EXCRETORY SYSTEM :

- Separation and elimination of nitrogenous metabolic wastes and excess of water from the body is known as **excretion.**
- The nitrogenous waste products include ammonia, urea and uric acid besides creatinine etc. Based on the excretory products, animals are classified into three categories, namely —
- **1. Ammonotelic animals** - Excrete nitrogenous wastes in the form of ammonia. e.g., *Hydra,* Some bony fishes.
- **2. Ureotelic animals -** Excrete nitrogenous wastes in the form of urea. e.g., Cartilagenous fishes, amphibians and mammals.
- **3. Uricotelic animals -** Excrete nitrogenous wastes in the form of uric acid. e.g., Insects, reptiles and birds.
- In mammals, kidneys and sweat glands perform excretory function.
- In addition, kidneys also eliminate excess water and excess salts, thereby maintaining salt and water balance in the body fluids. This phenomenon is called **homeostasis**. [Maintenance of constant internal environment within the body is called homeostasis].

Excretory organs of rabbit includes

1. A pair of kidneys
2. Ureters
3. Urinary bladder
4. Urinogenital duct
5. Urinogenital aperture

1. Kidneys:

- Rabbits have a pair of bean shaped, dark red **metanephric kidneys.**
- Kidneys are situated on either side of the vertebral column in the abdominal cavity between the dorsal abdominal wall and dorsal peritoneum.
- They are **retroperitoneal organs**, *i.e.* they are covered by peritoneum on ventral side only.
- Each kidney is ensheathed by a fibrous renal capsule.
- fibrous renal capsule covered by **perirenal fat**
- Right kidney is placed some what more anterior to the left kidney (probably this is due to presence of stomach on the left side, which pushes the left kidney backwards).
- The outer surface of each kidney is convex and inner surface is concave, where, it has a notch called hilus.
- A renal artery enters the kidney and a renal vein and a ureter exits the kidney at hilus.

Internal structure of kidney

- When a vertical section of kidney is observed, it shows that the kidney is demarcated into outer cortex and inner medulla.
- Inside the kidney, the ureter is expanded as a funnel shaped cavity called **pelvis**.
- The free end of pelvis has number of cup like cavities called **calyces** (singular number -calyx).
- Medulla projects into the calyces as conical processes, called **renal pyramids.** The tips of pyramids are called renal papillae. Cortex spreads among the renal pyramids as **columns of Bertini.**
- In man, right kidney in slightly on the lower level due to the fact that the right side of abdominal cavity is occupied by the liver.

Microscopic structure of kidney

- Each kidney is composed of numerous, minute, convoluted tubules called **nephrons.**
- They are embedded in loose connective tissue. In addition, kidneys contain a net work of blood capillaries, lymph sinuses, nerves and interstitial fluid in inter cellular spaces.

Structure of nephron

Two classes of nephrons are present in each kidney 1.**cortical nephrons** and 2.**juxtamedullary nephrons**

cortical nephrons with short henle's loop and juxtamedullary nephrons are with long henle's loop

- Nephron is formed by a Malpighian body and a convoluted tubule.

A. Malpighian body

- Malpighian body begins as a blind tube in the outer portion of the cortex and consists of two parts, namely, a **Bowman's capsule and a glomerulus.**
- Bowman's capsule is a thin walled, double layered cup like structure formed by the invagination of the tubule at the proximal end and consists of simple squamous epithelial cells called podocytes.
- A branch of renal artery (called **afferent arteriole**) enters the cavity of Bowman's capsule and splits into fine branches.

- These branches unite with one another and come out of the Bowman's capsule as an **efferent arteriole.**
- The network of capillaries formed by afferent and efferent arterioles in the Bowman's capsule that appears like a net is known as **glomerulus.**
- The diameter of efferent arteriole is comparatively less than that of afferent arteriole.
- Each human kidney has more than one million nephrons. Nephrons are considered as structural and functional units of kidney.
- The wall of Bowman's capsule and walls of capillaries of glomerulus (formed by a single layer of endothelium) are in close contact. The blood in glomerular capillaries and the fluid in the lumen of Bowman's capsule are separated by a very thin barrier *i.e.,* squamous epithelium of Bowman's capsule and endothelium of blood capillaries of glomerulus.

B. Convoluted tubule:

- A narrow, delicate tubule arises from the posterior part of Bowman's capsule called **neck**.
- It opens into a long narrow convoluted tubule, which is divisible into three parts, namely, proximal convoluted tubule, **loop of Henle** and distal convoluted tubule.

a) Proximal convoluted tubule

- Neck of Bowman's capsule is continued as a long, convoluted tubule, known as proximal convoluted tubule.
- It is lined by cuboidal epithelium. Free surfaces of these cells have **microvilli, (brush borders)** which greatly increase the area of absorption. It lies in the cortex.

