

4

HUMAN URINARY SYSTEM



Students Learning Outcomes

After studying this chapter, students will be able to:

- Identify the different organs of urinary system.
- Relate the structure of the kidney with its function.
- State that nephron is the excretory unit of kidney.
- Locate the different parts of nephrons and relate them with their function.
- State that main role of the kidney is urine formation.
- Describe that urine formation involves three processes i.e., filtration, reabsorption and secretion.
- Explain that the kidney plays an important role in osmoregulation.
- Identify the causes and treatment of kidney stones.
- Outline the causes of kidney failure and treatments.

The urinary system regulates the internal environment of body. It ensures that waste products and excess substances are removed from body. In this chapter, we will study the structure and functions of the human urinary system and the related kidney disorders.

4.1 HUMAN URINARY SYSTEM

The human **urinary system** (excretory system) consists of a pair of kidneys, a pair of ureter, a urinary bladder and a urethra. **Kidneys** remove extra water, salts and nitrogenous wastes from blood and make urine. From each kidney, a tube called **ureter** carries urine to the urinary bladder. The **urinary bladder** temporarily stores urine. The **urethra** is the tube that carries urine from the urinary bladder to the outside.

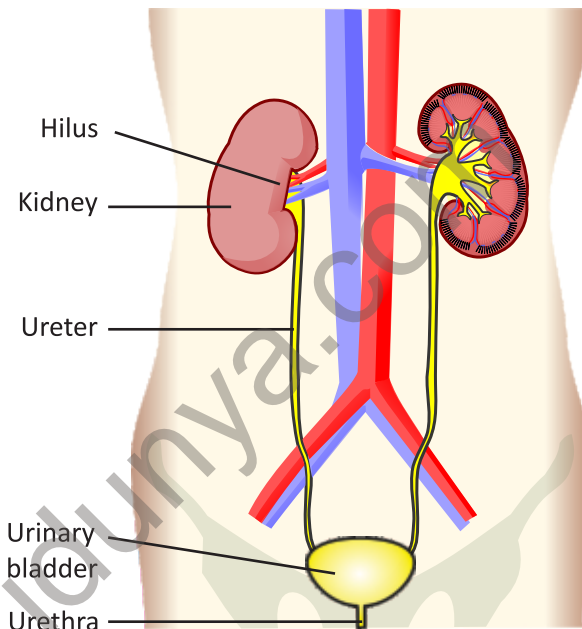


FIGURE 4.1: The Urinary System

The Kidneys

Kidneys are the major organs of urinary system. Renal arteries supply them blood with metabolic wastes (e.g., urea, extra water and salts). Kidneys filter these wastes from blood and then excrete them in the form of urine.

Kidneys are bean-shaped organs having a concave and a convex side. They are present in the abdominal cavity, below the diaphragm, on the sides of vertebral column. The concave side of each kidney is towards vertebral column. The left kidney is a little higher than the right. Kidneys are dark-red in colour. Each kidney is about 10 cm long, 5 cm wide and 4 cm thick.

Structure of the Kidney

External structure: Kidney is surrounded by a tough tissue called **renal capsule**. On the concave side of kidney, there is a depression called **hilus**. It is the point from where renal artery enters in kidney and renal vein and ureter leave kidney.

Internal structure:

Internally, a kidney is divided into two regions. The outer region is called **renal cortex** while the inner one is called **renal medulla**. There are many cone-shaped areas in renal medulla, called **renal pyramids**. The base of each pyramid faces the renal cortex while its tip is in a cavity called **renal pelvis**. It extends to outside of kidneys and forms a ureter.

