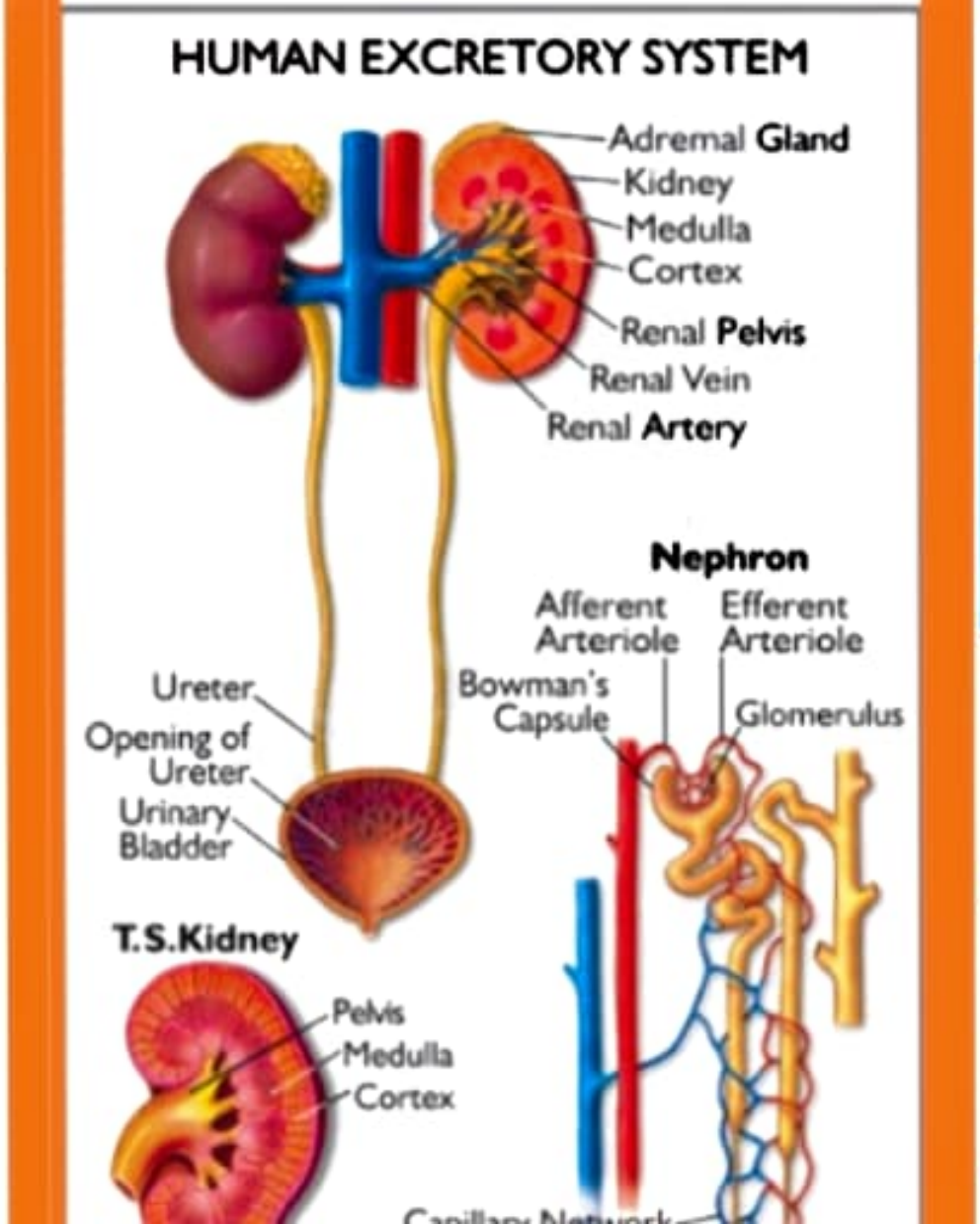
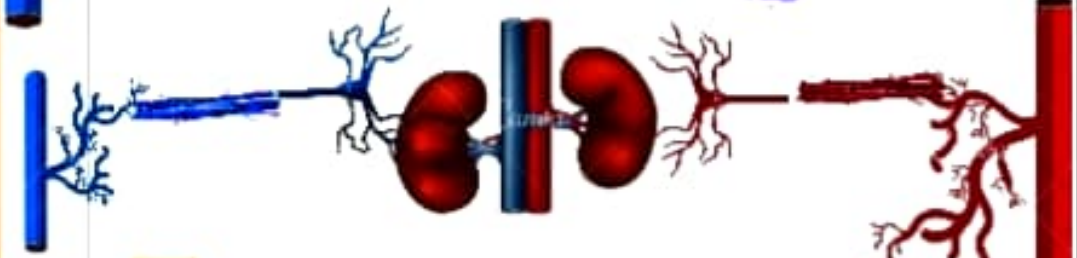
Class -10



