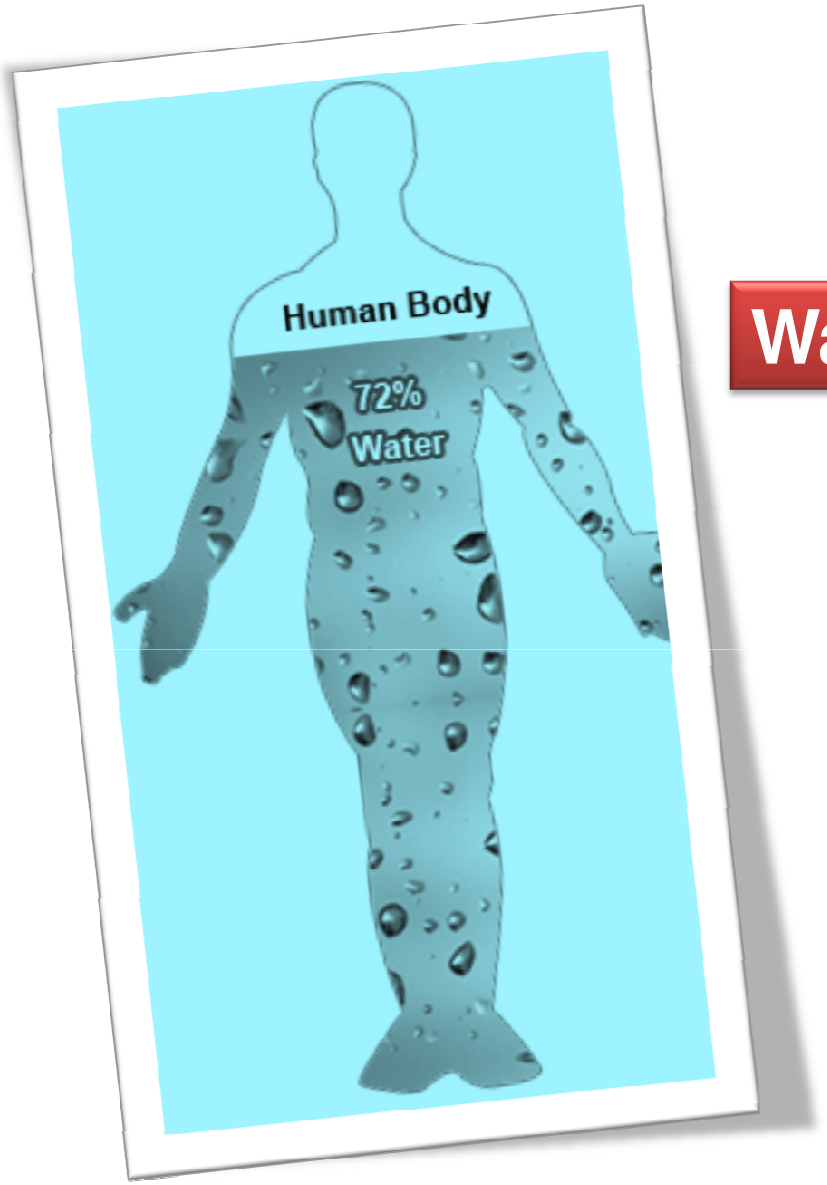


Water and biological buffer

363 113 2/2559

Patcharee Boonsiri

https://empoweryourknowledgeandhappytrivia.files.wordpress.com/2014/09/human-body-water.jpg

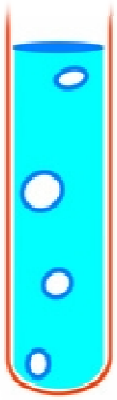
Objectives

1.Water

- **Chemical structure related with water properties**
- **Role of water in human body**

2.Biological buffer

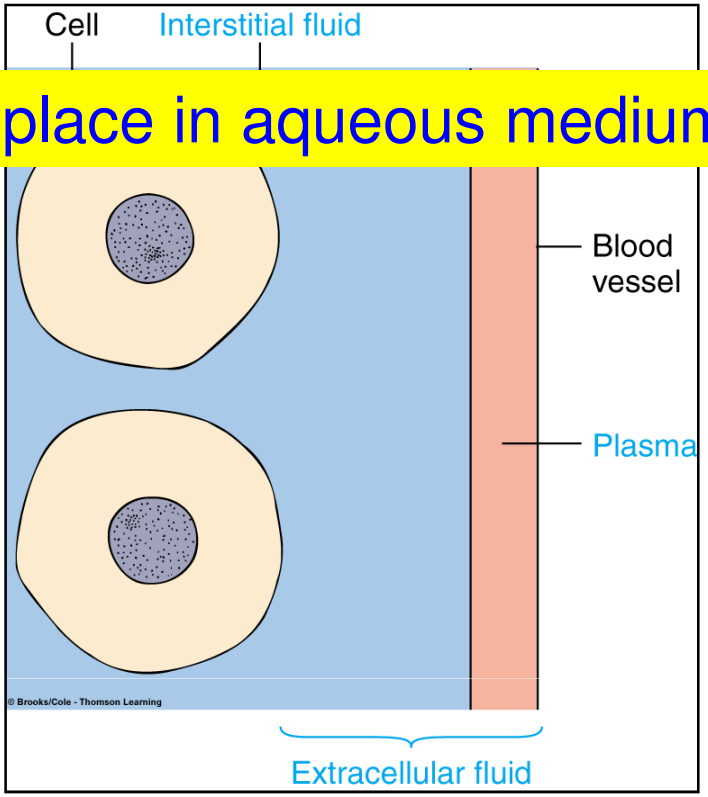
- **Role of buffer**
- **Composition related with buffer mechanism**
- **Buffer capacity**
- **Important buffers in human body**

