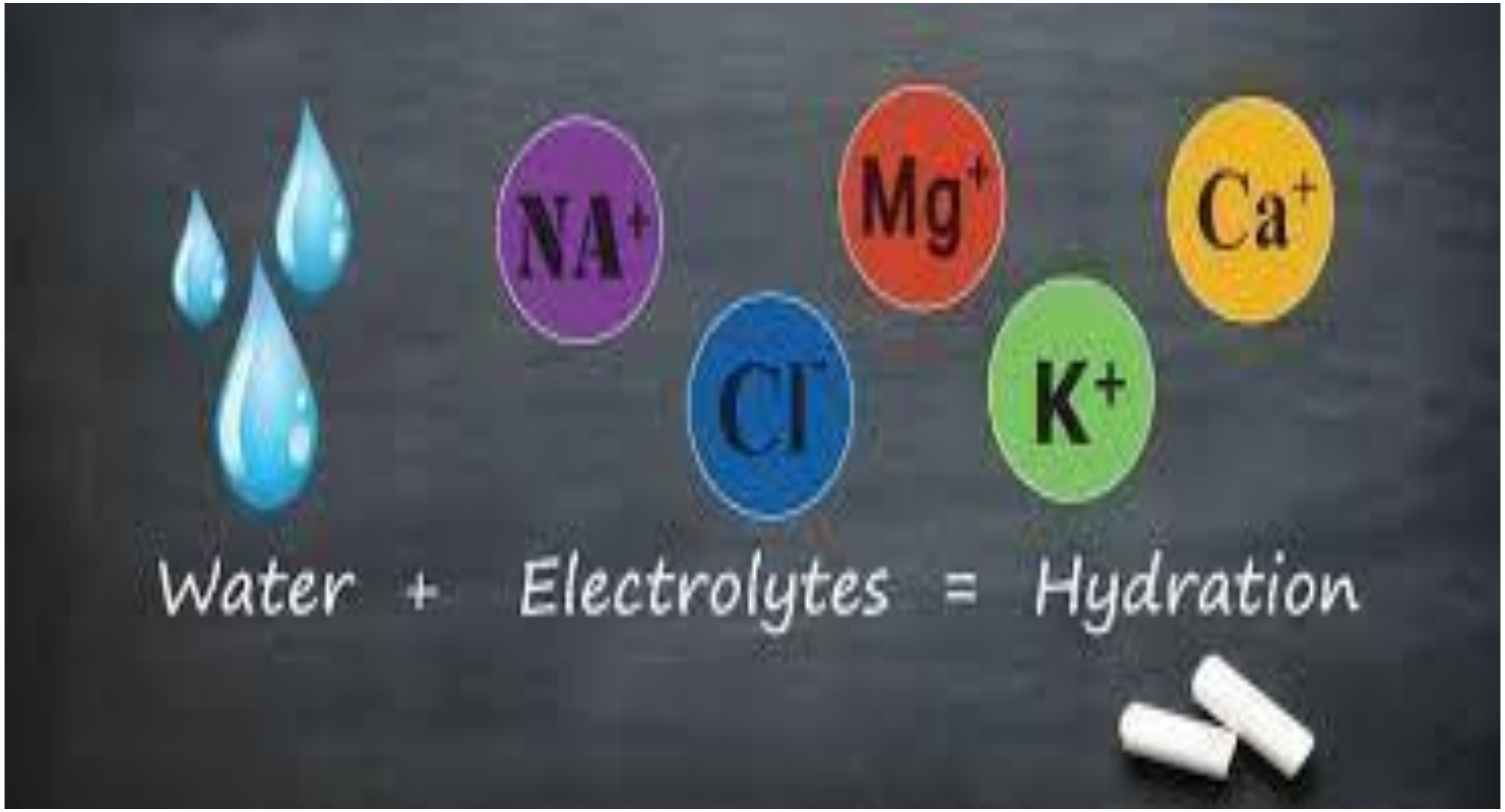
DEPTH OF BIOLOGY

UNIT II **10 Hours**

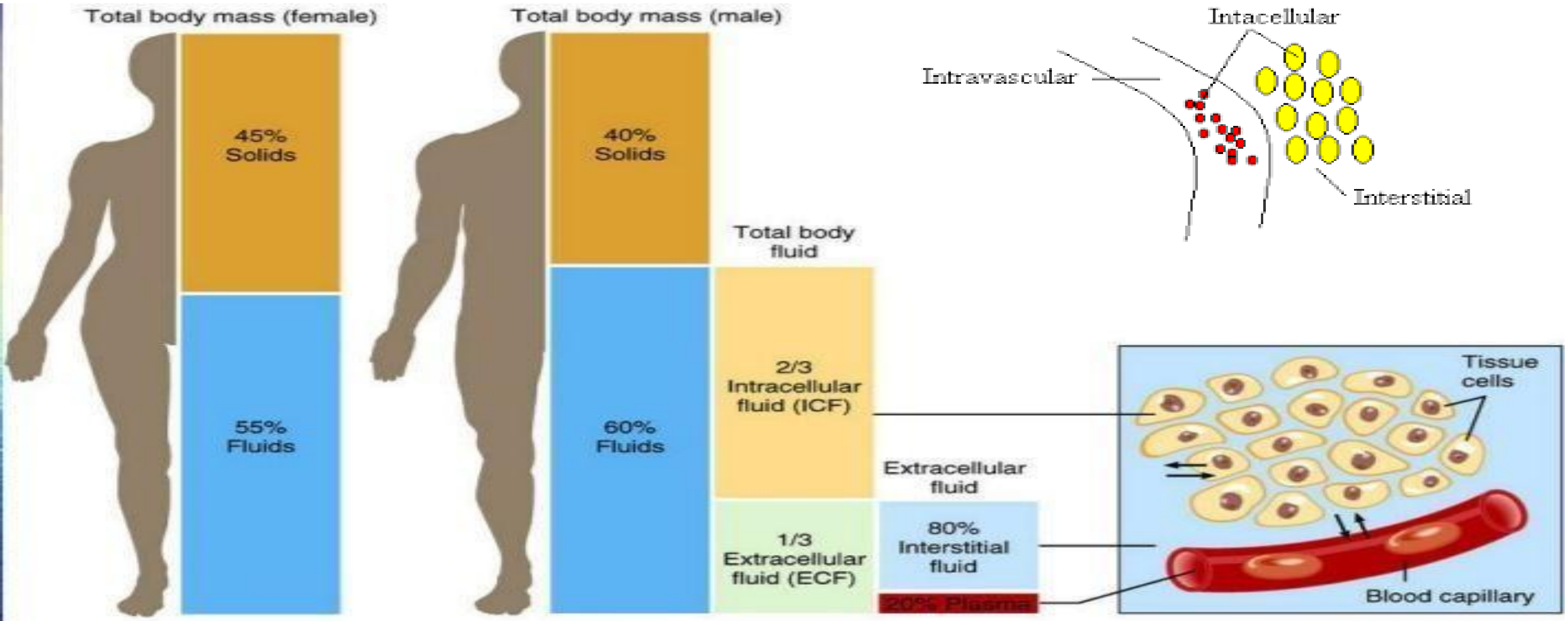
- **Acids, Bases and Buffers:** Buffer equations and buffer capacity in general, buffers in pharmaceutical systems, preparation, stability, buffered isotonic solutions, measurements of tonicity, calculations and methods of adjusting isotonicity.
- **Major extra and intracellular electrolytes**: Functions of major physiological ions, Electrolytes used in the replacement therapy: Sodium chloride*, Potassium chloride, Calcium gluconate* and Oral Rehydration Salt (ORS), Physiological acid base balance.
- **Dental products**: Dentifrices, role of fluoride in the treatment of dental caries, Desensitizing agents, Calcium carbonate, Sodium fluoride, and Zinc eugenol cement.

