RENAL ANATOMY HISTOLOGY

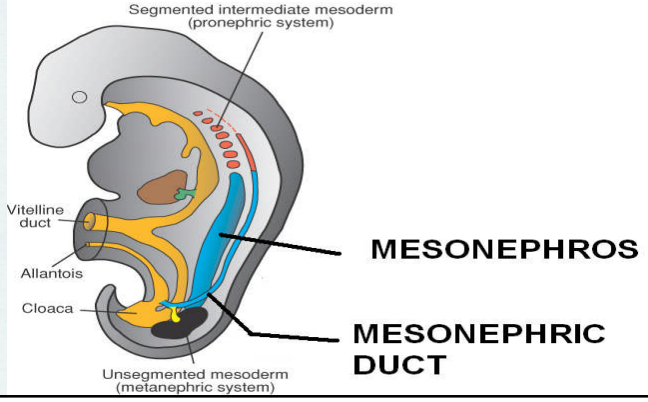
D.Hammoudi.MD

Renal system is formed at 12 weeks [actually all organ are formed by 12 weeks]

Table 5.6. Development of Genital and Urinary Tracts by Embryologic Age

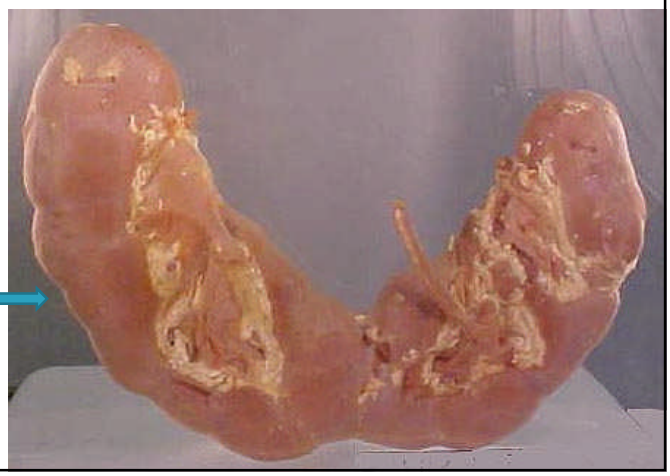
Weeks of Gestation	*Genital Development*	*Urinary Development*
4–6	Urorectal septum	Pronephros
	Formation of cloacal folds, genital tubercle	Mesonephros/mesonephric duct
		Ureteric buds, metanephros
	Genital ridges	Exstrophy of mesonephric ducts and ureters into bladder wall
6–7	End of indifferent phase of genital development	Major, minor calyces form
	Development of primitive sex cords	Kidneys begin to ascend
	Formation of paramesonephric ducts	
	Labioscrotal swellings	
8–11	Distal paramesonephric ducts begin to fuse	Kidney becomes functional
	Formation of sinuvaginal bulbs	
12	Development of clitoris and vaginal vestibule	
20	Canalization of vaginal plate	
32		Renal collecting duct system complete

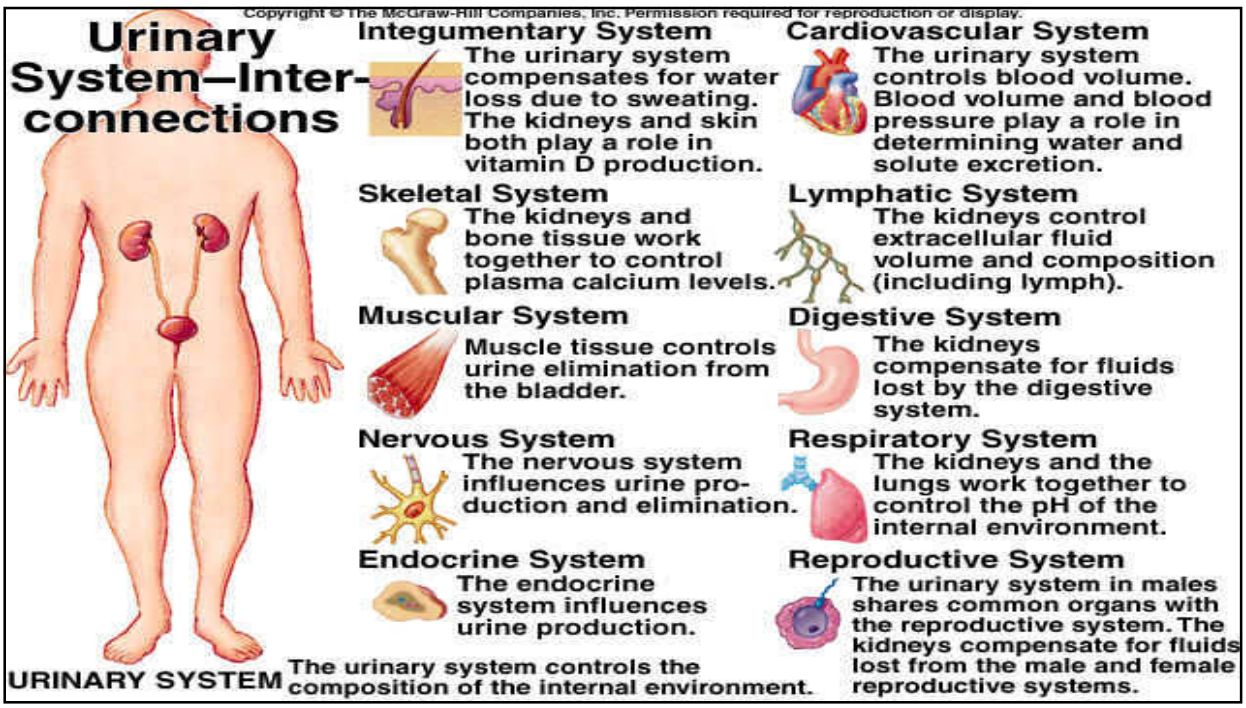
•The human kidney is a product of the **metanephric** system.
•Recall, pronephros, mesonephros, metanephros, woolffian, muellerian
•Metanephrose =➔kidney
•Uteric bud =➔collecting system
•Ureteric bud=➔must make contact with the metanephros or kidney will not develop



Congenital Malformations

- Renal agenesis➔oligohydramnios [in the amniotic sac of the mother]
  - Unilateral
  - Bilateral
- Renal hypoplasia
- Congenital cystic kidneys
  - Types 1 -5
- Horseshoe (fused) kidneys
- Wilms tumor



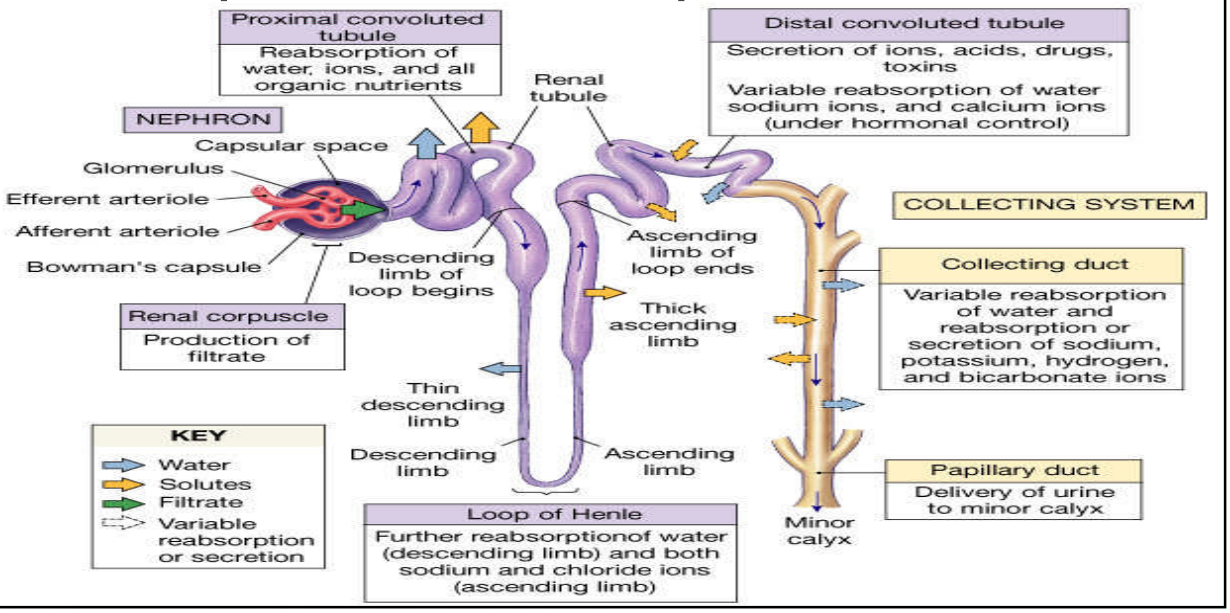


4 Functions of the Urinary System

1. Excretion:
   - removal of organic wastes from body fluids
2. Elimination:
   - discharge of waste products
3. Homeostatic regulation:
   - of blood plasma volume and solute concentration
4. **Endocrine - produces renin, erythropoietin and prostaglandins**

- The kidney accomplishes these homeostatic functions both independently and in concert with other organs, particularly those of the endocrine system.
- Various endocrine hormones coordinate these endocrine functions; these include
  - renin,
  - angiotensin II,
  - aldosterone,
  - antidiuretic hormone,
  - atrial natriuretic peptide, …..

A Representative Nephron



Kidneys

- Organs that excrete urine

Urinary Tract

- Organs that eliminate urine:
  - **ureters (paired tubes)**
  - **urinary bladder (muscular sac)**
  - **urethra (exit tube)**

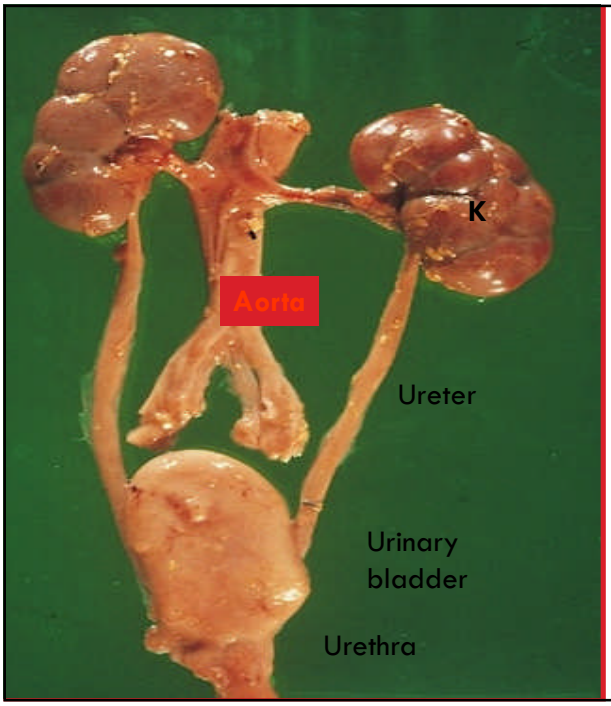
Urination or Micturition

- Process of eliminating urine
- Contraction of muscular urinary bladder forces urine through urethra, and out of body

5 Homeostatic Functions of Urinary System

1. **Regulate blood volume and blood pressure:**
   1. by adjusting volume of water lost in urine
   2. releasing erythropoietin and renin
2. **Regulate plasma ion concentrations:**
   - sodium, potassium, and chloride ions (by controlling quantities lost in urine)
   - calcium ion levels (through synthesis of calcitriol)
3. **Help stabilize blood pH:**
   - by controlling loss of hydrogen ions and bicarbonate ions in urine

4. Conserve valuable nutrients:
   - by preventing excretion while excreting organic waste products
5. Assist liver to detoxify poisons



Components of the Urinary System

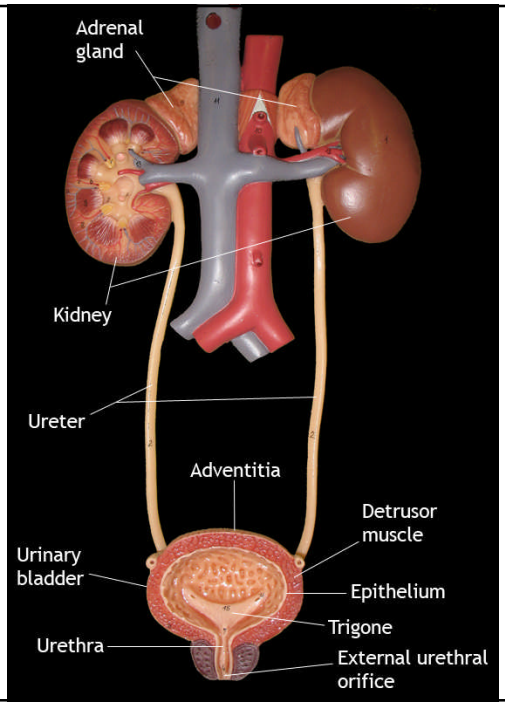
Kidneys **Ureters**

Urinary Bladder

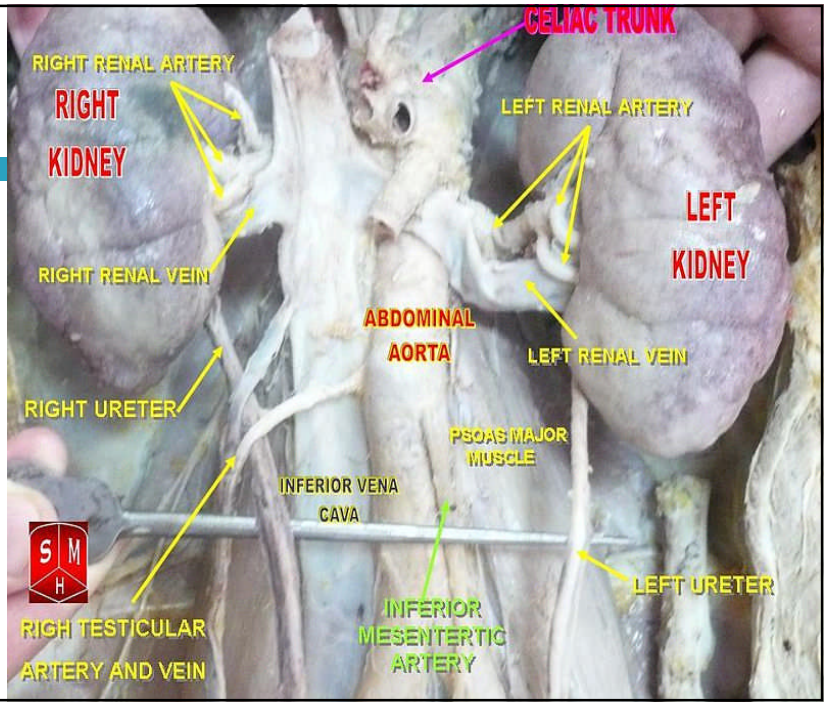
Urethra

Kidney Anatomy External

The **renal artery, renal vein** and **ureter** enter the kidney via the **hilus.**
The kidney and it's vessels are embedded in a mass of fatty tissue called the **perirenal fat** which extends into a central cavity, the **renal sinus.**



THE KIDNEYS



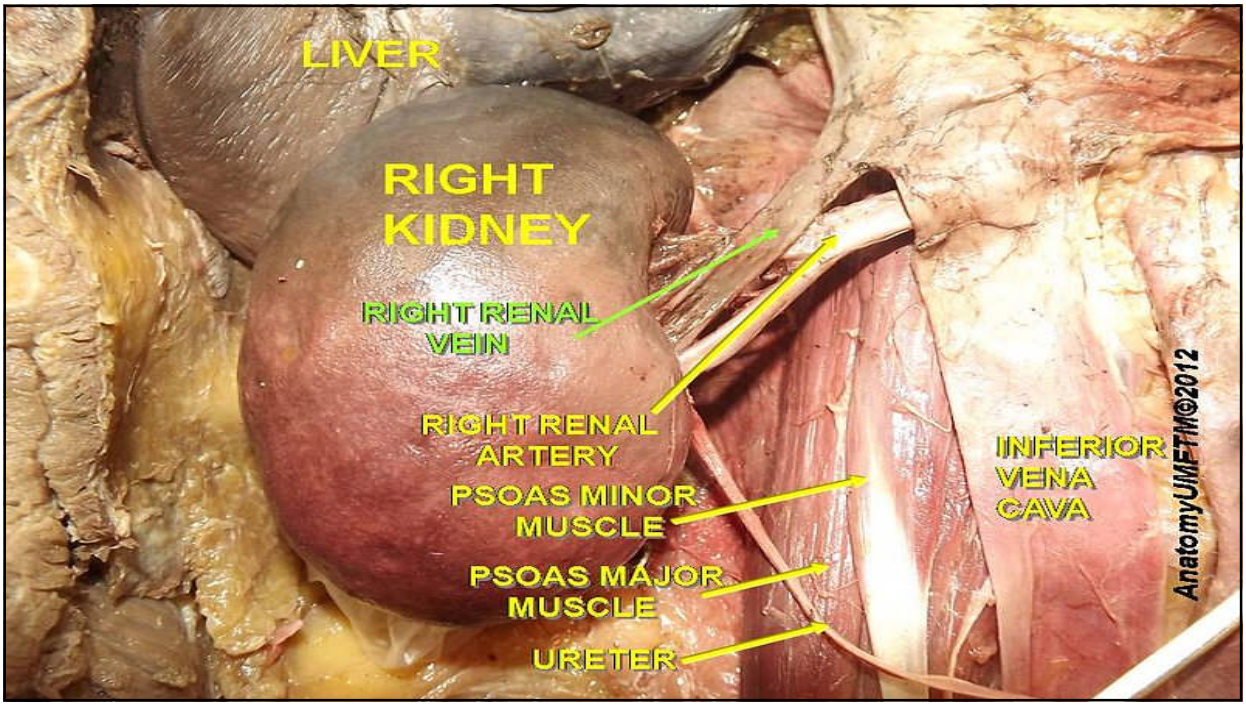
The kidneys are a pair of fist sized organs located in the small of the back behind the peritoneum.

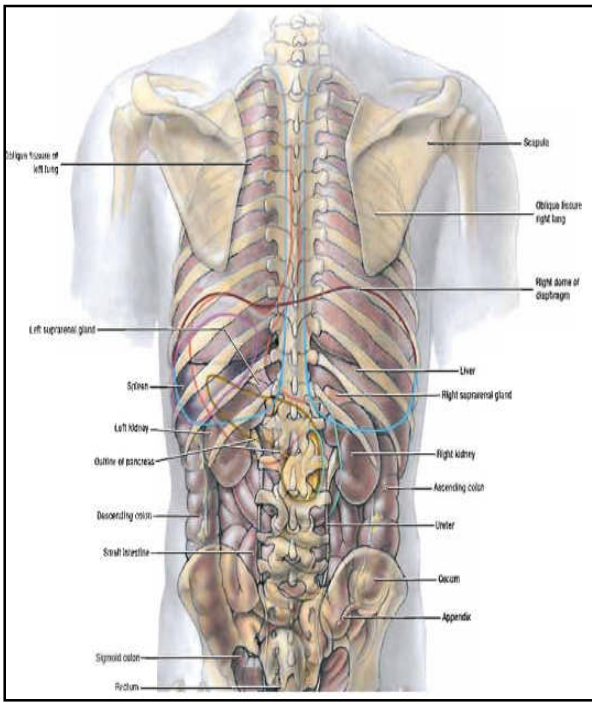
Each kidney weighs about 115g-170g and have the following approximate dimensions: 11 cm in length, 6 cm in width, and 3 cm thick.

Each kidney is perfused at a rate of 600 ml/min by way of the renal artery.

Each renal artery branches into interlobar arteries, arcuate arteries, interlobular arteries, and then into 1.2 million afferent arterioles that each feed each nephron, the functional unit of the kidney.

After blood has been filtered through the glomerulus and transported through the nephron's vasculature it passes through the interlobular, arcuate, and interlobar that merge into the renal vein and back in to systemic circulation.





Move as much as 1 inch during respiration

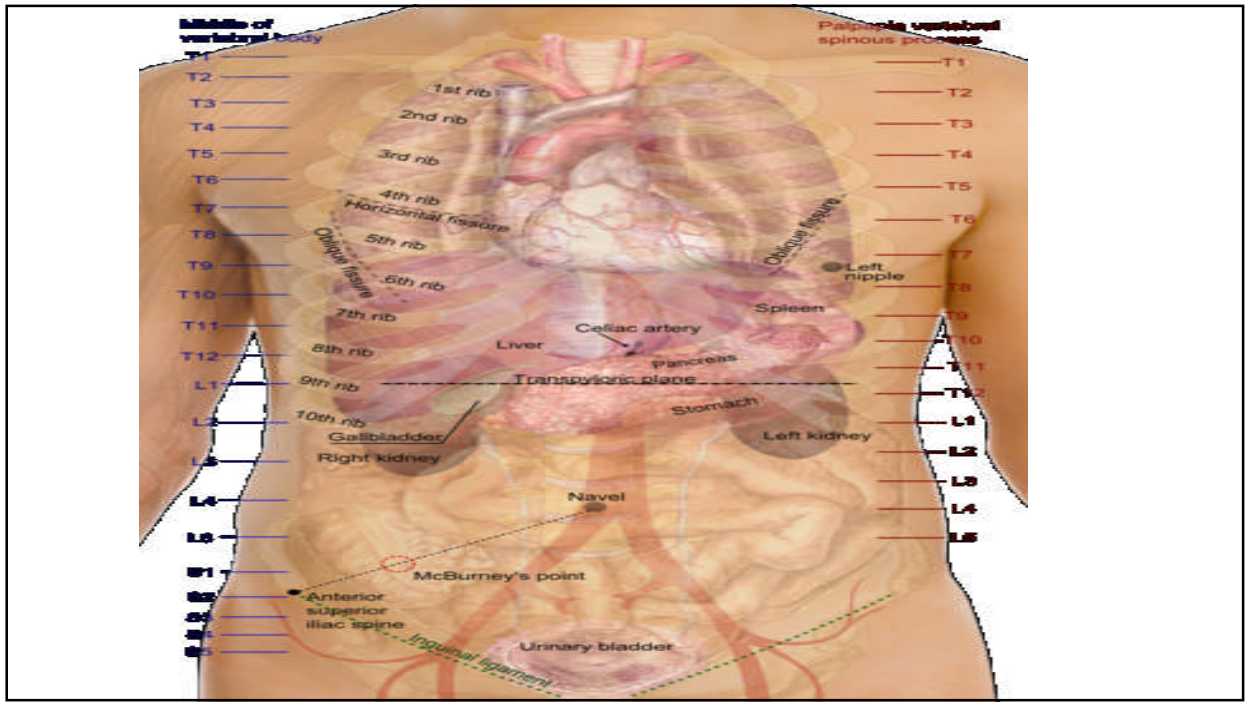
- The kidneys lie in a retroperitoneal position on the posterior abdominal wall in the superior lumbar region T11-T2

- The right kidney is lower than the left

- The lateral surface is convex; the medial surface is concave –

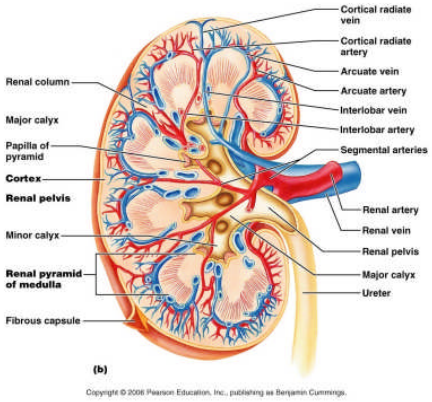
Hilum:

- Renal vein, 2 branches of the renal artery, the ureter, another branch of renal artery (VAUA)
- Lymph vessels and sympathetic fibres also pass through hilum



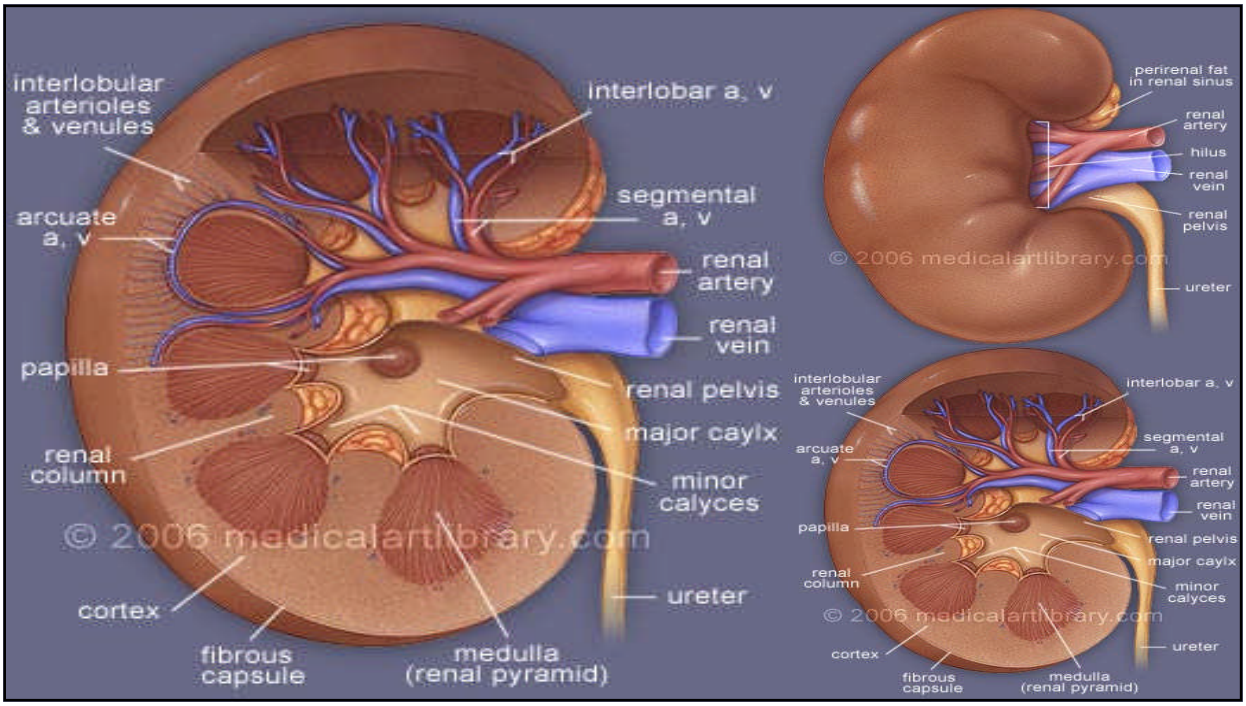
The kidneys receive blood from the renal arteries, left and right, which branch directly from the abdominal aorta.

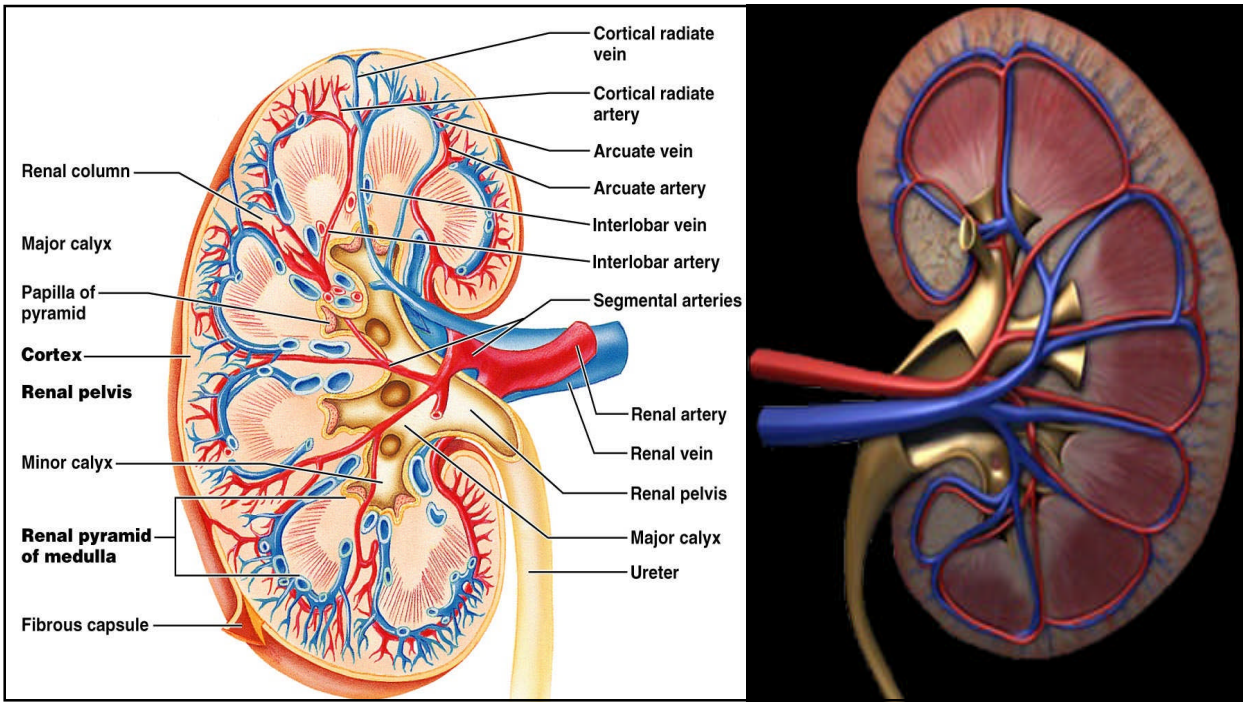
Despite their relatively small size, the kidneys receive approximately 20% of the cardiac output.

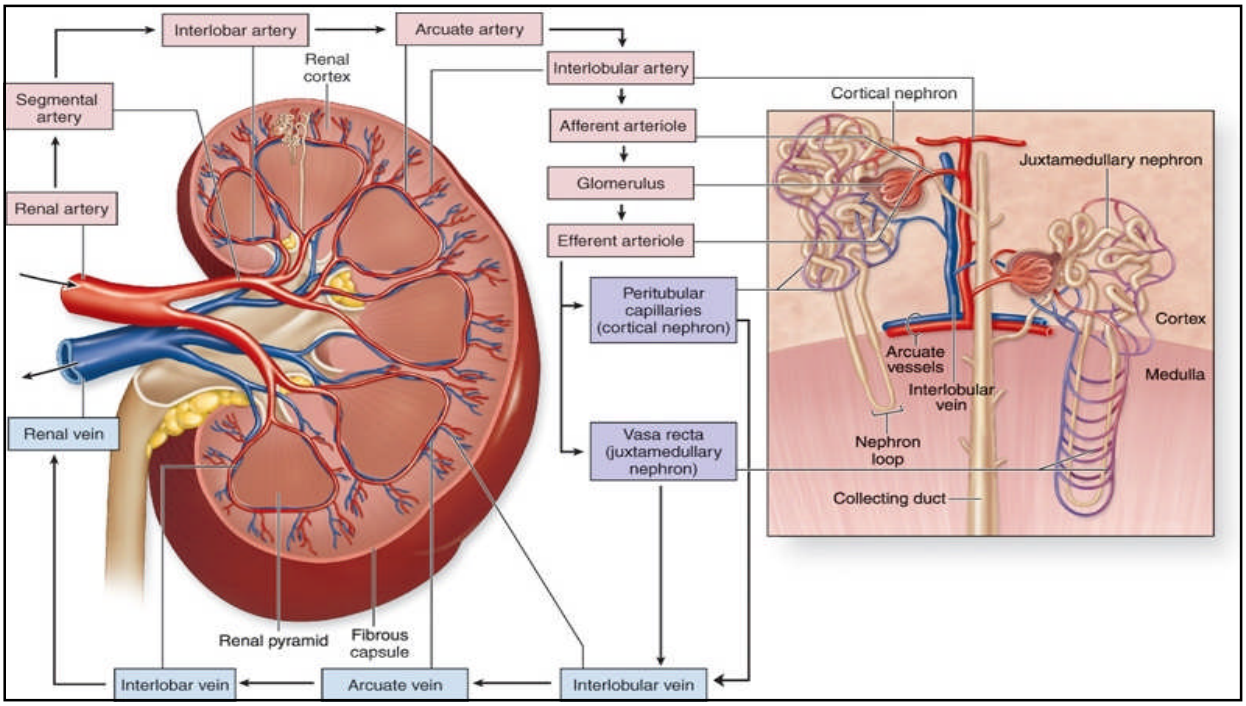


Aorta → Renal artery → Segmental artery → Interlobar artery → Arcuate artery → Cortical radiate artery → Afferent arteriole → Glomerulus (capillaries) → Efferent arteriole → Peritubular capillaries and vasa recta → Cortical radiate vein → Arcuate vein → Interlobar vein → Renal vein → Inferior vena cava

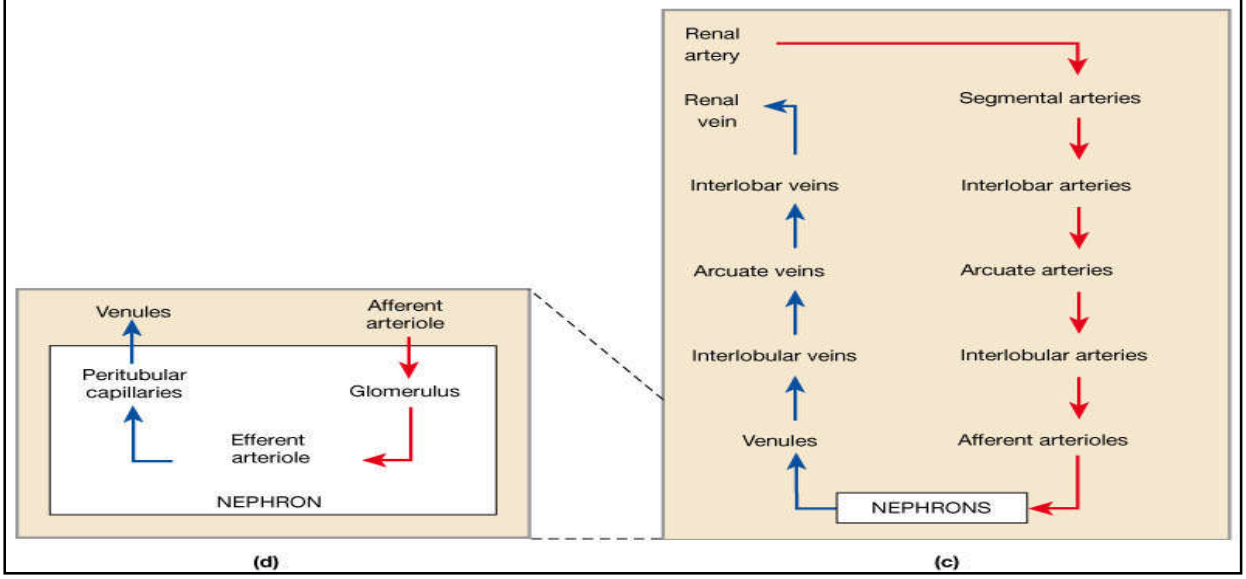
(c)

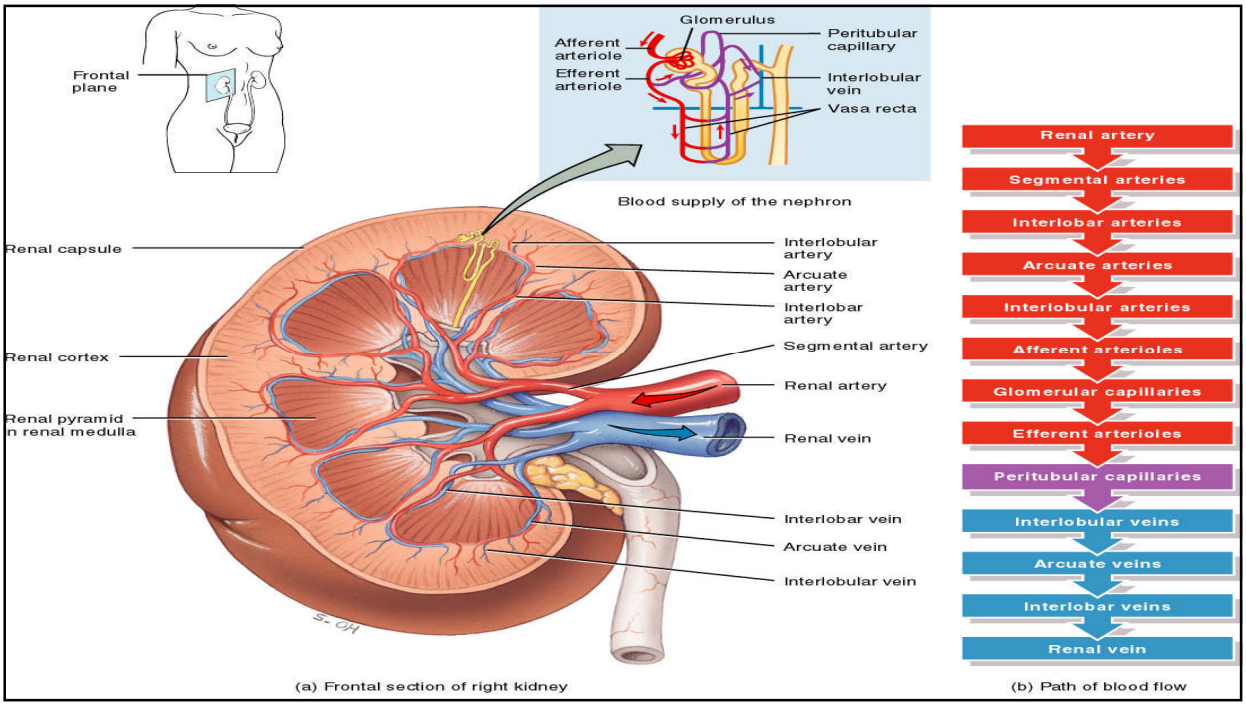

interlobular arterioles & venules
interlobar a, v
arcuate a, v
segmental a, v
renal artery
renal vein
papilla
renal pelvis
major caylx
renal column
minor calyces
ureter
cortex
fibrous capsule
medulla (renal pyramid)
© 2006 medicalartlibrary.com
perirenal fat in renal sinus
renal artery
hilus
renal vein
renal pelvis
ureter


Cortical radiate vein
Cortical radiate artery
Arcuate vein
Arcuate artery
Interlobar vein
Interlobar artery
Segmental arteries
Renal column
Major calyx
Papilla of pyramid
Cortex
Renal pelvis
Minor calyx
Renal pyramid of medulla
Fibrous capsule
Renal artery
Renal vein
Renal pelvis
Major calyx
Ureter

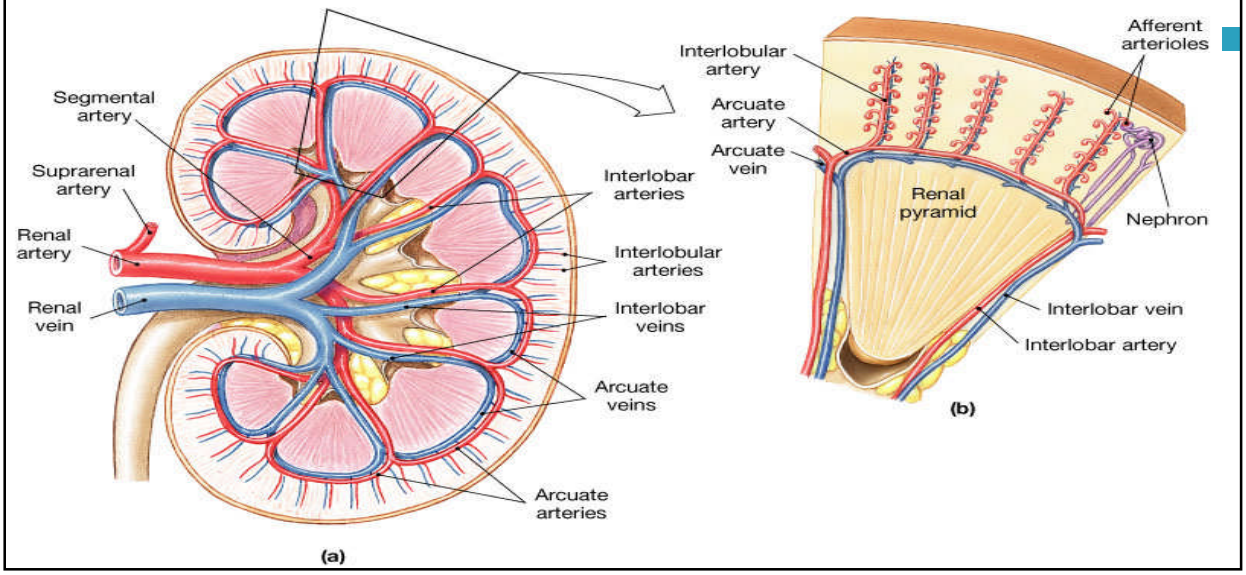


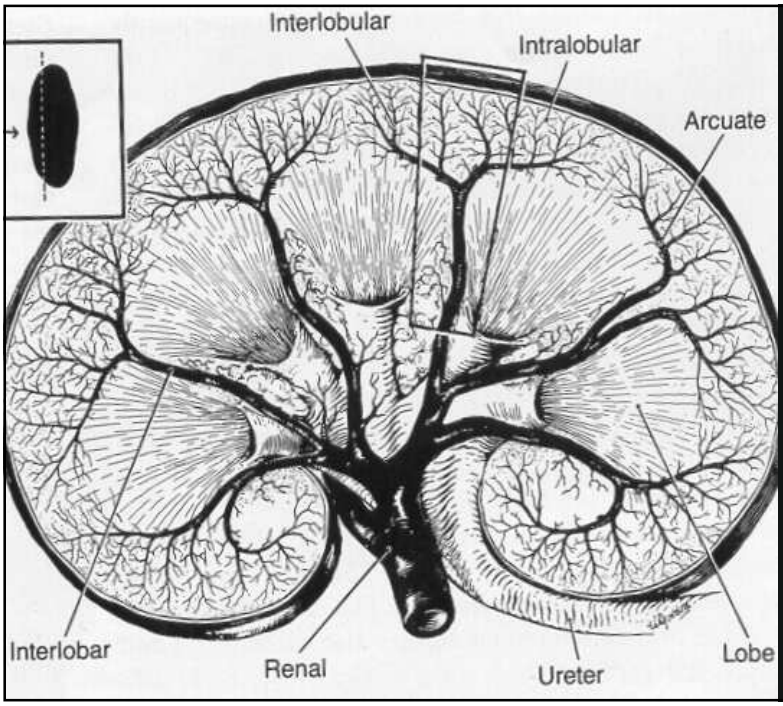
The Blood Supply to the Kidneys

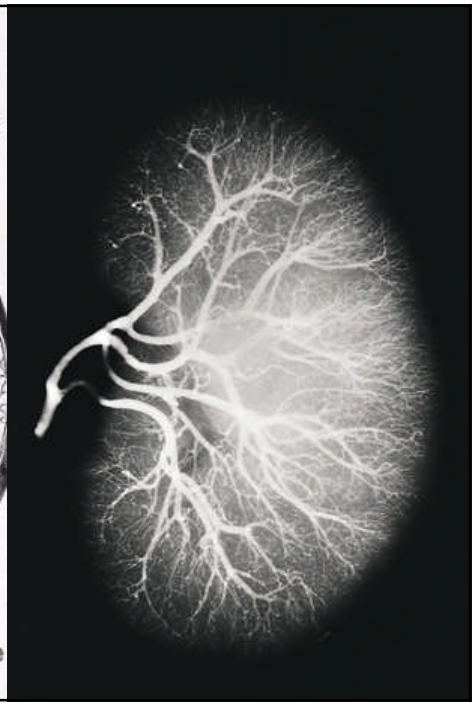


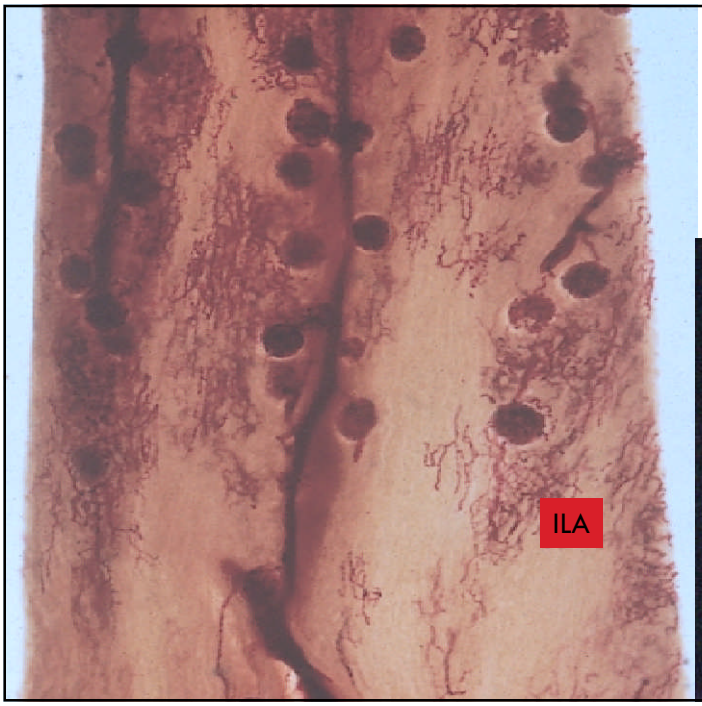


The Blood Supply to the Kidneys







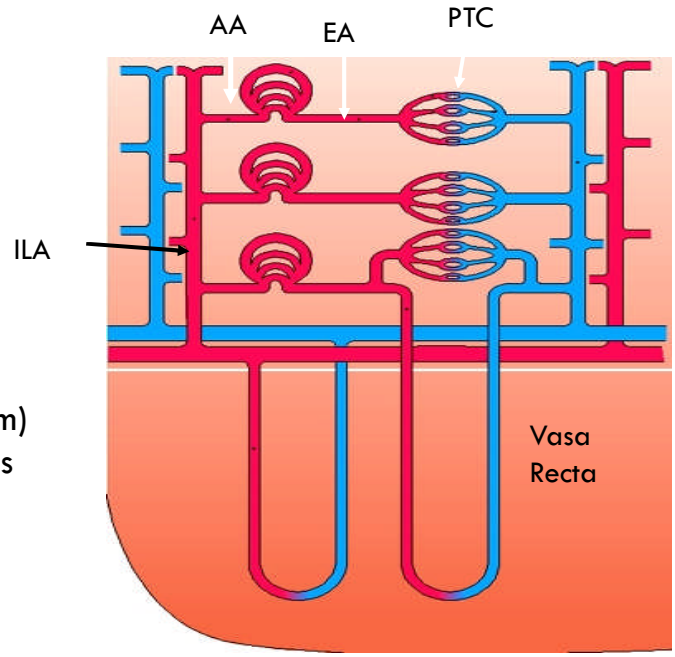


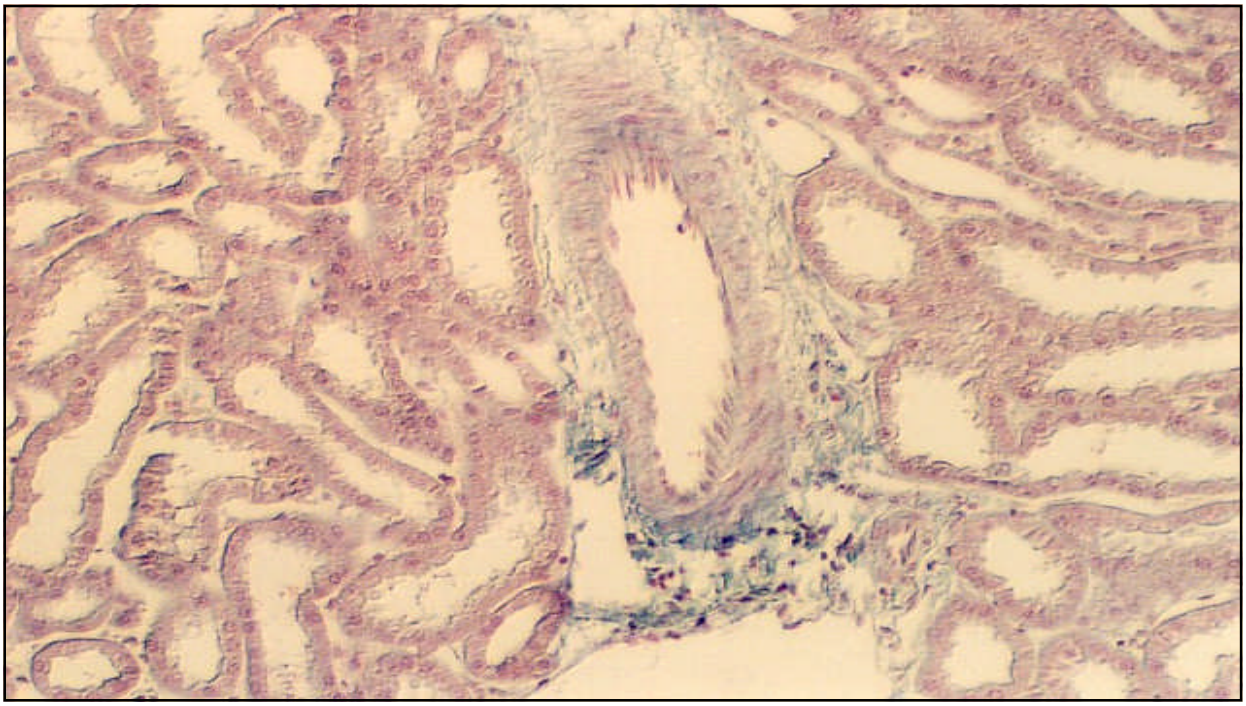
ILA - Interlobular Artery

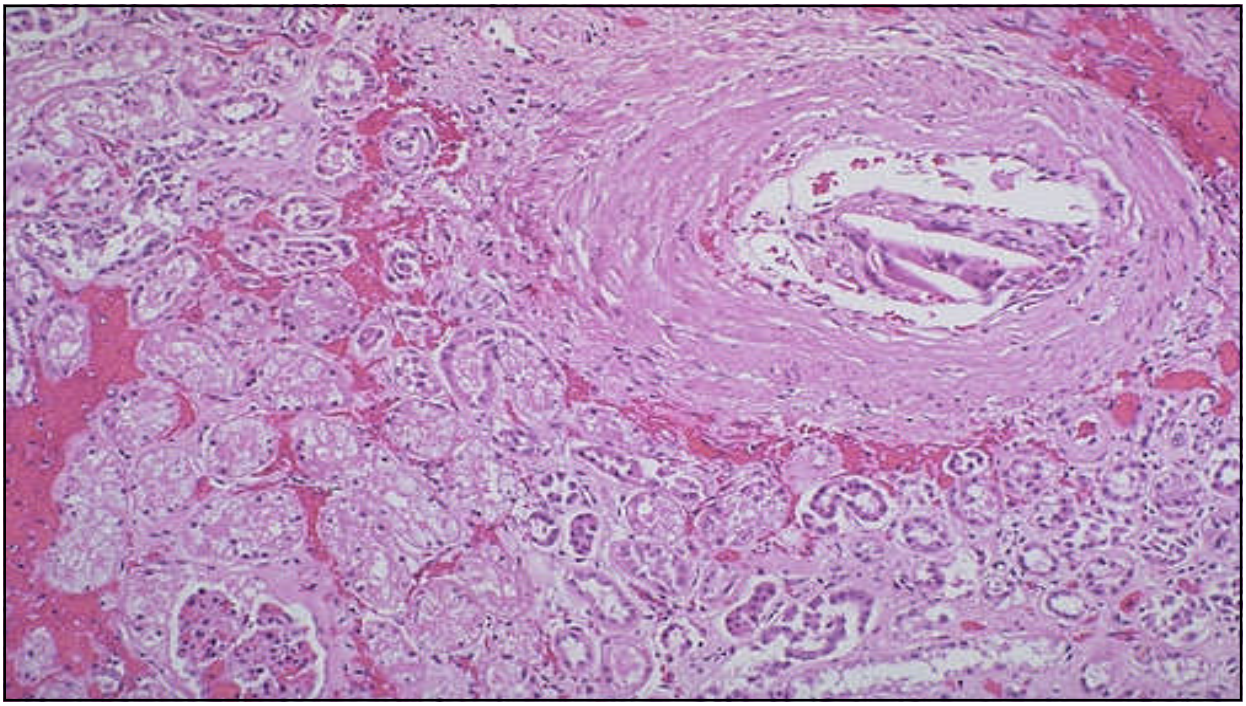
Branches supply the glomerulus as Afferent arterioles

