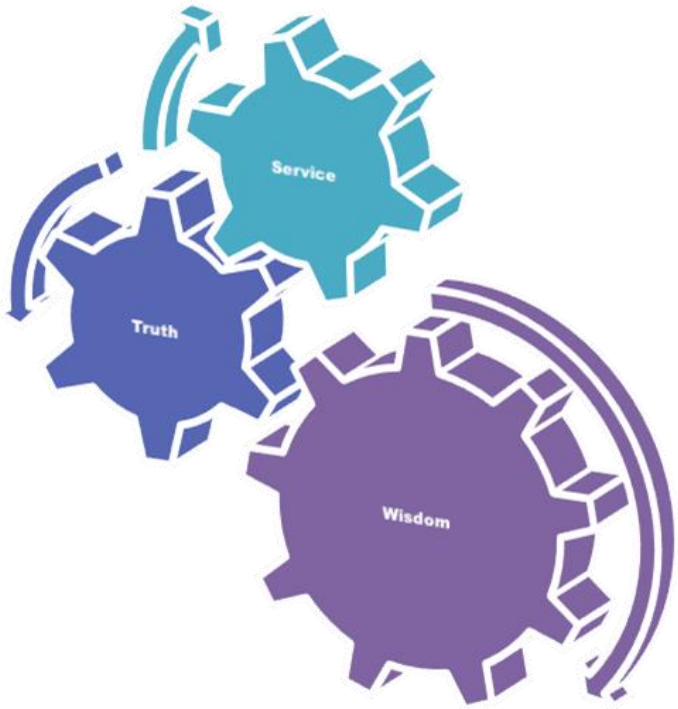

بسم الله الرحمن الرحيم

Motto Vision; The Dream/Tomorrow



- To impart evidence based research oriented medical education
- To provide best possible patient care
- To inculcate the values of mutual respect and ethical practice of medicine

Renal Module

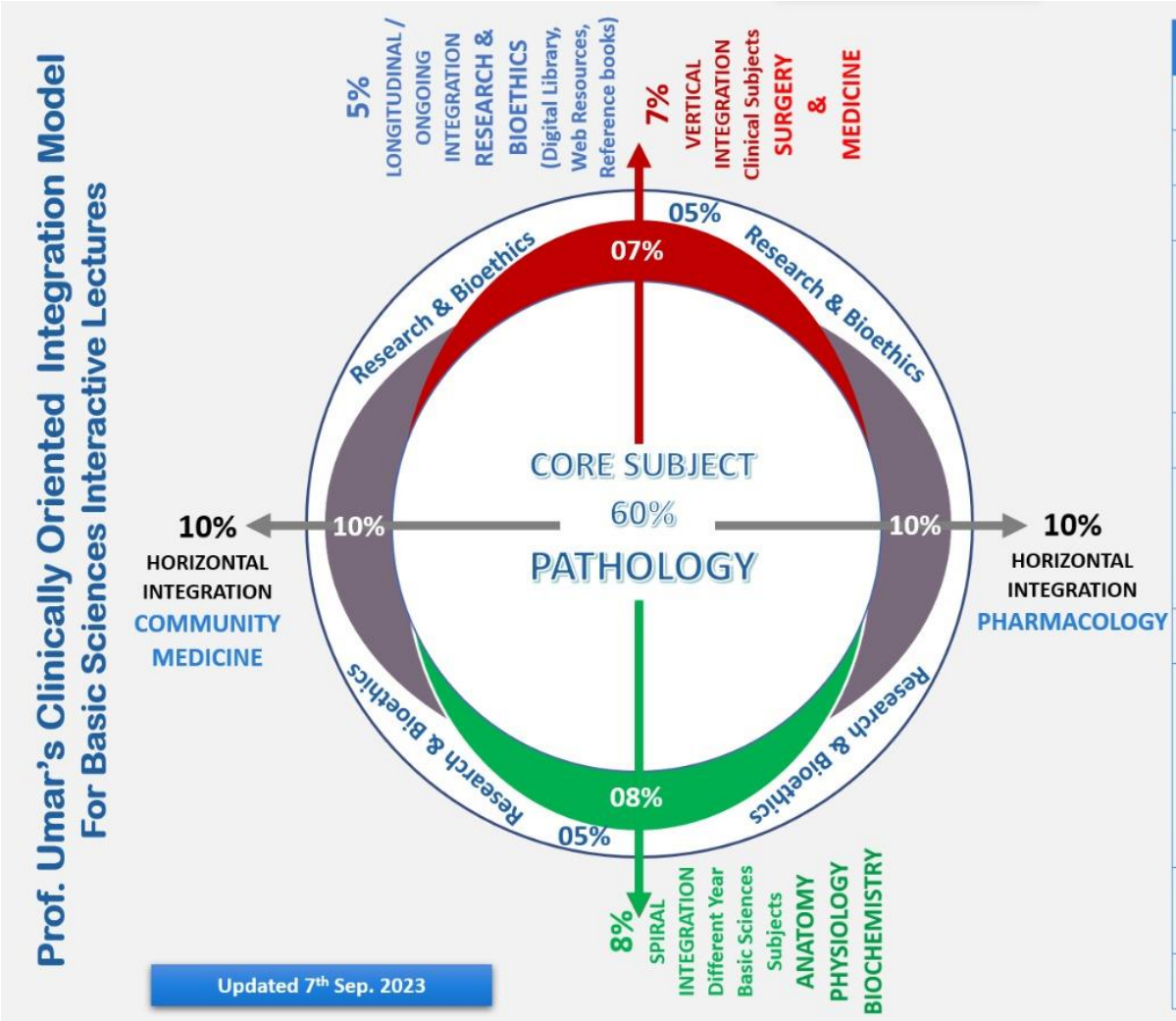
2nd Year MBBS (LGIS)

Potassium & Bicarbonate Metabolism - 2

Presenter: Dr Nayab Ramzan
Deptt of Biochemistry
RMU

Date: 13-02-25

Professor Umar Model of Integrated Lecture



Model 3rd Year Pathology LGIS (≈30 slides)	
Core Subject – 60% (≈ 18-20 slides)	
Pathology (≈ 18-20 slides)	
Horizontal Integration – 20% (≈ 5-6 slides)	
Same Year Subjects	• Pharmacology (10%) (≈ 2-3 slides) • Community Medicine (10%) (≈ 2-3 slides)
Vertical Integration – 07% (≈ 2-3 slides)	
Clinical Subjects	• Medicine (3-5%) (≈ 1-2 slides) • Surgery (3-5%) (≈ 1-2 slides)
Spiral Integration – 08% (≈ 2-3 slides)	
Different Year Basic Sciences Subjects	• Anatomy (1-3%) (≈ 1-2 slides) • Physiology (1-3%) (≈ 1-2 slides) • Biochemistry (1-3%) (≈ 1-2 slides)
Longitudinal / Ongoing Integration – 05% (≈ 1-2 slides)	
Research & Bioethics (≈ 1-2 slides)	

Learning Objectives

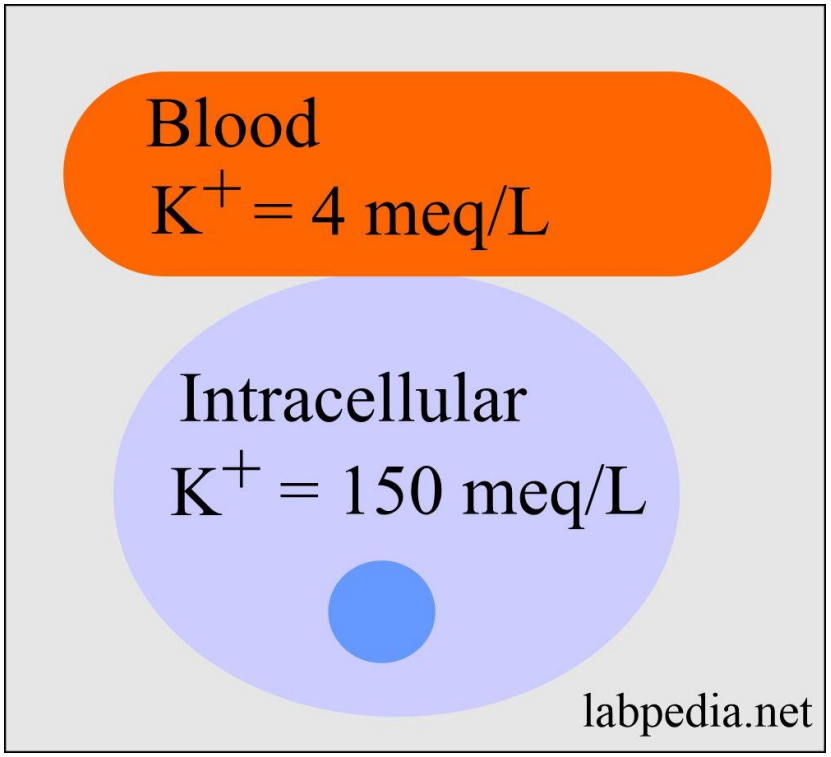
At the end of the lecture, students will be able to:

- Explain the daily requirements, sources and functions of Potassium.
- Describe causes and effects of hypokalemia and hyperkalemia
- Explain the sources, functions, daily requirements of bicarbonate along with it's deficiency and toxic effects on body.
- Practice the principles of bioethics & apply strategic use of A.I in the related clinical condition.
- Read relevant research articles related to the Core Knowledge.

Core Knowledge

Potassium Metabolism

- **Principal Cation of Intracellular fluid**
- **Normal daily requirement of K^+ is 1.5-4.5 gram but average diet contains 4-8 grams of K^+.**
- **Average person takes in about 4 gram K^+ daily of which 90% is absorbed from the GIT.**
- **Sources being dates, tomatoes, fruits and fruit juices, potato, fish, milk, spinach, melons, banana, beans and beef**



Normal serum K^+ levels: 3.5-5 mEq/l

Potassium Metabolism

- **K^+ is reabsorbed in PCT and lesser extent in ascending limbs of loop of Henle.**
- **The remaining unabsorbed K^+ is secreted into the tubular lumen in DCT and collecting ducts → excreted**
- **Distal nephron regulates K^+ through**

