بسم الله الرحمن الرحيم

Solution and Methods of Expressing Concentration

3rd Lecture of medical chemistry

by

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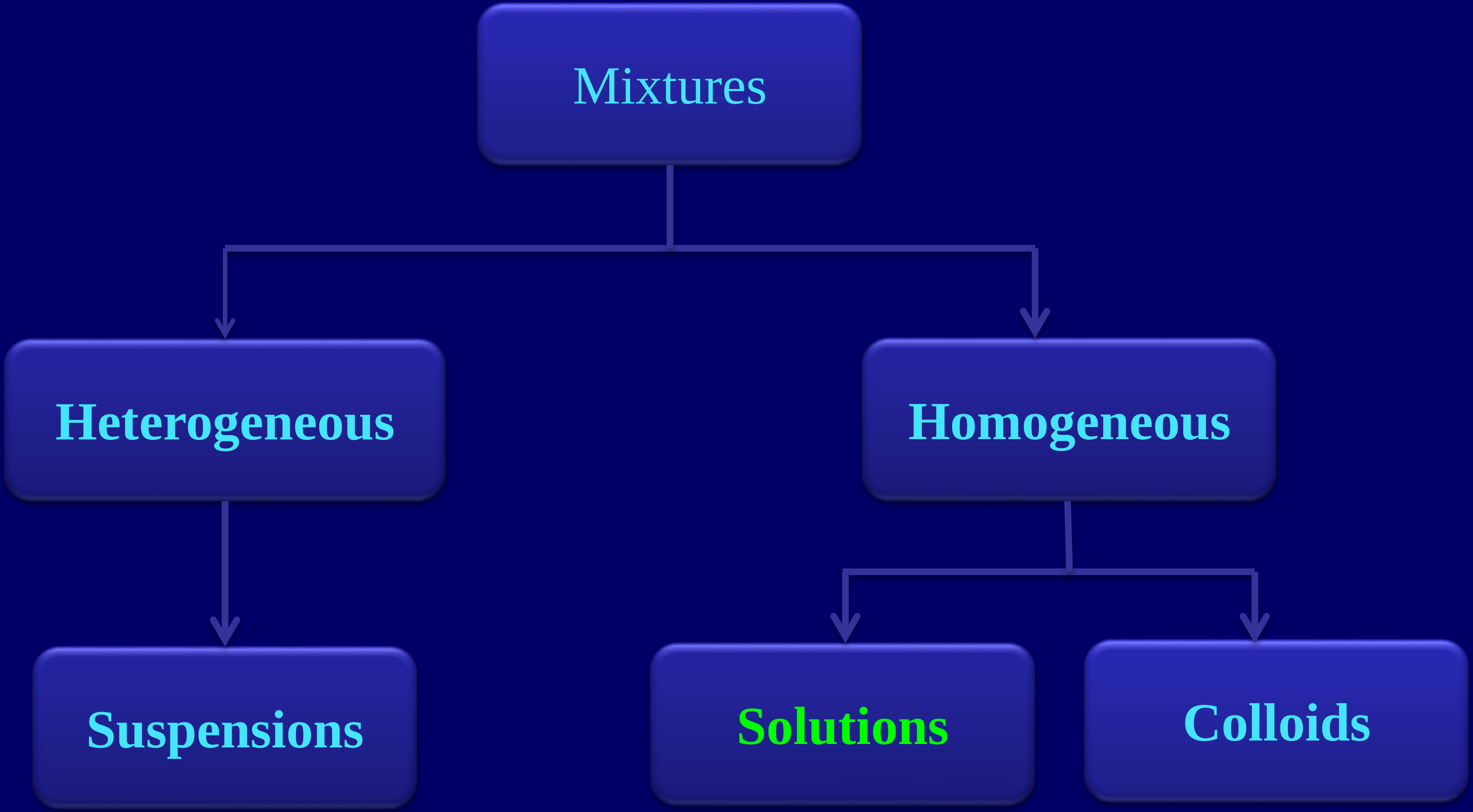
TYPES OF MIXTURES



Mixtures

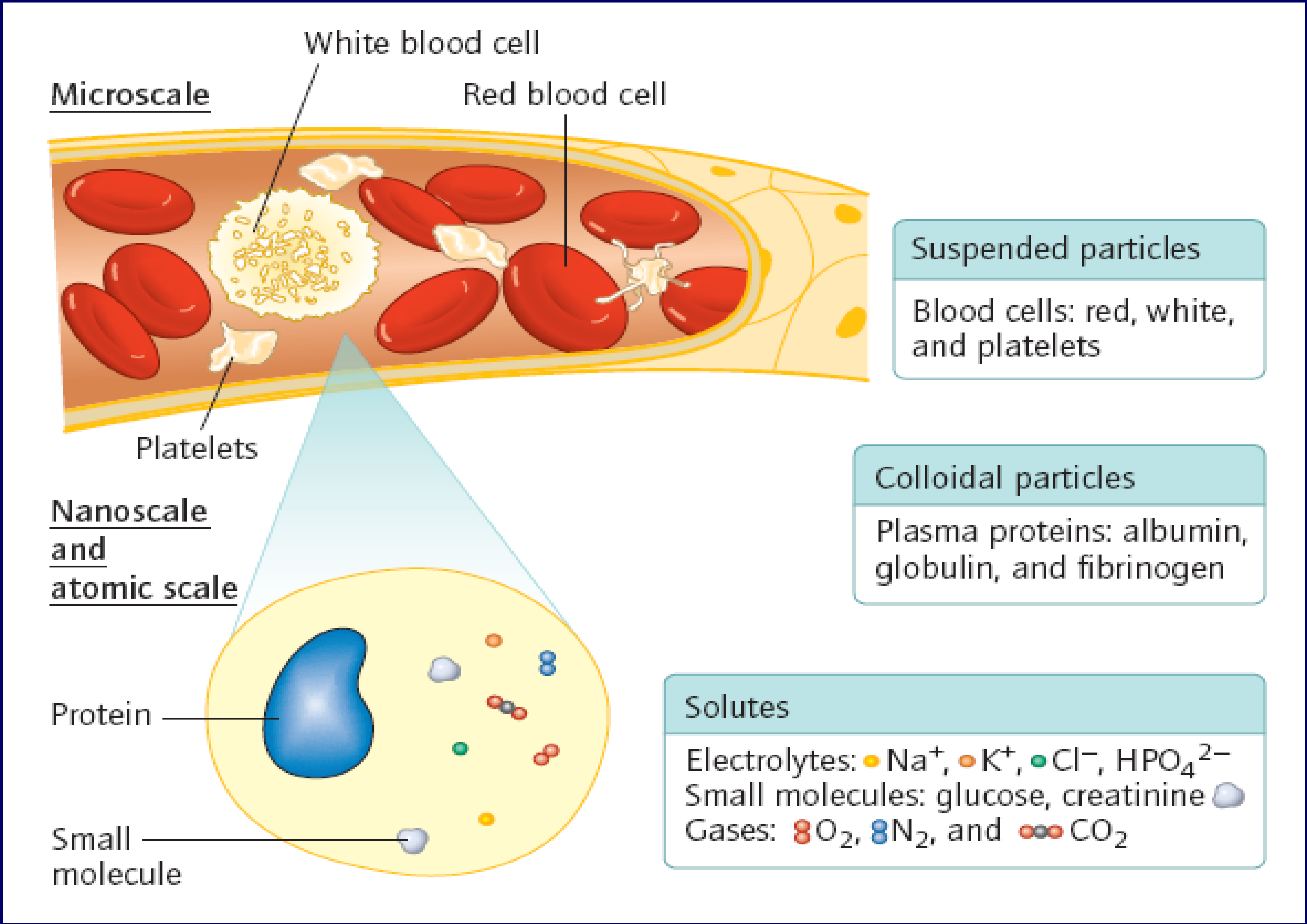
Heterogeneous

Homogeneous

Suspensions

Solutions

Colloids



Suspended particles

Blood cells: red, white, and platelets

Colloidal particles

Plasma proteins: albumin, globulin, and fibrinogen

Solutes

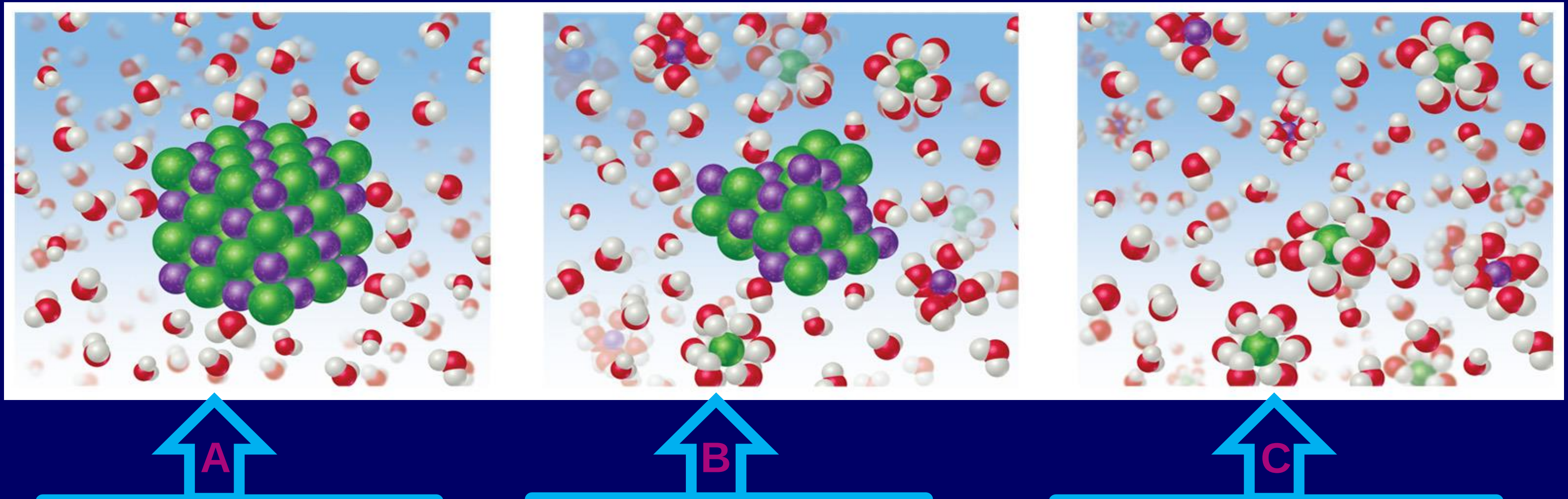
Electrolytes: ● Na^+, ● K^+, ● Cl^-, HPO_4^{2-}
Small molecules: glucose, creatinine
Gases: O_2, N_2, and CO_2

Solutions

- **Solutions** are homogeneous mixtures of two or more pure substances.
- In a solution, the solute is dispersed uniformly throughout the solvent.

