The University Of Jordan
Faculty Of Medicine

Histology Of The Urinary system

By

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Learning Objectives

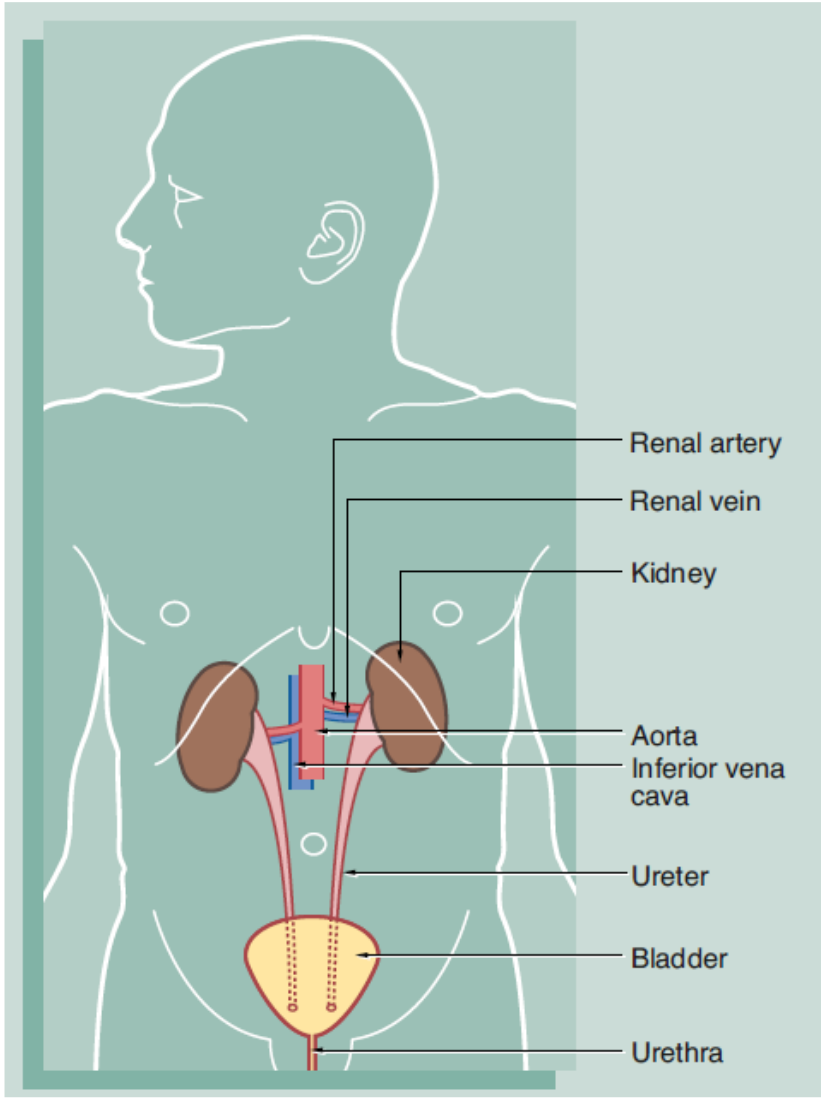
By the end of the topic the learner should be able to:

- 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, 6th 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.

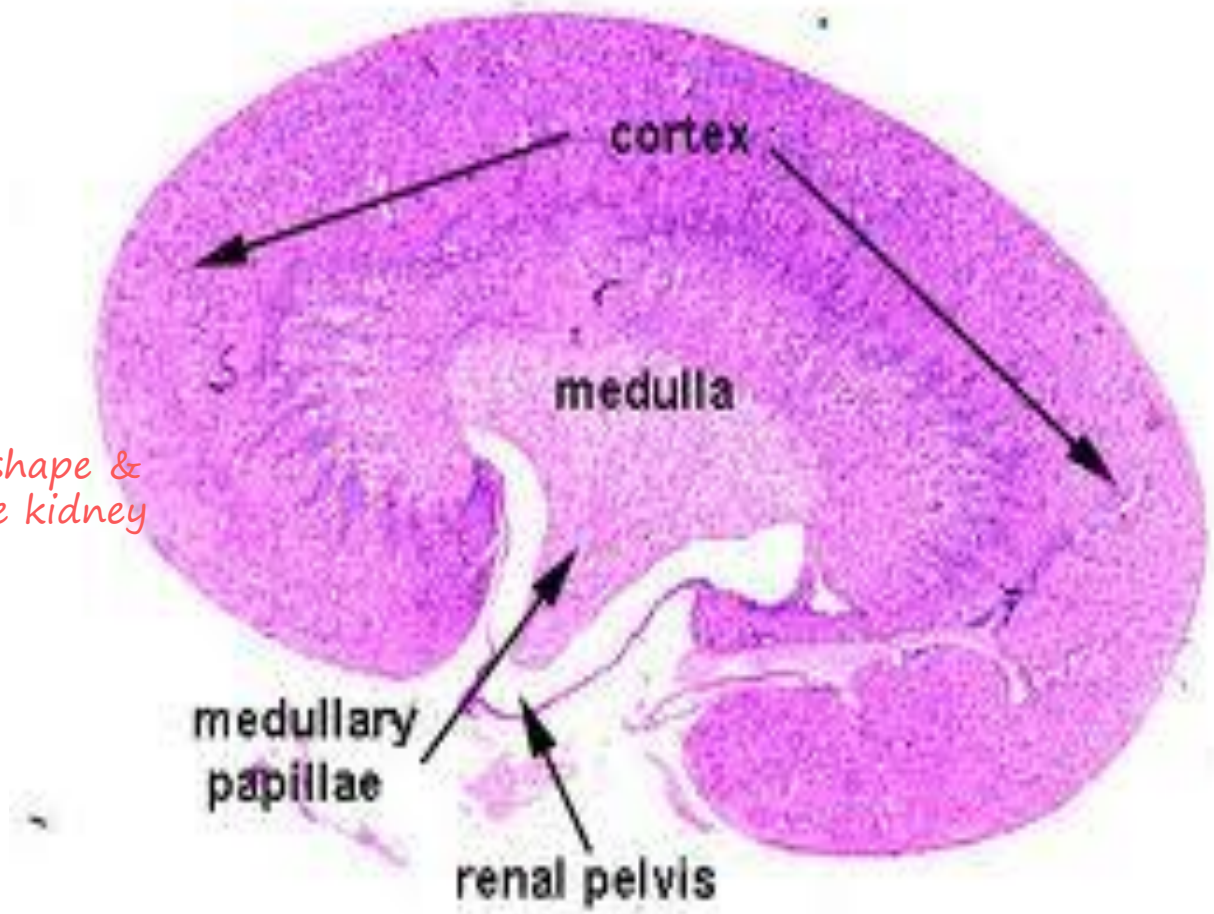
Kidney structure

Stroma

- Capsule
- Trabeculae
- Reticular stroma — *maintains the shape & structure of the kidney*

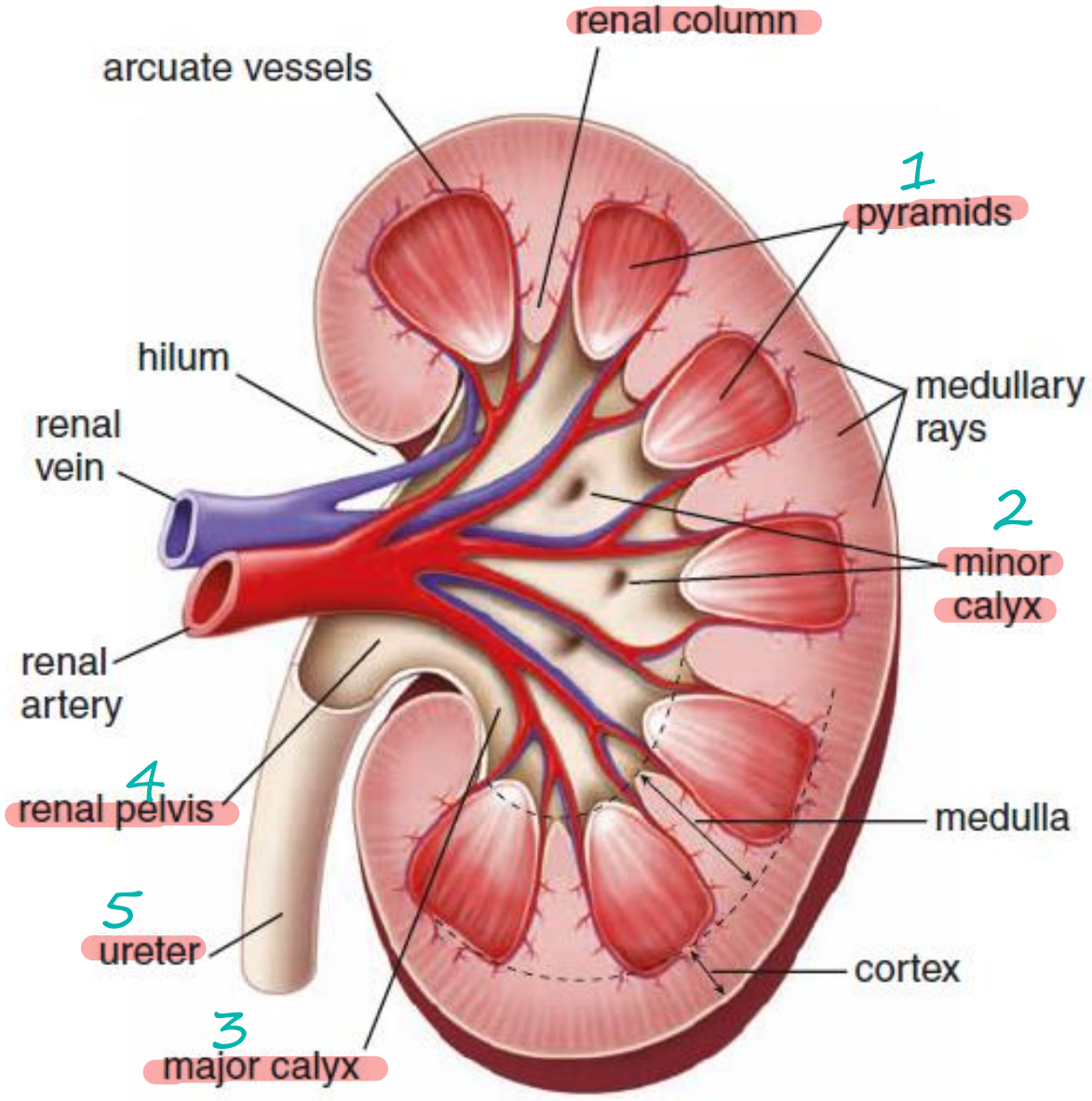
Parenchyma — *functional unit*

- Uriniferous tubules



Kidney – General structure

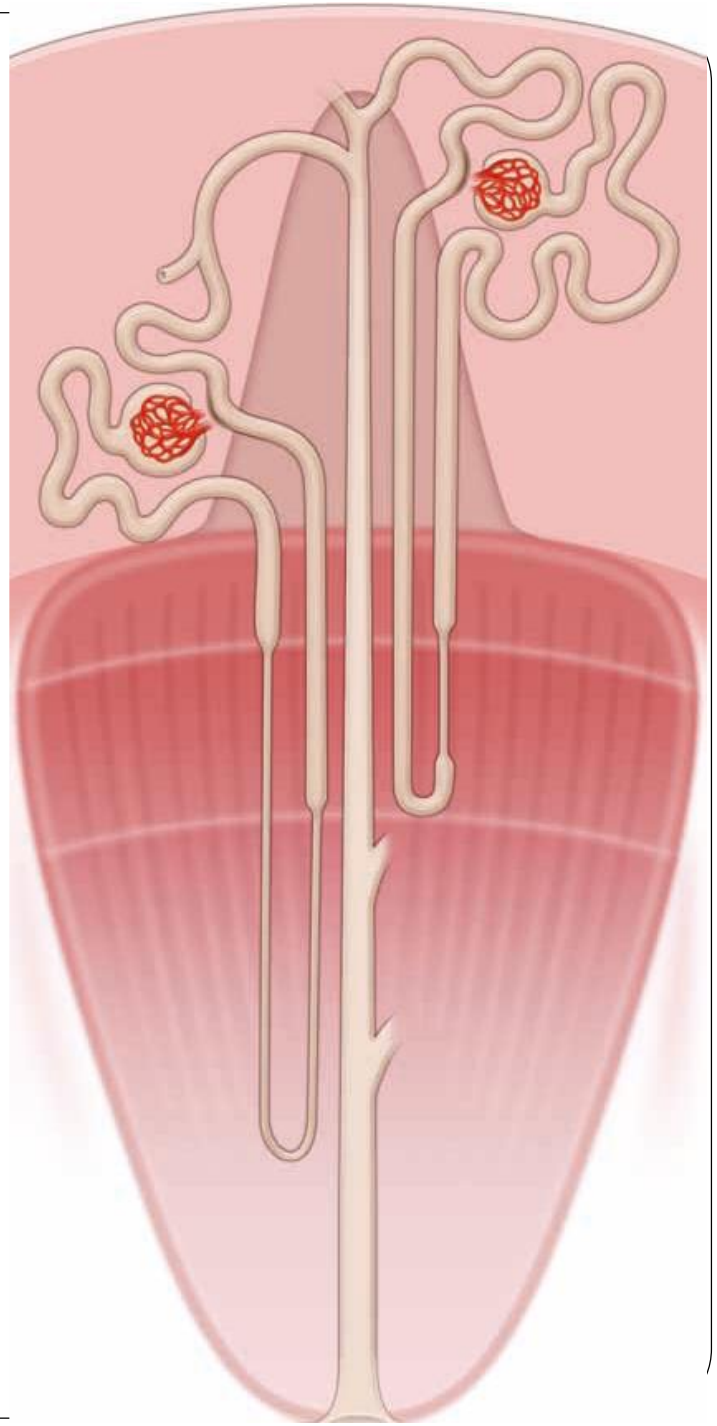
- Divided into cortex and medulla
- The cortex forms an outer shell and also forms columns that lie between the individual units of the medulla
- The medulla is composed of medullary pyramids the base of each cone is continuous with the inner limit of the cortex and the apex of the pyramid protrudes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

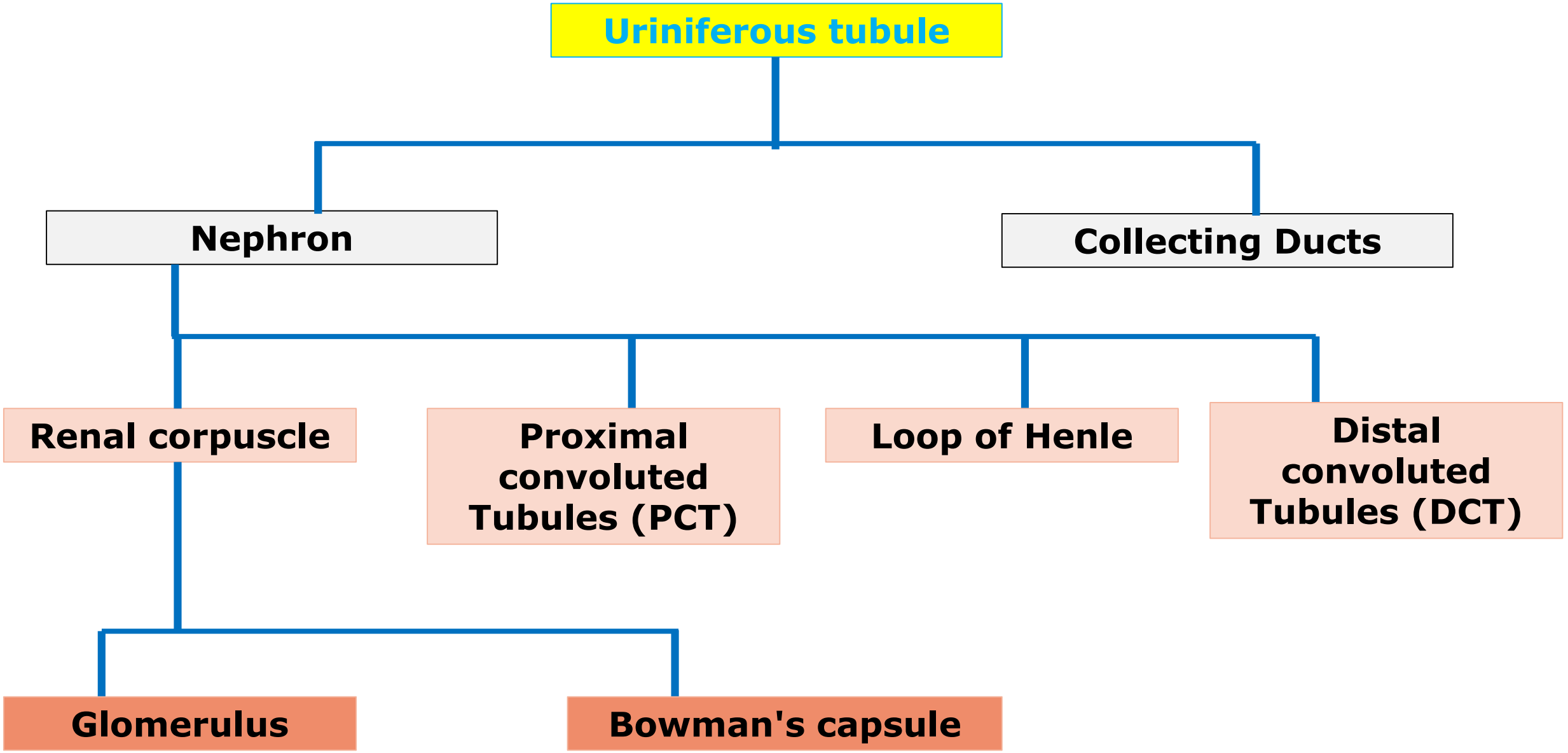


Kidney – lobes and lobules

- 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

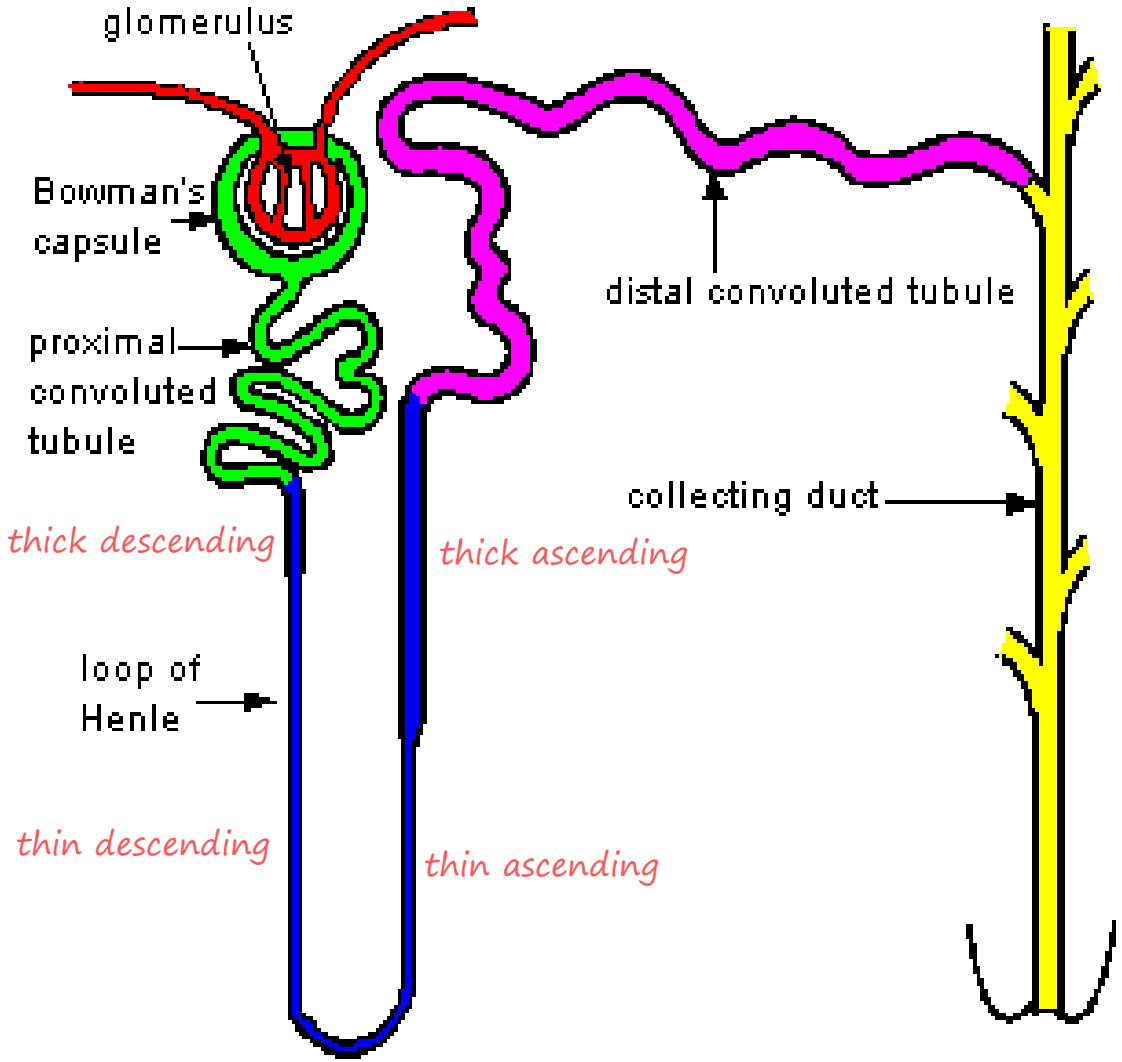
- ***Therefore, the lobule consists of a collecting duct and all the nephrons that it drains constituting the renal secretory unit***




Uriniferous tubule
Nephron
Collecting Ducts
Renal corpuscle
Proximal convoluted Tubules (PCT)
Loop of Henle
Distal convoluted Tubules (DCT)
Glomerulus
Bowman's capsule

