HOMEOSTASIS

Chapter 15

Major Concept

In this Unit you will learn:

- Homeostasis
- Osmoregulation
- Excretion
- Urinary system of Man
- Disorders of Urinary Tract
- Thermoregulation

HOMEOSTASIS

The term homeostasis was introduced by Walter B. Cannon (1871–1945). He described it as a self-regulating process by which biological systems maintain stability while adjusting to the changing conditions. Homeostasis is essential for the continuity of life as it is responsible for the stability of body functions according to the environment.

Organisms live in terrestrial and aquatic environments. These environments have variable conditions, i.e., moderate to extreme conditions which influence upon the organisms and they tend to develop physical and physiological changes in their body accordingly. In view of the environmental changes, organisms need to maintain their internal body environment up to suitable limits. The body environment comprises of different components including body fluids, tissues, organs, systems etc. These components are physiologically well integrated and efficiently controlled and coordinated by endocrine as well as nervous systems. These systems ensure the proper performance of the homeostatic regulatory functions like **osmoregulation**, **excretion** and **thermoregulation**, in the body and adjust to maintain the balance between the external and internal body environment.

15.1 ELEMENTS OF HOMEOSTASIS

Homeostatic surveillance is based upon necessary physiological check and balance mechanism of the body functions that maintain its normal state called **feedback system**. Feedback mechanism develops through some integrated components **i.e., receptors, control center and effectors.** Receptors are the sensory organs that are neurologically connected with the nervous system, detect any external or internal environmental changes and send messages to the central nervous system (CNS). CNS act as control center and respond by concerned effector organs to bring back the normal state of the body.

15.1.1 Feedback systems

Feedback, in biology, a response within a system (molecule, cell, organism, or population) that influences the continued activity or productivity of that system. There are two types of feedback

mechanisms that counter act upon each other called positive and negative feedback.

The **positive feedback** is concerned with the increase or initiate the change of output for any biological process, e.g. if body is injured and bleeds positive feedback begins by the action of platelets. Platelets reached at the site of injury through circulating blood, recognize the damaged area and begin to stick together to stop the loss of blood and patch up the tear in the wall. Eventually blood clot is formed, the loss of blood is kept to a minimum, and the positive feedback ends. Positive feedback does not maintain a stable, homeostatic condition rather it intensifies the change that is happening to the body.

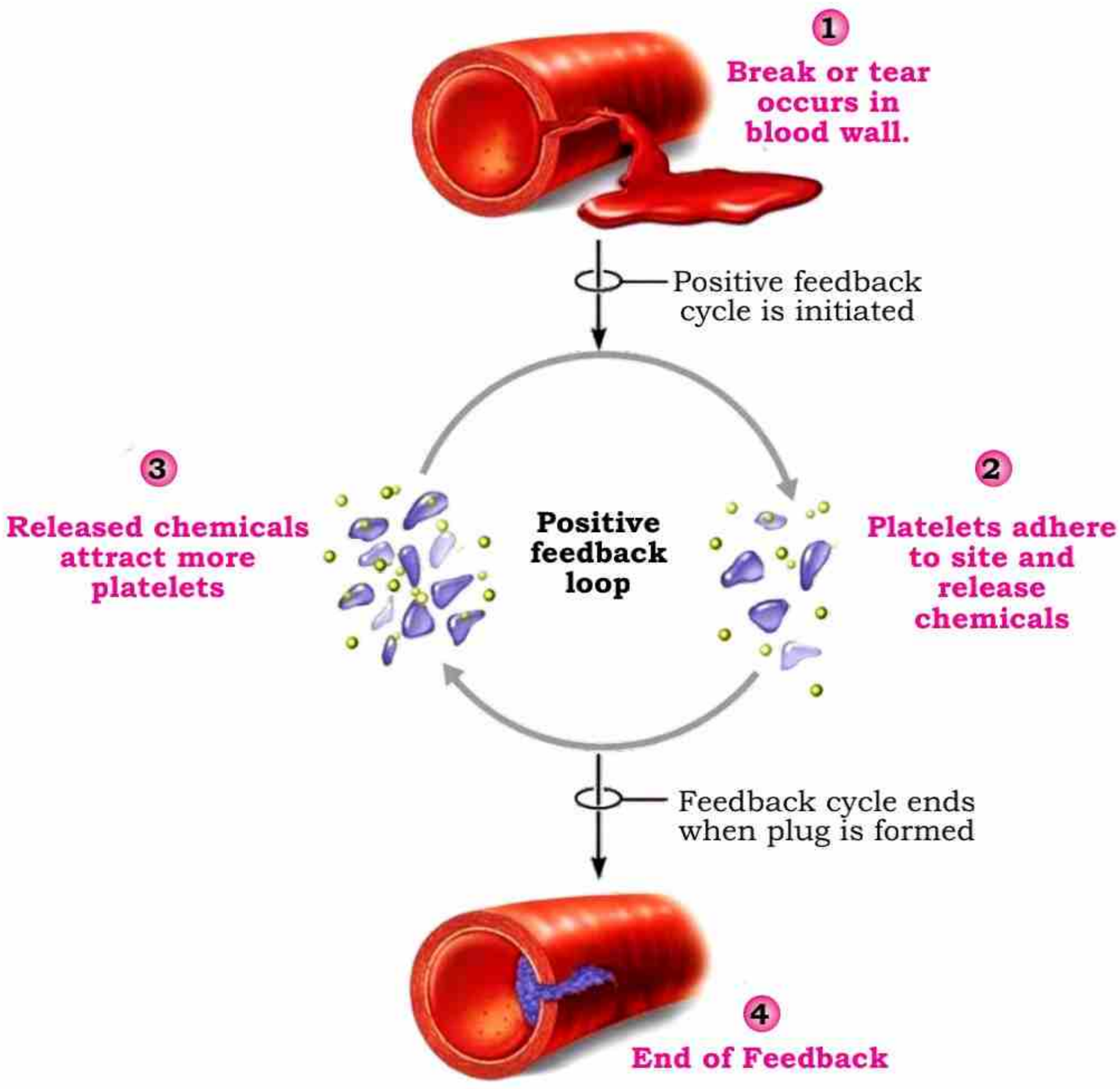

Fig.15.1 Positive feedback mechanism

The **Negative feedback** suppresses the normal physiological activities to bring body back to normal state e.g. when it is cold out,

and body temperature decreases below the set point range. A **set point** is the physiological value around which the normal range fluctuates. A **normal range** is the restricted set of values that is optimally healthful and stable. The negative feedback loop will cause the body to shiver producing heat and ultimate body temperature will return within the set point.

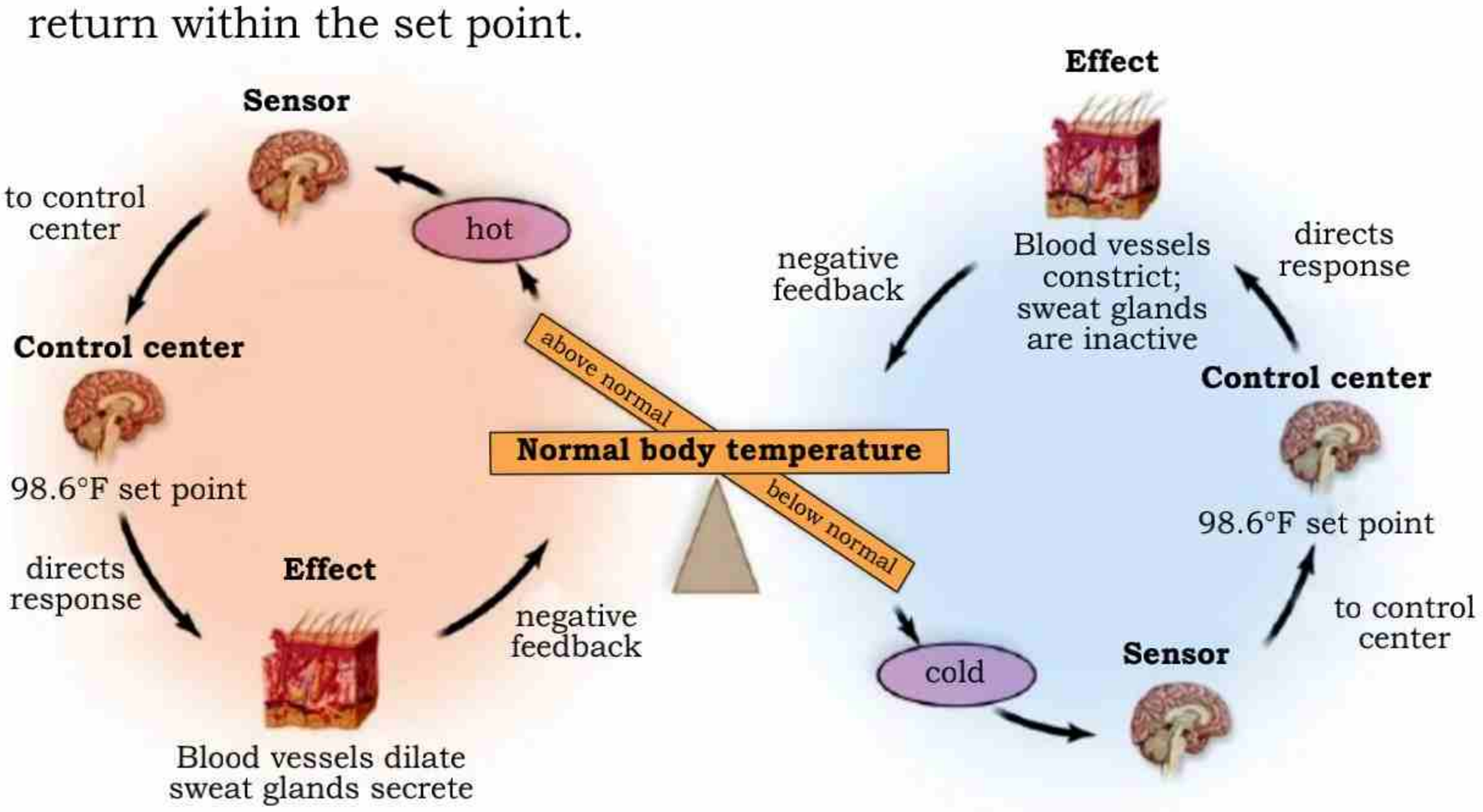

Fig.15.2 Negative feedback mechanism

15.2. OSMOREGULATION

Organisms must need appropriate amount of water and minerals in their body to perform many vital functions.

Extra Reading Material

Osmoconformers are another group. This does not mean that they have the similar solutes in their body as present outside instead they contain urea and trimethylamine oxide (TMAO) in their blood to adjust osmotic balance. TMAO accumulates in the tissue and protects against the protein-destabilizing effects of urea, for examples shark and most of the marine invertebrates like echinoderms (such as starfish), mussels, marine crabs, lobsters, jellyfish, ascidians are osmoconformers.

