15. Excretion and Osmoregulation

Can you recall?

1. Why are various waste products produced in the body of an organism ?
2. How are these wastes eliminated ?

Have you ever observed ?

1. When does urine appear deeply coloured?
2. If we consume onion and garlic, we get bad breath. Why?

Think about it

1. Do organisms differ in type of metabolic wastes they produce?
2. Do environment or evolution have any effect on type of waste produced by an organism?
3. How do thermoregulation and food habits affect waste production ?

Array of chemical processes occur in the body of an organism. Sum total of these processes is called 'metabolism'. Metabolism involves catabolic (breaking down) and anabolic (building up) processes. Metabolism produces a variety of by-products, some of which need to be eliminated. Such byproducts are called metabolic 'waste products'.

Metabolic waste products might be fluid, gaseous, organic or inorganic. Depending on the type, they are eliminated through various organs of the body of an organism.

15.1 Excretion and excretory products :

Elimination of metabolic waste products from the body is called excretion. Unlike digestive wastes, which are primarily composed of unabsorbed or undigested substances that have never entered the cells, metabolic wastes are produced inside body cells.

Let us try to enlist various excretory waste products produced in human body; Fluids such as water, gaseous wastes like CO_2, nitrogenous wastes like ammonia, urea and uric acid, creatinine, mineral, salts of sodium, potassium, calcium, etc. which if, are present in body in excess are excreted through urine, faeces and sweat. Pigments formed due to breakdown of haemoglobin are like bilirubin (excreted through faeces) and urochrome (eliminated through urine). Also, the pigments present in foodstuff like beet root consumed by organism, excess of vitamins, hormones and drugs taken are eliminated. Spices we consume contain volatile substances that are excreted through lungs.

Body of an organism can store excess carbohydrates and fats but is unable to store excess amino acids. Hence, excess amino acids are essentially broken down by a process called as deamination. In this process, amino group is separated from the amino acid and ammonia is formed. Toxic ammonia is either excreted as it is or further converted to less toxic forms like urea or uric acid before excretion.

There is no clear correlation between the phylogenetic relationship of organisms and their major excretory products, but it's habitat has. e.g. Tadpole of frog excretes ammonia and adult frogs mostly are ureotelic. Some terrestrial turtles excrete uric acid whereas others excrete urea or ammonia.

Animals can be broadly classified into three types based on nitrogenous wastes they produce : Ammonia is the basic product of deamination process. But it is highly toxic. Hence, it is to be diluted immediately. If there is no or limited access to water, need for conversion of ammonia becomes necessary. Thus, availability of water plays key role in deciding mode of excretion of an organism. These are of mainly three types :

Think about it

Endotherms consume more food in order to meet energy requirements. Also, carnivorous diet contains more proteins than herbivorous. Does it affect excretion of nitrogenous waste ?

Ammonotelism : Elimination of nitrogenous wastes in the form of ammonia is called as ammonotelism. It is basic in nature. Hence, it would disturb pH of body, if retained. Slight increase in pH would disturb all enzyme-catalyzed reactions in body and would also make the plasma membrane unstable. It is readily soluble in water and needs large quantity of water to dilute and reduce the toxicity. However, it is energy saving mechanism of excretion. Hence all animals that have plenty of water available for dilution of ammonia, excrete nitrogenous wastes in the form of ammonia. Such animals are called ammonotelic. 1 gm ammonia needs about 300 – 500 ml of water for elimination.

Ammonotelism is found in aquatic invertebrates, bony fishes, and aquatic / larval amphibians. Animals without excretory system are also ammonotelic. e. g. Protozoa

Ammonotelic animals excrete ammonia through general body surface (skin), gills and kidneys.

Ureotelism : Elimination of nitrogenous wastes in the form of urea ($H_2N\text{-}CO\text{-}NH_2$) is called as ureotelism. Urea is less toxic and less water-soluble than ammonia. Hence it can be concentrated to some extent in body. Due to this, it requires less water for elimination. (Compared to ammonia, about 100 time less water in human, several hundred times in camel, kangaroo rat and shark). As it is less toxic and less water soluble; hence, ureotelism is suitable for animals those need conservation of water to some extent. Hence it is common in terrestrial animals, as they have to conserve H_2O. It takes about 50 ml H_2O for removal of 1 gm NH_2 in form of urea. Mammals, cartilaginous fishes (sharks and rays), many aquatic reptiles, most of the adult amphibians, etc. are ureotelic. They convert ammonia to urea in liver by operating ornithine / urea cycle (Krebs and Hanseleit, 1932). 3 ATP molecules are used to produce one molecule of urea.

Sharks retain more urea in their body fluid (blood) to make their blood isotonic to surrounding marine water. This helps them to prevent possible loss of water by exosmosis.

Uricotelism ($C_5H_4O_3N_4$) : Elimination of nitrogenous wastes in the form of uric acid is called as uricotelism. Uric acid is least toxic. Hence, it can be retained in the body for some time in concentrated form. It is least soluble in water. Hence minimum (about 5—10 ml for 1 gm) or no need of water for its elimination. Hence, animals those need to conserve more water follow uricotelism. Ammonia is converted into uric acid by 'inosinic acid pathway' in the liver of birds. Birds, some insects, many reptiles, land snails, are uricotelic; because they need to conserve the water. However, they have to spend more energy.

Use your brain power

Why ammonia is highly toxic?

Always Remember

Animals like spiders, scorpions and penguins excrete guanine. This mode of excretion is called guanotelism.

Find out

You will study about a type of arthritis called gouty arthritis caused due to accumulation of uric acid in joints. Where does uric acid comes from in case of ureotelic human beings?

Observe and Discuss

These are blood reports of patients undergoing investigations for kidney function. What is creatinine ? What is your observation and opinion about the findings ? Why is it used as an index of kidney function?

Report A

PERFECT PATHOLOGY Reg. No. :- _____

Dr. _____ Date :-

Patient name :-_____ Age :-____ M/F

Reference :- Dr._____

Examination of Blood

Test	Result	Normal values
Creatinine	1.92	Male : 0.6 to 1.4 mg/dl.
		Female : 0.6 to 1.2 mg/dl.

Report B

PERFECT PATHOLOGY Reg. No. :- _____

Dr. _____ Date :- _____

Patient name :-_____ Age :-_____

M/F

Reference :- Dr._____

Examination of Blood

Test	Result	Normal values
Fasting blood sugar	185	70 - 110 ml/dl

Chemical Examination of Urine

Test	Result	Normal values
Sugar	Present ++	Absent

Plasma creatinine is produced from catabolism of creatinine phosphate during skeletal muscle contraction. It provides ready source of high energy phosphate. Normally blood creatinine levels remain steady because the rate of production matches it's excretion in urine. Hence, level above normal is an indication of poor renal function.

Excretory organs play an important role in maintenence of constant internal environment of the body called homeostasis. It requires osmoregulation, the process of controling solute concentrations and water balance. It can be rightly said that composition of blood (and internal environment) is determined not by what mouth ingests but by what excretory organs retain.

Marine birds like Albatross spend their life on the sea. That means water, they drink is salty ! How do they manage osmoregulation then?

They have special glands called salt glands near nostrils. These are capable of secreting salts by active transport and help to manage osmotic balance. Many marine organisms like sea turtles and marine iguanas also have such salt excreting glands.

Animals can either be isoosmotic to the surrounding (osmoconformers) or control internal environment independent of external environment (osmoregulators). Marine organisms mostly are osmocomformers because their body fluids and external environment are isoosmotic in nature.

Fresh water forms and terrestrial organisms are osmoregulators.

Think about it

During summer, we tend to produce less urine, why is it so ?

Use your brain power

What would happen if human being has no option but to drink sea water ?

Think about it

Like ectothermic and endothermic animals, do organisms differ in the way they maintain salt balance ?

Find out

How do freshwater fishes and marine fishes carry out osmoregulation ?

Whether conformers or regulators, most organisms can tolerate only narrow range of salt concentrations. Such organisms are called stenohaline organisms. (steno : narrow)

Those who are capable of handling wide changes in salinity are called euryhaline organisms ex. barnacles, clams etc.

