Life Processes

Introduction

Life

Earth happens to be the only known planet having life. There are beings which live, die and become part of nature again. The living organism can be differentiated from the inanimate entities on various parameters of life processes.

Life Process

- Maintenance of living organism is essential even if they are moving, resting or even sleeping.
- The processes which together perform the function of maintenance of 'life' are called as life processes.
- Nutrition, respiration, circulation, excretion are the examples of essential life processes.
- In unicellular organisms, all these processes are carried out by that single cell.
- In multicellular organisms, well-developed systems are present to carry out the processes.

Nutrition

Nutrition

The process of acquiring food that is needed for nourishment and sustenance of the organism is called nutrition.

- There are two main modes of nutrition, autotrophic and heterotrophic.
- Heterotrophic nutrition has subtypes as holozoic, saprophytic and parasitic nutrition.

Autotrophic Nutrition

If an organism can nourish itself by **making its own food** using sunlight or chemicals such mode of nutrition is called as autotrophic nutrition.

- Plants photosynthesize (use light energy) and are called photoautotrophs.
- Few bacteria use chemicals to derive energy and are called chemoautotrophs.

Photosynthesis

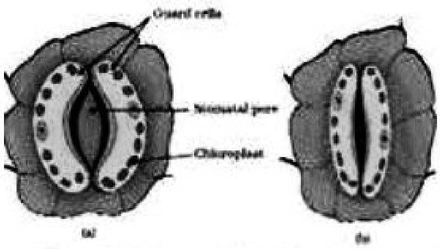
- Photosynthesis is the important process by which food is formed.

The plants make food using sunlight and water, which provides nourishment to other organism and themselves.

- Chlorophyll present in the green parts absorbs light energy.
- This light energy is used to split water into hydrogen and oxygen.
- Hydrogen is then used to reduce carbon dioxide into carbohydrates, typically glucose.
- Chlorophyll is essential for photosynthesis and stomata facilitate intake of carbon dioxide.

Stomata

- Stomata are pores on the leaves that help in exchange of gases.
- They are mostly found on the underside of the leaf.
- Each stoma is guarded by guard cells, which control the opening and closing of the pore.
- The water content of the guard cells is responsible for their function.



Stoma in open and closed state

Saprophytic Nutrition

Some organism feed on **dead and decaying organic matter**. This mode of nutrition is called saprophytic nutrition.

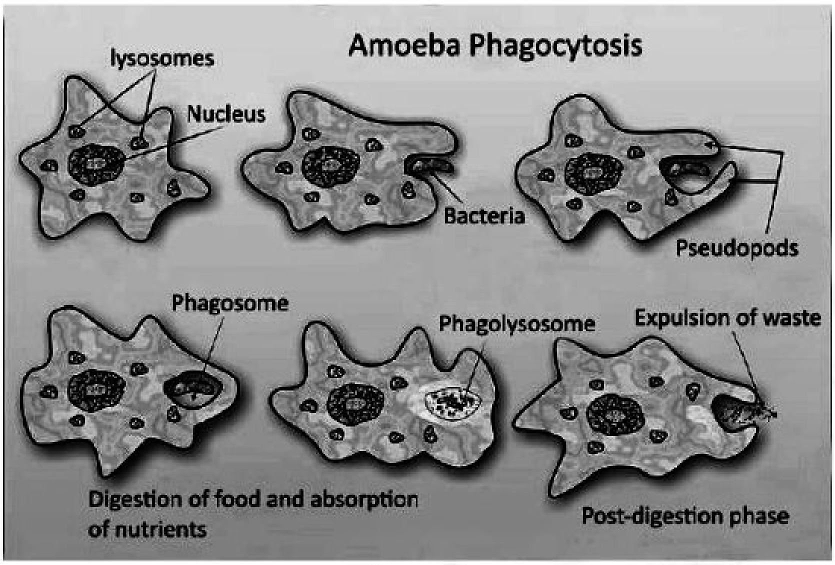
- The food is partially digested outside the body and then it is absorbed.
- E.g. Fungi are saprophytes.

Parasitic Nutrition

Some organisms feed on the expense of another organism and in turn causing it harm. This is called parasitic mode of nutrition.

- These organisms live on the body or in the body of a host organism and derive the nutrients directly from the body of the host.
- E.g. Leech is an ectoparasite while Ascaris is an endoparasite. Cuscuta is a parasitic plant.

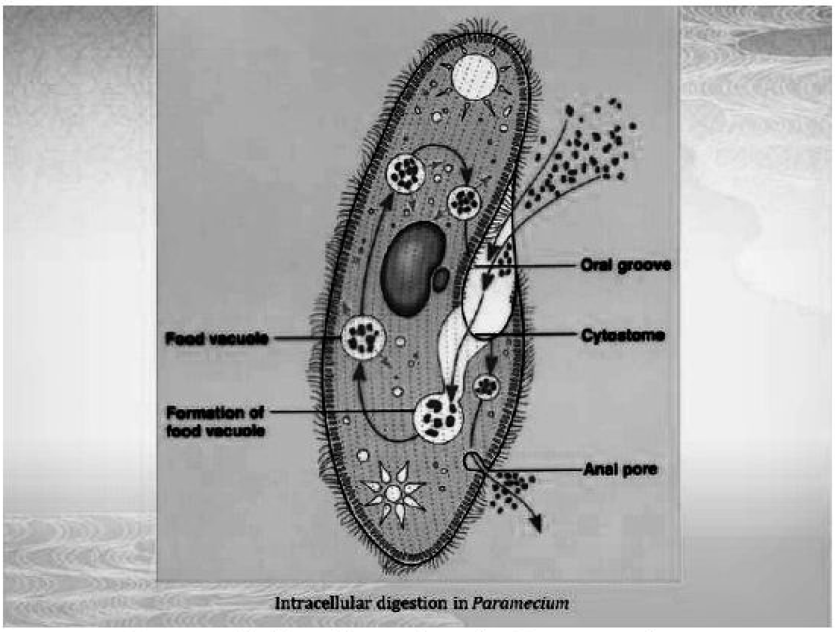
- Amoeba feeds by holozoic mode of nutrition.
- It engulfs the food particle using pseudopodia, the process is called as phagocytosis.
- The engulfed food gets enclosed in a food vacuole.
- As the food vacuole passes through the cytoplasm, digestion, absorption and assimilation take place.
- When the food vacuole opens to outside, egestion of undigested food takes place.



Holozoic Nutrition in Amoeba

Nutrition in Paramoecium

- Paramoecium also exhibit holozoic nutrition.
- However, they have cilia that help them to engulf the food through the oral groove.
- A food vacuole is created enclosing the food.
- It moves through the cytoplasm, the process is called cyclosis.
- Food digested in the food vacuole is absorbed by the cytoplasm.
- Undigested food is given out to a tiny pore called anal pore or cytopyge.



Intracellular digestion in Paramecium

Nutrition in Humans

- Humans are omnivores, they can eat plant-based food as well as animal-based food.
- Being more complex, humans have a very complicated nutrition system.
- The digestive system has an alimentary canal and associated digestive glands, which together function to nourish the body.
- There are five stages in human nutrition; Ingestion, Digestion, Absorption, Assimilation and Egestion.
- Four stages i.e. ingestion, digestion, absorption and egestion take place in the alimentary canal while assimilation of food takes place in the whole body.

Alimentary Canal

- Alimentary canal in humans is a long tube of varying diameter.
- It starts with mouth and ends with the anus.
- Oesophagus, stomach, small intestine and large intestine are the parts of the alimentary canal.

