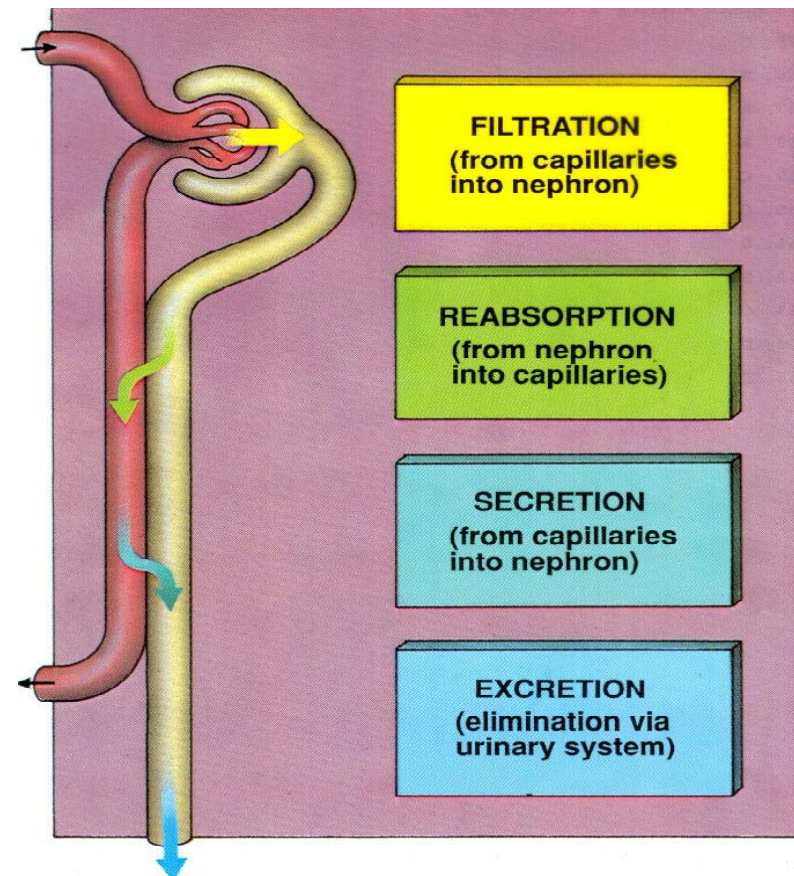


# Urinary system

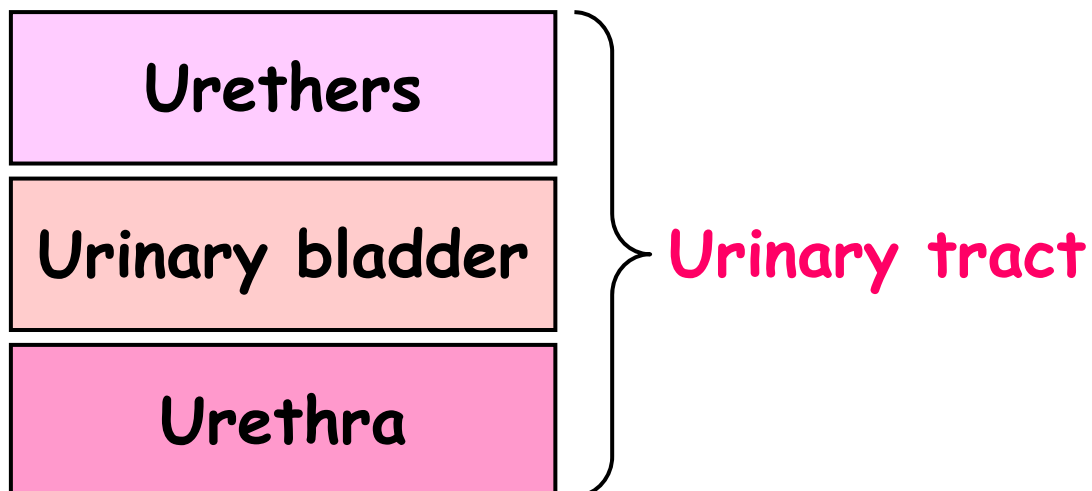
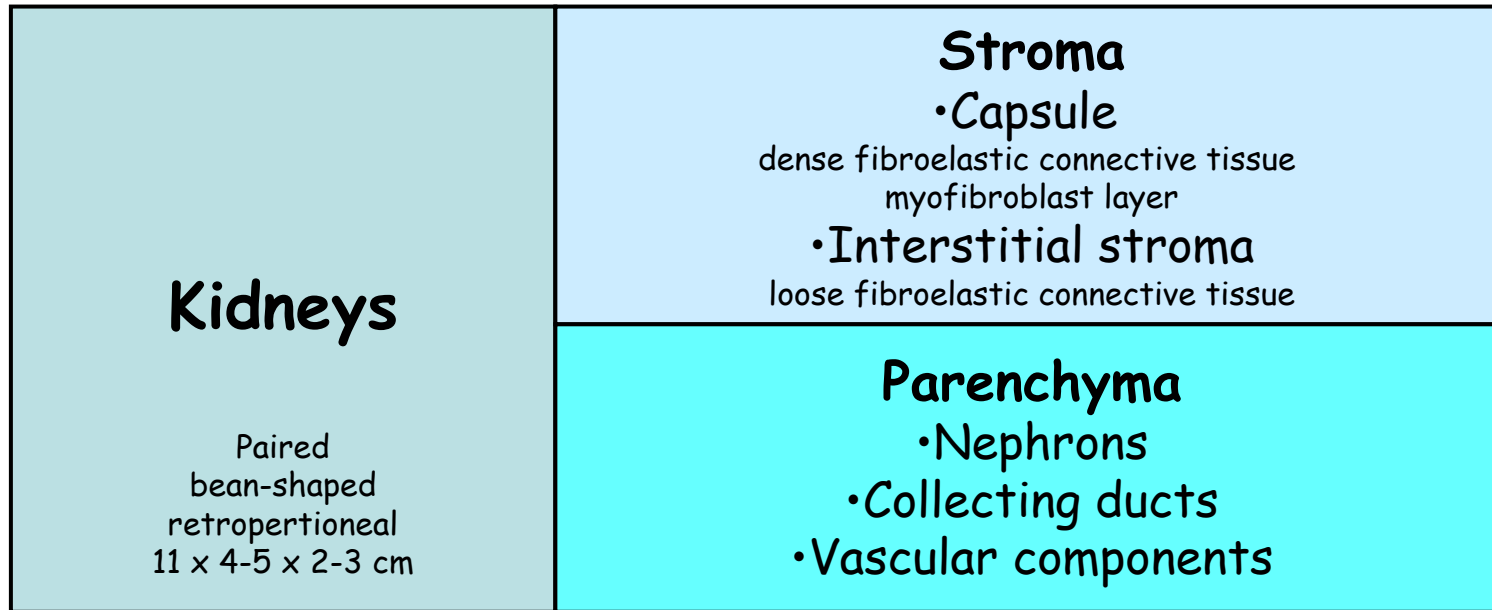
Aleš Hampl

# Functions of urinary system

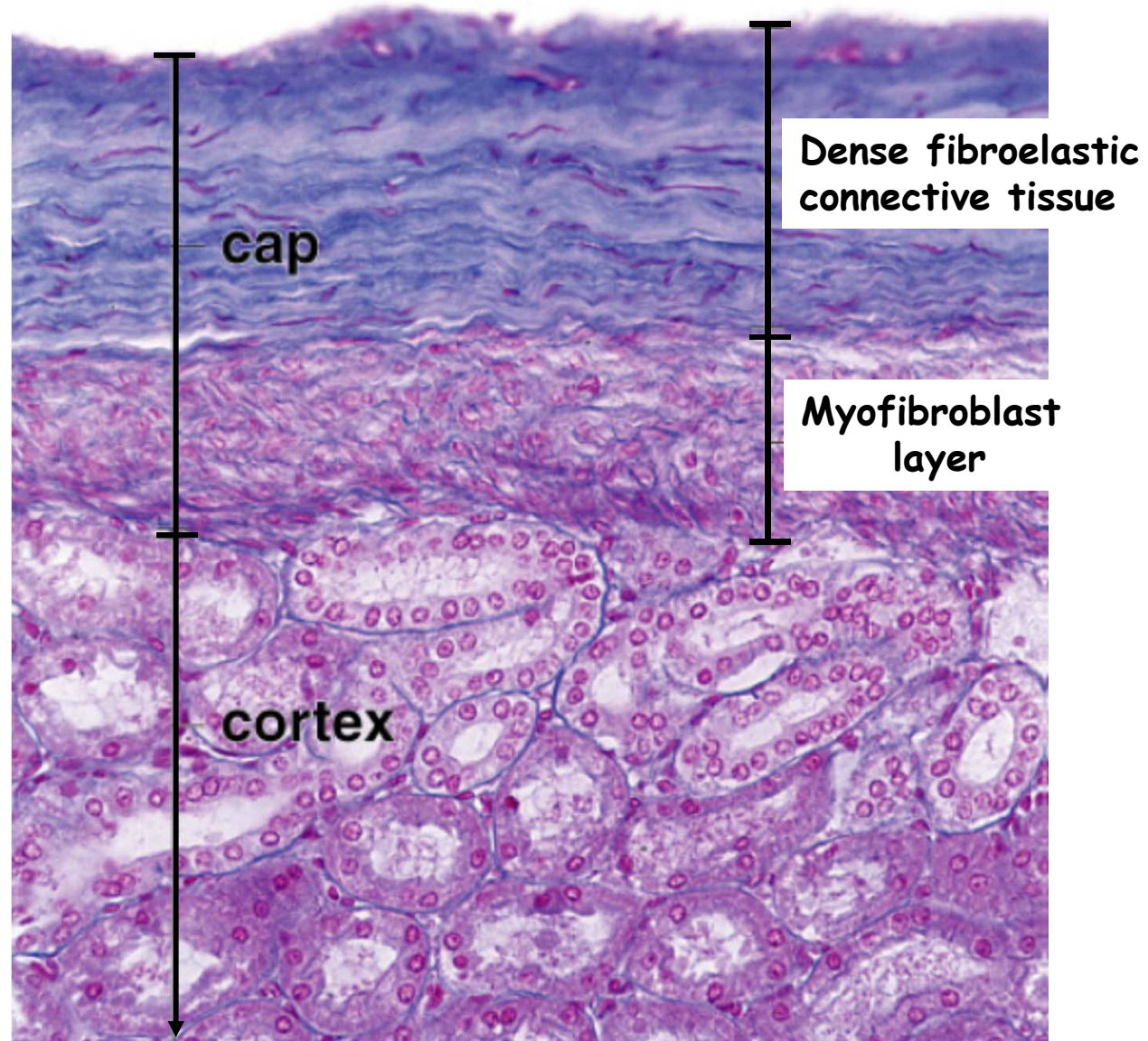
- 1. Regulating blood volume and pressure
- 2. Regulating plasma concentrations of sodium, potassium, chloride and other ions
- 3. Stabilising blood pH
- 4. Conserving nutrients
- 5. Detoxifying poisons (with the liver)



# Components of urinary system

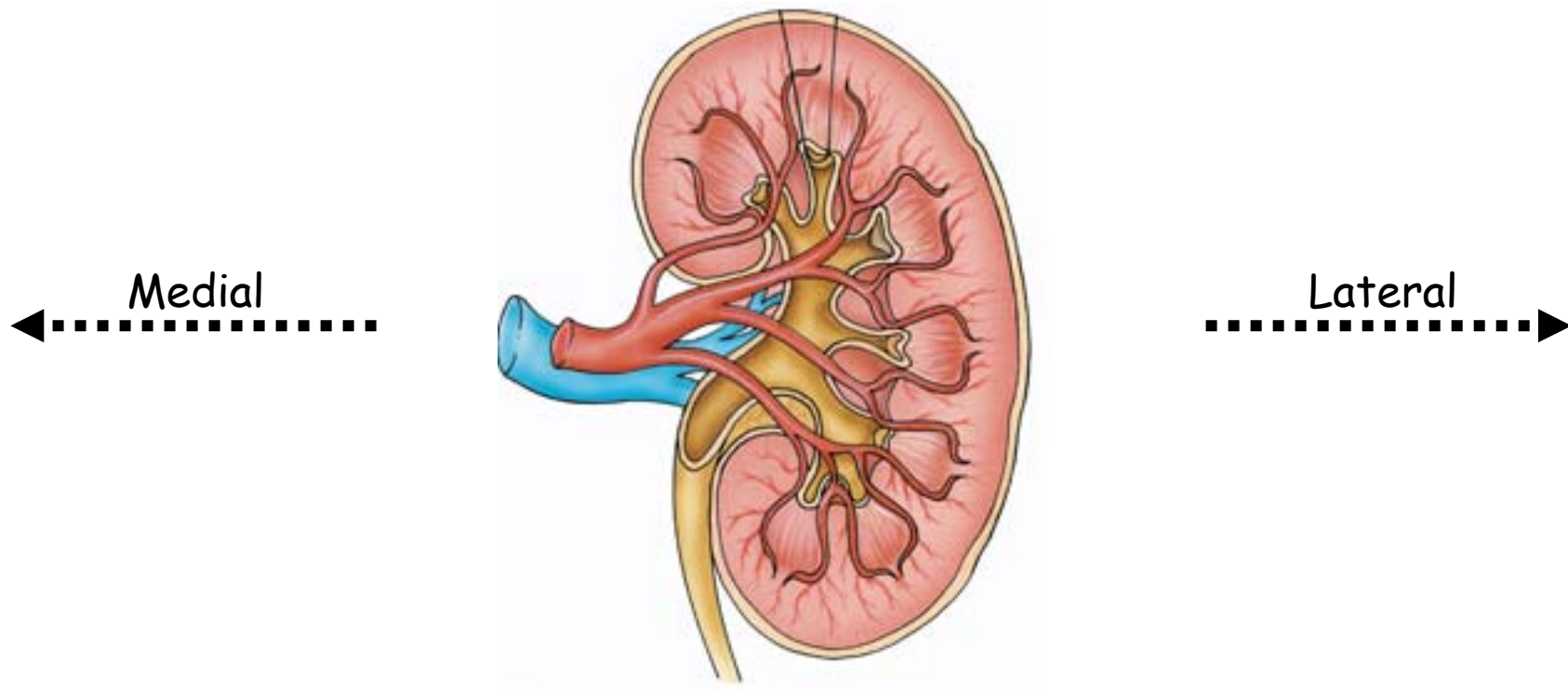


# Kidneys capsule





# Overall organization of kidney

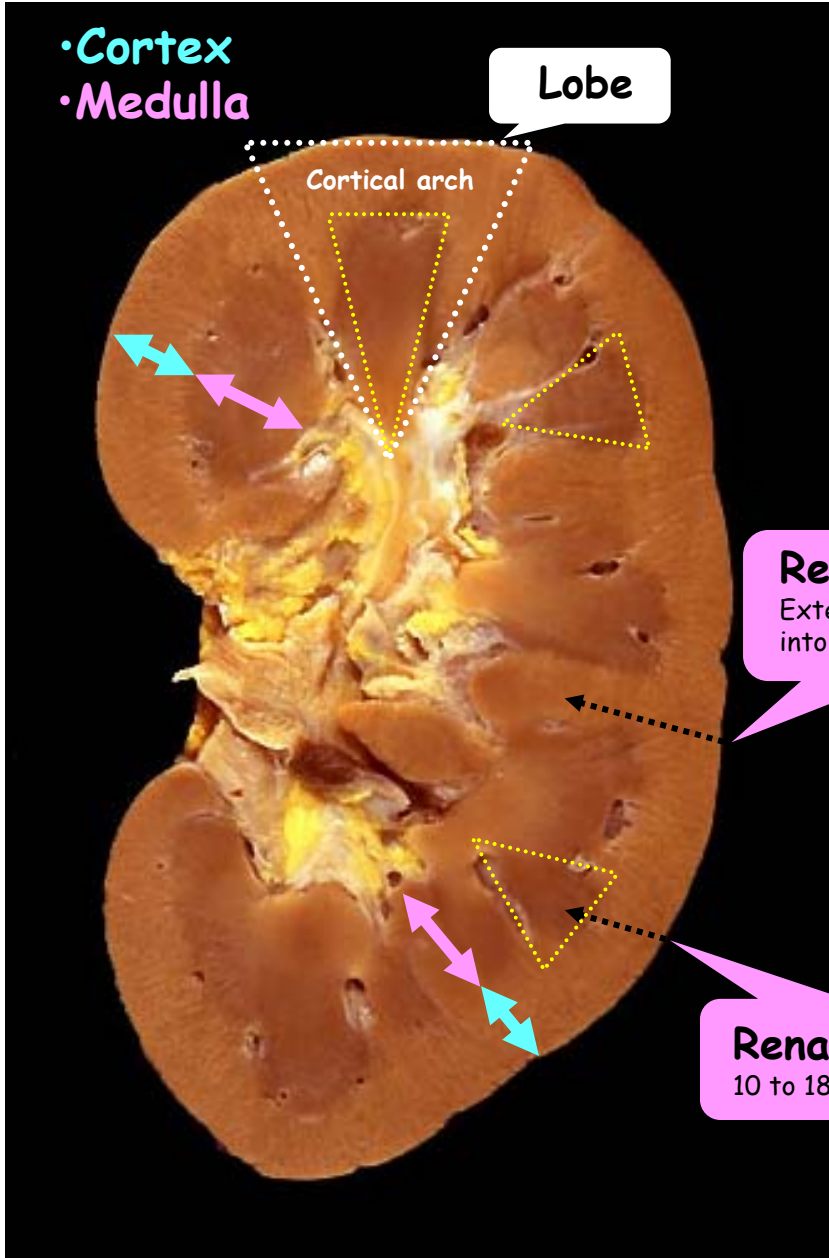


**Hilum** - portal for renal vessels, nerves and urether

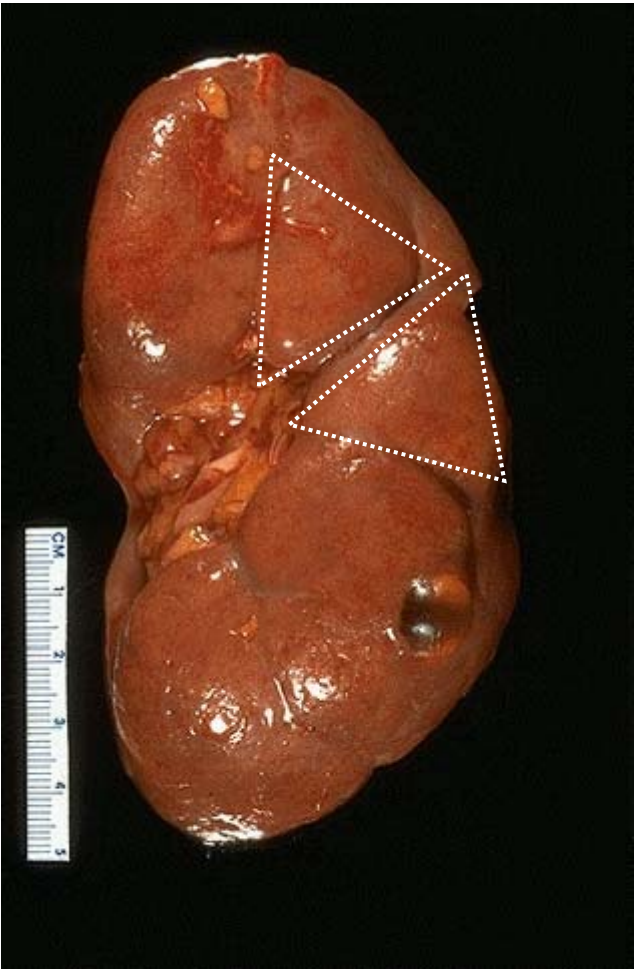
**Renal sinus** - cavity deep to hilum occupied by renal pelvis and vessels

**Renal pelvis** - expansion of ureter, extension to **major and minor calyces**

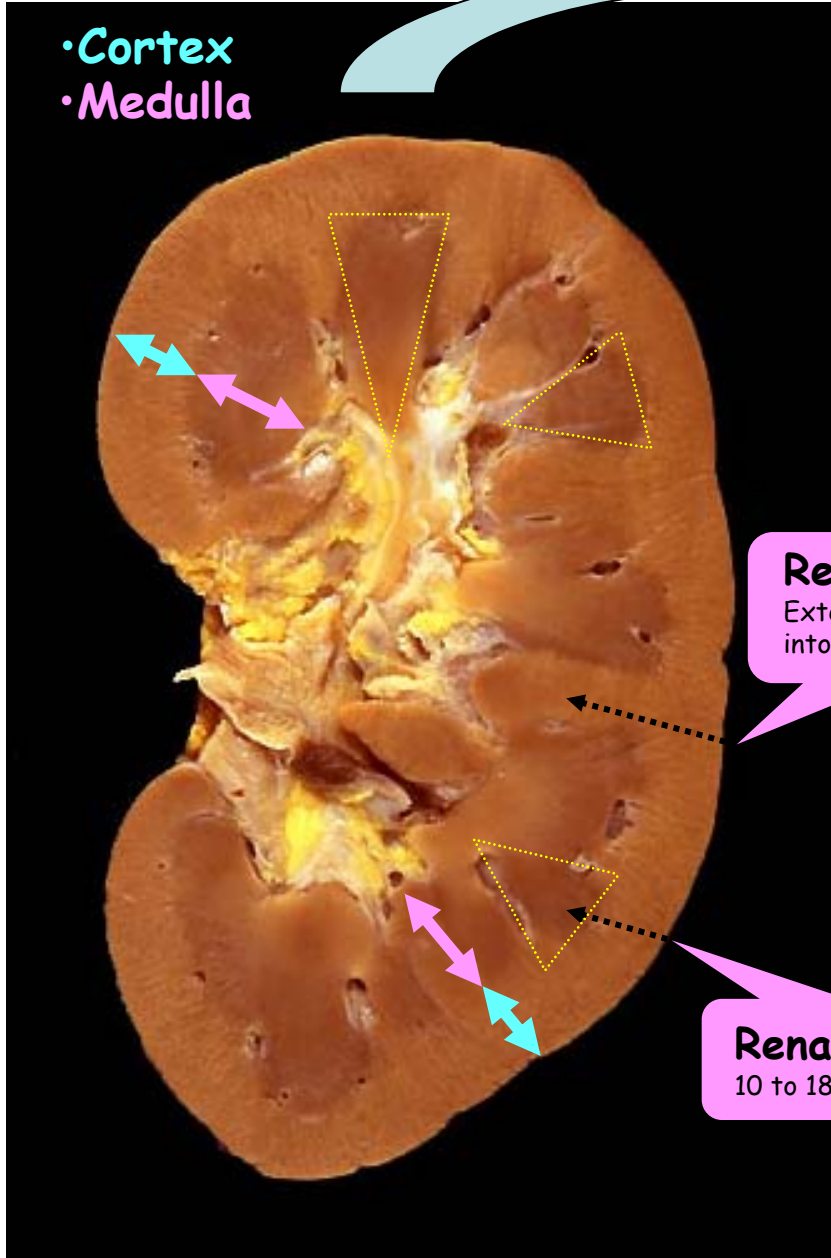
**Renal parenchyma** - medulla + cortex



### Lobular structure of the kidney

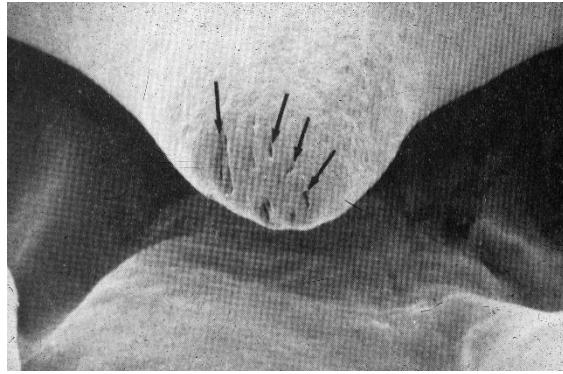
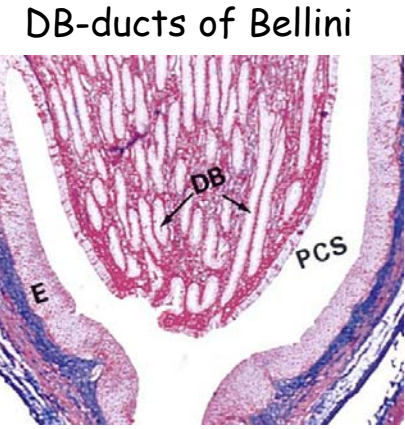
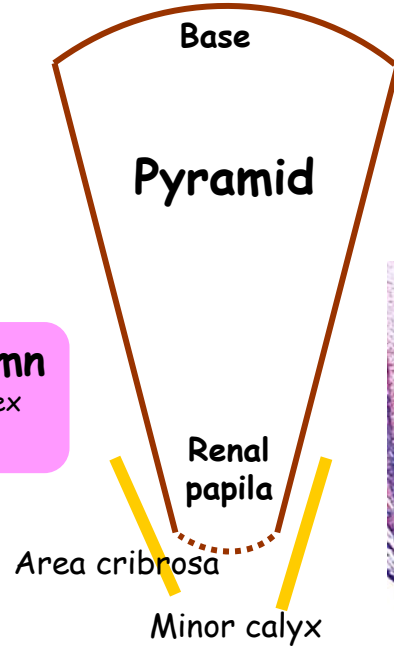


