
بسم الله الرحمن الرحيم

The Urinary System

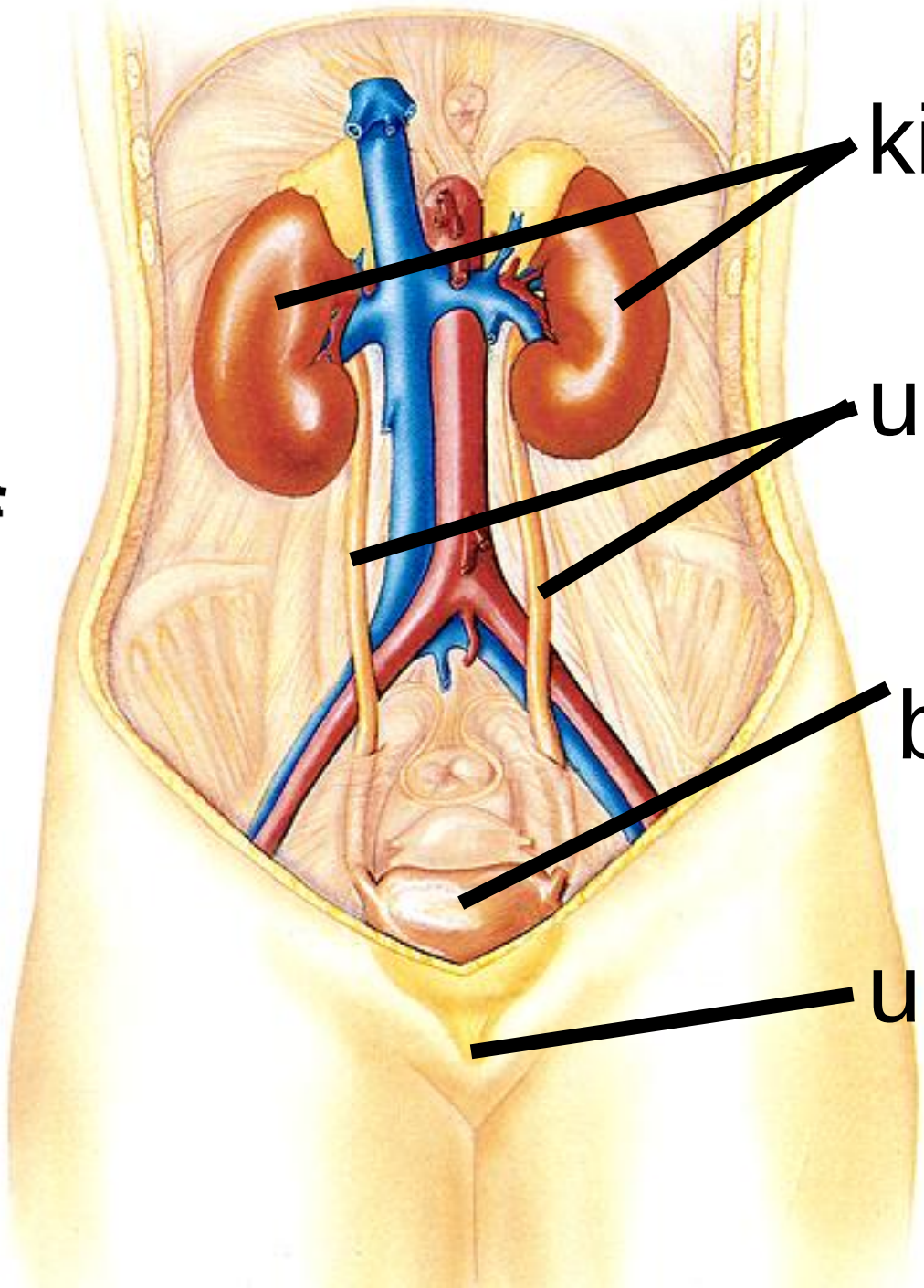
By

Dr. Mareb Hamed

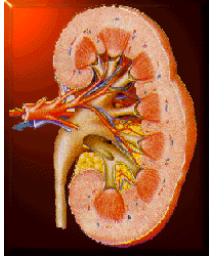
Mosuel University
IRAQ

Lecture 1

Organs of the Urinary System



Kidney Functions



- Filters blood plasma, eliminates waste, returns useful chemicals to blood
- Regulates blood volume and pressure
- Regulates osmolarity of body fluids
- Secretes renin, activates angiotensin, aldosterone
  - controls BP, electrolyte balance
- Secretes erythropoietin, controls RBC count
- Regulates P_{CO_2} and acid base balance
- Detoxifies free radicals and drugs

Anatomy of Kidney

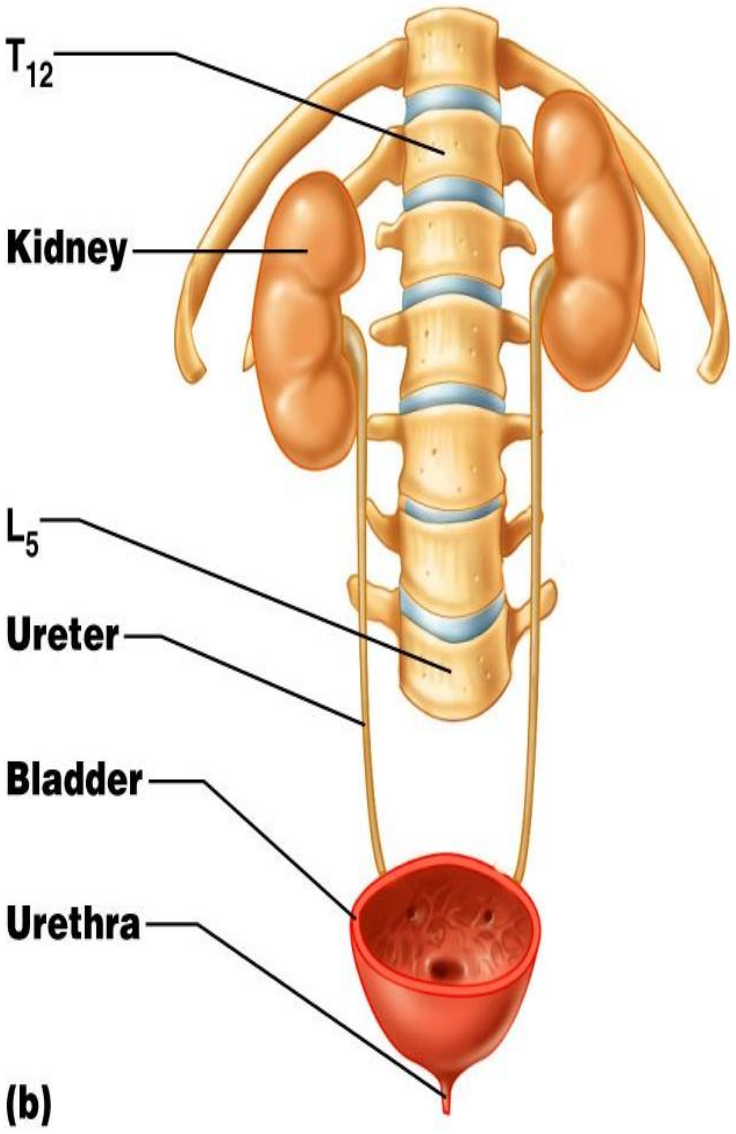
- Position, weight and size
  - retroperitoneal,
  - level of T12 to L3
  - about 160 g each
  - size

  10 cm long,

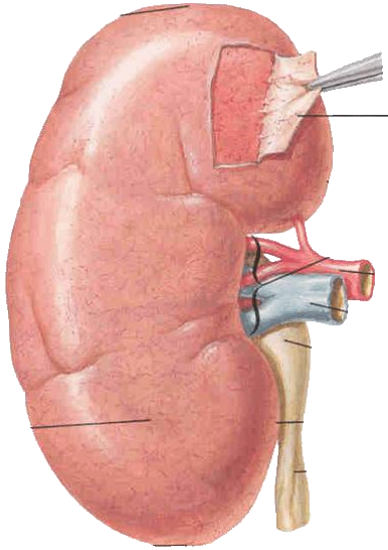
  5 cm wide,

  2 cm thick
  - The left kidney is always

  higher and nearer to the median plane than the right

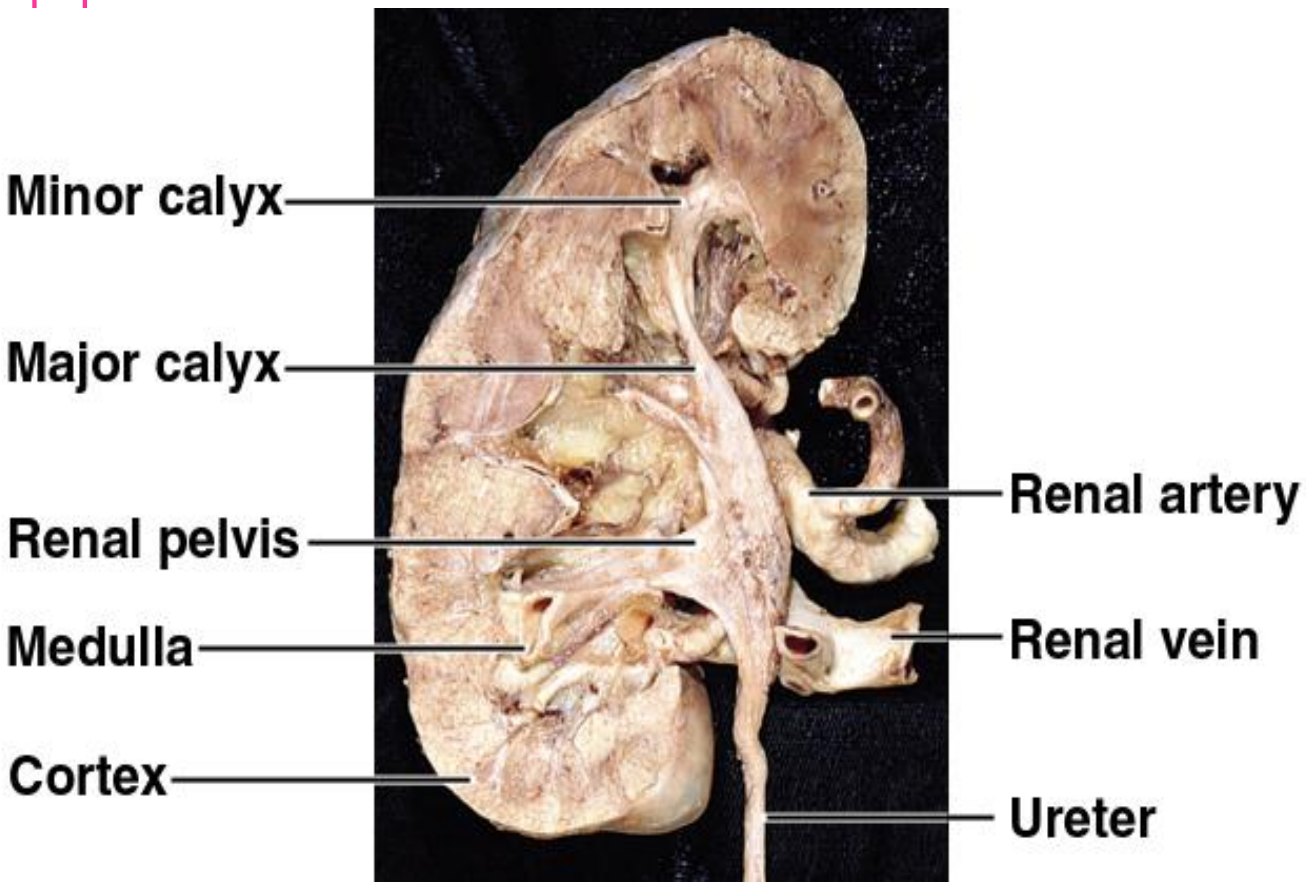


- Shape
  - lateral surface - convex; medial - concave
- CT coverings
  - renal fascia: binds to abdominal wall
  - adipose capsule: cushions kidney
  - renal capsule: encloses kidney like cellophane wrap

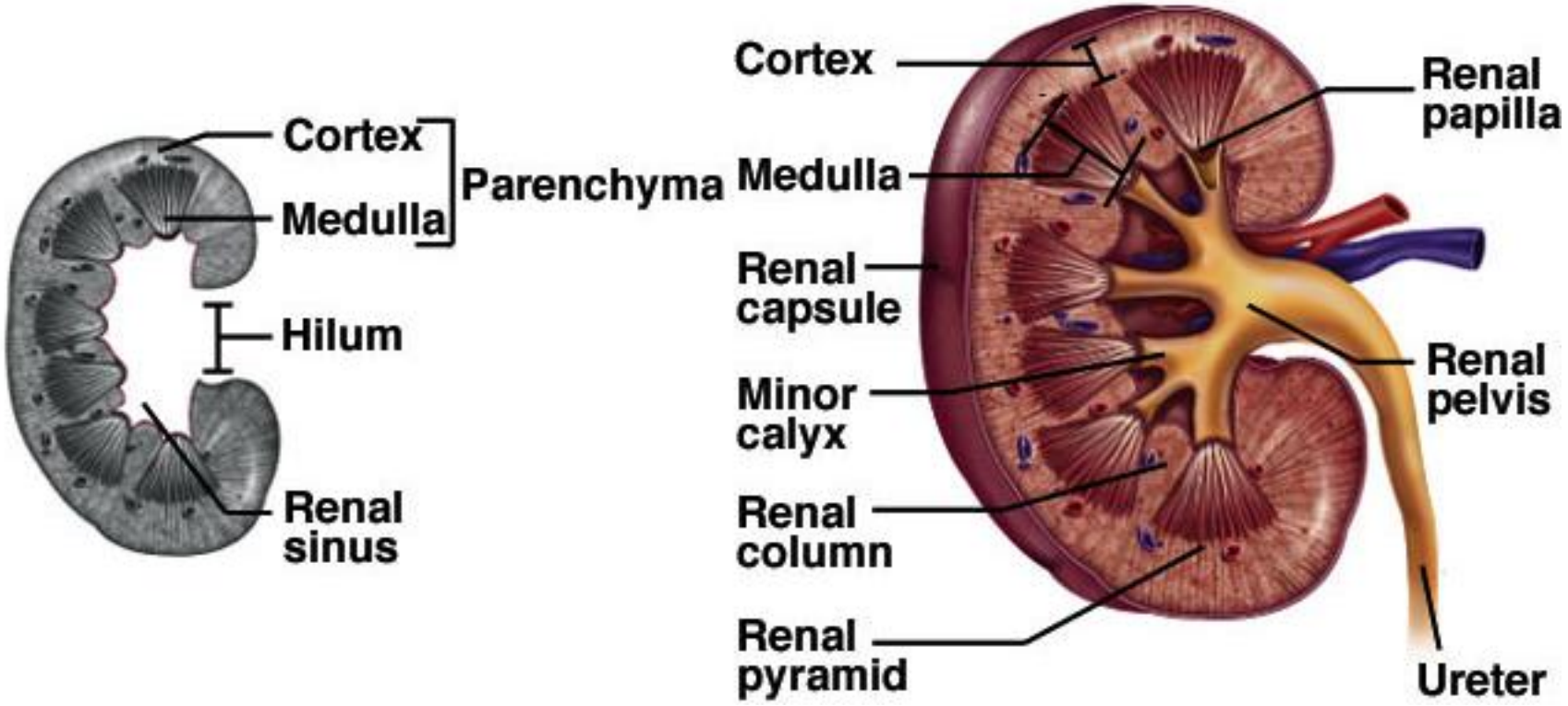


- Concave medial hilum leads to concave renal sinus containing renal vessels, lymphatics, sympathetic nerves, fat and renal pelvis.

