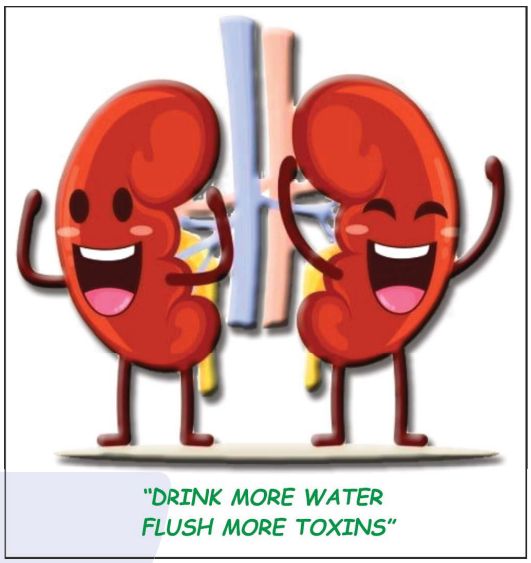
Excretory Products and Their Elimination

- Organisms carry out thousands of metabolic reactions to perform activities like growth, reproduction, movement, etc. During these metabolic reactions, many toxic substances are produced, and many substances are left unused. Such substances are considered wastes and thus, are passed into the blood to be eliminated from the body by the process of **excretion**.
- Excretion differs from **defecation** as defecation involves egestion of faeces consisting of undigested food particles from the anus.
- Excretion and **osmoregulation** are important life processes for maintaining body's **homeostasis**, which is the tendency of an organism's body to maintain a constant internal environment despite of the changing external environment.



TYPES OF EXCRETORY WASTES

- Depending on the chemical composition, there are two types of excretory waste products: Nitrogenous and Non-nitrogenous.

Nitrogenous Wastes

- Major nitrogenous metabolic wastes include ammonia, urea, and uric acid.
- Amino acids, creatine and creatinine, hippuric acid, bilirubin and biliverdin are other minor nitrogenous waste products excreted by the human body.

Ammonia

- Out of the major food components, human body cannot store excess protein digestion products, i.e., amino acids.
- Oxidative deamination of amino acids forms ammonia in the body, which is the most toxic form of nitrogenous waste products.
- Ammonia is highly soluble in water and thus, requires large amount of water for its elimination.

Definitions

Excretion: The process of elimination of metabolic waste products and unused materials from an organism's body.
Osmoregulation: The process of regulation of the salts and water concentration in the body.

Gray Matter Alert!!!

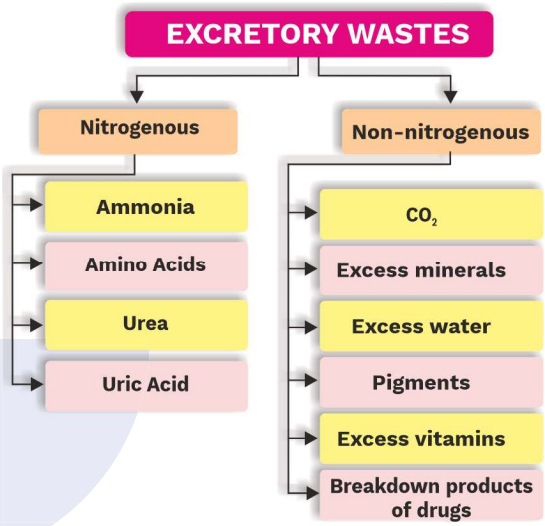
Creatine and creatinine: Creatine is synthesised in the liver and transported to the skeletal muscles where it is involved in energy transfer as phosphocreatine. Phosphocreatine is metabolised to creatinine to be excreted by the kidneys.

Urea

- Urea is comparatively less toxic than ammonia and less soluble in water. It can, therefore, be concentrated in the body for longer time than ammonia and requires comparatively less water for its elimination.

Uric Acid

- Uric acid is formed in the liver and intestinal mucosa by the metabolism of excess proteins, ammonia and purines in the diet.
- Uric acid is least toxic for the body and requires very less water for its elimination as it is almost insoluble in water.
- Uric acid is generally passed out as a paste or pellet along with faeces and is often seen as a small white patch on one side of faecal matter.



Non-Nitrogenous Wastes

- Major non-nitrogenous wastes include carbon dioxide, non-metabolised minerals and vitamins, excess of water, pigments, hormones and drugs in the body.
- Carbon dioxide is eliminated through the lungs in the respiratory system, excess of water is removed by sweating, urination and as moisture in the expired air.
- Excess of minerals, vitamins and pigments are excreted along with urine, sweat or faecal matter.

MODES OF EXCRETION

Major Modes of Excretion

- Depending upon the main excretory products, there are three types of major nitrogenous excretions—ammonotelism, ureotelism and uricotelism.

Ammonotelism

- Animals which excrete ammonia are called **ammonotelic** and the phenomenon is called ammonotelism.

Gray Matter Alert!!!

Toxic ammonia is converted into less toxic urea in the liver cells by the process of urea cycle or **ornithine cycle**, which involves combination of two molecules of ammonia with one molecule of carbon dioxide. The urea formed is released in the blood which is filtered and expelled out by the kidneys.

- Ammonotelism is carried out by protozoan protists, poriferans, cnidarians, flatworms, roundworms, annelids like earthworm and leech, most aquatic crustaceans and aquatic insects, most aquatic molluscs, lungfishes, bony fishes, larvae of amphibians, aquatic tailed amphibians, crocodiles, etc.
- Elimination of ammonia can be done by directly diffusing out of the whole surface as in soft-bodied invertebrates or as ammonium ions (NH_4^+) from the gill epithelium of fish.
- Kidneys do not perform any significant role in removal of ammonia.

Ureotelism

- Animals which excrete urea are called **ureotelic** and the phenomenon is called ureotelism.
- Ureotelism is seen in *Ascaris*, earthworm, cartilaginous fishes (shark, stingrays), adult semi-aquatic amphibians like frogs and toads, many reptiles like turtles, terrapins and alligators, mammals including man, etc.
- Since urea can be concentrated in the body without toxic effects, cartilaginous fishes maintain a high concentration of urea in their blood and body fluids for osmoregulation against seawater.

Uricotelism

- Animals which excrete uric acid are called **uricotelic** and the phenomenon is called uricotelism.
- Animals practicing uricotelism include terrestrial crustaceans, most insects like cockroaches, land snails, land reptiles like lizards and snakes and all birds.

Minor Modes of Excretion

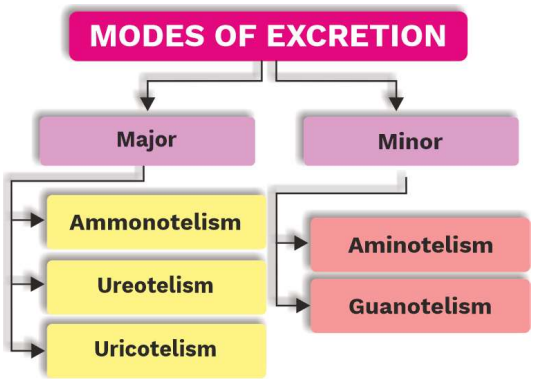
- Minor modes of excretion include aminotelism and guanotelism.

Previous Year's Question

Ureotelic animals:
(1) Lack urease
(2) Do not excrete urea
(3) Cannot form uric acid
(4) Live in water

Rack your Brain

How is ureotelism a mechanism to conserve water in terrestrial life forms?



Aminotelism

- Animals which excrete amino acids are called **aminotelic** and the phenomenon is known as aminotelism.
- Aminotelism occurs in some molluscs like *Pila, Unio, Lymnaea* and some echinoderms like starfish and *Holothuria*.

Guanotelism

- Animals which excrete guanine are called **guanotelic** and the phenomenon is known as guanotelism.
- Scorpions and spiders show guanotelism.

Mixed Excretion

- Some animals excrete more than one excretory product depending on their immediate environment, e.g., earthworm, prawn, lungfishes and African toad *Xenopus*, certain reptiles, man, etc.
- **Earthworm** excretes ammonia in water rich soil and urea in drier soil. **Prawn** is both ammonotelic and ureotelic.
- Lungfish and African toad *Xenopus* are ammonotelic in water and ureotelic outside water.
- Crocodiles, alligators, tortoise, and turtles produce more ammonia under water and more uric acid outside water along with urea.
- Although being ureotelic, humans also excrete out uric acid along with the urine.

DIFFERENT EXCRETORY STRUCTURES IN ANIMAL KINGDOM

Protonephridia

- A protonephridium consists of a network of closed tubules and capillaries, which end in **flame cells** having a tuft of cilia in their wide lumen. Lumen of a flame cell opens into an excretory capillary. Excretory capillaries form tubules which open to

Gray Matter Alert!!!

Guano, the faecal matter of sea birds, is used as a fertiliser due to its high concentration of potassium, nitrogen and phosphate

Previous Year's Question

Nitrogenous waste products are eliminated mainly as:
(1) urea in tadpole and ammonia in adult frog
(2) ammonia in tadpole and urea in adult frog
(3) urea in both tadpole and adult frog
(4) urea in tadpole and uric acid in adult frog

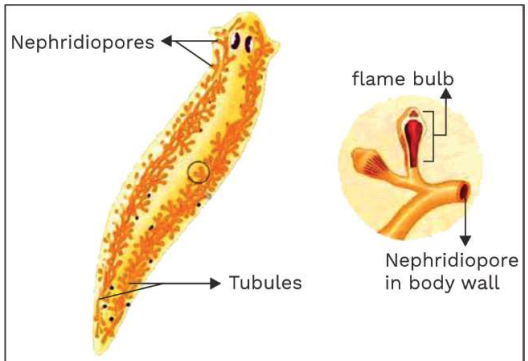
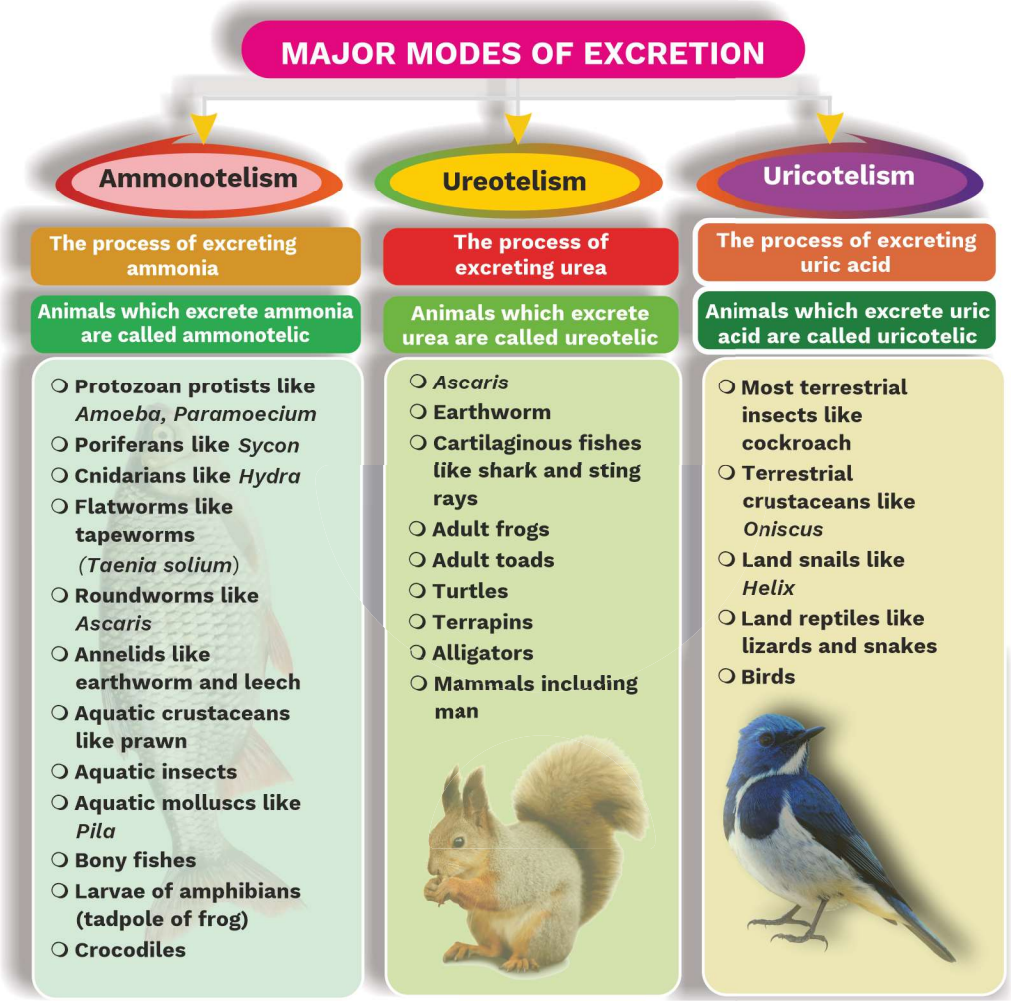


FIGURE: PROTONEPHRIDIA



the outside through one to numerous excretory pores or nephridiopores.

- Flame cells or protonephridia are found in platyhelminthes like *Planaria*, rotifers, larvae and adults of some annelids and cephalochordates like *Amphioxus*.
- Protonephridia mainly performs **osmoregulation**.

Renette or Giant Cell

- Roundworms consist of an H-shaped excretory system of renette or giant cell consisting of four canals. The middle point of all these canals have a bridge in the form of a network called canaliculi which lies exactly beneath the pharynx.