b) Loop of Henle

- Proximal convoluted tubule leads into a hair pin like (U-shaped) tubule known as loop of Henle, formed deep in the medulla. Each loop consists of a descending limb and an ascending limb.
- The walls of the descending limb and the lower end of the ascending limb are very thin. They are formed by squamous epithelium without brush borders.
- The distal portion of the ascending limb becomes thick and at the end of it, squamous epithelium becomes cuboidal epithelium.

iii) Distal convoluted tubule

- The ascending segment of loop of Henle enters the cortex and becomes the distal convoluted tubule, which lies near the Malpighian body.
- The lumen of early distal convoluted tubule is lined by active simple cuboidal epithelium.
- The late distal convoluted tubule is lined by two types of cuboidal epithelial cells-**principal cells** and **intercalated cells.**
- At the place of contact of DCT with afferent arteriole, the crowded cells of tubule together called **macula densa**
- Along side of macula densa the wall of afferent arteriole contains the modified smooth muscle fibres called **juxta glomerular cells**
- macula densa along with **juxta glomerular cells** forms juxta glomerular apparatus

Collecting tubules and ducts :

- The terminal part of the distal convoluted tubule is the **collecting tubule** or **connecting segment**.
- Several collecting tubules join to form a **collecting duct**.
- These collecting ducts descend into the renal medulla. Collecting duct also contain principal cells and intercalated cells.
- In the renal medulla these collecting ducts merge to form the **duct of Bellini**. Duct of Bellini opens at the end of the renal papilla.

iv) Capillary net

- The efferent arteriole reaches the uriniferous tubule and divides into a net of capillaries around it.
- The capillary net close to the proximal and distal convoluted tubules is called **peritubular net** and that is present close to the loop of Henle is called **vasa recta**.
- The capillaries of these nets join to form a renal venule. All such renal venules unite and form a renal vein. It comes out of the kidney at hilus.

v) Collecting tubule

- The junction tubule opens into a straight collecting tubule. It enters the renal pyramid. In its way, it receives many junction tubules.
- Several collecting tubules join to form a **collecting duct**. These collecting ducts descend into the renal medulla.
- Collecting ducts also contain principal cells and intercalate cells.
- Finally collecting ducts merge to form the duct of Bellini, which opens into the pelvis at the tip of renal papilla.

2. Ureters :

- The pelvis of each kidney is continued as a ureter and emerges out at hilus.
- Ureter is a long and muscular tube. Ureters of both sides extend posteriorly and open into the urinary bladder.

3. Urinary bladder, urethra / vestibule :

- Urinary Bladder is a thin walled, pear shaped, white transparent sac, situated in the pelvis, ventral to rectum.
- It temporarily stores the urine. Urinary bladder opens into urino genital canal. In males, it is called **urethra** and in females, it is called **vestibule**.
- Urethra opens out through urinogenital aperture at the tip of penis. Vestibule opens out through vulva.

Formation of urine

- The excretory system helps to eliminate waste material from the body.
- These waste materials include nitrogenous compounds like ammonia, urea, uric acid, excess water, excess salts etc.
- All these are eliminated as an aqueous solution called urine. The process of formation of urine involves three stages, as described below:

1. Glomerular filtration

The endothelial cells of the glomerular capillary together with the podoytes of the Bowman's cup form the filtration membrane.

- The hydrostatic pressure of the blood while flowing in the glomerulus is 70 mm Hg (GHP). It is opposed by blood colloid osmotic pressure (BCOP) of 35 mmHg and capsular hydrostatic pressure(CHP) of 25 mmHg. The nect filtration pressure (NFP) is 10 mmHg.
- On account of this high pressure, all the dissolved substances are filtered through the thin wall of capillaries and Bowman's capsule into its lumen. [As the RBC, WBC and plasma proteins are having high molecular weight, they are unable to pass out during ultra filtration].
- This process of pressure filtration through glomerular capillaries in the Bowman's capsule is known as **ultra filtration**.
- The filtrate is known as **glomerular filtrate** or **renal fluid** or **primary urine**.
- It is hypotonic to urine that is actually excreted.
- Renal fluid contains not only metabolic wastes (urea, uric acid, creatinine, toxins etc.) but also water, amino acids, glucose, salts of Na, K, Ca, Mg etc.
- The renal fluid pass through the convoluted tubule, where selective reabsorption and tubular secretion takes place.

2. Selective reabsorption

- It is the process by which essential substances of renal fluid are reabsorbed into the blood, while they pass through various parts of uriniferous tubule.

a) In proximal convoluted tubule (PCT) :

- Proximal convoluted tubule is highly permeable to water and solutes. 65% of filtered load of sodium and water, and slightly lower percentage of filtered chlorine are reabsorbed in the PCT.
- The cells in the PCT have high capacity for active and passive reabsorption. Water is reabsorbed by passive transport.
- This fraction is known as **obligatory water reabsorption.**
- Sodium ions, glucose and amino acids are reabsorbed by active transport. $Cl^-, K^+, Ca^{2+}, Mg^{2+}$ etc. passively diffuse from the lumen.
- In PCT organic acids and bases like bile salts, oxalates, hippuric acid and urates are secreted into the renal fluid. H^+ ions are also secreted into the lumen. The renal fluid is **isotonic** to the cortical fluid and blood.

