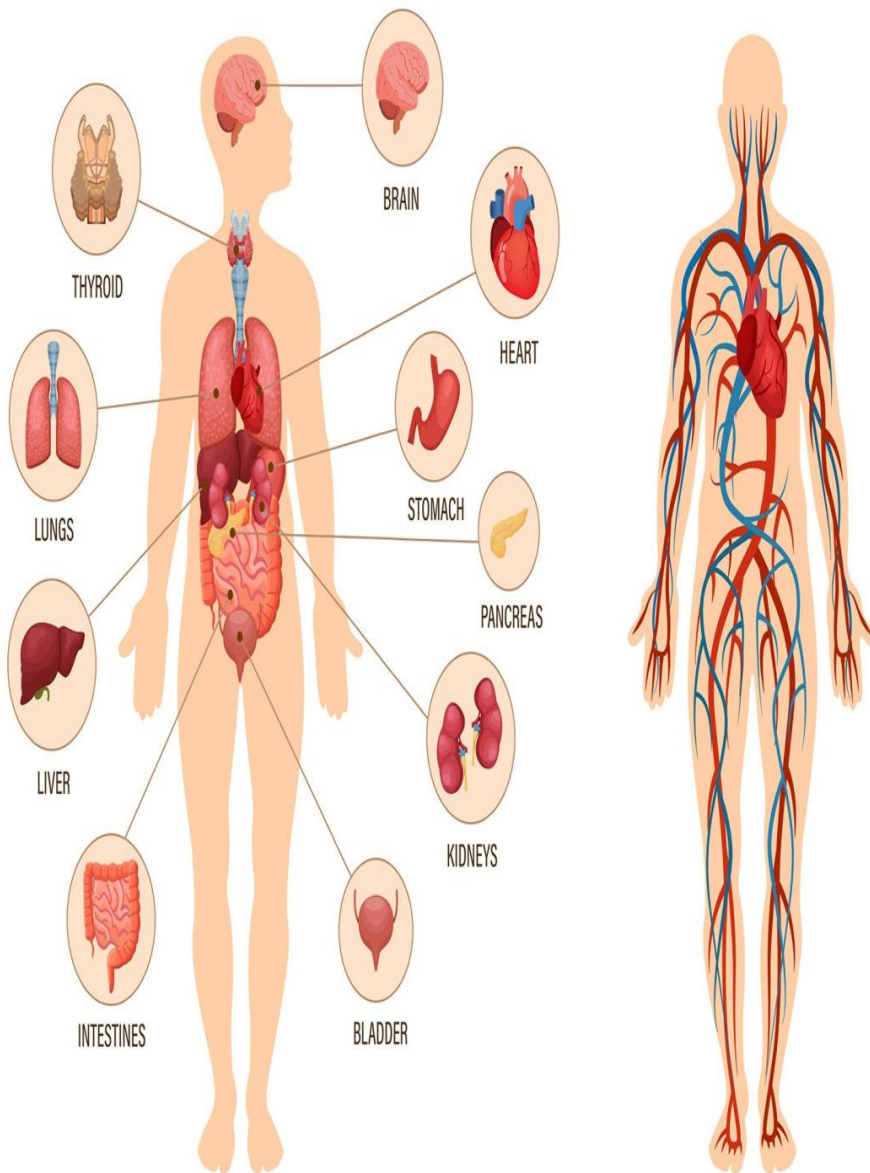




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Principles of Body System Physiology (MED 1104)

Lecture 1

**Introduction to human body fluid, and
their physiological significance**

Objectives

- State the water content of the body.
- Describe the physiologic factors that determine the body's water content.
- Discuss water balance in the body with regards to intake and output.
- Describe the physiologic mechanisms involved in water balance
- Enumerate the different body fluid compartments and state their normal volume.
- Define osmolarity and state the normal osmolarity of body fluids.