KRISHNAGAR ACADEMY

Biology

CHAPTER- 8



Excretory System

SYLLABUS

- *Excretory system : Elementary treatment of the structure and function of the kidneys; the kidneys treated as comprising cortex and medulla and consisting of a branched system of tubules well supplied with blood vessels leading to the ureter (details of the courses of the tubules and their blood vessels not required).*
- *External and internal structure of the kidney; parts of the excretory system along with the blood vessels entering and leaving it should be taught with the help of charts or models. Students should be able to draw the diagrams with correct labelling and know the functions of various parts. A general idea of the structure of a kidney tubule nephron should be given. A brief idea of ultra filtration, selective reabsorption and tubular secretion in relation to the composition of blood plasma and urine formed.*

The life is a sum total of different types of reactions taking place in the cells of living organisms. During these reactions certain waste products are formed which need to be removed from the cells. Thus, excretion is defined as the removal of metabolic wastes from the cells or the body of an organism.

EXCRETORY SYSTEM

In most animals, the body has certain organs which are specialised to carry out the excretion. These organs are called *excretory organs*. *Kidneys* are *chief excretory organs* of man and all other vertebrates. They help in the removal of nitrogenous wastes, specially urea and uric acid, water and salts. Besides the kidneys, the *skin*, *lungs* and *intestine* are also involved directly or indirectly in the excretion in man and other vertebrates. All excretory organs present in the body of an animal constitute the excretory system.

Organs of the Excretory System : The excretory system of humans is made up of two kidneys, two ureters, one urinary bladder and one urethra.

HUMAN EXCRETORY SYSTEM

The excretory system of human beings consists of the following organs:

Kidneys

The kidneys are two reddish-brown, bean-shaped structures, 10 cm long and 6 cm wide. These are located just below the stomach in the abdominal cavity, one on either side of the backbone, and are protected by the last two ribs.

The right kidney is a little lower than the left kidney because of the large space occupied by the liver. The inner concave surface of each kidney has a notch, called **hilum**. Inner to the hilum is a broad, funnel-shaped space called the **renal pelvis** from which the ureter arises.

Ureters

Ureters are two ducts or tubes each arising from the hilum of renal pelvis of each kidney. At the other end, they open into a bag-like structure called **urinary bladder** (Fig. 9.1).

The ureters transport urine from the kidneys downwards into the urinary bladder.

> The ureters open obliquely into the bladder. These oblique openings act like valves and prevent the back flow of urine into the kidneys.

Urinary Bladder

The urinary bladder is a single median structure situated in the pelvic cavity (lower part of abdomen). It is a muscular structure because of which it can contract easily. The urine passes **through the ureters** and continuously trickles into the bladder, which acts as a temporary storage bag of urine. When the bladder is full, it contracts and expels the urine.

Urethra

The urinary bladder opens to the outside through a muscular tube called **urethra**. The urethra is

short in females, while in males it is longer. This is the reason that females are more prone to urinary tract infections. The opening of urethra is guarded by a sphincter* which keeps the urethral opening closed. However, at the time of urination, these muscles relax because of which urethra opens and the urine flows out.