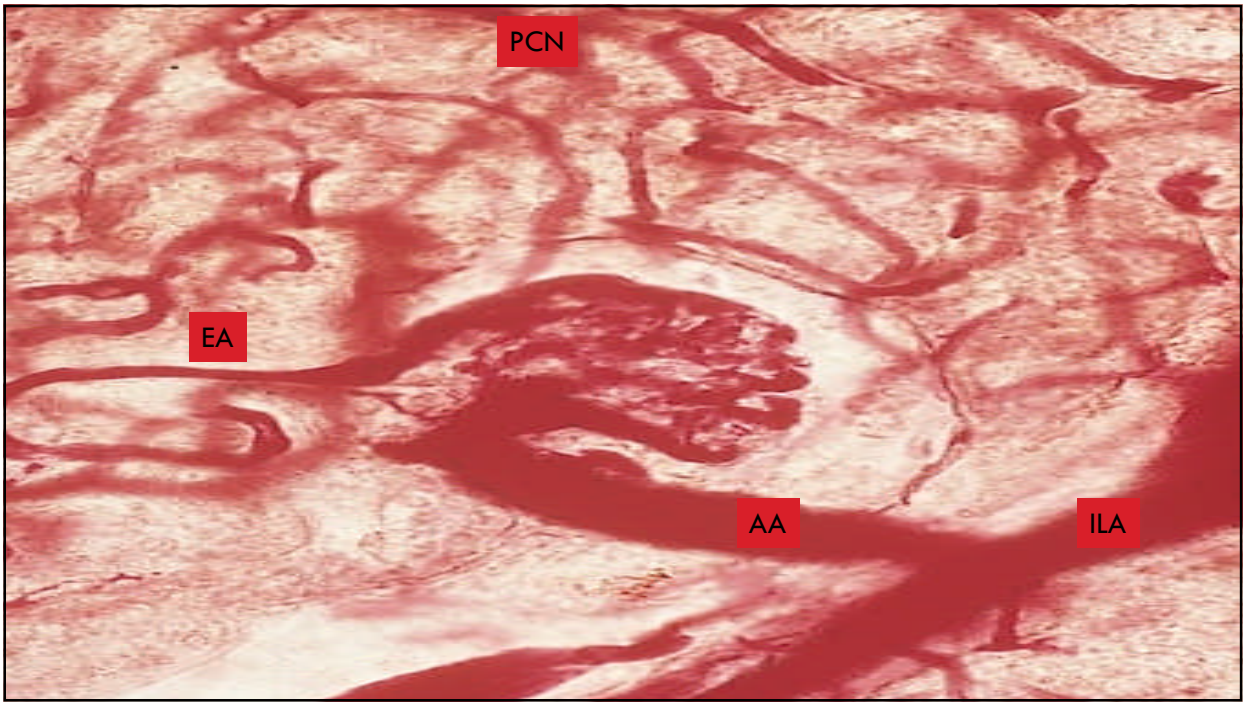
KIDNEY: BLOOD SUPPLY

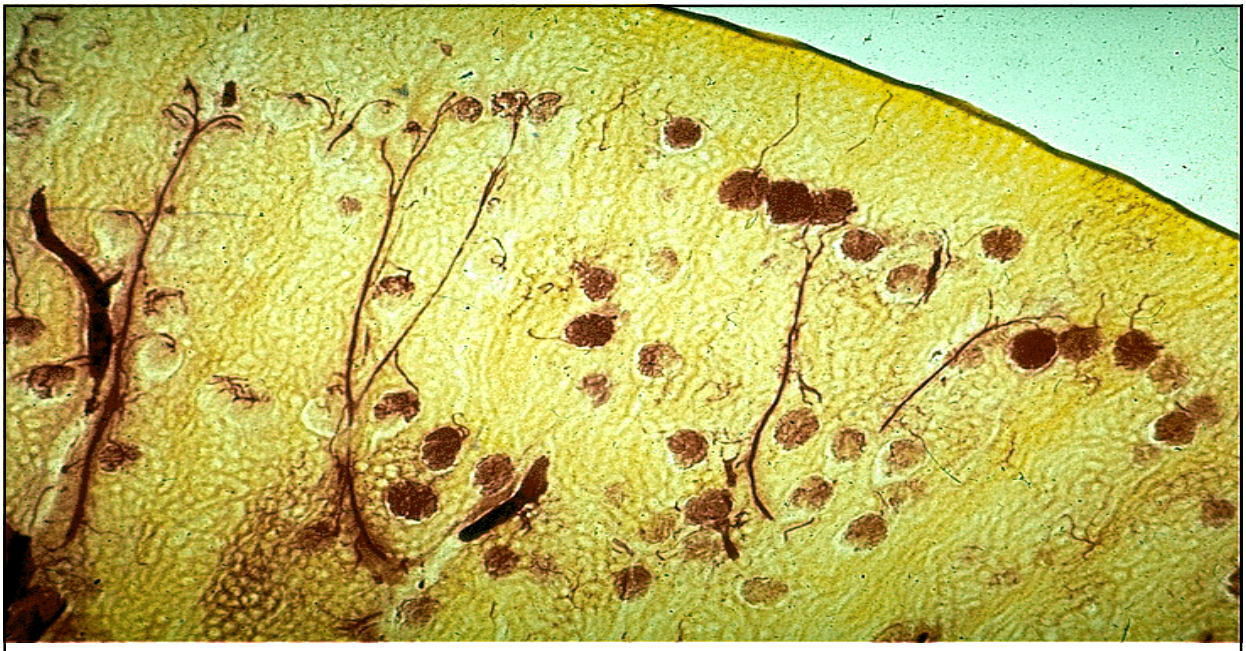
- Efferent arterioles drain the glomeruli & form capillary networks
- Drain cortical nephrons and form peritubular capillary network (take up substances resorbed by tubular epithelium)
- Drain juxtamedullary nephrons and form vasa recta (countercurrent exchange system)





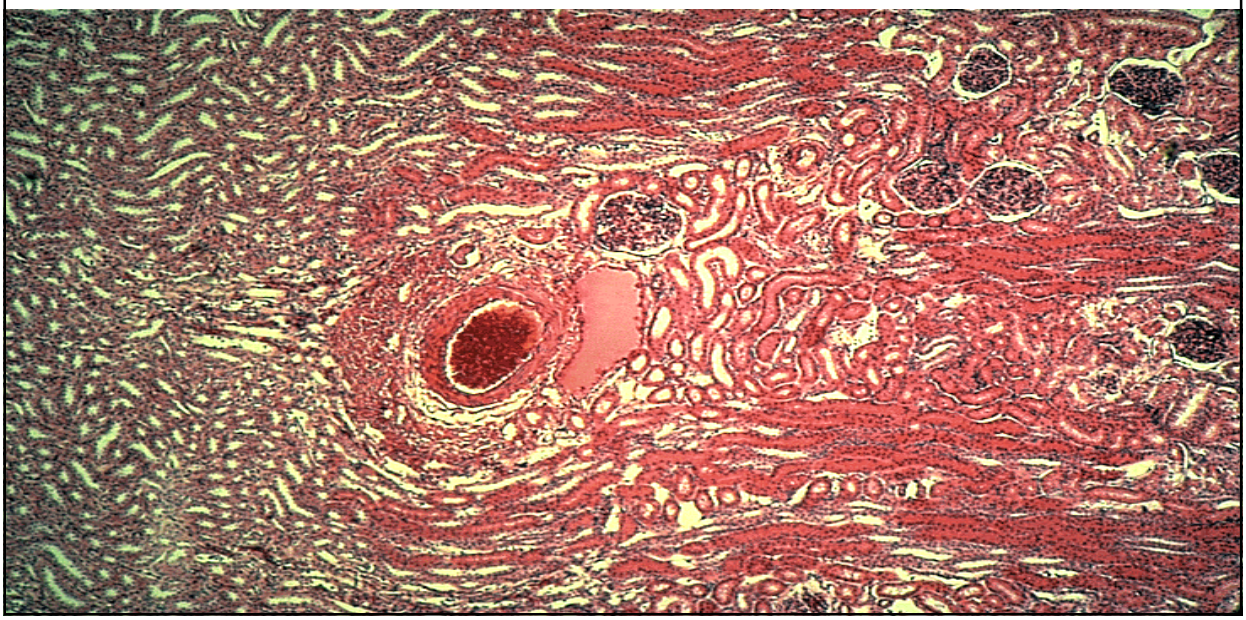



PCN
EA
AA
ILA



Cortex – Injected Vasculature

Arcuate Artery and Vein – Cross Section



•Innervation

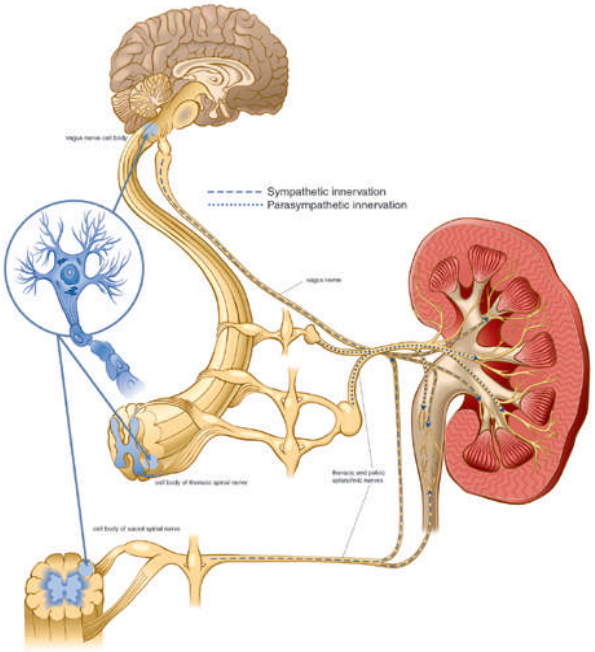
•The kidney and nervous system communicate via the renal plexus, whose fibers course along the renal arteries to reach the kidney.

• Input from the sympathetic nervous system triggers vasoconstriction in the kidney, thereby reducing renal blood flow.

• The kidney is not thought to receive input from the parasympathetic nervous system.

•Sensory input from the kidney travels to the T10-11 levels of the spinal cord and is sensed in the corresponding dermatome.

• Thus, pain in the flank region may be referred from the kidney.



Location and Relations – Right Kidney

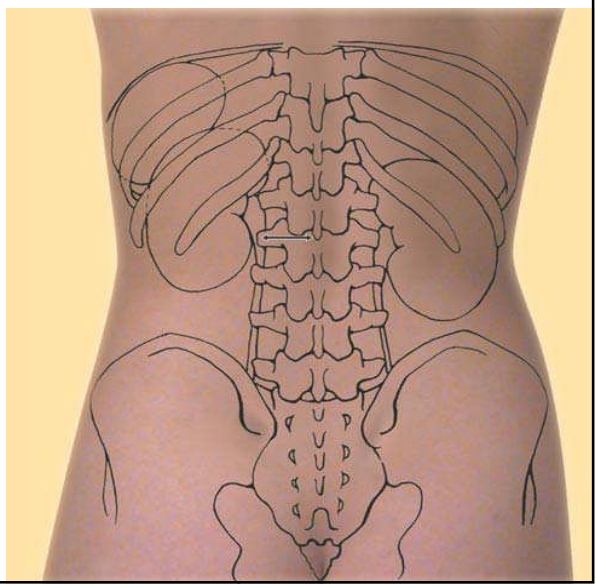
- • **Anteriorly**

– Adrenal gland, the liver, 2nd duodenum, right colic flexure

- • **Posteriorly**

– Diaphragm (and **costodiaphragmatic recess**), 12th rib, psoas MUSCLE,

- – subcostal (T12) iliohypogastric and ilioinguinal nerves (L1) run downwards and laterally



Location and Relations – Left Kidney

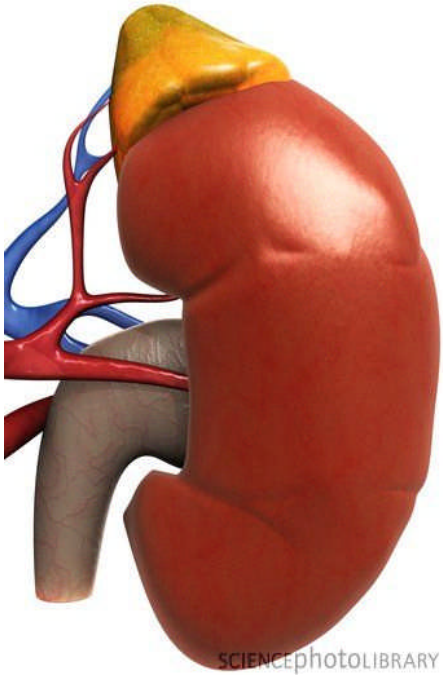
• **Anteriorly**

– Adrenal, spleen, stomach, pancreas, left colic flexure

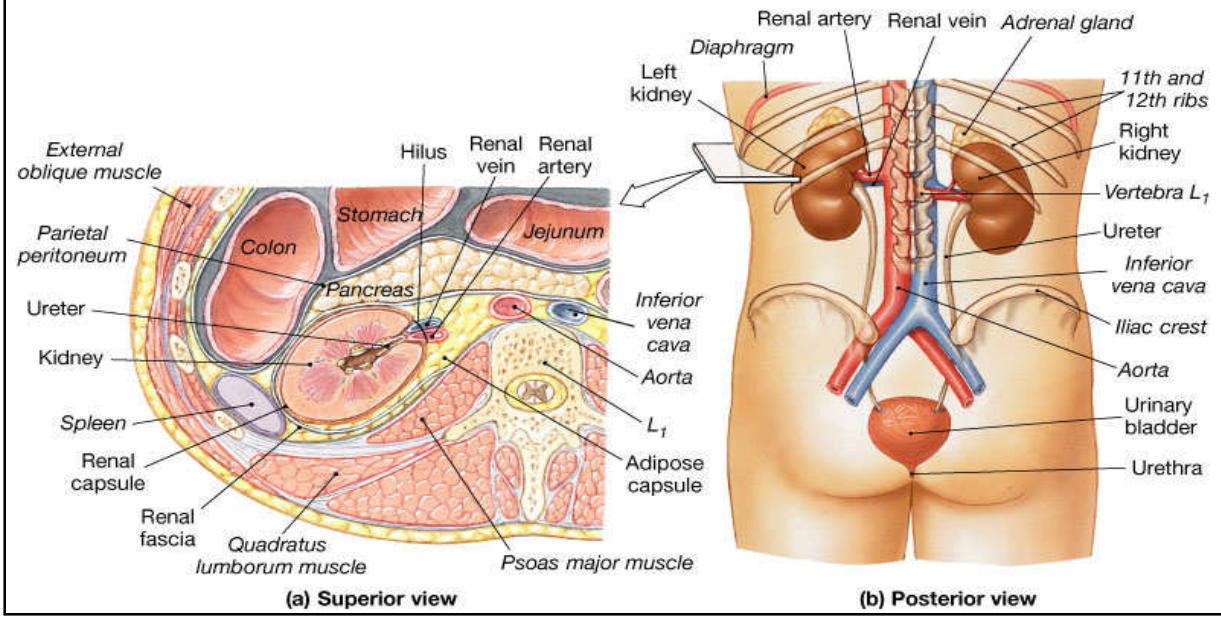
• **Posteriorly**

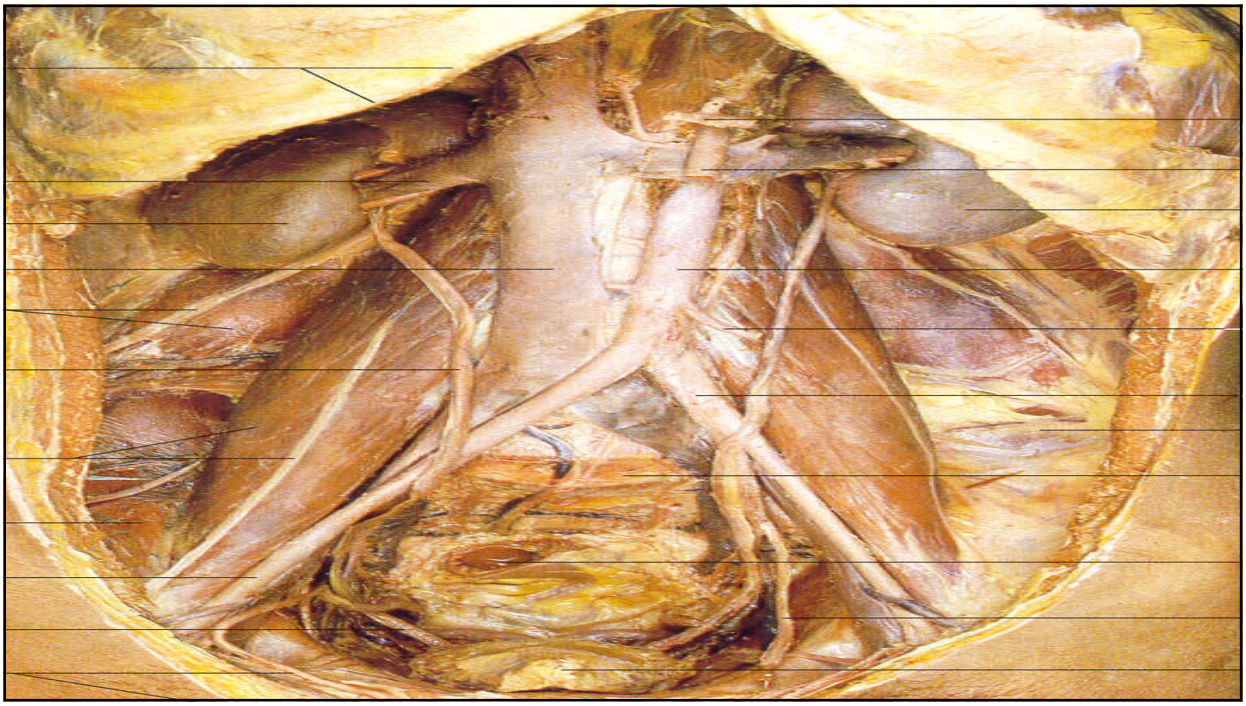
– **Diaphragm (and costodiaphragmatic recess),** 11th and 12th rib, psoas,

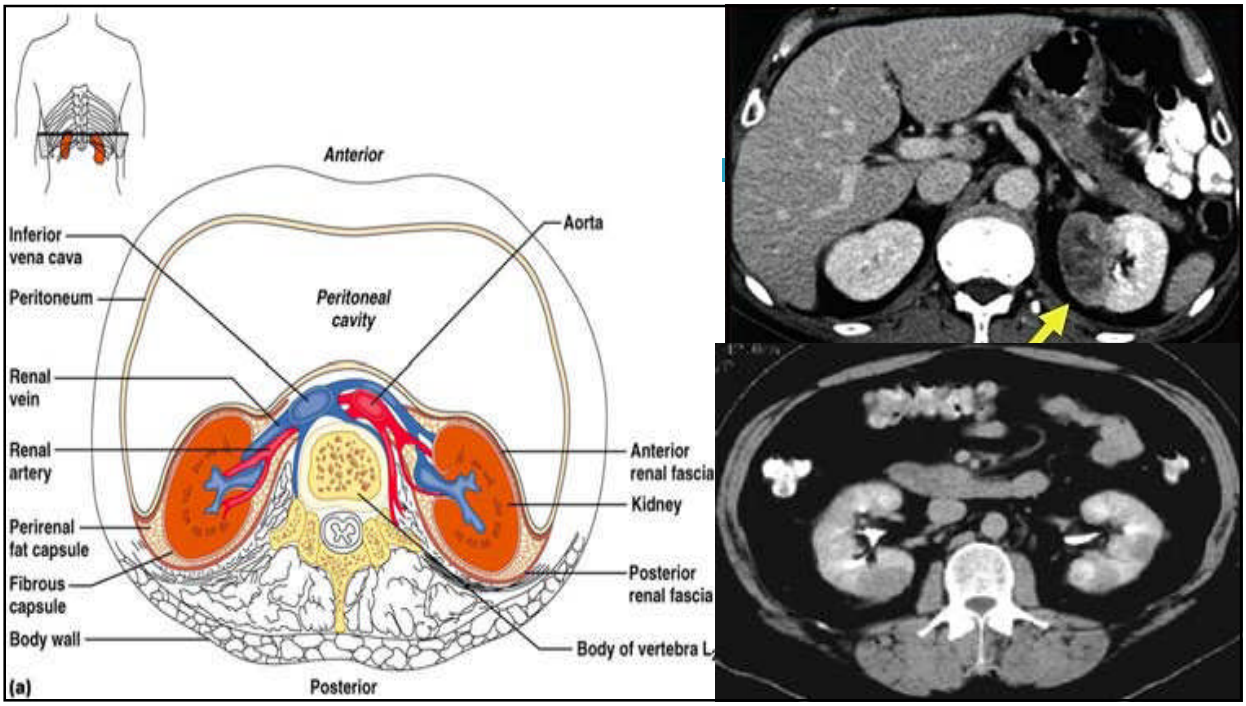
– subcostal (T12) iliohypogastric and ilioinguinal nerves (L1) run downwards and laterally

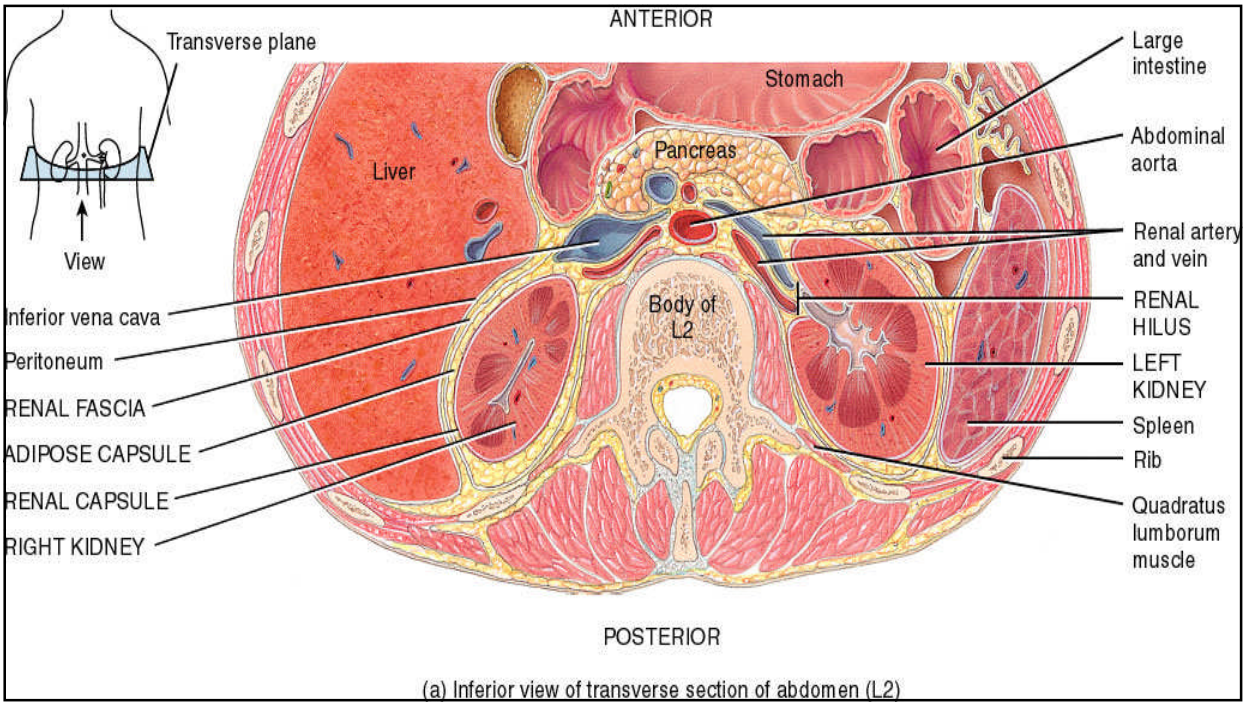


The Position of the Kidneys

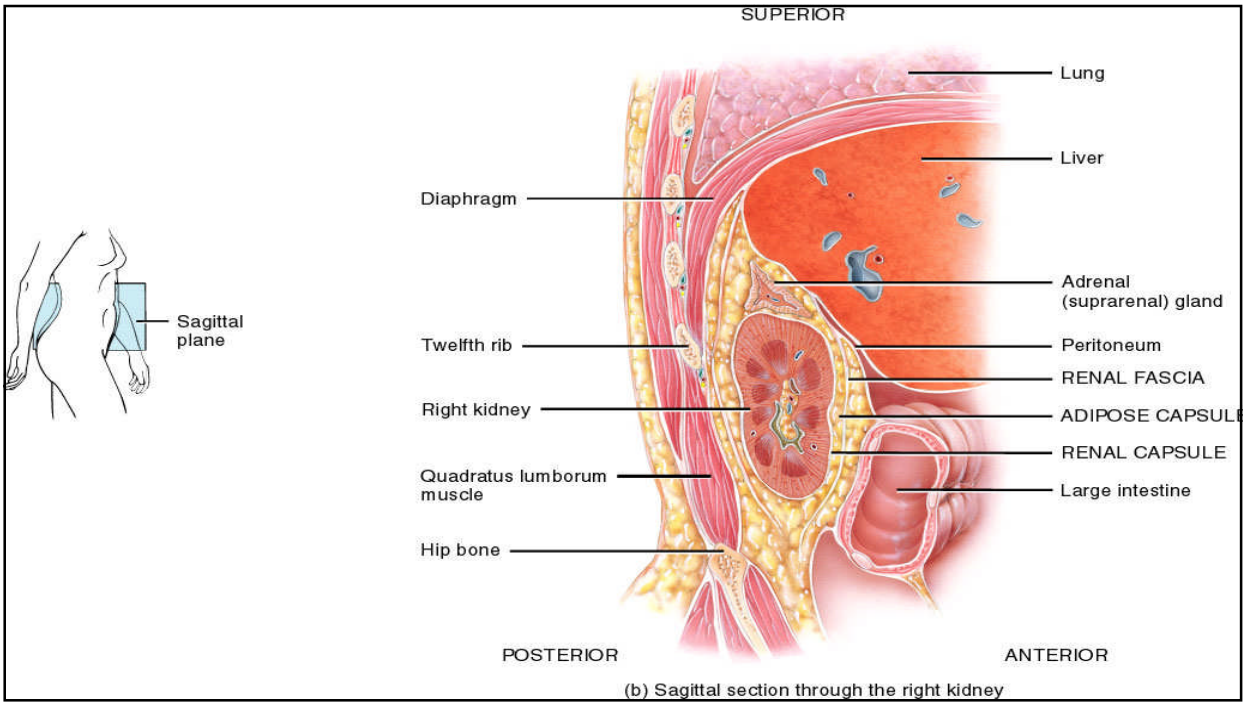





Anterior
Inferior vena cava
Peritoneum
Peritoneal cavity
Aorta
Renal vein
Renal artery
Perirenal fat capsule
Fibrous capsule
Body wall
Anterior renal fascia
Kidney
Posterior renal fascia
Body of vertebra L
(a)
Posterior



(a) Inferior view of transverse section of abdomen (L2)



(b) Sagittal section through the right kidney

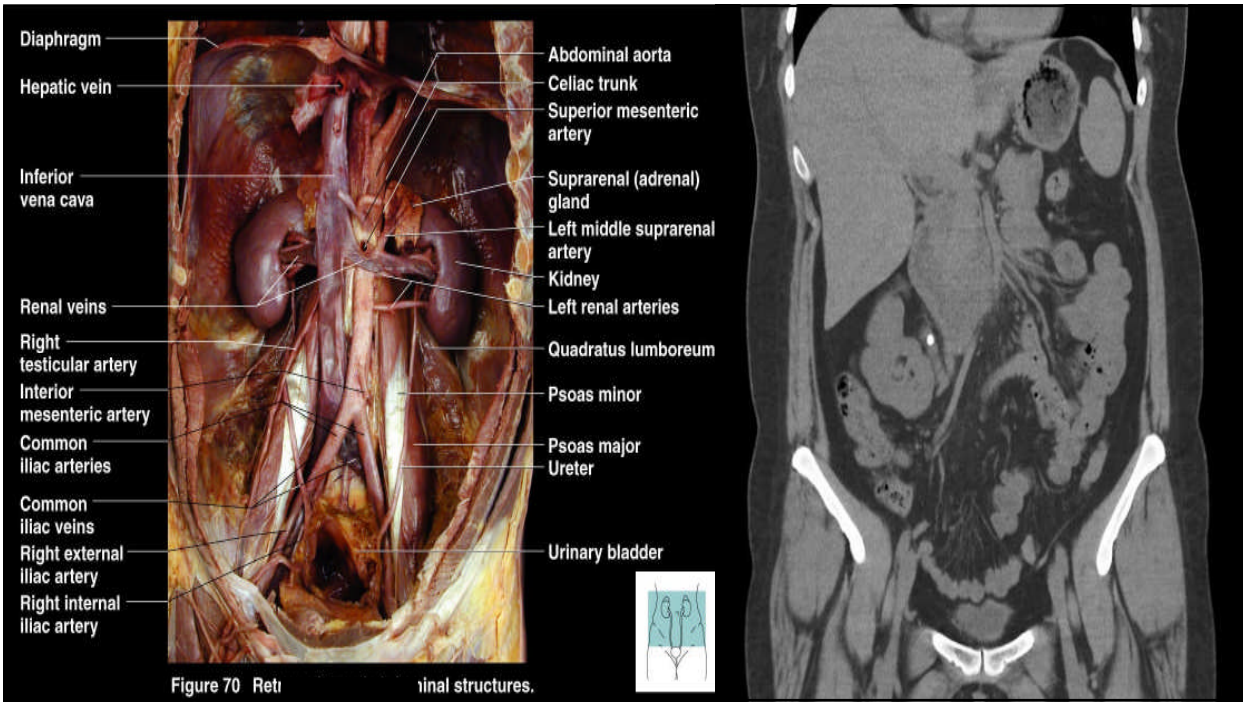
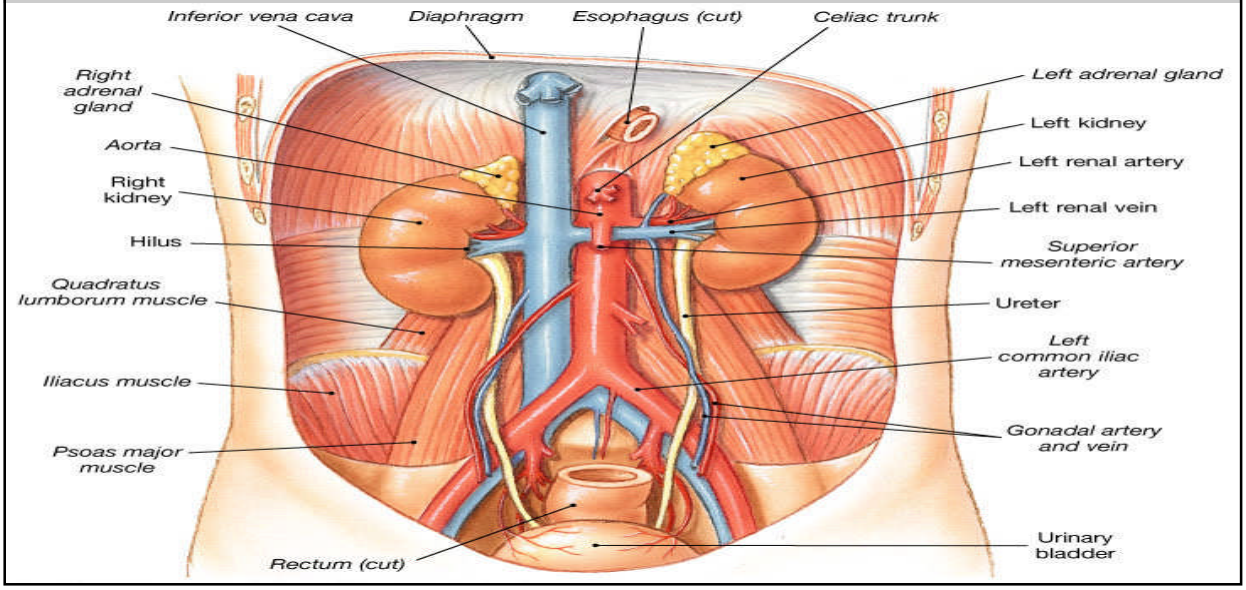


Figure 70 Reti inal structures.

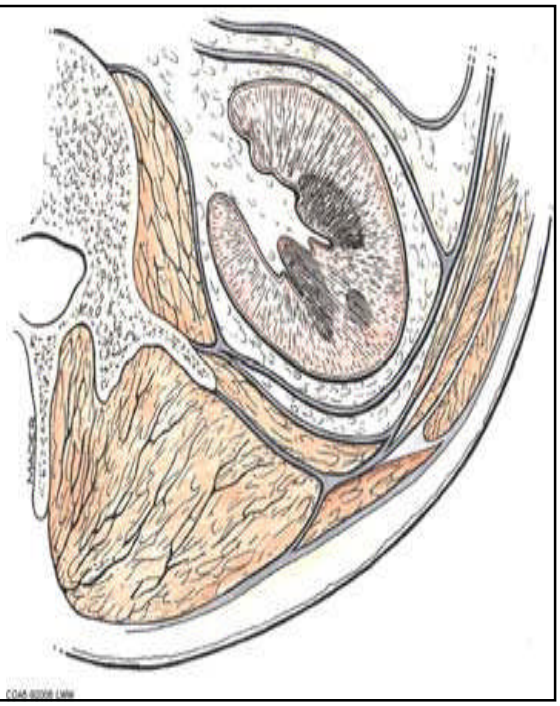
The Urinary System in Gross Dissection



Kidney morphology

Coverings of the Kidneys

- **Renal / fibrous capsule** - that prevents kidney infection
- **Perirenal fat** – fatty mass that cushions the kidney and helps attach it to the body wall
- **Renal fascia** – outer layer of dense fibrous connective tissue that anchors the kidney
- **Pararenal fat** – external to the renal fascia



Perirenal Fat	A layer of adipose tissue (fat) partially surrounds the kidney. It is usually a radilogy finding but occassional a tumor can arise from it.
Renal Capsule	The thin but tough covering of the kidney. It helps protect the kidney. During a kidney biopsy, may feel a "pop" as the needle goes through the renal capsule
Renal Cortex	The outer shell of the kidney between the renal capsule and the renal medulla. The renal cortex contains the renal corpuscles (particularly the glomeruli) and most of the renal tubules (except for the loop of Henle). It is about 1 centimeter thick and also goes down between the renal pyramids. Many kidney diseases affect the glomeruli so the goal of a kidney biopsy is to sample this area.
Renal Medulla	The innermost area of the kidney. It is separated into 8 to 18 cone-shaped sections called the medullary pyramids. If the biopsy needle goes in too far, you may only get medulla and the biopsy will likely have to be repeated.
Medullary Pyramid	An important part of the inner kidney. It consists primarily of collecting tubules as well as loops of Henle. The base of the medullary pyramid is next to the cortex and it tapers to form the renal papillae. There are between 8 to 18 medulla pyramids in each kidney.
Calyx	An extension of the renal pelvis that surrounds the renal papillae. It collects urine from the papillary ducts. Several minor calyces drain into a major calyx and then onto the renal pelvis.
Renal Pelvis	The area where the urine collects before entering the ureters. Two or three major calices come together to enter the renal pelvis. Cancers and kidney stones can form in renal pelvis and cause blood to be lost in the urine.
Renal Sinus	A cavity in the kidney that contains the calices and the renal pelvis. It also contains the blood vessels, nerves, and fat.

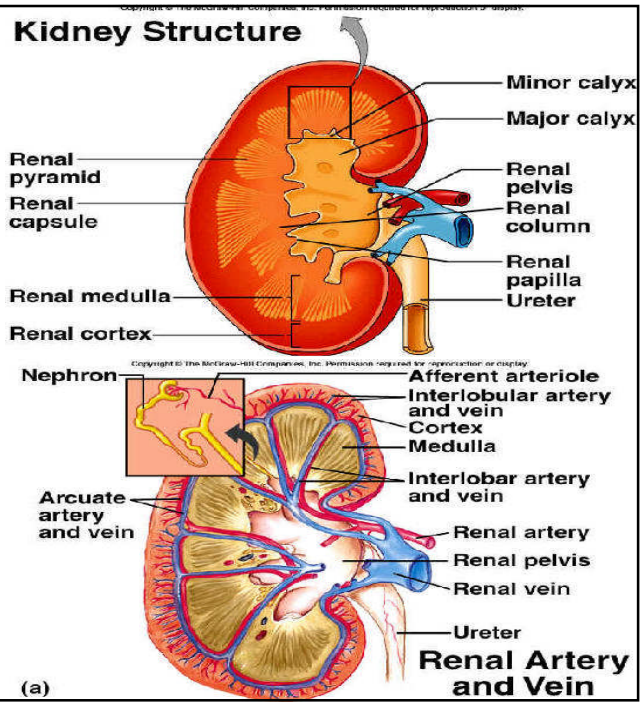
KIDNEY

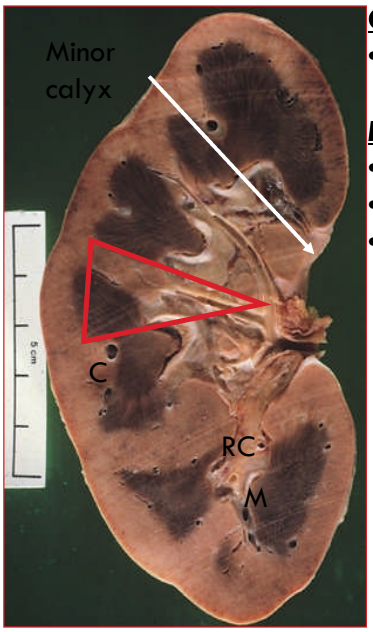
- Basic structural unit = nephron (renal tubule or kidney tubule)

Hilum = depression thru which urine exits and blood vessels enter (and exit) the kidney

Renal Pelvis = expansion of upper part of ureter within the hilum, divided into large and small cups (major and minor calyces).

