FYBSc (CZ), Sem I
Zoology paper I

Respiration

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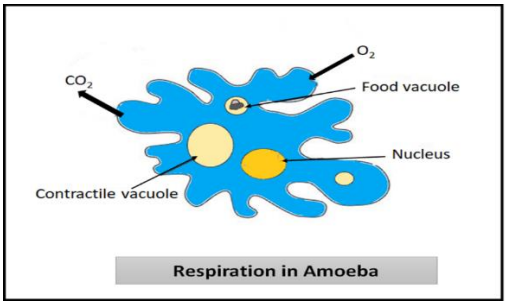
Respiration is a metabolic process common to all living things. It includes breathing, transport of gases as well as the oxidation of food leading to liberation of CO2 & energy.

For efficient gaseous exchange, a respiratory surface must be thin, moist, highly vascular, permeable to the gases i.e. O2 & CO2 having large surface area & it must be in direct contact with the source (air or water).

Respiration in Amoeba-

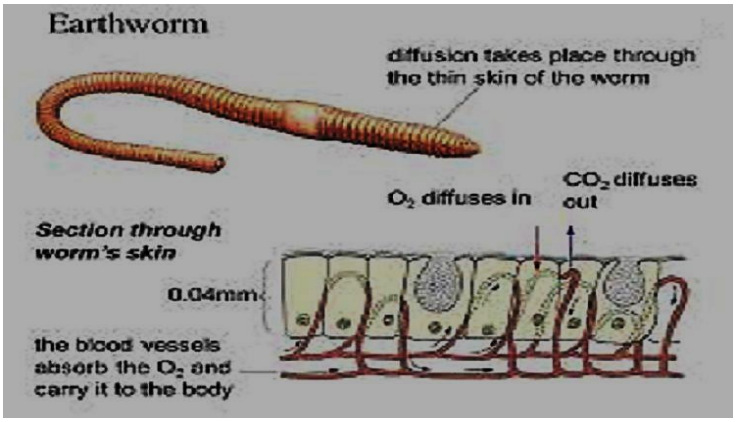
Amoeba is an unicellular eukaryotic organisms. Amoeba has no respiratory organs and no respiratory pigments. Respiration in Amoeba occurs by diffusion through the general body surface (plasmalemma). Amoeba is an aerobic, takes in oxygen & gives off carbon dioxide like other animals. The oxygen dissolved in the surrounding water passes into the cytoplasm of Amoeba by diffusion. Since the concentration of oxygen in the water is higher than that of Amoeba's cytoplasm, oxygen constantly enters & is immediately used up in the burning of food. Thus, the concentration of oxygen within the animal always remains lower than that in the outside water, & oxygen continuously enters the animal & is available for energy requirements. During metabolic activities the oxygen burns or oxidizes the living matter or cytoplasm of Amoeba & breaks it into simpler compounds. As a result, water, carbon dioxide & urea are formed and energy is liberated which is stored in the high energy bonds of ATP & used in the life activities of the organism. Carbon dioxide diffuses to the outside because it is always at a high concentration within the body of Amoeba than in the surrounding water. If an Amoeba is placed in hydrogen instead of oxygen, then movements cease & death results, if carbon dioxide is introduced in place of oxygen then the Amoeba first encysts but finally dies.



Respiration in Amoeba

Respiration in Earthworm-

In earthworm the entire body surface performs respiration. Since the skin acts as the respiratory surface, it is called cutaneous respiration. The skin is highly vascular & is kept moist by the integument glands & the ceolomic fluid. Exchange of gases takes place through the moist skin which is permeable to respiratory gases. If the skin dries, the earthworm dies of suffocation.
The blood contains the respiratory pigment haemoglobin which is dissolved in the plasma. The epidermis of the body wall acts as a permeable membrane through which atmospheric oxygen diffuses in its capillaries & combines with haemoglobin to form oxyhemoglobin & is circulated to the tissues where the oxygen tension is low. The oxyhemoglobin breaks up to release oxygen & hemoglobin in reduced state. The oxygen is used for oxidization of food. The carbon dioxide released mixes in the blood & is diffused out of the body through the moist skin.



Source:https://www.goconqr.com/p/5270460-breathing---gaseous-exchange-and-respiration-notes

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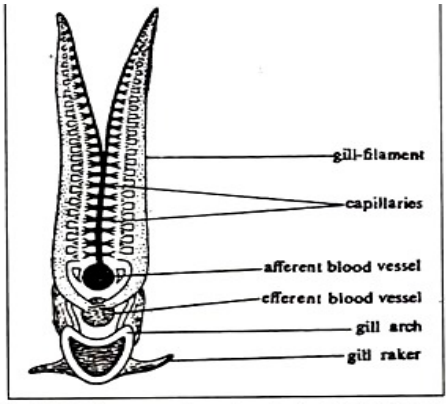
Gills of bony fish-

There are four pairs of gills contained in the branchial chambers. Each branchial chamber is covered by operculum and the branchiostegal membrane which is attached to the posterior margin of the operculum. The wall of the pharynx is perforated by five gill slits on each side and is separated by four gill-arches or inter-branchial septa.
There are four pairs of gills and the gills are holobranch type. Each gill has a double row of gill-filaments (holobranch) and is supported by gill-arch with gill-rakers. The two rows of gill lamellae are separated by the inter-branchial septum which is short and compact.
Each gill arch bears one afferent and two efferent branchial vessels (Fig. 6.24). The pseudo branch of the hyoid arch consists of a comb-like body. Each pseudo branch is composed of a single row of giIl-filaments on the inner surface of operculum.



Source:https://www.biologydiscussion.com/fisheries/bony-fish/rohu-systematic-position-distribution-and-structure-bony-fish/40661#:~:text=Each%20gill%20has%20a%20double,6.24).

