

**The University Of Jordan  
Faculty Of Medicine**



# **Histology Of The Urinary system**

**By**

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## Learning Objectives

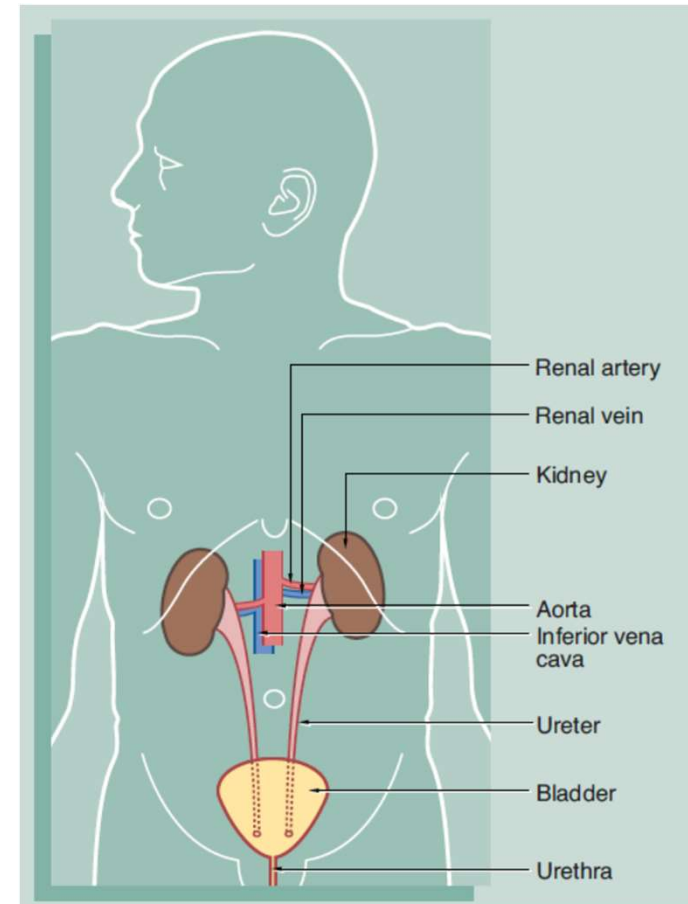
By the end of the topic the learner should be able to:

- Describe the histological structure of the kidney.
- Illustrate the ultrastructure of the blood renal barrier.
- Know the histological structure of the urinary passages.

# Urinary system

## Parts

- Paired kidneys
- Paired ureters
- Bladder
- Urethra



(Wheater's Functional Histology, A Text and Color Atlas, 6<sup>th</sup> Ed.)

## Functions of the Kidney

1. Controlling the water and electrolytes balance
2. Regulating the extracellular fluid volume
3. Eliminating waste products, toxins and drugs; most importantly Urea
4. Controlling the acid-base balance of blood
5. Has a hormonal and metabolic function
  - Secretion of **Renin** by juxtaglomerular cells which regulate blood pressure
  - Secretion of **Erythropoietin** that stimulates the production of erythrocytes in the bone marrow and thus regulates the oxygen-carrying capacity of the blood
  - Conversion of prohormone **Vitamin D**, to the active form which regulates calcium balance.

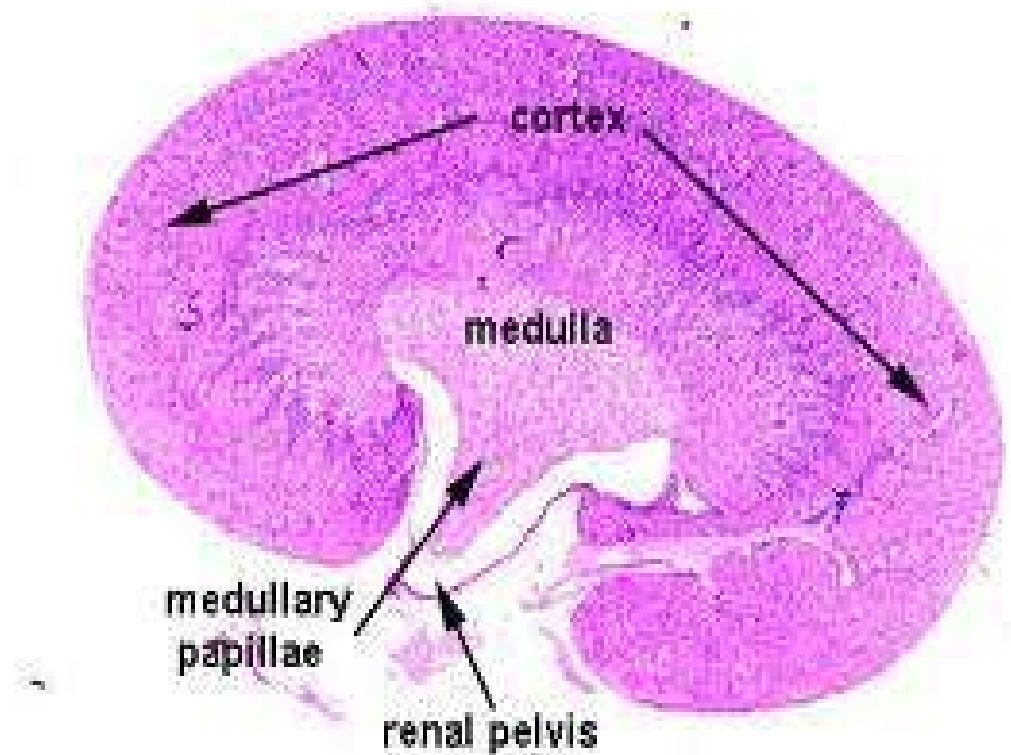
# Kidney structure

## Stroma

- Capsule
- Trabeculae
- Reticular stroma

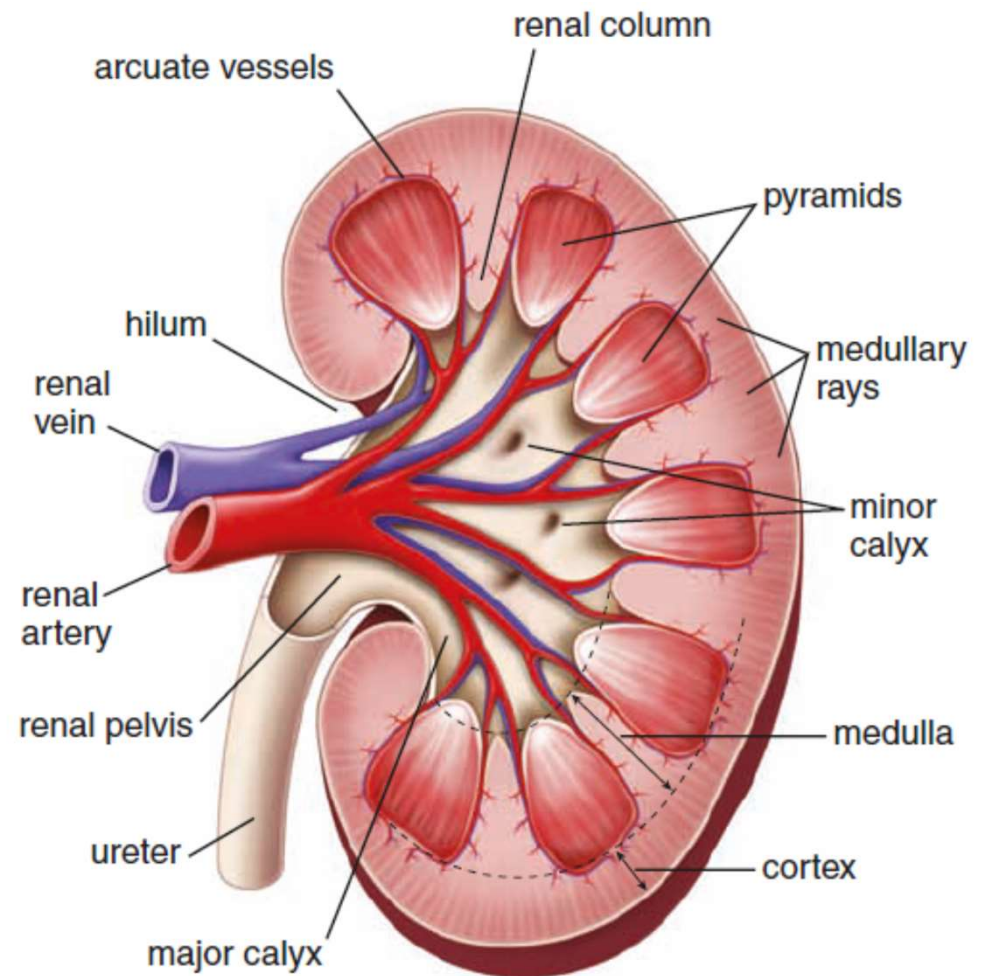
## Parenchyma

- Uriniferous tubules



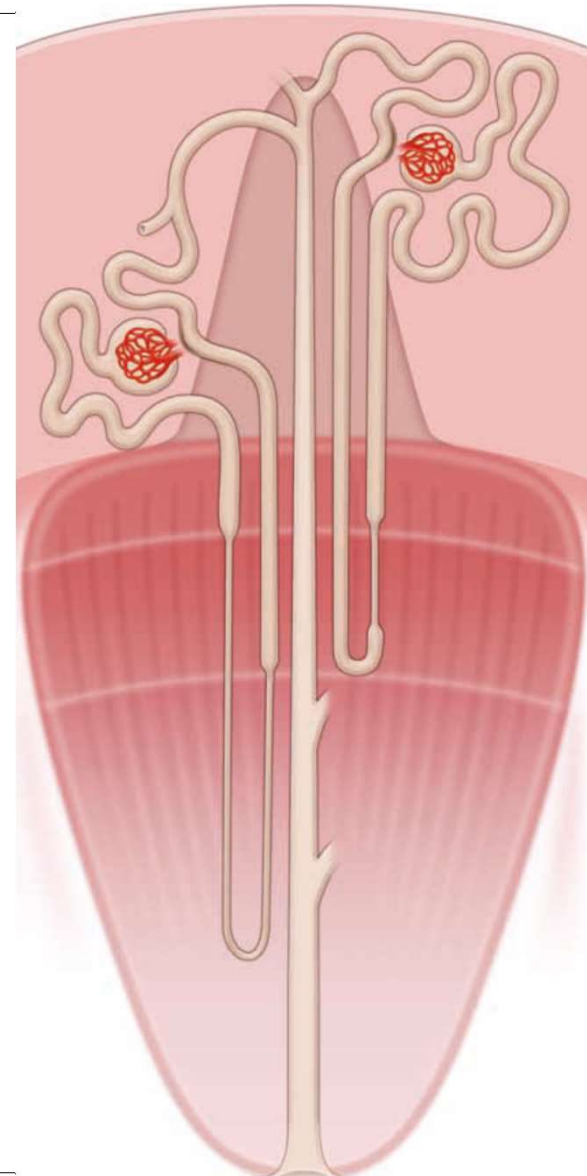
## Kidney – General structure

- Divided into cortex and medulla
- The cortex forms an outer shell and also forms columns that lie between the individual units of the medulla
- The medulla is composed of medullary pyramids the base of each cone is continuous with the inner limit of the cortex and the apex of the pyramid protrudes into the calyceal system that is known as the ‘papilla’



## Kidney – lobes and lobules

- Lobe :medullary pyramid and the associated cortical tissue at its base and sides
- Lobule: a central medullary ray and the surrounding cortical tissue.
- The medullary ray contains the collecting ducts for a group of nephrons that drain into it
- **Therefore, the lobule consists of a collecting duct and all the nephrons that it drains constituting the renal secretory unit**



**Uriniferous tubule**

**Nephron**

**Collecting Ducts**

**Renal corpuscle**

**Proximal convoluted Tubules (PCT)**

**Loop of Henle**

**Distal convoluted Tubules (DCT)**

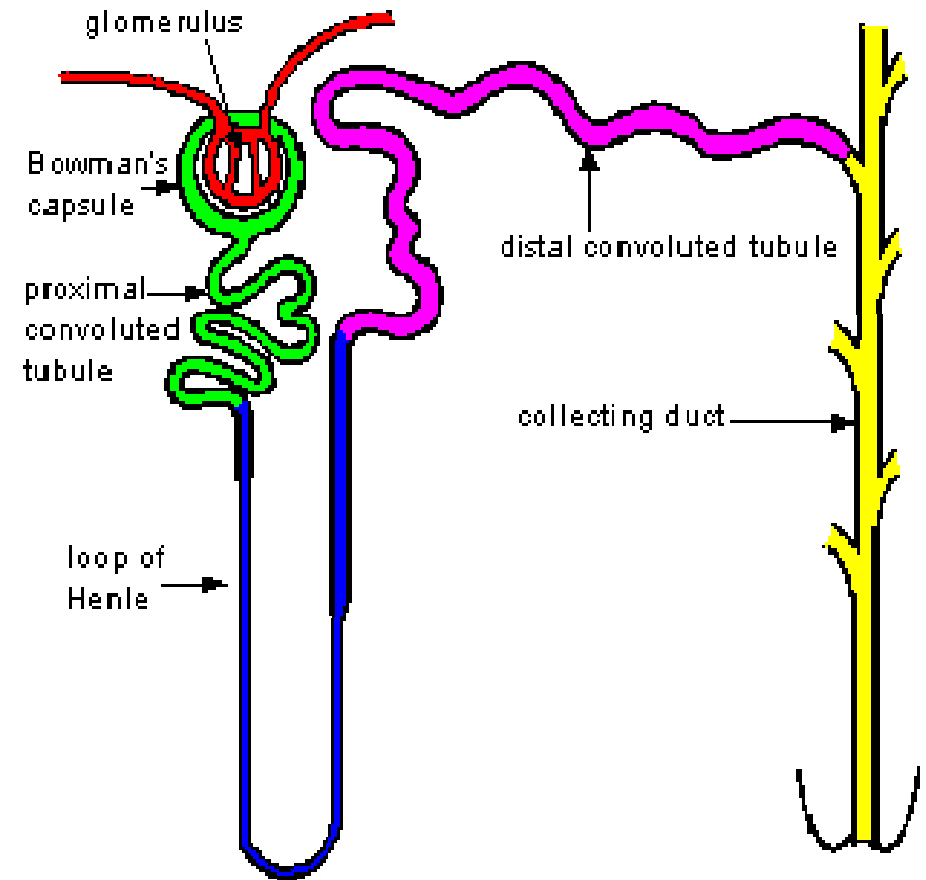
**Glomerulus**

**Bowman's capsule**



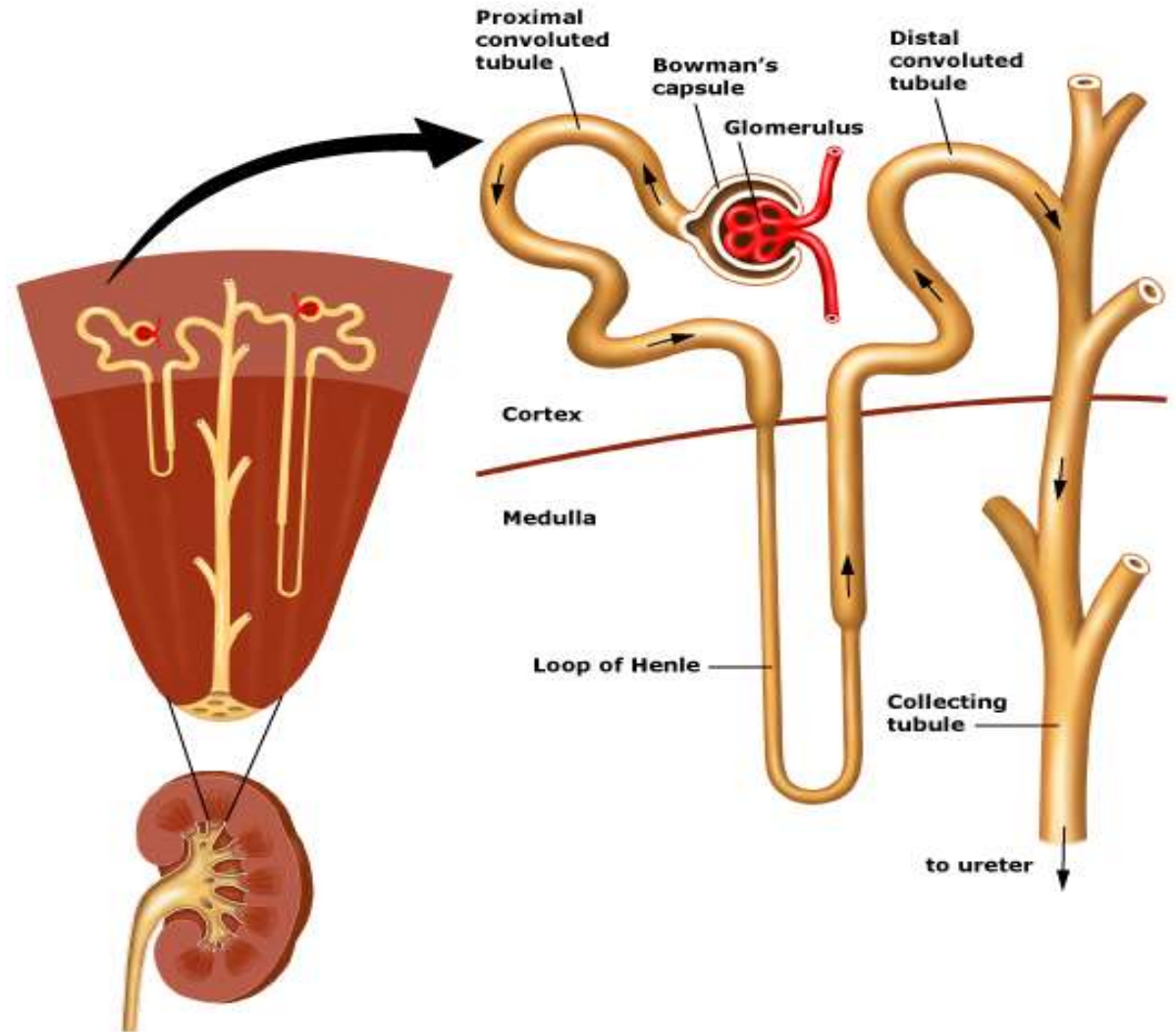
## Uriferous tubule

- Functional unit of the kidney
- Highly convoluted
- Densely packed
- Consists of nephron and collecting ducts
- 1.3 million nephrons in each kidney
- Several nephrons are drained by a single collecting duct



# Nephron

- Consists of:
  - Renal corpuscle
  - Proximal convoluted Tubules (PCT)
  - Distal convoluted Tubules (DCT)
  - Loop of Henle



# Nephron

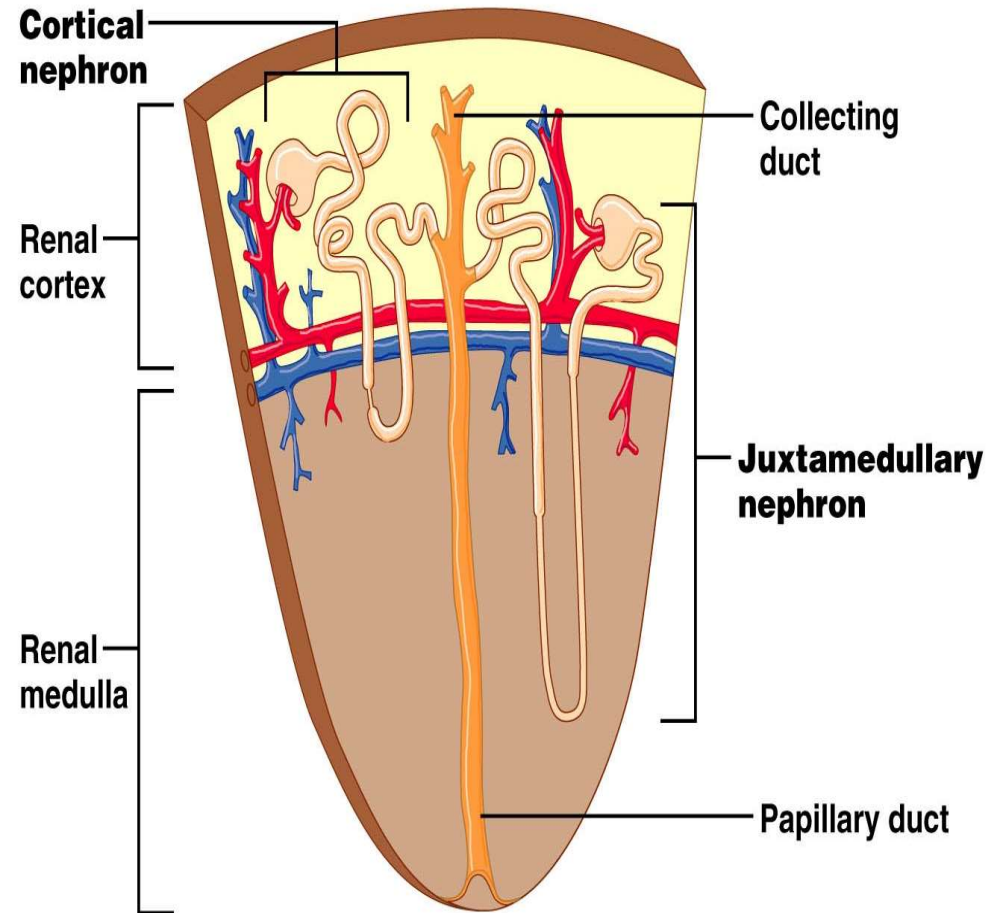
Two types:

## A. Cortical nephrons

- Most numerous
- Present in superficial part of cortex
- Loop of Henle are short

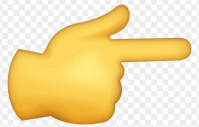
## B. Juxtamedullary nephrons.