DEPTH OF BIOLOGY

Major Intra & Extracellular ELECTROLYTES



Major extra and intracellular ELECTROLYTES



(b) Exchange of water among body fluid compartments

DEPTH OF BIOLOGY

- Chemical substance dissolved in body fluid can be categorized into:

A. Non-electrolytes: Organic molecules, Do not generate ions in solution form.

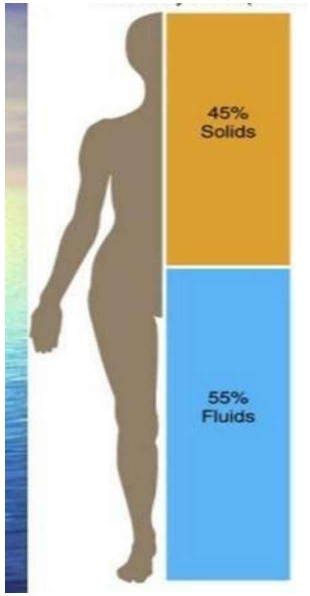
e.g., Glucose, Urea, Creatine etc

B. Electrolytes: Mostly inorganic substances, Dissociates into ions (+ve/-ve) in the body fluid.

e.g., Acids, Bases, Salts, few organic molecules like Citric acid, Lactic acid, Oxaloacetic acid etc

Body: "Both are necessary to perform physiological functions"!

DEPTH OF BIOLOGY



Body water – ***Dissolved***
Necessary Elements

Substance Required

To:

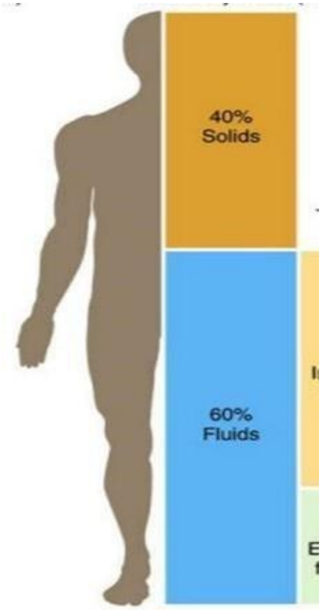
Metabolize Nutrients & Drugs

Generate Energy

Maintain & Mfg. Body Components

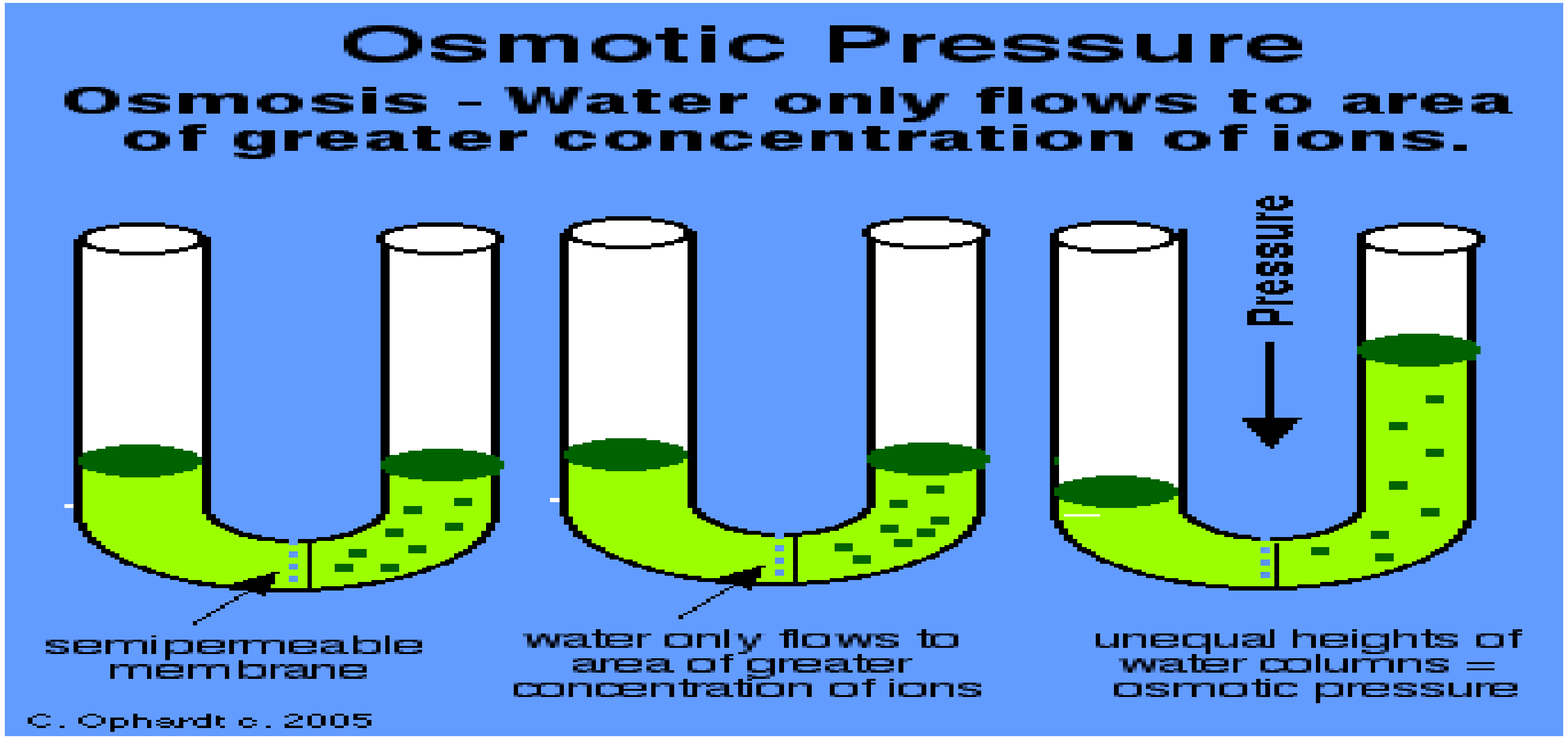
Eliminate:

by-products & waste



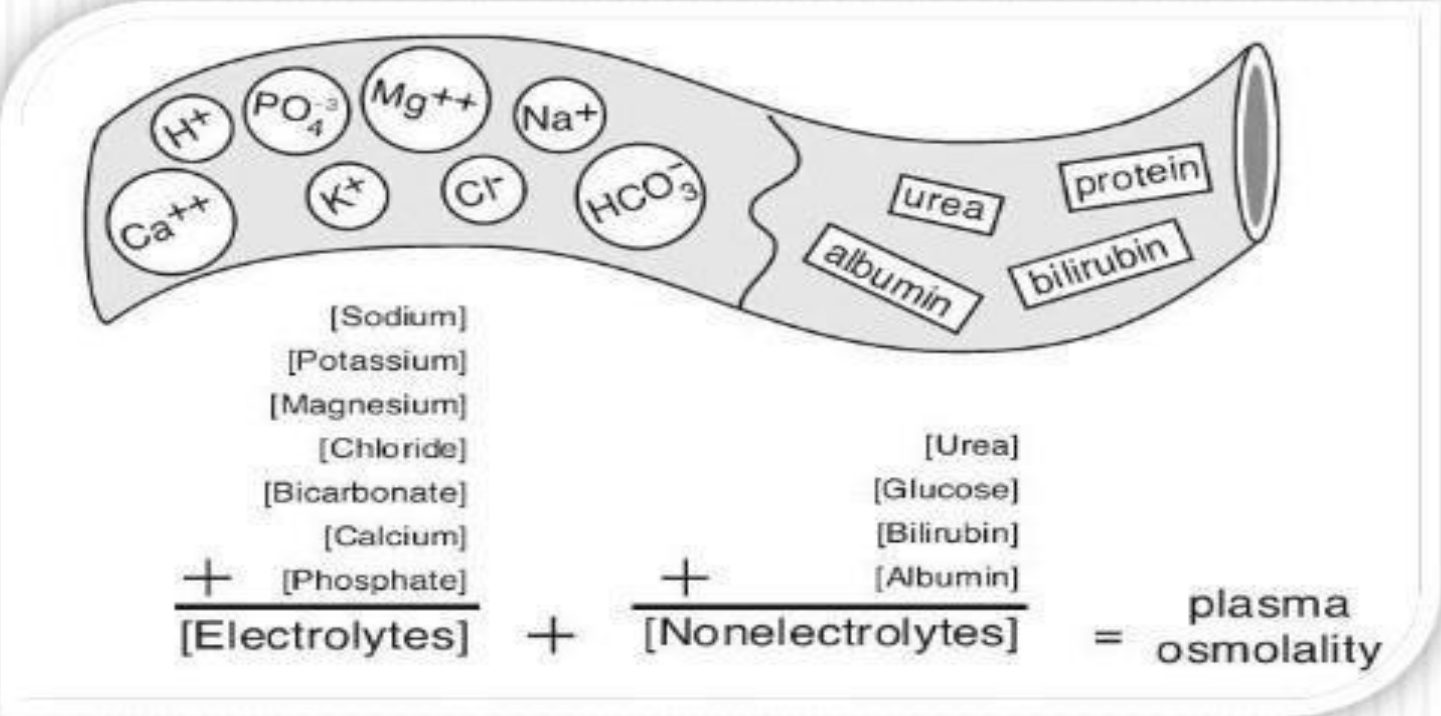
Internal Homeostasis (ionic, osmotic, pH balance)

- Osmotic Pressure: concentration of electrolytes (dissolved ions) in each compartment that creates the osmotic pressure that holds water in the appropriate space.

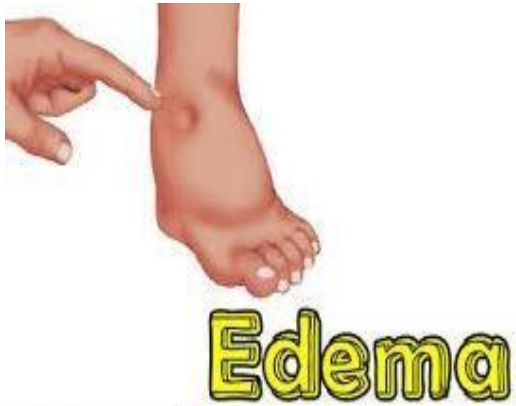


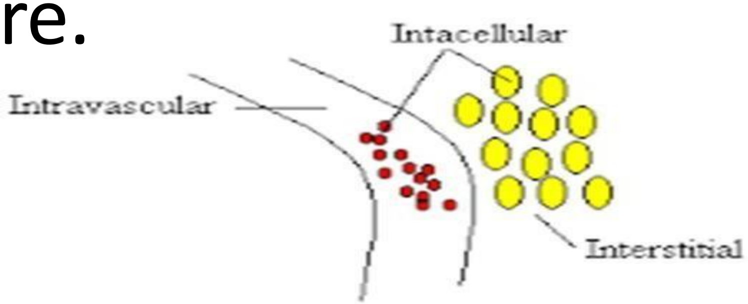
Osmolality

- is the number of particles (mmol) contained in one liter of water, so measured in mmol/L.
- i.e. it is the concentration by number