- Renal pelvis (expanded upper end of ureter) is divided into 2-3 major calyces, each divided into 2-3 minor calyces.
  Minor calyx: cup over papilla collects urine



Anatomy of Kidney



- Renal cortex: outer 1 cm
- Renal medulla: renal columns, pyramids - papilla

Cortex & Medulla

- **Cut section reveals** outer cortex and inner medulla .

- **Cortex** is granular due to RC,PCT & DCT.
- **Medulla** is striated due to LOH, CT & CD.

Medullary pyramids:

- 10-18.
- Bases towards cortex & apices towards hilum forming **renal papillae.**
- Separated by cortical tissues called **columns of Bertini.**

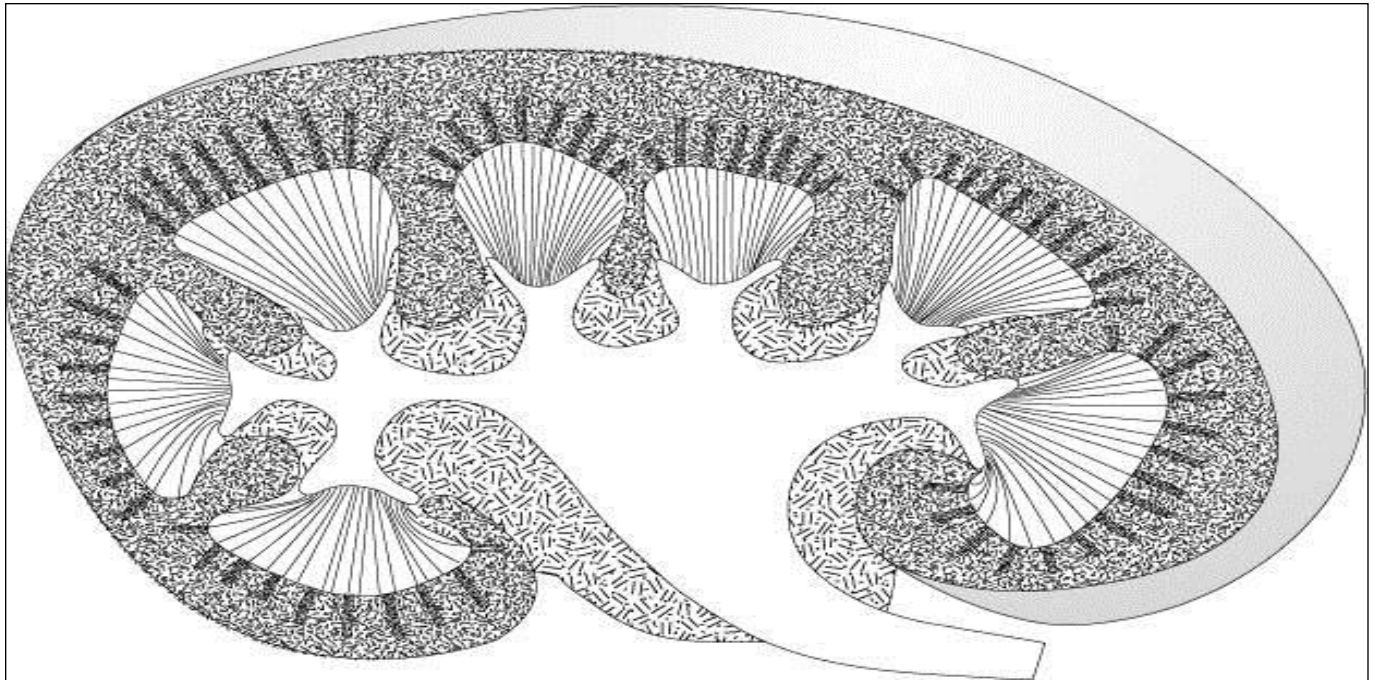
Medullary rays: extend from bases of pyramids to cortex.

lobes & lobules

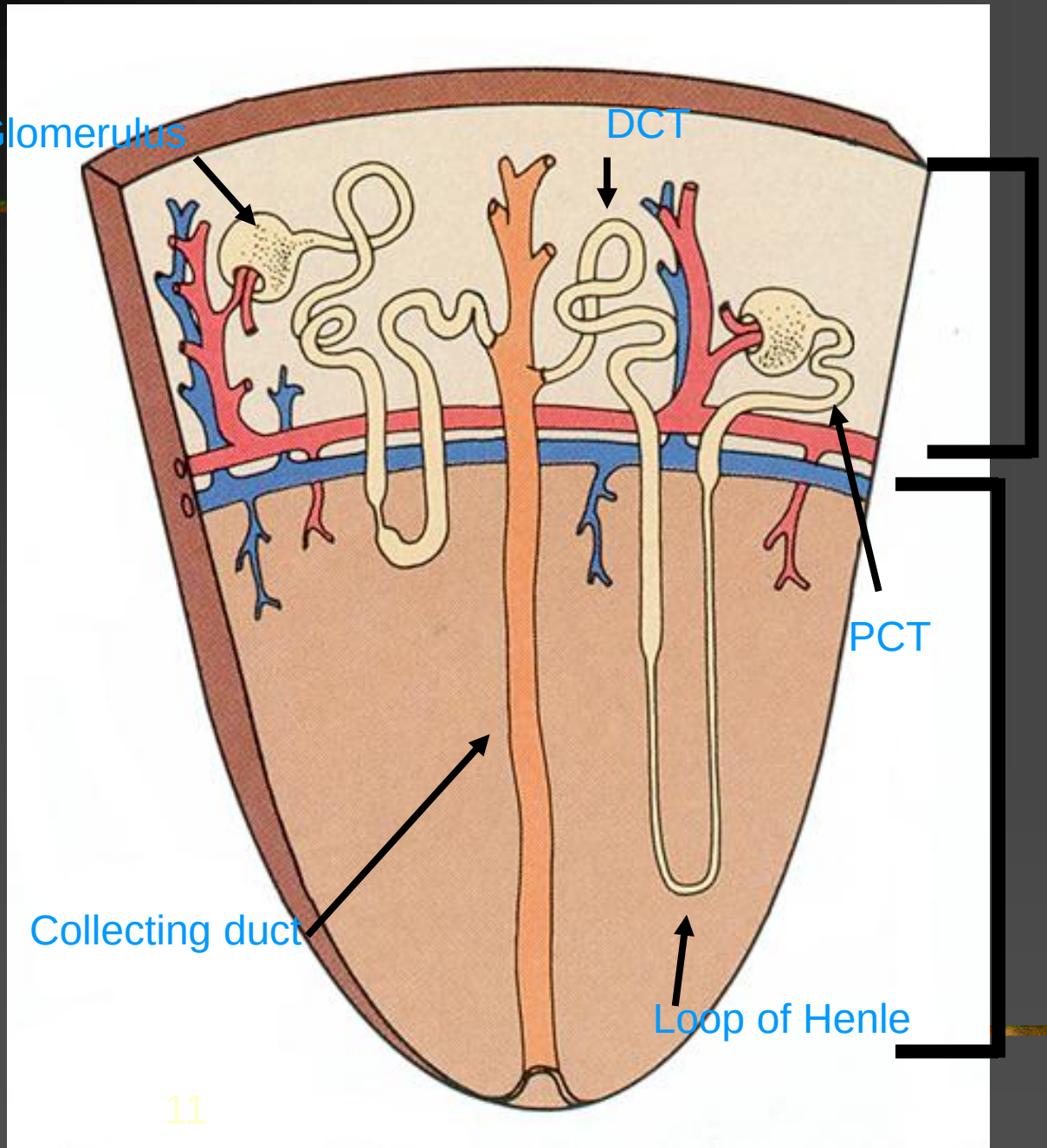
- Each kidney is divided into **lobes & lobules.**

Renal lobe: 1 medullary pyramid + associated cortical tissue .

Renal lobule: 1 medullary ray + associated cortical tissue **No C.T.** septa between renal lobe & lobules.



Each kidney contains over 1 million nephrons and thousands of collecting ducts



renal cortex

renal medulla

Histological aspects

Stroma

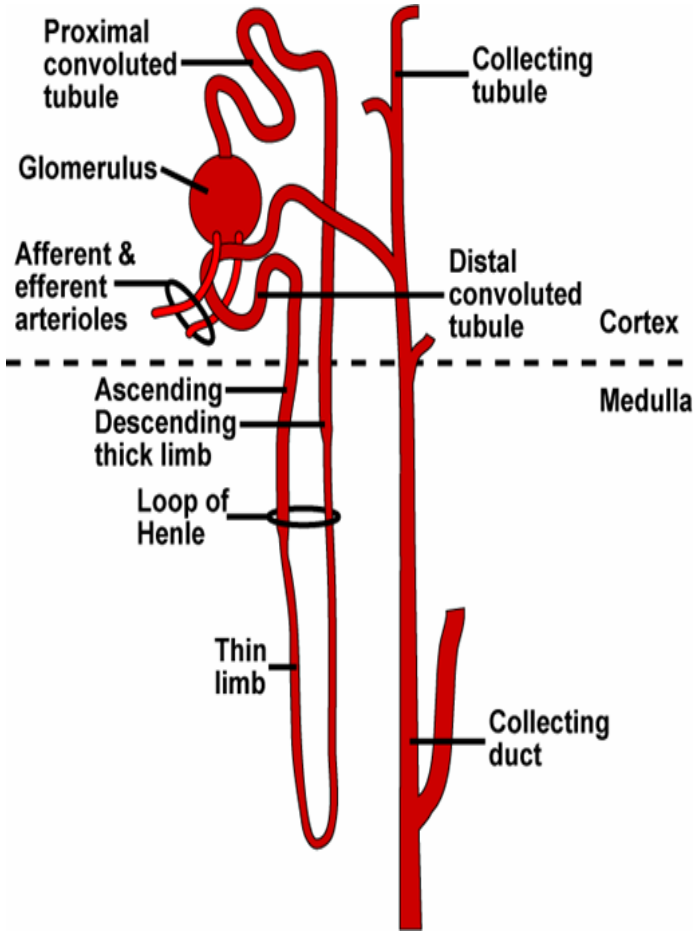
- C.T capsule surrounded by fat.
- Very little CT around BV

& reticular tissue between parenchyma

Parenchyma

Uriniferous tubules:

- **Nephron**
- **Collecting tubule & duct**



NEPHRON

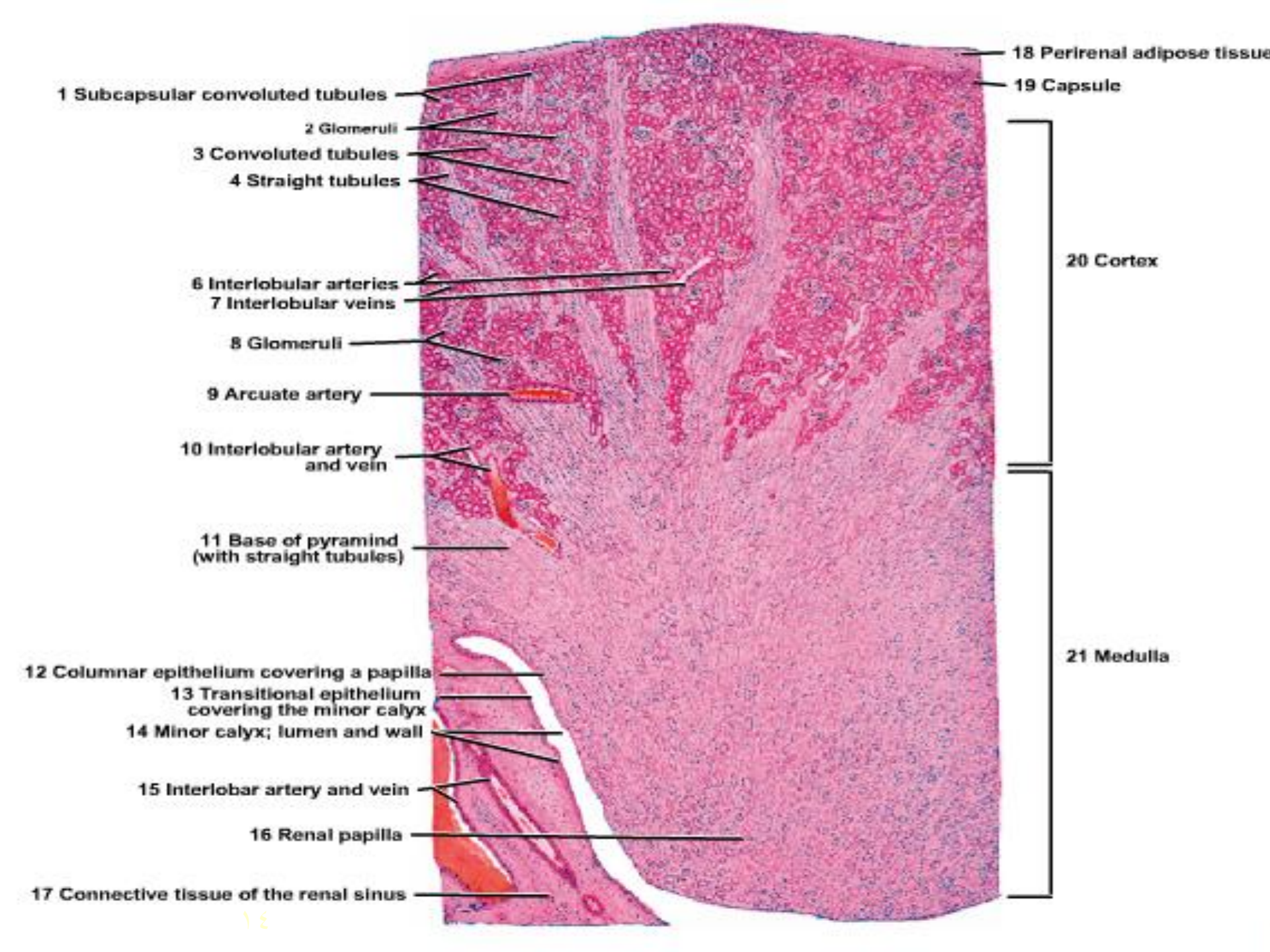
- Structural and functional unit of kidney .
- Each kidney formed of 1-4 million nephrons .
- 2-3 nephrons drain by 1 CT that join forming **duct of Bellini** .

