Excretion: Patterns of excretion in relation to different habitats

Definition of Excretion: It is the elimination of metabolic waste products from the animal body to regulate the composition of the body fluids and tissues. The terms excretion and defecation should not be confused. Defecation is the removal of wastes and undigested food, collectively called faeces, through the anus.

Modes of Excretion: Depending upon the excretory product, animals show five types of nitrogenous excretion in which ammonotelism, ureotelism and uricotelism **are major types and** aminotelism and guanotelism **are minor types.**

Nitrogenous waste substances such as ammonia, urea or uric acid are produced during protein metabolism according to the species.

Small amount of nitrogenous waste substances are also produced during the metabolism of nucleic acids. Ammonia is the most toxic, followed by urea and uric acid. The latter is the least toxic.

1. Ammonotelism

Many aquatic animals like protozoans, (e.g., Amoeba, Paramecium), sponges (e.g., Sycon), cnidarians or coelenterates (e.g., Hydra), liver fluke, tape worms, Ascaris, Nereis, Earthworm, Leech, most aquatic arthropods (e.g., Prawn), most aquatic molluscs (e.g., Pila) bony fishes (e.g., Labeo), Amphibian tadpole (e.g., tadpole of frog), tailed amphibians (e.g., Salamanders), and crocodiles excrete ammonia.

Animals which excrete ammonia are called ammonotelic and excretion of ammonia is termed as the ammonotelism.

2. Ureotelism

Excretion of urea is known as ureotelism and the animals which excrete urea are called ureotelic. Ureotelic animals include Ascaris, earthworm (both are ammonotelic and ureotelic), cartilaginous fishes like sharks and sting rays, semi-aquatic amphibians such as frogs and toads, aquatic or semi aquatic reptiles like turtles, terrapins and alligators, and man and all other mammals.

Urea is less toxic and less soluble in water than ammonia. Hence, it can stay for some time in the body. Sharks retain large quantity of urea in their blood, therefore, blood osmotic pressure approaches that of sea water, which minimizes water loss from their body.

How Urea is produced?

Liver converts toxic ammonia (NH_3) into much less toxic urea which is excreted in urine. Urea is the end product of protein metabolism (amino acid metabolism).

Urea is synthesized in liver and transported to kidneys for excretion in urine. Urea is produced through urea cycle which was discovered by Hans Krebs and Kurt Henseleit (1932), hence it is known as Krebs-Henseleit cycle. The individual reactions, however, were described in more detail later on by Ratner and Cohen.

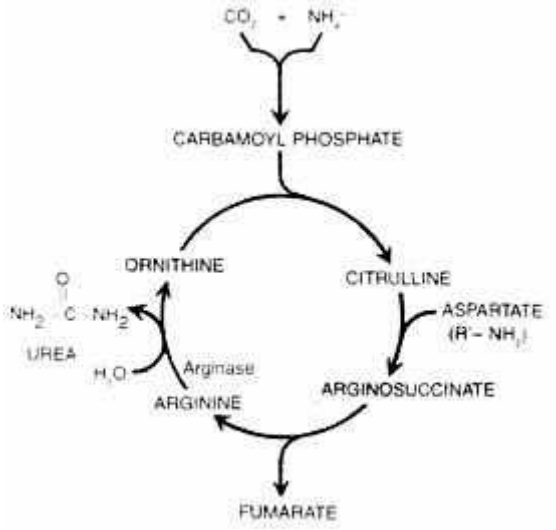


Fig. 19.1. Urea Cycle.

Urea has two amino (-NH_2) groups, one derived from NH_3 and the other from aspartate. Carbon atom is supplied by CO_2. Urea cycle includes five steps involving five distinct enzymes. The first two enzymes are present in mitochondria while the rest are localized in cytosol (the cytoplasm minus the mitochondria and endoplasmic reticulum).

(i) Synthesis of Carbamoyl Phosphate:

Carbamoyl phosphate synthase 1 (CPS 1) of mitochondria catalyses the condensation of NH_4^+ ions with CO_2 to form carbamoyl phosphate. This step consumes two ATPs.

