- Excretion is the elimination of waste products from the body of an organism. Waste products are unwanted and toxic by-product which are removed to maintain homeostalis and protect the body from their toxicity.
- Defaecation is eliminated of undigested food residue from alimentary canal while secretion is discharge of specially syntheised product. Example, hormone by endocrine gland, saliva from salivary glands.
- Osmoregulation is the regulation of water content and salt concentration in the body of an organism.
- Homostasis is maintenance of a constant favourable internal environment despite fluctuations in water content, solute concentrations formation of toxic waste metabolites.

OSMOLARITY

- It is solute concentration expressed as molarity or moles of solute per litre of solution. Unit of measurement is milliosmole (1000 of osmole which is amount of solute forming one mole of active particles), osmolarity of fresh water is less than 50 mosm/lt, fresh water vertebrates 200-300 mosm/lit, human blood 300 mosm/lt. While sea water has an osmolarity of about 1000 mosm/lit
- Two solutions of same osmolarity are isotonic, one with higher osmolarity or concentration is hypertonic, while the one with lower concentration or dilute solution is known as hypotonic.

METABOLIC WASTE PRODUCTS

1. Nitrogenous waste products.

They are formed during metabolism of excess proteins, amino acids, nucleic acids, alkaloids etc. Nitrogen waste products include ammonia, urea, uric acid, creatine, creatinine, hippuric acid, xathine, guanine, trimethylamine oxide and allantonin.

2. Non-nitrogenous waste products

Oxalic acid, lactic acid

3. Excess chemicals

Sodium, calcium, magnesium, lead, chloride, phosphate, iodine, pigments, drugs, cholesterol, hormones, vitamins, wax etc.

4. Bile pigments

Bilirubin, biliverdin and urochrome are break down products of haemoglobin formed by liver

5. CO_2

6. Excess water

TYPES OF ANIMALS BASED ON EXCERTORY PRODUCTS

- Depending upon the forms in which the nitrogenous wastes are excreted from the body, the organisms are grouped under three categories, ammonotelic animals, ureotelic animals and uricotelic animals

AMMONOTELIC ANIMALS

- Animals excreting their nitrogenous wastes in the form of ammonia are known as ammonotelic animals and the phenomenon of excretion of ammonia is known as ammonotelism
- Ammonia is the first metabolic waste product of protein metabolism. It is highly soluble in water with which it forms ammonium hydroxide (NH_4 OH) which injures cells directly by alkaline caustic action. Hence, excretion of ammonia requires large amounts of water to be lost from the body. That is why such a mode of excretion is suitable for aquatic organisms, which have a constant access of water
- No energy is required to produce ammonia. Many aquatic animals like protozoans (e.g. amoeba, paramecium) sponge (sycon), cnidarians or coelenterates (hydra), liver flukes, tape worms, Ascaris, Nereis, earthworms, leech, most aquatic arthropods (Prawn) most aquatic mollusks (Pila), bony fish (Labeo), amphibian tad pole, tailed amphibian (salamanders) and crocodiles excrete ammonia.
- About 300 to 500 ml of water is required for elimination of 1 gm of ammonia.

URICOTELIC ANIMALS

- Animals which excrete their nitrogenous wastes mainly in the form of uric acid are known as uricotelic animals and the phenomenon of excretion of uric acid is known as uricotelism.
- Conversion of ammonia to uric acid (which requires more energy) and its subsequent elimination requires lesser amount of water as it is comparatively less soluble in water and less toxic as compared to ammonia. Hence, it is observed in terrestrial animals that do not have constant access to water or rather have limited access to water.
- Synthesis of uric acid from ammonia takes place in liver by ionosinic pathway.
- Uric acid is formed in the body by breakdown of purine and pyrimidine of muleic acid.
- Reptiles, birds, land snails and insects excrete uric acid in the form of pellet.
- About 10 ml of water is required for elimination of 1gm of uric acid

UREOTELIC ANIMAL

- Animals which excrete their nitrogenous wastes mainly in the form of urea are known as ureotelic animals and the phenomenon of excretion of urea is known as ureotelism.
- Urea can be stored in body for considerable period of time, as it is less toxic and less soluble in water than ammonia. It is eliminated in the form of urine.
- Urea formation requires expenditure of energy. I is formed in liver by ornithine cycle.
- About 50 ml of water is required to eliminate 1gm of urea.
- Ureotelism is exhibited by semi terrestrial animals. E.g. some earthworms, adult amphibians, cartilaginous fishes, semi aquatic reptiles like turtles, terrapins and alligators and mammals including man
- Sharks retain large amount of urea in their blood, therefore, blood osmotic pressure approaches that of sea water which minimizes water loss from their body

EXCRETORY ORGANS IN DIFFERENT ANIMAL GROUPS

1. Protozoans

Excretory organs: Plasmalemma, pellicle. Nitrogenous waste : Ammonia

2. Poriferans

Excretory organ: General body surface. Nitrogeneous waste : Ammonia

3. Coelenterates

Excretory organs: General body surface. Nitrogenous waste : Ammonia

4. Platyhelminths

Excretory organ: Protonephridium with flame cells. Nitrogenous waste : Ammonia

5. Aschelminths

Excretory organ: Renette cells (Ascaris). Nirogenous waste : Ammonia, urea

6. Annelids

Excretory organs:

i) Metanephridia (Nereis and leach)

ii) Metanephridia and chloragogen cells (earthworm)

Nitrogenous waste:

i) Ammonia

ii) Ammonia, urea on land

7. Molluscs

Excretory organ: Renal gland or organ of Bojanus (Pila and unio) and Keber's organ (Unio)

Nitrogenous waste: Ammonia in aquatic and uric acid in land forms

8. Arthropods

Excretory organs

i) Malphigian tubules, uricose gland, urate cells, nephrocyte.

ii) Malphigian tubules, coxal gland, hepato-pancreas and nephrocytes (spiders and scorpions)

iii) Green glands or antennary glands in a crustaceans.

