UNIT 15

HOMEOSTASIS

Major Concept

15.1 Homeostasis
15.2 Osmoregulation
15.3 Excretion
15.4 Excretory system of Man
15.5 Disorders of Urinary Tract
15.6 Thermoregulation

Learning Outcomes

Students will be able to:

- Describe three elements i.e., receptors, control centre and effectors which operate homeostatic mechanisms.
- Relate the homeostatic mechanisms with the negative and positive feedback systems.
- Differentiate between osmoconformers and osmoregulators.
- Define osmoregulation.
- Explain the problems faced by osmoregulators.
- Explain the different methods of osmoregulation found in freshwater, marine water and terrestrial habitats.
- List various nitrogenous compounds excreted during the process of excretion.
- Explain the nature of excretory products in relation to habitat.
- Explain different organs of urinary system. Describe the structure of kidney and relate it with its function.
- Explain the detailed structure of nephron.
- Explain the processes of glomerular filtration, selective re-absorption and tubular secretion as the events in kidney functioning.
- Explain that concentration of urine is regulated by counter-current and hormonal mechanisms.
- Justify the functioning of kidneys as both excretion and osmoregulation.
- Compare the function of two major capillary beds in kidneys i.e., glomerular capillaries and peritubular capillaries.
- List urinary tract infections and the bacteria responsible.
- Explain the causes and treatments of kidney stones.
- Outline the causes of kidney failure.
- Explain in detail the mechanism and problems related to dialysis.
- Describe the principles and the problems associated with kidney transplant.

- Define thermoregulation and explain its needs.
- Classify animals on the basis of the source of body's heat i.e. ectotherms and endotherms.
- Classify animals on the bases of the ability to thermoregulate i.e. poikilotherms and homeotherms.
- Describe the regulatory strategies in man for thermoregulation.

Introduction

The **environment** is everything that makes up our surrounding and affects our ability. There are two types of environments.

a) **External Environment**, that occurs outside of organism.

b) **Internal Environment**, that occurs within an organism.

All living organisms must regulate their internal environment to continue their life processes and ultimately to survive. The term homeostasis was coined by physiologist Walter Cannon in 1932 in his famous book "Wisdom of the body". The term is derived from Greek roots meaning "similar" and "a state of stability".

In this unit we will study the mechanism of homeostasis, concept of feedback mechanism, elements of homeostasis *i.e.* osmoregulation, excretion and thermoregulation and some disorders of urinary tract and their management in human.

15.1 Homeostasis

Homeostasis is the ability of an organism to maintain a relatively stable internal state that persists despite changes in the outside environment. There are three components of homeostasis *i.e.* **Osmoregulation** (maintenance of water and dissolved solutes in nearly constant state), **Excretion**, (Removal of metabolic wastes from body, especially nitrogenous wastes), **Thermoregulation**, (The maintenance of constant body temperature).

15.1.1 Mechanism of Homeostasis

The internal changeable factors of body like solutes, water and temperature are called **variables**. These are influenced by external environmental changes. The variables have ideal or normal value in the internal environment. This normal value is called **set point**. This value is "set" or "stored" in memory. There are three components of homeostasis.

i) **Receptor:** The part of control system which detects the change (stimulus). The change may be either external or internal environment (variable.)

ii) **Control Centre:** Information travels along

Extra Information

Hypothalamus plays a significant role in maintaining homeostasis by regulating, temperature, water balance regulating, hormone production, *etc.*

(afferent) pathway to the control centre which determines the approximate response and course of action. Information sent from control centre travels down the (efferent) pathway to the effector.

iii) Effector: The effector gives response which balances out the original stimulus to maintain homeostasis.

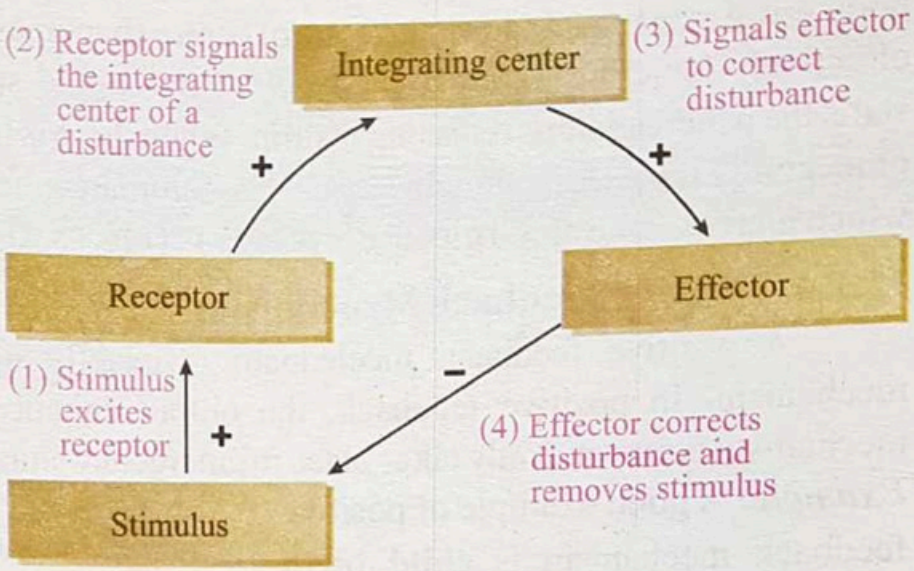

Fig. 15.1: Components of Biological Control System

Example: The maintenance of constant body temperature in human *i.e.* 98.6F. When our body temperature rises above this temperature, we start sweating to cool ourselves so that our body temperature is maintained. (Fig.15.1)

15.1.2 Concept of Feed Back Mechanism in Homeostasis

A feedback mechanism is a loop system wherein the system responds to a perturbation (change or disturbance). The response may be in the same direction (positive feedback) or in the opposite direction (negative feedback).

In **biological sense,** a feedback mechanism involves a biological process that tends to initiate or inhibit the production of any product (enzyme, hormone) in the body.

The feedback mechanism may be observed at the levels of cells, tissues and organs. It regulates homeostasis to achieve certain range of optimal conduction.

15.1.3 Negative Feedback Mechanism

Almost all homeostatic control mechanisms are negative feedback mechanisms. These mechanisms change the variable back to its original state or "ideal value" thus creates stability.

Example: The control of blood glucose by insulin is a good example of negative feedback mechanism. When blood sugar (glucose) rises, receptors in the

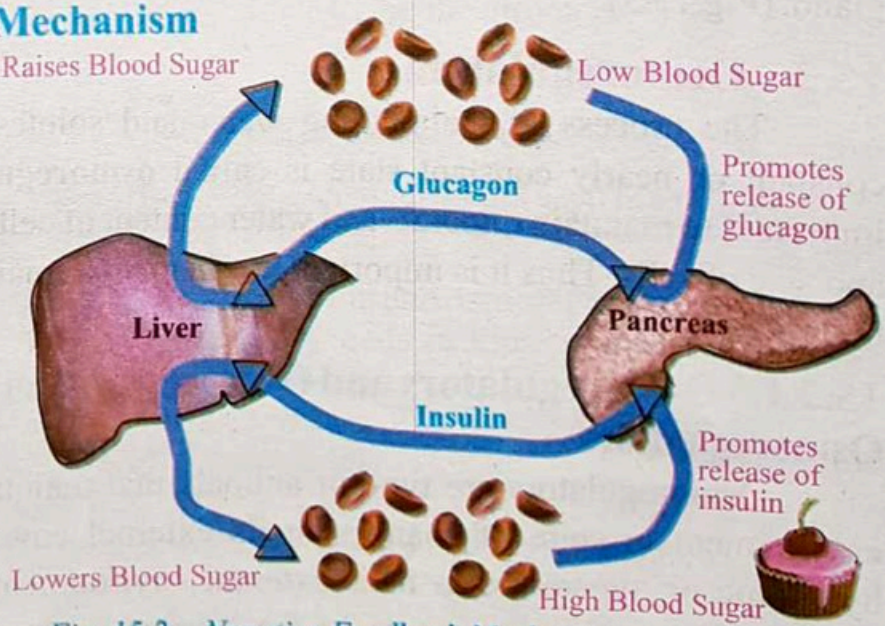

Fig. 15.2: Negative Feedback Mechanism

body sense a change. In turn, the control centre (pancreas) secretes insulin into the blood effectively lowering blood sugar levels. Once blood sugar level reaches homeostatic state, the pancreas stops releasing insulin. When there is low level of glucose in blood, the glucagon is released from pancreas. This stimulates the production of glucose in liver which increases the blood glucose level again. (Fig.15.2)

15.1.4 Positive Feedback Mechanism

A positive feedback mechanism is exactly opposite of negative feedback mechanism. In positive feedback, the output enhances the original stimulus. This mechanism is rare and only takes place in emergency situations *i.e.* creates instability.

