



Biochemistry I

Biochemistry and electrolyte

Sawa University

جامعة ساوة الاهلية

College of health and medical techniques

كلية التقنيات الصحية والطبية

Department of Medical Laboratories

قسم تقنيات المختبرات الطبية

Stage : 2nd

المرحلة : الثانية

محاضرة رقم 5

الجانب النظري

¹Lecture No. 5

Theoretical

تدريسي المادة : م.د. عبدالرحمن يسر خليفه

Topic

❑ Biochemistry and electrolyte:

❑ Subtopics:

- Electrolyte Imbalance
- Sodium (Na^+)
- Potassium (K^+)
- Calcium (Ca^{++})
- Magnesium (Mg^+)
- Chloride (Cl^-)
- Phosphorus (P)

ELECTROLYTES

- ❑ **Electrolytes**: is a substance that produces an electrically conducting solution when dissolved in water. **Electrolytes** carry a charge and are essential for life.
- **Electrolytes** regulate our **nerve and muscle function, our body's hydration, blood pH, blood pressure, and the rebuilding of damaged tissue.**
- Various mechanisms exist in our body that keeps the concentrations of **electrolytes** under strict control.
- Our **muscles** and **neurons** are sometimes referred to as the "**electric tissues**" of the body.
- They are reliant on **electrolyte** movement between **intracellular** and **extracellular fluid** (**fluid inside, outside or between cells**).
- The **electrolytes** in human bodies include: **Sodium, potassium, calcium, bicarbonate, magnesium, chloride, phosphate.**

❑ **Water distribution** mainly is observed between two compartments:

❑ **Intracellular fluid (ICF)**

❑ **Extracellular fluid (ECF)**, which includes:

- The difference in the distribution of ions in different water compartments is achieved by **selective permeability of biological membranes** and **active transport**.
- In every fluid compartment, the sum of **anions** and **cations** (**positive** and **negative** charges) are equal.

Cations	Units
sodium	135-145 meq/l
potassium	3.5-5.5 meq/l
calcium	9-11 mg/dl
magnesium	1.5-2.5 meq/l

Anion	Units
chloride	96-106 meq/
phosphorus	2.8-4.5 mg/dl

□ General Considerations:

A) Disassociate into ions in water:

- 1) **Cations**: positively charged; Sodium (Na^+), Potassium (K^+), Calcium (Ca^{++}), and Magnesium (Mg^+).
- 2) **Anions**: negatively charged; Bicarbonate (HCO^{3-}), Chloride (Cl^-), Phosphate (PO^{4-}).

B) Composition of Fluid Compartments:

- 1) **ICF**: K^+ primary cation; PO^{4-} primary anion.
- 2) **ECF**: Na^+ primary cation; Cl^- primary anion.

C) Functions: regulate water distribution & acid-base balance, transmit nerve impulses; important for blood clotting and ATP generation.

Electrolyte Imbalance

□ **Definition:** **Electrolyte imbalance** occurs when the levels of **electrolytes** in the body deviate from their normal ranges, affecting essential bodily functions.

□ **Causes of Electrolyte Imbalance:**

- 1) **Dehydration:** Loss of water from the body leads to an increase in the concentration of electrolytes like **sodium**.
- 2) **Severe diarrhea or vomiting:** Loss of fluids causes a drop in electrolytes like **potassium** and **chloride**.
- 3) **Kidney failure:** Kidney problems result in the accumulation of excess electrolytes, such as **potassium**.
- 4) **Medications:** Certain medications, such as **diuretics**, can lead to the loss of electrolytes (especially **potassium** and **sodium**).
- 5) **Chronic medical conditions:** Conditions like **diabetes** or **heart disease** that affect fluid and electrolyte balance.

❑ Common Types of Electrolyte Imbalance:

1. **Hypernatremia:** Elevated sodium (Na^+) levels in the blood.
2. **Hyponatremia:** Low sodium (Na^+) levels.
3. **Hyperkalemia:** High potassium (K^+) levels in the blood.
4. **Hypokalemia:** Low potassium (K^+) levels.
5. **Hypercalcemia:** Elevated calcium (Ca^+) levels in the blood.
6. **Hypocalcemia:** Low calcium (Ca^+) levels.

