WATER AND THE MAJOR IONS

Water

The living cell is made up of approximately 70% of water. It is an irregular tetrahedron molecule with oxygen at its center. It is essential for life and solubilizes and modifies the properties of biomolecules. H_2O is its chemical formula.

PROPERTIES

- It is dipolar(It has unequally distributed electrical charge)
- The elements of this compound are joined by weak hydrogen bonds which accounts for its liquidity at room temperature
- It is highly viscous
- It has a high surface tension.
- good solvent: water dissolves more compounds than any other liquid
- high heat capacity
- high melting and boiling point

Sources; water as such by drinking, water in the feed supply and metabolic water obtained from the oxidation of carbohydrates, fat and protein in the body.

FUNCTIONS

1. It's a vital constituent of cells and provides medium for chemical reactions
2. It provides fluidity to blood and other body fluids e.g. saliva, cerebrospinal fluid, gastric juices etc hence serves as a lubricant in the transport of feed to tissues
3. It acts as a medium of heat dissipation in the body.
4. An aid in excretion
5. A buffering agent to regulate pH (acidity or alkalinity) of body fluids 70% of the body is composed of water which is distributed in two major compartments in the body.
6. Water can act as both hydrogen donor and hydrogen acceptor i.e. acid and base, the basis of which it acts as a solvent to compounds which can also accept or donate protons themselves for H-binding with Water.

A number of factors affect the amount of water consumed by an animal including physiologic states, environmental temperature, and type of diet and so on. Dissolved within the body water are solutes composed chiefly of three categories of substances:

1. Organic compounds of large molecular e.g. proteins and these aid in distribution of water between the compartments of the by its effect on osmotic pressure.
2. Organic compounds of small molecular size e.g. glucose, urea etc exert little or no osmotic pressure but when in large quantities aid in retention of water.
3. Inorganic electrolytes or ions, these are found in large quantities within the fluids hence play a vital role in retention and distribution of body water.

MAJOR IONS: H^+, NA^+, K^+, CL^- AND HCO_3^-

Electrolytes are elements or compounds that dissociate in solution for example NaCl , KCl to give the constituent ions Na^+, K^+ and Cl^-, ions that are completely surrounded by water molecules. Positive ions are called cations while negative ions are called anions. These elements are involved in the maintenance of homeostasis (water, osmotic and PH status).the law of electrical neutrality states that the total number of +ve ions always equals the total number of –ve ions.

Hydrogen ion (proton) - H^+

H^+ ions are present in all body compartments and the maintenance of appropriate concentrations is essential for normal cellular functions. It has the largest concentration amongst cations in the plasma. It has negligible osmotic activity

The gradient of H^+ concentration between inner and outer mitochondrial membranes acts as a driving force for oxidative phosphorylation. In addition H^+ concentration in a fluid medium determines the ionization of weak acids and hence their functions within the body. Also H^+

Levels affect the surface charge and physical properties of proteins that make up the body. PH level is a measure of the H^+ concentration, hence H^+ concentration determines the PH of blood and determines optimum environment for body chemical reactions.

H^+ is excreted in urine as $H_2PO_4^{2-}$.

Sodium ion (Na^+)

It is the major cation of the ECF and helps to regulate the volume of the ECF. Total body sodium is about 4000mEq, 50% is found in bones, 40% in ECF and 10% in soft tissues. Na^+ as well as other cations constitutes osmotically active particles. Sodium pump operates in all cells to keep the levels of Na^+ in the ECF always higher than that in the ICF, its activity is usually accompanied by opposite movement of K^+. Normal plasma concentration of Na^+ is about 136-145mEq/l while in the ICF its 12mEq/l.

NaCl (common salt) is the major source of Na^+ to the body, although it is also widely distributed in food materials mainly of animal sources.
Na^+ is readily absorbed from the intestines by sodium pump located in the Basal and lateral plasma membrane enterocytes and renal cells and Na-pump actively transports Na into the ECF.
FUNCTIONS

1. It maintains the crystalloid osmotic pressure of ECF, helping to retain water in the ECF.
2. It's involved in neuromuscular excitability/irritability.
3. It maintains viscosity by the sodium salt and along with K^+ helps to maintain the degree of hydration of plasma proteins.
4. It plays an active role in resting membrane potential, by keeping the Na conc. Far in the ECF than in the ICF (known as the resting membrane potential) causing a polarization creating a potential difference of up -70 to -90mV across the membranes.
5. In the same vein, the sudden increased permeability of the membrane to Na causing a rapid influx of Na into the cell occurs in the generation of action potential.

