CHAPTER

11 Homeostasis

Animation 11.1: Homeostasis
Source & Credit: Lionden

Homeostasis may be defined as the maintenance of the internal conditions of body at equilibrium, despite changes in the external environment. For example, the core temperature of human body remains at about 37°C despite fluctuations in the surrounding air temperature. Similarly, the blood glucose level remains about 1g per litre despite eating a meal rich in carbohydrates. Body cells need the internal environment in which conditions do not change much. Stable internal conditions are important for the efficient functioning of enzymes. The following are some process of homeostasis.

Osmoregulation: It is maintenance of the amounts of water and salts in body fluids (i.e. blood and tissue fluids). We know that the relative amounts of water and salts in body fluids and inside cells control by the processes of diffusion and osmosis, which are essential for the functioning of cells (Recall "the concept of tonicity" from Grade IX Biology).

Thermoregulation: The maintenance of internal body temperature is called thermoregulation. The enzymes of body work best at particular temperatures (optimum temperature). Any change in body temperature may affect the functioning of enzymes.

Excretion is also a process of homeostasis. In this process, the metabolic wastes are eliminated from body to maintain the internal conditions at equilibrium.

Metabolic waste means any material that is produced during body metabolism and that may harm the body.

11.1 Homeostasis In Plants

Plants respond to environmental changes and keep their internal conditions constant i.e. homeostasis. They apply different mechanisms for the homeostasis of water and other chemicals (oxygen, carbon dioxide, nitrogenous materials etc).

11.1.1 Removal of Extra Carbon dioxide and Oxygen

In daytime, the carbon dioxide produced during cellular respiration is utilized in photosynthesis and hence it is not a waste product. At night, it is surplus because there is no utilization of carbon dioxide. It is removed from the tissue cells by diffusion. In leaves and young stems, carbon dioxide escapes out through stomata.

In young roots, carbon dioxide diffuses through the general root surface, especially through root hairs. Oxygen is produced in mesophyll cells only during daytime, as a by-product of photosynthesis. After its utilization in cellular respiration, the leaf cells remove the extra amount of oxygen through stomata.

11.1.2 Removal of Extra Water

We know that plants obtain water from soil and it is also produced in the body during cellular respiration. Plants store large amount of water in their cells for turgidity. Extra water is removed from plant body by transpiration.

At night, transpiration usually does not occur because most plants have their stomata closed. If there is a high water content in soil, water enters the roots and is accumulated in xylem vessels. Some plants such as grasses force this water through special pores, present at leaf tips or edges, and form drops. The appearance of drops of water on the tips or edges of leaves is called **guttation** (Fig 11.2).

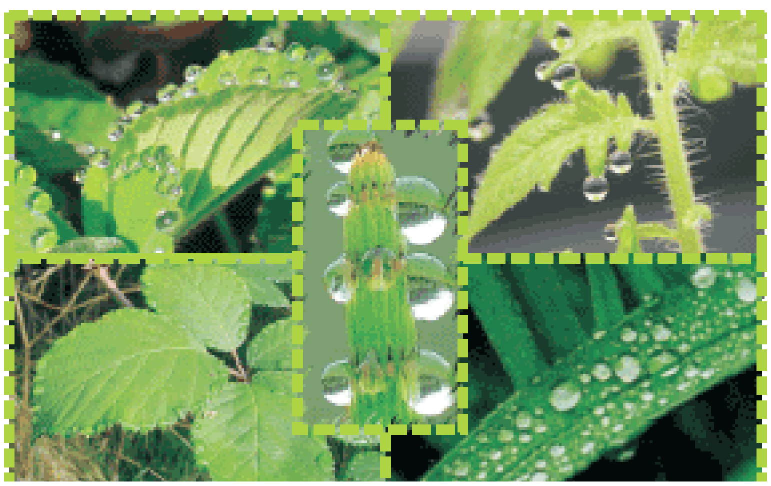

Figure 11.1: Guttation in different plants

Recalling

Transpiration is the loss of water from plant surface in the form of vapours.

Guttation is not to be confused with dew, which condenses from the atmosphere onto the plant surface.

11.1.3 Removal of Other Metabolic Wastes

Plants deposit many metabolic wastes in their bodies as harmless insoluble materials. For example, calcium oxalate is deposited in the form of crystals in the leaves and stems of many plants e.g. in tomato (Fig. 11.2).

Figure 11.2: Calcium oxalate needles in a leaf cell

The removal of excretory products is a secondary function of leaf fall. If the leaves are not shed, the calcium oxalate just remains as harmless crystals in the leaves

In trees which shed their leaves yearly, the excretory products are removed from body during leaf fall.
Other waste materials that are removed by some plants are resins (by coniferous trees), gums (by keekar), latex (by rubber plant) and mucilage (by carnivorous plants and ladyfinger) etc. (Fig. 11.3).

Resin drops from a cut tree

Latex being extracted from a tree

Mucilage drops on a carnivorous plant

Figure 11.3: Removal of some wastes in plants

11.1.4 Osmotic Adjustments in Plants

On the basis of the available amount of water and salts, plants are divided into three groups.