15.2.1 Osmoconformers and Osmoregulators

Osmoconformers	Osmoregulators
Organisms that have internal body solute composition equals or isotonic to the external environment	Organisms maintain a constant internal osmotic environment in spite of changes in their external environment
These are marine organisms.	They live in marine, fresh water and terrestrial environments.
Can survive in wide range of salinities	Can survive in a narrow range of salinities

15.2.2. Problems faced by Osmoregulators

Fresh water animals have an external hypotonic environment while they retain salts in their body, they have hypertonic internal body environment. In this case water enters the body by endosmosis through their organs like skin and gills and disturbs the internal osmotic balance. This problem is resolved by different adaptations to remove excessive water from the body.

Marine animals have hypertonic external environment and they face the problem of severe dehydration. Therefore, they need to intake or drink water but in this case another problem develops which is about the retaining salts that enters with water which also imbalance the osmoregulatory components of the body.

Terrestrial organisms retain water in their body, while bearing external hot environment they perspire and not only dehydrates but also lose essential salts which disturbs the osmotic balance of the body.

15.2.3 Methods for osmoregulation in fresh water, marine and terrestrial habitat

Osmoregulation in fresh water Habitat

Fresh water animals have internal hypertonic and external hypotonic environment. Fresh water fishes face the problem of osmotic incursion of water from gills and skin and minimize the loss of salt by urine and by diffusion across the gills. The water influx and salt removal are balanced from the kidney by producing dilute urine. The filtration rate in kidney is high and they are specialized to actively

reabsorb salts and send back into the blood. Fresh water organisms also have specialized cells located in their gills and in skin called **ionocytes** which actively extract Na^+, Cl^- and Ca^{++} from external medium and excrete (H^+) or basic (HCO_3^-) for acid base balance in the body fluids.

Osmoregulation in marine water Habitat

Marine animals also need to retain water in their body for their metabolic requirements. They have higher concentration of water in their blood than their surrounding environment. They don't gain water like fresh water organisms due to their external hypertonic environment, therefore they intend to drink lot of water and also digest its salts which are harder than fresh water salts. In marine bony fishes, the gills, kidney and digestive tract are involved in maintenance of body fluid balance, as the main osmoregulatory organs. These fishes are capable of digesting marine salts which are added in their blood along with water, excessive salts are extracted and remove by specialized rectal glands in intestine and salt glands located in gills. These fishes reabsorb water some salts and excrete very small amount of urine with excessive salts mainly divalent ions, mainly Mg^{++}, SO_4^{--}, Na^+, Cl^-, Ca^{++} from the kidney.

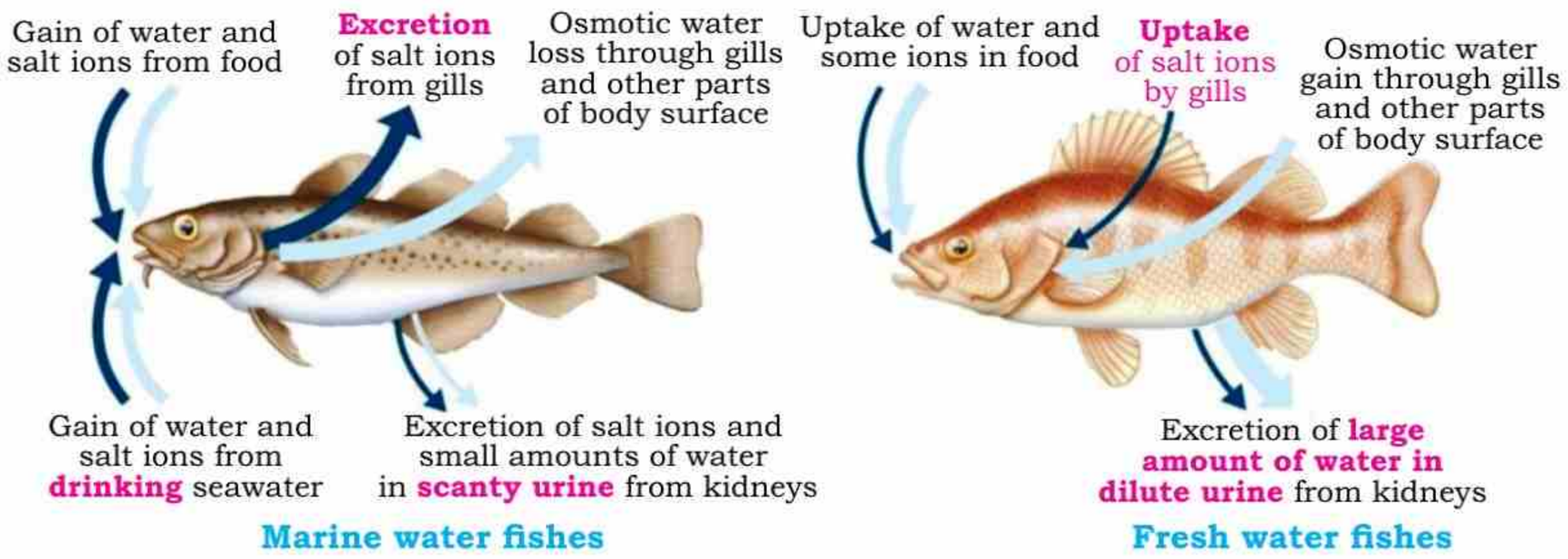

Fig.15.3 Osmoregulation in marine and freshwater fishes

Osmoregulation in terrestrial Habitat

Terrestrial animals live in moderate to extreme environmental conditions on land. Some are immensely exposed to scorching sun and

temperature and face the severe problem of dehydration like in desert while others live in moderate environment but all of them need to conserve water and essential solutes in their body. These organisms can lose water from integument, excretion and exhaling during breathing, therefore they have evolved many adaptations in response to environmental stresses. These adaptations are related with preventing removal of water from skin or body covering, not losing much water by excretion and maintaining osmotic balance of the body fluid by metabolic activities within the body. To prevent water loss from the skin they develop water proof external covering as exoskeleton made up of keratin, chitin and $CaCO_3$ found in various arthropods and other organisms. Animals produce excretory waste which require less amount of water like uric acid and conserve water through efficient reabsorption in kidney and intestine. Some animals like camel, kangaroo-rat, etc., in the absence of environmental water get it through metabolic water by breakdown of fats and other compounds during cellular oxidation reactions as a byproduct.

Extra Reading Material

The major cause of water loss in terrestrial insects is due to its tracheal system. Certain terrestrial arthropods have the ability to extract water vapor directly from air.

15.3.1. EXCRETION

Excretion is a process of removal of metabolic waste produced during biochemical reactions in the body. It is an important homeostatic activity as in broader sense it involves controlling the osmotic pressure, the balance between inorganic ions and water and maintaining acid base balance of the body. Though the waste includes variety of compounds like CO_2, nitrogenous waste including ammonia, urea and uric acid, in a restricted sense, we are going to discuss the removal of nitrogenous wastes only.

15.3.2. Excretory products in relation to habitat:

Animals produce different types of nitrogenous excretory waste. The major types of nitrogenous wastes are **ammonia, urea, uric acid, and creatinine**. Both wastes and their removal depend upon firstly, the nature of food like herbivores do not excrete as much urea as

carnivores because carnivores eat more protein, and therefor excrete more nitrogen, secondly, availability of water and third the animal's habitat. Nitrogenous waste produced as a byproduct due to the breakdown of protein and nucleic acids.

Extra Reading Material

Animals live in aquatic places generate large amount of ammonia are called ammonotelic because they need lot of water to dissolved ammonia in it. Terrestrial animals excrete urea are called ureotelic and for producing uric acid called uricotelic later two products require comparatively less amount of water to dissolved then ammonia as land animals occasionally face shortage of water in their habitat.

Ammonia:

Ammonia is an immediate and highly toxic gaseous waste initially produced by the breakdown of nitrogenous compounds in the body. It is exceedingly soluble in fresh water and body fluids and raises the pH therefore should be present in low concentration in the body. Ammonia reduces its toxicity in water and requires lot of fresh water to dissolved and generate non-toxic ammonium (NH_4^+) ions, therefore produced in aquatic animals in gaseous form and mostly diffused out from the body while some amount also excreted through urine as urea. Ammonia is also produced in terrestrial animals and converted in to another nitrogenous product i.e., urea and excreted through urine from the body. Chemically it is alkaline, corrosive and 100,000 times more toxic than urea. Animals that excrete ammonia are said to be **ammonotelic.**

Urea:

Urea $CO(NH_2)_2$ is the nitrogen containing liquid waste product produced by the breakdown of protein in mammals, amphibians, in some fishes and excreted in urine. It is also called carbamide, neither acidic nor alkaline and highly soluble in water. Liver combines ammonia with CO_2 molecule to form some intermediate compounds and then produces urea in the urea cycle or ornithine cycle. Animals produce urea are called **ureotelic.** Urea is not only a waste product in the body but also plays important role in the absorption of important ions and water in kidneys.

Extra Reading Material

Urea is beneficial as a raw material source of nitrogen for making fertilizers in chemical industry. In humans blood nitrogen test (BUN) is performed to check the renal function for the removal of urea and other nitrogenous waste.

Uric acid:

Uric acid is another nitrogenous compound and oxidative metabolic product of purines present in nucleic acids. It is also structurally resembled with purines, weak acidic and less soluble in water than ammonia and urea. It is about 10,000 times less toxic than ammonia. Animals that produce and excrete uric acid are called **uricotelic** which include reptiles, birds and numerous arthropods like insects etc. Uric acid can be stored in the body tissues without any toxic effect or harm. Excretory wastes contain uric acid appears thick paste like and needs less amount of water and animals get the advantage to conserve water in their bodies. In humans 75% uric acid is excreted by kidneys and 25% is excreted by intestine.

