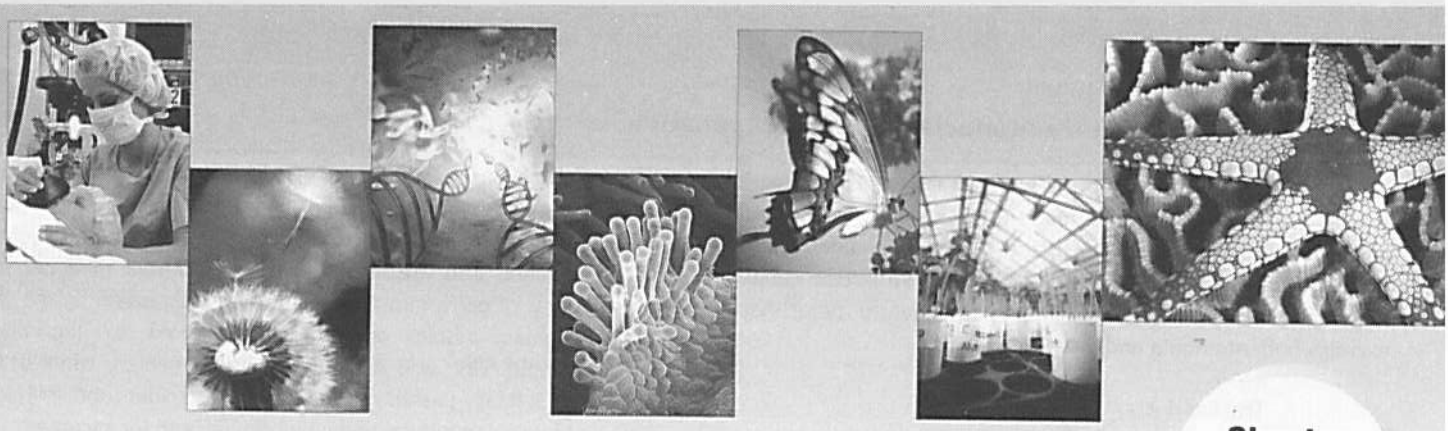


Chapter

5.4

Excretory Products and their Elimination

The component structural and functional units of the bodies of all organism are cells which have been looked as "miniature chemical factories" because of continuous metabolism taking place in these. It yields certain waste products which are, not only useless, but harmful to the cells and the body. Cells, therefore, throw out these wastes, by diffusion, into their surrounding medium. Finally, these wastes are eliminated by the body into its external environment. This is, thus an important vital activity of all organism. It is called excretion.

Excretory organs of different organism

(1) **Protozoans :** In protozoans like Amoeba and Paramecium carbon dioxide and ammonia are mostly excreted out by diffusion through general body surface. It is considered that the contractile vacuoles also play some role in the removal of excretory products.

(2) **Sponges :** In sponges, the nitrogenous metabolic waste (ammonia) leaves the body in the outgoing water current by diffusion.

Most of the sponges are marine and have no problem of surplus water in their cells. A few sponges lie in hypotonic fresh water and have contractile vacuoles in most of their cells.

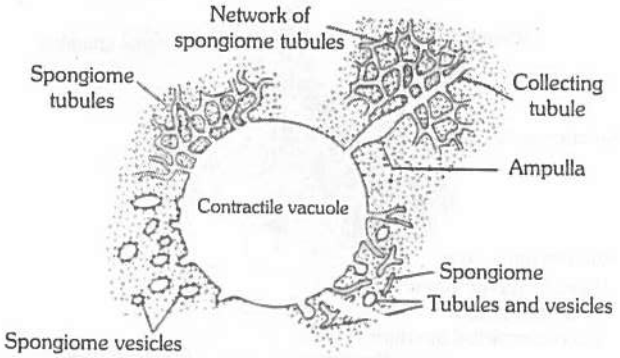


Fig : 5.4-1 Contractile vacuole in sponge

(3) **Coelenterates :** Hydra also lacks special excretory organs. The nitrogenous waste products like ammonia are removed through the general surface of the body by diffusion. Some nitrogenous waste products are also thrown along with indigestible matter through the mouth.

(4) **Platyhelminthes :** Planaria, liverfluke and tapeworm possess a large number of excretory cells called the flame cells (solenocytes) or protonephridia and long excretory ducts (also called canals of vessels). The flame cells open into the ductules which in turn open into the excretory duct.

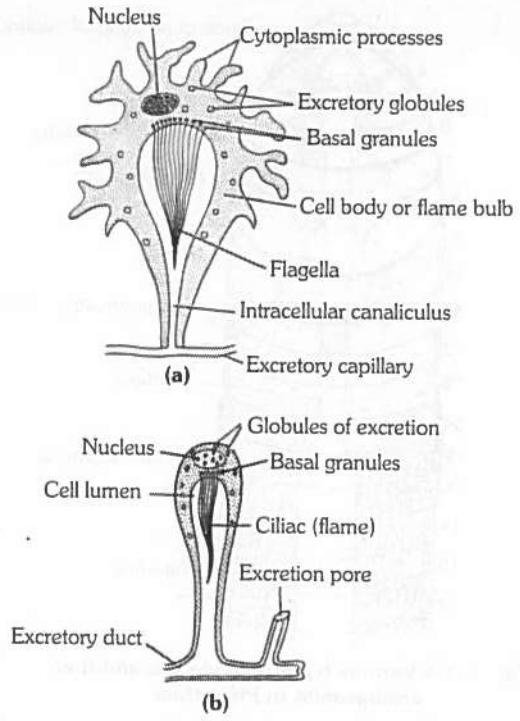


Fig : 5.4-2 Flame cell (a) Fasciola (b) Planaria

(5) **Nematoda :** The round worms such as *Ascaris* have H-shaped excretory system. It is made up of a single Renette cell, in entire length of body. It consists of two longitudinal excretory canals connected anteriorly by a network of transverse canals. A short terminal duct opens outside via excretory pore. Ascaris excretes both ammonia and urea.

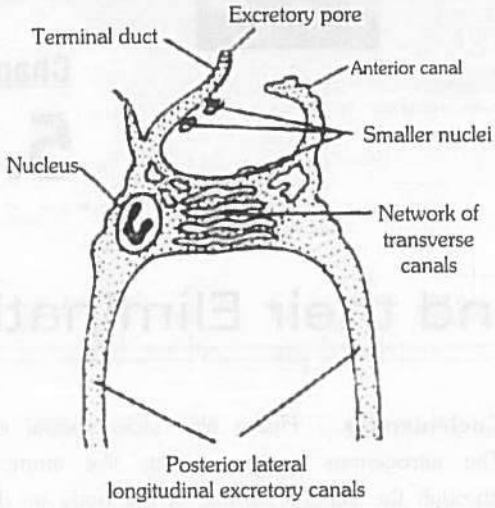


Fig : 5.4-3 Renette cell of Ascaris

(6) **Annelids (Earthworm) :** In earthworm excretory system is known as nephridial system, which consist of 3 types of nephridia pharyngeal, septal, and integumentary nephridia. All nephridia commonly called micronephridia. Earthworm excrete 40% urea, 20% ammonia, 40% amino acids. Earthworm is mainly ureotelic. Chloragogen cells found in coelomic fluid are also excretory in nature. Blood gland in earthworm found in 4, 5, 6 segment, serves for excretion, manufacture of blood corpuscles and Hb.

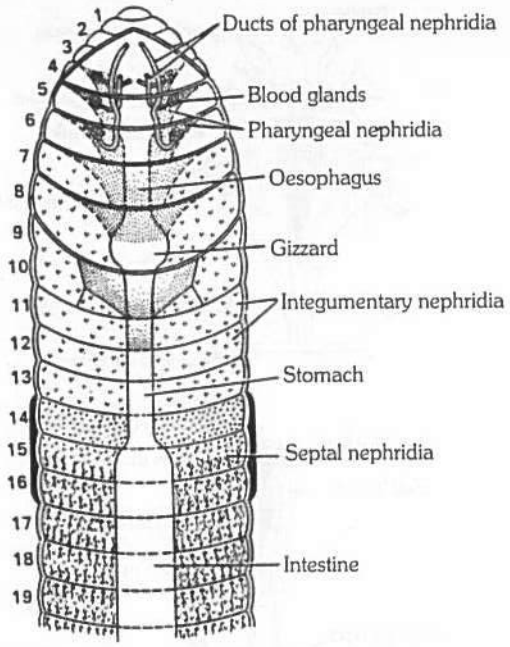


Fig : 5.4-4 Various types of nephridia and their arrangement in Pheretima

(7) **Arthropods :** The excretory system of the adult Prawn (crustacean) consists of a pair of antennary or green glands, a pair of lateral ducts and a single renal sac.

Insects, centipedes, millipedes and arachnids like scorpion and spider posses Malpighian tubules as their principal excretory organs. In the Malpighian tubules bicarbonates of potassium and sodium, water and uric acid are formed. A large amount of water and bicarbonates of potassium and sodium are reabsorbed by the cells of Malpighian tubules and then transferred to the blood (haemolymph). Uric acid is carried to the alimentary canal of the insect and is finally passed out through anus. Spiders and scorpions possess Malpighian tubules and coxal glands both for excretion.

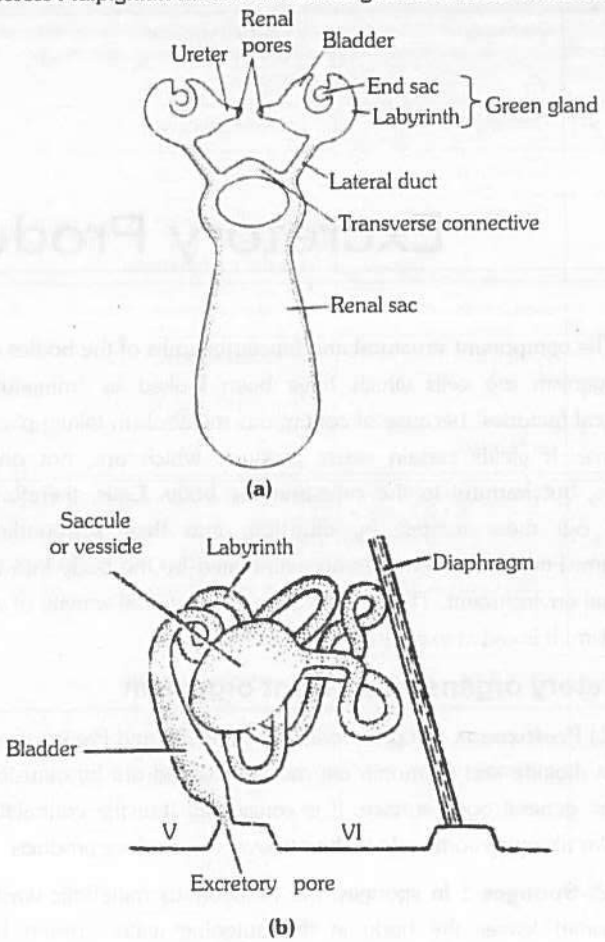


Fig : 5.4-5 (a) Antennary gland of Prawn
(b) Coxal gland of Scorpion

(8) **Molluscs :** They have one or two pairs of kidneys or organs of bojanus and keber's organ for excretion in unio.

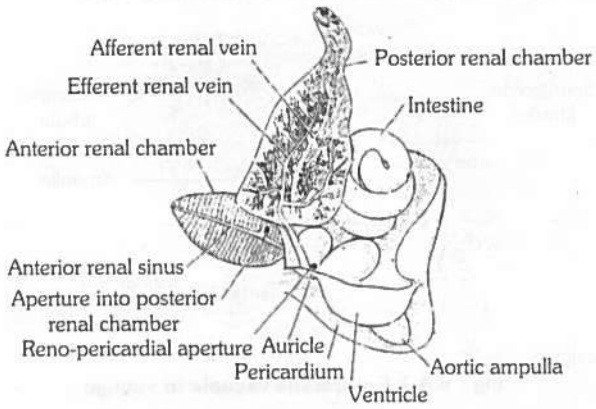


Fig : 5.4-6 Organ of Bojanus (Pila – mollusca)

(9) **Echinoderms :** Specialized excretory organs are absent in echinoderms (*e.g.*, Starfish). The excretory products, chiefly ammonia, urea, and creatinine are eliminated by diffusion through dermal branchiae (primitive gills) and tube feet. Amoeboid coelomocytes also excretory.

Table : 5.4-1 Excretory organs of different organisms

S.No.	Phylum	Excretory/osmoregulatory Organ/Organelle and principal N_2-waste	Function	Example
I. Invertebrates				
(1)	Protozoa	Contractile vacuole Ammonia	Ammonotelic Osmoregulatory	Amoeba Paramecium
(2)	Porifera	General surface of body	Ammonotelic	Sycon, Leucon
(3)	Coelenterata	Ammonia, General surface of body	Ammonotelic	Hydra
(4)	Platyhelminthes	flame cells (=Solenocytes) form the protonephridial system	Ammonotelic	Taenia, fasciola, planaria
(5)	Nematoda	H-shaped excretory organ, Renette cells	Ammonotelic	Ascaris
(6)	Annelida	Nephridial system, (Metameric), various types	Ammonotelic	Pheretima
(7)	Arthropoda			
a.	Class-Insecta	Malpighian tubule, Nephrocyte, Uricose gland (Uric acid)	Uricotelic	Periplaneta, House fly, mosquito
b.	Class Crustacea	Antennary (=green) gland, Hepatopancreas Uric acid	Uricotelic	Palaemon
c.	Class Arachnida	Coxal glands, Malpighian tubule, Hepatopancreas, Nephrocytes	Uricotelic, Guanine and Xanthine in small amount	Spider, Scorpion
(8)	Mollusca	(a) Kidneys or organs of Bojanus (b) Keber's organ (c) Renal organs (d) Renal sacs Ammonia in aquatic condition Excrete uric acid in terrestrial condition	Guanine Guanine Ammonotelic in aquatic, & uricotelic in terrestrial Guanine Ammonotelic Uricotelic	Unio Unio Pila, Limax Sepia
(9)	Echinodermata	Dermal branchiae (primitive gills) tube feet, body surface (Ammonia), coelomocytes	Ammonotelic mainly	Cucumaria Asterias
(10)	Hemichordata	Glomerulus or proboscis gland	Ammonotelic	Balanoglossus saccoglosses
(11)	Urochordata	Neural gland, Nephrocyte	Xanthine + uric acid (Uricotelic)	Herdmania
(12)	Cephalochordata	(a) Protonephridia (b) Solenocytes (c) Brown funnel (d) Renal papilla (e) Hatschek nephridia	Ammonotelic	Amphioxus (Branchiostoma)

Excretory products in different organisms

(1) **Waste products of protein metabolism**

(i) **Amino acids :** These are end products of protein digestion absorbed into the blood from small intestine. Certain invertebrates, like some molluscs (*eg Unio, Limnae, etc.*) and some echinoderms (*eg* Asterias) excrete excess amino acids as such. This is called aminotelic excretion or aminotelism.

(ii) **Ammonia** $\left(NH_4^+ \text{ or } NH_3\right)$ **:** In most animals, excess amino acids are deaminated, i.e. degraded into their keto and ammonia groups. The keto groups are used in catabolism for producing ATP, whereas ammonia is excreted as such or in other forms. Ammonia is highly toxic and highly soluble in water. Its excretion as such, therefore, requires a large amount of water. That is why, most of the aquatic arthropods, bony and freshwater fishes, amphibian tadpoles, turtles, etc excrete ammonia. This type of excretion is called ammonotelic excretion or ammonotelism.

(iii) **Urea** $CO(NH_2)_2$**:** This is less toxic and less soluble in water than ammonia. Hence, it can stay for some time in the body. Many land vertebrates (adult amphibians, mammals) and such aquatic animals which cannot afford to lose much water (*e.g.* elasmobranch fishes) marine bony fish, adult frog, earthworms, nematodes, turn their ammonia into urea for excretion. This type of excretion is called ureotelic excretion or ureotelism.

(iv) **Uric acid :** Animals living in dry conditions, such as land gastropods, most insects, land reptiles (snakes and lizards), birds and Kangaroo rat (mammal) *etc* have to conserve water in their bodies. These, therefore, systhesize crystals of uric acid from their ammonia. For the formation of uric acid xanthine oxidase enzyme is necessary. Uric acid crystals are nontoxic and almost insoluble in water. Hence, these can be retained in the body for a considerable time before being discharged from the body. Uric acid is the main nitrogenous excretory product discharged in solid form. This excretion is called uricotelic excretion or uricotelism.

(v) **Trimethylamine oxide :** Certain marine molluscs, crustaceans and teleost fishes first form trimethylamine from their ammonia by a process known as methylation. Then, the trimethylamine is oxidised to trimethylamine oxide for excretion.This oxide is soluble in water, but nontoxic.

(vi) **Guanine :** Spiders typically excrete their ammonia in the form of guanine. Some guanine is also formed in unio, penguin, birds and it is insoluble in water. Hence, no water is required for its excretion.

(2) **Waste products of nucleic acid metabolism**

As a result of nucleic acid digestion, nitrogenous organic bases – purines (adenine and guanine) and pyrimidines (cytosine, thymine and uracil) – are absorbed from intestine into the blood. Most of these are excreted out. About 5% of the total excretion of body accounts for these substances. In man, purines are changed to uric acid for excretion. In most other mammals, nitrogenous organic bases are excreted in the form of allantoin. Insects, amphibians, reptiles and birds also excrete these bases in the form of uric acid. Some freshwater molluscs and crustacean arthropods excrete these in the form of ammonia.

(3) **Some sundry excretory substances (Others excretory products)**

(i) **Hippuric and ornithuric acids :** Sometimes food of rabbit and other mammals may contain traces of benzoic acid, or this acid may be formed in small amounts during fat metabolism. It is highly toxic. As it is absorbed in blood, it is combined with glycine and changed into less toxic hippuric acid for excretion. In birds, benzoic acid is combined with ornithine and changed into ornithuric acid for excretion.

(ii) **Creatine and creatinine :** Muscle cells contain molecules of creatine phosphate, which are high energy molecules and serve for storage of bioenergy like ATP. It is synthesised by 3 amino acids (G.A.M.) (Glycine, Argenine and Methionine). Excess amount of this phosphate is, however, excreted out as such, or after being changed into creatinine.

Excretory system of man

Mammalian (human) urinary system consists of a pair of kidneys, a pair of ureter, a urinary bladder and a urethra.

(1) **Kidneys :** The kidneys are dark-red, bean-shaped organs about 11 *cm* long, 5 *cm* wide and 3 *cm* thick, each weight about 150 *gm* in an adult male and about 135 *gm* in adult female. They are placed against the back wall of the abdominal cavity just below the diaphragm, one on either side opposite the last thoracic and first three lumbar vertebrae. The 11th and 12th pairs of ribs protect them.

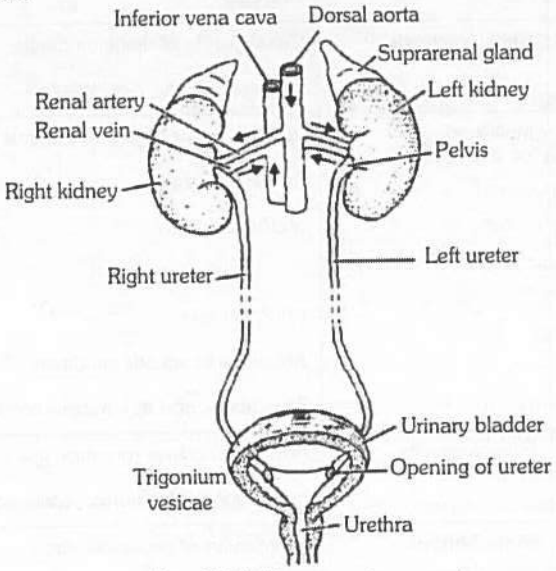


Fig : 5.4-7 Human urinary system

The kidneys are covered by peritoneum on the front (ventral) side only. thus, they are retroperitoneal. The right kidney is attached more anterior than the left in rabbit. This asymmetry is just the reverse of that found in man.

In man left kidney occurs at a slightly higher level than the right one, because right side has prominent right liver lobe. In rabbit the condition is little differ due to quadropedilism *i.e.* left kidney is in normal position while the right kidney shift ahead to provide place for stomach below it.

In mammals, the kidney is concavo convex. The center of concave inner surface is called as hilum or hilus which gives out a ureter. From this hilus surface the renal artery enters into the kidney, the renal vein comes out and the renal nerves enter into the kidney.

