

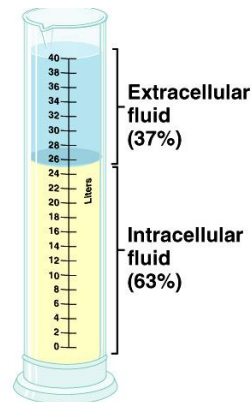
Anatomy and Physiology

Body Fluids and Regulation of Acid - Base Balance

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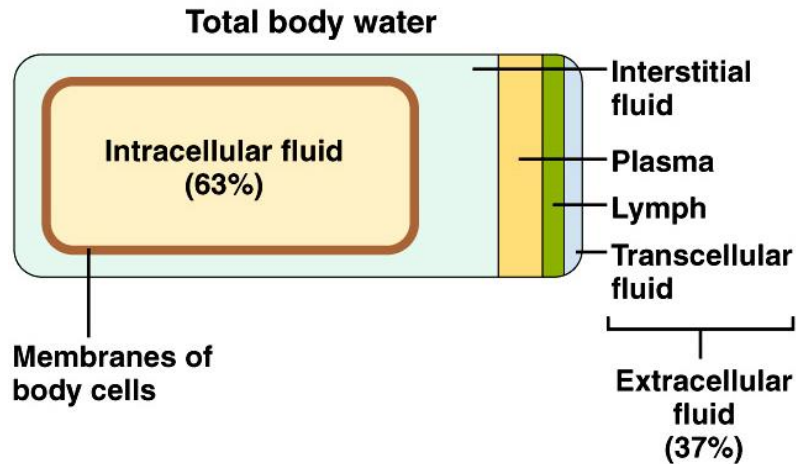
Water, Electrolyte, and Acid-Base Balance

Of the 40 liters of water in the body of an average adult male, about two-thirds is **intracellular**, and one-third is **extracellular**



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Fluid Compartments



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Body Fluids

ECF Present as

- (i) plasma, the fluid in the vascular system in which blood cells are bathed and
- (ii) (ii) interstitial fluid, the fluid that lies in the spaces between the cells in the tissues and outside the vascular system such as lymph.

ICF Present as fluid found within the cells in all parts of the body.

Blood contains **both ECF** (plasma) and **ICF** (fluid inside the blood cells).

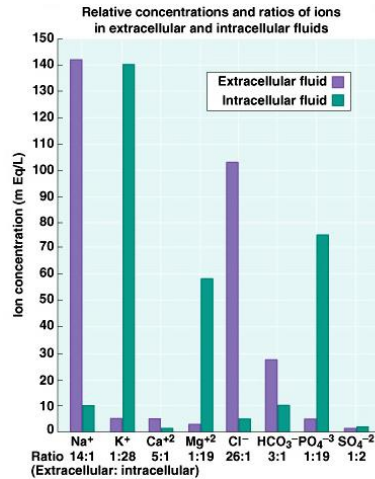
Body Fluid Composition

• **EC fluids**

- high concentrations of sodium, calcium, chloride & bicarbonate ions

• **IC fluids**

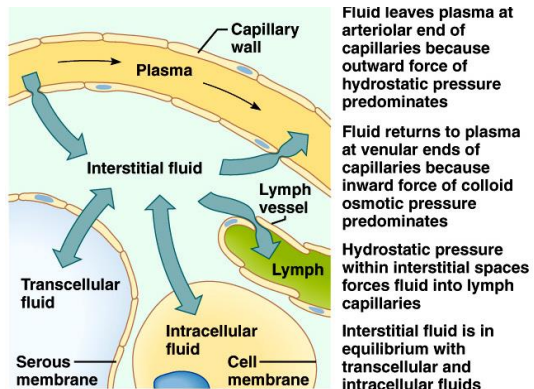
- high concentrations of potassium, magnesium, phosphate, & sulfate ions



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Movement of Fluids Between Compartments

Net movements of fluids between compartments result from differences in hydrostatic and osmotic pressures



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Measurement of Fluids Volume in the Compartments

- Done by placing an **appropriate substance** in the compartment,
- allowing it to **disperse evenly** throughout the fluid, and
- then measuring the extent to which the substance has **become diluted**.
- The commonly used method of measuring compartmental fluid volumes is by **use of tracers** (either **dyes, enzymes or radioactive materials**).⁷

Dilution Principle

The most commonly used tracer in the measurement of total volume is **Tritiated water (TOH)**.

