ACID-BASE BALANCE & Electrolytes

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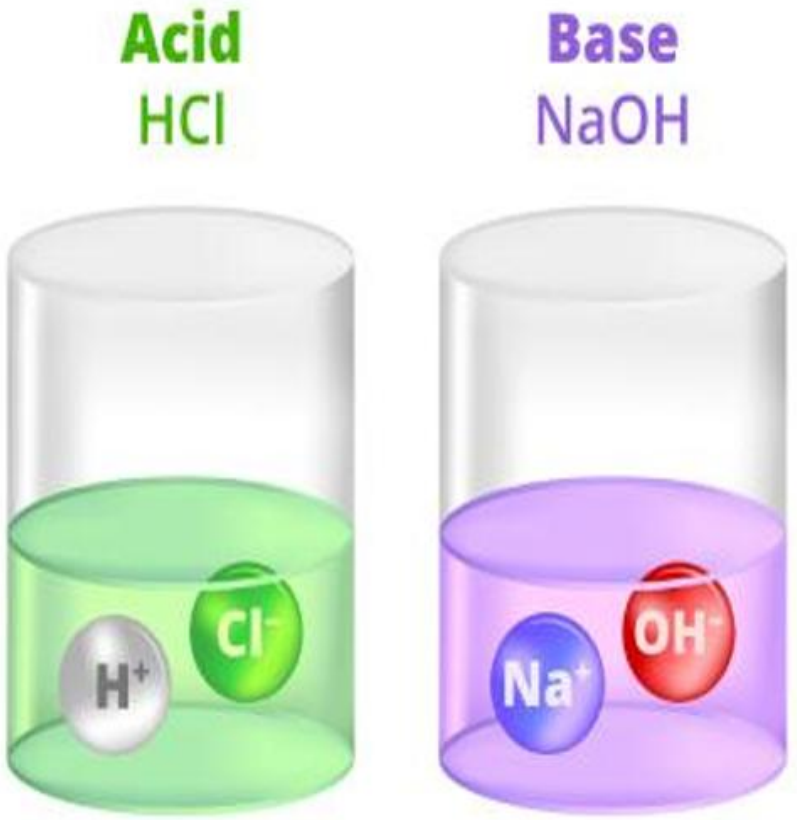
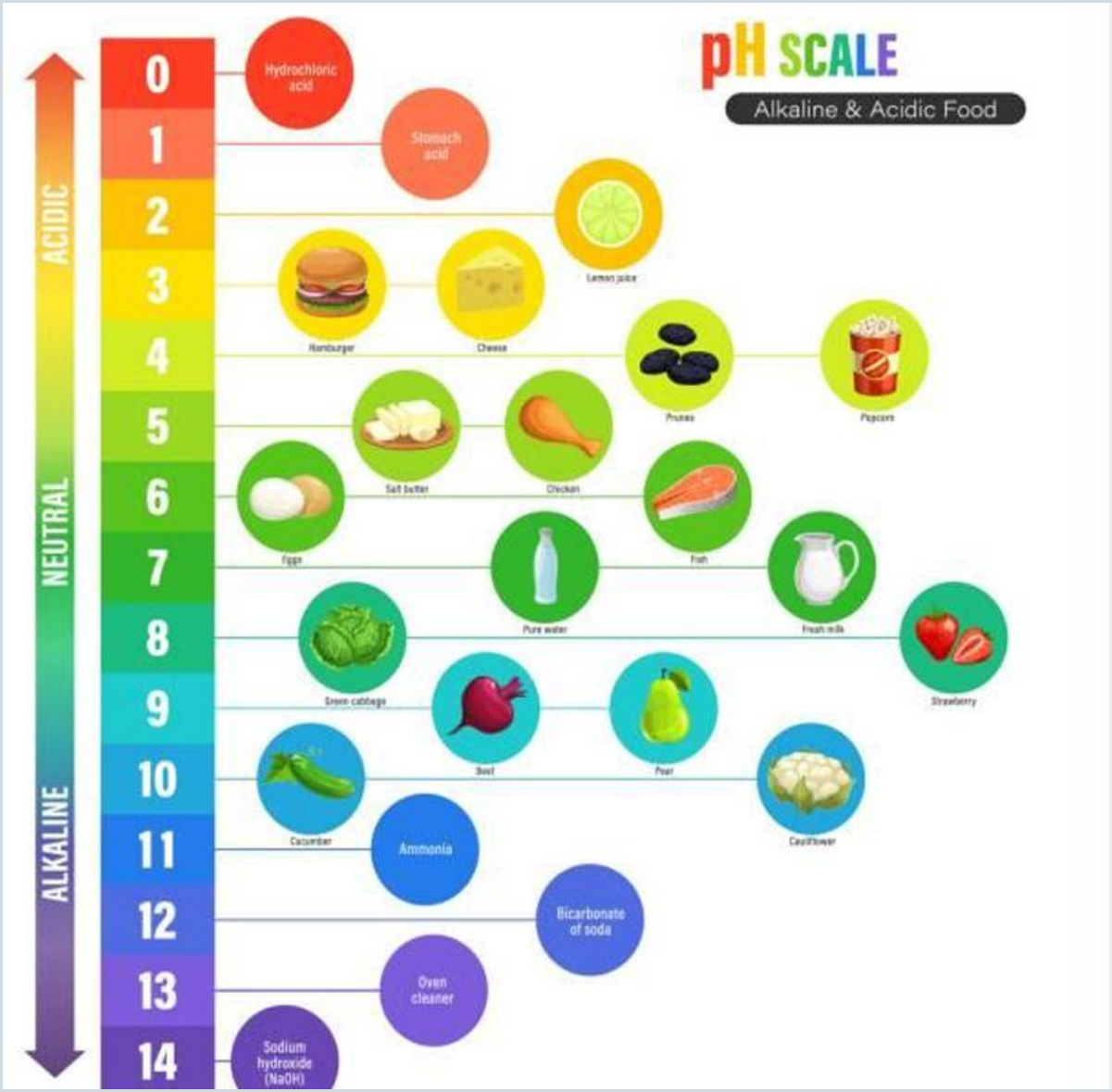