Mouth

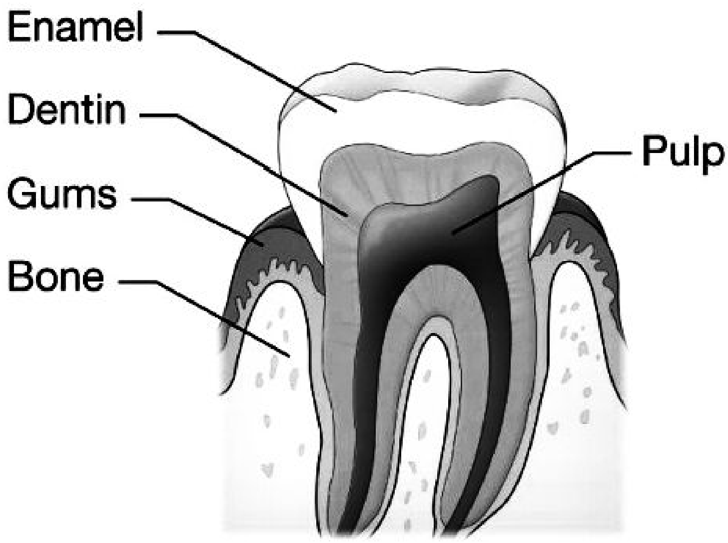
- It is the opening of the alimentary canal and helps in ingestion of food.
- The buccal cavity which is present behind the mouth is also commonly referred as mouth.
- The buccal cavity has teeth and tongue.
- The set of teeth helps in mastication of food.
- The tongue has taste buds on it and thus helps in tasting the food.
- The salivary glands open also in the buccal cavity and pour saliva which initiates the process of digestion.

Teeth

- Teeth are the hard structures present in the buccal cavity.
- They help us to cut, shear and masticate the food we eat.
- Vertical section of a tooth shows four layers as enamel, dentine, cement and dental pulp.
- Enamel is outermost, shiny, highly mineralized and hardest part of the human body.
- Dentine makes the bulk of the tooth and contains 70% inorganic salts.
- Cement is present at the lining of a tooth and bony socket.
- Dental pulp is the central soft part of a tooth and contains nerve endings, blood and lymph vessels along with connective tissue.
- There are four types of teeth in humans, Incisors, canines, molars and premolars, each with a specific function.

Incisors cut the food, canines tear the food while molars and premolars crush it.

- The dental formula in adult humans is 2:1:2:3.



Structure of a Tooth

Oesophagus & Stomach

Oesophagus

- The swallowed food passes into the oesophagus.
- It is a muscular tube, about 25 cm long, with a sphincter (valve/opening) at each end.
- Its function is to transport food and fluid, after being swallowed, from the mouth to the stomach.
- Food is pushed down by peristaltic movements.

Stomach

- The stomach is thick-walled bag-like structure.
- Its receives food from the oesophagus at one end and opens into the small intestine at the other end.
- The inner lining of the stomach secretes mucus, hydrochloric acid and digestive juices
- Food is churned into semi-solid mass in the stomach and is called chyme.
- Enzymes present in the gastric juice break down the food.
- Hydrochloric acid helps in partial digestion of proteins and also kills harmful bacteria.
- Mucus secreted by the wall of stomach resists the action of HCl on itself.

Small Intestine

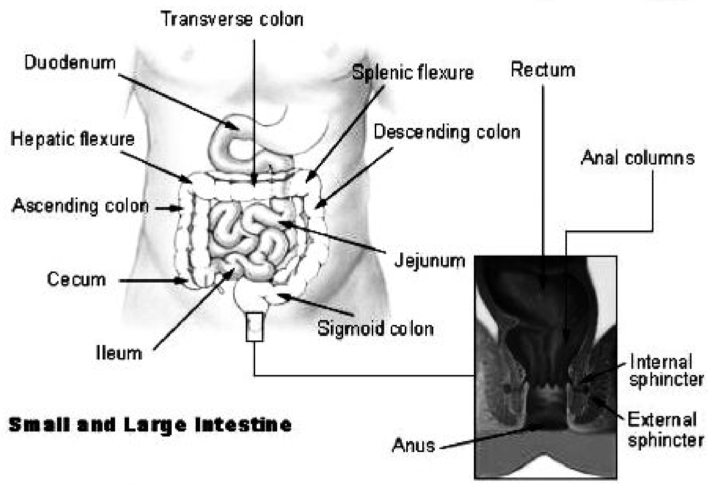
- The small intestine is the longest part of the alimentary canal, about 20 feet long in humans.
- It has regions, duodenum, the region which follows stomach, jejunum is the middle part and ileum is the later region which continues further into the large intestine.

The internal surface of the small intestine is folded into finger-like projections called villi.

- A common pancreatic duct from pancreas and liver opens into the duodenum.
- Most of the chemical digestion and absorption takes place in the small intestine.

Large Intestine

- Large intestine in humans is about 5 feet long.
- It has two regions, colon (about 1.5 m) and rectum (10 cm in length in the adult).
- The region of large intestine after ileum is called colon while the last part is called rectum.
- Colon has three regions as, ascending colon, transverse colon and descending colon.
- At the base of ascending colon, a small finger-like out-growth is seen and is called an appendix.
- It houses many useful bacteria required for digestion of food.
- Rectum opens to outside by anus.
- The anus has internal and external anal sphincters.



Small and Large Intestine

Peristalsis

A constant wave-like movement of the alimentary canal right from the oesophagus to the small intestine is called as peristalsis.

- Muscles present in the wall of the alimentary canal are responsible for peristalsis.
- This movement helps to push the food through the alimentary canal.

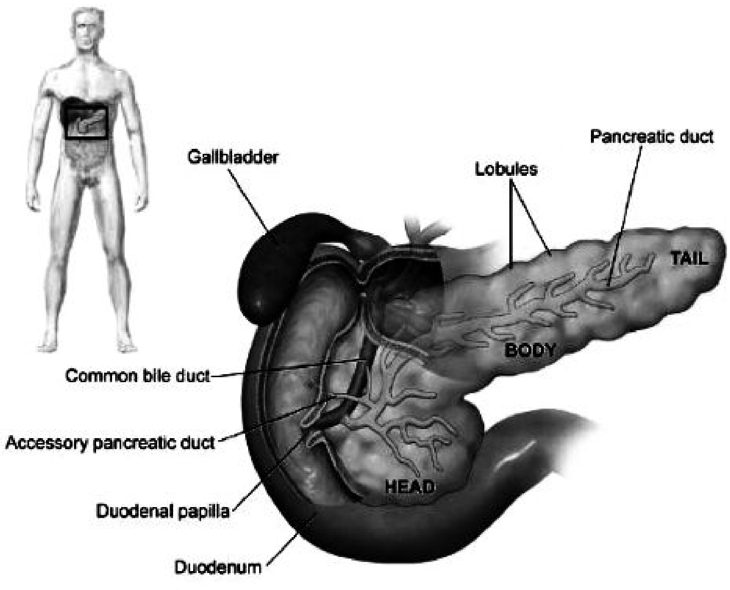
Digestive Glands

- Several glands produce digestive juices that help in digestion of the food.
- Salivary glands, Gastric glands, Liver, Gallbladder, Pancreas are few to name.
- Salivary glands secrete saliva which initiates digestion in the mouth itself.

- Gastric glands present in the wall of the stomach secrete hydrochloric acid and enzyme pepsin.
- The liver secretes bile which is stored in the gallbladder. Bile helps in digestion of fats
- The pancreas secretes many digestive enzymes and its secretion is called as pancreatic juice.
- Enzymes like trypsin, chymotrypsin, lipase, amylase are present in the pancreatic juice.

Pancreas

- The pancreas is a long, flat gland present behind the stomach in humans.
- It is one of the major digestive glands and is of mixed nature i.e. endocrine as well as exocrine.
- As an endocrine organ, it secretes two hormones called insulin and glucagon which maintain the blood sugar level.
- As an exocrine gland, it secretes pancreatic juice which is nothing but a mixture of many digestive enzymes.
- The digestive enzymes secreted by pancreas include trypsin and chymotrypsin and proteases which digest proteins.
- It also includes amylase which digests the starch content of the food.
- Pancreatic lipases are the pancreatic enzymes that help in digestion of fats.



Anatomy of Human Pancreas

Holozoic Nutrition

The mode of nutrition in which animals take their food as a whole is called as holozoic nutrition.

In holozoic nutrition, food passes through five steps as ingestion, digestion, absorption, assimilation and egestion.

Physiology of Digestion

- Mechanical digestion of food takes place in the buccal cavity where teeth masticate the food, saliva gets mixed and it turns into a bolus.
- Digestion of starch starts in the buccal cavity itself, with the action of salivary amylase present in the saliva.
- Salivary amylase converts starch into maltose.
- In the stomach, the churning of food takes place due to the muscular contraction and relaxation of its wall. It breaks down the food into simpler substances.
- Digestion of proteins starts in the stomach with the action of pepsin. Proteins are broken down into smaller fragments called peptide by the action of pepsin.
- The bolus after mixing with gastric juice, turn into a fine soluble form known as the chyme.
- Chyme enters into the small intestine where complete digestion takes place due to the action of various enzymes present in the pancreatic juice, bile and intestinal juice.
- The digested food is completely absorbed by the villi and microvilli of the small intestine.
- Undigested food then enters into the large intestine.
- Colon is responsible for absorption of water and salts whereas rectum stores the undigested food temporarily before defaecation.