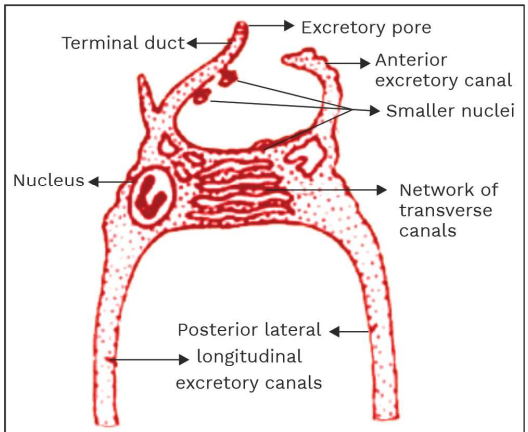


FIGURE: RENETTE CELL OF ASCARIS

Nephridia

- Nephridia are the main excretory structures of annelids like **earthworm**.
- A nephridium usually has a ciliated funnel-shaped opening called nephrostome. The other end of a nephridium has an opening called nephridiopore. Beating of cilia allows the coelomic fluid to enter in the tubule where salts are reabsorbed by the epithelium and later the fluid is transported to the blood from where it is drained out through a nephridiopore.
- Nephridia carry out both **excretion** of nitrogenous waste and the process of **osmoregulation**.

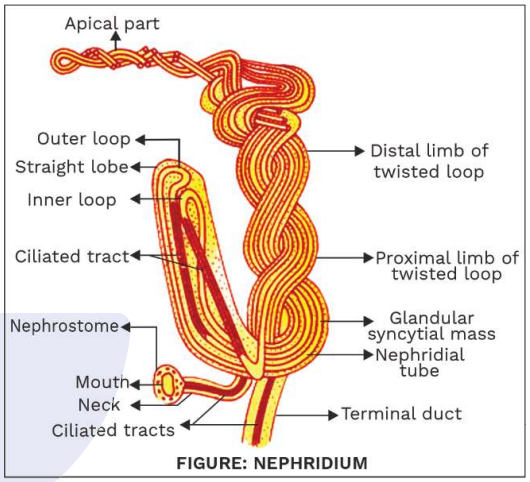


FIGURE: NEPHRIDIUM

Malpighian Tubules

- Malpighian tubules are the main excretory structures of most insects like cockroach.
- They are a group of fine, unbranched, blind tubes which open into the alimentary canal at the juncture of midgut and hindgut.
- Malpighian tubules take part in both excretion and osmoregulation.

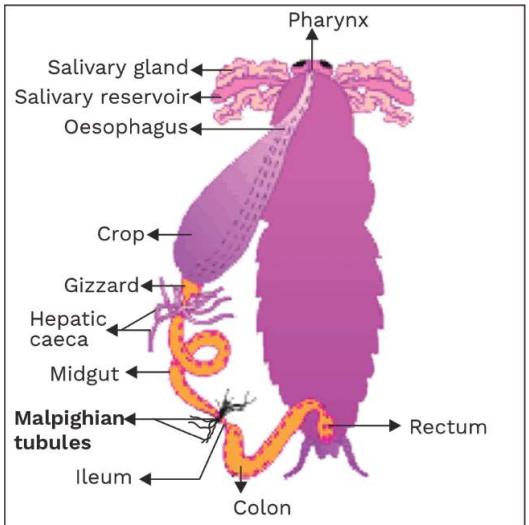


FIGURE: MALPIGHIAN TUBULES IN COCKROACH

Previous Year's Question

Flame cells are excretory organs of:

(1) Prawn
(2) *Planaria*
(3) Silverfish
(4) *Hydra*

Antennal Glands

- Antennal glands or green glands are paired glands present in crustaceans like prawns, crayfish, etc., which perform the function of excretion and osmoregulation.

HUMAN EXCRETORY SYSTEM

- It consists of a pair of kidneys and their blood supply, a pair of ureters, a urinary bladder and a urethra.

Kidneys

- They are a pair of dark brown or reddish brown, bean-shaped, metanephric structures originated from the embryonic **mesoderm**.
- They are situated on either side of the body's middle line, close to the dorsal inner wall of the abdominal cavity, below the diaphragm, between the levels of last (twelfth) thoracic and third lumbar vertebra. Two pairs of floating ribs (11th and 12th) protect the kidneys from the front side,

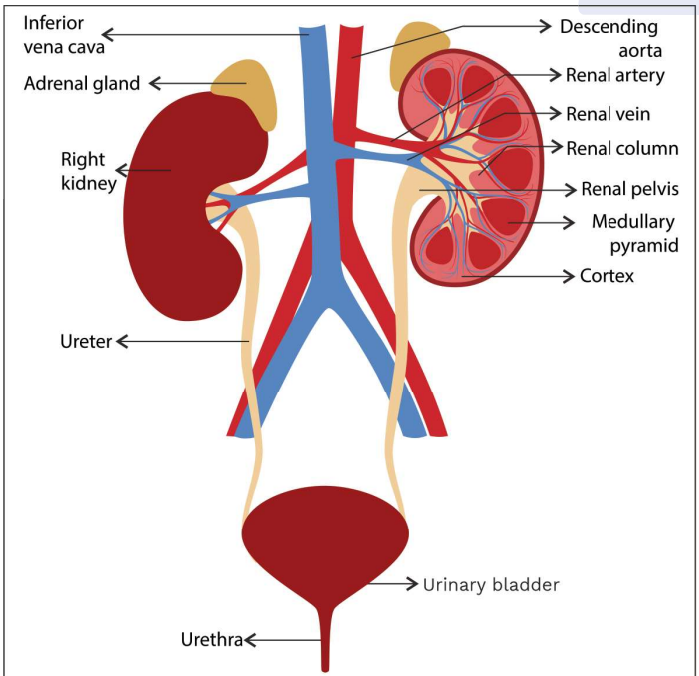


FIGURE: HUMAN EXCRETORY SYSTEM

Rack your Brain

How are kidneys protected in our body?

Previous Year's Question

Urine flows in ureters from:

(1) Kidney pelvis
(2) Urinary bladder
(3) Urethra
(4) Collecting ducts

whereas thick abdominal muscles protect them from the backside.

- Each kidney of an adult human measures **10-12 cm** in length, **5-7 cm** in width, **2-3 cm** in thickness and weighs **120-170 g** on an average (150-170 g in adult male and 120-145 g in adult female).
- Left kidney is placed higher than the right kidney because of the presence of the liver on the right side. Left kidney is also slightly longer and narrower than the right one.
- The outer side of each kidney is convex whereas the inner or medial side of each kidney is concave and bears a notch called the **hilum** or hilus renalis, through which various structures like blood vessels, lymph vessels, nerves and ureter enter or leave the kidney.
- Kidneys are covered by an outer layer of tough **renal capsule** made of white fibrous connective tissue with a few yellow elastic fibres and few muscles, which protects them from injuries. Outer to the renal capsule, a layer of fat or adipose tissue called the **adipose capsule** is present, which acts as a shock absorber. The kidney is attached to the abdominal wall by an outermost fibrous covering called **renal fascia**.
- Inside the kidney, hilum is connected with a broad funnel-shaped space called **renal pelvis** which projects into major and minor **calyces**.
- Kidney tissue is differentiated into two functional zones, outer renal cortex and inner renal medulla.
  - **Renal Cortex:** It is the outer part which consists of glomeruli, Bowman's capsule, proximal and distal convoluted tubules.
  - **Renal Medulla:** It is the inner part which consists of loops of Henle and collecting tubules of the nephrons.
- Medulla is divided into 15-16 conical masses called as medullary pyramids.
- A medullary pyramid has a broad base towards the cortical side and a pointed apex called

Gray Matter Alert!!!

Human kidneys are called **retroperitoneal kidneys** as they are covered by a double fold of peritoneum only on the ventral side.

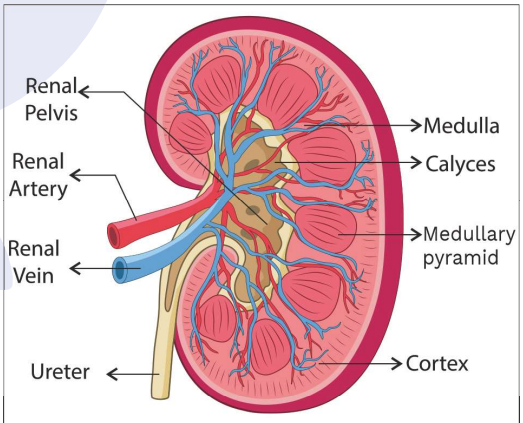


FIGURE: LONGITUDINAL SECTION OF HUMAN KIDNEY

Rack your Brain

Which part of the kidney acts as a gateway for ureter, nerves and blood vessels?

the **renal papilla** towards the pelvis. 1-3 renal papillae projects into 7-13 minor calyces. **Minor calyces** join up and form 2-3 **major calyces** which further join to form the renal pelvis. It is lined by transitional epithelium and leads into ureter.

- The cortex projects in between the medullary pyramids as renal columns called the **columns of Bertini**.
- Structural and functional units of kidney are called nephrons or uriniferous tubules. There are about 1 million nephrons in each kidney.

Ureters

- Ureters are a pair of fine muscular, 25-30 cm long tubes with a diameter of about 3-4 mm.
- Ureters leave from the renal pelvis from the hilum region and run along the abdominal wall to open into the urinary bladder in the region of trigone by oblique slits, one on each side.
- There are three layers in the wall of ureter: external adventitia, middle muscular layer and inner mucosal layer. External adventitia is formed of connective tissue and consists of blood vessels, lymphatics and nerve fibres. Muscular layer has smooth muscle fibres. Mucosal layer has connective tissue towards muscular coat and transitional epithelium towards the lumen.
- Ureters carry urine from the kidneys to urinary bladder by peristalsis in their wall.

Urinary Bladder

- Urinary bladder is a muscular, sac-like, temporarily urine-storing structure which is present in the pelvic region and is composed of transitional epithelium.
- It varies in shape and size according to the amount of urine contained in it. An empty bladder is somewhat tetrahedral whereas a fully distended bladder becomes ovoid.
- The wall of urinary bladder consists of a coat of smooth muscles called **detrusor muscle** which

Keywords

- Renal capsule
- Renal fascia
- Medullary pyramid
- Calyx
- Columns of Bertini
- Renal pelvis
- Trigone

Previous Year's Question

Urine is excreted out of the body through:
(1) Pelvis
(2) Ureter
(3) Urinary bladder
(4) Urethra

further consists of inner and outer layers of involuntary longitudinal muscle fibres and middle layer of circular muscle fibres.

- Some of the involuntary circular muscles of the urinary bladder modify to form the **internal sphincter** in the region of urinary bladder and urethra. Some voluntary muscles, inferior to the internal sphincter, also modify to form an **external sphincter**. Both the sphincters undergo relaxation during the act of passing out urine.
- Body of the urinary bladder has a triangular area called **trigone**. The trigone consists of the two openings of ureters and an internal urethral orifice.
- Normally urinary bladder holds **300-400 ml** of urine. However, it can hold upto 700-800 ml of urine.
- The wall of urinary bladder is innervated by both sympathetic and parasympathetic neural system.

Urethra

- Urethra is present only in mammals. It extends from the neck of the urinary bladder and opens to the exterior through a urethral orifice.
- Urethra is short in females (about **4 cm**) and passes out urine through urethral orifice present in front of the vaginal aperture.
- Urethra is longer in males (about **20 cm**) and passes through the ejaculatory duct, prostate gland, Cowper's glands and penis. It brings out urine as well as semen through urinogenital aperture present at the tip of the penis.
- Urethra consists of very well-developed smooth muscle fibres. Urethral sphincter keeps the urethra closed all the times except at the time of urination.

STRUCTURE OF NEPHRON

- Complex tubular structures called nephrons are the structural and functional units of kidney. A nephron consists of two parts, glomerulus and renal tubule.

Gray Matter Alert!!!

Nearly 10% nephrons decrease with age in every ten years after the age of 40 years (Dunnil and Halley, 1973).

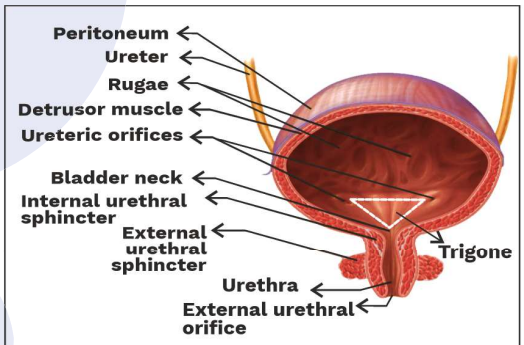
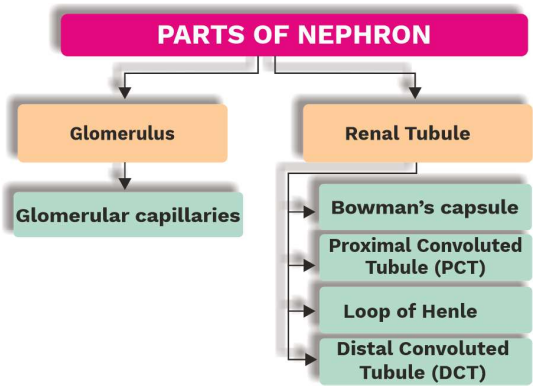


FIGURE: TRIGONE OF THE URINARY BLADDER



Glomerulus

- From the dorsal aorta, a renal artery enters each kidney and divides into many fine branches called the afferent arterioles which form a tuft of capillaries, the **glomerulus**, in each nephron. Blood from the glomerulus is carried away by an efferent arteriole. Efferent arterioles have narrower diameter than that of the afferent arterioles which aids in ultrafiltration of blood. The blood vessels of glomerulus are covered by a single layer of endothelial cells. They are about **100-500** times more permeable than blood capillaries.

Renal Tubule

- Renal tubule is about **3 cm** long and 20-60 μm in diameter and begins with a double-walled structure called Bowman's capsule which continues further to form proximal convoluted tubule (PCT), Henle's loop and distal convoluted tubule (DCT). Glomerulus is enclosed within the Bowman's capsule to form **malpighian body** or **renal corpuscle**.

