

Introduction

is a group of organs in the body concerned with filtering out excess fluid and other substances from the bloodstream. The substances are filtered out from the body in the form of urine. Urine is a liquid produced by the kidneys, collected in the bladder and excreted through the urethra. Urine is used to extract excess minerals or vitamins as well as blood corpuscles from the body. The Urinary organs include the kidneys, ureters, bladder, and urethra. The Urinary system works with the other systems of the body to help maintain homeostasis. The kidneys are the main organs of homeostasis because they maintain the acid base balance and the water salt balance of the blood.

Functions of the Urinary System

1- Regulation of plasma ionic composition

Ions such as sodium, potassium, calcium, magnesium, chloride, bicarbonate, and phosphates are regulated by the amount that the kidney excretes.

2- Regulation of plasma osmolarity

The kidneys regulate osmolarity because they have direct control over how many ions and how much water a person excretes.

3- Regulation of plasma volume

Your kidneys are so important they even have an effect on your blood pressure. The kidneys control plasma volume by controlling how much water a person excretes. The plasma volume has a direct effect on the total blood volume, which has a direct effect on your blood pressure. Salt (NaCl) will cause osmosis to happen the diffusion of water into the blood.

4- Regulation of plasma hydrogen ion concentration (pH)

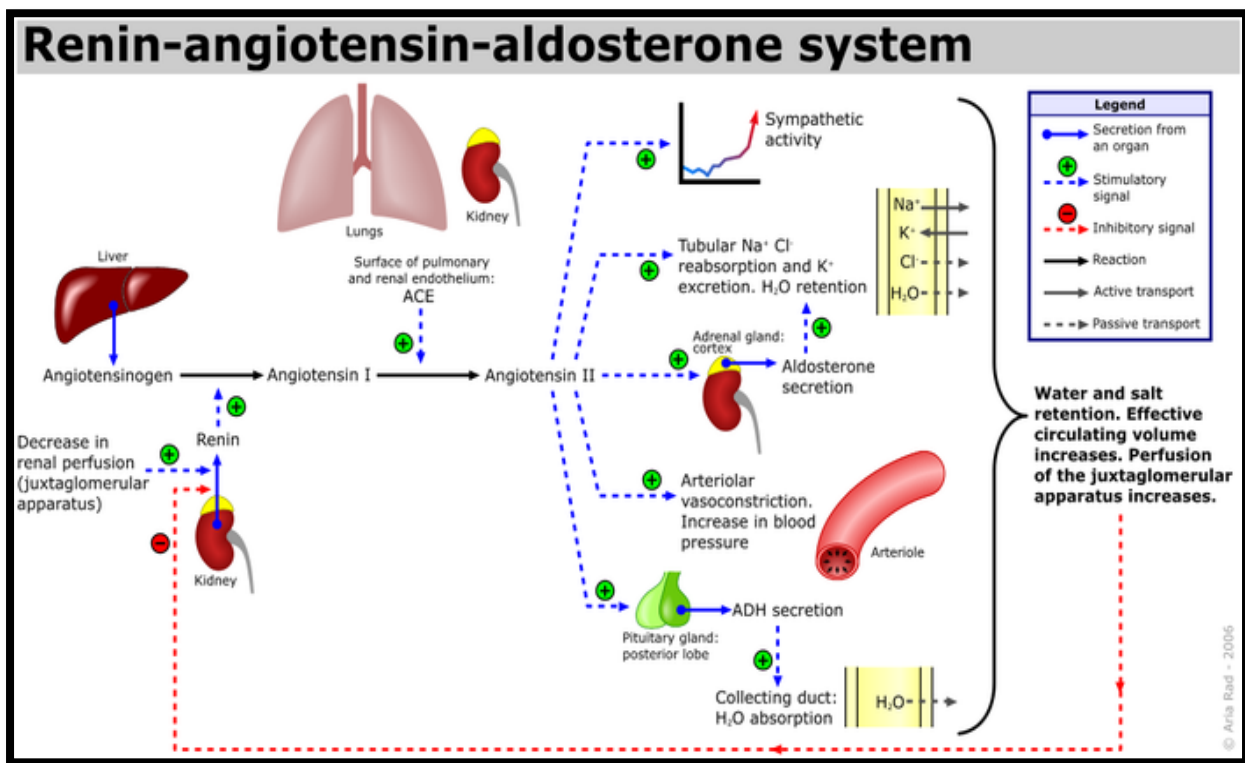
The kidneys partner up with the lungs and they together control the pH. The kidneys have a major role because they control the amount of bicarbonate excreted or held onto. The kidneys help maintain the blood PH mainly by excreting hydrogen ions and reabsorbing bicarbonate ions as needed.