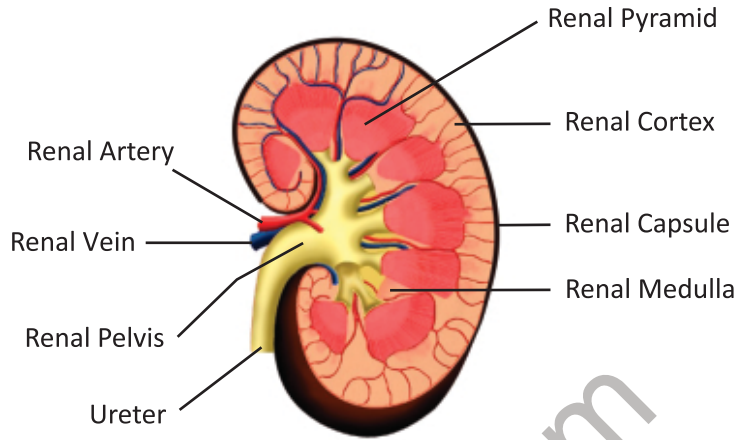


FIGURE 4.2: Structure of Kidney

Nephron

The functional unit of kidney are called **nephrons**. There are more than one

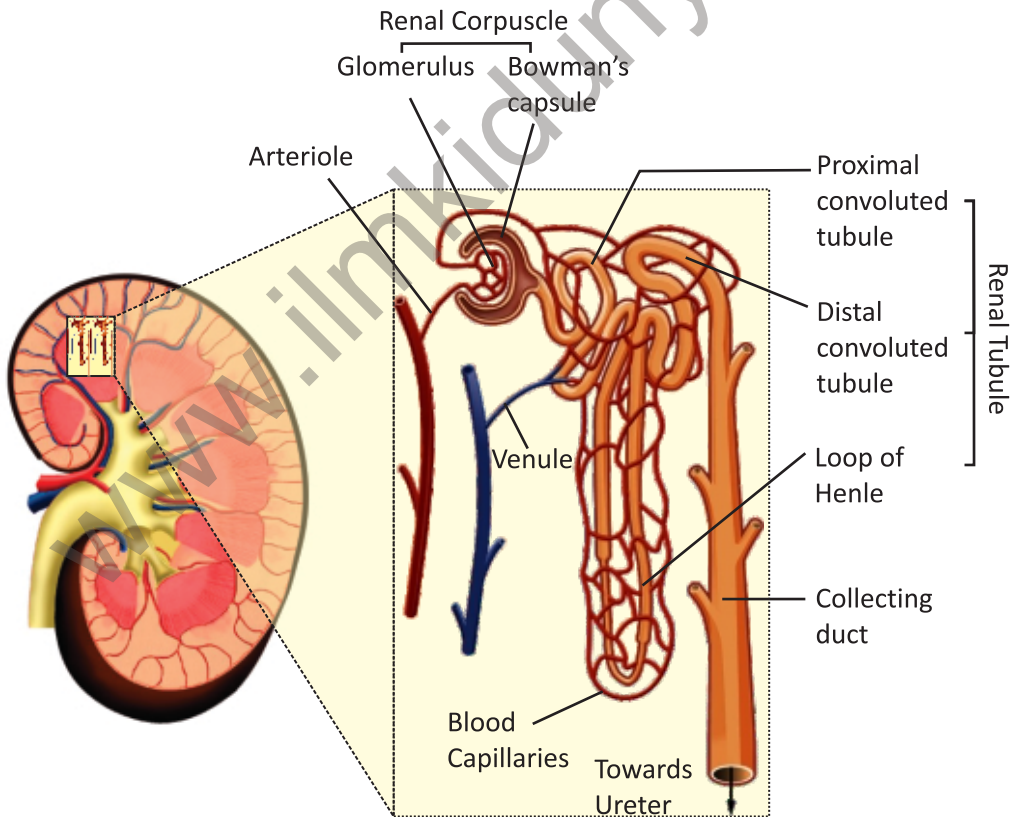


FIGURE 4.3: The Structure of Nephron

million nephrons in each kidney. A nephron consists of two parts i.e., renal corpuscle and renal tubule.

- 1. Renal corpuscle:** It is the first part of nephron and is composed of glomerulus and the Bowman's capsule. The **glomerulus** is a network of capillaries while the **Bowman's capsule** is the cup-shaped structure around the glomerulus.
- 2. Renal tubule:** It is a long tube attached with the Bowman's capsule. It has three parts. The first part is convoluted and is called the **proximal convoluted tubule**. The middle part is U-shaped and is called the **Loop of Henle**. The last part is again convoluted and is called the **distal convoluted tubule**.

The distal convoluted tubules of many nephrons open in a single **collecting duct**. Many collecting ducts join together and open into the renal pelvis.

4.2 FUNCTIONING OF THE KIDNEY

Kidneys control the chemical composition of blood. They take waste materials from blood and convert them to urine. It occurs in three steps.

1. Pressure Filtration

Blood enters kidney through a renal artery. The artery divides into many arterioles. Each arteriole divides into the capillaries of glomerulus. When blood reaches glomerulus, its pressure is very high. So, many small molecules (water, salts, glucose and urea etc.) move out of the glomerulus. These materials enter Bowman's capsule. This step is called **pressure filtration**. The filtered material in Bowman's capsule is called **glomerular filtrate**. It is about 20% of the blood plasma that enters the glomerulus.

Blood cells and proteins are not filtered through the glomerular capillaries because they are relatively larger in size.

