Histology of urinary system

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The urinary system

The urinary system consists of two kidneys, two ureters, urinary bladder and urethra. It helps maintain homeostasis by:

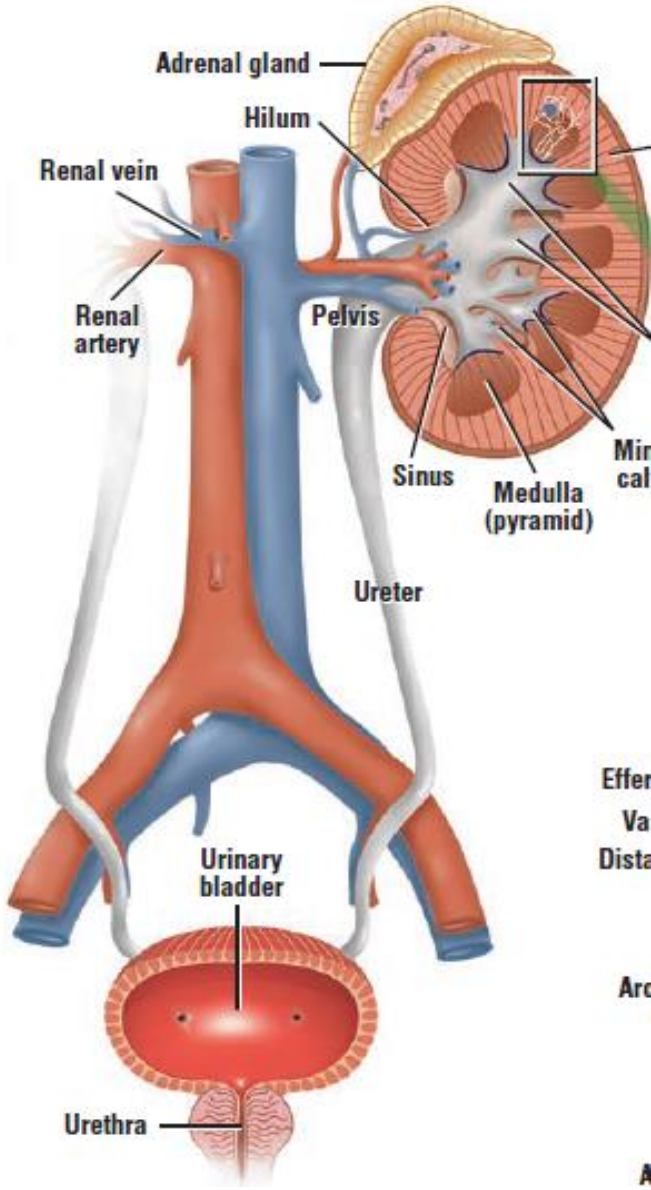
1- Filtration of cellular wastes from blood.

2- Selective reabsorption of water and solutes.

3 - Excretion of wastes (urea, uric acid) and excess water as urine.

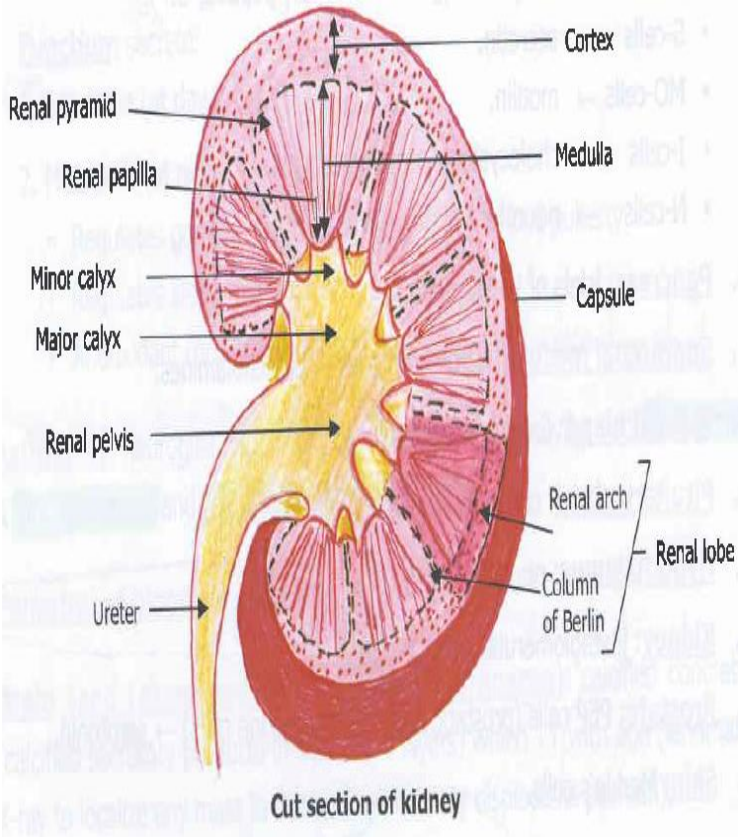
4- Regulation of fluid and electrolyte balance of the body.

5- Secretion of renin, erythropoietin and medullipin I.



KIDNEYS

Each kidney has a lateral convex surface and a medial concave one (hilum) where nerves enter, ureter exit and blood vessels enter and exit.



Cut section of kidney

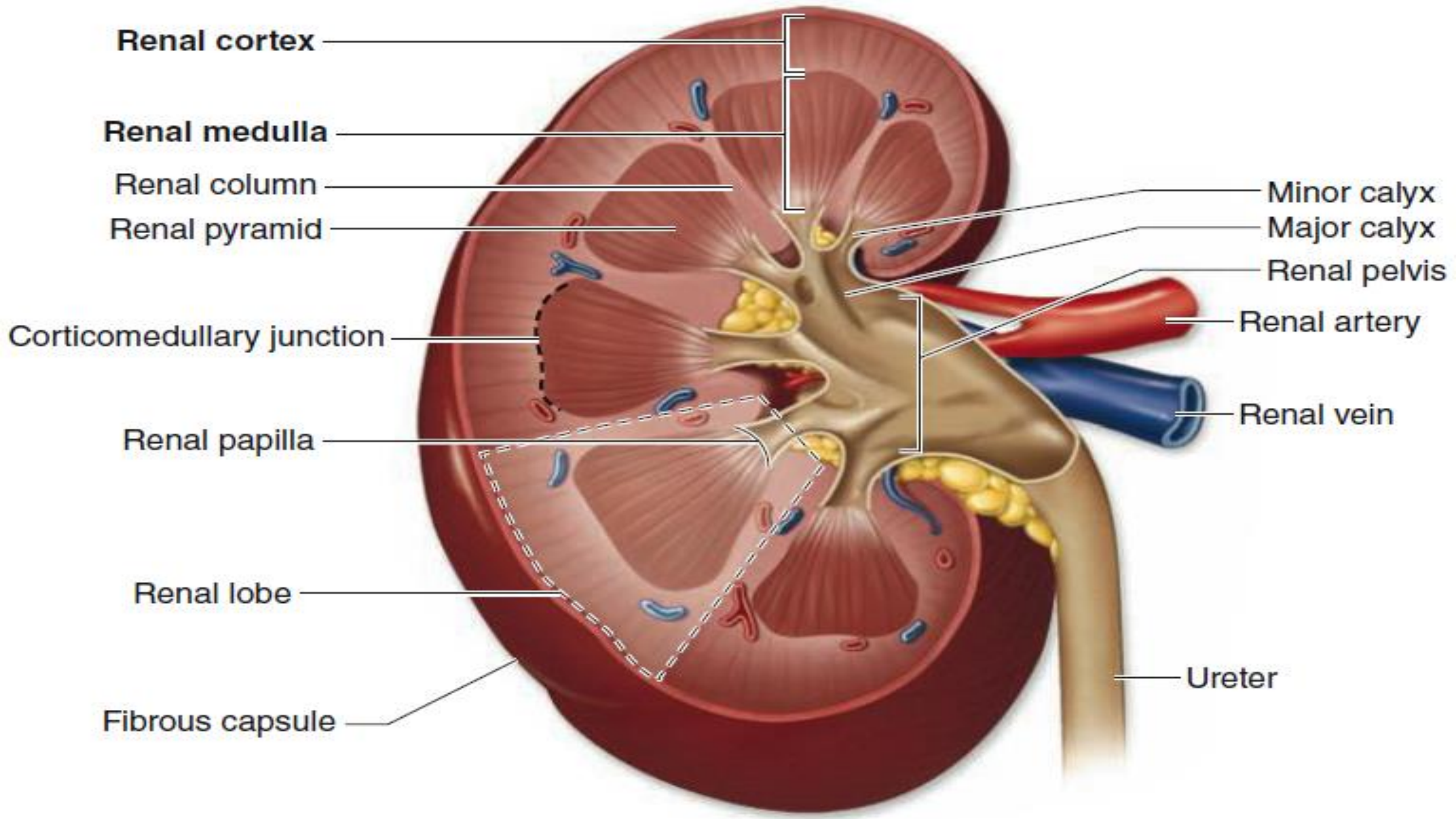
Histological Structure of the Kidney

The kidney is a large compound tubular gland formed of:

1. Stroma:

A- Capsule: Thin fibrous C.T., surrounded by adipose tissue.

B- Renal Interstitium: minimal in the cortex, and increases slightly in medulla. It contains fibroblasts, macrophages and interstitial cells that secrete Medullipin I which is converted in the liver to Medullupin II, a potent vasodilator that lowers blood pressure.


Renal cortex
Renal medulla
Renal column
Renal pyramid
Corticomedullary junction
Renal papilla
Renal lobe
Fibrous capsule
Minor calyx
Major calyx
Renal pelvis
Renal artery
Renal vein
Ureter

