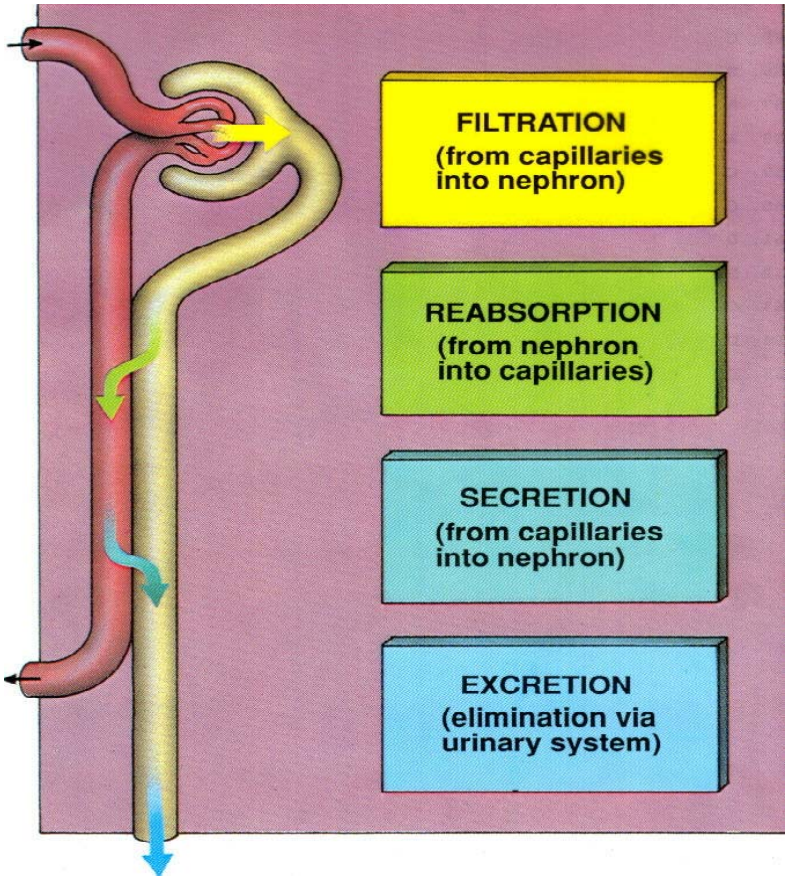
Urinary system

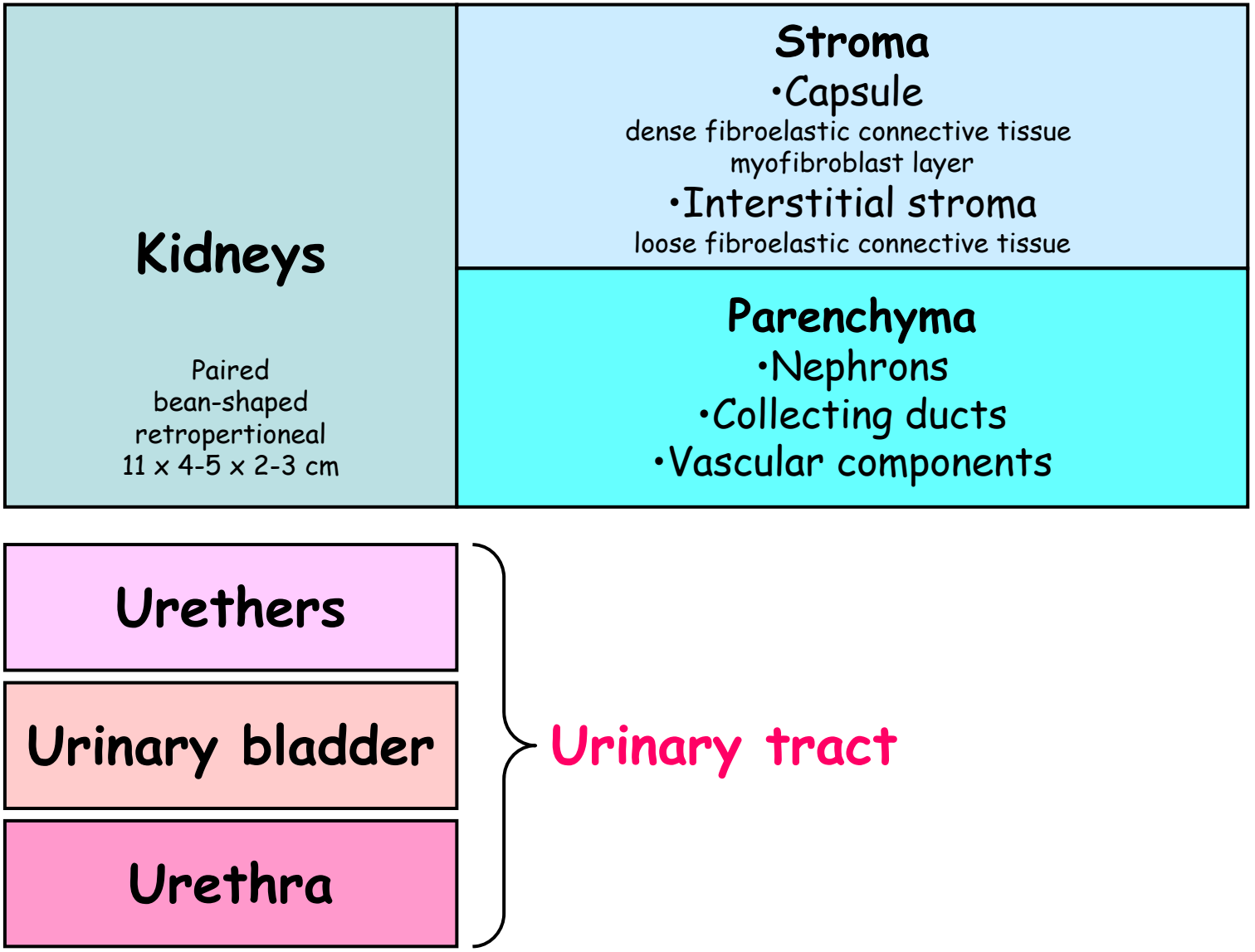
Aleš Hampl

Functions of urinary system

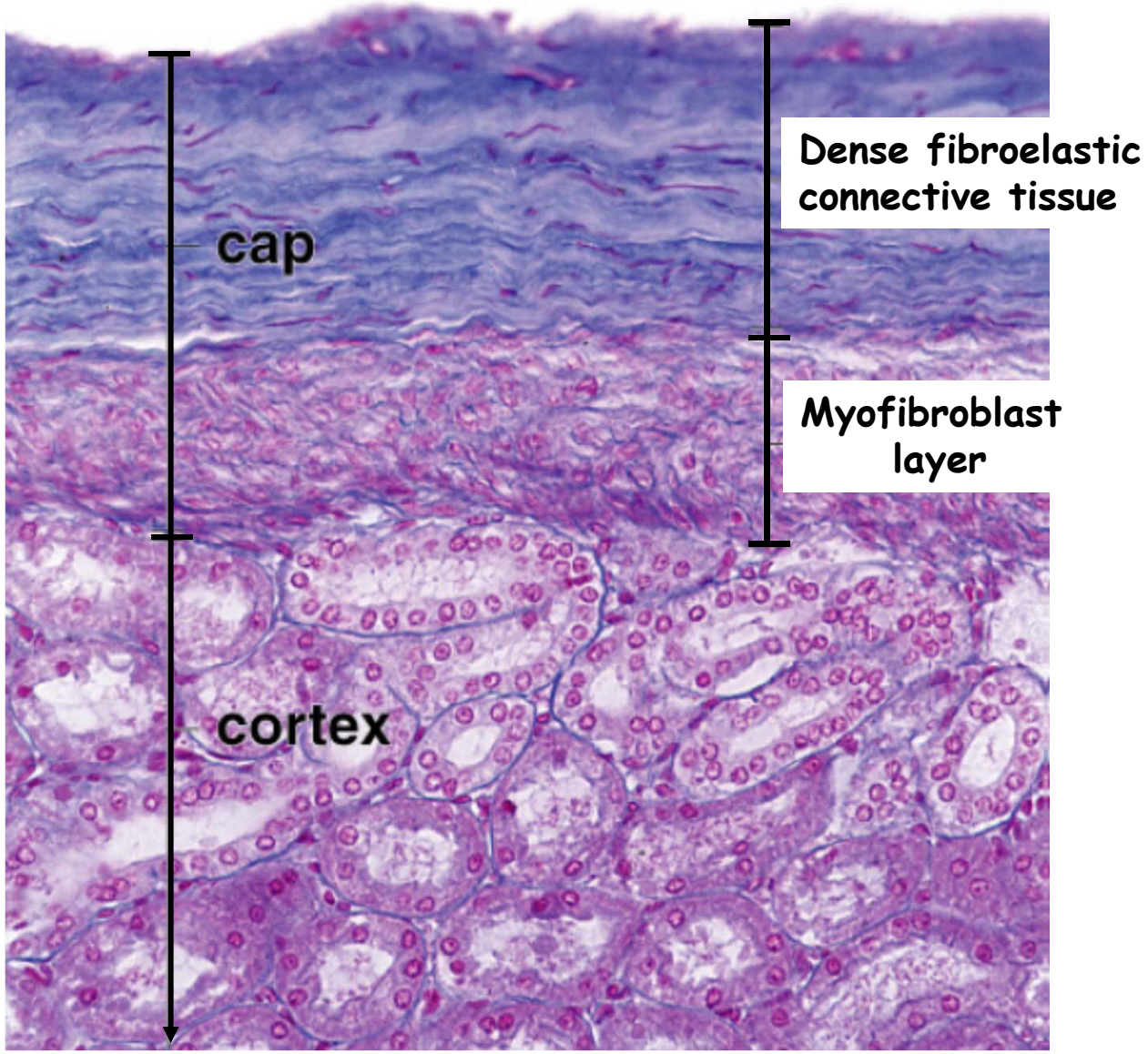
- 1. Regulating blood volume and pressure
- 2. Regulating plasma concentrations of sodium, potassium, chloride and other ions
- 3. Stabilising blood pH
- 4. Conserving nutrients
- 5. Detoxifying poisons (with the liver)



Components of urinary system

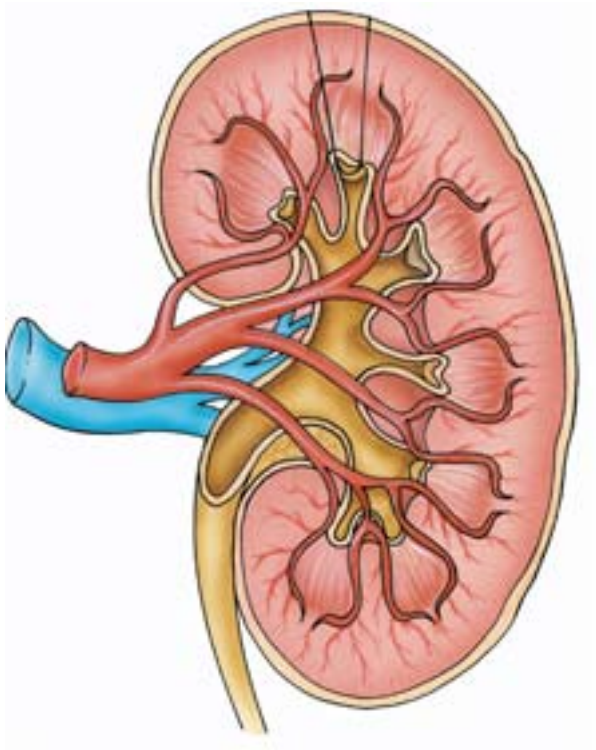


Kidneys capsule



Overall organization of kidney

Medial



Lateral

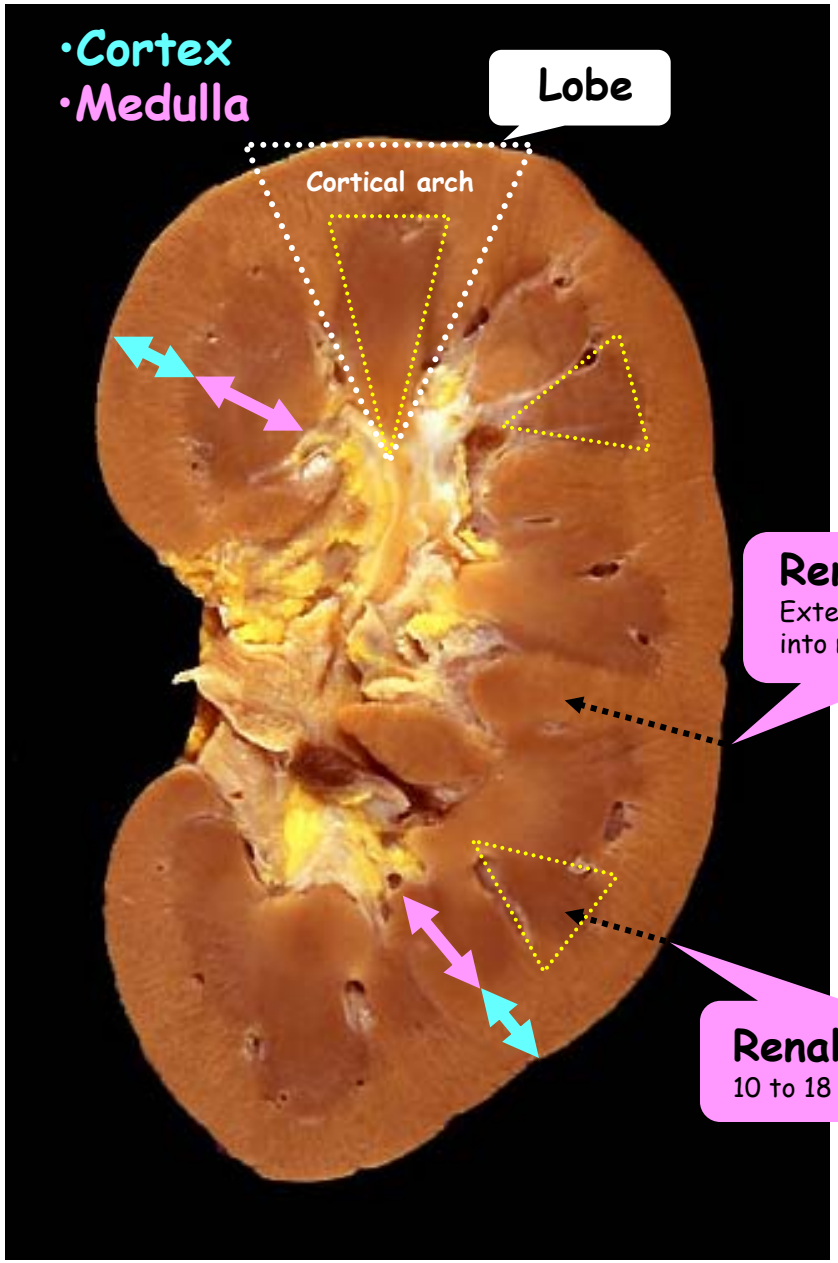
Hilum – portal for renal vessels, nerves and urether

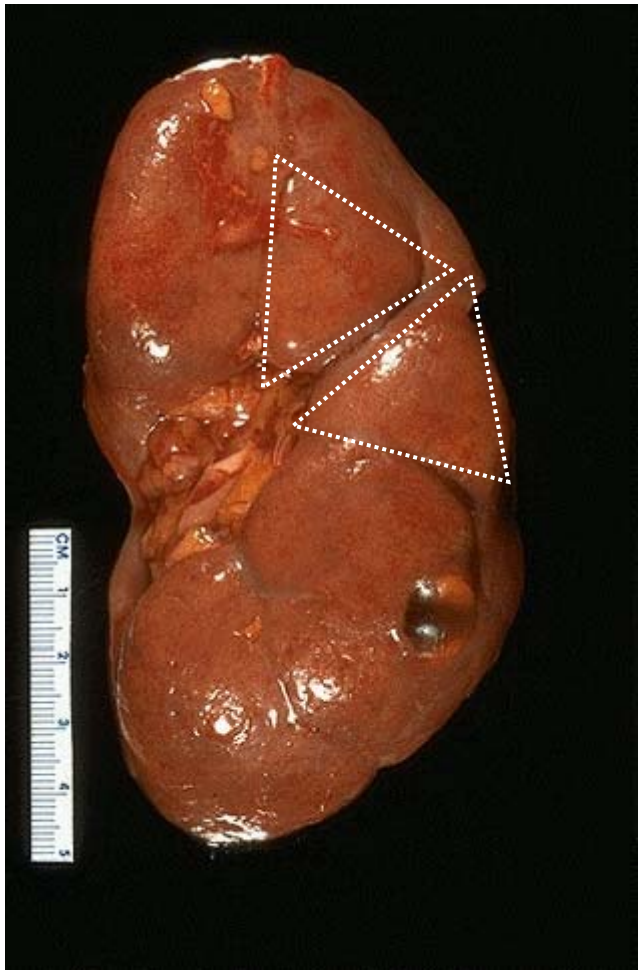
Renal sinus – cavity deep to hilum occupied by renal pelvis and vessels

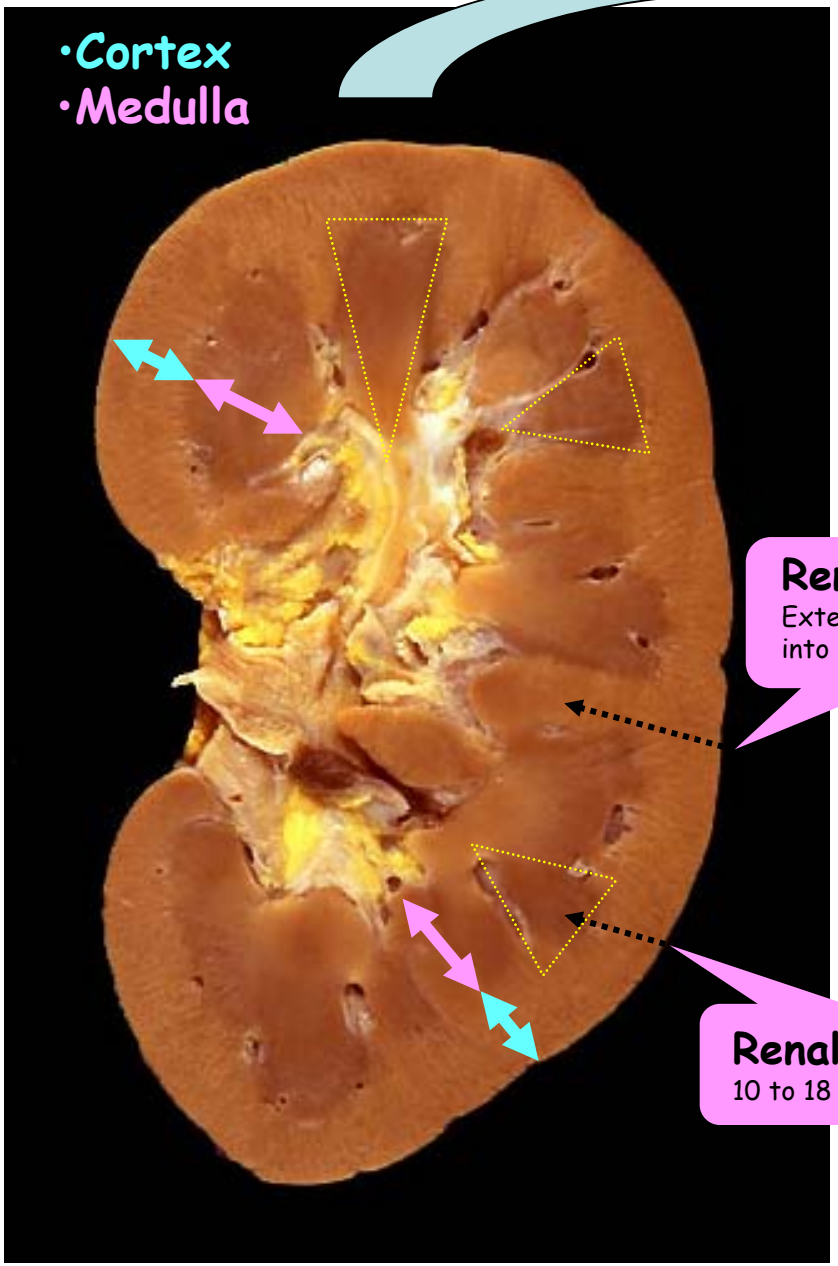
Renal pelvis – expansion of ureter, extension to **major and minor calyces**

Renal parenchyma – medulla + cortex

Lobullar structure of the kidney

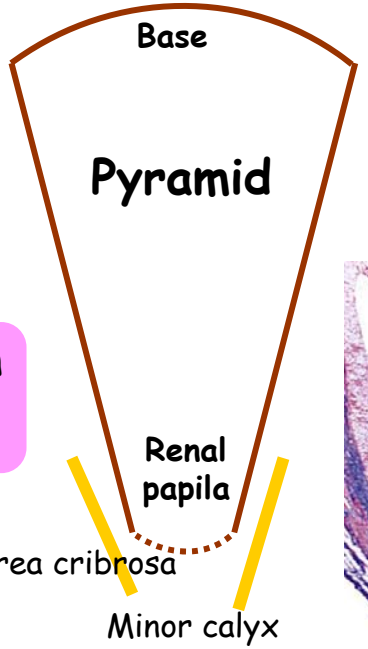




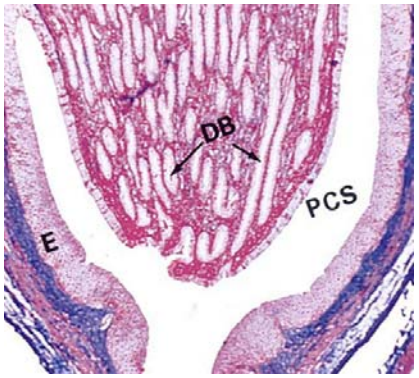


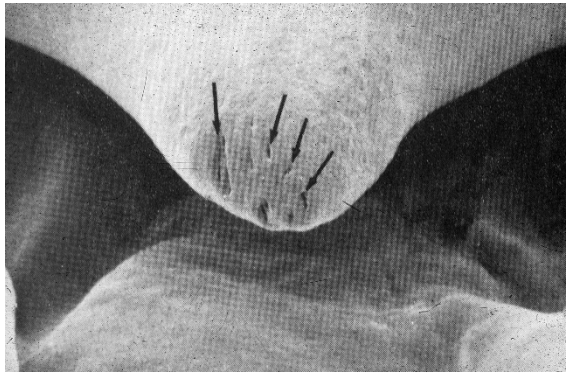
Renal collumn
Extension of cortex into medulla