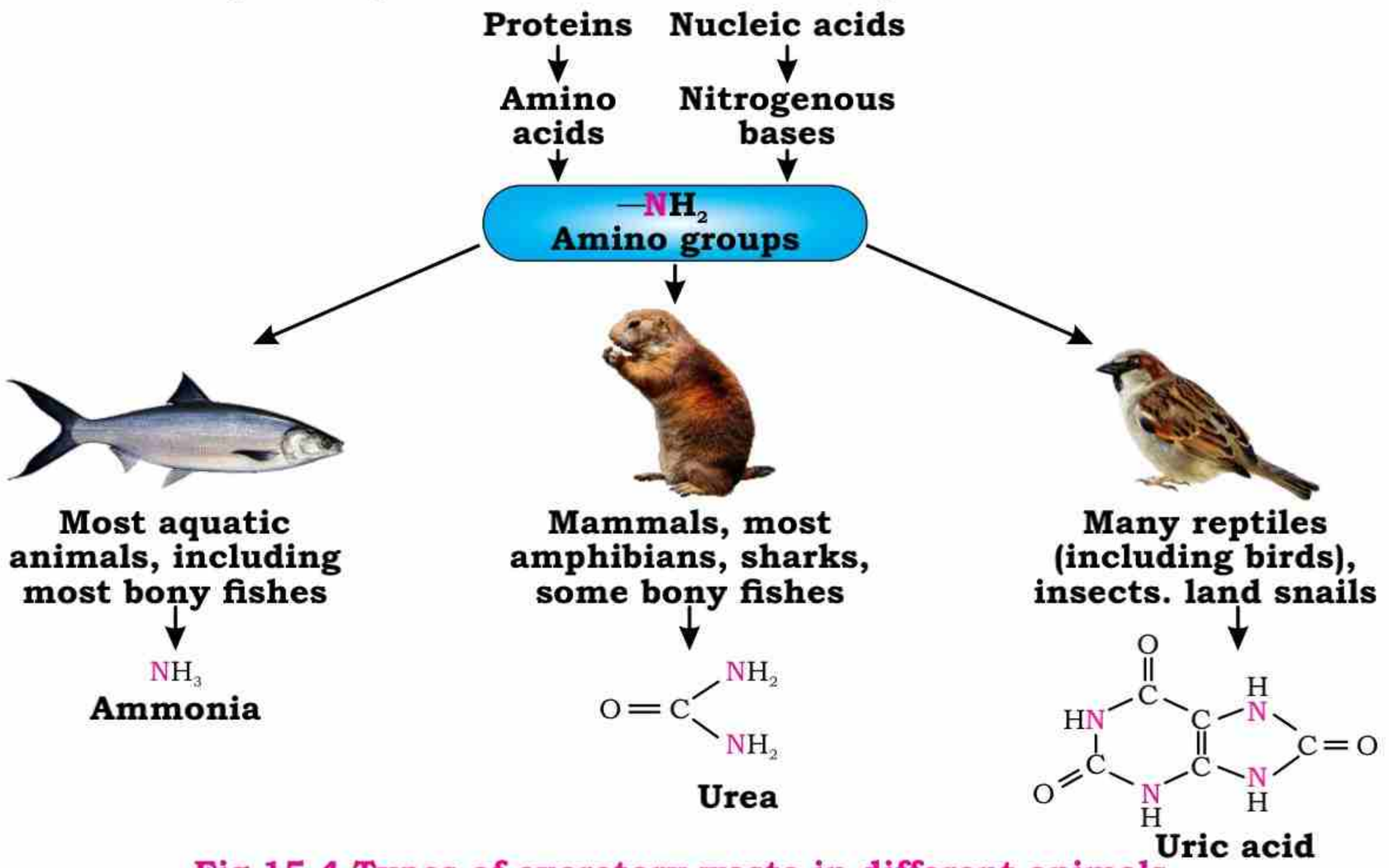

Fig.15.4 Types of excretory waste in different animals

15.4.1 Urinary System of Man

The **urinary system** or renal system is a system for removing waste from the body. This system not only removes the toxins but also maintain the body's homeostasis regulating the body acid base balance by controlling the electrolytes and metabolites, blood pressure and blood pH. The organs associated in urinary system are a pair of kidneys, ureters, a bladder and urethra.

Extra Reading Material

In humans the normal range of ammonia in blood is 15 to 45 µmol /L (11 to 32 µmol/L) while 100 µmol /L can lead to disturbance of consciousness. A blood ammonium concentration of 200 µmol /L is associated with coma and convulsions.

Kidneys are the blood purifier. These are paired, bean shaped structures located in abdominal cavity. Blood enters in to the kidney by renal arteries, both kidneys filter and remove waste substances from the blood and form filtrate. That filtrate ultimately becomes urine which flows down through the ureter. **Ureters** are 25 to 30 cm long tubes connected anteriorly with kidneys by wide opening called **renal pelvis** posteriorly they become narrow and extended downward to join urinary bladder. Ureters drain urine in to the **urinary bladder** where it is temporarily stored. The wall of the bladder is thick muscular and strong enough to hold half liter of urine in adults for some time then it is excreted out from the body by a connected muscular thin tube called urethra.

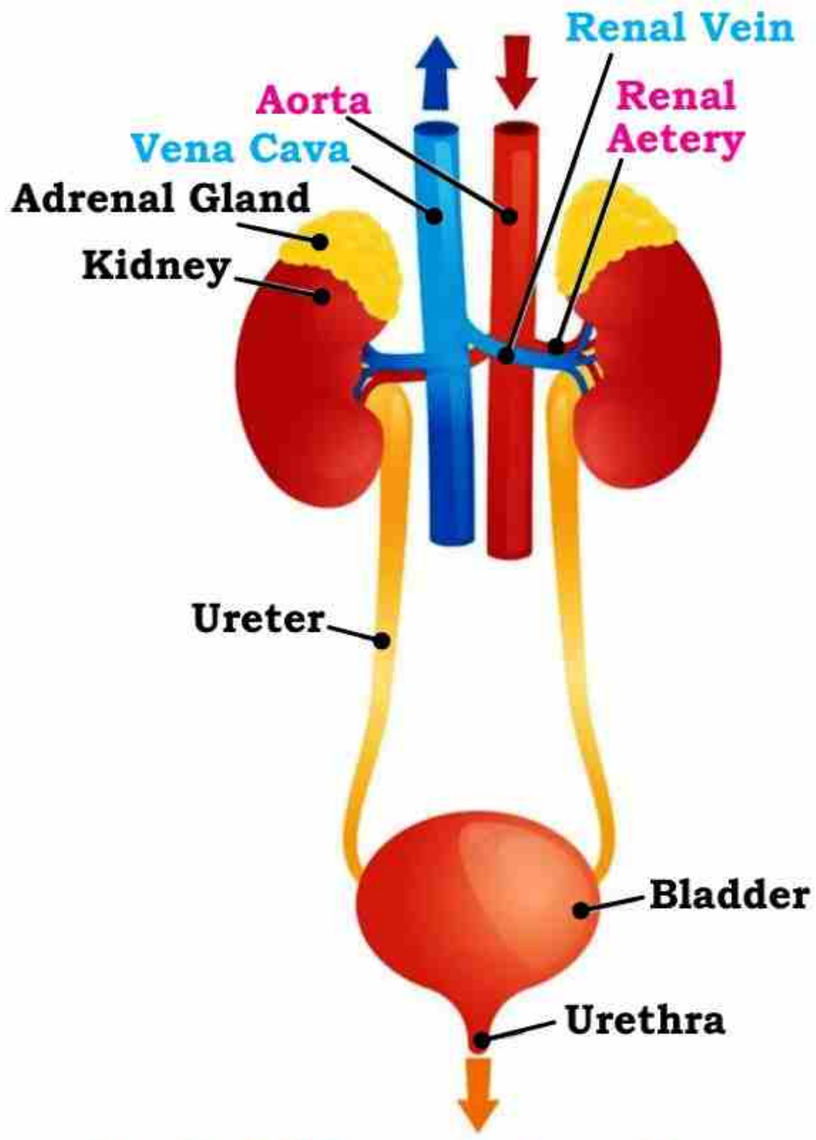

Fig.15.5 Urinary system of man

Urethra has valves called sphincters that control the flow of urine. The internal urethral sphincter regulates involuntary control of urine flow from the bladder to the urethra, and the external urethral sphincter provides voluntary control of urine flow from the bladder to the urethra.

15.4.1. Structure and Function of Kidney

Kidneys are symmetrical, bean shaped reddish brown structures located just below the rib cage, one on each side of the vertebral column between the 12th thoracic and 3rd lumber vertebrae. Kidneys positioned retroperitoneal in the abdominal cavity. These are 4 to 5 inches long almost size of the fist. The right kidney is located slightly below the left kidney providing space to adjust liver. Left kidney is slightly larger and closer to the heart.

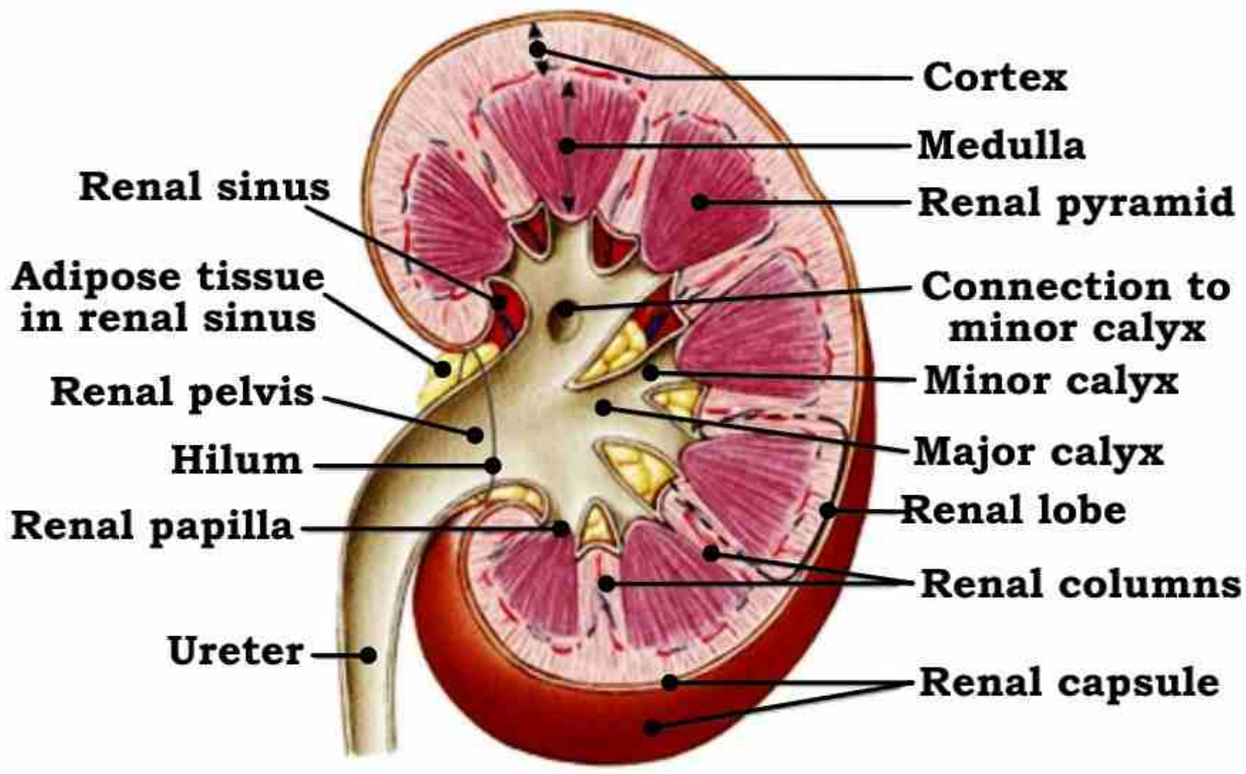

Fig.15.6 L.S of Human kidney

Externally kidneys are surrounded by a layer tough connective tissue called **renal fascia** behind that another fatty layer is present and the inner most layer covers the kidneys called **renal capsule**. Kidneys are laterally convex laterally and the medial side is deeply concave this medial depression hollow from inside called **renal sinus**. In the medial depression a small convex region is called hilum is present which has hollow sinus inside and serve as an important location for the entrance of blood vessels, nerves, lymphatic vessels and the ureter into the kidney.

Kidneys have two distinct regions internally: an outer cortex and inner **medulla**. Renal **cortex** is surrounded by renal capsule which provides shape to the kidney. Renal cortex contains arteriole and venule and the cells called **nephron**. This is outer thin region then the medulla and produces an important hormone **erythropoietin** necessary for the synthesis of RBC's.