(i) **Structure of kidney :** The kidneys are metanephric in mammals. The kidney is divisible into two parts outer-cortex and inner-medulla. Three layers of tissue surround each kidney.

(a) The innermost, renal capsule made up of fibrous connective tissue.

(b) The intermediate layer, adipose capsule of fatty tissue.

(c) The outermost, renal fascia of dense connective tissue.

Renal pyramids or medullary pyramids : The medulla is subdivided into 8 to 18 conical masses – the renal pyramid, each having broad base towards the cortex and a narrow end called renal papilla towards the pelvis.

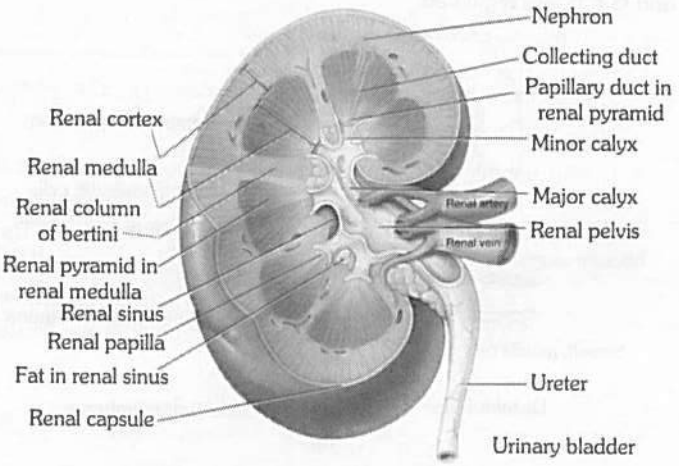


Fig : 5.4-8 L.S. of human kidney

Path of urinary drainage : Collecting duct → Papillary duct in renal pyramid → Minor calyx → Major calyx → Renal pelvis → Ureter → Urinary bladder

Renal columns of bertini : Between the pyramids, the cortex extends into the medulla or renal columns of bertini.

Calyx : Each renal papilla projects into the cavity of a minor calyx, minor calyx join to form major calyx. The major calyx open into a wide funnel like structure, the pelvis. The latter leads into the ureter. In rabbit, the pelvis is unbranched hence, it is without calyx.

In frog ventral surface of each kidney has many ciliated funnels called nephrostomes. They drain wastes from body cavity (coelom) and connect to renal veins in frog or to uriniferous tubules in tadpoles.

(ii) **Histology of kidney :** Histologically a kidney is made of innumerable thin, long, much convoluted tubular units called uriniferous tubule or nephron.

Nephron is the structural and functional unit of kidney. One human kidney may contain about one million (10 lac nephron) nephron (In rabbit each kidney bear about 2 lac nephron). In frog each kidney bears about 2 thousand nephron.

(a) **Structure of nephron :** A nephron or uriniferous tubules consist of two parts :

Malpighian body / Renal Corpuscles : The proximal end of each nephron forms a blind or closed, enlarged and double walled cup, the Bowman's capsules in the cortex. (name Bowman's capsule is based on English physiologist and histologist William Bowman).

Each capsule contains a network of blood capillaries the glomerulus which receives blood through afferent arteriole and the blood comes out through the efferent arteriole .The diameter of the efferent arteriole is comparatively lesser. Bowman's capsule and glomerulus receives about 20 – 25% of the cardiac out put (blood) at rest.

The composite structure of Bowman's capsule and glomerulus is known as Malpighian body or Malpighian corpuscles after the Italian microscopist Marcello Malpighi.

Tubule : The tubule is differentiated into 3 parts P.C.T., Henle's loop and D.C.T.

The Bowman's capsule opens into a proximal convoluted tubule (P.C.T.) the anterior part of the P.C.T. is more coiled where as its posterior part is almost straight. The P.C.T. opens into a Henle's loop. The Henle's loop is a U- shaped structure or makes hair pin turn, which has a distinct descending limb and an ascending limb. The ascending limb opens into the distal convoluted tubule. The D.C.T. is a coiled structure. Many D.C.T. unite to form a collecting duct. The collecting ducts of one pyramid unite to form a duct of Bellini. The duct of Bellini lead into the pelvis part.

(b) **Arrangement of nephron :** The malpighian body and most of the P.C.T. and D.C.T. are situated in the cortex. Henle's loop and collecting ducts are found in the medulla.

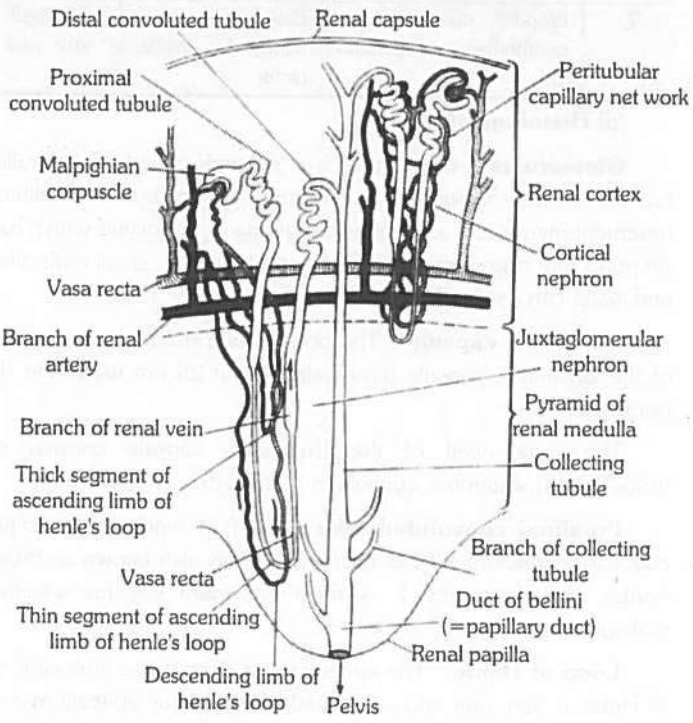


Fig : 5.4-9 Position, structure and blood supply of cortical and juxtamedullary nephrons in a mammalian kidney

Vasa recta : The efferent arteriole of juxta-glomerular nephron forms a peritubular capillary system around the Henle's loop which is called vasa recta. Each of the vasa recta makes U turn at the inner most part of the medulla and return to the venous circulation near the junction of medulla and cortex. The efferent arteriole and peritubular capillaries technically constitute a renal portal system. All amniotes as reptiles, birds and mammals have this renal portal system of efferent arteriole and peritubular capillaries.

(c) **Types of nephron :** Nephrons are of two types cortical and juxtamedullary, with regard to their location in the kidney. The cortical nephrons form about 80% to 85% of total nephron.

Remaining 15 – 20% are juxta medullary nephron.

Table : 5.4-2 Differences between cortical and Juxtamedullary nephrons

S.No.	Cortical Nephrons	Juxtamedullary Nephron
1.	Form 80 – 85% of total nephrons.	Form only 15 – 20% of total nephrons.
2	Are small in size.	Are large in size.
3.	Lie mainly in the renal cortex.	Have Bowman's capsules in the cortex near its junction with the medulla.
4	Henle's loops are very short and extend only a little into the medulla	Henle's loop are very long and extend deep into the medulla.
5.	Control plasma volume when water supply is normal.	Control plasma volume when water supply is short.
6.	Glomeruli in superficial region of cortex	Glomeruli deep in cortex
7.	Blood supply from peritubular capillaries only.	Blood supply from both peritubular capillaries, and vasa recta.

(d) **Histology of nephron**

Glomerulus : Glomerulus is a network of upto 50 parallel branching and anastomosing capillaries covered by endothelium, basement membrane and epithelium made of podocytes which has slit pores that restrict passage of colloids. However, small molecules and water can easily pass through them into the P.C.T.

Bowman's capsule : The podocytes forming the inner wall of the Bowman's capsule have gaps (about 25 *nm* wide) the slit pores.

The outer wall of the Bowman's capsule consists of unspecialized squamous epithelium (flattened).

Proximal convoluted tube : P.C.T. is made up of simple cuboidal epithelium . It has microvilli so it is also known as brush border epithelium. P.C.T. is most important site for selective reabsorption.

Loop of Henle : The epithelium of descending limb of loop of Henle is very thin and composed of squamous epithelium and ascending limb is made up of two parts. First is thin ascending limb lined by squamous epithelium and second thick ascending limb lined by cuboidal epithelium. The ascending limb is impermeable to water and permeable to *NaCl*.

Distal convoluted tube : D.C.T. is made up of cuboidal epithelium which is glandular in nature.

Collecting ducts : The collecting ducts are lined by cuboidal epithelium in different regions. At intervals, the cuboidal cells are ciliated.

Juxta-glomerular apparatus : This specialized cellular apparatus is located where the distal convoluted tubule passes close to the Bowman's capsule and afferent arteriole. Cells of the D.C.T. epithelium in contact with afferent arteriole are denser than other epithelial cells known as maculla densa. Maculla densa has special Lacis cell or Polkisson's cell. These cells secrete renin hormone that modulate blood pressure and thus renal blood flow and G.F.R. are regulated.

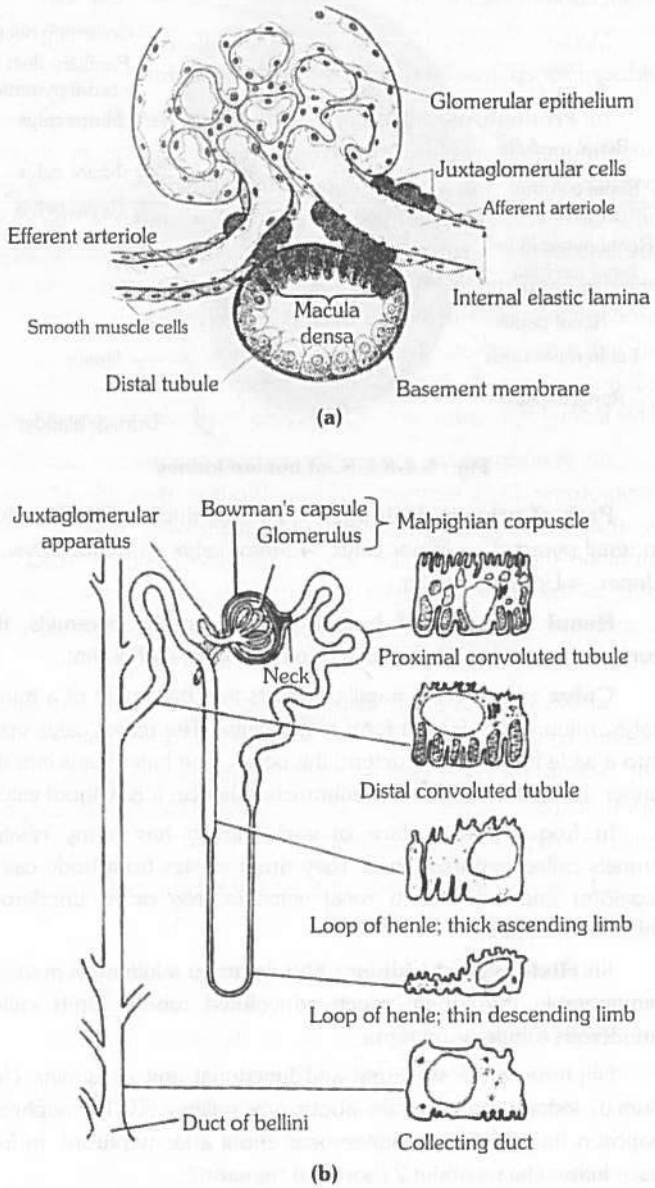


Fig : 5.4-10 (a) Juxta glomerular apparatus (b) Juxtamedullary nephron and epithelial cells in the wall of its various parts

Origin and types of kidneys in different vertebrate

Kidney tubules (nephrons) arise in the embryo in a linear series from a special part of mesoderm called mesomere or nephrotome.

Number, complexity and arrangement of nephrons differ in different groups of vertebrates. A nephron is differentiated into three parts – peritoneal funnel, tubule and malpighian body. Peritoneal funnel (nephrostome) are normally present in embryos and larvae and considered as vestigeal organ of hypothetical primitive kidneys.

(1) **Archeonephros kidney :** Archeonephros is the name given to the hypothetical primitive kidney of ancestral vertebrate. It is also called as holonephros or complete kidney. (It extended entire length of coelom) Its tubules are segmentally arragned and nephrostome is present. Glomerulus is external (without capsule). Its duct is called as archeonephric duct. *e.g.*, Larva of myxine and some apodan amphibians.

Modern vertebrates exhibits three different kinds of adult kidney Pronephros, Mesonephros and Metanephros.

(i) **Pronephros :** It originates from the anterior part of the nephrotome. It is also termed head kidney due to its anterior position. There are only 3 pronephrine tubule (nephron) in frog embryo, 7 in human embryo, and about 12 in chick embryo which are segmentary arranged. Nephrostome is present, glomerulus is external and unite to form glomus in some cases. Duct is pronephric duct or mullerian duct. A pair of pronephros appear in all vertebrate embryos but they becomes functional kidneys in adult myxine and embryos of all anamniotes (fish, amphibian). This kidney is found as transitory kidney in all vertebrates embryos.

(ii) **Mesonephros :** It originates from the middle part of the nephrotome. Duct is mesonephric or Wolffian duct. Nephrostome is absent except some embryos of anamniotes. Example – In amniotes (reptiles, birds and mammals) mesonephros is functional only in the embryos, replaced by metanephros in the adult. In anamniotes (fishes and amphibian) mesonephros is functional in both embryo as well as adults. Also found in adult petromyzon.

❑ In fish and amphibians, tubules extend through length of coelom behind pronephros and formed from entire nephrotome left behind the pronephrus called opisthonephric kidney. The opisthonephric kidney specially in males is differentiated into anterior genital and post renal part.

❑ In frog mesonephric duct is also known as Bidder's canal which carry sperm and urine both.

(iii) **Metanephros :** It originates from the posterior part of the nephrotome. When metanephric tubules develop, all the mesonephric tubules disappear except those associated with the testes in male and forming vasa efferentia. Nephrostome absent. A thin, U-shaped loop of Henle forms between P.C.T. and D.C.T. which is incomplete in Reptiles and Birds and well developed in mammals. Duct is metanephric or ureter. Reproductive duct is separate. The kidney is highly compact which possesses innumerable nephrons. Example – All amniotes – Reptile, Birds and mammal.

(2) **Ureters :** From the hilum of each kidney emerges a whitish tube the ureter. The ureters are about 28 *cm* long. Their wall consists of transitional epithelium surrounded by a layer of muscle fibres. Openings of the two ureters in the bladder are separate, but closely placed. These are oblique, so that the urine cannot regurgitate into the ureters when the bladder contracts. Peristalsis of ureters also checks regurgitation of urine. Like kidneys, the ureters are retroperitoneal.

(3) **Urinary bladder and Urethra :** The urinary bladder is pear-shaped hollow muscular organ situated in pelvic cavity, which is made up of smooth and involuntary muscles. The muscles are also known as detrusor muscles (muscles that has the action of expelling a substance). The lower part or neck of the bladder leads into the urethra. There is a smooth triangular area, called trigonium vesicae. The lumen of the urinary bladder is lined by transitional epithelium which has great power of stretching. The neck of bladder is guarded by two sphincters, inner is involuntary controlled by spinal reflex and outer is voluntary controlled by cerebral cortex. A person feels the sensation of micturition when the quantity of urine in the bladder is about 300 c.c. The average capacity of urinary bladder is 700 – 800 *ml*. In general, urinary bladder capacity is smaller in females because the uterus occupies the space just superior to bladder. Mucosa of bladder with folds called rugae. (rugae also present is stomach and vagina).

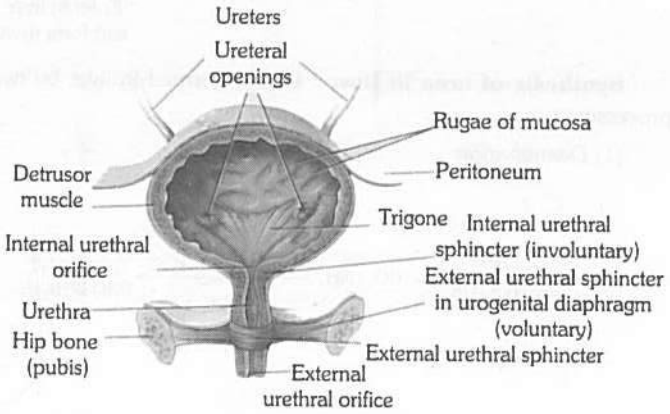


Fig : 5.4-11 Parts of ureters, trigone of the bladder, sphincters and urethra

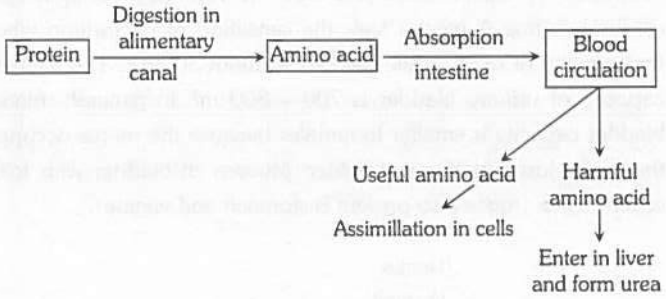
(4) **Urethra :** The urinary bladder leads into the urethra. In female, it is quite short, only about 3 to 5 *cm* long, and carries only urine. It opens by urethral orifice, or urinary aperture in the vulva infront of the vaginal or genital aperture. In a male urethra is much longer, about 20 *cm* and carries urine as well as spermatic fluid. It passes through the prostate gland and the penis. It opens out at the tip of the penis by urinogenital aperture. In males the epithelium of spongy urethra is stratified or pseudostratified columnar epithelia, except near external urethral orifice, which is non keratinized stratified squamous epithelia. The prostatic urethra is lined by transitional epithelia, while membranous urethra is lined by pseudostratified columnar.

Table : 5.4-3 Differences between male and female urethra

S. No.	Male urethra	Female urethra
1.	It is about 20 cm long.	It is just 3 – 5 cm long.
2.	It has 3 regions : prostatic urethra (3–4 cm), membranous (1 cm) and penile (15 cm)	It is not differentiated into regions.
3.	It opens out at the tip of the penis by urinogenital aperture.	It opens into the vulva by urinary aperture.
4.	It carries urine as well as semen to the exterior.	It carries only urine to the exterior.
5.	It has 2 sphincters.	It has a single sphincter.

Physiology of excretion

Major nitrogenous excretory substance in frog, rabbit and human is urea, i.e. these are ureotelic animals. The excretory physiology in these animals may be considered under two phases, viz urea synthesis and formation and excretion of urine.



Synthesis of urea in liver : Urea is formed in liver by two processes.

(1) Deamination (2) Ornithine cycle

(1) **Deamination :** The amino acid is oxidised using oxygen. This results in removal of the amino group (NH_2) and leaves pyruvic acid. The pyruvic acid can enter the Krebs cycle and be used as a source of energy in cell respiration. The amino group is converted to ammonia (NH_3) during deamination. Deamination is also known as oxidative deamination.

$$\underset{\text{(Amino acid)}}{\overset{\overset{CH_3}{|}}{CH-NH_2}\overset{\overset{|}{COOH}}{}} + \frac{1}{2}O_2 \longrightarrow \underset{\text{(Pyruvic acid)}}{\overset{\overset{CH_3}{|}}{CO}\overset{\overset{|}{COOH}}{}} + NH_3$$

With the help of a number of enzymes and energy of A.T.P. two molecules of ammonia are combined with CO_2 to form urea according to the ornithine cycle.

(2) **Ornithine cycle (Kreb-Henseleit cycle) :** In liver one molecule of CO_2 is activated by biotin and combines with two molecules of NH_3 in the presence of carbamyl phosphate synthatase enzyme (C.P.S.) and 2 ATP to form carbamyl phosphate and one molecule of H_2O is released. Carbamyl phosphate react with ornithine and form citrulline. Citrulline combines with another molecule of ammonia and form arginine. Arginine is broken into urea and ornithine in the presence of an enzyme arginase and water.

$$2NH_3 + CO_2 \xrightarrow{\text{Arginase}} \underset{\text{(Urea)}}{NH_2-CO-NH_2} + H_2O$$

Liver cells, thus, continuously remove ammonia and some CO_2 from blood and release urea into the blood. Kidneys continuously remove urea from the blood to excrete it in urine.

