HISTOLOGY OF THE KIDNEY

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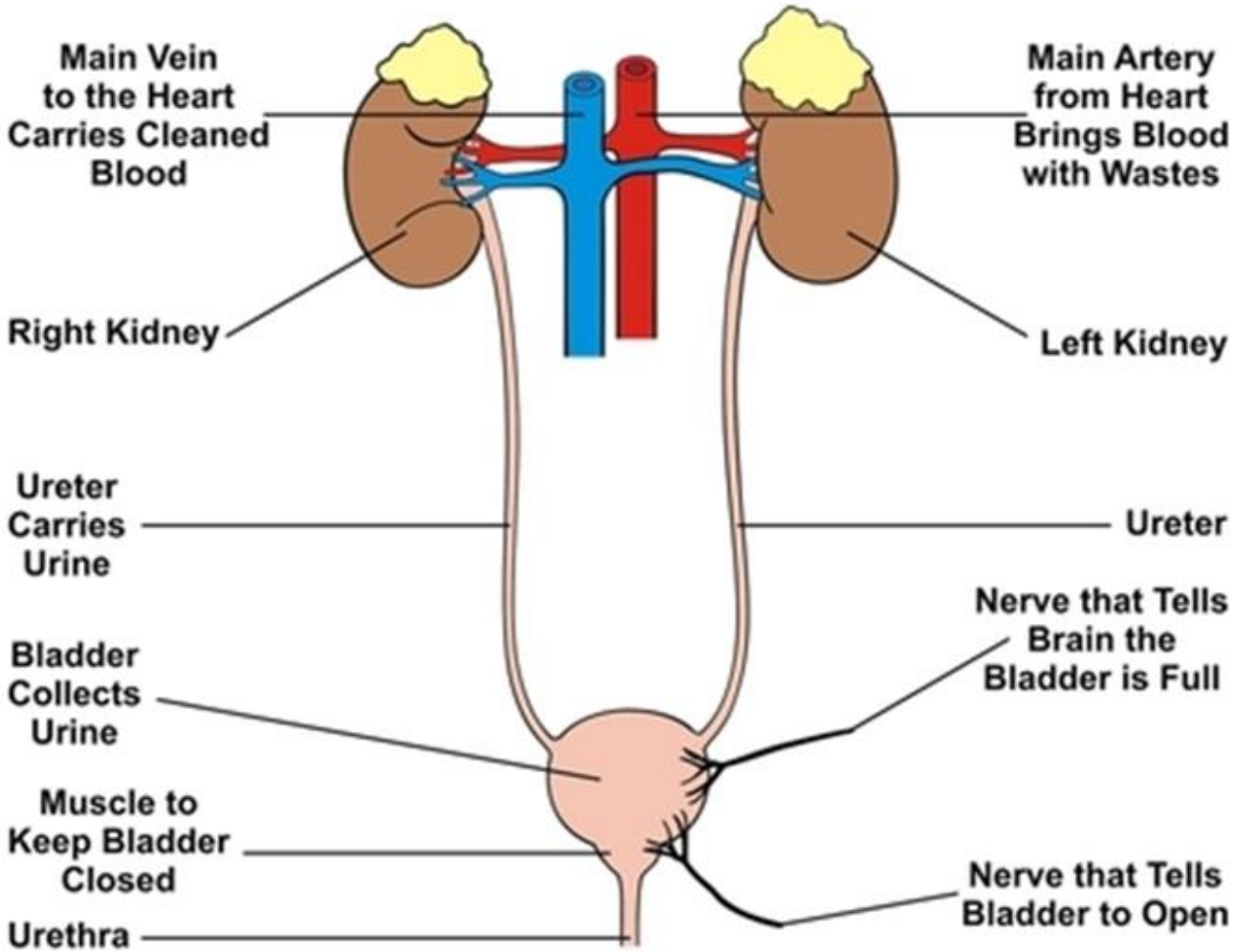
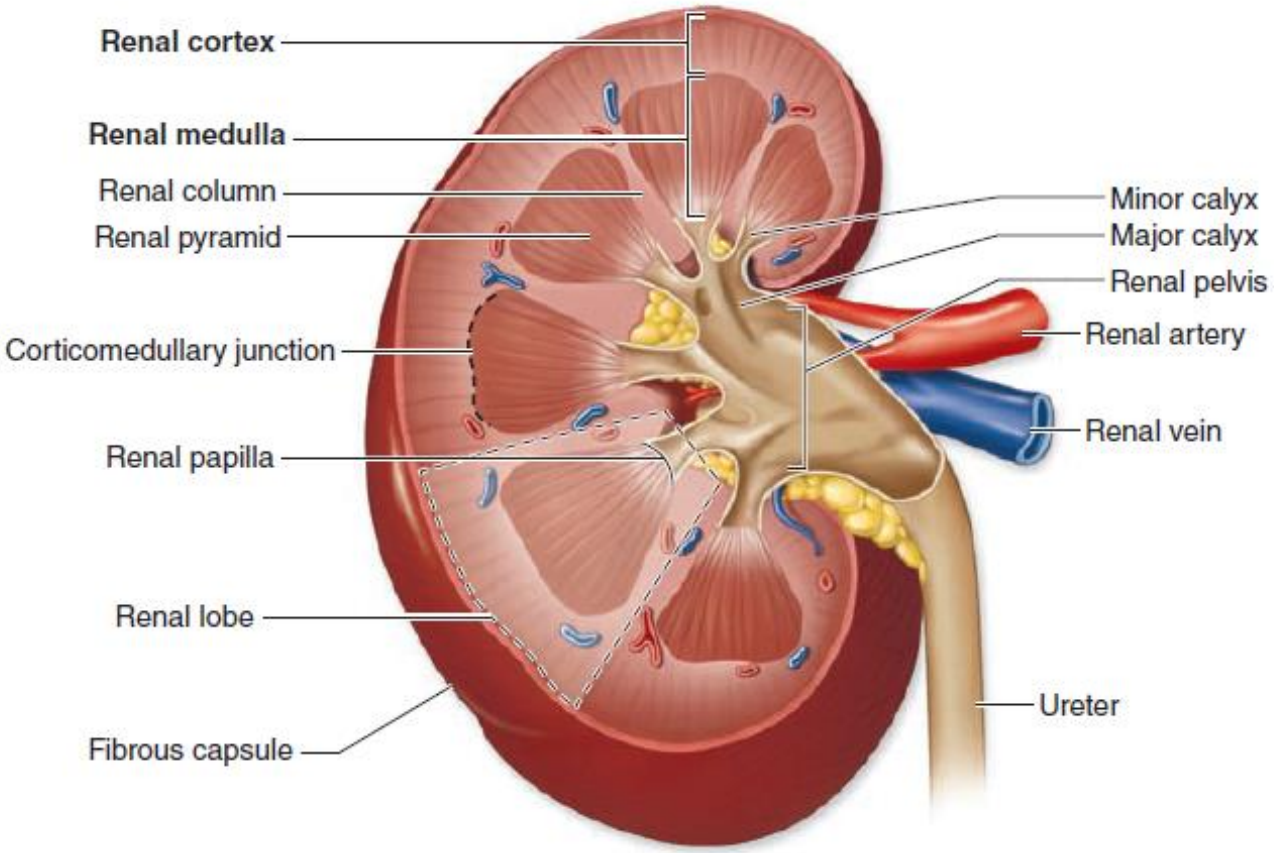
2020

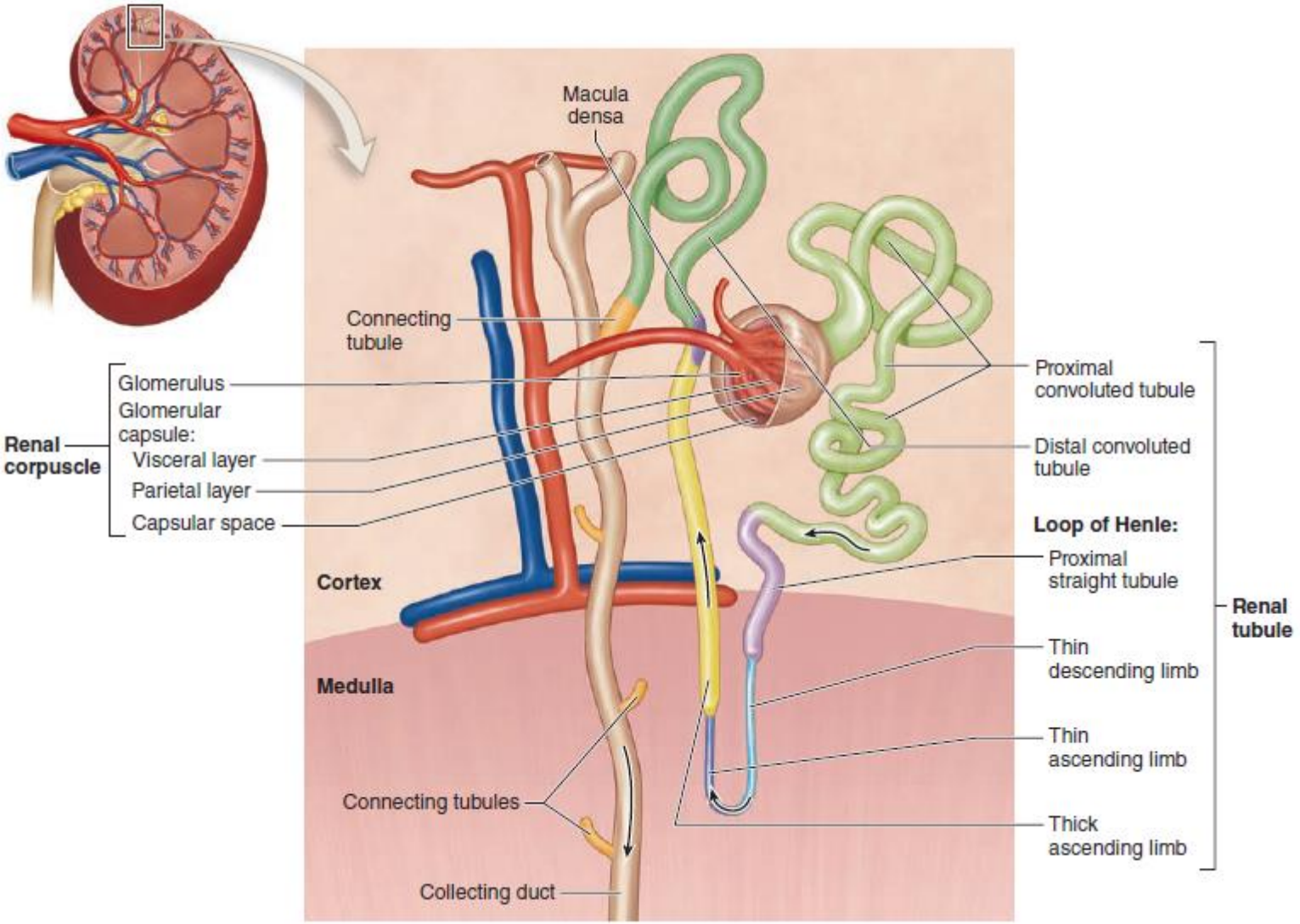
URINARY SYSTEM



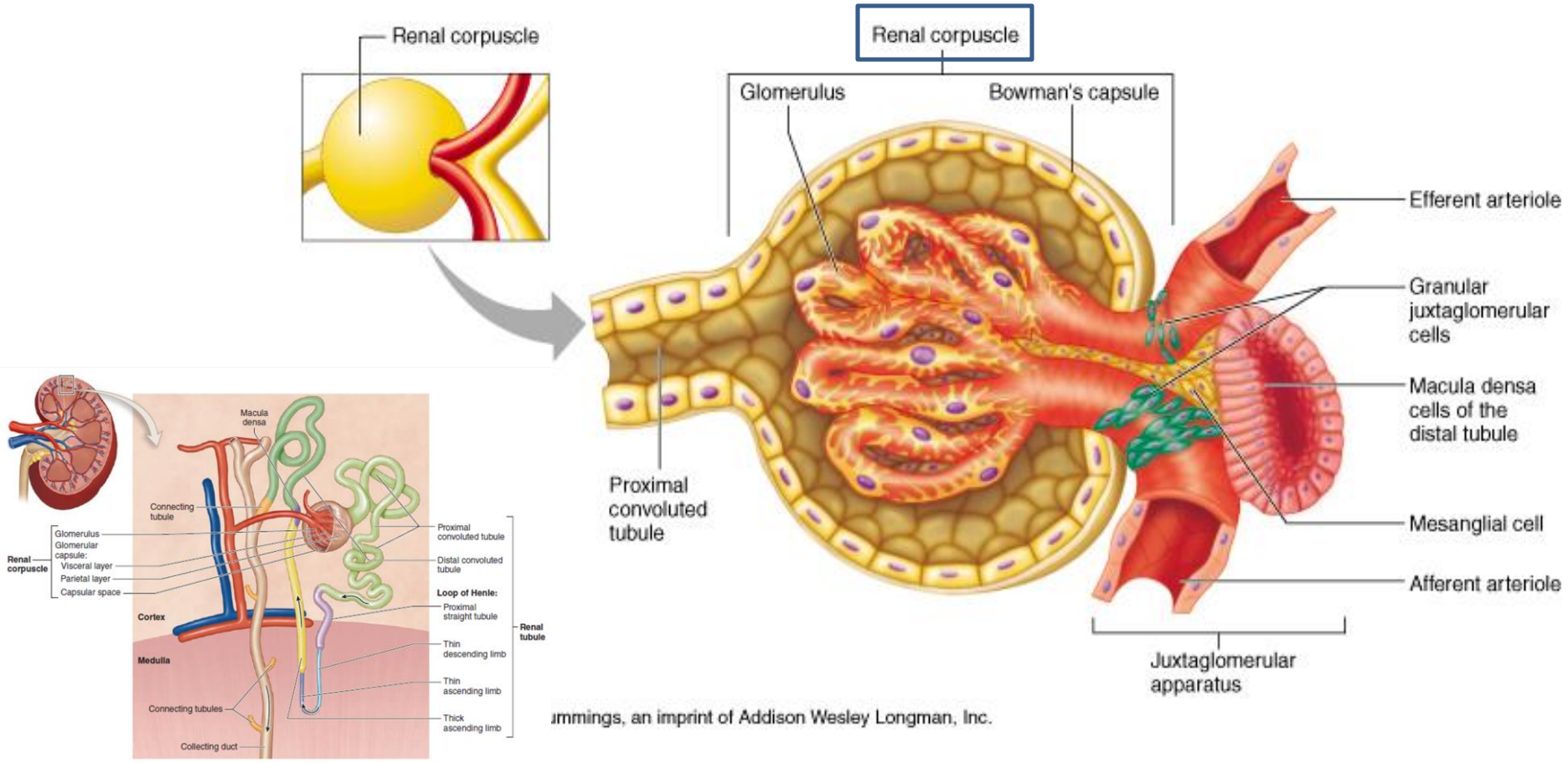


Each kidney is bean-shaped, with a concave **hilum** where the ureter and the renal artery and veins enter. The ureter divides and subdivides into several **major and minor calyces**, around which is located the renal sinus containing adipose tissue. Attached to each minor calyx is a medullary **pyramid**, a conical region of medulla delimited by extensions of **cortex**. The cortex and hilum are covered with a fibrous capsule.