- Cortex
- Medulla

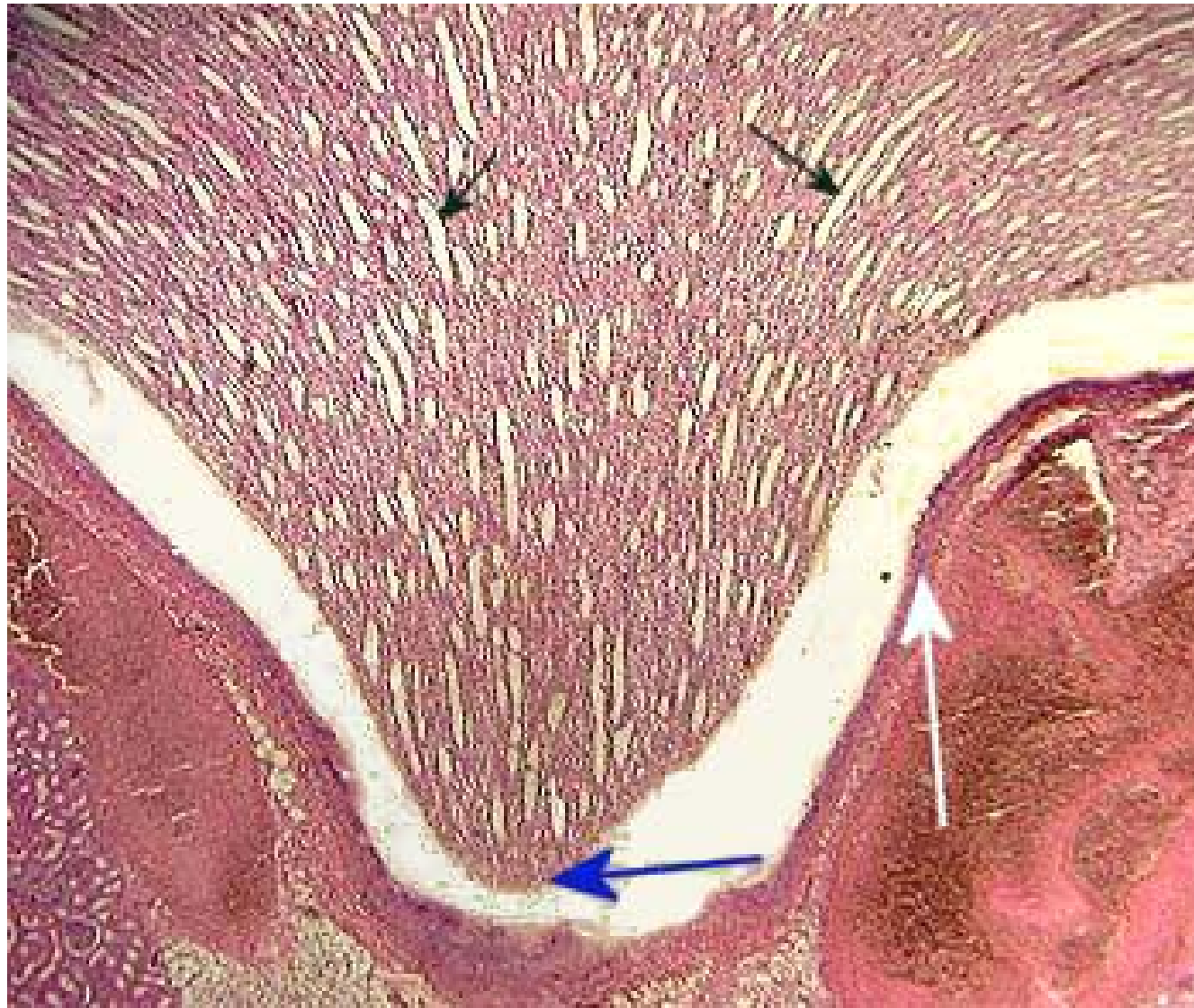


**Renal collumn**  
Extension of cortex into medulla

**Renal pyramid**  
10 to 18 per kidney

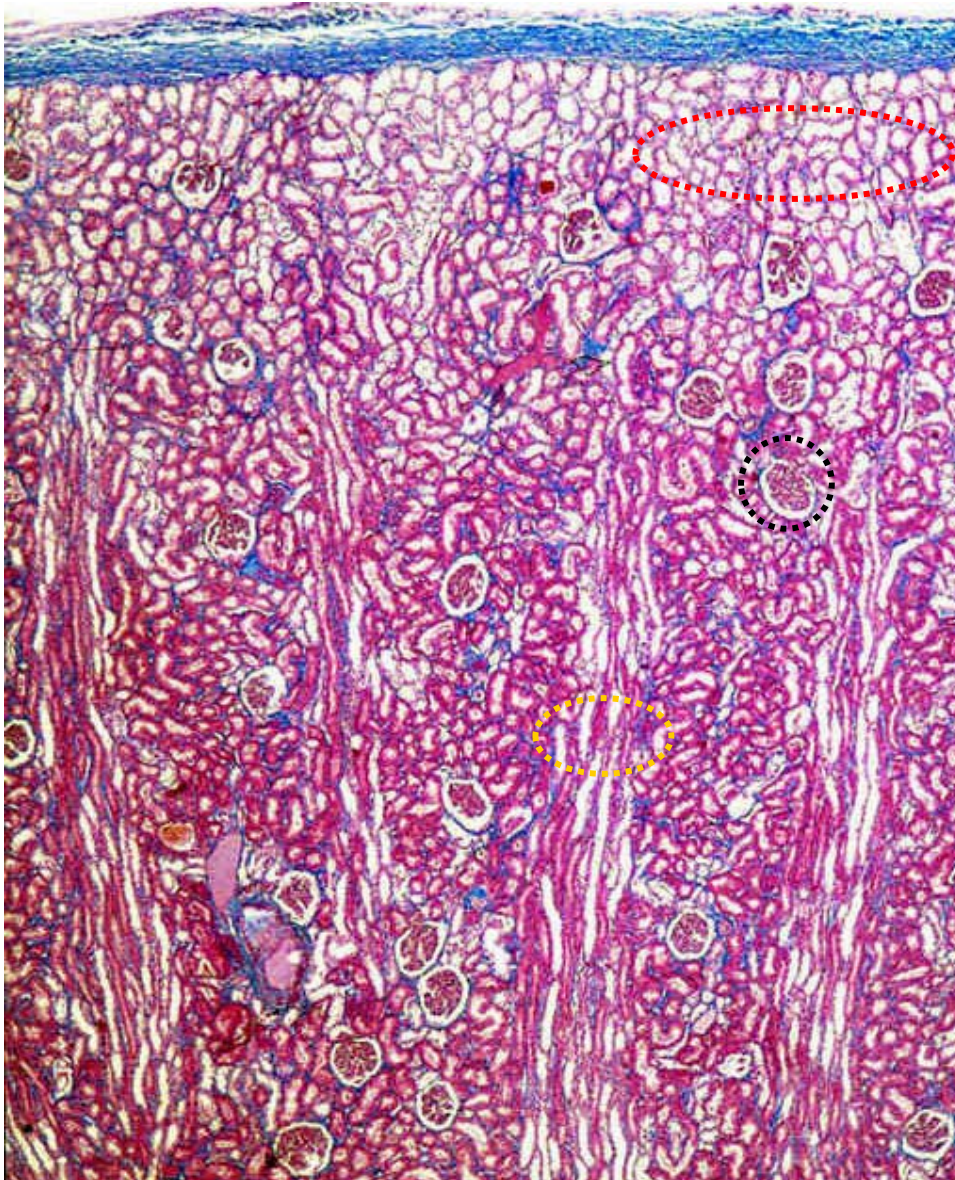


# Kidney medulla





# Kidney cortex



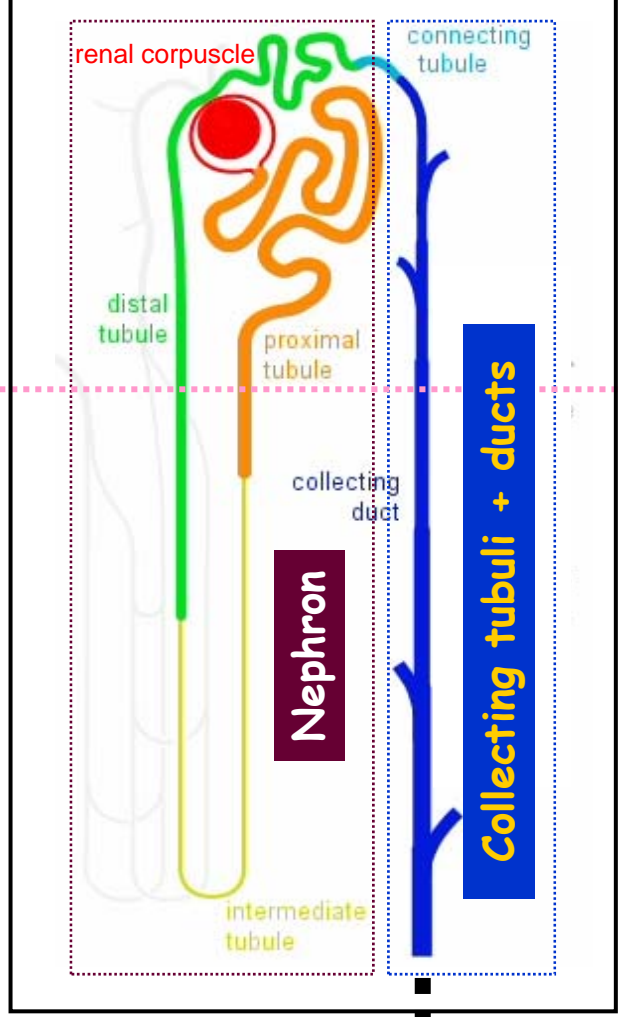
**Cortical labyrinth**  
(convoluted tubules)

**Renal corpuscles**

**Cortical rays**  
(continuation of collecting  
ducts from renal pyramids)

# Urineriferous tubule

= The functional unit of the kidney



Cortex

Medulla

Ducts of Bellini

1 to 1.4 millions of nephrons in one kidney

Area cribrosa  
Minor calyx

Nephrons X Collecting tubuli + ducts  
Different embryological origin

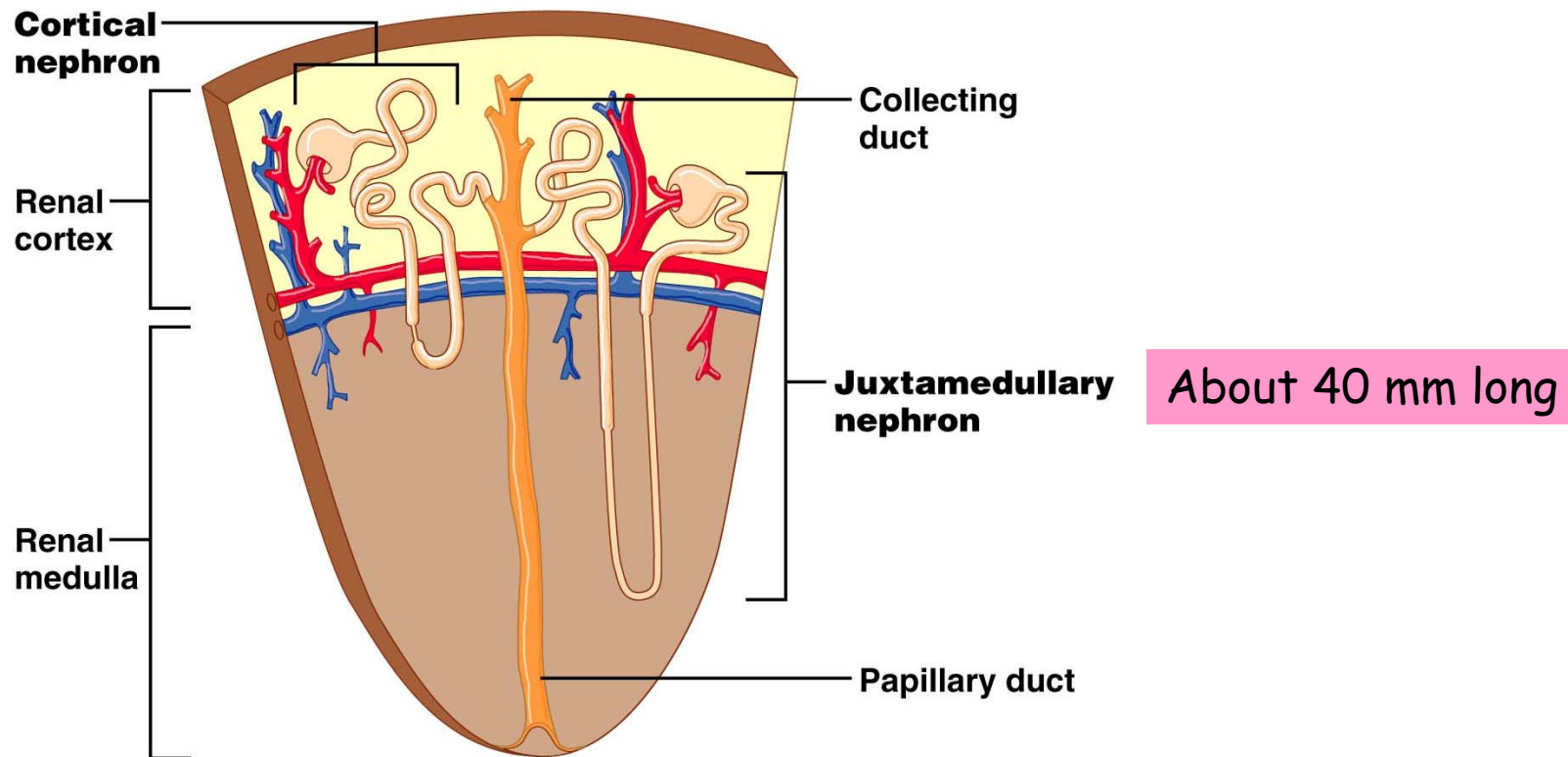
# Nephron

**Cortical nephrons**

85% of nephrons

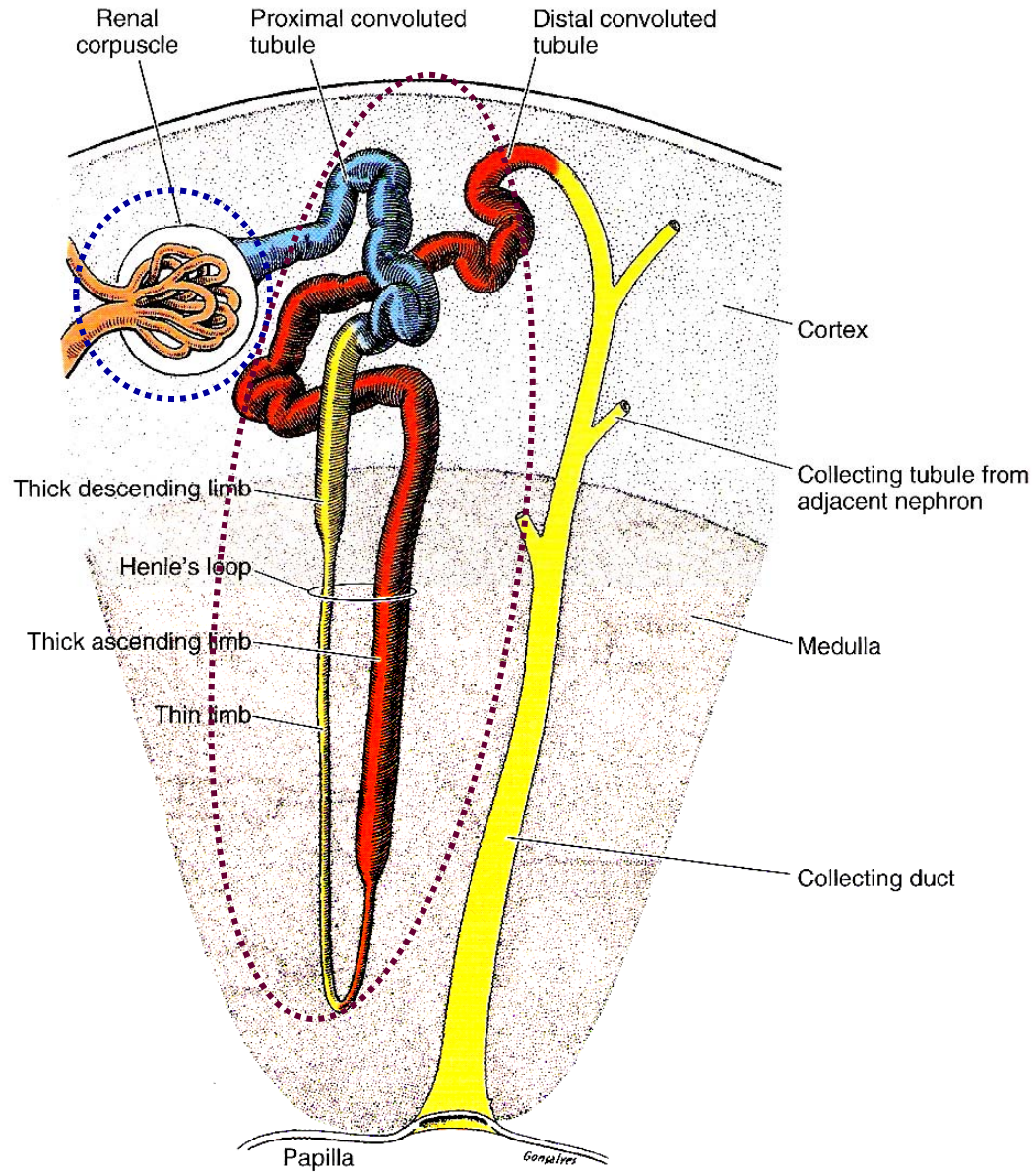
**Juxtamedullary nephrons**

15% of nephrons





# Nephron

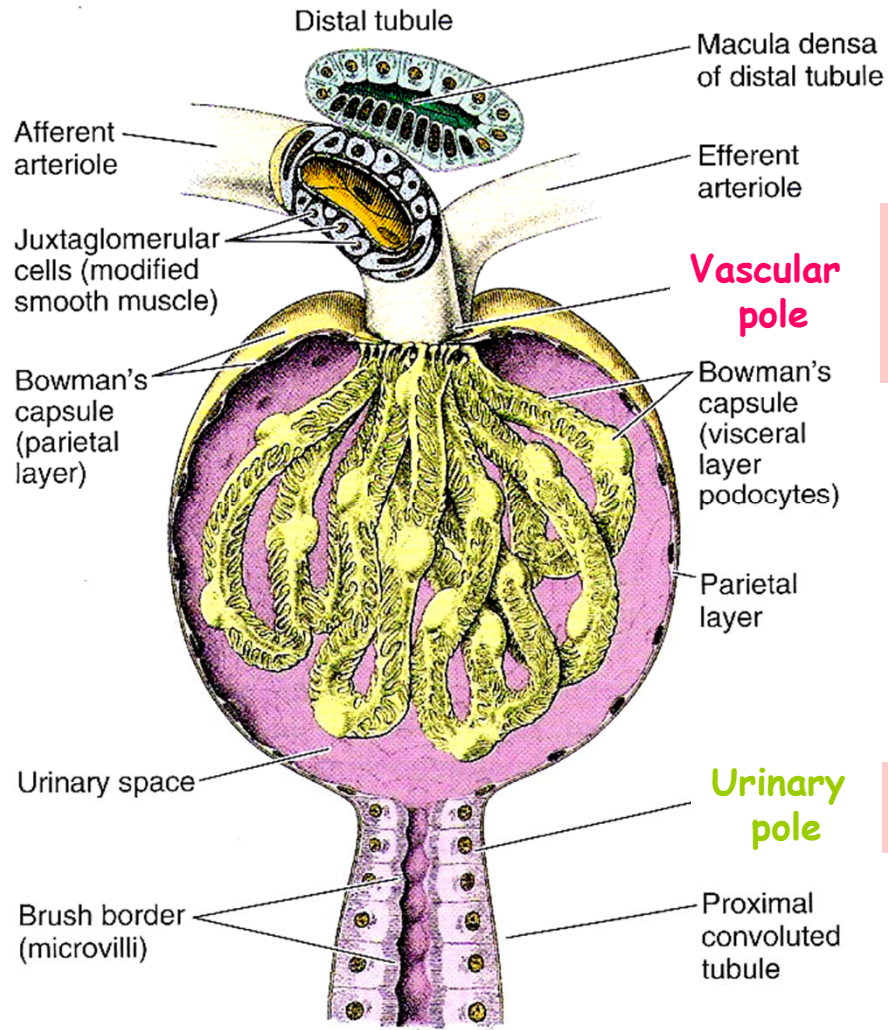




# Nephron - Renal corpuscle 1

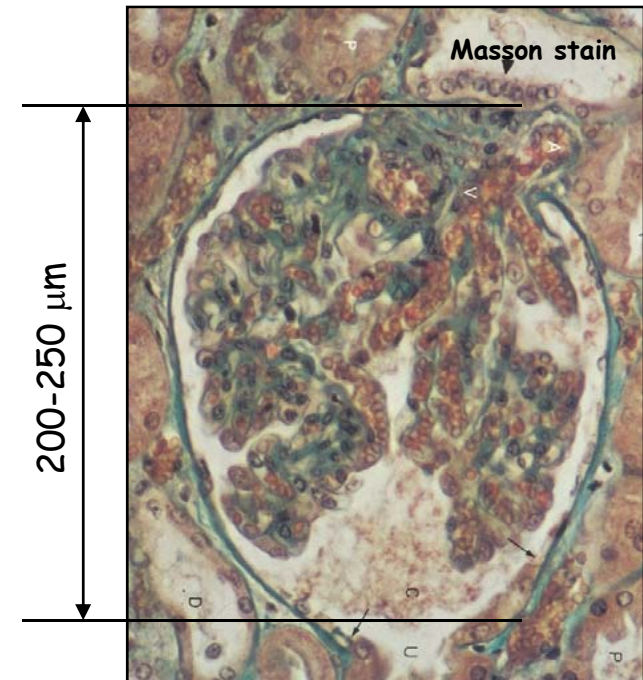
**Glomerulus** - tuft of capillaries

**Bowman's capsule** - invaginated dilatation of proximal tubule

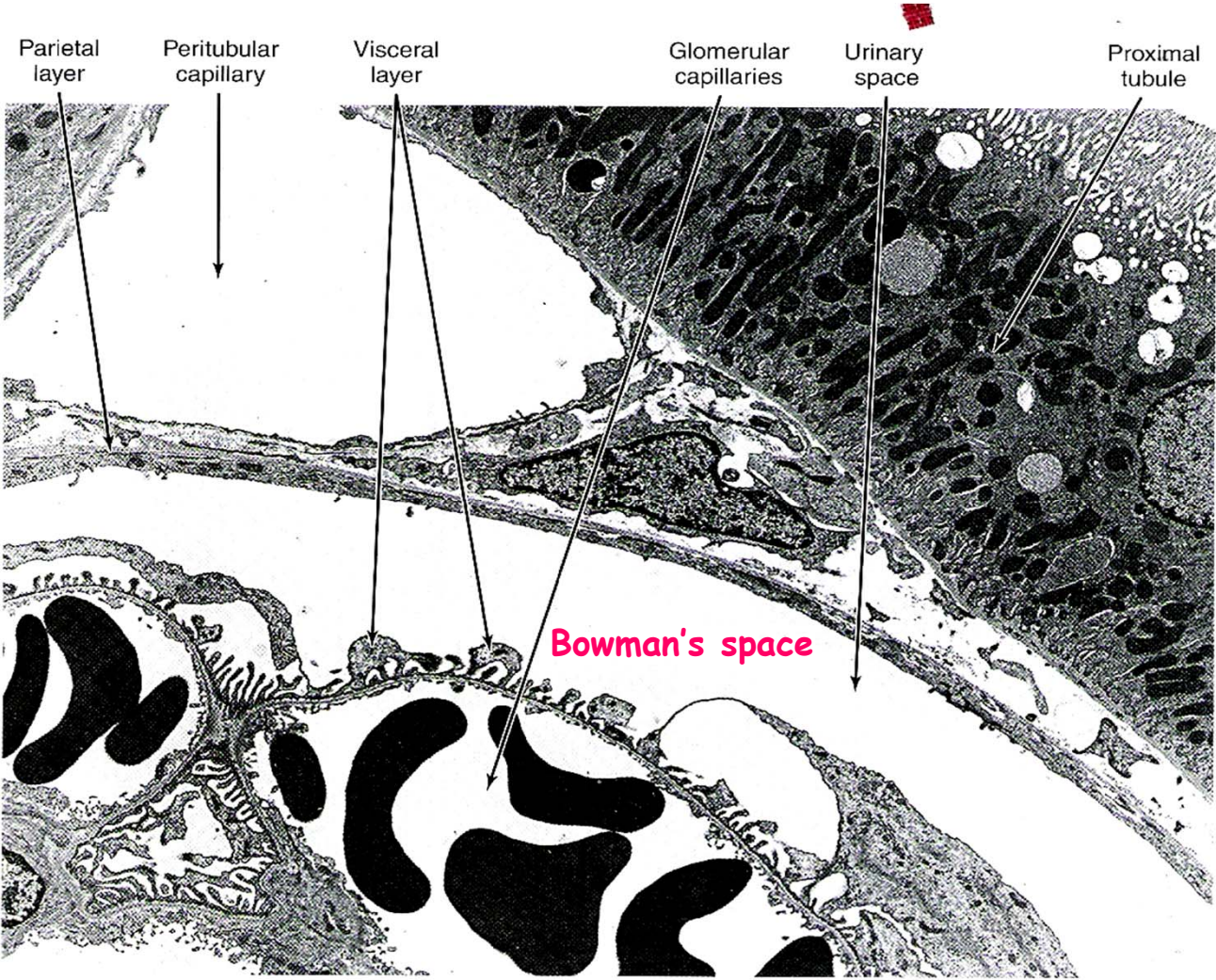


side of the corpuscle where the afferent arterioles and efferent arterioles enter and exit, respectively

side of the corpuscle where the PCT exits.



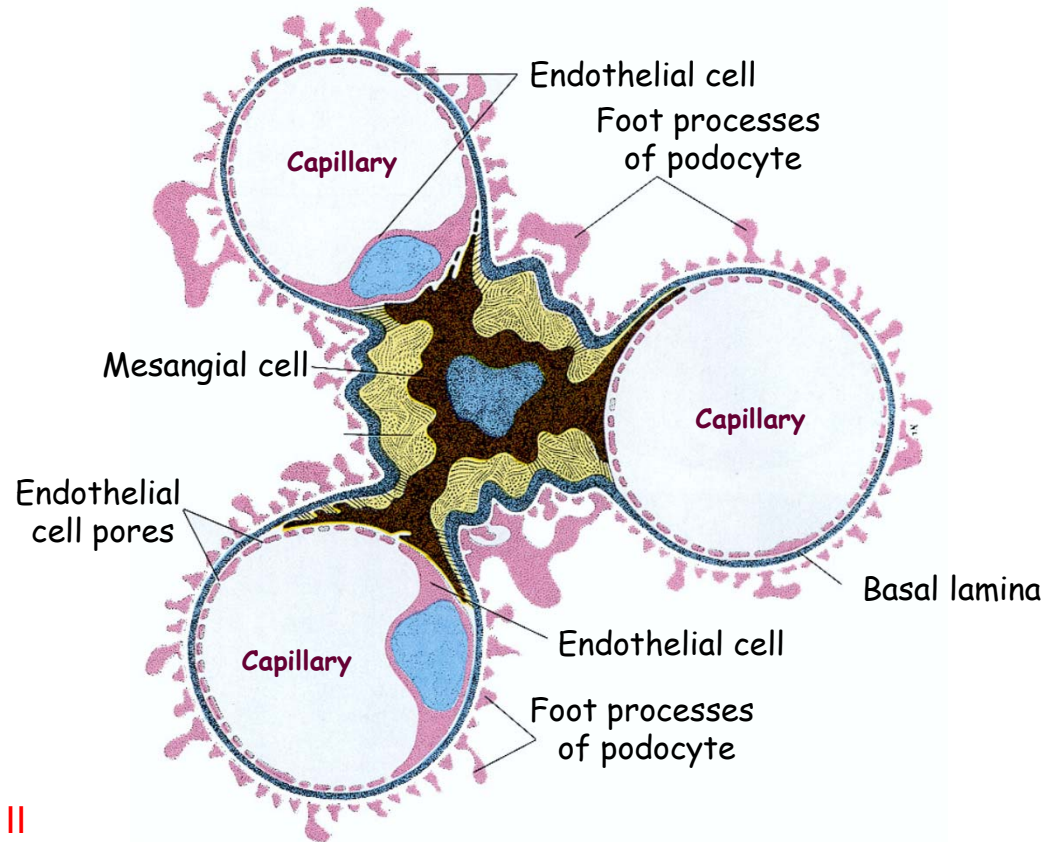
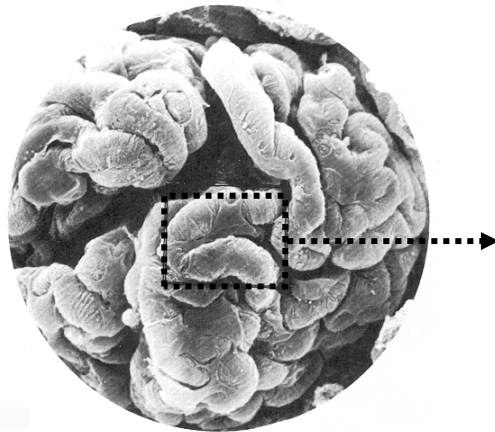
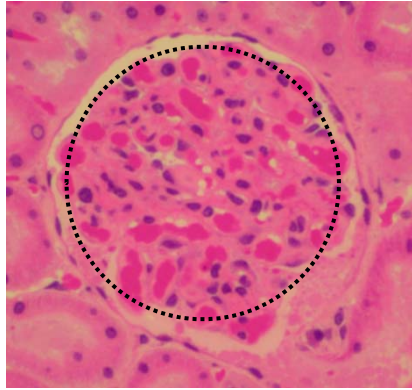
# Nephron - Renal corpuscle 2





