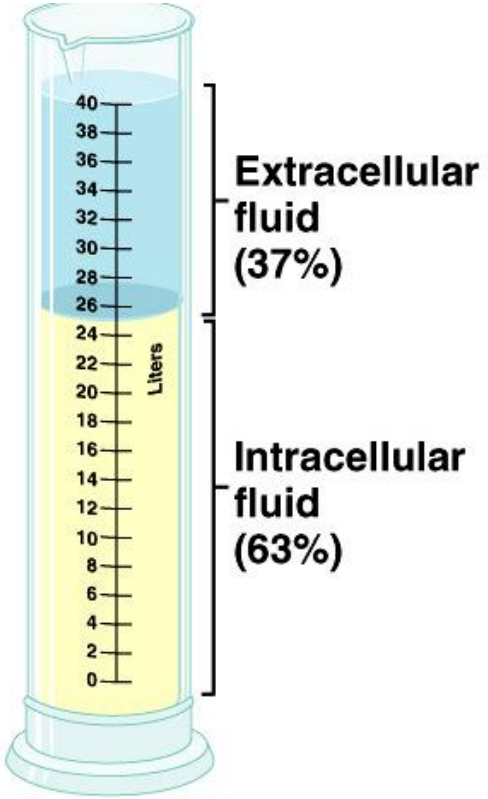
# Anatomy and Physiology

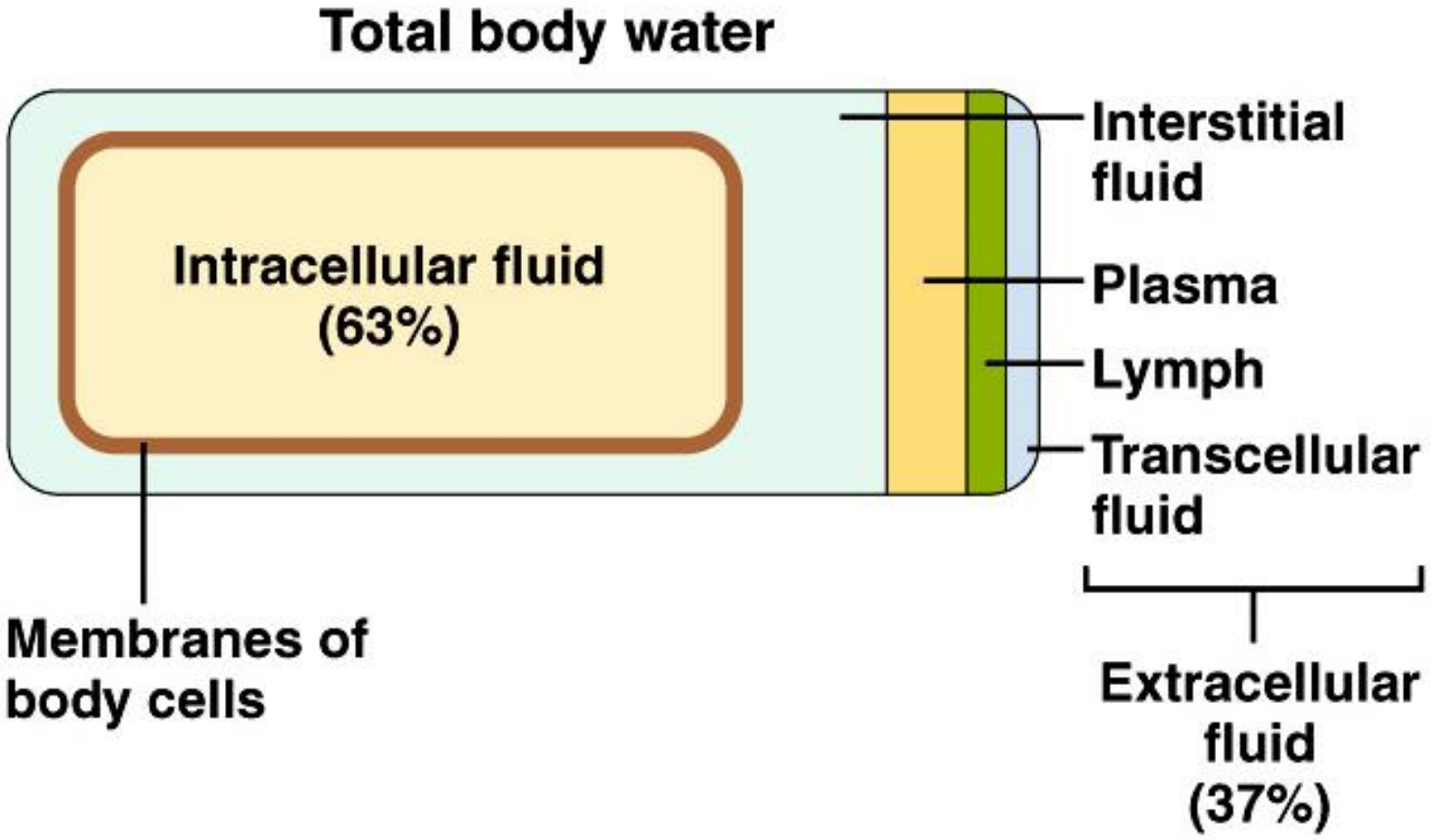
## Body Fluids and Regulation of Acid - Base Balance