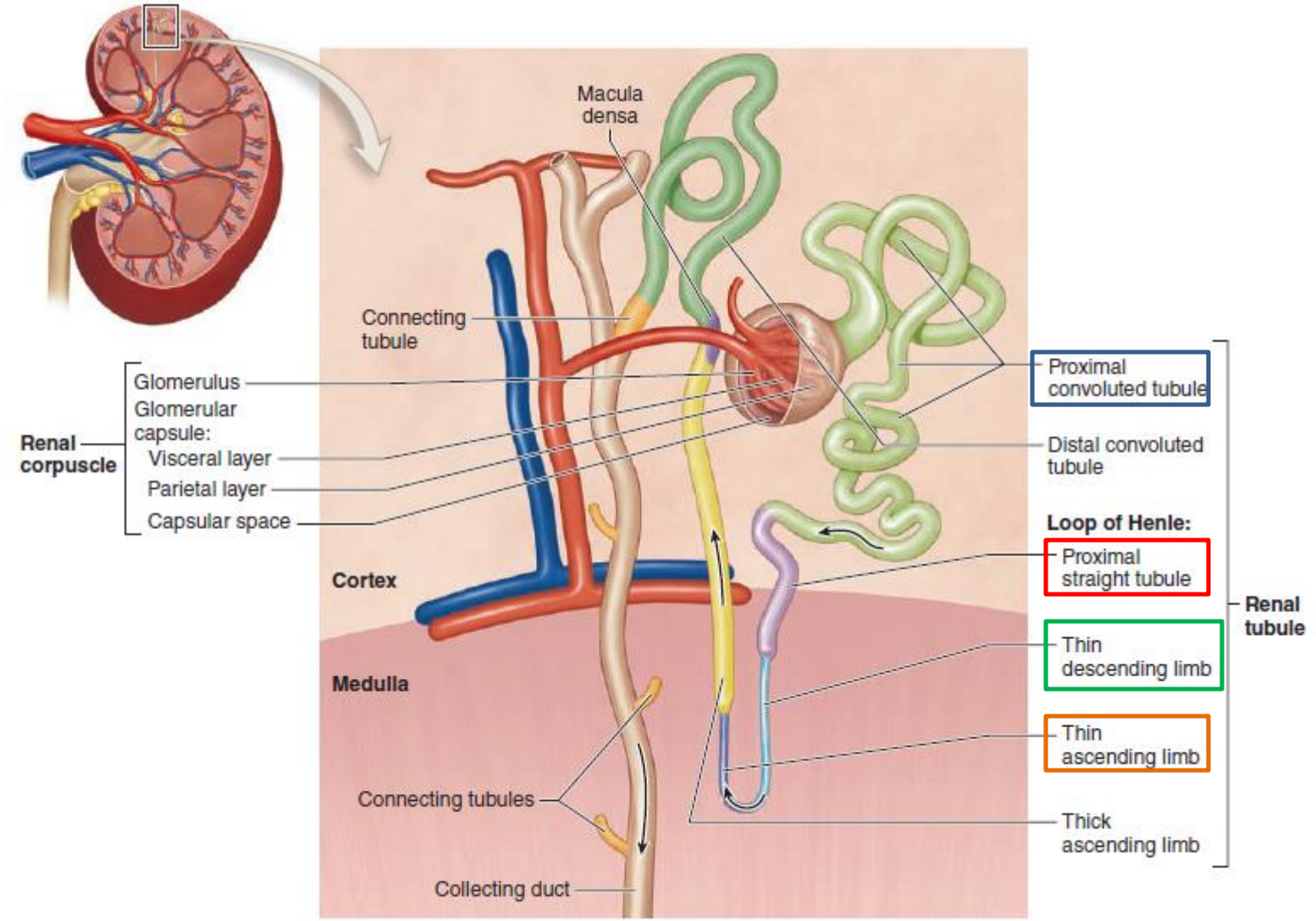
Renal corpuscles and blood filtration



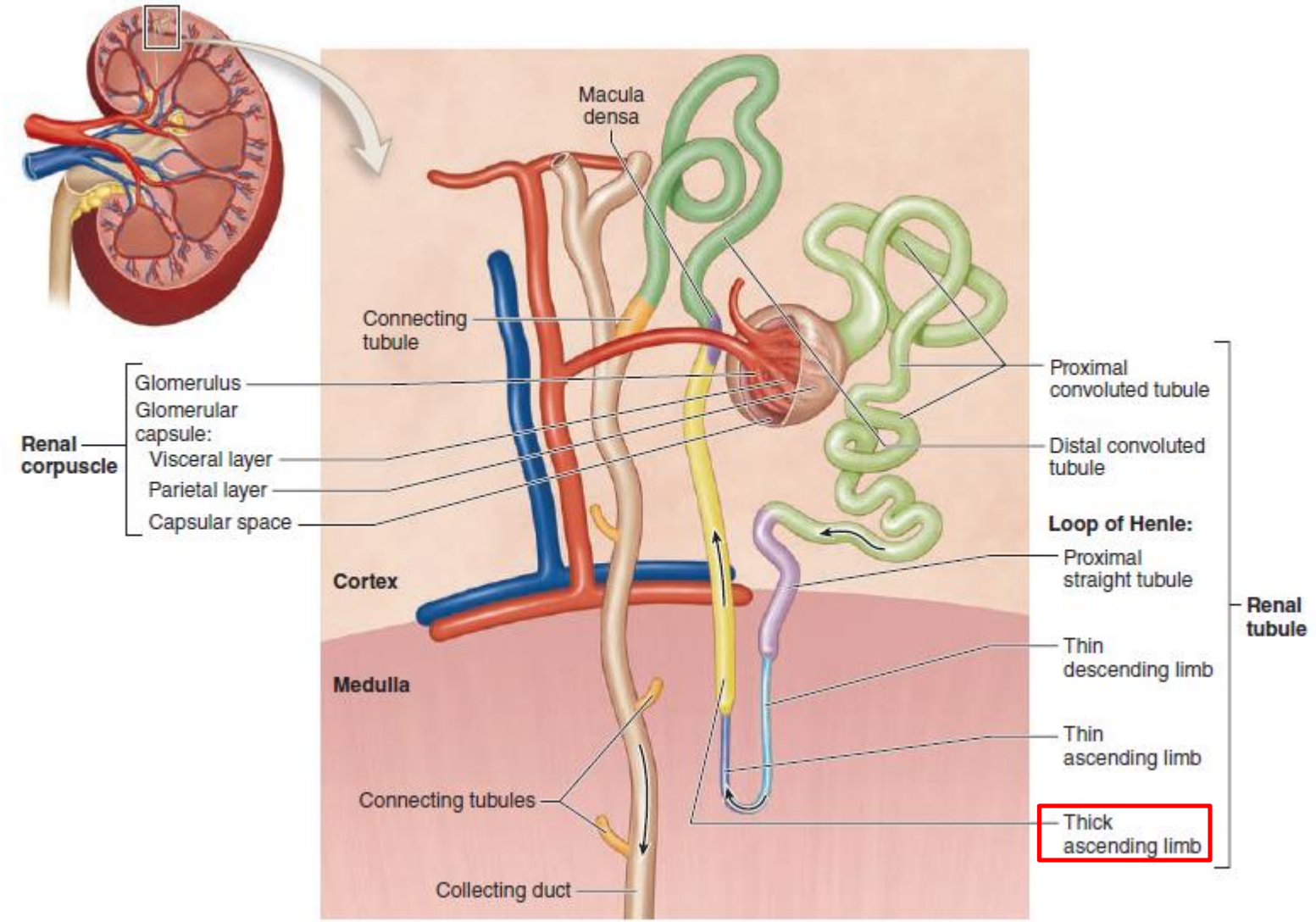
Each contains approximately 1 million functional units called nephrons



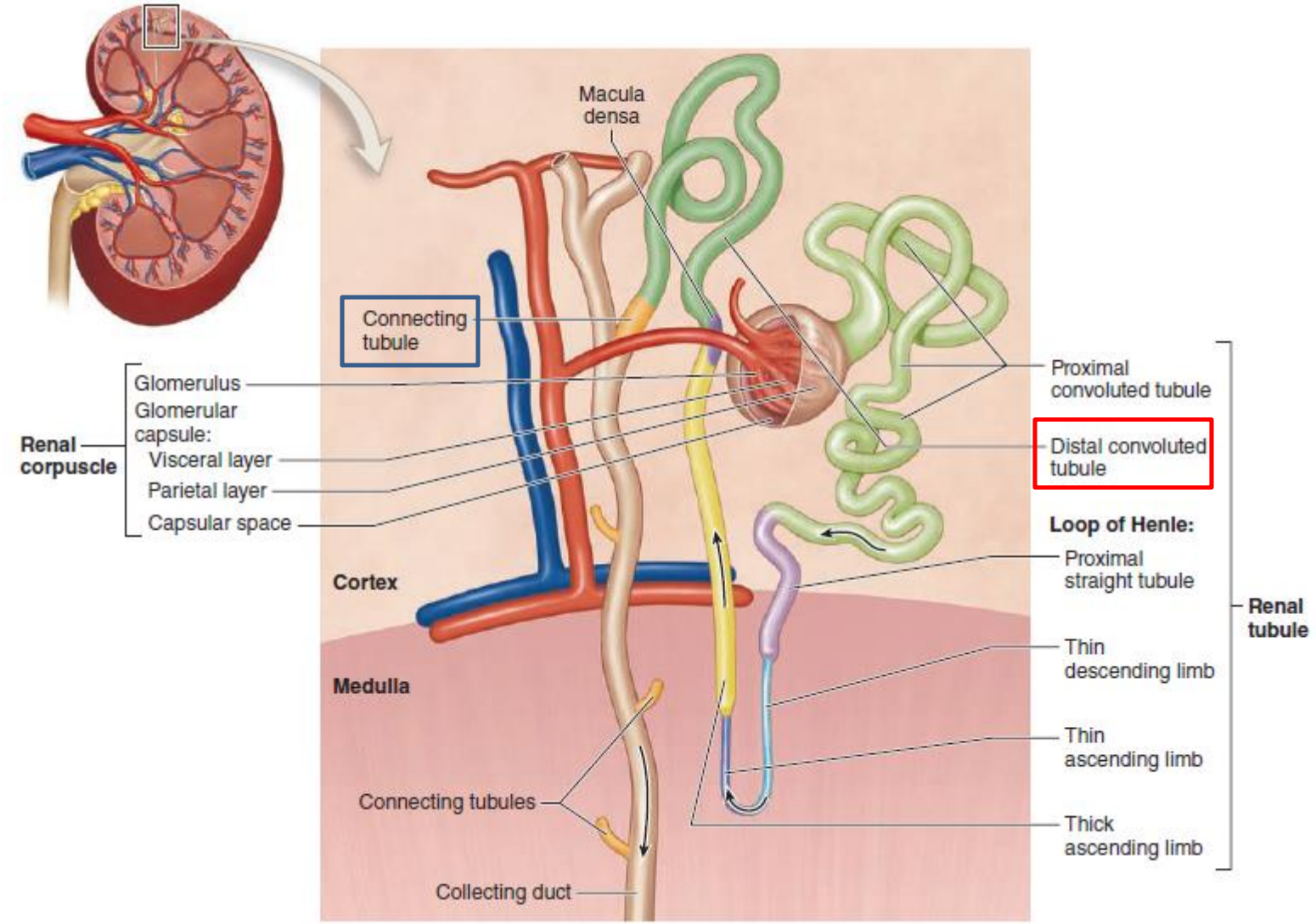
- Each nephron originates in the cortex.
- Bowman's capsule is initial part of nephron ; it is a double walled cup that encloses a tuft of capillaries known as glomerulus. The capsule and the capillary tuft together form the corpuscle.