Unicellular forms have contractile vacuoles which collect and discharge waste products outside the cell. Excretion in sponges takes place by diffusion of waste material in water which is discharged through osculum.

True organs of excretion are found in those animals that show bilateral symmetry. Most common type is simple or branching tube that opens to exterior through pores called nephridiopores.

Two major types of nephridia :

Protonephridia : These are network of dead end tubes called flame cells. These are found mostly in animals that lack true body cavity e.g. Platyhelminthes. Protonephridia are also found in rotifers, some annelids and *Amphioxus*.

Metanephridia : These are unbranched coiled tubes that connect to body cavity through funnel like structures called nephrostomes. Body fluid enters the nephridium through nephrostome and gets discharged through nephridiopore. eg. Earthworms.

In most of the insects, excretion takes place by set of blind ended tubules called malpighian tubules. Crustaceans have green glands as excretory organs. Members of phylum Echinodermata do not have any specialised excretory organs. Waste materials directly diffuse into water or are excreted through tube feet. Mammalian kidneys are a collection of functional units called nephrons, which are well designed to extract metabolic waste.

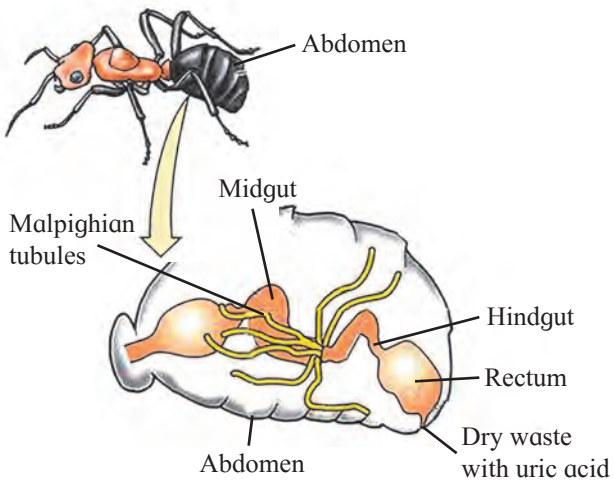


Fig. 15.3 Insects excretion

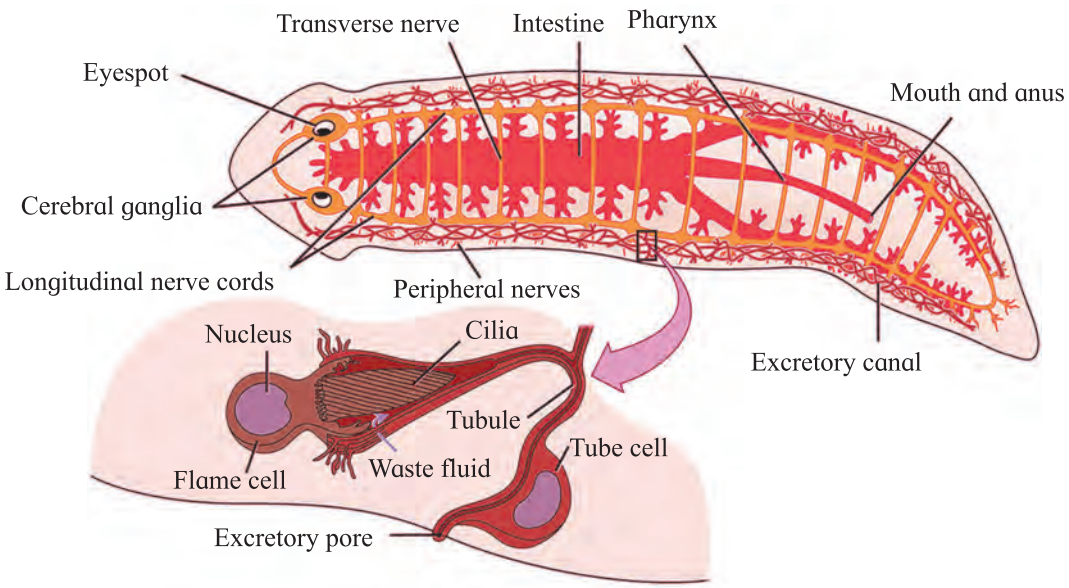


Fig. 15.2 Excretory system in platyhelminthes

Make a table

1. The details of modes of excretion of nitrogenous wastes.
2. The excretory organs found in various animal phyla.

Use your brain power

Creatinine is considered as index of Kidney function. Give reason.

15.2 Excretory system in human being :

Observe and complete

Label the adjacent diagram and complete following paragraphs.

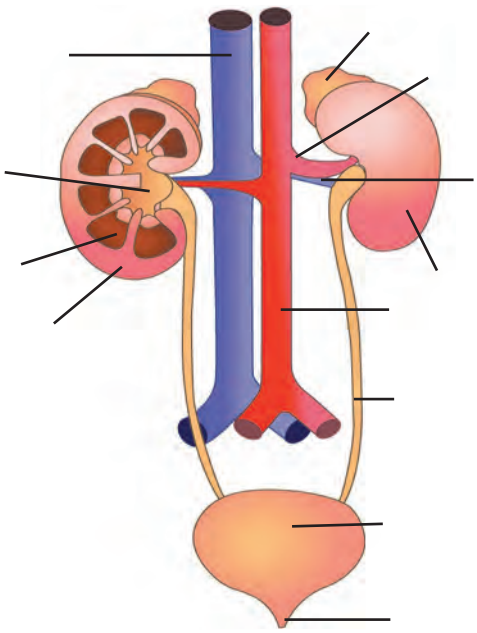


Fig. 15.4 Excretory system

Kidney : A pair of ..... shaped kidneys are present on either side of ..... from 12th thoracic to 3rd Lumbar vertebra. Kidneys are present behind ..... Hence are called Retroperitoneal. Dimensions of each kidney are 10 x ..... x ..... cms. Average weight is ..... g in males and 135 g in ..... Outer surface is ..... and inner is concave. Notch on the inner concave surface is called ..... Renal artery enters and renal vein as well as ureter leave the kidney through hilus. Each kidney has almost 1 million functional units called .....

Ureters : A pair of ureters arise from .....of each kidney. Each ureter is a long muscular tube 25-30 cm. in length. Ureters open into ..... by separate openings, which are not guarded by valves. They pass obliquely through the wall of urinary bladder. This helps in prevention of ..... of urine due to compression of ureters while bladder is filled.

Urinary bladder : It is a median ..... sac. A hollow muscular organ, the bladder is situated in pelvic cavity posterior to public symphysis. At the base of the ..... there is a small inverted triangular area called Trigone. At the apex of this triangle is opening of urethra. At the two points of the base of the triangle are openings of ureters. Urinary bladder is covered externally by peritoneum. Inner to peritoneum is muscular layer. It is formed by detrusor muscles which consist of three layers of smooth muscles. Longitudenal -circular-longitudenal respectively. Innermost layer is made up of transitional..... It helps bladder to stretch.

Urethra : It is a ..... structure arising from urinary bladder and opening to the exterior of the body. There are ..... urethral sphincters between urinary bladder and urethra.

a. Internal sphincter : Made up of ..... muscles, involuntary in nature.

b. External sphincter : Made up of ..... muscles, voluntary in nature.

If this valve is not functioning properly during inflammation of bladder, it can lead to kidney infection.

Kidneys bring about separation and elimination of nitrogenous waste, excess water and toxic substances from the body. They maintain homeostasis by way of their role in osmoregulation and regulation of pH of body fluids. They produce calcitriol and renin. Erythropoietin secreted by kidneys is essential for production of RBCs. Ureters transport urine from renal pelvis to urinary bladder. Urinary bladder is a temporary storage organ for urine. It helps to expel urine (micturition). Urethra is a passage way for discharging urine from body. In males, it acts as urinogenital organ.

Do you know ?

Micturition : Average capacity of urinary bladder is 700 ml. When urinary bladder is almost half filled, stretch receptors in urinary bladder transmit impulses to spinal cord. This initiates conscious desire to expel urine. Micturition reflex center of spinal cord transmit impulses to the wall of urinary bladder and internal urethral sphincter. Bladder muscles contract and muscles of internal urethral sphincter relax. Then external sphincter receives impulses from conscious centre of brain and relaxes. This leads to expellation/ elimination of urine from bladder.

