7.4.3

Kidneys

Our most powerful defense against changes in pH is the urinary system, specifically the kidneys. Of our three lines of defense, the urinary system is the only one that can restore all of the components to their normal values. It does this by either excreting or reabsorbing bicarbonate ions and hydrogen ions or through the production of new bicarbonate ions. Also, the kidney is responsible for excreting the non-volatile acids that are produced in the body each day. Unlike the blood buffers and the respiratory system which can respond within seconds or minutes to acid-base disturbances, the response of the kidneys takes more time, ranging from hours to days. The kidneys perform several important tasks in terms of regulating acid-base balance. First, they must reabsorb all the bicarbonate that is filtered each day (see the first image below). In the lumen of the PCT, filtered bicarbonate and hydrogen ions combine to form carbonic acid. Carbonic anhydrase (not shown) in the PCT lumen catalyzes the conversion of carbonic acid into carbon dioxide and water. The carbon dioxide (non-polar) can then diffuse into the PCT cell where carbonic anhydrase converts it back into carbonic acid, and subsequently bicarbonate and hydrogen ions. The hydrogen ion is then transported back into the PCT lumen in exchange for sodium ion and the sodium ion and bicarbonate co-transport back into the blood. The end result is the reabsorption of the filtered bicarbonate. Under normal conditions, virtually all of the filtered bicarbonate can be reabsorbed back into the blood. This process takes place primarily in the proximal convoluted tubules.

The kidneys are also able to produce new bicarbonate from carbon dioxide in the blood using carbonic anhydrase, or from the metabolism of the amino acid glutamate.

The other important functions of the kidneys pertain to their ability to secrete hydrogen ions while retaining bicarbonate ions or to secrete bicarbonate ions while retaining hydrogen ions. This is how the kidneys help balance blood pH. In the collecting ducts of the nephrons, there are two types of cells that are involved in regulating acid/base balance designated as Type A and Type B intercalated cells (bottom two images below). The type A cells are able to secrete H^+ while retaining HCO_3^-. The Type B cells do just the opposite, they retain H^+ while secreting HCO_3^-.

If you look closely at the two diagrams below you will notice that there is a difference in the location of the carriers that transport the various ions across the membranes. The factor that determines which cell is active is the pH of the blood. In conditions of acidosis, the cells that secrete H^+ into the nephron lumen are active, while in conditions of alkalosis, the cells that secrete HCO_3^- into the nephron are active. Notice that as H^+ is moving across the membranes, K^+ is moving the opposite direction. Another consequence of acid-base imbalances is that it can cause a disruption of normal K^+ concentrations in the body. Acidosis can result in hyperkalemia (too much K^+) and alkalosis can result in hypokalemia (too little K^+). Either condition can have tragic effects due to their effect on membrane potentials. It is important that the excreted H^+ be buffered in the urine. This is accomplished by the phosphate or ammonia buffer systems. This prevents the pH of the urine from becoming too low, which could damage the cells of the kidney tubules.

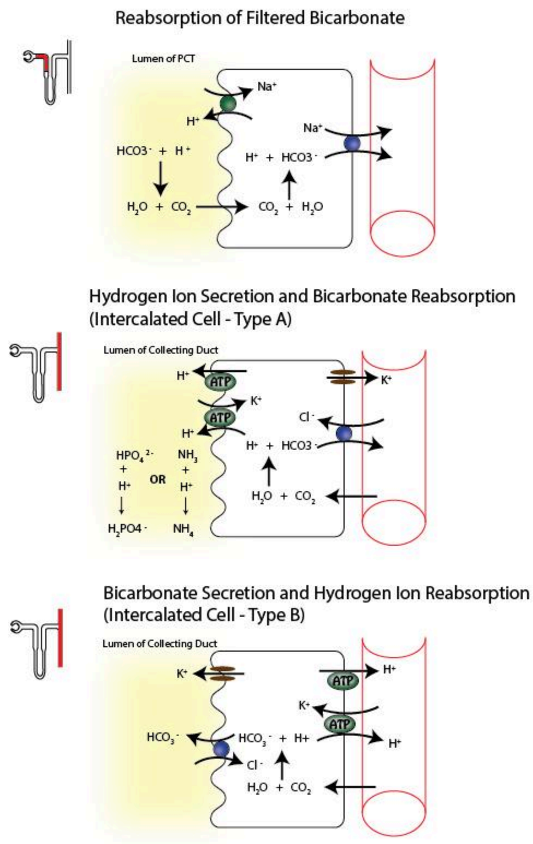

Image by J. Shaw at BYU-Idaho Spring 2014