

MODULE - 2

Forms and Functions of
Plants and animals



Notes



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14

RESPIRATION AND ELIMINATION OF NITROGENOUS WASTES

Every living organism needs energy to perform various life activities, and the process of respiration fulfils this energy requirement. You have already learnt in the lesson on food and nutrition that animals take in high energy organic molecules in the form of food. During respiration, this food is broken down in the presence of oxygen and energy is released during respiration. Respiration also produces carbon dioxide, a toxic substance which is eliminated from the body. Thus, uptake of oxygen and removal of carbon dioxide is an essential requirement of all animals.

At the same time numerous other toxic wastes such as ammonia, and urea are also produced in the tissues during various cellular activities. Such toxic wastes need to be removed from the body. In this lesson you will learn about removal of nitrogenous wastes and maintenance of water and salt balance in the body.



OBJECTIVES

After completing this lesson you will be able to :

- *define respiration, breathing, inspiration, expiration and vital capacity;*
- *describe briefly the gaseous exchange in earthworm and cockroach;*
- *describe the parts of respiratory system in the human body and mention their functions;*
- *draw a labeled diagram of human respiratory system;*
- *differentiate between breathing and respiration; and inspiration and expiration;*
- *describe the mechanism of breathing and its regulation;*
- *describe the exchange of respiratory gases in the lungs and their transport to and from tissues;*

- name some common ailments of respiratory system and suggest their prevention;
- define excretion and mention its importance;
- explain the terms such as ammonotelism, ureotelism and uricotelism;
- list the organs of excretion in cockroach;
- list the parts of human excretory system and mention their functions;
- explain ultrafiltration and describe how urine is formed in humans;
- draw the microscopic structure of the human kidney;
- list the normal and abnormal components of urine;
- explain the mechanism of osmoregulation and its regulation by ADH;
- explain the role renin-angiotensin system in regulating blood volume and blood pressure.
- explain the role of dialysis and kidney transplantation in case of kidney failure;
- explain the role of liver in excretion.



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14.1 RESPIRATION

Respiration is the stepwise oxidation of glucose (and other nutrients) which results in the release of energy that is stored in the cytosol in the form of ATP (adenosine triphosphate). Whenever energy is required by our body, ATP is broken down and large amount of energy is released.

Respiration is completed in following steps :

Step-1 Gaseous exchange

It involves exchange of gases between the cell and its surrounding medium. The cells obtain oxygen from the environment and return carbon dioxide and water vapour to it. In most higher animals this exchange of gases takes place in two phases :

- (a) exchange of gases between the animal body and its external environment, also called **ventilation** or **breathing**.
- (b) transport of gases O_2 and CO_2 between the respiratory surface and the cells. Oxygen obtained from the atmosphere is used up in the second step i.e. during **cellular respiration**, which occurs inside the cell.

Step 2 Cellular Respiration

It is a complex and elaborate process which occurs in the cytoplasm and the mitochondria. It involves :

- (i) the uptake of oxygen by tissues,
- (ii) stepwise oxidation of glucose molecules and other nutrients, and
- (iii) release of carbon dioxide and energy.

Thus ultimate goal of respiratory system is to provide oxygen to the tissues for oxidation of food and removal of carbon dioxide from them.



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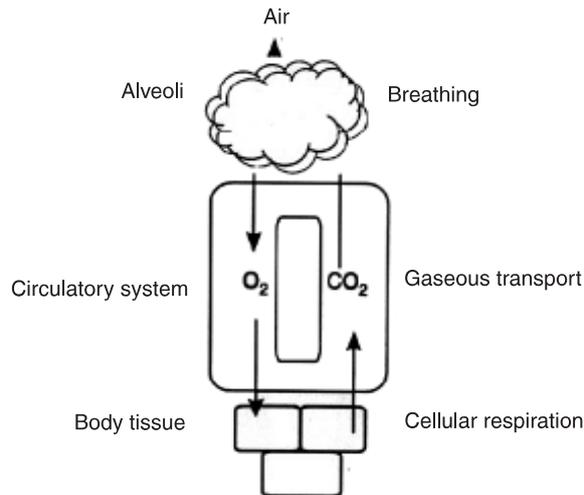


Fig. 14.1 General features of respiration

14.1.1. Respiratory Exchange in Different Animals

- All animals exchange gases with their surroundings by the mechanism of diffusion.
- A gas diffuses across a membrane from outside where its concentration (partial pressure) is higher than inside where its concentration is lower.
- Thus oxygen is taken up and carbon dioxide is released from the respiratory surface.
- For efficient gas exchange the respiratory surface should be large, moist, highly vascular, thin and easily permeable to oxygen and carbon dioxide.
- To fulfill this requirement complex respiratory systems have evolved in the animal world. You will study a few of them in this lesson.

14.1.2 Gas exchange through the general body surface in earthworm – cutaneous respiration

- Earthworm has no respiratory organs. The entire skin on the body of earthworm functions as the respiratory surface.
- The skin of earthworm is thin, moist and has a rich supply of blood capillaries. Thus, it is very suitable for respiration.
- The body surface is covered with a moist film consisting of secretions of mucous glands, coelomic fluids and excretory wastes.
- The capillaries on the skin take up O_2 dissolved in the water (in the moisture) on the surface of skin and release CO_2 into the atmosphere.
- Earthworms have a closed circulatory system which means that blood flows within blood vessels. The respiratory pigment haemoglobin remains dissolved in blood plasma and not in any cell. In human beings and other vertebrates, Haemoglobin is inside RBC
- There is regular rhythmic contraction of blood vessels which helps in the circulation of blood and hence in the transport of dissolved gases in the body.

Even frogs show cutaneous respiration (respiration through skin) across their moist skin, particularly during hibernation when they become inactive during the winter to avoid cold. However, frogs are mainly lung breathing animals.

14.1.3 Tracheal System in Cockroach

You must have noticed that the insects keep expanding and contracting their abdomen. This is to allow gaseous exchange.

- Like majority of insects, cockroach respire by means of internal tubes called **tracheae**.
- These tubes branch out extensively inside the body and carry air directly to the tissues from the atmosphere.
- In cockroach, respiration does not involve blood as shown in the flow chart given below and therefore it is very fast and very efficient. Tracheae open up to the exterior by paired slit like apertures called **spiracles**. Spiracles are found on the sides in the thorax and abdomen.
- The fine branches of tracheal trunks called **tracheoles** finally penetrate the cells of the body and allow diffusion of respiratory gases directly into and from the cells.
- The ends of the tracheoles are thin and filled with fluid in which respiratory gases dissolve. The inflow and outflow of air is affected by alternate contraction and expansion of the abdomen.

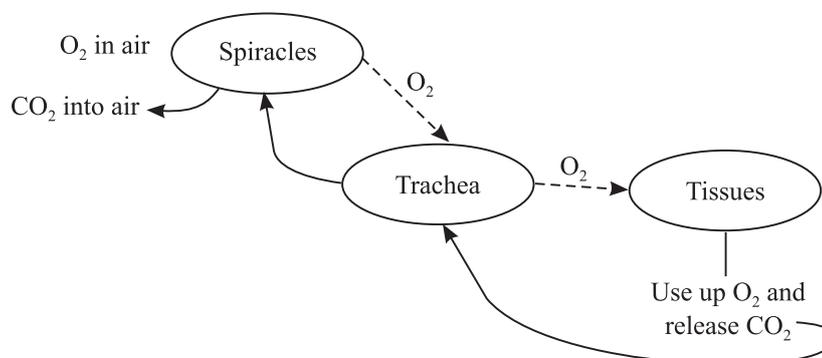


Fig. 14.2 Tracheal system in a cockroach

14.1.4 Respiratory system in humans (pulmonary respiration)

- Humans have a well developed respiratory system suitable for meeting the higher requirement of oxygen in their bodies.
- The respiratory system consists of nostrils, nasal cavity, pharynx, larynx, trachea, and bronchi.
- The two bronchi branch extensively into bronchioles, terminal bronchioles and ultimately end in the air sacs called alveoli. The bronchioles, their branches and air sacs are enclosed in a double membrane called pleural membrane to form the lungs. The lungs are the main respiratory organs.