(ii) Formation of Citrulline:

Citrul- line is synthesized from carbamoyl phosphate and ornithine by ornithine transcarbamoylase. Ornithine is regenerated and used in urea cycle. Ornithine and citrulline are basic amino acids.

(iii) Synthesis of arginosuccinate:

Arginosuccinate synthase condenses citrulline with aspartate to produce arginosuccinate. This step requires ATP.

(iv) Cleavage of arginosuccinate:

Arginosuccinate cleaves arginosuccinate to give arginine and fumarate. Fumarate liberated here provides a connecting link with Krebs cycle, gluconeogenesis, etc.

(v) Formation of Urea:

Arginase is the fifth and final enzyme that cleaves arginine to form urea and ornithine. This ornithine enters mitochondria for its reuse in the urea cycle. The urea cycle (also called ornithine cycle) is irreversible.

3. Uricotelism

Excretion of uric acid is known as uricotelism and the animals which excrete uric acid are called uricotelic. Animals which live in dry conditions have to conserve water in their bodies. Therefore, they synthesize crystals of uric acid from their ammonia. Uric acid crystals are non-toxic and almost insoluble in water.

Hence, these can be retained in the body for a considerable time. Uricotelic animals include most insects, (e.g., cockroach) some land crustaceans (e.g., Oniscus commonly known as “wood louse”), land snails (e.g., Helix commonly known as “land snail”), land reptiles (e.g., lizards and snakes) and birds.

The concentration of uric acid is so high in guano (waste matter dropped by sea birds, used as fertilizer) that uric acid is commercially extracted from guano which is collected from uninhabited marine or littoral (part of country which is along the coast) islands. Primates including man also excrete some uric acid which is formed in their body by the breakdown of nucleic acids.

4. Aminotelism:

Certain invertebrates like some molluscs (Unio, Limnaea, etc.) and some echinoderms (e.g., Asterias) excrete excess amino acids as such. These animals are called aminotelic and their mode of excretion is called aminotelism.

5. Guanotelism:

Spiders excrete guanine and are said to be guanotelic and their mode of excretion is called guanotelism.

Other Nitrogenous Wastes:

1. Creatine and Creatinine

2. Trim ethylamine oxide (TMO

3. Ornithuric acid

4. Hippuric acid

5. Bilirubin and Biliverdin

6. Allantoin

Other Excretory Wastes

1. Bile Salts

2. Excretion of Drugs, Hormones and Other Substances

3. Carbon Dioxide

4. Water

5. Vitamins

6. Spices

Ultrastrucuture of Kidney of man

Bean shaped, outer surface convex and inner surface is concave. The inner surface has a deep notch called **Hilus**. The ureters, renal artery,renal vein and nerves enter through hilus.

In the section of the kidney, peripheral portion appears dark reddish brown is called **cortex** and the central portion appears light red called as **medulla.**

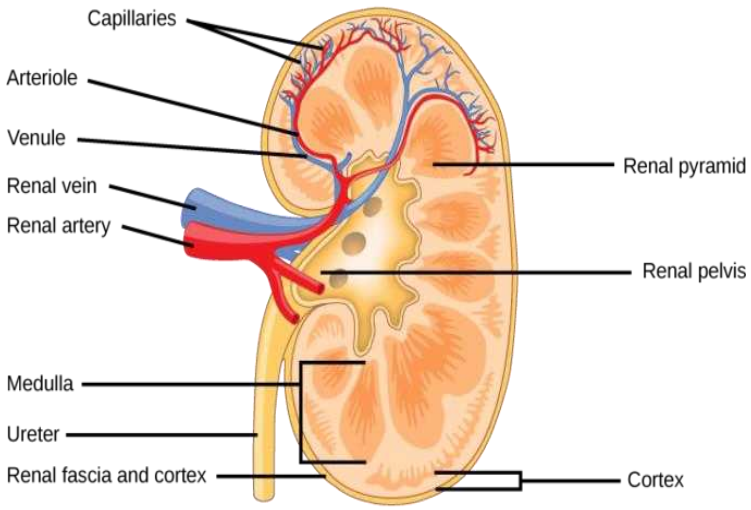
The ureter entering the hilus expands to form a funnel like structure called **pelvis.** The pelvis is produced in to number of cub like structures called **calyces or calyx**.

