BIOLOGY - EXCRETORY SYSTEM IN MAN  
CLASS – X

As a result of various metabolic activities taking place in the body, various waste substances are produced. If these waste substances accumulate in the body, it would poison body cells and this would result in the death of the organism. Hence it is important for our body to get rid of these toxic waste products.

The elimination of metabolic wastes, excess of salts and water from the body is called EXCRETION.

The organs concerned with the process of excretion are called Excretory organs. The major excretory organ in man is the kidney. Other organs such as the liver, lungs, skin and large intestine also eliminate wastes besides performing their normal functions. They are called the additional excretory organs.

What are the excretory waste products produced by our body?

1. Carbon-di-oxide - is eliminated through the lungs
2. Water - becomes a part of the water in our body and eliminated as sweat or urine.

1. Ammonia, urea, and uric acid are excreted through the kidneys.

Excess of mineral salts taken along with food are also toxic. They are eliminated from the body along with sweat, urine or faeces.

65% of our body is made of water. When this limit exceeds, it is eliminated along with urine, sweat & faeces.

They are formed by the breakdown of haemoglobin in dead RBC’s. A large amount of these pigments is eliminated through faeces and some through urine.
EXCRETORY SYSTEM OR THE URINARY SYSTEM

Organs which are concerned with the formation, storage and elimination of urine constitute the Excretory system.

![Diagram of the urinary system]

**Fig. 43.47. Diagram to show the kidneys, ureters and urinary bladder in man**

The excretory system in human beings consists of:-

- A pair of kidneys
- A pair of ureters
- Urinary bladder
- Urethra

**Kidneys** :-

- A pair of reddish brown, bean shaped structures which lie along the posterior abdominal wall on either side of the vertebral column.
- The right kidney is placed slightly lower than the left kidney as the right kidney is pushed down by the large liver.
- The outer margin of the kidney is convex and the inner margin is concave.
- On the inner concave side of the kidney is present a notch called **hilum**. This leads to space called the renal sinus.
- The renal artery, renal vein, ureters, enter or leave the kidney from the hilum.
Ureters:

- They arise from within the renal sinus of the kidneys at the hilum. The anterior part of each ureter is a funnel shaped structure, the pelvis.
- The ureters transport urine from the kidneys to the urinary bladder.
- Each ureter opens into the urinary bladder by an aperture.
- Valves at the openings of the ureter prevent the back flow of urine.

Urinary Bladder:

- This is a muscular sac like structure which temporarily stores urine.
- It is situated in the lower end of the abdomen.
- The neck of the urinary bladder is surrounded by sphincter muscles which remain closed till the time of urination.

Urethra:

- It is a short muscular tube which arises from the neck of the urinary bladder and leads to the outside.
- The opening of the urethra is also guarded by a ring of sphincter muscle. It relaxes during urination.

Renal artery:

- This is a branch of the Aorta which enters the kidney at the hilum. It brings with it oxygenated blood containing nitrogenous waste.
- On entering the kidney, the renal artery divides repeatedly to form thin vessels called afferent arterioles.

Renal vein:

- It is formed by the union of the renal venules in the kidney.
- The renal vein leaves the kidney at the hilum carrying with it deoxygenated blood, free from all toxic waste products.
- The renal vein returns blood to the inferior vena cava.
A longitudinal section of the kidney shows two layers –

1. outer dark **cortex**
2. inner light **medulla**.

**Cortex** – This region is dotted in appearance and appears darker in colour.

**Medulla** - This region is subdivided into 15 or 16 conical masses, the **renal pyramids**. Each pyramid has narrow **renal papilla** toward the pelvis and a broad base toward the cortex. Each renal papilla projects into the cavity of a **minor calyx**. These minor calyces join to form 2-3 major calyces, which open into a wide funnel-like structure, the **pelvis**, which leads into the ureter.

**Structure of the Nephron**

Each kidney has about 1.25 million highly coiled tubules called **uriniferous tubules** or **nephrons**.

