CHAPTER 19
EXCRETORY PRODUCTS AND THEIR ELIMINATION

Excretion:

The removal of unwanted substance from the body is called excretion.

Ammonia, urea and uric acid are the major forms of **nitrogenous wastes** excreted by the animals.

1.Ammonotelism

- The process of excreting ammonia is **Ammonotelism**.
- The organism that excrete ammonia is called **ammonotelic**
- Ammonia, as it is readily soluble, is generally excreted by **diffusion across body surfaces or through gill surfaces (in fish)** as ammonium ions.
- Kidneys do not play any significant role in its removal.
- Ammonia is the most toxic form and requires large amount of water for its elimination.
- **Eg**: Many bony fishes, aquatic amphibians and aquatic insects are ***ammonotelic*** in nature.

2. Urecoltelism

- The process of excreting uric acid is called **urecotelism**.
- The organism that excrete uric acid is called **uricotelic.**
- **Eg** :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 .**
- **Uric acid is the least toxic** nitrogenous material

3. Ureotelism

- The process of excreting Urea is **Ureotelism.**
- The organism that excrete urea is called **Ureotelic.**

Eg : Mammals, many terrestrial amphibians and marine fishes mainly excrete urea.

- **Ammonia produced by metabolism is converted into urea in the liver of these animals (This cycle is called urea cycle) and released into the blood which is filtered and excreted out by the kidneys.**

Excretory organs

a) Protonephridia or flame cells

- They are the excretory structures in **Platyhelminthes** (Flatworms, e.g., *Planaria*), **rotifers, some annelids and the cephalochordate – Amphioxus**.
- The chordates in which the excretory organ is protonephredia is the **cephalochordates**
- Protonephridia are primarily concerned with ionic and fluid volume regulation, i.e., osmoregulation.

b) 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

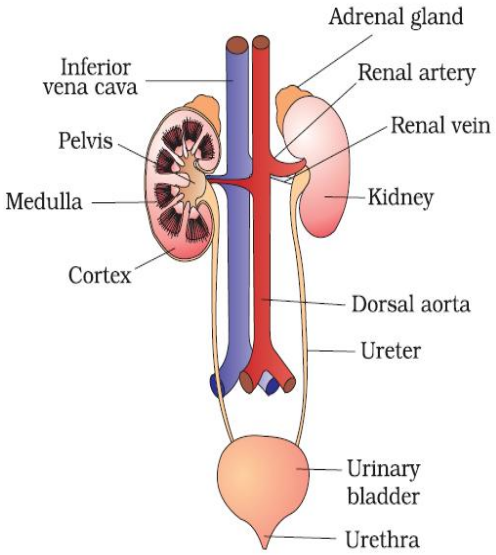
c) Malpighian tubule

- Malpighian tubules are the excretory structures of most of the insects including **cockroaches**.
- Malpighian tubules help in the removal of nitrogenous wastes and osmoregulation.

d) Antennal glands or green glands

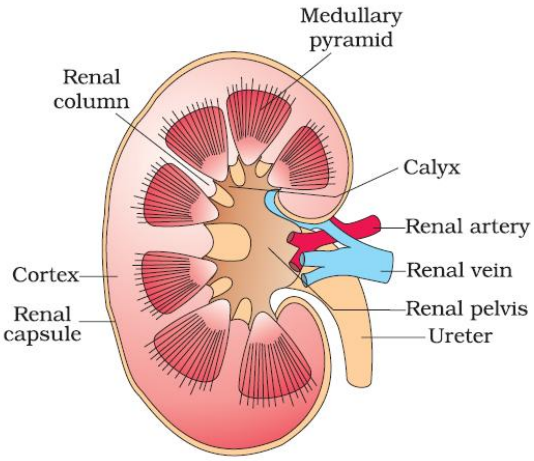
- It perform the excretory function in **crustaceans like prawns**.

