

The renal system

The renal system, also known as the urinary system, consists of:

- Kidneys, which filter the blood to produce urine
- Ureters, which convey urine to the bladder
- Urinary bladder, a storage organ for urine until it is eliminated
- Urethra, which conveys urine to the exterior.

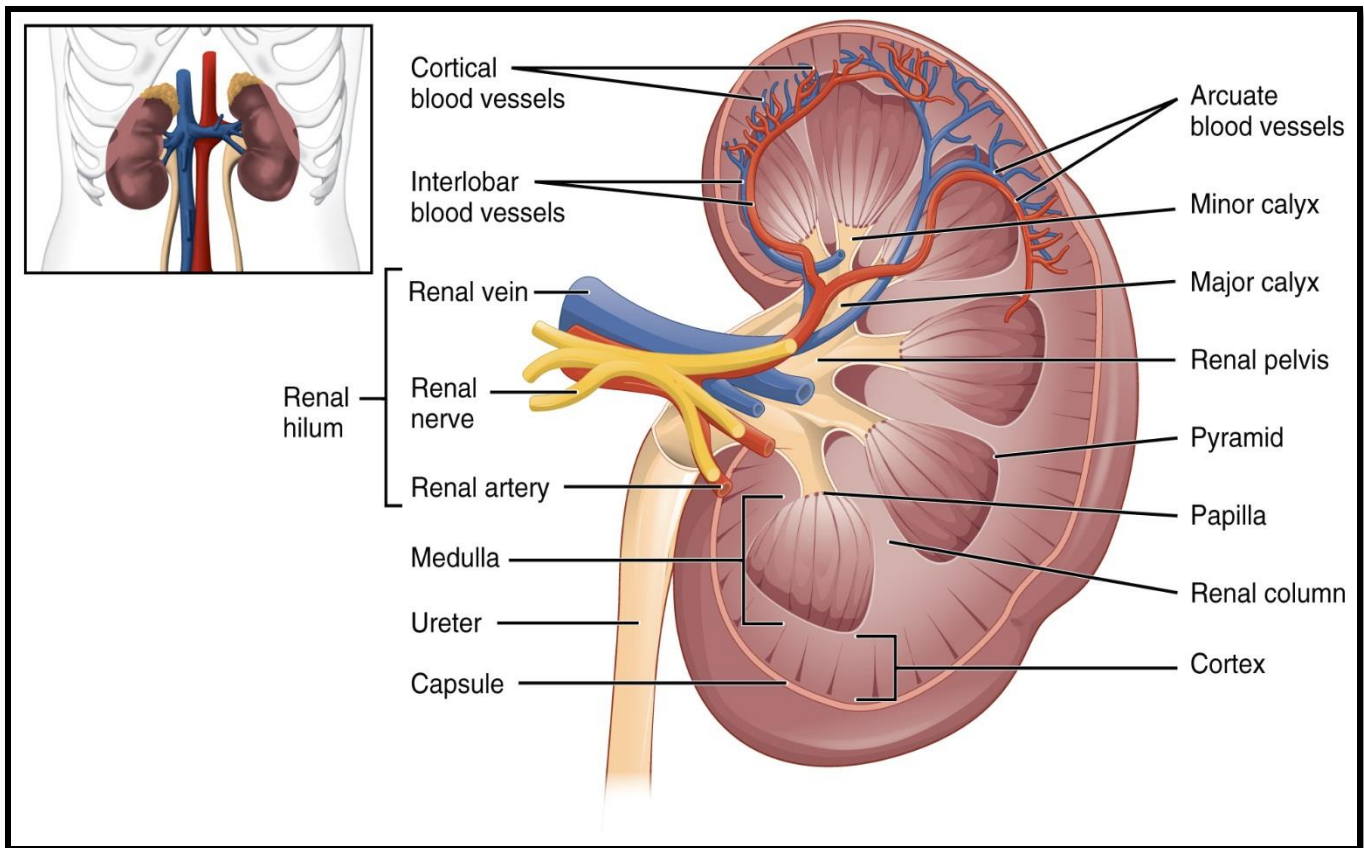
The major functions of the urinary system are removes waste products from the circulatory system, regulate blood pH, ion balance, and fluid balance and assist in regulating blood pressure.

The kidney structure

The kidneys are bean-shaped organs. They lie on the posterior abdominal wall to either side of the vertebral column. A connective tissue renal capsule surrounds each kidney.

On the medial side of each kidney are the **hilum**, where the renal artery and nerves enter and where the renal vein and ureter exit the kidney. The hilum opens into a cavity called **the renal sinus**.