Example: A good example of positive feedback mechanism is **child birth** (contraction of uterus send impulse to pituitary gland). During labour period a hormone called oxytocin is released from pituitary gland that stimulates the contractions of uterus wall. The increase in contractions causes more oxytocin to be released and the cycles go on until the birth process is completed. The oxytocin is made by neurosecretory cells in hypothalamus and stored in posterior lobe of pituitary gland. (Fig.15.3)

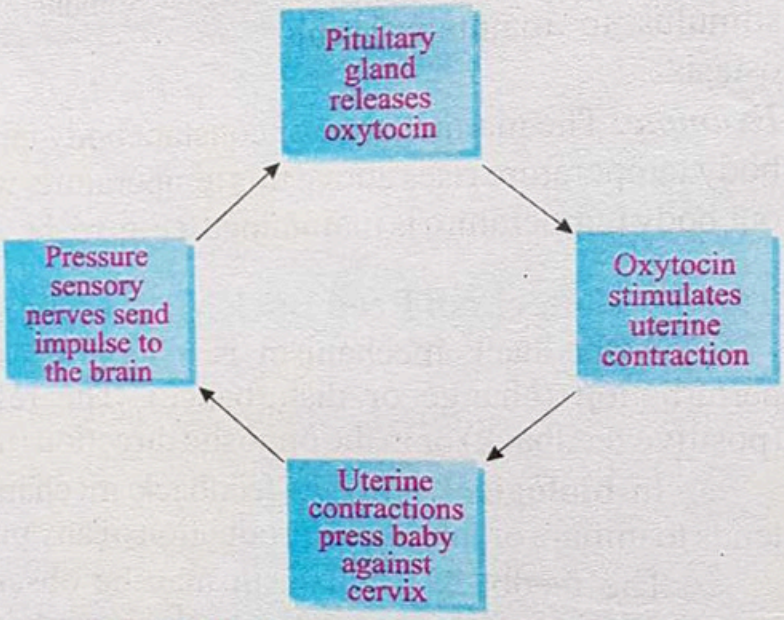

Fig. 15.3: Positive Feedback Mechanism

15.2 Osmoregulation

The process of maintaining water and solutes concentration in the body at constant or nearly constant state is called **osmoregulation**. The osmoregulation is important to maintain minerals and water content of cells and it also maintains the shape and size of cells. Thus it is important mechanism to maintain homeostatic conditions of body.

15.2.1 Osmoregulators and Osmoconformers

Osmoregualtors

Osmoregulators are type of animals that maintain a constant internal osmotic environment in spite of changes in its external environment. These organisms are hypotonic or hypertonic to their external environment. These organisms can live in almost all types of environments. *i.e.* fresh water, marine water and on land.

Osmoconformers

Osmoconformers are such organisms whose body fluids are in osmotic balance with their environment. However, their ionic composition may be different from that of external environment but their internal environment is isotonic to the external environment. These organisms can live only in marine environment. Generally, most marine invertebrates are osmoconformers.

Problems faced by Osmoregulators

Osmoregulators usually face following problems.

a) In hypotonic medium, endosmosis occurs so they have to face the problem of excess of water. Therefore, osmoregulators must eliminate excess of water.

b) In hypertonic medium, exosmosis takes place. Therefore, they must continuously take water.

c) The marine animals have to face the problem of excess of salts in their body, which come in their body along with water, so they have to get rid of extra salts.

15.2.3 Osmoregulatory Adaptations in Animals

i) Fresh-water Animals

The fresh water environment is hypotonic to animals. Therefore, the main osmoregulatory problem of these animals is excess of water. So fresh water animals show following adaptations to overcome this problem. (Fig.15.4)

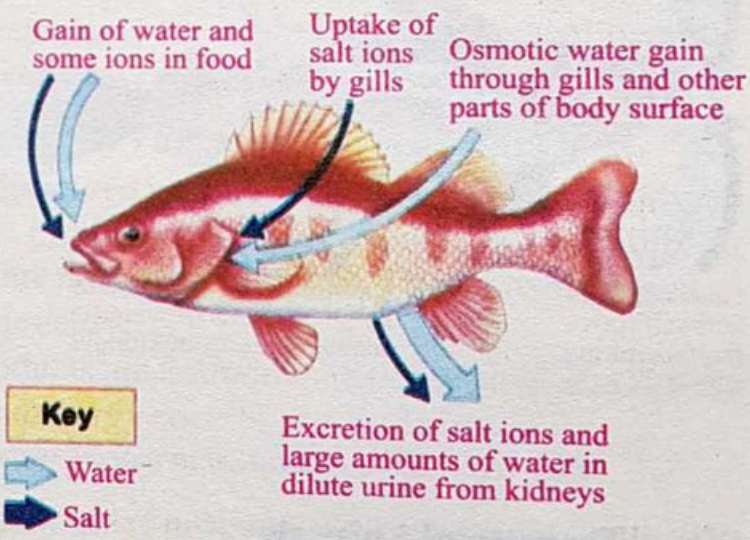

Fig.15.4 Osmoregulation in Fresh Water Fish

- These animals continuously excrete large volume of dilute urine. Their kidneys reabsorb salts that are required in the body.
- They remove extra salts in the form of ions to make their internal environment less hypertonic. The ion removing cells are called **ionocytes** which are located in amphibian skin and gills of fish.
- The animal like protists of fresh water possess contractile vacuole to store and remove extra water.

ii) Marine Animals

The marine water has high salt concentration and therefore, the animals who live in such environment have to face the problems of shortage of water and excess of salts. To

tackle these problems, the marine animals show following adaptations.

- Teleost (bony fish) continuously drink large amount of water to compensate water loss.
- Some marine fishes possess rectal glands in rectum which store and remove extra salts along with faeces.
- Some marine fishes retain urea in their body to make their internal environment less hypotonic. To counteract the toxicity of urea these fishes possess **trimethylaminoxide (TMAO)** in their blood. The urea and TMAO also act as **osmolytes** (Any substance that contributes to the regulation of osmotic pressure in cells and tissues).
- Excretion of salts ions from gills and urine.

These are low molecular weight organic compounds that influence the properties of biological fluids. *e.g.* amino acid, urea, *etc.* (Fig.15.5)

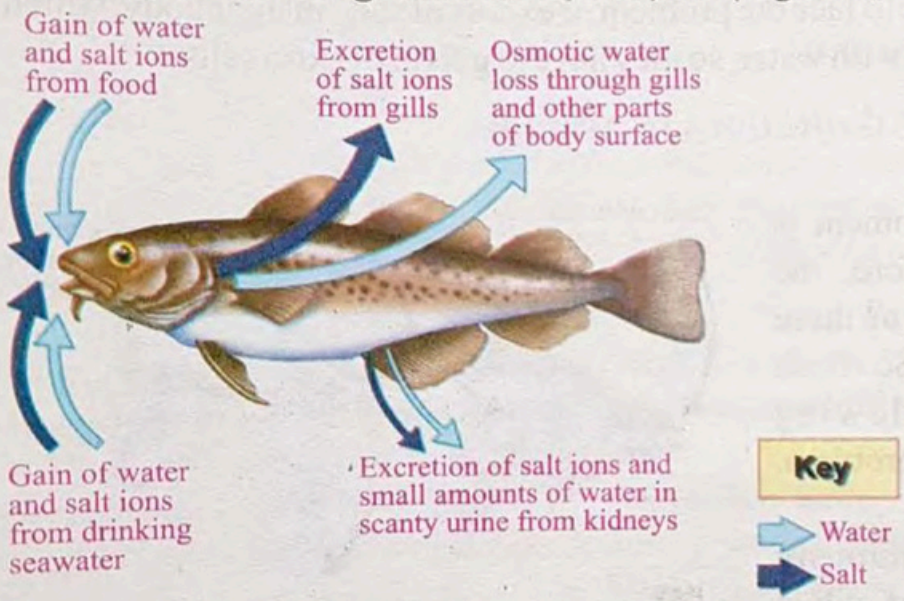

Fig. 15.5: Osmoregulation in marine water

Interesting Information

Although fishes are poikilothermic but there are some fishes such as great white shark can raise their body temperature. This help them hunt for prey in cold water.

iii) Terrestrial Animals

The insects and most mammals are the successful groups of land animals. The threat of dehydration is their major problem. Adaptations that reduce water loss are key to survival on land. These both groups of animals show number of adaptations to conserve water in their bodies.

- Insects have waxy exoskeleton, excrete their nitrogenous wastes in

Fig. 15.6: Tradigrade

the form of uric acid.

