EXCRETORY SYSTEM

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INTRODUCTION

- Excretion is the process by which the unwanted substances and metabolic wastes are eliminated from the body.
- A large amount of waste materials and carbon dioxide are produced in the tissues during metabolic process.
- In addition, residue of undigested food, heavy metals, drugs, toxic substances and pathogenic organisms like bacteria are also present in the body.
- All these substances must be removed to keep the body in healthy condition.

- Various systems/organs in the body are involved in performing the excretory function, viz.

1. **Digestive system :** excretes food residues in the form of feces. Some bacteria and toxic substances also are excreted through feces.
2. **Lungs :** remove carbon dioxide and water vapor.
3. **Skin :** excretes water, salts and some wastes. It also removes heat from the body.
4. **Liver :** excretes many substances like bile pigments, heavy metals, drugs, toxins, bacteria, etc. through bile.
5. **Kidneys :** These are the primary means for eliminating waste products like **Excretion of Metabolic Waste Products, Foreign Chemicals, Drugs, and Hormone Metabolites** etc. Along with it perform several vital functions and play the principal role in homeostasis.

THE RENAL SYSTEM

- Although various organs are involved in removal of wastes from the body, their excretory capacity is limited.
- But renal system or urinary system has maximum excretory capacity and so it plays a major role in homeostasis.
- It includes:

1. A pair of kidneys
2. Ureters
3. Urinary bladder
4. Urethra.

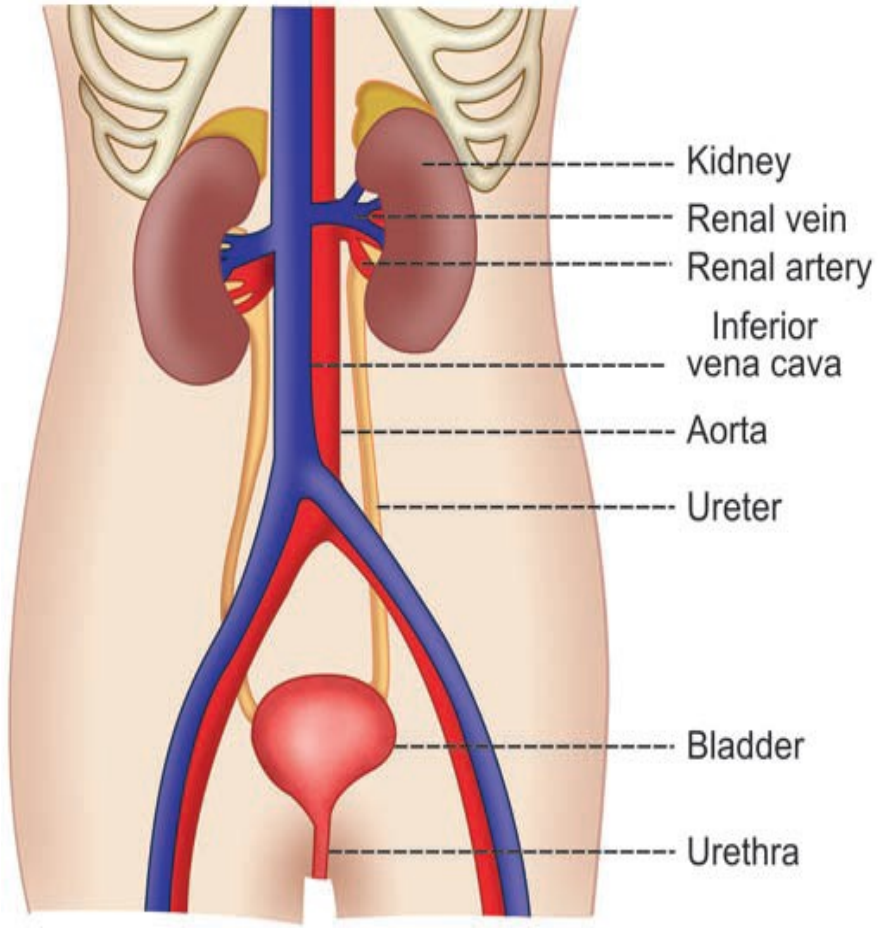
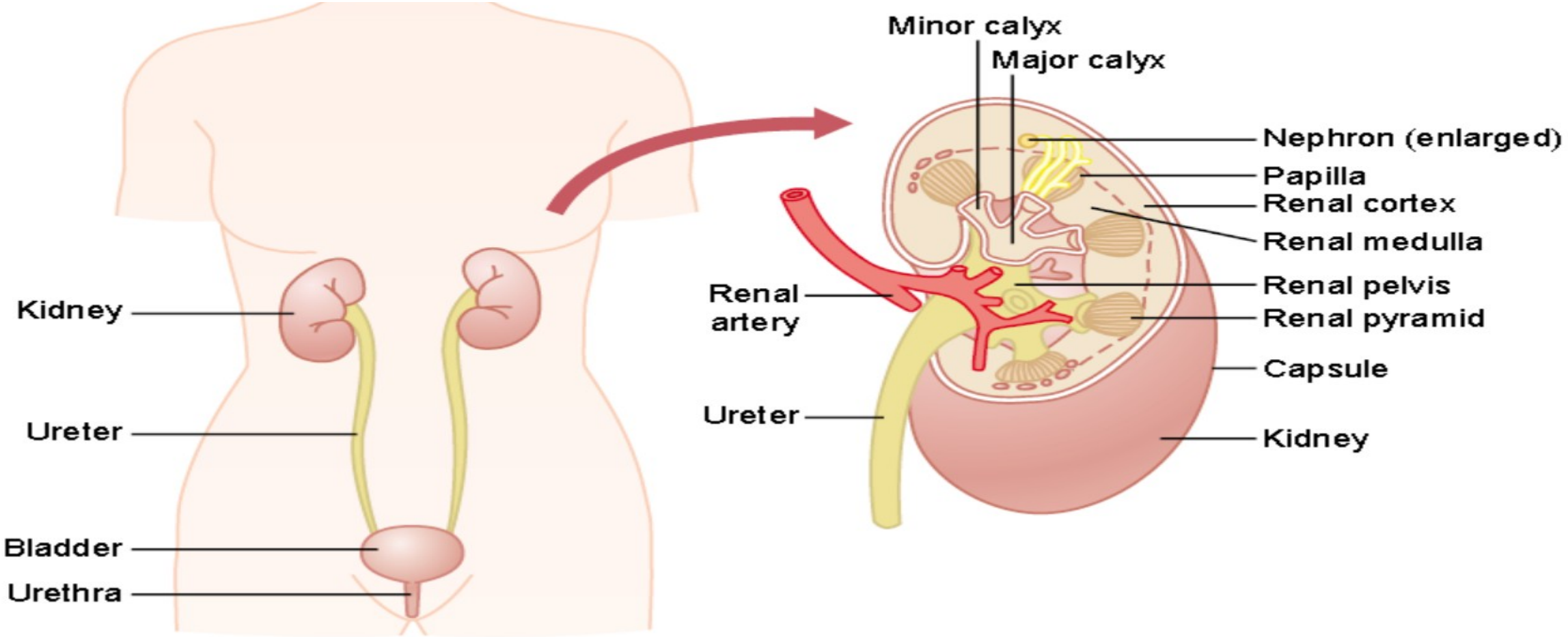


FIGURE : URINARY SYSTEM

- Kidneys produce the urine. Ureters transport the urine to urinary bladder. Urinary bladder stores the urine until it is voided (emptied).
- Urine is voided from bladder through urethra.

FUNCTIONAL ANATOMY OF KIDNEY

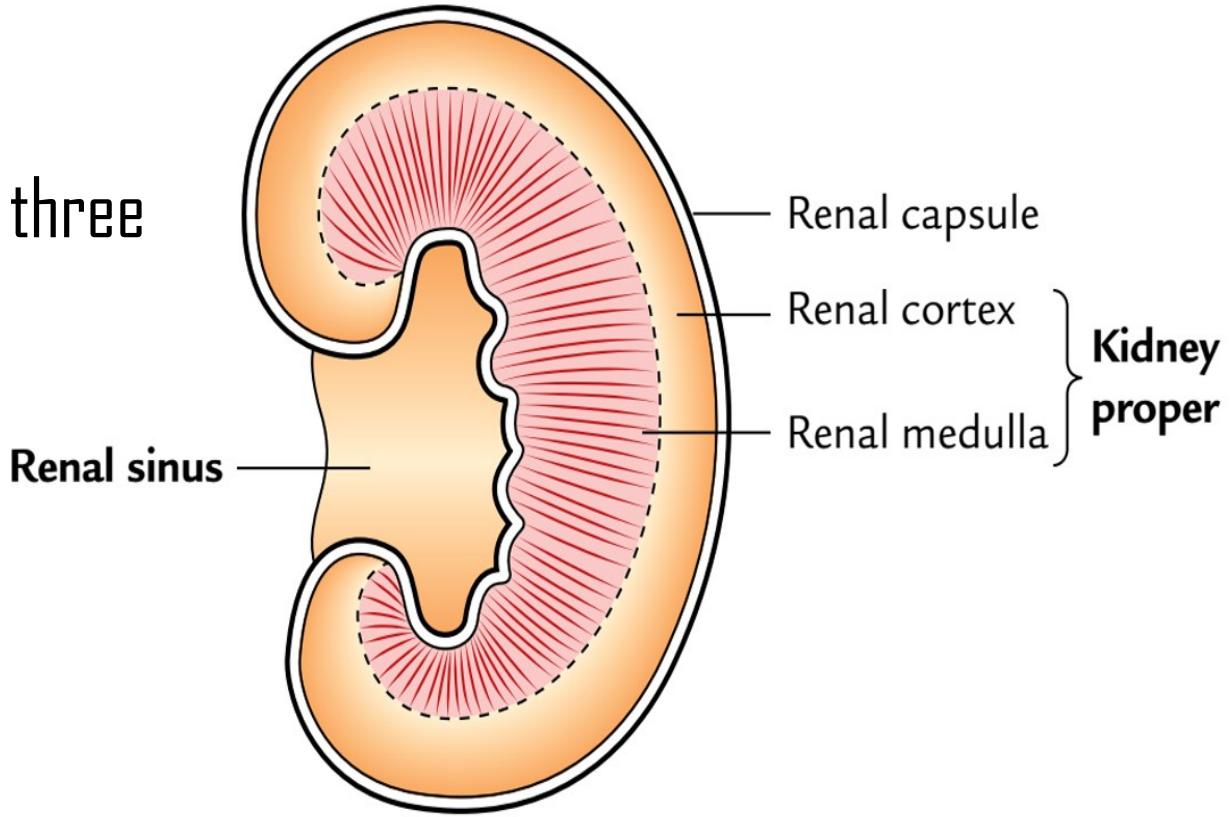
- Kidney is a compound tubular organ covered by a connective tissue capsule.
- There is a depression on the medial border of kidney called hilum, through which renal artery, renal veins, nerves and ureter pass.