State of solution	State of solvent	State of solute	Example
Gas	Gas	Gas	Air
Liquid	Liquid	Gas	Air in water
Liquid	Liquid	Liquid	Alcohol in water
Liquid	Liquid	Salt	Salt in water
Solid	Solid	Gas	Hydrogen in palladium
Solid	Solid	Liquid	Mercury in silver
Solid	Solid	Solid	Silver in gold

Formation of Solution



Solvent molecules attracted to surface ions

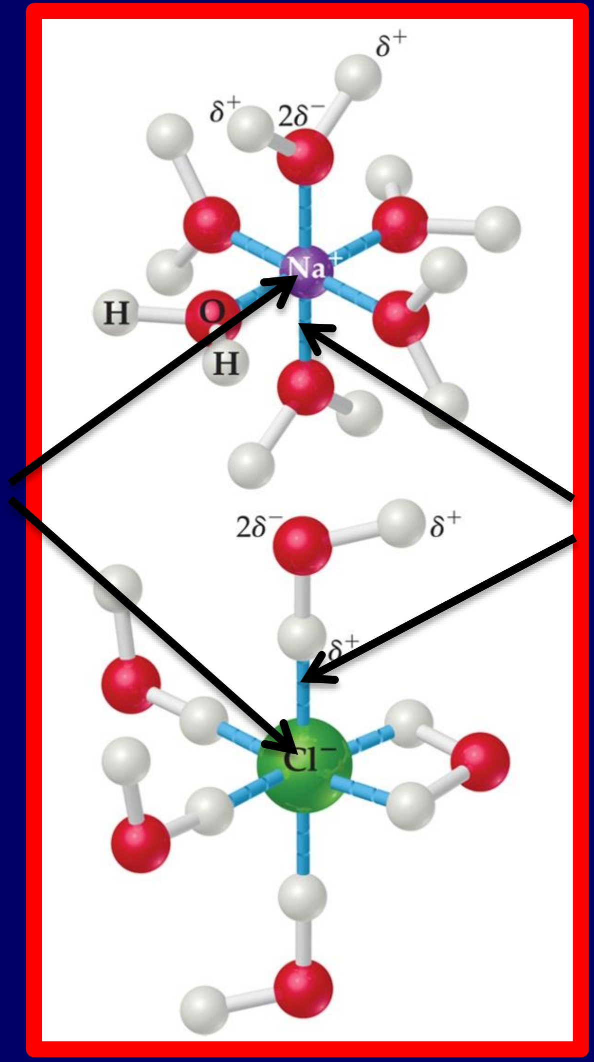
Each ion is surrounded by solvent molecules

The ions are **solvated** (surrounded by solvent)

Water Solution

Solvated ions in water (surrounded by water) are said to be **hydrated**

The intermolecular force here is **ion-dipole**



Hydrated Ions

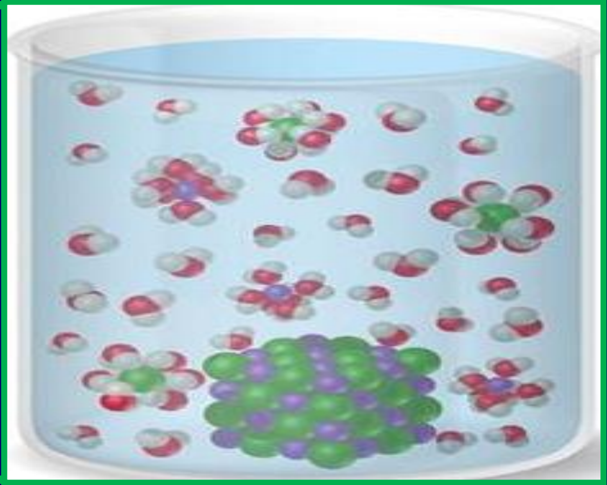
ion-dipole

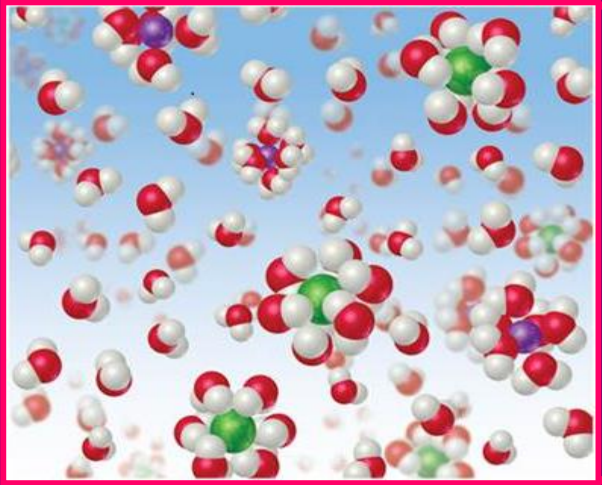
Degree of saturation

Saturated Solution

1.Solvent holds as much solute as it possible at that temperature.

2. Undissolved solid remains in flask.
3. Dissolved solute is in dynamic equilibrium with solid solute particles





Unsaturated Solution

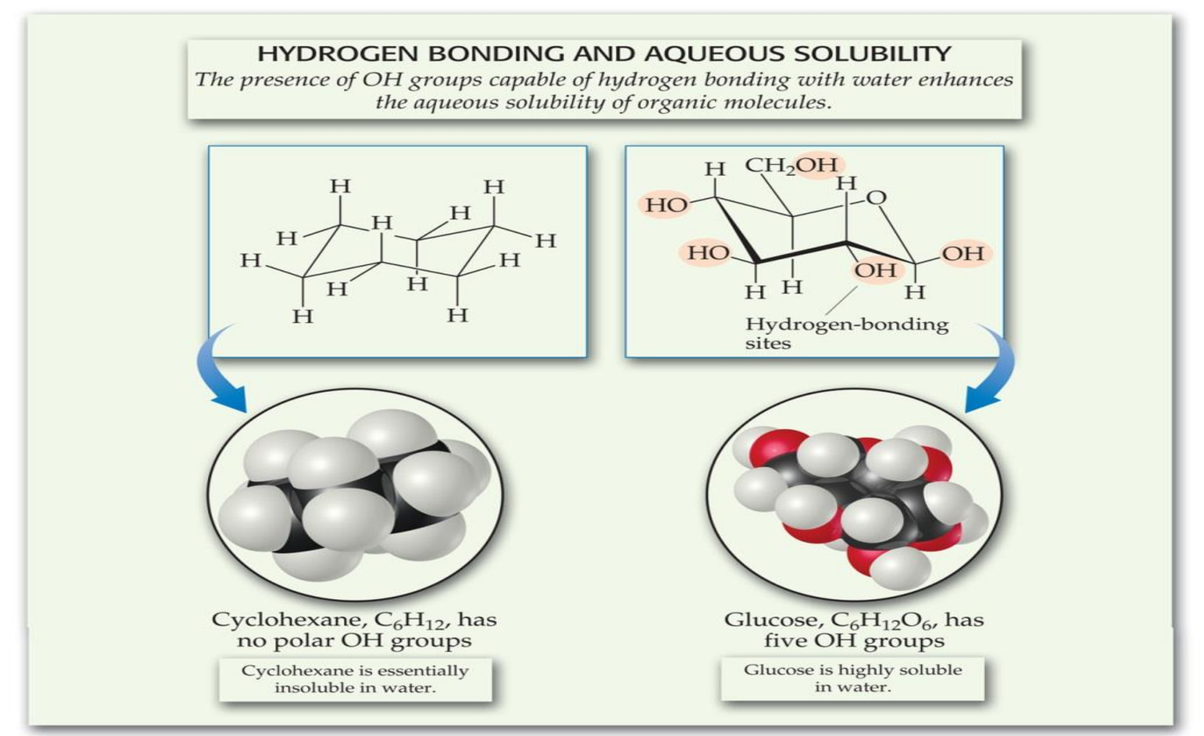
1. Less than the maximum amount of solute for that temperature is dissolved in the solvent.
2. No solid remains in flask.

Factors Affecting Solubility

The stronger the intermolecular attractions (H-bonds; ion-dipole forces) between solute and solvent, the more likely the solute will dissolve.

Glucose which has hydrogen bonding is very soluble in water

Cyclohexane which only has dispersion forces is not water-soluble.



HYDROGEN BONDING AND AQUEOUS SOLUBILITY

The presence of OH groups capable of hydrogen bonding with water enhances the aqueous solubility of organic molecules.

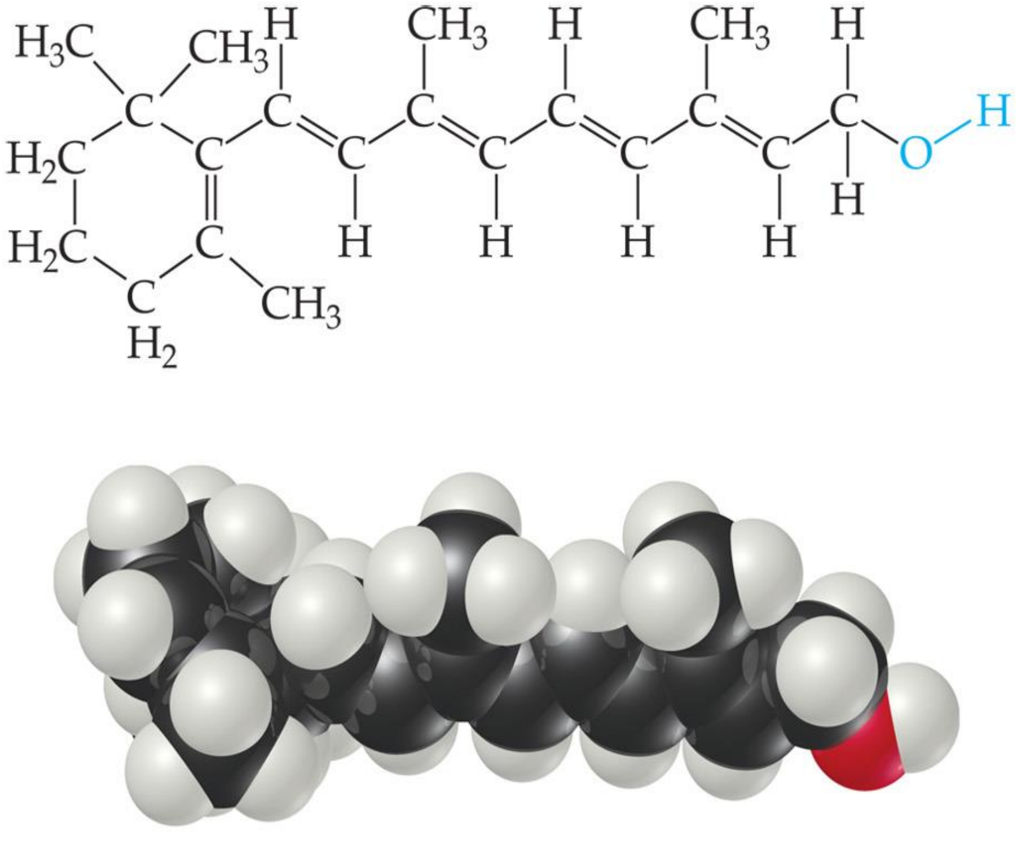
Cyclohexane, C_6H_{12}, has no polar OH groups

Cyclohexane is essentially insoluble in water.

