EXCRETORY SYSTEM

Homesostasis: Maintenance of steady state (Walter Cannon).

Homeostatic mechanism are important for normal life as they maintain condition within a range in which, the animals metabolic processes, can occur, The process which is concerned with removal of nitrogenous waste mterials (e.g. urea, uric acid, CO_2, Ammonia, Salts, excess water etc.) is termed excretion.

OSMOCONFORMERS & OSMOREGULATORS

Osmorgulation:

The regulation of solute movement and hence water movement (which follows solutes by osmosis) is called osmorgulation.

On the basis of osomoregulation, animals are either osmoconformer or osmoregulatores.

Osmoconformers:

These animals can not actively control the osmatic condition of their body fluids. Instead of this, they change or adapt the osmolarity of body fluids according to the osmolarity of the surrounding medium.

Example:

- All marine invertebrates and some fresh water invertebrates.
- Hagfish (myxine) which is a marine cyclostome fish, is the only vertebrate osomoconformer.

Osmoconformes show an excellent ability to tolerate a wide range of cellular osmotic environments.

Osmorgulators:

These animals maintain an internal osmolarity different from the surrounding medium in which they inhabit.

Osmoregulator animals must either eliminate excess water if they are in hypotonic medium or they should continoulsy take in water to compensate for water loss if they are in hypertonic medium. Due to this the osmoregulator animals have to spend energy

Strict osmorgulators. Are animals which maintain the composition of body fluids within a narrow osmotic range.

Eg. Most verterbrates (except Hag fish and elasmobranch like shark & rays fish)

Water and solute regulation in freshwater environment:

Body fluids of fresh water animals (osmolarity 200-300m osm L^{-1}) are hypertonic to surrouniding medium (osmolarity 50m osm L^{-1}) Due to this, the freshwater animals constantly face tow problems:

(1) They gain water passively due to osmotic gradient

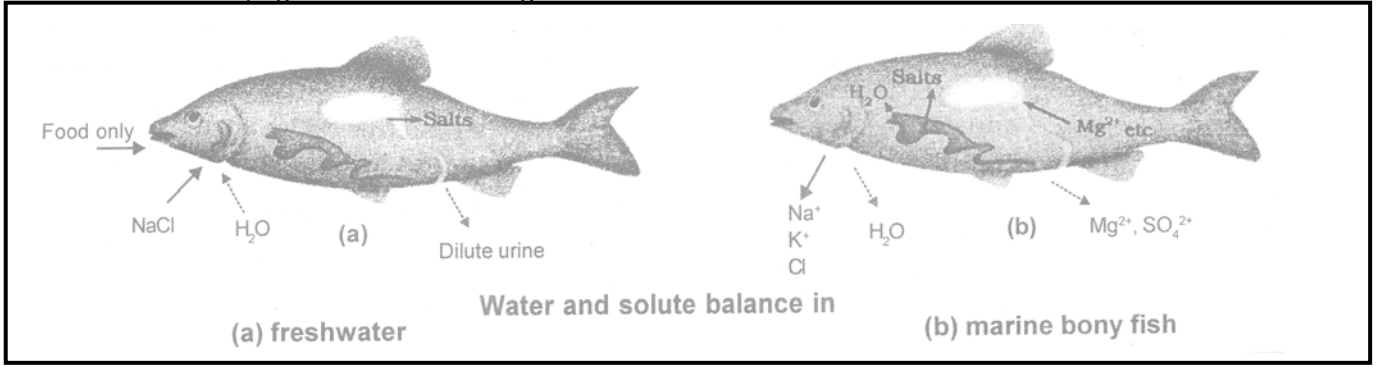
(2) Continuous loss of body salts to surrounding low salt containing medium occurs.

To encounter these problems the fresh water fishes perform following acts:

(1) They do not drink water

(2) Specialised cells called ionocytes or chloride cells are present in the gill membrane of fresh water fi sh.

These cells can actively import Na^+& Cl^- from surrounding water (containing less than 1mM NaCl) against concentration gradient.



Water and solute regulation in marine environment:

Body fluids of marine bony fishes is hypotonic to seawater (osmolarity 1000 m osm L^{-1}). So the osmoregulatory problems are opposite here:

(1) Marine fishes loose water from the body through permeable surfaces (like gill membranes, oral and anal membranes.)

(2) To compensate this water loss the marine fishes have to drink water, this drinking results in gain of excess salts.

These problems are encountered by marine bony fishes by following acts:

(1) The ionocytes or chloride cells of the gill membrane eject out excess of monovalent ions.

(2) Excess of Divalent cations are excreted with faeces.

- When fishes like Hilsa & Salman (which live in both sea & fresh water) migrate from fresh water to sea water they drink water and excrete excess salts through gill membranes.
- Body fluids of marine invertebrates, ascidians and hag fishes are isosmotic to sea water.
- Elasmobranch fishes (shark & rays) and coelacanths (lobe fin fish) reduce the osmorgegulatory challenges by raising the osmolarity of body fluids. This is done by accumulation of osmolytes like urea & trimethylamine oxide (TMAO).This makes the body fluids of shark and coelcaths slightly hyperosmotic to sea water,
- Osmolarity of human blood is about 300 mosm L^{-1}

Water and solute regulation in terrestrial environment:

Land animals continuosly loose water through oral, nasal or respiratory surface during breathing. A loss of 12 perce3nt of body water may lead to death in humans. The water loss is compensated by drinking & eating moist Food. Some example of water conservation in different animals are as follows.

- Kangaroo rats loose very little water, because they can recover 90 percent of the loss by using metabolic water.

- When water is not available, the camels do not produce urine but store urea is tissues and solely depend on metabolic water. When water is available they rehydrate themselves by drinking upto 80 litres of water in 10 minutes.

Water balance in humans and desert kangaroo rats

		Kangaroo	Human
Water gain (mld^{-1})	Ingested in	0	1500 (60%)
	Liquid ingested in food	6(10%)	75(3%)
	Derived from metabolism	54(90%)	250 (10%)
		60(100%)	2500(100%)
Water loss ($ml\ d^{-1}$)	Evaporation	43.9(73%)	900(36%)
	Urine	13.5(23%)	1500(60%)
	Faeces	2.6(4%)	100(4%)
		60(100%)	2500(100%)

ELIMINATION OF NITROGENOUS WASTES

One the basis of excretory products (ammonia, urea or uric acid) three types of animals are present.

(1) Ammonotelics: Most aquatic animals excrete nitorigenous water as ammonia, the water soluble ammonia molecules diffuse across the body surface into surrounding water. In fishes most of the ammonia (NH_3) is lost as ammonium ions (NH_4^+) across the gill epithelium.

Eg of ammonotelic animals are teloest (modern bony fish), tadpoles and aquatic insects.

(2) Ureotelics: Animal like mammals, most adult amphibians living on land, marine fish and turtles, face the problem of conserving water. Excretion of urea is beneficial for these animals than ammonia because of following reasons.

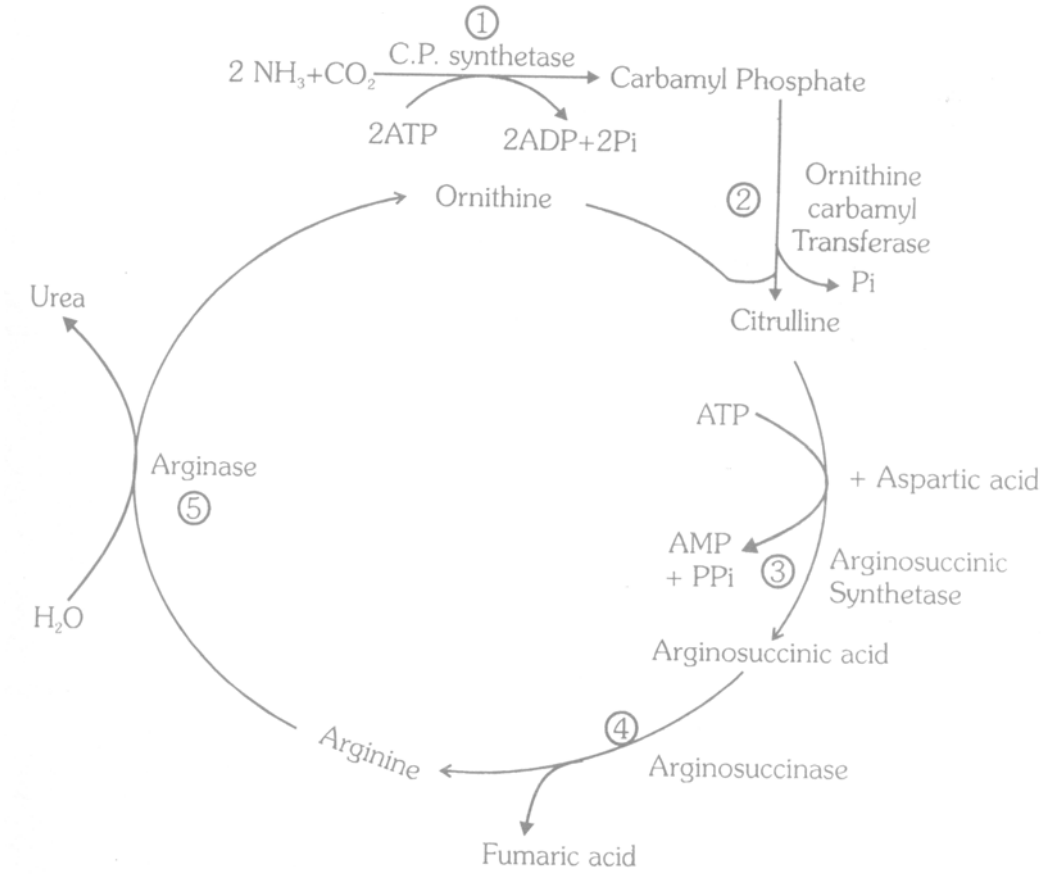
(1) Urea can be tolerated in much more concentrated form because it is 100000 times less toxic than ammonia.

(2) Urea excretion helps to sacrifice less water while disposing off the nitrogenous wastes.
In mammals urea is excreted by kidney. However entire amount of urea producet is not excreted immediately but some portion of it is retained in the kidneys for osmoregulation. (important for water reabsorption)

- Sharks retain some amount of urea produced to balance the osmolarity of body fluids with surrounding sea water. Thus urea here acts as an osmolyte.

Urea is produced in the liver by urea cycle.

Ornithine Cycle:- It is also termed as the Kreb-Henseleit cycle. In this cycle, 2 molecules of NH_3 react with 1 molecule of CO_2, resultants a molecule of urea is formed. The formation of urea through this cycle takes place by the following steps-



1. Firstly -2 molecule of NH_3, 1molecule of CO_2 combine to form carbamyl – phosphate. This reaction is catalysed by the carbamyl-phosphate synthetase enzyme. 2 ATP's are used in this reaction.

2. In next step- carbamyl-phosphate reacts with ornithine amino-acid to form the citurlline amino-acid.

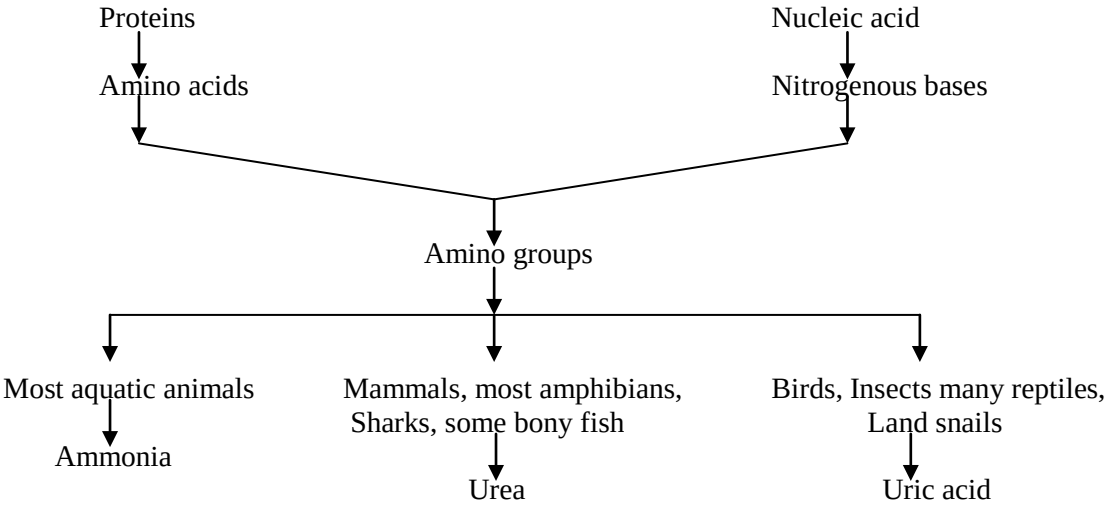
3. In next step-Citrulline reacts with Aspartic acid to form Argino-succinic acid. This reactions is catalysed by Argino-succinic synthetase. 1 molecule of ATP is used in this process.