# Nephron - Glomerulus 1

Endothelial cell + Basal lamina + Podocytes + Mesangial cells



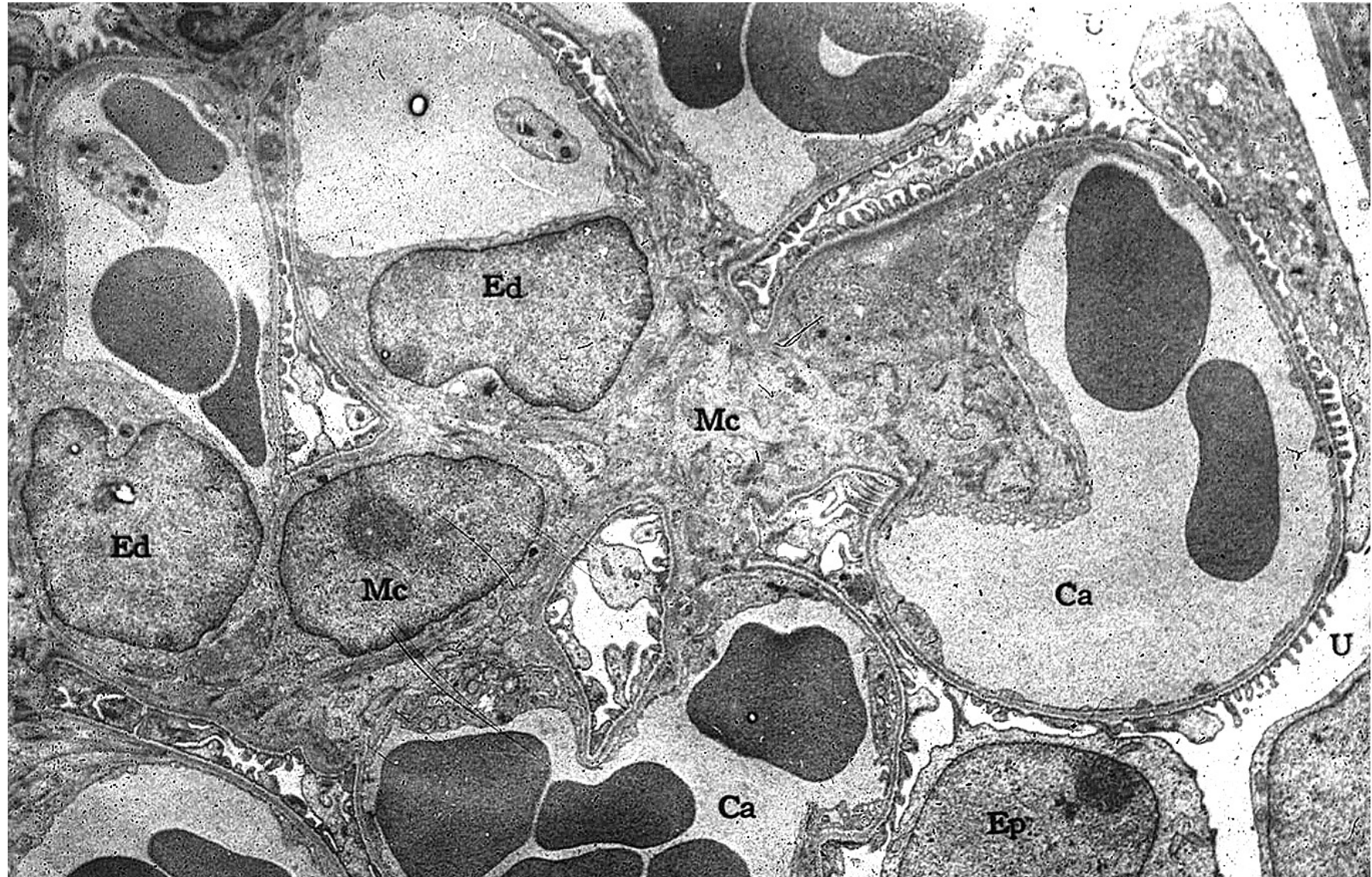
## Mesangial cells

- **Contractile** - receptors for angiotensin II
- Give structural support to the glomerulus, synthesize ECM
- Endocytose and dispose of normal and pathologic molecules trapped by the glomerular basement membrane
- Produce chemical mediators such as cytokines and prostaglandins

*Lamina Rara* - contain fibronectin (bind them to cells) - **physical barrier**  
*Lamina Densa* - meshwork of Type IV collagen and laminin in a matrix contg (-) charged heparan sulfate that restricts passage of cationic molecules - **charge barrier**

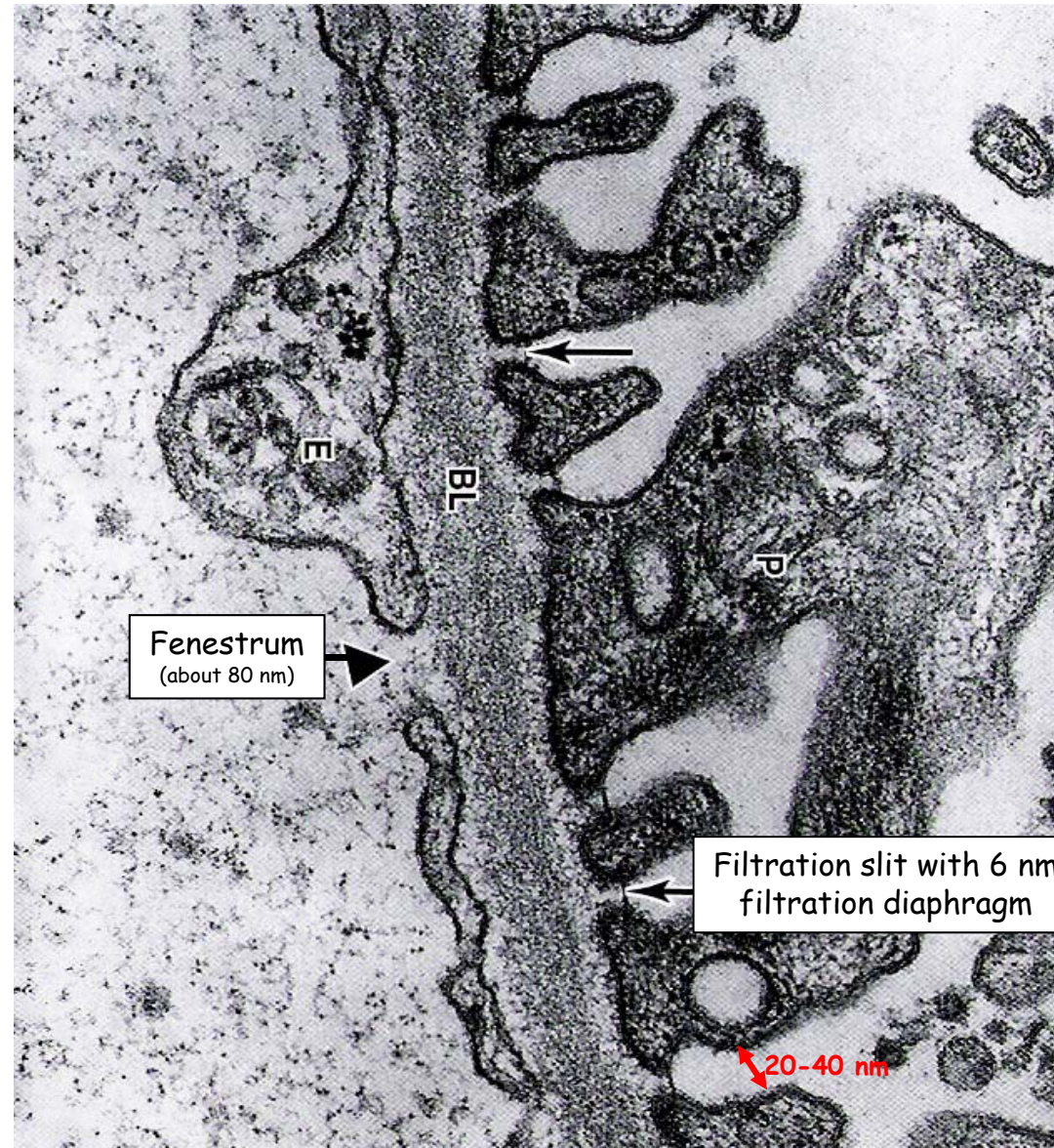
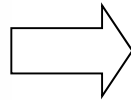
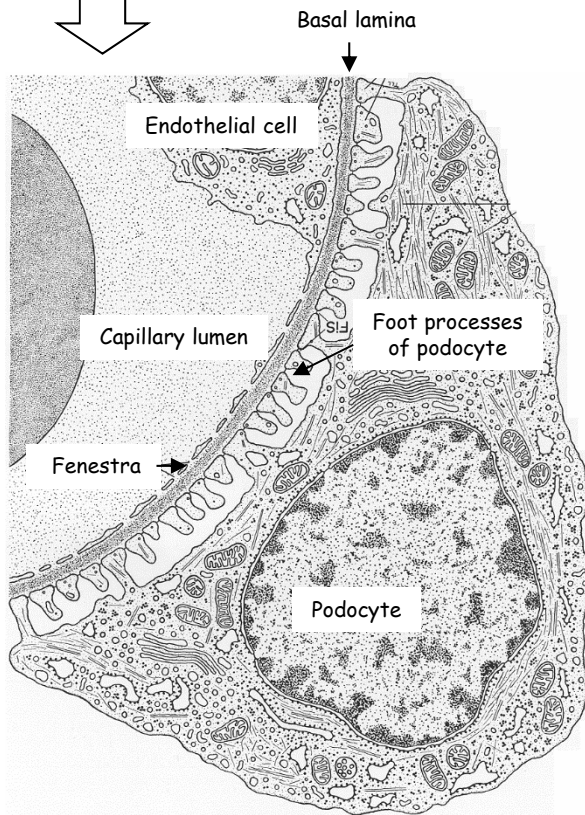
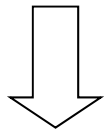
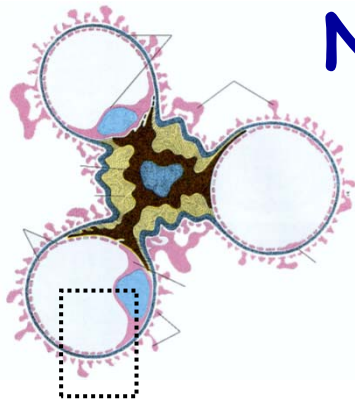


# Nephron - Glomerulus 2





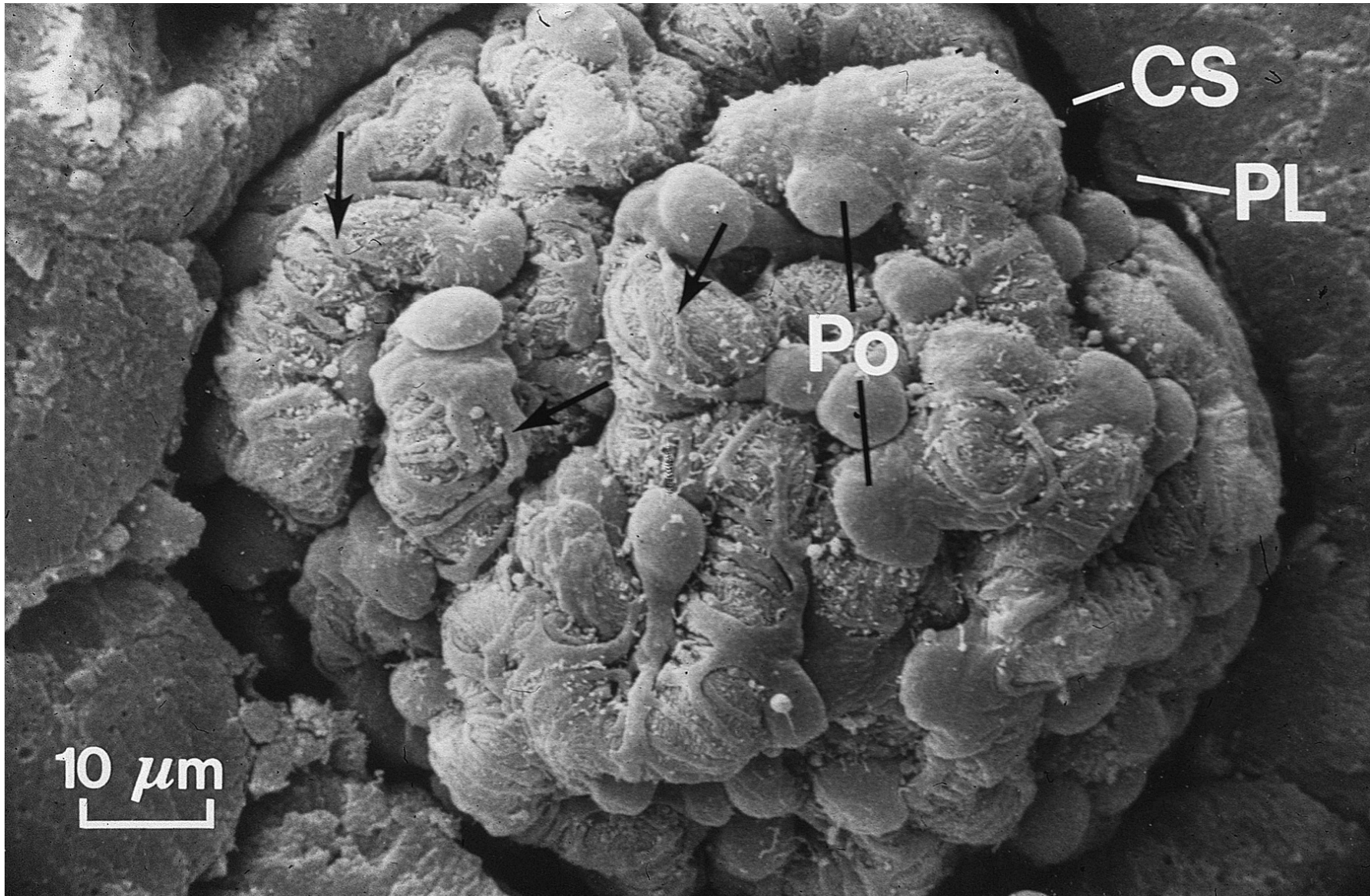
# Nephron - Glomerulus 3



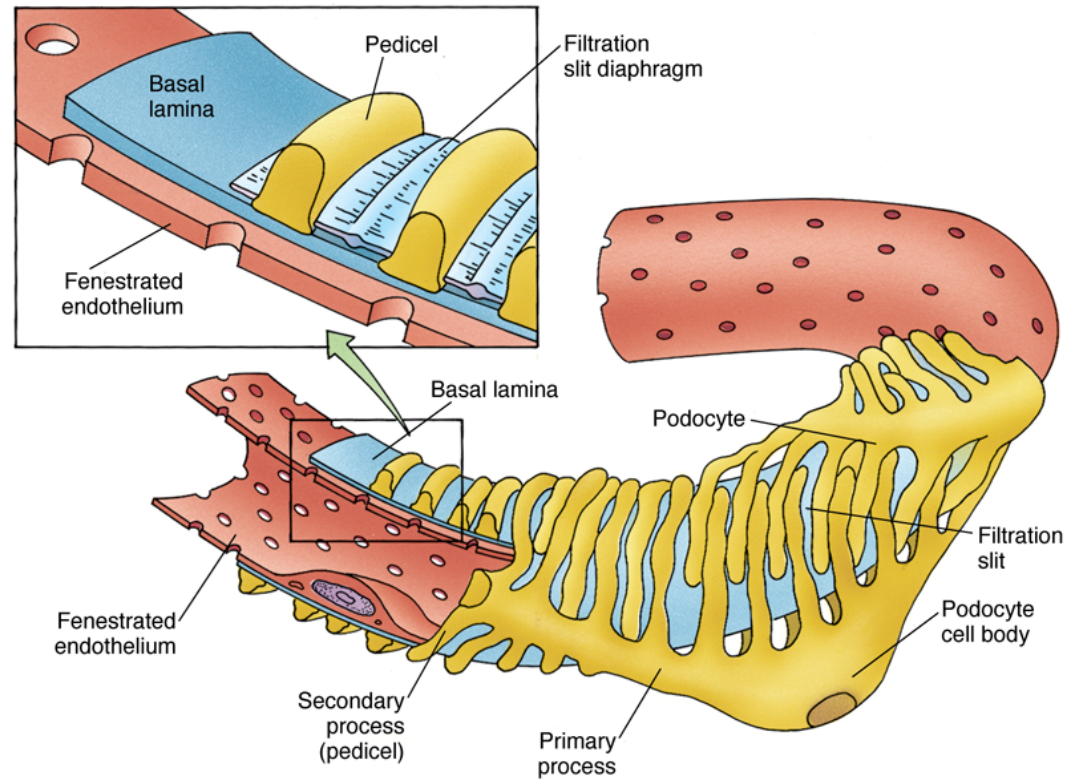
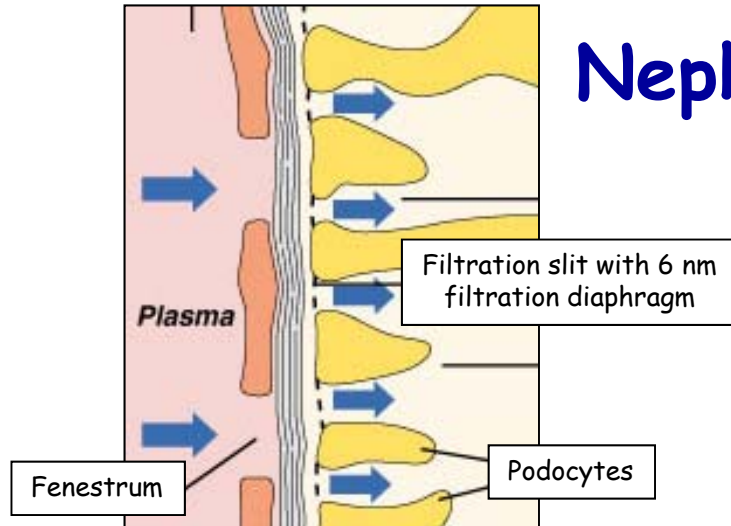
Fenestra: 70 - 90 nm



# Nephron - Glomerulus - Podocyte 1



# Nephron - Glomerulus - Podocyte 2



Primary processes  
X  
Secondary processes

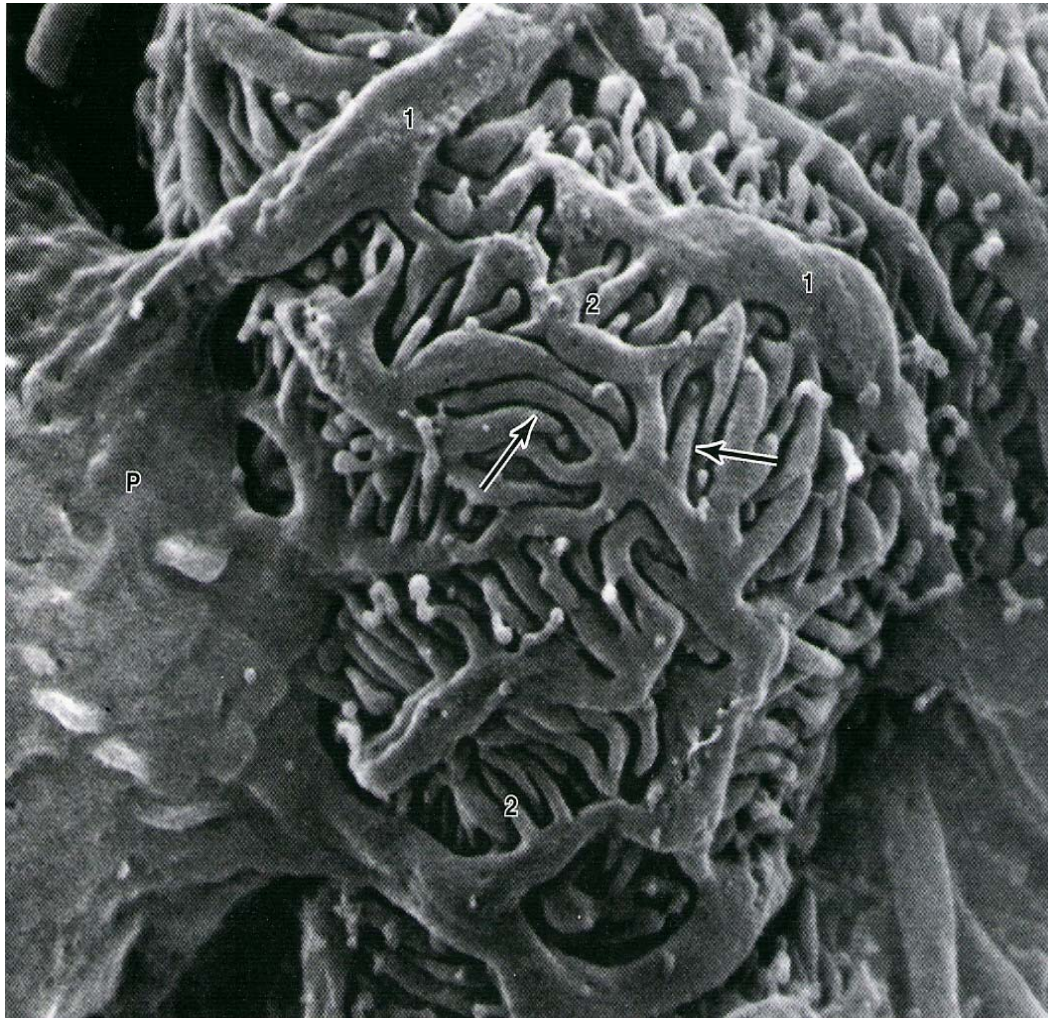






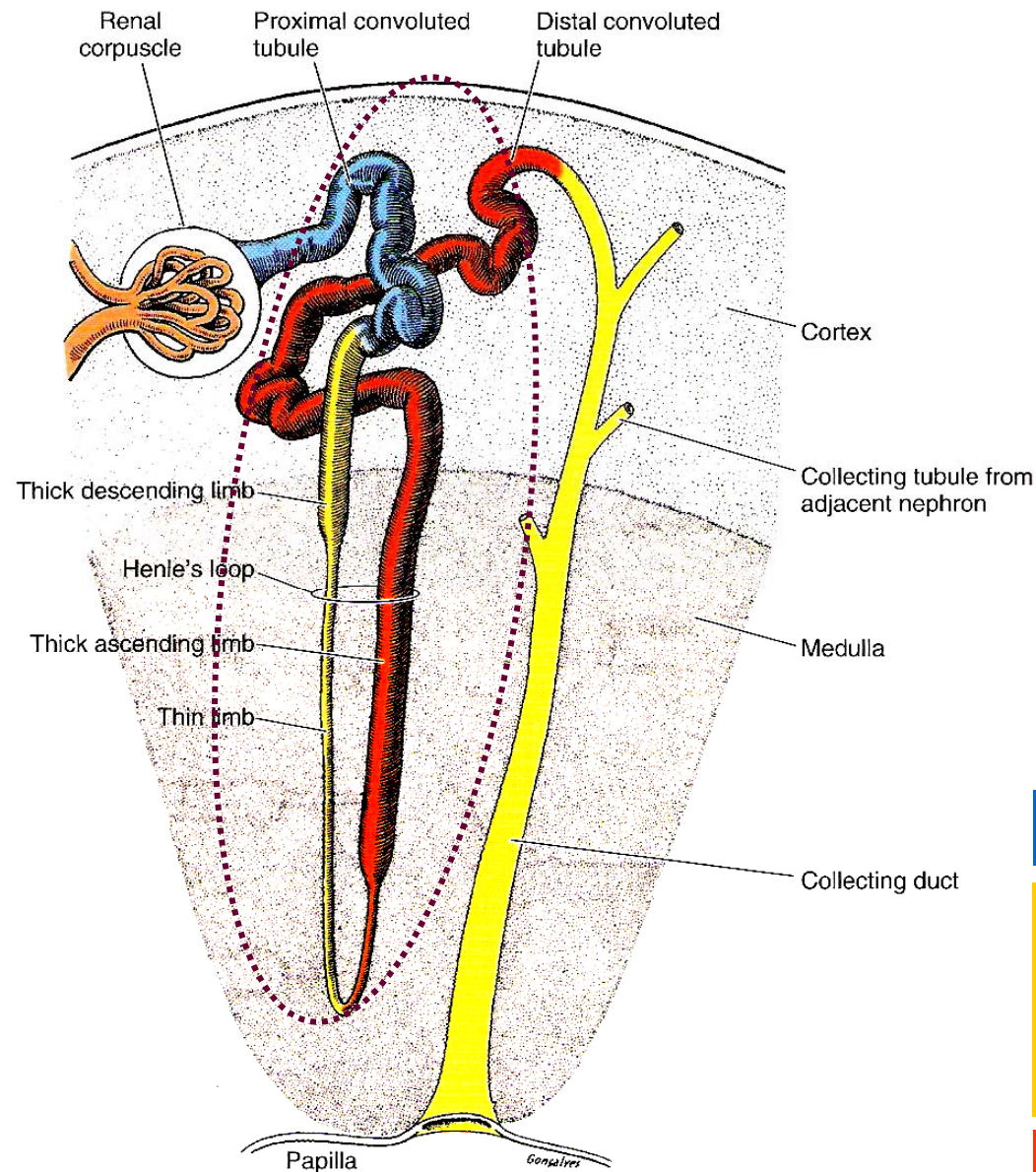
# Nephron - Glomerulus - Podocyte

„Octopus-like cell“





# Nephron - Tubular section 1



**Proximal convoluted tubulus**

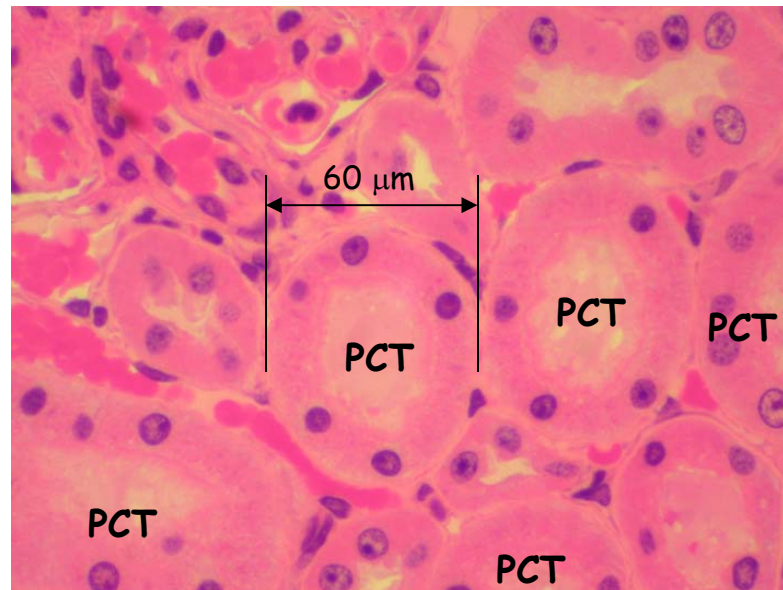
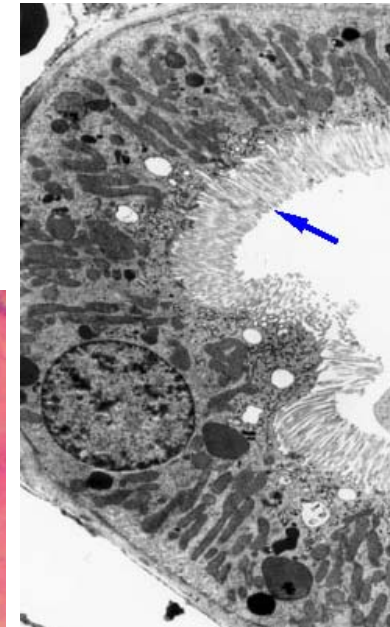
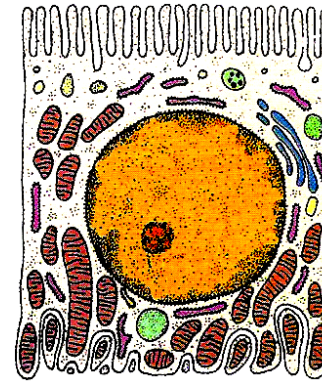
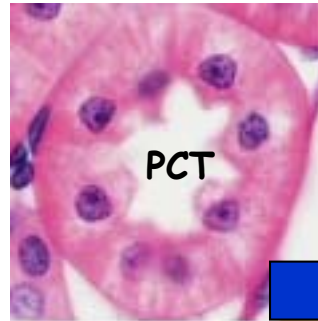
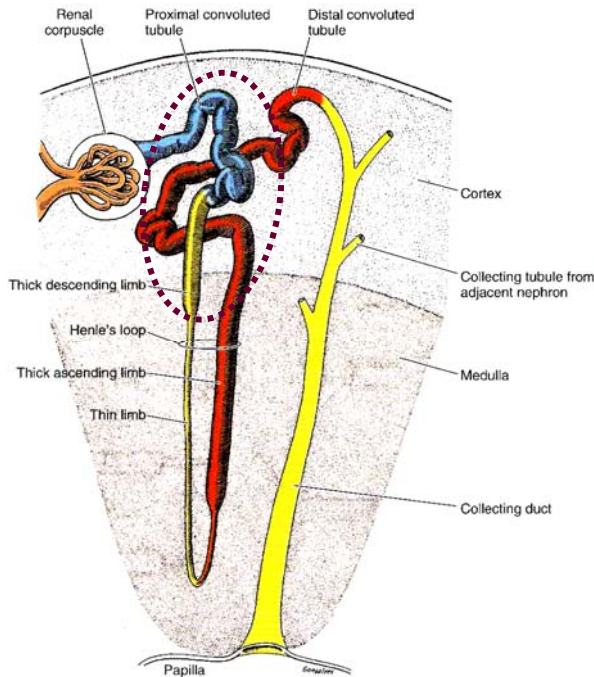
**Henle`s loop**