HUMAN EXCRETORY SYSTEM



- In humans, the excretory system consists of
  - **a pair of kidneys,**
  - **one pair of ureters,**
  - **a urinary bladder and**
  - **a urethra.**

- Kidneys are **reddish brown, bean shaped** structures .
- It is situated between the levels of last thoracic and third lumbar vertebra close to the dorsal inner wall of the abdominal cavity.
- **Length :10-12 cm**
- **Width : 5-7 cm**
- **Thickness :2-3cm**
- **Weight :120-170g**
- 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**..
- 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 **nephrones** , which are **the functional units of kidney** . Each nephrones has two parts –

a) Glomerulus

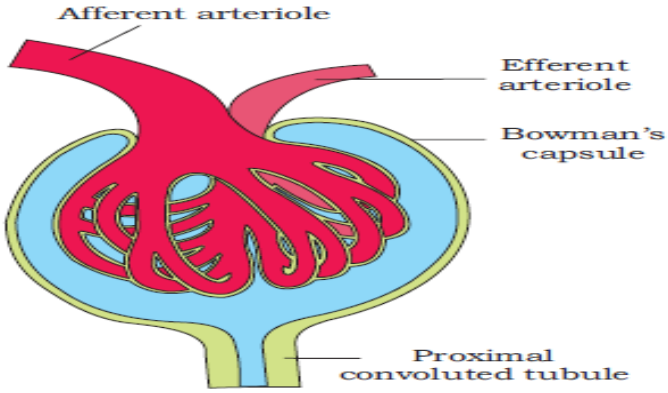
b) Renal tubule.

a) Glomerulus:

- it 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**.

b)Renal tubule

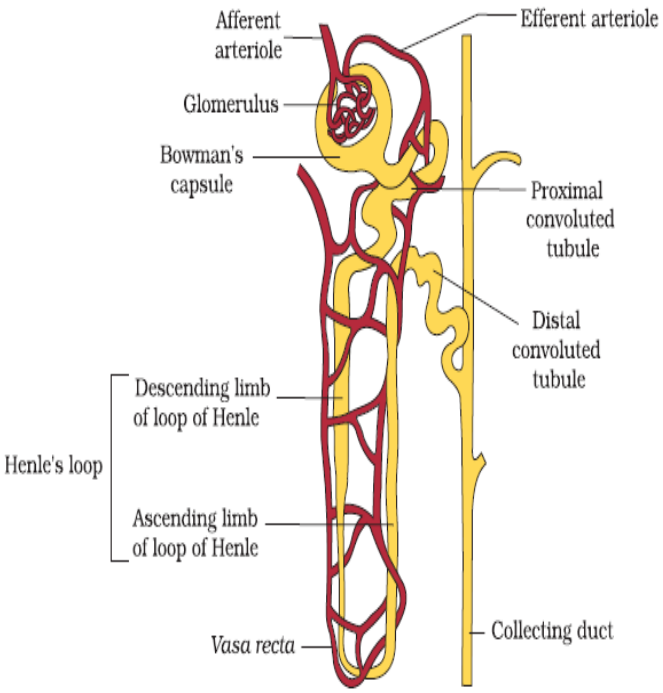
- The renal tubule begins with a **double walled cup-like structure called Bowman's capsule**, which encloses the glomerulus.
- Glomerulus alongwith Bowman's capsule**, is** called the **malpighian body or renal corpuscle**.



- 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**.



Peritubular capillaries and vasarecta

- The efferent arteriole emerging from the glomerulus forms **a fine capillary network around the renal tubule** called the **peritubular capillaries**.
- A minute vessel of Peritubular capillary network runs parallel to the Henle's loop forming **a 'U' shaped vasa recta.**

Types of nephrones

a)Cortical nephrons

- 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.
- Vasa recta is **absent or highly reduced** in cortical nephrones

b)Juxtamedullary nephron

- 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.

JGA (Juxta glomerular apparatus)

It is a special sensitive region formed by cellular modifications in the distal convoluted tubule and the afferent arteriole at the location of their contact.

