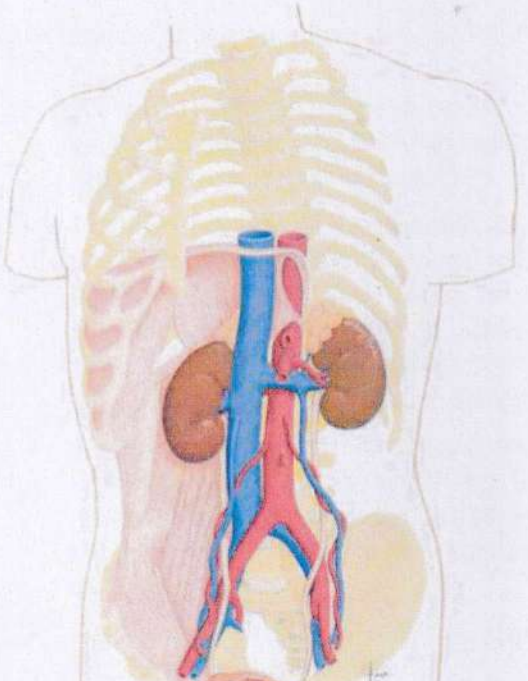
MODERN COLLEGE OF ARTS SCIENCE AND COMMERCE, SHIVAJINAGR, PUNE -05

SUBMITTED TO DEPARTMENT OF ZOOLOGY

EXCRETION IN ANIMALS

SUBMITTED TO – MRS. SHUBHANGI PURANIK



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DEPARTMENT OF ZOOLOGY

MCASC PUNE – 05

EXCRETION

The chemical reactions in the body of the animals are essential for their survival. Many of such reactions such as the oxidation of the organic substances release energy, which is utilized in setting off other reactions. However, these chemical reactions give rise to the end products, some of which may be harmful if allowed to accumulate in the body beyond certain limits. Therefore, removal of such substances from the body becomes more or less obligatory and this process is called the excretion. The major end products of the chemical reactions include CO_2, water, salts and nitrogenous compounds. Out of these, substance like CO_2 along with several volatile substances like alcohol, ketone bodies, aromatic oils, water vapors etc. are excreted through the lungs during expiration. Salts, water and fat derivatives are removed from the body through skin. For the elimination of the nitrogenous compounds which are the end products of the protein metabolism, specialized structures are developed and these are referred to as the excretory organs. The organs or the tissues involved in the elimination of the waste products are called the excretory organs. The organs are required for –

- Elimination of nitrogenous wastes
- Adjustment of water balance of the body
- Maintenance of iconic composition of the body fluids

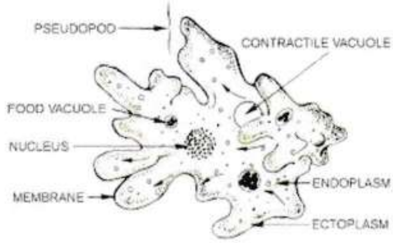
Based on the excretory product, five modes of excretion are known in animals. They are:

- **Ammonotelism** - The process of eliminating ammonia from the body is known as Ammonotelism, and the organisms which exhibit this nature are called ammonotelic. Most fish, protozoans, echinoderms, poriferans and crustaceans fall into this category.
- **Ureotelism** - In some mammals and amphibians, urea is excreted as a metabolic waste product. Such organisms are called ureotelic. In these organisms, ammonia that is produced is converted to urea in the liver of animals and is released back into the blood. The kidneys filter the urea and expel the urea outside the body. Some of the urea is retained in the matrix of the kidney to maintain a desired osmolarity in the organisms. Humans are ureotelic as we expel the urea through urine. Moreover, urea is comparatively less toxic than ammonia.
- **Uricotelism** -Uricotelic animals remove nitrogenous wastes as uric acid in the form of pellets or paste. Metabolically, this process is quite costly; however, the water loss is minimal, and it is the least toxic. Moreover, since uric acid is not readily soluble in water, the excrements form pasty white suspensions. Most reptiles, birds, and insects are classified as uricotelics.
- **Aminotelism** -Certain molluscs and echinoderms excrete excess amino acids. This feature is called Aminotelism.
- **Guanotelism** -Spiders convert the ammonia into guanine before excretion. This characteristic is also found in some reptiles, birds and earthworms. It is also insoluble in water; hence no water is required for its excretion.

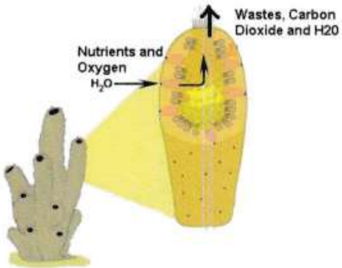
Excretory organs in Microorganisms and Invertebrate animals

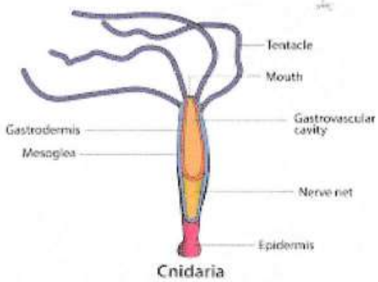
Microorganisms and invertebrate animals use primitive and simpler mechanisms to get rid of their metabolic wastes.

Microorganisms – Most microorganisms including protozoans, excrete their metabolic wastes by a simply diffusing them out into contractile vacuole followed by exocytosis. Example – excretion in amoeba.

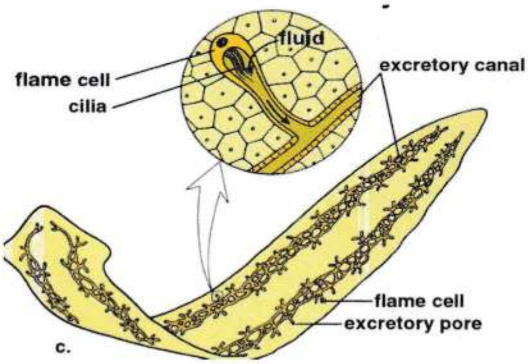


Porifera and Coelenterates- Almost all body cells are bathed in water and the excretory materials are given out by direct diffusion.

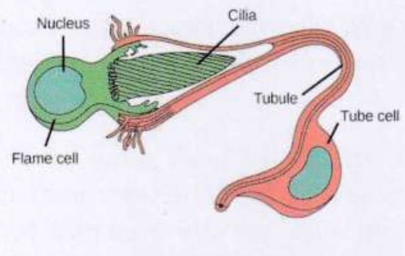




Platyhelminthes –

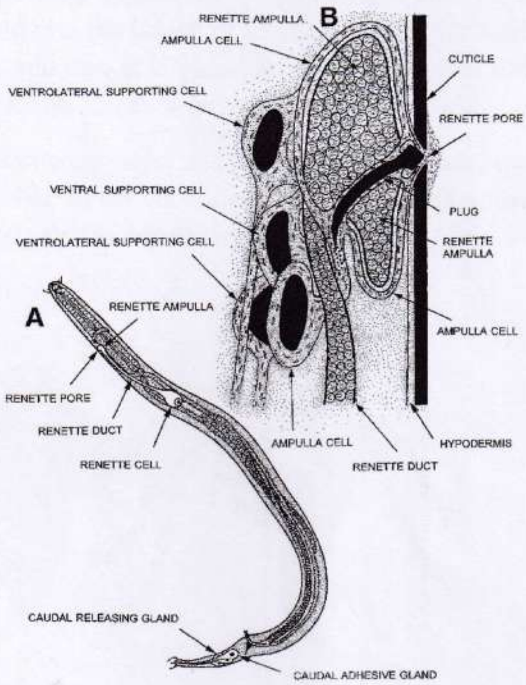


Flatworms such as Planaria have an excretory system with a network of 2 tubules connected to a highly branched duct system that opens into flame cells (or Protonephridia), which is the main excretory organ of flat worms. Flame cells have a cluster of cilia that beats (giving an appearance of flickering flame) to direct waste fluids concentrated in the tubules that lead to pores located all along sides of the body. Through these pores the waste filtrate moves out.