- Thick descending limb
- Thin limb
- Thick ascending limb

**Distal convoluted tubulus**

# Nephron - Tubular section 2

Proximal convoluted tubulus + Thick descending limb of HL  
= 14 mm in length

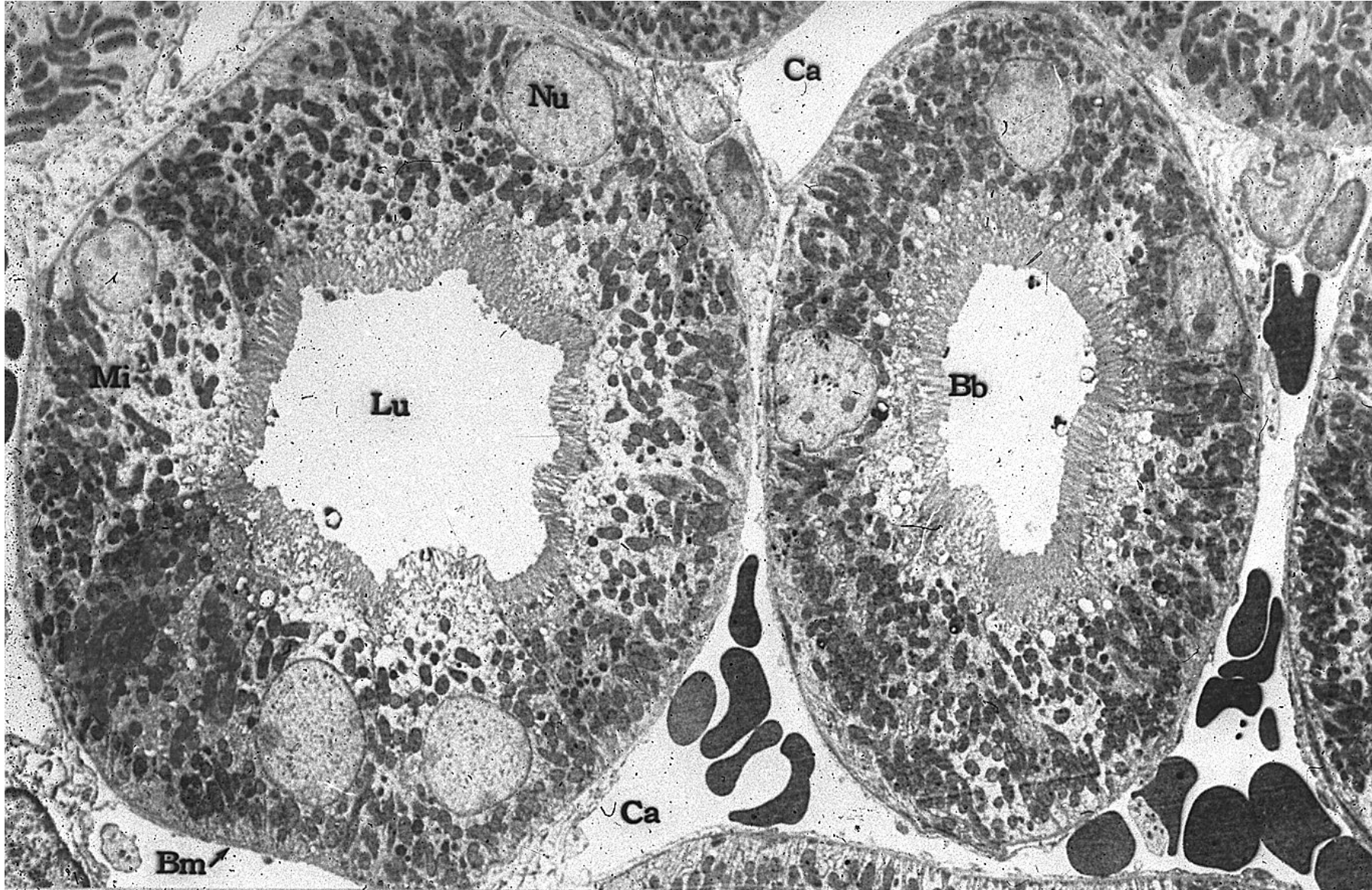


## Reabsorption

$\frac{3}{4}$  of sodium, Cl, K, H<sub>2</sub>O,  
amino acids, proteins



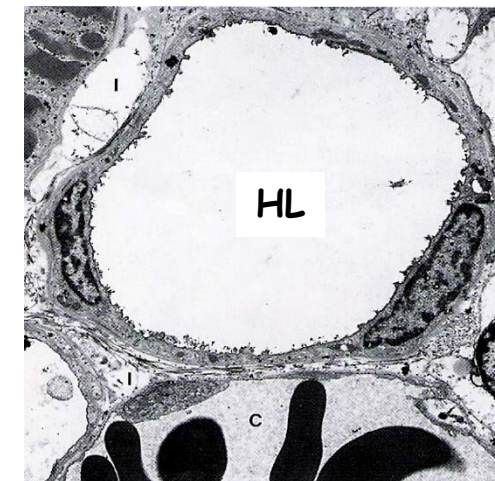
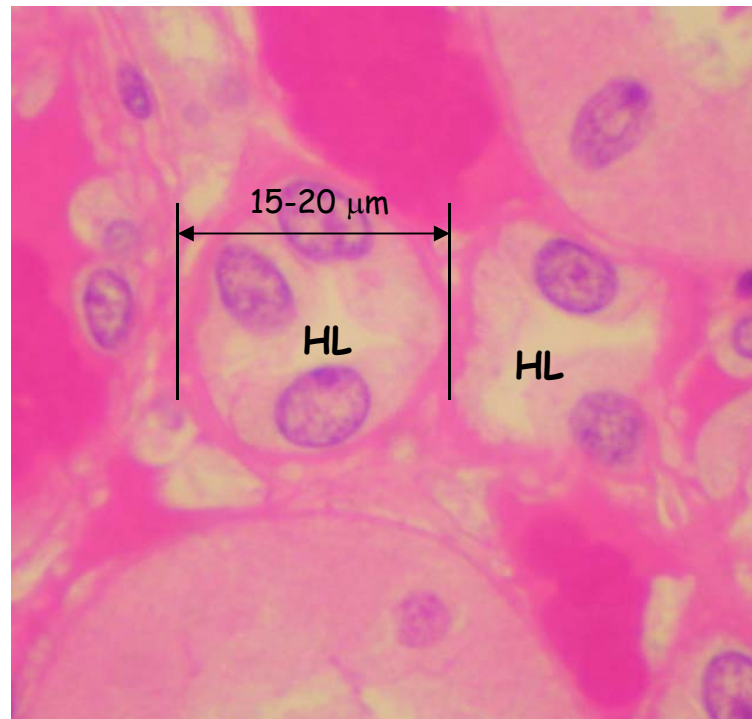
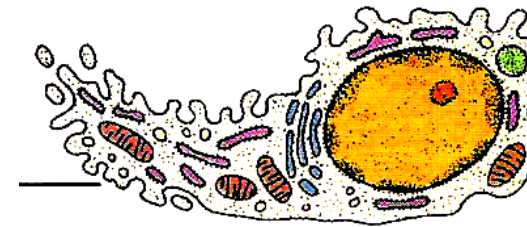
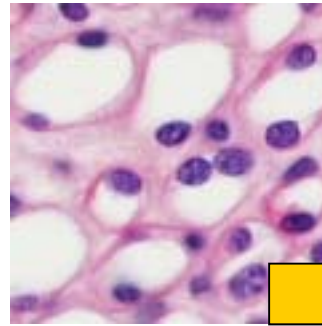
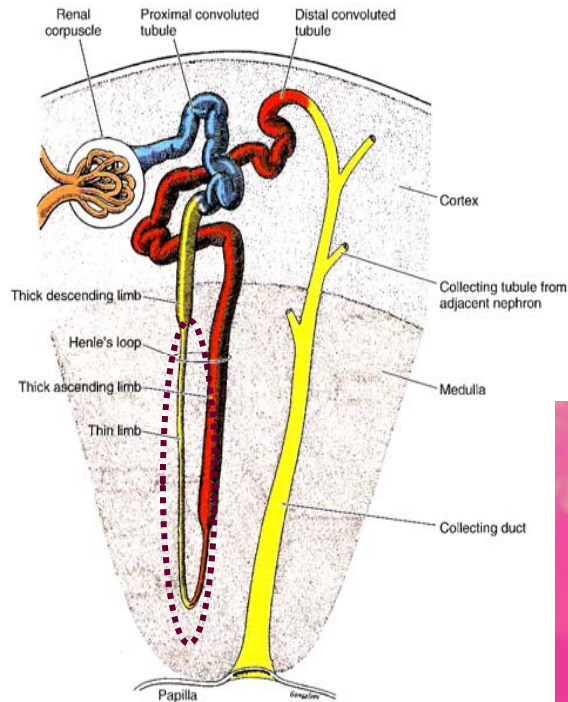
# Proximal convoluted tubuli





# Nephron - Tubular section 3

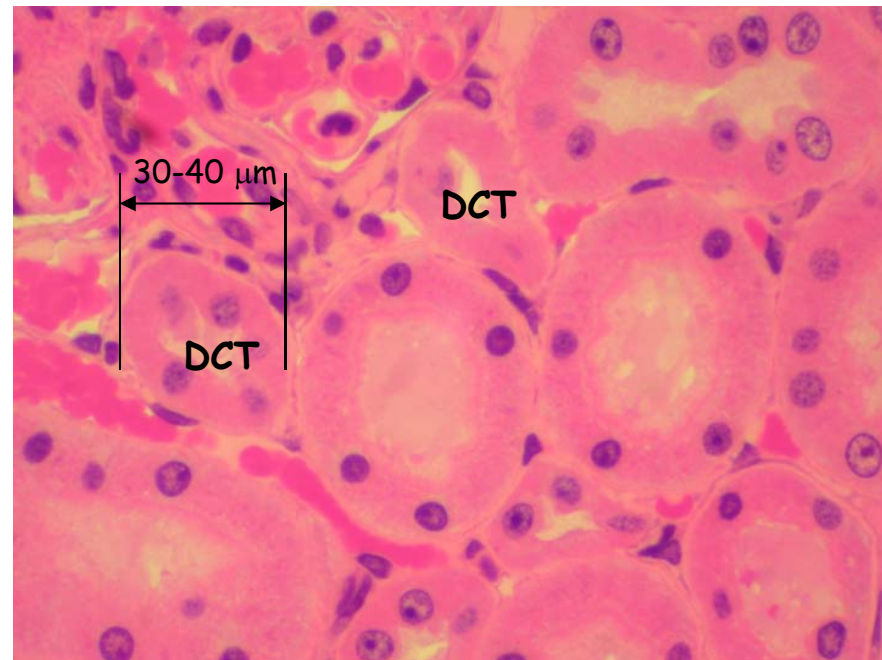
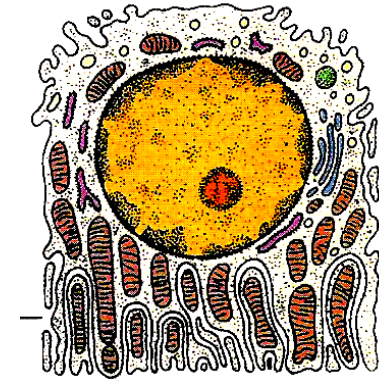
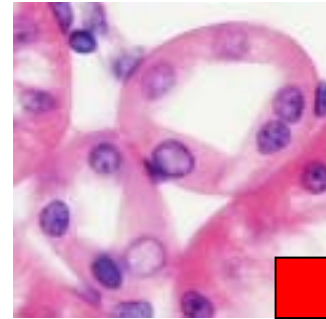
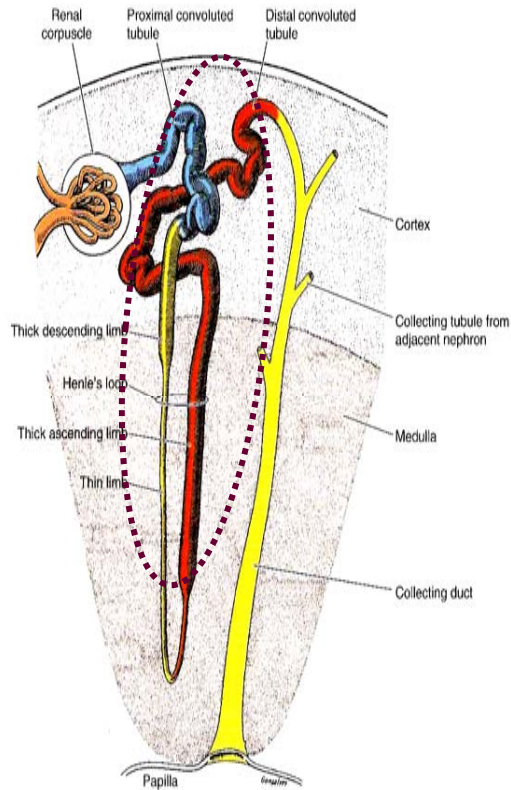
Thin descending limb of HL + Thin ascending limb of HL  
= 9-10 mm in length



**Reabsorption**  
H<sub>2</sub>O

# Nephron - Tubular section 4

Thick ascending limb of HL + Distal convoluted tubulus  
9-10 mm in length + 4-5 mm in length



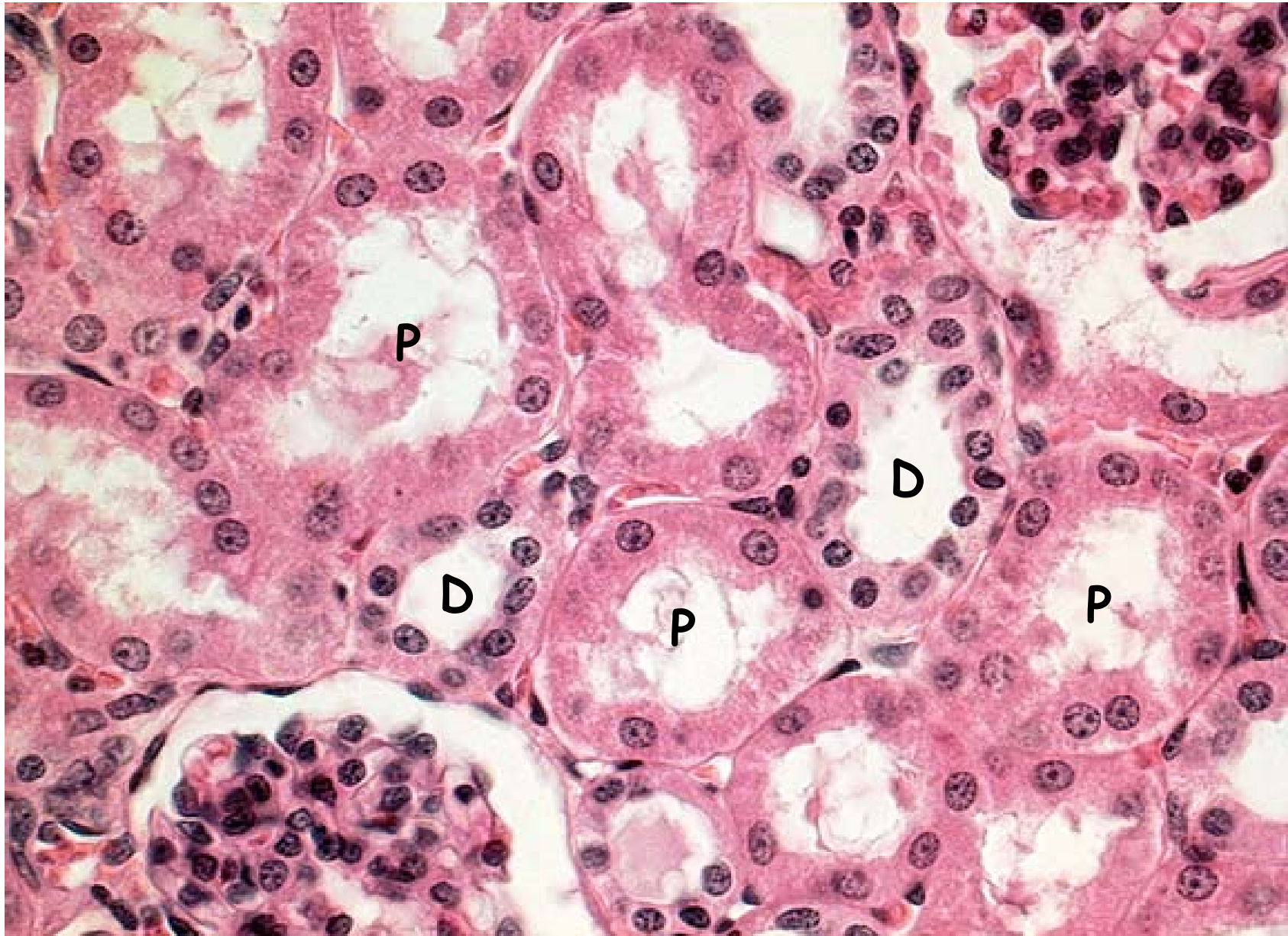
**Reabsorption**

Na, K, Cl

**Impermeable for water**

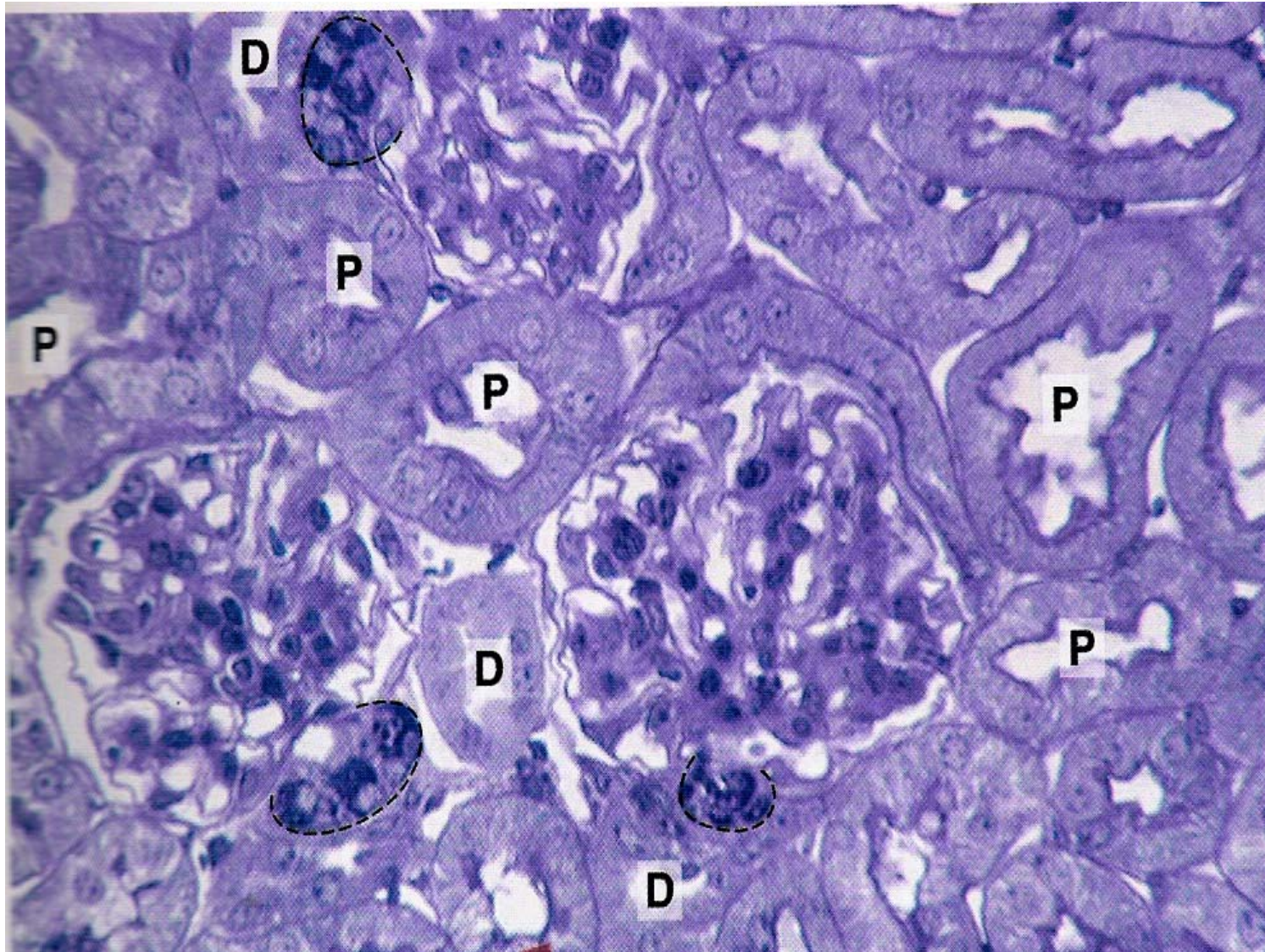


## Proximal and distal convoluted tubuli



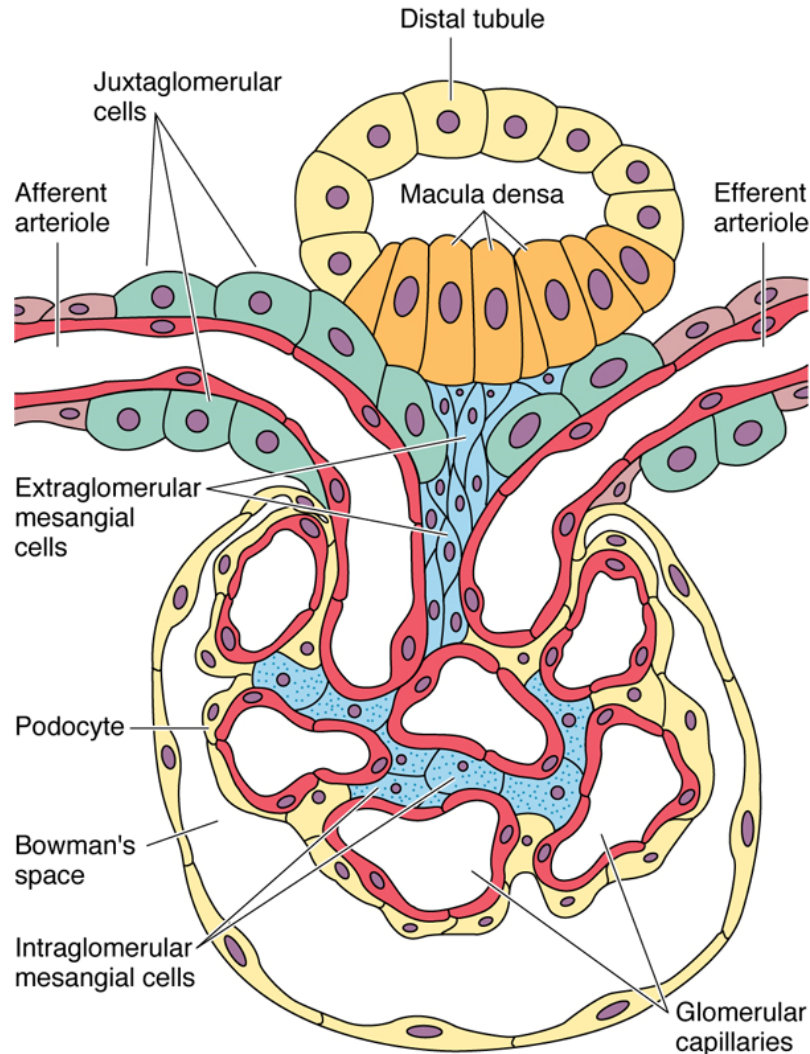
# Cortex

Proximal X Distal convoluted tubuli (7:1)





# Nephron - Tubular section - Juxtaglomerular apparatus 1



## Macula densa

Monitors osmotic concentration in the fluid in the nephron and secretes local hormones that alter JG cell secretion.

## Juxtaglomerular cells

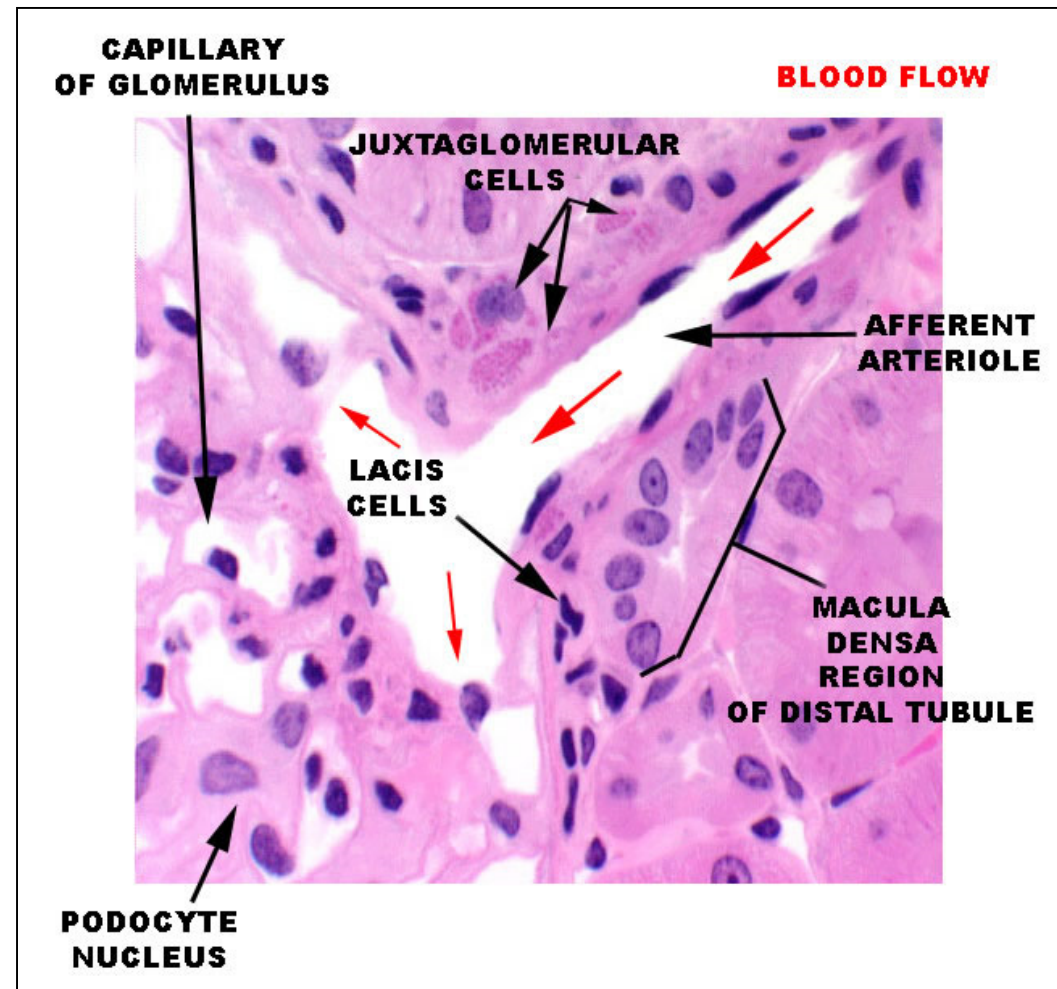
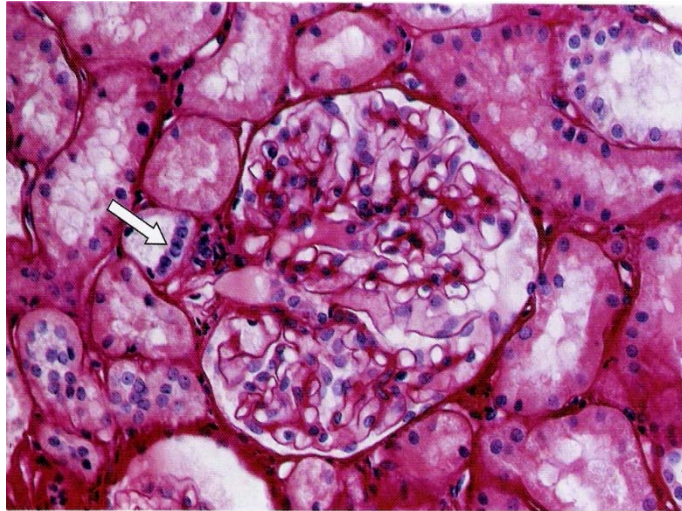
Monitor blood pressure in the afferent arteriole and secrete renin. **Renin** converts angiotensinogen in blood plasma to angiotensin I which is converted to angiotensin II in the lungs. **Angiotensin II** causes arteriole constriction throughout the body, raising blood pressure.