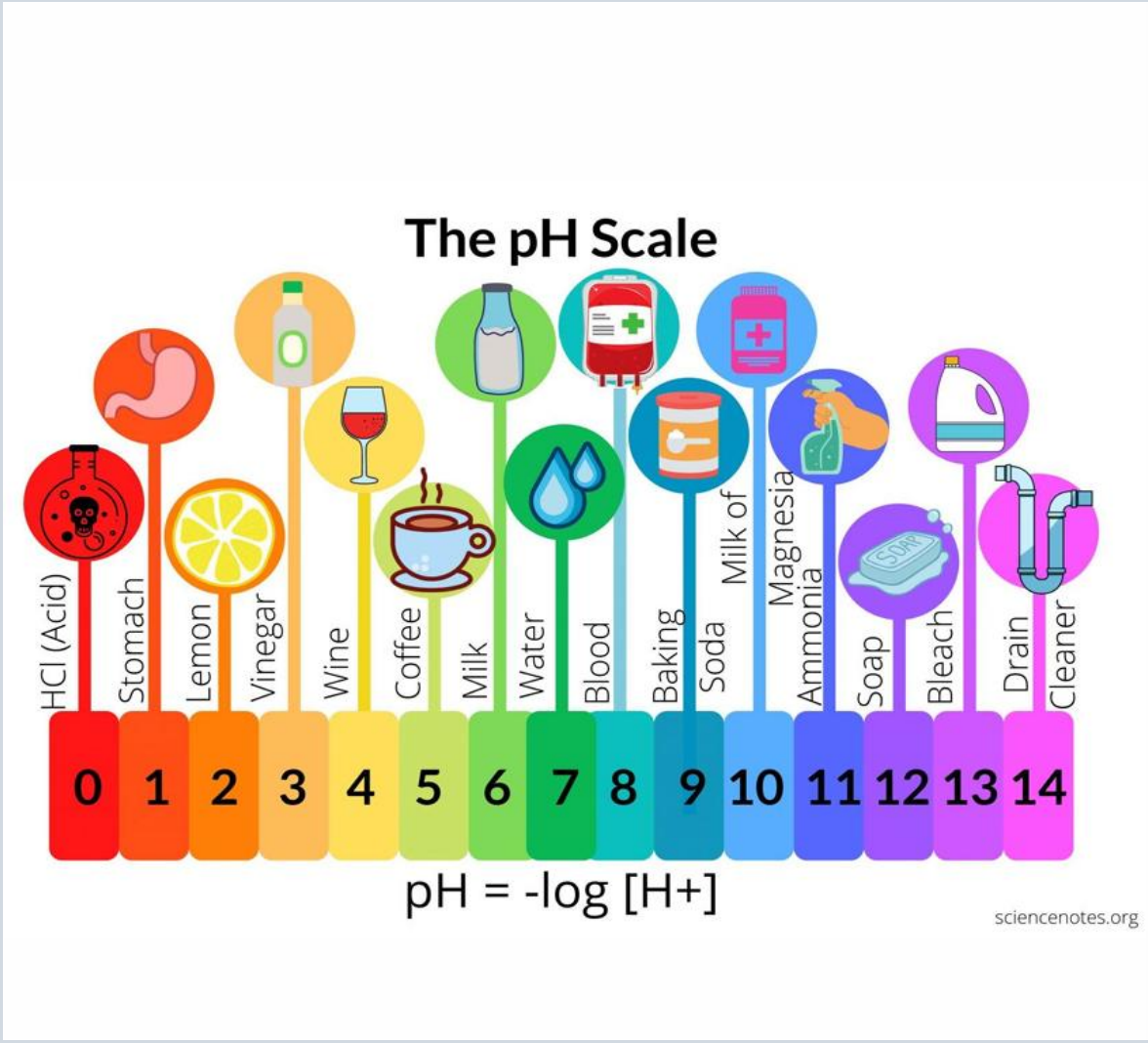
Introduction

- An acid is any hydrogen-containing substance that is capable of donating a proton (hydrogen ion) to another substance.
- A base is a molecule or ion able to accept a hydrogen ion from an acid.



Acid-base balance

- Acid-base balance is the physiological process by which the body **maintains a stable pH** essential for **normal cellular function**.
- Blood needs the right balance of **acidic and basic compounds** to function properly.
- **Kidneys and lungs** work to maintain the acid-base balance.