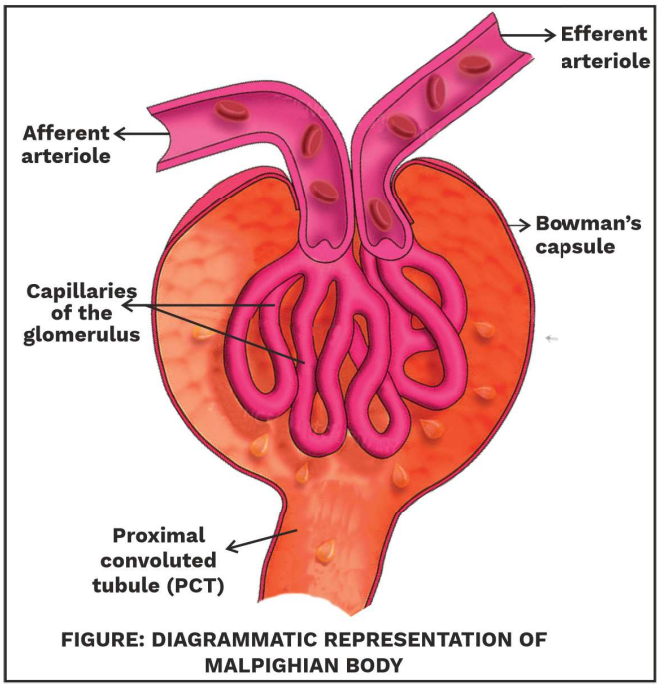


FIGURE: DIAGRAMMATIC REPRESENTATION OF MALPIGHIAN BODY

Definition

Malpighian body or renal corpuscle: Glomerulus along with the Bowman's capsule is called as malpighian body or renal corpuscle.

Rack your Brain

Why efferent arterioles have narrower diameter than the afferent arterioles?

Previous Year's Question

Which one of the four parts mentioned below does not constitute a part of single uriniferous tubule?
(1) Distal convoluted tubule
(2) Collecting duct
(3) Bowman's capsule
(4) Loop of Henle

- The wall of the **Bowman's capsule** consists of an inner visceral layer and outer parietal layer. The visceral layer surrounds the glomerulus and consists of specialised cells called **podocytes** or foot cells. The space between podocytes is called the **slit pores** or filtration slits of about 25 nm in diameter which help in passage of glomerular filtrate. The parietal layer consists of flat squamous epithelium. The space between the two layers of Bowman's capsule is called lumen or capsular space.
- Bowman's capsule has a short narrow neck which continues to form a highly coiled network called the **proximal convoluted tubule (PCT)**. Active absorption and secretion occur in the PCT. Thus, it is lined by cuboidal epithelial cells which possess brush borders with long microvilli to increase the surface area for maximum reabsorption of the glomerular filtrate. Also, PCT is surrounded by peritubular blood capillaries which branch from the efferent arteriole in which the reabsorbed materials are transported.
- Proximal convoluted tubule continues to form a hairpin loop-like structure called the Henle's loop or the **Loop of Henle** which has a proximal descending limb and a distal ascending limb. The **descending limb** of Henle's loop has a thick segment having a diameter equal to that of PCT and a later thin segment. The thick segment is also lined by cuboidal epithelium but with less microvilli. Thin segment is lined by squamous epithelial cells having sparse microvilli and few mitochondria. Thin segment curves to form the **ascending limb** which also consists of a proximal thin segment lined by squamous cells for passive movement of some solutes and a distal thick segment lined by cuboidal cells having microvilli and mitochondria for active secretion of NaCl.
- The ascending limb of Henle's loop extends to form the **distal convoluted tubule (DCT)** lined

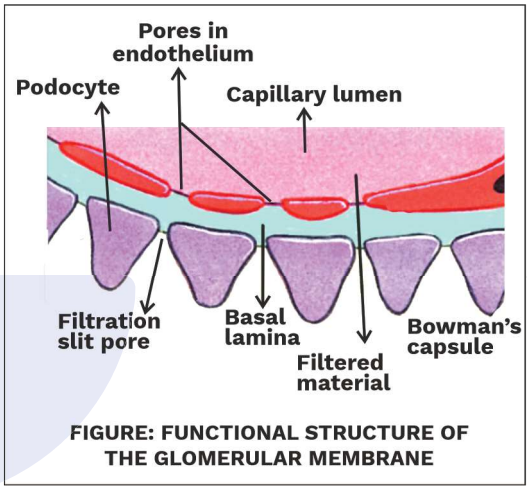


FIGURE: FUNCTIONAL STRUCTURE OF THE GLOMERULAR MEMBRANE

Previous Year's Question

Brush border is characteristic of:
(1) Neck of nephron
(2) Collecting duct
(3) Proximal convoluted tubule
(4) All of the above

by cuboidal epithelial cells with sparse, irregular microvilli and deep mitochondria. DCT lies close to the malpighian corpuscle in the cortical region of the kidney. Certain modified columnar cells of the DCT near the malpighian corpuscle, which are placed near to the afferent arteriole and efferent arteriole contain dense cytoplasm and show sensitivity to NaCl and are collectively called **macula densa**.

- The DCT of each nephron opens into **collecting ducts** which are lined by specialized cuboidal epithelium with very few microvilli. Collecting ducts unite to form ducts of Bellini which run through the renal papillae.

Gray Matter Alert!!!

Macula densa cells are highly sensitive to the concentration of NaCl in the DCT.

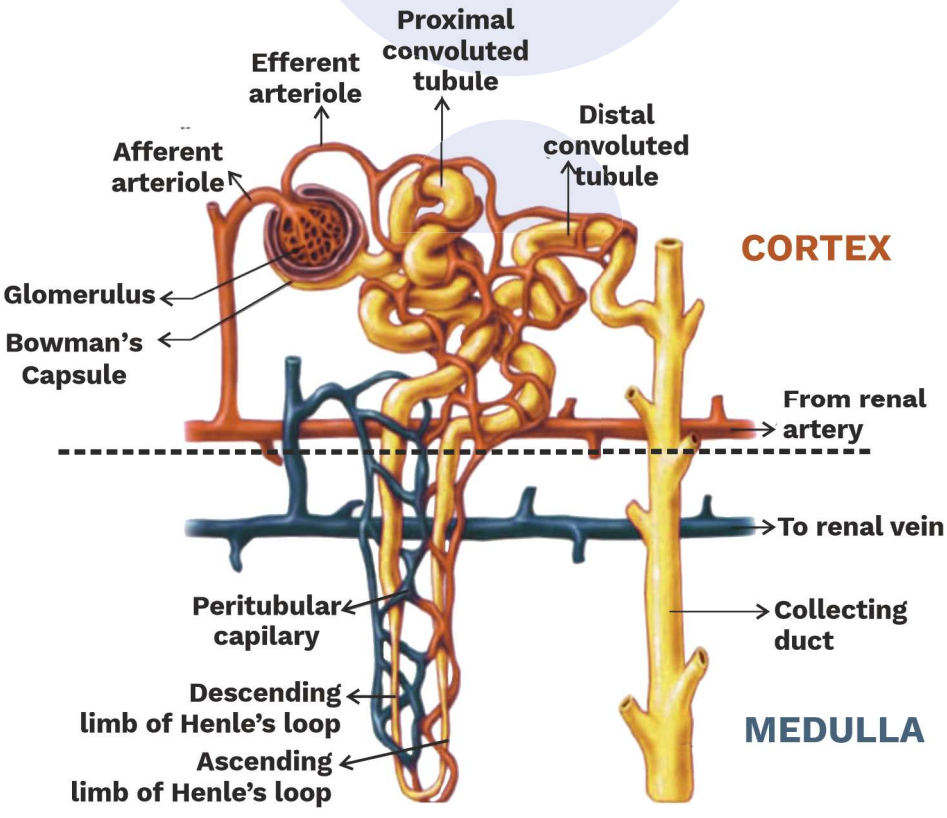


FIGURE: A DIAGRAMMATIC REPRESENTATION OF A NEPHRON SHOWING BLOOD VESSELS, DUCT AND TUBULES

- The entire renal tubule is covered by a network of blood capillaries arising from the efferent arteriole called the **peritubular capillaries**. From the peritubular capillary network arise minute vessels which run parallel to the Henle's loop to form a 'U' shaped **vasa recta**.
- The peritubular capillaries join to form renal venules which further join to form the renal vein.
- The renal corpuscles, proximal convoluted tubule and distal convoluted tubule are situated in the cortical region of the kidney whereas the Henle's loop is located in the medulla.

Juxta glomerular Apparatus (JGA)

- Juxta glomerular apparatus (JGA) consists of juxta glomerular cells, macula densa and lacis cells.
- Some of the smooth muscle fibres in the wall of afferent arteriole and efferent arteriole modify to produce a hormone called **renin**. Such renin-producing cells are called the **juxta glomerular cells**.
- **Lacis cells** are present in between the macula densa and the afferent and efferent arterioles.
- JGA helps in the regulation of kidney function.

TYPES OF NEPHRONS

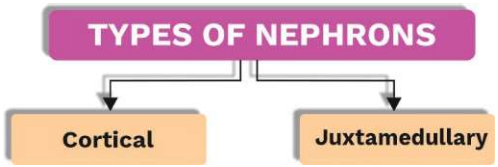
- Based on the location of nephrons, a kidney has two types of nephrons—cortical and juxtamedullary.
- **Cortical Nephrons:** They constitute about **85%** of the total nephrons. Cortical nephrons are smaller in size and majorly lie in the cortex. The renal tubule is much coiled. Loop of Henle is too short and extends into medulla to a short distance. Vasa recta are absent. Glomeruli lie in the outer cortex. Cortical nephrons mainly perform filtration of blood to remove nitrogenous wastes.
- **Juxtamedullary Nephrons:** They form about **15%** of the total nephrons present in the kidneys.

Previous Year's Question

Which one of the following is not a part of a renal pyramid?
(1) Peritubular capillaries
(2) Convoluted tubules
(3) Collecting ducts
(4) Loop of Henle

Gray Matter Alert!!!

Lacis cells play a role in the renal autoregulation of blood flow to the kidneys and systemic blood pressure regulation.



Juxtamedullary nephrons are larger in size and are present at the junction of cortex and medulla region of the kidney. They have a long loop of Henle which extends deep into the medulla. Vasa recta occur over the loops of Henle. Glomeruli occur in the inner cortex. Juxtamedullary nephrons perform the function of osmoregulation in the body.

Rack your Brain

Which type of nephron is involved in urine concentration?

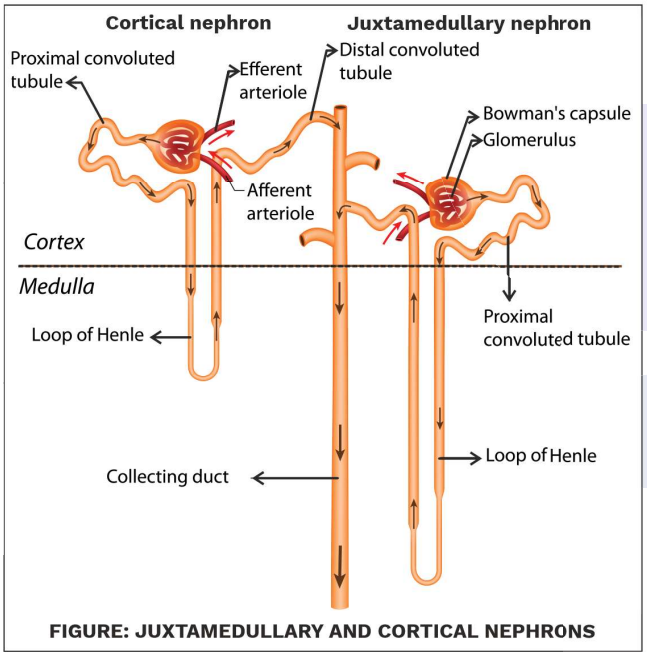
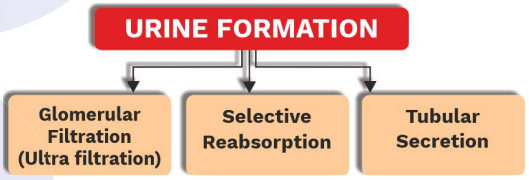


FIGURE: JUXTAMEDULLARY AND CORTICAL NEPHRONS



URINE FORMATION

- Urine formation occurs by three major processes—glomerular filtration, tubular reabsorption and tubular secretion.

Glomerular Filtration (Ultra filtration)

- Filtration of blood occurring in the glomerulus is called glomerular filtration.
- On an average, **1100-1200 ml** of blood is filtered by both the kidneys in one minute (i.e., about 1/5th of the blood coming out by the right and left ventricle of the heart in one minute).

Definition

Ultra filtration: The process of filtration of almost all the constituents of the blood plasma except proteins into the lumen of the Bowman's capsule.

- Blood flows through glomerular capillaries under a pressure. This pressure is partly because of the difference in the diameter of glomerular capillaries and afferent renal arterioles, the latter being wider than the glomerular capillaries and partly by the natural arterial pressure caused by pumping activity of heart.
- Blood pressure in glomerular blood (Glomerular Blood Hydrostatic Pressure, **GBHP**) is about **60 mm Hg**. Osmotic concentration of proteinaceous content of glomerular blood (Blood Colloidal Osmotic Pressure, **BCOP**) is equivalent to **32 mm Hg**. The pressure exerted by the filtrate in Bowman's capsule against the filtration is **18 mm Hg**. The pressure being exerted on glomerular blood for undergoing filtration or the pressure that promotes filtration is called glomerular filtration pressure or Effective Filtration Pressure (EFP).
  EFP = GBHP – BCOP – CHP = (60 – 32 -18) mm Hg = 10 mm Hg
- The blood flowing in the glomerular blood capillaries is separated from the capsular space of Bowman's capsule by **four layers**, i.e., endothelial covering of glomerular blood vessels, basement membrane of blood vessels, basement membrane of visceral layer of Bowman's capsule and the inner wall or visceral layer (epithelium) of Bowman's capsule.
- Endothelial covering of blood vessels contains fenestrations of **50-100 nm**. The epithelium of Bowman's capsule has cells called podocytes with filtration slits or slit pores. Therefore, the actual barrier between blood and capsular space consists of two basement membranes which are, however, permeable to small-sized molecules.