99% of Na^+ is filtered along in the glomerular filtrate and reabsorbed majorly in the proximal convoluted tubules. At the distal tubules , rennin (secreted from the juxtaglomerular cells) is produced due to decreased arterial pressure (decreased Na^+) and this stimulates the secretion of Aldosterone that causes reabsorbtion of Na^+, K^+ and to a lesser extent H^+ is lost in its place. Water subsequently moves in the direction of Na^+.

Potassium ion (K^+)
It is the major cation of the ICF and helps to maintain the intracellular osmotic pressure.
Total body K^+ is about 3500mEq/l.
This ion is easily obtained from many foods such as fruits and vegetables etc.
K^+ is easily absorbed into the blood.
FUNCTIONS

1. EC K^+ is an important factor in skeletal and cardiac muscle contraction.
2. It is also involved in acid –base balance in the body
3. It is also actively involved in nerve impulse transmission and neuromuscular irritability.
4. Certain enzymes such as pyruvate kinase require K^+ as cofactor.

Plasma levels are about 3.5-5mEq/l while IC levels reach up to 150mEq/l.
It is obligatorily lost during Na^+ reabsorbtion from the tubules. It is also excreted in gastrointestinal tract, saliva, gastric juices, bile, pancreatic and intestinal juices.

Chloride ion (Cl^-)

It is the major anion of the ECF and forms inorganic anion of greatest quantity in the body .it also forms part of the osmotically active particles in plasma.

Cl^- is obtained from NaCl, and many other food substances. It is readily absorbed.

FUNCTIONS

1. It is involved in water distribution
2. Osmotic pressure maintenance and
3. Anion-Cation balance in ECF
4. It is important in the formation of gastric juices and hydrochloric acid.

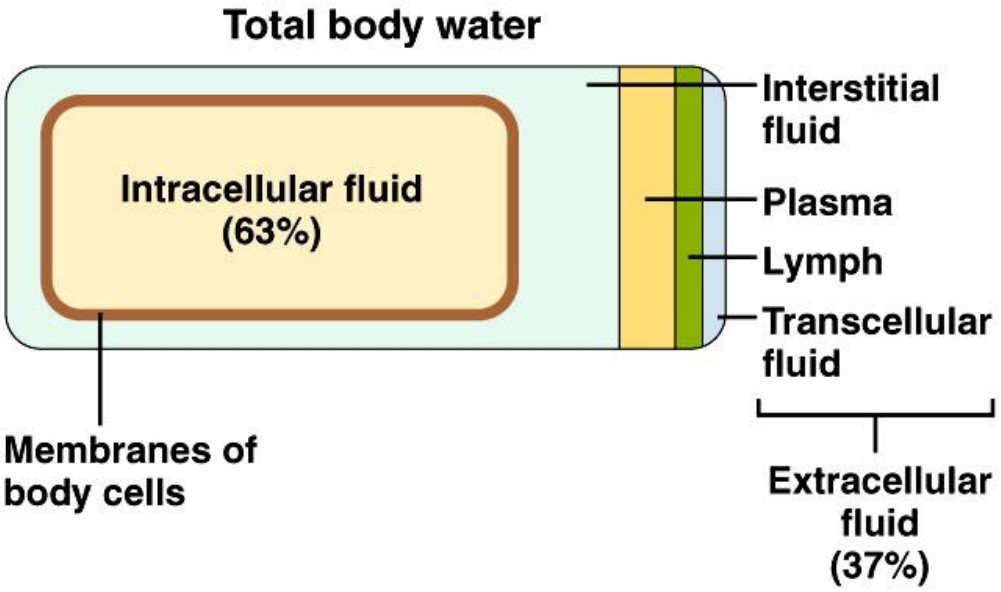
Intake, output and metabolism of Na^+ and Cl^- run in parallel; it is filtered in renal tubules and passively reabsorbed in the proximal tubules. Cl^- is also excreted in sweat.

FLUID AND ELECTROLYTE BALANCE

TOTAL BODY WATER

Total body water (TBW) is divided into two major compartments- the intracellular fluid (ICF) and the extra cellular fluid (ECF).the ICF accounts for approximately half to two third, the volume of body water while the ECF accounts for the rest. The two body fluid compartments differ markedly in solute and electrolyte compositions but are in osmotic equilibrium and water is freely diffusible between them. Movement of fluids is due to hydrostatic pressure and osmotic pressure.

The ECF Na^+ concentration largely determines the volume of the ECF, while that of the ICF is determined by K^+ concentration. Since water is freely permeable through cell membrane is no major osmotic gradient between ECF and ICF.