4. In next step – Argino- succinic acid converts into Arginine and fumaric –Acid in the presence of Argino-succinase enzme.

5. Arginine, now dissociates into ornithine and urea in presence of Arginase enzyme. Ornithine again enters the cycle.

(3) **Uricotelics:** These animals excrete uric acid as waste products.
Eg. Land snails, insects, birds & many reaptiles.
Excretion of wastes in the form of uric acid is particulary advantageous for land vertebrates which lay shelled eggs. This is because shelled eggs of reptiles & birds possess many fine pores which are permeable to gases only.
If the embryo would have produced ammonia or urea inside the shelled egg, the soluble nitrogenous waste would have accumulated to toxic concentration levels. But because the wastes are in the form, of uric acid which is thousand times less soluble than. NH_3 or urea, this uric acid precipitates our of the solution and can be stored in the shell as a solid waste which is left behind when the animal hatches.

- In birds and reptiles urine is eliminated in a past like form along with faeces.
- Tadpole and aquatic amphibian excrete ammonia, while their terrestrial adult forms excrete urea Aquatic turtles excrete both urea & is eliminated in a paste like form along with faeces.
- Most terrestrial reptiles excrete uric acid but crocodiles excrete ammonia in addition to uric acid.



Some Other Excretory Products

Tri-methyl amine-oxide – Some animals convert the ammonia into non-toxic tri-methly amine oxide and excrete. It has a typical fishy-smell. E.g. Marine-fishes, Marine molluscans and Marine crustaceans etc.

Guanine:- Spiders convert ammonia into guanine and then excrete it. It is similar to uric- acid; its structure is same as that of uric acid. It is insoluble in water. Guanine is excreted in the form of crystals. It is also an adaptation to check the water-loss.

Allantonin- Majority of mammals convert the Purines and Pyrimidines to allantonin and then excrete it. In man purines are excreted in the form of uric-acid and pyrimidines in the form of alanine and Iso-butyric acid .

Hippuric-acid:- In mammals, the Benzoic-acid is excreted out in the form of Hippuric acid

Benzoic – acid Glycine → Hippuric – acid

But in birds, the benzoic acid is treated with ornithine amino-acid, and ornithuric acid is excreted.

Benzoic acid + Ornithine → Ornithuric acid

Creatine:- In normal urine, creatine is absent, But in new-born infants, pregnant and lactating females the urine contains creatine. Creatine is obtained in the liver from amino-acids.

Creatinine:- Creatinine is the break down metabolic product of creatine. It is formed in the muscle from high energy compound creactinine phosphate. It is excreted along with urine.

Animal on the basis of excretory matter are divided into three categories:-

	Characters	Type of animals		
		Ammonotelic	**Ureotelic**	**Uricotelic**
1.	Excertory matter	Ammonia	Urea	Uric acid
2.	Requirement of water	Very large	Less than ammonia	Least
3.	Mechanism of excretion	By diffusion a across Body surfaces or through gill surface (in fish) as ammonium ion.	Ammonia produced By metabolism is converted into urea in the liver and released into the blood which is filtered and excreted out by the kidneys.	
4.	Toxicity	Highest	Less than ammonia	Least
5.	Examples	Teloests, Tadpoles, Aquatic insects	Mammals, Sharks	Birds, Insects, Land snails, Many reptiles

Excretory organs in animals :

Animals	Flatworms E.g. Planaria	Earthworm	Insects E.g., Cockroach	Crustaceans e.g., Prawn	All Chordates
Excretory Organs	Protonephridia (Flame cells)	Nephridia	Malpighian Tubules	Green glands	Kidneys

:

HUMAN EXCRETORY SYSTEM

Excretory organ are also termed as organs of homeostasis.
The main excretory organ in humans is kidney.
Other excretory organs are skin, liver, lungs & large intestine.
Human excretory system consists of:

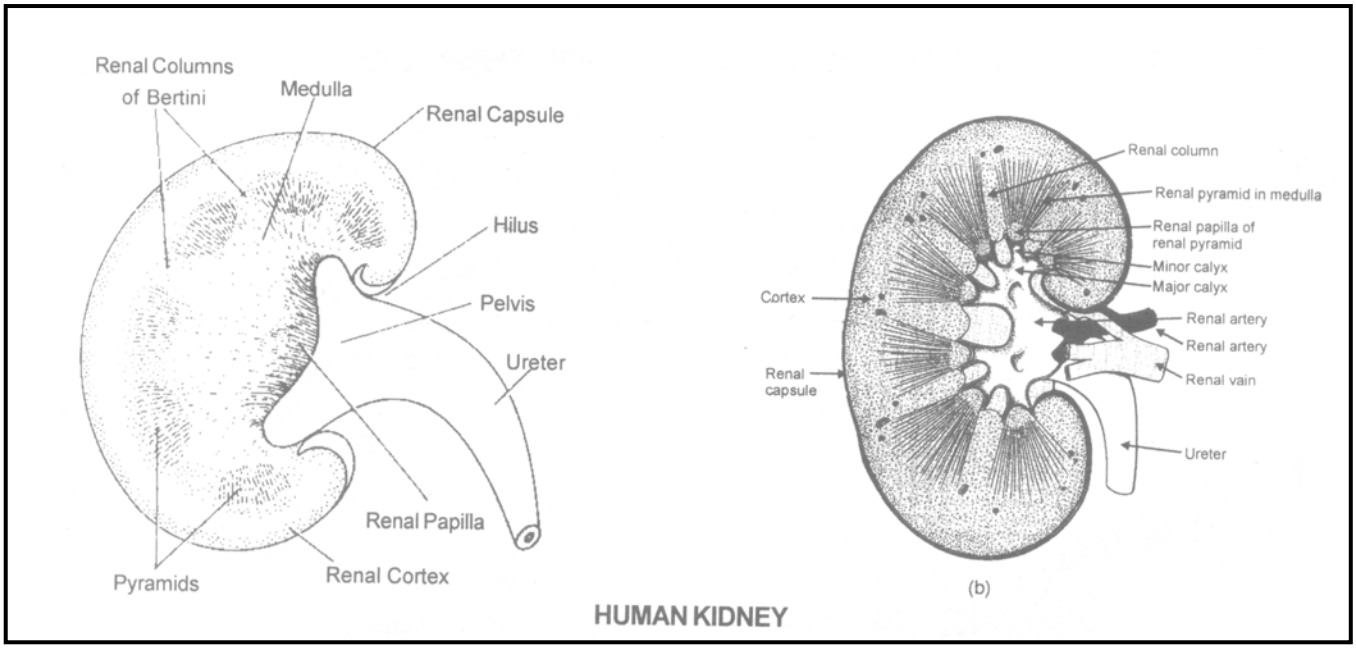
- Two kidneys & their blood supplies.
- A pair of ureters.
- Urinary bladder
- Urethra

LOCATION AND STRUCTURE OF KIDNEYS

Each individual normally has two kidneys located laterally on either side of vertebral column at the level of T_{12} L_1 & L_2.

In humans right kidney is at slightly lower level than left kidney while in rabbit the right kidneys is at slightly higher level (2.5 cm) than left kidney.

Dorsal surface of the kidney is attached to the dorsal abdominal wall, so only its ventral surface is covered by visceral. Peritoneum, Therefore this type of kidney is called retro-peritoneal kidney or extra peritoneal kidney. Mammalian kidneys are bean shaped , Dark brown coloured with a tough fibrous connective tissue covering capsule.



Each kidney measures 10cm in length, 5cm in breadth and 3 cm in thickness, weighing about125-170 gm in an adult. Lateral surfaces of kidney are convex while medial surfaces are concave.

On the concave margins of the kidney longitudinal opening called Hilum(Hilus renalis) is present. Through this, renal artery and nerve enter while renal vein and ureter leave the kidney.

The Hilum leads to a funnel shaped space called the renal pelvis.

The kidney tissue surrounding the pelvis is arranged in an outer functional layer renal cortex and inner functional layer renal medulla. Projections of renal cortex into medulla are termed renal columns of Bertini. Layer renal medulla. Projection of renal cortex into medulla are termed renal columns of Bertini.

The renal medulla forms conical pyramid shaped masses which project into the renal pelvis. These are called as medullary pyramids or renal pyramids (8to12 in humans, while only one pyramid is present in kidney of rabbit)

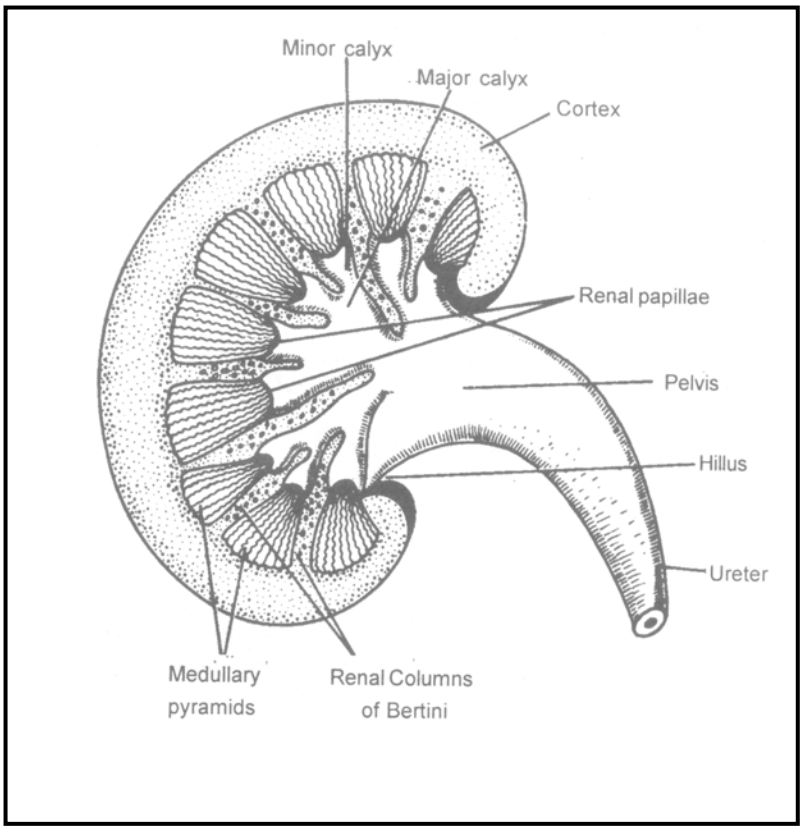
The functional units of mammalian kidney are called Nephrons.

These nephrons are arranged in a radiating fashion within the renal pyramids.

Urine produced by each nephron empties into collecting duct.

The collecting duct passes through a papilla into the renal calyx (Pleural-calyces).

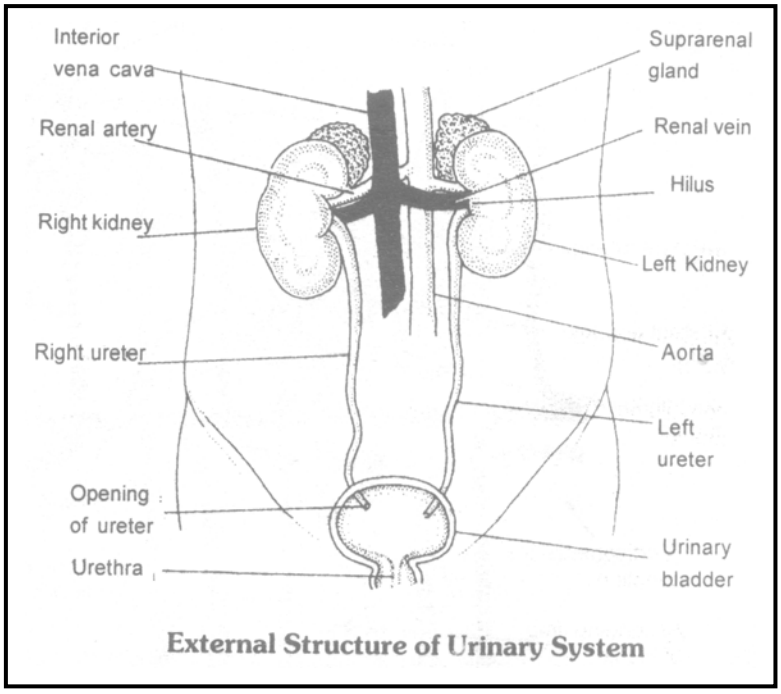
The renal calyces drain urine in the central cavity of renal pelvis. In rabbit, renal pelvis is unbranched, so the calyces and renal column of Bertini are absent.



POST RENAL URINARY TRACT

Urine passes from the pelvis into the ureter. Both the ureters open through separate oblique openings into the urinary bladder. The obliquity of the openings prevent the backflow of urine.