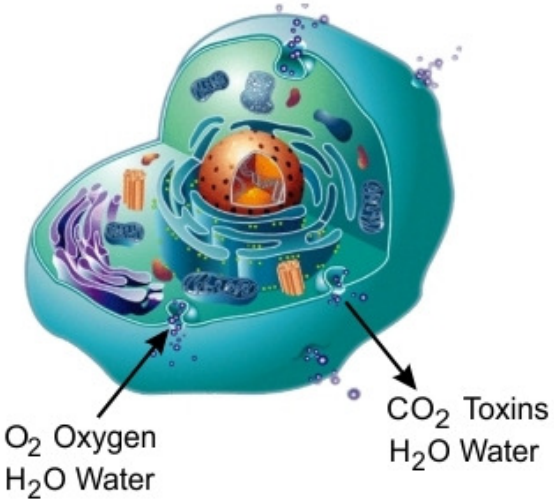


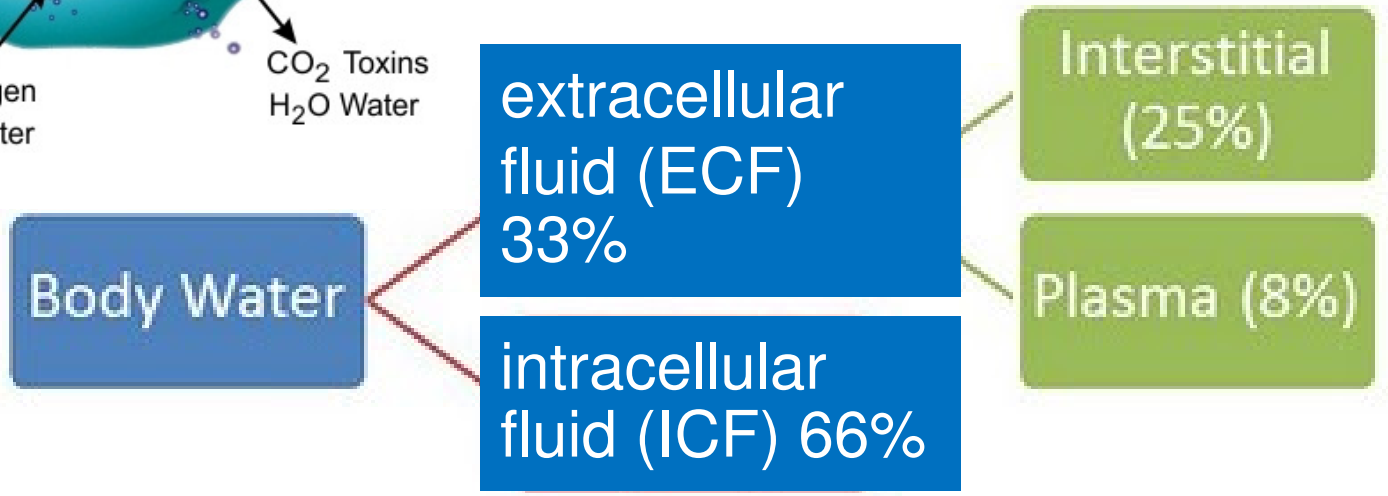
All chemical reactions take place in aqueous medium

Most compounds dissolves in body fluids

→ water participates in biochemical reactions



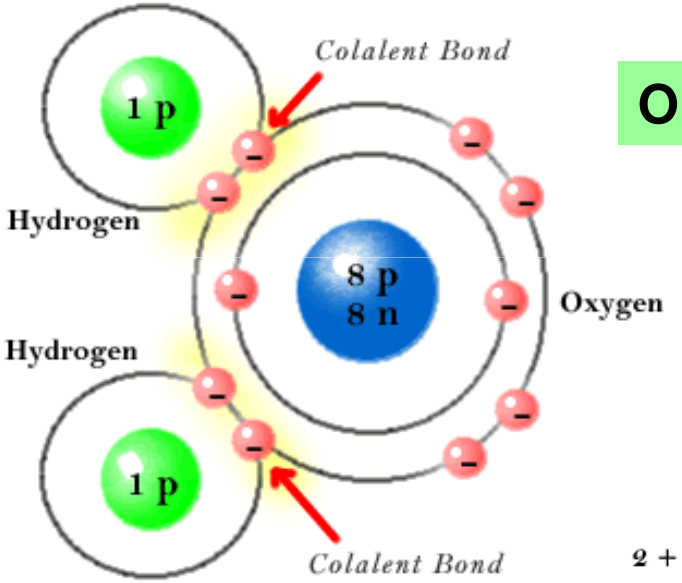




Molecular structure of water

unique properties of water are derived from its structure

1. H_2O is a polar molecule

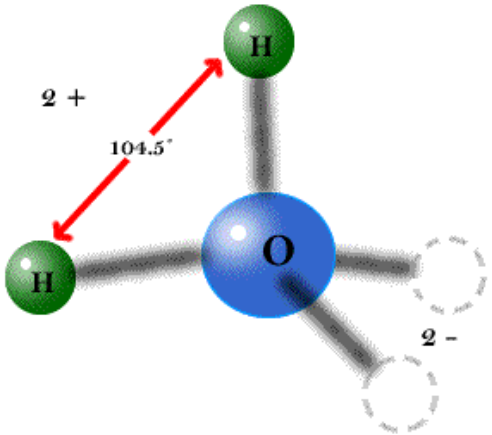


Bohr Model of H_2O

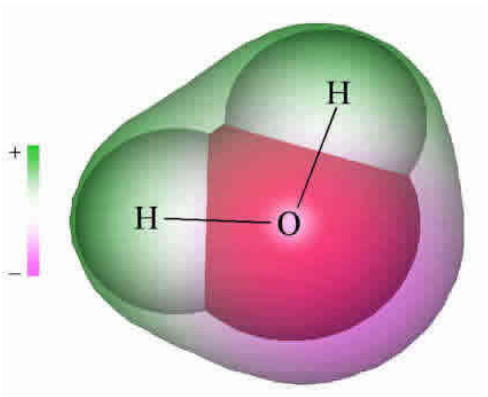
O has more electronegativity than H

two lone pair electrons at O atom

Nonlinear shape

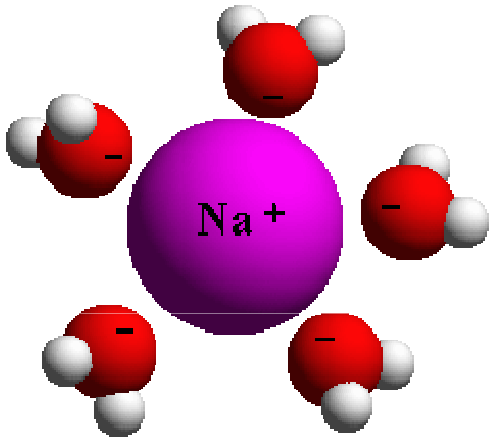


Ball and stick model of water.



