



WATER AND ELECTROLYTES II

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Advanced Clinical Biochemistry I (MA 407)

Summer Semester

Lecture Three

16/08/2025



Outlines

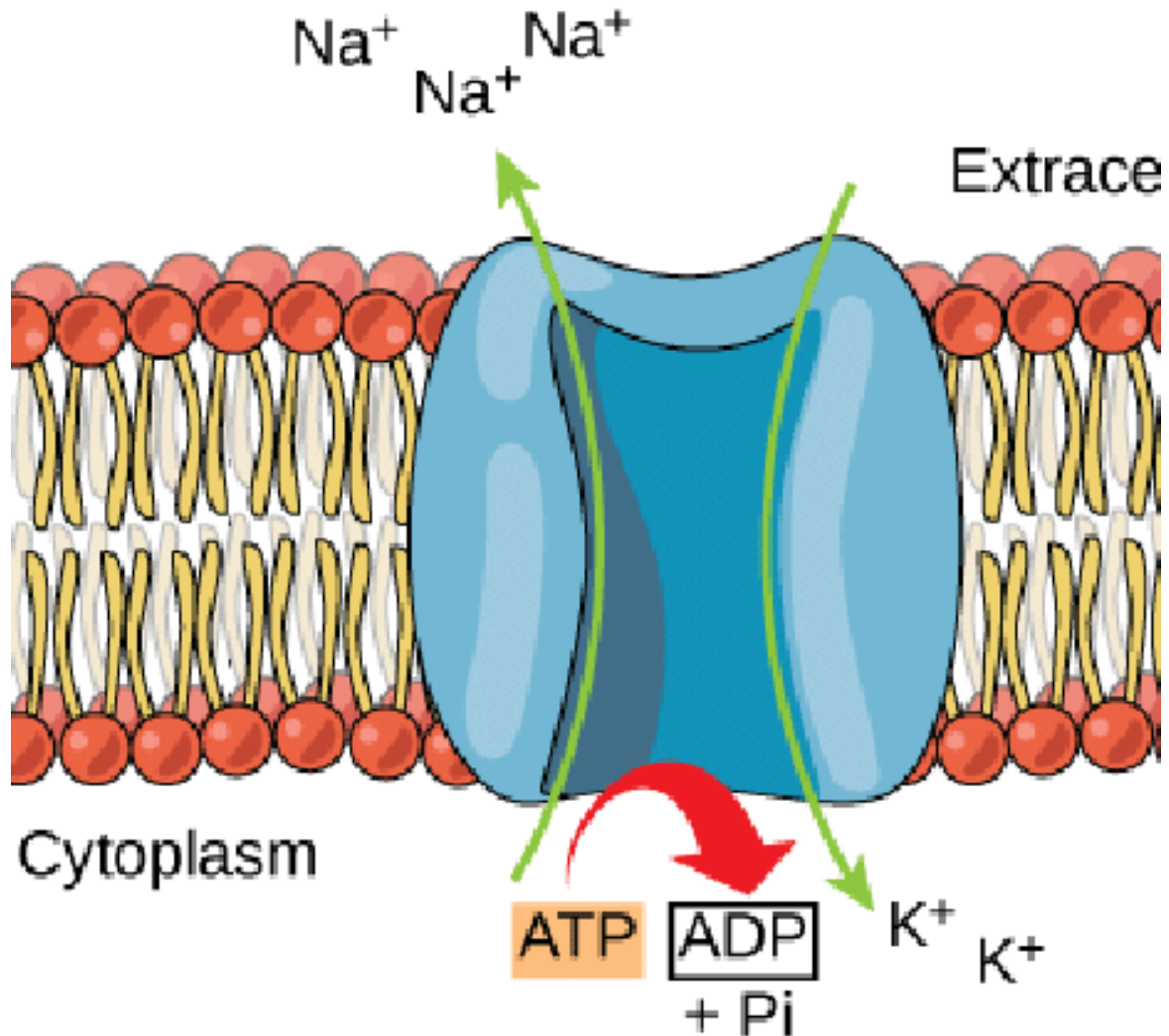
- Potassium
- Calcium
- Bicarbonate
- Magnesium
- Chloride
- Phosphorus

Objectives

- At the end of the lesson, the students should be able to:
- Know the important electrolytes, their functions and distributions.
- Know the average serum concentrations necessary for proper actions.
- Understand how electrolytes are regulated by kidney
- Know the clinical conditions associated with abnormal serum levels.



Sodium-Potassium Pump

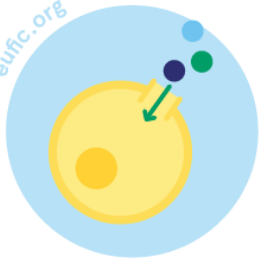


Potassium Ion

- Potassium is mainly an intracellular ion.
- The Na⁺-K⁺ ATP pump is primarily responsible for regulating the homeostasis of Na⁺ and K⁺.
- It pumps out sodium in exchange for potassium, which moves into the cells.
- In the kidneys, the filtration of potassium takes place at the glomerulus.