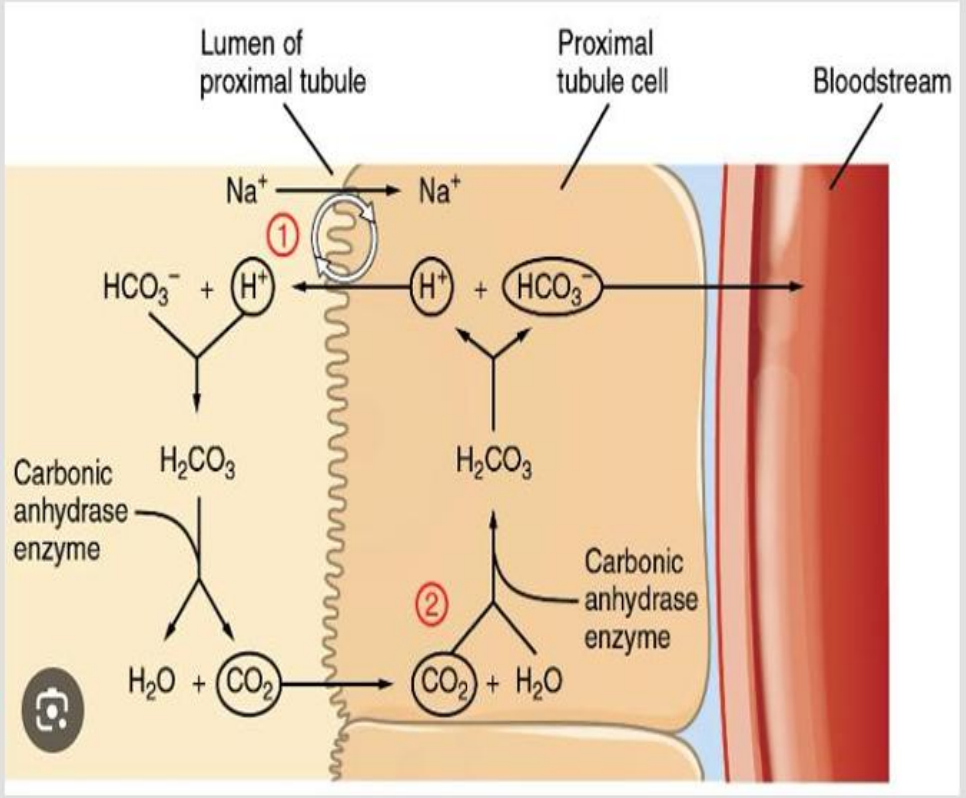


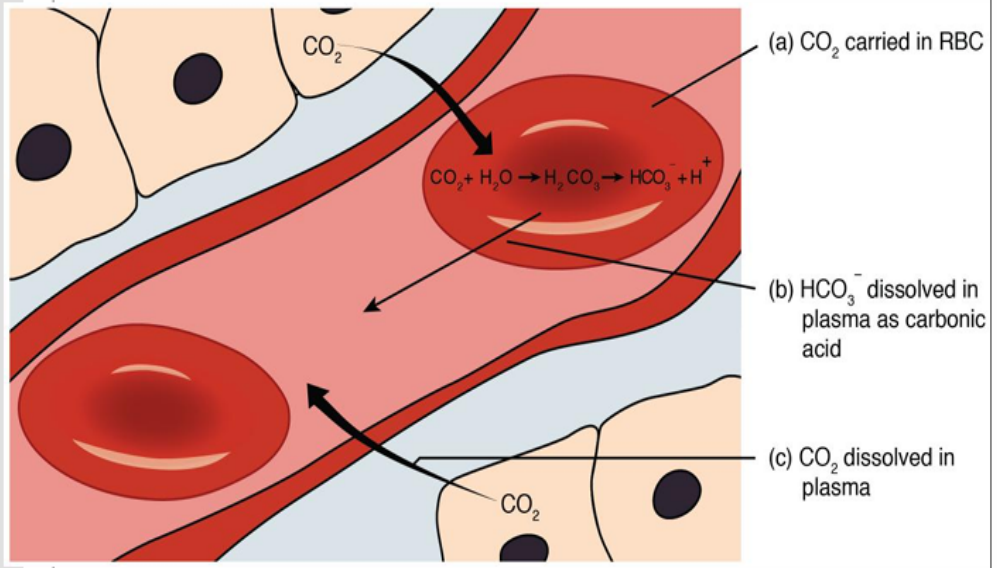
pH scale and important values

- Blood in the human body is typically slightly more alkaline than acidic.
- Normal body pH: 7.35 - 7.45
- Acidemia: the actual **condition of the blood** having a **pH below the normal range (less than 7.35)**.
- Alkalemia: the actual **condition of the blood** having a **pH above the normal range (greater than 7.45)**.

Maintenance of Acid-Base Balance by the Body

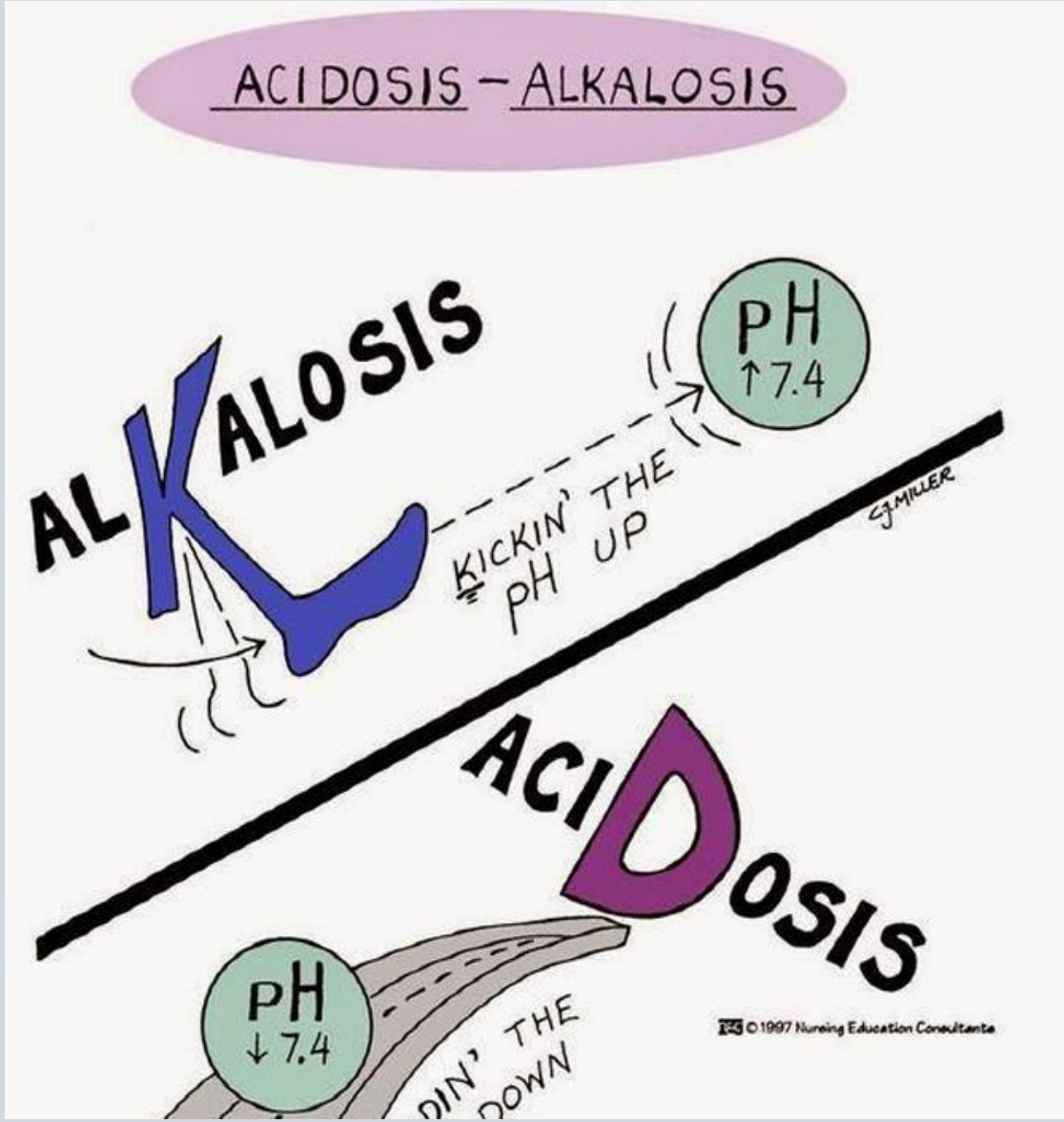
- Adequate level of acid and base in blood must be maintained in apparently healthy individuals.
- For the body to be in acid-base balance, the level of hydrogen ions must reach equilibrium.
- The kidneys maintain acid-base homeostasis by excreting hydrogen ions and generating bicarbonate.
- This phenomenon maintains blood plasma pH within the normal range.