Nitrogenous waste

i) Uric acid in land forms and ammonia in aquatic forms

ii) Guanine, some xanthine and uric acid

iii) Ammonia

9. Echinoderms

Excretory organs: Tubafeet (podia) and dermal branchiae (thin walls of gills). Nitrogenous waste : Ammonia

10. Hemichordates

Excretory organ: Glomerulus (Balanoglossus)

11. Chordates

a) Urochordates

Excretory organ: Neural gland (Herdmania)

b) Cephalochordates

Excretory organ: Pharyngeal nephridia and Hatschek's nephridium (Amphioxus)

c) Vertebrates

Excretory organ: One pair of kidneys are main excretory organs. Lungs, liver skin and intestine are accessory excretory organs in many vertebrates. Nitrogenous waste: Ammonia, urea, uric acid.

HUMAN EXCRETORY SYSTEM

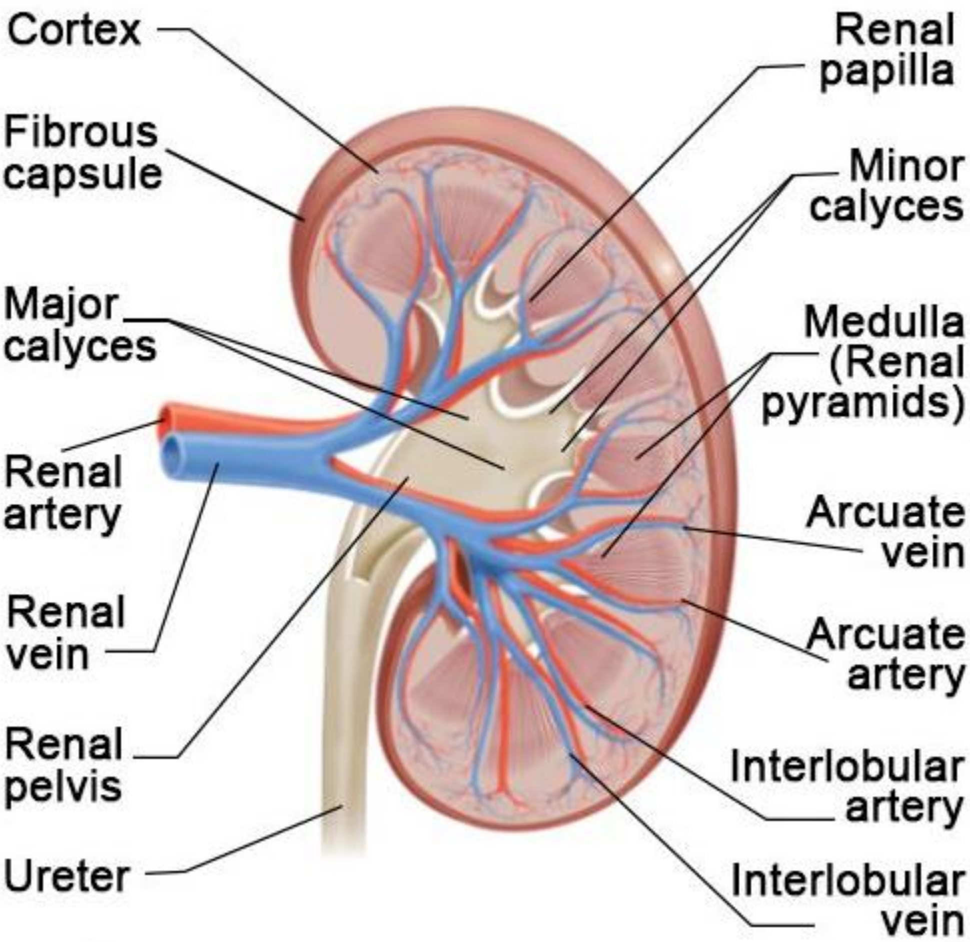
The mammalian (human) urinary system consists of two kidney which form the urine, two ureters which conduct the urine from kidney to urinary bladder, a urinary bladder for storage of urine and a urethra through which the urine is voided by bladder contractions.

KIDNEYS

- Kidneys are mesodermal in origin and arise from linearly arranged mesodermal somites
- They are reddish brown, bean shaped structures situated in the abdominal cavity just behind the vertebral column. The positioning of kidney is called retroperitoneal i.e. located outside peritoneal cavity
- They are situated between the levels of last thoracic and third lumbar vertebra close to the dorsal inner wall of the abdominal cavity. Last two pairs of ribs i.e. floating ribs protect the kidney from backside.
- An average sized kidney is about 10-12 cm in length, 5-7 cm in width and 3-4 cm in thickness. Weight is about 150gm in male and about 135gm in females. Usually, the right kidney is smaller than the left one and

positioned a bit lower as compared to the left kidney. Such a difference is seen as most of the portion of right side is occupied by liver.