Uriniferous tubule

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

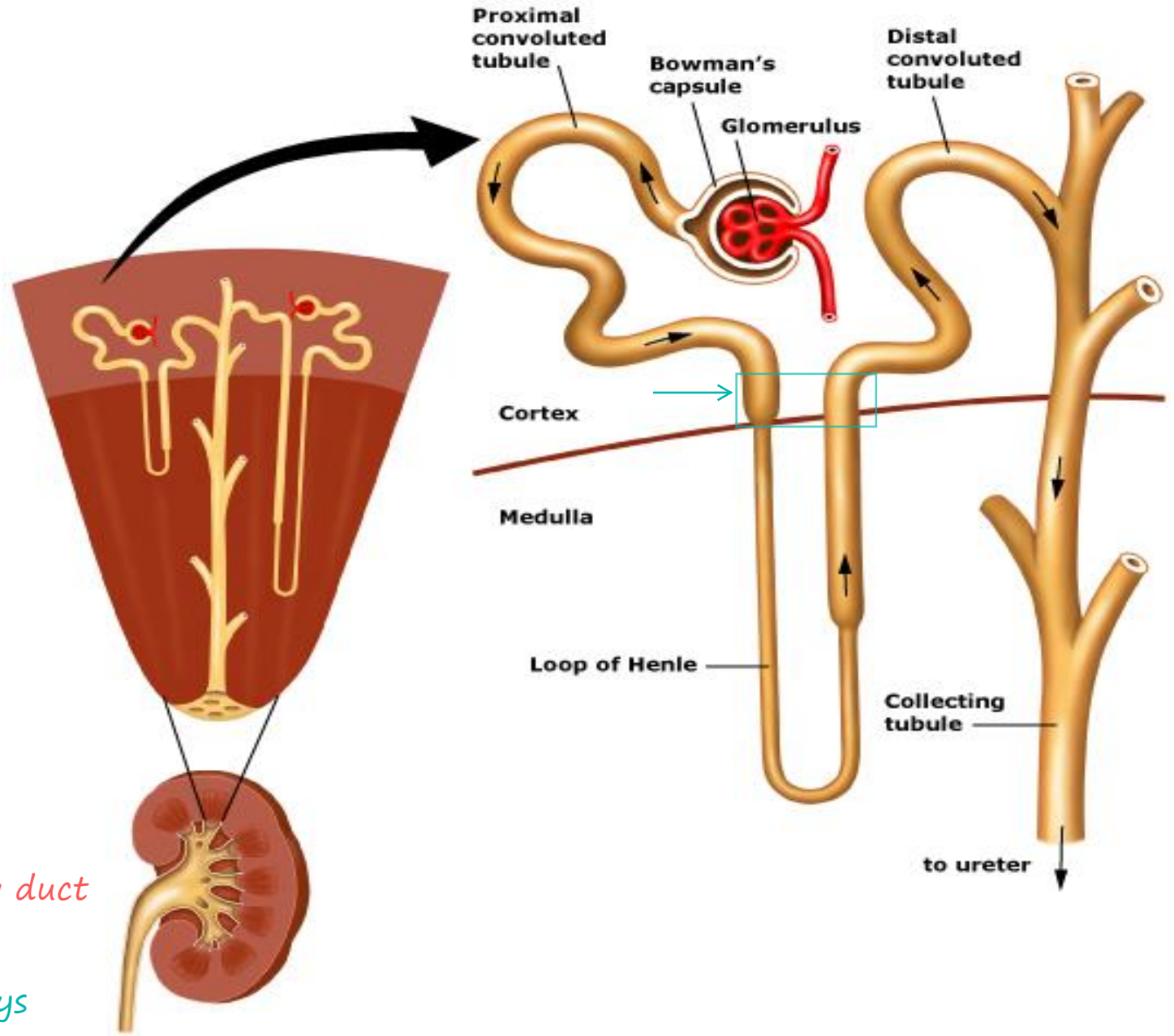


Nephron

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

In the cortex: renal corpuscle, PCT, and DCT
In the medulla: thin descending loop of henle, ascending loop, and lower part of the collecting duct

parts of loop of henle (arrow) + upper part of collecting duct are located in the medullary rays

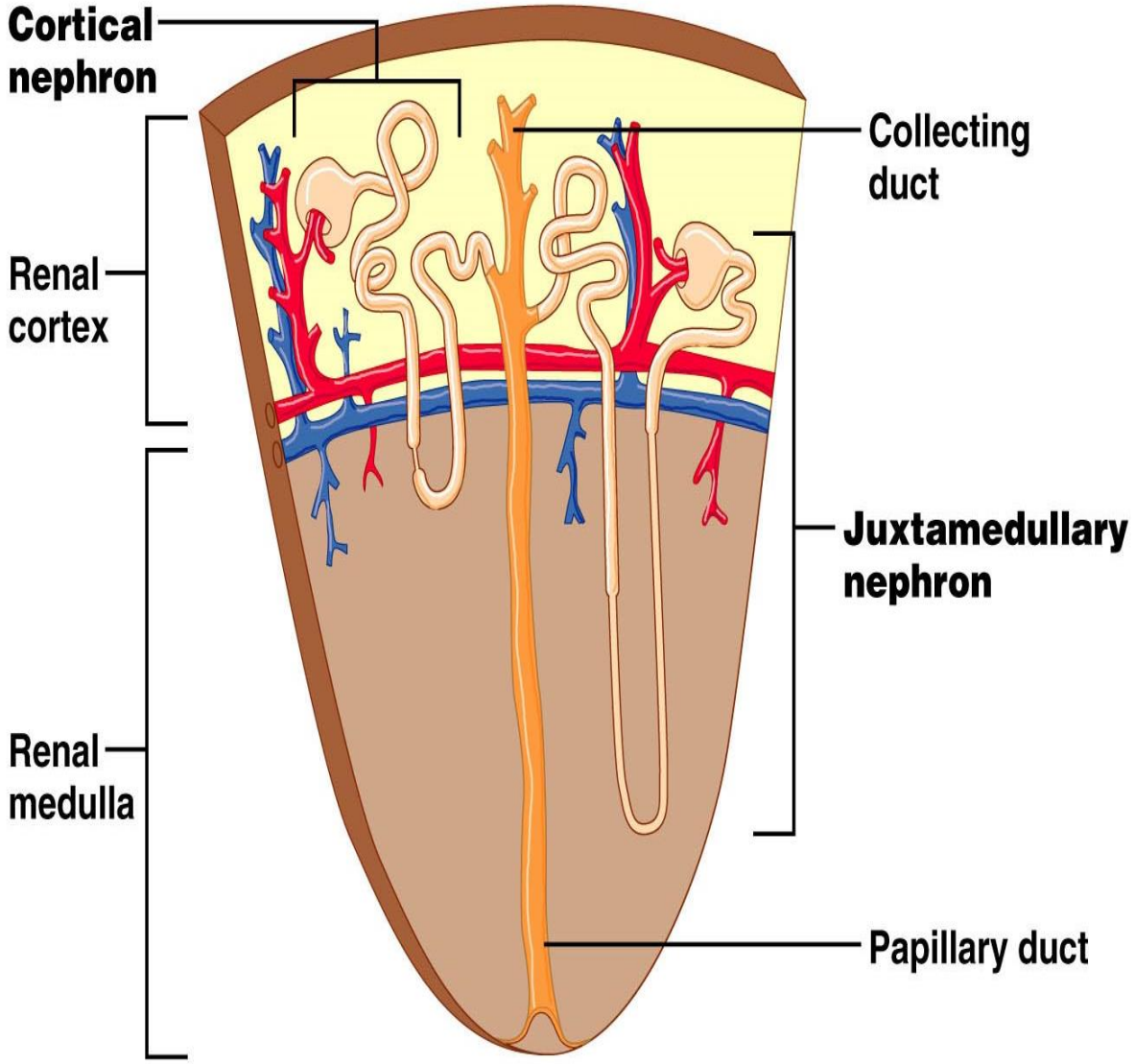


Nephron

Two types:

A. **Cortical nephrons**
- Most numerous
- Present in superficial part of cortex
- Loop of Henle are short

B. **Juxatamedullary 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.

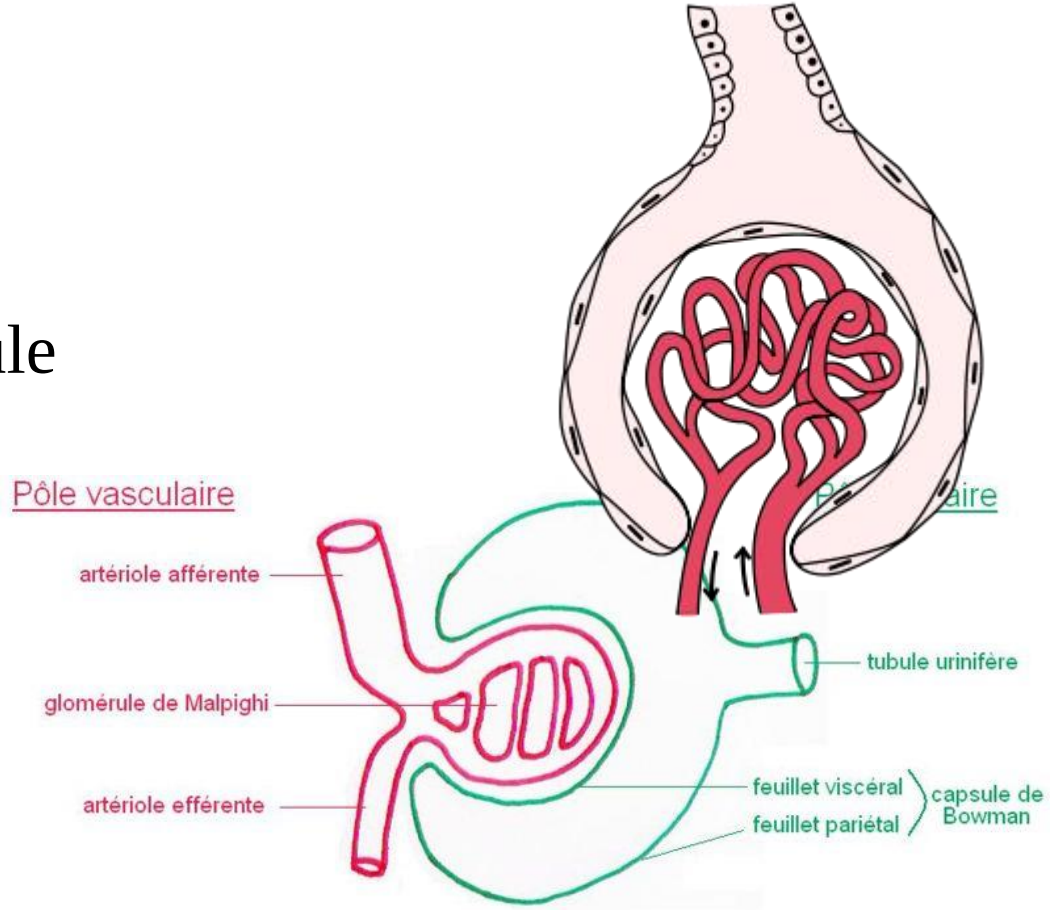
In case of (unilateral nephrectomy), as in kidney donation for transplant the remaining kidney undergoes compensatory growth with cellular hypertrophy in the proximal parts of the nephron tubules and an increase in the rate of filtration, which allow normal renal function to continue

Renal Corpuscle

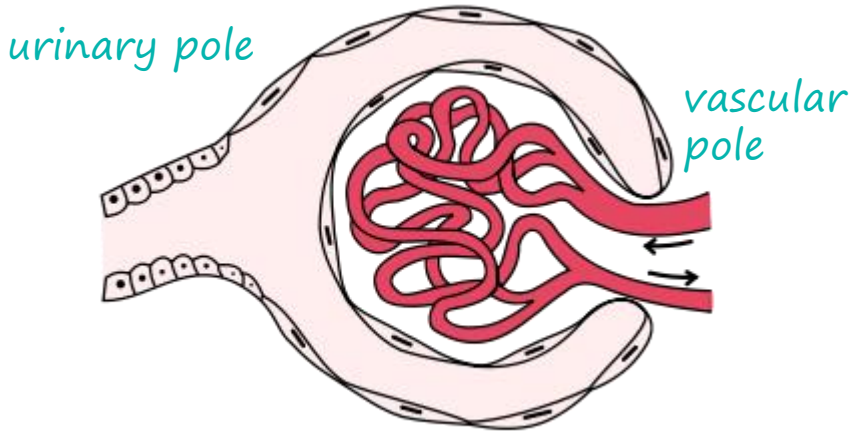
- Oval to round structure
- Found in renal cortex.
- Composed of glomerulus & Bowman's capsule

Function

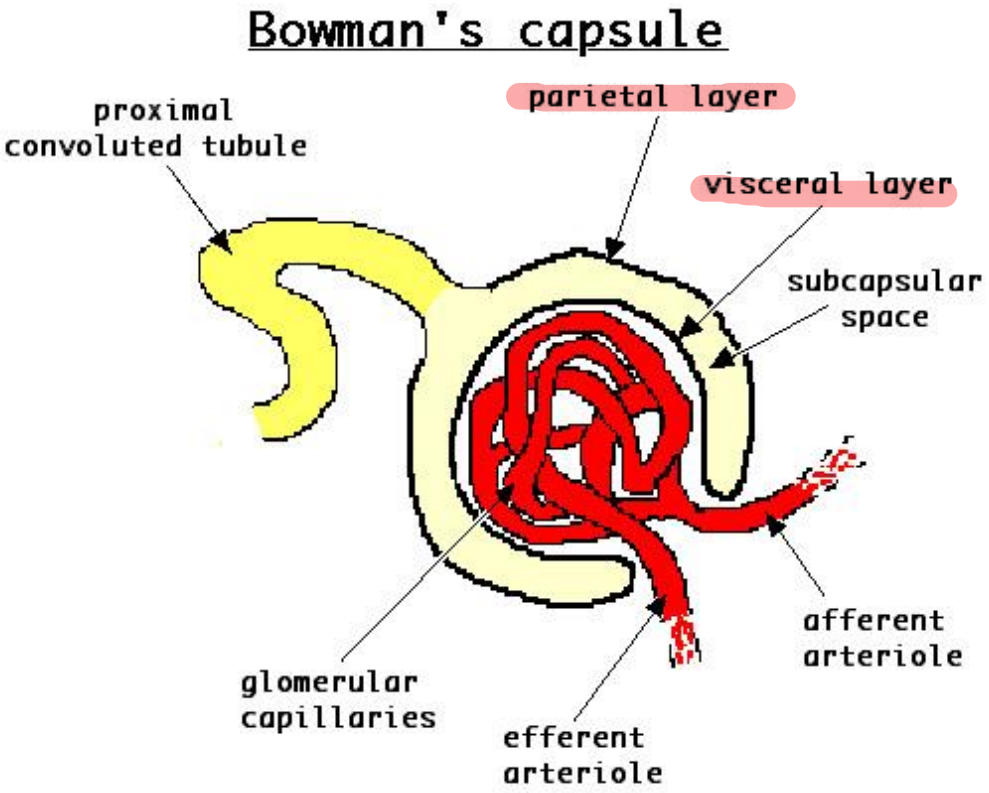
- Forms the glomerular filtrate by dialysis of the plasma (plasma minus its proteins) through filtration barrier



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

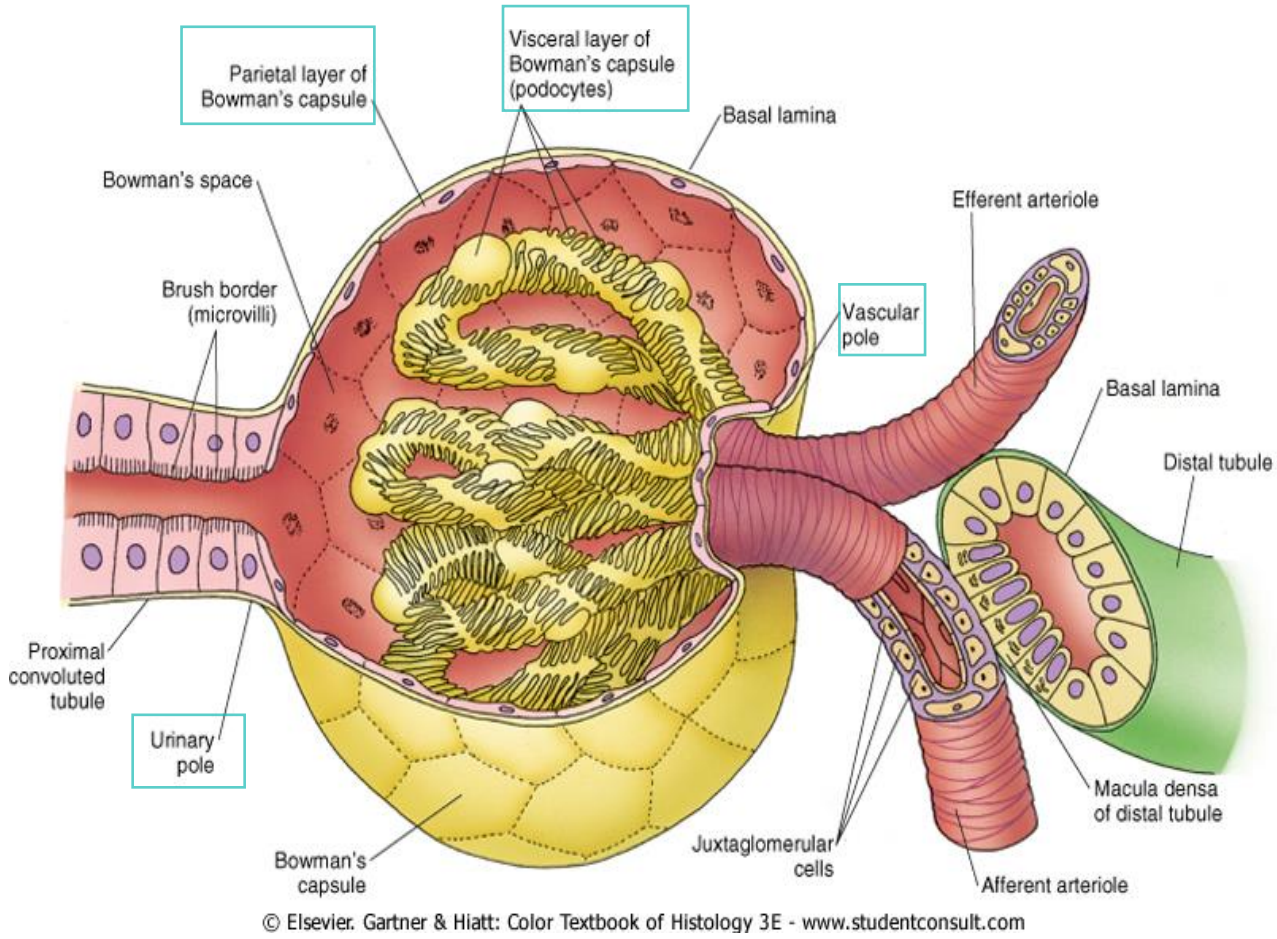


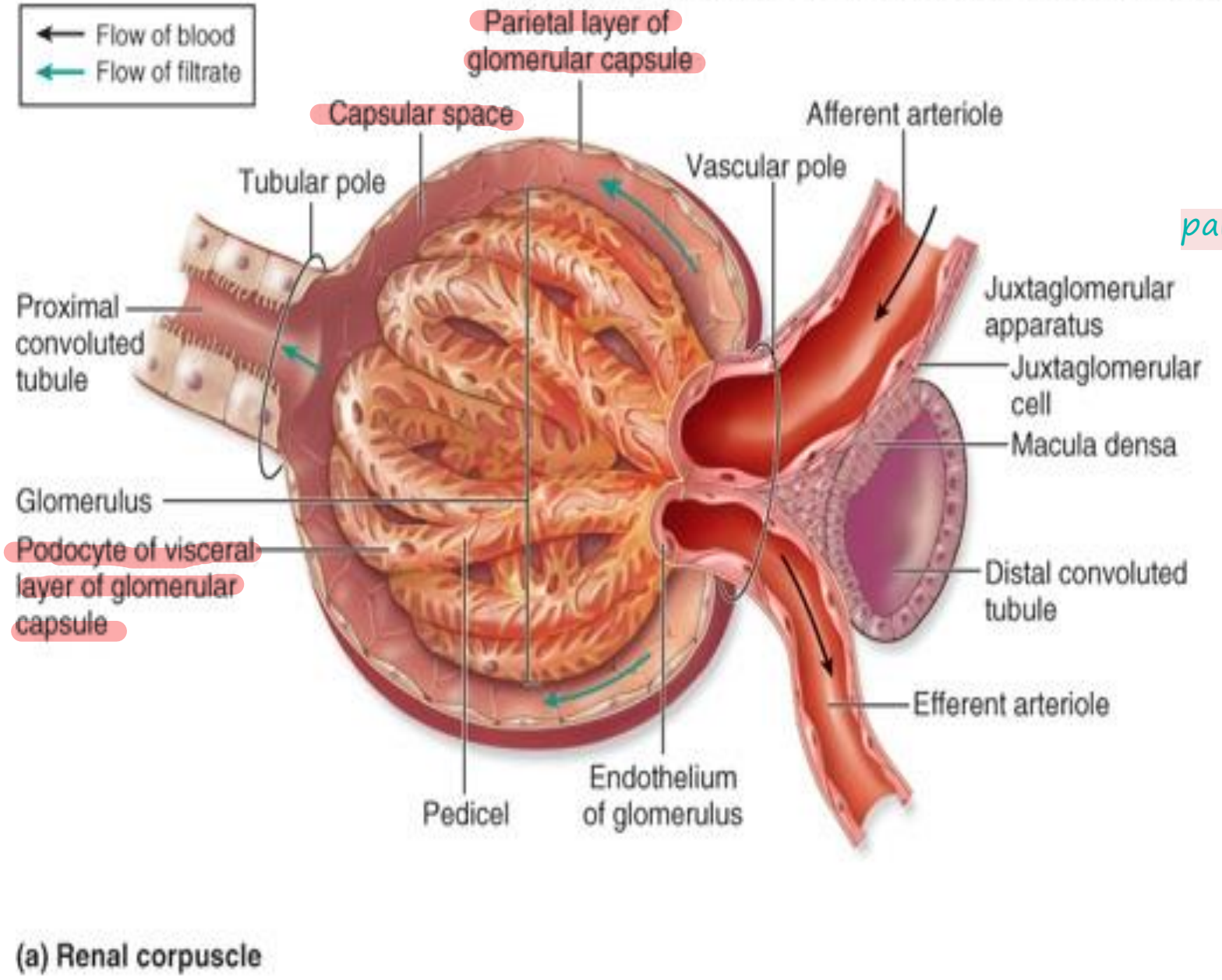
Bowman’s capsule

It has two layers:

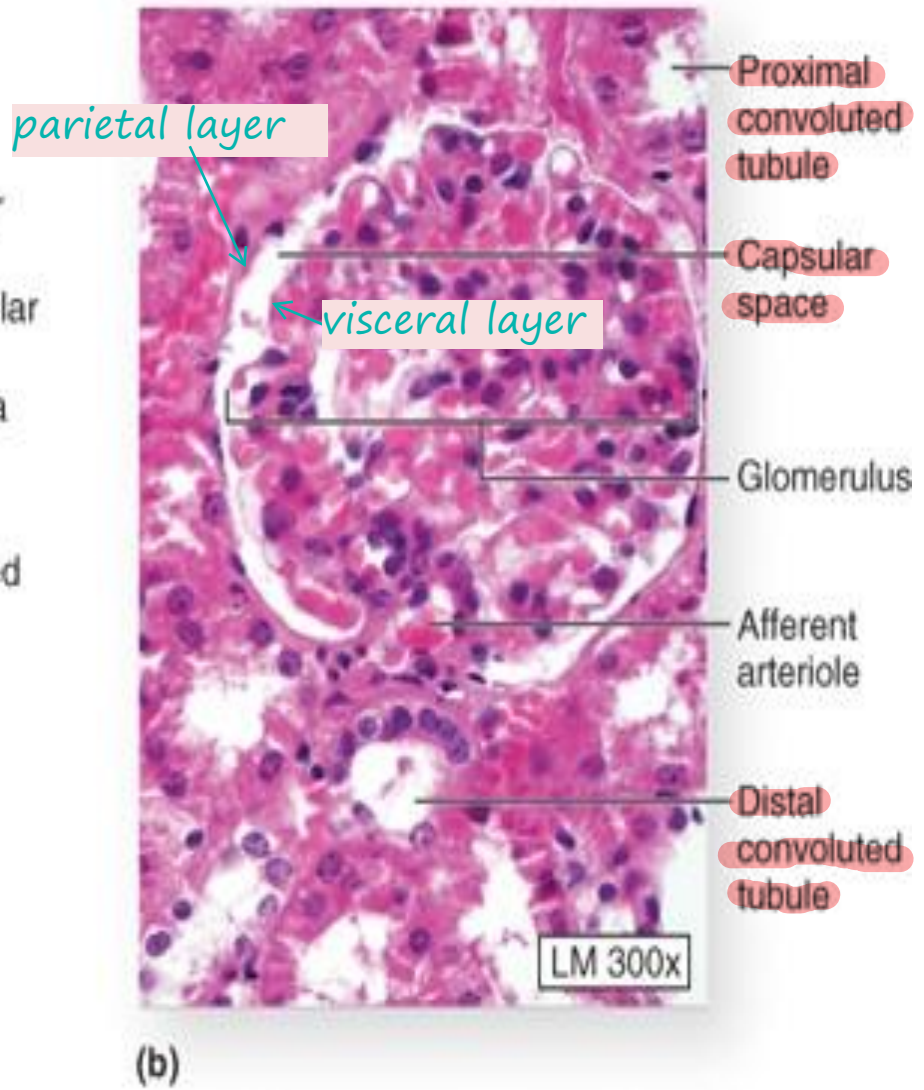
- Outer (parietal) layer
  - Called capsular epithelium
  - Lined by simple squamous epithelium
- Inner (visceral) layer
  - Called glomerular epithelium
  - Lined by modified epithelium (podocytes)

➢ Between the two layers is the urinary space which receives the fluid filtered through the capillary wall and visceral layer





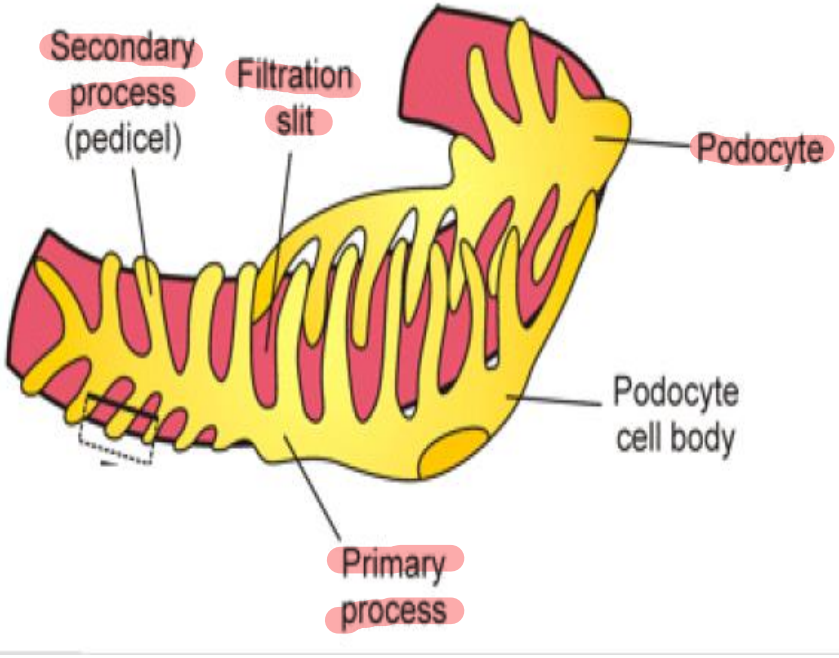
(a) Renal corpuscle

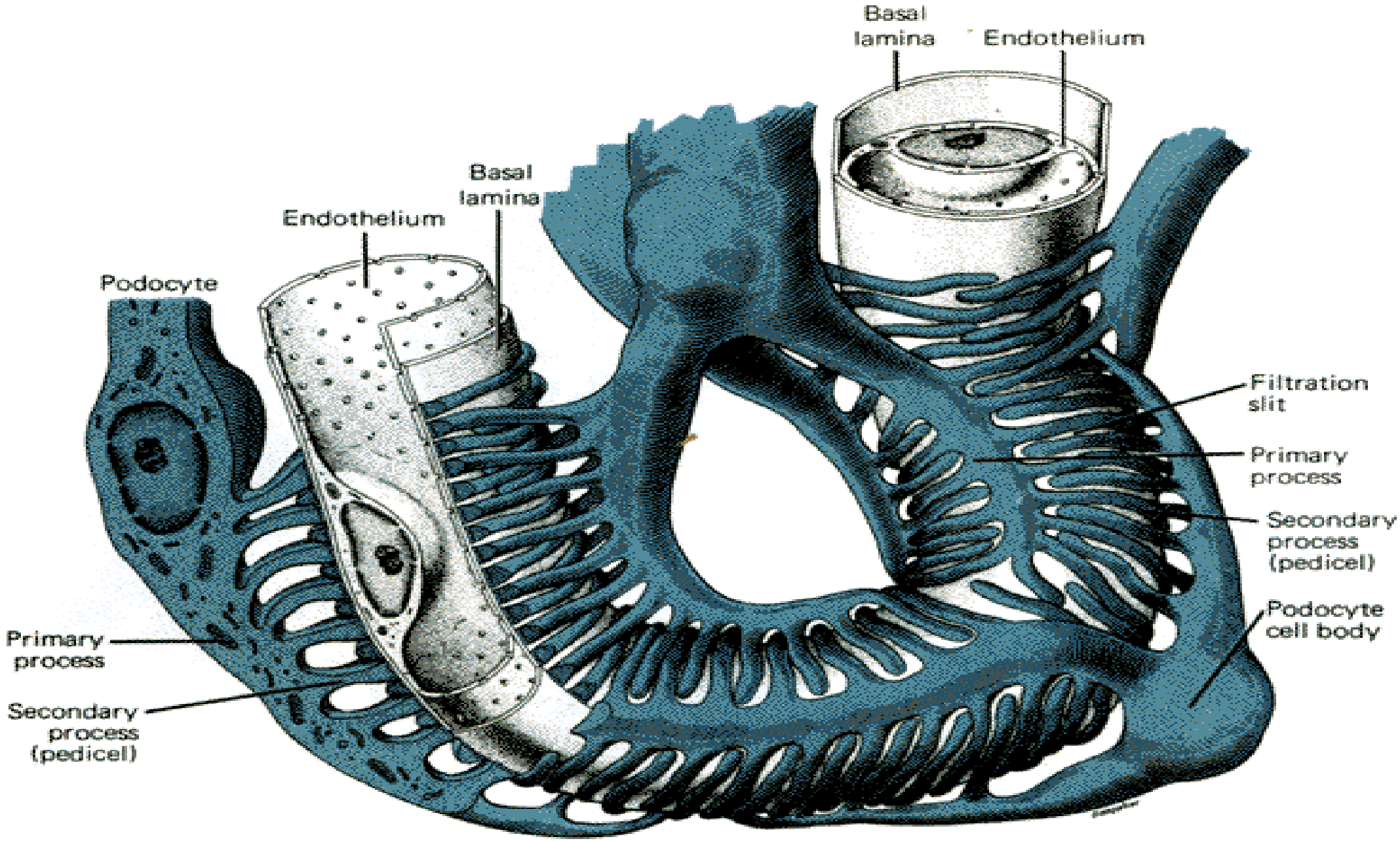


(b)

Podocytes

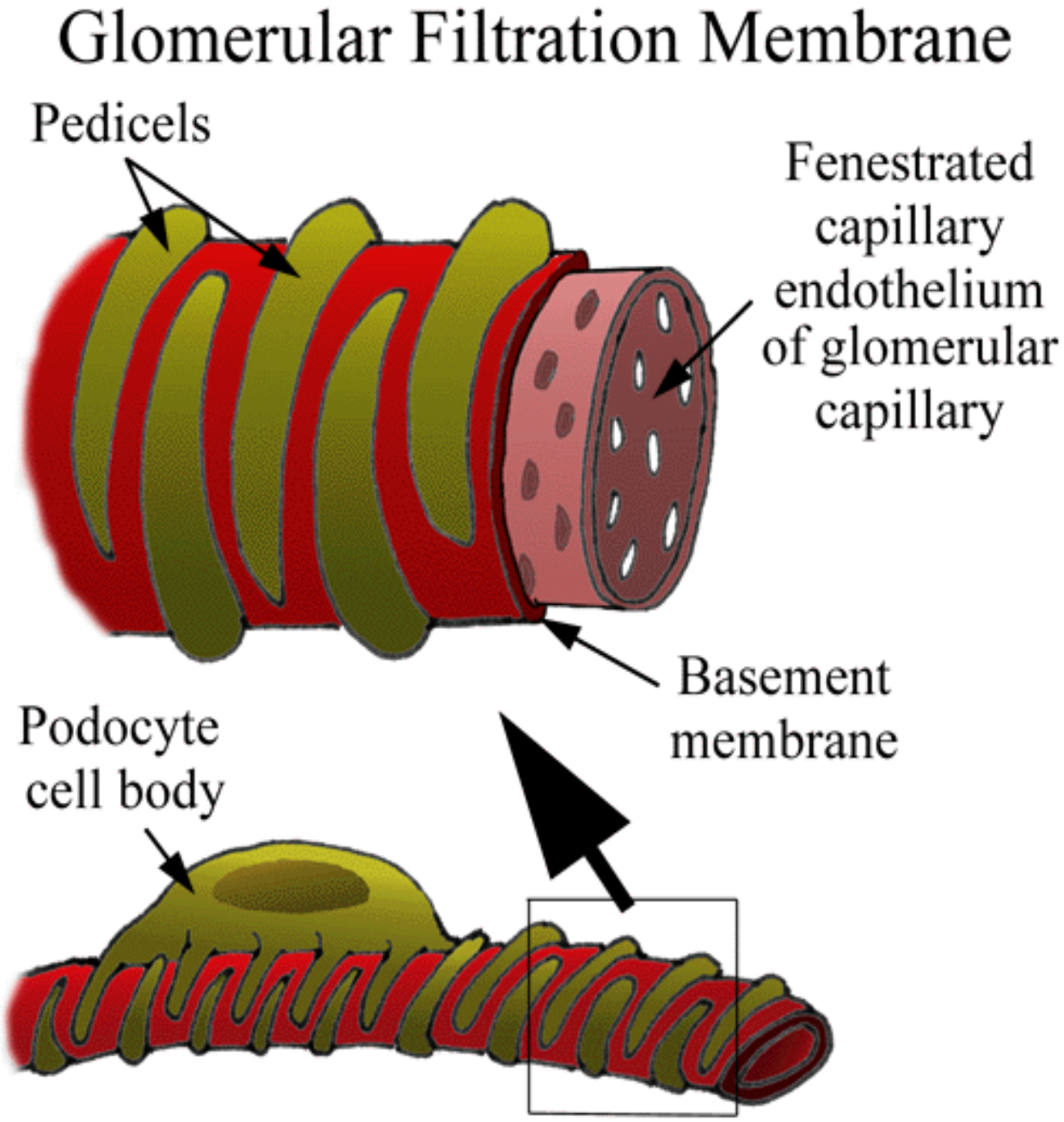
- Modified flat cells (stellate in shape)
- Have numerous long **primary** cytoplasmic (major) processes resemble feet
- Each primary process bears many **secondary** processes, known as pedicels which:
  - Completely envelop the glomerular capillaries
  - Terminate around BM of glomerular capillaries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




Basal lamina
Endothelium
Basal lamina
Endothelium
Podocyte
Filtration slit
Primary process
Secondary process (pedicel)
Podocyte cell body
Primary process
Secondary process (pedicel)

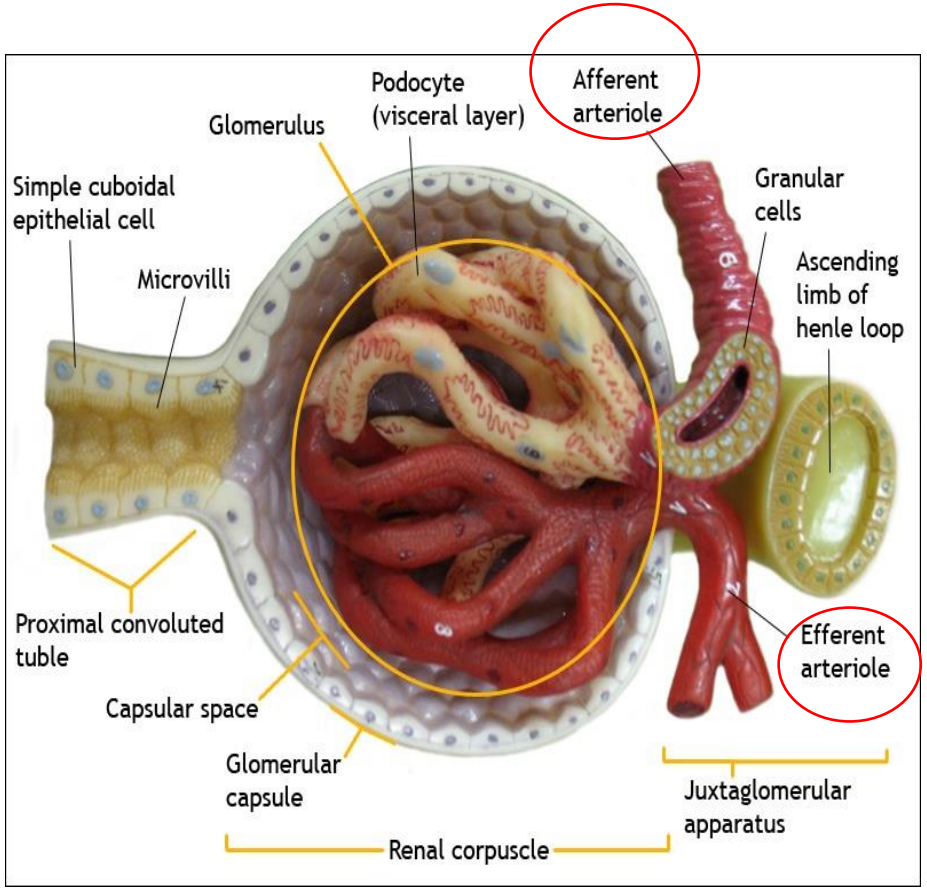
Function of Podocytes

- 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

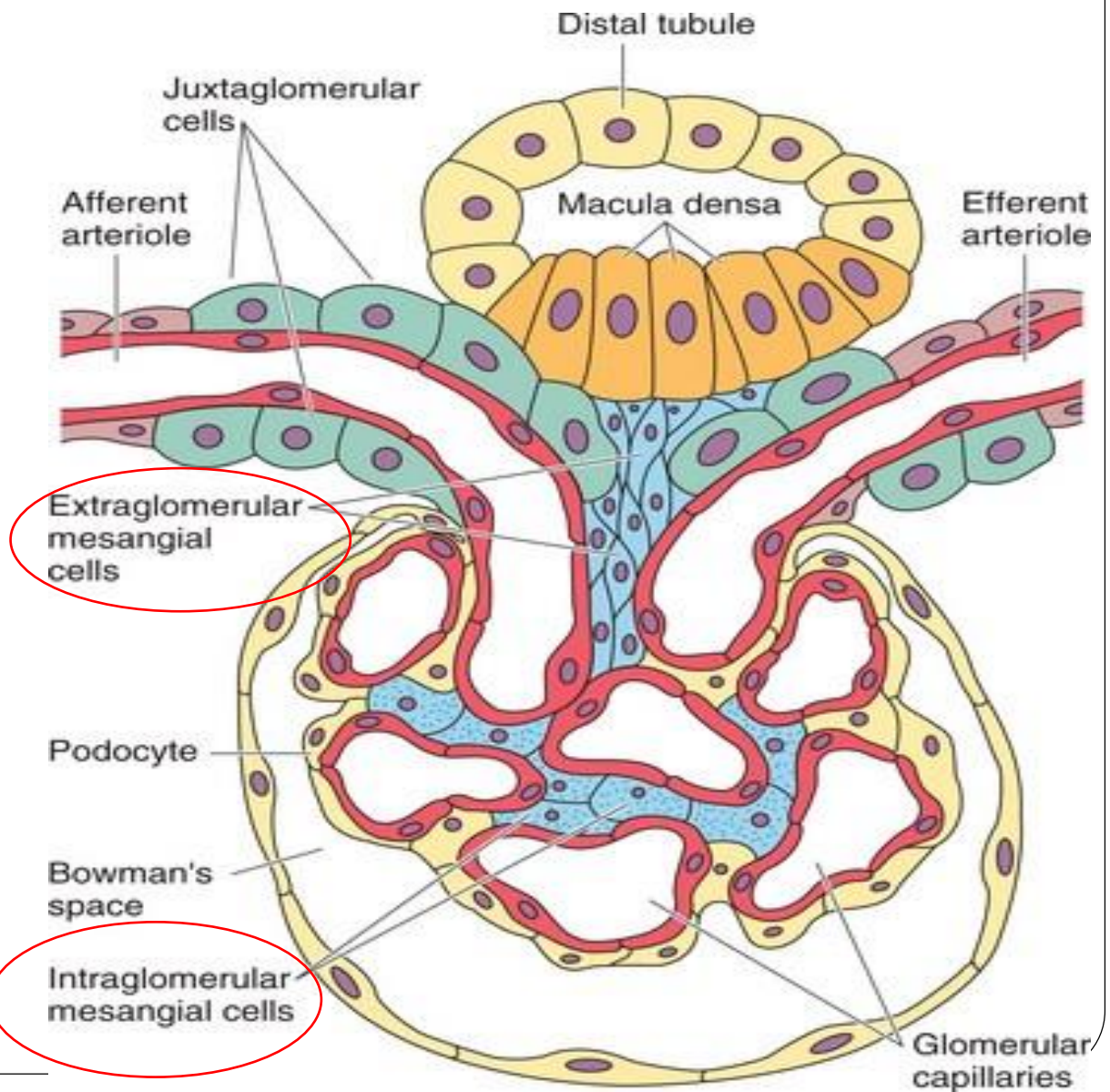
(Gr. *mesos*, in the midst + *angion*, vessel)

Location

- within stalk of capillary tuft (intraglomerular mesangium) as well as the vascular pole (extraglomerular mesangium) *between afferent and efferent arterioles*

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



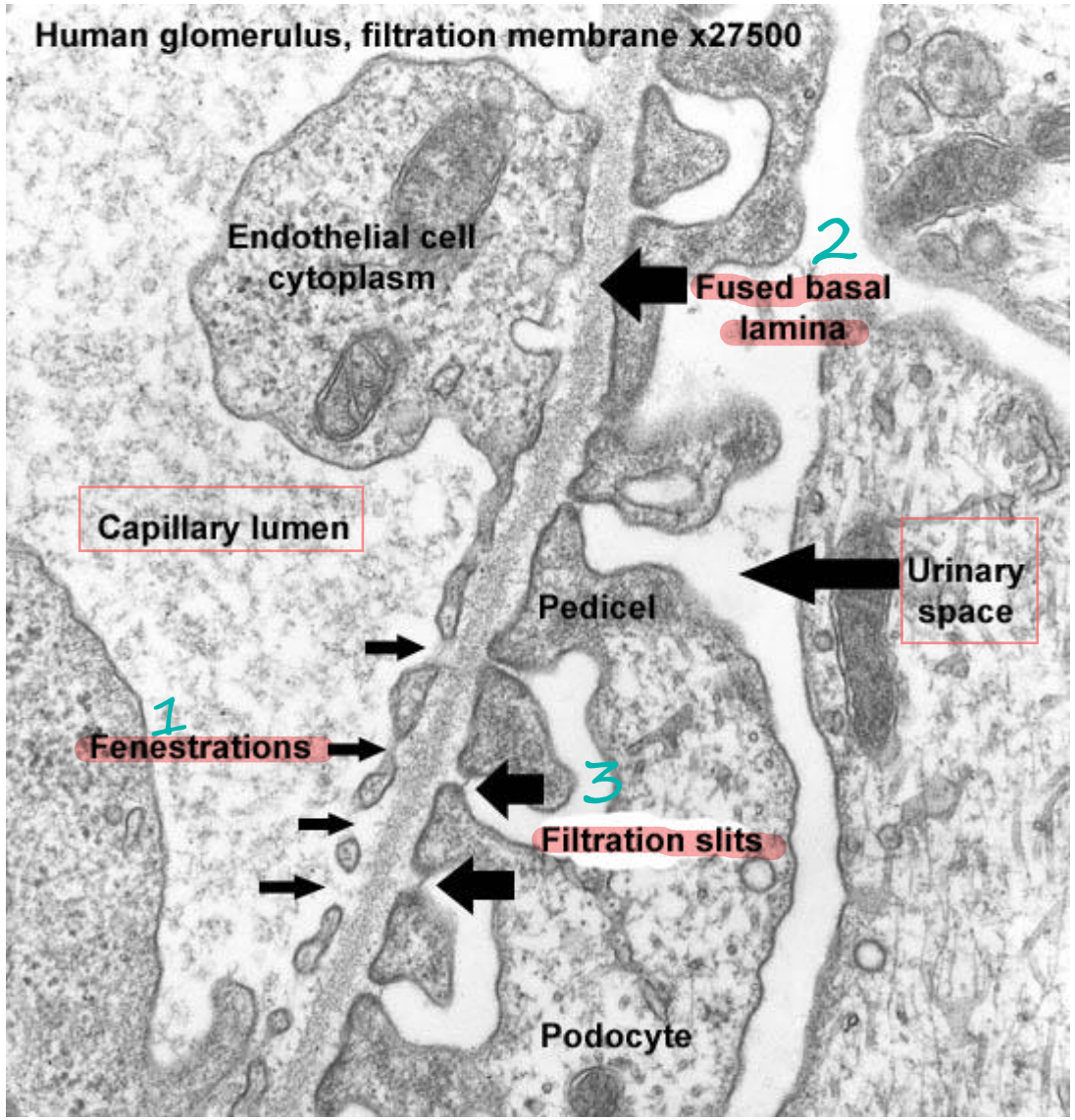
Blood renal barrier (filtration barrier)

between lumen of blood capillaries and the podocyes

fenestrated endothelium -> basement membrane -> filtration slits covered by diaphragmatic membrane