2. Reabsorption

The glomerular filtrate moves to the next part of nephron i.e., renal tubule. Many useful materials are reabsorbed from glomerular filtrate into the blood capillaries surrounding the renal tubule.

- Large amount of water, nearly 100% of glucose and amino acids, and most of the salts are reabsorbed from proximal convoluted tube.
- Some water is reabsorbed from descending limb of the loop of Henle. Large amounts of salts are reabsorbed from ascending limb of the loop of Henle.

- Some water is also reabsorbed from distal convoluted tubule and collecting duct.

3. Tubular Secretion

When useful materials are reabsorbed into blood, some of the remaining wastes present in blood are secreted from blood capillaries to renal tubule. It is an active transport process and is called tubular secretion.

After reabsorption and tubular secretion, the filtrate in the renal tubules is known as **urine**. Urine from all nephrons moves to the renal pelvis. From renal pelvis, urine moves to the urinary bladder via ureters. Here it is stored. When the urinary bladder is filled, urine is passed out through urethra.

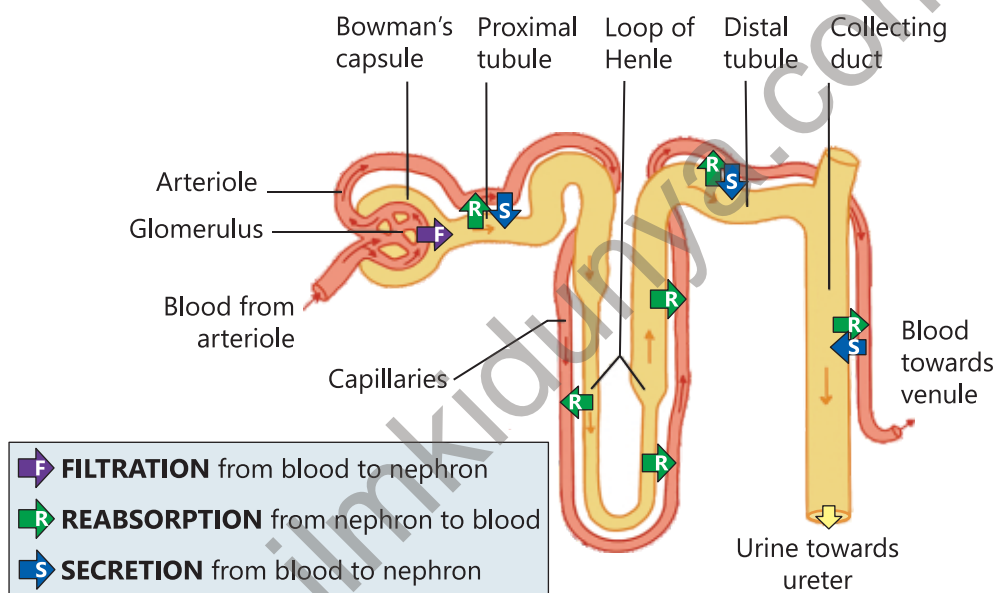


FIGURE 4.4: Functioning of Kidney

Role of Kidneys in Osmoregulation

Osmoregulation means the control of the amount of water according to body's needs. Kidneys are the main organs which work for osmoregulation. They control the amount of solutes in blood. So, the amount of solutes in other body fluids is also controlled.

- **Diluted Urine:** If there is excess water in blood, more water is filtered from the glomerulus to Bowman's capsule. There is less reabsorption of water from renal tubule to capillaries. In this way, abundant dilute urine is produced and the amount of water in blood is brought to normal.
- **Concentrated Urine:** If the amount of water in blood is less than normal,

less water is filtered from the glomerulus to Bowman's capsule. There is more reabsorption of water from renal tubule to capillaries. In this way, concentrated urine is produced and the water is retained in blood.

4.3 DISORDERS OF KIDNEY

1. Kidney Stones

Sometimes, the filtered minerals and salts (e.g., calcium oxalate, calcium and ammonium phosphate, and uric acid etc.) gather in kidneys and make hard, crystalline deposits. Such deposits cannot pass in urine and are called **kidney stones**. Some stones may leave kidneys and may be trapped in ureter or urinary bladder.

Symptoms: Severe pain in kidney or lower abdomen, burning in urethra, frequent urination, foul-smelling urine, blood and pus in urine, nausea, vomiting, bloating.

Causes: Presence of more calcium oxalate, calcium and ammonium phosphates in diet (green vegetables, fats, dairy products), extra amounts of vitamins C and D in diet, reduced water intake, excess uric acid in blood, urinary tract infections, and alcohol consumption.

Treatment: If kidney stones are small in size, the patient is advised to drink plenty of water so that stones can pass through the urine.