- **Hydrophytes** are the plants which live completely or partially submerged in freshwater. Such plants do not face the problem of water shortage. They have developed mechanisms for the removal of extra water from their cells. Hydrophytes have broad leaves with a large number of stomata on their upper surfaces. This characteristic helps them to remove the extra amount of water. The most common example of such plants is water lily.
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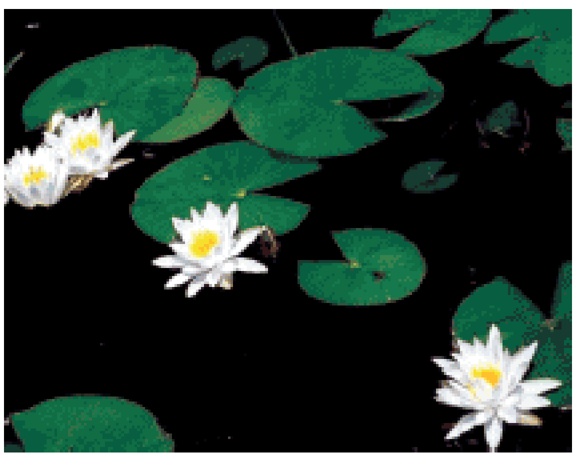
- **Xerophytes** live in dry environments. They possess thick, waxy cuticle over their epidermis to reduce water loss from internal tissues. They have less number of stomata to reduce the rate of transpiration. Such plants have deep roots to absorb maximum water from soil. Some xerophytes have special parenchyma cells in stems or roots in which they store large quantities of water. This makes their stems or roots wet and juicy, called **succulent organs.** Cacti (Singular Cactus) are the common examples of such plants.

- **Halophytes** live in sea waters and are adapted to salty environments. Salts enter in the bodies of such plants due to their higher concentration in sea water. On the other hand, water tends to move out of their cells into the hypertonic sea water. When salts enter into cells, plants carry out active transport to move and hold large amount of salts in vacuoles. Salts are not allowed to move out through the semi- permeable membranes of vacuoles. So the sap of vacuoles remains even more hypertonic than sea water. In this way, water does not move out of cells. Many sea grasses are included in this group of plants.

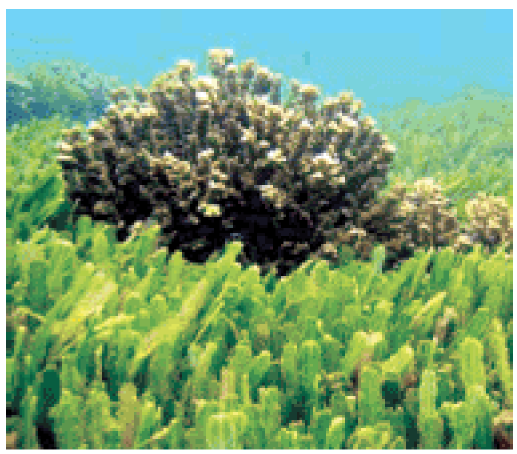
Animation11.2: Osmosis
Source & Credit: Leavingbio

Recalling

Osmosis is the movement of water from hypotonic solutions (less solute concentration) to hypertonic solutions (higher solute concentration), through semipermeable membrane.



Hydrophytes



Halophytes

Xerophytes

Figure 11.4: Three groups of plants

11.2 Homeostasis In Humans

Like other complex animals, humans have highly developed systems for homeostasis.
The following are the main organs which work for homeostasis:

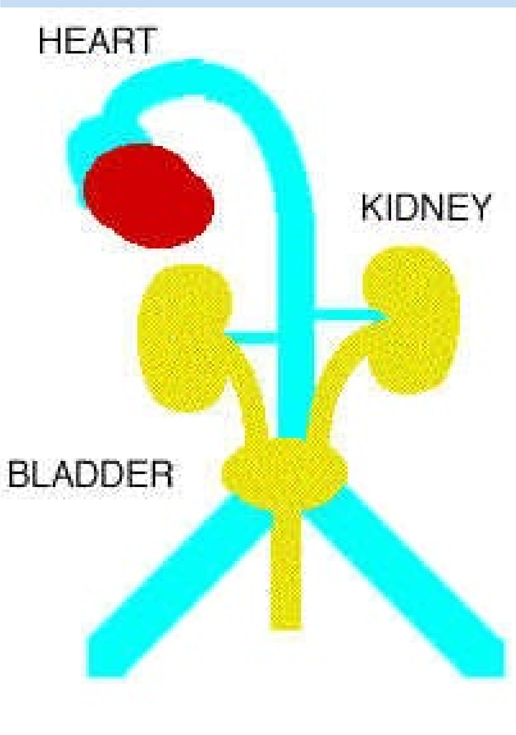
- Lungs remove excess carbon dioxide and keep it in balance.
- Skin performs role in the maintenance of body temperature and also removes excess water and salts.
- The kidney filters excess water, salts, urea, uric acid etc. from the blood and forms urine.

11.2.1 Skin

We know that our skin consists of two layers. Epidermis is the outer protective layer without blood vessels while dermis is the inner layer containing blood vessels, sensory nerve endings, sweat and oil glands, hairs and fat cells.
Skin performs important role in the regulation of body temperature. The thin layer of fat cells in the dermis insulates the body. Contraction of small muscles attached to hairs forms 'Goosebumps'. It creates an insulating blanket of warm air (Fig. 11.5).

Initiating and Planning

Hypothesize why the dogs hang their tongues out and pant



Animation11.3: The Skin,
Source & Credit: Leavingbio

Figure 11.5: Goose bumps

Similarly, skin helps in providing cooling effect when sweat is produced by sweat glands and excess body heat escapes through evaporation. Metabolic wastes such as excess water, salts, urea and uric acid are also removed in sweat.