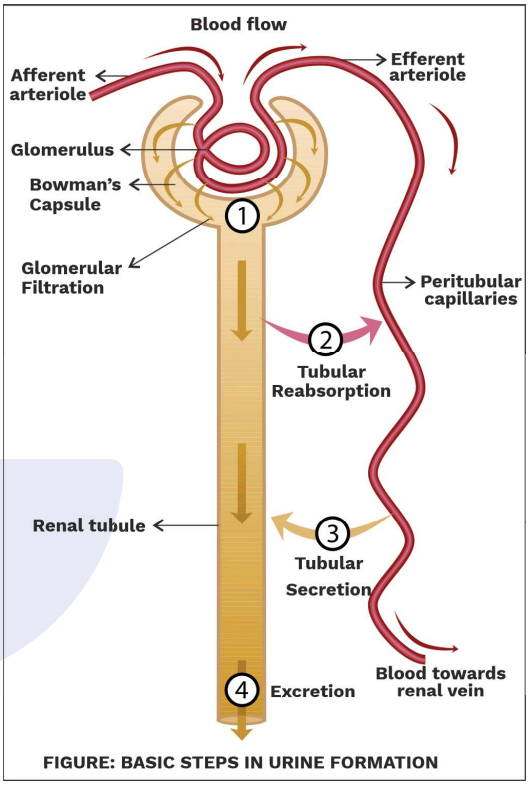


FIGURE: BASIC STEPS IN URINE FORMATION

Previous Year's Question

The net pressure gradient that causes the fluid to filter out of the glomeruli into the capsule is:
(1) 50 mm Hg
(2) 75 mm Hg
(3) 20 mm Hg
(4) 30 mm Hg

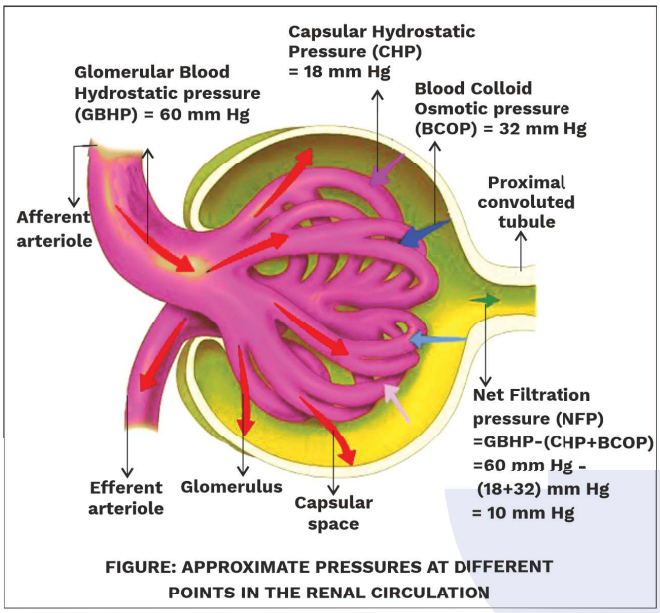


FIGURE: APPROXIMATE PRESSURES AT DIFFERENT POINTS IN THE RENAL CIRCULATION

- The blood pressure in the glomerular capillaries is high enough for carrying out a continuous process of ultra filtration, i.e., filtration under pressure.
- The blood components smaller than the slit pores (all the constituents of the plasma except larger proteins) pass through endothelial fenestrations, basement membranes and filtration slits of podocytes and enter the lumen of Bowman's capsule and is called the **glomerular filtrate**.
- The glomerular filtrate consists of nearly **15-25%** of water and solutes from the blood plasma including urea, uric acid, creatinine, amino acids, glucose, sodium, potassium, vitamins, ketone bodies, etc. It excludes large sized particles like fats, proteins, platelets, leucocytes, and erythrocytes.
- In a healthy adult human, approximately **125 ml** of glomerular filtrate is formed by the kidneys per minute, i.e., **180 litres** in a day. This is called as **glomerular filtration rate** (GFR).
- The renal blood pressure and glomerular filtration rate (GFR) are automatically regulated by the body.

Previous Year's Question

The plasma resembles in its composition to the filtrate produced by the glomerulus except the presence of:

(1) Glucose
(2) Chloride
(3) Amino acids
(4) Proteins

Rack your Brain

Normally, urine is not red in colour like the blood. Why?

- An increase in blood pressure should normally increase blood flow through glomeruli. Increased blood flow tends to stretch afferent arteriole. The smooth muscle fibres in the wall of afferent arteriole increase passage of Ca^{2+} ions from sarcoplasmic reticulum into the sarcoplasm resulting in their contraction. Contraction checks overstretching of vascular walls and increases vascular resistance so that the rate of blood flow and GFR are brought down to normal **(Myogenic Autoregulation)**.
- Cells of the **juxta glomerular apparatus (JGA)** release renin that regulates the blood pressure and thus the renal blood flow and the GFR.
- Nerve fibres of the sympathetic neural system innervate blood vessels of the kidney. These nerve fibers, on activation, contract the renal arteries and cause decrease in renal blood flow as well as glomerular filtration rate (**Neural Control**).

Definition

Reabsorption: The absorption of useful essential substances from glomerular filtrate by epithelial cells of renal tubules either by active or passive mechanisms is called reabsorption.

Tubular Reabsorption

- A normal, healthy individual releases only **1.5 litres** of urine in a day. Considering the amount of total glomerular filtrate produced in a day, i.e., 180 litres, it is evident that nearly **99 %** of the glomerular filtrate is taken back (**reabsorbed**) into the body.
- Reabsorption occurs in all parts of renal tubule—proximal convoluted tubule, loop of Henle, distal convoluted tubule, collecting tubule.
- **Reabsorption in Proximal Convoluted Tubule (PCT):**
  - PCT is the major site of reabsorption. Almost all the essential nutrients, and **70%-80%** of electrolytes and water are reabsorbed by the PCT.
  - This is due to the presence of simple cuboidal brush-border epithelial cells with abundant mitochondria and microvilli, which greatly increase the absorptive surface of PCT.

Rack your Brain

Which part of nephron actively reabsorbs sodium?

- Glucose, amino acids, Na^+, K^+ and Ca^{2+} are reabsorbed through to active transport. Cl^- and other anions are reabsorbed through diffusion. Water moves out by the process of osmosis.
- There is a selective secretion of hydrogen ions, potassium ions and ammonia into the filtrate and absorption of bicarbonate ions from the filtrate which maintains the pH and ionic balance of the body fluids.
- The filtrate, however, remains isotonic to blood.

- **Reabsorption in Loop of Henle:**
  - **Descending Limb:** Thick segment is nearly impermeable. Thin segment is permeable to water but almost impermeable to electrolytes. Thus, it loses a lot of water due to osmosis. It makes the filtrate hypertonic as the concentration of NaCl becomes high.
  - **Ascending Limb:** It is impermeable to water but allows transport of electrolytes actively or passively. The thin segment loses NaCl to interstitial fluid through diffusion. The thick segment actively transports NaCl into the outer interstitial fluid. This causes high osmolarity of medullary interstitial fluid. Due to loss of NaCl, the filtrate becomes hypotonic to blood plasma in the ascending limb of loop of Henle.
- **Reabsorption in Distal Convoluted Tubule (DCT):**
  - DCT performs conditional reabsorption of sodium ions and water, along with reabsorption of bicarbonate ions and selective secretion of hydrogen and potassium ions and ammonia. This maintains the pH and sodium-potassium balance in blood.
  - This **conditional reabsorption** depends on the production of **aldosterone** and antidiuretic hormone (**vasopressin**). Under the influence of aldosterone, Na^+ is actively reabsorbed

Previous Year's Questions

Glucose is taken back from glomerular filtrate through:
(1) Active transport
(2) Passive transport
(3) Osmosis
(4) Diffusion

Previous Year's Question

Which of the following causes an increase in the reabsorption of sodium in the distal convoluted tubule?
(1) Increase in aldosterone levels
(2) Increase in antidiuretic hormone levels
(3) Decrease in aldosterone levels
(4) Decrease in antidiuretic hormone levels

from the filtrate, whereas Cl^- accompanies it passively. HCO_3^- also passes out. Vasopressin helps in reabsorption of water.

- **Reabsorption in Collecting Ducts:**
  - Collecting ducts extend from the cortex to the inner medullary region of the kidney.
  - Their walls become permeable and allow

Rack your Brain

Which hormone controls the reabsorption of Na^+ in the DCT?

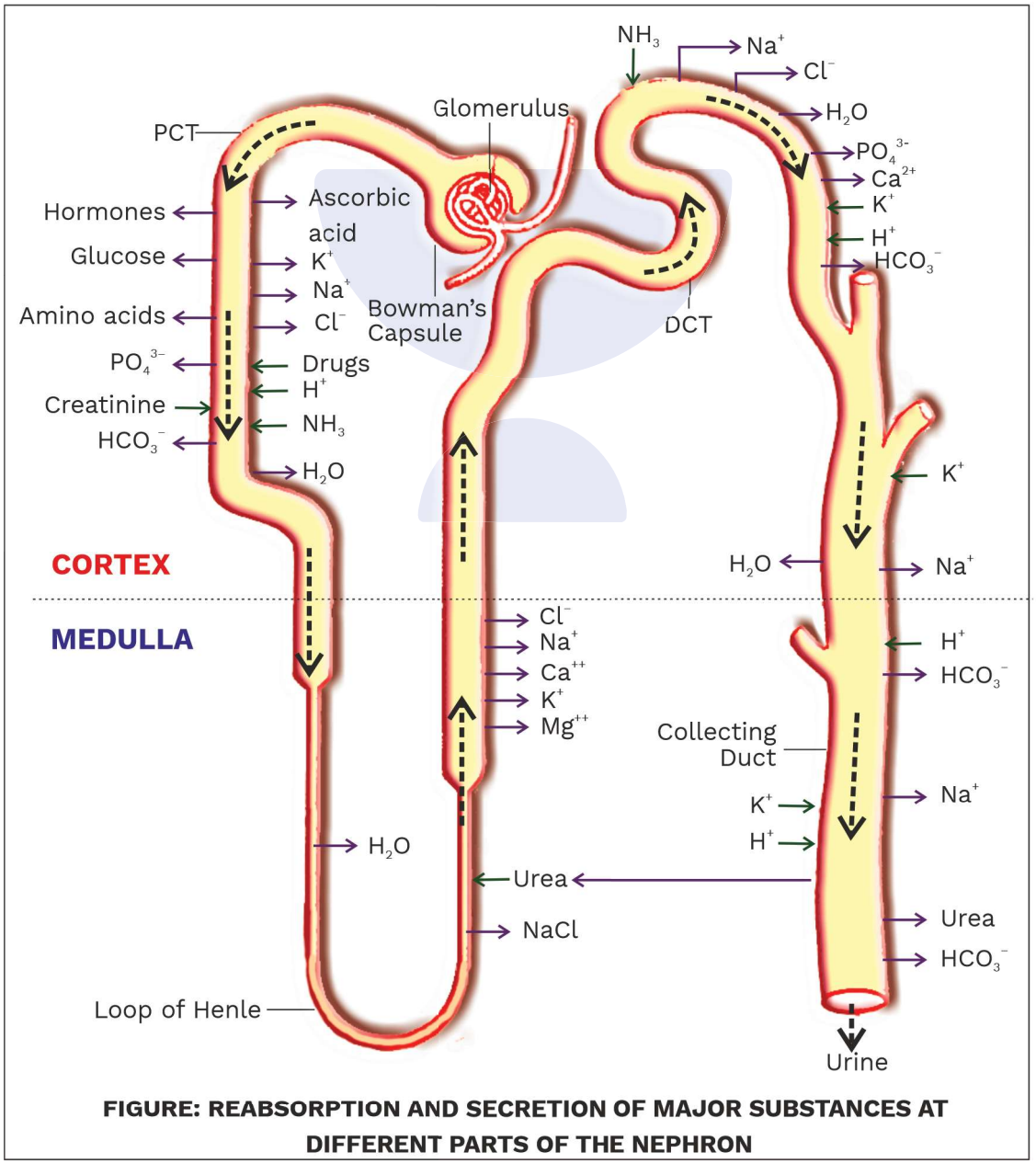


FIGURE: REABSORPTION AND SECRETION OF MAJOR SUBSTANCES AT DIFFERENT PARTS OF THE NEPHRON

reabsorption of water under the influence of vasopressin or ADH.

- Large amounts of water could be reabsorbed from the filtrate to produce concentrated urine.
- A part of urea diffuses out of the lower parts of collecting ducts into medullary interstitium, which keep up the osmolarity. It makes the medulla hyperosmotic.
- It also maintains pH and ionic balance of the blood by selective secretion of hydrogen ions and potassium ions.

Definition

Tubular secretion: The phenomenon of active secretion of metabolic wastes from peritubular capillaries and interstitial fluid into filtrate is called tubular secretion.