Digestive System in Other Animals

- Digestive systems in different animals vary in structure and function.
- The structure of the digestive system depends on the food habits of the animal.
- Alimentary canal in herbivores is long as the cellulose content of their plant-based diet takes a long time to digest.
- On the other hand, alimentary canal of carnivorous animals is comparatively shorter because meat gets digested faster.

Anatomy of Digestive Tract

- Alimentary canal in humans approximately 30 feet (9m) long.
- It starts with mouth and ends in the anus.
- Between these two openings, alimentary canal is the tube of varying diameter.
- Oesophagus, stomach, small intestine (divided into three regions as duodenum, jejunum and ileum) and large intestine(having two regions as colon and rectum) are the parts of the alimentary canal.
- Salivary glands, pancreas and liver act as major digestive glands.
- Glands present in the wall of the stomach and small intestine also contribute towards digestion of food.

Role of HCl

- Hydrochloric acid in the stomach is secreted by the gastric glands present in its wall.
- pH of the gastric acid is usually between 1.5 to 3.5
- This acid serves following functions:

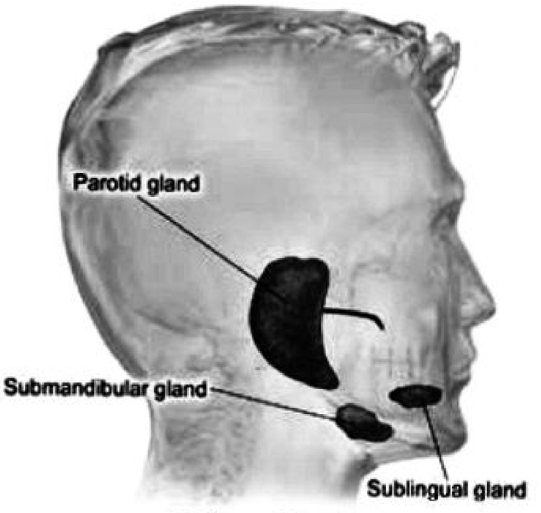
1. Converts inactive pepsinogen and pro-rennin into active pepsin and rennin respectively.
2. Provides acidic medium for protein digestion.
3. Kills bacteria entered through food and prevents infection.
4. Prevents putrefaction of food in the stomach.

- A thick layer of mucus secreted by the mucus glands of the stomach prevent itself from the action of the gastric acid.
- Excess acid damages gastric mucosa and causes gastric and duodenal ulcers.

Salivary Glands

- Salivary glands are the exocrine glands that secrete saliva and through a system of ducts, it is poured into the mouth.
- In humans, three major pairs of salivary glands are present, parotid, submandibular and sublingual.
- In healthy individuals between 0.5 to 1.5 litres of saliva is produced per day.
- Saliva serves following functions in the oral cavity.

1. It lubricates and protects the soft and hard tissues of the oral cavity
2. It also gives protection from dental caries
3. Saliva prevents microbial growth in the oral cavity.
4. Saliva can encourage soft tissue repair by decreasing clotting time and increasing wound contraction
5. Saliva contains the enzyme amylase that hydrolyses starch into maltose and dextrin. Hence saliva allows digestion to occur before the food reaches the stomach
6. Saliva acts as a solvent in which solid particles can dissolve in and enter the taste buds located on the tongue.



Salivary Glands

Heterotrophic Nutrition

When an organism depends on others for food, such a mode of nutrition is called as a heterotrophic mode of nutrition.

- These organisms depend on autotrophs for their nutritional requirements.
- E.g. Animals which eat plants as their food are called herbivores.
- Animals which eat other animals as their food are called carnivores.
- Holozoic, saprophytic and parasitic nutrition are all types of heterotrophic nutrition.

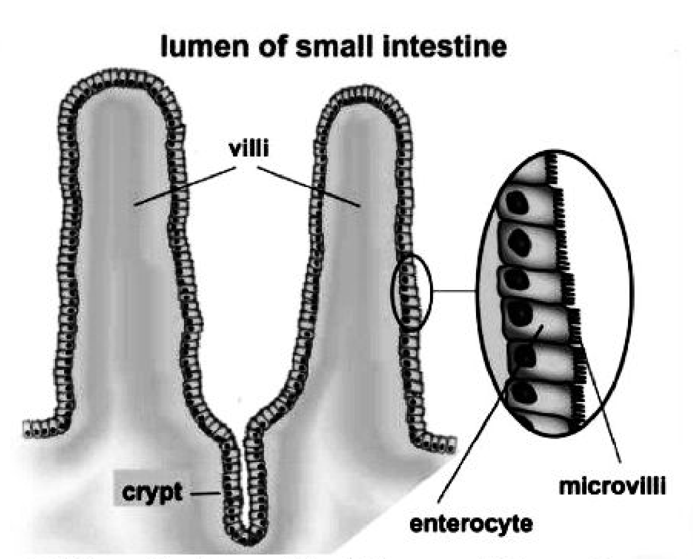
Glandular Epithelium

- Many small glands present in the inner layer of stomach and intestine take part in the digestion of food.
- These glands are present in the epithelial lining of stomach and intestine.
- The glands present in different regions of the stomach are called as gastric glands.
- They are responsible for the secretion of mucus, hydrochloric acid and enzymes like pepsinogen.
- The glands present in the epithelial lining of the small intestine and large intestine are called as intestinal glands.
- Glands of the small intestine are responsible for the secretion of intestinal juice also called as succus entericus.
- Intestinal juice contains hormones, digestive enzymes, alkaline mucus, substances to neutralize hydrochloric acid coming from the stomach.
- Intestinal juice completes the digestion started by pancreatic juice.
- Glands of the large intestine are associated with absorption of water and electrolytes.

Villi and Micro Villi

- Complete digestion and absorption of food take place in the small intestine.
- Pancreatic juice coming from the pancreas, bile from the liver and intestinal juice secreted by the intestinal glands complete the digestion of food material.
- All the digested nutrients are absorbed by the long finger-like projections present in the ileum of the small intestine.
- These small finger-like projections of the inner wall of intestine are called as villi (singular: villus).
- Each villus has its cell membrane of the lumen side again folded into microscopic processes, called microvilli.

- Villi increase the internal surface area of the intestinal walls making available a greater surface area for absorption.
- Digested nutrients pass into the semipermeable villi through diffusion.
- Villi also help in chemical digestion of food by secreting digestive enzymes.



Villi and microvilli of the small intestine

Liver

- The liver is the largest and major digestive gland of humans
- Liver, in humans, is located in the upper right-hand portion of the abdomen.
- This organ is dark reddish brown in colour due to an extensive blood supply.
- Some of the important functions of the liver are as follows:

1. It secretes bile that helps in digestion.
2. It filters the blood coming from digestive tract before passing it to the rest of the body.
3. It detoxifies various metabolites and drugs
4. The liver makes proteins important for blood clotting and other functions.
5. It stores and releases glucose as needed.
6. It processes haemoglobin, from the dead and worn out RBCs, for the iron content (the liver stores iron).
7. Conversion of harmful ammonia to urea takes place in the liver.

Digestive Juices

- Pancreatic juice, bile and intestinal juice (succus entericus) are collectively called as digestive juices.
- A common duct from digestive glands pours the secretions into the duodenum.
- Chyme enters into the small intestine where complete digestion takes place due to the action of various enzymes.

- In the duodenum, the acidity of chyme is turned to alkalinity by the action of bile coming from the liver. This is necessary for pancreatic enzyme action.
- Bile also emulsifies the fats into smaller globules.
- Pancreatic and intestinal amylases break down the carbohydrates into glucose.
- Trypsin and chymotrypsin are the proteases responsible for the breakdown of proteins finally into amino acids.
- Lipase is the enzyme which acts on the emulsified fats and breaks them down into glycerol and fatty acids.