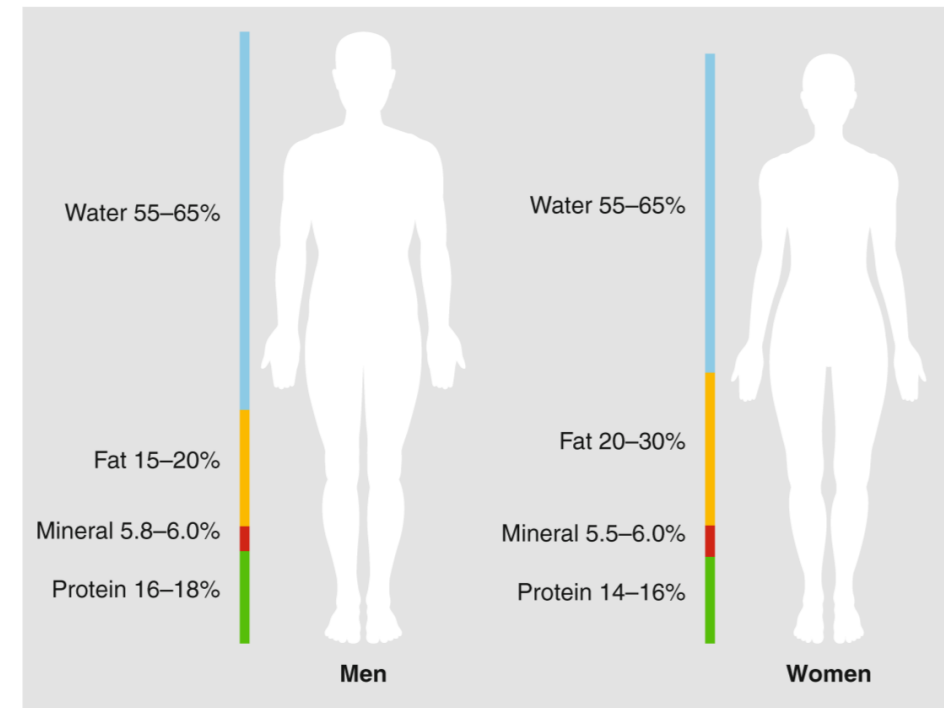


Introduction

Normal body composition:

- An average adult **male (of 70kg)** is composed of:
 - **Water** **60%** (42 Kg)
 - **Proteins** **18%** (12.6 Kg)
 - **Fats/Lipids** **18%** (12.6 Kg)
 - **Minerals** **5%** (2.8 Kg)

In **females** these values are slightly **less** except **fat** that is **higher** than **male**.



Key terms

- **Solvent:** a solution (e.g., body water) that can dissolve a solute.
- **Solute:** Substance (e.g., oxygen, electrolytes, and glucose) dissolved in a liquid (solvent).
- **Semipermeable:** Selectively permeable (All membranes in the body allow some solutes to pass through the membrane without restriction but will prevent the passage of other solutes).
- **Diffusion:** the movements of **molecules** through a semipermeable membrane from an area of higher concentration to an area of lower concentration. For example, oxygen moves from the alveoli into the pulmonary capillaries and carbon dioxide moves from the pulmonary capillaries into the alveoli.
- **Filtration:** a process whereby fluid and solutes moves together across membrane from an area of high pressure to an area of lower pressure.
- **Osmosis:** is a specific kind of diffusion in which **water** moves across cell membranes from the less to the more concentrated solution.



Key terms

- **Osmolarity:** the number of osmoles of a solute per litre of solution.
- The normal osmolarity of body fluids is ≈ 300 mOsm/L

High osmolarity = High concentration of solutes = Low concentration of water.
Low osmolarity = Low concentration of solutes = High concentration of water

Terms of Concentration

Osmole is the unit used in place of grams to express the concentration in terms of number of osmotically active particles in a given solution.

Osmolarity : Osm / L



Body fluid

Water: (universal solvent)

- Water makes up about **60% of total body weight**, but this can vary widely (**from 50% to 80%**) depending on factors like **age, sex, body mass, and composition**.

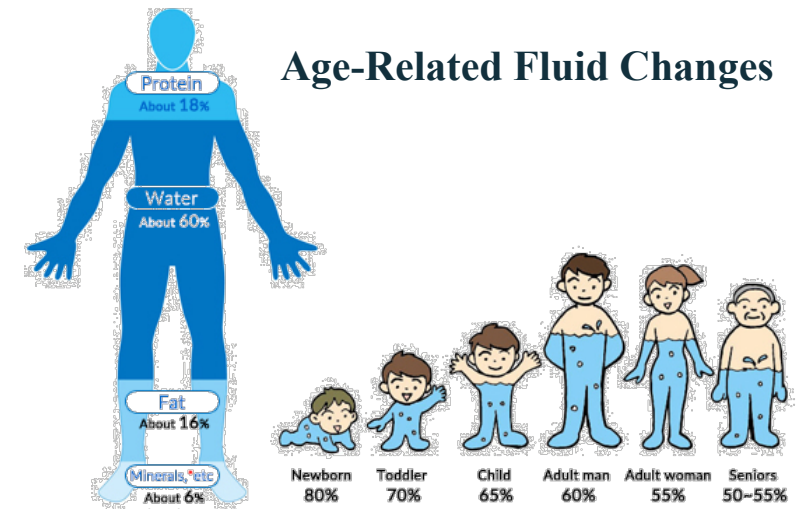
- **Adult Male: 60%**
- **Adult Female: 55%**

- **Consistency of Water Levels:**

- The body's water content stays relatively stable because **the kidneys efficiently regulate water balance**.