- Near the junction of cortex & medulla
- Loop of Henle are Long





The number of nephrons decreases slightly in older adults, a process accelerated by high blood pressure.



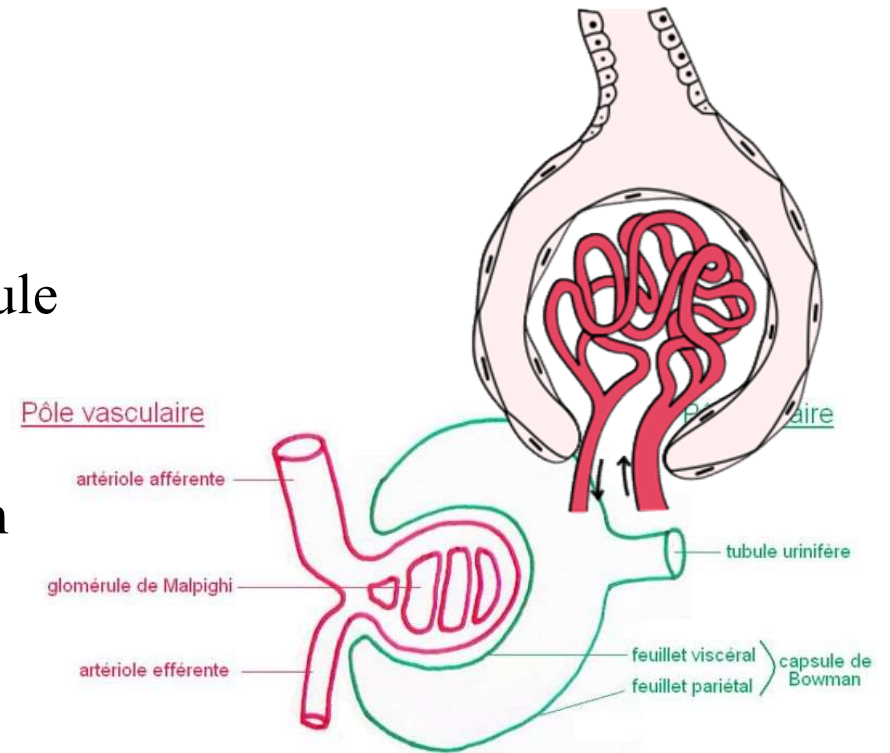
In case of (unilateral nephrectomy), as in kidney donation for transplant the remaining kidney undergoes compensatory growth with cellular hypertrophy in the proximal parts of the nephron tubules and an increase in the rate of filtration, which allow normal renal function to continue

# Renal Corpuscle

- Oval to round structure
- Found in renal cortex.
- Composed of glomerulus & Bowman's capsule

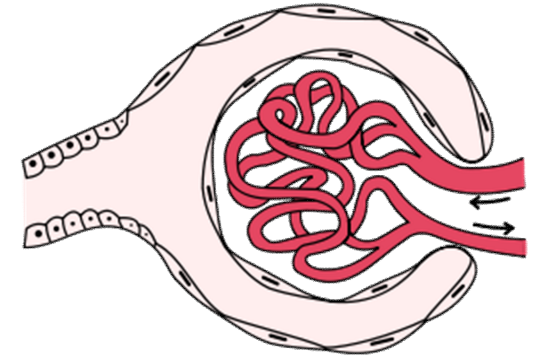
## Function

- Forms the glomerular filtrate by dialysis of the plasma (plasma minus its proteins) through filtration barrier

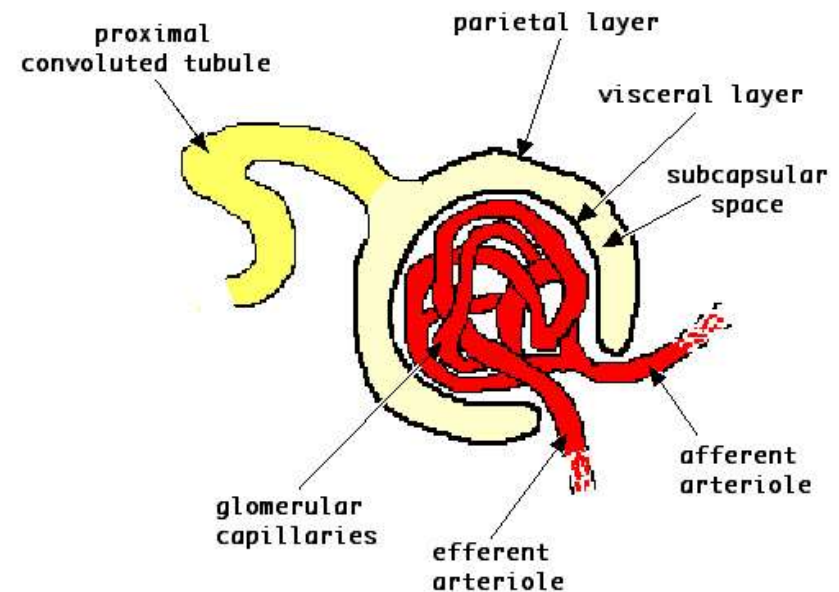


## Bowman's capsule

- Originally was a hollow epithelial sphere (blind end of nephron)
- Has two poles:
  - Urinary pole which is continuous with the PCT.
  - Vascular pole which where the afferent arteriole enters and the efferent arteriole leaves



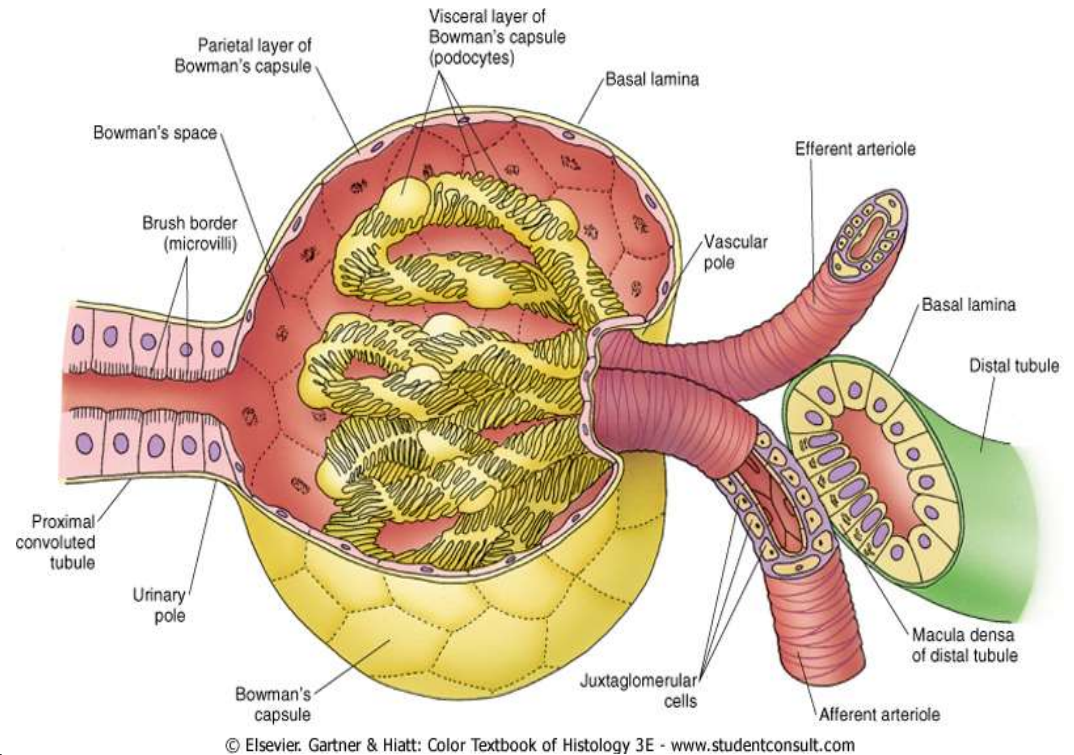
**Bowman's capsule**



# Bowman's capsule

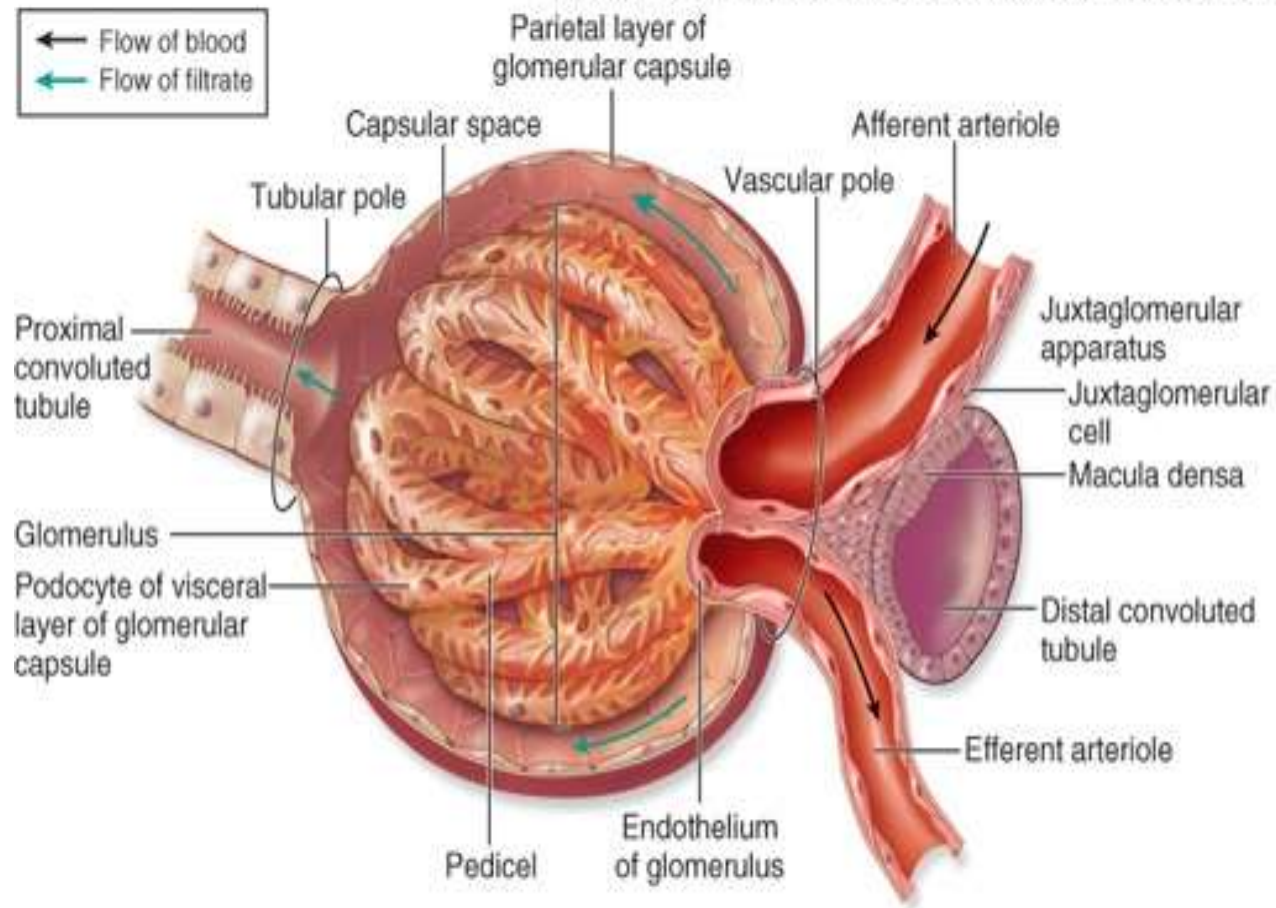
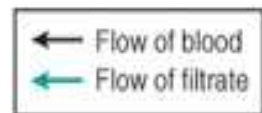
It has two layers:

- Outer (parietal) layer
    - Called capsular epithelium
    - Lined by simple squamous epithelium
  - Inner (visceral) layer
    - Called glomerular epithelium
    - Lined by modified epithelium (podocytes)
- Between the two layers is the urinary space which receives the fluid filtered through the capillary wall and visceral layer

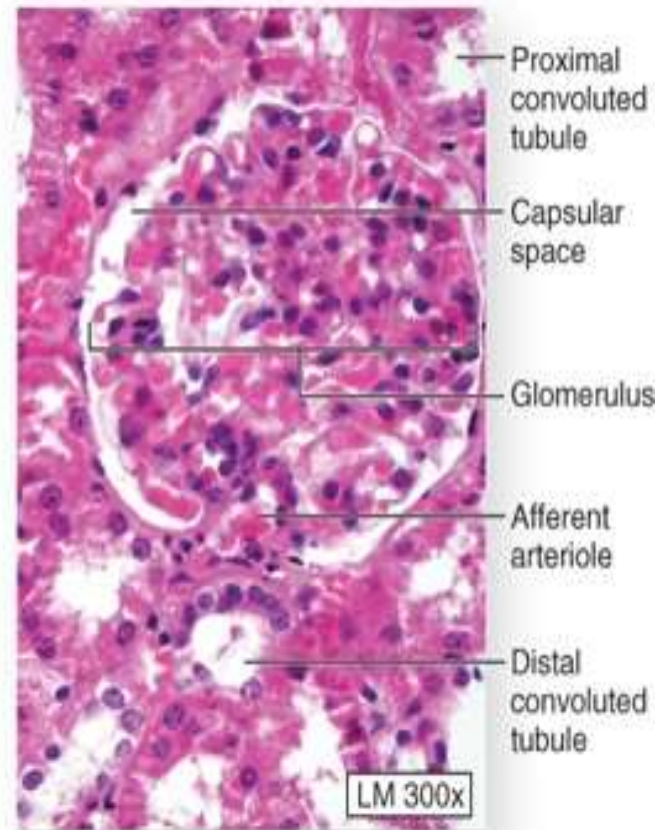




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(a) Renal corpuscle

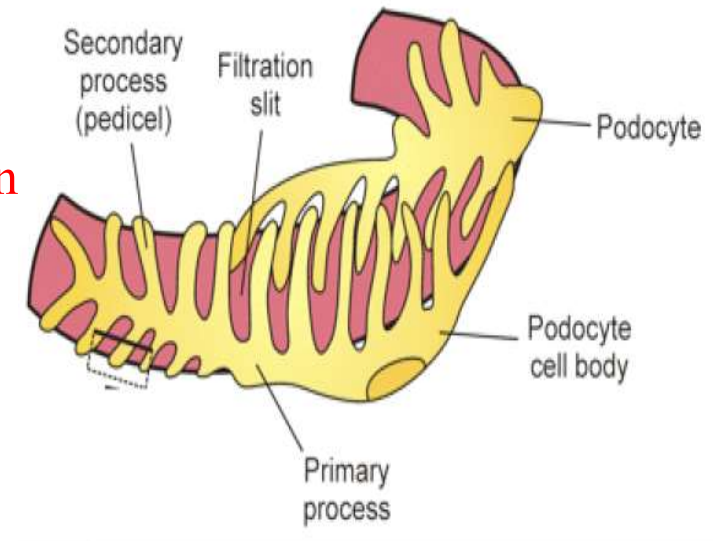
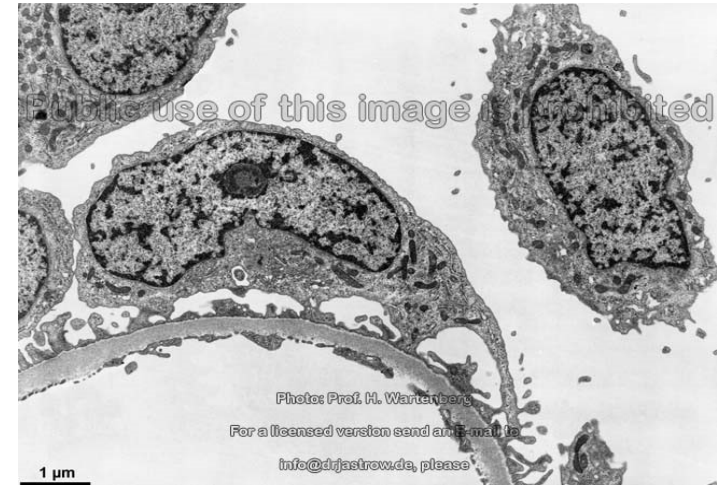


