Excretory Product and their Elimination

CHAPTER 19

EXAM DRILL

ANSWERS

1. **(d) :** Loss of glucose through urine always takes place due to insufficient reabsorption, but not due to insufficient filtration.

2. **(c) :** The function of counter current mechanism is to concentrate sodium chloride in the interstitial fluid and thereby cause water to diffuse out of the collecting ducts and concentrate the urine.

3. **(b)**

4. **(b) :** Glucose is completely reabsorbed by active transport (secondary) in proximal convoluted tubule (PCT) of the nephron.

OR

(a) : Juxtaglomerular apparatus (JGA) is a special sensitive region formed by cellular modifications in the DCT and the afferent arteriole at the location of their contact.

5. **(b) :** Presence of albumin in urine is called albuminuria. It usually occurs in nephritis. In such condition the size of filtering slits enlarges.

6. Animals living in dry conditions are mostly uricotelic. They have to conserve water in their bodies, therefore, they synthesise crystals of uric acid from ammonia.

7. Ammonia

8. Renal capsule covers the kidneys and protects them from infection and injuries.

9. Bowman's capsule

10. Urine imparts bad odour due to the formation of ammonia from urea. This conversion takes place due to bacterial degradation.

11. **(c) :** On the basis of location, the nephrons are of two types. In majority of nephrons, the loop of Henle is too short and extends only little into the medulla. These nephrons are called cortical nephrons and form 85% of the total nephrons. In some of the nephrons, the loop of Henle is very long and runs deep into the medulla. These nephrons are called juxtamedullary nephrons and form 15% of the total nephrons.

12. **(d) :** Glomerular filtration occurs because the pressure of the blood flowing in the glomerular capillaries is higher than the pressure of the filtrate in Bowman's capsule. In other words, blood pressure drives glomerular filtration, and because the process takes advantage of a pressure gradient, glomerular filtration does not require the expenditure of energy by kidney cells.

13. **(d) :** The descending limb of loop of Henle is permeable to water but almost impermeable to electrolytes. This concentrates the filtrate as it moves down. The ascending limb is impermeable to water but allows transport of electrolytes actively or passively. Therefore, as the concentrated filtrate pass upward, it gets diluted due to the passage of electrolytes to the medullary fluid.

14. **(c) :** The micturition is the process of evacuation of the formed urine from the bladder time to time. Urine 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. 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.

15. **(i) (c) :** In the given figure P is cortex, Q is renal papilla, R is medullary pyramid and S is ureter.

(ii) (b)

(iii) (d)

(iv) (a) : Inner to the renal capsule, there is an outer dark region called cortex and inner lighter region called medulla.

(v) Part R are the conical areas called medullary pyramids, present in inner medulla region of kidney. Their broad base is towards the cortex and each pyramid terminates in structure, the renal papilla.

16. **(i) (a) :** In the given figure A is Glomerular filtration, B is tubular reabsorption, C is tubular secretion and D is excretion.

(ii) (d) : Glomerular filtration is autoregulated by (i) myogenic mechanism where increase in blood pressure in arterioles increases the blood flow in glomerulus and *vice versa*. (ii) JGA cells secrete renin that regulates the glomerular filtration rate. (iii) Sympathetic nerve fibres, when stimulated

cause constriction of renal arteries and hence, decrease the glomerular filtration rate.

(iii) (d) : As filtrate flows in the descending limb of loop of Henle, the water gets reabsorbed while sodium and other solutes are not reabsorbed. This makes the filtrate hypertonic to blood plasma. In the ascending limb, the water does not pass through ,but K^+, Cl^-, Na^+ and Mg^+ are reabsorbed in the thick part. It is also partially permeable to urea. This makes the filtrate hypotonic to blood plasma.

(iv) (b) : Urine is composed of 95% water and 5% other substances that are organic and inorganic. Organic substances include urea, creatinine, creatine, ammonia, uric acid, amino acids, hormones, vitamins, etc., and inorganic substances include chloride, phosphate, sulphate, potassium ions, etc.