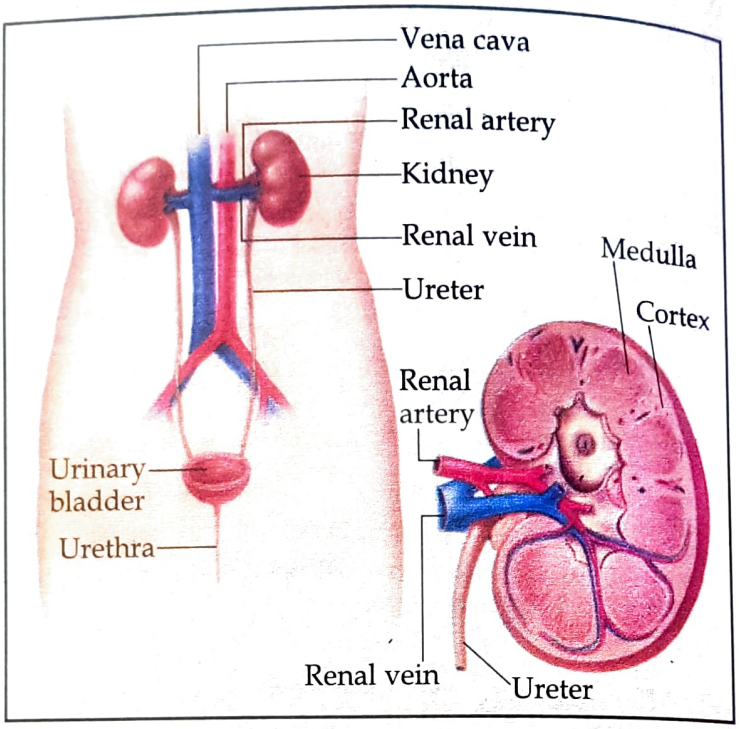


Fig. 9.1 (a): Human excretory system

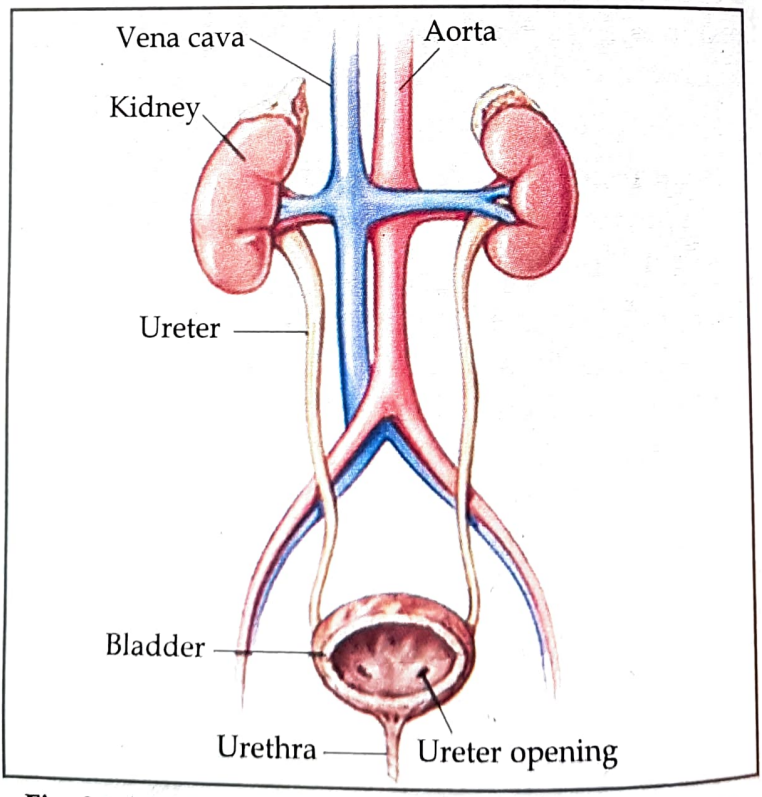


Fig. 9.1 (b): Diagrammatic view of the excretory system

INTERNAL STRUCTURE OF THE KIDNEY

The longitudinal section (L.S.) of kidney shows two main regions, an outer, dark red **cortex** and an inner, pale **medulla**.

Cortex

Cortex is the outer region of the kidney. It extends in between the medullary pyramids. These extensions are called **Columns of Bertini**. Cortex is not uniform in texture because of the granular substances present in it.

Medulla

The medulla of a kidney is divided into conical masses called **medullary** or **renal pyramids**. The base of each pyramid is in contact with the outer cortex region, whereas the apical part of the pyramid, called **papilla**, projects into the pelvis region of the kidney.

