Regulating extracellular fluid volume

About 60% of an adult human body is fluid, mainly a water solution of ions and other substances. Most of this fluid is inside the cells and in known as the intracellular fluid, but about one third is in the spaces outside the cells. This is the extracellular fluid (ECF). The ECF is divided into several smaller compartments, mainly blood plasma fluid and interstitial fluid which constitute 20% and 80% of the ECF respectively. (Guyton and Hall 2006) The distribution of fluid between these two compartments is determined by the balance between two opposing forces, hydrostatic pressure which is the pressure in the circulatory system that exerted by the volume of blood and osmotic pressure which is the pressure required to maintain an equilibrium in movement of particles between the fluid compartments. The concentration of these particles dissolved in a fluid its called osmolality. The blood plasma fluid communicates with the interstitial fluid across the walls of small capillary vessels within the organs. (Mohrman and Heller 2006)

The extracellular fluid contains large amounts of electrolytes that are dissolved in body fluids, such as sodium, calcium and potassium, but and nutrients and other substances that required by the cells to maintain cell life. All body systems, principally the cardiovascular, nervous and endocrine systems contribute to maintaining fluid and electrolyte balance something that is necessary for the proper functioning of the cells. (Guyton and Hall 2006)

The hypothalamus helps in regulation of these electrolytes, nutrients and water as monitors the composition of the blood, maintaining homeostasis. That makes it an important center for information concerning the internal environment. This information is then used to control the release of hormones from the pituitary.

Sodium is the major electrolyte that regulates the extracellular fluid levels in the body. Because of its osmotic effects, changes in sodium content in the body can influence the extracellular fluid volume, including plasma volume which must be closely regulated to help maintain blood pressure. Excess sodium leads to the retention of water and an increase to plasma volume which leads to an increase in arterial blood pressure, while sodium deficit leads to water loss and decreased plasma volume which leads to a decrease in blood pressure.

Therefore sodium balance is very important in the long term regulation of extracellular fluid volume and is achieved when sodium intake is equal to sodium output. (Kelly 2005)

The kidneys adjust salt and water excretion to maintain a constant extracellular fluid volume and osmolality regulating the sodium chloride balance. Around 8-15 g of NaCl are absorbed every day and the kidneys have to excrete the same amount over time to maintain sodium ECF homeostasis. Changes in sodium content leads to changes in extracellular fluid volume and that is regulated mainly by Renin-angiotensin system (RAS), atrial natriuretic hormone (ANT), aldosterone and andidiuretic hormone (ADH) which stimulates water conservation and the thirst center. (Despopoulos and Silbernagl 2003)

ADH is the most important regulator of blood osmolality. It is released into the bloodstream from the posterior pituitary, which is an extension of the brain when its receptors detect an increase in sodium concentration and is mediated through cells in the hypothalamus.

Antidiuretic hormone reduces renal excretion of water by acting on the collecting ducts of the kidney and influence urinary output rate. An increase in sodium concentration which can be brought about by increased salt intake, dehydration or hemorrhage which is loss of blood cause an increase in ADH secretion which has as effect an increase of water reabsorption in the kidney and the production of small volume of concentrated urine which has as a result a decrease of blood osmolality as reabsorbed water dilutes the blood. On the other hand a decrease in sodium concentration cause a decrease in ADH secretion which has as effect a decrease of water reabsorption in the kidney and the production of large volume of dilute urine and that result in an increase of blood osmolality as water is lost from the blood into the urine.

ADH can also be affected by blood volume and cardiac output and is activated by significant decreases in blood pressure. A decrease in arterial blood pressure can cause an increase in ADH secretion from the posterior pituitary mediated through baroreceptors. This has as affect an increase of water reabsorption in the kidney and the production of a small volume of concentrated urine which results in an increase of blood pressure because of increased blood volume and in a decrease of blood osmolality. An increase of blood pressure causes a decrease in ADH secretion which in turn causes a decrease of water reabsorption in the kidney and the production of a large volume of dilute urine which results in a decrease of blood pressure and in an increase of blood osmolality. (Rushton 2004)

Because the kidneys receive extensive sympathetic innervations, changes in sympathetic activity can alter renal sodium and water excretion as well as regulation of ECF volume. A reduction of blood volume in case of a hemorrhage causes a reduction in blood pressure which can result in reflex activation of the sympathetic nervous system. This in turn increases renal sympathetic nerve activity, which has several effects including the stimulation of renin release. (Guyton and Hall 2006)

Renin is an enzyme that is produced in the kidneys and catalyzes the formation of angiotensin I from angiotensinogen, a serum glycoprotein. Angiotensin I is then converted to angiotensin II by the action of angiotensin-converting enzyme that is located on the surface of endothelial cells. This sequence of events is known as Renin angiotensin-aldosterone system. Angiotensin II stimulates the release of aldosterone by adrenal cortex which increases blood volume and therefore blood pressure. (Mohrman and Heller 2006) An increase in aldosterone secretion results on the increase of sodium reabsorption in the kidney, an increase of water reabsorption as water follows the sodium and a decrease in urine volume, which in turn cause an increase of blood pressure while blood osmolality is maintained because both sodium and water are reabsorbed. On the other hand a decrease in aldosterone secretion decreases sodium reabsorption in the kidney and water reabsorption as less sodium is reabsorbed and increases urine volume. This result in a decrease of blood pressure as blood volume decreases while blood osmolality is maintained as both water and sodium lost in the urine. (Rushton 2004) Angiotensin II also acts on the brain to induce drinking behavior and is a very potent vasoconstrictor agent. (Mohrman and Heller 2006)

Another important factor that regulates ECF volume is atrial natriuretic hormone (ANH). This is a hormone that causes blood vessels to dilate and the kidneys to produce more urine. That results in a decrease of blood pressure and a reduction of blood volume by excreting more water. (Rushton 2004) Atrial natriuretic hormone is release by specific cells of atria the upper chambers of the heart and acts on several parts of the body. (Despopoulos and Silbernagl 2003)

A reduction of ANH causes an increase of water and sodium reabsorption in the kidney as water follows the sodium and a decrease in urinary volume. That results in an increase of blood pressure. An increase of ANH causes water and sodium reabsorption reduction as water is lost with sodium in the urine and that results in an increase of blood pressure and a reduction of cardiac output. Either ANH excretion is increase or decreased, blood osmolality is maintained as both water and sodium are either reabsorbed or lost in the urine. The central nervous system is affected by ANH by the inhibition of ADH release and a decrease in water and salt appetite. (Rushton 2004)

Thus when there is an increase of sodium in the extracellular fluid, the osmolality of the fluid increases and this in turn stimulates the thirst center in the brain making a person to reduce the amount of water in his body returning the extracellular sodium concentration back to normal, and that increases the extacellular fluid volume. On the other hand an increase of water in the body reduces the osmolality of extracellular fluid. (Guyton and Hall 2006)