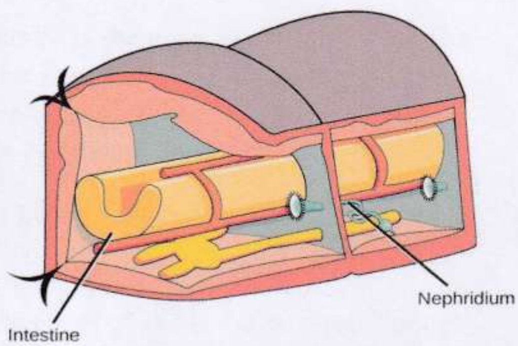


(a) Flame cell of a planarian

Nematoda - Among round worms, the excretory organ is represented in the form of longitudinal tubes. In Ascaris there is a long excretory cell as renette cell for the purpose.



Annelida – Excretory system here is slightly more evolved with tubular reabsorption by a capillary network. Nephridia are the excretory organs found in group Annelida. These are similar to flame cells in having a tubule with cilia. Nephridia filters fluid from coelom. Beating cilia at the opening of nephridium draws the fluid from coelom into a tubule. As the filtrate passes down the tubules, nutrients and other solutes get reabsorbed from it by capillaries. The resulting filtered fluid rich in wastes is then removed through a pore called nephridiopore located at side of the body.

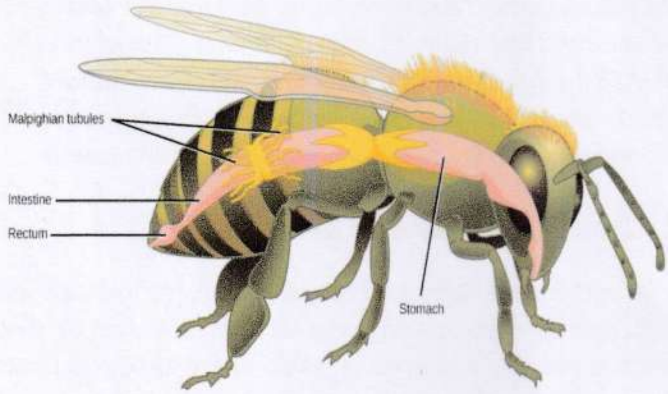


(b) Nephridium of an earthworm

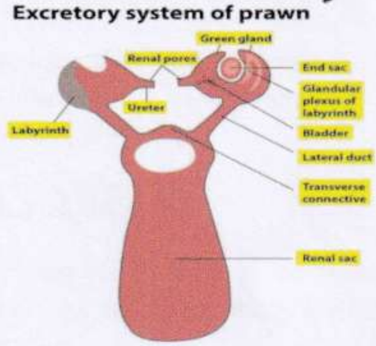
Arthropoda - Antennary glands are the excretory organs among crustaceans. These glands are opaque-white, pea seed sized structures, enclosed in the coxa of each 2nd antenna. In the Onychophora, there are 14 to 40 nephridia functioning as excretory units. In insects and arachnids, the Malpighian tubules function as excretory structures.

Malpighian tubules are found lining the gut in insects. These are usually found in pairs and the number of tubules varies from species to species. These tubules are convoluted, increasing their surface area, and are lined with microvilli for reabsorption and maintenance of osmotic balance. Malpighian tubules work cooperatively with specialized glands found in walls of rectum. In this urine is produced by tubular secretion mechanisms by cells lining the Malpighian tubules that directly bathe in Haemolymph. Metabolic wastes such as uric acids directly diffuse into tubules. The tubules are also lined with exchange pumps that actively transport H+ ions into the cells and K+ and Na+ ions out into the lumen of tubules. These ions alter the osmotic pressure which draws water, electrolytes, and uric acid passively into the tubules forming urine. The urine thus formed is passed into the rectum and then excreted out of the body

In low water environments, water and electrolytes get reabsorbed in the organism due to which the concentrated waste rich in uric acid that gets excreted as a thick paste or powder. This is done to conserve water especially in dry environments.



Excretory system of prawn



Mollusca- <u>Renal gland</u> which is modification of nephridia is the main excretory organ. The renal gland is a relatively wide tube opening from a sac (the pericardium) surrounding the heart, at one end, and to the mantle cavity (effectively to the exterior) at the other. There is a single pair of renal glands; in some forms one member of the pair may be reduced or absent.

Echinodermates - Definite excretory organs are not found. Some coelomic corpuscles like amoebocytes perform excretory functions.

Hemichordates / Stomochordata - Here excretion of waste takes place through proboscis gland. The gland collects the waste from blood and passes it into the coelom of proboscis from where it is finally excreted through the Proboscis pore. This pore is present at anterior region of proboscis.

Excretion in Protochordates / Acraniates – In case of Urochordates, excretion occurs through **Neural Gland**. In Cephalochordates, excretion occurs via **Protonephridia with solenocytes.**

EXCRETORY ORGAN OF VERTEBRATES

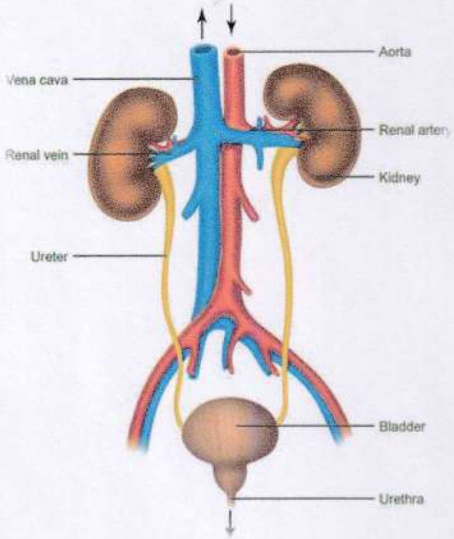
KIDNEY

This is the principal structure found in vertebrates to remove the major contents of nitrogenous wastes. Kidney is originated from embryonic mesoderm. On the basis of the developmental stages different kinds of kidney have been reported. In Anamniota, there are Pronephros and Opisthonephros. In Amniota, there are Pronephros, mesonephros and metanephros kidneys.

- **Pronephric kidney –** refers to a paired organ with a single enormous nephron that filters blood filtrate produced by glomeruli or glomerate—large embryonic glomeruli. The pronephros is the first kidney to develop in the embryo of more evolved vertebrates and disappears in adults. It is quickly replaced by the Mesonephros kidney.
- **Mesonephric kidney** – mesonephros is a permanent kidney that develops posterior to and replaces the pronephros of the embryonic and larval stages in amphibians and most fish. It's a paired organ made up of nephrons with capsules that filter blood from the glomerulus and tubules with cells that reabsorb water and nutrients while secreting nitrogenous waste.
- **Metanephric kidney -** it is the functional adult kidney of amniotes. The mesonephros develops in the embryo in more evolved vertebrates like in reptiles, birds, and mammals. the metanephros takes over mesonephros kidney after the 10th week in humans.