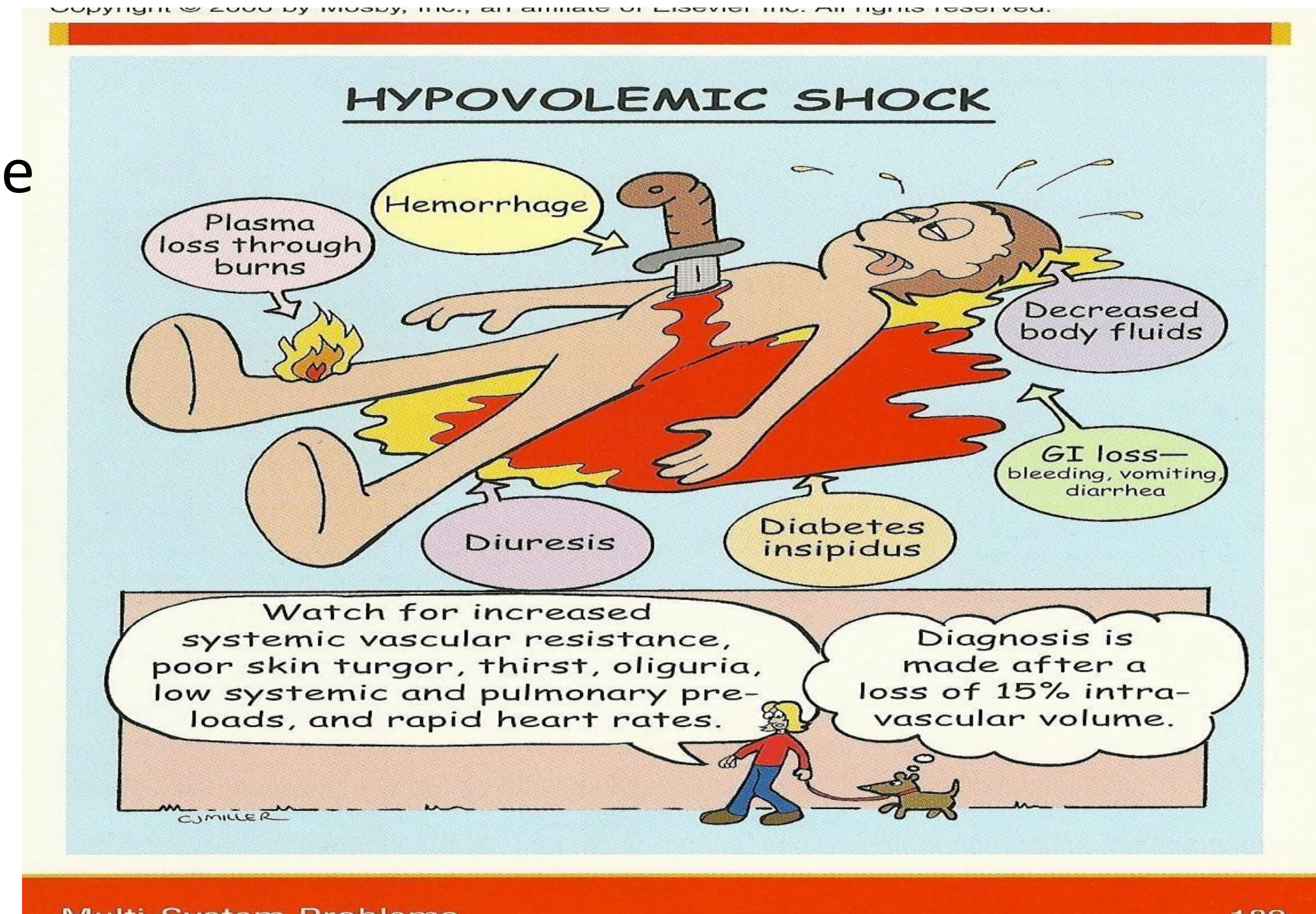
- Dehydration: state in which water volume is low in all 3 compartments (Intracellular, interstitial & plasma fluid).
- Edema: State in which fluid accumulates in the interstitial space due to low Oncotic (Protein) pressure.





DEPTH OF BIOLOGY

- Hypovolemia:
  - ➢ State in which intravascular volume is low.

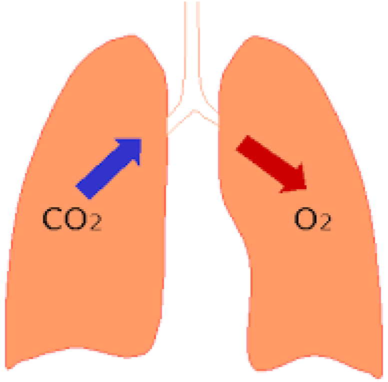


DEPTH OF BIOLOGY

Salt & water balance:

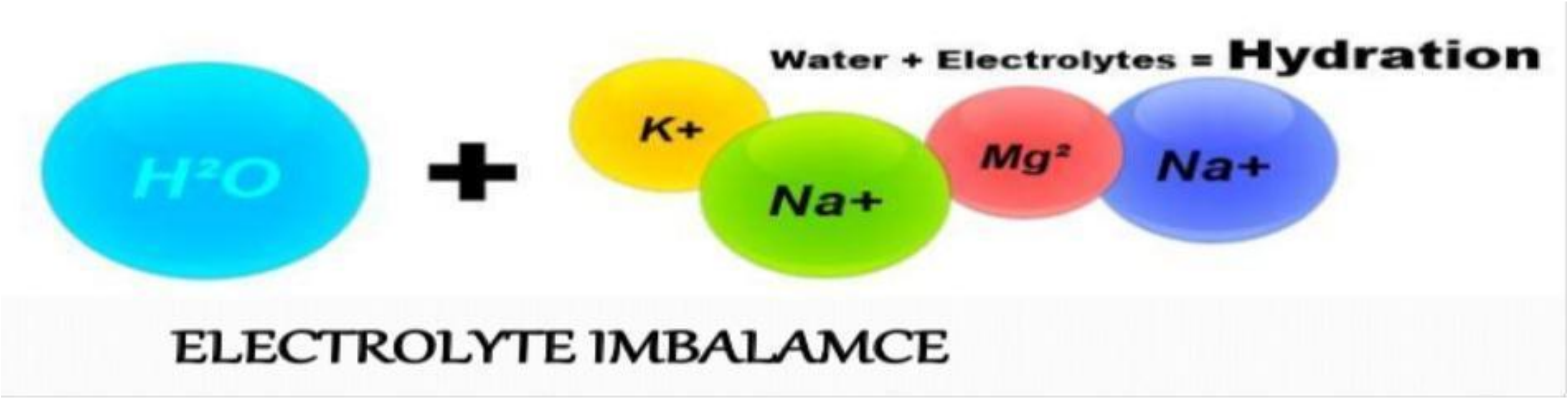
- Oral intake of fluid & electrolytes

- Evaporation of solute – free water across the skin and lungs.