DIFFERENT LAYERS OF KIDNEY

- Components of kidney are arranged in three layers :

1. Outer cortex
2. Inner medulla
3. Renal sinus.

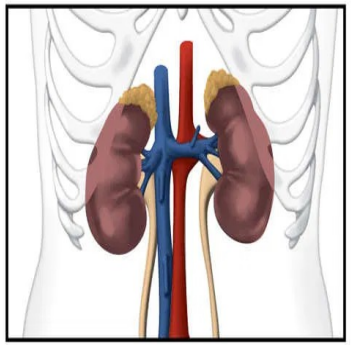


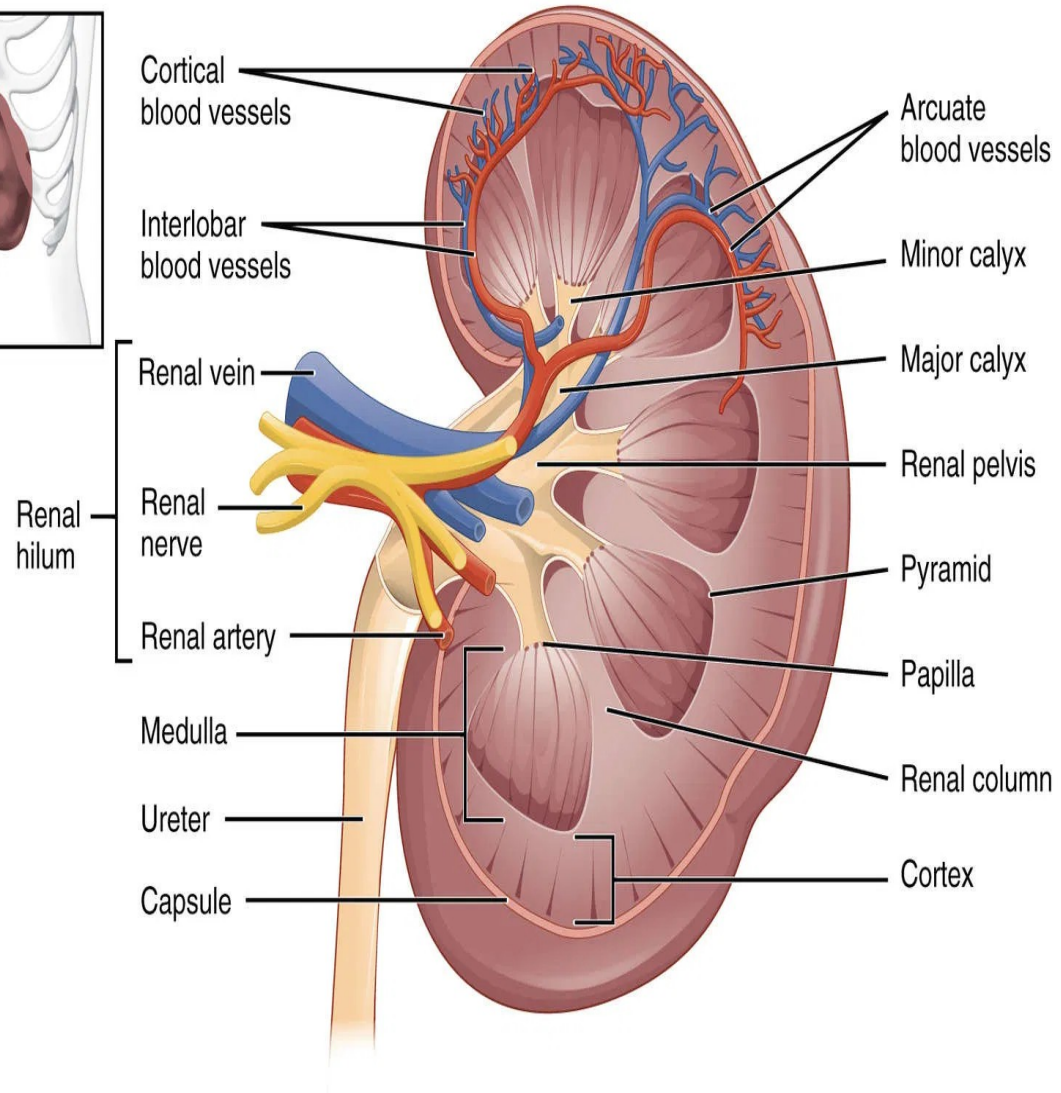
1. OUTER CORTEX

- Cortex is dark and granular in appearance. It contains renal corpuscles and convoluted tubules.
- At intervals, cortical tissue penetrates medulla in the form of columns, which are called renal columns or **columns of Bertini.**

2. INNER MEDULLA

- Medulla contains tubular and vascular structures arranged in parallel radial lines.
- Medullary mass is divided into 8 to 18 **medullary** or **Malpighian pyramids.**
- Broad base of each pyramid is in contact with cortex and the apex projects into **minor calyx.**





3. RENAL SINUS

- Renal sinus consists of the following structures:

i. Upper expanded part of ureter called **renal pelvis.**
ii. Subdivisions of pelvis: 2 or 3 **major calyces** and about 8 minor calyces.
iii. Branches of nerves, arteries and tributaries of veins.

TUBULAR STRUCTURES OF KIDNEY

- Kidney is made up of closely arranged tubular structures called **uriniferous tubules.**
- Blood vessels and interstitial connective tissues are interposed between these tubules.
- Uriniferous tubules include:

1. **Terminal or secretary tubules called nephrons,** which are concerned with formation of urine.
2. **Collecting ducts** or tubules, which are concerned with transport of urine from nephrons to pelvis of ureter.

   Collecting ducts unite to form **ducts of Bellini,** which open into minor calyces through **papilla.**

FUNCTIONS OF KIDNEY

- Kidneys perform several vital functions besides formation of urine.
- By excreting urine, kidneys play the principal role in homeostasis.
- Thus, the functions of kidney are:

1. ROLE IN HOMEOSTASIS

- Primary function of kidneys is **homeostasis.**
- It is accomplished by the formation of urine.
- During the formation of urine, kidneys regulate various activities in the body, which are concerned with homeostasis such as:

A. EXCRETION OF WASTE PRODUCTS

- Kidneys excrete the unwanted waste products, which are formed during metabolic activities:

i. Urea (end product of amino acid metabolism)
ii. Uric acid (end product of nucleic acid metabolism)
iii. Creatinine (end product of metabolism in muscles)
iv. Bilirubin (end product of hemoglobin degradation)
v. Products of metabolism of other substances.
vi. Kidneys also excrete harmful foreign chemical substances such as toxins, drugs, heavy metals pesticides, etc.

B. MAINTENANCE OF WATER BALANCE

- Kidneys maintain the water balance in the body by conserving water when it is decreased and excreting water when it is excess in the body.
- This is an important process for homeostasis.

C. MAINTENANCE OF ELECTROLYTE BALANCE

- Maintenance of electrolyte balance, especially sodium is in relation to water balance.
- Kidneys retain sodium if the **osmolarity** of body water decreases and eliminate sodium when osmolarity increases.

D. MAINTENANCE OF ACID–BASE BALANCE

- The pH of the blood and body fluids should be maintained within narrow range for healthy living. It is achieved by the function of kidneys.
- Body is under constant threat to develop **acidosis,** because of production of lot of acids during metabolic activities.
- However, it is prevented by kidneys, lungs and blood buffers, which eliminate these acids. Among these, kidneys play major role in preventing acidosis.
- In fact, kidneys are the only organs, which are capable of eliminating certain metabolic acids like sulfuric and phosphoric acids.

2. HEMOPOIETIC FUNCTION

- Kidneys stimulate the production of erythrocytes by secreting **erythropoietin.**
- Erythropoietin is the important stimulating factor for erythropoiesis.
- Kidney also secretes another factor called **thrombopoietin,**
- which stimulates the production of thrombocytes.

3. ENDOCRINE FUNCTION

- Kidneys secrete many hormonal substances in addition to erythropoietin and thrombopoietin.
- Hormones secreted by kidneys

i. Erythropoietin
ii. Thrombopoietin
iii. Renin
iv. 1,25-dihydroxycholecalciferol (calcitriol)
v. Prostaglandins.

