Fluid and Electrolytes

PART 3
Electrolytes

- Salts, acids and bases
  - Ingestion to add materials
  - Excretion to remove materials
    - Kidneys play a key role
Electrolytes

• Importance of electrolytes
  ○ Controlling fluid movements
  ○ Excitability of cells
  ○ Membrane permeability

In addition to these general considerations, each electrolyte has its own specific physiological effects.
Pica

- Eating non-food substances, often due to mineral deficiency
  - Examples: Consumption of chalk, clay, match tips
Membrane Potential

(a) **Depolarization**: The membrane potential moves toward 0 mV, the inside becoming less negative (more positive).

(b) **Hyperpolarization**: The membrane potential increases, the inside becoming more negative.
Membrane Potential

- Polarized across resting membrane
  - Inside negative relative to outside
  - Nerst equation
Membrane Potential

- **Depolarization**
  - Reduced membrane potential
    - Smaller stimulus needed to reach threshold

- **Hyperpolarization**
  - Increased membrane potential
    - Larger stimulus required to reach threshold
### Membrane Potential

<table>
<thead>
<tr>
<th>Hyperpolarized</th>
<th>Depolarized</th>
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<tbody>
<tr>
<td>Hyponatremia</td>
<td>Hypernatremia</td>
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<tr>
<td>Hypokalemia</td>
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<td>Hypercalcemia</td>
<td>Hypocalcemia</td>
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<td>Hypermagnessemia</td>
<td>Hypomagnessemia</td>
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<tr>
<td>Hyperchloremia</td>
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Now let’s look at specific electrolytes...
Sodium

- **Major extracellular cation**
  - Normal: 135-145 mEq/L
  - Na$^+$ leaks into cells and is pumped out against its electrochemical gradient

- **Primary roles**
  - Necessary for impulse transmission
    - Nervous and muscle tissue
  - Primary regulator of ECF volume
Sodium

- Variations in Na\(^+\) can alter ECF volume
  - Imbalances summary
    - Hypervolemic hyponatremia
      - Gain of water only (dilutes sodium)
    - Hypovolemic hyponatremia
      - Loss sodium first then water follows (more sodium lost)
    - Hypervolemic hypernatremia
      - Gain of sodium and water (more sodium gained)
    - Hypovolemic hypernatremia
      - Loss of sodium and water (more water lost)
Sodium (different than SG)

- **Hyponatremia**
  - Hypervolemic
    - Replacing water (not electrolytes) after perspiration
    - Freshwater near-drowning
    - SIADH
    - Renal failure
  - Hypovolemic
    - GI disease (decreased intake, loss through vomiting and diarrhea)
    - Aldosterone deficiency (Addison’s)
    - Diuretics
Sodium

**Hyponatremia**
- **Symptoms**
  - Feeling of “impending doom”
  - Abdominal cramps
  - Nausea and vomiting
  - Anorexia
  - BP changes
  - Cellular swelling
  - Cerebral edema possible
    - Lethargy, confusion
    - Muscle twitching or convulsions
Sodium

• Hypernatremia
  - Hypervolemic
    - Saltwater near drowning
    - Excessive salt intake
    - Hyperaldosteronism
  - Hypovolemic
    - Decreased fluid intake
    - Excessive water loss (fever)
Sodium

- Hypernatremia
  - Not as common
  - Unconscious or confused patients higher risk
Sodium

- **Hypernatremia**
  - **Symptoms**
    - Reduced interstitial fluid
      - Dry sticky mucous membranes, intense thirst, dry tongue
    - Reduced perspiration
      - Flushed skin
    - Cerebral cellular dehydration
      - Lethargy, muscle weakness, twitching, seizures
      - Severe cases: disorientation, delusions, hallucinations
    - Altered neuromuscular activity
      - Muscle weakness, twitching
    - Low blood volume
      - Hypotension, tachycardia
Potassium

- **Major intracellular cation**
  - Normal range 3.5-5.5 mEq/L
  - Normal kidney function required for balance

- **Importance**
  - Affects RMP in neurons and muscle cells
    - Especially cardiac muscle
  - Maintenance of cellular volume
  - pH regulation
Potassium

- **Regulation**
  - **Aldosterone**
    - Stimulates $K^+$ secretion and $Na^+$ reabsorption
  - **Dietary sources**
    - Very important since potassium is poorly stored in the body
Potassium

- Acid-base balance
  - $H^+$ shifts in and out of cells in response to pH
    - Leads to corresponding potassium shifts in the opposite direction to maintain cation balance
    - Shifts may cause changes in ECF potassium levels
Potassium

- Hypokalemia
  - Causes
    - GI losses
      - Intestinal fistula, NG suctioning, vomiting, diarrhea
    - Redistribution
      - Alkalosis, insulin administration
  - Medications
    - Diuretics, natural licorice (mimics aldosterone), steroids, certain drugs (amphotericin B is an antifungal)
  - Disorders
    - Hyperaldosteronism, Cushing’s, acute renal failure, alcoholism, liver disease
Potassium

- Hypokalemia
  - Symptoms
    - Slowed smooth muscle contraction
      - Anorexia, constipation, GI distention
    - Slowed skeletal muscle contraction
      - Muscle weakness, cramping, paralysis
    - Decreased myocardial contraction
      - Dysrhythmias, hypotension, weak pulses
Potassium