Internet my friend

Find out what is floating kidney?

Can you recall?

Observe the figure carefully and label various regions of L.S. of kidney.

Always Remember

Infants up to 2 years of age show lack of voluntary control over micturition. This is because neurons to the external sphincter muscles are not developed.

Each kidney is covered by 3 layers of tissue. Outermost Renal fascia is made up of thin layer of fibrous connective tissue. It anchors the kidney to abdominal wall as well as surrounding tissue.

Middle layer is a mass of fatty tissue called adipose capsule. Protects kidneys by shock absorption. Innermost layer, renal capsule is a smooth transparent fibrous membrane that is continuous with outer layer of ureters. It acts as a barrier against spread of infections in kidney. L.S. of kidney shows two distinct regions within capsule.

Histologically, kidney is divisible into two regions as renal cortex and renal medulla. Renal cortex is outer / peripheral, red coloured and granular region. Cortex contains Malpighian bodies, convoluted tubules and blood vessels. Medulla is inner region of kidney with pale red colour and striated appearance. Medulla mainly consists of Loops of Henle and collecting ducts. All these are arranged in conical manner to form renal pyramids. Cortex extends in medulla as columns of Bertini / renal columns between pyramids. Narrow tip of pyramid is called as renal papilla.

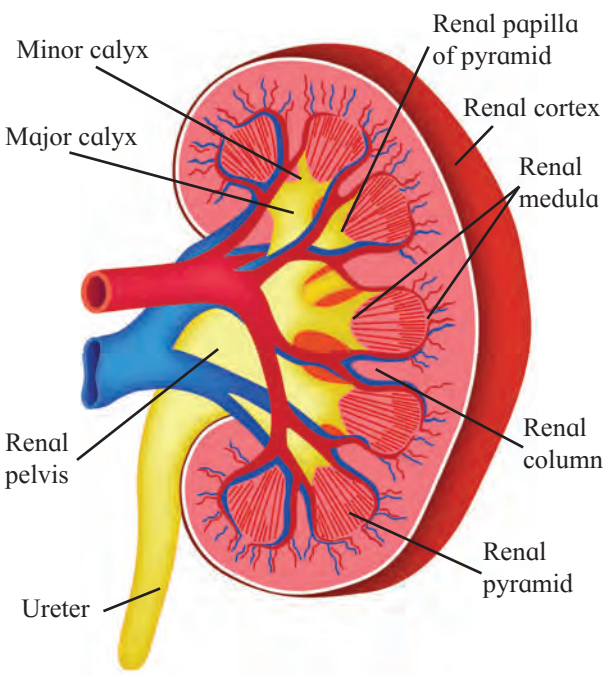


Fig. 15.5 L. S. of Kidney

There are several pyramids. Renal papilla open into minor calyx. Minor calyces merge together to form major calyces and major calyces unite together to form renal pelvis. Renal pelvis (renal sinus) is funnel-shaped area in the region of medulla of kidney. Renal pelvis continues as ureter which leaves kidney through hilus.

Do you know ?

Nephrology is branch of biology that deals with structure, function and disorders of male and female urinary system.

Nephron : Nephrons are structural and functional units of kidney. Each nephron consists of about 4 - 6 cm long thin-walled tube- 'renal tubule' and a bunch of capillaries- 'glomerulus'. Wall of renal tubule is made up of single layer of epithelial cells. Its proximal end is wide, blind, cup-like, called as Bowman's capsule. Distal end is open. It is divisible into Bowman's capsule, neck, proximal convoluted tubule (PCT), Loop of Henle (LoH), distal convoluted tubule (DCT) and collecting tubule (CT).

Glomerulus is present in the cup-like cavity of Bowman's capsule and both are collectively known as renal corpuscle or Malpighian body.

Each Malpighian body is about 200µm in diameter and consists of a Bowman's capsule and glomerulus.

Glomerulus : Glomerulus is a bunch of fine blood capillaries lying in the cup of Bowman's capsule. A small terminal branch of renal artery called as afferent arteriole enters the cup cavity and undergoes extensive fine branching to form network of several capillaries. This bunch is called as glomerulus. Capillary wall is fenestrated. All capillaries reunite and form an efferent arteriole that leaves the cup cavity. Diameter of afferent is greater than efferent arteriole to create a high hydrostatic pressure in glomerulus. It is important for ultrafiltration.

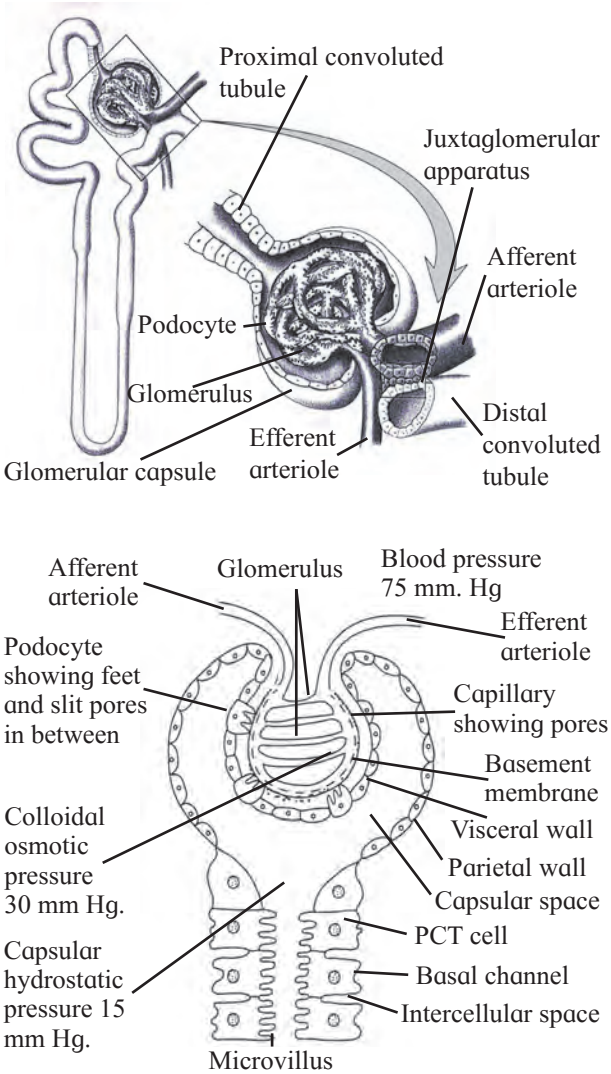


Fig. 15.6 Bowman's capsule and glomerulus

Bowman's capsule : It is a cup-like structure having double wall. Both walls are composed of squamous epithelium. Outer wall is called as parietal and inner wall is called as visceral wall. There is a space called as capsular space / urinary space in between two walls. Visceral wall consists of special type of squamous cells called podocytes having a foot-like pedicel. These podocytes are in close contact with the walls of capillaries of glomerulus.

There are small slits called as filtration slits in between adjacent podocytes. Parietal wall is thin consisting of simple squamous epithelium. It continues into neck.

The wall of neck is made up of ciliated epithelium. Lumen of neck is called urinary pole. Neck leads to proximal convoluted tubule.

Proximal Convoluted Tubule : This is highly coiled part of nephron. It is lined by cuboidal cells with brush border (microvilli) and surrounded by peritubular capillaries. It is place of selective reabsorption. Due to convolutions (coiling), filtrate flows slowly and remains in the PCT for longer duration. This ensures the reabsorption of maximum amount of useful molecules.

Loop of Henle : This is 'U' shaped tube consisting of descending and ascending limb. Descending limb is thin walled and permeable to water. It is lined with simple squamous epithelium. Ascending limb is thick walled and impermeable to water. It is lined with simple cuboidal epithelium. LoH is surrounded by capillaries called vasa recta. Its function is to operate counter current system - a mechanism for osmoregulation. Regulation of salt and water balance in body is called as osmoregulation. Ascending limb of Henle's loop leads to DCT.

