Chapter - 25
Excretory System of Human

The waste materials are produced due to the metabolic activities in the body which are not only unnecessary but are also harmful; as CO_2 water, nitrogenous wastes (ammonia, urea, uric acid) etc. CO_2 and water are gradually excreted out through respiration, excrement-urine (excreta) and perspiration, while the process to excrete out the nitrogenous wastes from body is called excretion. The nitrogenous waste materials produced due to protein metabolism are excreted after complex chemical reactions by specific excretory organs. Organs of the body which help in excreting out the wastes are called excretory organs. Excretory organs together form the excretory system.

Elimination of nitrogenous waste products

Different types of nitrogenous waste materials are produced in animals by the protein metabolism for which excretion is performed-

1. Ammonia: Ammonia is produced due to decomposition of amino acids and proteins ammonia is very harmful for the body. It is necessary to excrete it out for its being most poisonous.

Thus, those animals in which nitrogenous wastes are excreted in the form of ammonia, are called ammonotelic animals. Ammonia is very soluble in water, hence need of more water is necessary for its excretion. That's why, only simple aquatic animals perform excretion of ammonia, Examples-Protozoa, Porifera, *Hydra*, Annelida, aquatic arthropods, molluscans animals, fresh water fishes etc.

2. Urea: Urea is less harmful than ammonia, so most of the terrestrial animals transform ammonia into urea. Urea maybe retained in the body for more time. Urea is water soluble. For the excretion of urea water is necessary. Such animals. Which excrete mainly urea, are known as ureotelic animals. Examples- Annelids, cartilaginous fish, bony fish, amphibians and mammalians (rabbit, human) etc.

3. Uric acid : Uric acids is less poisonous and is nearly insoluble in water. It can be stored for more time in the body due to its being less poisonous. Water is not necessary for its excretion. Such animals which excrete mainly uric acid are call uricotelic animals. Examples-insects, reptiles and mammals living in desert habitat.

Human Excretory System

In human, kidneys are main excretory organs. Besides kidneys, ureter, urinary bladder and urinary passage or urethra also take part in excretion.

1. Internal structure of kidney : In human, one pair of kidneys are found, which are situated at dorsal side of abdominal cavity on both the sides of vertebral column. The right kidney is somewhat anterior to the left kidney. Both the kidneys are attached with the dorsal wall of abdomen by means of a fold of membranous, thin peritoneum. Kidney are formed from the embrynic mesoderm and these are of the metanephric type.

Human kidney are dark red and bean shaped. Each kidney is about 10-11 cm in length, 5-6 cm in width. 205-3 cm thick and about 120-170 gm in weight. The outer surface of the kidney is convex

and the inner surface concave. Pit-like structure on the concave side, is called hilum. Renal artery and nerve enter kidney from the hilum side. Renal vein, lymph duct and ureter comes out of the kidney. A cap like endocrine gland adrenal glands, covers the upper end of the kidney.

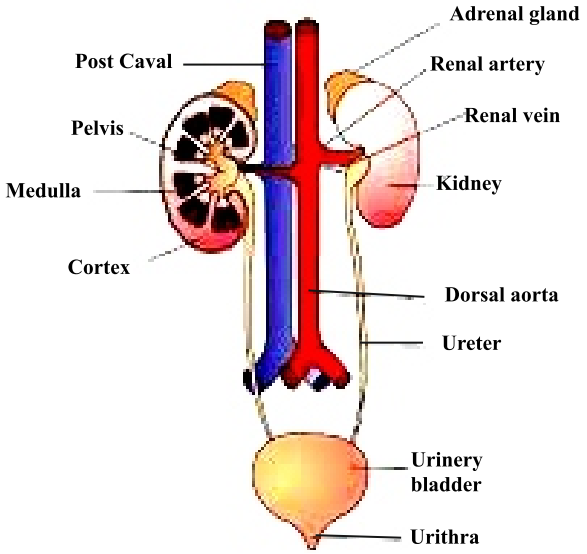

Fig. 25.1 Excretory system of Human

2. Ureters : A narrow tube with thick muscular walls comes out from the hilum of kidney, is called ureter. Its proximal part in the kidney is wide and funnel shaped, which is called **pelvis**. Both the ureters, starting from the pelvis open below in **urinary bladder.** The walls of ureters are thick and muscular. These muscles, to forward urine by developing peristaltic waves.