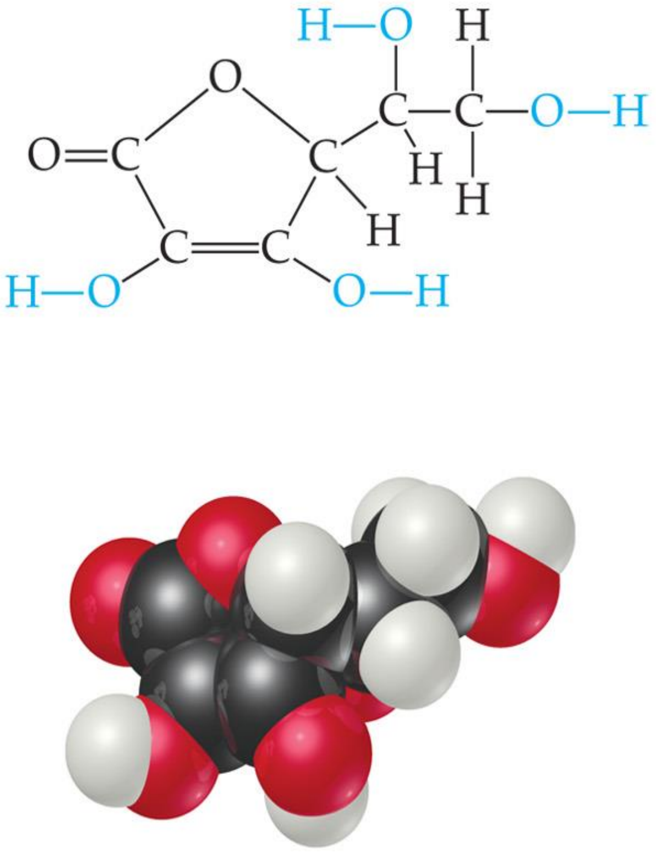
Glucose, $C_6H_{12}O_6$, has five OH groups

Glucose is highly soluble in water.

Vitamin A is soluble in nonpolar compounds (like fats).While Vitamin C is soluble in water. Why?

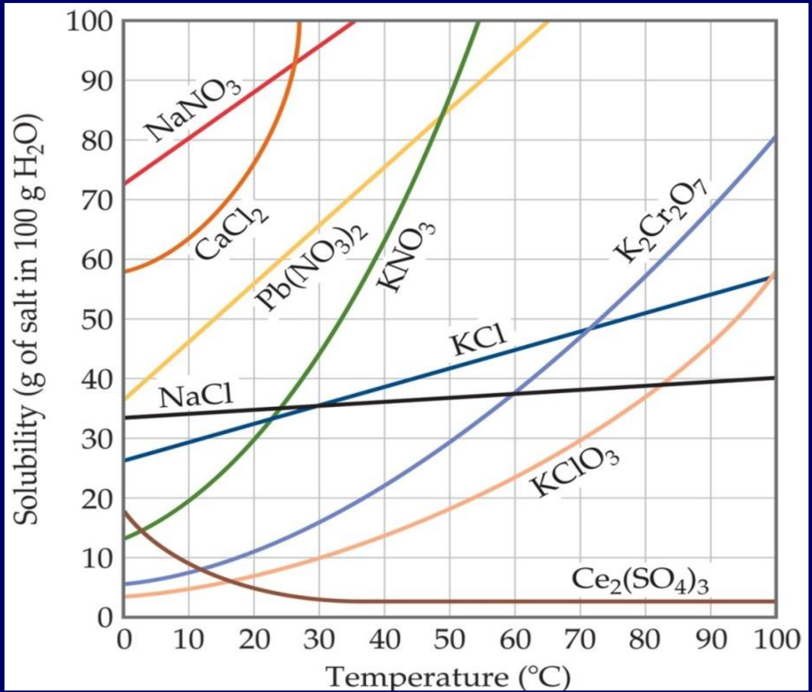


Vitamin A



Vitamin C

- The solubility of gases in water increases with increasing mass because larger molecules have stronger dispersion forces.



- Generally, the solubility of solid solutes in liquid solvents increases with increasing temperature. The opposite is true of gases. High temperature drives gases out of solution

- The solubility of liquids and solids does not change appreciably with pressure. But, the solubility of a gas in a liquid is directly proportional to its pressure

$$S_g = kP_g$$

S_g :solubility of the gas.
k :Henry’s law constant for the gas solvent.
P_g: partial pressure of the gas.

Methods of expressing Concentration

The term **concentration** is used to refer to the amount of solute that is dissolved in a solvent.

Concentration by Percent

In general, percentage can be defined as:

$$\% = \frac{\text{Part}}{\text{Whole}} \times 100$$

In chemistry, we are usually interested in percent by mass:

$$\%\ \text{Mass} = \frac{\text{Mass of Part}}{\text{Total Mass}} \times 100$$

Concentration by Percent

Percent means the same thing as “parts per hundred”, so when percent is used as a concentration unit, the number of parts of solute present in every 100 parts of solution is being specified.

There are three commonly used percent measurements for concentration:

1. weight/weight %(w/w)
2. volume/volume %(v/v)
3. weight/volume %(w/v)

$$\% \text{ (Weight/Weight)} = \frac{\text{grams of Solute}}{\text{grams of Solution}} \text{ x } 100\%$$

$$\% \text{ (Vol/Vol)} = \frac{\text{mL of Solute}}{\text{mL of Solution}} \quad 100\%$$

$$\% \text{ (Weight/Vol)} = \frac{\text{grams of Solute}}{\text{mL of Solution}} \text{ x } 100\%$$

Example :Potassium iodide (KI) is used to tread iodine deficiencies. What is the %(w/v) of a 75 mL solution containing 2.0g of KI? (answer2.7%(w/v))

Parts per thousand, parts per million, and parts per billion

These units are mostly used for very dilute solutions.
Recall that % is *parts per hundred*:

$$\% \text{ (Weight/Vol)} = \frac{\text{grams of Solute}}{\text{mL of Solution}} \times 100\%$$

We can easily calculate *parts per thousand*:

$$\text{ppt (Weight/Vol)} = \frac{\text{grams of Solute}}{\text{mL of Solution}} \times 1000$$

parts per million

$$\text{Ppm (Weight/Vol)} = \frac{\text{grams of Solute}}{\text{mL of Solution}} \times 10^6$$

parts per billion:

$$\text{ppb (Weight/Vol)} = \frac{\text{grams of Solute}}{\text{mL of Solution}} \times 10^9$$

Example : Many cities add sodium fluoride to their drinking water to help reduce dental cavities. If 25 L of city water contains 0.018g of sodium fluoride, what is the concentration in parts per billion?
Answer : **720 ppb**

Molarity

Molarity (M) is defined as the number of moles of solute present in each liter of solution.

$$\text{Molarity (M)} = \frac{\text{moles of Solute}}{\text{liters of Solution}}$$

Example : A solution is prepared by dissolving 0.10 moles of the amino acid alanine in enough water to give a final volume of 75 mL. What is the molarity of the solution?

Answer : 1.3 M or 1.3 moles/L

Concentration in Osmolarity

- Osmolarity is the number of osmoles per liter of solution.
- An osmole is the number of moles of dissolved particles that are contained in a solution.

$$\text{Osmolarity} = \frac{\#\ \text{osmoles}}{\text{L of solution}}$$

Example:

One mole of NaCl is equal to 2 osmole. (NaCl ionizes)

One mole of sucrose is equal to 1 osmole.(non-ionizing)

How many osmole(s) in 1 mole of $CuCl_2$?

$CuCl_2 \rightarrow Cu_2^+ + 2\ Cl^-$

Concentration in Molality

Molality (m) is another way to express moles of solute in a solution.

Molality is the number of moles of solute per kg of solvent (moles/kg).

$$\text{Molality } (m) = \frac{\text{\# moles}}{\text{kg of solvent}}$$

Concentration in Osmolality

Osmolality is the number of osmoles per kg of solvent

$$\text{Osmolality} = \frac{\text{osmoles}}{\text{kg solvent}}$$

Concentration in equivalents (Eq/L)

An equivalent (Eq) is the number of moles of charge that a solute contributes to a solution.

$$(\text{Eq/L}) = \frac{\text{\# equivalents}}{\text{L of solution}}$$

Example:

One mole of NaCl is equal to 2 equivalents.

One mole of sucrose has no equivalents.(non-ionizing)

How many equivalents are in 1 mole of dissolved $CuCl_2$?

$CuCl_2 \rightarrow Cu_2^+ + 2\,Cl^-$

Answer / 4 ⟶ 2 from Cu_2^+ and 2 from each Cl^-

Example: 4.35 moles of $CuCl_2$ is dissolved in enough water to make 5.80 L of solution. What is the concentration in Eq/L of the solution?

Colligative properties

Colligative property- a property of a solution that depends on concentration of solute (the number of solute particles dissolved) but NOT on type of solute.