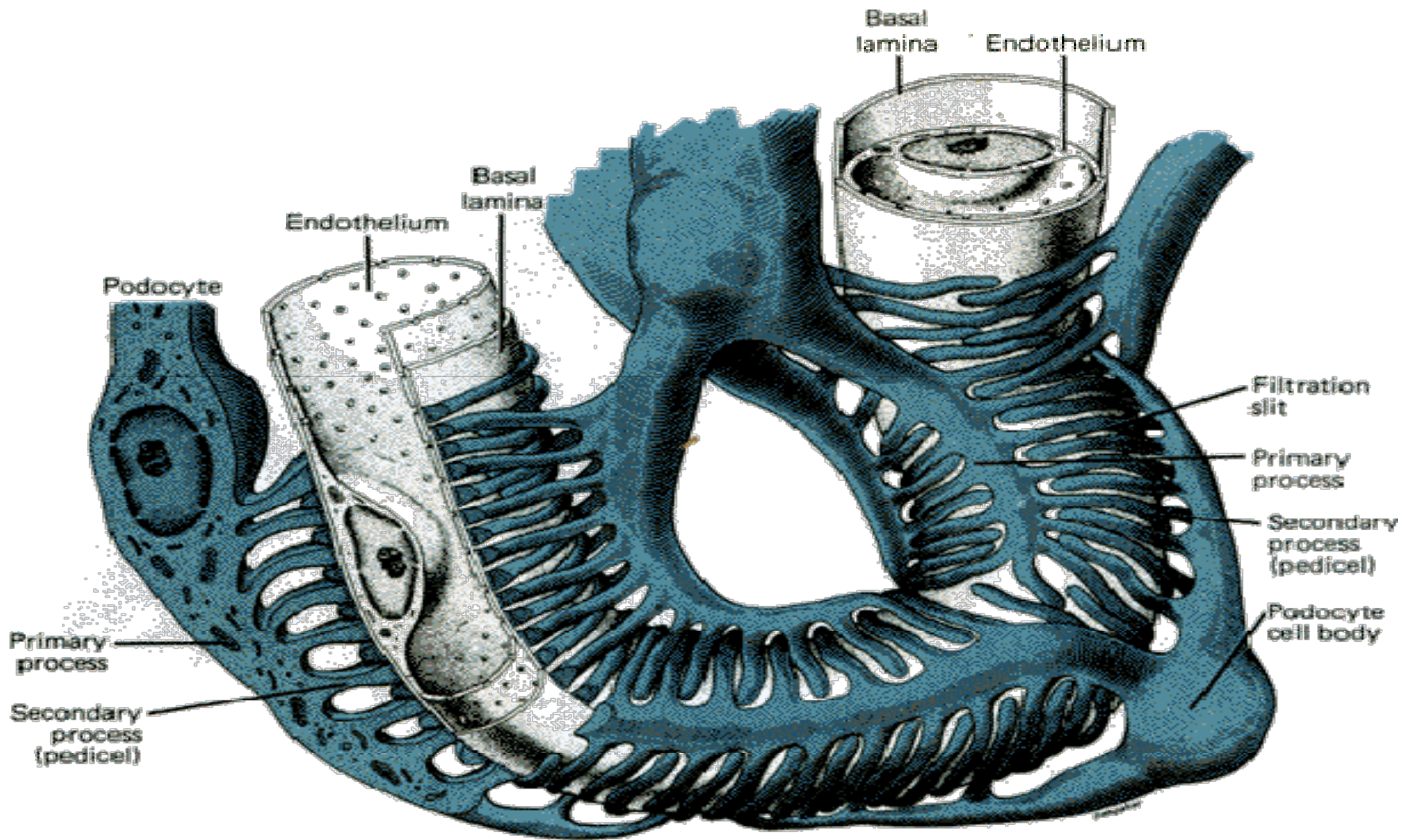
(b)



# Podocytes

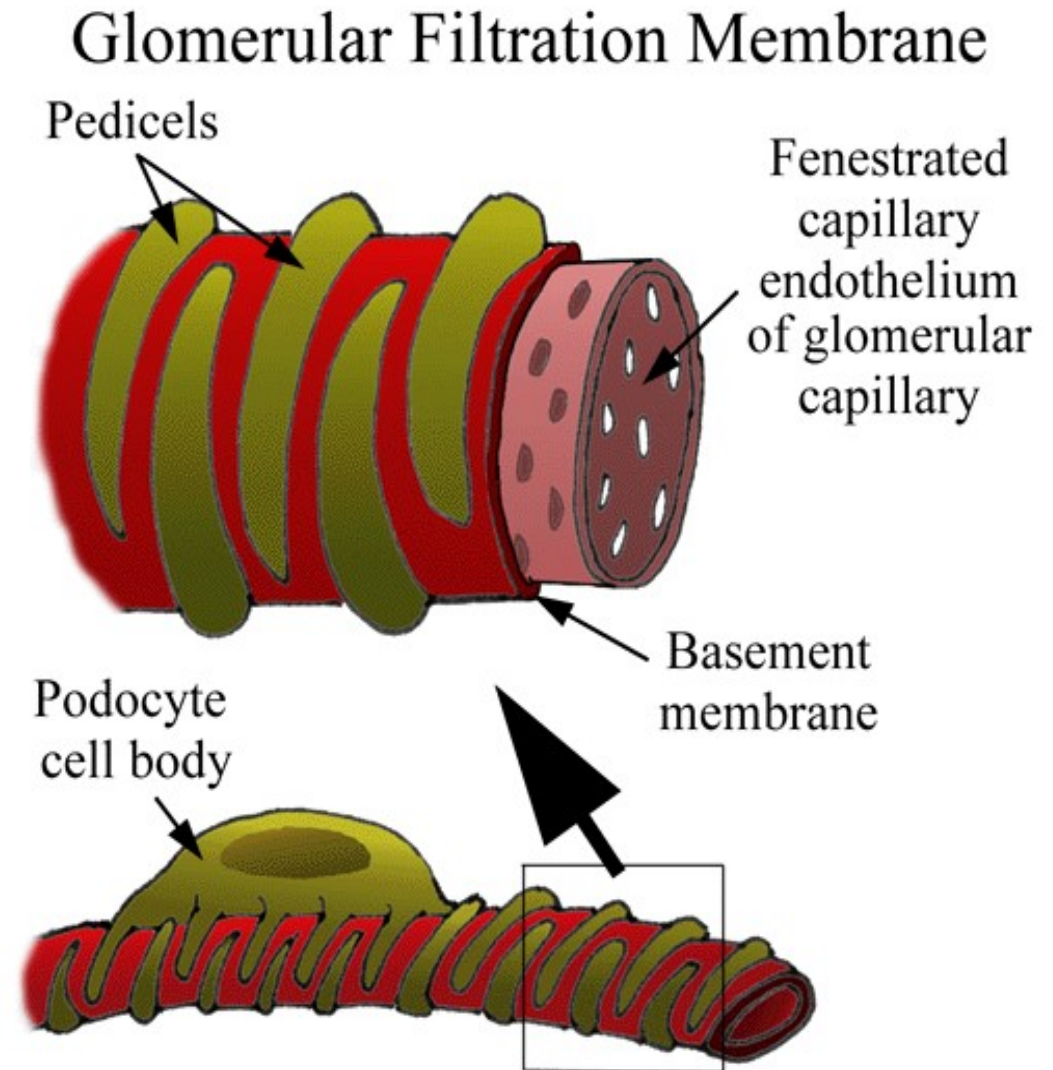
- Modified flat cells (stellate in shape)
- Have numerous long **primary** cytoplasmic (major) processes resemble feet
- Each primary process bears many **secondary** processes, known as **pedicels** which:
  - Completely envelop the glomerular capillaries
  - Terminate around BM of glomerular capillaries
- The spaces between the minor processes are called **filtration slits** which are closed by **slit diaphragm**





## Function of Podocytes

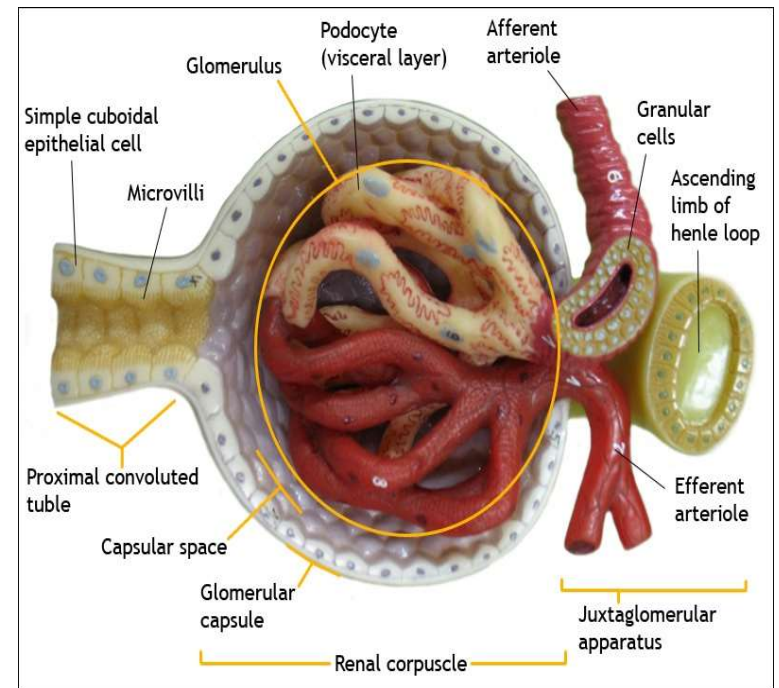
- Play an important role in filtration
- Concerned with the renewal of glomerular capillaries BM





# Glomerulus

- Tuft of about 50 tortuous capillary loops
- Arising from afferent arteriole, enter the corpuscle then recollect into efferent arteriole which leave the corpuscle
- Capillaries lined by fenestrated endothelial cells
- Resting on thick continuous BM



# Mesangial cells

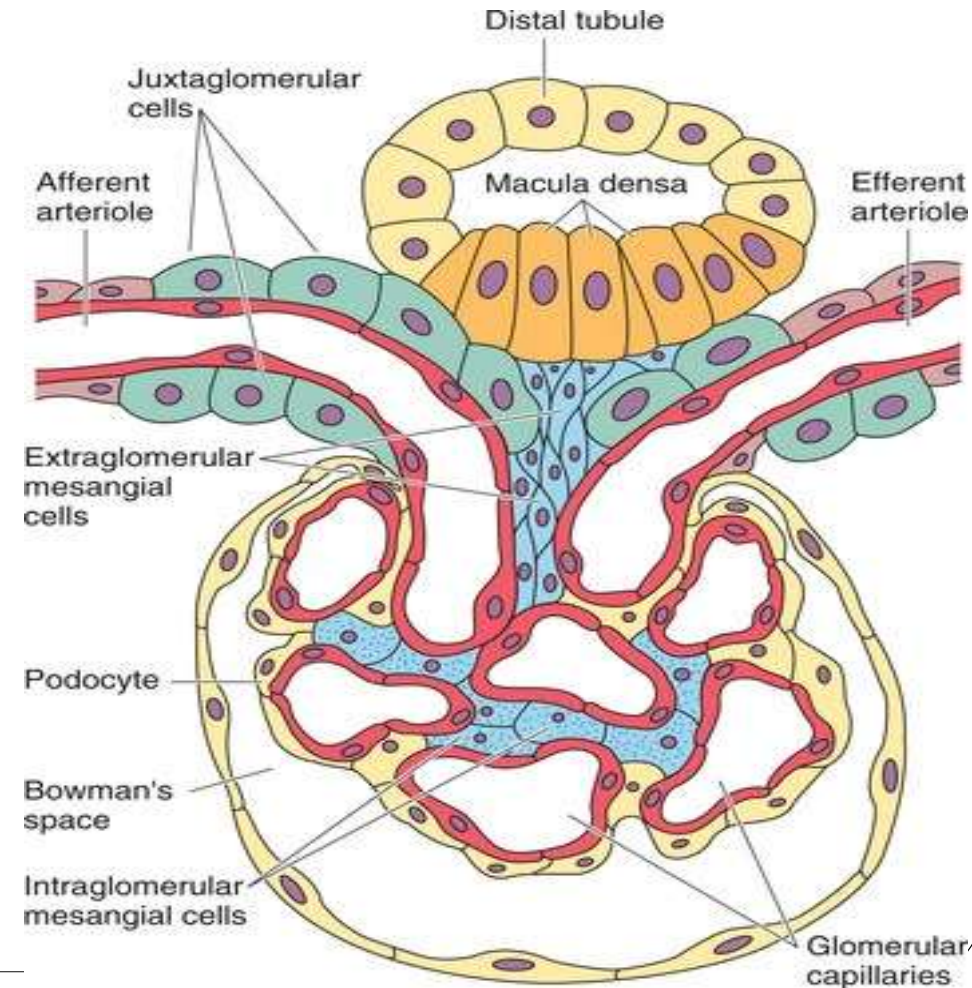
(Gr. *mesos*, in the midst + *angion*, vessel)

## Location

- within stalk of capillary tuft (**intraglomerular mesangium**) as well as the vascular pole (**extraglomerular mesangium**)

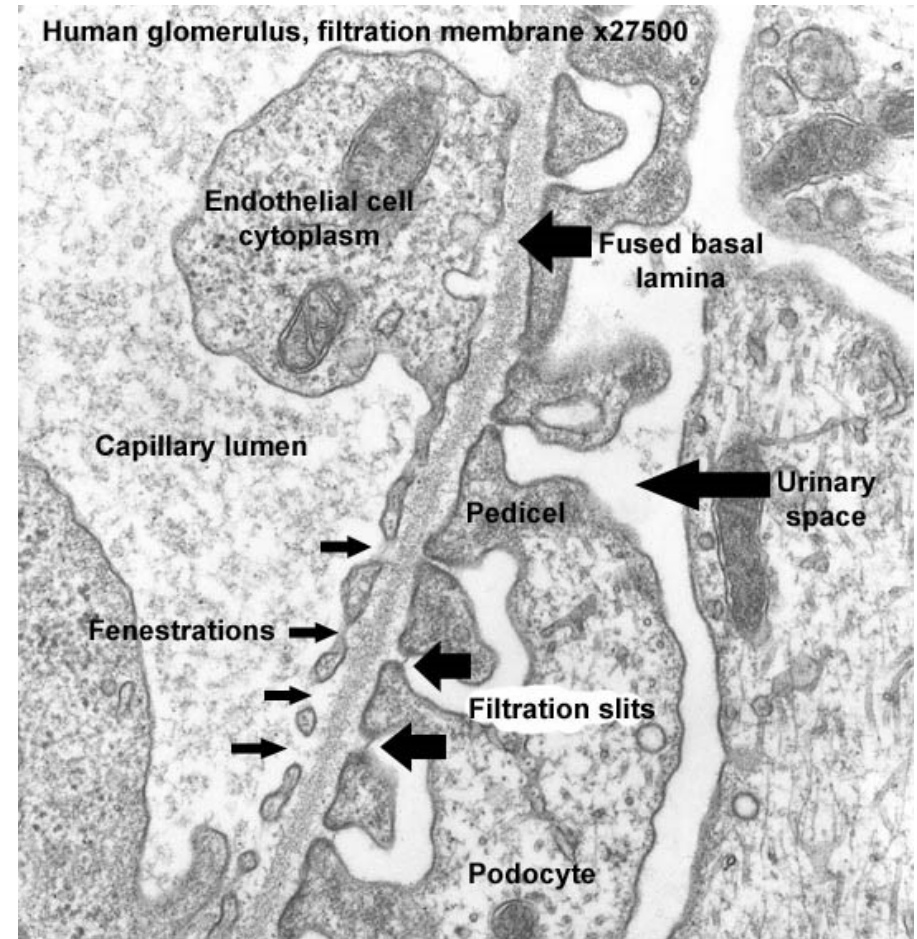
## Function :

- Participate in maintenance of basement membrane through phagocytosis and structural support
- Physical support of capillaries within the glomerulus
- Has a role immune defence and repair in the glomerulus
- Adjusted contractions in response to blood pressure changes, which help maintain an optimal filtration rate



## Blood renal barrier (filtration barrier)

- It is the barrier that separates the blood (in the glomerular capillaries) from the capsular space of Bowman's capsule
- It consists of:
  - 1-The pores in the capillary endothelium; prevent the passage of RBCs but anything less than RBCs diameter can pass

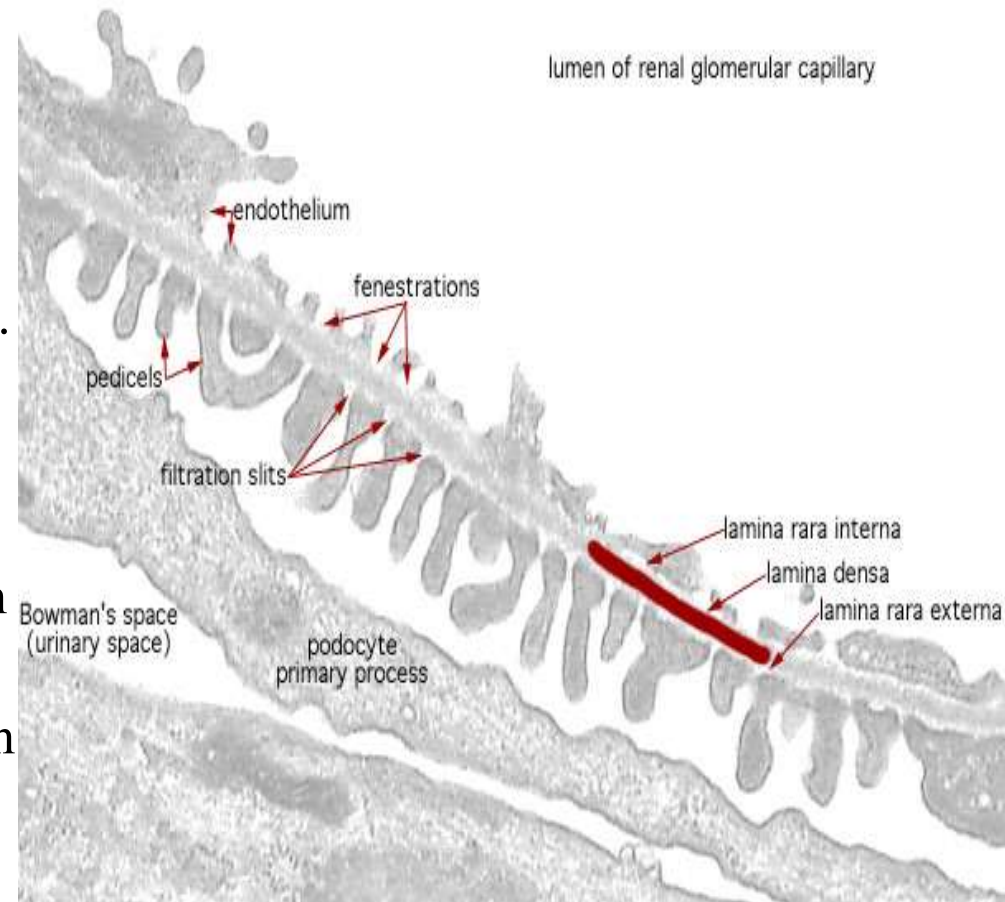


**2-** The continuous BM of glomerular capillaries basal lamina fused with basal lamina of the podocytes

By EM the BM has 3 layers:

- a) Lamina rara externa (adjacent to epithelium).
- b) Lamina rara interna (adjacent to endothelium). Both of them are electron lucent area
- c) The intermediate zone appears more electron dense.