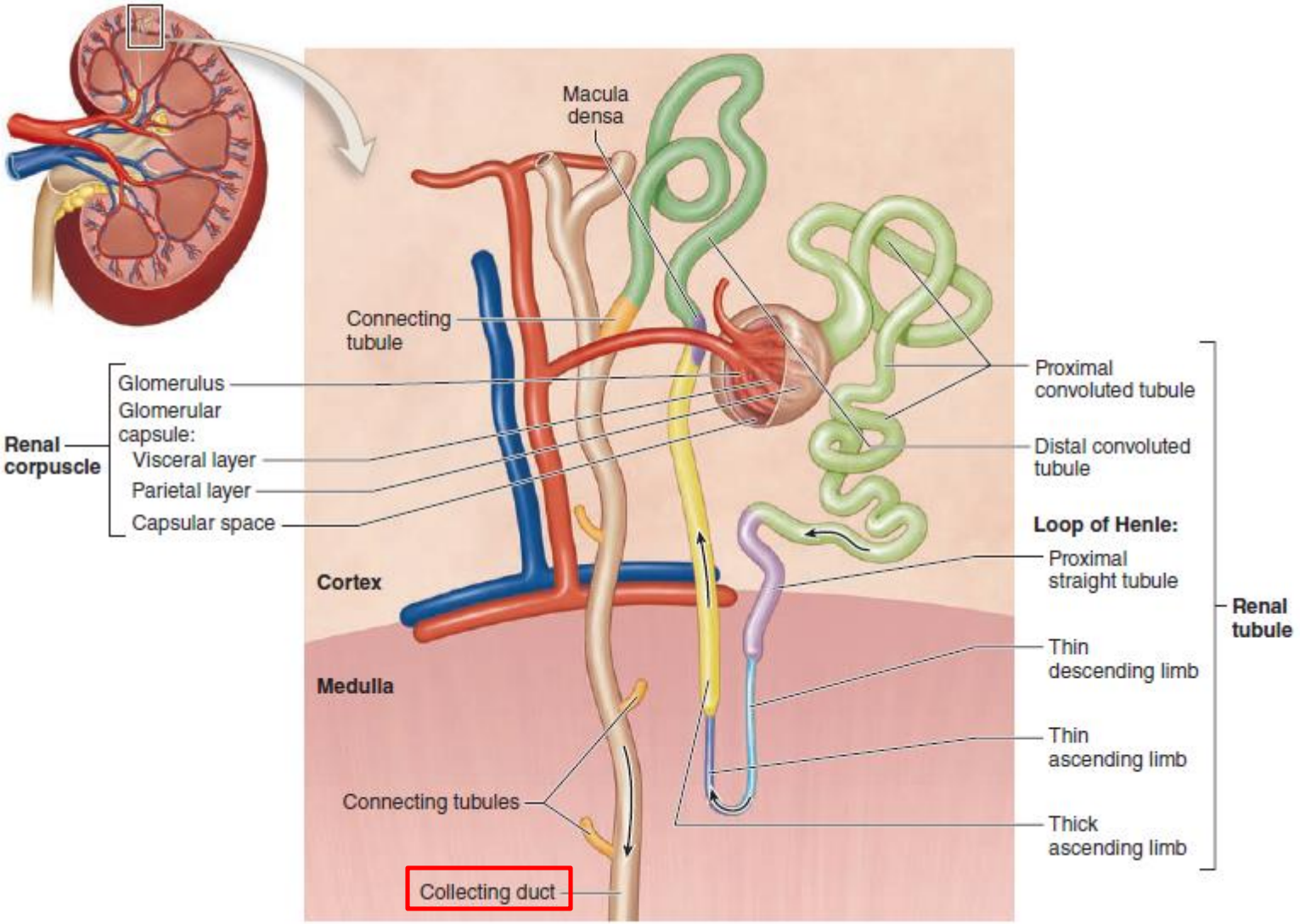
- Extending from the corpuscle is the long proximal convoluted tubule which leads to short proximal straight tubule that enters the outer medulla.
- This tubule continues as the thin descending limb and the thin ascending limb of the nephron's loop of Henle in the medulla.



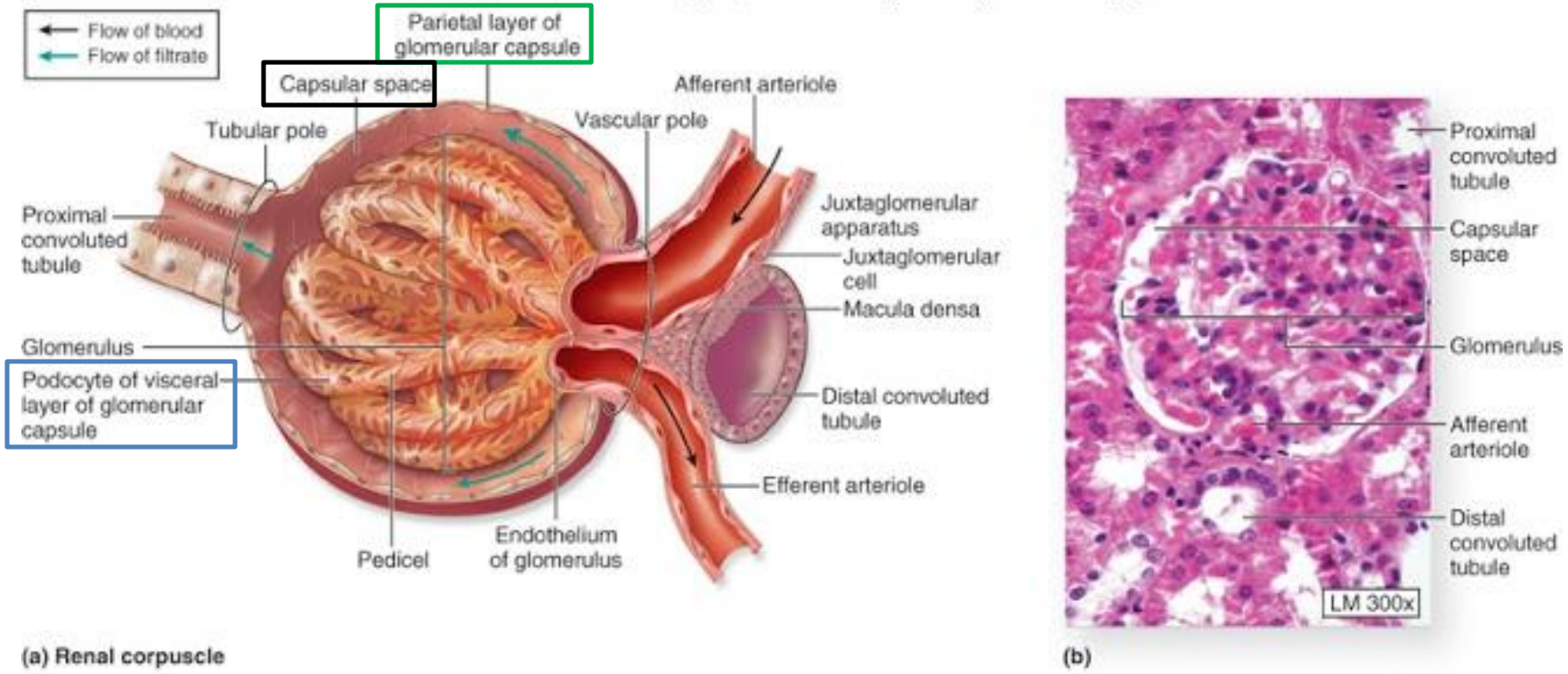
- The loop of Henle ends with a thick ascending limb, a straight tubule that reenters the cortex and ends at its thickened macula densa area where it contacts the arterioles entering the glomerulus



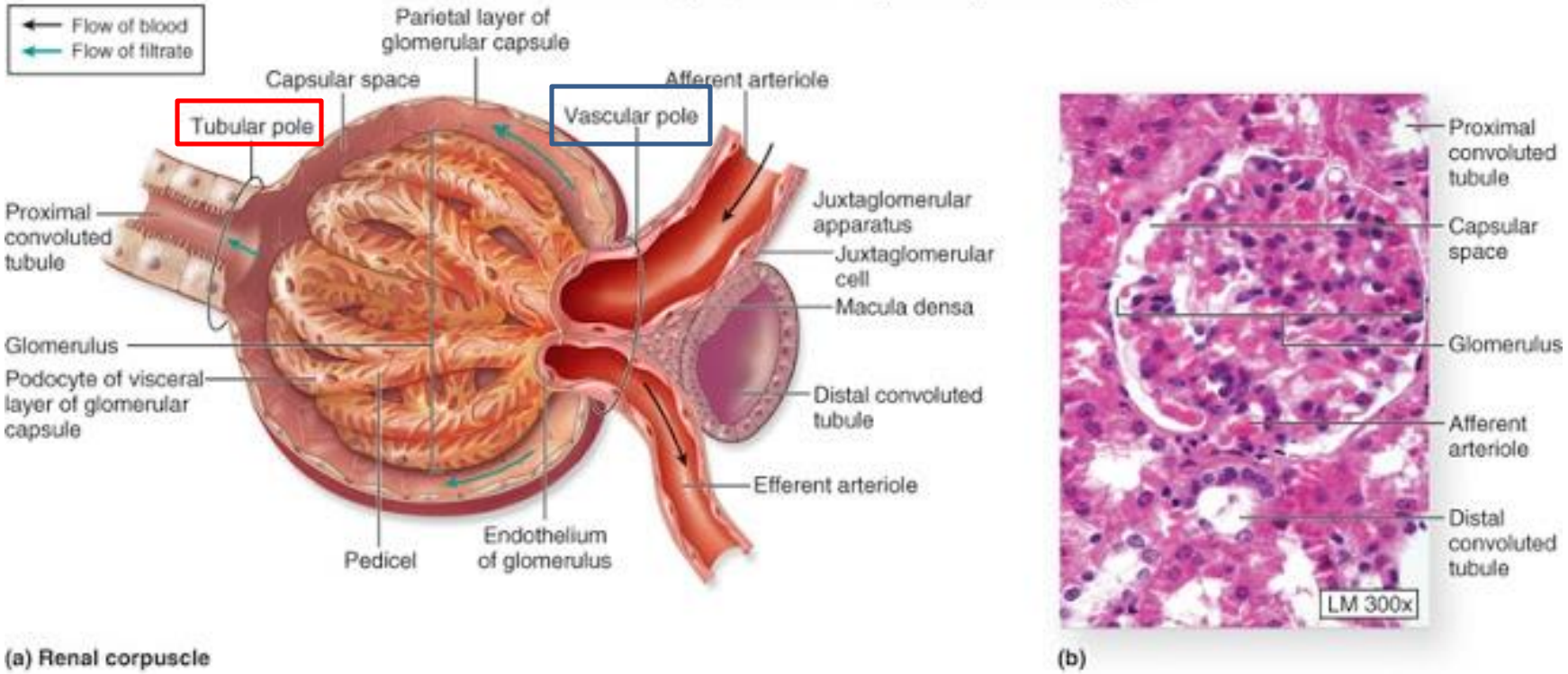
- Beyond the macula densa this tubule is the distal convoluted tubule, the end of which is the short connecting tubule.



- Connecting tubules from many nephrons merge into cortical collecting tubules and a collecting duct that transports urine to the calyx.

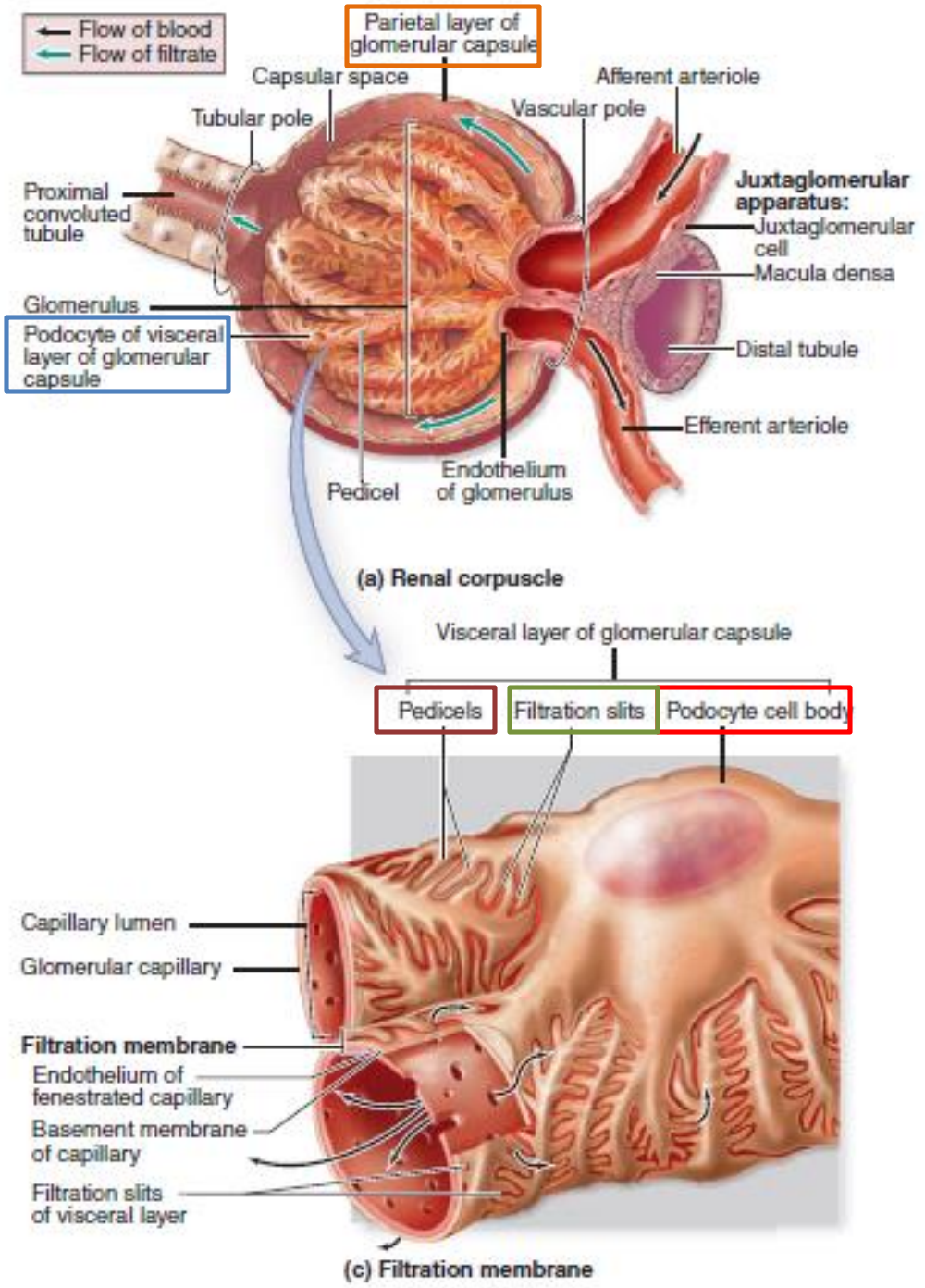


- At the beginning of each nephron is a renal corpuscle, containing a tuft of glomerular capillaries, surrounded by a double-walled epithelial capsule called the glomerular (Bowman) capsule.
  - The internal layer called visceral layer
  - The outer layer called parietal layer
- Between the two capsular layers is the capsular (or urinary) space.