## Extraglomerular mesangial cells (Lacis cells)

# Nephron - Tubular section - Juxtaglomerular apparatus 2

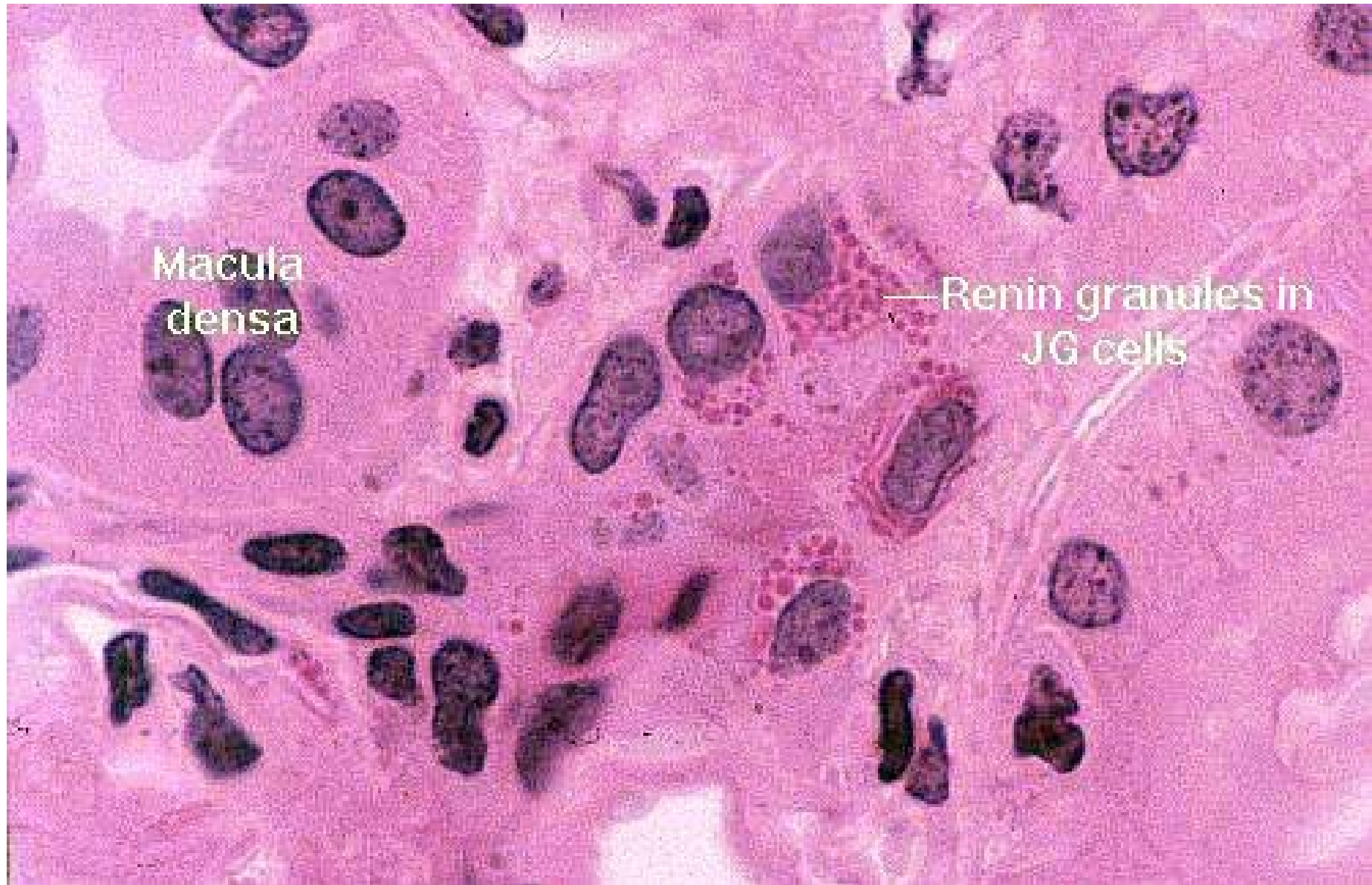
## Macula densa

Modified DCT in proximity of vascular pole of renal corpuscle





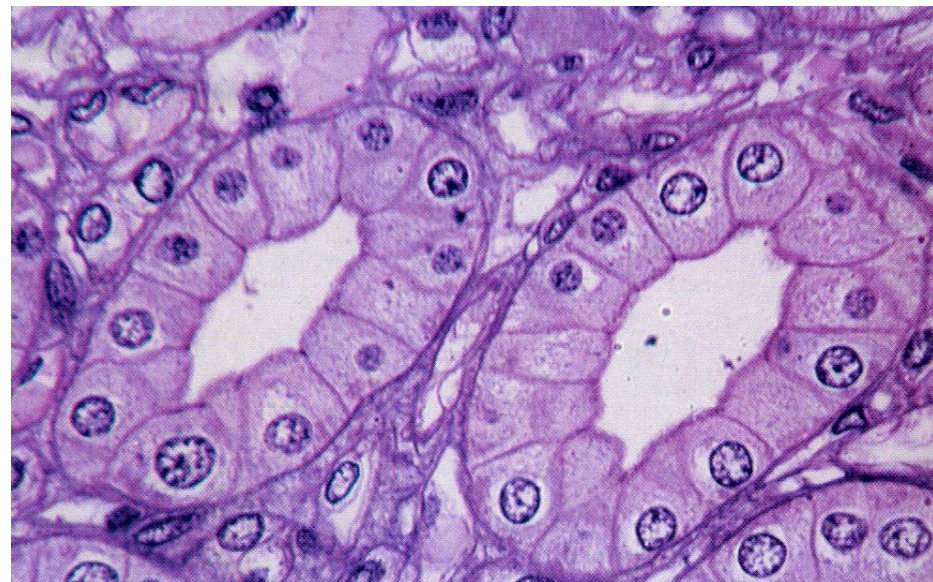
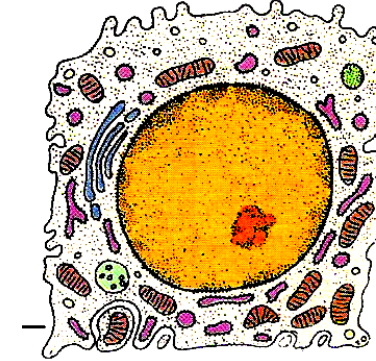
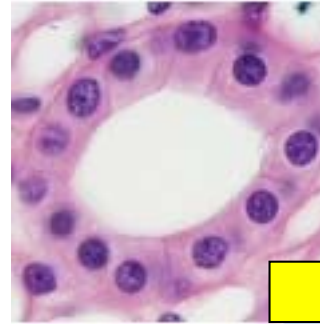
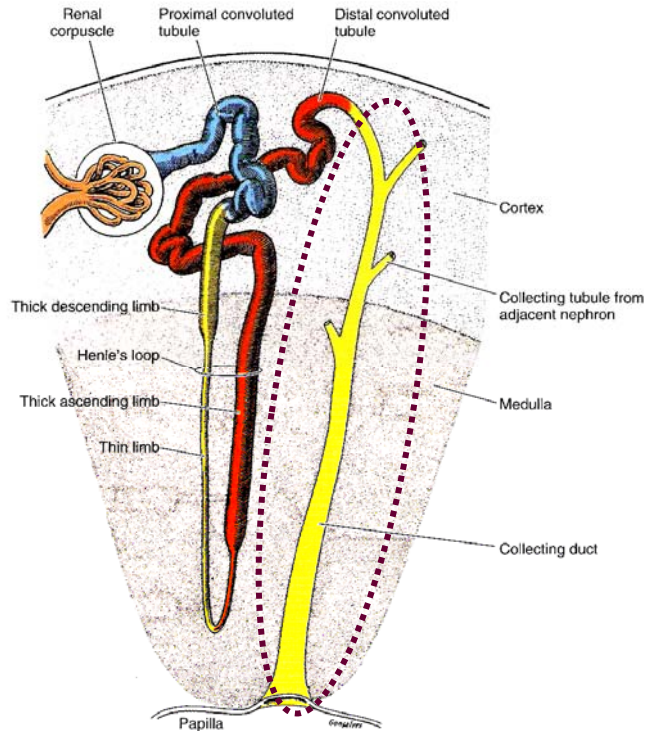
## Juxtaglomerular cells



# Collecting tubuli

Cortical + Medullary + Papillary = 20 mm in length

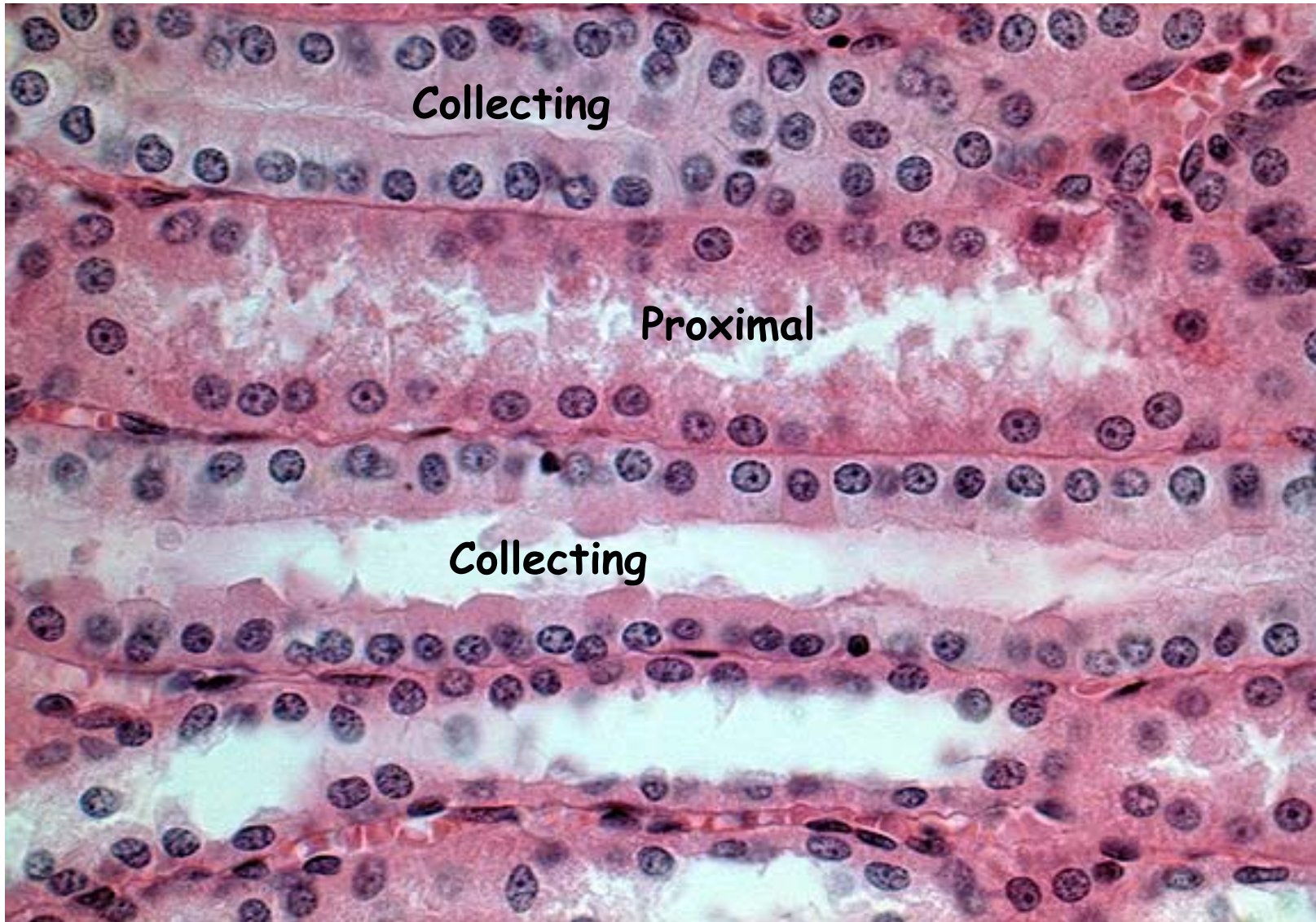
↓  
200 - 300 μm



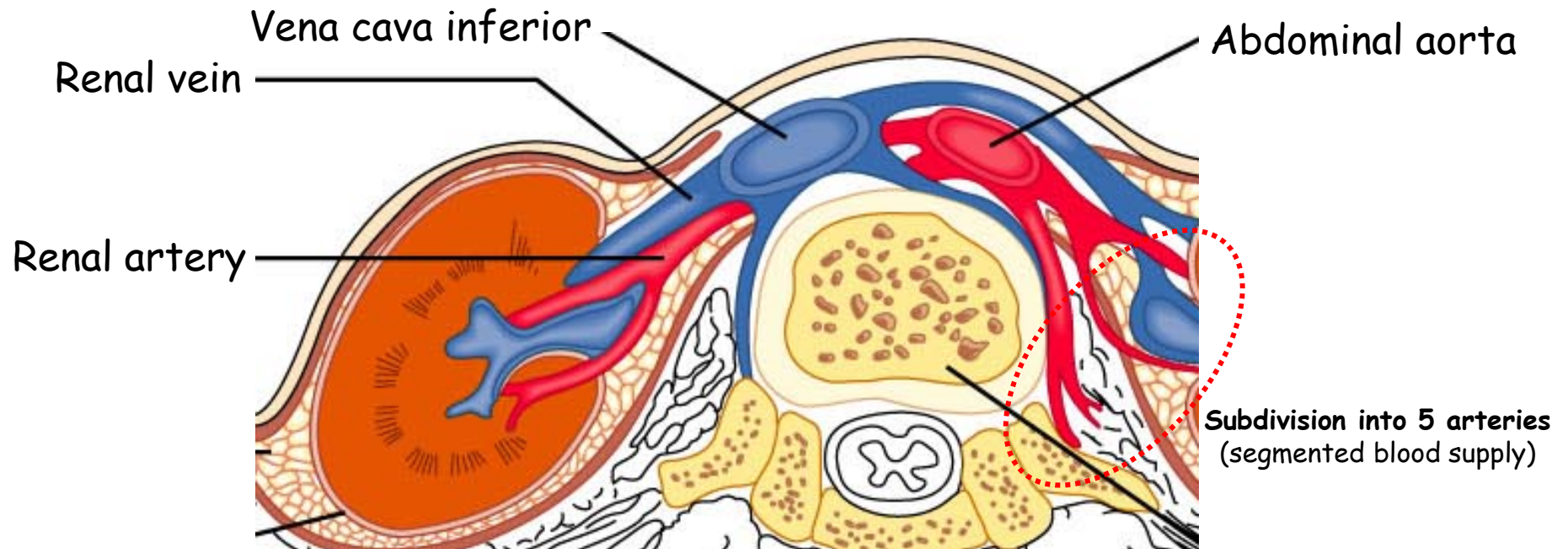
- Conserve body fluids
- Reacts to **ADH** (antidiuretic hormone) of the posterior pituitary gland
- ADH increases the permeability of the collecting tubules and distal tubules to water so more is reabsorbed
- This decreases the total volume of urine
- Alcohol inhibits the release of ADH, so less water is reabsorbed producing copious amounts of dilute urine (can cause dehydration)



## Long section of Collecting and proximal tubuli

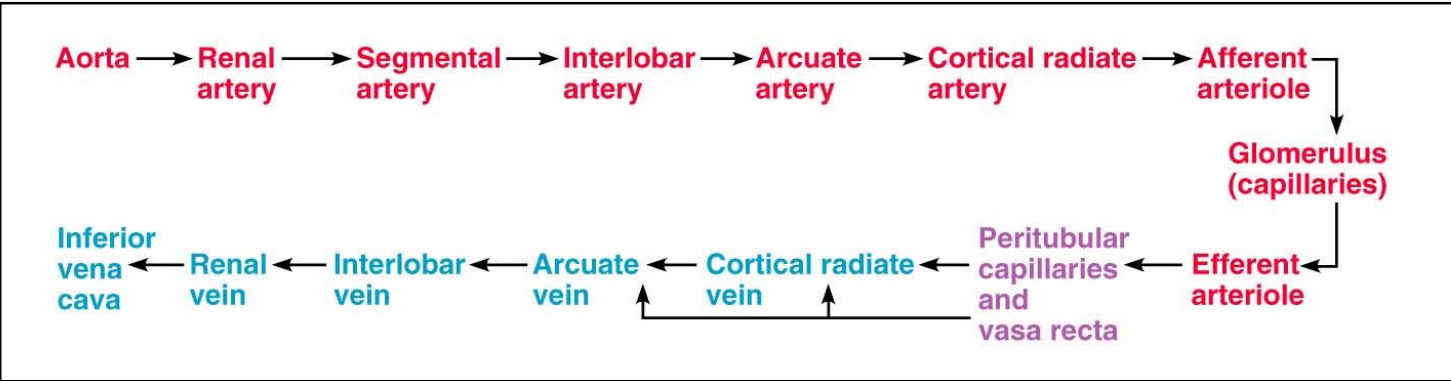
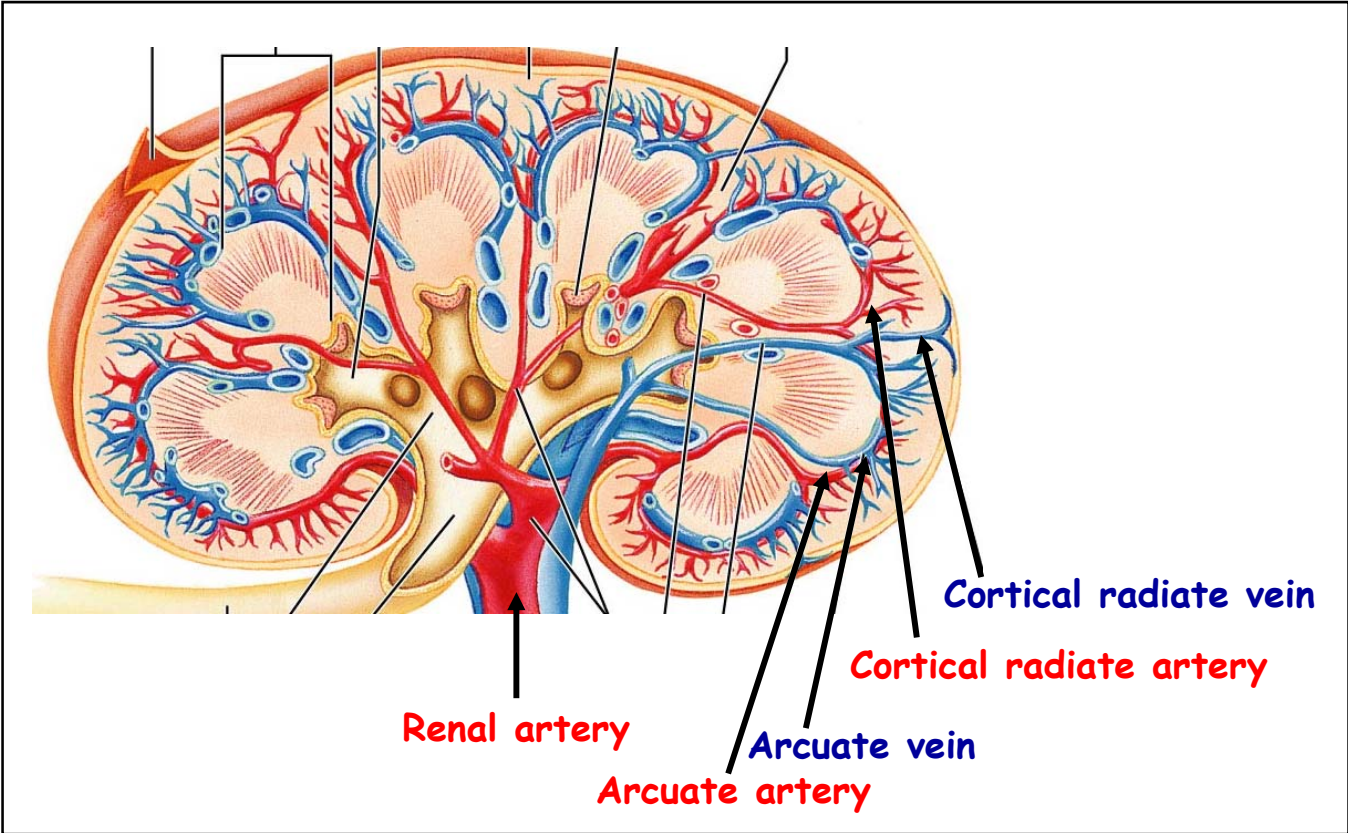