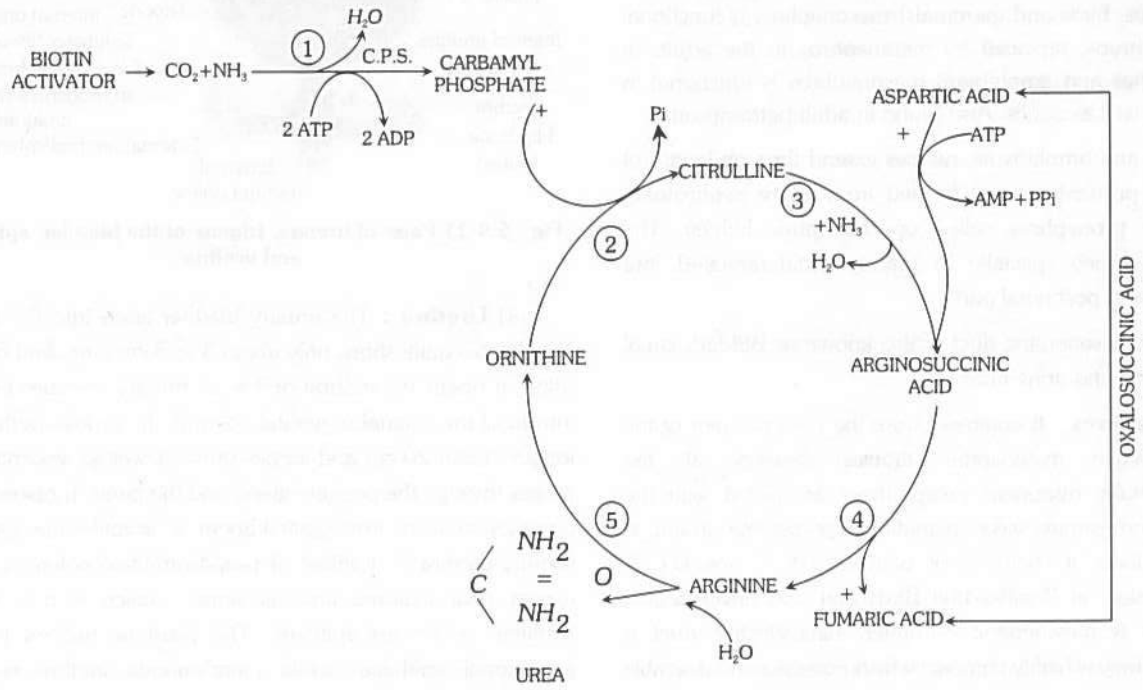


Fig : 5.4-12 Ornithine cycle

Urine formation : Urine formation occurs in the kidneys. It involves three processes glomerular filtration, reabsorption and tubular secretion.

(1) **Ultra filtration (Starling's hypothesis)**

(i) It is a passive process which takes place from the glomerulus into the Bowman's capsule. The glomerular epithelium has various micropores (diameter = 50 – 100 *nm* or 0.05 – 0.1 *μm*) which increase the rate of filtration.

(ii) The non colloidal part of the plasma as urea, water, glucose, salts, vitamin, minerals, nitrogenous waste are forced out from the glomerular capillaries into the Bowman's capsule by the high pressure of the blood in the glomerular capillaries. The pressure and resistence is high because the glomerular capillaries are narrower than the afferent renal arteries. Glomerular capillaries are about 50 times more permeable than capillaries elsewhere. Pressure is highest in glomerular capillaries than in capillaries else where, produce more filtrate.

(iii) The effective filtration pressure that causes ultrafiltration is determined by three pressures.

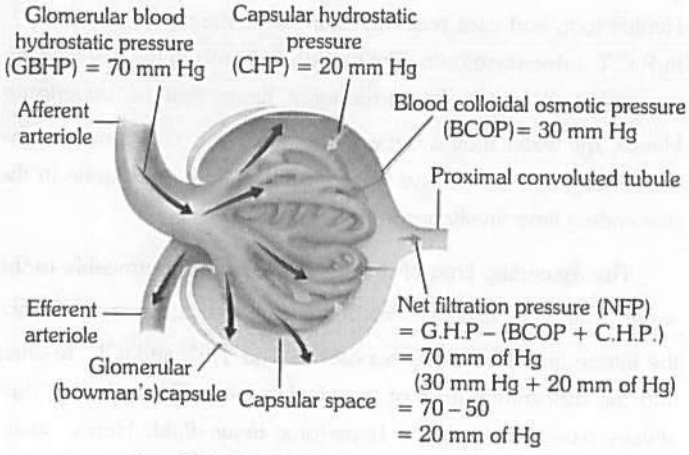


Fig : 5.4-13 Ultra filtration

(a) **Glomerular blood hydrostatic pressure (G.B.H.P.) :** Hydrostatic pressure is force that a fluid under pressure exerts against the walls of its container.

G.B.H.P. = +70 *mm Hg.*

(b) **Blood colloidal osmotic pressure (B.C.O.P) :** The B.C.O.P. is the osmotic pressure created in the blood of glomerular capillaries due to plasma proteins albumin, globulin, and fibrinogen. It resists the filtration of fluid from the capillaries.

B.C.O.P. = 30 *mm Hg.*

B.C.O.P. in other body capillaries is 25 *mm* Hg

(c) **Capsular hydrostatic pressure (C.H.P) :** C.H.P. is the pressure caused by fluid (filtrate) that reaches into Bowman's capsule and resists filtration.

C.H.P. = 20 *mm Hg.*

Effective filtration pressure (E.F.P.)/Net filtration pressure (N.F.P.) : E.F.P. is glomerular blood hydrostatic pressure minus the colloidal osmotic pressure of blood and capsular hydrostatic pressure.

E.F.P. = G.B.H.P. – (B.C.O.P. + C.H.P.)

= 70 *mm Hg* – (30 *mmg Hg* + 20 *mm Hg*)

= 70 – 50

E.F.P. = 20 *mm Hg*

- Net opposing filtration pressure

(N.O.F.P.) = B.C.O.P.+C.H.P.

= 50 *mm Hg.*

Glomerular filtrate : The plasma fluid that filters out from glomerular capillaries into Bowman's capsule of nephrons is called glomerular filtrate. It is a non colloidal part and possess urea, water, glucose, amino acid, vitamins, fatty acid, uric acid, creatine, creatinine, toxins, salts etc.

R.B.Cs, W.B.Cs, platelets and plasma proteins are the colloidal part of the blood and do not filtered out from glomerulus. Glomerular filtrate is isotonic to blood plasma.

Glomerular filtrate or Nephric filtrate

= Blood – (Blood cells + Plasma protein)

or

= Blood – (R.B.Cs + W.B.Cs + platelets + plasma protein)

or

= Plasma – Protein

Glomerular filtration rate (G.F.R.) : G.F.R. is the amount of filtrate formed per minute in all nephrons of the paired kidney. There is a sexual difference. In male the rate is 120 – 125 *ml/min*, in female it is 110 *ml/min*. G.F.R. is affected by volume of circulating blood, neural activity, stretch response to pressure of the wall of the arteriole.

180 litre of filtrate is formed per day, out of it, only 1.5 litre of urine is produced per day which is 0.8% of the total filtrate.

Renal plasma flow : About 1250 *ml* (25% of cardiac output or total blood) blood circulates through kidneys each minute and of this blood, about 670 *ml* is the plasma. The latter is called the renal plasma flow (R.P.F.)

R.P.F. = 670 *ml.*

Filtration fraction : This is the ratio of G.F.R. to R.P.F., and it is called filtration fraction.

$$\text{Filtration fraction} = \frac{G.F.R.}{R.P.F.} = \frac{120}{670} = 0.17$$

(2) **Selective reabsorption :** Discovered by Richard and supporters.

Proximal convoluted tubule : P.C.T. is the pivotal site for reabsorption. Glucose, amino acid and Na^+, K^+ ions are reabsorbed by active transport. Cl^- are reabsorbed by passive transport following the positively charged ions.

Active uptake of ions reduces the concentration of the filtrate and an equivalent amount of water passes into the peritubular capillaries by osmosis. (Here 80% water is reabsorbed by passive transport. It is also known as obligatory water reabsorption). Most of the important buffer bicarbonate (HCO_3^-) is also reabsorbed from the filtrate. P.C.T. absorb nearly 80–90% of filtered bicarbonate. Some urea is reabsorbed by diffusion . The rest remain in the filtrate to be removed in the urine.

Henle's loop : See counter current mechanism.

Distal convoluted tubule : When the level of plasma water falls, the posterior pituitary lobe release the antidiuretic hormone (ADH) which increases the permeablity of the distal convoluted tubule and the collecting duct to water. Water is reabsorbed from the filtrate by osmosis and a reduced amount of concentrated urine is produced (Here 13% water is reabsorbed by facultative reabsorption)

The distal convoluted tubule and the collecting duct actively reabsorbs sodium from the filtrate under influence of the adrenal hormone aldosterone which makes their walls permeable to ions. The reabsorption of Na^+ brings about the uptake of an osmotically equivalent amount of water. But duct of Bellini is relatively impermeable to water. Bicarbonate ions are also reabsorbed in D.C.T.

(3) **Tubular secretion :** It occurs as under –

(i) Creatinine, hippuric acid and foreign substances (pigments, drugs including penicillin) are actively secreted into the filtrate in the PCT from the interstitial fluid. Hydrogen ions and ammonia (NH_3) are also secreted into the PCT.

(ii) Potassium, hydrogen, NH_4^+ and HCO_3^- ions are secreted by active transport, into the filtrate in the DCT.

(iii) Urea enters the filtrate by diffusion in the thin region of the ascending limb of Henle's loop.

Removal of H^+ and NH_4^+ from the blood in the PCT and DCT helps to maintain the *pH* of the blood between 6 to 8. Any variation from this range is dangerous.

Tubular secretion probably plays only a minor role in the function of human kidneys, but in animals, such as marine fish and desert amphibians which lack glomeruli and Bowman's capsules, tubular secretion is the only mode of excretion. When the blood pressure, and consequently the filtration pressure, drop below a certain level, filtration stops and urine is formed by tubular secretion only.

High threshold substances : Such substances are absorbed almost all. Example – Sugar, amino acids, vitamins, HCO_3^- and Na^+ etc.

Low threshold substances : They are absorbed in low concentration. Example – Urea, phosphate, uric acid, H^+, K^+.

Non threshold substances : They are not reabsorbed. Example – Creatinine and hippuric acid.

Diuretic substances : Normally, the amount of urine formed depends on the intake of water, dietary constituents, environmental temperature, mental and physiological states of the person. However, there are some substances which increase the volume of urine to be excreted, these substances are called diuretic substances. Exmaple – Tea, Coffee, alcohol etc.

Mechanism of urine concentration (Counter current mechanism of urine concentration) : Mammals form hypertonic urine. The urine is made hypertonic with the help of counter current multiplier system. This process takes place in the Henle's loop and vasa recta and it involves mainly Na^+ and Cl^-. In P.C.T. urine is isotonic. The descending limb of loop of Henle is permeable to water. Its surrounding tissue fluid is hypertonic. Hence, the water moves out and the Na^+ and Cl^- moves in the descending limb by passive transport. Therefore, the filtrate in the descending limb finally becomes hypertonic.

The ascending limb of the Henle's loop is impermeable to the water. The Na^+ and Cl^- moves out by active transport. Hence the filtrate finally becomes hypotonic. The Na^+ and Cl^- re-enter into the descending limb of the Henle's loop. The collecting duct always passes through the hypertonic tissue fluid. Hence, water comes out osmotically making the filtrate hypertonic. Now in collecting duct glomerular filtrate is known as urine. Term urine first time used in collecting duct.

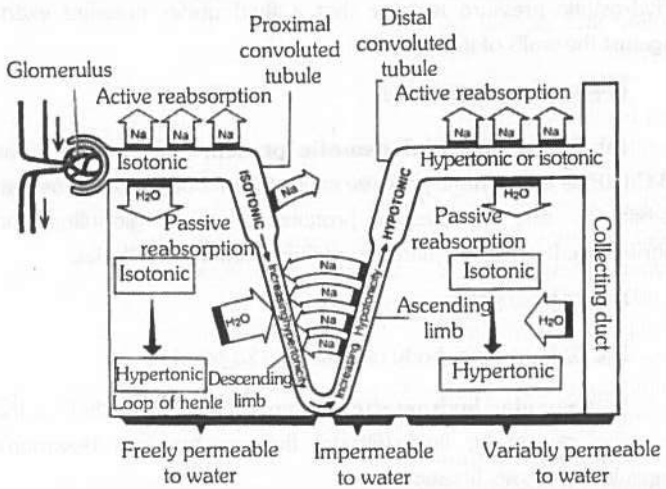


Fig : 5.4-14 Counter current multiplier in Henle's loop

Table : 5.4-4 Summary of events occurring in a nephron

S.No.	Materials transferred in traces	Nephron region	Process involved	Mechanism
1.	Glucose, Amino acids, protein albumin, Vitamins, Hormones, Na^+, K^+, Mg^{2+}, Ca^{+2}, H_2O, HCO_3^-, Urea, Uric Acid, Creatinine, Ketone Bodies.	Bowman's capsule	Glomerular filtration	Ultrafiltration
2.	Glucose, Amino Acids, Hormones, Vitamins, Na^+, K^+, Mg^{2+}, Ca^{+2}	Proximal convoluted tubule	Reabsorption	Active transport
3.	Cl^-	Proximal convoluted tubule	Reabsorption	Passive transport
4.	H_2O	Proximal convoluted tubule	Reabsorption	Osmosis
5.	Urea	Proximal convoluted tubule	Reabsorption	Diffusion
6.	H_2O	Narrow region of descending limb of Henle's loop	Reabsorption	Osmosis
7.	Na^+,K^+,Mg^{+2},Ca^{+2},Cl^-	Narrow region of ascending limb of Henle's loop	Reabsorption	Diffusion
8.	Inorganic ions as above	Wide part of ascending limb of Henle's loop	Reabsorption	Active transport
9.	H_2O	Distal convoluted tubule, collecting tubule, collecting duct	Reabsorption with ADH Help	Osmosis
10.	Na^+	Distal convoluted tubule, collecting tubule, collecting duct	Reabsorption with aldosterone help reabsorption secretion	Active transport
11.	Urea	Last part of collecting duct	Reabsorption with aldosterone help reabsorption secretion	Diffusion
12.	Creatinine, Hippuric Acid, Foreign substances	Proximal convoluted tubule	Reabsorption with aldosterone help reabsorption secretion	Active transport
13.	K^+, H^+	Distal convoluted tubule	Reabsorption with aldosterone help reabsorption secretion	Active transport
14.	NH_3	Distal convoluted tubule	Reabsorption with aldosterone help reabsorption secretion	Diffusion
15.	Urea	Ascending limb of Henle's loop (Thin part)	Reabsorption with aldosterone help reabsorption secretion	Diffusion

Urine

The fluid and dissolved waste substances excreted by the kidneys constitute urine.

Quantity : An adult man normally passes about 1 to 1.8 litres of urine in 24 hours. The volume of urine depends upon (i) the fluid intake, (ii) level of physical activity, (iii) type of food taken and (iv) environmental temperature increase urine output. Less fluid intake and profuse sweating due to heavy physical work and high temperature reduce urine output. Certain substances such as tea, coffee and alcohol, increase urine output. These are said to be diuretic.

Physical properties : Urine is transparent yellowish fluid, but becomes turbid (cloudy) on standing, its colour depends on its concentration. Its colour is due to a pigment urochrome derived from the breakdown of haemoglobin from the worn-out RBCs. Colour of the urine is altered by certain materials taken such as beet, vitamin B complex and some drugs and diseases. It is hypertonic to blood plasma. Its specific gravity ranges between 1.001 to 1.035, being slightly higher than that of water. Its *pH* is 6. It depends on the diet. High protein food and fruits increase acidity whereas vegetables increase alkalinity. Urine has a characteristic unpleasant odour. If allowed to stand, urea is degraded by bacteria to ammonia which imparts a strong smell to urine.

Chemical composition : Urine consists of water and organic and inorganic substances. Water alone forms about 95% of it, other substances form only 5%. The organic substances are mainly nitrogenous organic compounds include urea, uric acid, creatinine and hippuric acid. Of these, urea is the principal component of human urine. The non nitrogenous organic compounds include vitamin C, oxalic acid, phenolic substances include ammonia, and mineral salts such as chlorides, sulphates and phosphates of sodium, potassium, calcium and magnesium. Sodium chloride is the principal mineral salt of the urine. Urine also contains some other substances, such as pigments and drugs, and some epithelial cells, leucocytes, mucin, enzymes, and hormones.

Abnormal materials : Presence of proteins (albumins), bile salts, bile pigments, ketone bodies, blood, pus, microbes and more than a trace of glucose in the urine is pathological condition. Presence of glucose, protein, blood, ketone bodies and pus in the urine is called glucosuria, proteinuria, haematuria, ketonuria and pyuria respectively.

Renal threshold : A negligible amount of glucose is present in the urine. The highest concentration of a substance in the blood upto which it is fully reabsorbed from the glomerular filtrate is called its threshold. If its concentration in the blood exceeds its renal threshold, some of the filtered out substance is not reabsorbed and is excreted in the urine. For example, the renal threshold of glucose is 180 *mg.* per 100 *ml.* of blood. If its blood level exceeds 180 *mg.*, some of the filtered out glucose is not reabsorbed and is passed in urine.

Conduction of urine and Micturition : Urine is produced and drained continuously by the nephrons into the renal pelvis. From here, it is carried down the ureters by peristaltic waves into trigonum vesicae and then into the body of the urinary bladder. The bladder serves to store the urine temporarily and also to pass it out at suitable intervals. The process of passing out urine from the urinary bladder is called urination or micturition, As urine collects, the muscular walls of the bladder distend to accommodate it. Distension of its walls stimulates the sensory nerve endings in the bladder wall and this sets up reflexes, which cause an urge to pass out urine. During the discharge of the urine, the bladder and urethral sphincters relax and the smooth muscles of the bladder wall gradually contract. This slowly drives the urine from the bladder through the urethra to the exterior. Reflux of the urine into the ureters is prevented because the terminal parts of the ureters pass obliquely through the bladder wall and are consequently closed when the bladder wall contracts around them. Relaxation and contraction of the urinary bladder are caused by impulses from the sympathetic and parasympathetic nerve fibres.

Micturition may be voluntarily postponed for some time until the pressure in the bladder rises too high to control. Micturition may also be voluntarily achieved even before sufficient urine has accumulated in the bladder. Normally an urge for micturition starts when the bladder is a little more than halffull of urine.

Table : 5.4-5 Urine constituants in man (in gram)

1.	Total volume	1,200 *ml* – per 24 *h*
2.	Water	1,140 *ml*
3.	Total solids	50 *gm*
4.	Glucose	0
5.	Protein	0
6.	Ketones	0
7.	Urea	30 *gm*
8.	Creatinine	1.6 *gm*
9.	Creatine	0.1 *gm*
10.	Hippuric acid	0.7 *gm*
11.	Urobilinogen	0.4 *mg*
12.	Porphyrins	50 – 300 µg
13.	Uric acid	0.7 *gm*
14.	*NaCl*	15.0 *gm*
15.	*K*	3.3 *gm*
16.	*Ca*	0.3 *gm*
17.	*Mg*	0.1 *gm*
18.	*Fe*	0.1 *gm* 0.005 *gm*
19.	SO_4	2.5 *gm*
20.	PO_4	2.5 *gm*

Table : 5.4-6 Urine constituents in man (in %)

1.	Water	96%
2.	Urea	2%
3.	Uric acid	0.2%
4.	NH_3	0.25%
5.	Creatinine	0.5%
6.	Hippuric acid	0.025%
7.	Salt	1%

Hormonal control of renal function

Hormonal controls of the kidney function by negative feedback circuits can be identified :

(1) **Control by antidiuretic hormone (ADH) :** ADH, produced in the hypothalamus of the brain and released into the blood stream from the pituitary gland, enhances fluid retention by making the kidneys reabsorb more water. The release of ADH is triggered when osmoreceptors in the hypothalamus detect an increase in the osmolarity of the blood above a set point of 300 mosm L^{-1}. In this situation, the osmoreceptor cells also promote thirst. Drinking reduces the osmolarity of the blood, which inhibits the secretion of ADH, thereby completing the feedback circuit.