- The kidney is covered by a layer of fibrous connective tissue, the renal capsule, which protects it from infection and injuries. Around the capsule there is a layer of fat, the adipose capsule and another outer fibrous membrane, the renal fascia. Both the fat and the fascia help to protect the kidney
- Internally the kidney consists of the outer dark region, the cortex and the inner light region, the medulla. Both the region contains uriniferous tubules or nephron



- The renal cortex is granular in appearance because the tubules here are much convoluted (proximal and distal convoluted tubules) and contain malphigian corpuscales.
- The medulla consists of 10 to 15 multilobular conical masses, the medullary pyramids or renal pyramids, whose bases are adjacent to the cortex are adjacent to the cortex and apices from the papillae. These papillae project into cup shaped channels called minor calyces (7-13 in

number). The minor calyces lead into major calcyces (2-3 in number). The major calyces join to form the pelvis which leads into the ureter.

- Between the medullary pyramids the substance of the cortex extends into the medulla and forms the renal columns of Bertin.
- The medial concave border of kidney contains a notch known as hilus through which the renal artery enters and the renal vein and ureter leave the kidney.

DIFFERENT TYPES OF KIDNEYS IN VERTEBRATES

a) Archinephric or Holonephric kidney

- It extends through the entire length of coelom. This hypothetical kidney is found in the larval of certain cyclostomes e.g. Myxine. It is supposed to give rise to all other kidney types.

b) Pronephric or head kidney

- It appears dorsal to the anterior end of coelom and is associated with pronephric tubules. In pronephric kidney glomerulus is external and naked. It is functional only in embryonic and larval stages and soon replaced by the next stage

c) Mesonephric or middle kidney

- It develops from middle part of the intermediate mesoderm. It is also called Wolffian body. It is functional in both larvae and adults of most fishes and amphibians.

In amniotes, it is functional in embryonic stage and gets replaced by metanephric kidney in adults

d) Opisthonephric or tail kidney

- The functional nephrons in this kidney belongs to the posterior region of coelom, which are displaced from their position

- It is found in sharks and caecilians.

e) Metanephric kidney

- In metanephric kidney, functional posterior nephreons are displaced from the original position to anterio lateral position. The nephrons of this kidney are highly differentiated. Which forms loop of henle in mammals. It is functional in all amniotes i.e. reptiles, birds and mammals

FUNCTION OF KIDNEY

The functions of kidney are as follows

i) Osmoregulation: Kidney removes excess of water from the body

ii) Elimination of nitrogenous waste: Kidney removes nitrogenous waste such as urea and uric acid from the blood.

iii) Maintenance of pH : Kidney removes excess of acids and alkalies from the blood to maintain proper pHof blood (about 7.4)

iv) Maintenance of salt contents: Kidney maintain proper amount of mineral salt such as sodium and potassium in the body.

v) Removal of other substances: Kidneys removes toxic substances, drugs, pigments, excess vitamins from blood.

vi) Maintenance of blood pressure: Kidney controls the fluid balance in the body, therefore, it maintains blood pressure.

vii) Secretion of rennin: kidney secrete an enzyme, the rennin (acts as harmone) which converts the aniotensinogen (produced by liver) into angiotensin. The latter stimulates adrenal cortex to secrete aldosterone (hormone). Which increases the rate of reabsorption of Na^+ in the nepherons.

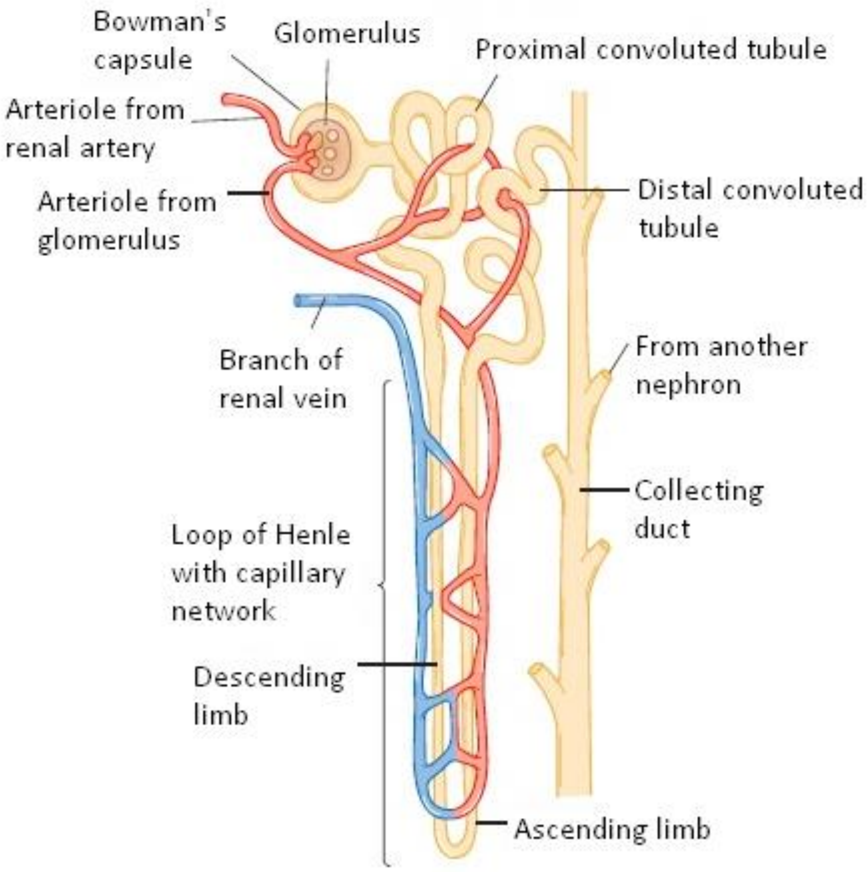
viii) Erythropoietin production: The kidney produces erythropoietix hormone which stimulates the formation of red blood corpuscles. The stimulus for secretion of erythropoietin is less oxygen in the blood (hypoxia) but it is also stimulated by male sex hormones and cobalt salt

ix) Homeostasis: Because kidney removes various unwanted materials from the blood it helps in keeping the internal environment of the body constant.