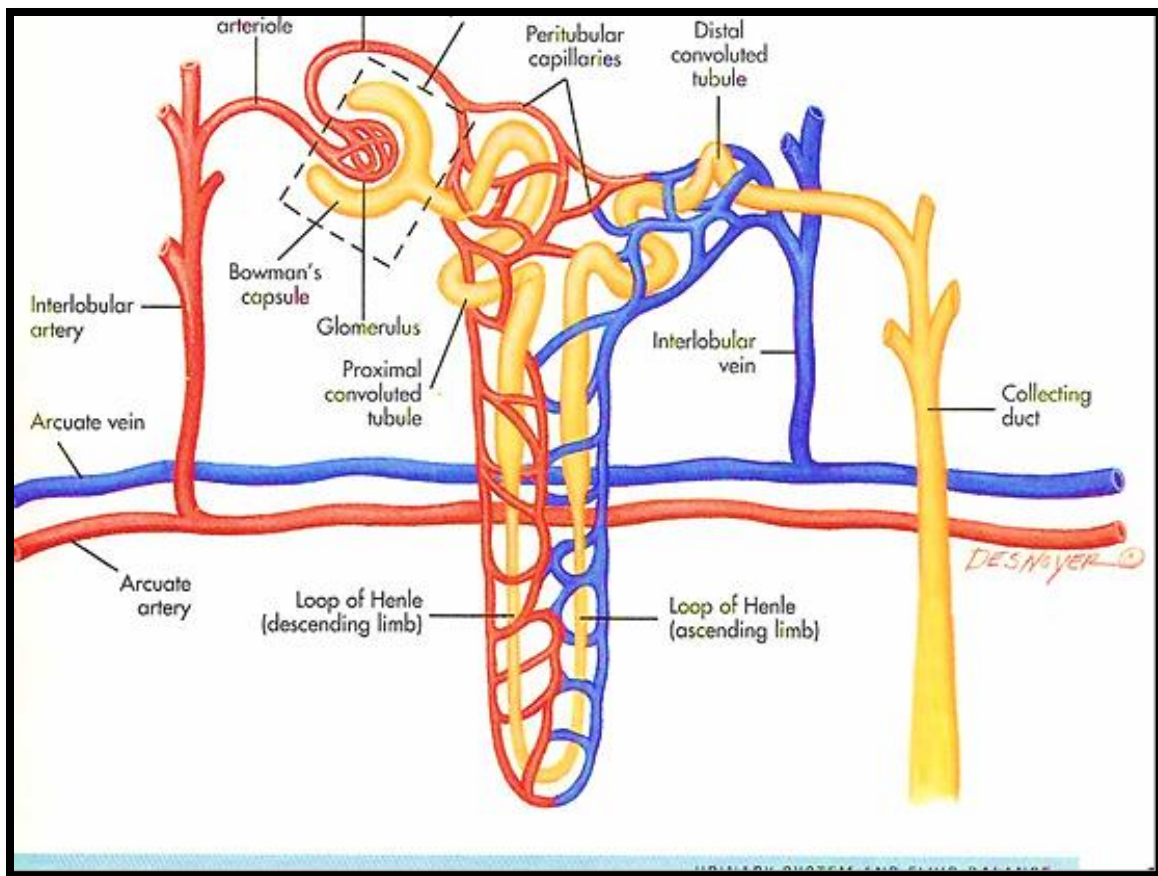
The kidney is divided into an outer cortex and an inner medulla, which surrounds the renal sinus. The bases of several cone-shaped renal pyramids are located at the boundary between the cortex and the medulla, and the tips of the pyramids project to the center of the kidney. A funnel-shaped structure called a **calyx** surround tip of each pyramid. The calyces from the entire pyramids join together to form a larger funnel called **renal pelvis**, which is located in the renal sinus. The renal pelvis then narrows to form a small tube, **the ureter**, which exits the kidney and connects to the urinary bladder. *Urine passes from the tips of the pyramids into the calyces. From the calyces, urine collects in the renal pelvis and exits the kidney through the ureter.*



The functional unit of the kidney is the **nephron**, which consists of an enlarged ending called a **renal corpuscle**, a **proximal convoluted tubule**, a **loop of Henle**, and a **distal convoluted tubule**. The distal convoluted tubule empties into a **collecting duct**, which carries urine from the cortex of the kidney through the medulla to a calyx.

The **renal corpuscle** of the nephron consists of **Bowman's capsule** and the **glomerulus**. The cavity of Bowman's capsule opens into a **proximal convoluted tubule**, which carries fluid away from the capsule.

Renal arteries give rise to branches that lead to afferent arterioles, which supply the glomeruli. Efferent arterioles carry blood from the glomeruli to the peritubular capillaries, which surround the proximal and distal convoluted tubules and the loop of Henle. Blood from the peritubular capillaries enters the renal veins.