Lithotripsy is another method for the removal of kidney stones. In lithotripsy, non-electric shock waves are fired on kidney from outside. The waves hit the stones and break them into smaller pieces, which pass out through urine.

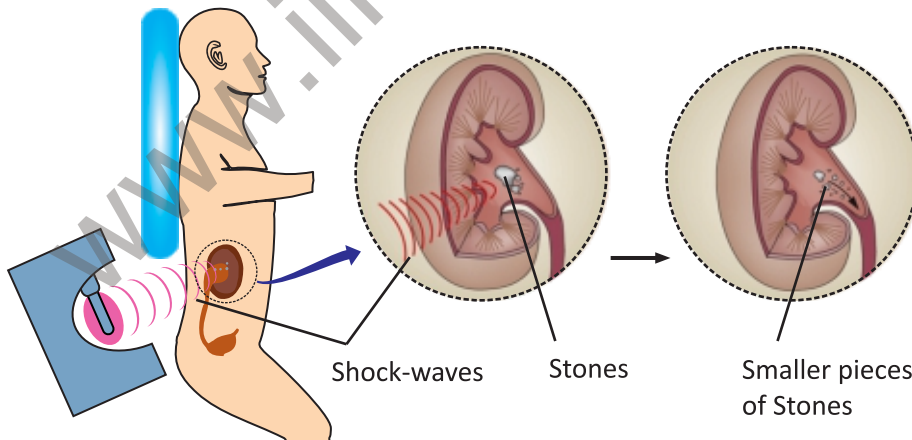


FIGURE 4.5: Lithotripsy

If stones are large and cannot pass easily, the patient has to undergo **surgery** for the removal of stones.

2. Kidney (Renal) Failure

When one or both kidneys are not able to perform their function (removing waste materials from blood and then passing them out), the condition is called kidney failure.

Symptoms: Increases concentration of wastes in blood, rise in volume of body fluids, weight loss, and blood in urine, swelling in legs, feet and face.

Causes: Long-term diabetes mellitus, and hypertension, dehydration, severe kidney infections, overuse of certain medicines (e.g., nonsteroidal anti-inflammatory drugs - NSAIDs), large kidney stones, physical damage to kidneys, heart or liver failure.

Treatment of Kidney Failure

a. Dialysis

Dialysis is a method in which wastes are extracted from blood by using a **dialysis fluid**. There are two methods of dialysis.

1. Haemodialysis: In haemodialysis, the patient's blood is pumped through a machine called **dialyzer**. The dialyzer contains long tubes. Blood flows inside the tubes while dialysis fluid flows outside. Extra water and wastes move from blood and enter the dialysis fluid. The purified blood is then returned back to the body.

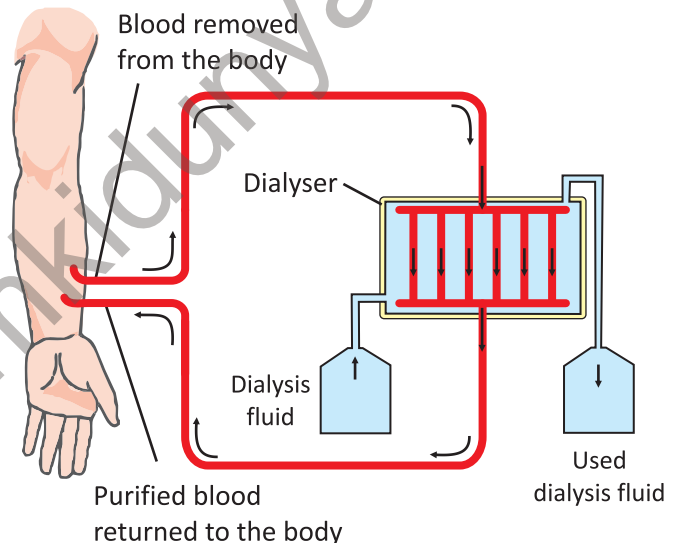


FIGURE 4.6: Haemodialysis

2. Peritoneal Dialysis: In this method, dialysis fluid is pumped into the peritoneal cavity (the space around gut in abdomen). The walls of peritoneal cavity are lined with peritoneal membrane. The wastes pass from the blood present in blood vessels of peritoneal membrane into the dialysis fluid. After some time, the dialysis fluid is drained.

b. Kidney Transplantation

Kidney transplantation is done for advanced treatment of kidney

In Punjab, organ transplantation is controlled by **Punjab Human Organ Transplant Authority**. It ensures that people can have suitable transplantation with safety and quality.

