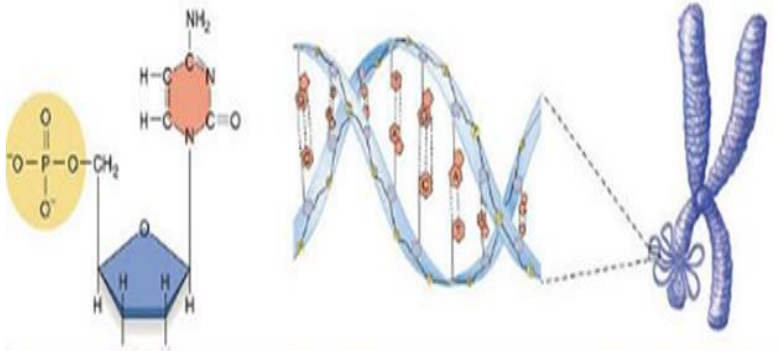

College of Medicine
Medical Chemistry
Lecture No. 4,5
Matter, energy, acids, bases, buffer solution, osmosis, electrolytes, metals, and ionic bonding
First stage
Prof. Dr. Talat T.K.

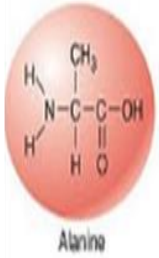
Matter and Energy in Medical Chemistry

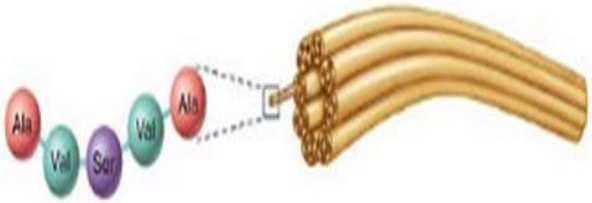
Matter in Medical Chemistry: Matter forms the basic of all biological molecules such as proteins, lipids, carbohydrates, and nucleic acids.(In general , physical substance that which occupies spices and has rest mass)

Monomer	Polymer	Cellular structure
Nucleotide	DNA strand	Chromosome

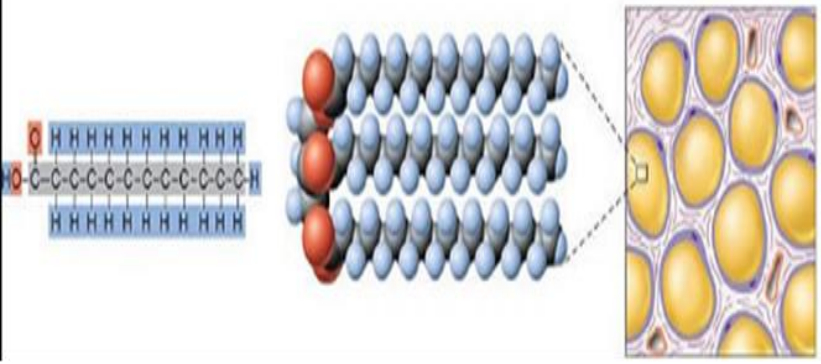


Monomer	Polymer	Cellular structure
Amino Acid	Polypeptide	Intermediate filament

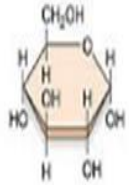


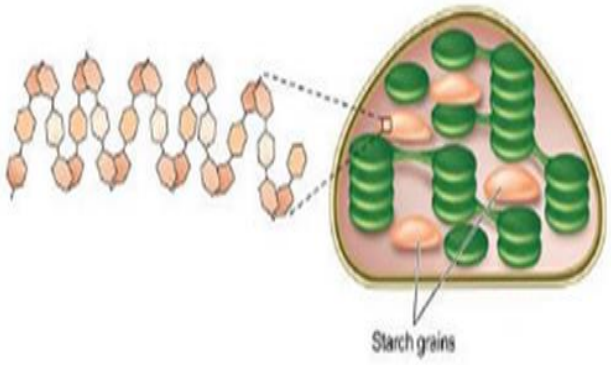


Fatty acid	Fat molecule	Adipose cells with fat droplets



Monosaccharide	Starch	Starch grains in a chloroplast





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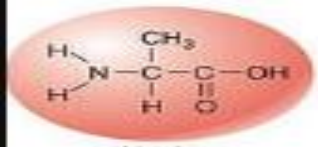

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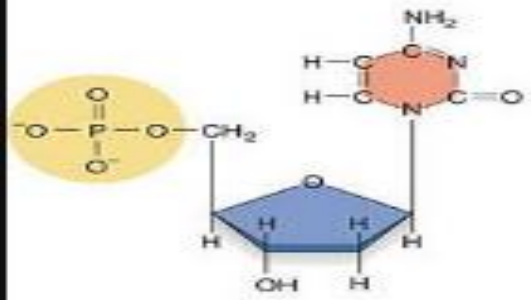

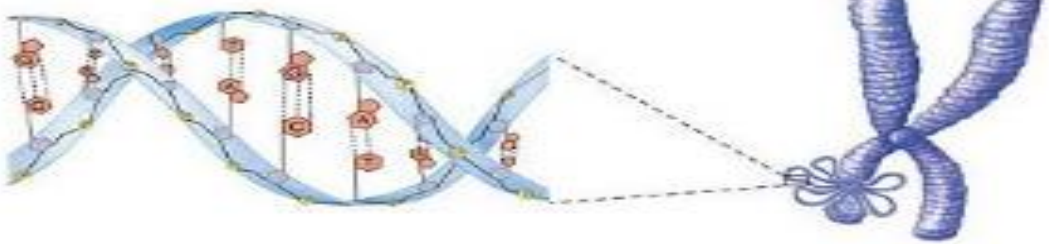

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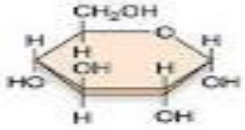