17. Capsular hydrostatic pressure (CHP) is the pressure exerted against the filtration membrane by the filtrate in the Bowman's capsule during filtration. This pressure also opposes filtration and represents a back pressure of about 18 mmHg.

18. Juxtamedullary nephrons are about 15 percent of total nephrons. Their glomeruli lie close to the inner margin of the cortex. Cortical nephrons are about 85 per cent of total nephrons. Their glomeruli lie in the outer cortex.

19. When lung fishes and *Xenopus* (African toad) live in water they are normally ammonotelic but they become ureotelic when they lie immobile in moist air or mud during summer.

Similarly, earthworms excrete ammonia when sufficient water is available while they excrete urea instead of ammonia in drier surroundings.

20. Ammonotelic – *Amoeba*, *Hydra*, *Pila*, Tapeworm, Prawn

Uricotelic – *Helix*, Cockroach, Lizards, Birds

Ureotelic – Mammals, Frogs, Toads, Turtles, Sharks

21. Bowman's capsule is a double layered cup-shaped structure inside mammalian kidney. The lumen of the capsule is continuous with the narrow lumen of the renal tubule. There are two layers of Bowman's capsule, *i.e.*, outer parietal layer and inner visceral layer. The parietal layer consists of squamous cells and the visceral layer surrounds the glomerulus and is composed of special type of cells, called podocytes.

22. The thick segment of descending limb is lined by cuboidal epithelium and has the same diameter as that of proximal convoluted tubule (PCT). It's cells have much less microvilli and mitochondria compared to PCT. The thin segment is lined by epithelial cells and has thinly scattered microvilli and very few mitochondria as compared to thick segment.

OR

(i) A fall in glomerular blood/glomerular blood pressure/ glomerular filtrate (GFR) can activate the juxtaglomerular (JG) cells to release renin.

(ii) Macula densa

23. (i) Ultrafiltration : The first step in urine formation is the filtration of blood. It is carried out by the glomerulus and is called glomerular filtration. Glomerular filtration occurs because the pressure of the blood flowing in the glomerular capillaries is higher than the pressure of the filtrate in Bowman's capsule. Glomerular filtration does not require any expenditure of energy by kidney cells. The epithelial cells of Bowman's capsule called podocytes are arranged in an intricate manner so as to leave some minute spaces called filtration slits or slit pores. Blood is filtered so finely through these membranes, that almost all the constituents of the plasma, except the proteins pass into the lumen of the Bowman's capsule. Therefore, it is considered as a process of ultrafiltration.

(ii) Tubular secretion : It occurs in DCT and PCT and ascending limb of Henle where the wastes from the blood stream are excreted into the filtrate by the process of active transport. It is the removal of selected materials from the blood of the peritubular blood capillaries into the nephric filtrate. Here, removal of ammonia, urea, uric acid, creatine, creatinine, hippuric acid, etc., takes place.

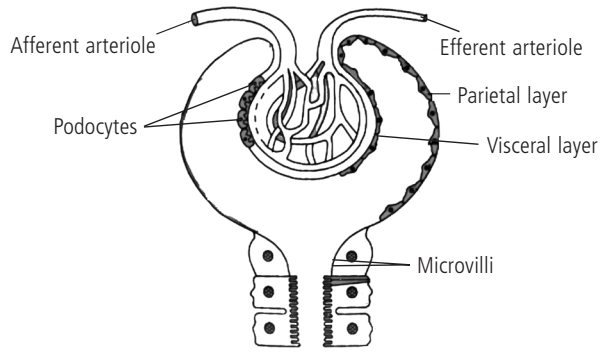
24. (i) Proximal convoluted tubule – It is present in the cortex region of kidney and is convoluted. It is lined by cuboidal epithelial cells bearing a brush border of tall microvilli (finger - like processes) at free end which increase the surface area. The cells have numerous mitochondria near the basolateral surface, which allows the transportation of salts by active transport. About 70 - 80% of the eletrolytes and water are reabsorbed here.