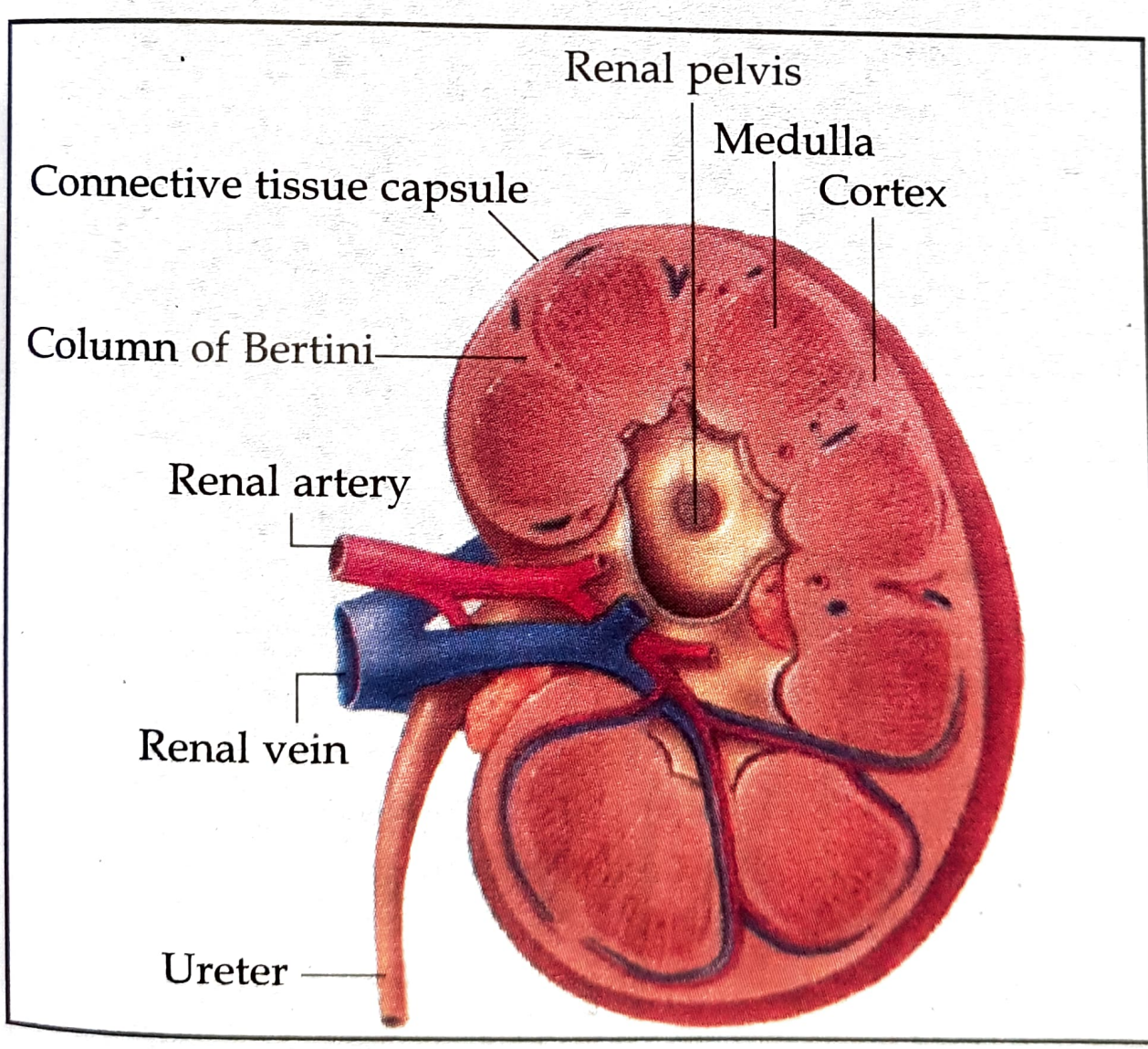


Fig. 9.2: Internal structure of kidney

NEPHRON—THE STRUCTURAL AND FUNCTIONAL UNIT OF KIDNEY

Each kidney is made up of nearly one million tubular structures. These are called *nephrons* or uriniferous tubules. These are the structural and functional units of the kidney. Major part of each nephron is present in the cortex, but its tubule extends into the medulla.

The nephrons of the kidney are responsible for the formation of urine. Each nephron consists of the following parts:

Bowman's Capsule (in cortex)

Bowman's capsule is a double-walled, cup-like structure which forms the beginning of the nephron. A tubular system arises from the base of Bowman's capsule, whereas the outer concave part of the capsule encloses a mass of blood capillaries called **glomerulus**. *Bowman's capsule and glomerulus are collectively called* ***Malpighian corpuscle*** *or* ***renal capsule.*** This whole part of the nephron is present in the cortex region of the kidney.

Bowman's capsule was discovered by a British physician **Sir William Bowman** and has been named after him.

Proximal Convoluted Tubule (PCT) (in cortex)

A tiny convoluted tubule arises from the Bowman's capsule which forms a coiled network in the cortex of kidney. This is called **proximal (near to Bowman's capsule) convoluted tubule** or **PCT**.

Loop of Henle (in cortex and medulla)

PCT leads to a long, thin-walled, U-shaped tube called the **loop of Henle**. It runs down into the medulla, takes a U-turn and returns to the cortex region to continue into the next part of the nephron.

Distal Convoluted Tubule (DCT) (in cortex)

In the cortex region, the loop of Henle leads to another coiled tubular structure called **distal convoluted tubule** or **DCT**. This is just like the proximal convoluted tubule but lies away from Bowman's capsule, thus called **distal**. It opens into the final part of the nephron called **collecting duct**.

Collecting Duct (in medulla)

DCT finally opens into a **collecting duct** which receives urine from the distal convoluted tubules of many nephrons. It passes through the medulla and carries urine to renal pelvis which empties into the ureter.

Types of Nephrons

The nephrons are of two types, depending upon the length of loop of Henle:

- **Cortical Nephrons:** The loop of Henle of these nephrons is very short and only a small part of it extends into the medulla.
- **Juxtamedullary Nephrons:** These nephrons have a very long loop of Henle and they extend deep into the medulla.