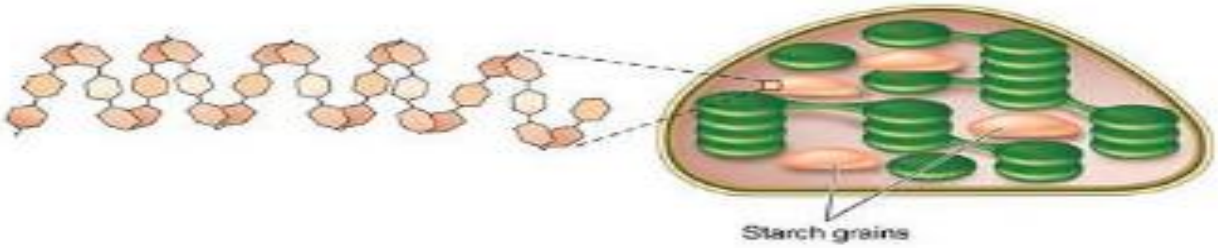

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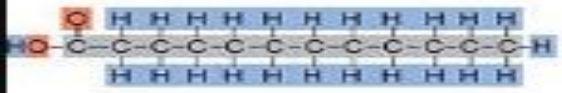
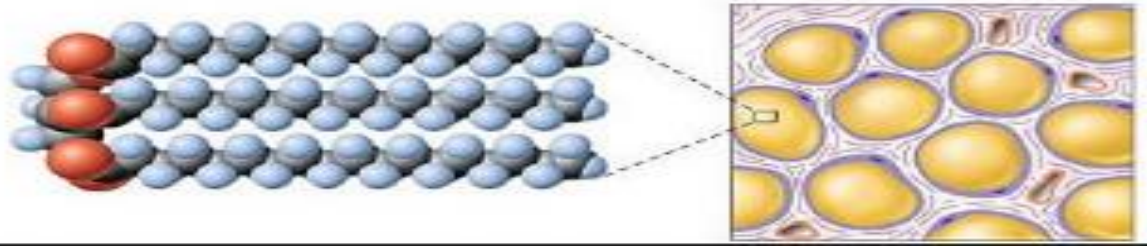
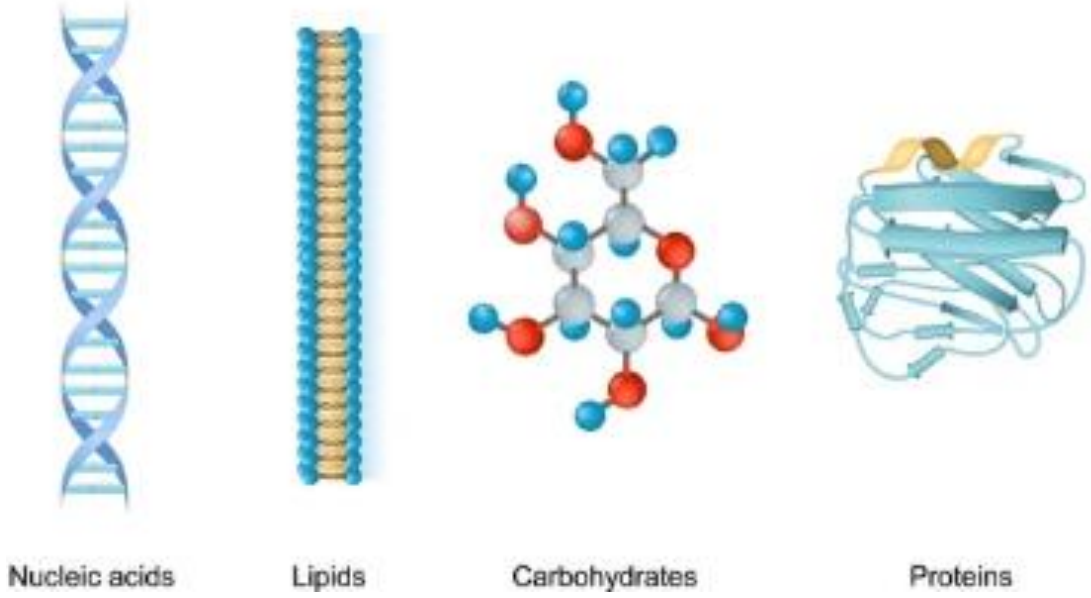






It exists in three states: 1)**solid (bones, teeth), 2)liquid (blood, plasma),** and 3)**gas (oxygen, carbon dioxide in respiration) states**.

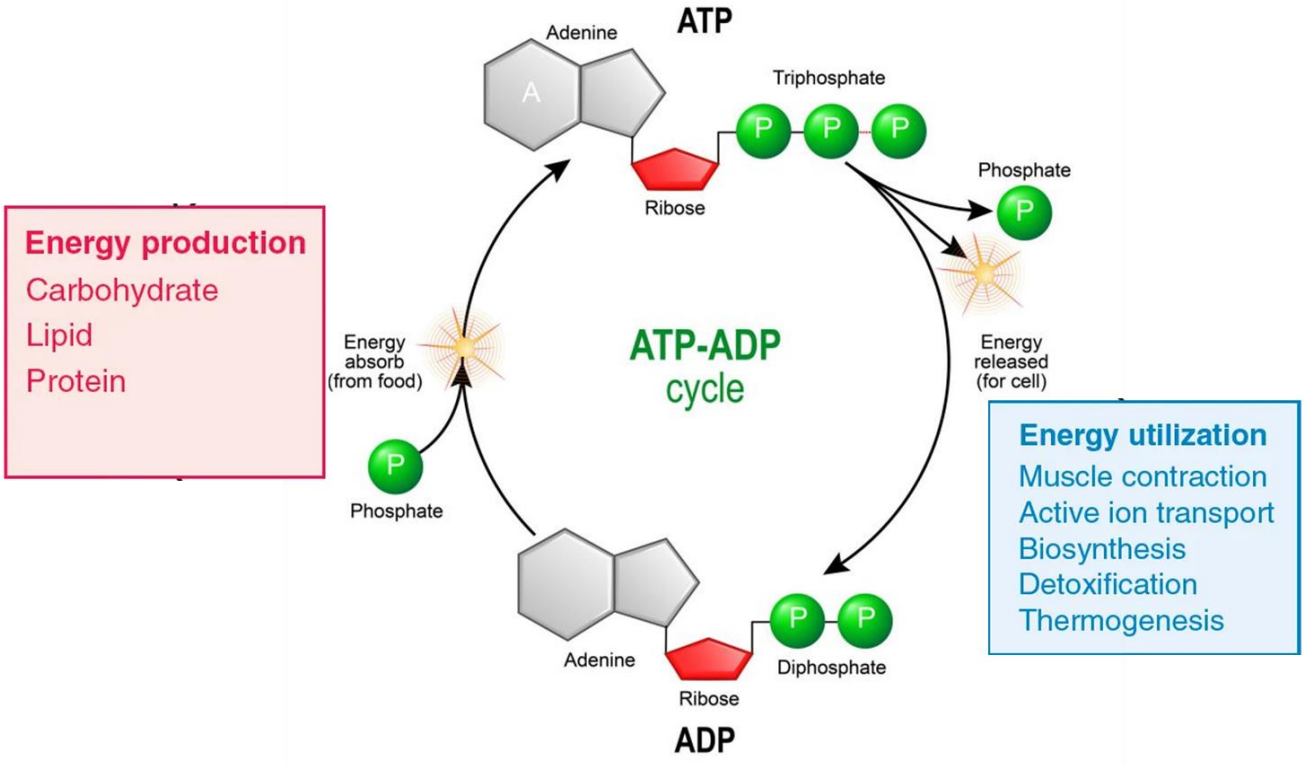
The interaction of atoms and molecules is **fundamental in drug formulation, metabolism, and biochemical reactions.**

Chemical properties of matter determine drug solubility, absorption, distribution, and elimination in the body.