11.2.2 Lungs

In the previous chapter we have learned how lungs maintain the concentration of carbon dioxide in the blood. Our cells produce carbon dioxide when they perform cellular respiration. From cells, carbon dioxide diffuses into tissue fluid and from there into blood. Blood carries carbon dioxide to lungs from where it is removed in air.

11.3 The Urinary System Of Humans

The excretory system of humans is also called the urinary system. It is formed of one pair of kidneys, a pair of ureters, a urinary bladder and a urethra.

Kidneys filter blood to produce urine and the ureters carry urine from kidneys to urinary bladder. The bladder temporarily stores urine until it is released from body. Urethra is the tube that carries urine from urinary bladder to the outside of body.

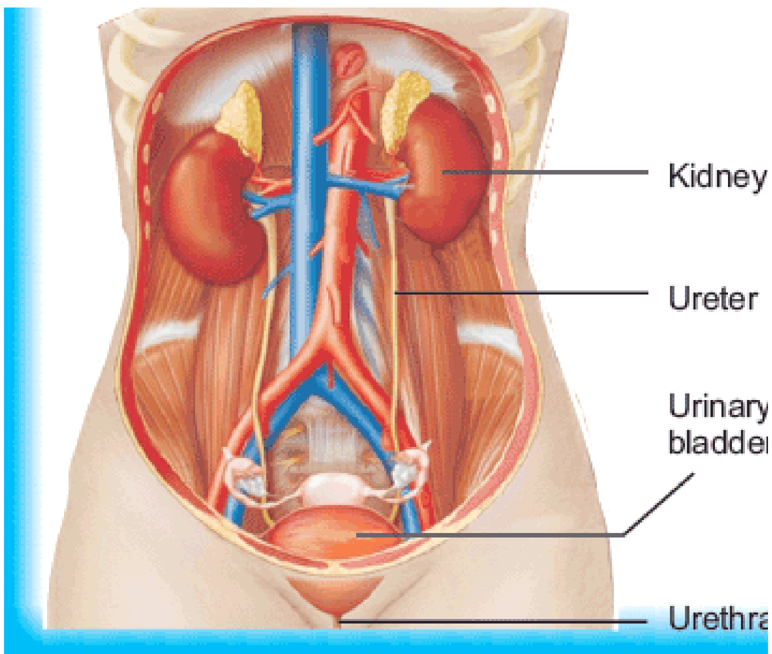


Figure 11.6: The urinary system of humans

11.3.1 Structure of Kidney

Kidneys are dark-red, bean shaped organs. Each kidney is 10 cm long, 5 cm wide and 4 cm thick and weighs about 120 grams. They are placed against the back wall of abdominal cavity just below diaphragm, one on either side of vertebral column. They are protected by the last 2 ribs. The left kidney is a little higher than the right.

The concave side of kidney faces vertebral column. There is a depression, called **hilus**, near the centre of the concave area of kidney. This is the area of kidney through which ureter leaves kidney and other structures including blood vessels, lymphatic vessels and nerves enter and leave kidney.

The longitudinal section of the kidney shows two regions (Fig 11.7). Renal cortex is the outer part of kidney and it is dark red in colour. Renal medulla is the inner part of kidney and is pale red in colour. Renal **medulla** consists of several cone shaped areas called renal **pyramids.** Renal pyramids project into a funnel-shaped cavity called renal **pelvis**, which is the base of ureter.

