Acid/Base Balance

some of most critical ions in body fluids are H⁺ (hydrogen) and OH⁻ (hydroxyl) ions

the concentrations of these two ions affect the acidity or alkalinity of body fluids

acidity/alkalinity is measured on pH scale
  1pH unit = 10 fold change in [H⁺]
  pH of 7 is neutral
  pH < 7: more H⁺, fewer OH⁻
  pH > 7: fewer H⁺, more OH⁻

large organic molecules, especially proteins, are extremely sensitive to changes in pH
  → easily denatured

since proteins serve a wide variety of roles in the body (enzymes, fibers, carriers, hormones, oxygen transport, immunity, etc)
  → variations in pH affect almost every aspect of physiology and cell metabolism

even slight changes in pH can be fatal
  blood = 7.35 – 7.45
  ≤7 or ≥7.8 is fatal

various acids and bases continually enter and leave body:
  in foods and drink
  gastric secretions
  bicarbonates from pancreas
  etc

need some mechanism to neutralize them:

body is protected against large changes in pH in two step process:
  1. buffers – absorb excess hydrogen or hydroxyl ions to prevent drastic changes in pH
  2. elimination – acids (or bases) are removed from body by:
     kidneys - can secrete H⁺ and HCO₃⁻
     lungs - as CO₂ is eliminated H⁺ are converted to water
     skin - can excrete some acids in sweat

Buffers
A buffer is a substance that prevents marked changes in pH of a solution when acids or bases are added.

\[
\text{eg. 1 drop of HCl in pure water} \\
\text{pH} = 7 \quad \rightarrow \quad 3.5 \\
\text{1 drop of HCl in plasma} \\
\text{pH} = 7.41 \quad \rightarrow \quad 7.27
\]

→ blood is buffered

Buffers act by combining with strong acids or bases and taking them out of solution

→ “absorbs” the H or OH ions

Buffers consist of weak acid and its salt

Major buffers in body fluids:
- Bicarbonate
- Phosphate
- Hemoglobin
- Plasma proteins

All buffers have limited capacity

Buffering alone cannot maintain homeostasis indefinitely

At some point the acids and bases must actually be removed from the body

Two main removal systems:
1. Respiratory Mechanisms
2. Excretory Mechanisms

**Respiratory Mechanisms**

Respiration plays a vital role in removing excess acids

With each expiration, CO₂ and therefore H⁺ are removed

\[
\text{carbonic anhydrase} \\
\text{CO}_2 + \text{H}_2\text{O} \longrightarrow \text{H}_2\text{CO}_3 \longrightarrow \text{H}^+ + \text{HCO}_3^-
\]

pH receptors in arteries can increase or decrease respiratory rate based on buildup of acids in blood

Acidosis → stimulates hyperventilation
Excretory Mechanisms

cells of DCT and CT can secrete H⁺ & HCO₃⁻

if blood pH decreases below normal levels tubules will increase secretion of H⁺

more efficient mechanism than respiratory system

usually urine is slightly acidic
→ normal diet produces more acid than alkaline waste products

Acid/Base Imbalances

1. Acidosis
   → accumulation of excess acids
   → excessive loss of bases

   a. Respiratory Acidosis
      factors that cause buildup of CO₂ in blood

      generally due to factors that hinder pulmonary ventilation

      symptoms:
      labored breathing
cyanoisis
depression of CNS → drowsiness, disorientation
coma → death

      can be compensated for by kidneys

   b. Metabolic Acidosis
      accumulation of non-respiratory acids or
      excessive loss of bases
      eg. poor kidney function
      prolonged diarrhea
      severe vomiting → loss of duodenal fluids
      diabetes mellitus → ketone bodies are acidic

2. Alkalosis
   → accumulation of excess bases
   → excessive loss of acids

   a. Respiratory Alkalosis
      caused by hyperventilation
      anxiety
      fever
some poisonings

**symptoms:**
light headedness
agitation
tingling
dizziness

**b. Metabolic Alkalosis**
caused by:
- gastric drainage (lavage)
- prolonged vomiting of stomach contents
- too many antacids
Summary of Acid-Base Homeostasis

<table>
<thead>
<tr>
<th>Acids produced by Metabolism</th>
<th>Acids produced by respiration</th>
<th>Acids in foods and drinks</th>
<th>Excessive loss or gain of acids or bases</th>
</tr>
</thead>
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- Breathing Rate
  - Stimulated by CO₂ & H⁺ ions
  - Regulates CO₂ in plasma

- Tubular Secretion
  - Secrete excess H⁺ or HCO₃⁻ into urine
  - Regulates pH of blood

Buffers
- [bicarbonates; phosphates; proteins]

Acids and Bases combine with chemical buffers to prevent harmful changes in pH and allow time for lungs and kidneys to remove them.

Acid/Base Homeostasis