- Each renal corpuscle has a vascular pole, where the afferent arteriole enters and the efferent arteriole leaves, and a tubular pole, where the proximal convoluted tubule begins

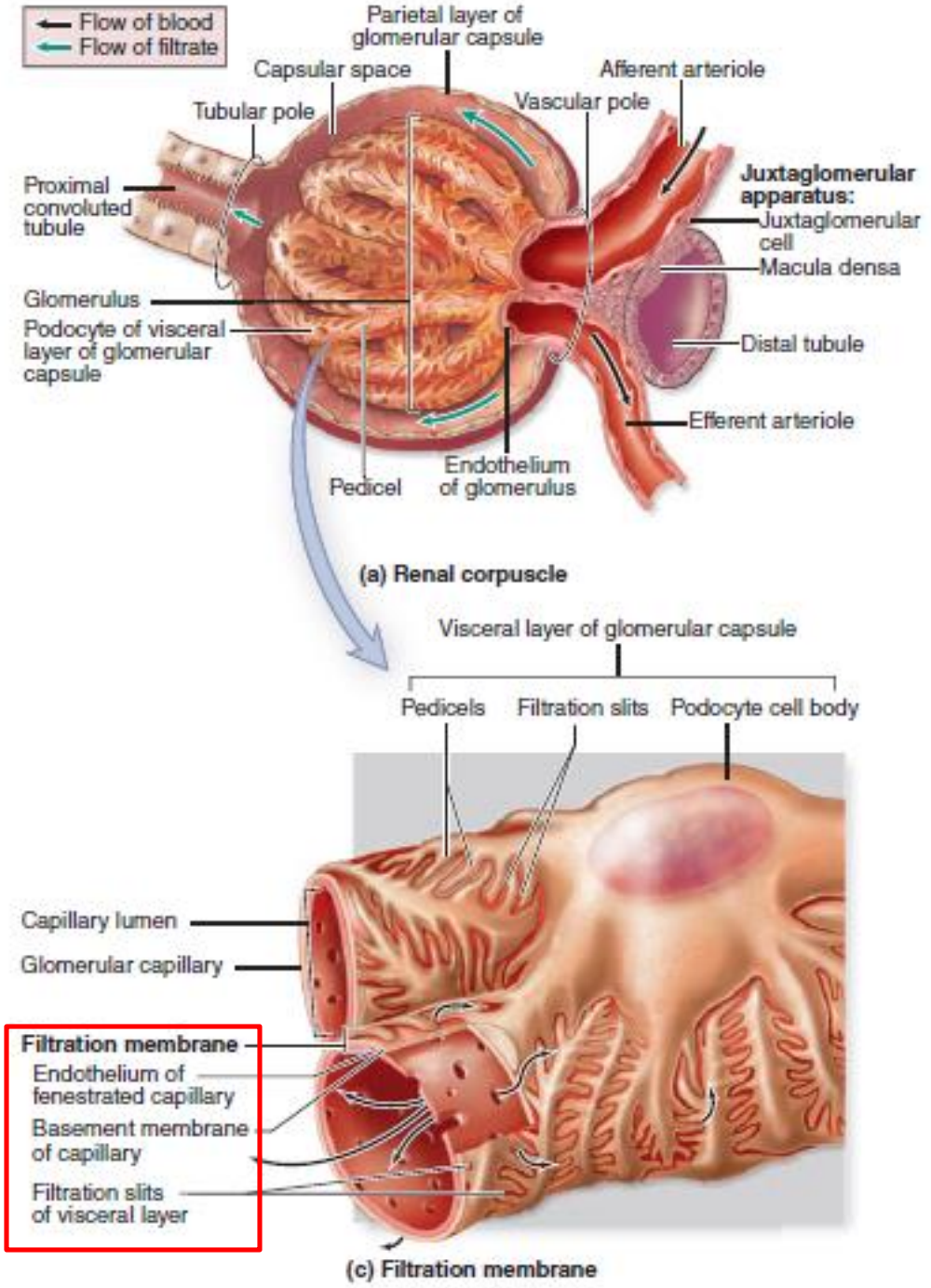
- visceral layer (epithelial cells called podocytes) →
  - The podocytes have a cell body which arise several primary processes.
  - Each primary process gives rise to many parallel, interdigitating secondary processes or pedicels envelops the glomerular capillaries.
  - Between the pedicels are elongated spaces, or filtration slit pores. Spanning adjacent pedicels and bridging the slit pores are zipper-like slit diaphragms
- parietal layer (simple squamous epithelium) →forms the surface of the capsule.

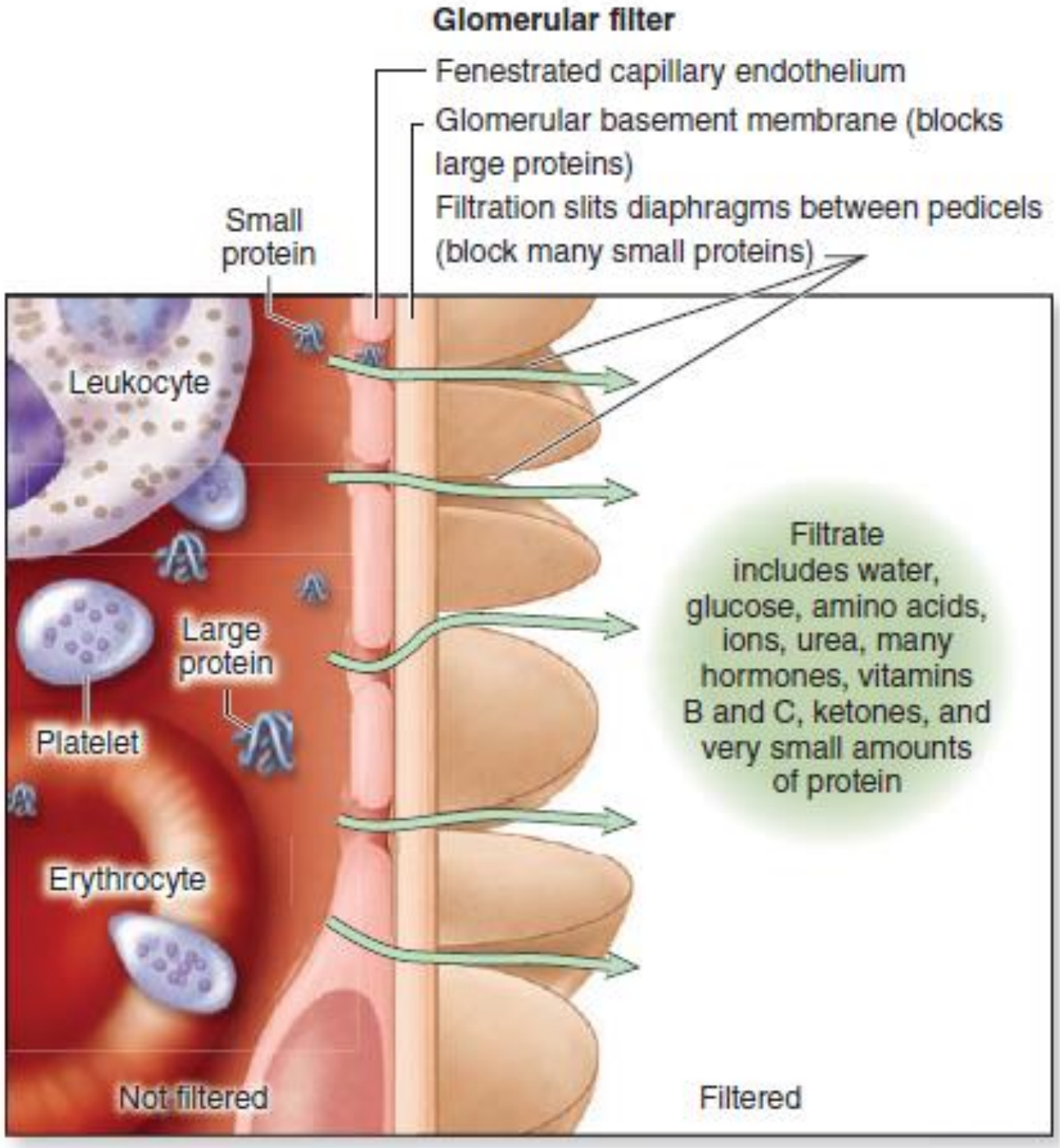


Between the endothelial cells of the capillaries and the covering podocytes is the thick glomerular basement membrane→ This membrane is the most substantial part of the filtration barrier that separates the blood from the capsular space.

Filtration occurs through a structure with three parts:

- **The fenestrations of the capillary endothelium**, which blocks blood cells and platelets
- **The thick, combined basal laminae,** which restricts large proteins and some organic anions
- **The filtration slit diaphragms between pedicels,** which restrict some small proteins and organic anions.

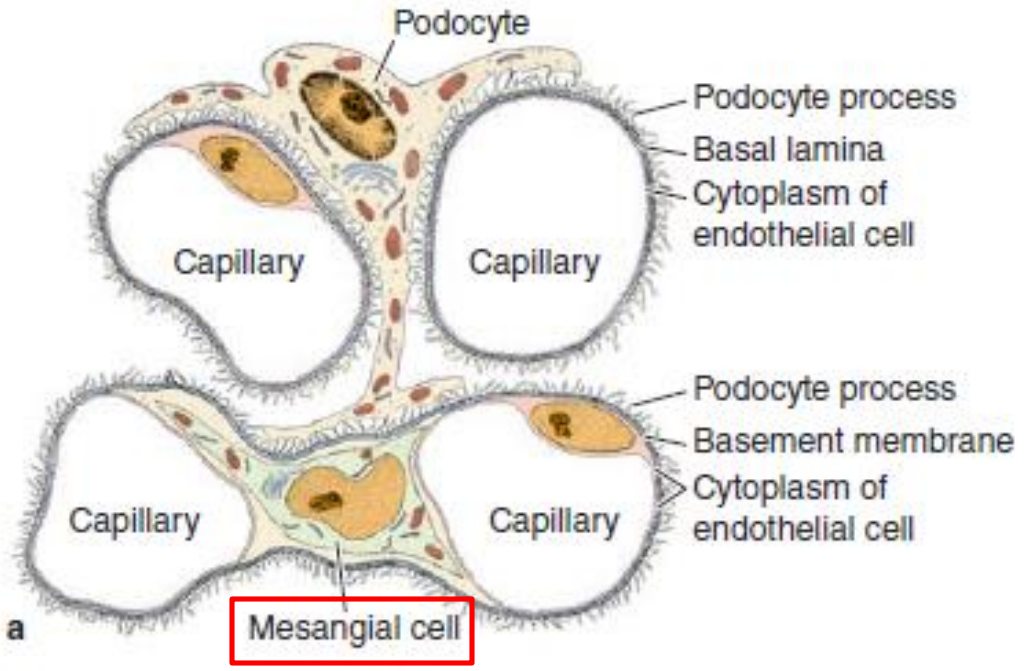


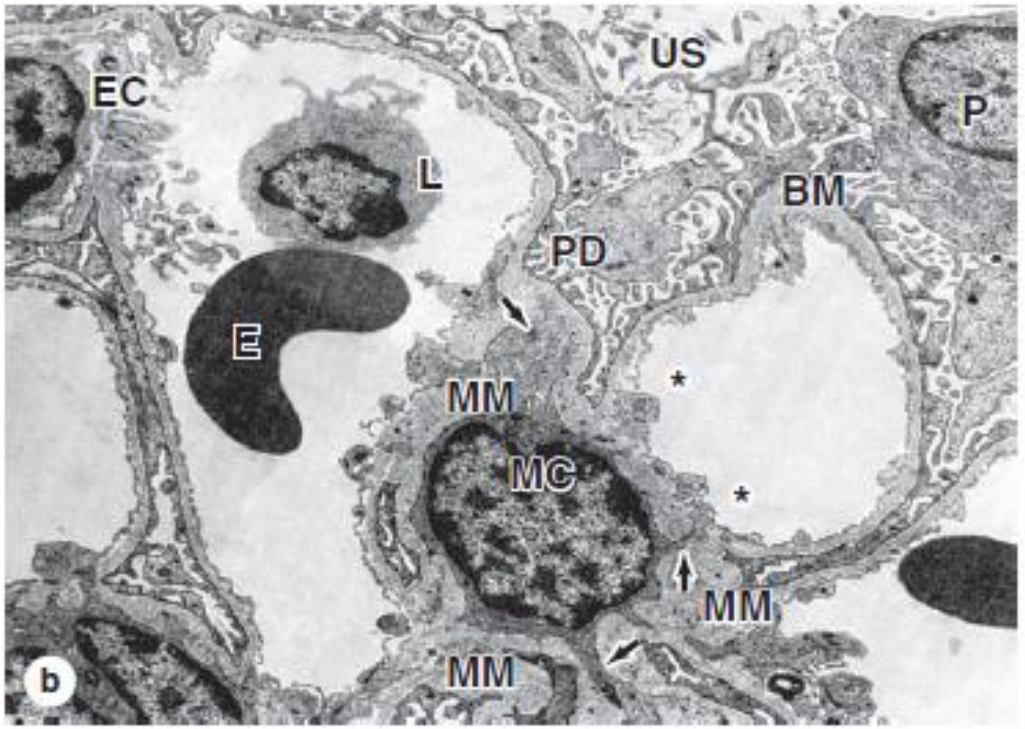

Glomerular filter
Fenestrated capillary endothelium
Glomerular basement membrane (blocks large proteins)
Filtration slits diaphragms between pedicels (block many small proteins)
Small protein
Leukocyte
Large protein
Platelet
Erythrocyte
Filtrate includes water, glucose, amino acids, ions, urea, many hormones, vitamins B and C, ketones, and very small amounts of protein
Not filtered
Filtered

In addition to capillary endothelial cells and podocytes, renal corpuscles also contain mesangial cells.