TOH is a molecule that is **very similar** to a **water (H₂O)** molecule and therefore, has the **property to spread out in all areas** of the body without any difficulty.

How does this principle work?

- ✓ **Inject** a known amount of **TOH** into the body
- ✓ **Allow time** (normally several hours) for the substance to disperse all over the body, until it is well mixed with the body fluids.
- ✓ **Draw a fluid** sample from the body (**ex blood**), and using appropriate scientific methods, analyze the amount of TOH.
- ✓ From the **chemically determined** amount, **calculate the concentration**, from which you can **further calculate the total volume of fluids** in the body.

Calculations

$$\text{Conc.} = \frac{\text{Amount of TOH determined (mg)}}{\text{Vol. of fluid drawn (mL)}} \quad \begin{matrix} [0.005] \\ [5] \end{matrix}$$

$$\text{Volume} = \frac{\text{Original Quantity of TOH injected (mg)}}{\text{Conc. of dispersed fluid}} \quad \begin{matrix} [10] \\ [0.001] \end{matrix}$$

[10,000 mL]

Note that the TOH is very short lived and does not persist in the body of an animal

Half-life may be in minutes (ex 12 mins)

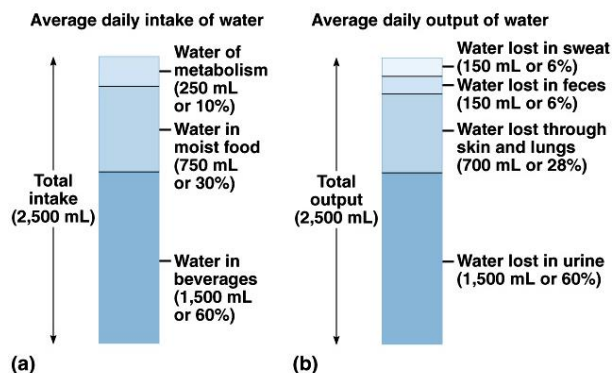
Suitable Substance (Tracer)

must only **spread through** the blood but not any other compartment and must be able to **remain** in the **circulatory system long enough** for measurements to be done.

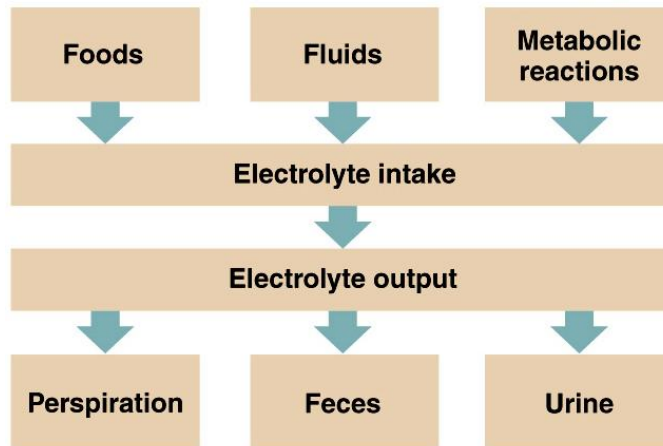
Two major groups of substances that satisfy these conditions (i) able to combine with **red blood cells (RBC)** radioactive **iron, chromium and phosphate**; (ii) substances that combine with the **plasma proteins** **dyes, enzymes, and radioactive iodine** .