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- Air passes through nostrils into bronchi, to bronchioles and into air sacs which are thin walled sacs with a single layer of cells and heavily covered with blood capillaries. O_2 from alveoli passes into capillaries and CO_2 from other capillaries diffuses into alveoli for being removed. Alveoli are the organs where the actual gaseous exchange occurs.
- The double layer pleural membrane covers the lungs for its protection. It contains pleural fluid, which makes the movement of the lungs easy.
- Each lung consists of a tree like system of branched bronchial tubes.
- The finest of them terminate into millions of tiny sac like structures called alveoli.
- Alveolar membrane is very thin, moist and richly supplied with blood capillaries.
- The walls of both the capillaries and alveoli consist of a single layer of flattened epithelial cells.

Refer to the following table 14.1 to get an idea of the structure and functions of different parts of the human respiratory system.

Table 14.1 Respiratory organs of human body

Organ	Structure	Function
Nostril Nasal Cavity	Opening of Nose Covered with mucous membrane and cilia	Filtration of unwanted particles. Traps dust, bacteria; warms and moistens the air in the pharynx.
Pharynx (Throat)	Muscular Tube	The common passage for both respiratory gases and food moving into digestive passage, separated by epiglottis Epiglottis is a flap like structure that closes the tracheal opening (opening of the wind pipe) called glottis when food is swallowed.
Larynx (Voice Box)	A small cartilaginous organ with vocal cords : lined by ciliated epithelium	Connects pharynx to the trachea; helps in sound production.
Trachea (Wind pipe)	Supported by C-shaped cartilaginous rings to prevent it from collapsing. Trachea divides into two bronchi and enters the two lungs	Passage for air upto bronchi.
Bronchus (Plural : Bronchi)	Elastic, ciliated and covered with mucous epithelium	Enters the lungs and divides to form secondary bronchi, tertiary bronchioles and ultimately terminal bronchioles. Together they form the bronchial tree.

Bronchioles	Small terminal branches of bronchus leading to alveoli	Convey air into alveoli.
Alveoli (Air sacs)	Supplied with blood capillaries, thin moist	Exchange of Gases.



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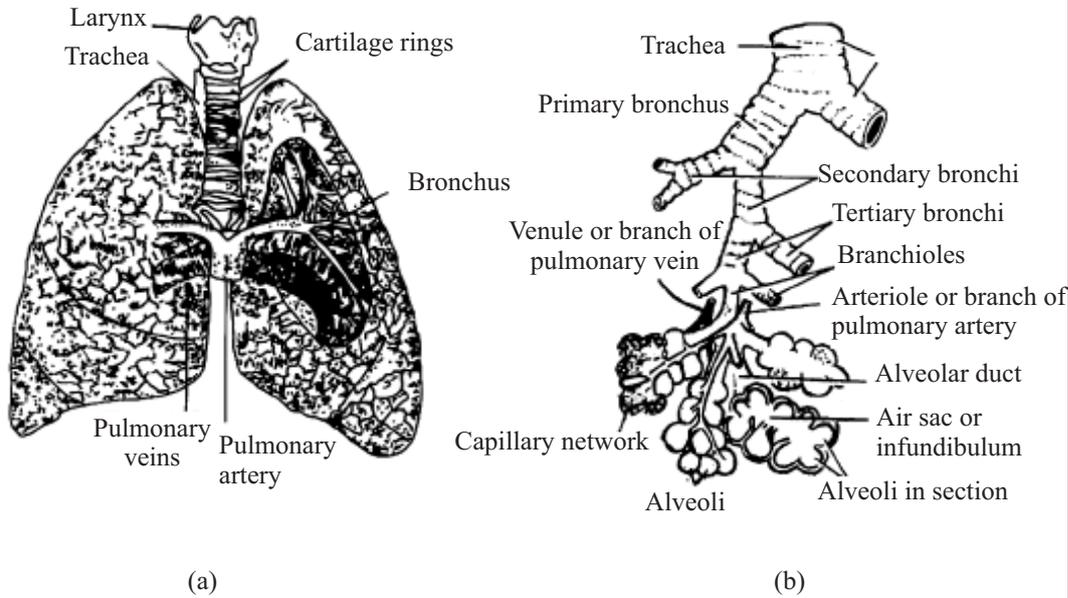


Fig. 14.3 (a) Human lungs (b) branching of bronchi upto terminal alveoli

Table 14.2 : Differences between breathing and respiration

Breathing	Respiration
1. Physical process	1. Bio-chemical process involving enzymes
2. Takes place only in reptiles, birds and mammals	2. Occurs in all organisms
3. It is a rhythmic process	3. It is a continuous process
4. It is an extracellular process	4. It is an intracellular process
5. It involves gaseous exchange between the animal and its external environment	5. It involves enzymatic breakdown of glucose in the presence or absence of Oxygen to release energy



INTEXT QUESTIONS 14.1

- Define respiration
.....
- Name the two gases that are exchanged during respiration.
.....



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3. What is cutaneous respiration? Name one animal that undertakes cutaneous respiration.
.....
4. What is the colour of the blood of the earthworm? Name the pigment responsible for the colour.
.....
5. How is oxygen transported to the cells in the cockroach?
.....
6. Name the group of animals in which blood is not involved in gaseous exchange.
.....
7. How does trachea communicate with the exterior in cockroach?
.....
8. Trace the path of air from the nostrils to the lungs in the human body.
.....
9. Name the part of the respiratory system where air is filtered, moistened and warmed in humans
.....
10. What is the function of the epiglottis in humans?
.....

14.2 MECHANISM OF PULMONARY RESPIRATION

The main purpose of respiratory system is to provide oxygen to the tissues and to remove carbon dioxide from them. This entire process is achieved through the following steps:

- (i) Breathing or pulmonary ventilation leading to exchange of oxygen and carbon dioxide between the atmospheric air and the lungs.
- (ii) Exchange of gases at the alveolar surface.
- (iii) Transport and exchange of gases in the tissues.
- (iv) Cellular respiration.

14.2.1 Breathing or pulmonary ventilation

It is a mechanical process of taking in atmospheric air into the lungs and giving out carbon dioxide. Breathing is an involuntary process but under special conditions it can become voluntary also. It consists of two steps during which lungs are contracted and expanded alternately.

1. Inspiration or taking air in, and
 2. Expiration or forcing air out (refer to Fig. 14.4).
- 1. Inspiration (The intake of air) :** A muscular dome shaped diaphragm is present at the base of the lungs. On contraction it becomes flattened and lowered. The lower surface of lungs is pulled downwards and the volume of lungs increases.

External intercostal muscles present between the ribs contract, the rib cage moves outwards and upwards. These contractions together increase the volume of the chest cavity, lower the air pressure within the lungs and the atmospheric air rushes in filling the lungs with fresh air. Thus, inspiration is an active phase of breathing.