Energy in Medical Chemistry:

Energy is crucial in metabolic reactions, where the body converts food into usable energy (ATP).

Energy production is that reactions release energy from food (fuel source) (example carbohydrate, protein, lipid), while energy utilization that reactions require energy (e.g., muscle contraction, active ion transport, biosynthesis, detoxification, thermogenesis)

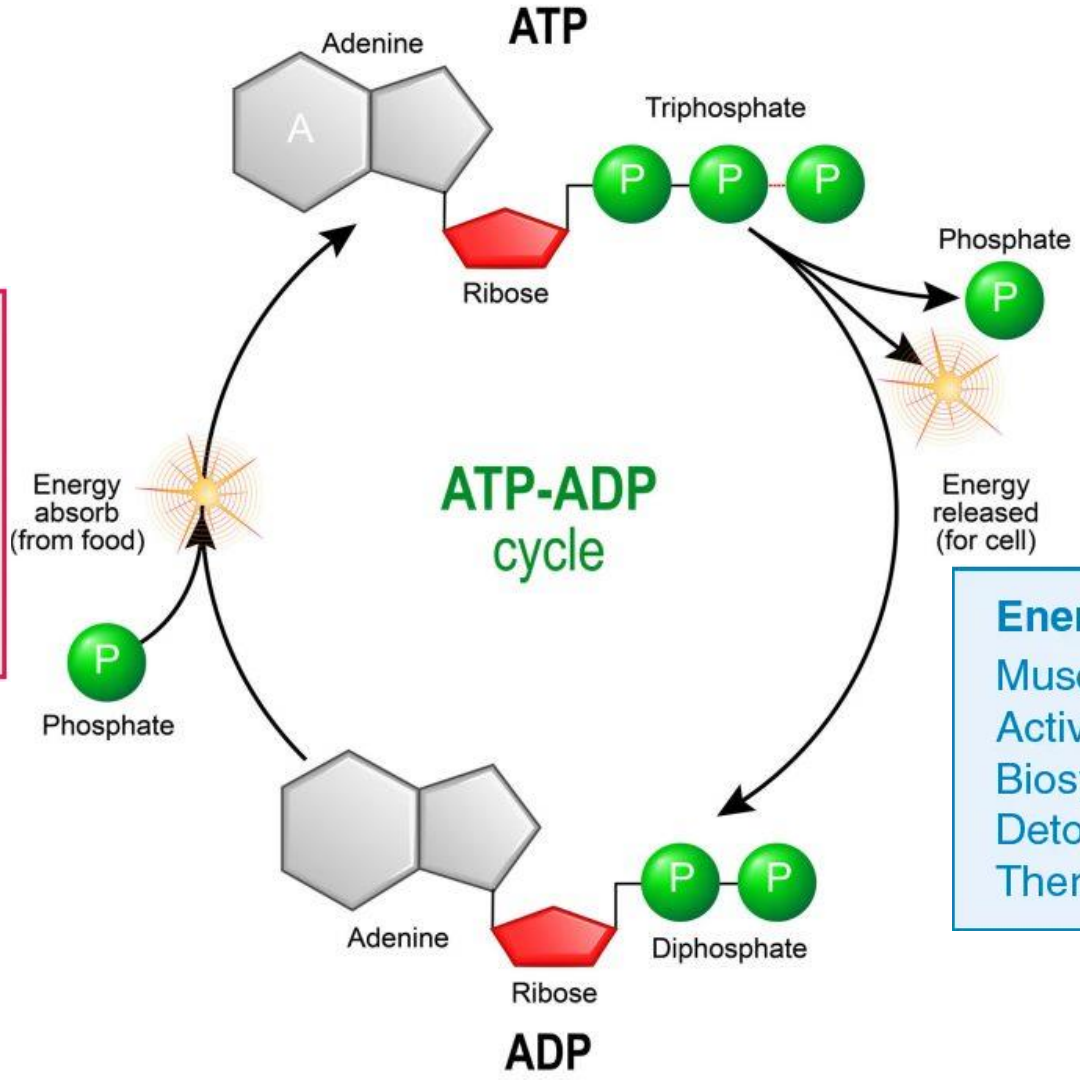


Energy production

Carbohydrate

Lipid

Protein



Energy utilization

Muscle contraction

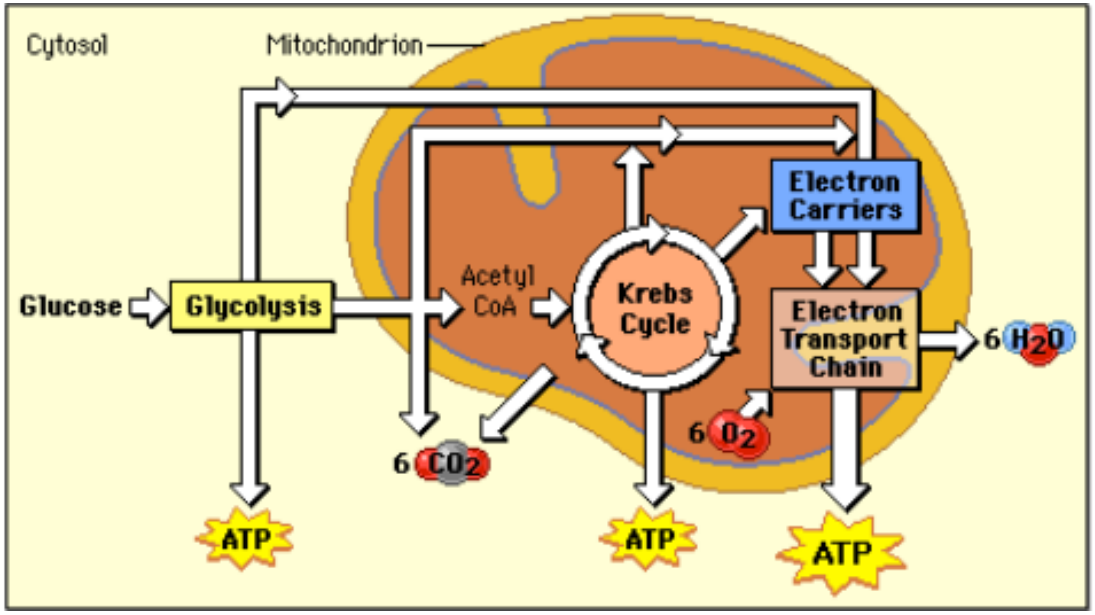
Active ion transport

Biosynthesis

Detoxification

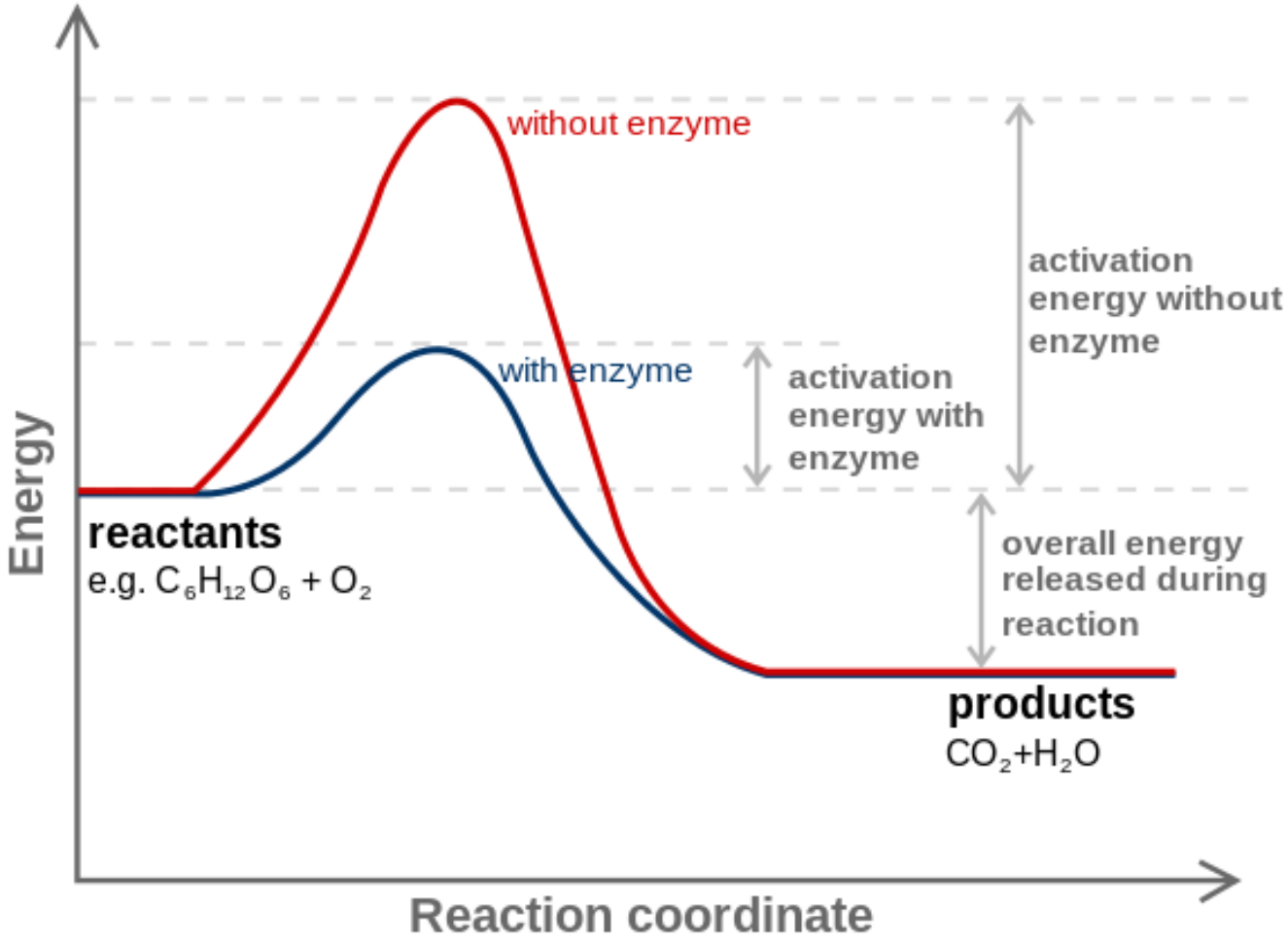
Thermogenesis

Energy transformations in cells occur through pathways like glycolysis, the Krebs cycle, and Electron transport chain (oxidative phosphorylation).



Cellular respiration consists of three metabolic stage : glycolysis, the Krebs cycle, and the electron transport chain. Glycolysis occurs in the cytosol, but the Krebs cycle and electron transport chain occur inside the mitochondria. These three metabolic stages need to enzyme for a complete reactions(metabolism

Enzymes are biological macromolecules that act as catalysts in biochemical reactions (metabolism). Enzymes basically decrease the activation energy (lower activation energy) led to make biochemical reactions faster and more efficient



Acid-base balance

Acid-base balance is very important for the homeostasis of the body and almost all the physiological activities depend upon the acid- base status of the body.