Collecting Ducts = empty into calyces, these are structures into which renal tubules drain

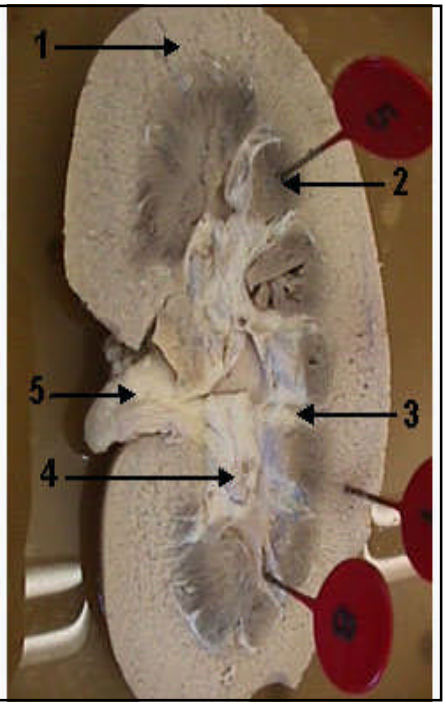




Cortex
- renal columns

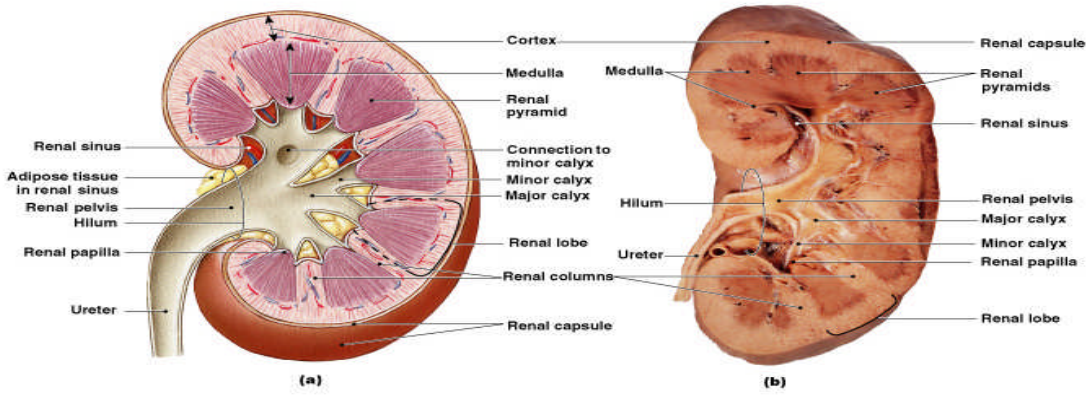
Medulla
- medullary pyramids
- minor calyx
- medullary rays

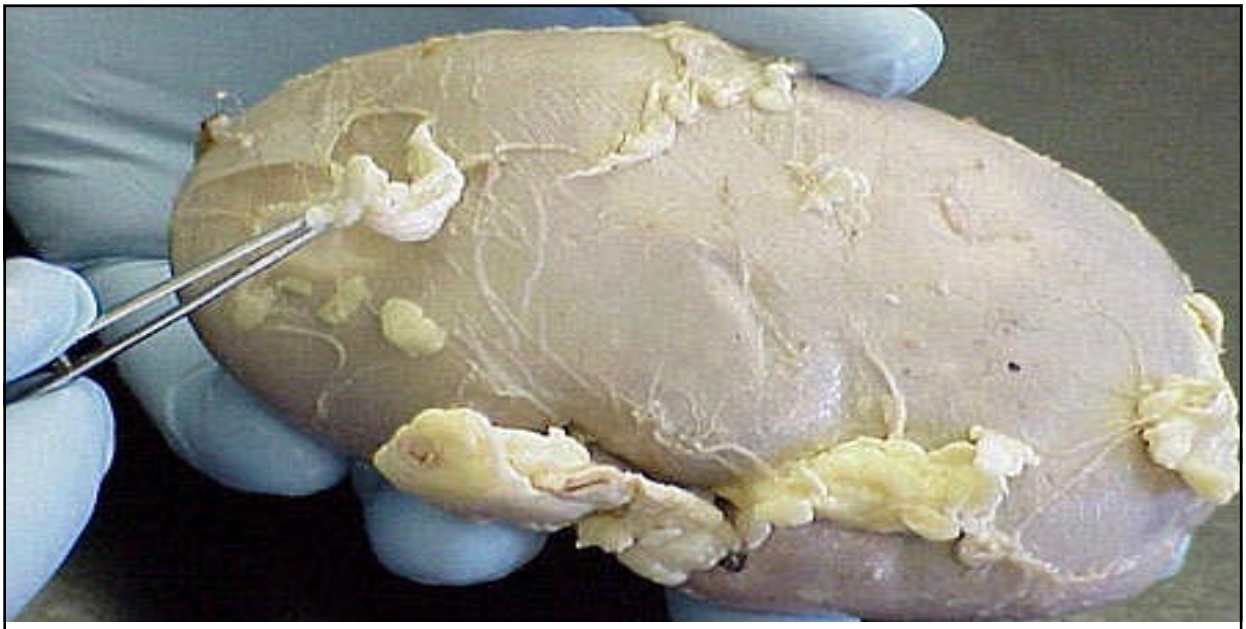
1renal cortex
2renal pyramid
3renal column
4renal pelvis
5ureter



Renal Capsule

- Bound to outer surfaces of structures in renal sinus
- Stabilizes positions of ureter, renal blood vessels, and nerves





The Renal Capsule of a Human Kidney

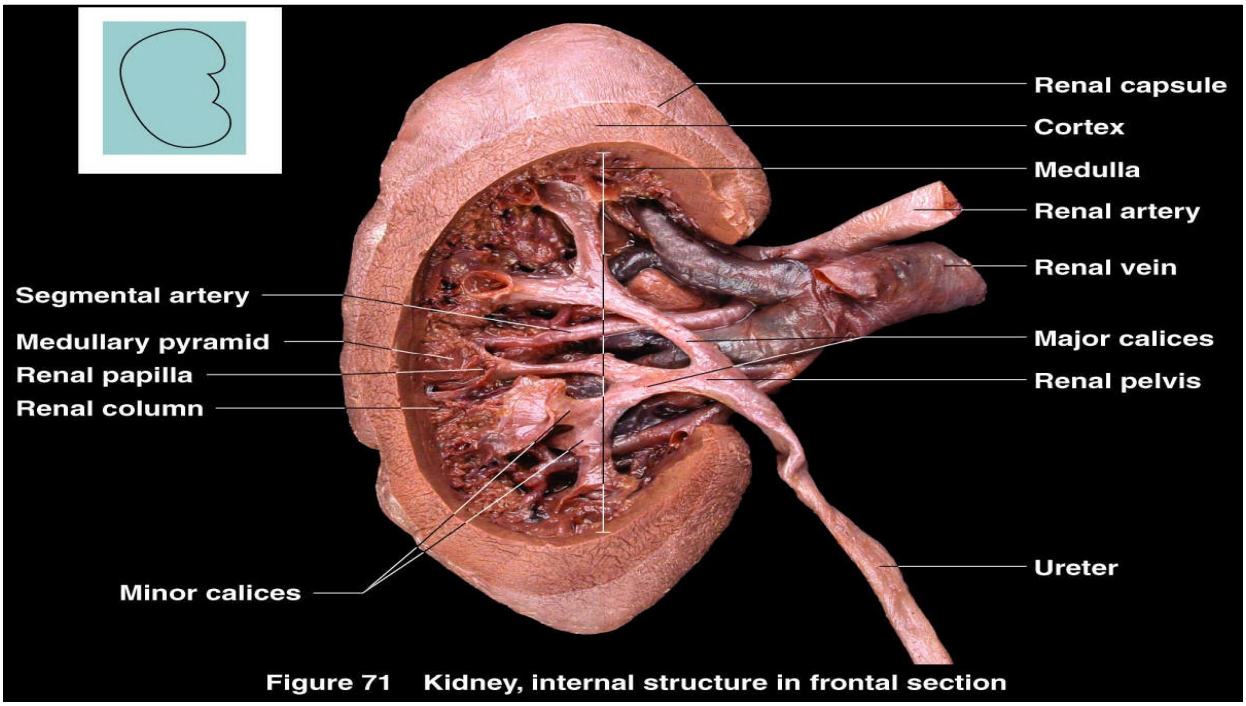
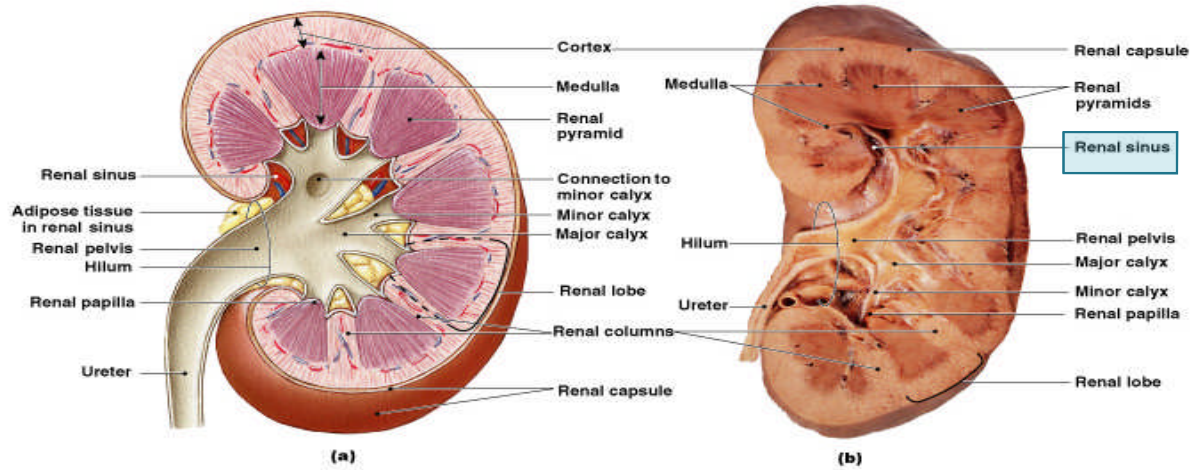


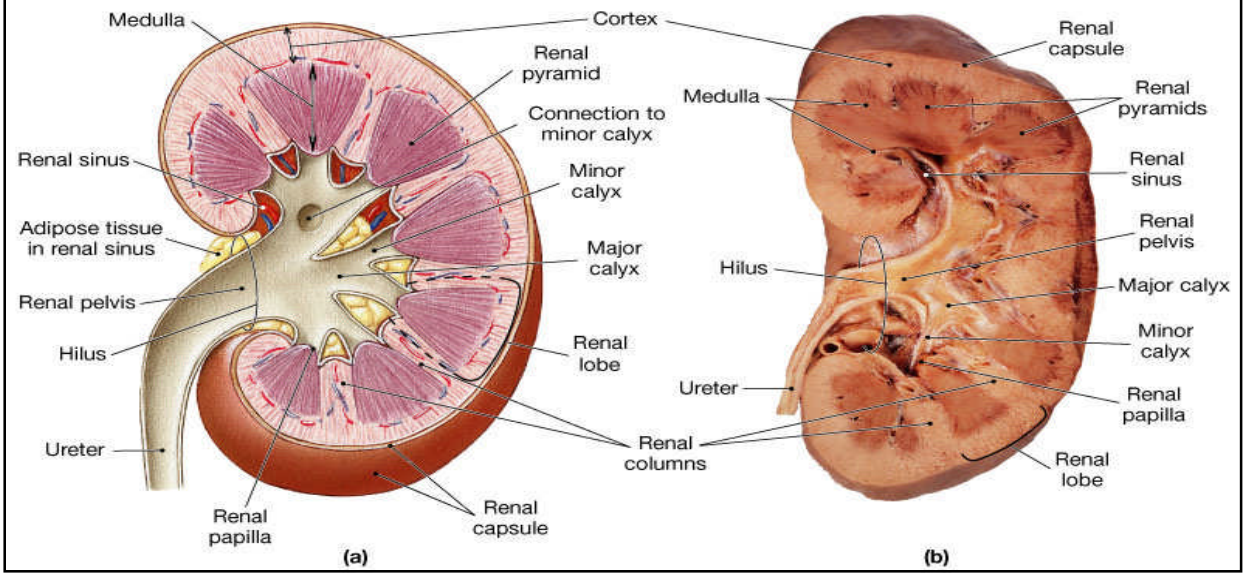
Figure 71 Kidney, internal structure in frontal section

Renal Sinus

- The **renal sinus** is a cavity within the kidney which is occupied by the renal pelvis, renal calyces, blood vessels, nerves and fat.
- Lined by fibrous renal capsule

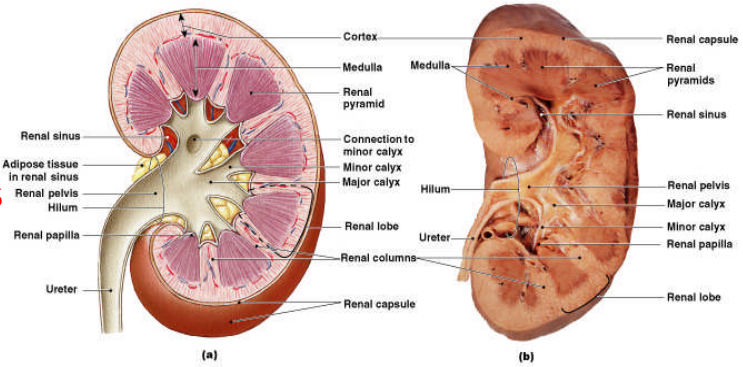


The Structure of the Kidney

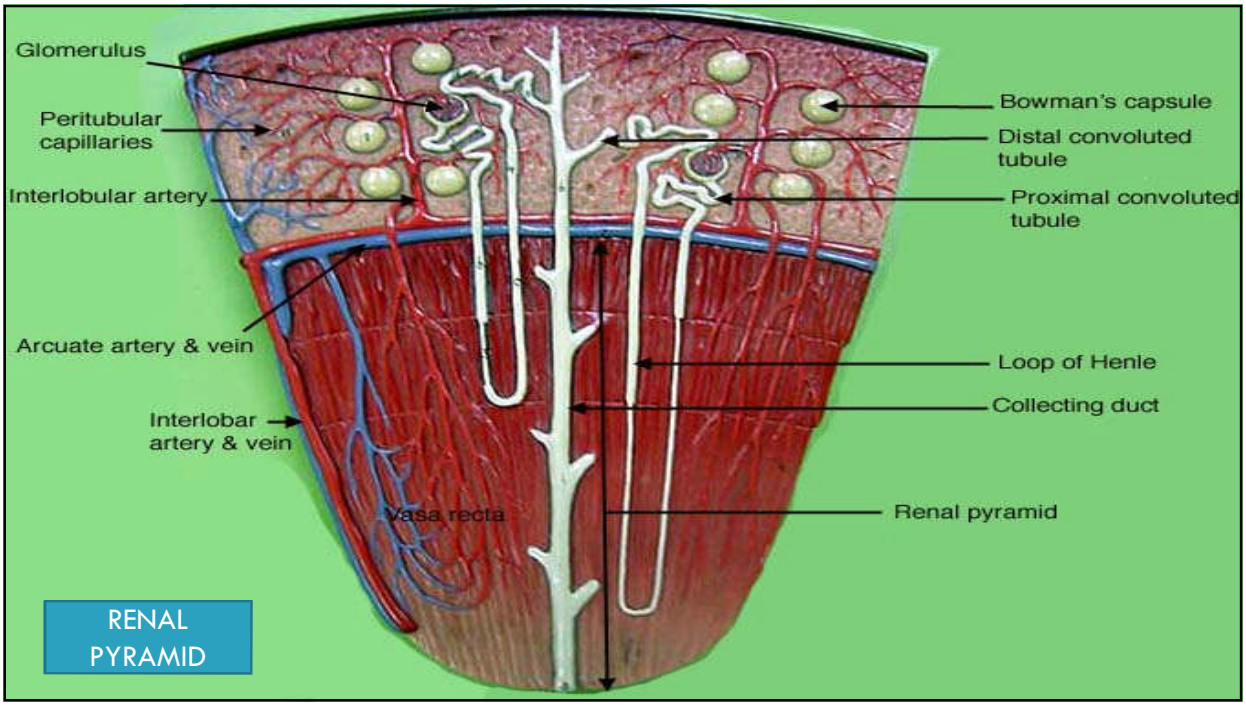


Renal Pyramids

= **malpighian pyramids**



- 6 to 18 distinct conical or triangular structures in renal medulla:
  - base abuts cortex
  - tip (renal papilla) projects into renal sinus

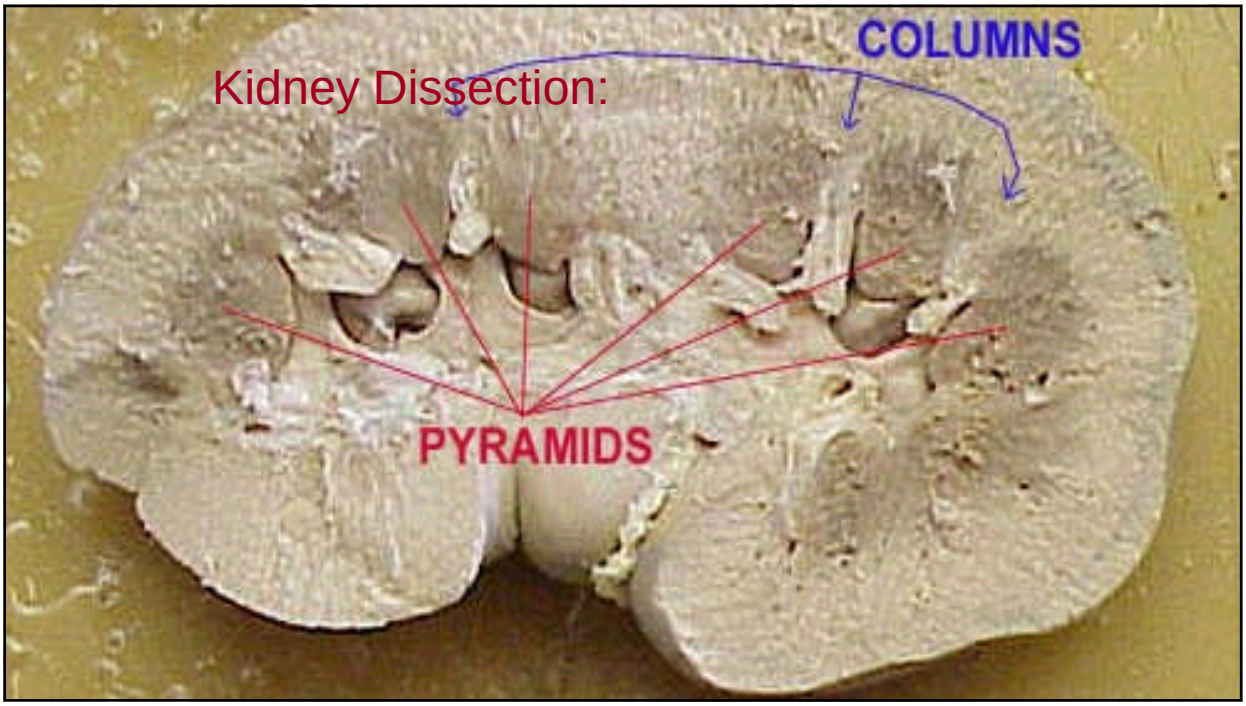


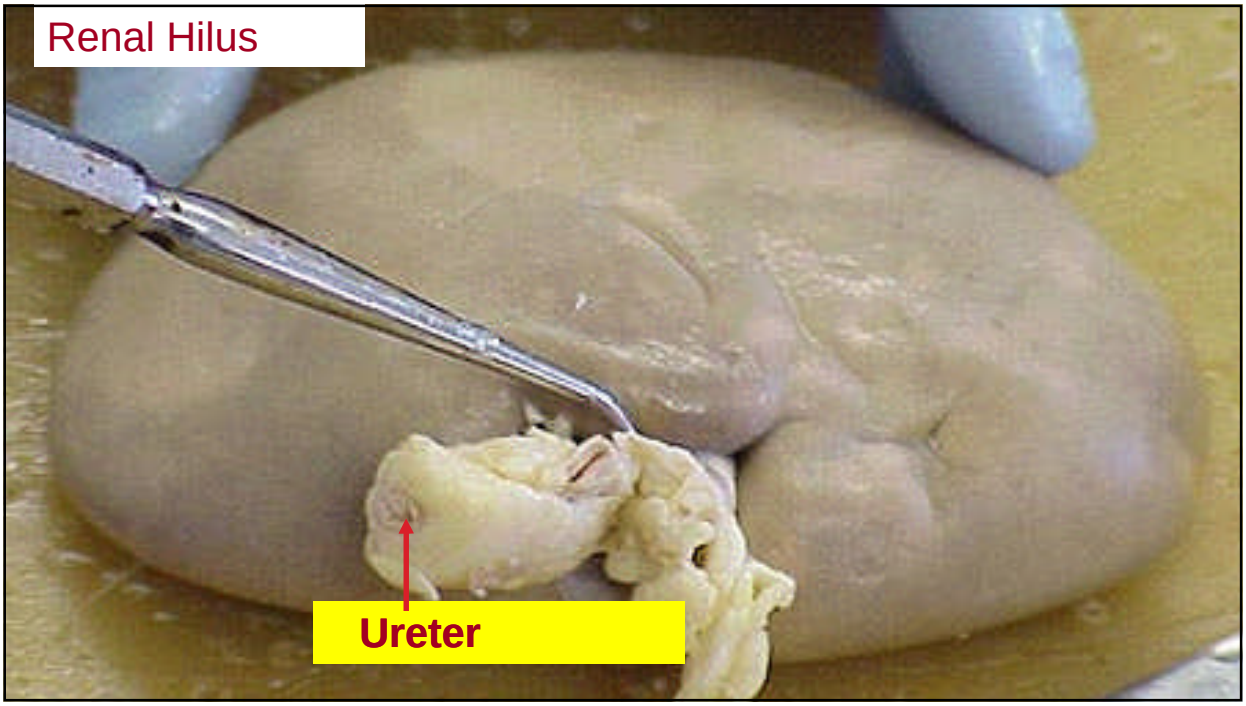
The **renal column** (or **Bertin column,** or **column of Bertin**)

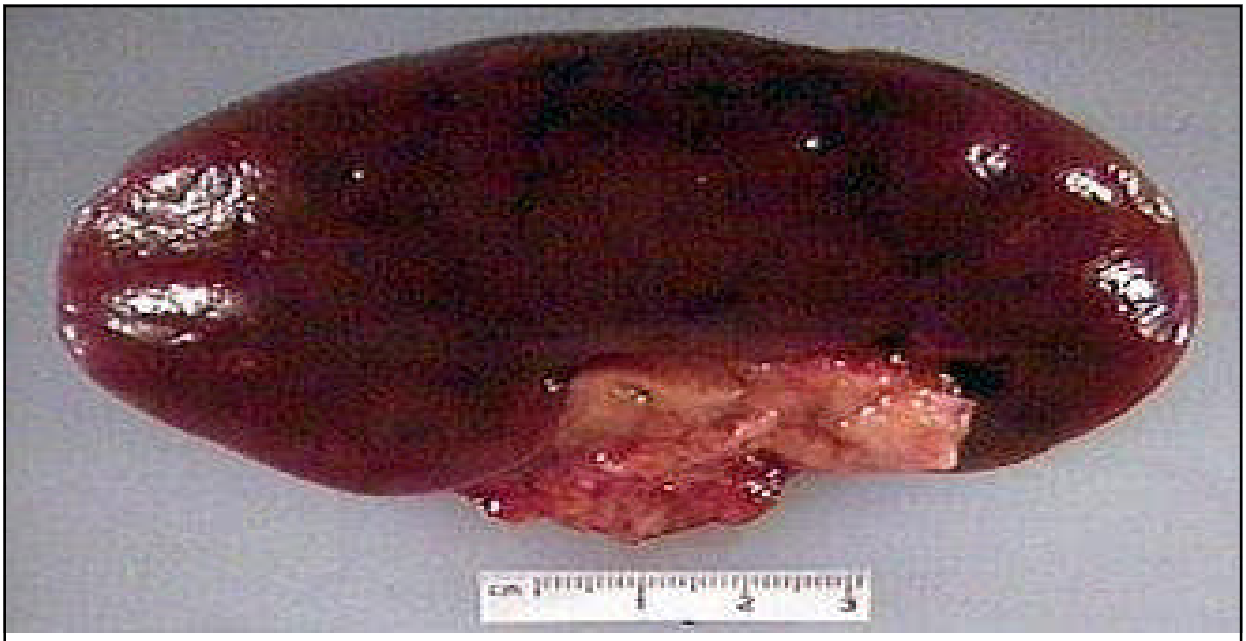
is a medullary extension of the renal cortex in between the renal pyramids.

It allows the cortex to be better anchored.

Each column consists of lines of blood vessels and urinary tubes and a fibrous material.



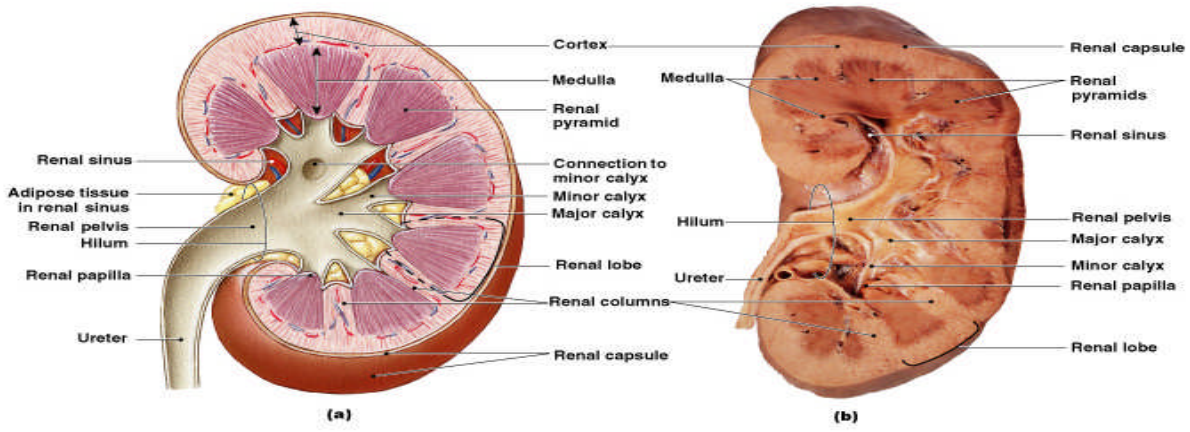




Normal Human Kidney, Unfixed

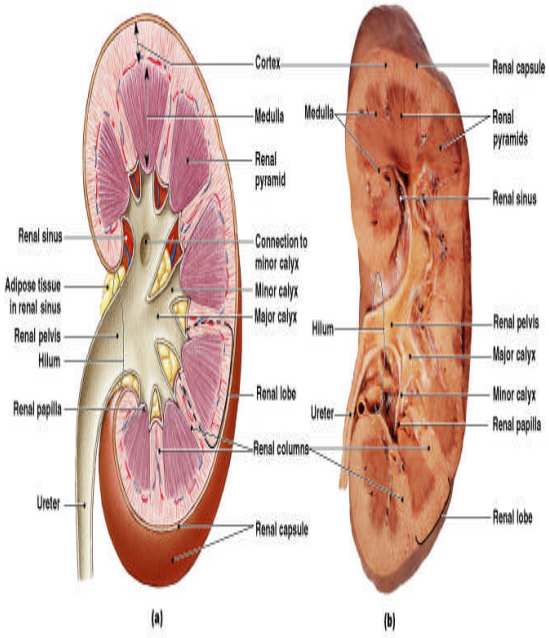
Major Calyx

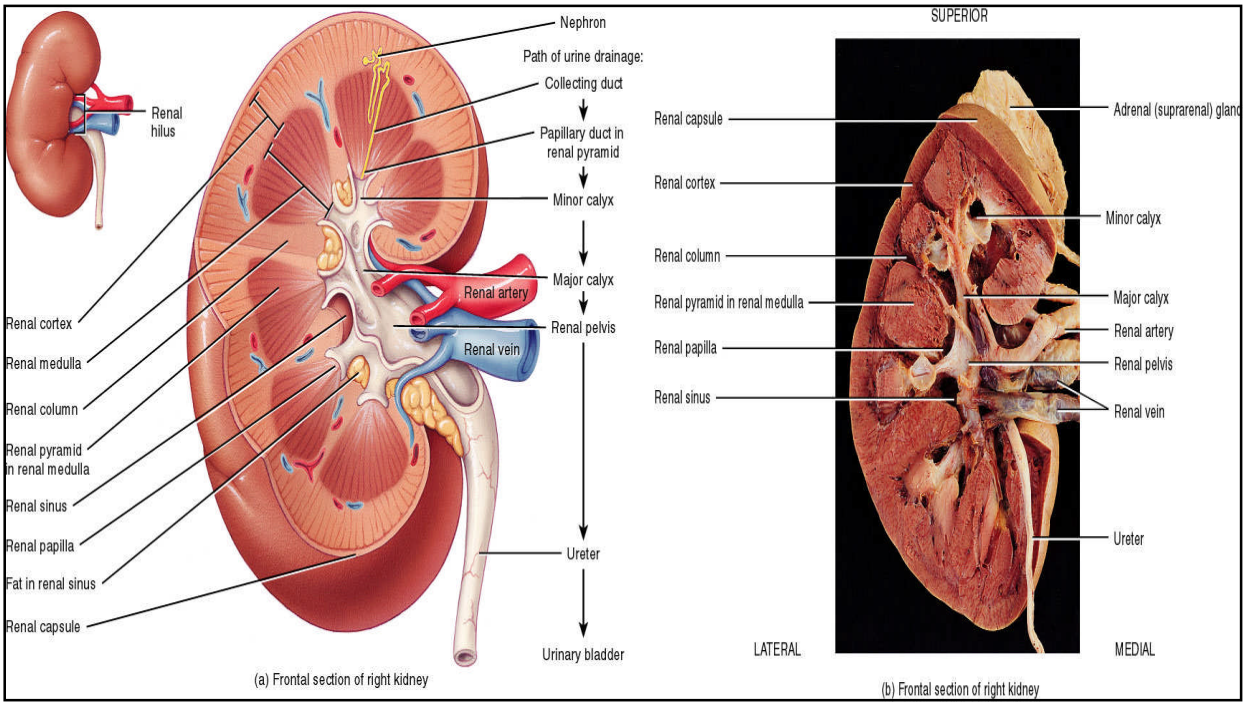
- Formed by 4 or 5 minor calyces

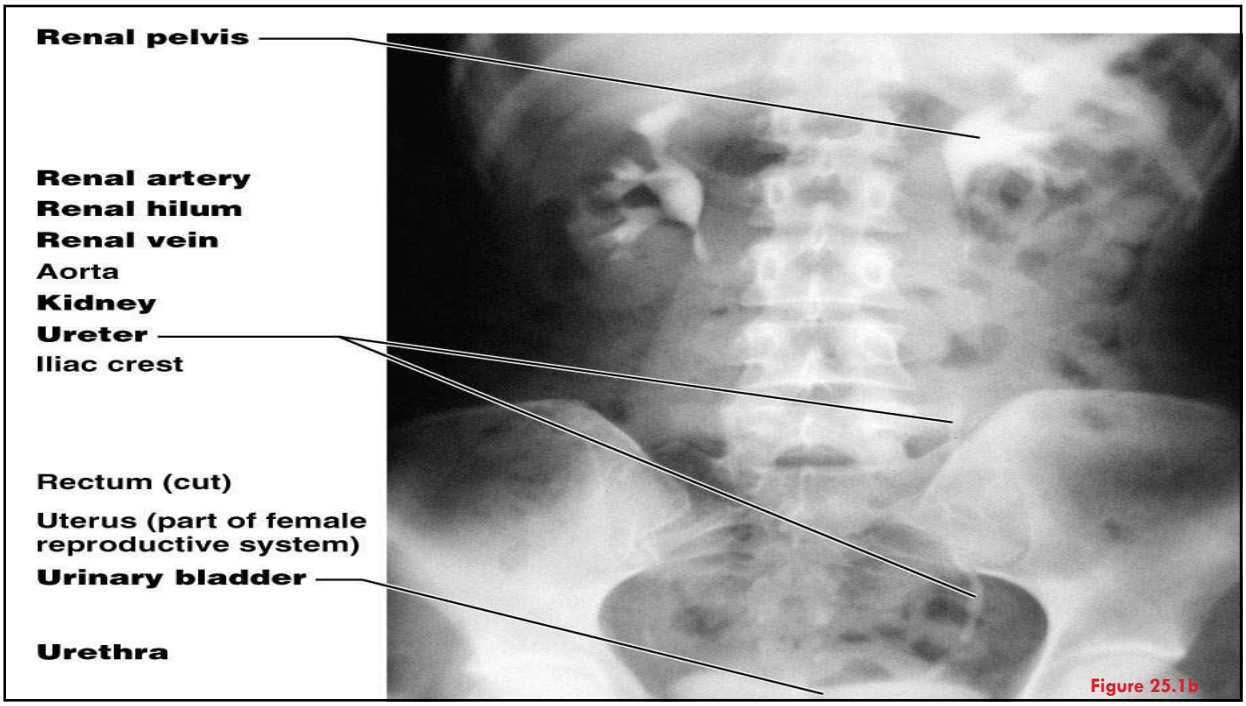


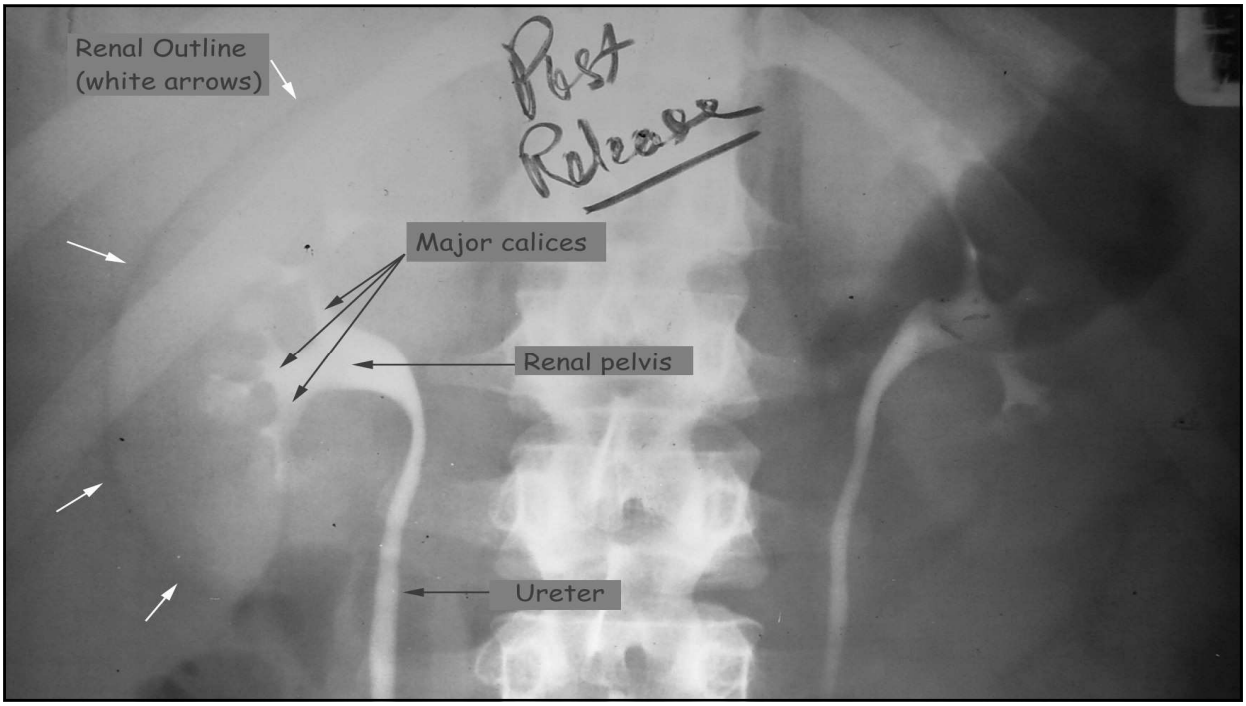
Renal Pelvis

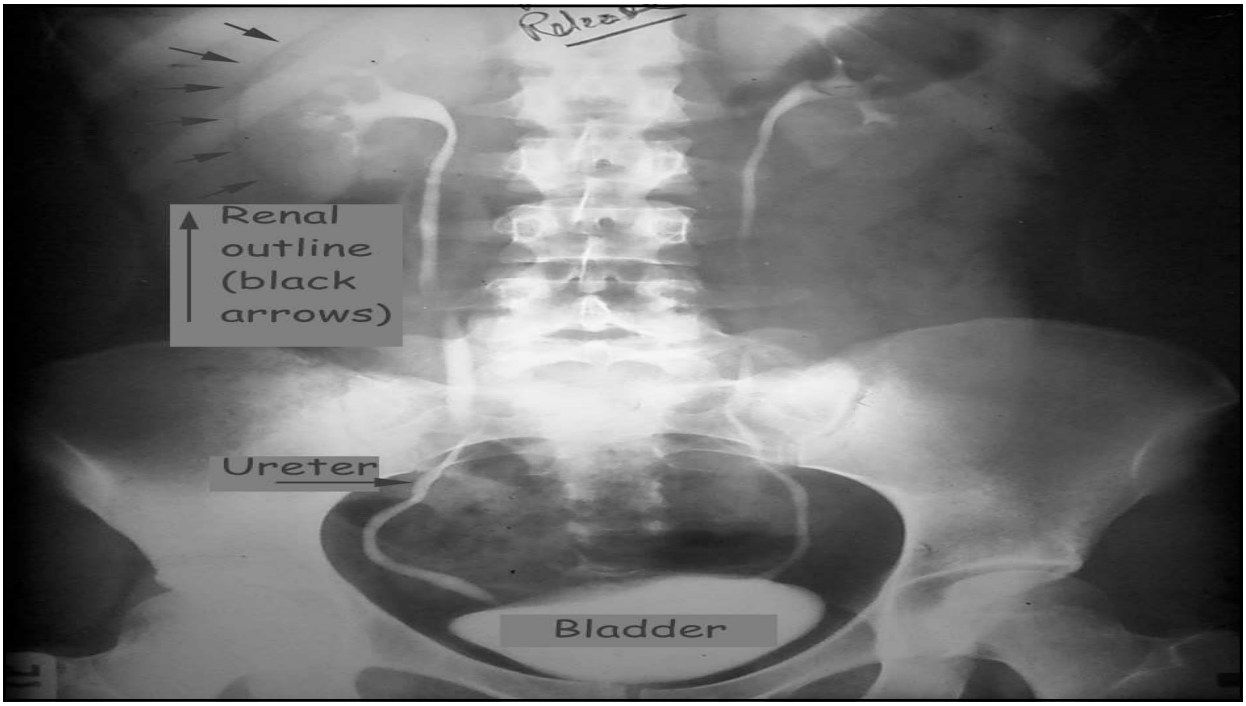
- Large, funnel-shaped chamber
- Consists of 2 or 3 major calyces
- Fills most of renal sinus
- Connected to ureter, which drains kidney



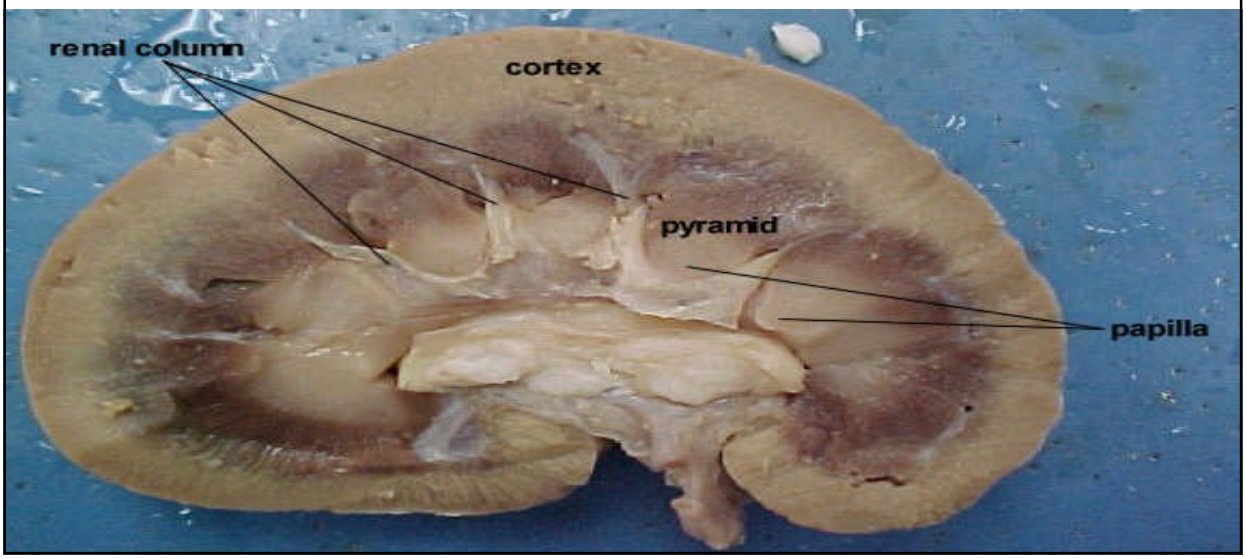

Renal hilus
Nephron
Path of urine drainage:
Collecting duct
Papillary duct in renal pyramid
Minor calyx
Major calyx
Renal pelvis
Ureter
Urinary bladder
Renal artery
Renal vein
Renal cortex
Renal medulla
Renal column
Renal pyramid in renal medulla
Renal sinus
Renal papilla
Fat in renal sinus
Renal capsule
(a) Frontal section of right kidney
SUPERIOR
Renal capsule
Renal cortex
Renal column
Renal pyramid in renal medulla
Renal papilla
Renal sinus
Adrenal (suprarenal) gland
Minor calyx
Major calyx
Renal artery
Renal pelvis
Renal vein
Ureter
LATERAL
MEDIAL
(b) Frontal section of right kidney


Renal pelvis
Renal artery
Renal hilum
Renal vein
Aorta
Kidney
Ureter
Iliac crest
Rectum (cut)
Uterus (part of female reproductive system)
Urinary bladder
Urethra
Figure 25.1b


Renal Outline
(white arrows)
Post
Release
Major calices
Renal pelvis
Ureter

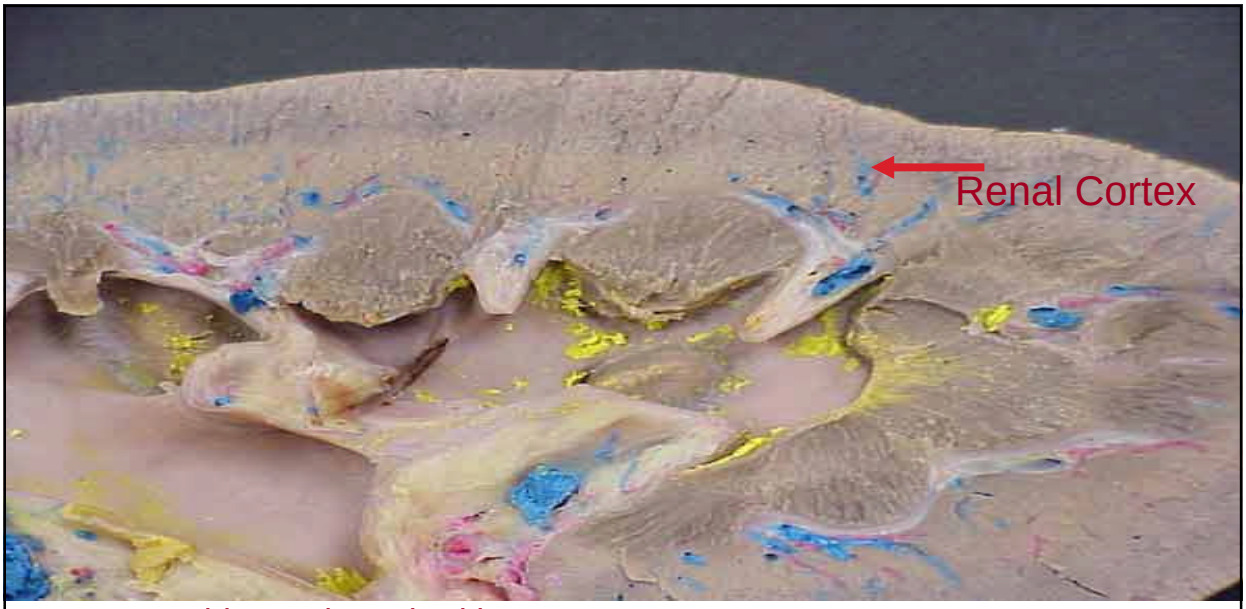

Renal
outline
(black
arrows)
Ureter
Bladder

HISTOLOGY



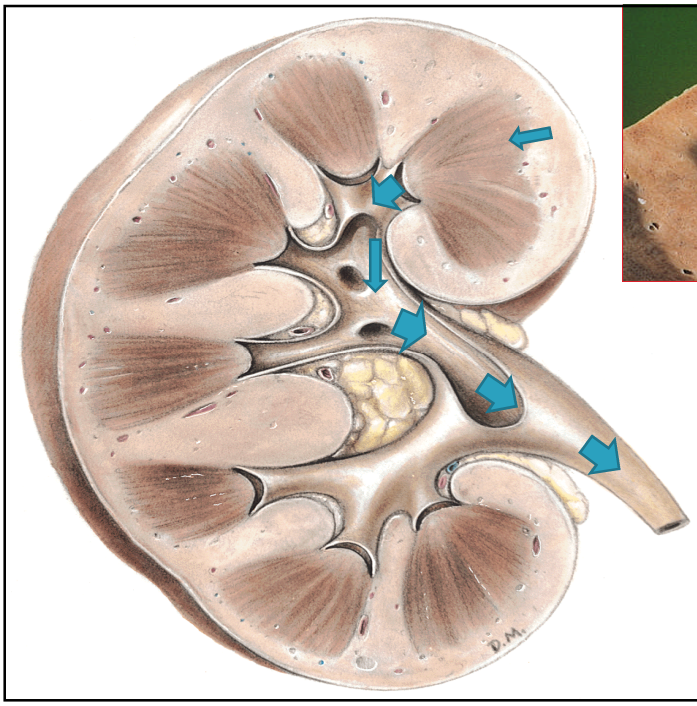
Cortex

Medulla



Kidney Injected With Latex

-red (arteries), blue (veins), yellow (urine)



Minor calyces

↓

Major calyces

↓

Renal pelvis

↓

Ureter

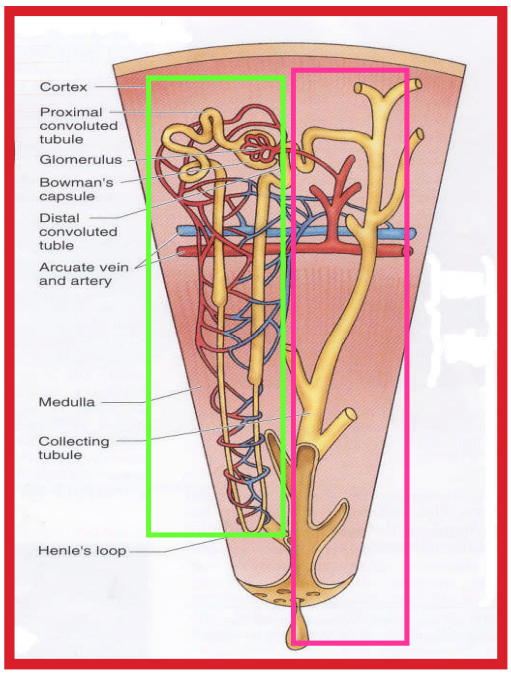
Two or three minor calyces converge to form a major calyx.