- Excretion of water & electrolytes through the kidneys : ⇅ output – antidiuretic hormone (ADH) & aldosterone.

DEPTH OF BIOLOGY



- The fluid in each compartment is ionically balanced.
- Body has the capacity to adjust slight variations in electrolytic concentration of the fluid compartments.
- If concentration of electrolytes changes – water will migrate across the cell membrane to reestablish <u>Osmotic equilibrium</u>.

Replacement Therapy

- When body itself fails to correct an electrolyte imbalance.

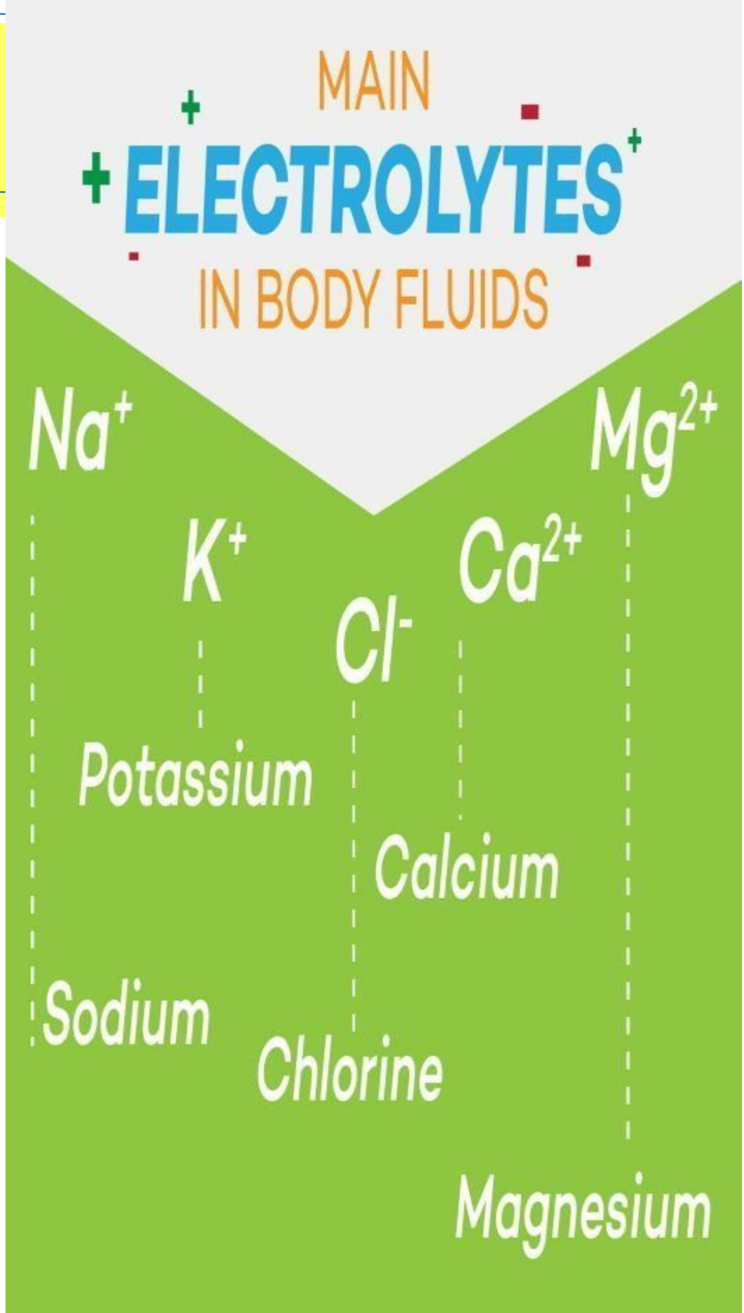
Products:

- Electrolytes
- Acids & Bases
- Blood Products
- Carbohydrates
- Amino acids
- Proteins

Electrolytes

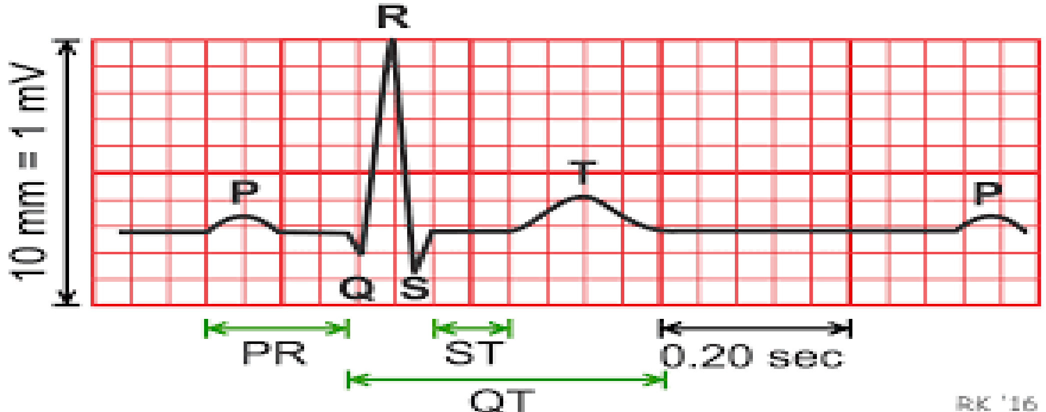
- Mineral salts (inorganic compounds) are necessary within the body for all body process.
- They are usually required in small quantities.
- Main elements:

Calcium & Phosphorus: bone & teeth Iron: haemoglobin - convey oxygen & CO2. Na & K: Transmission of nerve impulses & contraction of muscles



Important Functions:

- Control of osmosis of water between body compartments.
- Maintain the acid-base balance required for normal cellular activates.
- Help to generate action potentials & graded potentials.
- Help to control secretion of some hormones
- (e.g., Aldosterone, Thyroid hormones) and neurotransmitters.