functions of potassium

eufic.org



helps our cells uptake
nutrients & water



helps our muscles
contract



helps our nerves carry
messages between the
brain & the body



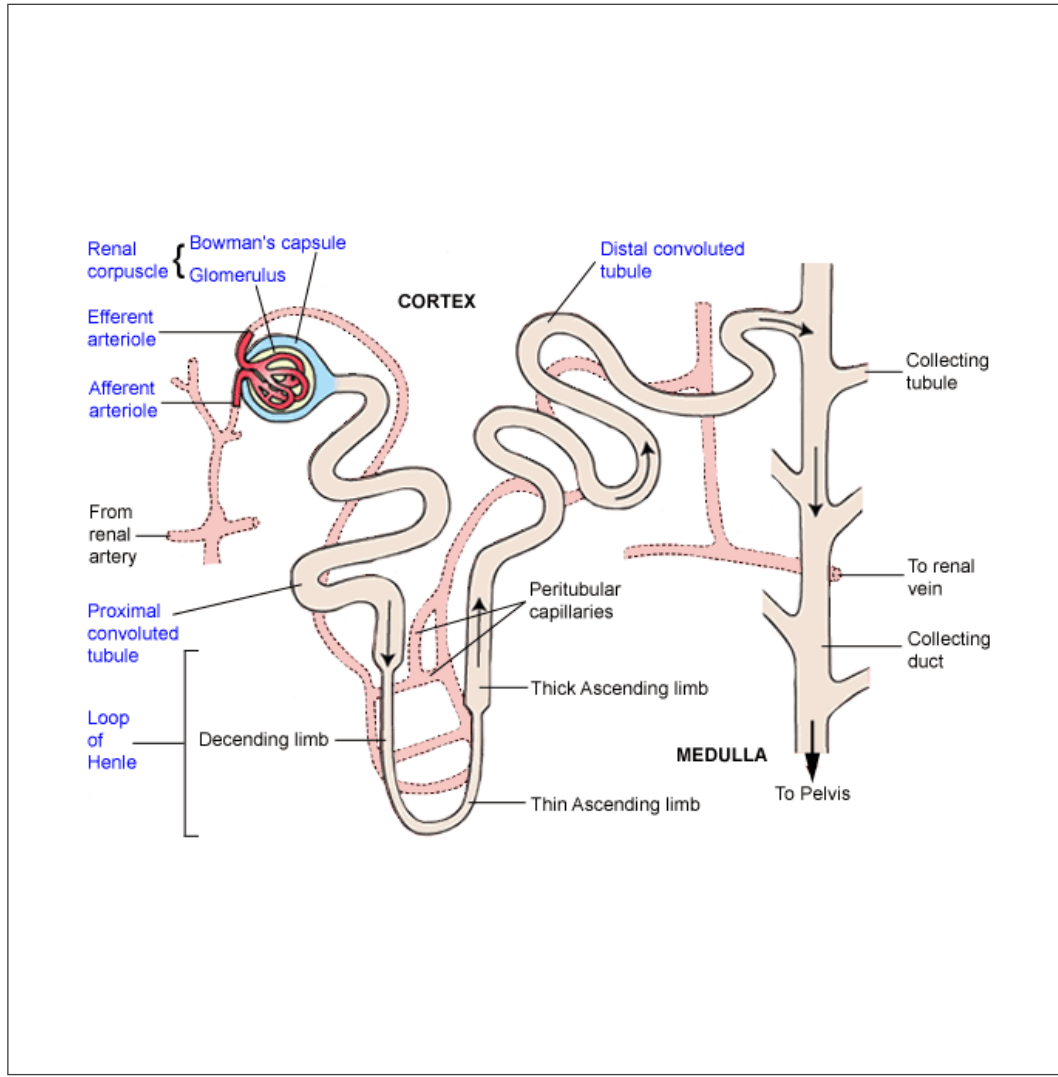
balances our bodies'
fluids & regulates
blood pressure



helps our bodies
digest foods

Biochemical Function of Potassium

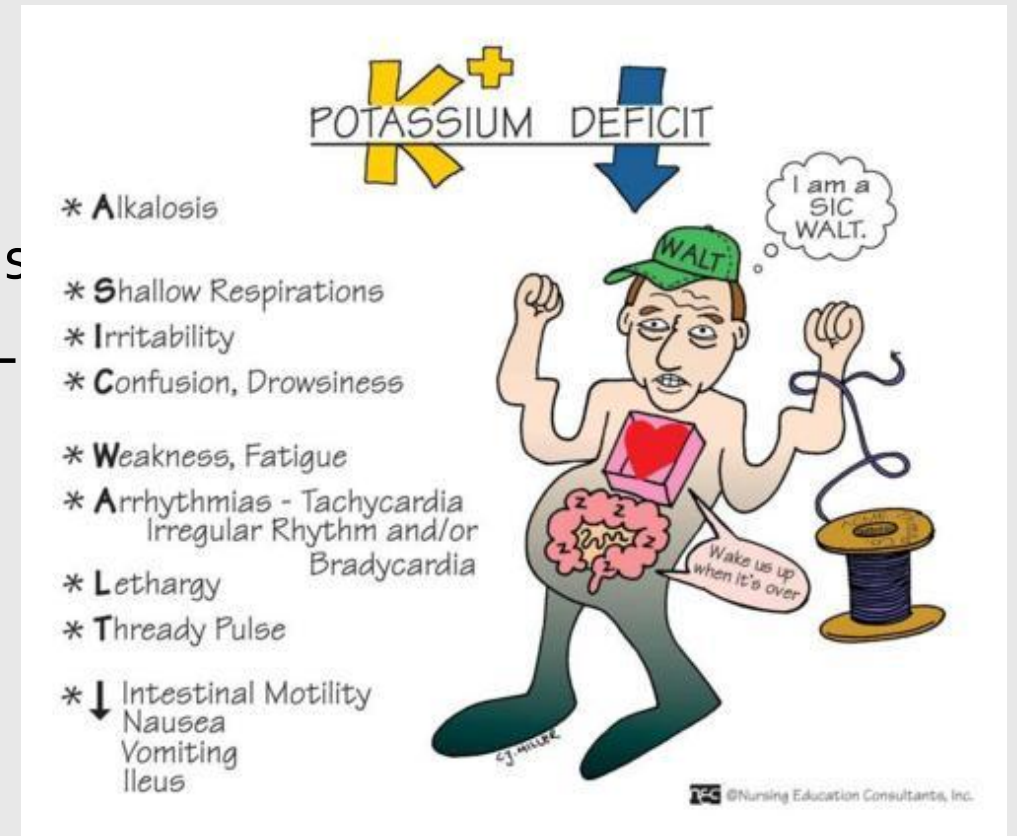
- Potassium's functions are vital for the body in these ways:
- Maintaining electrical gradients.
- Supporting normal muscle and nerve function.
- Regulating fluid, electrolyte, and acid-base balance.



- Potassium reabsorption occurs at the proximal convoluted tubule and ascending loop of Henle.
- Potassium secretion occurs at the distal convoluted tubule, where aldosterone increases the potassium secretion.
- Potassium channels and potassium-chloride cotransporters at the apical tubular membrane also secrete potassium.