URINE FORMATION

Urine formation involves three main processes namely,

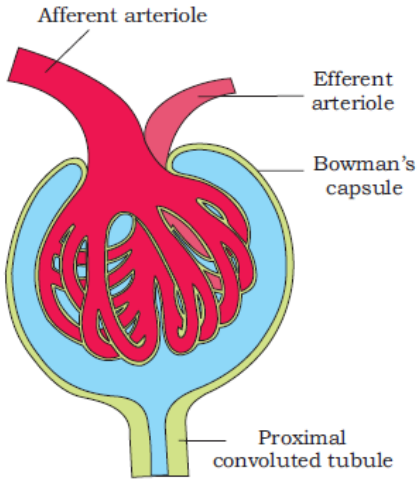
A) Glomerular filtration,
B) Tubular reabsorption
C) Tubular secretion

A) Glomerular filtration

- 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 so as 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 **ultrafiltration.**



B) Tubular reabsorption

- 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 .**
- A normal human being will not excrete such an amount of urine**.**
- **He will excrete 1.5l/day, it shows the 99% of glomerular filtrate is re absorbed.**

i)Re absorption in PCT

- PCT is lined by simple cuboidal brush border epithelium which increases the surface area for reabsorption.
- **Nearly all of the essential nutrients, and 70-80 % of electrolytes and water are reabsorbed by this segment**

ii)Re absorption in Henles loop

- Reabsorption in this segment is **minimum**. However, this region plays a significant role in the maintenance of high osmolarity of medullary interstitial fluid

a)Re absorption in descending limb:

- The descending limb of loop of Henle is **permeable to water but almost impermeable to electrolytes.** This concentrates the filtrate as it moves down

b)Reabsorption in the ascending limb :

- The ascending limb is **impermeable to water but allows transport of electrolytes actively or passively**. Therefore, as the concentrated filtrate pass upward, concentration decreases.

iii)Reabsorption in DCT

- Conditional reabsorption of Na^+ and water takes place in this segment. DCT is also capable of reabsorption of HCO^{3-}

iv)Tubular reabsorption in collecting duct

- Large amounts of water could be reabsorbed from this region to produce a concentrated urine.

C) Tubular secretion

- 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.
- Tubular secretion in various parts is given below

i)Tubular secretion in PCT

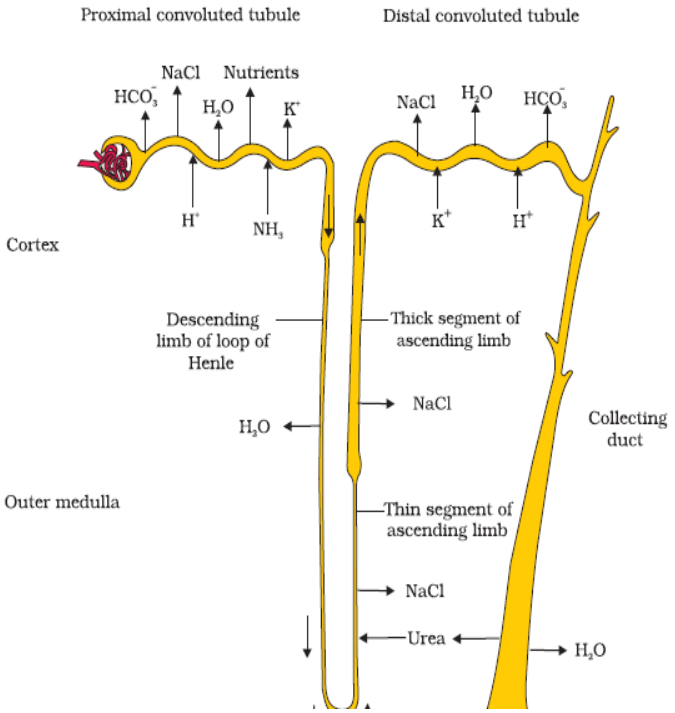
PCT also helps to maintain the pH and ionic balance of the body fluids by **selective secretion of hydrogen ions, ammonia and potassium ions into the filtrate** and by absorption of HCO^{3-} from it.

ii)Tubular secretion in DCT

DCT is also capable of reabsorption of HCO^{3-} and **selective secretion of hydrogen and potassium ions and NH_3** to maintain the pH and sodium-potassium balance in blood.