Types :

- **Cortical** under capsule.
- **Juxtamedullary** near medulla.

Parts:

1- Renal corpuscle (Malpighian corpuscle)
2- Proximal convoluted tubule (PCT)
3- Loop of Henle (LOH)
4- Distal convoluted tubule (DCT)


1 Subcapsular convoluted tubules
2 Glomeruli
3 Convoluted tubules
4 Straight tubules
6 Interlobular arteries
7 Interlobular veins
8 Glomeruli
9 Arcuate artery
10 Interlobular artery and vein
11 Base of pyramind (with straight tubules)
12 Columnar epithelium covering a papilla
13 Transitional epithelium covering the minor calyx
14 Minor calyx; lumen and wall
15 Interlobar artery and vein
16 Renal papilla
17 Connective tissue of the renal sinus
18 Perirenal adipose tissue
19 Capsule
20 Cortex
21 Medulla

Renal corpuscle (RC)

- **Present in:** cortex.

- **Formed of:**

a) Glomerulus (tortuous tuft of capillaries).

b) Bowman's capsule (double layer epithelial capsule)

- **Has two poles:**

a) Vascular pole: afferent arteriole enters & efferent leaves.

b) Urinary pole: PCT begins.

- **Diameter:** 200 um.
- **Function:** filtrate blood and form urine.

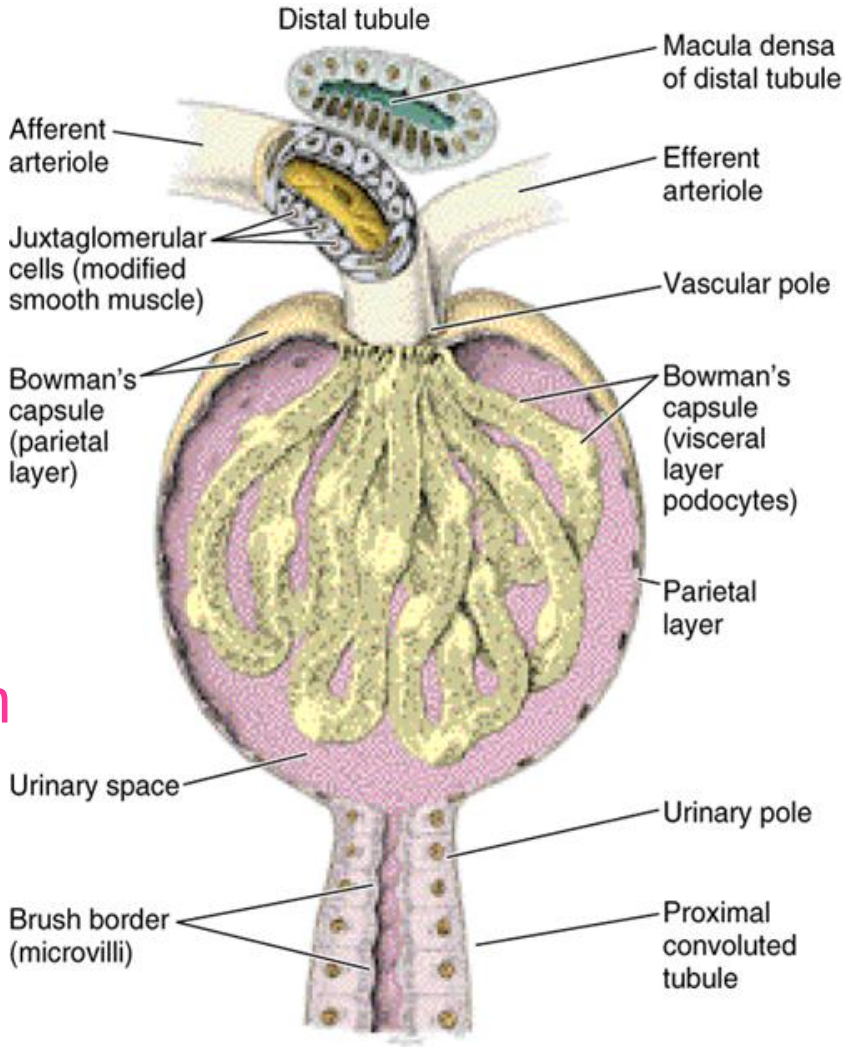
a) Glomerulus

- **Tuft of anastomosing capillaries.**

- **Afferent arteriole**
- enters RC at vascular pole
- gives glomerulus
- unite forming
- **Efferent arteriole**

Glomerular capillaries

- lined by fenestrated endothelium
- no diaphragm
- rest on basement membrane



Basement membrane

- 300 nm thick.
- Formed of 3 layers:
- Middle lamina densa (collagen IV)

- Outer and inner laminae rarae

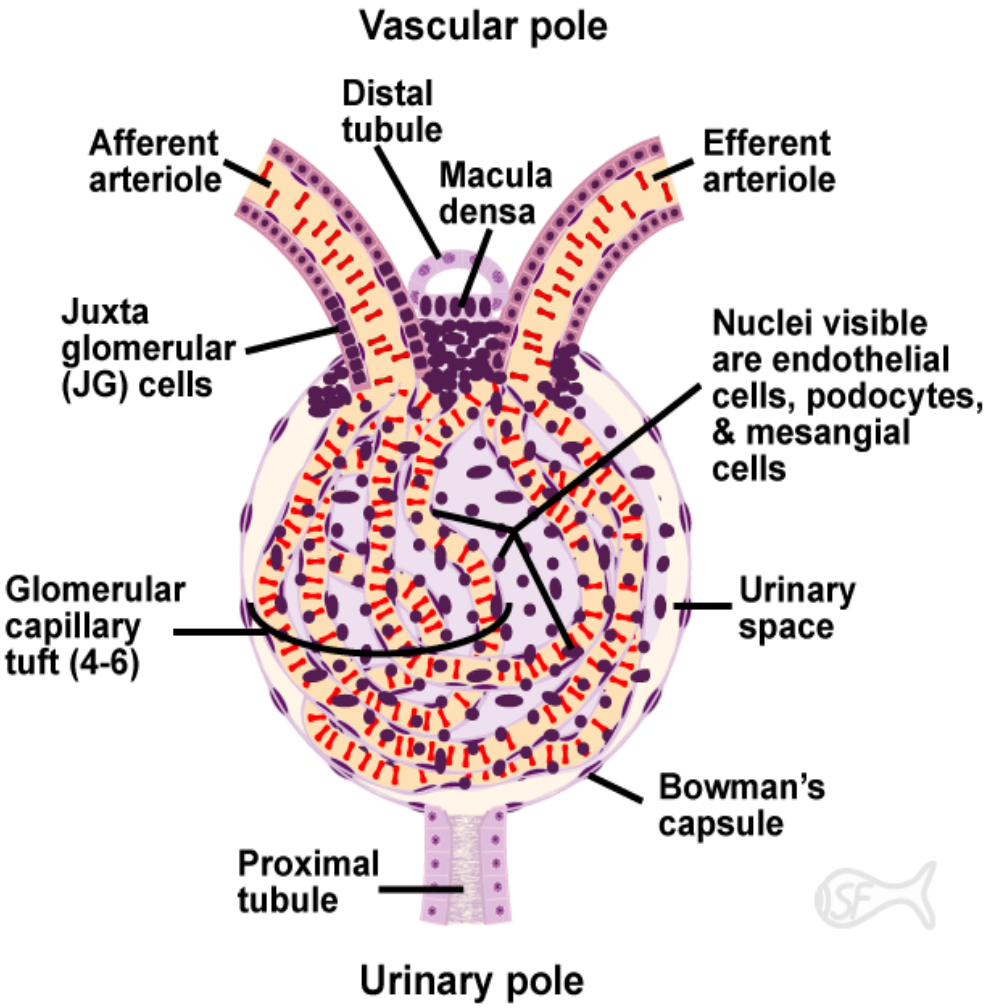
-less electron dense.

-glycoproteins: laminin+fibronectin

-proteoglycans.

Afferent & Efferent arterioles

- Lumen width is the same but diameter of afferent is larger due to thicker muscle layer to regulate hydrostatic pressure in glomerular capillaries.



Intraglomerular mesangial cells

- Present inbetween loops of capillaries
- to support them where a basement membrane is lacking.

b) Bowman's capsule

Two layers:

A-Outer parietal layer: simple squamous epithelium .

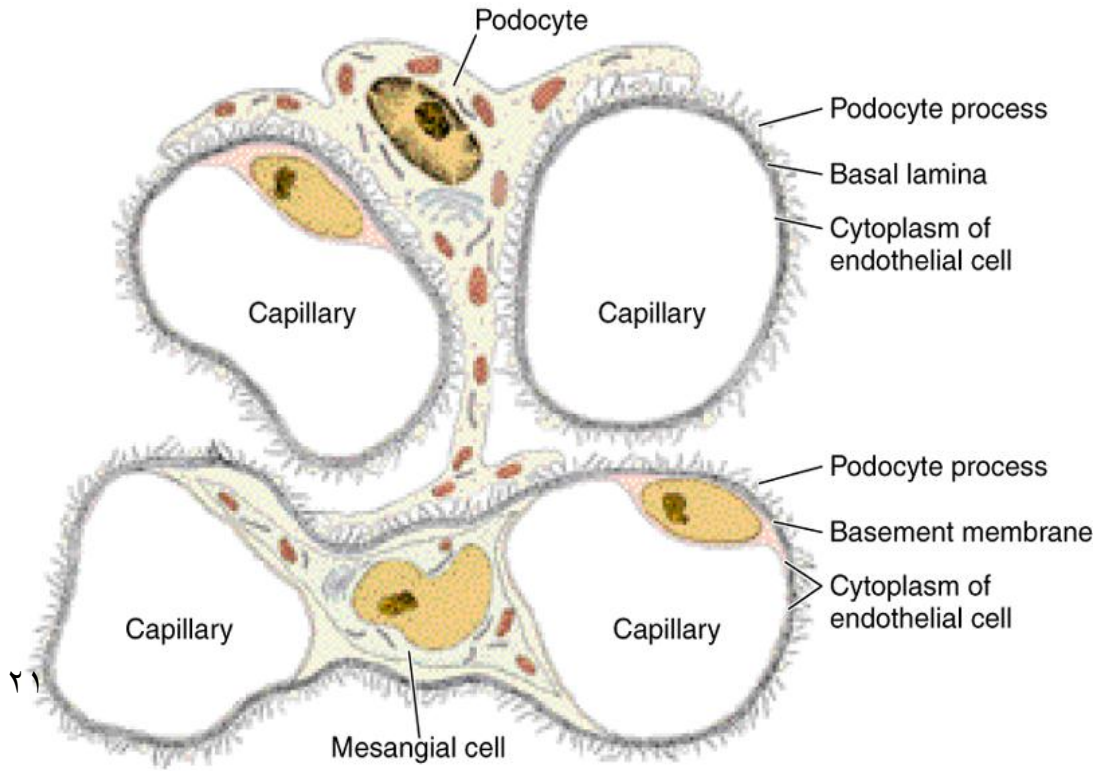
B-Inner visceral layer: podocytes adherent to glomerular capillaries.

The capsular space

- between parietal & visceral layers
- receives glomerular filtrate
- continuous with PCT.

Podocyte L/M

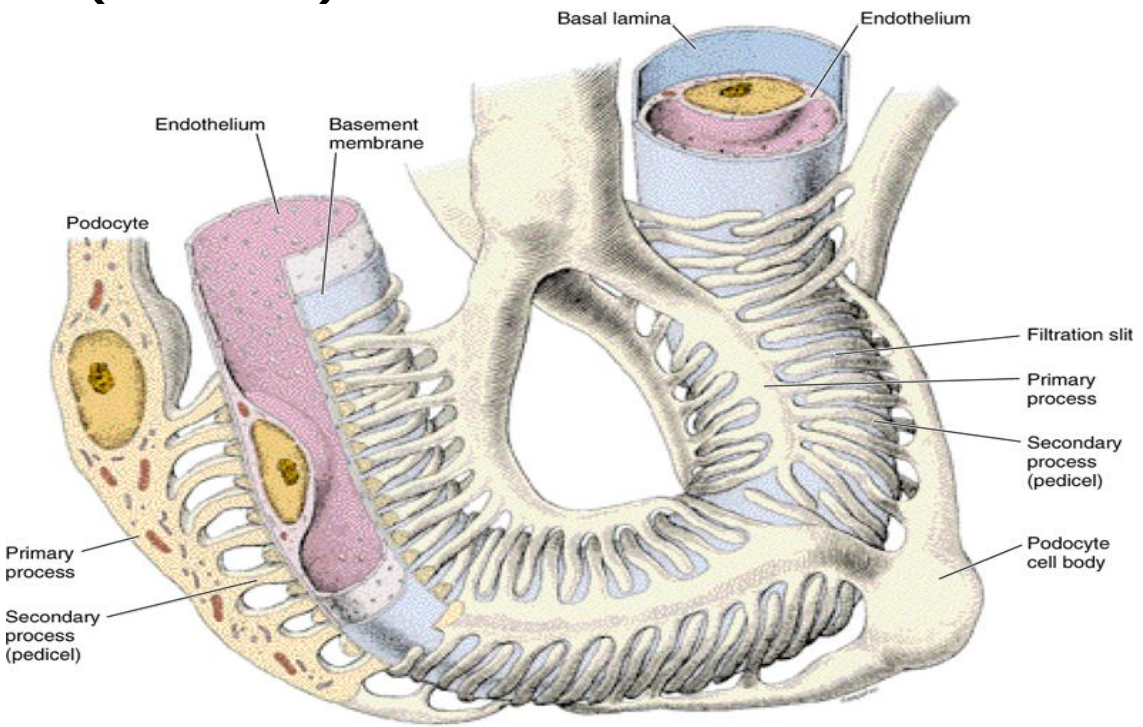
- Star shaped
- multiple processes.