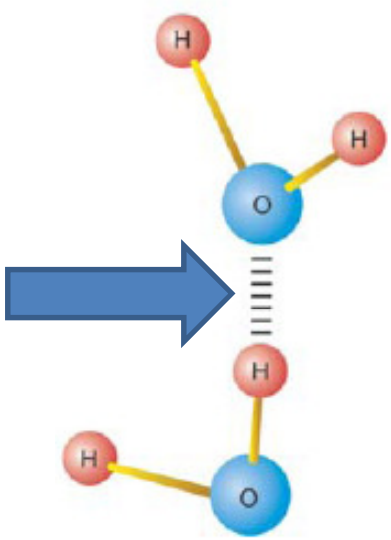
bond angle 104.5°

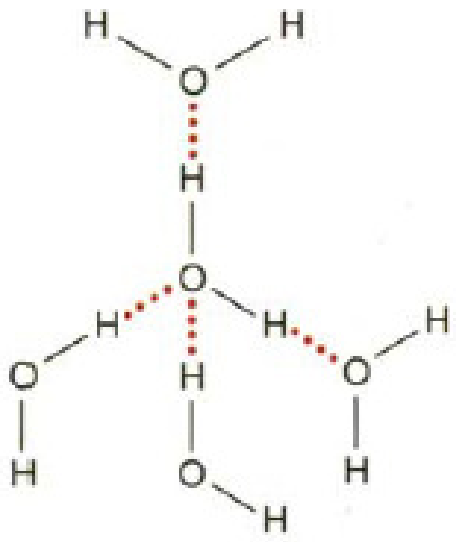
Hydrophilic molecules form favorable interaction with water

