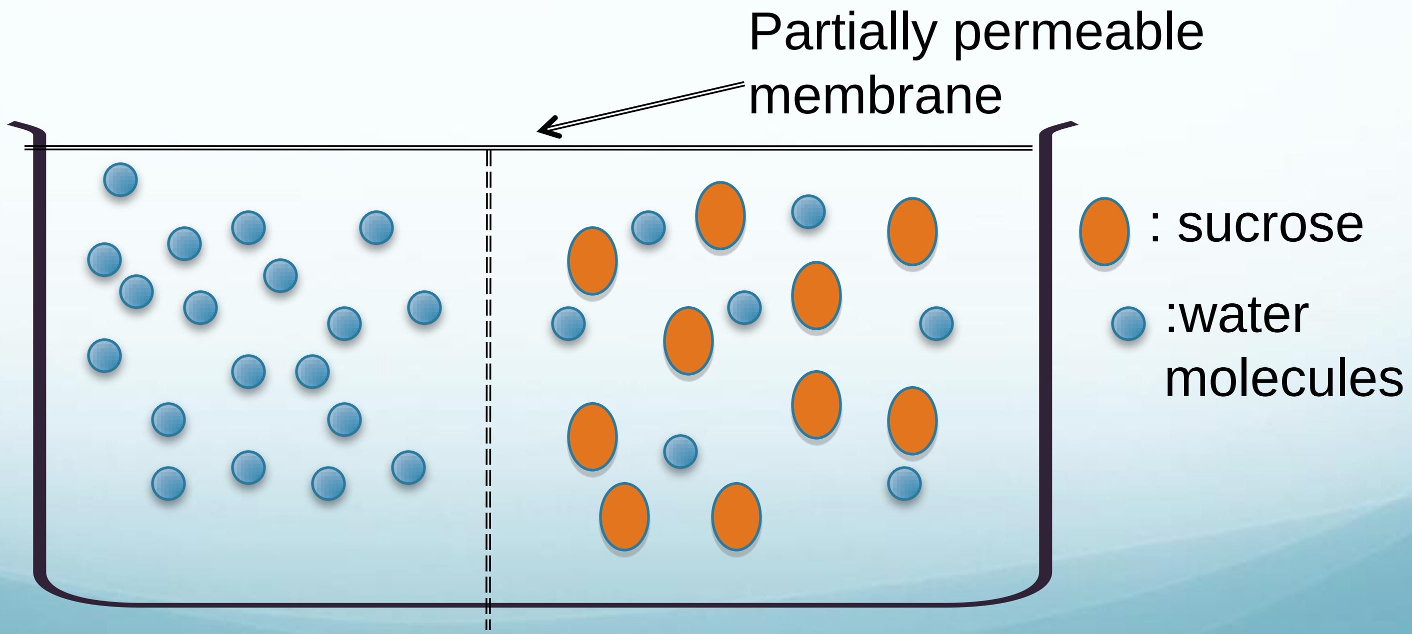
- Fig. shows two 1-L compartments separated by a membrane permeable to *both solute and* water.

- Initially the concentration of solute is
  - 2 Osm in compartment 1
  - 4 Osm in compartment 2.
- This difference in solute concentration means there is also a difference in water concentration across the membrane:
  - 53.5 M in compartment 1
  - 51.5 M in compartment 2

- There will be a net diffusion of water from the higher concentration in 1 to the lower concentration in 2, and of solute in the opposite direction, from 2 to 1.
- When diffusion equilibrium is reached, the two compartments will have identical solute and water concentrations, 3 Osm and 52.5 M.
- One mol of water will have diffused from compartment 1 to compartment 2
- 1 mol of solute will have diffused from 2 to 1.
- Since 1 mol of solute has replaced 1 mol of water in compartment 1, and vice versa in compartment 2.
- There is no change in the *volume* of either compartment.

The movement of **water molecules** through a **partially permeable membrane**

•**Only water molecules passes** through the **partially permeable membrane** (sucrose solution too big to pass through the partially permeable membrane).

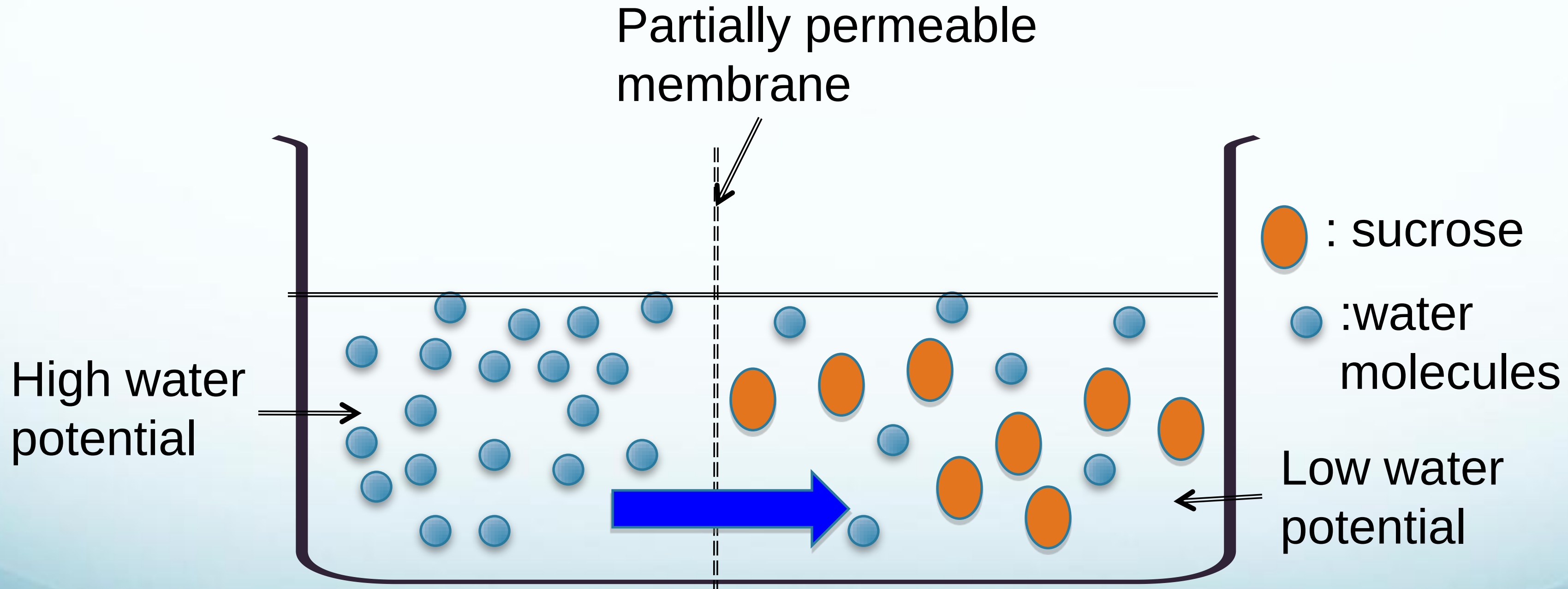


Water Potential

- **Water potential** is the measure of the tendency of water to move from one place to another.
  - **Dilute Solution**: High water potential
  - **Concentrated Solution**: Low water potential
  - Same concentration: Equal water potential
- **Water potential Gradient**:
  - Water molecules move from a high water potential to a lower water potential.
  - **Down water potential Gradient**

From a solution of **high water potential,** to a solution of **lower water potential.**

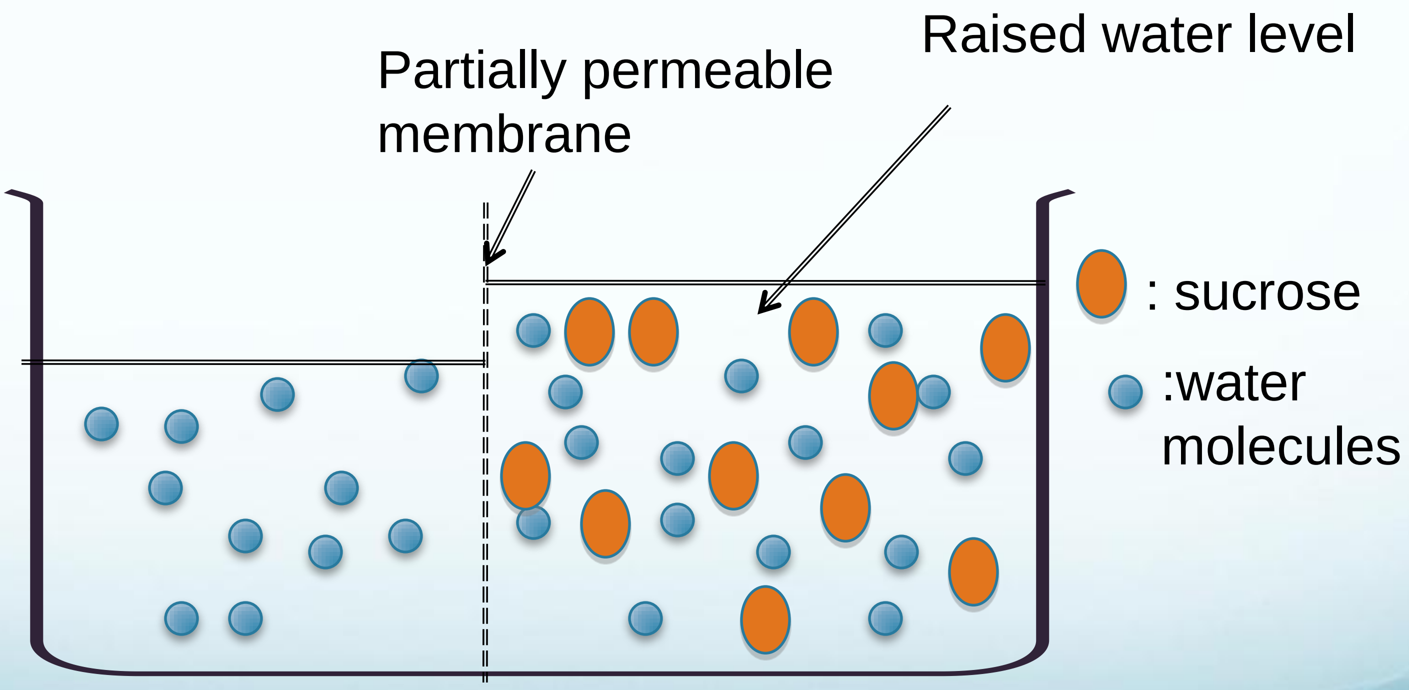
- Only water molecules passes through the partially permeable membrane (sucrose solution too big to pass through the partially permeable membrane).