Renal medulla is composed of compact seven to eighteen conical shaped masses of tissues called renal pyramids. The spaces in between pyramids are called renal columns. Medulla regions mostly contain the loop of Henle part of nephron and the collecting ducts. Urine enters the collecting duct and then flow towards the hilum and then collected by pelvis and ureter to remove from the body.

15.3.2. STRUCTURE OF NEPHRON

Both kidneys are consisted of millions of functional units called nephrons. These nephrons are about one million in each kidney and mainly perform filtration of blood. There are two types of nephrons present in the kidneys. The juxta medullary nephrons have longer loop of Henle penetrates deep inside the medulla and cortical nephrons with shorter loop of Henle restricts only in cortex region. Juxta medullary nephron consists of a **renal corpuscle** and a **renal tubule**.

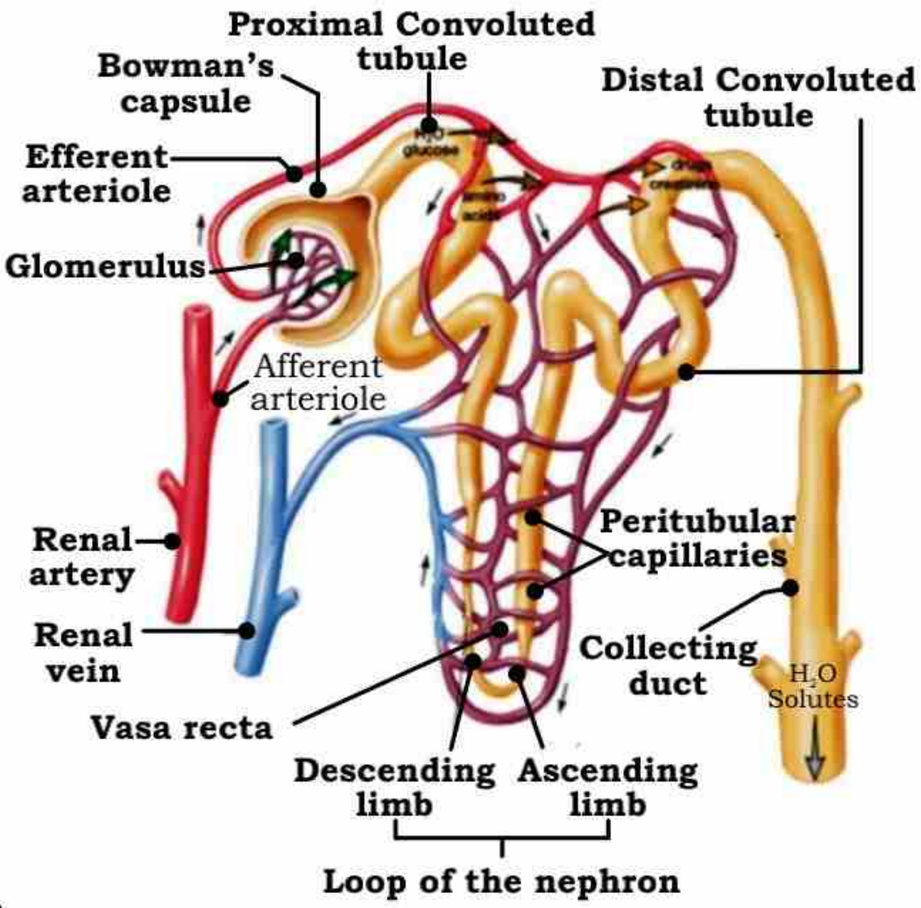

Fig. 15.7 Structure of Nephron

Renal corpuscle consists of a dense cluster of blood capillaries network called **glomerulus** surrounded by thin-walled covering called **Bowman's capsule** or glomerular capsule and both are collectively called **malpighian body**. Glomerulus is the ball like structure which arises from afferent arterioles. High volume and pressure of blood facilitates the ultra-filtration in this region. Glomerular capillaries have pores of about 70 nm in diameter which prevents the large molecules and blood cells to

pass through it. Glomerulus have specialized **Podocyte cells** that are wrapped around blood capillaries. These cells have small slits like opening that play an active role in preventing plasma proteins from entering the urinary ultrafiltrate. All the glomerulus capillaries fuse to form efferent arteriole, which exit the malpighian body.

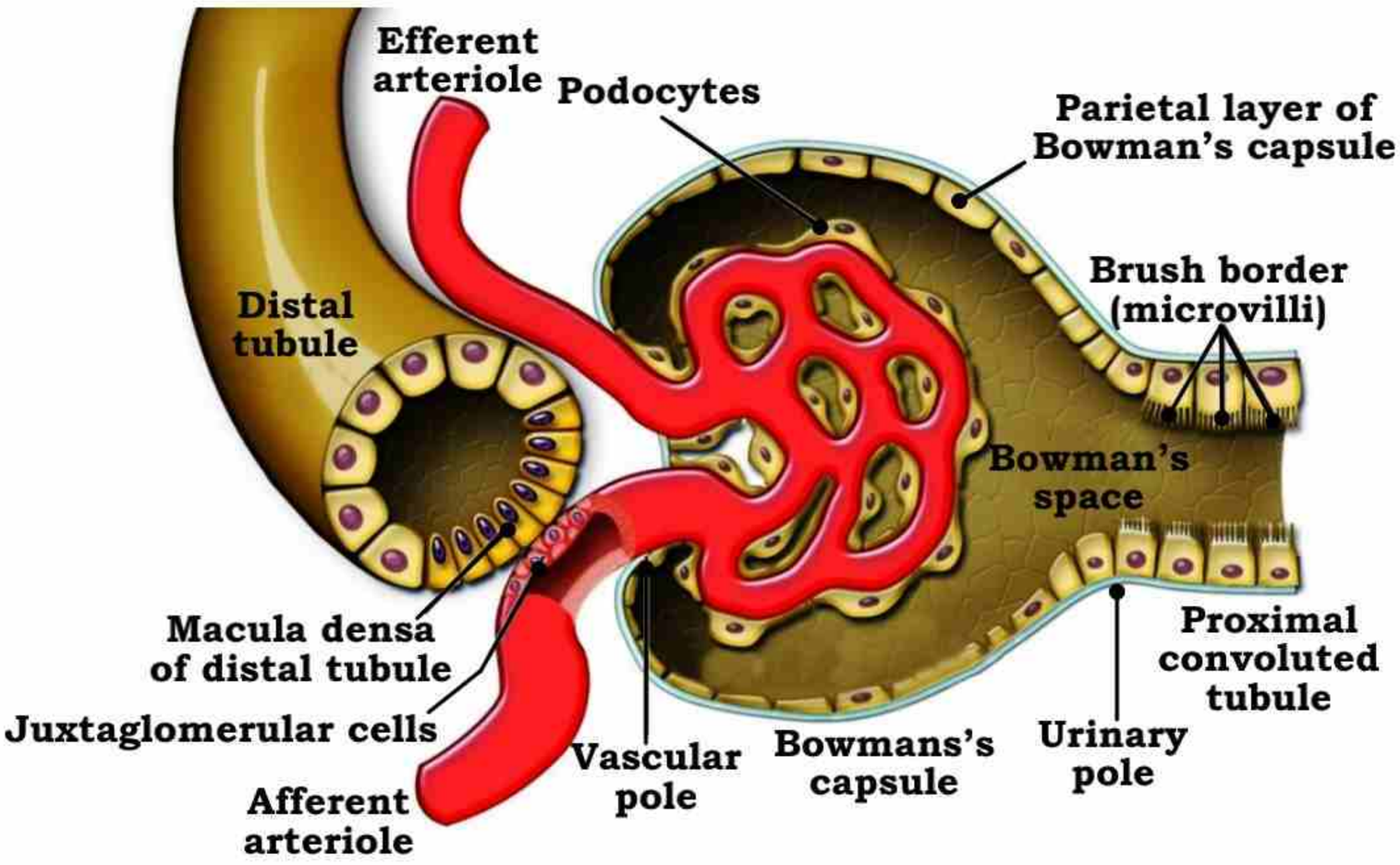

Fig.15.8 Nephron Glomerulus and Podocytes

Bowman's capsule further extended and form **renal tubule** which becomes highly coiled. This coiled region is called **proximal convoluted tubule (PCT)**, most of the essential compounds like glucose, amino acids, electrolytes and water is reabsorbed in this region. The PCT runs down towards the renal pyramids of medulla to become descending limb of loop of Henle. The tubule then turns back towards the bowman's corpuscle making an ascending limb and then coiled again and is called **distal convoluted tubule (DCT)**. Several DCT joins the common duct called **collecting duct**. Which carry urine to the renal pelvis to exit from the kidney.

Blood supply to the nephron

Renal artery enters in kidney at hilus, which further divides into numerous smaller arterioles. One of the arterioles such as afferent arteriole forms the dense network as glomerulus and leaves it as efferent arteriole. The diameter of afferent arteriole is larger than

efferent arterioles, due to difference in diameter between these arterioles, high pressure in glomerulus than other capillaries elsewhere.

The efferent arterioles extended down and forming a network of capillaries called **peritubular capillaries** that surround the both PCT and DCT. It provides nutrients and oxygen to the renal cortex. It moves downward along with loop of henle give branches which are laterally connected with the capillaries of renal vein or venule in the region of medulla. This complex network capillaries over the loop of henle called **vasa recta**. After passing through the vasa recta blood flow through peritubular capillaries system and enters in to the renal vein to join venous circulation and leaves the kidney.

15.3.3. Functions of the kidney

Kidneys are very important homeostatic organs. It filters our blood and excretes waste and extra fluid from our body by urine. Kidneys also work as an endocrine organ and secrete some vital hormones like **renin** and **erythropoietin**. Renin maintains the blood pressure while erythropoietin is involved in red blood cells production. Kidney produces an active form of vitamin D3 which helps to absorb calcium and phosphorus in our bones. These important minerals keep bones strong. Kidneys balance the pH of our body by making changes and adjusting amount of bicarbonate HCO^{3-} from the urine back to the blood and by secretion of H^+ ions into the urine. Kidney regulates the water balance by producing dilute and concentrated urine according to the external environmental changes. The process of producing urine occurs in three stages glomerular filtration, selective reabsorption, and tubular secretion.