4. REGULATION OF BLOOD PRESSURE

- Kidneys play an important role in the long-term regulation of arterial blood pressure by two ways:

I. By regulating the volume of extracellular fluid.
II. Through **renin-angiotensin** mechanism.

5. REGULATION OF BLOOD CALCIUM LEVEL

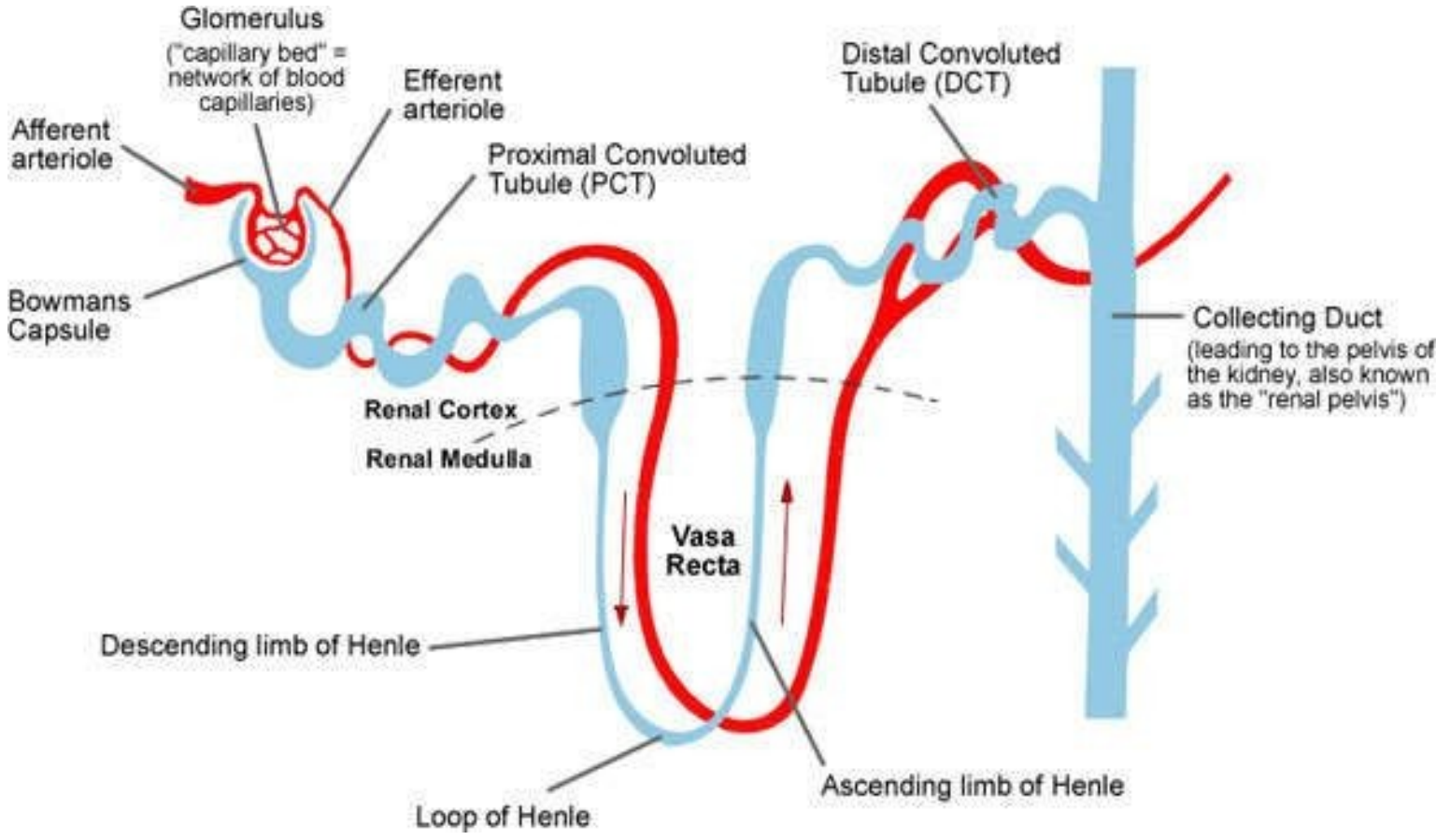
- Kidneys play a role in the regulation of blood calcium level by activating 1,25-dihydroxycholecalciferol into **vitamin D.**
- Vitamin D is necessary for the absorption of calcium from intestine.

NEPHRON

- Nephron is defined as the structural and functional unit of kidney.
- Each kidney consists of 1 to 1.3 millions of nephrons.
- The number of nephrons starts decreasing after about 45 to 50 years of age at the rate of 0.8% to 1% every year.

- Each nephron is formed by two parts:

1. A blind end called renal corpuscle or **Malpighian corpuscle.**
2. A tubular portion called **renal tubule.**

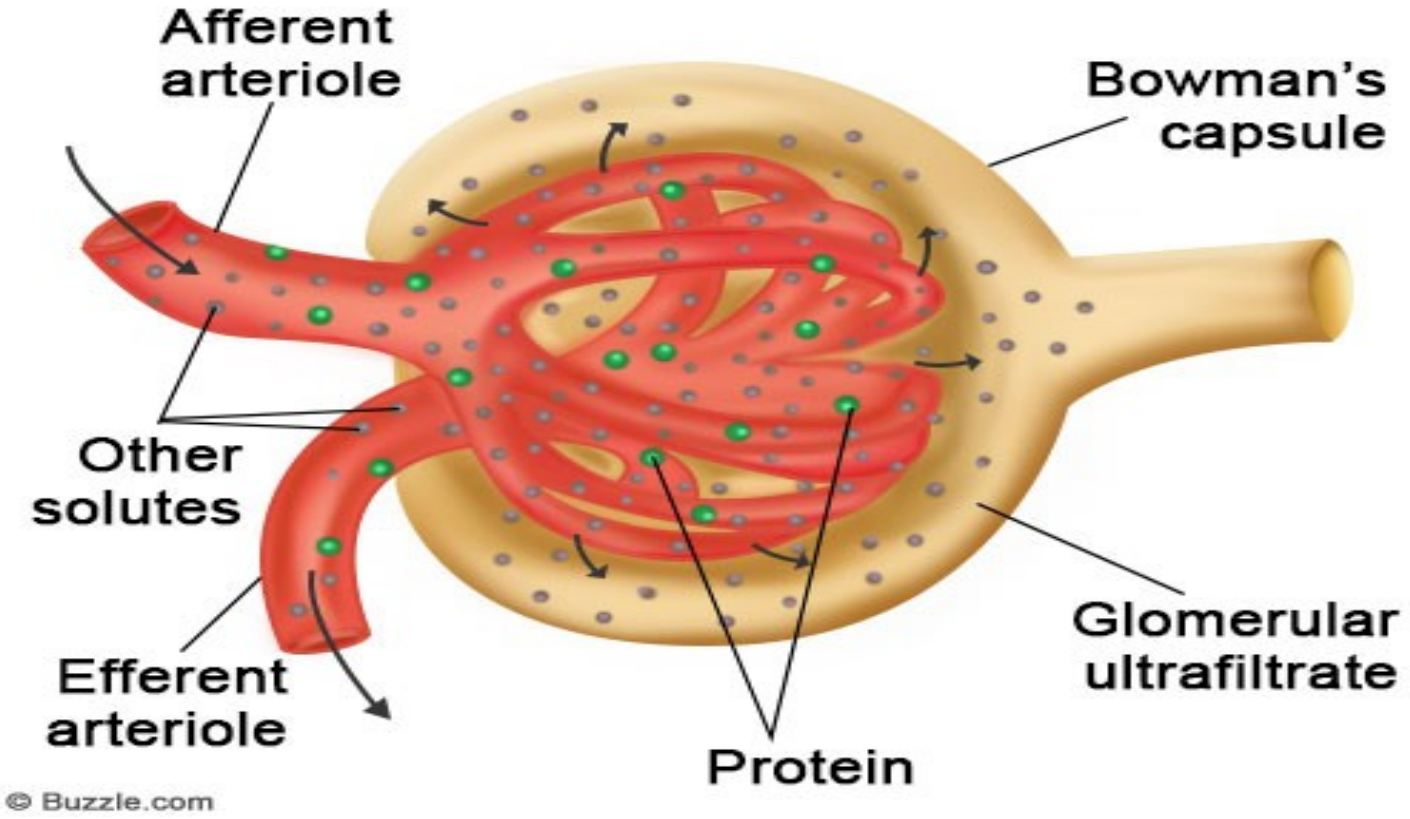


1. RENAL CORPUSCLE

- Renal corpuscle or Malpighian corpuscle is a spheroidal and slightly flattened structure with a diameter of about 200 μ.
- Function of the renal corpuscle is the filtration of blood which forms the first phase of urine formation.

SITUATION OF RENAL CORPUSCLE

- Renal corpuscle is situated in the cortex of the kidney either near the periphery or near the medulla.