Renal pyramid
10 to 18 per kidney

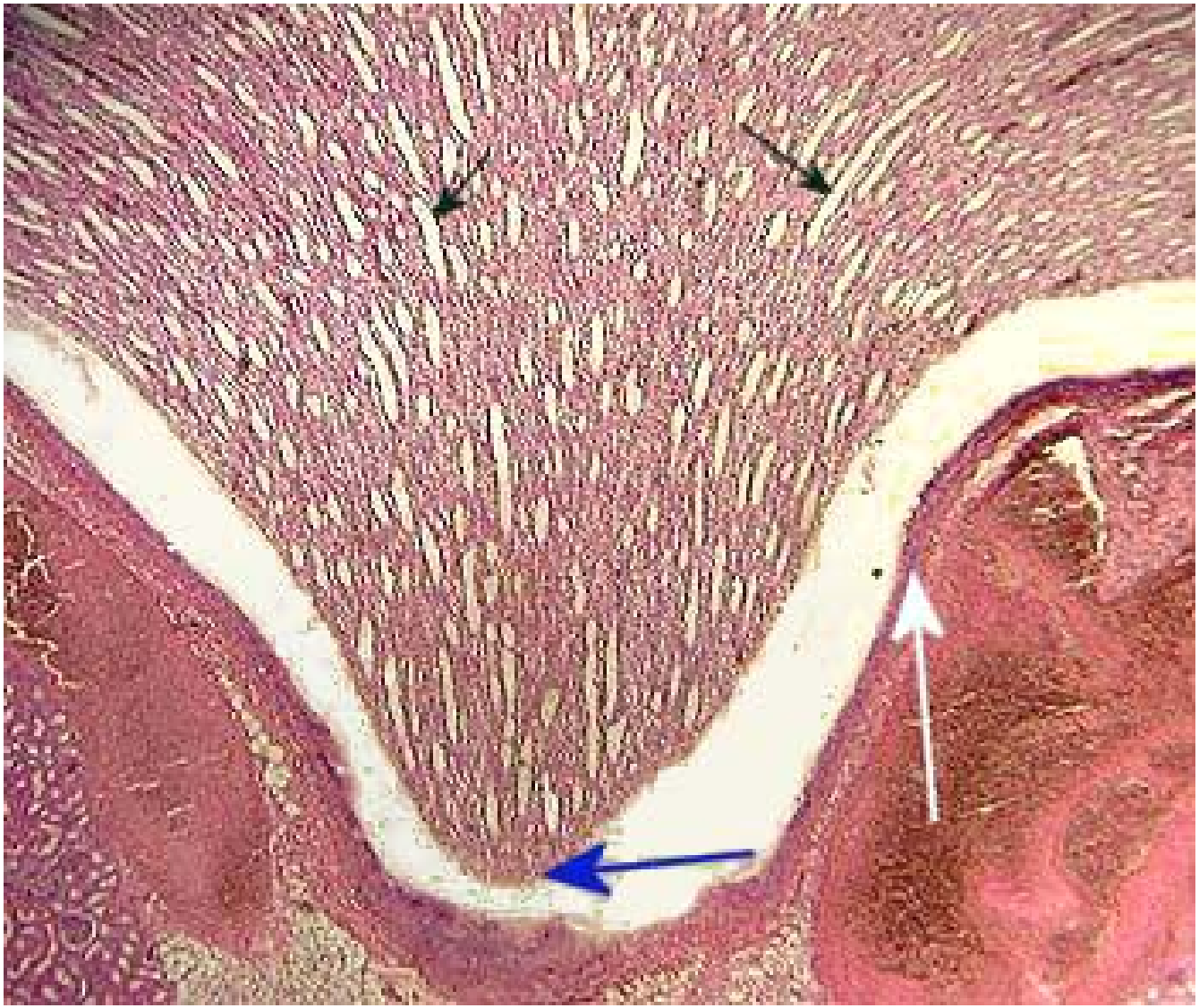


DB-ducts of Bellini

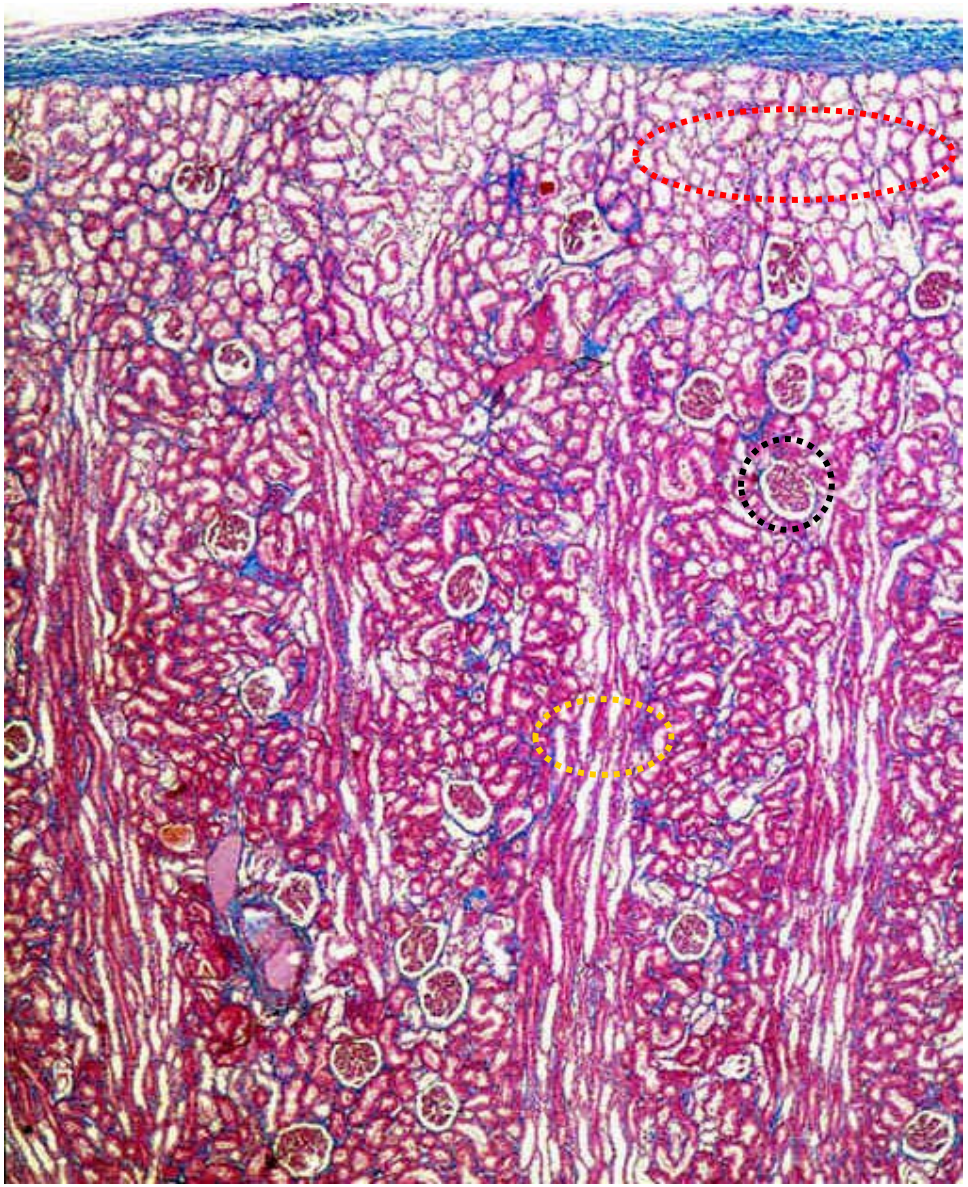




Kidney medulla



Kidney cortex

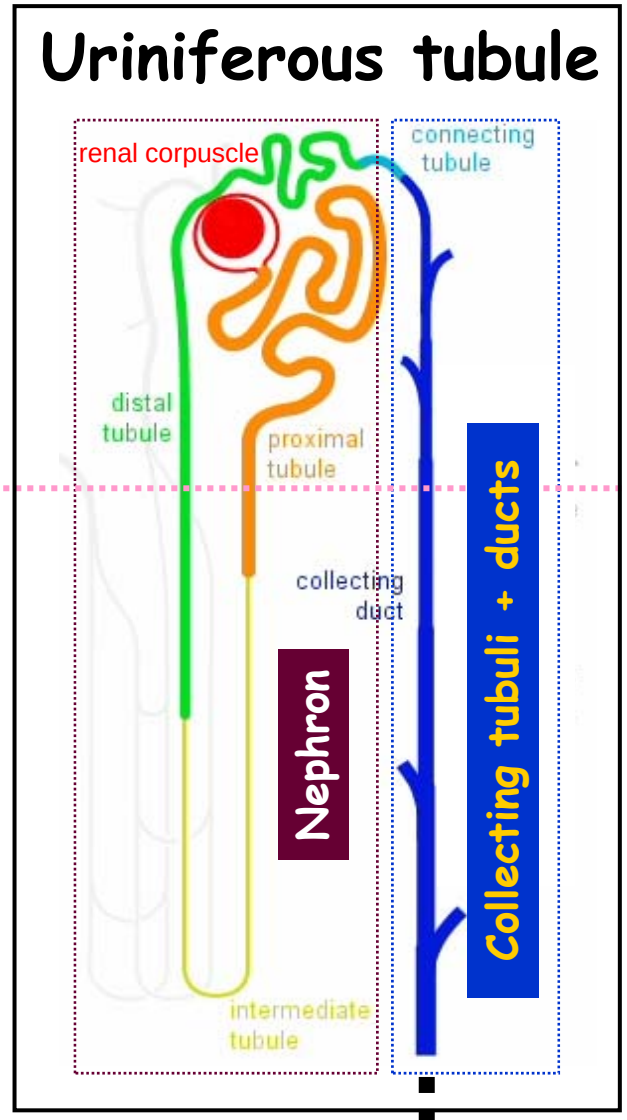


Cortical labyrinth
(convoluted tubules)

Renal corpuscles

Cortical rays
(continuation of collecting ducts from renal pyramids)

Uriniferous tubule = The functional unit of the kidney



Cortex

Medulla

Ducts of Bellini

Area cribrosa

Minor calyx

1 to 1.4 milllions of nephrons in one kidney

Nephrons X Collecting tubuli + ducts
Different embryological origin

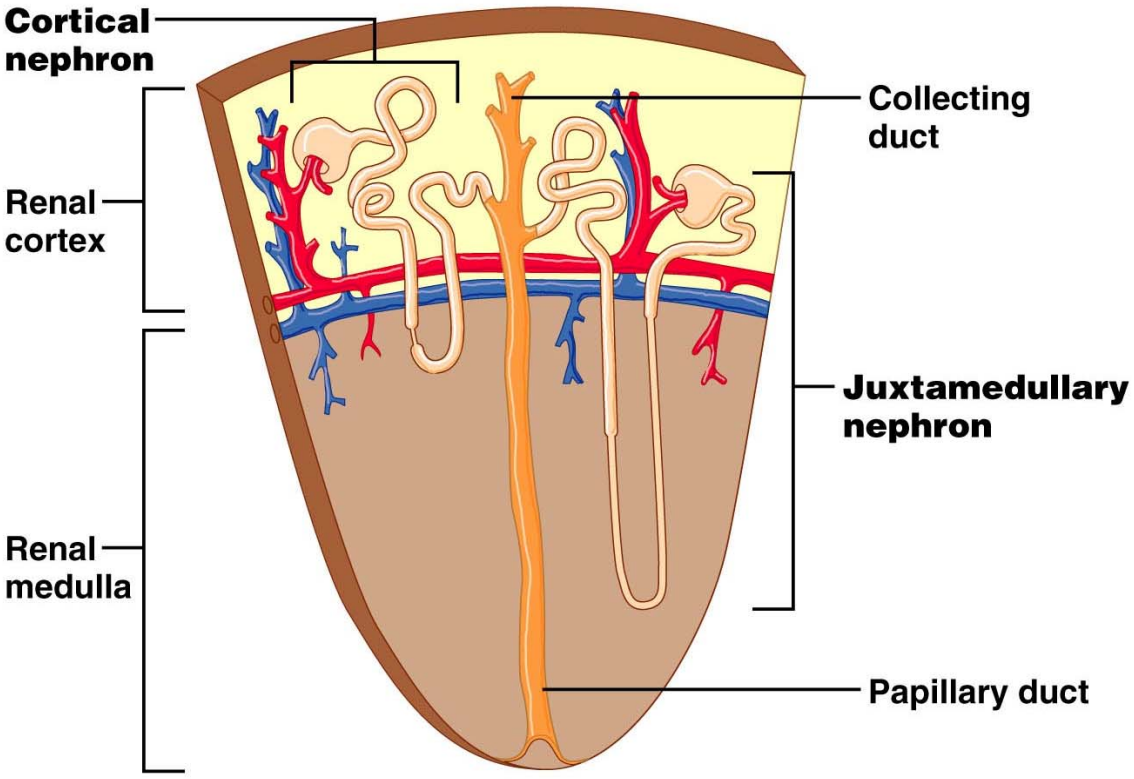
Nephron

Cortical nephrons

85% of nephrons

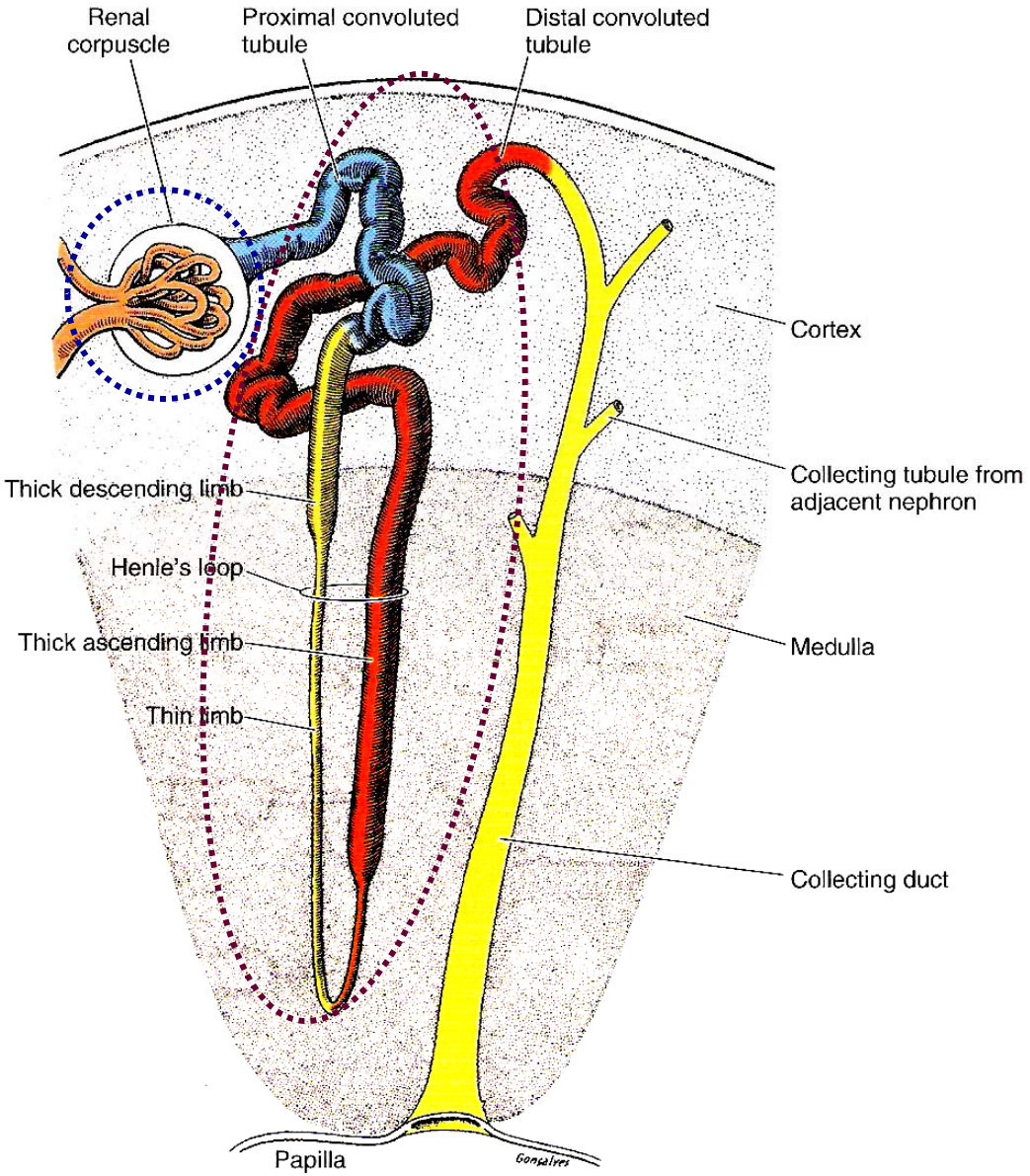
Juxtamedullary nephrons

15% of nephrons



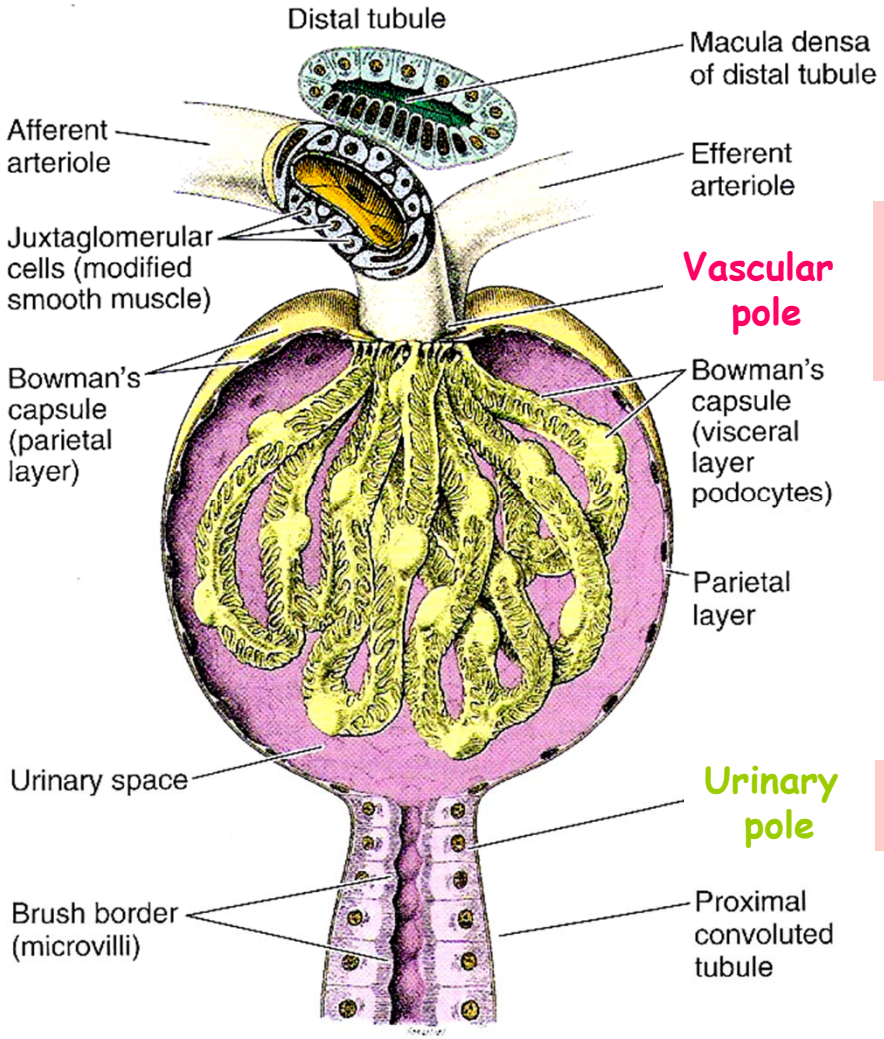
About 40 mm long

Nephron


Renal corpuscle
Proximal convoluted tubule
Distal convoluted tubule
Cortex
Collecting tubule from adjacent nephron
Thick descending limb
Henle's loop
Thick ascending limb
Thin limb
Medulla
Collecting duct
Papilla
Gonçalves

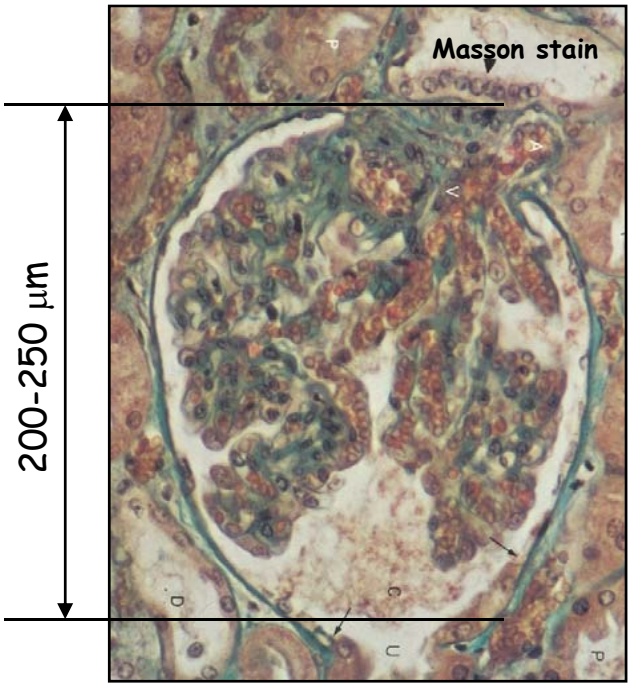
Nephron – Renal corpuscle 1

Glomerulus – tuft of capillaries
Bowman`s capsule - invaginated dilatation of proximal tubule

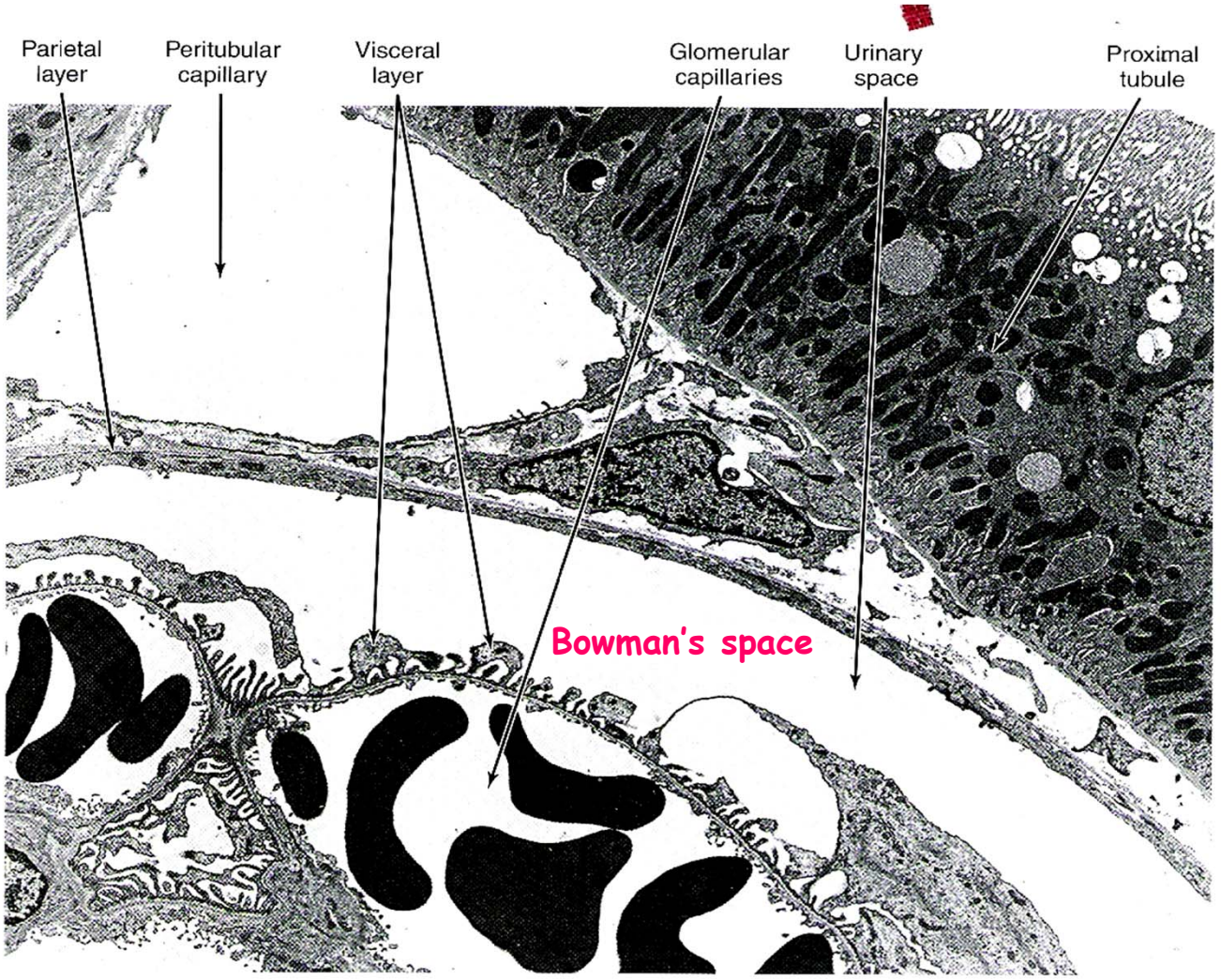


side of the corpuscle where the afferent arterioles and efferent arterioles enter and exit, respectively

side of the corpuscle where the PCT exits.

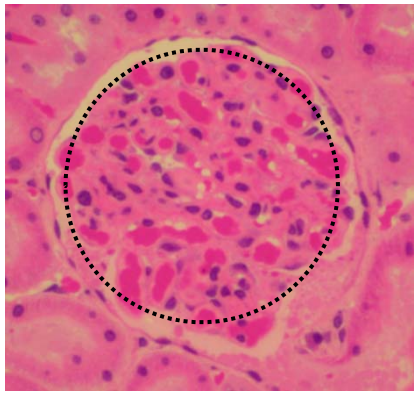


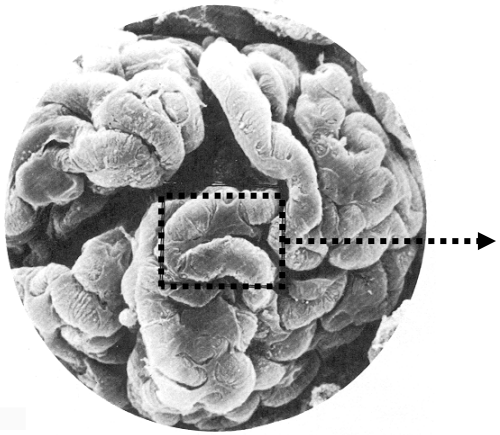
Nephron – Renal corpuscle 2

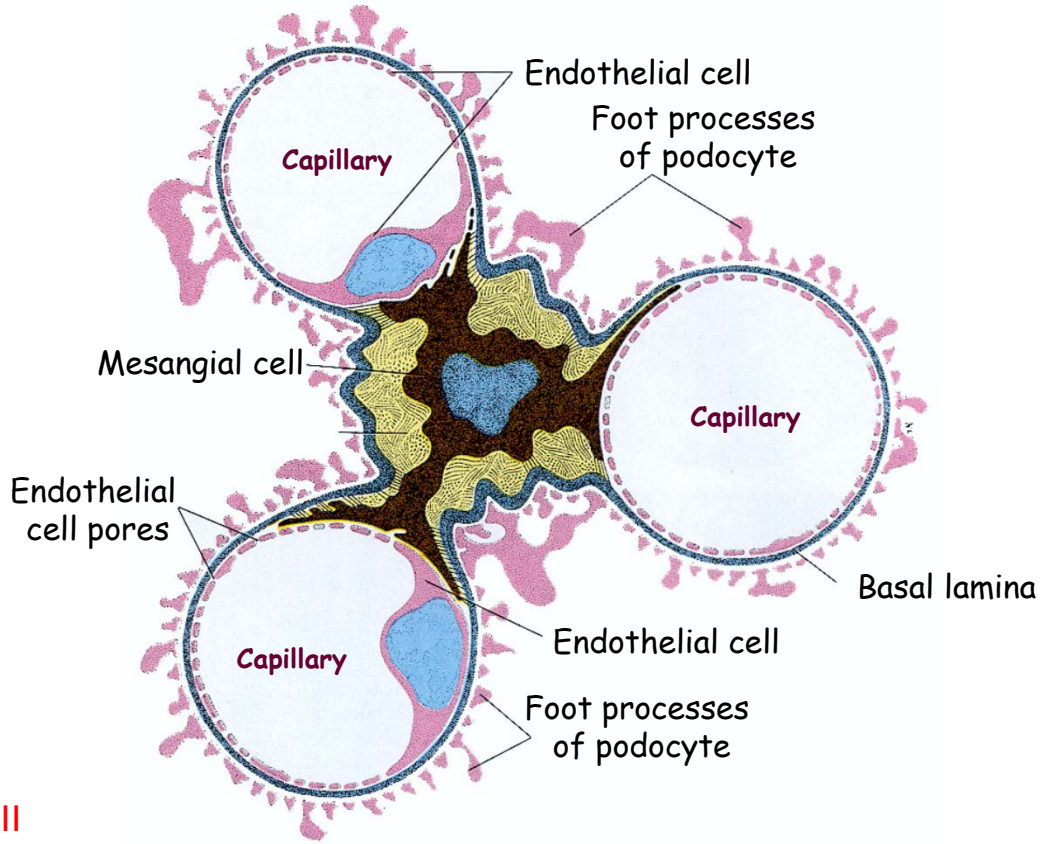


Nephron – Glomerulus 1

Endothelial cell + Basal lamina + Podocytes + Mesangial cells





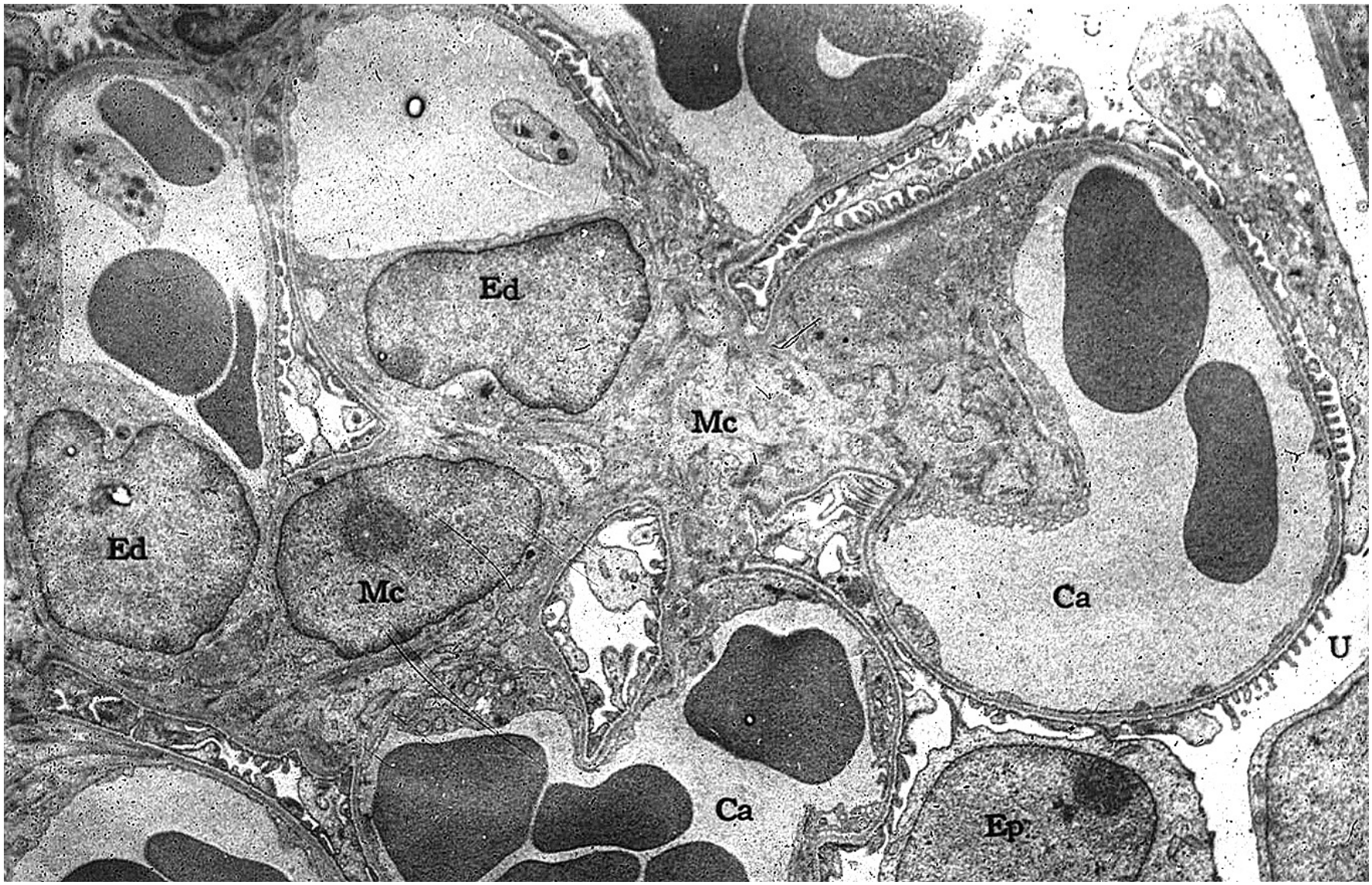


Mesangial cells

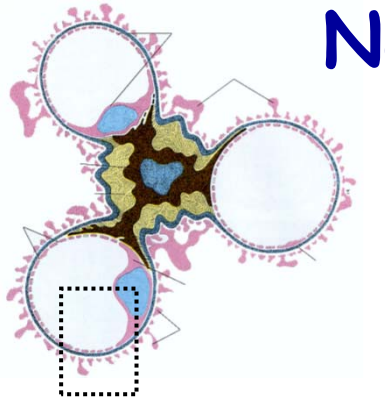
- Contractile - receptors for angiotensin II
- Give structural support to the glomerulus, synthesize ECM
- Endocytose and dispose of normal and pathologic molecules trapped by the glomerular basement membrane
- Produce chemical mediators such as cytokines and prostaglandins