Tubular Secretion

- Tubular secretion is an important process in urine formation as it maintains ionic and acid base balance of the body fluids.
- **Secretion in Proximal Convoluted Tubule:** Active secretion of hippuric acid, creatinine, pigments, drugs like penicillin occurs in the PCT. Ammonia, hydrogen ions, bile salts, oxalates, catecholamines, toxins, etc, are also secreted in the PCT.
- **Secretion in Loop of Henle:** There is no secretion in the descending limb of loop of Henle. Diffusion of urea occurs in the filtrate in the thin segment of ascending limb of Henle's loop.
- **Secretion in Distal Convoluted Tubule:** K^+, H^+, ammonia and bicarbonate ions are mainly actively secreted into the filtrate in the DCT along with smaller quantities of uric acid, creatinine, and extra salts.

MECHANISM OF CONCENTRATION OF THE FILTRATE

- The Henle's loop and vasa recta play a significant role in producing concentrated urine by a **counter current mechanism**. The length and depth of Henle's loop indicate the urine concentrating ability of the kidneys.

Previous Year's Question

Which one of the following correctly explains the function of a specific part of the human nephron?

(1) Podocytes: create minute spaces (slit pores) for the filtration of blood into the Bowman's capsule

(2) Henle's loop: most reabsorption of the major substances from the glomerular filtrate

(3) Distal convoluted tubule: reabsorption of K^+ ions into the surrounding blood capillaries

(4) Afferent arteriole: carries the blood away from the glomerulus towards renal vein

TUBULAR REABSORPTION AND TUBULAR SECRETION OF VARIOUS SUBSTANCES

Nephron region	Reabsorbed	Secreted
PCT	❍ Glucose, amino acids, hormones, vitamins, Na^+, K^+, Mg^{2+}, Ca^{2+} (active transport) ❍ Cl^- (passive transport) ❍ H_2O (osmosis)	❍ Hippuric acid, creatinine, pigments, drugs, (active transport) ❍ H^+ and NH_3 (diffusion)
Henle's loop	❍ H_2O (reabsorbed in thin segment of descending limb through osmosis) ❍ Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^- (reabsorbed in thin segment of ascending limb through diffusion and in thick segment of ascending limb through active transport)	❍ Diffusion of urea in the thin segment of ascending limb
DCT	❍ H_2O (reabsorbed with the help of ADH through osmosis) ❍ Na^+(reabsorbed with the help of aldosterone through active transport) ❍ Cl^- and HCO_3^- (diffusion)	❍ K^+, H^+, NH_3 (active transport) ❍ Some drugs (active transport)
Collecting duct	❍ H_2O (reabsorbed with the help of ADH through osmosis) ❍ Na^+(reabsorbed with the help of aldosterone through active transport) ❍ Urea (reabsorbed with the help of aldosterone through diffusion	❍ H^+ (active transport) ❍ NH_4^+ (diffusion) ❍ K^+ (controlled by aldosterone through active transport) ❍ Some drugs (active transport)

- Counter current mechanism is facilitated by the special arrangement of Henle's loop and vasa recta. Loop of Henle lies in the **hypertonic** medullary interstitial fluid. Its descending limb is permeable to water. Therefore, water passes out of filtrate and the filtrate becomes concentrated. Water is unable to dilute interstitial fluid as

Rack your Brain

Vasa recta in present in which part of nephron?

it enters the ascending limb of vasa recta. Ascending limb of Henle's loop loses a lot of NaCl to medulla. Some of the excess NaCl is picked up by descending limb of vasa recta to enable it to take away water in the ascending limb. NaCl is passed back into medulla by ascending limb of vasa recta.

- This counter current pattern is formed because the filtrate in the descending limb and the ascending limb of Henle's loop flows in **opposite direction** and the blood in the limbs of vasa recta also flows in opposite direction.
- An increase in osmolarity occurs towards the inner medullary interstitium (**300 mOsmolL-1** in the cortex to about **1200 mOsmolL-1** in the inner medulla) due to the proximate positioning between the Henle's loop and vasa recta and the counter current in them.
- This gradient in osmolarity from cortex to

Previous Year's Question

Concentration of urine depends upon which organ?

(1) Bowman's capsule
(2) Length of Henle's loop
(3) PCT
(4) Network of capillaries arising from glomerulus

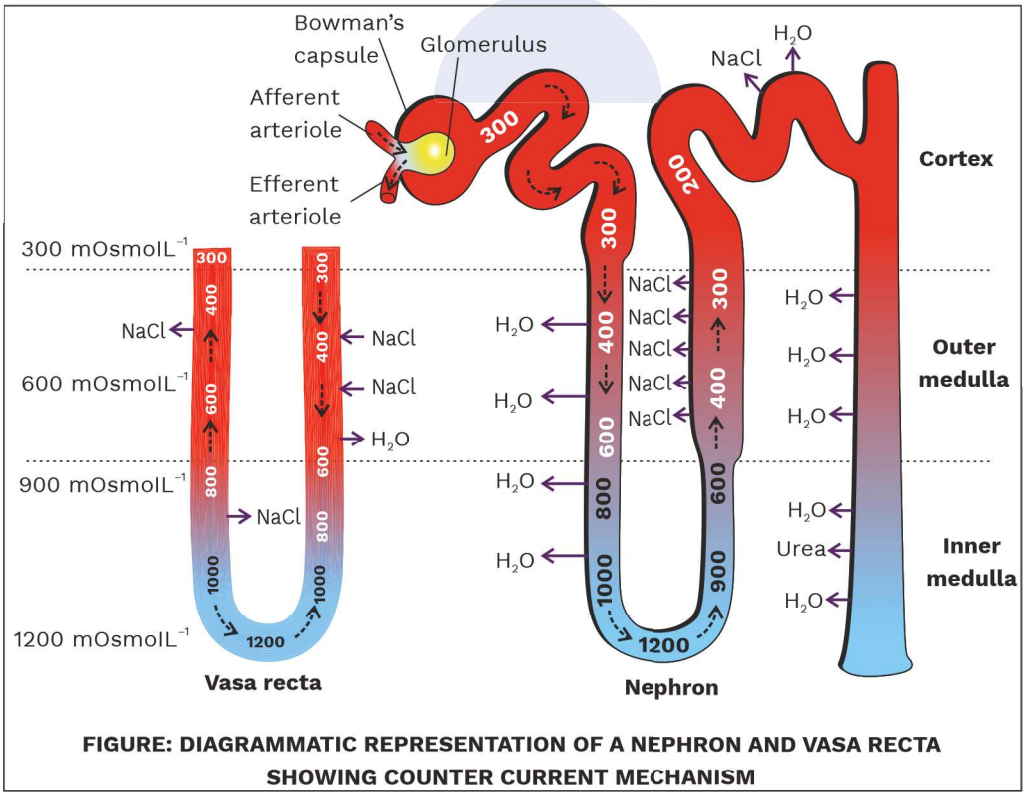
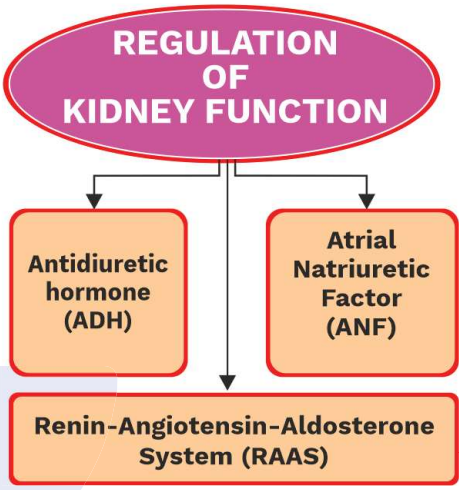


FIGURE: DIAGRAMMATIC REPRESENTATION OF A NEPHRON AND VASA RECTA SHOWING COUNTER CURRENT MECHANISM

inner medulla is mainly caused by NaCl and urea.

- NaCl is reabsorbed from the ascending limb of Henle's loop into the descending limb of vasa recta and is then returned to the interstitium by the ascending limb of vasa recta. Again, some amount of urea which enters the thin segment of ascending limb of Henle's loop is transported back to the interstitium by the collecting tubule.
- Counter current mechanism maintains a concentration gradient in the medullary interstitium which helps in unhindered movement of water from the collecting tubule, thereby, allowing the concentration of the filtrate in the collecting tubule (**urine**). Human kidneys have an ability to produce urine nearly **four times** concentrated than the initial filtrate formed.



REGULATION OF KIDNEY FUNCTION

- The functions of the kidneys are efficiently controlled and regulated by hormonal negative feedback mechanisms involving the hypothalamus (Antidiuretic hormone), Juxtaglomerular apparatus (Renin-Angiotensin-Aldosterone-System) and heart (Atrial Natriuretic Factor)

Regulation by Antidiuretic Hormone (ADH)

- An increase in blood osmolarity above 300 $mOsmolL^{-1}$ due to excessive loss of fluid from the body (i.e., decrease in body fluid volume or decrease in blood pressure) causes activation of osmoreceptors in the body which sends stimulating signals to the hypothalamus to release antidiuretic hormone (ADH) or vasopressin from the posterior pituitary (neurohypophysis) and to promote thirst.
- ADH causes water reabsorption in the distal

Previous Year's Question

Which of the following factors is responsible for the formation of concentrated urine?

(1) Low levels of antidiuretic hormone
(2) Maintaining hyperosmolarity towards inner medullary interstitium in the kidneys
(3) Secretion of erythropoietin by juxta glomerular complex
(4) Hydrostatic pressure during glomerular filtration

convoluted tubule (DCT), thereby preventing loss of water in the urine (diuresis). This increases the body fluid volume (blood pressure increased).

- ADH also acts as a **vasoconstrictor** by decreasing the diameter of the blood vessels. This constrictory effect of ADH on the blood vessels also increases the blood pressure, thereby increasing the glomerular blood flow followed by increase in glomerular filtration rate (GFR).
- Increase in body fluid volume produces a negative feedback and switch off the osmoregulators, thereby suppressing the release of ADH from the posterior pituitary.

Regulation by Juxta glomerular Apparatus (JGA) or Renin-Angiotensin-Aldosterone-System (RAAS)

- A decrease in the blood volume (decrease in blood pressure), lowers the glomerular blood flow, thereby decreasing the glomerular filtration rate.
- This results in activation of Juxtaglomerular (JG) cells. The activated JG cells secrete renin.
- **Angiotensinogen** is a protein produced in the liver and released into the blood. **Renin** converts angiotensinogen into angiotensin I.
- **Angiotensin I** is converted into angiotensin II by angiotensin-converting enzyme (ACE) produced by the vascular endothelial cells in the lungs.
- **Angiotensin II** increases the blood volume by three ways:
  - Angiotensin II acts as a **vasoconstrictor** by decreasing the diameter of the blood vessels, which in turn increases the glomerular blood pressure (increase in glomerular filtration rate).
  - Angiotensin II stimulates adrenal cortex to secrete **aldosterone**. Aldosterone causes reabsorption of sodium ions and water from distal convoluted tubule, thus increasing the blood volume.

Previous Year's Question

Which one of the following statements is correct with respect to kidney function regulation?

(1) When someone drinks lot of water, ADH release is suppressed.
(2) Exposure to cold temperature stimulates ADH release.
(3) An increase in glomerular blood flow stimulates formation of angiotensin II.
(4) During summer when body loses lot of water by evaporation, the release of ADH is suppressed.

Definition

Juxtaglomerular cells: Specialised cells present in the wall of afferent arterioles which produce renin and erythropoietin.

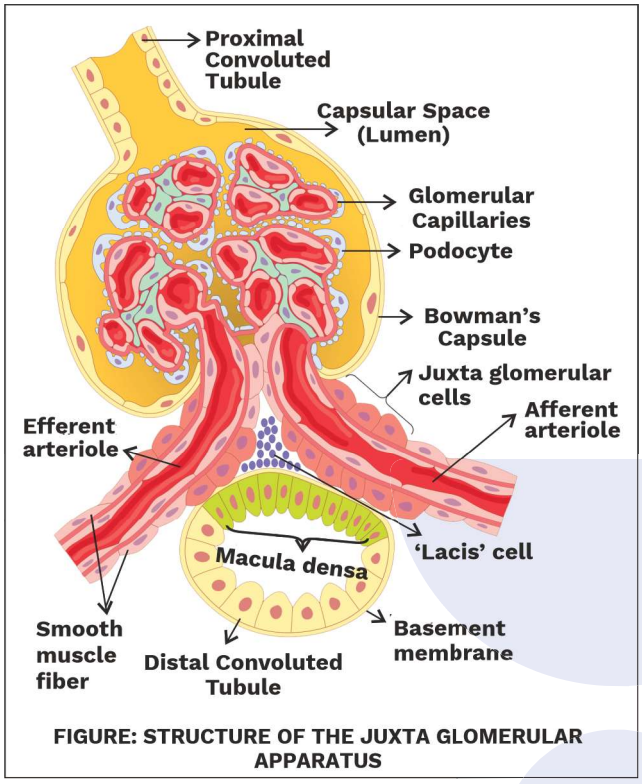
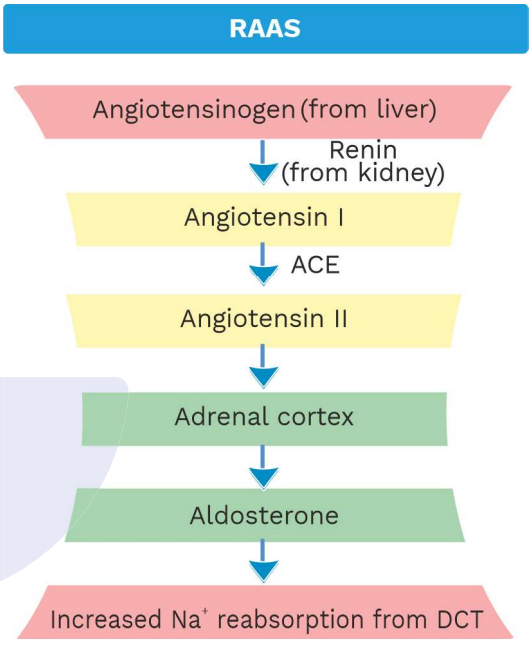


FIGURE: STRUCTURE OF THE JUXTA GLOMERULAR APPARATUS



- Angiotensin II also stimulates proximal convoluted tubule (PCT) to reabsorb more NaCl and water resulting in an increase in blood volume.