URETERS, URINARY BLADDER AND URETHRA

- Ureters are thin muscular tubes emerge out from the hilum of kidneys. Urine enters the ureter from the renal pelvis and is conducted along the ureter by peristaltic waves on its walls. Ureters are lined by flexible transitional epithelium and carry urine from the kidneys to urinary bladder.
- Urinary bladder is a sac-like structure which stores urine temporarily. Bladder has three parts. Apex, fundus (body) and neck. Body has triangular area called trigone. Neck region possesses two sphincter and involuntary external sphincter. Urinary bladder is also lined by flexible transitional epithelium.
- Uretha is membranous tube. Which conducts urine to the exterior. The urethral sphincters keep the urethra closed except during voiding of urine.
- Length of urethras in male is much longer than female.

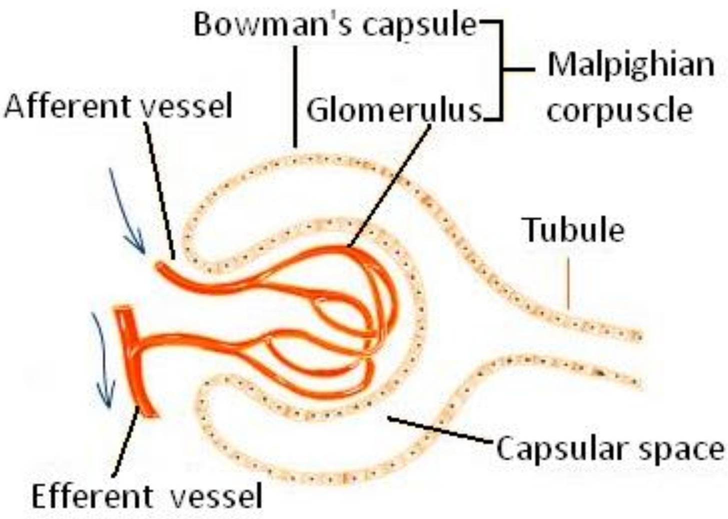
NEPHRONS



- Nephrons are the functional unit of kidney. A human kidney contains about one million thin, long, much convoluted tubular unit called nephrons or uriniferous tubules.
- Two types of nephrons present in kidney are : Cortical and juntamedullary nephrons. Cortical nephrons (about 85%) lie in the renal cortex their glomeruli lie in outer cortex. They have a shorter loop of Henle and peritubular capillary network. They do not have Vasa recta. They control plasma volume when water supply is normal. Tuxtamedullary nephrons (about 15%) lie at the junction of renal loop of Henle and Vasa recta. They control plasma volume when water supply is short.
- A nephron consists of two parts – an initial filtering component, the renal corpuscle or Malphigian corpuscle and long tubule, the renal tubule – both made of simple cuboidal epithelium.

Renal Corpuscle

- Malphigian corpuscle is named after Marcello Malpighi
- The renal corpuscle filters out large solutes from the blood and delivers water and small solutes to the renal tubule for modification
- The renal corpuscle is composed of a capillary network called glomerulus and a Bowman's capsule or glomerular capsule
- Bowman's capsule and glomeruli are absent in marine fishes and desert amphibians hence their nephrons are called aglomerular.



- Bowman's capsule is named after Sir William Bowman, a British surgeon and anatomist. It is a double layered, cup-shaped structure. The lumen of capsule is continuous with the narrow lumen of renal tubule. Bowman's capsule consists of two layers- outer parietal layer (simple squamous epithelium) and inner visceral layer (layer of special epithelial cell) called podocytes containing filtrate filters.

- Glomerulus is a capillary network within the Bowman's capsules. Blood enters glomerular capillaries through afferent arterioles and leaves through efferent arterioles. The diameter is much more than that of efferent arteriole.
- The walls of the afferent and efferent arterioles contain the rennin-secreting juxtaglomerular cell.

RENAL TUBULE

- Attached to each Bowman's capsule is a long, thin tubule with three distinct regions – proximal convoluted tubule (PCT), loop of Henle and distal convoluted tubule (DCT)

Proximal convoluted tubule

The first region of renal tubule is called the proximal convoluted tubule. It is about 14 m long and lined by a single layer of brush bordered cuboidal epithelium which increase surface area and contains mitochondria. Which provide energy for reabsorption of salts by active transport.

Henle's loop

- Henle's loop is a U-shaped tube, which plays a significant role in maintaining high osmolarity of tissue surrounding the loop
- The loop of Henle consists of a descending limb and ascending limb
- Descending limb of loop of Henle is lined by feat cells i.e. simple squamous epithelium. It is permeable to water and impermeable to electrolytes. Due to this the filtrate moving down through the limb becomes concentrated.
- Ascending limb of loop of Henle is comparatively thicker and is composed of flattened cuboidal epithelium. It is impermeable to water and permeable to electrolyte like K^+, Cl^- and Na^+

Distal convoluted tubule

- It is situated in the cortex region of kidney and it is about 4.5 – 5.5 mm long. The diameter of this region is 20 – 50 μm and it is lined by cuboidal epithelium. The epithelium here is with elevations but without any true brush border. Conditional reabsorption of Na^+, water and HCO_3^- takes place in this segment.

Collecting duct

- The last part of nephron is called collecting duct which is 20mm long and lined by the cuboidal cells. Several collecting tubules of different nephron join successively to form the duct of Bellini or papillary duct, which opens at the apex of renal pyramid.