(ii) Distal convoluted tubule – It is convoluted and is lined by cuboidal epithelial cells with few irregularly spaced microvilli (no brush border). The terminal part of the distal convoluted tubule is straight and is called junctional tubule. Many DCTs of nephrons open into collecting duct, lined by cuboidal or columnar epithelium. Conditional reabsorption of sodium ions and water takes place in this segment.

25. Kidneys are reddish brown, bean-shaped structures situated between the levels of last thoracic and 3rd lumbar vertebra. Each kidney is 10-12 cm in length, 5-7 cm in width and 2-3 cm in thickness. The kidney is covered by layer of fibrous connective tissue, the renal capsule, which protect it from infection and injuries. On the concave side of kidney, there is an opening called hilum or hilus through which blood

vessels, nerves, lymphatic ducts and ureter enter the kidney. Hilum leads to funnel-shaped cavity called renal pelvis with projections called calyces. Each kidney has an outer dark region called cortex and inner light region called medulla. Medulla is divided into a number of conical projections called renal (medullary) pyramids projecting into minor calyces. Each kidney has nearly one million complex tubular nephrons.

26. The labelled structure of malpighian corpuscle is as follows:



27. Physical properties of urine : It is a transparent, light yellow liquid with slightly acidic pH. The pH range of urine is normally between 4.5 and 8.2 and may be affected by foods. The specific gravity of urine is usually between 1.015 and 1.025 .

Chemical composition : About 95 per cent of the volume of urine is water, other substances are only about 5 per cent. Organic substances include nitrogen, urea, creatine, creatinine, allantoin, vitamins, hormones, etc., Inorganic substances include chloride, phosphate, sulphate, potassium, sodium, etc. No glucose is normally found in the urine.

28. Partial or total inability of kidneys to carry on excretory and salt-water regulatory functions is called renal or kidney failure. In acute renal failure (ARF), both the kidneys abruptly stop working. The main feature of ARF is either oliguria (scanty urine production) which is daily urine output less than 250 mL or anuria (daily urine output less than 50 mL).

The causes of renal failure are : (i) low blood volume, (ii) decrease cardiac output, (iii) dyes used to observe blood vessels in angiograms, (iv) kidney stones and (v) non-steroid, anti-inflammatory drugs.

OR

The three factors that are tested for recipient-donor match during kidney transplantation are :

(i) Blood group : Recipient's blood group should match with donor's blood group.

(ii) Human leucocyte antigen (HLA) : It is located on the surface of the leucocytes (WBCs). An individual inherits a set of three antigens from the father and three antigens from the mother. A high number of matching of these antigens increases the chances of lasting kidney graft for a long time.

(iii) Antibodies : Small amount of blood of recipient and donor are mixed in a tube. If no reaction occurs, the recipient will be able to accept the kidney.

29. (i) Urine is yellow in colour due to presence of a pigment urochrome, formed due to breakdown of haemoglobin of old red blood corpuscles.

(ii) Blood plasma contains proteins but glomerular filtrate does not because filtration slits in the epithelium of renal corpuscle are about 25 mm wide, too small for most of the proteins to pass through. Only small solute molecules like glucose may be filtered out.

30. The kidneys have a special mechanism for concentrating the urine. This is called counter current mechanism. This mechanism depends on the loop of Henle, *vasa recta*, collecting duct and interstitial fluid. Counter current mechanism helps to concentrate the filtrate which occurs in loop of Henle and *vasa recta* in the medulla region of the kidney. It helps to maintain a concentration gradient in the medullary interstitial fluid which helps in an easy absorption of water from the filtrate present in the collecting duct so that the concentration of filtrate (urine) is increased.

The flow of filtrate in the two limbs of loop of Henle is in opposite directions and thus forms a counter current. The flow of blood in two limbs of *vasa recta* is also in opposite direction and, therefore form a counter current.

31. (a) Grafting a kidney from a compatible donor to restore kidney functions in a recipient suffering from kidney failure is called kidney or renal transplantation.

(b) Transplantation of kidney is done under general anaesthesia. Cut is given in the lower abdomen of the patient and the donor's kidney is transplanted retroperitoneally in the iliac fossa. Artery and vein of new kidney are connected to the iliac artery and vein of the recipient. Ureter of new kidney is connected to the urinary bladder of the recipient. The transplanted kidney takes over the work of two failed kidneys.