Distal convoluted tubule: This is another coiled part of nephron. Its wall consists of simple cuboidal epithelium.

DCT performs tubular secretion / augmentation / active secretion in which, wastes are taken up from surrounding capillaries and secreted into passing urine.

Blood Supply to Kidney

Renal artery
↓
Renal arteriole
↓
Afferent arteriole
↓
Glomerular capillary
↓
Efferent arteriole
↓
Peritubular capillaries network
↓
Renal veinule
↓
Renal vein

DCT helps in water reabsorption and regulation of pH of body fluids.

Collecting tubule: This is a short, straight part of DCT. Collecting tubule reabsorbs water and secretes protons. Collecting tubule opens to collecting duct.

There are two types of nephrons in human kidney. Cortical nephrons with shorter loop of Henle which extend very little in medulla. Most of the nephrons are cortical nephrons. Few nephrons have longer loop of Henle that runs deep into medulla. These are called Juxtamedullary nephrons.

A small branch of efferent arteriole forms peritubular capillary network around DCT, PCT and Henle's loop of cortical nephrons also forms loop-shaped vasa recta around Henle's loop of juxtamedullary nephrons.

Nephrons are responsible for elimination of waste and osmoregulation. Hence are richly supplied with blood. About one fourth of cardiac output is supplied to kidneys!

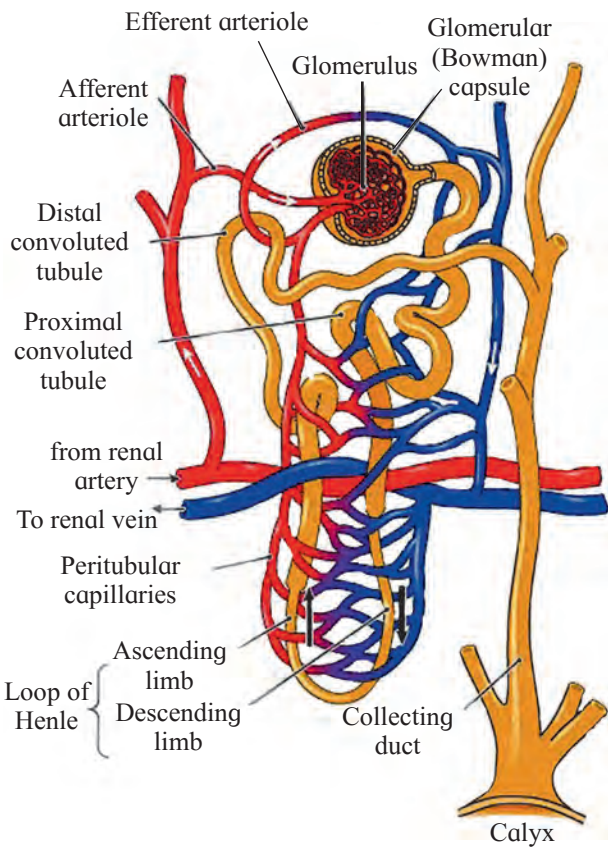


Fig. 15.7 Nephron and peritubular capillaries network

Juxta Glomerular Apparatus :

Some smooth muscle cells of the wall of afferent arteriole are modified in such a way that their sarcoplasm is granular. These cells are called 'juxtaglomerular (JG) cells.

In each nephron, beginning part of DCT makes contact with the afferent arteriole of same nephron. Cells in the wall of DCT in this region are packed more densely than those in other region of DCT. This is called macula densa. Macula densa and the JG cells together form Juxta Glomerular Apparatus (JGA) that plays important role in blood pressure regulation within kidney.

Can you tell?

1. Why are kidneys called 'retroperitoneal'?
2. Why urinary tract infections are more common in females than males?
3. What is nephron? Which are it's main parts? Why are they important?

Think about it

How much blood is supplied to kidney?

17.3 Urine formation :

Process of urine formation is completed in three successive steps as- Ultrafiltration / Glomerular filtration, Selective reabsorption, Tubular secretion / Augmentation.

a. Ultrafiltration / Glomerular filtration :

Diameter of afferent arteriole is greater than efferent arteriole. Diameter of capillaries is still smaller than both arterioles. Due to such difference in diameter, blood flows with greater pressure through glomerulus. This is called as glomerular hydrostatic pressure (GHP) and normally, it is about 55 mm Hg.

This pressure is opposed by osmotic pressure of blood (normally, about 30 mm Hg) and capsular pressure (normally, about 15 mm Hg). Hence net / effective filtration pressure (EFP) is 10 mm Hg.

Walls of capillaries are extremely thin. Under the effect of high pressure, walls become permeable to major components of blood (except blood cells and macromolecules like protein). Thus plasma except proteins oozes out through wall of capillaries. About 600 ml blood passes through each kidney per minute.

$\therefore$ EFP = Hydrostatic pressure in glomerulus - (Osmotic pressure of blood + filtrate hydrostatic pressure)

10 mmHg = 55 - (30 +15)

Glomerular filtration	Tubular reabsorption	Tubular secretion
The movement of substances from the blood within the glomerulus into the capsular space.	The movement of substances from the tubular fluid back into the blood.	The movement of substances from the blood into the tubular fluid.