NEPHRON’S BLOOD SUPPLY

- There is an intimate association between the blood vessels and the nephrons of the kidney. This association permits both extensive filtration from the blood and selective reabsorption back into the blood.
- After entering each kidney, the renal artery branches repeatedly forming smaller and smaller arteries, until tiny arterioles reach each of the 1 million nephrons. An afferent arteriole delivers blood to glomerulus for filtration, an efferent arteriole drains filtered blood away from the same glomerulus.
- The efferent arteriole connects to the second network of capillaries, the peritubular capillaries, which are closely associated with the nephron tubule. It is into these peritubular capillaries that water, ions and nutrients are reabsorbed from the filtrate in the nephron tubule. From the peritubular capillary network arise the capillaries of vasa recta, which extends parallel to the loops of Henle and collecting ducts in the medulla. The vasa recta consist of descending capillaries and ascending capillaries. All the capillary network join to form renal venules which join to form renal vein that opens into the inferior vena cava.

URINE FORMATION IN KIDNEY

- The process of formation of urine is called uropoiesis.

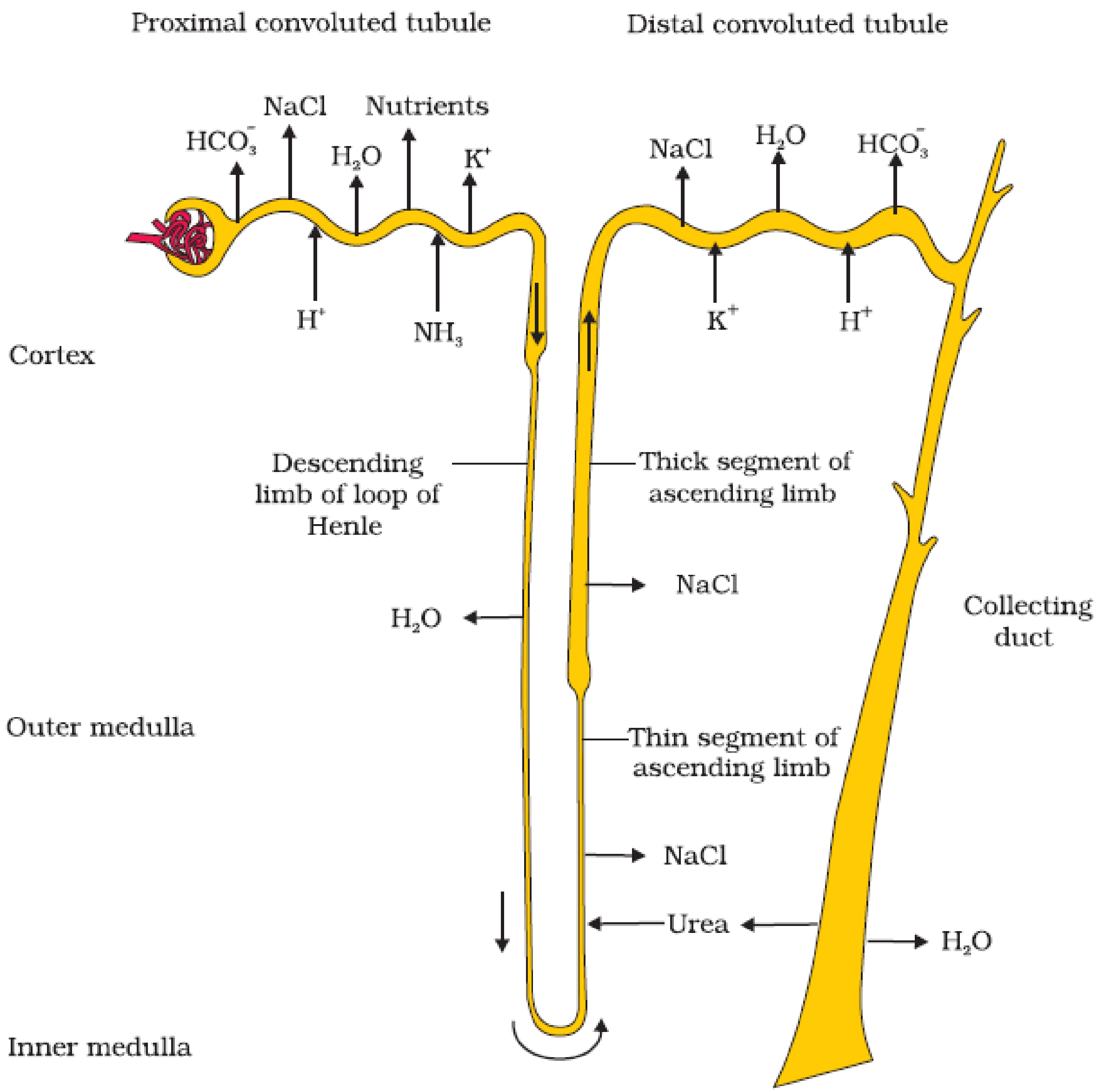
- Formation of urine by the kidneys can be divided into following three steps

i. Glomerular filtration or ultra filtration
ii. Selective reabsorption
iii. Tubular secretion

GLOMERULAR FILTRATION OR ULTARFILTRATION

- The blood pressure is largely responsible for ultrafiltration. In kidney, the glomerular capillary is known as high pressure bed, which the peritubular network are known as low pressure beds.
- The pressure of blood is about 100 mm of Hg in glomerulus, it falls to about 70mm of Hg in glomerulus while it goes down to the extent of about 18 mm of Hg in efferent arteriole. Within the peritubular network, the pressure around PCT is about 14mm of Hg and around DCT is 6mm of Hg, while it is lowest around the collecting tubule is about 2mm of Hg. When blood enters the glomerulus, the blood pressure forces out water and dissolved blood components through the filtration membrane.
- The resulting fluid is called filtrate. The glomerular filtrate contains essentially all the constituents of blood except the blood cells, proteins, certain drugs, pigments, dyes, etc., if present in the blood.
- The amount of filtrate formed by the kidneys per minute is called Glomerular Filtration Rate (GFR). GFR of healthy individual is 125mL/minute i.e., 180L/day.