Acids in Medical Chemistry

In medicine, acids are substances that donate protons (H^+) in biological systems. There are two types of acids are produced in the body: 1. Volatile Acids: Volatile acids are derived from CO2 like H2CO3. (Large quantity of CO2 is produced during the metabolism of carbohydrates and lipids). 2. Non-volatile Acids: Non-volatile acids are produced during the metabolism of other nutritive substances such as proteins.

The pH of blood (normally ~7.35–7.45) is tightly regulated. Even slight changes can be dangerous.

Acids are involved in drug ionization. Many drugs are weak acids (e.g., aspirin = acetylsalicylic acid). Acid drugs are better absorbed in acidic environments like the stomach.

Acidosis: a condition where blood becomes too acidic (e.g., in diabetic ketoacidosis)

Bases in Medical Chemistry

Definition:

Bases accept protons (H^+) or release OH^- in solution.

Many drugs are weak bases (e.g., codeine, morphine).

Weak bases are better absorbed in alkaline environments (like the intestines).

The pH of different body fluids affects how drugs move and where they act.

Alkalosis: blood becomes too basic, potentially caused by prolonged vomiting or overuse of antacids.

Buffer systems like bicarbonate (HCO_3^-) help regulate pH in blood.

Electrolytes in Medical Chemistry

Definition:

Electrolytes are ions (charged particles) in body fluids that conduct electrical impulses.