- 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

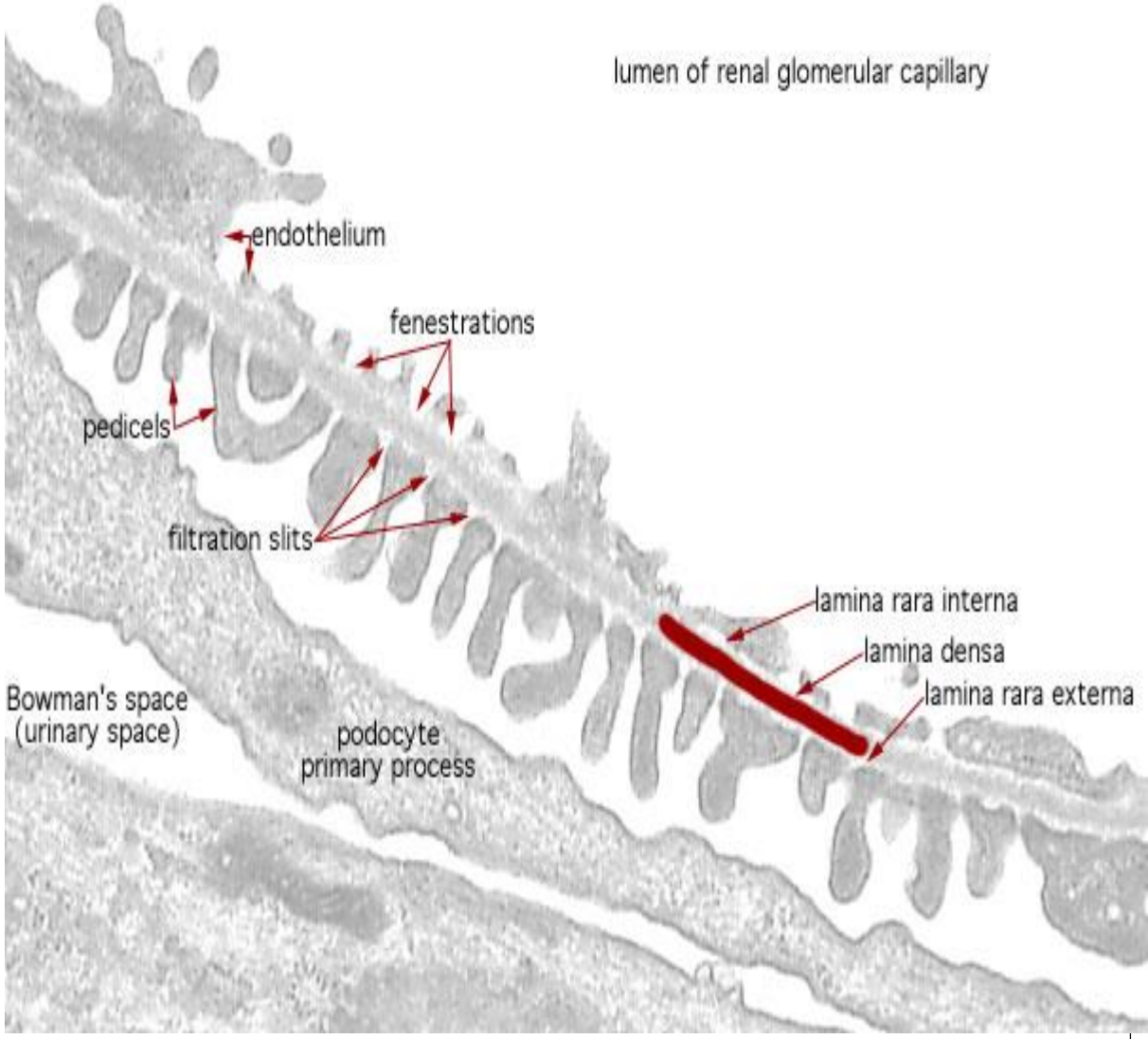
By EM the BM has 3 layers:

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

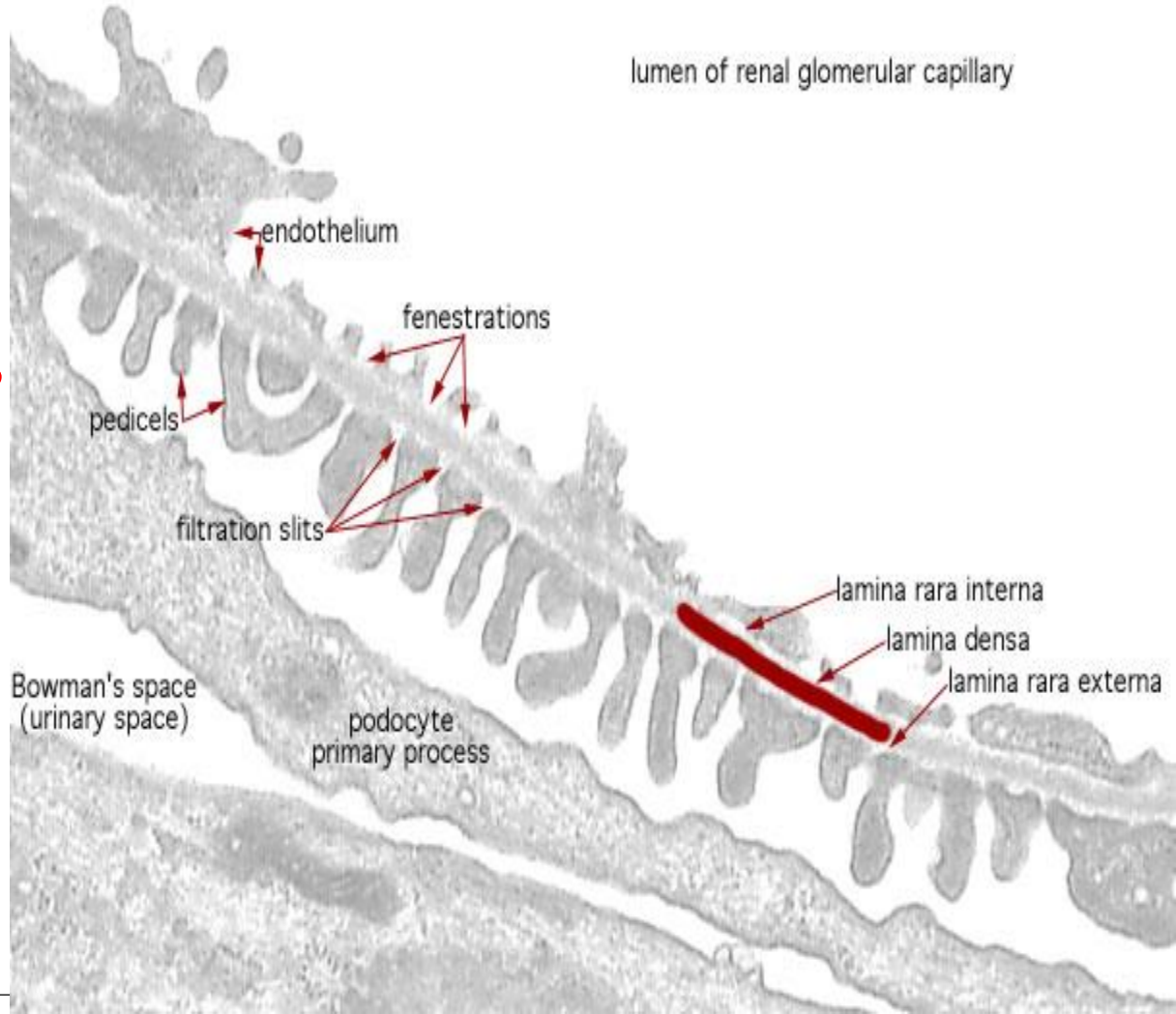


Slit diaphragms

- 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

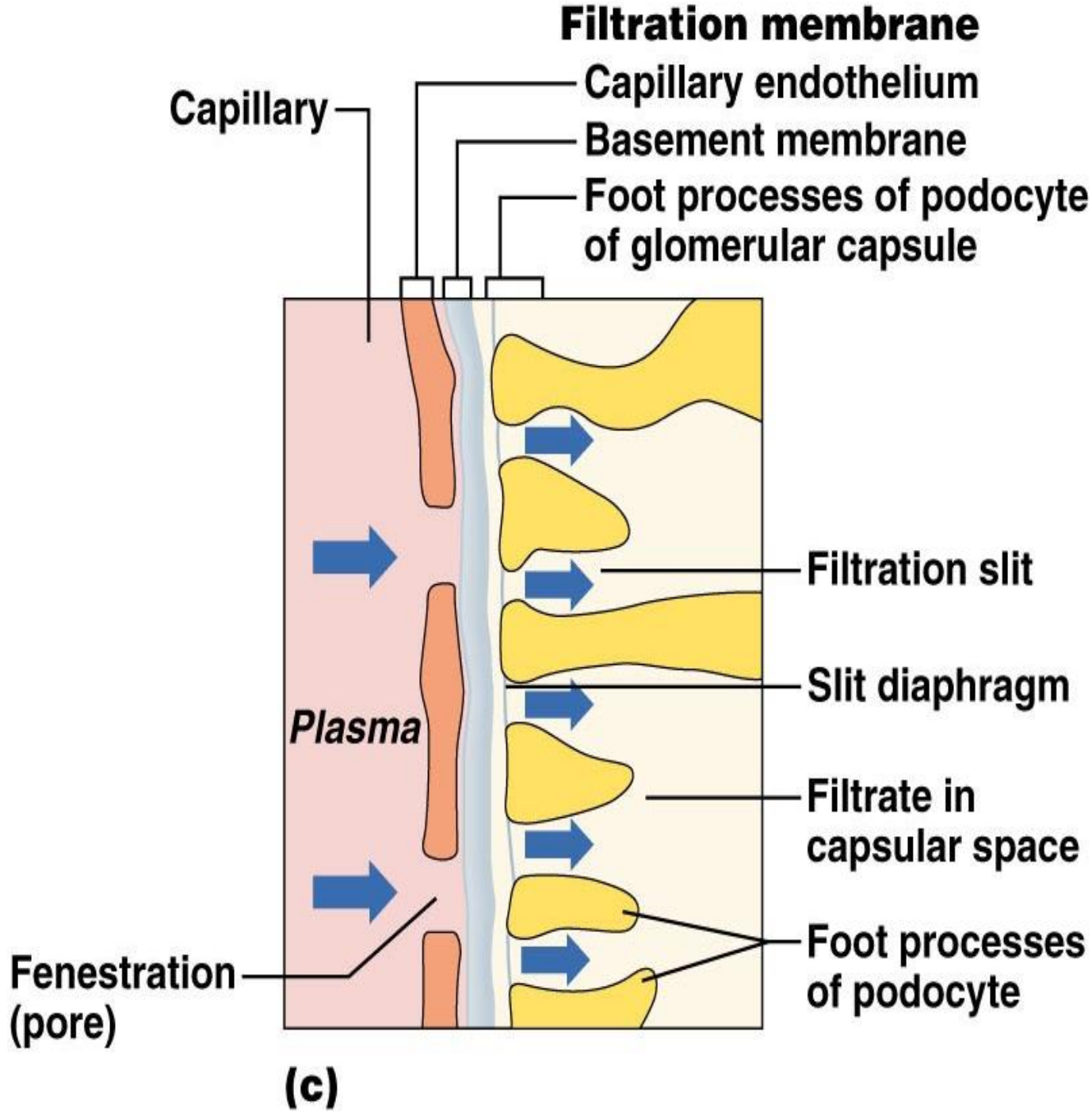
Function of the filtration barrier:

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



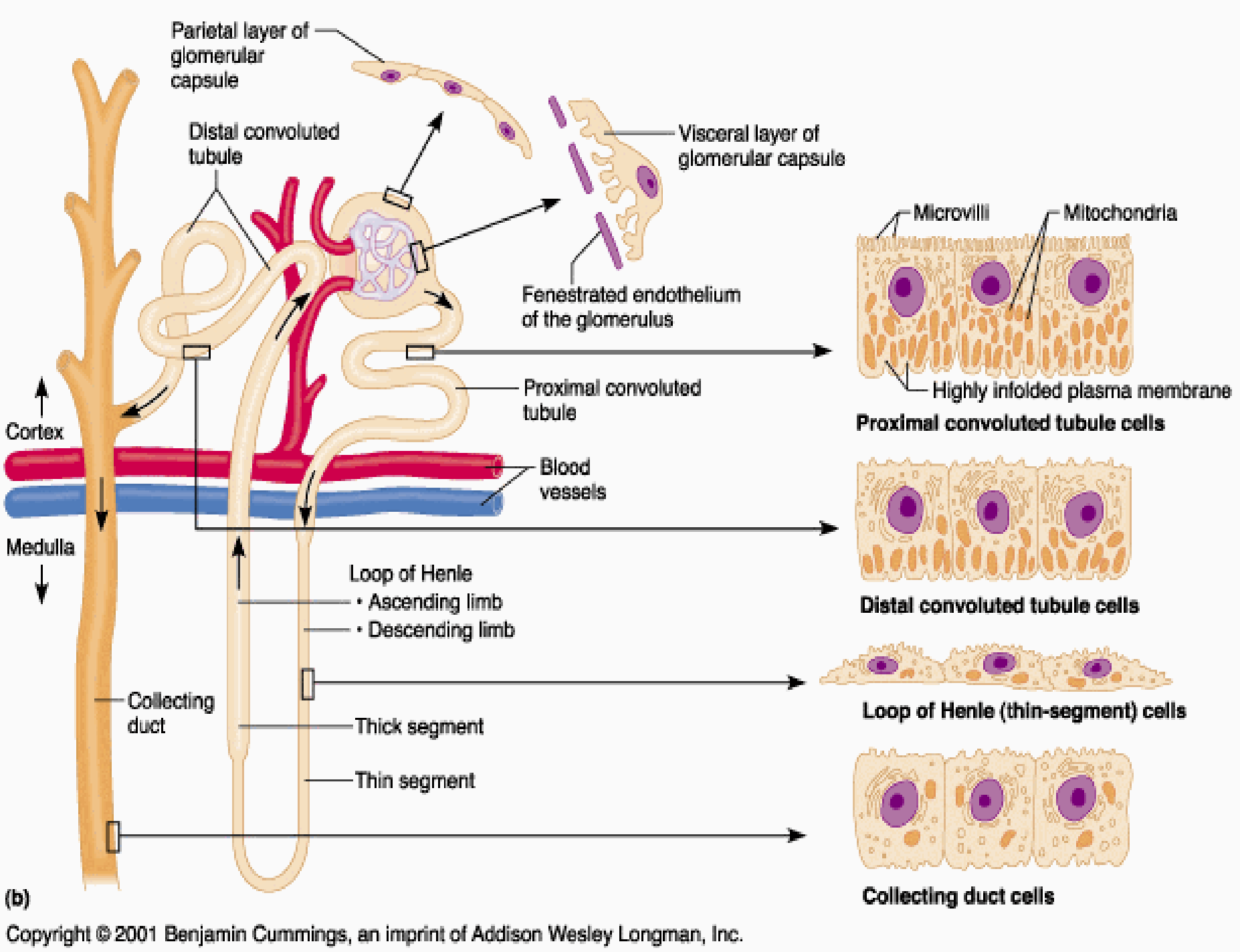
Diabetes mellitus and glomerulonephritis

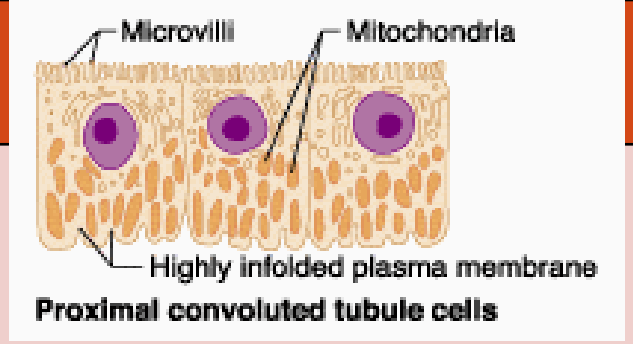
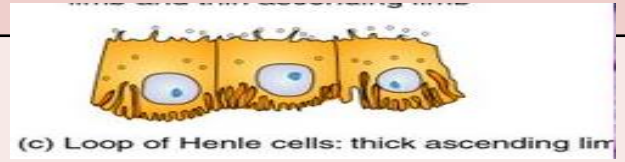
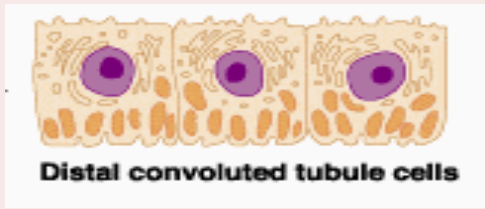
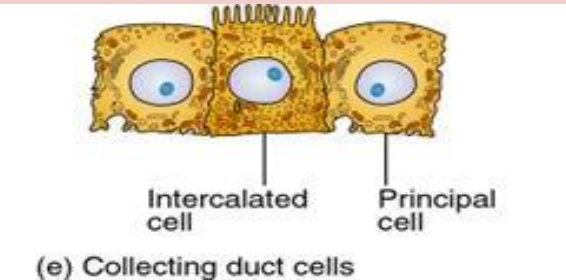
The glomerular filter is altered and becomes much more permeable to proteins, so the patient has (**proteinuria**).


Filtration membrane
Capillary endothelium
Basement membrane
Foot processes of podocyte of glomerular capsule
Capillary
Filtration slit
Slit diaphragm
Plasma
Filtrate in capsular space
Foot processes of podocyte
Fenestration (pore)
(c)

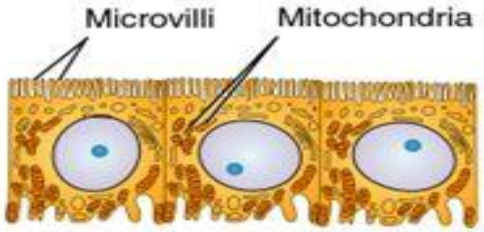
Renal tubules

- PCT
- Loop of Henle
- DCT



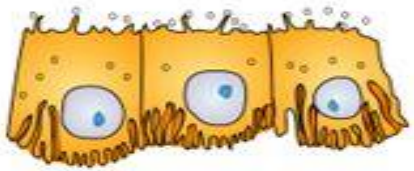
Region of Tubule	Histological Features	Locations Major	
PCT	Simple cuboidal epithelium; cells well-stained, with numerous mitochondria, prominent basal folds and long microvilli, lumens often occluded	Cortex	
Loop of Henle Thick limbs	Simple cuboidal epithelium; no microvilli, but many mitochondria	Medullary rays and Medulla	
Loop of Henle Thin limbs	Simple squamous epithelium; few mitochondria	Medulla	
DCT	Simple cuboidal epithelium; cells smaller than in PCT, short microvilli and basolateral folds, more empty lumens	Cortex	
Collecting system **Principal cells**	Cuboidal to columnar (closer to the DCT & cortex; closer to the medulla) pale-staining, distinct cell membranes	Medullary rays and medulla	
Intercalated cells	Few and scattered; slightly darker staining		