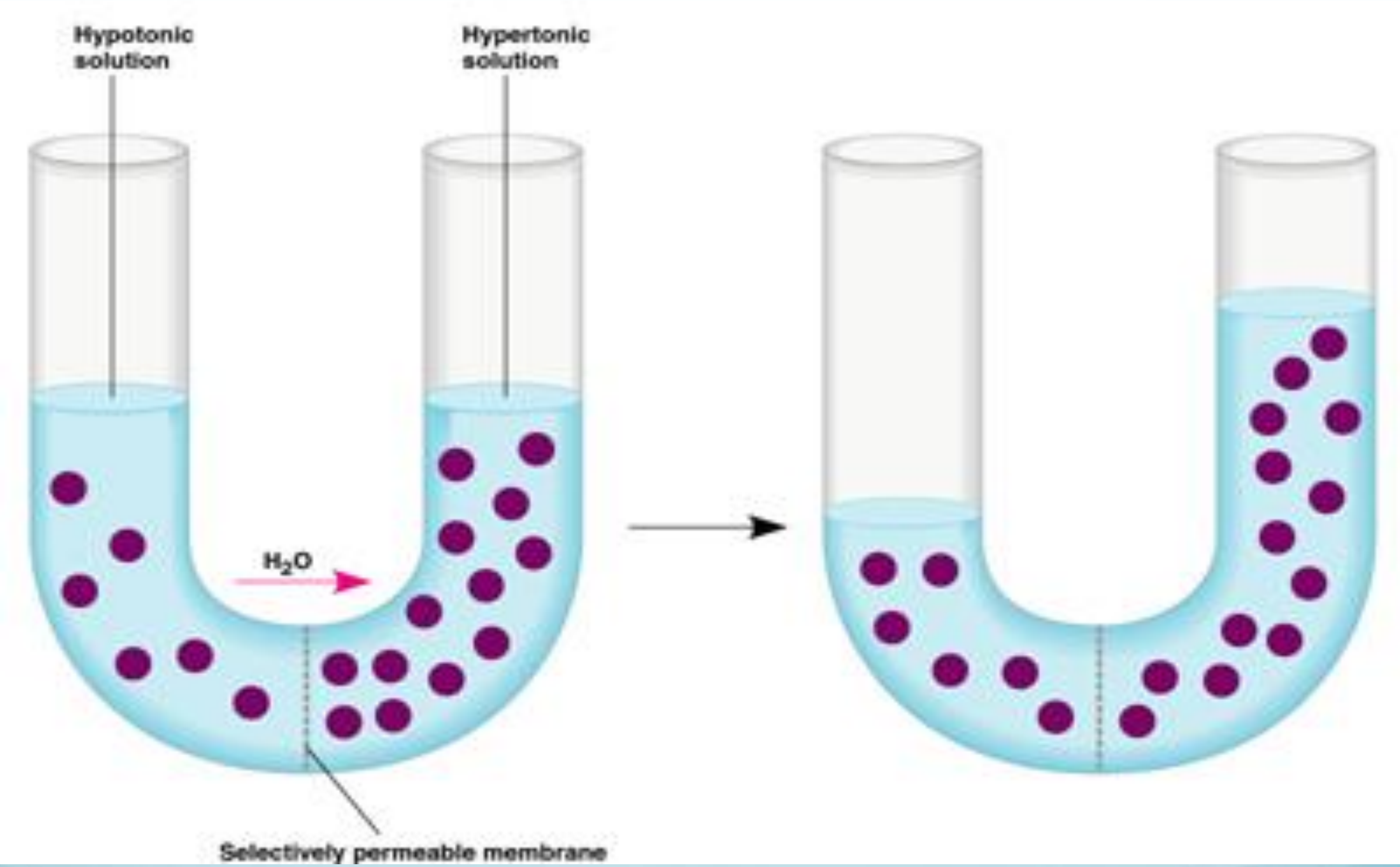


Movement of water molecules

<u>From a solution of **high water potential,** to a solution of **lower water potential.**</u>

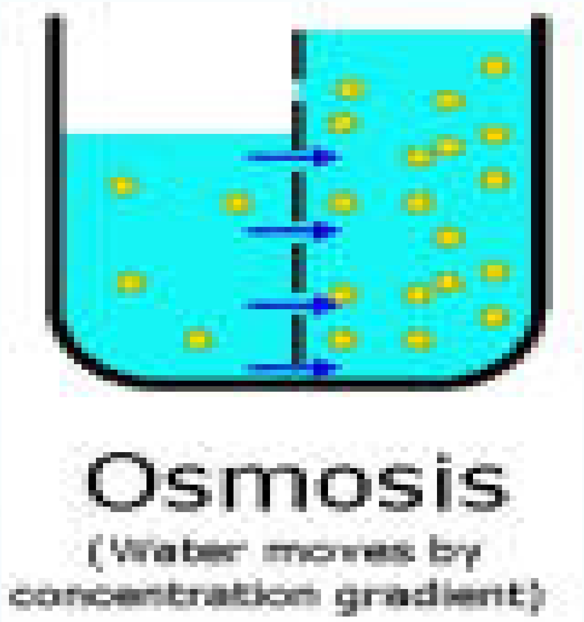
- Only water molecules passes through the partially permeable membrane (sucrose solution too big to pass through the partially permeable membrane).

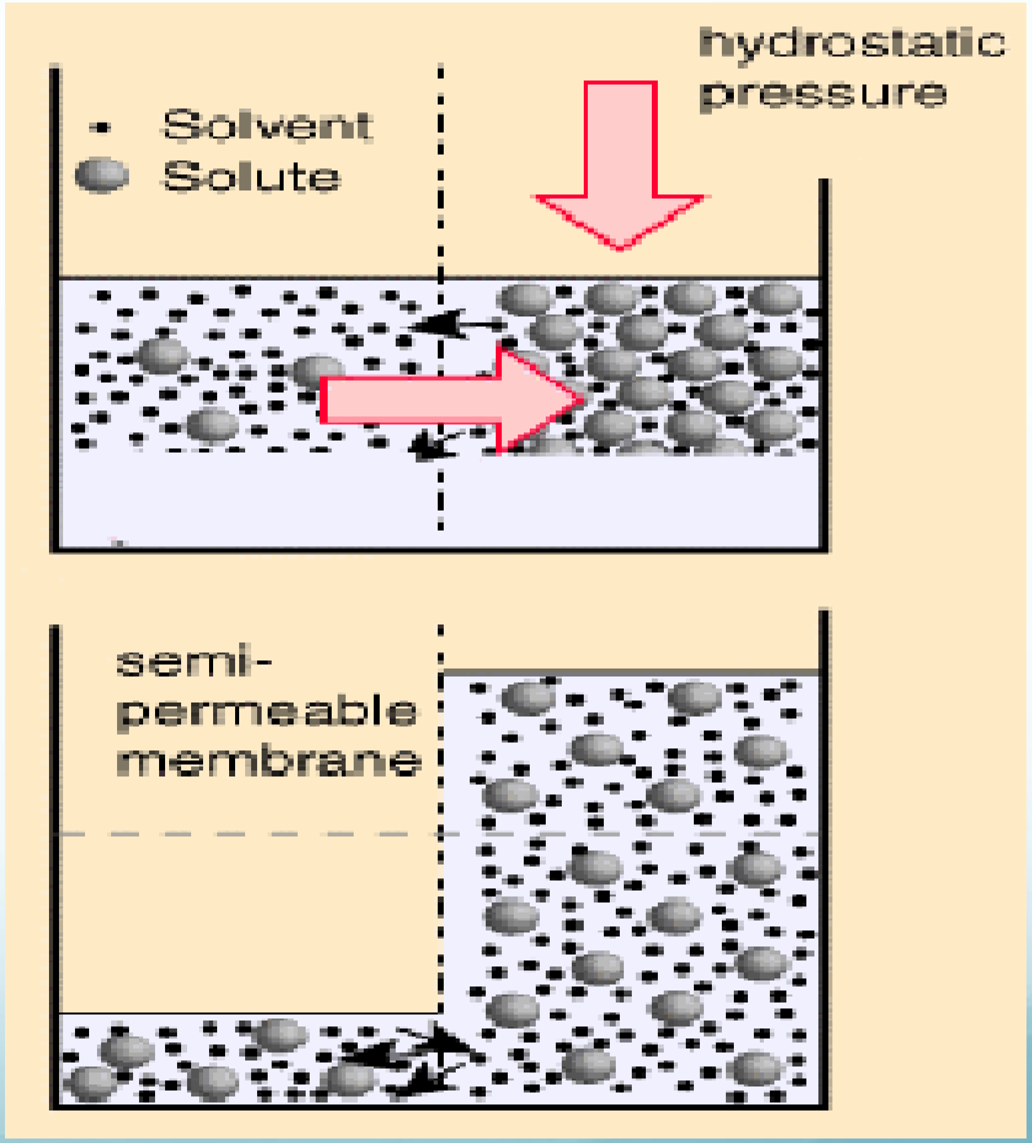




Hypotonic
solution
Hypertonic
solution
H_2O
Selectively permeable membrane

Diffusion of a solvent across a membrane





- Since the liquid level is higher on the right, the fluid pressure will act on water molecules and force them to go back
- When the liquid column high enough, hydrostatic pressure prevents further transfer of solvent molecules
- The maximum difference in height is a measure of the difference in “osmotic pressure”

Osmotic Pressure

- The pressure that needs to be applied to a solution to stop the movement of a solvent into it, when the solution and solvent are separated by a semipermeable membrane that only allows the solvent pass through.

van't Hoff Equation

- $\Pi = \Phi\, i\, R\, T\ (C1 + C2 + \ldots\ldots\ldots\ldots. + Cn)$
- Π : osmotic pressure (atm or mm Hg)
- R is the gas constant (0.08205 L/ atm.K.mol)
- T is the absolute temperature (K)
- C1, ……., Cn are the molar concentrations of all the solutes (mol / L)

- Φ : osmotic coefficient: deviation from ideal
  - For non-electrolytes (e.g.glucose) > 1
  - For electrolytes <1 (electrical interactions)
  - For macromolecules >>1 (Hg : 2.57)
  - Physiologic electrolytes <1
  - Approaches to 1 as solution becomes diluted
- i : number of ions formed by dissociation of a solute molecule
- Φ. i. C : osmotically effective concentration or osmolarity of the solution (osmoles/liter)