Physiology of respiration in bony fish (Rohu)-

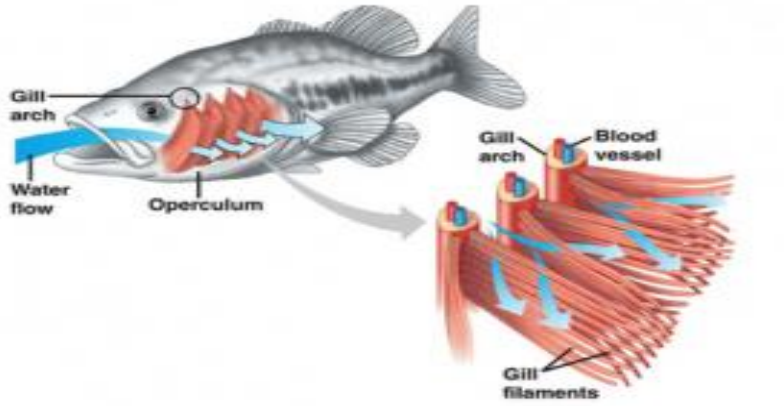
Inspiration:
During inspiration, the outer opening of the gill-chamber remains tightly closed to the body wall by the branchiostegal membrane and the two opercula bulge out to increase the accommodating capacity of the pharyngeal and buccal cavities. As a consequence, water from exterior rushes inside through the opened mouth and fill in the bucco-pharyngeal cavity.

Expiration:
Immediately with the entry of water, the pharyngeal and the buccal cavities contract and exert pressure to the contained water. As the mouth, by this time, becomes closed by oral valves, the contained water finds the way out through the gill-slits. The operculum as well as the branchiostegal mem-brane is lifted by this time and the water from the gill-chambers goes out through the opening of the gill-chamber. The dilatation and the contraction of the pharyngeal cavity are caused by the alternate retraction and protraction of the hyoid arch supporting the bucco-pharyngeal cavity.

Physiology of gaseous exchange in Rohu-

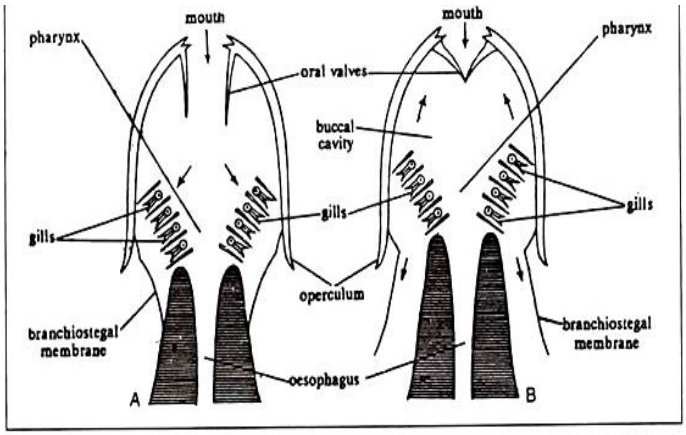
The gills are highly vascular structures. The afferent branchial artery carrying the deoxygenated blood is situated very superficially on the outer edge of the gill. The afferent brachial artery breaks up into capillaries in the substance of the gill.
During the transit of water through the gill-slits, the deoxygenated blood in the capillaries of the gill-filaments takes oxygen dissolved in water and gives out carbon dioxide by diffusion. The blood thus aerated, is collected by efferent branchial arteries and is conveyed to the different

parts of the body.



Source:https://byjus.com/biology/respiration-fish-mechanism/

Physiology of respiration in Rohu-



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Respiration in frog-

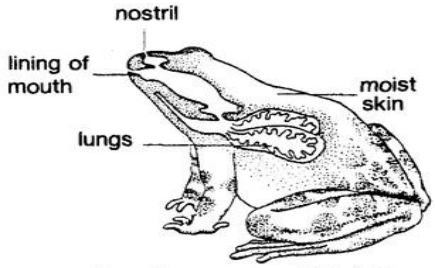
Frog is an amphibian having three respiratory surfaces that it uses to exchange gases with the surroundings, namely the skin, the lining of mouth & lungs.

When the frog is underwater, respiration is carries on entirely by the skin. The skin is thin, permeable to water contains large network of blood vessels. Oxygen gets dissolved in the film of water covering the skin & is absorbed by the capillaries having low oxygen concentration. The presence of the respiratory pigment, hemoglobin enhances the absorption of oxygen. Respiration by skin is a continuous process & goes on in water & on land as well. When the frog is out of

the water, mucus glands in the skin keep the frog moist which helps absorb dissolved oxygen from the air this is termed as cutaneous respiration.

The highly vascular bucco-pharyngeal membrane also acts as a respiratory surface. While at rest, this process is their predominate form of breathing & is known as bucco-pharyngeal respiration.

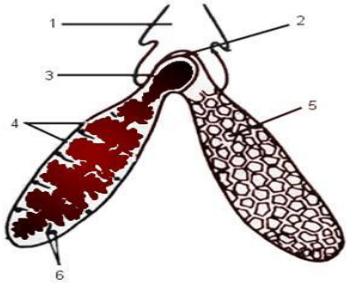
During bucco-pharyngeal respiration, the mouth remains closed, air is taken in through the nostril & passed into the bucco-pharyngeal cavity. The lowering of the floor of the buccopharyngeal cavity causes the air to enter the cavity. The oxygen dissolved in the mucous & goes into the blood. When the floor of the buccopharyngeal cavity is raised, carbon dioxide is expelled. The glottis remains closed to prevent the air from entering the lungs. This is the main form of breathing while at rest because the lungs are poorly developed.



Breathing organs of the frog

Source:https://www.askmattrab.com/notes/347-respiration-in-frog

Respiration with the help of lungs is termed pulmonary respiration. This method of respiration is used occasionally when the need of oxygen is more. A pair of lungs is located in the anterior region of coelom on the dorsolateral side of the heart. They are a pair of thin-walled sacs connected to the mouth through an opening, the glottis. The frogs do not have trachea. The lungs are delicate, thin-walled, elastic sac-like structures covered by visceral peritoneum. The inner surface of the lungs is thrown into a large number of irregular & radially arranged folds. The space between two consecutive folds of the inner surface of the lungs forms an alveolus. The alveoli greatly increase the inner respiratory surface of the lungs & are richly supplied with blood vessels. The muscle fibres in the wall of lungs allow it to expand & contract.