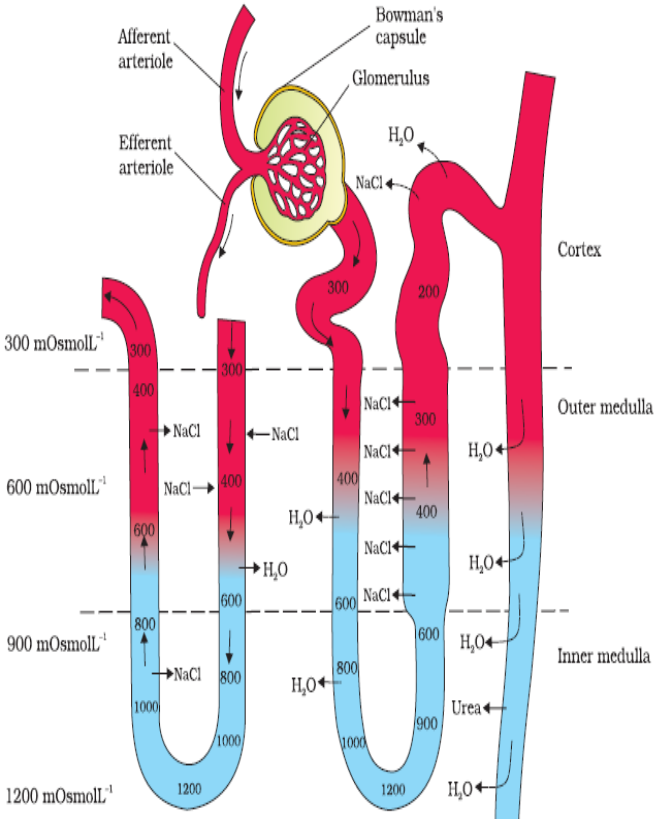
iii)Tubular secretion in Collecting duct

selective secretion of H+ and K+ ions occurs here.



MECHANISM OF CONCENTRATION OF THE FILTRATE

- Mammals have the ability to produce a **concentrated urine**. The **Henle's loop** and **vasa recta** play a significant role in this.
- The flow of filtrate in the two limbs of Henle's loop is in opposite directions and thus forms **a counter current.**
- The flow of blood through the two limbs of vasa recta is also in a counter current pattern.
- The proximity between the Henle's loop and vasa recta, as well as the counter current in them help in maintaining an increasing osmolarity towards the inner medullary interstitium, i.e., from **300 $mOsmolL^{-1}$ in the cortex to about 1200 $mOsmolL^{-1}$** in the inner medulla. This gradient is mainly caused by **NaCl and urea**.
- NaCl is transported by the ascending limb of Henle's loop which is exchanged with the descending limb of vasa recta. NaCl is returned to the interstitium by the ascending portion of vasa recta.
- Similarly, small amounts of urea enter the thin segment of the ascending limb of Henle's loop which is transported back to the interstitium by the collecting tubule. The above described transport of substances facilitated by the special arrangement of Henle's loop and vasa recta is called the **counter current mechanism**
- This counter current mechanism helps to maintain a concentration gradient in the medullary interstitium. Presence of such interstitial gradient helps in an easy passage of water from the collecting tubule thereby concentrating the filtrate (urine).
- **Human kidneys can produce urine nearly four times concentrated than the initial filtrate formed**.



Regulation of kidney function

1. Regulation by hypothalamus

- **Osmoreceptors** in the body are activated by changes in blood volume, body fluid volume and ionic concentration.
- An excessive loss of fluid from the body can activate these receptors which **stimulate the hypothalamus to release antidiuretic hormone (ADH) or vasopressin** from the **neurohypophysis**.
- **ADH facilitates water reabsorption from latter parts of the tubule, thereby preventing diuresis (The loss of excess water through urine is called diuresis)**.

- An increase in body fluid volume can **switch off the osmoreceptors** and suppress the ADH release to complete the feedback.
- ADH can also affect the kidney function by its **constrictor effects on blood vessels**, hence ADH is also called **vasoconstrictor**. This causes an increase in blood pressure. An increase in blood pressure can increase the glomerular blood flow and thereby the GFR.