- 2. Expiration (releasing air) :** This step involves the relaxation of external intercostal muscles and contraction of internal intercostal muscles. As a result the rib cage lowers and moves inwards. The diaphragm also relaxes and rises again into its original dome shaped condition. The abdominal organs press up against the diaphragm. This change decreases the volume of the chest cavity, thus, increasing the air pressure within the lungs and the air, which is laden with CO_2 and is forced out.

Forced breathing. It is possible that during forced breathing both inspiration and expiration are active processes because some more intercostal muscles and the abdominal muscles are brought into action for deeper breathing movements

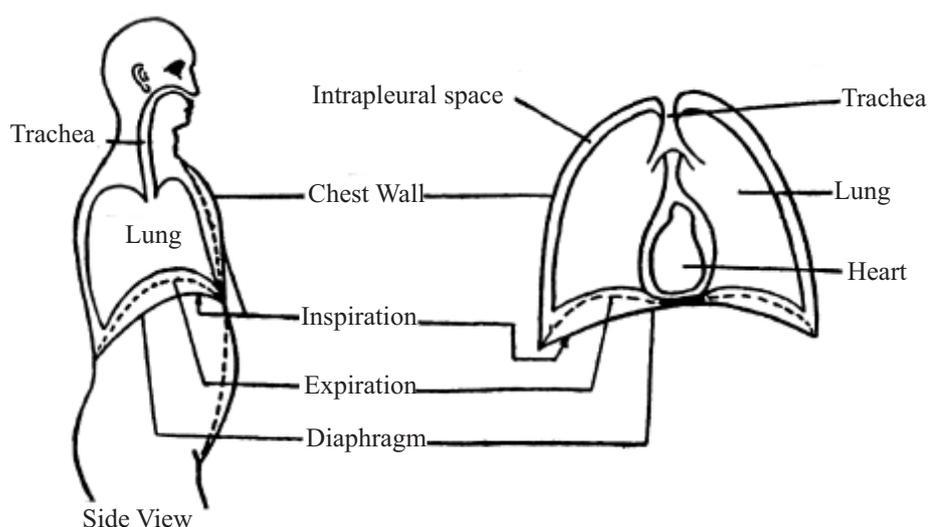


Fig. 14.4 Breathing movements

14.2.2 Exchange of gases at the alveolar surface

- Blood is the medium for the transport of oxygen from the lungs to the different tissues and carbon dioxide from tissues to the lungs.
- The deoxygenated blood is brought to the lungs by pulmonary artery which divides into fine capillaries that surround alveoli.
- Both alveoli and capillaries are made up of thin walled single layer of epithelial cells and therefore allow gaseous exchange easily.
- There is more oxygen in alveolar air and more carbon dioxide in the capillaries. Due to the pressure difference of oxygen and carbon dioxide between the alveoli and blood capillaries, the oxygen diffuses from alveolar air into the blood



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capillaries. At the same time carbon dioxide diffuses from blood capillaries into the alveolar air.

- Oxygenated blood is taken from the lungs to the heart by pulmonary vein.

Volumes exchanged

Following table 14.3 shows the air volumes exchanged during breathing in a normal adult human being.

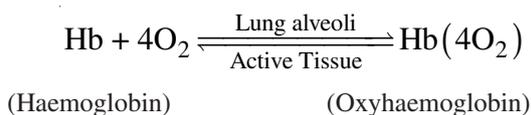
Table 14.3 : Air volume exchanged during breathing

Tidal volume (TV)	Volume of air inhaled and exhaled without any noticeable effort (normal breathing).	500mL
Vital capacity (VC)	Volume of air that can be maximally breathed out after a maximum inspiration (VC = IRV+TV+ERV).	3400-4800mL
Inspiratory reserve volume (IRV)	Volume of air that can be taken in by forced inspiration over and above the normal inspiration.	2000-3000 mL
Expiratory reserve volume (ERV)	Volume of air that can be expelled by forced expiration over and above the normal expiration.	1000 mL
Residual volume (RV)	Volume of air that cannot be forced out even on forced expiration. This is the air that remains in the lungs and in the air passage.	1000-1500mL
Total lung capacity	Sum of all lung volumes (maximum air that remains in the lungs after a maximum inhalation).	5500-6000mL

Vital capacity may be highly reduced in smokers and people suffering from tuberculosis. Athletes and singers on the other hand have higher vital capacity.

14.2.3 Transport of oxygen by blood from lungs to tissues

Efficient transport of oxygen is by a complex blood protein called haemoglobin. This iron rich protein is packed in Red Blood Corpuscles (R.B.Cs) giving blood a red colour. About 97 percent of the total oxygen is transported from lungs to the tissues in combination with haemoglobin. Only 3% of oxygen is transported in dissolved form by plasma. Oxygenation of blood takes place in lungs. Four molecules of oxygen form a reversible bond with haemoglobin forming the compound oxyhaemoglobin.

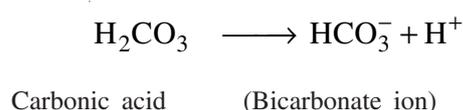
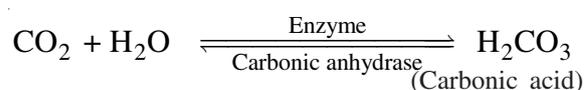


When the oxygenated blood reaches the tissue surface there is high concentration of CO₂ in the tissues, oxygen having been used up and low concentration of O₂. As a result the bonds holding oxygen and haemoglobin in Hb (4O₂) becomes unstable and blood releases oxygen and takes up CO₂.

14.2.4 Transport of carbon dioxide (from tissues to lungs)

Blood transports carbon dioxide with comparative ease because of its high solubility. Active tissues constantly produce CO₂. This CO₂ is transported to the lungs in three ways:

- CO₂ is physically dissolved in blood plasma (only 5-7% of the total CO₂ is transported).
- CO₂ directly combines with haemoglobin of RBCs to form carbaminohaemoglobin (about 21-23% only).
- As bicarbonate it is dissolved in plasma but produced in RBCs catalysed by the enzyme carbonic anhydrase and then diffuses into plasma (largest fraction of CO₂, about 75% to 80%) to be transported in this manner.



Bicarbonate is extremely soluble and dissolves in blood plasma. It again passes into RBC and breaks into CO₂ and H₂O in the alveoli. Inside the lungs the CO₂ is transported to lungs from tissues in the three ways mentioned above and is released into the alveolar air and finally breathed out (Fig. 14.5).

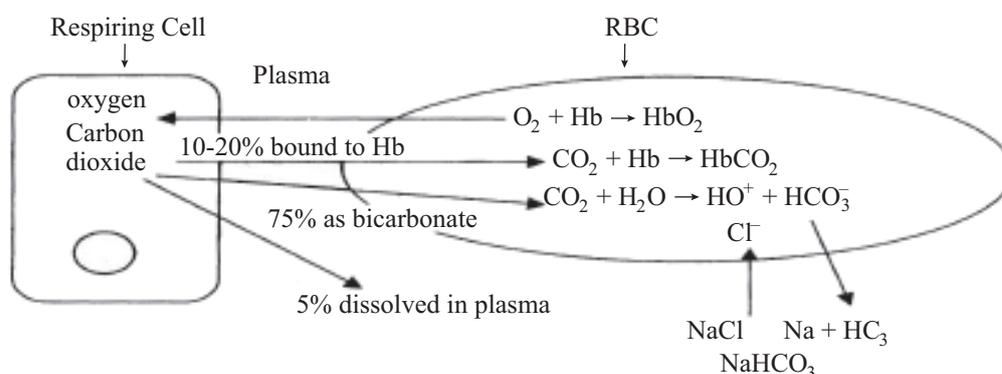


Fig. 14.5 Transport of carbon dioxide in the blood.