# 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**



# Fluid Compartments



# Body Fluids

**ECF Present** as

(i) plasma, the fluid in the vascular system in which blood cells are bathed and

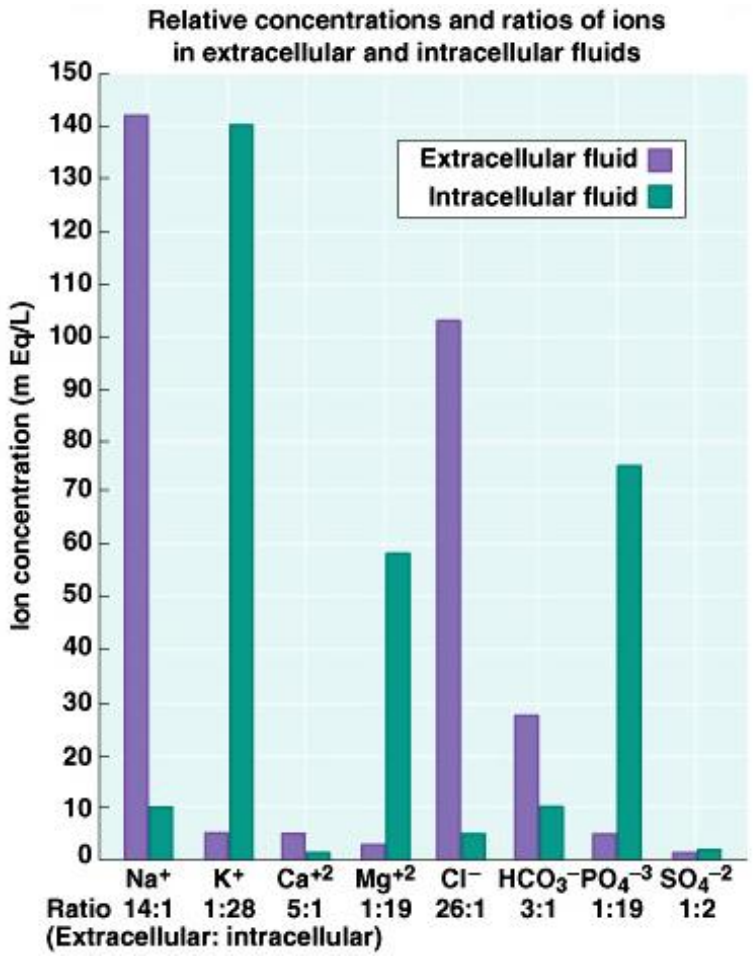
(ii) (ii) interstitial fluid, the fluid that lies in the spaces between the cells in the tissues and outside the vascular system such as lymph.