Major Physiological Ions

- **Nature/Properties**
- **Important Role/Major Physiological role**
- ↑↓s

Sodium (Na^{+}),
Chloride (Cl^{-}),
Potassium (K^{+}),
Calcium (Ca^{2+}),
Magnesium (Mg^{2+}),
Phosphate ($H_2PO_4^{-}$, HPO_4^{2-}, PO_4^{3-}),
Bicarbonate (HCO_3^{-})

Prepare a Simple Report

Electrolytes used in the Replacement Therapy

- In a healthy person, at least 70 liters of fluids are exchanged (secreted and reabsorbed) across the walls of the intestines per day.
- The brain, heart, kidney, and virtually every other vital organ depend on these fluids to function.
- As the body takes in the water and salts it needs, it loses or excretes those it does not need through urine, stools, and sweat.
- Thus, the secretion and absorption rates are kept in balance.

DEPTH OF BIOLOGY

- In various condition like prolonged fever, sever vomiting or diarrhea creates a tremendous outpouring of water (heavy loss of water) & electrolytes (body salts) state of dehydration and impairs the capacity to reabsorb the fluid & electrolytes in our system.

- To compensate this loss, Electrolyte Replacement Therapy / Oral Rehydration Therapy is required.

"Replace what it Lost"

- 2 types of solutions used

1. A solution for rapid initial replacement:

Name	Concentration Range
Sodium	130 – 150 mEq/L
Chlorine	98 – 110 mEq/L
Potassium	4 – 12 mEq/L
Bicarbonate	28 – 55 mEq/L
Calcium	3 -5 mEq/L
Magnesium	3 mEq/L

These electrolyte concentrations thus closely resemble with the electrolyte concentrations found in extracellular fluids!

Name	mOsm/Litre
Sodium	75
Potssium	20
Dextrose	75
Chloride	65
Citrate	10
Toal osmolarity in approx. 200ml water	245

2. A solution for subsequent replacement:

Name	Concentration Range
Sodium	40 – 120 mEq/L
Chlorine	30 – 105 mEq/L
Potassium	16 – 35mEq/L
Bicarbonate	16 – 53 mEq/L
Calcium	10 - 15 mEq/L
Magnesium Phosphorus	03 - 06 mEq/L 0 – 13 mEq/L

DEPTH OF BIOLOGY

PHYSIOLOGICAL ACID-BASE BALANCE

- Electrolytes also play an important role in regulating body's acid-base balance
- Body fluids contain balanced quantities of acids & bases.

Acidity of the solution: No of [H^+] present in fluid/solution - ECF

Sources: [H^+]

- Food
- Cellular metabolism of Glucose, Fatty acids, & Amino acids etc
- Reabsorption

- **Biochemical reactions:** Very sensitive to change in pH (acidity/alkalinity)

e.g., enzyme Pepsin in the stomach– helps in digestion of dietary proteins at low pH.

enzyme Ptyalin in saliva – helps in digests carbohydrates at pH between 5.4 - 7.5.

Body Fluid	pH value
Urine	4.5 – 08
Blood	7.4 – 7.5
Gastric juice	1.5 – 3.5
Saliva	5.4 – 7.5
Bile	6.0 8.5

Kidney – removes excess acid – make urine acidic

Metabolic activity – Produces acid/bases - Alter the blood pH

Buffer Systems

Acids-bases are continually taken into & formed by the body, the pH of fluids inside & outside cells remain fairly constant because of the presence of 'BUFFER SYSTEMS'.

•Consists of a weak acid & the salt of that acid

Functions:

- to convert strong acids or bases into weak acids or bases.
- to prevent drastic change in pH of the blood.

Note: However, it will be effective only if excess acid/alkali excreted out by lungs and/or kidneys.

Types of Buffer systems:

- Carbonic Acid (H_2CO_3) – Bicarbonate (HCO_3^-) Buffer System
- Phosphate ($H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}) Buffer System
- Protein (Hemoglobin/HbH) Buffer System

Carbonic Acid (H_2CO_3) – Bicarbonate (HCO_3^-) Buffer System

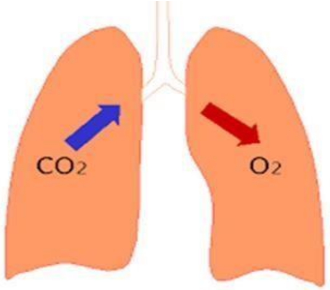
- Major buffer of metabolic acid/base present in Plasma & Kidneys.
- Regulates blood pH

Some CO_2, the end product of cellular metabolism, is carried to the lungs for elimination, and the rest dissolves in body fluids, forming carbonic acid that dissociates to produce bicarbonate (HCO_3^-) and hydronium (H_3O^+) ions.

More of the HCO_3^- is supplied by the kidneys.

$$CO_2 + H_2O \leftrightarrow H_2CO_3$$

$$H_2CO_3 + H_2O \leftrightarrow H_3O^+ + HCO_3^-$$



Regulation of blood pH

- The lungs and kidneys play important role in regulating blood pH.
- The lungs regulate pH through retention or elimination of CO_2 by changing the rate and volume of ventilation.
- The kidneys regulate pH by excreting acid, primarily in the ammonium ion (NH_4^+), and by reclaiming HCO_3^- from the glomerular filtrate (and adding it back to the blood).