- Some insects have nocturnal habit and their eggs have impermeable membrane to prevent water loss.
- The mammals of terrestrial habitat usually have dead, keratinized, water resisting cells in their skin.
- Some are nocturnal in habit, which reduces water loss due to evaporation because of the lower temperature and higher humidity of night air.
- Camel can store water and can survive even losing 25% of water of body.
- Some mammals have developed the ability of **anhydrobiosis** (life without water). *e.g.* **Tradigrade** (an invertebrate). Infact these animals mainly feed on carbohydrates, which produce large amount of water when metabolized.
- Energy is utilized for osmoregulation activities, therefore, these animals eat more food. (Fig.15.6)

Extra Information

On average person pees about 3000 times a year. The average adult's urinary bladder can hold 16-24 ounces of urine.

15.3 Excretion

Excretion is a Latin word which means shifted out. It is the process by which animals remove metabolic wastes. The organisms through excretion, control osmotic pressure and maintain acid-base balance. In this way excretion promotes homeostasis.

15.3.1 Relationship between Excretory Products and Habitats

Most of metabolic wastes must be dissolved in water to be excreted from body, so the type and quantity of an animal's waste products mainly depends on availability of water. Most significant excretory products are nitrogenous wastes. These are produced as a result of breakdown of proteins and nucleic acids.

The main nitrogenous excretory products are ammonia, urea and uric acid. These wastes vary significantly in their toxicity and energy costs of producing them.

Ammonia

Animals that excrete ammonia as their chief nitrogenous wastes, need access to lots of water because 1gm of ammonia needs 500 ml water for its elimination. Moreover, ammonia is most toxic and cannot be stored in the body. It can only be tolerated at a very low concentration.

This large amount of water is only available in freshwater animals. Therefore, ammonia is the chief nitrogenous waste of fresh water animals. Such animals which excrete ammonia as their chief nitrogenous wastes are called **ammonotelic** animals.

Urea

Most terrestrial animals and many marine species simply do not have access to sufficient water to excrete ammonia. Therefore, these animals convert ammonia into urea

in their liver, and excrete urea as their chief nitrogenous waste.

The main advantage of urea is its low toxicity and needs less water for its elimination. 1g of urea requires only 50 ml of water for its removal. The main disadvantage is its energy cost *i.e.* energy is consumed for conversion of ammonia into urea. Animals which excrete urea as their main nitrogenous waste are called **ureotelic**.

Uric Acid

Insects, many reptiles and birds excrete uric acid as their chief nitrogenous waste. Uric acid is least toxic and does not readily dissolve in water. It therefore, can be excreted as a semisolid paste with very little loss of water. 1gm of uric acid consumes only 1ml of water for its excretion. It is a product of the metabolic breakdown of purine nucleotides. The uric acid is even more energetically expensive than urea, requiring considerable ATPs for synthesis from ammonia. Animals excreting uric acid as their primary nitrogenous waste are called **uricotelics**.

Extra Information

In human adult males are particularly susceptible to gout, a painful joint inflammation caused by deposition of uric acid crystals.

15.4 Excretory system of man

In human, excretory system consists of a pair of **kidneys**, each about 10cm in length, a pair of **ureters** for transporting urine. The two ureters drain into a common sac called **urinary bladder**. During urination, urine is expelled from the urinary bladder through a tube called **urethra**, which empties to the outside near the vagina in females and through the penis in males. **Sphincter muscles** near the junction of the urethra and bladder regulate urination. (Fig.15.7)

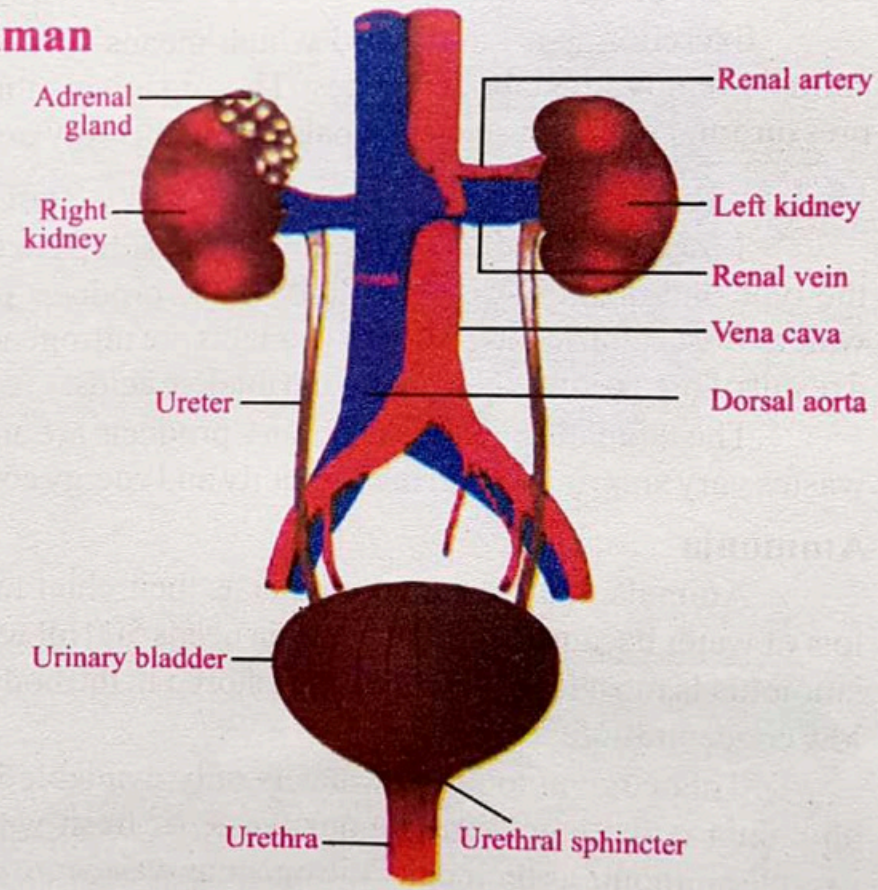

Fig. 15.7: Excretory System of Man

15.4.1 Structure and Function of Kidney

The human kidney is bean shaped structure, reddish brown in color, located in

lumber region on both side of vertebral column. The left kidney is about 1.5 – 2cm higher than the right kidney. Each kidney has an **outer renal cortex** and **inner renal medulla** region. The medulla contains cone shaped structures called **pyramids**. The pointed end of pyramid is directed towards hilus. The **hilus** is the depressed area of kidney in the middle. Both regions are supplied with blood by a renal artery and drained by a renal vein. Within the cortex and medulla lie tightly packed excretory tubules (nephrons) and associated blood vessels. The excretory tubules carry and process a filtrate produced from the blood entering the kidney. Nearly all of the fluid in the filtrate is reabsorbed into peritubular capillaries. The remaining fluid leaves the excretory tubules as urine.

Extra Information

Nephrology is the study of structure, functions and diseases of kidney.

Kidneys filter about 180-liter blood in 24 hours and only 1 – 1.5 liter urine is formed. (Fig.15.8)