**The nephron is the structural and functional unit of the kidney.**

Each nephron is differentiated into two parts - 1. Malpighian corpuscle or renal capsule

2. Renal tubule
1. **Malpighian corpuscle**: It lies in the cortex of the kidney. It is further differentiated into two parts-

   a. Bowman’s capsule

   b. Glomerulus

   a. **Bowman’s capsule**: It is a double walled, cup shaped structure made of thin semi-permeable squamous epithelial cells. It forms the dilated blind end of a nephron.

   b. **Glomerulus**: It is a knot of capillaries present in the cup of the Bowman’s capsule. The afferent arteriole (incoming blood vessel) enters the Bowman’s capsule and branches to form a network of capillaries. This network is called **glomerulus**. These capillaries reunite to form the efferent arteriole (outgoing blood vessel).

2. **Renal tubule or nephric tubule**: The Bowman’s capsule leads into a coiled part of the nephron called **Renal tubule**. It can be divided into three major regions:-

   a. Proximal convoluted tubule (PCT)

   b. Loop of Henle

   c. Distal convoluted tubule (DCT)

   a. **Proximal convoluted tubule**: It is the initial highly coiled tubular part that lies in the cortex. The cells lining this part are made of columnar epithelium and have microvilli on their free surface which appears like a brush border. This increases surface area for absorption.

   b. **Loop of Henle**: It is a ‘U’ shaped part of the renal tubule. It consists of a descending limb, hair pin loop and ascending limb. It is found in the medulla of the kidney. The descending limb is lined with squamous epithelial cells, while the ascending limb is lined with cuboidal epithelium.

   c. **Distal convoluted tubule**: It is again highly coiled part found in the cortex of the kidney. It is lined by cuboidal epithelium. It opens into the collecting tubule.

The open ends of so many nephrons open into a wider tube called **collecting tubule**. These tubules open into a larger tube called the **collecting duct**. They extend from the cortex to the medulla. They are present in groups called pyramids. The collecting duct receives the contents of many renal tubules and pours it as urine in the pelvis, which leads into the ureter.
Malpighian corpuscle

Uriniferous tubule with blood vessels
BLOOD VESSELS OF THE KIDNEYS

The kidneys are highly vascular organs through which 1200 ml of blood flow through every minute.

- A pair of renal arteries branch from the Dorsal Aorta and supply oxygen rich blood to each kidney.
- In the kidney, the renal artery branches repeatedly to form thin vessels called afferent arterioles.
- The afferent arteriole on entering the Bowman’s capsule, forms a network of capillaries called glomerulus.
- These capillaries again reunite to form the efferent arteriole.
- On leaving the Bowman’s capsule the efferent arteriole again breaks up to form a network of capillaries around the renal tubule. This is called the peritubular network or secondary capillaries.
- Capillaries of this system again unite to form the renal venules.
- Renal venules join to form the larger renal vein.
- The renal vein returns deoxygenated blood purified of all waste products to the inferior vena cava.

MECHANISM OF URINE FORMATION

As result of deamination in the liver, nitrogenous waste products are formed. Ammonia is one of the main nitrogenous wastes. As this is very toxic, urea is formed from ammonia and carbon dioxide in the liver cells. Urea is less toxic and highly soluble in water. This is then transported by the blood to the kidneys along with small amounts of uric acid, excess of water, mineral salts, bile pigments etc., for elimination in the form of urine.

The formation of urine is accomplished in the following three steps:-

A. ULTRAFILTRATION :

Definition: The filtration of blood under tremendous hydrostatic pressure in the malpighian corpuscle is called ultrafiltration.

- When blood passes from the afferent arteriole having a larger diameter to the efferent arteriole having a smaller diameter, a pressure is built up in the capillaries of the glomerulus.
- Due to this hydrostatic pressure, all the substances in the blood that can pass through the capillary walls get filtered out and enter into the Bowman’s capsule.
- This occurs because the walls of these capillaries have fine pores and most of the substances in the blood are small enough to pass through these pores, into the Bowman’s capsule.
- As blood cells, fat droplets and proteins are too large to pass through, they remain in the blood. Hence, the blood in the efferent arteriole is thicker than the blood in the afferent arteriole.
- The fluid filtered into the Bowman’s capsule is called glomerular filtrate or nephric filtrate or primary urine. It consists of useful substances such as glucose, salts, various elements and a
large amount of water. It also contains nitrogenous waste products such as urea, uric acid, ammonia etc.

