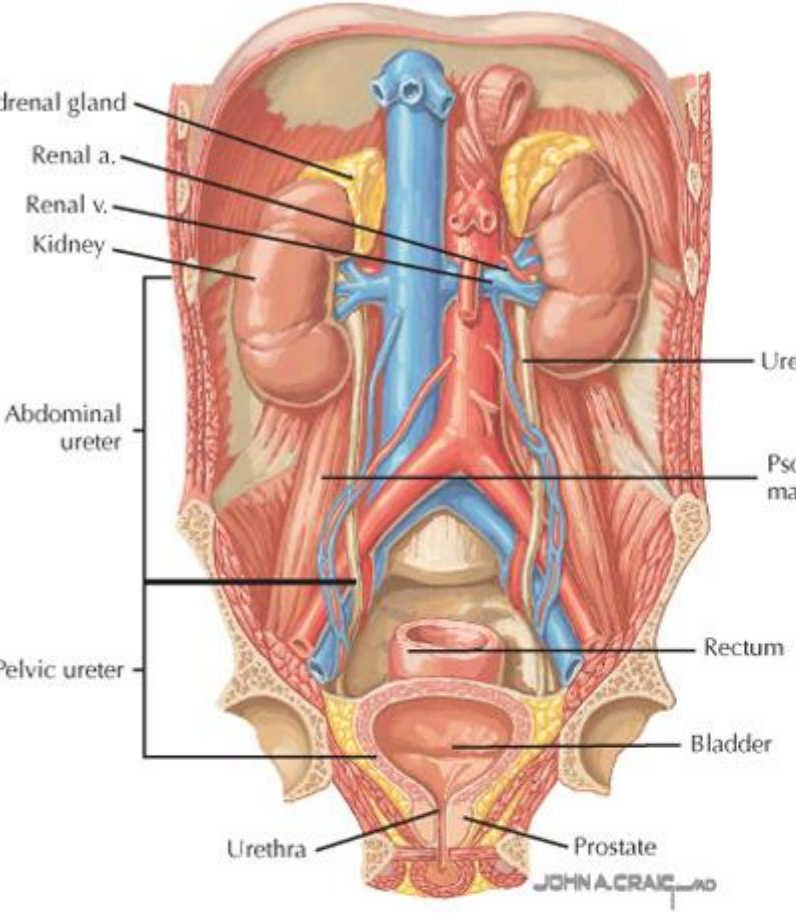
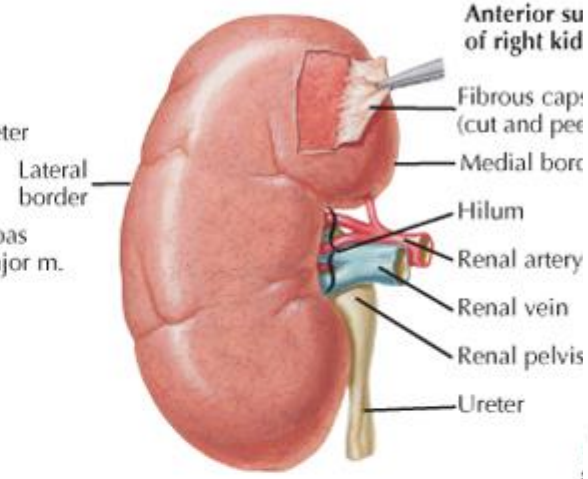
Urinary system

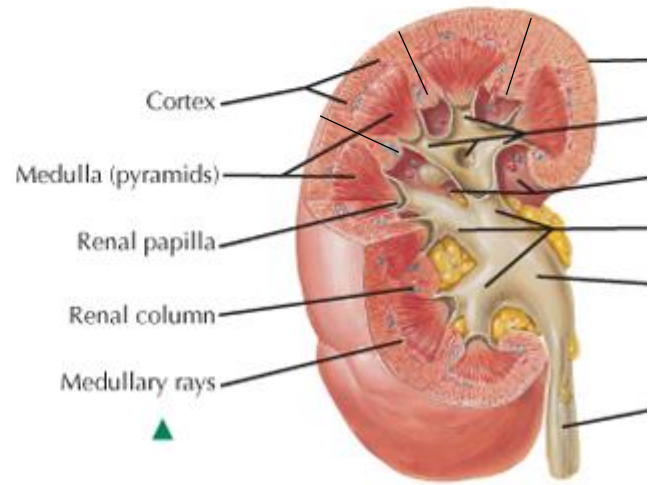
MUDr. Pavel Roštok



▲ **Regional anatomy of the urinary system.** The kidneys, mbedded in fat, lie in a retroperitoneal position (behind the eritoneum, outside the abdominal cavity), just anterior to nuscles of the posterior abdominal wall.

