CHAPTER

6

Osmoregulation and Excretion in Animals

Introduction

- **Excretion** is the elimination of harmful waste products from the animal body to regulate the composition of the body fluids and tissues.
- **W B Cannon** (1929) gave the term homeostasis. **Homeostasis** (Gr. *homouos*-same, *stasis*-standing) is the maintenance of a constant internal environment. It includes osmoregulation.
- **Osmoregulation** is the maintenance of proper internal salt and water concentrations in a cell or in the body of a living organism.
- Other than kidney, skin, lungs, liver and intestine also help in removing metabolic wastes to some extent and are called as **accessory excretory organs**.
- Excretory products are mainly nitrogenous wastes like urea, ammonia, uric acid, amino acid, creatine, guanine etc.
- Bile pigments include **bilirubin**, **biliverdin** and **urochrome**.
- **Bilirubin** and **biliverdin** are excreted through bile. Jaundice is a disease due to high level of bilirubin in blood resulting in yellowness of skin and eyes.
- CO_2 is a gas which is produced during cellular respiration. It is excreted primarily by the lungs.
- Nitrogenous waste products are formed due to break down of proteins and nucleic acid (DNA and RNA) during various metabolic processes.

Types of Animals Based on Excretory Products

Ammonotelic

- **Animals** which excrete **ammonia** as a waste product are called as **ammonotelic** animals and this phenomenon is termed as **ammonotelism**.
  Examples : protozoans, sponges, coelenterates, liver fluke, tapeworm. *Ascaris*, earthworm, leech, many aquatic arthropods, many aquatic molluscs, bony fishes, amphibian tadpole, tailed amphibians and crocodiles.

Ureotelic

- Animals which excrete **urea** as a waste products are called as **ureotelic** animals and this phenomenon is called **ureotelism.**
  Examples : *Ascaris*, earthworm, cartilagenous fishes like sharks, frogs, toads, turtles, alligators, human and all other mammals.

Uricotelic

- Animals which excrete **uric acid** as a waste product are called as **urecotelic** animals and this phenomenon is termed as **urecotelism.**
  Examples : Most insects, some land crustaceans, land snails, land reptiles and birds.

Aminotelic

- Animals which excrete **amino acids** as a waste products are called **aminotelic** animals and this phenomenon is termed as **aminotelism**.
  Examples : Some molluscs (*Unio*, *Limnaea*) and some echinoderms (*Asterias*).

Human Excretory System

Kidneys

- They are about 11 cm long, 5 cm wide and 3 cm thick, each weight about 150 g in an adult male and about 135 g in adult female.
- Kidney of man is **metanephric** and covered by **peritoneum** on the ventral side.
- **Renal Pyramids** are the triangles of the tissues line up with the medulla.
- Each kidney has about one million nephrons present in the cortex and pyramid region. Each nephron has two parts **Malpighian corpuscle and Renal tubule.**
- **Malpighian corpuscle** consists of glomerulus and Bowman's capsule. **Renal tubule** is long tube consisting of PCT (Proximal Convoluted Tubule) Henle's loop, DCT (Distal Convoluted Tubule) and **collecting tubule**
- Kidneys have two types of nephrons : **Cortical nephrons** (80–85%) and **juxtamedullary nephrons** (15–20%).
- Duct of Bellini found in papilla of pyramids is formed by many collecting tubes.

Ureters

- These are two in number and each emerges from their respective kidneys.
- Each ureter opens their respective kidneys to urinary bladder and thus, helps in transfer of urine from kidney to urinary bladder.

Urinary Bladder

- It is one in numbers, sac like, bean shaped muscular structure.
- It has three openings, two openings due to two ureters, coming from kidneys and one opening through which the urethra leaves the bladder. The main function of urinary bladder is to store urine temporarily.

Urethra

- It is a canal like structure present in both male and female, longer in male than female.
- Urethra extends from neck of urinary bladder to the exterior and helps in excretion of urine.

Physiology of Excretion

Urea Formation (Ornithine Cycle)

- Urea cycle removes two waste products (NH_3 and CO_2) from the blood in liver.
- Three amino acids (Ornithine, citrulline and arginine) are involved in urea cycle.
- **Arginase enzyme** takes part in urea cycle.
- **Hans Krebs** and **Kurt Henseleit** (1932) discovered Ornithine cycle or urea cycle or Krebs-Henseleit cycle. It is the detoxification of ammonia.
- Ornithine cycle involves the union of two molecules of ammonia and carbon dioxide. It takes place in liver cells.