Some Properties of Osmosis

- Total number of solute molecules are important : !!! NOT the chemical properties
- COLLIGATIVE
- Each ion makes a contribution
- Osmotic pressure of physiological solutions is large
- Osmotic pressures due to macromolecules: colloid osmotic pressure

- Osmotic pressure is a real pressure
- It is higher in concentrated solutions
- It depends on the amount of solute and temperature of the solution
- It depends on the number of particles in the solution

- Osmotic coefficients of certain solutes :

NaCl	0.93
KCl	0.92
$NaHCO_3$	0.96
Glucose	1.01
Sucrose	1.02
Lactose	1.01

Osmotic coefficient depends on : the concentration of solute + on its chemical properties

- What is the osmotic pressure at 0°C of a 154 mM NaCl solution?
- Using Φ= 0.93 for NaCl:

Π = 22.4 l.atm/mole x 0.93 x 2 x 0.154 mole/l

Π = 6.42 atm

Π What is the osmolarity of this solution:

Φ i c = 0.93 x 2 x 0.154 = 0.286 osmolar

Measurement of osmotic pressure

- It is easier to estimate osmotic pressure by measuring depression of freezing point:

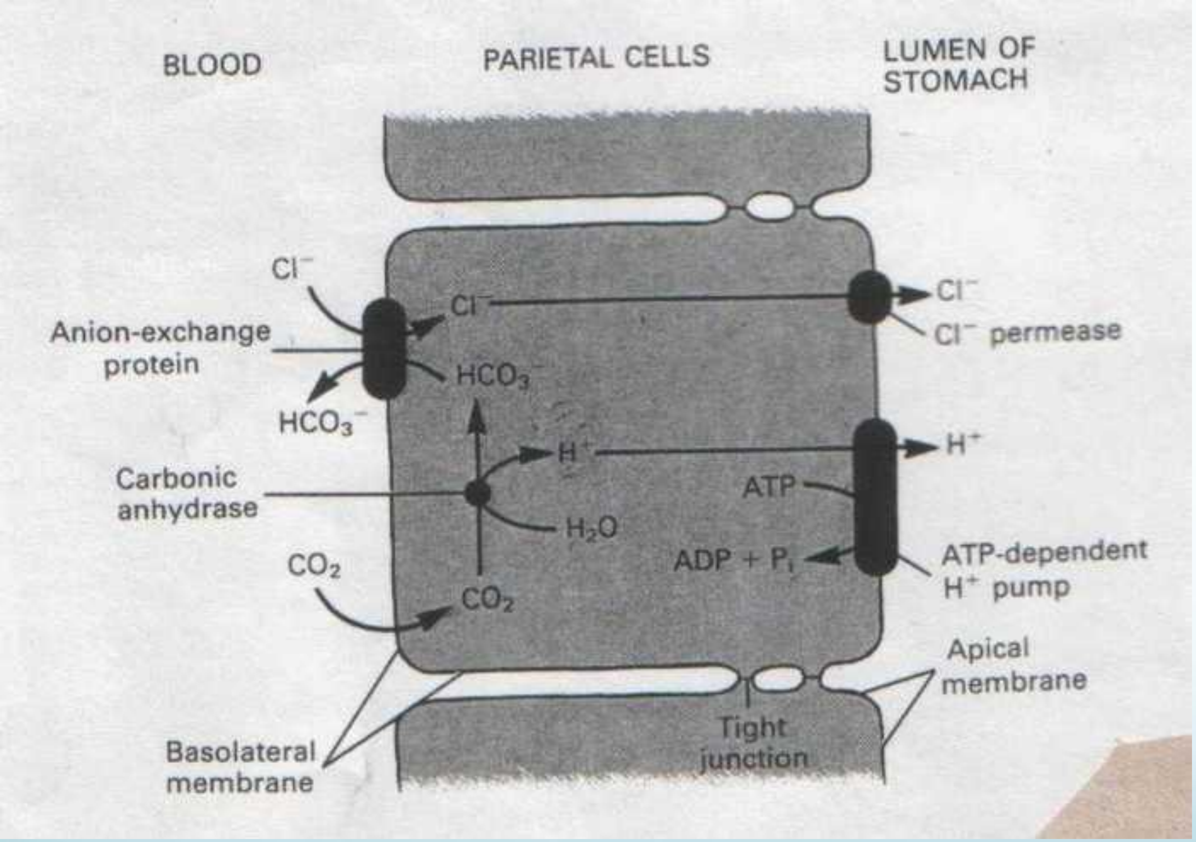
- Osmolarity = depression of freezing point /constant
- $\Phi\ i\ c = \Delta T_f / 1.86$ again a colligative property

- **Osmotic pressure in physiological systems:**
- 2/3 of body ICF; 1/3 ECF. ¾ of ECF is ISF; while ¼ is plasma
- Because of its abundance, Na is the major determinant of the osmolality of the ECF
- Major difference between ISF and plasma composition is the proteins in plasma

- Normal plasma osmolality ranges ~ 285-295 mOsm/kg H_2O
- Because water is in equilibrium across capillary wall and plasma membrane of cells, measuring the plasma osmolality also provides a measure for ECF and ICF

- The steady-state volume of the cell is determined only by the conc. of impermeant solutes
- Permeant solutes cause only transient changes
- Greater permeability, more rapid the transient changes
- Osmotic flow of water by impermeant solutes:
- $V = L\,\Delta\pi$
- Permeant solutes cause less osmotic flow ($V = \sigma L\,\Delta\pi$)

Example: Epithelial cells lining stomach



The net movement of water across a membrane can be caused by one of the two circumstances:

- Difference in the concentration of dissolved substances (osmotic pressure)
- Difference in hydrostatic pressure

- *If total osmotic pressures of two solutions are equal, the solutions are said to be isotonic*
- *If solution A has higher pressure (higher conc.) : hypertonic w.r.t. B*

If solution B has lower pressure (lower conc.) : hypotonic w.r.t. A

- ***The solvent will move from the hypotonic to the hypertonic solution.***

Hypotonic Vs Hypertonic

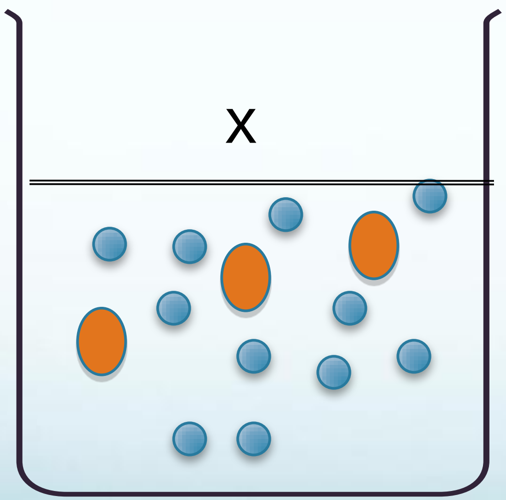
Used to compare 2 solutions.

Hypotonic to ____ / **Hypertonic** to _____.