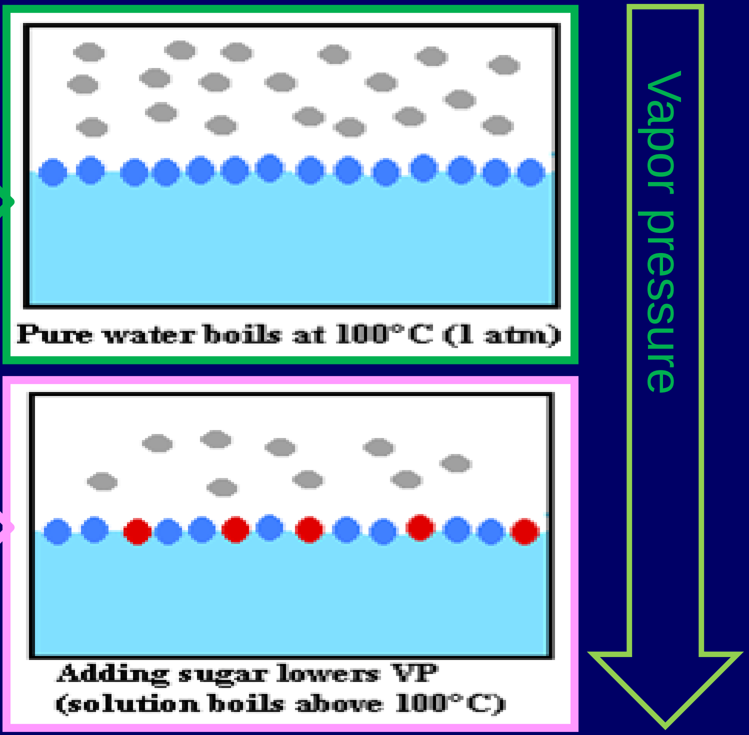
Four important colligative properties of solutions:

1. Vapor pressure is *always* lower
2. Boiling point is *always* higher
3. Freezing point is *always* lower
4. Osmotic pressure drives solvent from lower concentration to higher concentration

Vapor Pressure

At equilibrium
Vaporization = condensation
Solvent higher Vapor pressure then the solution

Solute particles occupy volume reducing rate of evaporation the number of solvent molecules at the surface


Pure water boils at 100°C (1 atm)

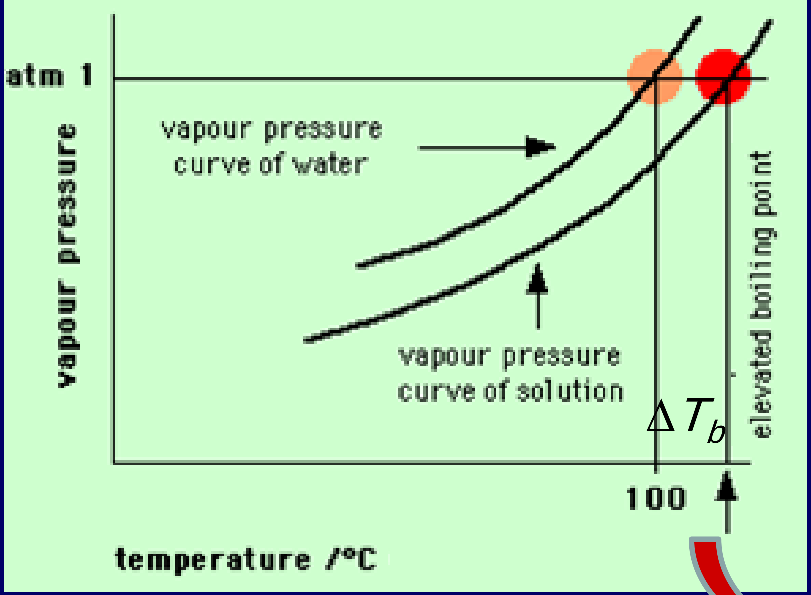
Adding sugar lowers VP (solution boils above 100°C)

The rate of evaporation decreases and so the vapor pressure above the solution must decrease to recover the equilibrium

● vapor
● water
● sugar

Boiling point

Because of the decrease in vapor pressure, additional kinetic energy must be added to raise the vapor pressure of the liquid phase of the solution to atmospheric pressure to initiate boiling



Boiling point elevate the same value of difference in temperature between the boiling point of the solution and the boiling point of the pure solvent (water).

Boiling Point Elevation

The change in boiling point is proportional to the molality of the solution:

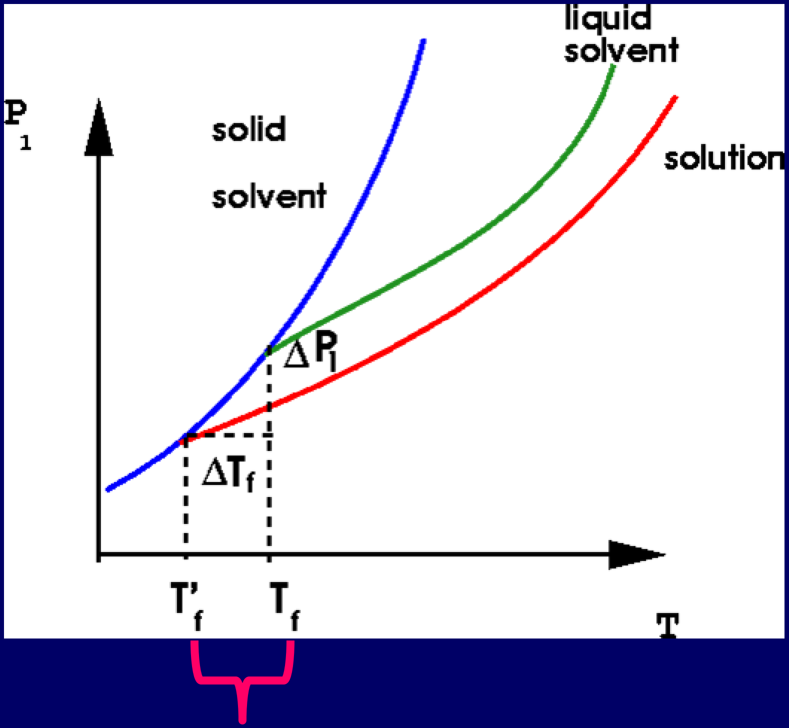
$$\Delta T_b = K_b \cdot m$$

where K_b is the molal boiling point elevation constant, a property of the solvent.

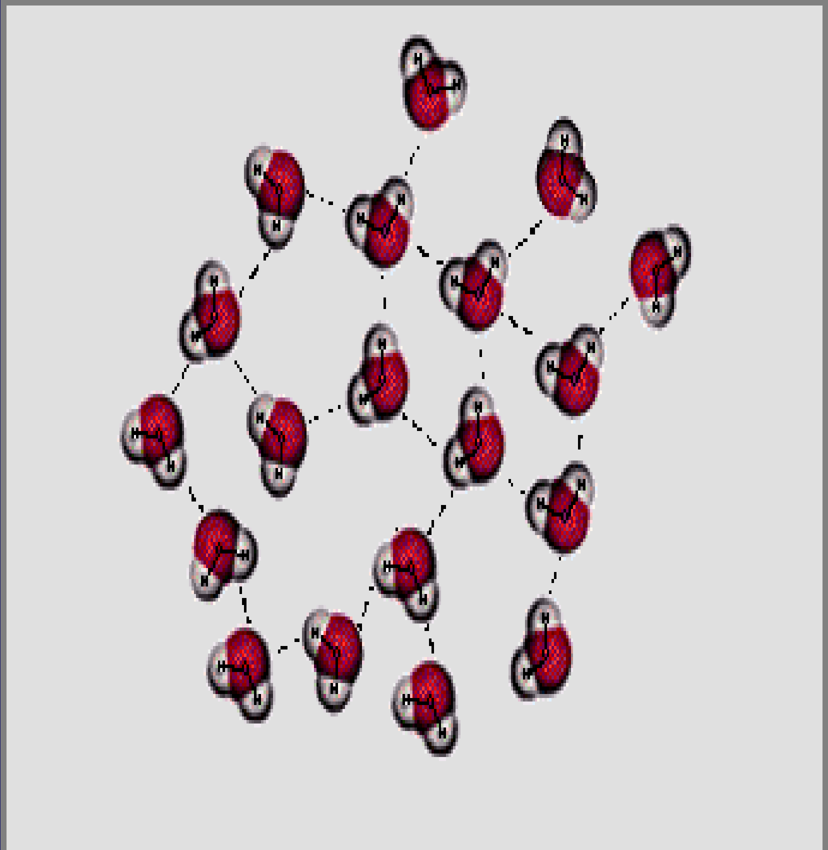
Freezing-Point

Since vapor pressure of the solution is lowered, the freezing point of a solution is lower than the freezing point of the pure solvent

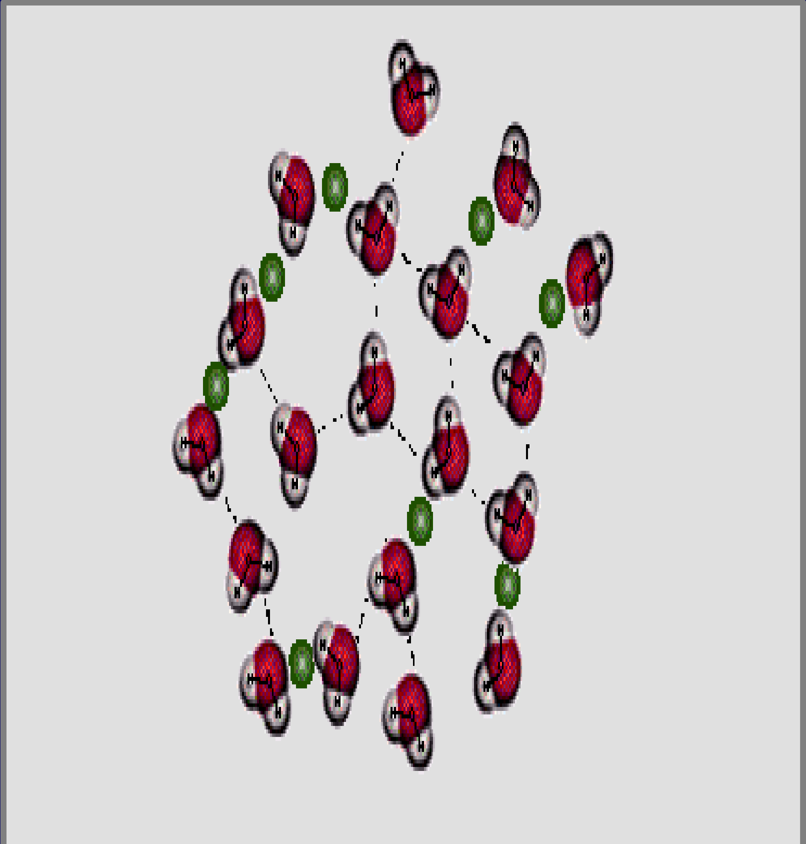
The presence of a solute in water disrupts the formation of the orderly pattern of ice. Therefore more kinetic energy must be withdrawn from a solution than from the pure solvent to cause the solution to solidify.