Podocyte E/M

Large cell:

- Body
- 1ry processes (major)
- 2ry processes (minor)



- Cell body:
- Central nucleus (extended chromatin),
- Cytoplasm: mitochondria, Golgi, RER, microtubules & microfilaments.
- Processes: microtubules & microfilaments

1ry process:

- parallel to long axis of blood capillary.
- gives rise to numerous 2ry processes.

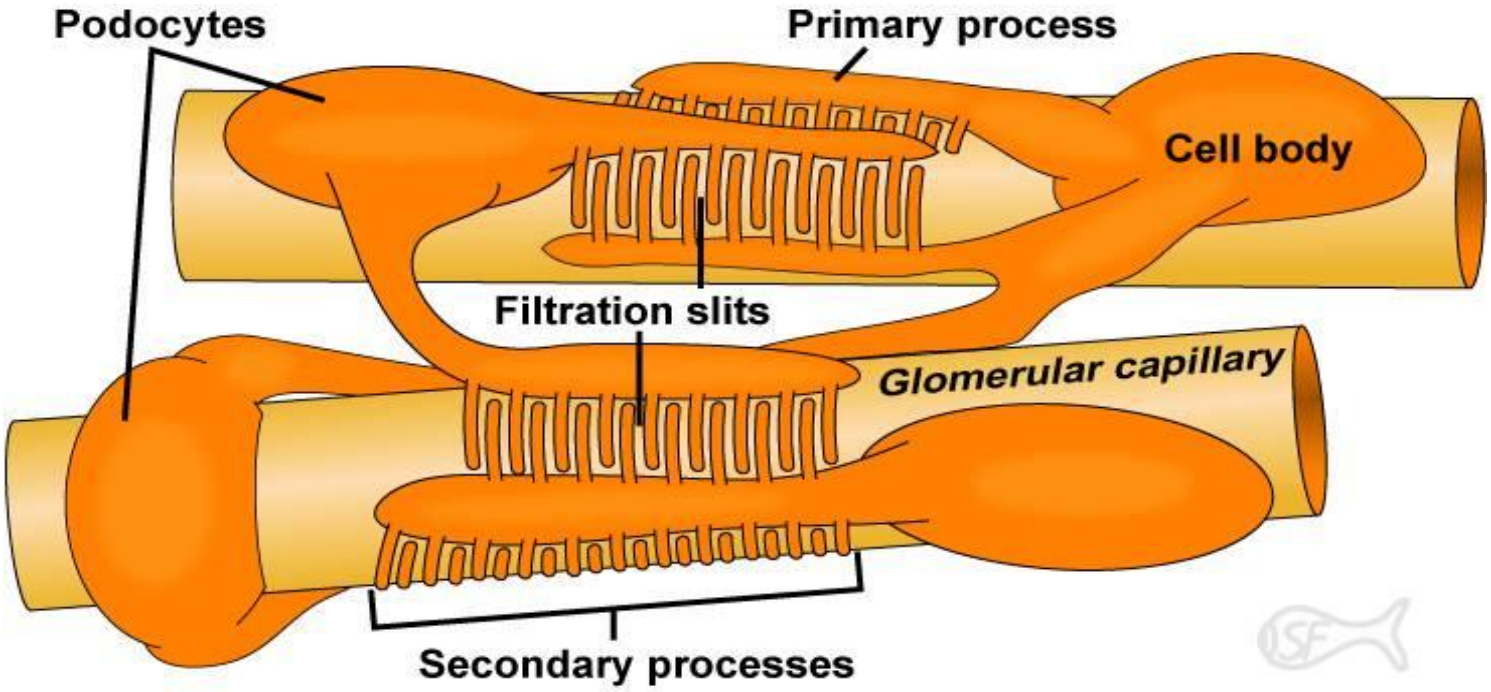
. 2ry processes:

- end in feet like structures on basement membrane of glomerular capillaries and hence name of cell .

- Inbetween the feet, there are filtration slits covered with diaphragm.

- **Podocyte Function**
- Blood renal barrier.
- Regeneration of basement membrane.

Podocytes team up to make filtration slits



Blood-renal barrier

Formed of:

1- Fenestrated endothelium of glomerular capillaries:

Hold back RBCs, WBCs & platelets.

2- Thick basement membrane: (the only continuous layer).

High molecular weight protein (> 68,000) can not pass.

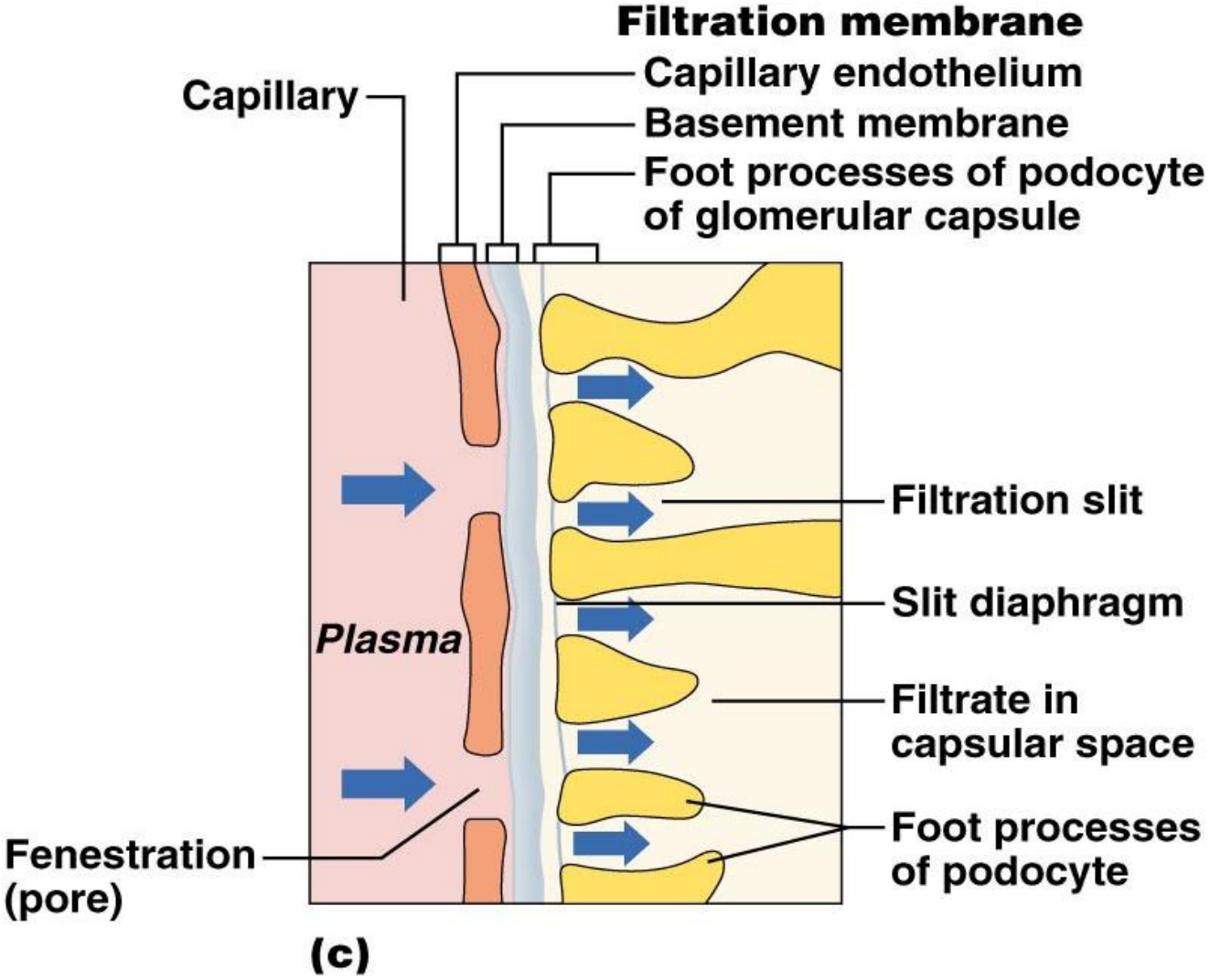
Small molecular weight sugar, amino acids & protein can pass.

3- Filtration slits (60-100nm) **& overlying diaphragms:**

Prevent molecules according to their electrostatic charge.

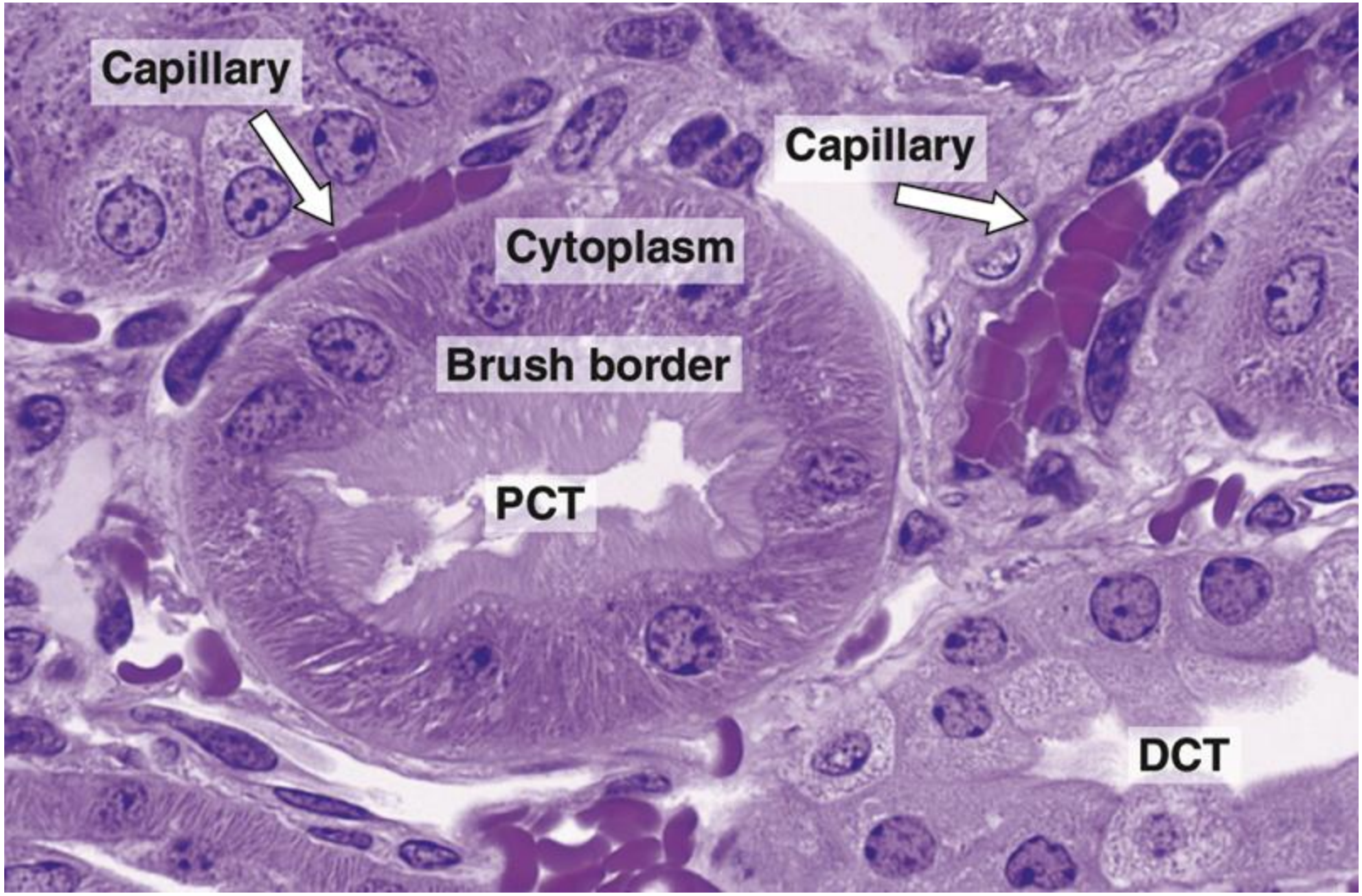
Function: Formation of glomerular filtrate.

Renal Corpuscle and the Filtration Membrane

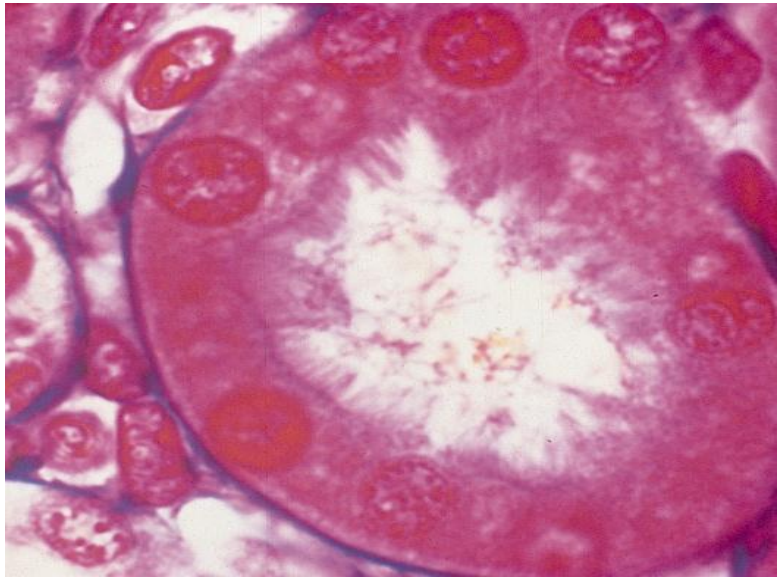


Proximal convoluted tubules

- Begins in cortex at urinary pole of renal corpuscle.
- At first highly convoluted then straightens to continue with descending thick segment of LOH in medulla.
- Small lumen with 60 um diameter and 14 mm long.
- Lined with single layer of pyramidal cells
- Rest on basement membrane.