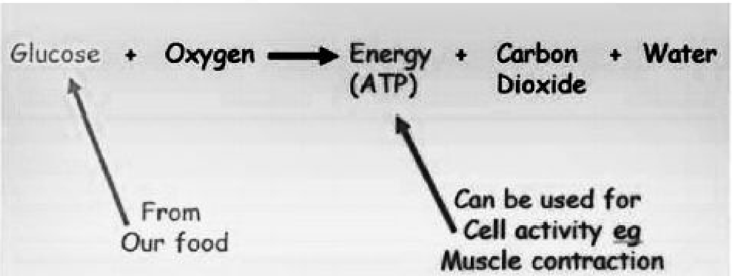
Water Absorption in Large Intestine

- The large intestine is not involved in digestion of food or absorption of nutrients.
- The major function of the large intestine is to absorb water from the remaining indigestible food matter and make the stool solid.
- The large intestine also helps in absorption of vitamins made by bacteria that normally live in the large intestine.
- The innermost layer of the large intestine also acts as a barrier and protects from microbial infections and invasions.
- Rectum stores the undigested food temporarily until defaecation.

Respiration

Introduction to Respiration

- Respiration broadly means the exchange of gases.
- Animals and plants have different means of exchange of gases.
- At a cellular level, respiration means the burning of the food at the for generating the energy needed for other life processes.
- Cellular respiration may take place in the presence or absence of oxygen.



A General Reaction of Respiration

Respiration in Humans

- The human respiratory system is more complex and involves breathing, exchange of gases and cellular respiration.
- A well defined respiratory system helps breathing and exchange of gases.

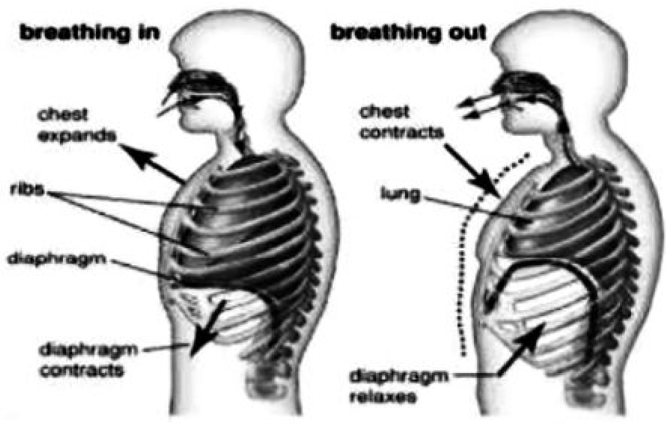
- Breathing involves inhalation of oxygen and exhalation of carbon dioxide.
- The gaseous exchange takes place in the lungs and oxygen is supplied to all cells of the body.
- Cellular respiration takes place in each and every cell.

Respiratory System

- The human respiratory system involves the nose, nasal cavities, pharynx, larynx, trachea/windpipe, bronchi, bronchioles and alveoli.
- Bronchioles and alveoli are enclosed in a pair of lungs.
- Rib cage, muscles associated with the rib cage and diaphragm, all help in inhalation and exhalation of gases.
- Exchange of gases takes place between an alveolar surface and surrounding blood vessels.
- Alveoli provide a large surface area for exchange of gases.

Physiology of Respiration

- Breathing in humans is facilitated by the action of internal intercostal and external intercostal muscles attached to the ribs and the diaphragm.
- When the dome-shaped diaphragm contracts and becomes flattened and the rib cage is expanded due to the action of intercostal muscles, the volume of the lungs increases, pressure there drops down and the air from outside gushes in. This is inhalation.
- To exhale, the diaphragm relaxes, becomes dome-shaped again, chest cavity contracts due to the action of intercostal muscles, the volume inside the lungs decreases, pressure increases and the air is forced out of the lungs.
- Inhaled air increases the concentration of oxygen in the alveoli, so oxygen simply diffuses into the surrounding blood vessels.
- Blood coming from cells has more concentration of carbon dioxide than outside air and thus carbon dioxide simply diffuses out of the blood vessels into the alveoli.
- Thus, breathing takes place due to the combined action of intercostal muscles and diaphragm while the exchange of gases takes place due to simple diffusion.

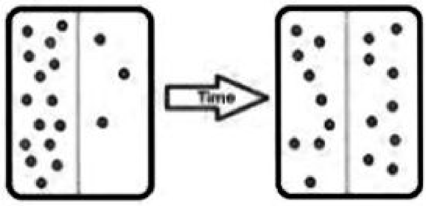


Inhalation and Exhalation

- The process of taking in air rich in oxygen is called **inhalation**.
- Similarly, the process of giving out air rich in carbon dioxide is called **exhalation**.
- One breath comprises one inhalation and one exhalation.
- A person breathes several times in a day.
- The number of times a person breathes in one minute is termed as his/her **breathing rate**.

Diffusion

Diffusion is the movement of molecules from high concentration area to the low concentration area without spending any enrgy.

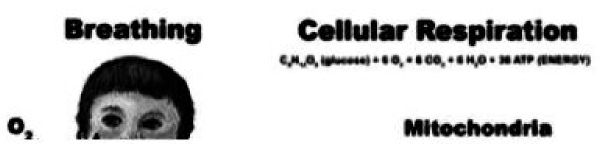


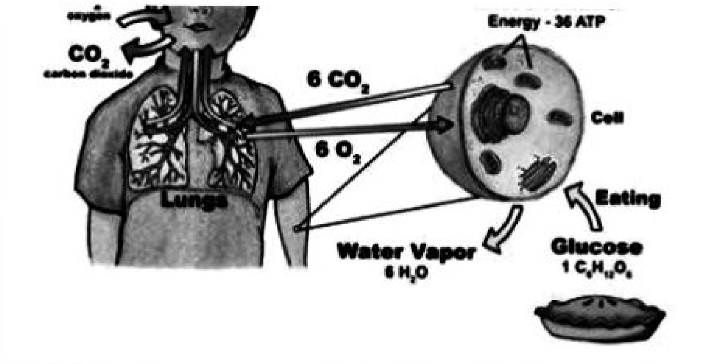
Diffusion of gas molecules

Cellular Respiration

Cellular respiration is set of metabolic reactions occurring inside the cells to convert biochemical energy obtained from the food into a chemical compound called adenosine triphosphate (ATP).

- Metabolism refers to a set of chemical reactions carried out for maintaining the living state of the cells in an organism. These can be divided into two categories:
- **Catabolism** – the process of breaking molecules to obtain energy.
- **Anabolism** – the process of synthesizing all compounds required by the cells.
- Therefore, respiration is a catabolic process, which breaks large molecules into smalle ones, releasing energy to fuel the cellular activities.
- Glycolysis, Krebs cycle and electron transport chain are the important processes of the cellular respiration.





Interlinking of Breathing and Cellular Respiration

Aerobic Respiration

Aerobic respiration is a process in which the food i.e. glucose is converted into energy in the presence of oxygen.

- The general equation of aerobic respiration as a whole is as given below-

Glucose + oxygen ⇒Carbon-dioxide + Water + Energy

- This type of respiration takes place in animals, plants and other living organisms.

Respiration in Lower Animals

- Lower animals lack a sophisticated respiratory system like lungs, alveoli etc.
- Respiration in them takes place by simple exchange mechanisms.
- Animals like earthworms take in gases through their skin.
- Fishes have gills for gaseous exchange.
- Insects have a tracheal system, which is a network of tubes, through which air circulates and gaseous exchange takes place.
- Frogs breathe through their skin when in water and through their lungs when on land

Respiration in Muscles

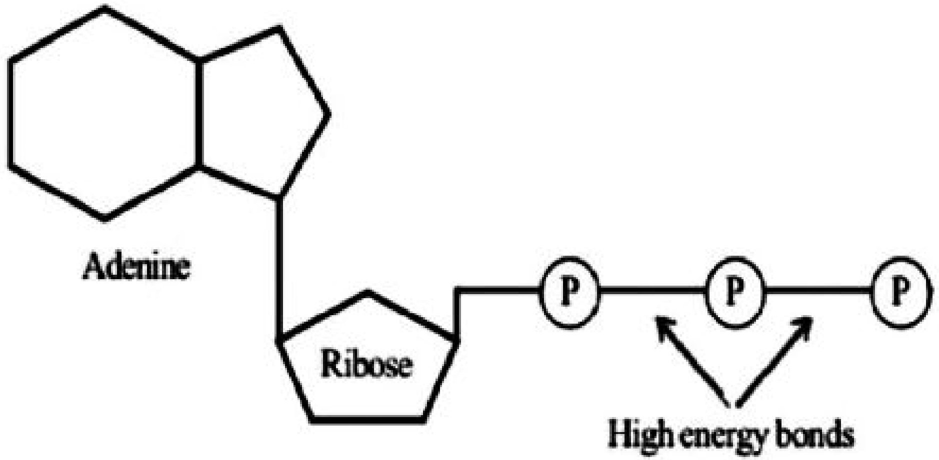
- Respiration in muscles can be anaerobic when there is not enough oxygen.
- Glucose gets broken down to carbon dioxide and lactic acid.
- This results in the accumulation of lactic acid that makes the muscles sore.
- This type of anaerobic respiration is also known as lactic acid fermentation.

