Physiology

Transport Mechanisms Across Cell Membranes and Fluid Compartments of the Body

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The movement of substances across cell membranes is essential for maintaining homeostasis and cellular function.

Additionally, the body's fluid compartments play a crucial role in distributing nutrients, removing waste, and maintaining electrolyte balance.

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Transport Mechanisms Across Cell Membranes

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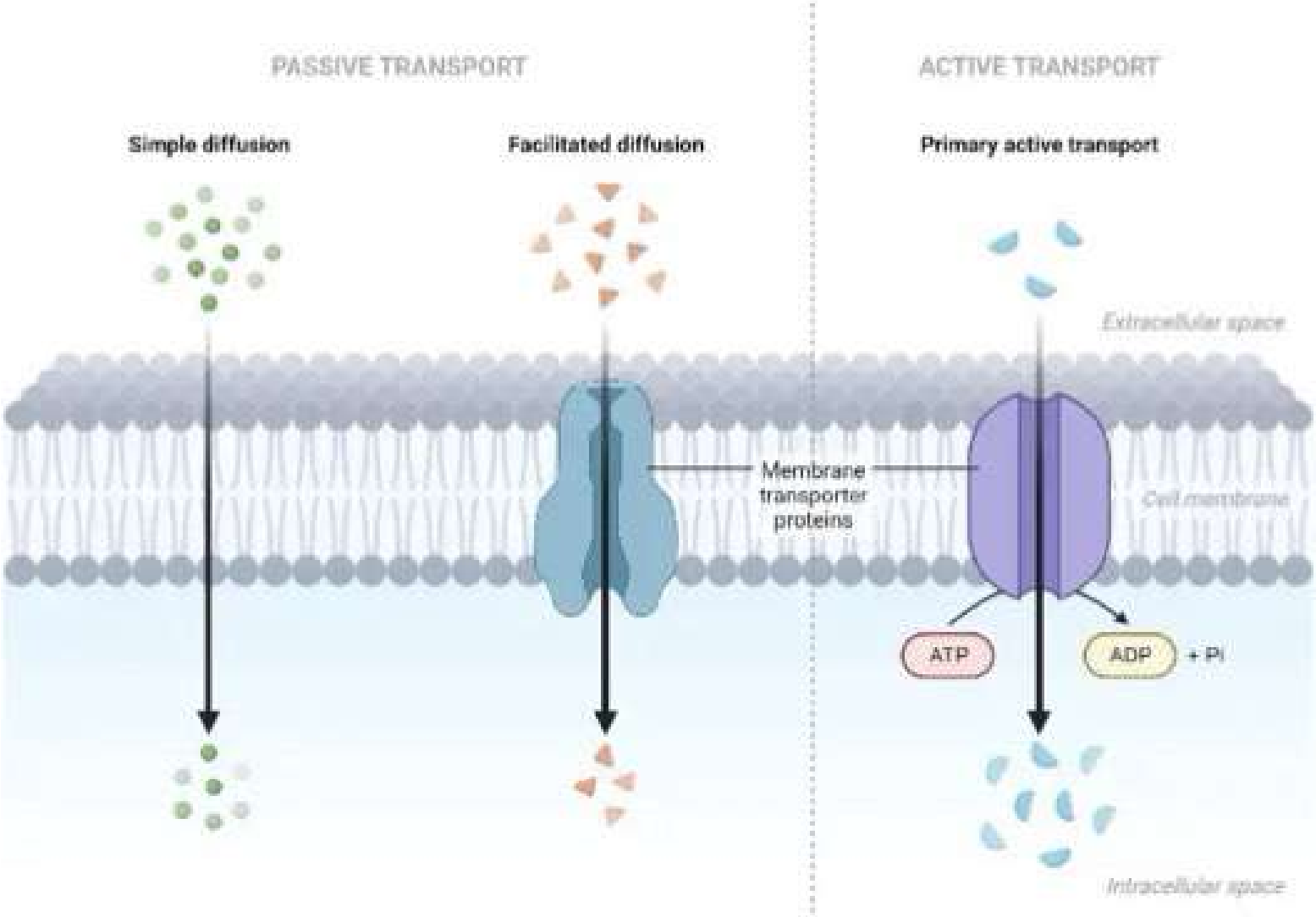
Cell membranes are selectively permeable, allowing certain molecules to pass while restricting others. Transport occurs via passive and active mechanisms.



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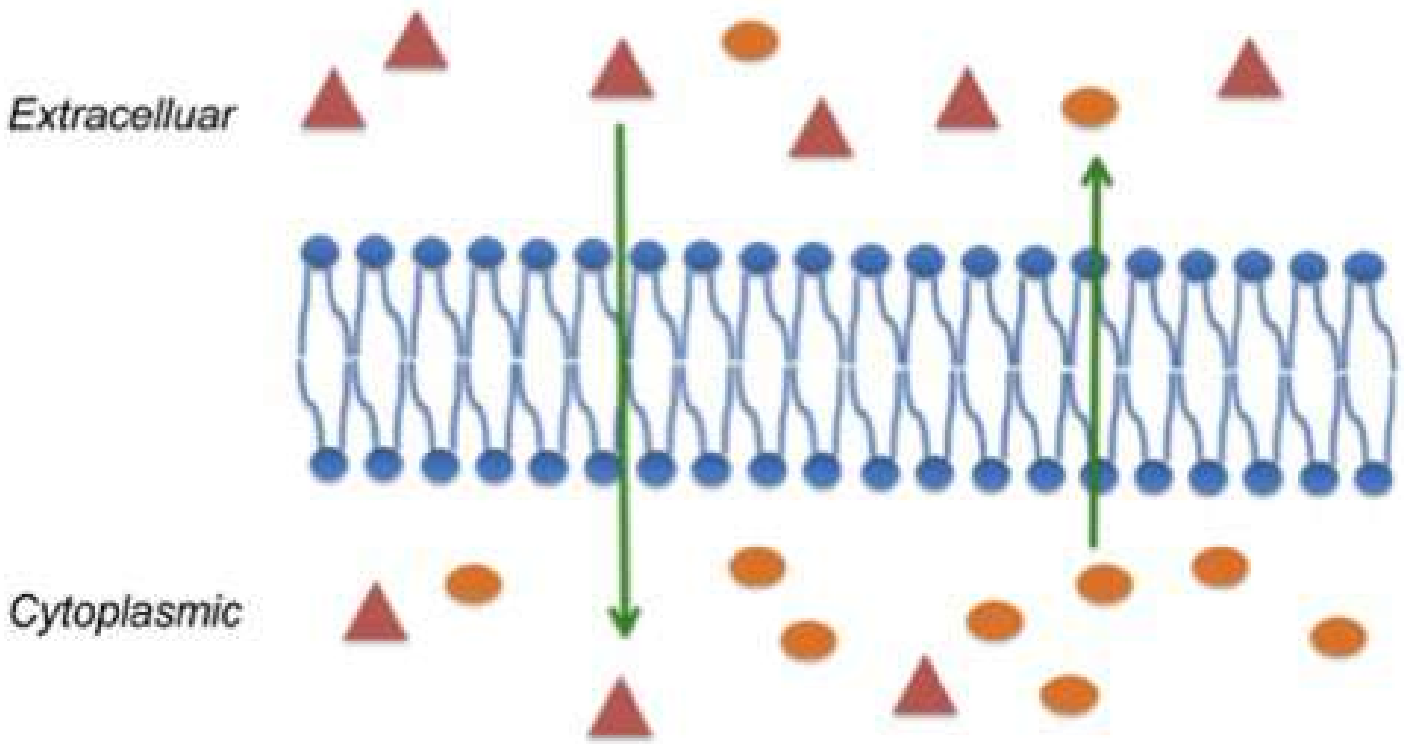
A. **Passive Transport** النقل السلبي

Passive transport does not require energy and occurs due to concentration or electrochemical gradients. It includes:



One solute is more concentrated on the extracellular side of the membrane. Since it is small and hydrophobic, it directly diffuses through the membrane down its electrochemical gradient. The other solute moves down its gradient in the opposite direction

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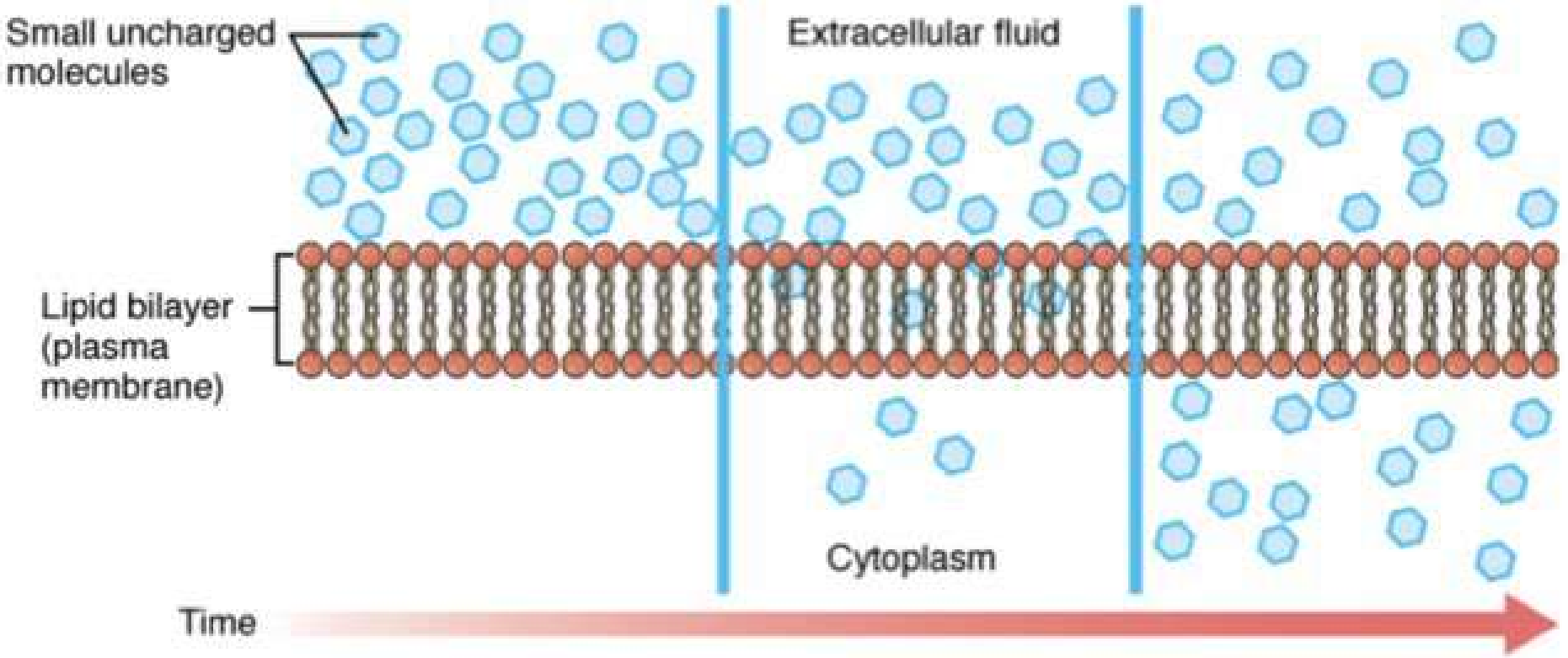
1. Simple Diffusion الانتشار البسيط

- Movement of small, non-polar molecules (e.g., O_2, CO_2) directly through the lipid bilayer.
- Follows a concentration gradient (high to low).