Capillary
Capillary
Cytoplasm
Brush border
PCT
DCT

L/M & E/M



- Cells 4-5 pyramidal acidophilic.
- Lumen narrow.
- Boundaries indistinct (Lateral interdigitations).
- Nuclei rounded central.
- Apical brush border (microvilli).
- Basal acidophilic striations (Mitochondria inbetween infoldings).

Functions

- Reabsorption of:

- 85% of sodium activly and 85% of water passivly.
- all glucose & amino acids.
- low molecular weight protein by pinocytosis → endosomes → amino acids.

- Excretion of:

- metabolites, dyes,drugs, urea and uric acid.

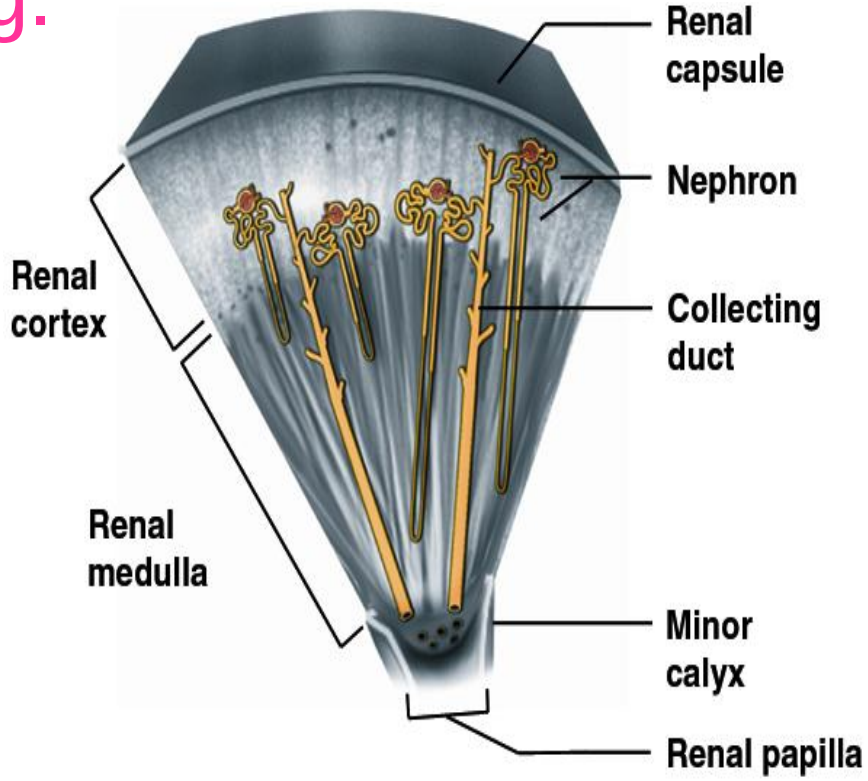
- The end result is isotonic solution.

Loop of Henle

- U shaped tube present mainly in medulla .

Four parts :

- Thick & thin descending.
- Thin & thick ascending.



1-Thick descending part

- Starts in cortex and extends to medulla.
- Similar to PCT in structure and function.

2-Thin descending part

- In medulla.
- Lined with simple squamous epithelium

- Similar to capillary wall but with no blood cells in lumen.

- Permeable to water.
- Impermeable to sodium.
- Urine becomes **hypertonic.**

3-Thin ascending part

- In medulla.
- Lined with simple squamous epithelium.

4-Thick ascending part

- Starts in medulla and extends to cortex.
- Similar to DCT in structure and function.

- Permeable to sodium.
- Impermeable to water.
- Urine becomes **hypotonic.**

- Subcapsular nephrons (short LOH) → turn of LOH in thick ascending part.
- Juxtamedullary nephrons (long LOH) → turn of LOH in thin descending part.

Distal convoluted tubules

- In corticomedullary zone: continuation of thick ascending LOH.
- In cortex: joins collecting tubules.

Three parts:

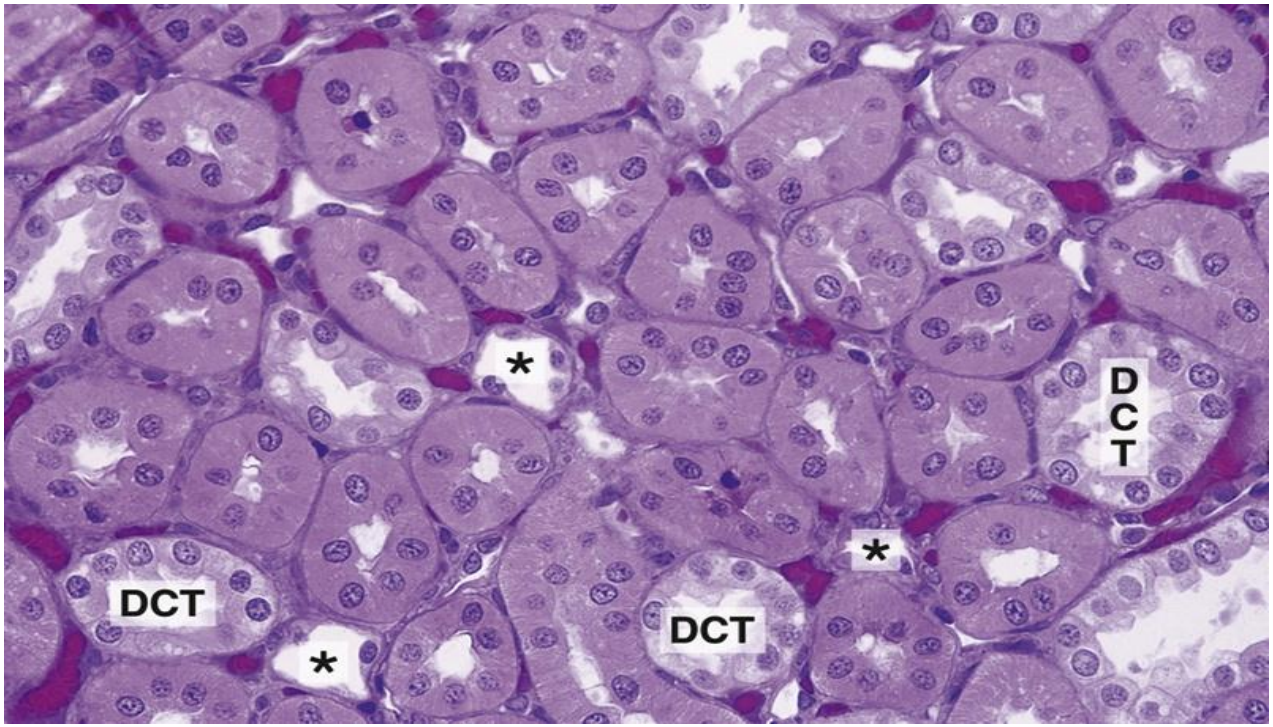
1-Straight part: continuous with ascending thick limb of LOH.

2-Macula densa: close to afferent and efferent arterioles. A part of juxtaglomerular apparatus.

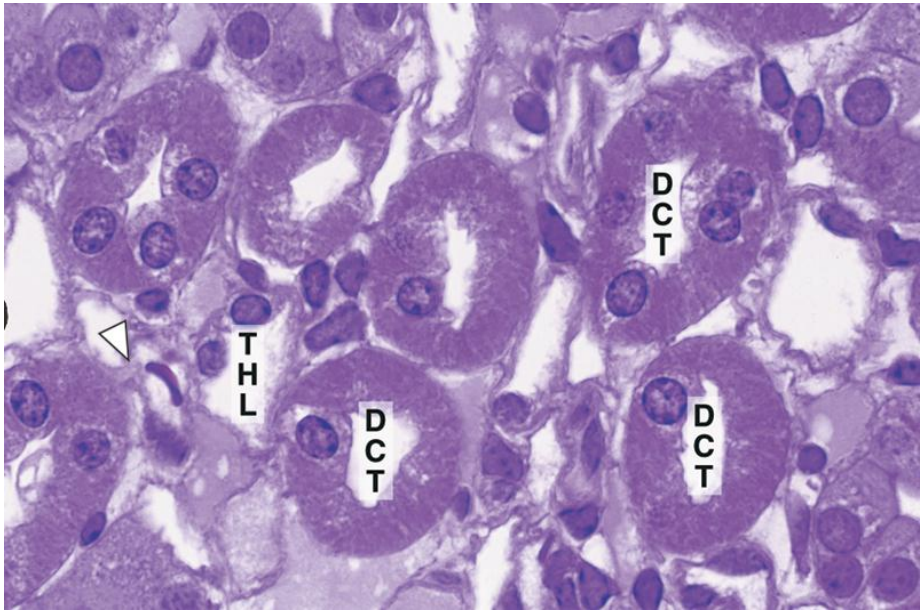
3-Convoluted part: opens in collecting tubules .

L/M & E/M

- **Cells:** 5-8 cubical small acidophilic.
- **Lumen:** wide.
- **Boundaries:** distinct (Less lateral interdigitations).