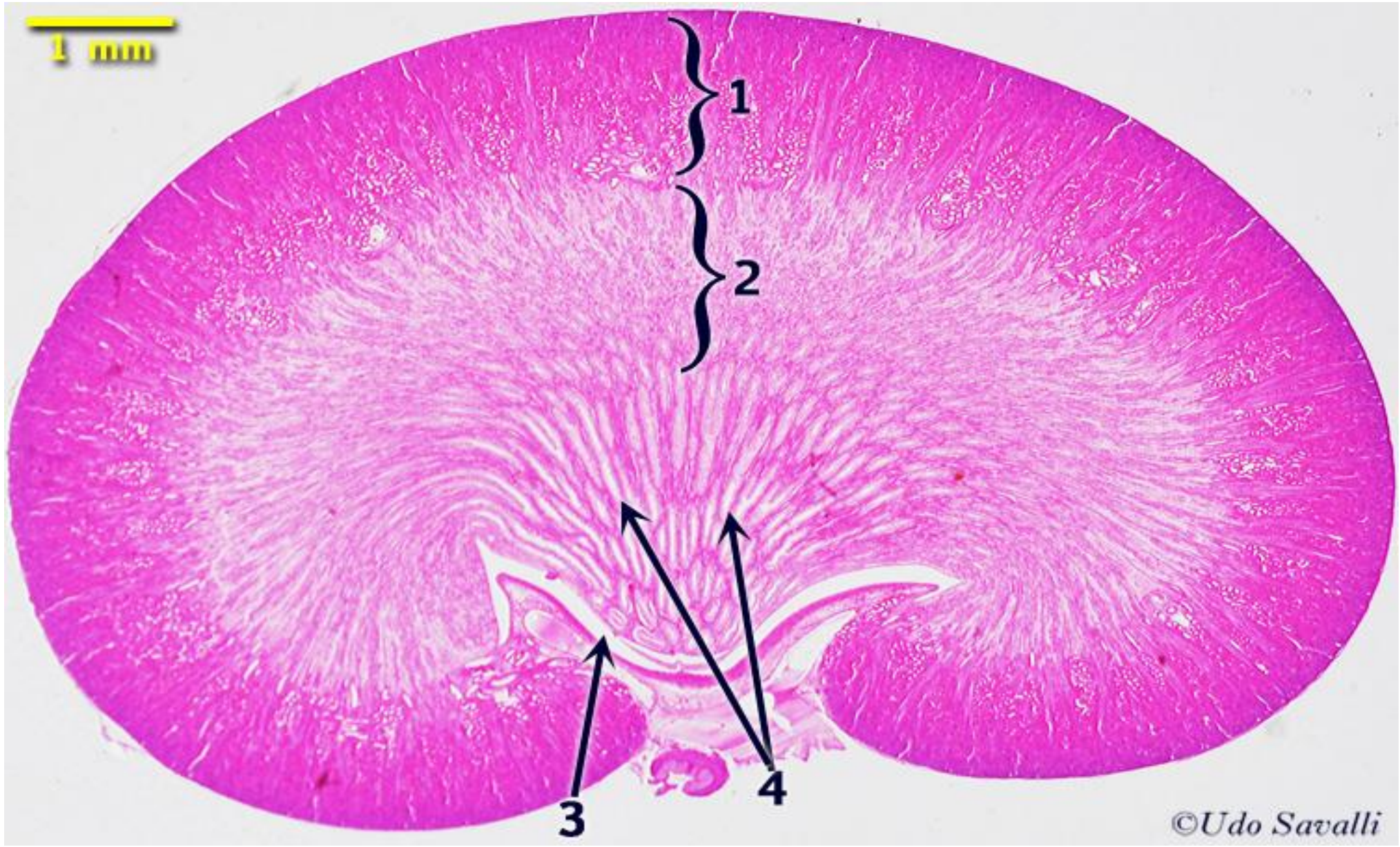
2- Parenchyma:

A- Cortex:

- It is the outer region which appears granular (due to presence of renal corpuscles), reddish brown (due to its high vascularity).
- It contains: renal corpuscle's, convoluted tubules, medullary rays and peri- tubular capillaries.
- It is formed of:

i) Cortical Labyrinth: cortical tissue surrounding medullary rays (the parallel straight tubules of loop of Henle and collecting tubules in the cortex)

ii) Columns of Bertin: cortical tissue on either side of renal pyramids in the medulla


1 mm
1
2
3
4
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B. Medulla:

It is the inner, pale, radially striated region. It is formed of 10-18 medullary pyramids. Each pyramid has a broad base towards cortex at the cortico-medullary border and an apex (renal papilla) pointing towards the renal pelvis.

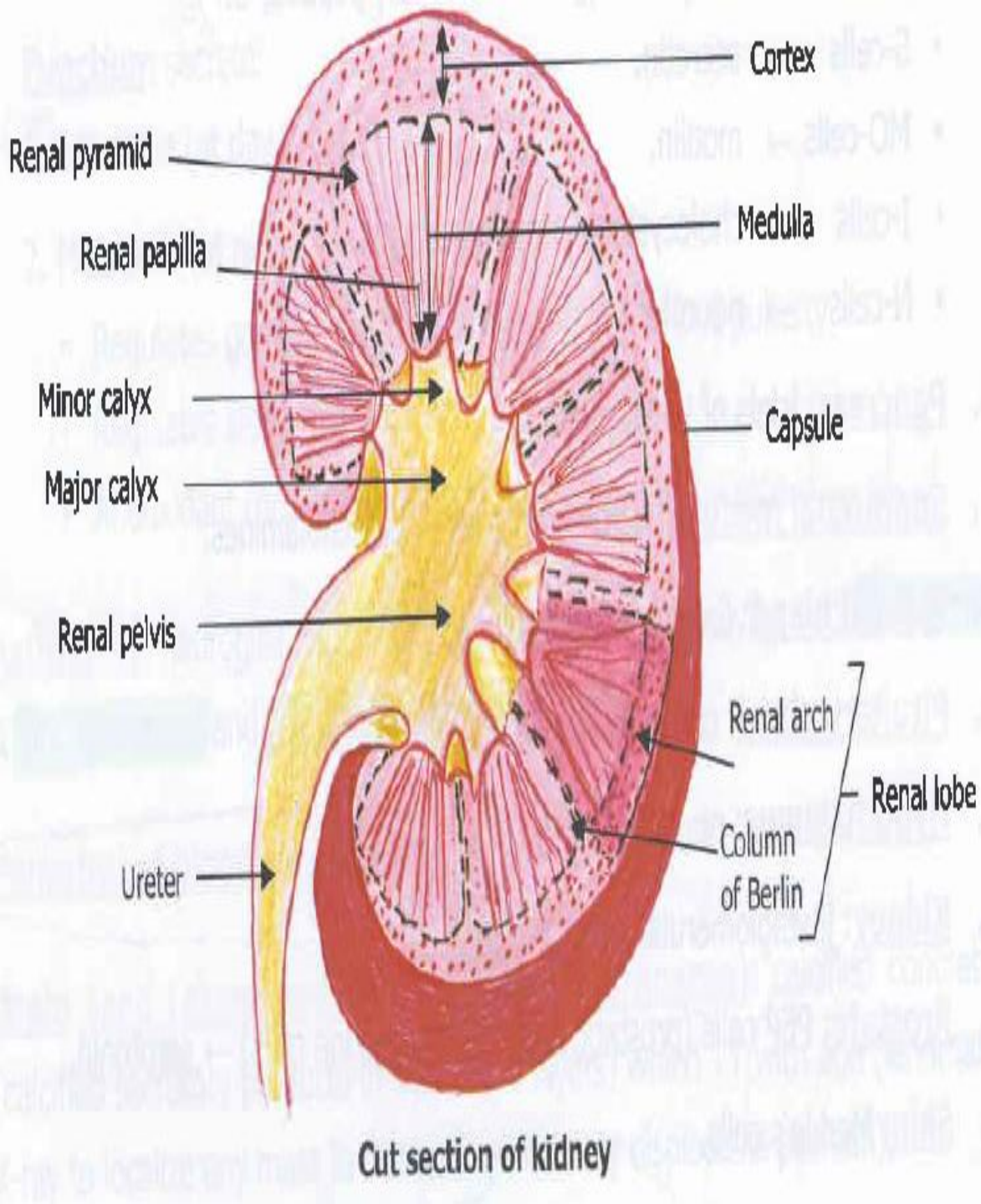
Each pyramid shows radial striations that are attributed to the presence of parallel straight tubules of loop of Henle, collecting tubules, ducts of Bellini and vasa rectae.

The apex of the pyramid is perforated by 20 or more openings of collecting ducts (ducts of Bellini).

The apex projects into a minor calyx. 3-4 minor calyces join to form a major calyx which empty in renal pelvis (the expanded upper end of the ureter)

Subdivisions of the Kidney:

- **Renal lobe:** consists of a renal pyramid with its surrounding cortical arch (cortical tissue overlying the base of each pyramid) and columns of Bertin (cortical tissue on either side of the renal pyramid).
- **Renal lobule:** a part of the renal lobe containing a single collecting duct and all the nephrons that it drains. Lobules are demarcated by interlobular arteries.



The Uriniferous Tubule

Consist of two parts:

A- Nephron: the structural and functional unit of the kidney which produces urine.

B- Collecting duct: concentrates and carries urine to the minor calyx.

A) Nephron

Each kidney contains 1-4 million nephrons.

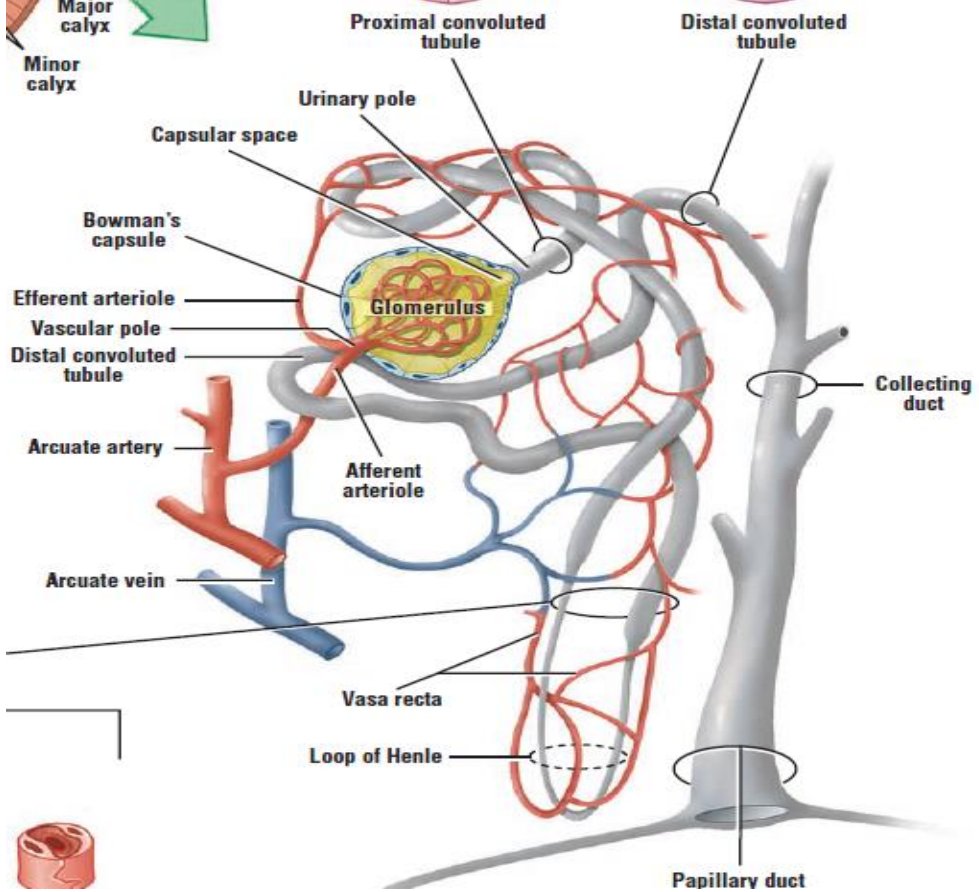
Each nephron consists of:

1- Renal (Malpighian) Corpuscle

2- Proximal convoluted tubule (PCT)

3-Distal convoluted tubule (DCT).

4- Loop of Henle



Classification of Nephrons: *Nephrons are classified according to location of renal corpuscles and length of loop of Henle into:*

a. Cortical nephrons(present in cortex) have short loop of henle.

b. Juxta medullary nephrons(present closely to medulla) have long loop of henle.