5- Removal of metabolic waste products and foreign substances from the plasma.

One of the most important things the kidneys excrete is nitrogenous waste. As the liver breaks down amino acids it also releases ammonia. The liver then quickly combines that ammonia with carbon dioxide, creating urea which is the primary nitrogenous end product of metabolism in humans. The liver turns the ammonia into urea because it is much less toxic. We can also excrete some ammonia, creatinine and uric acid. The creatinine comes from the metabolic breakdown of creatine phosphate (a high-energy phosphate in muscles). Uric acid comes from the breakdown of nucleotides. Uric acid is insoluble and too much uric acid in the blood will build up and form crystals that can collect in the joints and cause gout.

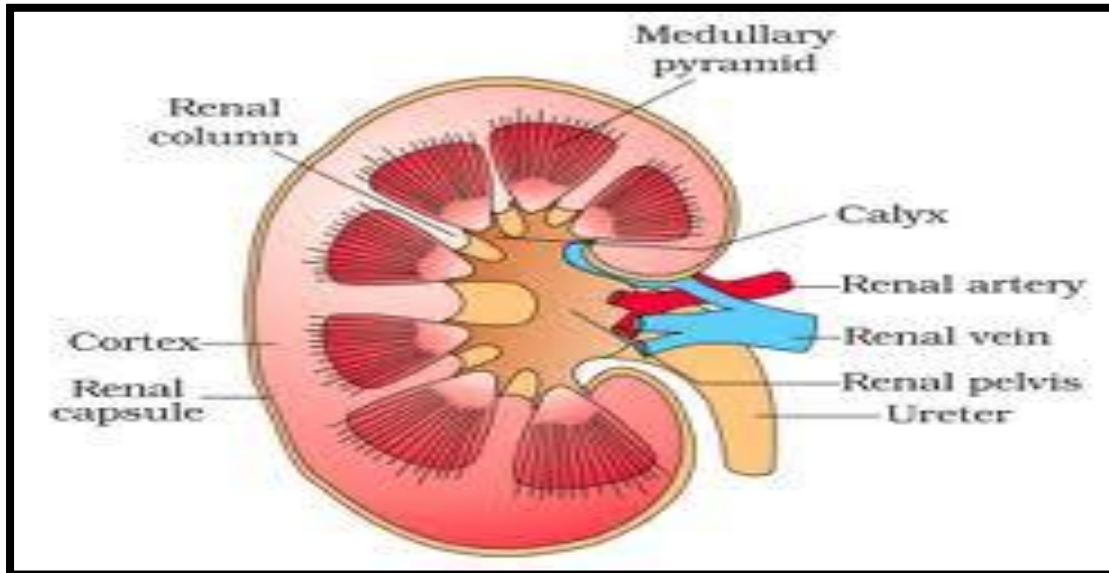
6- Secretion of Hormones

The endocrine system has assistance from the kidney's when releasing hormones. Renin is released by the kidneys. Renin leads to the secretion of aldosterone which is released from the adrenal cortex. Aldosterone promotes the kidneys to reabsorb the sodium (Na^+) ions. The kidneys also secrete erythropoietin when the blood doesn't have the capacity to carry oxygen. Erythropoietin stimulates red blood cell production. The Vitamin D from the skin is also activated with help from the kidneys. Calcium (Ca^+) absorption from the digestive tract is promoted by vitamin D.



Kidneys And Their Structure

The kidneys are a pair of **bean shaped**, brown organs about the size of your **fist**. It measures 10-12 cm long. They are covered by the renal capsule, which is a tough capsule of fibrous connective tissue. Adhering to the surface of each kidney is **two layers** of fat to help cushion them. There is a concaved side of the kidney that has a depression where a renal artery enters, and a renal vein and a ureter exit the kidney. The kidneys are located at the rear wall of the abdominal cavity just above the waistline, and are protected by the **ribcage**. They are considered retroperitoneal, which means they lie behind the peritoneum. There are **three major regions** of the kidney, renal cortex, renal medulla and the renal pelvis. The outer granulated layer is the renal cortex, The cortex stretches down in between a radially striated inner layer. The inner radially striated layer is the renal medulla. This contains pyramid shaped tissue called the renal pyramids, separated by renal columns. The ureters are continuous with the renal pelvis and is the very center of the kidney.