Freezing-Point depressed the value of the difference in temperature between the freezing point of a solution and the freezing point of the pure solvent (*water*).



When the solvent is absolutely pure, its individual particles can interact without any obstruction.



When impurities are introduced to the solution, they disturb the stabilizing intermolecular bonds between solvent molecules.

Boiling Point Elevation

The change in boiling point is proportional to the molality of the solution:

$$\Delta T_b = K_b \cdot m$$

where K_b is the molal boiling point elevation constant

.

Freezing Point Depression

The change in freezing point can be found similarly:

$$\Delta T_f = K_f \cdot m$$

Here K_f is the molal freezing point depression constant of the solvent.

Incomplete dissociation

Not all ionic substances dissociate completely

Van’t Hoff factor accounts for this

Van’ t Hoff factor:

i = moles of particles in soln/moles of solute dissolved

For solutes which are not completely dissociated, the van’t Hoff factor is applied to modify m:

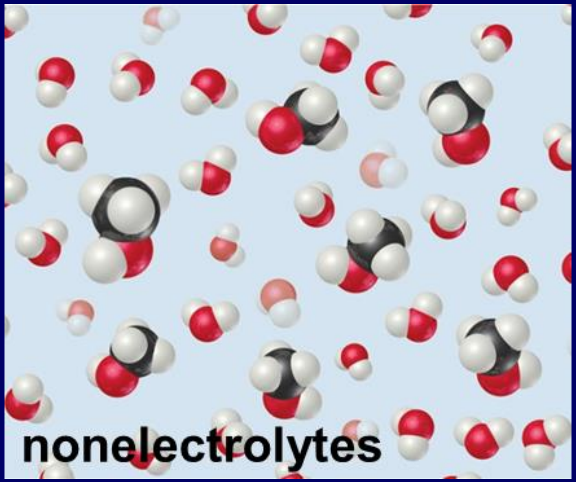
$$\Delta T_b = K_b \cdot m.\ i$$
$$\Delta T_f = K_f \cdot m.\ i$$

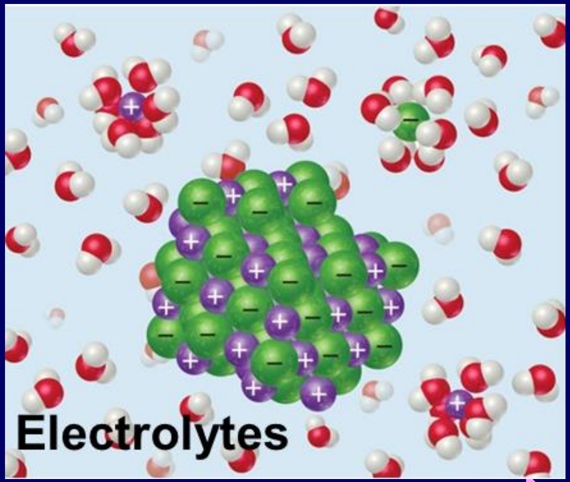
In both equations, ΔT does not depend on *what the solute is*, but only on *how many particles* are dissolved.

Colligative Properties of Electrolytes

These properties depend on the number of particles dissolved. So, Solutions of electrolytes (which dissociate in solution) show greater changes than those of nonelectrolytes.

e.g. NaCl dissociates to form 2 ion particles its limiting van’t Hoff factor is 2





Increase the changes e.g. B. p, F.p, Vo.pr , Os. Pr.

Counting particles

The influence of the solute depends only on the number of particles

Molecular and ionic compounds will produce *different* numbers of particles per mole of substance

1 mole of a molecular solid → 1 mole of particles
1 mole of NaCl → 2 moles of particles
1 mole of $CaCl_2$ → 3 moles of particles

Van' t Hoff factor *i*

While
i = 1 for non-elecrtolytes

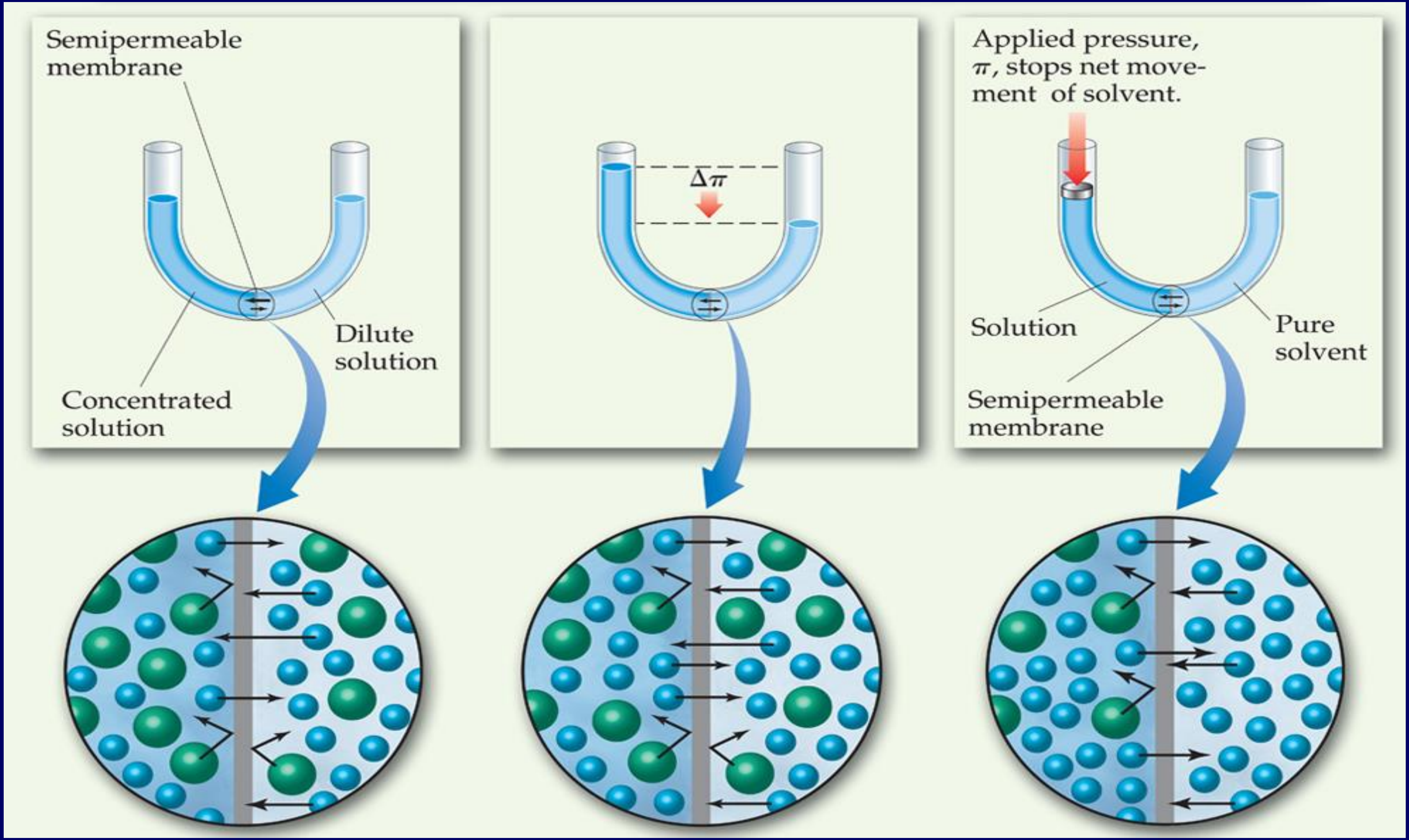
Osmosis

- Semipermeable membranes allow some particles to pass through while blocking others.

- In biological systems, most semipermeable membranes (such as cell walls) allow water to pass through, but block solutes.

- In osmosis, there is net movement of solvent from the area of **higher solvent concentration** (*lower solute concentration*) to the are of **lower solvent concentration** (*higher solute concentration*).

Osmosis



Water tries to equalize the concentration on both sides until pressure is too high.

Osmotic pressure

- ✓ Solvent passes into more conc. solution increasing its volume
- ✓ The passage of the solvent can be prevented by application of a pressure
- ✓ The pressure to prevent transport is the *osmotic pressure*