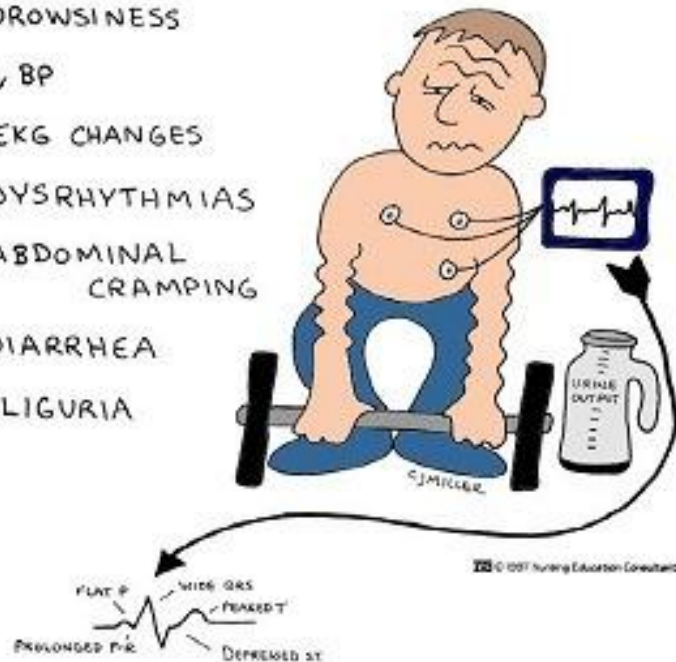
Common clinical Conditions

- Potassium imbalances may result in cardiac arrhythmias.
- **Hypokalemia** occurs when serum potassium levels are significantly below the lower limits 3.6 mmol/L
- The features of hypokalemia include weakness, fatigue, and muscle twitching.
- **Hypokalemic** paralysis is generalized body weakness that can be either familial or sporadic.



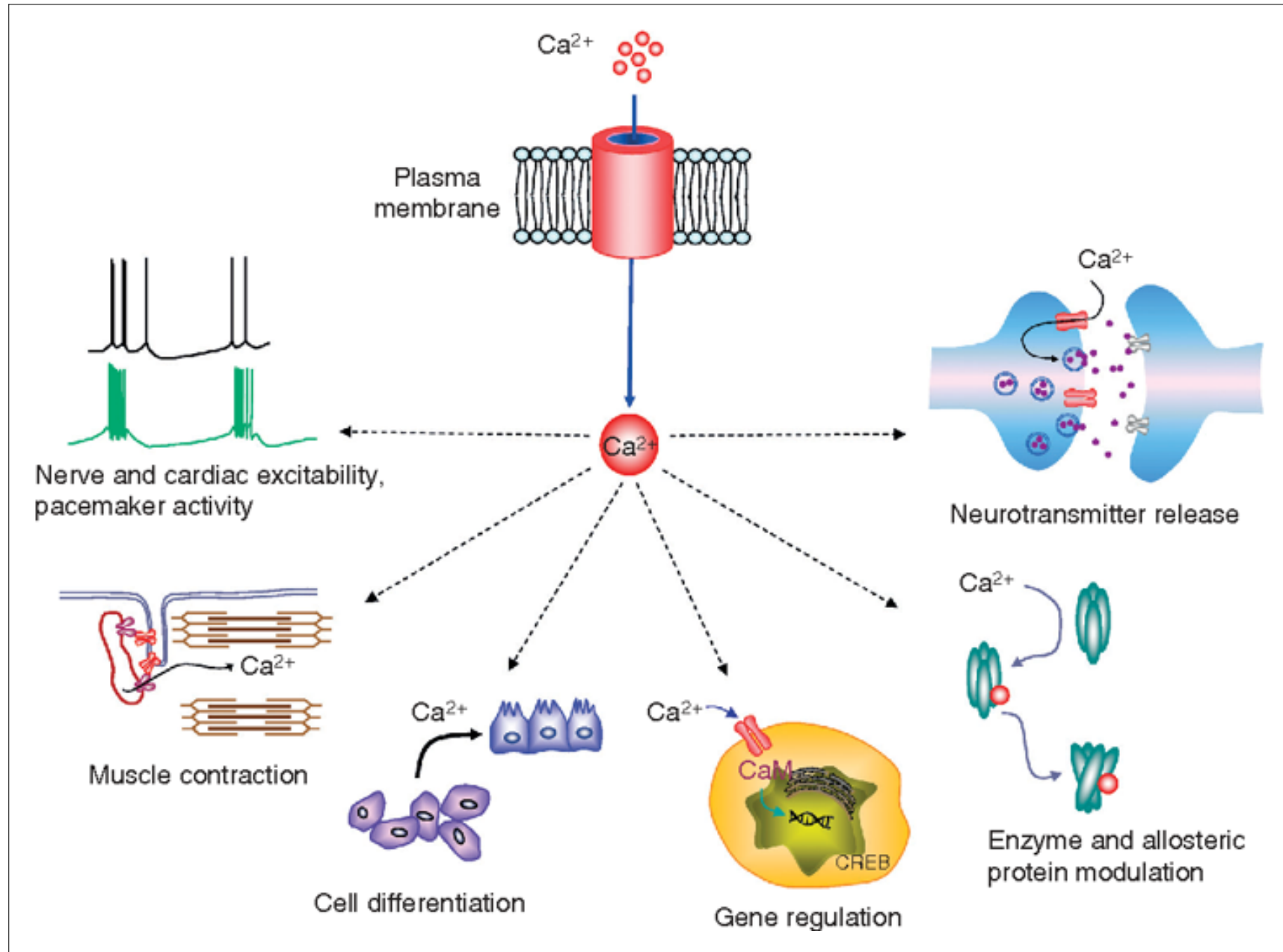
HYPERK⁺ K⁺ ↑

- * MUSCLE CRAMPS → WEAKNESS → PARALYSIS
- * DROWSINESS
- * ↓ BP
- * EKG CHANGES
- * DYSRHYTHMIAS
- * ABDOMINAL CRAMPING
- * DIARRHEA
- * OLIGURIA