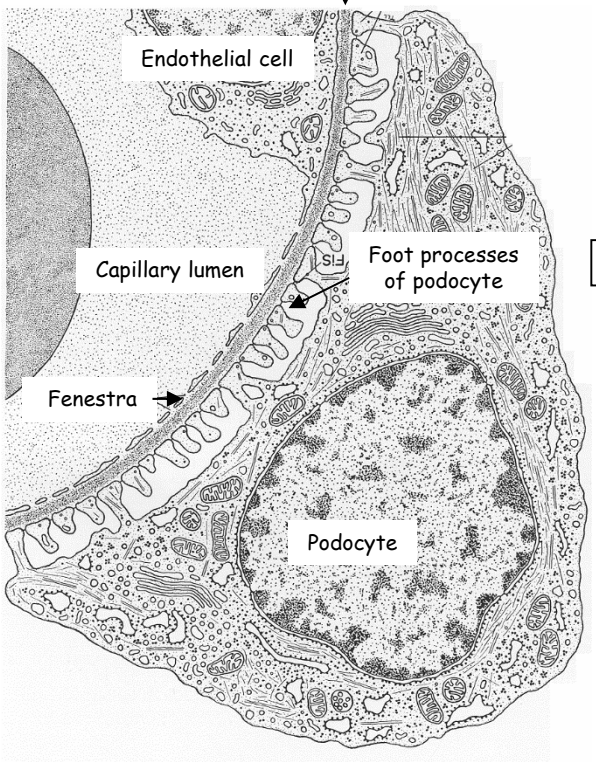
Lamina Rara – contain fibronectin (bind them to cells) – physical barrier
Lamina Densa – meshwork of Type IV collagen and laminin in a matrix contg (-) charged heparan sulfate that restricts passage of cationic molecules – charge barrier

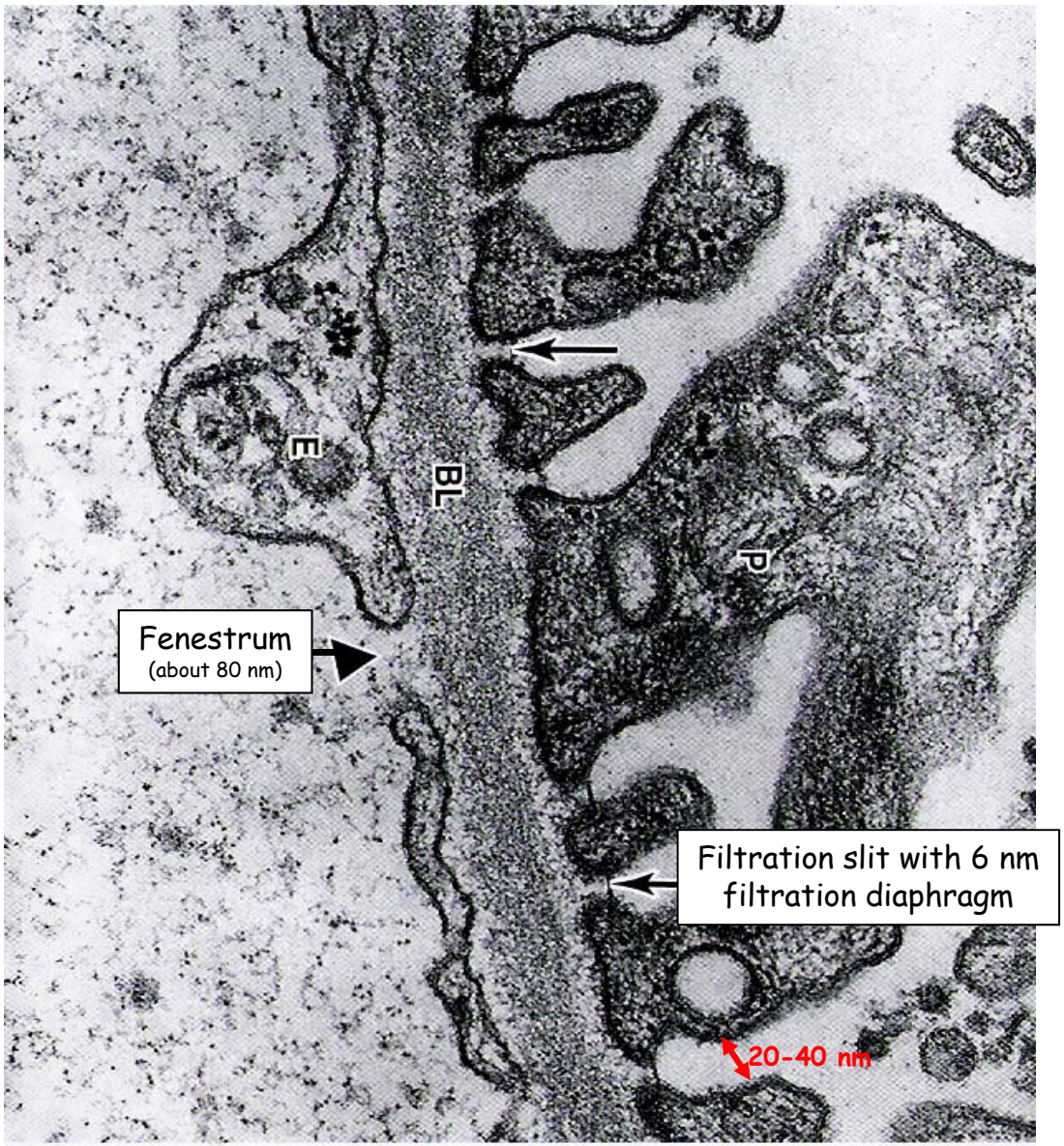
Nephron – Glomerulus 2



Nephron – Glomerulus 3

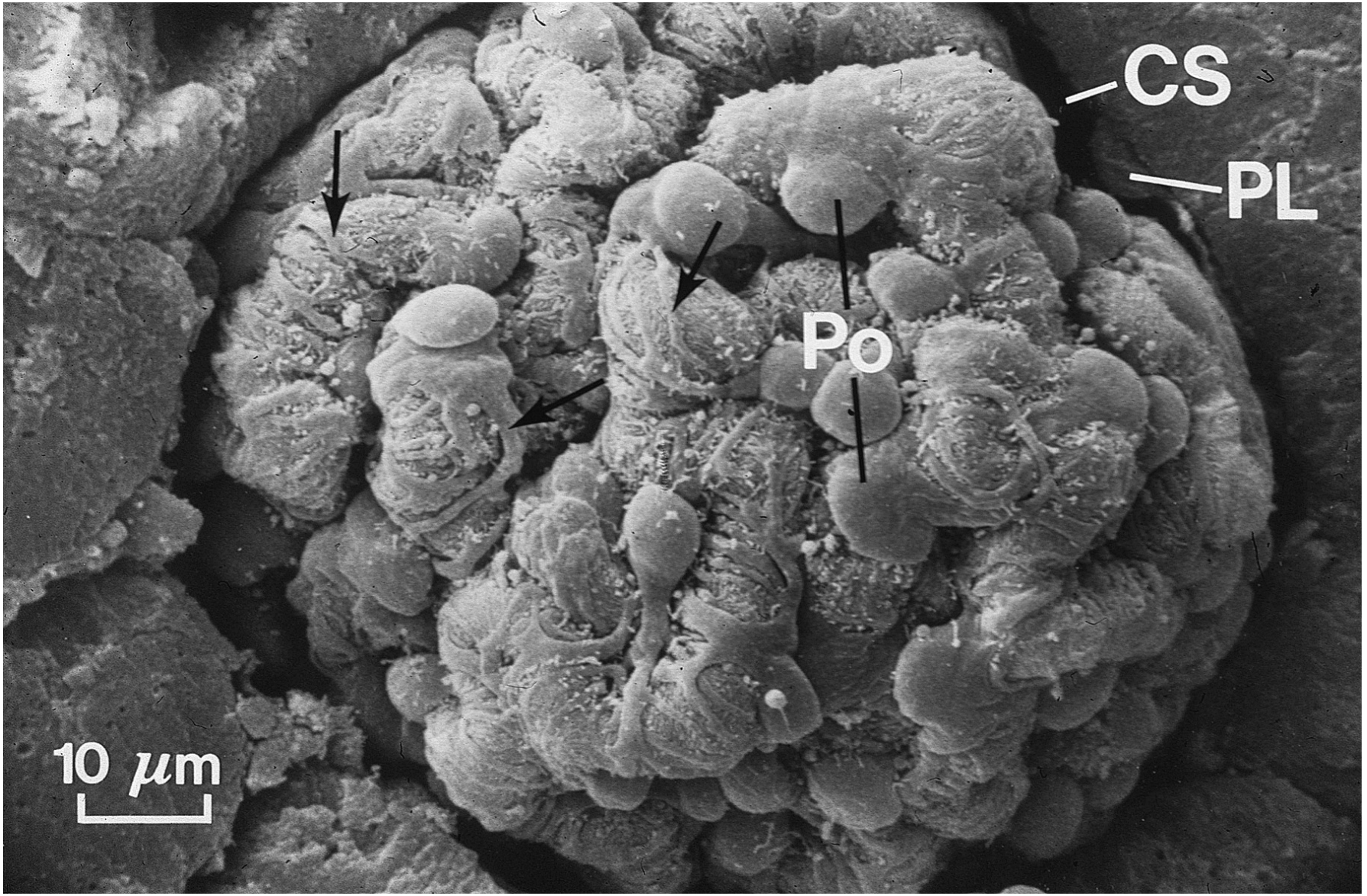




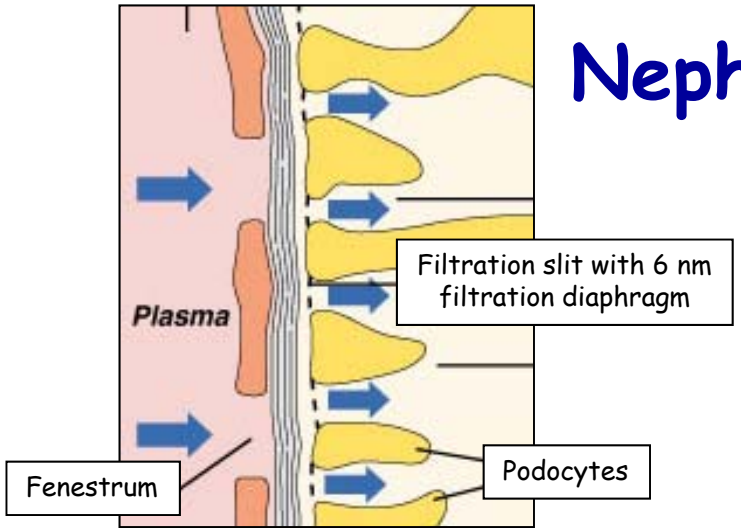


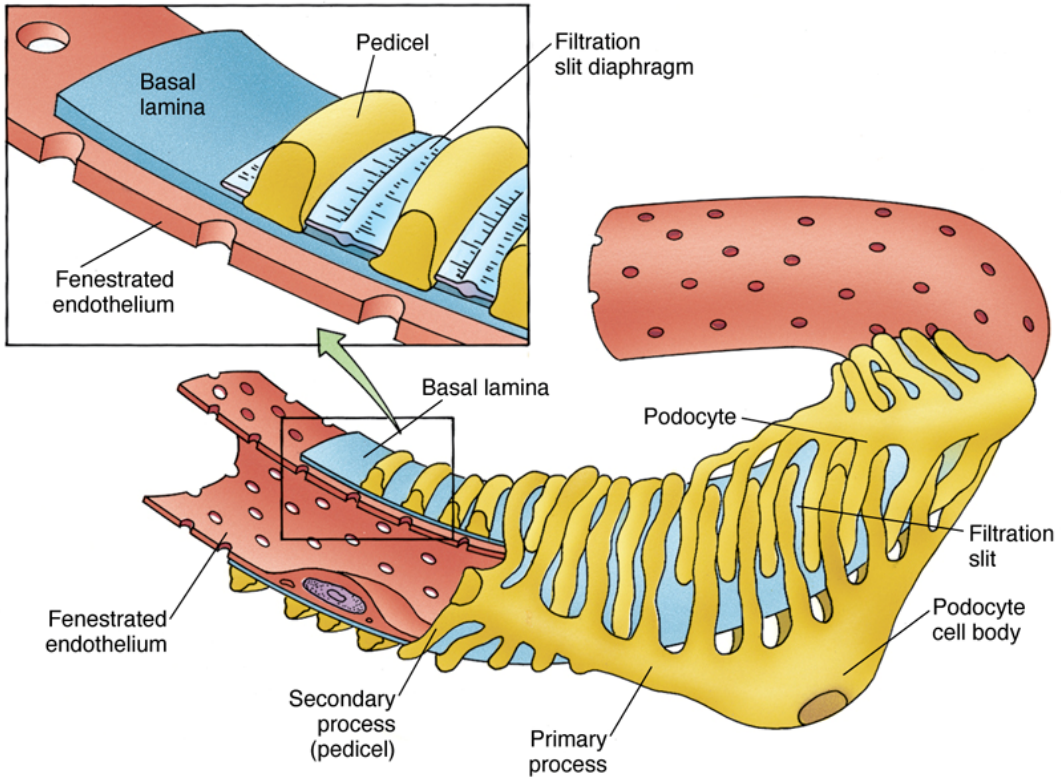
Fenestra: 70 – 90 nm

Nephron – Glomerulus – Podocyte 1



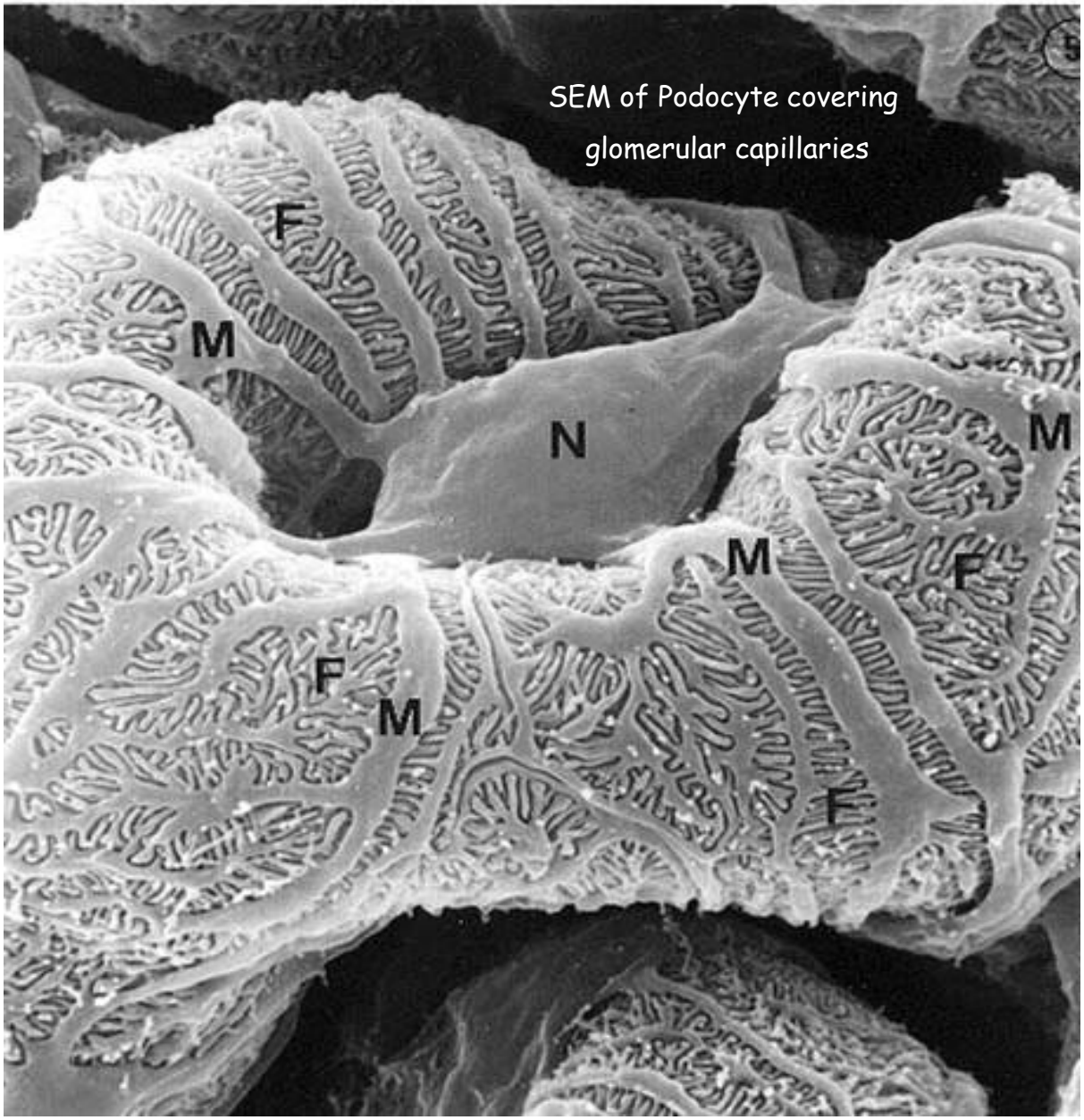
Nephron – Glomerulus – Podocyte 2





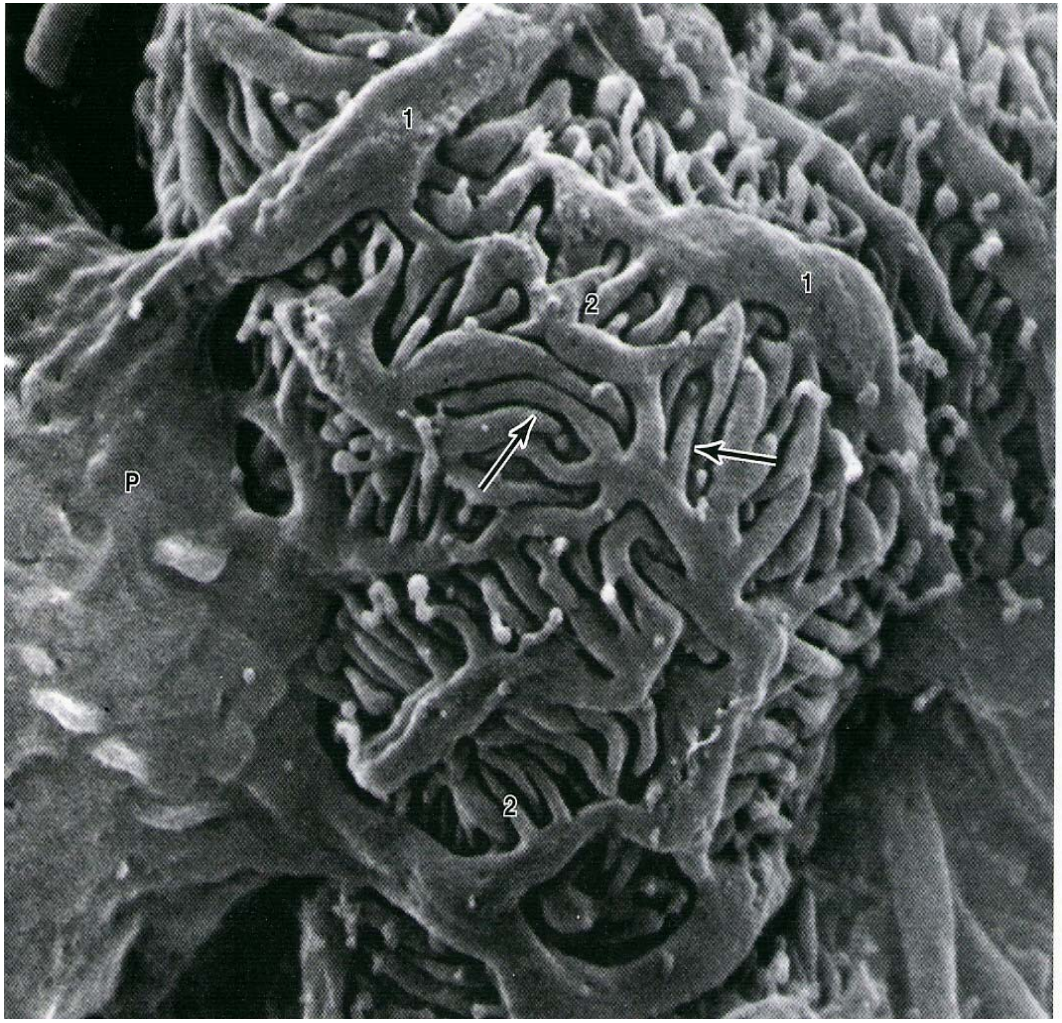
Primary processes
X
Secondary processes

Nephron – Glomerulus – Podocyte 3

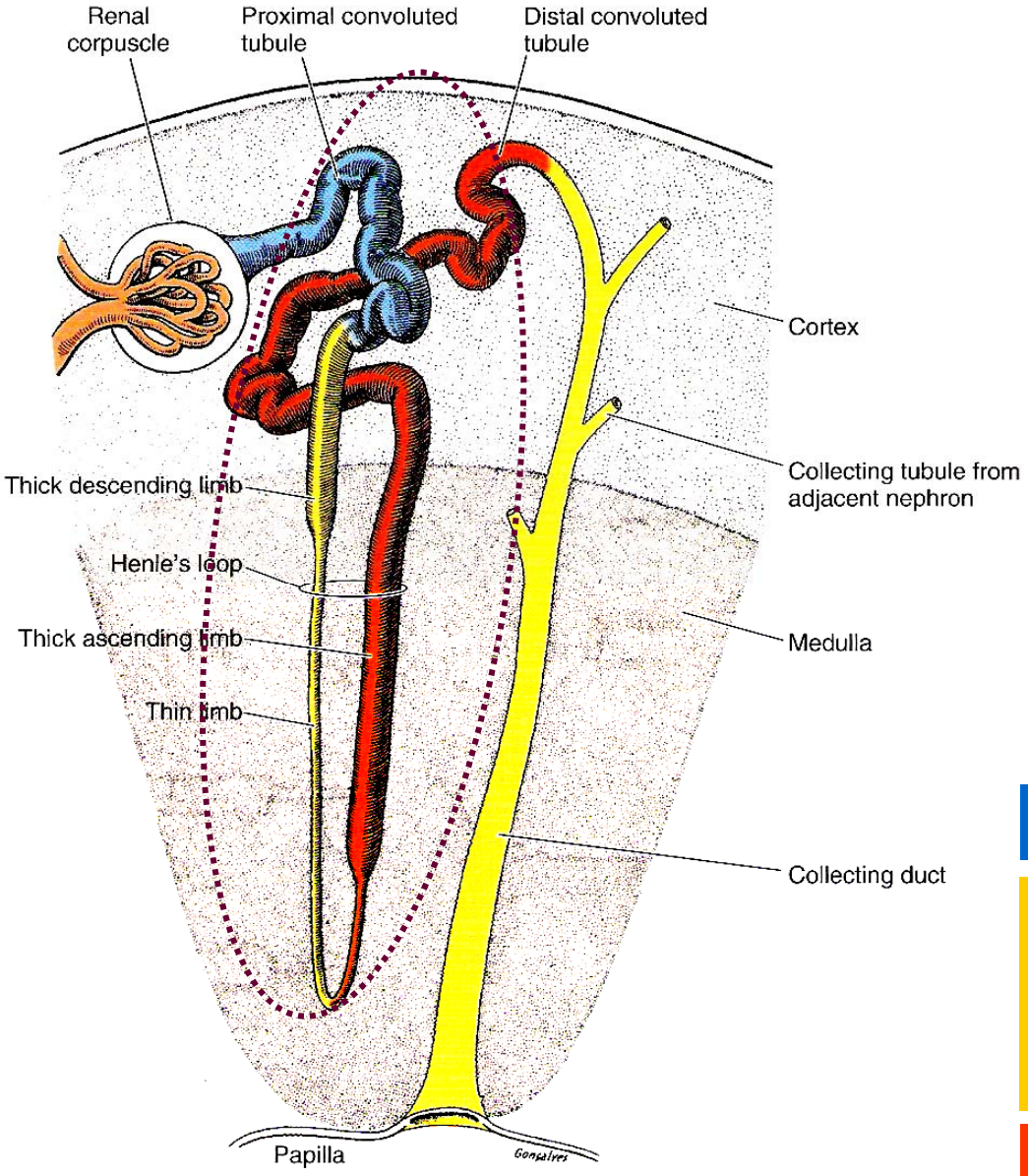


Nephron – Glomerulus – Podocyte

„Octopus-like cell"