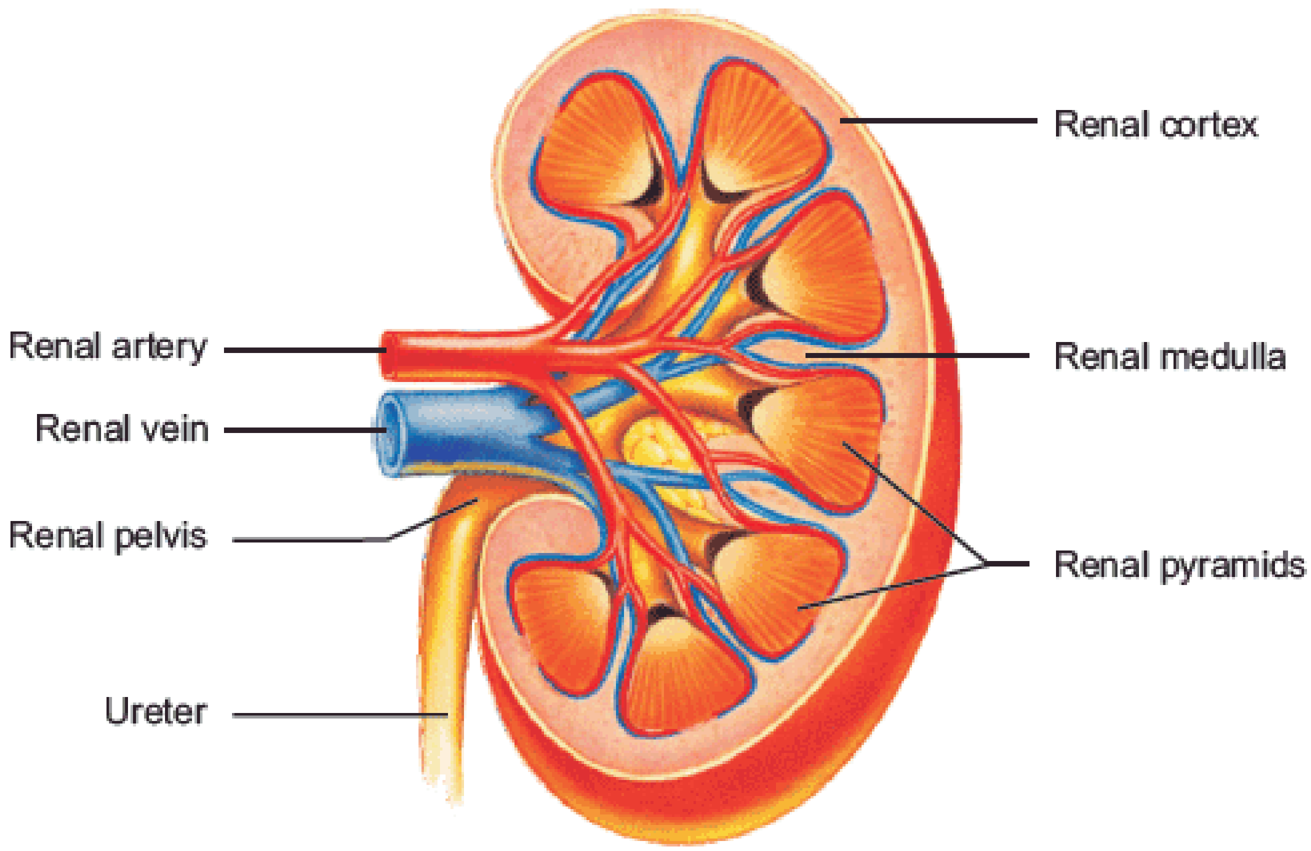


Figure 11.7: The anatomy of a kidney

The functional unit of the kidneys is called **nephron**. There are over one million nephrons in each kidney. There are two parts of a nephron i.e. renal corpuscle and renal tubule (Fig. 11.8). The renal corpuscle is not tubular and has two parts i.e. glomerulus and Bowman's capsule. Glomerulus is a network of capillaries while Bowman's capsule is a cup-shaped structure that encloses glomerulus. The **renal tubule** is the part of nephron which starts after Bowman's capsule. Its first portion is called the **proximal convoluted tubule**. Next portion is U-shaped and is called the **Loop of Henle**. The last portion of renal tubule is the **distal convoluted tubule.** The distal convoluted tubules of many nephrons open in a single collecting duct. Many **collecting ducts** join together to form several hundred **papillary ducts** which drain into renal pelvis.

The capillaries of the glomerulus arise from the afferent arteriole and join to form the efferent arteriole

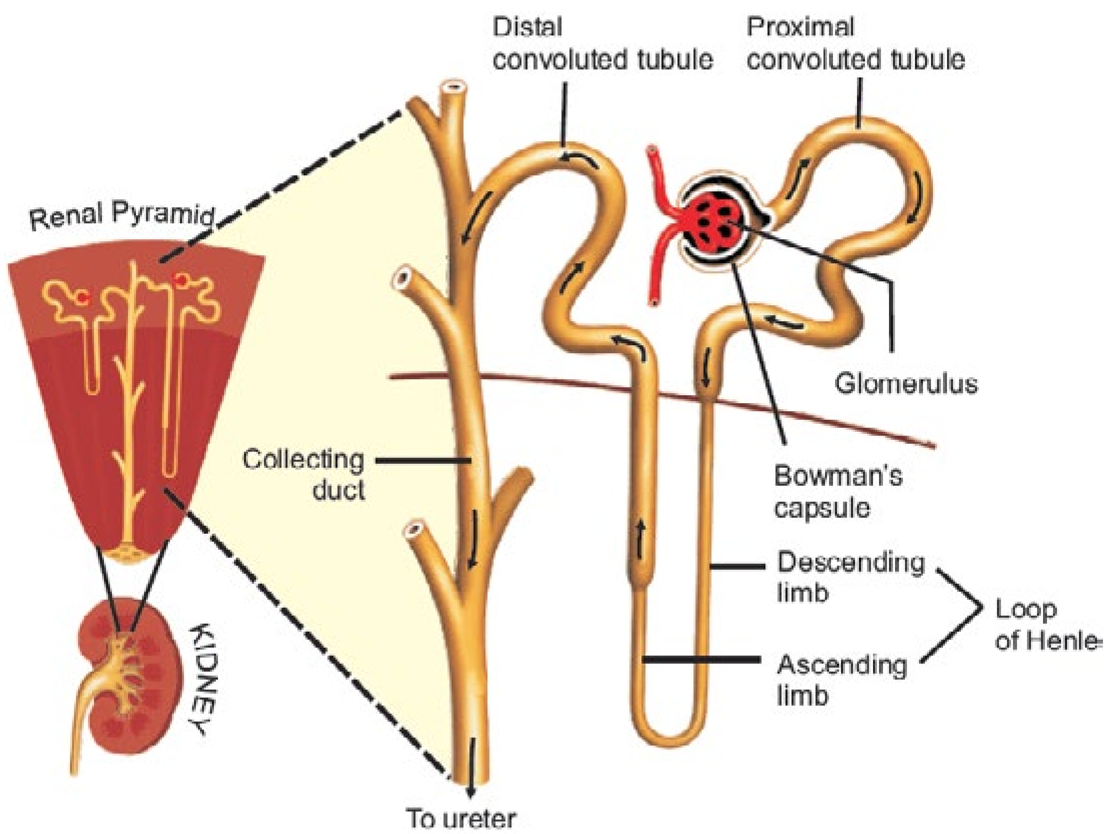


Figure 11.8: The structure of a nephron
(The capillaries surrounding the renal tubule are not shown for simplicity)