**3-** The filtration slits and their closing diaphragm





## Slit diaphragms

- Are modified occluding or tight junctions composed of **nephrins**, other proteins, glycoproteins, and proteoglycans important for renal function.
- A thick glomerular basement membrane lies between the highly fenestrated endothelial cells of the capillaries and the covering podocytes
- This basement membrane restricts passage of proteins larger than 70 kDa (Kilodalton)
- Smaller proteins that are filtered from plasma are degenerated , and the amino acids reabsorbed

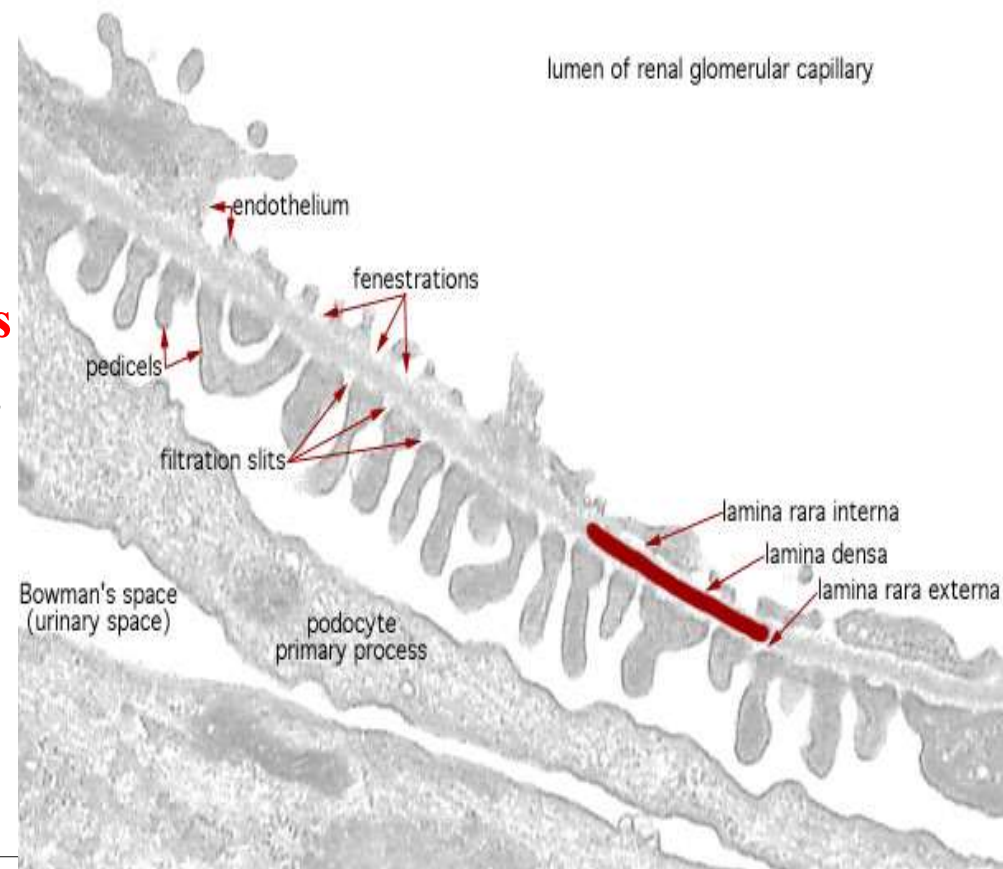


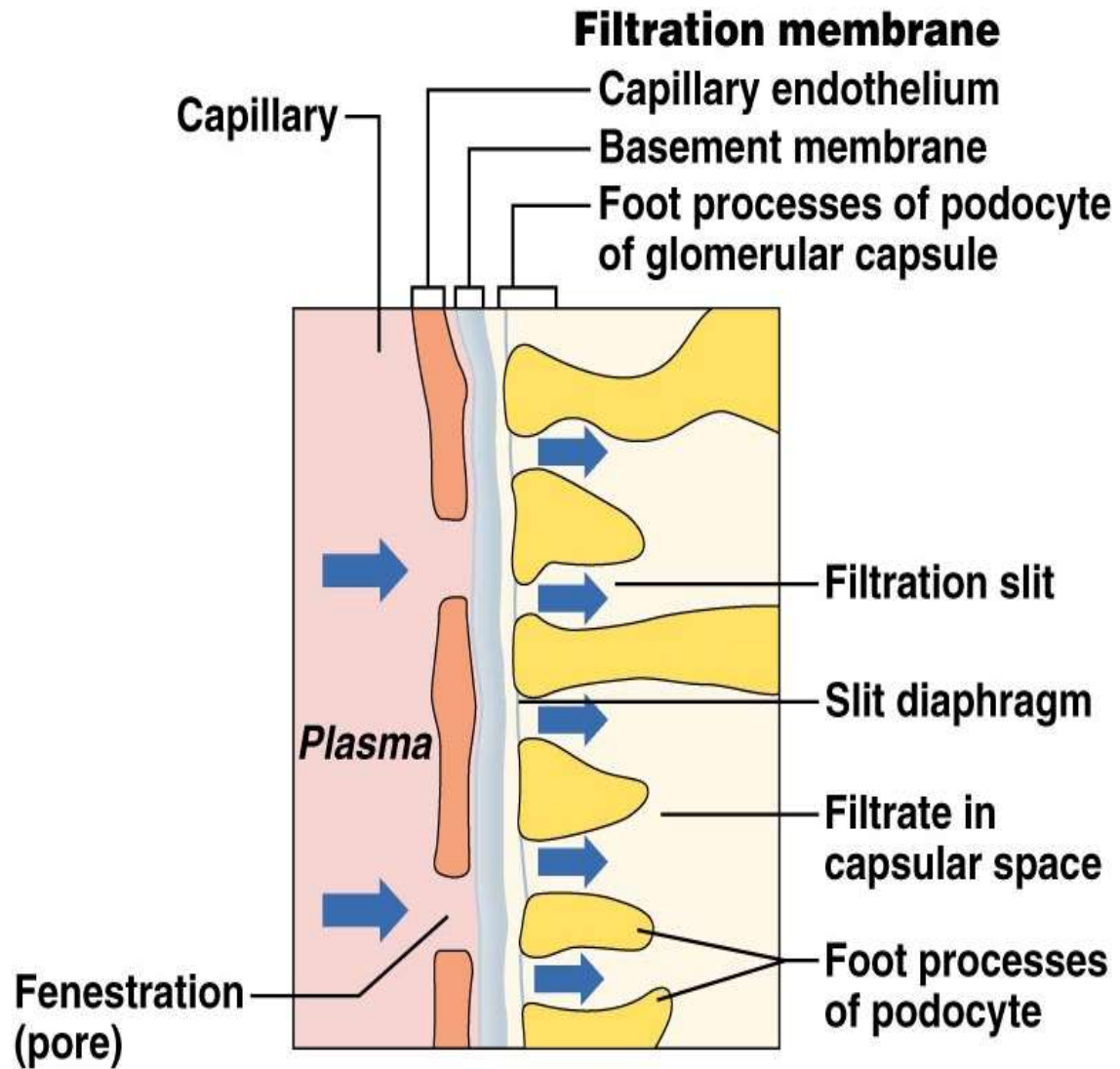
## Function of the filtration barrier:

- Filters blood plasma
- Allows water, ions & small molecules to enter the capsular space
- Prevents large plasma protein molecules from entering the capsular space.

## Diabetes mellitus and glomerulonephritis

👉 The glomerular filter is altered and becomes much more permeable to proteins, so the patient has (**proteinuria**).

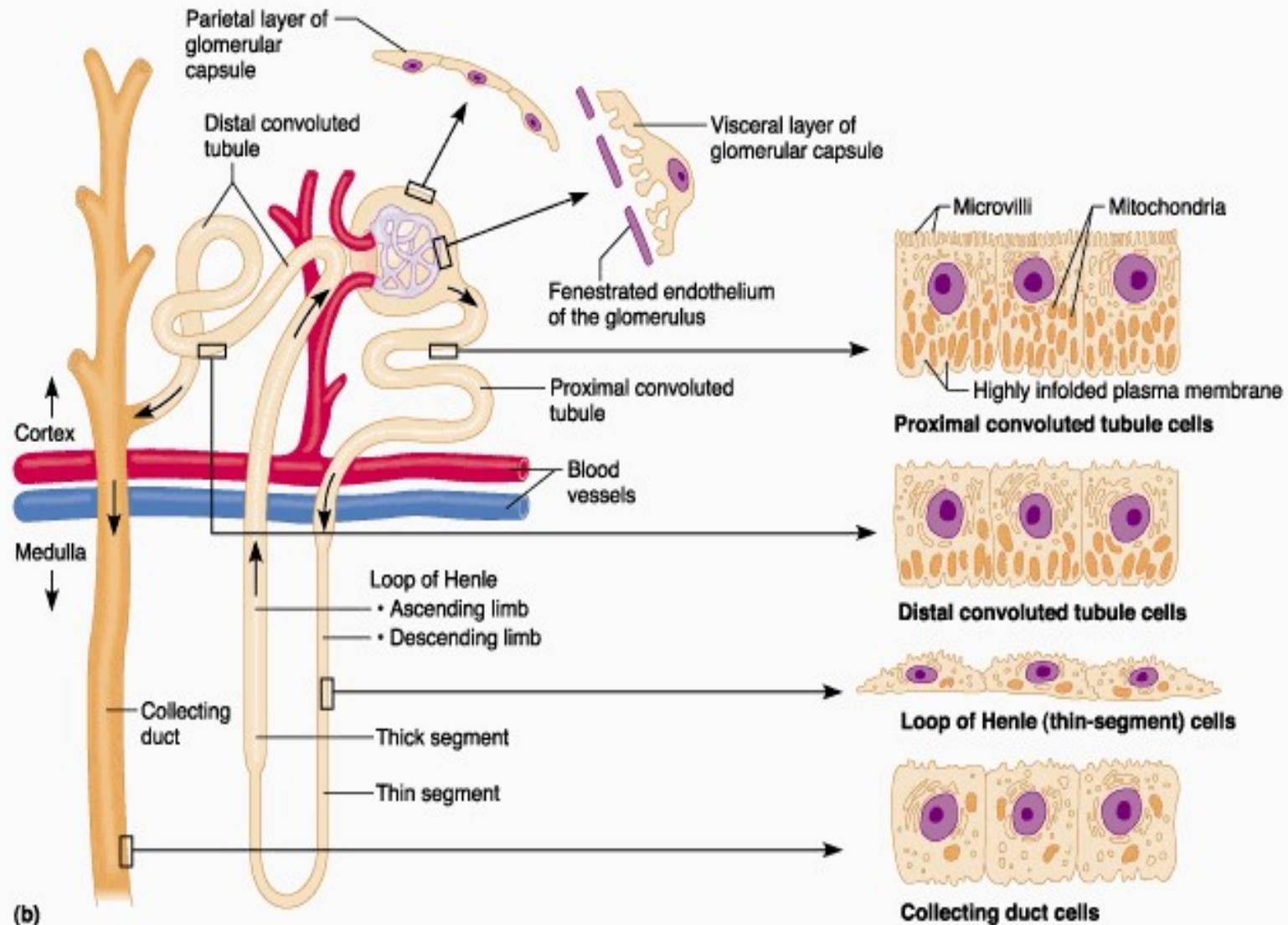


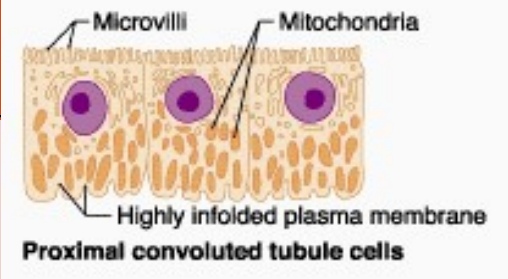
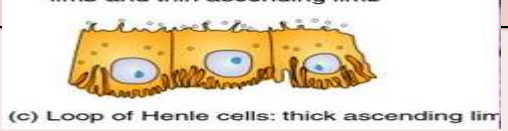


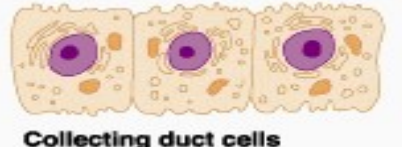
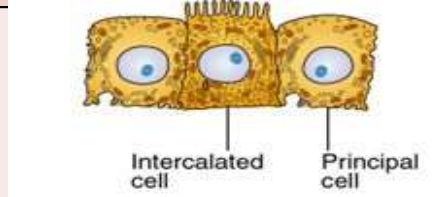


(c)

# Renal tubules

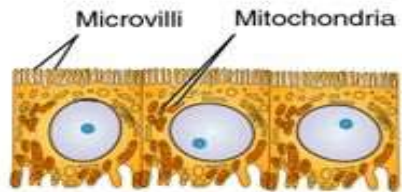
- PCT
- Loop of Henle
- DCT



Region of Tubule	Histological Features	Locations Major	
PCT	Simple cuboidal epithelium; cells well-stained, with numerous mitochondria, prominent basal folds and long microvilli, lumens often occluded	Cortex	 <p>Microvilli Mitochondria Highly infolded plasma membrane Proximal convoluted tubule cells</p>
Loop of Henle Thick limbs	Simple cuboidal epithelium; no microvilli, but many mitochondria	Medullary rays and Medulla	 <p>(c) Loop of Henle cells: thick ascending limb</p>
Loop of Henle Thin limbs	Simple squamous epithelium; few mitochondria	Medulla	 <p>Loop of Henle (thin-segment) cells</p>
DCT	Simple cuboidal epithelium; cells smaller than in PCT, short microvilli and basolateral folds, more empty lumens	Cortex	 <p>Distal convoluted tubule cells</p>
Collecting system <b>Principal cells</b>	Cuboidal to columnar pale-staining, distinct cell membranes	Medullary rays and medulla	 <p>Collecting duct cells</p>
<b>Intercalated cells</b>	Few and scattered; slightly darker staining		 <p>Intercalated cell Principal cell (e) Collecting duct cells</p>



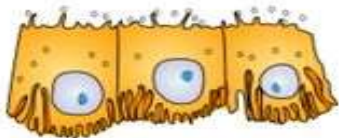
# Histology of Renal Tubule & Collecting Duct



(a) Proximal convoluted tubule cells



(b) Loop of Henle cells: descending limb and thin ascending limb



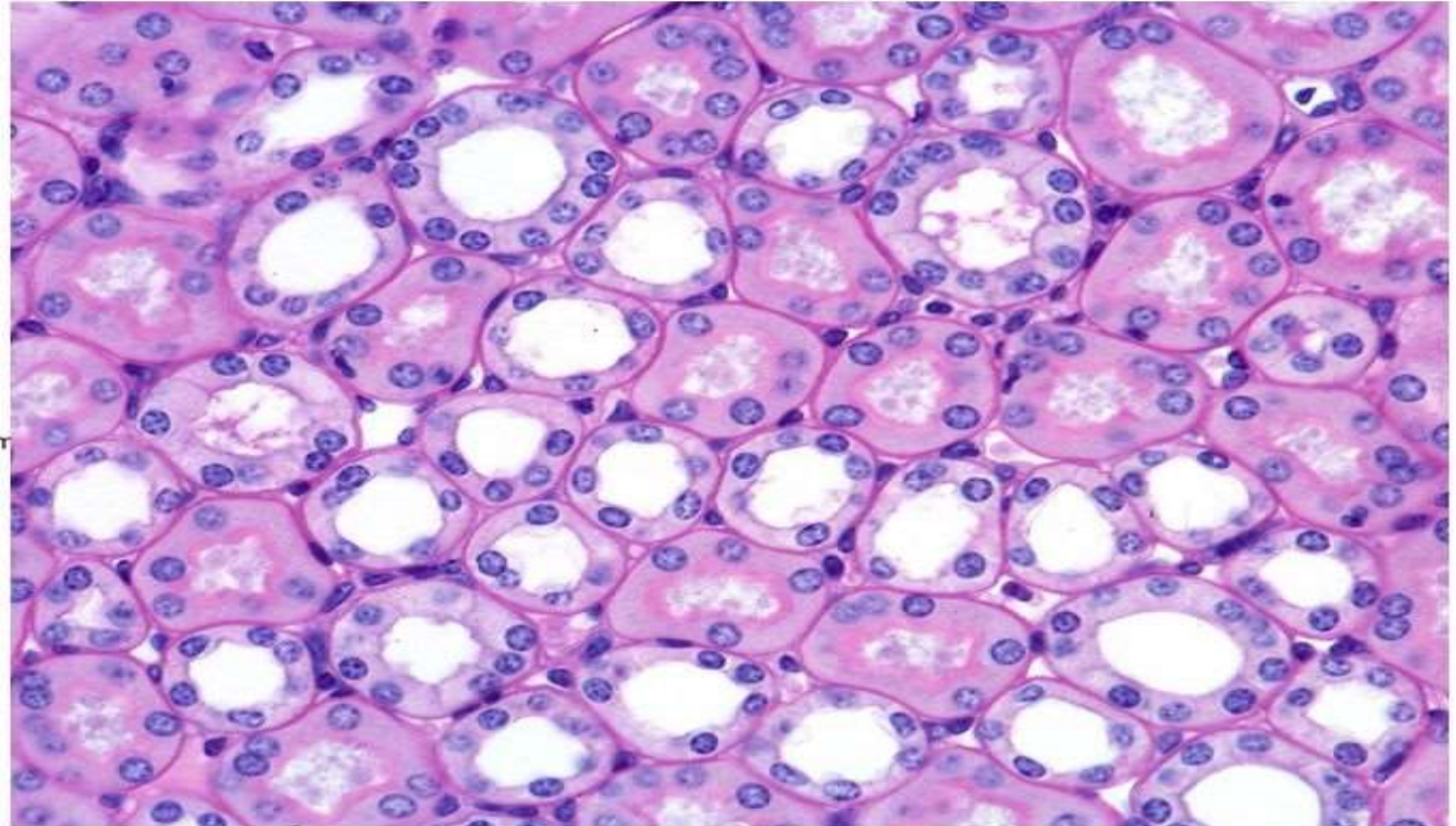
(c) Loop of Henle cells: thick ascending limb