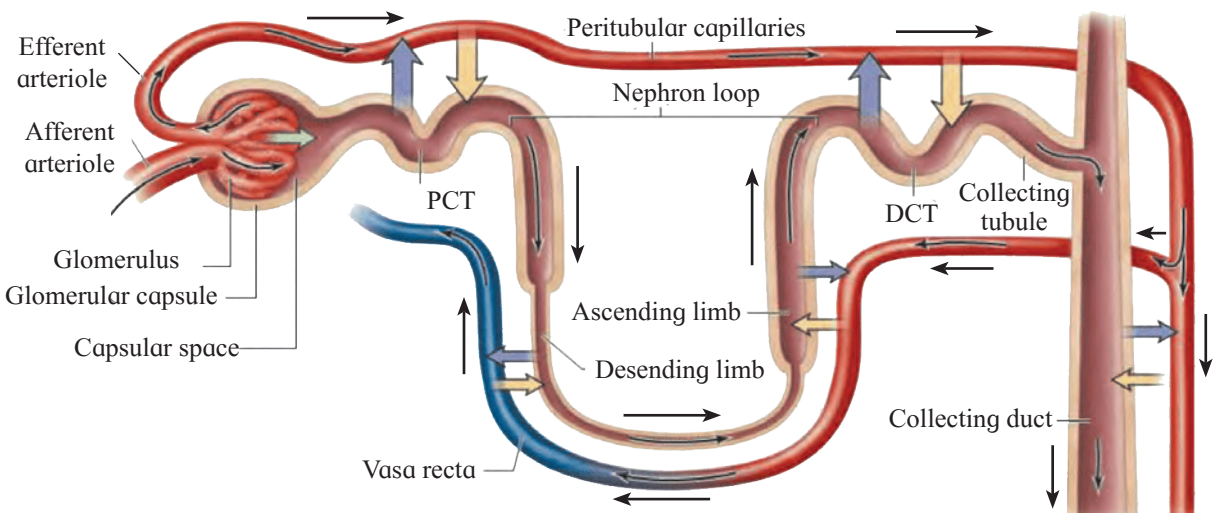


Fig. 17.8 Process of urine formation

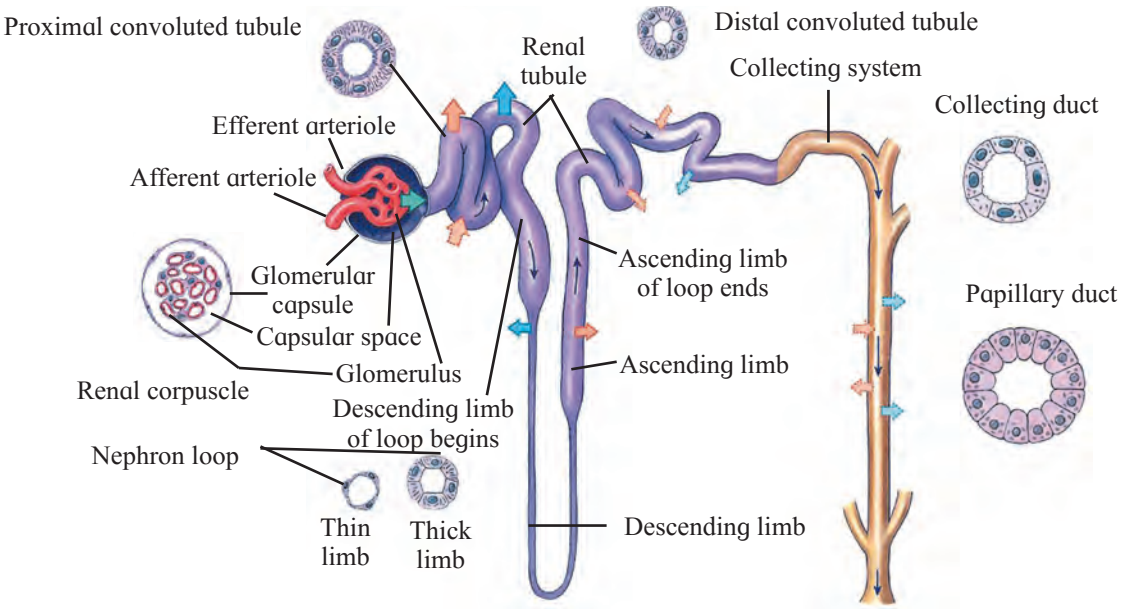


Fig. 15.9 Reabsorption

The blood (plasma) flowing through kidney (glomeruli) is filtered as glomerular filtrate - at a rate of 125 ml / min. (180 L/d).

Glomerular filtrate / deproteinized plasma/primary urine is alkaline, contains urea, amino acids, glucose, pigments, and inorganic ions.

Glomerular filtrate passes through filtration slits into capsular space and then reaches the proximal convoluted tubule.

b. Selective reabsorption :

PCT is place of reabsorption. It is highly coiled so that glomerular filtrate passes through it very slowly. Columnar cells of PCT are provided with microvilli due to which absorptive area increases enormously. This makes the process of reabsorption very effective.

These cells perform active (ATP mediated) and passive (simple diffusion) reabsorption.

Substances with considerable importance (high threshold) like - glucose, amino acids, Vit.C, Ca^{++}, K^{+}, Na^{+}, Cl^{-} are absorbed actively, against concentration gradient. Low threshold substances like water, sulphates, nitrates, etc. are absorbed passively. In this way, about 99% of glomerular filtrate is reabsorbed in PCT and DCT.

Do this

Check blood reports of patients and comment about possibility of glucosuria.

c. Tubular secretion / Augmentation :

Finally filtrate reaches the distal convoluted tubule via loop of Henle. Peritubular capillaries surround DCT. Cells of distal convoluted tubule and collecting tubule actively absorb the wastes like creatinine and ions like K^{+}, H^{+} from peritubular capillaries and secrete into lumen of DCT and CT, thereby augmenting the concentration of urine and changing its pH from alkaline to acidic.

Secretion of H^{+} ions in DCT and CT is an important homeostatic mechanism for pH regulation of blood. This process is called as tubular secretion or augmentation.

Tubular secretion is only mode of excretion in marine bony fishes and desert amphibians.

15.4 Concentration of urine :

Under the conditions like low water intake or high water loss due to sweating, human can produce concentrated urine. It can be almost four times concentrated i.e. 1200 mOsm/L than the blood (300 mOsm/L). For this purpose, a mechanism called countercurrent mechanism is operated in human kidneys.

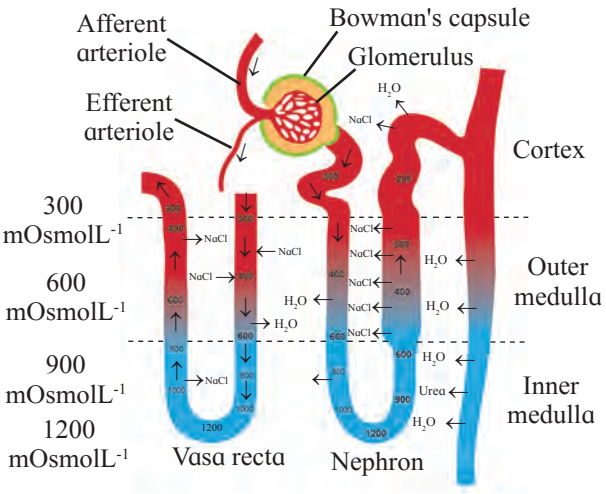


Fig. 15.10 Concentration of urine

Limbs of Henle's loop of juxtamedullary nephrons and vasa recta operate countercurrent mechanism as follows-

This mechanism involves the passage of fluid from descending to ascending limb of Henle's loop. Flow of tubular fluid is in opposite direction through both limbs; hence the name-counter (opposite) current (flow). In case of vasa recate, blood flows from ascending to descending parts of itself.

Wall of descending limb is thin and permeable to water where as that of ascending limb is thick and impermeable to water. In the region of descending limb, water diffuses from tubular fluid into tissue fluid due to which, tubular fluid becomes concentrated. Ascending limb of Henle's loop is thick walled and its cells can reabsorb Na^+ and Cl^- from tubular fluid and release into tissue fluid.

Due to this, tissue fluid around descending limb becomes concentrated. This makes the more water to move out from descending limb into tissue fluid by osmosis. Thus, as tubular fluid passes down through descending limb, its osmolarity (concentration) increases gradually due to water loss and on the other hand, progressively decreases due to Na^+ & Cl^- secretion as it flows up through ascending limb.

Besides, whenever water retention is necessary, pituitary secretes ADH.

ADH makes the cells in the wall of collecting ducts permeable to water. Due to this, water moves from tubular fluid into tissue fluid, making the urine concentrated.

Cells in the wall of deep medullar part of collecting ducts are permeable to urea. As concentrated urine flows through it, urea diffuses from urine into tissue fluid and from tissue fluid into the tubular fluid flowing through thin ascending limb of Henle's loop. This urea cannot pass out from tubular fluid while flowing through thick segment of ascending limb, DCT and cortical portion of collecting duct due to impermeability for it in these regions. However, while flowing through collecting duct, water reabsorption is operated under the influence of ADH. Due to this, urea concentration increases in tubular fluid and same urea again diffuses into tissue fluid in deep medullar region. Thus, same urea is transferred between segments of renal tubule and tissue fluid of inner medulla. This is called urea recycling; operated for more and more water reabsorption from tubular fluid and thereby excreting small volumes of concentrated urine.

Osmotic gradient is essential in the renal medulla for water reabsorption by countercurrent multiplier system. This osmotic gradient is maintained by vasa recta by operating countercurrent exchange system. Vasa recta also have descending and ascending limbs. Blood that enters the descending limb of the vasa recta has normal osmolarity of about 300 mOsm/L. As it flows down in the region of renal medulla where tissue fluid becomes increasingly concentrated, Na^+, Cl^- and urea molecules diffuse from tissue fluid into blood and water diffuse from blood into tissue fluid. Due to this, blood becomes more concentrated which now flows through ascending part of vasa recta. This part runs through such region of medulla where tissue fluid is less concentrated. Due to this, Na+, Cl^- and urea molecules diffuse from blood to tissue fluid and water from tissue fluid to blood. This mechanism helps to maintain the osmotic gradient.

So as to reabsorb water to maximum capacity, loops of Henle are longer in desert mammals like camel. Due to this, camel excretes concentrated urine.

Can you tell?

1. Explain the process of urine formation in details.
2. How does counter current mechanism help concentration of urine?

Use your brain power

In which regions of nephron the filtrate will be isotonic to blood?

Try this

Read the given urine report and prepare a note on composition of normal urine.

Report A

PERFECT PATHOLOGY Reg. No. :-_____

Dr. _____ Date :-_____

Patient name :-_____Age :-_____ M/F

Reference :- Dr._____

URINE ROUTINE

Quantity	
Colour	Pale yellow
Appearence	clear
Deposits	Absent
Reaction	Acidic
Specific gravity	1.02
Albumin	Absent
Sugar	Absent
Ketone bodies	Absent
Bile salts	Absent
Bile pigments	Absent
Occult blood	Negative
Casts	Absent

Think and appreciate

How do kidneys bring about homeostasis? Is there any role of neuroendocrine system in it ?