CLASSIFICATION OF NEPHRONS

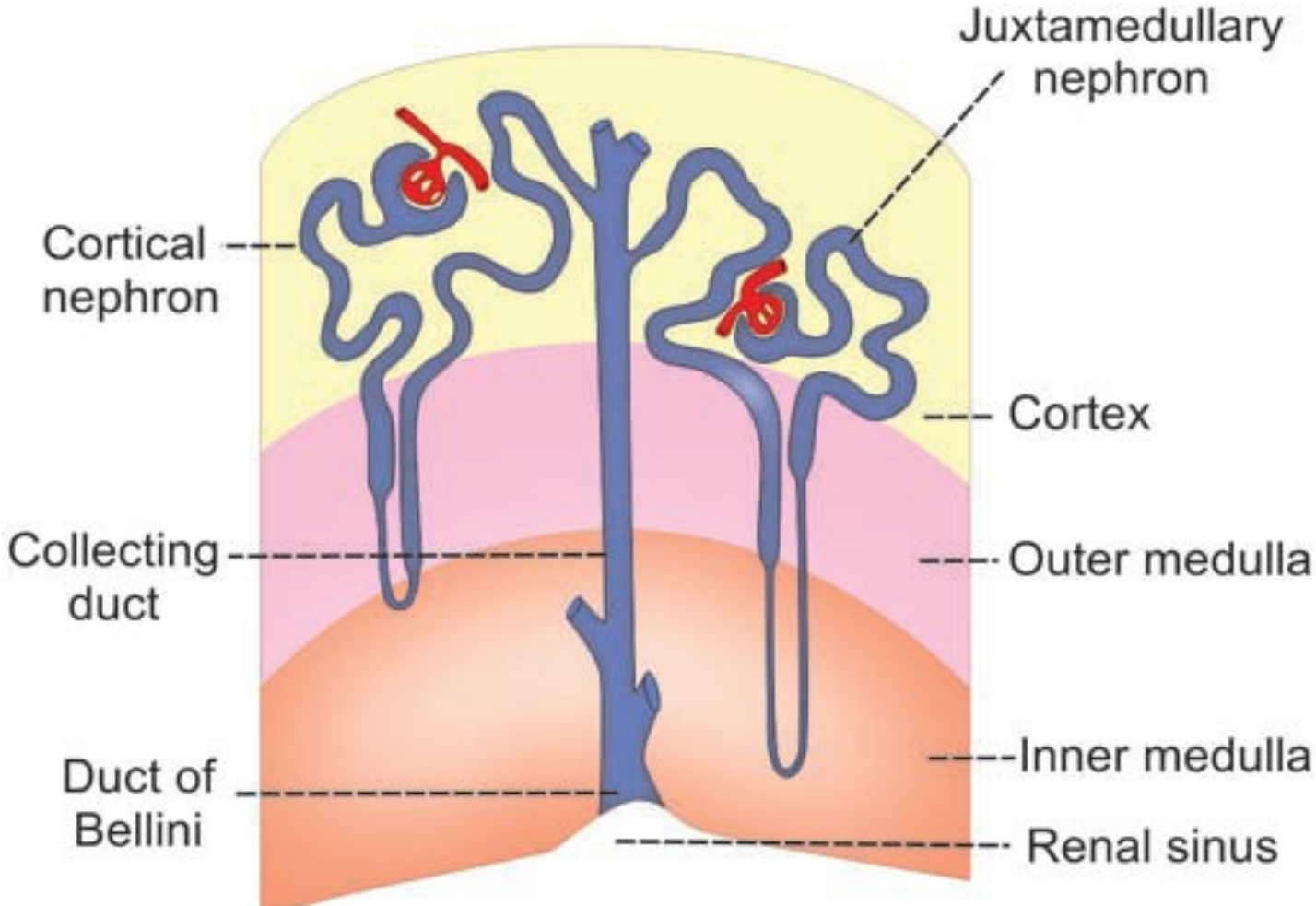
- Based on the situation of renal corpuscle, the nephrons are classified into two types:

1. CORTICAL NEPHRONS OR SUPERFICIAL NEPHRONS:

- Nephrons having the corpuscles in outer cortex of the kidney near the periphery.
- In human kidneys, 85% nephrons are cortical nephrons.

2. JUXTAMEDULLARY NEPHRONS:

- Nephrons having the corpuscles in inner cortex near medulla or corticomedullary junction.



- Features of the **CORTICAL NEPHRONS** and **JUXTAMEDULLARY NEPHRONS** are given below in the table.

Features	Cortical nephron	Juxtamedullary nephron
Percentage	85%	15%
Situation of renal corpuscle	Outer cortex near the periphery	Inner cortex near medulla
Loop of Henle	Short	Long
	Hairpin bend penetrates only up to outer zone of medulla	Hairpin bend penetrates up to the tip of papilla
Blood supply to tubule	Peritubular capillaries	Vasa recta
Function	Formation of urine	Mainly the concentration of urine and also formation of urine

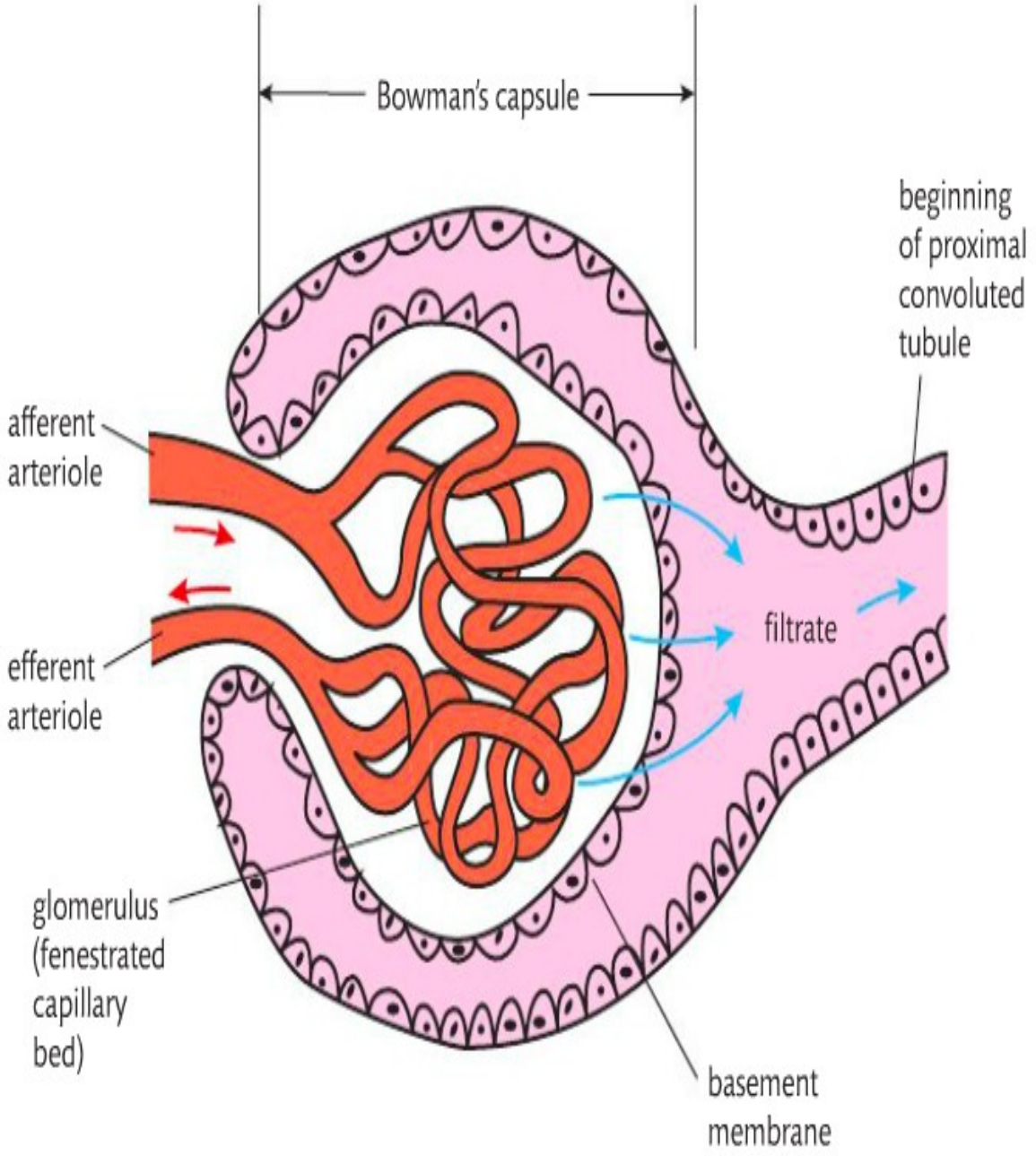
STRUCTURE OF RENAL CORPUSCLE

Renal corpuscle is formed by two portions:

i. Glomerulus
ii. Bowman capsule.

I. GLOMERULUS

- Glomerulus is a tuft of capillaries enclosed by Bowman capsule.
- It consists of glomerular capillaries interposed between afferent arteriole on one end and efferent arteriole on the other end. Thus, the vascular system in the glomerulus is purely arterial.
- Glomerular capillaries arise from the afferent arteriole.



- After entering the Bowman capsule, the afferent arteriole divides into 4 or 5 large capillaries.
- Each large capillary subdivides into many small capillaries.
- These small capillaries are arranged in irregular loops and form anastomosis.
- All the smaller capillaries finally reunite to form the efferent arteriole, which leaves the Bowman capsule.
- Diameter of the efferent arteriole is less than that of afferent arteriole.
- This difference in diameter has got functional significance.

FUNCTIONAL HISTOLOGY

- Glomerular capillaries are made up of single layer of endothelial cells, which are attached to a basement membrane.
- Endothelium has many pores called **fenestrae** or **filtration pores.**
- Diameter of each pore is 0.1 μ. Presence of the fenestra is the evidence of the filtration function of the glomerulus.