Table 15.1
Composition of plasma and urine

Substance	% in plasma	% in urine
Water	90	95
Protein	8	0
Glucose	0.1	0
Urea	0.03	2
Uric acid	0.004	0.05
Ammonia	0.0001	0.04
Creatinine	0.001	0.075
Na^+	0.32	0.35
K^+	0.02	0.15
Cl^-	0.37	0.60
PO_4^{-3}	0.009	0.27
SO_4^{-3}	0.002	0.18

a) Glomerular filtration

Urine is the ultimate kidney product and based upon waste removed from the blood with addition of some other fluids and ions. This process is initiated in the glomerulus when blood is filtered out under hydrostatic pressure leaving the small molecules of waste and other compounds as **glomerular filtrate** this process is called **ultra-filtration**. Filtrate primarily includes water, electrolytes, some amino acids, bicarbonates and nitrogenous wastes like urea, uric acid and creatinine. Glomerular filtration rate (GFR) is directly proportional to the hydrostatic pressure exerted in its wall. This pressure is increased due to the difference in diameter of both afferent and efferent arterioles as mention earlier. Kidney receives 180 liters of blood by circulation in 24 hours and after filtration it produces 2.5 liters urine in normal climatic conditions. GFR usually remains constant by autoregulation however it may change depending upon the fluid intake or its variable amount in the body.

b) Selective reabsorption

The composition of glomerular filtrate and the urine is different it means that the fluid contents become change while passing through the renal tubules including PCT, loop of henle and DCT in nephron. For example, glucose if present in the filtrate but absent in the urine of a healthy person. The amount of urea and uric acid present more in urine than the filtrate. These changes are the outcome of selective reabsorption and the tubular secretion. **Selective reabsorption** is the process whereby certain molecules after being filtered out of the capillaries along with nitrogenous waste products (i.e., urea) and water in the glomerulus, are reabsorbed from the filtrate as they pass through the nephron and return back to the blood circulation. Most of the selective reabsorption of molecules takes place in proximal convoluted tubule (PCT). Water (about 67%), Na^+ and K^+, variable quantities of Cl^- (about 50%), Ca^{2+}, Mg^{2+}, and HPO_4^{2-} ions, important nutrients like glucose (100%), amino acids, vitamins and other organic substances are reabsorbed in PCT and given back to the blood circulation. Water is absorbed passively while glucose and sodium are absorbed actively. Na^+ drags the other negatively charged ions due to opposite charge interaction. Hormone aldosterone facilitates the sodium and ADH facilitates the water reabsorption.

c) Tubular secretion

In this process certain substances moves in to the filtrate of PCT and DCT from blood plasma. This includes waste that escape during ultra-filtration and remained in the blood. These substances are absorbed actively and include urea, creatinine, hydrogen ions, potassium ions, some hormones and drugs if present. Tubular secretion mostly performed by proximal convoluted tubule (PCT) but some of the K^+ are also secreted from DCT and collecting duct due to reciprocal exchange of Na^+ with K^+. it adjust the pH of urine.

d) Counter current mechanism

The counter current mechanism is biological processes intend to allow maximum exchange of molecules between two fluids of different concentration which are moving in opposite directions. This mechanism involves loop of henle and the environment of medulla. In medulla region of the kidney, the **ascending limb of loop of henle** is permeable to Na^+, K^+ and Cl^- ions while impermeable to water. The **descending limb of loop of henle** is permeable to water.

Ascending limb cells have specialized ionic co-transporter protein, each allow one Na^+ with one K^+ and two Cl^- hence allow lot of ions to move out from the entire limb. when these ions are actively reabsorbed from the ascending limb and accumulated in medulla, it makes medulla environment hypertonic. This movement of ions is also facilitated by a steroid-based hormone called **aldosterone** secreted from the cortex region of adrenal gland. Movement of water molecules is facilitated by **anti-diuretic hormone (ADH)** secreted from posterior lobe of pituitary gland. Another compound that increases the osmotic gradient in inner medulla is the **Urea,** it enters in the medulla from the collecting duct and along with other ions, helps the reabsorption of water. This process is called **counter current multiplier**. Now there is another counter current mechanism performed in between nephron loop of Henle and the peritubular capillaries or vasa recta.

The loop of Henle is surrounded by peritubular capillaries containing blood. These capillaries are permeable to both water and ions so due to high ionic concentration in the interstitium, water is diffusing out and solutes diffuse inside the capillaries that travel

alongside the descending limb, if this blood is carried away it destroy the medullary concentration gradients. Therefore, to counter act this effect the peritubular capillaries alongside of **ascending limb** releases the extra solutes which diffuse back in to the medulla hence maintaining the concentration gradient inside medulla and making blood more dilute. This process of exchange of gradient in vasa recta or peritubular capillaries is called **counter current exchange.** So, the water is secreted then reabsorbed in to the system. Solutes are reabsorbed then secreted in to the medulla. Normally the blood flow is slower in peritubular capillaries or vasa recta to allow time for passive diffusion.

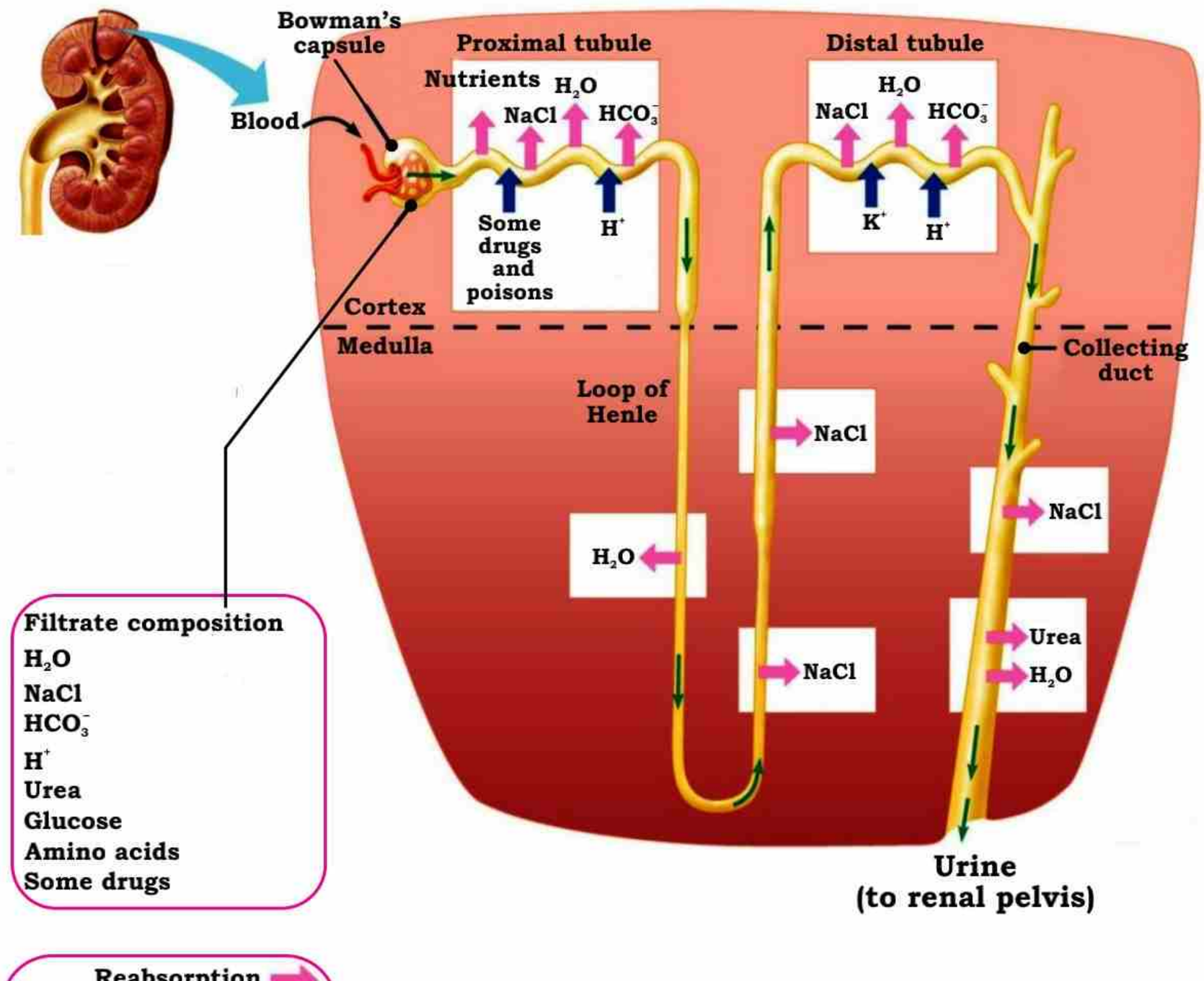

Fig.15.9 Urine formation

15.4. DISORDERS OF URINARY TRACT

Urinary tract infections are the infections in organs associated with urinary system. These infections are usually caused by bacteria and viruses that invade or enter through anus or urethral opening or by other means. The site of infections could be any part of the urinary system like kidneys, bladder ureters and urethra

The most common urinary tract infections among others are **Pyelonephritis, Cystitis and Urethritis.**

Name of the disease	Cause	Symptoms
Pyelonephritis	E. coli	if bacterium reaches in the kidneys it brings nausea, vomiting, back pain, high fever with cold
Urethritis	E. coli, Chlamydia, Neisseria gonorrhea	Feeling the frequent or urgent need to urinate, Difficulty starting urination, Pain during sex, Discharge from the urethral opening or vagina
Cystitis	E. coli	A strong urge to urinate, Pain or a burning feeling when urinating, Passing frequent, small amounts of urine, Blood in the urine, Passing cloudy or strong-smelling frequent urine, Pelvic discomfort, A feeling of pressure in the area below your belly button (abdomen), Low-grade fever.

15.5.2 Kidney Stones

Urine contains many dissolved mineral and salts that form different compounds. The components of these compounds include calcium, sodium, potassium, oxalates, uric acid and phosphate. Increased level of calcium in urine is called **hypercalciuria** and high level of oxalates in urine is called **hyperoxaluria**. When these components in the urine get too high or urine becomes too acidic or basic, they combine to form crystals. The crystals progressively grow and become detectable stones in months or a year. This presence of stones in the kidney is called **Nephrolithiasis** or **Urolithiasis** and the

inflammation in kidneys due to irritation of kidney stones is called **Lithonephritis.** Kidney stones hinder the flow of urine and cause severe pain in the back. **Calcium oxalate** is the most common type of crystals to form 80 % of kidney stones. Other 5 to 10% of less common type of kidney formed by **calcium phosphate or uric acid**. Some stones are formed by **magnesium ammonium phosphate** (struvite) in alkaline urine due to bacterial activity. These stones are about 10 percent and called struvite or infectious stones. Less than 1 percent of urines stones are formed by an amino acid cystine. **Cystine** stones are usually formed in childhood.

