

## Biology

THE URINARY SYSTEM AND  
EXCRETORY SYSTEM

## Chapter

**T**he urinary system consists of the kidneys, ureters, urinary bladder, and urethra. The kidneys filter the blood to remove wastes and produce urine. The ureters, urinary bladder, and urethra together form the urinary tract, which acts as a plumbing system to drain urine from the kidneys, store it, and then release it during urination. Besides filtering and eliminating wastes from the body, the urinary system also maintains the homeostasis of water, ions, pH, blood pressure, calcium and red blood cells.

## ANATOMY

## Kidneys

The kidneys are a pair of bean-shaped organs found along the posterior wall of the abdominal cavity. The left kidney is located slightly higher than the right kidney because the right side of the liver is much larger than the left side. The kidneys, unlike the other organs of the abdominal cavity, are located posterior to the peritoneum and touch the muscles of the back. The kidneys are surrounded by a layer of adipose that holds them in place and protects them from physical damage. The kidneys filter metabolic wastes, excess ions, and chemicals from the blood to form urine.

## STRUCTURE OF THE KIDNEY

The kidney has three distinct regions:

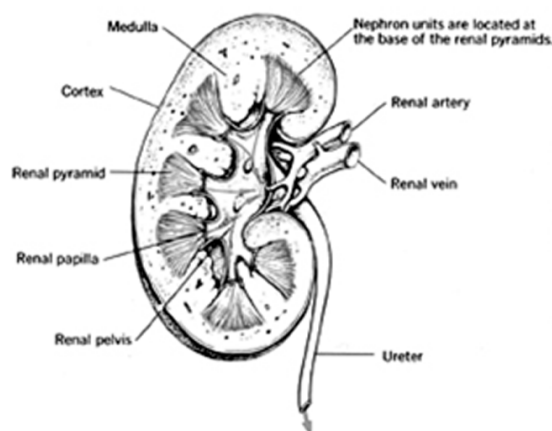
## 1. RENAL CORTX

The outer region of kidney and its function is to filter blood.

## 2. RENAL MEDULLA

This is the middle region of the kidney. Made

up of collecting ducts. Its function is to collect filtrate( filtered materials from the blood) and carries it to the renal pelvis.

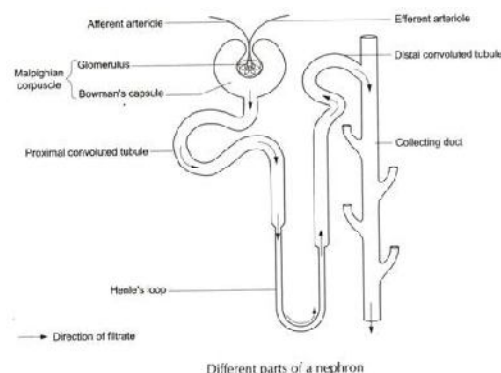


## 3. RENAL PELVIS

This is the inner section of the kidney. It is a cavity in the center of a kidney, connected to the ureters. The filtrate (now called urine) drains from the pelvis into the ureters for removal.

## Nephron

The basic functional unit of a kidney. This is the structure responsible for filtering the blood and maintaining proper water balance. There are about 1.25 million nephrons per kidney. The kidney Nephron extends from the renal cortex (glomerulus/Bowman's capsule) into the renal medulla (Loop of Henle).



## Parts of a Nephron

- a. Renal Artery: This is the artery that carries blood TO the kidney to be filtered.
- b. Renal Vein: This is the vein that carries blood FROM the kidney AFTER it has been filtered.
- c. Glomerulus: A tight ball of blood capillaries located in the Bowman's capsule of Nephron. Blood Pressure created here causes materials to be filtered from the blood.
- d. Bowman's Capsule: A cup-shaped structure that receives filtrate from the glomerulus.
- e. Proximal Tubule: Tube connected to the Bowman's capsule. Filtrate enters the proximal tube from the Bowman's capsule. *Reabsorption of amino acids and glucose occurs here.*
- f. Loop of Henle: Long U-shaped tube that extends into the renal medulla. Responsible for maintaining salt balance by reabsorbing or releasing salt in the filtrate.
- g. Distal Tubule: Tube extending from the loop of henle. It also reabsorbs materials from the filtrate. *Tubular secretion occurs here.* Materials such as creatinine and drugs are added to the filtrate.
- h. Collecting Tubule: Tube that extends from the distal tubule to the renal pelvis. This portion of the Nephron is mainly responsible for reabsorption of water.

## THE FORMATION OF URINE

Urine (A liquid of water ,urea and salts) is created in two stages.

### Filtration

During this stage, blood in the glomerulus is put under pressure and materials such as urea, glucose, salt and water are forced out of the blood and into the Bowman's capsule.

## Reabsorption

This is the reabsorbing of materials from the filtrate back into the body. This happens all the way along the Nephron, especially in the collecting tubules. When all materials possible have been reabsorbed into the body by the Nephron, what remains is called Urine.