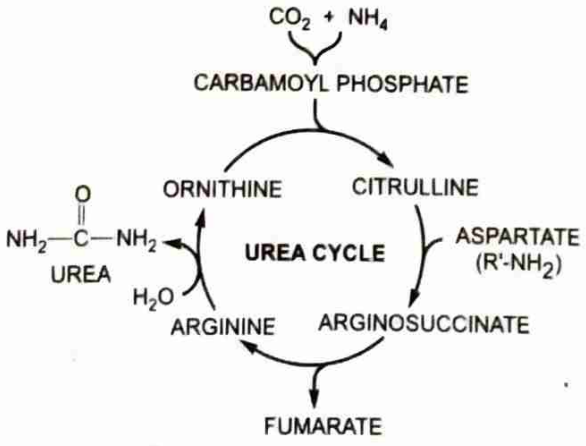

Fig. 6.1 Synthesis of urea

Mechanism of Urine Formation

The three basic processes are involved in urine formation :

(a) Glomerular filtration

- Glomerular filtration is passive process which takes place from the glomerulus into the Bowman's capsule.
- Glomerular capillaries are about 50 times more permeable than capillaries else where.

- Glomerular Hydrostatic Pressure (GHP) = 70 mm Hg, Blood Colloidal Osmotic Pressure (BCOP) = 30 mmHg, Capsular Hydrostatic Pressure (CHP) = 20 mmHg.
- Special cells called **podocytes** are also present in the walls of Bowman's capsule.
- GHP is due to larger afferent arteriole BCOP is due to plasma proteins albumin, globulin, fibrinogen and CHP is due to fluid already occupying the capsular space and renal tubule.
- NFP is Net Filtration Pressure

$$NFP = GHP - (BCOP + CHP) = 70 - (30 + 20) = 70 - 50 = 20 \text{ mm Hg}$$

- The plasma fluid that filters out from glomerular capillaries into Bowman's capsule of nephrons is called **glomerular filtrate**.
- Glomerular filtrate = Blood – (Blood cells + Plasma protein)
  = Blood – (RBCs + WBCs + Platelets + Plasma protein)
  = Blood plasma – Proteins
- 180 L of filtrate is formed perday, out of it only 1.5 L of urine is produced per day which is 0.8% of the total filtrate.
- Filtration fraction is the ratio of GFR and RPF.

  GFR — Glomerular Filtration Rate
  RPF — Renal Plasma Flow

$$\text{Normal filtration fraction} = \frac{GFR}{RPF} = \frac{120}{670} = 0.17$$

(b) Tubular reabsorption

- Tubular reabsorption involves both passive and active transport. By tubular reabsorption the composition of filtrate is changed and volume of filtrate is reduced.

(i) Proximal Convoluted Tubule (PCT)

- ➤ Cells of PCT are provided with microvilli. Brush border is present in PCT.
- ➤ PCT is the pivotal site for reabsorption. Glucose amino acid and Na^+, K^+ ions are reabsorbed by active transport. Cl^- are reabsorbed by passive transport.
- ➤ Sulphates and creatinine are not reabsorbed.

(ii) Loop of Henle

- ➤ Loop of Henle is found in medulla of kidney. It is long in mammals and birds but short or absent in other vertebrates like reptiles.
- ➤ About 80% of water is reabsorbed in PCT and loop of Henle. This is called obligatory water reabsorption.

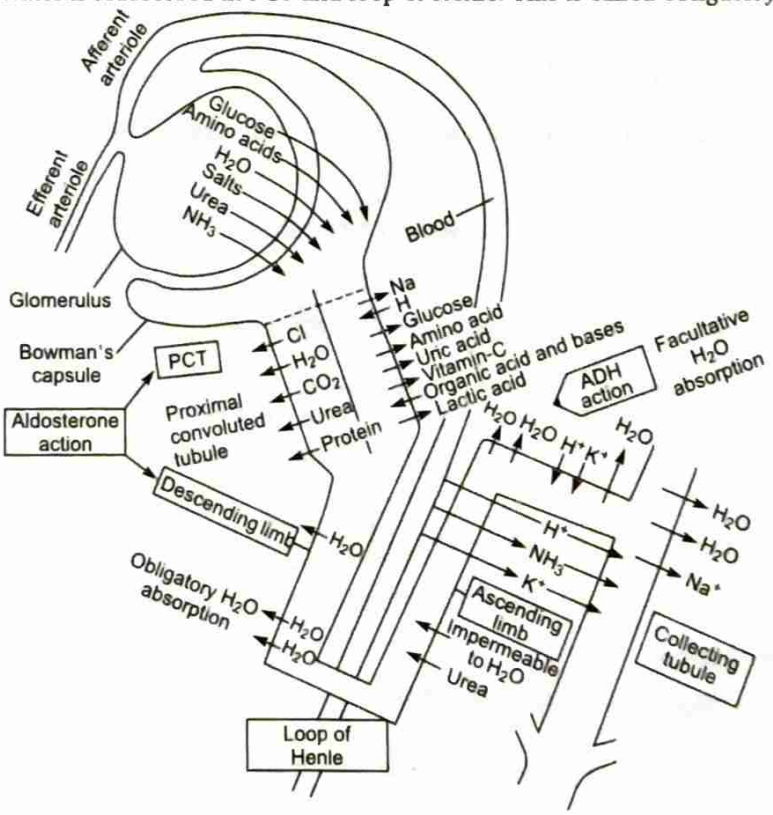

Fig. 6.2 Physiology of excretion

(iii) Distal Convoluted Tubule (DCT)