ATP

- It is the energy currency of the cell.

ATP stands for Adenosine Tri-Phosphate.

- This molecule is created as a result reaction like photosynthesis, respiration etc.
- The three phosphate bonds present in the molecule are high energy bonds and when they are broken, a large amount of energy is released.
- Such released energy is then used for other metabolic reactions.



Structure of ATP

Respiration in Plants

- Unlike animals and humans, plants do not have any specialized structures for gaseous exchange
- They have stomata (present in leaves) and lenticels (present in stems) which are involved in the exchange of gases.
- Compared to animals, plant roots, stems, and leaves respire at a very lower rate.

Excretion in Humans

Excretion

Excretion is the process of removal of metabolic waste material and other non-useful substances.

- Organisms like animals have an advanced and specialized system for excretion.
- But plants lack a well-developed excretory system like that in animals.
- They do not have special organs for excretion and thus excretion in plants is not so complex.

Excretion in Unicellular Organism

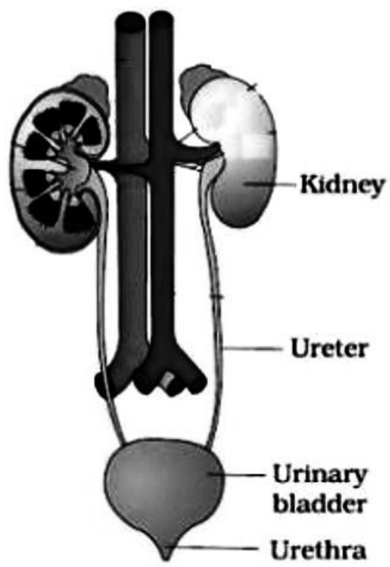
- In unicellular organisms such as amoeba and bacteria, the waste product is removed by simple diffusion through the general body surface.

Unicellular organisms like amoeba, paramecium excrete excess through tiny organelles called contractile vacuoles.

- Undigested food in unicellular animals is excreted when the food vacuole merges with the general body surface and opens to outside.

Excretory System of Humans

- The excretory system in humans includes
  - a pair of kidneys,
  - a pair of ureters,
  - a urinary bladder and
  - urethra.
- It produces urine as the waste product.



Human Excretory System

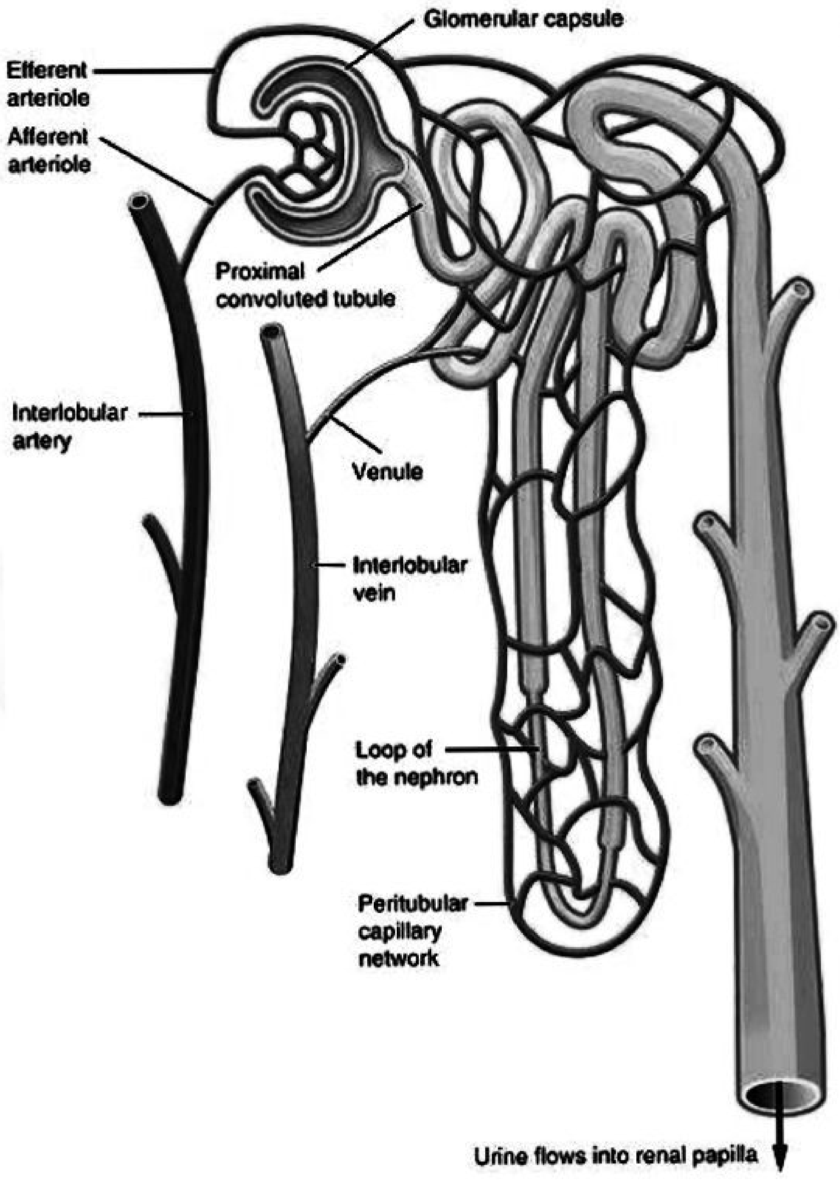
Kidneys

- Paired kidneys are the main excretory organs of the body.
- They are basically the filtration units of the human body.
- Each kidney is made up many tiny filtration units called **nephrons**.
- Kidneys perform crucial functions like:

Nephron

Nephrons are the structural and functional unit of kidney.

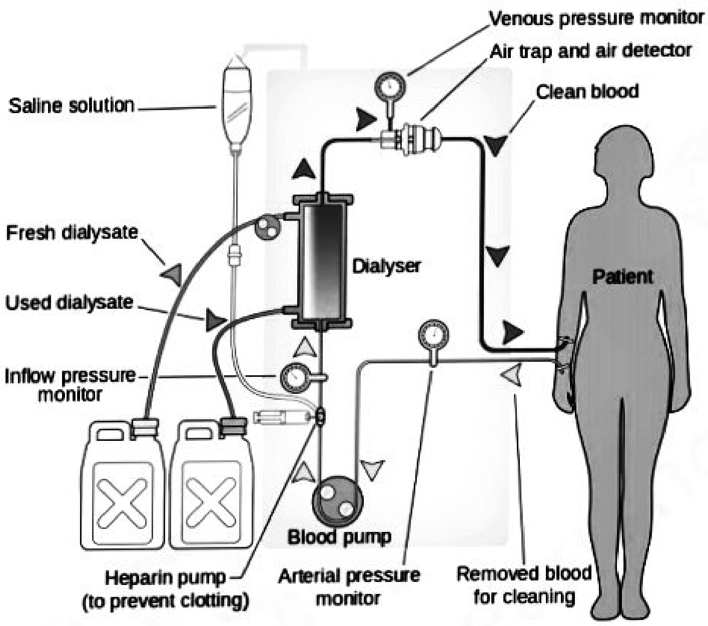
- Each kidney has millions of nephrons and it forms the basic structural and functional unit of the kidney.
- Each nephron has two parts: Malpighian body and renal tubule.
- Malpighian body is made up of cup-like structure called Bowman's capsule which encloses a bunch of capillaries called glomerulus.
- They together filter waste materials along with many useful substances.
- Renal tubule has regions called proximal convoluted tubule, Loop of Henle and distal convoluted tubule.
- These regions absorb back useful substances into the blood and also filter remaining waste substances.
- The output from nephrons is called as urine.