- **Why the Variation in Water Content?**

- Adipose Tissue (Fat): Contains very little water (only 10%).
- Plasma: Extremely water-rich, with more than 90% water.
- Soft Tissues (e.g., skin, muscles, internal organs): Composed of 70-80% water.
- Bones (Skeleton): Have relatively low water content, about 22%



♀ = ↑ body fat / ↓ muscle mass

Functions of water in the body

- **Transports** nutrients, wastes, hormones, and blood cells.
- **Supports** metabolism and chemical reactions.
- **Dissolves** electrolytes and substances.
- **Regulates** body temperature.
- **Aids** digestion and waste removal.
- **Lubricates** joints and tissues.
- **Protects** organs and provides cell structure.

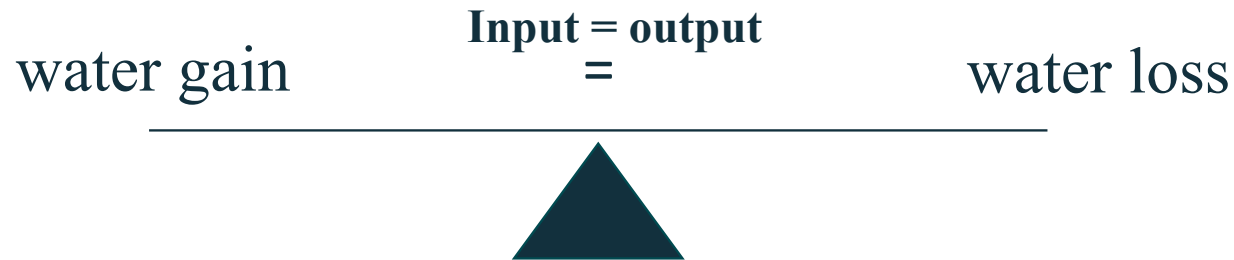


Regulating body fluids

- **Body Fluid balance (Maintaining homeostasis)**
 - Homeostasis: Fluid **intake** must equal fluid **output**.

Water gained through (2500-2600 ml/day)	Water lost through:
• Ingested liquid 1500 ml • Ingested foods 800 ml • Metabolic water (from chemical reactions): 300 ml	• Sensible losses (Measurable): • Kidney (Urination) 1500 ml • GIT (Defecation) 100 ml • Insensible losses (Unnoticed): • Evaporation from skin (sweat) 600 ml • Respiratory loss from lungs (exhalation) 400 ml • Abnormal losses • Wound drainage, Dehydration, Burns, Vomiting

Water steady state



Regulating body fluid: Fluid Imbalance

- **Excess Fluid Volume (Hypervolemia)**
 - Caused by excess sodium, leading to fluid retention.
 - Effects: Swelling, high blood pressure.
- **Deficient Fluid Volume (Hypovolemia)**
 - Caused by dehydration, burns, and vomiting.
 - Effects: Low blood pressure, dizziness

Factors affecting total body water

- **Physiological:**
 - Age, Sex, Body Fat
- **Pathological:**
 - Vomiting, Diarrhea, Blood Loss, Burns, Diseases (e.g., Diabetes)
- **Other:**
 - Climate, Habits, Physical Activity

Body Water Distribution, Where's this Water?

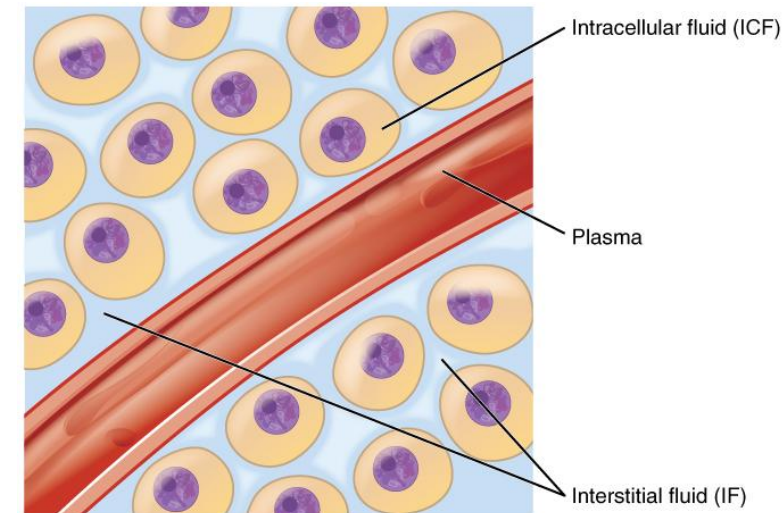
Body water is distributed between **two major fluid compartments**

1. Intracellular fluid (ICF)

- Found **within (inside)** the body cells,
- Makes up two thirds (2/3) of the **total body fluid** in **adults**

2. Extracellular fluid (ECF)

- Found **outside** the body cells
- Makes up one thirds (1/3) of the total body fluid in **adults**.