Externally, the bladder is lined by detrusor muscle, it is involuntary in nature while internally the bladder it lined by transitional epithelium or urothelium. This epithelium has great capacity to expand so that large volume of urine can be stored if required. Opening of urinary bladder is controlled by sphincters made of circular muscles. These normally remain contracted and during micturition these relax to release urine. (In rabbit a single sphincter is present while in human two sphincters, inner involuntary & outer voluntary, are present.)



External Structure of Urinary System

Passage of urine:

Nephron → Collecting → duct→Papilla→Renal calyx→ Renal pelvis→ Ureters→Urinary→ bladder →Urethra

During act of micturition urine leaves the urinary bladder and enters the membranous duct celled Urethra.

The urethra leads to end of the penis in males and into the vulva in females. In males the urethra has three parts, prostatic, membranous & penile uretha respectively. (Prostatic urecthra is absent in females, therefore both sphincters are present in membranous urethra)

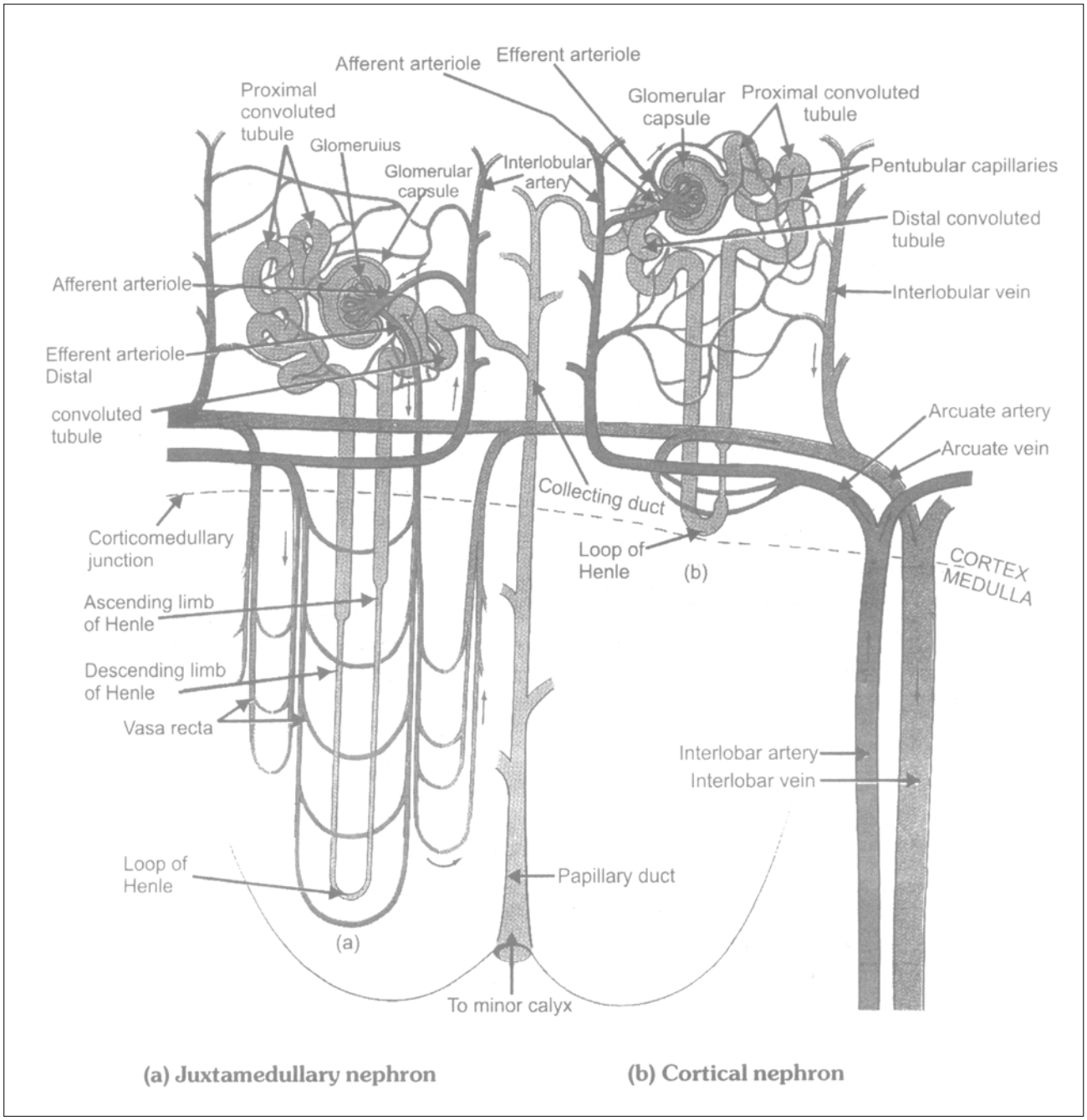
Physiology of Micturition

Micturitions is the term used for urination, ie the process by which the urinary bladder emptied when it becomes filled. It is basically a reflex reaction, called "micturition reflex". This reflex is inttiated when interoceptors, present in the wall of urinary bladder, get stimulated by the tension created due to stretching of bladder wall as the bladder gradually fills whit urine brought into it by the ureters. The reflex may cause instanteaneous urination, as sometimes occurs in children, but normally, it causes a conscious desire to urinate by stimulation certain "brain centres".

The bladder is anatomically divisible into a large, collapsible chamber or "body", and a short, narrow "neck" That the continues into the urethra. The bladder wall is mostly formed of smooth muscle called detrusor muscle, whose fibres extends in al direction, so that their contration brings about a contraction of entire bladder wall at the same time. Now the sphinchters open and the urine is released out of the body.

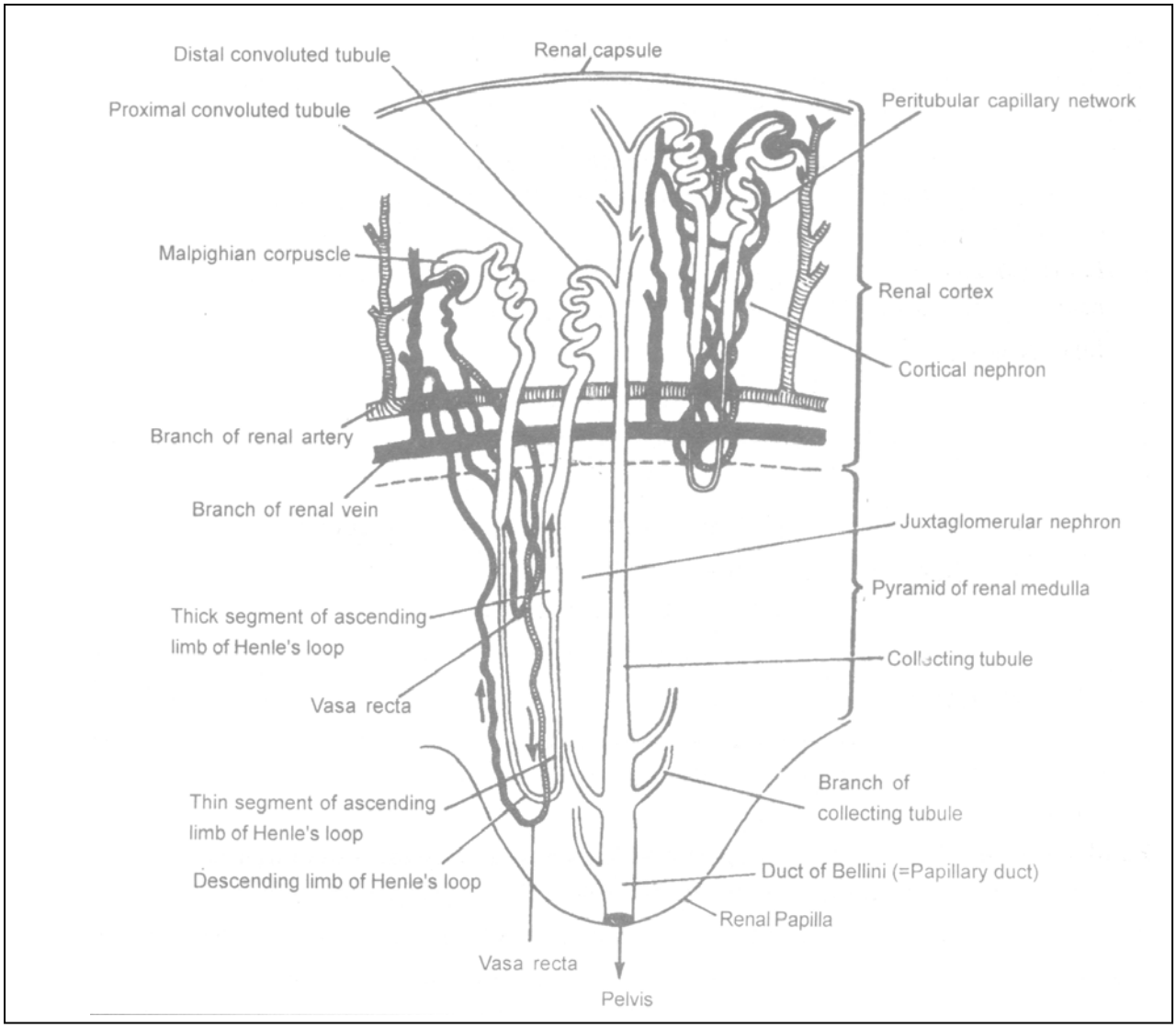
STRUCTURE OF NEPHORN

Nephron is the structural and functional unit of kidney. It is epithelial tube which is about 3cm long and 20-60 μ M IN diameterl.(Each kidney has about one million nephrons in humans & 2lakh in rqabbit)



A nephron can be divided into three regions:

(I) Proximal nephorn (Bowman's capsule+ Proximal convoluted tubule)
(II) Loop of Henle (Asecending+ Descending limb)
(III) Distal nephron (Distal convoluted tubule which opens into collecting duct)

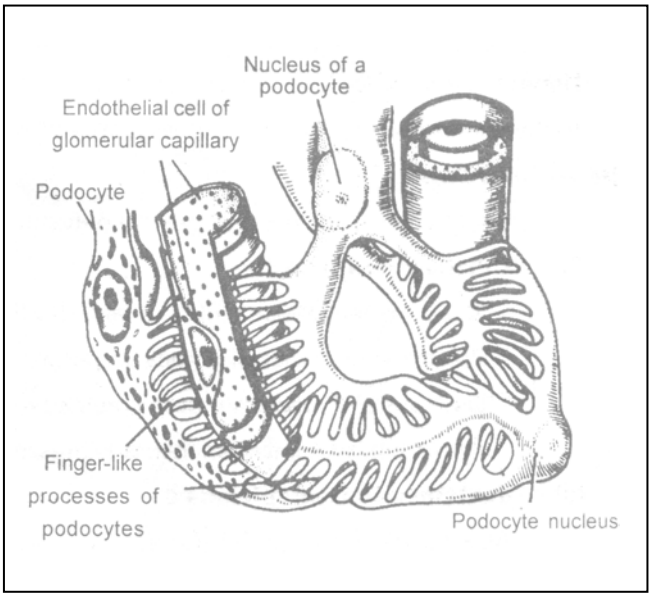


(I) Proximal nephron: Nehphron tubule is closed at its proximal (starting) end but its distal end is open and continues into the loop of Henle. At the proximal or closed end the nephron is expanded and curved inwardly to form a double walled cup shaped Bowman's capsule. Within the bowman's capsule a network or tuft of capillaries is present, it is called Glomerulus. Diameter of afferent arteriole is greater than efferent arteriole.

Malpighian corpuscle: Glomerulus and its surrounding Bowman's capsule together form this specialized structure.

The outer wall of Bowmans capsule is composed of flattened squamous cells.

The inner, invaginated wall that lines the concavity of Bowmans capsule is composed of a special type of cells called Podocytes.



These cells bear finger like projection which are coiled around the capillaries of glomerulus. The Bowmans capsule is followed by a neck part lined by ciliated epithelium.

Proximal convoluted tubule: The epithelial cells of the region are specialized for transport of salts and other substances from the lumen to the interstitial fluid.

The membranes of these calls facing the tubule lumen has numerous microvilli (figer like projection or Brush Borders) which increase the surface area. Near its basolateral surface, the mitochodria are concentrated, to allow reabsorption of salts by active transport.

(I) **Loop of Henle**: It starts after the proximal convoluted tubule , It ends before the distal convoluted tubule. This hairpin like loop has a descending limb, followed by an ascending limb.

(a) **Descending limb:**

Its upper part	-Constitutes thick segment
	-has the same diameter as PCT
	-is also lined by cuboidal epithelium
	-has less microvilli and mitochondira in comparison to cells of PCT
Its lower part	-Constitutes thin segment
	-is lined by flat epithelial cells
	-has very less microvilli and mitochondria

(b) **Ascending limb:**

- This part too has a thin segment first which widens abrupthy at medullary zone to form thick segment. Lower thin segment is lined by simple squamous epithelium while upper thick segment is lined by cuboidal epithelium.