1. Aldosterone

2. Greater K^+ excreted if hyperkalemia is present

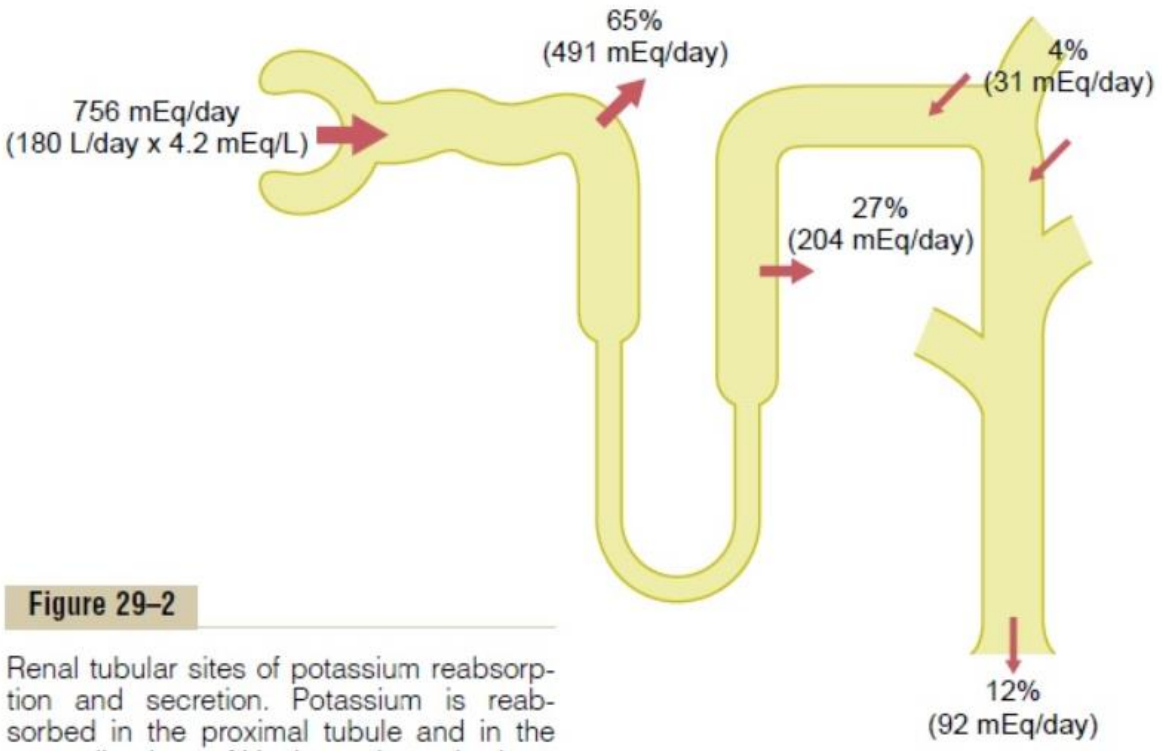
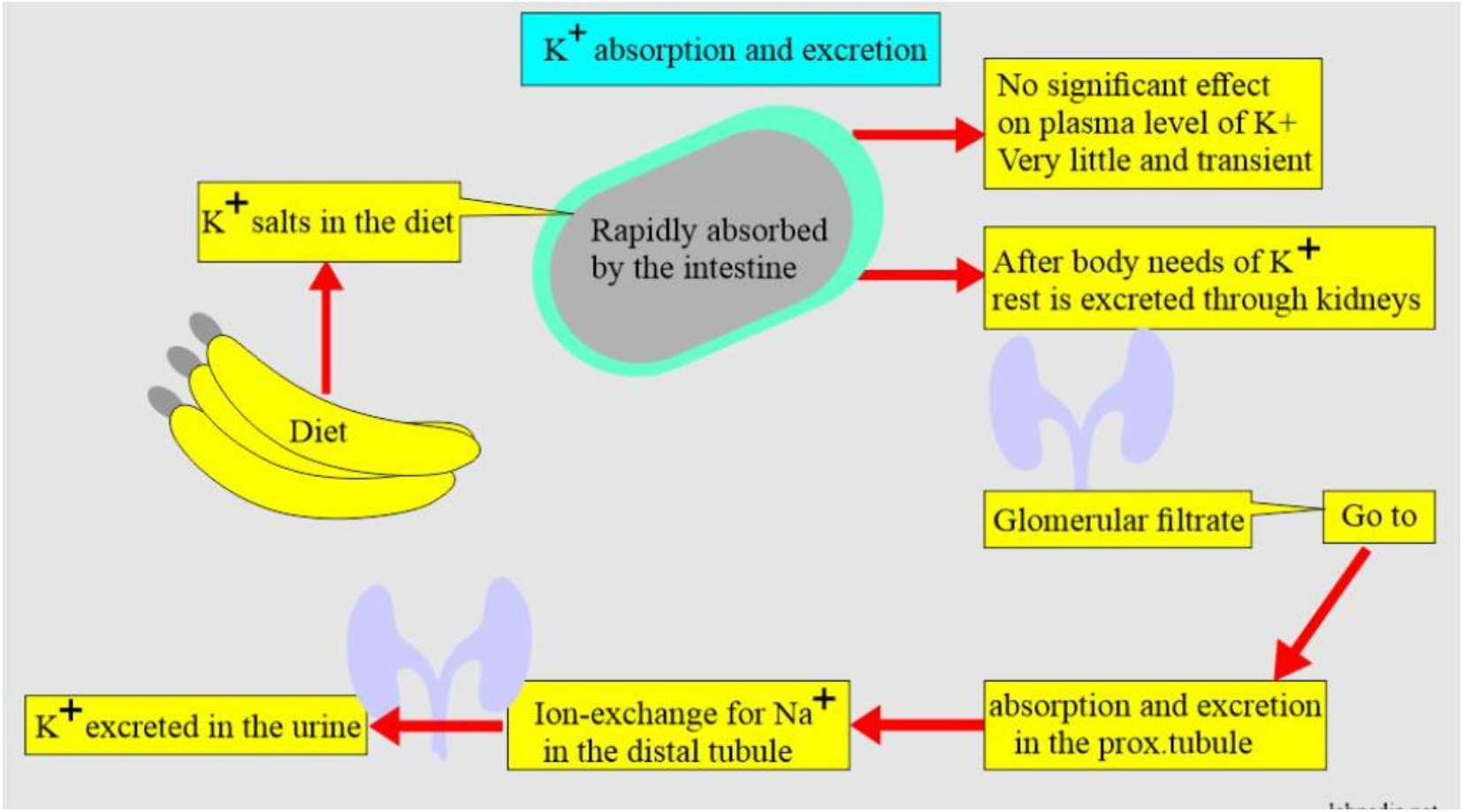


Figure 29–2

Renal tubular sites of potassium reabsorption and secretion. Potassium is reabsorbed in the proximal tubule and in the ascending loop of Henle, so that only about

Core Knowledge

Potassium Metabolism

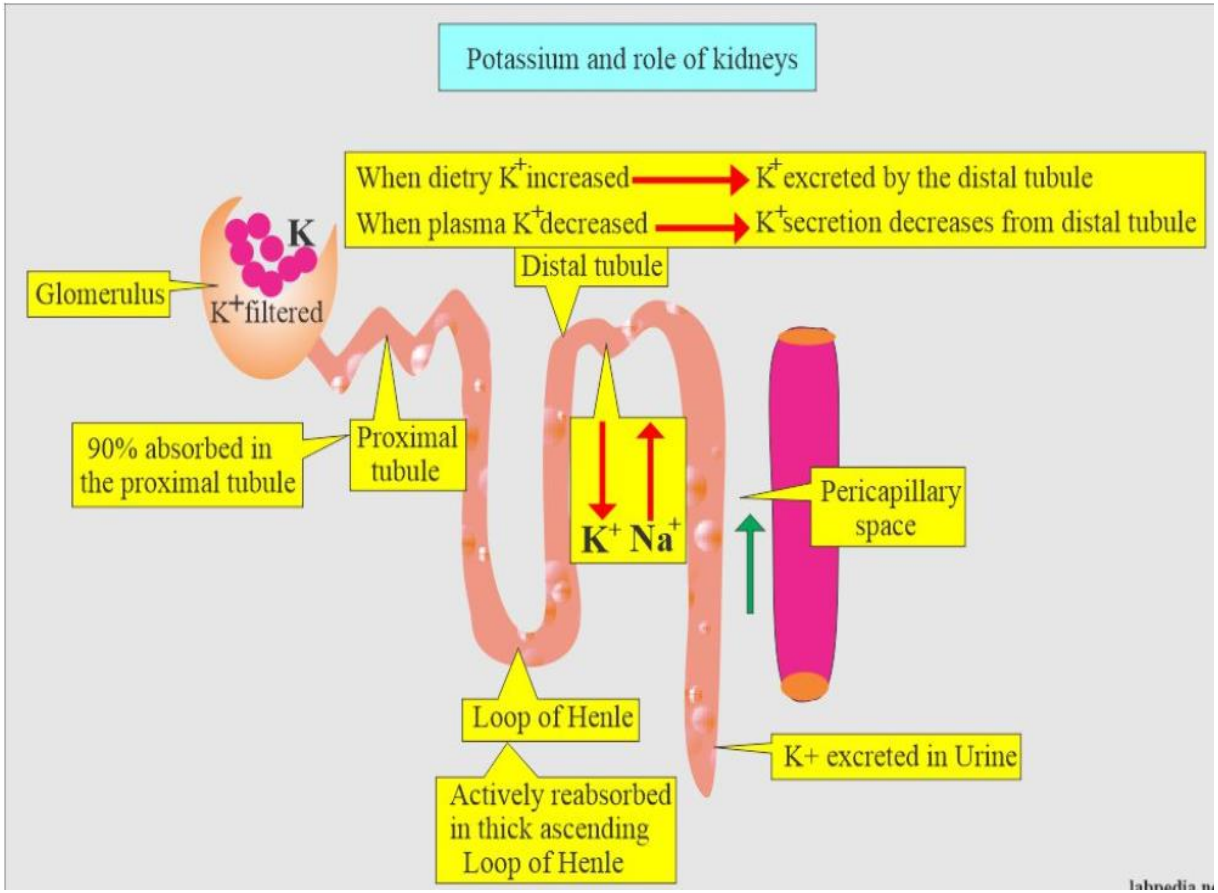


- **K^+ readily absorbed in the small intestine (absorbed K^+ is made to enter cells by insulin released on food and by basal levels of plasma catecholamines, this prevents post prandial hyperkalemia).**

Potassium Metabolism

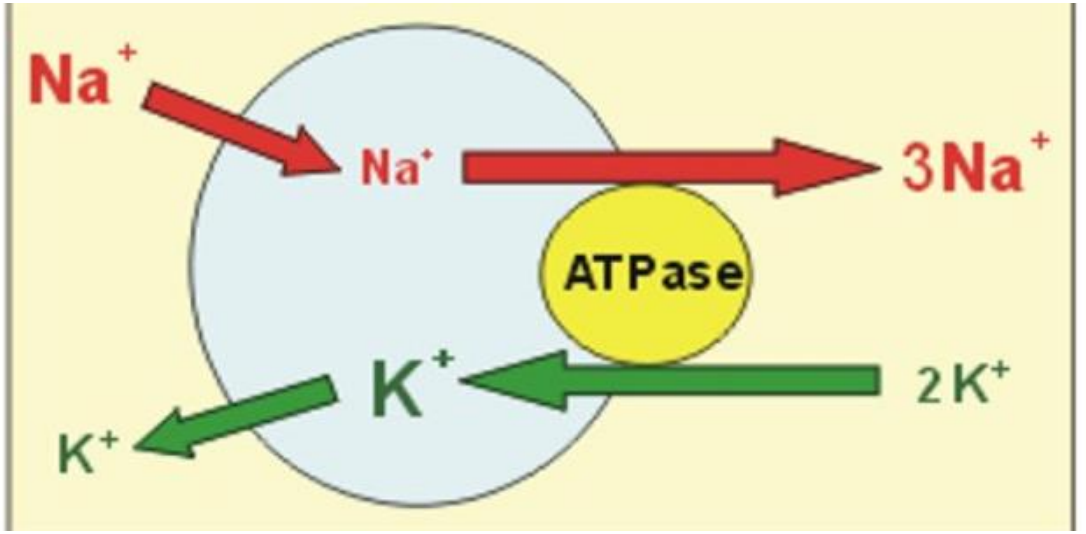
- The kidney cannot preserve K^+ so effectively as it can Na^+ and conservation of Na^+ is at the expense of K^+, so there is some obligatory K^+ loss in urine which amounts to about 40 mEq or 160 mg/day.