2. Renin angiotensin mechanism/ Renin angiotensin aldosterone mechanism (RAAS)

- A fall in glomerular blood flow/glomerular blood pressure/GFR can activate the **JG cells** to release **renin** which converts angiotensinogen in blood to angiotensin I and further to angiotensin II.
- Angiotensin II, being a powerful **vasoconstrictor**, increases the glomerular blood pressure and thereby GFR.
- Angiotensin II also activates the adrenal cortex to release **Aldosterone**. Aldosterone causes reabsorption of **Na+ and water** from the distal parts of the tubule.
- This also leads to an increase in blood pressure and GFR. This complex mechanism is generally known as the **Renin-Angiotensin mechanism**

3.Atrial Natriuretic factor (ANF)

- An increase in blood flow to the atria of the heart can cause the release of Atrial Natriuretic Factor (ANF).
- ANF can cause **vasodilation** (**dilation of blood vessels**) and thereby **decrease the blood pressure.**
- ANF mechanism, acts as a **check on the renin-angiotensin mechanism**

Micturition

- The passing out of the urine is called **micturition.**
- Urine formed by the nephrons is ultimately carried to the **urinary bladder** where it is stored till a voluntary signal is given by the central nervous system (CNS).
- This signal is initiated by the **stretching of the urinary bladder** as it gets filled with urine.
- In response, the **stretch receptors** on the walls of the bladder send signals to the CNS.
- The CNS passes on **motor messages**. to initiate the **contraction of smooth muscles of the bladder** and simultaneous **relaxation of the urethral sphincte**r causing the release of urine.

URINE

- An adult man excrete **1 to 1.5 litres** of urine /day
- Color= Yellow
- pH=6 (slightly acidic)
- On an average **25-30gm** urea **per day**
- Analysis of urine helps in **clinical diagnosis** of many metabolic disorders as well as malfunctioning of the kidney.

For example,:

Presence of glucose **(Glycosuria)** and ketone bodies **(Ketonuria)** in urine are indicative of **diabetes mellitus**

ROLE OF OTHER ORGANS IN EXCRETION

a)Lungs

✓ Lungs remove large amounts of CO_2 **(200ml /minutes)** and also significant quantities of **water** every day.

b)Liver :

✓ Liver, the **largest gland** in our body, secretes bile-containing substances like bilirubin, biliverdin, cholesterol, degraded steroid hormones, vitamins and drugs.

✓ Most of these substances ultimately pass out alongwith digestive wastes.

c)Glands in the skin:

i)sweat gland:

- ✓ The sweat gland in the skin can eliminate certain substances through their secretions.
- ✓ Sweat produced by the sweat glands is a watery fluid containing **NaCl, small amounts of urea, lactic acid**, etc.
- ✓ **The primary function** of sweat is to facilitate a **cooling** effect on the body surface, it also helps in the removal of containing NaCl, small amounts of urea, lactic acid

ii)sebaceous glands:

- ✓ Sebaceous glands eliminate certain substances like sterols, hydrocarbons and waxes through sebum.
- ✓ This secretion provides a protective oily covering for the skin.

d)salivary gland :

- ✓ Small amounts of nitrogenous wastes could be eliminated through saliva

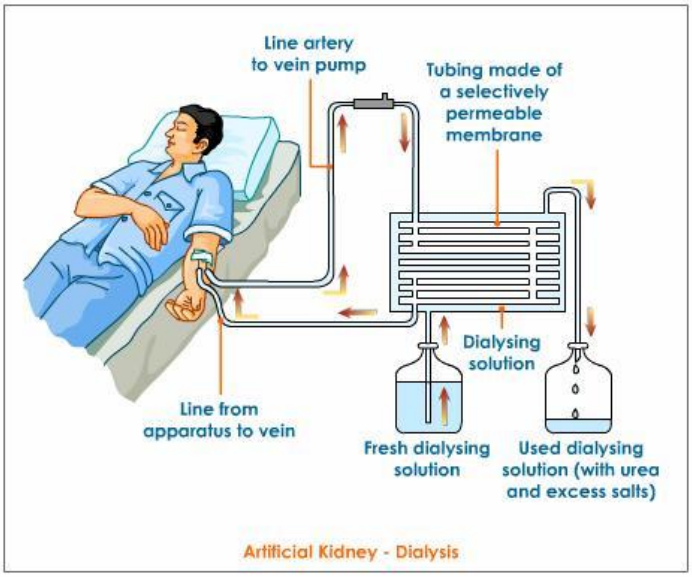
DISORDERS OF THE EXCRETORY SYSTEM

1. Uremia :

- ✓ Malfunctioning of kidneys can lead to **accumulation of urea in blood**, a condition called **uremia**,
- ✓ In such patients, urea can be removed by a process called **hemodialysis**.