The **major calyx,** in the kidney, surrounds the apex of the renal pyramids.

Urine formed in the kidney passes through a

=➔renal papilla at the apex into a minor calyx then into major calyx before passing through the renal pelvis into the ureter.

Peristalsis of the smooth muscle originating in pace-maker cells originating in the walls of the calyces propels urine through the renal pelvis and ureters to the bladder.

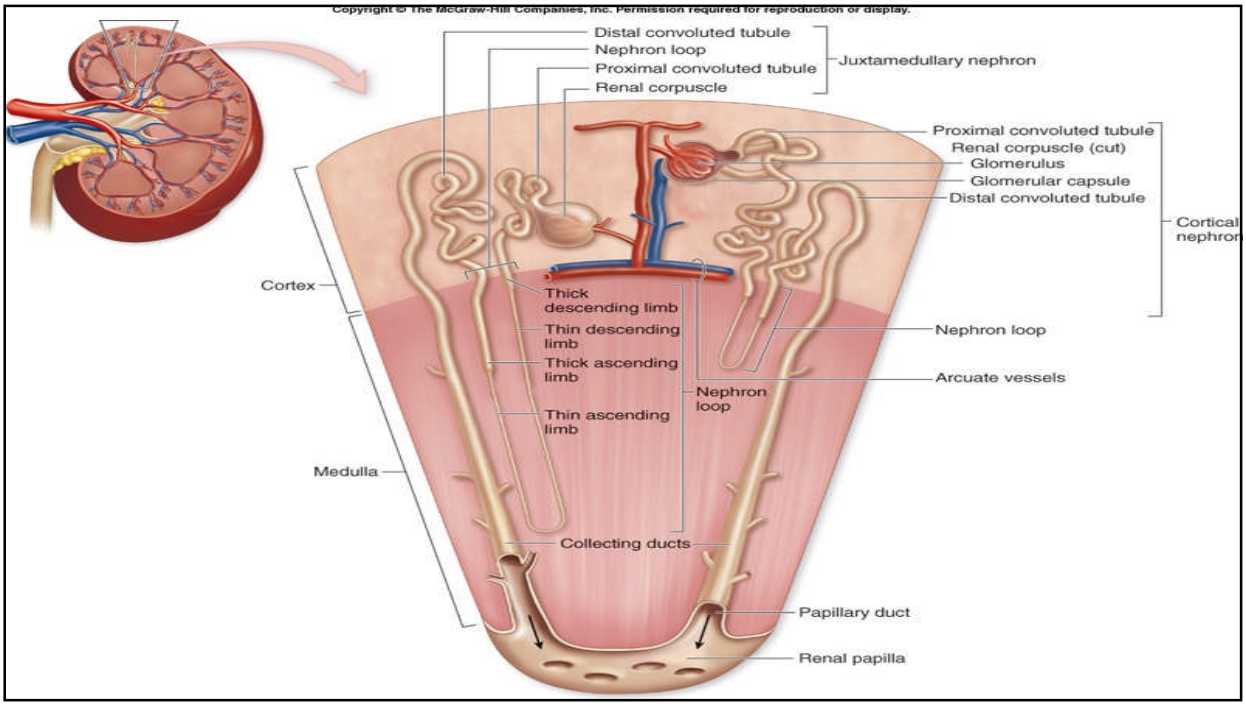


Uriniferous Tubule

Functional unit of the kidney.

Modify filtrate to form urine.

Composed of a nephron
& a collecting tubule (embryologically distinct).

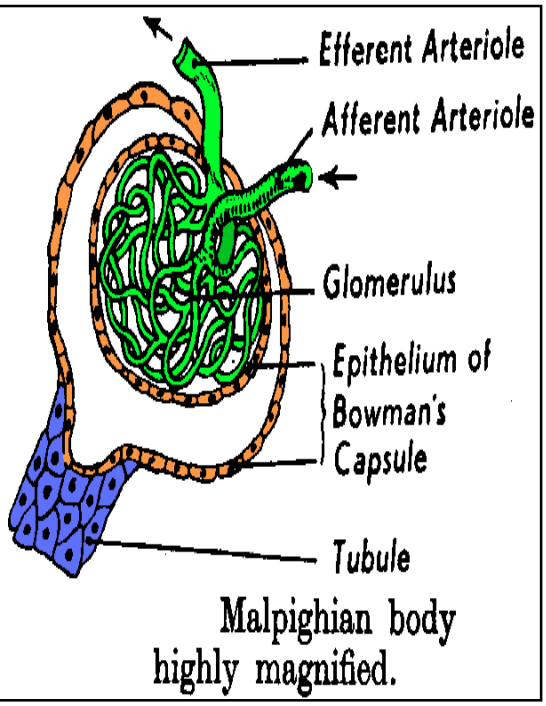


Each nephron consists of:

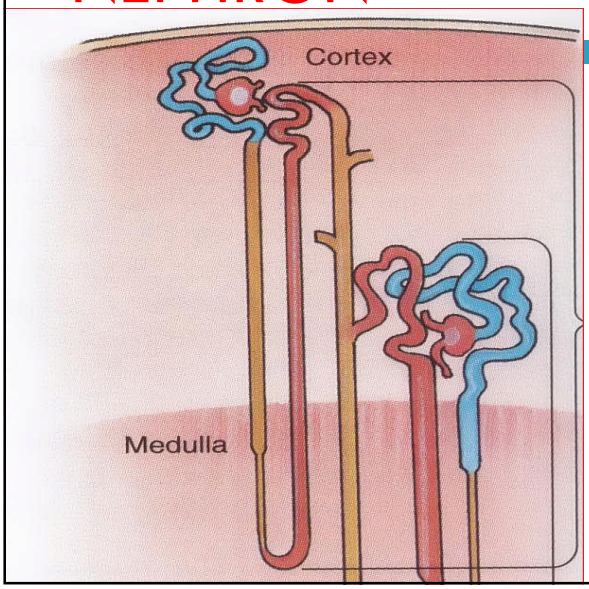
- **Renal corpuscle** (Renal body, Malpighian body)
- **Proximal convoluted tubule**
- **Loop of Henle**
- **Distal convoluted tubule**
- **Collecting duct** (Some authors do not include the collecting duct as a part of the nephron owing to its different embryologic origin).

All the components of the nephron are epithelial structures, with a continuous basal lamina and surrounded by a delicate reticular fiber network.

- **Renal corpuscles (Malpighian bodies)**



NEPHRON



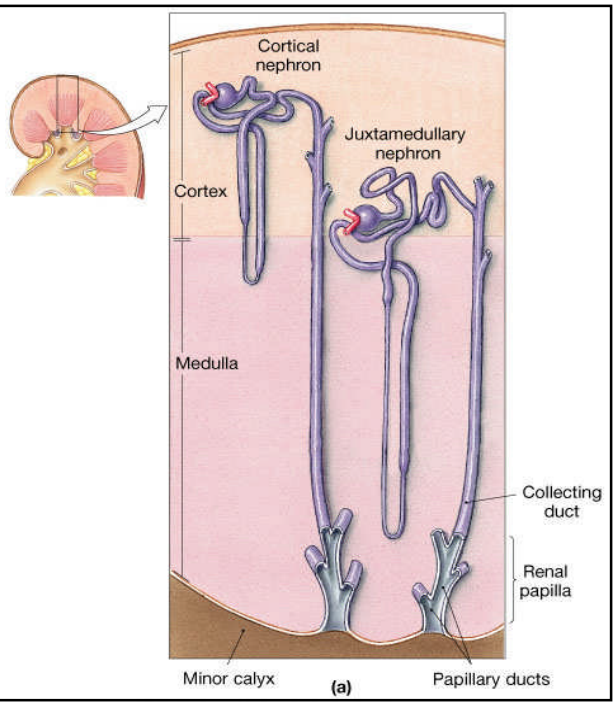
- Parts are modified for specific physiological functions
- Renal corpuscle filters fluid from blood
- Tubular portion modifies filtrate into urine

Nephron functions include:

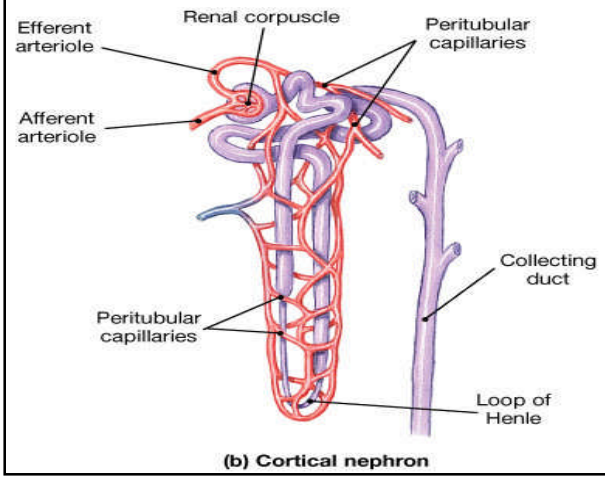
- **Production of filtrate**
- **Reabsorption of organic nutrients**
- **Reabsorption of water and ions**
- **Secretion of waste products into tubular fluid**

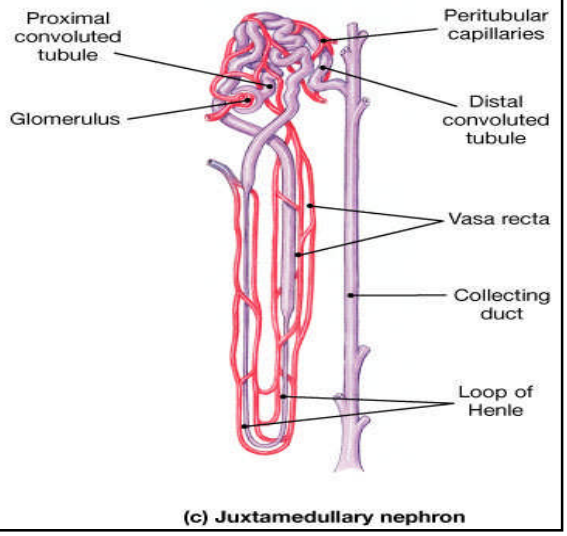
Two types of nephron

- **Cortical nephrons**
  - **~85% of all nephrons**
  - **Located in the cortex**
- **Juxtamedullary nephrons**
  - **Closer to renal medulla**
  - **Loops of Henle extend deep into renal pyramids**



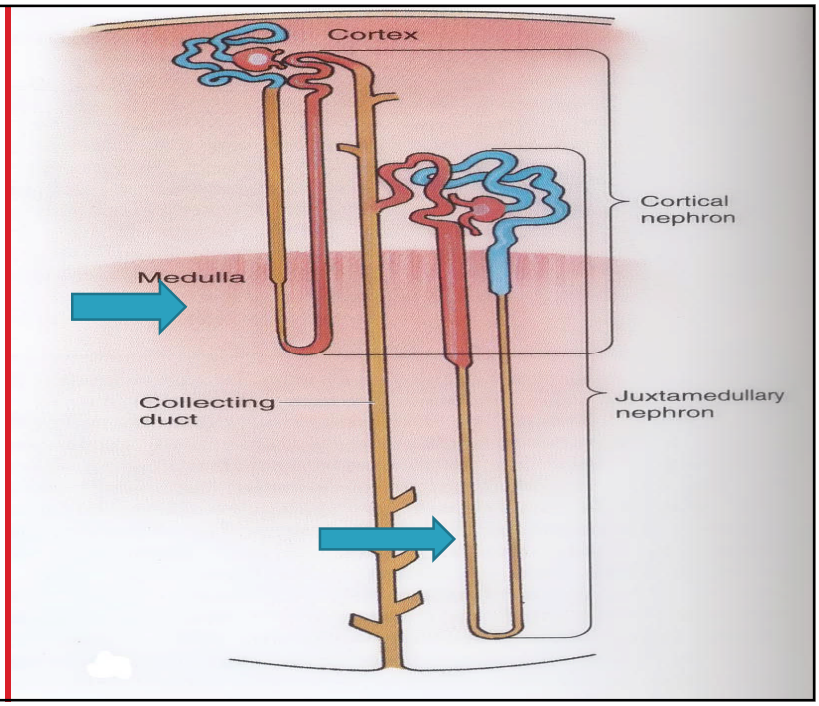
Cortical and Juxtamedullary Nephrons

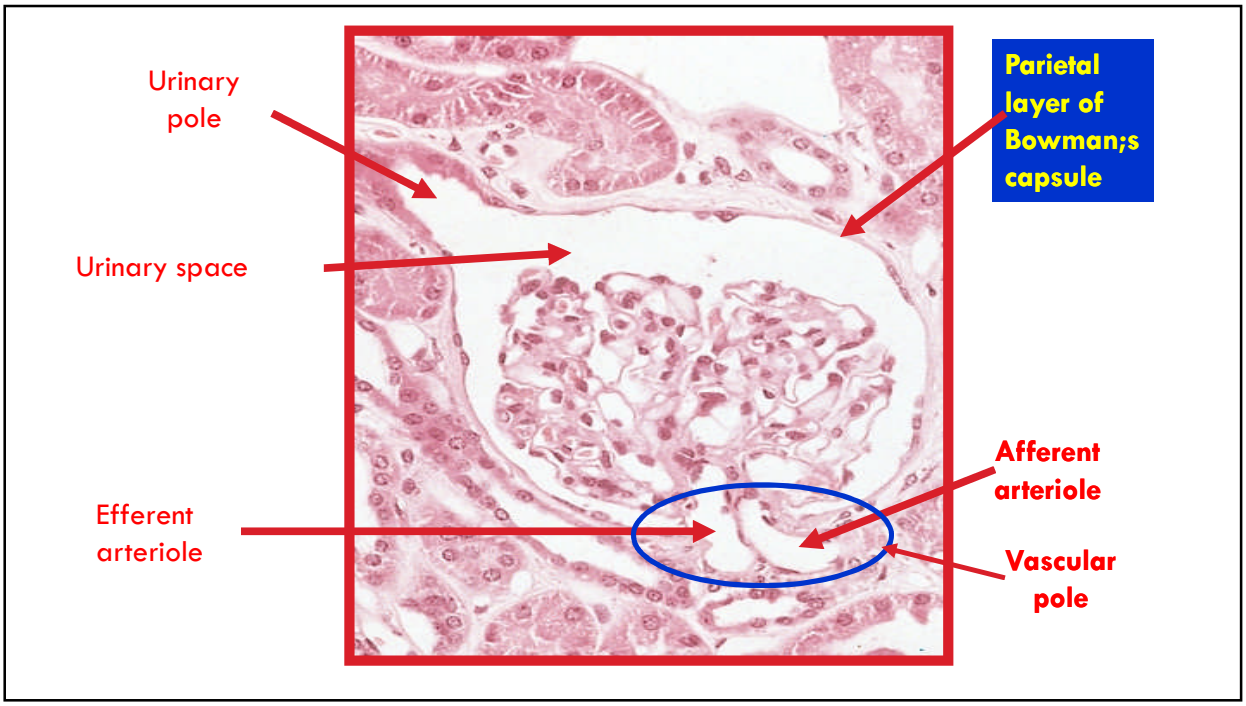


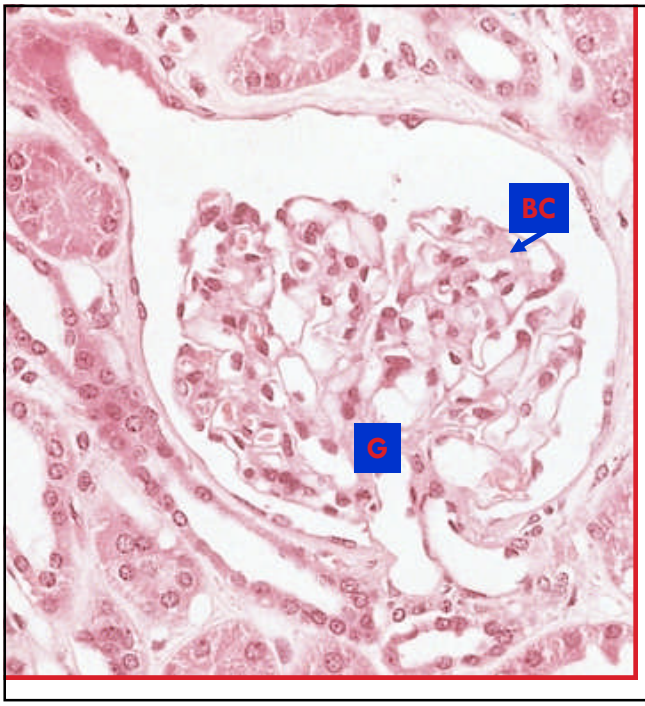


NEPHRON

- **Two types depending on location of their Henle loop**
- **Cortical (short)**
- **Juxtamedullary (long)**





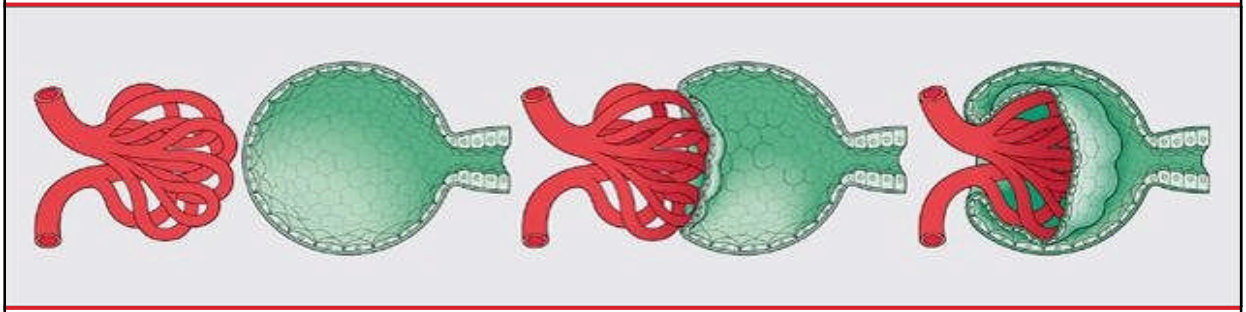


Tuft of fenestrated capillaries - the glomerulus

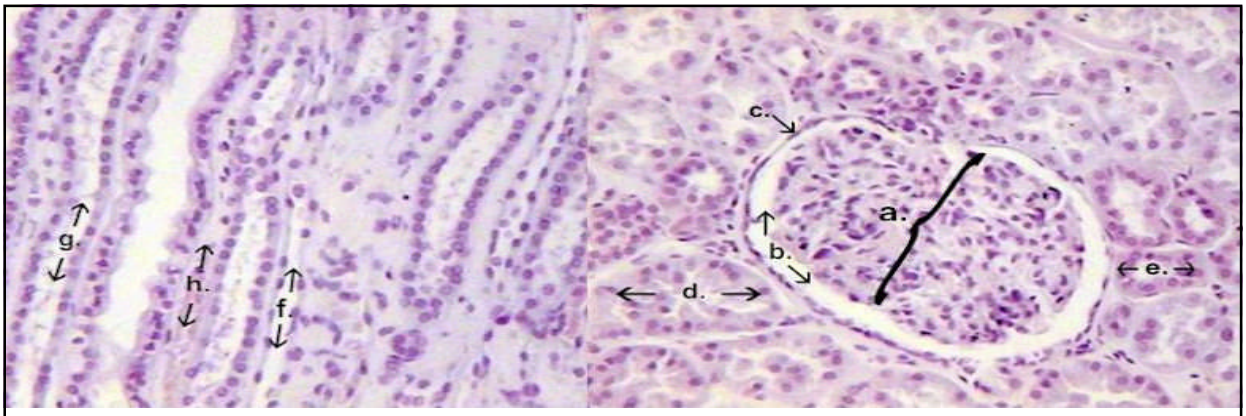
Surrounded by Bowman's capsule

Renal corpuscle

Capillaries invaginate into Bowman's capsule.



- Capillaries are in contact with the visceral layer (podocytes).
- Parietal layer is simple squamous epithelium.
- Separated by the urinary space.



a. **Glomerulus with fenestrae** a filtration capillary network covered by podocytes.

b. **Bowman's capsule** collects the filtrate.

c. Parietal **capsule wall** made of simple squamous.

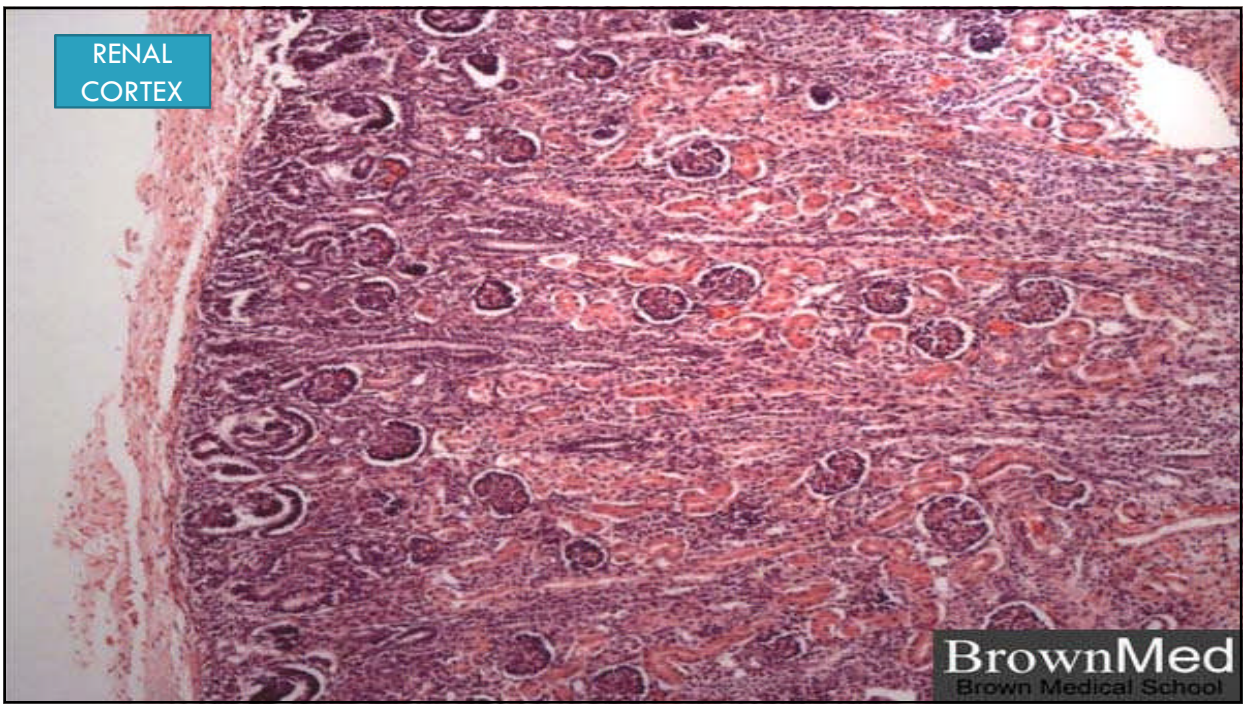
d. **Proximal** convoluted tubule -cuboidal cells with long microvilli

e. **Distal** convoluted tubule - small compact cuboidal cells

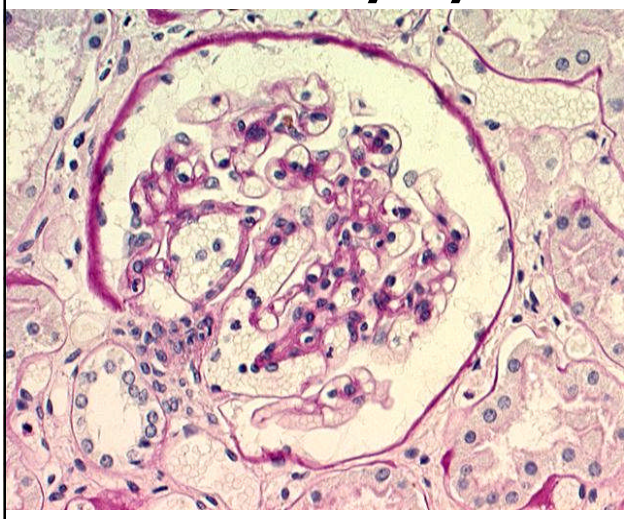
f. **Nephron loop** - thin limb with simple squamous cells

g. **Collecting duct** - lined with cuboidal cells

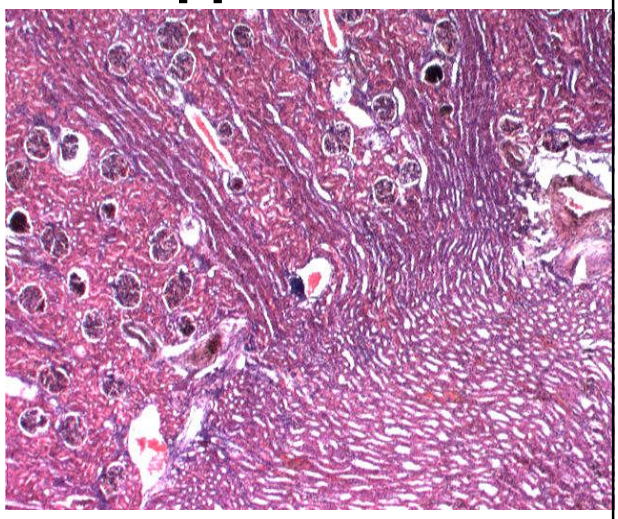
h. **Peritubular capillary** filled with red blood cells.



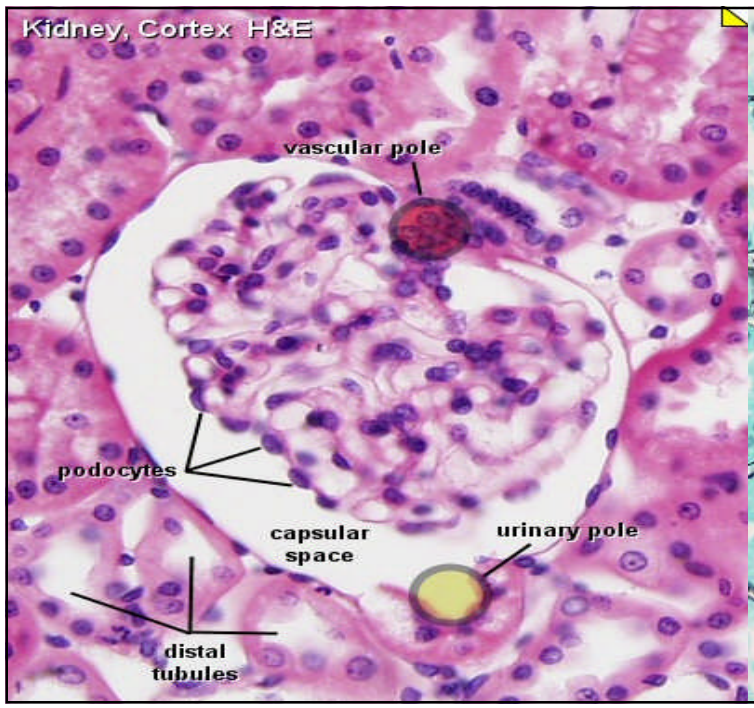
Urinary System Lab Supplement

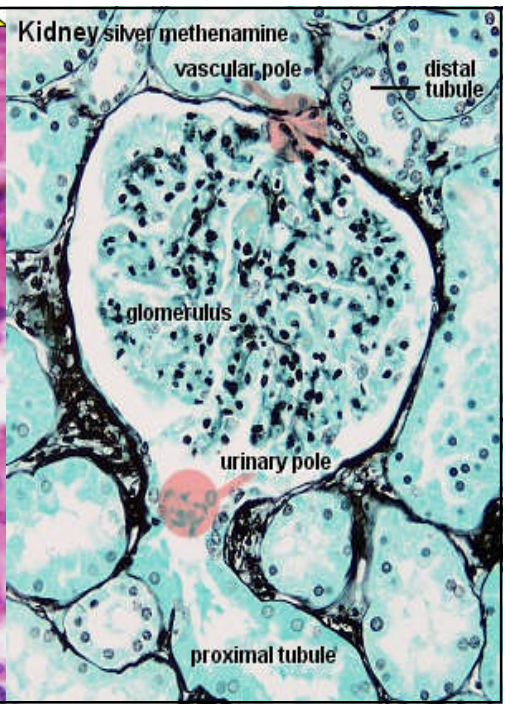


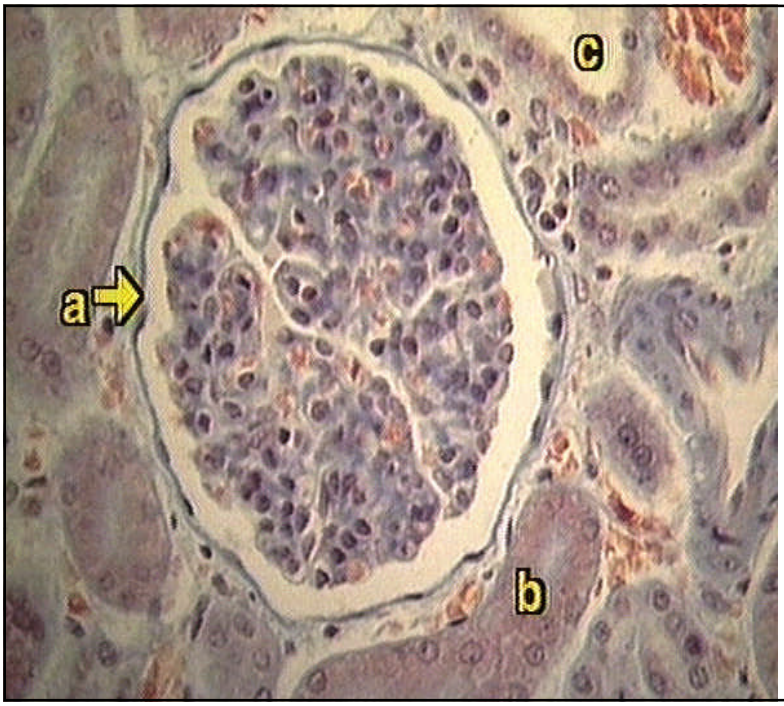
A Renal Corpuscle



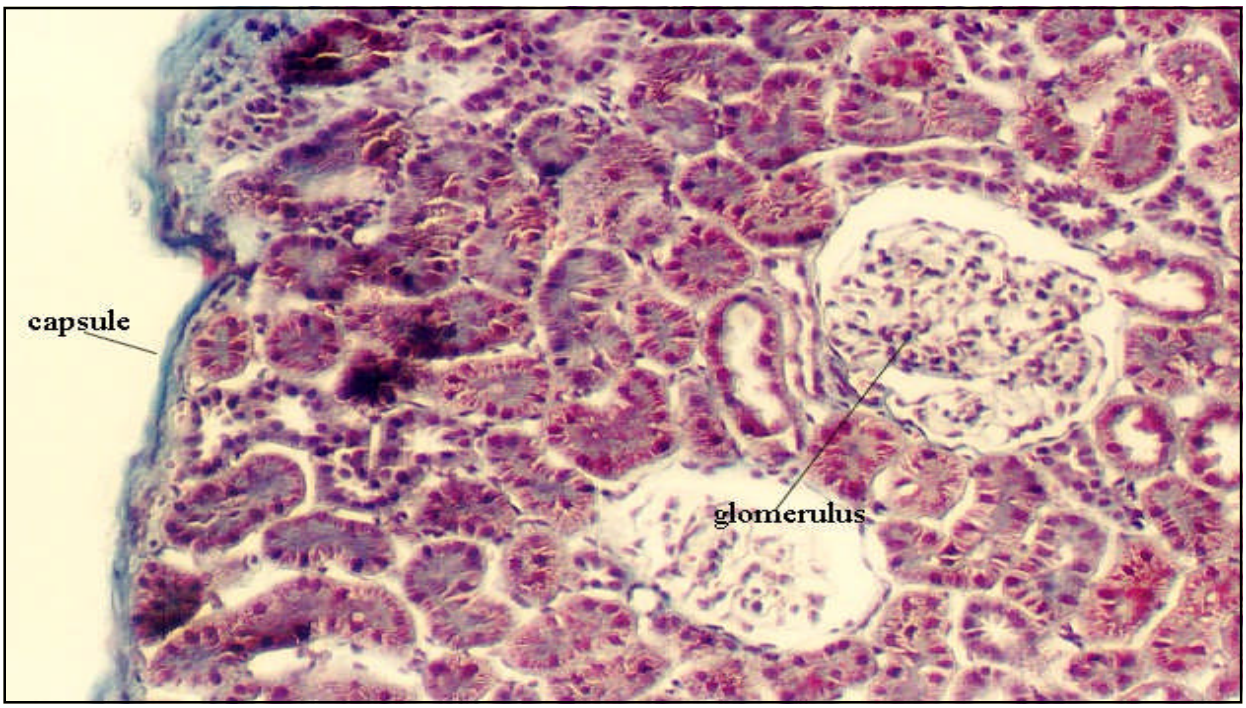
Medulla vs. Cortex

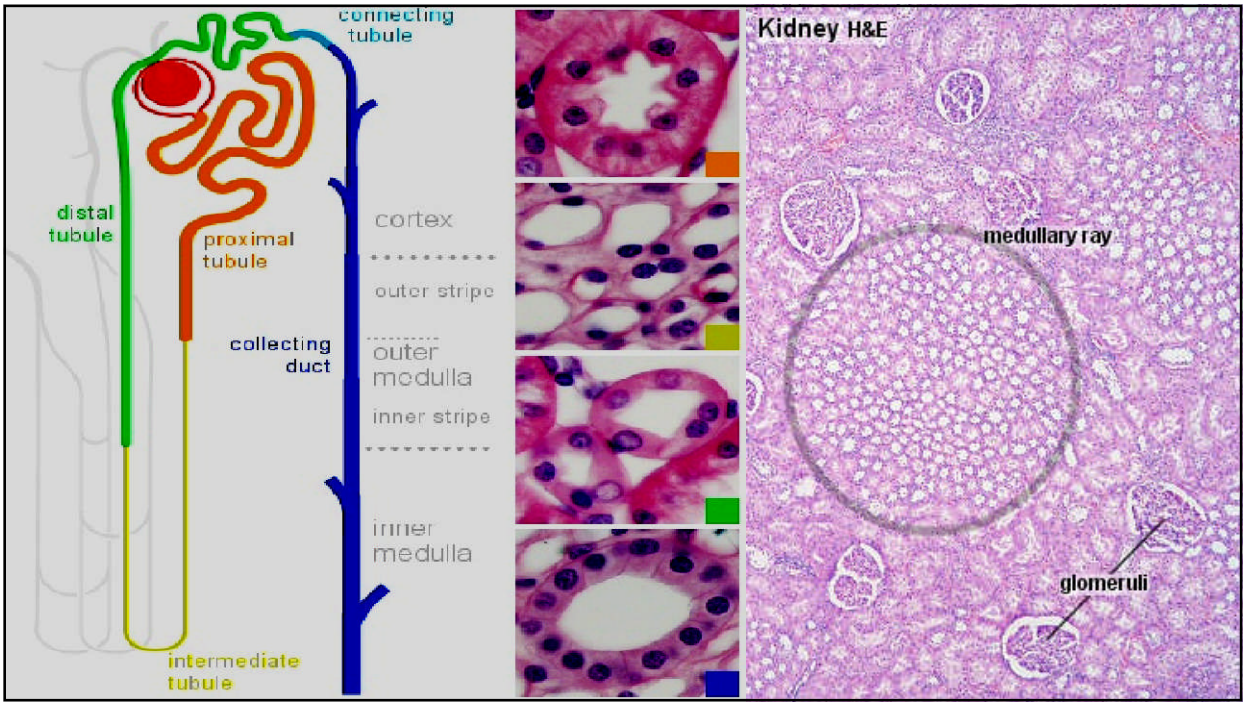


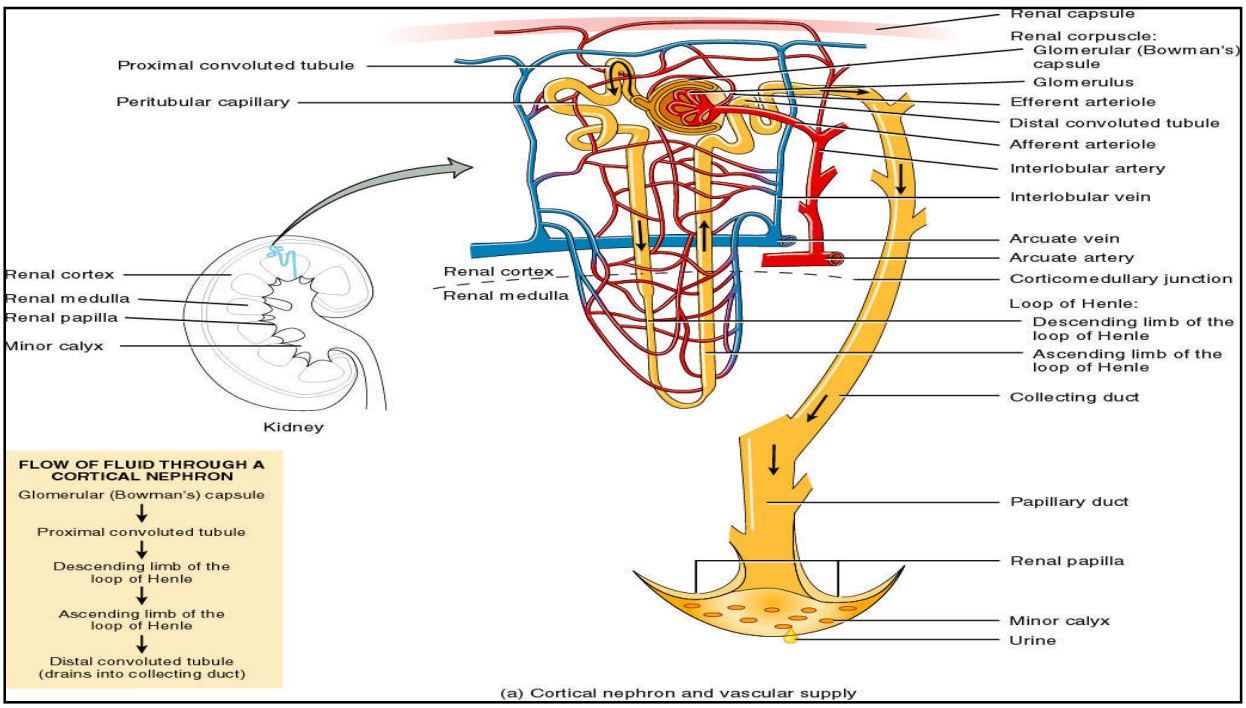


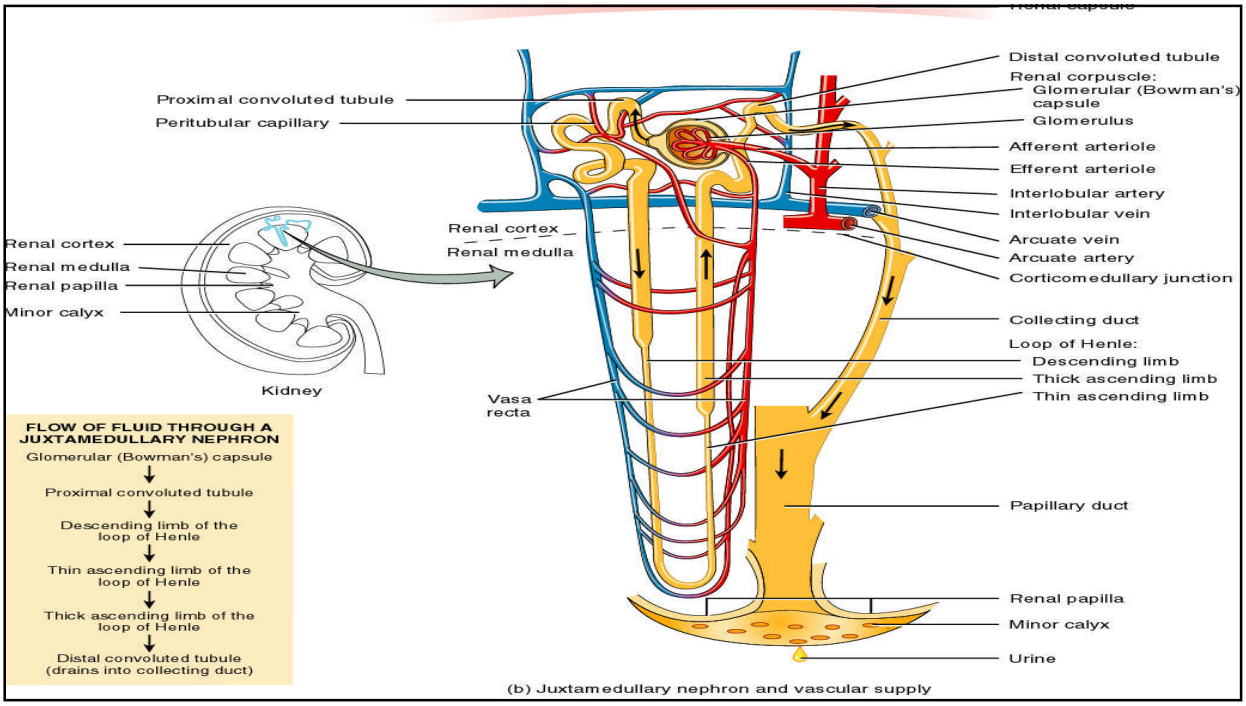


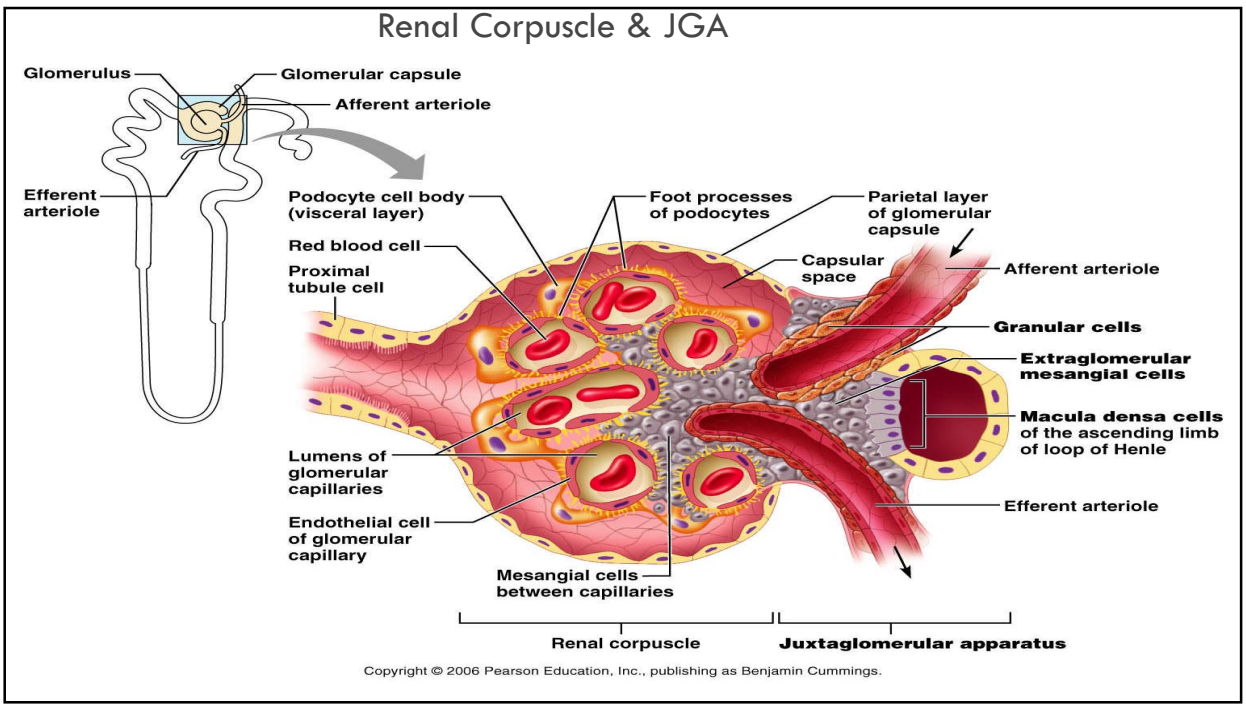
The prominent round structure shown here is a glomerulus. Also of note here are the flattened nuclei of the squamous cells lining forming the parietal layer of Bowman's capsule. The visceral layer cannot be distinguished with the preparation shown here, but this layer functions as the functional filter. The basement membrane of Bowman's capsule (a) is stained blue. Bowman's space is actually continuous witht the lumen of the proximal convoluted tubule (b), but the junction is not seen in this section. Due to fixation techniques, the glomerulus is smaller than it would be in vivo, and so Bowman's space is artifically enlarged. At the top right of the screen may be seen cross-sections of two distal convoluted tubules (c).




connecting tubule
distal tubule
proximal tubule
collecting duct
intermediate tubule
cortex
outer stripe
outer medulla
inner stripe
inner medulla
Kidney H&E
medullary ray
glomeruli


Proximal convoluted tubule
Peritubular capillary
Renal cortex
Renal medulla
Renal papilla
Minor calyx
Kidney
Renal capsule
Renal corpuscle:
Glomerular (Bowman's) capsule
Glomerulus
Efferent arteriole
Distal convoluted tubule
Afferent arteriole
Interlobular artery
Interlobular vein
Arcuate vein
Arcuate artery
Corticomedullary junction
Loop of Henle:
Descending limb of the loop of Henle
Ascending limb of the loop of Henle
Collecting duct
Papillary duct
Renal papilla
Minor calyx
Urine
FLOW OF FLUID THROUGH A CORTICAL NEPHRON
Glomerular (Bowman's) capsule
Proximal convoluted tubule
Descending limb of the loop of Henle
Ascending limb of the loop of Henle
Distal convoluted tubule (drains into collecting duct)
(a) Cortical nephron and vascular supply