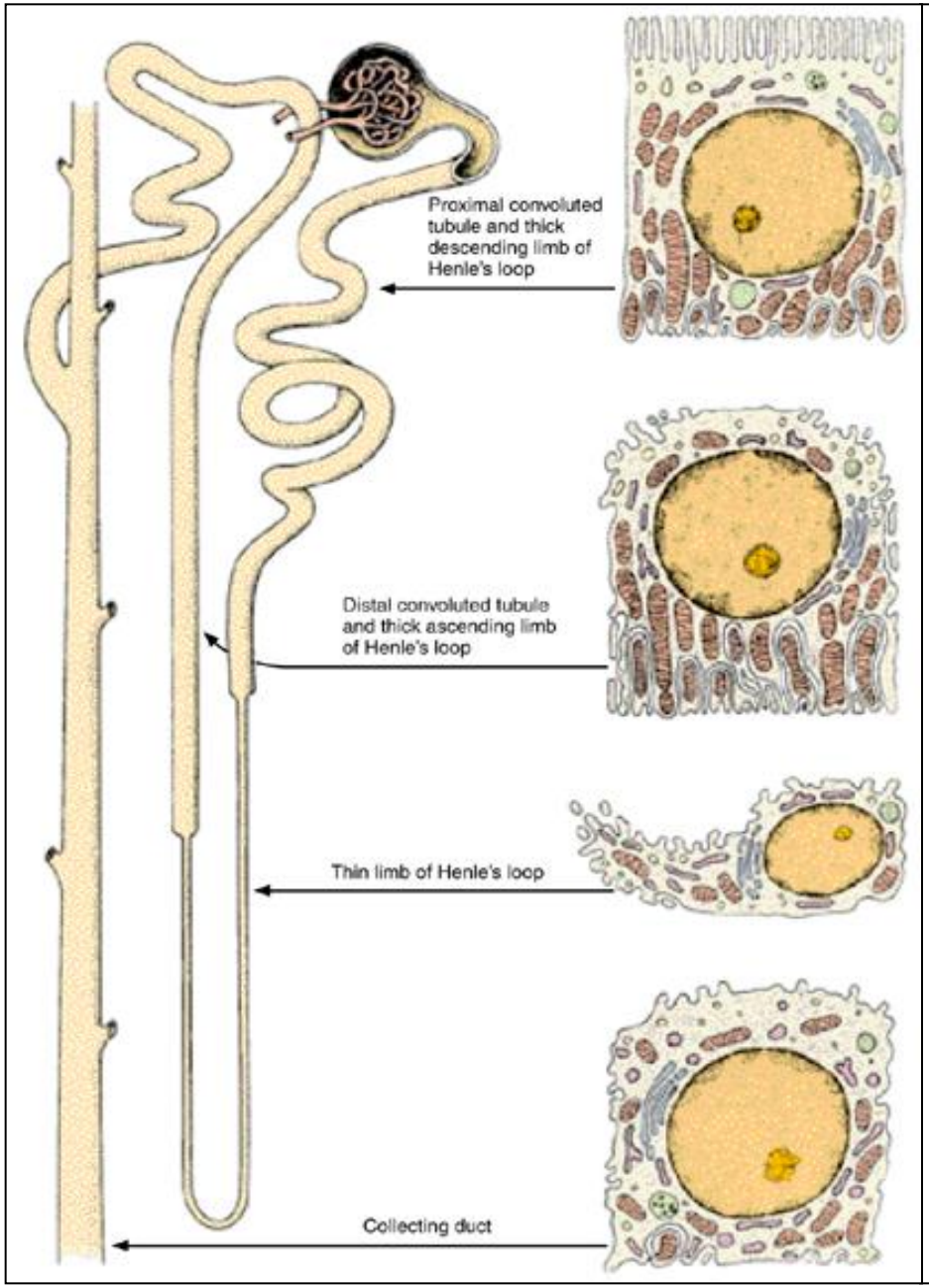


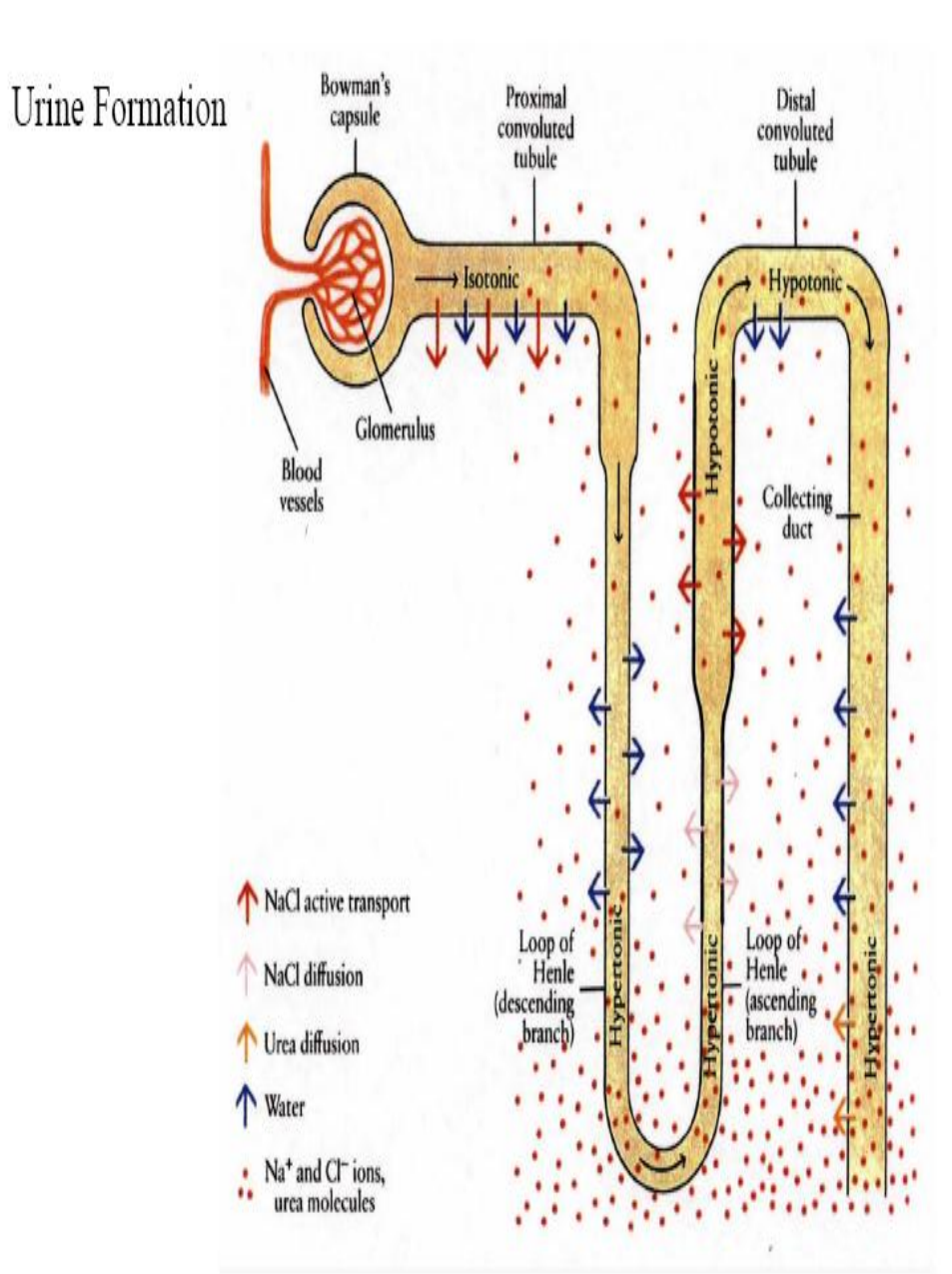
- **Nuclei:** rounded central.
- **Apical** surface: no brush borders (few short microvilli).
- **Basal** acidophilic striation (mitochondria inbetween infoldings).



Functions

- Reabsorb 15% sodium (activly) under control of aldosterone.
- Reabsorb 15% water (convoluted part) under control of ADH.
- Excrete hydrogen, ammonium & potassium ions.
- Maintain acid-base balance of body.


Proximal convoluted tubule and thick descending limb of Henle's loop
Distal convoluted tubule and thick ascending limb of Henle's loop
Thin limb of Henle's loop
Collecting duct


Urine Formation
Bowman's capsule
Proximal convoluted tubule
Distal convoluted tubule
Isotonic
Hypotonic
Glomerulus
Blood vessels
Collecting duct
Hypotonic
Hypertonic
Hypertonic
Hypertonic
Loop of Henle (descending branch)
Loop of Henle (ascending branch)
NaCl active transport
NaCl diffusion
Urea diffusion
Water
Na+ and Cl− ions, urea molecules

Juxtaglomerular apparatus

Is formed at the site of the contact between the distal convoluted tubules with the afferent arterioles Composed of:

1-Juxtaglomerular cells.

2-Macula densa.

3-Polar cushion.

Afferent arteriole

- Tunica intima: endothelium + C.T. + internal elastic lamina.
- Tunica media: smooth muscle cells.
- Tunica adventitia

1- Juxtaglomerular cells

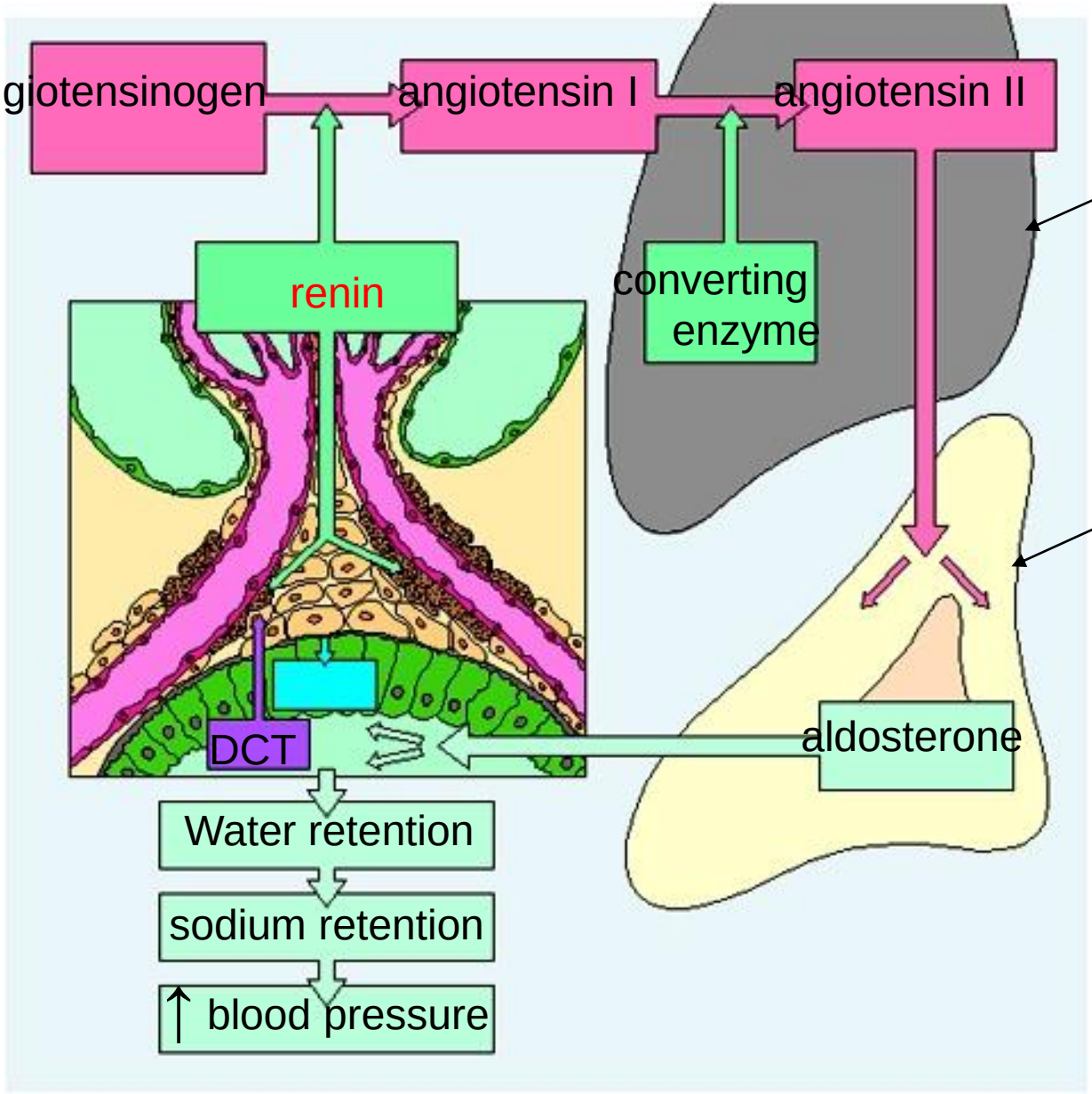
- Modified smooth muscle cells of tunica media of afferent arterioles.
- Cells: large cubical cells + rounded nuclei + cytoplasm containing many PAS+ve secretory granules.
- EM: RER, Golgi and mitochondria.
- Internal elastic lamina is absent,
- so juxtaglomerular cells are in contact in one side with blood and endothelium
- and in other side with macula densa due to absence of its basement membrane.

Function

1-Secrete renin →

- converts plasma angiotensinogen into angiotensin I →
- by converting enzyme in lung → angiotensin II →
- produce aldosterone by adrenal cortex →
- acts directly on DCT →
- water & sodium retention →
- increase blood pressure.

2-Secrete erythropoietin → formation of erythrocytes in bone marrow.


angiotensinogen
angiotensin I
angiotensin II
Lung
renin
converting enzyme
Adrenal cortex
DCT
aldosterone
Water retention
sodium retention
blood pressure

Macula densa

- The part of DCT in concavity between afferent & efferent arterioles of same nephron.
- Cells: columnar with packed nuclei + numerous microvilli and infranulear Golgi.

Functions

- Sensitive to chloride ion content of tubular fluid → signals for constriction of glomerular afferent arteriole → regulates rate of glomerular filtrate.

COLLECTING TUBULES

- Not part of nephron.
- Different embryonic origin.

- Union of 2-3 DCT → collecting tubule → medullary ray in cortex → main collecting tubule in medullary pyramid →

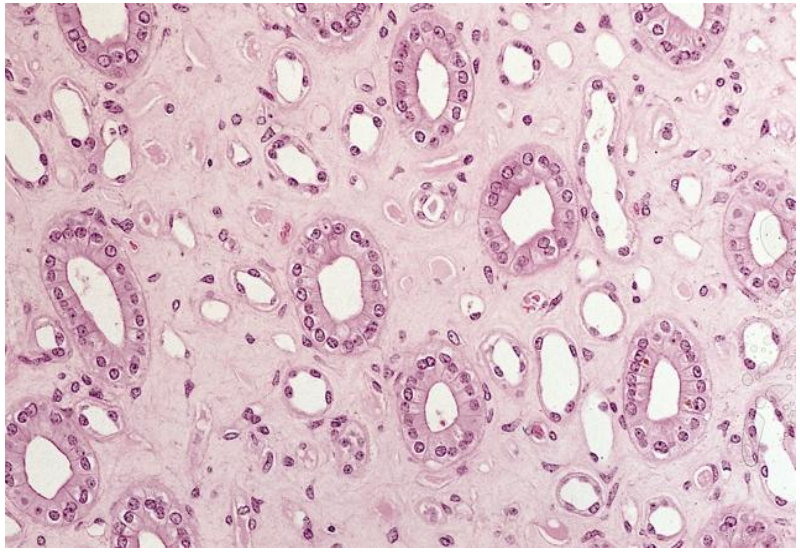
- Several medullary collecting tubules form straight papillary ducts of Bellini → apex of renal papillae → minor calyx.

- 2-4 minor calyces → major calyx → renal pelvis.

L/M & E/M

L/M :

- Lined with simple cubical epithelium (in small tubules) or simple columnar epithelium (in large tubules).
- Cytoplasm pale acidophilic.
- Cell borders distinct.
- Lumen wide.
- Nuclei dark central.



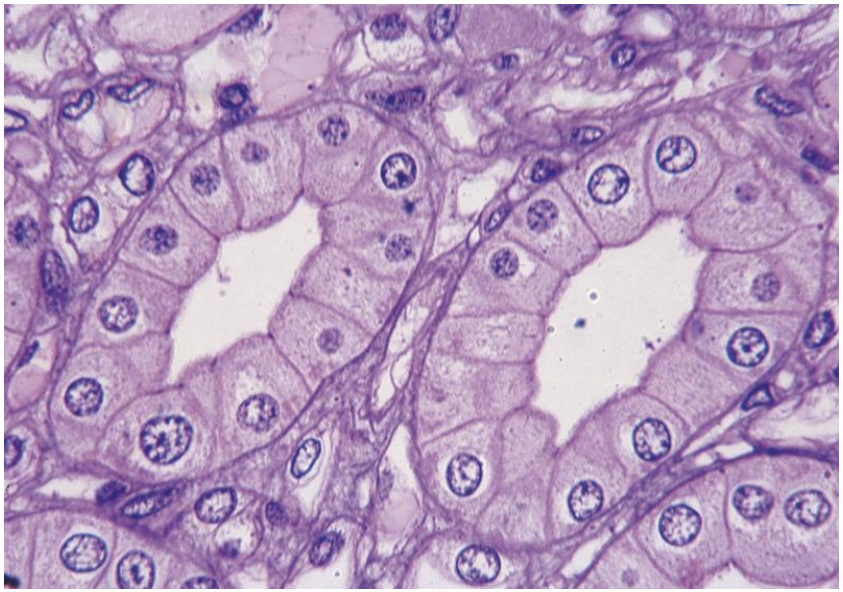
E/M :