(2) **Control by Juxtaglomerular apparatus (JGA) : (Low Blood pressure triggers the Reninangiotensin pathway)** JGA operates a multihormonal Renin-Angiotensin-Aldosterone System (RAAS). The JGA responds to a decrease in blood pressure or blood volume in the afferent arteriole of the glomerulus and releases an hormone, renin into the blood stream. In the blood, renin initiates chemical reactions that convert a plasma protein, called angiotensinogen, to a peptide, called angiotensin II, which works as a hormone. Angiotensin II increases blood pressure by causing arterioles to constrict. It also increases blood volume in two ways – firstly, by signaling the proximal convoluted tubules to reabsorb more *NaCl* and water, and secondly, by stimulating the adrenal gland to release aldosterone, a hormone that induces the distal convoluted tubule to reabsorb more Na^+ and water. This leads to an increase in blood volume and pressure, completing the feedback circuit by supporting the release of renin.

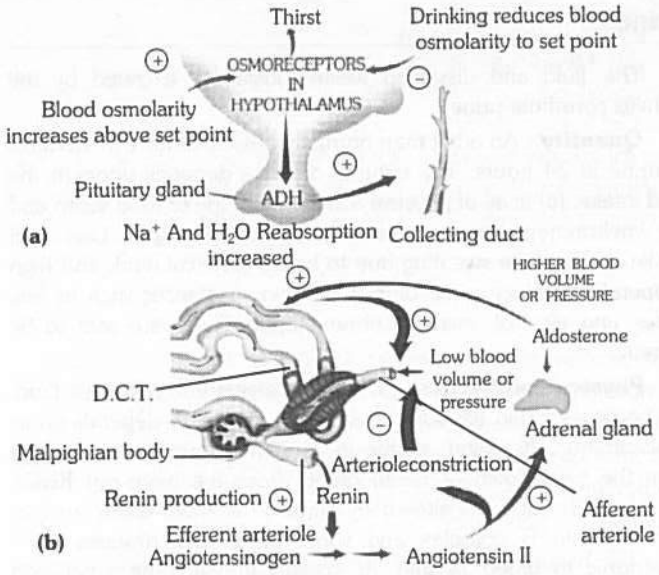


Fig : 5.4-15 Regulation of renal function by feedback circuits (a) Control by ADH (b) Control by RAAS

(3) **Parathormone :** The hormone increases blood Ca^{++} (Hypercalcaemia) and decreases PO_4 accordingly, it increases absorption of Ca^+, increases excretion of PO_4.

(4) **Thyrocalcitonin :** It increases excretion of Ca^{++} in the kidney.

(5) **Prostaglandin :** The renal pyramids produce fatty acids of prostaglandins (P.G.) which participates in blood pressure regulation.

(6) **Erythropoeitin :** It is secreted by juxtaglomerular apparatus and plays an important role in erythropoeisis (blood production).

Table : 5.4-7 Differences between Rennin and Renin

S.No.	Rennin	Renin
1.	It is secreted by peptic (zymogen) cells of gastric glands into the stomach.	It is secreted by specialised cells in the afferent arterioles of the kidney cortex.
2.	Its secretion is stimulated by food.	Its secretion is stimulated by a reduction of Na^+ level in tissue fluid
3.	It is secreted as an inactive form prorennin which is activated to rennin by *HCl*.	It is secreted as renin.
4.	It is a proteolytic enzyme.	It is a hormone that acts as an enzyme
5.	It helps in the digestion of milk protein casein.	It converts the protein angiotensinogen into angiotensin.

Homeostatic regulatory functions of kidneys

By continuously eliminating metabolic wastes and other impurities, and even the surplus quantity of useful materials from blood plasma in the form of urine, kidneys play a vital role in homeostasis. Kidneys also operate certain other homeostatic regulatory mechanisms. Proper maintenance of the internal environment is known as homeostasis. All regulatory functions of kidneys can be enumerated as follows –

(1) **Osmoregulation :** Being the universal solvent, water is the actual vehicle in ECF to transport materials between various parts of body. Water volume in ECF tends to vary considerably due to several reason, such as drinking, perspiration, diarrhoea, vomiting, etc. As described in previous pages, the kidneys maintain the water balance in ECF by diluting or concentrating urine.

(2) **Regulation of osmotic pressure :** Osmolality of cytoplasm is mainly due to proteins and potassium and phosphate ions, whereas that of the ECF is mainly due to sodium, chloride and bicarbonate ions. Inspite of marked difference in chemical composition, the two fluids – intracellular (cytoplasm) and extracellular (interstitium) – must be isotonic, because if ECF becomes hypotonic, cells will absorb water, swell retaining apropriate number, mainly of sodium and chloride ions, kidneys maintain the normal osmolality of ECF.

(3) **Regulation of *pH* :** Concentration of hydrogen ions ($NaH_2\ PO_4$) in ECF is to be regulated at a constant value usually expressed as *pH* (minus log of H^+). The normal *pH* of ECF is about 7.4. A low *pH*, i.e. a high H^+ concentration causes acidosis, while a high *pH*, i.e. a low H^+ concentration causes alkalosis. Both of these conditions severely affect cellular metabolism. Several special control systems, therefore, operate in the body to prevent acidosis and alkalosis. These system are called acid-base buffer system. Kidneys play a key role in maintenance and operation of these systems. Further, the kidneys regulate hydrogen ion concentration in ECF by excreting acidic or basic urine.

(4) **Regulation of electrolyte concentrations in ECF :** The kidneys regulate, not only the total concentrations of water and electrolytes in ECF, but also the concentrations of individual electrolytes separately. This regulation is complex and is accomplished by tubular reabsorption and secretion under the control of hypothalamic and adrenal hormones.

(5) **Regulation of RBC-count in blood :** In oxygen deficiency (hypoxia), kidneys secrete an enzyme into the blood. This enzyme reacts with plasma globulin to form erythropoietin. The latter substance stimulates bone marrow to produce more RBCs for enhancing O_2-intake in lungs.

(6) **Regulation of renal blood flow :** See (R.A.A.S.).

Disorders of kidneys

(1) **Pyelonephritis :** It is an inflammation of renal pelvis, calyces and interstitial tissue (*G.pyelos* = pelvis, tub; *nephros* = kidney; *itis* = inflammation). It is due to local bacterial infection. Bacteria reach here *via* urethra and ureter. Inflammation affects the countercurrent mechanism, and the victim fails to concentrate urine. Symptoms of the disease include pain in the back, and frequent and painful urination.

(2) **Glomerulonephritis :** It is the inflammation of glomeruli. It is caused by injury to the kidney, bacterial toxins, drug reaction, *etc.* Proteins and R.B.Cs pass into the filtrate.

(3) **Cystitis :** It is the inflammation of urinary bladder (*G.kystis* = bladder, *–itis* = inflammation). It is caused by bacterial infection. Patient has frequent, painful urination, often with burning sensation.

(4) **Uremia :** Uremia is the presence of an excessive amount of urea in the blood. It results from the decreased excretion of urea in the kidney tubules due to bacterial infection (nephritis) or some mechanical obstruction. Urea poisons the cells at high concentration.

(5) **Kidney stone (Renal calculus) :** It is formed by precipitation of uric acid or oxalate. It blocks the kidney tubule. It causes severe pain (renal colic) in the back, spreading down to thighs. The stone may pass into the ureter or urinary bladder and may grow, and cause severe pain of blockage. When in bladder, the patient experiences frequent and painful urination and may pass blood in the urine. Surgery may be needed to remove stone and relieve pain.

(6) **Kidney (Renal) failure (RF) :** Partial or total inability of kidneys to carry on excretory and salt-water regulatory functions is called renal or kidney failure. Kidney failure leads to (*i*) uremia, i.e., an excess of urea and other nitrogenous wastes in the blood (*G.ouron* = urine, *haima*-blood); (*ii*) Salt-water imbalance; and (*iii*) stoppage of erythropoietin secretion.

Causes : Many factors can cause kidney failure. Among these are tubular injury, infection, bacterial toxins, glomerulonephritis (inflammation of glomeruli) arterial or venous obstruction, fluid and electrolyte depletion, intrarenal precipitation of calcium and urates, drug reaction, haemorrhage etc.

Artificial kidney

Artificial kidney called haemodialyser is a machine that is used to filter the blood of a person whose kidneys are damaged. The process is called haemodialysis. It may be defined as the separation of small molecules (crystalloids) from large molecules (colloids) in a solution by interposing a semipermeable membrane between the solution and water (dialyzing solution). It works on the principle of dialysis, i.e. diffusion of small solute molecules through a semipermeable membrane (G. *dia* = = through, *lyo* = separate). Haemodialyser is a cellophane tube suspended in a salt-water solution of the same composition as the normal blood plasma, except that no urea is present. Blood of the patient is pumped from one of the arteries into the cellophane tube after cooling it to 0°C and mixing with an anticoagulant (heparin). Pores of the cellophane tube allow urea, uric acid, creatinine, excess salts and excess H^+ ions to diffuse from the blood into the surrounding solution. The blood, thus purified, is warmed to body temperature, checked to ensure that it is isotonic to the patient's blood, and mixed with an antiheparin to restore its normal clotting power. It is then pumped into a vein of the patient. Plasma proteins remain in the blood and the pores of cellophane are too small to permit the passage of their large molecules. The use of artificial kidney involves a good deal of discomfort and a risk of the formation of blood clots. It may cause fever, anaphylaxis, cardiovascular problems and haemorrhage. Kidney transplant is an alternative treatment.

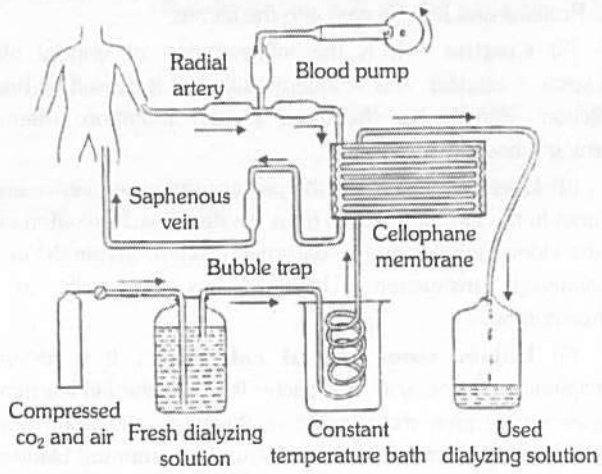


Fig : 5.4-16 Flow of blood through an artificial kidney for haemodialysis

Kidney (Renal) Transplantation

Meaning : Grafting a kidney from a compatible donor to restore kidney functions in a recipient suffering from kidney failure is called renal transplantation.

History : First kidney transplant was performed between identical twins in 1954 by Dr. Charles Hufnagel, a Washington surgeon, India's first kidney transplant was done on December 1, 1971 at Christian Medical College, Vellore, Tamilnadu. The recipient was a 35 years old person Shaninughan.

Eligibility : All patients with terminal renal failure are considered eligible for kidney transplantation, except those at risk from another life-threatening disease.

Donors : A living donor can be used in a kidney transplant. It may be in identical twin, a sibling, or a close relative. If the living donors are not available, a cadaveric donor may be used (cadaver is a dead body). Over half of the kidney transplants are from cadavers.

Success rate : A kidney transplant from an identical twin, called isogeneic graft or isograft, is always successful. A renal transplant from a sibling or a close relative or a cadaver, termed allogeneic graft or homograft, is usually successful with the use of an immunosuppressant that prevents graft rejection by body's immune response. Many renal transplant recipients are known to have retained functional grafts for over 20 years. Earlier, renal transplantation was limited to patients under 55 years. Now, however, with better techniques, kidney grafting has been done in selected patients in the 7th decade of life.

Pretransplant preparation : It includes haemodialysis to ensure a relatively normal metabolic state, and provision of functional, infection-free lower urinary tract.

Donor selection and kidney preservation : A kidney donor should be free of hypertension, diabetes, and malignancy. A living donor is also carefully evaluated for emotional stability, normal bilateral renal function, freedom from other systematic disease, and histocompatibility. Cadaveric kidney is obtained from previously healthy person who sustained brain death but maintained stable cardiovascular and renal function. Following brain death, kidneys are removed as early as possible, flushed with special cooling solutions, such as mannitol and stored in iced solution. Preserved kidneys usually function well if transplanted within 48 hours.

Recipient-Donor Matching : Recipient and donor are tested for 3 factors :

(1) **Blood groups :** Recipient's blood group should be compatible with donor's blood group.

(2) **Human leucocyte antigen (HLA) :** It is a genetic marker located on the surface of leucocytes. A person inherits a set of 3 antigens from the mother and three from the father. A higher number of matching antigens increases the chances that the kidney graft will last for a long time.

(3) **Antibodies :** Small samples of recipient's and donor's blood are mixed in a tube. If no reaction occurs, the patient will be able to accept the kidney.

Transplant procedure : Transplantation is done under general anaesthesia. Operation takes 3 or 4 hours. Cut is given in the lower abdomen. Donor's kidney is transplanted retroperitonealy in the iliac fossa. Artery and vein of new kidney are connected to the iliac artery and vein of the recipient. Ureter of the new kidney is connected to the urinary bladder of the recipient. Often the new kidney starts producing urine as soon as blood flows through it, but sometimes it may take a few weeks before it starts working. A week's stay in the hospital is necessary to recover from surgery, and longer if there are complications.

The new kidney takes over the work of two failed kidneys. Unless they are causing infection or high blood pressure, the old kidneys are left in place.

Immunosuppression : Immunosuppression means to depress the immune response of the recipient to graft rejection. Prophylactic immunosuppressive therapy is started just before or at the time of renal transplantation. An ideal immunosuppressant suppress immunity against foreign tissue but maintains immunity against infection and cancer. The drug, named cyclosporin, is such an immunosuppressant. Use of antiserum to human lymphocytes is equally useful. It destroys T-cell mediated immune responses, but spares humoral antibody responses.

Accessory excretory organs

(1) **Skin :** Many aquatic animals, such as Hydra and starfish, excrete ammonia into the surrounding water by diffusion through the body wall. In land animals, the skin is often not permeable to water. This is an adaptation to prevent loss of body's water. Mammalian skin retains a minor excretory role by way of its sudoriferous, or sweat glands and sebaceous, or oil glands.

(i) **Sweat gland :** Sweat glands pass out sweat. The latter consists of water containing some inorganic salts (chiefly sodium chloride) and traces of urea and lactic acid. It also contains very small amounts of amino acids and glucose.

(ii) **Sebaceous glands :** Oil glands pass out sebum that contains some lipids such as waxes, sterols, other hydrocarbons and fatty acids.

(2) **Lungs :** Carbon dioxide and water are the waste products formed in respiration. Lungs remove the CO_2 and some water as vapour in the expired air. Lungs have access to abundant oxygen and oxidise foreign substances, thus causing detoxification and also regulate temperature.

(3) **Liver :** Liver changes the decomposed haemoglobin of the worn-out red blood corpuscles into bile pigments, namely, bilirubin and biliverdin. These pigments pass into the alimentary canal with the bile for elimination in the faeces. The liver also excretes cholesterol, steroid hormones, certain vitamins and drugs *via* bile.

(4) **Large intestine :** Epithelial cells of the colon transfer some inorganic ions, such as calcium, magnesium and iron, from the blood into the cavity of the colon for removal with the faeces.

(5) **Saliva :** Heavy metals and drugs are excreted in the saliva.

(6) **Gills :** Gills remove CO_2 in aquatic animals. They also excrete salt in many bony fish.

Osmoregulation

The regulation of solute movement and hence water movement which follows solutes by osmosis, is known as osmoregulation. Osmosis may be defined as a type of diffusion where the movement of water occurs selectively across a semipermeable membrane. It occurs whenever two solutions, separated by semipermeable membrane (the membrane that allows water molecules to pass but not the solutes) differ in total solute concentrations, or osmolarity. The total solute concentration is expressed as molarity or moles of solute per litre of solution. The unit of measurement for osmolarity is milliosmole per litre (mosm L^{-1}). If two solutions have the same osmolarity, they are said to be isotonic. When two solutions differ in osmolarity, the solution with higher concentration of solute is called hypertonic, while the more dilute solution is called hypotonic. If a semipermeable membrane separates such solutions, the flow of water (osmosis) takes place from a hypotonic solution to a hypertonic one.

Osmoconformers are the animals that do not actively control the osmotic condition of their body fluids. They rather change the osmolarity of body fluids according to the osmolarity of the ambient medium. All marine invertebrates and some freshwater invertebrates are strictly osmoconformer. Osmoconformers show an excellent ability to tolerate a wide range of cellular osmotic environments.

Osmoregulators, on the other hand, are the animals that maintain internal osmolarity, different from the surrounding medium in which they inhabit. Many aquatic invertebrates are strict or limited osmoregulators. Most vertebrates are strict osmoregulators, i.e. they maintain the composition of the body fluids within a narrow osmotic range. The notable exception, however, are the hagfish (Myxine sp., a marine cyclostome fish) and elasmobranch fish (sharks and rays).

Osmoregulators must either eliminate excess water if they are in hypotonic medium or continuously take in water to compensate for water loss if they are in a hypertonic situation. Therefore, osmoregulators have to spent energy to move water in or out and maintain osmotic gradients by manipulating solute concentrations in their body fluids.

Tips & Tricks

- Anuria – Failure of kidney to form urine.
- Oligouria – is less urine output.
- Cystitis – Inflammation of urinary bladder.
- Filtration fraction – Ratio between GFR (glomerular filtration rate) and RPF (renal plasma flow).
- Gout – Painful great toe (arthiritis) due to deposition of uric acid.
- Haematuria – Presence of blood cells in urine.
- Oedema – Increased volume of interstitial fluid.
- Renal stone – Stone formation in the nephrons of kidney due to accumulation of mainly calcium oxalates some phosphates and uric acid.
- Polyuria – Increased urine volume as in Diabetes insipidus and mellitus.
- Allantoin and allantoic acid are nitrogenous excretory products formed during embryonic development of amniotes with shelled eggs. Allantoin is also called embryonic waste by allantoic acid is stored in allantois foetal membrane.
- Bright disease – Characterised by nephritis caused by streptococcal infection.
- Dysuria – Painful urination.
- Certain animals are both ammonotelic and ureotelic e.g. Ascaris, earthworm, lung fish (African toad), etc.
- Chordate with flame cells is Branchiostoma (also called Amphioxus).
- Nocturia – Increased volume of urine at night.

✍ Abnormal constituent of urine – (i.e. Not present in normal condition).

1. Protein – If protein is present in urine it may be due to infection or injury in kidney. (Mainly albumin is filtered)

2. Blood – Due to infection and injury of kidney blood may appear in urine.

3. Sugar – In diabetes mellitus sugar appear in urine.

4. Bile or bile pigment – In jaundice bile pigment appear in urine.

5. Ketone bodies – In starvation and diabetes. Ketone bodies appear in urine.

✍ Diabetes mellitus – Sugar appear in urine due to hyposecretion of insulin.

✍ Diabetes insipidus – Tasteless more urine passing due to hyposecretion of A.D.H.

✍ Diuretics – Diuretic are drugs that increase the rate of urine flow. (Naturally occurring diuretic include caffine in coffee, tea, and cola soda, which inhibit Na^+ reabsorption and alcohol in beer, wine and mixed drinks inhibits secretion of ADH).

✍ The most frequent protozoan seen in urine is *Trichomonas vaginalis*, a cause of vaginitis in females and urethritis in males.

✍ Both kidney and ureter are retroperitoneal organ.

✍ Urine gives a pungent smell if left for sometime. This smell is of ammonia formed by conversion of urea into ammonia by bacterial action.

✍ A starving person will excrete more urea because during starvation proteins are broken down for energy production.

✍ Cystolith – Stone of the bladder.

✍ Euryhaline are organisms that can tolerate a wide range of salinity, stenohaline are organisms that can live within a narrow range of salinity.

✍ Alkaptonuria – Condition characterised by excretion of large amount of homogentistic acid in urine as a result of incomplete metabolism of amino acids. This causes blackening of urine on standing.