b) In descending limb

- Descending limb is highly permeable to water and moderately permeable to solutes like sodium ions and urea.
- It allows only the diffusion of substances through its walls. In the descending limb about 15% of water diffuses into the interstitial fluid.
- Na^+ ions and urea passively diffuse into the lumen moderately from the interstitial fluid.
- As a result, the osmolarity of glomerular filtrate gradually increases.
- Hence, it is **hypertonic to the blood, but isotonic to the medullay fluid**. It reaches a maximum at the hairpin turn of the loop.

c) In the ascending limb

- The ascending limb has thin and thick segments. Thin segment is impermeable to water and less permeable to ions.
- The thick segment is impermeable to water but more permeable to Na^+, Cl^-, Mg^{2+}, K^+, HCO_3^- and Ca^{2+} ions.
- About 25% of the filtered load of these ions is actively reabsorbed in the thick region.
- The renal fluid is progressively diluted as it passes through the ascending limb.
- H^+ ions are secreted.

- The reabsorption capacity of thin segment is less. Renal fluid in the ascending limb is **hypotonic** to the medullary fluid and blood.

d) In distal convoluted tubule

- The distal convoluted tubule is permeable to water and ions. The principal cells reabsorb sodium and secrete potassium.
- Intercalated cells secrete H^+ ions, and reabsorb potassium and HNO_3^- ions.
- In this part, water is absorbed by both cells under the influence of antidiuretic hormone of the pituitary gland. It is called **facultative water reabsorption** (aided by ADH).
- The filtrate is **isotonic** to the cortical fluid and blood. Aldosterone (a corticoid hormone) aids in the reabsorption of Na^+ ions in this part.
- About 9% of filtered water is reabsorbed in the distal convoluted tubule.

e) In the collecting duct

- Water is absorbed in the cortical and medullary collecting ducts under the influence of ADH hormone. In the collecting duct about 10% of filtered water and sodium are reabsorbed.
- H^+ ions are secreted in to the collecting ducts. In the medullary collecting duct some amount of urea is also reabsorbed by passive transport.
- It is secreted into the descending limb and thin part of the ascending limb.
- Thus at the end of collecting duct, concentration of glomerular filtrate is high.
- Now the filtrate is called **urine**, which is **hyper-tonic** to blood and isotonic to the medullary fluid.

3. Tubular secretion

- The diffusion of materials (which could not be filtered in glomerulus) from capillary net into the interstitial fluid is called **tubular secretion** or **augmentation.**
- In this process K^+ ions, H^+ ions, ammonia, hippuric acid etc., are secreted into the lumen of the tubule.

4. Counter current mechanism :

- In the medullary fluid osmolarity increases from outer medulla to the inner medulla.
- Active transport of ions from the ascending limb, and collecting duct, and passive transport of urea from collecting duct maintain the concentration gradient of the interstitial fluid of medulla.
- The second contribution to the osmotic gradient in the medulla is the **counter current mechanism**.
- The fluid flowing in one limb of loop of Henle is opposite to the fluid flowing in the other limb.
- Blood also flows in the opposite directions in the descending and ascending parts of vasa recta.
- This flow is **counter flow.**
- While the blood descends into the medulla the osmolarity progressively increases while flowing towards the cortex.
- Under normal conditions, vasa recta carry away only the solutes and water absorbed from the loop of Henle with out altering the concentration of the medullary interstitial fluid. Thus osmotic gradient in the medulla is useful in producing the concentrated urine.

Substances of renal fluid

Threshold substances

- Some substances of glomerular filtrate are reabsorbed when their concentrations in plasma are in normal limits and they do not appear in the urine until their plasma levels are exceeded. Such substances are called threshold substances. These are of three types :

1. High threshold substances :

- These substances are essential for the body and are efficiently reabsorbed. *e.g.,* glucose, ainino acids, vitamins, some salts etc.

2. Low threshold substances :

- These substances are absorbed in very little amounts, e.g., Urea, uric acid.

3. Athreshold substances :

- These substances are not reabsorbed because they are actual excretory products, *e.g.,* creatinine, sulphates etc.

Composition of urine

- Urine is a pale yellow fluid. This colour is due to urochrome, a substance formed during break down of haemoglobin.
- Urine is slightly acidic (pH = 6.0). Urine of healthy individual contains 96% of water, 2% of urea, 2% of other dissolved solids (uric acid, cratinine, inorganic salts etc.).
- Little amounts of ammonia, urobilin, Haematoporphyrin etc. are also present in the urine.

Micturition

- The urine formed in the kidneys reaches the urinary bladder through the ureters.

- As more and more urine reaches the bladder, it distends. The sphincter at the base of bladder prevents the passage of urine.
- When the bladder dilates, stretch receptors in its wall are stimulated and send impulses to brain which cause the desire of urination.
- During urination, bladder contracts and urine goes out. The process of discharge of urine is called micturition.