(III) **Distal nephron**: The ascending limb of henle's loop merges into distal convoluted tubule. This is lined by cuboidal epithelial cell with a few microvilli. Coils of both PCT & DCT are intermingled.

The distal convoluted tubles of a numbe of adjacemnt nephrons open into a common collecting duct or tubule. Collecting ducts (present in medullary pyramids) are long tubules which traverse through the medulla in the pyramids. In the papilla of the medulla (in rabbit) or papilla of the individual medullary pyramid (in human), Several adjacent collecting ducts converge to open into a common short and thick duct of Bellini. (Present in papilla of medulla)

All ducts of billini then open at the tip of the papillae into the pelvis.

Renal cortex: The malpighian corpuscle, PCT & DCT of the nephrons are located here.

Renal medulla: Loop of henle, collecting duct and ducts of Bellini are found in this region.

Type of nephrons:

According to their position, nephrons are of two types.

(i) Cortical nephrons:

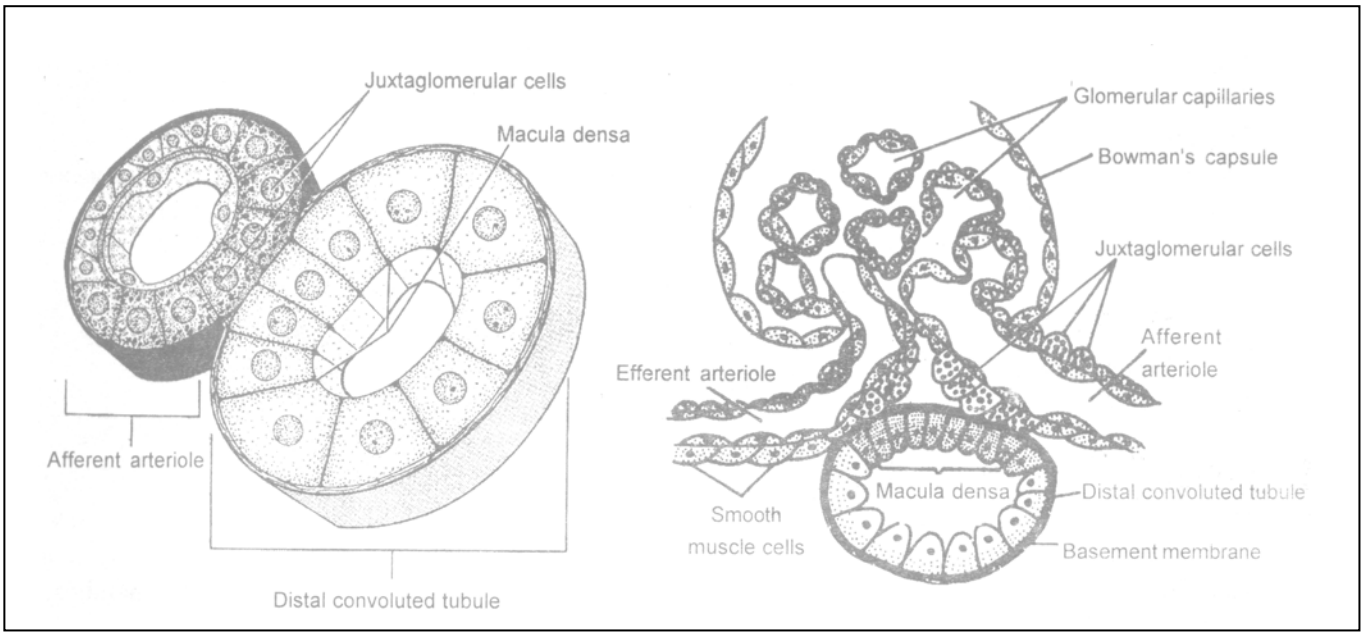
- These constitute about 85% of total. (75-85%)
- Malpighian corpuscles of cortical nephrons are located close to the kidney surface.
- Their loops of Henle are mostly confined to cortex and a very small part of it runs in the medulla.
- Only peritubular capillary network is present & vasa recta is absent.

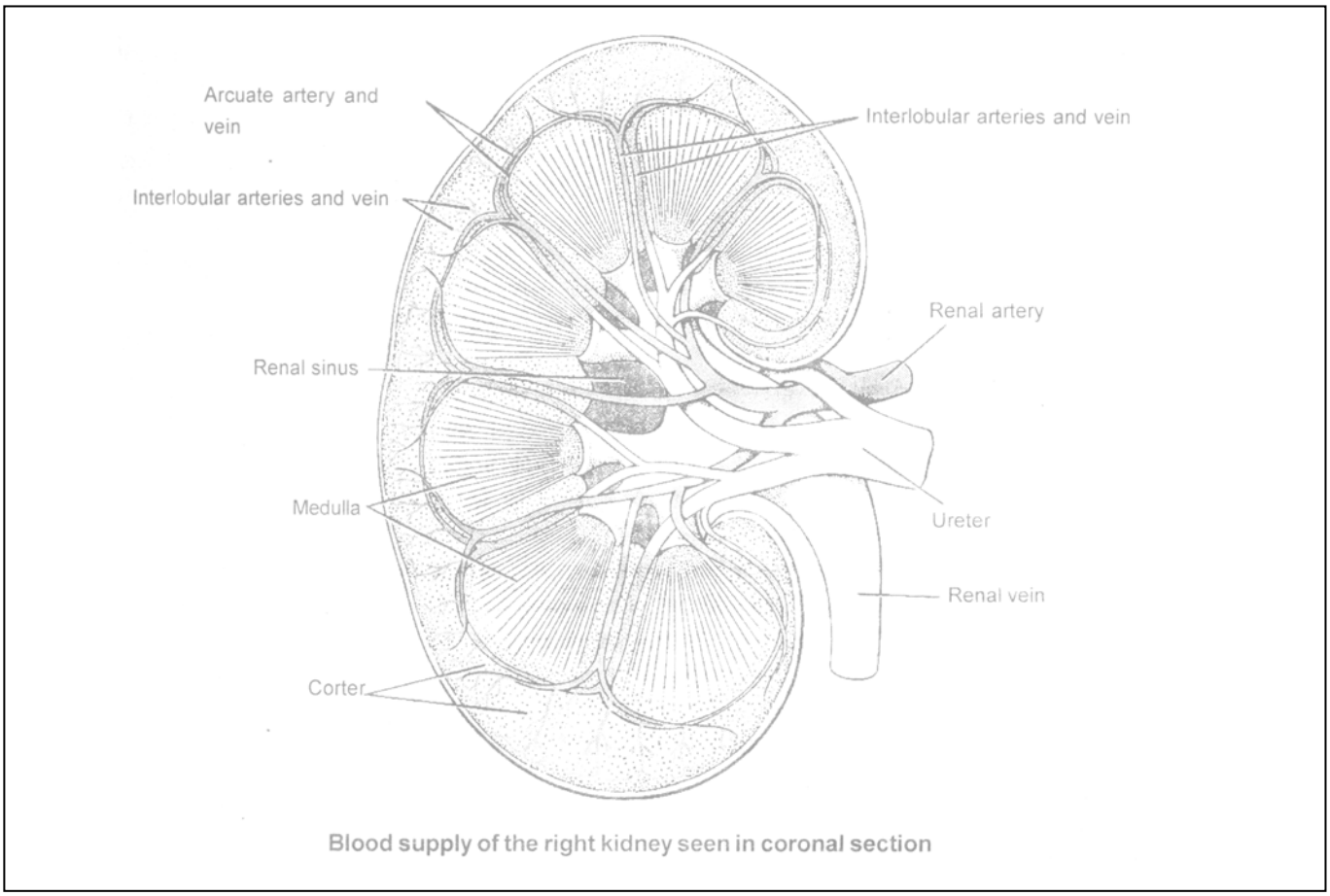
(ii) Juxtamedullary nephrons:

- About 15% of total. (15-25%)
- Malpighian corpusles of these nephrons are located at the junction of cortex and medulla.
- The loop of Henle of these nephrons are long, dipping deep down into the medulla.
- Both, PTC network and vasa recta are present.

- In these nephrons the intitial part of the DCT is located close to the mouth of Bowman's capsule, in contact with both afferent and efferent arterioles.

- **Macula densa:** The cells of DCT epithelium in contact with the arteriolar wall are denser then other epithelial cells. These are collectively called macula densa.
  Juxtaglomerular cells: The smooth muscle cells of the wall of both arterioles in contact with DCT epithelium are swollen and contain dark granules of inactive rennin. These are called **juxtaglomerular cells**.
  Juxtaglomerular apparatus: Juxtaglomerular cells+Macula densa.





Blood supply of the right kidney seen in coronal section

BLOOD VESSELS OF KIDNEY

Each kidney receives its blood supply by a single renal artery from dorsal aorta, and is drained off by a single renal vein, which opens in the inferior vena cava.

As the artery enters into the medulla after traversing through the hilum it divides into a number of branches. These branches enter into renal cortex through the columens of Bertini and subdivide into afferent arterioles which form glomerular capillaries. These capillaries are drained, not by venules, but by efferent arterioles.

In Cortical nephrons:

The efferent arterioles break up into dense Peritubular network of capillaries around their tubules.

In Juxtamedullary nephrons:

The efferent arterioles break up into a network of thin capillaries which form hair pin like loops called vasa recta.

This vasa recta dips into the medulla or its pyramids alongside the loops of Henle.

Both peritubular capillaries of cortical nephorns and vasa recta of juxtaglomerular nephrons lead into venules which join and rejoin to form small and large veins, all of which ultimately join to form renal vein.

MECHANISM OF URINE FORMATION

The mechanism of urine formation involves three steps or processes:

(I) Ultrafiltration or Glomerular filtration
(II) Selctive tubular reabsorption
(III) Tubular secretion

(I) Ultrafiltraition or Glomerular Filtration:

This process occurs in the Malpighian corpuscles of the nephrons. The glomerulus of a Malpighian corpuscle is a network of several (about fifty in man) parallel capillaries. From the blood flowing through glomerular capillaries, about 20% of plasma fluid filters out into the Bowman's capsule through a thin glomerular-capsular membrane due to a net or effective filtration pressure (EFP) of about 10 to 25 mm Hg.

The glomerular-capsular membrane through which ultrafiltration occurs comprises three layers, viz (1) endothelium, (2) basement membrane of the wall of glomerular capillaries and (3) squamous epithelial layer of the finger-like processes ([1]foot processes' or pedicels) of podocyte cells of capsular wall entwining the walls of capillaries. A special characteristic of glomerular-capsular membrane is that is about 100 to 500 times more permeable than the walls of blood capillaries in other tissues of body. Such a tremendous permeability of this membrane is because of the presence of literally thousands of small pores, called fenestrae, in the walls of glomerular capillaries (fenestrated capillaries).

The effective filtration pressure that causes ultrafiltration is determined by three pressures: (1) glomerular hydrostatic pressure (2) colloid osmotic pressure of blood and (3) capsular hydrostatic pressure.