The ideal gas law states $\boxed{PV = nRT}$

But n/V = M and so $\boxed{\Pi = MRT}$

Where M is the molar concentration of particles and Π is the osmotic pressure

Note: *molarity* is used not *molality*

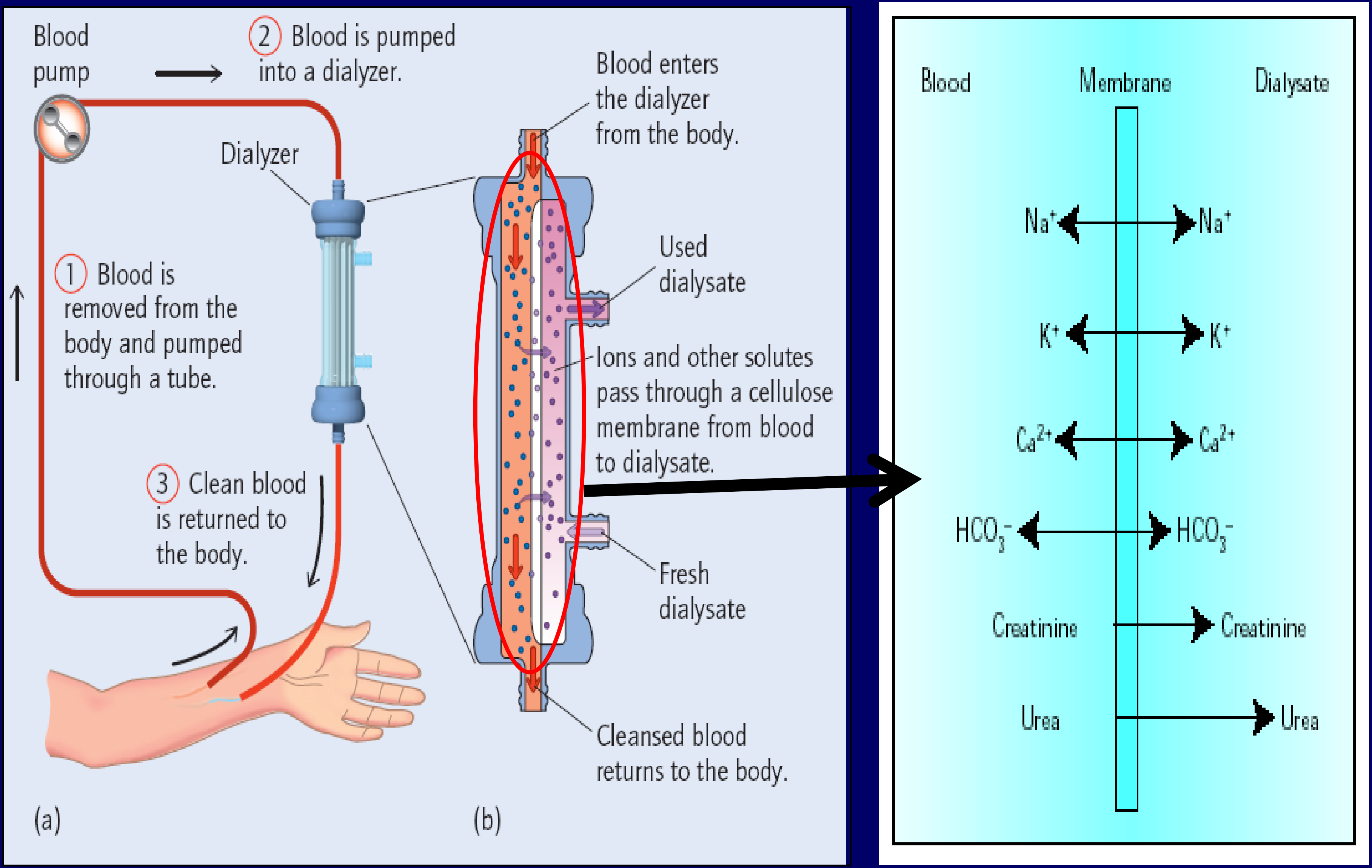
DIALYSIS

Occurs when solvent and small solute particles pass through a semipermeable membrane

Large particles retained inside

Hemodialysis is used medically (artificial kidney) to remove waste particles such as urea, creatinine and uric acid from blood.

This is the process for repletion of the bicarbonate deficit of the metabolic acidosis associated with renal failure in humans


Blood pump
② Blood is pumped into a dialyzer.
Blood enters the dialyzer from the body.
Dialyzer
① Blood is removed from the body and pumped through a tube.
Used dialysate
Ions and other solutes pass through a cellulose membrane from blood to dialysate.
③ Clean blood is returned to the body.
Fresh dialysate
Cleansed blood returns to the body.
(a)
(b)
Blood
Membrane
Dialysate
Na$^+$
Na$^+$
K$^+$
K$^+$
Ca^{2+}
Ca^{2+}
HCO$_3^-$
HCO$_3^-$
Creatinine
Creatinine
Urea
Urea

Determining molar mass

A solution contains 20.0 mg insulin in 5.00 ml develops an osmotic pressure of 12.5 mm Hg at 300 K

$$M = \frac{\Pi}{RT} \qquad M = \frac{12.5\,mmHg \;\; {}^{1}\!/_{760\,mmHg}}{0.0821\,\frac{L \bullet atm}{mol \bullet K}\;300\,K} = 6.68\times10^{-4}\,M$$

Moles insulin = MxV = $3.34\text{x}10^{-6}$ mol

Molar mass = mass of insulin/moles of insulin

= 0.0200 g/$3.34\text{x}10^{-6}$ mol

= 5990 g/mol

Osmotic Pressure of the Blood

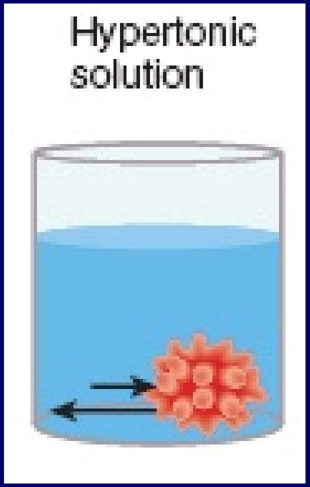
Cell walls are semipermeable membranes

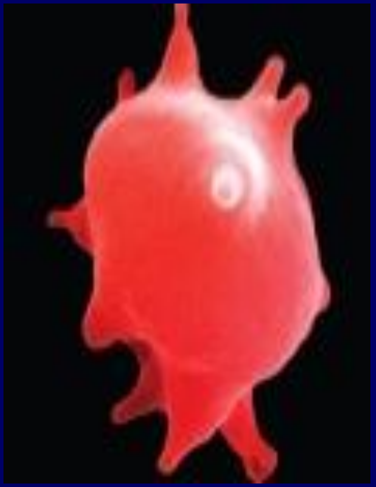
The osmotic pressure of blood cells cannot change or damage occurs.

The flow of water between a red blood cell and its surrounding environment must be equal

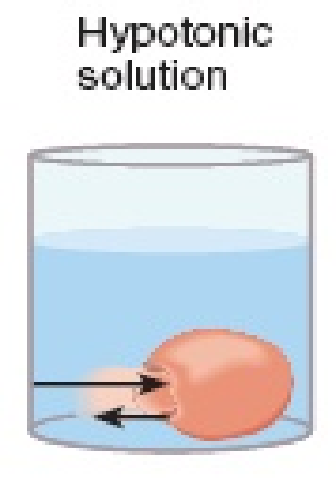
Osmosis in Blood Cells

If the solute concentration outside the cell is greater than that inside the cell, the solution is hypertonic. Water will flow out of the cell, and crenation results.





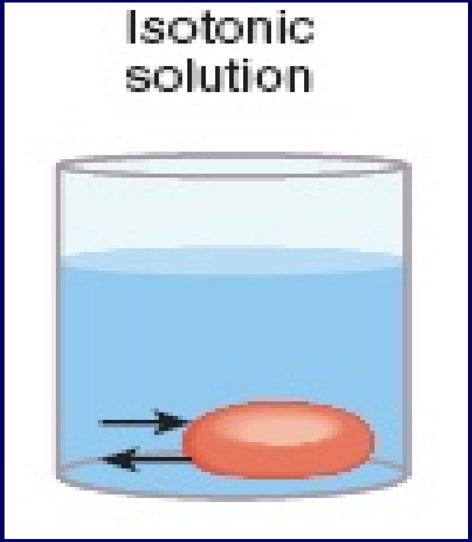
If the solute concentration outside the cell is less than that inside the cell, the solution is hypotonic. Water will flow into the cell, and hemolysis results.

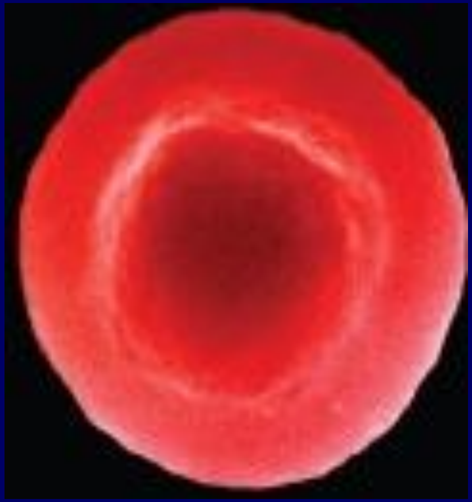


Isotonic Solutions

An **isotonic solution**

- exerts the same osmotic pressure as red blood cells.
- is known as a "physiological solution".
- of 5.0% glucose or 0.90% NaCl is used medically because each has a solute concentration equal to the osmotic pressure equal to red blood cells.





Colloids

colloid a mixture in which one substance is divided into minute particles (called colloidal particles) and dispersed throughout a second substance.

The mixture is also called a colloidal system, colloidal solution, or colloidal dispersion.

Familiar colloids include fog, smoke, homogenized milk, and ruby-colored glass.

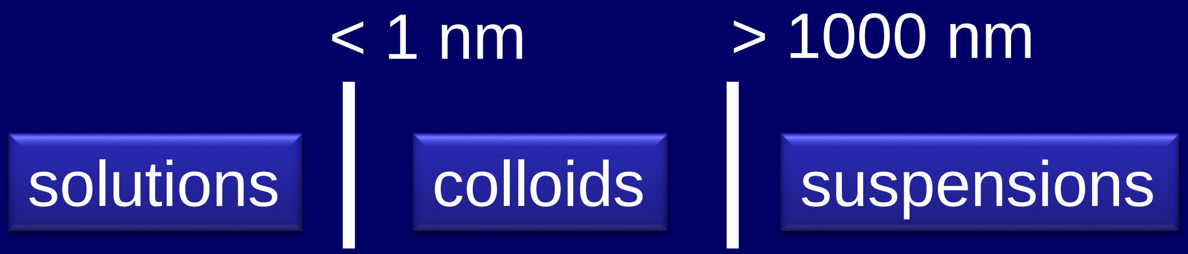
Phase of Colloid	Dispersing (Solventlike) Substance	Dispersing (Solutelike) Substance	Colloid Type	Example
Gas	Gas	Gas	-	Non all are Solution
Gas	Gas	Liquid	Aerosol	Fog
Gas	Gas	Solid	Aerosol	Smoke
Liquid	Liquid	Gas	Foam	Whipped Cream
Liquid	Liquid	Liquid	Emulsion	Milk
Liquid	Liquid	Solid	Sol	Paint
Solid	Solid	Gas	Solid Foam	Marshmallow
Solid	Solid	Solid	Solid Emulsion	Butter
Solid	Solid	Solid	Solid Sol	Ruby Glass

Colloidal

- ✓ Aggregates of atoms, molecules or ions macromolecules (proteins)

- ✓ They represent an intermediate kind of a mixture between true solution and suspension.

- ✓ The size of a colloidal particle **lies roughly between 1-1000 nm.**



- ✓ Colloids are also a **two-phase heterogeneous system** consisting of the dispersed phase and dispersion medium.