Water Balance

- urine production is most important in the regulation of water balance



Electrolyte Balance



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THE ACID-BASE BALANCE

Means **regulation of the Hydrogen ion concentration** (or simply the **regulation of pH**).

But why is this regulation of pH important?

Enzyme reactions are sensitive to changes in the pH

Cell membranes -acidosis decreases membrane permeability to Na^+ ions (leading to decreased excitability), while alkalosis causes opposite.

Biological activities at cellular level can only operate at optimal pH levels, any changes in pH adversely affect cell functioning and can actually lead to death.

pH Ranges

The **normal pH** of arterial blood is **7.4** while

If Arterial blood has **pH < 7.4 - acidosis**

If the **pH is > 7.4 - alkalosis.**

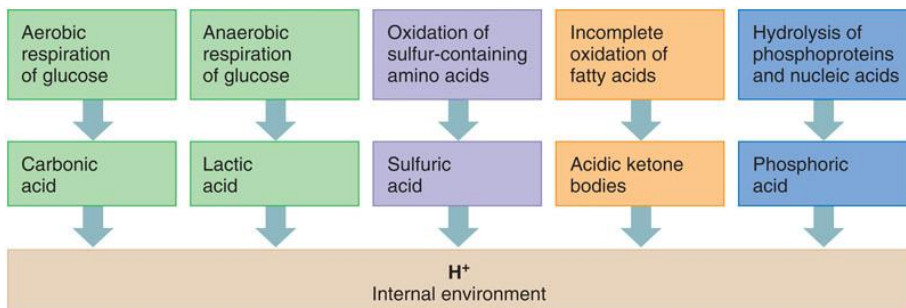
Venous blood and **interstitial fluid pH is 7.35**

An individual can live more than a few hours

Lower pH limit is 6.8;

Upper pH limit is 8.0.

Sources of Hydrogen Ions



**regulation of the acid-base balance means
regulation of the Hydrogen ion concentration
(or simply the regulation of pH)**

Bronsted-Lowry Definition

An **acid** is a **proton donor** or a molecule or ion that can **contribute** a **hydrogen ion** to a solution **$\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^- / \text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^-$**

Hydrochloric acid, carbonic acid, acetic acid, uric acid, acetoacetic acid, and monobasic sodium phosphate

A **base** is a **proton acceptor** or a molecule or ion that can **accept** a **hydrogen ion** from a solution **$\text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3 / \text{H}^+ + \text{Cl}^- \rightarrow \text{HCl}$**

Bicarbonate, OH^- or chloride ion are bases, Proteins (ex Hb^-) also function as bases because certain amino acids in the protein molecules function as negative ions that bind readily with excess H^+ ions.

Strengths of Acids and Bases

- **Strong acids** ionize more completely and release more H^+
- **Weak acids** ionize less completely and release fewer H^+
- **Strong bases** ionize more completely and release more OH^-
- **Weak bases** ionize less completely and release fewer OH^-

Defense Against Changes in pH

1. **Acid-base buffer systems** combine with any acid or alkali.
2. The **Respiratory Centre** is stimulated to alter rate of carbon dioxide removal from the body fluids.
3. **Then Kidneys Excrete** either an acid or alkaline urine thus readjust the pH

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Preferential Invocation

1. **Buffer systems** can act within a **fraction of a second** to prevent excessive changes in pH
2. The **respiratory system** is a bit slower, taking about **one to fifteen minutes** to readjust the pH after a sudden change has occurred.
3. The **kidneys**, although providing the most efficient of all the acid-base regulatory systems, require **several minutes to several days** to readjust the pH after a sudden change has occurred.