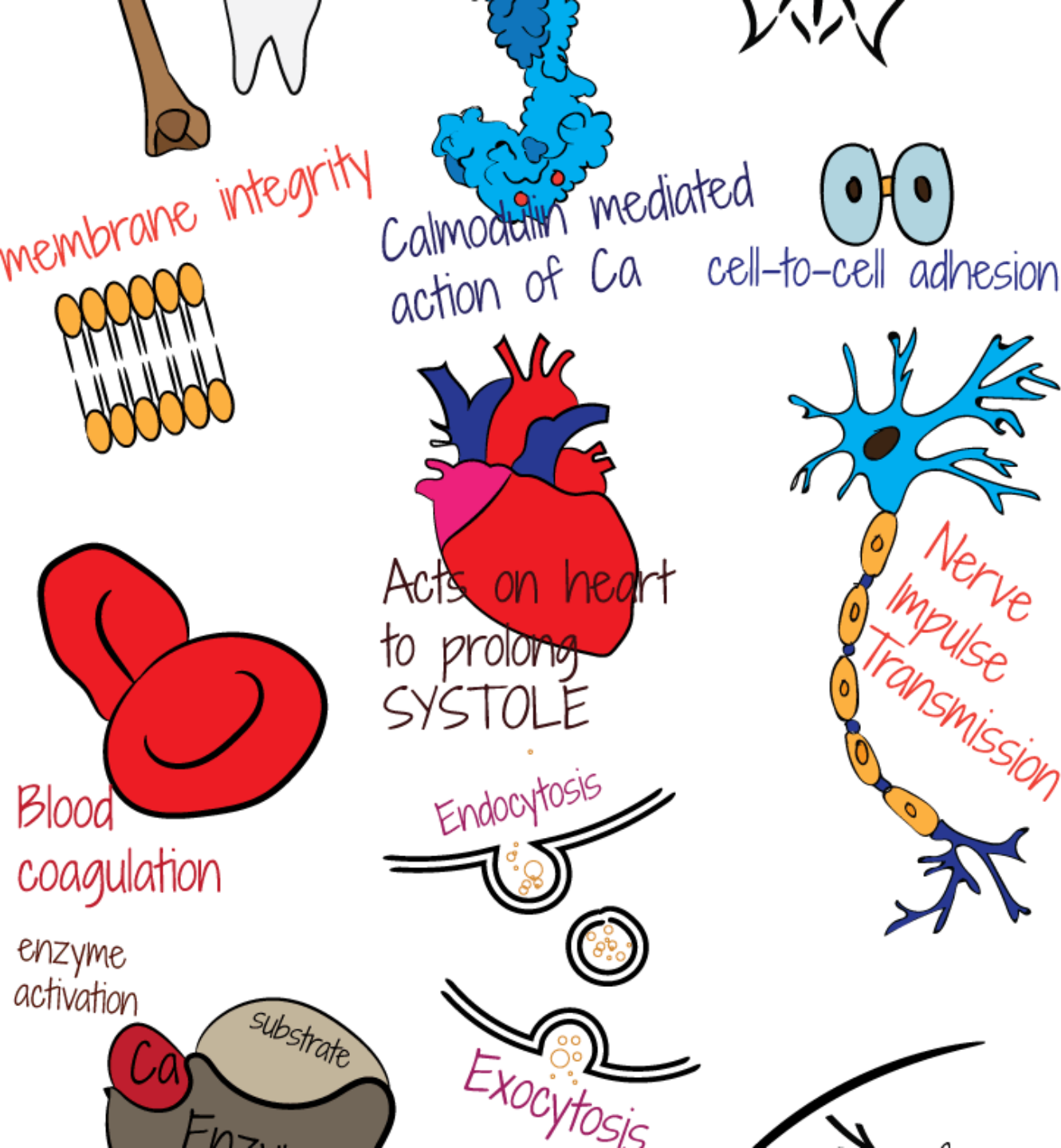
Cont.

- **Hyperkalemia** occurs when the serum potassium levels are above the upper limit (5.5 mmol/L), which can result in arrhythmias.
- Muscle cramps, muscle weakness, rhabdomyolysis, and myoglobinuria may present hyperkalemia signs and symptoms.



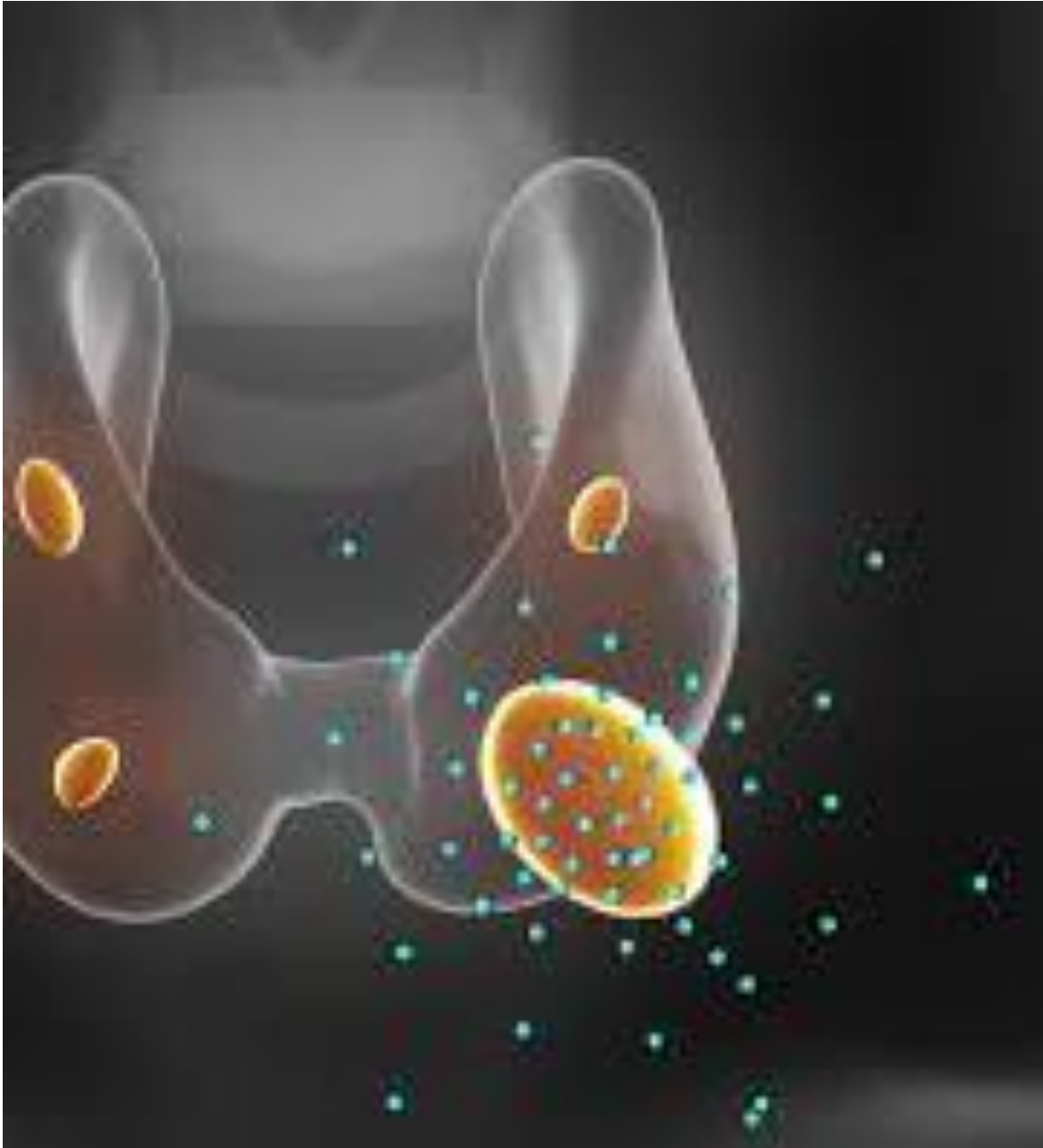
Calcium

- Calcium has a significant biochemical role in the body.
- It is involved in skeletal mineralization, contraction of muscles, transmission of nerve impulses, blood clotting, and hormonal secretion.
- The diet is the predominant source of calcium, and it is predominantly an extracellular cation.



