UNIT-3 ROLE OF KIDNEY IN ACID BASE BALANCE

- Kidney plays an important role in maintenance of acid base balance by excreting hydrogen ions and retaining bicarbonate ions.
- Normally, urine is acidic in nature with a pH of 4.5 to 6.
- Metabolic activities in the body produce large quantity of acids (with lot of hydrogen ions), which threaten to push the body towards acidosis.

Kidneys prevent this by two ways:

- Reabsorption of bicarbonate ions (HCO_3^-)
- Secretion of hydrogen ions (H^+).

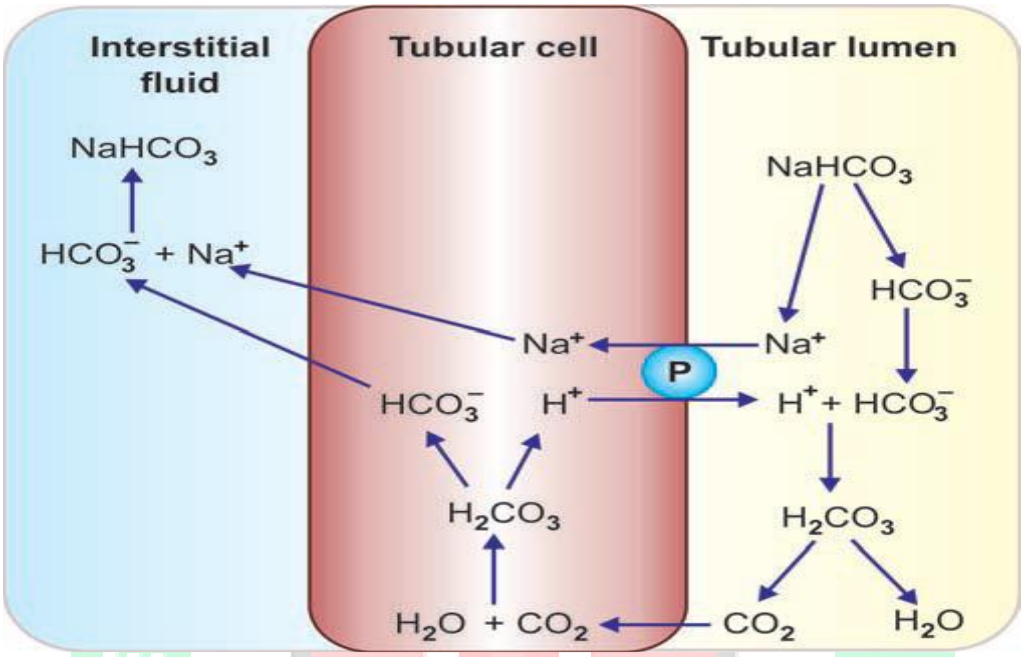
REABSORPTION OF BICARBONATE IONS

- About 4,320 mEq of HCO_3^- is filtered by the glomeruli everyday. It is called filtered load of HCO_3^-.
- Excretion of this HCO_3^- in urine will affect the acid-base balance of body fluids.
- So, HCO_3^- must be taken back from the renal tubule by reabsorption.

SECRETION OF HYDROGEN IONS

- Reabsorption of filtered HCO_3^- occurs by the secretion of H^+ in the renal tubules.
- About 4,380 mEq of H^+ appear every day in the renal tubule by means of filtration and secretion. Not all the H^+ are excreted in urine.
- Out of 4,380 mEq, about 4,280 to 4,330 mEq of H^+ is utilized for the reabsorption of filtered HCO_3^-.
- Only the remaining 50 to 100 mEq is excreted. It results in the acidification of urine.
- Secretion of H^+ into the renal tubules occurs by the formation of carbonic acid. Carbon dioxide formed in the tubular cells or derived from tubular fluid combines with water to form carbonic acid in the presence of **carbonic anhydrase.**

- This enzyme is available in large quantities in the epithelial cells of the renal tubules. The carbonic acid immediately dissociates into H+ and HCO3 –.



H+ is secreted into the lumen of proximal convoluted tubule, distal convoluted tubule and collecting duct. Distal convoluted tubule and collecting duct have a special type of cells called **intercalated cells (I cells)** that are involved in handling hydrogen and bicarbonate ions.

Secretion of H+ occurs by two pumps:

i. Sodium-hydrogen antiport pump

ii. ATP-driven proton pump.