Acid-Base Buffer Systems

Bicarbonate System

- the bicarbonate ion converts a strong acid to a weak acid
- carbonic acid converts a strong base to a weak base



Phosphate System

- the monohydrogen phosphate ion converts a strong acid to a weak acid
- the dihydrogen phosphate ion converts a strong base to a weak base



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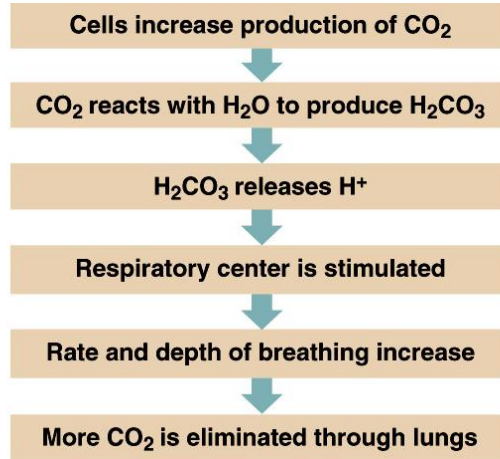
Acid-Base Buffer Systems

Protein Buffer System

- NH_3^+ group releases a hydrogen ion in the presence of excess base
- COO^- group accepts a hydrogen ion in the presence of excess acid

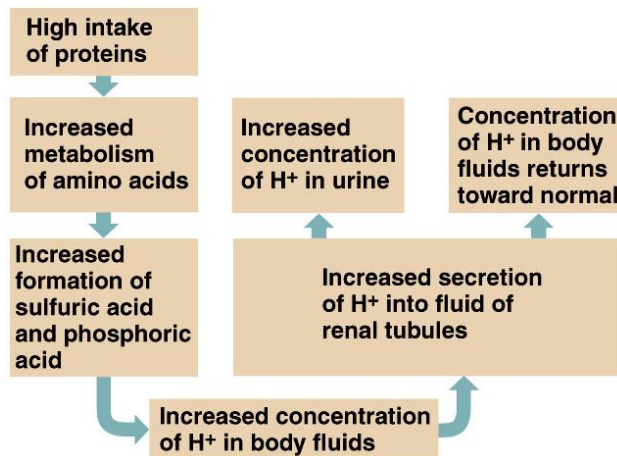
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Respiratory Excretion of Carbon Dioxide



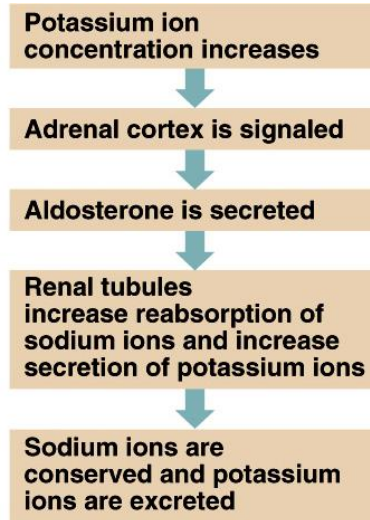
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Renal Excretion of Hydrogen Ions



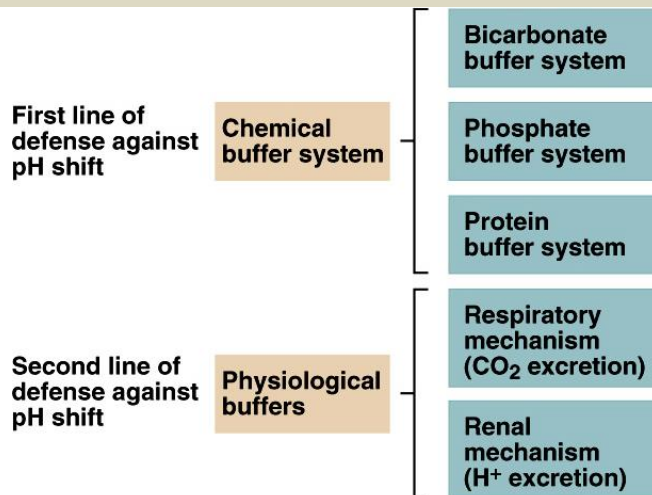
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Regulation of Electrolyte Output: Potassium and Sodium Balance



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Summary of Acid-Base Balance



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