11.3.2 Functioning of Kidney

The main function of kidney is urine formation, which takes place in three steps (Fig. 11.9).The first step is **pressure filtration.** When blood enters the kidney via the renal artery, it goes to many arterioles, and then to the glomerulus. The pressure of blood is very high and so most of the water, salts, glucose and urea of blood is forced out of glomerular capillaries. This material passes into the Bowman's capsule and is now called **glomerular filtrate.**

The second step is the **selective re-absorption**. In this step about 99% of the glomerular filtrate is reabsorbed into the blood capillaries surrounding renal tubule. It occurs through osmosis, diffusion and active transport. Some water and most of the glucose is reabsorbed from the proximal convoluted tubule. Here, salts are reabsorbed by active transport and then water follows by osmosis. The descending limb of loop of Henle allows the reabsorption of water while the ascending limb of Loop of Henle allows the reabsorption of salts. The distal convoluted tubule again allows the reabsorption of water into the blood. The third step is the **tubular secretion**. Different ions, creatinine, urea etc. are secreted from blood into the filtrate in renal tubule. This is done to maintain blood at a normal pH (7.35 to 7.45).

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

At the final stage urine is only 1% of the originally filtered volume. The typical volume of urine produced by an average adult is around 1.4 litres per day.

Initiating and Planning

- Predict about the functioning of body without a kidney.
- Relate too much sugar intake by a diabetic with the functioning of kidney.

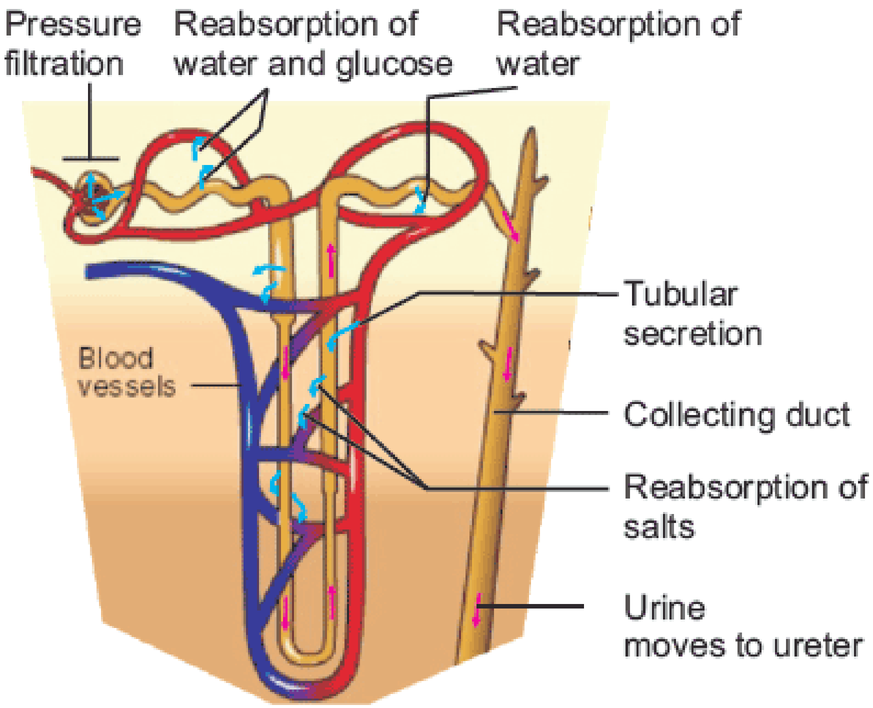


Figure 11.9: Functioning of kidney (nephron)

Table 11.1 Normal chemical composition of urine (Source: NASA Contractor Report)

Water	95%
Urea	9.3 g/l
Chloride ions	1.87 g/l
Sodium ions	1.17 g/l
Potassium ions	0.750 g/l
Other ions and compounds	Variable amounts

After the above mentioned steps, the filtrate present in renal tubules is known as **urine.** It moves into collecting ducts and then into pelvis.

11.3.3 Osmoregulatory Function of Kidney

Osmoregulation is defined as the regulation of the concentration of water and salts in blood and other body fluids. Kidneys play important role in osmoregulation by regulating the water contents of blood. It is an important process as excessive loss of water concentrates the body fluids whereas excess intake of water dilutes them.

When there is excess water in body fluids, kidneys form dilute **(hypotonic)** urine. For this purpose, kidneys filter more water from glomerular capillaries into Bowman's capsule. Similarly less water is reabsorbed and abundant dilute urine is produced. It brings down the volume of body fluids to normal.

When there is shortage of water in body fluids, kidneys filter less water from glomerular capillaries and the rate of reabsorption of water is increased. Less filtration and more reabsorption produce small amount of concentrated **(hypertonic)** urine. It increases the volume of body fluids to normal. This whole process is under hormonal control.

Practical: Examination of the longitudinal section of a mammalian kidney

- Teacher will make a kidney of a sheep or goat available in the laboratory or classroom.
- Teacher will dissect the kidney longitudinally.
- Students will observe the cut halves with the help of hand lenses and will locate the renal cortex, medulla, pyramids and pelvis.