Structure of a Nephron

Haemodialysis

- When the kidneys fail, it results in a lot of complications and to compensate this situation a technology called dialysis has been developed.
- It uses a machine filter called a dialyzer or artificial kidney.
- This is to remove excess water and salt, to balance other electrolytes in the body and remove waste products of metabolism.
- Blood from the body is removed and flowed through a series of tubes made up of a semipermeable membrane.
- A dialysate flows on the other side of the membrane, which draws impurities through the membrane

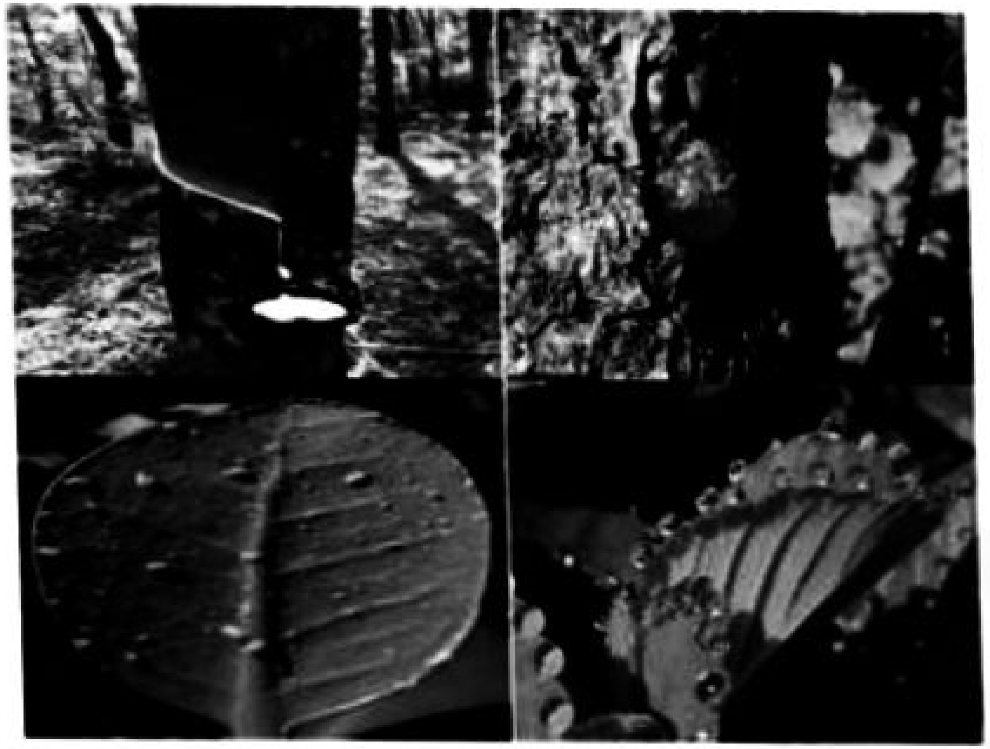


Hemodialysis and artificial kidney

Excretion in Plants

- The cellular respiration, photosynthesis, and other metabolic reactions produce a lot of excretory products in plants.
- Carbon dioxide, excess water produced during respiration and nitrogenous compounds produced during protein metabolism are the major excretory products in plants.
- Plants produce two gaseous waste products i.e. oxygen during photosynthesis and carbon dioxide during respiration.
- Excretion of gaseous waste in plants takes place through stomatal pores on leaves.
- Oxygen released during photosynthesis is used for respiration while carbon dioxide released during respiration is used for photosynthesis.
- Excess water is excreted by transpiration.

- Organic by-products generated by the plant are stored in different forms in different parts.
- The gums, oils, latex, resins, etc. are some waste products stored in plant parts like barks, stems, leaves, etc.
- Eventually, plants shed off these parts.
- Few examples of the excretory products of plants are oil produced from orange, eucalyptus, jasmine, latex from the rubber tree, papaya tree, and gums from acacia.
- Sometimes plants even excrete into the soil.



Different forms of excretory products in plants

. EXCRETION IN ANIMALS

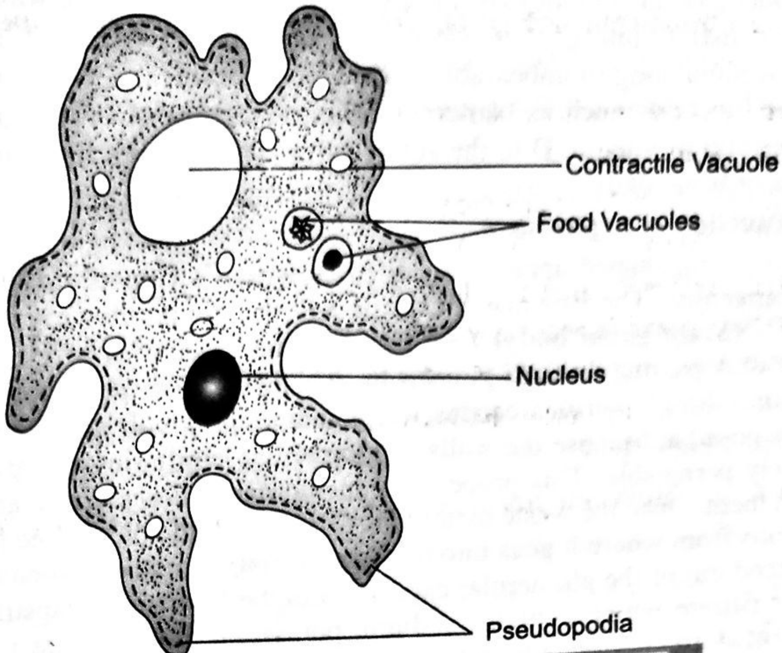
Animals usually have definite excretory organs through which they eliminate waste products and water. The protozoans, the single celled animals, lose waste matter by simple diffusion through the cell membrane into the surrounding water. Some excretion and osmoregulation occurs by way of contractile vacuoles. In sponges, the water enters through dermal ostia, passes through various canals, enters the spongocoel and finally leaves through the **osculum**. The waste matter entering the coelenteron in Cnidaria (*Hydra*) diffuses out through the oral opening. The main excretory matter in sponges and cnidaria is ammonia which leaves the cells by diffusion. In flat worms (tape worms, flukes, planarians, etc.), the main excretory units are single celled flame-cells (protonephridia) leading into tubules that open out by one or more excretory pores. The flame cells also bring about osmoregulation. The higher animals develop various tubular structures as their excretory organs. In earthworm, the excretion and osmoregulation occurs through tubular structures constituting **nephridia.** The insects, centipedes arachnids and millipedes have **malpighian tubules** for excretion. The mollusks and vertebrates have **kidneys** for excretion and osmoregulation. The urinary system of human beings consists of a pair of kidneys having nephrons. A nephron is a long tubule which is regarded as a unit of structure and function in a kidney. A kidney contains about 1 million nephrons, each about 3 cm long.

The major excretory products of animals are nitrogenous compounds such as ammonia, urea and uric acid, bile pigments, water and small amounts of other waste products.

1 Excretion in Amoeba

Amoeba is unicellular organism belonging to protozoa. It lives in fresh water and removes carbon dioxide and ammonia by simple diffusion over the entire surface of the cell.