The Nephron structure

Urine production

Urine is 96% water and approximately 4% solutes include organic waste products such as urea, uric acid, and creatinine, as well as excess ions such as sodium, potassium, chloride, bicarbonate, and hydrogen. ***The three processes critical to the formation of urine are filtration, reabsorption, and secretion.***

Filtration

is the movement of plasma through the filtration membrane of the renal corpuscle. The portion of the plasma entering the nephron becomes the ***filtrate***. An average of 21% of the blood pumped by the heart each minute flows through the kidneys. In all of the nephrons of both kidneys, about **180 liters** of filtrate are produced each day, but only about **1%** or less of the filtrate becomes urine.

The filtration membrane allows some substances, but not others, to pass from the blood into Bowman's capsule. Water and solutes of small molecular size readily pass through the openings

of the filtration membrane, but **blood cells** and **proteins**, which are too large to pass through the filtration membrane, do not enter Bowman's capsule.

The formation of filtrate depends on a pressure difference between the glomerular capillaries and Bowman's capsule, called the ***filtration pressure***, which forces fluid from the glomerular capillaries through the filtration membrane into Bowman's capsule.

Tubular reabsorption

is the movement of substances from the filtrate back into the blood of the peritubular capillaries. In general, the useful substances that enter the filtrate are reabsorbed, and metabolic waste products remain in the filtrate and are eliminated.

As the filtrate flows from Bowman's capsule through the proximal convoluted tubule, loop of Henle, distal convoluted tubule, and collecting duct, many of the substances in the filtrate are reabsorbed. About 99% of the filtrate volume is reabsorbed and enters the peritubular capillaries. The reabsorbed filtrate flows through the renal veins to enter the general circulation.

Tubular secretion

is the transport of substances, usually waste products, into the filtrate. Therefore, urine produced by the nephrons consists of the substances that are filtered and secreted from the peritubular capillaries into the nephron, minus those substances that are reabsorbed. Some substances, including by-products of metabolism that become toxic in high concentrations and drugs or molecules not normally produced by the body, are secreted into the nephron from the peritubular capillaries.

Hormonal control of tubular reabsorption and secretion

Four hormones play a role in the regulation of fluid and electrolytes:

Angiotensin and aldosterone

As the blood volume and blood pressure decrease, the juxtaglomerular cells secrete a hormone called renin. Juxtaglomerular cells are found near the glomerulus and these cells synthesize, store and secrete the hormone renin. Renin acts on a plasma protein called angiotensinogen and converts it into angiotensin I. Angiotensinogen is produced by the hepatocytes of the liver. Angiotensin I is transported by the blood to the lungs. In the lung capillaries there are enzymes called angiotensin - converting enzyme (ACE). ACE is predominately found in the lung

capillaries but this enzyme is also found throughout the body. ACE converts angiotensin I into angiotensin II. Angiotensin II is a short - acting, powerful vasoconstrictor, thus increasing blood pressure. Angiotensin II promotes the reabsorption of sodium, chloride and water in the proximal convoluted tubule. It also stimulates the adrenal glands to release a hormone called aldosterone which stimulates the cells in the collecting duct to reabsorb sodium and chloride and secrete potassium.

Antidiuretic hormone (ADH)

This hormone increases the permeability of the cells in the distal convoluted tubule and the collecting ducts. In the presence of ADH more water is reabsorbed from the renal tubules and therefore the patient will pass less urine. In the absence of ADH less water is reabsorbed and the patient will pass more urine. Thus ADH plays a major role in the regulation of fluid balance in the body.

Atrial natriuretic peptide (ANP)

Atrial natriuretic peptide hormone (ANP) is a powerful vasodilator and is a protein produced by the myocytes of the atria of the heart in response to increased blood pressure. ANP stimulates the kidneys to excrete sodium and water from the renal tubules thus decreasing blood volume, which in turn lowers blood pressure. The hormone also inhibits the secretion of aldosterone and ADH.

Characteristics of normal urine

- **Color:** Typically yellow- amber but varies according to recent diet, medication and the concentration of the urine. Drinking more water generally tends to reduce the concentration of urine and therefore causes it to have a lighter color. However, if a person does not drink a large amount of fluid, this may increase the concentration and the urine will have a darker color.
- **Smell:** The smell or odor, of urine may provide health information. For example, the urine of diabetics may have a sweet or fruity odor due to the presence of ketones (organic molecules of a particular structure). Generally, fresh urine has a mild smell but stale urine or infected urine has a stronger odor, similar to that of ammonia.
- **Acidity:** The pH of normal urine is generally in the range 4.6 – 8, a typical average being around 6.0. Much of the variation is due to diet. For example, high protein diets result in more acidic urine, but vegetarian diets generally result in more alkaline urine.