Buffering system in human body

- When any acidic substance enters the bloodstream, the bicarbonate ions neutralize the hydronium ions forming carbonic acid and water.
- Carbonic acid is already a component of the buffering system of blood.
- Thus, hydronium ions are removed, preventing the pH of blood from becoming acidic and vice vasa.



Acid-base Disturbances

- There are two types of abnormalities I respect to acid-base balance maintenance:
- **Acidosis**
- **Alkalosis**

- **Acidosis** is referred to as a physiological or biochemical disorder that leads to a **decrease in blood pH.**

- **Alkalosis is** referred to as a physiological or biochemical disorder that leads to an **increase in blood pH**

Acid-Base Disturbances

- **Respiratory acidosis or alkalosis** occurs when the lungs are removing **too little** CO_2 (acidic condition) or removing **too much** CO_2 (basic condition) due to a clinical situation of the lungs.

- **Metabolic acidosis or alkalosis** occurs when there is slow removal of **acidic specie (H^+)** or high production of basic specie (HCO_3^-) that results from kidney malfunction.

Four Acid-Base Disorders:

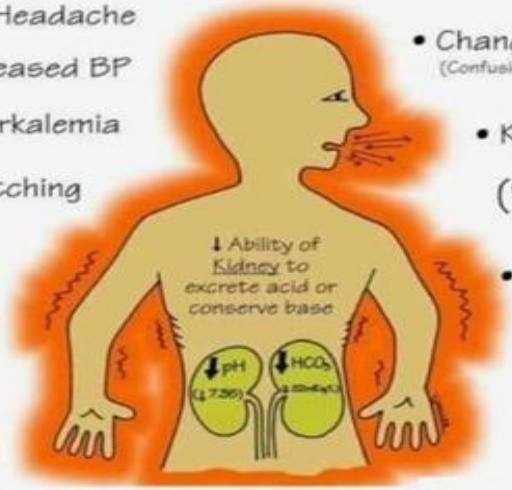
Respiratory

Metabolic

↑ CO_2	Acidosis
↓ CO_2	Alkalosis
↑ HCO_3^-	Alkalosis
↓ HCO_3^-	Acidosis

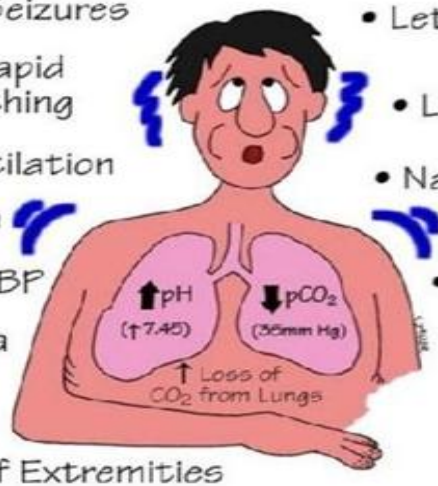
METABOLIC ACIDOSIS

- Headache
- Decreased BP
- Hyperkalemia
- Muscle Twitching
- Warm, Flushed Skin (Vasodilation)
- Nausea, Vomiting Diarrhea
- Changes in LOC (Confusion, ↑drowsiness)
- Kussmaul Respirations (Compensatory Hyperventilation)
- Causes: DKA, Severe Diarrhea, Renal Failure, Shock



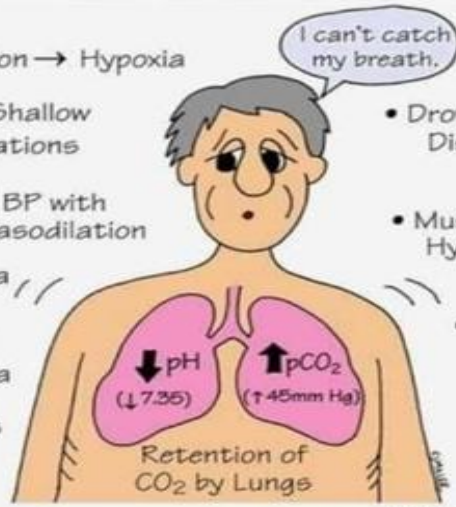
RESPIRATORY ALKALOSIS

- Seizures
- Deep, Rapid Breathing
- Hyperventilation
- Tachycardia
- ↓or Normal BP
- Hypokalemia
- Numbness & Tingling of Extremities
- Lethargy & Confusion
- Light Headedness
- Nausea, Vomiting
- Causes: Hyperventilation (Anxiety, PE, Fear), Mechanical Ventilation