Higher water potential compared to _____/ Lower water potential compared to ____

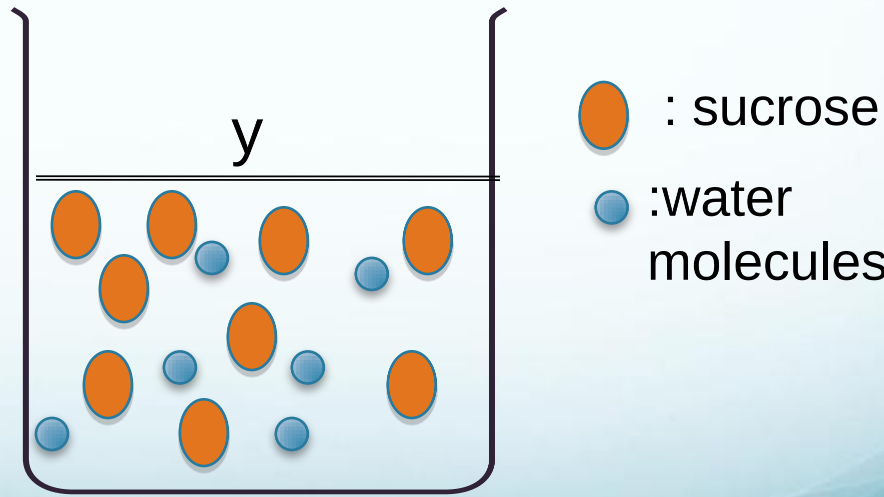
***Isotonic:** Same water potential

X is **Hypotonic** compared to y



Low concentration of sucrose : High water potential

Y is **Hypertonic** compared to x



High concentration of sucrose : Low water potential

Direction of Solvent Motion in Osmosis

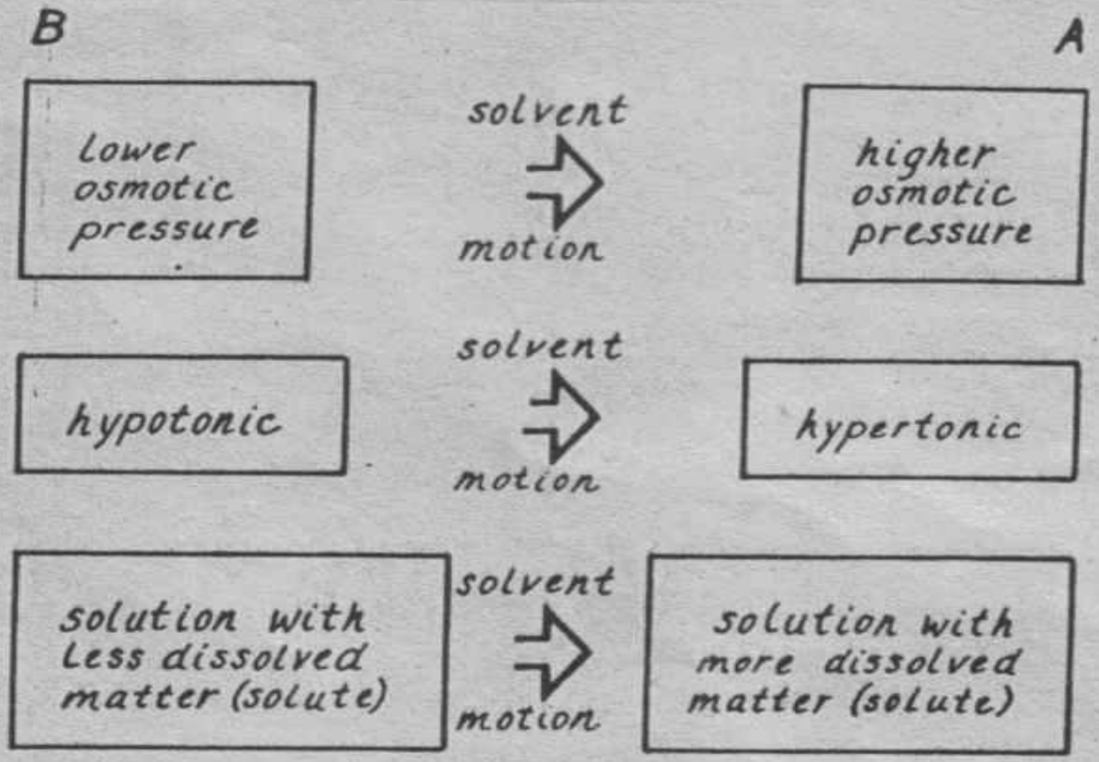
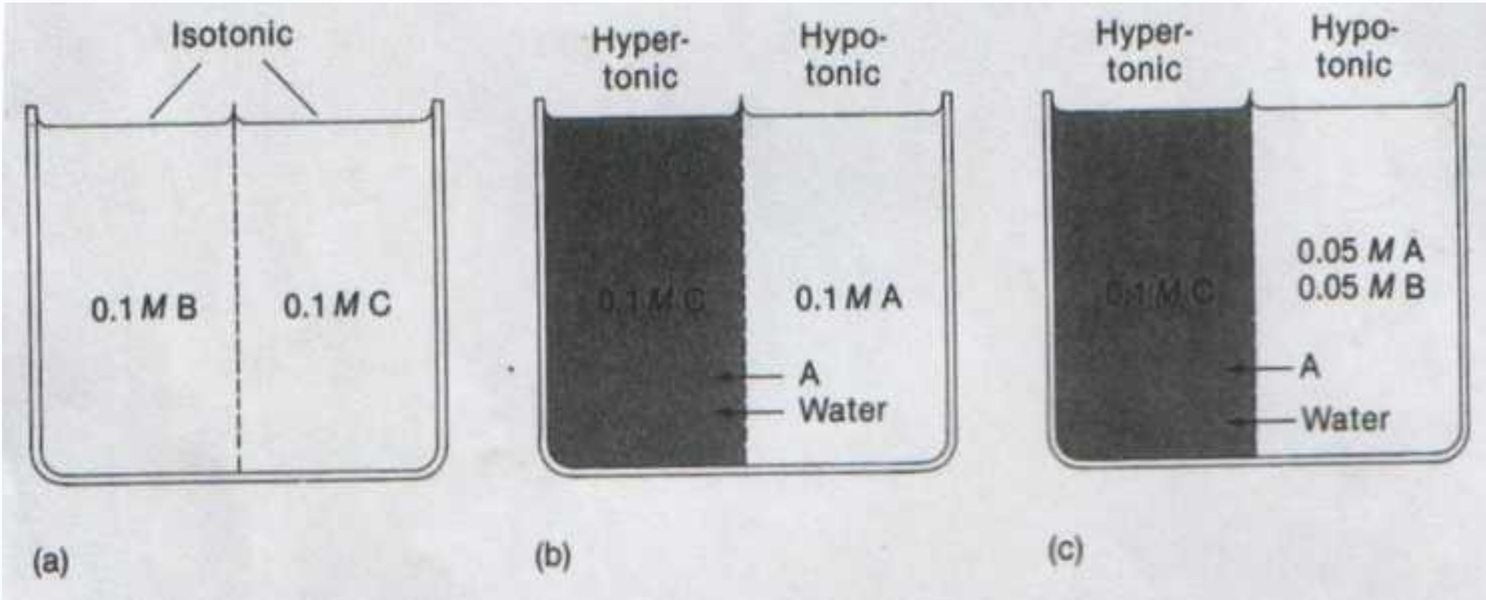


Figure ■-3 The direction of solvent motion in osmosis.

- The terms isotonic, hypotonic, hyertonic are relative terms and must be used w.r.t. some reference solution or solvent.
- When they are used for fluids in the body, the plasma is usually the reference fluid.
- An isotonic saline solution is one which would cause no water transfer across a membrane if normal plasma were on the other side.
- The fluid inside red blood cells is isotonic w.r.t. plasma.
- A solution of 0.9% NaCl is isotonic with the plasma and thus with the red blood cells. If a red blood cell were placed in such a solution , there would be no net transfer of water across the membrane.

Tonicity versus Osmotic Pressure



(a) No flow; isotonic

(b) A and water will move to left

(c) Again A and water will move to left

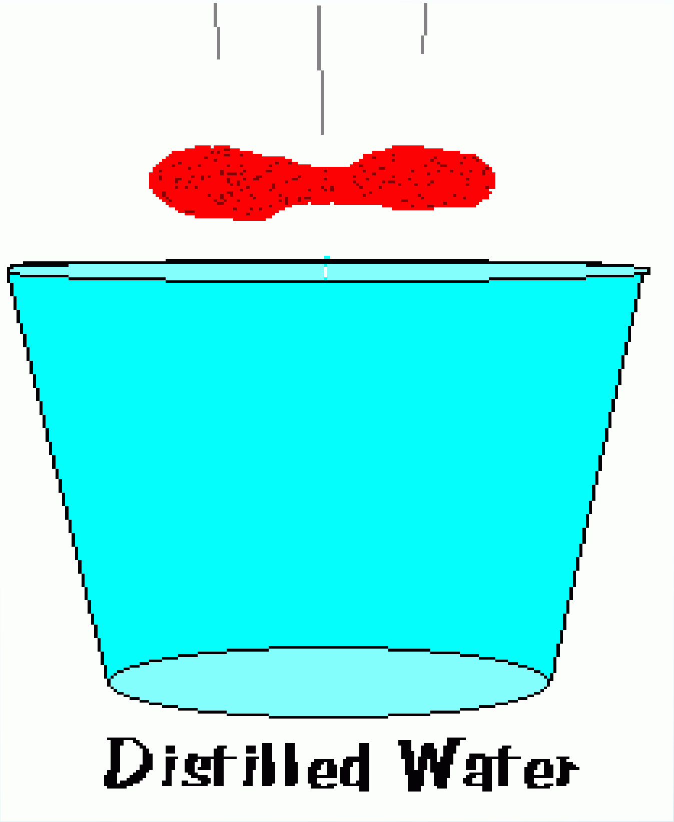
- The effective osmotic pressure of a solution with respect to a particular membrane is called tonicity.
- It is not a colligative property
- Mainly controlled by the concentration of the impermeable ion
- In equilibrium, the total osmotic pressures due to impermeable molecules and ions must be the same inside and outside the cell.

Osmotic swelling and shrinking of cells

- When osmotic pressure of ECF is increased, water leaves the cells – cells shrink until effective osmotic pressure of cytoplasm is again equal to the ECF.
- Within a certain range RBCs behave as osmometer. At 154 mM NaCl their volume euqal to that of plasma.

- Red blood cells : measuring hemoglobin content (hemolysis)
- At 1.4xoriginal volume :burst (lysis)
- Osmotic pressure by: hemoglobin, K, organic phosphates and glycolytic intemediates. It behaves as if it is filled with osmotically efective conc. Of 286 milliosmolar

- In this picture a red blood cell is put in a glass of distilled water. Because there is a higher concentration of water outside the cell, water enters the cell by OSMOSIS. In this case too much water enters and the cell swells to the point of bursting open.



Osmosis in living organisms

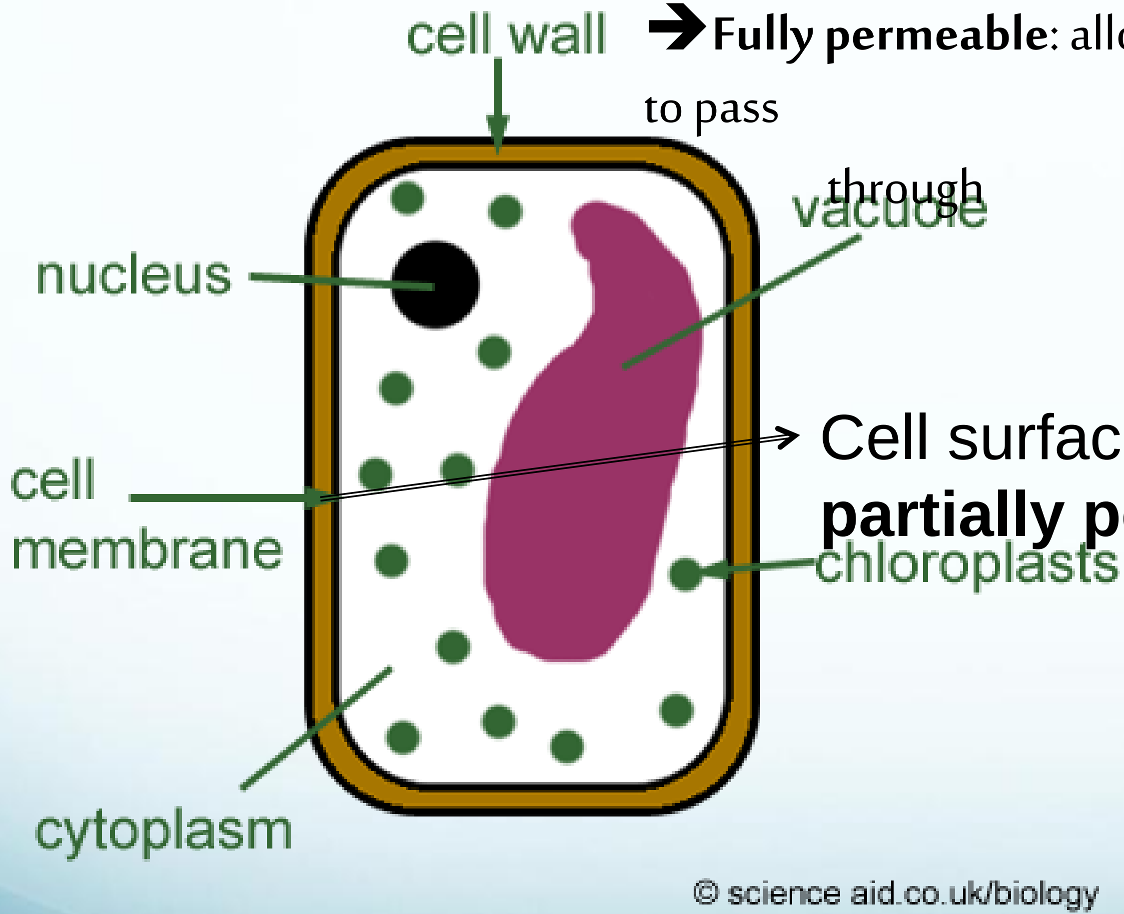
Plant Cells

Animal Cells

Plant cell behaves differently from animal cell when placed in solutions with differing water potentials.