- As the system operates through renin—angiotensin—aldosterone, it is called **RAAS** or renin-angiotensin-aldosterone system.

Regulation by Atrial Natriuretic Factor (ANF)

- Increase in blood volume and blood pressure stimulates the release of Atrial Natriuretic Factor (ANF) from the walls of the atria of heart.
- ANF brings the blood volume back to its normal state by:
  - Acting as a **vasodilator** which increases the diameter of the blood vessels and results in decrease in the blood flow, i.e., blood pressure.

Previous Year's Question

A fall in the glomerular filtration rate (GFR) activates:

(1) Juxta glomerular cells to release renin

(2) Adrenal cortex to release aldosterone

(3) Adrenal medulla to release adrenaline

(4) Posterior pituitary to release vasopressin

- Inhibiting the release of renin from JGA. This further inhibits NaCl and water reabsorption by DCT and collecting tubule, thereby increasing the urinary excretion.
- Reduces aldosterone release from the adrenal gland resulting in decreased reabsorption of salt and water, thus decreasing the blood volume and blood pressure.

- ANF mechanism, therefore, acts to check on the renin-angiotensin-aldosterone-system (RAAS).

MICTURITION

- Human kidneys continuously filter the body's blood and produce urine. This urine is poured into the ureters which deliver the urine to the urinary bladder.
- Urinary bladder temporarily stores the urine until it receives a voluntary signal of urine expulsion from the central nervous system.
- The process of release of urine from the urinary bladder is called **micturition** or urination.
- Micturition is regulated by nerves, both from CNS and ANS (sympathetic and parasympathetic). The detrusor muscle and the internal sphincter are both under the autonomic control whereas the external sphincter is a voluntary muscle under the control of the CNS.
- Urine is filled in the urinary bladder when the sympathetic nerve of the autonomic nervous system stimulates the relaxation of the detrusor muscle of the urinary bladder and constriction of the internal sphincter. This causes stretching of the wall of the urinary bladder.
- The capacity of urinary bladder is over **800 ml**. However, after a filling of around 500 ml (in some persons 300-400 ml) the sensory stretch receptors present in the wall of urinary bladder sends signals to the central nervous system (CNS).
- The parasympathetic nerve of the autonomic nervous system stimulates the contraction of

Previous Year's Question

Which of the following does not favour the formation of large quantities of dilute urine?
(1) Renin
(2) Atrial natriuretic factor
(3) Alcohol
(4) Caffeine

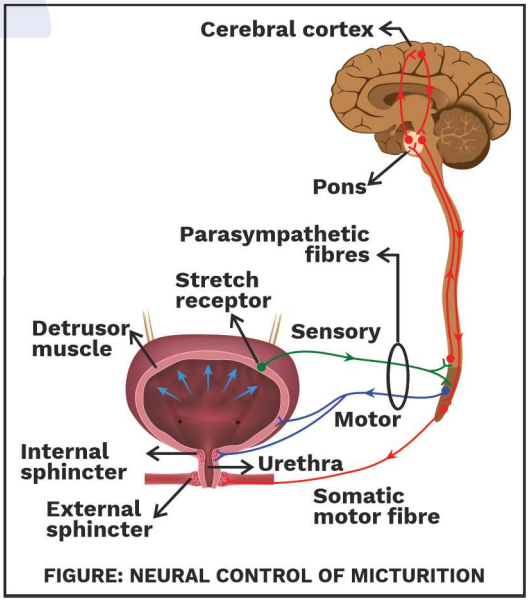


FIGURE: NEURAL CONTROL OF MICTURITION

<table>
<tr><th colspan="4">MICTURITION REFLEX</th></tr>
<tr><td rowspan="3">Urinary bladder filling
(A relaxed bladder)</td><td>CNS
(Voluntary control)</td><td colspan="2">PNS
(Involuntary control)</td></tr>
<tr><td>Somatic nerves</td><td>Sympathetic nerves</td><td>Parasympathetic nerves</td></tr>
<tr><td rowspan="2">External sphincter contracted</td><td>Detrusor muscle relaxed</td><td></td></tr>
<tr><td>Internal sphincter contracted</td><td></td></tr>
<tr><td colspan="4">Stretch receptors on the wall of the bladder send signals to the CNS</td></tr>
<tr><td rowspan="2">Urinary bladder emptying
(A contracted bladder)</td><td rowspan="2">External sphincter relaxed</td><td></td><td>Detrusor muscle contracted</td></tr>
<tr><td></td><td>Internal sphincter relaxed</td></tr>
</table>

detrusor muscle of the urinary bladder and relaxes the internal sphincter which results in the release of urine.

- The external sphincter is always constricted due to tonic contraction of its skeletal muscle fibers under the control of the somatic nerve (voluntary control).
- During micturition, the CNS passes on motor signals which initiate the inhibition of the pudendal nerve that causes relaxation of the external urethral sphincter along with contraction of the detrusor muscle.
- This mechanism starting from sensory stretch receptors of the distended urinary bladder to CNS and back to urinary bladder for its emptying is called the **micturition reflex.**

URINE

- Normally, human beings excrete out transparent, pale yellow, acidic, hypertonic urine which has a specific gravity of 1.015-1.025 and a characteristic unpleasant smell.

Previous Year's Question

What will happen if the stretch receptors of the urinary bladder wall are totally removed?

(1) Micturition will continue
(2) Urine will continue to collect normally in the bladder
(3) There will be no micturition
(4) Urine will not collect in the bladder

- The usual yellow colour of the urine is due to **urochrome** pigment but can also become coloured from various food ingredients and drugs.
- The average **pH** of urine is **6.0** but it becomes alkaline on standing (4.5 → 8.2). Consumption of fruit and proteinaceous diet increases acidity whereas consumption of vegetables increases alkalinity.
- Bacterial degradation of urea into ammonia causes the unpleasant smell of urine.
- On an average, an adult human produces about **1-1.5 litres** of urine per day. The amount of urine varies depending on consumption of **diuretic** substances like tea, coffee and alcohol, intake of excess fluid, physical activity of a person, type of food consumption and environmental temperature (less urination in summer and more urination in winter).
- Urine chemically consists of water (96%), organic ingredients (2.5%) and inorganic ingredients (1.5%). Organic ingredients include nitrogenous organic compounds like urea (on an average, **25-30 gm** of urea is excreted in 24 hours), uric acid, creatinine, creatine, allantoin, ammonia, amino acids, hippuric acid and non-nitrogenous compounds like oxalic acid, phenolic acid, water-soluble vitamins, hormones, etc., in traces. Inorganic substances include chlorides, sulphate, phosphate, sodium, potassium, calcium, magnesium, iodine, arsenic and lead.

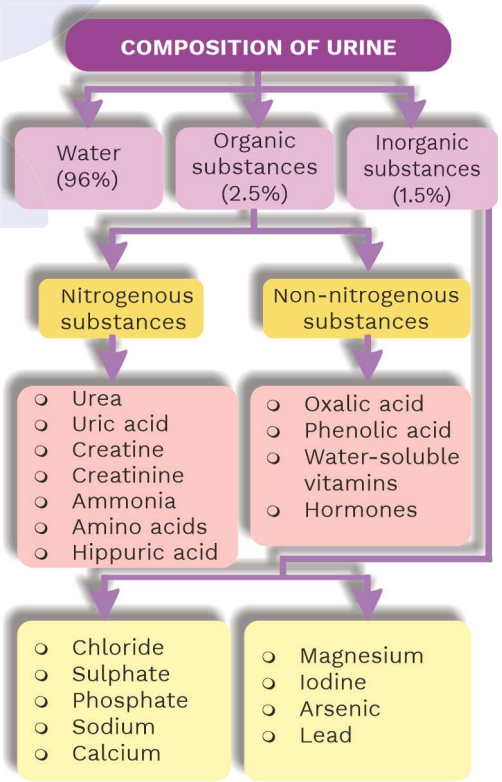
Abnormal Constituents in Urine

- The abnormal constituents of urine are formed due to metabolic disorders and kidney malfunctioning.
- The important abnormal constituents are glucose, albumin, ketone bodies, blood cells, pus cells, etc.

Definitions

Urochrome: The pigment produced by the breakdown of haemoglobin from the worn-out RBCs.

Diuretics: Substances that increase urine formation and thereby reduces water content from the body.



CONDITION	ABNORMAL CONSTITUENT IN URINE
Proteinuria/ Albuminuria	Occurrence of albumin or serum proteins in urine due to inflammation of glomeruli
Ketonuria	Occurrence of ketone bodies in urine due to metabolism of fats during starvation, diabetes mellitus and pregnancy
Glycosuria	Occurrence of glucose in urine as in diabetes mellitus
Haematuria	Occurrence of blood or blood cells in urine due to injury in urinary tract and kidneys caused by kidney stones and infections
Pyuria	Occurrence of WBCs or pus cells in the urine indicating destructive changes or infection in kidney
Haemoglobinuria	Occurrence of free haemoglobin in the urine

KIDNEY FUNCTIONS

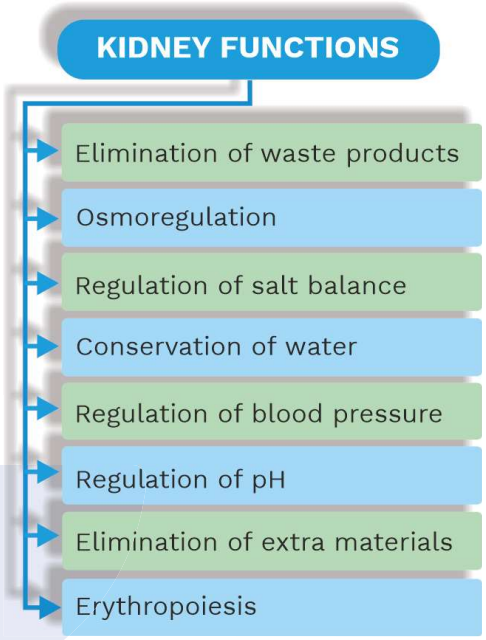
- **Elimination of waste products:** Kidneys primarily function to filter out and remove metabolic nitrogenous and non-nitrogenous wastes from the blood.
- **Regulation of salt and water balance (osmoregulation):** Kidneys maintain a balance between ions and water between the blood and interstitial fluid by selective reabsorption or secretion. **Hypotonic** urine is excreted if the body has excess water whereas the urine is **hypertonic** if the body is water deficit.
- **Regulation of salt balance:** Kidneys maintain a proper **sodium-potassium ion balance** which is important for the proper functioning of nerves, muscles and other cells.

Previous Year's Question

The principal nitrogenous excretory compound in human is synthesised:

(1) In kidneys but eliminated mostly through liver
(2) In kidneys as well as eliminated by kidneys
(3) In liver and also eliminated by the same through bile
(4) In the liver, but eliminated mostly through kidneys

- **Conservation of water:** Kidneys help in conservation of water by removing water from the urine because of the presence of a very high osmotic concentration in interstitial fluid of the renal medulla which is about 1200 mOsmol/L.
- **Regulation of blood pressure:** Blood pressure is regulated through secretion or non-secretion of renin from the juxtaglomerular apparatus.
- **Regulation of pH:** Kidneys regulate pH of the body fluids by removing excess of H^+ ions or HCO_3^- ions.
- **Elimination of extra materials:** Extra vitamins, drugs, pigments, salts and toxic chemicals are eliminated from the body by the kidneys.
- **Erythropoiesis:** In response to decreased RBC count, the juxta glomerular cells produce a hormone called **erythropoietin** which stimulates the bone marrow to increase the rate of formation of red blood corpuscles.



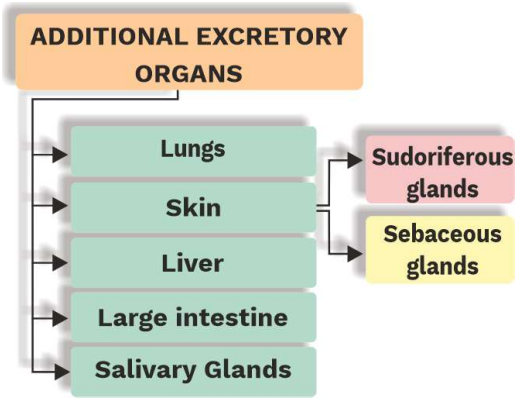
ROLE OF OTHER ORGANS IN EXCRETION

- In humans, accessory or additional excretory organs include lungs, liver, skin, large intestine and salivary glands, which help in the elimination of excretory wastes.
- **Lungs:** Lungs remove approximately 200 ml of CO_2 per minute and 16.5 ml of water per hour in a normal resting condition.
- **Liver:** Liver breaks down the haemoglobin of aged RBCs into bilirubin and biliverdin (bile pigments) which are released into duodenum along with bile and eliminated along with the faecal matter. Liver also excretes inactivated derivatives of steroid hormones, cholesterol, few vitamins, and drugs. **Deamination** of excess of amino acids occurs in the liver resulting in the production of **ammonia** which combines with CO_2 to form urea. The urea is filtered by the nephrons for removal along with urine.
- **Skin:** In human beings, skin has a very less contribution in excretion. Sweat produced by

Previous Year's Question

Which of the following is an accessory excretory organ?

(1) Liver
(2) Stomach
(3) Intestine
(4) Heart



the **sweat (sudoriferous) glands** present in skin helps in the removal of NaCl, lactic acid, urea and amino acids. **Sebaceous glands (oil glands)** which are usually associated with hair, produce an oily secretion called sebum. These glands eliminate substances like oils, fatty acids, waxes, sterols and some hydrocarbons through sebum.