Histology of Renal Tubule & Collecting Duct



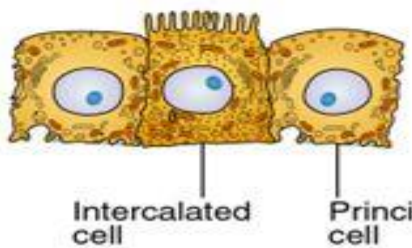
(a) Proximal convoluted tubule cells

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

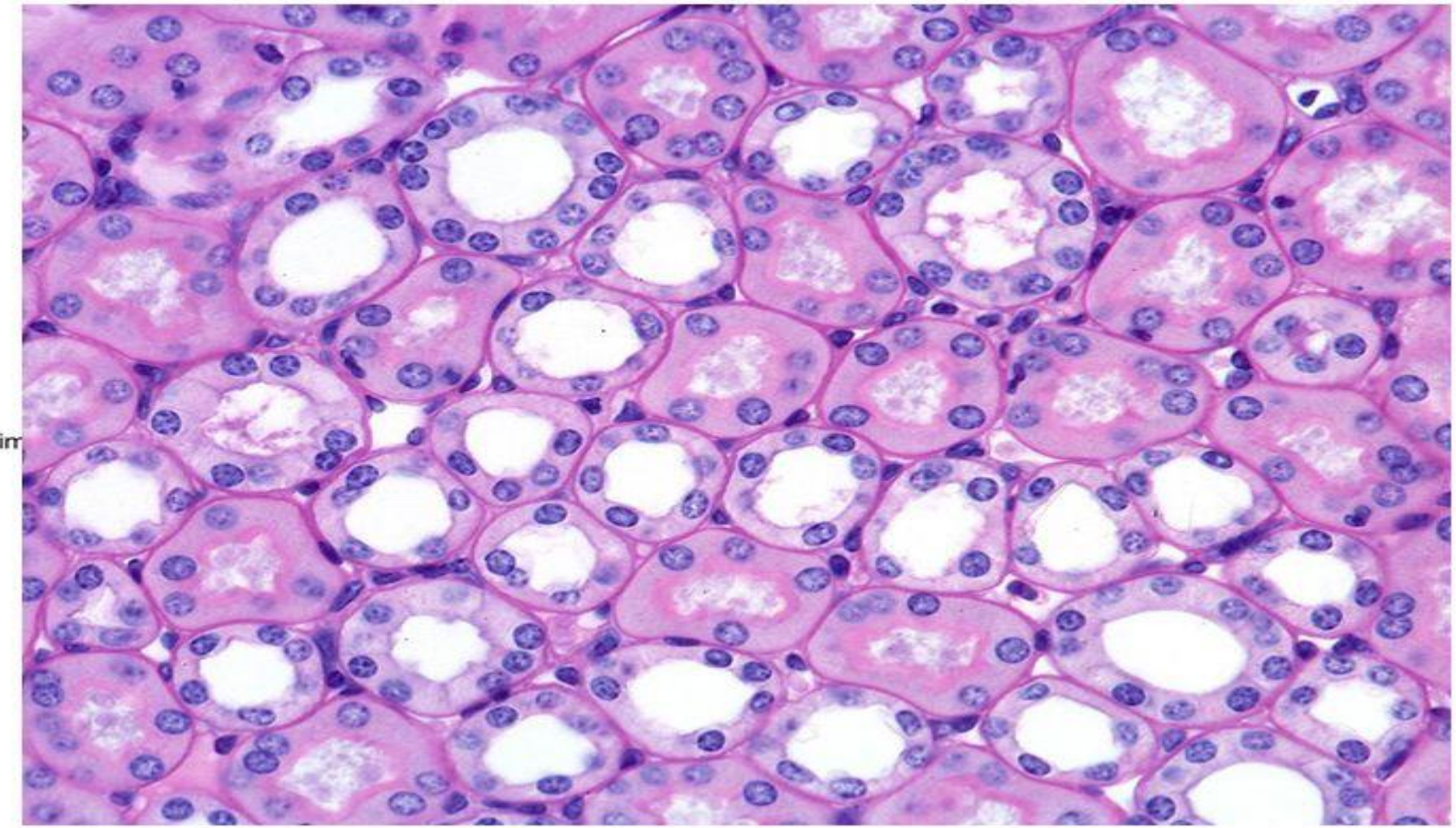


(c) Loop of Henle cells: thick ascending lim

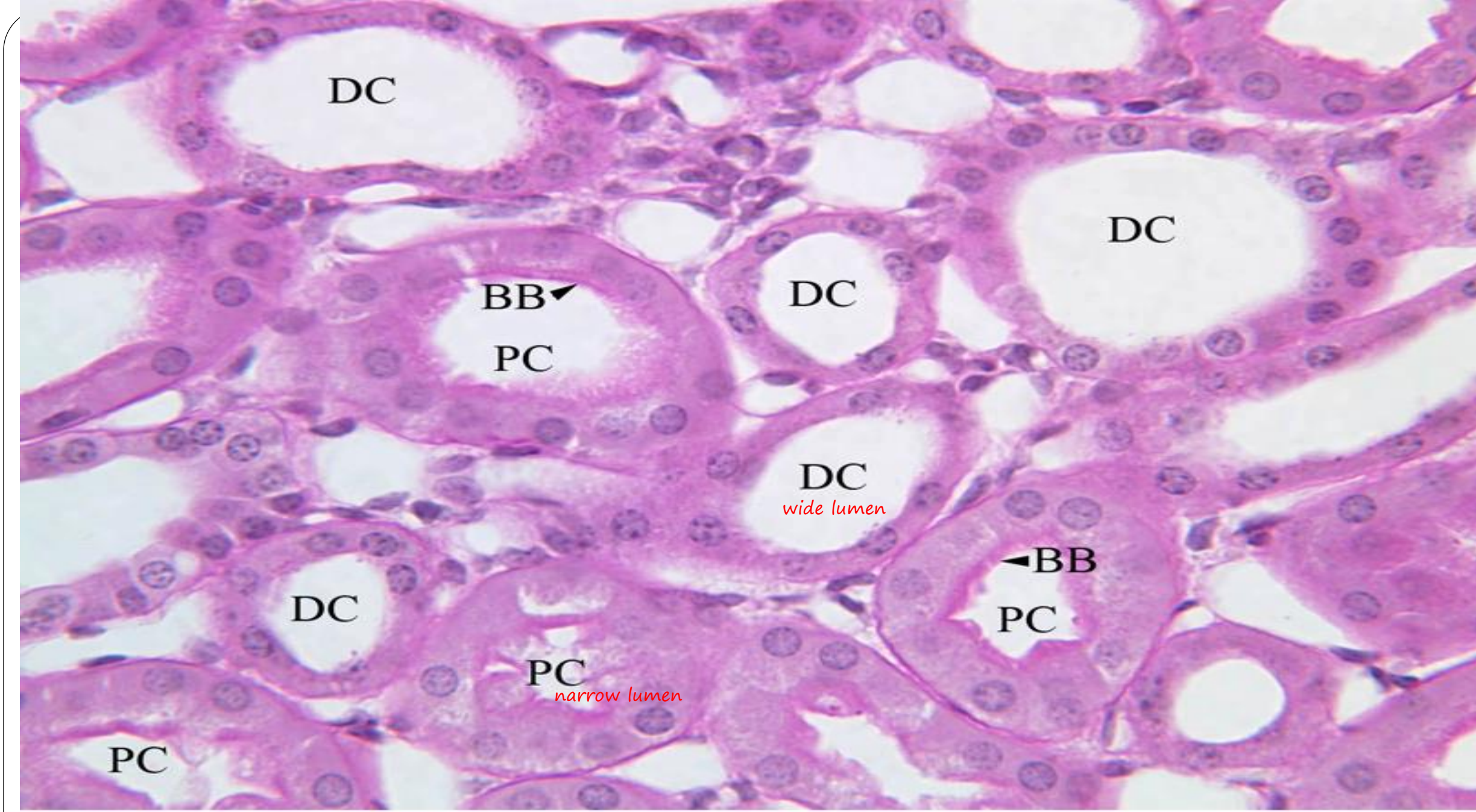
(d) Distal convoluted tubule cells



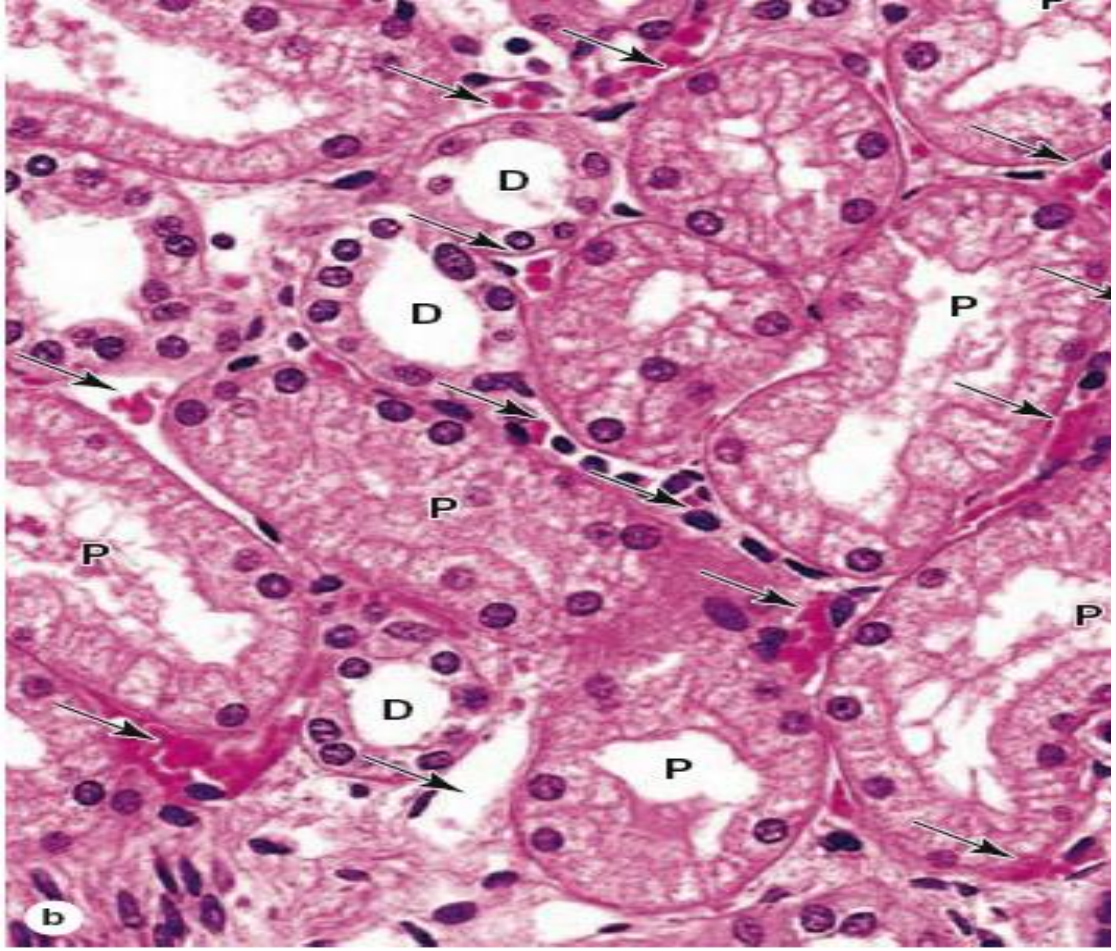
(e) Collecting duct cells

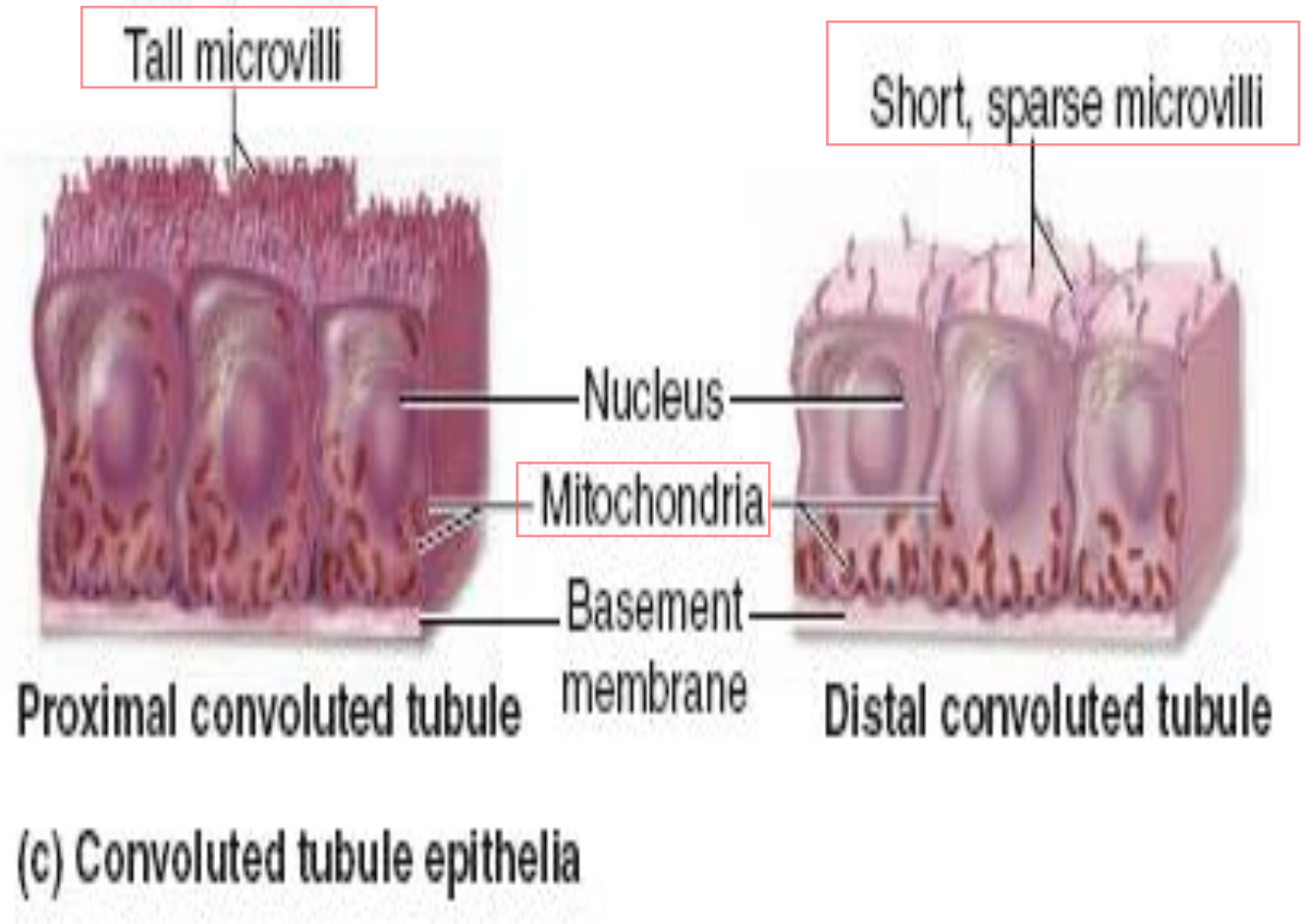


Region of Tubule	Functions (REED ONLY)
PCT	Reabsorption of all organic nutrients, all proteins, most water and electrolytes; secretion of organic anions and cations, H+, and NH4+
Loop of Henle Thick limbs	Active reabsorption of various electrolytes
Loop of Henle Thin limbs	Passive reabsorption of Na+ and Cl–
DCT	Reabsorption of electrolytes
Collecting system Principal cells	Regulated reabsorption of water & electrolytes; regulated secretion of K+
Collecting system Intercalated cells	Reabsorption of K+ (low-K+ diet); help maintain acid-base balance



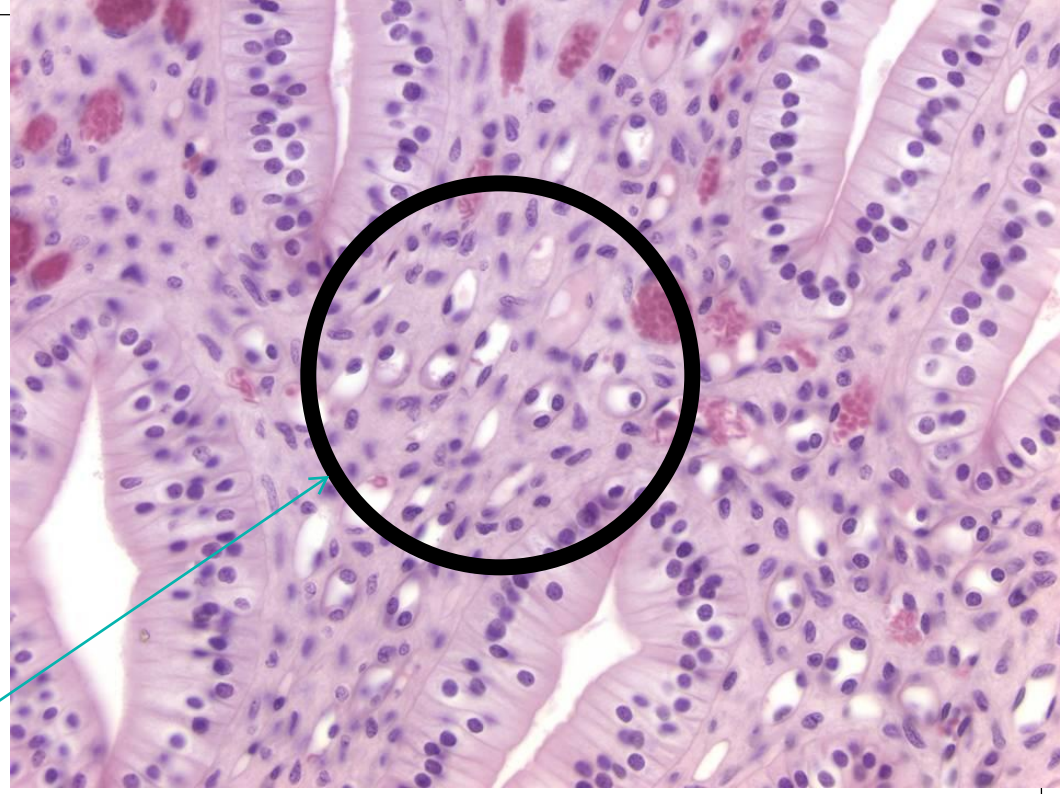
DC - distal convoluted tubule PC - proximal convoluted tubule BB - brush border





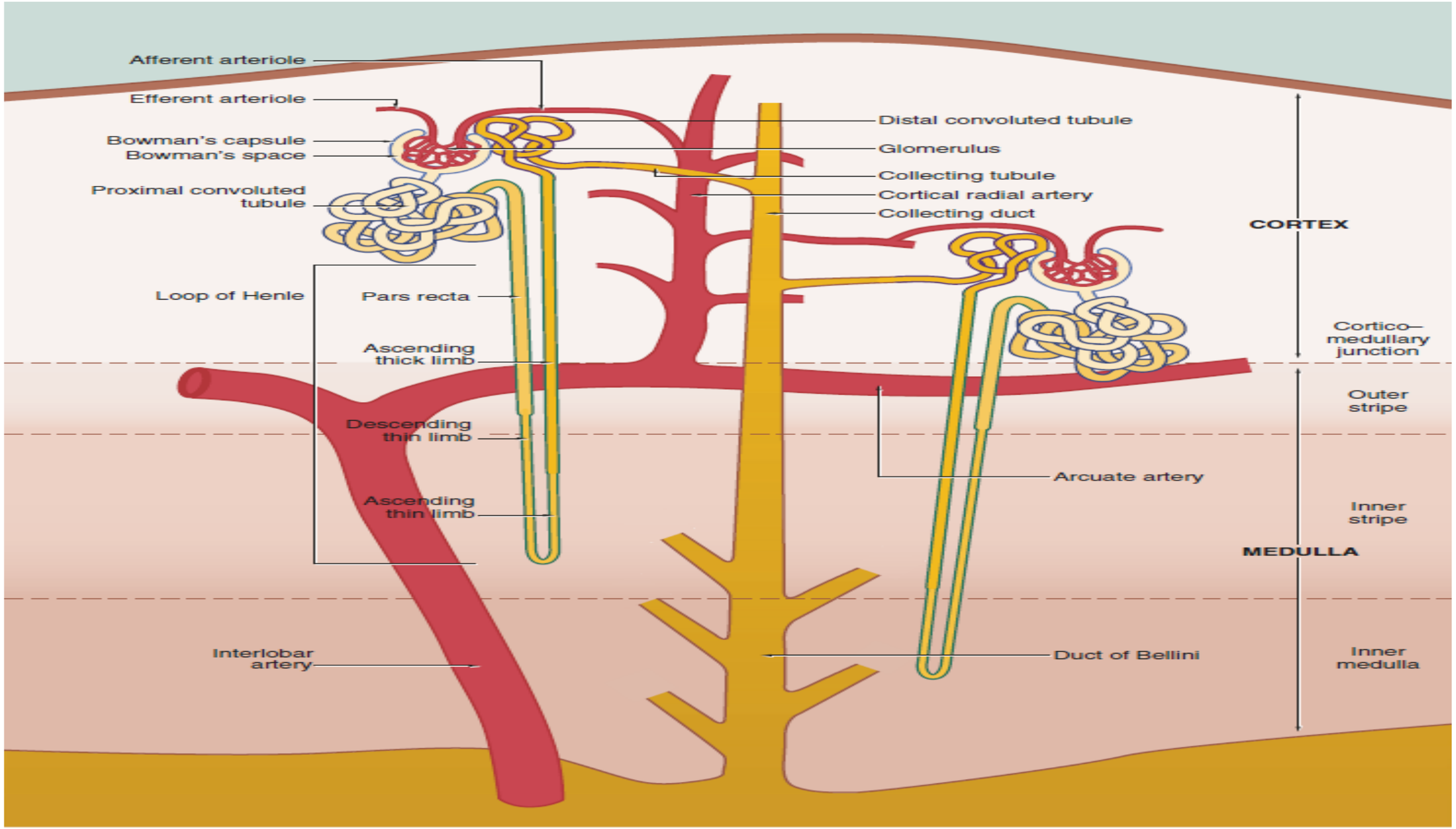
Abundant peritubular capillaries and draining venules (arrows)
Proximal (P) Distal (D) convoluted tubules

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

but please keep in mind that capillaries have RBCs in their lumen, while tubules are empty


Afferent arteriole
Efferent arteriole
Bowman's capsule
Bowman's space
Proximal convoluted tubule
Loop of Henle
Pars recta
Ascending thick limb
Descending thin limb
Ascending thin limb
Interlobar artery
Distal convoluted tubule
Glomerulus
Collecting tubule
Cortical radial artery
Collecting duct
Arcuate artery
Duct of Bellini
CORTEX
Cortico–medullary junction
Outer stripe
Inner stripe
MEDULLA
Inner medulla

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**

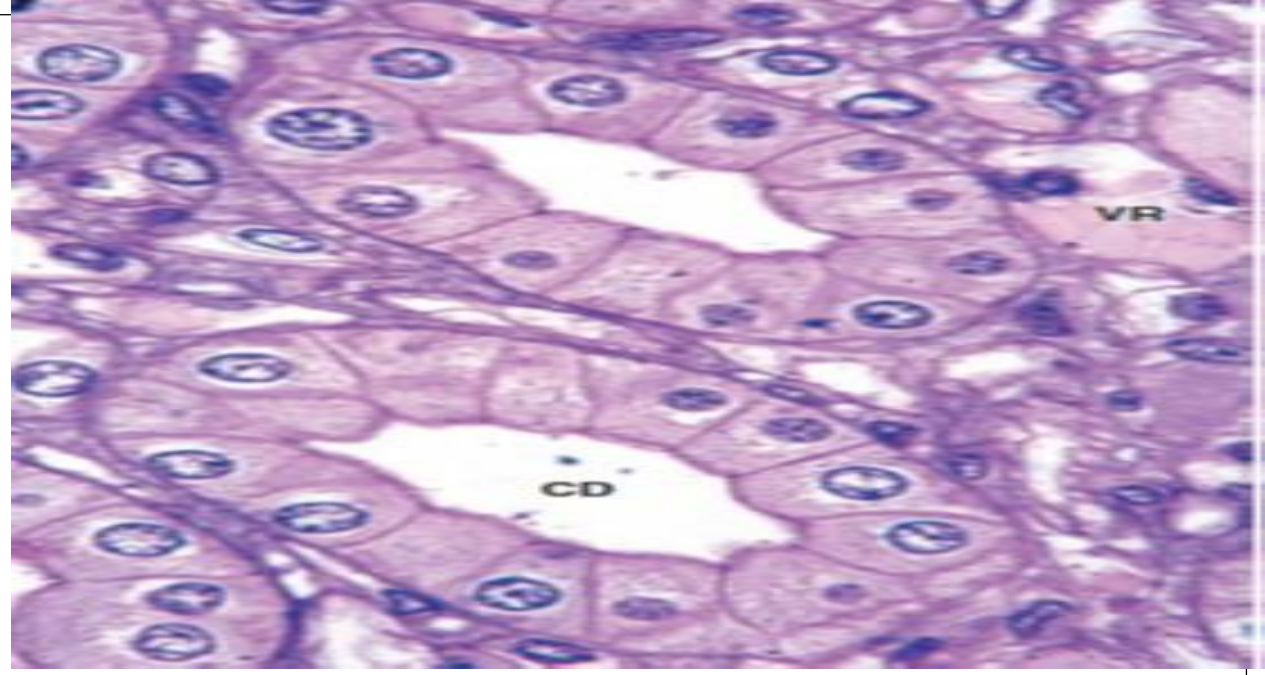
Medullary Collecting ducts : lined by columnar cells and are larger and straighter .