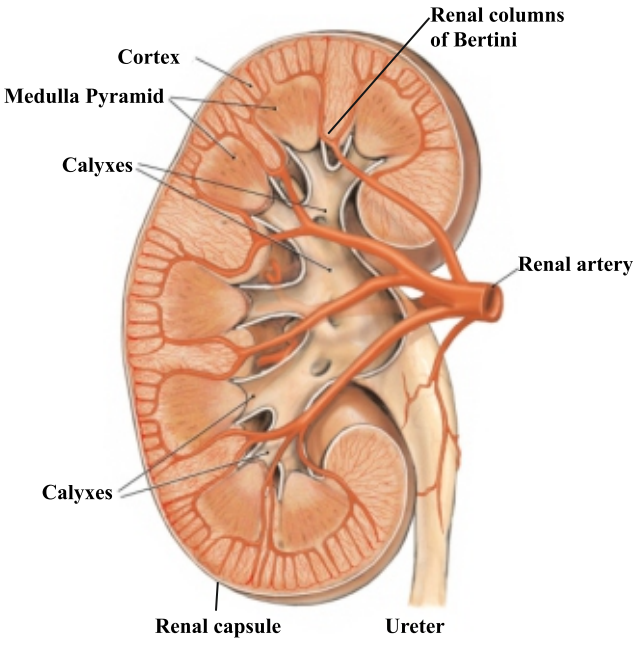

Fig. 25.2 Internal Structure of Human Kidney

3. Urinary bladder : It is a muscular beg like structure in which urine is collected permanently. There are three layers in its wall-

External layer : Serosa of peritoneum, **middle** unstripped muscle layer and **internal-** mucous layer. Urinary bladder is cone shaped of which the upper part is wide and lower part is narrow. The narrow part opens by a aperture in urethra. This aperture has a sphincter made of stripped muscles. In male, the urinary bladder is situated in front of rectum and in female just above vagina, 700-800 m**l** urine could be collected in urinary bladder.

4. Urethra : A duct, comes out from the neck urinary bladder, which is called **urethra.** Urine is excreted out through urethra. Sphincter muscle is present on the urethra which normally, keeps the urethra closed tightly. At the time of passing urine, sphincter relaxes as such urine excretes out easily. In male's urethra is about 15 cm long and passes through the penis. Urine and seaman both do pass out through it. In females, urethra is about 4 cm long and only urine passes out through it.

In male urethra is made of three parts-

(i) Prostatic or urethral part : It is 2.5 cm long which passes through the prostate gland. Both the vasa deferentia opens in this part.

(ii) Membranous part : This is the small part in between prostate gland and penis.

(iii) Penile part : This is about 15 cm long passage, which opens externally on the top of glans penis as urogenital aperture, passing through **corpus spongiosum** of the penis.

Internal and Histological Structure of Human Kidney

In human, each kidney is covered with firm, fibrous connective tissue cover, which is called renal capsule. Inside renal capsule the kidney is differentiated into two parts-outer part, **cortex** and the inner part **medulla**.

(a) Cortex : It is situated inner to the capsule and due to Malpighian bodies looks like granular. This is the outer region of dark red columns. Some narrow elongations of cortical region are embedded in the outer medullary part. These are called **Renal columns of Bertini.** In the cortical part, Malpighian bodies, proximal convoluted parts and distal convoluted parts or uriniferous tubules are found.

(b) Medulla : This is the interior part of kidney, in this **Henle's loop** and **collecting tubules** are found. Due to the embedded corticular parts in the outer part of medulla, conical elevations are seen there, which are called pyramids. Pyramid is situated in a cup shaped cavity, which is called **calyx**. Calyxes joint together open in it **pelvis**, which is funnel shaped and open in ureter.

Structure of Uriniferous Tubules or Nephrons

Uriniferous tubules are the structural and functional units of kidney. There are about 10-12 lacs of thin, long and coiled tubules found in each kidney of human. These tubules are known as renal tubules or nephrons. Formation of urine is done in these tubules in which nitrogenous substance are dissolved.