II. BOWMAN CAPSULE

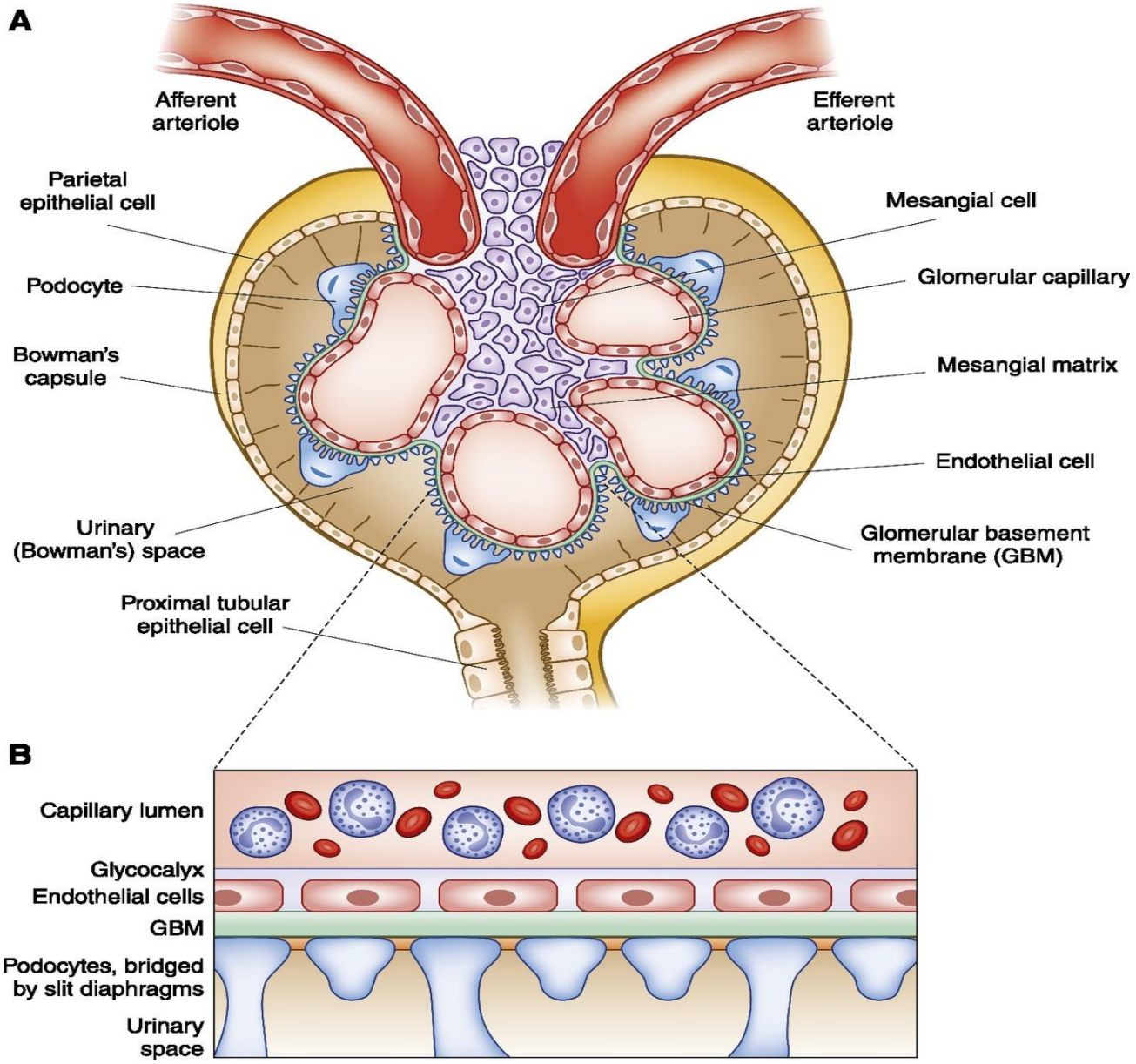
- Bowman capsule is a capsular structure, which encloses the glomerulus.
- It is formed by two layers:

i. INNER VISCERAL LAYER

- It covers the glomerular capillaries. It is continued as the parietal layer at the visceral pole.

ii. OUTER PARIETAL LAYER

- This layer continued with the wall of the tubular portion of nephron.



- The cleftlike space between the visceral and parietal layers is continued as the lumen of the tubular portion.
- Functional anatomy of Bowman capsule resembles a funnel with filter paper. Diameter of Bowman capsule is 200 μ.

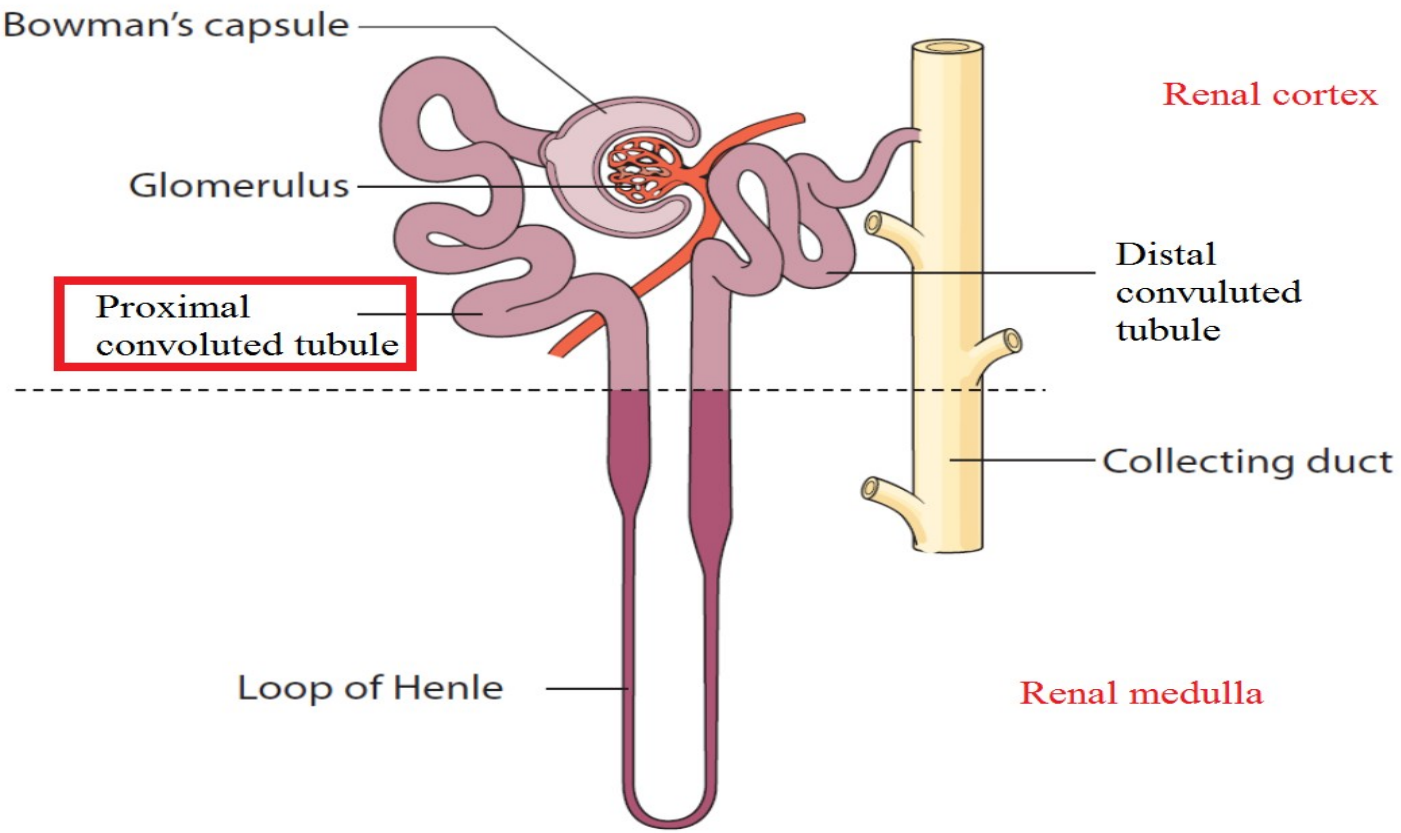
2. TUBULAR PORTION OF NEPHRON

- Tubular portion of nephron is the continuation of Bowman capsule.
- It is made up of three parts:

1. Proximal convoluted tubule
2. Loop of Henle
3. Distal convoluted tubule.

PROXIMAL CONVOLUTED TUBULE

- Proximal convoluted tubule is the coiled portion arising from Bowman capsule.
- It is situated in the cortex.
- It is continued as descending limb of loop of Henle.