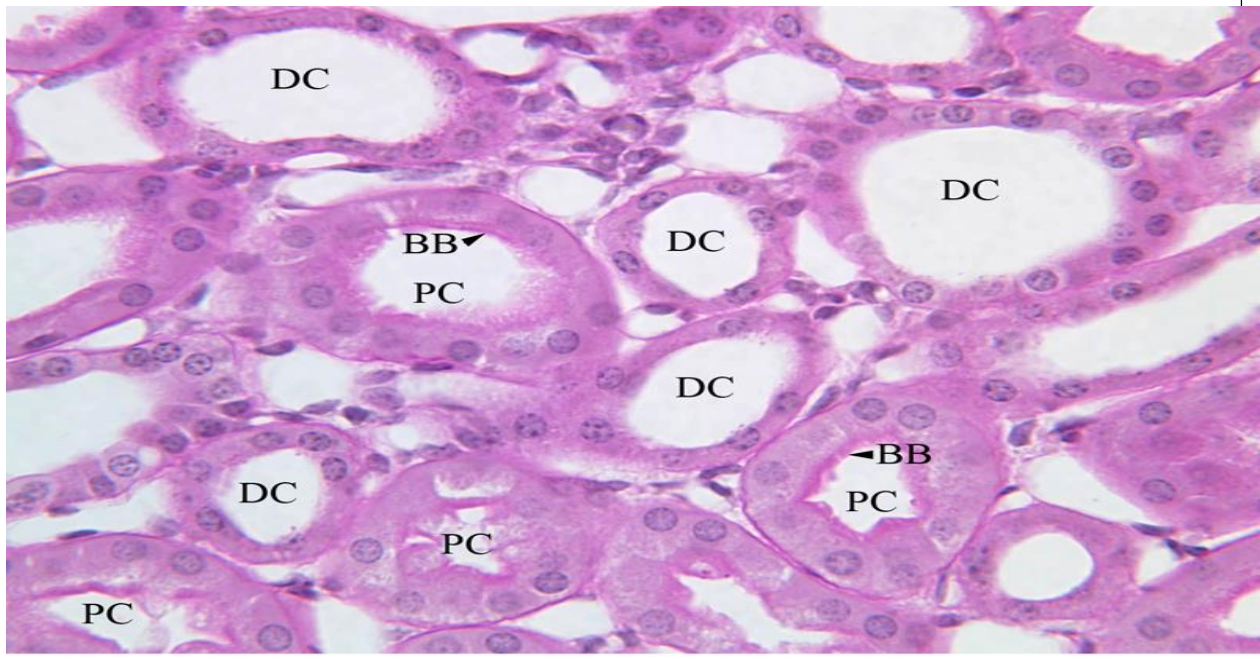
They are running parallel with the descending and ascending limbs of the loops of Henle and vasa recta

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



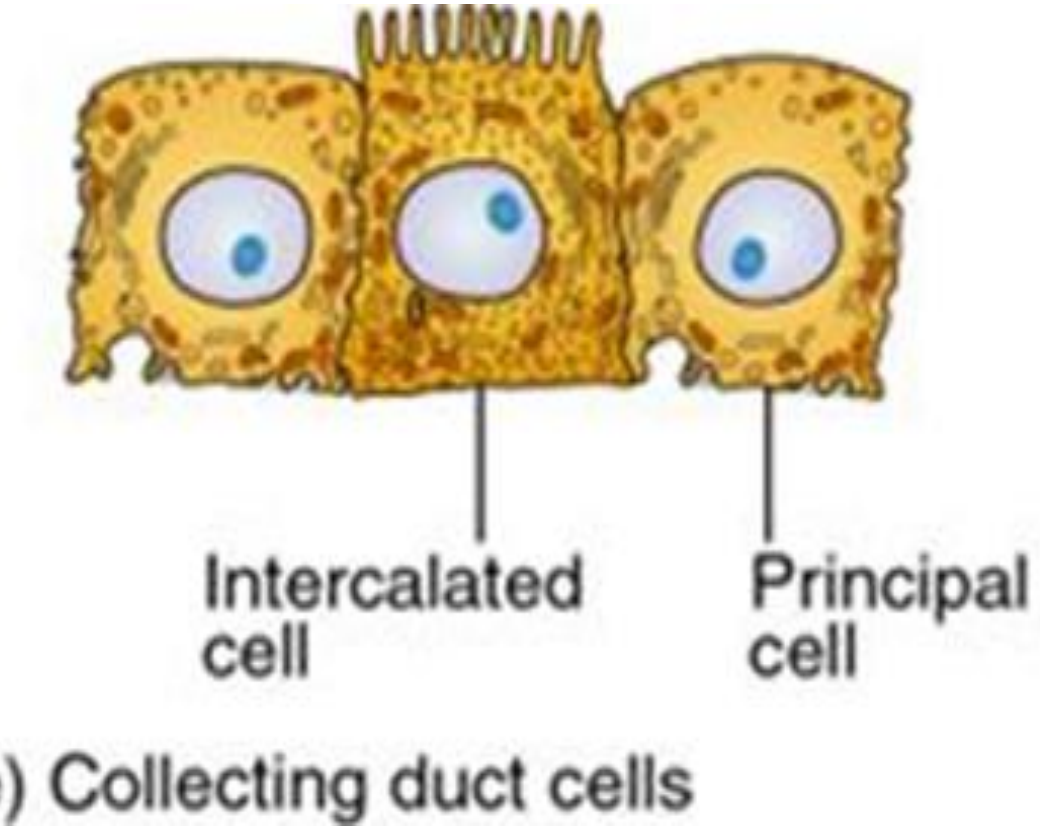


DC - distal convoluted tubule PC - proximal convoluted tubule BB - brush border

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 Na^+, secrete K^+,
- **Respond to aldosterone and ADH.**



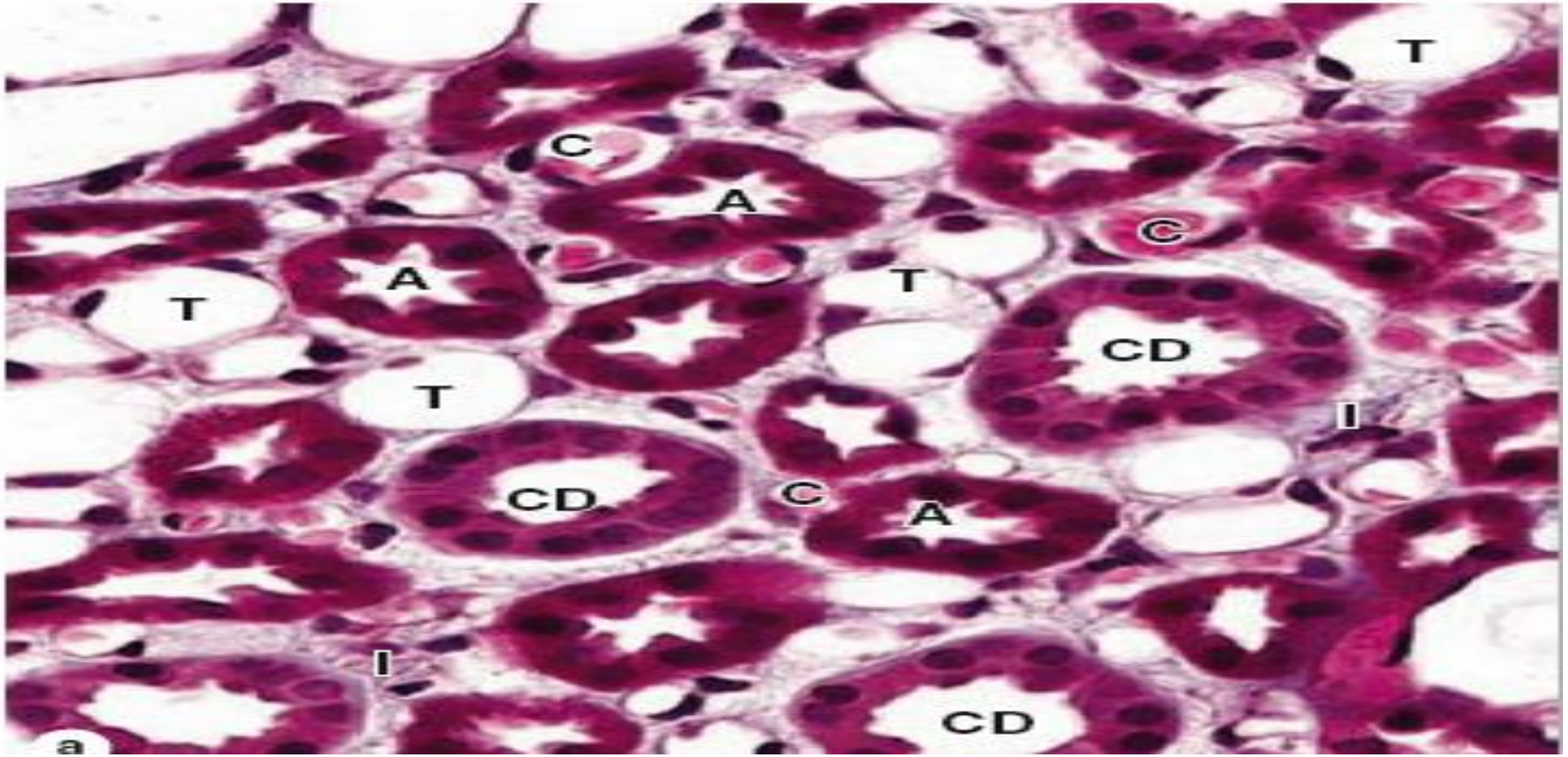
(e) Collecting duct cells

2- Dark (intercalated) cells

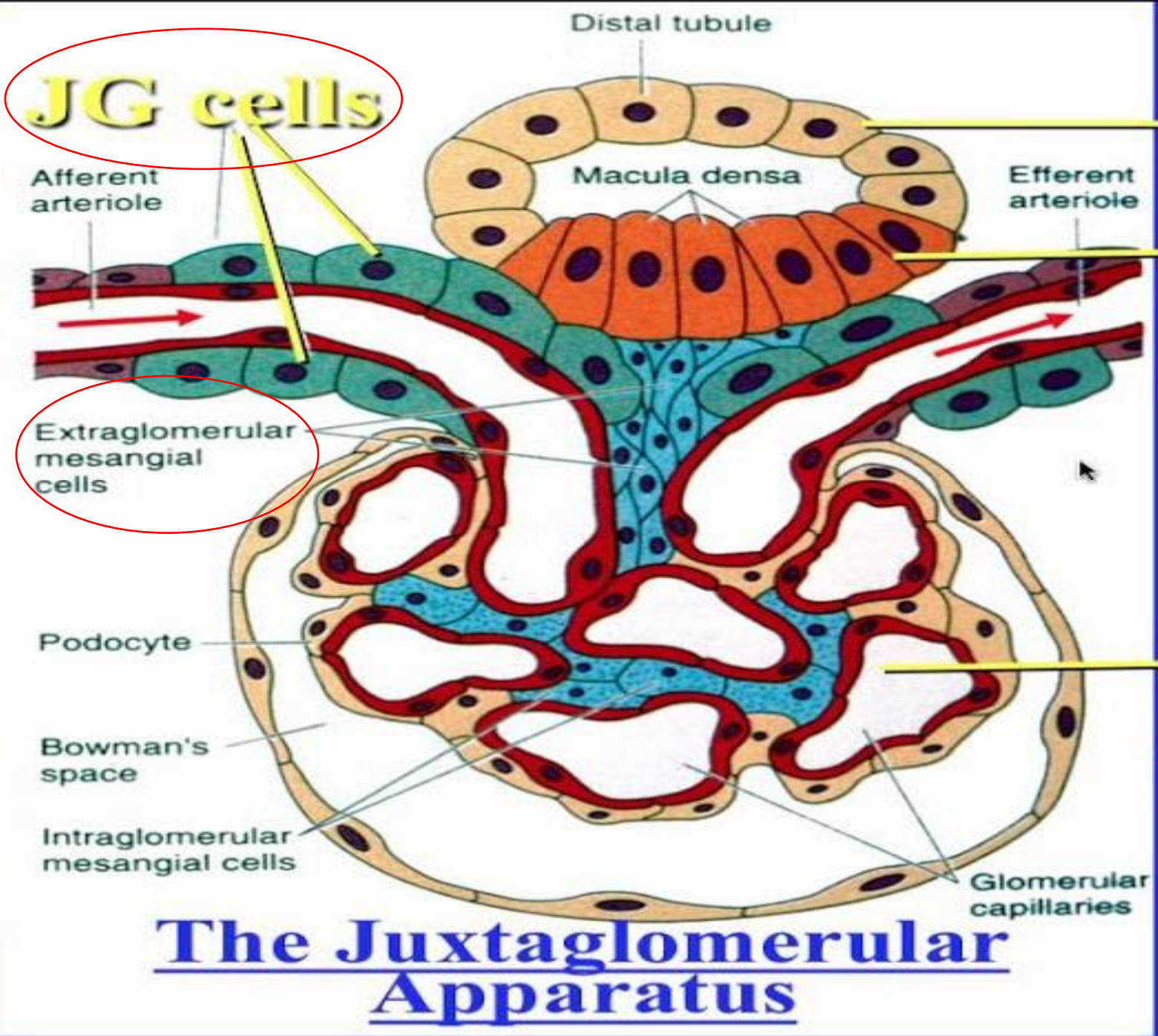
- Rich in organelles
- Well developed microvilli
- No basal infoldings
- Maintain acid-base balance by secreting

either **H+** (from type **A or α** intercalated cells) *in case of acidosis*

or **HCO3 –** (from type **B or β** intercalated cells). *in case of alkalosis*



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**).



The Juxtaglomerular Apparatus

Distal tubule

Macula densa

Glomerular capillaries

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

  they can contract to release renin

- Contain mature and immature membrane –bound granules of the enzyme renin

3- Extraglomerular mesangial cells (Lacis cells)

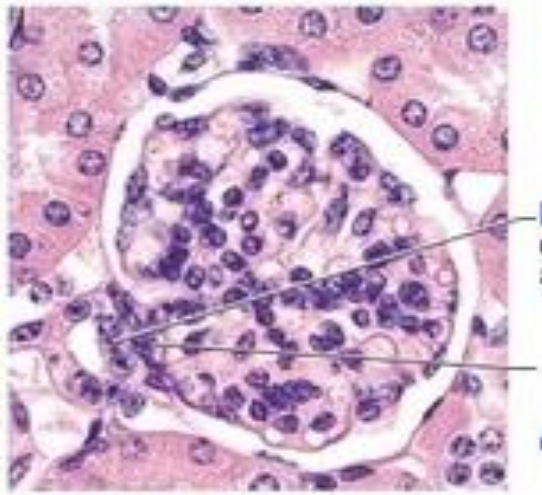
- Formed of a mass of small cells with pale nuclei.
- It is found in the triangular region between the afferent and efferent arterioles at sides and macula densa at the base.

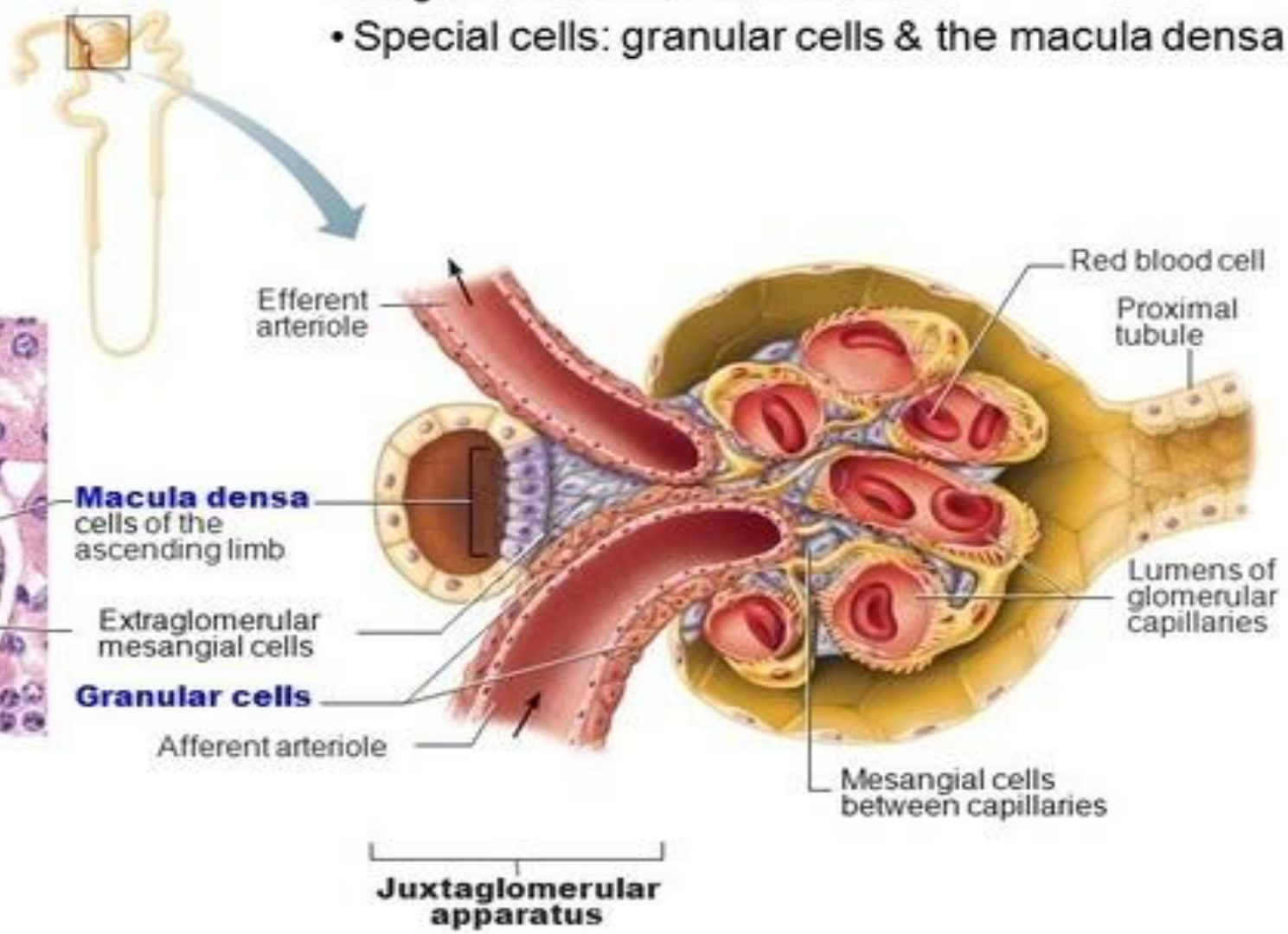
- The apex of the triangle is formed by the glomerular mesangial cells at the vascular pole

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

Juxtaglomerular Apparatus

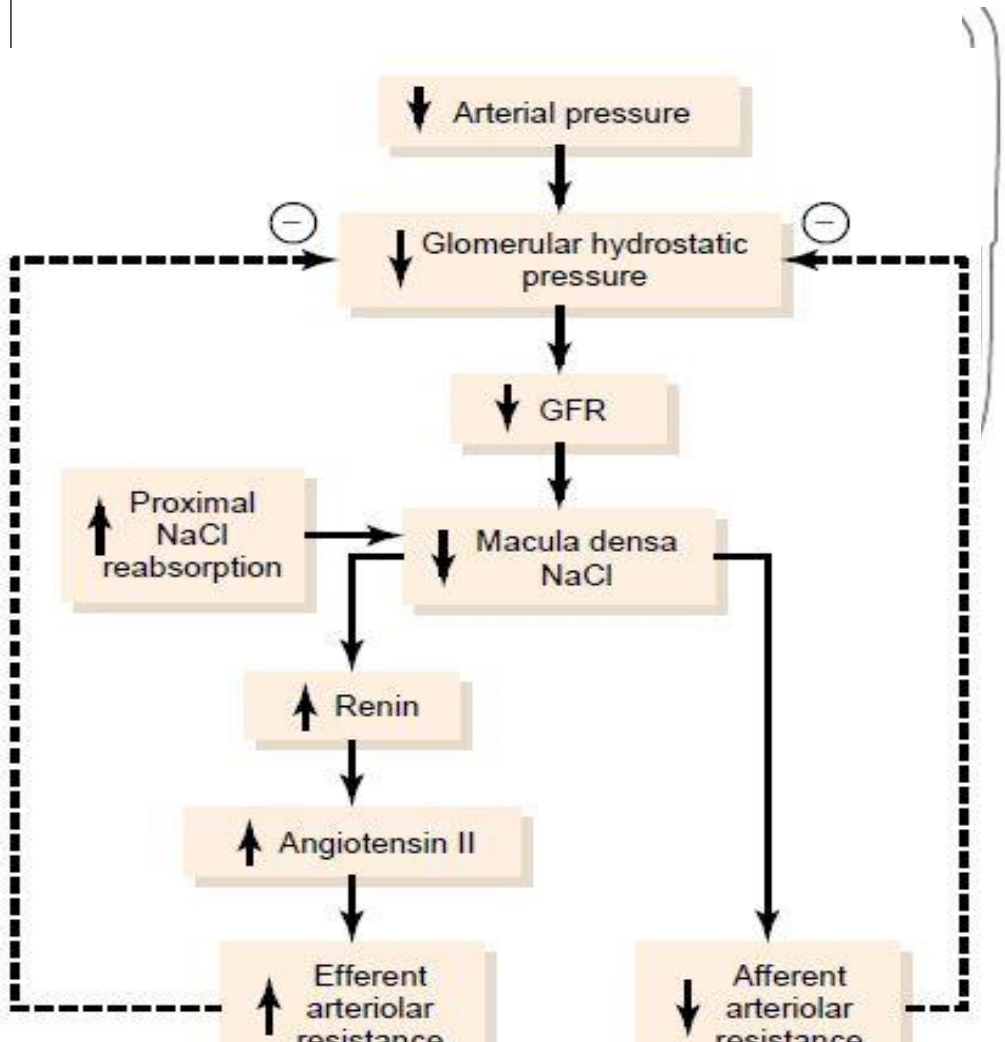
- Regulates salt & fluid balance
- Special cells: granular cells & the macula densa