The glomerular hydrostatic pressure it the blood pressure in glomerular capillaries. It is the chief determinant of effective filtration pressure,

i.e. the mian driving force to cause filtration. (it is 60 to 75 mm Hg)

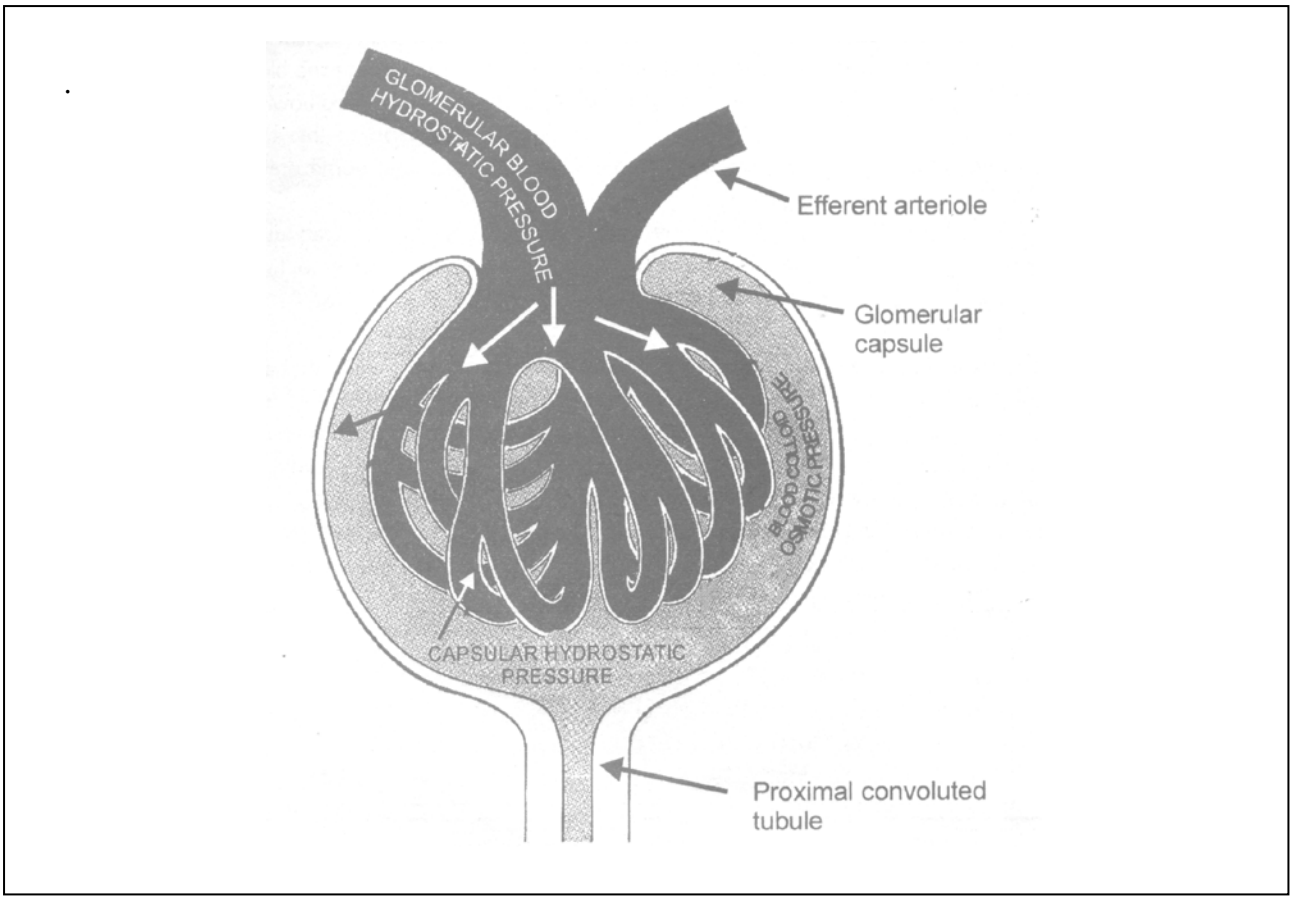
The colloid osmotic pressure is the osmotic pressure created in the blood of glomerular capillaries due to plasma proteins. It resists the filtration of fluid from the capillaries. (it is 30 to 32 mm Hg)

The capsular hydrostatic pressure is the pressure caused by fluid (filtrate) that reaches into bowman's capsule and resists filtration. (It is about 10 to 18 mm HG)

Normally, the blood pressure in an arteriole that feeds a typical systemic capillary network is about 35 to 40 mm Hg. The pressure in afferent arteriole of glomerulus is about 60 to 75 mm Hg and since the efferent arteriole is thinner in diameter than afferent arteriole, this blood pressure (glomerular hydrostatic pressure) is maintained throughout the glomerulus. The colloid osmotic and capsular hydrostatic pressures, which resist ultrafiltration, are respectively about 30 to 32 mm and 10 to 18 mm Hg. Thus, the net effective filtration pressure is about 10 i.e. (60) – (32+18) mm Hg. That is why, the glomerulus is a 'high pressure capillary bed'.

EFP = GHP-[COP+CHP]

∴ **EFP ranges from 10 to 25 mm Hg.**



The Plasma fluid that filters out from glomerular capillaries into Bowman's capsules of nephrons is called glomerular filtrate.

The quantity of glomerular filtrate, formed each minute in all the nephrons of both kidneys is called Glomerular filtration rate (GFR). In a normal adult human being, a glomerular filtration pressure of 1 mm Hg causes filtration of about 12.5 mL of plasma fluid from glomerular capillaries per minute. Thus the GFR in a normal adult person is 125 (12.5x10)mL of plasma fluid per minute. As already described in the chapter of circulatory system, an average adult person of about 70 kg possesses about five litres of blood all of which is pumped by the heart (cardiac output) into the arteries and received back through veins each minute. About 1250 mL (25% of total blood) of this blood circulated through kidneys each minute, and of this blood, about 650 mL is the blood plasma (52%). This 650 mL is called renal plasma flow (RPF). Obviously, 125/650 i.e. about one-fifth (20%) of the blood plasma, therefore, filters out into kidneys nephrons per minute. This is the ratio of GFR to RPF, and it is called filtration fraction.

With a glomerular filtration rate (GFR) of 125 mL per minute, about 180 litres of plasma fluid from about 1800 litres of blood circulating through both kidneys of an average person each day filters out into kidney nephrons. But only about 1.45 litres (about 0.8% part) of the total glomerular filtrate is excreted out as urine per day, the rest is reabsorbed into the blood from the nephrons.

Due to continuous beating of the cilia of neck cells, the glomerular filtrate is continuously made to flow behind from Bowman's capsules into the proximal convoluted tubules of the nephrons.

(II) Selective tubular reabsorption:

The glomerular filtrate is like blood plasma minus plasma proteins (colloids) in chemical composition. Thus, it is mostly water with all soluble and diffusible solutes of plasma which include nutrients (glucose, amino acids, etc), electrolytes of salts (Na^+,K^+Cl^-, HCO_3^-,H^+, etc) and waste products of protein metabolism (urea, uric acid, creatinine, etc). In contrast to glomerular filtrate, the urine which is ultimately extracted from the filtrate in nephrons, contains water, urea, uric acid, creatinine and useless electrolytes in considerably higher concentrations, whereas nutrients are almost absent in it. This proves that, while the filtrate flows through a uriniferous tubule, not only its volume is reduced, but its composition is also considerably changed. These changes are obviously

due to an exchange of materials between the filtrate and the blood of Peritubular capillaries.

This exchange involves, (1) a selective reabsorption of useful materials into the blood from the filtrate and (2) Absorption of remaining unfiltered amount of excretory substance from blood flowing in the perigubular capillaries, by the cells of uriniferous tubules and then subsequent secretion of these substances into the filtrate. The selective reabsorption and secretion are finely tuned to maintain homeostatic balances in body fluids.

The blood flows rapidly in perituburlar capillaries and with a very low pressure (only) about 13 mm(Hg) Due to this reason fluid can diffuse into these capillariesfrom surrounding tissue fluid, but cannot filter out of them. This reabsorption involves both active and passive processes.

(I) Tubular secretion:

In addition to its role in selective reabsorption of material from the glomerular filtrate back into the blood of peritubular capillaries via the renal interstitium, the distal part of proximal conveoluted tubule also alters the composition of filtrate by a process of secretion. Epthelial cell in this part extract certain excretory substances from the blood of peritubular capillaries and secrete these into the filtrate. For example, uric acid filtered by glomerulus is almost completely reabsorbed in the first part of proximal tubule, but is later withdrawn from blood and secreted into the filtrate in distal part of proximal tubule, other secreted substances include H^+, K^+, NH_4^+, creatinine, etc and certain dyes and drugs, like phenol red, penicillin, hippuric acid and its derivatives, etc. Secretion of H_+ helps in controlling blood pH.

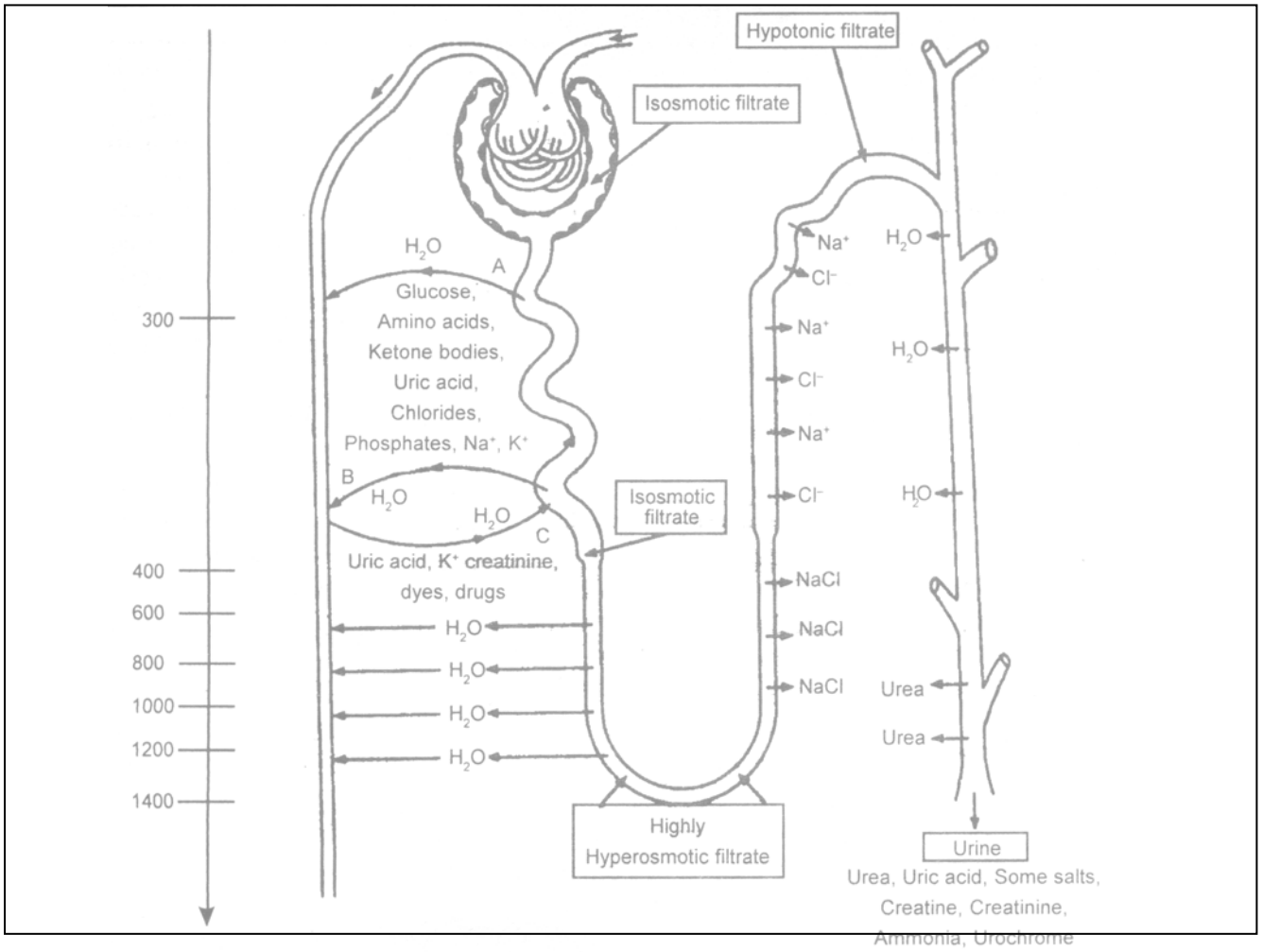
Permeability chart

PCT ⟶ Water, NaCl

Descending loop ⟶ Water only

Thin ascending loop ⟶ NaCl only and urea (inwards)

Thick ascending loop ⟶ Na+,K+, Pumps and Cl- Follows passively



Changes occurring stepwise in the filtrate while it flows through the tubules:

(1) Bowman's capsule: Since all plasma solutes, except proteins, freely enter into glomerular filtrate from blood, the total solute concentration (osmolality 300 milliosmoles per litre) of the filtrate is essentially the same as that of plasma. Here the filtrate is thus isotonic (isosmotic) to the plasma.

∴ Condcentration ↔,Volume ↔

(2) **Proximal convoluted tubule:** The microvilliof the "brush-border" columnar cells of the epithelium of this tubule increase the internal surface of the epithelium about 20 times. Hence, this epithelium becomes most suitable for reabsorption. About 65% to 80% of the filtrate is reabsorbed into the blood of peritubular capillaries through this epithelium and surrounding tissue fluid (renal interstitium). Most of the solutes like glucose, amino acids, vitamins, ketone bodies, acetoacetic acid, uric acid, chloriedes, sodium, potassium, phosphates etc of he filtrate are reabsorbed into the blood by diffusion and active transport. Some urea is also reabsorted . Sulphates, creatinine, inulin and PAH (para amino hippuric acid) are not reabsorbed. As most of the solutes are reabsorbed, Water automatically goes back into the blood by osmosis leaving the osmotic pressure in the filtrate unchanged. Thus, the filtrate is reduced in volume, but it still remains isotonic to the plasma.

∴ Condcentration ↔,Volume ↓

(3) Descending limb of henle's loop: The lop of Henle is divisible into four parts, namely Thick descending limb, the Thin descending limb, the Thin segment of ascending limb, and the Thick segment of ascending limb.