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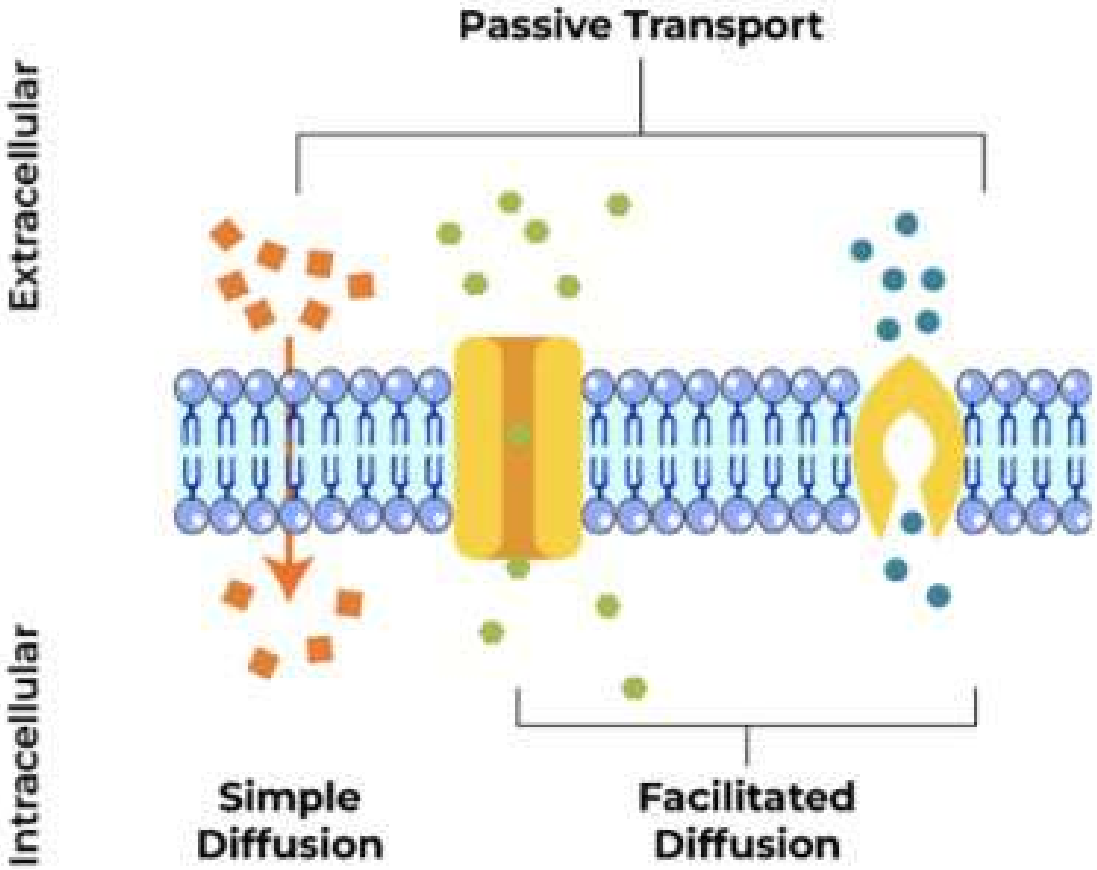
2. **Facilitated Diffusion** الانتشار الميسر

- Movement of larger or polar molecules (e.g., glucose, amino acids, ions) via membrane proteins.
- Can occur through:
- Channel proteins (e.g., ion channels for Na^+, K^+, Cl^-).
- Carrier proteins (e.g., glucose transporters).



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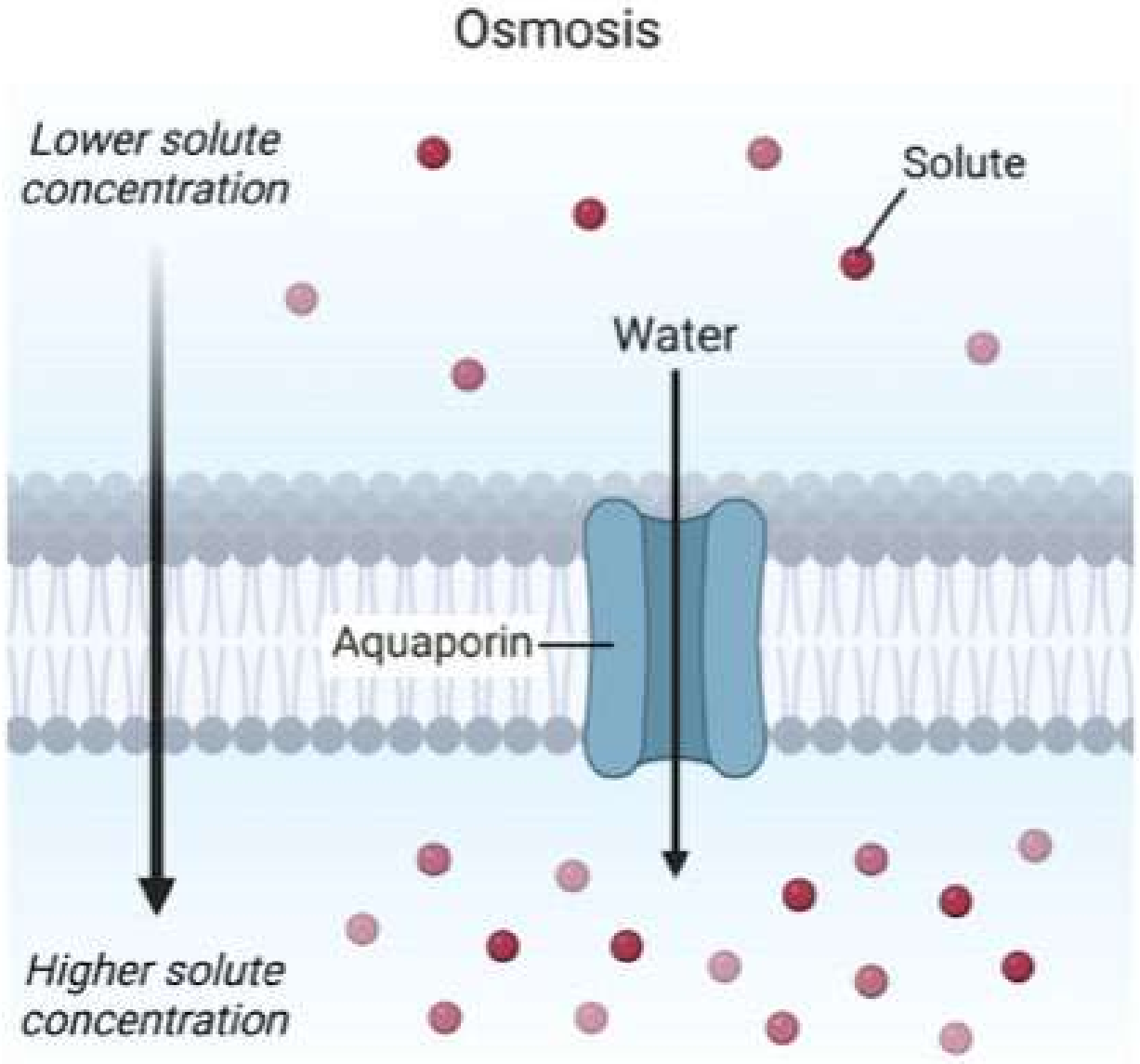
3. **Osmosis** التناضح

• Diffusion of water through aquaporins (water channels) from a region of low solute concentration to high solute concentration.



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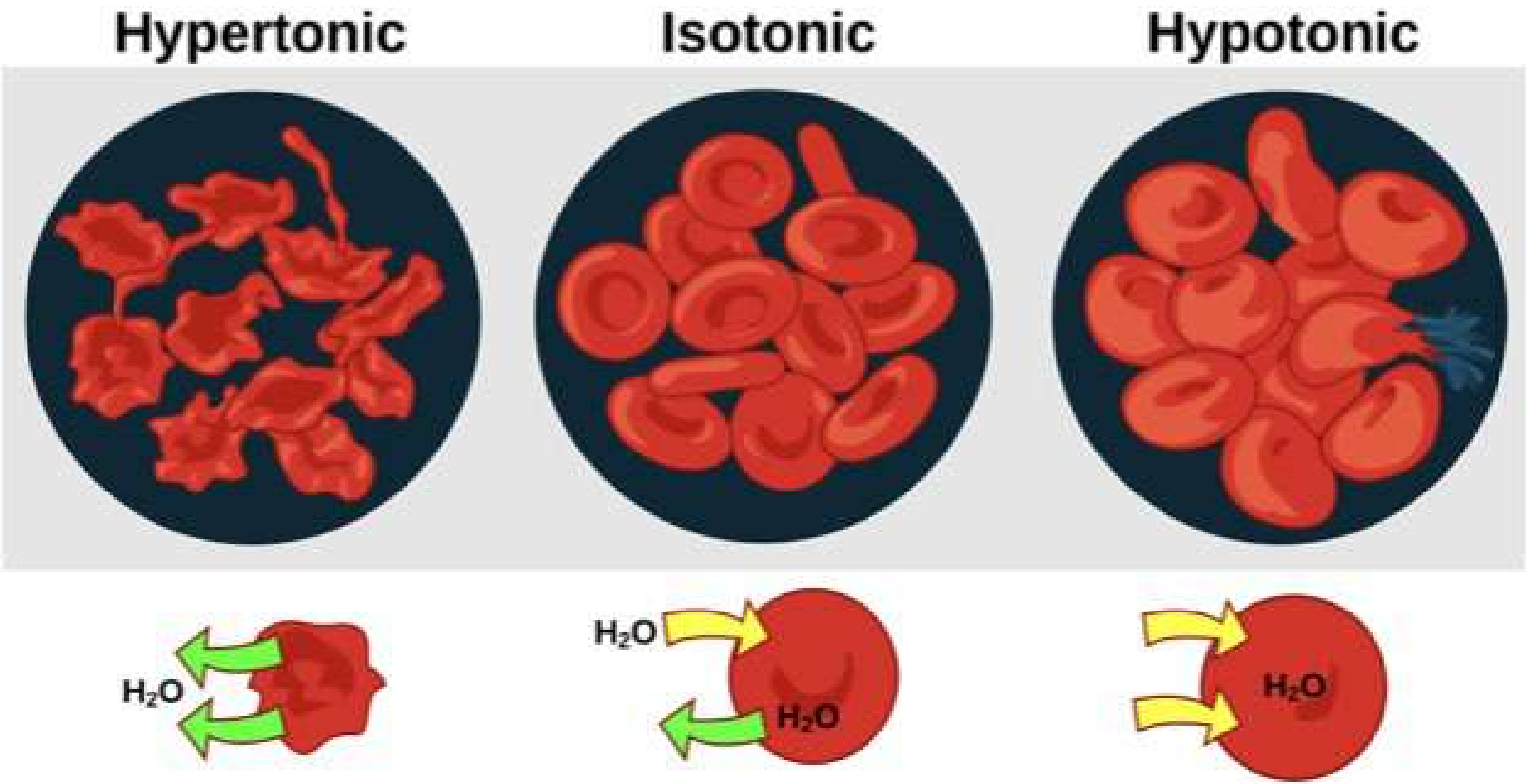