- Due to presence of cell wall in plants.

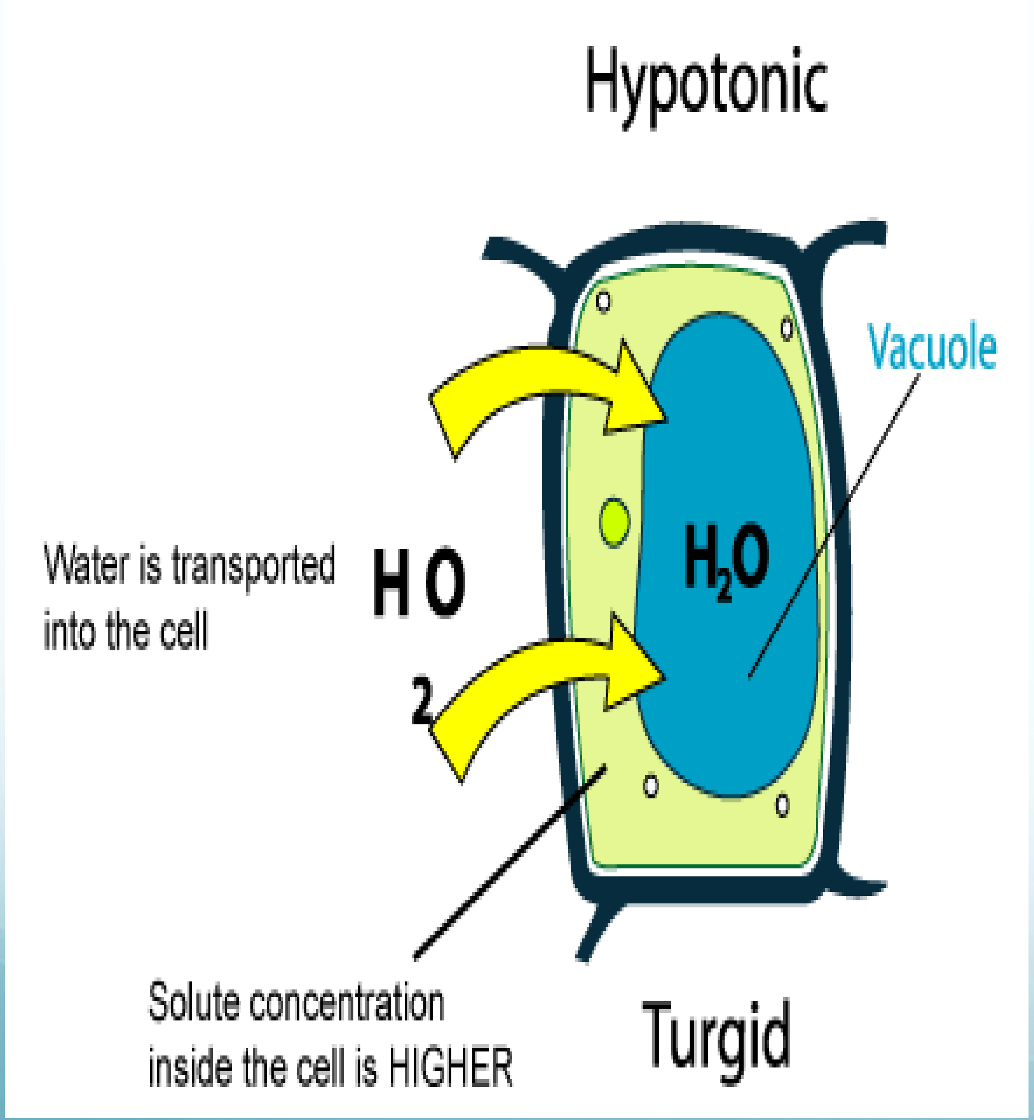
Osmosis in plant cell



➔**Fully permeable**: allows most dissolved substances to pass through

Cell surface membrane is a **partially permeable membrane**

Plant cell in High water potential



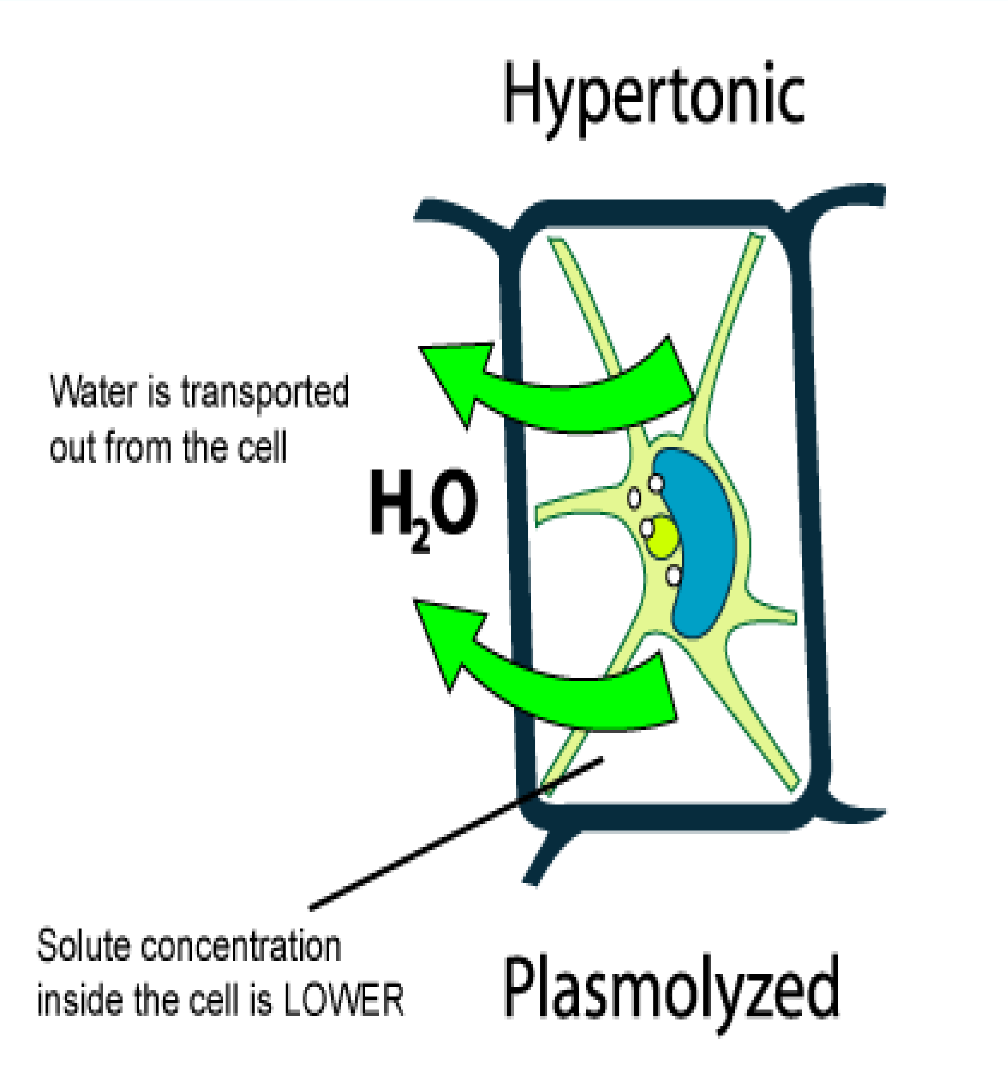
1. Cell vacuole has lower water potential compared to solutions outside cell
2. Water enters cell by osmosis.
3. Vacuole increases in size, pushes against cell wall
4. Cell wall exerts opposing pressure (against **turgor pressure**)
5. Plant cell expands and become **turgid** (cell does not bursts) ➔ **Turgor**

Why is turgor important?

- Maintain the shape of soft tissues in plants
  - Able to remain firm and erect because of turgor pressure.
- High rate of evaporation of water from cells.
  - Lose turgidity and will wilt.
- Movement of plant parts
  - Flowers open during the day and close at night
    - Changes in the turgidity of the plants on the opposite surfaces of the petals
  - Mimosa plants
  - Opening and closing of stomata due to changes in turgidity in guard cells.