- ECF is subdivided into **two main compartments** and one minor:
 - **a. Interstitial fluid (ISF):** found **between** cells or fluid that surrounds the cells, accounts approximately 75-80% of ECF.
 - **b. Intravascular or plasma** found **inside** the vascular system, accounts approximately 20-25% of ECF.
 - **c. Minor ECF compartment:** lymph, and transcellular fluid

Body Water Distribution (Transcellular fluid)

← Lymph

👤 Milk

🧠 Cerebrospinal fluid

📅 Amniotic fluid

👁️ Aqueous humor

⚠️ Sweat

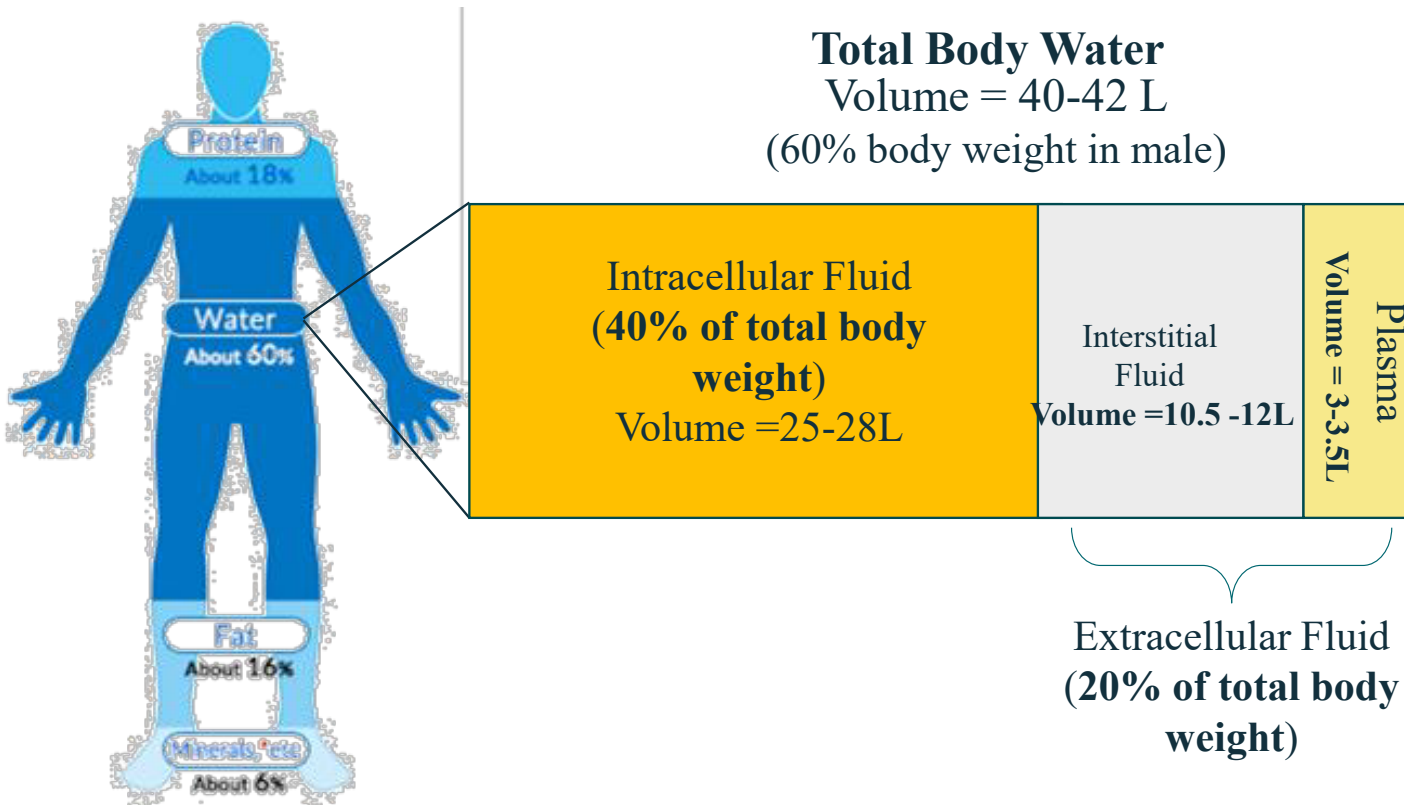
😞 Tears

Normal: small amount of fluids

Pathological: Accumulation of fluids (effusion)