- In man about 180 litres of glomerular filtrate is formed each day.

**B. TUBULAR REABSORPTION :**

**Definition :** Selective tubular reabsorption is the process of absorption of all useful substances from the glomerular filtrate into the blood running through the secondary network of capillaries.

- The glomerular filtrate entering the renal tubule contains several useful substances such as glucose, amino acids, certain salts (esp. of Na⁺ and K⁺) and water.
- All these substances have to be reabsorbed into the blood so that the normal concentration and fluidity of the blood is restored.
- The process of reabsorption is brought about by two processes – simple diffusion and active transport.
- **In the PCT**, 65-80% of water, glucose, amino acids, and minerals like Na, Ca and K is reabsorbed.
- **In the descending limb**, 5% water is reabsorbed by the process of osmosis, as it is permeable to water.
- **In the ascending limb**, only minerals, mainly Na⁺, Cl⁻ are reabsorbed by active transport. (It is the movement of molecules against a concentration gradient which requires energy). This part of the limb is impermeable to water.
- **In the DCT and collecting ducts**, Na⁺ is reabsorbed under the influence of hormone Aldosterone. Water is reabsorbed under the influence of the hormone ADH (anti-diuretic hormone or vasopressin).

**C. TUBULAR SECRETION:**

**Definition :** The secretion of harmful substances from the blood into the filtrate through the walls of the DCT is called tubular secretion.

- This process is the converse of tubular reabsorption. While tubular reabsorption removes substances from the filtrate into the blood, tubular secretion adds materials to the filtrate from the blood.
- The tubules secrete specific enzymes that mediate active transport of substances like creatinine and elements like K⁺ and H⁺ from the blood into the filtrate.
- Certain drugs like penicillin and other antibiotics are also removed from the blood in this manner.
- Thus, this process helps rid the body of certain toxic substances and also helps in maintaining the acid-base balance (Pₐₕ) of the body.
- The filtrate left after tubular reabsorption and tubular secretion is called urine.
- At the end of the process 180 litres of glomerular filtrate changes to 1.0-1.5 litres of urine per day.
Role of the nephron in urine formation

CONDUCTION OF URINE

The liquid passing into the collecting tubules is the final urine. The collecting tubules fuse to form the collecting duct which releases urine into the renal pelvis and then into the ureter.

Movement of the urine through the ureters into the urinary bladder is induced by gravity and ureteral peristalsis. Valves present at the base of the ureters prevent the backflow of urine.

The bladder has two sphincter muscles - 1. Bladder sphincter: It is located at the exit of the bladder 2. Urethral sphincter: It is located below the bladder sphincter where the urethra opens to the outside.

Urine is expelled from the bladder as a result of the simultaneous contraction of the bladder and the relaxation of the sphincter muscles, under an impulse from the nervous system.

Micturition is the expulsion of the urine from the bladder along the urethra to the outside.

Diuresis is the process of formation and elimination of urine from the body.

Diuretics are substances that increase the formation of urine in the body. Eg. tea, coffee, alcoholic beverages.

OSMOREGULATION

The process of maintaining the water and salt contents constant in the body is called osmoregulation.

The kidneys along with certain hormones is responsible for maintaining osmoregulation in our body.
Why is osmoregulation important?

This is important because changes in the amount of water in the blood and tissue fluid have a great effect in the body cells.

When there is an excess amount of water in the body fluids, the urine passed out is hypotonic—more dilute than the body fluids. In this manner, the volume of the body fluids is brought down.

If the body fluid falls below normal, the urine is discharged in small amounts and will be concentrated (hypertonic). This raises the volume of body fluids to normal.