1.Renal (Malpighian) Corpuscle

- A vascular ball, 200 um in diameter, formed by invagination of the spherical blind end of the nephron by a tuft of capillaries (glomerulus) changing it into a double-walled cup (Bowman's capsule)

Each renal corpuscle has two poles :

a. Vascular pole: where afferent arteriole enters and efferent arteriole leaves the corpuscle.

b. Urinary pole: where the renal corpuscle becomes continuous with the proximal convoluted tubule.

Each renal corpuscle consists of: -

Glomerulus of blood capillaries. -

Bowman's Capsule.

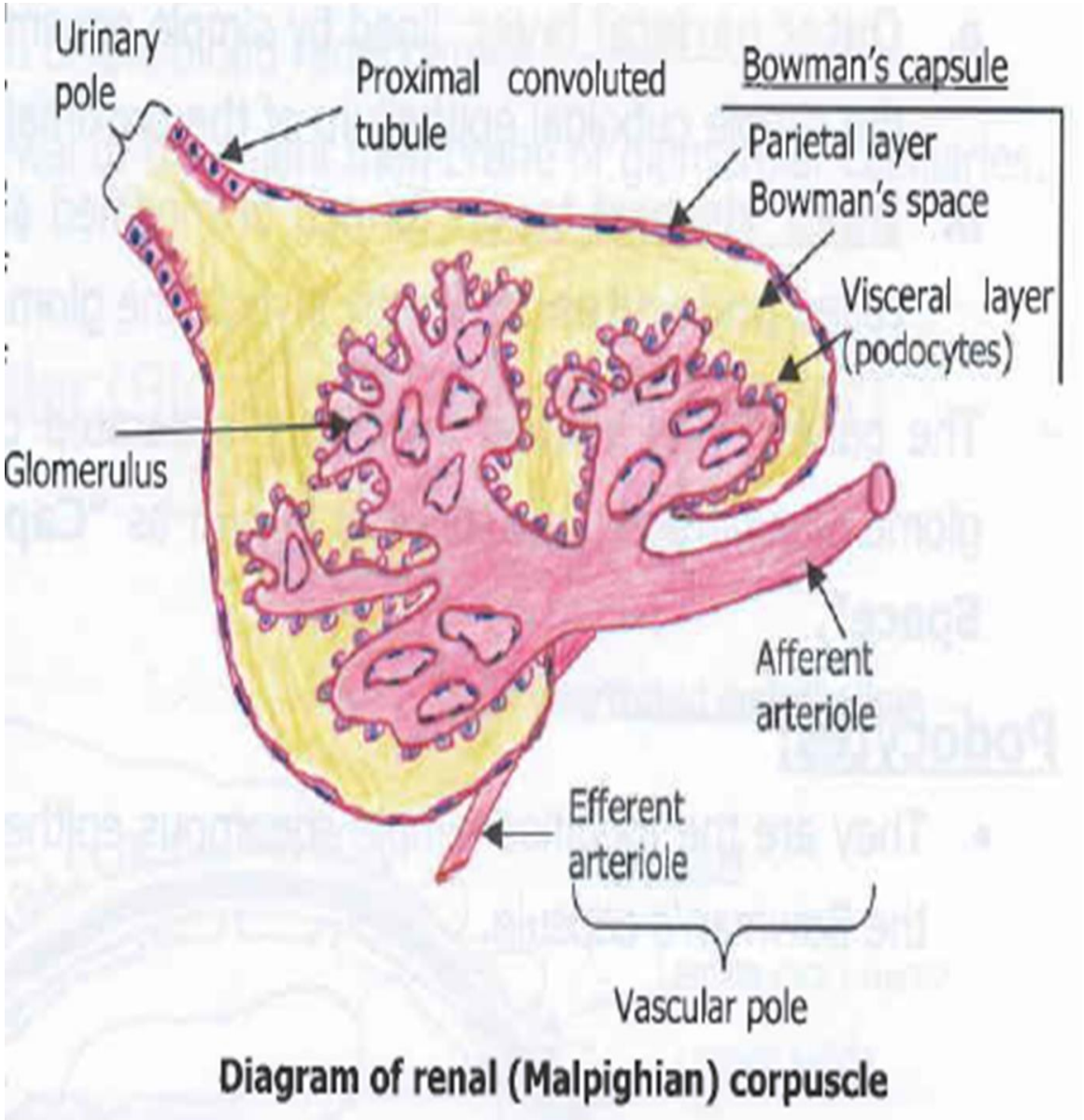
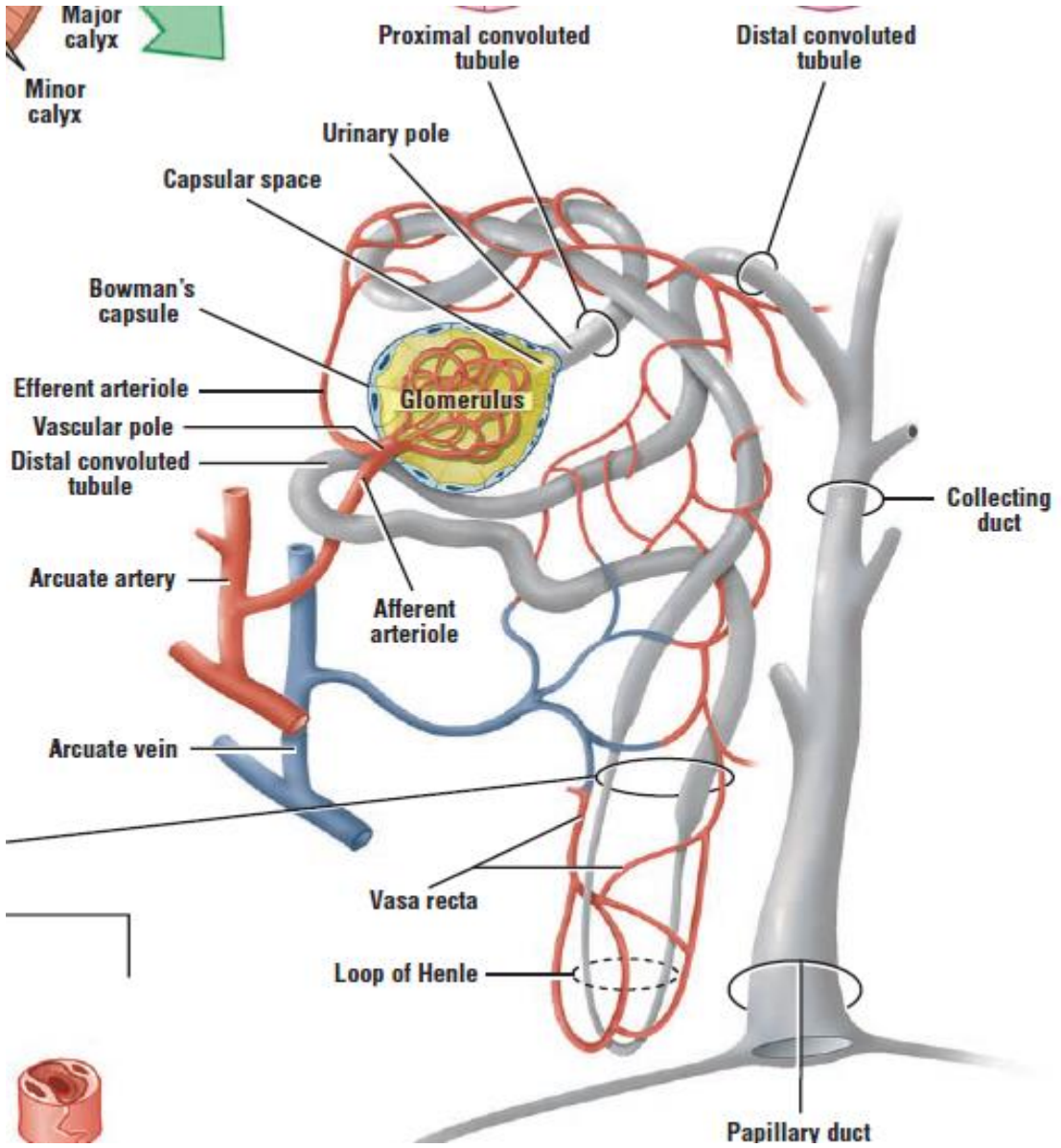


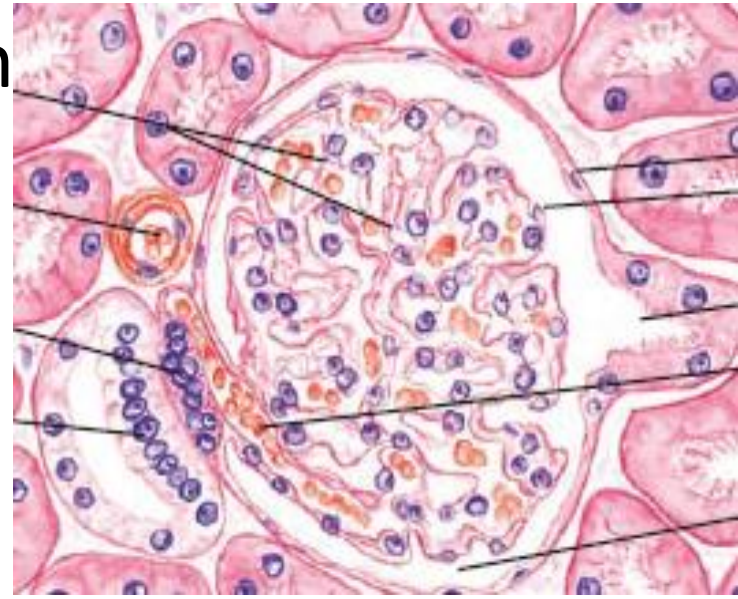
Diagram of renal (Malpighian) corpuscle



Glomerulus

At the vascular pole of the renal corpuscle, the afferent arteriole, carrying unfiltered blood, divides and subdivides forming a tuft of capillaries that drains into the efferent arteriole which carries filtered blood outside the nephron.

The afferent arteriole has a thicker media and a larger diameter than the efferent arteriole (this creates a h glomerular pressure to produce large quantities of glomerular filtrate).



- LM:-Lined by simple squamous endothelium, surrounded by a thick, continuous basement

- EM:-The Endothelium is fenestrated with open pores (up to 100 nm in diameter). Pores are NOT covered by diaphragms.

- The Glomerular Basement Membrane (GBM) is formed 3 layers: (1) Lamina rara (lucida) externa: an outer electron-lucent layer.

(2) Lamina rara (lucida) interna: an inner electron-lucent layer.

(3) Lamina densa: an electron-dense central layer, lies between the laminae rarae.

Bowman's Capsule

Formed of two continuous layers:

a. Outer parietal layer: lined by simple squamous epithelium continuous with the simple cuboidal epithelium of the proximal convoluted tubule.

b. Inner visceral layer: formed of modified simple squamous epithelial cells called podocytes. It directly invests the glomerular capillaries.

The parietal and visceral layers are separated by a space which receives the glomerular filtrate. This space is known as "Capsular Space" or "Bowman's Space".