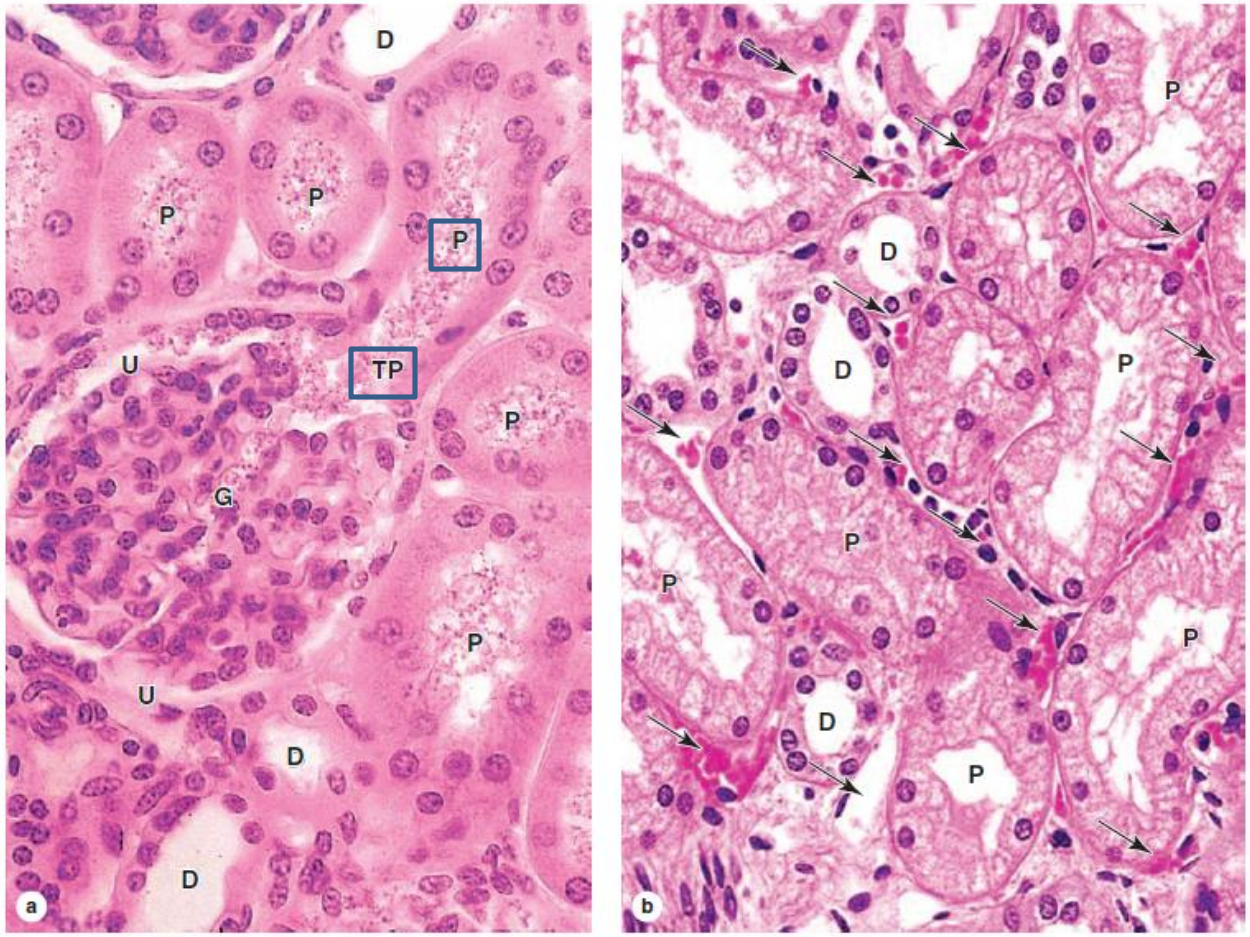
Functions of the mesangium include the following:

- Physical support of capillaries within the glomerulus.
- Adjusted contractions in response to blood pressure changes, which help maintain an optimal filtration rate.
- Phagocytosis of protein aggregates adhering to the glomerular filter, including antibody-antigen complexes abundant in many pathological conditions.
- Secretion of several cytokines, prostaglandins, and other factors important for immune defense and repair in the glomerulus.



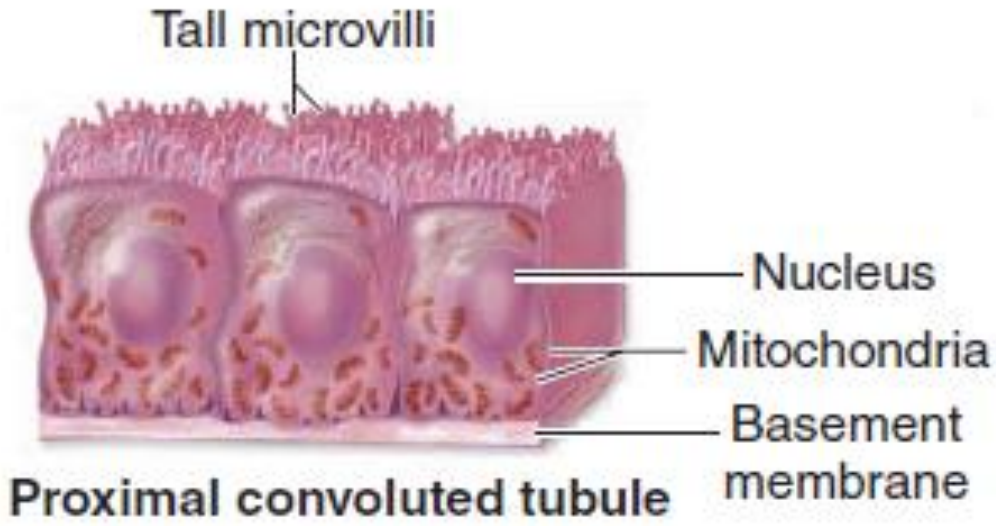


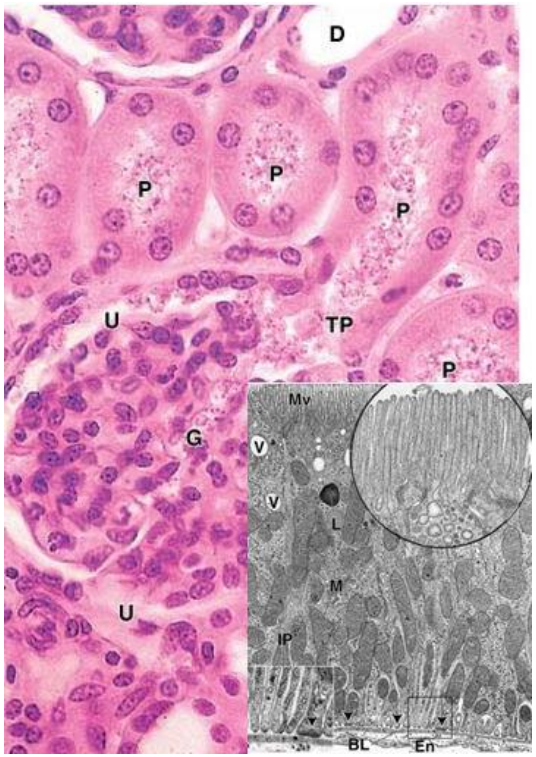
Proximal convoluted tubule



D→ distal convoluted tubules
G →glomerulus
P → proximal convoluted tubule
TP → renal corpuscle's tubular pole.
U → urinary space

- At the tubular pole of the renal corpuscle, the simple squamous epithelium of the capsule's parietal layer is continuous with the simple cuboidal epithelium or low columnar epithelium of the proximal convoluted tubule.
- These long, tortuous tubules fill most of the cortex.

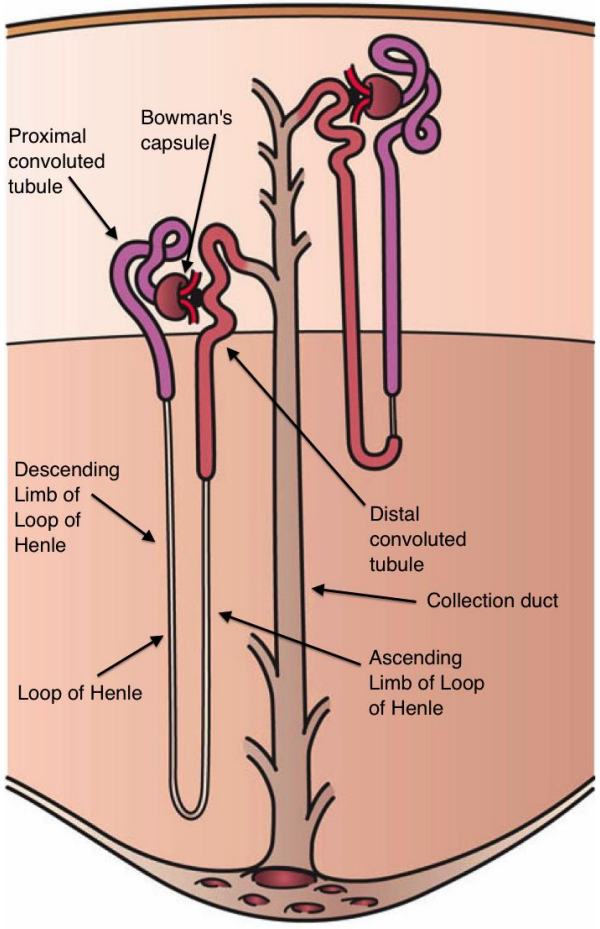


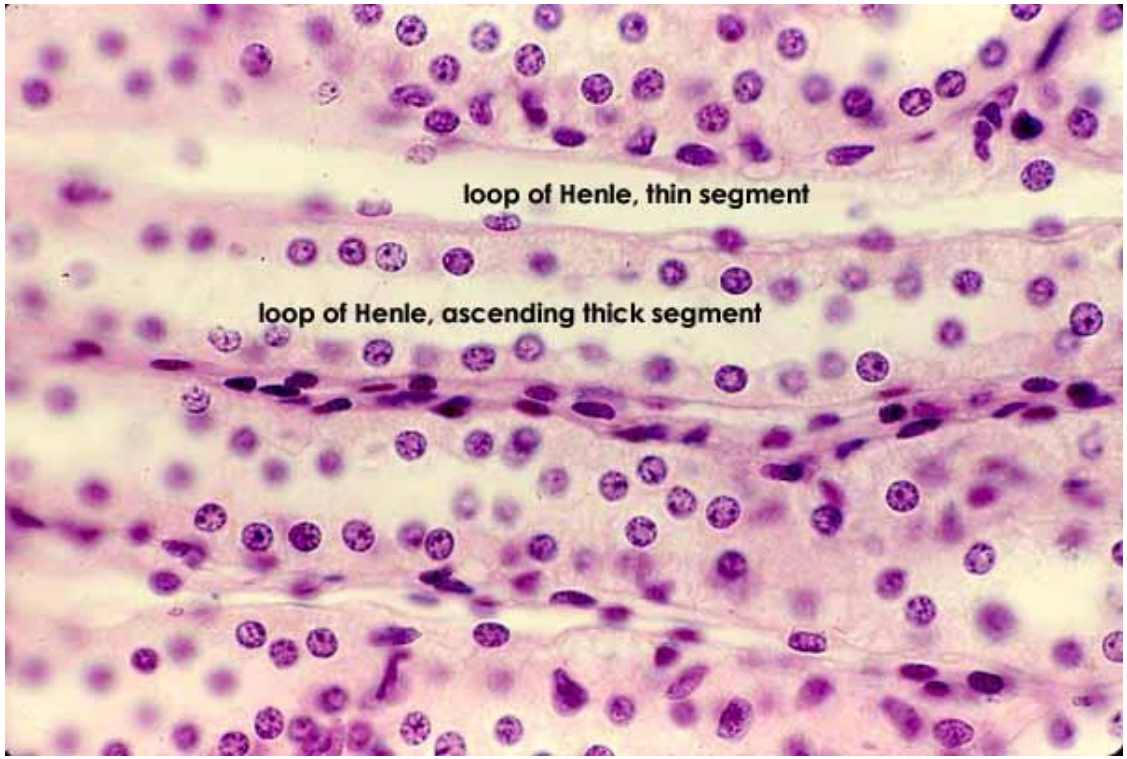


- The cell apex has very many long microvilli that form a prominent brush border in the lumen that facilitates reabsorption.

- Proximal convoluted tubule cells are for:
  - Reabsorption
  - Secretion
  - Perform hydroxylation of vitamin D and release to the capillaries.

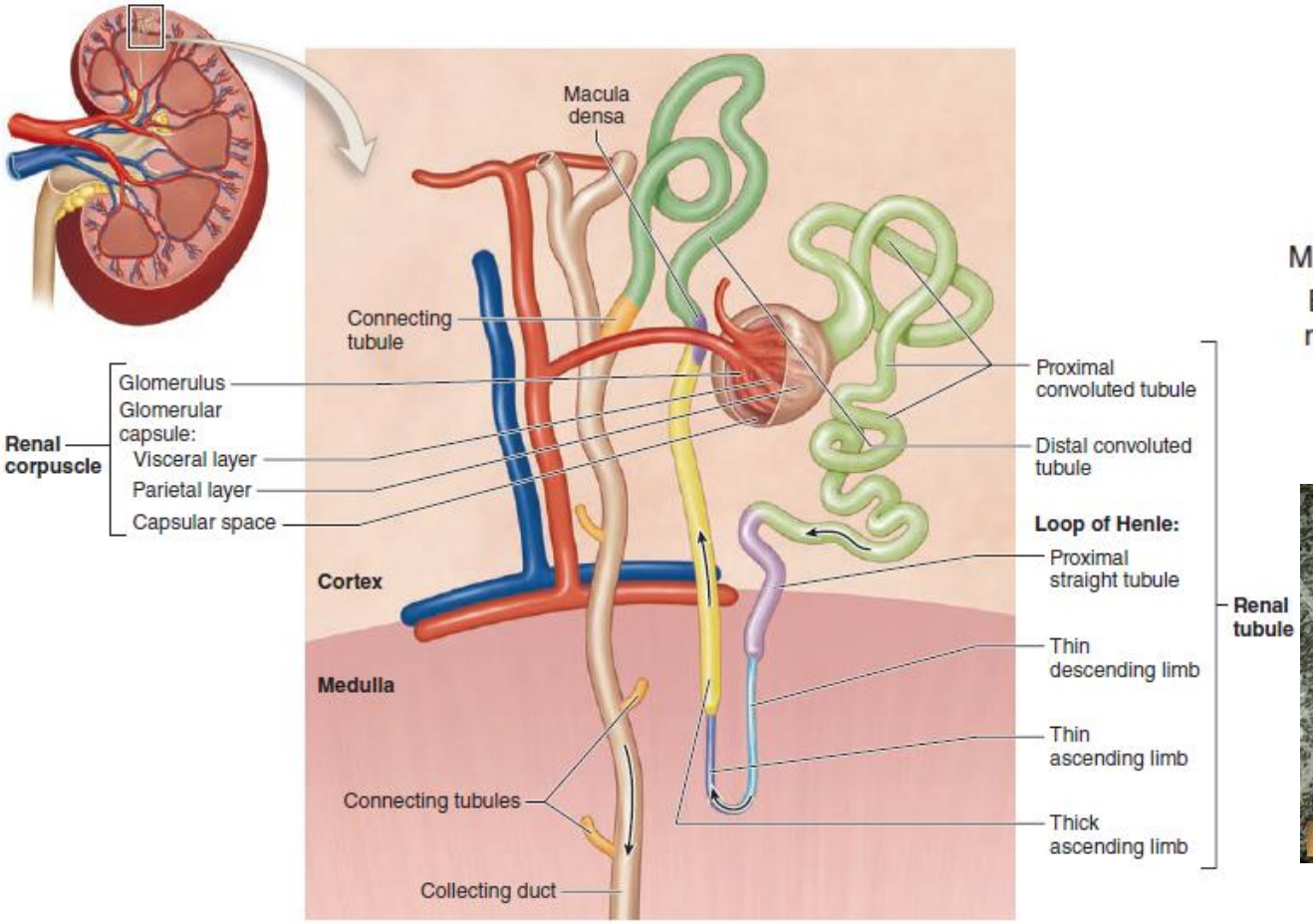
Loop of Henle

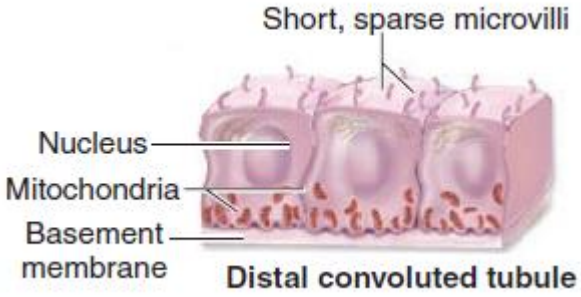


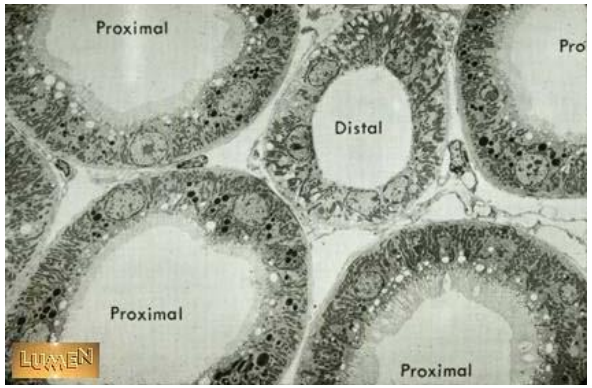


- The proximal convoluted tubule continues with the much shorter proximal straight tubule that enters the medulla and continues the nephron's loop of Henle.
- Henele's loop is a U-shaped structure consisting of a :
  - Thick descending limb (simple cuboidal epithelium and many mitochondria)
  - Thin descending limb (simple squamous epithelia)
  - Thin ascending limb (simple squamous epithelia)
  - Thick ascending limb (simple cuboidal epithelium and many mitochondria)