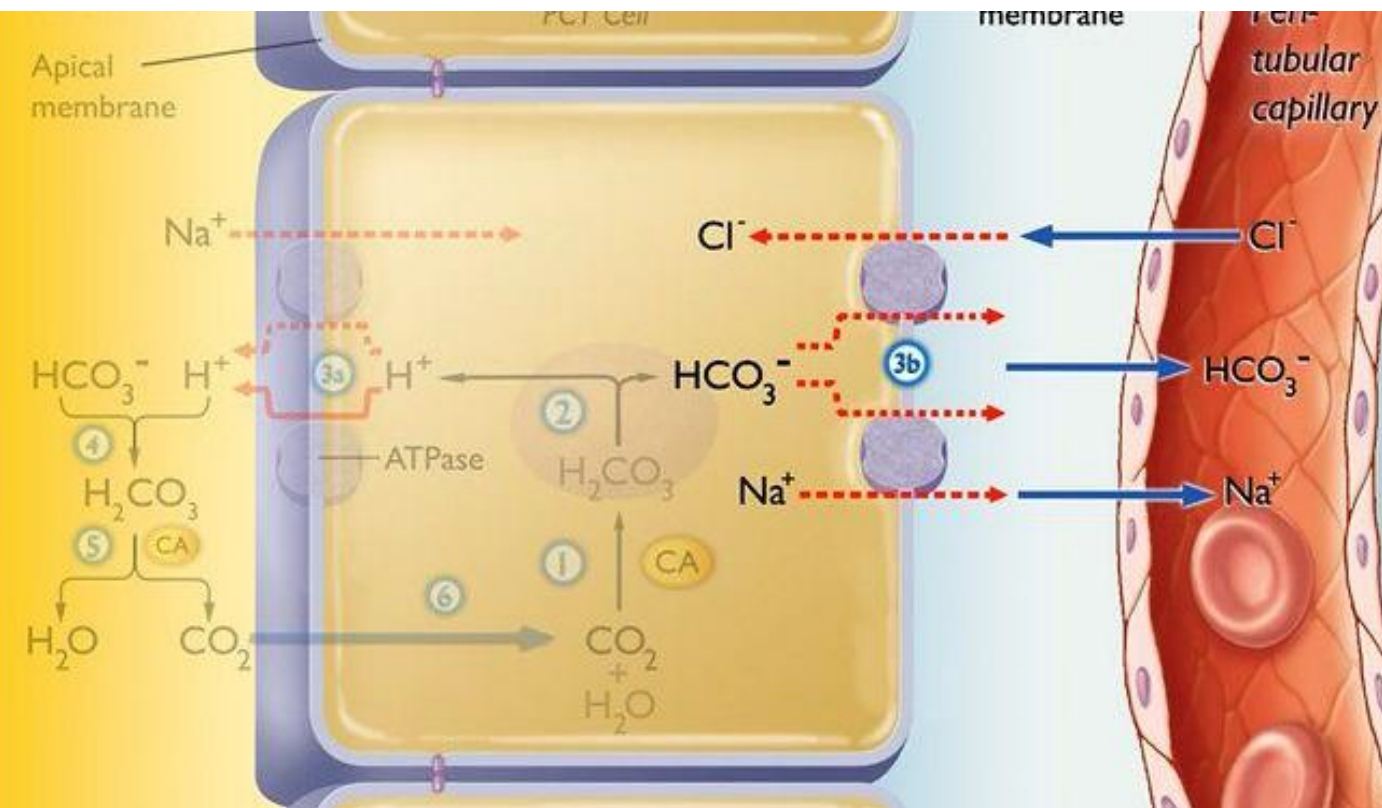
Calcium

- Calcium absorption in the intestine is primarily controlled by the hormonally active form of vitamin D (1,25-dihydroxy vitamin D₃).
- Parathyroid hormone also regulates calcium secretion in the distal tubule of the kidneys.
- Calcitonin acts on bone cells to decrease calcium levels in the blood.