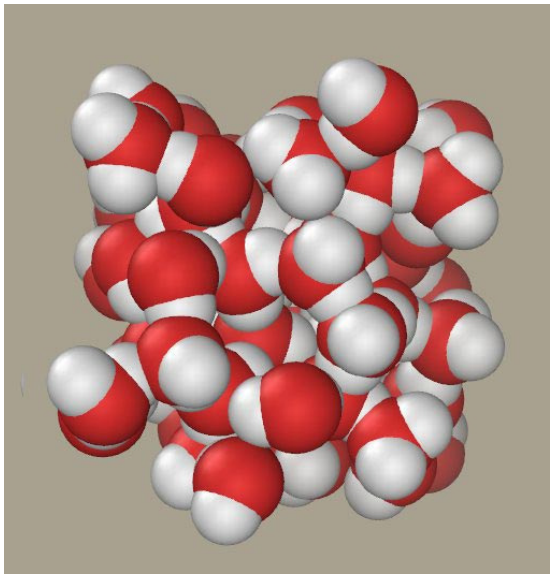


Solvate Na^+

4.Water form H-bond with the other water molecules



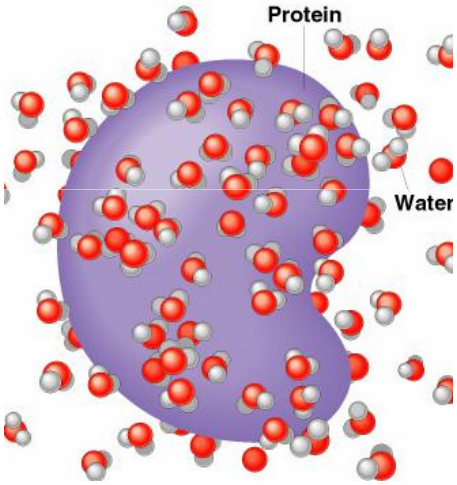




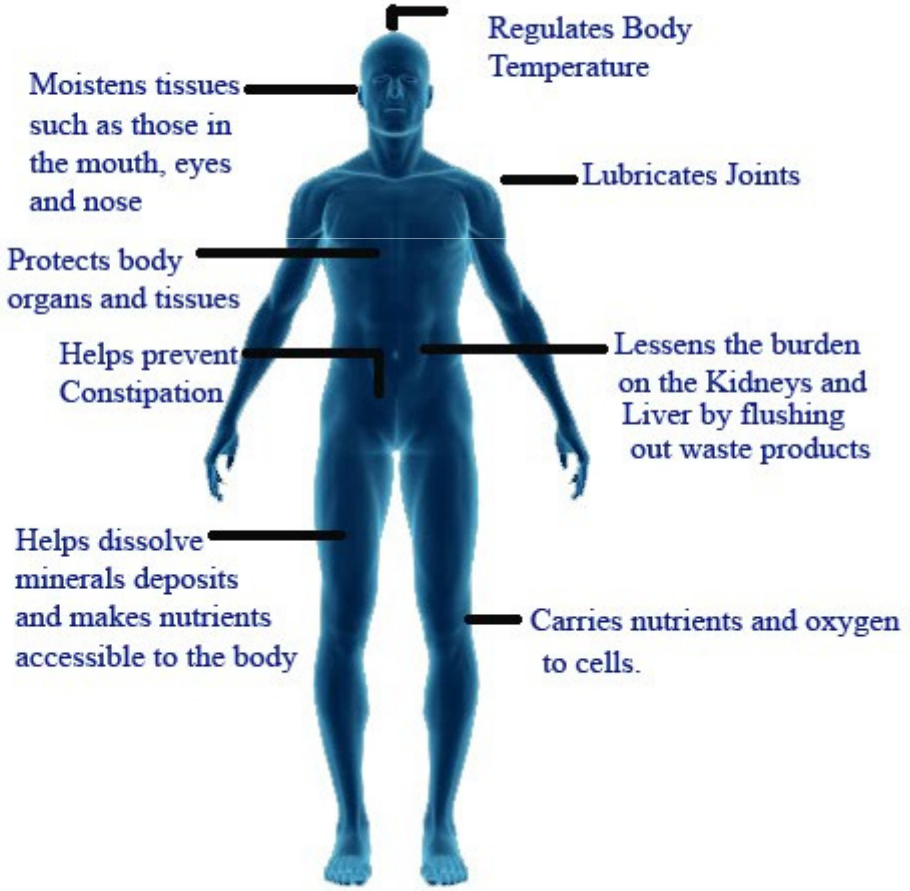
Role of water in human body

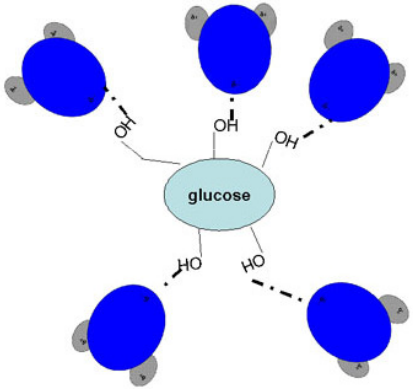
1.Solvent polar → plays a major role in metabolism

Like dissolves like



Solvate protein

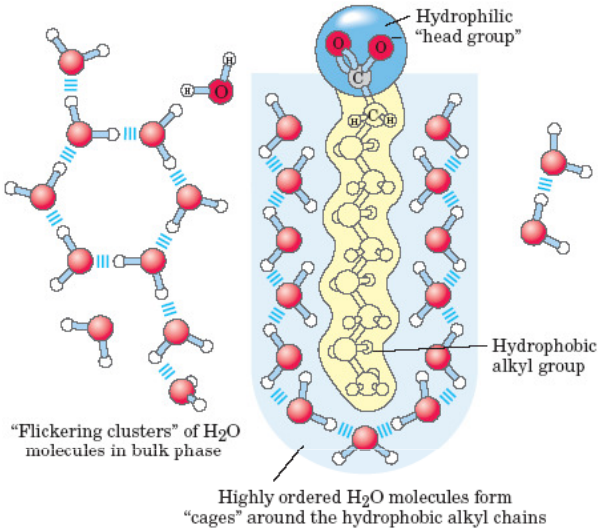


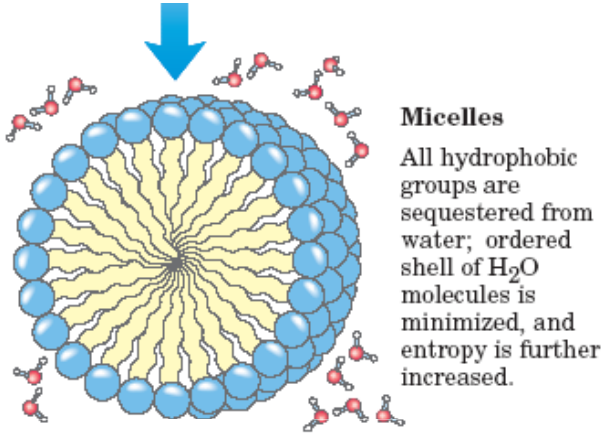


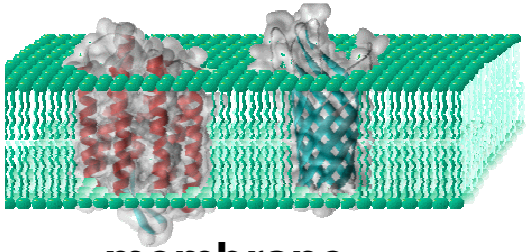
Solvate sugar

http://www.isabelsbeautyblog.com/wp-content/uploads/Function-of-Water-in-Body.jpg

H_2O cannot dissolve non-polar compounds
→ creates supermolcular assemblies e.g. membranes,
and drives the folding of proteins