Nephron – Tubular section 1



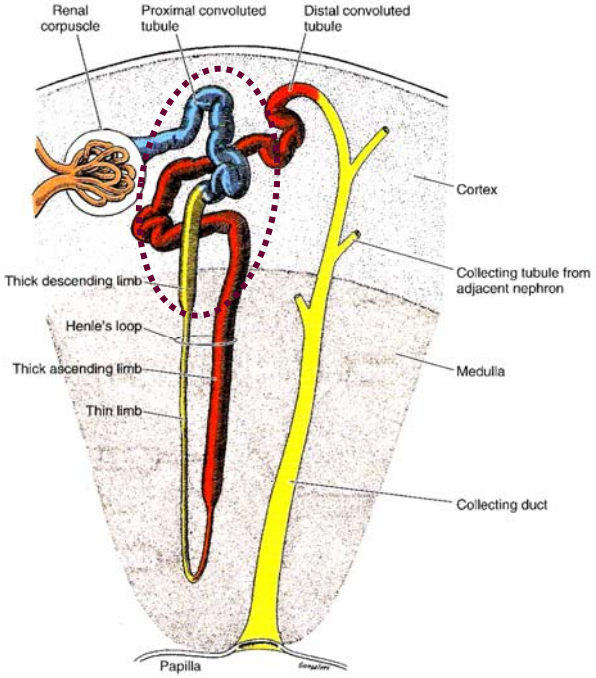
Proximal convoluted tubulus

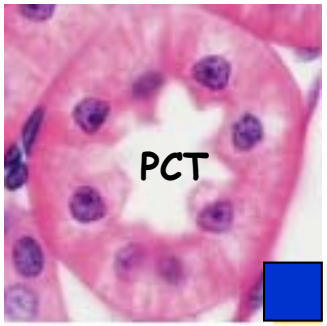
Henle`s loop
- Thick descending limb
- Thin limb
- Thick ascending limb

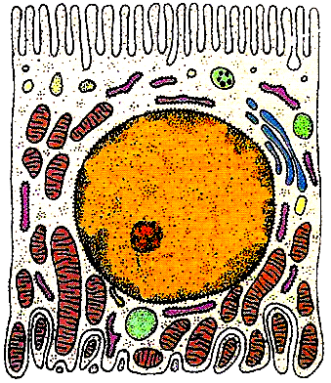
Distal convoluted tubulus

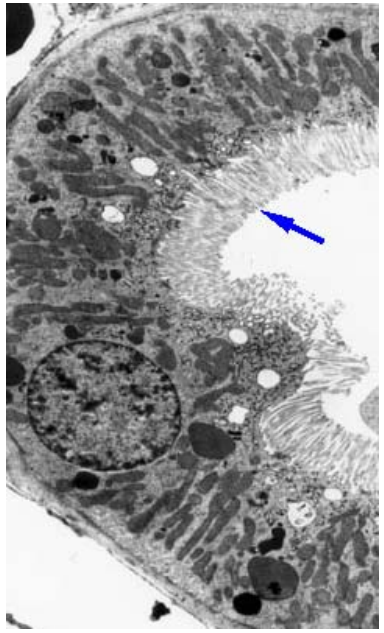
Nephron – Tubular section 2

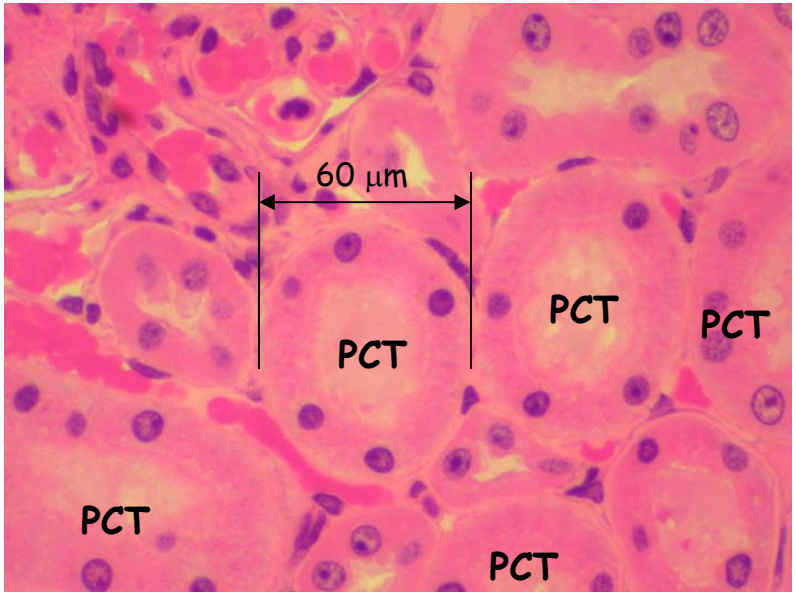
Proximal convoluted tubulus + Thick descending limb of HL
= 14 mm in length







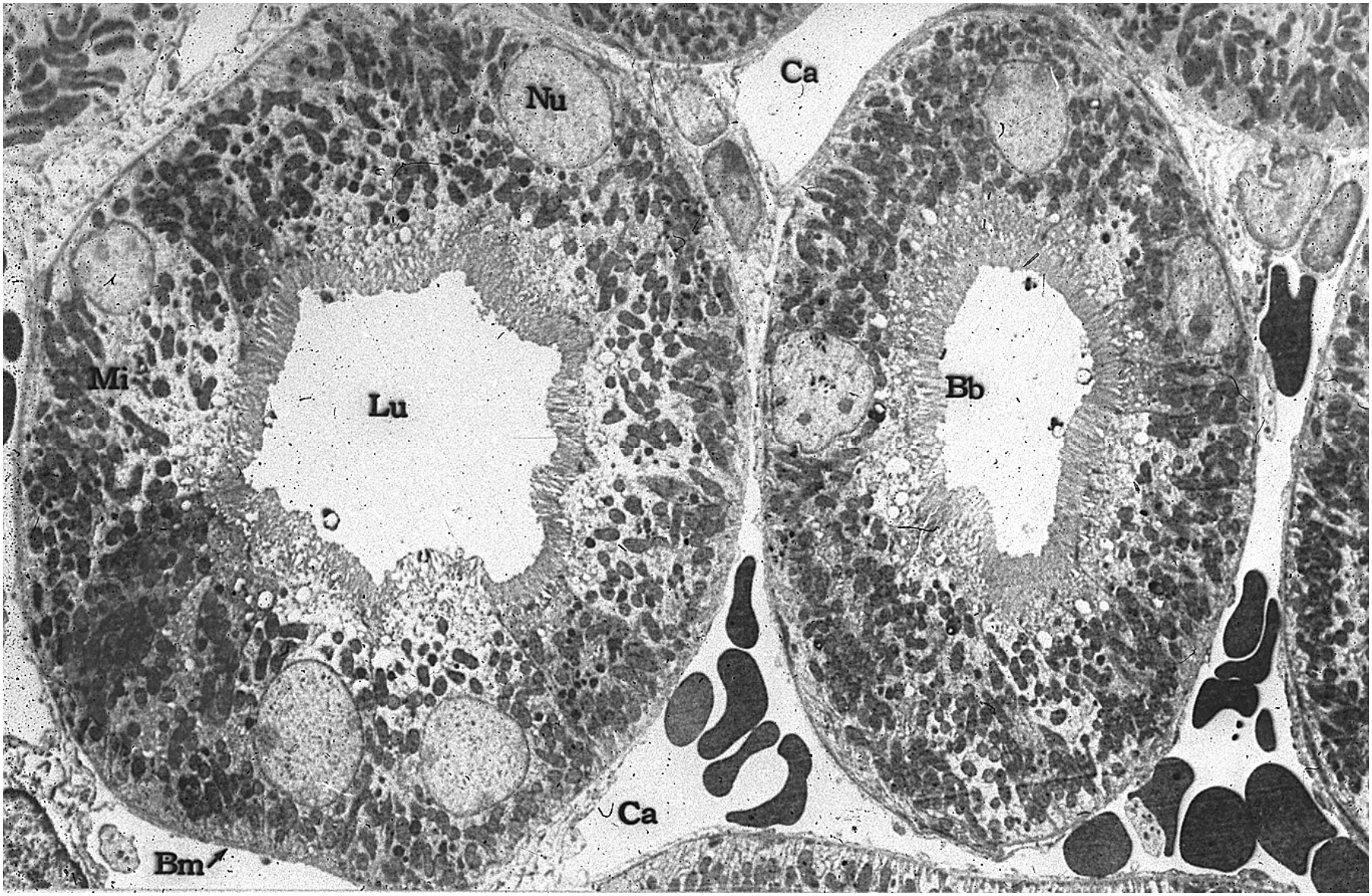




Reabsorption

$\frac{3}{4}$ of sodium, Cl, K, H_2O, amino acids, proteins

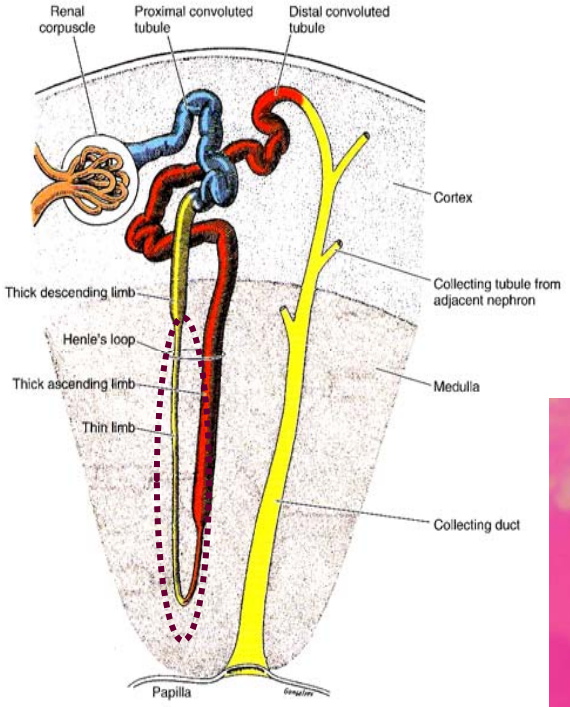
Proximal convoluted tubuli

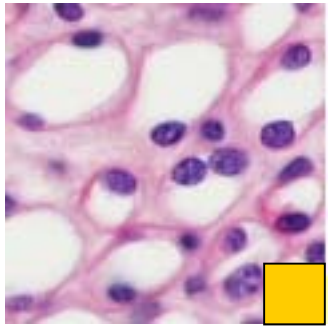


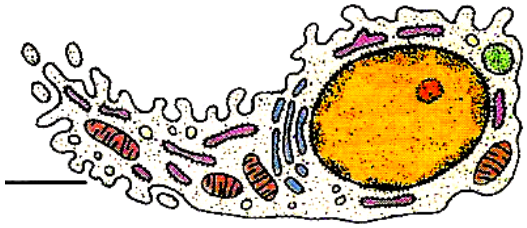
Nephron – Tubular section 3

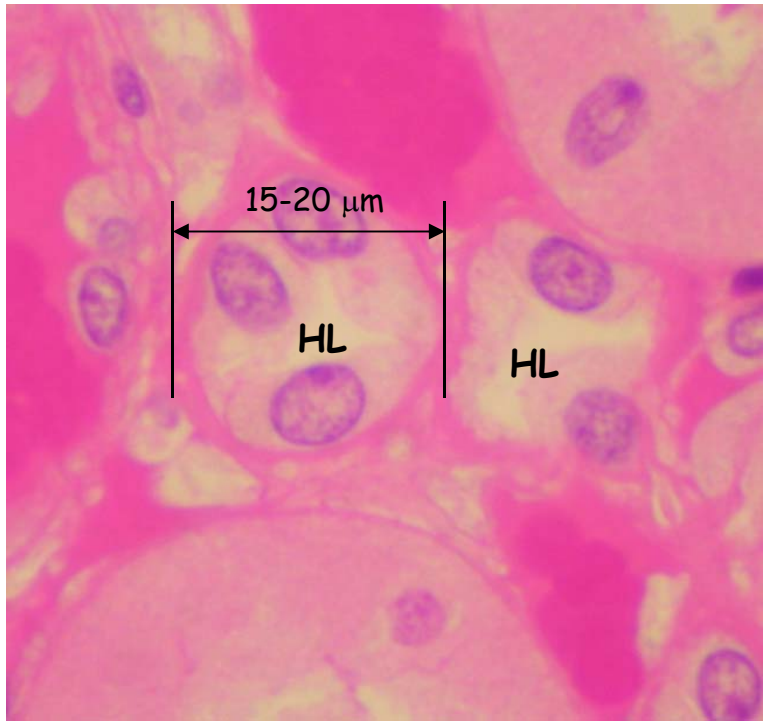
Thin descending limb of HL + Thin ascending limb of HL

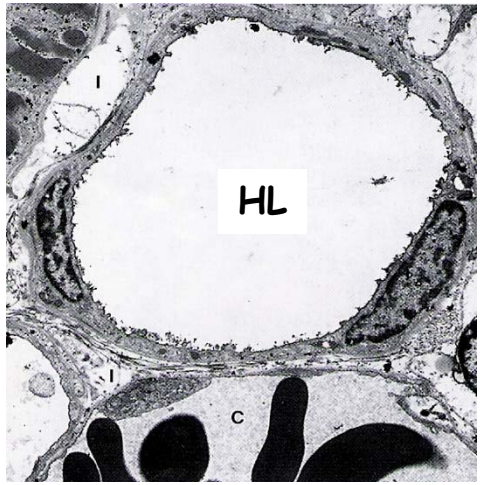
= 9-10 mm in length











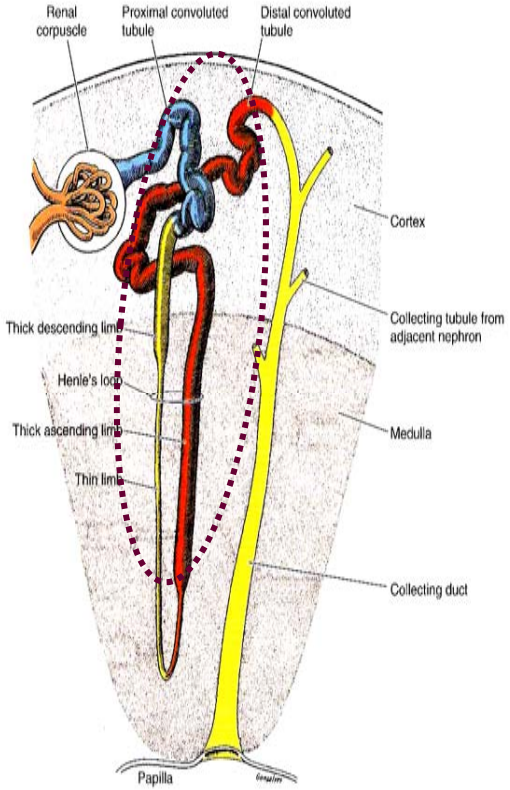
Reabsorption

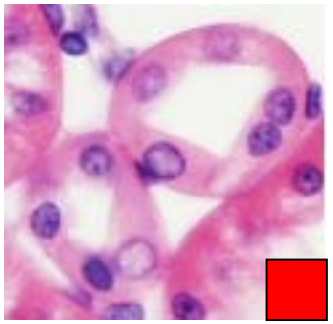
H_2O

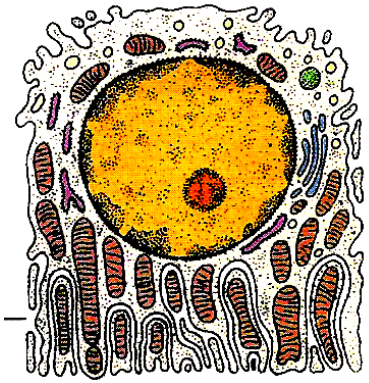
Nephron – Tubular section 4

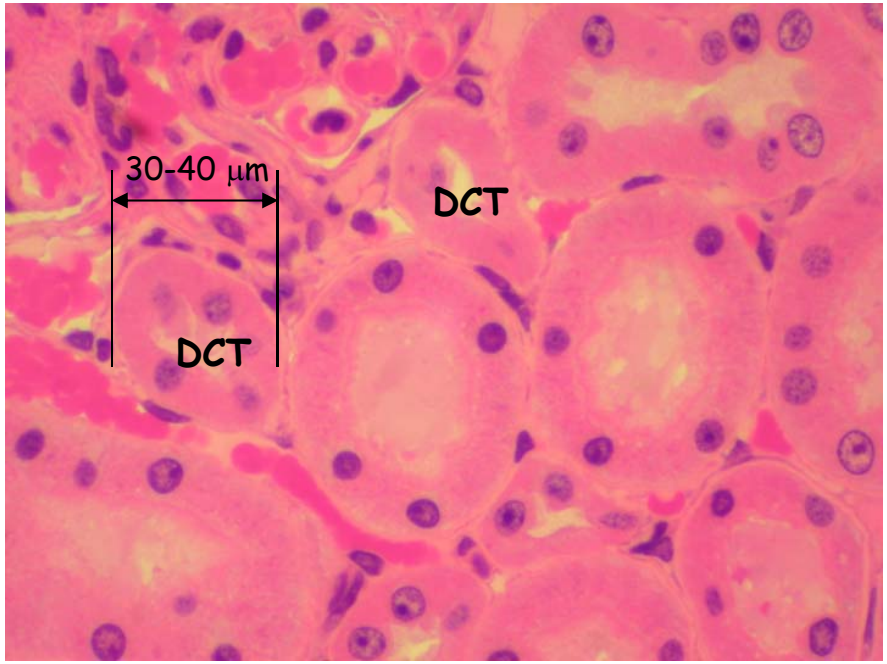
Thick ascending limb of HL + Distal convoluted tubulus

9-10 mm in length + 4-5 mm in length





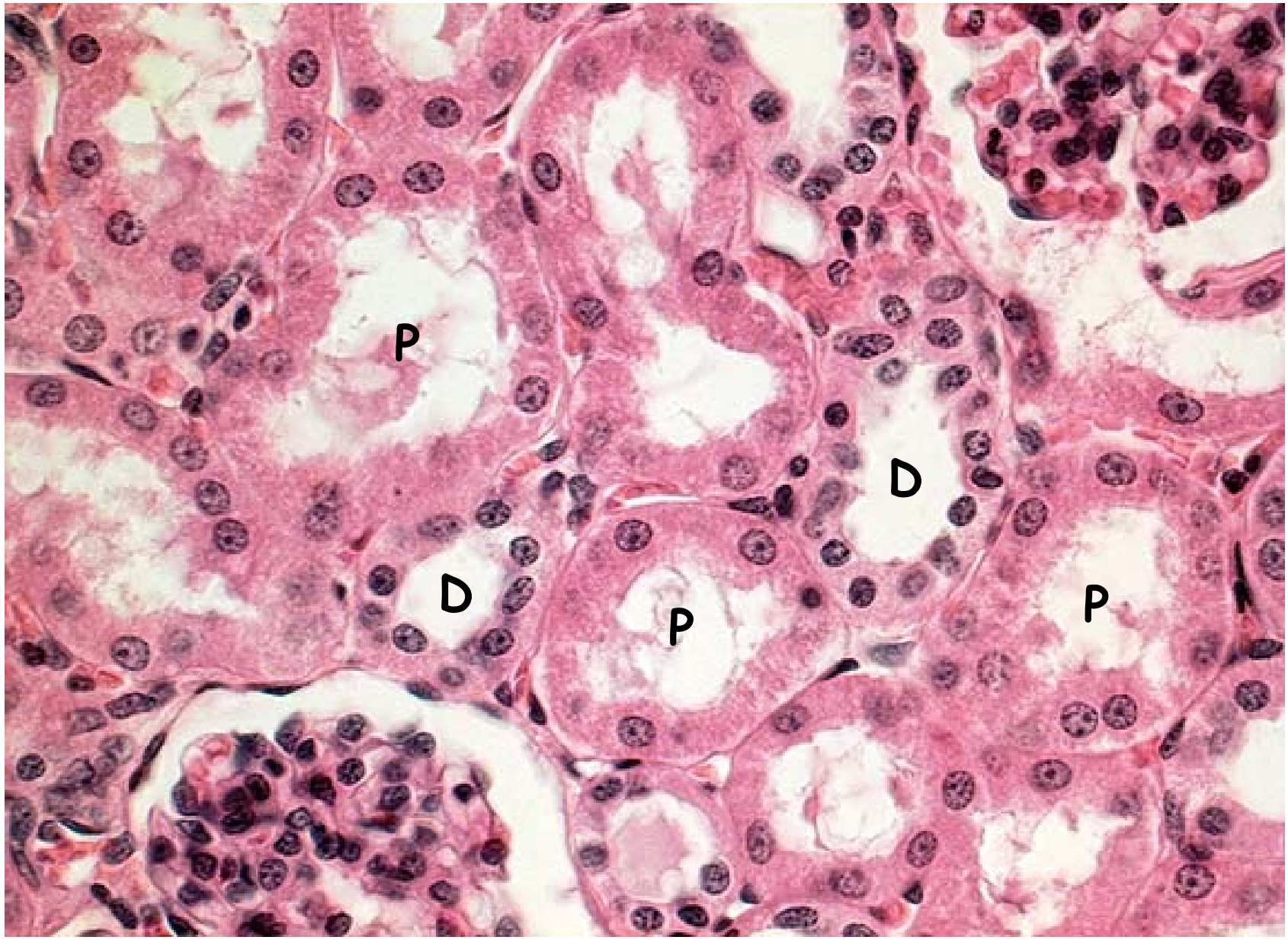




Reabsorption
Na, K, Cl

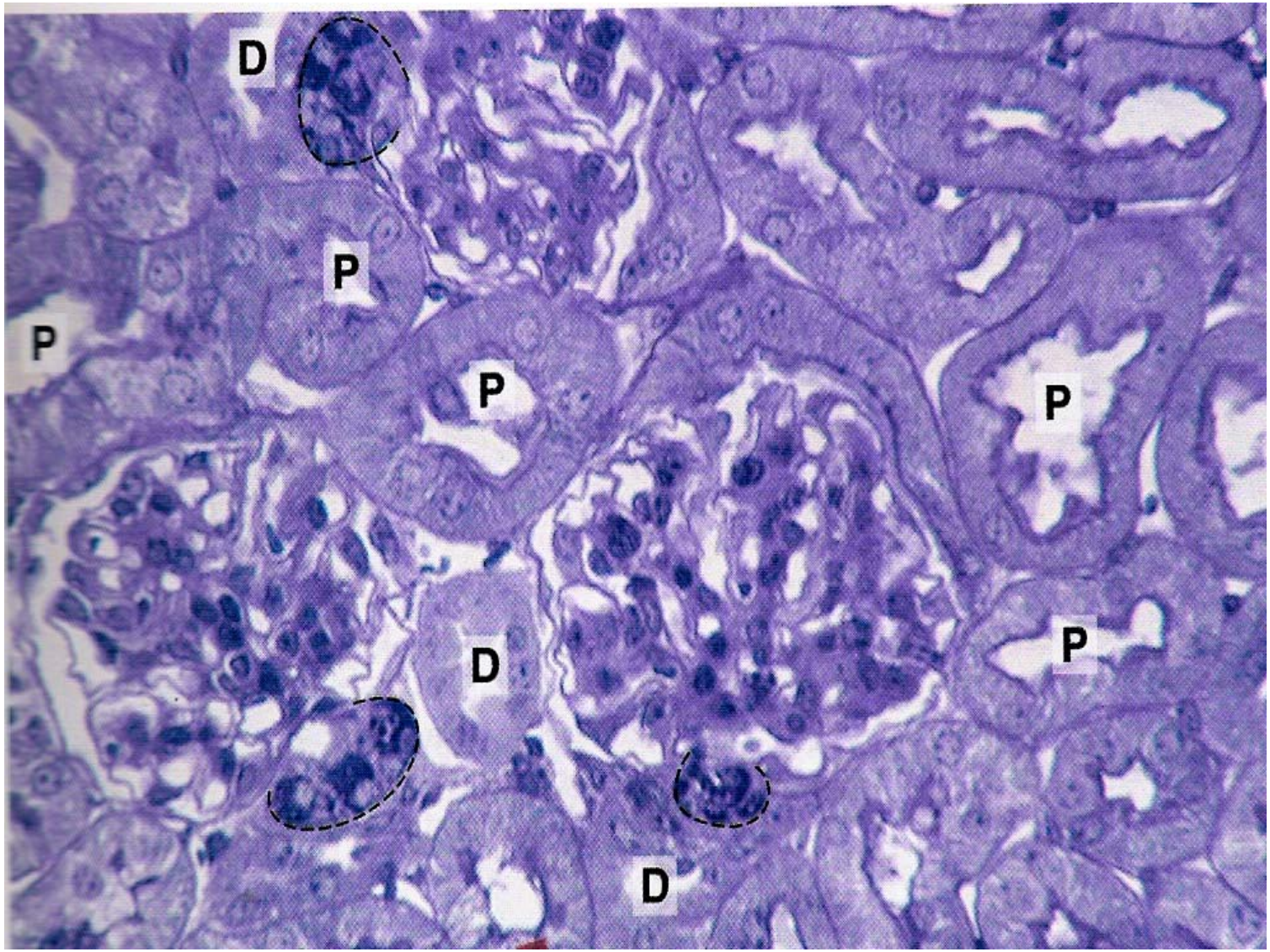
Impermeable for water

Proximal and distal convoluted tubuli

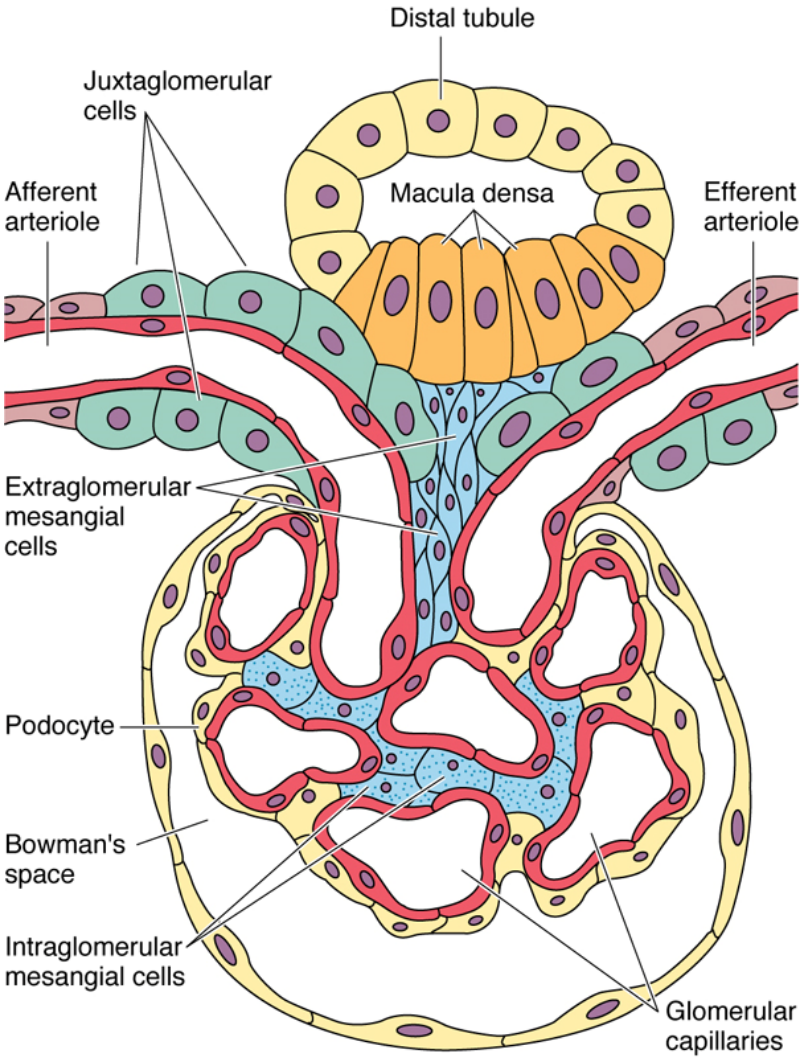


Cortex

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.