1. Hyoid apparatus 2. Glottis
3. Laryngeotracheal chamber
4. Alveoli 5. Right lung

(A) Structure of lung

Source: https://socratic.org/questions/what-does-a-frog-s-trachea-do

Mechanism of respiration in frog-

The muscles in the buccal cavity as well as the hyoid apparatus present on the floor of the buccal cavity aids in the air being drawn into & expelled out. The buccal cavity has two pairs of muscles, a pair of sternohyal muscles & a pair of petrohyal muscles. These muscles are attached to the under surface & upper surface of the hyoid apparatus respectively. These bring about rhythmic lowering & raising of the floor of the buccal cavity. When the sternohyal muscles contract, the hyoid apparatus & the floor of the buccal cavity is lowered & air comes in through the external nares into the buccal cavity. Tightening of the jaws close the external nares. The air is trapped in the mouth. The glottis opens. The petrohyals contract & raise the hyoid & the floor of buccal cavity. The air is pushed down the glottis & into the lungs. This process is inspiration. During expiration carbon dioxide from the lungs is expelled from the body. With the external nares closed, the sternohyal muscles contract, floor of the buccal cavity is raised & the air is forced out. Frog lungs do not inflate & collapse on their own, they are poorly developed compared with those of other vertebrates.

Respiratory system of pigeon-

The respiratory system comprises the respiratory tract, the lungs & the air sacs. The respiratory tract includes the nares, nasal sacs, glottis, rudimentary larynx, trachea & the syrinx.

1. Nares & nasal sacs-There is one pair of slit like openings at the base of the upper beak which are known as the external nares. They are overlapped by a sensitive pad of skin called cere. The external nares open into the nasal sacs which open into the pharynx by internal nares.

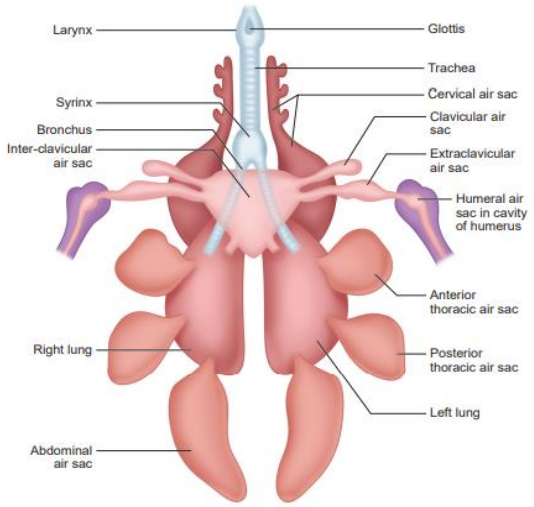
2. Glottis- The glottis is present near the base of the tongue & it opens into a rudimentary larynx situated at the anterior most part of the trachea.

3. Trachea- The larynx opens into a long, cylindrical & flexible tube called trachea,which runs through the neck & lies ventral to the esophagus. The trachea is supported by compete rings of cartilage. It divides into two bronchi, each entering in lung on that side.

4. Syrinx- At the division of the trachea into bronchi the syrinx is present for sound production in birds. It is a characteristic feature of birds and is not present in any other vertebrate. The syrinx is an expanded chamber at the posterior end of the trachea before the junction of bronchi.

5. Lungs- There is one pair of bright red & spongy lungs present in the pleural cavities. The bronchus enters into the lungs & is known as pulmonary bronchus.

The bronchus continues as a main trunk to the distal end of the lung & it known as mesobronchus. From the mesobronchus arise the secondary bronchi which branch into tubes with uniform diameter known as parabronchi. The parabronchi are anastomosing fine tubules or air capillaries. The parenchyma of the lungs shows hexagonal areas each consisting of a central parabronchus surrounded by air capillaries & blood capillaries. The parabronchus & air capillaries work as a respiratory surface where exchange of gases takes place. Thus a series of parabronchial tubes with looped air capillaries carry on respiration instead of alveoli.



Source:https://www.brainkart.com/article/Anatomy-of-Pigeon--Endoskeleton,-Digestive,-Respiratory,-Circulatory,-Arterial,-Nervous,-Venous-system_33187/

Air sacs in pigeon-

Presence of air sacs in an important feature of the respiratory system of birds. Four secondary bronchi do not stop at the lung wall of each side: rather they pass through the walls of the lungs and are continued as thin walled sacs. The air sacs are bladder-like thin walled, membranous, non-muscular and non-vascular structures. There are nine air sacs in pigeon and all of them remain in communication with the pneumatic cavities of bones.

A. Interclavicular air sac- this is an unpaired and median air sac with two ducts, one opening into each lung. Each side of this air sac gives off two extensions viz. clavicular air sac & humoral air sac. These sacs communicate with the cavities of the bones.

B. Cervical air sacs- These are paired air sacs and are places at the base of the neck & lie in front of the lungs. Each sac sends diverticula into the cervical vertebrae & the skull.

C. Anterior thoracic air sacs- One pair of anterior thoracic air sacs is present at the ventral side of the lung. They are in close contact with the ribs.

D. Posterior thoracic air sacs- This is one pair of air sacs which overlaps the posterior end of the corresponding lung.

E. Abdominal air sacs- This is one pair of air sacs each one arising from the distal end of its lung. They lie along the dorsal wall of the abdomen. It is ventral to the kidney & in close contact of the small intestine.

The air sacs are not respiratory organs but they are accessory respiratory organs active as reservoir of gases. They act as balloons giving buoyancy during flight.

Mechanism of respiration in pigeon-

When the bird is at rest, the inspiration is brought about by intercostal muscles. By the contraction of these muscles the ribs are raised & the sternum area is lowered. The area of thoracic & abdominal cavities is increases. As a result, pressure on the lungs is reduced & air is drawn in into the lungs & passes into the air sacs also. Exchange of gases takes place in the air capillaries. The process of expiration is brought about by the movements of thoracic & abdominal muscles, hence these muscles are expiratory. The area of thoracic & abdominal cavities decrease & as a result, pressure on lungs increases. The air goes out of the lungs & finally through the external nostrils. By the compression of the air sacs, the air goes into air capillaries. This is a secondary supply of fresh air to the air capillaries.