Proximal convoluted tubule
Peritubular capillary
Renal cortex
Renal medulla
Renal papilla
Minor calyx
Kidney
Renal cortex
Renal medulla
Vasa recta
Distal convoluted tubule
Renal corpuscle:
Glomerular (Bowman's) capsule
Glomerulus
Afferent arteriole
Efferent arteriole
Interlobular artery
Interlobular vein
Arcuate vein
Arcuate artery
Corticomedullary junction
Collecting duct
Loop of Henle:
Descending limb
Thick ascending limb
Thin ascending limb
Papillary duct
Renal papilla
Minor calyx
Urine
FLOW OF FLUID THROUGH A JUXTAMEDULLARY NEPHRON
Glomerular (Bowman's) capsule
Proximal convoluted tubule
Descending limb of the loop of Henle
Thin ascending limb of the loop of Henle
Thick ascending limb of the loop of Henle
Distal convoluted tubule (drains into collecting duct)
(b) Juxtamedullary nephron and vascular supply


Renal Corpuscle & JGA
Glomerulus
Glomerular capsule
Afferent arteriole
Efferent arteriole
Podocyte cell body (visceral layer)
Foot processes of podocytes
Parietal layer of glomerular capsule
Red blood cell
Proximal tubule cell
Capsular space
Afferent arteriole
Granular cells
Extraglomerular mesangial cells
Macula densa cells of the ascending limb of loop of Henle
Lumens of glomerular capillaries
Endothelial cell of glomerular capillary
Efferent arteriole
Mesangial cells between capillaries
Renal corpuscle
Juxtaglomerular apparatus
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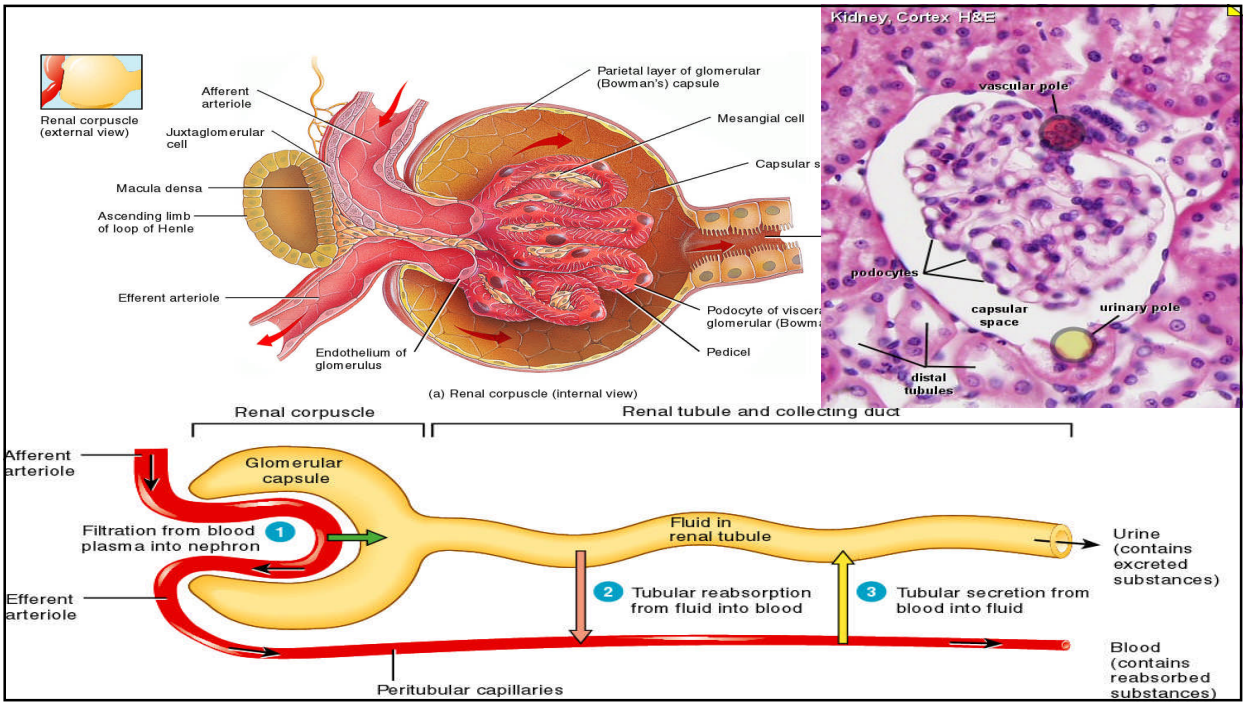
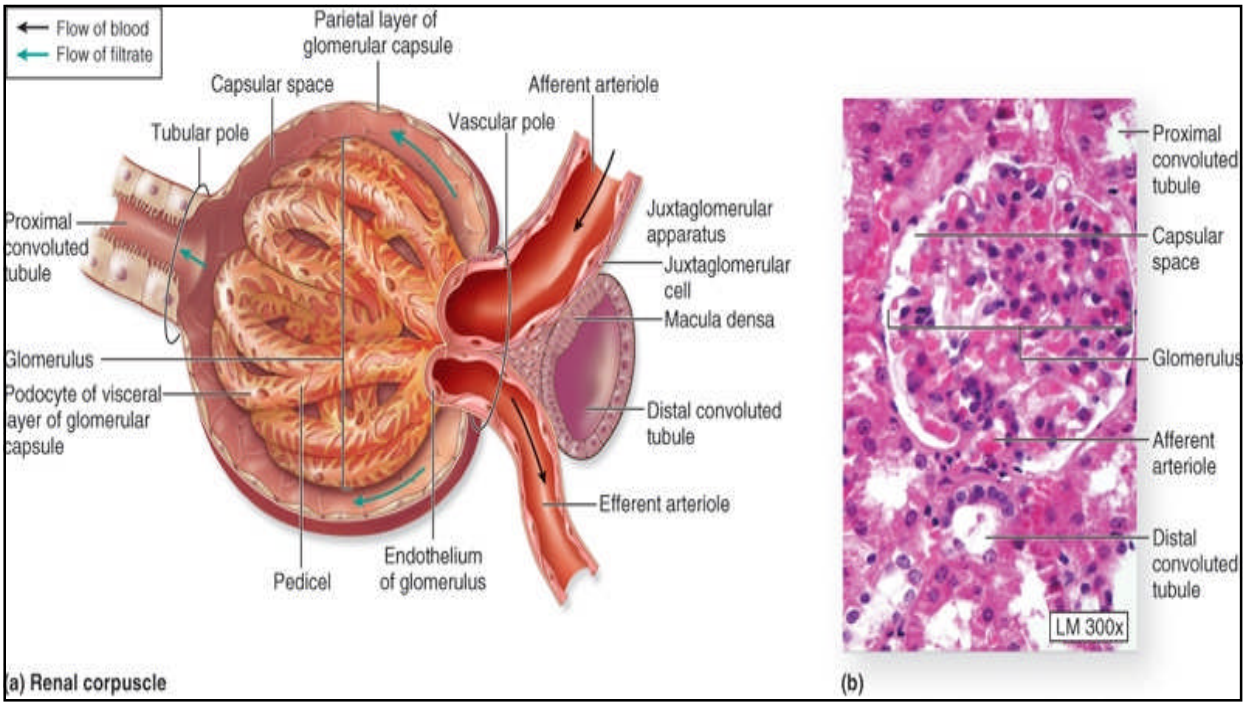
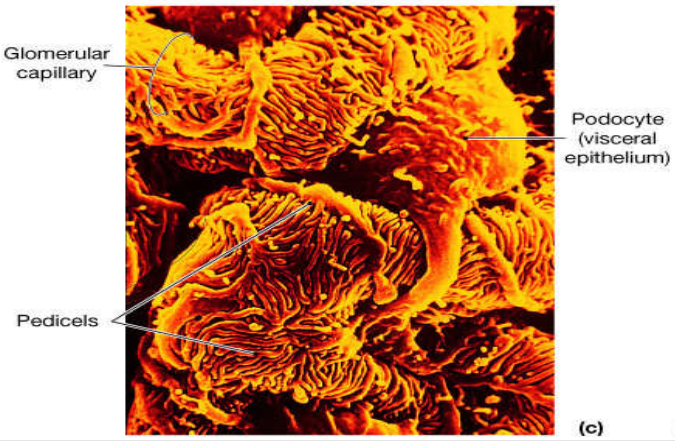
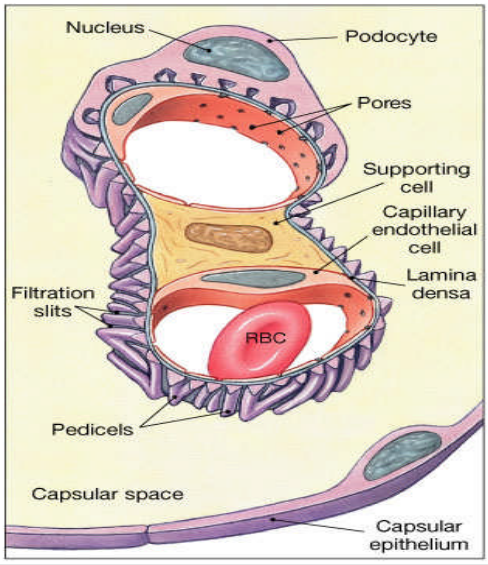
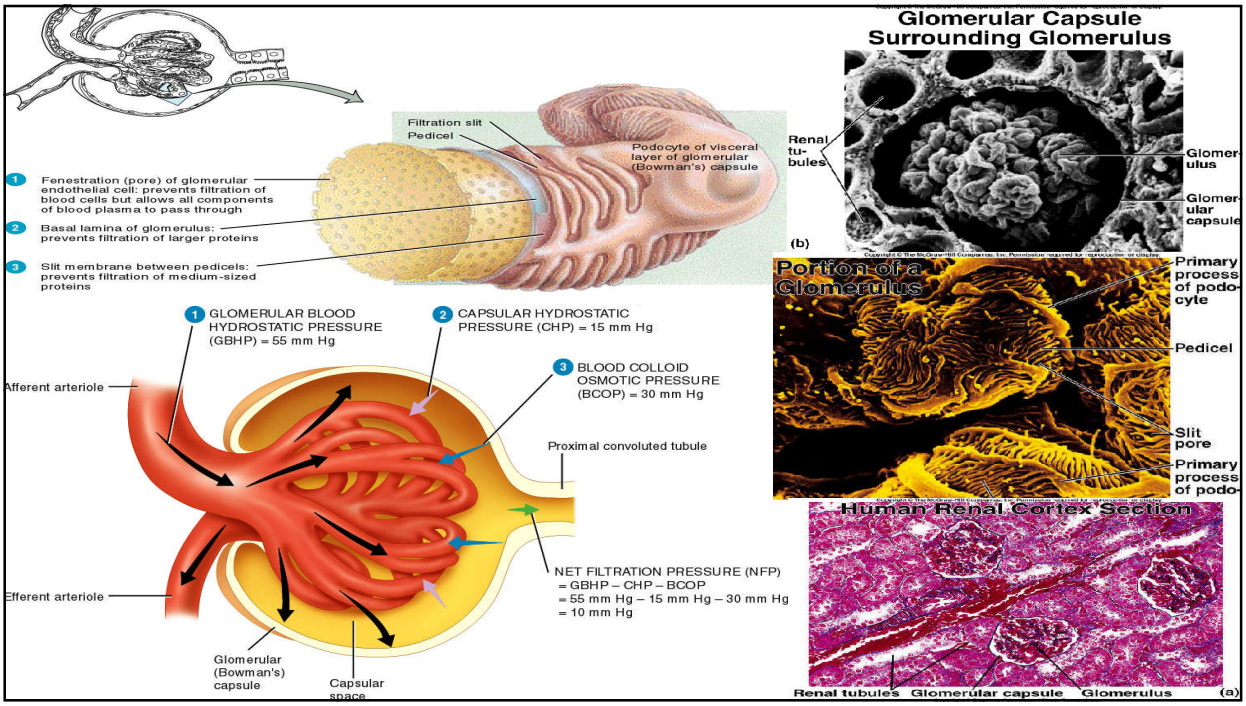

Renal corpuscle (external view)
Afferent arteriole
Juxtaglomerular cell
Macula densa
Ascending limb of loop of Henle
Efferent arteriole
Endothelium of glomerulus
Parietal layer of glomerular (Bowman's) capsule
Mesangial cell
Capsular s
Podocyte of visceral glomerular (Bowm
Pedicel
(a) Renal corpuscle (internal view)
Kidney, Cortex H&E
vascular pole
podocytes
capsular space
urinary pole
distal tubules
Renal corpuscle
Renal tubule and collecting duct
Afferent arteriole
Glomerular capsule
Filtration from blood plasma into nephron
1
Efferent arteriole
Fluid in renal tubule
2
Tubular reabsorption from fluid into blood
3
Tubular secretion from blood into fluid
Urine (contains excreted substances)
Blood (contains reabsorbed substances)
Peritubular capillaries

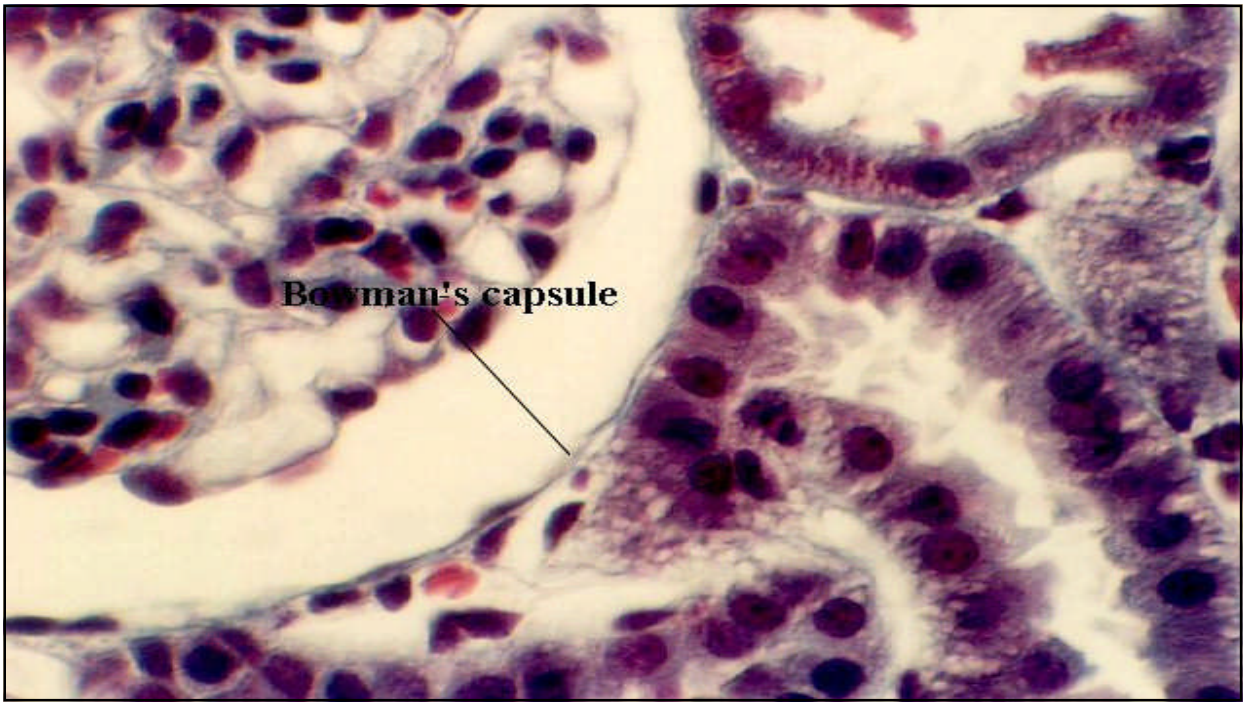

Flow of blood
Flow of filtrate
Parietal layer of glomerular capsule
Capsular space
Tubular pole
Vascular pole
Afferent arteriole
Proximal convoluted tubule
Juxtaglomerular apparatus
Juxtaglomerular cell
Macula densa
Glomerulus
Podocyte of visceral layer of glomerular capsule
Distal convoluted tubule
Efferent arteriole
Pedicel
Endothelium of glomerulus
(a) Renal corpuscle
Proximal convoluted tubule
Capsular space
Glomerulus
Afferent arteriole
Distal convoluted tubule
LM 300x
(b)

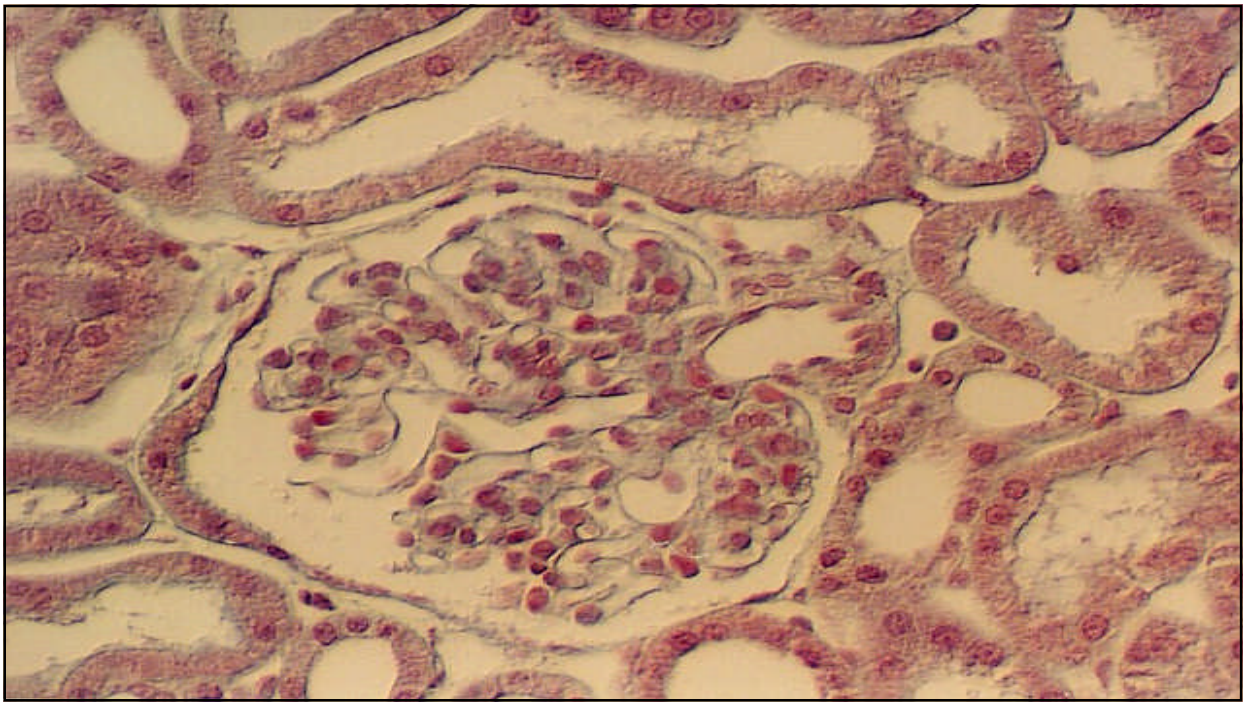
The Renal Corpuscle

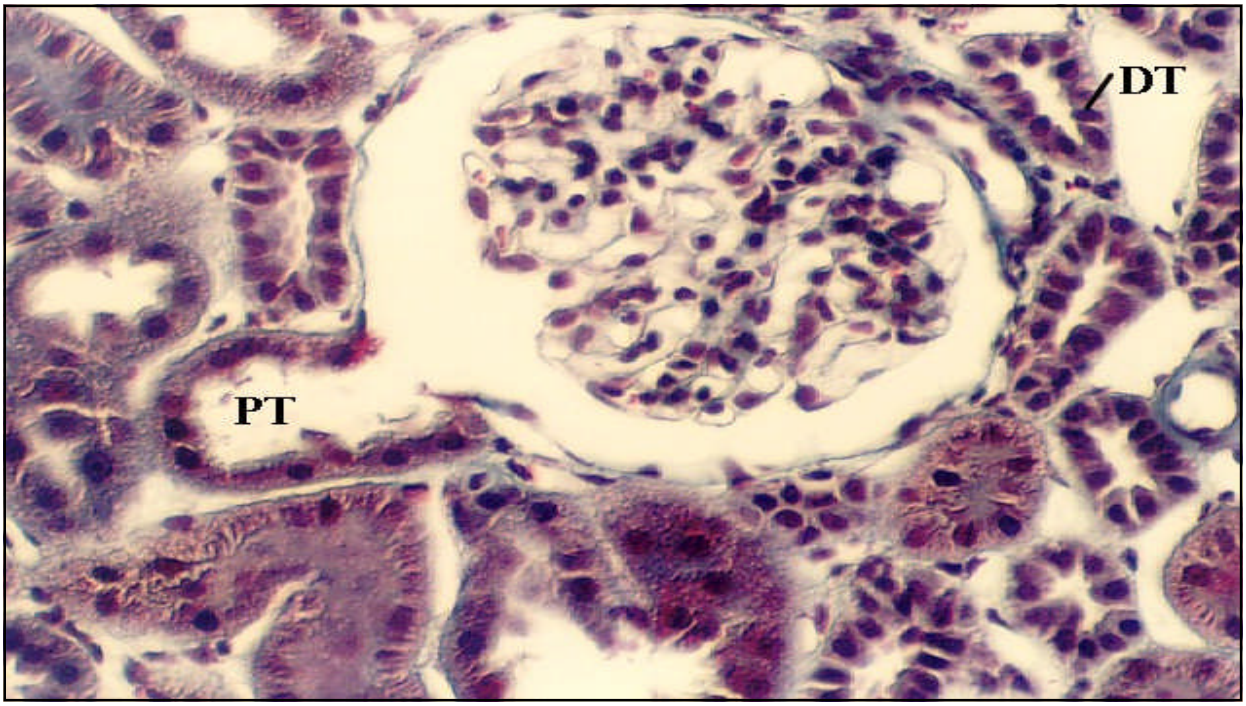


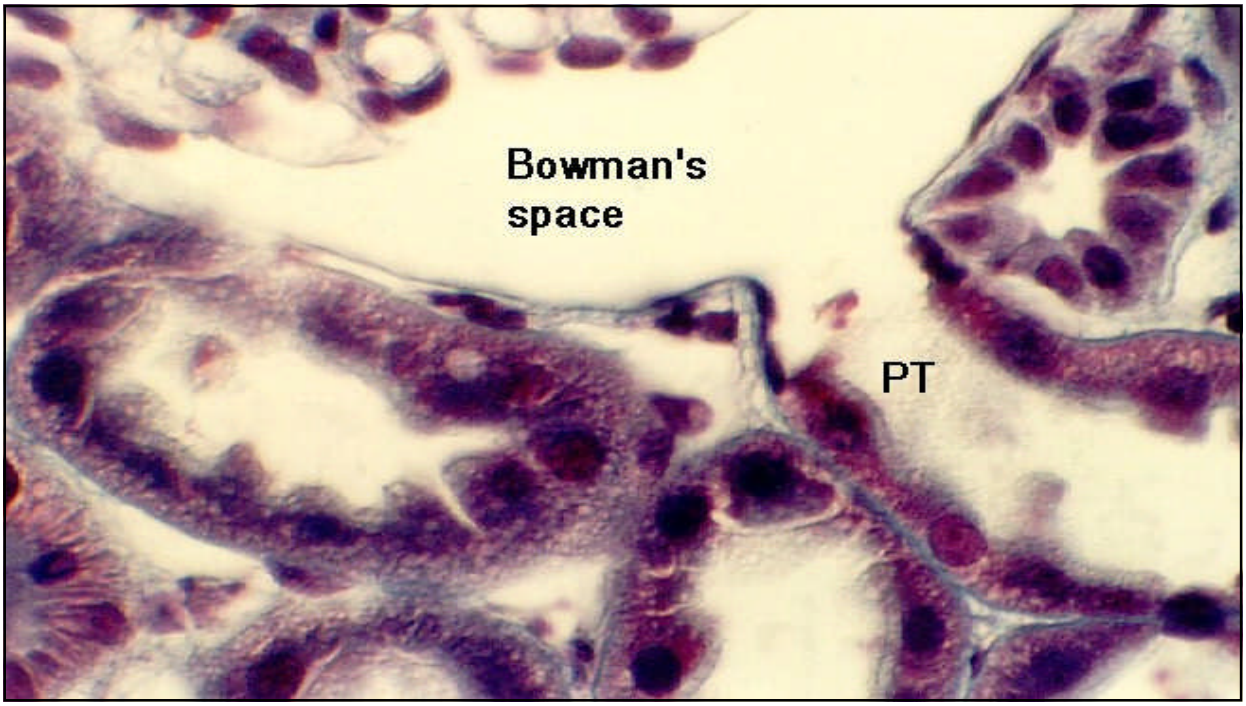


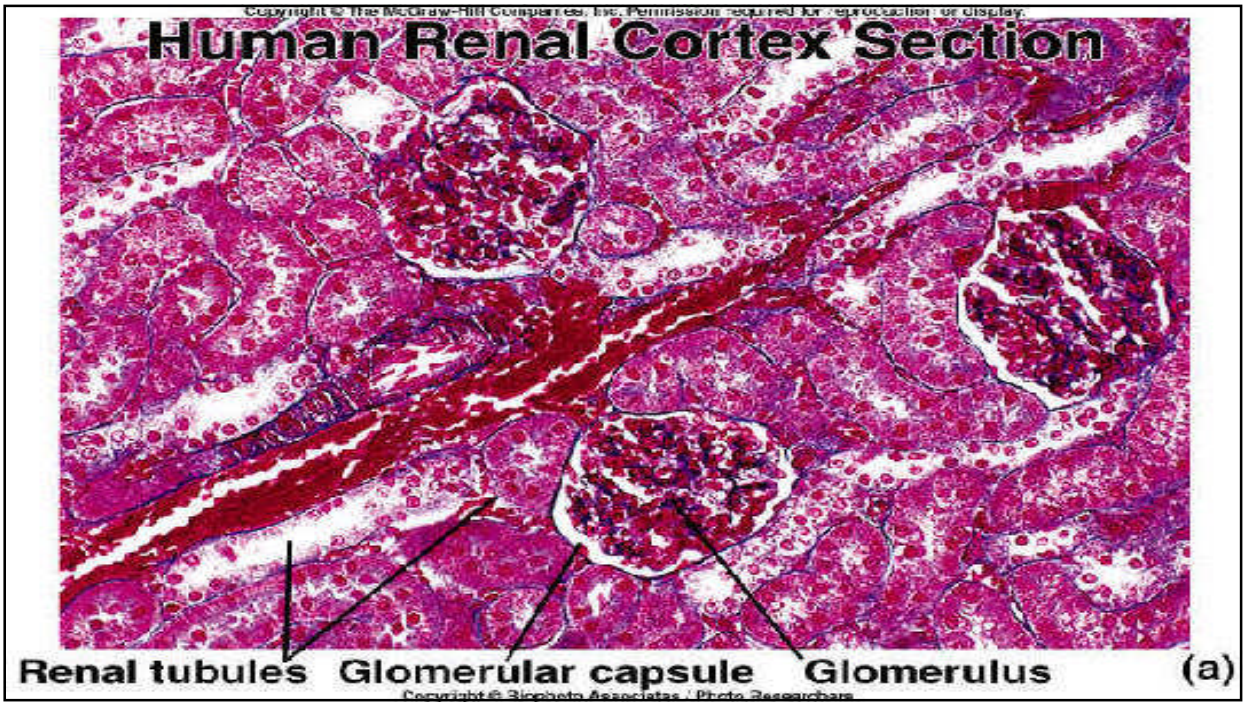


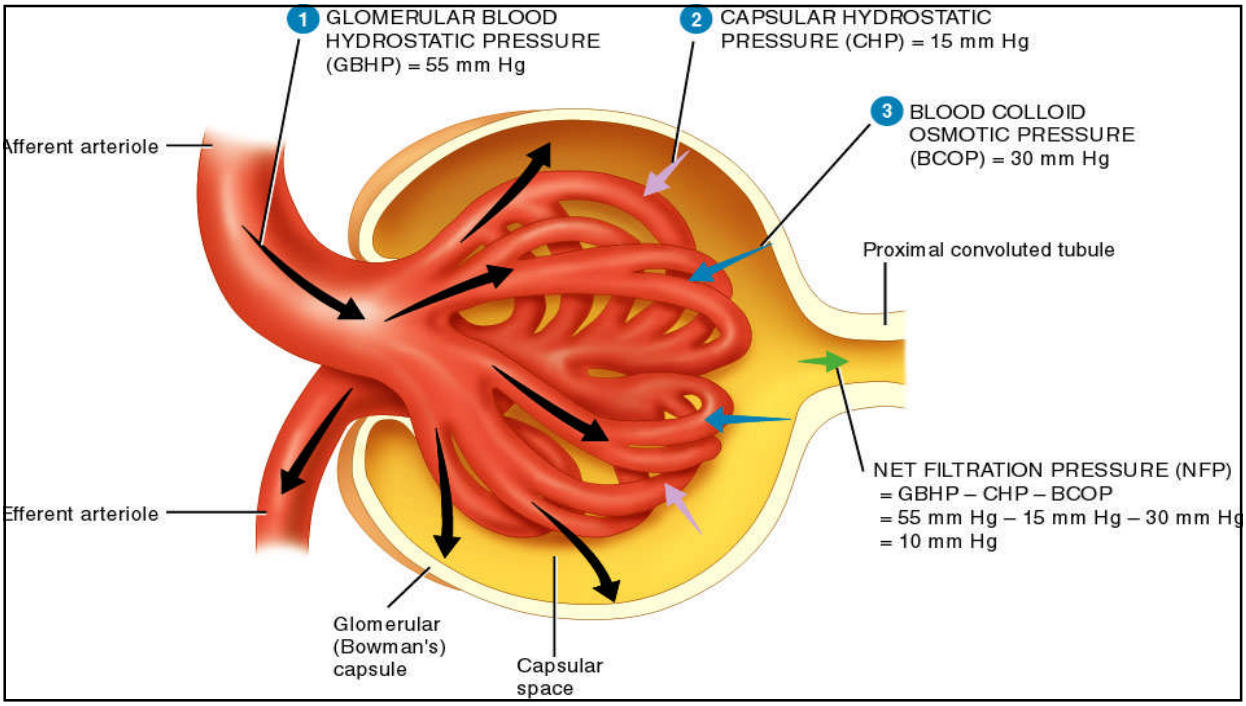

Bowman's capsule




DT
PT

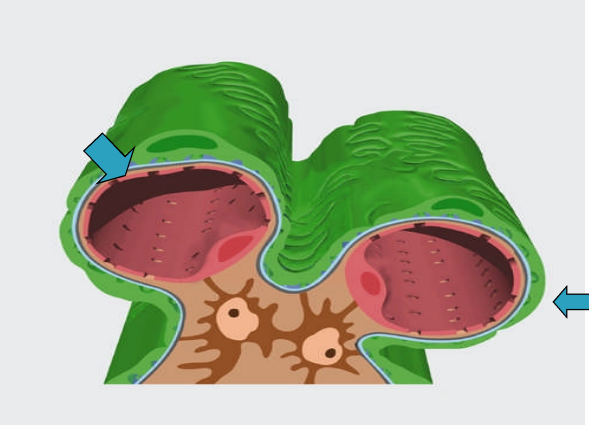

Bowman's
space
PT


Human Renal Cortex Section
Renal tubules
Glomerular capsule
Glomerulus
(a)


1 GLOMERULAR BLOOD HYDROSTATIC PRESSURE (GBHP) = 55 mm Hg
2 CAPSULAR HYDROSTATIC PRESSURE (CHP) = 15 mm Hg
3 BLOOD COLLOID OSMOTIC PRESSURE (BCOP) = 30 mm Hg
Afferent arteriole
Proximal convoluted tubule
NET FILTRATION PRESSURE (NFP)
= GBHP – CHP – BCOP
= 55 mm Hg – 15 mm Hg – 30 mm Hg
= 10 mm Hg
Efferent arteriole
Glomerular (Bowman's) capsule
Capsular space

- Fluid from capillaries leaks into the urinary space through a complex filtration barrier
- Capillary endothelium
- Basal lamina
- Podocytes of the visceral layer of Bowman's capsule
- High polyanionic charge on some components of both basal lamina and surface of podocyte processes

Glomerular capillaries



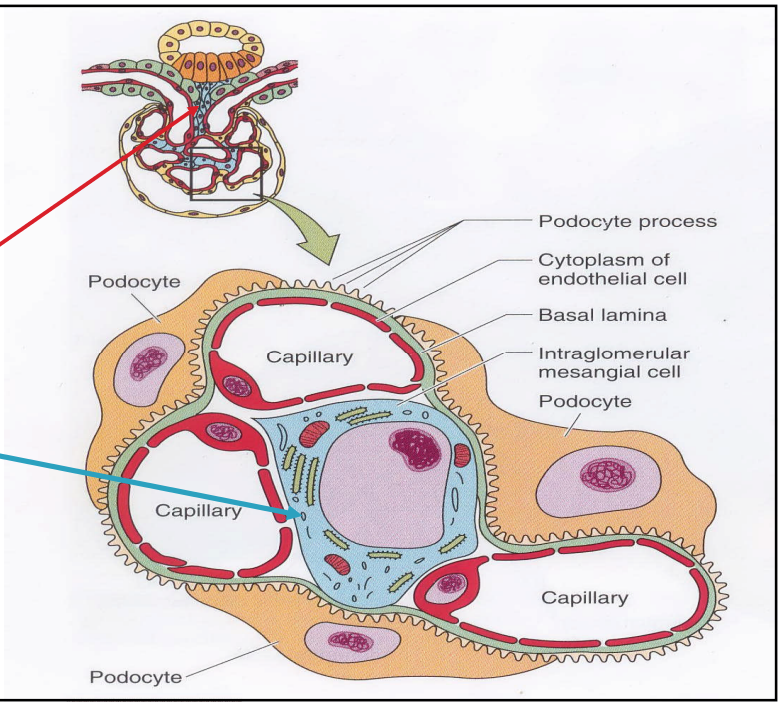
- Fenestrated
- Large pores not covered by a diaphragm
- Barrier only to formed elements in blood & large macromolecules

Mesangial cells

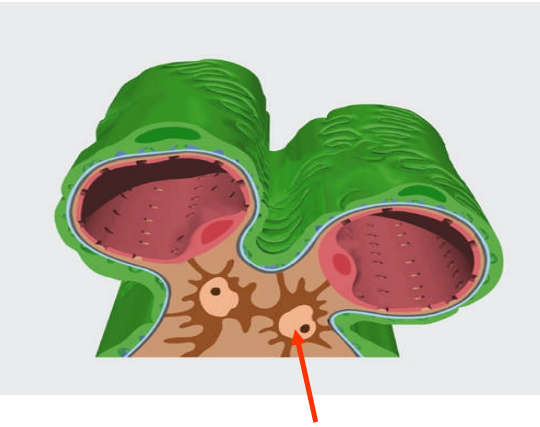
Supporting cells, Modified smooth Muscle

Extraglomerular (vascular pole)

Intraglomerular

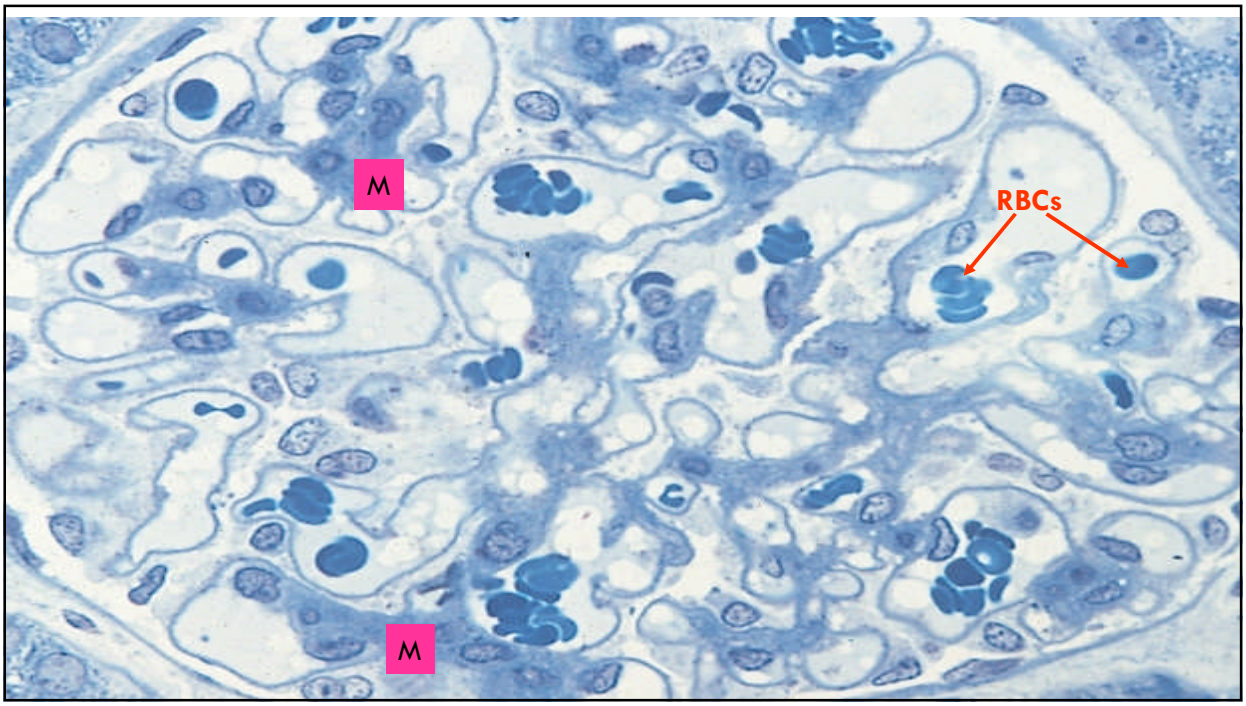


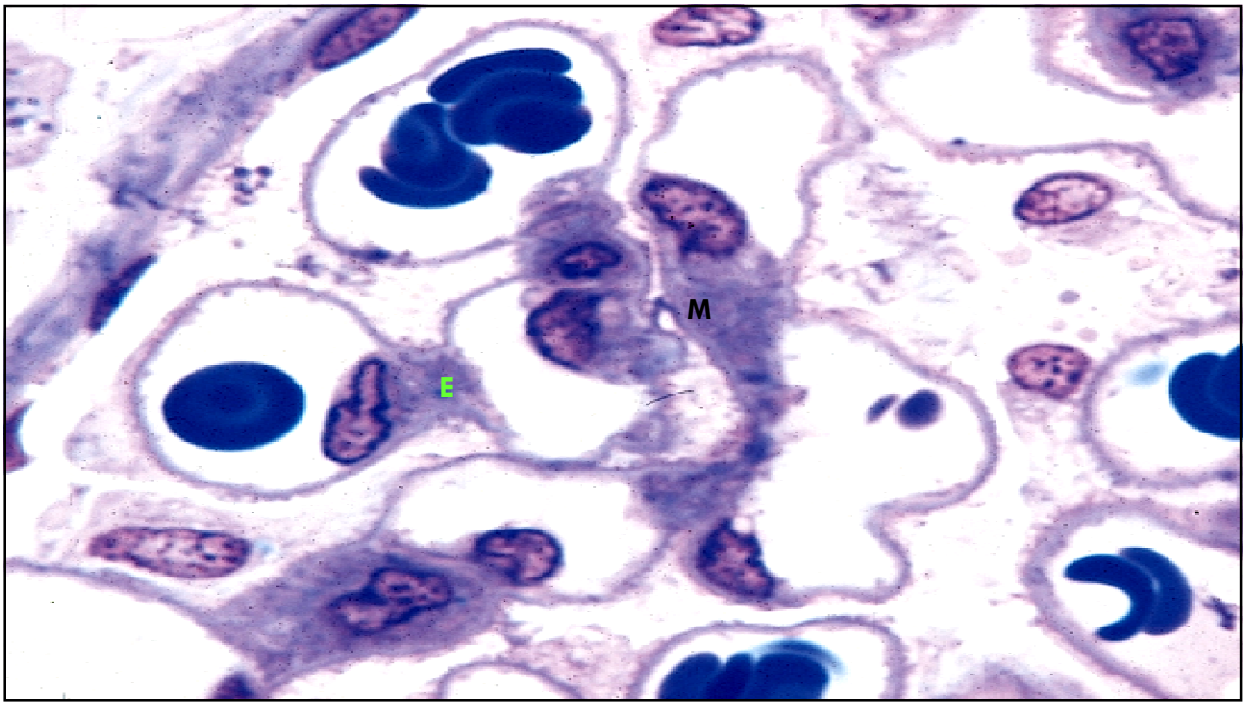
Functions of Mesangial Cells

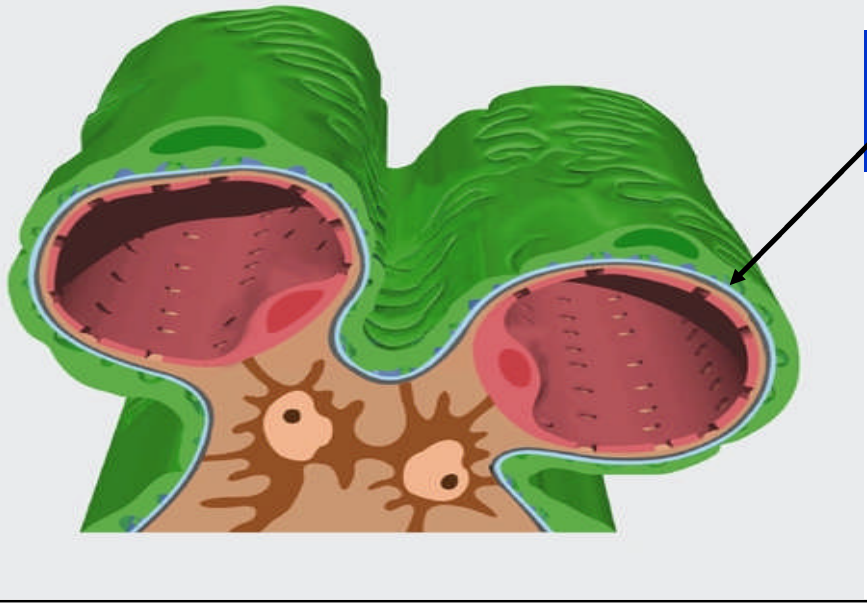


Intraglomerular mesangial cells

- Contractile
- Supportive
- Phagocytic


M
RBCs
M


M
E

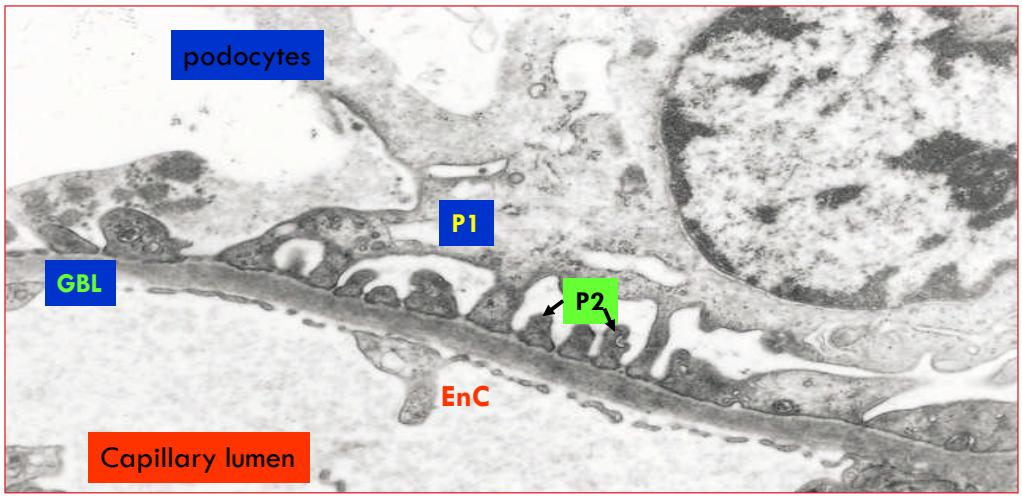


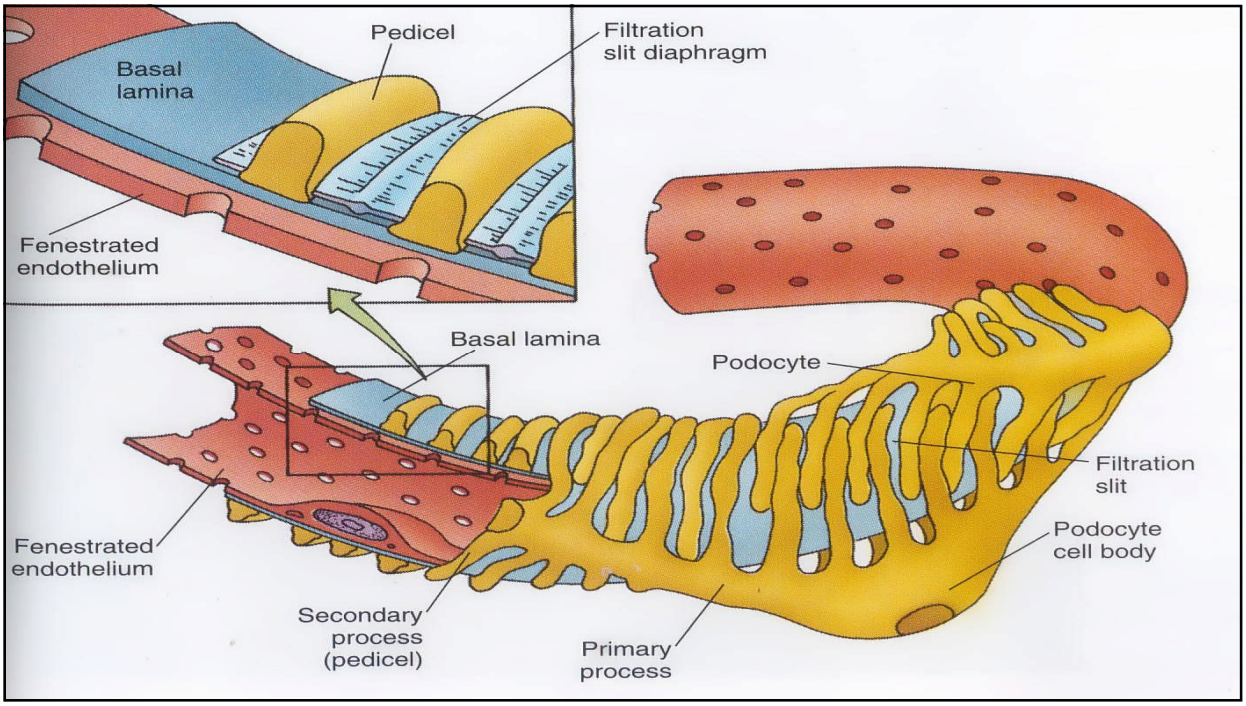
Basal Lamina

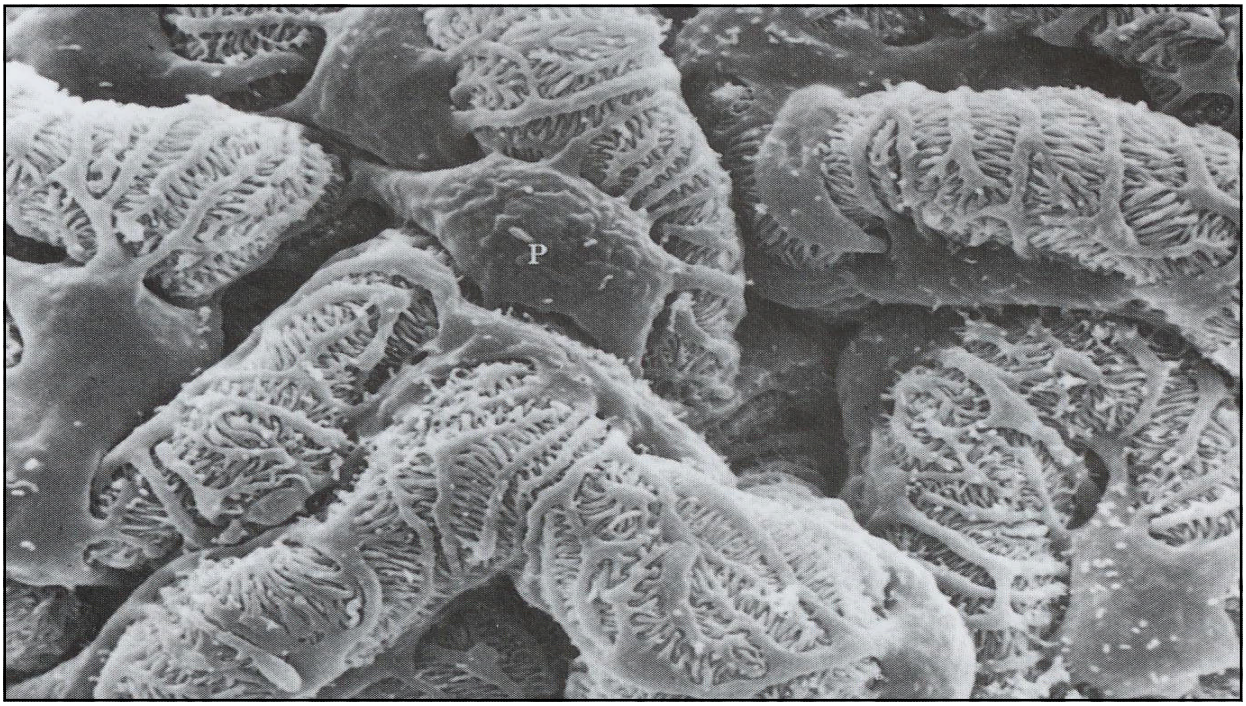
Lamina rarae contain:
Laminin
Fibronectin
Negatively-charged proteoglycans