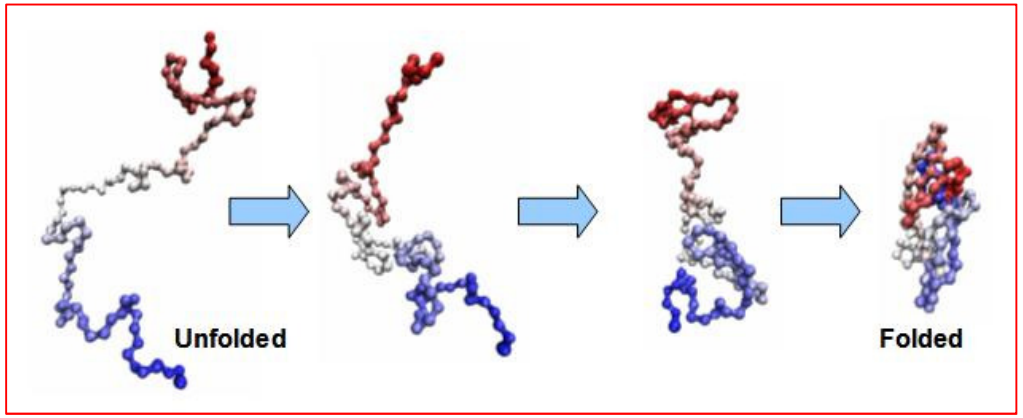




membrane

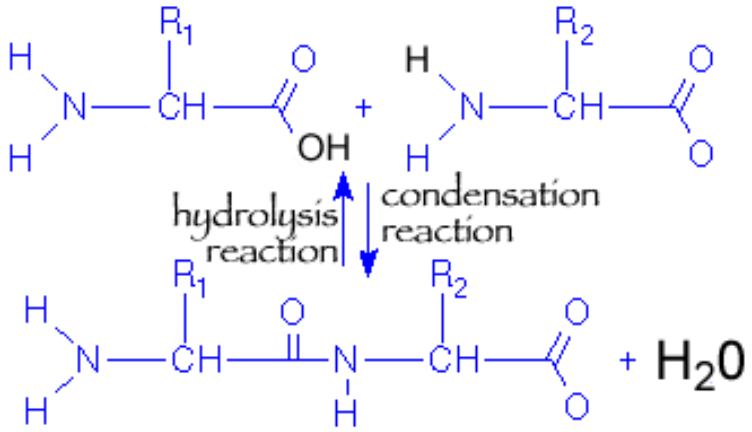
Fatty acid (hydrophobic) molecule caged by water

folding of proteins



pH also influence the 3-dimensional structure of proteins and activity of enzymes

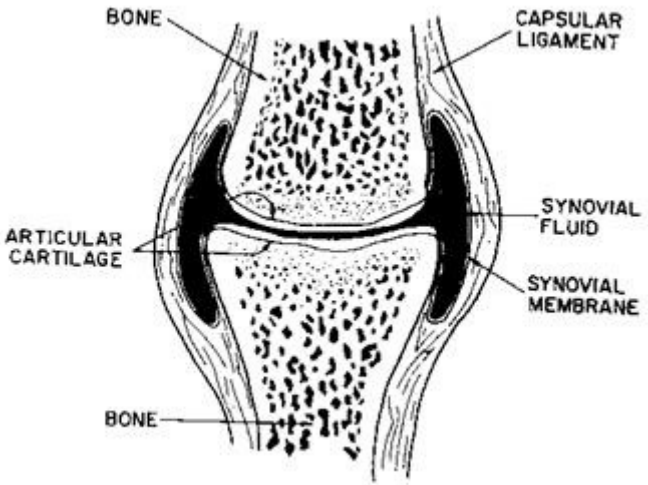
2. Reactant → water is a good nucleofile
→ participant in reactions e.g. hydrolysis and condensation



virtuallaboratory.colorado.edu/BioFun-Support/AllGraphics/peptideBond.gif

3. Transportation absorption, transport, digestion, excretion as well as maintenance of body temperature.

4. Temperature stabilizer - maintenance of body temperature (latent heat)



http://elektroarsenal.net/img/721/image516.jpg

5. Lubricants

Aquaporin (water channel) is integral membrane protein

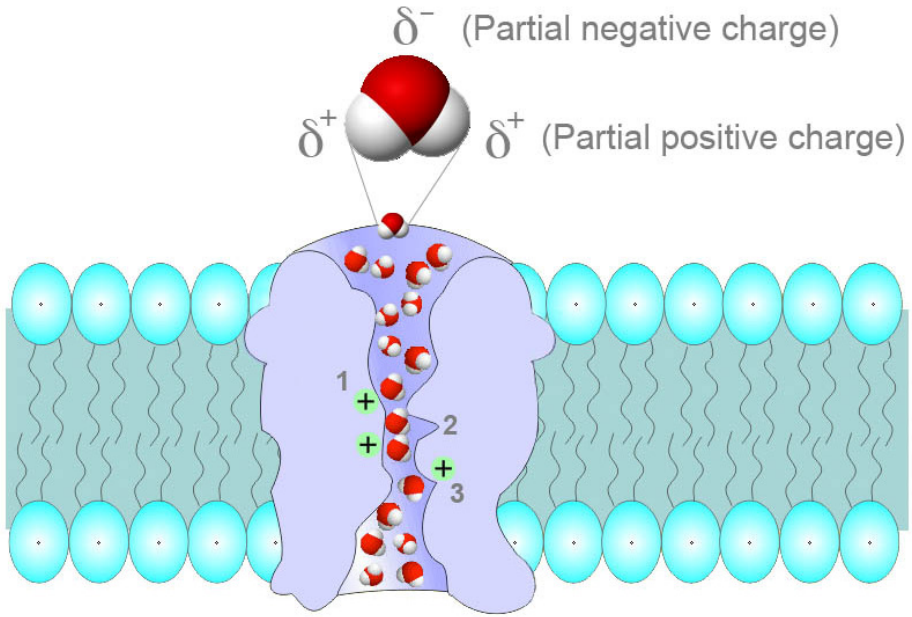
Select water in and out of cell but prevent passage of ions and solutes