Haemodialysis/Artificial kdiney

- ➢ Blood drained from a convenient **artery** is pumped into a **dialysing unit** after adding an **anticoagulant like heparin**.
- ➢ The unit contains a coiled **cellophane tube surrounded by a fluid called dialysing fluid.**
- ➢ **This fluid** has the same composition as that of plasma except the nitrogenous material.
- ➢ This allows the passage of molecules based on concentration gradient.
- ➢ As nitrogenous wastes are absent in the dialysing fluid, these substances freely move out, thereby clearing the blood.
- ➢ The cleared blood is pumped back to the body through a vein after adding anti-heparin to it.



Kidney transplantation

- ✓ Kidney transplantation is the ultimate method in the correction of acute renal failures (kidney failure).
- ✓ A functioning kidney is used in transplantation from a donor, preferably a close relative, to minimise its chances of rejection by the immune system of the host.

2. Renal calculi:

- ✓ Stone or insoluble mass of crystallised salts (**oxalates**, etc.) formed within the kidney.

3.Glomerulonephritis:

- ✓ **Inflammation** of glomeruli of kidney.

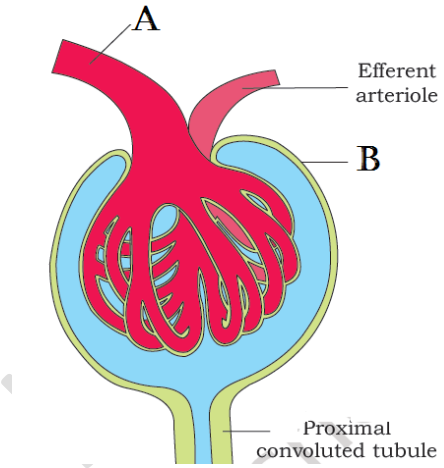
Previous year question paper

1. Some conditions related to kidney disease are given (HSE-Aug-2018)(2)
   - Accumulation of urea in blood.
   - mlalfunction of kidney

   a) Name the condition.
   b) In your opinion, suggest the treatments for kidney failure and acute kidney failure?

2. a)Expand GFR
   b) Even though GFR in a healthy person is 180 liters per day, the amount of urine released Per day is only about 1.5 litres. Give a reason. (HSE-March 2018)(2)

3. a) Write the significance of reabsorption in urine formation' (HSE-Model-2018)(2)
   Of the following substances which one is reabsorbed by active transport ?
4. Glucose, Nitrogenous waste, Water
5. Fish : ammononotelic :: Cockroach:…….. (HSE-Model-2018)(1/2)
6. "The functioning of the kidneys is efficiently monitored and regulated by the heart to certain extent"
   Do you agree with this statement
   Justify your answer ? (HSE-Model-2018)(2)
7. Observe the given diagram of malpighian body (Renal corpuscle)and answer the following (HSE-July-2017)(2)

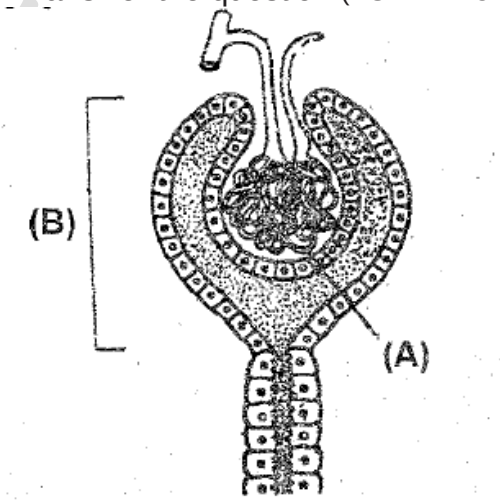


   a)Identify the parts A and B.
   b)Specify the functions of Proximal convoluted tubule in urine formation?