Common clinical Conditions

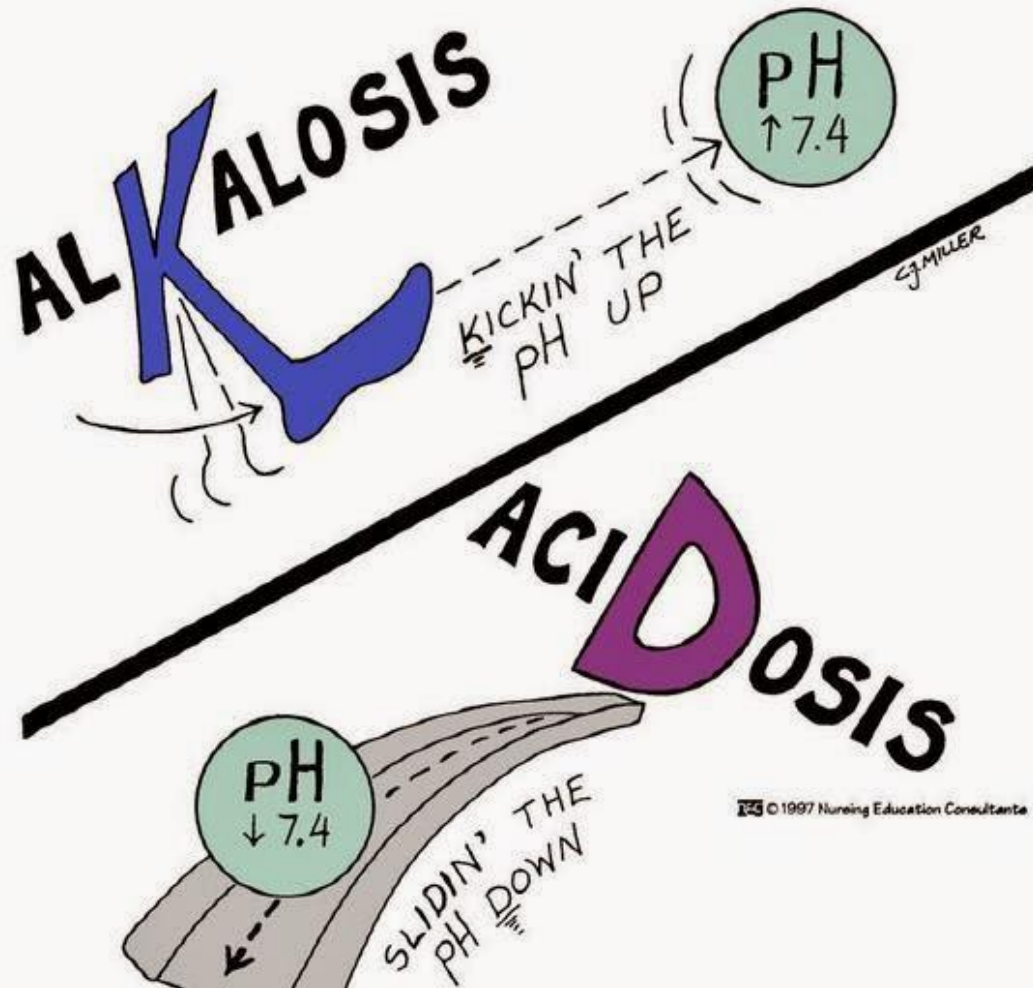
- **Hypocalcemia** diagnosis requires checking the serum albumin level to correct for total calcium.
- **Hypocalcemia is** diagnosed when serum calcium is <8.8 mg/dL, as in vitamin D deficiency or hypoparathyroidism.
- **Hypercalcemia** is when serum calcium level is > 10.7 mg/dL, as seen with primary hyperparathyroidism.
- Humoral hypercalcemia presents in malignancy, primarily due to PTHrP secretion.



Bicarbonate

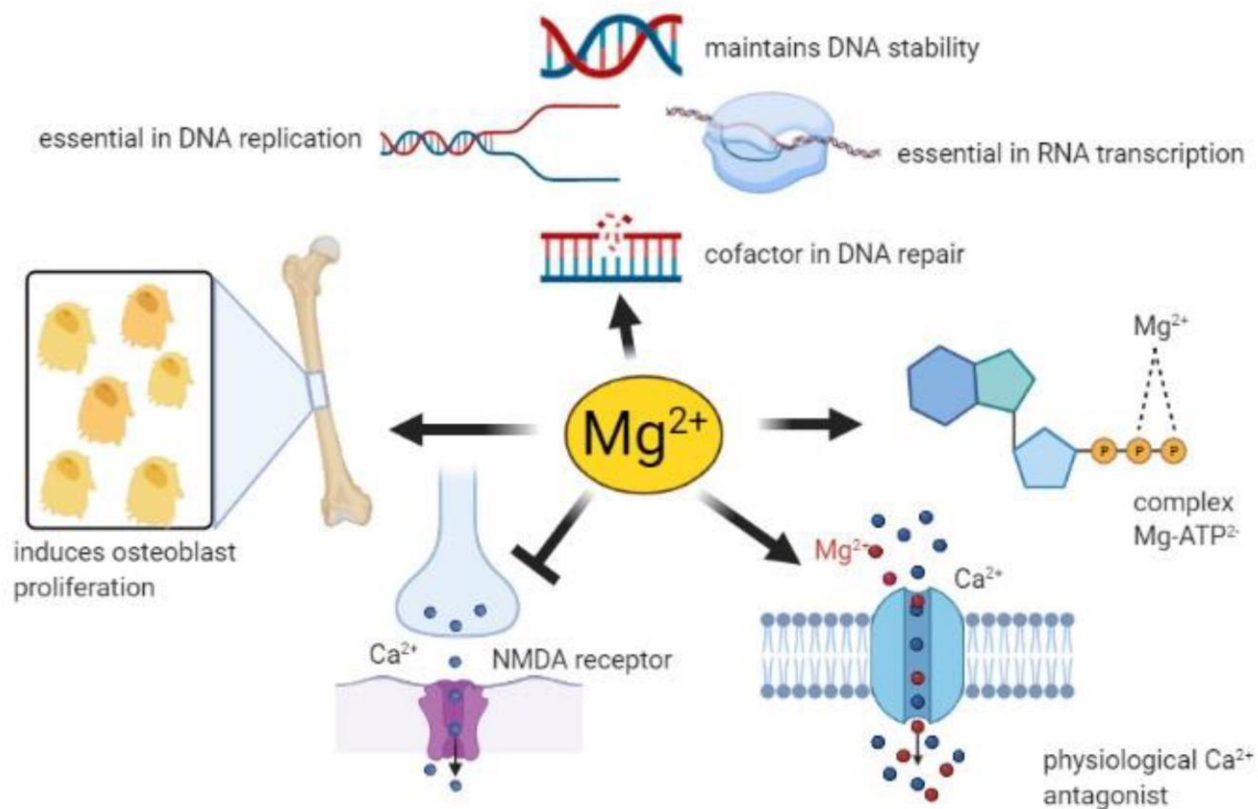
- The acid-base status of the blood drives bicarbonate levels.
- Kidneys regulate bicarbonate levels and maintain acid-base balance.
- Kidneys reabsorb the filtered bicarbonate and generate new bicarbonate by net acid excretion.
- Diarrhea usually results in bicarbonate loss, causing an imbalance in acid-base regulation.

ACIDOSIS – ALKALOSIS



Common clinical conditions

- Many kidney-related disorders can result in imbalanced bicarbonate metabolism leading to excess bicarbonate in the body.
- Low levels of bicarbonate in the blood may cause metabolic acidosis.
- High levels of bicarbonate in the blood may cause metabolic alkalosis.



Magnesium

- Magnesium is an intracellular cation and is supplied to the body via diet (nuts).
- Magnesium is mainly involved in ATP metabolism, proper muscle functioning, neurological functioning, and neurotransmitter release.
- When muscles contract, calcium re-uptake by the calcium-activated ATPase of the sarcoplasmic reticulum is triggered by magnesium.