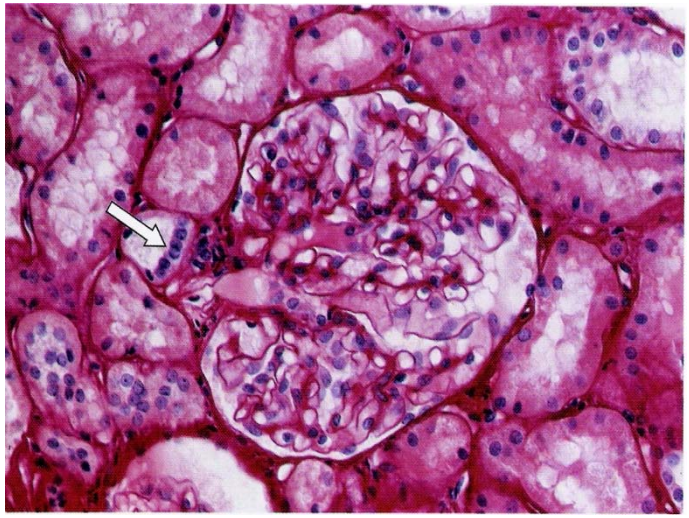
Juxtaglomerular cells
Monitor blood pressure in the afferent arteriole and secrete renin. **Renin** converts angiotensinogen in blood plasma to angiotensin I which is converted to angiotensin II in the lungs. **Angiotensin II** causes arteriole constriction throughout the body, raising blood pressure.

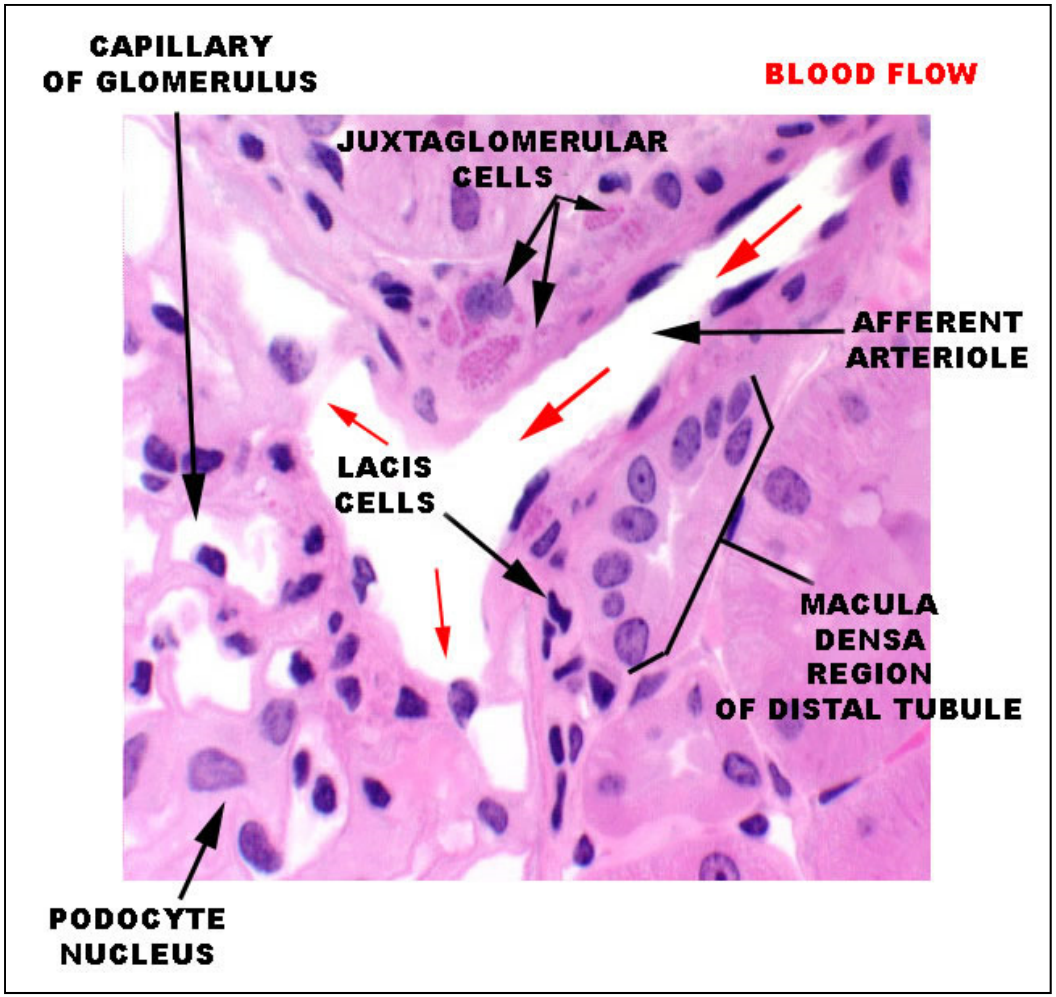
Extraglomerular mesangial cells (Lacis cells)

Nephron – Tubular section –
Juxtaglomerular apparatus 2

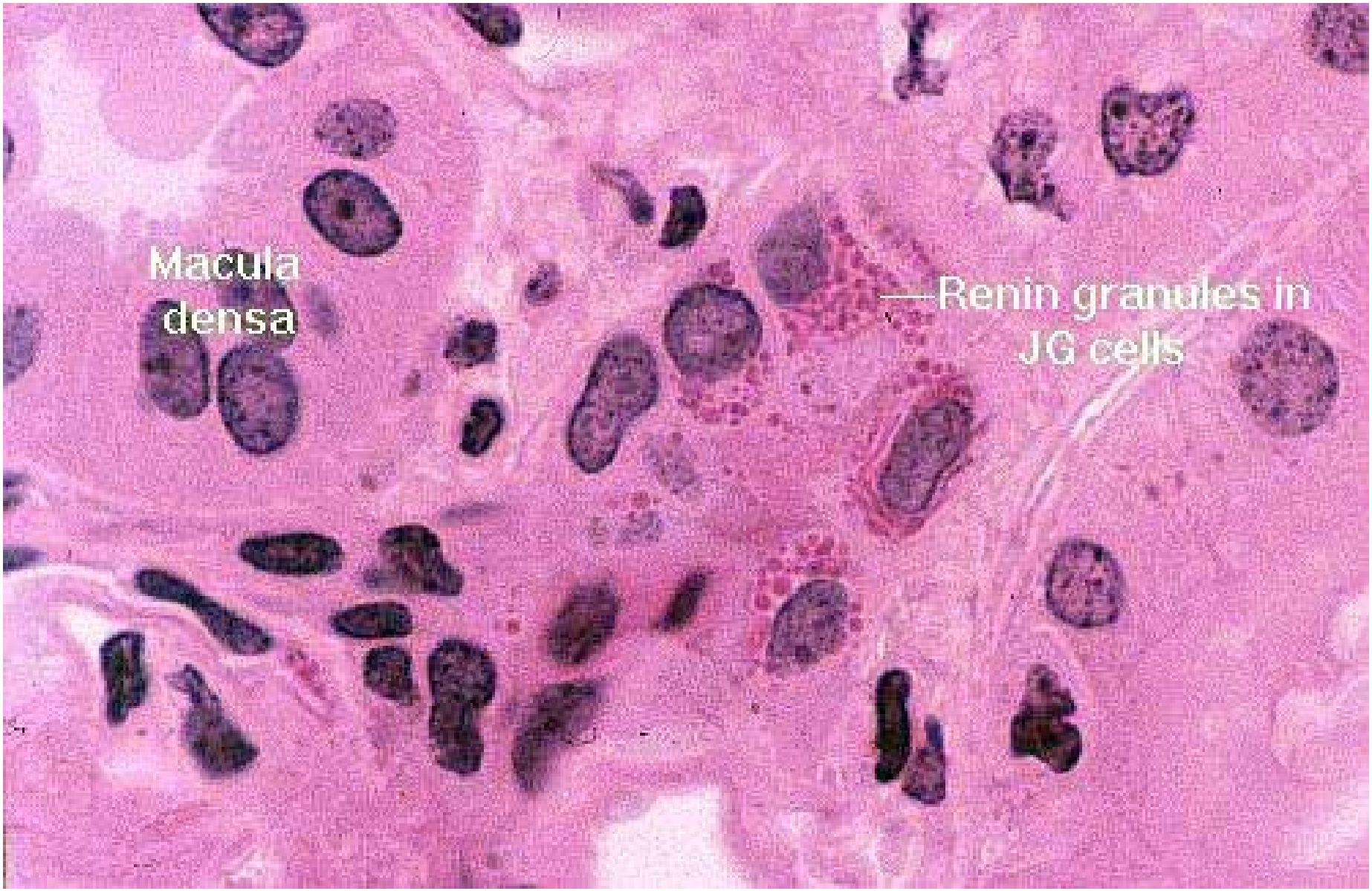
Macula densa

Modified DCT in proximity of vascular pole of renal corpuscle



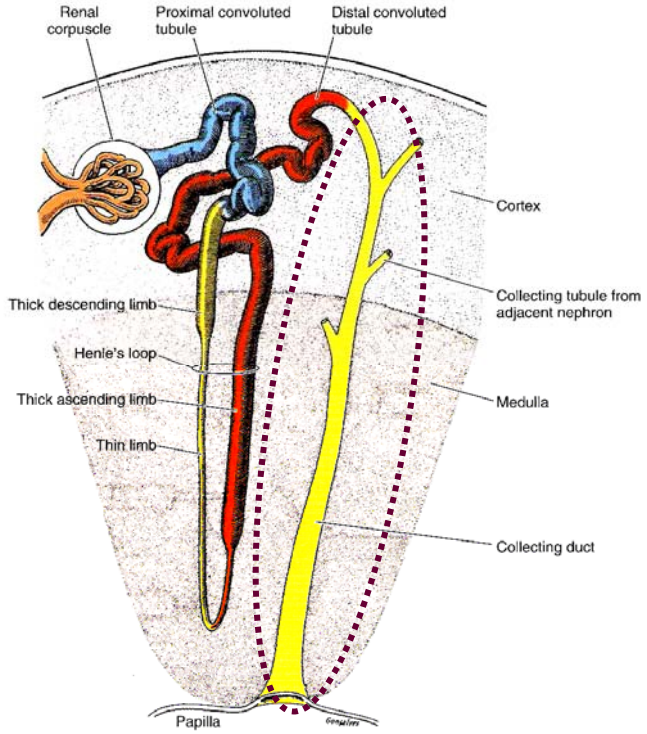


Juxtaglomerular cells

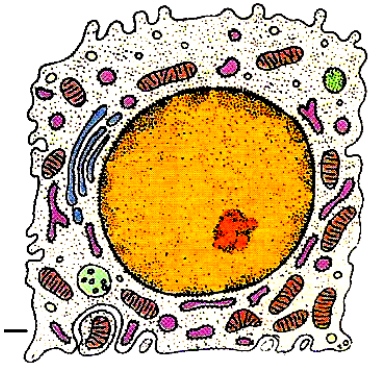


Collecting tubuli

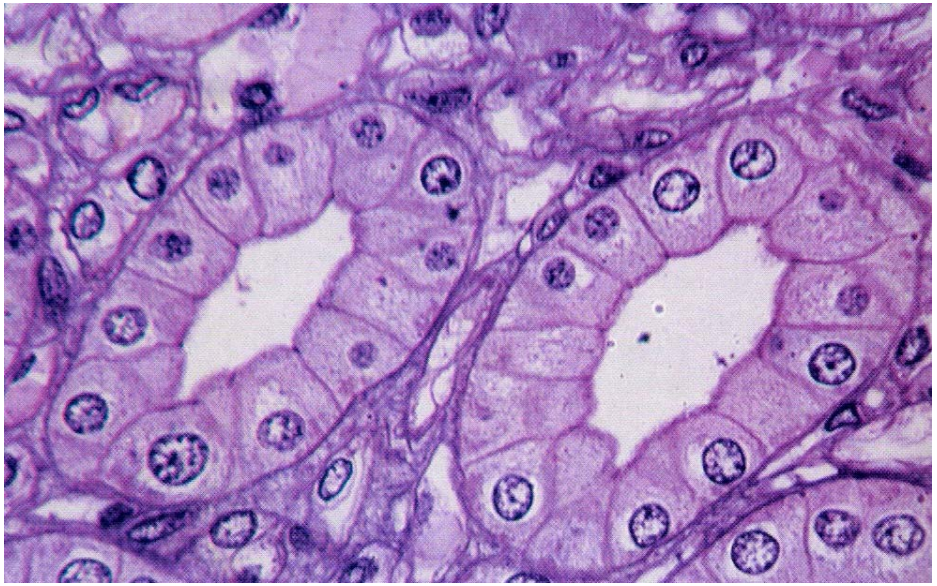
Cortical + Medullary + Papillary = 20 mm in length



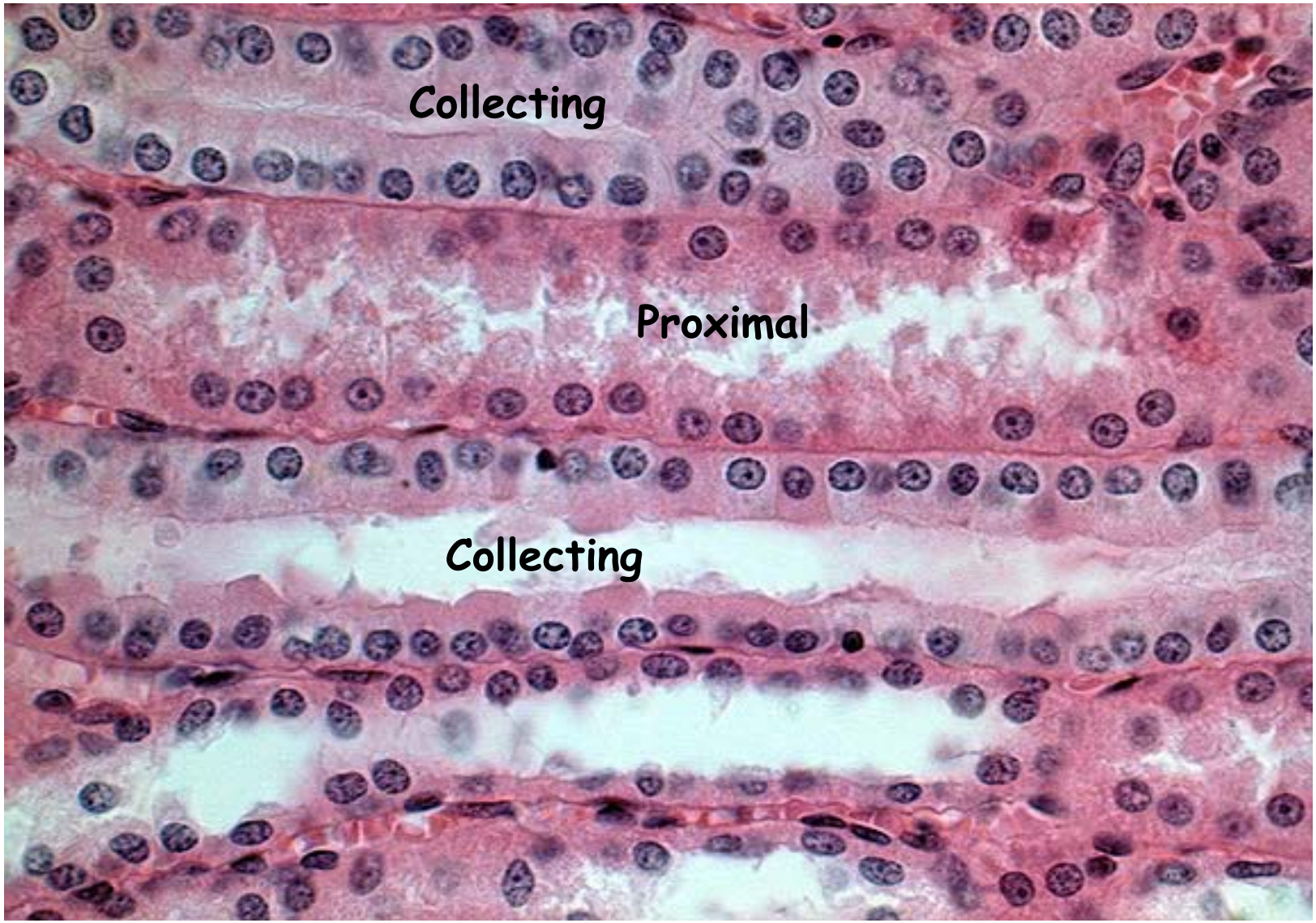
200 -300 μm



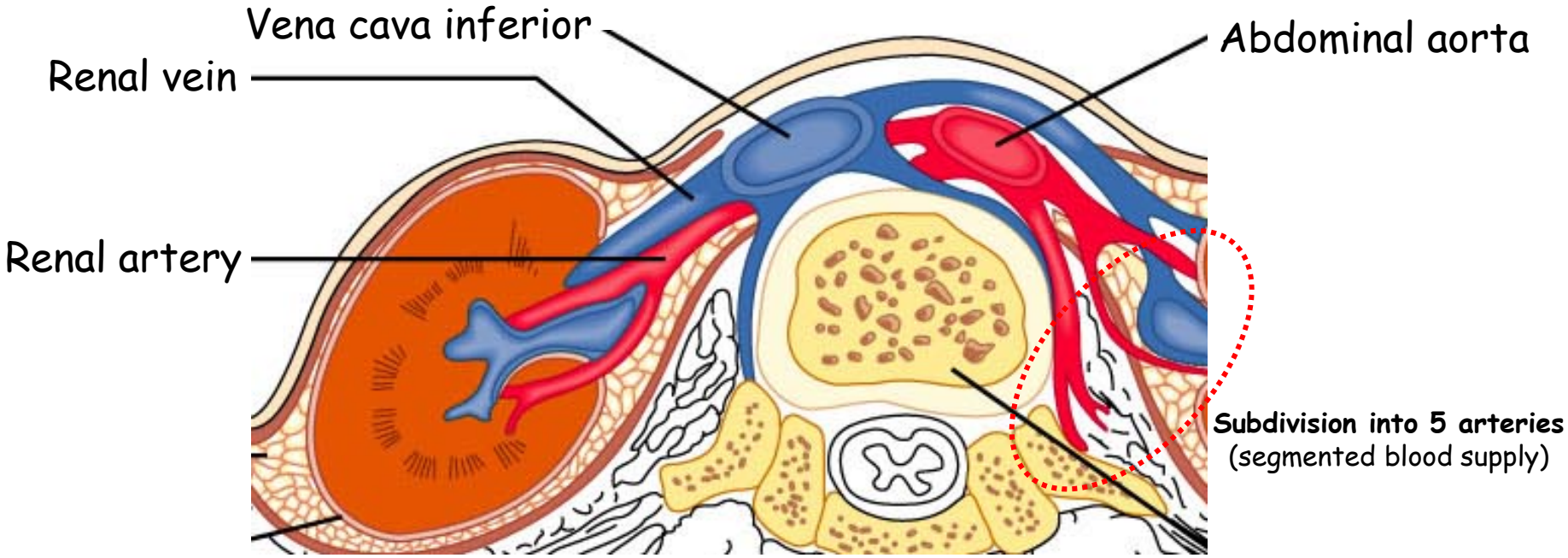
- Conserve body fluids
- Reacts to **ADH** (antidiuretic hormone) of the posterior pituitary gland
- ADH increases the permeability of the collecting tubules and distal tubules to water so more is reabsorbed
- This decreases the total volume of urine
- Alcohol inhibits the release of ADH, so less water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



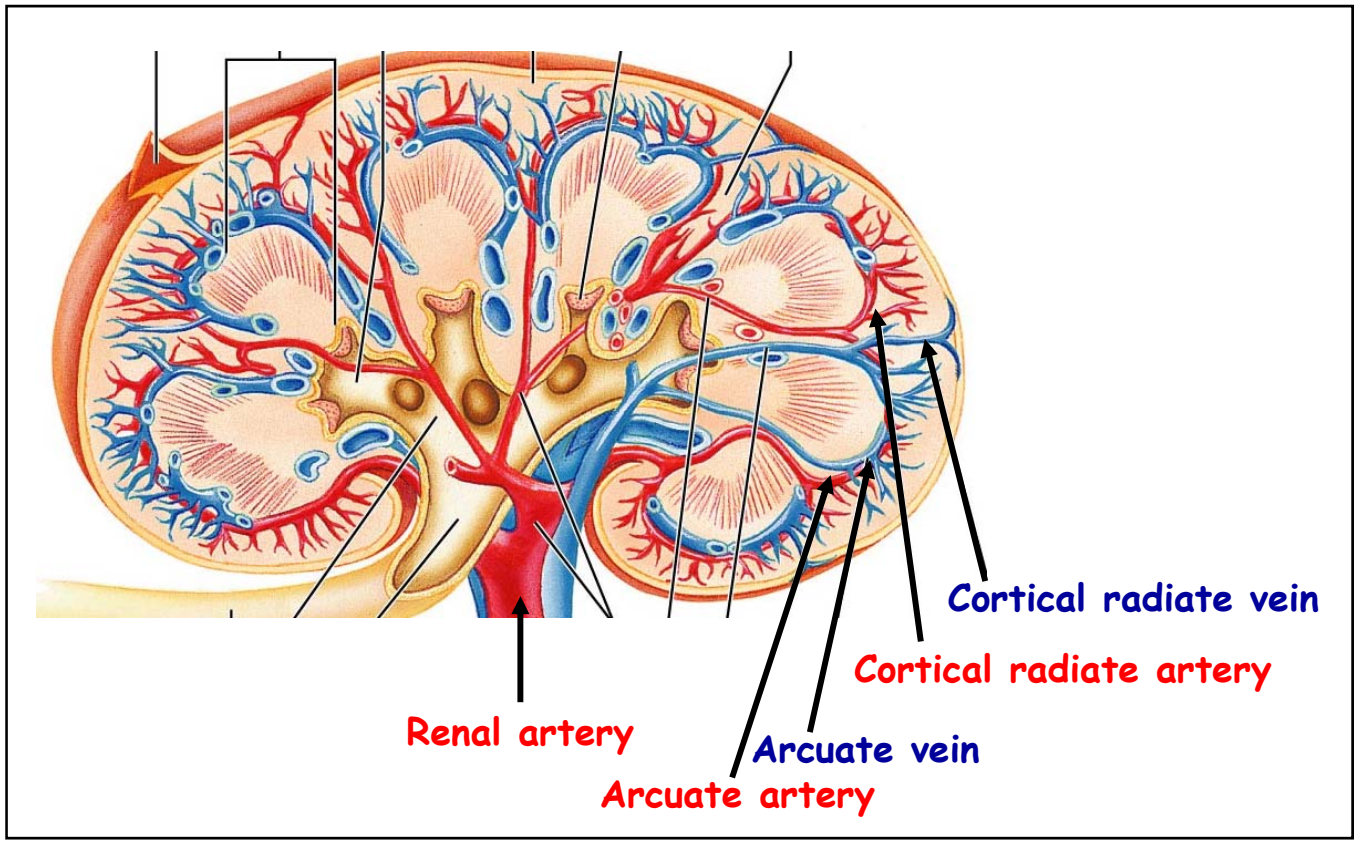
Long section of Collecting and proximal tubuli