Some Interesting Facts

- Each kidney contains about one million nephrons.
- The two kidneys filter about 180 litres of fluid and remove about 1.5 litres of waste fluid from the body in the form of urine every 24 hours. This means that 99% of the fluid from the filtrate is reabsorbed.
- The urine can be stored in the bladder for 1 to 8 hours.
- The bladder can collect 300-400 mL of urine.
- The entire blood present in the human body passes through the kidneys every five minutes.
- Half of one kidney can do the work that two kidneys usually do.
- Kidneys represent about 0.5% of the total weight of the body.

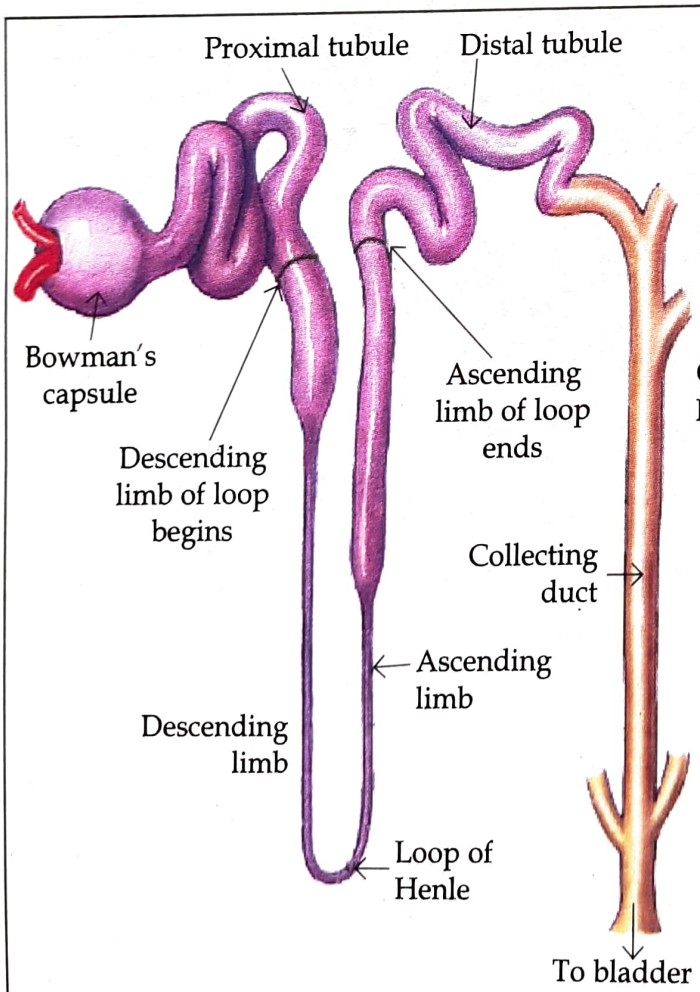


Fig. 9.3 (a): Diagrammatic view of a nephron

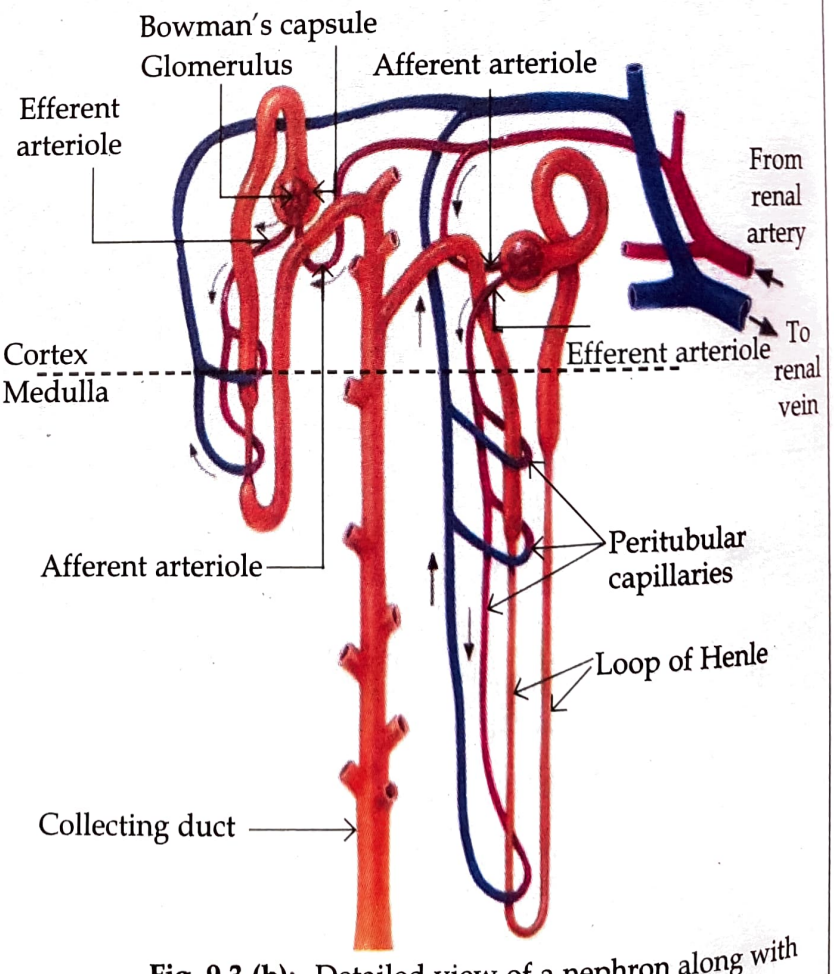


Fig. 9.3 (b): Detailed view of a nephron along with its blood supply

BLOOD SUPPLY TO THE KIDNEY

Each kidney is supplied by a branch of dorsal aorta called **renal artery** which carries the oxygenated blood.

- The renal artery branches and re-branches several times and forms a number of **afferent** (incoming or entering) **arterioles**.
- One such arteriole enters each Bowman's capsule and divides into a network of capillaries, forming a knot-like mass called **glomerulus**.
- The glomerular capillaries reunite to form the **efferent** (outgoing or leaving) **arteriole** which comes out of the glomerulus.

- The efferent arteriole runs towards the proximal convoluted tubule (PCT) and forms a secondary network of capillaries called **peritubular capillaries**.
- This second capillary network surrounds the proximal convoluted tubule, loop of Henle and distal convoluted tubule. The capillary network around the loop of Henle is called **vasa recta**.
- These capillaries join together again to form a number of **venules** which join to form a branch of renal vein.
- The different branches, finally, unite to form **renal vein** which leaves the kidney at hilum.
- The renal vein drains the purified blood into the posterior vena cava.

FUNCTIONS OF THE KIDNEY

The kidneys carry out many important functions required for the regulation of composition of blood and maintenance of a constant internal environment. This is termed as **homeostasis**.

Regulation of Fluid Balance

The kidneys help to keep the amount of water constant in the body by regulating the amount of urine output. For example, if a patient is losing body fluids because of diarrhoea and vomiting, and also not taking enough fluids to compensate this loss, then the kidney will excrete less amount of urine in order to maintain the fluid balance in the body.

