REMOVAL OF HYDROGEN IONS AND ACIDIFICATION OF URINE

Role of Kidney in Preventing Metabolic Acidosis

Kidney plays an important role in preventing metabolic acidosis (Chapter 5) by excreting H^+.

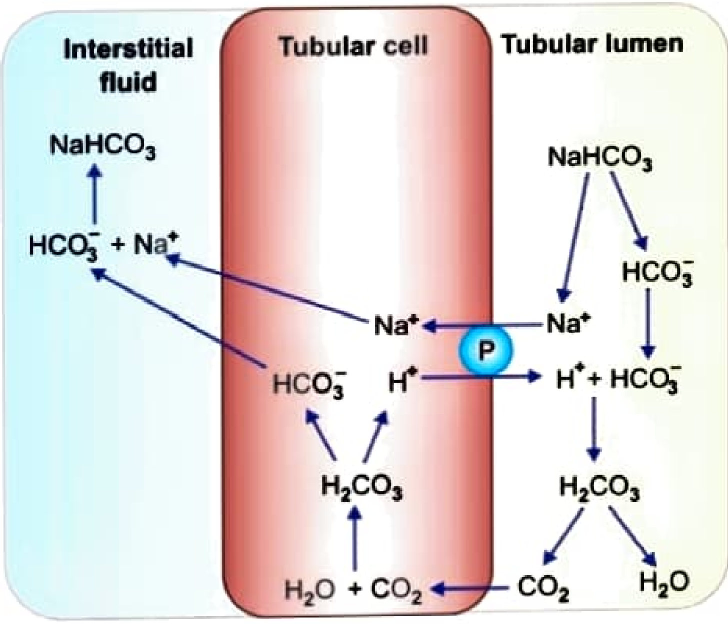

FIGURE 54.1: Reabsorption of bicarbonate ions by secretion of hydrogen ions in renal tubule. P = sodium-hydrogen antiport pump

BICARBONATE MECHANISM

All the filtered HCO_3^- 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 HCO_3^- utilizes the H^+ secreted into the renal tubules.

H^+ secreted into the renal tubule, combines with filtered HCO_3^- forming carbonic acid (H_2CO_3). 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 HCO_3^-. HCO_3^- from the tubular cell enters the interstitium. Simultaneously Na^+ is reabsorbed from the renal tubule under the influence of aldosterone. HCO_3^- combines with Na^+ to form sodium bicarbonate ($NaHCO_3$). Now, the H^+ is secreted into the tubular lumen from the cell in exchange for Na^+ (Fig. 54.1).

Thus, for every hydrogen ion secreted into lumen of tubule, one bicarbonate ion is reabsorbed from the tubule. In this way, kidneys conserve the HCO_3^-. The reabsorption of filtered HCO_3^- 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 HCO_3^-. HCO_3^- 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 HCO_3^-. H^+ is secreted into the tubular lumen from the cell in exchange for Na^+ (Fig. 54.2).

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.

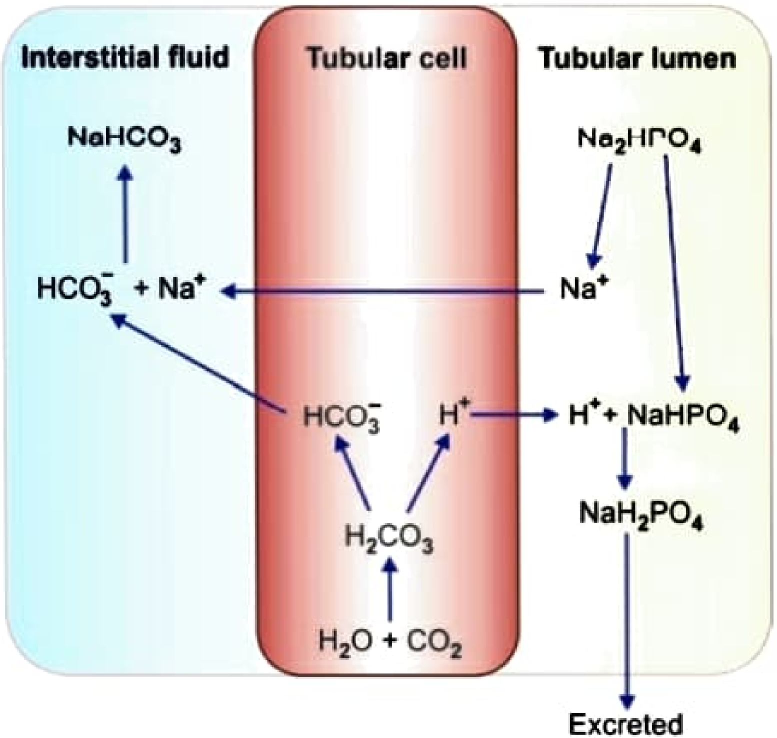

FIGURE 54.2: Excretion of hydrogen ions in combination with phosphate ions

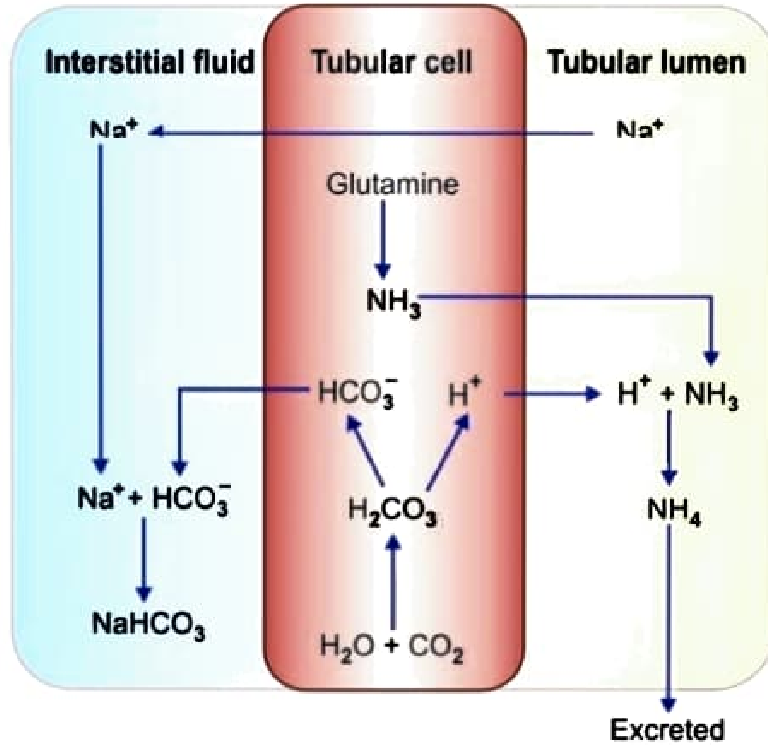

FIGURE 54.3: Excretion of hydrogen ions in combination with ammonia

■ 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 (Fig. 54.3).

Ammonia (NH_3) formed in tubular cells is secreted into tubular lumen in exchange for sodium ion. Here, it combines with H^+ to form ammonium (NH_4). 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 NH_4 excreted one HCO_3^- 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 HCO_3^-, kidneys produce acidic urine and help to maintain the acid-base balance of body fluids.