Each tubule can be divided in the following parts-

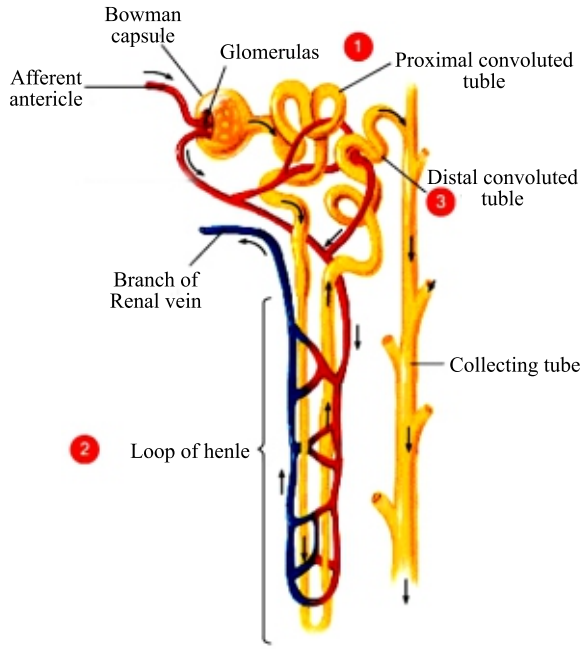

Fig. 25.3 Nephron showing blood vessels, vessels and tubules

1. Malpighian body 2. Neck 3. proximal convoluted tubule 4. Loop of Henle 5. Distal convoluted tubule 6. Collecting parts.

(1) Malpighian body : The anterior part of each uriniferous tubul is called malpighian body. It is formed by two parts (a) Bowman's capsule (b) Glomerulus.

(a) Bowman's capsule : This is a cup-shaped structure in which the glomerulus is inserted. The wall of Bowman's capsule is thin and double layered. These layers are formed of squamous epithelium. The inner layer contains specific type of cells, which are called podocytes. The processes of podocytes and the wall of blood capillaries together form the thin glomerulus membrane. In this membrane there many microspores are found, **fenestra**, due to which the membrane is more permeable.

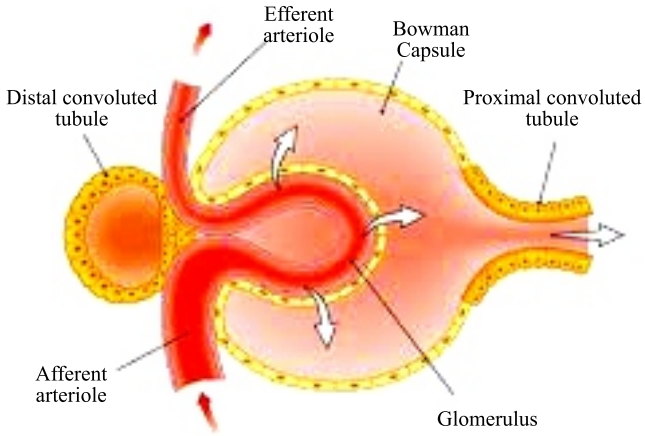

Fig. 25.4 Bowman's Capsule

(b) Glomerulus : Glomerulus is found in the cavity of Bowman's capsule. Afferent arteriole from renal artery supplies blood to glomerulus and efferent arteriole takes out the blood. Afferent arteriole divides into 50 branches to form the glomerulus. The diameter of afferent arteriole is more in comparison to efferent arteriole. The wall of capillaries is made of endothelium and in this are found pores of 500-1000^{0}A diameter. The endothelium of blood capillaries and the endothelium of Bowman's capsule together work as filtration layer.

2. Neck : This part is a narrow small tube-like structure next to Bowman's capsule. Its wall is made

of ciliated epithelium.

3. Proximal convoluted tubule : This structure is a long thick coiled tubule, next to neck. It is stratified by cuboidal epithelium and on its inner edge many micro villi are found which together form the brush border. Due to presence of micro villi the absorption surface is increased. These cells have much more mitochondria which provide energy for active absorption. In this part two third part of glomerular filtrate is reabsorbed.

4. Henle's loop : It is the middle part of uriniferous tubule situated next to proximal tubule, thin and of 'U' shaped tubule part, called **Henle's loop**. It is differentiated into two arm- **descending arm** and **ascending arm**. The proximal convoluted tubule opens in descending arm. Descending arm is lined inside by scaly epithelium The ascending arm opens in distal convoluted tubule and its wall is thick and lined by cuboidal epithelium.

5. Distal convoluted tubule : The ascending arm of Henle's loop opens in distal convoluted tubule which is situated in the cortex region of kidney. This portion is also lined by cuboidal epithelium like proximal convoluted tubule. Micro villi are not found on these cells.