14.2.5 Regulation of respiration

Count the number of times you breathe during normal resting condition and when climbing up the stairs. How is the change in the breathing rate brought about? You will now study about regulation of respiration.



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The regulation of respiration is under nervous control. There are three groups of neurons called respiratory centres present in the medulla oblongata and pons the brain. These are:

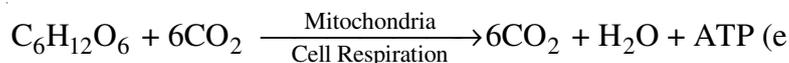
- (a) **Dorsal respiratory group** – generates basic respiratory rhythm. It stimulates the external intercostal muscles, the diaphragm contracts and inspiration occurs. When the stimulation ceases, these muscles relax and expiration takes place.
- (b) **Ventral respiratory group** sends signals under enhanced respiratory needs. It controls both inspiration and expiration.
- (c) **Pneumotaxis center** in the pons controls switch off point of inspiration and thereby smoothens the transition between inspiration and expiration.

Increase in blood carbon dioxide and hydrogen ions increase the rate of respiration.

If we try to hold our breath, we are not able to hold it for long time. This is because the respiratory centres of the medulla automatically reinstate breathing when the concentration of CO₂ in blood reaches a critical level.

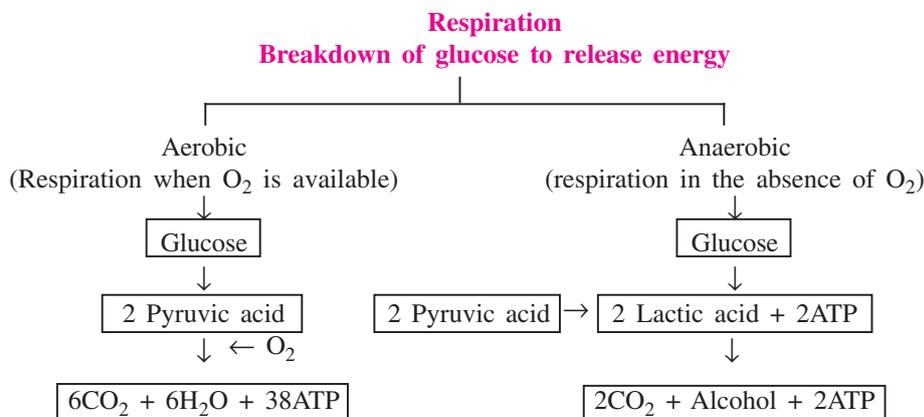
14.2.6 Cellular respiration

Oxygen taken in the blood is utilised in all the living cells during cellular respiration. It is a complex process that is completed in the mitochondria. During cellular respiration, glucose is oxidized to release energy. Energy released is stored in ATP (Adenosine Triphosphate) molecules and is readily available for cell use. The process can be summed up as follows:



Respiration that takes place in the presence of O₂ is called **aerobic respiration**. It is more efficient as 38 molecules of ATP are released on the oxidation of one glucose molecule.

Absence of oxygen for sometime may lead to **anaerobic respiration**. It is inefficient as only 2 molecules of ATP are produced from one glucose molecule (Refer lesson 12 for details).



14.3 Common respiratory disorders and their prevention

Disease	Cause	Symptoms	Prevention
Bronchial asthma	It is an allergic disease caused due to certain foreign substance in the air.	Causes difficulty in breathing and coughing because excess mucous secretion may narrow down (clog) the bronchioles.	Avoiding exposure to the foreign substance is the best preventive measure.
Bronchitis	Inflammation of bronchi caused by infection. It can also be caused by smoking and by exposure to air pollution.	Regular coughing with greenish blue sputum	Avoiding exposure to smoke and dust prevents bronchitis.
Pneumonia	Acute inflammation caused by diplococcus infection in the alveoli of the lung.	It causes fever, pain and severe cough. Most of the air space is occupied by fluid and dead W.B.C.	Avoid crowded places where infection is prevalent.
Tuberculosis	It is a bacterial infection that spreads through droplets of infected persons	It can affect many other organs but pulmonary T.B. is most common. Weight loss and cough are common symptoms. It is accompanied by low fever. In extreme cases blood may come out while coughing.	BCG vaccine can prevent T.B. Well – ventilated dwellings and protein rich diet is also essential for T.B. patients.
Occupational lung hazards	Caused due to exposure to harmful substance like silica, asbestos, dust etc. present in the environment where a person works.	It is expressed after exposure of 10-15 years or more. It causes fibrosis of the lungs.	Such diseases can be prevented by minimizing the exposure to such substances by using protective masks and clothing. Regular health check – up is necessary.



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The suffix 'itis' means inflammation of an organ. Bronchitis, pharyngitis or tonsillitis affects different respiratory tissues. Can you tell the specific organ affected?



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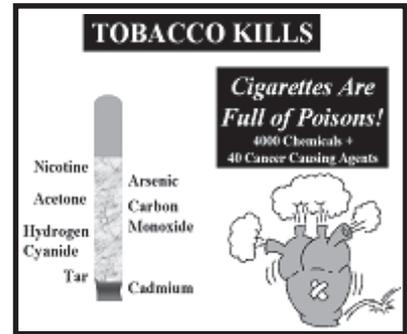


Some Basic Facts

Why is cigarette smoking harmful?

Cigarette smoking is harmful because it leads to:

- diminished or extinguished sense of smell and taste
- smoker's cough
- gastric ulcers
- chronic bronchitis
- increase in heart rate and blood pressure
- premature and more abundant face wrinkles
- heart disease
- stroke
- cancer of the mouth, larynx, pharynx, oesophagus, lungs, pancreas, cervix, uterus, and bladder



14.2.7 Emphysema

Emphysema is a respiratory disorder caused by excessive cigarette smoking and chronic bronchitis. Either the bronchioles or the alveolar sacs get distended abnormally in Emphysema resulting in loss of elasticity of these parts. Gradually due to continuous distention, lung increases in size and air remains in lungs even after expiration.

Emphysema can be prevented by giving up smoking before damage is done to alveoli. Cure is difficult as elasticity is lost irreversibly.



INTEXT QUESTIONS 14.2

1. What is breathing?
.....
2. What is the position of the diaphragm at the time of expiration?
.....
3. What is the capacity of tidal volume?
.....



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4. What is the maximum number of oxygen molecules with which haemoglobin can combine?
.....
5. Name the blood vessel that takes oxygenated blood from the lungs to the heart.
.....
6. What are the three forms in which carbon dioxide is transported by the blood?
.....
7. Name the vaccine used for prevention of TB.
.....
8. What is an occupational hazard.
.....
9. What is the difference between bronchitis and asthma?
.....
10. The alveoli of a heavy smoker were damaged, their surface area was reduced and elasticity was lost. What is the technical term for this condition.
.....

14.3 EXCRETION

All animals possess some mechanism of getting rid of the waste substances produced in their body during metabolic activities. These waste substances include CO₂, water, urea, uric acid and ammonia. Such substances can be harmful if retained in the body.

Besides metabolic wastes, excess salt (eg. NaCl taken in food), H₂O and even excess of some vitamins needs to be eliminated. Certain medicines (antibiotics) too are removed from the blood in the urine. **Removal of all harmful, unwanted products (specially nitrogenous wastes) from the body is called excretion.** Excretory system is primarily associated with removal of nitrogenous wastes.