Ordinary Thinking

Objective Questions

Excretory waste products

1. Kidney crystals are solid clusters of **[CBSE PMT 1990]**
(a) Calcium nitrate and uric acid
(b) Phosphate and uric acid
(c) Calcium carbonate and uric acid
(d) Calcium metabisulphite and uric acid

2. Waste products of adenine and guanine (Purines) metabolism are excreted by man as **[CBSE PMT 1991; J & K CET 2002]**
(a) Ammonia (b) Urea
(c) Uric acid (d) Allantois

3. Uricotelism is a method of conserving **[CPMT 1992]**
(a) Na^+ and K^+ (b) Space
(c) Water (d) Energy

4. In man, the urea is mainly produced in **[CPMT 1992, 93, 2001; Manipal 1995; MP PMT 1998; RPMT 1999; BVP 2002; Kerala CET 2003; Odisha JEE 2005]**
(a) Liver (b) Kidneys
(c) Gall bladder (d) Spleen

5. A man takes large amount of protein. He is likely to excrete more amount of **[CPMT 2004]**
(a) Water (b) Glucose
(c) Urea and uric acid (d) Salts

6. Which one of the following blood vessels in mammals would normally carry the largest amount of urea **[MP PMT 1995, 97; BHU 2008; NEET (Phase-I) 2016]**
(a) Hepatic portal vein (b) Hepatic vein
(c) Renal artery (d) Hepatic artery

7. Which one of the following is likely to accumulate in a dangerous proportion in the blood of a person whose kidney is not working properly
Or
The chief nitrogenous waste in urine of rabbit or terrestrial mammals is **[CPMT 1992, 93]**
(a) Lysine (b) Ammonia
(c) Sodium chloride (d) Urea

8. The glomerular filtrate consists of **[JIPMER 1993]**
(a) Urea, sodium chloride, fibrinogen and water
(b) Glucose, amino acids, urea, oxytocin and calcitonin
(c) Both (a) and (b)
(d) Urea, glucose, salts and water

9. The body cells in cockroach discharge their nitrogenous waste in the haemolymph mainly in the form of **[AIPMT 2015]**
(a) Potassium urate (b) Urea
(c) Calcium carbonate (d) Ammonia

10. The characteristic that is shared by urea, uric acid and ammonia is/are
(A) They are nitrogenous wastes
(B) They all need very large amount of water for excretion
(C) They are all equally toxic
(D) They are produced in the kidneys **[NCERT; KCET 2009]**
(a) A, C and D (b) A and D
(c) A, C and B (d) A only

11. Which one of the following characteristics is common both in humans and adult frogs **[NCERT; CBSE PMT (Mains) 2012]**
(a) Four-chambered heart
(b) Internal fertilisation
(c) Nucleated RBCs
(d) Ureotelic mode of excretion

12. Uric acid is the chief nitrogenous component of the excretory products of **[CPMT 2009; CBSE PMT 2009]**
(a) Man (b) Earthworm
(c) Cockroach (d) Frog

13. Which of the following nitrogenous substance is highly toxic **[NCERT; CPMT 1995; CBSE PMT 2001]**
Or
If liver from body is removed then which component of blood increases **[HPMT 2005]**
(a) Urea (b) Uric acid
(c) Amino acid (d) Ammonia

14. Almost all the aquatic animals excrete ammonia as the nitrogenous waste product. Which of the following statement is not in agreement with this situation **[KCET 2006]**

(a) Ammonia is easily soluble in water

(b) Ammonia is released from the body in a gaseous state

(c) Ammonia is highly toxic and needs to be eliminated as and when formed

(d) Ammonia gets converted into a less toxic form called urea

15. The urine is **[NCERT; EAMCET 2009]**

(a) Hypotonic to blood and isotonic in medullary fluid

(b) Hypertonic to blood and isotonic to medullary fluid

(c) Isotonic to blood and hypotonic to medullary fluid

(d) Isotonic to blood and hypertonic to medullary fluid

16. Aquatic reptiles are **[CBSE PMT 1999; BHU 2000; CPMT 2003]**

(a) Ammonotelic (b) Ureotelic over land

(c) Ureotelic (d) Ureotelic in water

17. Which of the following is the nitrogenous waste **[CPMT 1999; JIPMER 2001]**

(a) Creatinine (b) Creatine

(c) Guanine (d) All the above

18. Choose the wrong statement **[Kerala PMT 2012]**

(a) In ureotelic organisms, ammonia is not a product of metabolism

(b) In mammals some amount of urea may be retained in the kidney matrix of ureotelics to maintain osmolarity

(c) In fishes, kidneys do not play any significant role in the removal of ammonium ions

(d) Urea and uric acid are less toxic than ammonia

(e) Ammonia is readily soluble and can diffuse easily

19. Which of the following are uricotelic animals **[NCERT; AIIMS 2002; CBSE PMT 2004; CBSE PMT (Pre.) 2011]**

(a) Rohu and frog (b) Lizard and crow

(c) Camel and frog (d) Earthworm and eagle

20. Marine teleosts, undergoing putrefaction, emit sharp characteristic foul odour, which is due to the production of **[MP PMT 2002]**

(a) Trimethylamine (b) Hydrogen sulphide

(c) Ammonia (d) Lactic acid

21. Which of the following is a metabolic waste of protein metabolism **[NCERT; MP PMT 2002; BHU 2008]**

(a) NH_3, urea and CO_2

(b) Urea, Oxygen and N_2

(c) Urea, ammonia and alanine

(d) Urea, ammonia and creatinine

22. Excretion of nitrogenous waste products in semisolid form occur in **[NCERT; Kerala CET 2003]**

(a) Ureotelic animals (b) Ammonotelic animals

(c) Uricotelic animals (d) Amniotes

23. Which one is not correct **[BHU 2003]**

(a) Humans – Uriotelic (b) Birds – Uricotelic

(c) Lizards – Uricotelic (d) Whale – Ammonotelics

24. Man is **[Wardha 2005; CPMT 2010]**

(a) Ureotelic (b) Uricotelic

(c) Ammonotelic (d) Both (b) and (c)

25. Which one of following statements is false **[Kerala PMT 2007]**

(a) Presence of albumin in urine is albuminuria

(b) Presence of glucose in urine is glycosuria

(c) Presence of ketose sugar in urine is ketonuria

(d) Presence of excess urea in blood is uremia

(e) Presence of haemoglobin in urine is haemoglobinuria

26. Animal which excrete urea produced during metabolism of amino acids is **[AFMC 2004]**

(a) Ureotelism (b) Uricotelism

(c) Ammonotelism (d) Aminotelism

27. Which one of the following options gives the correct categorisation of six animals according to the type of nitrogenous wastes (A,B,C), they give out **[NCERT; HP PMT 2005; CBSE PMT (Mains) 2012]**

	A-AMMONOTELIC	B-UREOTELIC	C-URICOTELIC
(a)	Pigeon, Humans	Aquatic Amphibia, Lizards	Cockroach, Frog
(b)	Frog, Lizards	Aquatic Amphibia, Humans	Cockroach, Pigeon
(c)	Aquatic Amphibia	Frog, Humans	Pigeon, Lizards, Cockroach
(d)	Aquatic Amphibia	Cockroach, Humans	Frog, Pigeon, Lizards

28. The most abundant, harmful and universal waste product of metabolism is **[CPMT 2004]**

(a) CO_2 (b) Uric acid

(c) H_2O (d) None of these

29. The main nitrogenous waste of *Hydra* is **[CPMT 2004]**

(a) Ammonia only (b) Urea only

(c) Uric acid only (d) Both (a) and (c)

30. A person is undergoing prolonged fasting. His urine will be found to contain abnormal quantities of **[CBSE PMT 2005]**

(a) Fats (b) Aminoacids

(c) Glucose (d) Ketones

31. Urea is directly produced in mammals from **[CPMT 2005]**

(a) Ammonia released by oxidative deamination

(b) Oxidative deamination of purines

(c) Breakdown of ornithine

(d) Breakdown of arginine

32. Nitrogenous waste products are eliminated mainly as **[KCET 2007]**

(a) Urea in tadpole and uric acid in adult frog

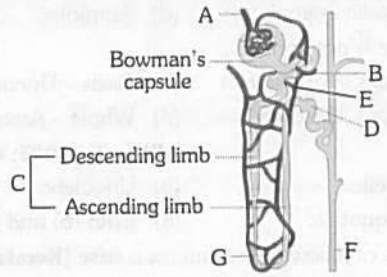
(b) Urea in adult frog and ammonia in tadpole

(c) Urea in tadpole as well as in adult frog

(d) Urea in tadpole and ammonia in adult frog

Excretory organs of different organism

1. See the following diagram and identify A, B, C, D, E, F and G **[NCERT]**



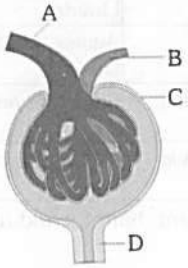
(a) A - Afferent arteriole, B - Henle' s loop, C - Collecting duct, D - PCT, E - DCT, F - Peritubular capillaries, G- Vasa recta

(b) A - Afferent arteriole, B - Peritubular capillaries, C - Henle' s loop, D - DCT, E - PCT, F - Collecting duct, G- Vasa recta

(c) A - Efferent arteriole, B - PCT, C - Henle' s loop, D - DCT, E - Peritubular capillaries, F - Collecting duct, G- Vasa recta

(d) A - Afferent arteriole, B - Proximal convoluted tubule, C - Henle' s loop, D - Distal convoluted tubule, E - Peritubular capillaries, F - Collecting duct, G- Vasa recta

2. The given diagram represent the Malpighian body. Identify A to D **[NCERT]**



(a) A - Afferent arteriole, B - Efferent arteriole, C - Bowman' s capsule, D - DCT

(b) A - Afferent arteriole, B - Efferent arteriole, C - Bowman' s capsule, D - Proximal convoluted tubule

(c) A - Afferent arteriole, B - Efferent arteriole, C - renal corpuscle, D - Proximal convoluted tubule

(d) A - Efferent arteriole, B - Afferent arteriole, C - Bowman's capsule, D - Proximal convoluted tubule

3. Which of the following does not have an excretory system **[Kerala PMT 2011]**

(a) *Myxine* (b) *Carcharodon*
(c) *Balanoglossus* (d) *Asterias*
(e) *Catla*

4. One of the following does the same work as is done by nephridia in earthworm **[CBSE PMT 1996]**

(a) Flame cells in liverfluke (b) Myotomes in fish
(c) Statocysts in prawn (d) Parotid gland in toad

5. Which one of following correctly explains the function of a specific part of a human nephron **[NCERT; CBSE PMT (Pre.) 2011]**

(a) Afferent arteriole : Carries the blood away from the glomerulus toward renal vein

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

(c) Henle's loop : Most reabsorption of the major substance from the glomerular filtrate

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

6. Which of the following is not an excretory organ of vertebrates **[Odisha JEE 2010]**

(a) Lungs (b) Skin
(c) Liver (d) Hepatopancreas

7. The hormone secreted by kidney is **[NCERT; MP PMT 2001]**

(a) Gastrin (b) Secretin
(c) Erythropoietin (d) Aldosterone

8. Select the option which shows correct matching of animal with excretory organs and excretory product **[NEET (Karnataka) 2013]**

	Animal	Excretory organs	Excretory product
(a)	*Labeo* (Rohu)	Nephridial tubes	Ammonia
(b)	Salamander	Kidney	Urea
(c)	Peacock	Kidney	Urea
(d)	Housefly	Renal tubules	Uric acid

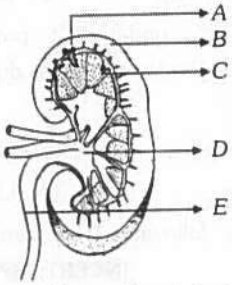
9. Forest of nephridia are present in **[RPMT 2005]**

(a) Pharyngeal region (b) Clitellar region
(c) Anal region (d) None of these

10. Proboscis gland in *Balanoglossus* is associated with **[Kerala PMT 2011]**

(a) Digestion (b) Respiration
(c) Circulation (d) Excretion
(e) Reproduction

11. Refer the following diagram and identify the parts of a kidney indicated **[Kerala PMT 2006]**



(a) A=cortex, B=nephron, C=pelvis, D=medulla, E=ureter
(b) A=cortex, B=medulla, C=nephron, D=pelvis, E=ureter
(c) A=nephron, B=cortex, C=medulla, D=ureter, E=pelvis
(d) A=nephron, B=cortex, C=medulla, D=pelvis, E=ureter
(e) A=nephron, B=ureter, C=pelvis, D=medulla, E=cortex

12. Which one of the following is correct with reference to haemodialysis **[Kerala PMT 2009]**
(a) Absorbs and resends excess of ions
(b) The dialysis unit has a coiled cellophane tube
(c) Blood is pumped back through a suitable artery after haemodialysis
(d) Anti-heparin is added prior to haemodialysis
(e) Nitrogenous wastes are removed by active transport

13. The nephrostomes, in the kidneys, are functional in **[AFMC 1999]**
(a) Rabbit (b) Adult frog
(c) Tadpole (d) Cockroach

14. Two examples in which the nitrogenous wastes are excreted from body in the form of uric acid are **[NCERT; Pb. PMT 1999; CPMT 2000; AFMC 2004; Kerala PMT 2009]**
(a) Birds and lizards
(b) Mammals and mollusc
(c) Insects and bony fishes
(d) Frogs and cartilaginous fishes

15. Intestinal excretory organs of *Pheretima* has a function of **[CBSE PMT 2000; BHU 2000]**
(a) Locomotion
(b) Respiration
(c) Water balance
(d) Excretion of nitrogenous waste

16. The region of the nephron found in the renal medulla is **[Kerala PMT 2007]**
(a) Malpighian corpuscle
(b) Proximal convoluted tubule
(c) Distal convoluted tubule
(d) Henle's loop
(e) Glomerulus

17. Urinary bladder is absent in **[MP PMT 2000; PET (Pharmacy) 2013]**
(a) Lizards (b) Snakes
(c) Crocodiles (d) All the above

18. Which one of the following is associated with osmoregulation in amoeba **[RPMT 2000]**
(a) Endoplasm (b) Mitochondria
(c) Contractile vacuole (d) Plasma membrane

19. Excretory system of *Ascaris lumbricoides* is made up of **[RPMT 2000]**
(a) 4 cells (b) Many cells
(c) One cell (d) Two cells

20. Which one is the excretory organ in the following **[Kerala CET 2003; MP PMT 2013]**
(a) Archaeocyte (b) Choanocyte
(c) Pinacocyte (d) Solenocyte

21. Haemodialysis helps in the patient having **[NCERT; BHU 2003]**
(a) Uremia (b) Anaemia
(c) Diabetes (d) Goitre

22. Which pollutant accumulates in liver and kidney **[RPMT 2000]**
(a) Copper (b) Mercury
(c) Lead (d) Cadmium

23. Correct order of excretory organs in Cockroach, Earthworm and Rabbit respectively **[AFMC 2000; RPMT 2001; BVP 2001; AIIMS 2002; Bihar CECE 2006; Kerala PMT 2007]**
(a) Skin, malpighi tubules, kidney
(b) Malpighi tubules, nephridia, kidney
(c) Nephridia, malpighi tubule, kidney
(d) Nephridia, kidney, green gland

24. Malpighian tubules remove excretory products from **[CPMT 1998; AIIMS 2000]**
(a) Haemolymph (b) Alimentary canal
(c) Both (a) and (b) (d) None of these

25. "Columns of Bertini" in the kidney of mammals are formed as the extension of **[CBSE PMT 1991]**
(a) Medulla into cortex (b) Cortex into medulla
(c) Medulla into pelvis (d) Pelvis into ureter

26. Each human kidney has nearly **[NCERT; CBSE PMT 1992; CPMT 1992; MP PMT 1996]**
(a) 10,000 nephrons (b) 50,000 nephrons
(c) 1,00,000 nephrons (d) 1 million nephrons

27. The liquid which is collected in the cavity of Bowman's capsule is **[MP PMT 2003, 04; WB JEE 2008]**
(a) Concentrated urine
(b) Blood plasma minus blood proteins
(c) Glycogen and water
(d) Sulphates and water

28. Bowman's capsule and glomerulus together constitute **[NCERT]**
(a) Nothing (b) A nephron
(c) Malpighian corpuscle (d) Nephric corpuscle

29. The proximal convoluted tubule has a brush border which is due to **[CBSE PMT 1990]**
(a) Microvilli (b) Minute hairs
(c) Endothelium (d) Folded tubes

30. All Bowman's capsules of the kidney are found in **[AIIMS 1998; CPMT 1999; JIPMER 2001; Odisha JEE 2011]**
(a) Cortex (b) Medulla
(c) Pelvis (d) None of these

31. The glands which help in absorbing odoriferous substances to stimulate olfactory nerve are **[Kerala PMT 2009]**
(a) Cerumenous glands (b) Meibomain glands
(c) Bowman's glands (d) Cowper's glands
(e) Bidder's glands

32. Loop of Henle is concerned with **[Odisha JEE 2005]**
(a) Excretory system (b) Reproductive system
(c) Nervous system (d) Muscular system

33. Which is common to kidney and skeleton in mammals **[MP PMT 2009]**
(a) Cortex (b) Medulla
(c) Pelvis (d) Radius

34. If excess water passes out from the tissue without being restored by the kidneys, the cells would **[CBSE PMT 1994]**
(a) Not be affected at all
(b) Shrivel and die
(c) Burst open and die
(d) Take water from the plasma

35. The size of filtration slits of glomerulus **[WB JEE 2009]**
(a) 10 nm (b) 15 nm
(c) 20 nm (d) 25 nm

36. Which type of kidneys are found in amphibian (frog) **[BCECE 2001; RPMT 2002]**
(a) Holonephric (b) Mesonephric
(c) Pronephric (d) Metanephric

37. Match the excretory organs listed under column I with the animals given under column II. Choose the answer which gives the correct combination of alphabets of the two columns

Column I (Excretory organs)		Column II (Animals)	
A.	Nephridia	p.	Hydra
B.	Malpighian tubules	q.	Leech
C.	Protonephridia	r.	Shark
D.	Kidneys	s.	Round worms
		t.	Cockroach

[KCET 2004]
(a) A = q; B = t; C = s; D = r
(b) A = s; B = q; C = p; D = t
(c) A = t; B = q; C = s; D = r
(d) A = q; B = s; C = t; D = p

38. The principal nitrogenous excretory compound in humans is synthesised **[CBSE PMT (Pre.) 2010]**
(a) In the liver, but eliminated mostly through kidneys
(b) In kidneys but eliminated mostly through liver
(c) In kidneys as well as eliminated by kidneys
(d) In liver and also eliminated by the same through bile

39. What is the characteristic of metanephric kidney **[MP PMT 2000]**
(a) Hypotonic urine production
(b) Excess secretion of uric acid
(c) Loop of Henle
(d) Hormone production

40. Integumentary nephridia are also called **[DPMT 2004]**
(a) Enteronephric
(b) Exonephric
(c) Sometimes enteronephic and sometimes exonephric
(d) Both (a) and (b)

41. In the urinogenital organs of rabbit which one of following part is present in male but not in female **[CPMT 2005]**
(a) Urethra (b) Fallopian tube
(c) Vagina (d) Vas deferens

42. Loop of Henle is meant for absorption of **[MP PMT 1996, 2002, 12; AFMC 1999; BHU 2000]**

Or

What is removed from the filtrate at loop of Henle **[Odisha JEE 2009, 11]**
(a) Potassium (b) Glucose
(c) Water (d) CO_2

43. Juxtaglomerular apparatus is made up of **[WB JEE 2012]**
(a) Juxtaglomerular cell, macula densa and lacis cell
(b) Juxtaglomerular cell, Purkinje cell and chief cell
(c) Juxtaglomerular cell, lacis cell and myoepithelial cell
(d) Juxtaglomerular cell, macula densa and argentaffin cell

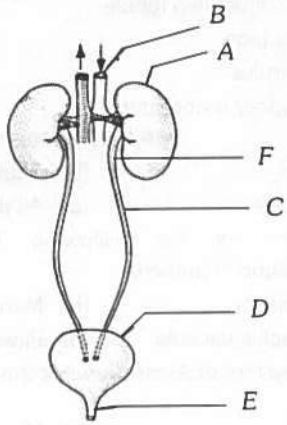
44. Which of the following passage way is part of cloaca of vertebrates **[DPMT 2004]**
(a) Rectum (b) The reproductive tract
(c) The urinary tract (d) All of these

45. Renin is secreted by **[MP PMT 1996, 2001, 02; Odisha JEE 2004; Kerala PMT 2005; MH CET 2015]**
(a) Cortex (b) Medulla
(c) Juxta glomerular cells (d) Podocytes