(d) Distal convoluted tubule cells

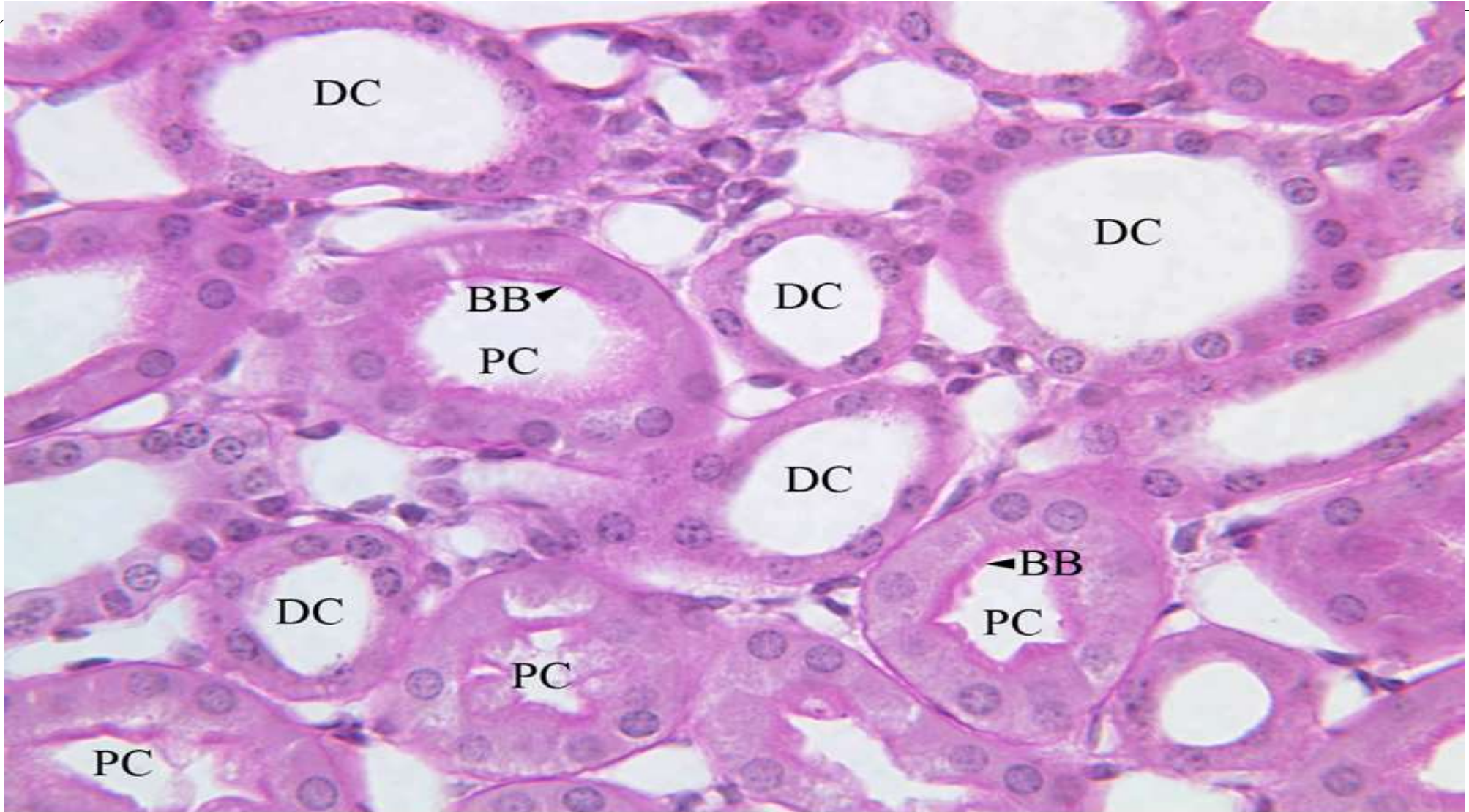


(e) Collecting duct cells

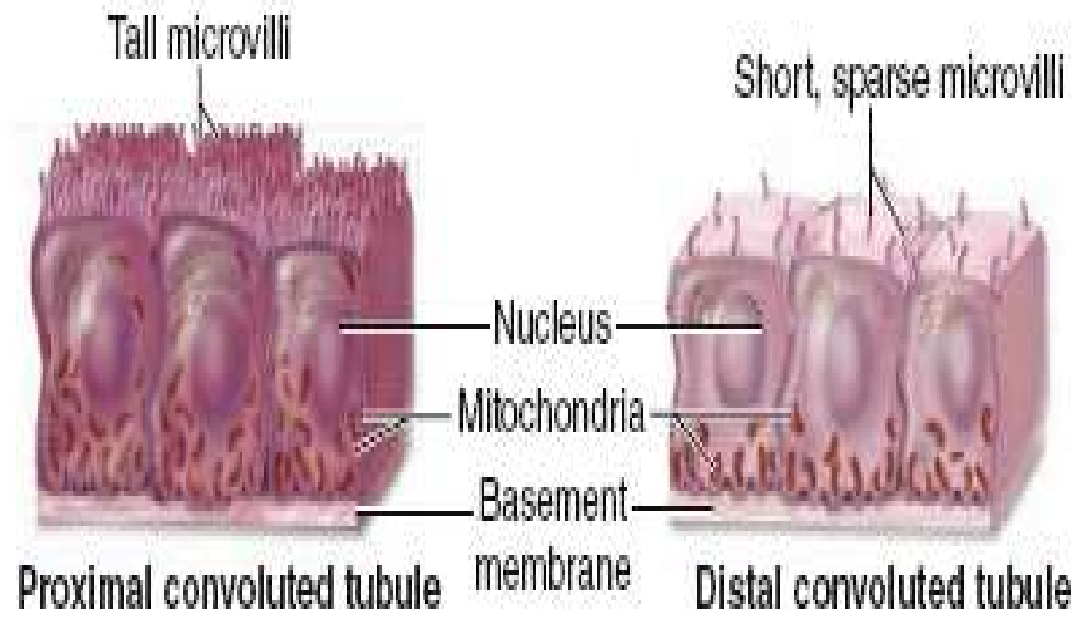
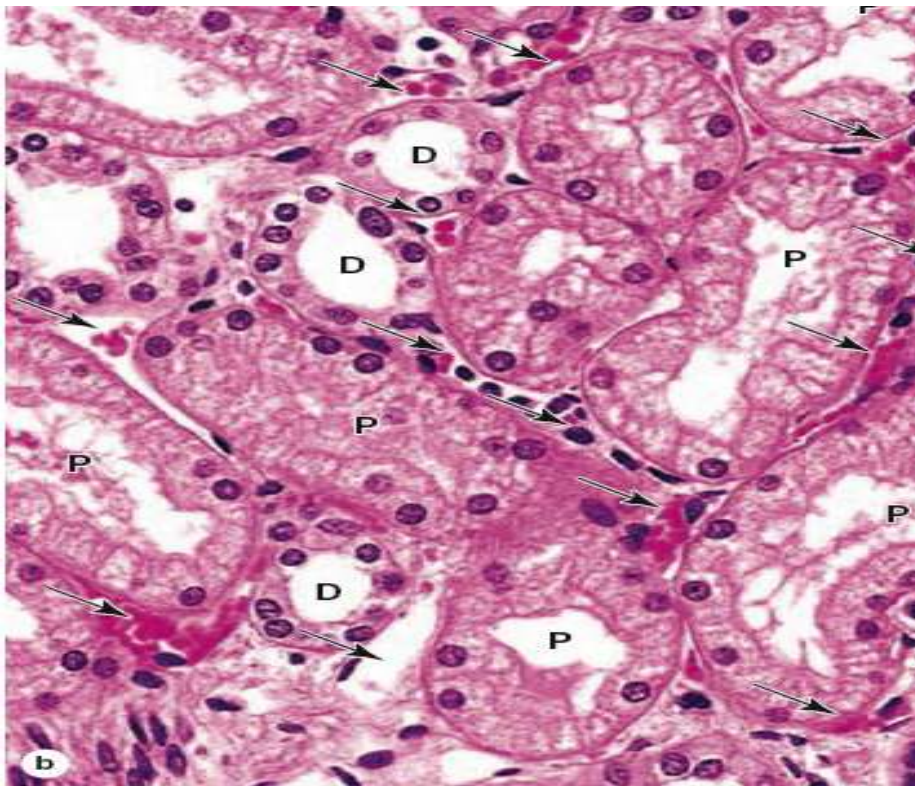


Region of Tubule	Functions (REED ONLY )
PCT	Reabsorption of all organic nutrients, all proteins, most water and electrolytes; secretion of organic anions and cations, H <sup>+</sup> , and NH <sub>4</sub> <sup>+</sup>
Loop of Henle Thick limbs	Active reabsorption of various electrolytes
Loop of Henle Thin limbs	Passive reabsorption of Na <sup>+</sup> and Cl <sup>-</sup>
DCT	Reabsorption of electrolytes
Collecting system Principal cells	Regulated reabsorption of water & electrolytes; regulated secretion of K <sup>+</sup>
Collecting system Intercalated cells	Reabsorption of K <sup>+</sup> (low-K <sup>+</sup> diet); help maintain acid-base balance





DC - distal convoluted tubule    PC - proximal convoluted tubule    BB - brush border



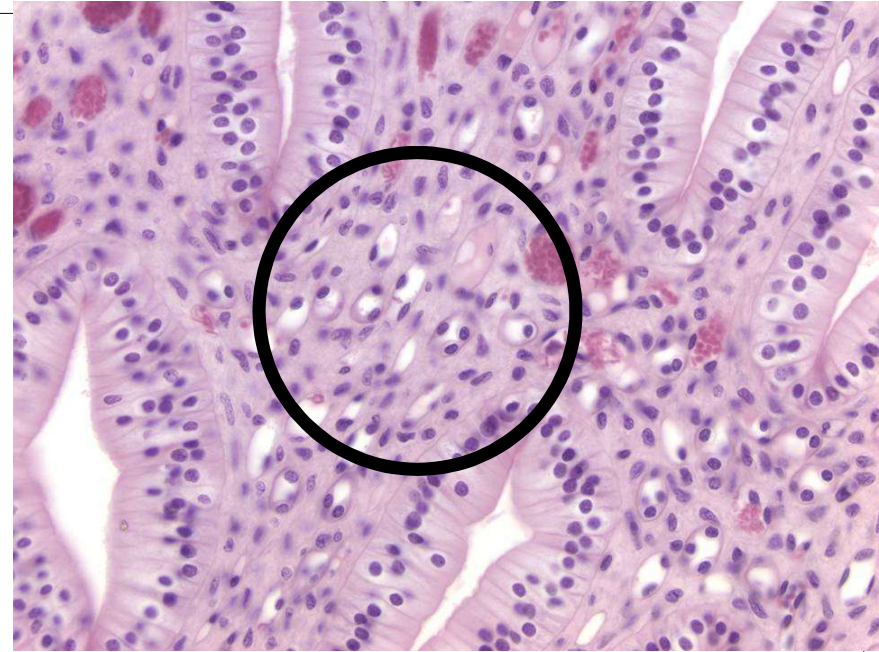
(c) Convoluted tubule epithelia

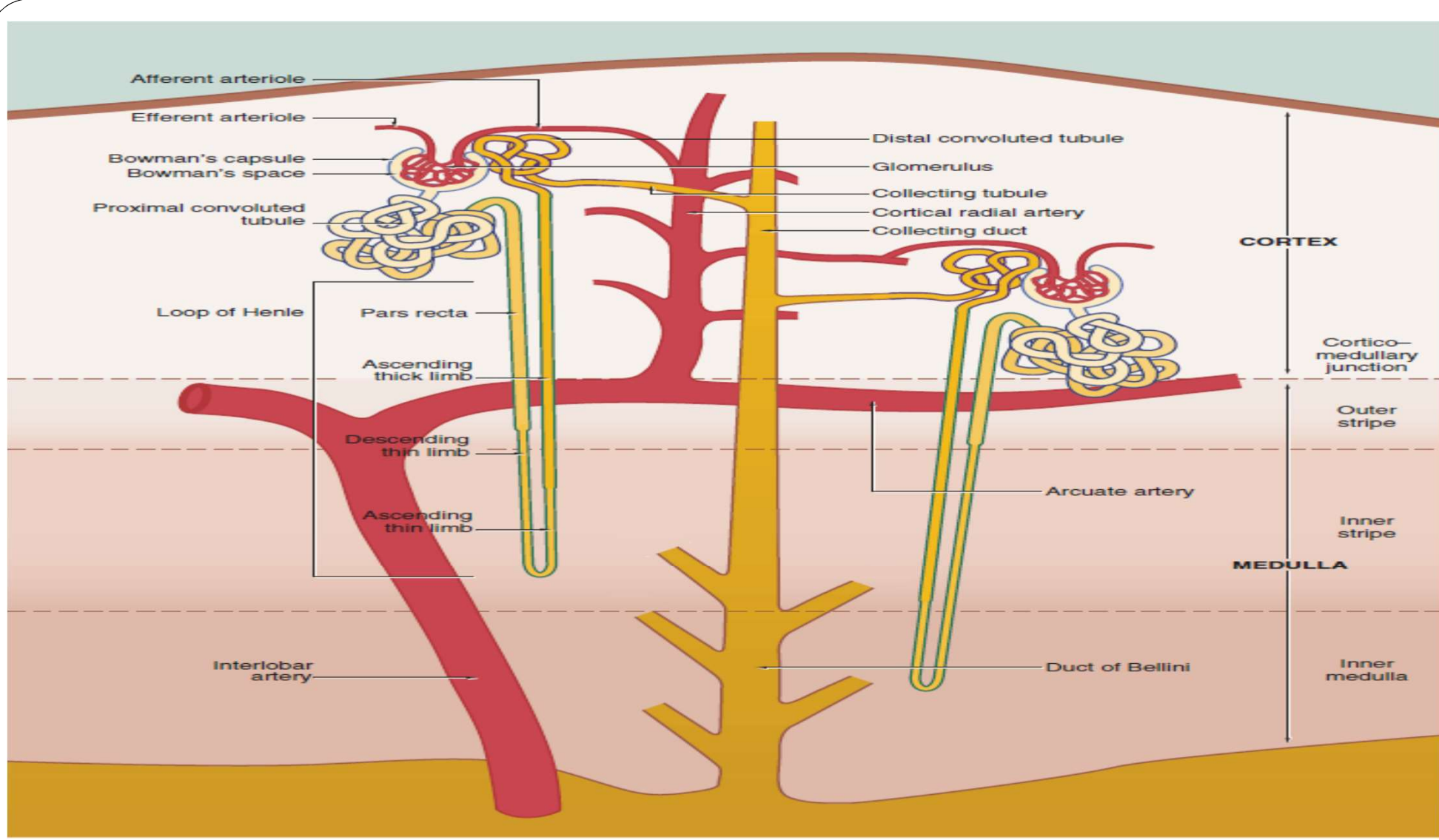
Abundant peritubular capillaries and draining venules (arrows)  
 Proximal (P) Distal (D) convoluted tubules



## Loop of Henle

- Present between the proximal and distal convoluted tubules
  - A U-shaped structure with;
    - A thick descending limb
    - A thin descending limb
    - A thin ascending limb
    - A thick ascending limb (TAL) with simple cuboidal epithelium
  - The thin parts are lined by simple squamous epithelia
  - The nuclei of the cells lining the thin limbs bulge into the lumen of the tubule; these limbs resemble capillaries in cross section





## Collecting ducts

It transport the filtrate from PCT to a minor calyx

**Connecting tubule :** extends from each nephron and several join together to form collecting ducts .

The connecting tubules join the distal convoluted tubule to the collecting duct

**Cortical Collecting ducts :** (lined by simple cuboidal epithelium ) It passes through **cortical medullary rays**

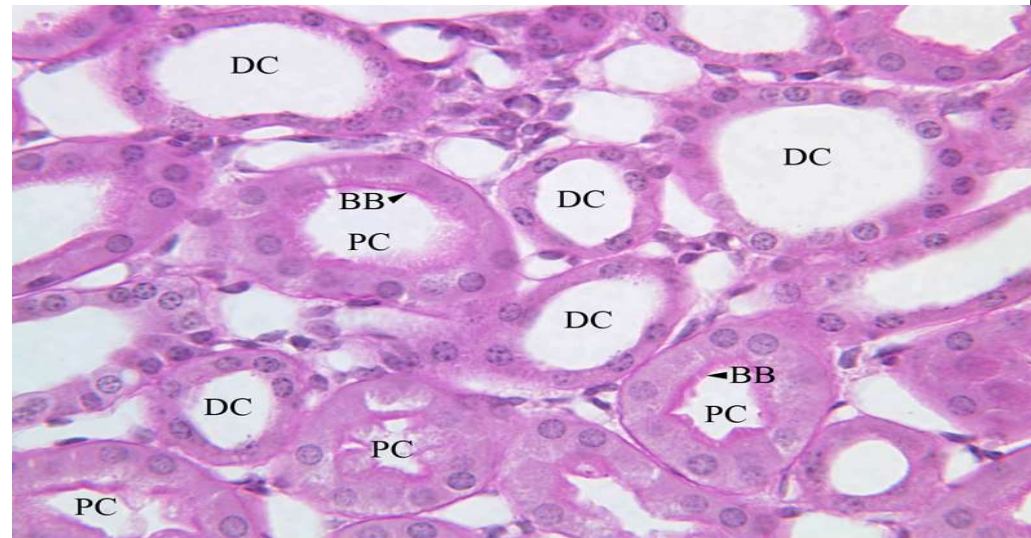
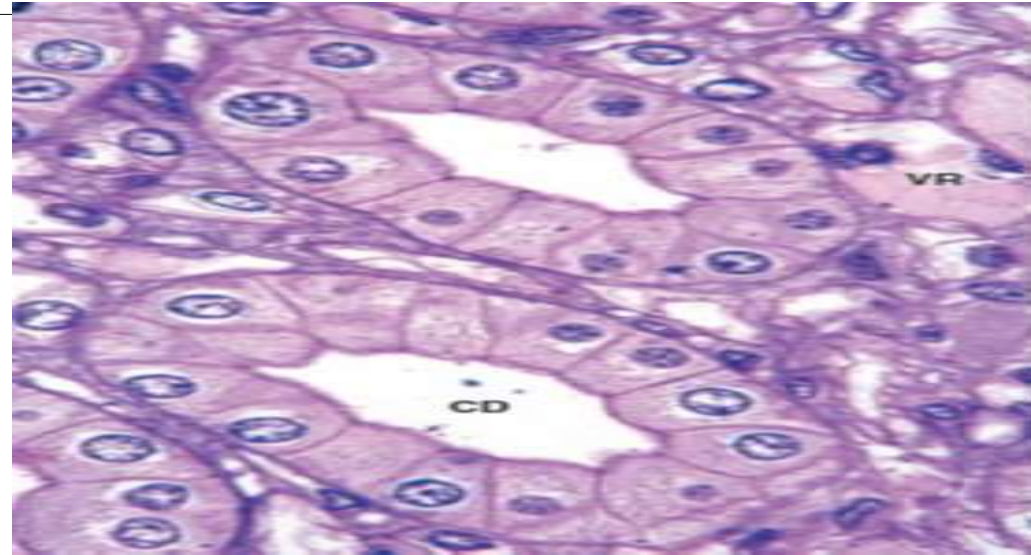
**Medullary Collecting ducts :** lined by columnar cells and are larger and straighter .

They are running parallel with the descending and ascending limbs of the loops of Henle and vasa recta

**Papillary duct (or duct of Bellini) :** several medullary collecting ducts merge again to form Papillary duct at the apex of each renal pyramid

## Collecting ducts

- The collecting ducts are distinguished from proximal and distal tubules by prominent of the cell boundaries



DC - distal convoluted tubule PC - proximal convoluted tubule BB - brush border



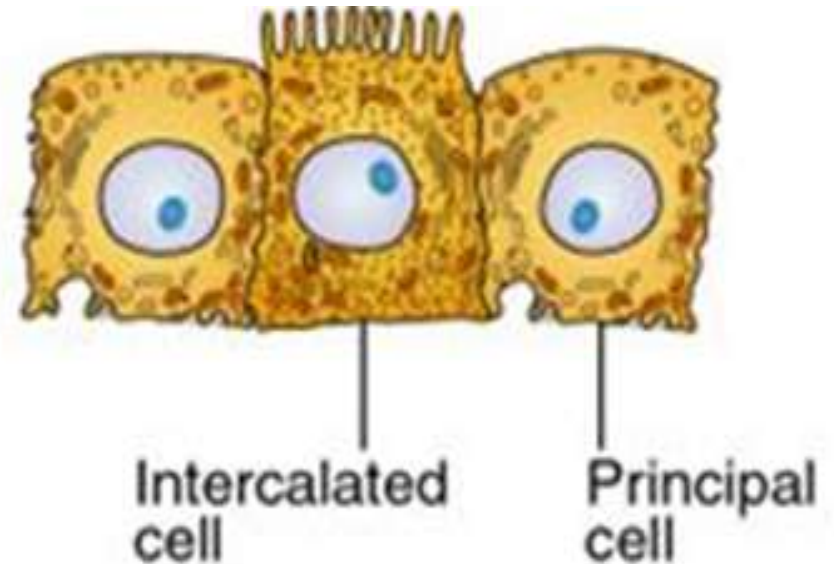
It has two types of cells

### 1- Principal (light) cells

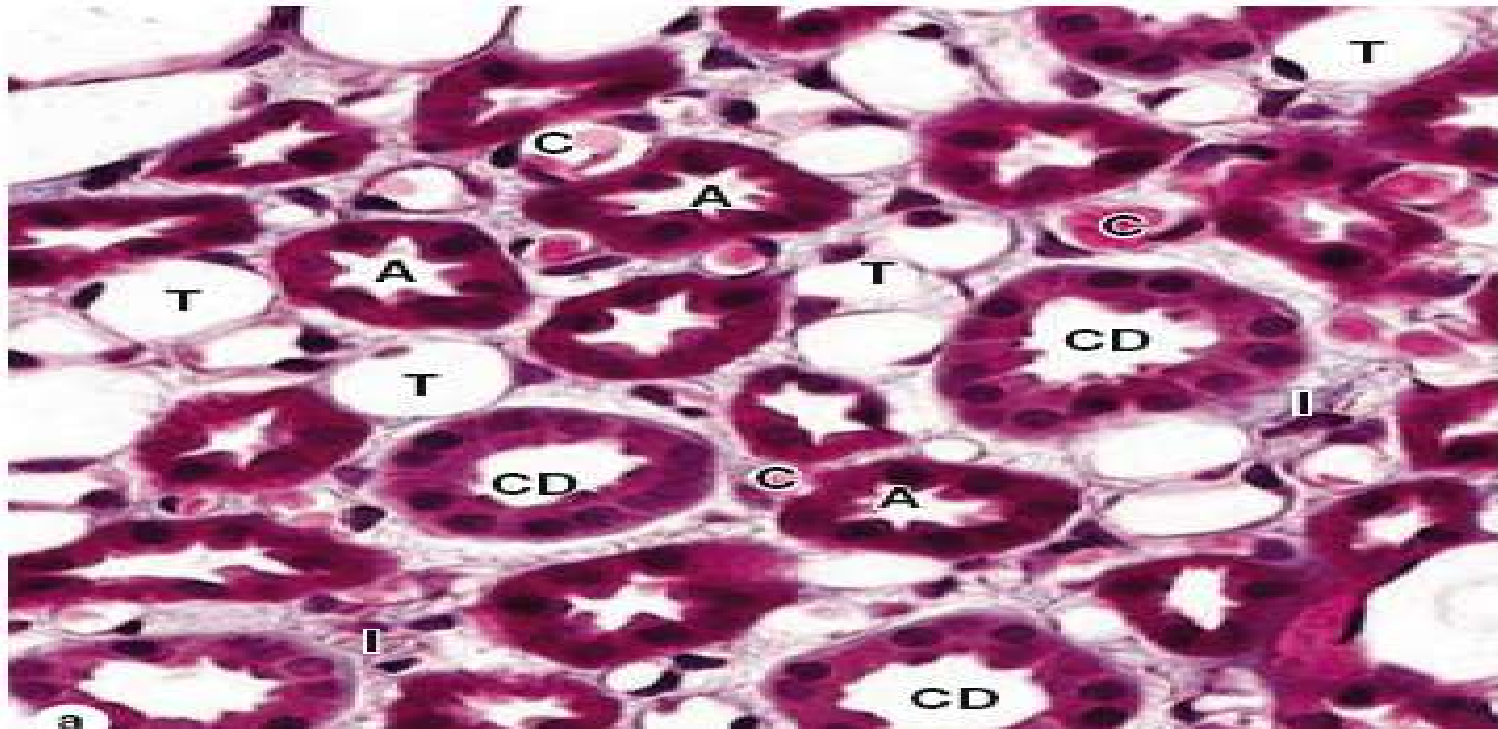
- Cuboidal, then increase in tall distally to become columnar
- Central round nuclei
- Light cytoplasm
- Basal infoldings
- Short microvilli
- Reabsorb  $\text{Na}^+$ , secrete  $\text{K}^+$ ,
- **Respond to aldosterone and ADH.**