- When K^+ intake falls below the minimal requirement, serum K^+ concentration drops and cells begin to utilize H^+ in place of K^+ resulting in intracellular acidosis and extra cellular alkalosis.



Functions of Potassium

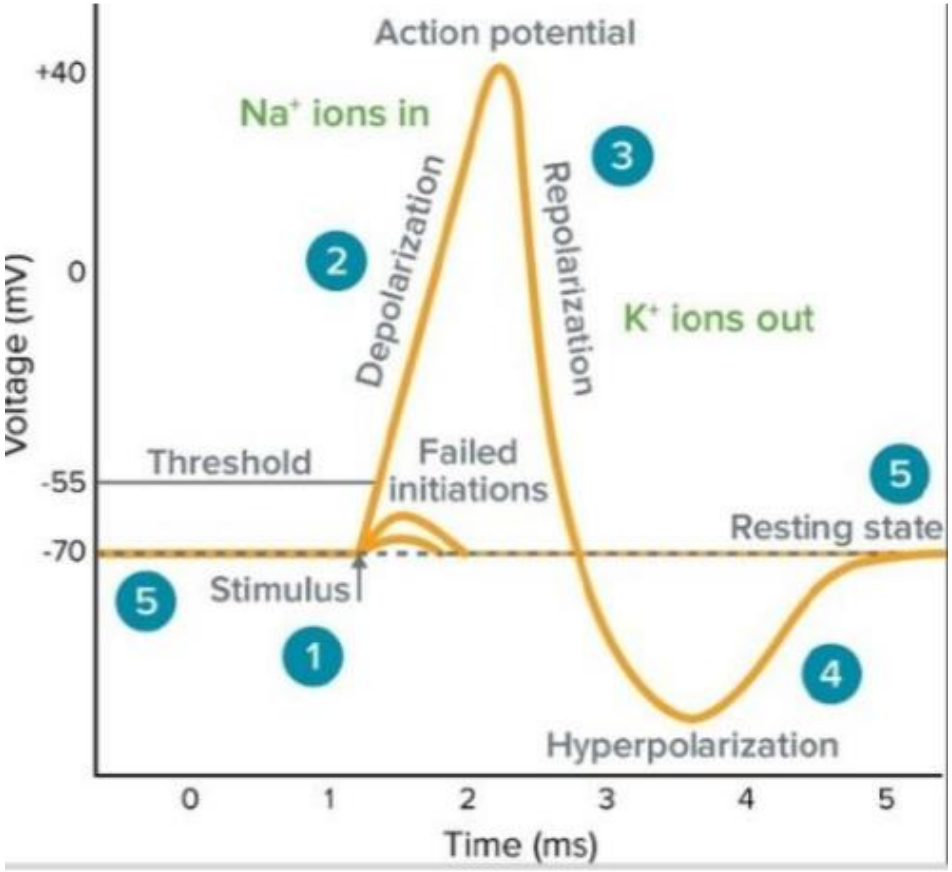
- **1. Along with Na+ ions, the K^+ ions are req for the activity of Na+K+ATPase pump.**
- This pump is stimulated by a raised intracellular Na+ and is inhibited in chronic illnesses e.g heart failure and renal failure and by cardiac glycosides (e.g. digoxin)



- **2. K^+ is needed for many enzyme reactions, glycogenesis require presence of K^+**

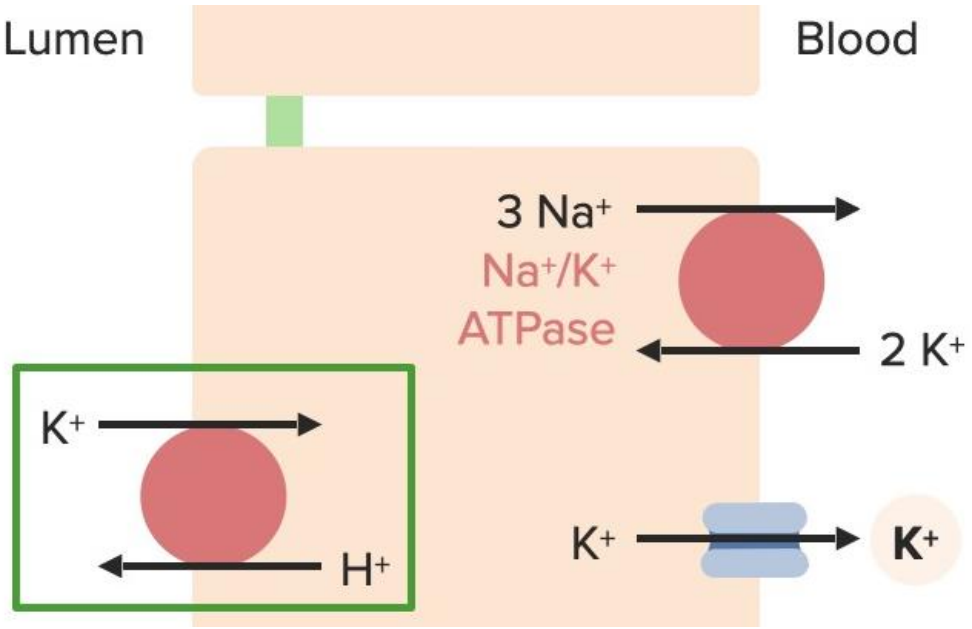
Functions of Potassium

- **3. K^+ ions are needed for neuron and muscle activity i.e. production of resting membrane potential.**
- **K^+ ions bring about the repolarization phase of action potentials.**
- **4. A proper plasma K^+ level is essential for normal heart functioning (myocardial relaxation-diastole) and contraction of skeletal muscle.**



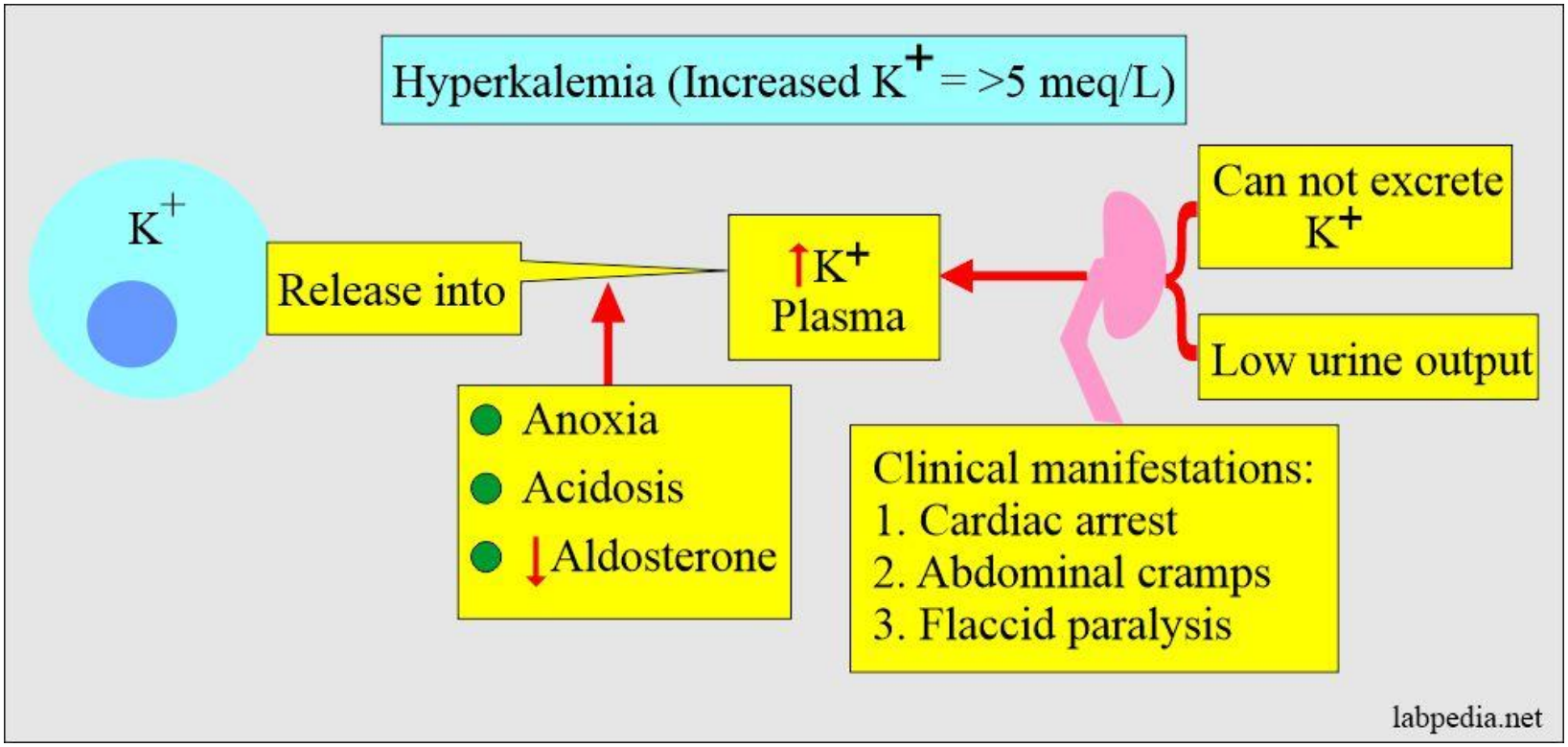
Functions of Potassium

- **5. In kidney (renal tubules) K^+ ions are required for exchange with Na^+.**



- **6. K^+ is the chief cation of intracellular fluid and is retained in much greater amounts during growth and pregnancy**

Hyperkalemia

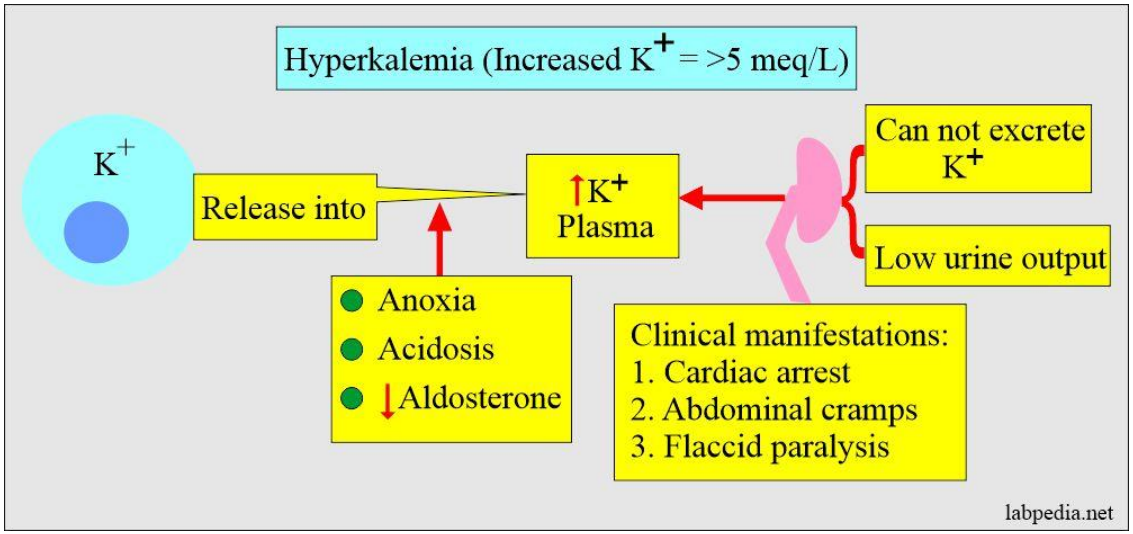


- **Hyperkalemia (Increased concentration of K^+ in the blood):**

1. This is due to the following:
    1. Increased potassium is released into the blood.
    2. Or due to the kidney, which cannot excrete the potassium.
    3. Or due to low urine output

Conditions with Hyperkalemia

- **1. Release of cellular K^+:** Large amounts of K^+ may be liberated from injured or infected muscles, Intra vasc hemolysis, rhabdomyolysis, burnt tissues or hematomas, severe exercise, sudden tumor lysis with chemotherapeutic agents e.g Burkitt's lymphoma→release so much K+ →fatal hyperkalemia.
- Insulin deficiency and hyperglycemia also promote shifting of cellular K+ into ECF →hyperkalemia



2. Chronic dehydration and shock: It leads to decreased urine formation leading to K^+ retention

3. Fever: Raised body temperature results in excessive breakdown of body proteins which liberates cellular K^+ ions which enter the plasma producing hyperkalemia.