MAMMALIAN EXCRETORY SYSTEM

The excretory system is a vital biological system that removes excess and waste products from the body to maintain homeostasis. The excretory system or the urinary, or renal, system, of mammals mainly consists of the kidneys, ureters, a bladder, and a urethra.



Human excretory system

KIDNEY – THE MAIN OSMOREGULATORY ORGAN

The paired kidneys are reddish organs that resemble beans in shape. the kidneys are retroperitoneal, (located outside of the peritoneal cavity). Relatively to the vertebral column, the kidneys are located between the levels of the last thoracic and third lumbar vertebrae. The right kidney is slightly lower than the left because of the large area occupied by the liver. The adrenal glands sit on top of each kidney and are also called the suprarenal glands. Kidneys filter blood and purify it. Simultaneously it produces urine that is stored in the bladder prior to elimination through the urethra. The average adult kidney measures about 11 to 13 cm. long, 5 to 7.5 cm. wide and 2.5 cm. thick. Each kidney weighs about 150 gm in the adults.

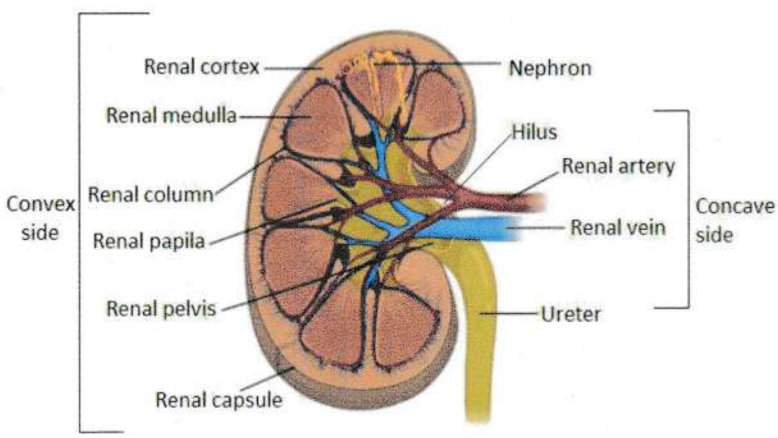
➢ KIDNEY STRUCTURE

Externally, the kidneys are surrounded by three layers. The outermost layer is a tough connective tissue layer called the renal fascia. The second layer is called the perirenal fat capsule, which helps anchor the kidneys in place. The third and innermost layer is the renal capsule.

Internally, the kidney has three regions—an outer cortex, a medulla in the middle, and the renal pelvis in the region called the hilum of the kidney. The hilum is the concave part of the bean-shape where blood vessels and nerves enter and exit the kidney; it is also the point of exit for the ureters.

The renal cortex is granular due to the presence of nephrons—the functional unit of the kidney.

The medulla consists of multiple pyramidal tissue masses, called the renal pyramids. In between the pyramids are spaces called renal columns through which the blood vessels pass. The tips of the pyramids, called renal papillae, point toward the renal pelvis. There are, on average, eight renal pyramids in each kidney. The renal pyramids along with the adjoining cortical region are called the lobes of the kidney. The renal pelvis leads to the ureter on the outside of the kidney. On the inside of the kidney, the renal pelvis branches out into two or three extensions called the major calyces, which further branch into the minor calyces. The ureters are urine-bearing tubes that exit the kidney and empty into the urinary bladder.



Internal structure of Kidney

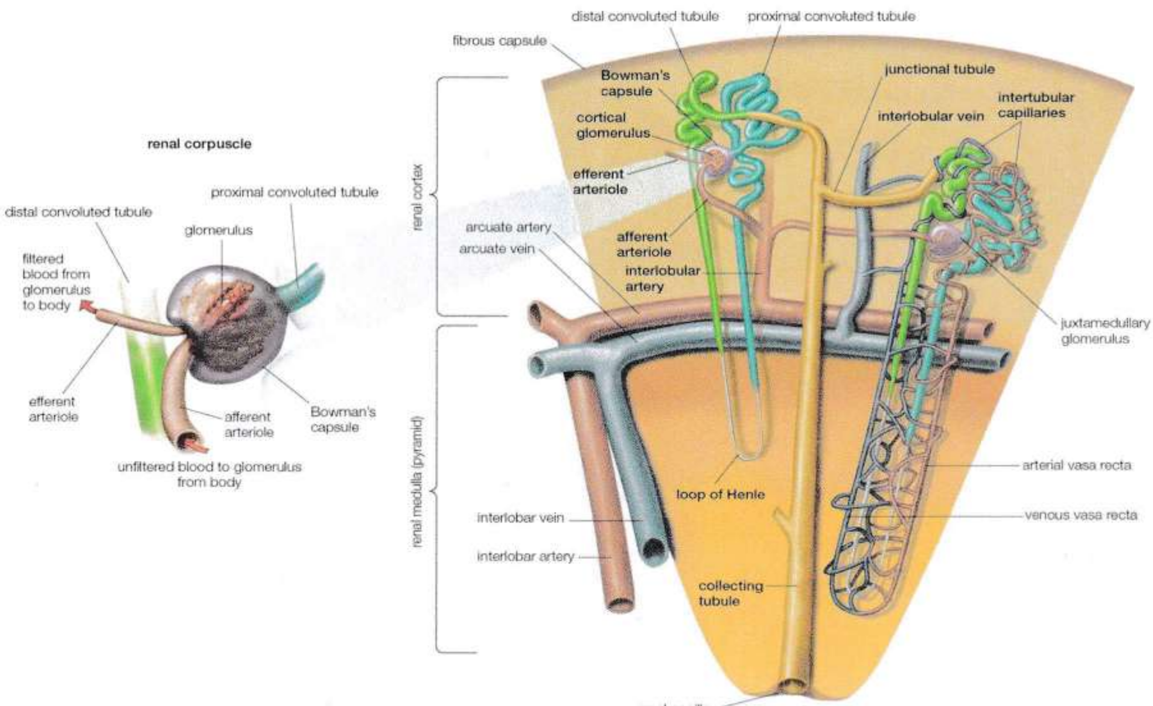
The arteries, veins, and nerves that supply the kidney enter and exit at the renal hilum. Renal blood supply starts with the branching of the aorta into the renal arteries (which are each named based on the region of the kidney they pass through) and ends with the exiting of the renal veins to join the inferior vena cava.

The renal arteries split into several segmental arteries upon entering the kidneys. Each segmental artery splits further into several interlobar arteries and enters the renal columns, which supply the renal lobes. The interlobar arteries split at the junction of the renal cortex and medulla to form the arcuate arteries.

The arcuate "bow shaped" arteries form arcs along the base of the medullary pyramids. Cortical radiate arteries, as the name suggests, radiate out from the arcuate arteries. The cortical radiate arteries branch into numerous afferent arterioles, and then enter the capillaries supplying the nephrons. Veins trace the path of the arteries and have similar names, except there are no segmental veins.

➢ NEPHRON

The functional unit of the kidney is the nephron. Each kidney is made up of over one million nephrons that dot the renal cortex, giving it a granular appearance when sectioned sagittally. There are two types of nephrons— cortical nephrons (85 percent), which are deep in the renal cortex, and juxtamedullary nephrons (15 percent), which lie in the renal cortex close to the renal medulla. A nephron consists of three parts—a renal corpuscle, a renal tubule, and the associated capillary network, which originates from the cortical radiate arteries.