ECF

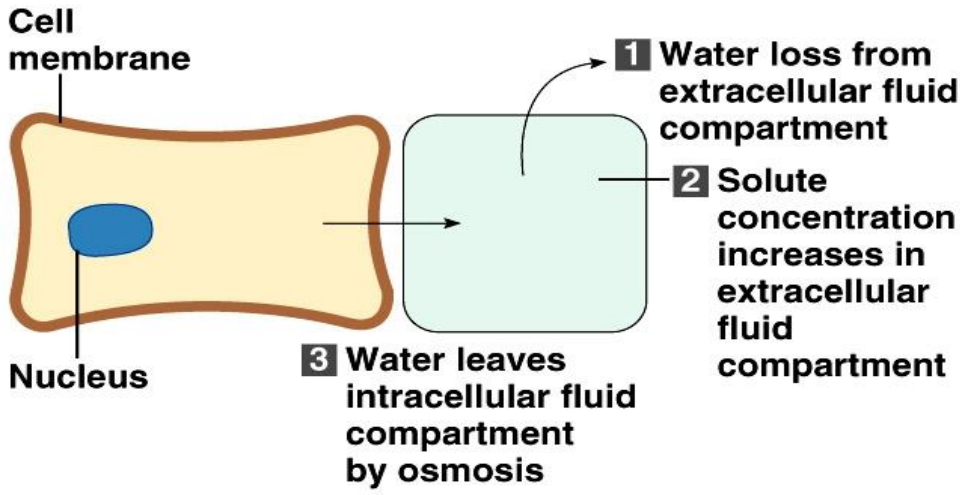
This consists of all the fluids located outside the cell including fluid in plasma (5-8%of TBW), interstitial fluid (25%), lymph, transcellular fluid (fluid content of gastrointestinal, respiratory tracts, intraocular fluids etc; 1-2%). All these fluid content Na^+ as the predominant cation at values ranging between 130-150mEq/l, this determines the ECF volume.

Deficient in Na^+ results in decrease in ECF volume whereas excess results in water retention in the compartment and can results to a condition called Edema (accumulation of fluids within the interstitial spaces). Cl^- and HCO_3^- are the major anions found in this compartment. Fluid generally moves from plasma to interstitial space via hydrostatic pressure and from IF to plasma through the force of colloid osmotic pressure and from the IF to lymph to venous plasma.

Homeostasis is maintained in response to changes that occur in the ECF.

ICF

This is all the fluid contained within the cells in the body. K^+ provides the osmotic skeleton for the ICF just as Na^+ does for the ECF. Changes in tonicity of the ECF are rapidly reflected in the ICF as also changes in tonicity as a result of movement of water out of the cells, thereby changing the ICF volume.

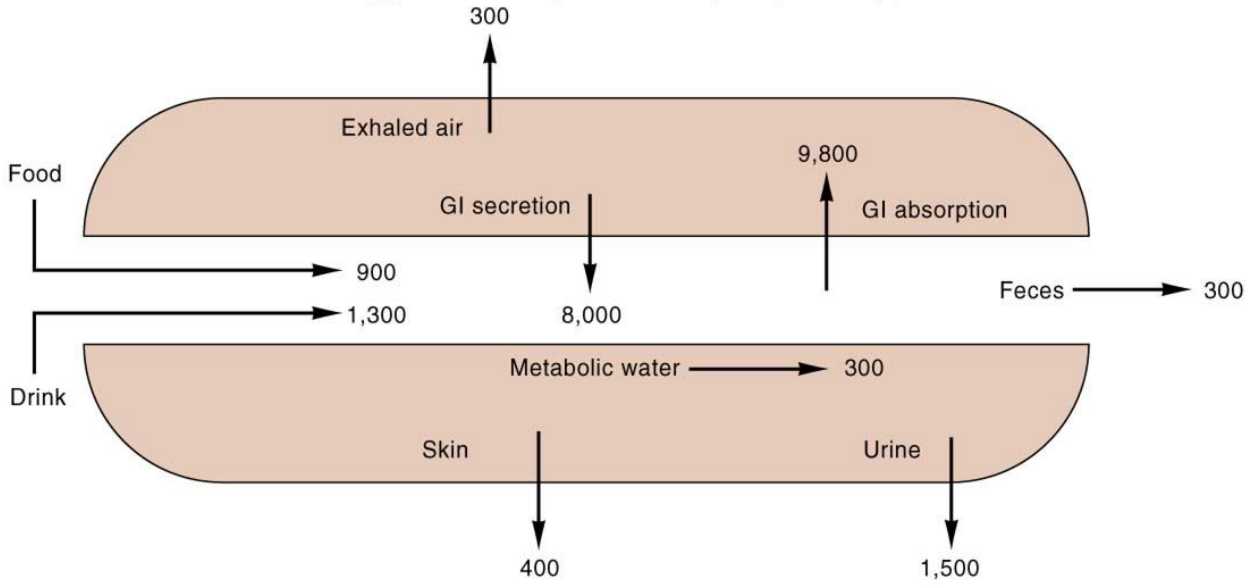


Hence when there is water retention in the ECF, Na^{+} concentration decreases, whereas the ICF volume increases. Other major ions found in this compartment are; Mg^{+2}, $HPO_4^{-2}$and proteins^{-}. Rapid fluid movement occurs between the ECF and ICF in response to changes in concentration of the ECF, and to ensure a balance, fluid or electrolyte gains must be equal to loss.