Conditions with Hyperkalemia

- 4. Renal failure: The kidney (DCT) is not capable of secreting excessive K^+, retention of K^+ takes place.
- 5. Addison's disease: In this less K^+ is secreted by distal convoluted tubules, it is due to def of aldosterone
- 6. Iatrogenic: Administration of K^+ by I/V route may result in hyperkalemia, precautions should be taken when K^+ is given intravenously with repeated ECG exams &/or serum potassium levels.
- Spironolactone
- Digoxin
- Succinylcholine

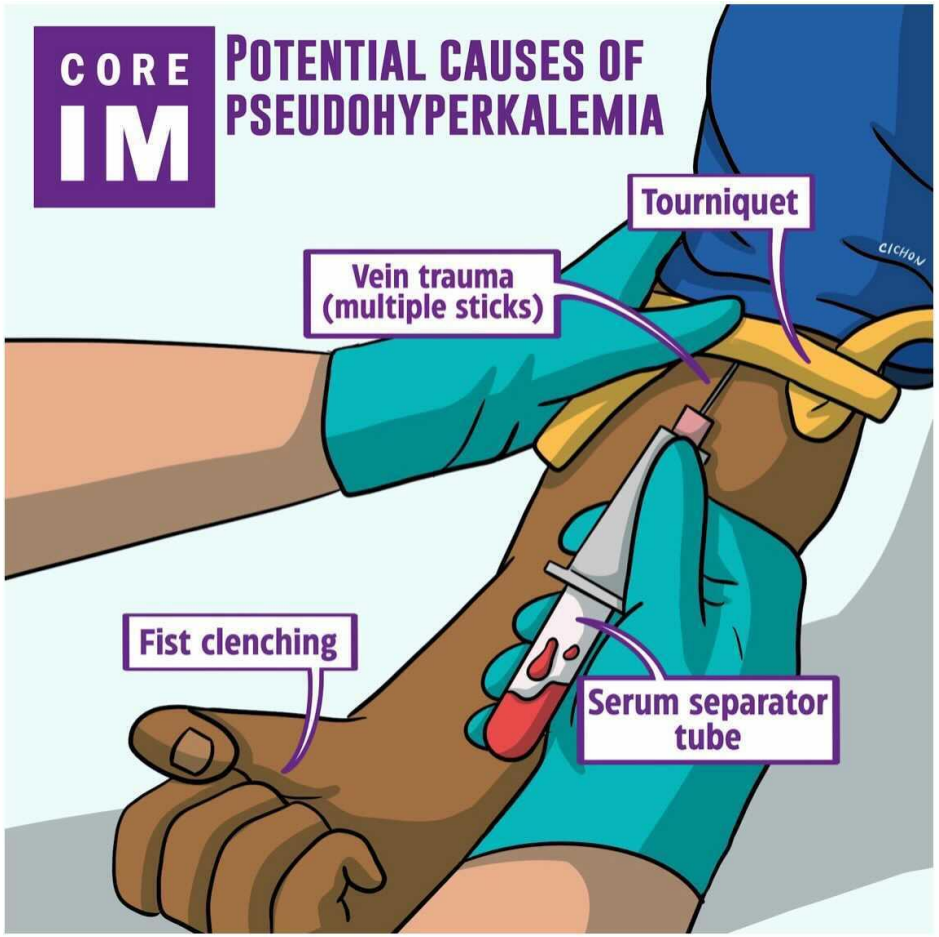
Vertical Integration

Conditions with Hyperkalemia

- 7. Metabolic acidosis: H+ ions displace K^+ ions from cells

- 8. Pseudohyperkalemia: This is brought about by a movement of K^+ ions from RBCs to the plasma during drawing blood of patient; it occurs due to prolonged use of a tourniquet, with or without repeated fist clinching, hemolysis and by marked leukocytosis and thrombocytosis.

- 9. Hyperkalemic periodic paralysis: It is a genetic disorder in which there is a mutation in the gene for the skeletal muscle Na channel and hyperkalemia may occur by stimuli that normally produce only a slight hyperkalemia.



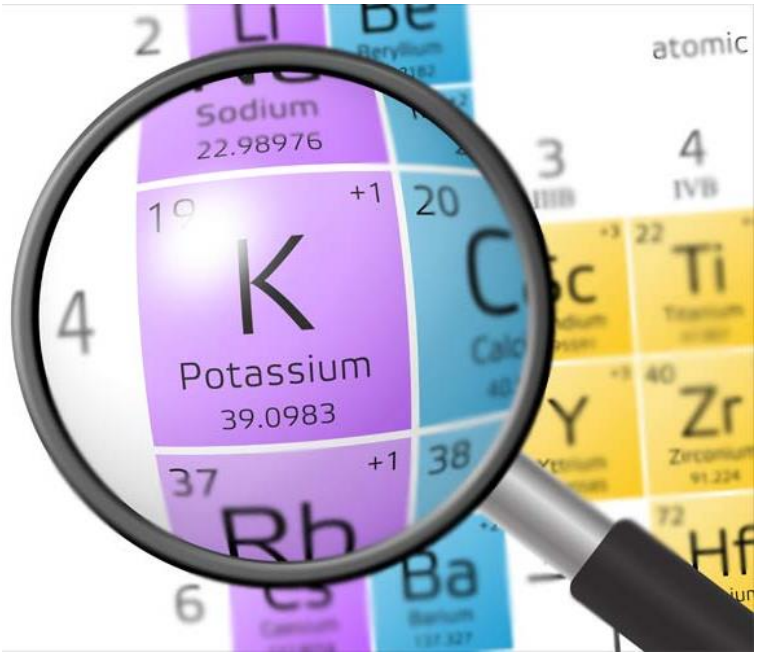
Hyperkalemia

SYMPTOMS:

- **Nervous symptoms include mental confusion, weakness of muscles and numbness and tingling sensations in extremities.**

TREATMENT:

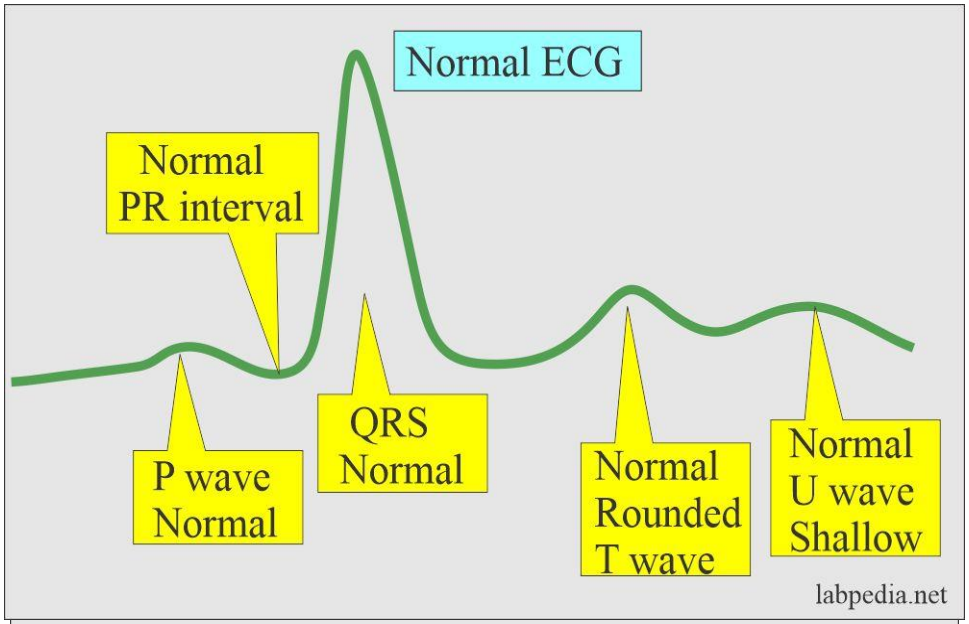
- **Hyperkalemia is treated by removing the primary cause if possible.**
- **Acidosis + salt or water deprivation is corrected.**
- **Insulin with glucose may be given to shift plasma K^+ into cells.**
- **Suitable ion exchange resins are administered to withdraw K^+ ions from plasma into gut**
- **Peritoneal dialysis**
- **Hemodialysis**

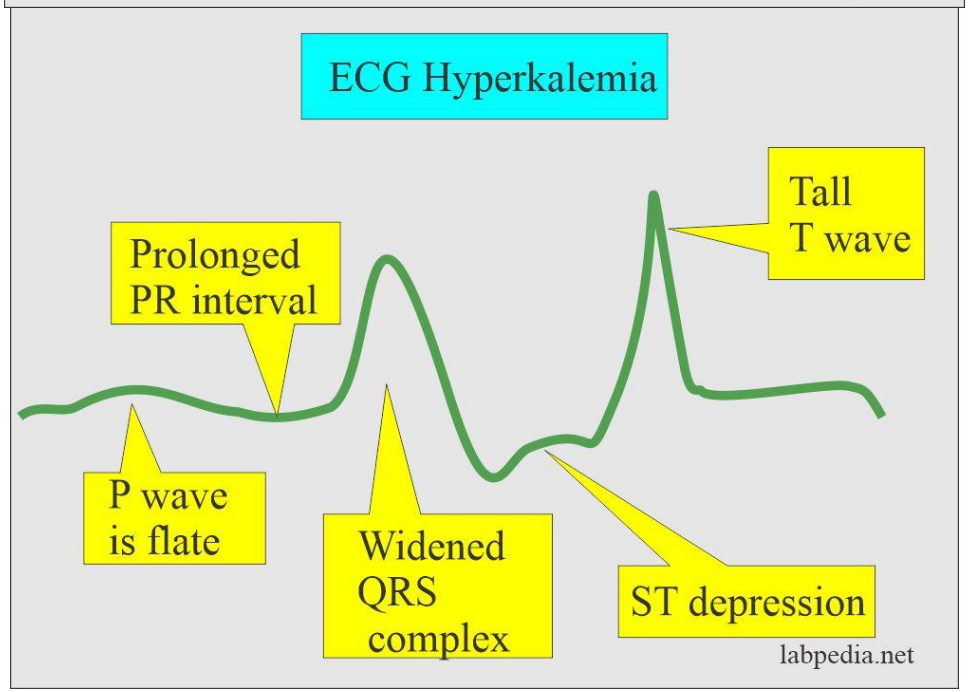


Hyperkalemia

- **Hyperkalemia exerts its chief effects on heart. The ECG changes are characteristic, the T wave become high and peaked tall and tented , P wave disappears and QRS complex become broad.**