➢ RENAL CORPUSCLE

The renal corpuscle, located in the renal cortex, is made up of a network of capillaries known as the glomerulus and the capsule, a cup-shaped chamber that surrounds it, called the glomerular or Bowman's capsule.

➢ RENAL TUBULE

The renal tubule is a long and convoluted structure that emerges from the glomerulus and can be divided into three parts based on function. The first part is called the proximal convoluted tubule (PCT) due to its proximity to the glomerulus; it stays in the renal cortex.

The second part is called the loop of Henle, or nephritic loop, because it forms a loop (with descending and ascending limbs) that goes through the renal medulla. The third part of the renal tubule is called the distal convoluted tubule (DCT) and this part is also restricted to the renal cortex

The DCT, which is the last part of the nephron, connects and empties its contents into collecting ducts that line the medullary pyramids. The collecting ducts amass contents from multiple nephrons and fuse together as they enter the papillae of the renal medulla.

➢ CAPILLARY NETWORK WITHIN THE NEPHRON

The capillary network that originates from the renal arteries supplies the nephron with blood that needs to be filtered. The branch that enters the glomerulus is called the afferent arteriole. The branch that exits the glomerulus is called the efferent arteriole. Within the glomerulus, the network of capillaries is called the glomerular capillary bed. Once the efferent arteriole exits the glomerulus, it forms the peritubular capillary network, which surrounds and interacts with parts of the renal tubule. In cortical nephrons, the peritubular capillary network surrounds the PCT and DCT. In juxtamedullary nephrons, the peritubular capillary network forms a network around the loop of Henle and is called the vasa recta.

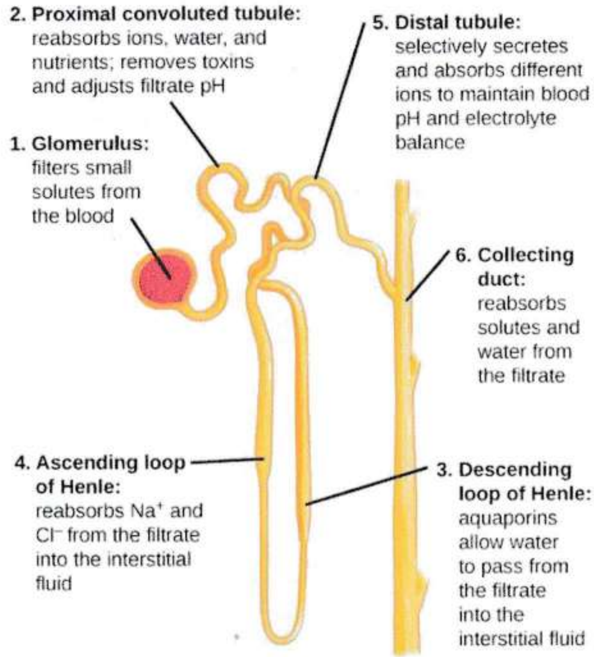
KIDNEY FUNCTION AND PHYSIOLOGY

The uriniferous tubules of the kidney form urine from the blood circulating in the glomerulus. Formation of urine by the kidneys is considered to be due to three types of activities glomerular filtration, tubular secretion and selective reabsorption.

First, the nephrons filter blood that runs through the capillary network in the glomerulus. Almost all solutes, except for proteins, are filtered out into the glomerulus by a process called glomerular filtration.

Second, the filtrate is collected in the renal tubules. Most of the solutes get reabsorbed in the PCT by a process called tubular reabsorption. In the loop of Henle, the filtrate continues to exchange solutes and water with the renal medulla and the peritubular capillary network.

Water is also reabsorbed during this step. Then, additional solutes and wastes are secreted into the kidney tubules during tubular secretion, which is, in essence, the opposite process to tubular reabsorption.



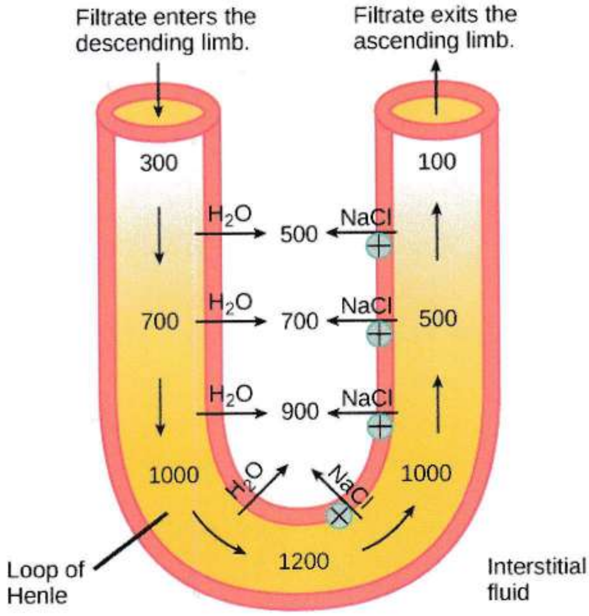
❖ **Glomerular Filtration**

Glomerular filtration filters out most of the solutes due to high blood pressure and specialized membranes in the afferent arteriole. The blood pressure in the glomerulus is maintained independent of factors that affect systemic blood pressure. All solutes in the glomerular capillaries, except for macromolecules like proteins, pass through by passive diffusion. There is no energy requirement at this stage of the filtration process Glomerular filtration rate (GFR) is the volume of glomerular filtrate formed per minute by the kidneys. GFR is regulated by multiple mechanisms and is an important indicator of kidney function.

❖ **Tubular Reabsorption and Secretion**

Tubular reabsorption occurs in the PCT part of the renal tubule. Almost all nutrients are reabsorbed, and this occurs either by passive or active transport. Reabsorption of water and some key electrolytes are regulated and can be influenced by hormones. Sodium (Na+) is the most abundant ion and most of it is reabsorbed by active transport and then transported to the peritubular capillaries. Because Na+ is actively transported out of the tubule, water follows it to even out the osmotic pressure.

Water is also independently reabsorbed into the peritubular capillaries due to the presence of aquaporins, or water channels, in the PCT. This occurs due to the low blood pressure and high osmotic pressure in the peritubular capillaries. However, every solute has a transport maximum and the excess is not reabsorbed. In the loop of Henle, the permeability of the membrane changes. The descending limb is permeable to water, not solutes; the opposite is true for the ascending limb. Additionally, the loop of Henle invades the renal medulla, which is naturally high in salt concentration and tends to absorb water from the renal tubule and concentrate the filtrate. The osmotic gradient increases as it moves deeper into the medulla. Because two sides of the loop of Henle perform opposing functions; it acts as a countercurrent multiplier. The vasa recta around it acts as the countercurrent exchanger.



The loop of Henle acts as a countercurrent multiplier that uses energy to create concentration gradients. The descending limb is water permeable. Water flows from the filtrate to the interstitial fluid, so osmolality inside the limb increases as it descends into the renal medulla. At the bottom, the osmolality is higher inside the loop than in the interstitial fluid. Thus, as filtrate enters the ascending limb, Na+ and Cl- ions exit through ion channels present in the cell membrane. Further up, Na+ is actively transported out of the filtrate and Cl- follows. Osmolarity is given in units of milliosmoles per liter (mOsm/L).