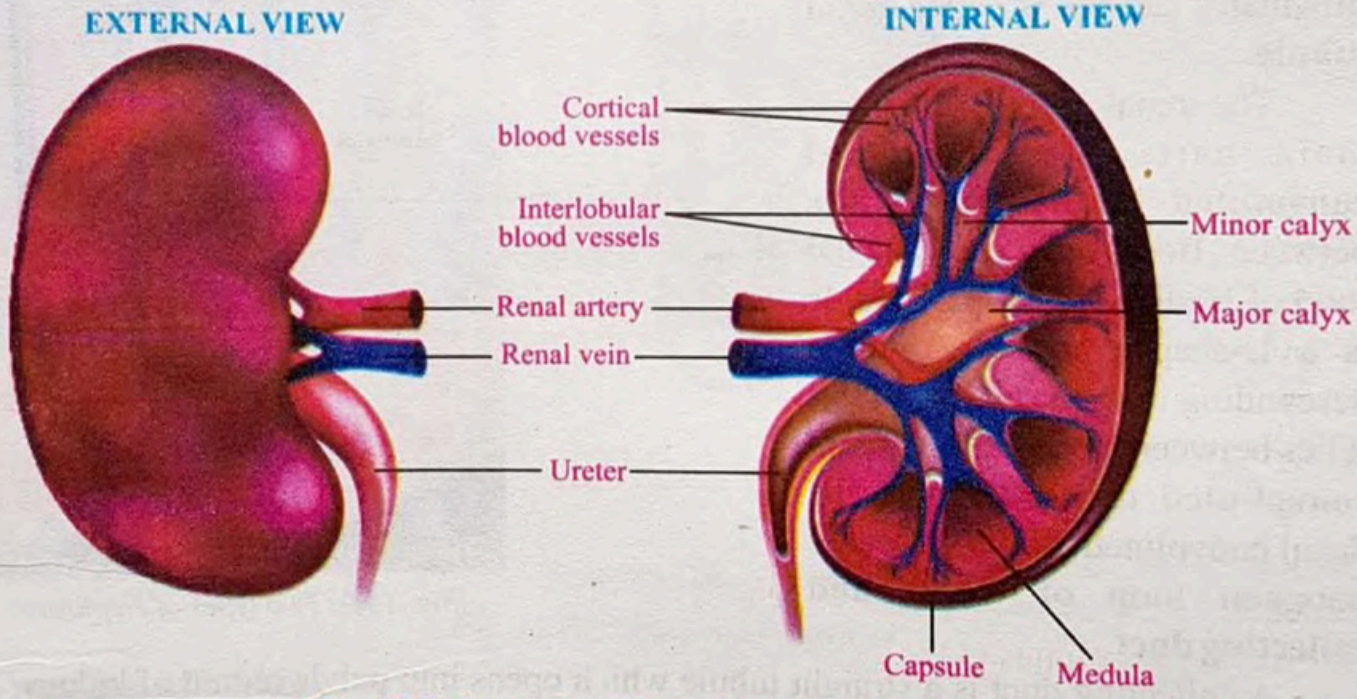

Fig. 15.8: External and Internal Structure of Kidney

Nephron

The nephrons are the structural and functional units of kidney. There are about 1million nephron in each kidney. There are two types of nephrons *i.e.* **cortical nephrons** which are located in cortex of kidney, more in number about 80-85% of total nephrons of kidney. The other type is **Juxtamedullary nephrons**. These

Information

* The blood flow in kidney is less high than the blood flow in liver but more high than brain.
* In adults, kidneys form only 0.5% of body weight.

nephrons have long **loop of Henle**, the coiled part of this nephron is located in the cortex while its loop of Henle (U shaped part) is located in medulla. The Juxtamedullary nephrons are essential for production of hypertonic urine. These nephrons are active when there is shortage of water in the body.

> **Extra Information**
>
> Once a person reaches the age of 40, the number of functional nephrons start falling at the rate of 1% a year.

Each nephron consists of a single long tubule as well as a ball of capillaries called the **glomerulus**. The blind end of the tubule forms a cup shape structure called **Bowman's capsule**, which surrounds the glomerulus. The part of nephron behind Bowman's capsule is called **renal tubule**.

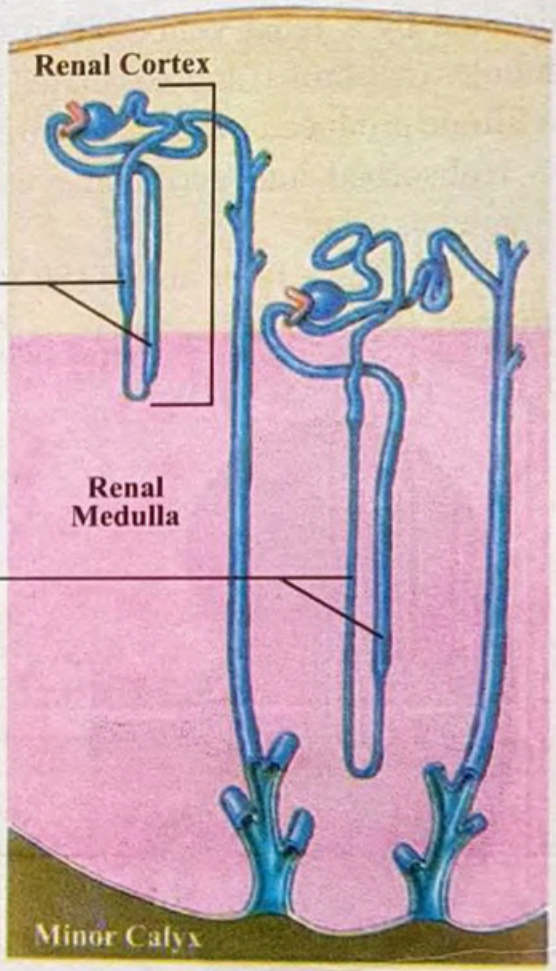

Fig. 15.9: Two types of Nephrons

The renal tubule has three main parts, *i.e.* **proximal convoluted tubule (PCT),** lies between Bowman's capsule and loop of Henle. The **loop of Henle** is a U-shaped structure with a descending and ascend-ing limbs. It lies between proximal and **distal convol-uted tubules(DCT)**. The distal convoluted tubule is located between loop of Henle and **collecting duct**.

A collecting duct is a straight tubule which opens into pelvis region of kidney. A single collecting duct receives many nephrons and many collecting ducts combine together to form large collecting duct. (Fig.15.9)

Blood Circulation in Nephron

Each nephron is supplied with blood by an **afferent arteriole** which brings blood from **renal artery**. The afferent arteriole gives bunch of capillaries called **glomerulus**. From glomerulus, **efferent arteriole** carry blood to **peritubular capillaries** which surrounds

> **Extra Information**
>
> The right kidney is a bit smaller and sits a little lower than your left kidney because, it is needed to make room for the liver.

the nephron and extend downward to form the **vasa recta** in the base of loop of Henle at medulla region of kidney. The peritubular capillaries drain into **renal venules** and venules drain into **renal vein.** (Fig.15.10)

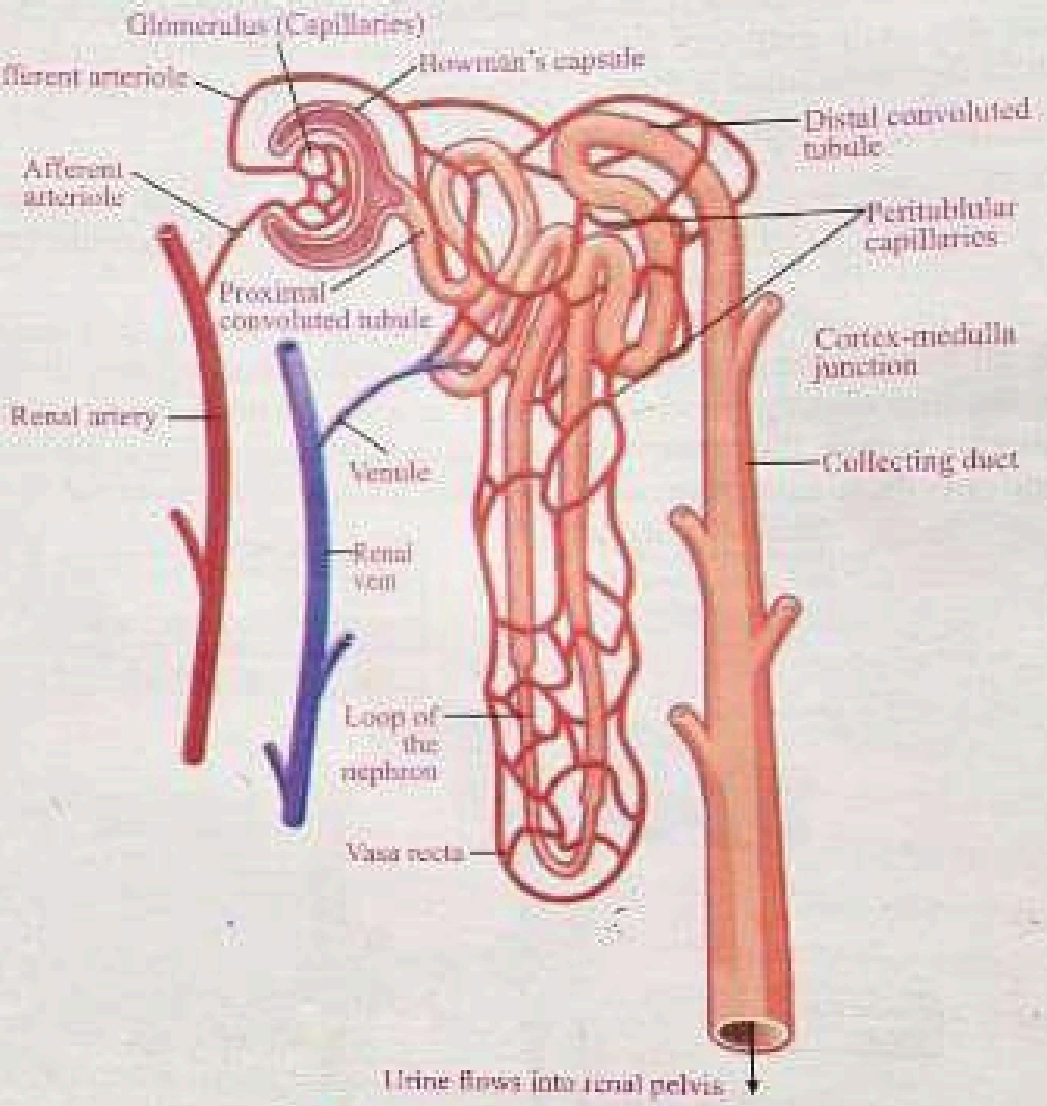

Fig. 15.10: Structure of Nephron

Function of Kidney

The kidney is a vital homeostatic organ of the body which performs number of functions. These functions include production of hormones, (*e.g.* renin, erythropoietin), regulation of fluid balance, control on blood pressure *etc.* However, the primary function of kidney is to make urine and purify blood.