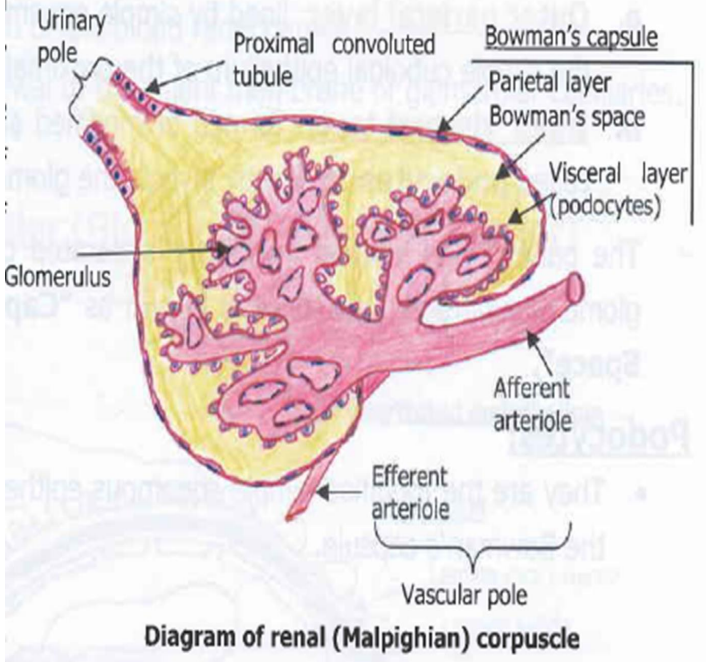


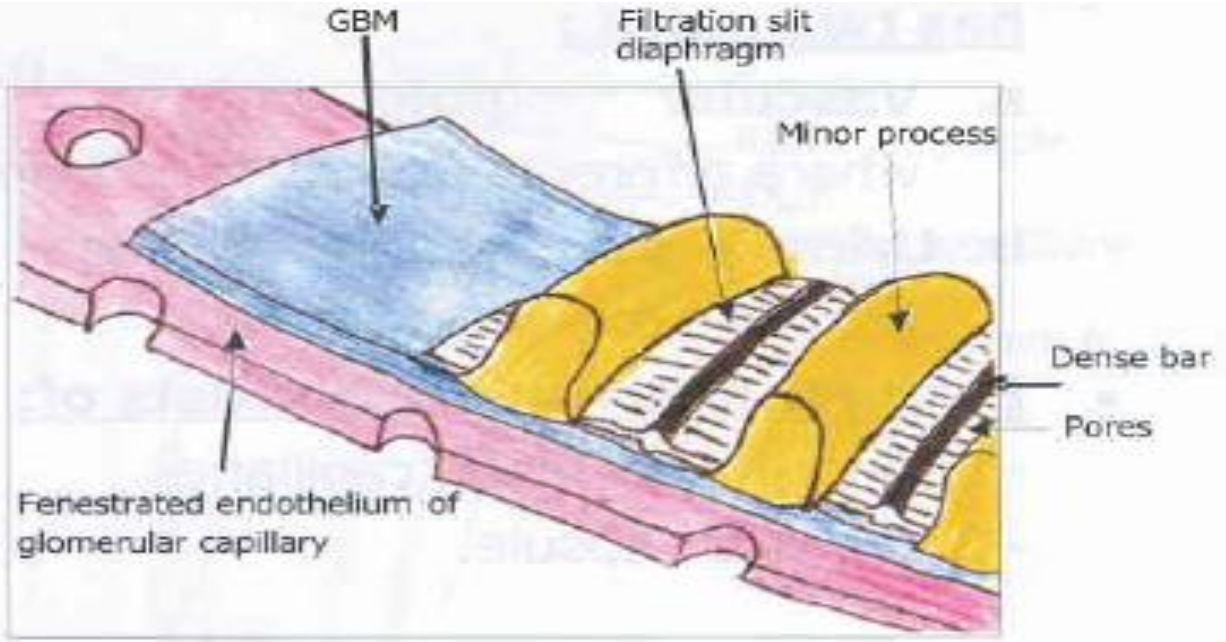
Diagram of renal (Malpighian) corpuscle

Podocytes:

They are the modified simple squamous epithelial cells of the visceral layer of the Bowman's capsule.

E.M. Picture of Podocyte:

- *Have a cell body from which arise* several primary (major) processes, which give rise to secondary (minor) processes or pedicels, that embrace a portion of the glomerular capillary.



EM diagram of filtration slit diaphragm

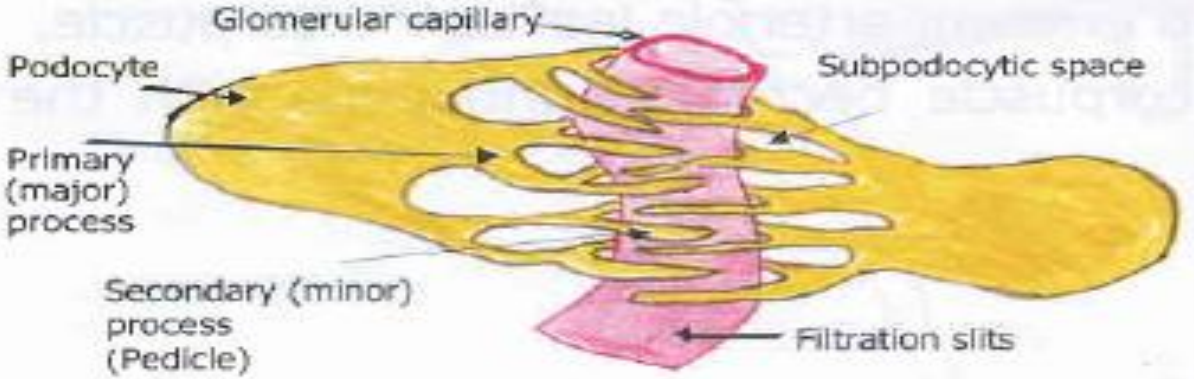


Diagram of Podocyte

- *Minor processes of adjacent podocytes interdigitate leaving gaps in-between them.*
- *These gaps are called filtration slits, which are covered by a thin semipermeable diaphragm named filtration slit diaphragm.*

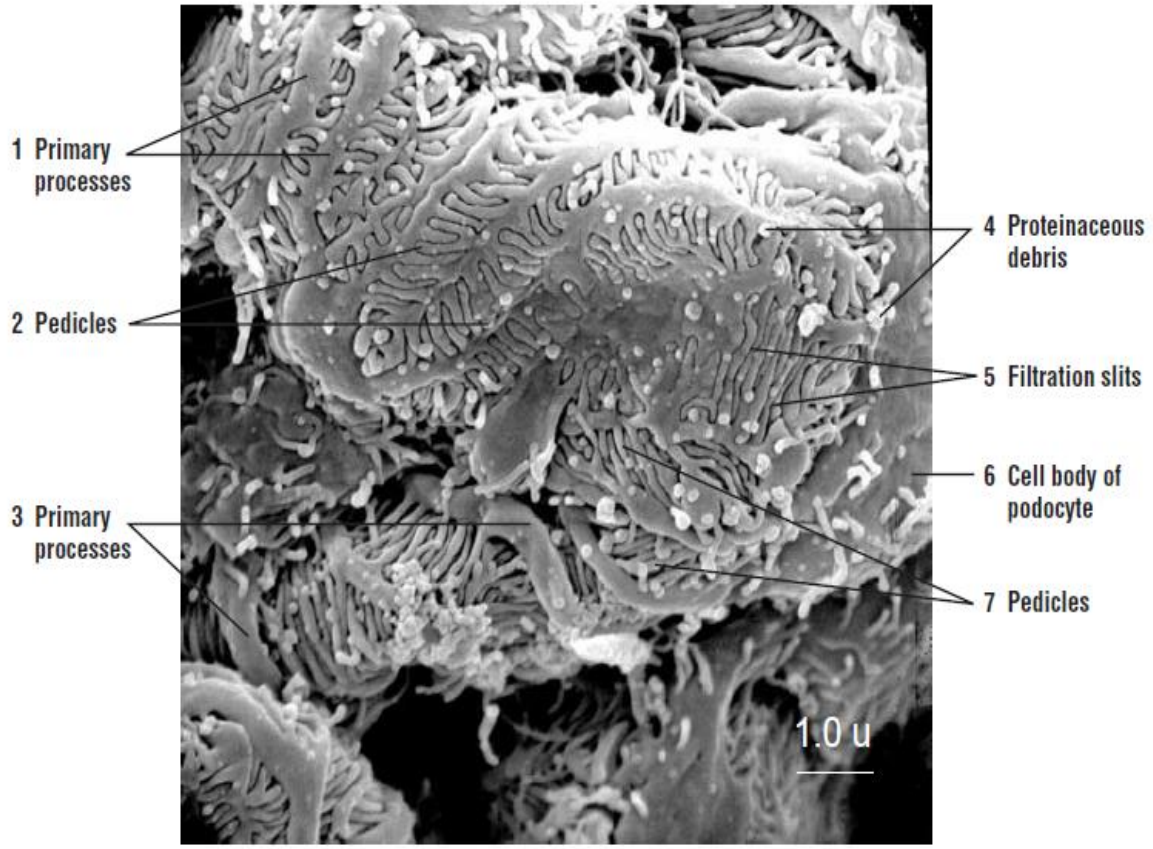


FIGURE 16.5 ■ Kidney: scanning electron micrograph of podocytes (visceral epithelium of glomerular (Bowman's) capsule) surrounding the glomerular capillaries.