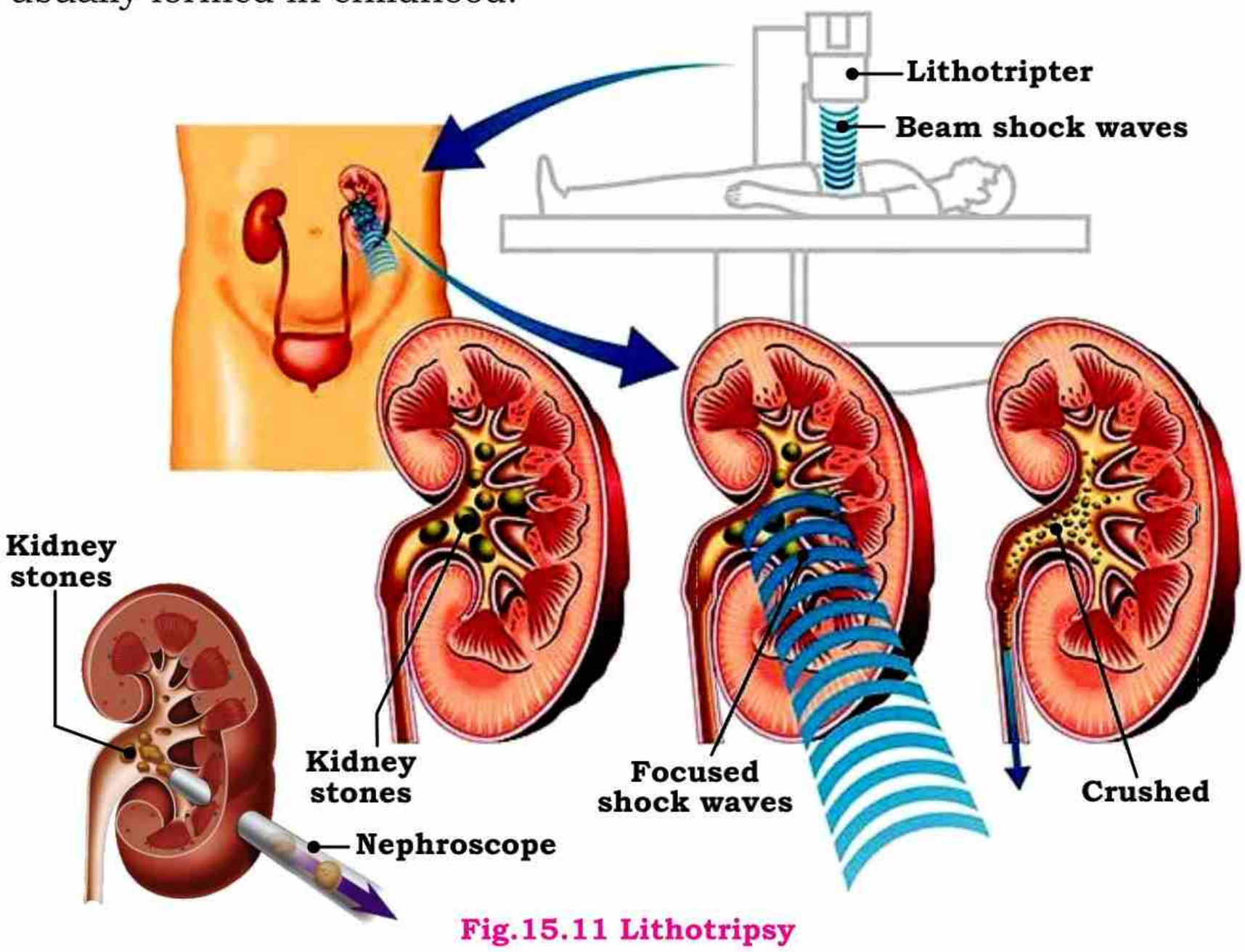

Fig.15.11 Lithotripsy

Kidney stones can be treated from outside the body by shock waves. This treatment is called **extracorporeal (outside the body) shock wave lithotripsy (ESWL).** Another treatment for kidney stone is **percutaneous nephrolithotomy (PCNL)**. This procedure is used to remove kidney stones when they can't pass on their own. This is made under the general anesthesia in which patient will be a sleep. During

this procedure one catheter is placed in the bladder to drain urine out of the body then another catheter is inserted into the ureter to track down the stone by attached visual device. Once the stone is detected it is crushed and nephroscope grasper is used to pull out the pieces of stone from the kidney. If the stones are too many or large then **laparoscopic pyelolithotomy** procedure is used in which kidneys are cut open to remove stones physically.

15.4.2 Kidney Failure

Kidney failure is the condition in which kidneys fail to extract nitrogenous waste products and perform osmoregulatory activity in the body. In this medical condition more than 85% of the both kidneys are affected. Kidney failure is classified as acute and chronic.

Acute kidney failure is concerned with the suddenly loss of filtering abilities of the kidney. This condition develops in a few days particularly in those who are already having renal abnormalities and hospitalized. The diseases that could cause the kidney failure are blood loss due to injury, heart attack, liver failure, severe allergic condition, and sudden dehydration due to sweating or excessive urination, urinary tract obstruction due to stones or any infection.

Chronic kidney disease involves a gradual loss of kidney function. Initially this disease shows no symptoms in the body but periodic blood or urine test indicate the problem. Its symptom includes fatigue, short breath, swollen hands or feet, blood in urine. The causes are hypertension, hyperglycemia, high cholesterol, cyst develop inside the kidney, kidney stones and inflammation.

15.4.3. Dialysis

Dialysis is a medical procedure to separate unwanted and toxic substances from the blood by artificial means. It is performed when kidneys are failed to remove waste from the blood body feels unrest particularly in breathing and later on non-adjusted biochemical components cause serious damages to the body like dementia or heart failure. There are different types of dialysis applied on patient depending upon the need and intensity of disorder, these are **hemodialysis**, **continuous renal replacement therapy (CRRT)** and **peritoneal dialysis.**

The **hemodialysis** is performed by a machine regarded as artificial kidney. This artificial kidney contains a number of tubules with a semipermeable lining suspended in a tank filled with a dialyzing fluid. This fluid has the same osmotic pressure as blood except it lacks nitrogenous waste.

To begin the procedure a surgeon, make a small incision to connect artery with a vein by a graft i.e., a small plastic tube that connect the both artery and vein also called a **fistula**. When the circuit is completed two needles are inserted in to the AV fistula. The one needle is connected to the artery and at the other end it is connected to the dialysis device where blood is collected from patient for filtration. During this process the waste product from the blood passing into the dialyzing fluid by diffusion. The purified blood is pumped back into the vein of the patient which is connected to other end of the dialysis device.

This is similar to the function of the kidney but it is different since there is no reabsorption involved. Hemodialysis is normally performed as 4-hour treatment, 3 times a week. The complications in this process may include the risks of blood infection, thrombosis and internal bleeding due to the added anticoagulant.

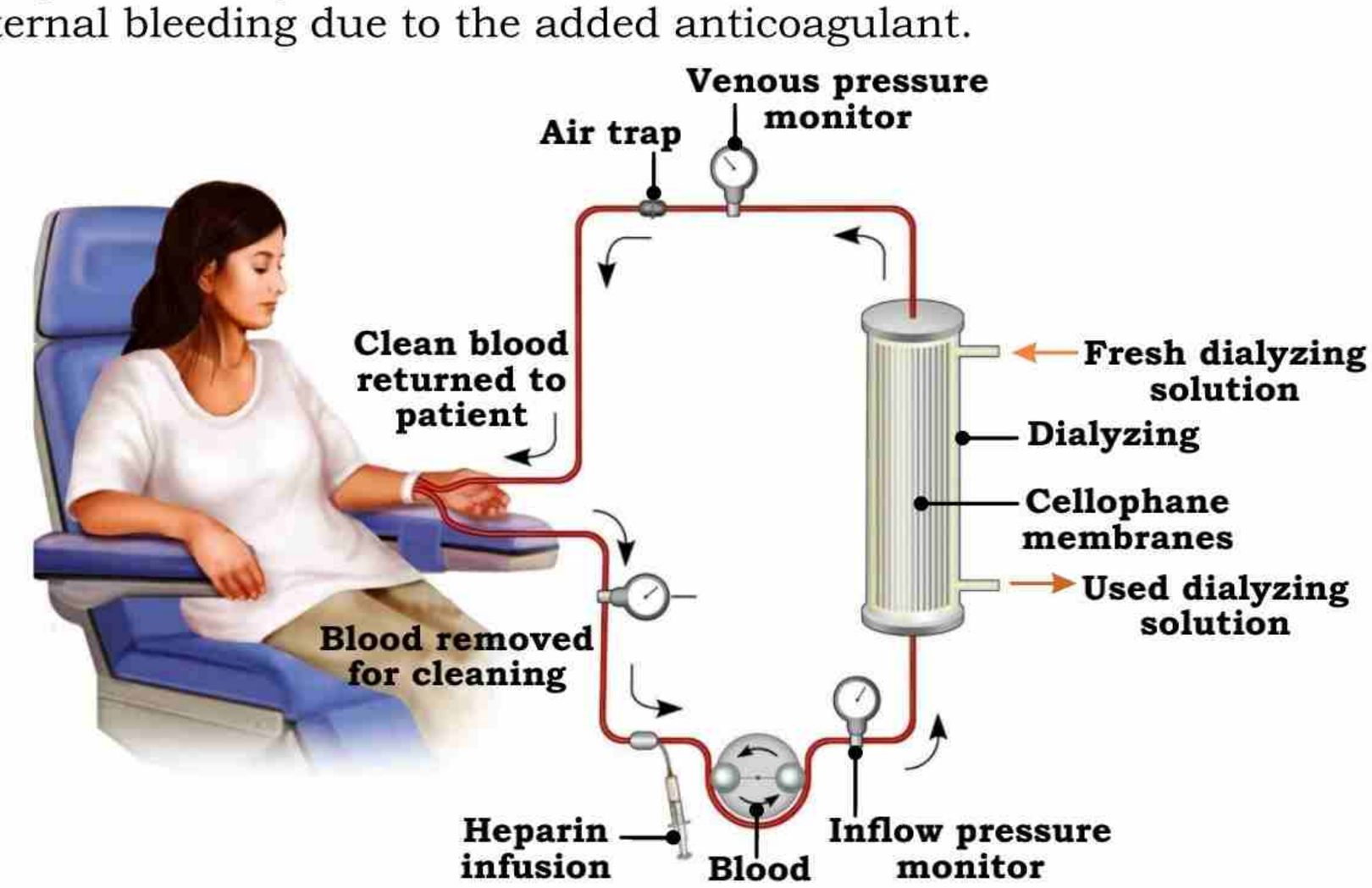

Fig.15.12 Haemodialysis

Continuous renal replacement therapy (CRRT) is the same class as hemodialysis. It is used for the patients who are in critical condition and it is design for the patients who are unable to tolerate the repeated procedures of hemo. or peritoneal dialysis. This procedure is running continuously 24 hours a day once started.

In **peritoneal** dialysis, abdominal cavity is used to filter blood. This procedure starts when doctor makes an incision at the lower abdominal cavity to implant or pass catheter. Which is soft tube that allows dialysate to pour in to and out of the abdominal cavity. Abdominal cavity is internally lined with the peritoneum which serves as the natural filtering membrane. When the dialysate is poured inside the abdominal cavity it pulls toxins from the blood that pass-through peritoneum membrane from its high concentration to the low concentration. The fluid remains in the body of several hours allowing exchange and equilibrium of ionic components with the blood running in the underlying vessels before being discarded. The dialysate is removed when it appears saturated and this process is repeated again if needed. Peritoneal dialysis can be repeated 4 to 5 times a day. It is less effective than hemodialysis but because it can be performed for longer periods of time. Peritoneal dialysis offers more flexibility, is better tolerated by patient, and less expensive but it is more often complicated with abdominal infections.