COMPOSITION OF URINE

Physical and Chemical Nature of Normal Urine

<table>
<thead>
<tr>
<th>Physical Characteristics</th>
<th>Chemical Composition</th>
<th>Quantity (g/litre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Volume: One to two litres per day but varies considerably.</td>
<td>Organic Compound</td>
<td></td>
</tr>
<tr>
<td>2. Colour: Clear, yellow or amber liquid due to the pigment urochrome. Colour varies with diet and concentration. Stored urine is turbid due to sediment of salts and mucous.</td>
<td>Urea</td>
<td>2.3</td>
</tr>
<tr>
<td>3. pH (5.0 to 8.0): Normal urine is slightly acidic (pH = 6). A protein diet makes the urine acidic while a vegetable diet makes it alkaline.</td>
<td>Creatinine</td>
<td>1.5</td>
</tr>
<tr>
<td>4. Odour: Aromatic, but becomes ammonia-like on standing (due to bacterial decomposition).</td>
<td>Uric acid</td>
<td>0.7</td>
</tr>
<tr>
<td>5. Specific gravity: 1.001 - 1.035</td>
<td>Other substances</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>Inorganic Compound</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sodium chloride</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td>Potassium chloride</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Sulphuric acid</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Ammonia</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Other substances</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Give reasons for-

1. In winters, urine production is more.

In winters or when outside temperatures are low, sweat production is reduced and blood becomes dilute. The renal tubules now absorb water from the secondary capillaries and more urine is formed. Consequently, urination is frequent.

2. In summer, urine passed out is thicker.

In summers, or when outside temperatures are high, sweat production is increased as the sweat glands absorb water from the surrounding blood vessels. Therefore, the blood becomes thicker and more
3. Kidney cells have a higher concentration of mitochondria.

Urine formation is a complex process. **Ultrafiltration** is a function of the **cardio-vascular system**. **Absorption and Secretion** are functions of the **tubular cells**. All these functions require energy expenditure. Hence the oxygen demand of the kidneys is 6-7 times higher than that required by muscles. As such, kidney cells have a higher concentration of mitochondria.

4. A dog pants when it is hot.

Many animals have no sweat glands. Hence they lose excess water from their bodies by evaporation of moisture from the mouth and lungs. That is why a dog pants when it is hot.

5. **Oral rehydration solution (ORS) or saline drip is given to patients suffering from cholera.**

In cholera, there is frequent vomiting and diarrhea because of the inability of the intestine to absorb water. To maintain water content constant, kidneys absorb almost all the water from the glomerular filtrate and even some urea is also reabsorbed. Higher concentration of urea in the body is toxic and may prove fatal. The immediate treatment in such cases is to replenish the lost water in the blood. This is done by giving ORS through the mouth or introducing glucose-saline drip into the blood.

**A summary of the functions of the kidney:**

1. **Excretion**
   a. removes nitrogenous metabolic wastes
   b. removes excess salts and vitamins
   c. removes excess water.
   d. removes bile pigments

2. **Osmoregulation**

The kidneys maintain the water and salt balance in the body.

3. **Regulates the pH of the blood (acid-base balance):**

It modifies the rates of secretion of acid or alkaline phosphates when the blood becomes too acidic or alkaline.

**Common diseases related to abnormal composition of urine**

- Glycosuria – urine with sugar (as in Diabetes mellitus)
- Albuminuria – urine with albumen
- Ketonuria- urine with ketone bodies
- Jaundice- urine with bile pigments
- Pyuria – urine with pus cells
- Haematuria – urine with blood cells
- Diabetes insipidus – urine with excess of water (frequent passing out of large amounts of urine)

**Urinary tract infection (UTI)**
Infection of any part of the urinary tract or presence of large amounts of microbes is seen in the urine. General symptoms include inflammation of the part, burning on urination or painful urination.

**Kidney stones**
Excessive uric acid (uric acid is relatively less soluble in water, so forms crystals) and some salts like calcium oxalate are the main source of kidney stones. These salts and uric acid take the form of soft stones, in combination, which affects the functioning of the kidneys.