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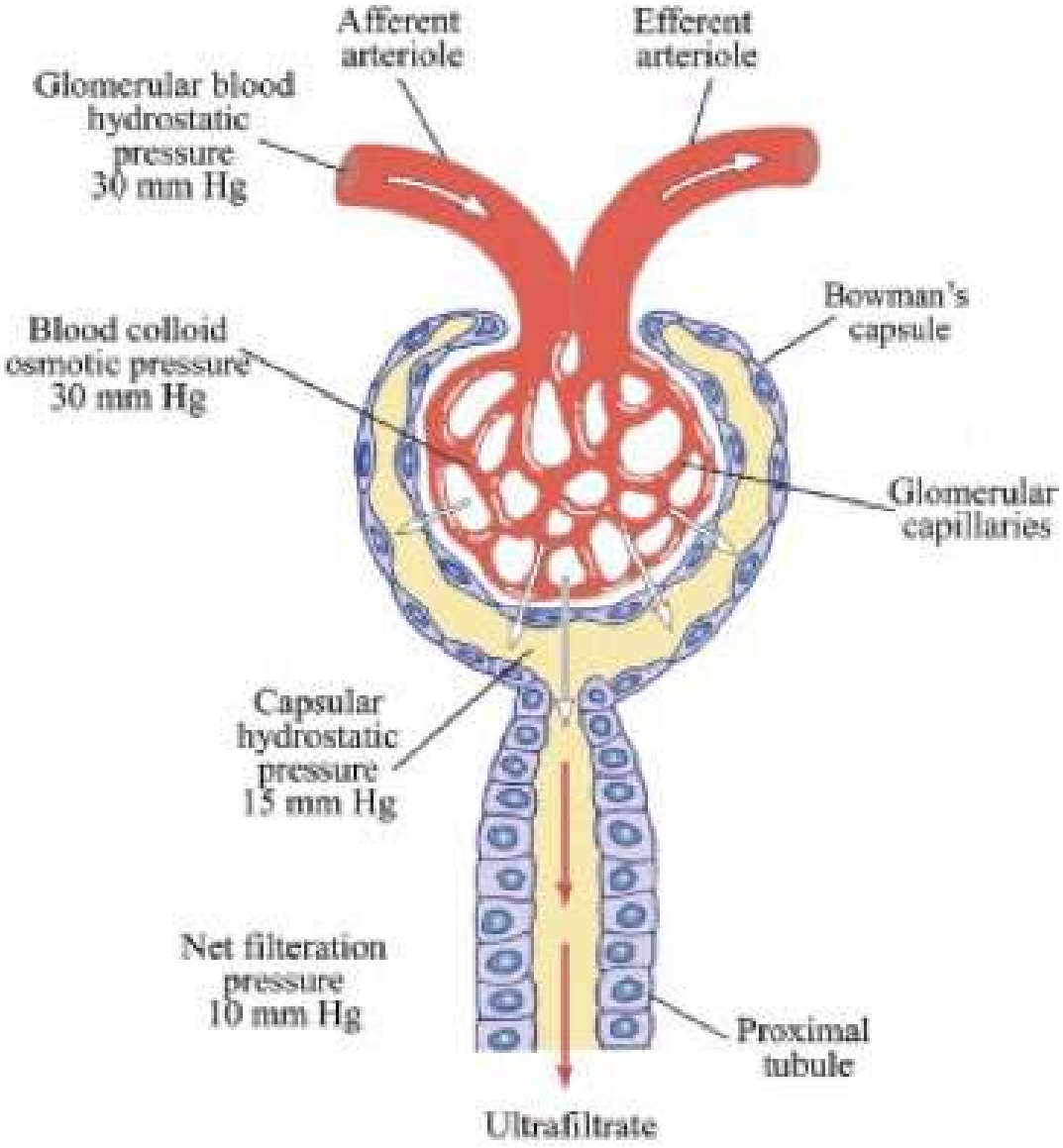
4. **Filtration**

• Movement of water and solutes due to hydrostatic pressure (e.g., capillary filtration in kidneys).



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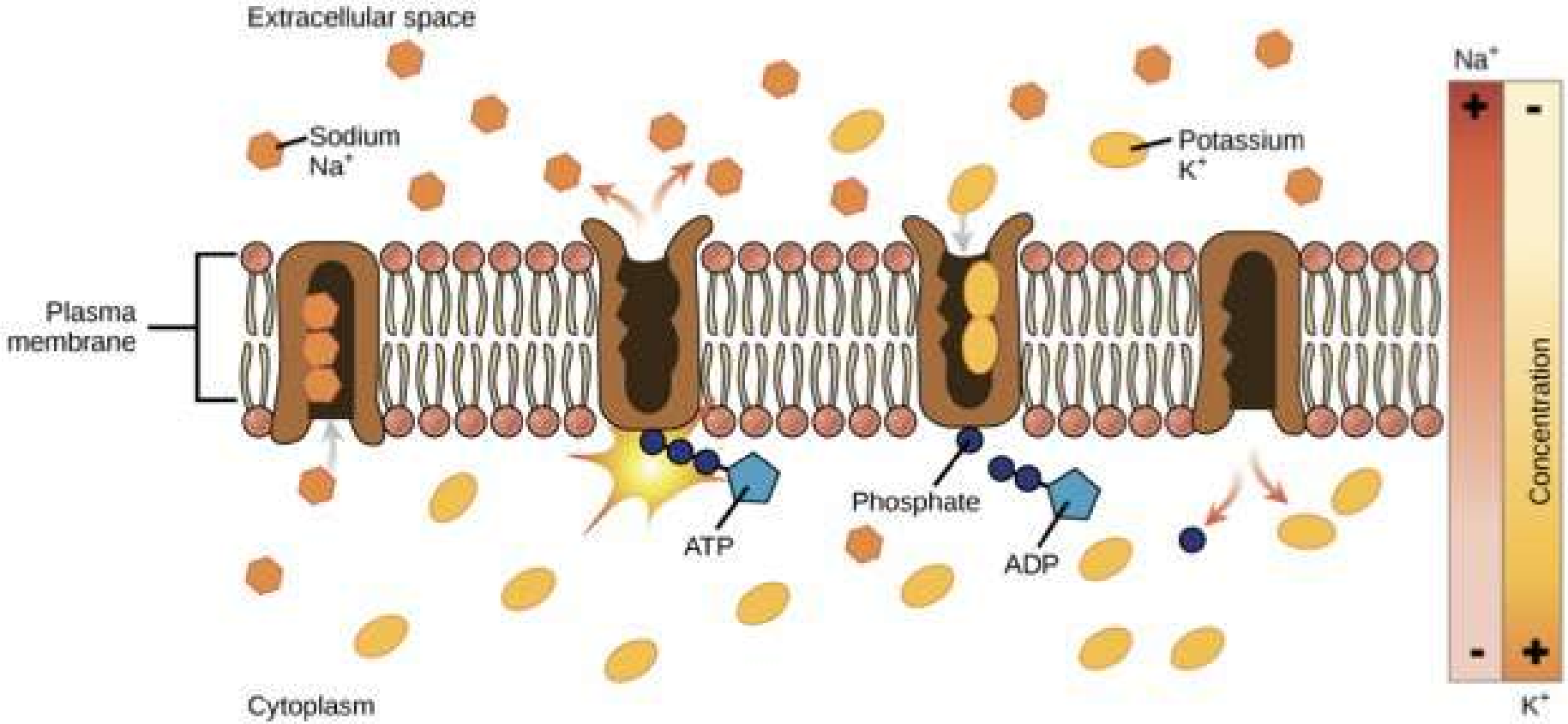
B. Active Transport

Active transport requires ATP to move substances against their concentration gradient.



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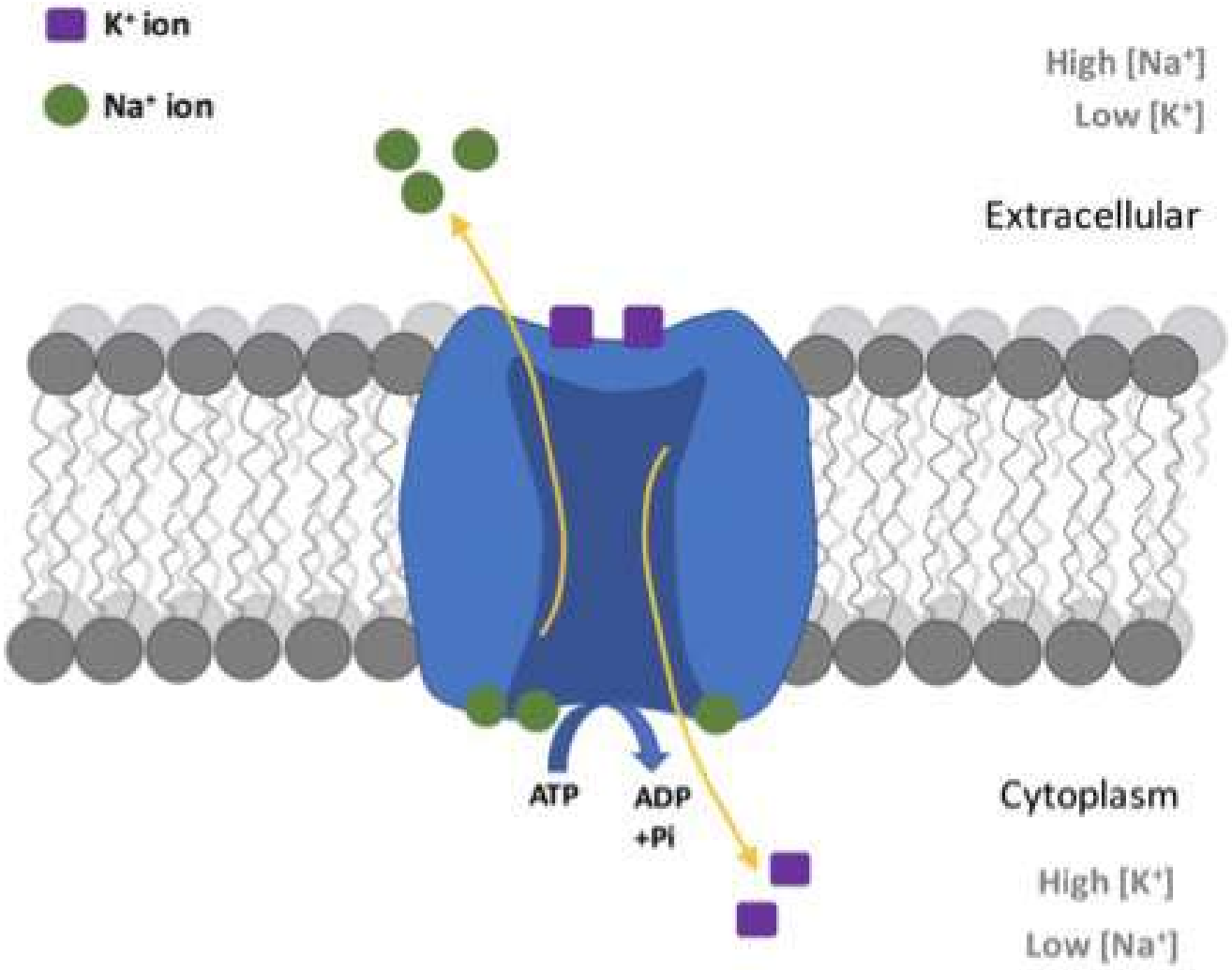
1. Primary Active Transport

- Uses ATP directly.
- Example: Na^+/K^+ ATPase pump (pumps 3 Na^+ out and 2 K^+ into the cell).