In tropical countries, individuals feel more thirsty and drink a lot of water during summer. Still, they urinate fewer times and produce thicker urine in summer than in winter. This is because of the reason that a considerable part of

body water is lost through sweating. As a result, kidneys reabsorb more water from the filtrate making the urine concentrated and thicker.

Regulation of Acid-Base Balance

The kidneys maintain the acid-base balance of the blood by removing various wastes from the body. For example, the nitrogenous wastes formed in the body are removed by the kidneys in the form of acidic urine. The kidneys also remove various other substances from the blood which may be harmful for the body. These include mineral salts (iodides, arsenic), bacteria and drugs (serotonin).

Regulation of Arterial Blood Pressure

The kidneys secrete a hormone called **renin**, which regulates the arterial blood pressure of the body.

MECHANISM OF URINE FORMATION

The mechanism of urine formation mainly involves three steps:

- Ultrafiltration,
- Tubular reabsorption and
- Tubular secretion.

These three steps take place in different parts of the nephron.

PHYSIOLOGY OF URINE FORMATION

Entire process of urine formation can be divided into three steps : ultrafiltration, selective reabsorption and tubular secretion.

1. Ultrafiltration : The afferent arteriole has a larger diameter than the efferent arteriole which creates a hydrostatic pressure (of about 65 mm Hg) in the capillaries of glomerulus. This is opposed by osmotic pressure of blood (about 30 mm Hg) and the hydrostatic pressure in the interstitial spaces of kidney. However, the hydrostatic pressure exceeds the sum of the opposing forces. In this way the effective filtration pressure is about 15 mm Hg. It causes the filtration of solutes from blood plasma into the Bowman's capsule. It is now called glomerular filtrate. The pores of the glomerular capillaries allow free passage of small molecules but do not allow passage of blood cells and large molecules such as plasma proteins (albumin, globulin and fibrinogen). These are not present in the ultrafiltrate. The ultrafiltration is *non-selective* because the filtrate, which comes into the urinary space of Bowman's capsule contains both useful substances and metabolic waste products. Most of the useful constituents of the filtrate (salts, glucose, amino acid, water and metabolites) are reabsorbed in the blood by the nephron.