**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).

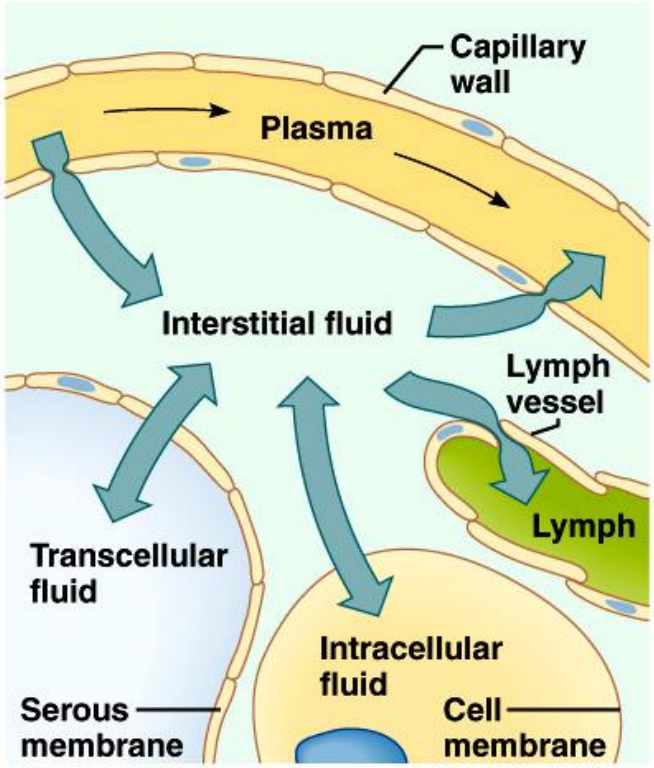
# Body Fluid Composition

- **EC fluids**
  - **high concentrations of sodium, calcium, chloride & bicarbonate ions**
- **IC fluids**
  - **high concentrations of potassium, magnesium, phosphate, & sulfate ions**



# Movement of Fluids Between Compartments

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




Fluid leaves plasma at arteriolar end of capillaries because outward force of hydrostatic pressure predominates

Fluid returns to plasma at venular ends of capillaries because inward force of colloid osmotic pressure predominates

Hydrostatic pressure within interstitial spaces forces fluid into lymph capillaries

Interstitial fluid is in equilibrium with transcellular and intracellular fluids

# 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).

# 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 ($H_2O$)** 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

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

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

[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)**

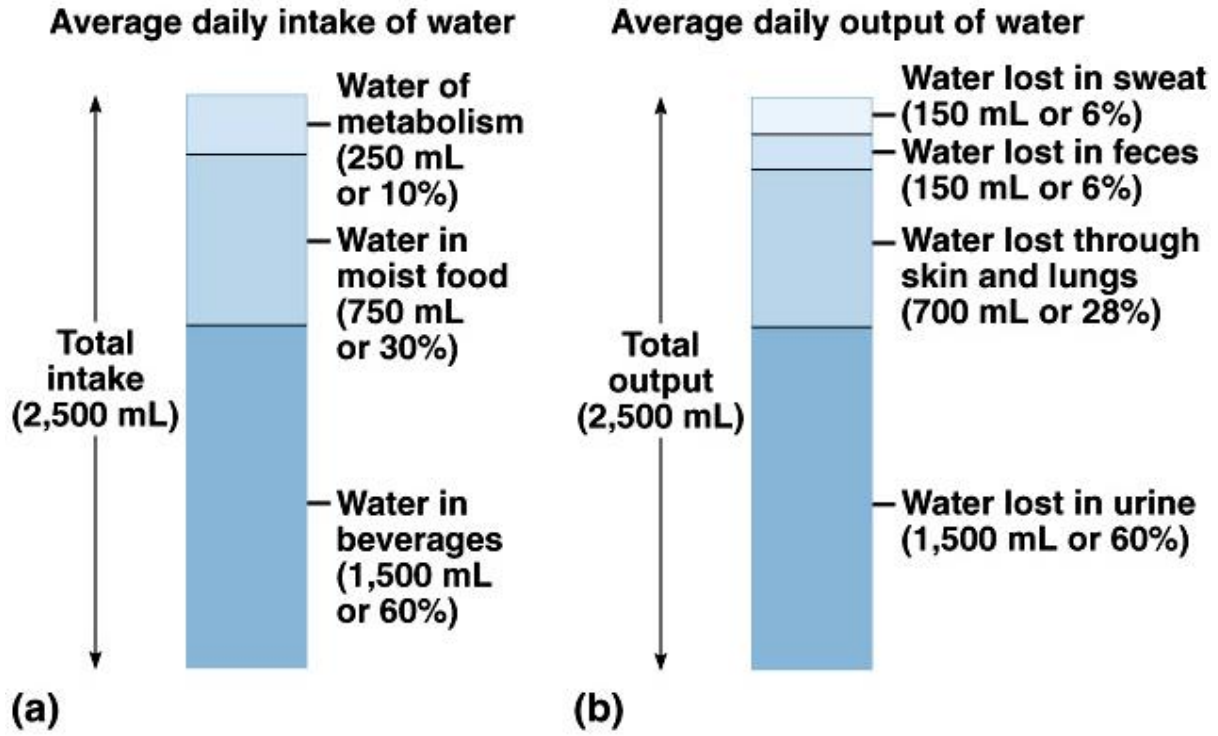
# Suitable Substance (Tracer)

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.