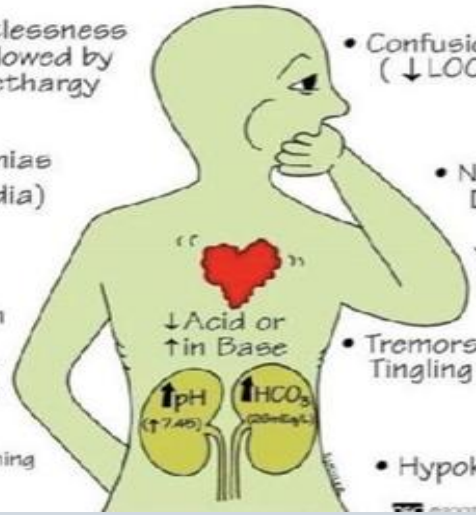
RESPIRATORY ACIDOSIS

- Hypoventilation → Hypoxia
- Rapid, Shallow Respirations
- ↓ BP with Vasodilation
- Dyspnea
- Headache
- Hyperkalemia
- Dysrhythmias (↑K)
- Drowsiness, Dizziness, Disorientation
- Muscle Weakness, Hyperreflexia
- Causes: ↓Respiratory Stimul (Anesthesia, Drug Overdose), COPD, Pneumonia, Atelectasis



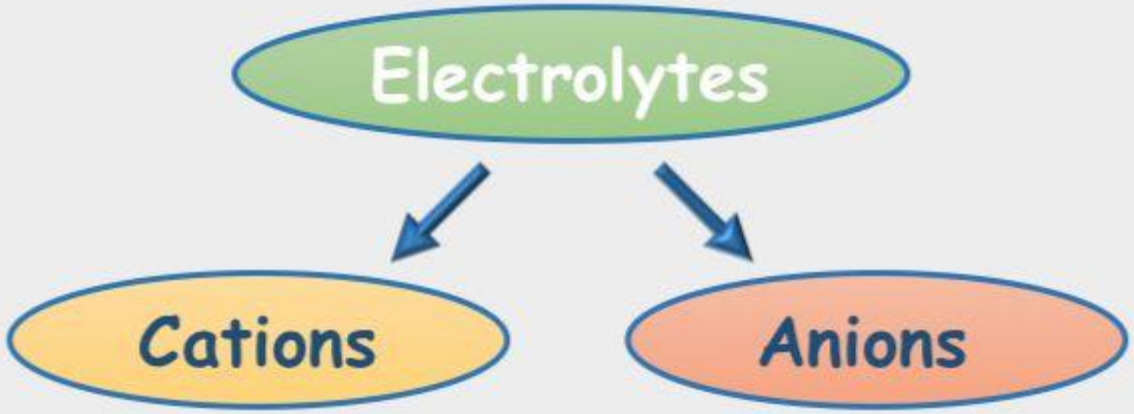
METABOLIC ALKALOSIS

- Restlessness Followed by Lethargy
- Dysrhythmias (Tachycardia)
- Compensatory Hypoventilation
- Causes: Severe Vomiting, Excessive GI Suctioning, Diuretics, Excessive $NaHCO_3$
- Confusion (↓LOC, Dizzy, Irritable)
- Nausea, Vomiting, Diarrhea
- Tremors, Muscle Cramps, Tingling of Fingers & Toes
- Hypokalemia



Electrolytes

- Electrolyte is an electrically charged mineral content that is in the human body.
- This substance is found in cells, tissues, and body fluids with different types and different functions.
- As electrolytes carry an Electric Charge, therefore, classified as:



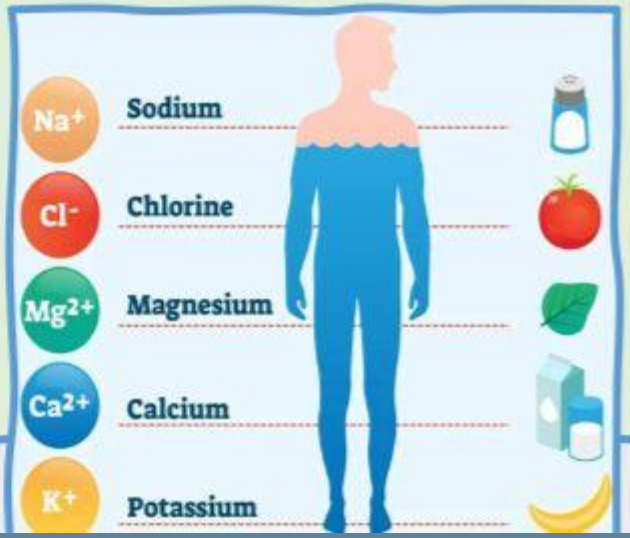
- Electrolytes are essential component of all living matter.
- There are various types of electrolytes, including:

➢ major Electrolytes such as Cations:

✓ Sodium Na
✓ Potassium K
✓ Calcium Ca
✓ Magnesium Mg

➢ Anions:

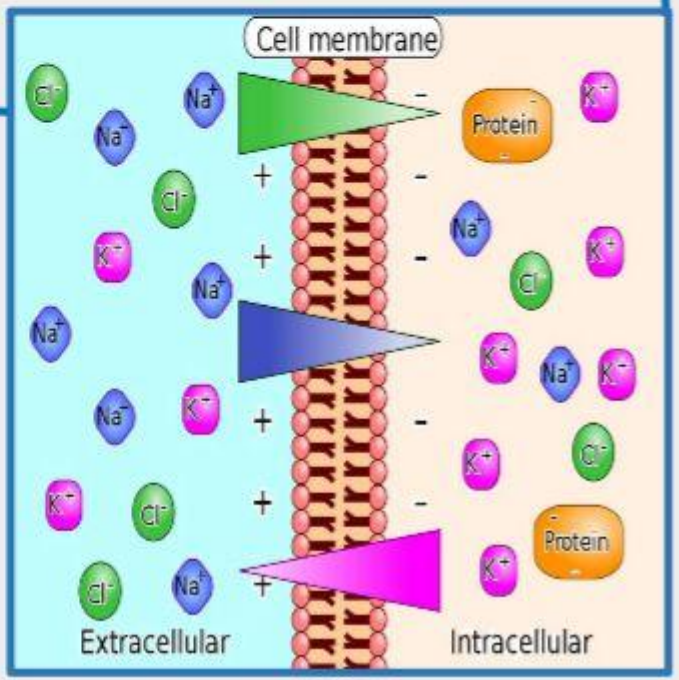
✓ Chlorine Cl
✓ Bicarbonate HCO3
✓ Phosphate HPO4



Functions of Electrolytes

- The general benefits of electrolytes:
- Regulation of the most Metabolic Pathways in the Body.
- Maintain of Osmotic Pressure and Hydration of the various Body Fluid compartment.
- Maintain of the Proper Body PH.