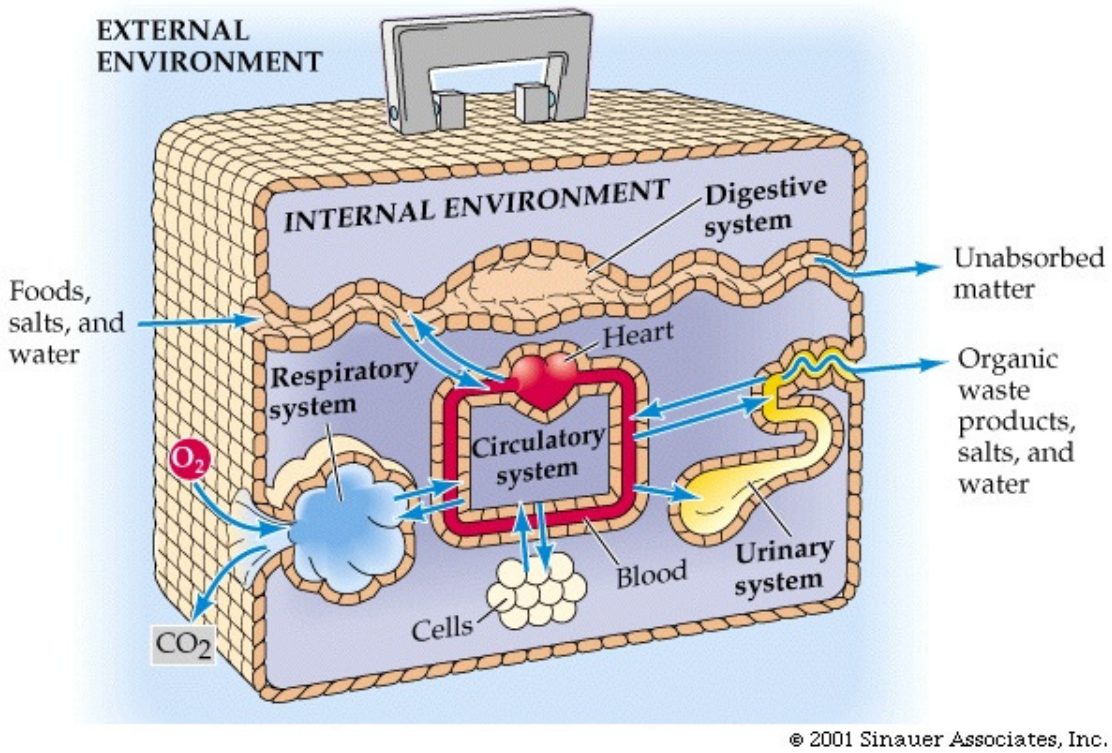
Nobel Lecture

Aquaporin Water Channels

Peter Agre held his Nobel Lecture December 8, 2003, at Aula Magna, Stockholm University. He was presented by Professor Bengt Nordén, Chairman of the Nobel Committee for Chemistry.

If we can manupulate aquaporin, we can solve medical problems e.g.fluid retention in heart disease and brain edema after stroke





Why pH is important?

- pH affects solubility of many substances
- pH affects structure and function of most protein, enzymes
- cells and organisms survive in a specific pH environment.

Factors that regulate homeostasis

- Concentration of nutrient molecules
- Concentration of water, salt, and other electrolytes
- Concentration of waste products
- Concentration of O_2 = 100mmHg and CO_2 = 40 mmHg
- Blood volume 4-6 L and pressure 120/80 mmHg
- pH = 7.35 Temperature = 37° C

http://bioserv.fiu.edu/~walterm/human_online/labs/homeostasis/homeostasis_files/image002.jpg