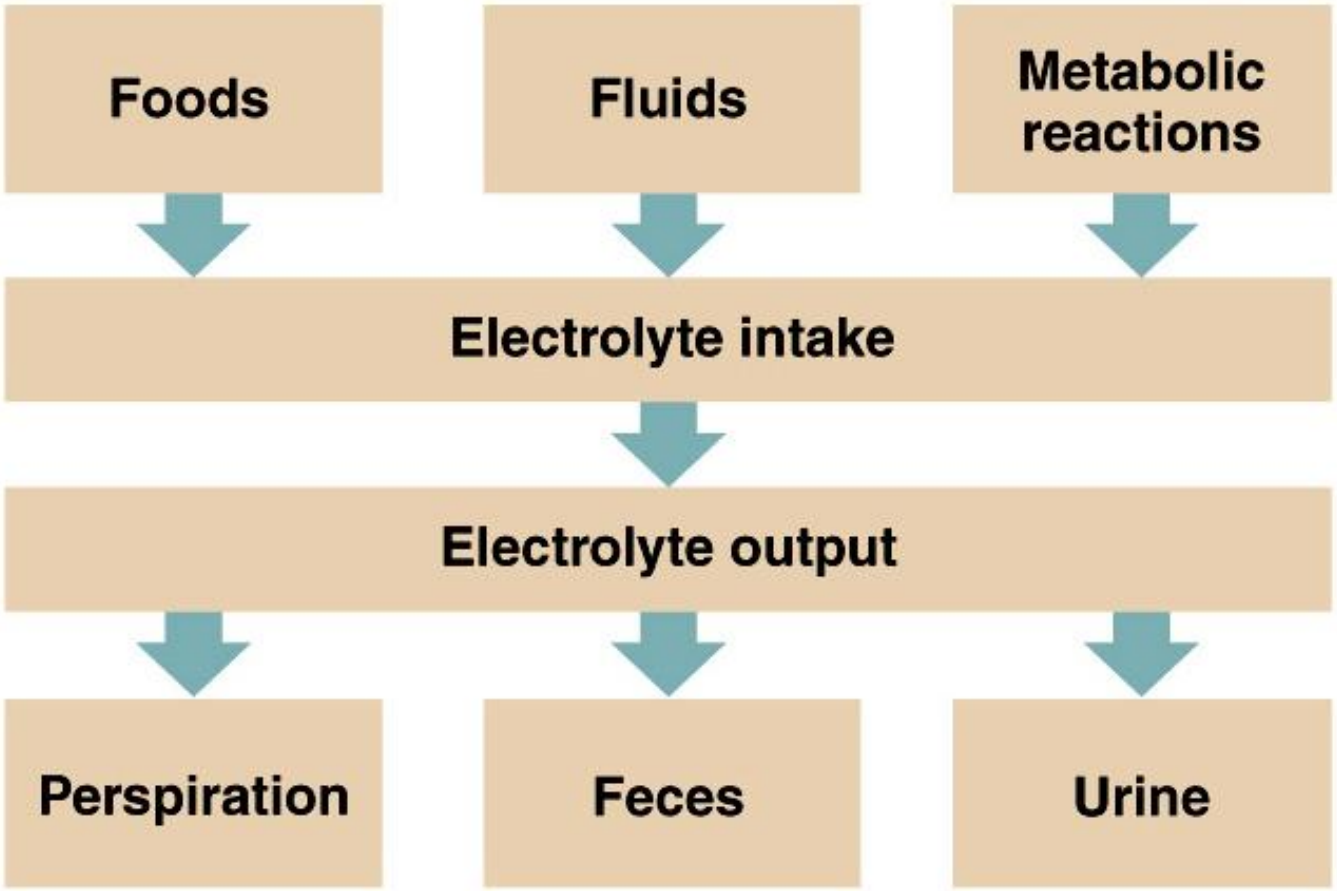
Two major groups of substances that satisfy these conditions (i) able to combine with **red blood cells** (RBC) radioactive iron, chromium and phosphate; (ii) substances that combine with the **plasma proteins** dyes, enzymes, and radioactive iodine **.**