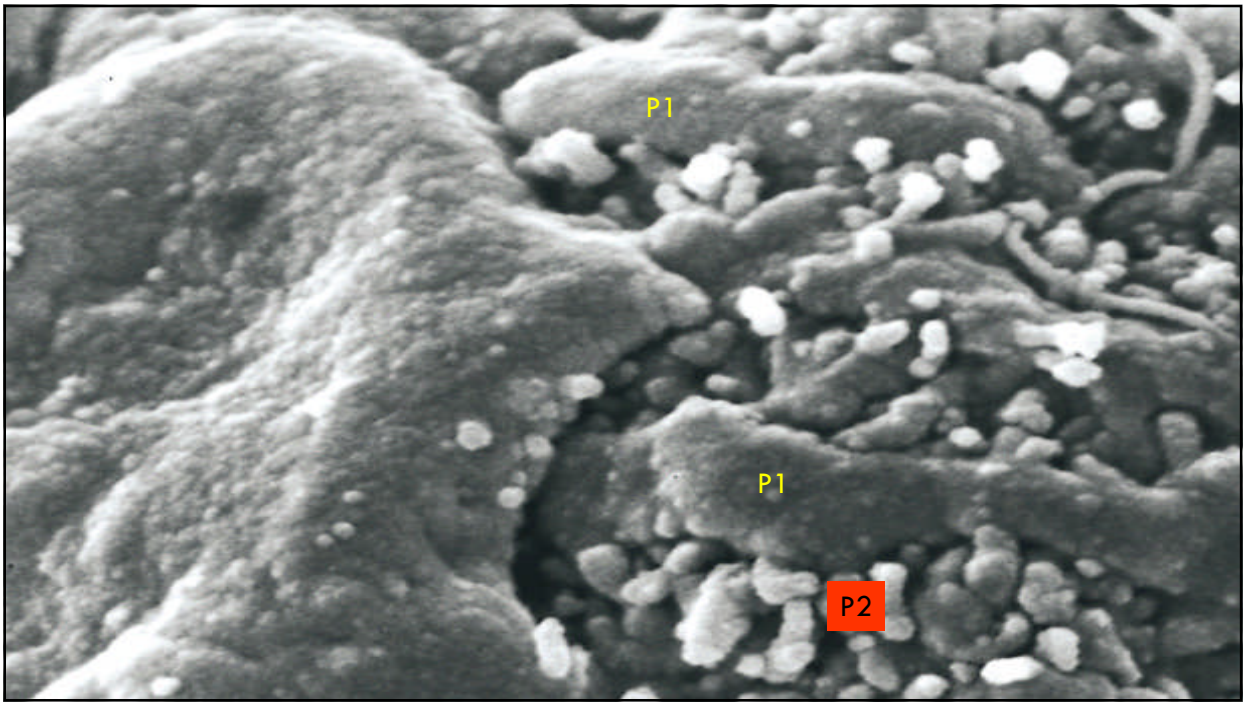
Lamina densa (IV)
Lamina rarae

Visceral Layer of Bowman's Capsule

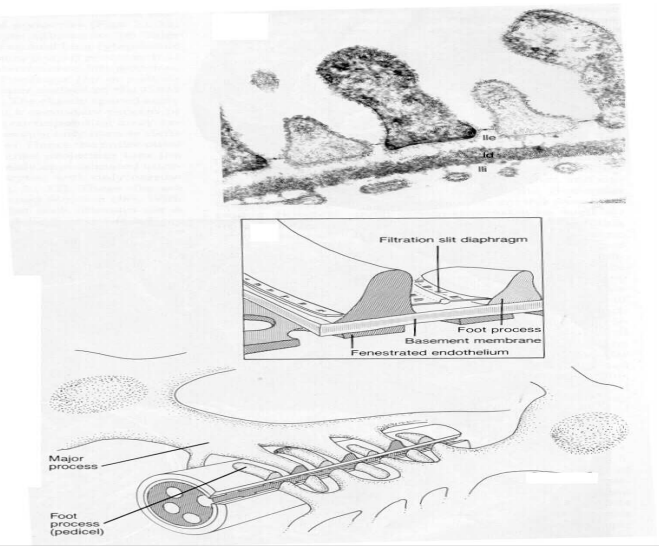





P


P1
P1
P2

Pedicels & Filtration slits



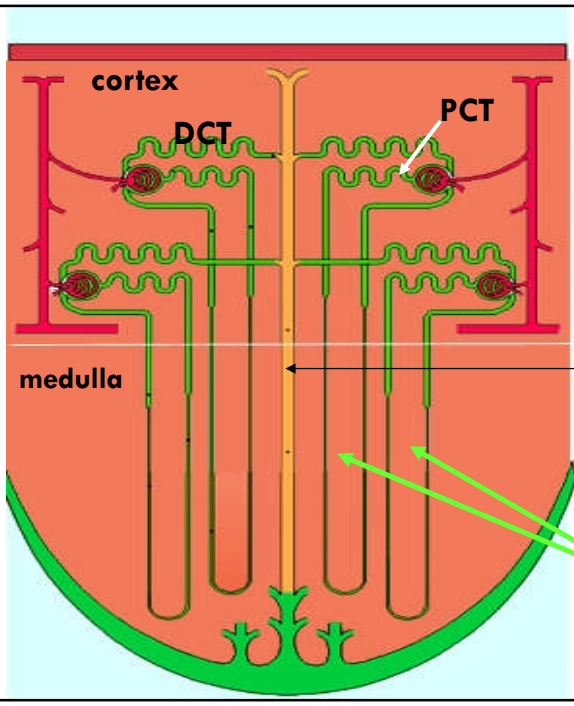
- Each pedicel has a glycocalyx of negatively-charged podocalyxin
- Separated by clefts – filtration slits
- Covered by a porous slit diaphragm

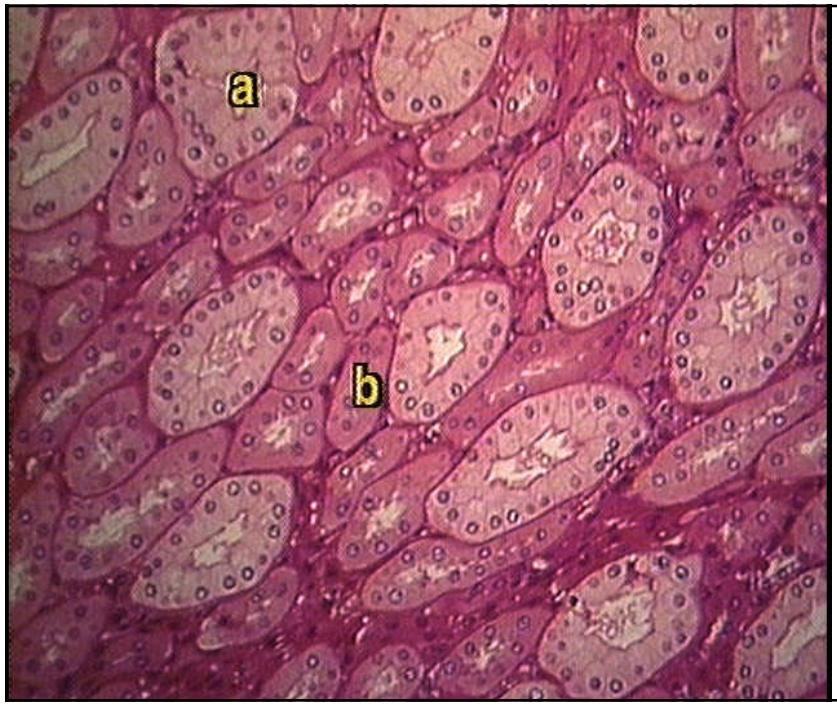
Filtration Process

- Blood enters glomerulus via afferent arteriole
- Arteriole pressure forces fluid through fenestrae of capillary endothelium
- Large molecules are trapped by the basal lamina
- Negatively charged molecules are stopped by the basal lamina & podocytes
- Fluid passes though pores in slit diaphragm to enter the urinary space.

Tubular and Collecting System

Glomerular ultrafiltrate leaves urinary space and enters tubule which modifies its composition





renal medulla demonstrates the arrangement of the various tubular and vascular structures. The formed connective tissue elements among the tubules and vessels are very sparse and sonsist mainly of fibroblasts, macrophages and fibers.

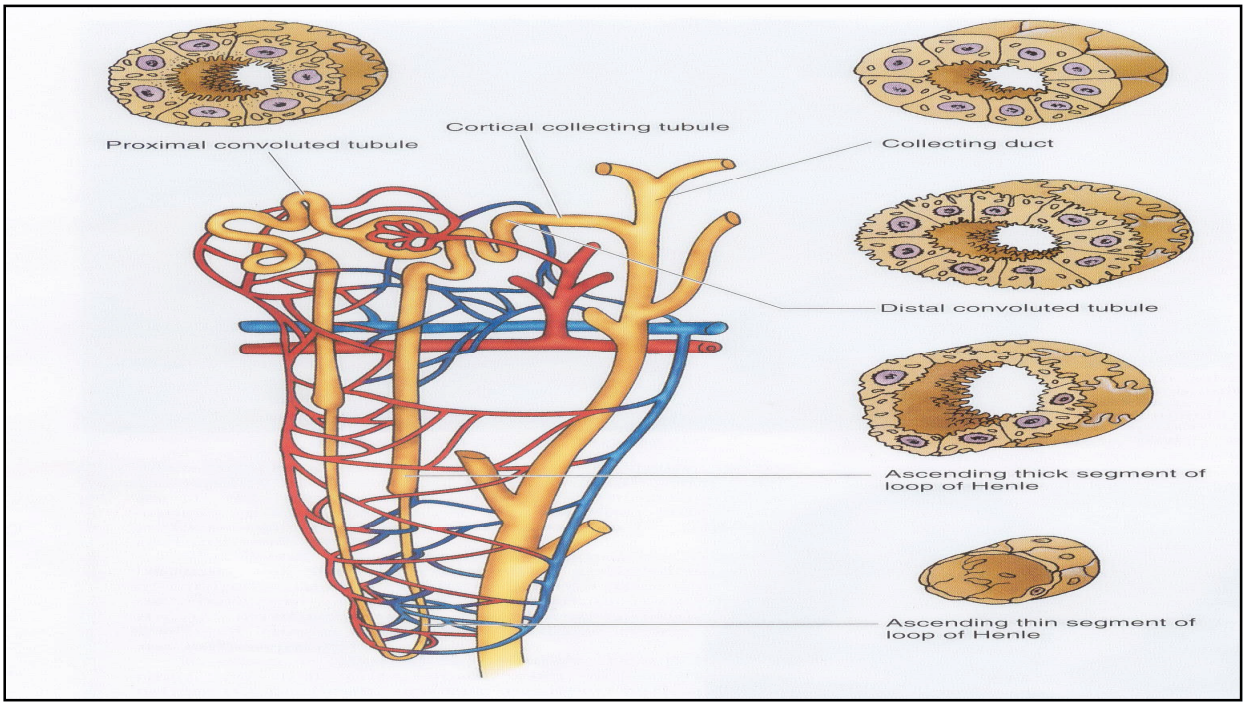
The major tubular elements in evidence are the collecting tubules (a), recognizable by the conspicuous lateral plasma membranes of their tall cuboidal cells, and the thick limbs of Henle's loop (b).

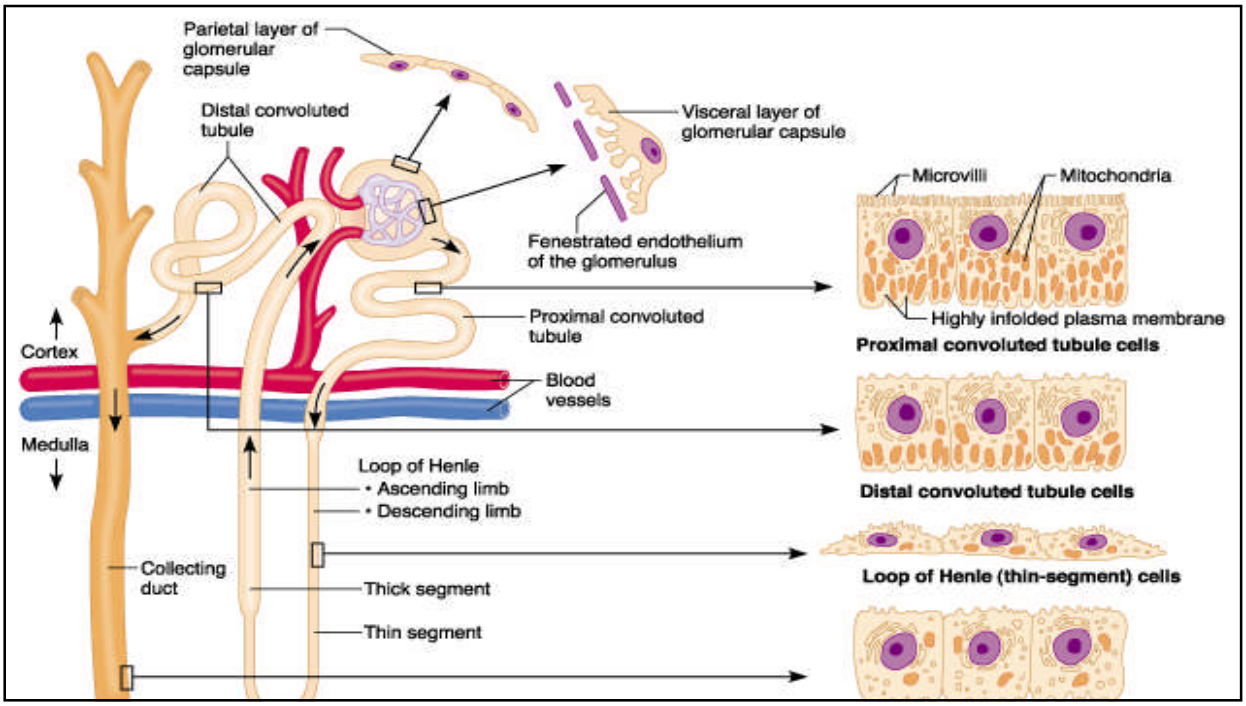
Functional anatomy of the nephron

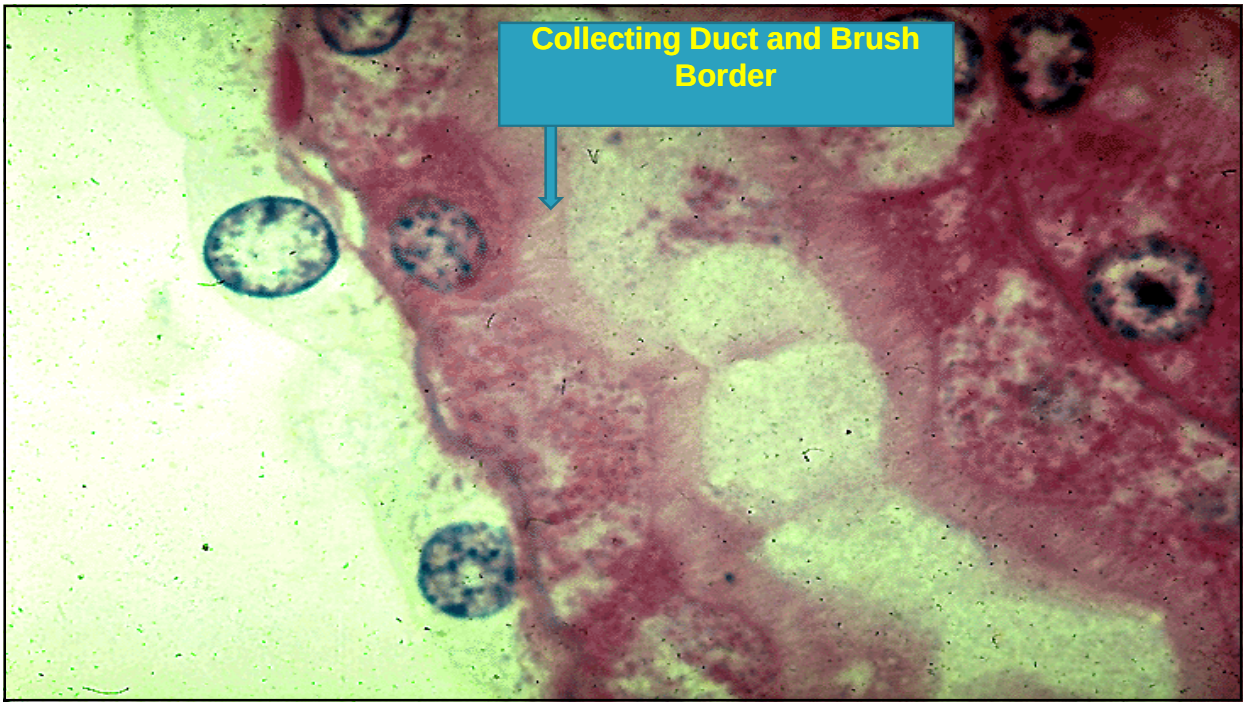
- **Proximal convoluted tubule (PCT)**
  - Actively reabsorbs nutrients, plasma proteins and ions from filtrate
  - Released into peritubular fluid
- **Loop of Henle**
  - Descending limb
  - Ascending limb
  - Each limb has a thick and thin section

Functional anatomy of the nephron

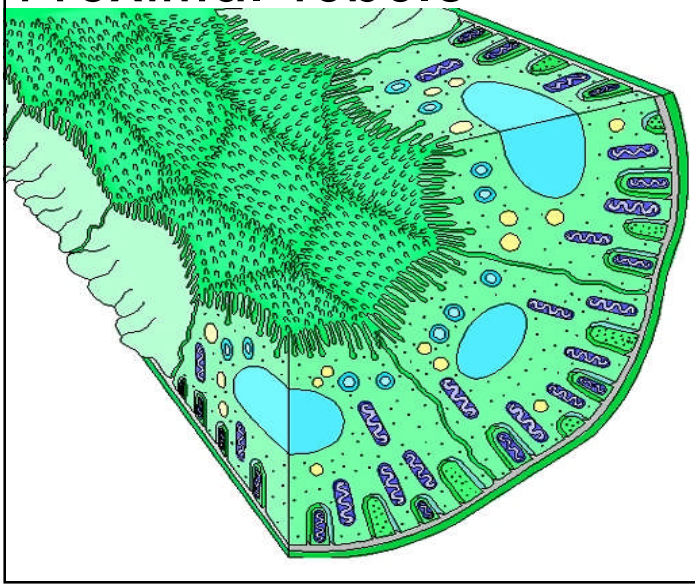
- **Distal convoluted tubule (DCT)**
  - Actively secretes ions, toxins, drugs
  - Reabsorbs sodium ions from tubular fluid


Proximal convoluted tubule
Cortical collecting tubule
Collecting duct
Distal convoluted tubule
Ascending thick segment of loop of Henle
Ascending thin segment of loop of Henle

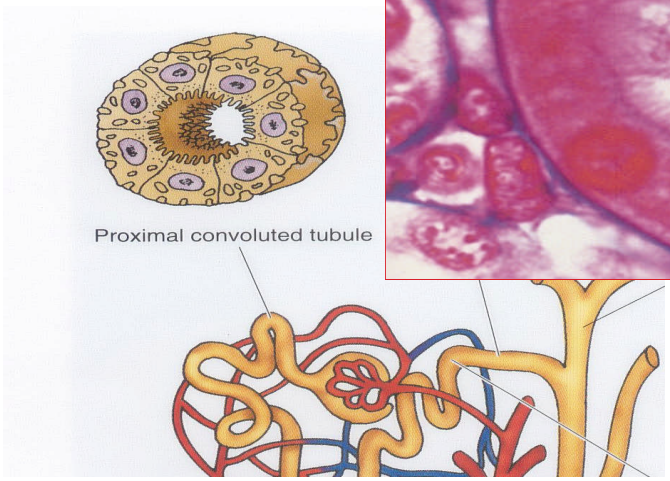

Parietal layer of glomerular capsule
Distal convoluted tubule
Visceral layer of glomerular capsule
Fenestrated endothelium of the glomerulus
Proximal convoluted tubule
Cortex
Blood vessels
Medulla
Loop of Henle
• Ascending limb
• Descending limb
Collecting duct
Thick segment
Thin segment
Microvilli
Mitochondria
Highly infolded plasma membrane
Proximal convoluted tubule cells
Distal convoluted tubule cells
Loop of Henle (thin-segment) cells

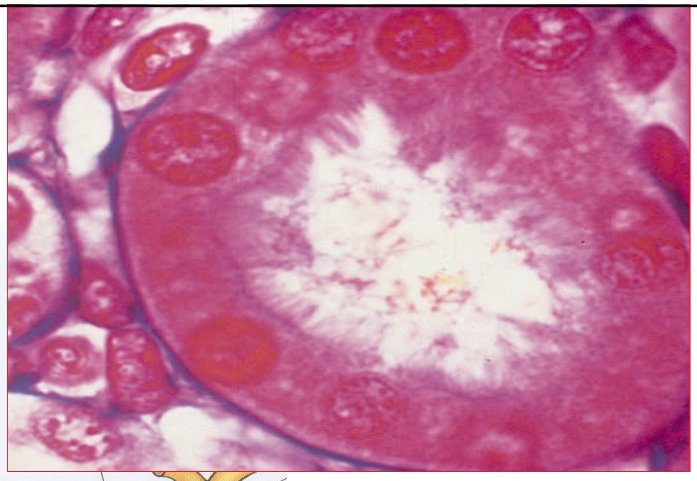


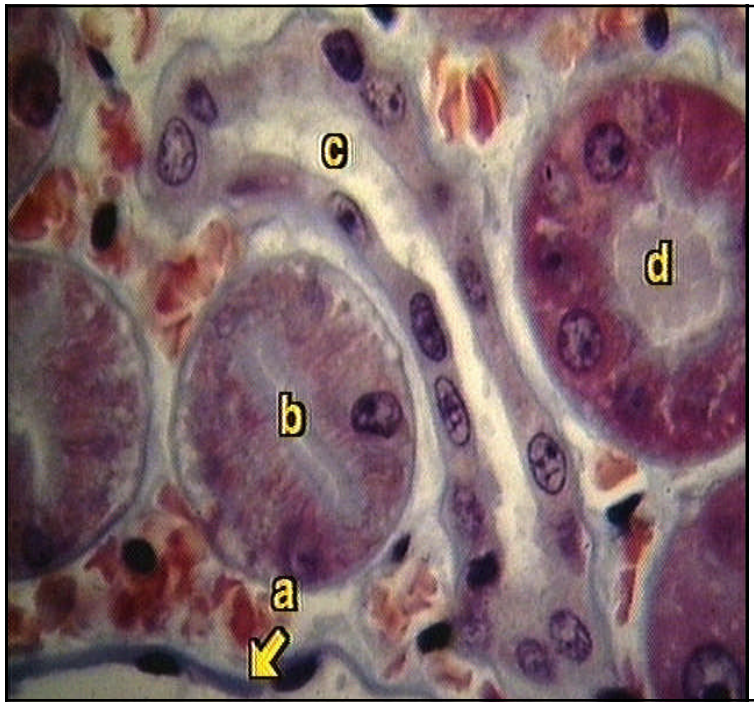
Proximal Tubule



- Begins at urinary pole
- Lined by eosinophilic cuboidal/ low columnar epithelium
- Centrally placed nucleus
- Microvilli & well-defined brush border
- Lateral border indistinct due to interdigitations







This frame demonstrates some of the differences between the proximal and distal convoluted tubules of the kidney.

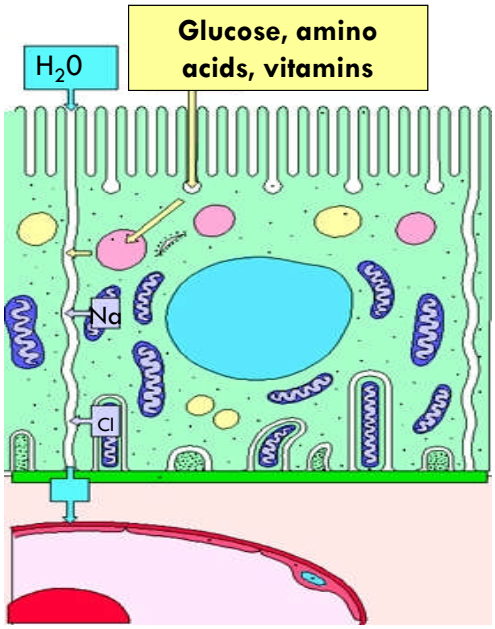
At the lower left is the simple squamous epithelium of the parietal Bowman's capsule (a).
The brush border of a proximal tubule is composed of microvilli and can be seen in cross-section at (b).
A more longitudinal section of another proximal tubule is seen at (c).
The lumen of a distal tubule is does not possess a brush border, as can be seen in the structure labeled (d).

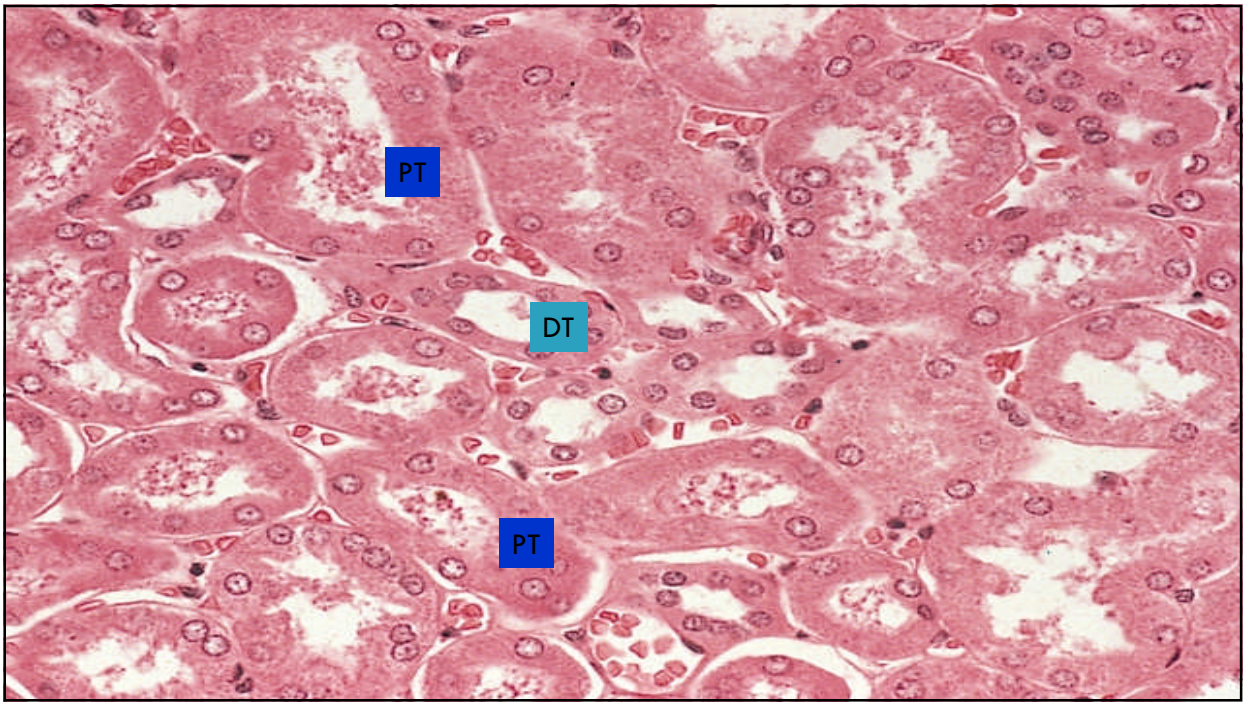
Proximal Tubule

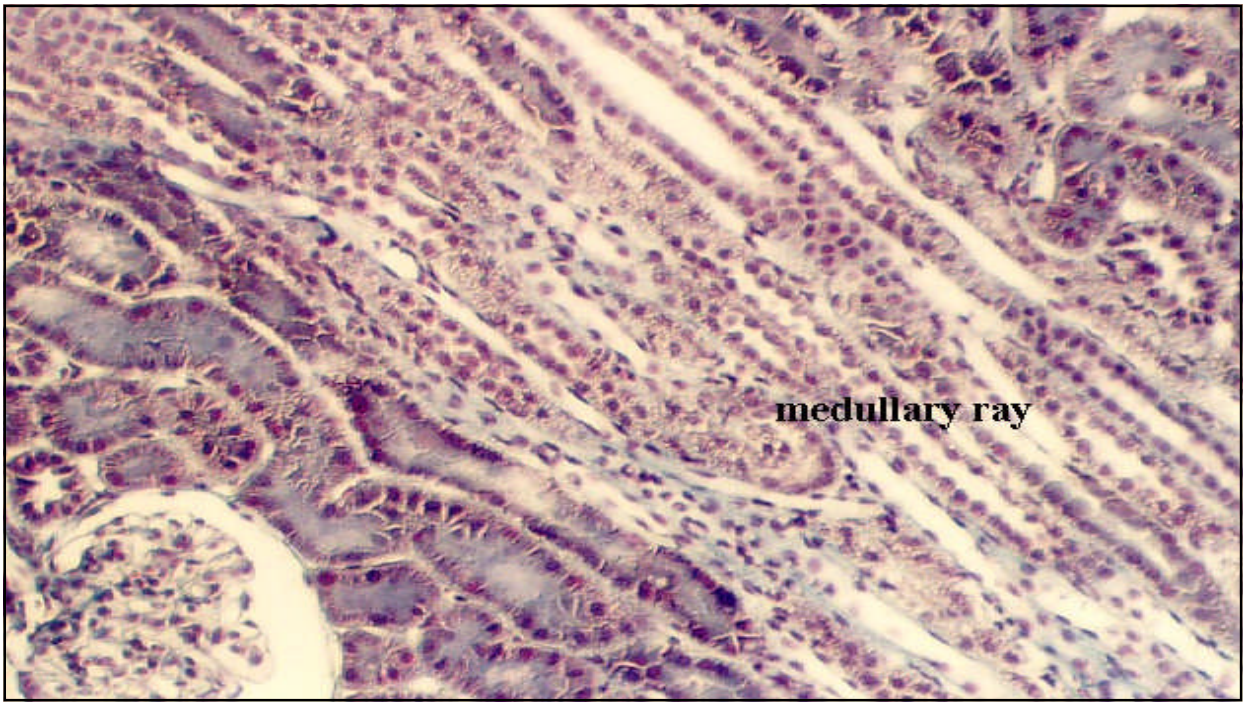
Extensive reabsorption of glomerular filtrate (microvilli).

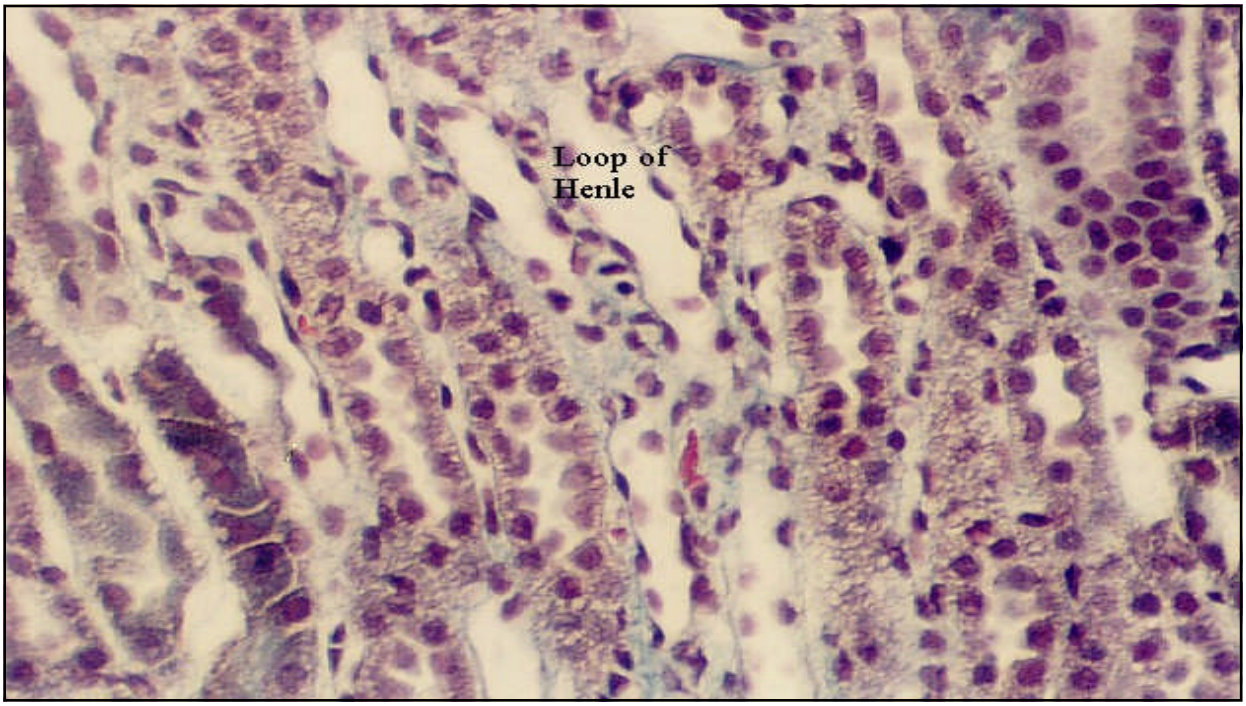
NA^+ (active transport)
Cl^- (passive diffusion)
H_20

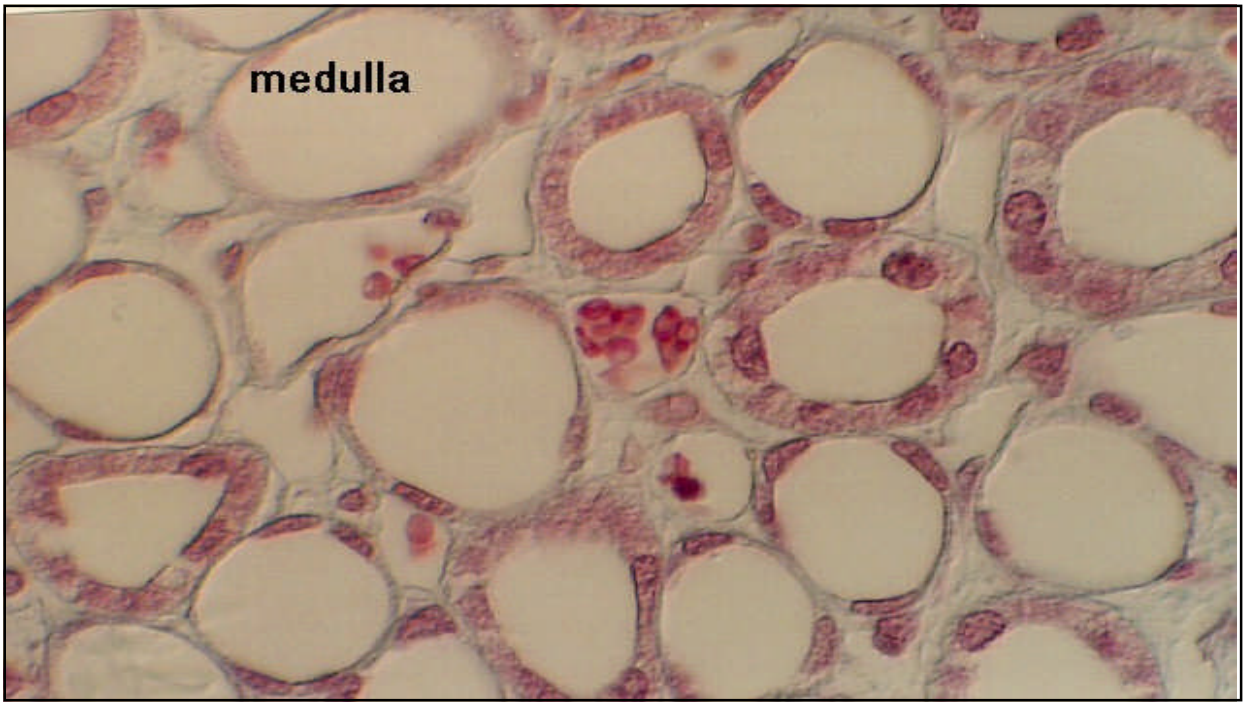
Reduction in fluid volume

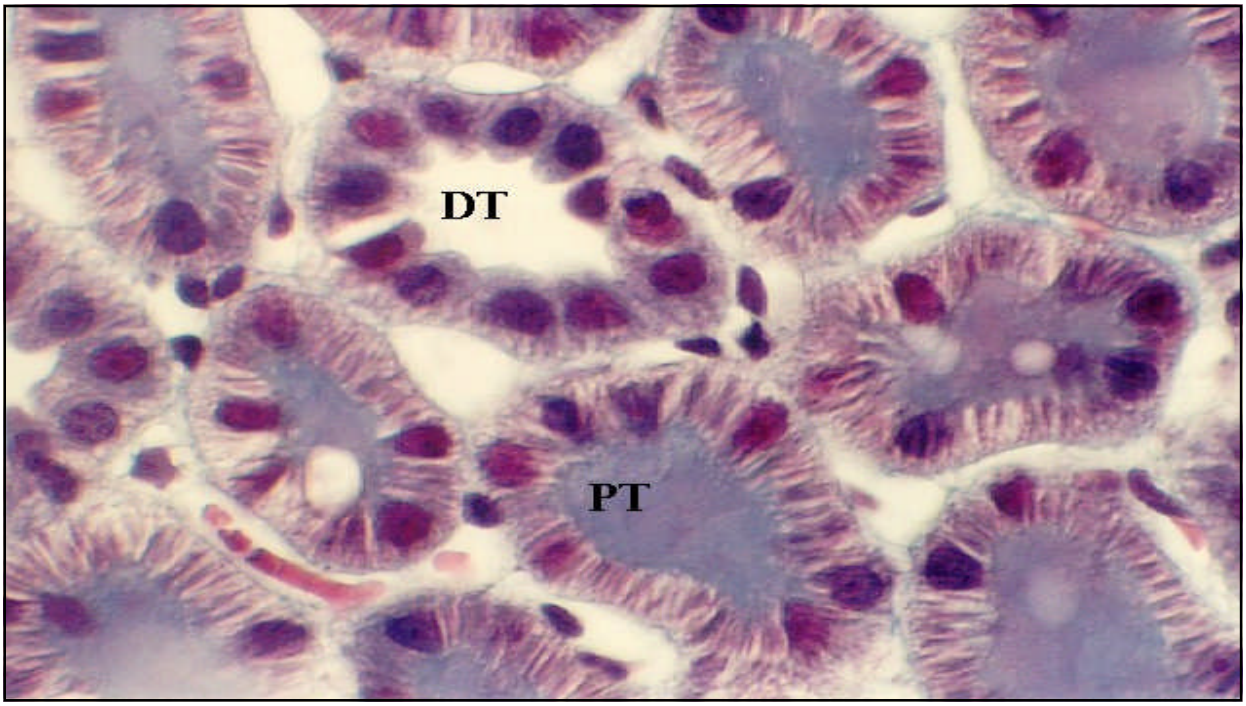


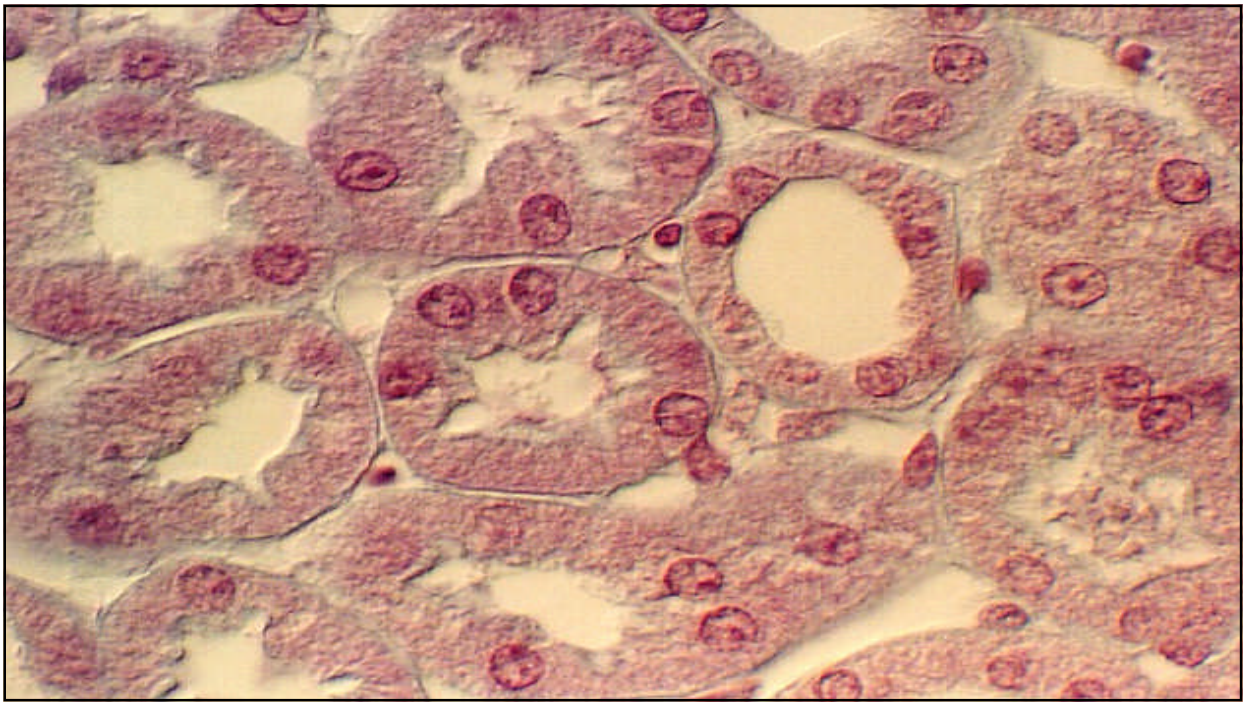



medullary ray


Loop of
Henle

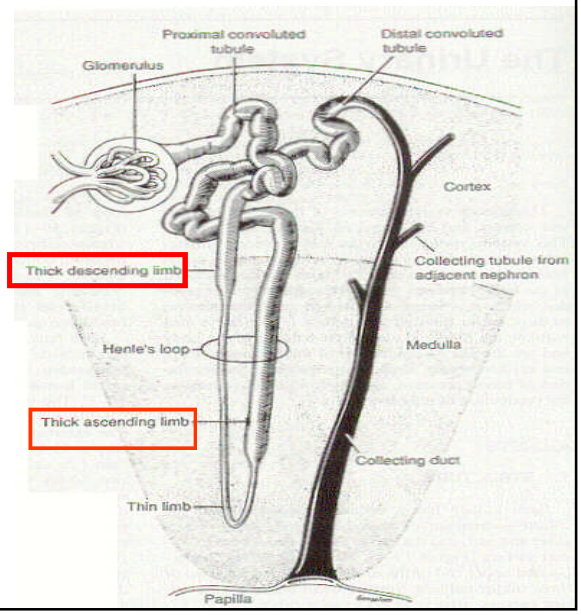

medulla


DT
PT



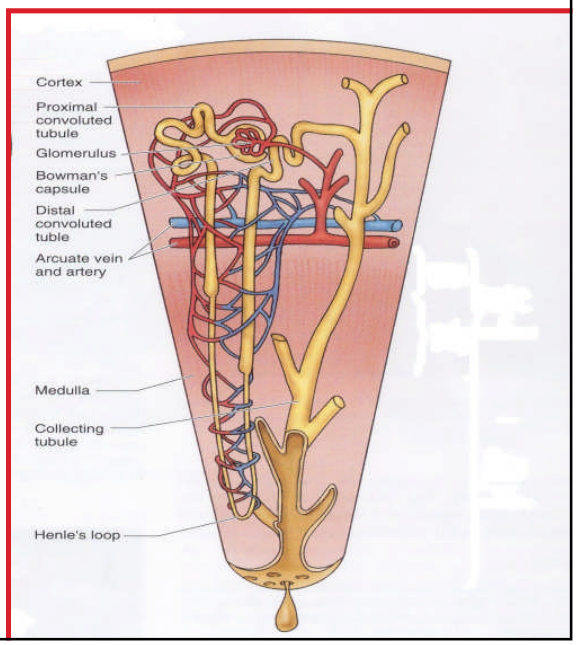
LOOP OF HENLE: STRUCTURE

- U-shaped epithelial tube
- Consists of a thick & thin descending limb and a thick & thin ascending limb
- Thick & thin denote and epithelial change (cuboidal to squamous) in both the descending and ascending limbs



LOOP OF HENLE: STRUCTURE

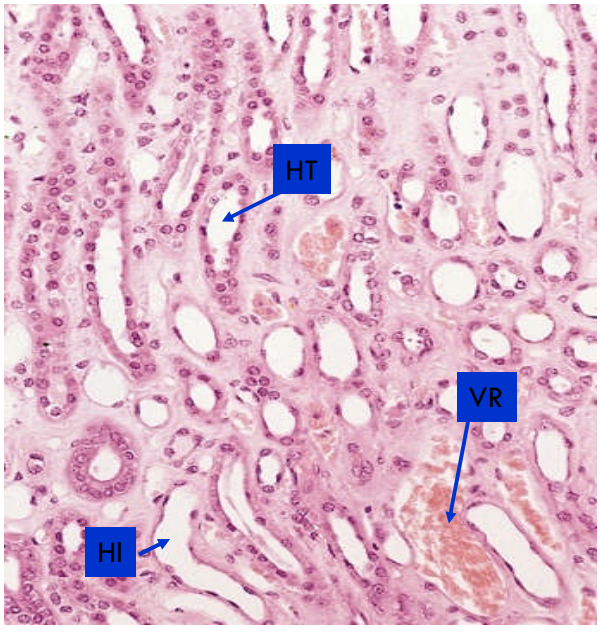
- Continuous with PT in cortex
- Travels into the medulla, then back to the cortex
- Empties into the distal convoluted tubule (DCT)



Thick portions are similar in histological appearance to both PT and DCT.