Loop diuretics are drugs sometimes used to treat hypertension. These drugs inhibit the reabsorption of Na+ and Cl–ions by the ascending limb of the loop of Henle. A side effect is that they increase urination.

By the time the filtrate reaches the DCT, most of the urine and solutes have been reabsorbed. If the body requires additional water, all of it can be reabsorbed at this point.
Further reabsorption is controlled by hormones, which will be discussed in a later section. Excretion of wastes occurs due to lack of reabsorption combined with tubular secretion. Undesirable products like metabolic wastes, urea, uric acid, and certain drugs, are excreted by

tubular secretion. Most of the tubular secretion happens in the DCT, but some occurs in the early part of the collecting duct. Kidneys also maintain an acid-base balance by secreting excess H+ ions.

Although parts of the renal tubules are named proximal and distal, in a cross section of the kidney, the tubules are placed close together and in contact with each other and the glomerulus. This allows for exchange of chemical messengers between the different cell types. For example, the DCT ascending limb of the loop of Henle has masses of cells called macula densa, which are in contact with cells of the afferent arterioles called juxtaglomerular cells. Together, the macula densa and juxtaglomerular cells form the juxtaglomerular complex (JGC).

The JGC is an endocrine structure that secretes the enzyme renin and the hormone erythropoietin. When hormones trigger the macula densa cells in the DCT due to variations in blood volume, blood pressure, or electrolyte balance, these cells can immediately communicate the problem to the capillaries in the afferent and efferent arterioles, which can constrict or relax to change the glomerular filtration rate of the kidneys.

SUMMARY OF FILTRATION REABSORPTION, AND SECRETION

REGION OF NEPHRON	ACTIVITY
Renal corpuscle (endothelial-capsular) membrane)	*Filtration* : of blood in glomerular capillaries under hydrostatic pressure results in the formation of filtrate that contains water, glucose, some amino acids, Na^+, Cl^-, HCO_3-, K^+, urea, uric acid, creatinine and other solutes in the same concentration as in blood plasma. Plasma proteins and cellular elements of blood normally do not pass through the endothelial - capsular membrane and are not found in filtrate.
Proximal convoluted tubule	*Reabsorption* : of solutes such as glucose, amino acids, Na^+, Cl^-, HCO^-_3, K^+, urea, water reabsorption along with reabsorption along with reabsorption of sodium and glucose. *Secretion* : of H^+, NH_4^+, and a little creatinine.
Descending limb of the loop of Henle	*Reabsorpatibn* : of water *Secretion* of urea.
Ascending limb of the loop of Henle	*Reabsorption* of Na^+, K^+ and Cl^- *Secretion* of urea.
Distal convoluted tubule	*Reabsorption* of Na^+, K^+ and Cl^- and $HCO3^-$, water reabsorption along with reabsorption of sodium glucose in early portion.
Collecting duct	*Reabsorption* of Na^+ under influence of aldosterone; HCO_3^-(new), Cl^-, and urea; water reabsorption under influence of ADH. *Secretion* of H^+ and K^+.

URINE AND ITS PROPERTIES

Urine is amber in Colour due to the presence of urobilin, a bile pigment altered in the intestine, reabsorbed then excreted by the kidneys. A healthy adult passes 1000 to 1500 ml.of urine per day. The amount of urine secreted and the specific gravity vary according to the fluid intake and the amount of solute excreted. During sleep and muscular exercise urine production is decreased. Any analysis of the volume and physical, chemical and microscopic properties of urine, called a **urinalysis,** tells us much about the state of the body.

The principal physical characteristics of urine are –

1) **Colour** - Yellow or amber but varies with concentration and diet. Color is due to urochrome (pigment produced from breakdown of bile). Concentrated urine is darker in Colour. Diet (reddish coloured urine from beels and green coloured from asparagus) and certain diseases (kidney stone may produce blood in urine) affect Colour.
2) **Turbidity** - Transparent when freshly voided but becomes turbid (cloudy) upon standing.
3) **Odor** - Aromatic but becomes ammonia - like upon standing. Some people inherit the ability to form methyl mercaptan from ingesting asparagus that gives urine a characteristic odor. Urine of diabetics has a sweet odor due to presence of ketone bodies.
4) **pH** - Ranges between 4.6 and 8.0; average 6.0; varies considerably with diet. High-protein diets increase acidity vegetarian diet increases alkalinity.
5) **Specific gravity** - The specific gravity of urine is between 1020 and 1030.
6) **Volume** - The volume of urine eliminated per day in the normal adult varies between 1000 and 2000 ml. (about 1 to 2 qt.) Urine volume is influenced by blood pressure, blood osmotic pressure, diet, temperature, diuretics, mental state, and general health. Low blood pressure triggers the renin angiotensin pathway, which increases reabsorption of water and salts in the renal tubules and decreases urine volume. When blood osmotic pressure decreases, for example, after drinking a large volume of water, secretion of ADH is inhibited and consequently a larger volume of urine is excreted. The reverse effects occur with high blood pressure and increased blood osmotic pressure.

Chemical composition of urine –

Water accounts for about 95% of the total volume of urine. The remaining 5% consists of solutes derived from cellular metabolism and outside sources such as drugs. Typical solutes present in urine are described below:-

ORGANIC CONSTITUENTS OF URINE

CONSTITUENT	AMOUNT (g)	COMMENT
Urea	25.0 to 35.0	Composes 60 to 90% of all nitrogenous material in urine. Derived primarily from deamination of amino acids to form ammonia
Creatinine	1.6	Normal constituent of blood. Derived primarily from breakdown of creatinine phosphate
Uric acid	0.4 to 1.0	Product of catabolism of nucleic acids (DNA and RNA) derived from food or cellular destruction. Because of insolubility, it tends to crystallize and is a common component of kidney stones.
Hippuric acid	0.7	Form in which benzoic acid (toxic substance in Fruit sand vegetables) is believed to be eliminated from body. High-vegetable diets increase quantity of hippuric acid excreted.
Indican	0.01	Potassium salt of indole. Indole result from bacterial breakdown of protein in large intestine and is carried by blood to liver, where it is probably changed to indican.
Ketone bodies	0.04	Also called acetone bodies. Normally found in small amounts. In cases of diabetes mellitus and acute starvation, ketone bodies appear in high concentrations.
Other substances	2.9	May be present in minute quantities, depending on diet and general health. Include carbohydrates, pigments, fatty acids, mucin, enzymes, and hormones.

INORGANIC CONSTITUENTS OF URINE

Constituent	Amount(g)	Commnets
Na^+, Cl^-	15.0	Principal inorganic salt. Amount excreted varies with intake.
K^+	3.3	Occurs as chloride, sulfate, and phosphate salts.
SO_4^{2-}	2.5	Derived from amino acids.
$H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}	2.5	Occur as sodium compounds (monosodium and disodium phosphate) that serve as buffers in blood and urine.

NH_4^+	0.7	Occurs as ammonium salts. Dervied from protein catabolism and from glutamine (amino acid) deamination in kidneys. Amount produced by kidney may vary with need to produce HCO_3^- to offset acidity of blood and tissue fluids.
Mg^{2+}	0.1	Occurs as chloride, sulfate, and phosphate salts.
Ca^{2+}	0.3	Occurs as chloride, sulfate and phosphate salts.

NOTE – These values are for a urine sample collected over 24 hours.