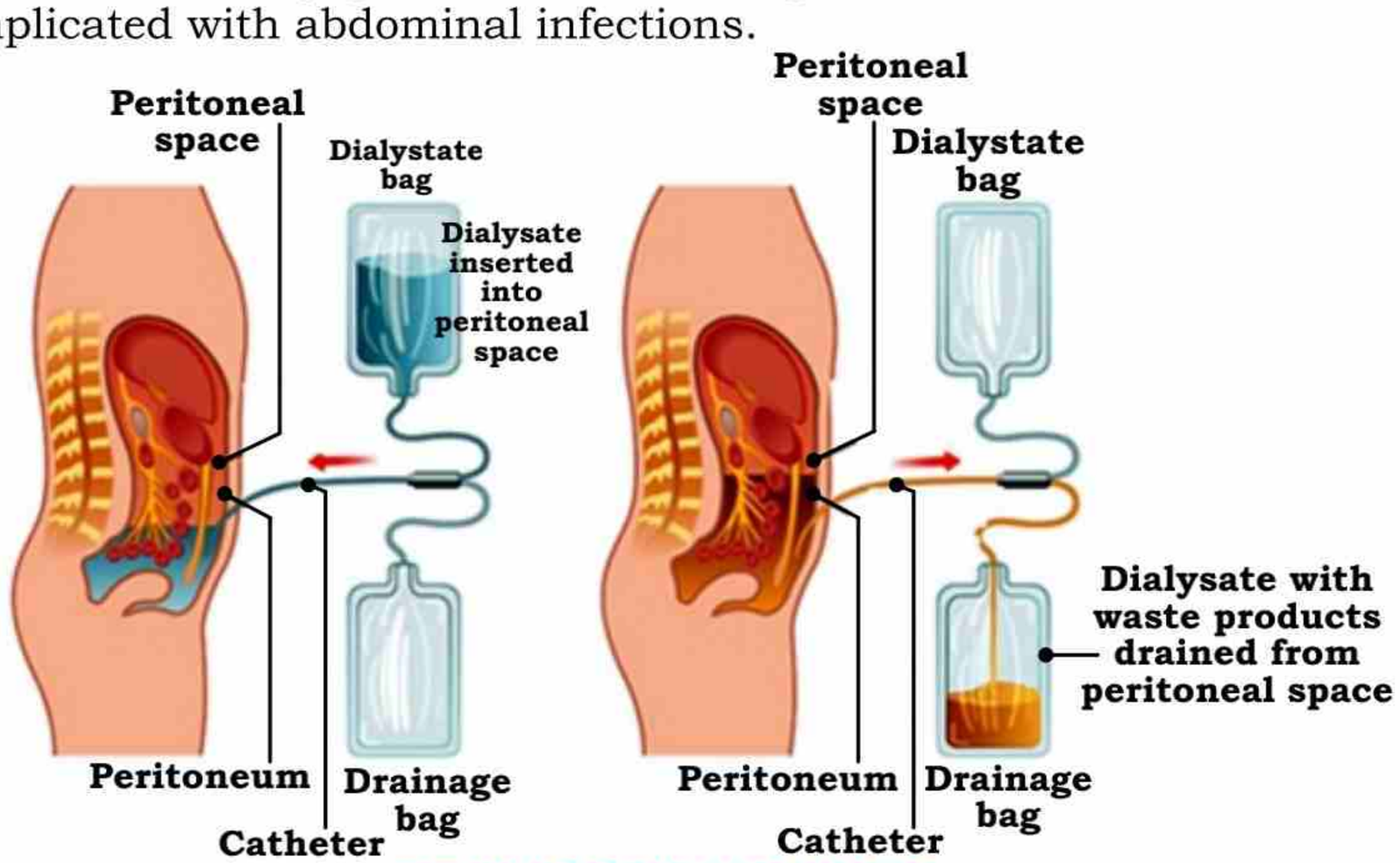

Fig.15.13 Peritoneal dialysis

15.4.4. Kidney Transplant

Kidney transplant is the major surgical treatment of kidney failure disorder. In this procedure, a healthy kidney from a living or deceased donor is acquired and is placed in the lower belly on the front side of the body. The diseased kidneys are usually left in place. Kidney transplant is done when the kidneys have lost about 90% of their ability to function normally due to some serious disorders like high blood sugar level and uncontrolled high blood pressure, kidney stones and polycystic kidney disease etc.

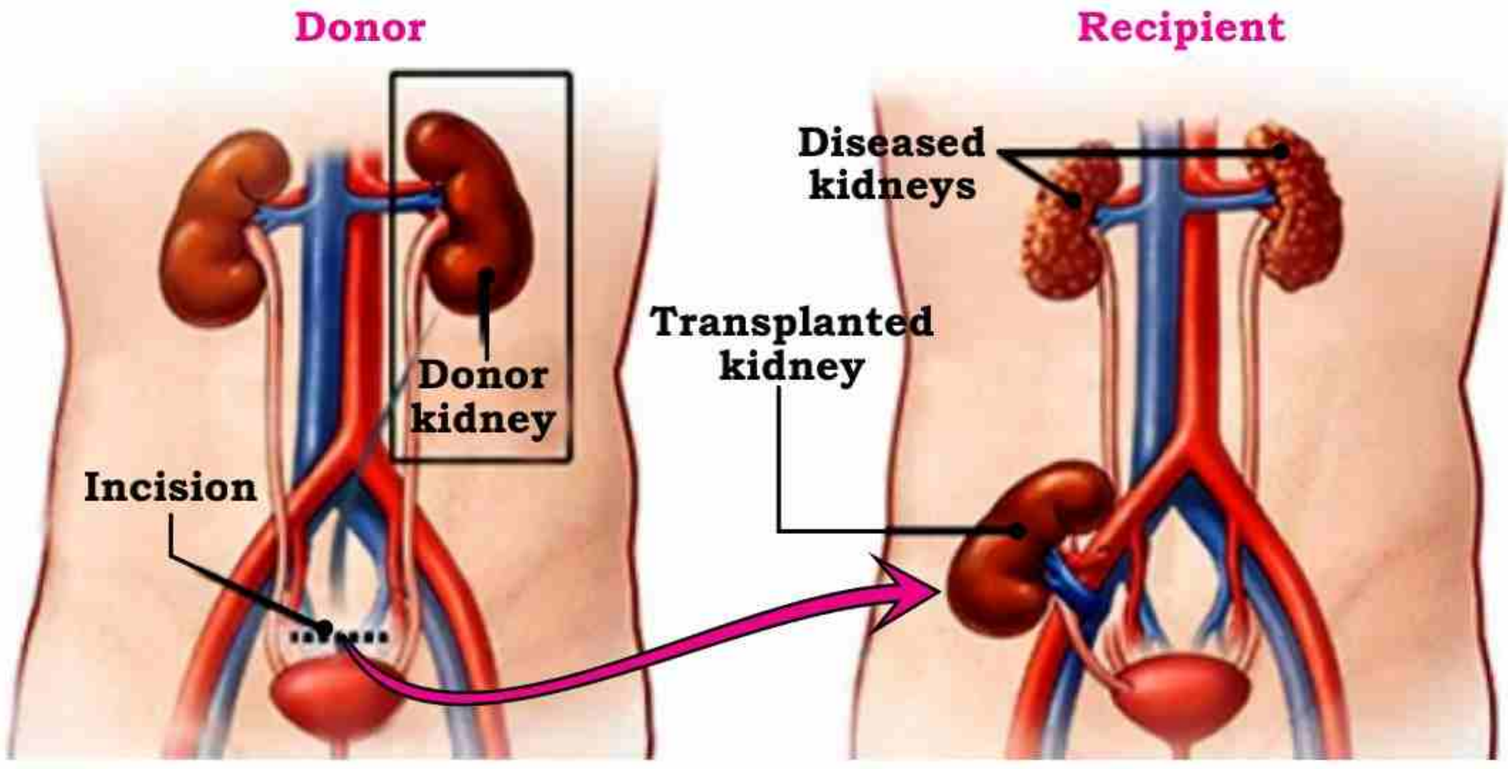

Fig.15.14 Kidney Transplant

Principles of kidney transplant

Kidney transplant requires the same matching blood group and biochemical components with the kidney donor and recipient. The compatibility is necessary without it, transplant cannot be done. The resistance against the implanted kidney by the immune system particularly from human leucocytes antigen system (HLA) should be minimize at the level that body accept new kidneys.

Problems associated with kidney transplant

After transplants the Immunosuppressant drugs like Cyclosporine are administered. This would be the risk factor along with treatment because at first it must be given to stop the body from rejecting the new kidney and minimize the side effects but at the other end it may invite some other opportunistic infections to enter the body

due to suppressed immune system. Kidney transplant surgery involves substantial complications like blood clots and bleeding, leaking from or blockage of the tube that links the kidney to the bladder (ureter), different bacterial Infection, those infections or cancer that can be passed on from the donated kidney, Death, heart attack and stroke. Besides all complications studies reveal that people who have done their kidney transplant live better and longer than those who keep on dialysis.

15.6. THERMOREGULATION

Thermoregulation is a homeostatic mechanism that keeps the body temperature of an organism up to suitable limits independent of external environmental temperature. It is all about keeping the stability of thermal energy expense in the body. This stability of temperature is necessary because if a person suffers with loss the body heat (i.e., hypothermia) in a very low external temperature then this condition may lead to low metabolic activities, cardiac arrest, brain damage and even death. Likewise, if the body temperature raises from 37^0C to 42^0C (i.e., hyperthermia) a person also suffers with many complications like fever, osmoregulatory imbalance, stroke or even death in rare cases. Temperature is the limiting factor for enzyme activities. Body metabolism depends upon the enzymes and change in temperature affect the working of enzymes which disturbs the metabolic activities.

15.6.1. Animals Classification on the Basis of Thermoregulation

Animals are classified on the basis of their capability to maintain body by utilizing different heat sources. Those animals who derives temperature to warm their bodies from external sources are called **ectotherms or poikilotherms.** Since ectotherms rely on environmental heat sources, they can operate at economical metabolic rates. Ectotherms live in environment where in which temperatures are constant such as tropics or ocean therefore, they would rather prefer to get heat by behavioral means rather than the physiological activities. These animals include invertebrates, fishes, amphibians and reptiles.

Animals who maintain a constant internal body temperature, usually within a narrow range of temperature are called **endotherms**

or homeotherms. These animals regulate their own body temperature through internal metabolic processes. When external environment becomes cold or hot, they autonomically monitor these changes and maintain the body temperature up to normal range through physiological and behavioral strategies. These animals include birds and mammals.

Some animals are called **heterothermic animals**. These animals can switch between homeotherms and endotherms. These changes in strategies typically occur on a daily basis or on an annual basis. These animals regulate body temperature usually as constant, but allows body temperature to fluctuate with the environment when inactive. Bats and hummingbirds go into what is known as torpor and bears hibernate. Both are examples of heterothermy; where the internal temperature of the animal drops during specific periods of time, usually when food is scarce

15.5.2. Thermoregulation in Humans

Humans maintain their body temperature at suitable limit that is 37^0C. We are adapted some behavioral and physiological strategies to adjust thermogenesis in cold and hot environment. Thermoregulation is controlled by an important part of our brain called hypothalamus which is considered as the thermostat or set point for temperature. Hypothalamus detects changes of the body temperature by receptors located in different parts of the body and responds accordingly.