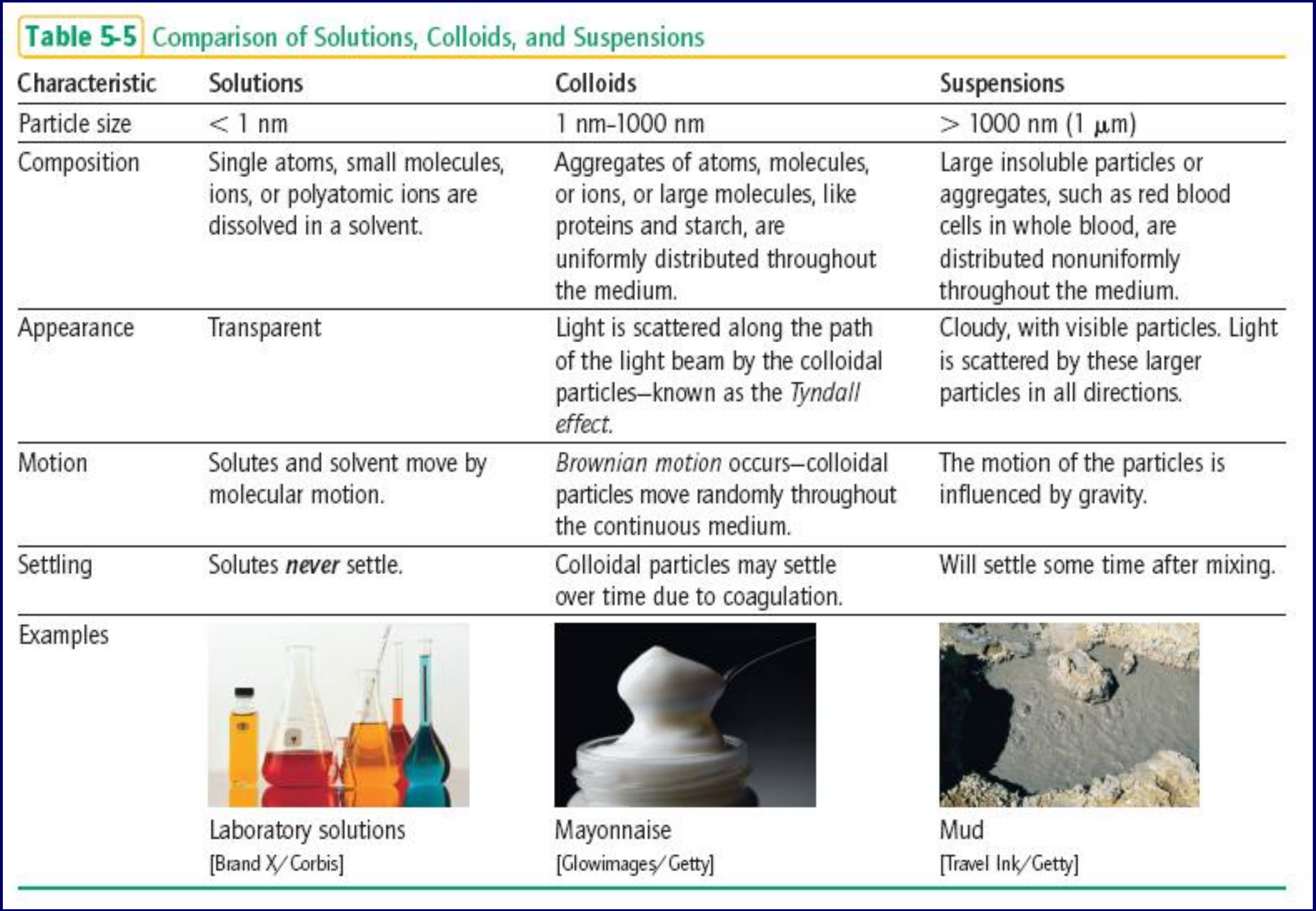


Table 5-5 Comparison of Solutions, Colloids, and Suspensions

Characteristic	Solutions	Colloids	Suspensions
Particle size	< 1 nm	1 nm–1000 nm	> 1000 nm (1 μm)
Composition	Single atoms, small molecules, ions, or polyatomic ions are dissolved in a solvent.	Aggregates of atoms, molecules, or ions, or large molecules, like proteins and starch, are uniformly distributed throughout the medium.	Large insoluble particles or aggregates, such as red blood cells in whole blood, are distributed nonuniformly throughout the medium.
Appearance	Transparent	Light is scattered along the path of the light beam by the colloidal particles—known as the *Tyndall effect*.	Cloudy, with visible particles. Light is scattered by these larger particles in all directions.
Motion	Solutes and solvent move by molecular motion.	*Brownian motion* occurs—colloidal particles move randomly throughout the continuous medium.	The motion of the particles is influenced by gravity.
Settling	Solutes ***never*** settle.	Colloidal particles may settle over time due to coagulation.	Will settle some time after mixing.
Examples	Laboratory solutions [Brand X/Corbis]	Mayonnaise [Glowimages/Getty]	Mud [Travel Ink/Getty]

Properties of Colloids

- **Heterogeneity:** a colloidal solution is heterogeneous system consisting of two phases of dispersed phase (colloidal particles of a solid) and the aqueous dispersion medium. Often a colloidal sol appears to be homogeneous as the particles are small in size and not visible to the naked eye

- **Stable nature** : colloidal solutions are quite stable. The colloidal particles do not settle at the bottom under the influence of gravity.

- **Filterability**: colloidal particles do not pass through ultrafilter papers, animal and vegetable membranes. The large pore size of ordinary filter paper enables colloidal particles to pass through.

Colligative properties of Colloids

- **In colloidal systems the number of colloidal particles per liter of the sol is relatively much smaller than solute particles in a true solution.**

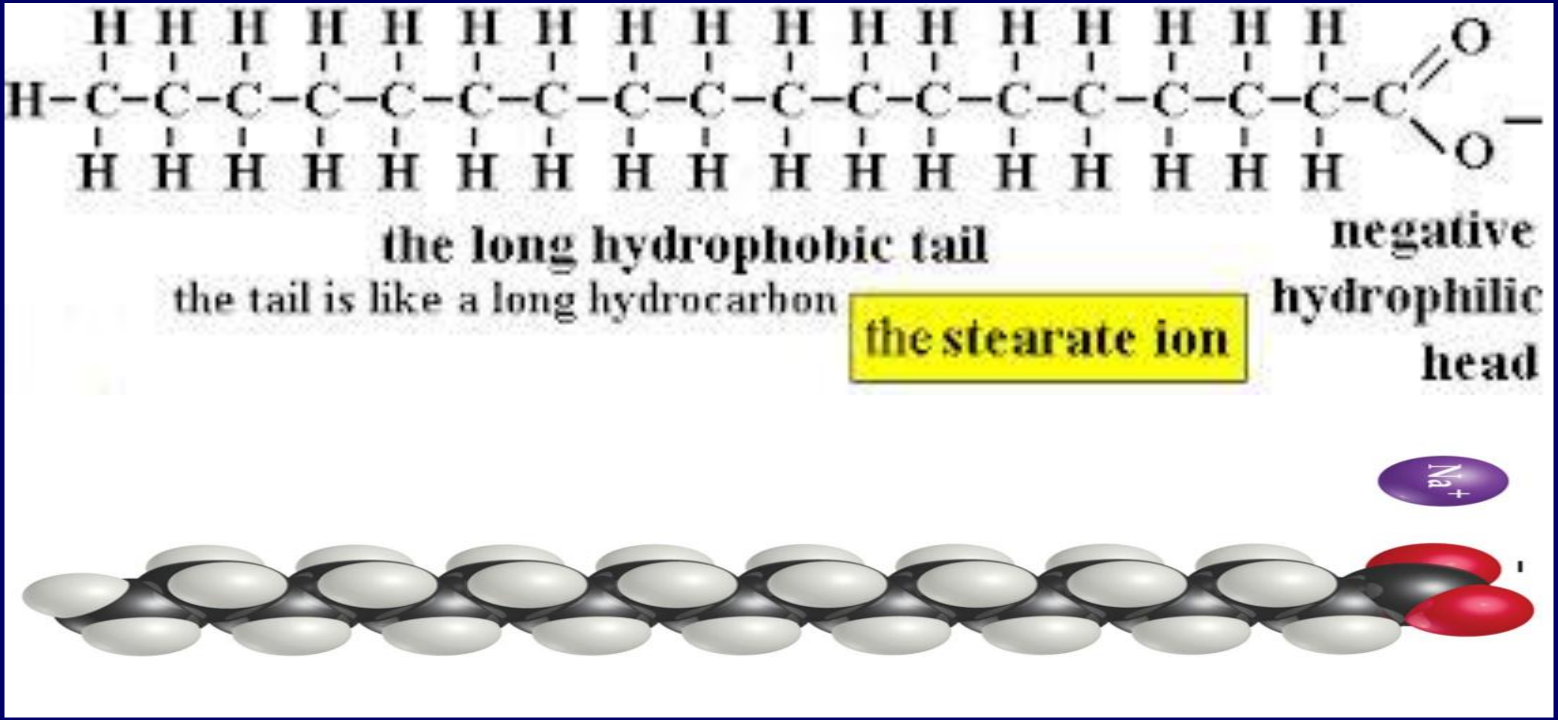
- **Colloidal particles are aggregates of simple molecules and colligative properties such elevation in boiling point, depression in freezing point and lowering of vapor pressure depend upon the number of colloid particles present in system and not on the nature of the particle.**

- **The values of colligative properties are consequently <u>much smaller</u> as compared to true solutions.**

