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Filtration of Blood.. Elimination of Wastes

EXCRETORY SYSTEM

- Animals accumulate ammonia, urea, uric acid, carbon dioxide, water, and ions like Na^+, K^+, Cl^-, phosphate, sulphate, etc., either by metabolic activities or by other means like excess ingestion.
- These substances have to be removed totally or partially.
- Ammonia, urea and uric acid are the major forms of nitrogenous wastes excreted by the animals.
- Ammonia is the most toxic form and requires large amount of water for its elimination, whereas uric acid, being the least toxic, can be removed with a minimum loss of water.

Ammonotelic animals

- Many bony fishes, aquatic amphibians and aquatic insects mainly excrete ammonia and are called ammonotelic animals.
- Ammonia, as it is readily soluble, is generally excreted by diffusion across body surfaces or through gill surfaces (in fish) as ammonium ions.

Ureotelic animals

- Mammals, many terrestrial amphibians and marine fishes mainly excrete urea and are called ureotelic animals.
- Ammonia produced by metabolism is converted into urea in the liver of these animals and released into the blood which is filtered and excreted out by the kidneys.
- Some amount of urea may be retained in the kidney matrix of some of these animals to maintain a desired osmolarity.
- Terrestrial adaptation necessitated the production of lesser toxic nitrogenous wastes like urea and uric acid for conservation of water.

Uricotelic animals

- Reptiles, birds, land snails and insects excrete nitrogenous wastes as uric acid in the form of pellet or paste with a minimum loss of water and are called uricotelic animals.

Excretory structures of animal kingdom

- In most of the invertebrates, these structures are simple tubular forms whereas vertebrates have complex tubular organs called kidneys.Some of these structures are mentioned here.

Protonephridia or flame cells

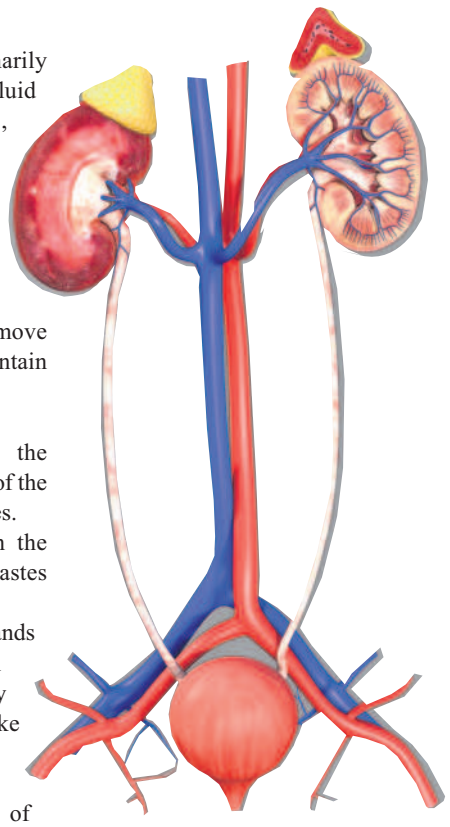
- Protonephridia or flame cells are the excretory structures in Platyhelminthes (Flatworms, e.g., Planaria), rotifers, some annelids and the cephalo chordate – Amphioxus.
- Protonephridia are primarily concerned with ionic and fluid volume regulation, i.e., osmoregulation.

Nephridia

- Nephridia are the tubular excretory structures of earthworms and other annelids.
- Nephridia help to remove nitrogenous wastes and maintain a fluid and ionic balance.

Malpighian tubules

- Malpighian tubules are the excretory structures of most of the insects including cockroaches.
- Malpighian tubules help in the removal of nitrogenous wastes and osmoregulation.
- Antennal glands or green glands
- Antennal glands or green glands perform the excretory function in crustaceans like prawns.
- In humans, the excretory system consists of a pair of kidneys, one pair of ureters, a urinary bladder and a urethra.