The cavity of each calyx is occupied by a cone-like structure called **pyramid** .The apex of pyramid is called **Papilla.**

Each kidney contains 10 to 15 pyramids. The pyramids are separated by the projections of cortex is called **renal column of Bertin**.

Each pyramid has thousands of tubules called **uriniferous tubules or nephron** and blood vessels. Ineach pyramid many uriniferous tubules join together to form a **collecting tubule or collecting duct.**

Finally this straight duct called **duct of Bellini** opens at the apex of pyramid.



Functions of Kidney:

1. **Endocrine functions:** kidney is also an endocrine glands. It secretes enzymes renin, dihydroxycholecalciferol, erythropoietin etc.
2. **Renin:** It is an enzyme secreted by cells of juxtaglomerular apparatus which helps in regulation of blood pressure.
3. **1, 25-dihydroxycholecalciferol:** it is a biological active form of vitamin D3 found in kidney.
4. **Erythropoietin:**it is essential for RBC formation
5. **Osmoregulation:** Kidney regulate osmotic pressure in the body by regulating fluids and electrolyte balance
6. **Homeostasis:** also regulate PH balance
7. **Excretion:** metabolic wastes of the body are excreted in the form of urea, creatinine, uric acid etc in urine.
8. **Excretion of Drugs and toxins**
9. **Selective reabsorption:** glucose, amino acids, water and electrolytes etc are selectively reabsorbed in the renal tubules
10. **Erythropoiesis:** helps in RBC formation and Blood pressure regulation

Physiology of urine formation

Every one of us, including plants and animals, depend on the excretion process for the removal of certain waste products from our body. During the process of excretion, Both the kidneys play an important role in filtering the blood cells.

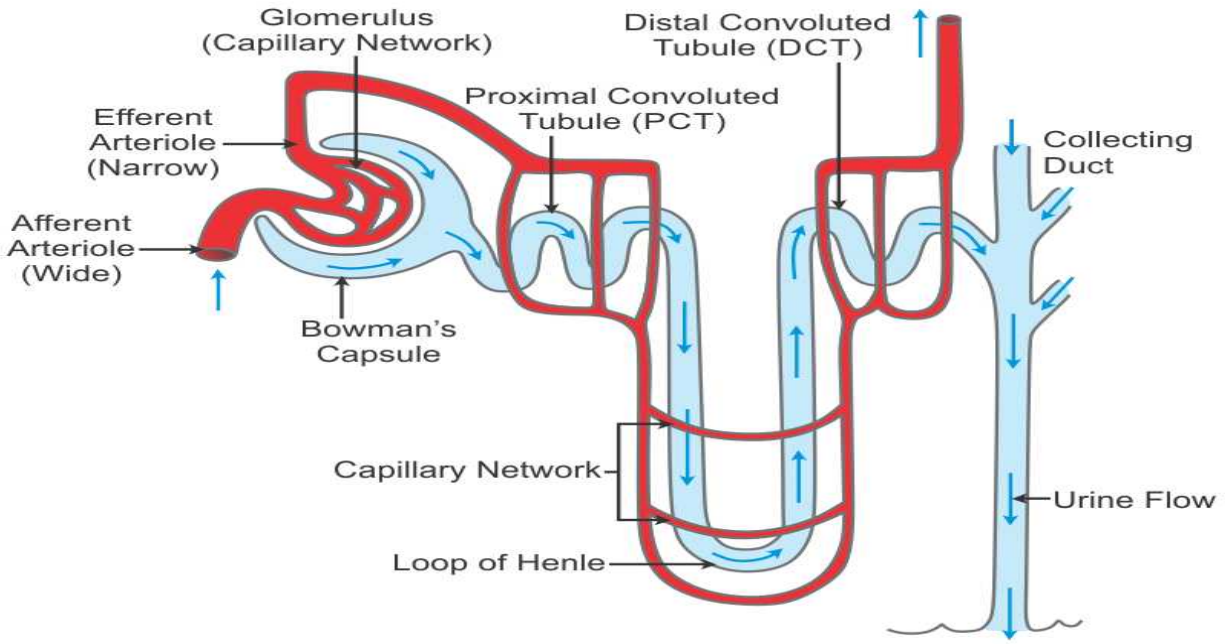
What is Excretion?