## Water Balance

The Nephron helps to maintain water balance in the body via the collecting tubules. The collecting tubules have cells whose permeability is affected by a hormone called *Vasopressin* or Antidiuretic Hormone (ADH) *Two cases to consider.*

### A. NOT ENOUGH WATER IN THE BODY,

ADH is released by the Pituitary. ADH causes cells in the collecting tubules to become permeable to water. Water is reabsorbed by the body.

**NOTE:** When this happens the colour of urine becomes much darker.

### B. TOO MUCH WATER IN THE BODY

ADH is not secreted and the cells in the collecting tubules do not reabsorb water. Excess water is secreted out through the ureters.

**NOTE:** When this happens the colour of urine becomes lighter.

## Ureters

The ureters are a pair of tubes that carry urine from the kidneys to the urinary bladder. The ureters are about 10 to 12 inches long and run on the left and right sides of the body parallel to the vertebral column. Gravity and peristalsis of smooth muscle tissue in the walls of the ureters move urine toward the urinary bladder. The ends of the ureters extend slightly into the urinary bladder and are sealed



at the point of entry to the bladder by the ureterovesical valves. These valves prevent urine from flowing back towards the kidneys.

## Urinary Bladder

The urinary bladder is a sac-like hollow organ used for the storage of urine. The urinary bladder is located along the body's midline at the inferior end of the pelvis. Urine entering the urinary bladder from the ureters slowly fills the hollow space of the bladder and stretches its elastic walls. The walls of the bladder allow it to stretch to hold anywhere from 600 to 800 milliliters of urine.

## Urethra

The urethra is the tube through which urine passes from the bladder to the exterior of the body. The female urethra is around 2 inches long and ends inferior to the clitoris and superior to the vaginal opening. In males, the urethra is around 8 to 10 inches long and ends at the tip of the penis. The urethra is also an organ of the male reproductive system as it carries sperm out of the body through the penis.

The flow of urine through the urethra is controlled by the internal and external urethral sphincter muscles. The internal urethral sphincter is made of smooth muscle and opens involuntarily when the bladder reaches a certain set level of distention. The opening of the internal sphincter results in the sensation of needing to urinate. The external urethral sphincter is made of skeletal muscle and may be opened to allow urine to pass through the urethra or may be held closed to delay urination.

## PHYSIOLOGY

### Maintenance of Homeostasis

The kidneys maintain the homeostasis of several important internal conditions by

controlling the excretion of substances out of the body.

□ **Ions.** The kidney can control the excretion of potassium, sodium, calcium, magnesium, phosphate, and chloride ions into urine. In cases where these ions reach a higher than normal concentration, the kidneys can increase their excretion out of the body to return them to a normal level. Conversely, the kidneys can conserve these ions when they are present in lower than normal levels by allowing the ions to be reabsorbed into the blood during filtration.

□ **pH.** The kidneys monitor and regulate the levels of hydrogen ions ( $H^+$ ) and bicarbonate ions in the blood to control blood pH.  $H^+$  ions are produced as a natural byproduct of the metabolism of dietary proteins and accumulate in the blood over time. The kidneys excrete excess  $H^+$  ions into urine for elimination from the body. The kidneys also conserve bicarbonate ions, which act as important pH buffers in the blood.

□ **Osmolarity.** The cells of the body need to grow in an isotonic environment in order to maintain their fluid and electrolyte balance. The kidneys maintain the body's osmotic balance by controlling the amount of water that is filtered out of the blood and excreted into urine. When a person consumes a large amount of water, the kidneys reduce their reabsorption of water to allow the excess water to be excreted in urine. This results in the production of dilute, watery urine. In the case of the body being dehydrated, the kidneys reabsorb as much water as possible back into the blood to produce highly concentrated urine full of excreted ions and wastes. The changes in excretion of water are controlled by antidiuretic



hormone (ADH). ADH is produced in the hypothalamus and released by the posterior pituitary gland to help the body retain water.

- ❑ **Blood Pressure.** The kidneys monitor the body's blood pressure to help maintain homeostasis. When blood pressure is elevated, the kidneys can help to reduce blood pressure by reducing the volume of blood in the body. The kidneys are able to reduce blood volume by reducing the reabsorption of water into the blood and producing watery, dilute urine. When blood pressure becomes too low, the kidneys can produce the enzyme renin to constrict blood vessels and produce concentrated urine, which allows more water to remain in the blood.

### Storage and Excretion of Wastes

After urine has been produced by the kidneys, it is transported through the ureters to the urinary bladder. The urinary bladder fills with urine and stores it until the body is ready for its excretion. When the volume of the urinary bladder reaches anywhere from 150 to 400 milliliters, its walls begin to stretch and stretch receptors in its walls send signals to the brain and spinal cord. These signals result in the relaxation of the involuntary internal urethral sphincter and the sensation of needing to urinate. Urination may be delayed as long as the bladder does not exceed its maximum volume, but increasing nerve signals lead to greater discomfort and desire to urinate.