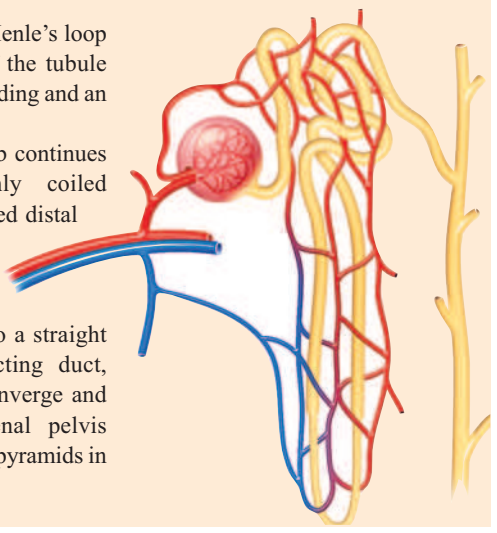
HUMAN EXCRETORY SYSTEM

Kidneys

- Kidneys are reddish brown, bean shaped structures situated between the levels of last thoracic and third lumbar vertebra close to the dorsal inner wall of the abdominal cavity.
- Each kidney of an adult human measures 10-12 cm in length, 5-7 cm in width, 2-3 cm in thickness with an average weight of 120-170 g.
- Towards the centre of the inner concave surface of the kidney is a notch called hilum through which ureter, blood vessels and nerves enter.
- Inner to the hilum is a broad funnel shaped space called the renal pelvis with projections called calyces.
- The outer layer of kidney is a tough capsule.
- Inside the kidney, there are two zones, an outer cortex, and an inner medulla.
- The medulla is divided into a few conical masses (medullary pyramids) projecting into the calyces (sing.: calyx).
- The cortex extends in between the medullary pyramids as renal columns called Columns of Bertini.

Nephron

- Each kidney has nearly one million complex tubular structures called nephrons, which are the functional units.
- Each nephron has two parts – the glomerulus and the renal tubule.
- Glomerulus is a tuft of capillaries formed by the afferent arteriole – a fine branch of renal artery.
- Blood from the glomerulus is carried away by an efferent arteriole.
- Renal tubule begins with a double walled cup-like structure called Bowman's capsule, which encloses the glomerulus.
- Glomerulus along with Bowman's capsule, is called the Malpighian body or renal corpuscle.
- The tubule continues further to form a highly coiled network–proximal convoluted tubule (PCT).
- A hairpin shaped Henle's loop is the next part of the tubule which has a descending and an ascending limb.
- The ascending limb continues as another highly coiled tubular region called distal convoluted tubule (DCT).
- The DCTs of many nephrons open into a straight tube called collecting duct, many of which converge and open into the renal pelvis through medullary pyramids in the calyces.
- The Malpighian corpuscle, PCT and DCT of the nephron are situated in the cortical region of the kidney whereas the loop of Henle dips into the medulla.
- In majority of nephrons, the loop of Henle is too short and extends only very little into the medulla. Such nephrons are called cortical nephrons.
- In some of the nephrons, the loop of Henle is very long and runs deep into the medulla. These nephrons are called juxta medullary nephrons.
- The efferent arteriole emerging from the glomerulus forms a fine capillary network around the renal tubule called the peritubular capillaries.
- A minute vessel of this network runs parallel to the Henle's loop forming a 'U' shaped vasa recta.
- Vasa recta is absent or highly reduced in cortical nephrons.



URINE FORMATION

- Urine formation involves three main processes namely, glome rular filtration, reabsorption, and secretion, that takes place in different parts of the nephron.
- The first step in urine formation is the filtration of blood, which is carried out by the glomerulus and is called glomerular filtration.
- On an average, 1100-1200 ml of blood is filtered by the kidneys per minute which constitute roughly 1/5th of the blood pumped out by each ventricle of the heart in a minute.
- The glomerular capillary blood pressure causes filtration of blood through 3 layers, i.e., the endothelium of glomerular blood vessels, the epithelium of Bowman's capsule and a basement membrane between these two layers.
- The epithelial cells of Bowman's capsule called podocytes are arranged in an intricate manner to leave some minute spaces called filtration slits or slit pores.
- Blood is filtered so finely through these membranes, that almost all the constituents of the plasma except the proteins pass onto the lumen of the Bowman's capsule.Therefore, it is considered as a process of ultra-filtration.
- The amount of the filtrate formed by the kidneys per minute is called glomerular filtration rate (GFR).
- GFR in a healthy individual is approximately 125 ml/minute, i.e., 180 litres per day.
- The kidneys have built-in mechanisms for the regulation of glomerular filtration rate.
- One such efficient mechanism is carried out by juxta glomerular apparatus (JGA).
- JGA is a special sensitive region formed by cellular modi fications in the distal convoluted tubule and the afferent arteriole at the location of their contact.
- A fall in GFR can activate the JG cells to release renin which can stimulate the glomerular blood flow and thereby the GFR back to normal.
- A comparison of the volume of the filtrate formed per day (180 litres per day) with that of the urine released (1.5 litres), suggest that nearly 99 per cent of the filtrate must be reabsorbed by the renal tubules. This process is called reabsorption.
- The tubular epithelial cells in different segments of nephron perform this either by active or passive mechanisms. For example, substances like glucose, amino acids, Na+, etc., in the filtrate are reabsorbed actively whereas the nitrogenous wastes are absorbed by passive transport. Reabsorption of water also occurs passively in the initial segments of the nephron.
- During urine formation, the tubular cells secrete substances like H+, K+ and ammonia into the filtrate. Tubular secretion is also an important step in urine formation as it helps in the maintenance of ionic and acid base balance of body fluids.

డాక్టర్ మోదాల మల్లేష్
విషయ నిపుణులు
పాలెం, నకిరేకల్,
నల్లగొండ
9989535675