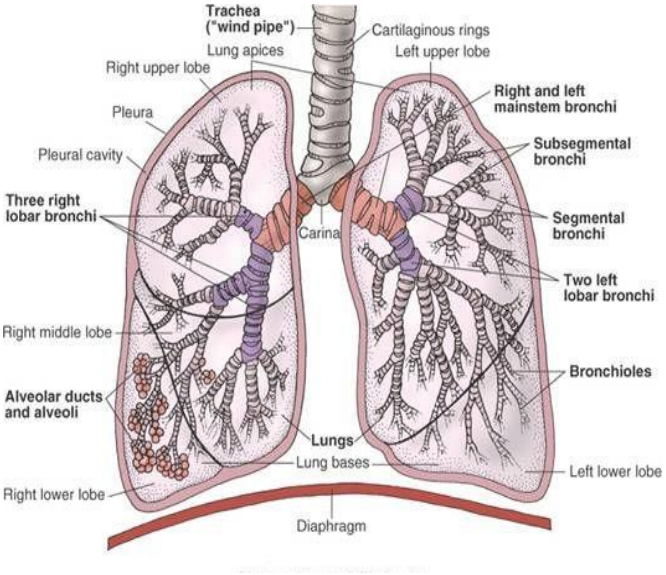
During flight, the skeleton is kept rigid during flight & the sternum becomes immovable. The area of the abdominal & thoracic cavities is increased or decreased by the movement of the pectoral muscles of flight. The pressure of viscera against the air sacs causes the air to circulate. The respiration takes place also by the movement of sternum towards the vertebral column & away from it. When the bird flies faster, rate or respiration is rapid.

Structure of lungs in man-

The human respiratory system consists of a respiratory tract or upper respiratory system, located outside the thoracic cavity and respiratory organs or lower respiratory system situated inside the thoracic cavity. The upper respiratory system consists of nose, pharynx & associated structures.

Lungs-The lungs are a pair of spongy organs lying in the thoracic cavity formed by the ribs. They are soft, elastic & spongy, separated from each other by the heart & other structures.

The right lung is slightly thicker & broader than the left. It is also somewhat shorter than the left because the diaphragm is higher on the right side to accommodate the liver which lies inferior to it. A two- layered sac, called the pleura, surrounds & protects the lungs. The parietal pleura attached to the wall of the thoracic cavity & the visceral pleura enclose the lungs.



Source:https://www.pinterest.com/pin/481392647646298295/

A fluid between the two layers reduces friction & allows smooth movement of the lungs during breathing. Each lung is divided into lobes by transverse & oblique grooves called fissures. The left lung is divided into two, a superior & an inferior lobe by an oblique fissure while the right lung is divided into 3 lobes, the superior & middle lobe is separated by a horizontal fissure & the inferior lobe by an oblique fissure. The left lung also has a cardiac notch along its antero-median border to accommodate the heart.

The structure of the lungs includes the bronchial tree, fine branches of bronchioles each one ending in a pulmonary alveolus. The pulmonary alveoli are tine sacs (air sacs) characterized by a single-layer membrane with blood capillaries at the other end. Each alveolus is lined by a flat squamous epithelium & is highly glandular & vascular. In the alveoli blood & air are separated by only two layers, the epithelium of alveoli & endothelium of the capillaries. The barrier between the two has a thickness of about 0.5micron which allows efficient exchange of gases. The number of alveoli in the lung is estimated to be approximately 750 million.

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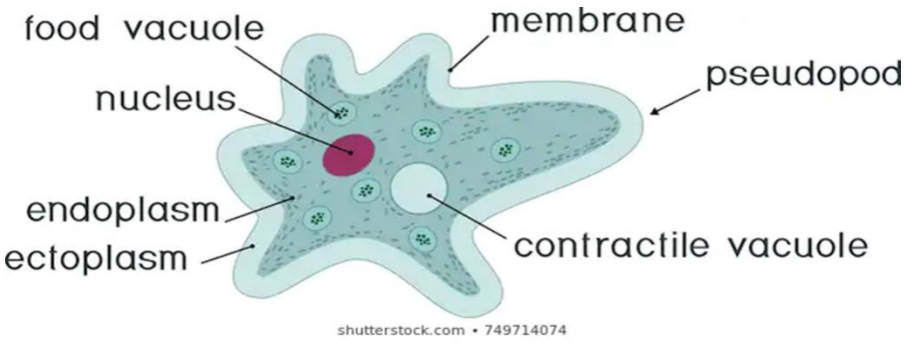
Excretion **Dr. Shirley**

Excretion

Contractile vacuole in Amoeba-

Amoeba is a unicellular animal, a protozoan in which the body is exposed directly to the environment. Waste material can be eliminated into the external medium by diffusion across the cell boundary. Amoeba eliminates most of its excretory matter through the general body surface. The contractile vacuole may help in excretion but its primary function is to regulate the water content of the body. The cytoplasm has high osmotic pressure compared to the surrounding water & hence water diffuses into the cell through the plasma membrane. This continuously accumulated water within the cell has to be eliminated; this is brought about by the contractile vacuole. Contractile vacuole is thus osmoregulatory in function. Marine species of Amoeba lack contractile vacuole since they are iso-osmotic with the sea water.

- **The contractile vacuole**- It is a prominent, clear, spherical & bubble-like body. It is surrounded by a unit membrane & many mitochondria. Mitochondria provide energy for actual formation & functioning of the vacuole. Water filled feeder vacuoles which are tiny & membrane-bound get incorporated into the contractile vacuole & fill it with the water. It keeps moving along the streaming endoplasm & when full, it reaches the plasma membrane & bursts due to contraction of surrounding cytoplasm expelling its contents. The phase of enlargement in the contractile vacuole is referred to as diastole & the phase of contraction as systole. Its position is not fixed, it contracts & disappears at regular intervals.



Source:https://www.google.com/search?source=univ&tbm=isch&q=formation+of+contractile+vacuole+in+amoeba+images&sa=X&ved=2ahUKEwi81