- Regulation of the Proper Function of Heart and Muscles.
- Involvement in Oxidation – Reduction reaction.
- Participation as Essential part of Co-factor of Enzyme.

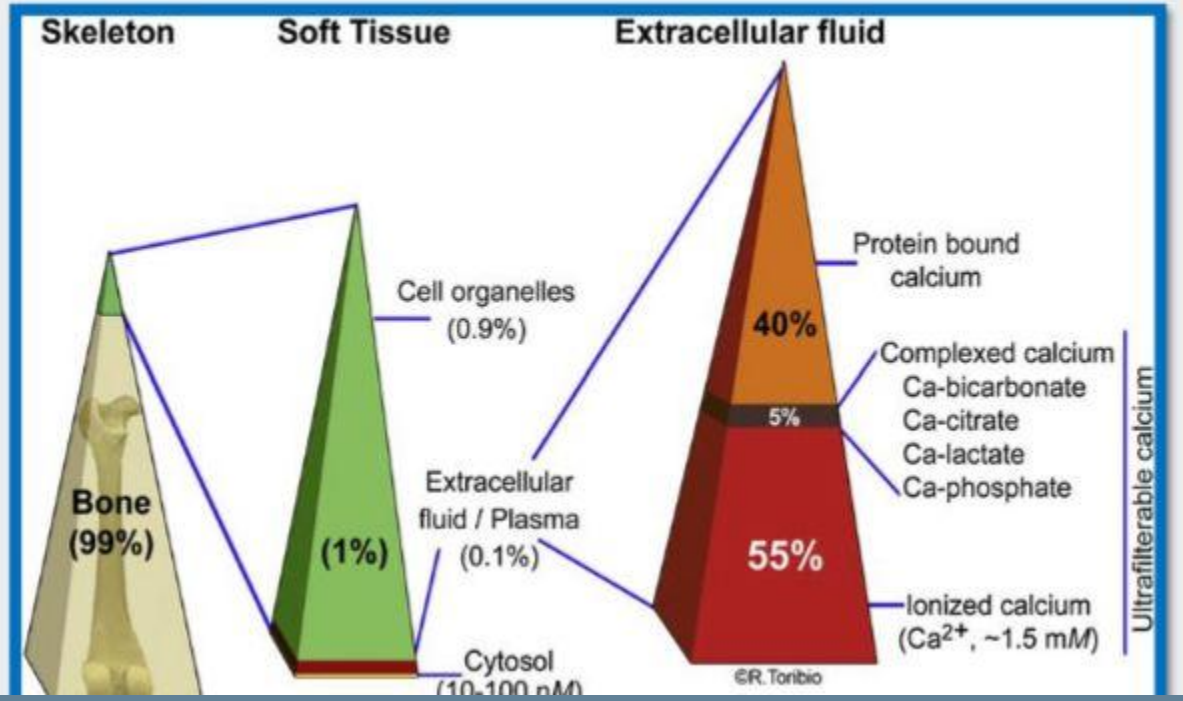


Calcium

- Calcium is the most abundant mineral found in the body and play many vital roles.
- Calcium average in adult body is approximately 1 Kg.
- Calcium is an important nutrient for body health. The daily intake is approximately 1000 mg/day. Absorption – duodenum and proximal jejunum.
- About 99% of calcium in the body are found in bones and teeth as Hydroxyapatite $Ca_{10}(PO_4)_3(OH)_2$. The remaining 1% is mostly found in the blood and other ECF.

Distribution of Calcium

- Ca^{2+} in Blood is distributed among Several Forms: About 50% as free Ca^{2+} ions (referred to as ionized Ca^{2+}). 40% is bound to Protein, mostly Albumin. 10% is bound to Anions, such as HCO_3, citrate, PO_4 and lactate. This distribution can change in disease.



Normal Value of Calcium

- In children: 8.8 – 10.8 mg/dl
- Adult: 8.6 – 10.0 mg/dl

Regulation of Calcium

- Three hormones are known to regulate serum Ca2+ by altering their secretion rate in response to changes in ionized Ca2+:

PTH Hormone – Vitamin D – Calcitonin

Functions of Calcium

- It is important for blood coagulation.
- Maintenance of normal muscle contractility.
- It also plays a role in hormone secretion.
- Is important in the transmission of nerve impulses.
- It is important for developing and maintaining bone structure and function.
- Acts as a cofactor for many enzyme in metabolic processes in the body.

Deficiency of Calcium

Hypocalcemia

- Tetany, increased neuromuscular excitability, neurological disorders.
- Result of vit. D deficiency, hypoparathyroidism, renal insufficiency.
- Symptoms are: rickets (children), osteomalacia (adults).

Hypercalcemia

- Toxicity – hypercalcemia (normally does not to occur)
- Hyperparathyroidism, vitamin D intoxication, cancer.