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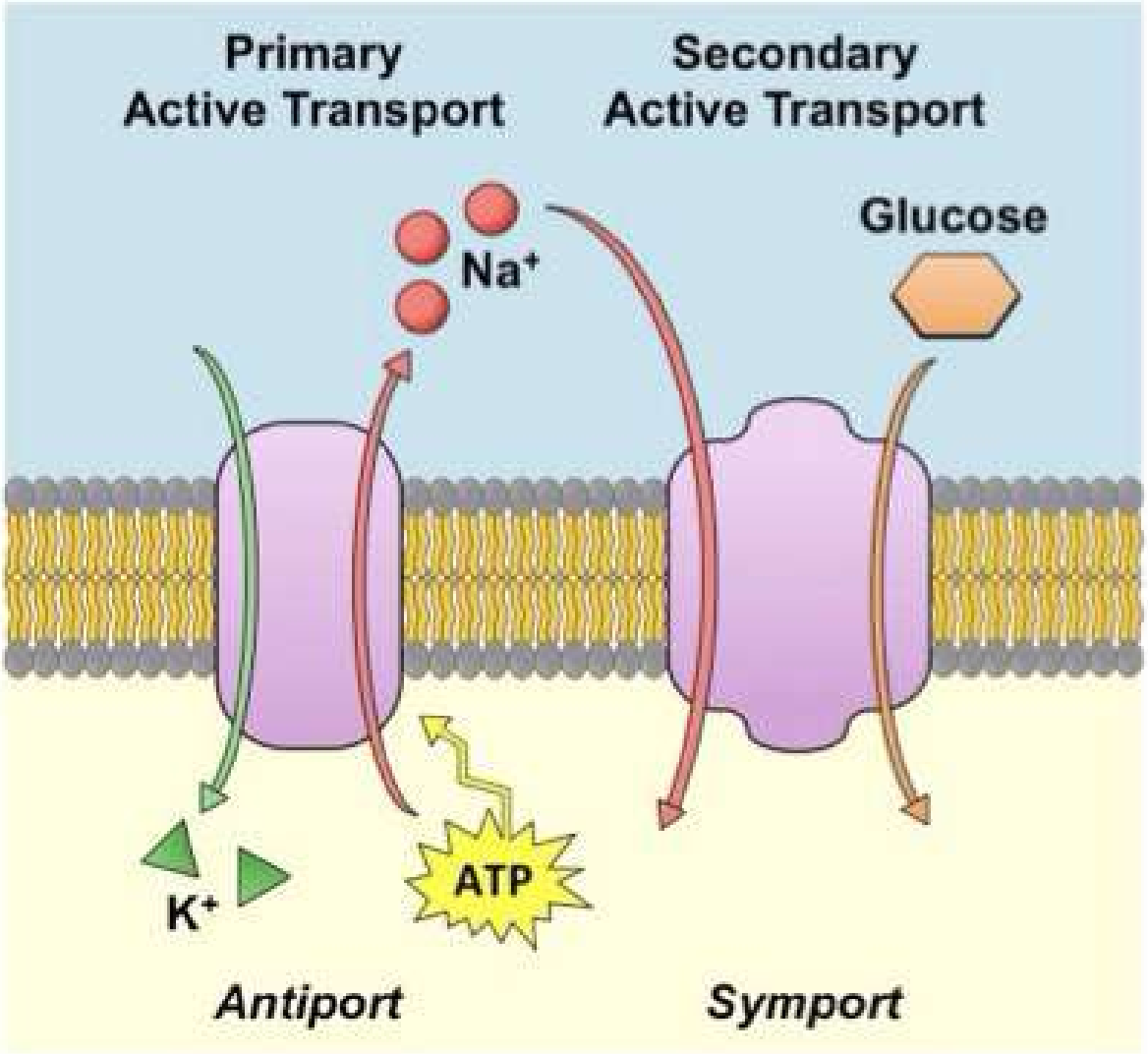
2. **Secondary Active Transport** (Coupled Transport)

- Uses the energy of an ion gradient created by primary active transport.
- Types:
- Symport (Co-transport): Both molecules move in the same direction (e.g., Na^+-glucose symporter).
- Antiport (Counter-transport): Molecules move in opposite directions (e.g., Na^+/Ca^+ exchanger).



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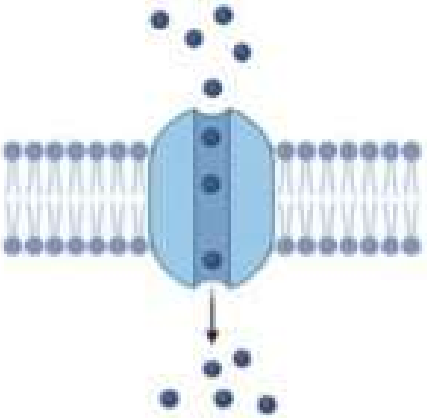
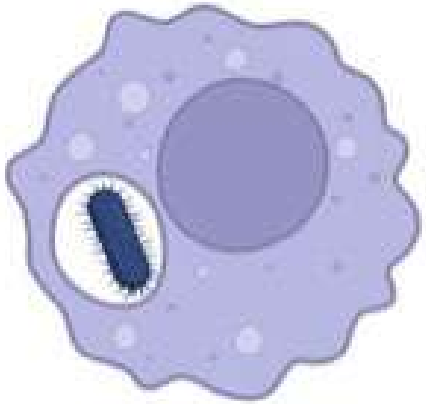
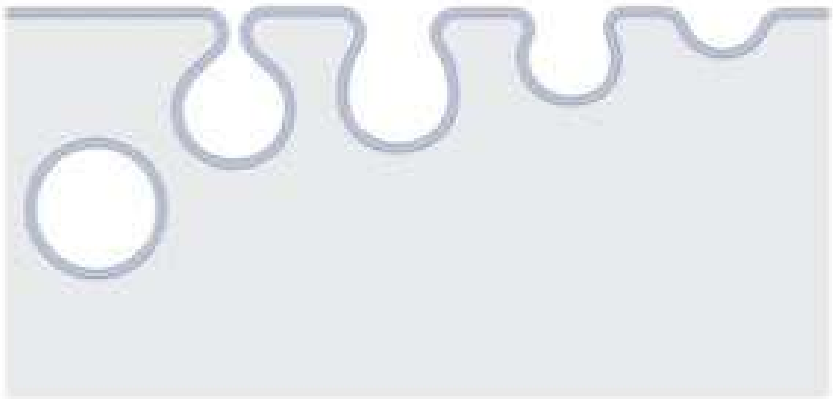
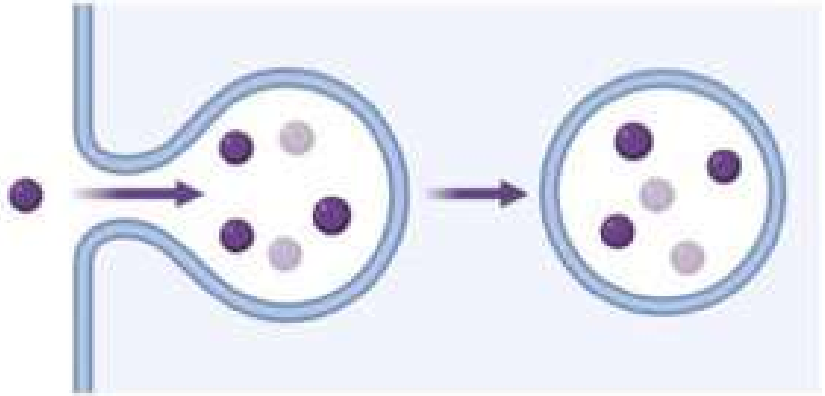
C. **Vesicular Transport** (Bulk Transport)
For large molecules or particles, transport occurs via vesicles.

Bulk Transport









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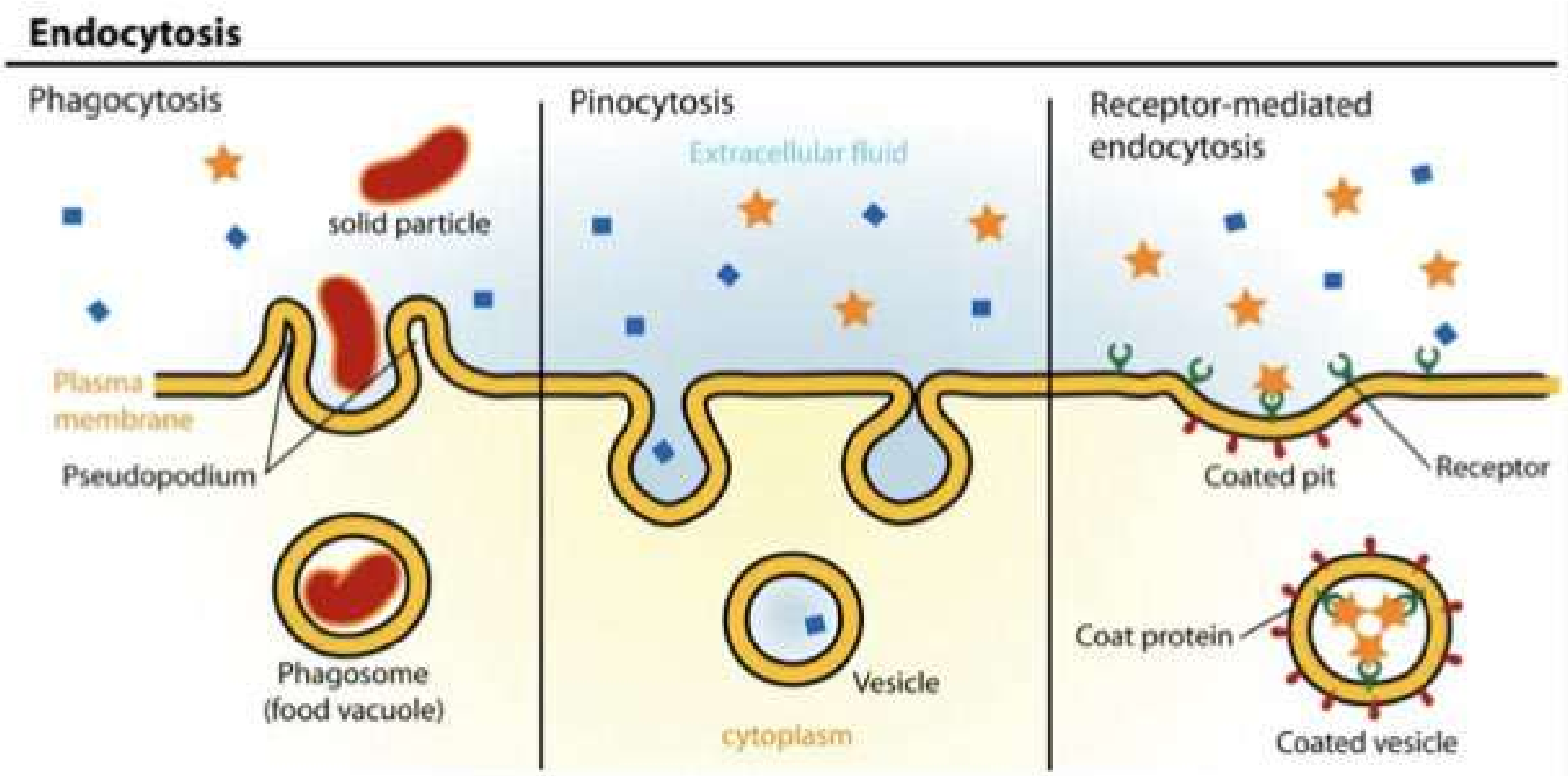
1. **Endocytosis** (Into the cell)

• Phagocytosis: "Cell eating" – engulfing large particles (e.g., bacteria by macrophages).