Buffer

Biochemical reactions are sensitive to pH

Role of buffer

Maintain pH of the solution when small amount of acid or base are added

Important biological buffer

1.phosphate buffer

2.bicarbonate buffer

3.proteinate buffer

Composition of buffer

Weak acid + its conjugate base

Weak base + its conjugate acid

$CH_3COOH + CH_3COONa$

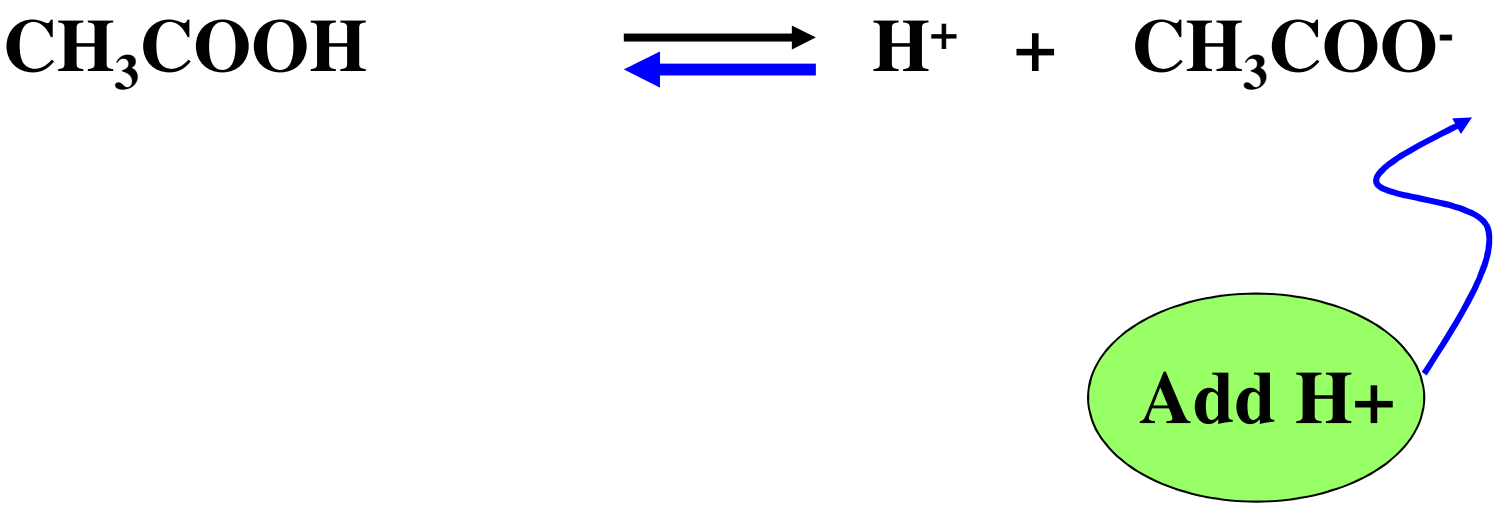
$NH_4OH + NH_4Cl$

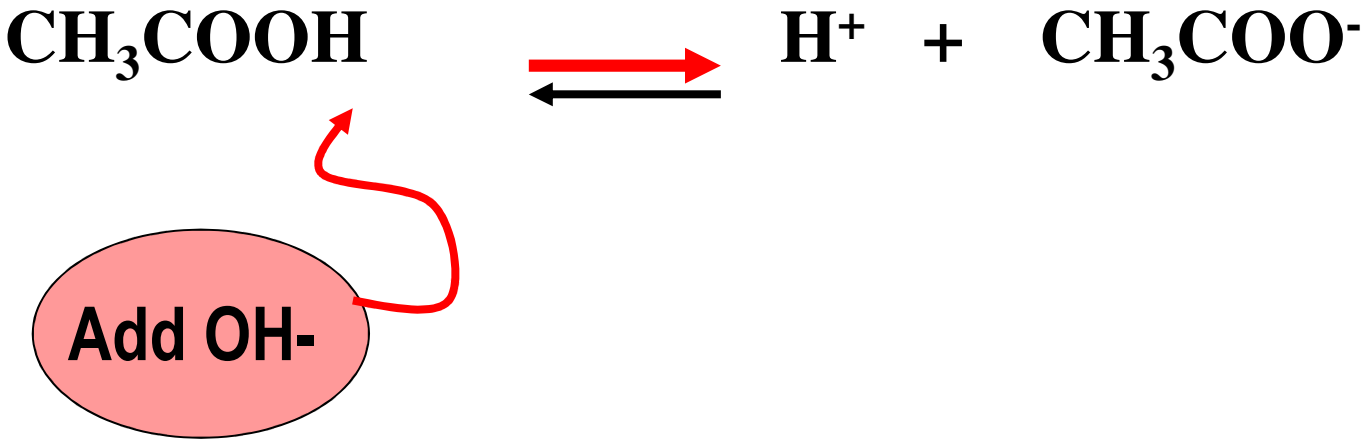
Henderson - Hasselbalch equation

$$pH = pKa + \log \frac{[\text{conjugate base}]}{[\text{acid}]}$$

Buffer mechanism

Chemical equilibrium





Buffer capacity

efficiency of a buffer in resisting changes in pH

buffer capacity depends on

1.Ratio of the salt to the acid or base.

buffer capacity is optimal when the ratio is 1:1; that is pH = pKa

2.Total buffer concentration.

The higher concentration, the higher buffer capacity

1.Phosphate buffer

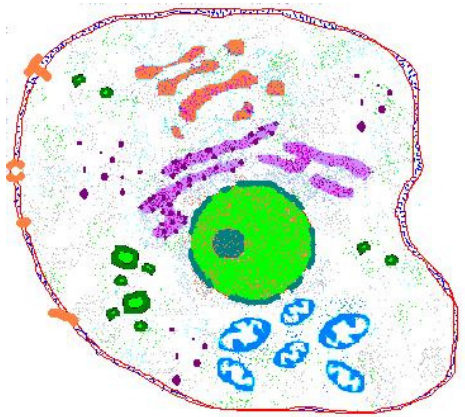
$H_2PO_4^-$ / HPO_4^{-2} (In Cell)

In mammals, cellular fluid pH 6.9 - 7.4

$$H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons HPO_4^{2-}(aq) + H_3O^+(aq)$$

$pK_{a_2} = 7.20$

Acid	Base	Conjugate base	Conjugate acid
		hydrogenophosphate ion	



When we add H+

$$H^+ + HPO_4^{-2} \rightarrow H_2PO_4^-$$

When we add OH-

$$OH^- + H_2PO_4^- \rightarrow H_2O + HPO_4^{-2}$$

2.Bicarbonate buffer

H_2CO_3 / HCO_3^- (Blood)

When we add H+

$$H^+ + HCO_3^- \rightarrow H_2CO_3 == H_2O + CO_2$$

When we add OH-

$$H_2CO_3 + OH^- \rightarrow H_2O + HCO_3^-$$

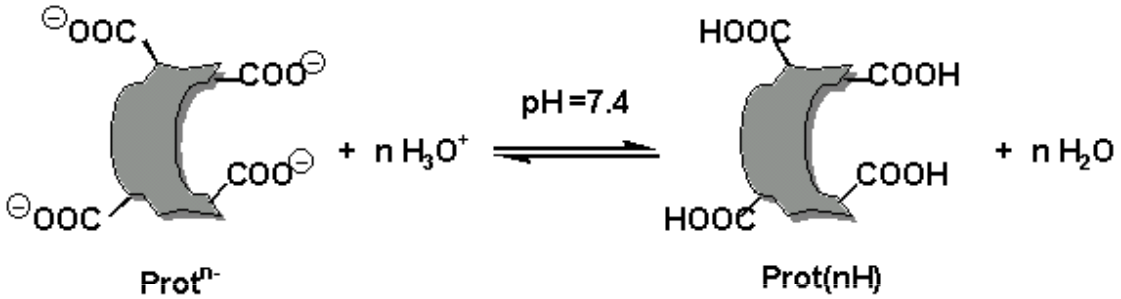
In blood plasma, the [HCO_3^-] is about 20 times [H_2CO_3]

The pH of arterial blood plasma is 7.4

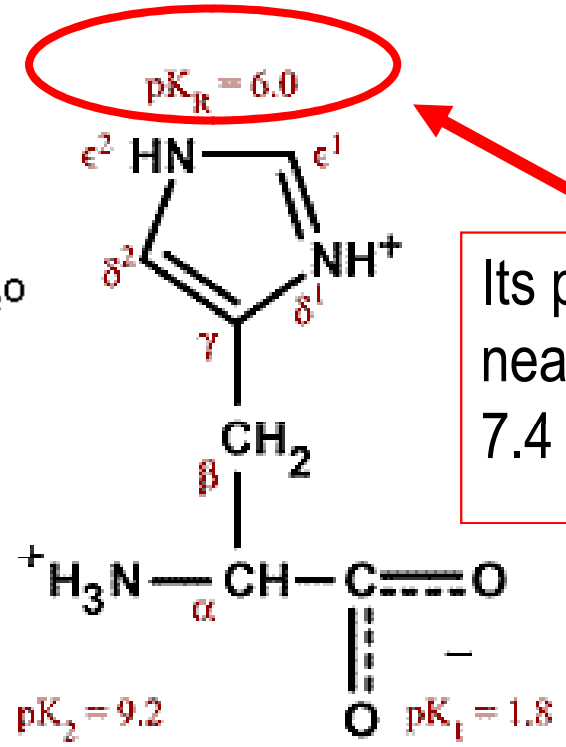
If the pH < 7.4, a condition called *acidosis*