6. Collecting tubules : The distal convoluted tubule of uriniferous tubule opens in collecting tubule. Several uriniferous tubules open in each collecting tubule. Many collecting tubules together form a single thick main collecting tubule which is called **duct of Bellini**. These tubules open in pelvis of the kidney, which is the wide funnel shaped part of ureter. Collecting tubules are situated in the pyramid of the kidney. The collecting tubules are lined by single layered glandular epithelium.

Mechanism of Excretion and Formation of Urine

Urea formed in the liver cells is carried in the kidney. The blood with urea from liver is poured in the post caval by hepatic vein. Urea is separated from the blood from post caval. This is called urine formation. The process of urine formation is completed in the following steps-

1. Ultrafiltration,
2. Selective reabsorption,
3. Secretion

1. Ultrafiltration : Bowman's capsule in the uriniferous acts function as a micro-sieve. The afferent arteriole carries with urea blood in this and efferent arteriole takes away blood from it.

The wall of capillaries of glomerulus has innumerable pores of about 0.1 µm diameter, from which the permeability of porous membrane in comparison to blood capillaries increase 100 to 1000 times. The substance dissolved in plasma can get through these pores. The afferent arteriole entering the glomerulus is more in diameter than efferent arteriole. So, blood flows fast in this, but at the time going out could not flow so fast. In a healthy person, the pressure of blood coming in the glomerulus (GHP glomerular hydrostatic pressure) is more (70 mm Hg). Blood corpuscles, blood protein, blood soluble colloids could not filter.

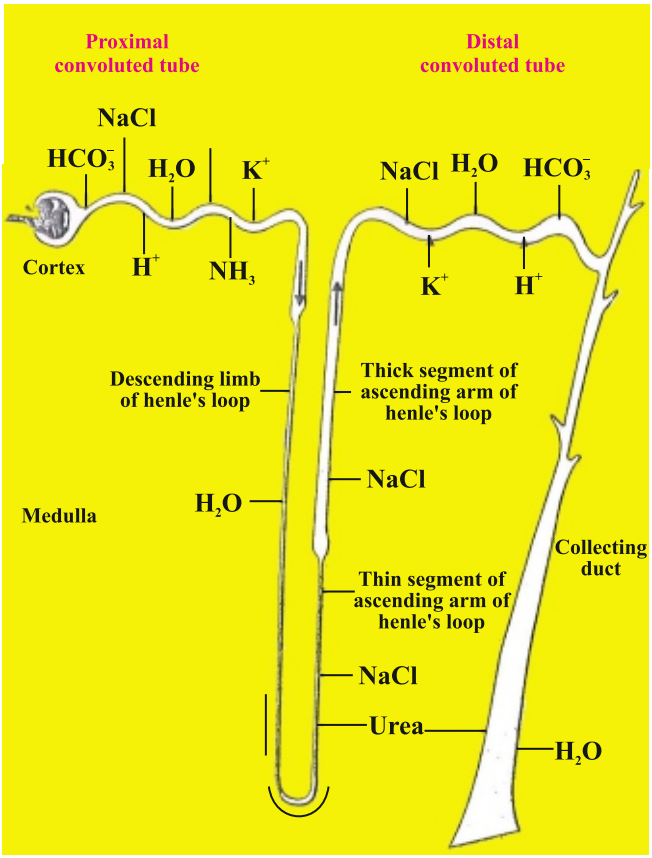

Fig. 25.5 Reabsorption and secretion of main substances by different parts of nephron (→ shows the direction of movement)

An opposite (30mm Hg) blood colloidal osmotic pressure (BCoP) is produced by the

colloidal substances, in the blood the filtrate in the Bowman's capsule cavity also produces about 20 mm Hg pressure which is called capsular hydrostatic pressure (CHP). Thus, the net Effective filtration pressure (EFP) on the glomerular fluid is about 20 mm Hg (70GHP- 30BCoP + 20 CHP) which works and the fluid plasma excretory substances remain moving in the cavity of Bowman's capsule.