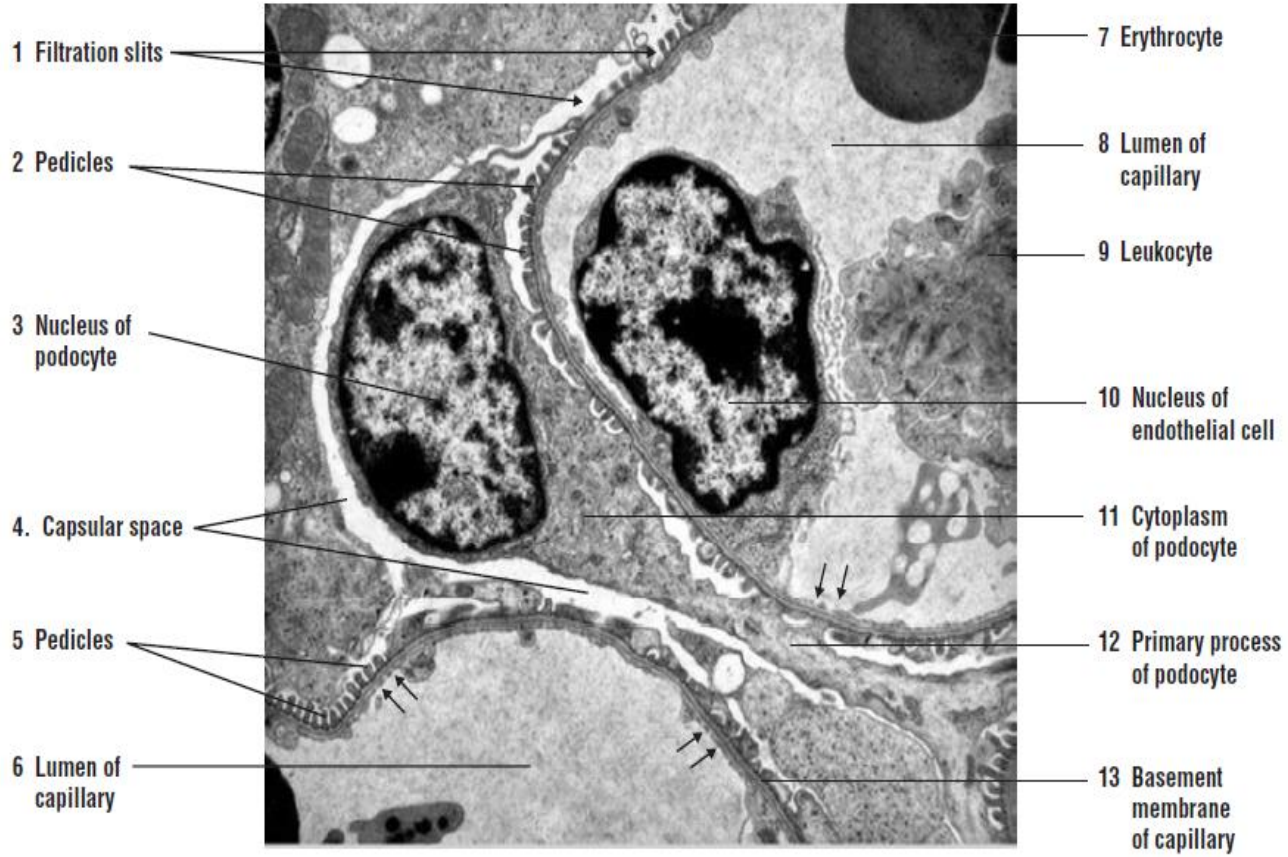


FIGURE 16.6 ■ Kidney: transmission electron micrograph of podocyte and adjacent capillaries in the renal corpuscle. ×6,500.

- *EM of filtration slit diaphragm: zipper-like sheet structure formed by transmembrane protein nephrin. Has a central dense bar with pores on both sides.*
- *The podocyte cell body is separated from glomerular basement* membrane by subpodocytic space.
- *The cytoplasm of podocytes contains numerous free ribosomes, rER,* mitochondria and prominent Golgi complex. Bundles of actin microfilaments are present in the cytoplasm and processes that give podocytes a contractile capacity.

- **Functions of Podocyte:**

1. Involved in formation of the blood renal barrier.
2. Responsible for renewal of basement membrane of glomerular capillaries.

Blood Renal Barrier (Glomerular Filtration Barrier) (GFB)

Definition: it is the barrier that separates the blood inside the glomerular capiliaries from the glomerular filtrate inside Bowman's space and through which filtration of blood occurs.

It is formed of 3 layers:

1. Fenestrated endothelial cells of glomerular capillaries: Filtration selectivity depends on molecular weight (M.W.) & size. It allows the passage of moecules smaller than blood cells and platelets e.g. plasma proteins.

2. Glomerular basement membrane (GBM):

It is the only continuous and the most effective layer of the barrier.

Filtration selectivity depends on:

a) Molecular weight: it prevents substances with large molecular weight (1160, 000 Daltons) as plasma proteins, but small molecules as simple sugars and amino acids can pass through it.

b) Molecular Charges: BOTH laminae rarae are negatively charged, so, impedes the passage of all negatively charged molecules e.g. albumin (although its M.W.is 69,000 Daltons)!

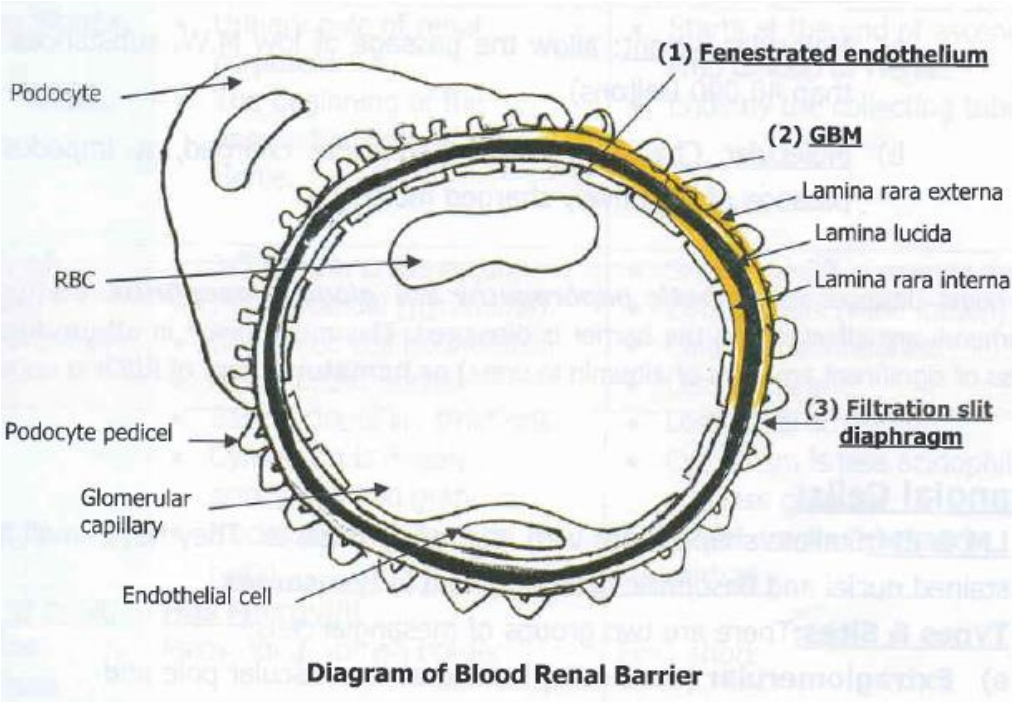


Diagram of Blood Renal Barrier

3. Filtration slit diaphragms: The diaphragms that covers the slits (gaps) between the podocyte minor processes (pedicels).

Filtration selectivity depends on:

a) Molecular weight: allow the passage of low M.W. substances (less than 40,000 Daltons).

b) Molecular Charges. As it is negatively charged, it impedes the passage of negatively charged molecules.

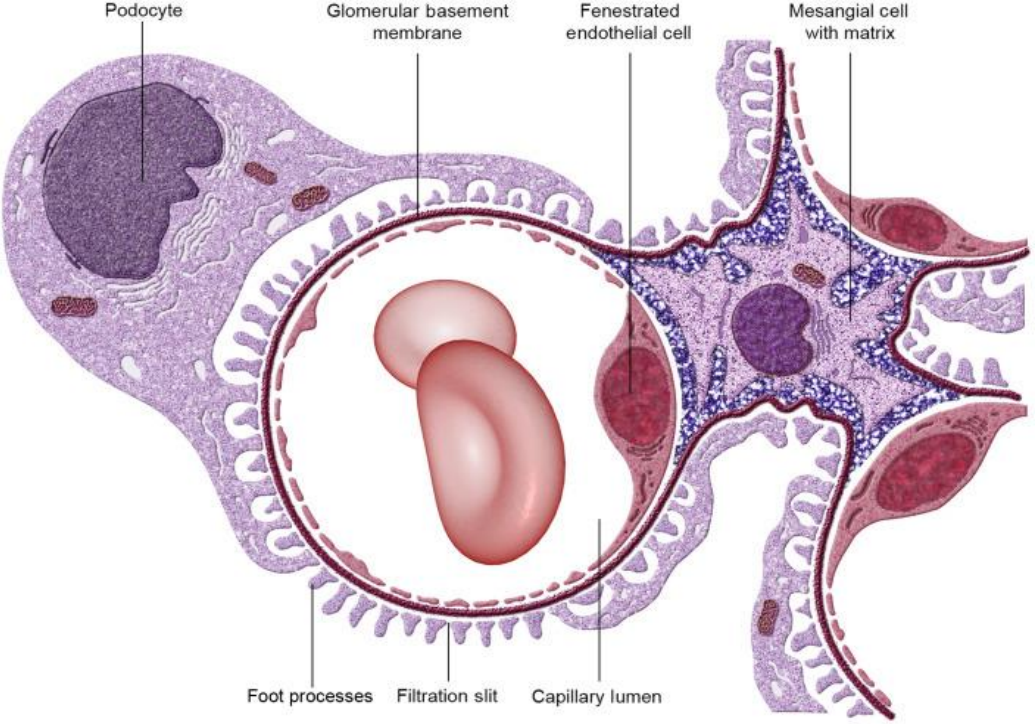
In some diseases as diabetic nephropathy and glomerulonephritis, the renal glomeruli are affected and the barrier is disrupted. This might result in albuminuria (loss of significant amounts of albumin in urine) or hematuria (loss of RBCs in urine).

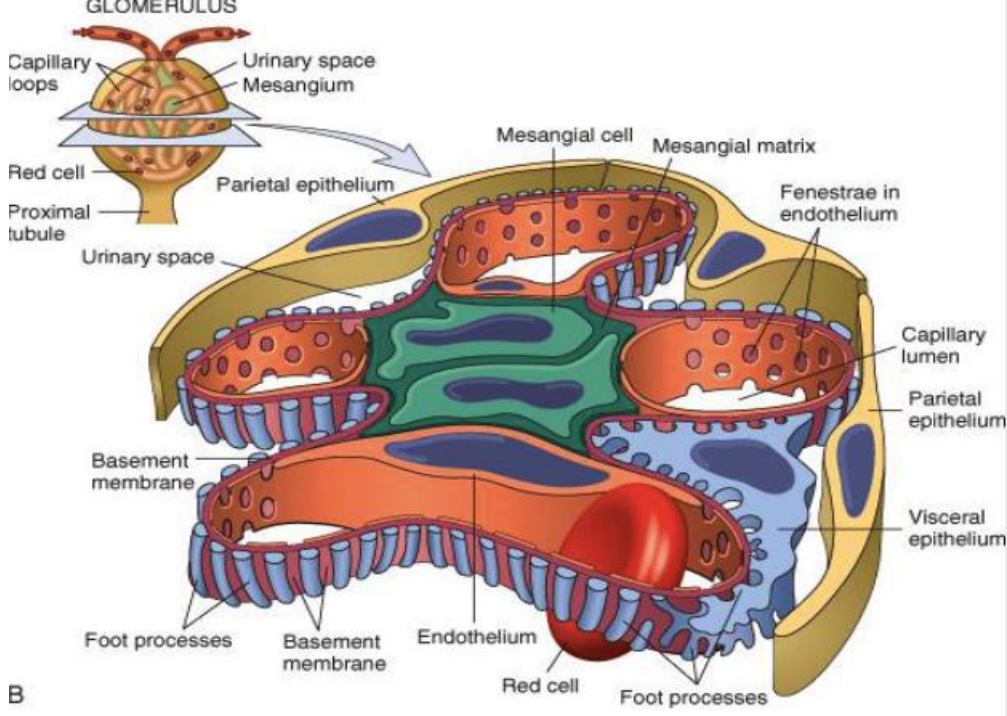
Mesangial Cells:

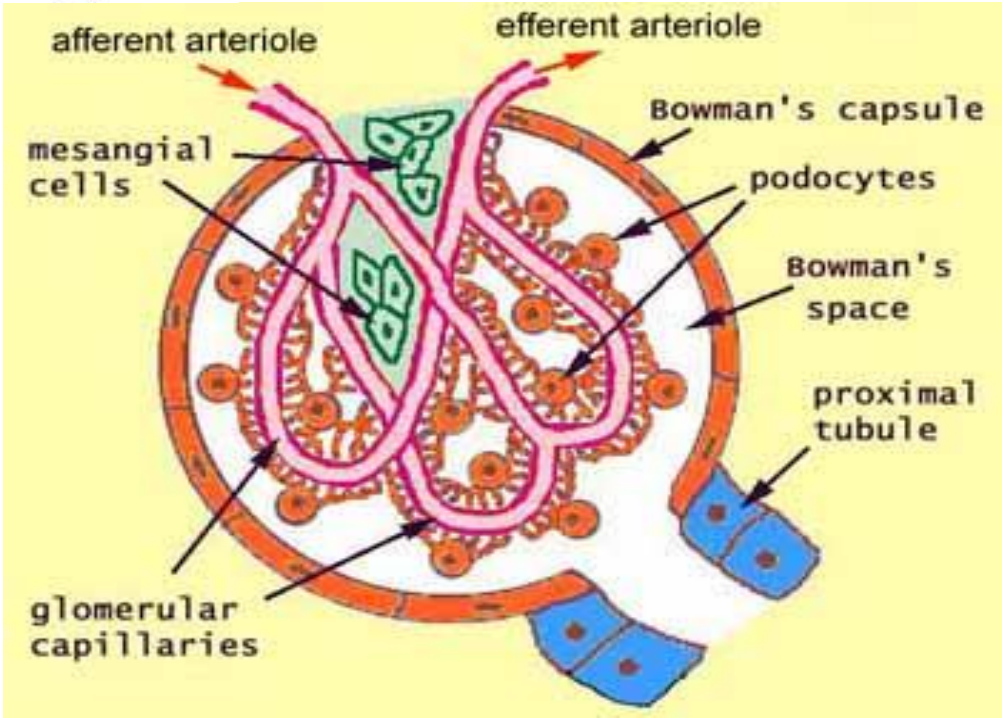
- LM & EM: Stellate shaped cells with multiple processes. They have small darkly stained nuclei and basophilic cytoplasm rich in lysosomes.
- Types & Sites : There are two groups of mesangial cells:

a) Extraglomerular (Lacis cells) located at the vascular pole and

b) Intraglomerular, located within the renal corpuscle, inbetween the glomerular capillaries.


Podocyte
Glomerular basement membrane
Fenestrated endothelial cell
Mesangial cell with matrix
Foot processes
Filtration slit
Capillary lumen


GLOMERULUS
Capillary loops
Urinary space
Mesangium
Red cell
Proximal tubule
Parietal epithelium
Mesangial cell
Mesangial matrix
Fenestrae in endothelium
Urinary space
Capillary lumen
Parietal epithelium
Basement membrane
Visceral epithelium
Foot processes
Basement membrane
Endothelium
Red cell
Foot processes
B


afferent arteriole
efferent arteriole
Bowman's capsule
mesangial cells
podocytes
Bowman's space
proximal tubule
glomerular capillaries

- Functions of Mesangial Cells:

1. Supportive function and renewal of GBM: by secretion of collagen, chondroitin sulphate, fibronectin and mesangial matrix.

2. Contractile function: Involved in regulating blood flow within the glomerular capillaries by responding to vasoactive substances

3. Phagocytic function: They can extend their processes between the endothelial lining of glomerular capillaries to phagocytose any foreign debris, or residues during renewal of GBM

3. Extraglomerular mesangial cells form part of the juxtaglomerular apparatus.

Difference between proximal and distal convoluted tubules

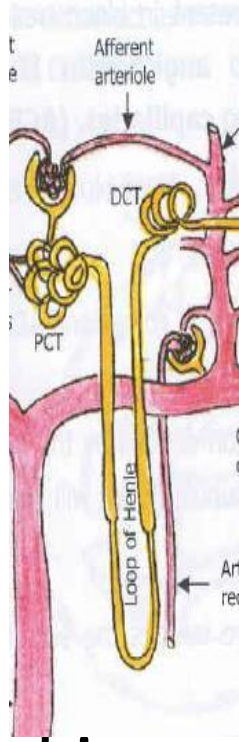
	2.Proximal convoluted tubule	3.Distal convoluted tubule
Shape and size	✓ More convoluted. ✓ Longer (15mm). ✓ Larger diameter(60um). ✓ Very narrow lumen.	✓ Less convoluted. ✓ Shorter(5mm). ✓ Smaller diameter(40um). ✓ Wider lumen.
Site: start **end**	✓ Urinary pole of renal corpuscle. ✓ The beginning of descending limb of loop of Henle.	✓ Start at ascending loop of Henle. ✓ Ends by collecting tubules.
L.M of lining epithelium	✓ 3-5 cell in cross section. ✓ High cuboidal (pyramidal). ✓ Ill defined cell boundaries. ✓ Apical brush border. ✓ Basal acidophilic striations.	✓ 5-8 , up to 20 in macula densa. ✓ Cuboidal cell (wide lumen). ✓ Clear cell boundaries. ✓ Less apparent. ✓ Less basal striations.

	✓ Cytoplasm is deeply acidophilic and granular. ✓ Nuclei are rounded and basal.	✓ Cytoplasm is less acidophilic and less granular. ✓ Nuclei are rounded and central.
EM of cells: Apical surface	**Has microvilli :** Many , long brush border	Few short
Lateral surface	**Has interdigitation:** Extensive indistinct cell boundaries	Less apparent and clear cell boundaries
Basal surface	**Show parallel striation due to:** Basal infoldings active ion transport Parallel mitochondria (many)	Less apparent
Function	✓ Active reabsorption of glucose and amino acid. ✓ Reabsorption of Na , Cl , K and H2O.	✓ Reabsorption of Na and H2O under the effect of aldosterone and ADH. ✓ Excretion of H2 and NH3.

4. Loop of Henle:

• A U-shaped tubule connecting the PCT with the DCT. Found in medulla and medullary rays in cortex.

• Juxtamedullary nephrons have very long Henle's loops, (important in mechanism of urine conc.) while cortical nephrons have short loops. • It is formed of:



1- Thick descending limb: similar to PCT lined with high cuboidal epithelium.

2- Thin descending limb: lined with simple squamous epithelium.

3- Thin ascending limb: lined with simple squamous epithelium.

4- Thick ascending limb: similar to DCT, lined with simple cubical epithelium.

Function: The loop of Henle and the surrounding tissue are involved in making urine hypertonic and conserving water

B. The Collecting Tubules

- They are the excretory portion of uriniferous tubules.

Each nephron drains into arched collecting tubules lined with simple cuboidal epithelium

Each 6-8 of these tubules open into a wide straight collecting duct of Bellini). As they penetrate deeper into medulla, their the lining epithelial cells increase in height till they become columnar.

The ducts of Bellini open into the tips of medullary pyramids (renal papilla). They are the major factor in urine concentrating mechanism under the effect of ADH.

- Two distinct types of cells are present in the collecting tubules and ducts: **Principal cells and Intercalated cells.**

- **Principal cells** Most abundant, cuboidal to columnar; pale-staining, distinct cell membranes
Medullary rays and medulla
Regulated reabsorption of water & electrolytes; regulated secretion of K^+
- **Intercalated cells** Few and scattered; slightly darker staining
Medullary rays
Reabsorption of K^+ (low-K^+ diet); help maintain acid-base balance

Juxtaglomerular Apparatus

- Site: Located at the vascular pole of the renal corpuscle. Consists of:

1) Macula Densa: It is the part of the DCT that fits between the afferent and efferent arterioles at the vascular pole of the renal corpuscle.

Cells show the following changes:

a) The length of cells increases, become columnar.

b) The nuclei of cells become apical, deeply-stained and closely packed, thus appear as a "dark spot" = macula, by L.M.

c) Golgi complex is situated infra-nuclear (basal).

d) Basement membrane is lost, so these cells come in contact with JG cells.

Function: Macula densa act as osmoreceptors that monitor the level of Na ions in the lumen of the DCT.

2) Juxtaglomerular cells (JG cells):

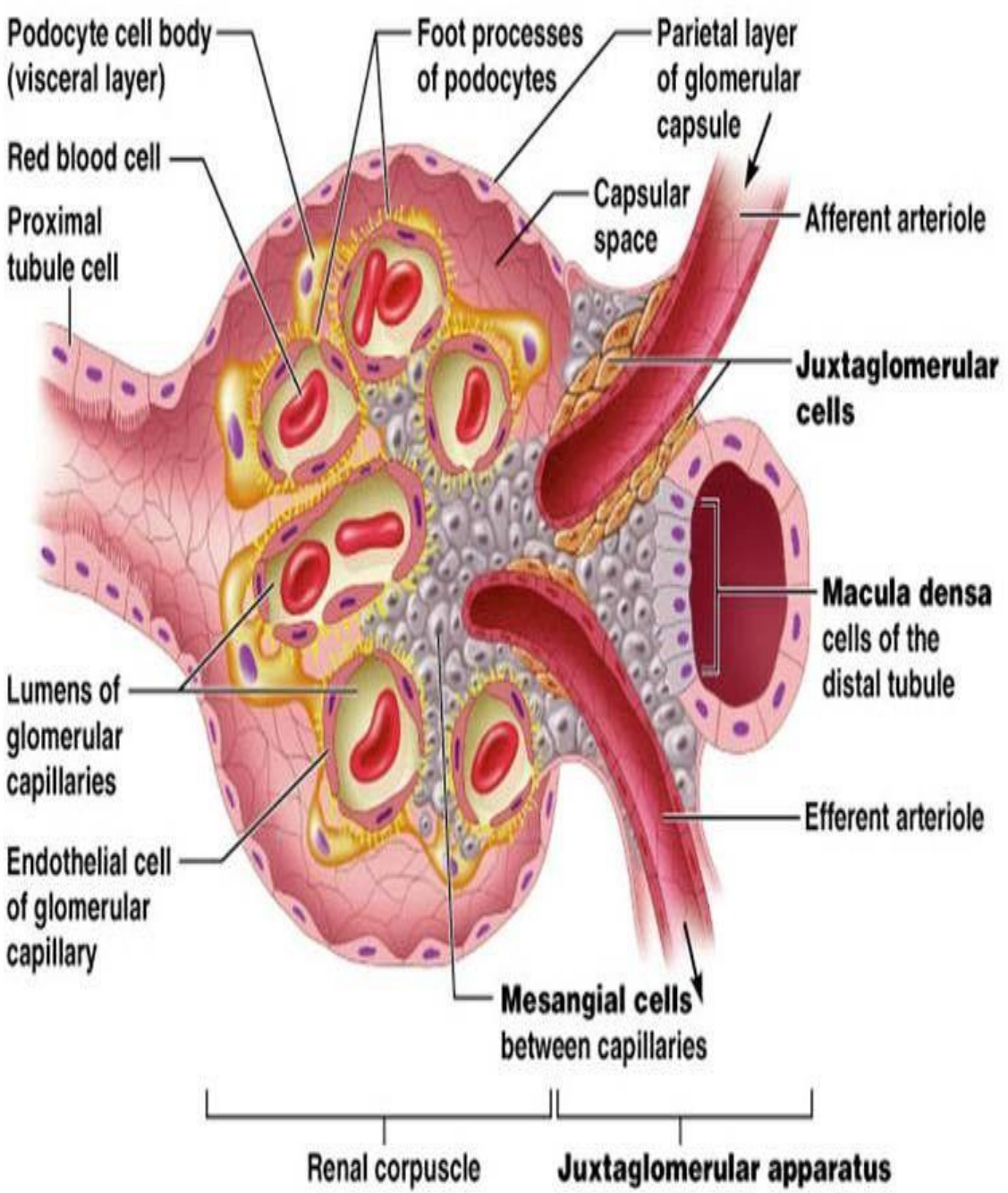
Modified, smooth muscle cells present in the tunica media of the adjacent afferent arteriole (and sometimes the efferent arteriole).