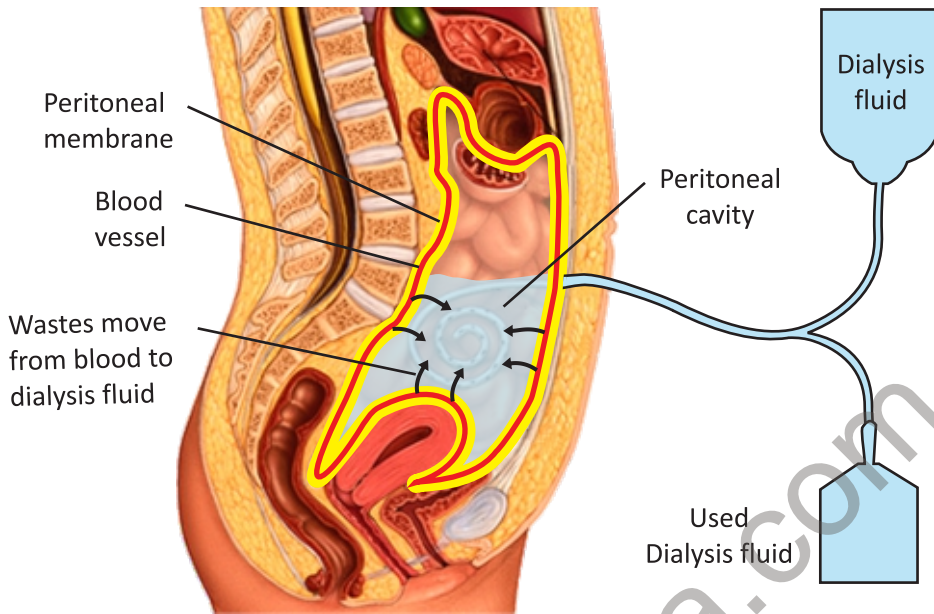


FIGURE 4.7: Peritoneal Dialysis

failure. In this treatment, a healthy kidney from some donor is transplanted in patient's body, along with the damaged kidney. The donor of kidney may be a deceased person or a living one. Living-donor may or may not be a relative of the patient. In all cases, the donor's kidney is matched with the patient's immune system. When a matching kidney is transplanted, it may work normally in patient's body for ten to fifteen years.

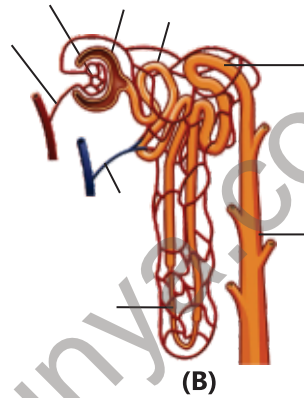
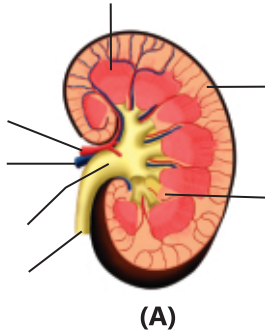


EXERCISE

A. Select the correct answers for the following questions.

- The process of regulating the amount of water in body fluid is called;
 - Filtration
 - Reabsorption
 - Tubular secretion
 - Osmoregulation
- What happens in the proximal convoluted tubule of nephron?
 - Blood is filtered by glomerulus
 - Reabsorption of water and nutrients occurs
 - Urine is stored
 - Water is secreted into the bloodstream
- Which structure is responsible for filtering blood to produce urine?
 - Nephron
 - Renal pelvis
 - Ureter
 - Renal capsule

7. Differentiate between:
 - i. Excretion and osmoregulation
 - ii. Renal cortex and renal medulla
 - iii. Renal corpuscle and renal tubule
 - iv. Pressure filtration and tubular secretion
 - v. Haemodialysis and peritoneal dialysis
8. Label the parts of the diagrams (A) and (B):



C. Write answers in detail.

1. Write a note on the structure of kidney.
2. Describe the structure of a nephron and draw a labelled diagram.
3. Describe the process of pressure filtration and re-absorption in kidneys.
4. What is tubular secretion? How it helps in removing wastes from blood?
5. Write a comprehensive note on kidney stones describing the causes, symptoms and treatments.
6. Write down the symptoms and causes of kidney failure.
7. Define dialysis and describe the processes of peritoneal dialysis and haemodialysis.

D. Inquisitive questions

1. "Along with excretion, kidneys also play role in osmoregulation." Comment on this statement.
2. How does the nephron ensure that essential nutrients are not lost in urine?
3. Why is long loop of Henle important in the balance of water and salts in body?
4. How can chronic diseases like diabetes lead to kidney failure?