SELECTIVE REABSORPTION



- From the Bowman's capsule, the glomerular filtrate enters the PCT. After ultrafiltration, rest both the processes proceed simultaneously into the tubular region. About 65% of glomerular filtrate is normally reabsorbed in PCT before reaching the loop of Henle.
- These include glucose, amino acids, vitamins, hormones, sodium, potassium, chlorides, phosphates, bicarbonates, most of water and some urea. Out of these

a) Na^+ and K^+ are reabsorbed through the active transport.
b) Glucose and amino acids are reabsorbed through passive transport.
c) Reabsorption of water takes place through osmosis.
d) Cl^-, urea and other solutes are reabsorbed through simple diffusion. Besides, reabsorption, secretion of certain substances (Actively) also

takes place in PCT like creatinine, hippuric acid, pigments, drugs along with H^+ and NH_3. Here, reabsorption means transportation of substances from the filtrate to back in the blood (flowing in peritubular network) through tissue fluid. Similarly, tubular secretion means transport of substances from blood towards the filtrate through the tissue fluid (from peritubular network to renal tubules).

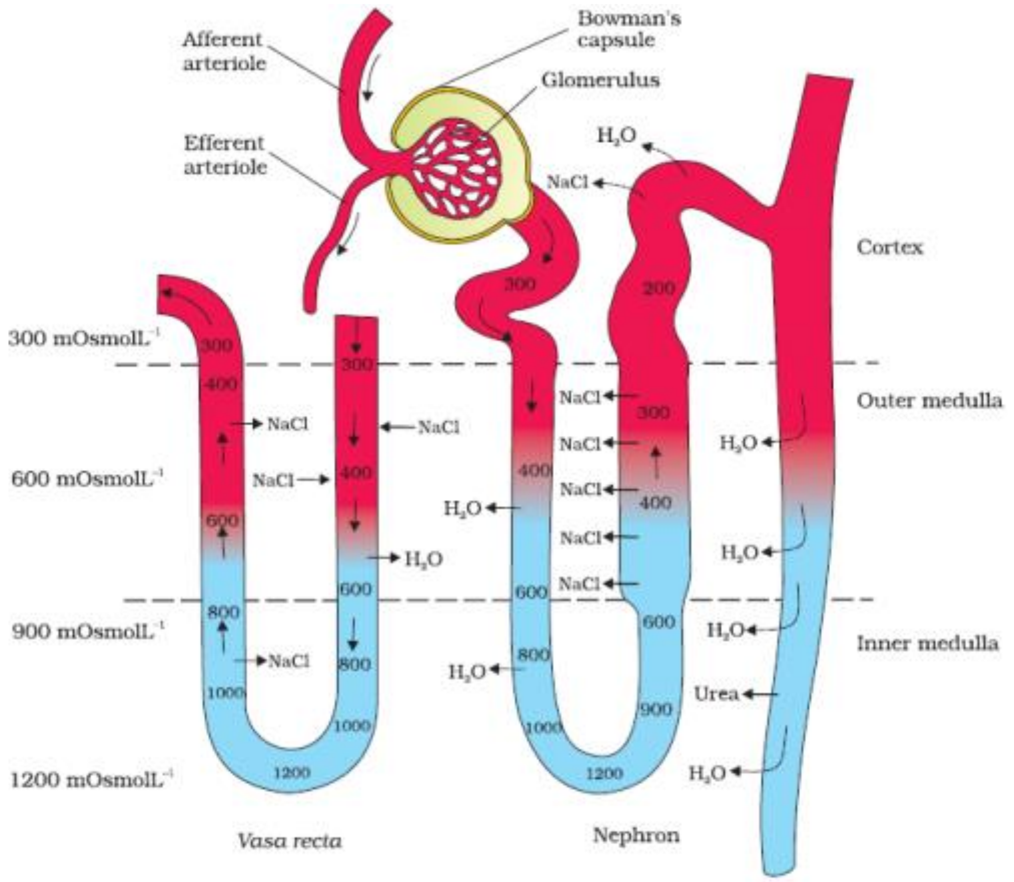
TUBULAR SECRETION

- The substances not reabsorbed in the selective reabsorption excrete in to the filtrate by the process of secretion. Tubular secretion is opposite to tubular reabsorption. The tubular cells secrete substances like H^+, K^+ and ammonia into the filtrate. Through K^+ ions enters the filtrate from the glomerulus and are almost totally reabsorbed but they are also secreted into the lumen of distal convoluted tubule and collecting ducts. The active secretion of K^+ ions is coupled with the active reabsorption of Na^+ ions. Most of the other substances that enters the tubule by tubular secretion move by the active transport.
- Tubular secretion plays a minor role in the function of human kidneys, but in animals like marine fishes and desert amphibians whose nephrons do not possess developed glomeruli, urine is formed mainly by the tubular secretion of urea, creatinine and mineral ions. The process of reabsorption involves both active and passive pathways.

COUNET CURRENT MECHANISM OF URINE CONCENTRATION

- Higher vertebrates (birds and mammals including man) have evolved a counter current mechanism to excrete hypertonic urine (urine more concentrated than blood) for conserving body water, so necessary for land life. The counter current refers to the fact that the fluid flows in opposite direction in the two sides of the loop, down one side and up the other. Henle's loop and capillary loop (vasa rectae) plays an important role in this mechanism.