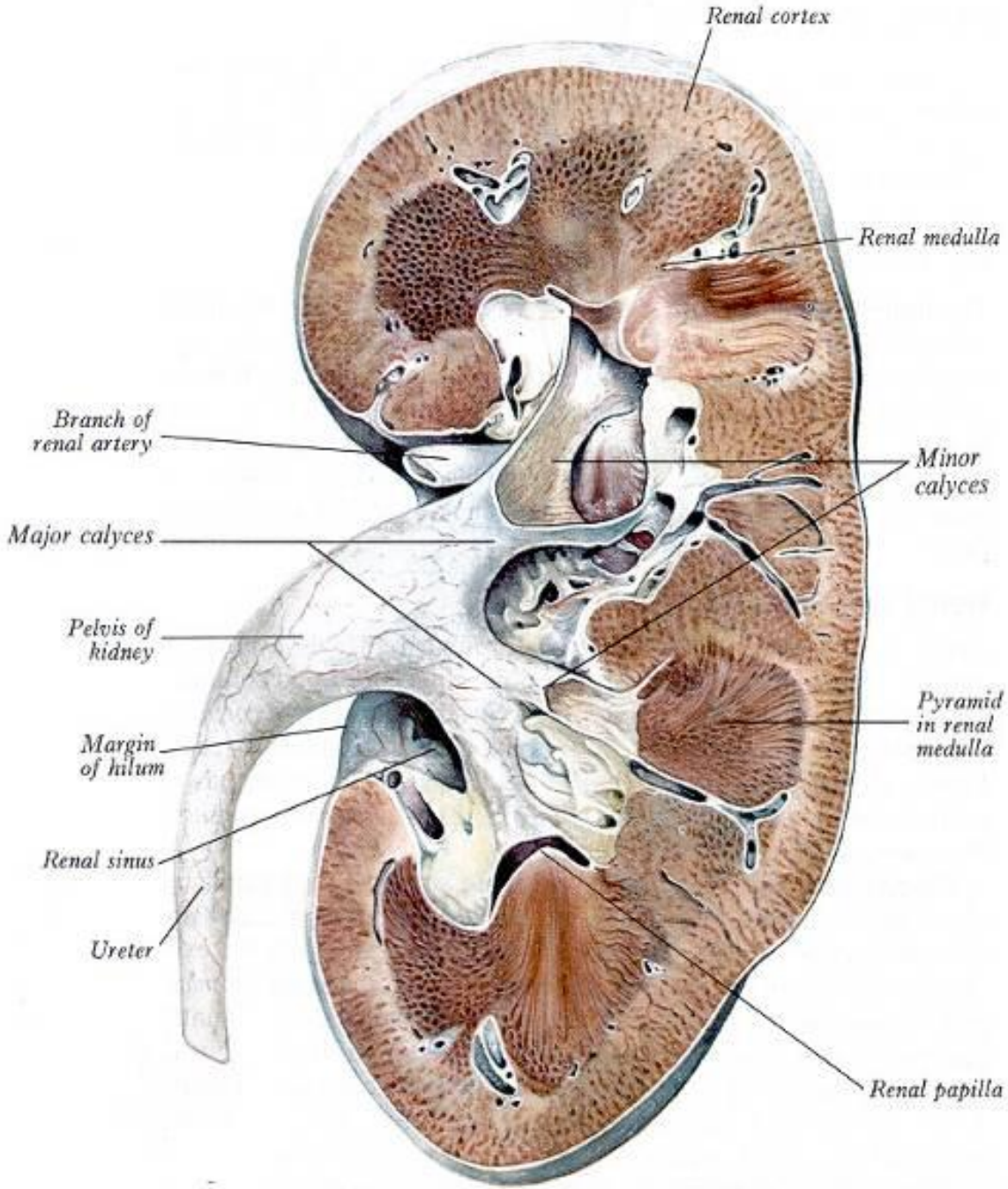
▼ **Gross structure of the kidney.**





▲