- DCT and the collecting duct actively reabsorbed sodium from the filtrate under influence of the adrenal hormone aldosterone which makes their walls permeable to ions.
- About 19% of water is reabsorbed by the action of the **Anti Diuretic Hormone** (ADH).
- Absence of ADH reduces the reabsorption of water in DCT causing dilute and increased urine. This condition is called **diabetes insipidus**.
- Water reabsorption in DCT mediated by ADH is called facultative water reabsorption. About 13% water is reabsorbed by facultative reabsorption.
- **Renin—Angiotensin—Aldosterone System (RAAS)**
- Kidney's juxtaglomerular cells secrete an enzyme **renin** which converts a plasma protein called **angiotensinogen** in liver into **angiotensin-I** which is then converted in lung into a peptide **angiotensin-II** by **Angiotensin Converting Enzyme** (ACE).
- Angiotensin-II stimulates the adrenal cortex to produce more aldosterone. Aldosterone brings about an increased Na^+ and water reabsorption.

(c) Tubular secretion

- Tubular secretion is a highly selective process in which substances from the interstitial fluid join the fluid in the kidney tubule.
- In mammals, secreted substances are uric acid, K^+, H^+, ammonia, creatinine, the drugs penicillin and para-aminohippuric acid.
- Most of the K^+ eliminated in the mammalian urine is secreted by the DCT and collecting ducts in exchange of the absorbed Na^+.

Composition of Human Urine

- Human urine contains 95% water, 2% salts, 2.6% urea and 0.3% uric acid.
- Colour of urine is pale yellow. It is due to pigment **urochrome**.
- pH of urine is 6.0 (mildly acidic).
- Volume of urine is 1 to 2 L per day.
- The highest concentration of urea is found in **hepatic vein** and least concentration is found in **renal vein**.
- **Route of urine formation** : glomerular capsule → proximal convoluted tubule → loop of Henle → distal convoluted tubule → collecting duct → papillary duct → minor calyx → major calyx → renal pelvis → ureter → urinary bladder → urethra.

Abnormal Urine

(a) *Albuminuria*	—	Presence of albumin in the urine.
(c) *Glycosuria*	—	Presence of glucose in urine.
(c) *Haematuria*	—	Presence of blood or blood cells in urine.
(d) *Ketonuria*	—	Presence of ketone bodies in urine.
(e) *Haemoglobinuria*	—	Presence of Hb in urine.
(f) *Pyuria*	—	WBCs or pus in the urine.

Haemodialysis

- **Haemodialysis** is the process of removal of excess urea from the blood of a patient (usually suffering uremia) using an artificial kidney.
- The blood of the patient is pumped out of the body, filtered to remove the waste products, a process termed **dialysis**.
- Blood from the artery of the patient is taken, cooled to 0°C, mixed with anti-coagulant like **heparin** and then passed through the artificial kidney.
- **Heparin** is added to the blood to prevent clotting.
- Blood coming out of the artificial kidney is warmed, mixed with anti heparin and restored through a vein.

Functions of Kidney

- Osmoregulation
- Elimination of Nitrogenous wastes
- Maintenance of salt contents
- Maintenance of pH
- Removal of toxic substances, drugs, pigments, excess vitamins from the blood
- Secretion of Renin enzyme.

Some Diseases of Urinary System

(a) ***Pyelonephritis*** It is an inflammation of the renal pelvis and the medullary tissue of the kidney.
(b) ***Cystitis*** It is inflammation of the urinary bladder that may be caused by an infection that has spread from the urethra or in males by pressure exerted by an enlarged prostate gland.
(c) ***Incontinence*** It is the inability to control the release of urine.
(d) ***Oedema*** Accumulation of excess fluid in tissues is called oedema.
(e) ***Renal stone*** Excessive hormonal imbalance, excess uric acid formation, excess milk intake, dehydration, metabolic disturbance etc are mainly responsible for **renal stones** or **calculi.**

Extra Points

1. **Micturition** : The expulsion of urine from the urinary bladder is called micturition.
2. **Urinalysis** : The examination of the physical and chemical properties of urine.
3. **Kidney stone** : Crystallized chemicals like uric acid, calcium oxalate and calcium phosphate.
4. **Bright's disease** : Inflammation of kidney.
5. **Dysuria** : Painfull urination.
6. **Anuria** : Absence of urine.
7. **Organs of Bajanus** and **Keber's organ** are excretory organs in *Unio*.
8. **RAAS** : Renin-Angiotensin-Aldosterone System.
9. **Bidder's canal** lies inside the kidney of male frog.