15.5 Composition of Urine :

Normal urine is pale yellow coloured transparent liquid. This colour is due to pigment urochrome. Composition of urine depends upon food and fluid consumed by the individual.

Well yes; let us find out how : There are two ways. One by regulating water reabsorption through ADH and other by electrolyte reabsorpion though RAAS.

Hypothalamus in midbrain has special receptors called osmoreceptors. They can detect change in osmolarity (measure of total number of dissolved particles per litre of solution) of blood.

If osmolarity of blood increases due to any reason such as after eating *namkeen* or due to sweating, in other words, due to water loss from the body, osmoreceptors trigger release of Antidiuretic hormone (ADH) from neurohypophysis. (posterior pituitary). ADH stimulates reabsorption of water from last part of DCT and entire collecting duct by increasing the permeability of cells. This leads to reduction in urine volume and decrease in osmolarity of blood. Once the osmolarity of blood comes to normal, activity of osmoreceptor cells decreases leading to decrease in ADH secretion. This is called negative feedback.

Think

What would happen if ADH secretion decreases due to any reason ?

In case of haemorrhage or severe dehydration too, osmoreceptors stimulate ADH secretion. ADH is important in regulating water balance through kidneys.

In absence of ADH, diuresis (dilution of urine) takes place and person tends to excrete large amount of dilute urine. This condition called as diabetes insipidus.

Another regulatory mechanism is RAAS (Renin Angiotensin Aldosterone system) by Juxta Glomerular Apparatus (JGA).

Whenever blood supply (due to change in blood pressure or blood volume) to afferent arteriole decreases (e.g. low BP/dehydration), JGA cells release Renin. Renin converts angiotensinogen secreted by hepatocytes in liver to Angiotensin I. Angiotensin converting enzyme further modifies Angiotensin I to Angiotensin II, the active form of hormone.

Angiotensin II has triple function

1. It constricts arterioles in kidney thereby reducing blood flow and increasing blood pressure.
2. Stimulates PCT cells to enhance reabsorption of Na^+, Cl^- and water.
3. It stimulates adrenal cortex to release another hormone called aldosterone that stimulates DCT and collecting ducts to reabsorb more Na^+ and water, thereby increasing blood volume and pressure.

Use your brain power

Can we use this knowledge in treatment of high blood pressure? Why high BP medicines are many a times diuretics?

Would only ADH or only RAAS be sufficient for homeostasis?

Both ADH and RAAS are essential. Only ADH can lower blood-Na^+ concentration by way of water reabsorption in DCT and collecting duct, whereas RAAS stimulates Na^+ reabsorption, thus maintains osmolarity of body fluid.

Action of ADH and RAAS leads to increase in blood volume and osmolarity. A large increase in blood volume and pressure stimulates atrial wall to produce atrial natriuretic peptide (ANP). ANP inhibits Na^+ and Cl^- reabsorption from collecting ducts inhibits release of renin, reduces aldosterone and ADH release too. This leads to a condition called Natriuresis (increased excretion of Na^+ in urine) and diuresis.

Can you tell?

How do skin and lungs help in excretion ?

Kidneys participate in synthesis of calcitriol, the active form of Vitamin D which is needed for absorption of dietary calcium. Deficiency of calcitriol can lead to brittle bones.

Something Interesting :

Vampire bat from south America is a nocturnal sanguivorous mammal. It feeds on blood of large birds and mammals. It has to fly long distances to locate suitable prey. Once found, it can even consume blood to an extent of more than half it's body mass. In such a case, the body of bat becomes too heavy to fly. To compensate for this, while the bat is feeding, it's kidneys excrete large amount of dilute urine (upto 24% of it's body mass). Now bat can fly back to the cave/tree where it can spend the day.

During day time, it cannot go to drink water. At the same time diet being high on proteins, large amount of nitrogenous waste is produced. Instead of diluting waste, kidneys resort to concentrating urine in order to conserve water. This capacity to rapidly change the osmolarity of urine is a classic example of adaptation.

15.6 Role of other organs in excretion :

Skin :

Skin of many organisms is thin and permeable. It helps in diffusion of waste products like ammonia. Human skin is thick and impermeable. It shows presence of two types of glands namely, sweat glands and sebaceous glands. Sweat glands are distributed all over the skin. They are abundant in palm and facial regions.

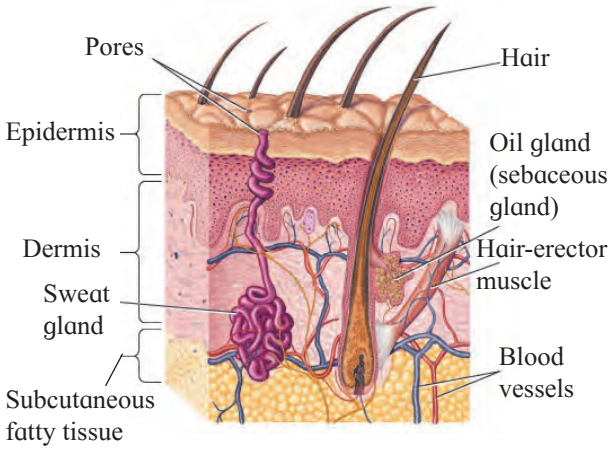


Fig. 15.11 L. S. of Skin

These simple, unbranched, coiled, tubular, glands open on the surface of skin through an opening called sweat pore. Sweat is primarily produced for thermoregulation but it also excretes substances like water, NaCl, lactic acid and urea.

Sebaceous glands :

They are present at the neck of hair follicles. They secrete oily substance called sebum. It forms a lubricating layer on skin making it softer. It protects skin from infection and injury.

Lungs :

Lungs are the respiratory organs. They help in excretion of volatile substances like CO_2 and water vapour produced during cellular respiration. They also excrete volatile substances present in spices and other food stuff.

Can you tell?

1. What is the composition of sweat?
2. When does kidney produce renin? Where is it produced in kidney?
3. Explain role of lungs and skin in excretion.
4. Explain how electrolyte balance of blood plasma maintained.
5. Refer to blood report A and B what is the significance of values of albumin, blood cells, casts etc?

15.7 Disorders and diseases :

Excessive albumin in urine (albuminuria) indicates injury to endothelial-capsular membrane as a result of increased blood pressure, injury or irritation of kidney cells by substances such as toxins or heavy metals. Presence of excessive quantities of ketone bodies in urine may be caused due to diabetes mellitus, starvation or too little carbohydrates in diet.

Presence of leucocytes in urine indicate possibility of infection of kidney or other urinary organs.

1. Kidney stones :

These are also called renal calculi - They may be formed in any portion of urinary tract-from kidney tubules to external opening.

Depending on composition they are classified into :

Calcium stones : Usually are calcium oxalate stones or calcium phosphate ones.

Struvite stones : These are formed in response to bacterial infection caused by urea splitting bacteria. These grow quickly and become quite large.

Uric acid stones : In people who don't drink enough water or consume high protein diet can suffer from this type of stones.

Cystine stones : It is a genetic disorder that causes kidney to excrete too much of certain amino acid.

Symptoms : Intermittent pain below rib cage in back and side ways. Hazy, brownish/reddish/pinkish urine. Frequent urge to pass urine. Pain during micturition.

Diagnosis : Uric acid content of blood, colour of urine, kidney X-ray, sonography of kidney are different diagnostic tests prescribed depending on symptoms.

2. Uremia :

Blood normally contains 0.01 to 0.03% urea; but if it rises above 0.05%, it is called uremia. It is harmful and may lead to kidney failure.

3. **Nephritis :** It is inflammation of kidenys characterised by proteinuria caused due to increased permeability of glomerular capsular membrane, permitting large amounts of proteins to escape from blood to urine. This lead to change in blood colloidal osmotic pressure, leading to movement of fluid from blood to interstitial spaces. It is reflected as edema.