# Blood circulation

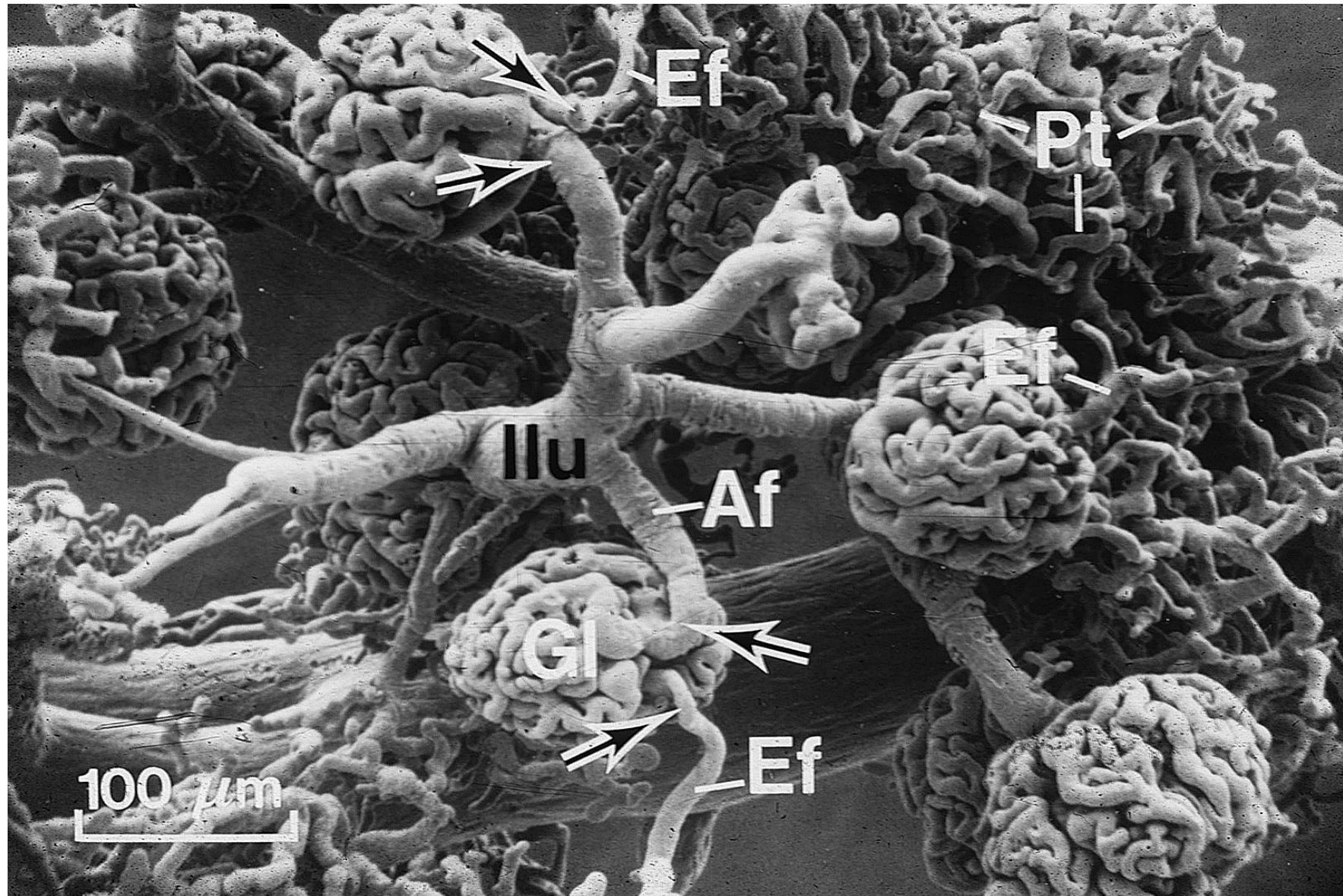




# Blood circulation

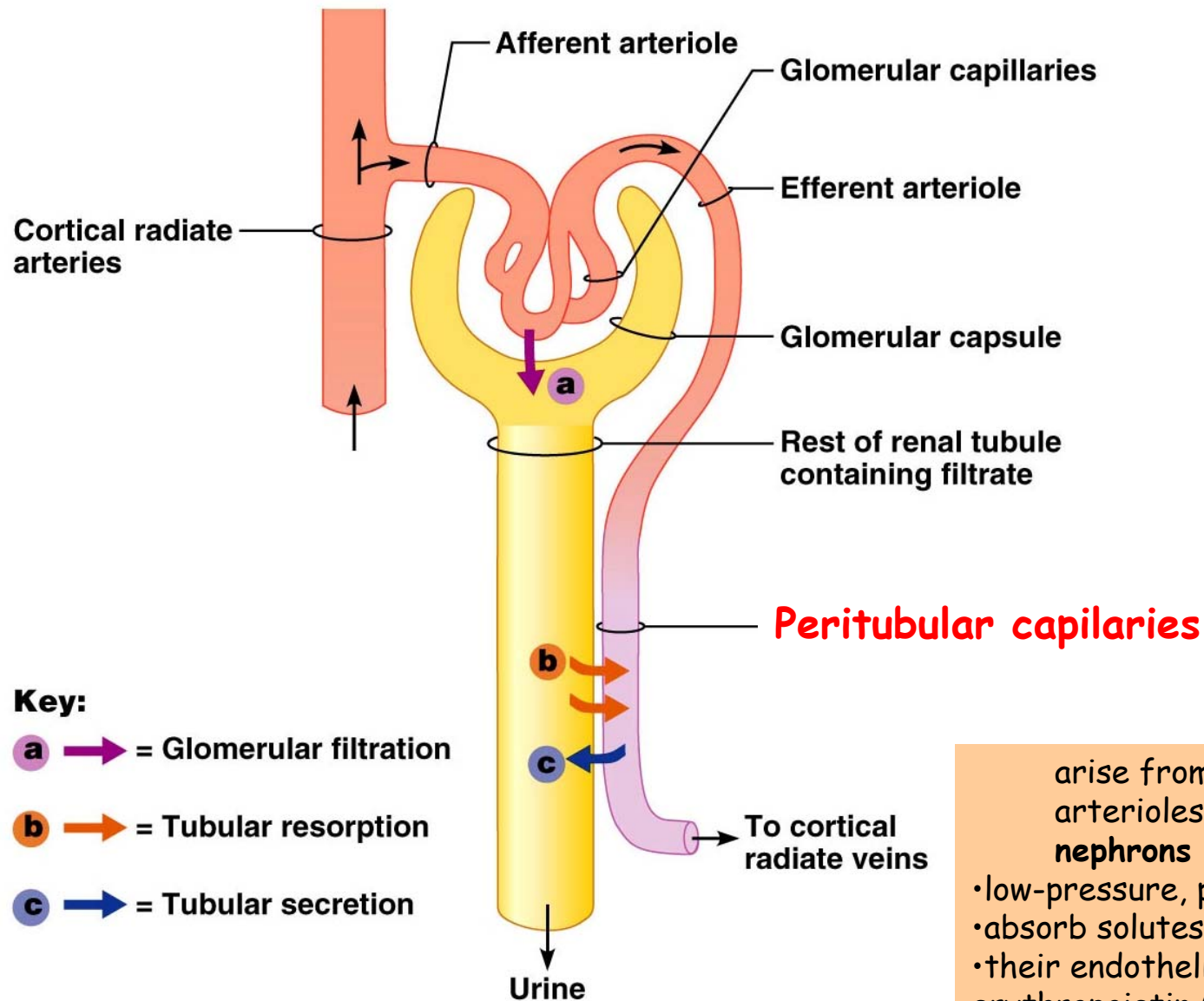


# Blood circulation - Afferent + Efferent arterioles





# Blood circulation - Peritubular capillaries

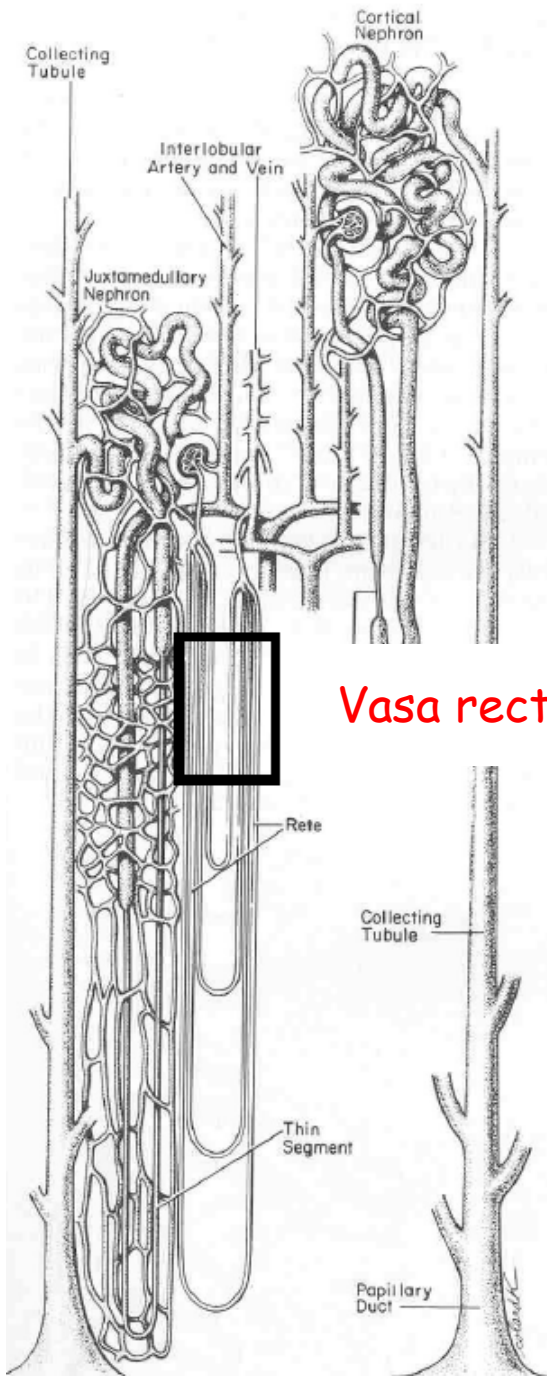


arise from efferent arterioles of **cortical nephrons**

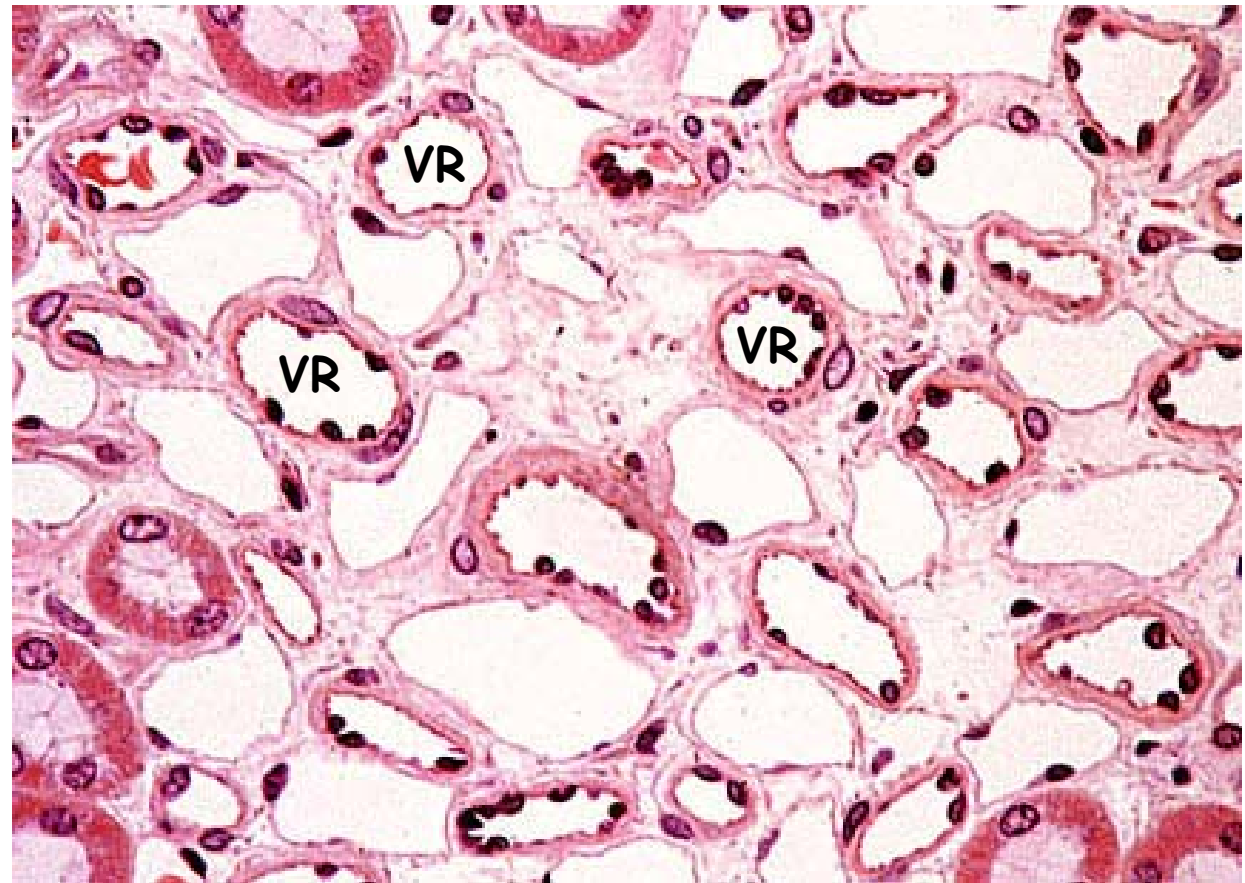
- low-pressure, porous capillaries
- absorb solutes
- their endothelia manufacture erythropoietin (?)

# Blood circulation - *Vasa recta*

- arose from efferent arterioles of juxtamedullary nephron
- thin walled looping vessels
- 10-25 mm long
- part of the kidney's urine-concentrating mechanism



*Vasa recta*





# Excretory passages

- Calyces (minor + major)
- Pelvis
- Ureters
- Urinary bladder
- Urethra

## General organizational pattern

(calyces, pelvis, ureters, bladder)

- **Mucosa**

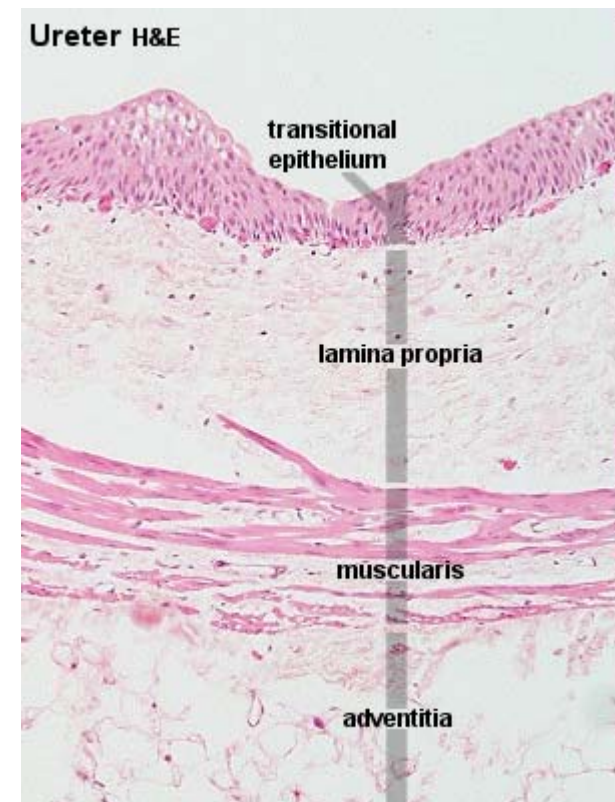
Luminal sheet epithelium (transitional)

Basal lamina

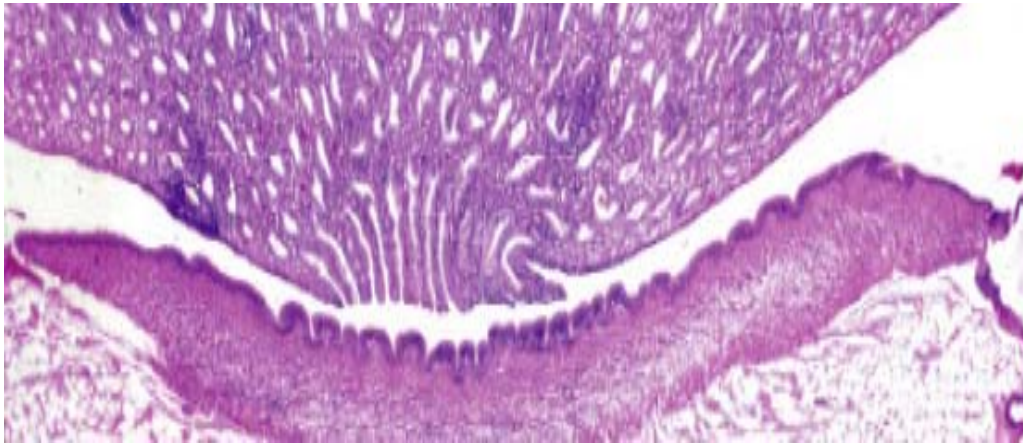
Lamina propria/submucosa (connective tissue)

- **Lamina muscularis** (smooth muscle)

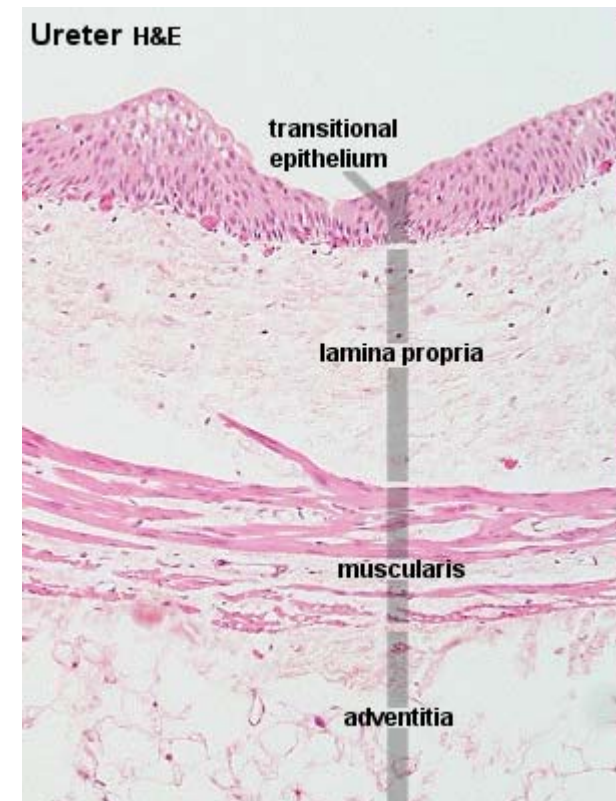
- **Lamina adventitia or serosa**



# Renal calyces + pelvis



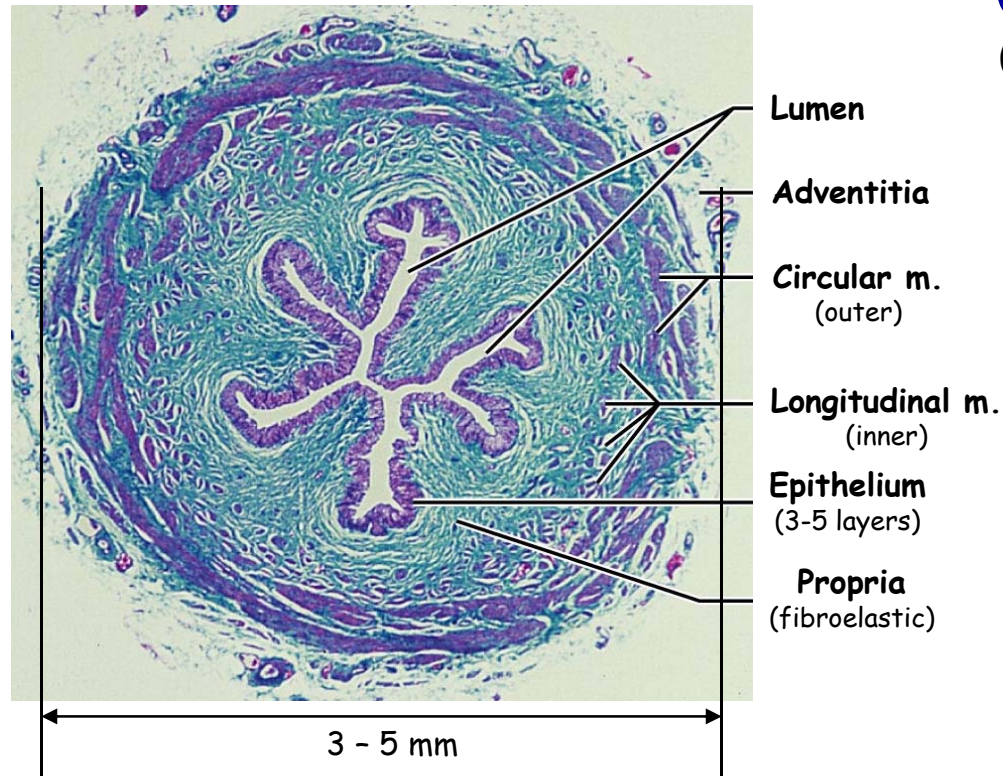
- Minimal lamina propria (submucosa)
- Thin tunica muscularis
- Tunica adventitia - blends with adipose tissue in the renal sinus



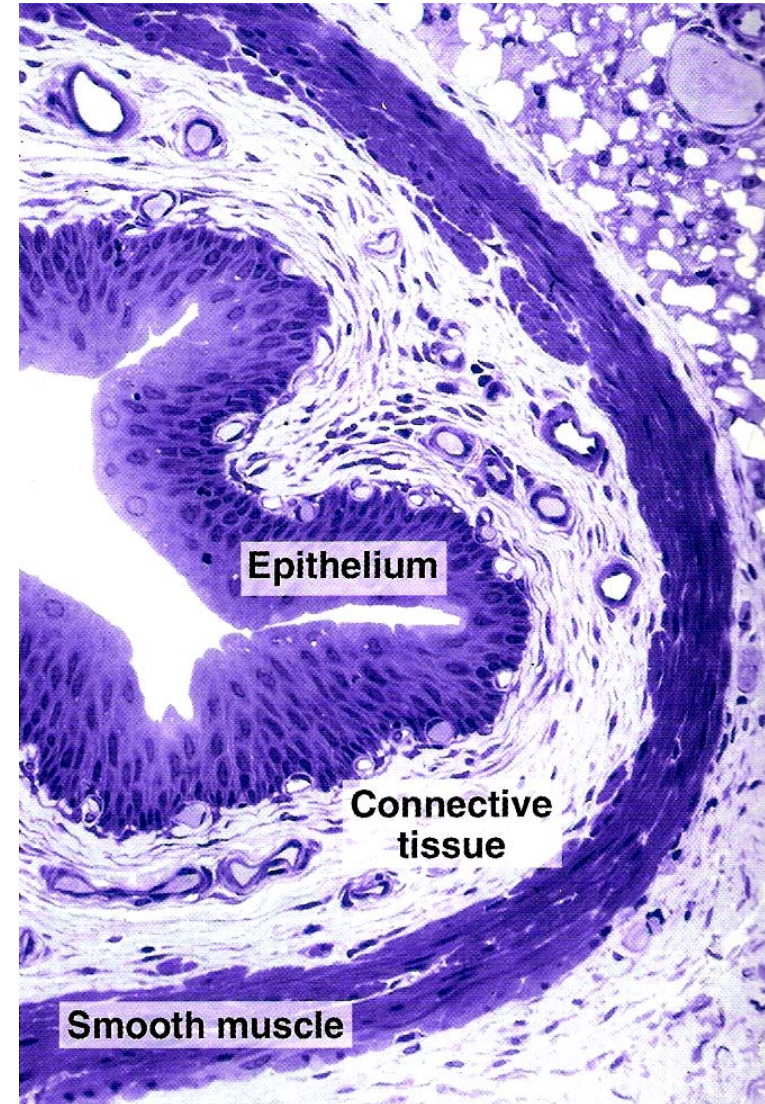


# Ureters

(25-30 cm long)

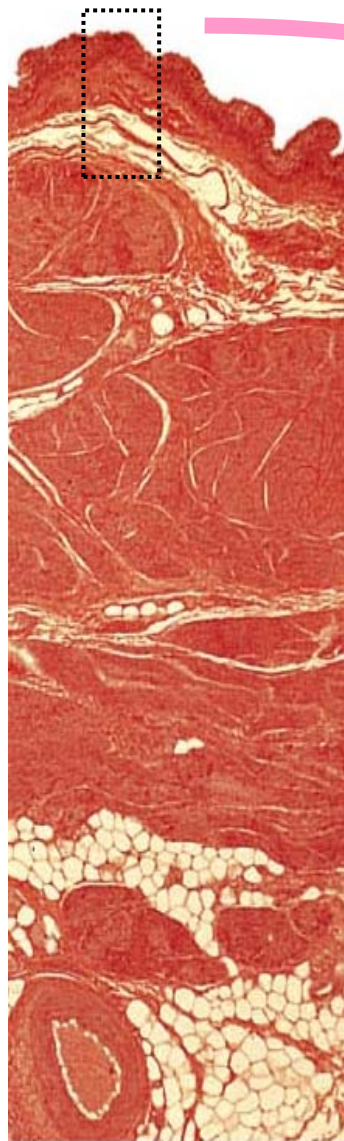


- Carry urine from renal pelvis to the urinary bladder
- Same wall layers as pelvis
- Ureter wall thickens and the muscle cells change from a helical to longitudinal array near the bladder
- Urine moves by active peristaltic motion



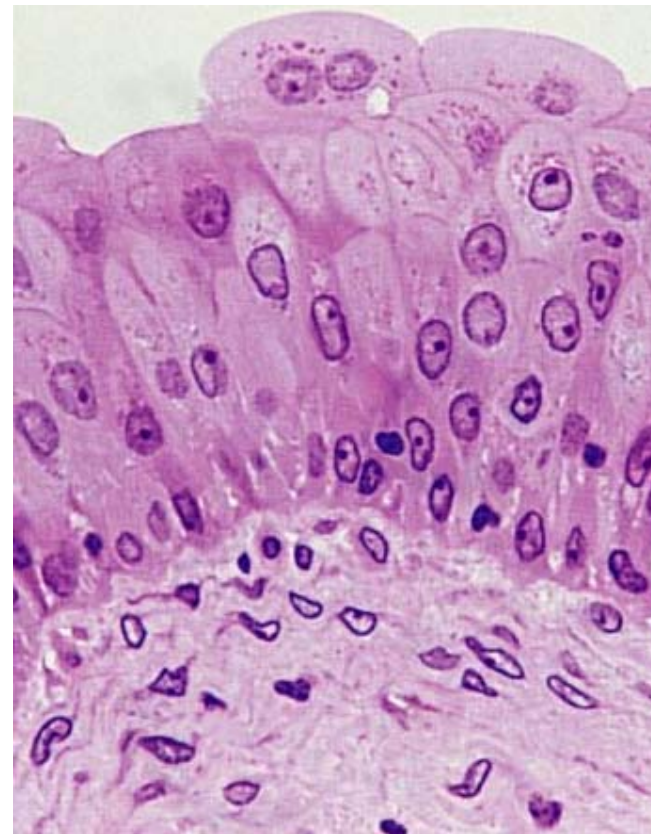


# Urinary bladder



- Epithelium
- Lamina propria
- Smooth muscle (detrusor muscle)  
longitudinal+circular+longitudinal  
thin + thick + thin
- Lamina adventitia

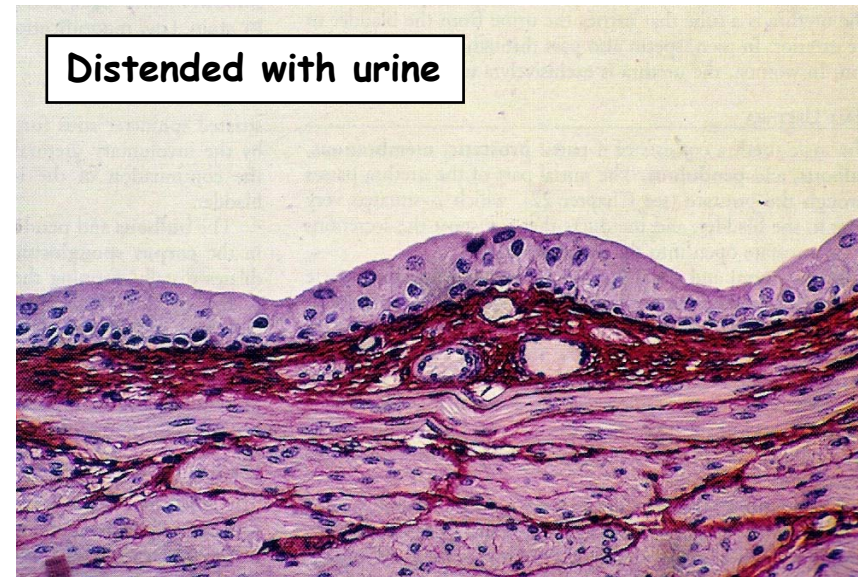
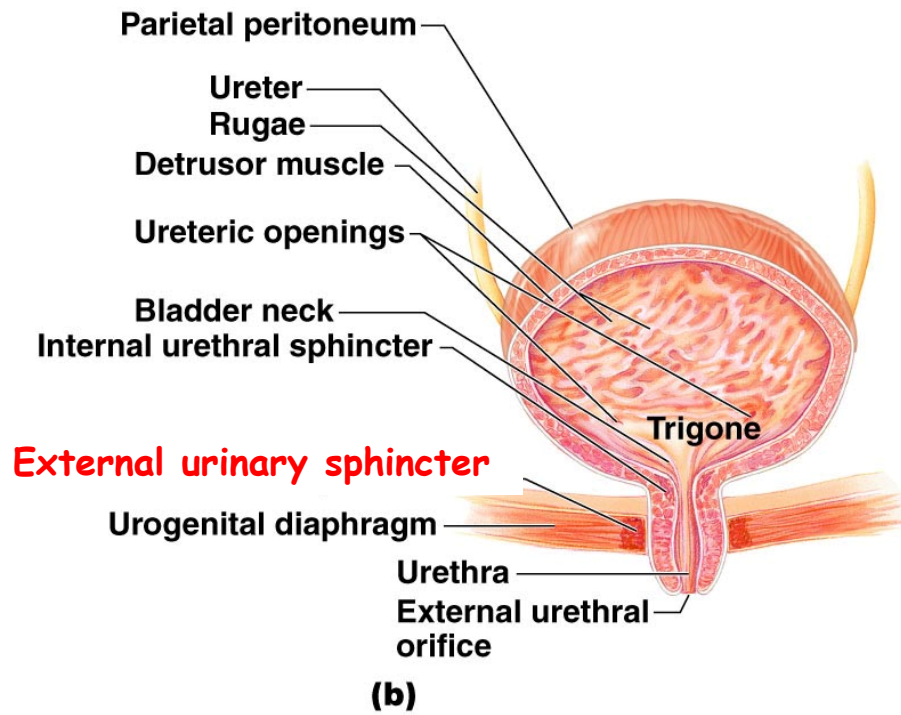
Thick muscularis - near the opening into the urethra → they form an involuntary **internal sphincter**.