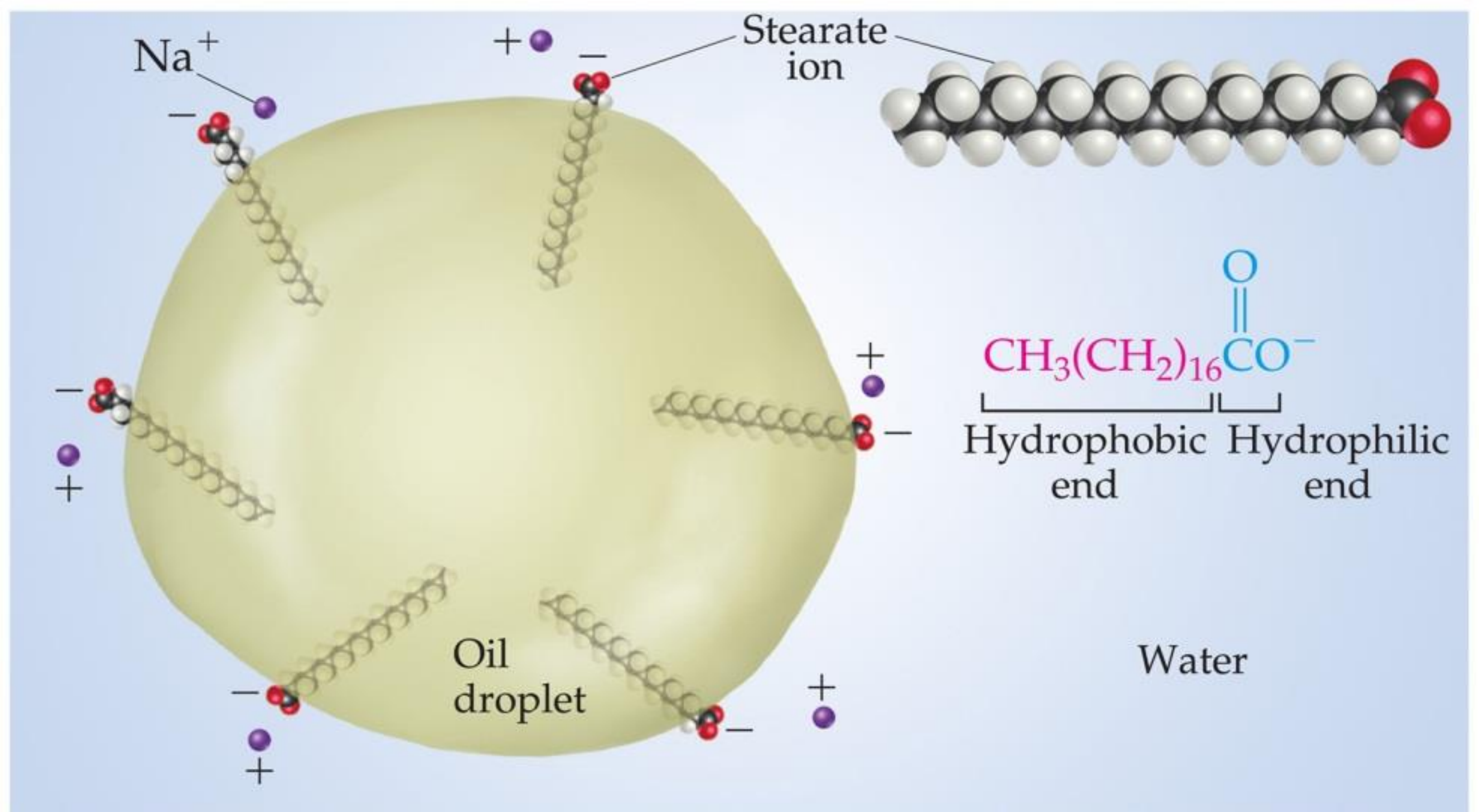
Colloids in Biological Systems

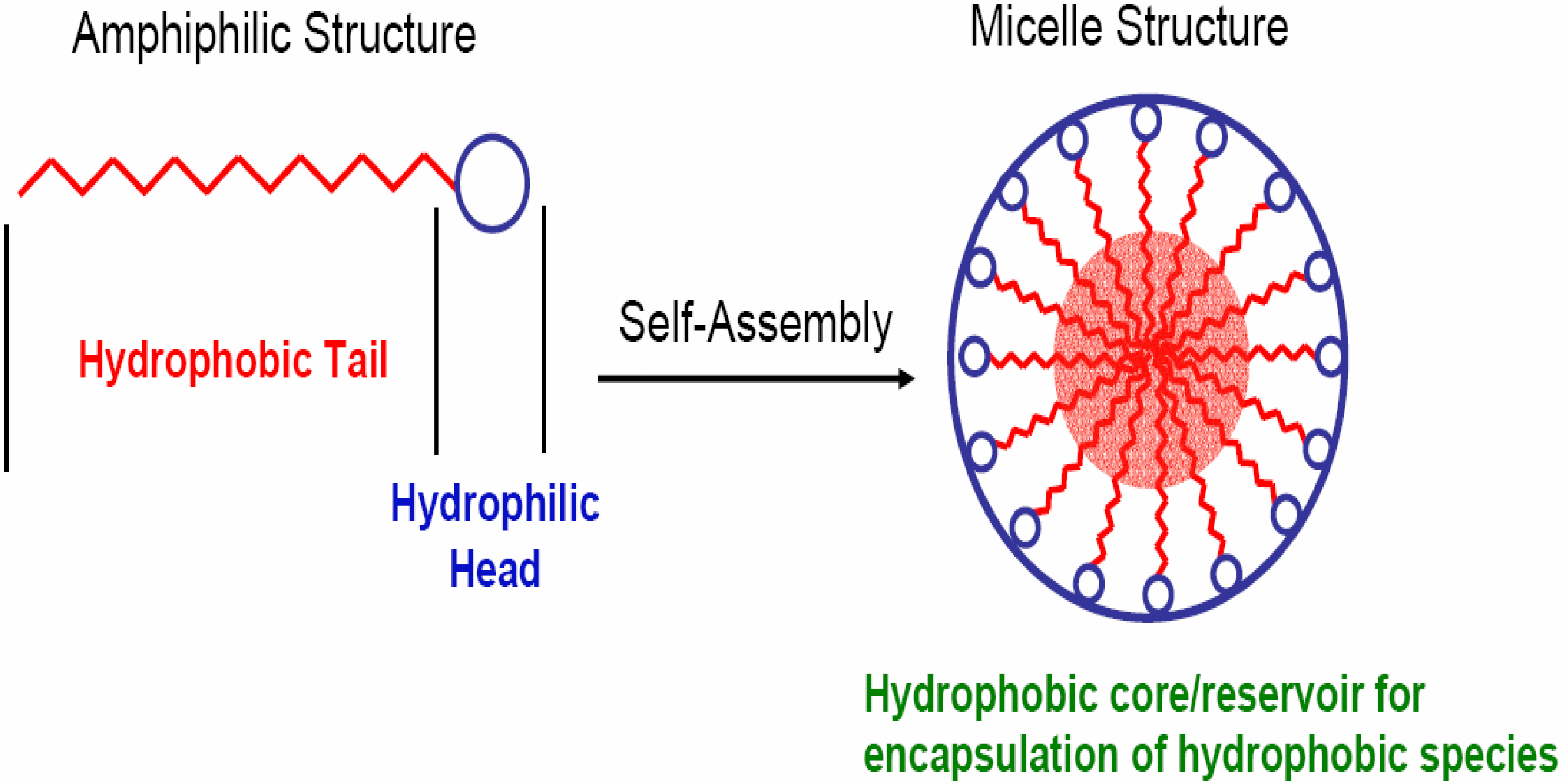
Some molecules have a polar, hydrophilic (*water-loving*) end and a nonpolar, hydrophobic (*water-hating*) end

Sodium stearate is one example of such a molecule



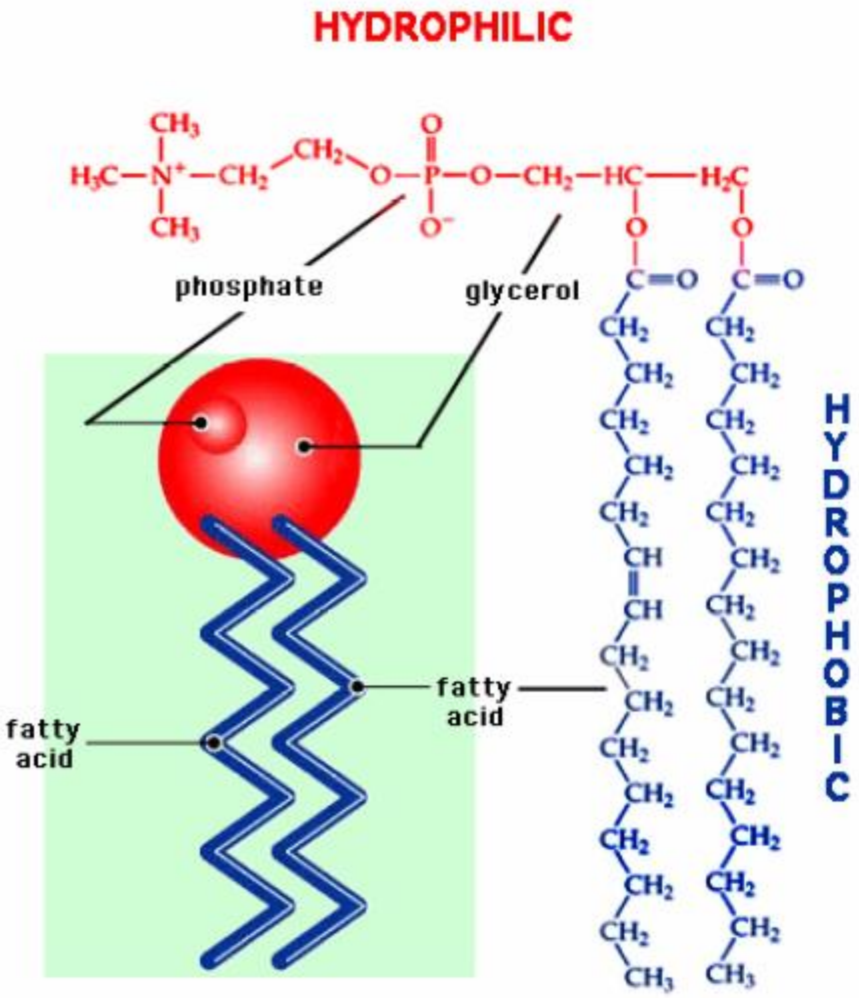
These molecules can aid in the emulsification of fats and oils in aqueous solutions





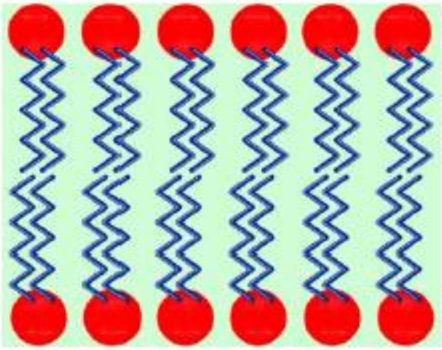
Cationic Surfactant	$CH_3(CH_2)_nN^+(CH_3)_3Br^-$
Anionic Surfactants	$CH_3(CH_2)_nSO_3^- Na^+$
Non-ionic Surfactants	$CH_3(CH_2)_n (CH_2CH_2O)_n\text{-}OH$

Surfactants as biocolloids



Phosphatidylcholin (Lecithin)

Phospholipids are the building block of biological membranes



plasma membranes are primarily lipid bilayers with associated proteins and Glycolipids (cholesterol is also a major component of plasma membranes)