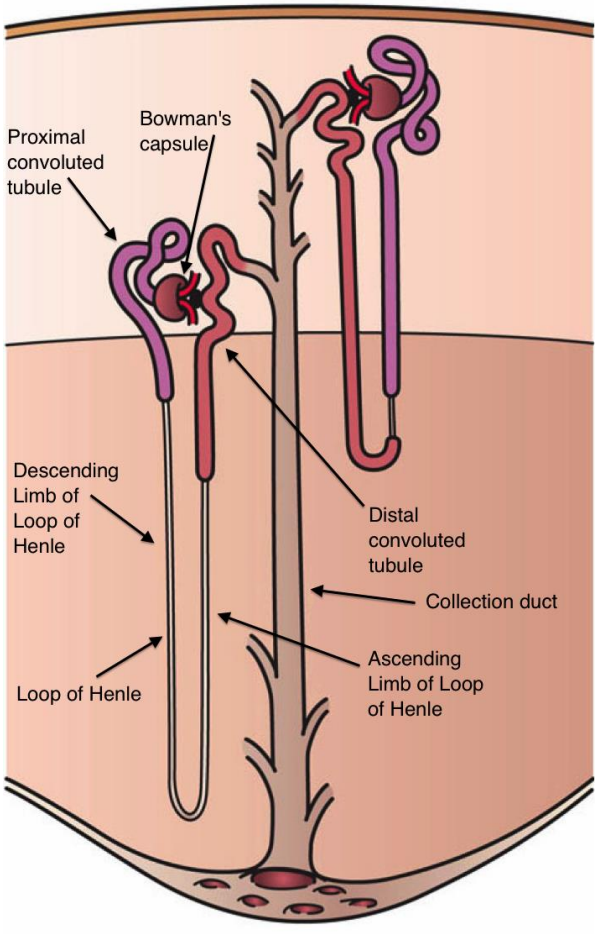
Distal Convoluted Tubule & Juxtaglomerular Apparatus

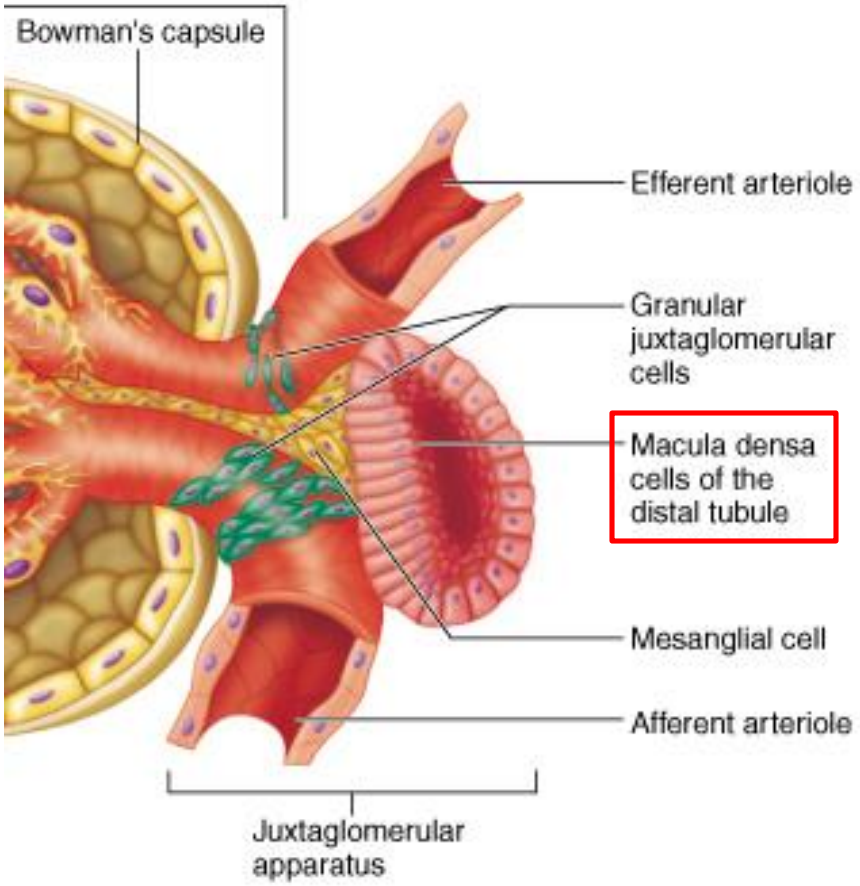






- The ascending limb of the nephron is straight as it enters the cortex , and then becomes tortuous as the distal convoluted tubule.
- The distal convoluted tubule lined with simple cuboidal epithelium and having no brush border.





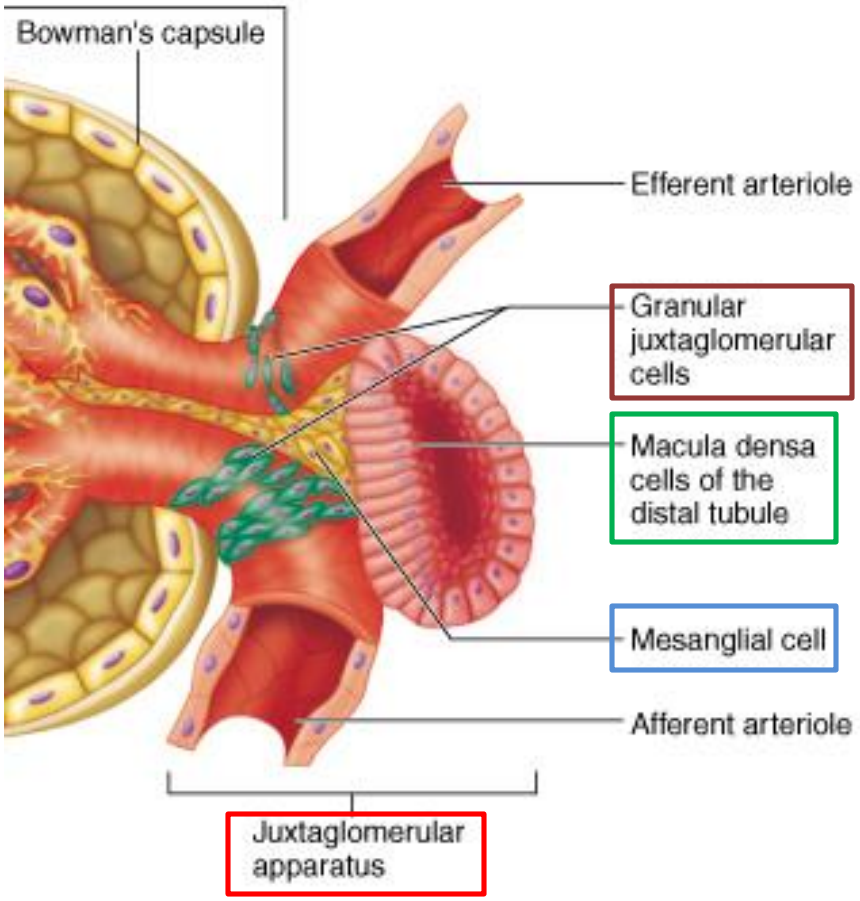
- The initial, straight part of the distal tubule contacts the arterioles at the vascular pole of the renal corpuscle of its parent nephron, its cells become more columnar and closely packed, forming the macula densa.
- Cells of the macula densa typically have apical nuclei, basal Golgi complexes, and a more elaborate and varied system of ion channels and transporters.

- **Juxtaglomerular Apparatus:**

  - The juxtaglomerular apparatus is a specialized structure formed by the distal convoluted tubule and the glomerular afferent arteriole.

  - It is located near the vascular pole of the glomerulus and its main function is to regulate blood pressure and the filtration rate of the glomerulus.

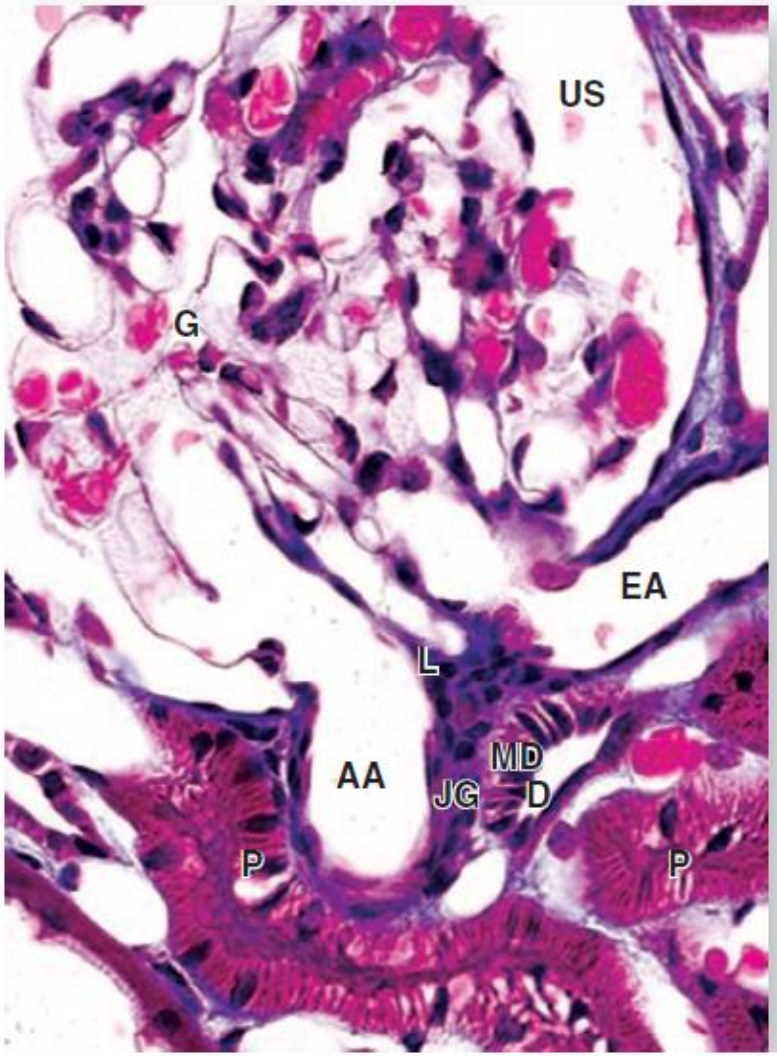
  - The juxtaglomerular apparatus consists of three types of cells:
    - The macula densa, a part of the distal convoluted tubule of the same nephron
    - Juxtaglomerular cells, (also known as granular cells) which secrete renin
    - Extraglomerular mesangial cells, have many supportive, contractile and defensive functions as these cells inside the glomerulus



- Decreased arterial pressure leads to increased autonomic stimulation to the juxtaglomerular apparatus as a result of baroreceptor function. This causes the juxtaglomerular cells to release renin, into the blood.

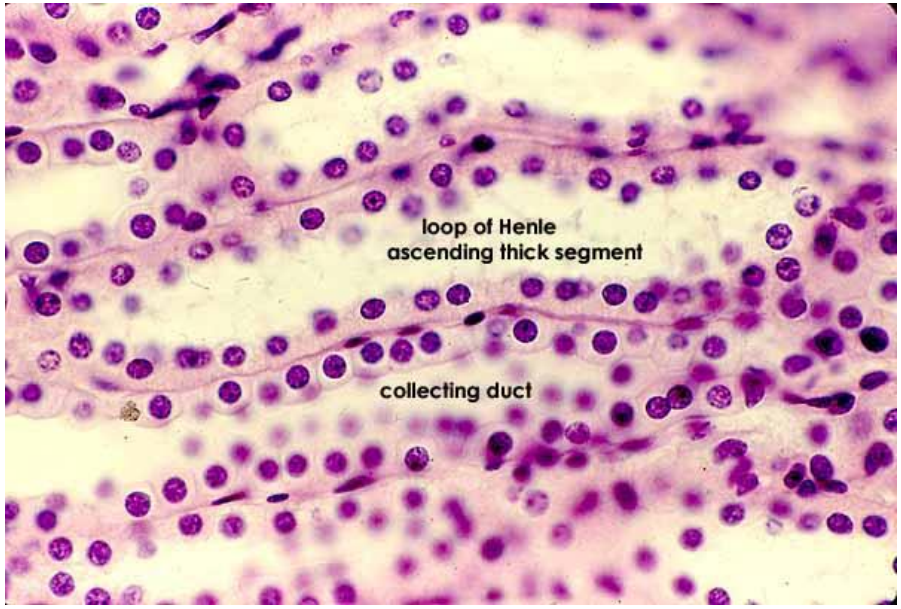
- renin act on plasma protein angiotensinogen to produce an inactive angiotensin I. Angiotensin-converting enzyme on lung capillaries clips this further to angiotensin II, a vasoconstrictor that directly raises systemic blood pressure and stimulates the adrenals to secrete aldosterone.