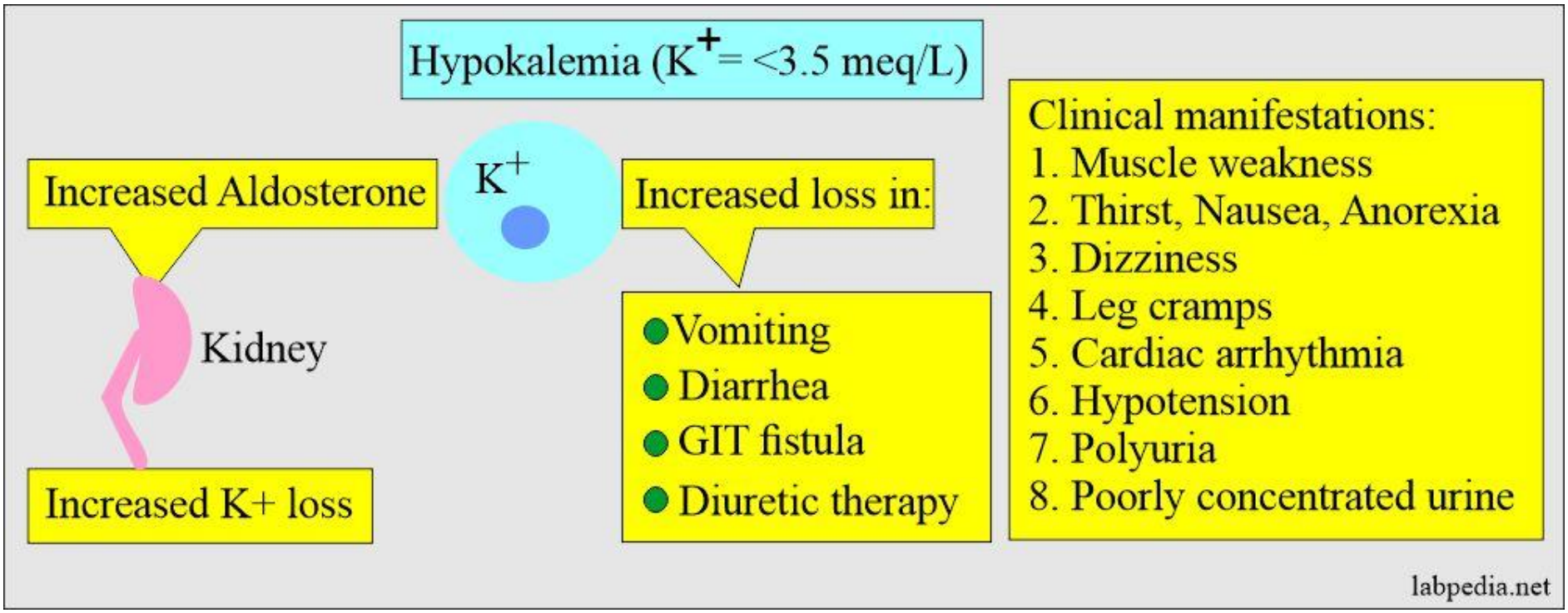
- **Widespread intra cardiac blocks appear first in atria, then at AV node and finally in ventricle. Bradycardia and arrhythmias appear, there may be sudden cardiac arrest in diastole.**





Vertical Integration

Hypokalemia



- **Hypokalemia (Decreased concentration of the K^+ in the blood):**

1. This is due to potassium loss in vomiting, diarrhea, GIT fistula, and diuretics.
2. Aldosterone increase leads to a decrease in potassium.

Hypokalemia

- **Hypokalemia is seen in the following circumstances:**

- **1. Decreased K^+ Intake as in starvation and when K^+ free fluids are given I/V for prolonged period (total parenteral nutrition), old age, kwashiorkor.**

- **2. Excessive Renal Loss as occurs in diuresis and diuretic (acting proximal to Collecting Ducts-furosemide and thiazides)-these drugs result in bringing more Na+ ions to DCTs, this leads to a greater exchange of K^+ ions which are lost in urine.**

- **3. Loss From GIT: as in vomiting, diarrhea, suctional drainage, laxative abuse and gastrointestinal fistulas.**

- **4. Excessive Transfer To Cells: This is seen in the following conditions:**

Hypokalemia

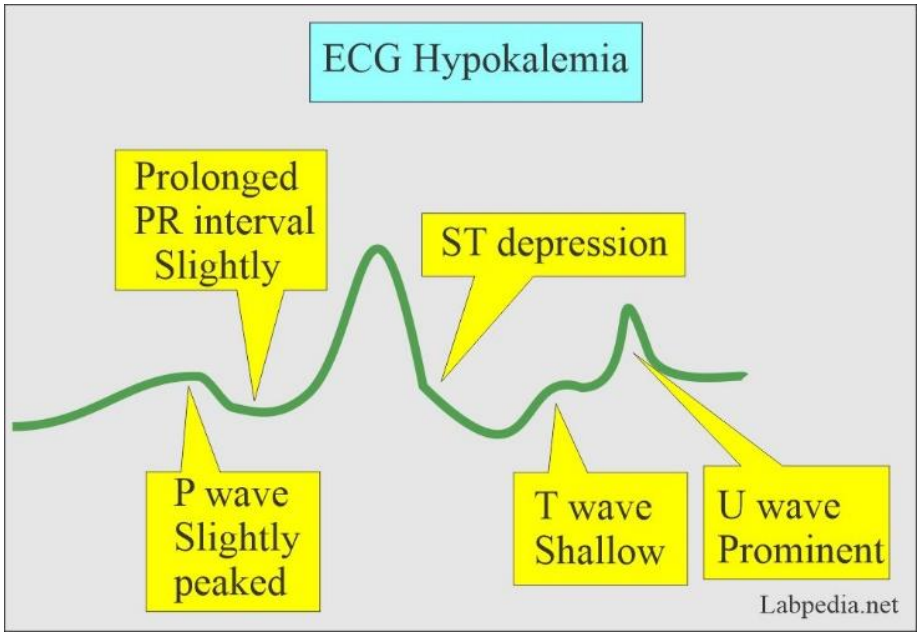
- **Symptoms include:**
- **Anorexia, nausea, muscle weakness and mental depression and confusion.**
- **There may be paralytic ileus(muscle contractions that move food through the intestines are temporarily paralyzed).**
- **Cardiovascular signs are irregular pulse and fall in BP.**
- **Hypokalemia → low insulin secretion → hyperglycemia.**
- **These changes are not specific but may pose a potentially fatal problem (with K^+ levels less than 1.5 mmol /L)**

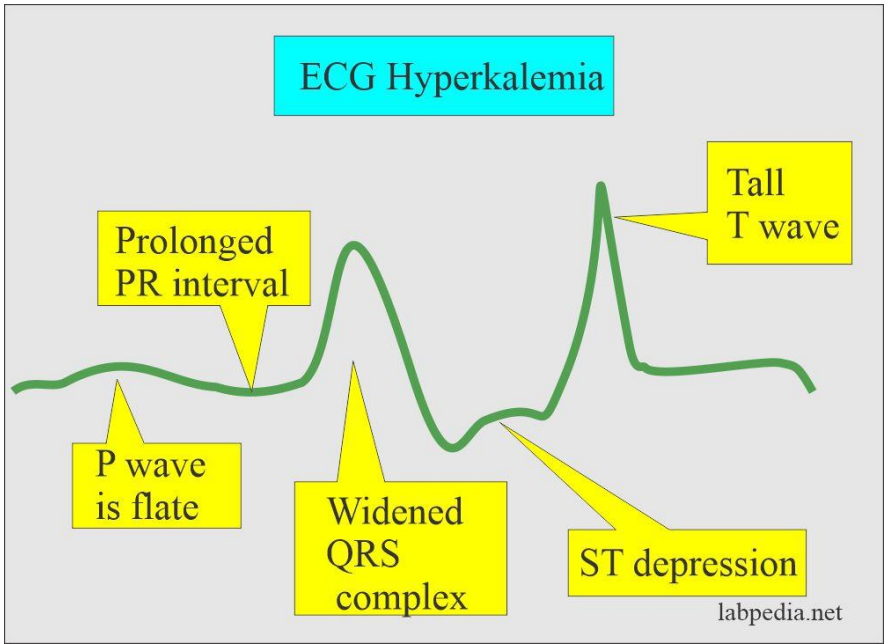
Hypokalemia

- Changes In ECG In Hypokalemia are the Following :

1. T – waves are depressed/inverted due to delayed vent repolarization
2. P – wave has peaked.
3. ST – depression.
4. U- appearance prominence of U wave.

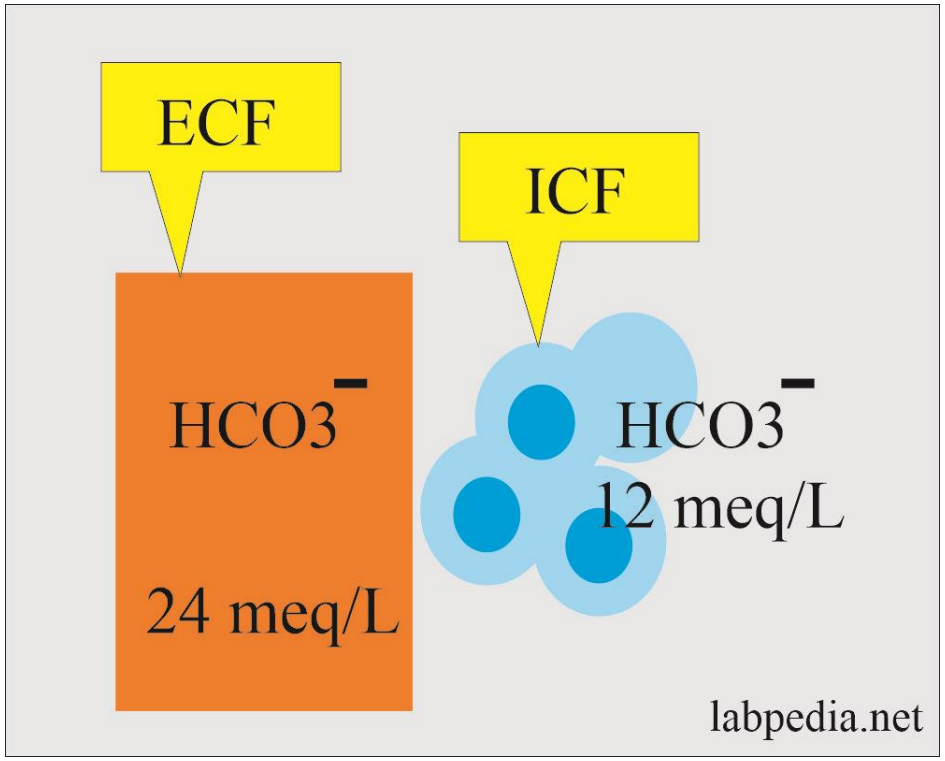
- Severe hypokalemia →prolonged PR interval, decreased voltage and ventricular arrhythmias