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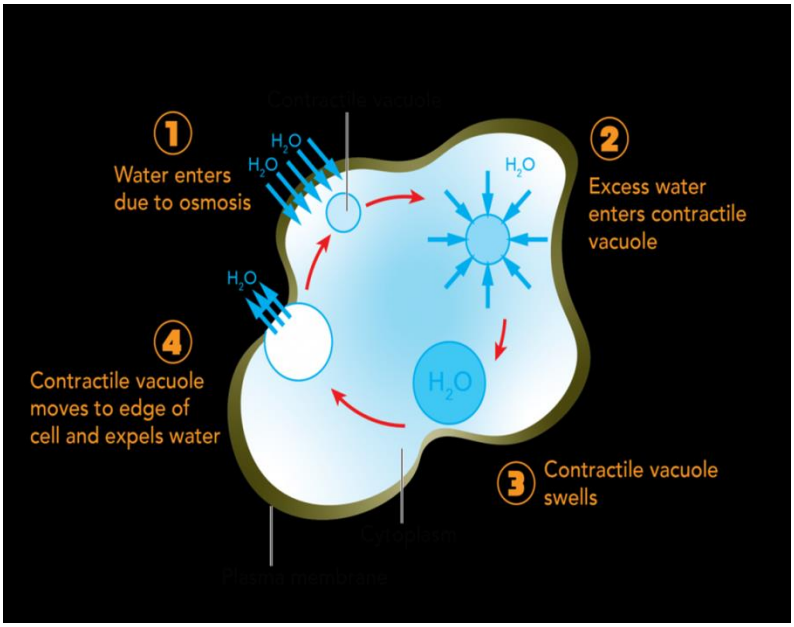

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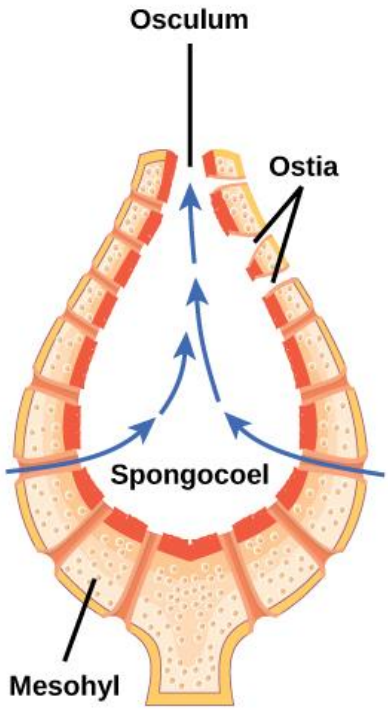
Excretion in sponges-

Sponges are aquatic sessile animals. They are attached to substratum. Sponges live in aquatic environment & feed themselves by filtering. Sponges allow water to circulate through them through their pores & channels of canal system.

Sponges do not have circulatory, respiratory, digestive & excretory systems. Water filters in & out of sponges to compensate. The sponges absorb oxygen from water flowing through canal system & produces carbon dioxide in the water. Ammonia is eliminated by diffusion. The waste is then transported through the mesohyl & then released into water flowing out of the sponge.



Basic sponge body plan

Source:https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_Concepts_in_Biology_(OpenStax)/15%3A_Diverstity_of_Animals/15.2%3A_Sponges_and_Cnidarians

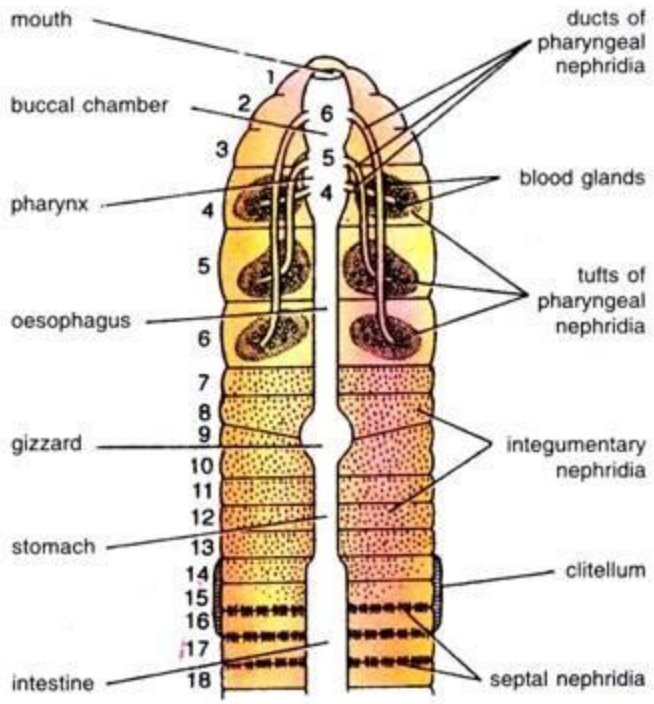
Excretion in earthworm-

Excretory organs of earthworm are segmentally arranged slender coiled tubules called nephridia. There are 3 types of nephridia according to their location in the body.

1. Septal nephridia 2. Integumentary nephridia 3. Pharyngeal nephridia

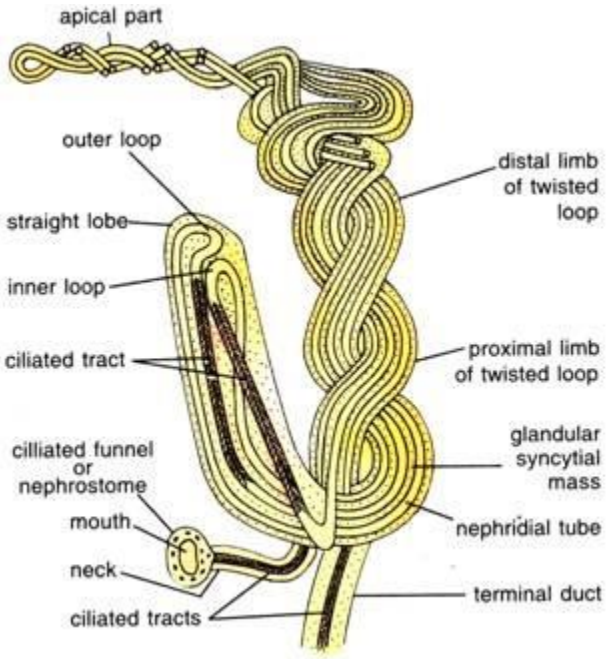
1. Septal Nephridia:

These are found situated on the inter-segmental septum 15th segment onwards.



Different types of nephridia & their distribution

The septal nephridia may be considered typical of all the nephridia of Pheretima (Earthworm). Each septal nephridium consists of nephrostome, neck, body of nephridium and the terminal duct.



Septal nephridium

(i) Nephrostome:

It is also known as ciliated funnel or nephridiostome. It is the proximal flattened funnel-shaped structure of the nephridium lying in the coelom.

It has an elliptical mouth-like opening leading into an intracellular canal of the large central cell, the margins of the opening are surrounded by a large upper lip and a smaller lower lip. The lips are provided with several rows of small ciliated marginal cells and the central canal is also ciliated.