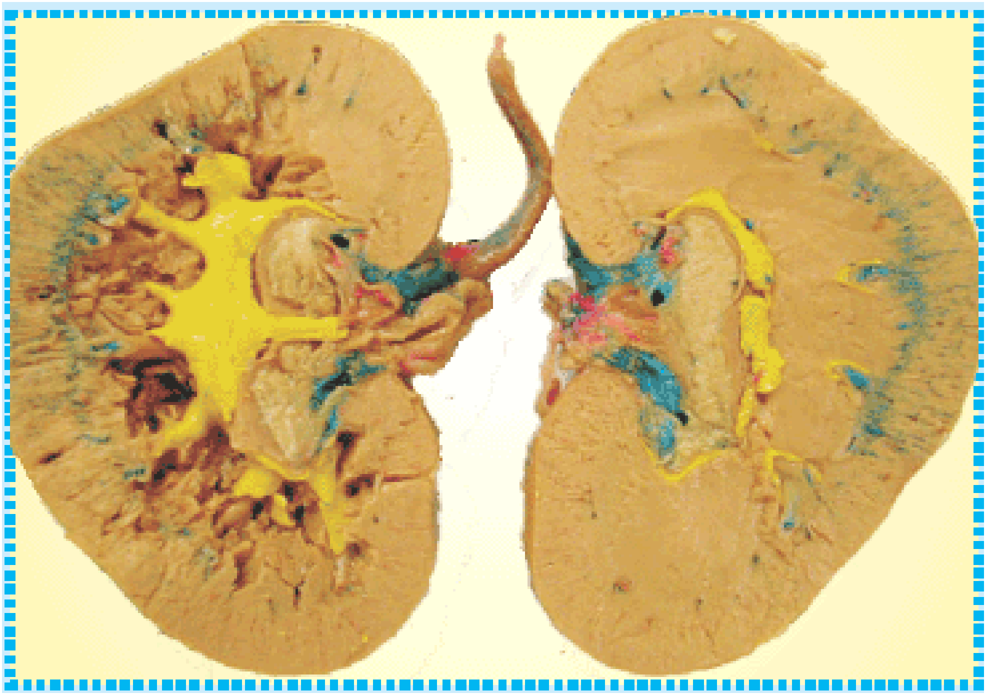


Figure 11.10: Kidneys of goat (longitudinal sections)

Students will draw the diagram of the longitudinal section of the kidney.

? What causes the material to move from glomerular capillaries to Bowman's capsule?

Blood pressure

What causes the material to move from glomerular capillaries to Bowman's capsule?

Blood pressure

Activity: Trace the movement of a molecule of urea from blood to urethra using a flow chart diagram.

11.4 Disorders Of Kidney

There are many different kidney disorders.

11.4.1 Kidney Stones

When urine becomes concentrated, crystals of many salts e.g. calcium oxalate, calcium and ammonium phosphate, uric acid etc. are formed in it. Such large crystals cannot pass in urine and form hard deposits called kidney stones.

Most stones start in kidney. Some may travel to ureter or urinary bladder.

The major causes of kidney stones are age, diet (containing more green vegetables, salts, vitamins C and D), recurring urinary tract infections, less intake of water, and alcohol consumption. The symptoms of kidney stones include severe pain in kidney or in lower abdomen, vomiting, frequent urination and foul-smelling urine with blood and pus.
About 90% of all kidney stones can pass through the urinary system by drinking plenty of water. In surgical treatment, the affected area is opened and stone(s) are removed. **Lithotripsy** is another method for the removal of kidney stones. In this method, non-electrical shock waves from outside are bombarded on the stones in the urinary system. Waves hit the dense stones and break them. Stones become sand-like and are passed through urine.

Abu Nasr al-Farabi (872-951) was a prominent scientist who wrote many books that contained information about kidney diseases. The genius Abu al-Qasim Al-Zahrawi (known as Albucasis: 936-1013), is considered to be Islam's greatest surgeon who invented many surgical procedures including the surgical removal of stones from the urinary bladder. His encyclopedia, Al-Tasrif ("The Method"), contained over 200 surgical medical instruments he personally designed.

11.4.2 Kidney (Renal) failure

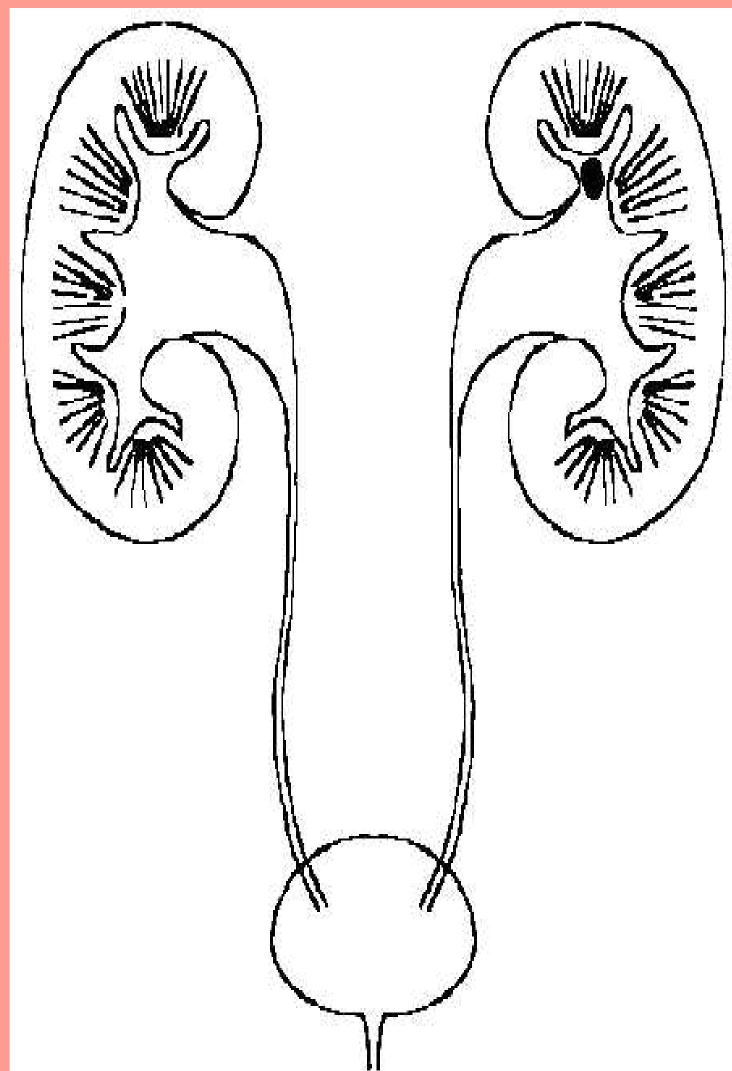
Kidney failure means a complete or partial failure of kidneys to function. Diabetes mellitus and hypertension are the leading causes of kidney failure. In certain cases, sudden interruption in the blood supply to kidney and drug overdoses may also result in kidney failure.