Thin portions of Henle's loop have moderate cytoplasm and bulging nuclei.

They may resemble capillaries except for the presence of RBCs.



LOOP OF HENLE

- Function – to assist in **forming hypertonic urine** by establishing an osmotic gradient in the interstitial fluid of the medulla.

LOOP OF HENLE: DESCENDING PORTION

- Permeable to both water and salt
- As filtrate (isotonic) in the lumen passes deeper into the medulla (hypertonic), it loses water to the interstitium
- Filtrate becomes more hypertonic
- Filtrate volume also decreases with loss of water

LOOP OF HENLE: ASCENDING PORTION

- Plays a more active role in setting up the osmotic gradient required to make the interstitium hypertonic
- Contains a Na+/K+/Cl- Pump (symporter)
- Constantly pumps these ions from the filtrate into the interstitium

LOOP OF HENLE: ASCENDING PORTION

- Impermeable to water (water cannot follow salt into interstitium)
- Loss of salt, but not water, causes the filtrate in Henle's loop to become isotonic or even hypotonic
- Filtrate ascends toward the DCT in the cortex

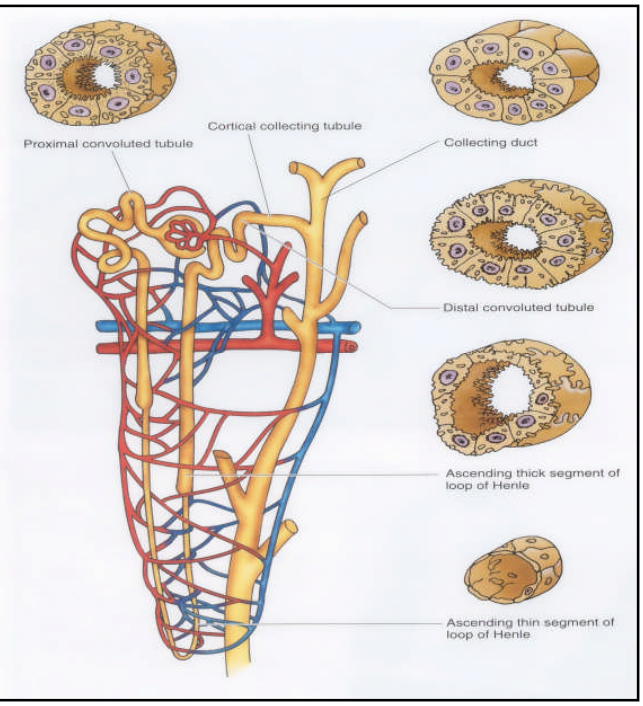
Distal Convoluted Tubule

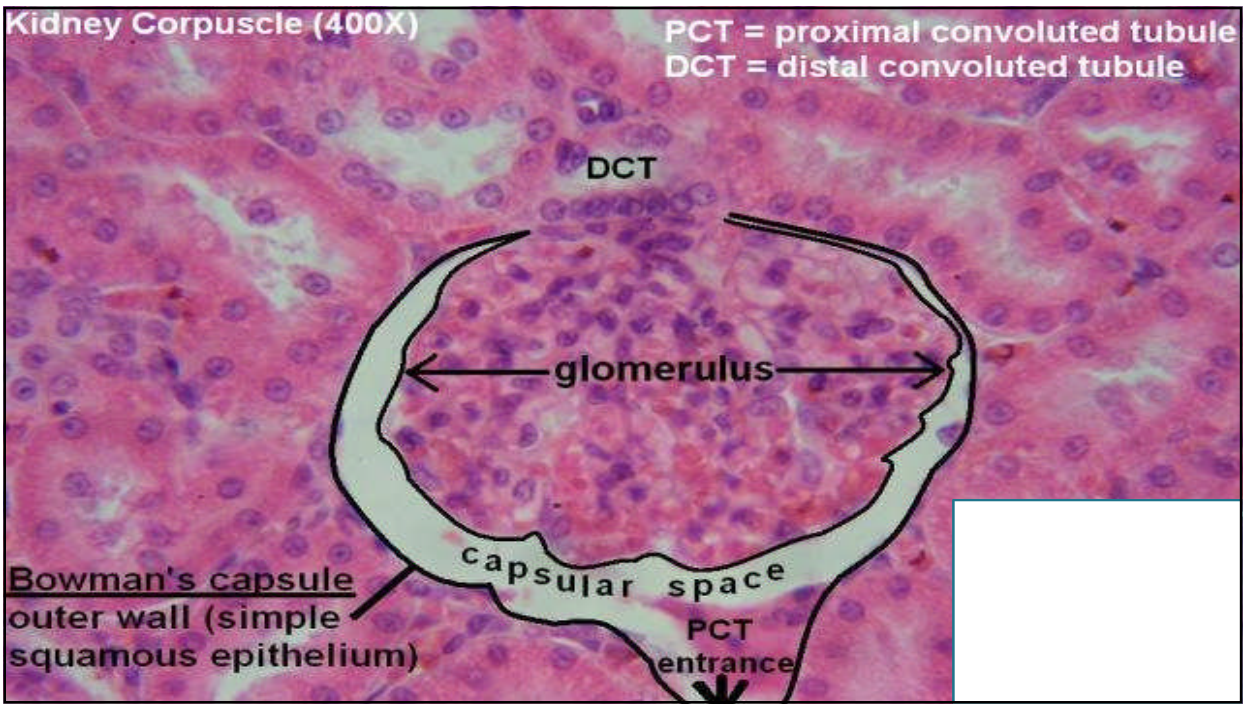
•Lined by pale-staining,
•low cuboidal epithelium

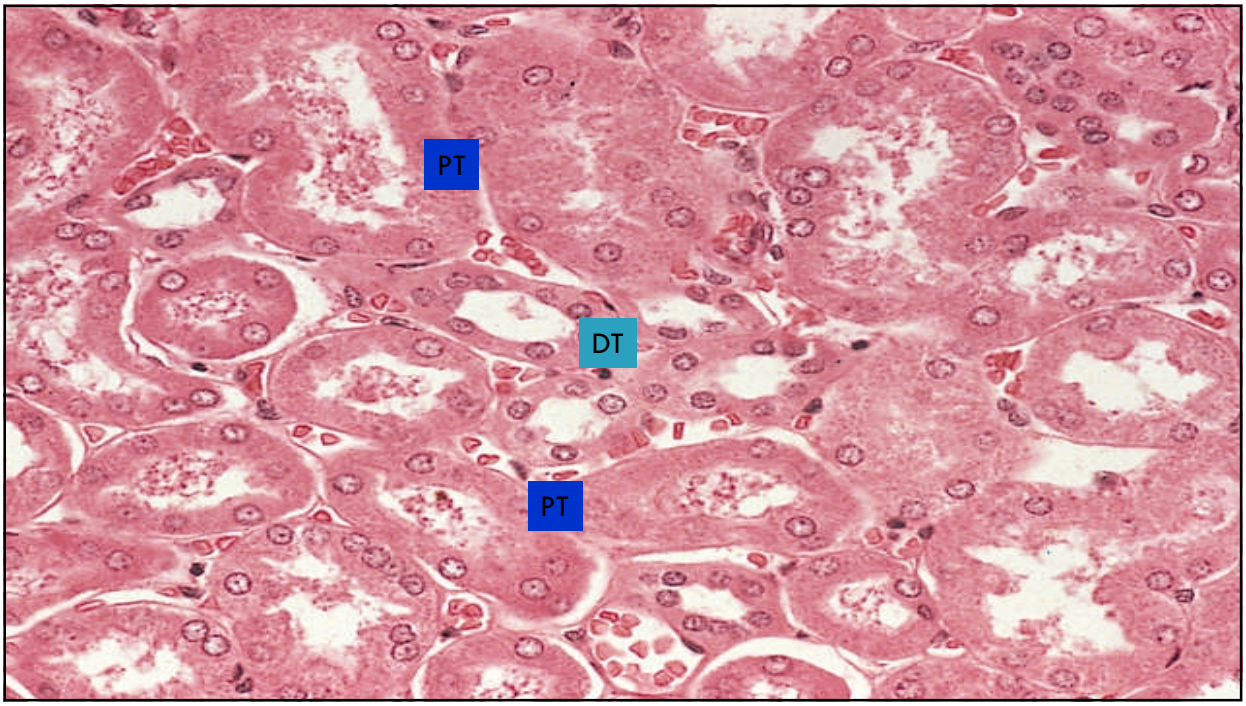
•Nuclei are round/oval
•apically laced

•Fewer microvilli in
•comparison to PT (lumen
•looks larger)

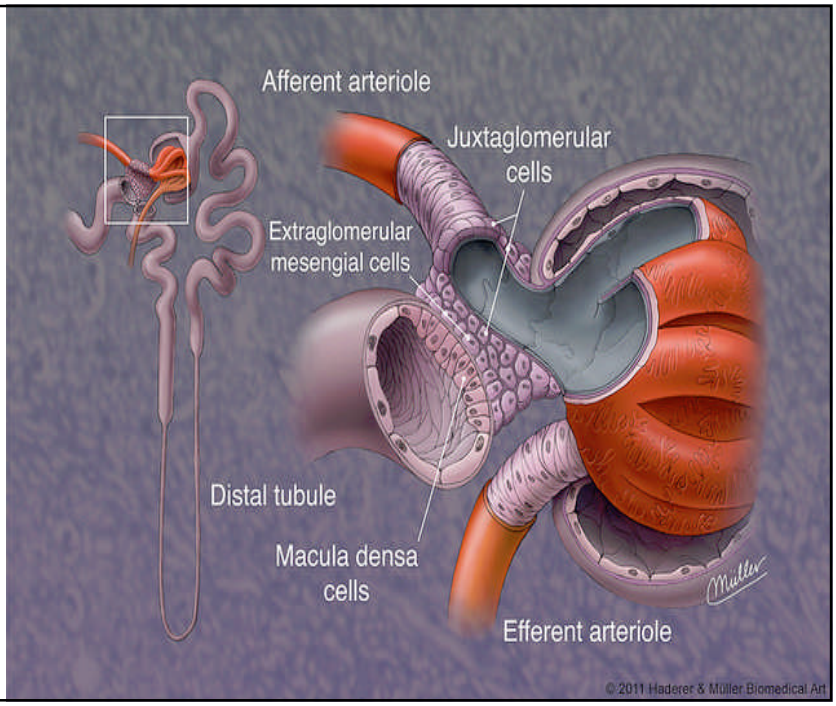
•Extensive basal and lateral
•interdigitations

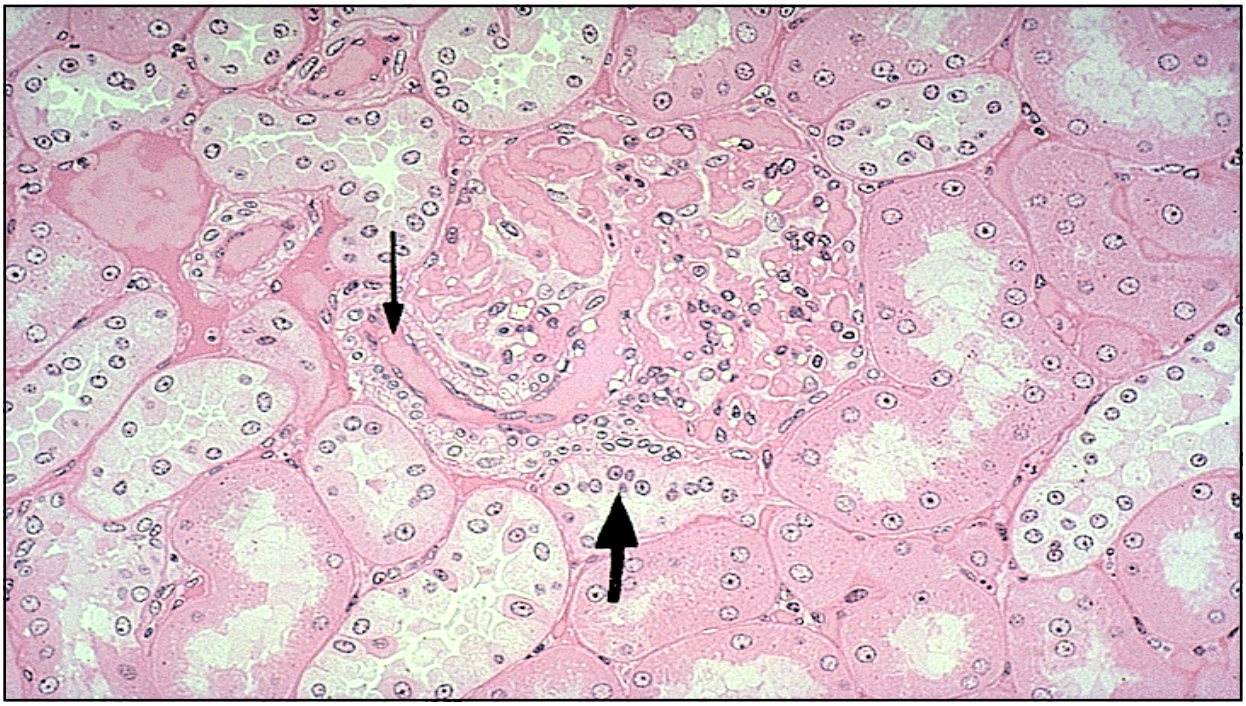


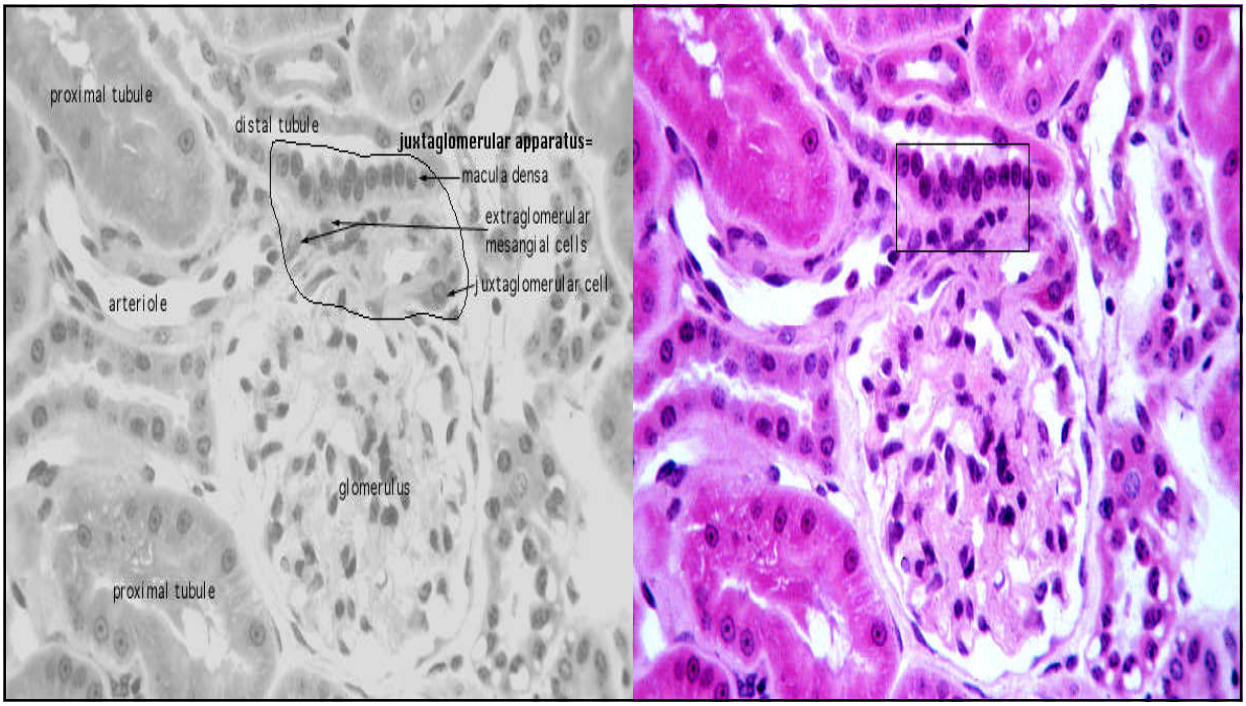




Juxtaglomerular Apparatus






proximal tubule
distal tubule
juxtaglomerular apparatus=
macula densa
extraglomerular mesangial cells
juxtaglomerular cell
arteriole
glomerulus
proximal tubule

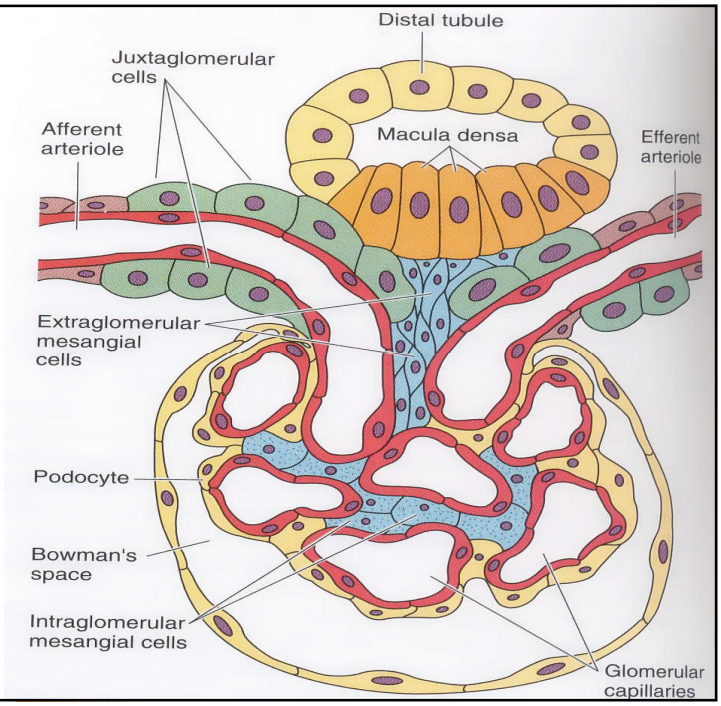
Juxtaglomerular Apparatus

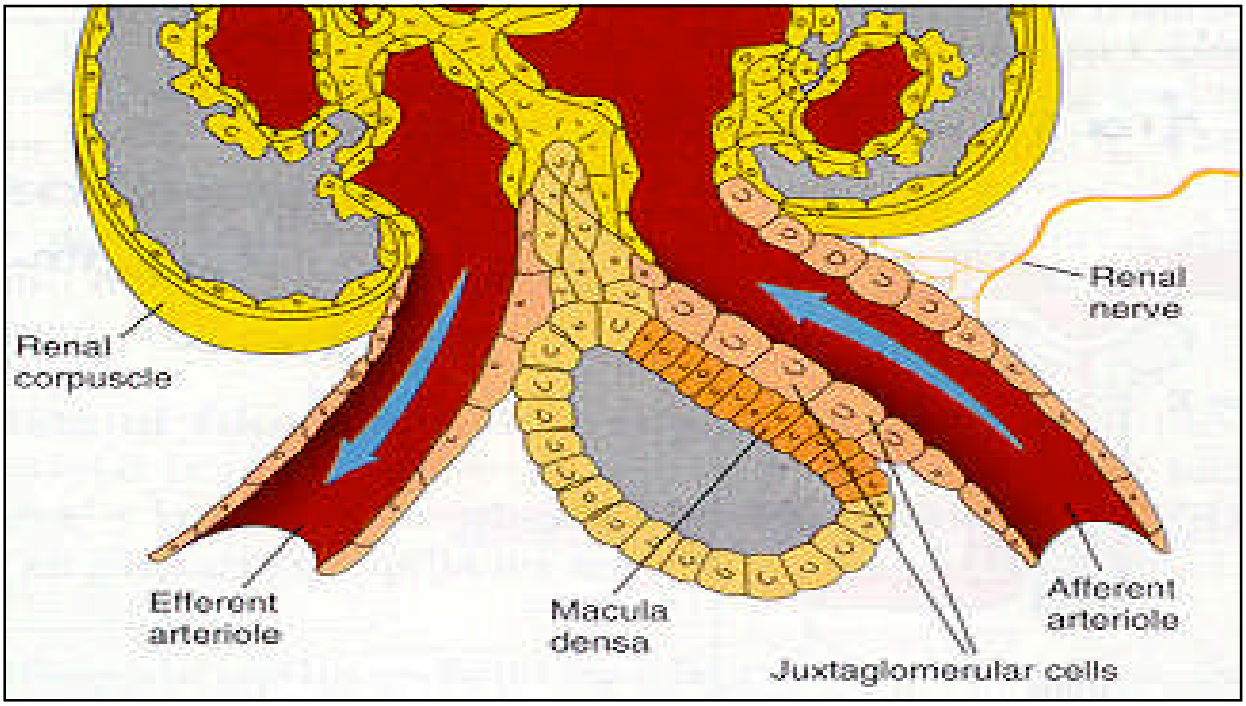
The three cellular components of the apparatus are

1. **the macula densa,**
2. **extraglomerular mesangial cells, lacis cells**
3. **juxtaglomerular cells.=Granular Cells**

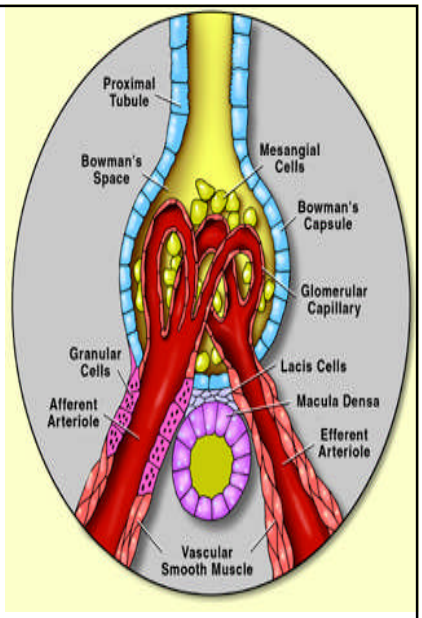
Involved in maintaining blood pressure and volume

Produces renin





The **Juxtaglomerular cells secrete renin** in response to:
•Beta1 adrenergic stimulation
•Decrease in renal perfusion pressure (detected directly by the granular cells)
•Decrease in NaCl reabsorption in the Macula Densa (often due to a decrease in glomerular filtration rate, or GFR, due to slower filtrate movement through the proximal tubule and thus more time for reabsorption. This results in a lower NaCl concentration by the time the filtrate reaches the Macula Densa).



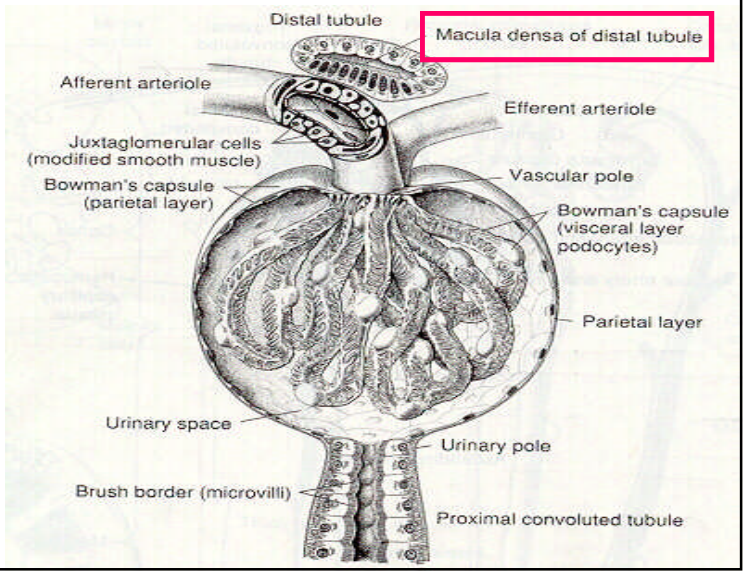
THE MACULA DENSA

•The macula densa senses sodium chloride concentration in the distal tubule of the kidney and secretes a locally active (paracrine) vasopressor which acts on the adjacent afferent arteriole to decrease glomerular filtration rate (GFR)

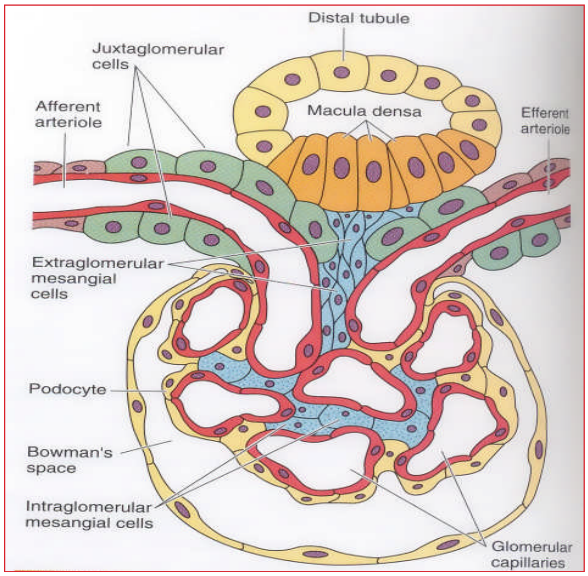
The specific function of **Lacis cells** is not well understood, although it has been associated with the secretion of erythropoietin?????.

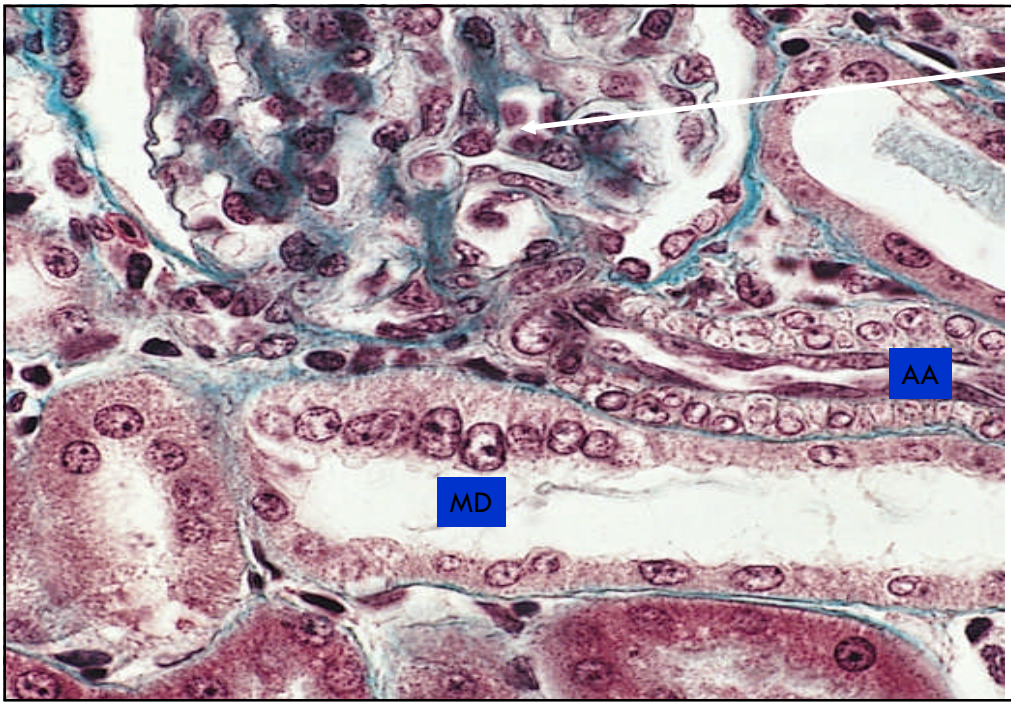
MACULA DENSA

- Modified segment of the DCT wall
- Sensitive to Cl^- ion content of tubular fluid



- Produces molecular signals promoting constriction of afferent arteriole
- Regulate the rate of glomeruar fitration (G.F.R.)

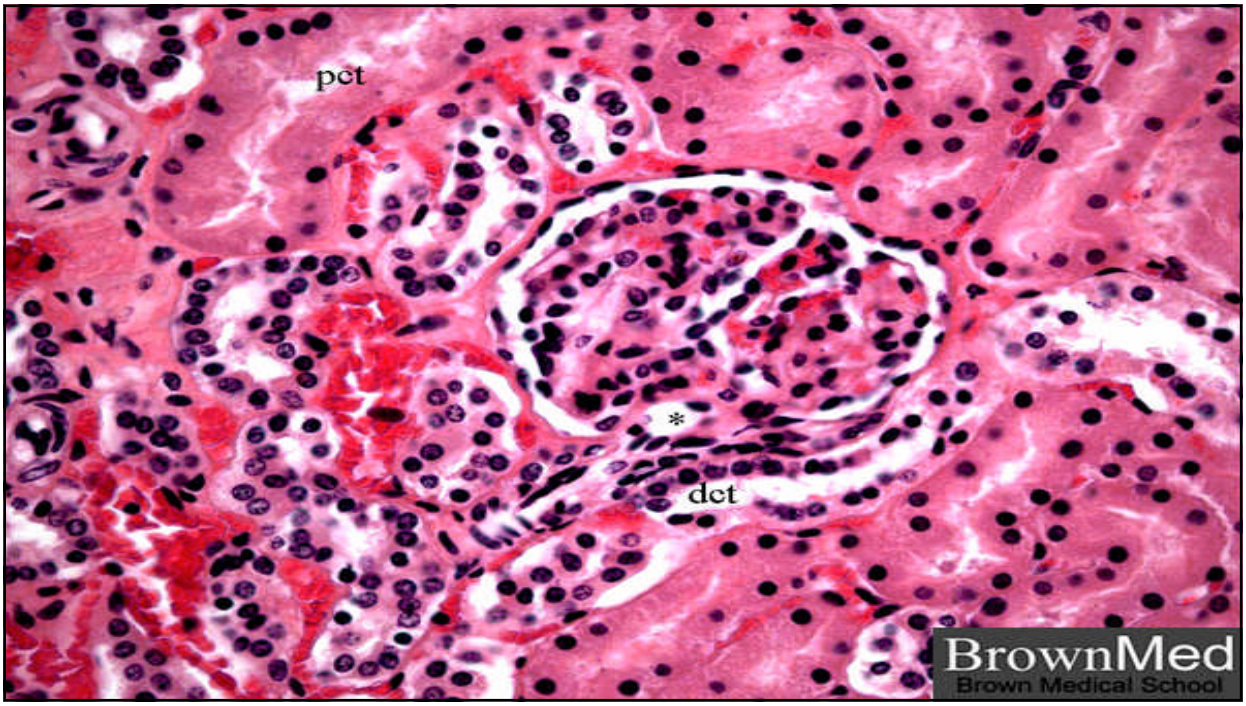




glomerulus

AA: Afferent Arteriole

MD: Macula Densa


pct
dct
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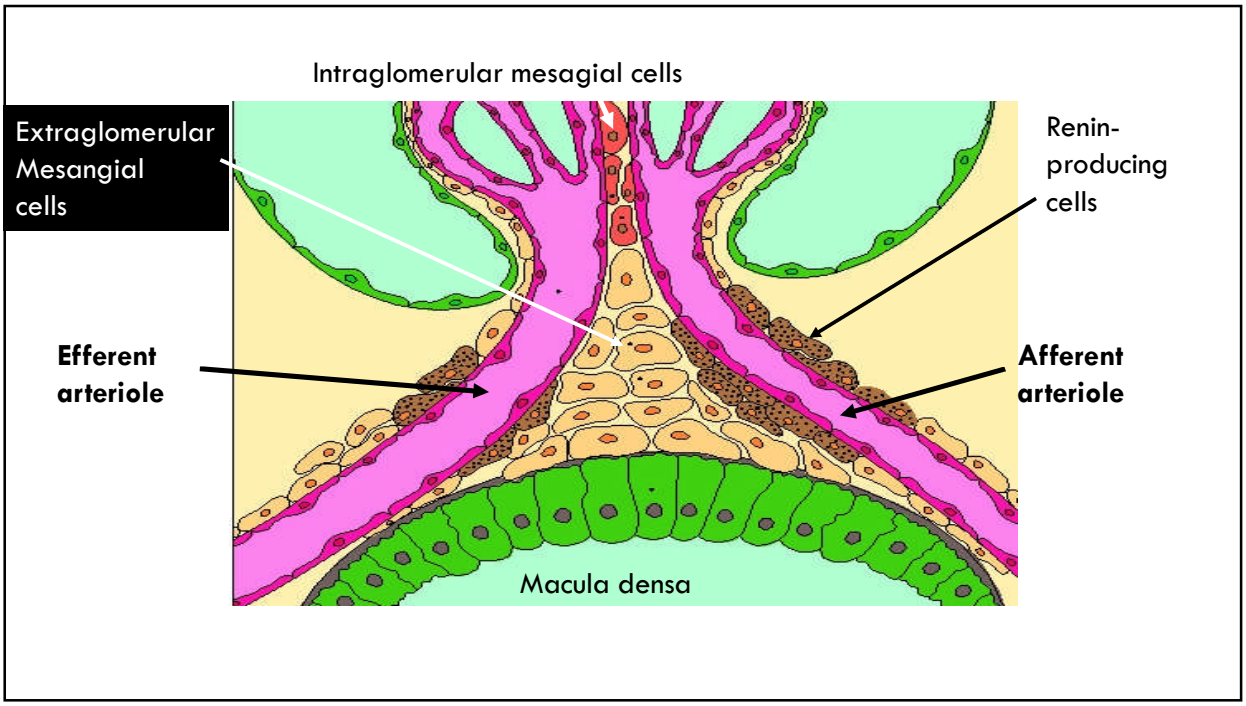
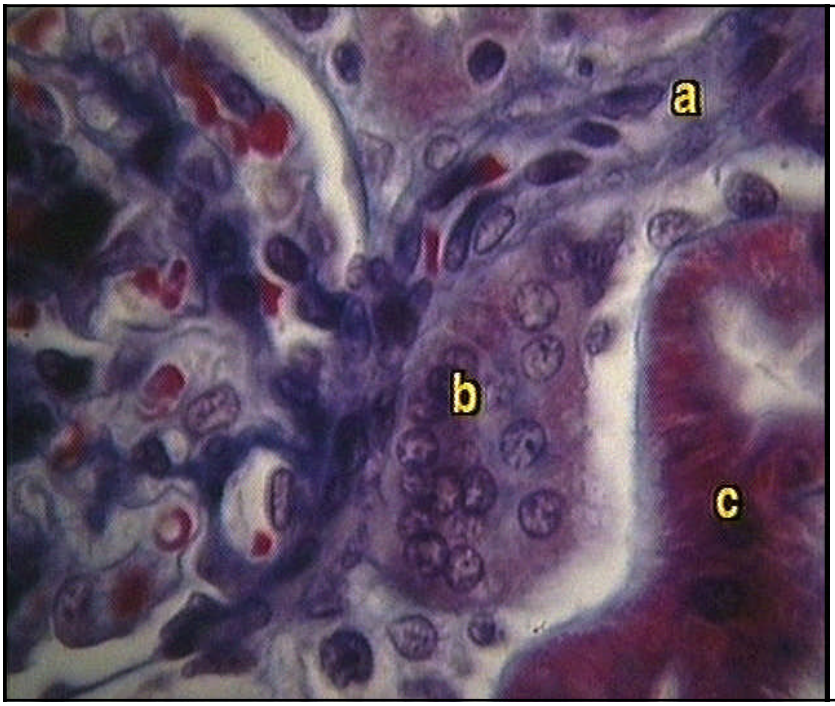
Brown Medical School

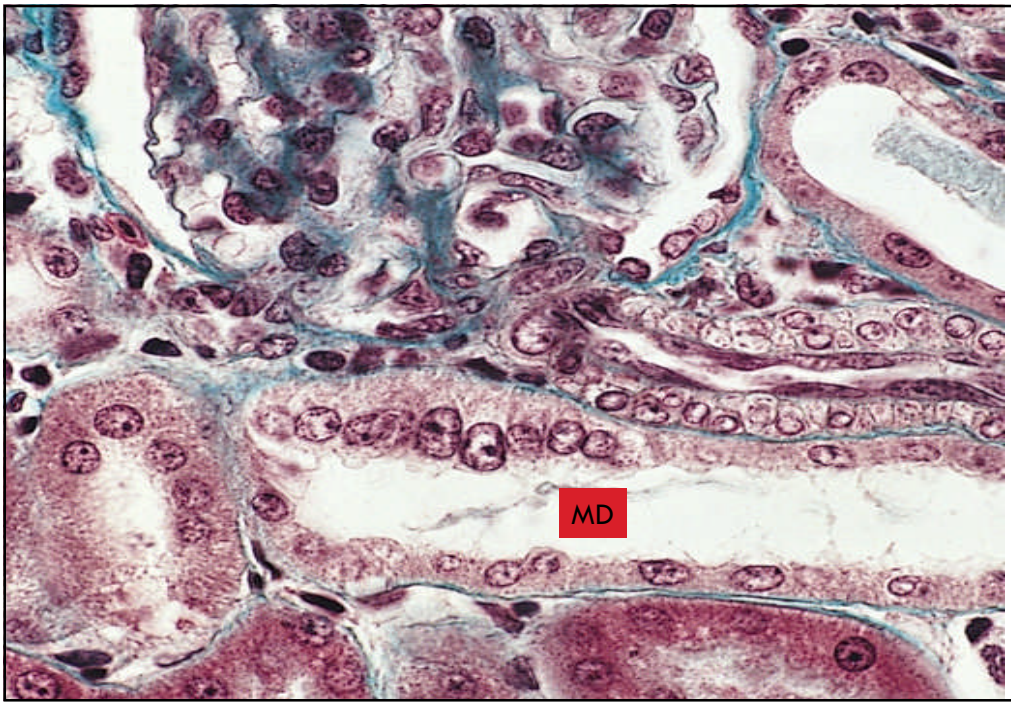

Intraglomerular mesagial cells
Extraglomerular Mesangial cells
Renin-producing cells
Efferent arteriole
Afferent arteriole
Macula densa



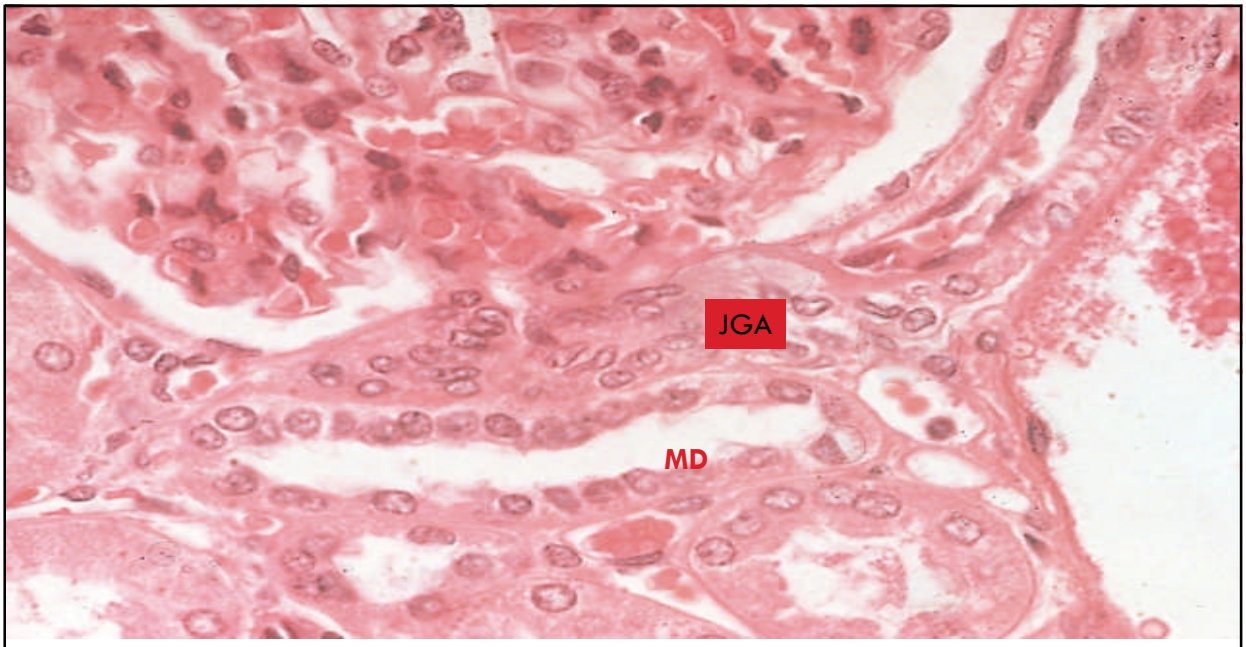
The juxtaglomerular apparatus is composed of the macula densa region of the distal tubule (c) and apparent juxtaglomerular cells (b) of the afferent glomerular arteriole (a).

Observe the granules in the juxtaglomerular cells, Which are believed to be the enzyme renin.