Plant cell in

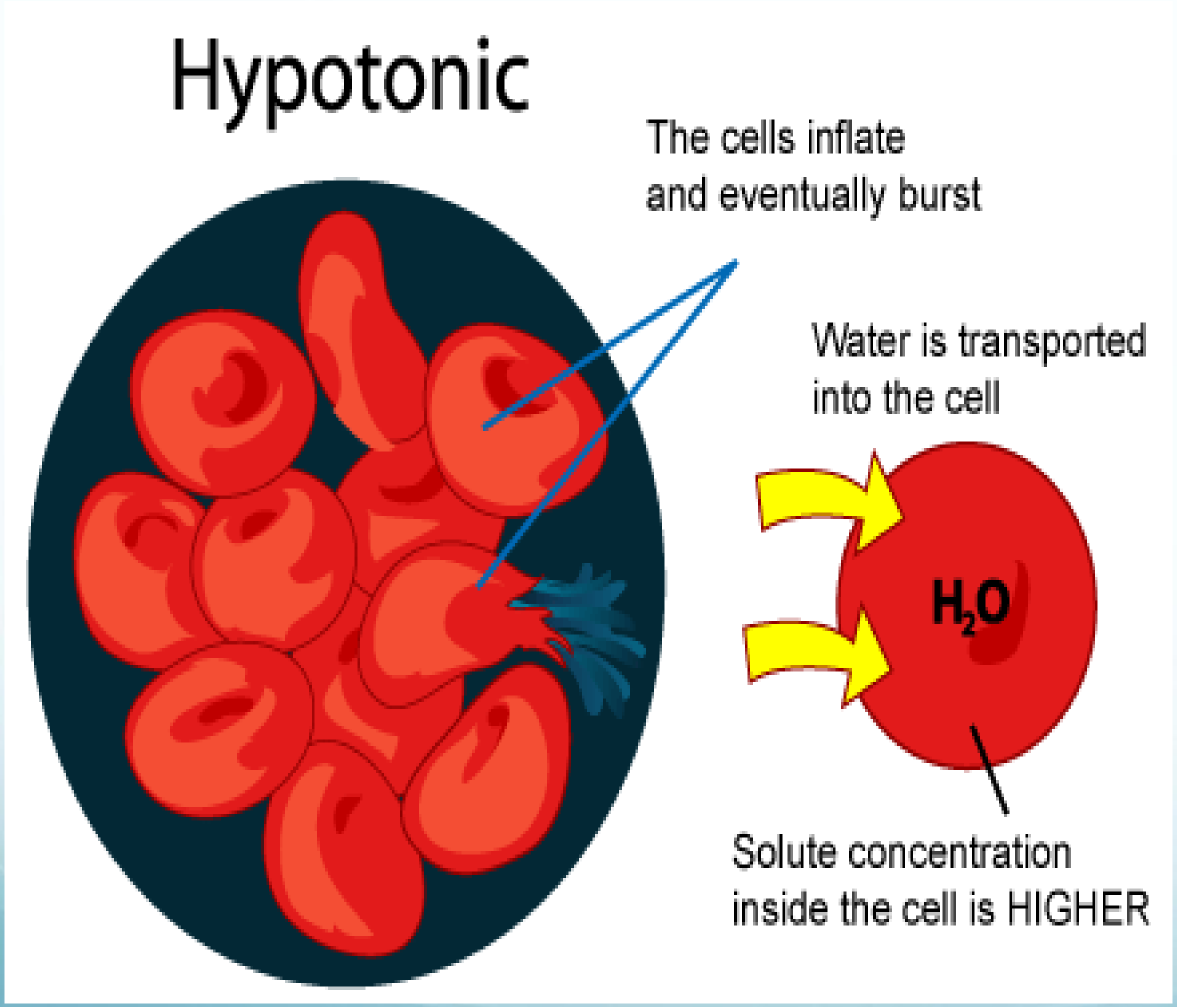
Low water potential



1. Vacuole has higher water potential compared to solution outside cell.
2. Water leave cells by osmosis
3. Vacuole decreases in size
4. Cytoplasm shrinks away from cell wall (**Plasmolysis**).

Animal cell in

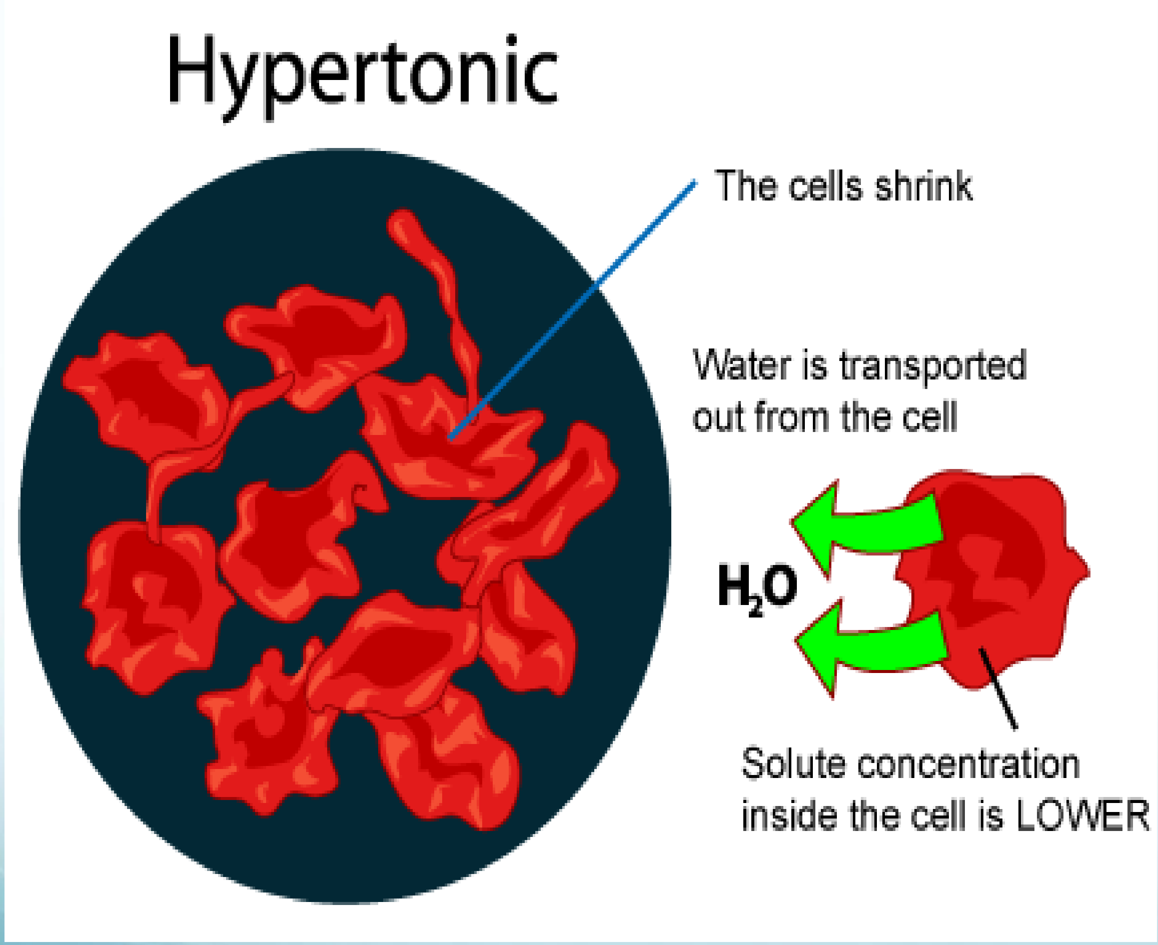
High water potential



1. Cytoplasm has lower water potential compared to solution outside cell
2. Water enters by osmosis
3. Animal cell will swell and may bursts as it does not have a cell wall to protect it.

Animal cell in

Low water potential



1. Cytoplasm has higher water potential compared to the solution outside the cell.
2. Water leaves by osmosis
3. Cell shrinks and little spikes appear on cell surface membrane (Crenation).

Why do you think cells are so small???

Why most large organisms are multi-cellular and not unicellular?

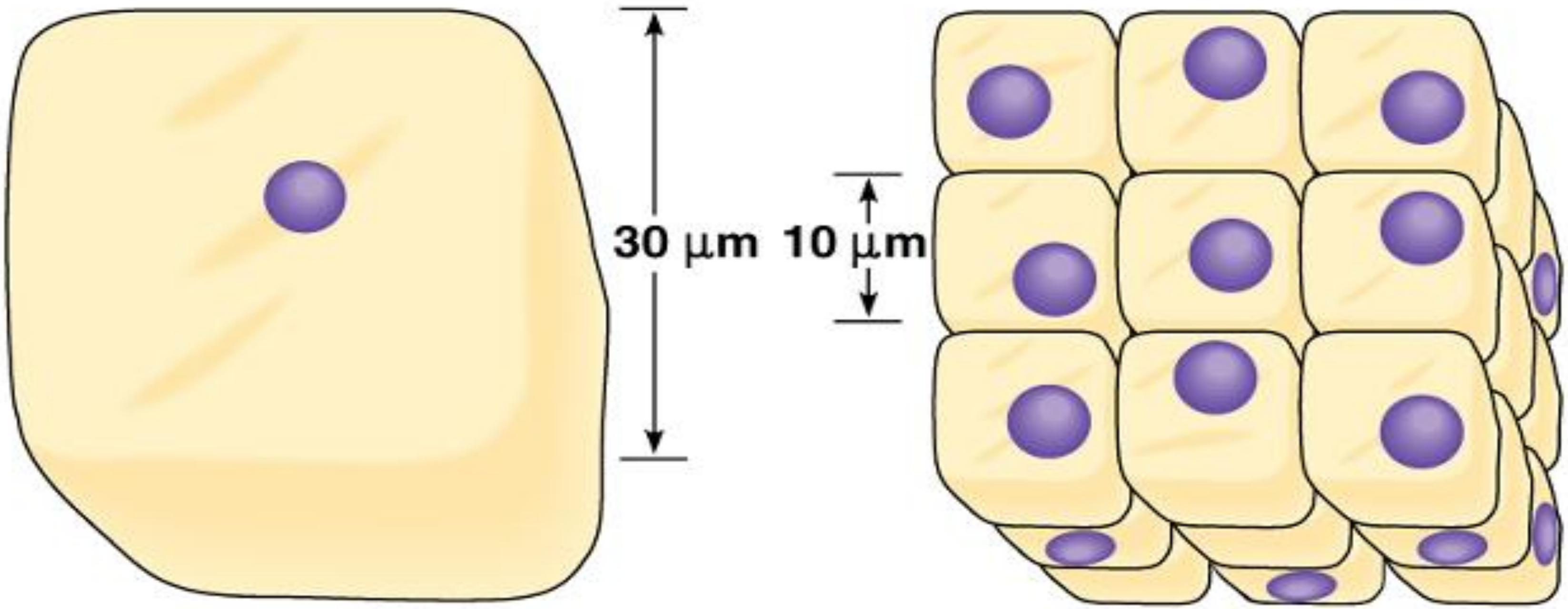
Surface Area to Volume Ratio

- **Affects rate of movement of substances across cell surface membranes.**
- **"The greater the surface area of cell surface membrane to per unit of volume, the faster the rate of diffusion of a substance for a given concentration gradient."**

???

Surface area to volume ratio

Which one has a bigger surface area?