• Pinocytosis: "Cell drinking" – uptake of fluids and small solutes.

• Receptor-mediated endocytosis: Specific molecule uptake via receptor-ligand interaction (e.g., LDL cholesterol uptake).



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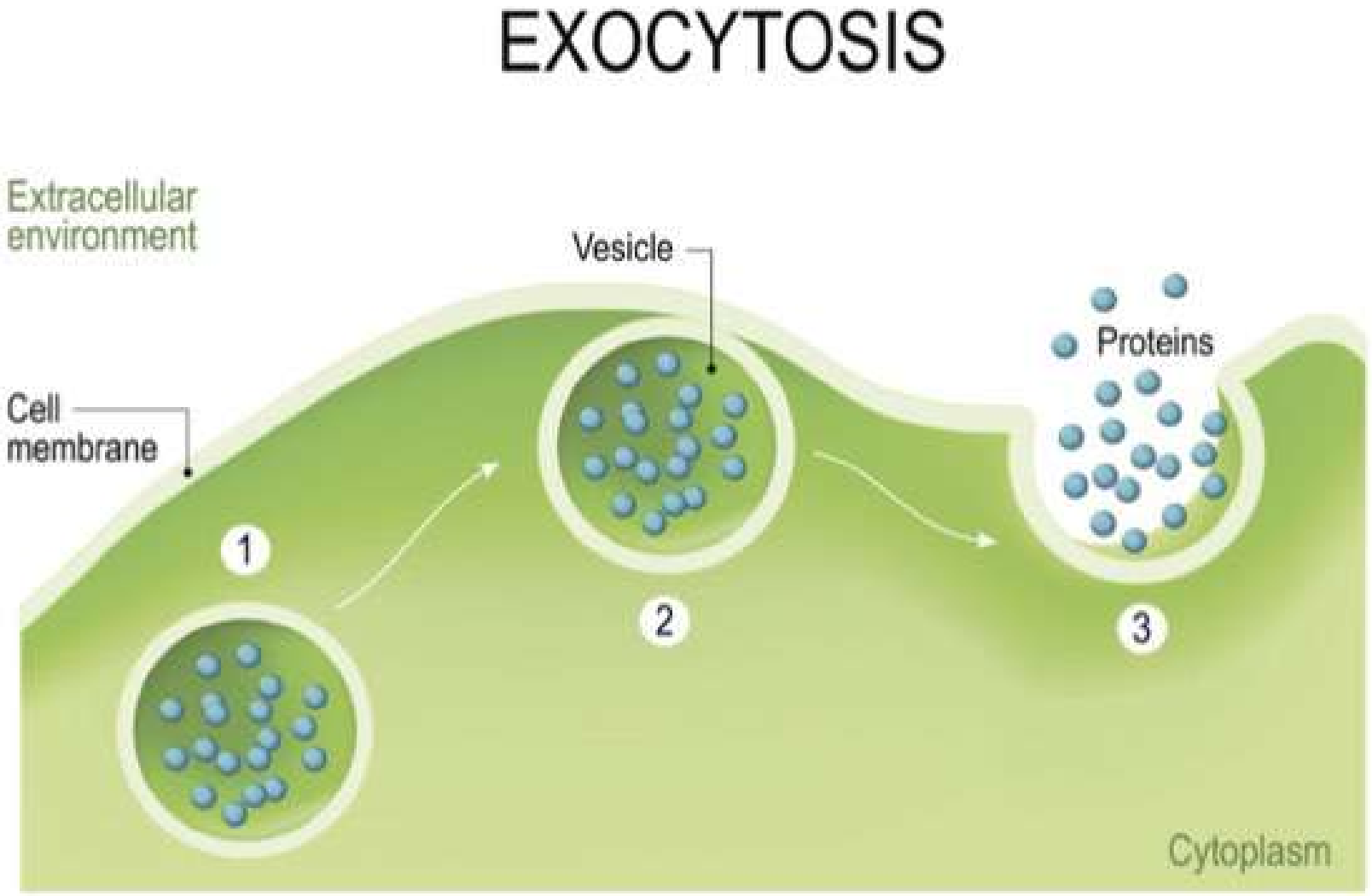
2. **Exocytosis** (Out of the cell)

• Vesicles fuse with the membrane to release substances (e.g., neurotransmitter release).



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Fluid Compartments of the Body, Their Ionic Composition, and Measurements

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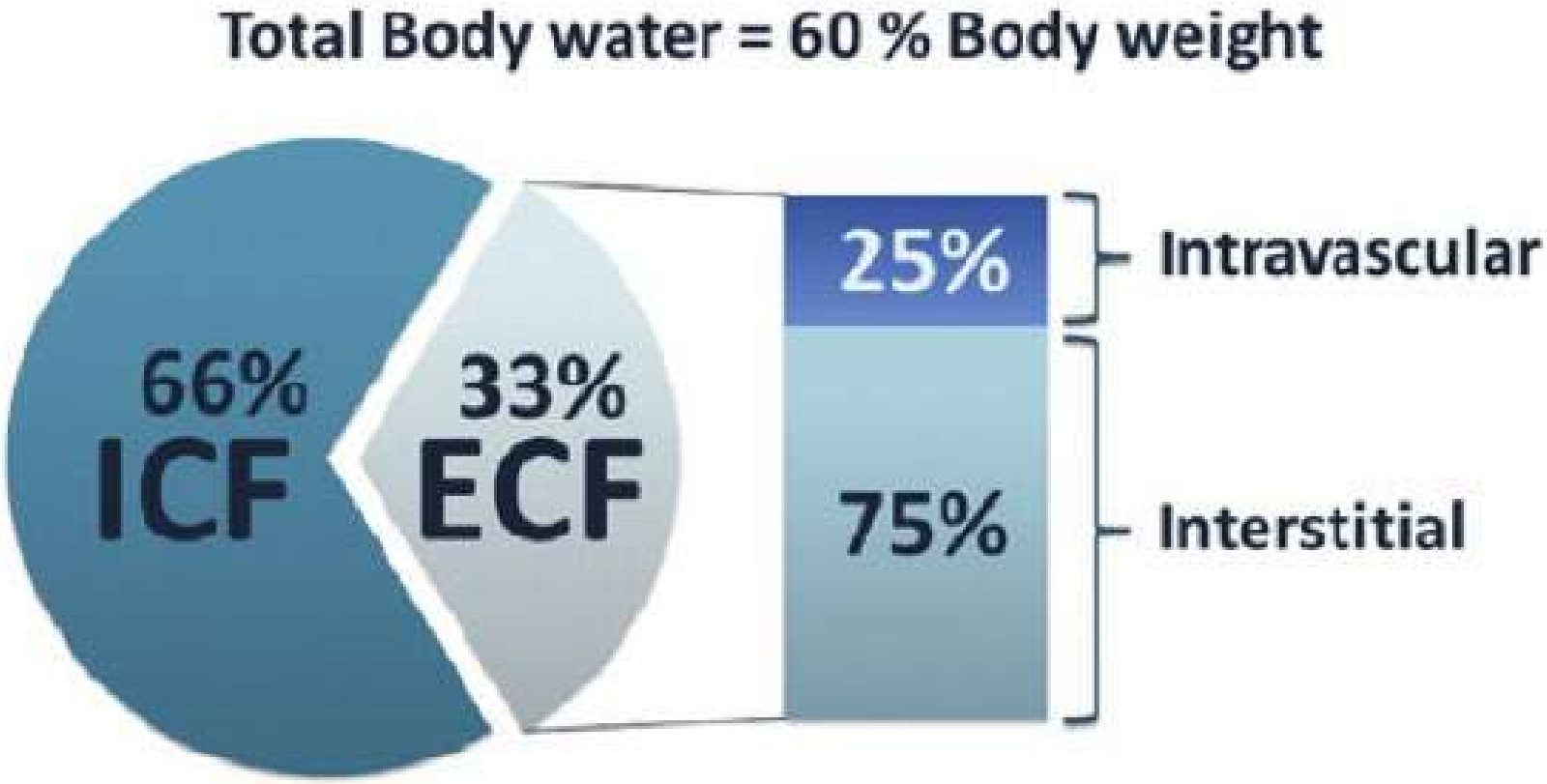
A. Body Fluid Compartments

Total body water (TBW) is about 60% of body weight and is distributed into:



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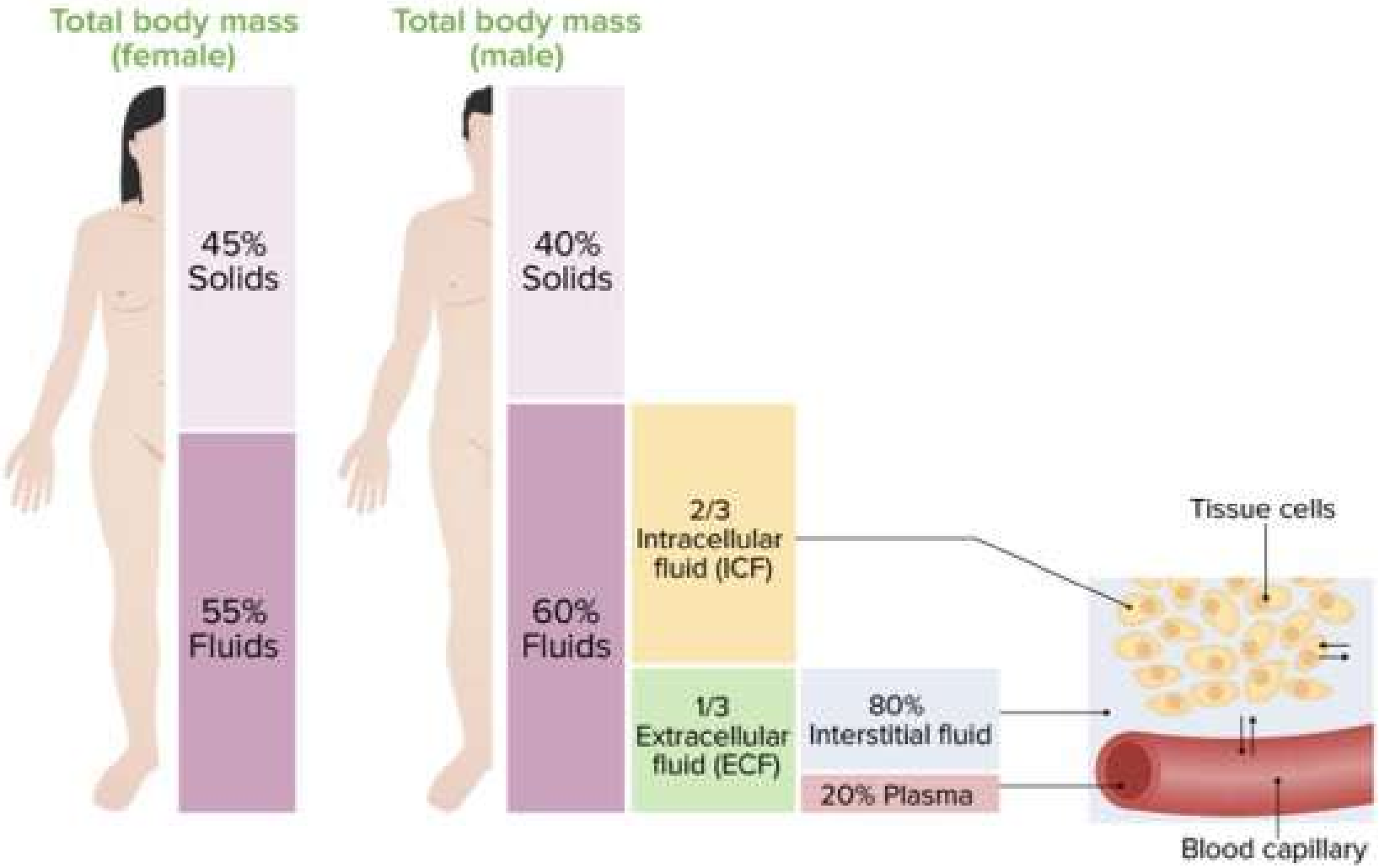
1. **Intracellular Fluid** (ICF) – 40% of body weight
- Fluid inside cells (~⅔ of TBW).
- High in K^+, Mg^{2+}, and proteins.



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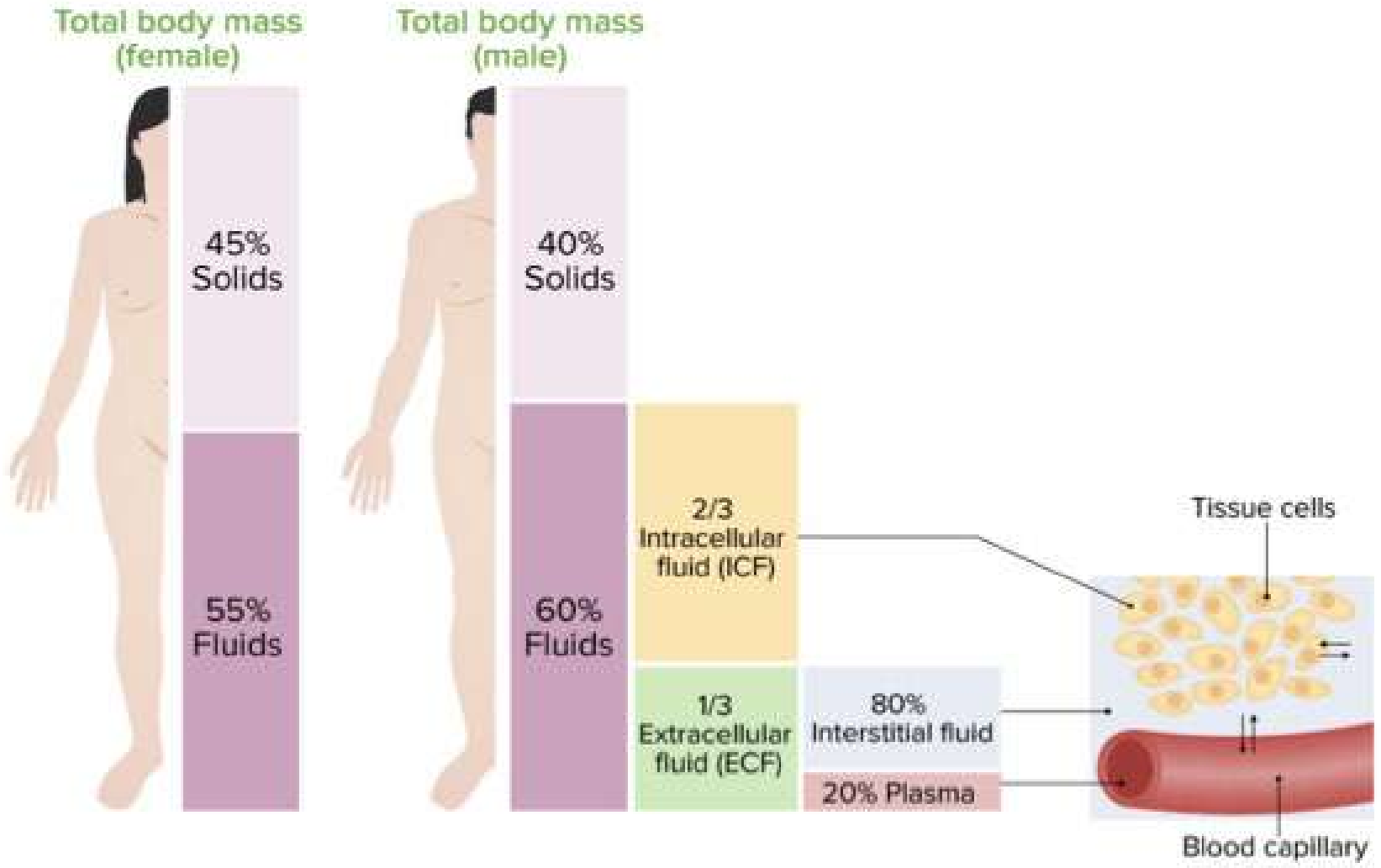
2. **Extracellular Fluid** (ECF) – 20% of body weight

- Fluid outside cells (~⅓ of TBW).
- Divided into:
- Interstitial fluid (15%) – Fluid between cells.
- Plasma (5%) – Fluid portion of blood.
- High in Na^+, Cl^-, and HCO_3^-.



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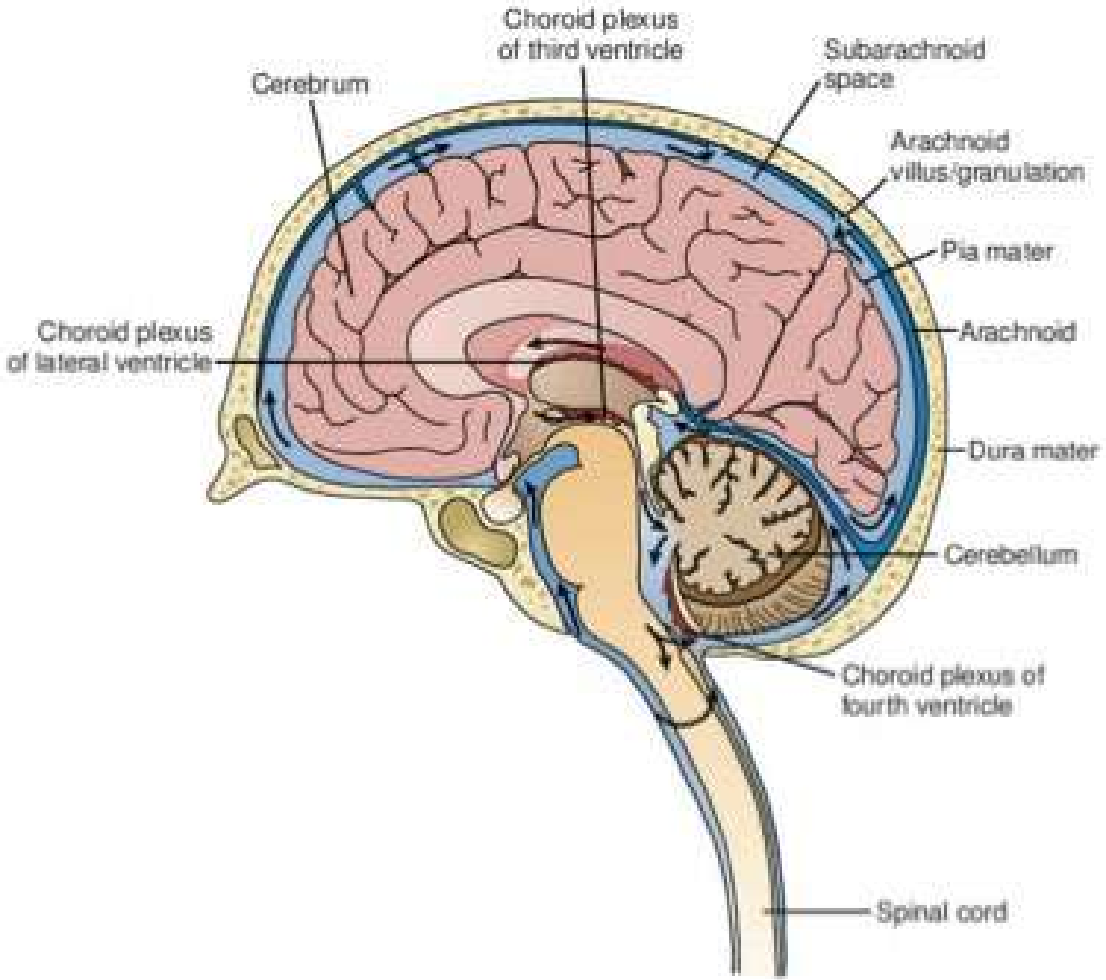
3. Other minor compartments:

• **Transcellular fluid** – Includes cerebrospinal fluid (CSF), synovial fluid, pleural fluid, and aqueous humor.