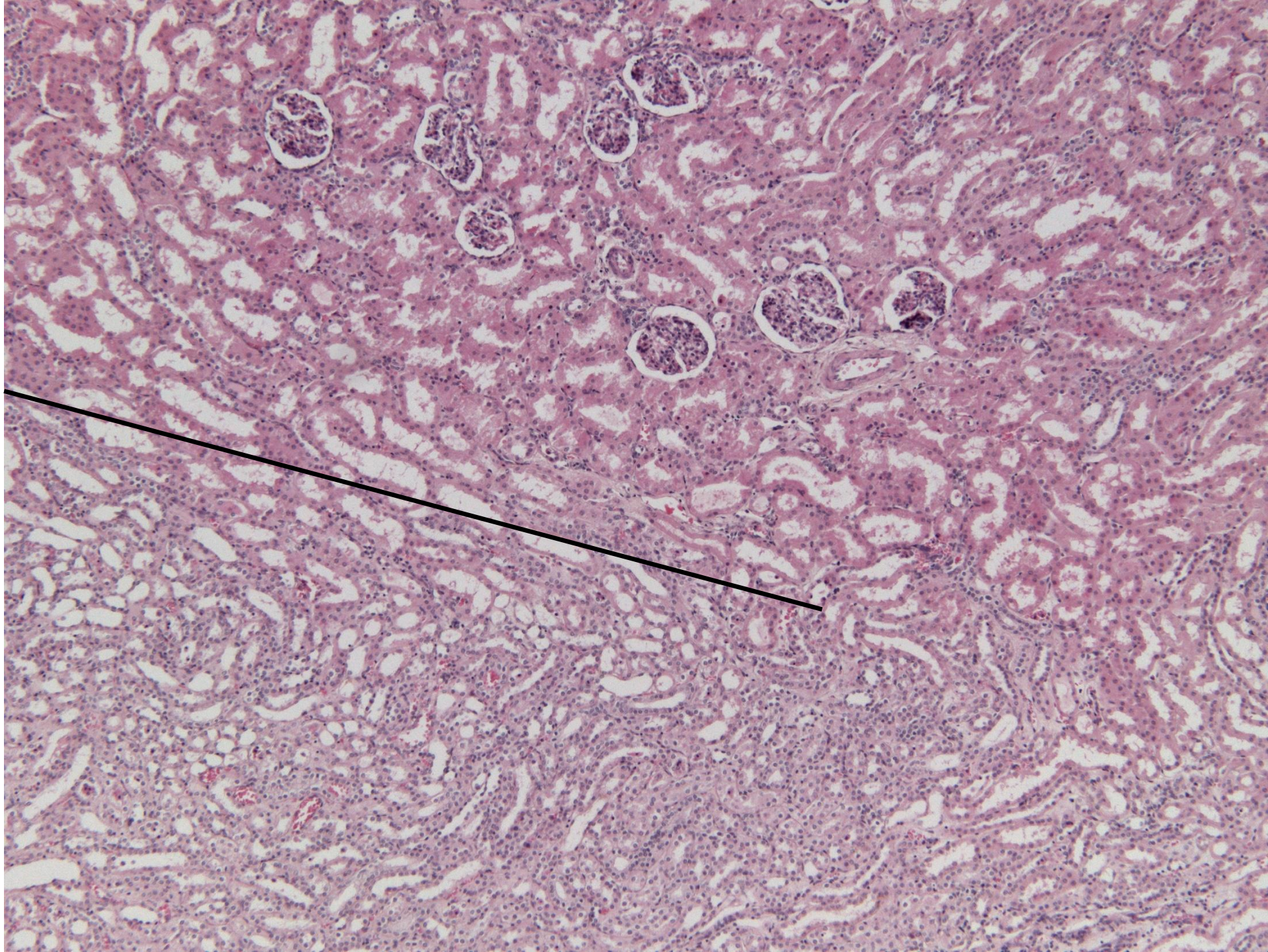
Right kidney sectioned in several planes parenchyma and renal pelvis.