# Water Balance

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



# Electrolyte Balance



# 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

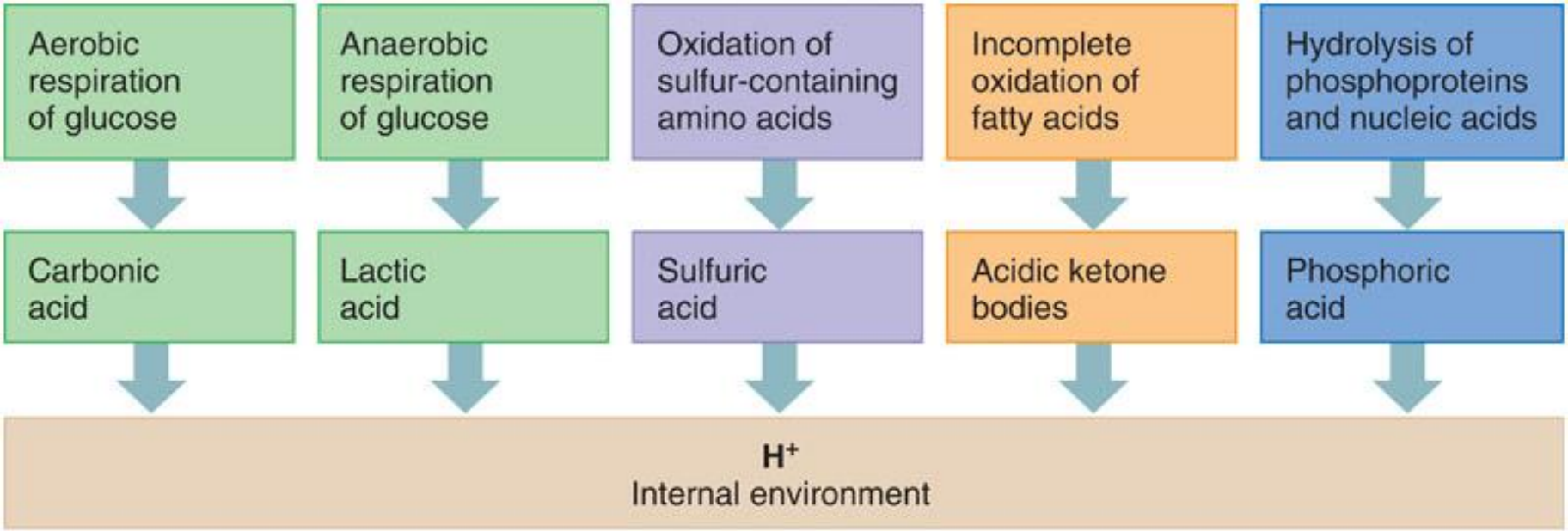
The **normal pH** of arterial blood is **7.4** while

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 **$HCl \rightarrow H^+ + Cl^-$ / $H_2CO_3 \rightarrow H^+ + HCO_3^-$**

*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 **$H^+ + HCO_3^- \rightarrow H_2CO_3$ / $H^+ + Cl^- \rightarrow HCl$**