FLUID AND ELECTROLYTE BALANCE(OSMOREGULATION)

OSMOREGULATION- A process by which organism regulates the fluid and electrolyte balance of its own body is called osmoregulation.

Two steps of osmoregulation- 1. Water balance 2. Electrolyte balance

Role of kidney in osmoregulation-

WATER BALANCE –

When amount of water consumed is equal to the amount of water exerted, this is called balanced condition of water.

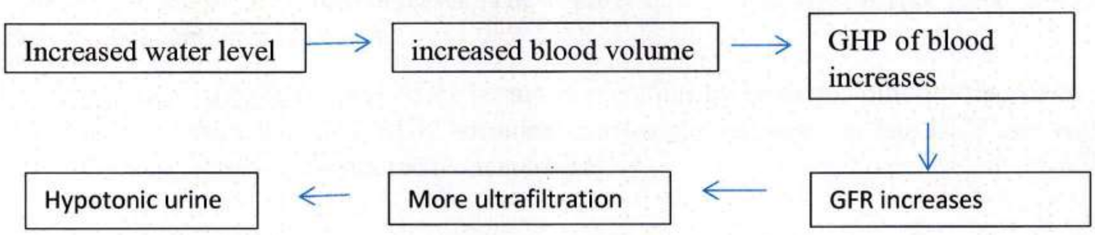
On a typical day, the average adult will take in about 2500 mL (almost 3 quarts) of aqueous fluids. Although most of the intake comes through the digestive tract, about 230 mL (8 ounces) per day is generated metabolically, in the last steps of aerobic respiration. Additionally, each day about the same volume (2500 mL) of water leaves the body by different routes; most of this lost water is removed as urine. The kidneys also can adjust blood volume though mechanisms that draw water out of the filtrate and urine. The kidneys can regulate water levels in the body; they conserve water if you are dehydrated, and they can make urine more dilute to expel excess water if necessary. Water is lost through the skin through evaporation from the skin surface without overt sweating and from air expelled from the lungs. This type of water loss is called insensible water loss because a person is usually unaware of it.

Regulation of Water Intake: Osmolality is the ratio of solutes in a solution to a volume of solvent in a solution. Plasma osmolality is thus the ratio of solutes to water in blood plasma. A person's plasma osmolality value reflects his or her state of hydration. A healthy body maintains plasma osmolality within a narrow range, by employing several mechanisms that regulate both water intake and output.

Water regulation by kidney-

When body has **excess of water**- in this condition **hypotonic urine** forms and water level maintained by excretion of more water. Following are methods of regulation.

1.By increasing ultrafiltration/GFR



GHP- glomerulus hydrostatic pressure . GFR – glomerulus filtrate rate

2. <u>Decreased water reabsorption</u>- when water level is high in the body the Nephric filtrate increases. In this condition the tubular portion of nephrons do not reabsorb more water. This makes urine hypotonic (dilute).

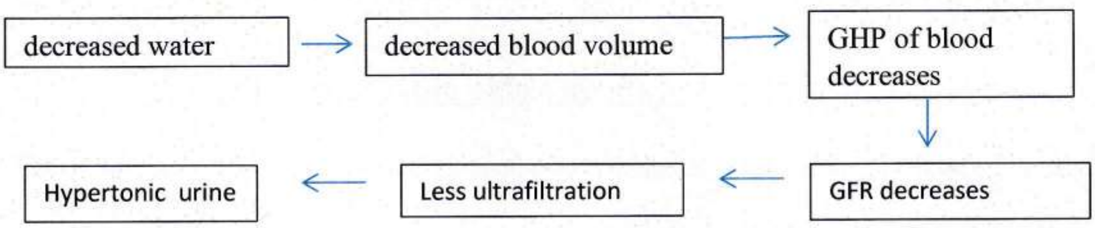
3 .<u>Decreased level of ADH/vasopressin</u> - ADH (antidiuretic hormone) helps in reabsorbtion of water. In excess of water condition the level of ADH decreases. When water is high ECF the blood volume increases, this gives a signal to pituitary to decrease the secreation of ADH. So water reabsorption do not takes place in late DCT and collecting duct and hypotonic urine forms.

Decreased blood volume resulting from water loss has two additional effects. First, baroreceptors, blood-pressure receptors in the arch of the aorta and the carotid arteries in the neck, detect a decrease in blood pressure that results from decreased blood volume. The heart is ultimately signaled to increase its rate and/or strength of contractions to compensate for the lowered blood pressure.

Second, the kidneys have a renin-angiotensin hormonal system that increases the production of the active form of the hormone angiotensin II, which helps stimulate thirst, but also stimulates the release of the hormone aldosterone from the adrenal glands. Aldosterone increases the reabsorption of sodium in the distal tubules of the nephrons in the kidneys, and water follows this reabsorbed sodium back into the blood.

<u>When body has **less water**</u> – in this condition hypertonic urine forms and water level maintained by conservation of water. Following are methods of regulation

1 <u>by decreasing ultrafiltration/ GFR.-</u>



GHP- glomerulus hydrostatic pressure . GFR – glomerulus filtrate rate

2<u>. Increased water reabsorption</u>- when body fluid has less volume of water reabsorption in tubular portion of nephrons increases. The counter current mechanism take place in LOH and urine concentration step occurs.

3. <u>Activity of ADH hormone</u>- ADH hormone secretion by posterior pituitary increases in this condition. By the activity of ADH hormone more water reabsorbs in late DCT and collecting duct. So urine becomes hypertonic (concentrated)

Electrolyte regulation by kidney-

The body contains a large variety of ions, or electrolytes, which perform a variety of functions. Some ions assist in the transmission of electrical impulses along cell membranes in neurons and muscles. Other ions help to stabilize protein structures in enzymes. Still others aid in releasing hormones from endocrine glands. All of the ions in plasma contribute to the osmotic balance that controls the movement of water between cells and their environment.

Electrolytes in living systems include sodium, potassium, chloride, bicarbonate, calcium, phosphate, magnesium, copper, zinc, iron, manganese, molybdenum, copper, and chromium. In terms of body functioning, six electrolytes are most important: sodium, potassium, chloride, bicarbonate, calcium, and phosphate. These six ions aid in nerve excitability, endocrine secretion, membrane permeability, buffering body fluids, and controlling the movement of fluids between compartments.

Sufficient level of electrolyte or solute in the body is called balanced condition of electrolyte
Imbalances of these ions can result in various problems in the body, and their concentrations are tightly regulated. Aldosterone and angiotensin II control the exchange of sodium and potassium between the renal filtrate and the renal collecting tubule. Calcium and phosphate are regulated by PTH, calcitriol, and calcitonin.
Excretion of sodium is accomplished primarily by the kidneys. Sodium is freely filtered through the glomerular capillaries of the kidneys, and although much of the filtered sodium is reabsorbed in the proximal convoluted tubule, some remains in the filtrate and urine, and is normally excreted.

When body has **less amount of electrolyte** – kidney regulates the low amount of electrolyte by following method.