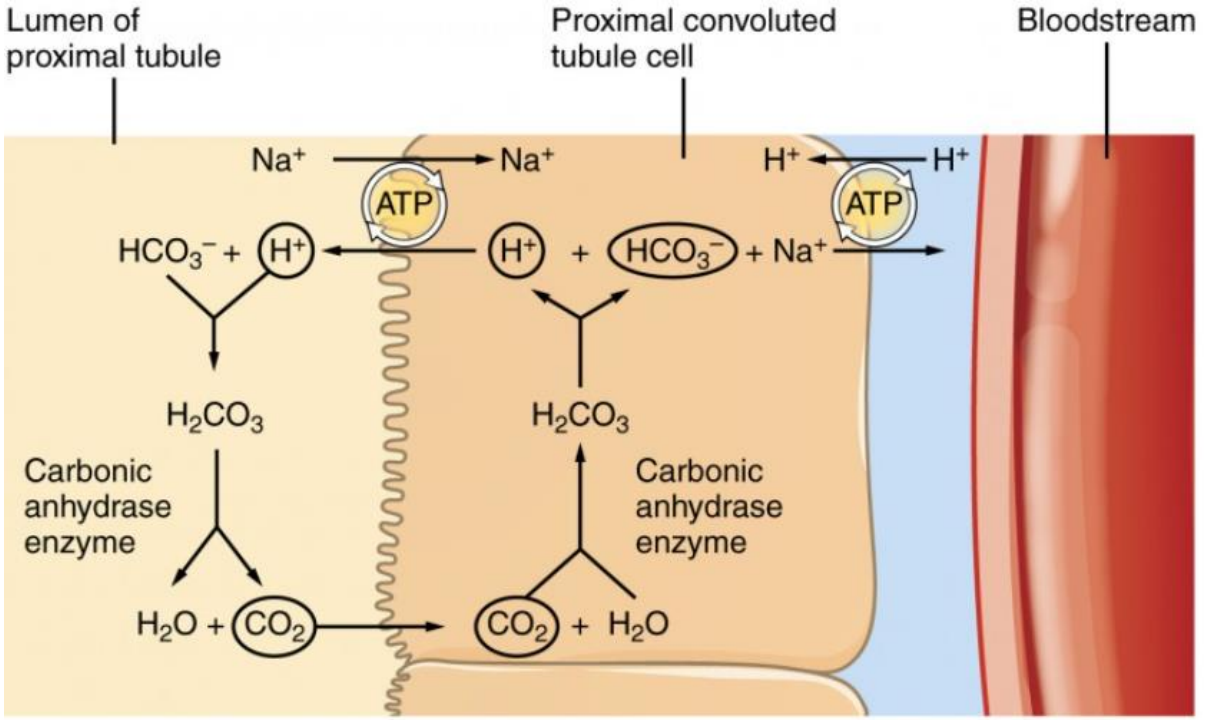
Bicarbonate

- Second most abundant anion (after chloride) in the ECF
- Total CO2 comprises the **bicarbonate ion (HCO3), carbonic acid (H2CO3),** and **dissolved CO2**, with HCO3 accounting for more than 90% of the total CO2 at physiologic pH.
- Because HCO3 composes the largest fraction of total CO2, total CO2 measurement is indicative of HCO3 measurement.

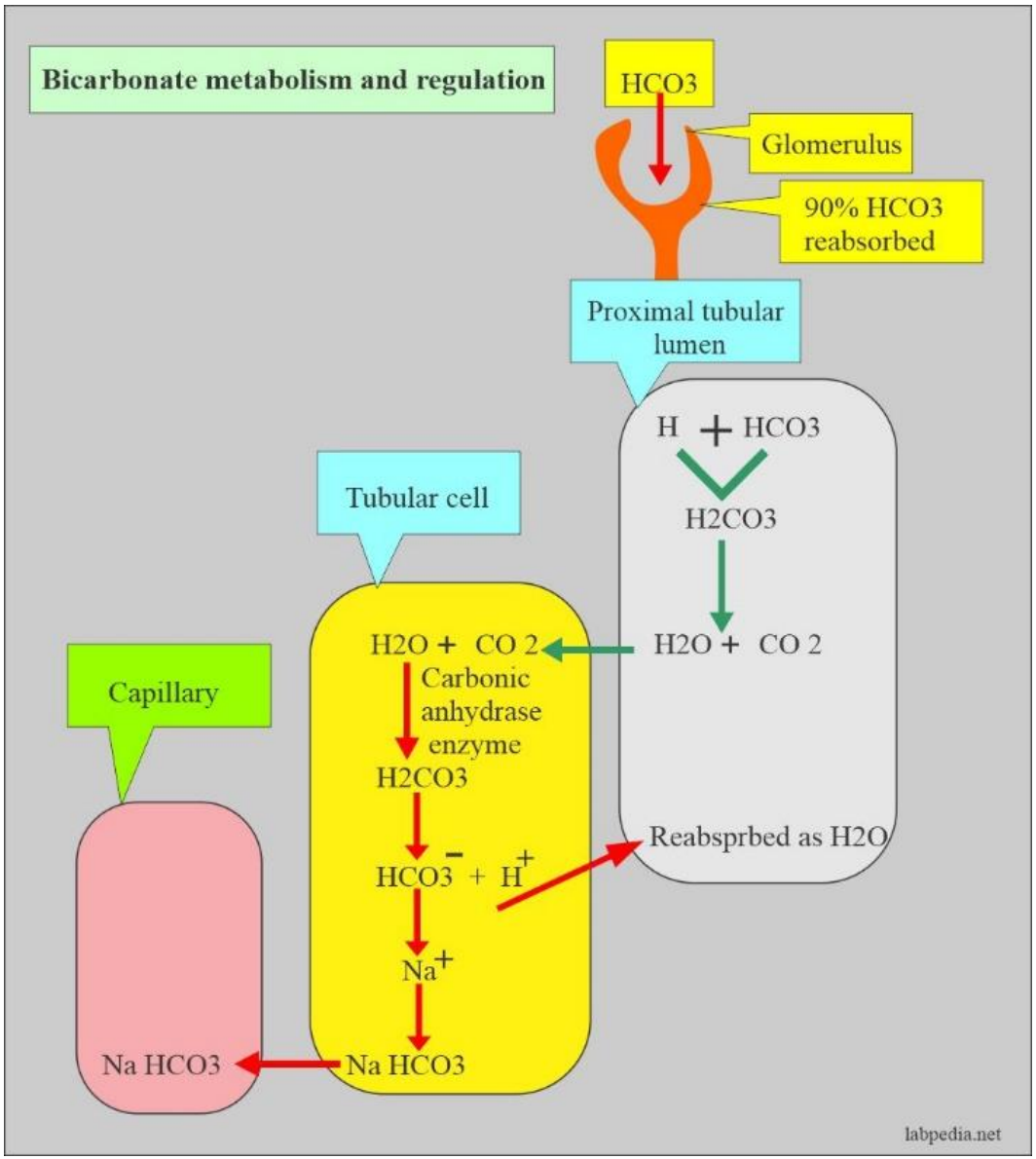


Bicarbonate as Buffer

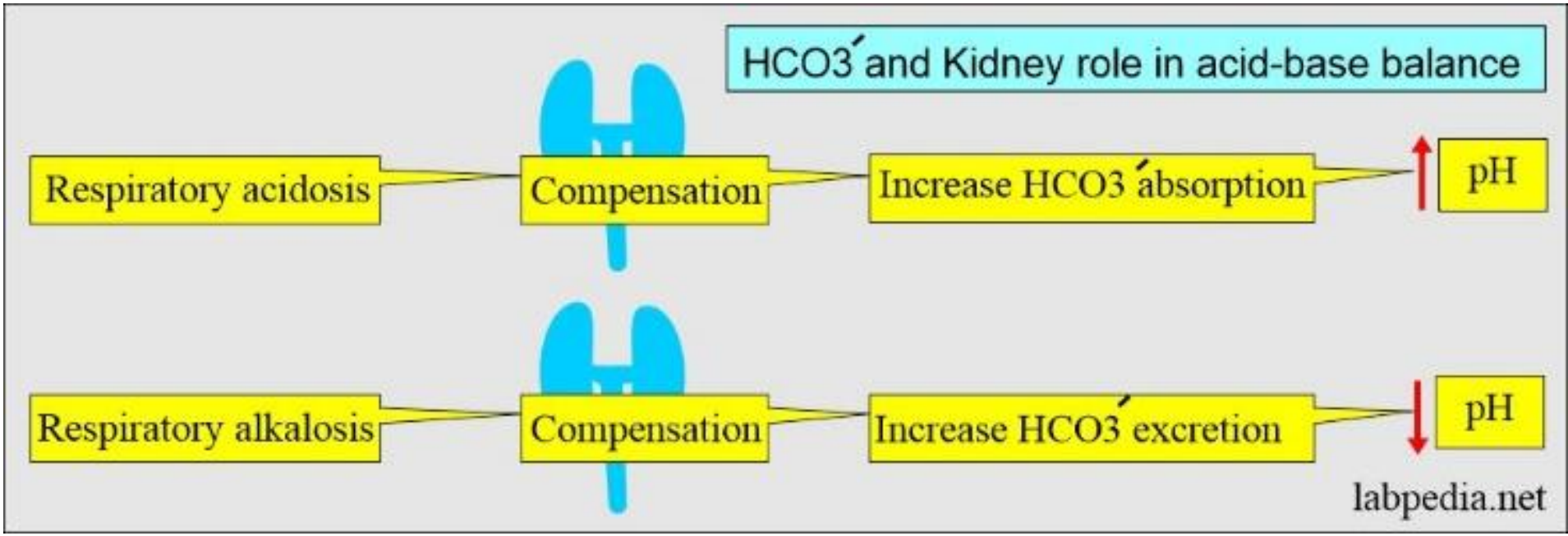
- HCO3 is the major component of the buffering system in the blood.
- Carbonic anhydrase in RBCs converts CO2 and H2O to carbonic acid, which dissociates into H+ and HCO3 .
- CO2 + H2O ←–CA→ H2CO3 ←–CA→ H+ HCO3 CA, carbonic anhydrase
- HCO3 diffuses out of the cell in exchange for Cl to maintain ionic charge neutrality within the cell (chloride shift)