- Hyperkalemia
  - Causes
    - Retention disorders
      - Renal failure (↓ GFR), Addison’s disease, hypoaldosteronism, transfusion with old RBC’s
    - Releases of intracellular potassium
      - Acidosis, trauma, severe burns, severe infection
    - Excessive administration
      - Oral or IV
Potassium

- Hyperkalemia
  - Symptoms
    - GI effects
      - Nausea, explosive diarrhea, intestinal colic, cramping
    - Musculoskeletal effects
      - Paresthesia, muscle weakness, muscle cramps, paralysis
    - Cardiac effects
      - Dysrhythmias (arrhythmias), hypotension, cardiac arrest, conduction abnormalities, ectopic foci
Calcium

- ECF levels closely regulated
  - 8.5-10.5 mg/dl
    - Nerve and muscle function
    - Blood clotting
    - Tissue development
    - Enzyme activation
Calcium Distribution

- Most is stored in bone
- Serum
  - Ionized form is active form (50%)
  - Plasma protein bound

pH determines equilibrium
Calcium

- **PTH**
  - Influences Ca\(^{2+}\) in bone, kidneys, and GI tract
  - Released when plasma Ca\(^{2+}\) concentration is low
    - Activates osteoclasts
      - Release calcium and phosphate from bone
    - Stimulates intestinal Ca\(^{2+}\) uptake
    - Increases renal tubule reabsorption

- **Calcitonin**
  - Inhibits osteoclasts
  - Remember, not as important in humans
Hypocalcemia (low blood Ca$^{2+}$) stimulates parathyroid glands to release PTH.

Rising Ca$^{2+}$ in blood inhibits PTH release.

1. PTH activates osteoclasts: Ca$^{2+}$ and PO$_4^{3-}$ released into blood.
2. PTH increases Ca$^{2+}$ reabsorption in kidney tubules.
3. PTH promotes kidney's activation of vitamin D, which increases Ca$^{2+}$ absorption from food.

Calcium is reabsorbed in the kidney and phosphate is selectively excreted.

\[ \text{Bloodstream} \rightarrow \text{Intestine} \rightarrow \text{Bone} \rightarrow \text{Kidney} \]
Calcium

- Hypocalcemia
  - Causes
    - Inactive parathyroid glands
    - Removal of parathyroid glands
    - Low dietary calcium
    - Renal failure
    - Reduced intestinal absorption
Calcium

- **Hypocalcemia**
  - **Symptoms**
    - Increased nerve cell permeability and excitability
      - Tetany, carpopedal spasms, convulsions, seizures
    - Tingling in fingers, mouth and feet
    - Trousseau’s sign
    - Cardiac arrhythmias
Calcium

**EXAMINATION TIP**

**Recognizing carpopedal spasm**

In the hand, carpopedal spasm involves adduction of the thumb over the palm, followed by flexion of the metacarpophalangeal joints, extension of the interphalangeal joints (fingers together), adduction of the hyperextended fingers, and flexion of the wrist and elbow joints. Similar effects occur in the joints of the feet.
Calcium

- **Hypercalemia**
  - **Causes**
    - Overactive parathyroid gland
    - Excess vitamin D intake
    - Acidosis
    - Leukemia
Calcium

- Hypercalemia
  - Symptoms
    - Decreased neuromuscular excitability
      - Muscle weakness
      - Poor coordination
    - Anorexia
    - Constipation
    - Renal calculi
    - Cardiac arrest
Magnesium

- Second most abundant intracellular cation
  - 1.5 – 2.5 mEq/liter
  - Activates many enzyme systems
  - Carbohydrate and protein metabolism
  - Important to neuromuscular function

- Location
  - Skeleton
  - Intracellularly
    - Heart, skeletal muscle, liver
  - Serum
    - Ionized and protein bound
Magnesium

• Hypomagnesemia
  • Causes
    ◦ Critical illnesses
    ◦ Alcohol withdrawal
    ◦ Malnutrition followed by nourishment
    ◦ Severe GI fluid losses
Magnesium

- Hypomagnesemia
  - Symptoms
    - Hyperexcitability with muscular weakness
    - Tremors
    - Athetoid movements
    - Tetany
    - Laryngeal stridor
    - Mood alterations
    - Cardiac arrhythmias
Magnesium

- **Hypermagnesemia**
  - **Causes**
    - Renal failure
    - Untreated DKA
    - Excessive administration
Magnesium

- **Hypermagnesemia**
  - **Symptoms**
    - **Acute elevations**
      - Depresses CNS
    - **Mild elevation**
      - Vasodilation → hypotension
    - **Moderate to high elevations**
      - Lethargy, dysarthria, drowsiness
      - Loss of deep tendon reflexes
      - Muscular weakness
Phosphate

- **Normal 2.5-4.5 mg/dl**
  - Phosphorus essential to mitochondrial function, RBC’s, and nervous system function
Phosphate

- **Hypophosphatemia**
  - **Causes**
    - Hyperventilation
    - Alcohol withdrawal
    - Poor dietary intake
    - DKA
    - Major thermal burns
• Hypophosphatemia
  ○ Symptoms
    ➢ Neurologic symptoms
      ▪ Irritability, apprehension, weakness, numbness, paresthesia, confusion, seizures, coma
    ➢ Tissue anoxia
    ➢ Infection
    ➢ Muscle pain
Phosphate

- Hyperphosphatemia
  - Causes
    - Renal failure
    - Chemotherapy
    - Excessive dietary intake
    - Muscle necrosis
  - Symptoms
    - Altered mentation and cardiac abnormalities