Major Electrolytes:

Sodium (Na^+) – controls fluid balance and nerve impulses

Potassium (K^+) – essential for heart function

Calcium (Ca^{2+}) – muscle contraction, blood clotting

Chloride (Cl^-) – maintains osmotic pressure

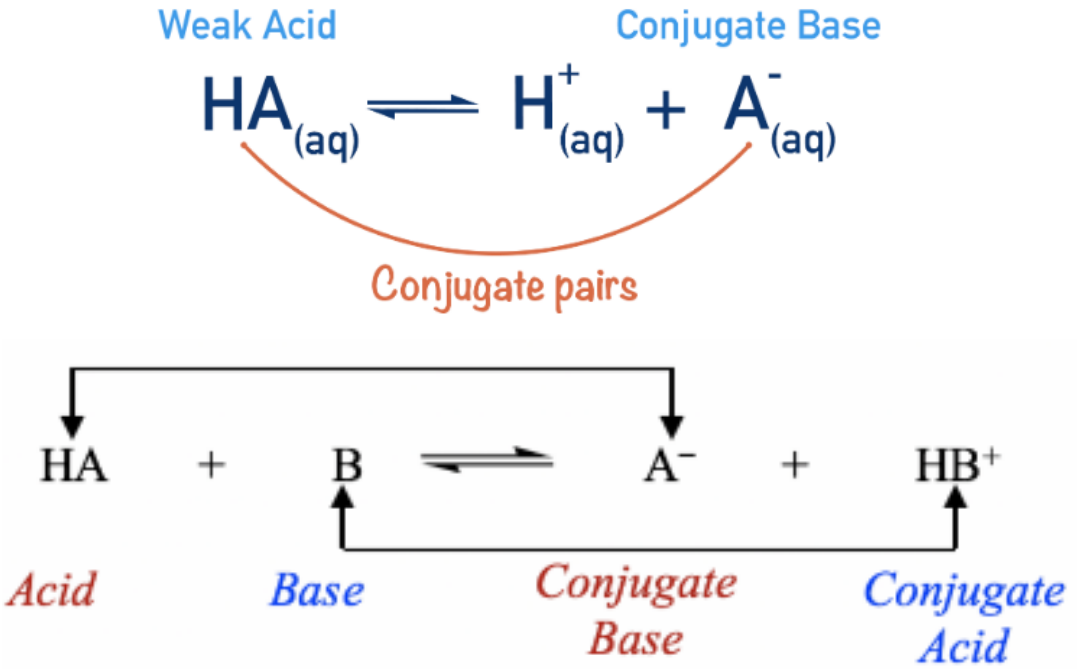
Bicarbonate (HCO_3^-) – pH buffer

Electrolyte imbalances can be life-menacing (e.g., hyperkalemia → cardiac arrest).

Intravenous (IV) fluids often contain electrolytes to restore balance example normal saline

Buffer Solutions in Medical Chemistry

An aqueous solution that resists any change in pH by adding a small amount of acid or base is called a buffer solution. A buffer solution consists of a weak acid and its conjugate base or a weak base and its conjugate acid.



Buffers (in medical chemistry) are essential in maintaining pH balance in biological fluids such as blood, urine, and intracellular fluid.

Advantage of buffer solution prevents drastic pH changes that can disrupt enzyme function, metabolic pathways, and drug stability.

The normal blood pH is 7.35–7.45; deviations can cause acidosis or alkalosis.

If Blood pH more than normal is called as alkalosis while the Blood pH less than normal is called as acidosis

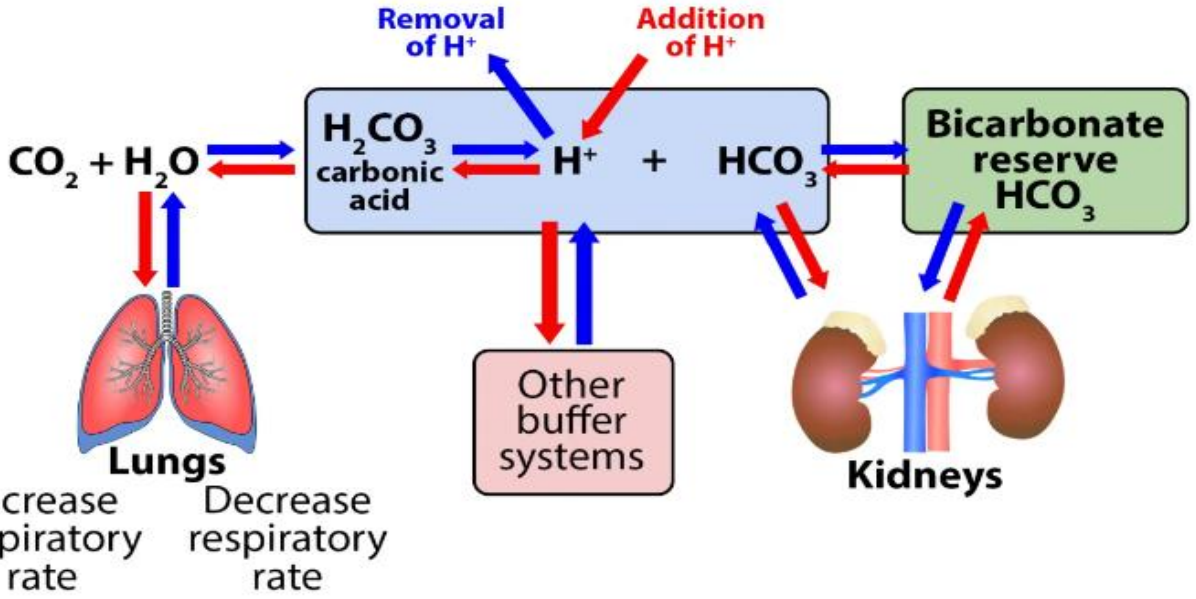
The three primary major buffering systems in the body are:

- **Carbonic Acid-Bicarbonate Buffer.**
- **Phosphate Buffer System.**
- **Protein Buffer System.**

1. Bicarbonate Buffer System (H_2CO_3/HCO_3^-)

The primary buffer in blood.

Maintains pH by regulating CO_2 and HCO_3^- through respiration and kidney function(Bicarbonate buffer system **is present in ECF (plasma).**



1-The respiratory system controls the release of carbon dioxide from the body through breathing rate

2-The kidneys regulate the levels of bicarbonate ions in the blood by absorbing or excreting based on the body's needs

When the CO_2 level in the blood rises (as it does when you hold your breath), the excess CO_2 reacts with water to form additional carbonic acid, lowering blood pH. Increasing the rate and/or depth of respiration allows you to exhale more CO_2. The loss of CO_2 from the body reduces blood levels of carbonic acid and thereby adjusts the pH upward, toward normal levels.