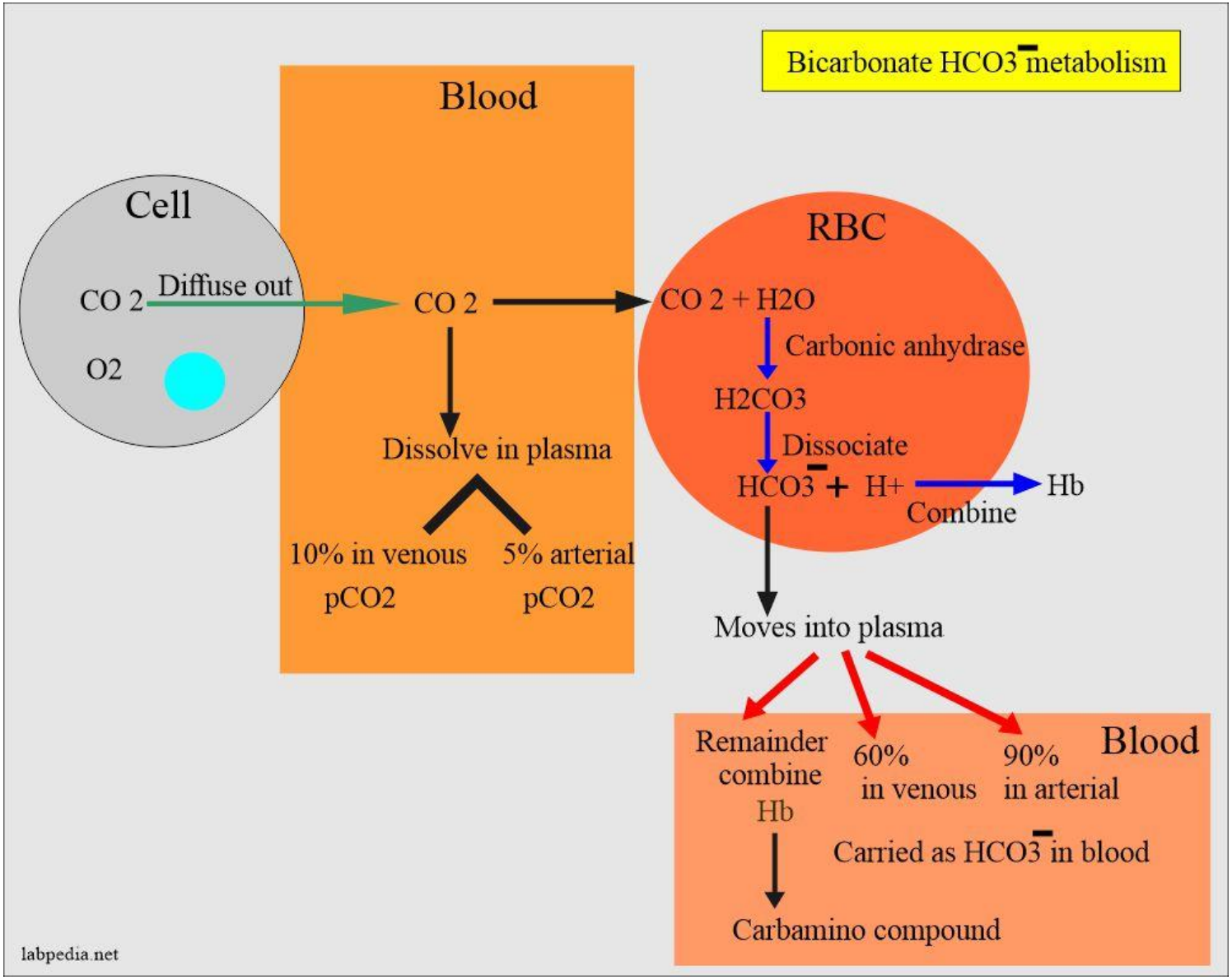
Bicarbonate Metabolism & Absorption



Bicarbonate Metabolism & Absorption

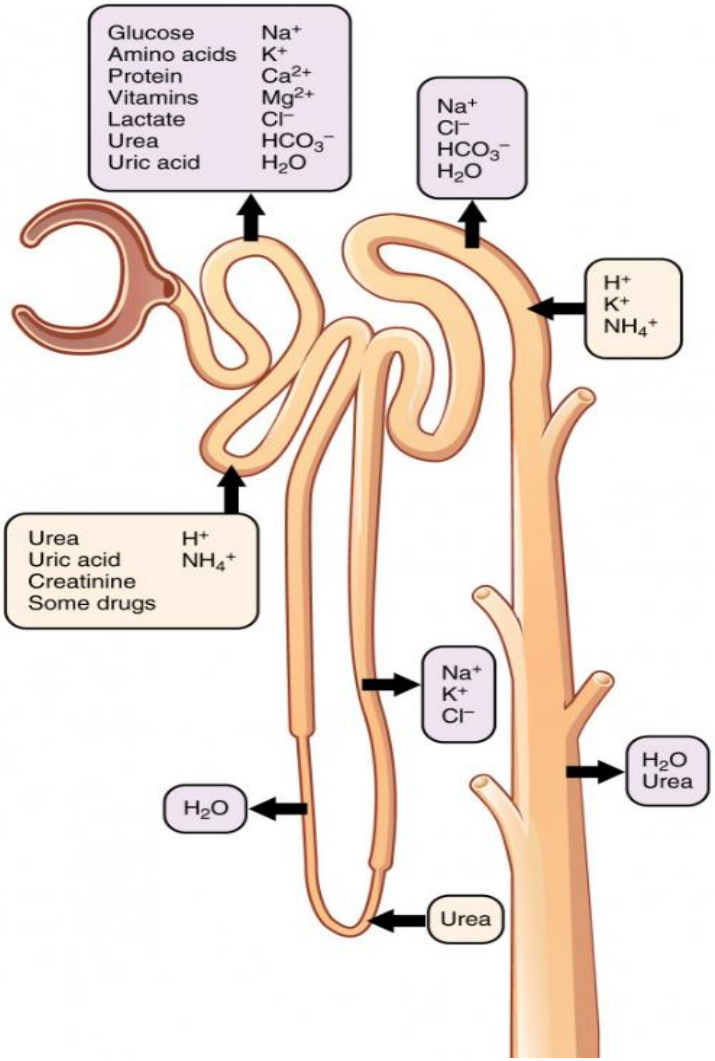


Bicarbonate Metabolism



Secretion and Reabsorption in the Nephron

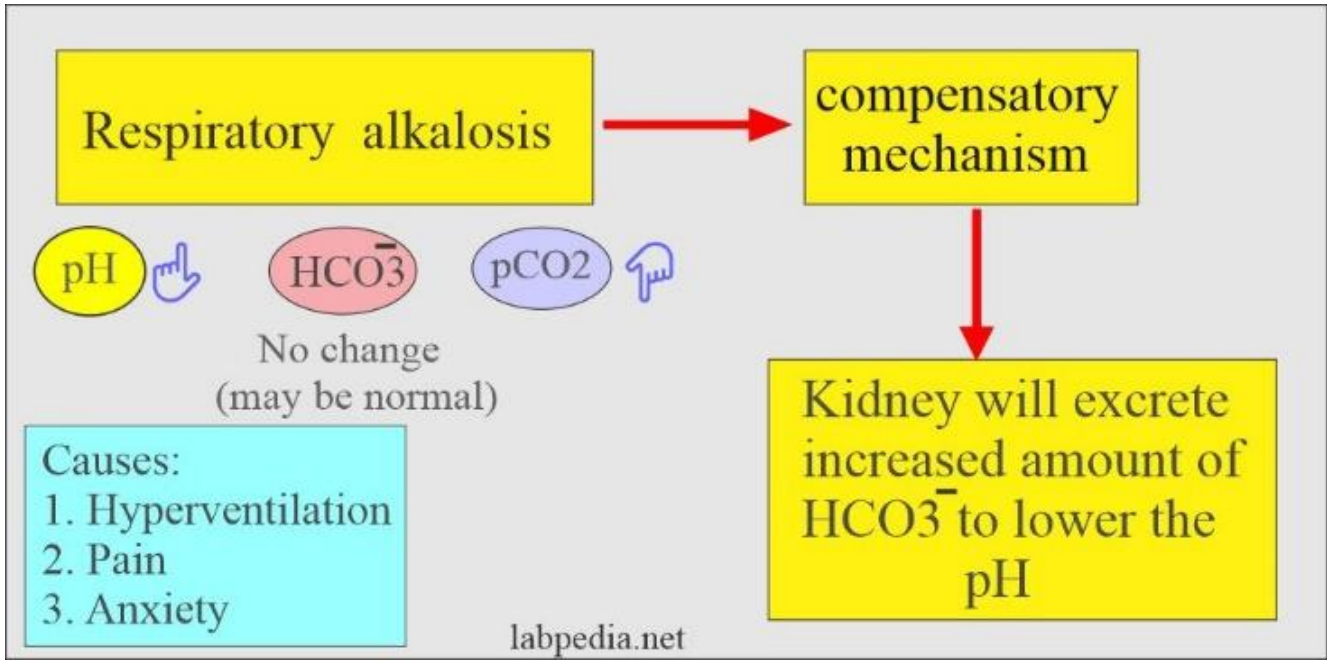
- **Locations of Secretion and Reabsorption in the Nephron.**
- **Arrows pointing away from the tubule indicate substances that are returning to the blood.**
- **Arrows pointing towards the tubule indicate additional substances being removed from the blood and moved into the filtrate.**



Clinical Correlates

Bicarbonate as a Buffer

- Converts potentially toxic CO2 in the plasma to an effective buffer: HCO3 .
- In alkalosis, with a relative increase in HCO3 compared to CO2, the kidneys increase excretion of HCO3 into the urine, carrying along a cation such as Na.
- This loss of HCO3 from the body helps correct pH

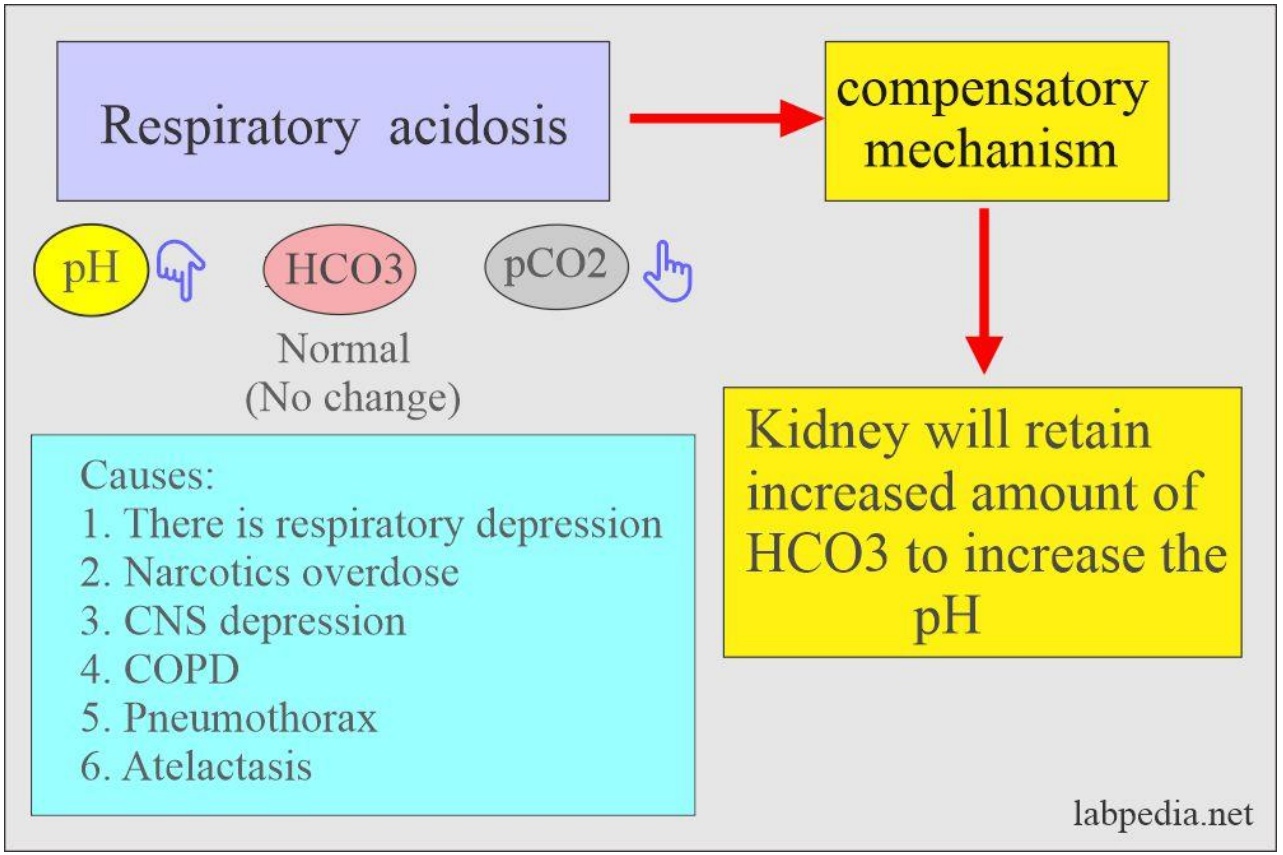


HCO3 buffers excess H by combining with acid, then eventually dissociating into H2O and CO2 in the lungs where the acidic gas CO2 is eliminated.