### 2- Dark (intercalated) cells

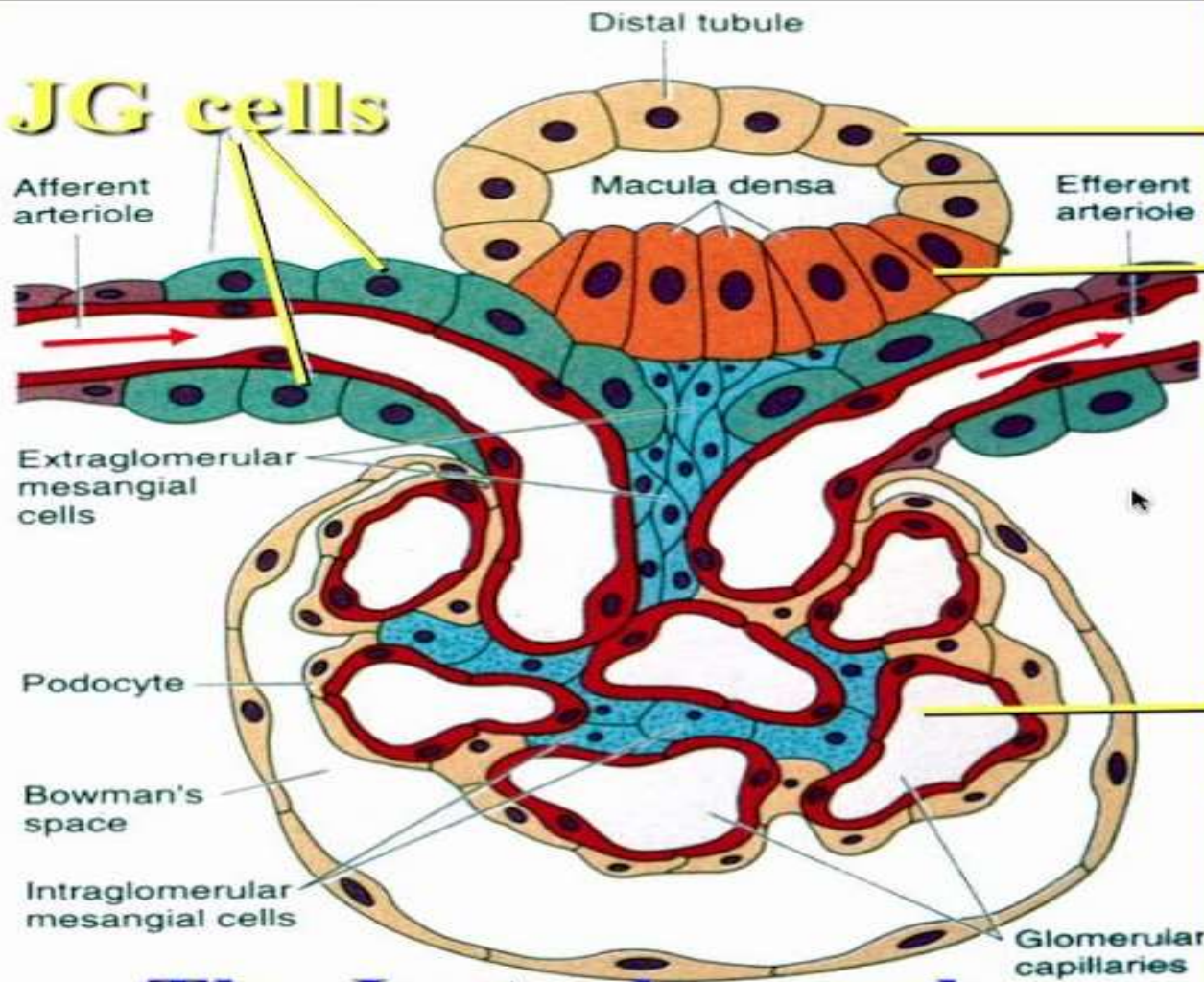
- Rich in organelles
- Well developed microvilli
- No basal infoldings
- Maintain acid-base balance by secreting either  $\text{H}^+$  (from type **A or  $\alpha$**  intercalated cells) or  $\text{HCO}_3^-$  (from type **B or  $\beta$**  intercalated cells).



(e) Collecting duct cells



A micrograph of a medullary renal pyramid cut transversely  
Thin descending and ascending limbs (**T**)  
Thick ascending limbs (**A**),  
Vasa recta capillaries containing blood (**C**)  
Collecting ducts (**CD**).



**JG cells**

**Distal tubule**

**Macula densa**

**Glomerular capillaries**

**The Juxtaglomerular Apparatus**

## **JUXTA-GLOMERULAR COMPLEX**

- It is involved in the regulation of systemic blood pressure
- It is located between glomerular afferent arteriole and distal convoluted tubule of corresponding nephron

### **Composition**

#### **1- Macula densa:**

- It is an area of closely packed, specialised cells lining the DCT close to the vascular pole
- They are columnar, crowded with prominent deeply stained nuclei
- It is sensitive to the concentration of sodium ions in the fluid within the DCT



## 2- Juxta-glomerular (JG) cells (Renin producing cells):

- They are modified smooth muscle cells of the **afferent arteriole**, small numbers are present in the efferent arteriole.
- It have features of myoepithelial cells with rounded nuclei and granular cytoplasm
- Contain mature and immature membrane -bound granules of the enzyme renin

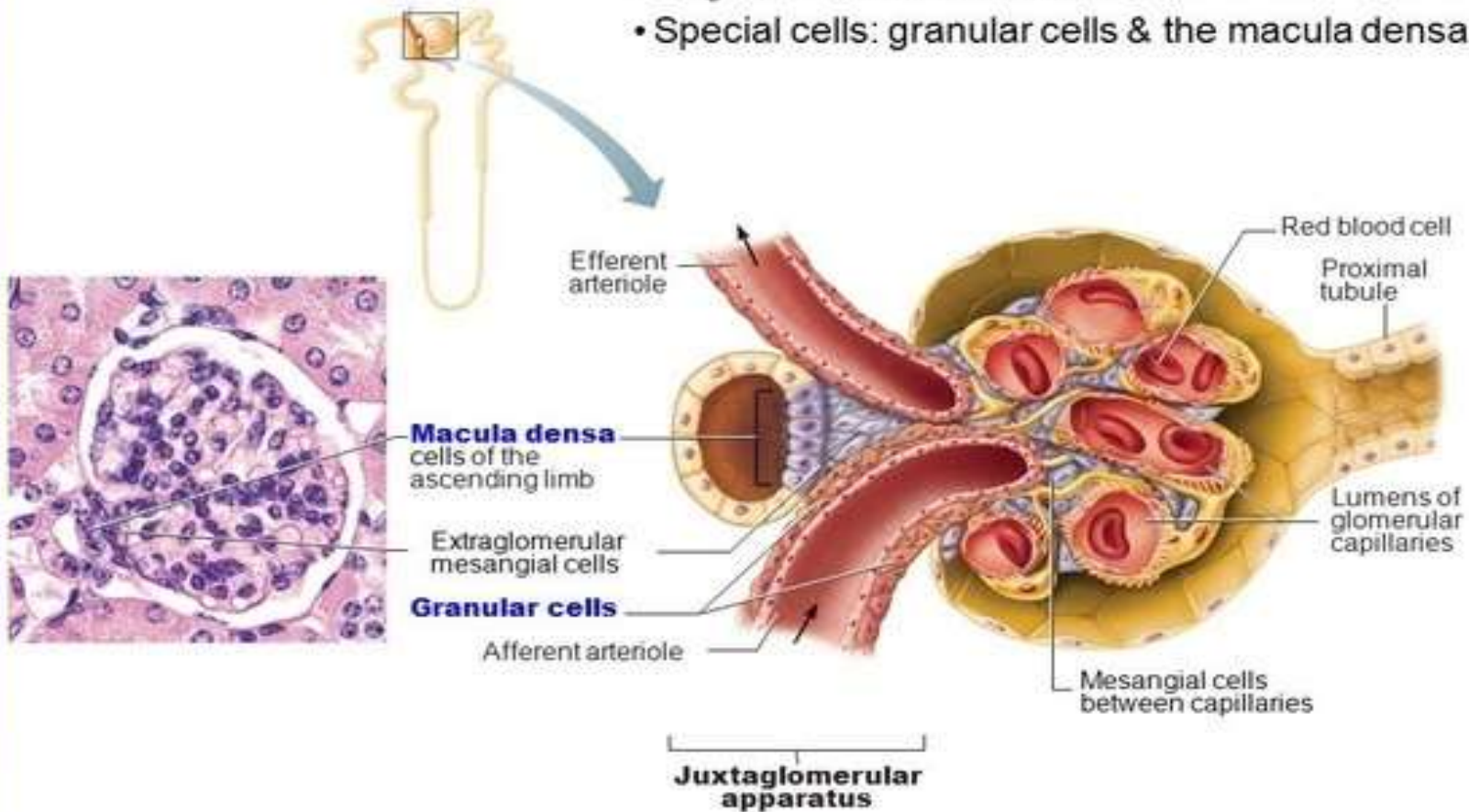
### 3- Extraglomerular mesangial cells (Lacis cells)

- Formed of a mass of small cells with pale nuclei.
- It is found in the triangular region between the afferent and efferent arterioles at sides and macula densa at the base.
- The apex of the triangle is formed by the glomerular mesangial cells at the vascular pole

*Three structures of the JG complex are in direct contact with each other*

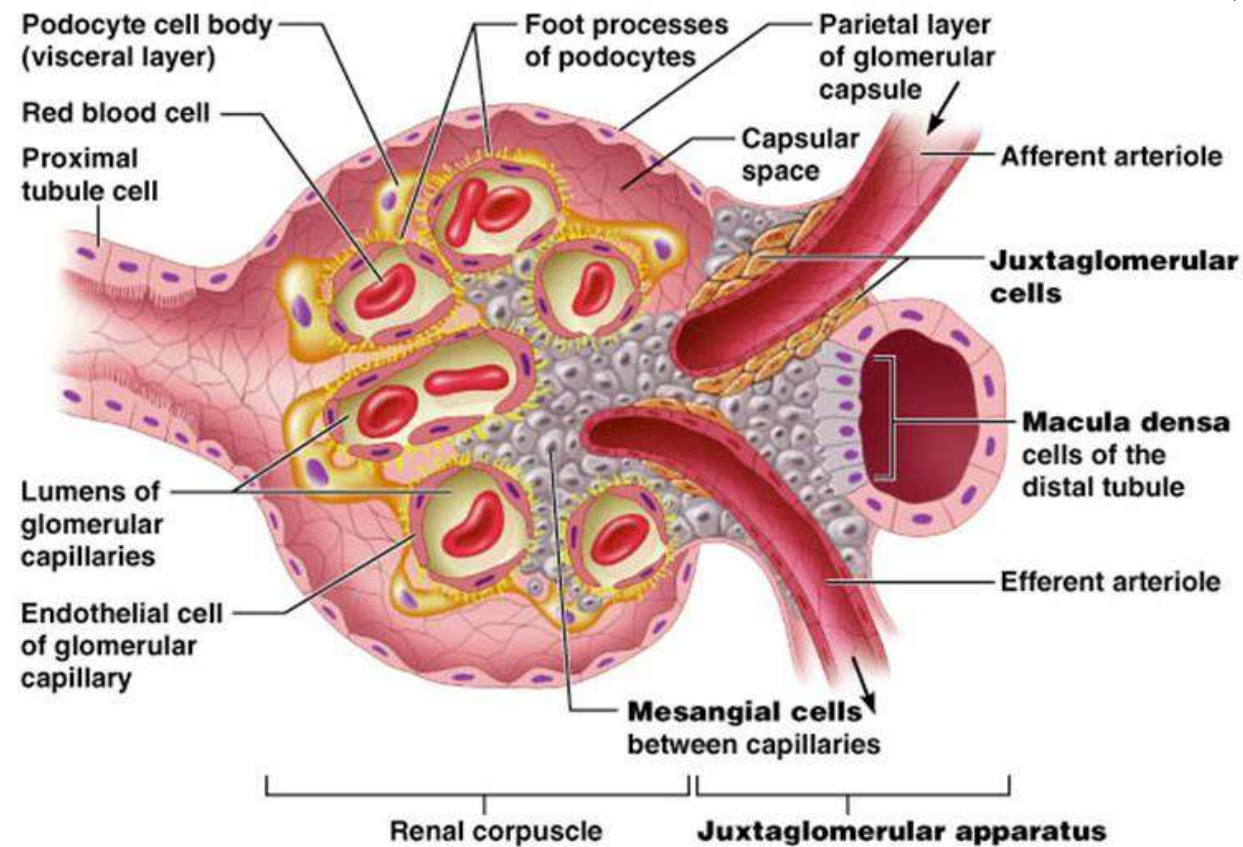
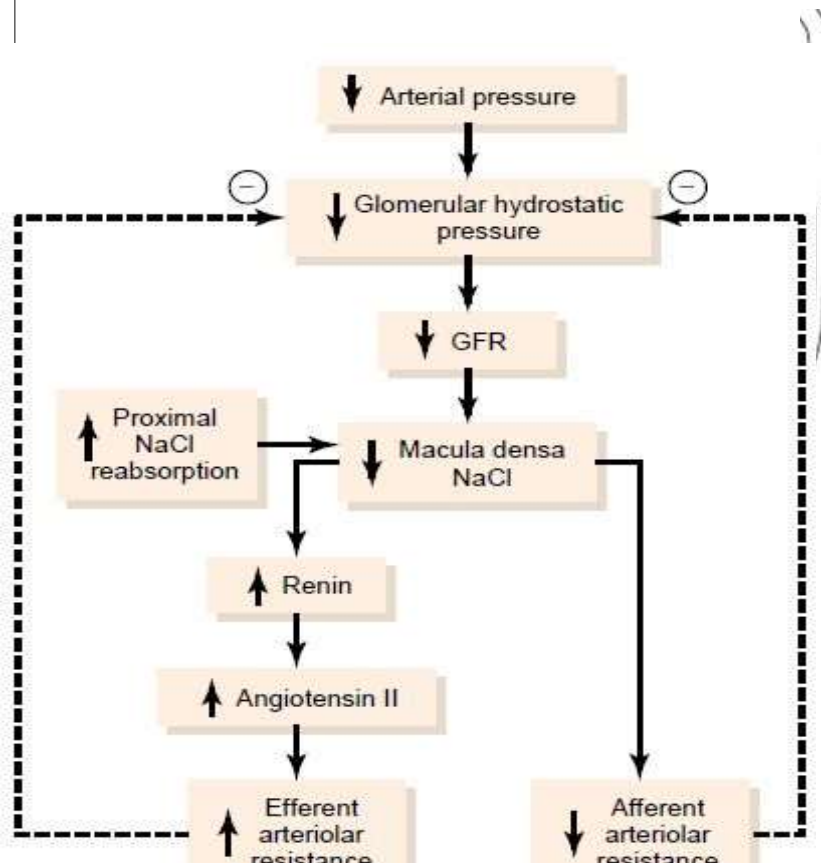
# Juxtaglomerular Apparatus

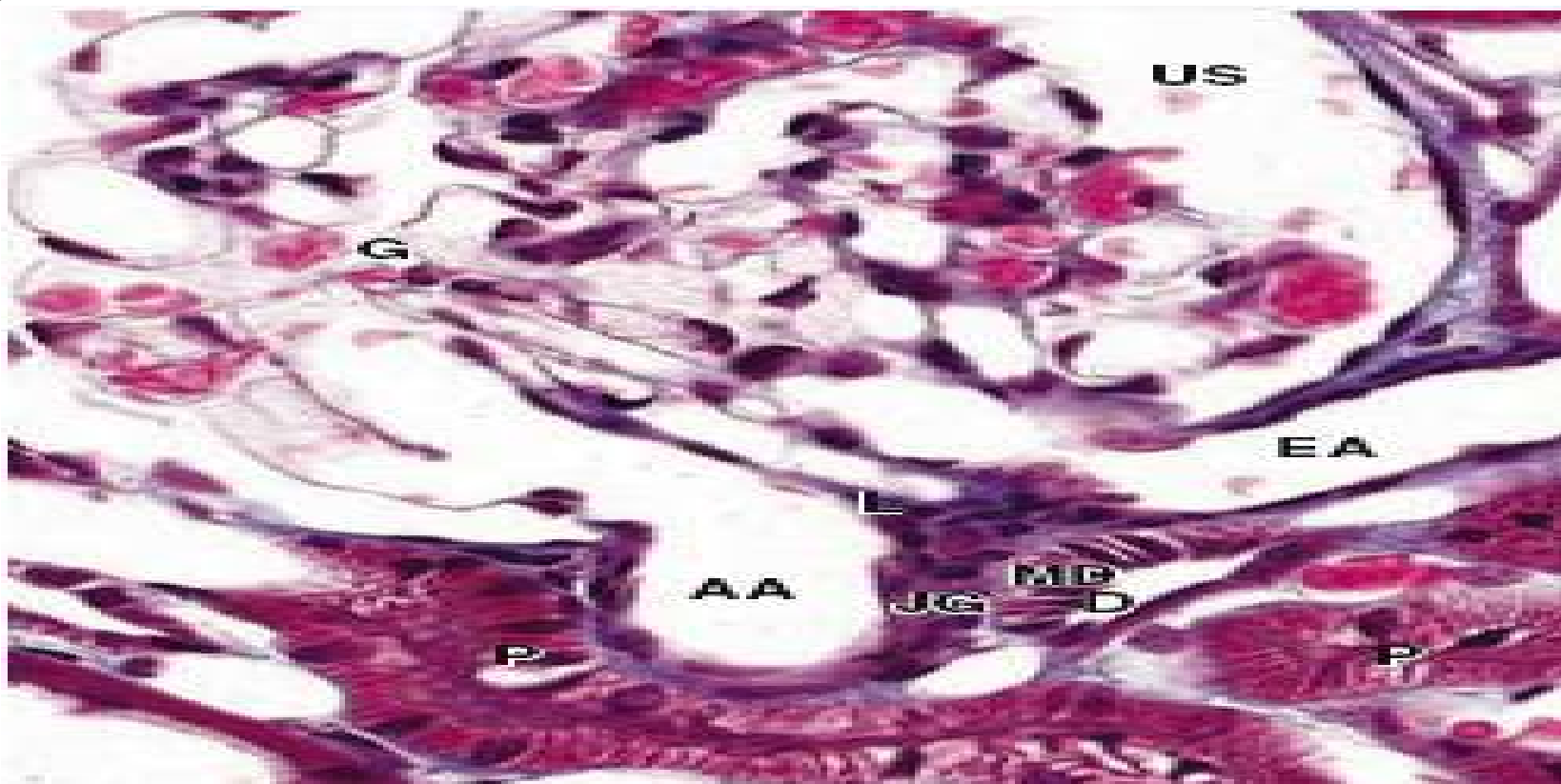
- Regulates salt & fluid balance
- Special cells: granular cells & the macula densa