Urine Formation

The kidneys filter unwanted substances from the blood and produce urine. There are 3 main steps of urine formation, *i.e.* glomerular filtration, selective reabsorption and tubular secretion.

i) Glomerular Filtration (Pressure filtration or ultra-filtration)

During filtration, blood enters the afferent arteriole and flows into the glomerulus where **filterable blood components**, such as water and nitrogenous wastes, will move towards the inside of the glomerulus and **non-filterable components,** such as cells and serum albumins will exit via the efferent arteriole. These filterable components accumulate in the glomerulus to form the glomerular filtrate.

ii) Selective Reabsorption (Tubular reabsorption)

The next step is reabsorption of useful substances. These substances include water, ions, glucose, *etc*. These substances are reabsorbed into peritubular capillaries from entire length of renal tubule and collecting duct.

Most of the water is reabsorbed by osmosis. Some mineral salts and in a normal individual, all of the glucose and amino acids are reabsorbed through the walls of the tubule into the surrounding blood capillaries. The selective reabsorption of these solutes requires energy. Hence, the process involved is active transport. It is a highly selective process, and only those substances which the body requires are reabsorbed readily.

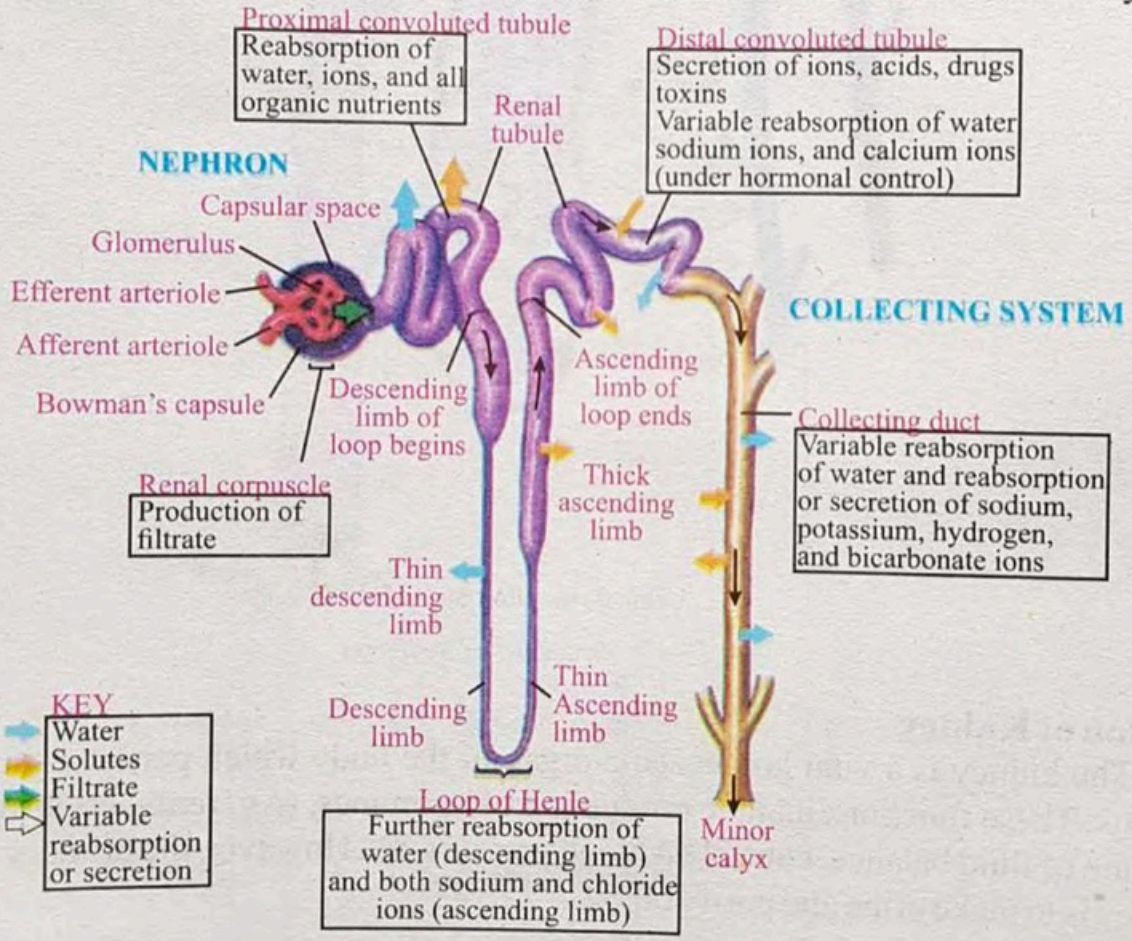

Fig. 15.11: Steps of Urine formation

Excess water, mineral salts and nitrogenous waste products (*e.g.* urea) are allowed to pass along the nephron and out through the collecting tubule into the renal pelvis as urine.

iii) Tubular Secretion

During the final step of urine formation some substances such as hydrogen ions, creatinine, and drugs will be removed from the blood through the network of peritubular capillaries into renal tubule and collecting duct. The end product of all these processes is urine, which is essentially a collection of substances that has not been reabsorbed during glomerulus filtration and tubular reabsorption. (Fig.15.11)

The Mechanism of Formation of Concentrated Urine (Counter Current Mechanism)

The mechanism in which kidneys produce concentrated urine when there is shortage of water in the body is called **counter current mechanism**.

This mechanism occurs in mammals and it is an adaptation to conserve water. The concentrated urine is formed in following ways:

- Na^+ and Cl ions are transported from the ascending limb of the Henle's loop by vasa recta.

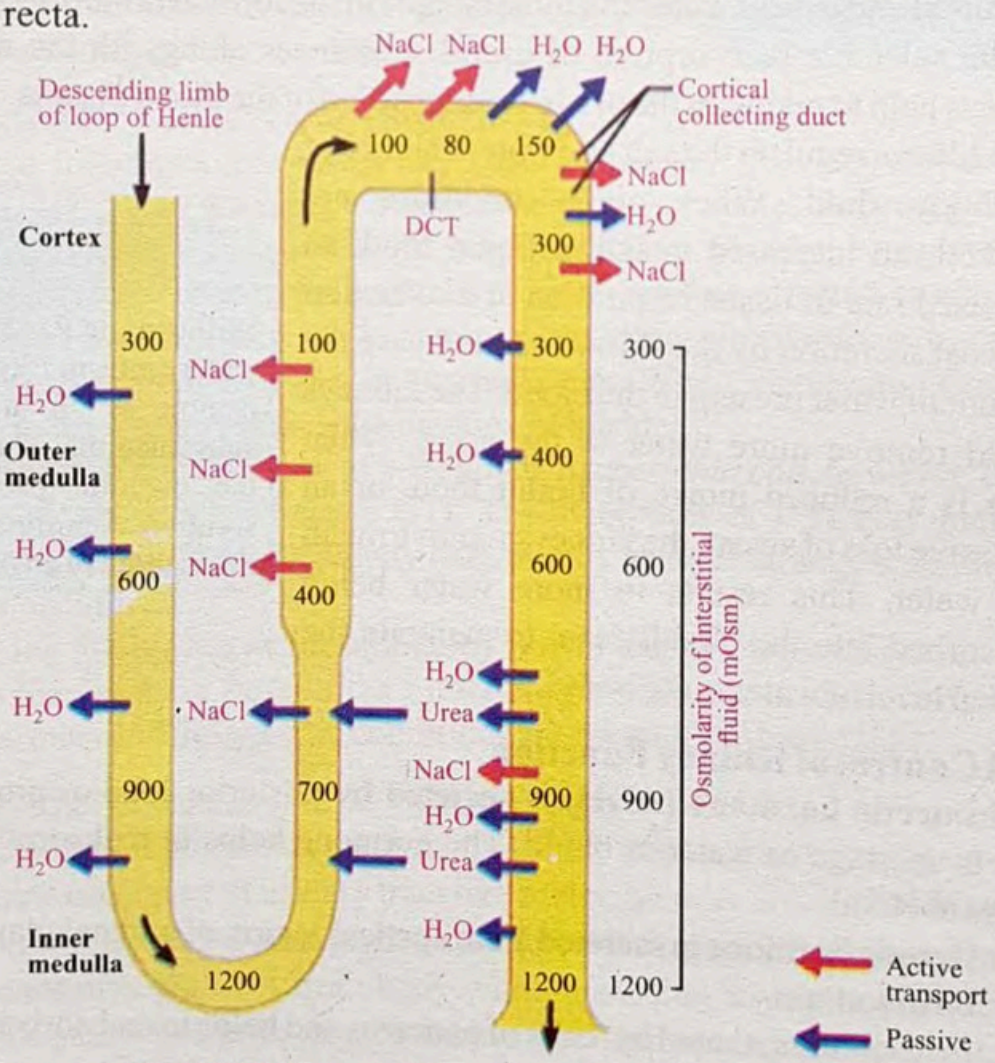

Fig. 15.12: Process of formation of concentrated Urine

- The ascending limb of the vasa recta, in turn, transport these ions to interstatium (the tissue between the loop of Henle and vasa recta).