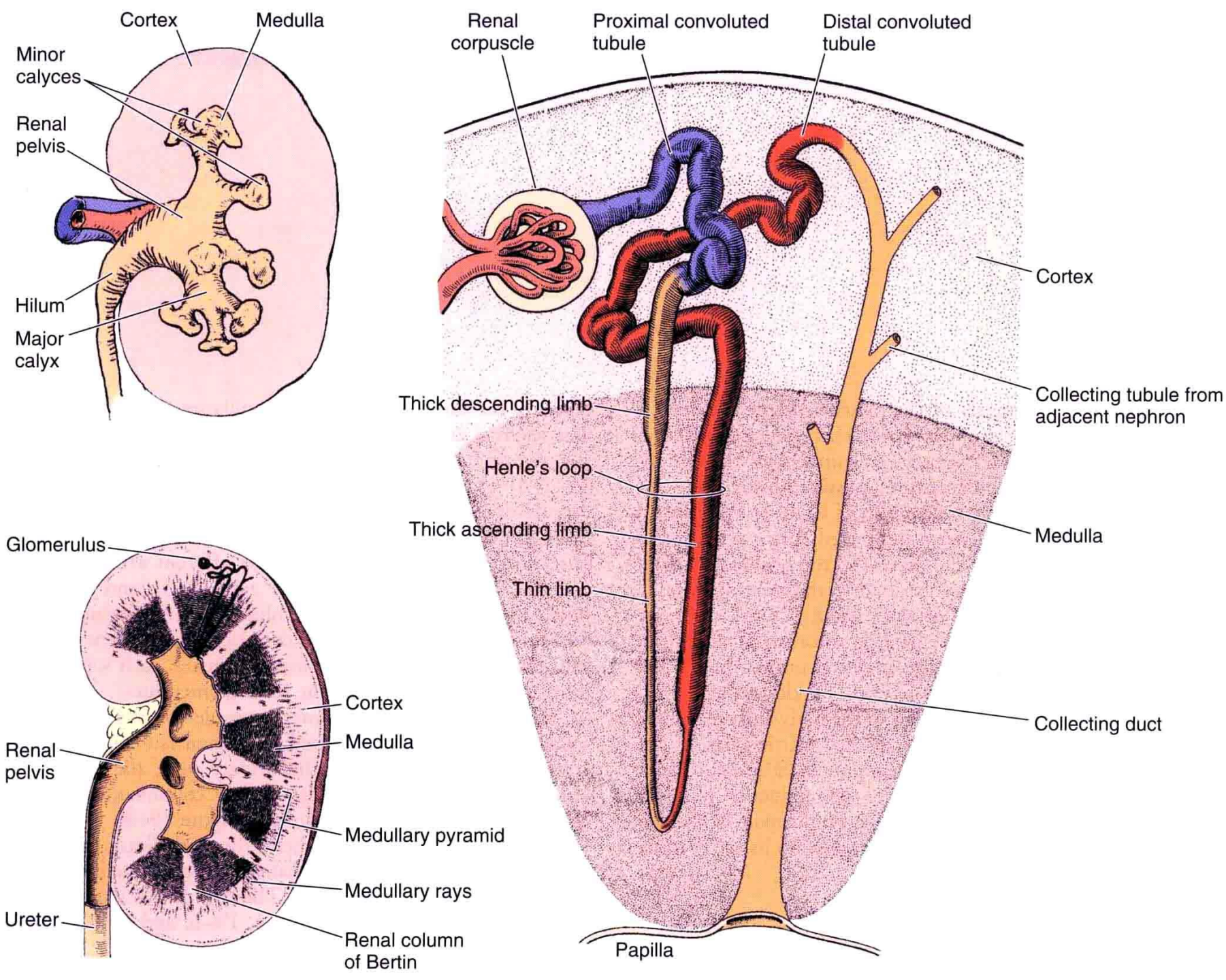


Renal capsule also contains myofibroblasts

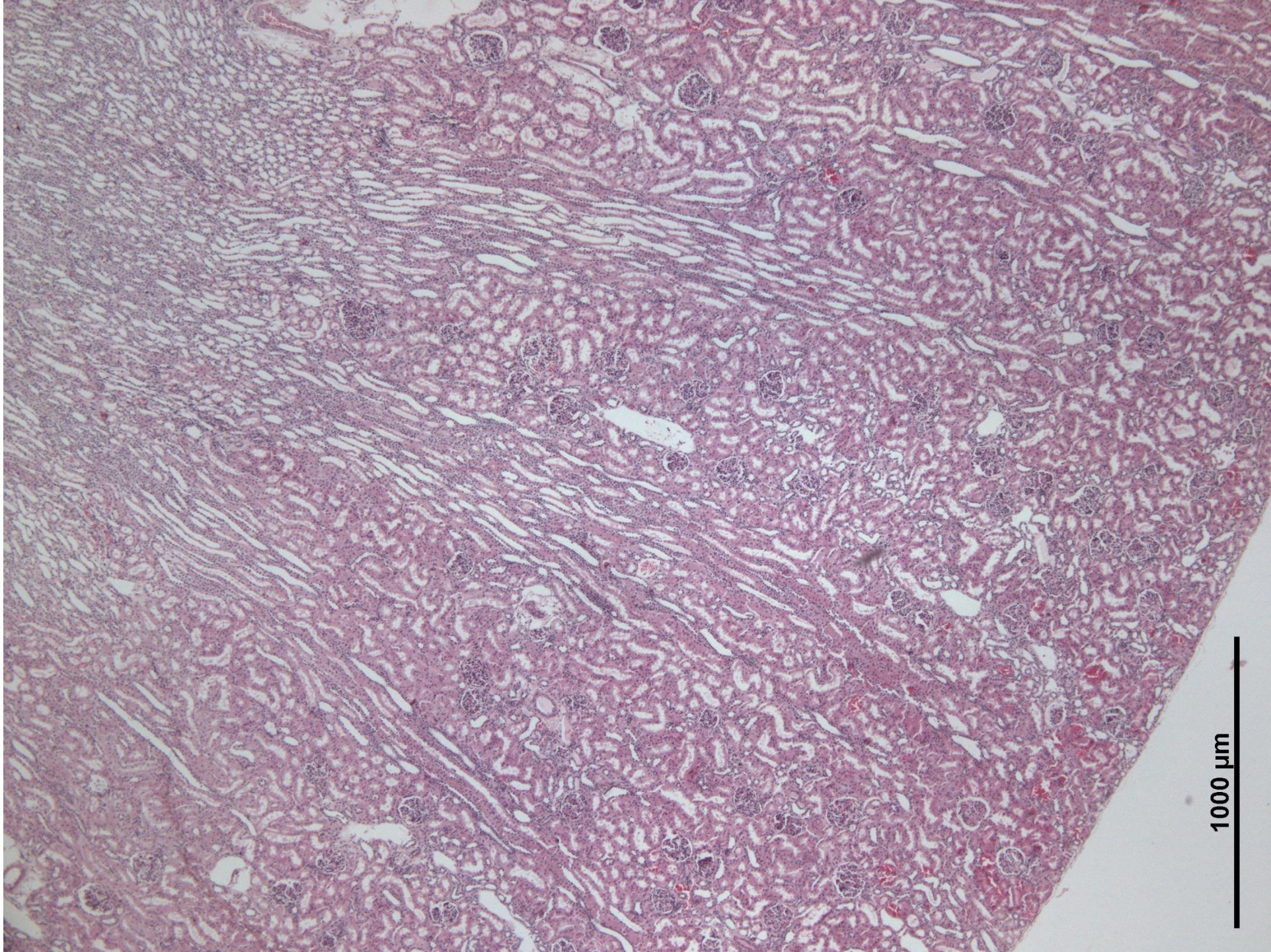
What‘s on the surface?