4. **Renal Failure :** It is decrease or cessation of glomerular filtration, is classified into two types.

a. Acute Renal failure (ARF) : ARF is sudden worsening of renal function that most commonly happens after severe bleeding. There is decrease in urine output (oligouria-scanty urine) (less than 400 ml/day or less than 0.5 ml/kg/h in children). Other causes of ARF may include acute obstruction of both ureters or nephrotoxic drugs. ARF can be detected biochemically by elevated serum creatinine level.

b. Chronic kidney disease (CKD) : It is progressive and generally irreversible decline in glomerular filtration rate (GFR). It may be caused due to chronic glomerulonephritis. It can be detected by reduced kidney size and possibility of anaemia.

Haemodialysis :

When renal function falls below 5 to 7%, accumulation of harmful substances in blood begins. In such a condition, the person has to go for artificial means of filtration of blood. You have already studied about haemodialysis wherein dialysis machine is used to filter blood. In haemodialysis, blood is filtered outside the body using dialysis unit. In this procedure, patients' blood is removed; generally from radial artery. It is passed through a cellophane tube that acts as a semipermeable membrane. The tube is immersed in a fluid called dialysate. Dialysate is isosmotic to normal blood plasma. Hence only excess salts if present in plasma pass through the cellophane tube into the dialysate.

Waste substances being absent in the dialysate, move from blood into the dialyzing fluid. Filtered blood is returned to vein. In this process it is essential that anticoagulant like heparin is added to the blood while it passing through the tube and before resending it into the circulation, adequate amount of anti-heparin is mixed. The blood has to move slowly through the tube and hence the process is slow.

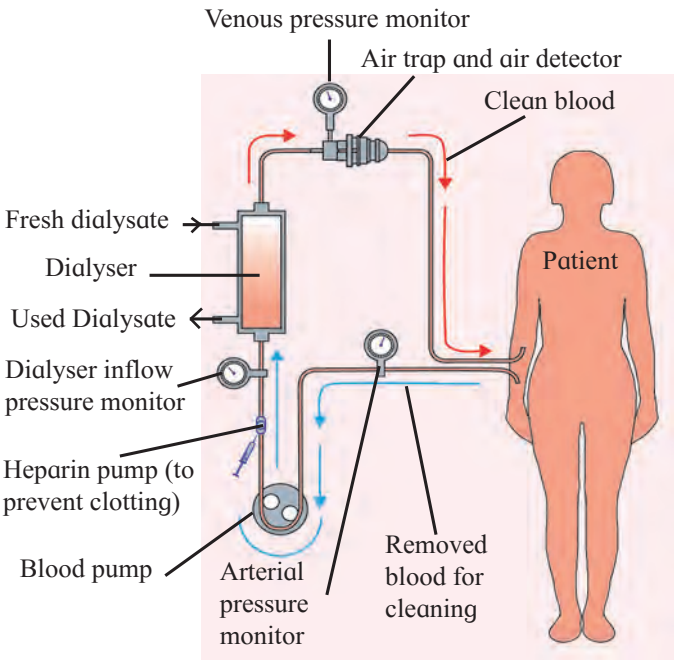


Fig. 15.12 Haemodialysis

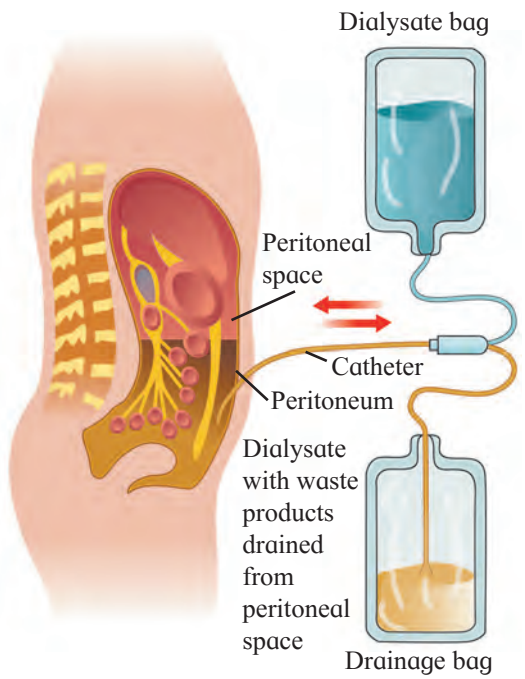


Fig. 15.13 Peritoneal dialysis

Always Remember

Dialysis is regarded as a 'holding measure' until a renal transplant can be performed or sometimes as the only supportive measure in those for whom a transplant would be inappropriate.

Peritoneal dialysis :

In this method, the dialyzing fluid is introduced in abdominal cavity or peritoneal cavity. The peritoneal membrane acts as semipermeable dialyzing membrane.

Toxic wastes and extra solutes pass into the fluid. This fluid is drained out after prescribed period of time. Peritoneal dialysis can be repeated as per the need of the patient. It can be carried out at home at work or while travelling. But it is not as efficient as haemodialysis.

Kidneys are associated with secretion of erythropoietin, renin and calcitriol which is not possible using dialysis machine.

5. Kidney transplant :

It is organ transplant of a healthy kidney into a patient with end stage renal disease. Kidney transplantation is classified as cadaveric (deceased donor) or living donor kidney transplant. Living donor kidney transplant are further classified as genetically related (living-related) or non-related (living non-related) transplants.

Use your brain power

If a person is undergoing kidney transplant, immunosuppresants are administered. Justify.

Internet my friend

1. Treatments other than surgical removal of kidney stone like Lithotripsy. (Breaking down of kidney stones using shock waves).
2. Dietary restrictions suggested for kidney patients.

Exercise

1. Choose correct option

A. Which one of the following organisms would spend maximum energy in production of nitrogenous waste?
a. Polar bear b. Flamingo
c. Frog d. Shark

B. In human beings, uric acid is formed due to metabolism of _____.
a. amino acids b. fatty acids
c. creatinine d. nucleic acids

C. Visceral layer : Podocytes :: PCT : _____
a. Cilliated cells
b. Squamous cells
c. Columnar cells
d. Cells with brush border

D. Deproteinised plasma is found in _____.
a. Bowman's capsule
b. Descending limb
c. Glomerular capillaries
d. Ascending limb

E. Specific gravity of urine would _____ if level of ADH increases.
a. remain unaffected b. increases
c. decreases d. stabilise

F. What is micturition?
a. Urination b. Urine formation
c. Uremia c. Urolithiasis

G. Which one of the following organisms excrete waste through nephridia?
a. Cockroach b. Earthworm
c. Crab d. Liver Fluke

H. Person suffering from kidney stone is advised not to have tomatoes as it has _____.
a. seeds b. lycopene
c. oxalic acid d. sour taste

I. Tubular secretion does not take place in _____.
a. DCT b. PCT
d. collecting duct d. Henle's loop

J. The minor calyx _____.
a. collects urine
b. connects pelvis to ureter
c. is present in the cortex
d. receives column of Bertini

K. Which one of the followings is not a part of human kidney?
a. Malpighian body
b. Malpighian tubule
c. Glomerulus
d. Loop of Henle

L. The yellow colour of the urine is due to presence of _____
a. uric acid b. cholesterol
c. urochrome d. urea

M. Hypotonic filtrate is formed in _____
a. PCT b. DCT c. LoH d. CT

N. In reptiles, uric acid is stored in _____
a. cloaca b. fat bodies
c. liver d. anus

O. The part of nephron which absorbs glucose and amino acid is_____
a. collecting tubule
b. proximal tubule
c. Henle's loop
d. DCT

P. Bowman's capsule is located in kidney in the _____
a. cortex b. medulla
c. pelvis d. pyramids

Q. The snakes living in desert are mainly_____
a. aminotelic b. ureotelic
c. ammonotelic d. uricotelic

R. Urea is a product of breakdown of _____
a. fatty acids b. amino acids
c. glucose d. fats

S. Volume of the urine is regulated by_____
a. aldosterone b. ADH
c. both a and b d. none

2. Answer the following questions

A. Doctors say Mr. Shaikh is suffering from urolithiasis. How it could be explained in simple words?

B. Anitaji needs to micturate several times and feels very thirsty. This is an indication of change in permeability of certain part of nephron. Which is this part?