8. Prepare 2 matching pairs from the given list of animals and excretory organs (HSE-March 2017)(2)

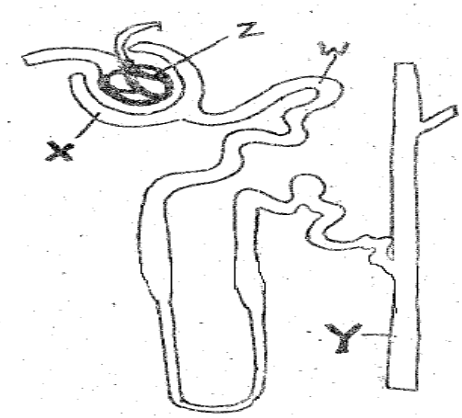
Animals	Excretory organs
a)Prawn	i)Nephredia
b)Cockroach	ii)Antennal gland
c)Earthworm	iii)Flame cell
	iv)Kidneys

9. Uricotelism is more advantageous than ureotelism and ammonotelism in strictly terrestrial animals on the basis of water conservation in then body. Justify ? (HSE-SEPT-2016)(2)
10. The functioning of human kidney is efficiently monitored and regulated by hormonal action of hypothalamus, pituitary, JGA and to certain extent by heart
    a)Do you agree with this statement ?
    b)justify your answer with suitable reason? (HSE-MARCH-2016)(2)
11. Terrestrial animals are either Ureotelic or Uricotelic not ammonotelic. Evaluvate the statement ? (HSE-SEPT-2015)(2)
12. Observe the figure given below and answer the question (HSE-MARCH-2015) (2)



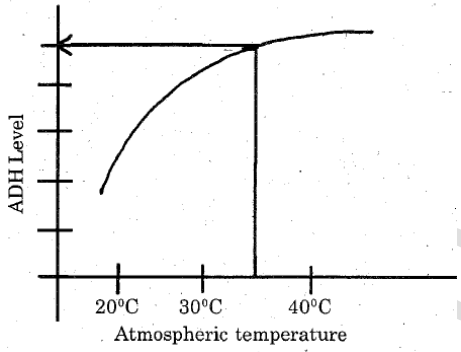
    a)Write the name of the figure?
    b)Name the labeled part A and B?
    c)which is the site of formation of ultra filtrate?

13. A diagrammatic representation of nephrones is given below

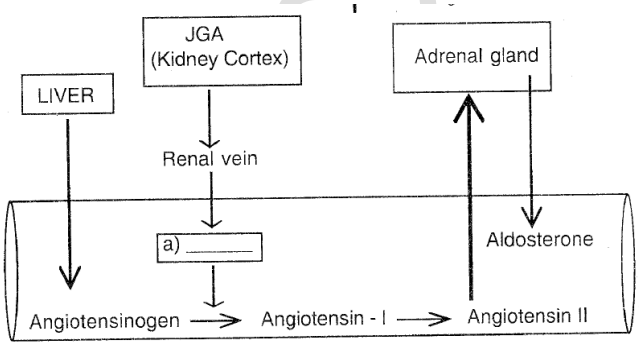


a)Identify the part labeled as X and Y
b)which part/parts of a nephron constitute malpighian body ?
(HSE-AUGUST-2014)(2)

14. The output of urine increase in cold days while decreased in hot and sunny days. Can you give the reason for this phenomenon as realized from the graph given below ? (HSE-MARCH-2014)(2)



15. Observe the schematic diagram showing the mechanism for regulating blood volume.



a) fill the gap in the diagram?
b) Illustrate how blood volume is regulated by this system ?
(HSE-SEPT-2013)(2)

16. In a biology class related to excretion in the human body, a student gave an opinion that in every minute about 2% of total blood volume is converted into GFR whereas only 1% of GFR is eliminated as urine. Evaluate this opinion and substantiate your answer?
(HSE-March-2012)(2)

17. How the counter current mechanism helps to maintain concentration gradient in medullary interstitium ?
OR
On a hot day would you expect your level of ADH in blood to be high or low? Explain? (HSE-sept-2012)(2)