- As the filtrate passes through the ascending limb of the loop of Henle, it loses NaCl to the interstitial fluid on the renal medulla by diffusion in the narrow region of the limb, and Na^+ and Cl^- ions by active transport in the wide region of the limb.
- The increased concentration of the solutes in the interstitial fluids draws out water by osmosis from the narrow region of the descending limb and also from the collecting duct, both being permeable to water. The water then quickly enters the vasa rectae and is carried away. This maintains high concentration of solutes in the interstitial fluid around the loop of Henle and the collecting duct, and turns the isotonic glomerular filtrate into a hypertonic urine.
- The endothelial cells forming the walls of the vasa recta are freely permeable to ions, water and urea.
- As the blood flows in the descending capillary of the vasa recta towards the renal medulla, water is drawn out from the blood plasma by osmosis due to the progressive increase in the concentration of the interstitial fluid sodium and chloride ions and urea enter the plasma by diffusion.
- As the blood flows in the ascending capillary towards the renal cortex, the reserve occurs, that is, water reenters the plasma and Na^+, Cl^- and urea leave it due to a progressive decrease in the concentration of the interstitial fluid.



REGULATION OF KIDNEY FUNCTIONS

CONTROL BY JUXTAGLOMERULAR APPARATUS (JGA)

- JGA works through Renin Angiotensin Aldosterone Sysytem (RAAS). The system normally operates when blood pressure is decreased in the afferent arteriole of glomerulus which is characterized by fall in glomerular filtration rate. At that time, rennin is released from JG cells.
- Renin works on a plasma protein angiotensinogen (produced by liver) and converts it to angiotensin I.
- Angiotensin I is then converted into angiotensin II.
- This angiotnesin II then increases the blood pressure by causing the aretrioles to constrict and increases blood volumes in the two ways.

i. By increasing water and NaCl reabsorption in PCT.

ii. By stimulating adrenal glands to secrete aldosterone, which works on DCT for the same cause.

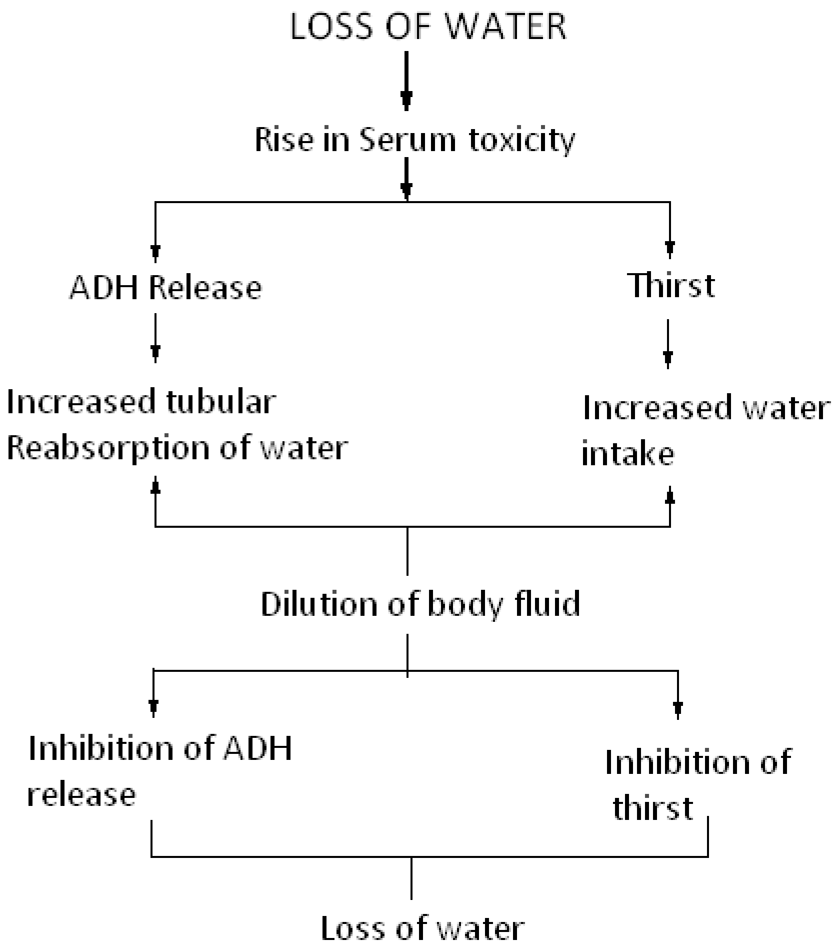
ATRIAL NATRIURETIC FACTOR

- This factor works opposite to RAAS when there is higher blood volume and pressure by causing vasodilation. Walls of atria(heart) produces a peptide hormone Atrial Natriuretic Factor (ANF) which inhibits rennin secretion by juxtaglomerular cells and ADH by pituitary gland. It inhibits NaCl reabsorption and concentration of urine.
- Birds cannot make urine as hypertonic as mammals can do. Reptiles produce only hypotonic urine.