Blood circulation

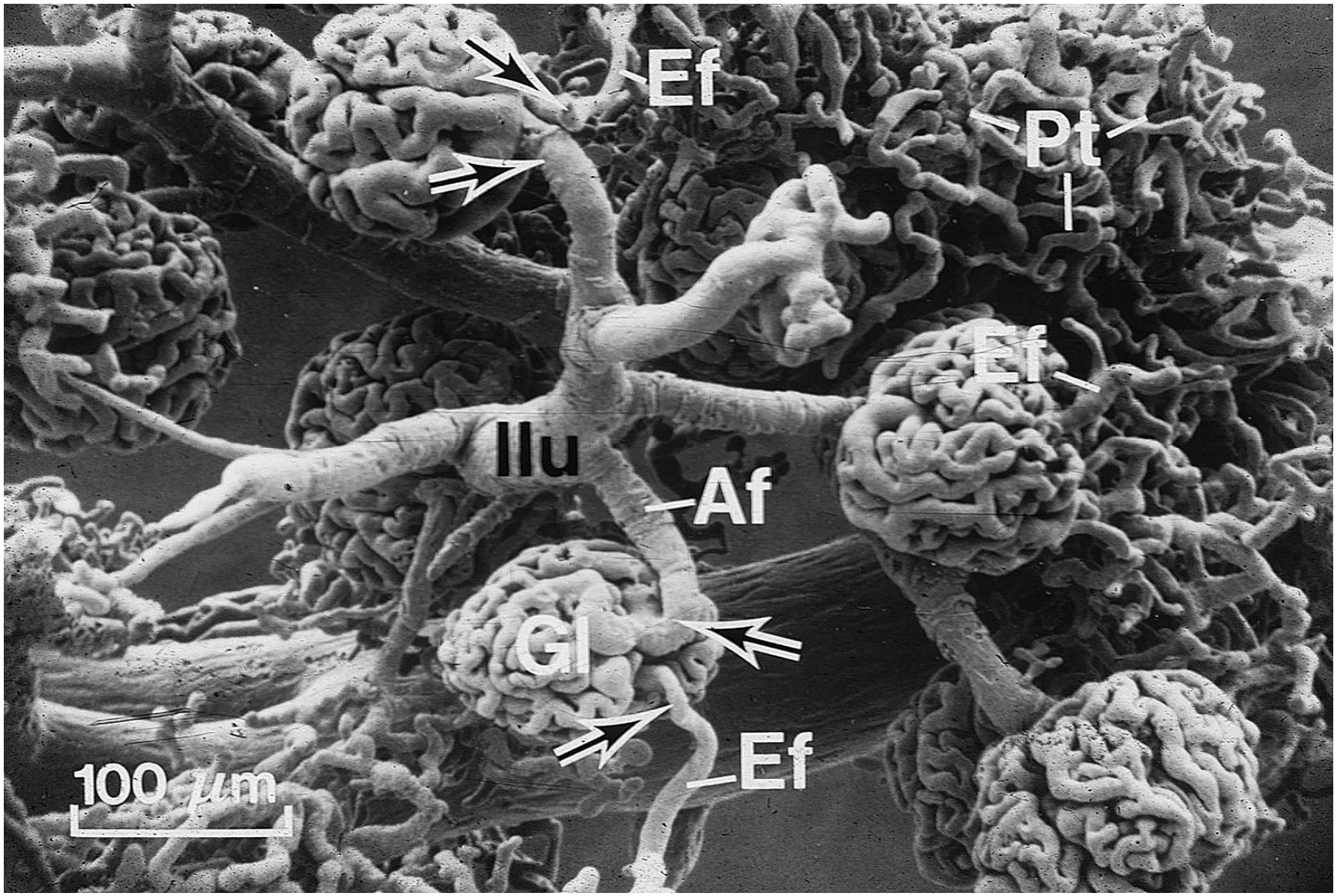


Blood circulation

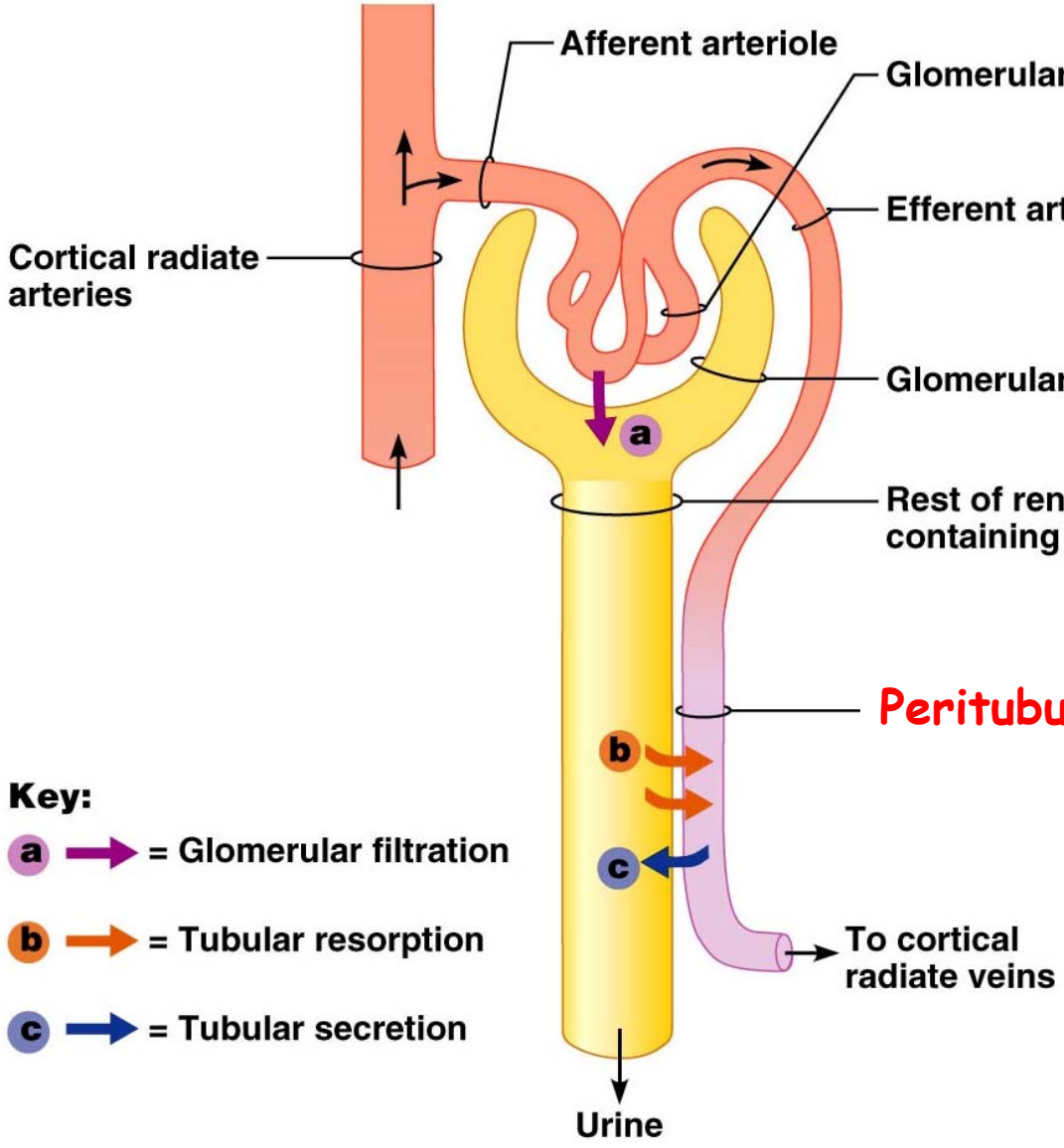


Aorta → Renal artery → Segmental artery → Interlobar artery → Arcuate artery → Cortical radiate artery → Afferent arteriole → Glomerulus (capillaries) → Efferent arteriole → Peritubular capillaries and vasa recta → Cortical radiate vein → Arcuate vein → Interlobar vein → Renal vein → Inferior vena cava

Blood circulation – Afferent + Efferent arterioles



Blood circulation – Peritubular capilaries

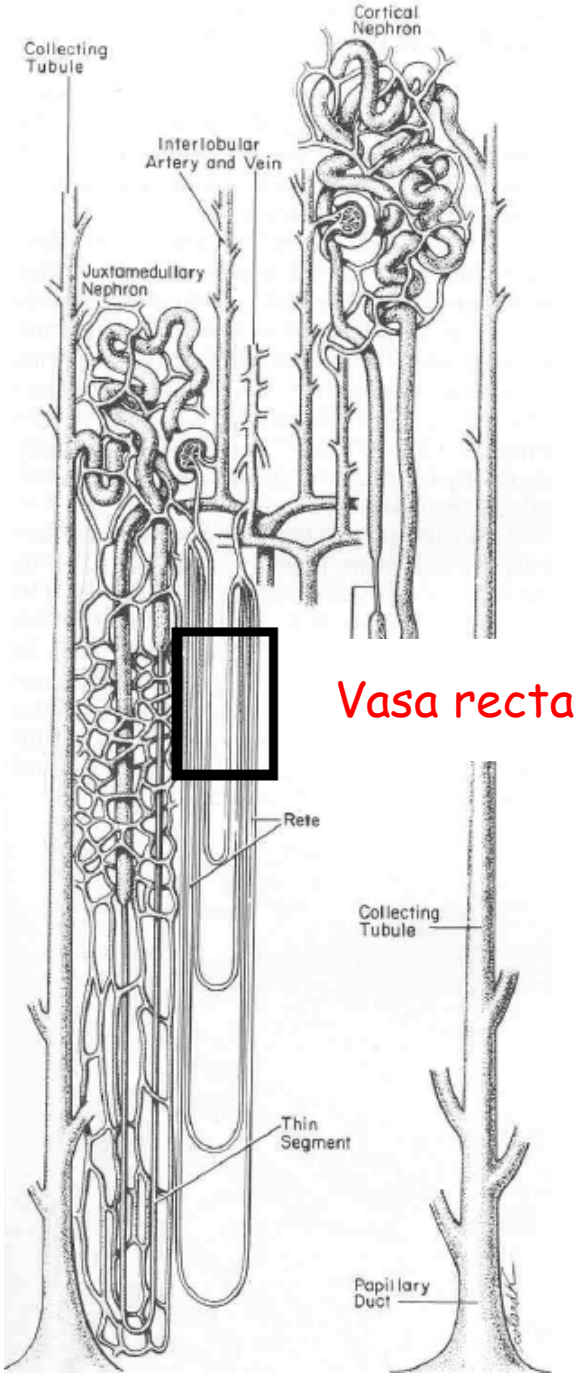


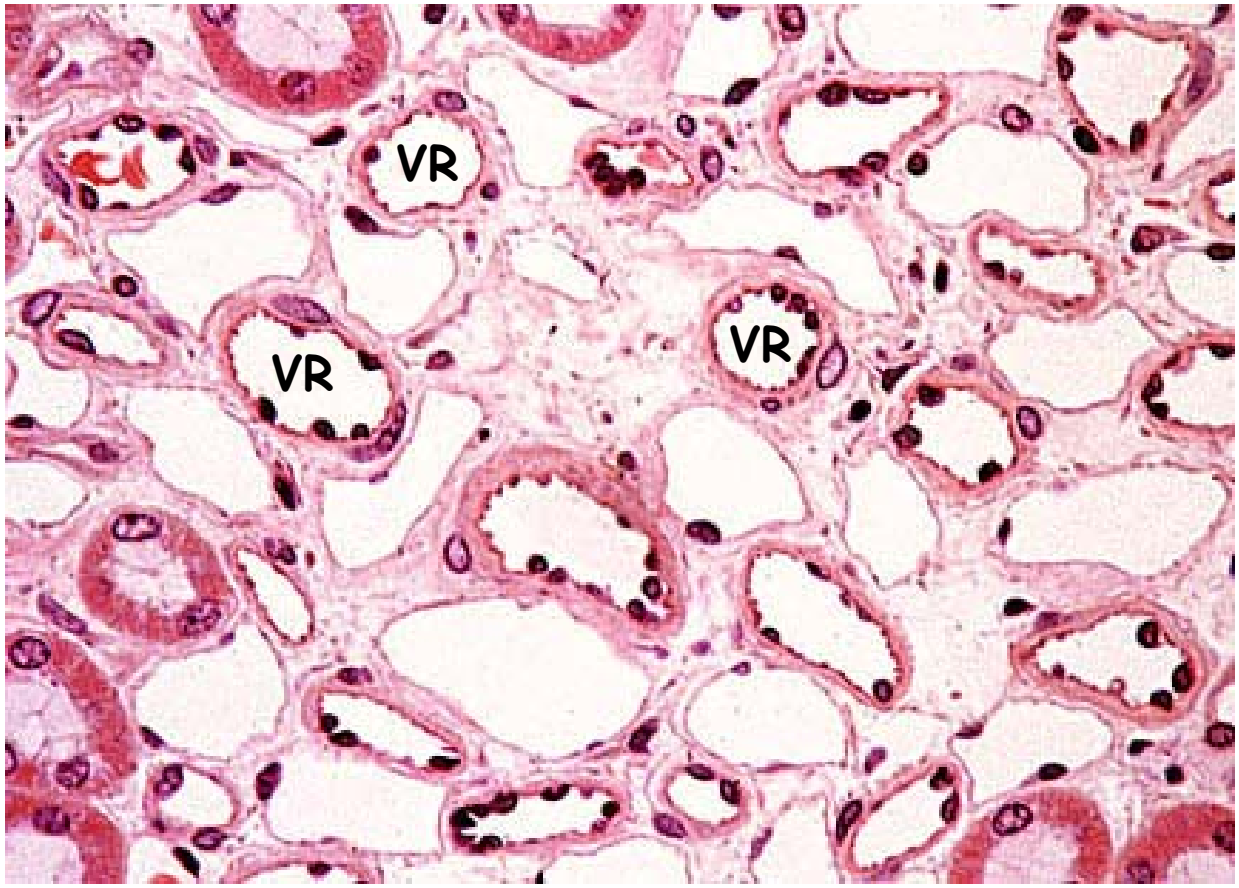
arise from efferent arterioles of **cortical nephrons**

- 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





Excretory passages

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

General organizational pattern

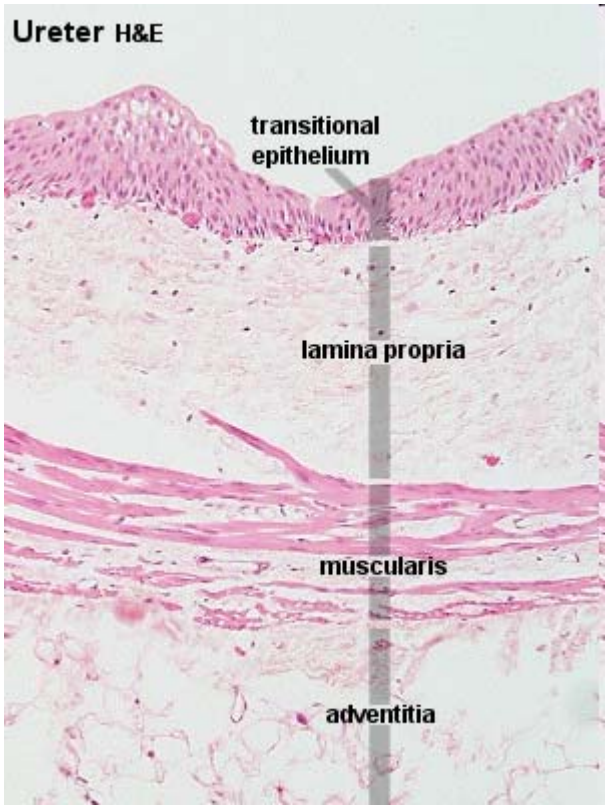
(calyces, pelvis, urethers, bladder)

- **Mucosa**

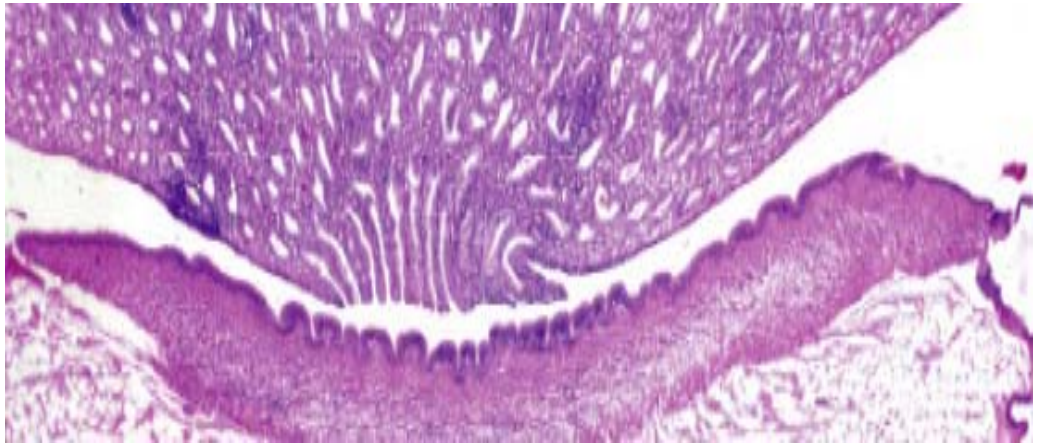
Luminal sheet epithelium (transitional)
Basal lamina
Lamina propria/submucosa (connective tissue)

- **Lamina muscularis** (smooth muscle)

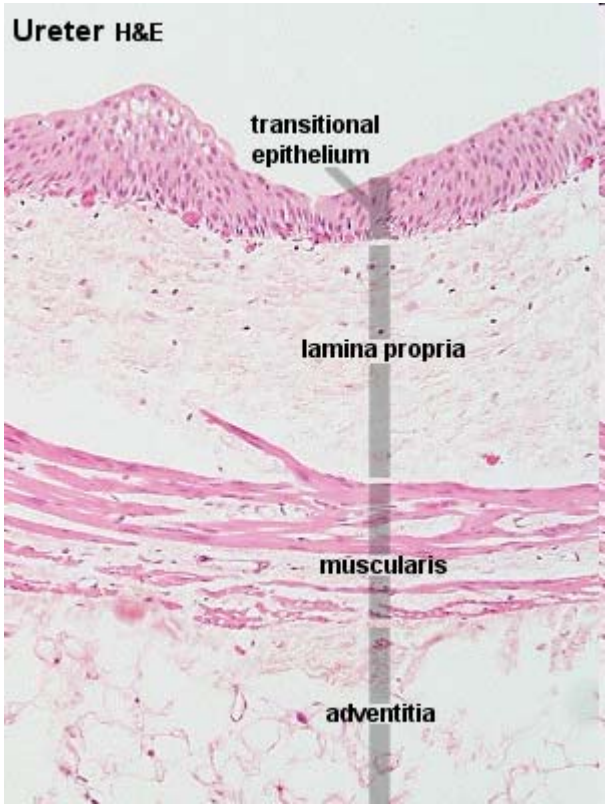
- **Lamina adventitia or serosa**



Renal calyces + pelvis

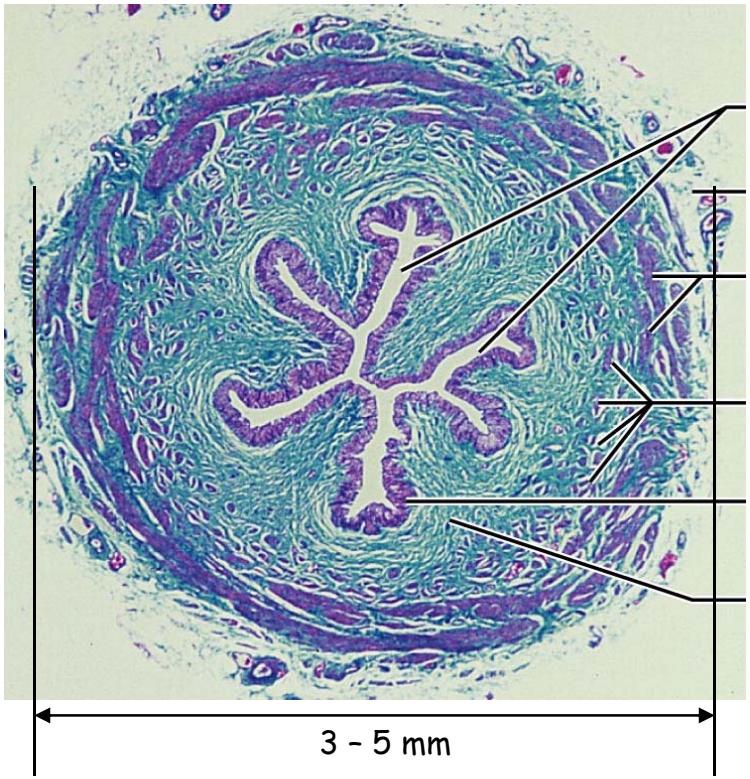


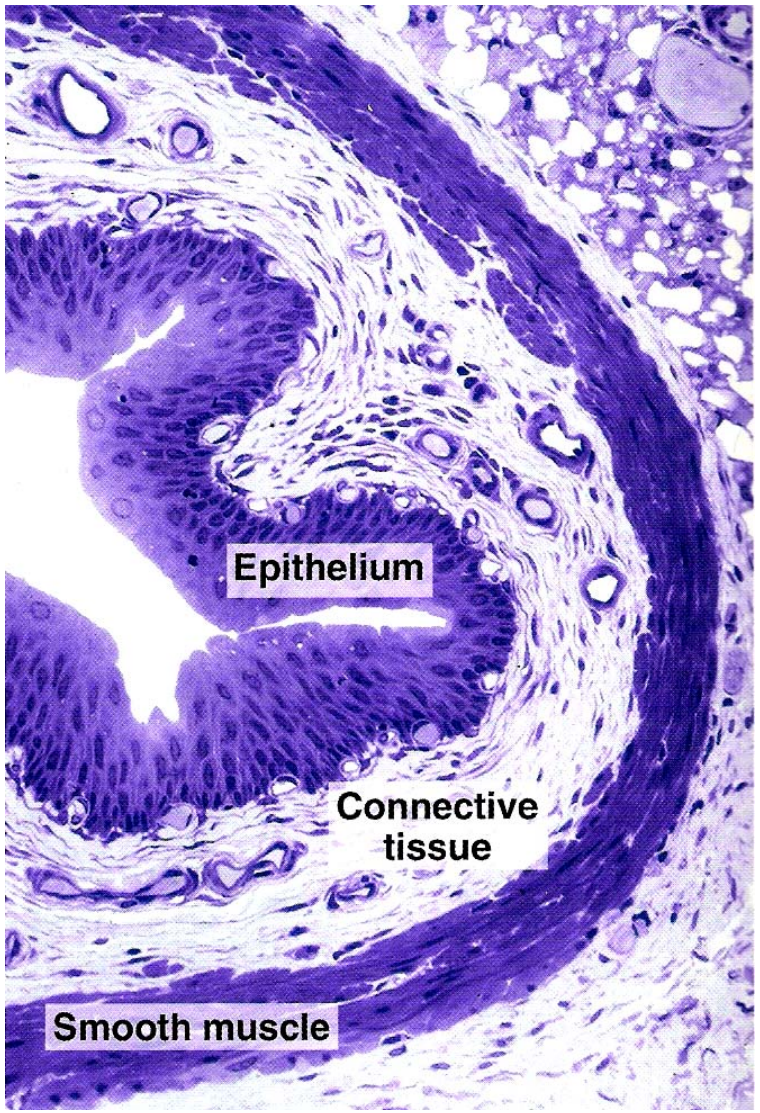
- Minimal lamina propria (submucosa)
- Thin tunica muscularis
- Tunica adventitia – blends with adipose tissue in the renal sinus



Ureters

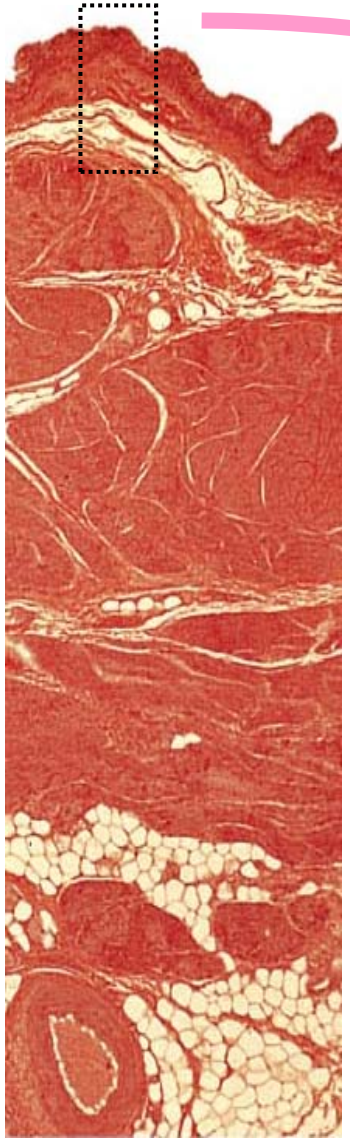
(25-30 cm long)





- 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



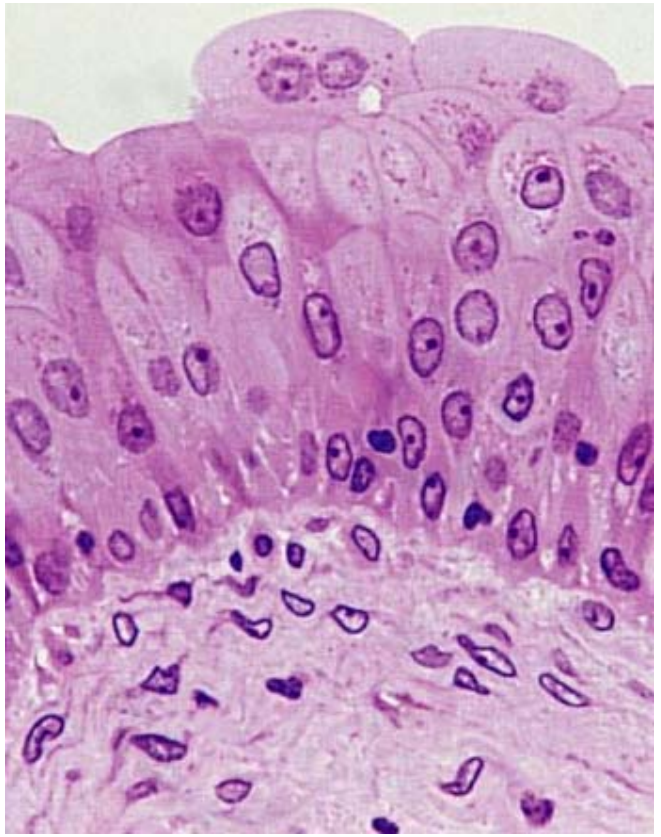
Epithelium

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**.

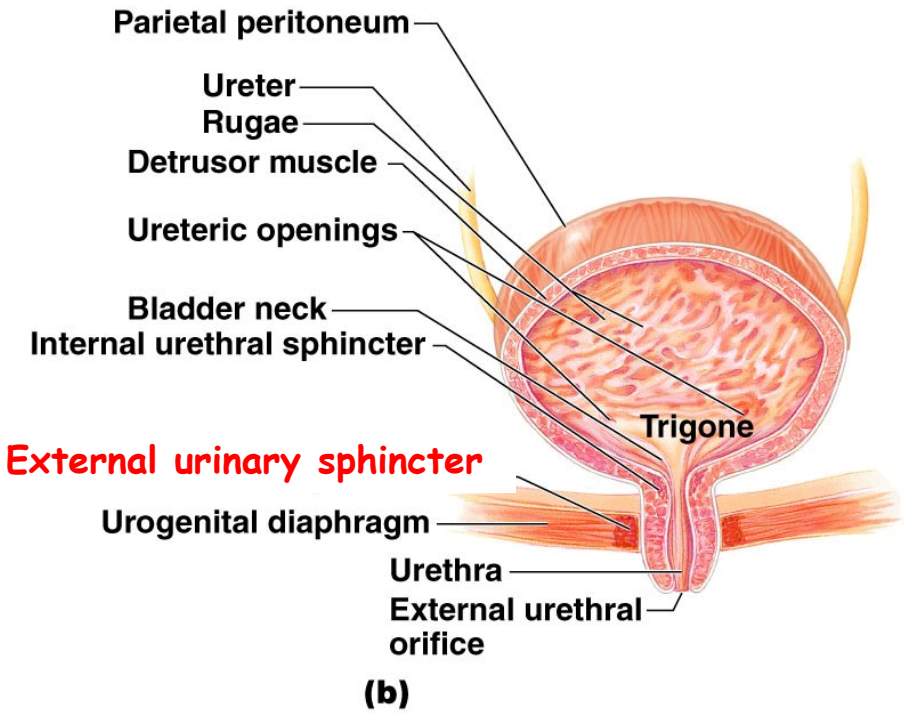


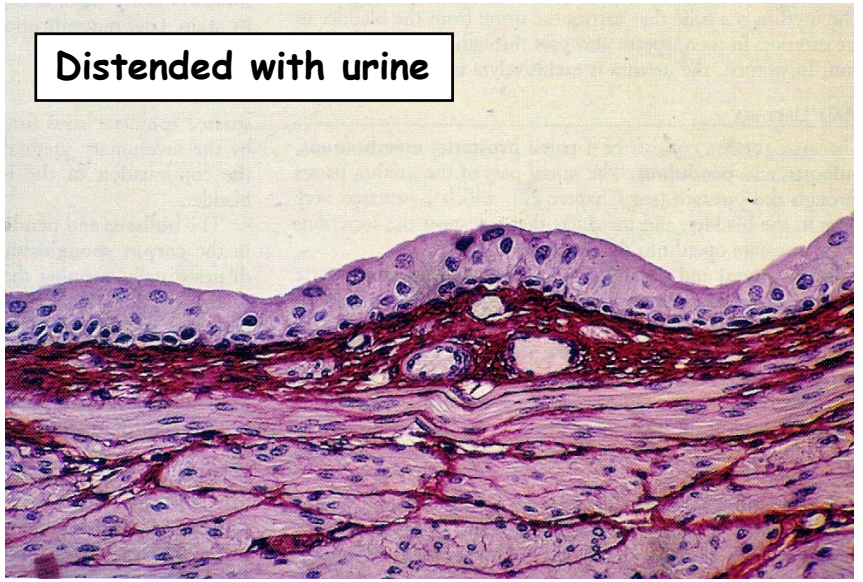
Epithelium

Basal membrane

Lamina propria

Urinary bladder





Female urethra

(4-5 cm in length)

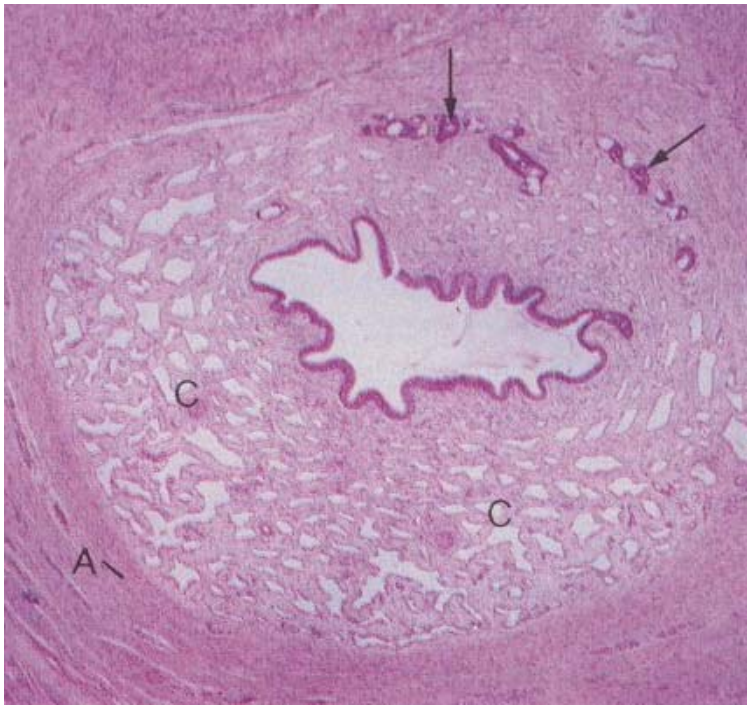
Transitional epithelium

- **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 collumnar ep., through the urogenital diaphragm
Spongy (penile) **urethra** – stratified collumnar + squamous ep.