The filtered plasma from the glomerulus is called glomerular filtrate. This fluid comes down in the cavity of Bowman's capsule. The process of filtration from the wall of blood capillaries of glomerulus of excretory and other utilizable substance is known as **ultra filtration.**

2. Selective reabsorption : The glomerular filtrate produced by ultra filtration contains urea, uric acid, creatinine etc., excretory substances also with glucose, amino acids some fatty acids, vitamins water and other useful salts. In the filtrate95% of the water in the blood also filters out, however about 0.8% part of this is transformed into urine, comes out. The useful substances present in this e.g. glucose, vitamin, amino acids etc. are reabsorbed by uriniferous tubules into the blood. The process by which the useful substances are reabsorbed in the blood from the uriniferous tubule is known as **selective reabsorption.**

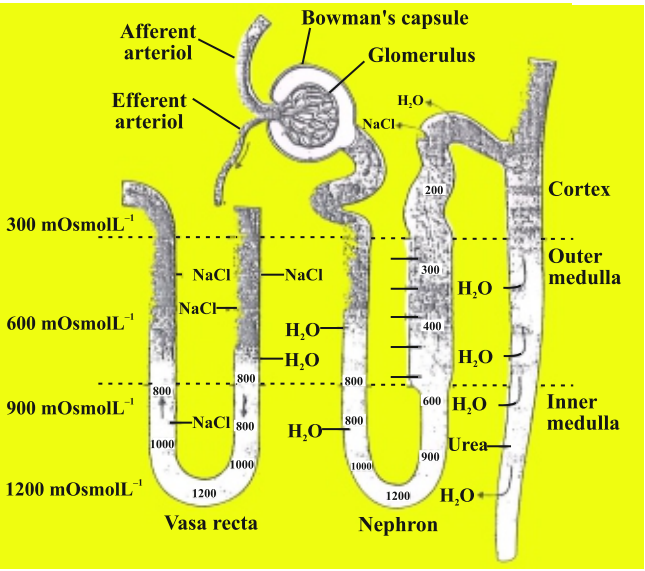

Fig. 25.6 The mechanism of counter current exchange formed by nephron and vasa recta

The process of reabsorption in the different parts of the uriniferous tubule is as follows-

(i) Reabsorption in proximal convoluted tubules : On the inner wall of this many microvilli are found due to this reabsorption capacity increases 20 times. In this part, most of the useful materials are reabsorbed form the filtrate by the cells of epithelium and send into the blood of glomerulus. Glucose, vitamins, amino acids, inorganic salts as calcium, sodium, potassium phosphate after reabsorption move away by active transport. At this time energy in the form of ATP is used. Water reaches by osmosis in the blood. 60-80% substances are reabsorbed. Reabsorption of substances is according to their **renal threshold value.**

Renal threshold value of a substance is the maximum concentration in the blood. High threshold substances (complete absorption of glucose amino acids), which is completely absorbed from the glomerular filtrate. Less absorption of low threshold substances (water, mineral salts etc.) and not the least absorption of non-threshold substances e.g. urea, uric acid, creatinine sulphate etc.

(ii) Reabsorption in Henle's loop : Reabsorption in different parts of Henle's loop is as follows-

(A) Reabsorption in descending arm: In the descending arm about 35% of the filtrate i.e. the renaming part reaches. Osmotically blood plasma in descending arm and filtrate are similar. These are isotonic due to the presence of sodium, potassium and chloride (Na^+, K^+, Cl^-). The thin wall of this arm is less permeable for urea, sodium and other than water for which it is more permeable. Here the filtrate becomes hypertonic.

(B) Reabsorption in ascending arm : The filtrate from descending arm reaches the thin part of the ascending arm. The wall of this is permeable for Na^+, Cl^- ions and impermeable for water. So, ions of inorganic salts (Na^+ and Cl^-) from filtrate diffuse out commonly. Here the filtrate changes to isotonic.

The wall of thick part of the ascending arm is impermeable for water, urea and other solutes. Form this Na^+, K^+ and Cl ions by active transport pass out in tissue fluid of renal medulla forms the filtrates

and by simple diffusion pass into blood, therefore, the filtrate becomes hypotonic.

(C) Reabsorption in distal convoluted tubule : The reabsorption of Na^+ and Cl^- remains continued in this tubule. Here the filtrate is isotonic in comparison with blood. Here, nearly 19% part of water is absorbed.

(D) Reabsorption in collecting tubule : Here water molecules are reabsorbed from the filtrate, thus the filtrate becomes hypertonic. The wall of collecting tubule in its interior part is slightly permeable for water molecules. The last part of Collecting tubule is slightly permeable for urea, as such urea coming out increases the osmotic value of the medullary tissue fluid.