Medulla and cortex

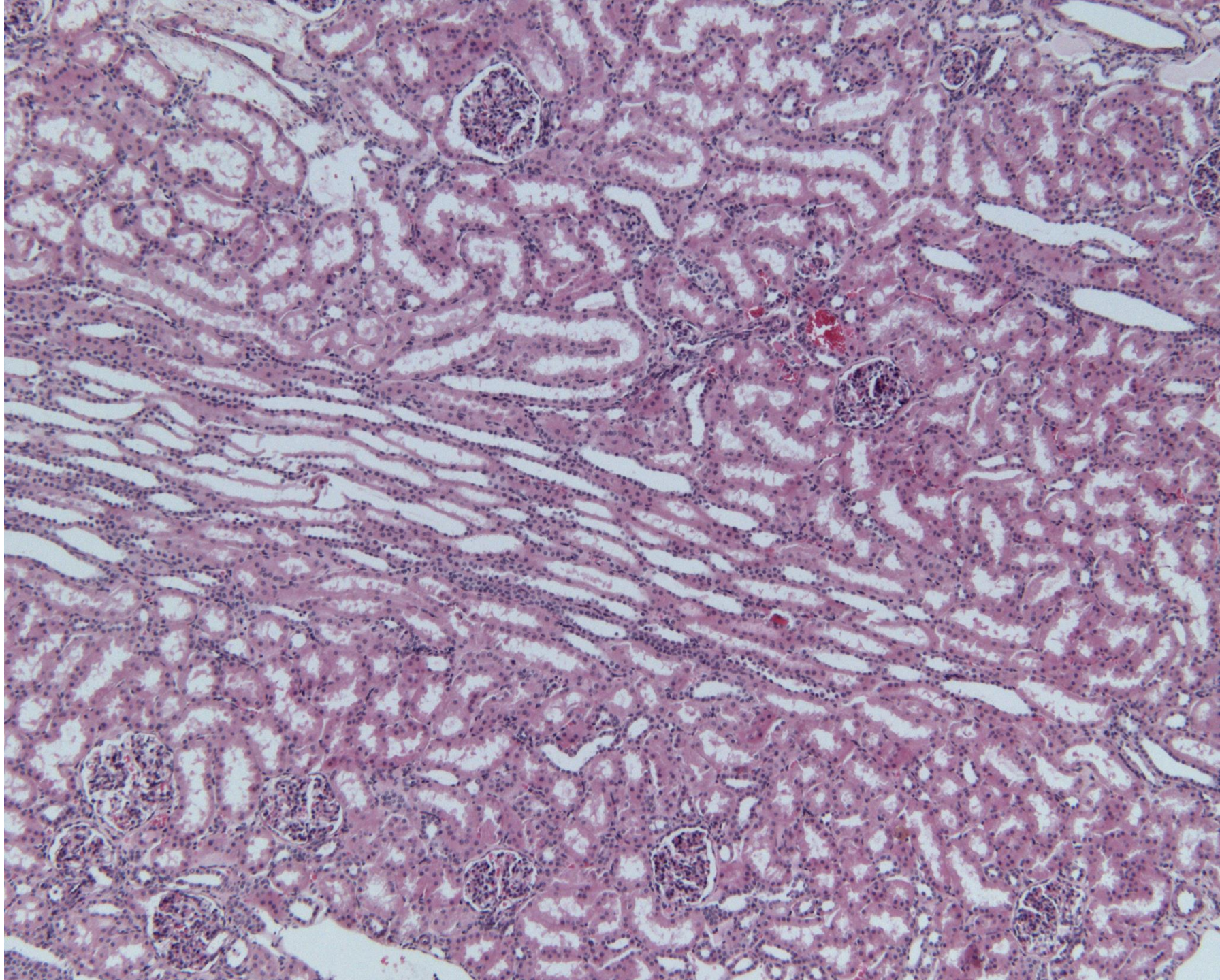


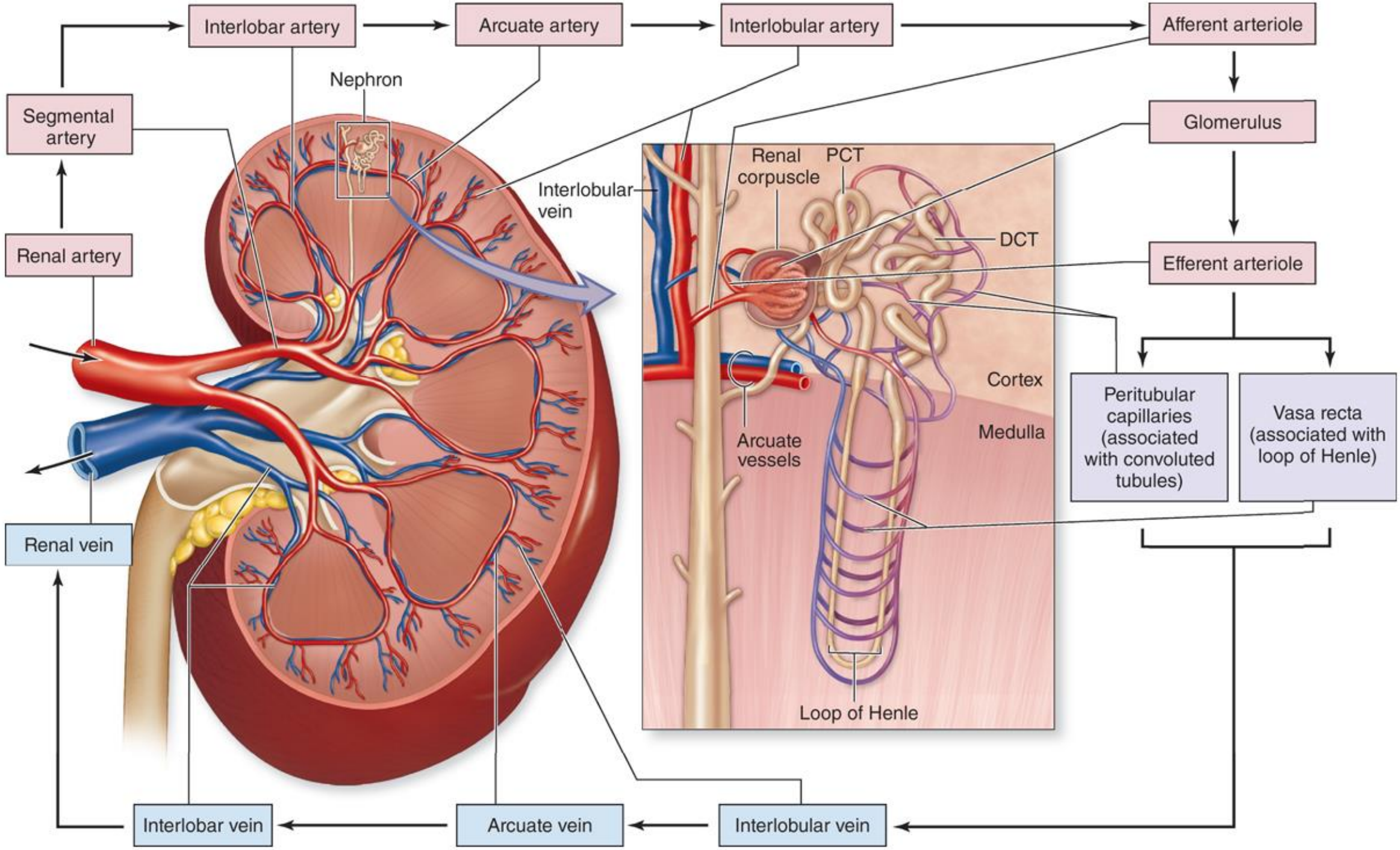

Cortex
Medulla
Minor calyces
Renal pelvis
Hilum
Major calyx
Glomerulus
Cortex
Renal pelvis
Medulla
Medullary pyramid
Medullary rays
Ureter
Renal column of Bertin
Renal corpuscle
Proximal convoluted tubule
Distal convoluted tubule
Cortex
Collecting tubule from adjacent nephron
Thick descending limb
Henle's loop
Thick ascending limb
Medulla
Thin limb
Collecting duct
Papilla