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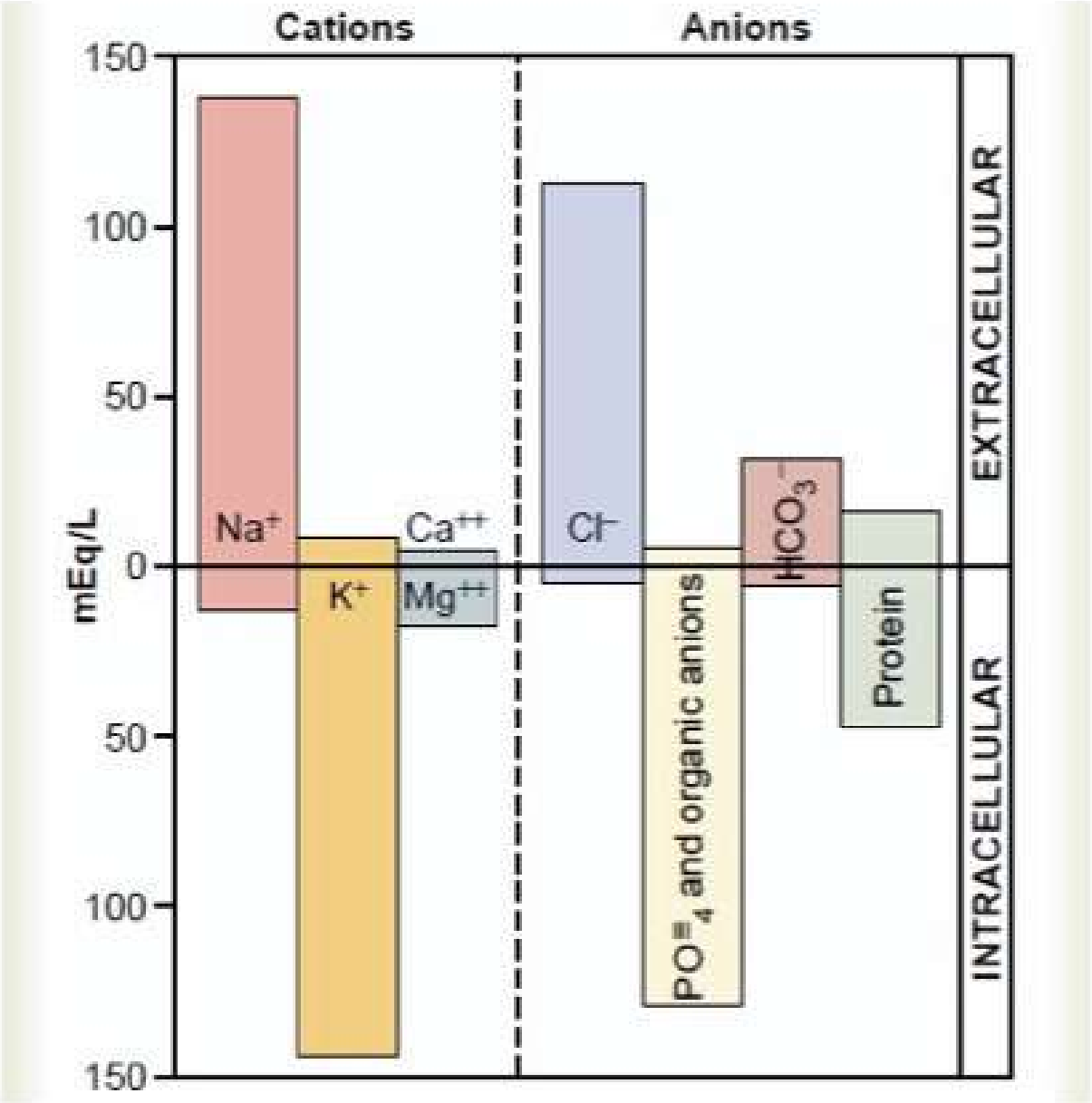
B. Ionic Composition of Fluid Compartments



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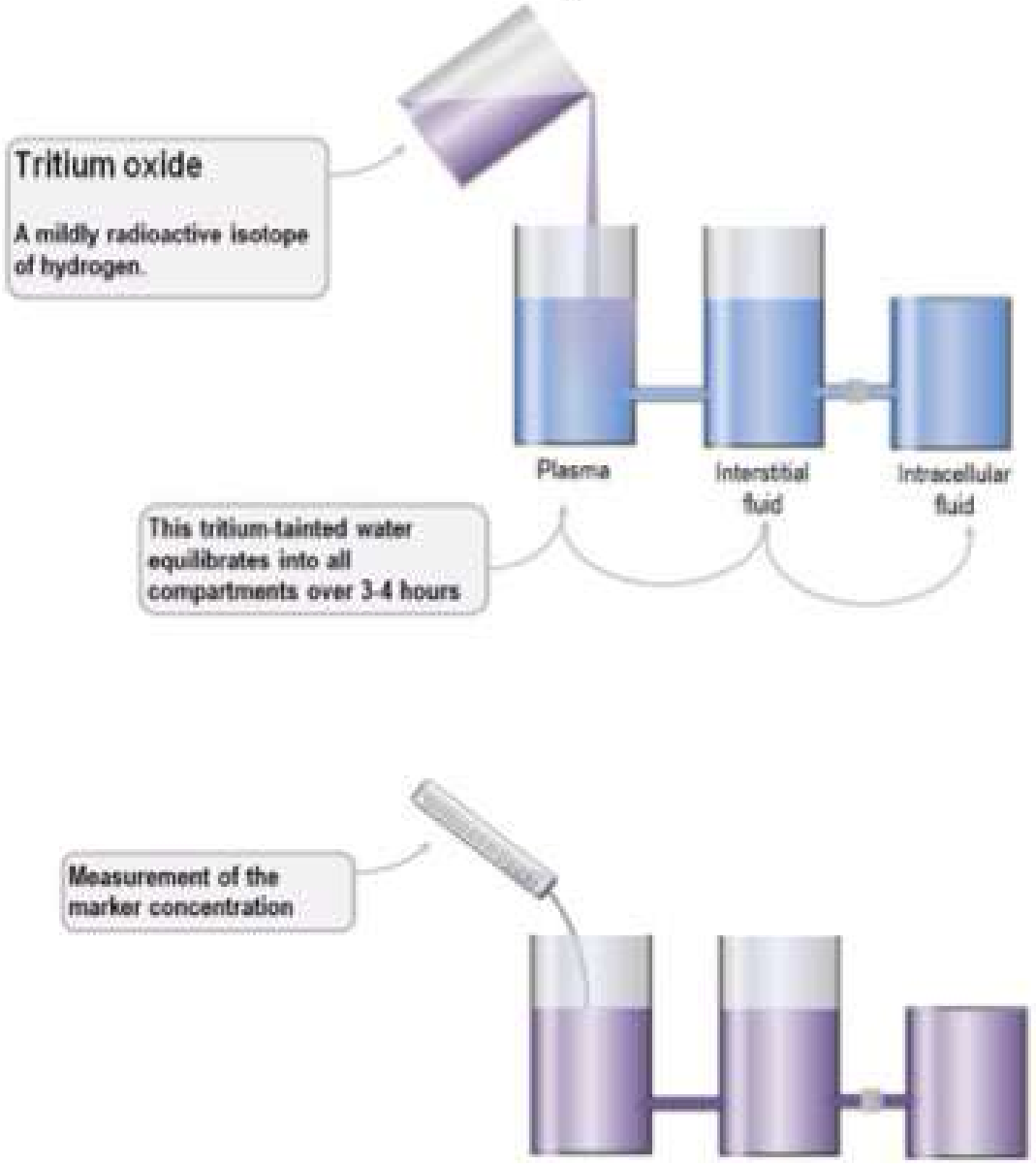
C. Measurement of Body Fluid Compartments

Compartment volumes are measured using indicator dilution techniques, where a known substance is introduced and its concentration is measured after equilibrium.



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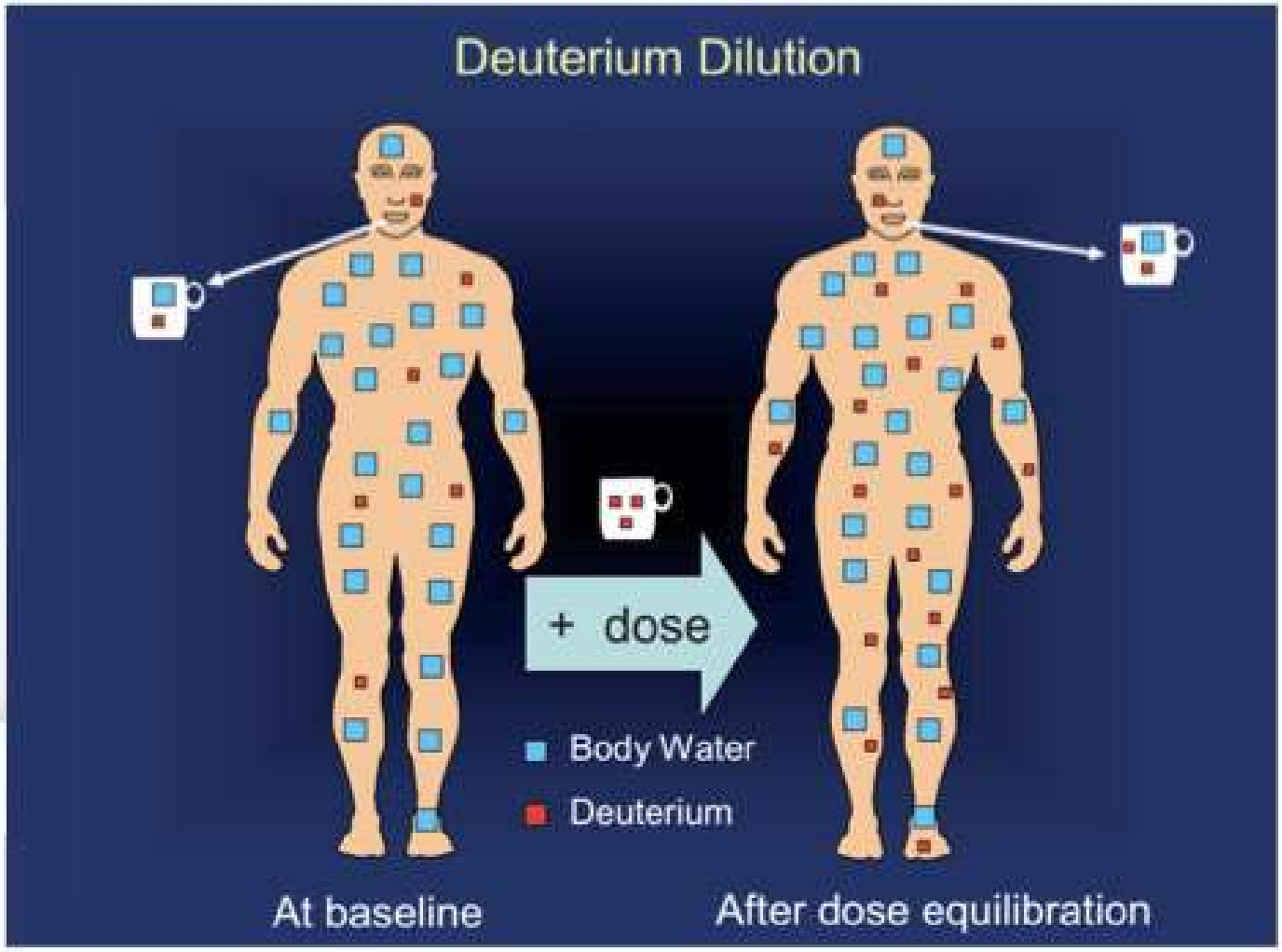
1. Total Body Water (TBW): Measured using **deuterium oxide** (D_2O) or tritiated water (^3H_2O).