3. Secretion : Some harmful materials like pigments, some medicines, uric acid, hippuric acid etc. could not sieve out at the time of ultra filtration in glomerulus filtrate. These waste materials let free in the uriniferous tubule cavity by active transport by epithelial cells of Henle's loop and proximal and distal convoluted arms. This activity is known as tubular Secretion.

Other excretory organs in Human

1. Skin : Extra water and some nitrogenous substances are excreted out of the body by the sweat glands situated in the human skin in the form of perspiration.

2. Lungs : CO_2 is an excretory substance formed during cellular respiration. It is excreted out by the process of respiration.

3. Liver : The hepatic cells are helpful in transforming nitrogenous part of amino acids more than necessary into ammonia and ammonia into less harmful urea to transform it into urine to excrete it out. Bile pigment are also formed by liver.

Disorders related to Excretion

Irregularities in the process of excretion in human creates several diseases. Such, some main diseases are following-

1. Uremia : When in blood amount of urea increases from10-30mg/100 ml then the state is known as uremia. Excessive storage of urea in blood leads to patient's death.

2. Gout : This is a hereditary disease in which uric acid increases in blood which collects in joints and kidney tissues. This disease increases due to dehydration, fast and diuretic.

3. Kidney stones : Commonly, crystals of uric acid, calcium oxalate, phosphate salts etc. deposit into renal pelvis in the form of stones. This creates pain in patient and obstruction in passing urine.

4. Bright's disease or nephritis : This disease is caused by the infection of bacteria-***Streptococci*** in glomerulus. Due to this glomerulus develops inflammation and its membranes becomes too much permeable so erythrocytes (RBC) and protein also sieve out in the filtrate.

5. Glycosuria : Presence of sugar in urine and excretion is called glycosuria. This disease is caused due to lack of insulin hormone. The disease is called **diabetes mellitus.**

6. Dysuria : Pain at the time of passing urine is called **dysuria.**

7. Polyuria : This is a phase when reabsorption of water by nephrons is stopped and the volume of urine increases. It is called diuresis.

8. Cystitis : Inflammation is urinary bladder due to bacterial infection, chemical or mechanical injury.

9. Diabetes Insipidus : Hypo secretion of antidiuretic hormone (ADH) develops check on the absorption on water in distal convoluted tubules and collecting tubules. This increases the volume of urine and the patient passes urine again and in increased volume.

10. Oligo urea : In this disease urine produces in less amounts.

11. Protein urea : Increase of protein quantity more than normal is known as protein urea.

12. Albuminuria : Due to this disease albumin protein quantity increases in urine.

13. Ketonuria : Increased quantity of ketones like aceto acetic acid etc. in urine is called **ketonuria.**

14. Hematuria : Passing out of red blood corpuscles (RBCs) in urine known as **hematuria.**

15. Hemoglobin urea : Presence of

hemoglobin in urine is called **hemoglobin urea**.

16. Pyuria : Presence of **puss cells** in urine is called **pyuria**.

17. Jaundice : Presence of excessive bile pigments in urine is called **jaundice**. This is seen normally in hepatitis or check in bile ducts.

18. Alcaptonurea : Presence of **alcapton** or **homogenetisic acid** in urine is known as **alcaptonurea**. When alcaptone is in contact with air, the urine shows black colour. This is also called **black urine disease.**

Hemodialysis :

When the kidney stops working. Then urea in quantity increases in blood. This state is known as uremia. Artificial renal device is needed for excreting out urea and other waste materials. Therefore, this process is known as **hemodialysis.**

In this process, firstly removal of blood form one main artery of the body and cool it at 0^0C then is mixed anti coagulant, **heparin**. After than this mixture is sent into an artificial kidney made of many for tubules covered with cellophane membrane. This membrane is impermeable for big size molecule like protein and permeable for urea, uric acid, creatinine and mineral salts. There is a fluid filled in the middle of these membranes which is called dialysis fluid. The nitrogenous waste substances excreted from the blood from down in the dialysis fluid. In this plasma protein is not decreased. This process in which the excretory materials diffuse out in the dialysis fluid of the device from the blood flowing in the tubules and the blood is made free from the excretory materials is known as **dialysis.**

After the process is over blood is taken out of the artificial kidney, warmed (on body temperature) and anti heparin is mixed again in the vein of body of the patient. The life span of a person having uremia disease can be increased.