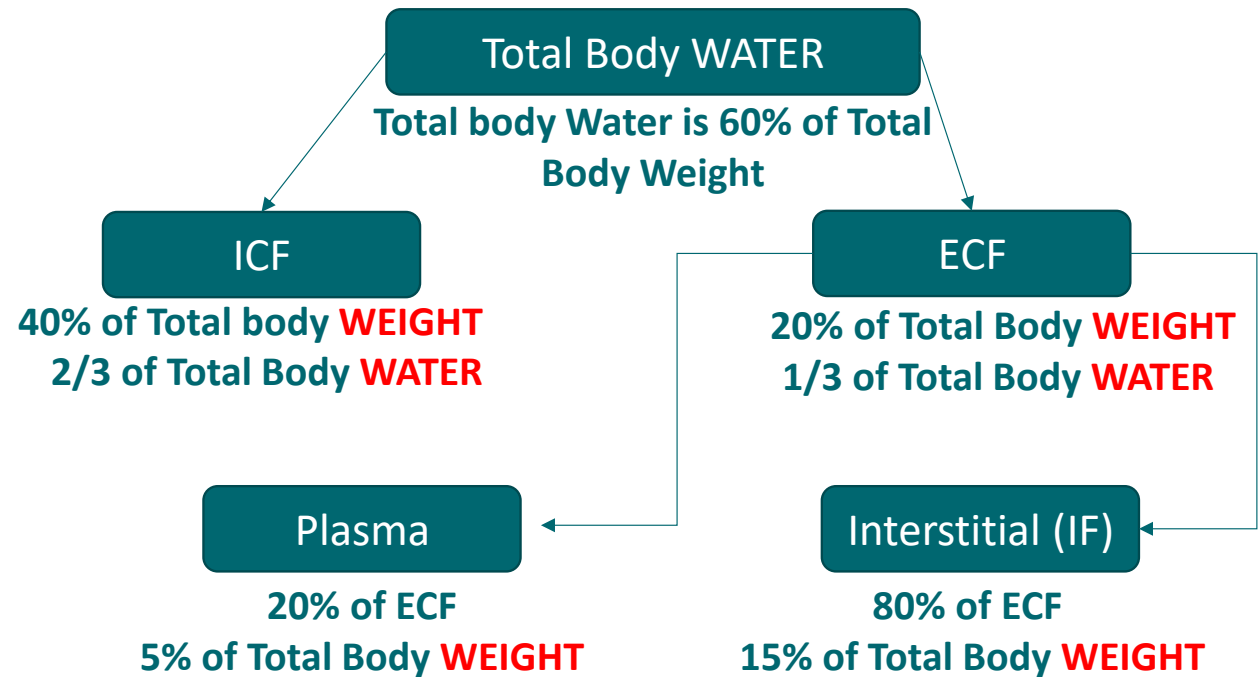
Body fluid Distribution



Compartment	Volume of Fluid (in Litres)	Percentage of Body Fluid	Percentage of Body Weight
Total Body Fluid	42	100	60
Intracellular Fluid (ICF)	28	67	40
Extracellular Fluid (ECF)	14	33	20
<i>Plasma</i>	3.5	8.3 (25% of ECF)	5
<i>Interstitial fluid</i>	10.5	25 (75% of ECF)	15
<i>Lymph</i>	Negligible	Negligible	Negligible
<i>Transcellular fluid</i>	Negligible	Negligible	Negligible

Adult Male

Body fluid Distribution (Summary)



Solutes

- A solute is **a substance that can be dissolved into a solution by a solvent.**
- A solute can be gas, a liquid, or a solid

A) Non-electrolytes

- Do not dissociate into ions (neutral).
- Mostly organic molecules (e.g., glucose, lipids, urea)

B) Electrolytes

- Electrolytes are **substances that have a natural positive or negative electrical charge when dissolved in water** (dissociate into ions in solution – **charged**)
- Positively charged ions (**cations**), negatively charged ions (**anions**)
- **Functions:**
 - **Regulate body fluid distribution.**

Examples:

- Inorganic salts: NaCl, CaCl₂.
- Inorganic acids: H₂SO₄.
- Organic acids: Lactic acid.
- Proteins.