Urea is the main nitrogenous waste in our body. It is formed by the breakdown of surplus amino acids and nucleic acids in the liver. Blood transports urea to the kidneys for filtration and removal in the form of urine.

14.3.1 Modes of removal of nitrogenous wastes

Depending upon the nitrogenous wastes excreted, animals can be classified as **ammonotelic, ureotelic** and **uricotelic**. Table 14.4 gives categories of animals on the basis of nitrogenous waste produced.



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Table 14.4 Categories of animals on the basis of nitrogenous waste produced

Category	Product formed	Solubility in water	Examples
Ammonotelic	Ammonia (highly toxic)	Highly soluble, therefore needs plenty of water for its excretion.	Fresh water aquatic animals e.g. bony fish, <i>Amoeba</i>
Ureotelic	Urea (less toxic)	Less soluble, thus needs less water for excretion	Mammals like humans, dog etc, marine fishes and amphibians like frog and toad
Uricotelic	Uric acid (least toxic)	Insoluble solids or semi solid. Needs very little water just to flush out the uric acid	Birds, reptiles and insects.

Importance of excretion

- (a) Excretion is necessary for the elimination of nitrogenous wastes formed during metabolism of proteins (amino acids) and nucleic acids.
- (b) Elimination of excess salts like NaCl, vitamins, bile pigments (from the breakdown of old RBCs) and certain medicines and drugs, and
- (c) Removal of excess of water or its retention in case of shortage of water. This is to maintain the required quantity of water (osmoregulation) in the body.



INTEXT QUESTIONS 14.3

1. Name the organ where urea is produced and the organ from where urea is excreted.
.....
2. Which is the most toxic form of nitrogenous waste? Name an organism that excretes it.
.....

14.3.2 Excretory organs in cockroach

- Cockroaches are adapted for terrestrial life and possess excretory organs called **Malpighian tubules** (Refer Fig. 14.6). They excrete uric acid, which is almost insoluble in water.
- The malpighian tubules are long, blind ended tubules attached to the alimentary canal at the junction of mid and hindgut.
- They lie in the abdomen and are bathed in haemolymph (blood of insects).

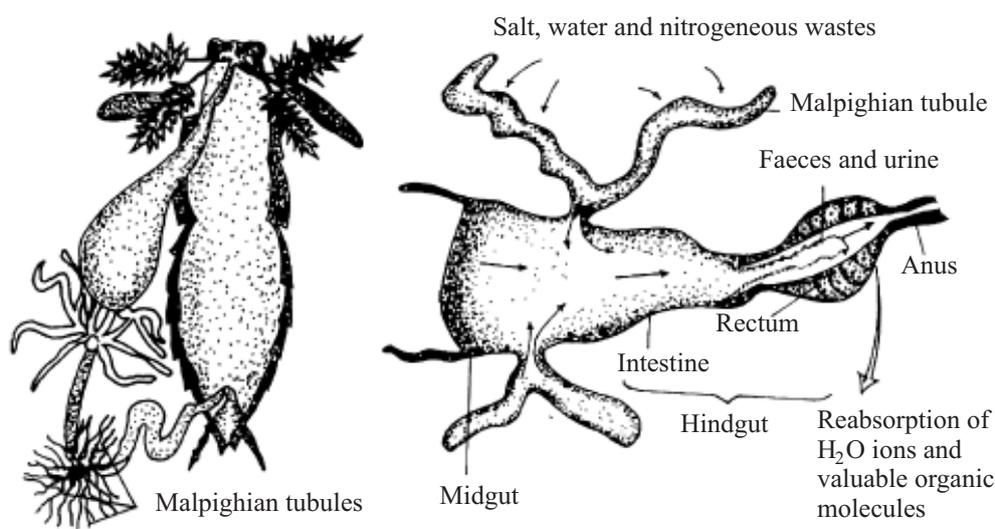


Fig. 14.6 Excretory organs of cockroach.

- The cells of tubules remove nitrogenous waste and certain salts from the haemolymph and then pump them into the lumen of the tubule.
- Fluid passes to the hindgut and in the process gets concentrated.
- This concentrated fluid then moves into the rectum and is excreted as concentrated urine along with faeces.
- Most of the salt and water is pumped back into the haemolymph by Malpighian tubules and in this way the nitrogenous wastes are eliminated as almost dry matter.

14.3.3 Excretory organs in humans

The human excretory system comprises of a pair of kidneys, a pair of ureters, a urinary bladder and urethra (Fig. 14.7)

- Kidneys are bean shaped organs located on either side of the vertebral column in the lower abdominal cavity.
- On the concave median margin of each kidney there is a notch called **hilum** which leads into funnel shaped space called **renal pelvis**.
- The renal pelvis is surrounded by an outer layer of tissue called **renal cortex** and an inner layer of tissue called the **renal medulla**.
- Kidneys filter metabolic wastes from the blood and excrete them as a liquid called urine. As kidneys form the urine, they also maintain the normal composition of blood, fluid and salt balance throughout the body tissues.
- Urine formed in the kidney is brought to the urinary bladder by two hollow muscular tubes called ureters.



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- Urethra is the small tube that leads urine to the outside of the body.
- From urinary bladder urine is passed outside via urethra during urination voiding of urinary bladder is called micturition.

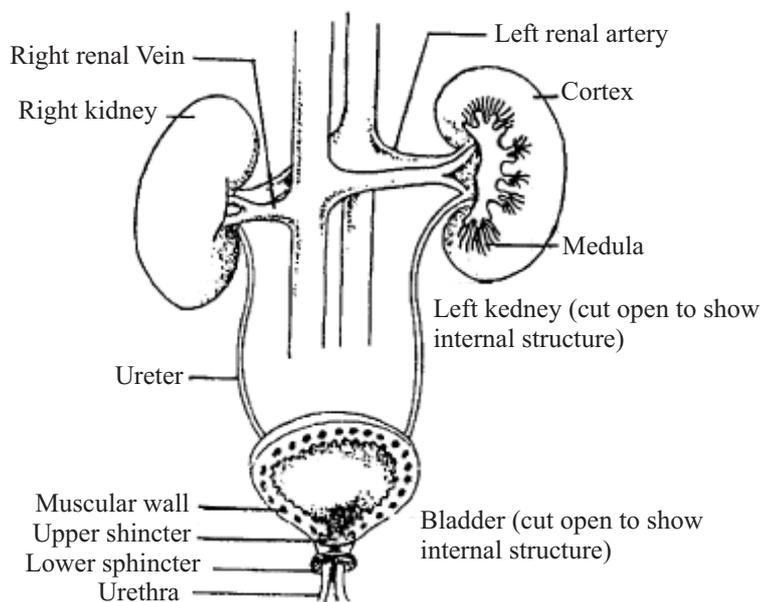


Fig. 14.7 Excretory organs of humans.

Structure of Kidney

Microscopic structure of kidney (Fig. 14.8)

- Kidney contains a large number of minute tubular structures called **nephrons** that are located partly in the renal cortex and partly in the renal medulla. They form urine and drain it ultimately into the pelvis of the kidney from where the ureters transport the urine to the urinary bladder.
- Nephrons are the structural and functional units of kidney associated with blood vessels and capillaries. There are about 1 million nephrons in each kidney which filter out about 180 litres of fluid per day most of which is reabsorbed. Each nephron can be divided into two regions (i) proximal nephron and (ii) loop of Henle. Further structural and functional components of a nephron are as follows:
 1. Renal corpuscle (is composed of cup-shaped Bowman's capsule and a tuft of capillaries (called glomerulus). Glomerulus receives the blood from a branch of renal artery.
 2. Proximal convoluted tubule (PCT)
 3. Descending limb of loop of Henle
 4. Ascending limb of loop of Henle

5. Distal convoluted tubule (DCT)
6. Collecting duct
7. Collecting ducts of all the nephrons join and ultimately form the renal pelvis from where the ureters arise.
8. Peritubular blood capillaries passing over the tubules join, and form the renal vein.