Sodium Na

- Sodium is a very important nutrient required by all humans and is one of the body's electrolytes. It is the major extracellular cation.
- The body obtains sodium through food and drink and loses it primarily in sweat and urine.
- Healthy kidneys maintain a consistent level of sodium in the body by adjusting the amount excreted in the urine.
- Around 800 mg/day is filtered by glomerulus in that 99% is reabsorbed by tubules. Reabsorption is controlled by Aldosterone.
- The recommended daily intake of sodium for healthy adults is 2,300 mg/day.
- Adults with high blood pressure should further limit salt quantities to less than 1,500 mg/day.
- Sodium is readily absorbed in GIT.

Normal value of Sodium

- Plasma concentration: 135 - 145 mmol/L.

Functions of Sodium

- BIOCHEMICAL FUNCTIONS:
  - ✓ Sodium regulates Osmotic pressure and fluid balance.
  - ✓ Regulates Acid-base balance in association with chloride and bicarbonate.
  - ✓ It helps in cell permeability.
  - ✓ It is involved in absorption of Glucose, Galactose & Amino acids.
  - ✓ It also plays a key role in normal nerve and muscle function.

Deficiency of Sodium

Hyponatremia

- Hyponatremia usually develops when the body retains too much fluid, as in the case of heart failure or liver disease.
- It is very commonly observed in people who drink too many fluids regularly, as well as those on diuretic medicines.
- Diarrhea, Vomiting, Chronic renal failure, Addison disease (adreno cortical Insufficiency), Moderate & severe - Low Blood pressure.
- Decrease in blood pressure and decreases in sodium concentration result in the production of renin → aldosterone production → decreases the excretion of sodium in the urine.

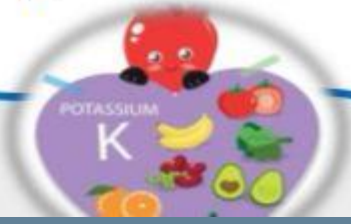
Hypernatremia

- Hypernatremia is associated with water depletion (dehydration).
- Cushing's syndrome.
- Prolonged administration of steroid hormones (Cortisone, ACTH, sex hormones).
- Severe dehydration (only water), as in case of Diabetes Insipidus: increased blood volume: hypertension.

Potassium K

- Like sodium, potassium is a cation: K+. This positively charged ion is most abundant cation in the fluid inside the cell.

- Plasma concentration - 3.5-5 meq/L.
- K+ level is controlled by aldosterone as aldosterone increases K+ excretion.
- Absorption is efficient (90%).
- Excretion is through urine, during absorption of Na+ there is obligatory loss of K+.
- Adults, both male and female, need 4.7 g or 4,700 mg/day from potassium.
- The adequate intake level for potassium is based on intake levels that have been found to lower blood pressure, reduce salt sensitivity, and minimize the risk of kidney stones.



Functions of Potassium

- ❑ BIOCHEMICAL FUNCTIONS:
- ✓ It maintains Intracellular Osmotic pressure, acid base balance.
- ✓ Involves in cardiac & skeletal muscle activities, Mainly K+ required in depolarization & contraction of Heart.
- ✓ Involved proper transmission of Nerve Impulses.
- ✓ Pyruvate kinase (of glycolysis) needs K+.
- ✓ Involved Biosynthesis of proteins.

Hypokalemia

- ❑ Hypokalemia: Serum K+ less than 3.5 meq/L
- ✓ Cushing syndrome
- ✓ Some forms of kidney disease
- ✓ Metabolic alkalosis, Diarrhea & vomiting.
- ✓ Diabetic coma treatment with Insulin & Glucose Diuretics.
- ✓ Overuse of laxatives, anorexia nervosa or bulimia, alcoholism.
- ✓ Muscle weakness, tachycardia, and cardiac arrest.