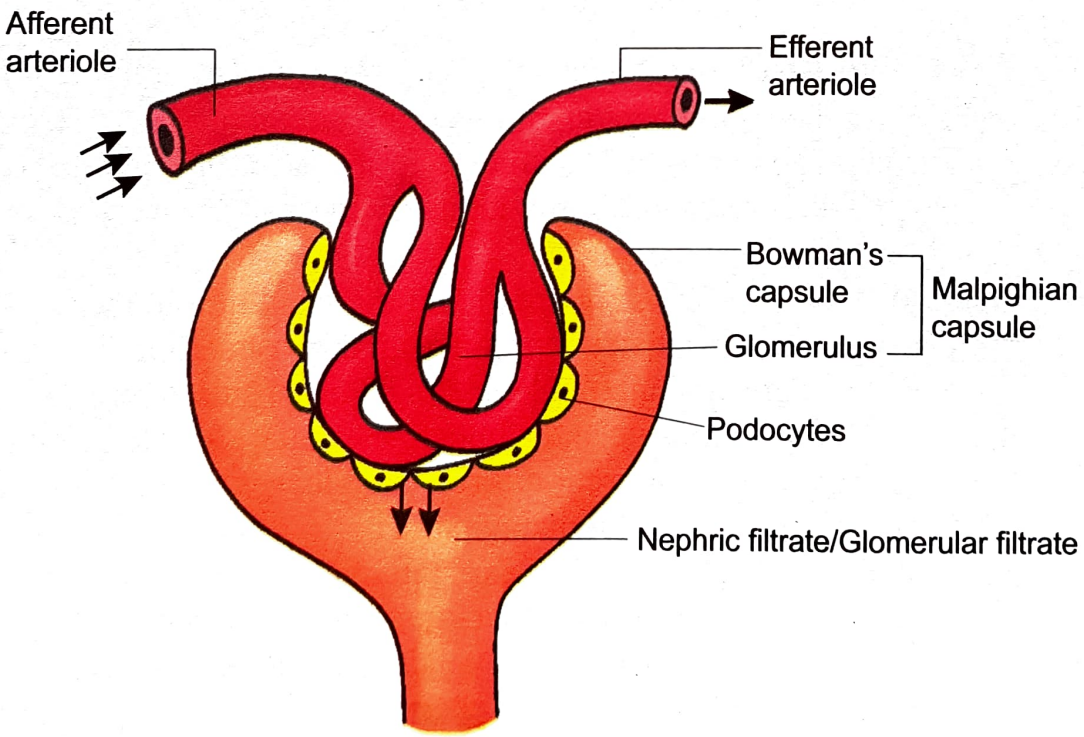


Fig. 4. Structure of Malpighian capsule

2. The Selective Reabsorption : It is a process whereby substances of the filtrate are transferred out of the tubule to the blood in the capillaries, which surround the nephron. In this way, the substances that have been temporarily lost from the plasma during the ultrafiltration are returned to the blood. The tubular reabsorption is a selective process; the wall of the nephron absorbs different substances differently. The proximal convoluted tubule reabsorbs water, glucose, sodium, potassium, bicarbonates and phosphates.

All glucose is reabsorbed, hence the urine of healthy person does not contain glucose but when a person suffers from *Diabetes mellitus,* there is loss of glucose through the urine (glycosuria).

The amino acids are also reabsorbed by the proximal convoluted tubule. Besides being reabsorbed by the proximal convoluted tubules, the water is also reabsorbed by Henle's loop, distal convoluted tubule and collecting tubules.

The reabsorption of urea and uric acid also takes place to some extent in the proximal convoluted tubule.

Reabsorption continues to the extent so that the normal concentration of these substances in the blood is restored.

3. Tubular Secretion : The cells of the proximal and distal convoluted tubules secrete actively (by using ATP) some substances from blood in lumen of these tubules. Main substances include potassium ions, hippuric acid, ammonia, creatinine and uric acid. The antibiotic penicillin, vitamin B-complex, pigments such as bilirubin and urochromes and some other drugs are secreted by the distal convoluted tubule.

After the selective reabsorption and tubular secretion, the filtrate left in the nephron is called the urine and the same is excreted out.

MICTURITION

The act of emptying the urinary bladder is called micturition. The emptying of the urinary bladder into the urethra is controlled by the external and internal sphincters, (thick rings of muscles) situated at junction of the bladder and urethra. As the bladder fills up with the urine, its wall is stretched. The stretching of its wall generates reflex action which causes relaxation of the bladder's sphincters. Simultaneously, the smooth muscles of the bladder's wall contract, forcing the urine out through the urethra. After the urine has passed out, the muscles of the bladder relax with the simultaneous contraction of the bladder's sphincters.

COMPOSITION OF URINE

1. An average adult excretes about 1.0 to 1.5 litre urine per day.
2. It normally contains 96% water and about 4% dissolved inorganic and organic solutes.
3. The pH of urine normally varies between 6 and 6.5, *i.e.*, it is acidic.

However, depending on the type of diet it can be as low as 4.5 and as high as 8.0.