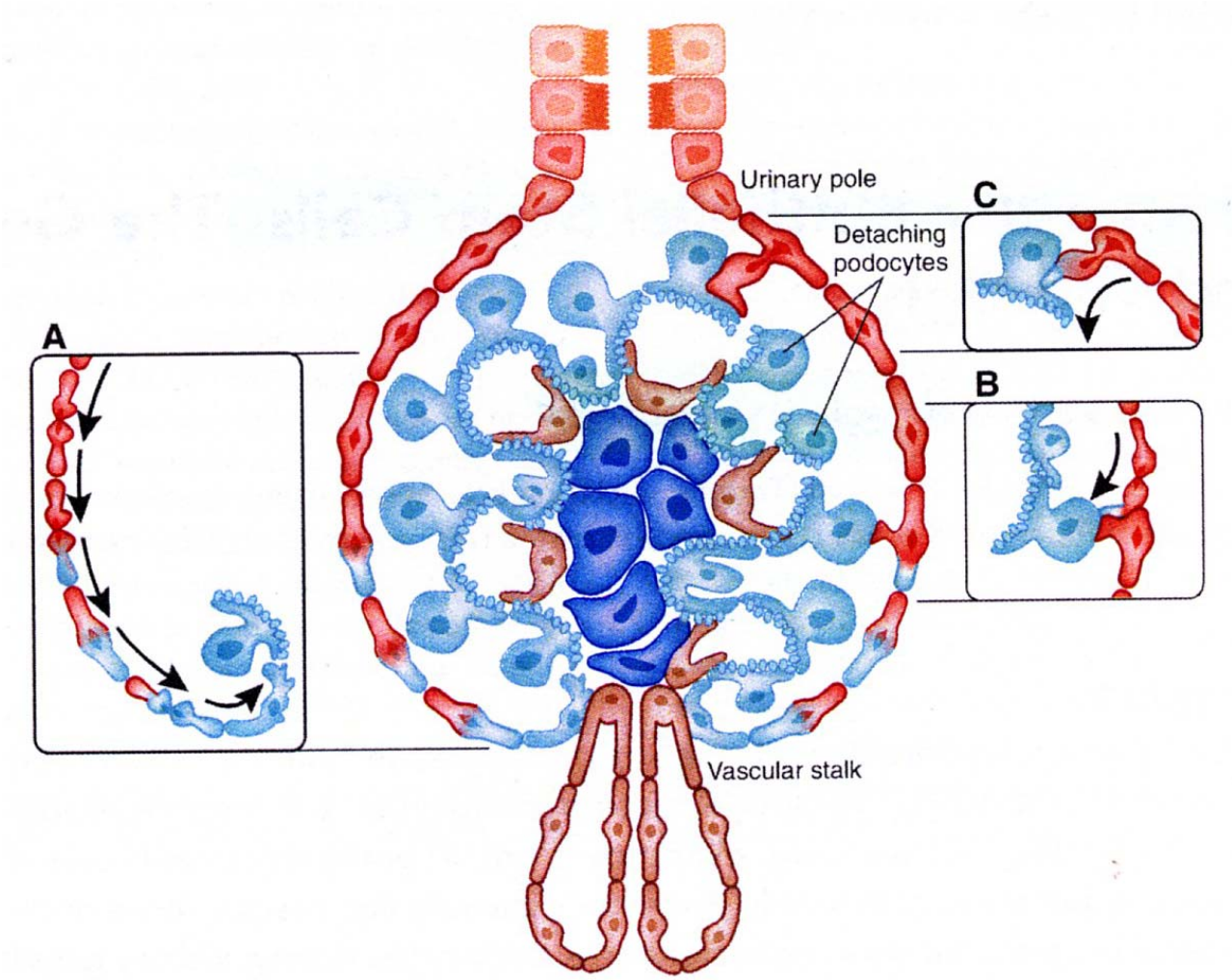


Spongy - penile

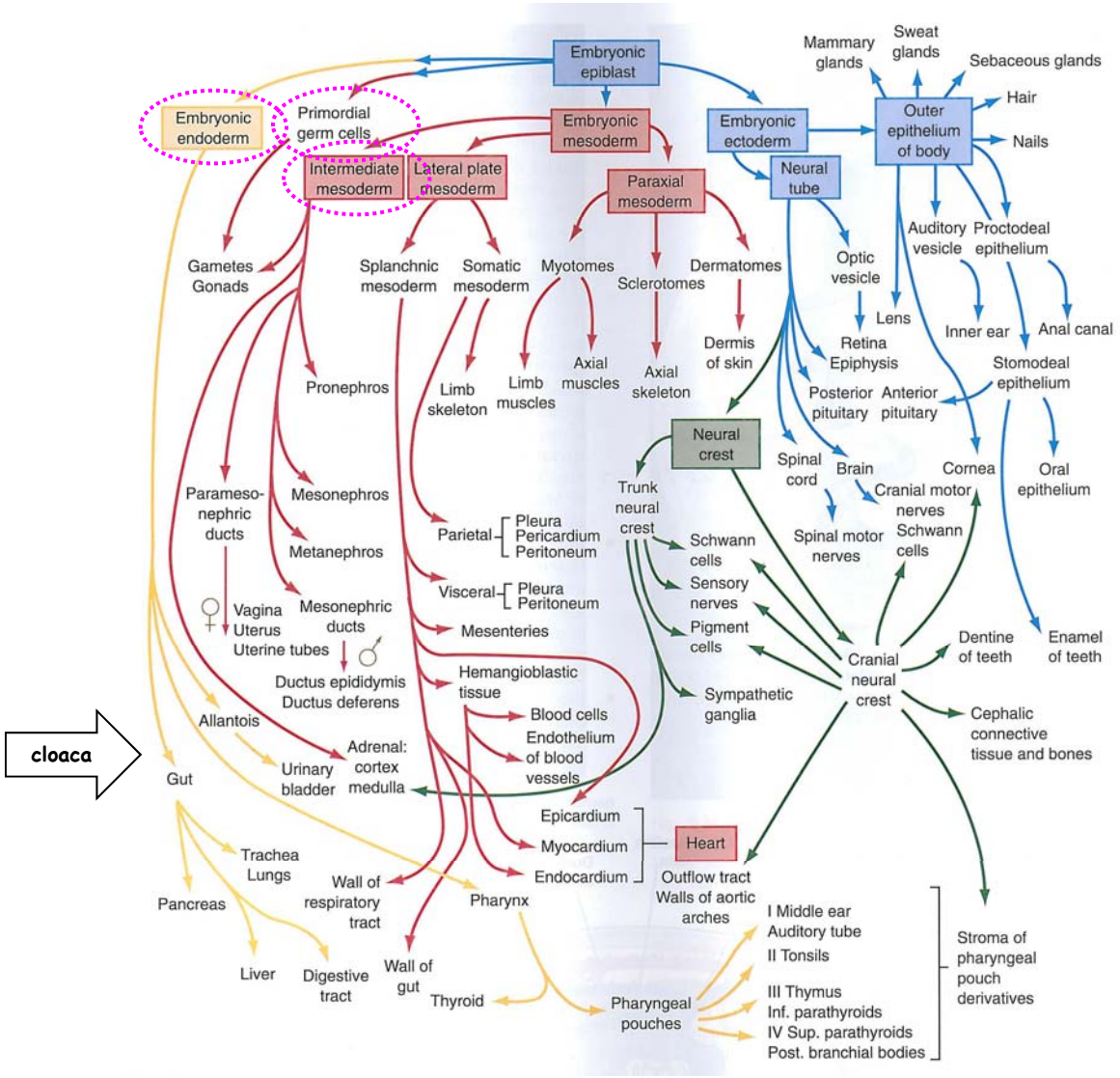
A) Tunica albuginea
C) Corpus spongiosum (erectile)
Arrows) Glands of Littre

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

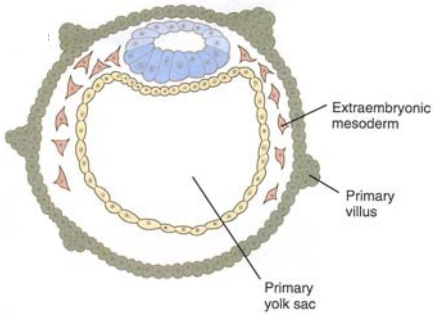
Dialysis x Kidney transplant x Kidney regeneration ?

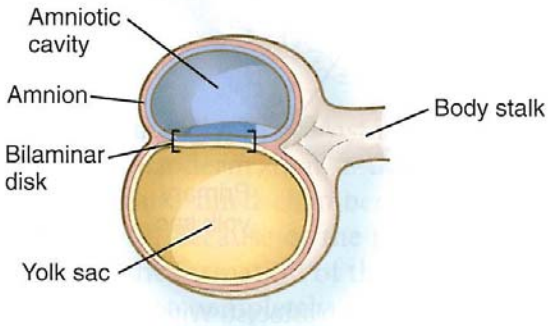


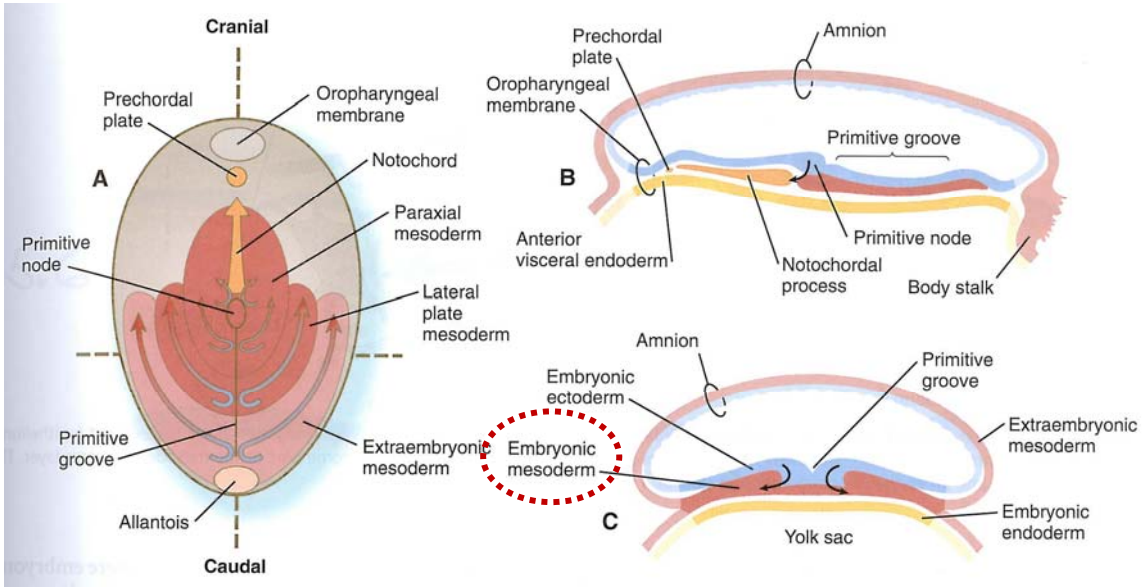
Urogenital system – Overall picture



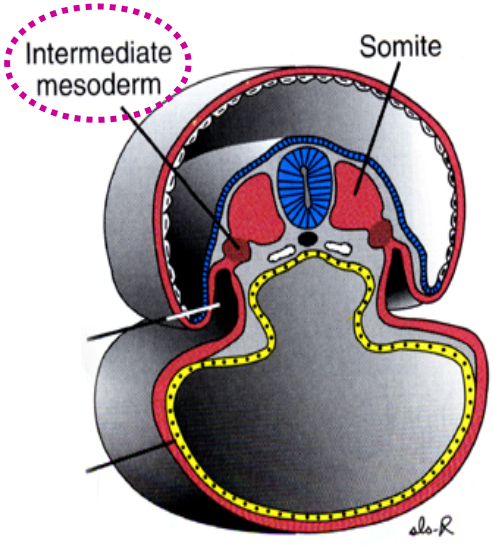
Urogenital system – Reminder

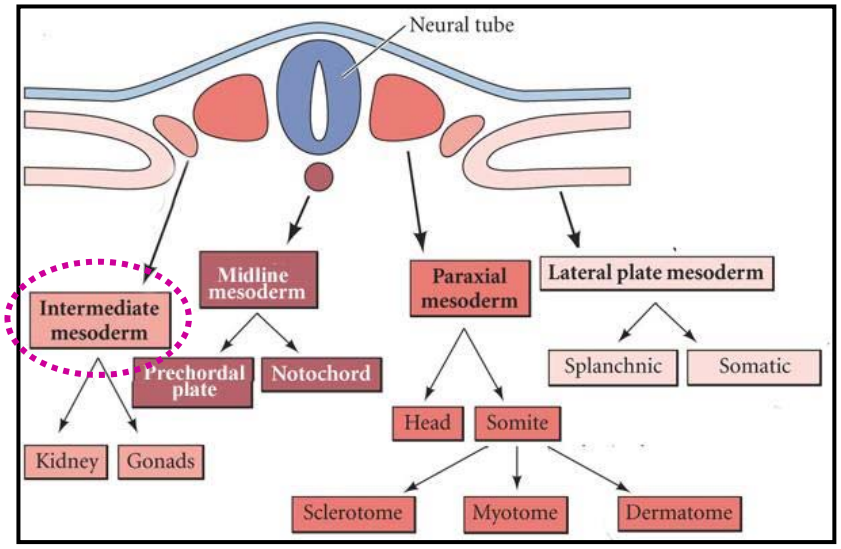


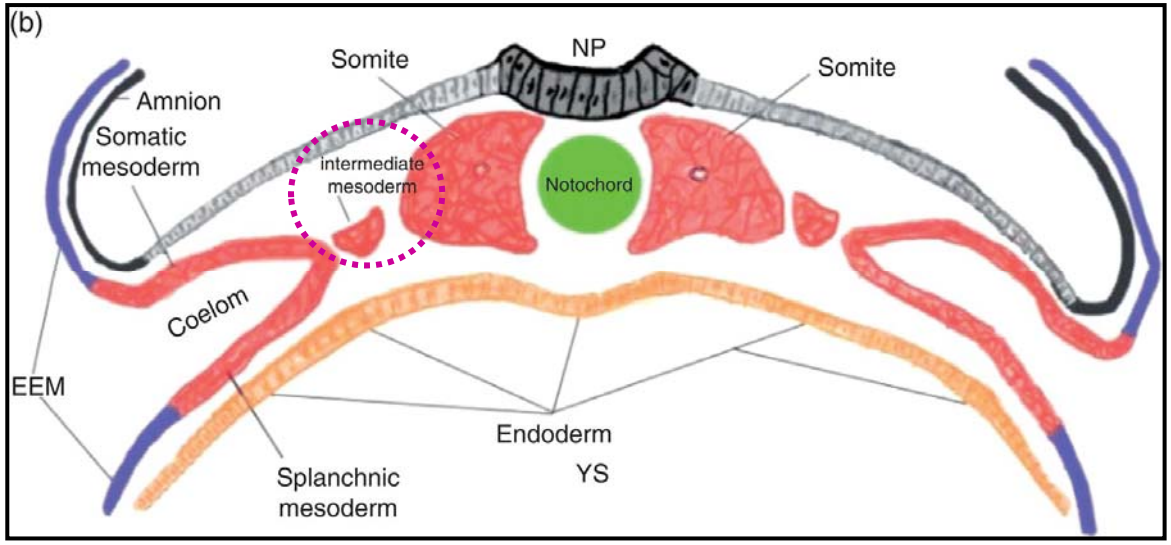




Urogenital system – Intermediate mesoderm



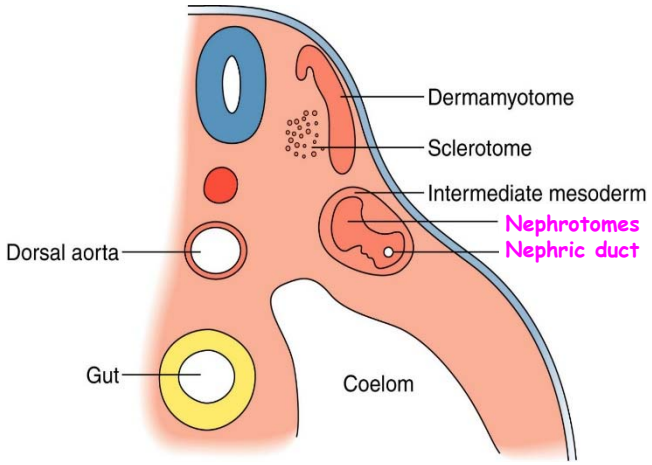


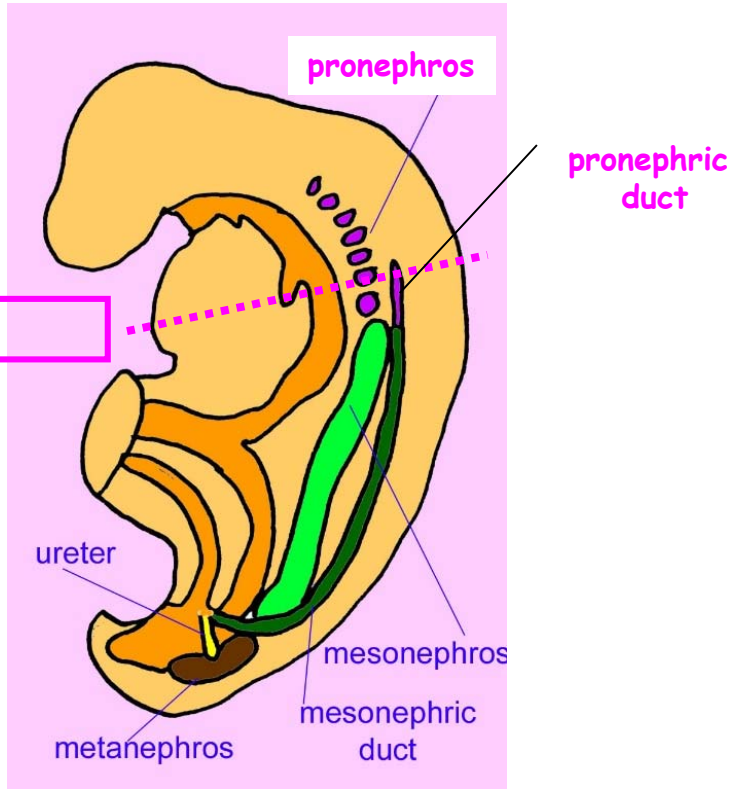


Urogenital system – Early forms of kidneys - Pronephros

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

- **pronephros**
- **mesonephros**
- **metanephros**



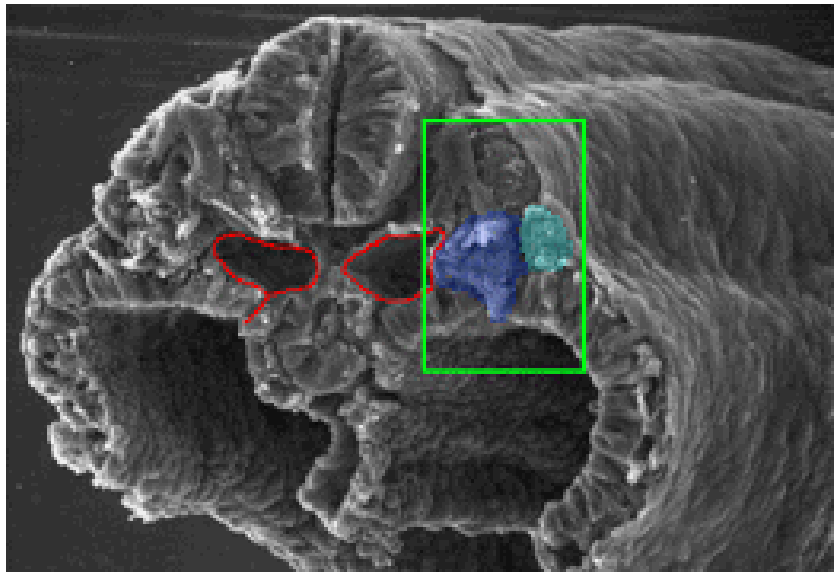


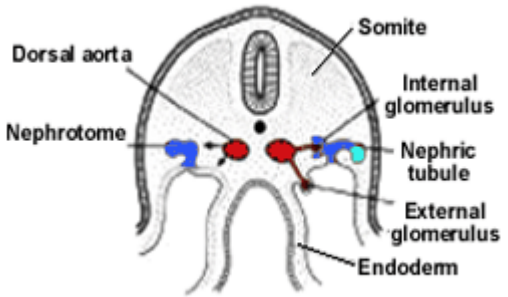
Nephrotomes

- 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

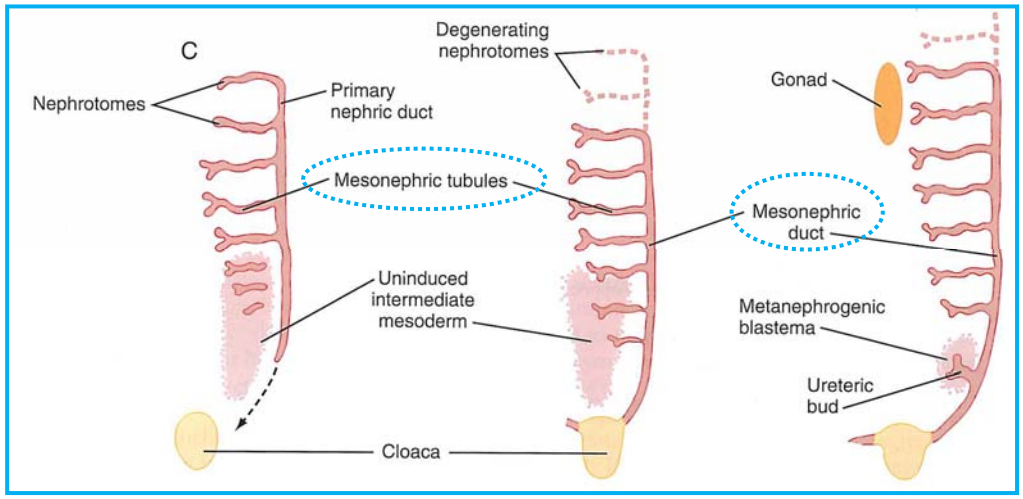
Mouse D9 – equivalent to human D27

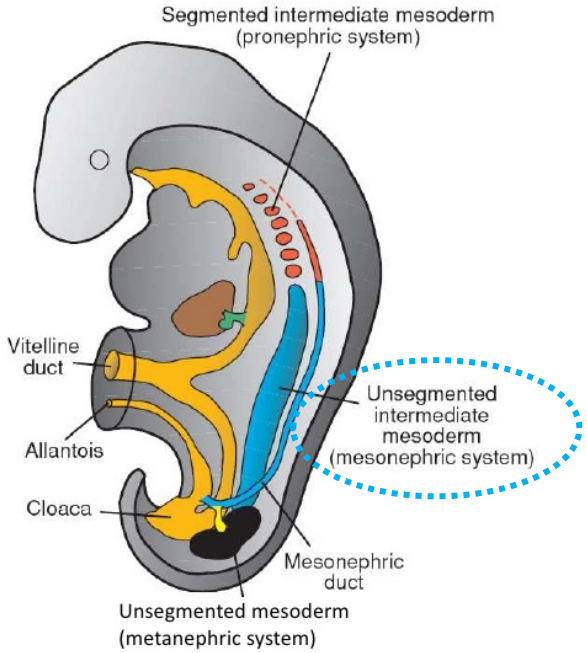




The lumen of each nephrotome opens into the primary nephric duct as well as into the body cavity. Glomeruli form as small vessels extend from the dorsal aortae.