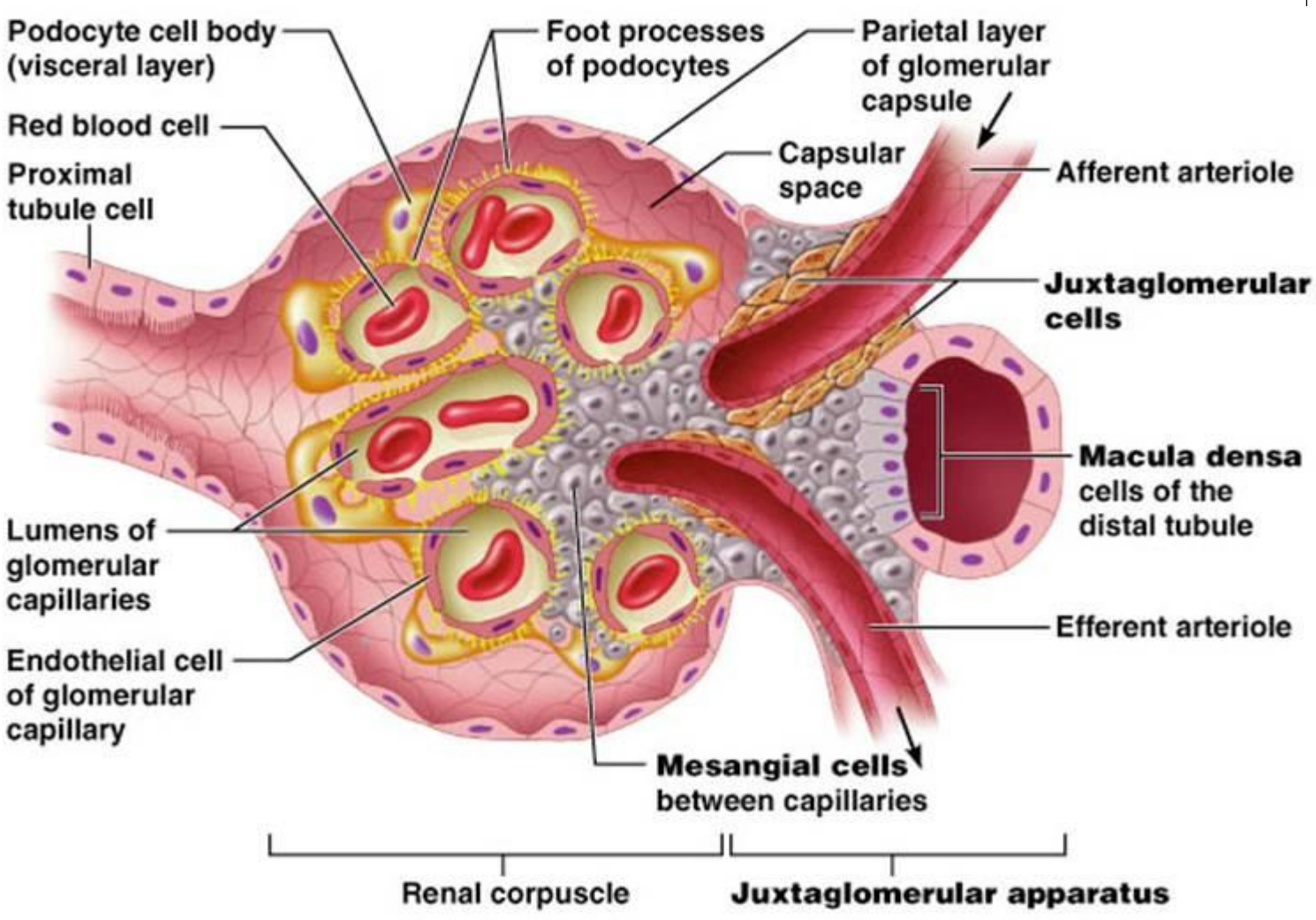


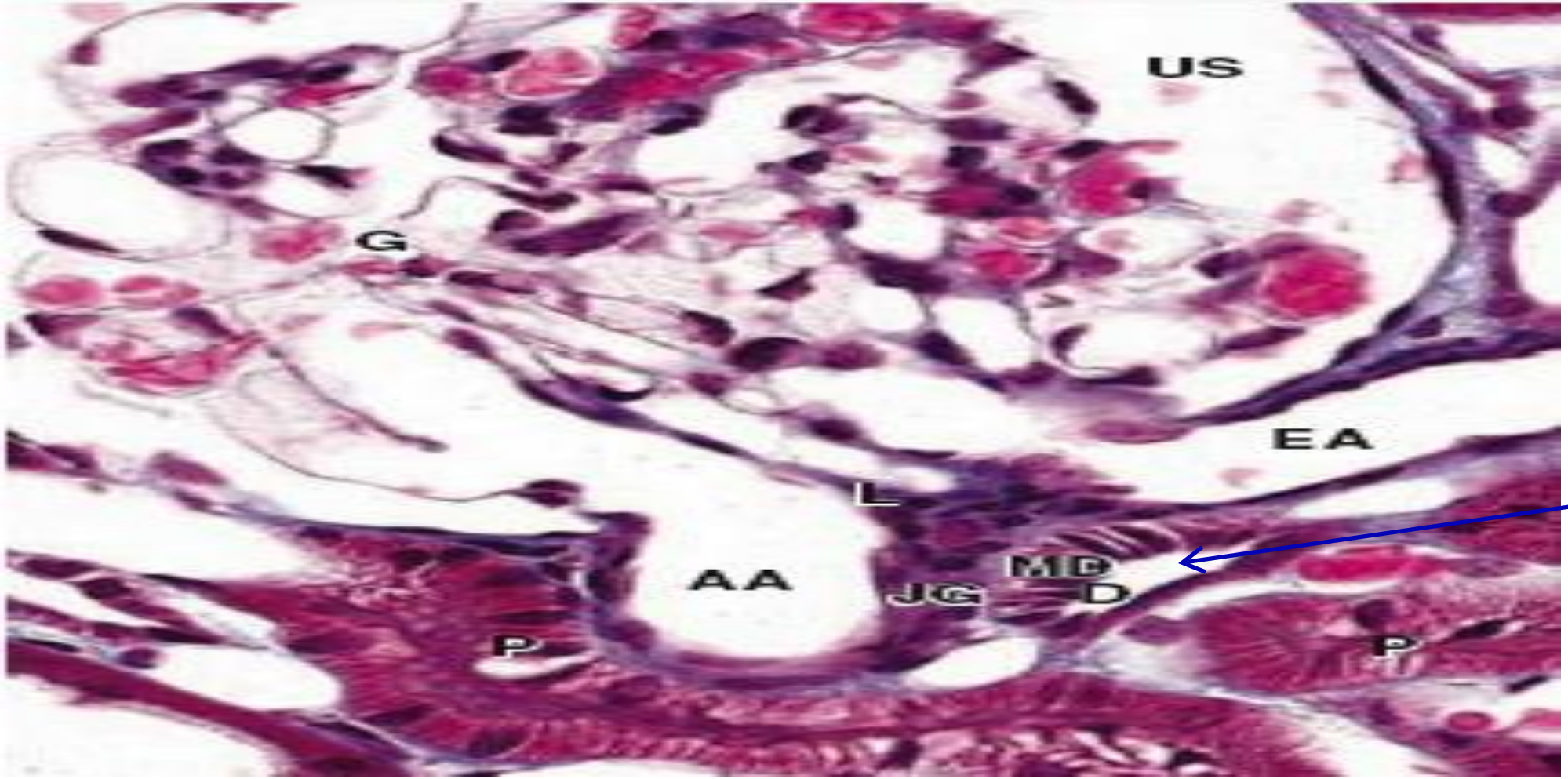


Function of juxta-glomerular complex :

- Secretion of erythropoietin *which stimulates RBCs formation in bone marrow*
- Secretion of renin *to control blood pressure*
- Regulation of Glomerular filtration rate *(by controlling the constriction of the afferent and efferent arterioles)*



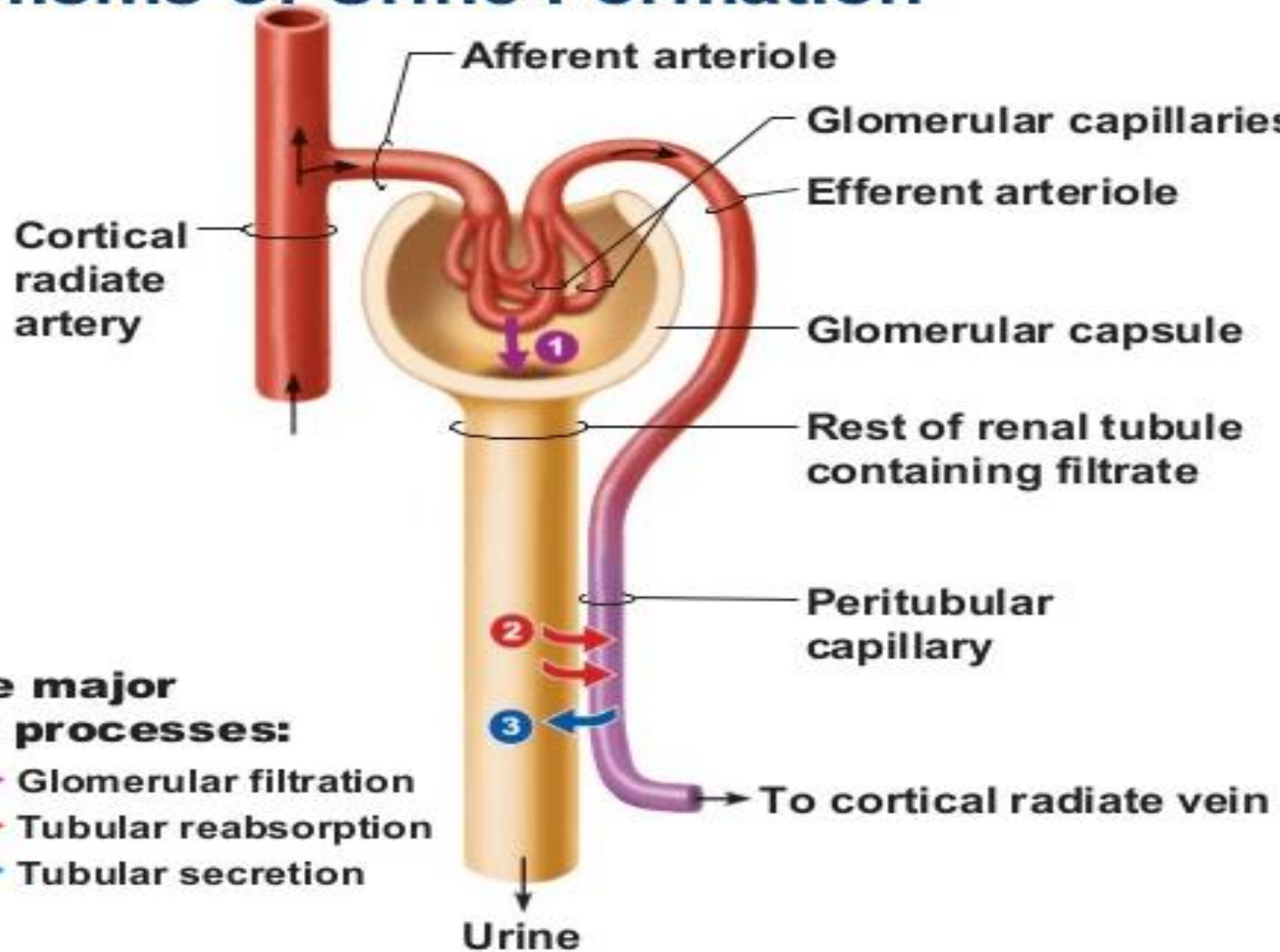




notice the DCT has a wide lumen, macula densa cells are lining the wall

Distal tubule (D) Vascular pole of its glomerulus (G).
Macula densa (MD) Afferent arteriole's (AA)
juxtaglomerular granule cells (JG) Efferent arteriole (EA)
Lacis cells (L), which are extraglomerular mesangial

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

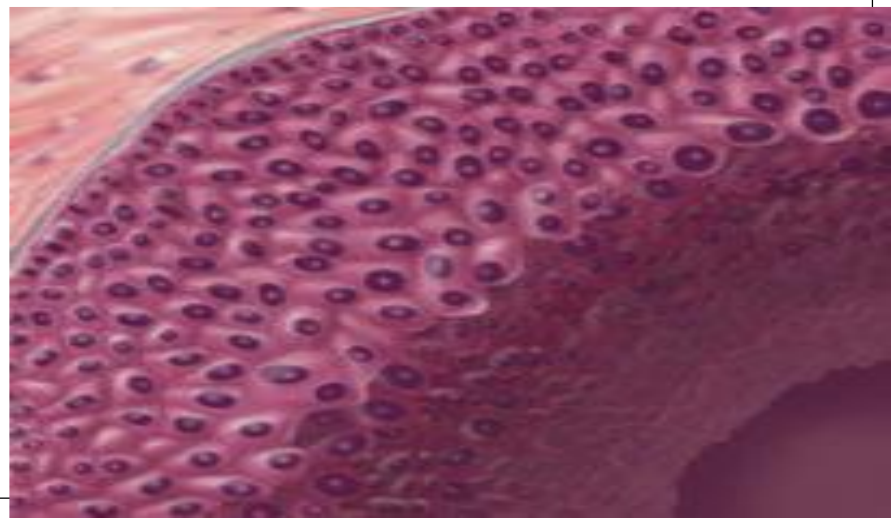
2- An intermediate region containing from one to several layers of cuboidal or low columnar cells

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

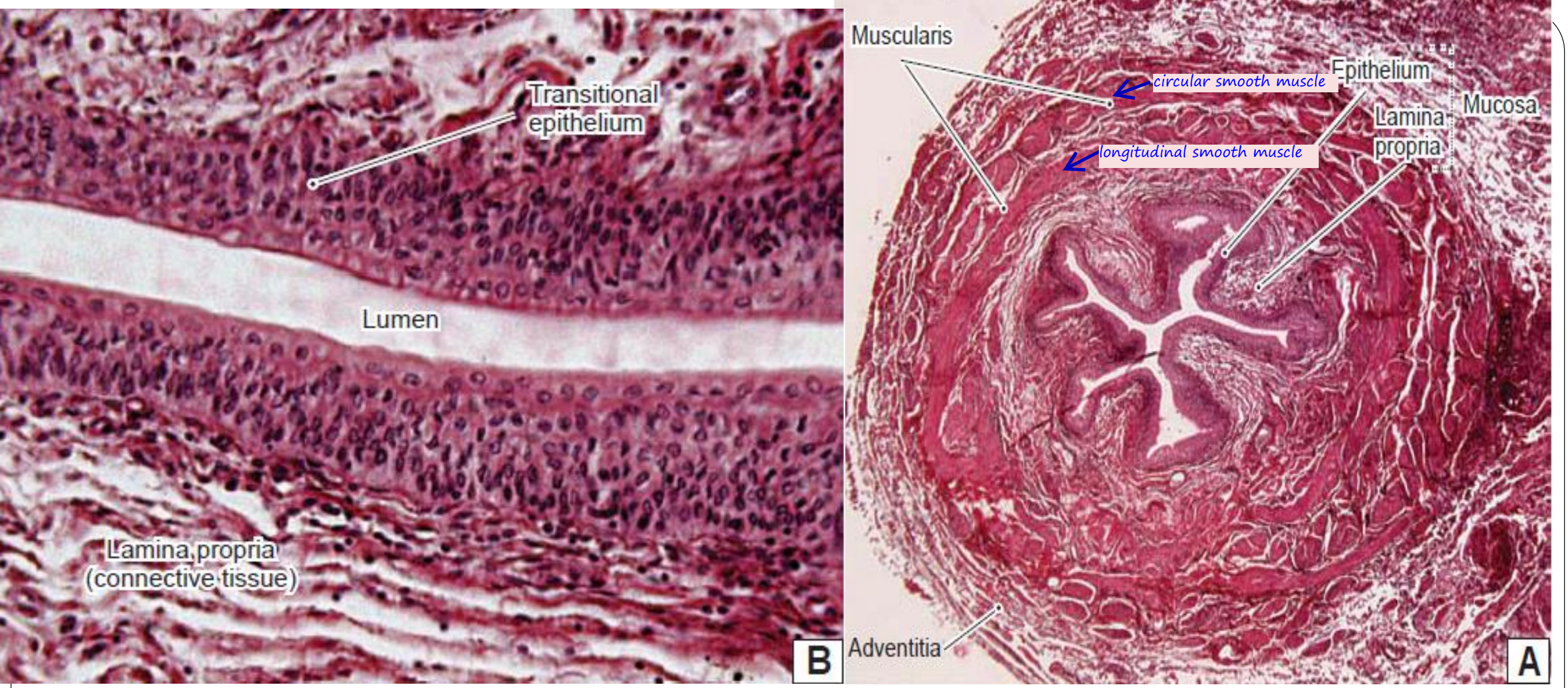
junctions serve as an osmotic barrier protecting against

hypertonic urine and preventing dilution of the stored urine



Ureter

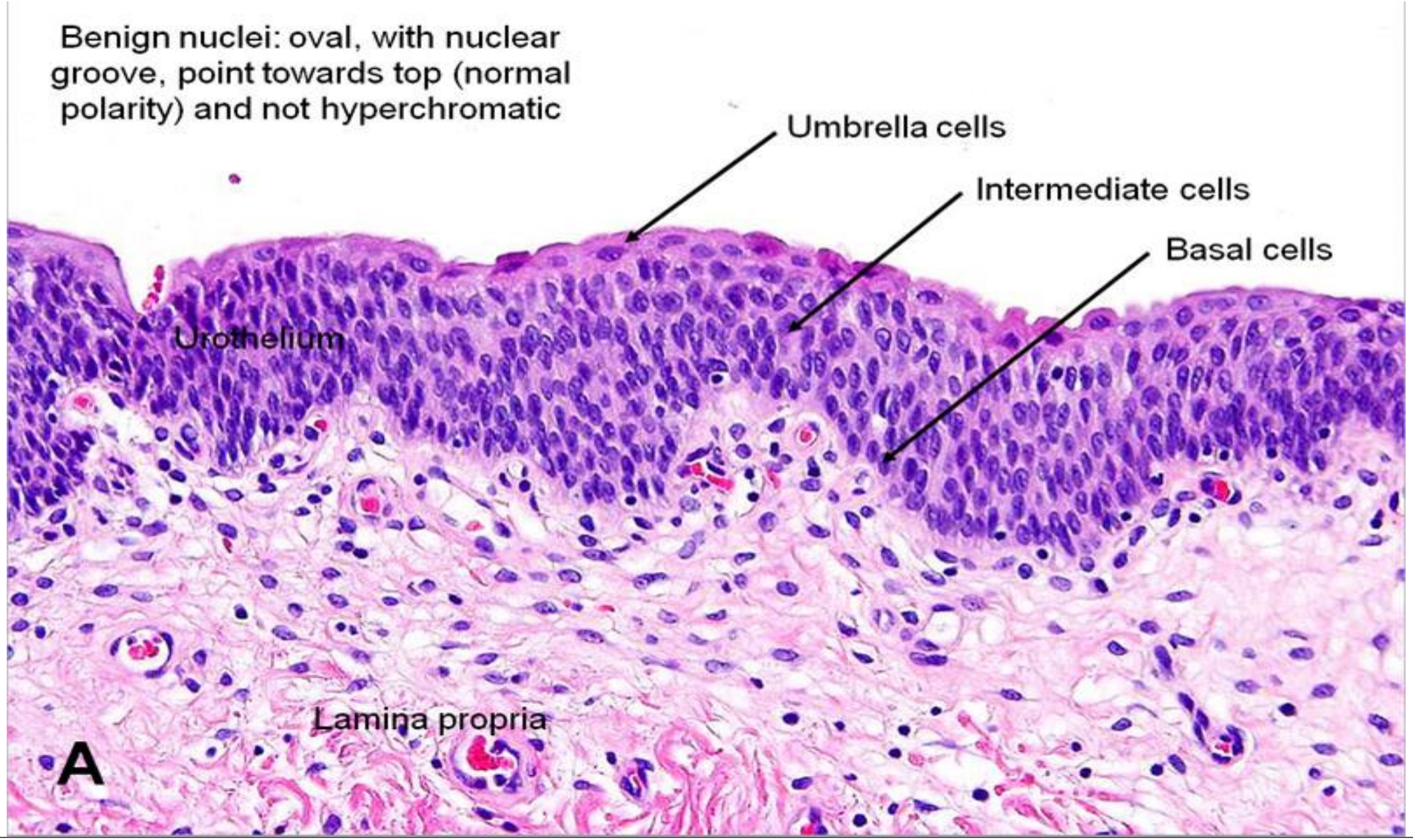
- Small muscular tubule.
- It carries urine from the renal pelvis to the urinary bladder.
- It has mucosa, muscularis, and adventitia.
- Mucosa consists of:
  - Transitional epithelium
  - loose connective tissue (lamina propria).
- Muscularis:
  - Inner longitudinal and outer circular smooth muscle 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.