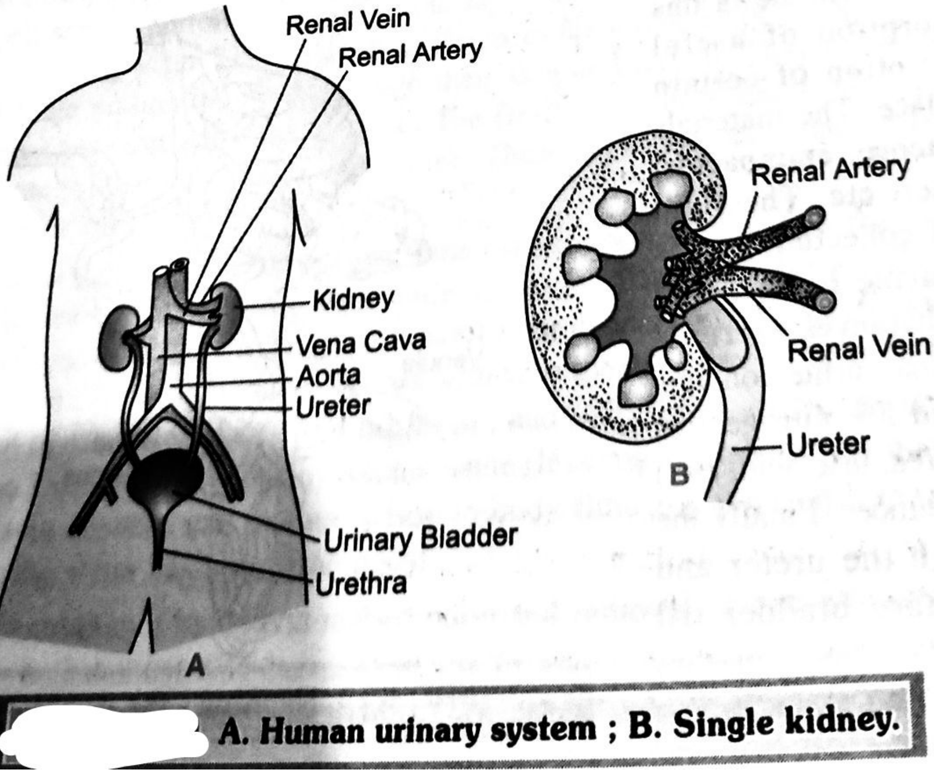
The fresh water protozoans such as *Amoeba* face the problem of eliminating water which they gain by osmosis from their surrounding medium. In fact, the osmotic concentration of the cytoplasm of the cells is higher in protozoans in comparison to the osmotic concentration of the surrounding water in which they live. We know that higher concentration of solution has lower water potential and lower concentration of solution has higher water potential. We also know that water moves from the region of higher water potential to the region of lower water potential. Thus, water moves from external water medium to the cell by the process of osmosis through the cell membrane. Water entering constantly into the cell must be eliminated in order to prevent the bursting of cell. This is done by osmoregulatory organelle known as **contractile vacuole**). In *Amoeba,* contractile vacuole can form anywhere within the cell. It enlarges in size by getting water from the cytoplasm. Some waste produced in the cell may also enter into the contractile vacuole. It gradually moves close to the plasma membrane. The contractile vacuole then releases its fluid into the external environment through a temporary pore at any points on the outer surface of the cell.



Contractile vacuole in *Amoeba*.

Excretion in Human Beings

Excretory system in human beings (also known as urinary system) (Fig. 1.24) consists of a pair of **kidneys** (sing. **kidney**), a pair of **ureters,** a urinary **bladder** and a **urethra**. The two kidneys are located towards the back of the lower part of the abdominal cavity, one on either side of the backbone. Left kidney is slightly larger and placed a little higher than the right kidney. The blood from aorta enters into kidneys via the renal arteries and returns to the posterior vena cava via renal veins. Urine formed in the kidneys passes by a pair of ureters to the bladder where it is stored until it is released via the urethra.



A. Human urinary system ; B. Single kidney.

Structure and function of kidneys :

There are two kidneys in humans. Each kidney is purplish-brown, slightly flattened and shaped somewhat like rajma bean. It is about 12 cm long, about 6 cm thick and weighs about 150 gms. Internally a kidney is made of numerous microscopic excretory units called nephrons (   ). Single kidney contains about a million nephrons, each approximately 3 cm long.

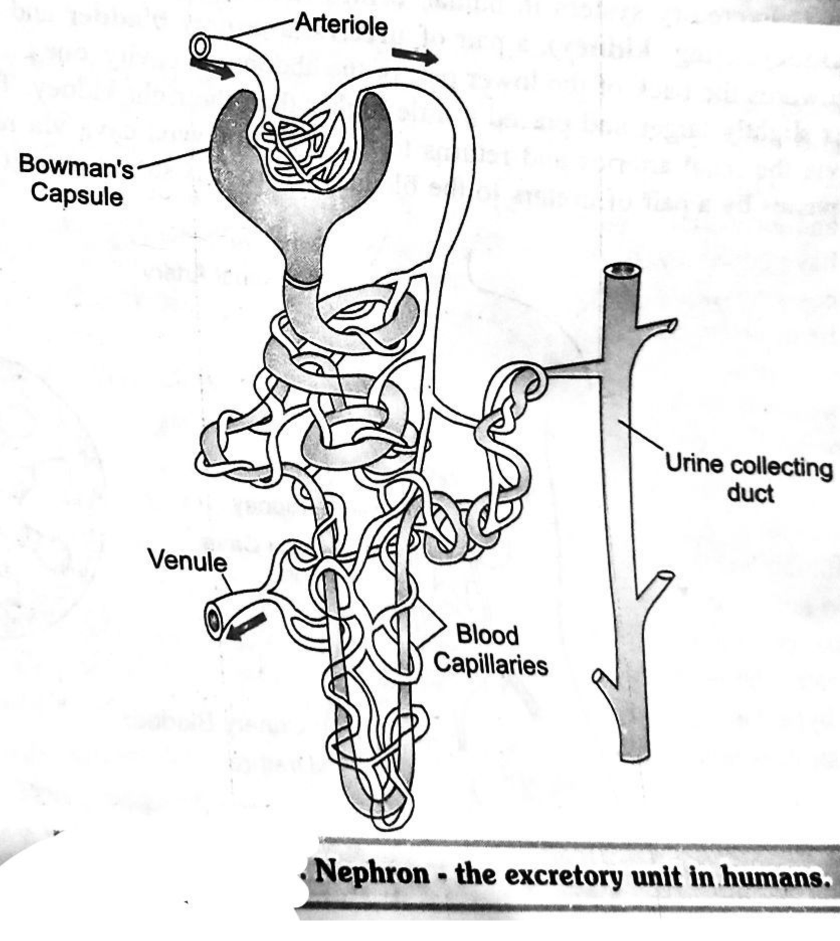
The most important function of kidneys is filtration of blood to excrete the waste products of metabolism. If these waste products, mainly nitrogenous waste such as urea and uric acid, are not removed from the blood, they will start accumulating to unbearable toxic levels. Besides filtering out the waste products, the kidneys perform other functions such as osmoregulation, secretion of erythropoietin, enzyme-renin and conversion of inactive form of vitamin D to the active form. The kidneys filter about 190 litres of blood to produce 0·9–1·9 litres of urine daily.

Structure nad function of nephrons :

Each nephron has a cup shaped upper end, called **Bowman's Capsule**. It contains a bundle of blood capillaries, called **glomerulus.** The Bowman's capsule and the glomerulus together form a globular body, called **renal corpuscle (Malpighian body)**. The blood in the capillaries of glomerulus comes from aorta via renal arteries and after passing through glomerulus it returns to the posterior vena cava via renal veins. The blood entering into the glomerulus carries waste materials which are filtered out in the Bowman's capsule. Filteration is possible because the walls of glomerular capillaries and Bowman's capsule are very thin and are selectively permeable. This property of membranes allows water and small molecules in the blood to pass through them. Once the waste material is filtered out, the blood free from these waste materials goes into the renal veins from where it goes into the heart through posterior vena cava. The fluid containing waste materials is forced out of the glomerular capillaries in the Bowman's capsule. The filtered out fluid is known as glomerular filtrate which contains sodium, potassium and chloride ions, glucose, amino acids along with urea, uric acid and a large amount of water.

Bowman's capsule is named after Sir William Bowmann (1816-1892), a British Surgeon and anatomist and Malpighian Corpuscles are named after Marcello Malpighi (1628-1694), an Italian physician and biologist.

Bowman's capsule leads into a long tubular structure into which the glomerular filtrate moves away. The tubular structure is convoluted, twisted, folded and has U-turn before meeting the collecting duct (Fig. 1.25). During the flow of glomerular filtrate in this long tube, reabsorption of useful materials and secretion of certain substances takes place. The materials reabsorbed are glucose, aminoacids, Na^+, K^+, Cl^-, water, etc. The fluid reaching the end of collecting duct is called **urine. The urine is fluid and dissolved waste substances excreted by the kidneys.** Human urine contains about 95% water and 5% nitrogenous substances (mostly urea, uric acid, etc.) and a few other substances. Finally the urine moves through the ureter and collects in the urinary bladder till thrown out of the body through urethra and urinary opening.