❑ Common Symptoms of Electrolyte Imbalance:

- 1) **Muscles:** Cramps, weakness, or twitching.
- 2) **Heart:** Irregular heartbeats (**arrhythmia**).
- 3) **Nervous system:** Confusion, headaches, dizziness, or loss of consciousness.
- 4) **Fatigue:** General weakness and lack of energy.
- 5) **Blood pressure:** Increased or decreased blood pressure.

1- SODIUM (Na^+)

- **Sodium** is a major **cation** and contributor to the **osmolality** of the **extracellular fluid** of the body, which is **one-third** of the body water in adults.
- The **sodium** content of natural food varies between **0.1** and **3.3 mmol/100 g**. In contrast, processed foods have a sodium content of **11–48 mmol/100 g**, and partly **sodium nitrate** is used as a preservative.
- **Sodium** is concentrated in **the extracellular fluid**, giving **osmolarity** and **charge moves** from the **extracellular** fluid into cells there is a change in charge and concentration.

Sodium depletion :

- ❑ **Sodium** is lost largely via the **urine**, with only minimal loss occurring via the **feces** or **skin**, unless there are abnormal situations such as **diarrhea** or **excessive sweating**.
- ❑ A reduced body **sodium** pool results in reduced **extracellular** fluid volume.
- ❑ Increased **sodium** loss in **urine** can occur in **diseases**, e.g., **diabetes mellitus** and **Addison's disease** (adrenal cortical insufficiency), following **excessive doses of diuretic drugs**, and in cases of renal tubular damage, as in chronic renal failure.
- ❑ Healthy kidneys maintain a consistent level of **sodium** in the body by adjusting the amount excreted in the **urine**. When **sodium** consumption and loss are not in balance, the total amount of sodium in the body is affected. The concentration of sodium in the blood may be:
 - Too high (**hypernatremia**).
 - Too low (**hyponatremia**).

Hypernatremia:

- The body contains too **little water for the amount of sodium**. The **sodium** level in the blood becomes abnormally high when **water loss** exceeds **sodium loss**.
- Usually, **hypernatremia** results from **dehydration**. For example, people may lose body fluids and become **dehydrated** due to: **Drinking too little, Vomiting, Having diarrhea, Using diuretics., Sweating excessively and Insufficient water intake** usually plays an important role.
- People with **diabetes mellitus** and high blood sugar levels may urinate in excessive amounts, causing **dehydration**.
- **Dehydration** can also be caused by **kidney disorders** and by **diabetes insipidus**, which also causes people to urinate in excessive amounts although without high blood sugar levels, and is due to inadequate or ineffective **vasopressin** (**Antidiuretic hormone ADH**) **secretion** or action.

2- POTASSIUM (K⁺):

- The **potassium** content in foods ranges from **2.8 to 10 mmol/kg**, mainly from fresh **vegetables** and **meat**.
- An average adult male contains **2800–3500 mmol (110–137 g)**, with 95% found intracellularly.
- **Plasma potassium levels (3.5–4.5 mmol/l)** depend on **intake, excretion, and the balance between compartments**.
- **Aldosterone** directly influences **plasma potassium**, and control occurs primarily through urinary loss.
- Increased **plasma potassium** also stimulates **insulin secretion**, enhancing cellular uptake of potassium.
- **Potassium** is necessary for the normal functioning of cells, **nerves**, and **muscles**. The body must maintain the **potassium** level in blood within a narrow range. A blood potassium level that is
 - Too high (**hyperkalemia**)
 - Too low (**hypokalemia**)

Hyperkalemia:

- the level of **potassium** in blood is too high. A high **potassium** level has many causes, including **kidney disorders**, **drugs that affect kidney function**, and **consumption of too much supplemental potassium**.
- Usually, **hyperkalemia** must be severe before it causes symptoms, mainly abnormal heart **rhythms**. Doctors usually detect **hyperkalemia** when blood tests or **electrocardiography** is done for other reasons.

Causes:

- Usually, **hyperkalemia** results from several simultaneous problems, including the following:
 - 1) **Kidney disorders** that prevent the kidneys from excreting enough **potassium**.
 - 2) Drugs that prevent the kidneys from excreting normal amounts of **potassium** (a common cause of mild **hyperkalemia**).
 - 3) A diet high in **potassium**.
 - 4) Treatments that contain **potassium**.

Hypokalemia:

- The level of potassium in the blood is too low.
- A low potassium level can make muscles feel weak, cramp, twitch, or even become paralyzed, and abnormal heart rhythms may develop.