2. Phosphate Buffer System ($H_2PO_4^-/HPO_4^{2-}$)

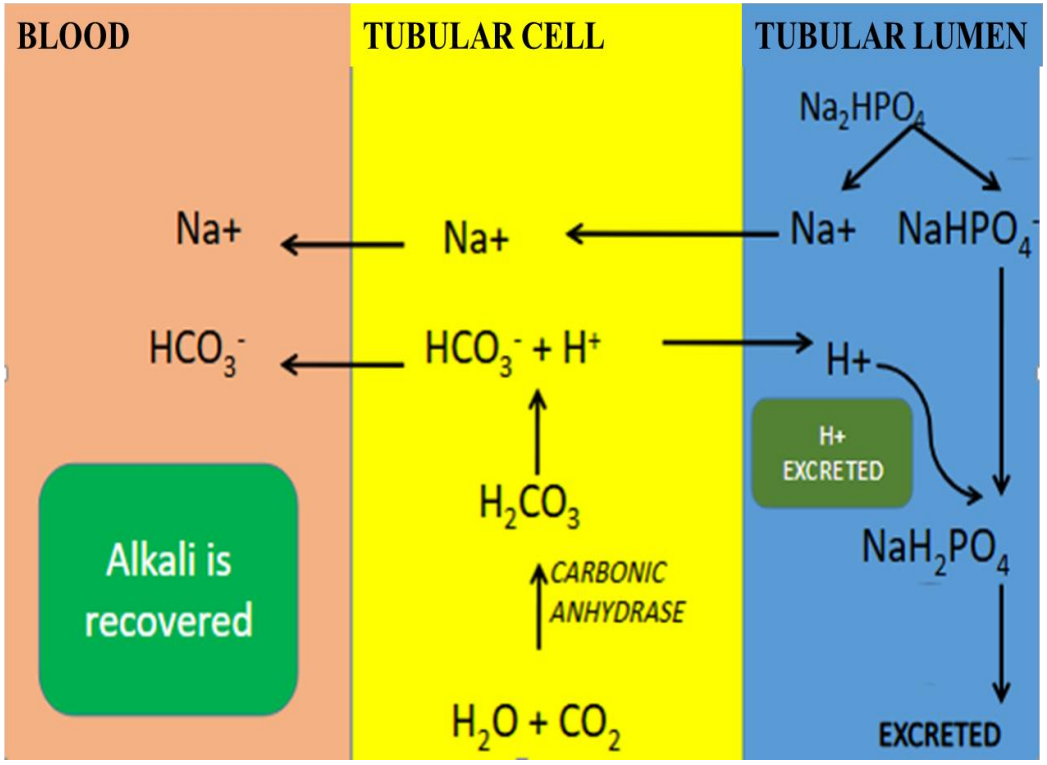
The phosphoric is triprotic acid

$$H_3PO_4 \leftrightarrow H_2PO_4^- \leftrightarrow HPO_4^{-2}$$

Phosphate buffer system is useful in the intracellular fluid (ICF), in red blood cells or other cells, as the concentration of phosphate is more in ICF than in ECF

Importance of phosphate buffer system: **phosphate buffer is useful in tubular fluids of kidneys.**

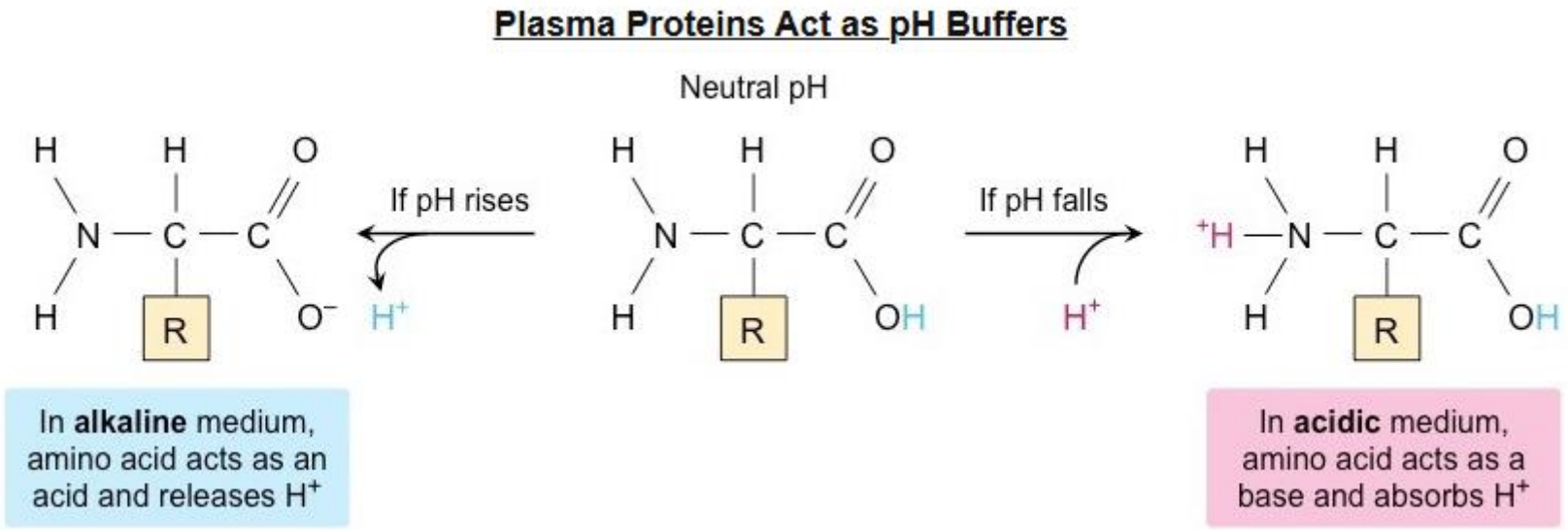
The monohydrogen phosphate ion (HPO4 -2) enters the renal tubular fluid in the glomerulus. A H+ combines with the HPO4 -2 to form H2PO4- and is then excreted into the urine in combination Na+.



Protein Buffer System (Hemoglobin, Albumin)