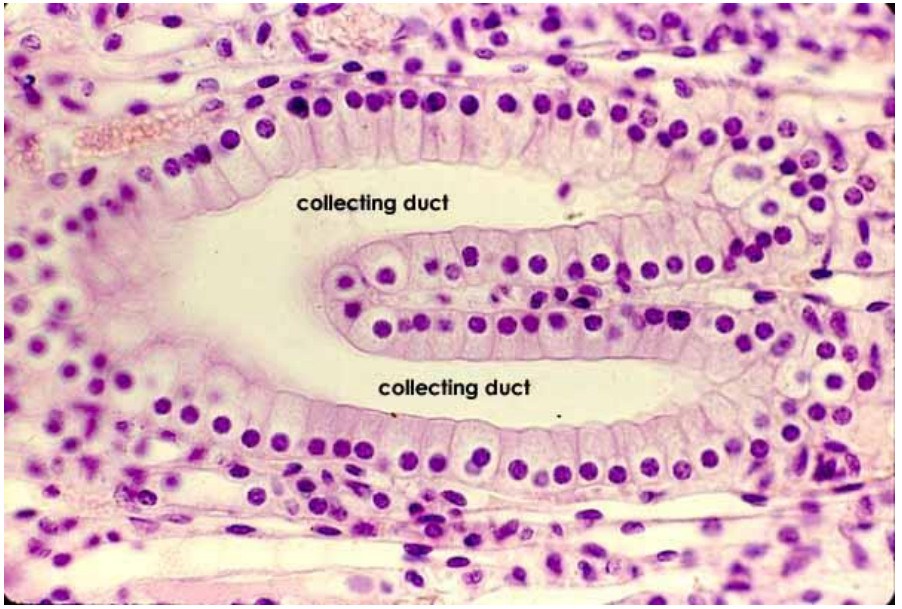
- Aldosterone promotes Na^+ and water reabsorption in the distal convoluted and connecting tubules, which raises blood volume to help increase blood pressure.



AA → afferent arteriole's
D → nephron's distal tubule
G →glomerulus
JG → juxtaglomerular granule cells
L → lacis cells
MD→ macula densa

Collecting Ducts



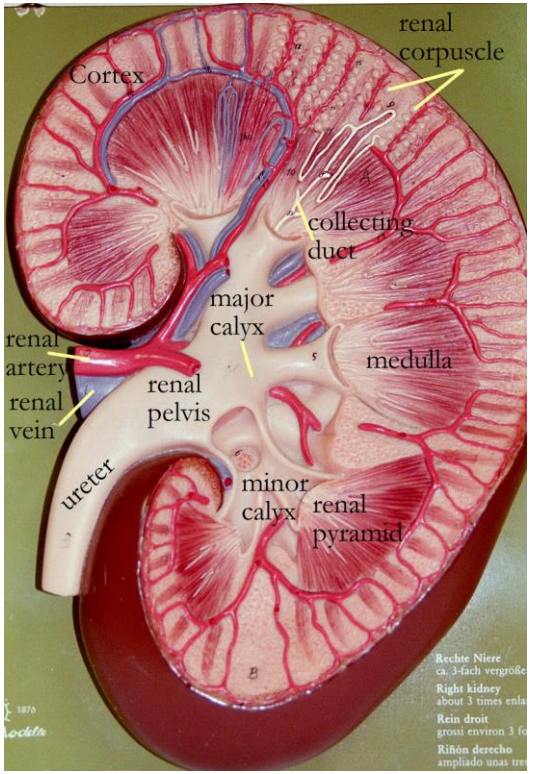


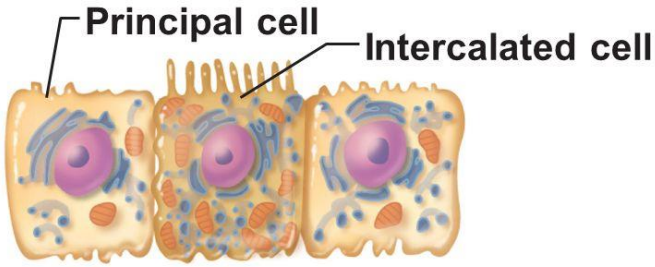
- The last part of each nephron, the connecting tubule, carries the filtrate into a collecting system that transports it to a minor calyx.
- A connecting tubule extends from each nephron and several join together in the cortical medullary rays to form collecting ducts of simple cuboidal epithelium
- In the outer medulla these merge further as larger, straight collecting ducts, which run to the tips of the medullary pyramids with increasingly columnar cells.

- In the apex of the pyramid, several collecting ducts merge further as a papillary duct which delivers urine to the minor calyx

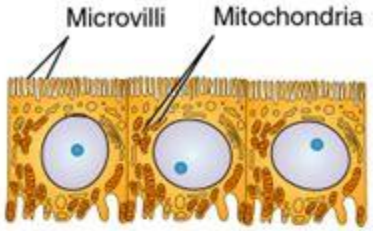
- Collecting ducts are composed mainly of two types of cells :
  - Principal cells with few organelles, sparse microvilli, and unusually distinct cell boundaries.
  - Intercalated cells, cube cells with microvilli and more mitochondria

- The medullary collecting ducts are the final site of water reabsorption from the filtrate.



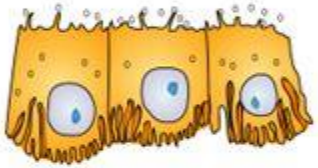


Histology of Renal Tubule & Collecting Duct

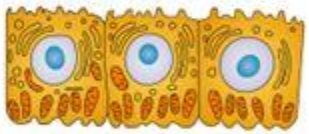


(a) Proximal convoluted tubule cells

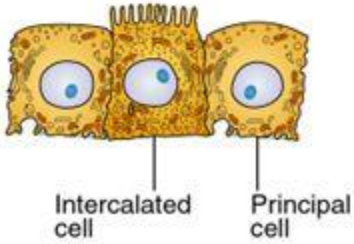
(b) Loop of Henle cells: descending limb and thin ascending limb



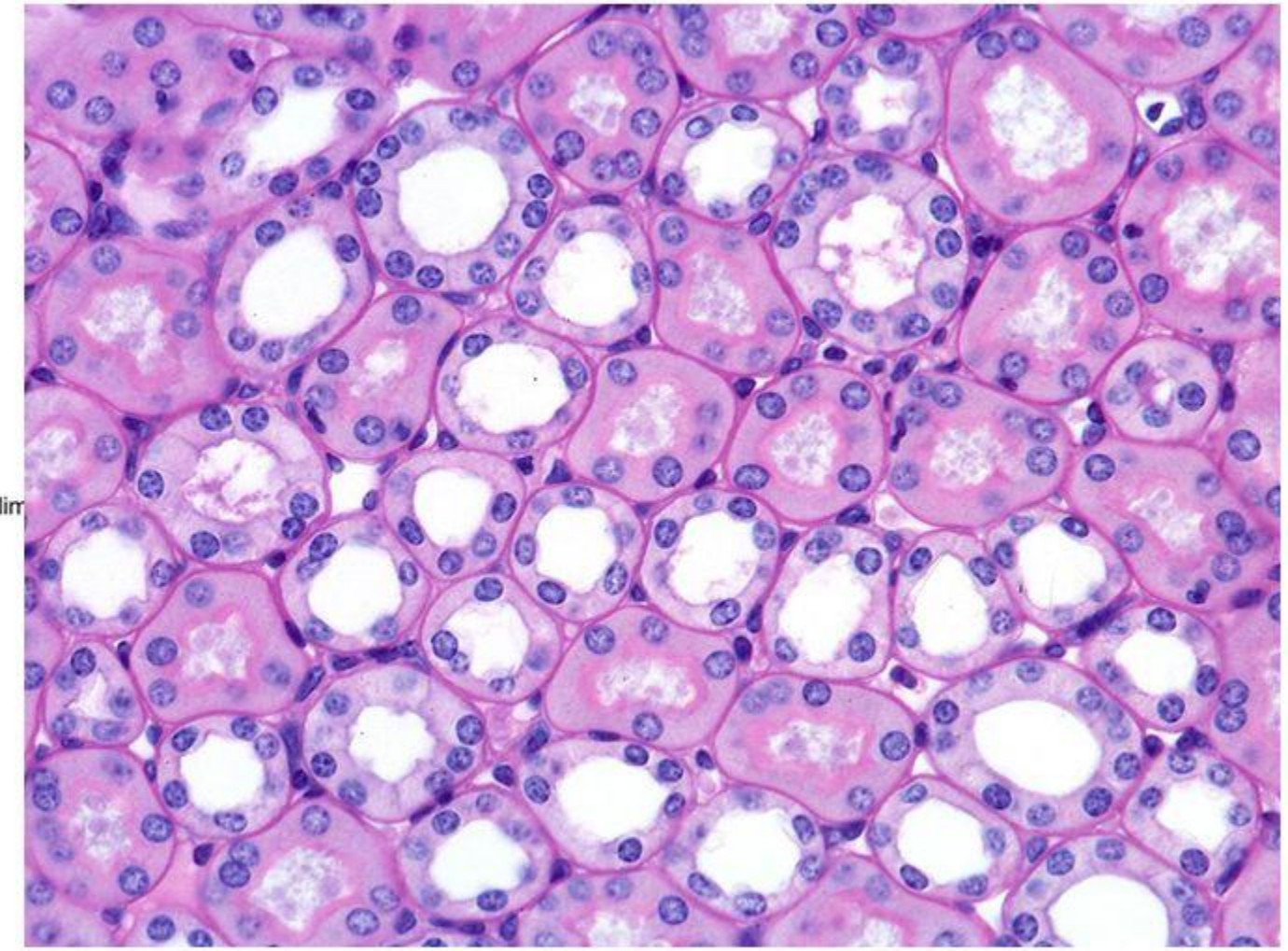
(c) Loop of Henle cells: thick ascending lim



(d) Distal convoluted tubule cells



(e) Collecting duct cells



Histology of the ureters, urinary bladder

URETER

- Conducts urine from kidney to bladder
- Has 3 tissue layers
  1. Tunica mucosa; lined by 5-6 cell layer of transitional epithelium that rests on lamina propria of loose connective tissue having blood vessels, lymphatics and with tubular mucus glands in the equidae
  2. (no submucosa).

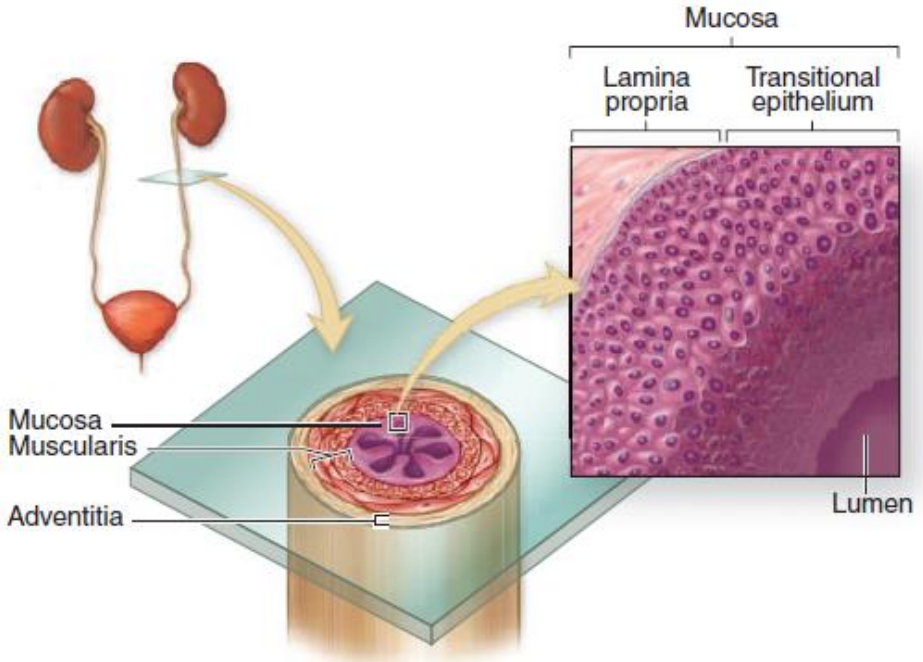
URETER

3. Tunica muscularis:

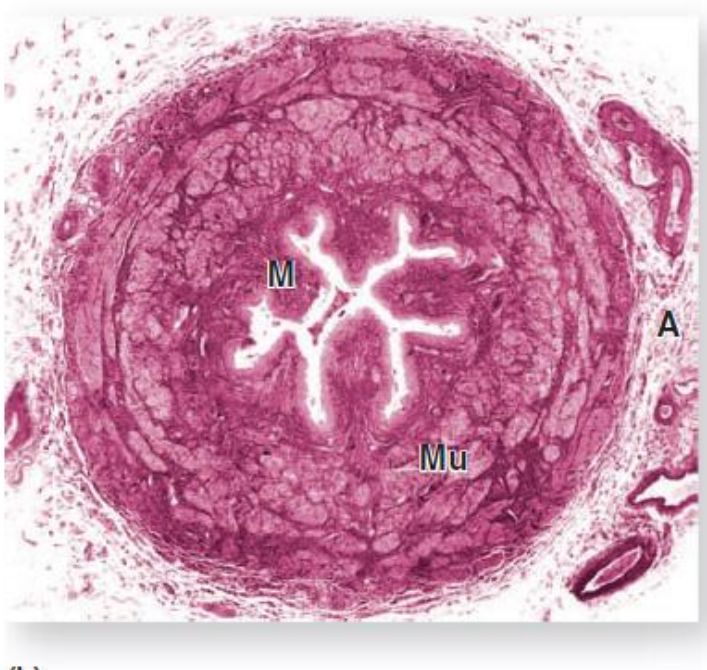
There is a layer of smooth muscle outside the mucosa:

- The upper two-thirds has two layers of smooth muscle: inner longitudinally arranged, and outer circularly arranged.
- The lower third has three layers of smooth muscle; Inner longitudinal, middle circular, outer longitudinal.