Ureters

The ureters are two tubes that transport urine from the kidneys to the bladder. Each ureter is a muscular tube about (25 cm) long. Muscles in the walls of the ureters send the urine in small spurts into the bladder, After the urine enters the bladder from the ureters, small folds in the bladder mucosa act like valves preventing backward flow of the urine. The outlet of the bladder is controlled by a sphincter muscle. A full bladder stimulates sensory nerves in the bladder wall that relax the sphincter and allow release of the urine.

Urinary Bladder

The urinary bladder is a hollow, muscular and distensible or elastic organ that sits on the pelvic floor . The urinary bladder can hold approximately (500 to 530 ml) of urine, however the desire to micturate is usually experienced when it contains about 150 to 200 ml. When the bladder fills with urine, stretch receptors send nerve impulses to the spinal cord, which then sends a reflex nerve impulse back to the sphincter at the neck of the bladder, causing it to relax and allow the flow of urine into the urethra. The Internal urethral sphincter is involuntary. The ureters enter the bladder diagonally from its dorsolateral floor in an area called the trigone. The trigone is a triangular shaped area on the postero - inferior wall of the bladder. The urethra exits at the lowest point of the triangle of the trigone.

Urethra

The urethra is a muscular tube that connects the bladder with the outside of the body. The function of the urethra is to remove urine from the body. It measures about (3.8 cm) in a woman but up to (20 cm) in a man. Because the urethra is so much

shorter in a woman it makes it much easier for a woman to get harmful bacteria in her bladder this is commonly called a bladder infection or a Urinary tract infection (UTI). The most common bacteria of a UTI is E-coli from the large intestines that have been excreted in fecal matter.

Nephrons

nephron is the basic structural and functional unit of the kidney. The name nephron comes from the Greek word (nephros) meaning kidney. Its chief function is to regulate water and soluble substances by filtering the blood, reabsorbing what is needed and excreting the rest as urine. Nephrons eliminate wastes from the body, regulate blood volume and pressure, control levels of electrolytes and metabolites, and regulate blood pH. Its functions are vital to life and are regulated by the endocrine system by hormones such as antidiuretic hormone, aldosterone, and parathyroid hormone.

Each nephron has its own supply of blood from two capillary regions from the renal artery. Each nephron is composed of an initial filtering component (the renal corpuscle) and a tubule specialized for reabsorption and secretion (the renal tubule). The renal corpuscle filters out large solutes from the blood, delivering water and small solutes to the renal tubule for modification.

Glomerulus

The glomerulus is a capillary tuft that receives its blood supply from an afferent arteriole of the renal circulation. The glomerular blood pressure provides the driving force for fluid and solutes to be filtered out of the blood and into the space made by Bowman's capsule. The remainder of the blood not filtered into the glomerulus passes into the narrower efferent arteriole. It then moves into the vasa recta, which are collecting capillaries intertwined with the convoluted tubules through the interstitial space, this then combines with efferent venules from other nephrons into the renal vein, and rejoins with the main bloodstream.

Glomerular Capsule or Bowman's Capsule

Bowman's capsule (also called the glomerular capsule) surrounds the glomerulus and is composed of inner (simple squamous epithelial cells) and parietal (simple squamous epithelial cells) (outer) layers.

The process of filtration of the blood in the Bowman's capsule is (glomerular filtration), and the normal rate of filtration is 125 ml/min, equivalent to ten times the blood volume daily. Measuring the glomerular filtration rate (GFR) is a diagnostic test of kidney function. A decreased GFR may be a sign of renal failure.

Any proteins that are roughly 30 kilodaltons or under can pass freely through the membrane. Any small molecules such as water, glucose, salt (NaCl), amino acids, and urea pass freely into Bowman's space, but cells, platelets and large proteins do not. As a result, the filtrate leaving the Bowman's capsule is very similar to blood plasma in composition as it passes into the proximal convoluted tubule. Together, the glomerulus and Bowman's capsule are called the renal corpuscle.

