

**Physiology Undergraduate
League of Students**

PHGY 209

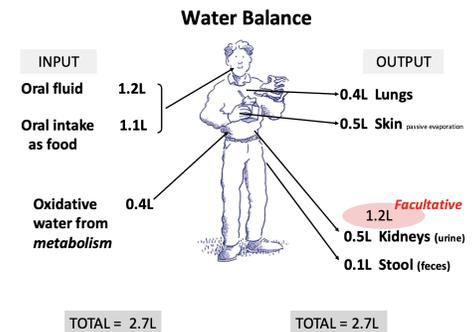
Lecture #3

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Summary of Lecture 2 - Body Fluids:

- Milieu Interieur & Homeostasis
- Body Water - variations with age, sex, and body fat
- Water Balance - “dynamic steady-state”
 - Exchanges between the individual and the external environment
 - Intake vs. output
 - Obligatory vs. facultative losses
 - Sweat is neither obligatory nor facultative, but is still an output
 - Negative water balance vs. water intoxication



Lecture 3 - Body Fluids

Dynamic Steady State:

Body water is in a “dynamic steady state”

- Internally: between different compartments

Internal water movement: no barrier for water to move in the body, allowing it to move freely between compartments

Body Water Compartments:

- Body water compartments differ in volume, composition and function
- Body water compartments and subcompartments are not rigidly isolated chambers. Rather, these compartments are continuously interacting in a **dynamic fashion**, with water exchanging freely between them
- Total Body Water = 60% of Body Mass
- There are 2 major compartments of bodily water:
 - **Intracellular fluid (ICF)**
 - **Extracellular fluid (ECF):** further subdivided into 2 major subcompartments and 2 minor subcompartments
- ICF is the fluid that is bound by the internal surfaces of cell membranes of all body cells, while ECF does not remain inside the cell.
- ICF contains $\frac{2}{3}$ of body water, and ECF contains $\frac{1}{3}$ of body water

Total body water: 60% of body mass	
ICF = 40%	ECF = 20%
Total body water volume: 42L	
ICF = 28L	ECF = 14L

Intracellular Fluid (ICF):

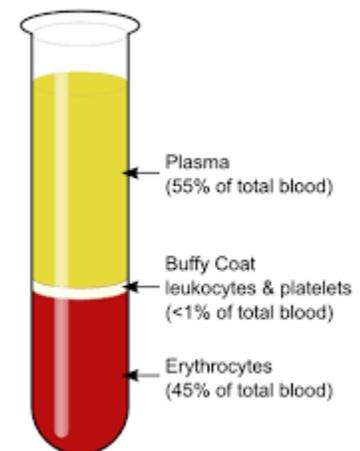
- ICF is an aggregate of fluid bound by the internal surfaces of all cell membranes
- Makes up $\frac{2}{3}$ of total body water (around 28 L)

Extracellular Fluid (ECF)

- The ECF is divided into 2 major and 2 minor subcompartments
 - **Major:** Plasma and Interstitial fluid (ISF)
 - **Minor:** Lymph and transcellular fluid

Plasma: the fluid medium in which blood cells are suspended

- Major ECF compartment
- Occupies 5% of body mass and is $\frac{1}{4}$ of the ECF
- Normally, it occupies 55% of the blood volume
 - The remaining 45% is occupied mainly by red blood cells (erythrocytes), but also a small percentage of a buffy layer composed of white blood cells (WBCs and platelets).
- It floats and appears a clear-ish yellow
- **Hematocrit (Ht):** measures the percentage of blood volume that is occupied by red blood cells (erythrocytes), thus giving an idea of the relative percentage of plasma in the bloodstream.
 - Can be used to understand one's oxygen-carrying capacity (e.g. to diagnose if someone is anemic)
 - Normal value: ~ 45%
 - Also known as Packed Cell Volume (PCV)



Hematocrit (Ht) = height of the erythrocyte column/height of the whole blood column

Interstitial Fluid (ISF): true “Milieu Interieur”

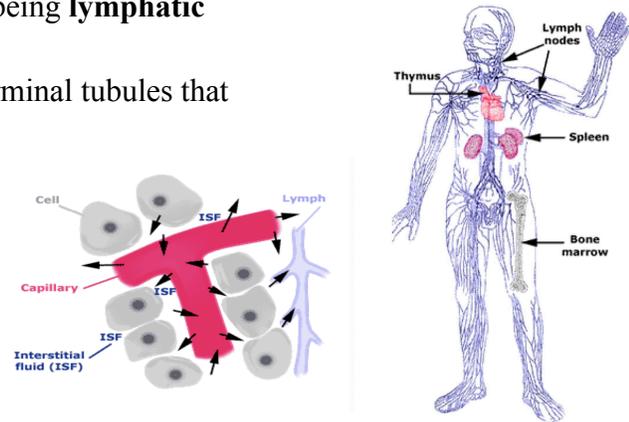
- Major ECF compartment
- ISF is the fluid moving between all cells in the body
- ISF is distributed by the capillaries, as once fluid leaves the capillaries, it becomes ISF
- Occupies 15% of body mass and is the remaining $\frac{3}{4}$ of the ECF