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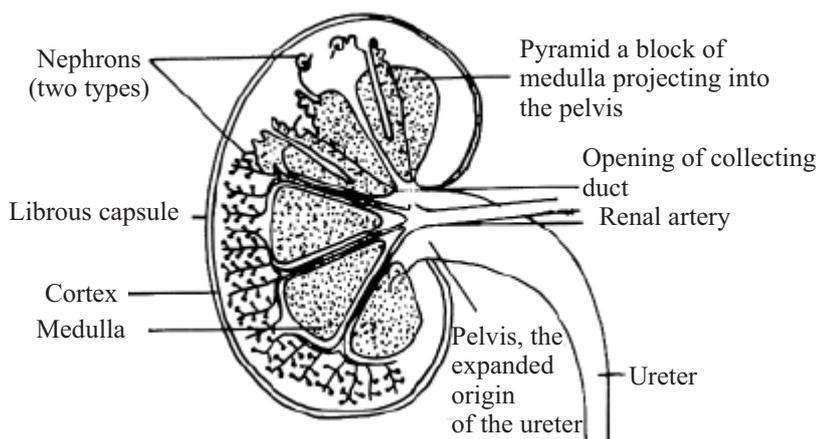


Fig. 14.8 Microscopic structure of human kidney

14.3.4 Formation of urine

Nephrons carry out excretory and osmoregulatory functions in the following steps-

1. Ultrafiltration
2. Selective reabsorption
3. Tubular secretion

1. Ultra-filtration

Each glomerular capillary receives blood flowing under high pressure through a branch of renal artery. There is continuous process of ultra filtration (filtration under pressure).

All small molecules like water, glucose, minerals, amino acids, urea and uric acid are filtered out of the blood plasma into the Bowman's capsule through the capillary walls. Proteins remain in the glomerular blood. Thus a protein free filtrate is collected in the lumen of the Bowman's capsule. The hydrostatic pressure of the circulating blood provides the pressure for filtration.

2. Selective reabsorption or tubular reabsorption

As the glomerular filtrate flows through the tubules several substances useful to the body such as glucose and amino acids and mineral ions needed to maintain the water and salt balance are reabsorbed through the walls of the renal tubule. The blood



Notes

capillary passing over the nephrons absorb these substances.

- (a) About 65%- 85% of filtrate is reabsorbed in Proximal Convolved tubule (PCT). It includes water, glucose, amino acids, and salts.
- (b) About 5% of water is reabsorbed in the descending limb.
- (c) Ascending limb is impermeable to water; hence only salts are reabsorbed here.
- (d) In Distal convoluted tubule (DCT) and collecting duct Na^+ is reabsorbed under the influence of the hormone **aldosterone** (secreted by adrenal cortex) . Water is absorbed under the influence of **ADH** (Anti diuretic Hormone) secreted by posterior pituitary.

3. Tubular Secretion

Cells of the renal tubule also directly secrete certain unwanted substances from the blood into the filtrate. These include uric acid, K^+ ions and ammonia. The filtrate is now known as urine.

Storage of Urine

The urine passes into urinary bladder via ureters and is stored there. The bladder can hold 400-500 cm^3 of urine. When about 200 cm^3 or more urine gets collected in urinary bladder, stretch receptors are stimulated leading to the desire to discharge urine.

14.3.5 Composition of urine (Table 14.5)

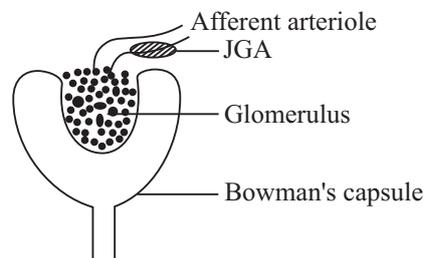
Table 14.5 Composition of urine

Normal components		Abnormal components	
Components	Amount/Day	Component	Cause
Water	1200-1500ml	Glucose	Diabetes mellitus
Urea	25-30 gms	Proteins	Kidney disease
Uric acid	0.7 gms	Acetones	Diabetes mellitus, starvation
Creatine	1.2 gms	Erythrocytes	Infection in urinary system
Ammonia	0.6 gms	Leucocytes	Large numbers indicate infection in urinary system
NaCl	10-15 gms	Uric acid crystals	Gout
KCl	2.5 gms		
Magnesium	0.2 gms		
Phosphate	1.7 gms		
Sulphate	2.0 gms		
Minute amounts of fatty acids, amino acids, pigments, mucin, enzymes, hormones, vitamins.			

14.3.6 Renin-angiotensin and Atrial Natriuretic Factor

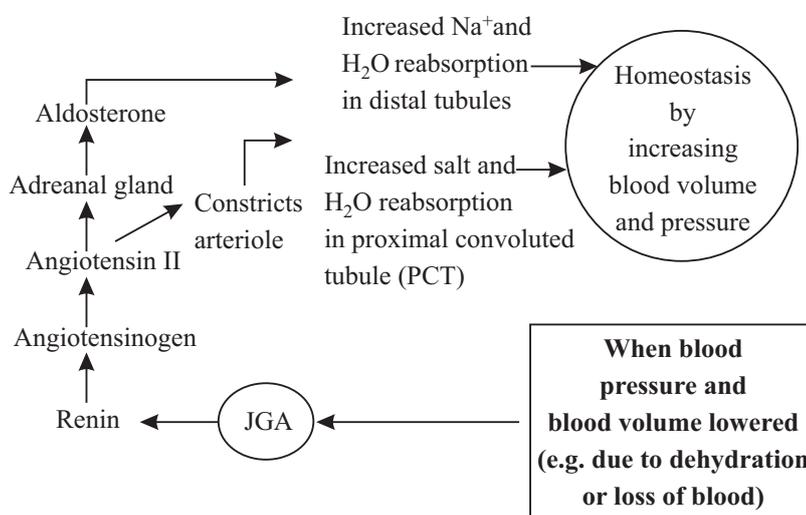
Renin-angiotensin is part of a feedback circuit which helps to regulate blood pressure and blood volume.

You know that nephron, the structural and functional unit of the human kidney has a cluster of capillaries called **glomerulus**. Recall its location from the Module 2, Unit 14 submit 14.3.3. Near the arteriole supplying the glomerulus lies a specialised tissue called **juxtaglomerular apparatus (JGA)**



Notes

When blood pressure or blood volume in the afferent arteriole drops, JGA secretes an enzyme called **renin**. Renin converts a plasma protein called **angiotensinogen** into **angiotensin II** which acts like a hormone, constricts the arteriole, which in turn elevates the blood pressure. Angiotensin II also stimulates the proximal convoluted tubules (PCT) of nephron (again, recall structure of nephron) to reabsorb more salt and water so that salt and water excreted in the urine are reduced. As a consequence, blood volume and blood pressure both increase. Angiotensin II also stimulates adrenal gland to release the hormone **Aldosterone** which makes distal tubules of nephron to reabsorb sodium and water. This also increases blood volume and blood pressure.