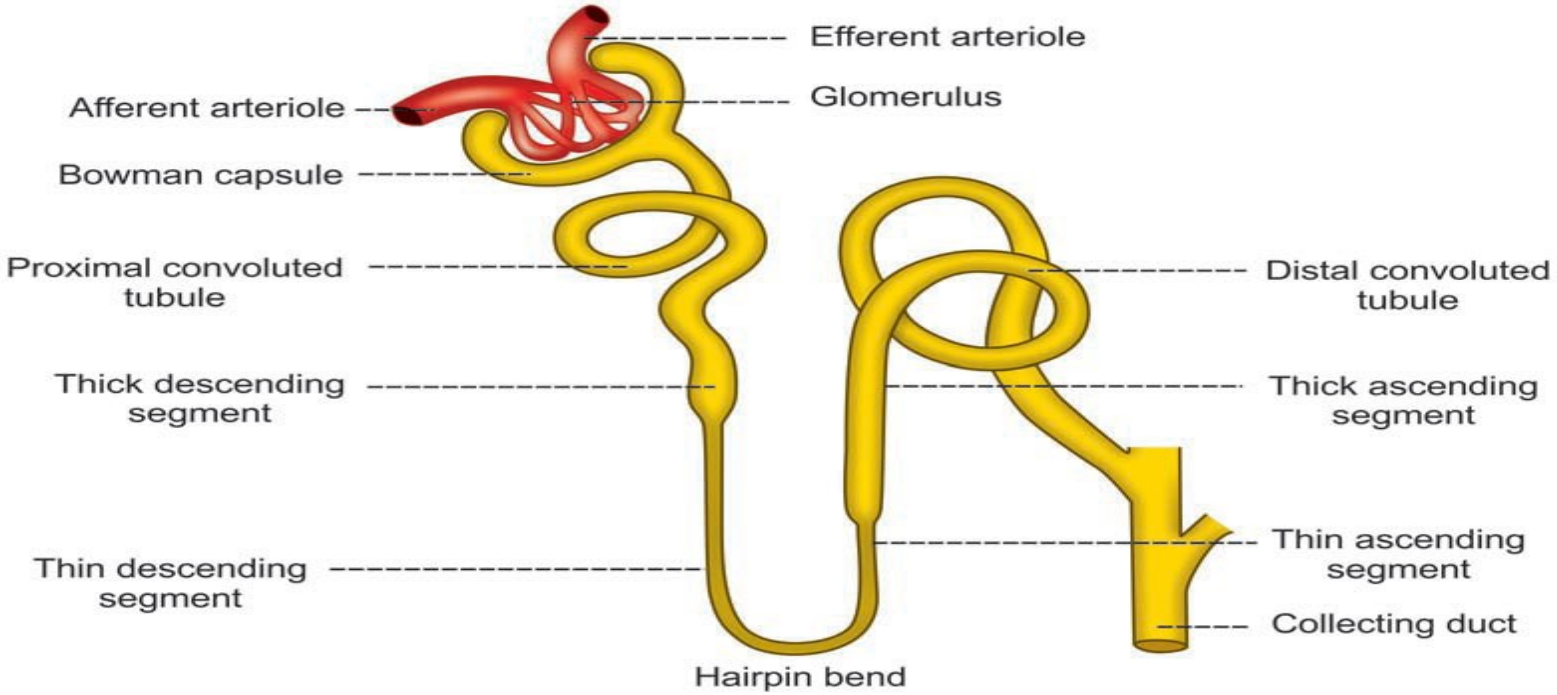
FUNCTIONAL HISTOLOGY

- Proximal convoluted tubule is formed by single layer of cuboidal epithelial cells.
- Characteristic feature of these cells is the presence of hair like projections directed towards the lumen of the tubule.
- Because of the presence of these projections, the epithelial cells are called **brush-bordered cells.**

LOOP OF HENLE

- Loop of Henle consists of:

i. Descending limb
ii. Hairpin bend
iii. Ascending limb.



I. DESCENDING LIMB

- Descending limb of loop of Henle is made up of two segments:

A. THICK DESCENDING SEGMENT

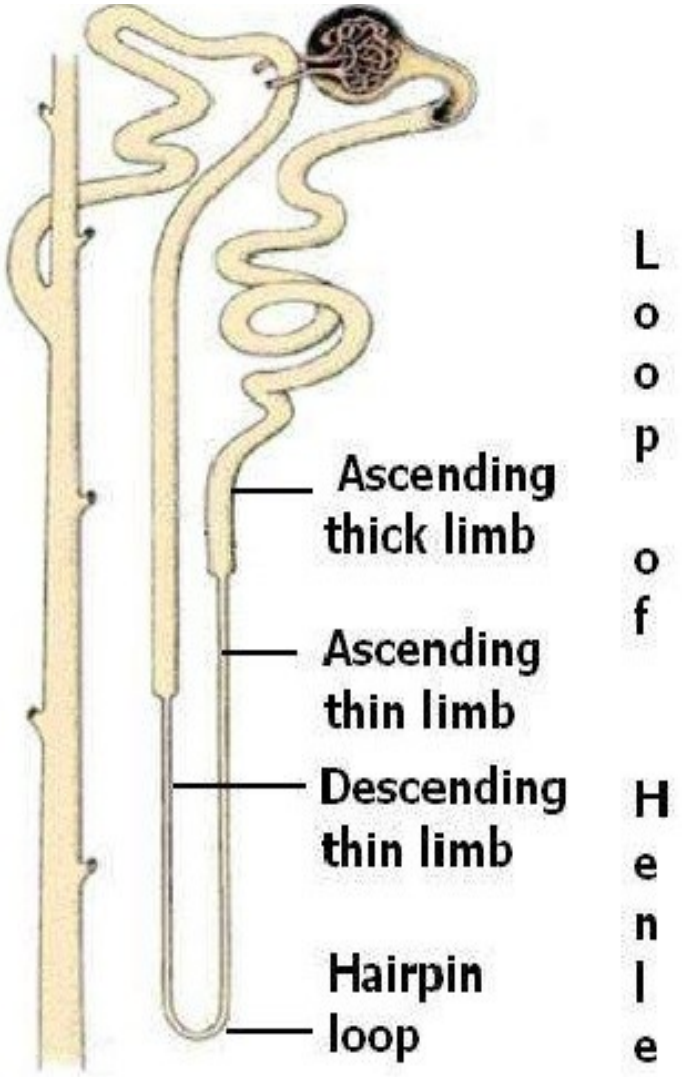
- Thick descending segment is the direct continuation of the proximal convoluted tubule.
- It descends down into medulla. It has a length of 6 mm and a diameter of 55 μ.
- It is formed by brush bordered cuboidal epithelial cells.

B. THIN DESCENDING SEGMENT

- Thick descending segment is continued as thin descending segment.
- It is formed by flattened epithelial cells without brush border and it is continued as hairpin bend of the loop.

II. HAIRPIN BEND

- Hairpin bend formed by flattened epithelial cells without brush border and it is continued as the ascending limb of loop of Henle.



III. ASCENDING LIMB

- Ascending limb or segment of Henle loop has two parts:

A. THIN ASCENDING SEGMENT

- Thin ascending segment is the continuation of hairpin bend.
- It is also lined by flattened epithelial cells without brush border.
- Total length of thin descending segment, hairpin bend and thin ascending segment of Henle loop is 10 mm to 15 mm and the diameter is 15 μ.
- Thin ascending segment is continued as thick ascending segment.

B. THICK ASCENDING SEGMENT.

- Thick ascending segment is about 9 mm long with a diameter of 30 μ.
- It is lined by cuboidal epithelial cells without brush border and continues as distal convoluted tubule.

LENGTH AND EXTENT OF LOOP OF HENLE

- Length and the extent of the loop of Henle vary in different nephrons:

i. In cortical nephrons, it is short and the hairpin bend penetrates only up to outer medulla.

ii. In juxtamedullary nephrons, this is long and the hairpin bend extends deep into the inner medulla.

DISTAL CONVOLUTED TUBULE

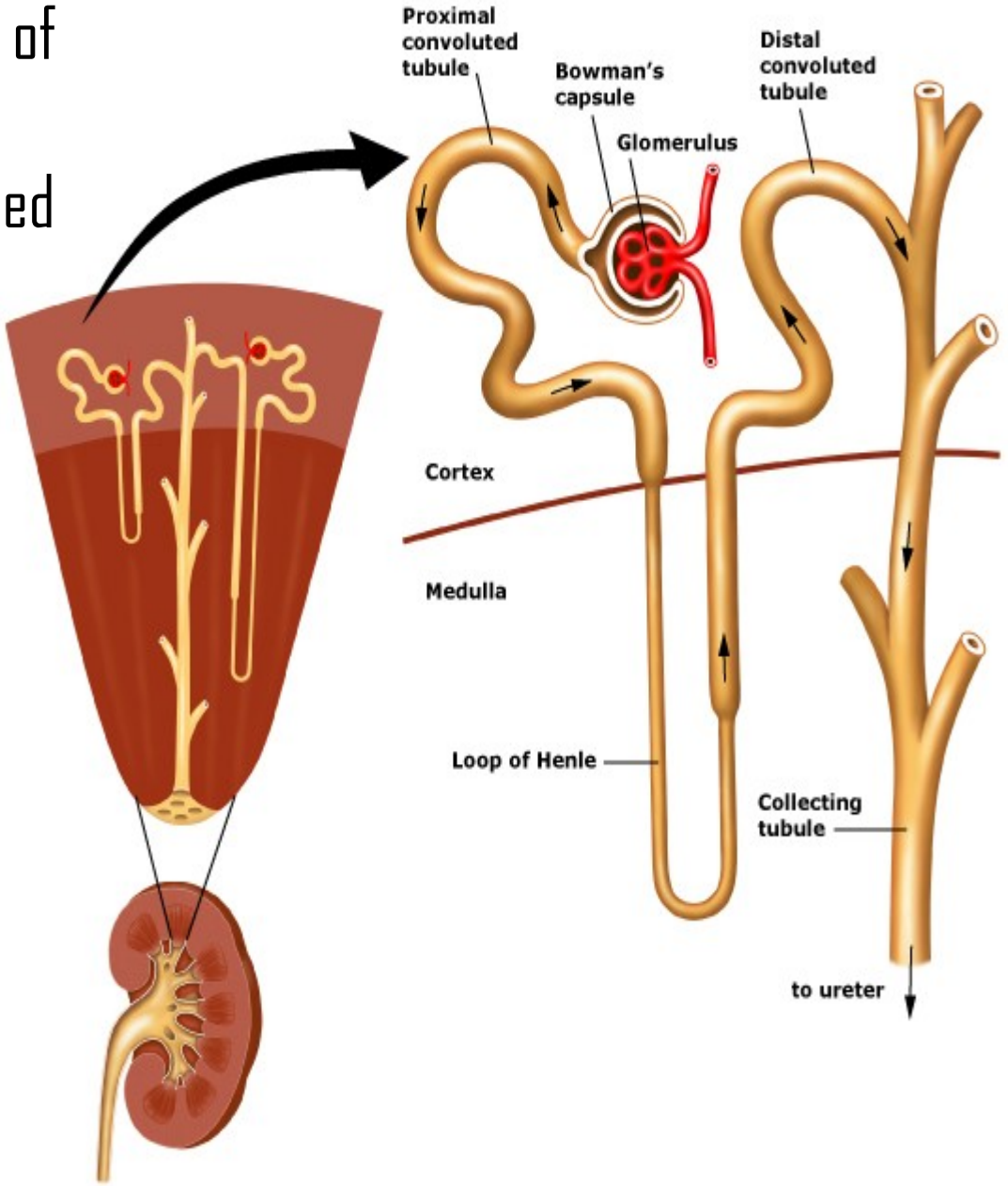
- Distal convoluted tubule is the continuation of thick ascending segment and occupies the cortex of kidney.
- It is continued as collecting duct.
- The length of the distal convoluted tubule is 14.5 to 15 mm. It has a diameter of 22 to 50 μ.