ARTIFICIAL KIDNEY

In some persons, kidneys are unable to work properly. This condition is called kidney failure. This is treated by dialysis, which is the process of artificial removal of the excretory substances from the blood of the person affected by the kidney failure. The dialysis is carried out by a kidney machine, a mechanical device through which a patient's blood is passed and then returned back to his body. The blood leaves the patient's body usually through the radial artery in the forearm for processing in the kidney machine and thereafter, returns to the body through the corresponding vein. In the machine, the blood flows over membranes which separate it from an aqueous dialysing fluid which contain the solutes in concentrations normally found in blood. The soluble constituents in excess of normal concentration diffuse into the dialysing fluid across the membranes. In this way, the wastes like urea are removed from the blood. However, blood cells and proteins are not filtered. This process is called renal dialysis.

OSMOREGULATION

The maintenance of the osmotic pressure of the body fluids is called osmoregulation. Any deviation from the normal osmotic pressure due to changed water and salt concentrations will create problem in the normal working of the organism.

In summers due to excessive sweating, the osmotic pressure of the body fluid increases. Thus to maintain proper osmotic pressure, the hypothalamus stimulates the posterior lobe of pituitary to release ADH which causes increased reabsorption of water in DCT and collecting duct thus osmotic pressure of the body is normalised. Urine becomes hypertonic.

In winters there is no loss of water by perspiration so osmotic pressure of the body is low thus ADH secretion is decreased and the urine becomes dilute.

SHORT ANSWER QUESTIONS

1. What will happen if a person does not excrete properly?
2. What are the different life processes which result in the production of wastes in the human body?
3. Name the various types of wastes produced and explain the modes of their elimination.
4. Why is nephron considered the structural and functional unit of the kidney?
5. Why is the process of tubular reabsorption important in excretion?
6. What is the function of sphincter muscle guarding the urethra?
7. Why does the absorption of glucose in blood require energy?
8. Name the hormone responsible for maintaining blood pressure of the body.
9. Why does urine smell strongly if allowed to stand?
10. What will happen if a person has excess of ADH in his blood?
11. What is the function of an artificial kidney?
12. What is the use of cellophane tubing in the dialysis machine?
13. Give the location of the following:

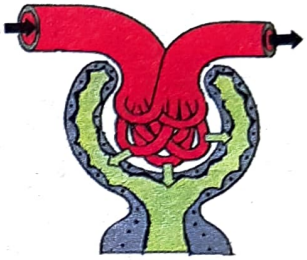
    (*a*) Renal pyramids (*b*) Hilum (*c*) Columns of Bertini (*d*) Pelvis.

LONG ANSWER QUESTIONS

1. Draw a well-labelled diagram of the human excretory system. Write the functions of each part.
2. How are kidneys important in maintaining homeostasis in the body?
3. Describe the structure of a nephron with diagram.
4. What is the difference between tubular reabsorption and tubular secretion?
5. Describe the course of blood supply in the kidney.
6. How is urine formed in the human body? Explain the process in detail.
7. What are the various constituents of urine?
8. How does an artificial kidney work?

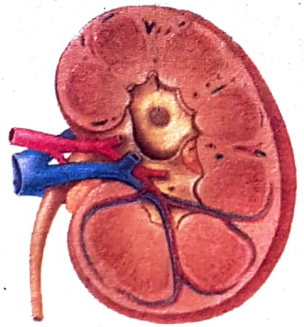
(iv)

5. Observe the figure given alongside and answer the following questions:



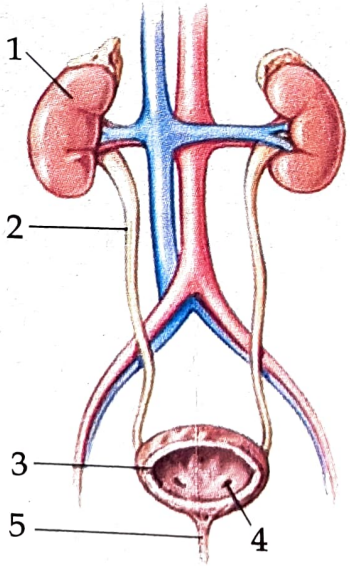
(i) Name the organ and its individual parts.
(ii) Which arteriole is afferent and which one is efferent? Give reasons.
(iii) Name the process which takes place here.
(iv) Write the significance of the process.

6. Given below is the section of a kidney. Answer the questions that follows:



(i) Does the figure represent longitudinal section or transverse section of the kidney?
(ii) Name the tube-like structure coming out of the kidney and the part from where it is arising.
(iii) Label the inner and outer regions of the kidney.
(iv) What are the conical masses present in the middle region?

7. Observe the figure given below and answer the following questions:



(i) Label the parts numbered 1 to 5.
(ii) What prevents the back flow of fluid from part 3 to part 2?
(iii) Why is part 3 contractile in nature?
(iv) What is the difference between the part 5 of males and females?
(v) Name the structural unit of part 1.