Causes

- Typically, the potassium level becomes low because too much is lost from the digestive tract due to **vomiting**, **diarrhea**, or **excessive laxative use**.
- Sometimes too much **potassium** is excreted in **urine**, usually because of **drugs** that cause the **kidneys to excrete excess sodium, water, and potassium (diuretics)**.
- In many **adrenal disorders**, such as **Cushing syndrome**, the adrenal glands produce too much **aldosterone**, a hormone that causes the kidneys to excrete large amounts of **potassium**.

3. CALCIUM (Ca^{++})

A. **Function**: major cation in **teeth** and **bones** (99% & combined with **phosphorus**); ~ equal concentrations in **ICF** and **ECF**; also in cell membranes (helps cells stick together & maintain shape); enzyme activator within cells; helps coagulation; affects cell membrane permeability, effect on nerve cells; important for muscle contraction; $\frac{1}{2}$ of serum **calcium** ionized (only part physiologically important) while other half is bound or combined with **anions**, protein mainly (albumin).

B. Hypocalcemia:

1. Causes include

- a) Decrease in total body **calcium** from **chronic renal failure** or **alcoholism**; **magnesium** or **vitamin D deficiencies** or **elevated phosphorus** and **GI losses** (pancreatitis and diarrhea).
- b) Decrease in ionized **calcium** from **Alkalosis**, large amounts of **citrated blood** or **hemodilution** ;

2. **Clinical manifestations** include **increased neuromuscular excitability** (e.g., **hyperactive reflexes, tetany**) and **diarrhea**.

C. Hypercalcemia:

1. Causes include:

- a) Increased total **calcium**: increased intake, intestinal absorption .

1) Increased ionized calcium (Ca^{++})

4. MAGNESIUM (Mg^+)

A. Function:

— ~55% in **bone**, ~44% in **cells**, ~1% in **ECF** ~2/3 **ionized** (physiologically important) while ~1/3 bound to protein with small amount complexed; contributes to enzyme and metabolic processes, particularly protein synthesis.

B. Hypomagnesemia:

- 1) Causes include decreased intake/absorption (e.g., malnutrition, malabsorption); increased GI (**vomiting, diarrhea.**) or renal (**diuretics, some drugs**).
- 2) Clinical manifestations include confusion, increased neuromuscular excitability, seizures and cardiac dysfunction.

C. Hypermagnesemia:

- 1) The primary causes of renal failure include increased magnesium intake.
- 2) Clinical manifestations (most from decreased peripheral/central neuromuscular transmission) .

5- CHLORIDE (Cl^-)

A. Function:

- Main **ECF anion** (high levels in cerebrospinal fluid; also in bile, gastric & pancreatic juices); helps maintain **ECF** osmolality, acid-base balance; associated directly with Na^+ and inversely with HCO_3^- .

B. Hypochloremia:

- 1) Causes include hypochloremic losses thru skin, GI tract, kidneys; changes in Na^+ , K^+ or acid base can alter Cl^- .
- 2) Clinical manifestations include, irritability, coma & seizures; arrhythmias; slow respirations; muscle cramps & weakness.

C. Hyperchloremia

- 1) Causes include increased intake (Na^+), drugs ,hyperaldosteronism .
- 2) Clinical manifestations include coma; hyperventilation, lethargy and weakness.

6- PHOSPHORUS (P)

A. Function:

— ~85% in **bones & teeth**, 14% soft tissue; <1% **ECF**; almost all **phosphorus** in body as **phosphate** (PO_4^{3-}), major **ICF** anion; promotes energy storage and **carbohydrate, protein, and fat metabolism**; **H⁺ buffer**; **oxygen transport**; **WBC** and **platelet function**.

B. Hypophosphatemia:

- 1) Causes include transient shift into cells (e.g., refeeding syndrome, respiratory alkalosis, extensive burns, hypothermia); increased urinary loss.
- 2) Clinical manifestations include **CNS, cardiac, platelet (bleeding/bruising) and leukocyte**, neuromuscular excitability.

C. Hyperphosphatemia:

- 1) Causes include primarily renal insufficiency/failure; also increased intake.
- 2) Clinical manifestations are usually few; majority related to hypocalcemia or metastatic calcifications (calcium phosphate precipitates in soft tissues, joints, &