<u>Sodium-hydrogen antiport pump</u>

When sodium ion (Na+) is reabsorbed from the tubular fluid into the tubular cell, H+ is secreted from the cell into the tubular fluid in exchange for Na+. The sodium hydrogen antiport pump present in the tubular cells is responsible for the exchange of Na+ and H+. This type of sodium-hydrogen counter transport occurs predominantly in distal convoluted tubule.

ATP-driven proton pump

This is an additional pump for H+ secretion in distal convoluted tubule and collecting duct. This pump operates by energy from ATP.

REMOVAL OF HYDROGEN IONS AND ACIDIFICATION OF URINE

Role of Kidney in Preventing Metabolic Acidosis

Kidney plays an important role in preventing metabolic acidosis by excreting H+.

Excretion of H+ occurs by three mechanisms:

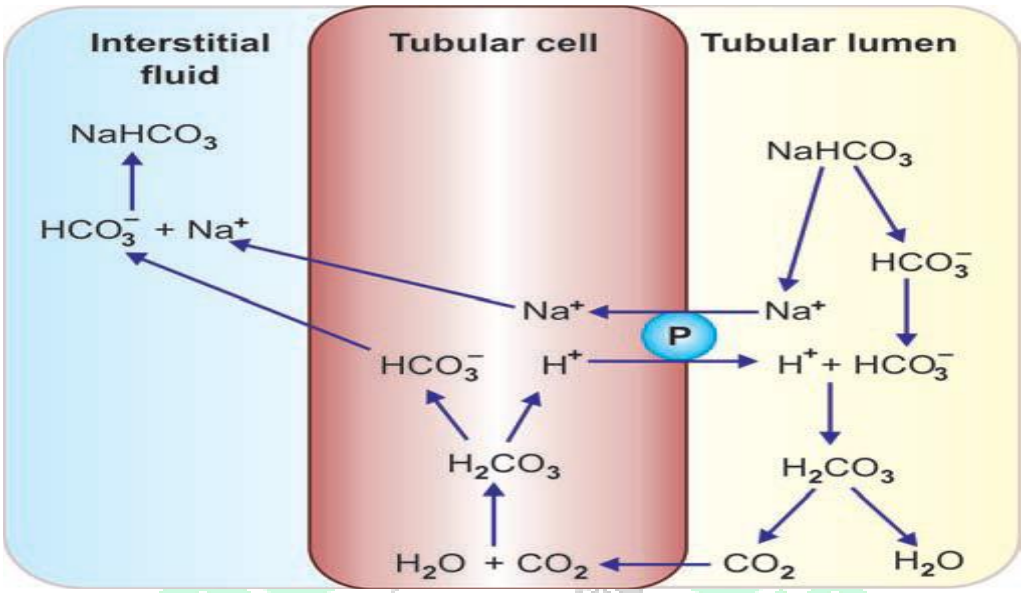
1. Bicarbonate mechanism

2. Phosphate mechanism

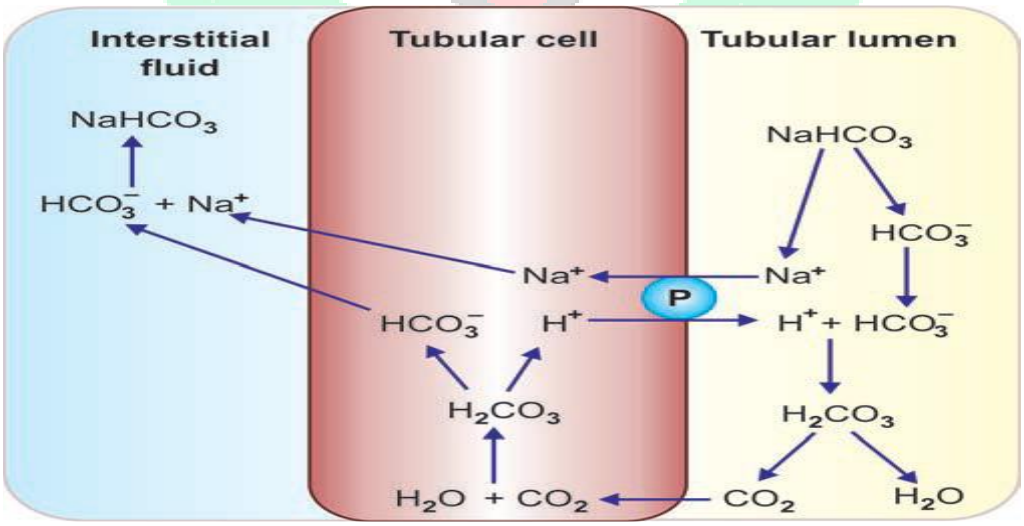
3. Ammonia mechanism.