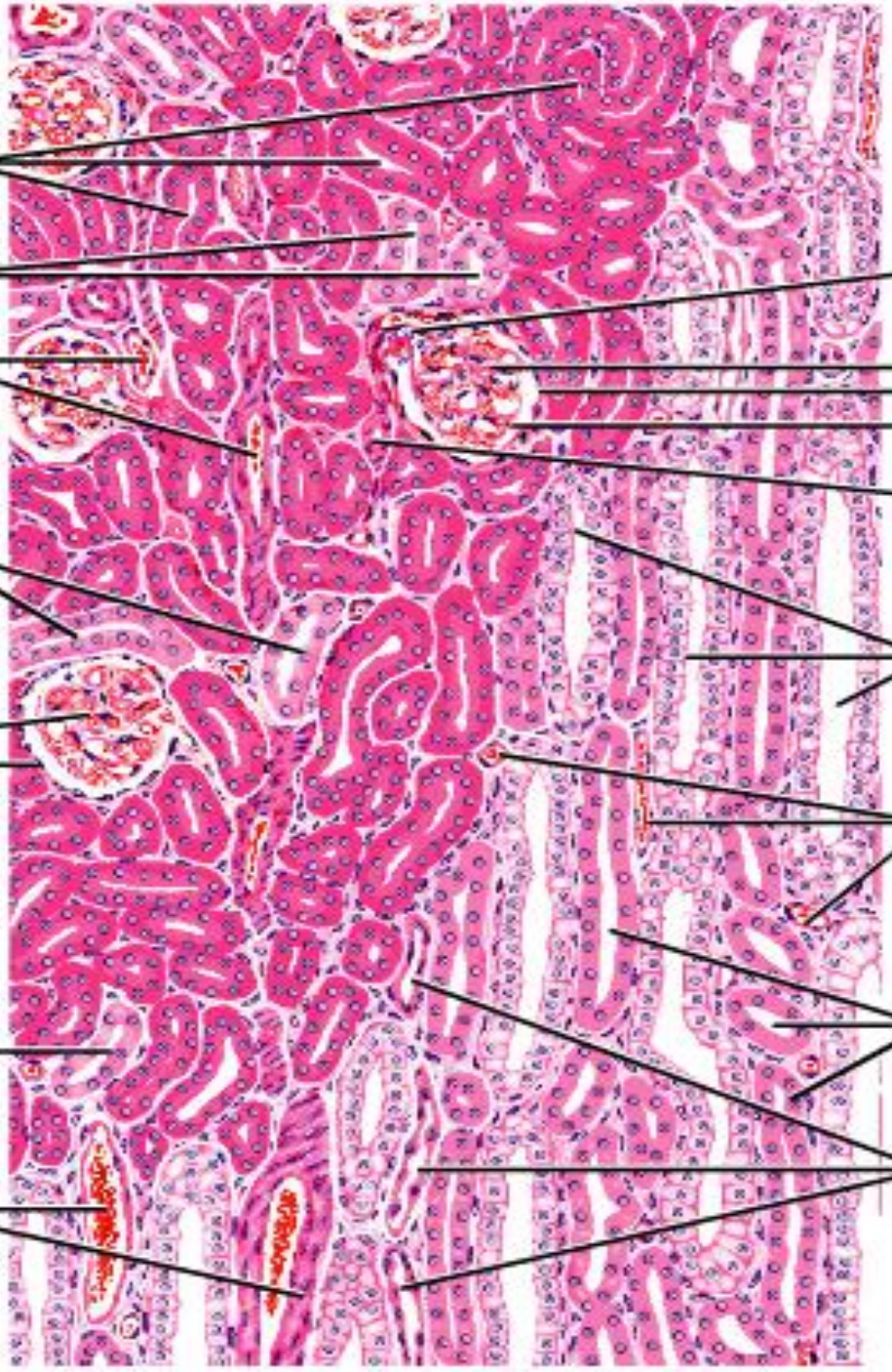
- Few organelles.
- Interdigitations between cells not marked.
- Few microvilli and basal infoldings.

Function

- Water is reabsorbed under control of antidiuretic hormone.

- Collect, concentrate and conduct urine to calyces.




1 Proximal convoluted tubules
2 Distal convoluted tubules
3 Interlobular blood vessels
4 Distal convoluted tubules
5 Renal corpuscle:
a. Glomerulus
b. Glomerular (Bowman's) capsule
6 Straight (ascending) segment of the distal tubule
7 Interlobular vein and artery
8 Vascular pole
9 Renal corpuscle:
a. Visceral layer
b. Parietal layer
10 Capsular space
11 Glomerular arteriole
12 Collecting tubules
13 Capillaries
14 Straight (descending) segment of the proximal tubule
15 Thin segments of the loop of Henle

Renal interstitial tissue

- The kidney is invested by C.T capsule easily stripped.
- Medullary interstitial CT cells are macrophages, fibroblasts & interstitial cells.

Interstitial cells:

- more numerous
- elongated nuclei
- numerous lipid droplets
- Synthesize medullipin I converted in liver into medullipin II (potent vasodilator lowers blood pressure).

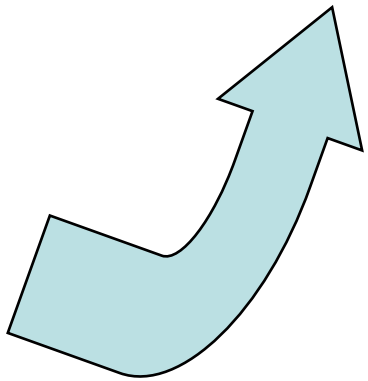
Renal Circulation

Renal Artery

Segmental arteries
Interlobar arteries
Arcuate arteries
Interlobular arteries
Afferent arterioles
Glomerulus
Efferent arterioles
Peritubular capillaries

Renal Vein

Segmental veins
Interlobar veins
Arcuate veins
Interlobular veins
Venules



Excretory passages

- Minor calyces, major calyces, renal pelvis, ureter, urinary bladder and urethra .
- Urine collected from ducts of Bellini → minor calyces.
- 2-4 minor calyces → major calyx → renal pelvis.

Urine collection:

Ducts within each renal papilla release urine into minor calyx

↓

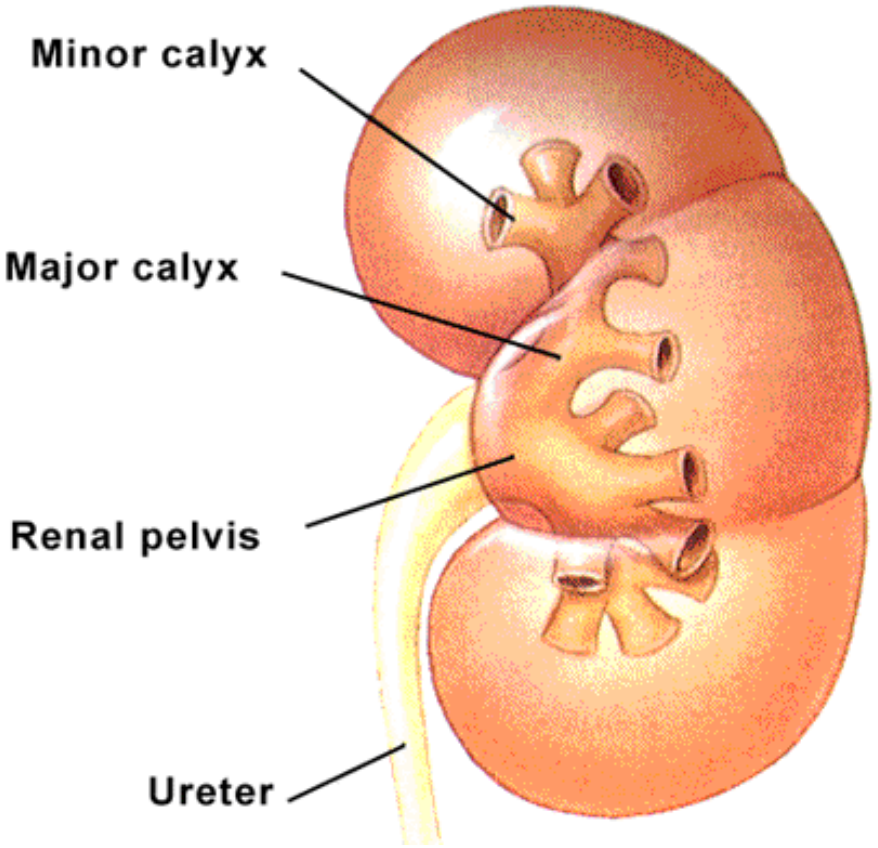
major calyx

↓

renal pelvis

↓

ureter



Histological structure

1-Mucosa:

a- Epithelium: transitional.

b- Lamina propria: loose C.T.

2-Muscle layer: Smooth muscle that becomes thicker from minor calyces to renal pelvis .

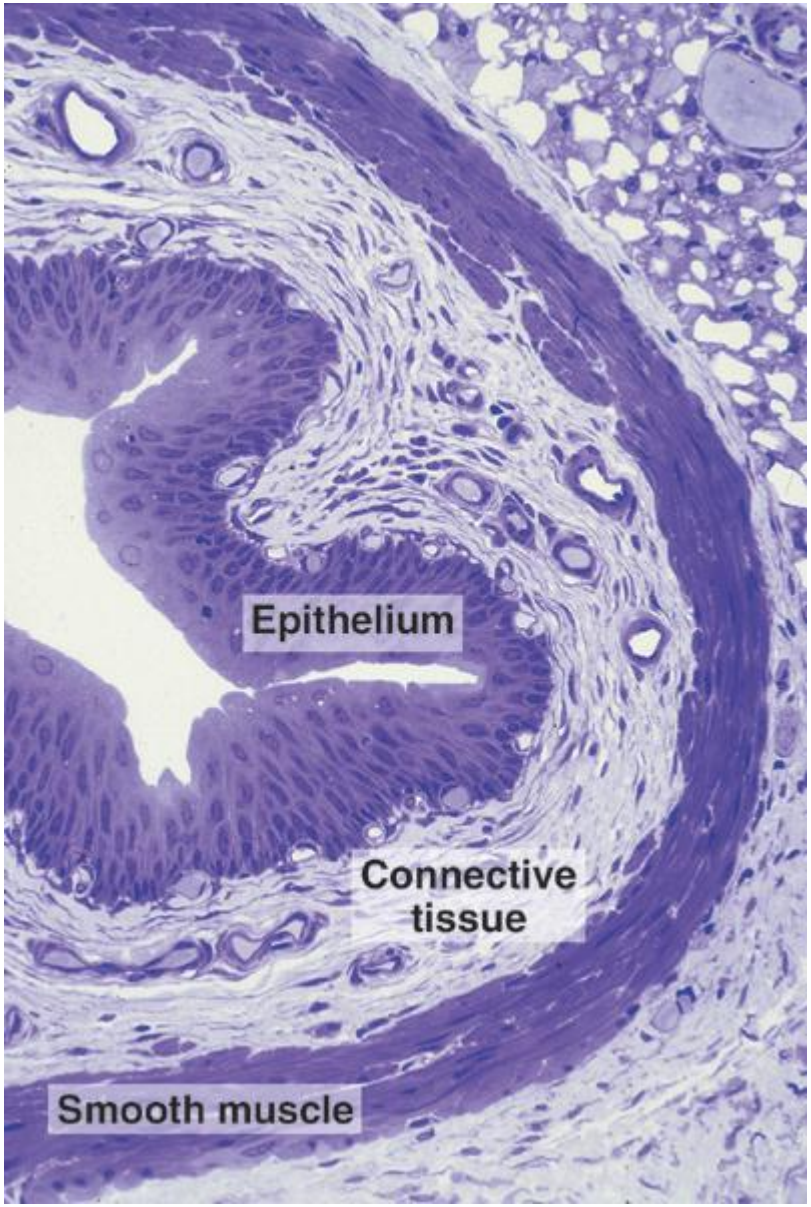
3-Adventitia: CT covering urinary passage except upper part of urinary bladder (peritoneum).

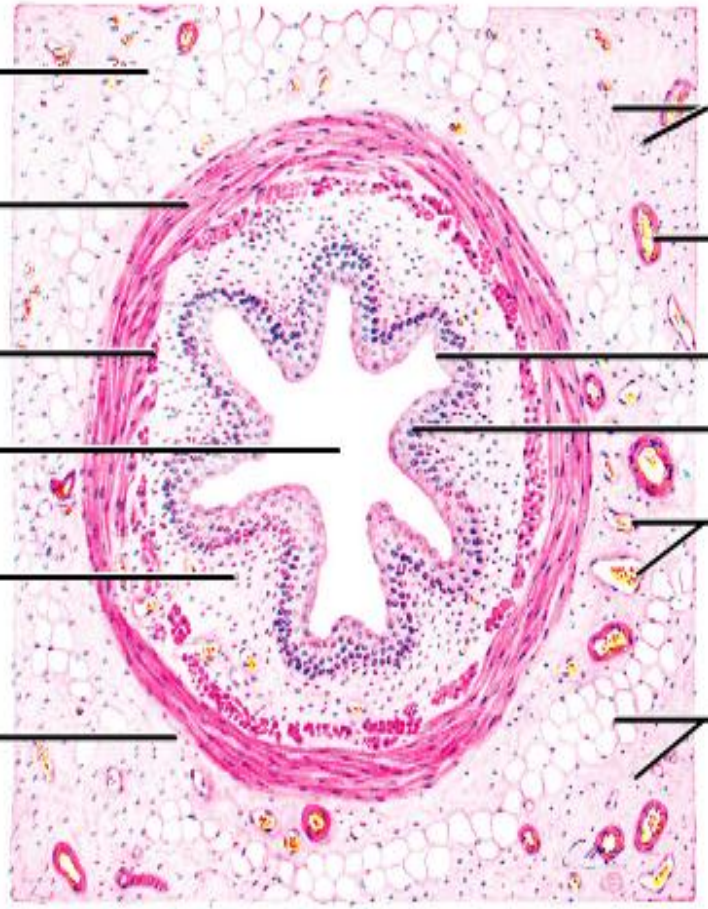
URETER

- 2 ureters
- Starts from renal pelvis.
- Ends in urinary bladder.

- 4 mm in diameter &
  30 cm long.

- Thin wall +
  star shaped lumen.




1 Adipose tissue
2 Circular smooth muscle layer
3 Longitudinal smooth muscle layer
4 Lumen
5 Lamina propria
6 Adventitia
7 Nerves
8 Artery
9 Transitional epithelium (superficial layer)
10 Transitional epithelium (basal layer)
11 Venules
12 Adipose tissue and fibroelastic connective tissue (subserous fascia)

Histological structure

1- Mucosa: longitudinal folds

a- Epithelium: transitional.

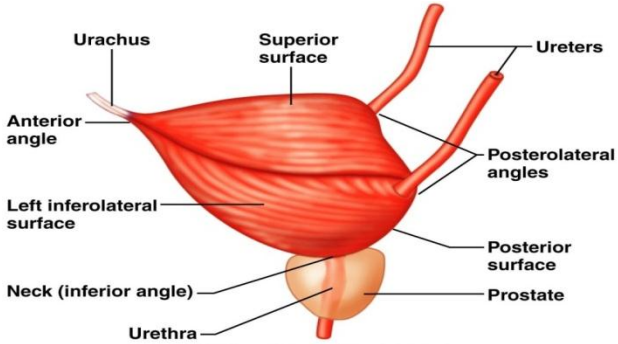
b- Lamina propria: dense CT, BV and lymphatic nodules**.**

2- Muscle layer: smooth muscles

a- In upper two thirds: 2 layers, inner longitudinal & outer circular.