*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

# 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

$$H^+ + HCO_3^- \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

## 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

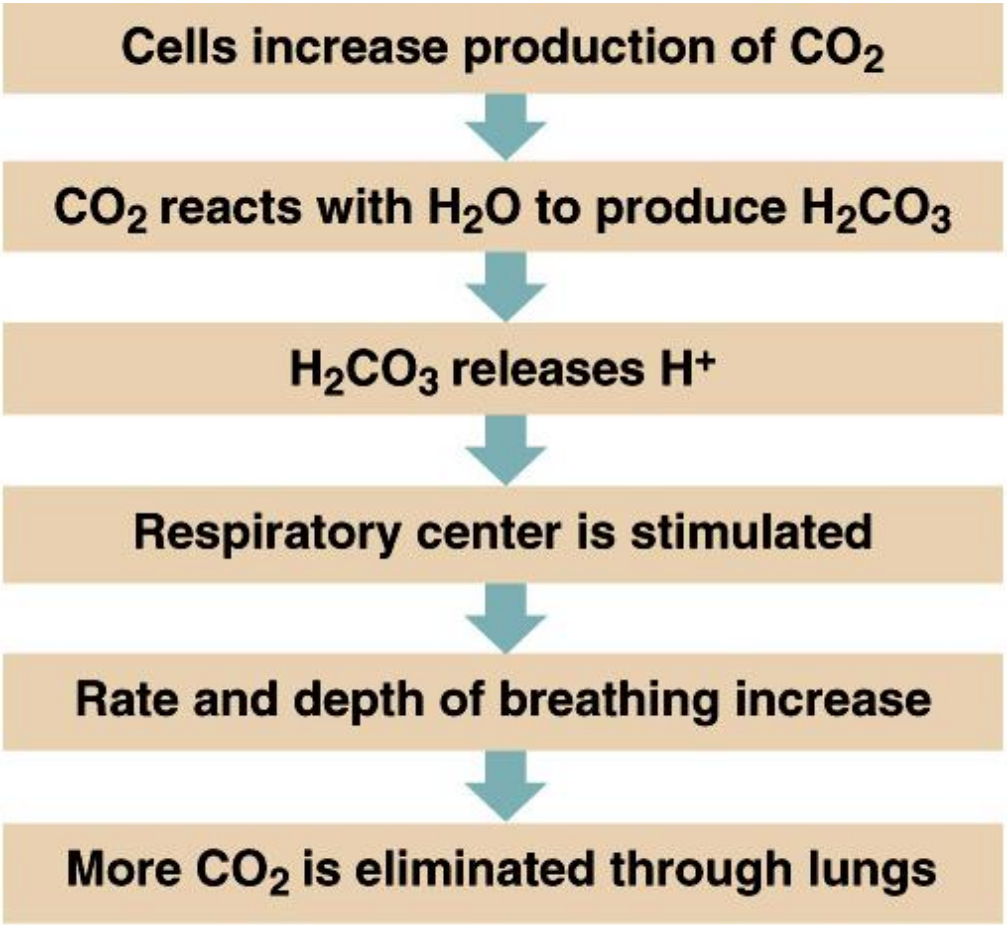
$$H^+ + HPO_4^{-2} \rightarrow H_2PO_4^- \rightarrow H^+ + HPO_4^{-2}$$