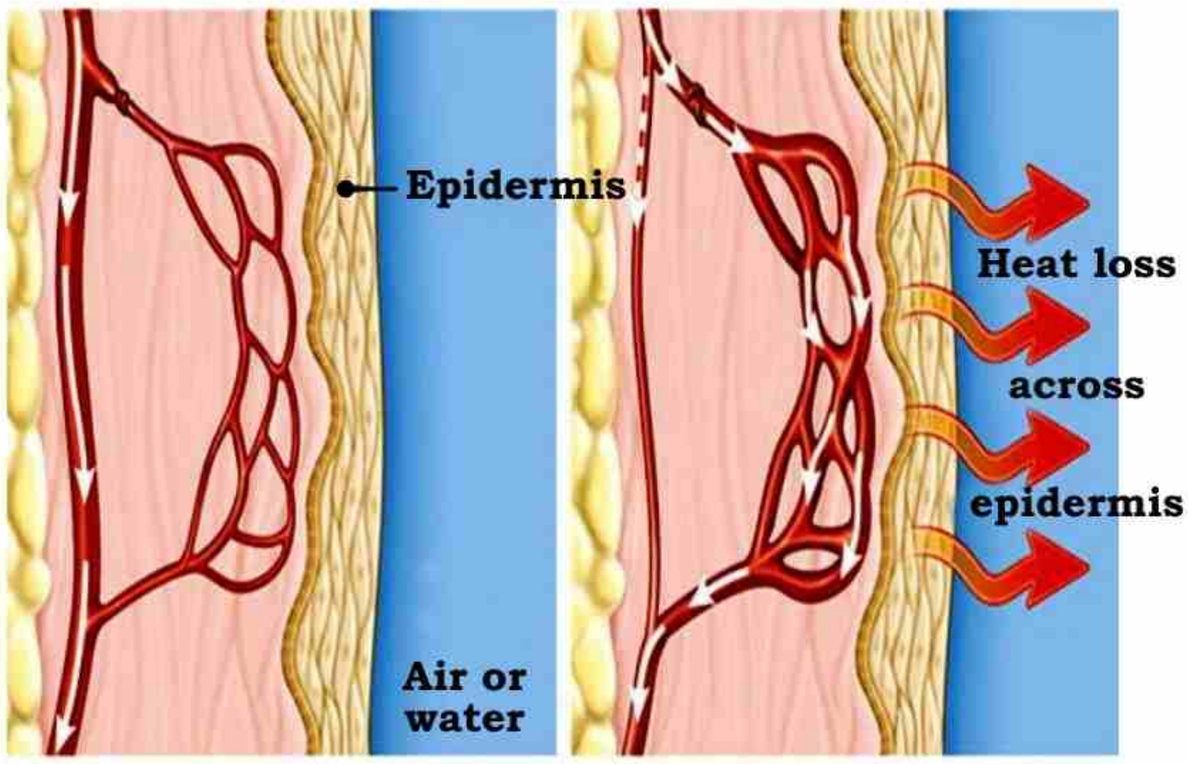

Fig.15.15 Vasoconstriction and Vasodilation

For example, if the surrounding environment becomes hot or a person do strenuous physical activity, the heat produced inside the body and raises body temperature above suitable limit this condition is called **hyperthermia**. That heat is transported to the blood which carries it near to the skin. When this elevated body temperature is detected by hypothalamus it neurologically activates the sweat glands to start secretion. As the skin perspires, the **evaporating sweat** take away the body heat from the blood into the surrounding environment. This cooled blood is then transported back through the body to prevent the body temperature from becoming too high. The blood vessels near to skin dilate in hot condition and facilitate the maximum transfer of heat away from inside the body. This dilation of blood vessels is called **vasodilation.** Thinning of hypodermis lowers the perspiration and this condition may lead to heat stroke and exhaustion. Humans can also transfer heat by conduction and **convection** as well. **Conduction** means heat transfer through some physical interaction for example prickly heat powder or ice pack makes a cooling effect on skin. Convection means transfer of body heat by movement of air or water molecules across the skin.

When the body experiences cold environment and body temperature tends to decrease this condition is called **hypothermia**. To conserve body heat in hypothermia, perspiration reduces and blood vessels become narrow and carrying blood down to skin. This condition of blood vessels is called **vasoconstriction**. The subcutaneous fats become thick and become an insulating layer to conserve heat in the body. In hypothermia sometimes body shivers and this involuntary action of muscles generate heat to warm the body. The vasoconstriction caused by hypothermia induces renal dysfunction and cold diuresis due to the decreased levels of ADH. These decreased levels of antidiuretic hormone result in dilute urine.

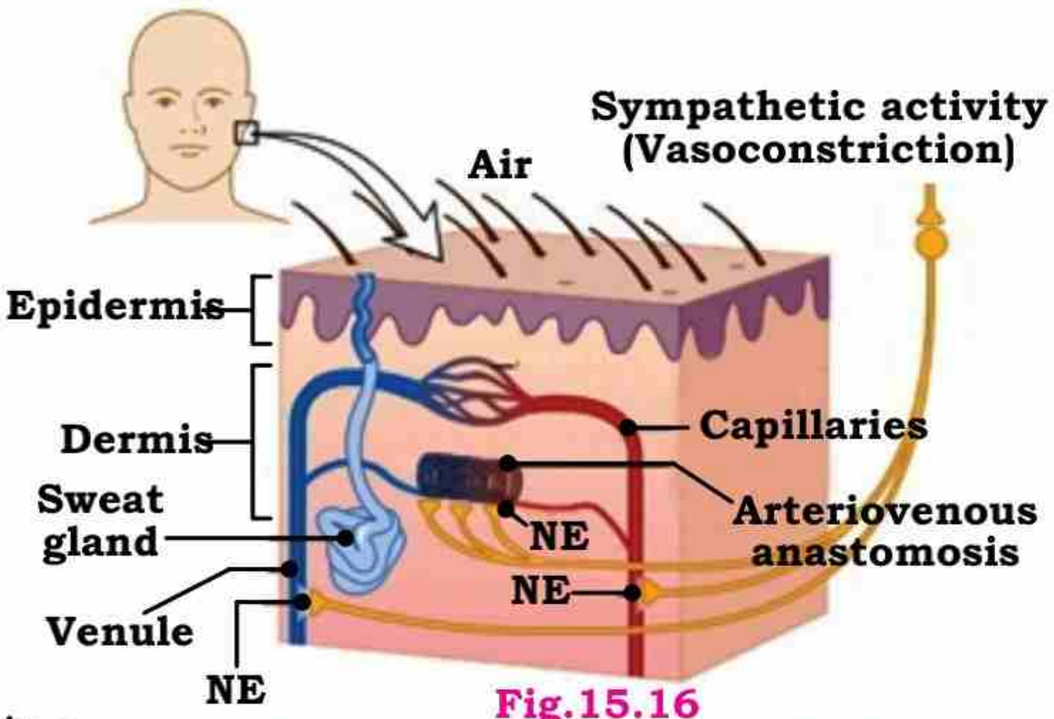

Fig.15.16
Thermoregulation through skin

SUMMARY

- Homeostasis is process by which biological systems maintain stability while adjusting to the changing conditions.
- Feedback, in biology, a response within a system. There are two types of feedback mechanisms that counter act upon each other called positive and negative feedback.
- Fresh water and marine water animals adjust their osmotic internal environment according to the changing external environment primarily by excretion.
- Animals produce different types of excretory waste to regulate their internal homeostatic environment.
- Urinary system is not only used for removing waste from the body, but also maintains the acid base balance of the body.
- Urinary system formed by mainly a pair of kidneys and associated organs.
- Kidney performs different functions including ultra filtration, selective reabsorption and counter current mechanism.
- Diseases of urinary tract are caused by bacteria and viruses that invade or enters through anus or urethral opening and by other means.
- Urine contains many dissolved mineral and salts that form different compounds.
- Kidney failure is treated by are hemodialysis, continuous renal replacement therapy (CRRT), peritoneal dialysis and in severe case kidney transplant.
- Thermoregulation is a homeostatic mechanism that keeps the body temperature of an organism up to suitable limits independent of external environmental temperature. It is all about keeping the stability of thermal energy expense in the body.
- Humans are endotherms means they maintain their body temperature at suitable limit that is 37^0C. Humans have adapted some behavioral and physiological strategies to adjust thermogenesis in cold and hot environment.

EXERCISE

1. Encircle the correct choice

i) A self-regulating process by which biological systems maintain stability while adjusting to the changing conditions called
(a) Homeostasis (b) Osmoregulation
(c) Excretion (d) Biological rhythms

ii) Which does not maintain a stable, homeostatic condition rather it intensifies the change that is happening to the body.
(a) Negative feedback (b) Positive feedback
(c) Feed back system (d) Excretion

iii) Fresh water organisms also have specialized cells located in their gills and in skin which actively extract Na^+, Cl^- and Ca^+ from external medium and excrete (H^+) or basic (HCO_3-) for acid base balance in the body fluids are called
(a) Granulocyte (b) Lymphocyte
(c) Ionocytes (d) podocyte

iv) Renal cortex produces an important hormone necessary for the synthesis of RBC's
(a) Erythropoietin (b) Leukopoietin
(c) Thrombopoietin (d) Renin

v) Glomerulus have specialized cells that are wrapped around blood capillaries that play an active role in preventing plasma proteins from entering the urinary ultrafiltrate called
(a) Epithelial cells (b) Podocyte cells
(c) Endothelial cells (d) None of them

vi) Tubules secretes ions such as hydrogen, potassium, and NH_3 into the filtrate while reabsorbing the HCO^{3-} from the filtrate are called
(a) Distal convoluted tubule (b) Proximal convoluted tubule
(c) Collecting duct (d) Loop of Henle

vii) Glomerular filtration rate (GFR) is in which proportional to the hydrostatic pressure exerted in glomerulus wall
(a) Indirectly proportional (b) Directly proportional
(c) Same proportional (d) High proportional

viii) Another compound that increases the osmotic gradient in inner medulla is the
(a) Urea (b) Water
(c) Sulphates (d) Phosphates

ix) The inflammation in kidneys due to irritation of kidney stones is called
(a) Lithonephritis (b) Edema
(c) Sarcoma (d) Encephalitis

x) If the surrounding environment becomes hot or a person do strenuous physical activity the heat produced inside the body and raises body temperature above suitable limit this condition is called
(a) Exothermia (b) Hyperthermia
(c) Hypothermia (d) Endothermia

2. Write short answers of the following questions:

i) Why the physiological integration of internal body environment is important for living organisms?
ii) Why it is important that positive and negative feedback mechanisms counter act upon each other?
iii) How the aquatic Osmoregulators overcome the osmoregulatory problems?
iv) Why animals excrete different types of excretory waste?
v) What is the use of counter current mechanism in kidney?
vi) What is the role of kidney as an endocrine organ?
vii) How kidney stones are formed?
viii) What is the impact over the human body if kidneys suddenly or gradually loss the filtering abilities?
ix) What are the problems associated with kidney transplant?
x) What is hypothermia? How body overcome this condition?

3. Write detailed answers of the following questions:

i) Explain the detailed structure of nephron with labelled diagram
ii) Explain the functions of kidney
iii) Explain the causes of kidney failure and its treatment