The main symptom of kidney failure is the high level of urea and other wastes in blood, which can result in vomiting, nausea, weight loss, frequent urination and blood in urine. Excess fluids in body may also cause swelling of legs, feet face and shortness of breath.

The kidney failure is treated with dialysis and kidney transplant.

a. Dialysis

Dialysis means the cleaning of blood by artificial ways. There are two methods of dialysis.



Animation 11.4: Stone Kidney,
Source & Credit: Renux.dmed

1. Peritoneal Dialysis

In this type of dialysis, the dialysis fluid is pumped for a time into the peritoneal cavity which is the space around gut (Fig. 11.11). This cavity is lined by peritoneum. Peritoneum contains blood vessels. When we place dialysis fluid in peritoneal cavity, waste materials from peritoneal blood vessels diffuse into the dialysis fluid, which is then drained out. This type of dialysis can be performed at home, but must be done every day.

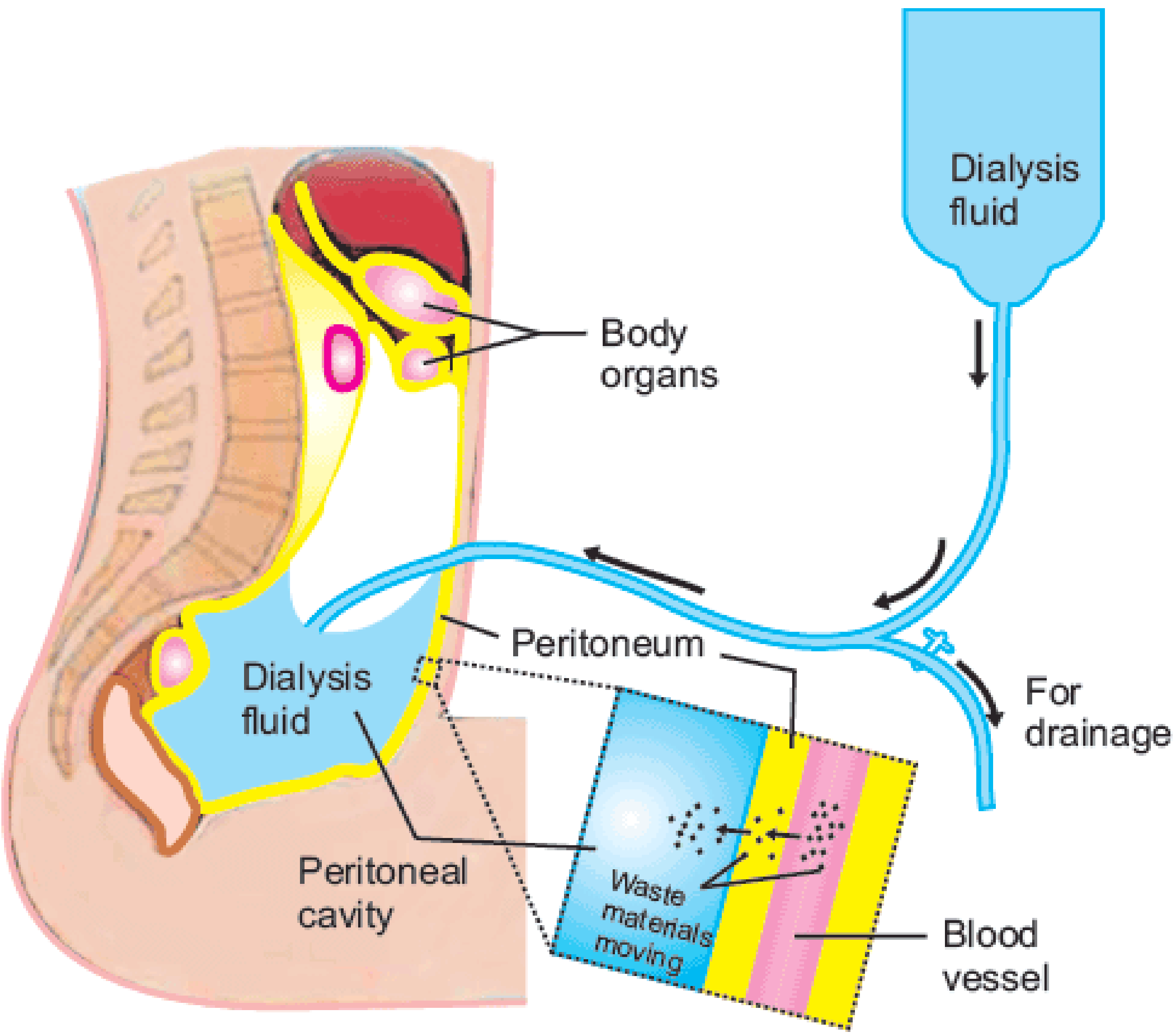


Figure 11.11: Peritoneal dialysis

2. Haemodialysis

In haemodialysis, patient's blood is pumped through an apparatus called **dialyzer.** The dialyzer contains long tubes, the walls of which act as semi-permeable membranes (Fig. 11.12). Blood flows through the tubes while the dialysis fluid flows around the tubes.
Extra water and wastes move from blood into the dialysis fluid. The cleansed blood is then returned back to body. The haemodialysis treatments are typically given in dialysis centres.