C. Effective filtration pressure was calculated to be 20 mm Hg; where glomerular hydrostatic pressure was 70 mm of Hg. Which other pressure is affecting the filtration process? How much is it?

D. Name any one guanotelic organism.

E. Why are kidneys called 'retroperitoneal'?

F. State role of liver in urea production.

G. Why do we get bad breath after eating garlic or raw onion?

3. Answer the following questions

A. John has two options as treatment for his renal problem : Dialysis or kidney transplants. Which option should he choose? Why?

B. Amphibian tadpole can afford to be ammonotelic. Justify.

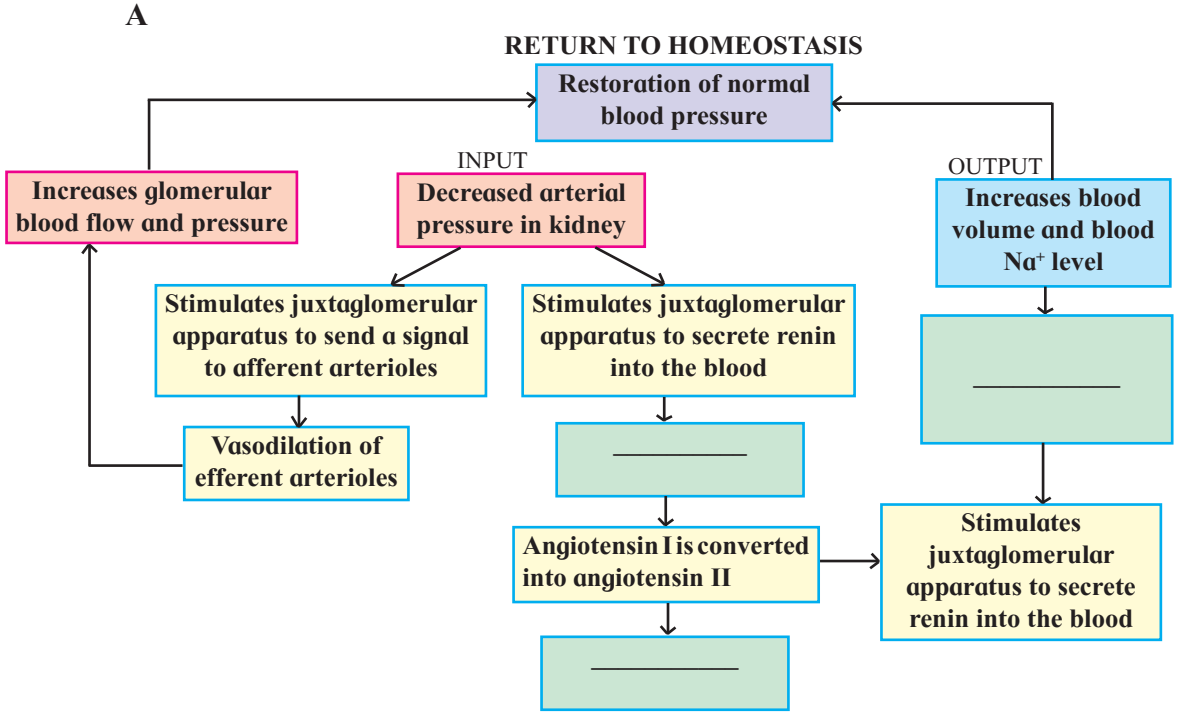
C. Birds are uricotelic in nature. Give reason.

4. Write the explanation in your word

A. Nitya has been admitted to hospital after heavy blood loss. Till proper treatment could be given; how did Nitya's body must have tackled the situation?

5. Complete the diagram / chart with correct labels / information. Write the conceptual details regarding it

A



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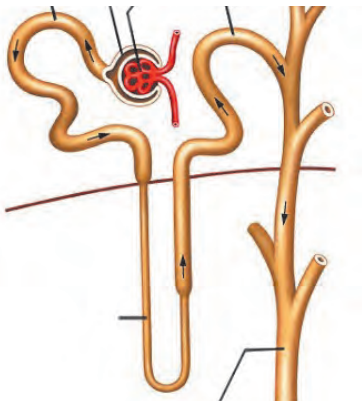

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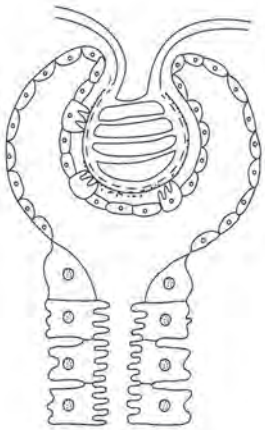

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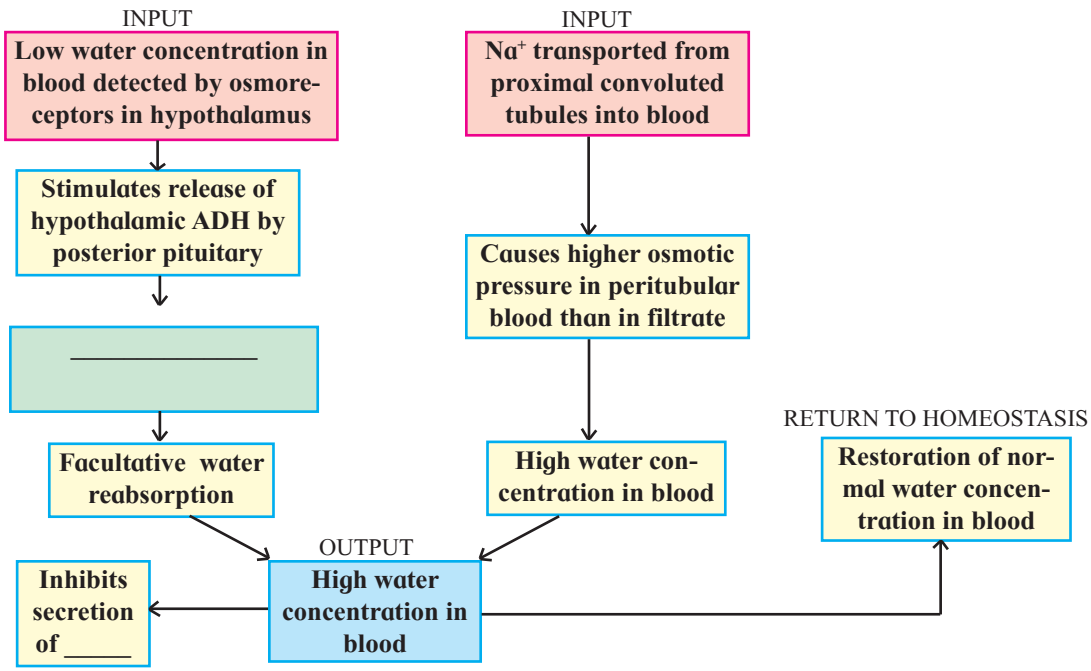

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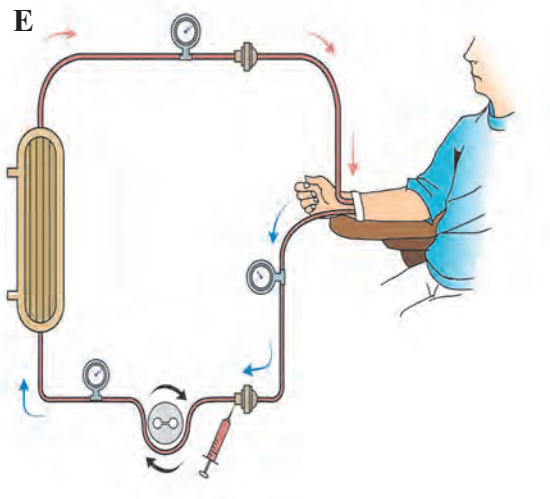

6. Prove that mammalian urine contains urea.

Practical / Project :

Visit to a nearby hospital or pathological laboratory and collect detailed information about different blood and urine tests.