Chapter 24 – Water, Electrolyte, and Acid-Base balance

Acids, Bases, and Buffers

One of the most important aspects of homeostasis:

- Metabolism depends on enzymes, and enzymes are sensitive to pH
- Slight deviation from the normal pH can shut down entire metabolic pathways
- Slight deviation from normal pH can alter the structure and function of macromolecules

7.35-7.45 is the normal pH range of blood and tissue fluid

Challenges to acid-base balance:

- Metabolism constantly produces acid
  - **Lactic acids** from anaerobic fermentation
  - **Phosphoric acid** from nucleic acid catabolism
  - **Fatty acids** and **ketones** from fat catabolism
  - **Carbonic acid** from carbon dioxide

pH of a solution is determined solely by its hydrogen ions (H^+)

Acids – any chemical that releases H^+ in solution
Strong acids such as hydrochloric acid (HCl) ionize freely

- Gives up most of its H^+
- Markedly lowers pH of a solution

Weak acids such as carbonic acid (H_2CO_3) ionize only slightly

- Keeps most H^+ chemically bound
- Small effects on pH

Bases – any chemical that accepts H^+
Strong bases, such as the hydroxide ion (OH^-), have a strong tendency to bind H^+, markedly raising pH
Weak bases, such as the bicarbonate ion (HCO_3^-), bind less available H^+ and have less effect on pH

Buffer – any mechanism that resists changes in pH: convert strong acids or bases to weak ones

Physiological buffer – system that controls output of acids, bases, or CO_2

- Urinary system: buffers greatest quantity of acid or base – takes several hours-days to exert its effect
- Respiratory system: buffers within minutes – cannot alter pH as much as the urinary system

Chemical buffer – a substance that binds H^+ and removes it from solution as its concentration begins to rise, or releases H^+ into solution as its concentration falls

- Restore normal pH in fractions of a second
- Functions as mixtures called buffer systems composed of weak acids and weak bases
- Three major chemical buffers: **bicarbonate**, **phosphate**, and **protein systems**
  - Amount of acid or base neutralized depends on the concentration of the buffers and the pH of the working environment

The bicarbonate buffer system – a solution of carbonic acid and bicarbonate ions

Carbonic acid and bicarbonate ions

Reversible reaction important in ECF

Functions best in the lungs and kidneys to constantly remove CO_2

- To lower pH, kidneys excrete HCO_3^-
- To raise pH, kidneys excrete H^+ and lungs excrete CO_2

Respiratory control of pH

Basis for the strong buffering capacity of the respiratory system

- The addition of CO_2 to the body fluids raises the H^+ concentration and lowers pH
- The removal of CO_2 has the opposite effects

Respiratory system neutralizes 2-3 times as much acid as chemical buffers

CO_2 is constantly produced by aerobic metabolism

- Normally eliminated by the lungs at an equivalent rate

Increased CO_2 and decreased pH stimulate pulmonary ventilation, while an increased pH inhibits pulmonary ventilation

The kidneys can neutralize more acid or base than either the respiratory system of chemical buffers

Renal tubules secrete H^+ into the tubular fluid

- Most binds to bicarbonate, ammonia, and phosphate buffers
- Bound and free H^+ are excreted in the urine actually expelling H^+ from the body
- Other buffer systems only reduce its concentration by binding it to other chemicals