Electrolytes

Electrolytes: Overview

- **Electrolytes** are minerals in body fluids (like blood, urine, and intracellular fluid) that carry an electric charge.
- They are essential for various physiological functions, including:
    - **Nerve conduction** (e.g., Na^+ and K^+ for action potentials)
    - **Muscle contraction**, especially in the heart
    - **Maintaining acid-base balance** (H^+, HCO_3^-)
    - **Regulating fluid balance** via osmosis and active transport

Major electrolytes in the body:

Cation (+)	Major Locations	Function
Sodium (Na^+)	Extracellular fluid (ECF)	Osmotic balance, nerve/muscle function
Potassium (K^+)	Intracellular fluid (ICF)	Muscle contraction, cardiac function
Calcium (Ca^{2+})	ECF, bones	Muscle contraction, blood clotting
Magnesium (Mg^{2+})	ICF, bones	Enzyme function, neuromuscular stability

Anion (–)	Major Locations	Function
Chloride (Cl^-)	ECF	Acid-base balance, osmotic balance
Bicarbonate (HCO_3^-)	ECF	Buffering of blood pH
Phosphate (HPO_4^{2-})	ICF, bones	Energy metabolism (ATP), buffering

Body Water

Definition

- Body water refers to the total amount of water present in the human body.
- Water is the **major component of the human body**, making up approximately **50–70% of total body weight**, depending on factors such as age, gender, and body composition.

Functions of Body Water

- **Solvent for biochemical reactions:** All cellular reactions occur in aqueous medium.
- **Transport medium:** Helps transport nutrients, gases, hormones, and waste products.
- **Thermoregulation:** Regulates body temperature via sweating and evaporation.
- **Lubrication and cushioning:** Present in synovial fluid (joints), cerebrospinal fluid, eyes, etc.

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- **Maintaining cell turgor:** Maintains shape and size of cells.

Factors Affecting Total Body Water

- **Age:** Infants have higher water content (~70–75%), while elderly have lower (~50–55%).
- **Sex:** Males generally have higher water content due to more muscle mass.
- **Body composition:** Fat tissue has less water compared to lean tissue; hence, obese individuals have lower percentage of body water.

Compartments of Body Water

Total Body Water (TBW)

TBW is divided into **two main compartments**:

A. Intracellular Fluid (ICF)

- **Definition:** Fluid within cells.
- **Volume:** About **2/3 of TBW** (approximately 28 liters in an average adult).
- **Main electrolytes:**
  - **Cations:** Potassium (K^+), Magnesium (Mg^{2+})
  - **Anions:** Phosphate (PO_4^{3-}), proteins

B. Extracellular Fluid (ECF)

- **Definition:** Fluid outside the cells.
- **Volume:** About **1/3 of TBW** (~14 liters in adults).
- **Subdivisions:**
  - **Interstitial fluid:** Fluid between cells (~10.5 liters)
  - **Plasma (intravascular):** Fluid component of blood (~3.5 liters)
  - **Transcellular fluid:** Minor compartment (~1 liter); includes cerebrospinal fluid, synovial fluid, peritoneal fluid, etc.
- **Main electrolytes:**
  - **Cations:** Sodium (Na^+), Calcium (Ca^{2+})
  - **Anions:** Chloride (Cl^-), Bicarbonate (HCO_3^-)

Movement Between Compartments

- Water moves freely across cell membranes via osmosis.
- Electrolyte movement is tightly regulated by active transport and ion channels (e.g., Na^+/K^+-ATPase pump).

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Water Balance

Definition

- Water balance refers to the equilibrium between **water intake** and **water loss**.
- The body maintains homeostasis by tightly regulating this balance.

Normal Daily Water Intake

- **From fluids:** ~1200–1500 mL/day
- **From food:** ~800–1000 mL/day
- **Metabolic water (oxidation):** ~300 mL/day
- **Total intake:** ~2500–2800 mL/day

Normal Daily Water Loss

- **Urine:** ~1200–1500 mL/day (major route)
- **Skin (insensible loss & sweat):** ~500–700 mL/day
- **Lungs (respiration):** ~300–400 mL/day
- **Feces:** ~100–200 mL/day
- **Total loss:** ~2500–2800 mL/day

Regulation of Water Balance

Controlled mainly by:

A. Thirst Mechanism

- Controlled by the **hypothalamus**
- Triggered by:
  - Increased plasma osmolality
  - Decreased blood volume/pressure

B. Antidiuretic Hormone (ADH)

- Secreted by **posterior pituitary**
- Increases water reabsorption in kidneys (collecting ducts)
- Reduces urine output → conserves water

C. Aldosterone

- Released from **adrenal cortex**
- Promotes sodium (and water) reabsorption in kidneys

D. Atrial Natriuretic Peptide (ANP)

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- Released from **atria of heart** when stretched
- Promotes excretion of sodium and water → lowers blood volume

Imbalances

- **Dehydration (negative water balance):** Due to excessive loss (diarrhea, vomiting, sweating), inadequate intake
- **Overhydration (positive water balance):** Due to excessive intake or impaired excretion (e.g., in renal failure)

Electrolyte Distribution

- Electrolytes are ions that carry electrical charges and are vital for various physiological processes such as **nerve conduction**, **muscle contraction**, **pH balance**, and **fluid movement**.

Major Electrolytes & Their Distribution

Electrolyte	Major Location	Normal Plasma Range	Role
Sodium (Na^+)	ECF	135–145 mEq/L	Regulates ECF volume and osmolality
Potassium (K^+)	ICF	3.5–5.0 mEq/L (plasma)	Maintains ICF volume, nerve/muscle function
Chloride (Cl^-)	ECF	98–106 mEq/L	Maintains osmotic pressure, acid-base balance
Bicarbonate (HCO_3^-)	ECF	22–28 mEq/L	Primary buffer for pH regulation
Calcium (Ca^{2+})	ECF (also in bones)	8.5–10.5 mg/dL	Muscle contraction, nerve function, clotting
Magnesium (Mg^{2+})	ICF	1.5–2.5 mEq/L	Enzyme function, neuromuscular activity
Phosphate (PO_4^{3-})	ICF	2.5–4.5 mg/dL	Energy production (ATP), bone mineralization

Mechanisms of Electrolyte Regulation

- **Kidneys:** Main organ for maintaining electrolyte balance via selective reabsorption or excretion
- **Hormonal Control:**
  - **Aldosterone:** Increases Na^+ reabsorption, K^+ excretion
  - **Parathyroid hormone (PTH):** Regulates Ca^{2+} and phosphate

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