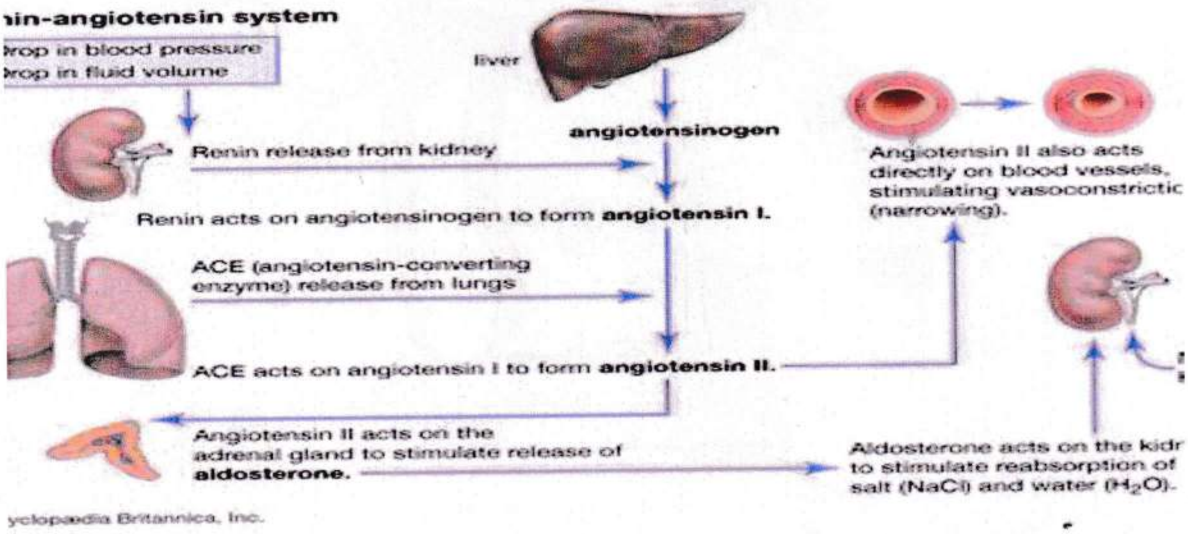
By activity of renin- angiotensin-aldosterone system(RAAS)-

The RAAS system is a hormone system which helps in regulation of blood pressure, blood volume and electrolyte balance.
This hormone system consists of three components-**Renin, angiotensin, aldosterone**

Mechanism of RAAS

Step 1. Release of enzyme renin from granular cells of juxtaglomular apparatus. Less sodium concentration is detected by macula densa cells (J.G.A.) which stimulates secretion of renin.
Step 2. Renin acts as catalyst and cleaves the angiotensinogen to angiotensin1. Angiotensinogen is a precursor protein produced in the liver. Angiotensin 1 is a decapeptide, acts as vasoconstrictor.
Step3. Angiotensin 1 again converted into angiotensin 2 by angiotensin converting enzyme (ACE). Angiotensin 2 is octapeptide and it causes the Na+ reabsorption and stimulates adrenal cortex to secrete aldosterone.

Step 4. Aldosterone (mineralocorticoid), is a steroid hormone which is releases from zona glomerulosa of adrenal cortex. Aldosterone is responsible for reabsorption of Na+ from nephric filtrate. It increases the epithelial Na+ channels to reabsorb urinary sodium.

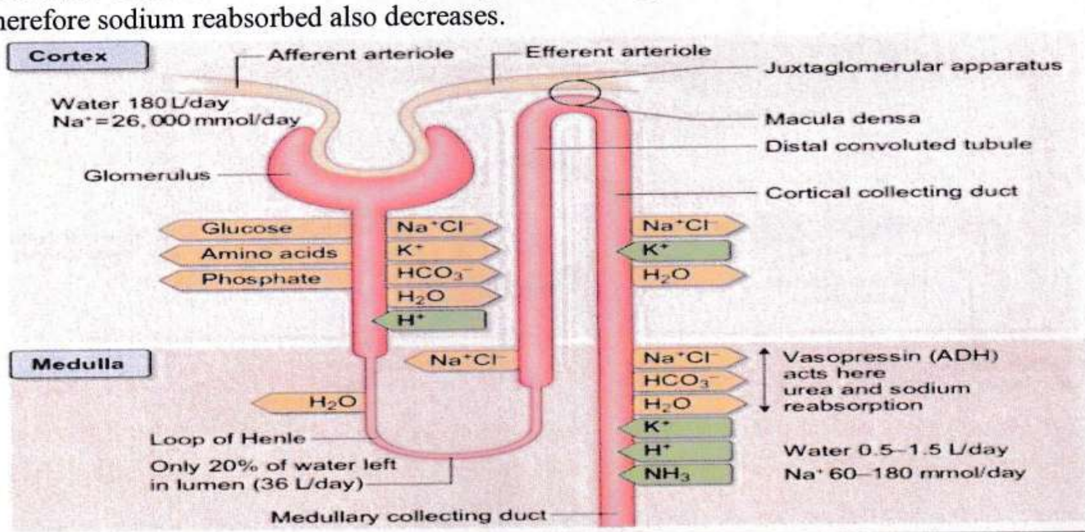


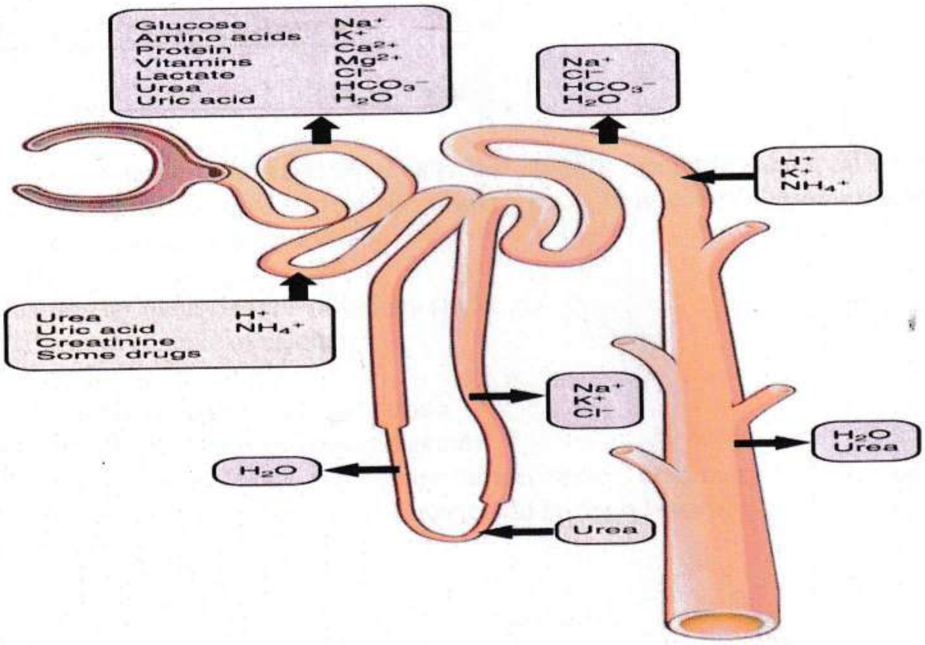
Dig. Of mechanism of RAAS.