Kidney Transplantation

When the kidney of a diseased person stops working completely then they may not be treated and kidneys from healthy person are transplanted. This kidney transfer process is known as **kidney transplantation**. The person giving kidney is known as kidney donor. Kidney donor should be close relative person, because blood and tissue structure is nearly same of the both relatives.

If the kidney of an unknown person is transplanted, then the immune system of the diseased may reject the new kidney. As such the new kidney could not work and the patient may die.

To face this, the immune system is inactivated with some specific medicines. Due to this, probability of acceptance by the diseased person for transplanted kidney increases more.

Important Points

1. To excrete out the nitrogenous waste materials from the body is known as excretion.
2. The organs which help in the excretion of waste materials are called **excretory organs**. Excretory organs together make the **excretory system**.
3. Those animals in which the excretion of nitrogenous waste is done in the form of ammonia are known as **amonotelic** animals.
4. Such animals which excrete mainly urea, are called **ureotelic animals.**
5. Such animals which excrete mainly uric acid are known as **uricotelic animals.**
6. The formation of kidney in human is from embryonic mesoderm and they are **metanephric** type.
7. There is, on the inner concave surface of the kidney a pit like structure, which is called **hilum.**
8. There are three layers found in the wall of urinary bladder - **external layer-serosa** of peritoneum, **middle**-unstripped muscular layer and **internal** mucous layer.
9. Kidney is differentiated in two parts -External part **cortex** and internal part **medulla**.
10. Uriniferous tubule or nephron is differentiated into following parts-

    (i) Malpighian body (ii) neck (iii) proximal convoluted tubule (iv) Henle's loop (v) distal convoluted tubule (vi) collecting tubules.
11. The process of urine formation is completed in

the following steps-

(1) ultra filtration

(2) selective reabsorption

(3) secretion

12. The structural and function unit of kidney is nephron or uriniferous tubule.

13. Artificial renal device is needed for excreting out urea and other waste materials from the body. Therefore, this process is called **hemodialysis.**

14. When in a diseased person kidneys completely stop working than these cannot be treated and kidneys from other healthy person are transplanted in place of them. This process of transfer of kidneys is known as kidney transplantation.

Practice Questions

Multiple Choice Questions

1. Main excretory material in human is-

(a) uric acid (b) ammonia

(c) urea (d) amino acid

2. Main excretory organ of human is-

(a) lung (b) kidney

(c) skin (d) liver

3. Henle's loop contains-

(a) urine (b) urea

(c)blood (d) glomerular filtrate

4. The relation of renal columns of Bertini is with-

(a) By kidney (b) By urinary bladder

(c) liver (d) By testis

5. Human kidneys are-

(a) pro nephric (b) meta nephric

(c) meso nephric (d) all types.

6. Where is ultra filtration occurs-

(a) glomerulus

(b) Bowman's capsule

(c) urinary bladder

(d) blood vessel

7. Glomerulus filtrate is-

(a) mixture of water ammonia and erythrocytes

(b) erythrocytes and blood without plasma protein

(c) blood without blood corpuscles

(d) urine

8. The vessel carrying blood in glomerulus is

(a) efferent arteriole

(b) renal artery

(c) afferent arteriole

(d) renal vein

Very Short Answer Questions

1. What is excretion?
2. What are called ammonia excreting animals?
3. What are uric acid excreting animals called?
4. What is ultra filtration?
5. Write the name of the unit of excretion in kidney.
6. Name the blood vessel coming out of glomerulus of kidney.
7. What is called the state of pain at the time of passing out urine?
8. Where is glomerulus found? What is its main function?
9. What is Malpighian body?
10. Where is Henle's loop found?
11. What are column of Bertini?
12. Write main function of kidneys in the body?
13. What is hemo dialysis?
14. What is called the presence of urea in blood?
15. What is glycosuria?

Short Answer Questions

1. Which are excretory organs other than kidneys in human? Describe.
2. What is Gout disease?
3. Explain Bright's disease.
4. What is the role of ultra filtration selective reabsorption in the formation of urine?

5. What do you understand by kidney transplantation? Explain in short.

Essay Type Questions

1. Describe excretory system of human with diagram.
2. Describe the functional anatomy of human uriniferous tubule.
3. Describe the other excretory organs of human.
4. Describe different diseases related to excretion.

Answer Key-

1. (c) 2. (b) 3. (d) 4. (a)
5. (b) 6. (a) 7. (b) 8. (c)