# Acid-Base Buffer Systems

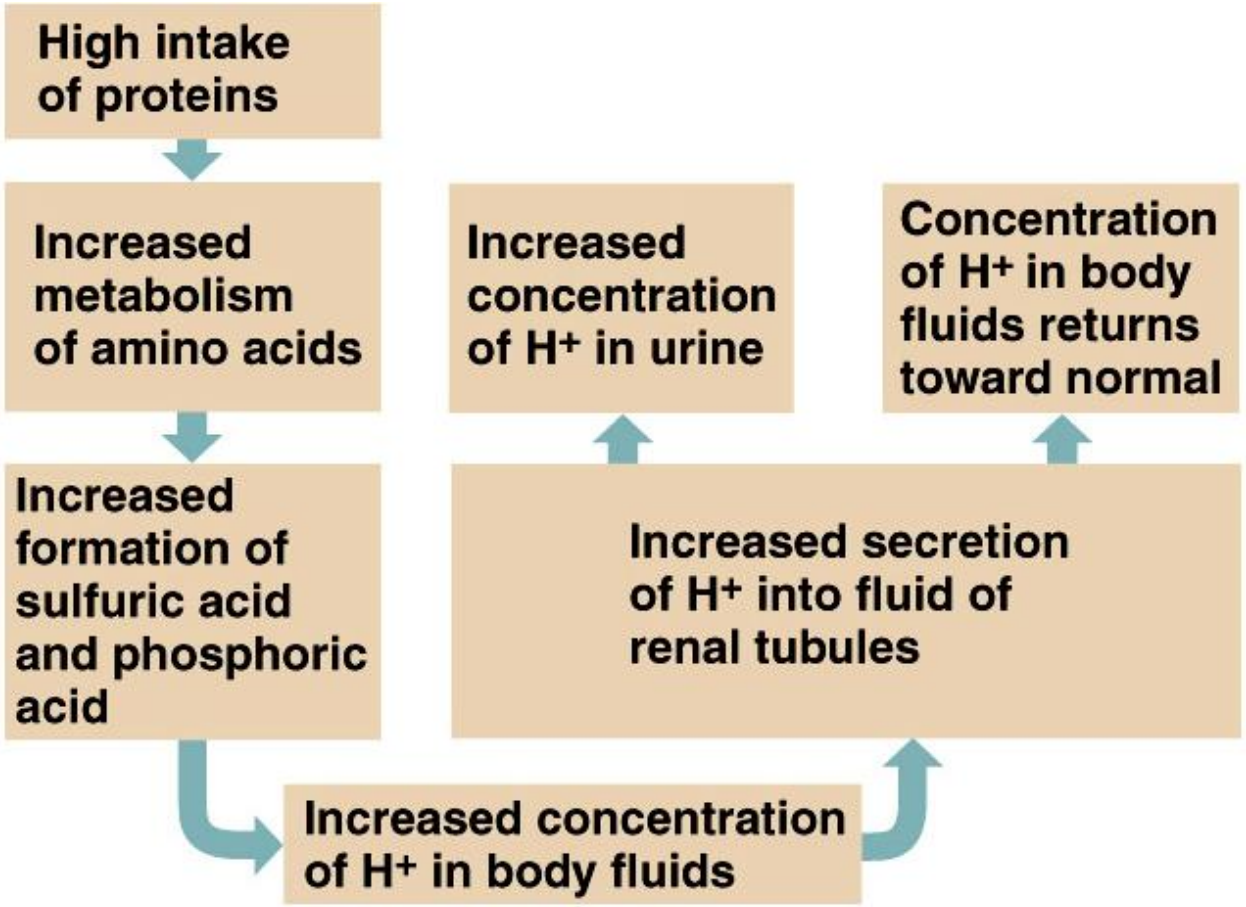
## Protein Buffer System

- $NH3^{+}$ group releases a hydrogen ion in the presence of excess base
- $COO^{-}$ group accepts a hydrogen ion in the presence of excess acid

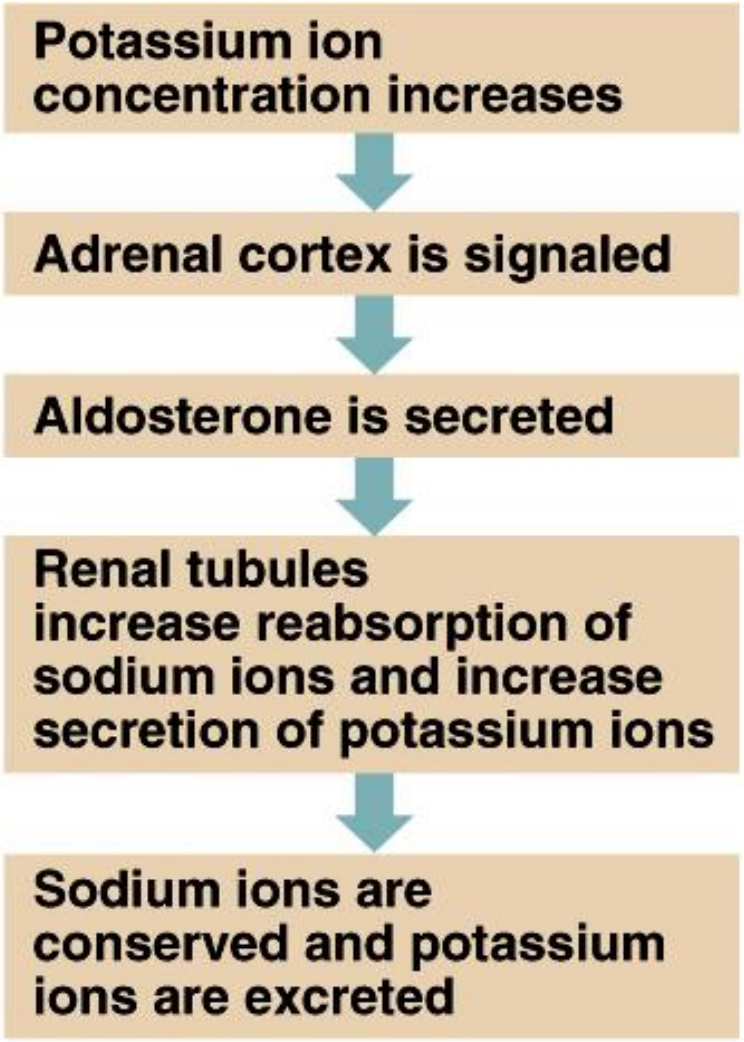
# Respiratory Excretion of Carbon Dioxide