- Drains into the lymphatic system

Total ECF: 20% of body mass	
ISF= 15%	Plasma = 5%
Total ECF volume: 14L	
ISF = 10.5 L	Plasma = 3.5L

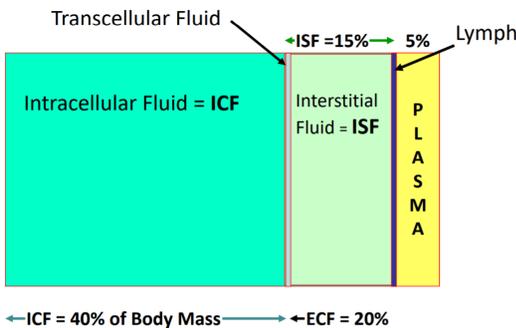
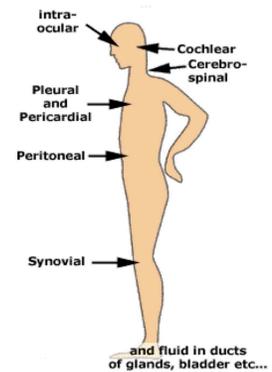
Lymph: fluid that flows through the lymphatic system, this being **lymphatic drainage**

- The lymphatic system is a network of blind-ended terminal tubules that coalesce to form larger lymphatic vessels, which converge to form large lymphatic ducts and then drain into the large veins in the chest to bring it back to central circulation.
- Minor ECF compartment
- Accounts for 1-2% of ECF
- Appears clear/white
- The movement of lymph is **unidirectional**



Transcellular fluid: an aggregate of small fluid volumes secreted by specific epithelial cells that line some body cavities.

- These fluids carry **specific functions** and are found in different parts of the body lined with epithelial cells.
- < 1-2% ECF
- Found in places such as the eyeball, inner ear, CSF (cerebrospinal fluid), synovial (joints), pleural and pericardial fluids
- Too much transcellular fluid in these areas can cause damage.
- Does not contribute significantly to overall body water exchange as local changes do not affect body fluid balance. However, locally, transcellular fluid plays an important role in function



Rules for Body Fluids:

- 1) The total **volume** in a compartment remains **constant**
- 2) The relative **distribution** between compartments remains **constant**

	Total H ₂ O	ICF	ECF	ISF	Plasma
(% Body Weight)	60%	40%	20%	15%	5%

- 3) Compartments exchange fluid; they are in a state of **dynamic equilibrium**

Determining Compartment Volumes:

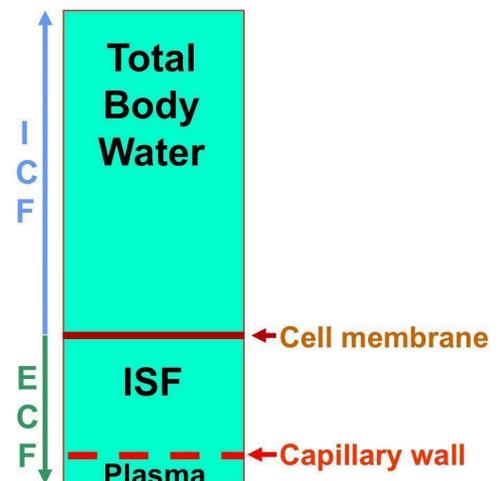
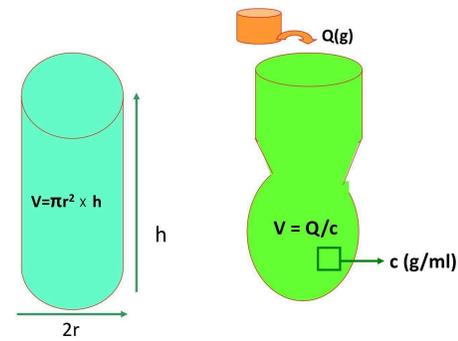
- Done either directly or indirectly

Direct: completely dehydrate (using a desiccator) an organism to determine the change in mass

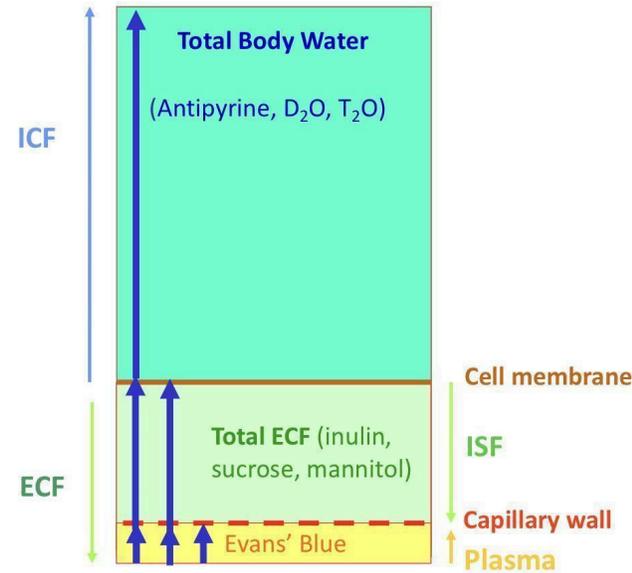
- Not very useful or applicable, as it causes death to the organism
- It is not widely used