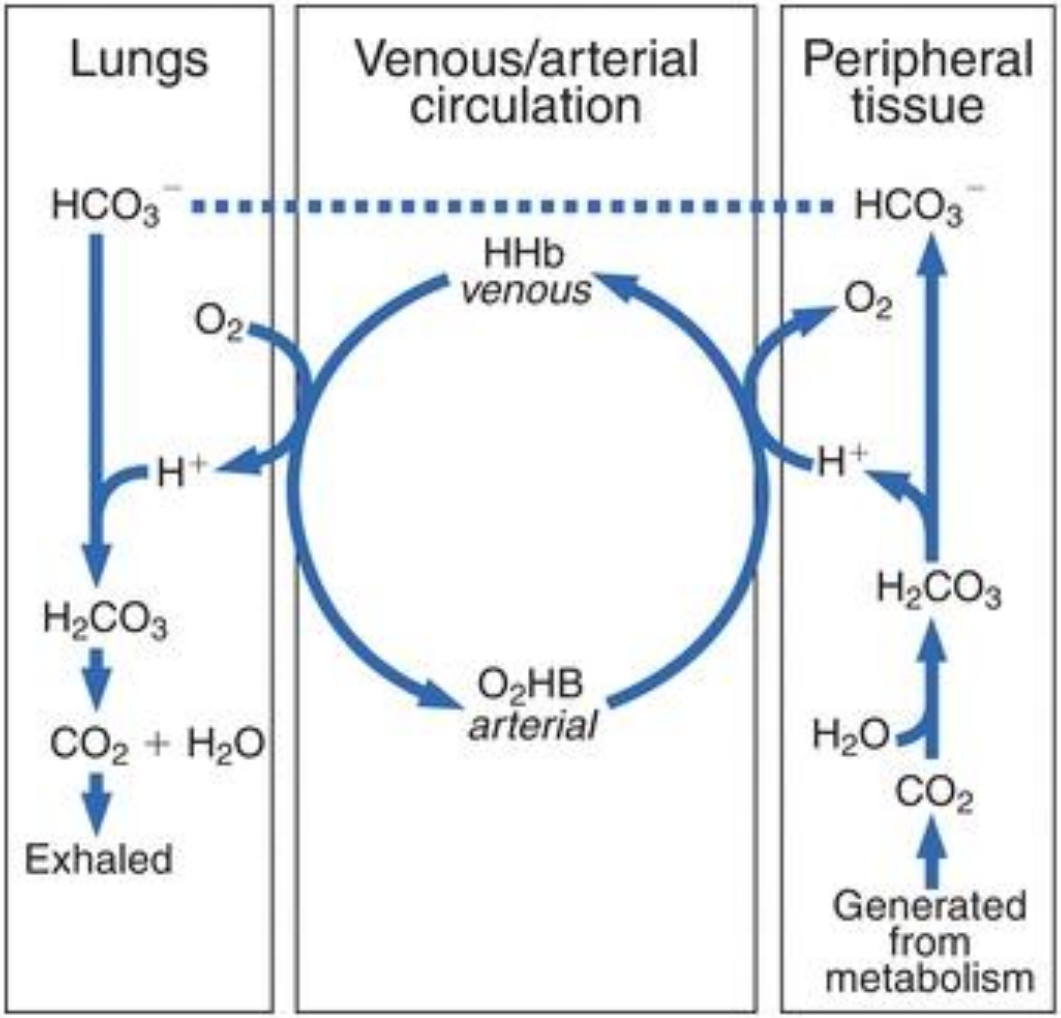
Protein buffer systems are present in the blood; both in the plasma and erythrocytes.

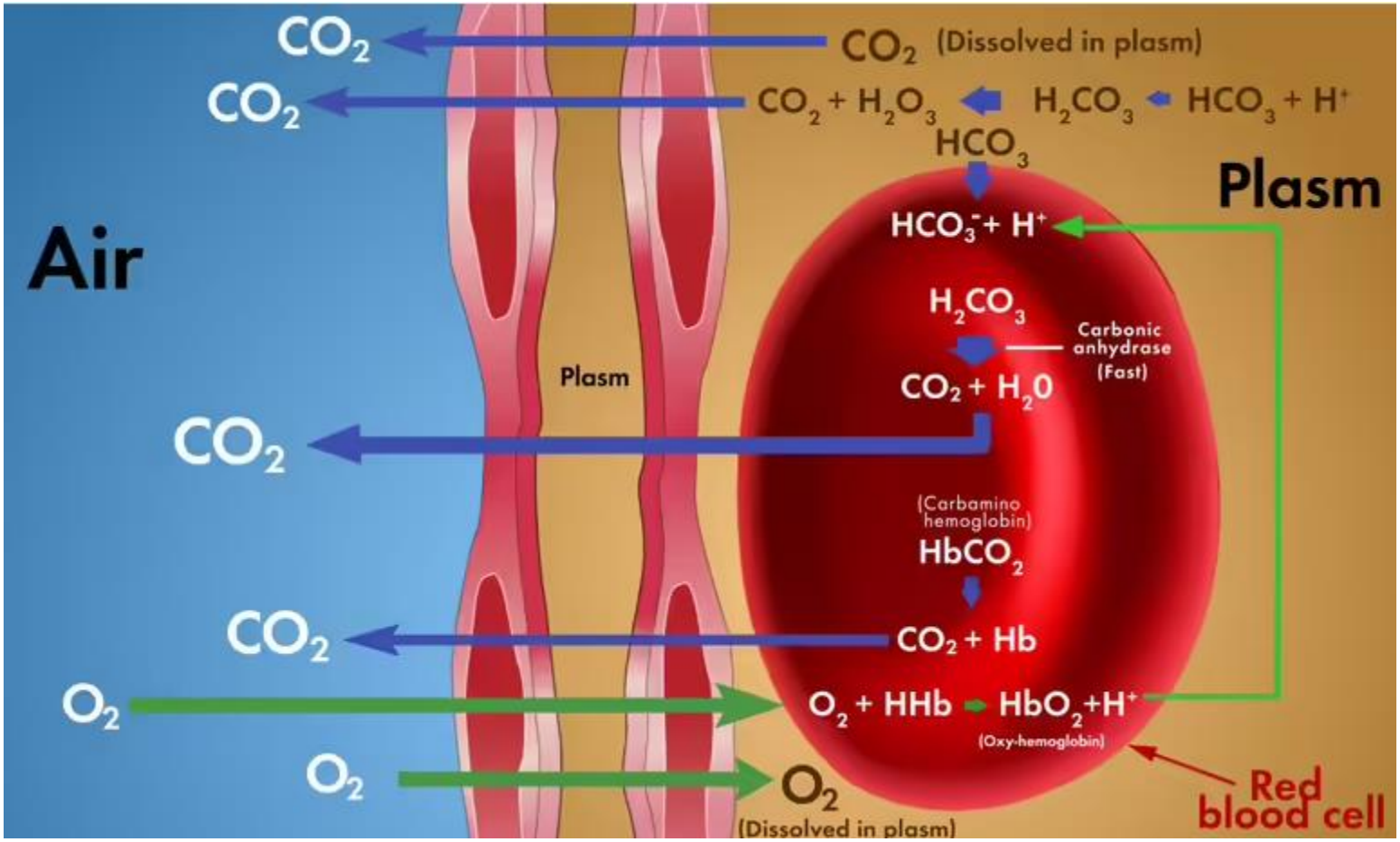
Proteins are made up of amino acids, which contain positively charged amino groups and negatively charged carboxyl groups. amino acids act as buffers in plasma and intracellular compartments, because buffering solution resists changes to pH by removing excess H^+ ions (↑ acidity) or absorbing H^+ ions (↑ alkalinity)



Hemoglobin helps buffer blood pH by binding or releasing H^+.

During the conversion of CO_2 into bicarbonate, hydrogen ions liberated in the reaction are buffered by hemoglobin, which is reduced by the dissociation of oxygen. This buffering helps maintain normal pH.