(ii) Neck:

The nephrostome leads into a short and narrow ciliated canal forming the neck. It joins the nephrostome to the body of nephridium.

(iii) Body of Nephridium:

The body of nephridium has two parts a short straight lobe and a long twisted loop. The loop is formed by two limbs— the proximal limb and the distal limb.

Both these limbs are twisted spirally around each other, the number of twists varies from nine to thirteen. The neck of nephridium and the terminal duct join together and remain connected with the proximal limb of the twisted loop, while the distal limb becomes the straight lobe.

Internally the nephridium is made of a connective tissue matrix having long coiled nephridial duct forming loops. There are four such canals in the straight lobe, three in the lower part and two in the upper part of the limbs of twisted loop. Two canals of the straight lobe out of the four are ciliated like the ciliated canal of the neck.

(iv) Terminal Duct:

It is short and narrow with a terminal excretory duct. It joins the nephridium with septal excretory canal.

Relation of septal nephridia with intestine:-

The nephridia hang freely in the coelom and are attached only by their terminal ducts. They open by their terminal ducts into two septal excretory canals lying on the posterior surface of the septum, one on each side of the intestine, each begins ventrally but dorsally it opens in the supra-intestinal excretory duct of its own side.

The supra-intestinal excretory ducts are two parallel longitudinal canals lying above the gut and below the dorsal vessel. These excretory ducts begin from the 15th segment and run to the last

segment, they communicate- with each other for a short space behind each septum, then either the right or the left duct opens by a ductule into the lumen of the intestine near the septum.

Thus, each segment has one such opening into the intestine of either the left or the right supra-intestinal excretory duct. The waste collected by the nephridia is discharged through the excretory canals and ducts into the lumen of the intestine. Such nephridia opening into the intestine are called enteronephric nephridia.

Physiology of Excretion:

Like other animals, in earthworms also, the protein catabolism results in the formation of nitrogenous waste substances like certain amino acids, ammonia and urea.

Uric acid is not found in the earthworms. However, the amino acids are degraded to form free ammonia and the urea is synthesised in the chloragogen cells which are released into the coelomic fluid and also in the blood for its removal. Free amino acids are not excreted but traces of creatinine occur in the urine.

In a well-fed earthworm, Ammonia is major nitrogenous excretory wastes, hence, it is ammonotelic, while in starved earthworm major nitrogenous waste is urea so they are ureotelic.

An earthworm excretes the nitrogenous wastes in the form of urine which generally contains urea, water, traces of ammonia and creatinine. Nephridia excrete these substances from the body of earthworm. The various excretory wastes from the coelomic fluid are drawn into the nephrostomes of septal nephridia or into the excretory canals of other nephridia along with some other useful substances.

These products are either discharged into the intestine (by enteronephric nephridia) or outside by the nephridiopores (by exonephric nephridia). The body of nephridia also absorbs some wastes. However, the useful substances are reabsorbed and the passing out waste remains concentrated for various nitrogenous compounds.

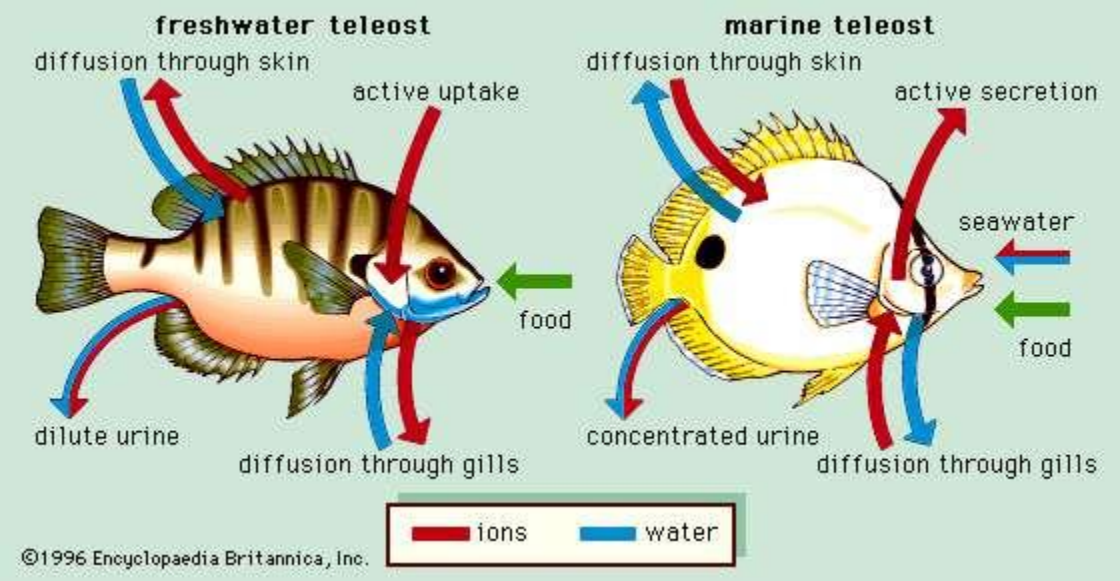
The excreted waste substances are removed out from the body with faeces. The nephridia, in addition to excretory, are also osmoregulatory in function.

The nephridia help in conserving water by reabsorption from the excreted products during summers and winters, so they pass hypertonic urine in relation to blood. During rainy season, the urine is dilute due to lesser reabsorption of water. The enteronephric nature of nephridia provides another device for conserving water.

Excretion in fish-

The primary excretory organ in fishes, as in other vertebrates, is the kidney. In fishes some excretion also takes place in the digestive tract, skin, and especially the gills where ammonia is given off. Compared with land vertebrates, fishes have a special problem in maintaining their internal environment at a constant concentration of water and dissolved substances, such as salts. Proper balance of the internal environment (homeostasis) of a fish is in a great part maintained by the excretory system, especially the kidney.

The kidney, gills, and skin play an important role in maintaining a fish's internal environment and checking the effects of osmosis. Marine fishes live in an environment in which the water around them has a greater concentration of salts than they can have inside their body and still maintain life. Freshwater fishes, on the other hand, live in water with a much lower concentration of salts than inside their bodies. Osmosis tends to promote the loss of water from the body of a marine fish and absorption of water by that of a freshwater fish. Mucus in the skin tends to slow the process but is not a sufficient barrier to prevent the movement of fluids through the permeable skin. When solutions on two sides of a permeable membrane have different concentrations of dissolved substances, water will pass through the membrane into the more concentrated solution, while the dissolved chemicals move into the area of lower concentration (diffusion).