Renin angiotensin system for regulating blood volume and blood pressure

Antinatriuretic factor

Antinatriuretic factor is a powerful vasodilator and is a polypeptide hormone secreted by the cells of heart muscles (myocytes or muscle cells). It is released in the atria of the heart in response to the high blood pressure and is involved in the homeostatic control of water, sodium, potassium and fat in the body.



Notes



INTEXT QUESTIONS 14.4

1. In what form the cockroaches excrete their nitrogenous waste? What is its advantage for cockroach?
.....
2. Where do Malpighian tubules of cockroach open?
.....
3. List the parts of human excretory system and their functions.
.....
4. Name the functional unit of kidney and its parts.
.....
5. List the substances that are filtered out during ultrafiltration
.....
6. What are the substances reabsorbed by the nephron?
.....
7. What is the importance of tubular secretion?
.....
8. Under which situation are the following present?
 - (a) Glucose in the urine
 - (b) Uric acid crystals
9. What is the normal volume of urine excreted per day?
.....
10. What will happen if JGA (juxtaglomerular apparatus) stops secreting the enzyme renin?
.....
11. Name a hormone, which is a polypeptide in nature and secreted by the heart muscles and is also a vasodilator.
.....

14.4 OSMOREGULATION BY KIDNEY

Maintaining the solute concentration of the body fluids is called osmoregulation. Fine control of the precise amount of water and salt reabsorbed into blood is an

important function of the distal convoluted tubules and collecting ducts. Depending on the need of the water in the body, kidneys excrete hypotonic (dilute) or hypertonic (concentrated) urine. Osmoregulation is controlled by the hormones ADH and aldosterone. Feedback circuits regulate their secretion.

- (a) When the water content of the body is more, leading to low osmotic pressure, less ADH (anti diuretic hormone) is released. Hence the wall of the DCT and collecting tubules remain less permeable and as a result plenty of dilute urine (hypotonic urine) is excreted.
- (b) When water content of the body is low, the posterior pituitary secretes more of ADH. The permeability of the tubules is increased. As a result more water is reabsorbed into the blood and reduced volume of concentrated urine is excreted (hypertonic urine). **Diuresis** means the production of increased amount of urine, so anti diuresis means reduction of urine volume and hence the name antidiuretic hormone or ADH.
- (c) Urine is also concentrated by the counter current system of the descending and ascending limbs of Henle's loop. About 5% of the water from the filtrate is absorbed in this part.
- (d) In response to low sodium ion concentration (or low blood pressure) another hormone, **aldosterone** is released by the adrenal cortex. It stimulates the kidney tubules to absorb sodium ions in exchange of potassium ions. This leads to reabsorption of water by osmosis. As a result of increased blood volume the blood pressure is increased. Similarly high sodium concentration will inhibit aldosterone release and as a result it would lead to lower sodium ion concentration in blood.

You will learn more about hormones in lesson 16.

14.5 HAEMODIALYSIS AND KIDNEY TRANSPLANTATION

Haemodialysis

1. The blood urea level rises abnormally (uraemia) in patients suffering from kidney failures. In such patients, an artificial kidney is used for removing excess urea from the blood by a process called **haemodialysis**. It is carried out in the following steps :
2. Blood is taken out from the artery of the patient and cooled to 0°C.
3. This blood is then passed through cellophane tubes of the artificial kidney. Cellophane is permeable to micro molecules such as urea, uric acid and mineral ions. It is not permeable to macromolecules such as plasma proteins.
4. Outside the cellophane tube is the dialyzing fluid, which has some solutes like those in blood plasma but no nitrogenous molecules like urea, and uric acid.
5. Hence the nitrogenous compounds from within the cellophane tubes flow into the dialyzing fluid by diffusion.
6. Blood coming out of the artificial kidney is warmed to the body temperature and returned to the vein of the patient.



Notes



Notes

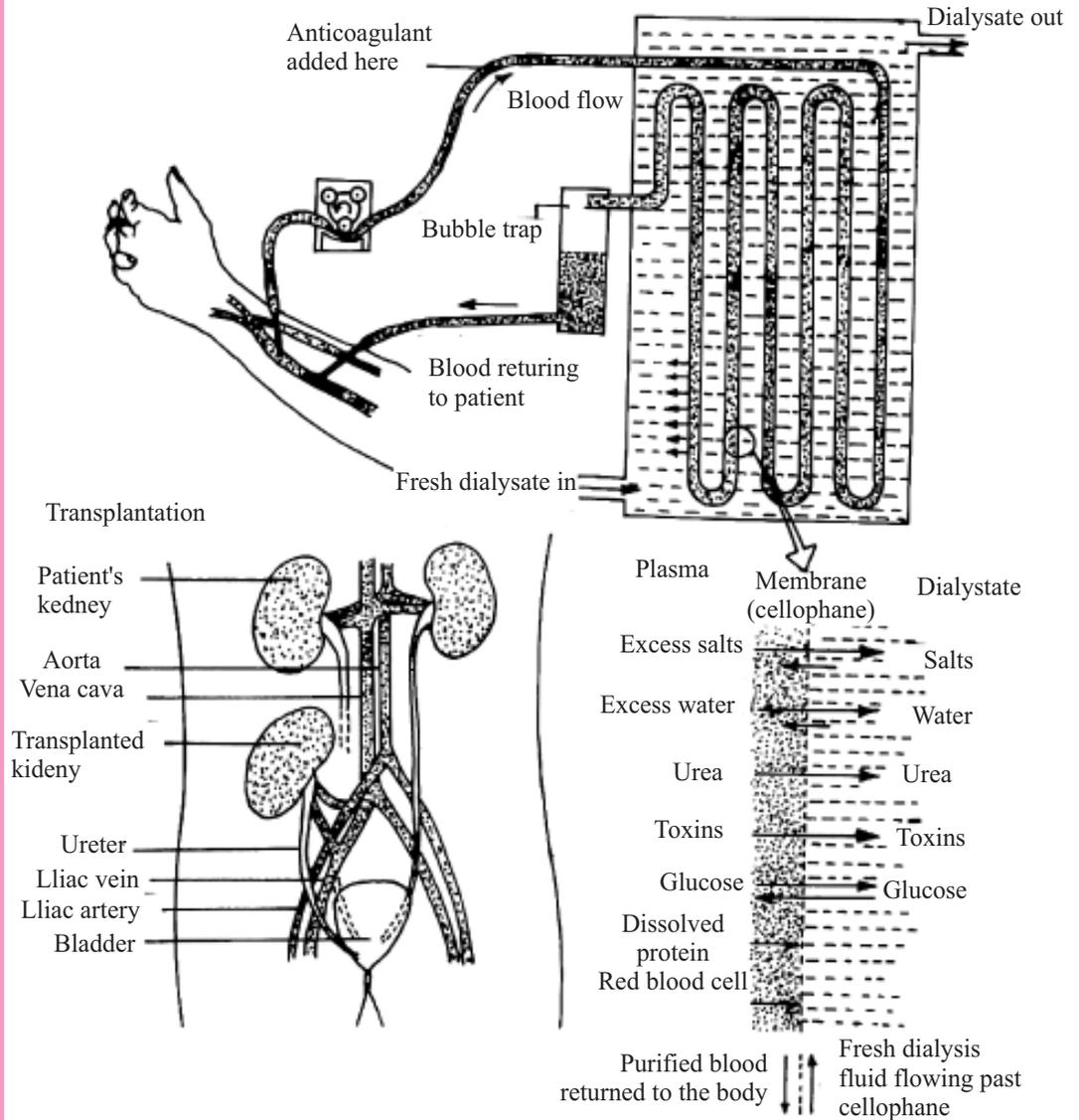


Fig. 14.9 Artificial kidney (haemodialysis)

Kidney transplantation

If kidney failure cannot be treated by other available means, kidney transplantation is advised.