FUNCTIONAL HISTOLOGY

- Distal convoluted tubule is lined by single layer of cuboidal epithelial cells without brush border.
- Epithelial cells in distal convoluted tubule are called intercalated cells (I cells).

COLLECTING DUCT

- Distal convoluted tubule continues as the initial or arched collecting duct, which is in cortex.
- The lower part of the collecting duct lies in medulla.
- Seven to ten initial collecting ducts unite to form the straight collecting duct, which passes through medulla.



- Length of the collecting duct is 20 to 22 mm and its diameter varies between 40 and 200 μ.
- Collecting duct is formed by cuboidal or columnar epithelial cells.

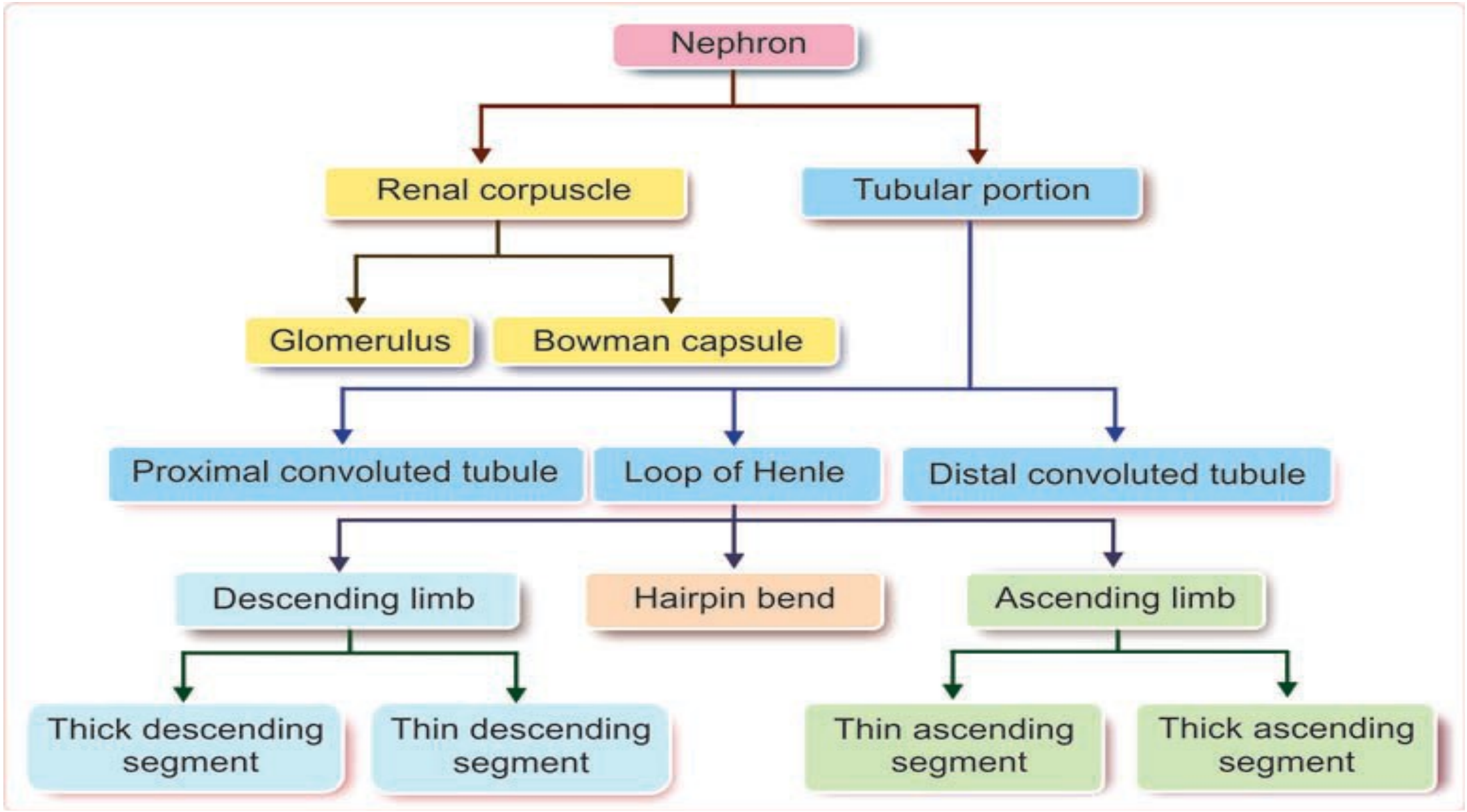
FUNCTIONAL HISTOLOGY

- Collecting duct is formed by two types of epithelial cells:

1. Principal or **P cells**
2. Intercalated or **I cells.**

These two types of cells have some functional significance.

FIGURE : PARTS OF NEPHRON



PASSAGE OF URINE

- At the inner zone of medulla, the straight collecting ducts from each medullary pyramid unite to form **papillary ducts** or **ducts of Bellini,** which open into a 'V' shaped area called **papilla.**
- Urine from each medullary pyramid is collected in the papilla.
- From here it is drained into a **minor calyx.**
- Three or four minor calyces unite to form one **major calyx.**
- From minor calyces urine passes through major calyces, which open into the **pelvis** of the **ureter.**
- Pelvis is the expanded portion of ureter present in the renal sinus.
- From renal pelvis, urine passes through remaining portion of ureter and reaches urinary bladder.

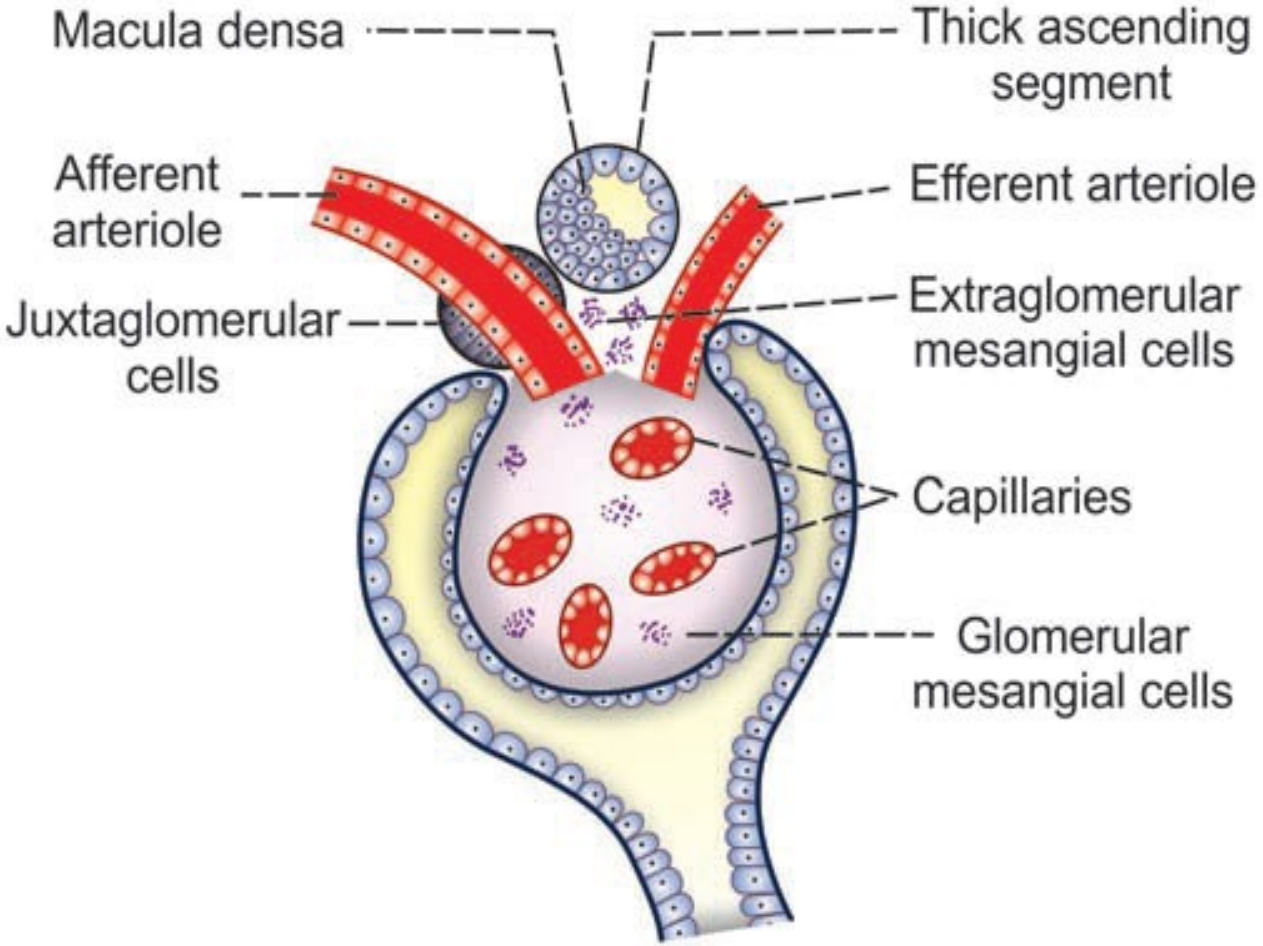
JUXTAGLOMERULAR APPARATUS

- Juxtaglomerular apparatus is a specialized organ situated near the glomerulus of each nephron (juxta = near).