Generalized osmotic regulation in freshwater and marine teleost fishes.

Encyclopædia Britannica, Inc.

The kidney of freshwater fishes is often larger in relation to body weight than that of marine fishes. In both groups the kidney excretes wastes from the body, but the kidney of freshwater fishes also excretes large amounts of water, counteracting the water absorbed through the skin. Freshwater fishes tend to lose salt to the environment and must replace it. They get some salt from their food, but the gills and skin inside the mouth actively absorb salt from water passed

through the mouth. This absorption is performed by special cells capable of moving salts against the diffusion gradient. Freshwater fishes drink very little water and take in little water with their food.

Marine fishes must conserve water, and therefore their kidneys excrete little water. To maintain their water balance, marine fishes drink large quantities of seawater, retaining most of the water and excreting the salt. Most nitrogenous waste in marine fishes appears to be secreted by the gills as ammonia. Marine fishes can excrete salt by clusters of special cells (chloride cells) in the gills.

Marine hagfishes, sharks, and rays have osmotic concentrations in their blood about equal to that of seawater and so do not have to drink water nor perform much physiological work to maintain their osmotic balance. In sharks and rays the osmotic concentration is kept high by retention of urea in the blood. Freshwater sharks have a lowered concentration of urea in the blood.

Categorization of animals based on principle nitrogenous excretory product-

- About 95% of the excreted nitrogen comes from break down of proteins & 5% from nucleic acids. These are toxic & cannot be stored in the body. They dissolve in water & are eliminated from body. Animals excrete a variety of nitrogenous products; ammonia, urea & uric acid are the main forms. The availability of water is an important factor in deciding the mode of nitrogen excretion.

- **1. Ammonotelic-** animals that excrete ammonia as the main end product of nitrogen metabolism are termed ammonotelic. Ammonia is formed by the deamination of amino acids in the liver. Deamination is the removal of amino group from amino acids & is brought about by various enzymes. The ammonia formed is highly toxic & is always removed in solution. It is excreted only where there is an abundance of water for its rapid removal. Hence, animals that live in aquatic environments release ammonia into the environment in water, ammonia forms ammonium hydroxide & can readily pass through the cell membranes efficiently. E.g. marine invertebrates & fresh water animals.

- **2. Ureotelic-** Animals that excrete urea as the main end product of nitrogen metabolism are termed ureotelic. Since ammonia is toxic to most vertebrates, it is kept in the body at low concentrations that is 0.001to 0.003 mg /100 ml of blood. Higher concentration can be lethal. Therefore, most of the ammonia formed from amino acid metabolism is converted to urea which is less toxic & can be stored at high concentrations. Urea requires less amount of water to be excreted out of the body. Most terrestrial animals posed with the threat of desiccation or those that need to drink water or eat food containing water to maintain a water balance produce a moderate amount of urine & are hence most suitable for ureotelic excretion. Ammonia that is formed due to deamination

of amino aides is converted to urea in the liver by Ornithine cycle or urea cycle. E.g. mammals & adult amphibians.

- **3. Uricotelic-** Animals that excrete uric acids as the main end product of nitrogen metabolism are terms as uricotelic. Birds, reptiles & some terrestrial arthropods excrete uric acid.

- It is formed to detoxify ammonia & has the advantage of being insoluble & easily precipitated from a solution. It is the only nitrogenous waste that can be removed in solid form. It permits nitrogen excretion without loss of water. Birds & reptiles produce shelled eggs & the shell is permeable to gases & not liquids.

- If the developing embryo of these animals would have excreted ammonia or urea within the shelled egg, it would have been out of soluble &accumulated producing toxic effects on the embryo. Uric acid, on the other hand, precipitates out of solution & is stored within the egg in a solid form. This precipitated excretory waste is left behind when the young one hatches out. Thus, excreting nitrogenous waste in the form of uric acid is advantageous to birds & reptiles.

Structure of kidney-

- Kidneys are attached at the back of the abdominal cavity & protected by the lowest pair of ribs & are a pair of dark red coloured, bean shaped kidneys. They lie behind the peritoneal lining of the abdominal cavity. Mammalian kidney is metanephric & drains contents through ureter. Each kidney is about 12 cm long & 3 cm thick. Externally the kidney is surrounded by 3 layers. The outermost layer, the renal fascia, is a tough connective tissue layer. The second layer, the perirenal fat capsule helps anchor the kidney in place. The third & innermost layer is the renal capsule. The kidney is convex on the outer side while on the inner side it is deeply concave or notched & has a depression called hilum/hilus. It is the region where blood vessels & nerves enter & exit the kidney. It is also the exit point for the ureter.

- **Internal structure- The L.S. of kidney** – It has following parts.

- **1. Capsule-** it is the outer envelope of tough fibrous connective tissue called tunica fibrosa.

- **2. Cortex-**This is the light, narrow, outer region of the kidney. It is granular & dotted with malpighian bodies.

- **3. Medulla-** This is the dark, striated, inner region of the kidney. Within the medulla there are eight or more cone shaped renal pyramid. At the apex of the renal pyramid is the renal papilla. The papillae are bundles of collecting ducts that transport urine made by