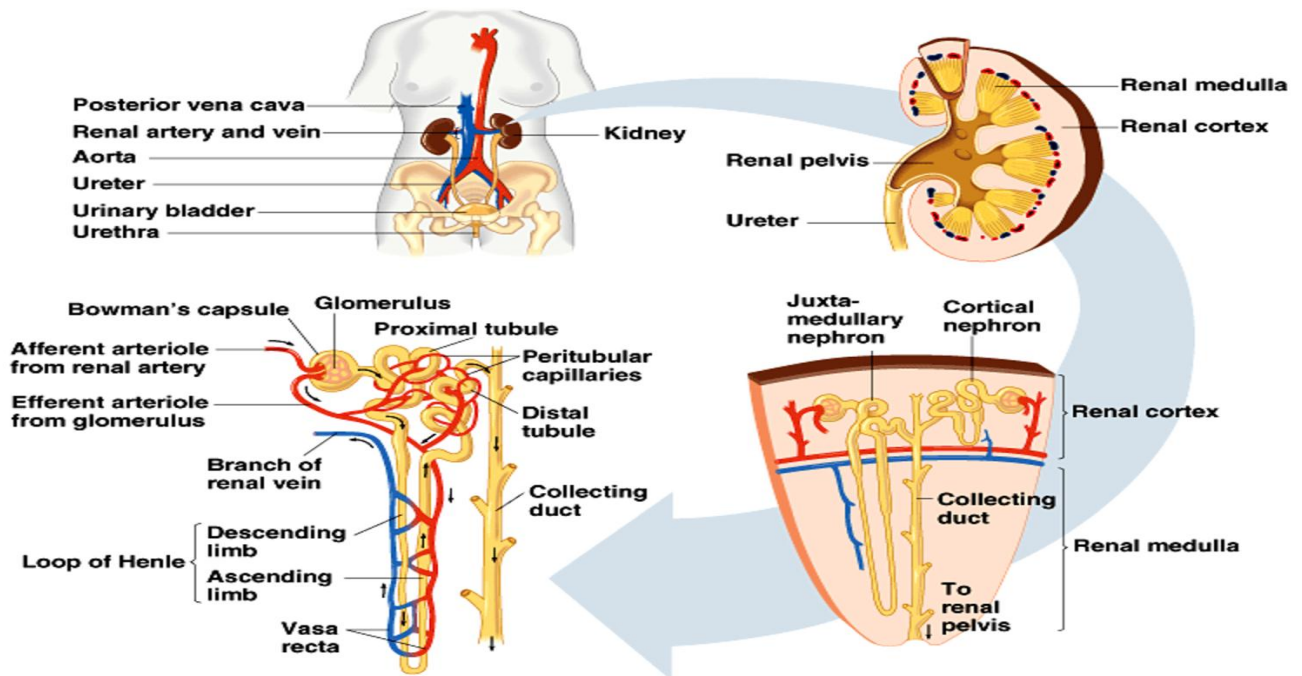
Proximal Convoluted Tubule (PCT)

The proximal convoluted tubule has one layer of cuboidal cells in the lumen. This is the only place in the nephron that contains cuboidal cells. These cells are covered with millions of microvilli. The microvilli serve to increase surface area for reabsorption.

Loop of the Nephron or Loop of Henle

The loop of Henle (sometimes known as the nephron loop) is a U-shaped tube that consists of a descending limb and ascending limb. It begins in the cortex, receiving filtrate from the proximal convoluted tubule, extends into the medulla, and then returns to the cortex to empty into the distal convoluted tubule.

The Human Kidney & Nephron



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Distal Convoluted Tubule (DCT)

The distal convoluted tubule is similar to the proximal convoluted tubule in structure and function. Cells lining the tubule have numerous mitochondria, enabling active transport to take place by the energy supplied by ATP. Much of the ion transport taking place in the distal convoluted tubule is regulated by the endocrine system. In the presence of parathyroid hormone, the distal convoluted tubule reabsorbs more calcium and excretes more phosphate. When aldosterone is present, more sodium is reabsorbed and more potassium excreted. Atrial natriuretic peptide causes the distal convoluted tubule to excrete more sodium. In addition, the tubule also secretes hydrogen and ammonium to regulate pH.

Collecting ducts

Though the collecting duct is normally impermeable to water, it becomes permeable in the presence of antidiuretic hormone (ADH). As much as three-fourths of the water from urine can be reabsorbed as it leaves the collecting duct by osmosis. Thus the levels of ADH determine whether urine will be concentrated or dilute. Dehydration results in an increase in ADH, while water sufficiency results in low ADH allowing for diluted urine.