Excretion is a biological process, which plays a vital role by eliminating toxins and other waste products from the body. In plants and animals including humans, as the part of metabolism, lot of waste products are produced. Plants usually excrete through the process of transpiration and animals excrete the wastes in different forms such as by urine, sweat, faeces, and tears. Among all these, the usual and the main form of excretion is the urine.

Urine Formation

Waste is excreted from the human body mainly in the form of urine. Our kidneys play a major role in the process of excretion. Constituents of normal human urine include 95 percent water and 5 percent solid wastes. It is produced in the nephron which is the structural and functional unit of the kidney. Urine formation in our body is mainly carried out in three phases namely

1. Glomerular filtration,
2. Reabsorption
3. Secretion.



Glomerular filtration

This takes place through the walls of the **glomerular capillaries and Bowman's capsule**.

The **afferent arterioles** supplying blood to glomerular capsule carries useful as well as **harmful substances.**

The **useful substances** are glucose, aminoacids, vitamins, hormones, electrolytes, ions etc.

And the **harmful substances** are metabolic wastes such as urea, uric acids, creatinine, ions, etc.

Due to this **difference in diameter of arteries**, blood leaving the glomerulus creates the pressure known as **hydrostatic pressure**.

The **glomerular hydrostatic pressure** forces the blood to leaves the glomerulus resulting in filtration of blood.
A capillary hydrostatic pressure of about 7.3 kPa (55 mmHg) builds up in the glomerulus. However this pressure is opposed by the **osmotic pressure** of the blood, provided mainly by plasma proteins, about 4 kPa (30 mmHg),
And by **filtrate hydrostatic pressure** of about 2 kPa (15 mmHg in the glomerular capsule.
The **net filtration pressure** is,

Therefore: 55-(30 +15) = 10mmHg.

By the net filtration pressure of 10mmHg, blood is filtered in the glomerular capsule.

Water and other small molecules readily pass through the filtration slits but Blood cells, plasma proteins and other large molecules are too large to filter through and therefore remain in the capillaries.

The **filtrate containing** large amount of water, glucose, aminoacids, uric acid, urea, electrolytes etc in the glomerular capsule is known as **nephric filtrate of glomerular filtrate**.

The volume of filtrate formed by both kidneys each minute is called the **glomerular filtration rate (GFR).**

In a healthy adult the **GFR is about 125 mL/min**, i.e. **180 litres of filtrate** are formed each day by the two kidneys.

Selective reabsorption

As the filtrate passes to the renal tubules, **useful substances** including some water, electrolytes and organic nutrients such as glucose, aminoacids,

vitamins hormones etc are **selectively reabsorbed** from the filtrate back into the blood in the **proximal convoluted tubule**.

Reabsorption of some substance is **passive**, while **some substances** are **actively transported**.

Major portion of water is reabsorbed by **Osmosis**.

Only 60–70% of filtrate reaches the Henle loop.

Much of this, especially water, sodium and chloride, is reabsorbed in the loop,

so that only 15–20% of the original filtrate reaches the distal convoluted tubule,

More electrolytes are reabsorbed here, especially sodium, so the filtrate entering the collecting ducts is actually quite dilute.

The main function of the **collecting ducts** is to reabsorb as much **water** as the body needs.

Nutrients such as glucose, amino acids, and vitamins are reabsorbed by **active transport**.

Positive charged ions ions are also reabsorbed by **active transport** while **negative charged** ions are reabsorbed most often by **passive transport**.

Water is reabsorbed by osmosis, and small proteins are reabsorbed by **pinocytosis**.