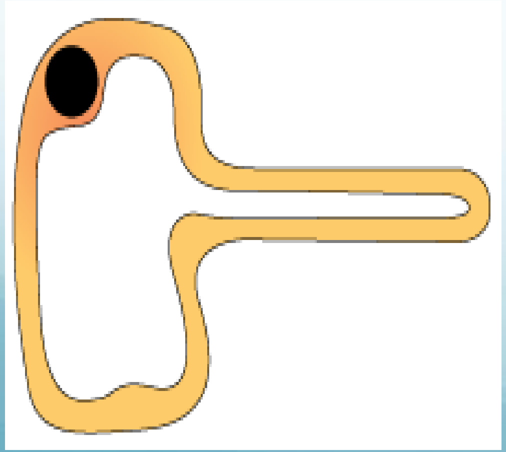


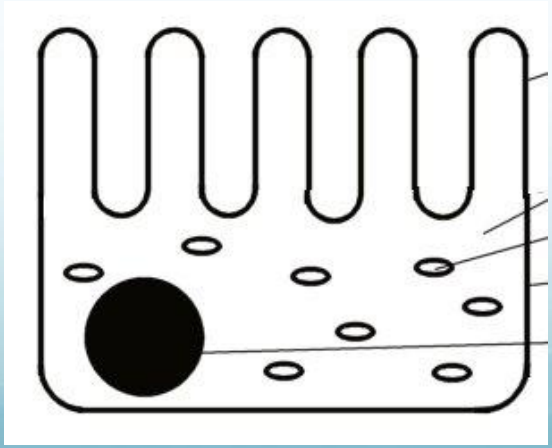
Surface area of one large cube = 5400 µm^2

Total surface area of 27 small cubes = 16,200 µm^2

Surface area to volume ratio

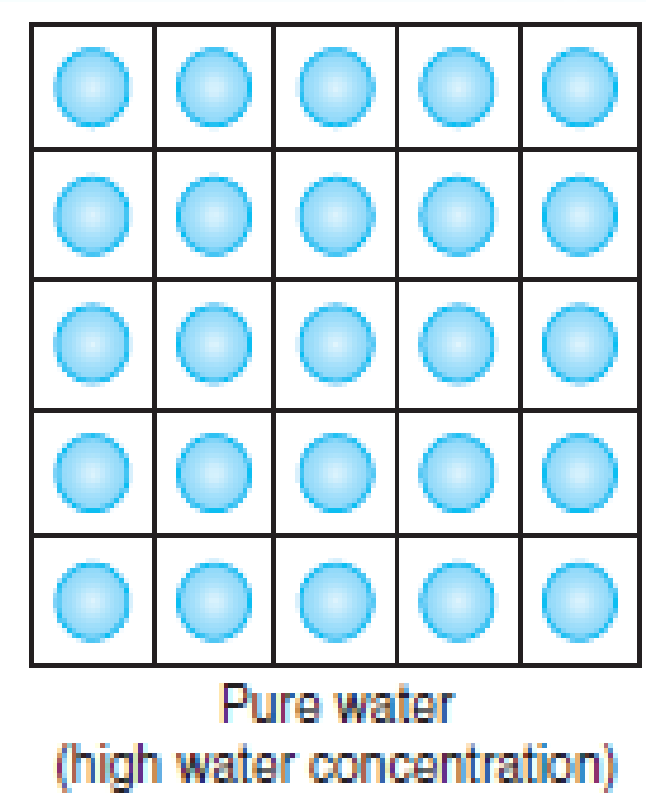
- The larger the surface area to volume ratio, the faster the rate of substance movements.
- Cells adaptations for better absorption of materials (increased surface area)
  - Root hair cells
  - Epithelial cells of small intestine
  - Red blood cells

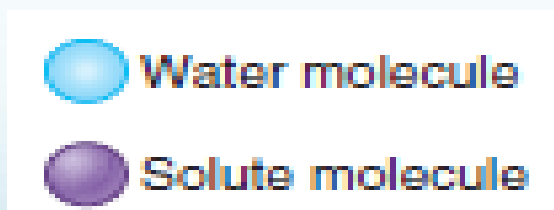


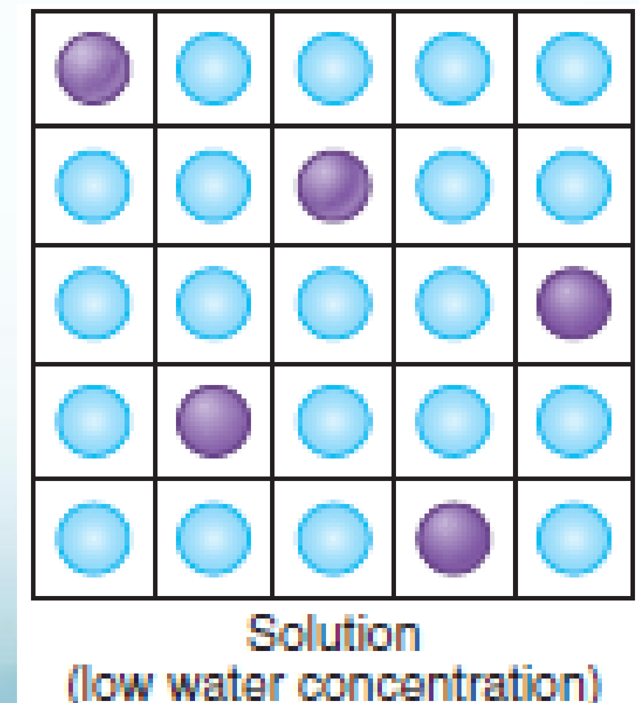


- **For example,**
  - if a solute such as glucose is dissolved in water, the concentration of water in the resulting solution is less than that of pure water.
  - The decrease in water concentration in a solution is approximately equal to the concentration of added solute.
  - In other words, one solute molecule will displace one water molecule. Just as adding water to a solution will dilute the solute, adding solute to a solution will "dilute" the water.

- **The addition of solute molecules to pure water lowers the water concentration in the solution.**







Why are diffusion & osmosis important?

- All living things have certain requirements they must satisfy in order to remain alive – maintain **homeostasis**
- These include exchanging gases (usually CO_2 and O_2), taking in water, minerals, and food, and eliminating wastes.
- These tasks happen at the cellular level.
- Molecules move through the cell membrane by diffusion
- A balance, or EQUILIBRIUM, must be maintained.

Movement of Substances

Diffusion

includes → Osmosis

definition:

Net movement of particles from a region of **high concentration** to a region of **low concentration**, **down the concentration gradient.**

Key Ideas:

1) Liquid/ Gas particles move from region of high concentration to low concentration
2) Movement of particles is random and dynamic in equilibrium (net)
3) Concentration gradient
4) Examples of diffusion

Osmosis

definition:

The movement of **water molecules** through a **partially permeable membrane** from a solution of **high water potential,** to a solution of **lower water potential.**

Opposites!

Key Ideas:

1) Only water molecules
2) Partially permeable membrane
3) High water potential to low water potential
4) Hypertonic & hypotonic
5) Osmosis in living cells
6) SA to Vol ratio
7) Adaptations

Active Transport

Movement of Substances

Diffusion

includes → Osmosis

Definition: **Net** movement of particles from a region of **high concentration** to a region of **low concentration**, **down the concentration gradient.**

Key Ideas:

1) Liquid/ Gas particles move from region of high concentration to low concentration
2) Movement of particles is random and dynamic in equilibrium (net)
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Osmosis

Definition: The movement of **water molecules** through a **partially permeable membrane** from a solution of **high water potential,** to a solution of **lower water potential.**

Key Ideas:

1) Only water molecules
2) Partially permeable membrane
3) High water potential to low water potential
4) Hypertonic & hypotonic
5) Osmosis in living cells
6) SA to Vol ratio
7) Adaptations

Active Transport

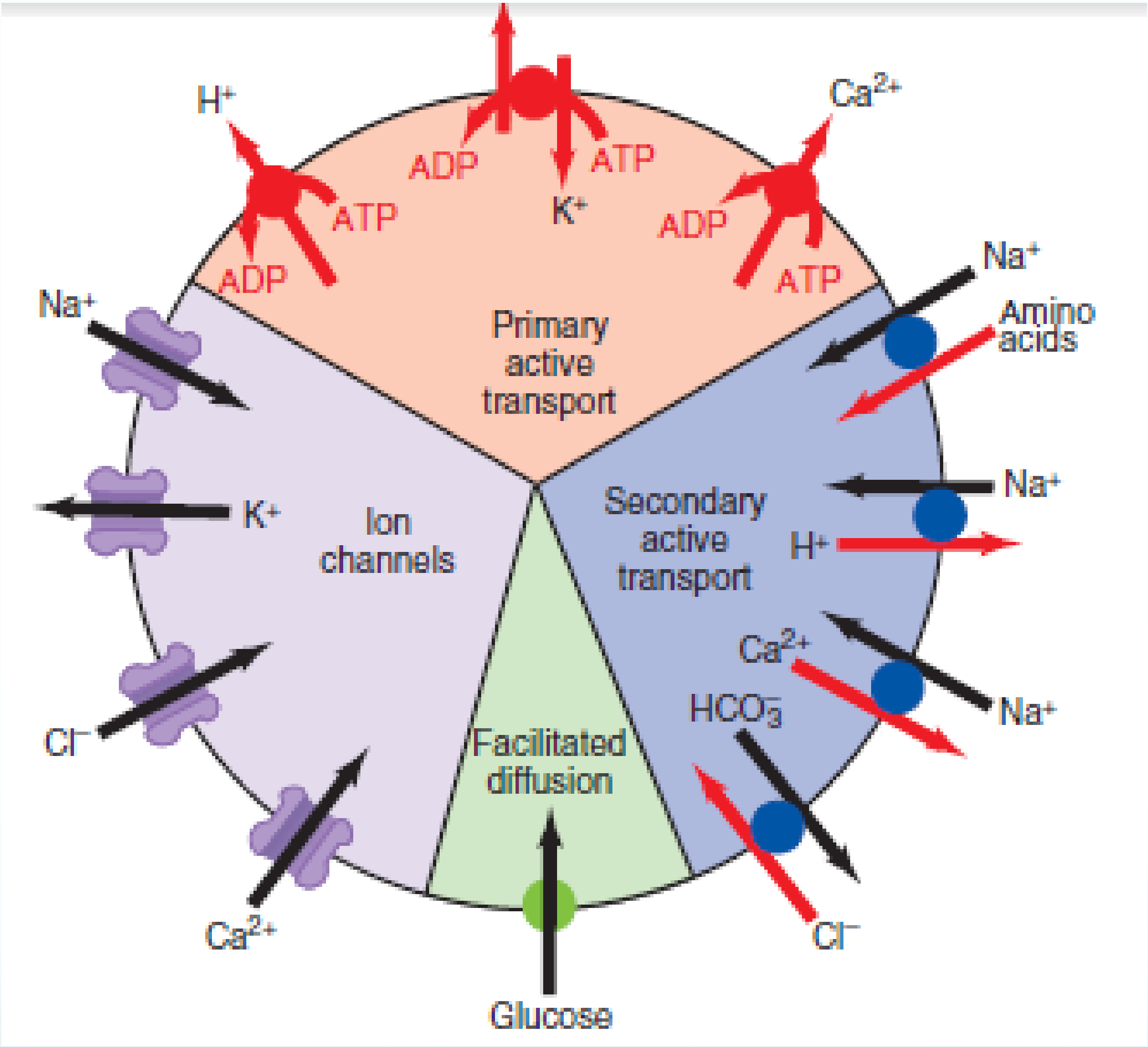
Definition: Energy **is used** to move particles against concentration gradient (**from a region of low concentration to a region of higher concentration**) , **up a concentration gradient**.