HYPO- MAGNESEMIA

VS

HYPER- MAGNESEMIA



Hippo-magnesium-magazine



Confusion



Increased DTRs



Neuromuscular
Irritability



Hiker-magnesium-magazine

Flushing



Decreased DTRs



Muscle Weakness

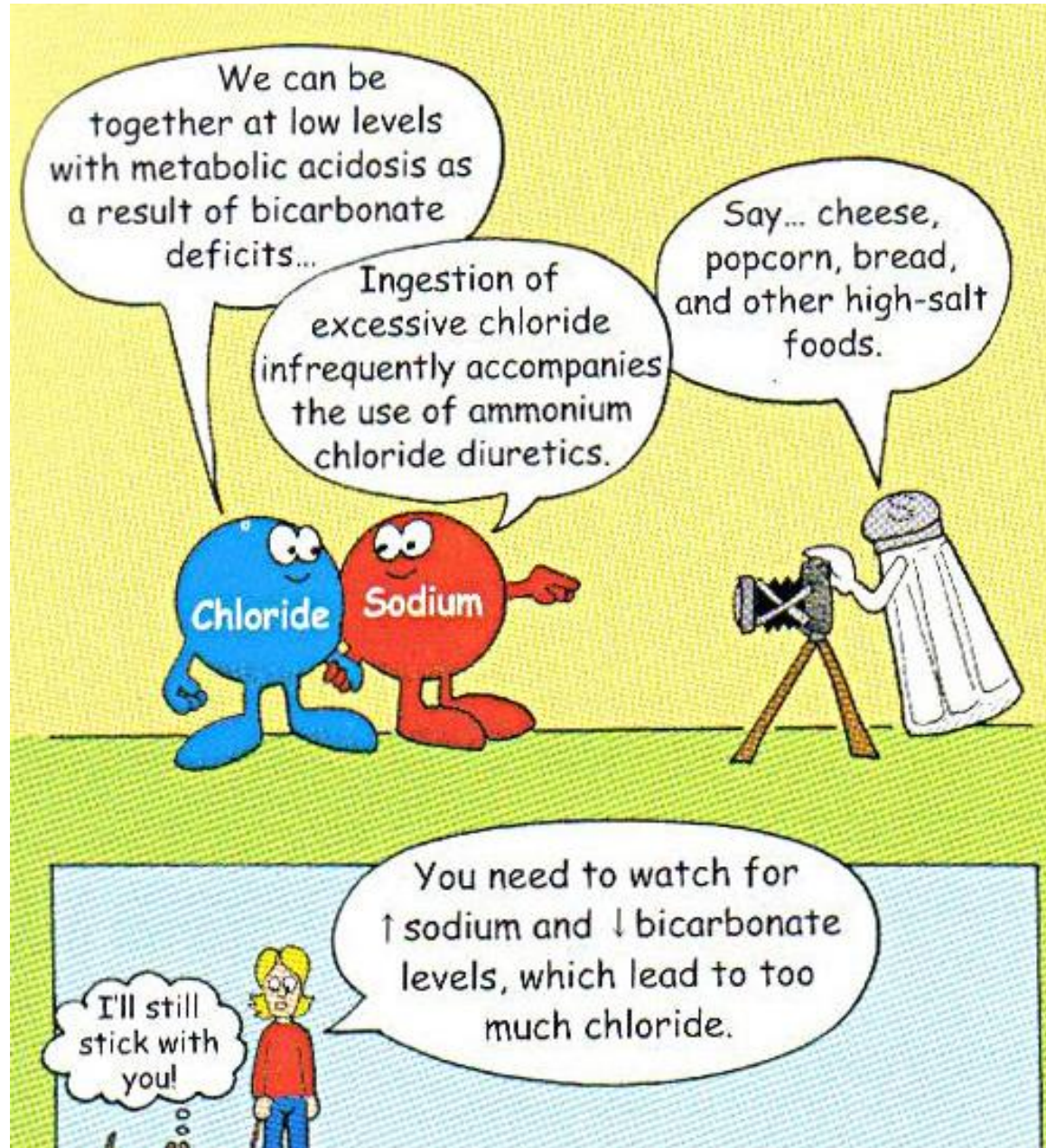


Common clinical condition(s)

- **Hypomagnesemia** occurs when the serum magnesium levels are less than 1.46 mg/dL.
- Alcoholism, GIT disease conditions, and excessive renal loss may result in hypomagnesemia.
- It commonly presents with ventricular arrhythmias, which include torsades de pointes.
- Hypomagnesemia may also result from the use of certain medications, such as omeprazole.

Chloride Ion

- Chloride is an anion found predominantly in the extracellular fluid.
- The kidneys predominantly regulate serum chloride levels.
- Most chloride, filtered by the glomerulus, is reabsorbed by both proximal and distal tubules by active/passive transport.
- **Hypochloremia** presents in gastrointestinal losses like vomiting or excess water gain like congestive heart failure.

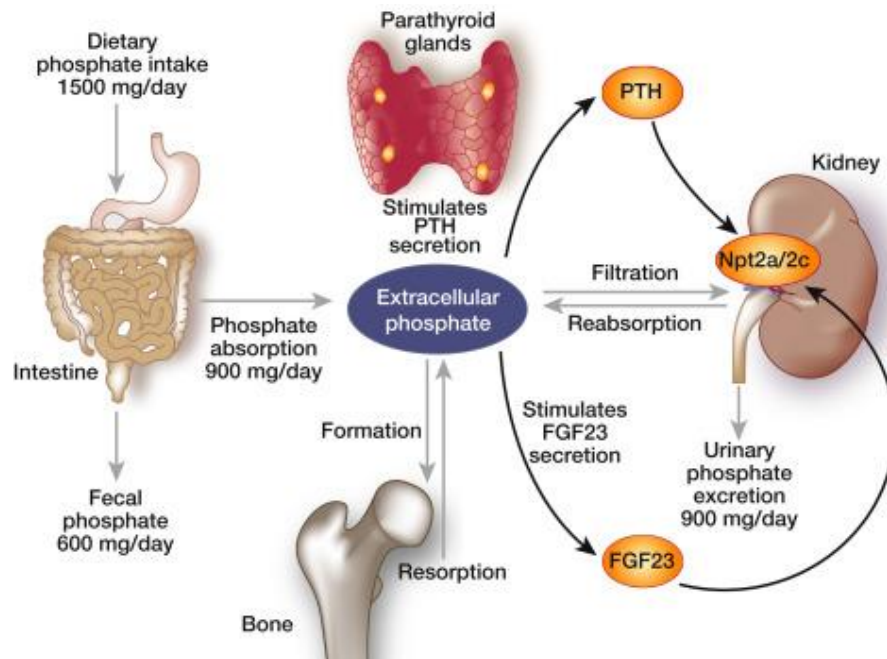


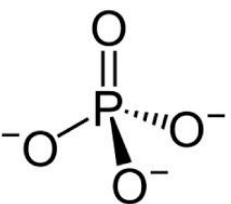
Common clinical condition(s)

- **Hyperchloremia**, can be caused by severe dehydration, diarrhea, or metabolic problems.
- In that case, the blood becomes too acidic, with eventual kidney disease development.
- A high salt diet can lead to an excessive intake of sodium chloride, which is associated with elevated blood pressure.