Tubular secretion

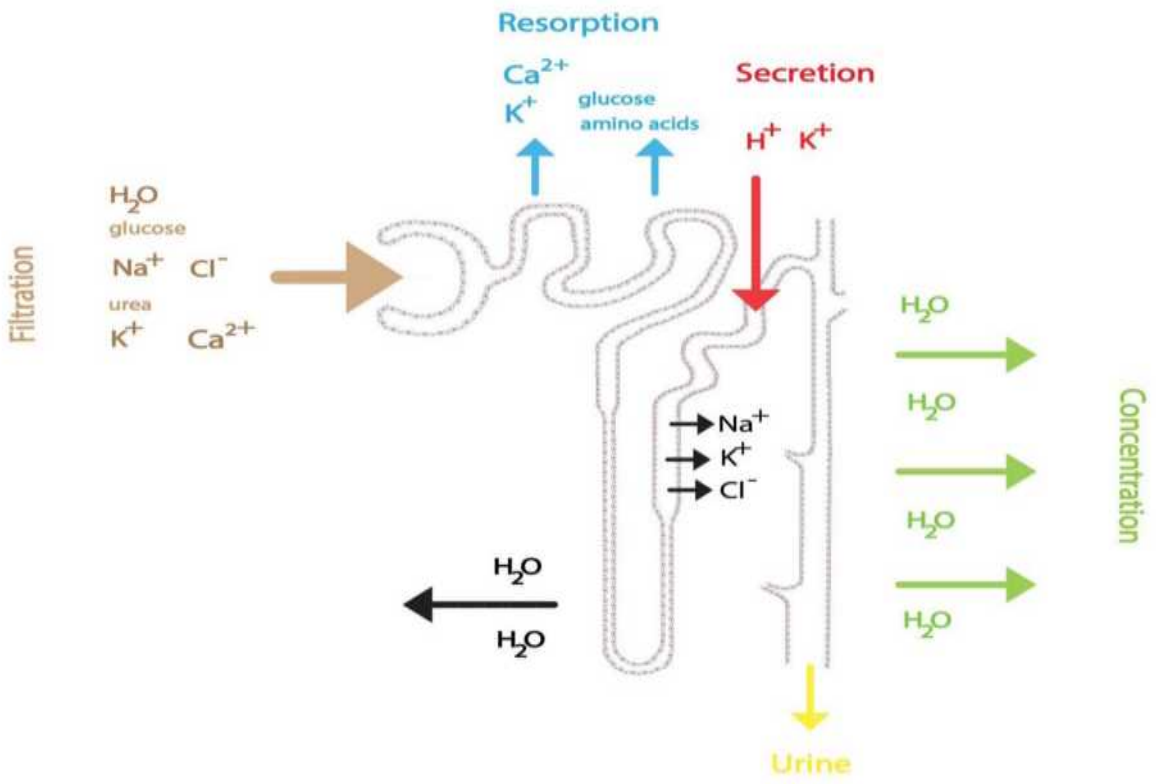
Tubular secretion takes place from the blood in the peritubular capillaries to the filtrate in the renal tubules and can ensure that wastes such as **creatinine or excess H+ or excess K+ ions** are actively secreted into the filtrate to be excreted.

Excess K+ ion is secreted in the tubules and in exchange Na+ ion is reabsorbed otherwise it causes a clinical condition **called Hyperkalemia**.

Tubular secretion of hydrogen ions (H+) is very important in maintaining **normal blood pH**.

Substances such as , e.g. **drugs including penicillin and aspirin**, may not be entirely filtered out of the blood because of the short time it remains in the glomerulus. Such substances are cleared by secretion from the peritubular capillaries **into the filtrate within the convoluted tubules**.

The **tubular filtrate is finally known as urine**. **Human urine is usually hypertonic**.



Composition of human urine

Water – 96%
Urea – 2%
Uric acids, creatinine, pigments- 0.3%
Inorganic salts – 2%
Bad smell is due to Urinoid
Pale yellow color due to urochrome or urobillin (which is a breakdown product of haemoglobin)

Micturation:

The process of time to time collection and removal of urine from urinary bladder is known as micturition. Collection of more than 300ml of urine in urinary bladder creates pressure on the wall. The pressure stimulates the desire for urination.