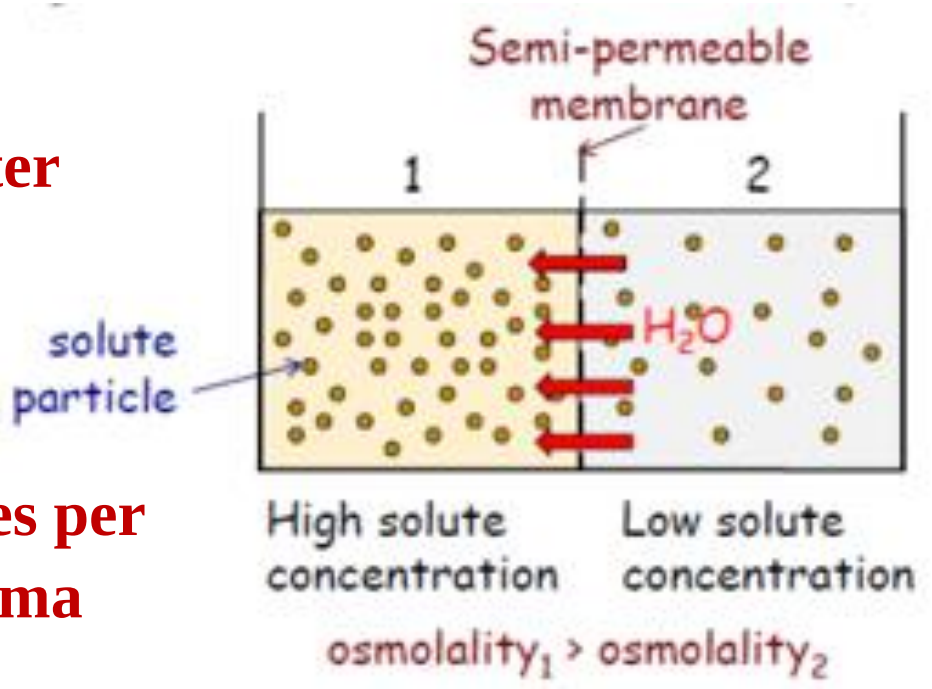



CO_2
CO_2
CO_2 (Dissolved in plasm)
$CO_2 + H_2O_3$
H_2CO_3
$HCO_3 + H^+$
HCO_3
Plasm
Air
$HCO_3^- + H^+$
H_2CO_3
Carbonic anhydrase (Fast)
Plasm
$CO_2 + H_20$
CO_2
(Carbamino hemoglobin)
$HbCO_2$
CO_2
$CO_2 + Hb$
O_2
$O_2 + HHb$
$HbO_2 + H^+$
(Oxy-hemoglobin)
O_2
O_2
(Dissolved in plasm)
Red blood cell

Osmolality in Medical Chemistry

In aqueous solution: Osmosis refers to a movement of water from a region of low solute concentration to one of high solute concentration across a semipermeable membrane.

The membrane is permeable to water but not to solute.



Osmolality : concentration of solutes per Kg of solvent (water) . Normal plasma osmolality: 275–295 mOsm/kg.

Osmolality is a key measure in clinical chemistry that reflects the concentration of dissolved solutes (electrolytes, glucose, proteins) in body fluids, therefore It affects fluid balance, hydration, and cellular function.

Osmotic Effects on Cells:

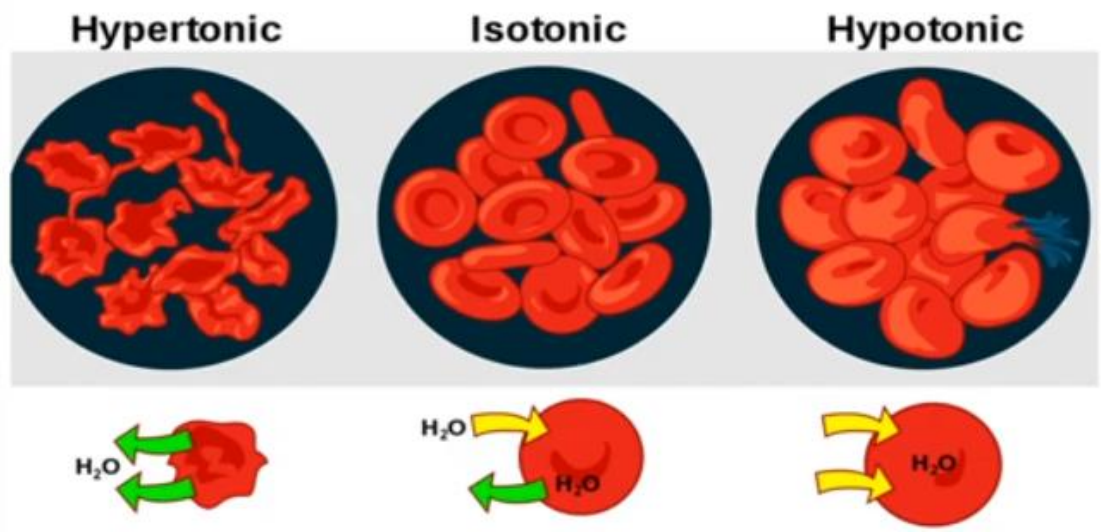
1. Isotonic Solution: No net water movement (e.g., saline solutions(0.9)

An isotonic solution is any external solution with the same solute and water concentrations as body fluids.

2. Hypertonic Solution: Water leaves cells → cell shrinkage (example glucose solution)

A hypertonic solution is any external solution with a high solute concentration and low water concentration compared to body fluids.

3. Hypotonic Solution: Water enters cells → swelling (example:



Metals in Medical Chemistry

Some metals are essential trace elements:

Iron (Fe) – hemoglobin, oxygen transport

Zinc (Zn) – immune function, wound healing

Magnesium (Mg^{2+}) – enzyme cofactor

Toxic metals (e.g., lead, mercury) can interfere with biological function.

Platinum compounds (e.g., cisplatin) are used in chemotherapy.

Lithium is used to treat bipolar disorder.

Used to bind and remove toxic metals (e.g., EDTA for lead poisoning).

Ionic Bonding in Medical Chemistry

Definition:

Ionic bonding is when electrons are transferred between atoms, forming charged ions that attract each other.

Drug solubility: Ionic drugs dissolve easily in water and can circulate in blood.

Ionized vs. non-ionized drugs: Ionized forms are more soluble, but less membrane-permeable. Non-ionized forms cross membranes more easily.

Electrolyte replacement therapies rely on ionized forms for bioavailability (e.g., NaCl IV solutions).

Sodium bicarbonate ($NaHCO_3$) dissociates into Na^+ and HCO_3^-, buffering acid in cases of metabolic acidosis.