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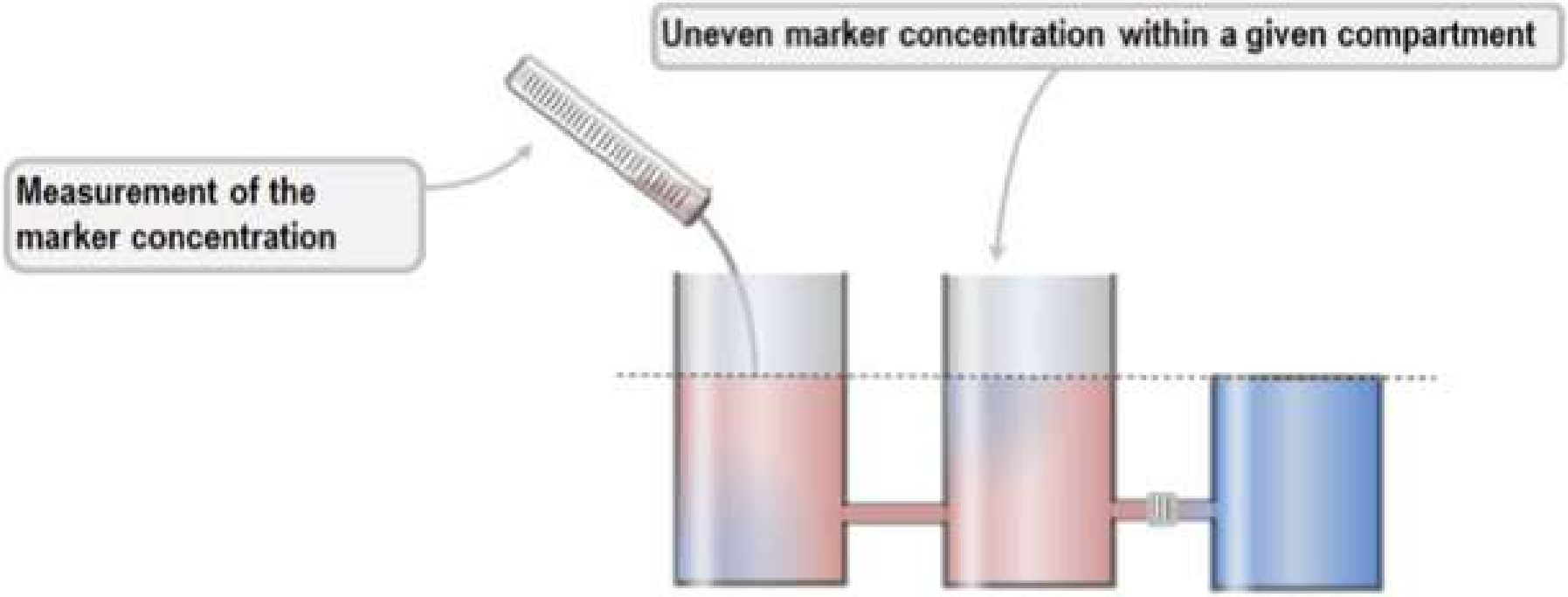
2. Extracellular Fluid (ECF): Measured using **inulin** or radioactive Na^+/Cl^-.



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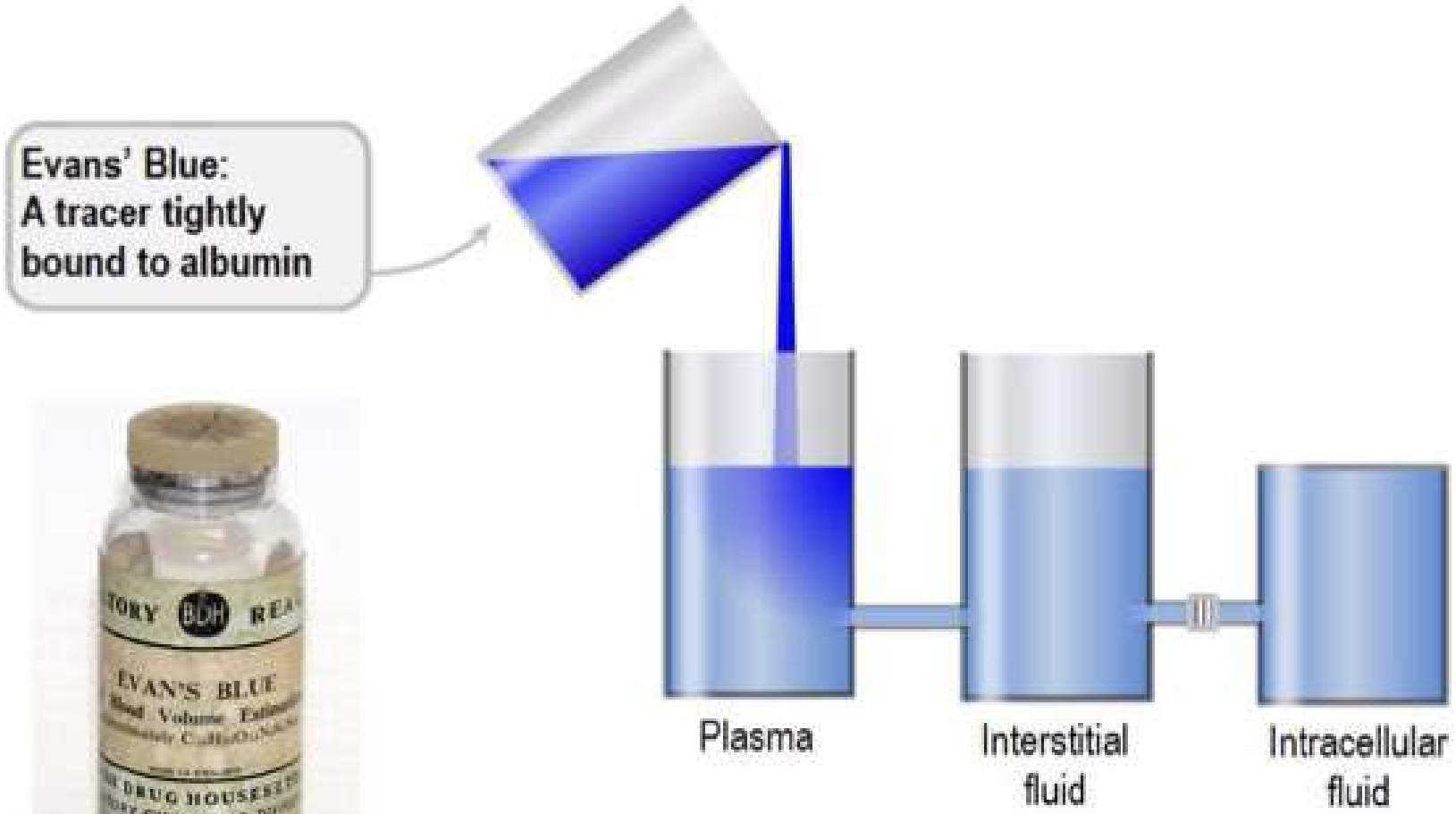
3. Plasma Volume: Measured using **Evans blue dye** (binds to albumin) or **radiolabeled albumin**.



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4. Interstitial Fluid: Indirectly determined as ECF – Plasma Volume.

$$TBW = \frac{D_{3H_2O} - E_{3H_2O}}{P_{3H_2O}}$$

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5. Intracellular Fluid: Indirectly determined as TBW – ECF.

$$TBW = \frac{D_{3H_2O} - E_{3H_2O}}{P_{3H_2O}}$$

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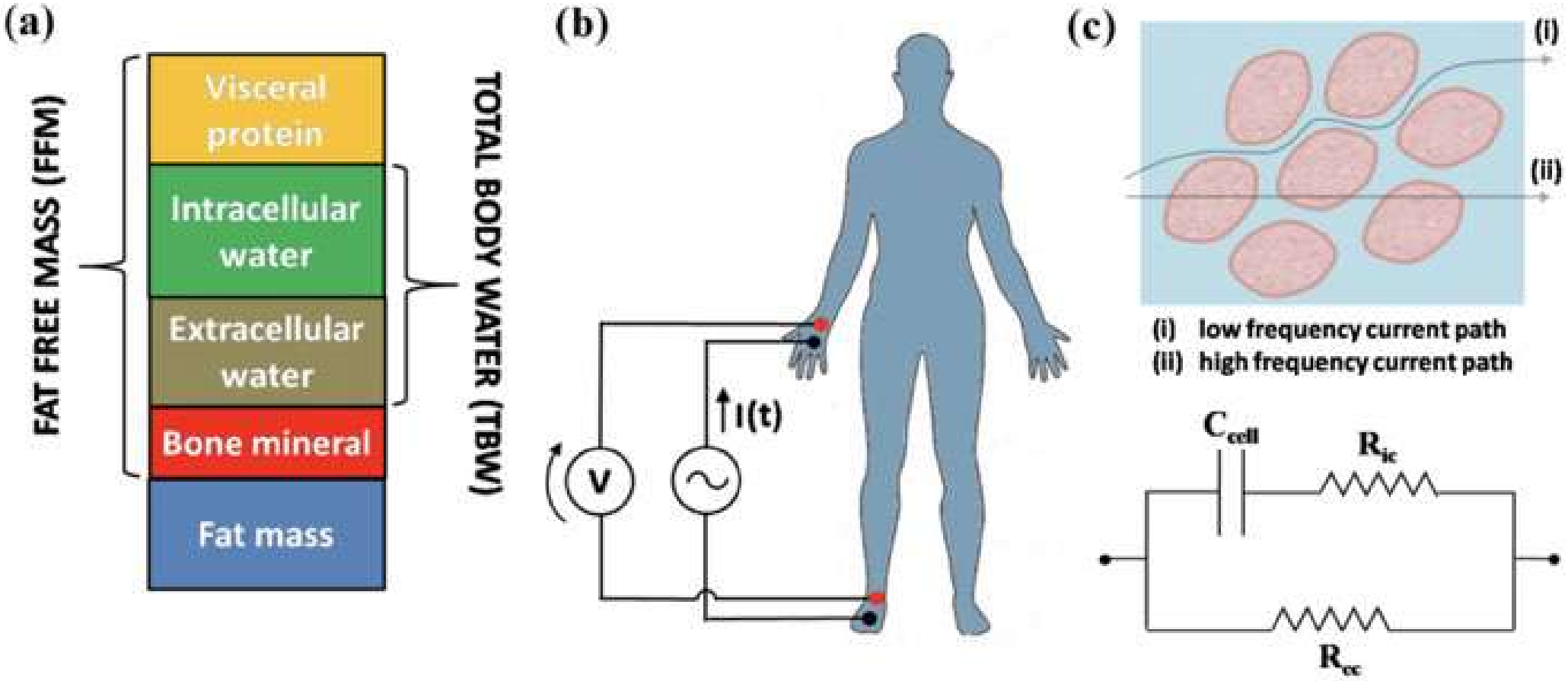
Bioelectrical Impedance Analysis (BIA): non-invasive methode



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Conclusion

- Understanding transport mechanisms helps explain how cells maintain ionic balance and nutrient uptake.
- The body's fluid compartments are essential for physiological processes, and their ionic compositions determine nerve conduction, muscle contraction, and acid-base balance.
- Measurement techniques allow us to assess hydration and diagnose disorders such as dehydration, edema, or electrolyte imbalances.

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