Thus a concentration gradient of 300 mm in the cortex to 1200 mm in the inner medulla is created.

- Urea contributes to this process by being transported from the descending limb of the loop of Henle to the interstation.
- As urine flows downwards in the collecting tubule, it counters higher and higher concentration of solutes in the interstatium. Hence, it goes on loosing water due to osmosis.
- This is how urine is concentrated, the antidiuretic hormone also plays a role in making concentrated urine by reabsorbing water from kidneys. (Fig.15.12)

The functions of kidneys as both Excretion and Osmoregulation

- The kidneys are excretory organs, removing mainly nitrogenous waste products (*e.g.* urea) and excess water and mineral salts in the form of urine.
- By the selective reabsorption of useful substances alongwith the nephron, the kidneys help to maintain the pH and composition of the blood plasma.
- The kidneys regulate the salt and water balance of the body fluid. When other conditions are constant, an increased intake of liquid food, an increased rate of tissue respiration or a reduction of sweat secretion by the skin would increase the amount of water present in the blood. The kidneys would remove more water in the urine. When there is a reduced intake of liquid food, or an excessive loss of sweat, the kidneys remove much less water. This results in more water being reabsorbed into the bloodstream to maintain the normal level of water in the body.

Extra Information

Milliosmole Per Kilo-gram of water (mOsm / kg water). An osmole is an amount of a substance that contrib-utes to the osmotic pressure of a solution. A milliosmole is one thousandth of an osmole.

Hormonal Control of Kidney Function

Antidiuretic hormone (ADH) is secreted by posterior lobe of pituitary gland when there is shortage of water in blood. The hormone helps in reabsorption of water from kidneys to blood.

Aldosterone hormone is secreted from cortical region of adrenal gland and helps in reabsorption of sodium.

Insulin hormone secreted by cells of pancreas and helps to reabsorb glucose from glomerular filtrate to blood. (Table.15.1)

Table 15.1: Comparison between Glomerulus and Peritubular

S.No.	Glomerular Capillaries	Peritubular Capillaries
i)	Located in the mouth of the Bowman's capsule.	Located in the renal tubule of nephron.
ii)	Has very low blood pressure.	Have comparatively high pressure.
iii)	Impermeable to most substances.	Permeable for most substances like glucose, mineral ions, *etc.*
iv)	Has a basement membrane.	Has no basement membrane.

15.5 Disorders of Urinary Tract

The urinary tract includes kidneys, ureters, urinary bladder and urethra. The urinary tract disorders include urinary tract infections, kidney stones, kidney failure, bladder control problems and prostate problems. Some urinary tract disorders last only for a short time while other are long lasting.

Extra Information

Urology is the branch of medical science which deal with urinary tract disorders and treatment.

15.5.1 Urinary Tract Infections (UTI)

Such infections that affect any parts of urinary tract are called urinary tract infection (UTI). These are more virulent to female than male, can you guess why? It is due to shorter urethra in women, do not empty their bladder completely, and large exposed surface area of external genitalia. Ureters are less infected as compare to other parts of urinary tract due to its acidic nature. When upper site of urinary tract is infected, it is known as **pyelonephritis** *e.g.* kidney infection. When lower site of urinary tract is infected, it is known as **cystitis**, *e.g.* infection of bladder.

The most common cause of infection is *Escherichia coli*, however, other bacteria, viruses and fungi may also cause UTI. The symptoms of UTI may include, burning feeling during pee (urination), cloudy dark bloody urine or strange smelling pee, feeling tired, fever or chill, *etc.*

Taking antibiotics as prescribed by doctor and drinking more water to flush out pathogens like bacteria from urinary tract are possible treatments. Sexual contact with infected partners and unhygienic conditions are the major cause of UTI.

15.5.2 Kidney Stones (Nephrolithiasis)

The hard mineralized material that cling together and form pebbles within the kidney or any other part of urinary tract like ureter, bladder is called **kidney stone**. These are small in size about **2-3 mm** in diameter and one to many in number. These very small kidney stones may pass out from body without causing any symptoms. The symptoms may include pain while urinating, blood in urine, sharp pain in back and lower abdomen, nausea and vomiting.

Calcium stones are the most common type of kidney stones. They are usually made of calcium oxalate and calcium phosphate. **Uric acid stones** form when urine is often too acidic. Uric acid can form stone by itself or mixing with calcium. (Fig.15.13)

Treatment:- The **treatment of kidney** stone depends on size, composition and location of stone. This can be traced out by x-ray, CT scan, blood test, urine test, *etc.*

Small stones are usually treated with medicine but large and complex stones usually need surgery or lithotripsy.

Lithotripsy

Lithotripsy is a medical procedure involving the physical destruction of hardened masses like kidney stones, **bezoars or gallstones**. The term is derived from the Greek words meaning 'breaking (or pulverizing) stones".

Types of Lithotripsy

There are two types of lithotripsy:

1. Extra corporeal Shock Wave

The **lithotripsy** uses shock waves to break up the kidney stones into small pieces. After the treatment, these small pieces will pass through urinary tract and out of body. This treatment usually takes 45 minutes to one hour and may be done under general anaesthesia so that patient does not feel pain.

2. Laser Lithotripsy

Another treatment is **ureteroscopy,** in which long tube shaped tool is used to find, remove and break stone. A **laser** is used to break the stone into small pieces so that these pieces may pass through the urinary tract.

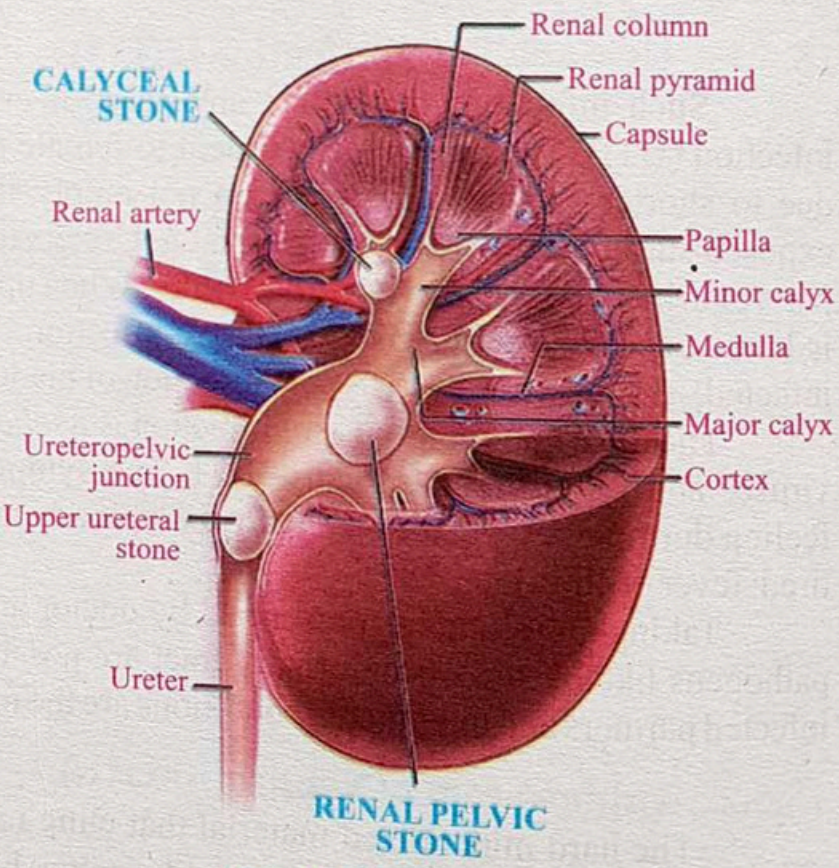

Fig. 15.13: Kidney Stone

15.5.3 Kidney Failure

Kidney failure, also called **end-stage renal disease (ESRD)**, is the last stage of chronic kidney disease. Kidney failure means that kidneys are not working well enough for survival of patient without dialysis or a **kidney transplant**.

There are many factors related to kidney failure. *e.g.* **Autoimmune diseases,** kidney stone, other health problems like diabetes, high blood pressure, use of drugs, bacterial infections.