Urine leaves the medullary collecting ducts through the renal papilla, emptying into the renal calyces, the renal pelvis, and finally into the bladder via the ureter. Because it has a different embryonic origin than the rest of the nephron (the collecting duct is from endoderm whereas the nephron is from mesoderm).

Renal Hormones

- 1. Vitamin D-** Becomes metabolically active in the kidney. Patients with renal disease have symptoms of disturbed calcium and phosphate balance.
- 2. Erythropoietin-** Released by the kidneys in response to decreased tissue oxygen levels (hypoxia).
- 3. Natriuretic Hormone-** Released from cardiocyte granules located in the right atria of the heart in response to increased atrial stretch. It inhibits ADH secretions which can contribute to the loss of sodium and water.

Formation of Urine

1- Filtration

Blood enters the afferent arteriole and flows into the glomerulus. Blood in the glomerulus has both filterable blood components and non-filterable blood components. Filterable blood components move toward the inside of the glomerulus while non-filterable blood components bypass the filtration process by exiting through the efferent arteriole. Filterable Blood components will then take a plasma like form called glomerular filtrate. A few of the filterable blood components are water, nitrogenous waste, nutrients and salts (ions). Non filterable blood components include formed elements such as blood cells and platelets along with plasma proteins.

2- Reabsorption

Within the peritubular capillary network, molecules and ions are reabsorbed back into the blood. Sodium Chloride reabsorbed into the system increases the osmolarity of blood in comparison to the glomerular filtrate. This reabsorption process allows water (H₂O) to pass from the glomerular filtrate back into the circulatory system.

Glucose and various amino acids also are reabsorbed into the circulatory system. These nutrients have carrier molecules that claim the glomerular molecule and release it back into the circulatory system. excess glucose or amino acids are set free into the urine. A complication of diabetes is the inability of the body to reabsorb glucose. If too much glucose appears in the glomerular filtrate it increases the osmolarity of the filtrate, causing water to be released into the urine rather than reabsorbed by the circulatory system. Frequent urination and unexplained thirst are warning signs of diabetes, due to water not being reabsorbed.

2- Secretion

Some substances are removed from blood through the peritubular capillary network into the distal convoluted tubule or collecting duct. These substances are Hydrogen ions, creatinine, and drugs. Urine is a collection of substances that have not been reabsorbed during glomerular filtration and tubular reabsorption.

Maintaining Water-Salt Balance

1- Reabsorption of water

Direct control of water excretion in the kidneys by the anti-diuretic hormone (ADH), released by the posterior lobe of the pituitary gland. ADH causes the insertion of water channels into the membranes of cells lining the collecting ducts, allowing water reabsorption to occur. Without ADH, little water is reabsorbed in the collecting ducts and dilute urine is excreted. There are several factors that influence the secretion of ADH. The first of these happen when the blood plasma gets too

concentrated. When this occurs, special receptors in the hypothalamus release ADH. When blood pressure falls, stretch receptors in the aorta and carotid arteries stimulate ADH secretion to increase volume of the blood.

2- Reabsorption of Salt

The Kidneys also regulate the salt balance in the blood by controlling the excretion and the reabsorption of various ions. As noted above, ADH plays a role in increasing water reabsorption in the kidneys, thus helping to dilute bodily fluids. The kidneys also have a regulated mechanism for reabsorbing sodium in the distal nephron. This mechanism is controlled by aldosterone, a steroid hormone produced by the adrenal cortex. Aldosterone promotes the excretion of potassium ions and the reabsorption of sodium ions. The release of Aldosterone is initiated by the kidneys. The juxtaglomerular apparatus is a renal structure consisting of the macula densa, mesangial cells, and juxtaglomerular cells. Juxtaglomerular cells (JG cells, also known as granular cells) are the site of renin secretion. Renin is an enzyme that converts angiotensinogen (a large plasma protein produced by the liver) into Angiotensin I and eventually into Angiotensin II which stimulates the adrenal cortex to produce aldosterone. The reabsorption of sodium ions is followed by the reabsorption of water. This causes blood pressure as well as blood volume to increase.

Hypernatremia

An increase in plasma sodium levels above normal is hypernatremia. Sodium is the primary solute in the extracellular fluid. Sodium levels have a major role in osmolarity regulation. For excitable cells the electrochemical gradient for sodium across the plasma membrane is critical for life. Water retention and an increased blood pressure usually are signs of hypernatremia. If the plasma sodium levels are below normal it is called **hyponatremia**. Signs of this are low plasma volume and hypotension.