(c) Immunosuppressants are drugs or medicines that lower the body's ability to reject a transplanted organ. It suppresses the immunity against foreign tissue but maintains immunity against infection, *e.g.*, cyclosporin.

When a kidney transplant from other person (allograft) except identical twin (isograft) is done, immunosuppressants are used to prevent the immune system from attacking/rejecting the donor organ.

OR

Urine formation in human beings involves three steps - Ultrafiltration, tubular reabsorption and tubular secretion :

(i) Ultrafiltration : The first step in urine formation is the filtration of blood. It is carried out by the glomerulus and

is called glomerular filtration. Glomerular filtration occurs because the pressure of the blood flowing in the glomerular capillaries is higher than the pressure of the filtrate in Bowman's capsule. Glomerular filtration does not require any expenditure of energy by kidney cells. The glomerular capillary blood pressure causes filtration of blood through three layers, *i.e.*, (i) the endothelium of glomerular blood vessels, (ii) the epithelium of Bowman's capsule and (iii) a basement membrane between these two layers. The epithelial cells of Bowman's capsule called podocytes are arranged in an intricate manner so as to leave some minute spaces called filtration slits or slit pores. Blood is filtered so finely through these membranes, that almost all the constituents of the plasma, except the proteins pass into the lumen of the Bowman's capsule. Therefore, it is considered as a process of ultrafiltration. The product is called nephric of glomerular filtrate. The quantity of glomerular filtrate formed each minute in all the nephrons of both kidneys is known as glomerular filtration rate (GFR) that is about 125 mL/min (180 litres/day).

(ii) Tubular reabsorption is the second process in the formation of urine from filtrate. As much as 99 percent of the material in the filtrate is reabsorbed, preventing the loss of water, nutrients and ions from the body. As a consequence, urine contains mostly waste materials and excess water. About 65 percent of the glomerular filtrate is normally reabsorbed in the PCT before reaching the loop of Henle. Glucose, amino acids, vitamins, hormones, sodium, potassium, chlorides, bicarbonates, water from filtrate are absorbed. The filtrate is isotonic to blood plasma.

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 becomes hypertonic to blood plasma. Ascending limb of loop of Henle is impermeable to water but permeable to K^+, Cl^- and Na^+ and partially permeable to urea, so the filtrate becomes hypotonic to blood plasma.

In distal convoluted tubules, there is active reabsorption of sodium ions from the filtrate under the influence of aldosterone. Water is reabsorbed here under the influence of antidiuretic hormone (ADH) secreted by posterior lobe of pituitary gland, this makes the filtrate isotonic to blood plasma. In collecting duct, further reabsorption of water takes place. Now, the filtrate becomes hypertonic to blood plasma. Sodium is reabsorbed in the collecting duct under the influence of aldosterone. The filtrate is now called urine. Thus, urine is hypertonic to blood plasma.

(iii) Tubular secretion : It occurs mostly in the distal convoluted tubule which is also surrounded by peritubular capillaries. Smaller amount of tubular secretion also takes place in the area of proximal convoluted tubule.

Tubular secretion is active secretion of waste products by blood capillaries. It cause removal of all waste products from blood, *viz.*, urea, uric acid, creatinine. Extra salts, K^+ and H^+ are also secreted into filtrate to maintain a proper concentration and pH of the urine.

32. (i) Uremia : Uremia refers to the malfunctioning of kidneys that lead to accumulation of urea in blood. It is highly harmful and may lead to kidney failure. In uremia patients, urea can be removed by a process called hemodialysis. This method is a boon for thousands of uremic patients all over the world.

(ii) Micturition : It is the process by which the urine from the urinary bladder is excreted. It is a reflex process, but in grown up children and adults, it can be controlled voluntarily to some extent. When the urine accumulates, the muscular walls of the bladder expand. As a result, the stretch receptors on its wall send impulses to CNS. The CNS passes on motor messages. It causes the contraction of smooth muscles of the bladder and simultaneous relaxation of the urethral sphincter causing micturition.