Key Ideas:

1) Requires energy
2) From low to high
3) Only in living cell
4) Active transport in living cells

Factors Affecting the Direction of Transport

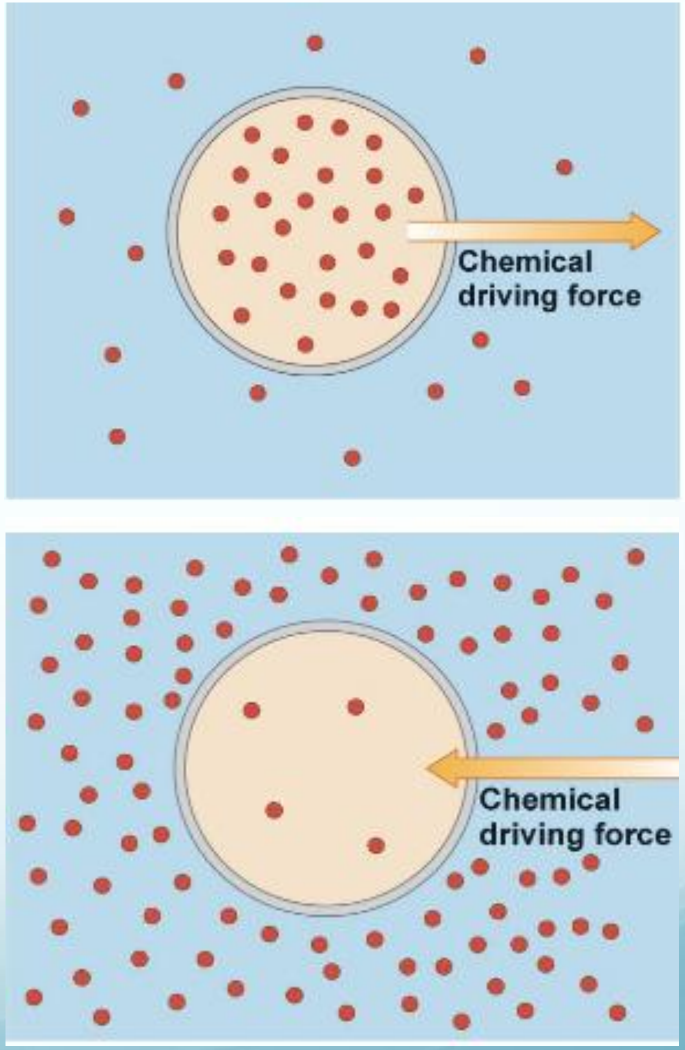
- If energy is not necessary to move molecules across a membrane the transport is called **passive transport.**
- When the transport of a molecule across the membrane requires energy the transport is called **active transport.**



Movements of solutes across a typical plasma membrane involving membrane proteins.

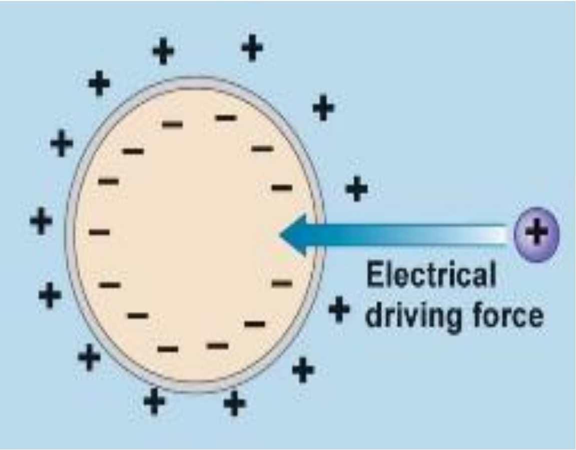
1. Chemical Driving Forces

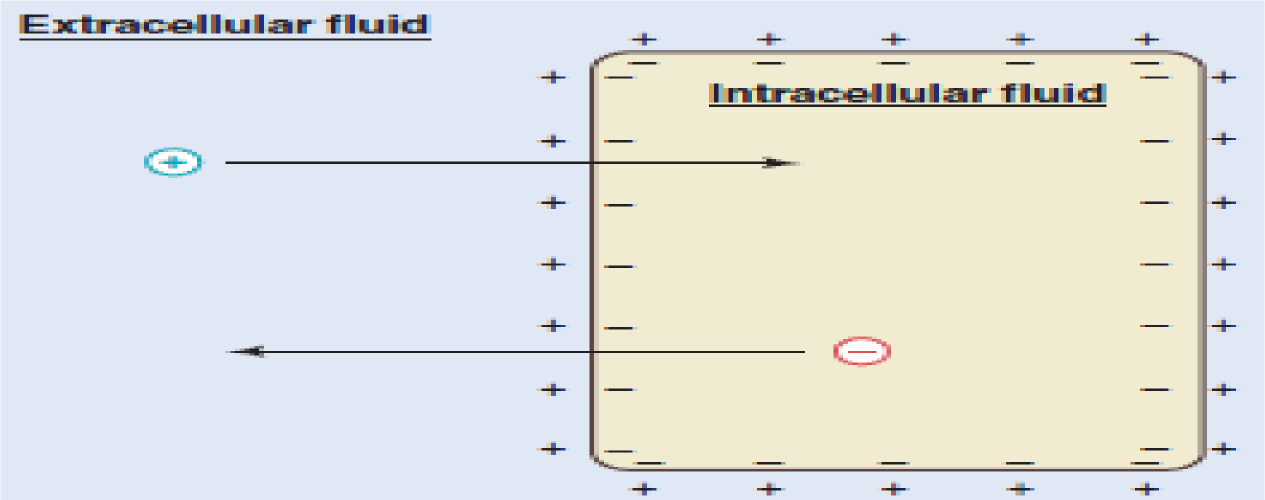
- This force is directly proportional to the concentration gradient.
- If there are more than one kind of molecule across a cell membrane each molecule has its own concentration gradient or chemical driving force.

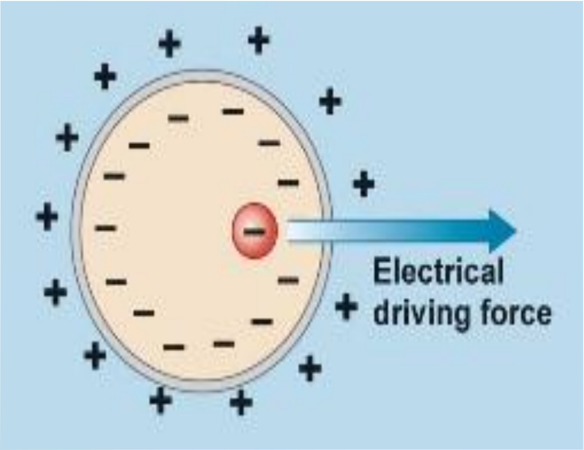


2. Electrical Driving Force

- Ions, atoms or molecules that have a charge, can be affected by an electrical driving force.
- This force across a cell membrane is expressed as the membrane potential. This potential results from an unequal distribution of charges across the membrane.







The separation of electrical charge across a plasma membrane (the membrane potential) provides the electrical force that drives positive ions into a cell and negative ions out.

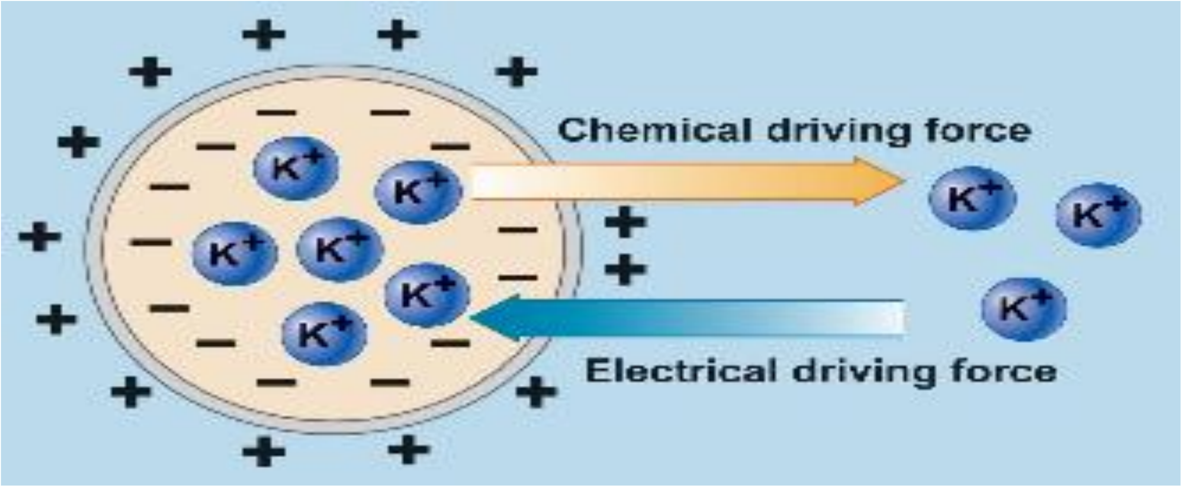
- <u>For example,</u>

  If the inside of a cell has a net negative charge with respect to the outside, there will be an electrical force attracting positive ions into the cell and repelling negative ions.

Even if there were no difference in ion concentration across the membrane, there would still be a net movement of positive ions into and negative ions out of the cell because of the membrane potential.

3. Electrochemical Driving Forces

- The direction and magnitude of *ion fluxes across membranes* depend on both the concentration difference and the electrical difference.
- These two driving forces are collectively known as the electrochemical gradient, also termed the electrochemical difference across a membrane.
- The net direction of electrochemical force is equal to the sum of both (electrical and chemical) forces.



- **The two forces that make up the electrochemical gradient may oppose each other.**

- **Thus, the *membrane potential (electrical gradient) may be driving* potassium ions, in one direction across the membrane, while the *concentration difference for potassium* is driving these ions in the opposite direction.**

- **The net movement of potassium in this case would be determined by the relative magnitudes of the two opposing forces—that is, by the electrochemical gradient across the membrane.**