Some of the symptoms of kidney failure are nausea and vomiting, muscle cramps, appetite loss, swelling in feet and ankles, too much urine, sleeplessness, *etc*. Acute kidney failure is usually caused by accidental injuries, vomiting, diarrhoea, shortage of water due to excessive sweating or excessive excretion of urine (diuresis), blockage of ureter due to kidney stone, severe nephritis, *etc*.

There are just few options for kidney failure patients. These include several types of dialysis and kidney transplant.

15.5.4 Dialysis

It is the temporary treatment for kidney failure patients. In this procedure, toxins and wastes are removed from the body by artificial means *i.e.* using dialyzing fluid. However, dialysis is not a permanent cure for kidney disease. There are following types of dialysis.

Extra Information

Diabetes is the leading cause of chronic kidney diseases 44% followed by high blood pressure 28%.

Hemodialysis

It is the most common type of dialysis. This process uses **artificial kidney (hemodialyzer)** to remove wastes, toxins and extra fluids from blood.

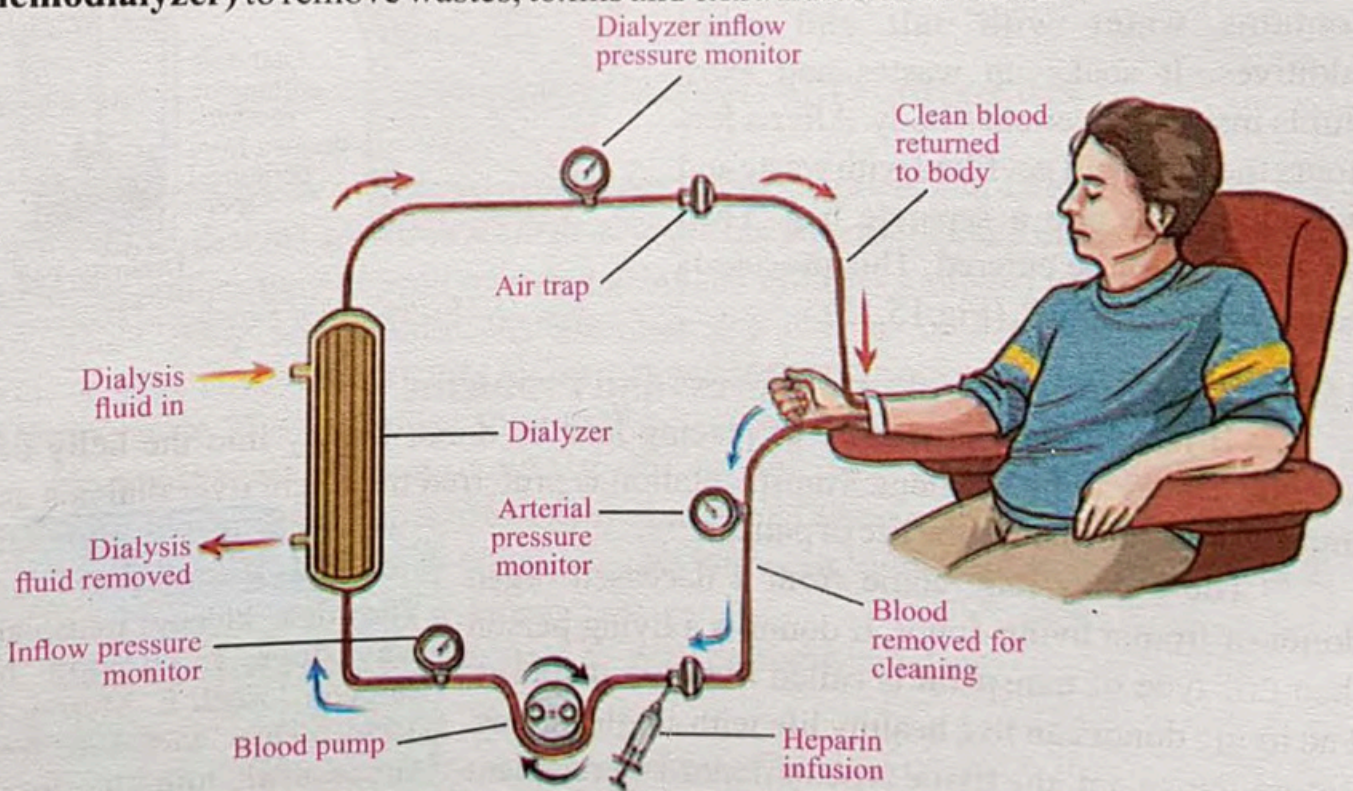

Fig. 15.14: Steps of Hemodialysis

During hemodialysis, blood passes from the patient's body to the dialysis machine through sterile tubing and into a filter called **dialyzing machine**. For this procedure, the patient has a specialized vascular tube placed between an artery and vein in the arm or leg called **gortex graft**. Sometimes a direct connection is made between an artery and vein in the arm. This procedure is called **cimino fistula**. Needles are then placed in graft or fistula and blood passes through the dialysis machine, through the filter and back to the patient. In the dialysis machine a solution on the other side of filter receives the waste products from the patient. (Fig.15.14)

Peritoneal Dialysis

This type of dialysis uses lining of abdomen called peritoneum to filter blood. A catheter is placed near the navel of patient a few weeks before the start of treatment. Once the area heals, the patient will be trained how to do peritoneal dialysis because patient can do this dialysis by himself. The catheter is used to transfer **dialysis solution** from a bag into patient's peritoneal cavity. This special fluid contains water with salt and other additives. It soaks up wastes and extra fluids inside the patient's body. After a few hours the fluid will get filled with waste and will drain out into a separate bag. Then fresh fluid will be entered. This process is called an "exchange". (Fig.15.15)

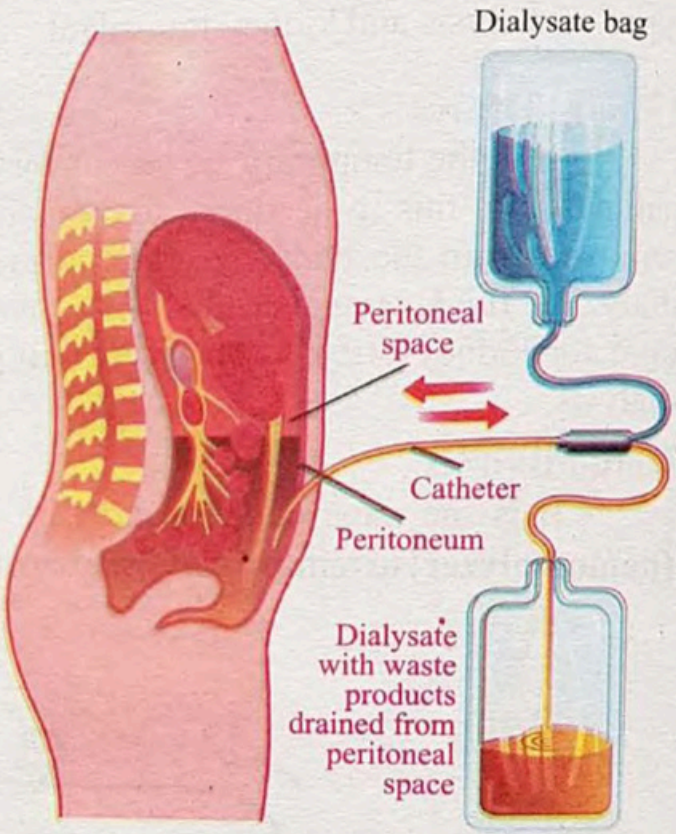

Fig. 15.15: Process of Peritoneal Dialysis

15.5.5 Kidney Transplant: Process and Problems

It is a surgical procedure of placing healthy donor kidney into the belly of a chronic kidney failure patient. Transplantation is preferred treatment over dialysis as it improves and normalize the life of patient.

The kidney may come from a deceased organ donor or from a living donor. If donor is a living person then this type of transplant is called **living transplant**. The living donor can live healthy life with single kidney. Before transplant, the tissue type of donor and recipient is made. A kidney transplant is done 3-4 hours' surgical

Extra Information

The first kidney transplant was done in Boston by surgeon Joseph E. Murray in 1954. This was the first successful human organ transplant.

procedure. A person getting a transplant most often gets one kidney. In rare cases, he or she may get 2 kidneys from a deceased donor. The affected kidney is usually left in place. The transplanted kidney is placed in the lower belly on the front side of the body and attached to a large artery. As soon as the transplanted kidney is connected to the blood vessels it will start the function of cleaning wastes from blood.

Extra Information

You don't need both of your kidneys to stay healthy. It might surprise you to learn that your body doesn't need two kidneys to perform an important job of removing wastes and regulating your metabolism. After donating your remaining kidney will take on the work of both kidneys.

Problems Associated with Kidney Transplant

A kidney transplant is a major operation. There are complications associated with kidney transplant. These include pain, delayed wound healing, bleeding and risk of infection, however, kidney rejection is the most serious problem. Medication like **cyclosporine** is given to suppress the immune system of recipient to prevent rejection of transplant kidney.