46. Human kidney has **[MP PMT 1993]**
(a) Ciliated nephron
(b) No loop of Henle
(c) Mesonephric duct
(d) Glomeruli concentrated in the cortex

47. Which of the following is not a function of kidneys **[DPMT 1993]**
(a) Regulation of blood pressure
(b) Removal of urea
(c) Regulation of acidity of fluids
(d) Secretion of antibiotics

48. In the diagram of excretory system of human beings given below, different parts have been indicated by alphabets; choose the answer in which these alphabets have been correctly matched with the parts which they represent **[KCET 2000; NEET 2013]**



(a) A = Kidney, B = Abdominal aorta, C = Ureters, D = Urinary bladder, E = Urethra, F = Renal pelvis
(b) A = Kidney, B = Abdominal aorta, C = Urethra, D = Urinary bladder, E = Ureters, F = Renal pelvis
(c) A = Kidney, B = Renal pelvis, C = Urethra, D = Urinary bladder, E = Ureters, F = Abdominal aorta
(d) A = Kidney, B = Abdominal aorta, C = Urethra, D = Urinary bladder, E = Renal pelvis, F = Ureters

49. In rabbit, the urinary bladder opens into **[Odisha JEE 2012]**
(a) Uterus (b) Urethra
(c) Ureter (d) Vestibule

50. In which one of the following organisms its excretory organs are correctly stated **[NCERT; CBSE PMT (Mains) 2010]**
(a) Humans - Kidneys, sebaceous glands and tear glands
(b) Earthworm - Pharyngeal, integumentary and septal nephridia
(c) Cockroach - Malpighian tubules and enteric caeca
(d) Frog - Kidneys, skin and buccal epithelium

51. Which one of the following body functions is not performed by kidneys **[RPMT 2002]**
(a) Excretion
(b) Osmoregulation
(c) Regulation of blood volume
(d) Destruction of dead blood corpuscles

52. The basic functional and structural unit of human kidney is **[NCERT; DPMT 1993; MP PMT 1995, 2012; CBSE PMT 1997; BHU 1999; RPMT 1999, 2005; AFMC 2001; CPMT 2002; J & K CET 2005; Bihar CECE 2006; Odisha JEE 2012]**

Or

Loop of Henle is found in **[CPMT 2001; MP PMT 2010; AMU (Med.) 2012]**
(a) Nephron (b) Pyramid
(c) Nephridia (d) Henle's loop

53. The kidneys of adult mammals are **Bihar MDAT 1995; MP PMT 1999; BHU 2012]**
(a) Opisthonephros (b) Pronephros
(c) Mesonephros (d) Metanephros

54. In which of these animals, antennal gland or green glands functions as excretory organ **[CPMT 2001; BHU 2003; Kerala PMT 2008]**
(a) Human being (b) Cockroach
(c) Planaria (d) Prawn
(e) Earthworm

Physiology of excretion

1. Nitrogenous waste in the Malpighian tubule flows into **[Odisha JEE 2008]**
(a) Haemocoel (b) Vacuole
(c) Intestine (d) Duodenum

2. The plasma resembles in its composition to the filtrate produced by the glomerulus except the presence of **[DPMT 1992]**
(a) Glucose (b) Chloride
(c) Amino acids (d) Proteins

3. What for the ascending limb of Loop of Henle is permeable **[MP PMT 1997; JIPMER 2002]**
(a) Glucose (b) NH_3
(c) Na^+ (d) Water

4. Water reabsorption in the distal parts of kidney tubules is regulated by **[CPMT 2002; MP PMT 1992; DPMT 1992; Pb. PMT 1999; BVP 2000, 01; Odisha JEE 2005; RPMT 2005; AFMC 2010]**
(a) STH (b) TSH
(c) ADH (d) MSH

5. A terrestrial animal must be able to **[CBSE PMT 2004]**
(a) Actively pump salts out through the skin
(b) Excrete large amounts of salts in urine
(c) Excrete large amounts of water in urine
(d) Conserve water

6. Urinary excretion of *Na* is regulated by **[AIIMS 1992]**
(a) Anterior pituitary (b) Posterior pituitary
(c) Adrenal cortex (d) Adrenal medulla

7. Mechanism of uric acid excretion in a nephron is **[AIIMS 1998]**
(a) Osmosis (b) Diffusion
(c) Secretion (d) Ultrafiltration

8. The yellow colour of urine of the vertebrates is due to **[CBSE PMT 1992; DPMT 1993; BHU 2004; MHCET 2011]**
(a) Cholesterol (b) Urochrome
(c) Uric acid (d) Melanin

9. Which segment of renal tubule is permeable to water but nearly impermeable to salts **[CBSE PMT 1992; DPMT 2006; AIIMS 2011; GUJCET 2014]**
(a) Proximal convoluted tubule
(b) Descending limb of Henle's loop
(c) Ascending limb of Henle's loop
(d) Distal convoluted tubule

10. Sodium, water and phosphate reabsorption is maximum in
(a) Loop of Henle (b) Proximal tubule
(c) Distal tubule (d) Collecting tubule

11. Human urine is usually acidic because **[AIPMT 2015]**
(a) Excreted plasma proteins are acidic
(b) Potassium and sodium exchange generates acidity
(c) Hydrogen ions are actively secreted into the filtrate
(d) The sodium transporter exchanges one hydrogen ion, for each sodium ion in peritubular capillaries.

12. Which of the following glands does not help in excretion **[Odisha JEE 2012]**
(a) Liver (b) Sweat glands
(c) Pancreas (d) Both (a) and (c)

13. At which stage of ornithine cycle arginase is used **[AFMC 2006; DUMET 2010]**
(a) Arginine– Ornithine (b) Ornithine– Citruline
(c) Fumaric acid–Arginine (d) Glycolysis–Urea

14. Which of the following does not favour the formation of large quantities of dilute urine **[AIPMT (Cancelled) 2015]**
(a) Caffeine (b) Renin
(c) Atrial-natriuretic factor (d) Alcohol

15. Inflammation of joints due to accumulation of uric acid crystals is called as **[NCERT; HP PMT 2005; J & K CET 2008; AFMC 2012; MH CET 2015]**
(a) Gout (b) Myasthenia gravis
(c) Osteoporosis (d) Osteomalacia

16. Protein rich diet brings about relatively no change in one of the following constituents of urine
(a) Urea (b) Creatinine
(c) Uric acid (d) Ammonium salts

17. When 2 to 3 drops of benedict's reagent are added to a urine sample and heated gently, it turns yellow. This colour change indicates that **[KCET 2011]**
(a) Urine contains 2% glucose
(b) Urine contains 0.5% glucose
(c) Urine contains 1.5% glucose
(d) Urine contains 1% glucose

18. Which of the following cycles in liver is mainly responsible for the synthesis of urea **[KCET 1994; BHU 2001; Kerala CET 2003; MP PMT 2003; J & K CET 2010]**
(a) Citruline cycle (b) Kreb's cycle
(c) Nitrogen cycle (d) Ornithine cycle

19. Proximal convoluted tubule (PCT) is lined with **[Kerala PMT 2008]**
(a) Cuboidal epithelium
(b) Simple brush border epithelium
(c) Simple cuboidal brush border epithelium
(d) Simple ciliated brush border epithelium
(e) Columnar epithelium

20. The part of a nephron which opens into the collecting duct is /are **[Kerala PMT 2012]**
(a) DCT (b) DCT and PCT
(c) Henle's loop (d) Glomerulus
(e) Bowman's capsule

21. Match the entries in column I with those in column II and choose the correct answer from the following

Column I	Column II
A. Uremia	1. Excess of protein level in urine
B. Hematuria	2. Presence of high ketone bodies in urine
C. Ketonuria	3. Presence of blood cells in urine
D. Glycosuria	4. Presence of glucose in urine
E. Proteinuria	5. Presence of urea in urine

[NCERT; Kerala PMT 2006, 11; DPMT 2007; CPMT 2010]
(a) A – 5, B – 3, C – 2, D – 4, E – 1
(b) A – 4, B – 5, C – 3, D – 2, E – 1
(c) A – 5, B – 3, C – 4, D – 2, E – 1
(d) A – 3, B – 5, C – 2, D – 1, E – 4
(e) A – 2, B – 1, C – 3, D – 4, E – 5

22. Which of the following disease shows the blockage of kidney tubules and causes severe back pain **[GUJCET 2015]**
(a) Renal calculi (b) Kidney failure
(c) Uremia (d) Nephritis

23. In distal convoluted tubule of the nephrons
(a) *Na* reabsorption requires energy
(b) Secretion of *K* ions does not require energy
(c) Water reabsorption requires energy
(d) Ammonia is secreted

24. The substance which is completely reabsorbed from the filtrate in the renal tubule under normal conditions is **[CPMT 1993, 95]**

Or

In nephrons there is complete absorption of **[MP PMT 1999]**
(a) Urea (b) Salt
(c) Glucose (d) Water

25. Effective filtration pressure in glomerulus is caused due to **[NCERT; KCET 2011]**
(a) Powerful pumping action of the heart
(b) Secretion of adrenaline
(c) Afferent arteriole is slightly larger than efferent arteriole
(d) Vacuum develops in proximal convoluted tubule and sucks the blood

26. Which of the following function is performed by collecting tubule of kidney **[GUJCET 2015]**
(a) In the maintenance of pH and ionic balance of blood by the secretion of H^+ and K^+ ions
(b) Maintenance of pH of blood and removal of Na^+ and K^+ ions
(c) Absorption of glucose and ammonia from the blood
(d) None of above

27. Which of the following causes an increase in sodium reabsorption in the distal convoluted tubule **[CBSE PMT 2014]**
(a) Decrease in aldosterone levels
(b) Decrease in antidiuretic hormone levels
(c) Increase in aldosterone levels
(d) Increase in antidiuretic hormone levels

28. A large quantity of fluid is filtered every day by the nephrons in the kidneys. Only about 1% of it is excreted as urine. The remaining 99% of the filtrate **[KCET 2009]**
(a) Gets collected in the renal pelvis
(b) Is lost as sweat
(c) Is stored in the urinary bladder
(d) Is reabsorbed into the blood

29. Reabsorption of glucose from the glomerular filtrate in the kidney tubule is carried out by

Or

Reabsorption in the tubules of nephrons occurs by the process of **[AIIMS 2001; AIEEE Pharmacy 2003]**
(a) Active transport (b) Osmosis
(c) Brownian movement (d) Diffusion

30. Maintenance of body potassium level is primarily by tubular **[AMU (Med.) 2010]**
(a) Absorption in PCT
(b) Secretion in DCT and /or cortical collecting duct
(c) Absorption in DCT
(d) Secretion in PCT

31. Which one of the following pair of waste substances is removed from blood in ornithine cycle **[CBSE PMT 1996, 2005; AFMC 2000; BHU 2001]**
(a) CO_2 and urea (b) Ammonia and urea
(c) CO_2 and ammonia (d) Urea and sodium salt

32. The amino acid that acts as a carrier of ammonia from skeletal muscle to liver **[DUMET 2010]**
(a) Alanine (b) Methionine
(c) Arginine (d) Glutamine

33. Which one of the following is correct for a normal human **[NCERT; WB JEE 2010; Kerala PMT 2012]**
(a) *pH* of urine is around 8
(b) On an average, 25-30 mg of urea is excreted via urine
(c) Presence of ketone bodies in urine is an indicator of diabetes mellitus
(d) Glycosuria can be treated with hemodialysis
(e) Relaxation of smooth muscles of bladder and simultaneous contraction of urethral sphincter causes release of urine

34. A fall in glomerular filtration rate (GFR) activates **[NCERT; CBSE PMT (Mains) 2012; KCET 2015]**
(a) Juxta glomerular cells to releases renin
(b) Adrenal cortex to release aldosterone
(c) Adrenal medulla to release adrenaline
(d) Posterior pituitary to release vasopressin

35. The end product of ornithine cycle is **[AIIMS 1999; MH CET 2000]**
(a) Urea (b) Ammonia
(c) Uric acid (d) Carbon dioxide

36. The glomerular filtrate contains **[NCERT; JIPMER 1993; CPMT 2005; KCET 2009]**
(a) Blood minus cells and proteins
(b) Blood minus cells
(c) Blood minus proteins
(d) Plasma minus cells and proteins

37. The vessel leading blood (containing nitrogenous waste) into the Bowman's capsule is known as **[MP PMT 2002]**
(a) Afferent arteriole (b) Efferent arteriole
(c) Renal artery (d) Renal vein

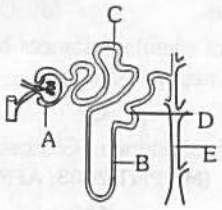
38. Match the excretory functions of section I with the parts of the excretory system in section II. Choose the correct combinations from among the answers given

	Section I		Section II
(i)	Ultrafiltration	(a)	Henle's loop
(ii)	Concentration of urine	(b)	Ureter
(iii)	Transport of urine	(c)	Urinary bladder
(iv)	Storage of urine	(d)	Malpighian corpuscles
		(e)	Proximal convoluted tubules

[Kerala CET 2005]
(a) (i) – (d), (ii) – (a), (iii) – (b), (iv) – (c)
(b) (i) – (d), (ii) – (c), (iii) – (b), (iv) – (a)
(c) (i) – (e), (ii) – (d), (iii) – (a), (iv) – (c)
(d) (i) – (e), (ii) – (d), (iii) – (a), (iv) – (b)
(e) (i) – (d), (ii) – (a), (iii) – (c), (iv) – (b)

39. Glomerular hydrostatic pressure is present in **[CPMT 2005]**
(a) Tubule of kidney
(b) Bowman's capsule
(c) Glomerulus of uriniferous tubule
(d) Malpighian tubule

40. The given diagram represents a single nephron from a mammalian kidney. Identify which of the numbered regions is



I. The site of ultrafiltration
II. Particularly sensitive to ADH
III. The main site for the reaborption of glucose and amino acid
IV. Largely responsible for the adjustment of blood pH **[NCERT]**
(a) I - A, II - B, III - D, IV - E (b) I - A, II - B, III - C, IV - E
(c) I - A, II - B, III - C, IV - D (d) I - A, II - E, III - C, IV – D

41. Select the correct statement with respect to locomotion in humans **[NEET 2013]**
(a) The joint between adjacent vertebrae is a fibrous joint
(b) A decreased level of progesterone causes osteoporosis in old people
(c) Accumulation of uric acid crystals in joints causes their inflammation
(d) The vertebral column has 10 thoracic vertebrae

42. Find the incorrect statement regarding mechanism of urine formation in man **[Kerala PMT 2009]**
(a) The glomerular filtration rate is about 125 *ml* per minute
(b) The ultrafiltration is opposed by the colloidal osmotic pressure of plasma
(c) Tubular secretion takes place in the PCT
(d) Aldosterone induces greater reabsorption of sodium
(e) The counter current systems contribute in diluting the urine

43. Separation of amino acid into amino and carboxyl group is known as **[CPMT 2002; RPMT 2005]**

Or

Removal of amino group of amino acid to transform it into keto acid is **[DPMT 2004]**
(a) Deamination (b) Excretion
(c) Amination (d) Egestion

44. The main function of Henle's loop is **[BVP 2001; Pb. PMT 2004; Wardha 2005]**
(a) Conservation of water (b) Filtration of blood
(c) Passage of urine (d) Formation of urine

45. Mark the wrong match from the following **[CPMT 2010]**
(a) Bowman's capsule - Glomerular filteration
(b) DCT - Absorption of glucose
(c) Henle's loop - Concentration of urine
(d) PCT - Absorption of Na^+ and K^+ ions

46. Active transport is **[BHU 1999]**
(a) Formation of ATP
(b) Against the gradient using ATP
(c) Along gradient without using ATP
(d) Against the gradient without using ATP

47. Ultrafiltration takes place in
(a) Blood capillaries (b) Tissue fluid
(c) Glomerulus (d) Urinary bladder

48. Reabsorption of useful substances back into the blood from the filtrate in a nephron occurs in **[J & K CET 2008]**

Or

In which part of kidney, Glucose and amino acids are reabsorbed **[MP PMT 2003; AFMC 2005; WB JEE 2011]**

Or

The maximum amount of electrolytes and water (70-80 Percent) from the glomerular filtrate is reabsorbed in which part of the nephron **[NCERT; CBSE PMT (Pre.)2012; WB JEE 2016]**

(a) Proximal convoluted tubule
(b) Loop of Henle
(c) Distal convoluted tubule
(d) Collecting duct

49. Filtration pressure in human kidneys is about
(a) +15*mm Hg* (b) +70*mm Hg*
(c) +45*mm Hg* (d) +55 *mm Hg*

50. Volume of urine is regulated by **[Kerala PMT 2004; J & K CET 2010; WB JEE 2010]**
(a) Aldosterone
(b) Aldosterone, ADH and testosterone
(c) Aldosterone and ADH
(d) ADH alone

51. Ornithine an amino acid is found
(a) As an intermediate of urea synthesis
(b) As an intermediate of methonine metabolism
(c) As a major fraction of the connective tissue
(d) In bile salts

52. Ornithine cycle is related to
(a) Respiration (b) Nutrition
(c) Excretion (d) Digestion

53. Substance which is finally excreted in the urine **[RPMT 1999; Odisha JEE 2012]**
(a) Amino acid (b) Urea
(c) Glucose and Glycogen (d) Uric acid

54. The extraction of urine from blood takes place through **[CPMT 1992, 93]**
(a) Glomerulus (b) Bowman's capsule
(c) Henle loop (d) Pelvis

55. Which one of the following statements in regard to the excretion by the human kidneys is correct **[CBSE PMT (Pre.) 2010]**
(a) Ascending limb of loop of Henle is impermeable to electrolytes
(b) Descending limb of Loop of Henle is impermeable to water
(c) Distal convoluted tubule is incapable of reabsorbing HCO_3^-
(d) Nearly 99 per cent of the glomerular filtrate is reabsorbed by the renal tubules

56. In micturition **[NCERT; Pb. PMT 1999; BVP 2001; DPMT 2004]**
(a) Urethra relaxes (b) Ureter contracts
(c) Ureter relaxes (d) Urethra contracts

57. The net pressure gradient that causes the fluid to filter out of the glomeruli into the capsule is **[CBSE PMT 2005]**
(a) 50 *mm Hg* (b) 75 *mm Hg*
(c) 20 *mm Hg* (d) 30 *mm Hg*

58. Vasopressin is related with **[MP PMT 1994]**
(a) Dilution of urine (b) Quick digestion
(c) Concentration of urine (d) Slow heart beat

59. Which one of the following is not a part of a renal pyramid **[NCERT; CBSE PMT (Pre.) 2011]**
(a) Loops of Henle (b) Peritubular capiliaries
(c) Convoluted tubules (d) Collecting ducts

60. Which of the following statement is/are true
(1) Urine is hypertonic in distal convoluted tubule
(2) When the urine passes into collecting tubule, it becomes hypotonic
(3) Urine is isotonic in proximal convoluted tubule
(4) Urine becomes more and more hypotonic as it passes through Henle's loop **[Kerala CET 2005]**
(a) 1 and 4 (b) 1, 2 and 3
(c) 2 and 3 (d) 3 only
(e) 1 only

61. In a healthy individual, GFR is about _____/min, the volume of the filterate per day is _____ litre, and amount of micturition per day is _____ litre **[NCERT; CBSE PMT 1992; WB JEE 2011; GUJCET 2014]**
(a) 100 ml., 150 lit., 1.8 lit. (b) 125 ml., 180 lit., 1.5 lit.
(c) 135 ml., 180 lit., 1.8 lit. (d) 140 ml., 150 lit., 1.8 lit.