BICARBONATE MECHANISM

- All the filtered HCO3– in the renal tubules is reabsorbed. About 80% of it is reabsorbed in proximal convoluted tubule, 15% in Henle loop and 5% in distal convoluted tubule and collecting duct.
- The reabsorption of HCO3– utilizes the H+ secreted into the renal tubules. H+ secreted into the renal tubule, combines with filtered HCO3 – forming carbonic acid (H2CO3).
- Carbonic acid dissociates into carbon dioxide and water in the presence of carbonic anhydrase.
- Carbon dioxide and water enter the tubular cell. In the tubular cells, carbon dioxide combines with water to form carbonic acid.

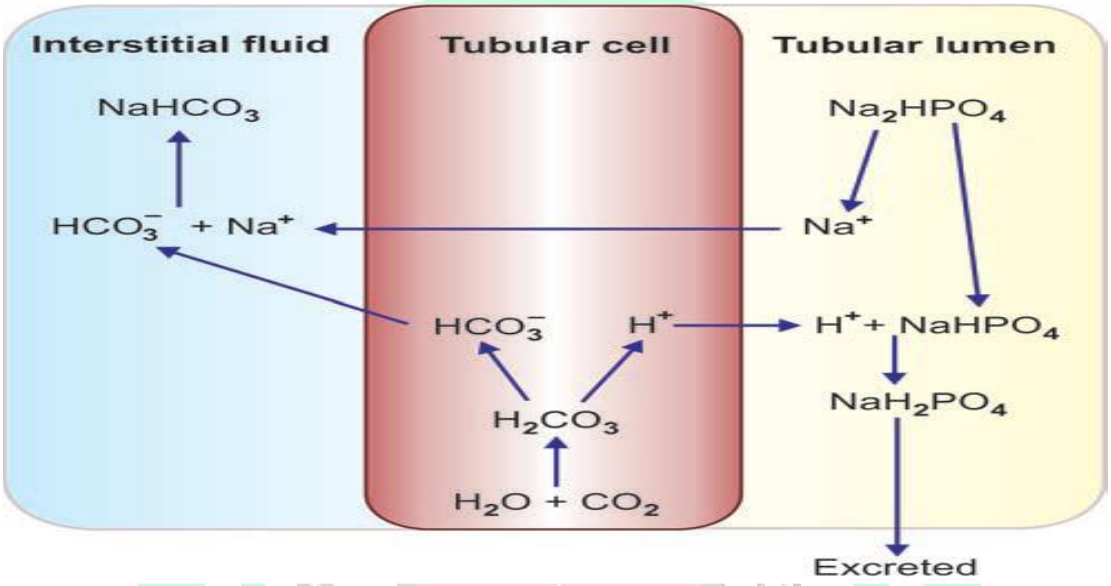


- It immediately dissociates into H+ and HCO3–. HCO3– from the tubular cell enters the interstitium.
- Simultaneously Na+ is reabsorbed from the renal tubule under the influence of aldosterone. HCO3– combines with Na+ to form sodium bicarbonate (NaHCO3).
- Now, the H+ is secreted into the tubular lumen from the cell in exchange for Na+.
- Thus, for every hydrogen ion secreted into lumen of tubule, one bicarbonate ion is reabsorbed from the tubule. In this way, kidneys conserve the HCO3.
- The reabsorption of filtered HCO3– is an important factor in maintaining pH of the body fluids.