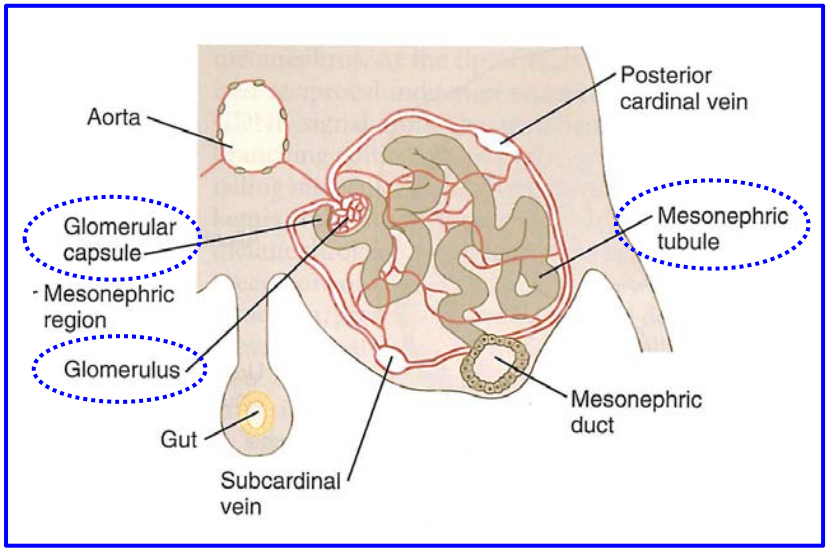
Urogenital system – Early forms of kidneys - Mesonephros



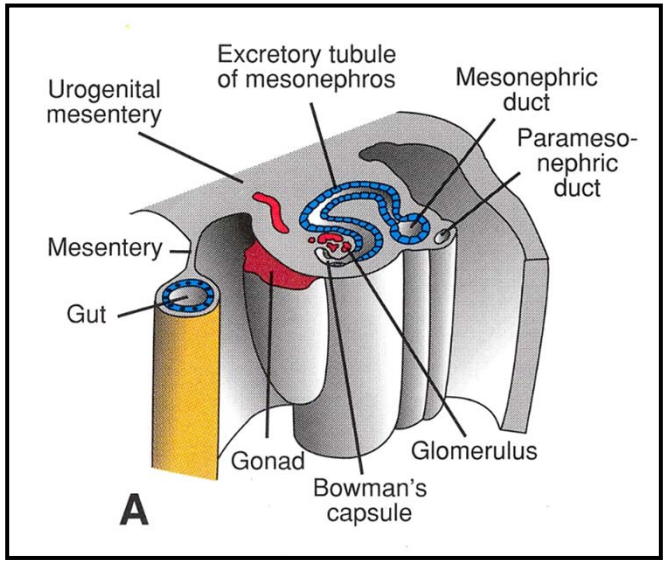


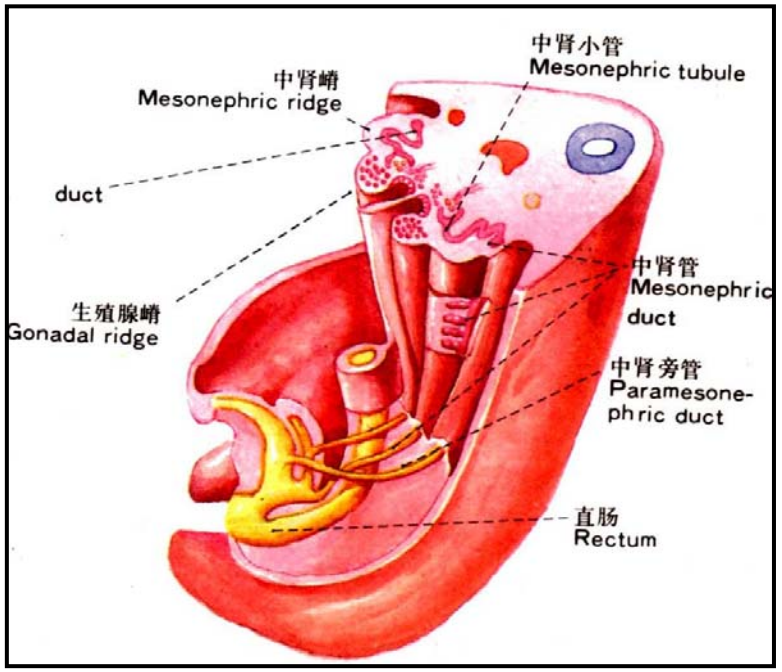
Mesonephros

- 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 diasappear fast
- mesonephric ducts persist in males

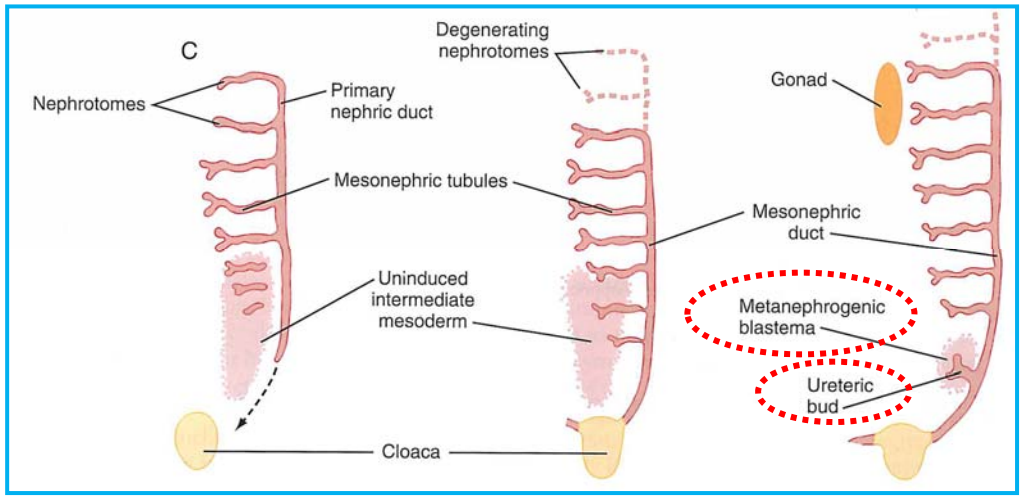


Urogenital system – Mesonephros - Another view





Urogenital system – Definitive kidneys - Metanephros

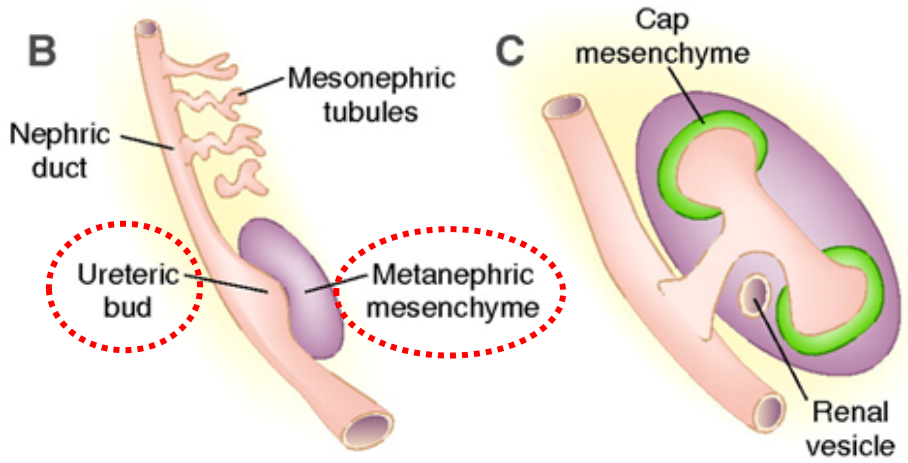


Develop since week 5

Ureteric bud = metanefric diverticulum

+

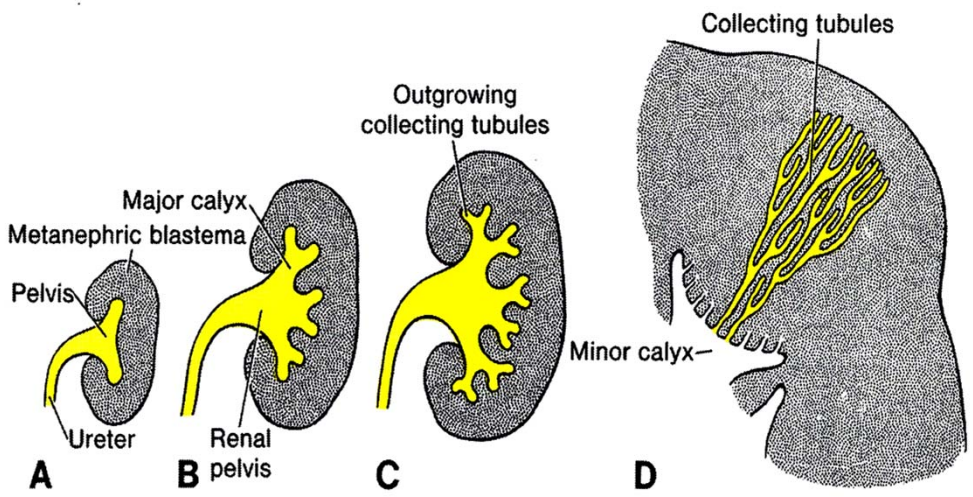
Metanephrogenic blastema (mesenchyme)



Branching and Elongation

14 to 15 x

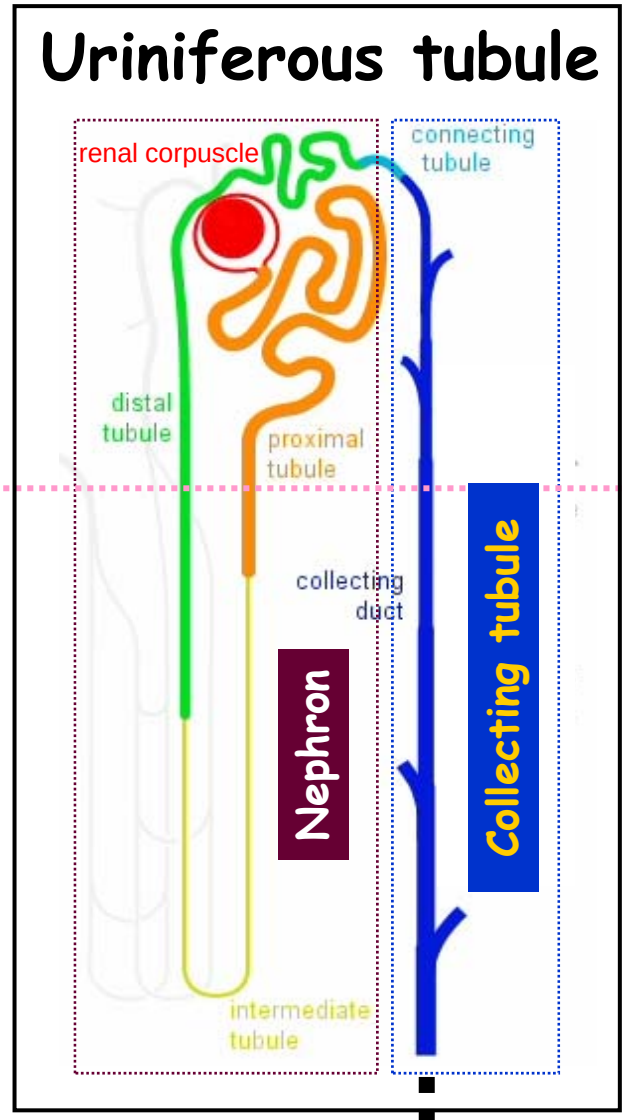
Urogenital system – Definitive kidneys - Metanephros



Repeated branching of ureteric bud produces:

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

Uriniferous tubule = The functional unit of the kidney

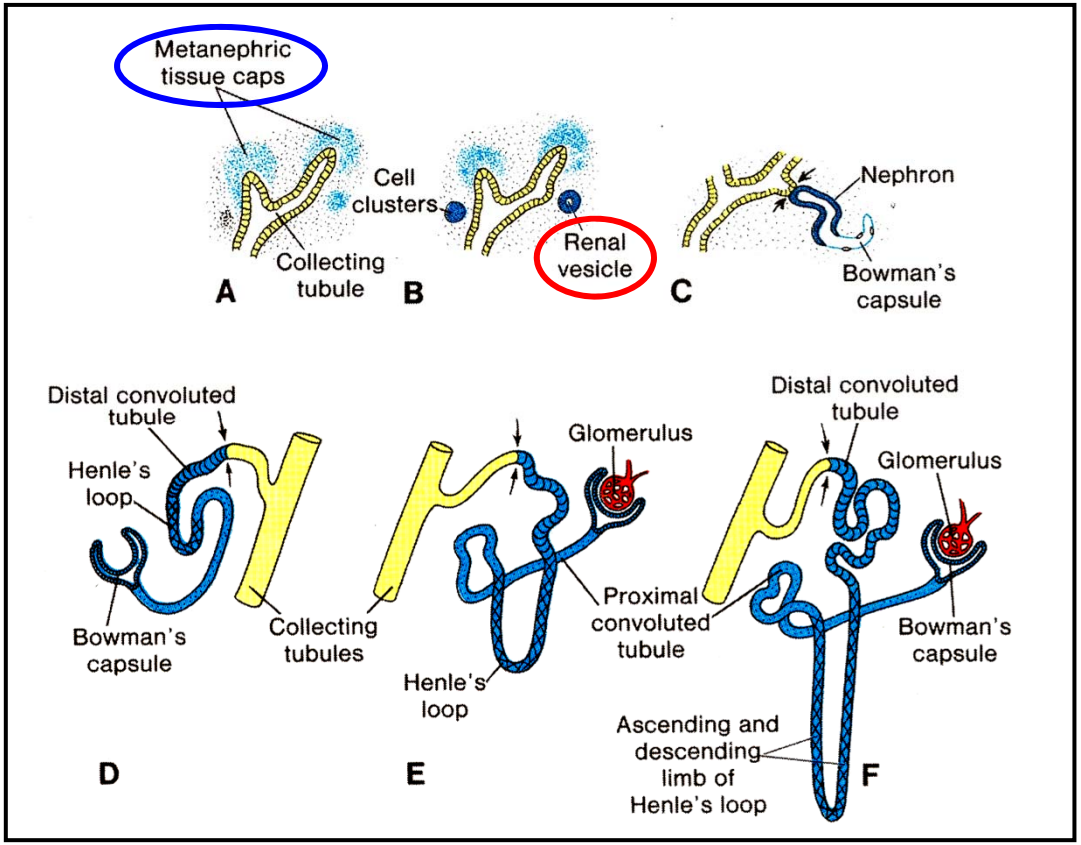


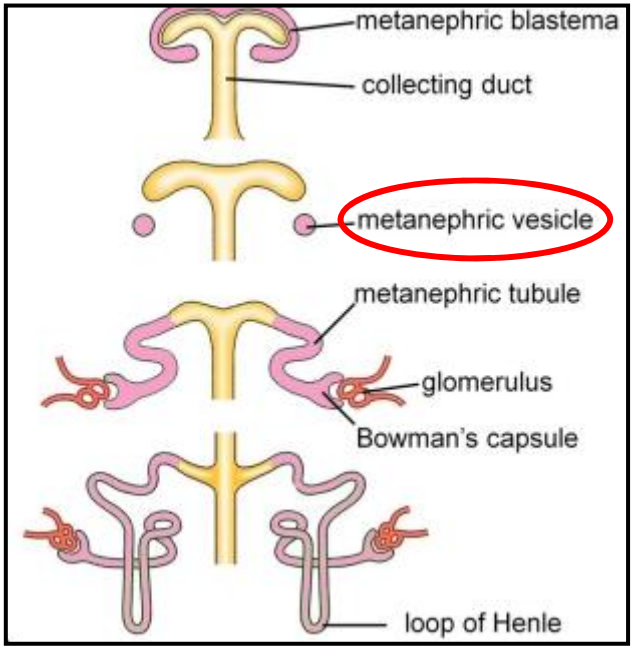
1 to 1.4 milllions of nephrons in one kidney

Area cribrosa
Minor calyx

Nephrons X Collecting tubules
Different embryological origin

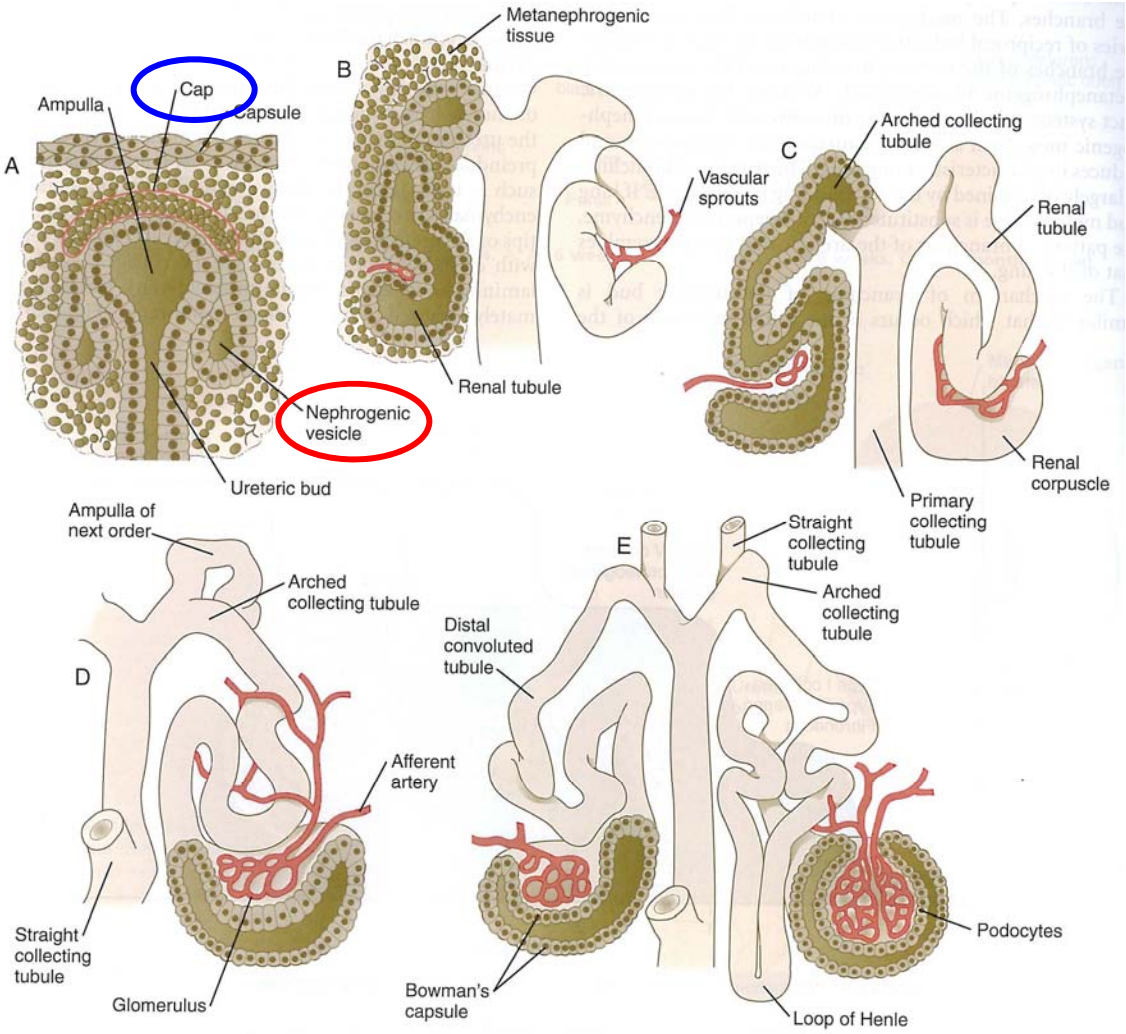
Urogenital system – Metanephros - Nephrons



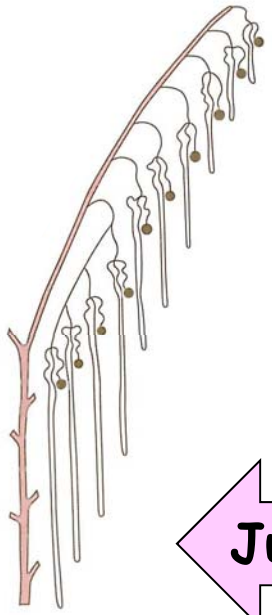


- arched ampulous endings of ureteric ducts (collecting tubuli) – **capping** by condensed mesenchyme
- part of the cap cells differentiate into **nephrogenic vesicle**
- vesicles elongate
- vesicles open to the collecting tubulus on one end
- distal from the ducts, the cells of elongating vesicles polarize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

Urogenital system – Metanephros - Nephrons



Urogenital system – Metanephros - Nephrons



Cortical nephrons

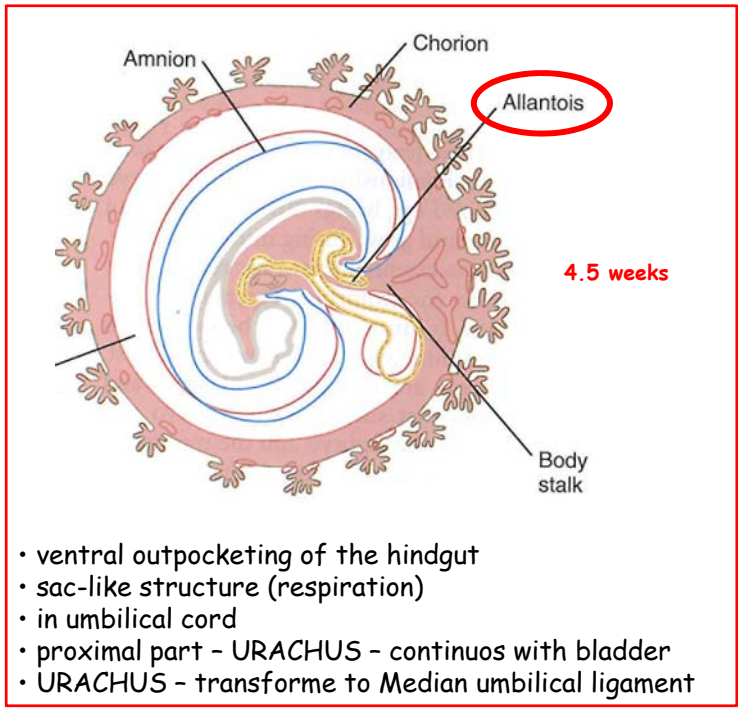
Juxtamedulary nephrons

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

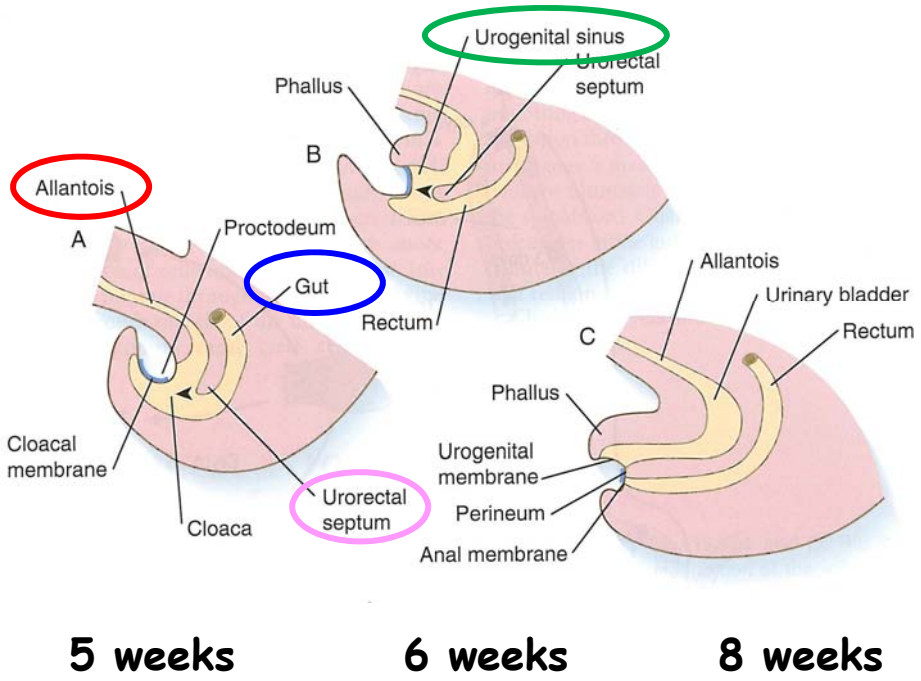
Urogenital system – Definitive kidneys - Metanephros

Urinary system - Bladder

Cloaca
=
terminal part of the hindgut + allantois



- ventral outpocketing of the hindgut
- sac-like structure (respiration)
- in umbilical cord
- proximal part – URACHUS – continuos with bladder
- URACHUS – transforme to Median umbilical ligament



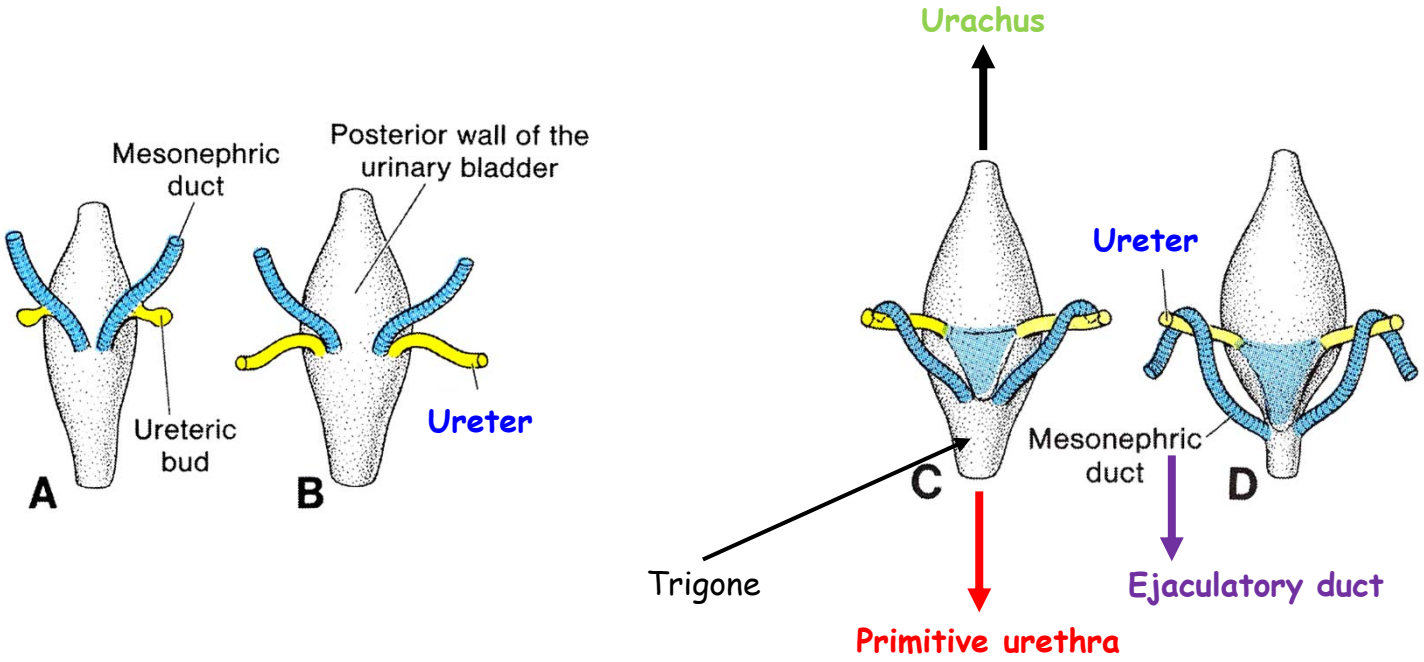
5 weeks **6 weeks** **8 weeks**

Cloaca

Urogenital simus	Urogenital membrane
Urogenital septum	Perineum
Primitive rectum	Anal membrane

Urinary system – Bladder + Ureters + Urethra

Posterior view



- alantois expands - urinary bladder
- initially bladder is continuos with alantois – then obliteration – urachus – median umbilical ligament
- caudal portions of mesonepric 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 position
5. Congenital polycystic kidney

Horseshoe kidney

Thank you for your attention !

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