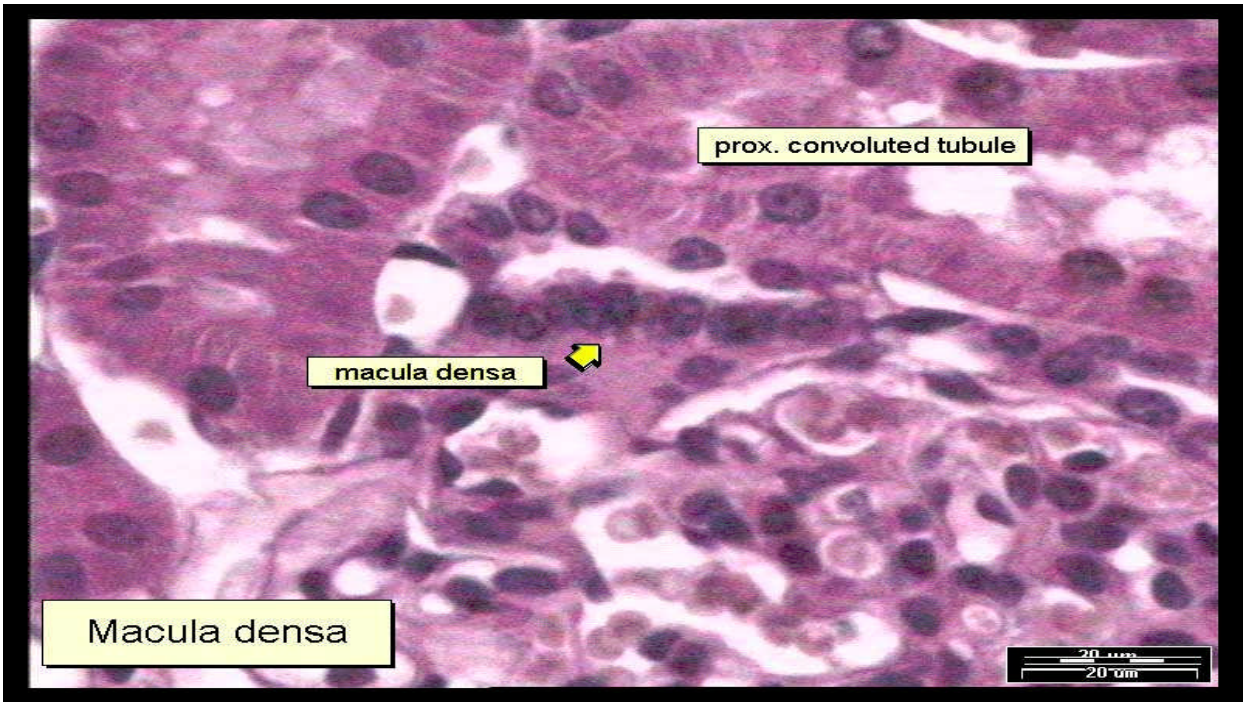
The large, round glomerulus dominates the left side of the screen.



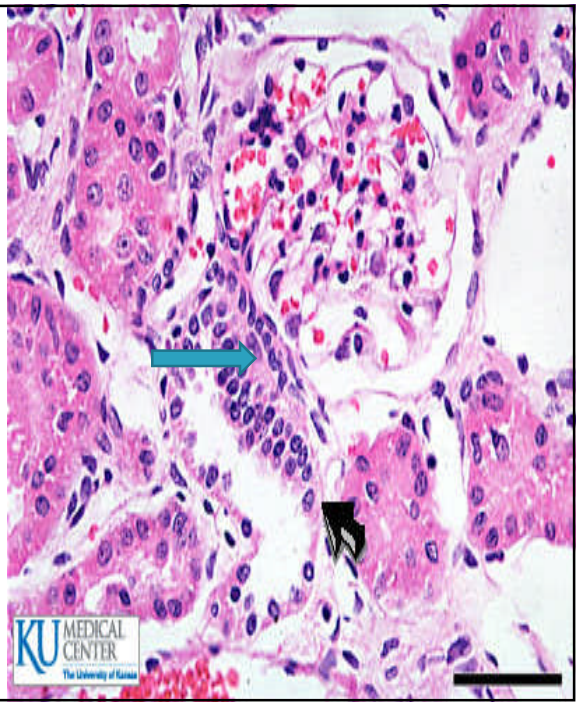
Tall cells, Tightly Packed nuclei



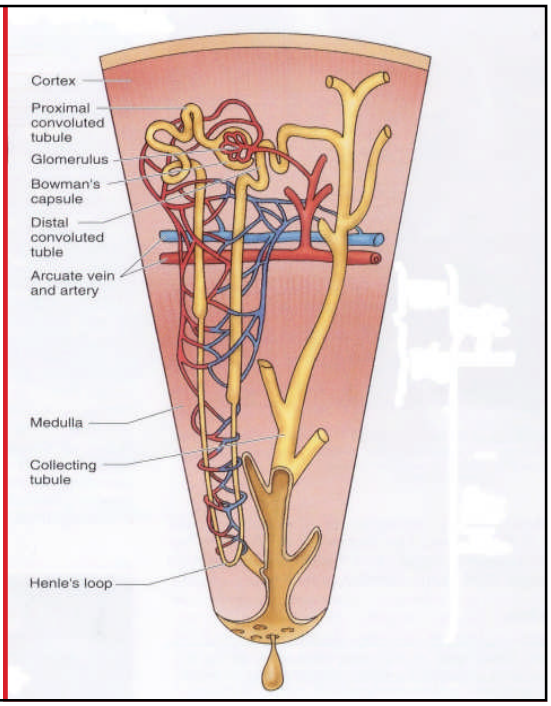
JGA & lacis cells require special stains



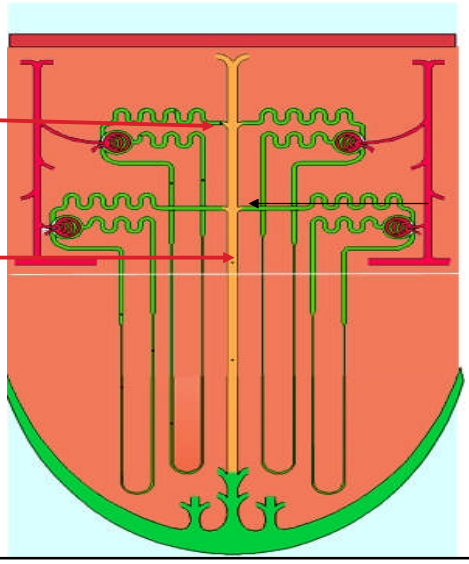
- **Macula densa acts as sensor, regulating juxtaglomerular function by monitoring Na+ & Cl- levels in the DCT**
- **Decrease blood volume/pressure elicits secretion of renin**
- **Angiotensinogen → active angiotensin**
- **Angiotensin causes adrenals to secrete aldosterone**



- Crucial to acid-base balance & urine concentration
- **Aldosterone (adrenal cortex) cause DCT cells to resorb remaining Na^+**
- Pump H^+ and K^+ ions into lumen
- Control body's extracellular K^+ level & urine acidity



- Urine passes from the DCT to collecting tubules
- Collecting tubules join to form larger, straight collecting ducts
- Play important role in final concentration of urine (interstitium & vasa recta)



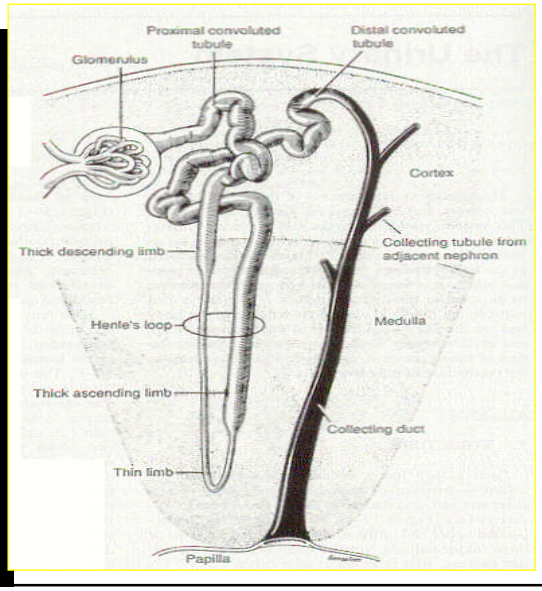
The collecting ducts are formed by the fusion of collecting tubules and convey urine to the renal calyces via the renal papillae.

The typical collecting duct is characterized by tall columnar epithelium, well defined cellular outlines, pale staining cytoplasm and the absence of a brush border.

No active reabsorption takes place from the collecting ducts, but in the presence of pituitary antidiuretic hormone (ADH) the collecting ducts become permeable to water

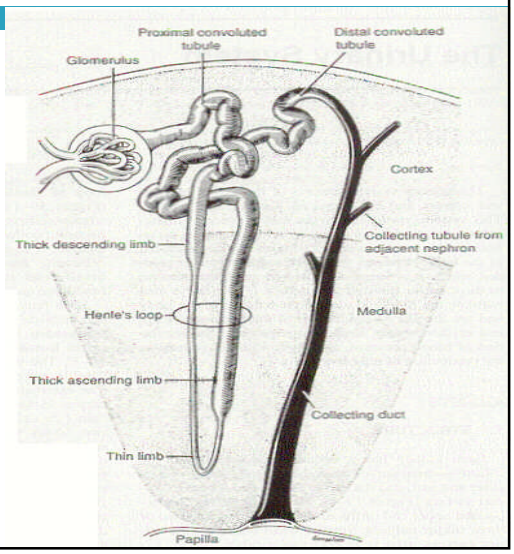
COLLECTING TUBULES AND DUCTS: FUNCTION

- **COLLECTING TUBULES** RECEIVE ISOTONIC URINE FROM D.C.T.
- **COLLECTING DUCTS** RECEIVE ISOTONIC URINE FROM COLLECTING TUBULES
- LEAVE CORTEX IN MEDULLARY RAYS AND ENTER MEDULLA
- COLLECTING DUCTS OPEN INTO A MINOR CALYX
- **COLLECTING DUCTS** IN THE MEDULLA CONTRIBUTE TO CONCENTRATION OF URINE…



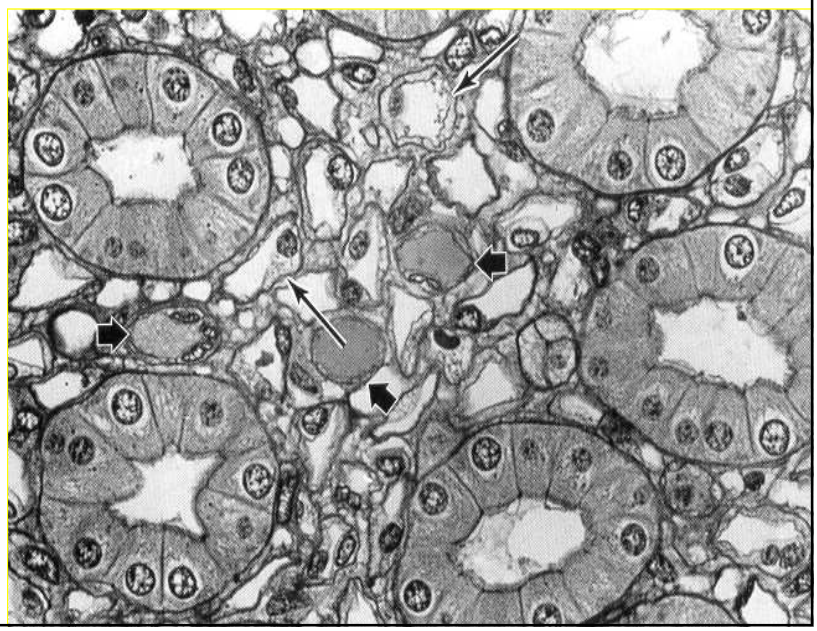
COLLECTING DUCTS: URINE CONCENTRATION

- **Epithelium responsive to ANTIDIURETIC HORMONE** (ADH; VASOPRESSIN) released by posterior pituitary
- ADH – water is lost from collecting ducts → hypertonic urine
- Without ADH – ducts remain impermeable to water → iso-/ hypotonic urine



COLLECTING TUBULES AND DUCTS: STRUCTURE

- Lining cells have distinct intercellular borders
- Lining cells are cuboidal (smaller tubules) to columnar (larger ducts)

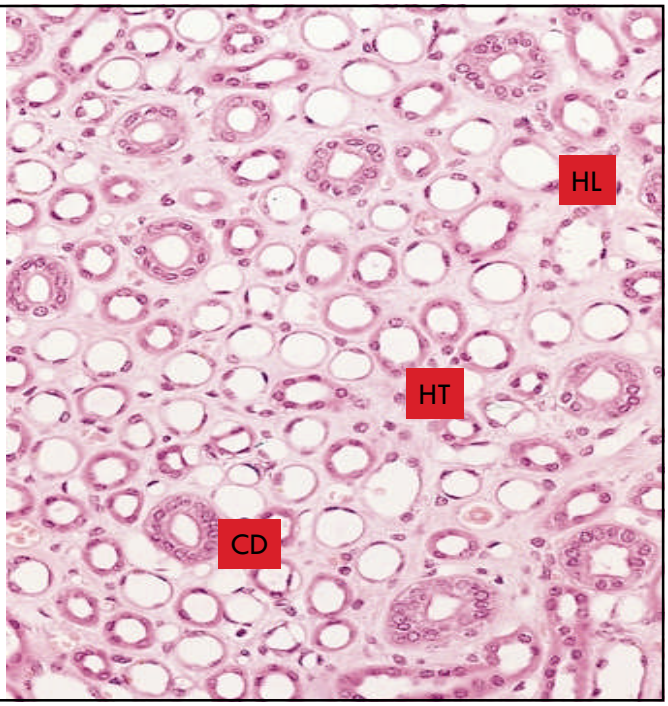


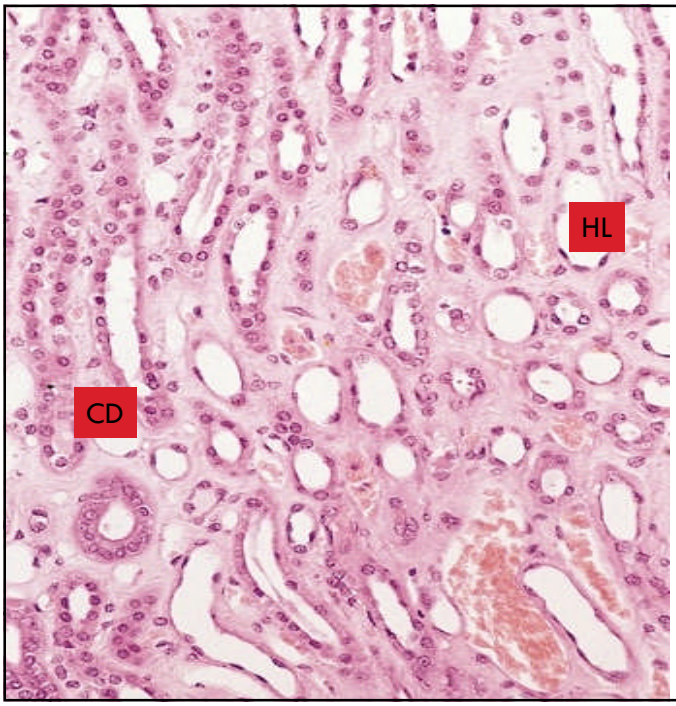
Collecting Tubules & Ducts

Lined by cuboidal epithelium. Cells have distinct borders and stain poorly (pale-white)

Seen in section in medulla
Will have thick & thin Henle's loops in field as well.

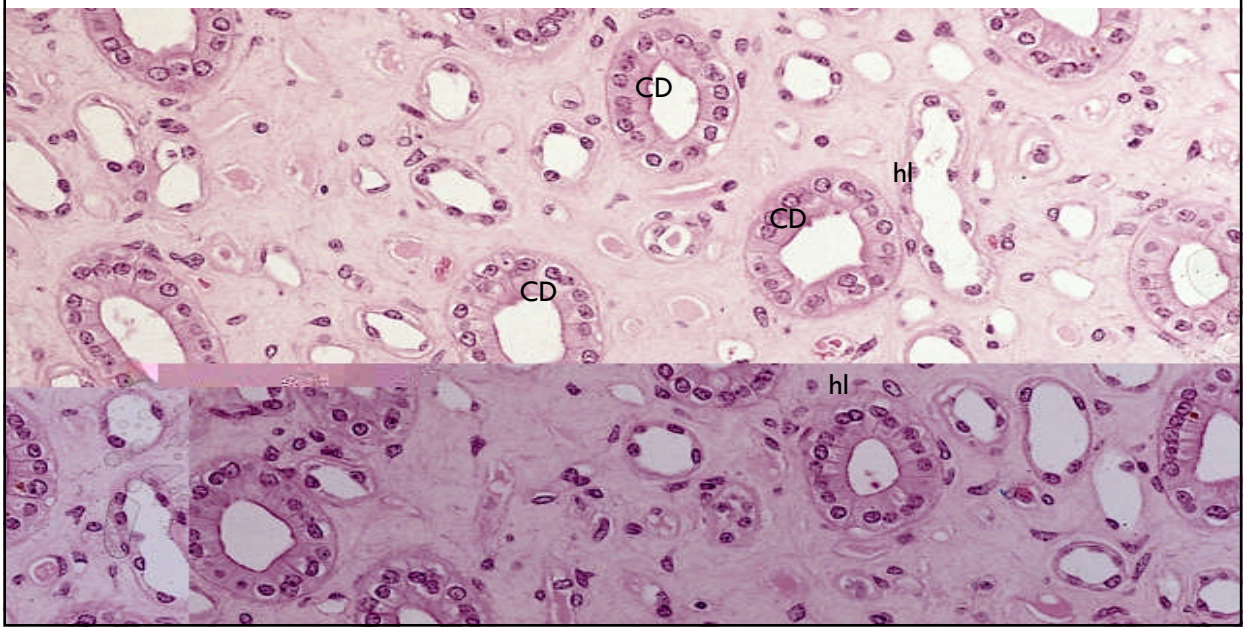
Medulla, cross-section



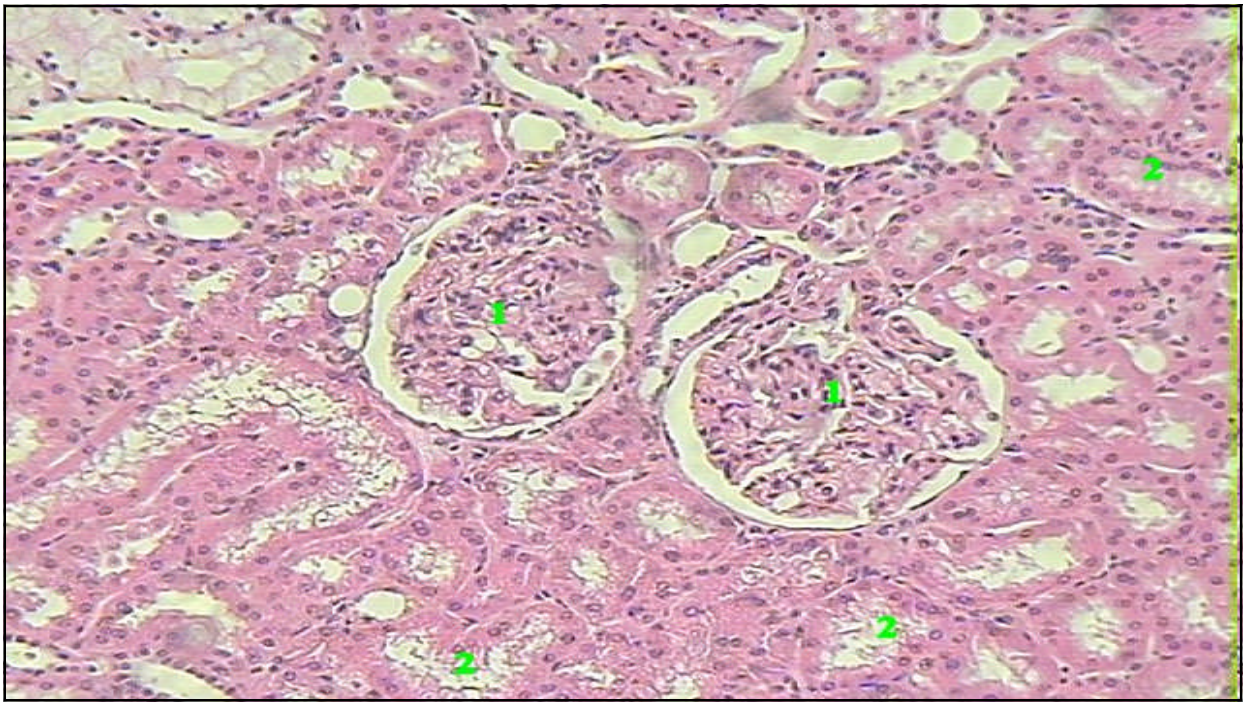


Medulla, longitudinal

Collecting tubules & thin Loops of Henle

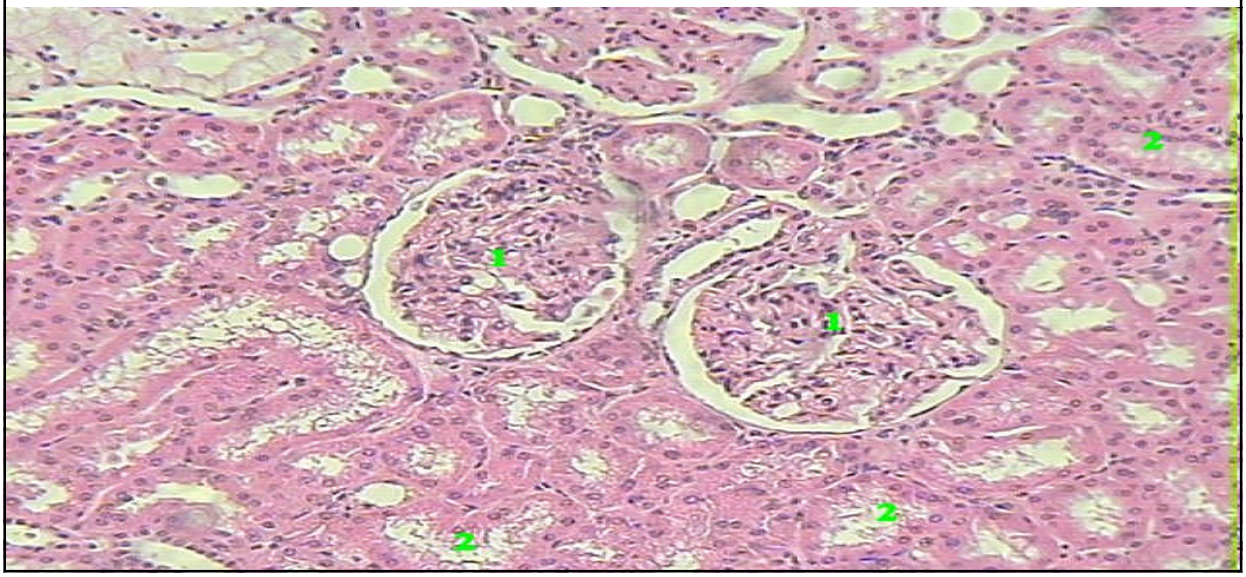


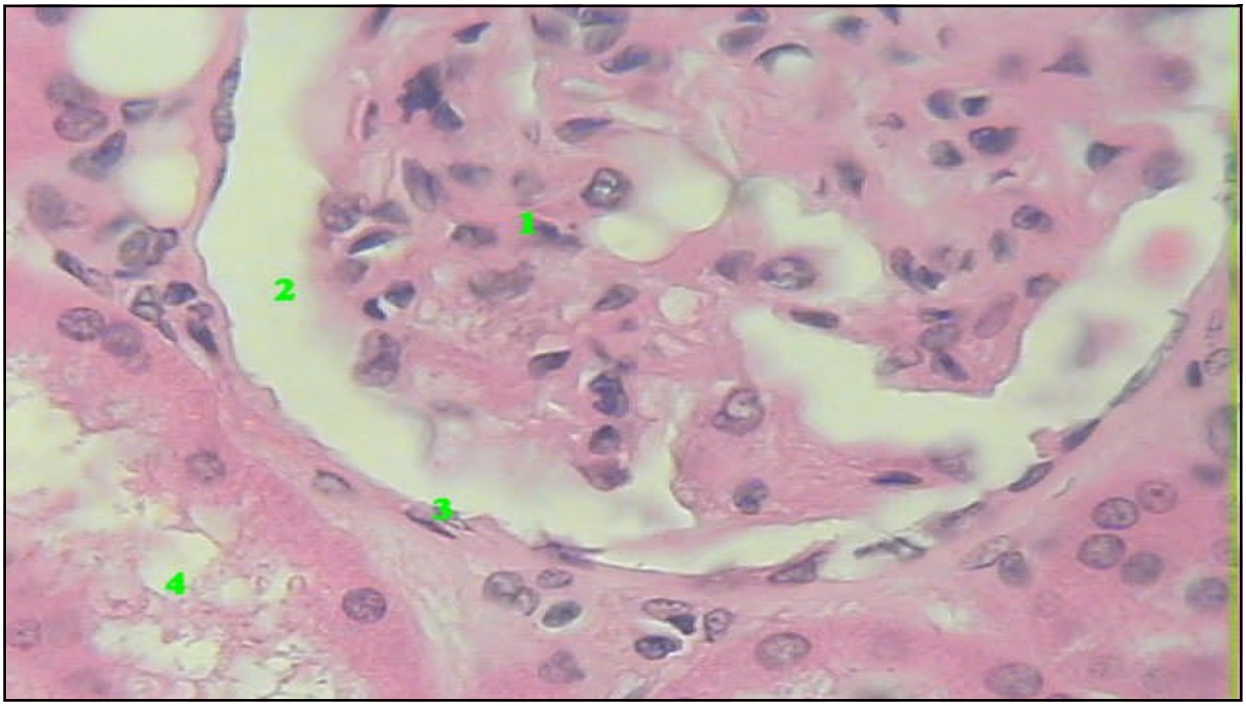
HISTO REVIEW



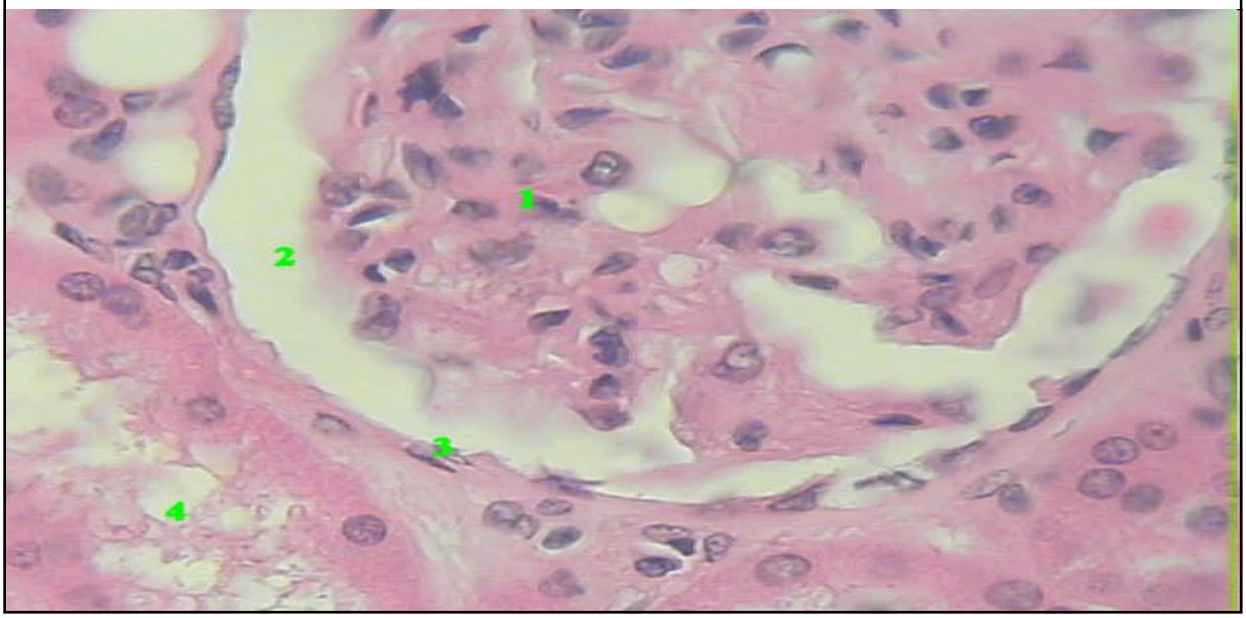
Renal Cortex

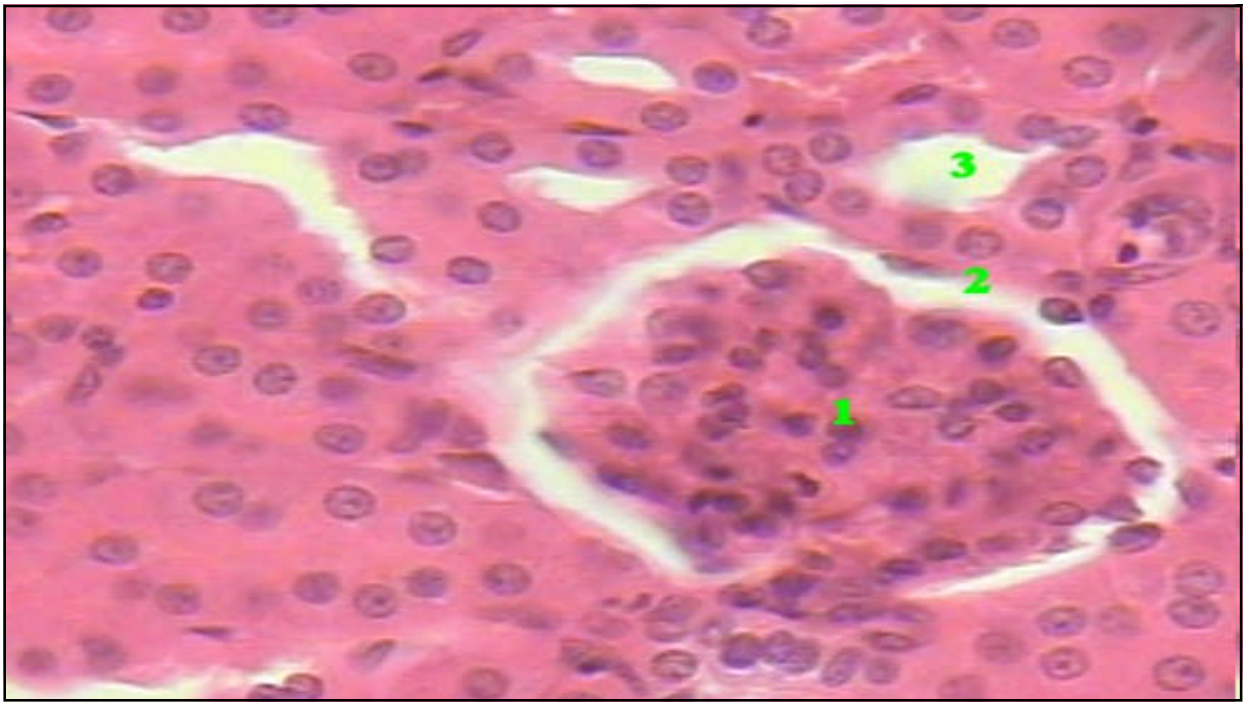
1. Renal corpuscle
2. Renal tubule



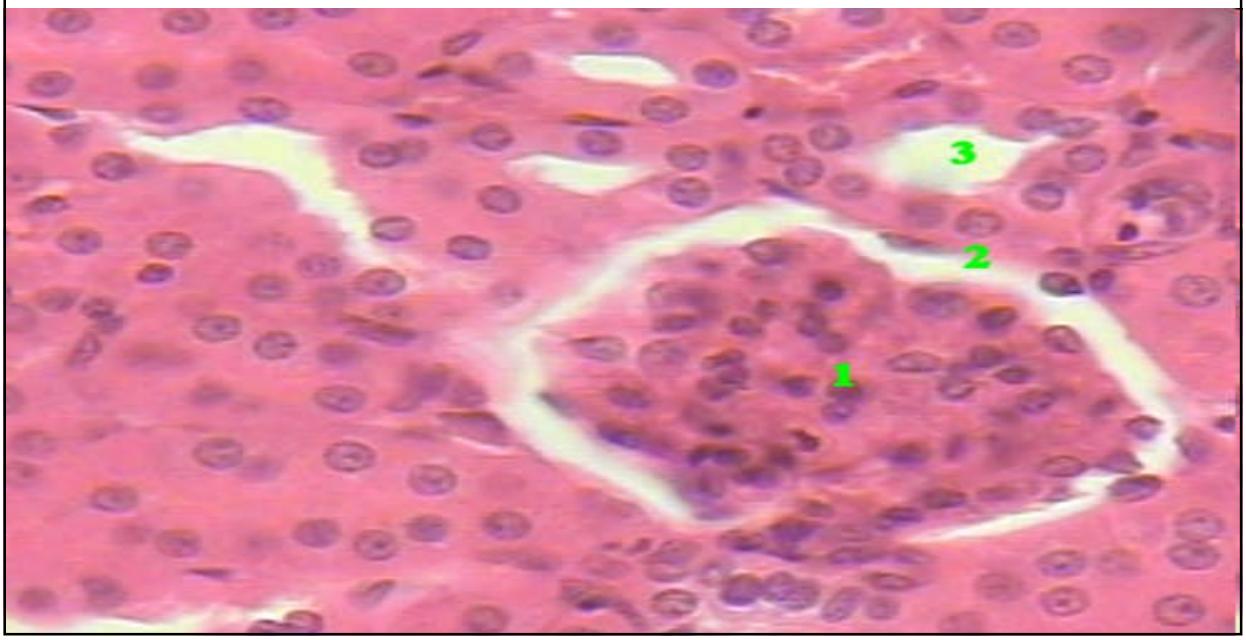


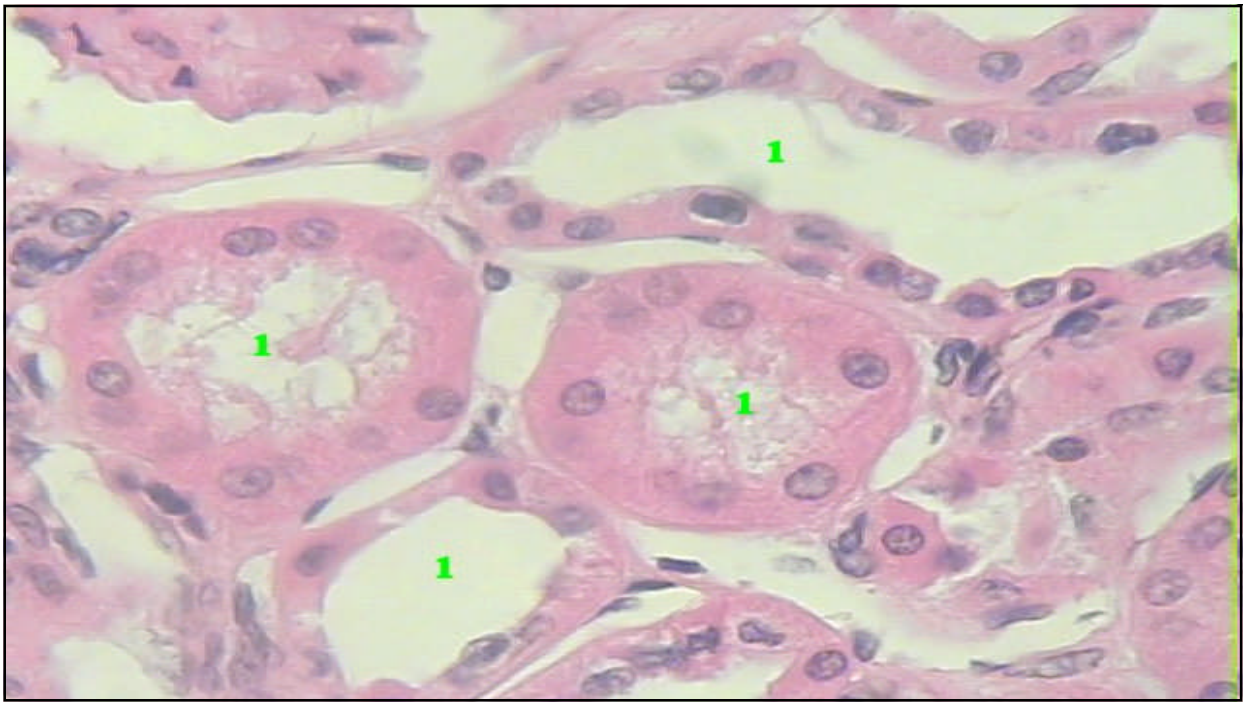
1. Renal Corpuscle 2. Lumen of Bowman's Capsule 3. Parietal Layer of Bowman's Capsule 4. Renal Tubule



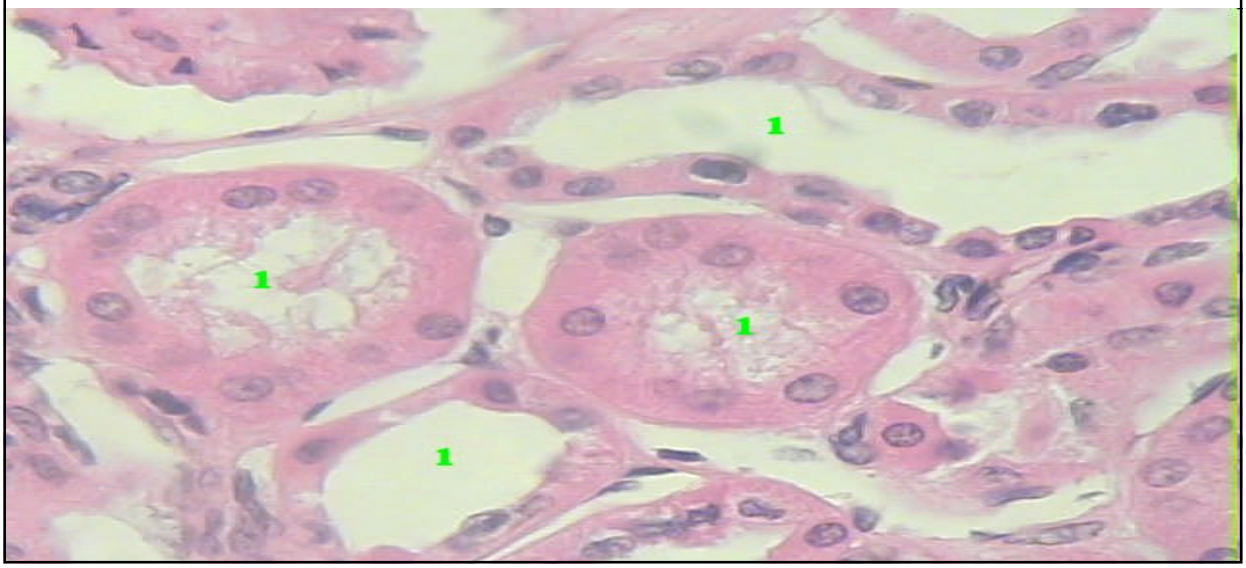


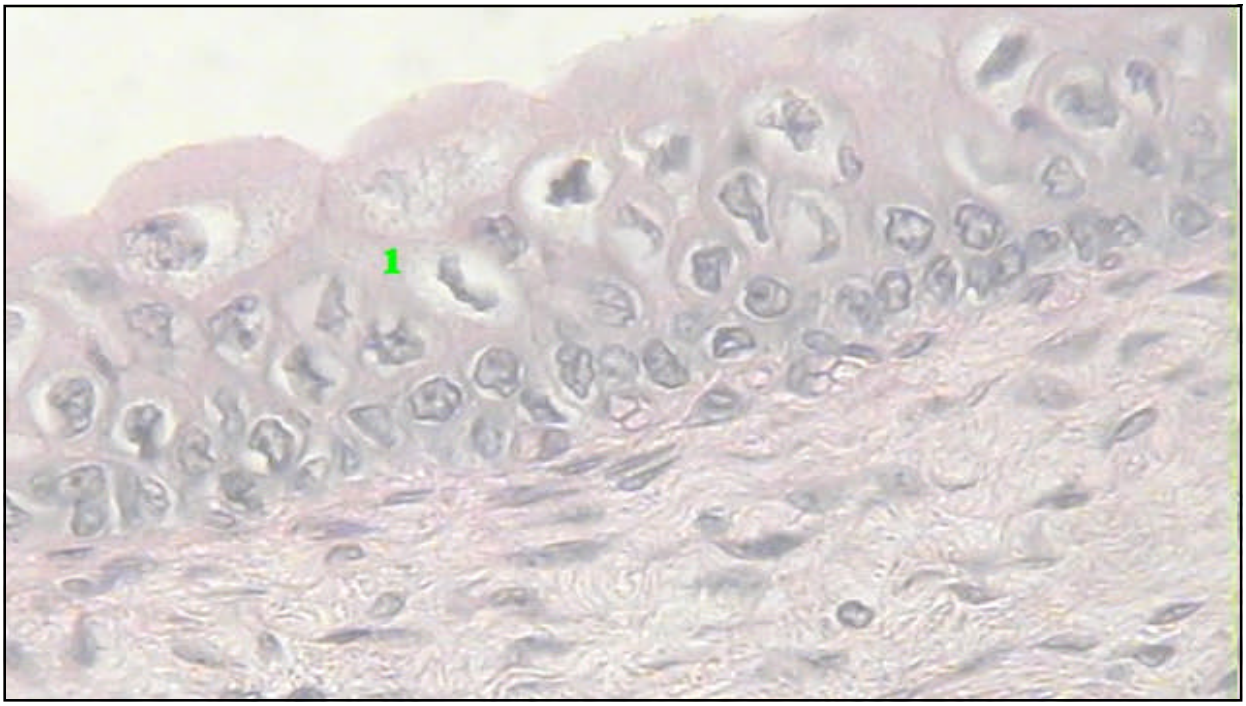
1. Renal corpuscle 2. Parietal layer of Bowman's capsule 3. Renal Tubule



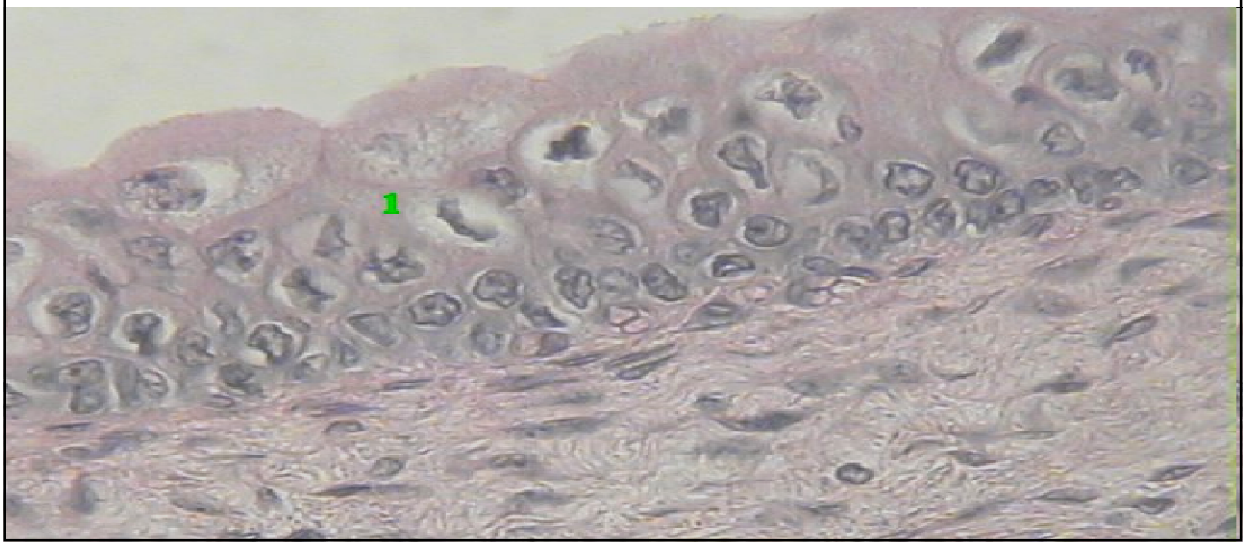


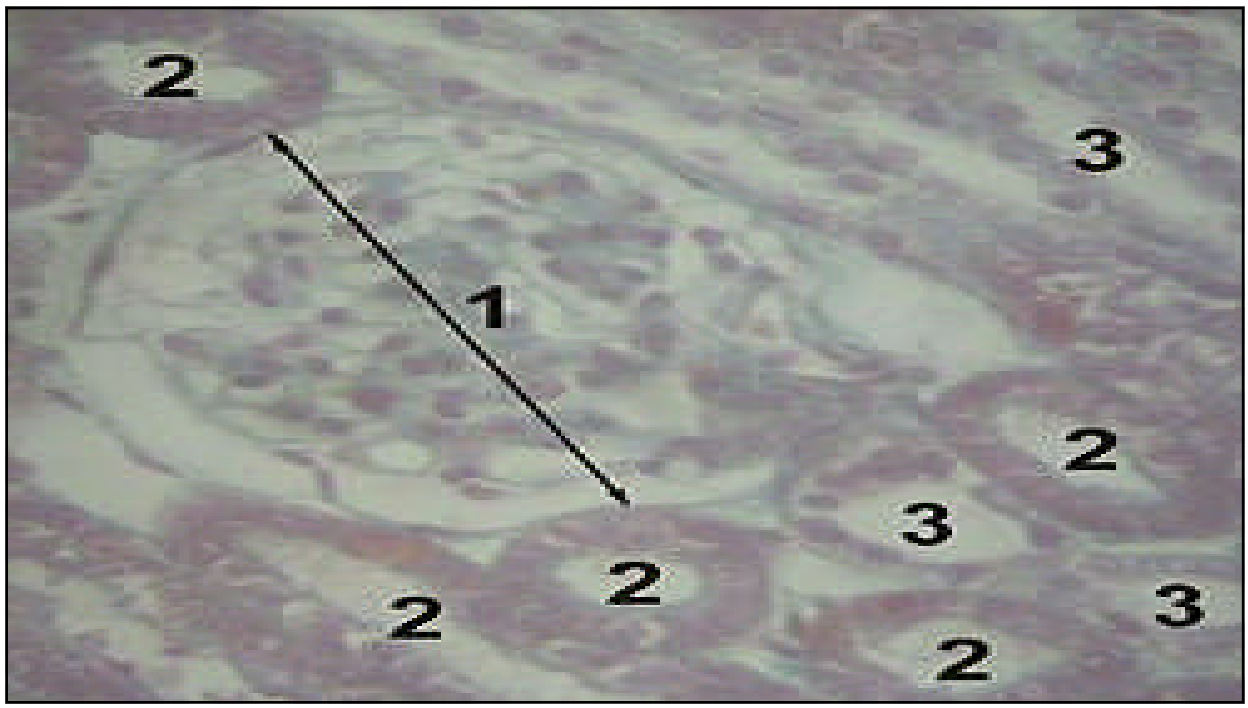
1. Renal tubule





High magnification of Urinary Bladder
1. Transitional Epithelium (mucosa)





1. Glomerulus 2. Proximal tubule 3. Distal tubule