Cells show the following changes:

a) Nuclei become rounded instead of being elongated.

b) Cytoplasm contains secretory granules (containing Renin) that stains with PAS.

- **Function:** Secrete Renin enzyme.



3) Extraglomerular mesangial cells (Lacis cells, pole cushions):

Small, pale stained cells that occupy the space bounded by the afferent arteriole, efferent arteriole and macula densa.

- **Function:** Supportive and may transmit signals from macula densa into glomerulus, affecting vasoconstriction there.

Function of Juxtaglomerular Apparatus:

It plays a key role in regulation of glomerular filtration rate and blood pressure through "The renin-angiotensin-aldosterone system as follows:

1. As a result of drop in blood pressure or blood volume (as in hemorrhage) glomerular filtrate volume decreases

2. Na and Cl ions concentration in the DCT decreases.

3- Macula densa monitors these changes and stimulates JG cells to secrete.

4. Renin changes angiotensinogen (present in bloodstream & formed in the liver) - angiotensin I, then into angiotensin II (by angiotensin converting enzyme present on lung capillaries. (ACE).

5- Angiotensin II, a potent vasoconstrictor, raises blood pressure by:

i) Constriction of peripheral blood vessels, and

ii) Release of aldosterone from the adrenal cortex and ADH from the pituitary gland.

6- Aldosterone promotes the reabsorption of Nacl by the DCT. ADH promotes reabsorption of water from collecting tubules. This will increase blood volume & blood pressure

N.B.: The return of normal blood pressure inhibits the secretion of renin by JG cells (feedback mechanism).

Blood Supply of the Kidney

- ✓ *Renal artery: enters the hilum, giving rise to interlobar arteries that extend between the pyramids.*
- ✓ *Interlobar arteries: at corticomedullary junction give off arcuate arteries which arch around the base of the pyramids.*
- ✓ *Arcuate arteries: give rise to small interlobular arteries that enter the cortical tissue in-between its lobules.*
- ✓ *Interlobular arteries: give off afferent glomerular arterioles and end as capsular capillaries.*
- ✓ *Afferent glomerular arterioles form the glomerulus and leave it as efferent arteriole.*

✓ *Efferent arterioles:*

Leave the glomerulus and break up into peritubular capillaries supplying convoluted tubules.

Efferent arterioles of juxtamedullary nephrons give rise to the straight arteriolae reactae that extend into medullary pyramids to supply it and collecting tubule.

- *These vessels drain into interlobular veins or arcuate veins, then into interlobar veins which form the renal vein at the hilum.*

URINARY PASSAGES

- They include calyces, renal pelvis, ureters, urinary bladder and urethra.

Each has the same histological structure: a mucosa consisting of uroepithelium (transitional epithelium) and lamina propria of fibroelastic C.T., musculosa and adventitia.

Ureters

They conduct urine from renal pelvis to urinary bladder. The wall of the ureter is formed of:

1- Mucosa:

Shows prominent longitudinal folds giving the lumen a stellate appearance.

Formed of uroepithelium (transitional epithelium) and underlying C.T. corium.

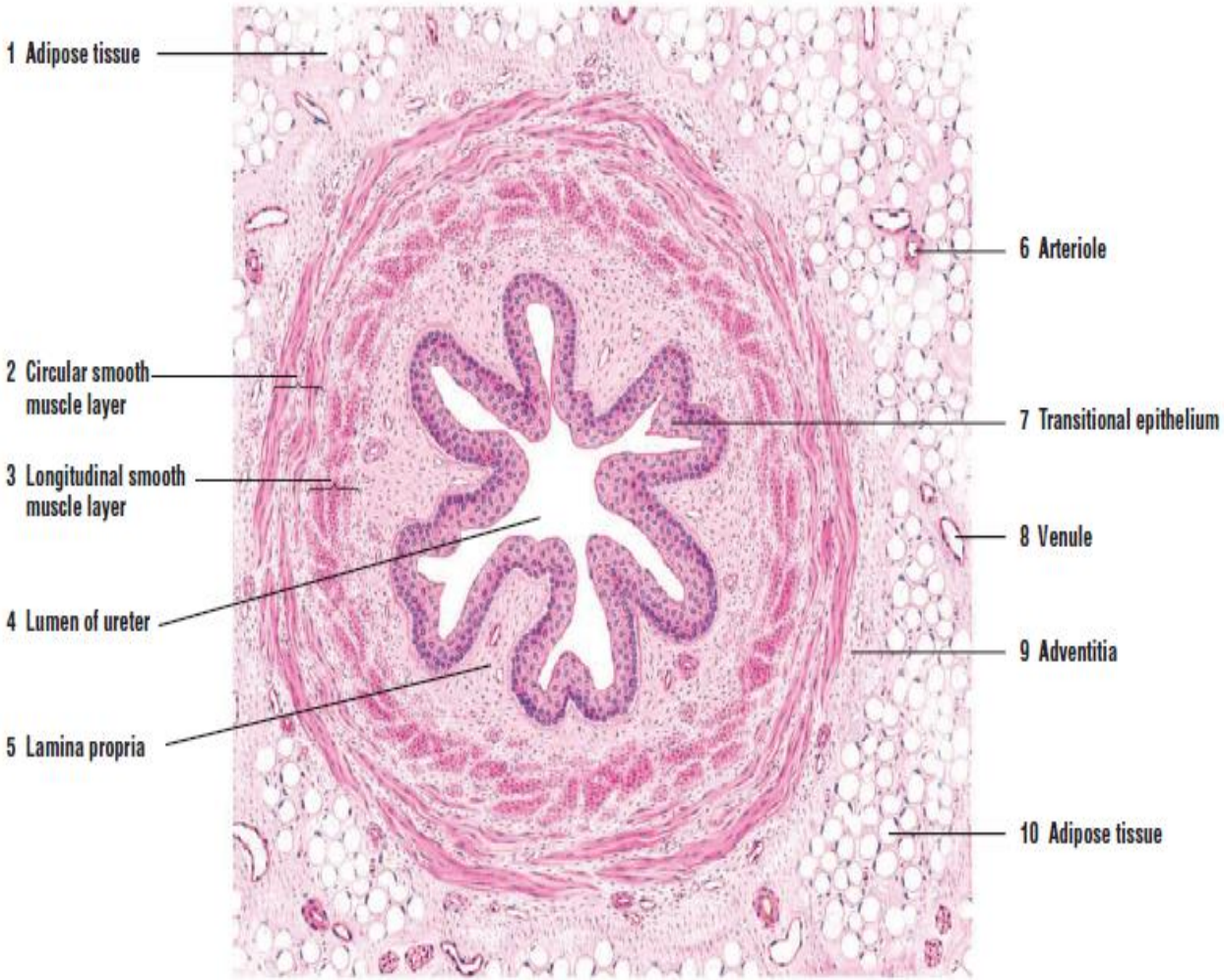


FIGURE 16.10 ■ Urinary system: ureter (transverse section). Stain: hematoxylin and eosin. Low magnification.

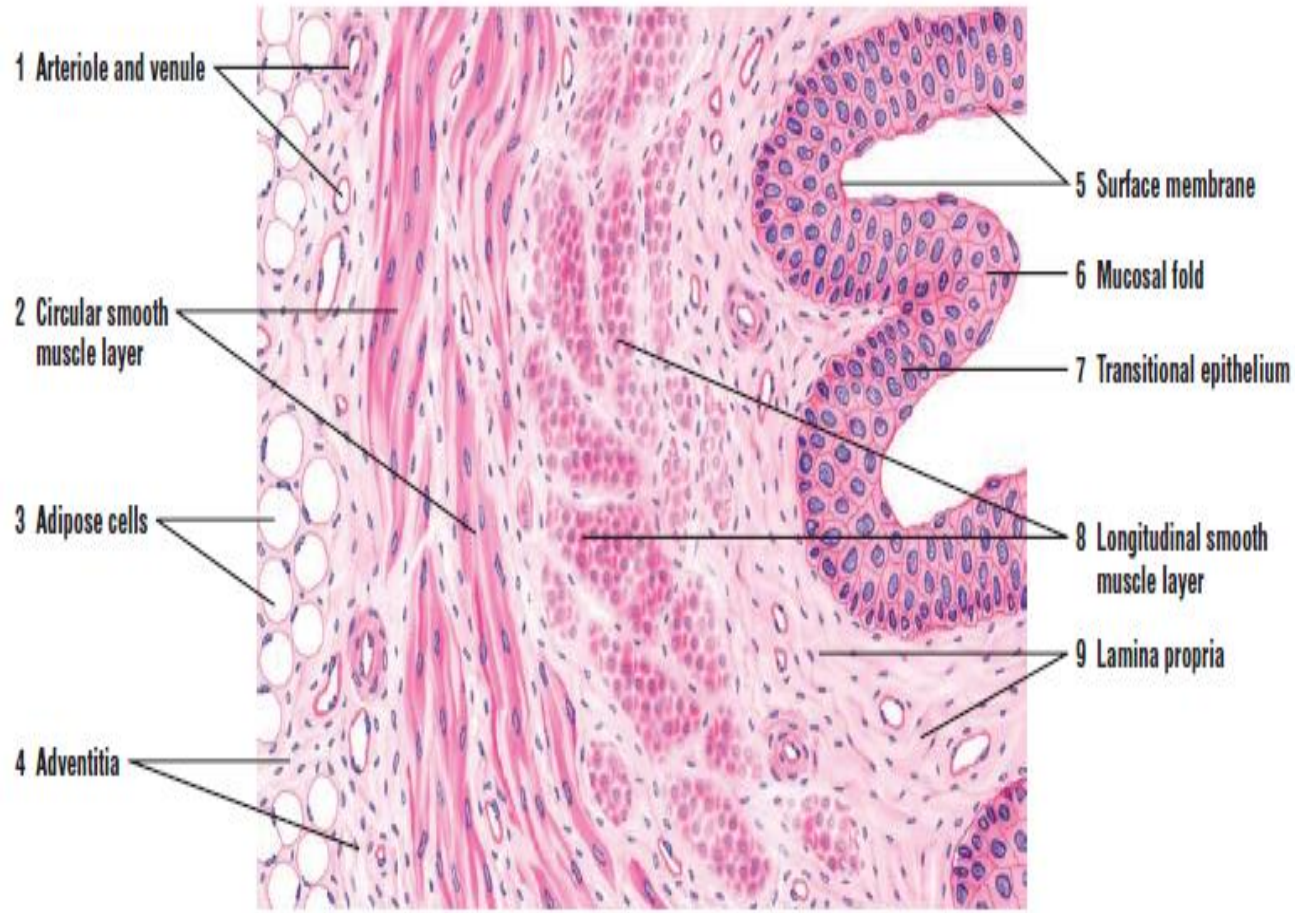


FIGURE 16.11 ■ Section of a ureter wall (transverse section). Stain: hematoxylin and eosin. Medium magnification.