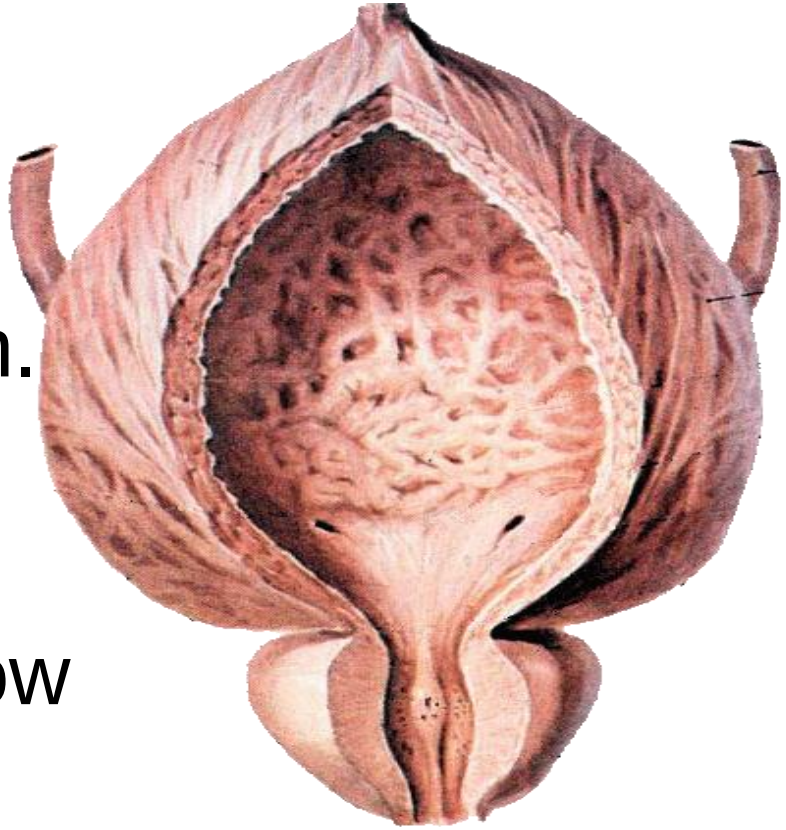
b- In lower third: 3 layers, inner & outer longitudinal & middle circular.

3- Adventitia: C.T.



URINARY BLADDER

- a temporary storage reservoir for urine.
- Thick wall with wide lumen.
- It is located in the pelvic cavity, posterior to the symphysis pubis, and below the **parietal peritoneum.**
- Empty (Folded).
- Full (Folds disappear).



Histological structure

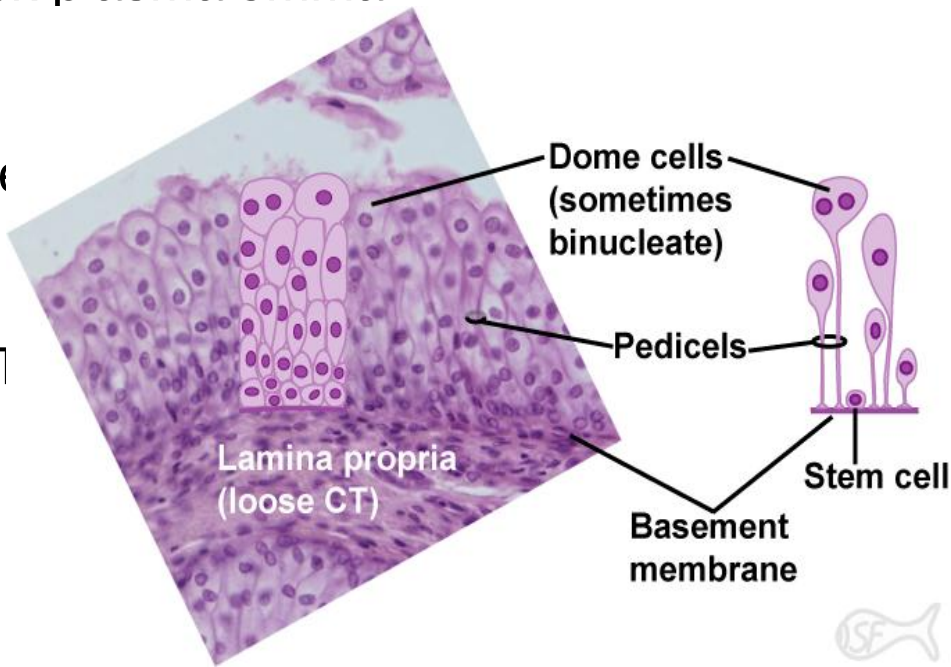
1-Mucosa:

A-Epithelium: transitional .

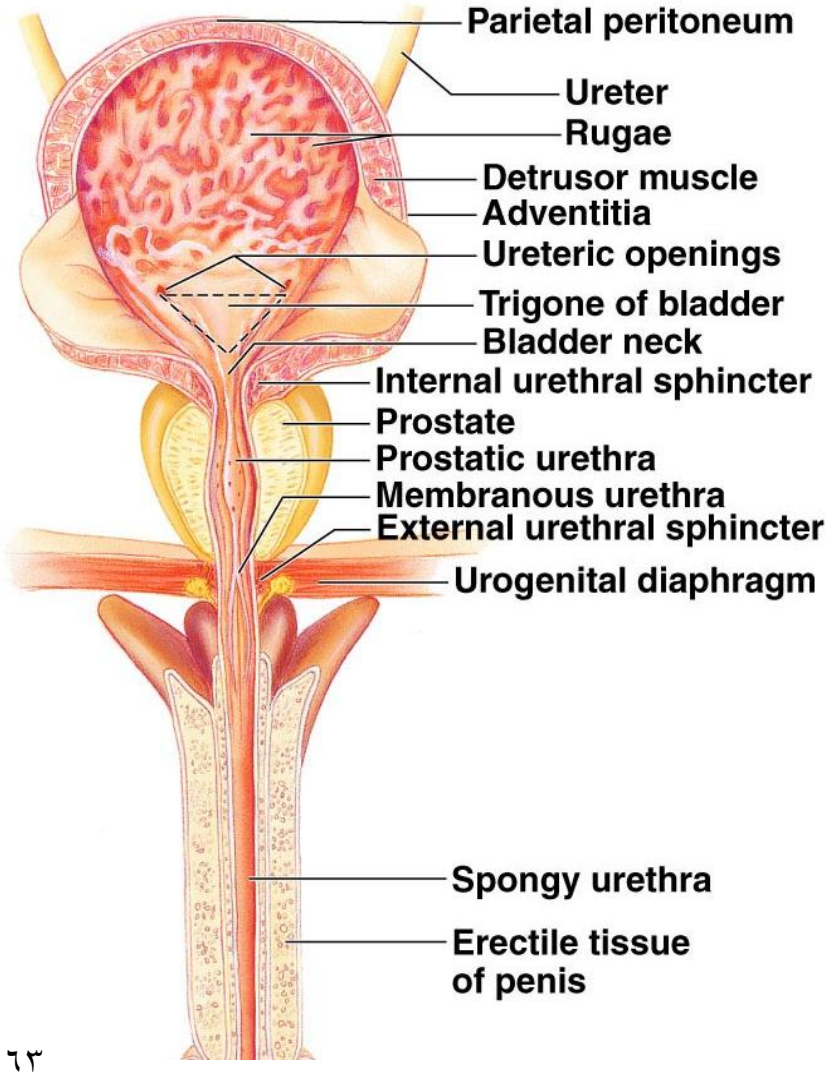
- Special stratified epithelium where numbers of layers change according to state of organ.
- Surface cells are large rounded (dome-shaped) with 1-2 nuclei.
- *In empty bladder* (epithelium has 6-8 layers).
- *In distended bladder* (epithelium has 2-3 layers).

- The surface epithelial layer has thick plasmalemma.
- Cells are attached together by interdigitation called plaques allowing cells to overlap each other when bladd is empty.

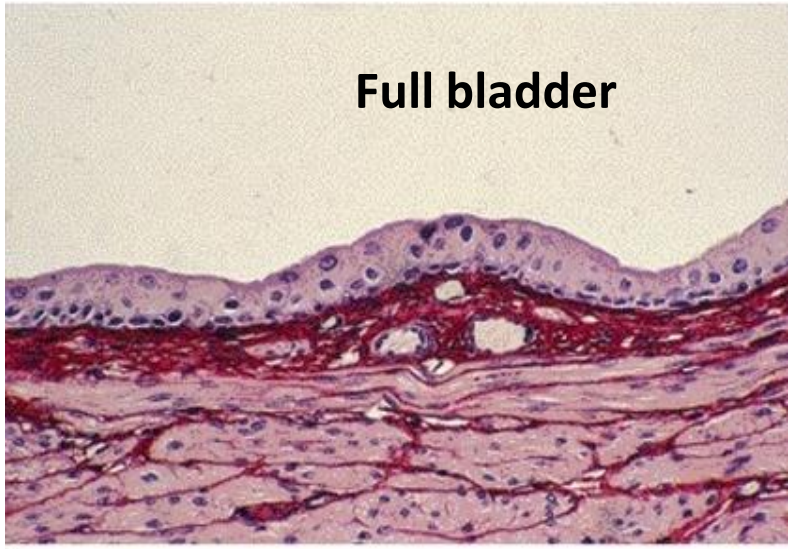
B-Lamina propria: loose to dense C.T



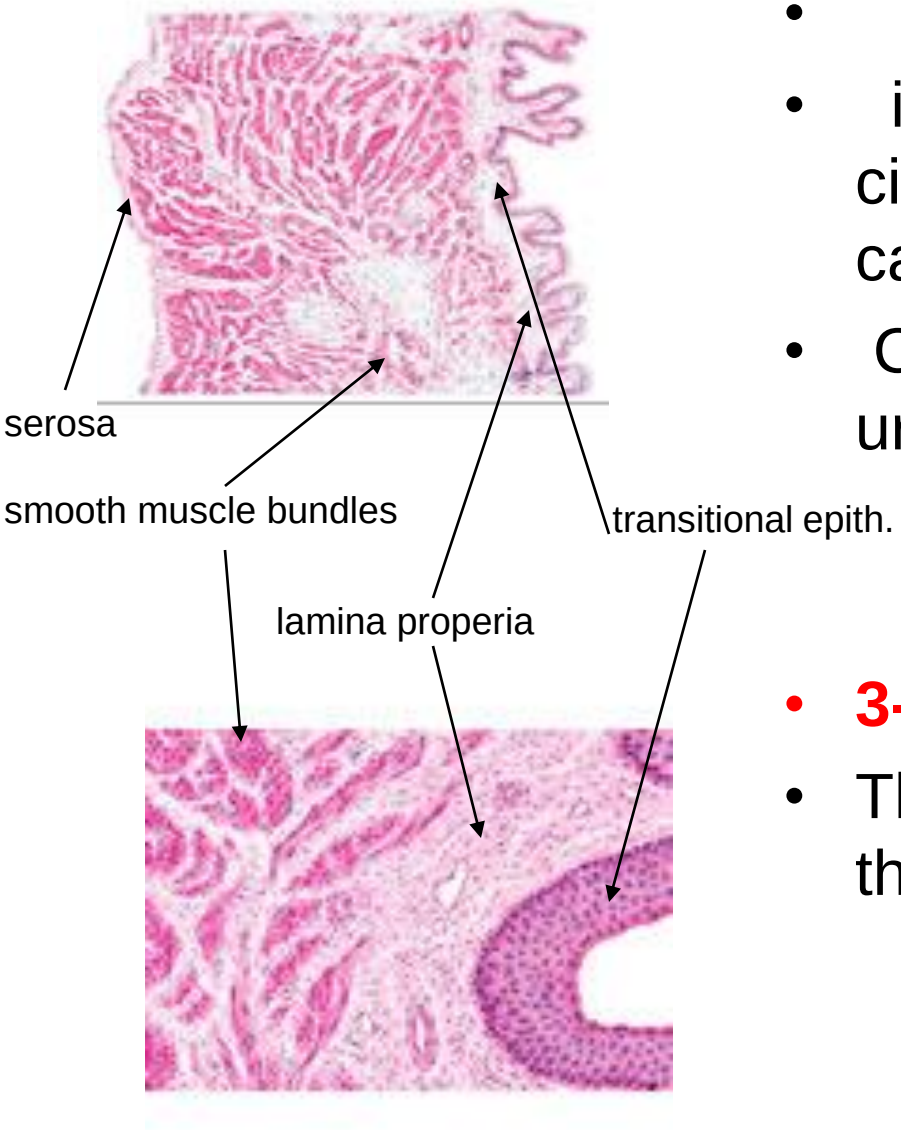
Empty (Folded).
Full (Folds disappear).



A



B



- **2-Muscular layer:**
- Thick smooth muscle fibers.
- inner & outer longitudinal. middle circular. collectively these are called the detrusor muscle.
- Contraction of this muscle expels urine from the bladder.

- **3-Adventitia:** C.T.
- The superior & posterior surface of the bladder covered by peritoneum

URETHRA

- Urethra of female differs from male in structure and length.

Urethra of female

- 5 cm in length.
- Extends from internal orifice at urinary bladder
- To external orifice above & anterior to vagina.

Histological structure

1-Mucosa :

a) Epithelium:

- Transitional at internal orifice.
- Stratified squamous at external orifice.
- Stratified columnar inbetween.

a) Lamina propria: fibroelastic along its length .

2-Muscle layer: smooth muscle

- Inner longitudinal.
- Outer circular.
- As urethra pierces uro-genital diaphragm, skeletal muscle forms sphincter for voluntary control of micturition.

Urethra of male

- 20 cm tube
- Conducts urine from urinary bladder & seminal fluid from male genitalia to outside body.

- Many glands open in course of male urethra. These are prostate, bulbo-urethral and littre glands.

- Three parts: prostatic, membranous & penile.

1- Prostatic urethra

- Present within prostate.
- Lined by transitional epithelium.
- An elevation (verumontanum) projects into its interior.
- Ejaculatory ducts open at sides of this elevation.

2- Membranous urethra

- 1 cm
- Lined by stratified and pseudostratified columnar epithelium.
- Surrounded by the voluntary external sphincter.

3- Penile urethra

Two portions:

a) Bulbous:

- Passes through corpus spongiosum.
- Lined by pseudostratified or stratified columnar epithelium.

b) Pendulous:

- Passes through glans penis.
- Lined by stratified squamous epithelium.

٧١