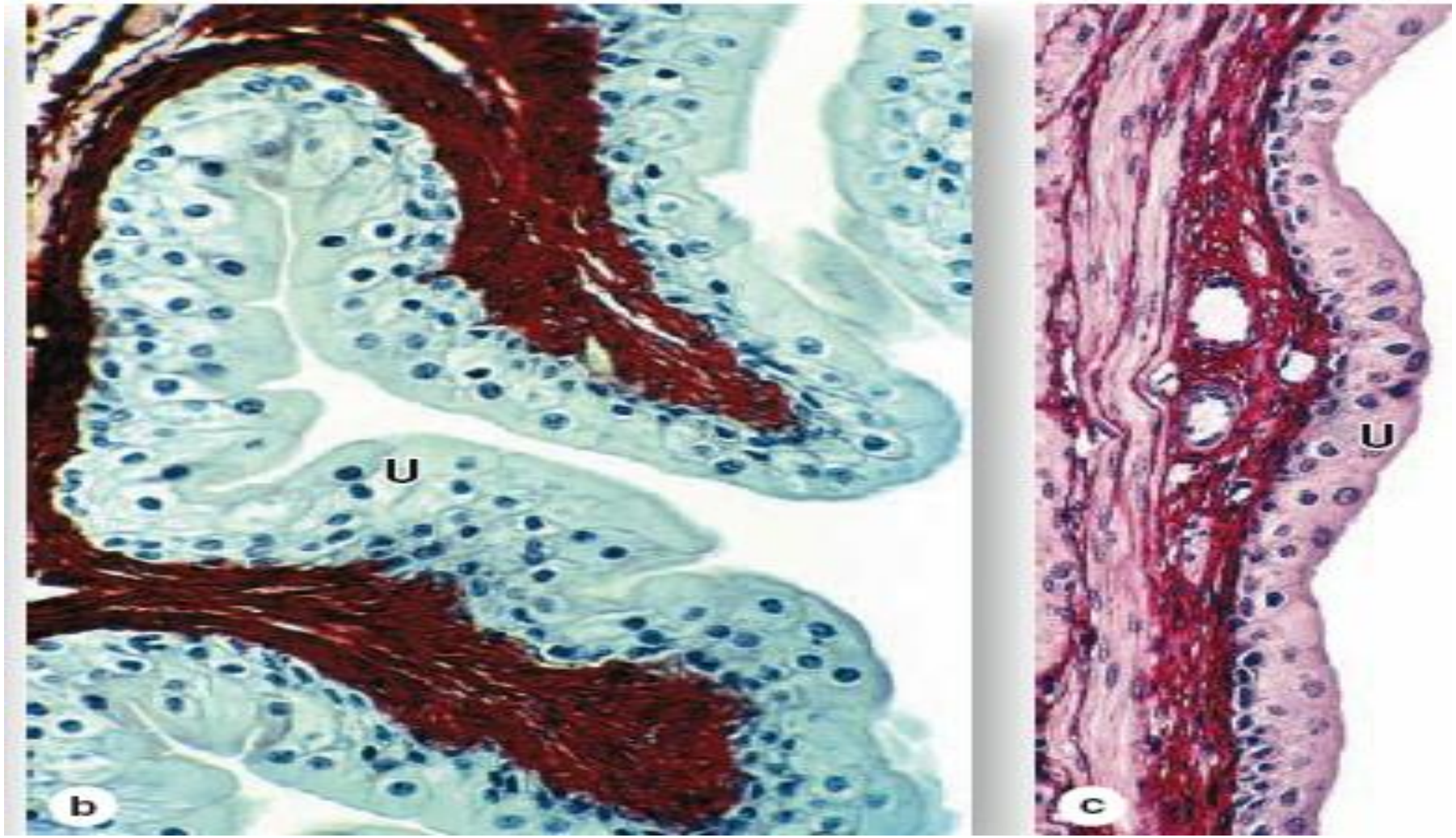

Transitional epithelium
Lumen
Lamina propria (connective tissue)
B
Muscularis
circular smooth muscle
Epithelium
Mucosa
Lamina propria
longitudinal smooth muscle
Adventitia
A

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





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

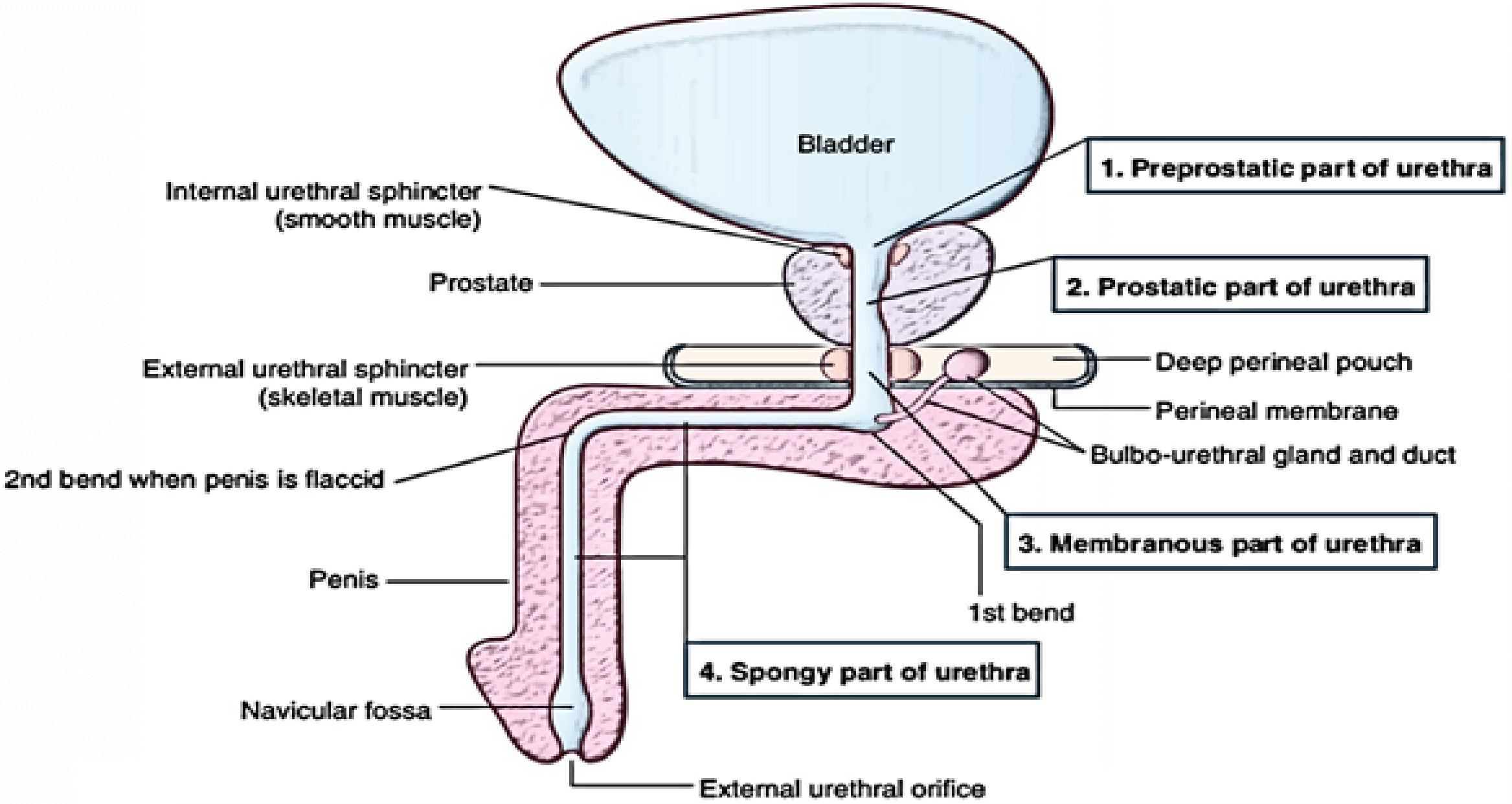
(c) When the bladder is full, the mucosa is pulled smooth, the urothelium (**U**) is thinner, and the umbrella cells are flatter.

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

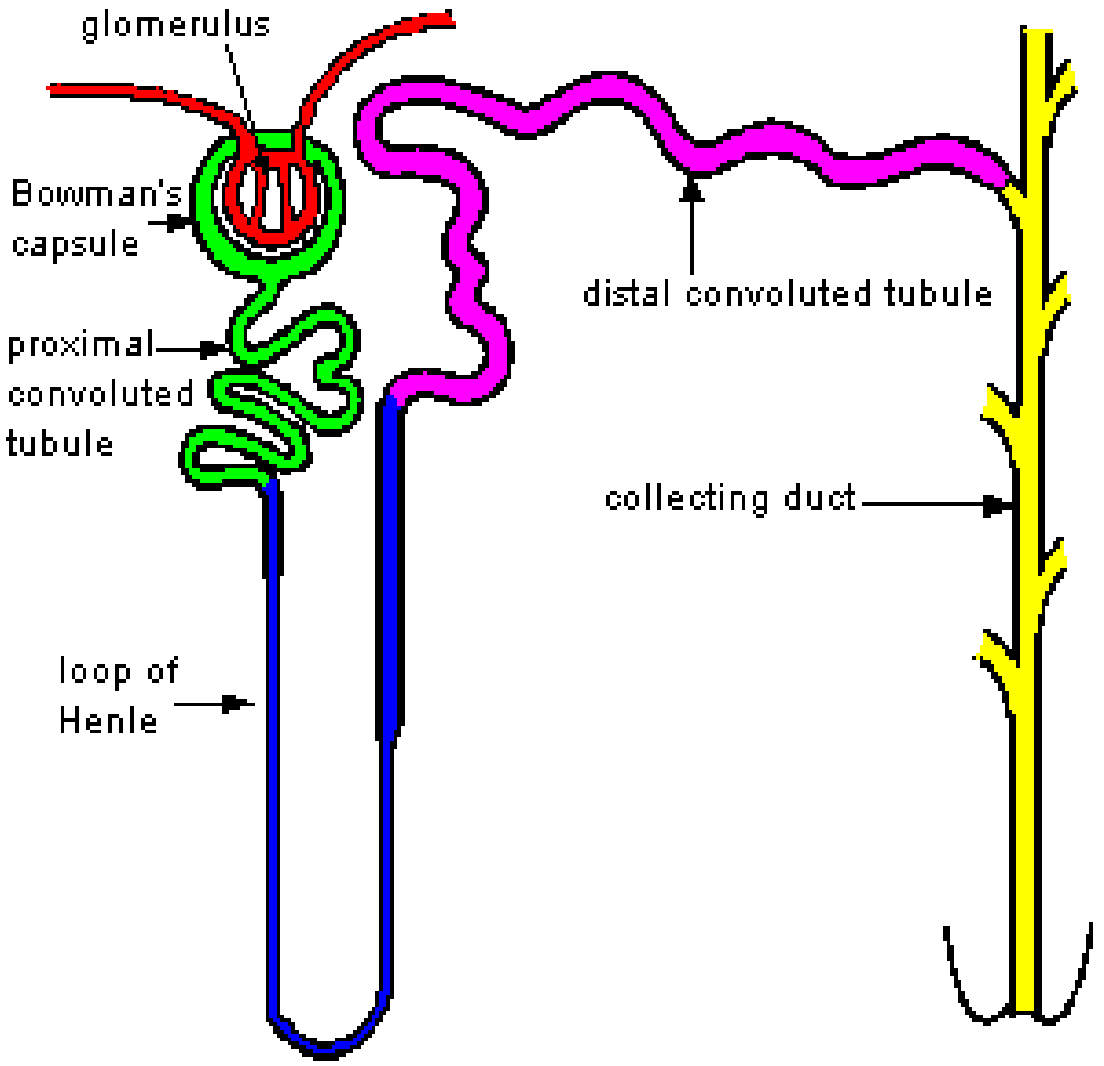

Bladder
1. Preprostatic part of urethra
Internal urethral sphincter
(smooth muscle)
Prostate
2. Prostatic part of urethra
External urethral sphincter
(skeletal muscle)
Deep perineal pouch
Perineal membrane
Bulbo-urethral gland and duct
2nd bend when penis is flaccid
3. Membranous part of urethra
Penis
1st bend
4. Spongy part of urethra
Navicular fossa
External urethral orifice

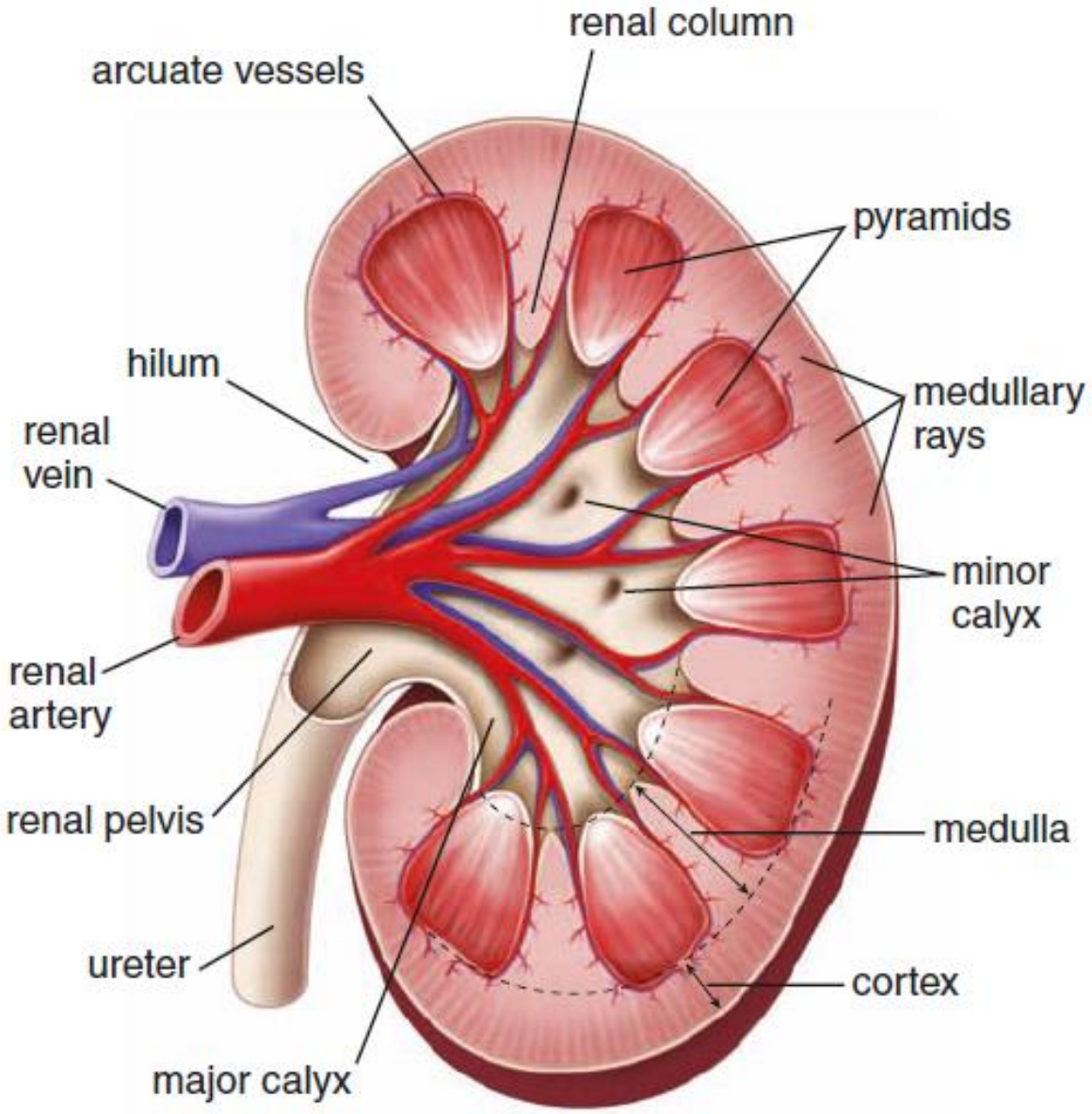
Men

Female urethra

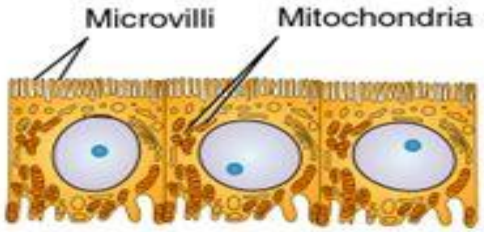
- The urethra is short, measuring 3 to 5 cm in length from the bladder to the vestibule of the vagina.
- The lining epithelium is initially transitional epithelium, a continuation of the bladder epithelium, but changes to stratified squamous epithelium before its termination
- The lamina propria is a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

nothing new, you can refer to the video at 46:30


glomerulus
Bowman's capsule
proximal convoluted tubule
loop of Henle
distal convoluted tubule
collecting duct

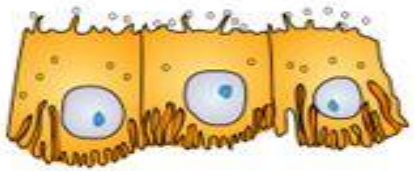

renal column
arcuate vessels
pyramids
hilum
medullary rays
renal vein
minor calyx
renal artery
renal pelvis
medulla
ureter
cortex
major calyx

Histology of Renal Tubule & Collecting Duct



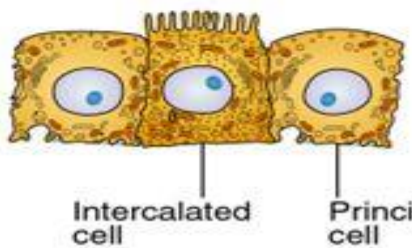
(a) Proximal convoluted tubule cells

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

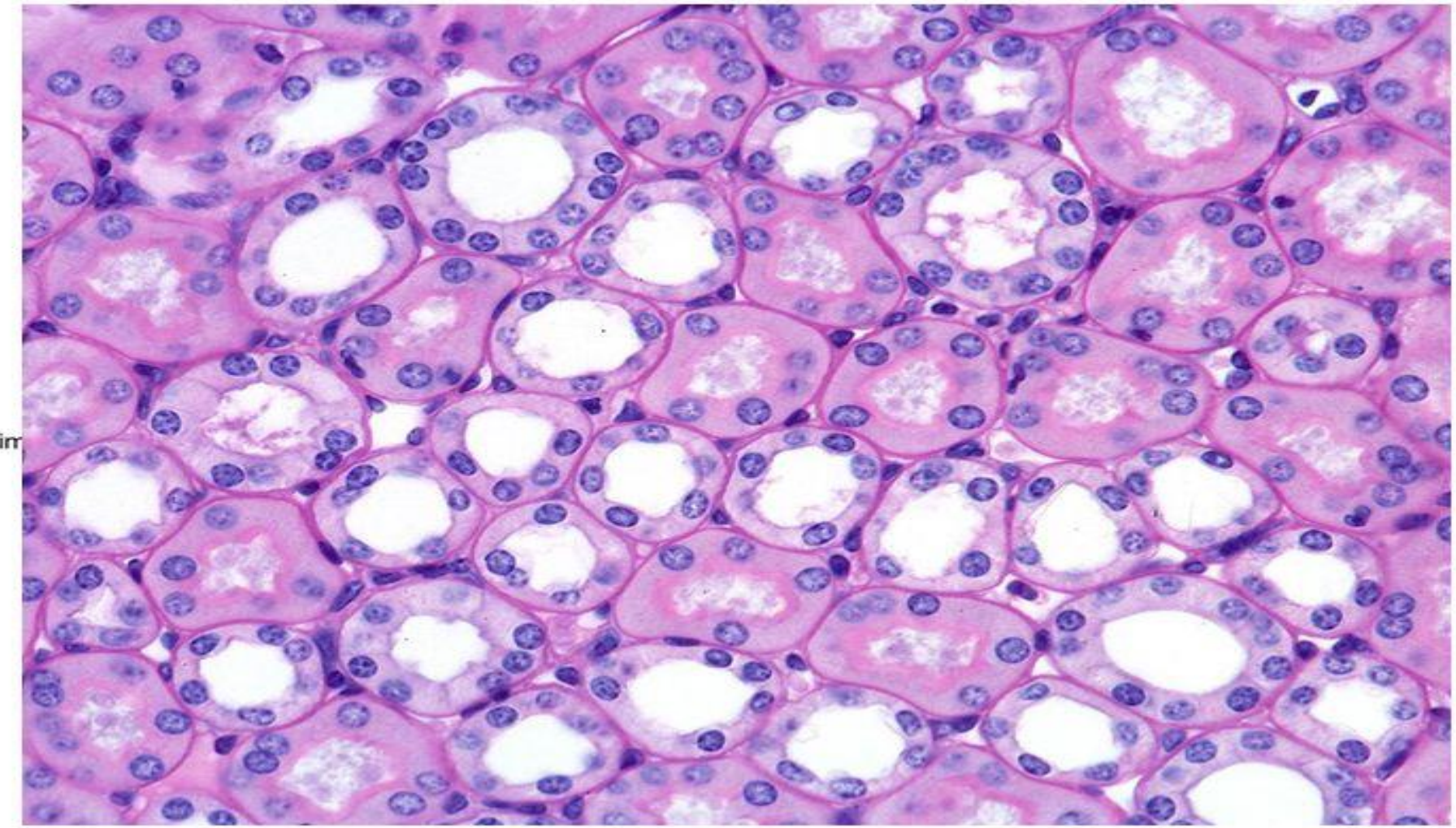


(c) Loop of Henle cells: thick ascending lim

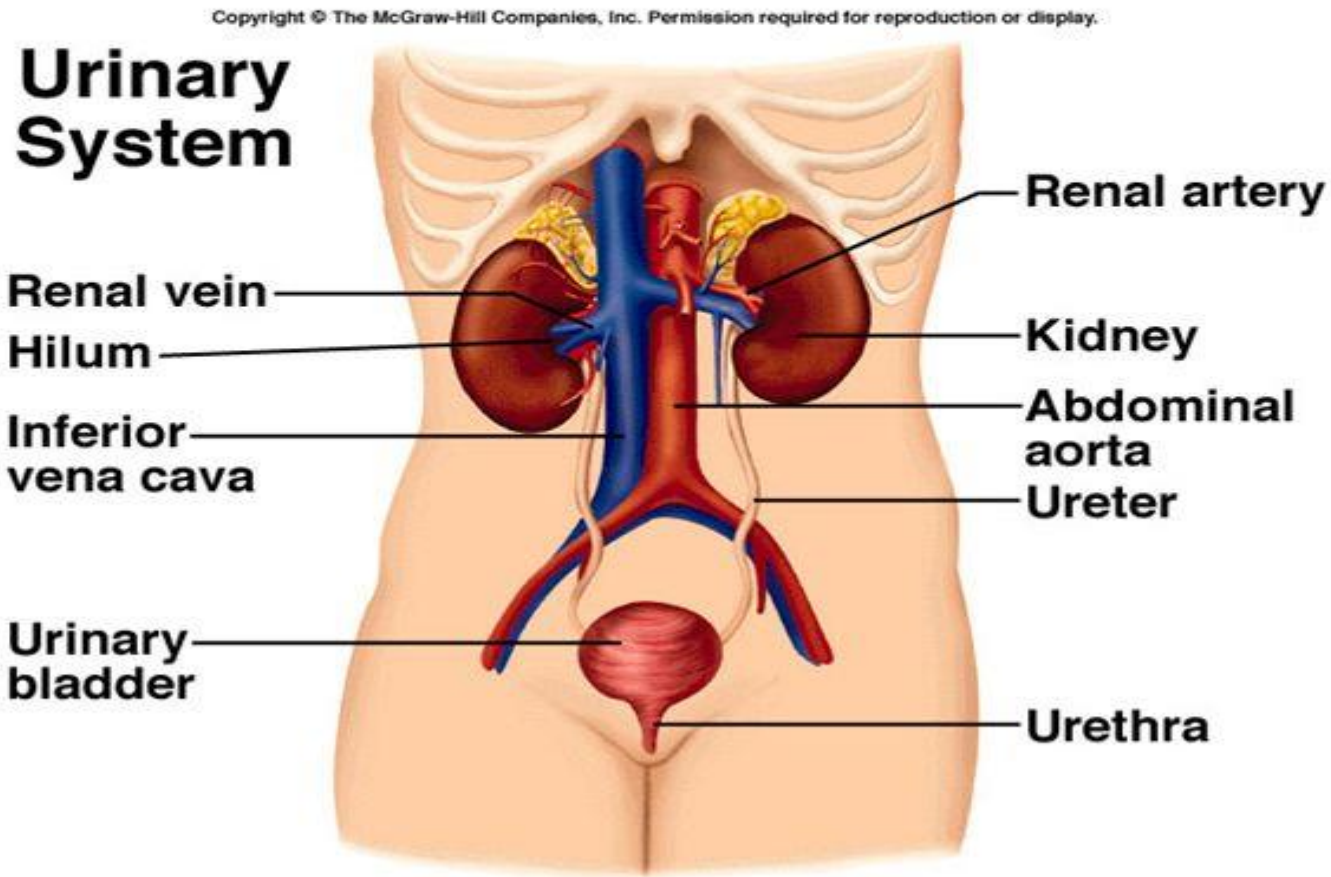
(d) Distal convoluted tubule cells



(e) Collecting duct cells



System Overview



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


Thank you