62. Blacking of urine when exposed to air a metabolic disorder in human beings. This is due to **[Kerala CET 2005]**
(a) Phenylalanine
(b) Tyrosine
(c) Valine replacing glutamine
(d) Homogentistic acid
(e) Glutamine replacing valine

63. In public urinals, the urine on standing gives a pungent smell, due to **[MP PMT 1997]**

Or

State urine smells like ammonia because of
(a) Conversion of both urea and uric acid into ammonia
(b) Conversion of uric acid into ammonia by Ornithine cycle
(c) Conversion of urea into ammonia by bacteria
(d) None of the above

64. Which one of the following statement is correct respect to kidney function regulation **[NCERT; CBSE PMT (Pre.) 2011]**
(a) During summer when body loses lot of water by evaporation, the release of ADH is suppressed
(b) When someone drinks lot of water, ADH release is suppressed
(c) Exposure to cold temperature stimulates ADH release
(d) An increase in glomerular blood flow stimulates formation of Angiotensin II

65. At menopause there is rise in urinary excretion of **[Odisha JEE 2005]**
(a) FSH (b) STH
(c) LH (d) MSH

66. Prostaglandins affect **[RPMT 2000]**
(a) Blood pressure (b) Defaecation
(c) Osmoregulation (d) Oxygen metabolism

67. Which one do not filter out from blood to Bowman's capsule in glomerular ultrafiltration **[RPMT 2001]**
(a) Amino acids (b) Polypeptide
(c) Glucose (d) Fatty acids

68. Which one is component of ornithine cycle **[MHCET 2003; BHU 2005; CPMT 2009]**
(a) Ornithine, citrulline and alanine
(b) Ornithine, citrulline and arginine
(c) Amino acid are not used
(d) Ornithine, citrulline and fumaric acid

69. Select the correct statement **[Kerala PMT 2011]**
(a) The juxta medullary nephrons have reduced Henle's loop
(b) Vasa recta is well developed in cortical nephrons
(c) The PCT and DCT are situated in the medulla of the kidney
(d) The glomerulus encloses the Bowman's capsule
(e) The ascending limb of the Henle's loop extends as the DCT

70. Ornithine is converted into citruline by an enzyme
(a) Glutamic dehydrogenase
(b) Aspartic glutamic transaminase
(c) Carbamyl phosphate synthetase
(d) Ornithine carbamyl transferase

71. Vasopressin stimulates reabsorption of water and reduction of urine secretion. Hence vasopressin is otherwise called **[NCERT; MP PMT 1996; Kerala CET 2005]**
(a) Sinovial fluid
(b) Antidiuretic hormone
(c) Neurotransmitter
(d) Growth regulating substance
(e) None of the above

72. The part of nephron involved in active reabsorption of sodium is **[NEET (Phase-II) 2016]**
(a) Descending limb of Henle's loop
(b) Distal convoluted tubule
(c) Proximal convoluted tubule
(d) Bowman's capsule

73. Which of the following statements on human kidney is false **[WB JEE 2016]**
(a) Renal plasma flow is normally 660 ml/minute
(b) Blood flow in the cortex is greater than that in the medulla
(c) Reabsorption of ions and water occurs mainly in the distal convoluted tubules
(d) The renal blood flow is decreased in dehydration

74. Which of the following statements is correct **[NEET 2017]**
(a) The ascending limb of loop of Henle is impermeable to water
(b) The descending limb of loop of Henle is impermeable to water
(c) The ascending limb of loop of Henle is permeable to water
(d) The descending limb of loop of Henle is permeable to electrolytes

NCERT Exemplar Questions

1. The following substances are the excretory products in animals. Choose the least toxic form among them **[NCERT]**
(a) Urea (b) Uric acid
(c) Ammonia (d) Carbon dioxide

2. Filtration of the blood takes place at **[NCERT]**
(a) PCT (b) DCT
(b) Collecting ducts (d) Malpighian body

3. Which of the following statements is incorrect **[NCERT]**
(a) ADH – prevents conversion of angiotensinogen in blood to angiotensin
(b) Aldosterone – facilitates water reabsorption
(c) ANF – enhances sodium reabsorption
(d) Renin – causes vasodilation

4. A large quantity of one of the following is removed from our body by lungs **[NCERT]**
(a) CO_2 only (b) H_2O only
(c) CO_2 and H_2O (d) Ammonia

5. The pH of human urine is approximately **[NCERT]**
(a) 6.5 (b) 7
(c) 6 (d) 7.5

6. Different types of excretory structure and animals are given below. Match them appropriately and mark the correct answer from among those given below **[NCERT]**

Excretory structure/organ		Animals
A. Protonephridia	i.	Prawn
B. Nephridia	ii.	Cockroach
C. Malpighian tubules	iii.	Earthworm
D. Green gland or Antennal gland	iv.	Flatworms

(a) (D) i, (C) ii, (B) iii and (A) iv
(b) (B) i, (C) ii, (A) iii and (B) iv
(c) (D) i, (C) ii, (A) iii and (B) iv
(d) (B) i, (C) ii, (B) iii and (A) iv

7. Which one of the following statements is incorrect **[NCERT]**
(a) Birds and land snails are uricotelic animals
(b) Mammals and frogs are ureotelic animals
(c) Aquatic amphibians and aquatic insects are ammonotelic animals
(d) Birds and reptiles are ureotelic

8. Which of the following pairs is wrong **[NCERT]**
(a) Uricotelic ------ Birds
(b) Ureotelic ------ Insects
(c) Ammonotelic -----Tadpole
(d) Ureotelic ------ Elephant

9. Which one of the following statements is incorrect **[NCERT]**
(a) The medullary zone of kidney is divided into a few conical masses called medullary pyramids projecting into the calyces
(b) Inside the kidney the cortical region extends in between the medullary pyramids as renal pelvis
(c) Glomerulus alongwith Bowman's capsule is called the renal corpuscle
(d) Renal corpuscle, proximal convoluted tubule (PCT) and distal convoluted tubule (DCT) of the nephron are situated in the cortical region of kidney

10. Match the terms given in Column I with their physiological processes given in Column II and choose the correct answer

Column I	Column II
A. Proximal convoluted tubule	i. Formation of concentrated urine
B. Distal convoluted tubule	ii. Filtration of blood
C. Henle's loop	iii. Reabsorption of 70-80% of electrolytes
D. Counter-current mechanism	i v. Ionic balance
E. Renal corpuscle	v. Maintenance of concentration gradient in medulla

Options **[NCERT]**
(a) A-iii, B-v, C-iv, D-ii, E-i
(b) A-iii, B-iv, C-i, D-v, E-ii
(c) A-i, B-iii, C-ii, D-v, E-iv
(d) A-iii, B-i, C-iv, D-v, E-ii

11. Match the abnormal conditions given in Column A with their explanations given in Column B and choose the correct option

Column A	Column B
A. Glycosuria	i. Accumulation of uric acid in joints
B. Renal calculi	ii. Inflammation in glomeruli
C. Glomerular nephritis	iii. Mass of crystallized salts within the kidney
D. Gout	iv. presence of glucose in urine

Options **[NCERT]**
(a) A-i, B-iii, C-ii, D-iv
(b) A-iii, B-ii, C-iv, D-i
(c) A-iv, B-iii, C-ii, D-i
(d) A-iv, B-ii, C-iii, D-i

12. We can produce a concentrated/dilute urine. This is facilitated by a special mechanism. Identify the mechanism. **[NCERT]**
(a) Reabsorption from PCT
(b) Reabsorption from collecting duct
(c) Reabsoption/Secretion in DCT
(d) Counter current mechanism in Henle's loop/Vasa recta

13. Dialysing unit (artificial kidney) contains a fluid which is almost same as plasma except that it has **[NCERT]**
(a) High glucose (b) High urea
(c) No urea (d) High uric acid

Critical Thinking

Objective Questions

1. A kidney stone is **[NCERT; Kerala CET 2003; Manipal 2005]**
(a) Blockage by fats
(b) Deposition of sand in kidney
(c) A salt such as oxalate crystallised in pelvis
(d) Blockage by proteins

2. What will happen if the stretch receptors of the urinary bladder wall are totally removed **[CBSE PMT 2009]**
(a) Urine will not collect in the bladder
(b) Micturition will continue
(c) Urine will continue to collect normally in the bladder
(d) There will be no micturition

3. Stool of a person contains whitish grey colour due to malfunction of **[CBSE PMT 2002]**
(a) Liver (b) Spleen
(c) Kidney (d) Pancreas

4. All of the following animals are ureotelic except **[MHCET 2015]**
(a) Frog (b) Snake
(c) Turtle (d) Toad

5. Which of these is not a ketone body **[CPMT 2004; WB JEE 2012]**
(a) Acetoacetic acid (b) Acetone
(c) Succinic acid (d) Betahydroxy butyric acid

6. Marine teleost fishes excrete **[DPMT 2006]**
(a) Uric acid (b) Ammonia
(c) Urea (d) None of these

7. Which one of the four parts mentioned below does not constitute a part of a single uriniferous tubule **[CBSE PMT 1994]**
(a) Bowman's capsule (b) Distal convoluted tubule
(c) Loop of Henle (d) Collecting duct

8. What will happen if one kidney of a person is removed
(a) He will still survive and remain normal
(b) He will die due to blood poisoning
(c) Urea will go on accumulating in blood
(d) Urination will stop

9. This is not a nitrogenous waste **[AMU (Med.) 2010]**
(a) Creatinine (b) Purines
(c) Allantoin (d) Citrulline

10. Consider the following statements
A. Flame cells are excretory structures in flatworms
B. Green glands are excretory organs in annelids
C. Columns of Bertini are the conical projections of renal pelvis into renal medulla between the renal pyramids
[Kerala PMT 2007]
(a) A and B correct (b) B and C incorrect
(c) A and C correct (d) A, B and C correct
(e) A, B and C incorrect

11. In which of the following organisms Malpighian tubule is found **[Odisha JEE 2008]**
(a) Honey bee (b) Frog
(c) Ascaris (d) Rabbit

12. Due to insufficient filtration in the Bowman's capsule, all are likely to happen except **[AIIMS 1992]**
(a) Accumulation of fluid in the body
(b) Increase in blood pressure
(c) Increase in blood urea level
(d) Loss of glucose through urine

13. Diuresis is a specific pathological condition which leads to **[MP PMT 2001]**
(a) Increased volume of urine excretion
(b) Decreased volume of urine excretion
(c) Increased glucose excretion
(d) Decreased electrolyte concentration

14. Podocytes are the cells, present in **[CPMT 2000; Odisha JEE 2004, 11; Kerala CET 2005]**
(a) Cortex of nephron
(b) Inner wall of Bowman's capsule
(c) Outer wall of Bowman's capsule
(d) Wall of glomerular capillaries

15. In peritoneal dialysis, ... **[KCET 2010]**
(a) The blood is removed from the body and a natural filter is employed
(b) The blood is not removed from the body and a natural filter is used
(c) The blood is not removed from the body and an artificial filter is used
(d) The blood is removed from the body and an artificial filter is employed

16. Which is not a basic renal function **[Odisha JEE 2008]**
(a) Reabsorption (b) Secretion
(c) Perfusion (d) Filtration

17. If Henle's loop were absent from mammalian nephron, which of the following is to be expected **[NCERT; CBSE PMT 2003]**

Or

Removal of proximal convoluted tubule from the nephron will result in **[AIPMT (Cancelled) 2015]**
(a) The urine will be more dilute
(b) There will be no urine formation
(c) There will be hardly any change in the quality and quantity of urine formed
(d) The urine will be more concentrated

18. Which of the following is both osmoregulator as well as nitrogenous product **[DPMT 2007]**
(a) NH_3 (b) Urea
(c) Uric acid (d) All of these

19. Which one of the following statements is correct with respect to salt water balance inside the body of living organisms **[AIIMS 2005]**
(a) When water is not available camels do not produce urine but store urea in tissues
(b) Salmon fish excretes lot of stored salt through gill membrane when in fresh water
(c) *Paramecium* discharges concentrated salt solution by contractile vacuoles
(d) The body fluids of fresh water animals are generally hypotonic to surrounding water

20. Fresh water bony fishes maintain water balance by **[MHCET 2000; BHU 2002, 04, 12]**
(a) Excreting a hypotonic urine
(b) Excreting salt across their gills
(c) Drinking small amount of water
(d) Excreting wastes in the form of uric acid

A R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

(a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion
(c) If the assertion is true but the reason is false
(d) If both the assertion and reason are false
(e) If the assertion is false but reason is true

1. Assertion : Ammonia should be eliminated from the body as rapidly as it is formed.
Reason : Ammonia is insoluble in water.

2. Assertion : Urinary bladder and ureters are lined by transitional epithelium.
Reason : Ureters carry the urine to urinary bladder where it is stored temporarily.

3. Assertion : Diabetes insipidus is marked by excessive urination and too much thirst for water.
Reason : Anti-diuretic hormone (ADH) is secreted by the posterior lobe of pituitary gland. **[AIIMS 2004]**

4. Assertion : During the physiology of excretion, deamination does not take place in liver cells.
Reason : Deamination is a process to make use of excess of amino acids which cannot be incorporated into the protoplasm. **[AIIMS 2001]**

5. Assertion : Phenylketonuria is a recessive hereditary disease caused by the body's failure to oxidize an amino acid phenylalanine to tyrosine, because of a defective enzyme.
Reason : It results in the presence of phenylalanine acid in the urine. **[AIIMS 2000]**

6. Assertion : Aquatic mammals like whales and seals are said to be ureotelic animals.
Reason : It is because of the fact that their main nitrogenous waste product is urea.

7. Assertion : In the descending limb of loop of Henle, the urine is hypertonic, while in ascending limb of loop of Henle, the urine is Hypotonic.
Reason : Descending limb is impermeable to Na^+, while ascending limb is impermeable to H_2O. **[AIIMS 1997; KCET 2010]**

8. Assertion : Camel can go without water for long periods.
Reason : Camel stores water in the pouches of their rumen and fat in their hump.

9. Assertion : Renal threshold of glucose is said to be 180 mg per 100 ml.
Reason : Glucose starts appearing in the urine when its blood level exceed 180 mg per 100 ml of blood.

10. Assertion : Earthworms excrete both ammonia and urea.
Reason : Excretion in earthworm depends on the environment.

11. Assertion : The antidiuretic hormone increases the water permeability of distal convoluted tubule.
Reason : In absence of ADH, water re-absorption is considerably reduced. **[AIIMS 1994]**

12. Assertion : In birds and reptiles, main excretory product is the combined form of urine and faeces.
Reason : Birds and reptiles have no separate chamber for excretion of urine and faeces.

13. Assertion : The glomerular filtrate resembles the protein free plasma in composition and osmotic pressure.
Reason : The glomerular capillary wall and inner membrane of Bowman's capsule are impermeable to large molecules.

14. Assertion : Kidneys maintain the osmotic concentration of the blood.
Reason : Kidneys eliminate either hypotonic or hypertonic urine according to the need of the body.

15. Assertion : During micturition, urine is prevented from flowing back into the ureters.
Reason : Urethral sphincters relax during micturition.

16. Assertion : Secreting hypotonic urine is effective in reducing urinary loss of water.
Reason : Hypotonic urine is more concentrated and higher in osmotic pressure than the blood.

17. Assertion : Urea is a less toxic excretory substance comparatively to uric acid
Reason : Birds and insects are uricotelic animals. **[AIIMS 2010]**

18. Assertion : Process of maintaining a constant internal environment is known as homeostasis.
Reason : Kidneys are excretory and homeostatic organs. **[AIIMS 2010]**

19. Assertion : The functional unit of excretory organs of lobsters is nephron.
Reason : The filtration of blood occur in the malpighian body (the glomerulus and Bowman's capsule). **[AIIMS 2010]**

20. Assertion : Mammals, living in deserts contain more concentrated urine.
Reason : They contain very long loop of Henle in their nephrons. **[AIIMS 2010]**

Answers

Excretory waste products

1	b	2	c	3	c	4	a	5	c
6	b	7	d	8	d	9	a	10	d
11	d	12	c	13	d	14	b	15	b
16	c	17	d	18	a	19	b	20	a
21	d	22	c	23	d	24	a	25	c
26	a	27	c	28	a	29	a	30	d
31	a	32	b						

Excretory organs of different organism

1	d	2	b	3	d	4	a	5	b
6	d	7	c	8	b	9	b	10	d
11	d	12	b	13	c	14	a	15	d
16	d	17	b	18	c	19	c	20	d
21	a	22	b	23	b	24	a	25	b
26	d	27	b	28	c	29	a	30	a
31	c	32	a	33	c	34	b	35	d
36	b	37	a	38	a	39	c	40	b
41	d	42	c	43	a	44	d	45	c
46	d	47	d	48	a	49	b	50	b
51	d	52	a	53	d	54	d		

Physiology of excretion

1	c	2	d	3	c	4	c	5	d
6	c	7	d	8	b	9	b	10	b
11	c	12	c	13	a	14	b	15	a
16	d	17	d	18	d	19	c	20	a
21	a	22	a	23	a	24	c	25	c
26	a	27	c	28	d	29	a	30	b
31	c	32	d	33	c	34	a	35	a
36	a	37	a	38	a	39	c	40	d
41	c	42	e	43	a	44	a	45	b
46	b	47	c	48	a	49	a	50	c
51	a	52	c	53	b	54	b	55	d

56	a	57	c	58	c	59	c	60	d
61	b	62	d	63	c	64	b	65	a
66	a	67	b	68	b	69	e	70	d
71	b	72	c	73	c	74	a		

NCERT Exemplar Questions

1	b	2	d	3	a	4	c	5	c
6	a	7	d	8	b	9	b	10	b
11	c	12	d	13	b				

Critical Thinking Questions

1	c	2	b	3	a	4	b	5	c
6	d	7	d	8	a	9	d	10	b
11	a	12	d	13	a	14	b	15	b
16	c	17	a	18	b	19	a	20	a

Assertion and Reason

1	c	2	b	3	b	4	e	5	a
6	a	7	a	8	c	9	a	10	a
11	b	12	a	13	a	14	a	15	b
16	d	17	e	18	b	19	d	20	a

Answers and Solutions

Excretory waste products

2. (c) Main sources of uric acid are purines. Purines like adenine and Guanine change into xanthine which changes into uric acid

Guanine
↓
Adenine → xanthine → uric acid

Nitrogenous waste substances such as Ammonia, urea, or uric acid are produced during protein metabolism according to the species. Small amount of nitrogenous waste substance are also produced during the metabolism of nucleic acids. Ammonia is the most toxic followed by urea and uric acid the latter is the least toxic.

3. (c) Excretion of uric acid is of greater advantage to land animals which have limited access to water. So uricotelism is an adaptation to terrestrial mode of life. Uric acid is expelled in solid state

4. (a) Ornithine cycle is a cyclic process of urea formation which operates in the mitochondria of liver cells and has been studied by kreb's and Henseleit.

5. (c) Because they are the ultimate products of protein catabolism.

6. (b) Since urea formation takes place in liver.

7. (d) Because kidney removes urea.

11. (d) Adult frog and human exhibit ureotelism because there excretory waste product is urea.

13. (d) The ammonia is highly toxic because it has high pH, So, it must either be metabolised or expelled immediately out of body, so its concentration remains low in the blood.

16. (c) Ureotelic animals include mainly amphibians and mammals besides its annelids (earthworm) elasmo branch fishes (shark) and aquatic animals are ureotelic.

19. (b) The animals which excrete mainly uric acid are uricotelic. Terrestrial reptiles (lizards and snakes), birds, most insects are uricotelic animals.

20. (a) Marine teleosts form trimethylamine from their ammonia by methylation process which produce foul smell on oxidation.

$$\text{Ammonia} \xrightarrow{\text{Methylation}} \text{Trimethylamine} \xrightarrow{\text{Oxidation}} \text{TMO.}$$

23. (d) Whale is ureotelic.

27. (c) Those animals who excrete Ammonia are called as Ammonotelic. Eg. Aquatic Amphibia.

Those animals who excrete Urea are called as Ureotelic. Eg. Frog, Humans

Those animals who excrete Uric Acid are called as Uricotelic. Eg. Pigeon, Lizards, Cockroach.

28. (a) CO_2 and H_2O are the end product of complete aerobic oxidation of food through kreb's cycle and electron transport chain (E.T.C.) CO_2 is most abundant, harmful and universal waste product of metabolism.

29. (a) The main nitrogenous waste of *Hydra* is ammonia. *Hydra* has no organ of excretion, therefore, excretion of waste nitrogenous matter occurs directly by diffusion through all membrane.

32. (b) The main excretory product of frog is urea but excretory product of tadpole larva is ammonia. The urea along with some unnecessary salts and water is collected into the urinary bladder in the form of urine. It will be stored there for some time and is sent out through cloaca. So frog is described as ureotelic animal.

Excretory organs of different organism

4. (a) Flame cells remove water and nitrogenous wastes in platyhelminthes.

5. (b) Podocytes are specialised squamous epithelial cells in the inner wall of Bowman's capsule. They give rise to foot like processes which form filtration slits for the filtration of blood into the Bowman's capsule.