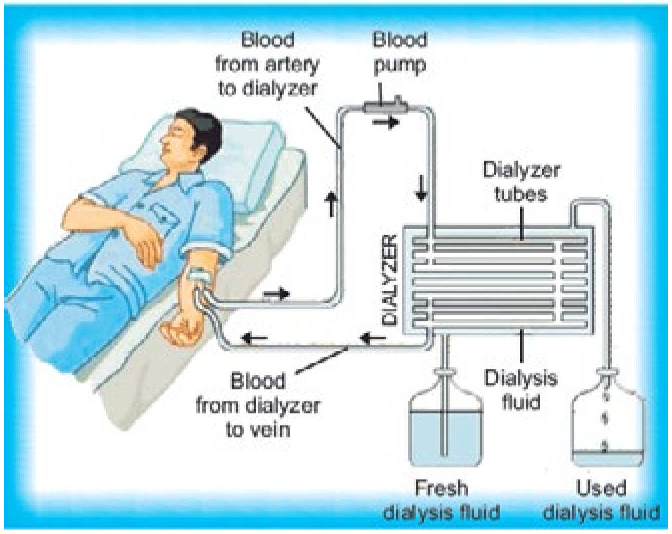


Figure 11.12: Haemodialysis

b. Kidney Transplant

We know that dialysis needs to be repeated after every few days and is unpleasant for patients and attendants. Another treatment for the end-stage kidney failure is kidney transplantation. It is the replacement of patient's damaged kidney with a donor healthy kidney.
Kidney may be donated by a deceased-donor or living-donor. The donor may or may not be a relative of the patient. Before transplant, the tissue proteins of donor and patient are matched. The donor's kidney is transplanted in patient's body and is connected to the patient's blood and urinary system. The average lifetime for a donated kidney is ten to fifteen years. When a transplant fails, the patient may be given a second kidney transplant. In this situation, the patient is treated through dialysis for some intermediary time. Problems after a transplant may include transplant rejection, infections, imbalances in body salts which can lead to bone problems and ulcers.

Analyzing and Interpreting

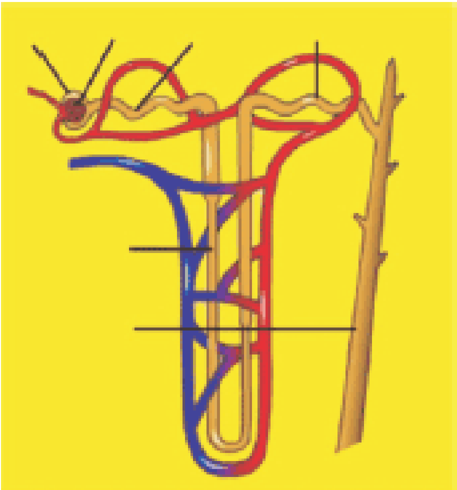
- Rationalize why dialysis machine is considered as artificial kidney.
- Design dialysis apparatus by cellophane paper and empty photographic film case.

UNDERSTANDING THE CONCEPT

1. Describe the process of selective re-absorption in the kidneys.
2. How do the plants excrete extra water and salts from their bodies?
3. What is the functional unit of the kidney? Describe its structure and draw labelled diagram.
4. What steps are involved in the formation of urine in the kidneys?
5. "Along with excretion, kidneys also play role in Osmoregulation." Comment on this statement.

SHORT QUESTIONS

1. What are the major organs involved in homeostasis in human body? State the roles of each of these organs.
2. Identify and label the following: diagram.



THE TERMS TO KNOW		
Bowman's capsule	Homeostasis	Renal pyramid
Collecting duct	Lithotripsy	Renal tubule
Dialysis	Loop of Henle	Selective reabsorption
Dialyzer	Nephron	Tubular secretion
Distal convoluted tubule	Osmoregulation	Ureter
Excretion	Papillary ducts	Urethra
Glomerular filtrate	Peritoneal dialysis	Urinary bladder
Glomerulus	Pressure filtration	Urinary system
Guttation	Proximal convoluted tubule	
Hemodialysis	Renal corpuscle	
Hilus	Renal pelvis	

ACTIVITIES

1. Examine the structure of kidney (sheep or goat kidney / model).
2. Trace the movement of a molecule of urea from blood to urethra using a flow chart diagram.

SCIENCE, TECHNOLOGY AND SOCIETY

1. Realize the importance of drinking plentiful water daily.
2. Predict how the kidney helps to overcome the problem of dehydration.
3. Recognize the right treatments of kidney problems.

ON-LINE LEARNING

1. biology-animations.blogspot.com/.../nephron-animation.html
2. highered.mcgraw-hill.com/sites
3. leavingbio.net/EXCRETION/EXCRETION.html
4. www.tutorvista.com/.../excretion/excretory-system-animation.php