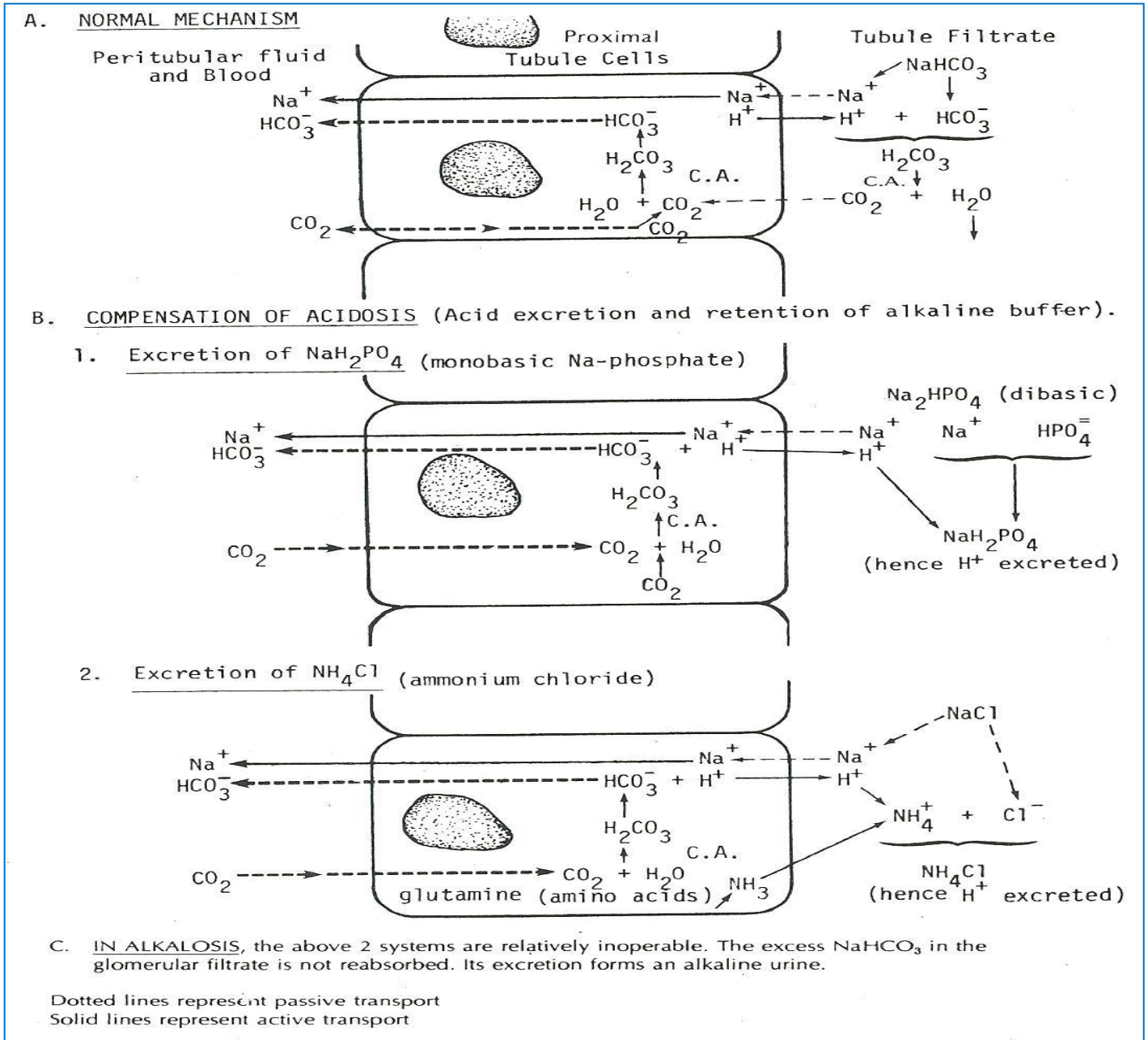
# Renal Excretion of Hydrogen Ions



# Regulation of Electrolyte Output:
## Potassium and Sodium Balance



# Kidney mechanism for maintenance of pH balance




C. IN ALKALOSIS, the above 2 systems are relatively inoperable. The excess $NaHCO_3$ in the glomerular filtrate is not reabsorbed. Its excretion forms an alkaline urine.

Dotted lines represent passive transport
Solid lines represent active transport

# Summary of Acid-Base Balance