The urinary bladder and the internal sphincter are supplied by both sympathetic and parasympathetic neural systems of autonomic neural system whereas the external sphincter is supplied by somatic nerves.

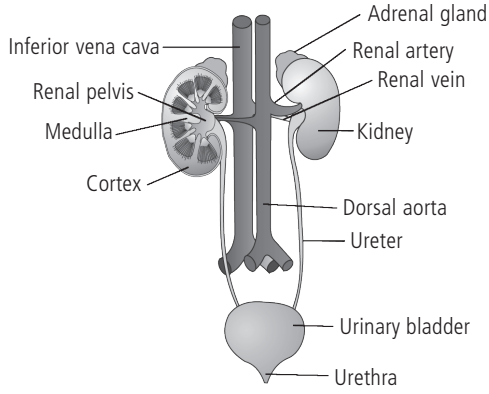
(iii) Sweat glands : Sweat produced by the sweat glands is a watery fluid containing NaCl, small amounts of urea, lactic acid, etc. The primary function of sweat is to facilitate a cooling effect on the body surface, it also helps in the removal of some of the waste substances.

OR

The Henle's loop and *vasa recta* play a significant role in producing a concentrated urine in mammals. A counter current is formed by the movement of the filtrate in the two limbs of Henle's loop in opposite directions. The flow of blood through the two limbs of vasa recta is also in a counter current pattern. An increased osmolarity towards the inner medullary interstitium is maintained by the proximity between the Henle's loop and vasa recta, as well as the counter current in them *i.e.*, from 300 $mOsmolL^{-1}$ in the cortex to about 1200 $mOsmolL^{-1}$ in the inner medulla. This gradient is mainly caused by NaCl and urea. NaCl is transported by the ascending limb of Henle's loop which is exchanged with the descending limb of *vasa recta*. NaCl is returned to the interstitium by the ascending limb of *vasa recta*. Similarly, small amounts of urea enter the thin segment of the ascending limb of Henle's loop which is transported back to the interstitium by the collecting tubule. This special arrangement of Henle's loop and *vasa recta* that facilitates the transport of substances is called counter current mechanism. This mechanism helps to maintain a concentration gradient in the medullary

interstitium. Presence of such interstitial gradient helps in an easy passage of water from the collecting tubule thereby concentrating the filtrate (urine).

33. The well labelled diagram of human excretory system is as follows:



Ureter : Ureter is about 25 to 30 cm in length. They are narrow, whitish, tubular structures, running backward along the abdominal wall to open into the urinary bladder. Ureters are composed of transitional epithelium and carry urine from the kidneys to the urinary bladder.

Urinary bladder : It lies in the pelvic cavity and is somewhat pear-shaped, muscular, sac–like structure. Its lining is composed of transitional epithelium. The muscular layer of the urinary bladder is well developed and is called detrusor muscle. The latter consists of three layers of smooth muscle inner and outer layers of longitudinal fibres and middle layer of circular fibres. Urinary bladder has a triangular area trigone, between the three openings – two openings through which the ureters enter the bladder and one openings through which the urethra leaves the bladder. It stores urine temporarily.

OR

(a) In proximal convoluted tubules, about 65% of glomerular filtrate is normally absorbed from reaching the loop of Henle. Glucose, amino acids, vitamins, hormones, sodium, potassium, chlorides, phosphates and some urea from the filtrate are absorbed back into body and prevent their loss in urine. Na^+, water and glucose are the main constituents that maintain homeostasis. Glucose is reabsorbed by sodium-glucose ATPase pump. Na is reabsorbed by Na^+K^+ ATPase pump. Water is reabsorbed along with salts. Thus, proximal convoluted tubules helps in maintaining homeostasis.

(b) The walls of the atria of the heart release Atrial Natriuretic Factor (ANF) in response to an increase in blood volume and pressure. ANF inhibits release of renin from the JGA and thereby inhibits NaCl reabsorption by the collecting duct and reduces aldosterone release from the adrenal gland. This way ANF opposes the regulation by renin – angiotension – aldosterone system (RAAS).

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