

Fluid, Electrolyte, and Acid-Base Balance

The human body consists of approximately 55% water (50% in ♀; 60% in ♂). Fluid input and output varies but is about 2500ml/day. Most input is ingested but some water is produced by cellular metabolism. Water occupies two main compartments within the body: the intracellular fluid and the extracellular fluid. The latter is divided into plasma and interstitial fluid. (There are other extracellular fluids as well, such as CSF.)

Water is the principle solvent of the body. Solutes are referred to as either electrolytes (the most abundant solutes) which are polar compounds that dissociate into ions in solution, and nonelectrolytes that do not dissociate and therefore do not form ions. Electrolytes have greater osmotic power than nonelectrolytes. Electrolytes are necessary for making certain structures (e.g. Ca is needed for bone) and for physiological processes (e.g. Na and K are needed for action potentials). Organic compounds, such as glucose, urea, lipids, generally do not dissociate. Some of the major positive ions (cations) are Na^+ , K^+ , Ca^{2+} , Mg^{2+} , H^+ . Some of the major negative ions (anions) are HCO_3^- , Cl^- , HPO_4^{2-} and SO_4^{2-} . The main extracellular fluid cation is Na^+ . The main intracellular fluid cation is K^+ . Water moves freely between the compartments along osmotic gradients. Exchanges between plasma and interstitial fluid occur across capillary membranes. The body's water volume is closely tied to ionic sodium.

Antidiuretic Hormone (ADH) is produced in the hypothalamus and stored in the posterior pituitary. When ADH levels are low, water is not reabsorbed by the kidney tubules, but continues in the urine. When ADH levels are high, water is reabsorbed and urine output is low. Osmoreceptors of the hypothalamus sense the extracellular fluid solute concentration and stimulate or inhibit the release of ADH from the pituitary. ADH release may also be affected by large changes in blood volume or blood pressure.

When the atria are stretched by an increase in blood volume, Atrial Natriuretic Hormone (ANH or ANP) is secreted. It causes an increase in the glomerular filtration rate thereby lowering blood volume.

Edema is an atypical accumulation of fluid in the interstitial space leading to tissue swelling.

Electrolyte Balance

Electrolyte balance, or salt balance, is necessary in controlling fluid movements within the body. Salts are lost in perspiration, urine, feces and may be lost excessively in diarrhea, vomitus and profuse sweating. Sodium is the most important electrolyte in maintaining electrolyte balance. Regulating the balance between sodium input and output is an important renal function. Most sodium is reabsorbed in the kidney tubules and even more sodium is reabsorbed if levels of the hormone aldosterone are high. Aldosterone is released by the adrenal glands in response to increasing levels of angiotensin II. Aldosterone has the opposite effect on potassium.

SO:

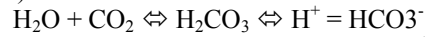
Low blood pressure leads to an increase angiotensin II → this leads to a release of aldosterone → This leads to more reabsorption of sodium in the kidney tubules → water follows the sodium leading to increased blood volume.

Afferent nerve receptors, called baroreceptors, are found in the heart, carotid arteries and aorta. As blood volume (pressure) increases, these receptors relay the information to the brain. Then sympathetic impulses to the kidneys decline allowing the afferent arterioles to dilate so that more sodium and water are forced into the filtrate.

Acid – Base Balance

Arterial blood must be kept at a pH of 7.35 to 7.45. Alkalosis results when the pH rises above 7.45 and acidosis results when the pH falls below 7.35. The quickest way (< 1sec) that blood pH is adjusted is by chemical buffers. Remember that buffers are molecules that act to resist changes in pH. The bicarbonate buffer system, a mixture of H_2CO_3 and NaHCO_3 , and protein buffers are important.

The regulation of the breathing rate in the brainstem can change blood pH but less quickly (seconds to minutes). A lower rate of ventilation will cause CO₂ to build up increasing the formation of acid:



Increasing ventilation blows off more CO₂, H⁺ ions drop and the blood becomes more alkaline. When the cause of the pH imbalance is a respiratory problem it is referred to as respiratory acidosis or respiratory alkalosis. For example, emphysema may cause CO₂ to accumulate, hyperventilation may cause alkalosis.

The kidneys also play a very important, but slower (minutes to hours), part in regulating blood pH. The primary method of doing this is by reabsorbing, excreting or generating new bicarbonate ion, HCO₃⁻. The hydrogen ion, H⁺, is also secreted into the filtrate in the proximal tubules.