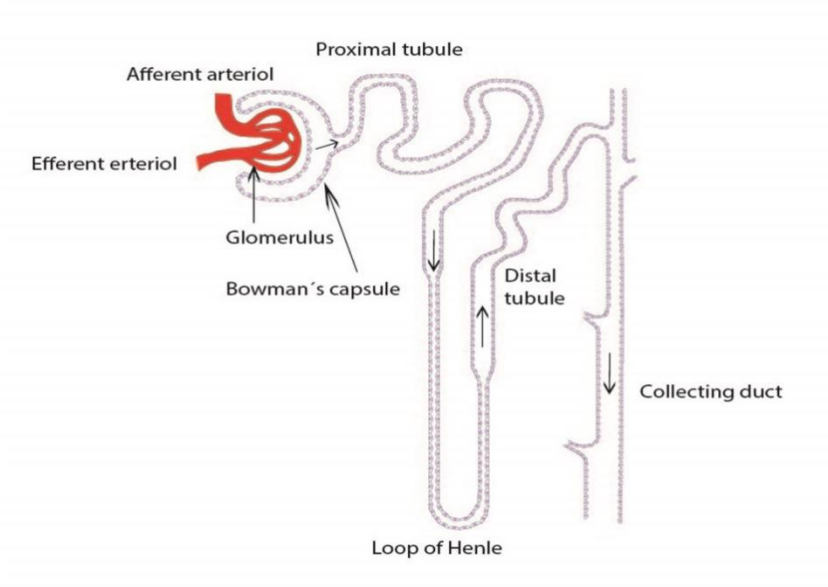
nephrons to the calyces of the kidney for excretion. Each renal papilla is attached to a small tube, minor calyx which collects urine. Two to three minor calyces merge to form the major calyx. There are two major calyces & eight minor calyces. The area between the pyramids is called renal column or columns of Bertini. The renal columns serve to section the kidney into 6-8 lobes & also to provide a supportive framework for the vessels that enter & exit the cortex. The major calyces then converge into ta funnel like cavity called pelvis.

- **4. Pelvis-** It is flattened, funnel shaped tube that channels urine into the ureter, which further carries it to the bladder.

Structure of uriniferous tubule (Nephron)-

- A nephron is the structural & functional unit of the kidney & comprises of two parts:
- **a) Malpighian capsule:** The proximal end of the nephron forms a blind (closed) enlarged double-walled cup called the Bowman's capsule, located in the cortex. A tuft or knot of blood capillaries called glomerulus is lodge inside the cup. Together the Bowman's capsule & glomerulus form a composite structure called renal corpuscle or malpighian capsule. The Bowman's capsule is double layered. It has an outer parietal layer made up of simple squamous epithelium & an inner visceral layer is made up of flattened epithelial cells called podocytes. Podocytes are flattened cells with many cytoplasmic processes called pedicels that lie in close contact with the capillaries. Together, the capillary wall & the podocyte layer form the filtration membrane through which fluid is filtered from the blood into the nephron. Under the electron microscope the glomerular capillaries show pores or fenestrae about 100^0A in diameter. These pores are covered by thin membranes & function as a sieve or biological filter.
- **b) Renal tubule-** the Bowman's capsule continues as the renal tubule & is differentiated into three regions.
- **i) Proximal convoluted tubule (PCT) –** It is the part which immediately follows the cup. It is highly coiled with a large diameter about 40-60 micrometer, has relatively thick walls & a small lumen. The cells of the tubule are cuboidal with microvilli on their inner border. This gives it a brush-like appearance & hence called brush-border cells. They greatly increase the surface area of absorption & help in reabsorbing 80% of the glomerular filtrate back into the circulation.
- **ii) Henle's loop**- The PCT descend straight into the medulla, forms a U-shaped segment called the Henle's loop & comes back into the cortex. The parts leading into & going away from the bend are called the descending & ascending limbs of the loop of Henle. This is the narrowest portion of the renal tubule & the diameter of the descending limb measures 15 micrometer & that of the ascending limb is about 20-25 micrometers.

- **iii) Distal convoluted tubule (DCT)-** The ascending limb continues as the DCT. It is convoluted & is present in the cortex. The DCT opens into the collecting tubule. Several collecting tubules unite to form a duct of Bellini. The duct of Bellini opens into calyces & further into the pelvis. The cells of DCT are columnar with large vesicles & some microvilli.



- Source:http://fblt.cz/en/skripta/vii-vylucovaci-soustava-a-acidobazicka-rovnovaha/3-tvorba-moci/

• Physiology of urine formation-

- The primary function of the kidney is to form urine by removing excess water, salts & the nitrogenous waste urea from blood. Man produces hypertonic urine.

• Steps in urine formation-

- **1. Glomerular filtration-** blood enters the Bowman's capsule through the afferent renal arteriole & passes into the glomerular capillaries. The glomerular capillary walls are thin porous & permeable. Small molecules can easily pass through them. Large molecules like plasma proteins, fats & RBCs cannot go through them. Diameter of the afferent arteriole entering the Bowman's capsule is greater than the efferent arteriole.

- Hence there is more blood entering the glomerulus than getting out of it. This builds up a pressure within the glomerulus & as a consequence a lot of water, dissolved electrolytes & small molecules are filtered out from the blood into the Bowman's capsule. This is called ultrafiltration.

- The filtrate contains mostly urea dissolved in water, glucose, amino acids, sodium & potassium ions, uric acid & many other constituents. The filtrate now passes into the tubule.

- **2. Selective reabsorption-** The ultrafiltrate contains a large number of substances that the body cannot afford to lose. Such substances are reabsorbed by the cells of the tubule & put back into the peritubular capillaries which surround them. The brush bordered cells of the PCT provide a large surface area of absorption. The walls of the tubule are selectively permeable & readily allow water, NaCl, amino acids, glucose, bicarbonates, etc to pass into blood. In the PCT, NaCl & other solutes like glucose, amino acids are reabsorbed actively. Water moves back into the blood passively.

- Diffusion of water, sodium & chloride ions occurs in the descending tubule of the Henle's loop since it is permeable to them. As the fluid passes through the Henle's loop since it is permeable to them. As the fluid passes through the Henle's loop, the filtrate becomes progressively hypertonic. Sodium is transported actively out of ascending limb of Henle's loop. It accumulates in the surrounding tissue spaces & some of it enters into the descending limb as well. The fluid that reaches the ascending limb now has a higher than before concentration of sodium. Now more can be transported out & diffused into the descending limb. Thus sodium is constantly being removed from the ascending limb & returned to the descending limb causing an accumulation of sodium in the loop. High concentrations of sodium are thus achieved. This is possible because of the Henle's loop & arrangement of the vasa recta which also form hair-pin loop parallel to the loop of Henle & operate as a counter current system. The high concentration of sodium in the tissue spaces causes water to move out passively from the distal tubule & collecting tubule leading to a concentration of fluid in them (urine).

- **3. Tubular secretion-** All substances excreted through urine do not come from the glomerular filtrate. Some substances like creatinine, ammonia, hydrogen & potassium ions & various drugs are brought into the tubule from blood against concentration gradient. This is called secretion.

The urine formed after the tubular secretion is highly concentrated.

The concentration & volume of urine is altered under the control of ADH (Anti-diuretic hormone).