STRUCTURE OF JUXTAGLOMERULAR APPARATUS

- Juxtaglomerular apparatus is formed by three different structures:

1. Macula densa
2. Extraglomerular mesangial cells
3. Juxtaglomerular cells.



1. MACULA DENSA

- Macula densa is the end portion of thick ascending segment before it opens into distal convoluted tubule.
- It is situated between afferent and efferent arterioles of the same nephron.

2. EXTRAGLOMERULAR MESANGIAL CELLS

- Extra glomerular mesangial cells are situated in the triangular region bound by afferent arteriole, efferent arteriole and macula densa.
- These cells are also called **agranular cells, lacis cells** or **Goormaghtigh cells.**

3. JUXTAGLOMERULAR CELLS

- Juxtaglomerular cells are specialized smooth muscle cells situated in the wall of afferent arteriole just before it enters the Bowman capsule.
- Juxtaglomerular cells are also called **granular cells** because of the presence of secretary granules in their cytoplasm.

FUNCTIONS OF JUXTAGLOMERULAR APPARATUS

- Primary function of juxtaglomerular apparatus is the secretion of hormones.
- It also regulates the glomerular blood flow and glomerular filtration rate.

I. SECRETION OF HORMONES

- Juxtaglomerular apparatus secretes two hormones:

1. RENIN

- Along with angiotensins, renin forms the renin-angiotensin system, which is a hormone system that plays an important role in the maintenance of blood pressure.

2. PROSTAGLANDIN

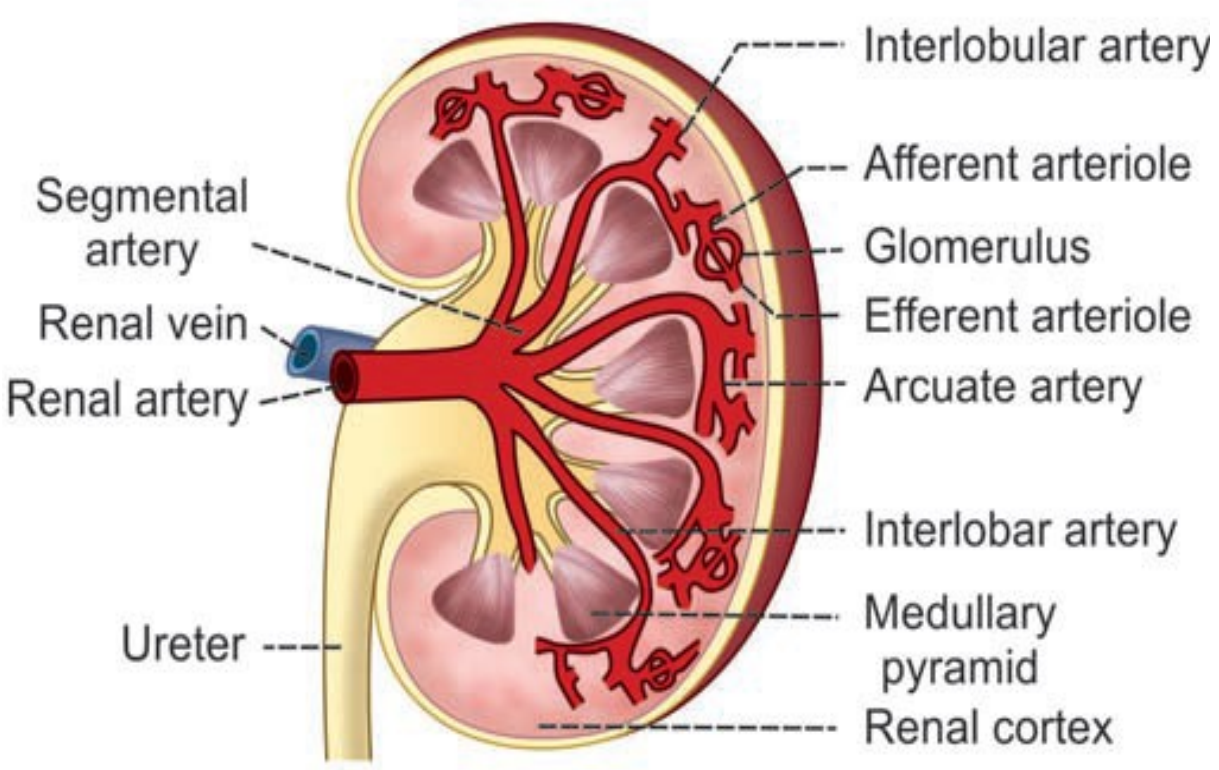
- Extraglomerular mesangial cells of juxtaglomerular apparatus secrete prostaglandin. Prostaglandin is also secreted by interstitial cells.

II. REGULATION OF GLOMERULAR BLOOD FLOW AND GLOMERULAR FILTRATION RATE

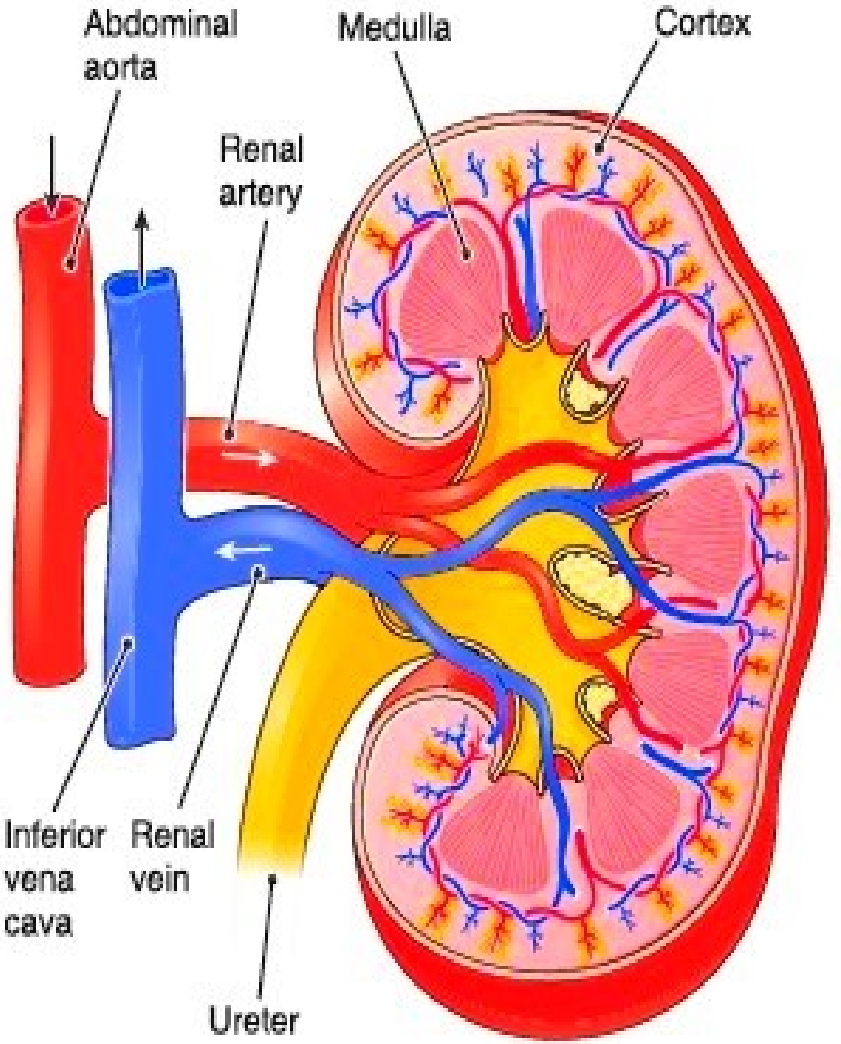
- Macula densa of juxtaglomerular apparatus plays an important role in the feedback mechanism called **tubuloglomerular feedback** mechanism.
- Which regulates the renal blood flow and glomerular filtration rate.

RENAL CIRCULATION

- Blood vessels of kidneys are highly specialized to facilitate the functions of nephrons in the formation of urine.
- In the adults, during resting conditions both the kidneys receive 1,300 mL of blood per minute.



Aorta → Renal artery → Segmental artery → Interlobar artery → Arcuate artery → Cortical radiate artery → Afferent arteriole → Glomerulus (capillaries) → Efferent arteriole → Peritubular capillaries → Cortical radiate vein → Arcuate vein → Interlobar vein → Renal vein → Inferior vena cava



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