- **Large Intestine:** Epithelial cells of large intestine excrete calcium, magnesium and iron into the lumen of intestine along with faecal matter.
- **Salivary glands:** Salivary glands secrete substances like potassium iodide, mercury, lead and thiocyanate.

Previous Year's Question

Haemodialysis helps the patient having:
(1) Goiter
(2) Anaemia
(3) Uremia
(4) Diabetes

DISORDERS OF THE EXCRETORY SYSTEM

Uremia

- It is the accumulation of urea and other nitrogenous end products like uric acid, creatinine, etc. in the blood due to malfunctioning of kidneys which is accompanied by vomiting, oedema, hypertension, pain and twitching of muscles, etc. It is corrected by the removal of urea by the process of **haemodialysis.**

Renal Failure

- Failure to eliminate all the nitrogenous wastes and retain useful electrolytes by the kidneys is called renal or kidney failure. It may cause oliguria (less than 250 ml of urine production in a day) or anuria (less than 50 ml urine production in a day), pulmonary oedema, coma or death.
- **Acute renal failure** is characterised by abrupt or sudden cessation of kidney function due to acute hypertension, obstruction of urinary tract, infection, haemorrhage, excessive diarrhoea. Immediate haemodialysis can give relief.
- Irreversible damage to kidneys causes **chronic renal failure**. Repeated dialysis and kidney transplantation are the only remedies.

Rack your Brain

Why does consumption of high content of alcohol causes excessive urination and dehydration?

Glomerulonephritis (Bright's Disease)

- Glomerulonephritis is characterized by the inflammation of glomeruli due to *Streptococcus* bacteria.
- The glomeruli become engorged with blood due to widening of the pore of the glomerulus. Antibiotics are given for treatment. Haemodialysis is suggested in severe conditions.

Renal Calculi

- Renal calculi (kidney stones) are precipitation of stone or insoluble mass of crystallised salts (**uric acid crystals** and **calcium oxalate crystals**, etc.) formed in the kidneys which cause a lot of pain.
- The stones are removed surgically.

Diabetes Insipidus

- Diabetes insipidus is caused by the deficiency of antidiuretic hormone (ADH) or vasopressin. ADH functions to regulate the blood pressure by instructing reabsorption of salts and water from the cells of the distal convoluted tubule.
- It is characterised by excretion of excessive dilute urine and intense sensation of thirst.

ARTIFICIAL KIDNEY

- Hemodialysis involves separation of metabolic wastes through the process of dialysis that involves both diffusion and ultrafiltration.
- The instrument used in haemodialysis is popularly called **artificial kidney** or haemodialyser which consists of dialysing fluid, a disposable dialyser made of a number of cellophane tubes fitted in a container, pumping system, heating and cooling apparatus, heparin and antiheparin.
- **Dialysing fluid** has the same osmotic composition as that of blood but lacks nitrogenous wastes, phosphates and sulphates.
- During haemodialysis, the blood from an artery (usually **radial**) is mixed with **heparin**, cooled

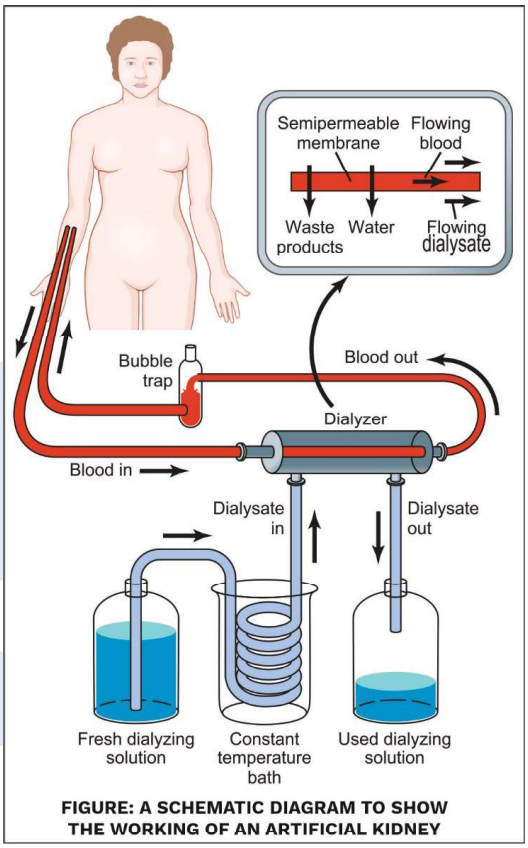


FIGURE: A SCHEMATIC DIAGRAM TO SHOW THE WORKING OF AN ARTIFICIAL KIDNEY

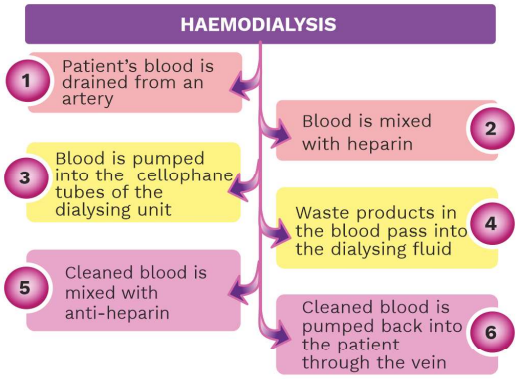
Previous Year's Question

Which one acts as artificial kidney in haemodialysis?

(1) Dialyzing liquid
(2) Bubble trap
(3) Blood pump
(4) Dialyser

to 0°C and then passed slowly into cellophane tubes of the dialyser.

- In the dialyser urea, uric acid, creatinine, phosphate, sulphate and other waste products in the blood pass into dialysing fluid based on their concentration gradient, thereby clearing the blood.
- The cleaned blood coming out of the **cellophane tubes** is warmed to the body temperature, mixed with **antiheparin**, and then pumped back into the patient through a vein.
- Depending upon the condition of the kidneys and accumulation of metabolic wastes, haemodialysis is carried out at regular intervals. It has saved and prolonged the life of thousands of uremic patients all over the world.



KIDNEY TRANSPLANTATION

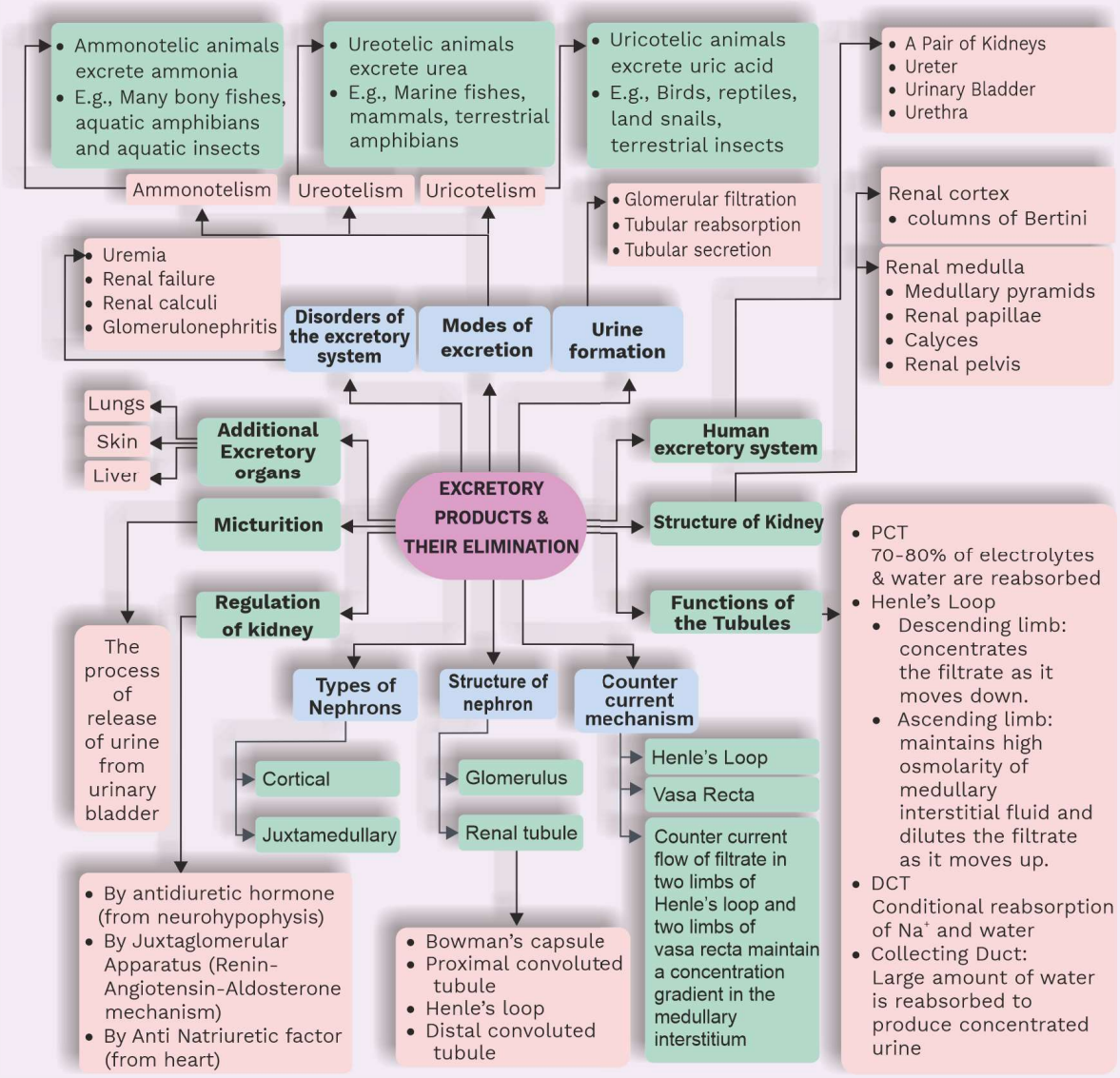
- It is replacement of the defective kidney/s of a patient with healthy functional kidney/s to restore the normal functioning of the body.
- Kidney is obtained from a **donor**. The best donor is a monozygotic twin (**isograft**), followed by a sibling and then any other voluntary donor (**allograft**).
- The success rate of any transplant depends on the compatibility between the donor and recipient cells. The **blood groups** of donor and recipient must be the same. Each individual carry 6 antigens on leucocytes, three from mother and three from father. They are called human leucocyte antigens or **HLAs**. Because of various combinations of these antigens, HLAs of two persons are similar in very fewer cases only. Kidney transplant success depends on the **HLA compatibility** between the donor and the recipient.
- Transplantation can be a success when the blood of both the donor and recipient are matched for antibodies and no reaction occurs.

Gray Matter Alert!!!

The world's first kidney transplant was done by Joseph Murray at the Peter Bent Brigham Hospital in Boston in 1954.
In India, the first kidney transplant was undertaken at the Christian medical college, Vellore, Tamil Nadu in 1971.

- Since 100% matching of the donor kidney is rare, drugs like cyclosporin are used to suppress immune system of the recipient which prevents attacking and damaging the transplanted kidney.