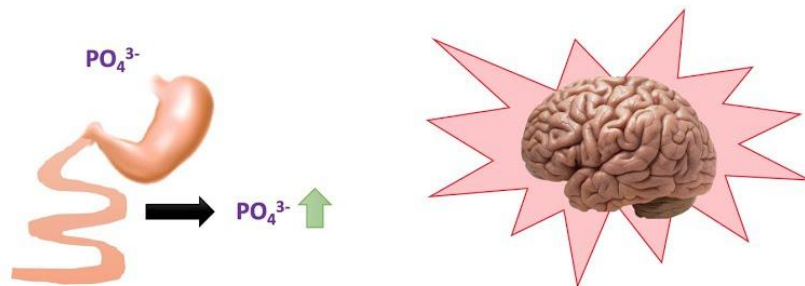
Phosphorus Ion

- Phosphorus is an extracellular fluid cation.
- 85% of the **total body phosphorus is in the bones and teeth in the form of hydroxyapatite.**
- Other parts of the body (soft tissues) **contain the remaining 15%.**
- Phosphate plays a crucial role in metabolic pathways.



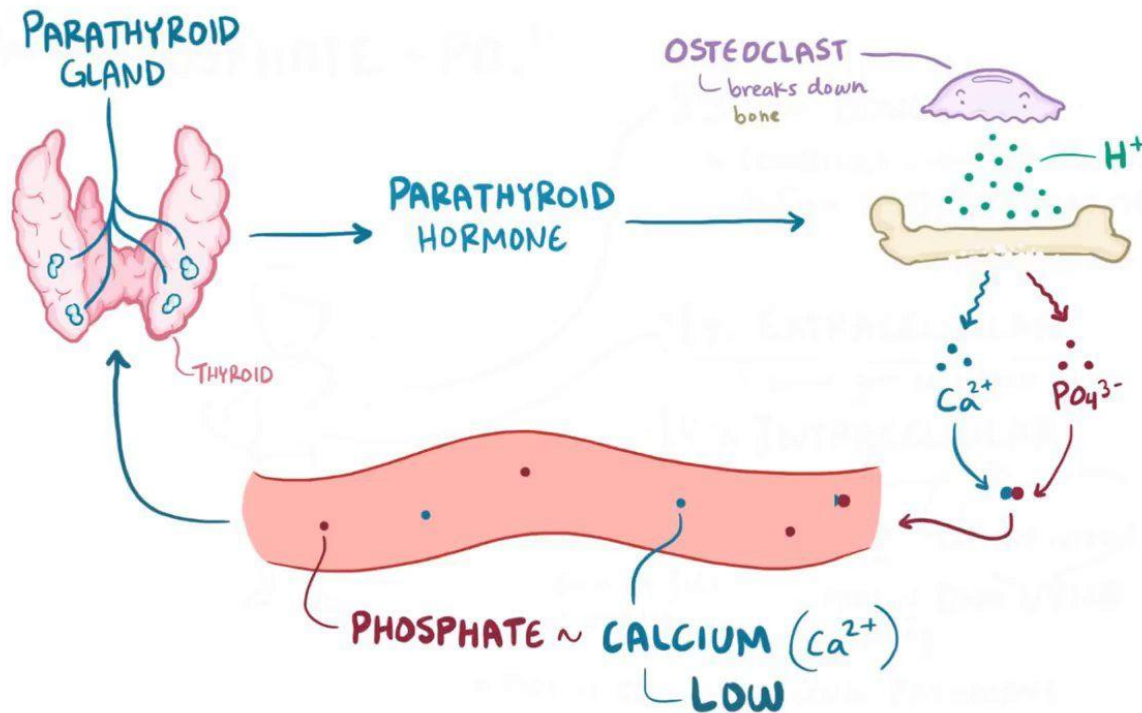


Low Phosphate (Hypophosphatemia)



Phosphorus Ion

- It is a component of many metabolic intermediates and, most importantly, of ATP and nucleotides.
- Phosphate is regulated by Vitamin D₃, PTH, and calcitonin. Its secretion is mainly controlled by the kidney.
- Phosphate imbalance is most commonly due to either impaired dietary intake, GIT disorders, or deranged renal excretion.



Common clinical condition(s)

- **Hypophosphatemia** is a common condition related to abnormal serum level of phosphorus.
- The condition is caused by malnutrition as in seen in alcoholism.
- The kidneys maintain phosphate levels in the normal range.
- **Hyperphosphatemia** is uncommon except when kidney GFR falls below 30 ml/min

Summary

- K^+ (ICF), Ca^{2+} (ECF), Bicarbonate (ECF), Mg^{2+} (ICF), Cl^- (ECF) and HPO_4^{-2} (ECF).
- Hyponatremia, hypernatremia, and hypomagnesemia can lead to neurological consequences such as seizures.
- Hypokalemia and hyperkalemia, as well as hypocalcemia, may cause cardiac arrhythmias.
- Bicarbonate imbalance can lead to metabolic acidosis or alkalosis.
- Some consequences of potassium, calcium, and magnesium abnormalities are fatigue, lethargy, and muscle weakness.

Take home message

- ✓ Classify the electrolytes based on the cellular fluid distribution.
- ✓ Mention the conditions that result in the high level of (1) Ca^{2+} , (2) Cl^- , and (3) Mg^{2+} in the blood.
- ✓ Explain the clinical consequences of serum bicarbonate imbalance.
- ✓ Which of the body tissues contain a larger percentage of phosphorus ions, and why?
- ✓ Enumerate the major clinical roles of magnesium ion.

Next Lecture

Acid-Base Balance & Disturbances