Nephron - the excretory unit in humans.

EXCRETION IN PLANTS

Plants do not face such problems of elimination of waste excretory products as the animals. Primarily, the plants are the **producers** and they synthesise all their organic requirements according to demands. The waste substances, if produced in metabolic processes of plants, are disposed off by the following methods :

1. The major waste substances, produced by certain metabolic activities of plants, are oxygen (O_2), carbon dioxide (CO_2) and water. Carbon dioxide and water are used by the process of photosynthesis. The oxygen, which inhibits photosynthesis in higher concentration, escapes from plants into the environment by diffusion.

2. Excess salt is removed through hydathodes along with guttation water (the water drops appear in the margins of some herbaceous plants)

3. Many breakdown products are recycled in the synthesis of new metabolic products.

4. Most of the toxic waste products are stored within dead permanent tissues such as heart wood (non functional part of xylem in the trunk and branches), leaves or bark which are removed periodically.

5. Some excess organic acids combine with excess cations and precipitate out as insoluble crystals (such as calcium oxalate, calcium pectate, etc.) which can be safely stored in plant cells.

6. Some waste substances are eliminated through petals, fruits and seeds.

7. Aquatic plants lose their waste products by diffusion directly into the water.

8. Some excretory products such as **latex, gums, essential oils,** etc. are stored in special type of tissues and glands. For example, laticiferous tissue collects latex (which is the source of natural **rubber**), resin ducts store **resin** (the resin of pine trees yields turpentine), mucilaginous ducts store mucilage, oil glands store essential oils, etc.

OSMOREGULATION

The mechanism of osmoregulation in organisms is structural, physiological and behavioural adaptation which regulates : (*i*) the concentration of solutes within the cells or body fluids, and (*ii*) the total volume of water present in the body. In other words, **osmoregulation is the process of regulating ion concentration and water content in the body.**

Osmoregulation is very much related to the habitats where the organisms live. Fresh water, marine and terrestrial environments pose its own osmotic problems for organisms. Fresh water animals generally have concentrated cell sap (hypertonic solution or the sap with lower water potential) in comparison to the concentration of surrounding water. These osmotic differences favour intake of water. The animals inhabiting fresh water take up large amount of water through their skin and mouth. They overcome the problem of excess water by frequent excretion of lot of urine. The fresh water protozoans have a constant intake of water by osmosis through their cell surface membrane. These organisms use contractile vacuoles to expel osmotic water from their cells.

The cells of marine animals have almost the same osmotic concentration as the sea water. Therefore, marine protozoans do not have functional contractile vacuoles. The land (terrestrial) animals, including human beings, need to conserve water in order to avoid the dangers of desiccation. Restriction of water loss on land is associated with : (*i*) Body surface covered with an impermeable cuticle or skin; (*ii*) Evolutionary change from excretion of ammonia to urea and uric acid ; and (*iii*) Ability of excretory system to reabsorb water. The mammalian kidney can produce hypotonic urine (less concentrated in comparison to body fluid) or hypertonic urine (more concentrated in comparison to body fluid) by reabsorption or removal of excess water depending upon the water balance of the body.

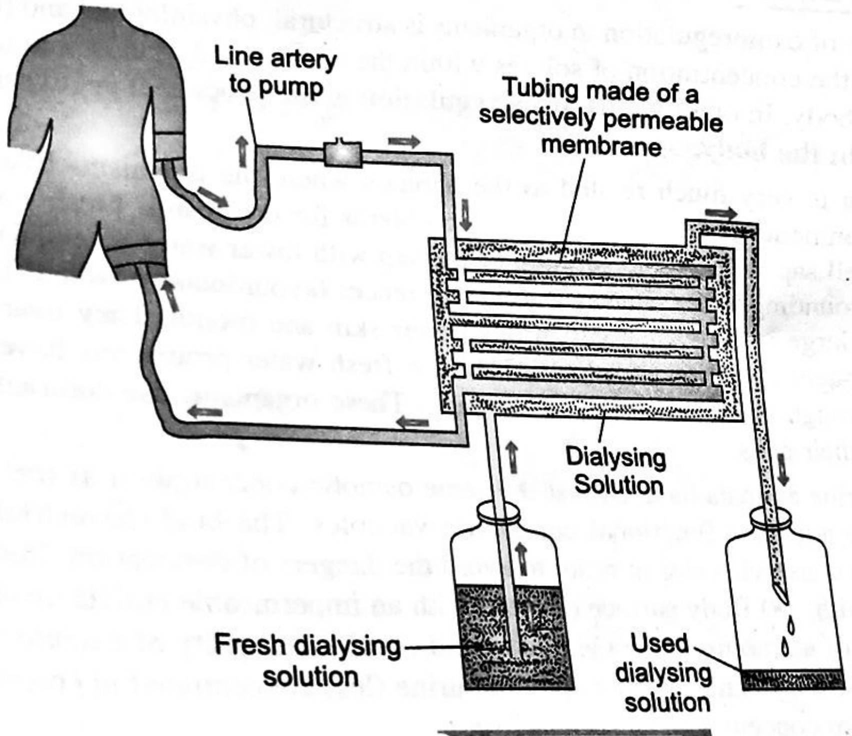
The osmotic concentration of blood and reabsorption and removal of water from the urinary track are under the control of hypothalamus. Any increase in the blood concentration results in the release of an antidiuretic hormone by the posterior pituitary gland. This causes uptake of water by reabsorption from the collecting ducts. Moreover, the hypothalamic thirst centre also initiates drinking water to restore the blood concentration. Thus, reabsorption and removal of excess water are under the control of hormones.

Kidneys, not only function to remove toxic waste, but also act as osmoregulatory organs by controlling the water balance and levels of mineral-ions in the body.

RENAL FAILURE AND TECHNOLOGY FOR SURVIVAL

Kidneys are most vital organs for survival of the organisms. Though the kidneys remain active throughout the life, its efficiency gradually declines with normal ageing process. For example, its activity declines to about 50% by the age of 70 in human beings. The other causes of decline in the normal functioning of kidneys are diseases such as kidney infection, injury or restricted blood flow to kidneys. These abnormalities result in kidney damage and malfunctioning. A general term for decline in the performance of kidney due to a disease is **kidney failure**. Though it is not common, it may result to death within a couple of weeks if not treated properly. Kidney failure is often due to build up of potassium ions which causes heart failure.

The failure of both kidneys immediately need medical intervention. There are two alternatives of kidney failure (*i*) A matching kidney from a healthy person may be transplanted, or (*ii*) An 'artificial kidney' machine may be employed in order to get rid of metabolic wastes from the blood and to maintain normal levels of water and mineral ions in body fluids. The artificial kidney functions on the same principle as the normal kidney and the procedure is called **dialysis**. The blood is pumped out of the body and made to flow into the dialysis machine. Heparin is added to the blood to prevent clotting. The blood circulates slowly through the long cellulose tubes coiled in a tank filled with dialysing solution. The cellulose membrane allows ions, very small molecules and water to diffuse through it. The blood corpuscles, platelets and protein molecules are too large and do not pass through the membrane. Finally the cleansed blood is pumped back into patient.



Renal dialysis.

1.10 EXCRETION

Under normal conditions, the living cells of organisms (both plants and animals) work all the time in order to sustain life of the organism. Most of this work is done in the form of biochemical reactions. Some examples of these reactions are — synthesis of proteins, fats, carbohydrates, hormones, pigments, oxidative breakdown of glucose, and many other catabolic (breakdown) and anabolic (synthetic) reactions. During these biochemical reactions — (*i*) Some metabolites are produced which may be toxic if accumulate in the cells and (*ii*) Water and salt content of the body may increase or decrease. The two important homeostatic processes occurring in living organisms which help to maintain the steady state are : **1.** Excretion and **2.** Osmoregulation.

1. Excretion : Excretion is a biological process by which an organism gets rid of excess or toxic waste products of metabolism. If allowed to accumulate these products of organism's cells would generally be harmful and prevent the maintenance of a steady state. The definition of excretion given above clearly states that the waste products have been made by the body itself and they are the products of metabolism. Therefore, **egestion** (removal of undigested food) is not regarded as excretion because it is not the product made by the human body. It is the leftover part of the material taken into the gut through mouth.