When body has **excess amount of electrolyte** – kidney regulates the high amount of electrolyte by following method

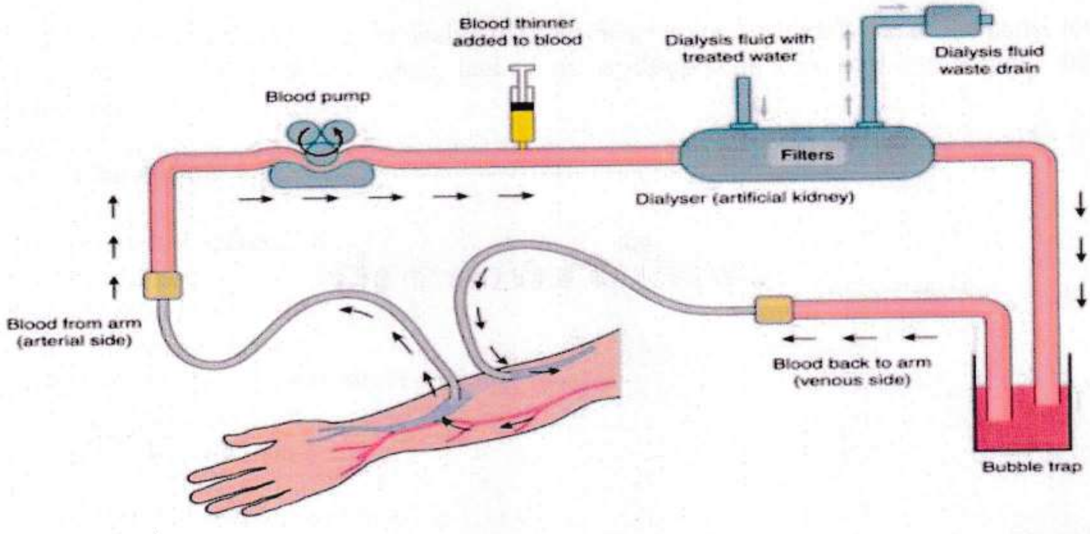
By activity of atrial natriuretic peptide/factor (ANP)

Atrial natriuretic peptide releases from atrial wall of heart. Natriuretic means salt excreting. It decreases secretion of renin from juxtaglomerular apparatus. Decreases aldosterone release, therefore sodium reabsorbed also decreases.





Dialysis- One needle will slowly remove blood and transfer it to a machine called a dialyser or dialysis machine. The dialysis machine is made up of a series of membranes that act as filters and a special liquid called dialysate. The membranes filter waste products from your blood, which are passed into the dialysate fluid.



Disorders of kidney -

1. Renal Calculi or Kidney stones

Kidney stones are the crystals of salts that solidify insoluble stones called renal calculi, which can be formed in any part of the urinary tract. It is composed of calcium oxalate, calcium phosphate, and uric acid crystals.

→ Causes:

Reasons for the formation of kidney stones are:-

1. Excessive intake of calcium
2. Less intake of water
3. Abnormally acidic or alkaline urine
4. Over activity of the parathyroid glands

These stones may block the kidney tubule, ureter, or urinary bladder and may grow. These blockages can cause severe pain. There could be the release of blood in the urine.

▶ Symptoms:

1. Painful urination
2. Back pain
3. Blood in urine

Treatment:

1. Surgery may be the only solution to remove a stone from a kidney or ureter.
2. A technique called shock wave lithotripsy (SWL) gives an easier way. High-intensity shock waves are released and passed through the body, which can break the stones into smaller pieces like that of green sand, which can be washed out with urine. In this technique, recovery time is minimal as no incision is made. About 1-2 thousand shock waves are needed to break the stones. This treatment takes about 45-60 min.

2. Kidney Failure

In this kidney failure, the kidney is unable to filter the excretory materials out of the body. It may lead to uremia, salt-water imbalance, less or no erythropoietin secretion, etc. Kidney failure could be due to several reasons.

→ Causes:

Some of the reasons are:-

1. Diabetes
2. Autoimmune diseases
3. Genetic diseases
4. Tubular injury
5. Acute or chronic disease
6. Long term high dose medications
7. Urinary Tract Infections
8. Excessive dehydration

▶ Symptoms:

1. Less or too much urine secretion
2. Swelling of legs, ankles, and feet due to accumulation of fluids and kidneys are unable to filter the same.
3. Shortening of breath.

4. Seizures
5. Fatigue
6. Loss of appetite
7. Coma

Treatment:

1. Dialysis– It should be started as soon as possible when kidney failure is diagnosed. In this method, an artificial kidney called a hemodialyzer is used to filter the blood, a process called hemodialysis.
2. Kidney Transplantation– Healthy kidney is transplanted from a healthy donor to the recipient suffering from kidney failure.

3. Glomerulonephritis

In this disease, there occurs inflammation of the glomeruli of the kidney, which leads to the presence of proteins and RBCs in the urine. In severe cases, glomeruli completely damages, leading to acute or chronic renal failure. It can be an autoimmune condition also.

→ Causes:

1. Injury in the kidney.
2. The bacterial infection started first in the throat.
3. Problems with the body's immune system.

▶ Symptoms:

1. Blood in urine
2. Swelling of face
3. Less urination than usual
4. Lack of appetite

Treatment:

1. Medications to treat the bacterial infection
2. Sometimes, an artificial kidney is required to remove extra fluid from the body.
3. Plasm apheresis, a process where proteins can be removed from the blood, can be done.
4. Doctors advise eating less proteins, potassium, and salt.

4. Uremia

It is the presence of an excessive amount of urea in the blood. There occurs decreased excretion of urea in the kidney tubules, which results in a high amount of urea in the blood.

→ Causes:

1. Bacterial infection (nephritis).
2. Chronic kidney disease.
3. Some mechanical obstruction.

▶ Symptoms:

1. Tiredness
2. Confusion and mental disorientation
3. Nausea
4. Headache
5. Loss of appetite

Treatment:

1. Dialysis- It is the process in which an artificial kidney removes the wastes from the blood.
2. Kidney transplant can also be done.

5. Diabetes Insipidus

This disease is not related to the common diabetes mellitus. It shares its name because it has the same symptoms as diabetes mellitus.

Causes:

1. In this disease, vasopressin is unable to regulate the water level of the body, which leads to too much urine production. Vasopressin is a hormone secreted by the hypothalamus, stored in the pituitary gland, and released when needed.
2. It is caused when the body does not produce enough ADH, or the kidney does not respond to it in a normal way.

Symptoms:

1. Thirst
2. Frequent urination

Treatments:

1. Increasing the intake of water for mild symptoms.
2. Medications like desmopressin have a stronger effect on kidneys than natural vasopressin.

6.Nephritis or Bright's Disease

Nephritis is generally the inflammation of the kidney. Glomerulonephritis is characterised by inflammation in the glomeruli of the kidney. In this case, the glomeruli are completely filled in blood. If many glomeruli become non-functional, the patient needs an artificial kidney.

7.Hypertension due to Renin Secretion

Hyper secretion of renin results in the formation of angiotensin which leads to hypertension.

8.Oedema

Oedema is the accumulation of excess fluid in the tissues. Excess sodium ions result in an increase in the volume of the interstitial fluid without a change in their osmolality.

How to Avoid Disorders of the Excretory System?

Disorders of the excretory system can be prevented by following steps

1. Drinking lots of water to maintain normal fluid balance.
2. Keeping blood pressure and sugar checked.
3. Cleaning the genitals regularly to avoid infections in the urinary tract.
4. Washing hands before and after washing genitals and rectum.
5. Urine should not be held.

Abnormalities in urine compostition-

1. Glycosuria – presence of glucose /sugar in urine.
2. Ketonuria - presence of ketone bodies in urine.
3. Albuminuria- presence of albumin protein in urine.
4. Haematuria- presence of blood cells in urine.
5. Jaundice - presence of bilesalt (bilirubin, billiverdin) in urine.
6. Pyuria - presence of pus cells in urine.
7. Alkaptonuria - presence of alkapton in urine.(gentic disorder)