4. Tunica serosa/ adventitia→ connective tissue



(a) Ureter cross section



(b)

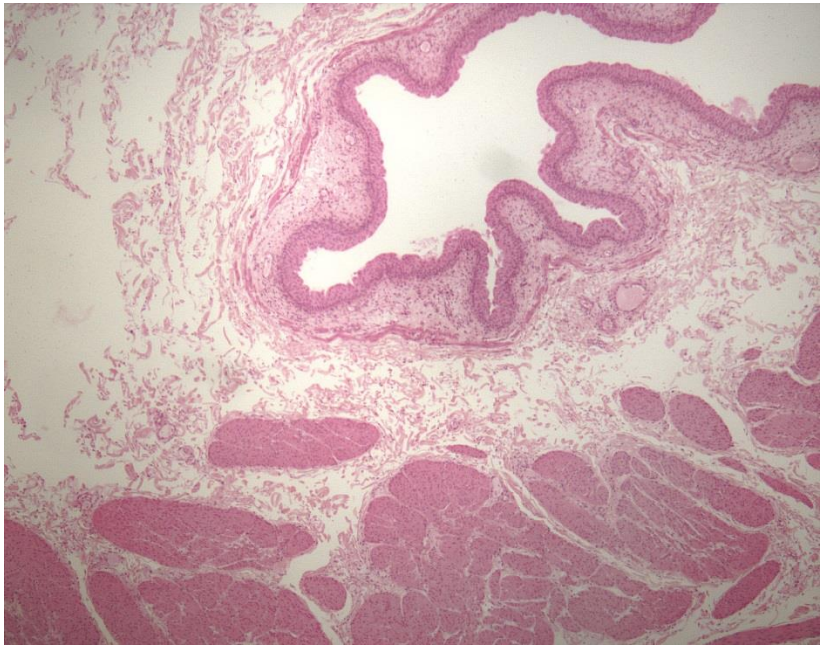
- The ureter, and bladder have somewhat similar histologic structure, with the walls becoming gradually thicker closer to the bladder.

- The mucosa of these organs is lined by the unique stratified transitional epithelium

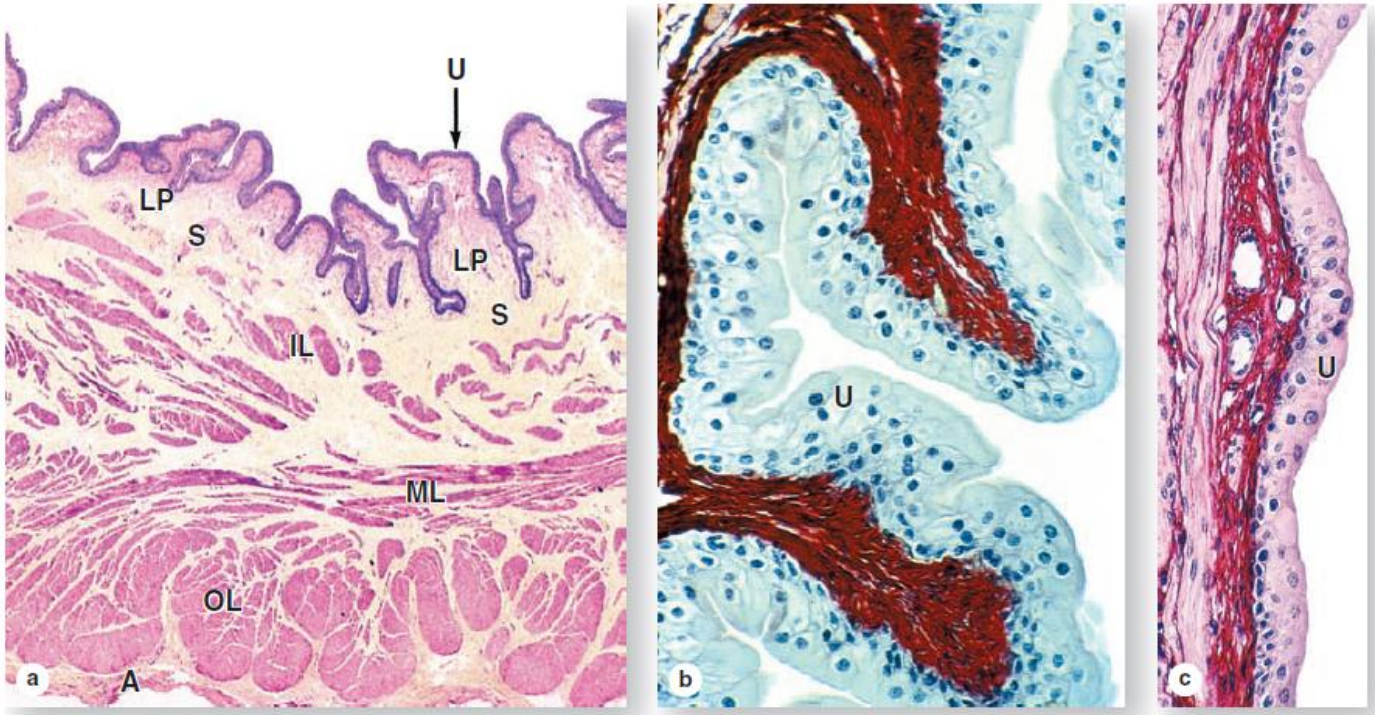
- Cells of this epithelium are organized as three layers:
  - A single layer of small basal cells resting on a very thin basement membrane
  - An intermediate region containing from one to several layers of more columnar cells
  - A superficial layer of very large, bulbous cells called umbrella cells that are occasionally bi- or multinucleated and are highly differentiated to protect underlying cells against the cytotoxic effects of hypertonic urine.

Urinary bladder

- Its wall has 4 tissue layers:
  1. Tunica mucosa; lined transitional epithelium that rests on lamina propria of loose connective tissue
  2. Tunica submucosa; highly vascular and rich in elastic fibers
  3. Tunica muscularis; has inner and outer longitudinal and middle layer of smooth muscles (dextruser muscles)
  4. Tunica serosa/ adventitia



- The longitudinal muscles form involuntary sphincters at ureterovesicular junction to prevent backflow of urine and at neck of bladder to regulate urine emptying



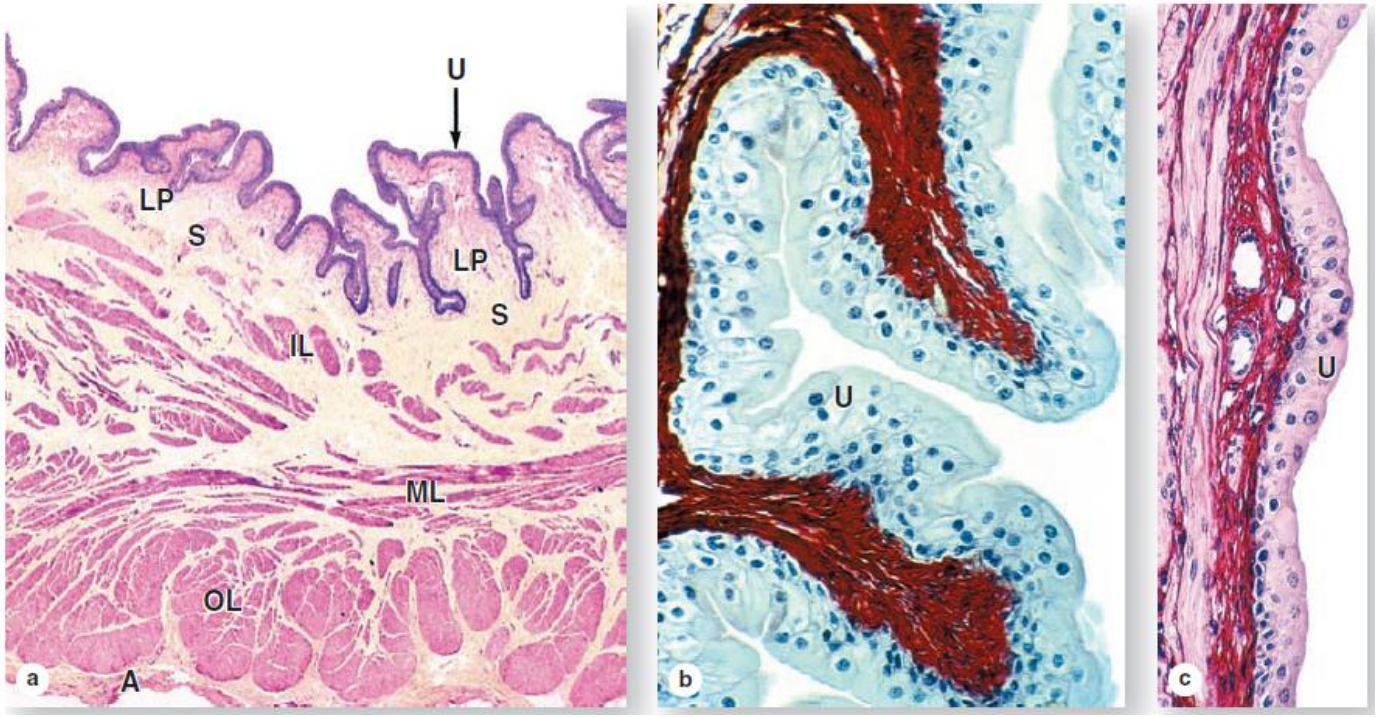
Empty bladder Full bladder

U → urothelium
LP → lamina propria
S → thin submucosa
IL, ML, and OL →inner, middle, and outer layers of smooth muscle.
A → adventitia

•The transitional epithelium of the bladder in the undistended state is five or six cells in thickness; the superficial cells are rounded and bulge into the lumen.

•When the bladder is full of urine, the epithelium is only three or four cells in thickness, and the superficial cells become squamous.

•The superficial cells of the transitional epithelium have a special membrane of thick plate separated by narrow bands of thin membrane that are responsible of the osmotic barrier between urine and tissue fluids.



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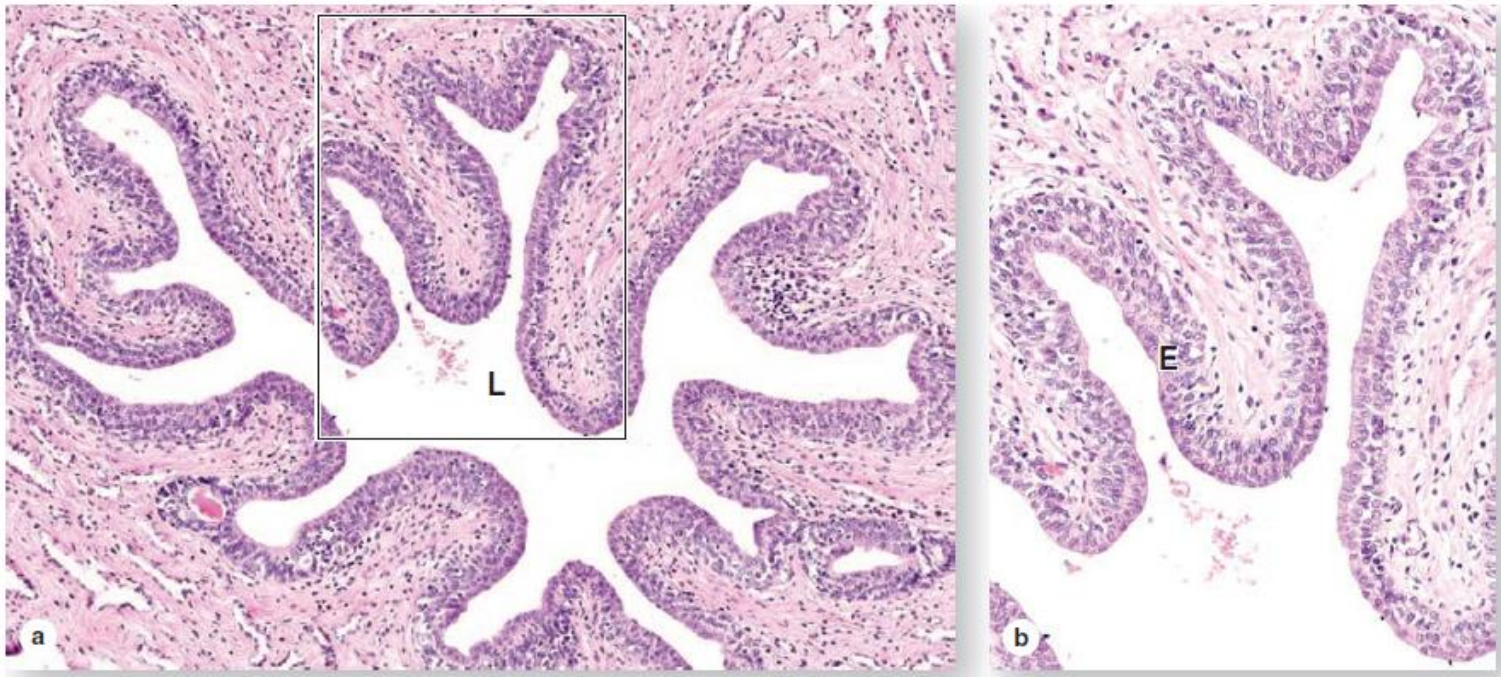
When the bladder contract, the membrane fold along the thinner regions, and the thick plates invaginate to form fusiform cytoplasmic vesicles →these vesicles used to cover the increased cell surface in the full bladder as the cell shape changes from round to flat.

- The muscular layers in the ureters have a helical arrangement, as the ureteral muscle cells reach the bladder, they become longitudinal.

- The muscle of the bladder run in every direction until they approach the neck of the bladder, where three distinct layers can be identified:
  - The internal longitudinal layer
  - Circular layer around the prostate and the prostatic parenchma in men. It extends to the external in women.
  - The outer longitudinal layer continues to the end of the prostate in men and to the involuntary external urethral meatus in women.

Histology of the urethra



E → urethral epithelium
L → lumen

- The urethra is a tube that carries the urine from the bladder to the exterior.
- The male urethra is longer and consists of three segments:
  - **The prostatic urethra**, is lined by urothelium (highly specialized epithelium lining the lower urinary tract) .
  - **The membranous urethra,** is lined by stratified columnar and pseudostratified epithelium.
  - **The spongy urethra,** is lined by stratified columnar and pseudostratified columnar epithelium with stratified squamous epithelium distally.
- In women, the urethra is lined initially with transitional epithelium, then by stratified squamous epithelium and some areas of pseudostratified columnar epithelium. The middle part of the female urethra is surrounded by the external striated muscle sphincter.

GOOD LUCK

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