If the pH > 7.4, the condition is called *alkalosis*

3.Proteinate buffer



$$pH = pK_{a\,av} + \log \frac{[Prot^{n-}]}{[Prot(nH)]}$$



Its pKa near pH 7.4

histidine

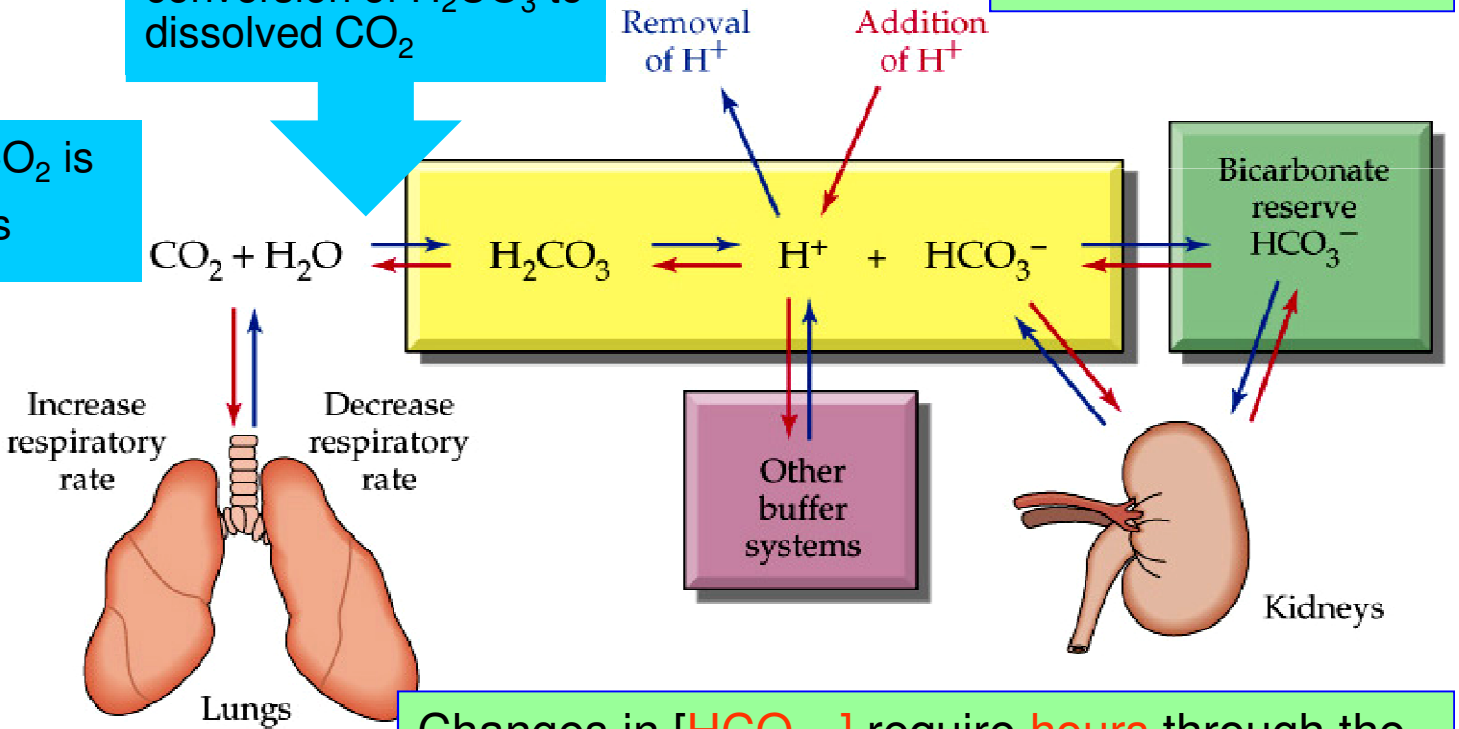
$[HCO_3^-]$ and $[H_2CO_3]$ are controlled by two independent physiological systems (lung and kidney)

$[HCO_3^-]$ is controlled through kidneys

Excess HCO_3^- are excreted in urine

Carbonic anhydrase catalyzes the conversion of H_2CO_3 to dissolved CO_2

Excess dissolved CO_2 is exhaled as CO_2 gas



Changes in $[H_2CO_3]$ can be effected within seconds through increased or decreased respiration

Changes in $[HCO_3^-]$ require hours through the relatively slow elimination through the kidneys

Disorder of acid-base balance

pH < 7.37 acidosis

pH > 7.44 alkalosis

- ***Respiratory acidosis***

  blood pH decrease

  as a result of decreased respiration (CO2 in blood increases → making the blood too acidic)

  asthma, pneumonia, emphysema, or inhaling smoke

- ***Metabolic acidosis***

  blood pH decrease

  as a result when excess acidic substances are in blood.

  prolonged physical exertion, by diabetes, or restricted food intake

  our body response by increase breathing to reduce CO2 in blood

- ***Respiratory alkalosis***

  blood pH increase

  as a result of hyperventilating

- ***Metabolic alkalosis***

  blood pH increase

  as a result of release of alkaline materials into the blood

  ingestion of alkaline materials, overuse of diuretics.

  Our body response by slowing breathing

Summary

Homeostasis is the maintenance of internal environment of the body. Water help regulating homeostasis.

Water is polar. It can form H-bond. It solvates some ions/biomolecules and affects 3-D structure e.g. protein folding. Water is a good solvent in our body. Water go into cells via aquaporin at cell membrane.

The body must maintain its pH (7.4) by using buffer system. Buffer composed of weak acid and its salt. Its mechanism is chemical equilibrium.

Important buffer systems are phosphate, bicarbonate and proteinate buffer.