Uroepithelium is formed of 3 layers:

1. Basal layer: one layer of small basal cells resting on a very thin basement membrane.

2. Intermediate layer: one to several layers of polyhedral cells.

3. Superficial layer: "umbrella cells" large dome shaped cells, may be binucleated.

N.B.: Both transitional epithelium and extensive longitudinal folds allow distention of the ureter, so small stones can be voided in urine.

2- Musculosa:

The upper two thirds of the ureter has an inner longitudinal and an outer circular layer of smooth muscles.

The lower third has an additional outer longitudinal layer.

Contraction of these muscle layers produces peristaltic waves which propel urine along it towards urinary bladder.

3- Adventitia: Formed of fibroelastic C.T. containing blood vessels, nerves and lymphatics.

Urinary bladder

1- Mucosa:

a. Epithelium: formed of uroepithelium in which umbrella cells are well developed and have extensive intercellular junctional complex forming a unique apical membrane as contact with urine is greatest.

- In empty bladder: uroepithelium is 5-6 layers thick. Superficial cells "umbrella cells" are dome shaped ,100um in diameter.
- In full bladder: uroepithelium is 3-4 layers thick. Superficial cells become squamous.

b. C.T. corium (lamina propria): formed of fibroelastic C.T

2- Musculosa:

- Formed of: inner longitudinal, middle circular and outer longitudinal smooth muscle.

Distal to the bladder neck, the inner longitudinal layer becomes circular to form the internal urethral sphincter.

3- Adventitia: the urinary bladder is covered by fibroelastic C.T. except the superior part which is covered by serosa (peritoneum).

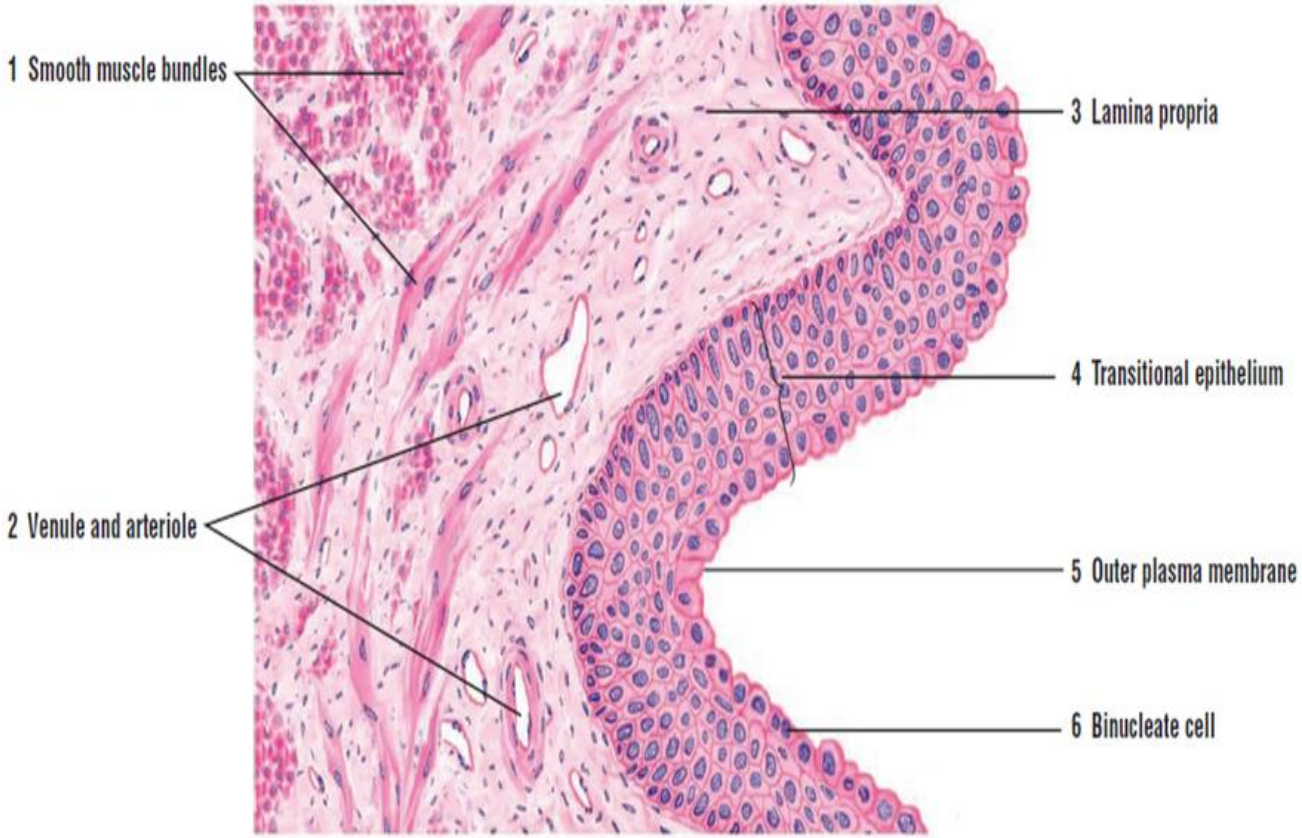


FIGURE 16.14 ■ Urinary bladder: contracted mucosa (transverse section). Stain: hematoxylin and eosin. Medium magnification.

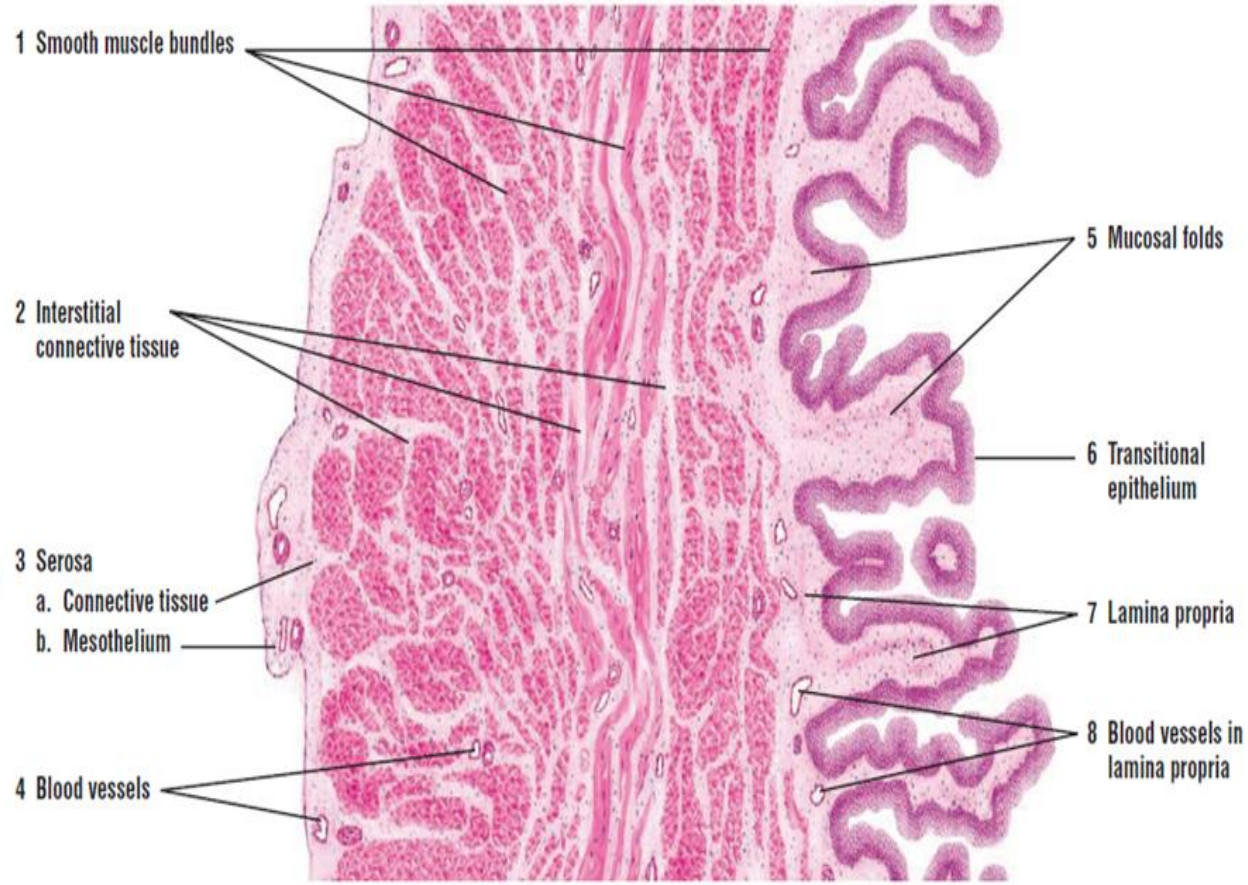


FIGURE 16.13 ■ Urinary bladder: wall (transverse section). Stain: hematoxylin and eosin. Low magnification.

Urethra

It is a tubular structure that carries urine from the bladder to exterior

A. Male urethra: *A curved tube about 20 cm in length. Also, serves as a pathway for semen during ejaculation. It is divided into:*

1- Prostatic urethra:

- *The initial part of urethra that passes through the prostate.*
- *Lined with transitional epithelium.*
- *It is surrounded by internal urethral sphincter.*

2- Membranous urethra:

- *A short part that passes through the urogenital diaphragm.*
- *Lined with stratified or pseudo-stratified columnar epithelium.*
- *It is surrounded by skeletal muscles of the pelvis forming external urethral sphincter.*

3- Penile (cavernous) urethra:

- *Located in corpus spongiosum of penis.*
- *Lined with stratified columnar epithelium, which changes to stratified squamous in its distal dilated part (fossa navicularis).*
- *Open into it the ducts of glands of Littré.*

B. Female urethra:

- *It is a short straight tube.*
- *Lined with transitional, stratified or pseudostratified columnar then stratified squamous epithelium at its distal end.*