Clinical Correlates

Bicarbonate as a Buffer

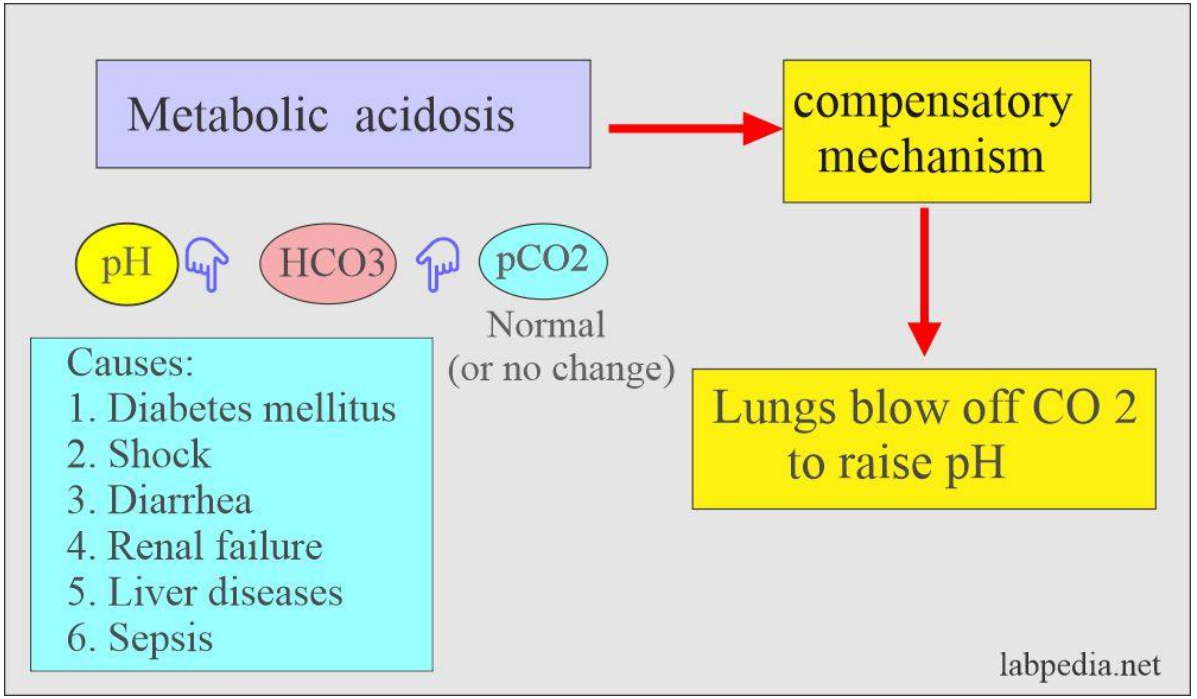
- Among the responses of the body to **acidosis** is an increased excretion of H into the urine.
- In addition, HCO3 reabsorption is virtually complete, with 90% of the filtered HCO3 reabsorbed in the proximal tubule and the remainder in the distal tubule



Clinical Correlates

Bicarbonate Buffer System

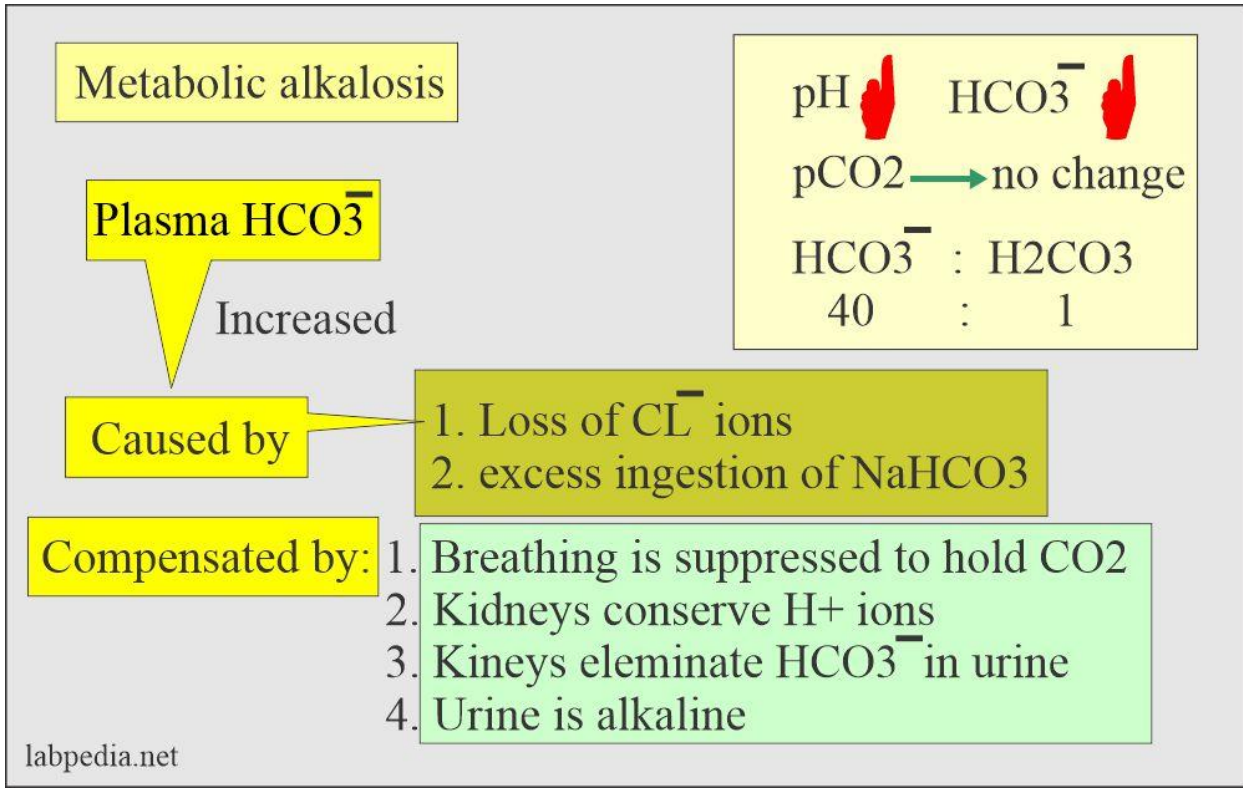
- Acid-base imbalances cause changes in HCO3 and CO2 levels.
- A **decreased HCO3** may occur from **metabolic acidosis** as HCO3 combines with H to produce CO2, which is exhaled by the lungs.
- The typical response to **metabolic acidosis** is compensation by hyperventilation, which lowers pCO2.



Clinical Correlates

Bicarbonate Buffer System

- Elevated total CO2 concentrations occur in **metabolic alkalosis** as HCO3 is retained, often with increased pCO2 as a result of compensation by hypoventilation. Typical causes of **metabolic alkalosis** include severe vomiting, hypokalemia, and excessive alkali intake



Management of Metabolic Alkalosis

Correct underlying cause:
•Identify and treat the cause (e.g., vomiting, diuretic use, or electrolyte imbalances).

Restore fluid and electrolyte balance:
Administer intravenous fluids (e.g., normal saline) to correct dehydration and electrolyte abnormalities, especially low potassium or chloride.

Acidifying agents:
In severe cases, administer medications like hydrochloric acid or acetazolamide to help lower the pH.

Discontinue causative drugs:
If diuretics or antacids are causing alkalosis, stop or adjust them as necessary.

Role of AI in Management of Hypertension

- AI can potentially aid in **enhancing diagnostic accuracy and efficiency.**
- AI-powered decision support systems can also help clinicians in **selecting appropriate treatment modalities**
- AI-driven predictive models may help **anticipate the risk of complications of the Disease** in susceptible populations

Ethical Considerations

- From an ethical standpoint, the scenario raises considerations regarding **patient autonomy**, **informed consent**, and **confidentiality**
- The physician must ensure that patient fully understands her diagnosis, treatment options, and potential implications
- Discuss the necessity of a healthy lifestyle & treatment plan. This requires clear communication and understanding of risks and benefits.
- Additionally, the physician must respect patient's privacy and confidentiality throughout the diagnostic and treatment process

Suggested Research Article

Link:

https://www.ncbi.nlm.nih.gov/books/NBK482291/

Journal Name: StatPearls [Internet]. 2023 July.

Title:

Physiology, Metabolic Alkalosis

Author Names:

- Joshua E. Brinkman;
- Sandeep Sharma

Abstract:

- Normal human physiological pH is 7.35 to 7.45. A decrease in pH below this range is acidosis, an increase over this range is alkalosis. Metabolic alkalosis is defined as a disease state where the body's pH is elevated to greater than 7.45 secondary to some metabolic process. Before going into details about pathology and this disease process, some background information about the physiological pH buffering process is important. The primary pH buffer system in the human body is the bicarbonate (HCO3)/carbon dioxide (CO2) chemical equilibrium system. Where:
- H + HCO3 <--> H2CO3 <--> CO2 + H2O
- HCO3 functions as an alkalotic substance. CO2 functions as an acidic substance. Therefore, increases in HCO3 or decreases in CO2 will make blood more alkalotic. The opposite is also true where decreases in HCO3 or an increase in CO2 will make blood more acidic. CO2 levels are physiologically regulated by the pulmonary system through respiration, whereas the HCO3 levels are regulated through the renal system with reabsorption rates. Therefore, metabolic alkalosis is an increase in serum HCO3

Learning Resources

- Essentials of Medical Biochemistry by Mushtaq Ahmed. Ninth edition, Vol 2, chapter 13, pages 201-205.
- BIOCHEMISTRY Lippincott Illustrated Reviews, Eighth Edition, Page 448
- Harper's Illustrated Biochemistry 32nd Edition
- Google Scholar
- Google Images

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5. Select your desired Institute.

6. A page will appear showing the resources of the institution

7. Journals and Researches will appear

8. You can find a Journal by clicking on JOURNALS AND DATABASE and enter a keyword to search for your desired journal.


Thank You!