- Donated kidney may come from a living person or a donor who has recently died.
- The genetic make up of the donor should be as close to the patient as possible, that is, if it is donated by a close relation, it reduces the chances of rejection.
- Drugs are, however, used to prevent rejection of the transplanted kidney by the body.

14.6 ROLE OF LIVER IN EXCRETION

- It excretes bile pigments, cholesterol, drugs and some vitamins.
- It excretes all the above mentioned substances in bile, which flows into the small intestine and from there these get removed with the faeces.
- Formation of urea and uric acid (from ammonia) also takes place in liver. These are removed from the body by the kidneys.



Notes

**INTEXT QUESTIONS 14.5**

1. Name the organ where urea is formed.
.....
2. Why is cellophane used in haemodialysis?
.....
3. What is the composition of dialyzing fluid?
.....
4. From which type of blood vessel artery or vein, is the blood taken out for dialysis?
.....
5. When is kidney transplantation advised?
.....
6. How is bile pigment removed from our body?
.....

**WHAT YOU HAVE LEARNT**

- Metabolic activities produce a number of waste products that need removal from the body.
- Breathing is a mechanical process of inhaling air (inspiration) and giving out of CO₂ rich air (expiration).
- Skin acts as the breathing organ for earthworm. It is thin, moist and richly supplied with blood capillaries.
- Cockroaches have air tubes called trachea for respiration. Air reaches directly to the tissues for gaseous exchange. Blood does not participate in gaseous transport.
- In humans, air passes through respiratory passage as follows-
Nostrils→Pharynx→Trachea→Bronchi→Bronchioles→Alveoli in lungs

**Notes**

- Cellular respiration is a chemical process which takes place within the cell and is associated with release of energy.
- Haemoglobin is an iron containing pigment that can easily combine with oxygen and transport it to different parts of the body.
- Carbon dioxide in blood is transported in three ways: (a) dissolved in plasma, (b) as carbaminohaemoglobin, and (c) as bicarbonates
- Aerobic respiration takes place in the presence of oxygen. 38 molecules of ATP, carbon dioxide and water are released during this process.
- Anaerobic respiration takes place in the absence of oxygen. 2 molecules of ATP, carbon dioxide and alcohol or lactic acid are produced during this process.
- Excretion is the removal of nitrogenous wastes from the body.
- Human excretory system consists of a pair of kidneys, a pair of ureters, a urinary bladder and a urethra.
- Nephrons are the filtering units of kidney.
- Urine formation by nephrons has three steps : ultrafiltration, reabsorption and tubular secretion.
- Urine consists of water, urea, unwanted salts and some drugs.
- Depending upon the kind of excretory product, animals may be classified as ammonotelic ureotelic, or uricotelic.
- An artificial kidney or dialysis machine may be needed in case of kidney failure.
- Malpighian tubules in cockroach remove uric acid from the body cavity into the digestive tract for removal.
- Cigarette smoking is injurious to health and causes emphysema in which alveoli lose their elasticity.
- JGA or Jux taglomerular apparatus in the nephron helps to restore blood volume and blood pressure when it falls by secreting an enzyme renin.
- Heart secretes a hormone called antinatriuretic factor which helps in maintaining homeostasis, related to control of water, sodium, potassium and fat in the body.

**TERMINAL EXERCISES**

1. List the major steps that are involved with respiration in humans.
2. How is oxygen transported in earthworm?
3. Name the respiratory pigment in earthworm.
4. What is the role of carbonic anhydrase in the transport of carbon dioxide in our body?
5. Which part of our respiratory system is known as the voice box?
6. Where are respiratory centres situated in our brain?



Notes

7. Name one nitrogenous waste removed by the kidney.
8. Name the hormone the absence of which will result in excretion of hypotonic urine.
9. What is the role of cellophane in dialysis?
10. Why is inspiration said to be an active phase and expiration as passive phase?
11. Differentiate between
 - (a) Breathing and respiration
 - (b) Inspiration and expiration
12. List the special features of alveoli that enable easy gaseous exchange.
13. What is vital capacity, tidal volume and residual volume?
14. Give reasons for the following :
 - (a) Exchange of gases at the alveolar surface continues even during expiration.
 - (b) Trachea and bronchi do not collapse when air pressure decreases inside them.
15. Draw the excretory system of human and label the parts.
16. Draw the structure of a nephron and label the parts.
17. What is the cause and symptoms of pneumonia and TB?
18. What is the role of liver in excretion?
19. Explain how nitrogenous wastes are removed from the body of cockroach.
20. How does ultrafiltration and reabsorption occur in nephrons?
21. Explain how gaseous exchange takes place in the lungs.
22. How is oxygen transported from the lungs to the tissues and carbon dioxide from tissues to the lungs?
23. How is (a) Water balance, and (b) Salt balance maintained by kidney?
24. List the parts of human respiratory system in correct sequence and state their functions.
25. List three characteristics of our lungs which make them suitable as respiratory surface.



ANSWERS TO INTEXT QUESTIONS

- 14.1**
1. Stepwise oxidation of glucose resulting in release of energy.
 2. O₂, CO₂
 3. Respiration by the skin; frog
 4. Red, haemoglobin
 5. Directly through tracheoles

**Notes**

6. Insects
 7. Through spiracles
 8. Nostrils → pharynx → bronchi → bronchioles → lungs
 9. Nasal cavity
 10. Prevent food from entering the trachea or food pipe
- 14.2**
1. mechanism of taking in air and then giving it out
 2. relaxed and dome shaped
 3. 500 mL
 4. 4 molecules
 5. Pulmonary vein
 6. (a) dissolved in plasma as carbon dioxide – 5%
(b) as carboxy carbamino haemoglobin in RBC – 20%
(c) as bicarbonate ions in RBC or plasma – 75%
 7. Bacillus Calmette Guerin (BCG)
 8. Silicosis or asbestosis
 9. Bronchitis is an infection of the bronchi and antibiotics can cure it whereas bronchial asthma is an allergic reaction.
 10. Emphysema
- 14.3**
1. (a) Liver (b) Kidney
 2. Ammonia; amoeba and fresh water fishes
- 14.4**
1. Uric acid; this is to prevent water loss as these animals need to conserve water
 2. Malpighian tubules open at the junction of mid and hind gut
 3. Kidney-filters nitrogenous wastes, excess of water and salt
Ureters-transport urine to the bladder
Urinary bladder-temporary storage of urine
Urethra-drains urine outside the body
 4. Nephron, consisting of renal corpuscles made up of Bowman's capsules and glomerulus, PCT, loop of Henle, DCT, collecting duct
 5. Water, amino acid, glucose, urea, uric acid, minerals, vitamins.
 6. Water, glucose, some salts, amino acid and small quantity of urea and uric acid.
 7. Direct elimination of certain minerals can take place such as ammonia and potassium.
 8. (a) Diabetes mellitus (b) Gout
 9. 1200 to 1500 mL
 10. Blood Pressure will remain abnormally low.
 11. Antinatriuretic factor.

- 14.5**
1. Liver
 2. Cellophane is impermeable to macromolecules like plasma proteins and blood corpuscles
 3. It contains some minerals and solutes like those in plasma but no urea and uric acid is present.
 4. Artery
 5. When kidney failure cannot be treated.
 6. Bile pigments are removed along with bile via the digestive tract.



Notes