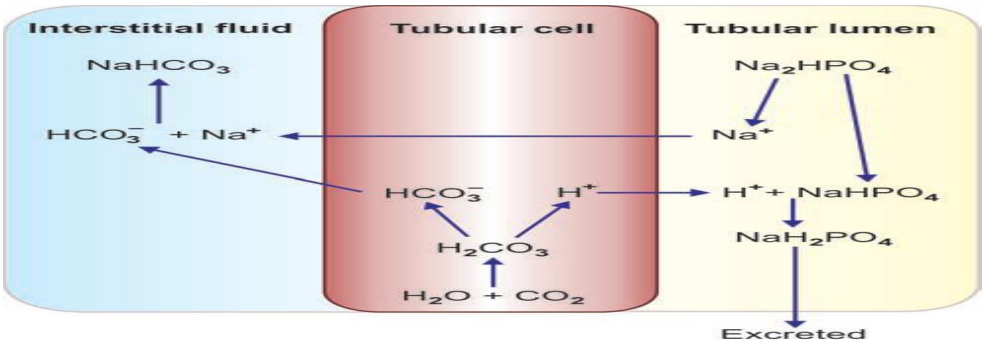


PHOSPHATE MECHANISM

- In the tubular cells, carbon dioxide combines with water to form carbonic acid. It immediately dissociates into H+ and HCO3–. HCO3 – from the tubular cell enters the interstitium.
- Simultaneously, Na+ is reabsorbed from renal tubule under the influence of aldosterone. Na+ enters the interstitium and combines with HCO3–. H+ is secreted into the tubular lumen from the cell in exchange for Na+.

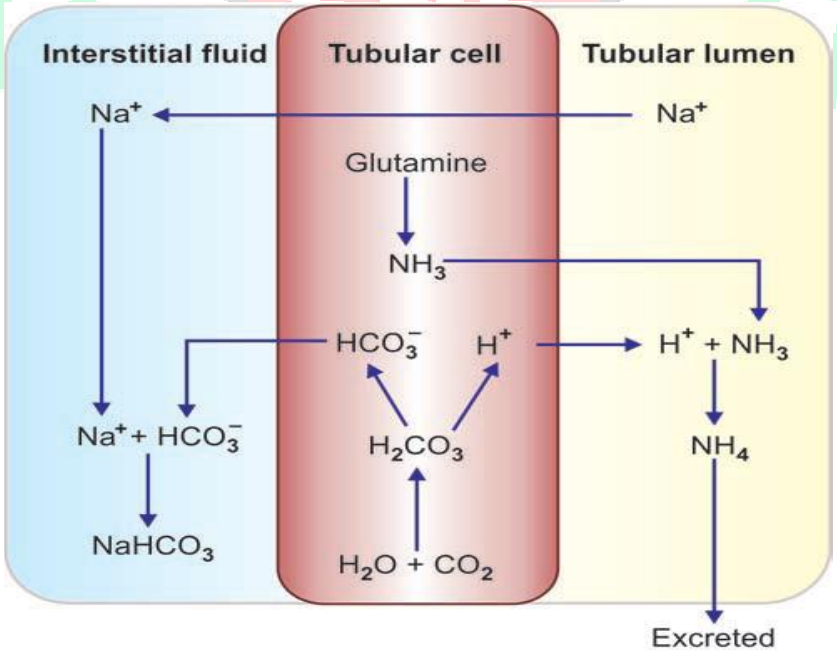


- H+, which is secreted into renal tubules, reacts with phosphate buffer system.
- It combines with sodium hydrogen phosphate to form sodium dihydrogen phosphate.
- Sodium dihydrogen phosphate is excreted in urine. The H+, which is added to urine in the form of sodium dihydrogen, makes the urine acidic.
- It happens mainly in distal tubule and collecting duct because of the presence of large quantity of sodium hydrogen phosphate in these segments.



AMMONIA MECHANISM

- This is the most important mechanism by which kidneys excrete H+ and make the urine acidic.
- In the tubular epithelial cells, ammonia is formed when the amino acid glutamine is converted into glutamic acid in the presence of the enzyme glutaminase.
- Ammonia is also formed by the deamination of some of the amino acids such as glycine and alanine.
- Ammonia (NH3) formed in tubular cells is secreted into tubular lumen in exchange for sodium ion. Here, it combines with H+ to form ammonium (NH4).



- The tubular cell membrane is not permeable to ammonium. Therefore, it remains in the lumen and then excreted into urine.

- Thus, H+ is added to urine in the form of ammonium compounds resulting in acidification of urine. For each NH4 excreted one HCO3– is added to interstitial fluid.
- This process takes place mostly in the proximal convoluted tubule because glutamine is converted into ammonia in the cells of this segment.
- Thus, by excreting H+ and conserving HCO3–, kidneys produce acidic urine and help to maintain the acid-base balance of body fluids.