When crystals of uric acid gets deposited in the joints of some bones it results in **GOUT**.

**Artificial kidney**
When one kidney is damaged or removed for some reason, a person can still survive with one kidney. But if both kidneys fail, it would lead to death. In such cases an artificial kidney or a **dialysis machine** is used, which filters the blood of a patient. The patient is said to be put on **dialysis** and the process of purifying blood by an artificial kidney is called **haemodialysis**. Here the patient’s blood is led from the Radial artery in the arm into the machine where the urea and excess salts are removed and the purified blood is returned to a vein in the same arm.

**BOARD QUESTIONS ON EXCRETORY SYSTEM **

**STD : X**

Q.I) Name the following:

i) The structural and functional unit of the kidney. – Nephron.

ii) The organ where urea is produced. – Liver.

iii) The hormone that helps to increase the reabsorption of water from the kidney tubules. - Antidiuretic hormone/ Vasopressin.

iv) Knot like mass of blood capillaries inside the Bowman’s capsule – Glomerulus.

Q. II) State whether the following statements are true or false. If false, rewrite the correct form of the statement by changing the first or last word only.

i) Urethra carries urine from kidney to the urinary bladder.
   False, Ureter carries urine from kidney to the urinary bladder.

Q. III) Study the diagram given below and then answer the questions that follow:
i) Name the region in the kidney where the above structure is present?
   Renal Cortex.

ii) Name the parts labeled 1, 2, 3 and 4.
   1 – Afferent arteriole                        2 - Glomerulus
   3 – Bowman’s capsule                     4 - Efferent arteriole.

iii) Name the stages involved in the formation of urine.
     Ultrafiltration and Selective reabsorption.

iv) What is the technical term given to the process occurring in 2 and 3? Briefly describe the process.
    Ultrafiltration – The efferent arteriole is narrower than the afferent arteriole. Due to this difference in diameter of the afferent arteriole and efferent arteriole a hydrostatic pressure is set up which causes the water and small molecules present in plasma to enter into the Bowman’s capsule.

Q.IV) Give reasons for the following:

i) Urine is slightly thicker in summer than in winter.
   In summer water is lost due to sweating so the kidneys have to reabsorb more water from the urine making it more concentrated.
   Whereas in winter, one does not sweat much hence the water is mainly lost through urine.

ii) The renal cortex has a dotted appearance.
   The renal cortex has a dotted appearance because of the presence of malpighian capsule.

Q.V) Given below is a set of five terms. Rewrite the terms in a logical sequence directed at
end of it.

i) Renal vein, Renal artery, Afferent arteriole, Efferent arteriole, Glomerulus. (Pathway of blood through glomerulus)

Renal artery, Afferent arteriole, Glomerulus, Efferent arteriole, Renal vein.

Q.VI) Differentiate between the following on the basis of point given in bracket.

i) Bowman’s capsule and Malpighian capsule (Parts included)

<table>
<thead>
<tr>
<th>Bowman’s Capsule</th>
<th>Malpighian Capsule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cup shaped, initial part of nephron without glomerulus.</td>
<td>Bowman’s capsule and glomerulus.</td>
</tr>
</tbody>
</table>

Q.VII) The diagram below shows the Excretory System of a human being. Study the same and then answer the questions the follow:
i) Name the parts labeled 1, 2, 3 and 4.
1 - Posterior vena cava
2 - Dorsal aorta
3 - Renal artery
4 - Renal vein

ii) Give the main function of the parts labeled 5, 6, 7 and 8.
5 – Ureter – Transports urine produced in the kidney to the urinary bladder.
6 – Urinary bladder – Temporary storage of urine.
7 – Sphincter muscle – Guards the opening of the urinary bladder into the urethra and relaxes only at the time of micturition.
8 – Urethra – Urine is expelled out from the urinary bladder through urethra.

iii) Name the endocrine gland that could be added in the diagram and state its location/position.
Adrenal gland. Located superior to each kidney fitting like a cap.