CONTROL BY ANTIDIURETIC HORMONE (ADH)

- ADH is secreted by neurohypophysis and produced by the hypothalamus of brain. The release of this hormone is normally seen when osmoreceptors in hypothalamus detect an increase in osmolarity of blood. In this situation, the osmoreceptors cells also promote thirst. It also increases the reabsorption of water in DCT and collecting duct.
- Excess of water in the body fluids signals the posterior pituitary lobe to stop release of the hormone vasopressin or antidiuretic hormone (ADH). Deficiency of this hormone lowers the permeability of the cells of the distal convoluted tubule and the collecting duct, thereby decreasing the reabsorption of water. However, active reabsorption of Na^+ from the filtrate continues in these regions of the nephrons. More filtration and less reabsorption of H_2O and normal reabsorption of Na^+ produce abundant urine and this brings down the volume of body fluids to normal.
- In case, the volume of the body fluids falls below normal, as in excessive bleeding, profuse sweating due to heavy muscular work or high temperature glomerular filtration slows down due to decrease in blood pressure and filtration pressure in the glomerular capillaries. This stimulates the posterior pituitary lobe to release ADH. This hormone increases the reabsorption of water in DCT and collecting tube.
- Continued Na^+ active reabsorption, makes the interstitial fluid hypertonic and this also favours reabsorption of water. Less filtration and more reabsorption of water lead to the discharge of small amount of hypertonic urine. This raises the volume of the body fluids to normal. In order to prevent the loss of Na^+ in the urine, these must be reabsorbed.

Reabsorption of sodium is controlled by a hormone aldosterone produced by the cortex of the adrenal glands.



MICTURITION

- The expulsion of urine from the urinary bladder is called micturition. It is a reflex process, but in grown up children and adults, it can be controlled voluntarily to some extent.
- The release of urine occurs by the contraction of smooth muscles of urinary bladder wall (due to pressure exerted by pressure receptors present on the wall) and relaxation of the urethral muscle sphincter around the opening of bladder. As the bladder wall is stretched by the gradual filling of the bladder, stretch receptor in the wall generate nerve impulses. These impulses are carried by sensory neurons to the spinal cord and brain, producing the sensation of fullness (around 500 mL).
- The sphincters are then released by the inhibition of motor impulses allowing the smooth muscle of the ladder wall to contract under

autonomic control. The neutral mechanism causing micturition is called micturition reflex.

COMPOSITION OF URINE

- Urine is transparent, amber coloured, hypertonic fluid with a slightly acidic pH (6.0).
- The yellow colour of the urine is due to the pigment urochrome, which is a breakdown product of haemoglobin from worn out RBCs.
- Volume of urine depends upon intake of fluids, external temperature and physical activities. Human excrete 1-2 litres urine per day.
- The urine of standing gives a pungent smell due to conversion of urea into ammonia by bacteria.
- Urine consists of Water- 96%, Urea- 2 to6%, uric acid- 0.3%, salts- 1.5%, traces of cretinine, ammonia, creatine, hormone, water soluble vitamins, etc.

ACCESSORY EXCRETORY ORGANS

1. Liver

Urea is formed in the liver which is eliminated through kidneys. Liver cells also degrade the haemoglobin of worn out red blood corpuscles into bile pigments (bilirubin and biliverdin).

Liver cells also excrete cholesterol, certain products of steroid hormones, some vitamins and many drugs. Liver secrete these substances in the bile. The bile carries these substances to the intestine and are passed out with faeces.

2. Skin

It helps the body to get rid of excess of water, salts and waste such as ammonia in aquatic animals.

The mammalian skin posses sweat gland and sebaceous glands that play excretory roles.

3. Intestine

Epithelial cells of colon excrete excess salts of calcium, magnesium and iron along the faeces.

4. Lungs

It helps in removing gaseous form of excretory wastes like CO_2 and little amount of water vapour.

5. Salivary glands

Heavy metals and drugs are excreted in the saliva.

DISORDERS OF EXCRETORY GLANDS

1. Renal calculi

Excessive hormonal imbalance, excess uric acid formation, excess milk intake, dehydration, metabolic disturbances are responsible for renal calculi or renal stones. They are forms by the precipitation of uric acid or oxalate.

2. Cystitis

It is an inflammation of the urinary bladder that may be caused by bacterial infection.

3. Nephritis (Bright's disease)

It is the inflammation of renal pelvis, calyces and interstitial tissue due to local bacterial infection. Bacteria reach in these organs through urethra and ureter. Inflammation affects the counter-current mechanism and the victim fails to concentrate urine. Symptoms of this disease are back pain and frequent and painful urination.

4. Polyuria

Amount of urine passed out is more than normal.

5. Haematuria

Presence of blood in urine.

6. Anuria

Failure of kidney to form urine.

7. Pyuria

Presence of pus or WBCs in urine.

8. Glycosuria

Presence of glucose in urine due to diabetes mellitus.

9. Ketosis

Presence of ketone in urine due to metabolism of fatty acids instead of glucose during diabetes, starvation and pregnancy.

10. Uraemia

Urea accumulation in blood is comparatively high.

11. Diuresis

It is a condition in which excretory volume of urine is increased.

ARTIFICIAL KIDNEY

- Artificial kidney called haemodialyzer is a machine that is used to filter the blood of damaged kidneys. The process is called haemodialysis. It may be defined as the separation of small molecules from large molecules in a solution by interposing a semi permeable membrane between the solution and water.
- Haemodialyser is a cellophane tube suspended in a salt water solution with same composition as the normal blood plasma, except that no urea is present. Blood of the patient is pumped from one of the arteries into the cellophane tube after cooling it to 0^0C and mixing with an anticoagulant (heparin).
- Pores of cellophane tube allow urea, uric acid, creatinine, excess salts and excess H^+ ions to diffuse from the blood into the surrounding solution. The blood this purified is warmed to body temperature and mixed with antiheparin to restore it to normal clotting power.

- It is then pumped into a vein of the patients. Plasma proteins remain in the blood as the pores of cellophane are too small to permit the passage of their large molecules.