In mammalian kidneys, the osmolality of renal intersititium is different in renal cortex and medulla. Whereast the cortical interstitium has the normal osmolality of 300 mL osmol/liter, the medullary interstitium has a gradient of increasing osmolality from the cortex upto the tips of the papillae. (300 to 1400 mL osmol/liter)

The thin wall of descending limb of Henles loop is permeable to water, but not to the solutes. As the isotonic tubular fluid flows down this limb, it gradually loses water by exosmosis due to increasing osmolality of medullary interstitium through which this limb extends. This leaves a small volume of concentrated (hypertonic to blood plasma) tubular fluid to enter into the ascending limb of Henle's loop.

∴ Condcentration ↓,Volume ↑

(4) **Ascending limb of Henles loop:** The thin segment of the ascending limb of henle's loop is structurally like the descending limp, but its permeability is different. It is quite permeable to NaCl but no to water. Due to decreasing osmolality of medullary interstitium towards cortex, the tubular fluid, therefore, loses Na^+ and Cl^- by diffusion , again becoming diluted and isotonic to plasma without changing in volume.

∴ Condcentration ↓,Volume ↔

The wall of the thick ascending limb of Henle's loop is virtually impermeable to both water and solutes, but the plasma membrane of its cells is very rich in Na^+ - K^+ pumps. These pumps pump out Na^+ by active transport, and Cl^- passively diffuse out following the outflux of Na+. Thus the process of dilution of the tubular fluid continues in this limb. Consequently, the tubular fluid becomes considerably hypotonic to blood plasma without a change in its volume.

∴ Condcentration ↓,Volume ↔

(5) Distal convoluted tubule (DCT): In the distal convoluted tubule, active reabsorption of Na^+ and that of Cl^- continues by facilitated diffusion and hence the tubular fluid becomes still more diluted. It also helps to regulate blood pH by reabsorption of HCO_3^- which is an important buffer.

∴ In proximal DCT Condcentration ↓,Volume ↔

(6) **Collecting duct:** From the distal convoluted tubule, the hypotonic tubular fluid flows into a collecting duct. This duct is quite permeable to water but not to salt (in presence of some ADH.) Hence the tubular fluid loses considerable amount of water by exosmosis as the duct runs down through the hypertonic medullary interstitium to empty into the calyx. The distal part of collecting duct is permeable to urea also. Hence same urea is also reabsorbed from tubular fluid and it adds to the hyperosmolality of medullary interstitium.

∴ Condcentration ↓,Volume ↑

After losing considerable amount of water and some urea, while flowing through the collecting ducts, the filtrate ultimately becomes urine.

Chemical composition and physical characteristics of urine: Normal urine contains about 95% water, 2% electrolytes (ions of salts, mainly chlorides, sulphates, phosphates and bicarbonates of sodium, potassium,ammounium, etc), 2.6% urea, .3% uric acid and traces of cratinine, Ammonia, creatine etc. It is transparent but pale yellow due to the presence of a trace of urochrome pigment. Urochrome is a byproduct of hemoglobin degradation fount I blood and filtered into glomerular filtrate Normal urine is slightly acidic with a pH of 6.00 (range is 4.5 to 8.2). Its specific gravity is 1.015 to 1.02. On standing, it becomes cloudy and acquires ammonia odour due to formation of ammonium carbonate.

OSMOREGULATION BY KIDNEYS

Kidney also perform the important function of somoregulation (regulation of osmolality) by regulating the amount of water in body fluids. The normally functioning kidneys produce a large volume of dilute urine when more water is taken, and a small volume of concentrated urine when water intake by the body is poor or there is considerable loss of water from the body. This function of kidneys is regulated by the antidiuretic hormone(ADH or Vasopressin) secreted by the posterior lobe of pituitary gland. This hormone increases the water permeability of the last part of distal convoluted tubules and proximal part of the collection ducts. In absence of ADH, these parts are almost impermeable to water and therefore the urine is dilute. But in presence of ADH, these parts become quite permeable to water, so that much of the water present in tubular fluid is reabsorbed and the urine becomes concentrated. Besides ADH, the hormone aldosterone, secreted by adrenal glands, also plays important role in osmoregulatory function of kidneys by increasing Na^+, K^+ and Cl- reabsorption from the filterate.

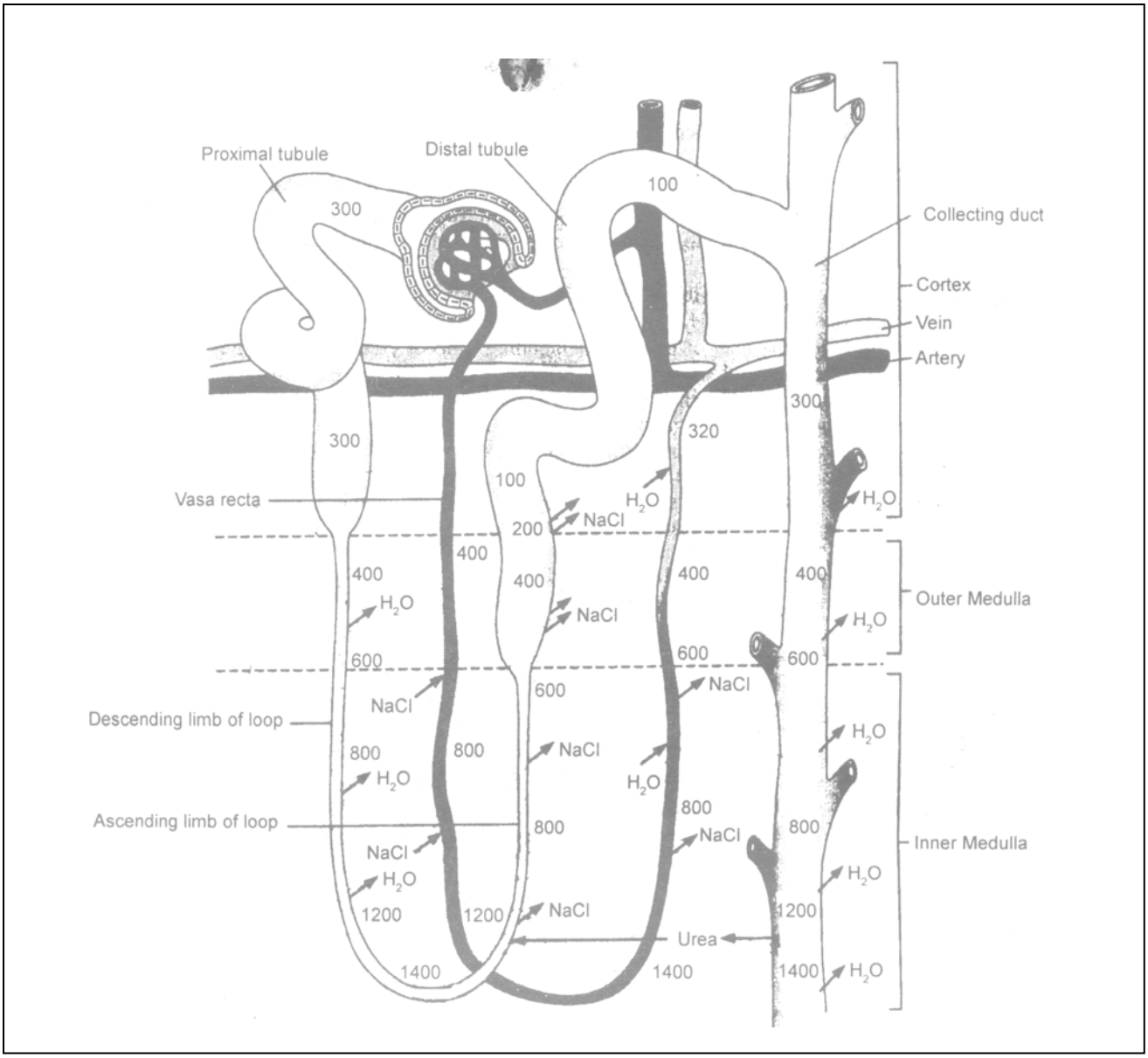
Dilution mechanism (cortical nephrons)

The osmolality of body fluids normally remains remains about 300 mL osmal per litre of water. When amount of water increases, this osmalality decreases. This switches off the secretion of a ADH from pituitrary gland, but stimulates secretion of aldosterone from adrenal glands. Absence of ADH makes the wall of distal convoluted tubules and collecting ducts almost completely impermeable to water. Contrarity, due to secretion of the aldosterone the walls of ascending limb of henle's loop, distal convoluted tubule and collecting duct become quite permeable to sodium, potassium and chloride ions. As a result of this Na^+ and Cl^- ions are reabsorbed from the filtrate flowing up the ascending limb of Henle's loop and mostly water and waste products remain in the filtrate. By the time this filtrate reaches into the distal tubule, it becomes very hypo-osmotic with only about 100mL osmol/litre osmolality. Then, as this diluted fluid passes through the distal tubule and collection duct, some more of the remaining ions, especially of sodium (Na+) are reabsorbed actively so that the osmolality of ultimate dilute urine is decreased to as low as about 65 to 70 mL osmol/litre. Dilution of urine mainly occurs in cortical nephrons.

Diuresis and Hypertension: Normally, we excete about 1.5 litres of urine per day. Diluted urine is excreted in larger volumes a condition called diuresis. When due to the inefficient regulation, the kidneys fail to adequately dilute the urine, the boyd fluids are diluted and their increased volume causes Hypertension (↑ BP) Glucose, urea, mannitol and other diuretic substances are administered to such patients. The kidneys excrete these substances and water is automatically excreted out with these. Caffeine of tea is also diuretic. That is why, urination becomes more frequent when more tea is taken. Contrarily, If secretion of ADH is permanently hampered or blocked in a patient, the urine becomes very dilute and tasteless (insipid). This condition is called diabetes insipidus. Intermittent urination at short intervals and thirts are the only discomforts in this condition.

Concentration mechanism (Juxtamedullary nephrons)

During times of low water intake or excessive water loss, for example, due to heavy perspiration, diarrhoea, vomiting, etc the kidneys must conserve water while still eliminating wastes and excess ions. The kidneys accomplish this by prodcing concentrated urine. It is primarily the long-looped juxtamedullary nephrons which establish the condition for producing Concentrated urine which may be four to five times more concentrated (1200 to 1400 mL osmol/litre) than plasma. Concentrating the urine is under regulation of ADH and depends on presence of a steep gradient of increasing hyperosmolarity in the interstitial fluids of medullary pyramids.



Medullary heperosmolality: The osmolalitry of renal cortical intersitium is same (300 mL osmol/litre) as in other tissues, but that of the interstitium of renal medulla is hypertnic with a gradient of hyperosmolality from renal cortex to the tips of medullary papillae. Under the conditions in which a concentrated urine is to be produced the hyperosmolality of medullary interstitium near the tips of the papillae is as high as 1200 to 1400 mL osmol/litre.

Countercurrent mechanism to maintain medullary hyperosmolality: The gradient of increasing hypersomolality of medullary interstitium is maintained by a peculiar countercuurent mechanism operated by the Henle's loops of juxtamedullary nephons and vasa recta. About 15% to 20% of the nephorns in mammalian kidneys are situated at the level where cortex and medulla meet and, hence called juxtamedullary nephrons. The henle's loops of these nephorns are thin and long and extend almost upto the tips of medullary papillae. The peritubular capillaries associated with these Henle's loops are also very thin and in the form of thin loops extending almost upto the tips of medullary papillae. These capillary loops are called vasa recta. A countercurrent can be defined as the flow of a fluid in opposite directions in the two arms of a U-tube if the arms are rather very close together. Thus, the Henle's loops of juxtamedullary nephrons and vasa recta are anatomically ideal for the operation of countercurrent mechanism. There are two aspects of this mechanism,

(1) Countercurrent multiplication and (2) countercurrent exchange. The Henle's loops play the role of contercurrent multipliers

The vasa recta plays the role of countercurrent exchanger.

Since the concentration of tubular fluid in dese ding limb reflects the concentration of medullary interstitium, and sicne the concentration in the interstitium is raised by extrusion of salt from ascending limb, a positive feedback mechanism is created. The more salt the ascending limb extrudes, the more concentrated will be the fluid that enters into it from descending limb. Obviously , this feedback mechanism is the key point in the countercurrent multiplier system.

Countercurrent exchange: In order for the countercurrent multiplier system to be effective in creating the gradient of medullary hyperosmolality, most of the salt extruded by the ascending limb of Henle's loop must remain in medullary interstitium, while must of the water coming out of the descending limb must be drained off into the blood. This is accomplished by the vasa recta by means of the mechanism known as countercurrent exchange. Salt is thus recirculated and trapped within the medullary interstitium, But contrarily, the water diffuses into the blood of ascending limb of vasa recta and is carried away into general blood circulation.

Significance of urea:

Permeability to urea is found only in the deeper parts of thin ascending limbs of Henle's loops and collecting ducts. Urea diffuses out of the collecting ducts and enters into the thin ascending limbs down its concentration gradients. A certain amoun urea recycled in this way is trapped in medullary interstitium.