- Epithelium
- Basal membrane
- Lamina propria

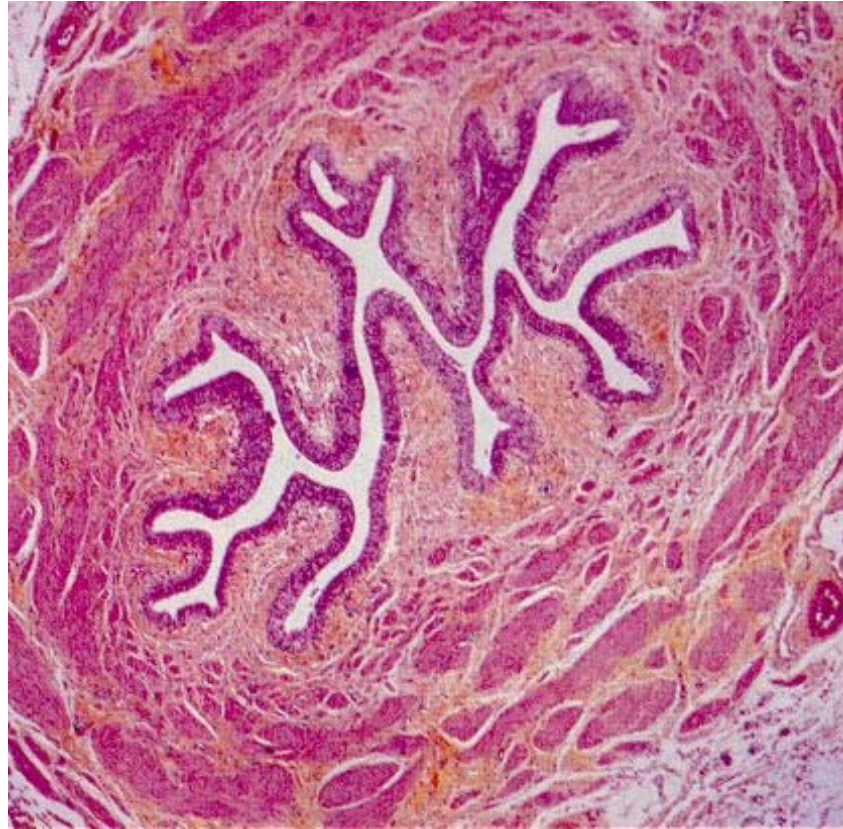


# Urinary bladder



# Female urethra

(4-5 cm in length)



Transitional epithelium

- **Transitional + stratified squamous nonkeratinizing ep.**
- **Folded mucosa** (due to fibroelastic propria)
- **Two-layered muscularis**
- **Glands of Littre**



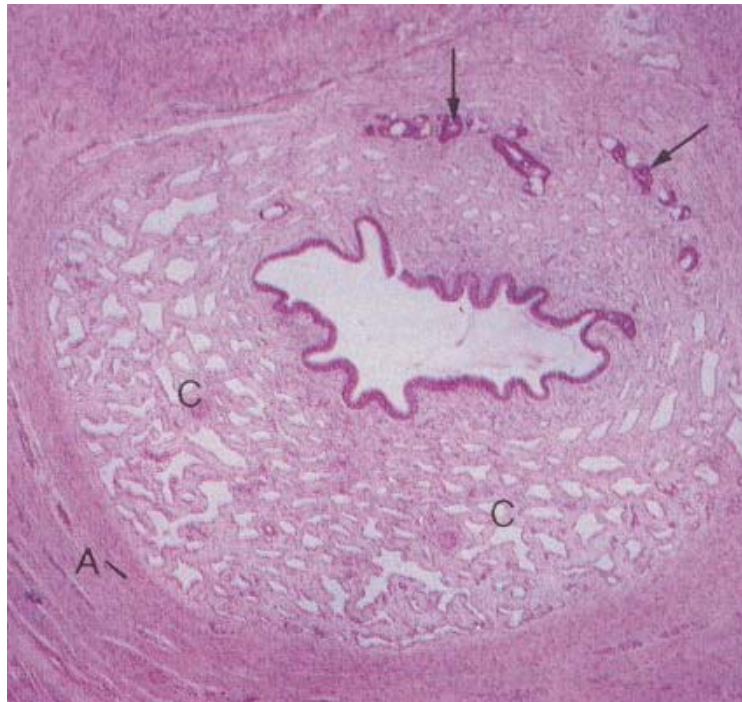
# Male urethra

(15-20 cm in length)

**Prostatic urethra** - transitional ep., openings of prostate gland

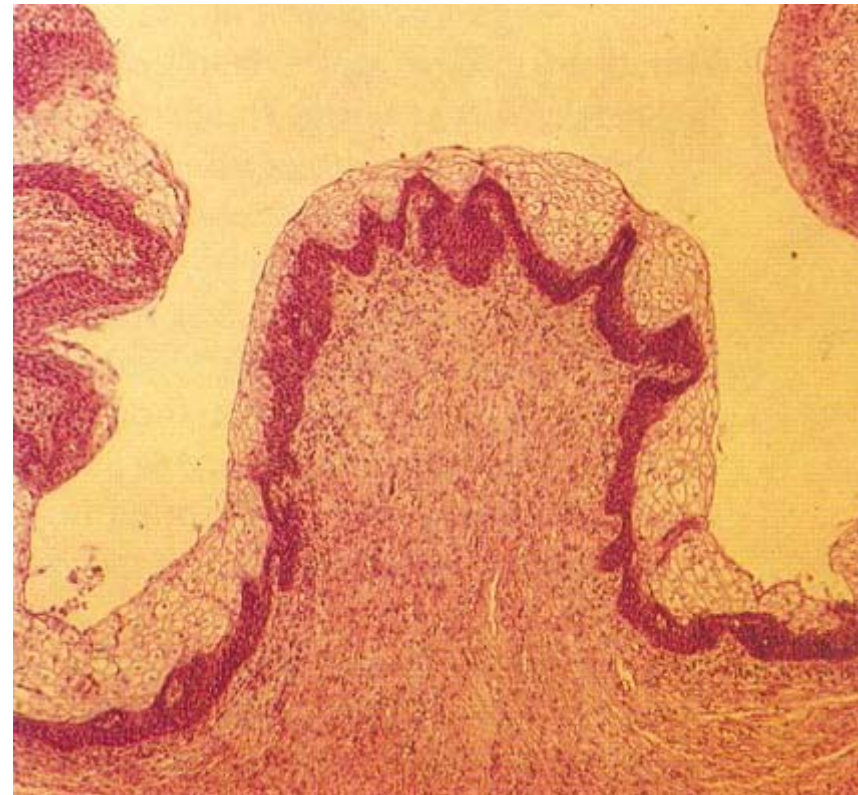
**Membranous urethra** - stratified columnar ep., through the urogenital diaphragm

**Spongy (penile) urethra** - stratified columnar + squamous ep.



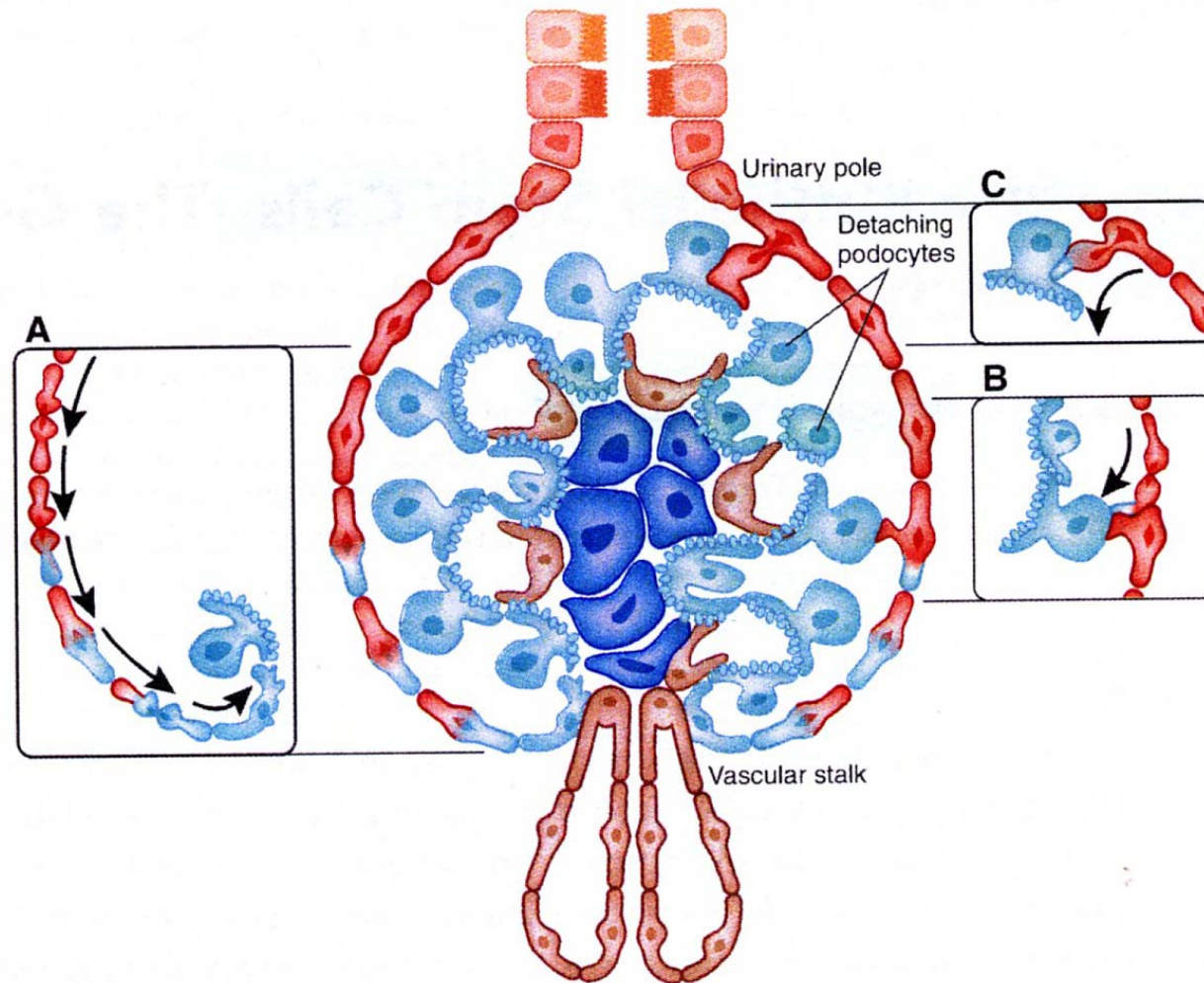
Spongy - penile

- A) Tunica albuginea
- C) Corpus spongiosum (erectile)
- Arrows) Glands of Littre



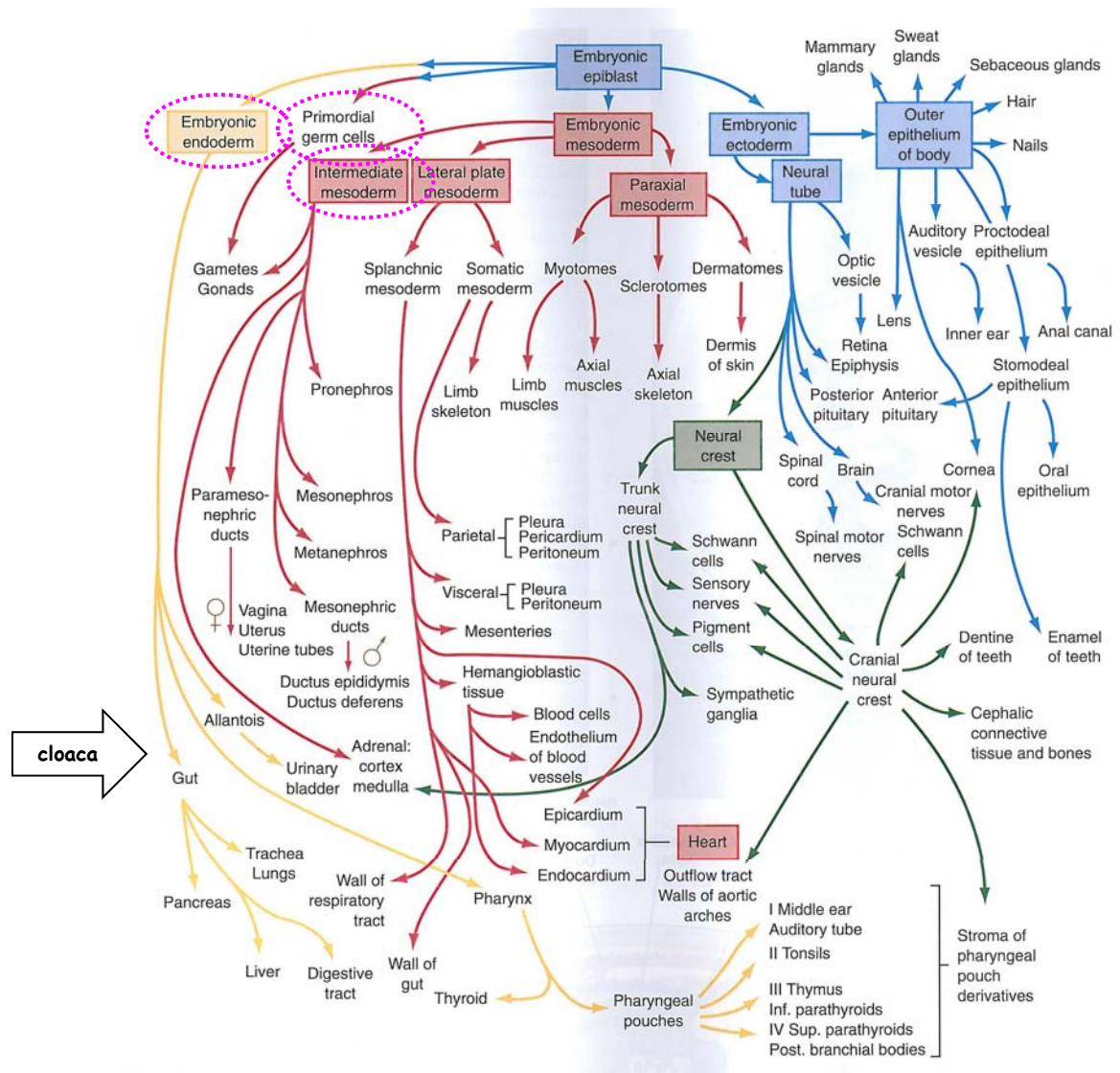
Near the tip of penis - fossa navicularis  
Stratified squamous epithelium (nonkeratinizing)

# Dialysis x Kidney transplant x **Kidney regeneration ?**

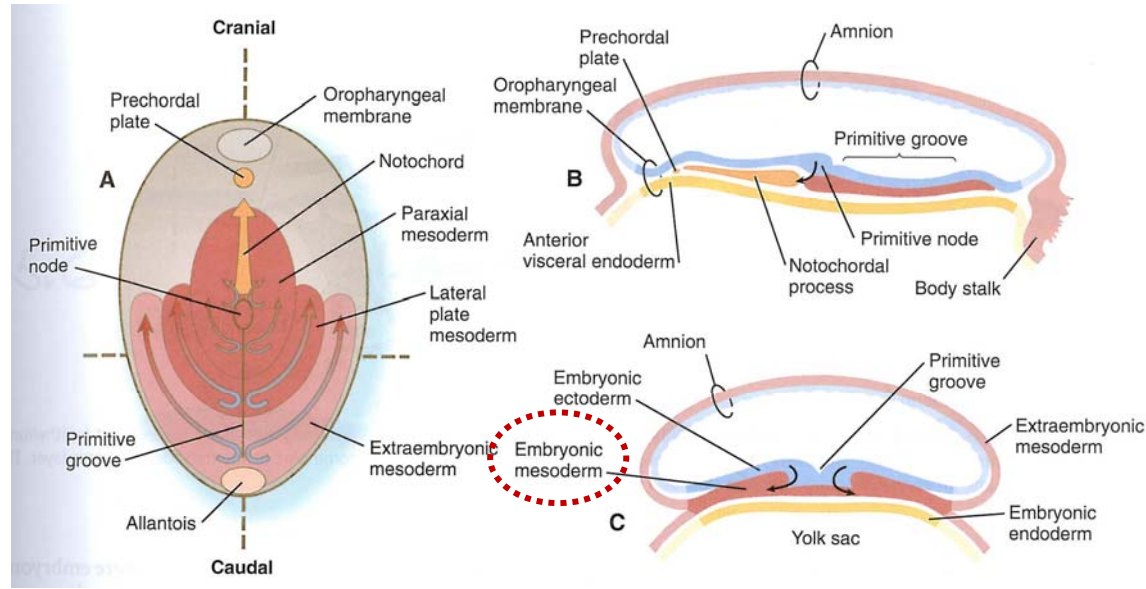
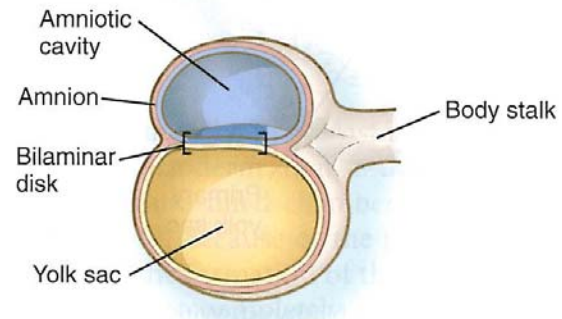
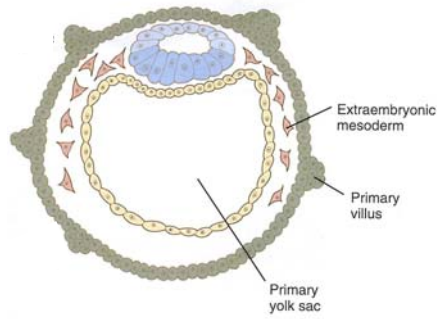




# Urogenital system - Overall picture

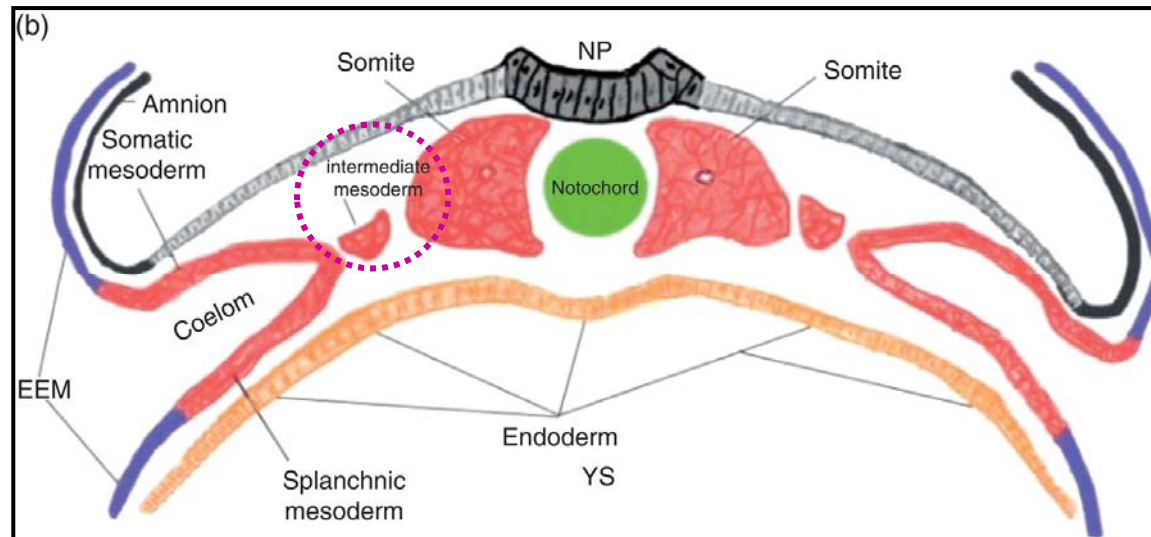
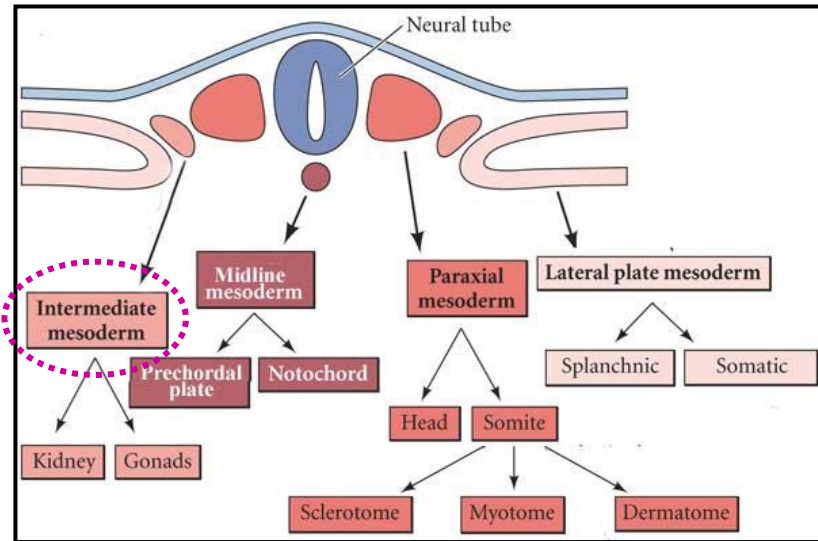
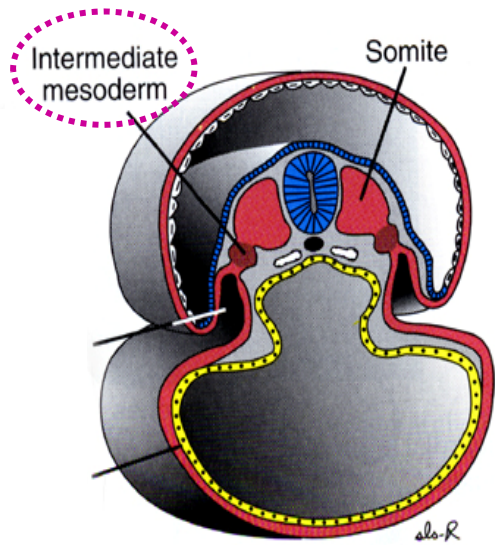


# Urogenital system - Reminder





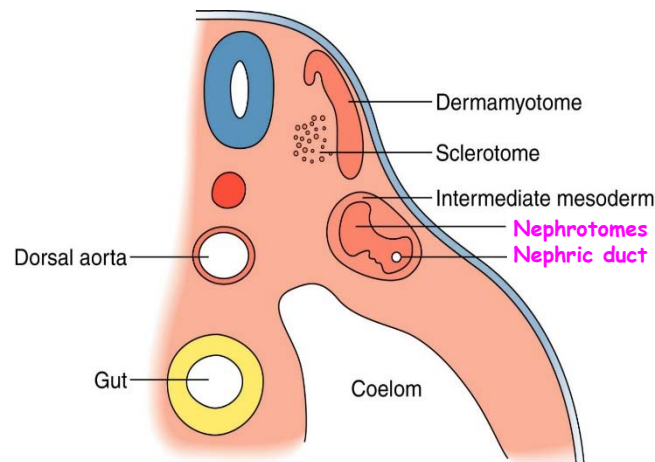
# Urogenital system - Intermediate mesoderm



# Urogenital system - Early forms of kidneys - Pronephros

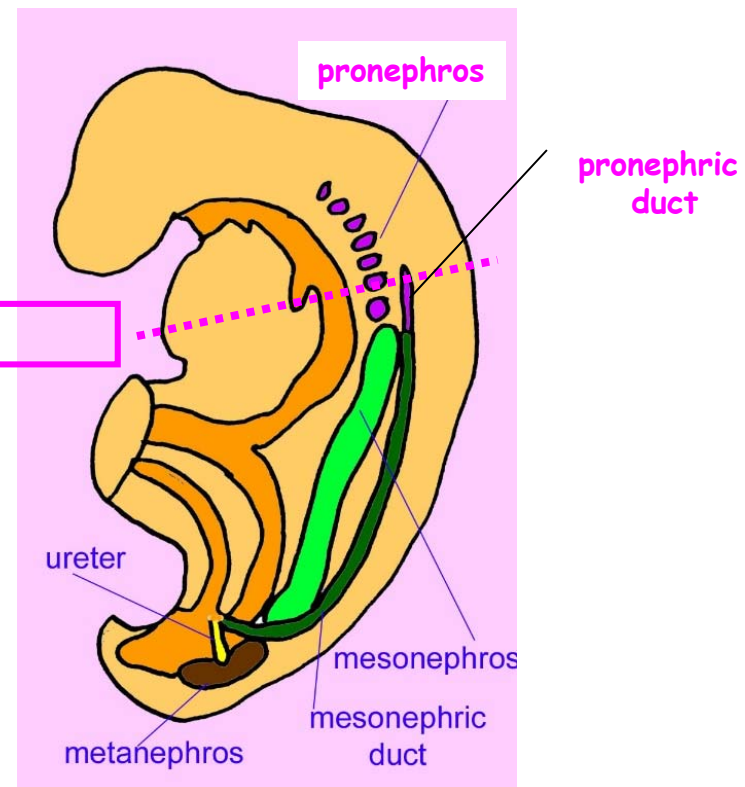
Recapitulation of three stages of evolution of kidneys in a cranial to caudal sequence:

- pronephros
- mesonephros
- metanephros



## Nephrotomes

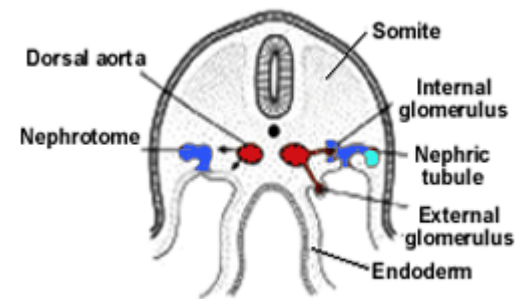
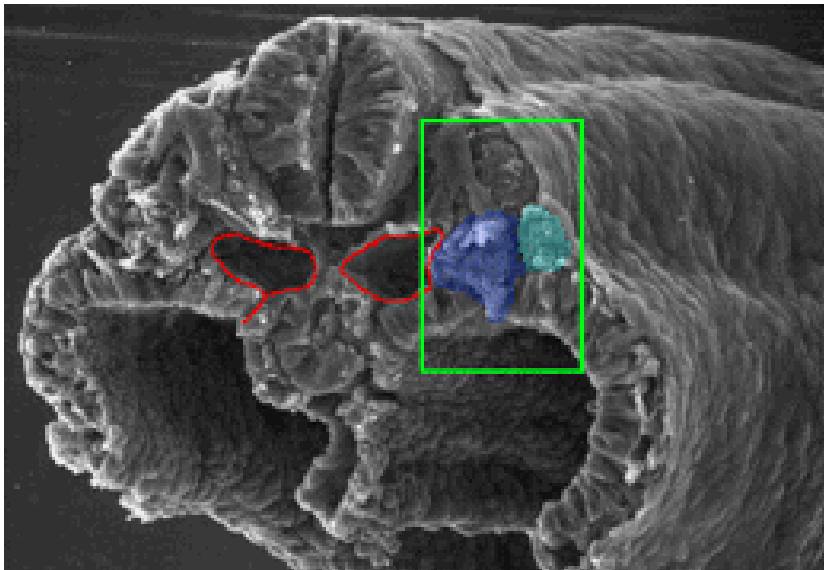
- at about day 22 in cervical part of nephrogenic cord
- 7 to 10 groups of epithelial cells
- connect to **pronephric duct**
- non-functional
- disappear by day 28





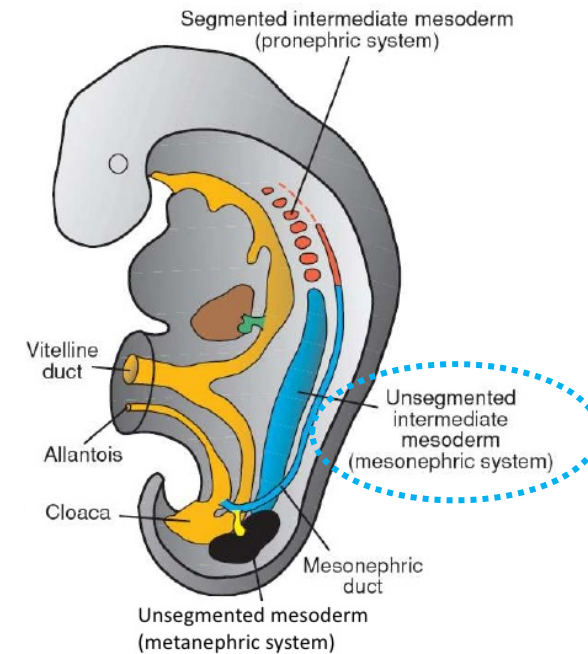
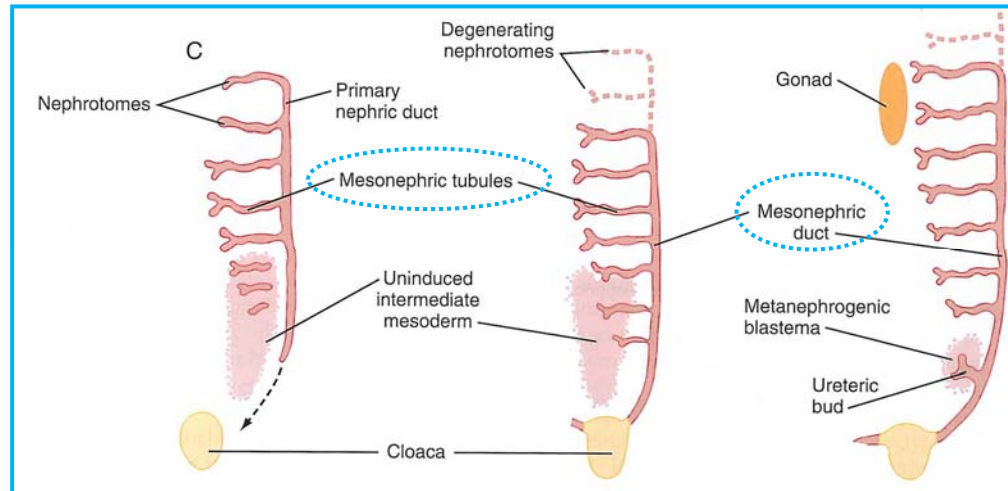
# Urogenital system - Early forms of kidneys - Pronephros

Mouse D9 - equivalent to human D27



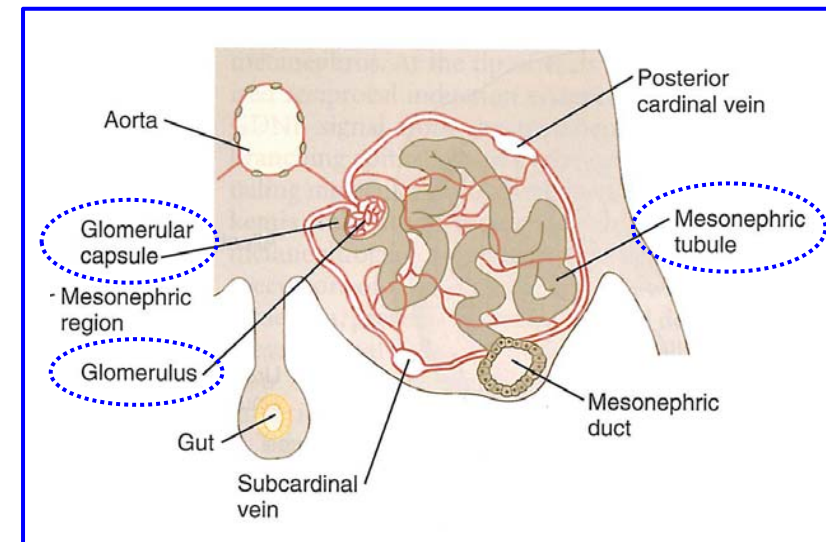
The lumen of each **nephrotome** opens into the **primary nephric duct** as well as into the body cavity. Glomeruli form as small vessels extend from the **dorsal aortae**.