Chapter Summary

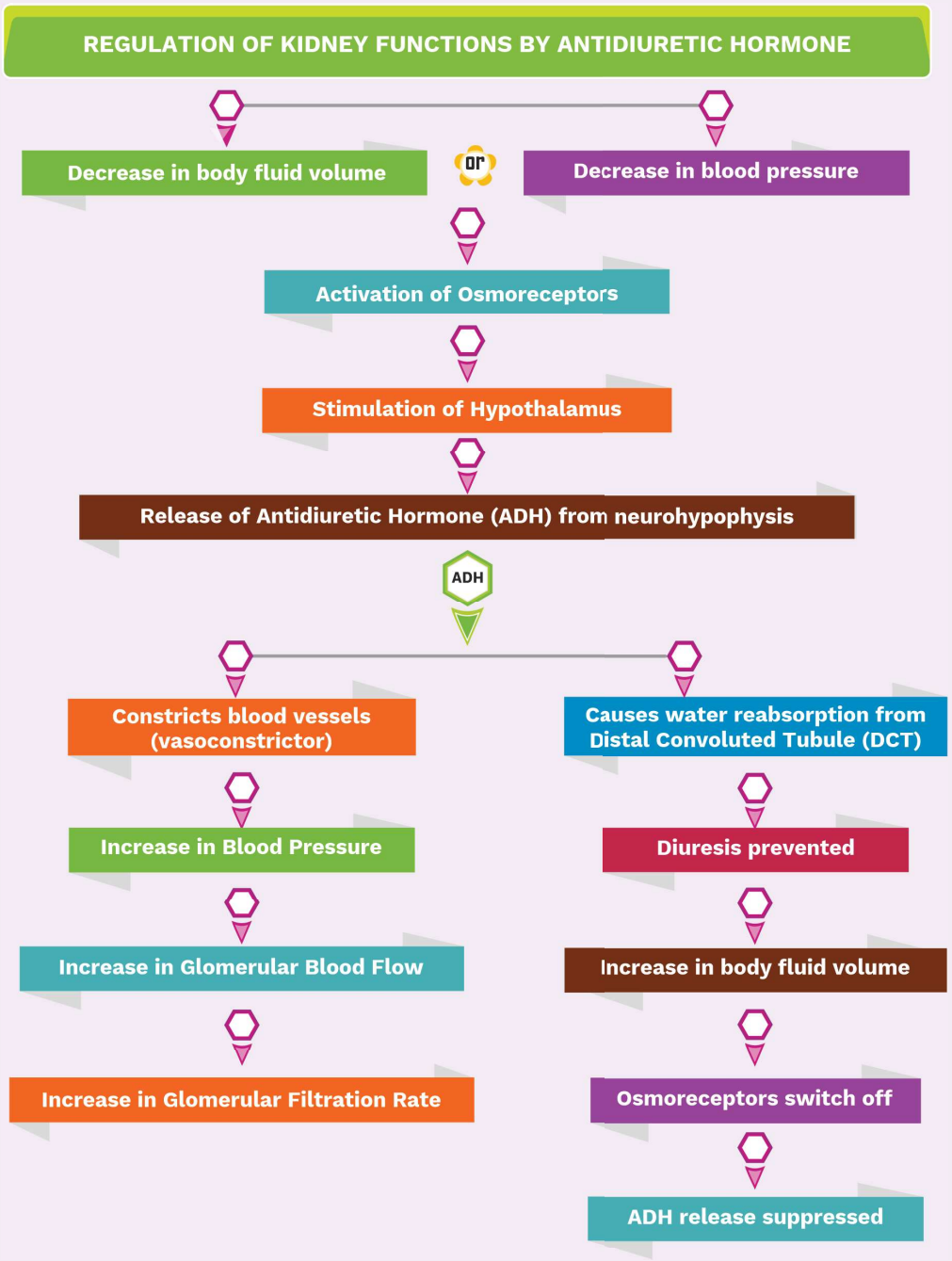


Chapter Summary

MAJOR MODES OF EXCRETION

	Ammonotelism	Ureotelism	Uricotelism
❖ Major excretory product	Ammonia	Urea	Uric Acid
❖ Toxicity level of excretory product in the body	Highly toxic	Less toxic	Least Toxic
❖ Solubility of excretory product in water	Highly soluble	Less soluble	Least soluble
❖ Water requirement for excretion of excretory product	Large amount of water	Less amount of water	Least amount of water
Examples	❖ Protozoan protists like *Amoeba, Paramoecium* ❖ Poriferans like *Sycon* ❖ Cnidarians like *Hydra* ❖ Flatworms like tapeworm (*Taenia solium*) ❖ Roundworms like *Ascaris* ❖ Polychaete annelids like earthworm and leech ❖ Aquatic crustaceans like prawn ❖ Aquatic insects ❖ Aquatic molluscs like *Pila* ❖ Bony fishes ❖ Larvae of amphibians (tadpole of frog) ❖ Crocodiles **(Animals which excrete ammonia are called ammonotelic)**	❖ *Ascaris* ❖ Earthworm ❖ Cartilaginous fishes like shark and sting rays ❖ Adults frogs ❖ Adults toads ❖ Turtles ❖ Terrapins ❖ Alligators ❖ Mammals including man **(Animals which excrete urea are called ureotelic)**	❖ Most terrestrial insects like cockroach ❖ Terrestrial crustaceans like *Oniscus* ❖ Land snails like *Helix* ❖ Land reptiles like lizards and snakes ❖ Birds **(Animals which excrete uric acid are called uricotelic)**

Chapter Summary



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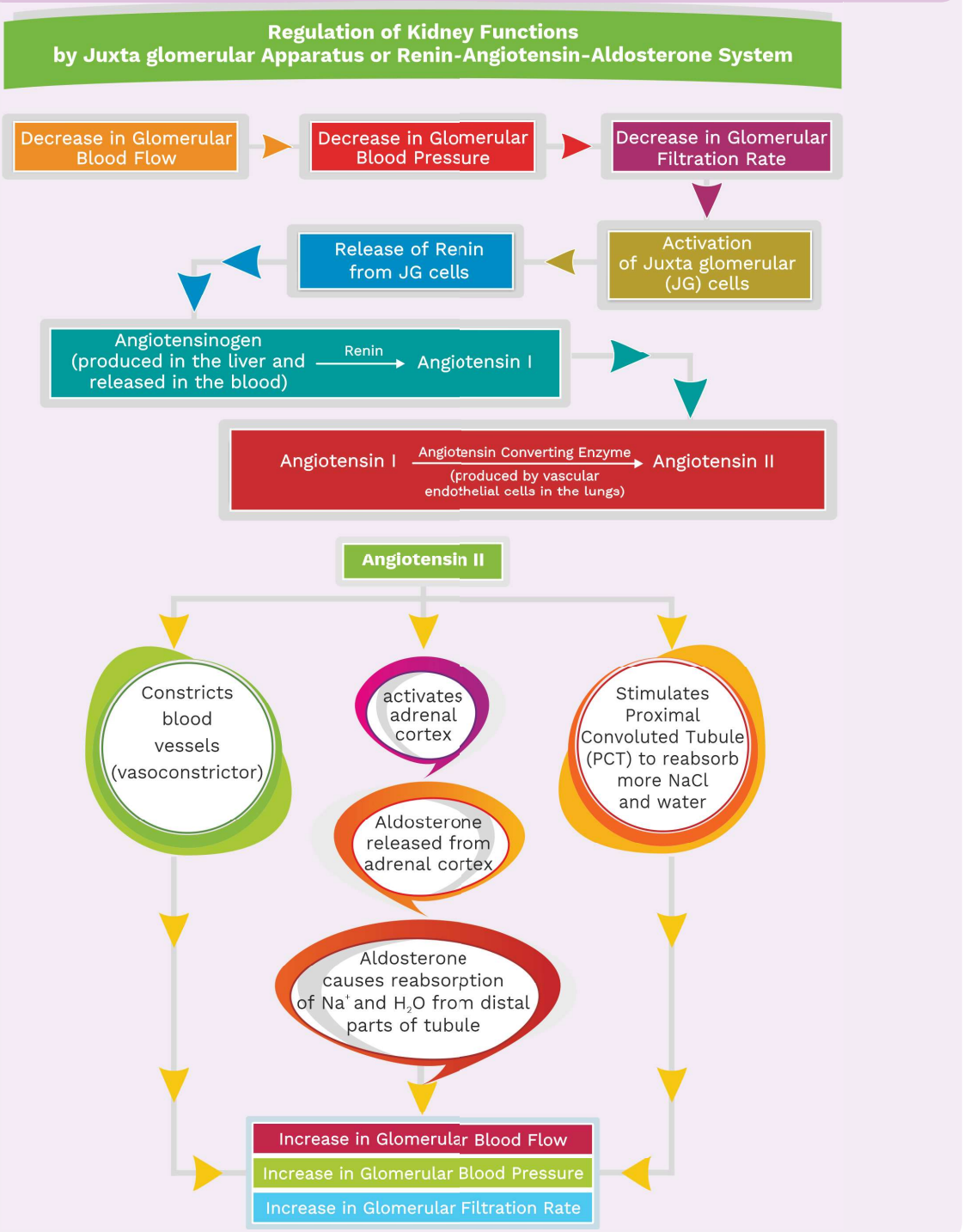

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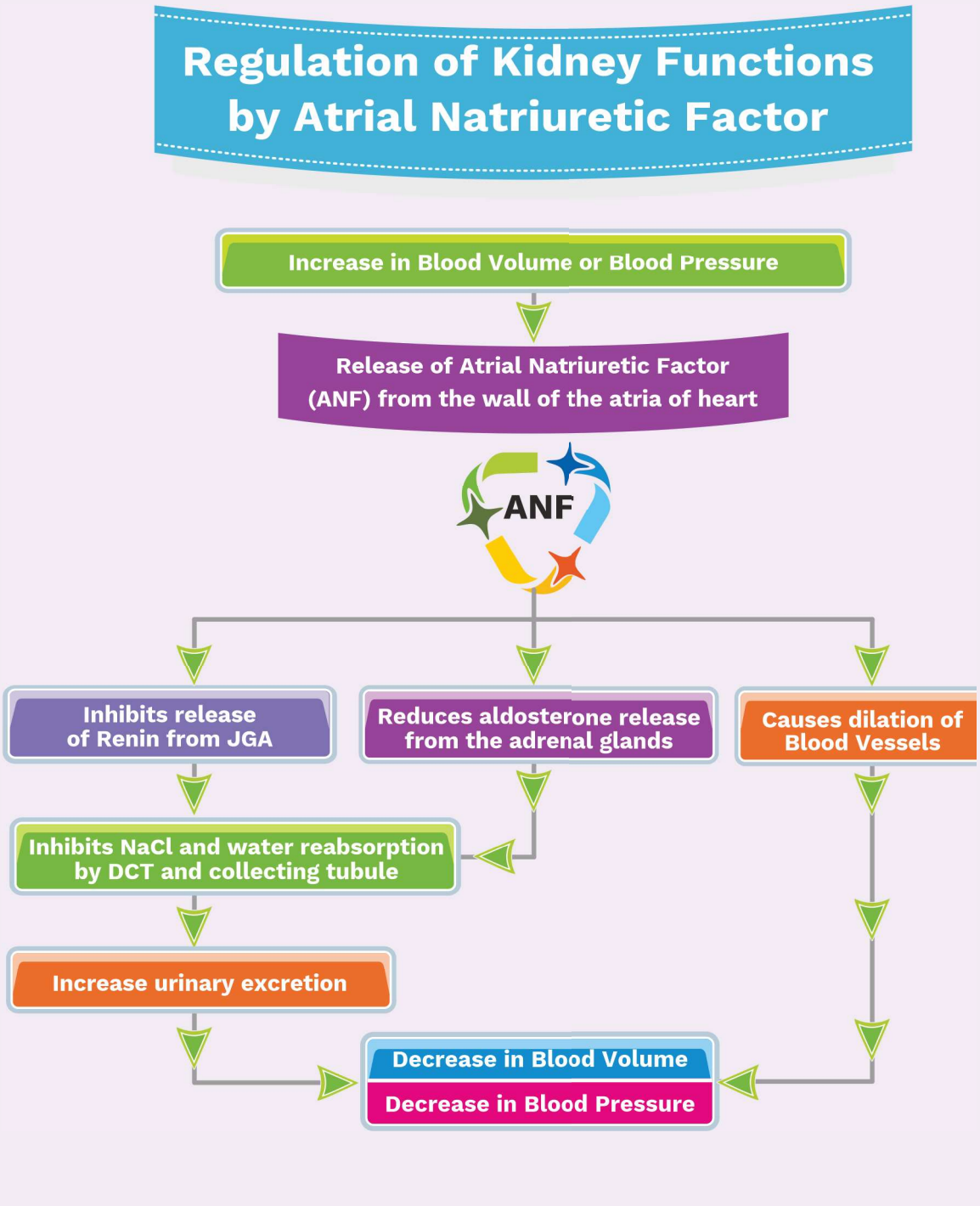

SOLVED EXAMPLES

Q1 **Which of the following is the structural and functional unit of kidney?**
(1) Neuron **(2) Medullary pyramids**
(3) Nephron **(4) Calyx**

A1 **(3)**
Nephron is the structural and functional unit of kidney.

Q2 **Select the correct pair of organisms which show mixed excretion.**
(1) Prawn and aquatic insects **(2) Bony fishes and poriferans**
(3) Earthworm and prawn **(4) Terrestrial insects and land snails**

A2 **(3)**
Earthworm and prawn excrete both ammonia and urea.
Aquatic insects, bony fishes and poriferans are ammonotelic.
Terrestrial insects and land snails are uricotelic.

Q3 **Select the correct statement from the following.**
(1) Renette cells are formed in nematodes.
(2) Nephridia are excretory structures present in *Amphioxus*.
(3) Green glands are present in *Planaria*.
(4) Malpighian tubules are the main excretory structures of platyhelminthes.

A3 **(1)**
Nephridia are excretory structures of annelids.
Green glands are present in Prawn.
Malpighian tubules are the main excretory structures of insects like cockroach.

Q4 **The major calyces open into:**
(1) Medullary pyramids **(2) Columns of Bertini**
(2) Renal pelvis **(4) Hilum**

A4 **(3)**
The major calyces open into renal pelvis.

Q5 **Out of the total nephrons in both the kidneys, cortical nephrons are about**
(1) 15% **(2) 50%** **(3) 95%** **(4) 85%**

A5 **(4)**
Cortical nephrons form about 85% of the total nephrons in both the kidneys.

Q6 **In a normal, healthy human being, the glomerular filtration rate is about:**
(1) 125 litres per day **(2) 125 millilitres per minute**
(3) 125 millilitres per day **(4) 125 litres per minute**

A6 **(2)**
In a normal, healthy human being, the glomerular filtration rate is about 125 millilitres per minute.

Q7 **Choose the incorrect statement about the Loop of Henle.**
(1) Descending limb of Henle's loop is impermeable to electrolytes and permeable to water.
(2) Filtrate in the descending limb of Henle's loop is hypertonic.
(3) Ascending limb of Henle's loop is impermeable to electrolytes and permeable to water.
(4) Filtrate in the ascending limb of Henle's loop is hypotonic.

A7 **(3)**
Ascending limb of Henle's loop is impermeable to water and allows active and passive transport of electrolytes.

Q8 **Human kidneys can produce urine nearly:**
(1) Two times concentrated than the initial filtrate formed.
(2) Five times concentrated than the initial filtrate formed.
(3) Three times concentrated than the initial filtrate formed.
(4) Four times concentrated than the initial filtrate formed.

A8 **(4)**
Human kidneys can produce urine nearly four times concentrated than the initial filtrate formed.

Q9 **Angiotensin II**
(1) Reduces blood pressure by constricting the blood vessels.
(2) Increases blood pressure by constricting the blood vessels.
(3) Reduces blood pressure by dilating the blood vessels.
(4) Increases blood pressure by dilating the blood vessels.

A9 **(2)**
Angiotensin II increases blood pressure by constricting the blood vessels.

Q10 **Diabetes insipidus is characterised by:**
(1) Excessive concentrated urine and intense thirst.
(2) Excessive dilute urine and intense thirst.
(3) Excessive concentrated urine and presence of large amounts of blood sugar in urine.
(4) Excessive dilute urine and presence of large amounts of blood sugar in urine.

A10 **(2)**
Diabetes insipidus is characterised by excessive dilute urine and intense thirst.