Role of distal convoluted tubule, collection duct and ADH: As described above, the role of countercurrent mechanism is to produce a small volume of higly hypotonic (osmolality only about100mL osmol/litre) tubular fluid which enters from the thick ascending limb of Henle's loop into the distal convoluted bubule and, thereafter into the collection duct. To finally produce a very small volume of highly concentrated urine from this hypotonic tubular fluid is the role of distal convoluted tubule and collecting duct under the influence of the antidiuretic hormone (ADH). ADH triggers synthesis of large a number of molecules of a specific protein, anamed aquaporin, in the epithelial cells of distal convuled tubule and more particularly of collecting duct. Molecules of aquaporin become incorporated in the plasma membrane of these cells as integral proteins and act as water channels. Consequently some water is lost from hypotonic tubular fluid by exosmosis while it flows through thhe distal conveoluted tubule, but most of the water of tubular fluid is lost across the wall of the collecting duct via aquaporin as this duct traverses through the medullary interstitium to empty into a calyx. Due to this, the osmolality of the urine emptied into the calyx becomes 1200 to 1400 mL osmol/litre.

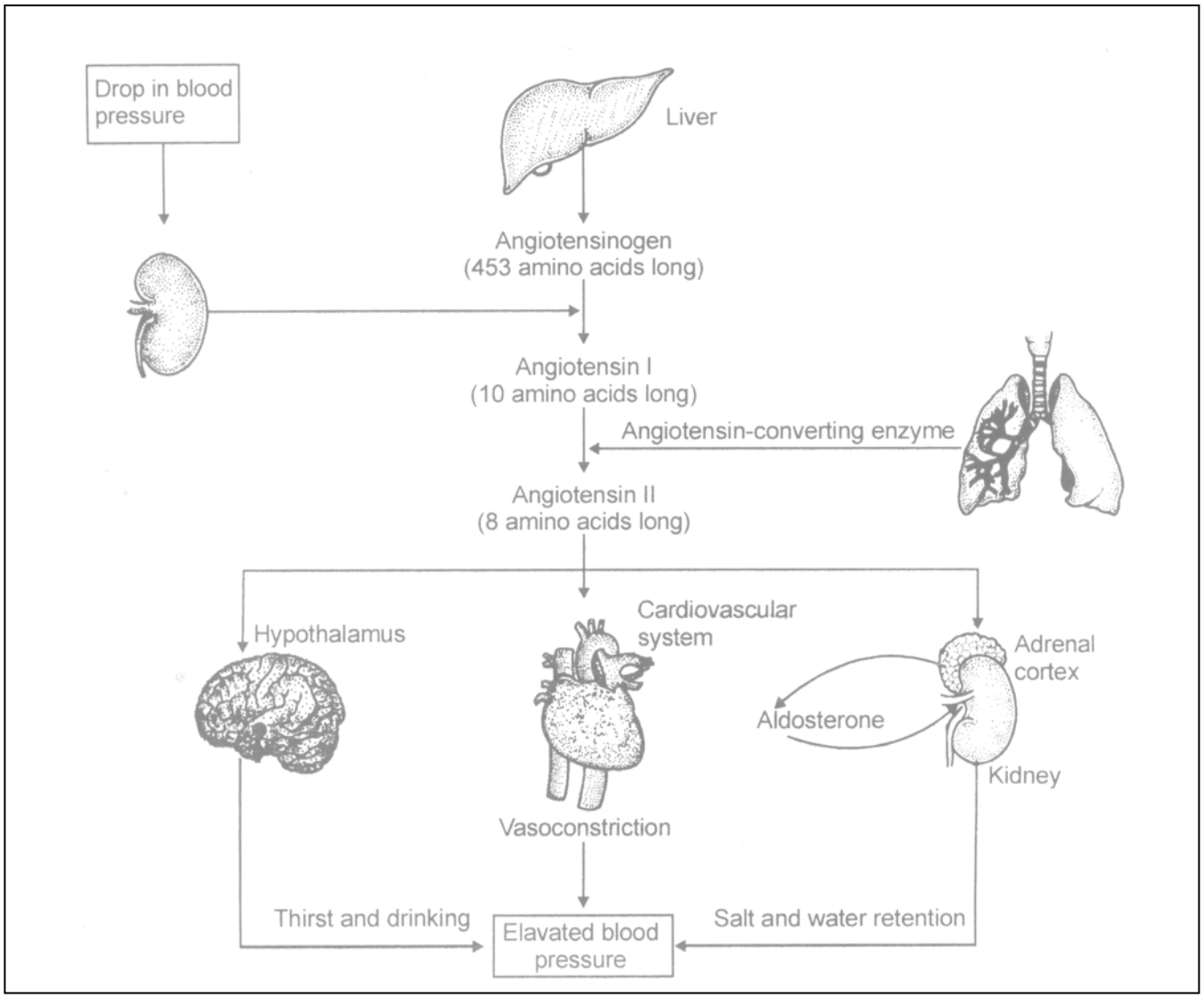
Regulation of Kidney Function by feedback circuits

Two important hormonal controls of the kidney function by negative feedback circuits. These are as follows:-

(i) **Control by Antidiuretic Hormone (ADH):-** ADH is produced in the hypothalamus from the pituitary glands. ADH enhances fluid retention by making the kidneys reabsorb more water. The release of ADH is triggered when osmoreceptors in the hypothalamus detect an increase in the osmolarity of the blood above a set point of 300 mosm L^{-1}. In this situation the osmoreceptor cells also promote thirst. Drinking reduces the osmolarity of the blood, which inhibits the secretion of ADH, thereby completing the feedback circuit.

(ii) **Control by Juxtaglomerular** Apparatus (JGA) :- JGA operates a multi-hormonal Renin-Angiotensin-Aldosterone System (RAAS). Whenever there is a fall in BP or blood volume, the JGA responds to this decrease in blood pressure or blood volume in the afferent arteriole of the glomerulos and releases an enzyme called rennin. Into the blood stream. In the blood, rennin intitiates chemical reactions that convert a plasma proteins, called angiotensinogen to a peptide, Called angiotension II, which works as a hormone. Angiotensin II increases blood pressure by causing arterioles to constrict. It also increases a blood volume in two ways.

(1) Firstly, by signaling the proximal convoluted tubules to reabsorb more NaCl and water.



(2) Secondly, by stimulating the adrenal gland to release aldosterone, a homone that induces the distal convoluted tubule to reabsorb more Na+ and water. This leads to an increase in blood volume and pressure, completing the feedback circuit by supporting the release of rennin.
Still another hormone, a peptide called Atrial Natriuretic Factro (ANF), opposes the regulation by RAAS. Whenever there is rise in the BP or blood volume, the walls of the atria of the heart release ANF in response to this increase in blood volume and pressure. ANF inhibits the release of rennin from the JGA, and thereby, inhibits NaCl reabosorption by the collecting duct and reduces aldosterone release from adrenal gland. Thus, ADH, the RAAS and ANF provide an elaborated system of checks and balance that regulate the kidney functioning, to control body fluid osmolarity, salt concentrations, blood pressure and blood volume.

Role of lungs in excretion

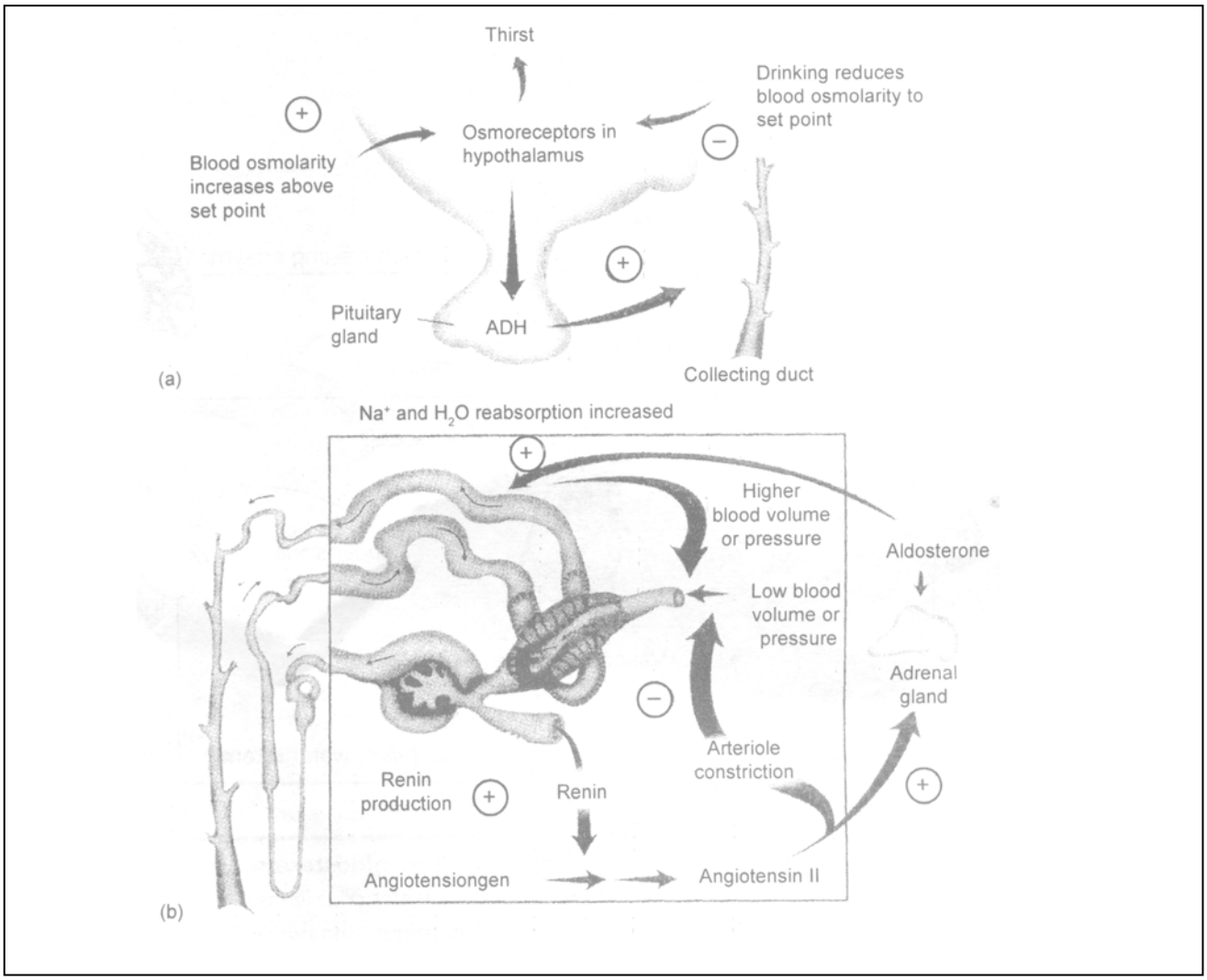
Human lungs eliminate around 18L of CO_2 per hour about 400 ml of water per in normal resting condition. Water loss via the lungs is small in humid climate and large in cold dry climates. The rate of ventilation, and ventilation pattern (i.e. breathing through mouth or nose) also affect the water loss through the lungs. Different volatile materials are also readily eliminated through the lungs.

Role of skin in excretion:

Human possess two types of glands:

(1) Sweat glands: These excrete sweat, Sweat contain 99.5%, water, NaCl, Lactic acid, Urea, Amino acid and glucose. Volume of sweat may vary from negligible to 14 litres a day.

(2) Sebaceous glands: These secrete sebum which contain waxes, sterols, other hydrocarbons and fatty acids.
Integument in many aquatic animals excretes ammonia in surrounding medium by diffusion.



Role of liver in excretion:

Liver is the main site for elimination of cholesterol, bile pigments (bilirubin & biiverdin), inactivated products of steroid hormones, some vitamins and many drugs. Bile carries these materials to the intestine from where they are excreted with the faeces.

SOME TERMS

1. **Oliguria:-** Less production of urea/urine

2. **Anuria:-** No production of urine

3. **Polyuria:-** Excess production of urine. More urine formation takes place due to less secretion of ADH. Due to less secretion of ADH, the amount of water. Increases in the urine. So, the patient fells thirsty again and again. This disease is called Diabetes-insipidus.

4. Glycosuria:- Excretion of Glucose through Urine. This sign is present in Diabets-mellitus. This disease is caused mainly due to less secretion of Insulin.