## Function of juxta-glomerular complex :

- Secretion of erythropoietin
- Secretion of renin
- Regulation of Glomerular filtration rate





Distal tubule (D)

Macula densa (MD)

juxtaglomerular granule cells (JG)

Lacis cells (L), which are extraglomerular mesangial

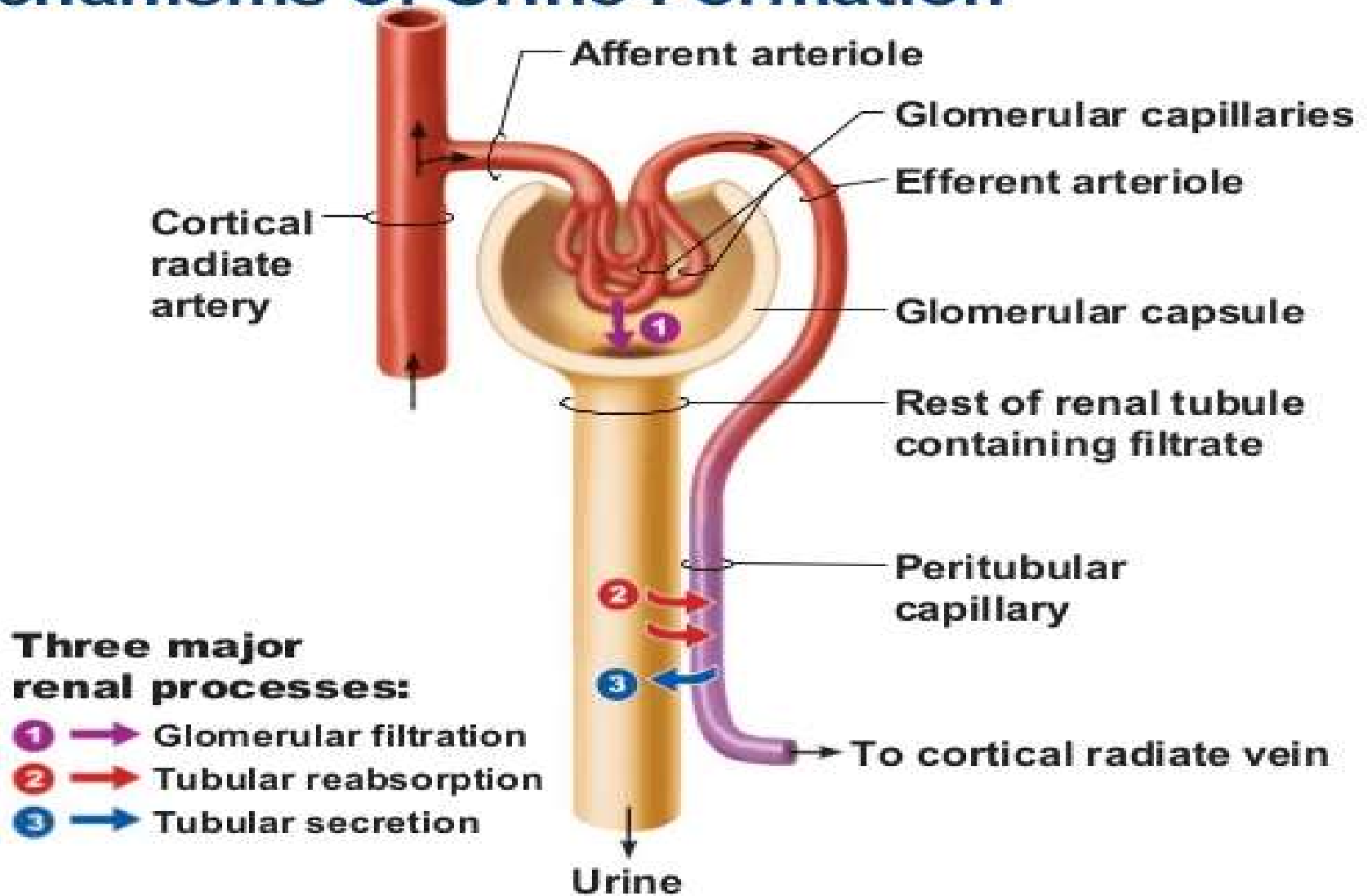
Vascular pole of its glomerulus (G).

Afferent arteriole's (AA)

Efferent arteriole (EA)



# Mechanisms of Urine Formation



## Urine formation

- **Filtration** involves the transfer of soluble components, such as water and waste, from the **blood into the glomerulus**.
- **Reabsorption** involves the absorption of molecules, ions, and water that are necessary for the body to maintain homeostasis **from the glomerular filtrate back into the blood**.
- **Secretion** involves the transfer of hydrogen ions, creatinine, drugs, and urea **from the blood into the collecting duct**, and is primarily made of water.
- **Blood and glucose** are not normally found in urine.

## **Urothelium or transitional epithelium**

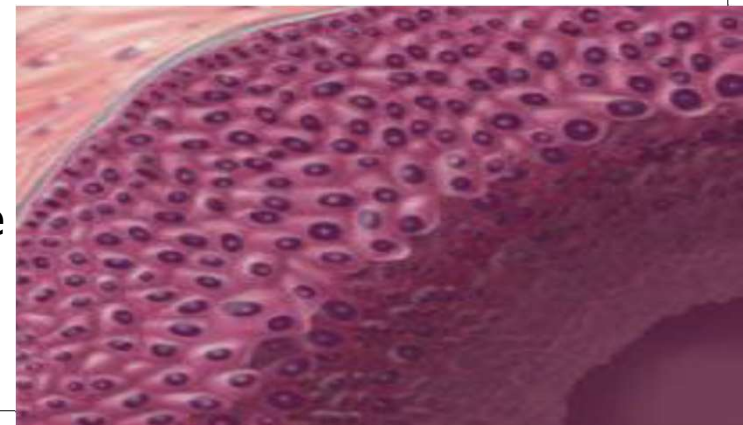
Cells of this epithelium are organized as three layers

1- A single layer of small basal cells resting on a very thin basement membrane

2- An intermediate region containing from one to several layers of cuboidal or low columnar cells

3- A superficial layer of large elliptical umbrella cells, highly differentiated to protect the underlying cells against cytotoxic effects of hypertonic urine.(well developed in the bladder)

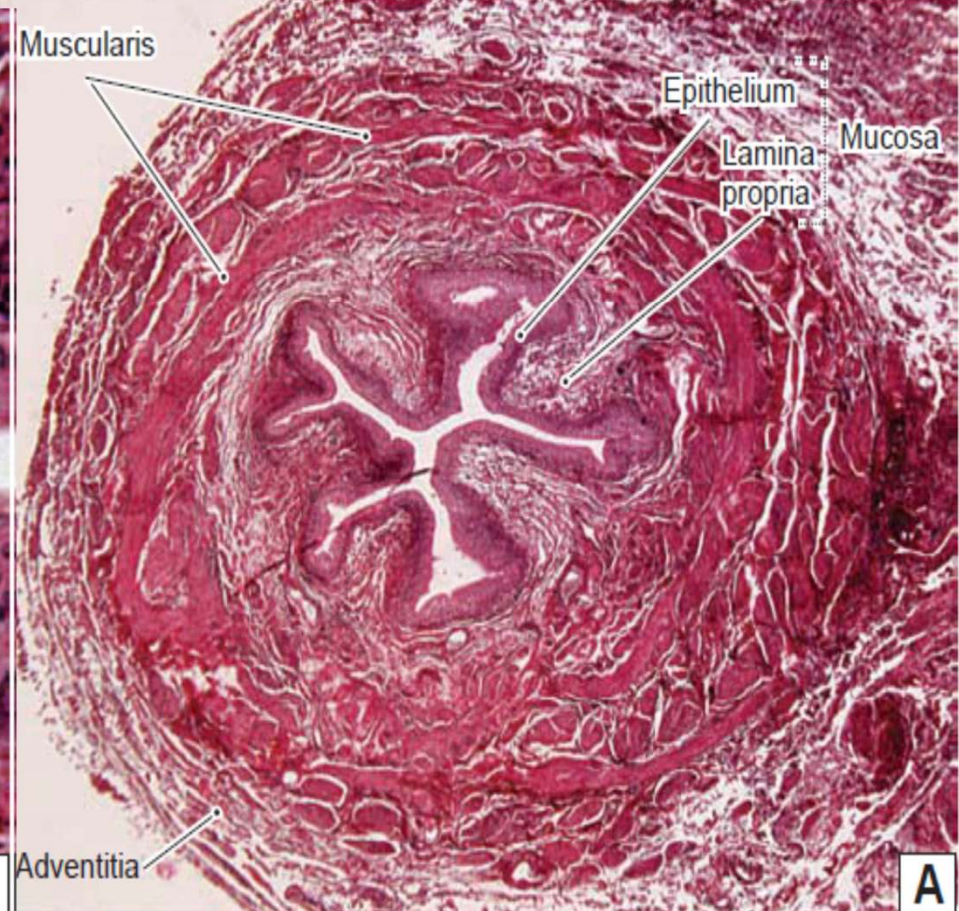
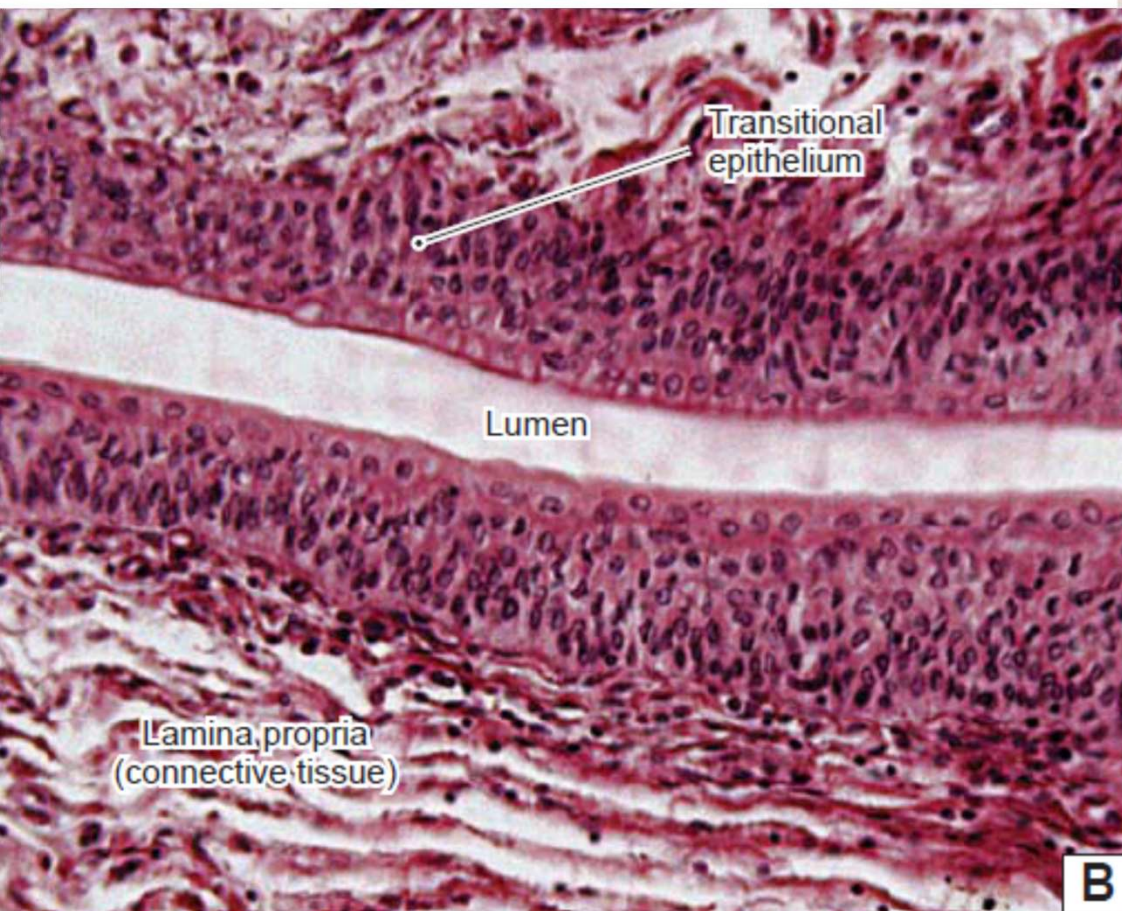
- ❑ Umbrella cells are have extensive intercellular junctional complexes surrounding unique apical membranes.
- ❑ This membrane containing integral membrane proteins called **uroplakins** that accumulate into arrays of stiffened plaques .
- ❑ The membranous plaques, together with the tight junctions serve as an osmotic barrier protecting against hypertonic urine and preventing dilution of the stored urine



# Ureter

- Small muscular tubule.
- It carries urine from the renal pelvis to the urinary bladder.
- It has mucosa, muscularis, and adventitia.
- Mucosa consists of:
  - Transitional epithelium
  - loose connective tissue (lamina propria).
- Muscularis:
  - Inner longitudinal and outer circular smooth muscle layers.
  - Difficult to distinguish.
  - As it approaches the urinary bladder, the ureter may also contain a third layer of smooth muscle.
- Adventitia : connective tissues, nerve fibers, and blood vessels.





**B**

**A**

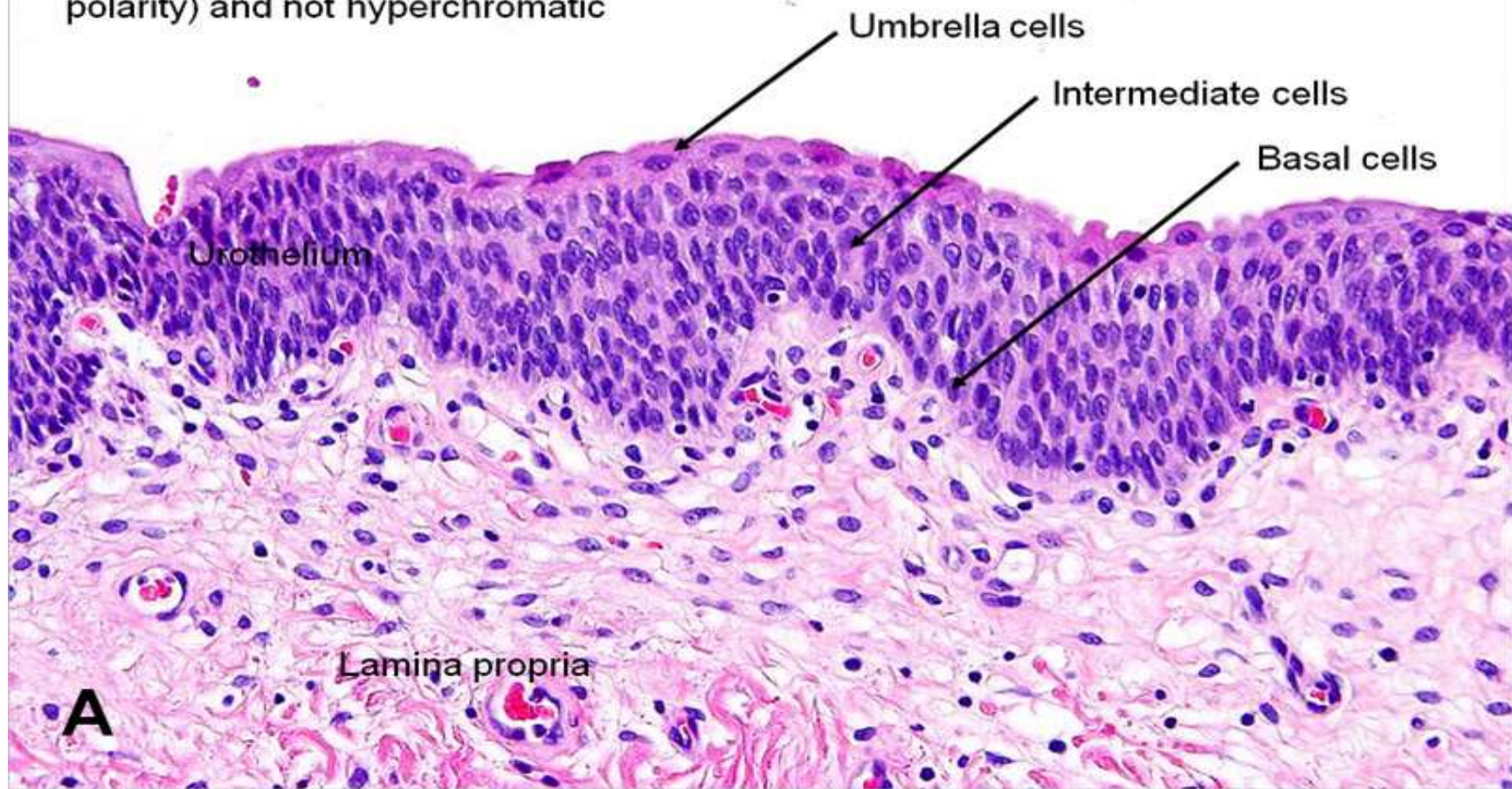


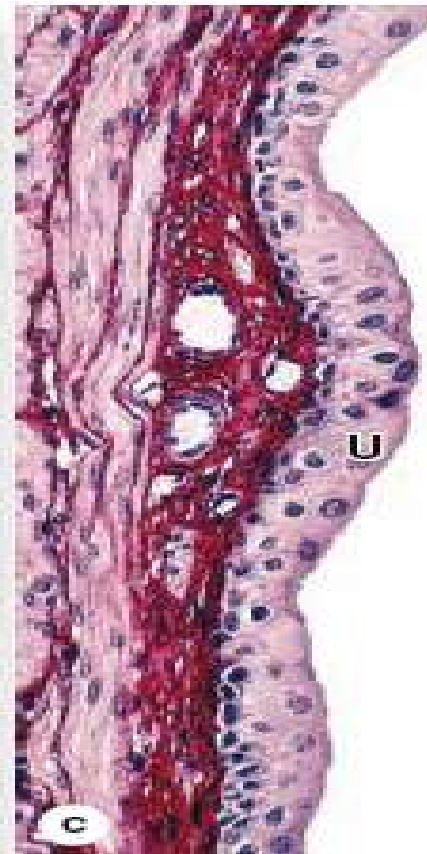
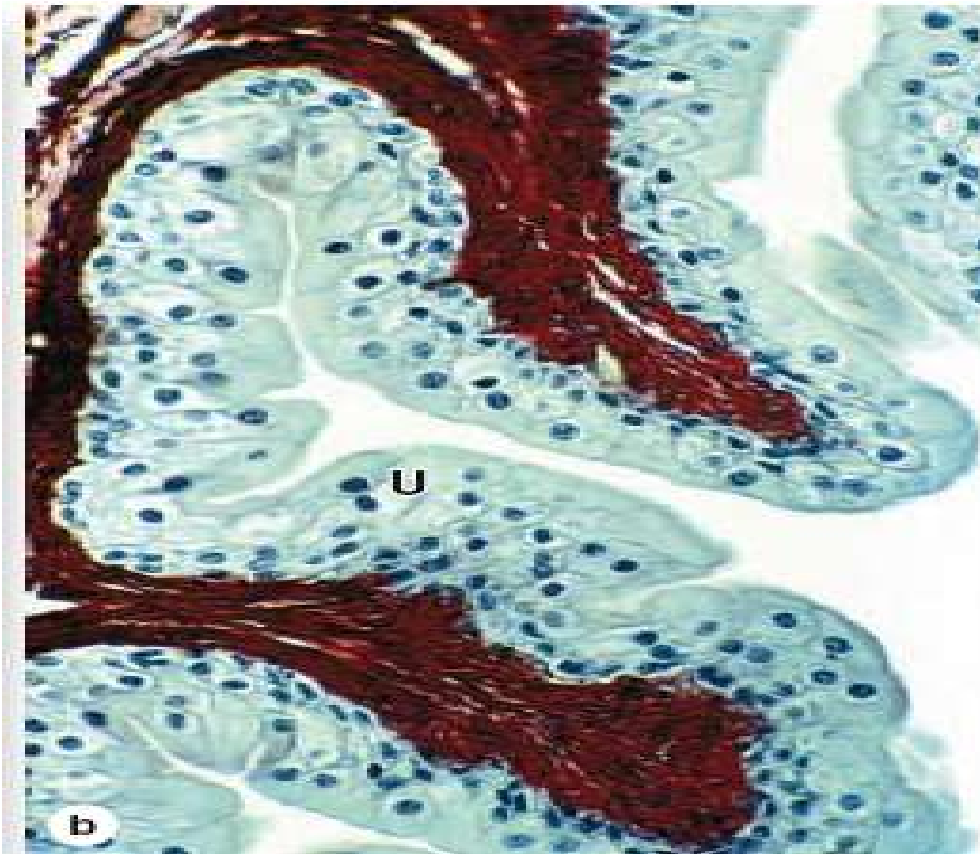
## Urinary bladder

- Three layers (mucosa, muscularis, and adventitia/serosa),
- The mucosa is composed of: **transitional epithelium** and lamina propria.
- The muscularis consists of three smooth muscle layers collectively called the detrusor muscle: These are the inner longitudinal, middle circular, and outer longitudinal smooth muscle layers. These three smooth muscle layers are arranged in two different orientations to help the urinary bladder contract to empty urine efficiently.
- Adventitia (connective tissue); the outer layer , its superior (free) surface is covered by serosa, which is a layer of connective tissue with a lining of mesothelium.