# Urogenital system - Early forms of kidneys - Mesonephros



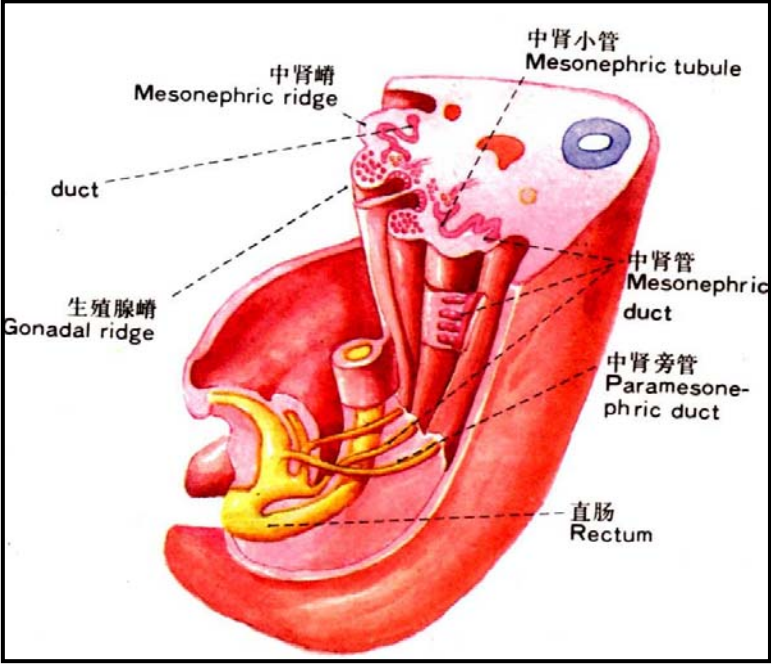
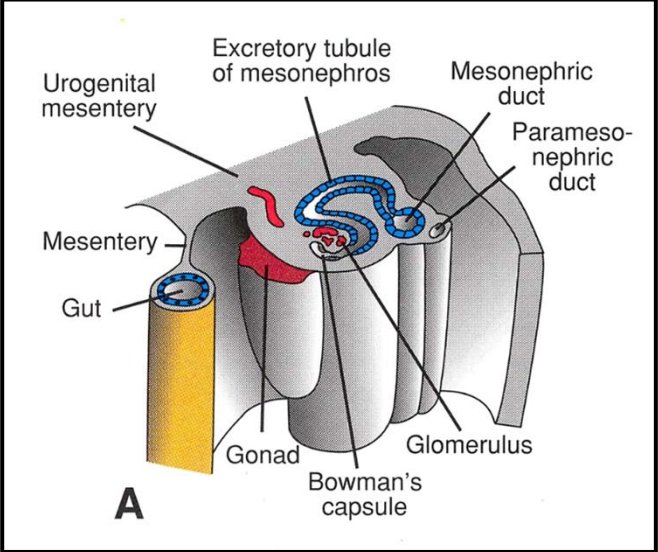
## Mesonephros

- caudal continuation of nephrogenic cord
- thoracolumbar region
- unsegmented intermediate mesoderm
- mesonephric ducts (paired) - Wolffian ducts
- mesonephric tubuli - open individually into m. duct
- 36 to 40 m. tubuli in total (on one side)
- some filtration - **mesonephric unit** →
- mesonephros is most prominent when metanephros start to shape - **active since week 6 til week 10**
- then they disappear fast
- mesonephric ducts persist in males

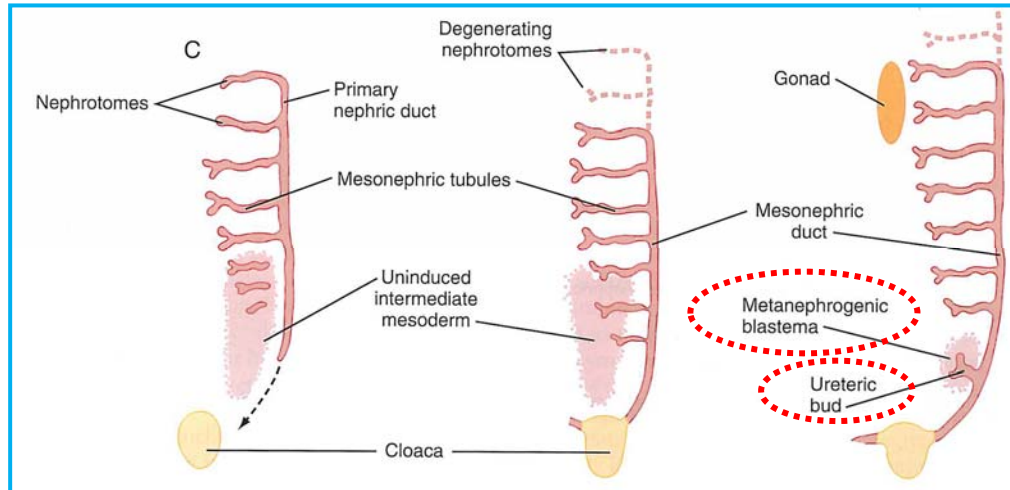




# Urogenital system - Mesonephros - Another view



# Urogenital system - Definitive kidneys - Metanephros



Develop since week 5

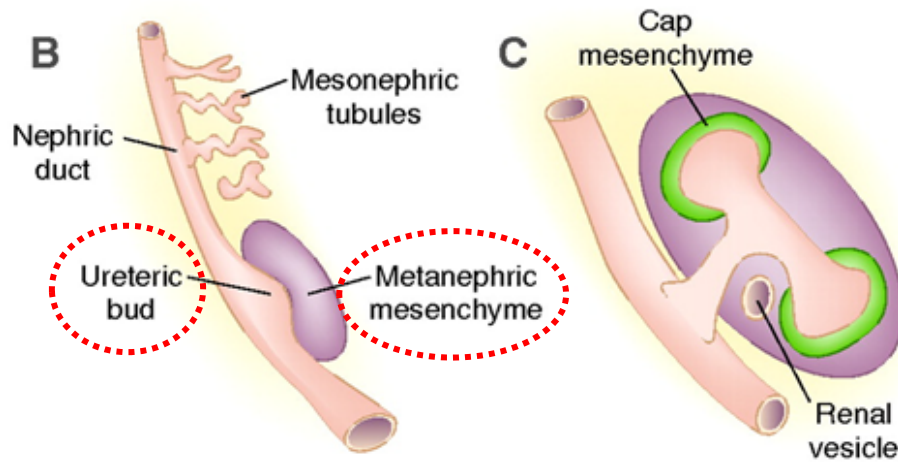
Ureteric bud = metanephric diverticulum

+

Metanephrogenic blastema  
(mesenchyme)

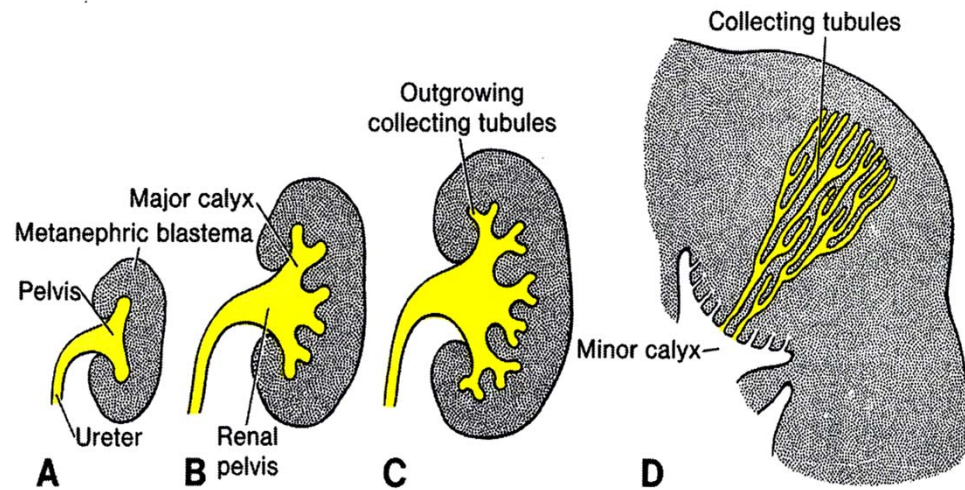
Branching  
and  
Elongation

14 to 15 x





# Urogenital system - Definitive kidneys - Metanephros

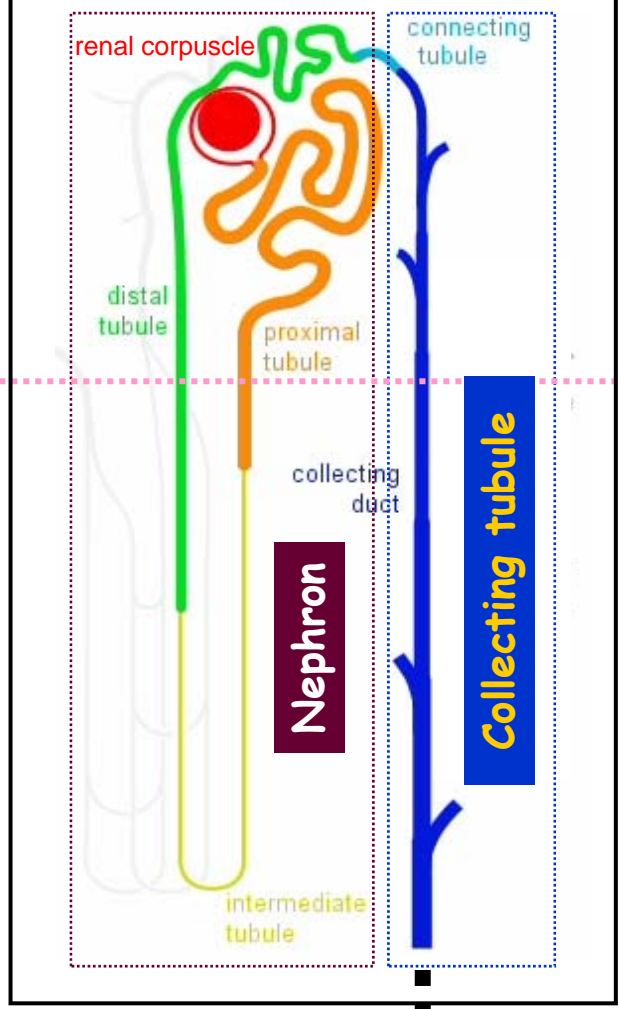


Repeated branching of ureteric bud produces:

- ureter
- pelvis
- calyces (major + minor)
- collecting tubuli (1 to 3 millions)

# Urineriferous tubule

= The functional unit of the kidney



Cortex

Medulla

Ducts of Bellini

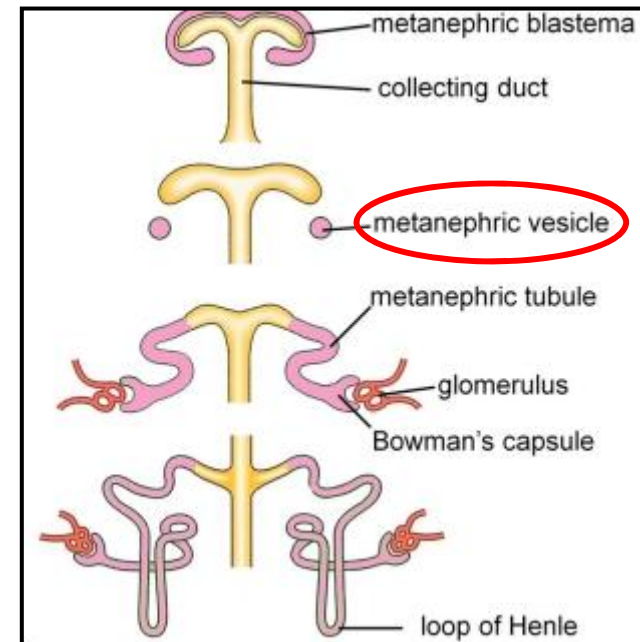
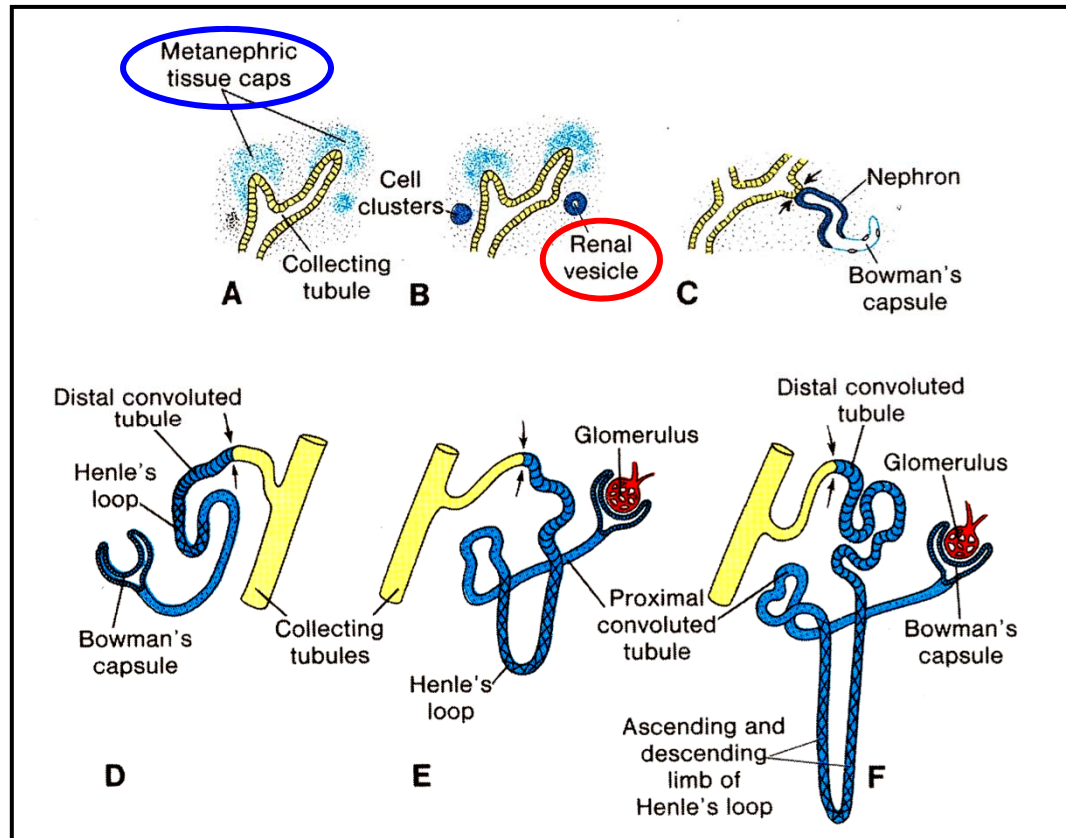
1 to 1.4 millions of nephrons in one kidney

Area cribrosa  
Minor calyx

**Nephrons X Collecting tubules**  
Different embryological origin

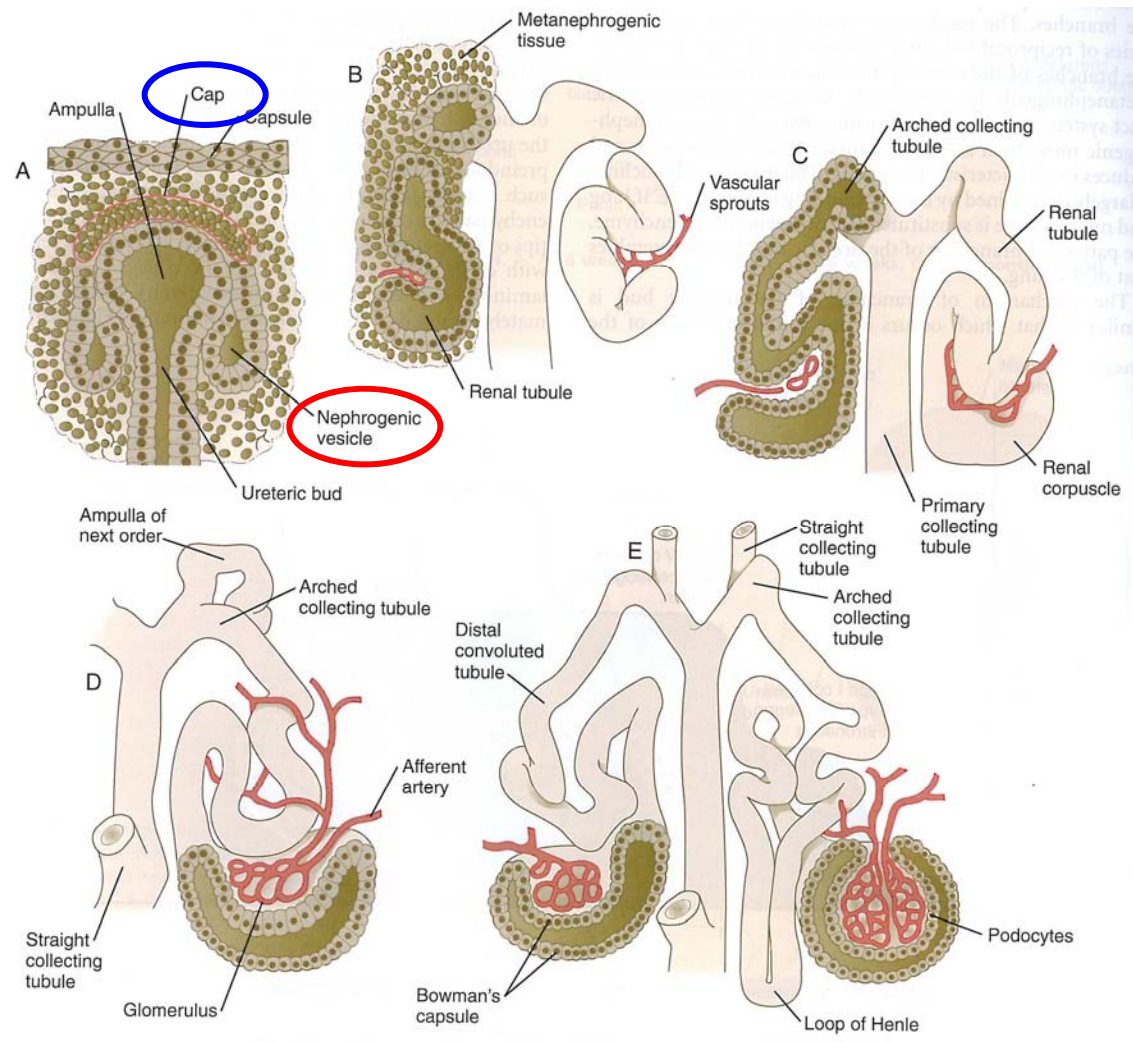


# Urogenital system - Metanephros - Nephrons



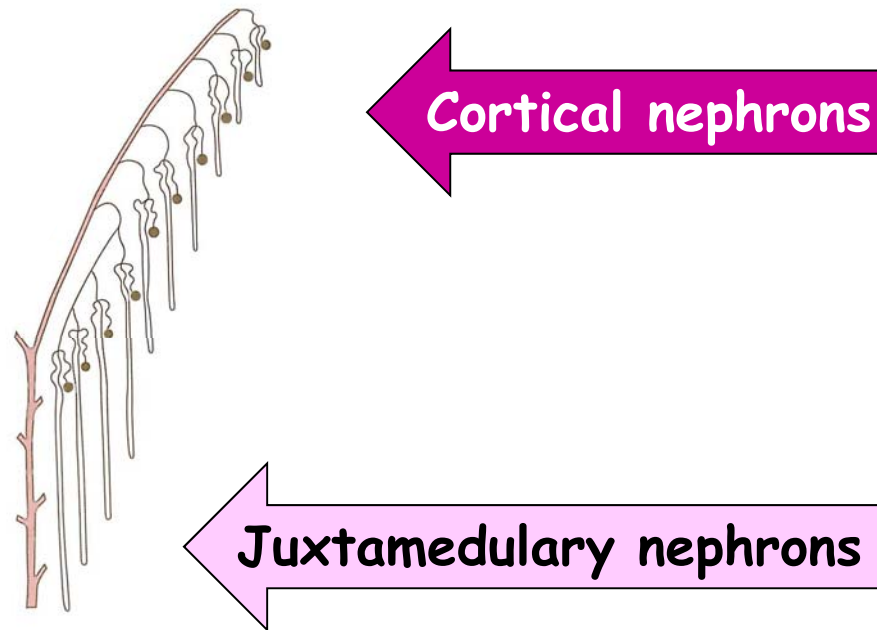
- arched ampulous endings of ureteric ducts (collecting tubuli) - **capping** by condensed mesenchyme
- part of the cap cells differentiate into **nephrogenic vesicle**
- vesicles elongate
- vesicles open to the collecting tubulus on one end
- distal from the ducts, the cells of elongating vesicles polarize and form **lumen and basal lamina**
- precursors of endothelia grow into this area - **glomerulus**
- endothelia connect to branches of dorsal aorta - **glomerular circulation**
- production of urine since week 10

# Urogenital system - Metanephros - Nephrons





# Urogenital system - Metanephros - Nephrons



- about 15 successive generations of nephrons in peripheral zone of kidney
- outermost nephrons are less mature

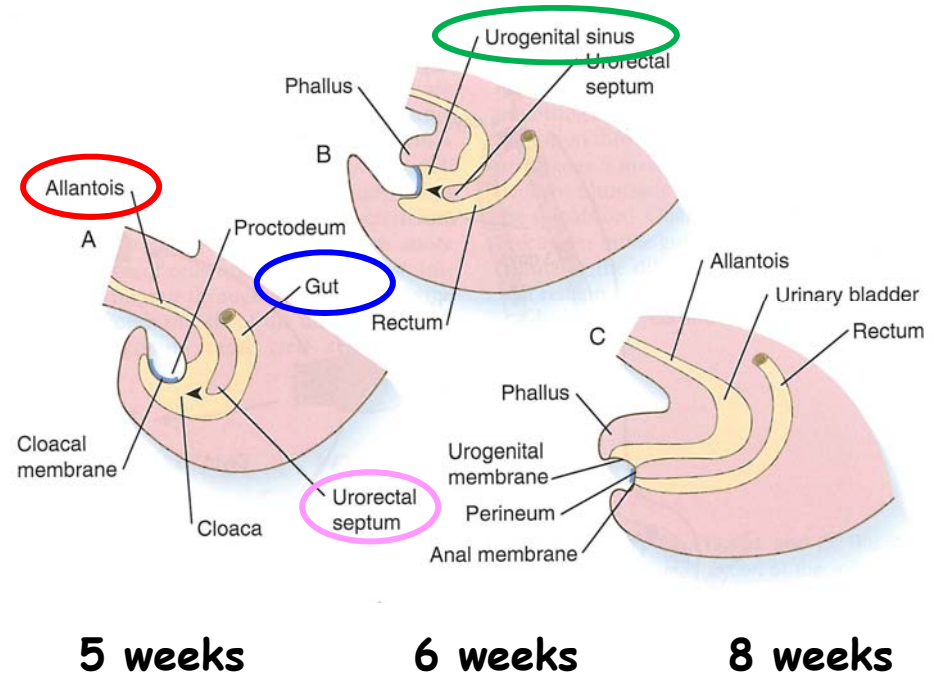
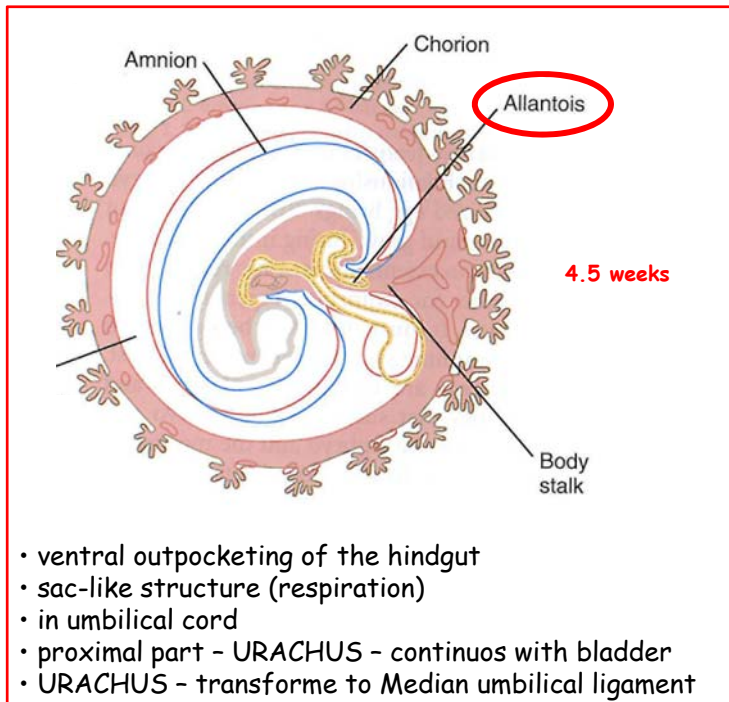
# Urogenital system - Definitive kidneys - Metanephros





# Urinary system - Bladder

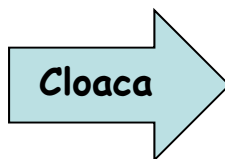
**Cloaca**  
= terminal part of the hindgut + allantois



5 weeks

6 weeks

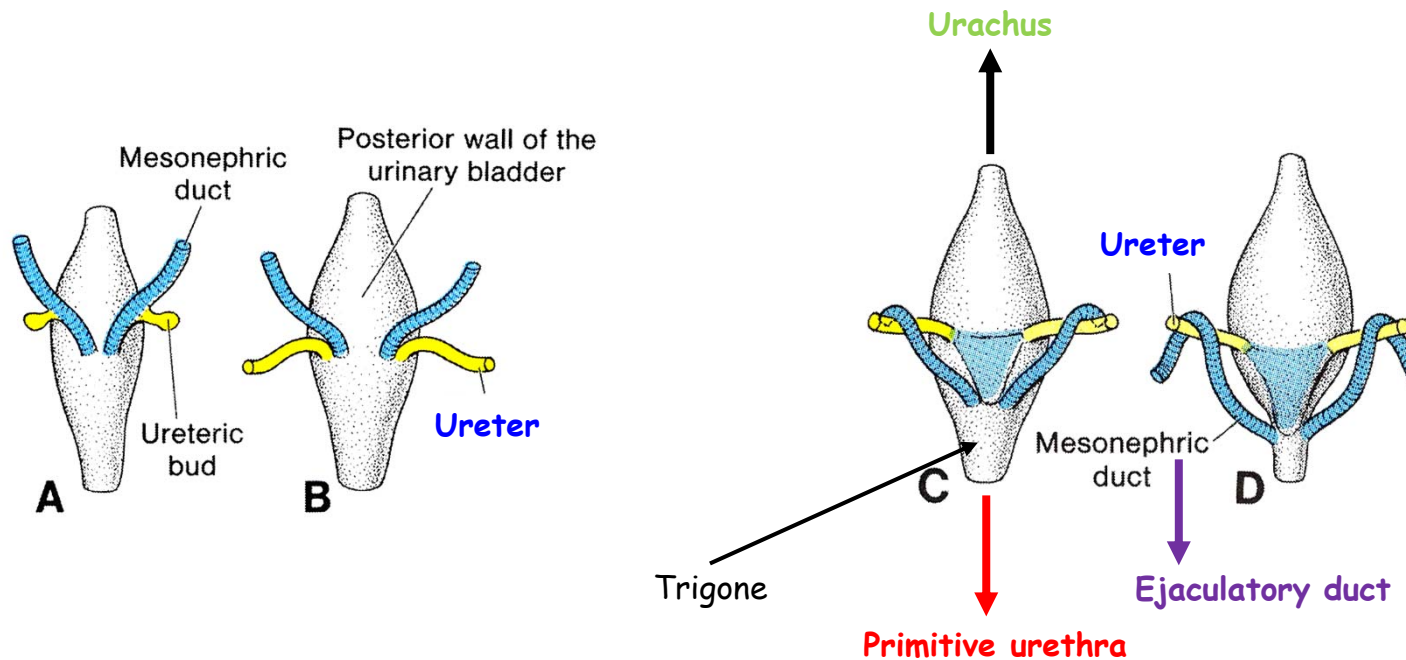
8 weeks



Urogenital sinus	Urogenital membrane
Urogenital septum	Perineum
Primitive rectum	Anal membrane

# Urinary system - Bladder + Ureters + Urethra

## Posterior view



- alantosis expands - urinary bladder
- initially bladder is continuous with alantosis - then obliteration - **urachus** - **median umbilical ligament**
- caudal portions of mesonephric ducts become absorbed by the bladder wall - separation - **ureters** + **ejaculatory ducts**



# Urinary system - Congenital anomalies

1. Agenesis
2. Duplication
3. Anomalies of shape
4. Abnormal of position
5. Congenital polycystic kidney

Horseshoe kidney



**Thank you for your attention !**

Questions and comments at:  
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