Fluid intake and output

Intake; fluid as water enters into the body by ingestion through drinking of water, as such, or from water in food. A small amount of water is also gotten from the metabolic breakdown of food products to carbon dioxide and water, via the oxidative phosphorylative pathway.

Output (or loss); is via kidneys (urine), sweat glands (insensible perspiration and sensible loss), & feces. Little amount of water is also lost through exhaled air.



REGULATION OF TOTAL BODY WATER AND ELECTROLYTES.

Generally homeostasis of water and electrolytes is maintained by ion transport, water movement and kidney functions.

1. Thirst can be stimulated to increase water intake.

2. An hormone ADH (anti diuretic hormone) can be secreted by the which causes the reabsorbtion of water at the kidney tubules; depending on the state of the body water content there may be either an increased secretion (to facilitate retention of more water e.g. as in time of dehydration) or decreased secretion (to facilitate loss of more water from the body as in cases of overhydration). The effects of either an increase or decrease in ADH secretion are an increase or decrease in urine output.

3. Renin is also secreted and this causes increased reabsorbtion of Na^+ and concurrently water by converting angiotensinogen to angiotensin I, which is subsequently converted to biologically active angiotensin II which exerts the effects. Renin is released in response to reduced renal perfusion produced by hypotension volume depletion or sympathetic activity.

4. Aldosterone produced in the adrenal cortex in response to changes in effective circulating fluid volume. It causes renal resorption of Na^+ in exchange for K^+ and H^+ in response to Na depletion.

5. Atrial Natriuretic Factor (ANF); this hormone results in natriuresis and duiresis by the kidneys.

Functions of electrolytes

Electrolytes are substances that exist as positive or negative charged particles in solution. To maintain electrical neutrality in biological fluids, there must be equal number of equivalents or milliequivalents of anions and cations in solution, therefore electrolytes in solution combine equivalents for equivalents i.e. positive and negative charges.

The osmotic properties of a solute in solution are related to the number of particles in solution and not on it weight or charge.

Concentrations of solutes in biological fluids are expressed as millimole (mmol/l), milliequivalents (mEq/l) or milliosmoles (mOsm/kg).

Electrolytes function to maintain the osmotic pressure and water balance between the compartment while individual electrolytes provide suitable environment for biological reactions and cell functions.

- Na^+ - major ion in ECF
    - Gain-loss imbalance is most common electrolyte problem
        1. Intake across digestive epithelium based on food content
        2. Loss in urine excretion & skin perspiration
    - Change in Na^+ level causes water movement, maintaining ECF Na^+ conc.

  Ex. Salty meal increases Na^+ level in digestive ECF, causing water input from digestive tract, increasing blood volume & pressure

    - Homeostatic mech: ADH, Aldosterone, Natriuretic peptides

- K^+ - major ion in ICF
    - Imbalance less common but more dangerous
    - Essential for nerve transmission
- Ca^{+2} - in ECF & ICF
    - Absorbed by active transport, increased by PTH & calcitriol
    - Essential in muscle contraction, neurotransmitter release, clotting, bone formation
- Mg^{+2} - mainly in ICF
    - Essential as enzyme cofactor, ATP use in contracting muscle, bone component
- PO_4^{-3} - most important function in ICF
    - Essential for bone mineralization, ATP, phosphorylation
- Cl^- - mainly in ECF, associated with Na

Dehydration and its correction

Dehydration occurs when there is more loss than gain of water or fluids and results in an increase in the osmotic concentration of the ECF relative to the ICF causing water to shift from ICF to the ECF with a resultant more concentration and lower volumes of both the ECF and ICF. It is usually caused by pathological conditions such as vomiting and diarrhea, or low water intake or exercise in hot weather.

The goal in correcting dehydration is not just to replace lost fluid but also lost electrolytes as well in order to increase the volume of both the ECF and ICF.

Overhydration

This occurs when there is more gain than loss of water from the body and results in the decrease in the osmotic concentration of the ECF and the shifting of water from the ECF into the ICF with resultant lower concentration in both compartments but higher volumes. It occurs in such conditions as excess intake of fluids, hypotonic solution infused, unable to eliminate urine, endocrine disorders etc