# Urinary bladder

Benign nuclei: oval, with nuclear groove, point towards top (normal polarity) and not hyperchromatic





**(b) When the bladder is empty**, the mucosa is highly folded the urothelium (**U**) has umbrella cells.

**(c) When the bladder is full**, the mucosa is pulled smooth, the urothelium (**U**) is thinner, and the umbrella cells are flatter.

# Male urethra

- **The prostatic urethra:**

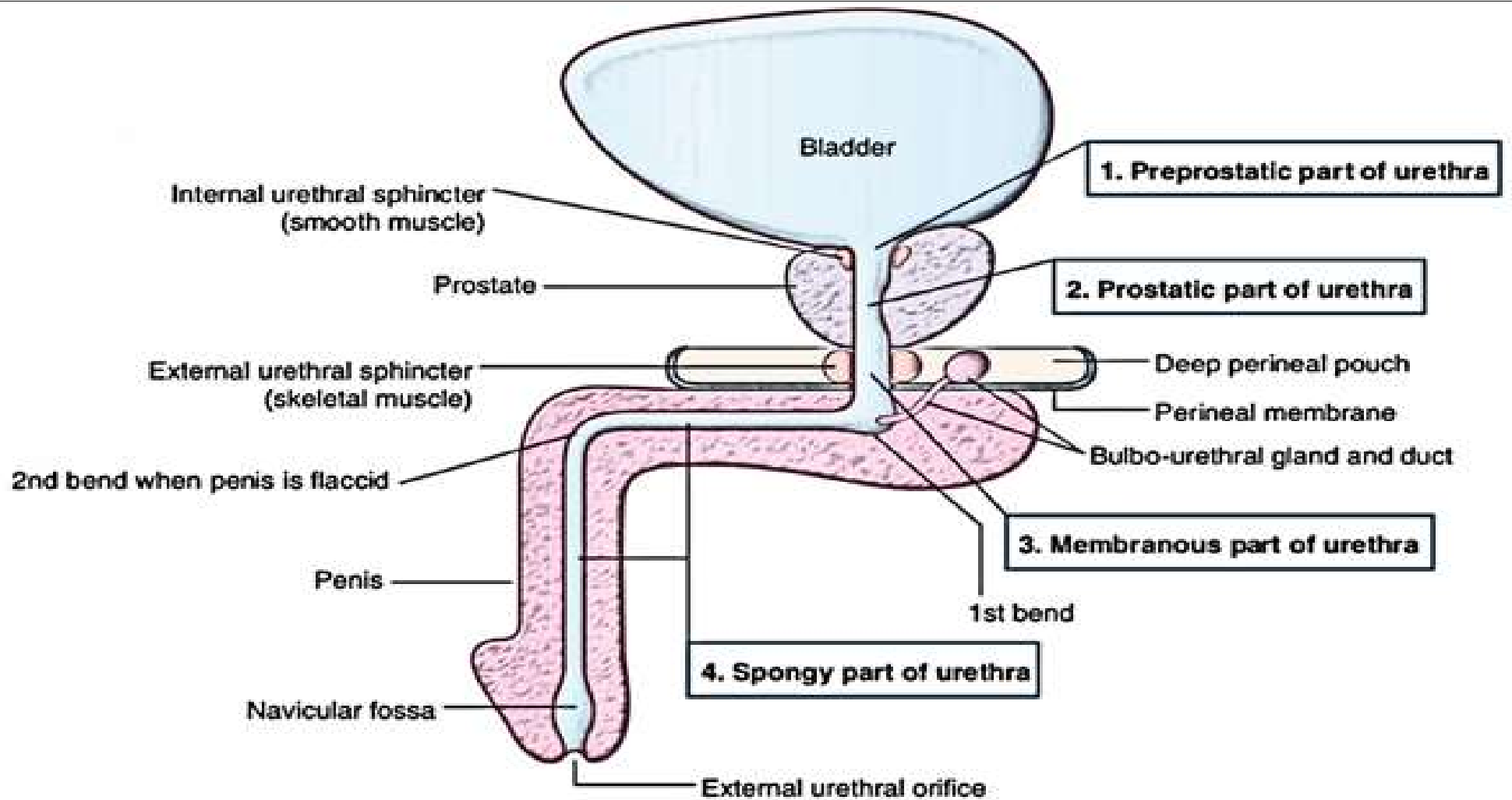
Extends through the prostate gland and is lined by urothelium (transitional epithelium )

- **The membranous urethra:**

- Passes through an external sphincter of striated muscle of the deep perineal pouch
- Lined by **stratified columnar and pseudostratified columnar epithelium**

- **The spongy urethra:**

- Enclosed within the erectile tissue of the penis
- Lined by **stratified columnar and pseudostratified columnar epithelium, with stratified squamous epithelium distally**



Men

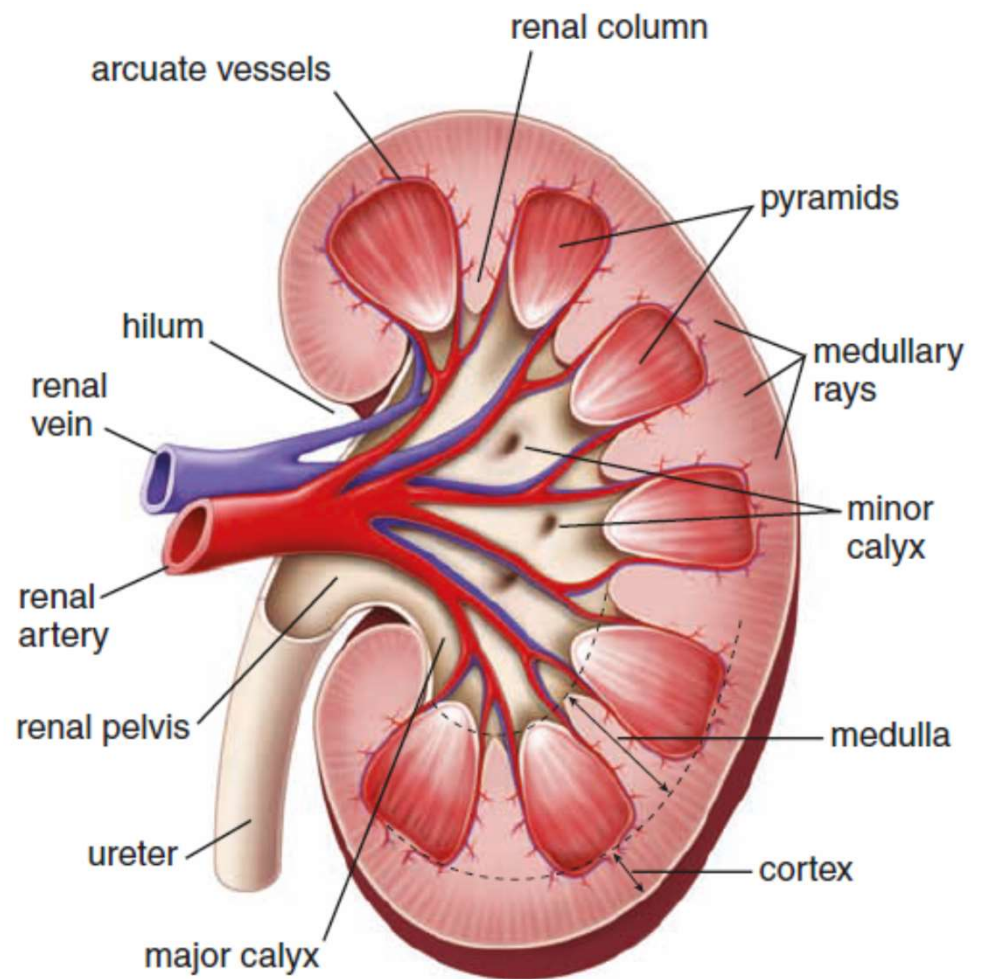
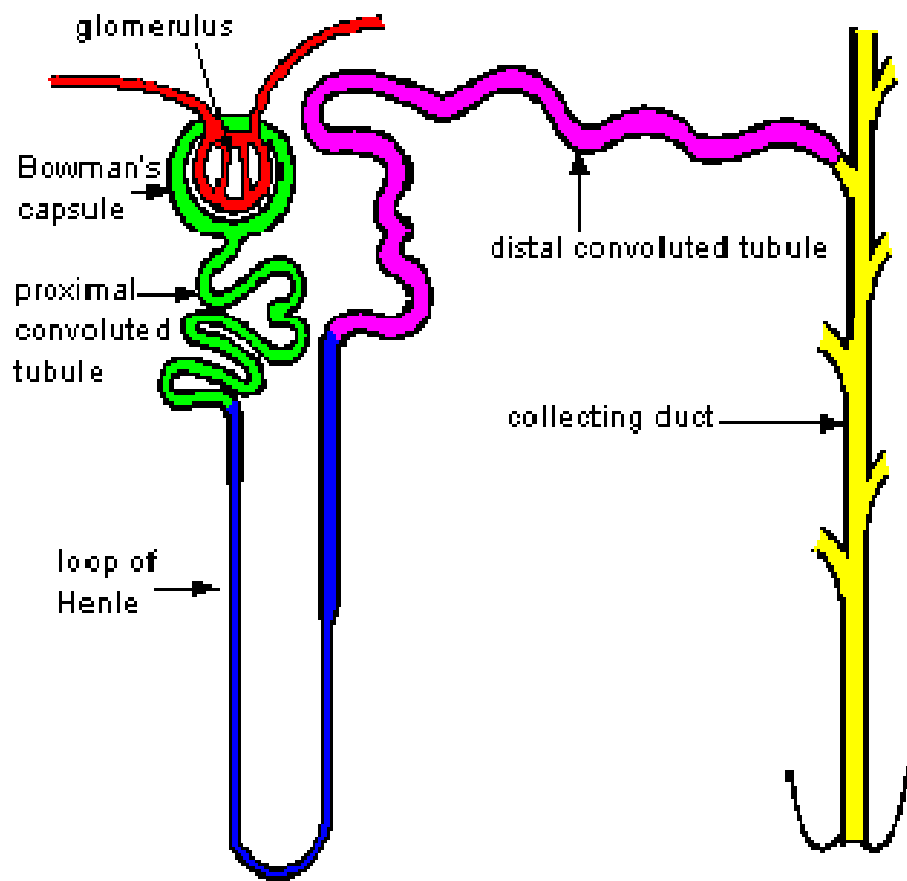


## Female urethra

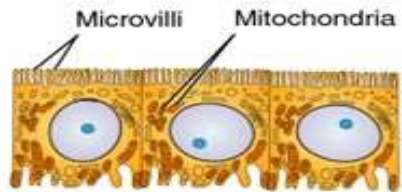
- The urethra is short, measuring 3 to 5 cm in length from the bladder to the vestibule of the vagina.
- The lining epithelium is initially **transitional epithelium**, a continuation of the bladder epithelium, but changes to **stratified squamous epithelium** before its termination
- The lamina propria is a highly vascularized layer of connective tissue
- The urethra penetrates the urogenital diaphragm whose striated muscle forms the external urethral sphincter



**summary**



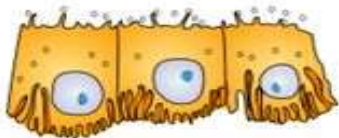
# Histology of Renal Tubule & Collecting Duct



(a) Proximal convoluted tubule cells



(b) Loop of Henle cells: descending limb and thin ascending limb



(c) Loop of Henle cells: thick ascending limb

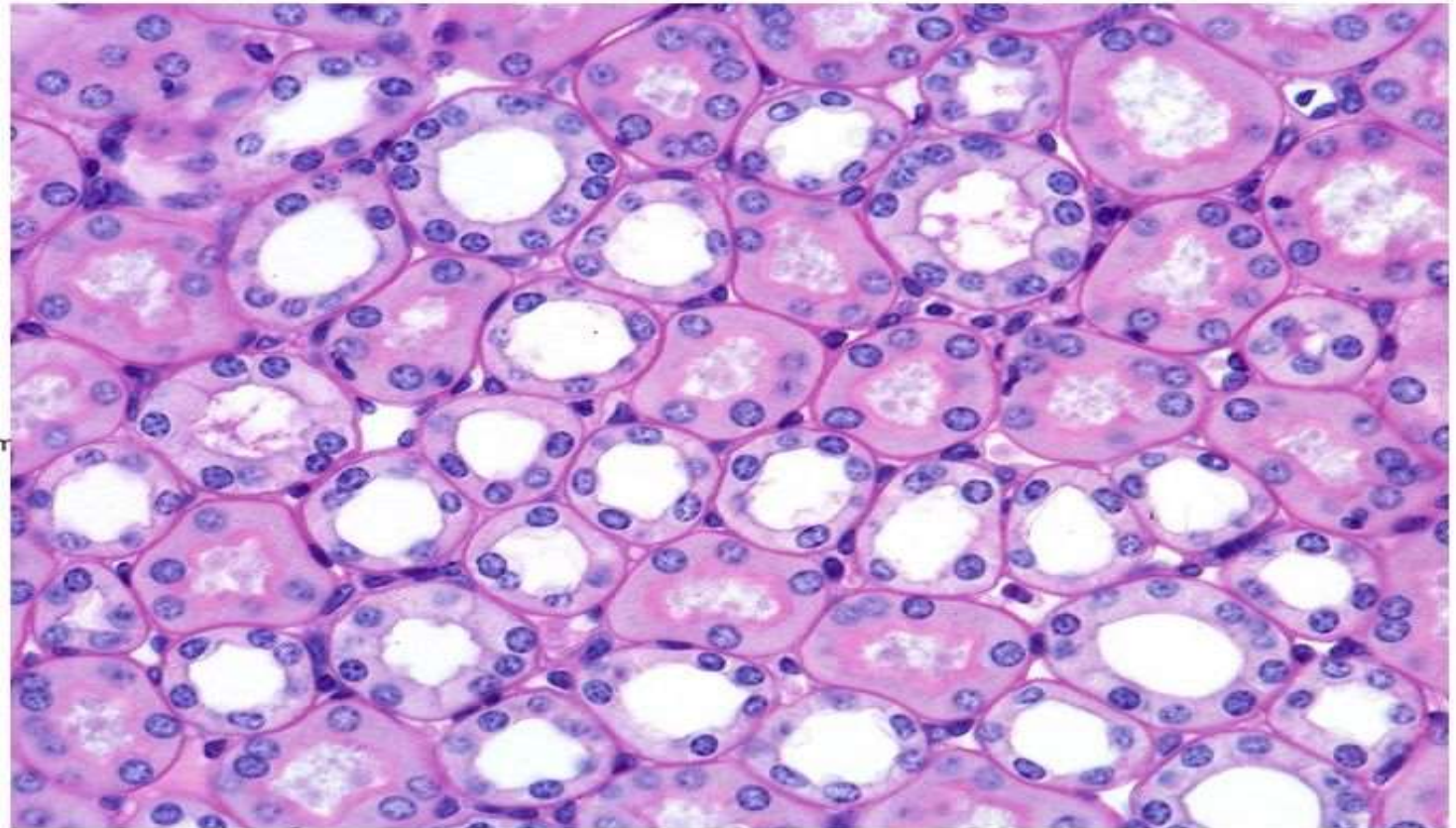


(d) Distal convoluted tubule cells



Intercalated cell  
Principal cell

(e) Collecting duct cells

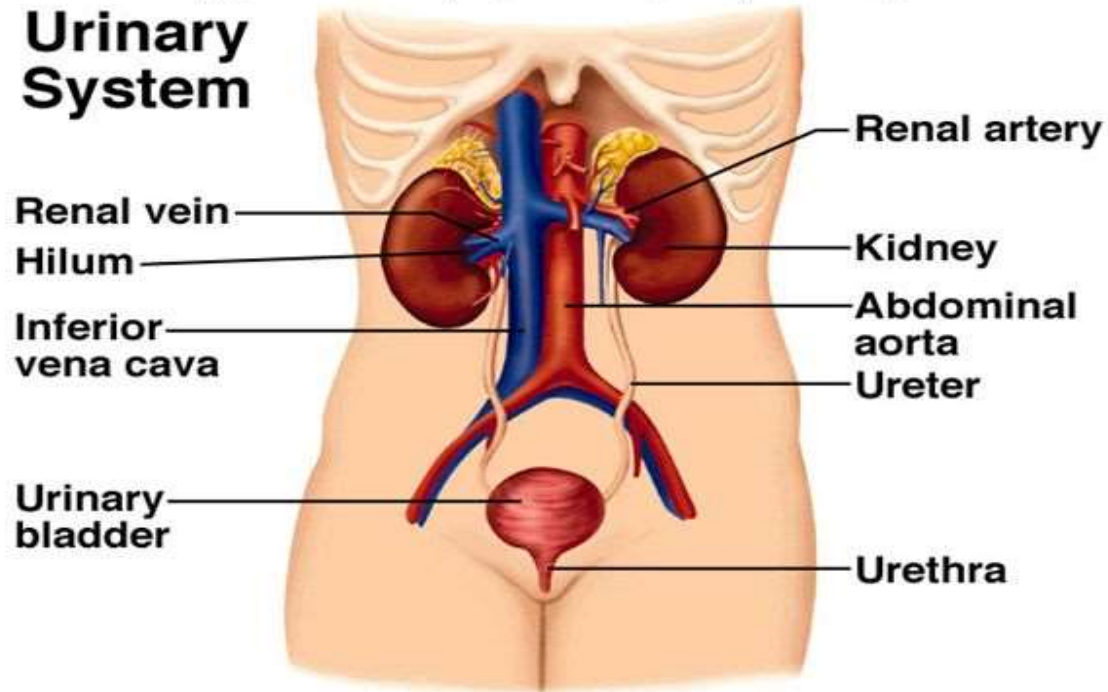




# System Overview

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## Urinary System



- Consists of:
  - Kidneys
  - Ureters
  - Urinary bladder
  - Urethra



*Thank you*