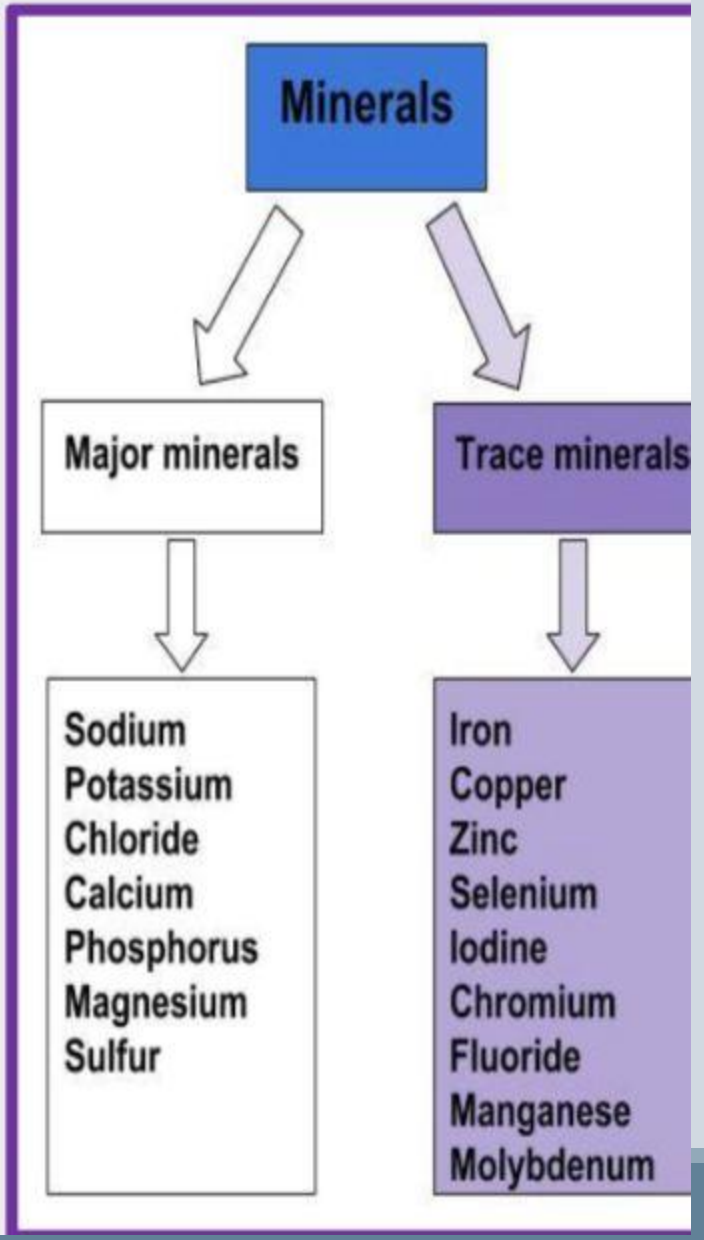
Hyperkalemia

- ❑ Hyperkalemia K+ > 5 meq/l
- ✓ Impaired excretion: Renal failure, mineralocorticoid deficiency, drugs; e.g. potassium sparing diuretics).
- ✓ Shifts of K+ out of cells: Tissue breakdown, acidosis, insulin deficiency.
- ✓ Addison's disease
- ✓ Severe dehydration.
- ✓ Intravenous administration of fluids with excessive potassium salts.
- ✓ Depression of CNS,
- ✓ Bradycardia.

Trace Elements

- Trace elements (or trace metals) are minerals present in living tissues in small amounts.
- They are called trace elements because of their body concentration, which is few milligrams per kg or less.
- They are required in amounts less than 100 mg/day.
- They are also known as micronutrients.

- Trace elements are vital for human body to maintain normal yet complex physiological functions related to body's growth & development. They also balance toxicity levels.
- Trace elements function primarily as catalysts in enzyme systems; some metallic ions, such as iron and copper, participate in oxidation-reduction reactions in energy metabolism.



- Trace elements are categorized as: essential, and non-essential.
- Essential Trace Elements:
  - ✓ iron, zinc, copper, cobalt, chromium, fluoride, iodine, manganese, molybdenum and selenium

- Essential Trace Elements are divided into two sub-groups:
- Trace Elements:
- Iron, Zinc and Copper.
- Ultra Trace-Elements:
- Manganese, Selenium, Cobalt, Chromium, Fluorine, Iodine and Molybdenum.

- The classification of these elements to essential and non-essential is based upon their biological effect, diseases that occur due to their deficiency and toxicity due to overdose.

Iron (Fe)

- Ferrous (Fe^{2+}) Reduced
- Ferric (Fe^{3+}) Oxidized

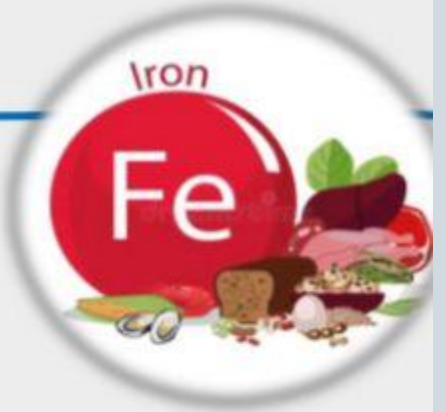
- Iron from animal products is heme iron.
- Iron from plant products is nonheme iron.
- Heme iron is more efficiently absorbed than nonheme iron.
- Iron from the diet is absorbed into the intestinal mucosal cells.
- Ferritin is the major iron storage protein.
- Transferritin is an iron transport protein in the blood.

Functions of Iron

- Chief functions in the body:
  - ✓ Part of the protein hemoglobin, which carries oxygen in the blood.
  - ✓ Part of the protein myoglobin in muscles, which makes oxygen available for muscle contraction
  - ✓ Necessary for the utilization of energy as part of the cells' metabolic machinery

- Recommended Dietary Allowance (RDA):
  - ✓ Male: 8 mg/day
  - ✓ Female (19-50 years): 18 mg/day
  - ✓ Female (51+ years): 8 mg/day

Iron Deficiency



- Iron deficiency is the most common nutrient deficiency worldwide
- Can occur if inadequate intake or blood loss.
- When iron is deficient, hemoglobin cannot be produced.
- When there is insufficient hemoglobin, red blood cells are microcytic and hypochromic and unable to deliver sufficient oxygen to the tissues. This is known as iron deficiency anemia.
- It is estimated that as much as 80% of the world's population may be iron deficient and 30% suffer from iron deficiency anemia.
- Deficiency symptoms: Microcytic, hypochromic anemia: weakness, fatigue, headaches impaired immunity, Pale skin, Concave nails, Inability to regulate body temperature

Iron Toxicity and Overload

- Iron is essential for cellular metabolism, but too much can be toxic.
- Iron poisoning can be life-threatening. It can damage the intestinal lining and cause abnormalities in body pH, and liver failure.
- Iron overload can happen over time and accumulates in tissues such as the heart and the liver.
- The most common form of iron overload is hemochromatosis.
- Iron poisoning – acute toxicity from overdose of iron supplements; can be deadly in small children
- Toxicity symptoms
- Iron overload: infections, fatigue, joint pain, skin pigmentation, organ damage

Zinc (Zn)

- Zinc is the most abundant intracellular trace element.
- Zinc is essential in the diet for growth and development.
- Zinc from animal sources is better absorbed than zinc from plant sources.
- Absorption: In order to pass from mucosal cells into the blood, zinc must bind to metallothionein.

- Recommended Dietary Allowance (RDA):
  - ✓ Male: 11 mg/day
  - ✓ Female: 8 mg/day

Functions of Zinc

- Major functions in the body:
  - ✓ Part of many enzymes for example: superoxide dismutase, carbonic anhydrase, lactate dehydrogenase, alkaline phosphatase.
  - ✓ Associated with the hormone insulin.
  - ✓ Involved in making genetic material and proteins.
  - ✓ Important to wound healing, taste perception, reproduction, vision (transports and activates Vit. A) & immune function.

Deficiency symptoms

- ✓ Failure of metabolism of nucleic acids (cell division, growth, and differentiation).
- ✓ In children, growth retardation and delayed sexual maturation.
- ✓ Impaired immune function.
- ✓ Eye and skin lesions.
- ✓ Loss of appetite and abnormal taste.
- ✓ Depressed immune function and poor wound healing.

❑ Note: toxicity - not likely, unless supplement abuse


thank you!