Indirect: done through the **indicator dilution method:**

- The indicator dilution method is done by adding a known quantity of a known substance into our unknown volume, then taking out a known volume and determining the concentration
- **What we need to know:**
 - Q - Total quantity of test substance introduced
 - C - Concentration of test substance in fluid after adding and equilibrating.
- **Equation:** $V = Q/C$, where V is the volume of fluid in the organism
- **Steps in a clinical setting:**
 1. Quantity of test substance (Q) is injected intravenously (IV)
 2. Allow time to equilibrate (to all parts of the body)
 3. Remove known volume of blood and centrifuge to isolate the plasma
 4. Measure the concentration (C) of the substance in the plasma
 5. Calculate using the equation above
- **Choosing an Indicator:**
 - Indicators must:
 - Be non-toxic
 - Diffuse readily and distribute evenly throughout the compartments to be measured. When we put the indicator, we need to know where it will go, i.e if it will cross the capillary wall and cell membrane.
 - Induce no changes in water distribution between compartments.



- *Example:* cannot change the permeability of the capillary wall.
 - Be easy to measure
- **Total body water indicators:** Antipyrine, D₂O, or T₂O
 - It can cross both the cell membrane and the capillary wall so that it can be in all the water of the body.
 - Normal amount of body water for a 70 kg man: ~42L
 - *Example:* $Q = 50 \text{ ml D}_2\text{O}$, $c = 0.001 \text{ ml D}_2\text{O/ml plasma}$, since $V = Q/c$, therefore, $V = 50/0.001 = 50,000 \text{ ml} = 50 \text{ L}$
- **Total ECF indicators:** radioactively labelled inulin, sucrose, or mannitol
 - Cannot permeate through the cell membrane
 - Normal ECF Value: ~14L
- **Total plasma indicators:** Evans blue, or albumin
 - Cannot cross capillary wall
 - Normal plasma volume value: ~3.5L
 - *Example:* $Q = 200 \text{ mg Evan's Blue}$, $c = 0.055 \text{ mg/ml plasma}$, since $V = Q/c$, therefore, $V = 200/0.055 = 3600 \text{ ml} = 3.6 \text{ L}$
- *In a clinical setting, the amount excreted or metabolized during the mixing of the indicator with the fluid must be taken into account.*



ICF and ISF volume determinations: requires the use of 2 indicators

- **ICF:** total body water - ECF = ICF
- **ISF:** ECF - Plasma = ISF

Example:

$$\begin{aligned} \text{Total Plasma Volume} &= 3\text{L} \\ &= 100\% - 40\% = 60\% \end{aligned}$$

Hematocrit (Ht) = 40%
(% of Blood Volume that is occupied by RBCs)

What is Total Blood Volume?

$$\begin{aligned} 100\% &= 40\% + 60\% \\ &= 2\text{L} + 3\text{L} = 5\text{L} \end{aligned}$$

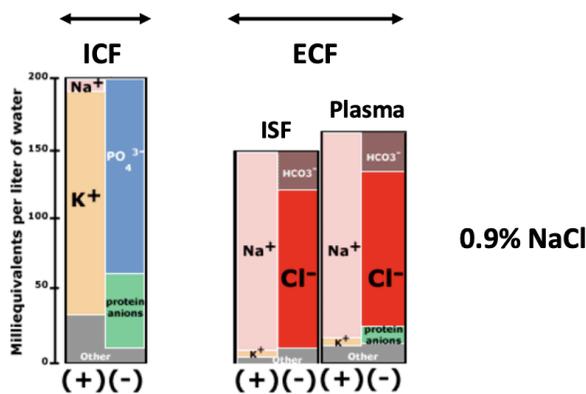
Explanation: Recall that blood volume is composed of RBC and plasma (and buffy layer, but it's not included in %). Because the hematocrit is 40%, the plasma volume corresponds to 60% of the total blood volume. Using this, we can determine that the total blood volume in this case is 5L.

Ionic Composition of Fluids:

- Body fluids are essentially aqueous solutions of inorganic ions with variable amounts of protein
- **ICF:** high in K^+
- **ECF:** high in Na^+ and Cl^-

Relative concentrations of ions in each type			
	K^+	Na^+	Cl^-
ICF	High	Low	Low
ECF	Low	High	High

- ICF also contains Mg^{++} (high relative concentration of it)
- ECF has about 0.9% NaCl (approximation)
- Important to note that plasma has a higher protein concentration than ISF, but otherwise they are ionically about the same.



Summary:

- The viability of cells depends on the **relative constancy of the “internal environment”** (the “Milieu Intérieur”)
- The viability of cells requires **exchanges** with the internal and (ultimately) the external environment