**Urination** is the process of releasing urine from the urinary bladder through the urethra and out of the body. The process of urination begins when the muscles of the urethral sphincters relax, allowing urine to pass through the urethra. At the same time that the sphincters relax, the smooth muscle in the walls of the urinary bladder contract to expel urine from the bladder.

### Production of Hormones

The kidneys produce and interact with several hormones that are involved in the control of systems outside of the urinary system.

- ❑ Calcitriol is the active form of vitamin D in the human body. It is produced by the kidneys from precursor molecules produced by UV radiation striking the skin. Calcitriol works together with parathyroid hormone (PTH) to raise the level of calcium ions in the bloodstream. When the level of calcium ions in the blood drops below a threshold level, the parathyroid glands release PTH, which in turn stimulates the kidneys to release calcitriol. Calcitriol promotes the small intestine to absorb calcium from food and deposit it into the bloodstream. It also stimulates the osteoclasts of the skeletal system to break down bone matrix to release calcium ions into the blood.
- ❑ Erythropoietin, also known as EPO, is a hormone that is produced by the kidneys to stimulate the production of red blood cells. The kidneys monitor the condition of the blood that passes through their capillaries, including the oxygen-carrying capacity of the blood. When the blood becomes hypoxic, meaning that it is carrying deficient levels of oxygen, cells lining the capillaries begin producing EPO and release it into the bloodstream. EPO travels through the blood to the red bone marrow, where it stimulates hematopoietic cells to increase their rate of red blood cell production. Red blood cells contain hemoglobin, which greatly increases the blood's oxygen-carrying capacity and effectively ends the hypoxic conditions.





- ❑ Renin is not a hormone itself, but an enzyme that the kidneys produce to start the renin-angiotensin system (RAS). The RAS increases blood volume and blood pressure in response to low blood pressure, blood loss, or dehydration.

## THE EXCRETORY SYSTEM

Excretion is the process of ridding the body of waste in order to maintain homeostasis. Only the organs specifically used for the excretion are considered a part of the excretory system. In the narrow sense, the term refers to the urinary system. However, as excretion involves several functions that are only superficially related, it is not usually used in more formal classifications of anatomy or function. As most healthy functioning organs produce metabolic and other wastes, the entire organism depends on the function of the system. Breaking down on one of more of the systems is a serious health condition, like renal failure.

The various structures involved in Excretion are:

### ❑ Skin

Sweat is removed by the skin as a waste product (trying to remove heat). Sweat glands in the skin secrete a fluid waste called sweat or perspiration; however, its primary functions are temperature control and pheromone release. Therefore, its role as a part of the excretory system is minimal. Sweating also maintains the level of salt in the body.

### ❑ Lungs

One of the main functions of the lungs is to remove waste gases such as  $\text{CO}_2$  from the bloodstream as a normal part of respiration.

### ❑ Liver

The liver detoxifies and breaks down chemicals, poisons and other toxins that enter the body. For example, the liver Removes Nitrogenous waste (Urea) from the body. The liver also produces bile, and the body uses bile to breakdown fats into usable fats and unusable waste.

### ❑ Kidney

### ❑ Large Intestine

The large intestine main function is to transport food particles through the body and expel the indigestible parts at the other end, but it will also collect waste from throughout the body. The typical brown colour of mammal waste is due to bilirubin, a breakdown product of normal heme catabolism. The lower parts of the large intestine also extracts any remaining usable water and then removes solid waste. At about 10 feet long in humans, it transports the wastes through the tubes to be excreted

### ❑ Eccrine

Like sweat glands, eccrine glands allow excess water to leave the body. The majority of eccrine glands are located mainly on the forehead, the bottoms of the feet, and the palms, although the glands are everywhere throughout the body. They help the body to maintain temperature control.

## Excretory System Disorders

These are problems associated with the kidneys, bladder, ureters.

## Urinary Tract Infections, UTI's

These are Bacterial infections of the kidneys, bladder or Urethra.



**There are 3 types of UTI's**

## 1. Cystitis

It is the infection of the Bladder.

## 2. Urethritis

It is the infection of the Urethra (tube leading from the bladder to the outside of the body)

## 3. Pyelonephritis

It is the Infection of the Kidney

**Causes of UTI's**

*The major causes are:*

- ☐ Bacteria from the anus (females), Blocked Prostate (men)
- ☐ Bacterial Infection from other areas of body.

**(ii) Kidney Stones**

These are hard crystals of calcium oxalate or uric acid that form in the kidney, bladder or ureter/urethra. They form when materials in the urine solidify.

**The main causes of kidney stones are:**

- ☐ Urinary tract infections
- ☐ Not drinking enough water
- ☐ Too much vitamin C and D.

