**Fluid & Electrolyte Balance**

Body is ~2/3\textsuperscript{rd}s water (males=63%; women=52%)

This water occupies three “compartments”:

- **intracellular** \(\rightarrow 63\%\) (or 40\% of body wt) \(25\text{L}\)
  - Facilitates chemical reactions, solvent

- **extracellular** \(\rightarrow 37\%\) (or 20\% of body wt) \([15\text{L}]\)
  - Provides internal environment for cells and transport, protection, etc

- **interstitial**
  - Transcellular (CSF, eye, synovial joints, bursae) \(30\%\) \(12\text{L}\)
  - Lymph
  - **plasma** (=intravascular) \(7\%\) \(3\text{L}\)

Total: \(40\text{L}\)*

*Based on 70kg(154lb) person

Total amount of water & solutes in each compartment remain relatively constant.

Water content and movement is tied to electrolytes and solute concentrations and movement.

E.g. If solutes leave a compartment by diffusion;
- Water also leaves by osmosis
- Water follows salt

Can’t talk about fluid balance without talking about electrolyte balance.

Balance means: **input = output**

**Inputs**
1. Digestive tract: food and drink
2. Metabolism: Each cell produces water in catabolism of glucose

**Outputs**
1. Urine (kidneys)
2. Lungs: Water vapor expired with air
3. Sweat (skin)
4. Feces (intestines)

Output is crucial element in control of fluids and electrolytes.
most important output organ is kidney

urine volume is controlled by:
  glomerular filtration rate
  reabsorption by tubules

glomerular filtration rate remains fairly constant
  → not a strong controlling influence on urine volume

major control of urine volume is reabsorption of water

reabsorption can be controlled to make output match input

controlled by two major hormones:

  **ADH**
  
  decrease in ECF volume stimulates release of ADH
  ?osmoreceptors in hypothalamus?
  makes distal & collecting tubes permeable to water
  → increases water reabsorption
  → decreases urine volume

  **Aldosterone**
  
  increases tubular reabsorption of sodium and other ions
  → increases water reabsorption by osmosis
  → decreases urine volume

additional factors that can affect fluid loss
1. urine volume can also be affected by amount of solutes in urine
  → the more solutes the more urine

  **Diabetes mellitus**
  excess glucose spills over into urine
  causes excess water to enter nephric tubule by osmosis
  results in excessive water loss & dehydration

2. hyperventilation
   over extended time can lose significant water from lungs
   may result in dehydration

3. prolonged vomiting or diarrhea

fluid input can also be regulated to some degree to help maintain fluid balance:
dehydration \rightarrow \text{salivary secretions decrease}  \\
\rightarrow \text{dry mouth} \rightarrow \text{thirst}

provides a stimulus for “behavioral modification”

but still requires \textit{voluntary} act

if fluid intake is stopped completely a balance cannot be maintained  \\
\rightarrow \text{even if kidneys shut down}  \\
\text{still lose water through lungs and skin}

\textbf{Composition of Fluids}

these fluid compartments contain critical electrolytes and solutes:

\text{cations: } \text{Na}^+; \text{Ca}^{++}; \text{K}^+; \text{Mg}^{++}  \\
\text{anions: } \text{Cl}^-; \text{CHO}_3^-; \text{HPO}_4^{--}; \text{Proteins}

These electrolytes function:
1. essential nutrients or building blocks
2. serve critical role in regulation of various metabolic pathways
3. affecting membrane potentials of muscle and nerve cells
4. control water movement between compartments by affecting osmotic pressures

Ions in \textbf{Extracellular Fluids} differ greatly from those in \textbf{Intracellular Fluids}:

<table>
<thead>
<tr>
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While the electrolyte content of the \textbf{Extracellular Fluid Compartments} (mainly Interstitial Fluids & Plasma) they do differ significantly in the amount of \textbf{protein} anions

\rightarrow \text{plasma has much more protein than interstitial fluids}  \\
\text{proteins generally cannot cross capillary walls or cell walls so they are less common in tissue spaces}

the chemical content of these compartments helps to control movement of water between them
**Water Movement Between Compartments**

2 major factors control the movement of water between compartments:

- **osmotic pressure (OP)** (electrolytes and solutes)
  - osmotic pressure develops in compartment with higher concentration of solutes
  - *tends to pull water into compartment*

- **hydrostatic pressure (HP)** (water pressure, blood pressure)
  - *tends to push water out of compartment*

The force that moves water between adjacent compartments = the **effective filtration pressure (EFP)**

If these four forces balance out
\[ \text{EFP} = 0 \]

there is no net movement of water between compartments

If: \[ HPA + OPB > HPB + OPA \]
\[ \rightarrow \text{fluid leaves A and enters B} \]

If: \[ HPA + OPB < HPB + OPA \]
\[ \rightarrow \text{fluid leaves B and enters A} \]

eg: if \( B = \text{blood} \)
  IF = interstitial fluid
  HP and OP measured as mmHg
arterial end of capillary bed:

\[
\begin{array}{c|c}
A & B \\
(BHP + ISFOP) & (ISFHP + BOP) \\
(37 + 0) & (1 + 25) \\
(37) & (26)
\end{array}
\]

venous end of capillary bed:

\[
\begin{array}{c|c}
A & B \\
(BHP + ISFOP) & (ISFHP + BOP) \\
(17 + 0) & (1 + 25) \\
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main factor that controls exchange of fluid between blood and tissue spaces is **hydrostatic pressure**

the mechanism that regulates water movement between capillaries and tissue spaces is essentially the same as that which regulates movement of water from cells to tissue spaces

in this case hydrostatic pressure in both “compartments” is almost 0 therefore major controlling factor is changes in **osmotic pressure**

changes in solutes is controlled by active transport across the cell membrane esp. sodium/potassium pump
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\[
\begin{array}{c|c}
\text{A} & \text{B} \\
\text{fluid compartment} & \text{fluid compartment} \\
\hline
\text{HPA} & \text{OPA} \\
\hline
\text{HPB} & \text{OPB} \\
\hline
\end{array}
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If: these four forces balance out then EFP = 0
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eg:

arterial end of capillary bed:

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- esp. sodium/potassium pump
**Water Balance Disorders**

1. **dehydration**

   output > input

   caused by:
   - excessive sweating
   - water deprivation
   - chronic diarrhea
   - excessive vomiting

   eg. athletes can lose up to 4l of water/hour
   but can only safely take in ~2l/hr

   Blood loses water \(\rightarrow\) ECF loses water \(\rightarrow\) cells lose water

   infants & elderly more likely to suffer dehydration
   since their kidneys are less able to conserve water

   treatment: replace water *and* lost electrolytes

2. **water intoxication**

   input > output

   often happens after dehydration
   \(\rightarrow\) water is taken in too quickly without electrolytes

   input \(\rightarrow\) to blood \(\rightarrow\) to tissue spaces \(\rightarrow\) to cells

   can cause edema as water collects in ISF

   causes cells to swell as it moves from tissue spaces into cells

   especially affects cells sensitive to ion concentrations: muscle and nerve cells

   can result in:
   - heat cramps
   - convulsions
   - confusion
3. edema

= abnormal accumulation of water in ECF

described by:

- decreases in plasma proteins due to
  - liver disease
  - kidney disease
  - starvation

- obstruction of lymphatic vessels

- increased venous pressure

- increased capillary permeability
  - eg. inflammation
  - sunburn