Phosphate Buffer System

- The phosphate buffer system ($HPO_4^{2-}/H_2PO_4^-$) plays a role in plasma and erythrocytes.
- $H_2PO_4^- + H_2O \leftrightarrow H_3O^+ + HPO_4^{2-}$
- Any acid reacts with monohydrogen phosphate to form dihydrogen phosphate

dihydrogen phosphate monohydrogen phosphate

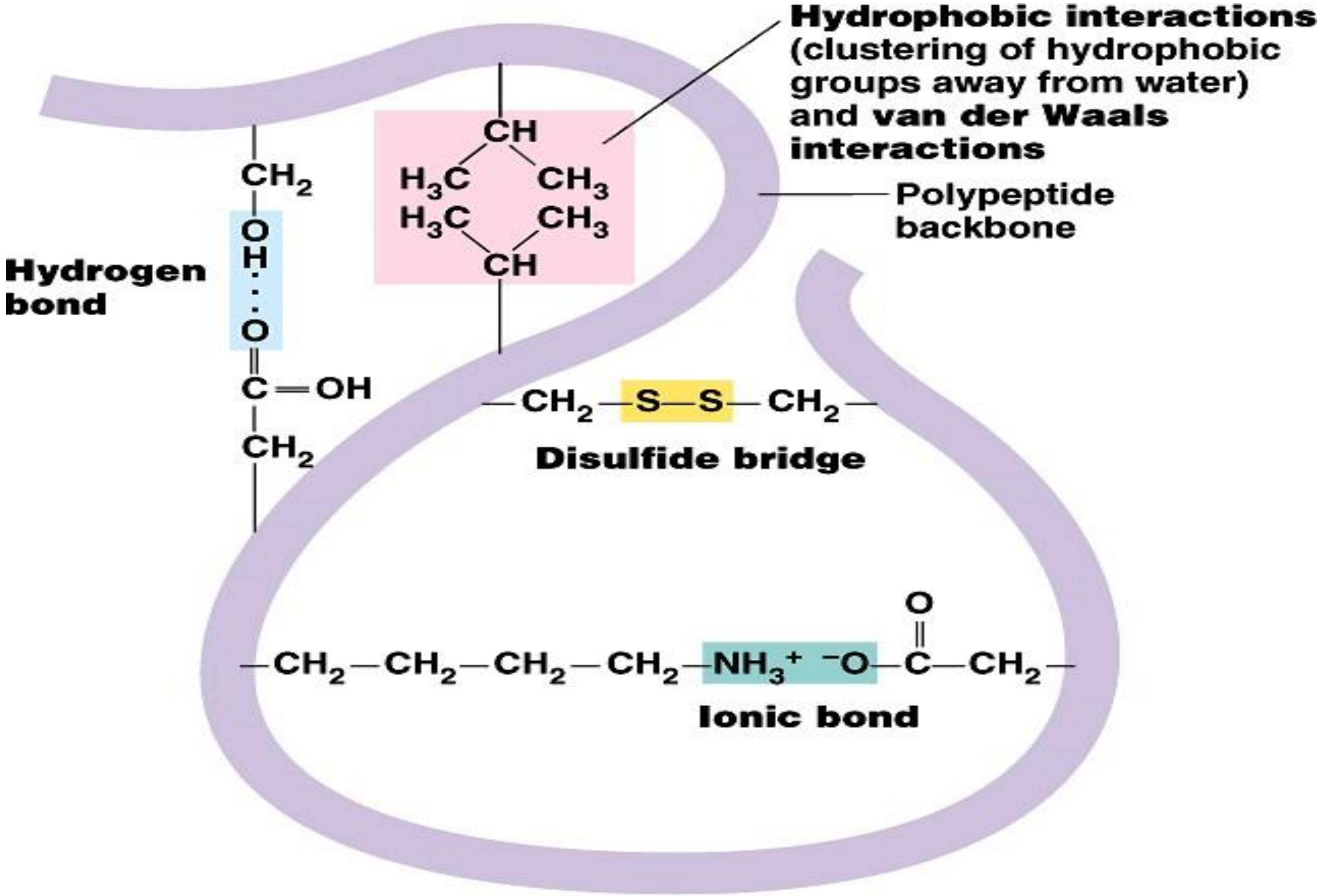
- $H_2PO_4^- + H_2O \leftarrow HPO_4^{2-} + H_3O^+$
- The base is neutralized by dihydrogen phosphate

dihydrogen phosphate monohydrogen phosphate

- $H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_3O^+$

DEPTH OF BIOLOGY

Protein Buffer System



Proteins act as a third type of blood buffer

- Proteins contain – COO^- groups, which, like acetate ions (CH_3COO^-), can act as proton acceptors.
- Proteins also contain – NH_3^+ groups, which, like ammonium ions (NH_4^+), can donate protons.
- If acid comes into blood, hydronium ions can be neutralized by the – COO^- groups
- $-COO^- + H_3O^+ \rightarrow -COOH + H_2O$
- If base is added, it can be neutralized by the – NH_3^+ groups
- $-NH_3^+ + OH^- \rightarrow -NH_2 + H_2O$

Properties, Preparation, Assay & Uses of

- Sodium Chloride
- Potassium chloride
- Calcium gluconate

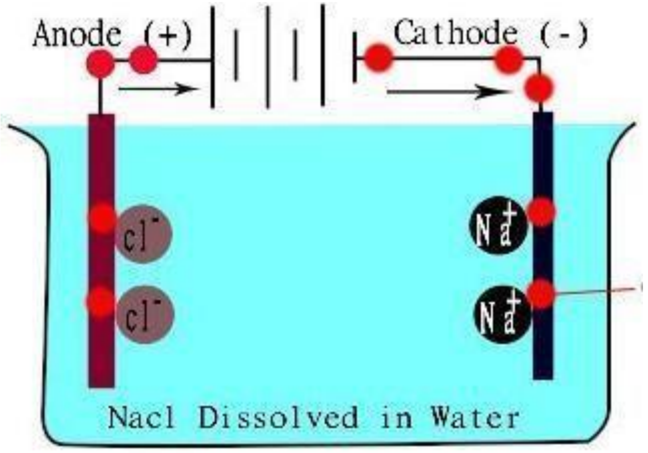
Electrolyte Replenisher

Sodium Chloride (NaCl)

- Sodium chloride is an ionic compound
- It is commonly called as table salt, halite or common salt (99.5% NaCl).
- It is the salt which is mainly responsible for the salinity of the seawater and for the extracellular fluid which is present in many multi-cellular organisms.
- It finds its application from household, medicines to industrial processes.
- Sea water is a major source of this salt.