7. (c) Erythropoietin is secreted from glomerular cells and is concerned with the regulation of normal erythropoiesis.

9. (b) The number of metanephridia varies from 2000-2500 in clitellar segments (but only 200-250 in each of the many other segments).

13. (c) In the tadpoles of frogs, the ciliated funnels, nephrostomes, internally open into the uriniferous tubules.

14. (a) Animals like birds and lizards, which live in dry conditions, have to conserve water for their survival. So, they excrete nitrogenous waste in the form of uric acid.

18. (c) Contractile vacuole found in Amoeba acts osmoregulatory processes.

19. (c) Ascaris has a '*H*'-shaped tubular excretory system. It is supposed to be formed by a huge single excretory renette cell.

20. (d) Solenocytes (flame cells) help in excretion in flatworms (platyhelminthes).

21. (a) Uremia is a condition of high concentration of urea, uric acid in blood etc. Through haemodialysis, waste molecules diffuse into dialysis fluid and the blood is then returned to the patient body.

25. (b) The renal columns of Bertini is the part of cortex continued inside medulla between pyramids.

26. (d) Nephrons are morphological and physiological units of kidney. Man has 10-12 lac (10^6) nephrons in each kidney.

28. (c) Malpighian corpuscle (renal corpuscle) consists of Bowman's capsule and glomerulus.

29. (a) The epithelial cells of PCT have brush border due to the presence of abundant microvilli .

40. (b) Integumentary nephridia are also called exonephric nephrida. These are smallest V-shaped and without nephrostome. Integumentary nephridia are scattered in body wall of Pheretima.

41. (d) Vas deferens or sperm duct is associated with male reproductive system which arises from cauda epididymis.

45. (c) Renin is an enzyme released by the juxtamedullary cells into plasma where it converts angiotensinogen into angiotensin I.

50. (b) Earthworm has 3 types of nephridia.

51. (d) Kidney is an excretory organ performing osmoregulation and regulation of blood volume and along with excretion of nitrogenous wastes but never associated with phagocytosis.

52. (a) Nephron is the structural and functional units of kidney, which extract wastes from the blood. It is also called renal tubules or tubule. Each nephron is about 6 *cm* long and is formed of two parts *i.e.*, Bowman's capsule and body of renal tubule.

53. (d) In amniotes (reptiles, birds and mammals) kidneys are mesonephros in embryonic life but are metanephros in adult stage.

54. (d) In crustaceans, antennary gland or green gland is the chief excretory organ which eliminate ammonia from the animal body.

Physiology of excretion

2. (d) Due to large size, protein can't be filtered through the filtration slits. So they are absent in glomerular filtrate.

4. (c) Water is reabsorbed in distal convoluted tubules under the influence of antidiuretic hormone (ADH) secreted by posterior lobe of pituitary gland.

5. (d) Uric acid is least soluble nitrogenous waste and one gm of uric acid needs only 10 ml of water to be expelled out of body. So excretion of uric acid is of greater advantage to land animals which have limited access to water. So uricotelism is an adaptation to terrestrial mode of life.

6. (c) Through mineralocorticoids which is secreted by adrenal cortex.

8. (b) Urine is a transparent, light yellow liquid with a slightly acidic *pH* (average pH 6.0) the colour of urine is caused by the pigment urochrome, which is a breakdown product of haemoglobin from worn out red blood corpuscles.

9. (b) In descending limb of loop of Henle, water is reabsorbed due to increasing osmolality of interstitial fluid. Sodium and other solutes are not reabsorbed here. The filtrate become hypertonic to blood plasma.
In ascending limb of loop of Henle, solutes (*Na, K, Ca, Mg, Cl*) are reabsorbed whereas it is impermeable to water.
In distal convoluted tubule, there is active reabsorption of sodium ions from the filtrate under the influence of aldosterone.
Collecting duct reabsorb the water and also Na^+ under the influence of aldosterone.

10. (b) About 65 percent of the glomerular filtrate is normally reabsorbed in the proximal convoluted tubule before reaching the loop of Henle. Glucose, amino acids, vitamins, hormone, sodium, potassium, chlorides, phosphates, bicarbonates, much of water and some urea from the filtrate are absorbed.

14. (b) Renin does not favour the formation of large quantities of dilute urine.

18. (d) The actual process of urea synthesis is a repetitive cyclic sequence of a few reactions occuring continuously in the liver cells. Formation and transformation of three amino acids, namely ornithine, citrulline, and arginine. This cycle is variously referred to as ornithine, arginine or urea cycle.

23. (a) Reabsorption of Na^+ in the tubules is an active process.

24. (c) Complete reabsorption by active transport takes places for glucose in the PCT.

27. (c) Aldosterone stimulates Na^+ and water reabsorption in DCT.

29. (a) Reabsorption of glucose from the glomerlular filtrate in the kidney tubule is carried out by active transport.

31. (c) Ornithine cycle removes two waste products from the blood in liver. These are NH_3 and CO_2.

35. (a) Ornithine cycle is meant for urea synthesis and ureotelic animals synthesize urea from ammonia in their liver cells.

36. (a) Glomerular filtrate = Blood – (Blood corpuscles + plasma proteins)
= Blood plasma – proteins

43. (a) Deamination is the removal of surplus amino acids or removal of amino group from carboxyl group with the formation of ammonia and keto acid.

44. (a) Loop of henle is a 'U' shaped segment of nephron located in the renal medulla. It helps in conservation of water during counter current mechanism.

46. (b) Active transport is movement across the cell membrane against the gradient with the use of ATP.

47. (c) Ultrafiltration takes place through semipermeable walls of glomerulus and Bowman's capsule.

48. (a) 100% reabsorption of useful substances *e.g.* glucose takes place at proximal convoluted tubules.

49. (a) Effective filtration pressure in man is + 15 *mm Hg* . In case of horse and some other mammals it is + 25 *mm Hg* .

50. (c) Water is reabsorbed in DCT under the influence of ADH secreted by posterior lobe of pituitary gland. This make the filtrate isotonic to blood plasma and aldosterone is associated with the excretion of K^+ and H^+ ions some Cl^- ions are also reabsorbed.

56. (a) Process of passing out of urine is called micturition. During discharge of urine urethral sphincters relaxes and smooth muscles of bladder wall contract gradually.

58. (c) About 19% water is reabsorbed by the action of the posterior pituitary Anti diuretic hormone (ADH) or vasopressin.

59. (c) In Bowman's capsule PCT and DCT are in renal cortex, whereas, loops of Henle are in medullary pyramids.

60. (d) The filtrate is isotonic to blood plasma (in proximal convoluted tubule) and the filtrate becomes hypertonic to blood plasma (in descending limb of loop of Henle) The filtrate is hypotonic to blood plasma (in ascending limb at loop of Henle) in distal convoluted tubule ADH make the filtrate isotonic to blood plasma.

61. (b) In a healthy adult individual, the golmerular filteration rate is 125 ml/min that is 180 liter/day, but about 99% of the filterate is reabsorbed producing around 1 to 1.5 liter urine/day.

63. (c) If urine is allowed to stand for some time it smells strongly of ammonia due to bacterial degradation of urea to ammonia.

64. (b) When someone drinks lot of water which is not required by his body, the osmolarity of the blood will decrease. The decrease in osmolarity will inhibit the release of ADH. ADH not released DCT becomes less permeable to water, and excess of water is eliminated.

66. (a) Thromboxanes are synthesized in platelets and upon release cause vasoconstriction and platelet aggregation. Prostaglandins release by blood vessels affect blood pressure.

68. (b) Ornithine cycle is also called urea cycle which takes place in the mitochondria of liver cells. The amino acid arginine and citrulline are formed during formation of urea.

73. (c) Reabsorption of ions and water occurs mainly in PCT

Critical Thinking Questions

1. (c) Kidney stone is a crystallized chemicals like uric acid, calcium oxalate and calcium phosphate.

3. (a) Since the liver gives colour to the faeces by changing the decomposed haemoglobin into bile pigments - bilirubin and biliverdin.

5. (c) In human and most other mammals, acetyl Co-A formed in the liver during oxidation of fatty acids can enter the citric acid cycle or can be converted to the "ketone bodies" (e.g., Acetone, Acetoacetate and D - β hydroxy butyrate) for export to other tissue.

7. (d) Collecting duct receives the collecting tubules of several nephrons.

8. (a) Other kidney will enlarge in size to perform extra work of missing kidney (compensatory hypertrophy).

12. (d) Insufficient filtration will increase the blood urea level because all the quantity of urea produced by liver would not be filtered through glomerular capsule. Loss of glucose through urine always takes place due to insufficient reabsorption.

14. (b) Podocytes or foot cells are specialised cells of peculiar shape present in the epithelium visceral inner layer of Bowman's capsule, surrounding the glomerulus. They possess foot like process or projections, the pedicers. Hence, called as foot cells.

17. (a) The main function of loop of Henle is absorption of water . Hence, in its absence, water is not absorbed and dilute urine is passed out.
Outer wall of Bowman's capsule is made of squamous cells.

19. (a) Camels produce nearly dry faeces and highly concentrated urine. In the scarcity of water they use only metabolic water and store urea in their body tissue.

20. (a) Fresh water bony fishes take a large amount of water. To get rid of excess water, they pass out hypotonic urine (which is more dilute than blood plasma).

Assertion and Reason

1. (c) Ammonia is the basic nitrogenous catabolite of proteins. It is highly soluble in water and highly toxic to the animal. So its concentration must be kept very low in the blood. For this reason ammonia should be eliminated as rapidly from the body as it is formed. A large volume of water is needed by the animals to dissolve ammonia and eliminate it from the body. So, its elimination in urine involves considerable loss of water from the body.

2. (b) Urinary bladder and ureters of excretory system are lined by transitional epithelium because it is a stretchable epithelium, hence the urinary bladder and ureters may be considerably stretched without getting torn when they are filled with urine. Ureters are thin muscular tubes which emerge from the hilum of each kidney. Urine enters the ureters from the renal pelvis and is conducted along the ureters by peristaltic waves on their walls. Ureters from both the kidneys finally open into urinary bladder which is a hollow muscular sac. In this way urine from both the kidneys is drained into the urinary bladder which stores it temporarily.

3. (b) Antidiuretic hormone (ADH) or vasopressin is secreted from posterior pituitary gland. It is released in response to a fall in the water content of blood plasma and lead to an increase in the permeability to water of the distal and collecting tubules of the nephron. Deficiency or hyposecretion of ADH results in diabetes insipidus. Diabetes insipidus is characterised by micturating dilute urine several times a day which results in excessive thirst (polydipsia) and dehydration.

4. (e) Deamination is to make use of excess of amino acid which cannot be incorporated into the protoplasm by removal or protein or aminoacids or amino group from carboxyl group with the formation of ammonia and keto acid.

5. (a) Phenylketonuria results when there is a deficiency of liver enzyme phenyl alanine hydroxylase that converts phenyl alanine into tyrosine. It results with a high level of phenyl alanine in blood, tissue fluids and urine.

6. (a) Ureotelism is defined as the urinary elimination of nitrogen mainly as urea. Aquatic mammals like whales and seals are said to be ureotelic animals because their major nitrogenous waste product is urea. As a matter of fact, ammonia is the basic nitrogenous catabolite of protein but since ammonia is highly toxic to the animals, therefore, its concentration must be kept very low in the blood.

7. (a) Descending limb is permeable to water but not to Na^+. Consequently water moves out into interstitium and concentration of Na^+ in tubular filtrate rises making the filtrate hypertonic. Ascending loop is impermeable to water but permeable to Na^+ and makes the filtrate hypotonic.

8. (c) Camels have the ability to withstand water deprivation for long periods. But they do not store any water in the pouches of their rumen. The fat of hump is not particularly useful as a source of water because respiration must be enhanced to oxidise fat for producing water and this enhances respiratory loss of moisture. They reduce urinary water loss by secreting small volume of the urine much more hypertonic than the human urine. They lose far less water in the sweat, because they sweat only when their body temperature rises by as much as 60°C, compared to all other mammals. These factors are mainly responsible for the camel's ability to go without water for long periods.

9. (a) Renal threshold of a substance is its highest concentration in the blood, upto which it is totally reabsorbed from the glomerular filtrate. Renal threshold of glucose is about 180 mg per 100 ml. It is totally reabsorbed and does not appear in the urine so long as its blood level does not exceed 180 mg. But when its blood level exceeds 180 mg, some of the filtered glucose is left unabsorbed in the tubules and consequently appears in the urine. Some substances which are either totally reabsorbed actively or most of their amounts are reabsorbed actively are called high threshold substances. High threshold substances are excreted in the urine only when their blood concentration is considerably high, for example glucose and amino acids.

10. (a) Earthworms excrete ammonia when sufficient water is available, because a large volume of water is needed by the animal to dissolve ammonia and eliminate it from, the body. Whereas in drier environment the animal eliminates urea as it requires only considerable amount of water for the excretion of urea because urea is very soluble in water.

11. (b) ADH is secreted by pituitary gland. It increases the water permeability of distal convoluted tubules and collecting tubules, hence, plays a significant role in water re-absorption. The absence of ADH will reduce water reabsorption which may lead to water diuresis or diabetes insipidus.

12. (a) In birds and reptiles, ureters and the rectum open into a common sac called the cloaca (as there is no chamber for urine and faeces) for these two which stores both, and reabsorbs water from them and ultimately excretes these white and brownish black material along with aqueous fluid.

13. (a) Glomerular filtrate is the protein free fluid which is filtered from the blood of glomerular capillaries to the lumen of the Bowman's capsule. This process is called glomerular filtration. About one-fifth of the total volume of plasma flowing through the kidneys is filtered out as the glomerular filtrate. The filtration occurs across the membrane made of the glomerular capillary wall and the inner membrane of the Bowman's capsule. The pores of this following membrane are impermeable to large molecules or particles. Large particles like blood cells and protein macromolecules do not normally enter into the glomerular filtrate. But smaller molecules like glucose, urea, creatinine, amino acids and mineral salts are filtered into the Bowman's capsule in concentrations more or less similar to their respective concentrations in the plasma. The filtrate therefore almost resembles the protein free plasma in composition and osmotic pressure.

14. (a) Kidneys play an essential role in maintaining the concentration and osmotic pressure (osmoconcentration) of blood. When water intake of an animal is very high, the urine excreted has to be hypotonic *i.e.*, dilute and lower in osmotic pressure than their blood in order to remove the excess of water contrary to this, when there is a threat of excessive water loss from the body; the urine needs to be hypertonic more concentrated and higher in osmotic pressure than their blood, to reduce the loss of water with urine. In this way, the osmotic concentration of the blood is maintained.

15. (b) The act of voiding the urine is called micturition. Besides functioning as a temporary reservoir of urine, the urinary bladder also evacuates the urine by the process of micturition at suitable intervals. When enough urine has accumulated in the bladder to distend the bladder and raise its pressure sufficiently, a spontaneous nervous activity (reflex) is initiated; this causes the smooth muscles on the bladder wall to contract and the urethral sphincters, which guard the urethra, to relax. Urine consequently flows from the bladder through the urethra to the exterior. But it is prevented from flowing back into the ureters, because the terminal part of each ureter passes obliquely through the bladder wall and is consequently closed due to compression by the contracting bladder muscles.

16. (d) When there is a threat of excessive water loss from the body of the animal, then the urine excreted needs to be hypertonic and not hypotonic because excessive water loss from the body posses the threat of a rise in osmoconcentration of the blood. Since hypertonic urine is more concentrated and higher osmotic pressure than the blood, therefore it helps in reducing the loss of water with urine. Mammals and birds can excrete hypertonic urine which is more concentrated than their blood. For this, an isotonic glomerular filtrate is first filtered into the Bowman's capsules of nephrons in kidneys. The tublues of nephrons then reabsorb a large volume of water from the glomerular filtrate not accompanied by the reabsorption of proportionate amounts of solutes. This leaves the urine more concentrated than the blood which is very effective in reducing the urinary loss of water.

17. (e) Urea is more toxic than uric acid and less toxic to ammonia
Ammonia > Urea > Uric acid
Urea formation takes place in kidneys.
Birds and insects are uricotelic animals.

18. (b) Walter Cannon (1932) was introduced the term homeostasis (homeios = same; stasis = standing). Homeostasis maintains the stability of the cell environment and this way provides the organism with a degree of independence of the environment; in order to achieve stability. Mammals have two kidneys which perform excretory function and maintain urea level in blood.

19. (d) Nephron is the principal functional unit of the kidney of vertebrates. Its number reaches to one million in each kidney.
Filtration of blood occurs in Malpighian body, later is composed of a tuft of capillaries called the glomerulus together with the cupped end of the renal tubules, known as Bowman's capsule.

20. (a) Functional unit of kidney is known as nephron. Later contains a tubular region between proximal and distal convoluted tubule, the loop of Henle. The length of loop of Henle is proportional to the concentration of urine. The mammals (chordates) living in desert contain longer loop of Henle in their nephrons. Due to this, these animals contain more concentrated urine.

Excretory Products and their Elimination

SET Self Evaluation Test

1. Column I contains some terms and Column II contains their meanings. Match them properly and choose the right answer

	Column I		Column II
A.	Glycogenesis	1.	Conversion of glycogen to glucose
B.	Glycosuria	2.	Conversion of glucose to glycogen
C.	Gluconeogenesis	3.	Excretion of glucose in urine
D.	Glycogenolysis	4.	Conversion of noncarbohydrate sources to glucose
		5.	Conversion of glucose to starch

[KCET 2011; Odisha JEE 2012]

(a) $A-1, B-2, C-3, D-4$ (b) $A-2, B-3, C-4, D-1$

(c) $A-2, B-1, C-3, D-4$ (d) $A-1, B-5, C-2, D-4$

2. A condition of failure of kidney to form urine is called **[CBSE PMT 1998; BVP 2001]**

(a) Deamination (b) Entropy

(c) Anuria (d) None of these

3. Marcello Malpighi after whom malpighian corpuscles are named was born in **[HP PMT 2005]**

(a) Germany (b) Italy

(c) Australia (d) Austria

4. The average quantity of urea excreted in urine by man per day is **[NCERT; Kerala PMT 2010; MP PMT 2011]**

(a) 1-5 *gm* (b) 25-30 *gm*

(c) 1-1.5 *litres* (d) 80 *gm*

(e) 100-500 *mg*

5. Many freshwater animals cannot live for long in sea water and *vice versa* mainly because of the **[Kerala PMT 2010]**

(a) Change in N levels

(b) Change in the levels of thermal tolerance

(c) Variations in light intensity

(d) Osmotic problems

(e) Spectral quality of solar radiation

6. The conversion of NH_3 into urea occurs in **[NCERT; CPMT 1998; RPMT 1995, MP PMT 2009]**

Or

Transamination process takes place in **[CPMT 1995]**

(a) Intestine (b) Spleen

(c) Kidney (d) Liver

7. The absorption of Na^+ and secretion of K^+ by the nephron is under the control of hormone

(a) ADH (b) Corticosterone

(c) Aldosterone (d) Progesterone

8. Filteration takes place in **[MP PMT 1998]**

(a) Malpighian corpuscles (b) Bowman's capsule

(c) Glomerulus (d) Collecting tubule

9. Angiotensinogen is converted into angiotensin by **[AIIMS 1999]**

(a) Parathyroid hormone (b) Androgen

(c) Aldosterone (d) Renin

10. A person who is starving, that is not having food and is surviving only on water will have **[CBSE PMT 2007]**

(a) More urea in his blood (b) Less urea in his urine

(c) Less fats in his urine (d) More glucose in his blood

AS Answers and Solutions

1	b	2	c	3	b	4	b	5	d
6	d	7	c	8	a	9	d	10	b

2. (c) The condition in which kidney failed to form urine is called anuria.

3. (b) The composite structure of Bowman's capsule and glomerulus in knows as malpighian body or malpighian corpuscles after the italian microscopist Marcello Malpighi.

6. (d) The process of urea formation operates in mitochondria of Liver cells. Transamination means transference of an amino group ($-NH_2$) from an amino acid to another substance. This process is essential for growth and in case of vertebrates it takes place in liver.

8. (a) Filtration takes place through semipermeable walls of glomerulus and Bowman's capsule. Glomerulus and Bowman's capsule are collectively called malpighian corpuscle.

9. (d) Renin change plasma protein, called angiotensinogen to a peptide called angiotensin.

10. (b) As urea is the main excretory product of mammals and if the person is starving, he will have less urea in his urine.

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