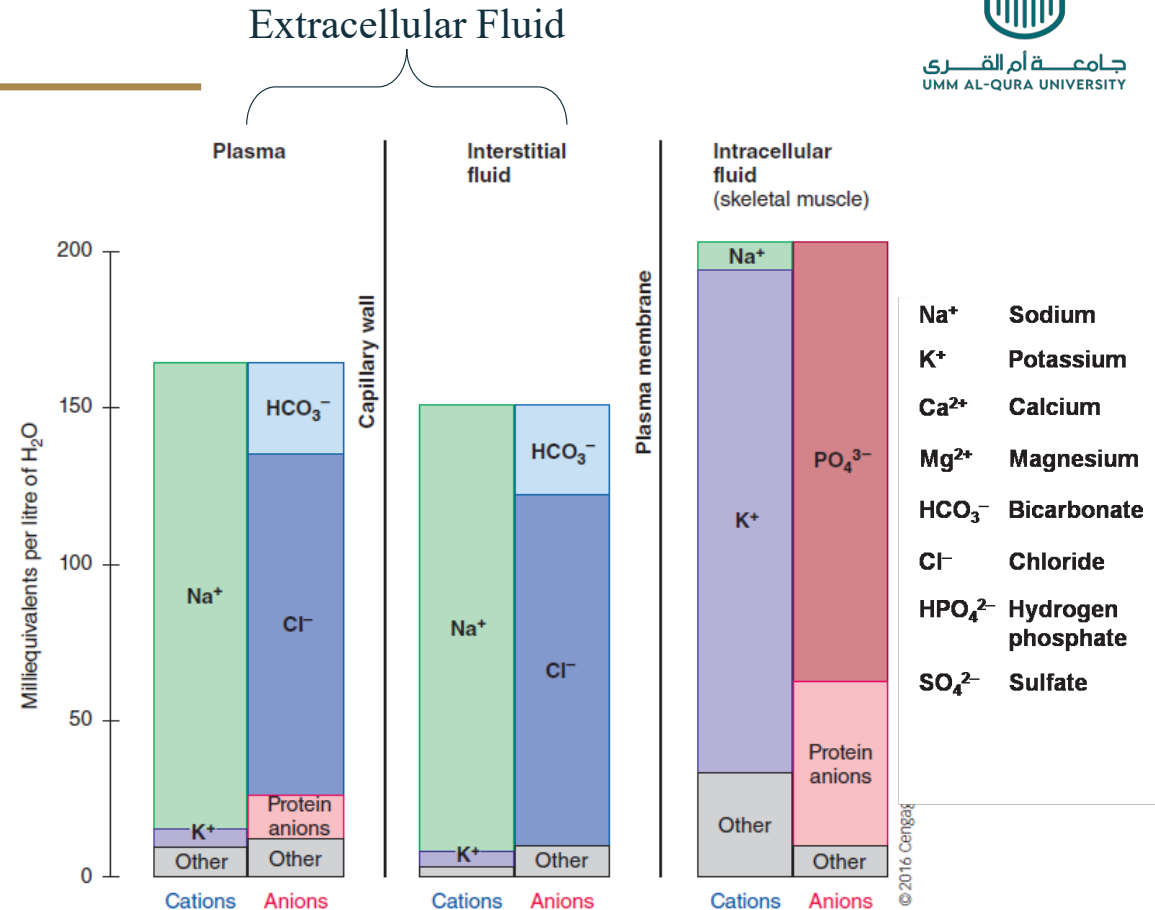


Functions of Electrolytes

1. Regulating Body Fluid Distribution
 2. Maintaining Fluid Balance
 3. Acid-Base Regulation
 4. Facilitating Enzyme Reactions
 5. Transmitting Neuromuscular Signals
- Cations (+)
 - Sodium
 - Potassium
 - Calcium
 - Magnesium
 - Anions (-)
 - Chloride
 - Bicarbonate
 - Phosphate
 - Sulfate

Electrolytes

- Major electrolytes
 - In ECF
 - Major cation is sodium Na^+
 - Major anion is chloride Cl^-
 - In ICF
 - Major cation is potassium K^+
 - Major anion is phosphate PO_4^{3-}



Ionic composition of the major body-fluid compartments

Movement between fluid compartments



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- **Barriers Between Compartments:**

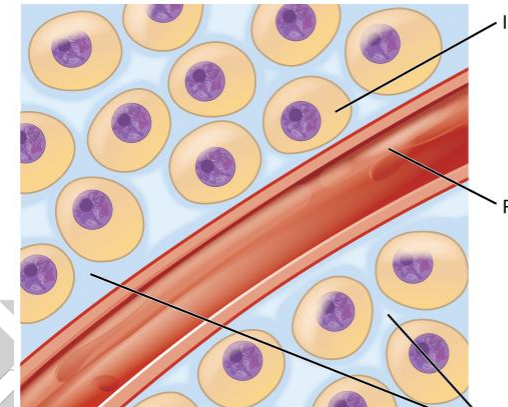
- Separate fluid compartments and control the movement of water (H_2O) and solutes to maintain balance.

1. Plasma $\leftrightarrow$ Interstitial Fluid:

- **Barrier:** Blood Vessel Walls.
- **Exchange:** Passive diffusion along the concentration gradient (**except plasma proteins**).
- **Note:** Interstitial fluid lacks plasma proteins.

2. ECF $\leftrightarrow$ ICF:

- **Barrier:** Cell Membranes.
- Cell membrane is **highly selective** and only permits the passage of certain materials
- Selective Transport
 - Active: Sodium (Na^+) and Potassium (K^+).
 - Passive: Oxygen (O_2) and Carbon Dioxide (CO_2).