Properties: NaCl

- It is easily soluble in water and partially in glycerine & alcohol.
- They are white crystals which does not have an odour but possess a taste.
- In its aqueous state NaCl acts as a good conductor of electricity due to the free movement of the ions.
- M.P. 801°C



Preparation of Sodium Chloride:

- 1 mol of sodium bicarbonate reacts with 1 mol of hydrochloric acid to generate 1 mol of salt, 1 mol of water, and/or 1 mol of carbon dioxide.

$$NaHCO_3 + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(aq)} + CO_2$$

Procedure:

- Accurately weigh 5 g of $NaHCO_3$ into evaporating dish.
- Add 5 to 6 mL of distilled water to the dish to wet the bicarbonate. Cover the dish with

  a watch glass.
- Move the watch glass aside slightly and add, in small portions, about 6 mL of concentrated hydrochloric acid from a 10 mL graduated cylinder.
- After the addition of 6 mL of acid, continue adding acid only as long as CO_2 (gas) continues to be evolved.
- Remove the watch glass and evaporate to dryness over a water bath.
- Allow the dish to cool, weigh & collect it out the crystals of NaCl.

- Assay: It is analysed by Precipitation Titration (Mohr's method)

$$NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$$

Sodium chloride reacts with silver nitrate solution using potassium chromate as an indicator

$$2\ AgNO_3 + K_2CrO_4 \rightarrow Ag_2CrO_4 + 2KNO_3$$

Reddish brown coloured

silver chromate

Uses:

- Normal saline (0.9%) that has the same osmotic pressure (isotonic) as body fluids.
- Wet dressings
- Hypotonic solution – when patient unable to take fluid & nutrients orally.
- Hypertonic solution/injections: patients suffers from excessive loss of sodium (1.6% w/v of NaCl).

Potassium Chloride (KCl)

- Colourless, odourless white granular powder or crystals.
- It has a saline taste and is stable in air.
- Soluble in water and insoluble in alcohol.

Assay: It is analysed by Precipitation Titration (Mohr's method)

$$KCl + AgNO_3 \rightarrow AgCl + KNO_3$$

- KCl reacts with silver nitrate solution using potassium chromate as an indicator

$$2\ AgNO_3 + K_2CrO_4 \rightarrow Ag_2CrO_4 + 2KNO_3$$

Reddish brown coloured silver chromate

Preparation:

Method 1: Potassium chloride can be prepared by treating potassium hydroxide (KOH) or other potassium

bases (potassium carbonate, potassium sulphate) with hydrochloric acid:

$$KOH + HCl \rightarrow KCl + H_2O$$

- This conversion is an acid-base neutralization reaction.
- The resulting salt can then be purified by recrystallization.

Method 2:

- By allowing potassium to burn in the presence of chlorine gas (exothermic reaction)

$$2\,K + Cl_2 \rightarrow 2\,KCl$$

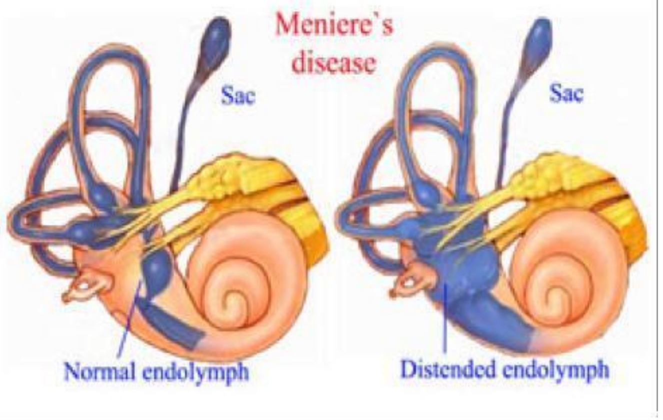
Uses of KCl

- Potassium replacement (hypokalemia or hypochloremic alkalosis condition).
- As an isotonic solution – alone

Or Mixed with NaCl or 5% dextrose solution

- Paralysis
- Menier's syndrome
- Digitalis intoxication

Note: cautiously given in heart & renal diseases.



Calcium Gluconate

- It appears odourless, tasteless, white crystalline granules or powder.
- Soluble in water and insoluble in alcohol & other organic solvents.
- Its solution remains neutral to litmus.
- Decomposed by dilute mineral acids (HCl) into Gluconic acid and Calcium chloride of the mineral acid used.

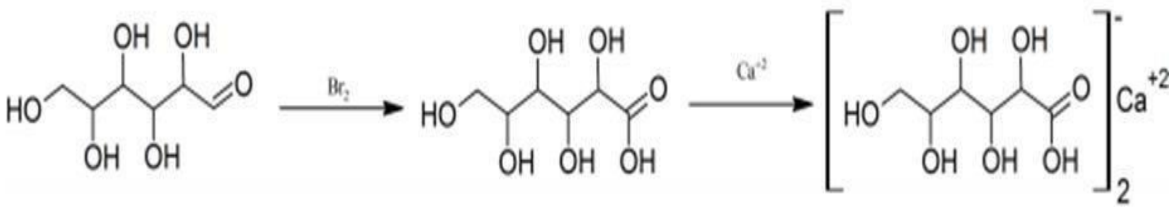
Assay: By Complexometric Titration

- An accurate weighed sample is dissolved in small quantity of water, acidified with dil. HCL.
- To the above solution add 1.0 N NaOH solution, murexide indicator and a solution of naphthol green and titrate against disodium EDTA (Ethylenediamintetraacetic acid) until deep blue colour develops.

Uses: Orally, I.V or I.M. in the treatment of Hypocalcaemia or in calcium deficiency.

Note: Calcium gluconate injection represents 92 – 103% of calcium gluconate with a between 6 – 8.2.

Preparation of calcium gluconate



- To a 200 g of anhydrous glucose in 1000 ml of water, 200 g of bromine are gradually added.
- After the reaction is over the excess of bromine is boiled off and the golden-yellow solution is cooled and the volume measured.
- Add lead carbonate to the above solution - lead gluconate is then formed and this prevents the lead bromide from crystallizing out.
- The resulting mixture is concentrated and allowed to stand in the ice box for 24 hours, after which the lead bromide is filtered off and washed with a little ice-cold water.
- In the presence of silver oxide or silver carbonate, and hydrogen sulfide is passed in to remove minute amounts of lead and silver ions in solution.
- Gluconic acid, is boiled with an excess of calcium carbonate. After cooling, and filtering off the excess of carbonate.
- Filter & concentrate the solution of calcium gluconate.