15.6 Thermoregulation

The maintenance of internal body temperature at nearly constant state so that the body can perform its metabolic activities at optimum level is called thermoregulation. Any change in temperature will affect the enzyme activity thus metabolic reactions will disturb.

15.6.1 Classification of Animals on the Basis of Temperature (Thermoregulation)

On the basis of temperature regulation, animals can be divided into two groups. **Poikilotherms** are those animals who are not able to regulate their internal body temperature, rather they depend on external source of heat (sunlight) to get themselves warm. Their body temperature changes with the change of external temperature. Therefore, they have to **hibernate** in low temperature and **aestivate** (summer sleep) in high temperature. These include fish, amphibians and reptiles.

Homeotherms are those animals who are able to regulate their internal body temperature and are not dependent on external source of heat.

These animals have high metabolic rate and need more food to generate heat in their body. These include birds and mammals.

On the basis of heat production, animals can be divided into three categories.

Ectotherms

Ectotherm animals generate metabolic heat at low level due to low metabolic rate. Therefore, they depend on external source of heat for their survival. These include

insects, fish, amphibians and reptiles.

Endotherms

Endotherms can generate enough heat to maintain their body temperature due to high metabolic rate, thus can survive in all sorts of habitats. These include birds and mammals.

Heterotherms

Heterotherms are type of animals with a thermoregulatory strategy, intermediate to ectotherm and endotherms. They produce heat in their body but also depend on external source of heat. They include small mammals like bat and small birds like humming bird.

15.6.2 Thermoregulatory Strategies in Man

The body temperature of human is regulated and stabilized by **hypothalamus** (a region of brain basically concerned with homeostasis). In case of any variation in set point, endocrine production initiates control mechanism to increase or decrease energy production or dissipation to return the temperature towards the set point. During hot (hyperthermia) conditions, following changes are noticed in body:

- Vasodilation *i.e.* expansion of blood capillaries under the skin so that more heat can be brought towards skin for dissipation of heat.
- Activation of sweat glands.
- Relaxation of hair erector muscle.

During cold (hypothermia), following changes occur to prevent heat loss and generate heat.

- Inactivation of sweat glands.
- Vasoconstriction.
- Increase in metabolic activities.
- Shivering may starts.
- Brown fats are consumed for more and rapid heat production.

Science, Technology and Society (STS)

1. Describe the importance of kidney donation for the benefit of kidney failure patients.

There is no doubt that being a living donor is a huge benefit to the recipients of living donor kidney, usually live longer, healthier life compared to those who receive a deceased donor kidney, it is important to recognize there can be benefit to donor as well. Such as, saving the life of other person giving a renewed and improved quality of

life to another person, greater understanding of your own health. If we can live with single kidney then why human being has two kidneys? Perhaps to donate one kidney to save the life of kidney failure patients.

2. Name the important kidney transplant centres in the Province.

There are many kidney transplant centre in Pakistan. These includes Shifa International Hospital, Kidney Transplant Program Agha Khan University Hospital, Kidney Transplant Doctors Hospital and Medical Centre Lahore, *etc*.

However, Sindh Institute of Urology and Transplantation (SIUT) is most prominent and pioneer in treating kidney related diseases in Pakistan. The Dr. Adeeb Rizvi has established this institute in 1971.

In the province of Balochistan only few kidney transplant centres have been established *e.g.* Balochistan Institute of Nephrology, Urology Quetta (BINUQ).

SUMMARY

- Ability of an organism to maintain internal environment at nearly constant state is called homeostasis.
- The internal changeable factors of the body are called variables.
- A feedback mechanism is a loop system within the system, responds to a perturbation.
- Almost all homeostatic control mechanisms are negative feedback mechanisms.
- The process of maintaining water and solute concentration in the body at nearly constant state is called osmoregulation.
- The fresh water environment is hypotonic to animals, therefore, the main osmoregulatory problem of these animals is excess of water.
- The mammals of terrestrial environment usually have dead, keratinized, water resisting cells.
- The process of removal of metabolic wastes from body is called excretion.
- 1 gram of ammonia needs 500 ml of water to be removed from body.
- The left kidney is about 1.5-20 cm higher than the right kidney.
- Nephrons are the structural and functional unit of kidney.
- The mechanism of producing concentrated urine when there is shortage of water in the body is called counter current mechanism.
- The urinary tract disorders include; UTI, kidney stone, kidney failure, prostate problem, bladder control problems, *etc*.
- Lithotripsy uses shock waves to break kidney stones.
- Kidney failure means that kidneys are not working well enough for survival of the patient.

- Dialysis is the temporary treatment of kidney failure patients, in which wastes are removed from body through a dialyzing fluid.
- Kidney transplant is a surgical procedure of placing healthy kidney into the belly of a chronic kidney failure patient.
- The maintenance of internal body temperature of body at a nearly constant state is called thermoregulation.
- Poikilothermic are those animals who cannot maintain their internal environment at constant state.

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Select the correct answer.

1. Body temperature regulation in human is based on complex homeostatic thermostat present in:
   (a) Thalamus (b) Pons
   (c) Hypothalamus (d) Amygdala
2. Trimethylamine oxide is produced in:
   (a) Cartilaginous / marine fish (b) Bony fish
   (c) Jawless fishes (d) Lung fishes
3. Which of the following structure of kidney is responsible for the production of concentrated urine?
   (a) Cortical nephrons (b) Juxtamedullary nephron
   (c) Vasa recta (d) Glomerulus
4. Animals that generate their own body heat through heat production as by product of metabolism:
   (a) Endotherms (b) Ectotherms
   (c) Heterotherms (d) All of these
5. The hormone affects ascending limb:
   (a) ADH (b) Aldosterone
   (c) Thyroxin (d) Both a and b
6. Concentrated urine is produced in mammals when there is
   (a) Excess of water in the body (b) Shortage of water in the body
   (c) Less urea in blood (d) Less glucose in blood
7. Water is mostly absorbed by
   (a) Proximal tubule (b) Distal tubule

(c) Loop of Henle (c) Collecting duct

8. Glomerulus are located in
   (a) Collecting duct (b) Renal tubule
   (c) Pelvis (d) Renal capsule
9. The ideal or normal value of variable is called
   (a) Set point (b) Output
   (c) Response (d) Stimuli
10. The salt secreting glands in some marine fishes are called
   (a) Sebaceous glands (b) Sweat glands
   (c) Rectal glands (d) Tear glands
11. The chief nitrogenous waste of fresh water animals is
   (a) Urea (b) Ammonia
   (c) Uric acid (d) Creatinine
12. The useful substances are reabsorbed from
   (a) Renal tubule (b) Renal capsule
   (c) Collecting duct (d) Vasa recta
13. Ureters are less affected as compare to other urinary tract infections due to:
   (a) Large surface area (b) Less acidic
   (c) Narrow tube (d) More acidic
14. The drug given to prevent kidney rejection is
   (a) Cyclosporine (b) Penicillin
   (c) Pain killers (d) Antibiotics

B. Fill in the blanks.

1. The maintenance of internal environment at constant state is called .....
2. The term homeostasis was introduced by .....
3. Those animals that can maintain their osmotic conditions at constant state are called .....
4. Marine fish usually have ..... to remove their extra salts.
5. Animals which excrete urea as their chief nitrogenous waste are called .....
6. The network of capillaries present in the mouth of Bowman's capsule is called .....
7. The process of formation of concentrated urine is called ..... mechanism.

8. Peritoneal dialysis uses the ..... cavity of body.
9. Hyperthermia is ..... body temperature.
10. The cyclosporine is used to prevent .....

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Define homeostasis and write its components.
2. Write the importance of negative feedback mechanism.
3. Write the importance of positive feedback mechanism for our body.
4. Differentiate between osmoregulator and osmoconformer.
5. Describe the problems faced by osmoregulators.
6. Write the importance of urea as chief nitrogenous waste of most terrestrial animals.
7. Illustrate the two types of nephrons.
8. Write the common causes of urinary tract infections.
9. Describe the three groups of animals on the basis of heat production.
10. Define Lithotripsy briefly describe laser lithotripsy.
11. Write the problems associated with kidney transplant.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Describe relationship between excretory products and habitats.
2. Define and explain structure of nephron.
3. Explain the steps of urine formation.
4. Define dialysis and explain the two types of dialysis.
5. Explain the kidney transplant process in detail.
6. Describe the osmoregulatory adaptations in different habitats.
7. Describe the external and internal structure of human kidney.
8. Define kidney stones. Explain types of lithotripsy.
9. Define feedback mechanism, describe in detail negative and positive feedback mechanism.
10. Explain classification of animals on the basis of temperature and also write thermoregulatory strategies in man.