Factors controlling fluid movement

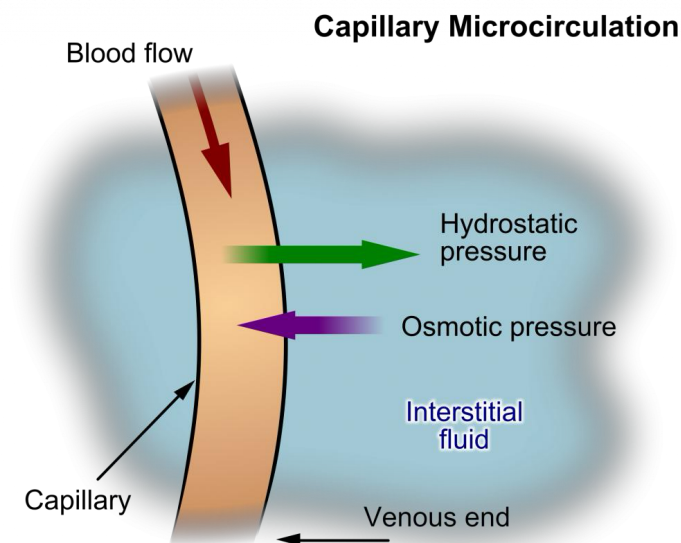
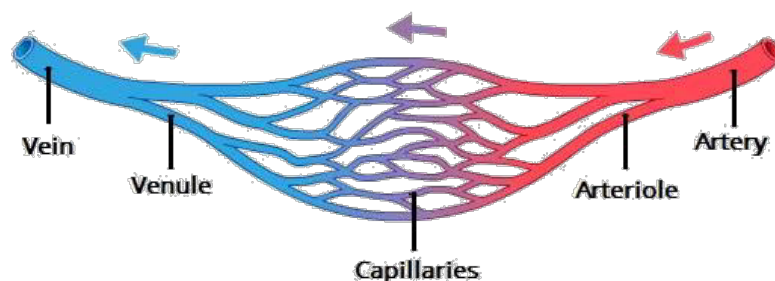
Fluid movement occurs inside the body due to:

1. Hydrostatic Pressure: Force exerted by a fluid

- At 32mmHg at the arteriolar end and 10mmHg at the venous end of capillaries, it forces (push) fluid out of the capillaries. (filtration).

2. Osmotic Pressure (sometimes referred to as oncotic pressure or colloidal): Pressure exerted by solutes

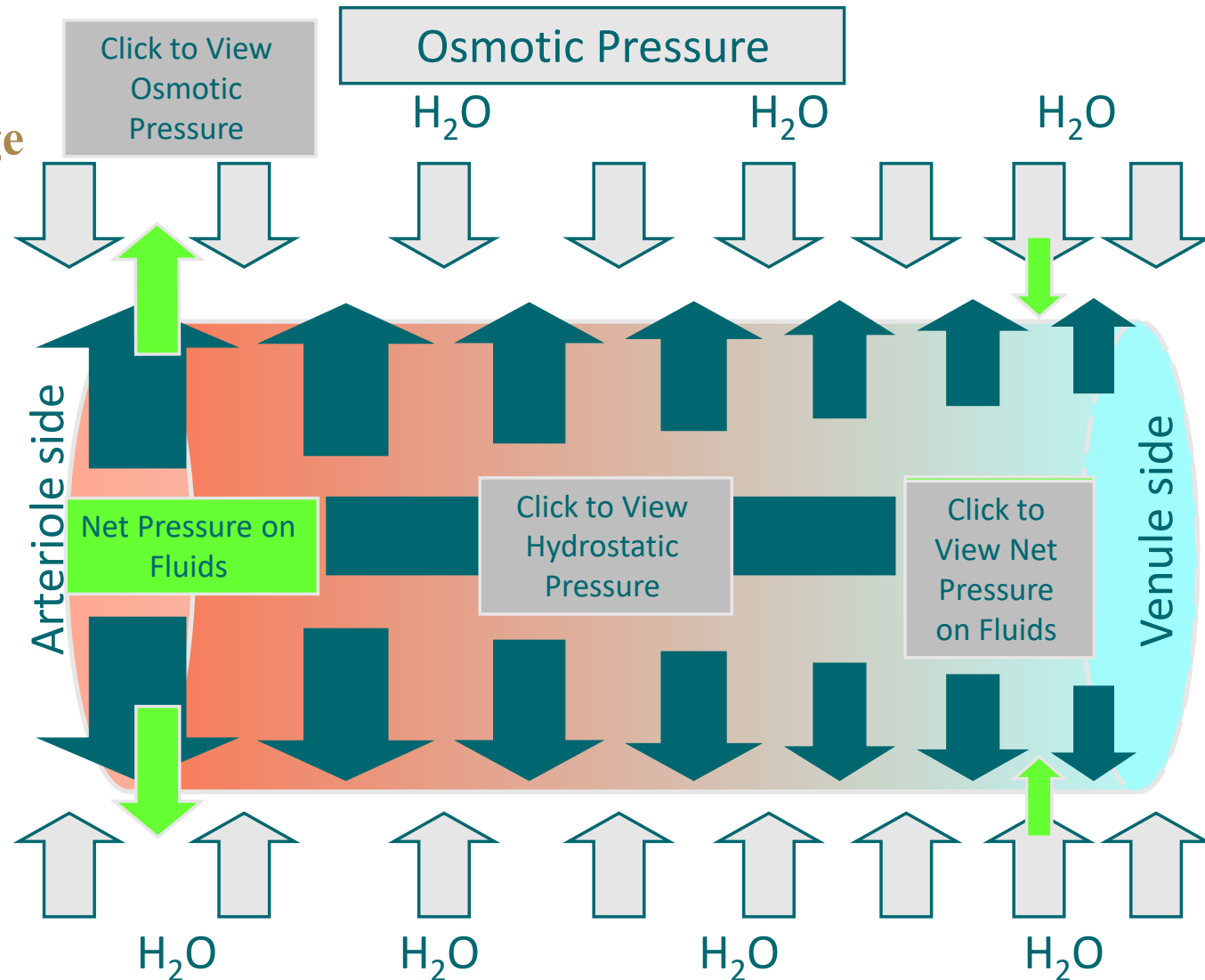
- At 25mmHg, due to plasma proteins like albumin, it pulls fluid back into the capillaries. (reabsorption).