5. Uremia :- Excess of urea in blood is termed as Uremia.
6. Calculi and cast :- It is also termed as kidney-stone. Due to deposition of Calcium-oxalate in kidney, stone is formed. Sometimes, calcium phosphate and calcium-sulphate are also found. These are insoluble-salts. Normally, these are not excreted by the urine.
7. Haematuria:- Excretion blood through urine. It is a symptom of many diseases like black water fever, Bacterial-infection.
8. Diuresis:_ The process of excess formation of urine in the kidney's is termed as diuresis.
9. Dysuria:- Condition of painful micturition
10. Urinode:- Charateristic smell of the urine is due to urinode substances.
11. Cystitis:- Infection of urinary-bladder is termed as cystitis.
12. A person who is starving, will have more urea and ketone bodies in his blood and less urea in urine.
13. (a) The urine on standing gives a pungent smell. It is due to conversion of urea into ammonia by bacteria
    (b) The volume of urine produced per day will Increase on a cold day, due to ↓, ADH seretion.
14. Highest concentration of urea is found in hepatic vein. (Because urea is synthesized in liver Least concentration of urea is found renal vein. Because urea is excreted through urine formed in kidney)
15. If one kidney is removed, the remaining one enlarge and performs function of both kidneys.
16. Camels can withstand water deprivation by reducing urinary water loss and water loss by sweat.
17. Earthworms excrete ammonia when sufficient water is available while they excrete urea instead of ammonia in drier surroundings.
18. When lung fishes and xenopus (African toad) live in water, they are normally ammonotelic but the become ureotelic when they live in moist air or mud during summer.
    Crocodiles= normally ammonotelic
19. Bean shaped kidney are present only in mammals.
20. Number of pyramids is man = 8-12
    Number of pyramids in Rabbit = only 1
    "Renal column of Bertini" absent in Rabbit
21. Uric acid is the last product of purine metabolism in human 2,6,8-trioxy purine is uric acid
22. Renal blood flow = 1200 -1300 ml./mt.
    Renal plasma flow = 650 ml./mt.
23. Inulin clearance can be used to Estimate GFR
24. PAH (Para Amino Hippuric Acid) clearance can be used to Estimate RPF (Renal Plasma Flow)
25. Test of urea in urine is specific urease test.

    $$Urea \xrightarrow{Urease} NH_3 + CO_2$$

    Phenol Red is used as a indicator
    Optimum temp for reaction 60^0C
26. In brain, the major mechanism for removal of Ammonia is glutamine formation & in liver, the most important pathway is urea formation.
27. Urinary Bladder – Stimulation for voiding urine= 220 cc.
    Genrally micturation occur -300-400 ml.

Discomfort condition after 500ml.
Capacity of bladder 1000cc.

28. Filltration fraction $= \frac{G.F.R}{R.P.F}$

29. Basement membrane is a meshwork of collage and prodteoglycan fibrils. It prevents filteration of plasma proteins because of strong negative charge present on it due to proteoglycans.

30. Urinary excretion rate = filteration rate- filteration rate- rebsorption rate= secretion rate.

31. High threshold substances are completely reabsorbed after filtration while athreshold substances like creatinine are freely filtered but not at all reabsorbed.

32. No. of functioning nephrons decrase 10% for every 10 years after the age of 40 years.

33. In each kidney there are about 250 collecting duct each of which collects urine from 4000 nephrons.

34. Functions of kidney:
- Regulation of water and electrolyte balance.
- Regulation of body fluid osmolality and electrolyte concentration.
- Regulation of acid base balance.
- Regulation of arterial pressure.
- Excretion of arterial pressure.
- Excretion of metabolic waste and foreign chemicals.
- Secretion of hormones like erythropoeithin and rennin.
- Gluconeogenesis from amino acids.

DISEASES RELATED WITH KIDNEY

1. Renal failure: It is a syndrome characterized by renal dysfunction, oliguria, anuria, sudden rise metabolic wste products like urea & creatinine in blood (Uremia). It is either of acute (sudden onset) or chronic (slow onset) nature.

2. Glomerulonephritis: It is a disease where due to infection or injury in the basement membrane, the inflame-maion of glomerulus progressively leads to renal failure and death.

3. Diabetic nephropathy: It is a complication due to diabetes mellitus weher the kidney progressively gets damaged leading to death ultimately due to renal failure.

4. Urolithiasis: Formation of calculi (stone) in the urogenital tract at any point. These calculi are made of calcium phosphate, uric acid., cystine or calcium oxalate.

Abnormal urine:

Various metabolic errors of kidney malfunctioning is reflected in the changes of the composition of urine. Occurrence of ketone bodies, glucose, albumin, blood cells, excess pigments, pus cells, calculi or casts (kidney stones) are some of the major abnormal constituents of urine. Notable abnormal conditions are as follows:
Proteinuria-excess protein level in urine.
Albuminuria –presence of albumin in urine, usually occurs in nephritis (inflammation of glomeruli), when the size of the filtering slits enlarges and basement membrane looses its negative charge.
Ketonuria –Presence of abnormally high ketone bodies in urine.
Haemoglobinuria- Presence of blood or blood cells in urine.

DEVILOPMENT OF KIDNEY

During embryonic development, nephrotome plate develops from mesoderm which is made up of fine tubules called nephros.

Nephrotome develops into kidney while nephros develops into Nephrons or urinferous tubules. One the basis of development, kidney are of 3 types;

(1) Pronephric Kidney:- Develop from anterior part (Pronephros) of Nephrotome plate, Its nephrons are in simple tubular shape. Nephrons are not differentiated

Eg. Cyclostomates & Tadpole of frog.

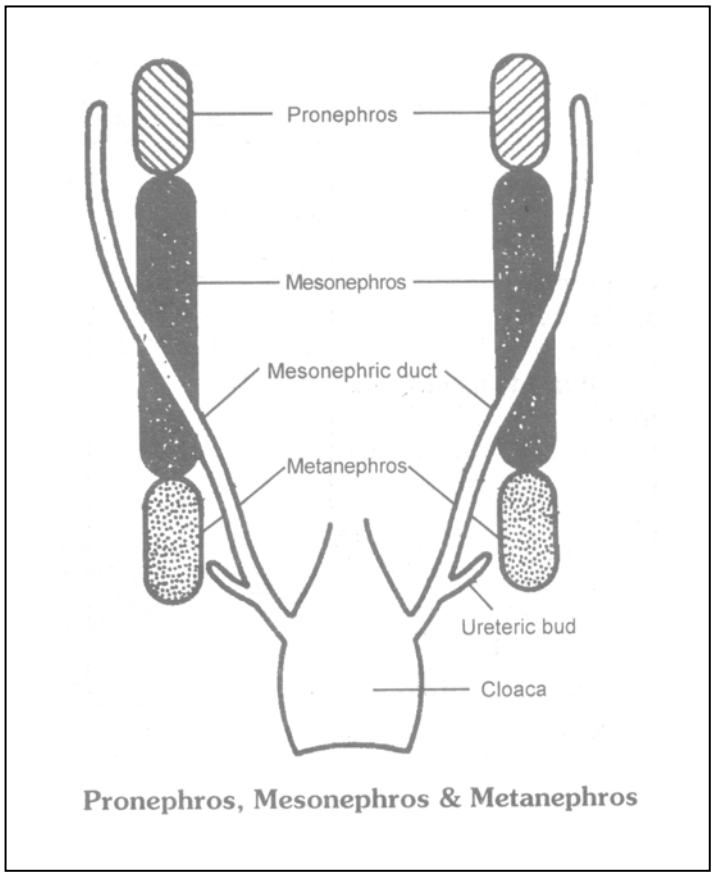
(2) Mesonephric Kidney or opisthonephros

:- Develop from middle part (Mesonephros) of Nephrotome plate & remaining part of nephtotome is destroyed. Only Bowman's capsule if found in nephrons while remaining part is simple tubular.

Eg. Most of the fishes& adult Amphibians.

(3) Metanephric Kidney:- Develops from posterior part (Metanephros) of nephrotome while remaining part is destroyed. Nephrons are well differentiated in to Bowman's capsule PCT, DCT & loop of Henle's capsule PCT, DCT & loop of Henle's

Eg. Reptile, Aves, Mammals



Pronephros, Mesonephros & Metanephros

Henle's Loop:-

- Less developed in Reptiles
- Incompletely Developed in Aves
- ☛ Mammals have most developed Henles loops.

Autoregulation of GFR

Two important intrinsic mechanisms provide autoregulation of glomerular filtration rate:

(a) Myogenic Mechanism: An increase in blood pressure will tend to stretch the afferent arteriole, which would be expected to increase the blood flow to the glomerulus. The wall of the afferent arteriole, however, responds to stretch by contraction, this reduces the diameter of the arteriole, and therefore causes increase in the resistance to flow. This myogenic mechanism, thus, reduces variations in flow to the glomerulus in case of fluctuation in blood pressure.

(b) Juxtaglomerular apparatus (JGA): This specialized cellular apparatus is located where the distal convoluted tubule passes close to the bowman's capsule between the apparatus is located where the distal convoluted tubule passes close to the Bowman's capsule between the afferent and efferent arterioles. JGA cells secrete enzymes like rennin that modulate blood pressure, and thus renal blood flow and GFR are regulated. This is discussed earlier in the sheet.

Thus, myogenic and juxtaglomerular mechanisms work together to autoregualte the GFR over a wide range of blood pressure.

BRIEF REVIEW

Structure of Nephron :

Structure of Nephron

Proximal nephron

Bowman's capsule

- Double wall cap Shaped structure
- Contain a tuft of Capil.aries called **Glomerulus.**
- Glomerulus contain Two arterioles – Afferent and efferent
- Diameter of afferent Arte4riole is more than efferent arteriole
- Glomerulus + Bowman's capsule = Malpighian corpusule

Proximal Convoluted tubule

- Contain numberous microvilli which Increase the surface area.
- Near its basolateral Surface, the mitochondria are Concentratd, to allow Reabsorption of salts by active transport.

Loop of Henle

Descending Lime

- Thick segment.
- Lined by cuboidal eptithelium
- has less microvilli and mitochondria in comparison to cells of PCT.

- Thin segment.
- Lined by flat epithelial cells
- Has very less microvilli and mitochondia.

Ascending limb

- Thin segment Widens Abruptly at medullary zone to formthick segmnet
- Thin segment. Thin segment. Is lined by simple squamous eptielial cells while thick sement is lined by cuboidal epithelial cells

Distal nephron

- Ascending limb Merges into distal convoluted tubule (DCT.)
- Coils of both PCT AND DCT are inte . 'es
- DCT Ⓡ ecti Duct or tubule Ⓡ Dcut of Bellini Ⓡ Pelvis

Renal cortex contain malpighian corpuscle, PCT and DCT.
Renal medulla contain loop of henle, collecting duct and ducts of Bellini

Types of nephron:

According to their position, nephrons are of two types.

	Cortrical nephrons		Juxtamedullary nephrons
1.	Constitute about 85% of total. (75-85%)	1.	About 15% of total. (15-25%)
2.	Malpighian corpuscles are located close to the kidney surface.	2.	Malpighian corpuscles are located at the junction of cortex and medulla.
3.	Their loop of Henle are mostly confined To cortex and a very small part of it runs in the medulla.	3.	The loop of Henle of these nephrons are long, dipping deep down into the medulla.
4.	Peritubular capillary network is present	4.	Peritubular capillary network is not well developed.

5.	Vasa recta is absent.	5.	Vasa recta present.

Composition of Urine:-

95%	=	Water
2%	=	Salts
2.7%	=	Urea
Rest 0.3%	=	Other materials like the drugs, Hippuric-acid, Uric Vitamin - C, Dyes etc.

☛☛ Pale yellow colour of urine is due to the Urochrome pigment. It is formed in the blood due to the reduction of Haemoglobin. So in the body of a healthy animal urochrome is found in a very less amount.

☛

☛ pH of urine = 6. The pH of urine is maintained by a Buffer-system. This is called the [Na_2HPO_4-NaH_2PO_4] Buffer system

☛ The specific –gravity of urine is 1.01 to 1.05

Osmoregulation by Kidneys :- Kidneys regulate the amount of water and salts in the Extra- cellular fluid. Some hormones help in this process, which are –

1. **ADH or petressin or Vasopressin :-** Main controlling hormone of volume of urine. It mainly act on DCT & early CT. It promotes reabsorbtion of H_2O. Due to deficiency. Of ADH, diuresis occurs & water loss is increased. This condition called as diabetes insipidus.

2. **Aldosterone:-** It is a hormone of the adrenal- cortex. The main salt found in the ECF is Na^+ ions. They regulate the osmolality of the ECF. If Na^+ number decreases in the blood the blood pressure also decreases and if Na^+ number increases in the blood pressure also increases. Aldosterone hormone, promotes the reabsorption of Na^+ in the nephrons, ie. It checks the loss of Na^+ ions through uring. When the ECF lacks Na^+ ions, the secretion of Aldosterone increases

3. **Renin:-** It is secreted by JG apparatus when there is decreased delivery of Na+ at macula denssa, when fall of BP & Sympathatic stimulation occurs, then rennin is secreted

4. **ANF (Atrial Natriuretic Factor) :-** It is released from atrial Muscles. It decrease the effect of rennin & aldosterone, It decrease BP & overload of heart & promotes vasodialation.