So **net** result will be 7mmHg pressure pushes the fluid out of capillaries into ISF at the arteriolar end (filtration) while 15mmHg reabsorbing the fluid at the venous end of capillaries (reabsorption)

Starling's principle of fluid exchange

- Each day about **20 L** of fluid filter out of capillaries in body tissues.
- **17 L** of this fluid are reabsorbed into blood capillaries and **3L** enter lymphatic capillaries.
- This balance ensures proper tissue hydration and prevents fluid accumulation (edema).



MINERALS

- **Major Minerals:**

- Required in more than 100 mg/day.
- Examples: Sodium, Potassium, Calcium, Phosphorus, Chlorine.

- **Trace Minerals:**

- Required in less than 100 mg/day.
- Examples: Iron, Zinc, Copper, Iodine, Fluorine.



Functions of Minerals

1. Structural Role:

- Contribute to the formation of bones and teeth.

2. Physiological Role:

- Maintain normal heart rhythm, muscle contractility, nerve conductivity, and acid-base balance.

3. Metabolic Role:

- Regulate cellular metabolism by activating enzymes and supporting hormone functions



Sodium Na^+

- **Most Abundant Cation:**
 - Found in the extracellular fluid (ECF).
- **Plasma Concentration:**
 - 136–148 mEq/L.
- **Function:**
 - Essential for the generation and conduction of action potentials in nerves and muscles.
- **Imbalances:**
 - $\downarrow \text{Na}^+ \rightarrow$ Hyponatremia (low sodium).
 - $\uparrow \text{Na}^+ \rightarrow$ Hypernatremia (high sodium).

Chloride Cl^-

- **Most Abundant Anion:**
 - Found in the extracellular fluid (ECF).
- **Normal Plasma Concentration:**
 - Approximately 113 mEq/L.
- **Function:**
 - Maintains proper anion balance between ECF and ICF.
 - **Forming a part of the hydrochloric acid (HCl) secreted in gastric juice in stomach.**

Potassium K^+

- **Main Intracellular Cation:**
 - Most abundant positively charged ion inside cells (~150 mEq/L).
- **Normal Plasma Concentration:**
 - ~4 mEq/L.
- **Functions:**
 1. Establishing Resting Membrane Potential
 2. Action Potential Repolarization
 3. Maintaining Intracellular Fluid Volume
 4. Regulating Body Fluid pH
- **Imbalances:**
 - ↓ K^+ (Hypokalemia): Low potassium levels.
 - ↑ K^+ (Hyperkalemia): High potassium levels.

Bicarbonate HCO_3^-

- Second most abundant extracellular anion.
- Normal Plasma Concentration: 22–26 mEq/L.
- **Function:**
 - Maintains anion balance between ECF and ICF.
 - Regulates acid-base balance by acts as a major buffer in the blood, maintaining pH stability.

Calcium Ca^{2+}

- Important cation in ECF.
- Normal plasma concentration = 4.5-5.5 mEq/liter
- **Function:**
- **Bone and Teeth Strength:**
 - Provides hardness and structural integrity.
- **Blood Clotting and Neurotransmitter Release:**
 - Essential for coagulation and releasing neurotransmitters.
- **Excitability of Nervous and Muscle Tissue:**
 - Regulates nerve impulses and muscle contractions.

Phosphate PO_4^{3-}

- The **main intracellular anions** (100 mEq/liter).
- Normal plasma Concentration = **1.7-2.6 mEq/liter**.

Functions:

- Structural Component:
 - Builds bones and teeth.
- Acid-Base Balance:
 - Acts as a buffer in regulating pH.

Magnesium Mg^{2+}

- **Second most abundant intracellular cation.**
- **Normal Plasma Concentration: 1.3–2.1 mEq/L.**
- **Function:**
 - Essential for enzymes and the sodium-potassium pump.
 - Supports normal nerve and muscle function.
 - Synaptic transmission: involved in transmitting signals between neurons.
 - Myocardial function: important for proper heart muscle function.
 - Aids in the secretion of parathyroid hormone.



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