Medullary rays

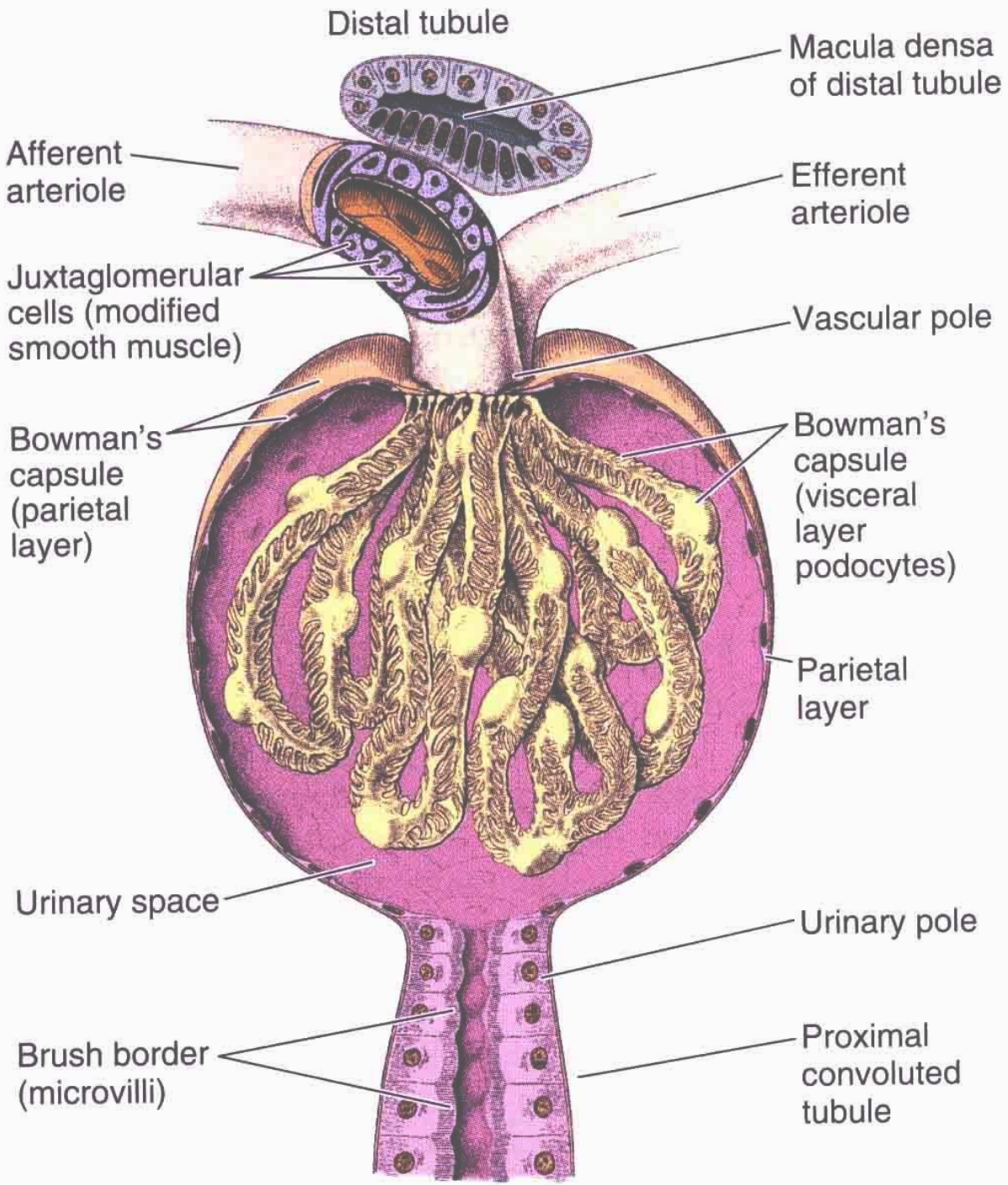


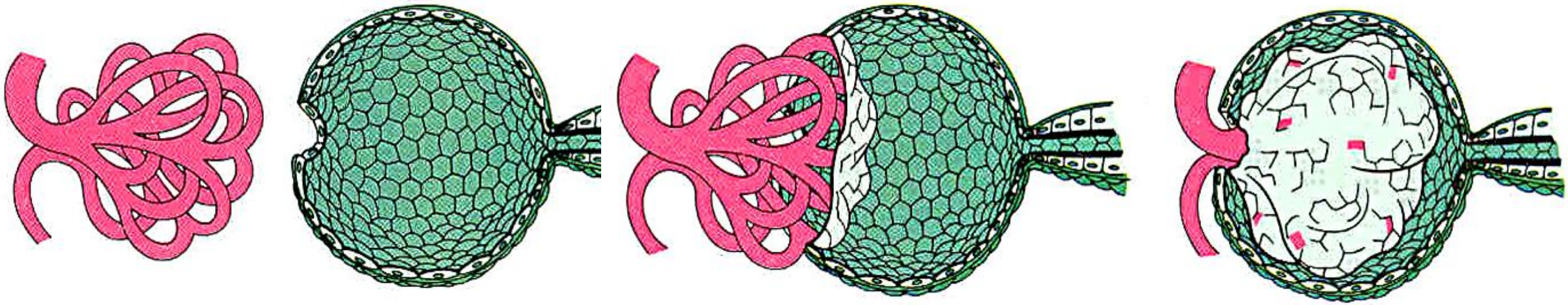
Close up on a medullary ray

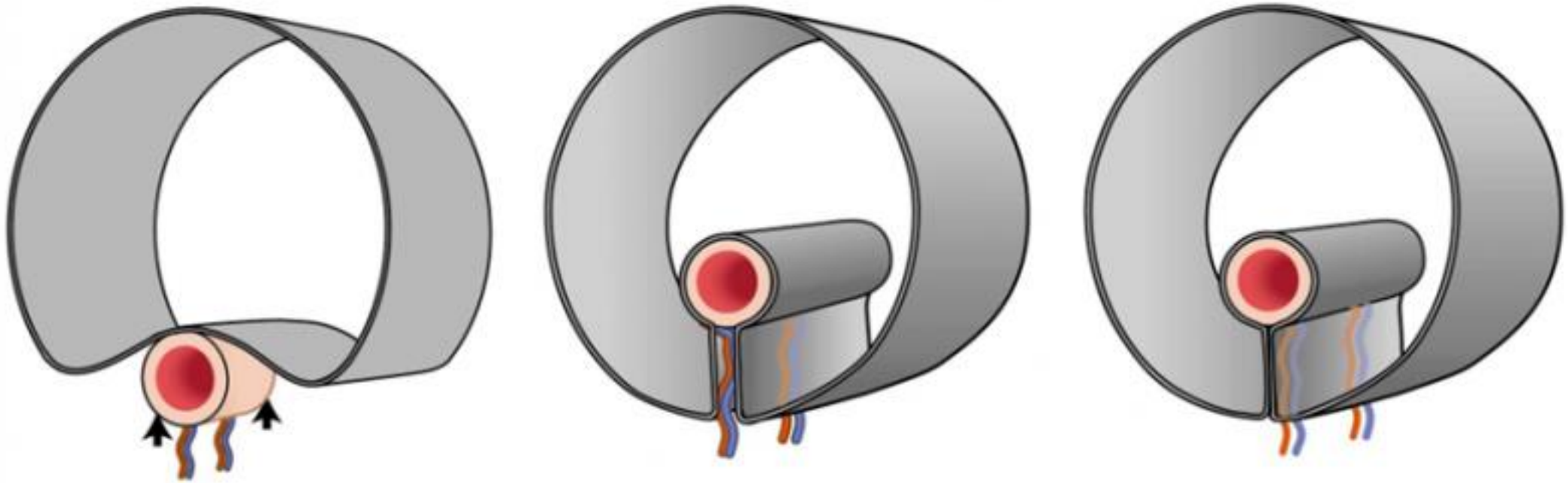


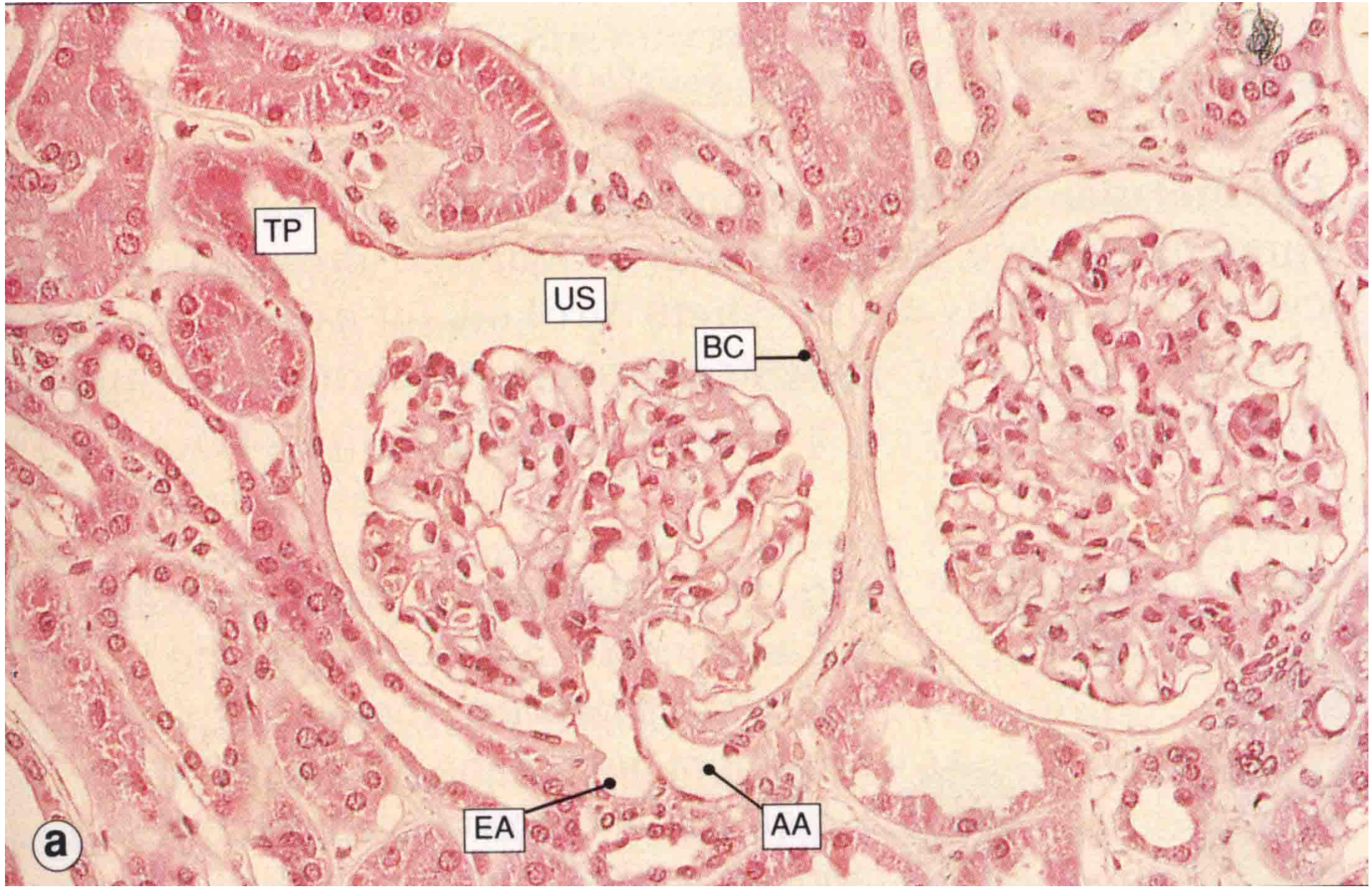

Interlobar artery
Arcuate artery
Interlobular artery
Afferent arteriole
Nephron
Segmental artery
Glomerulus
Interlobular vein
Renal corpuscle
PCT
DCT
Renal artery
Efferent arteriole
Cortex
Medulla
Arcuate vessels
Peritubular capillaries (associated with convoluted tubules)
Vasa recta (associated with loop of Henle)
Renal vein
Loop of Henle
Interlobar vein
Arcuate vein
Interlobular vein

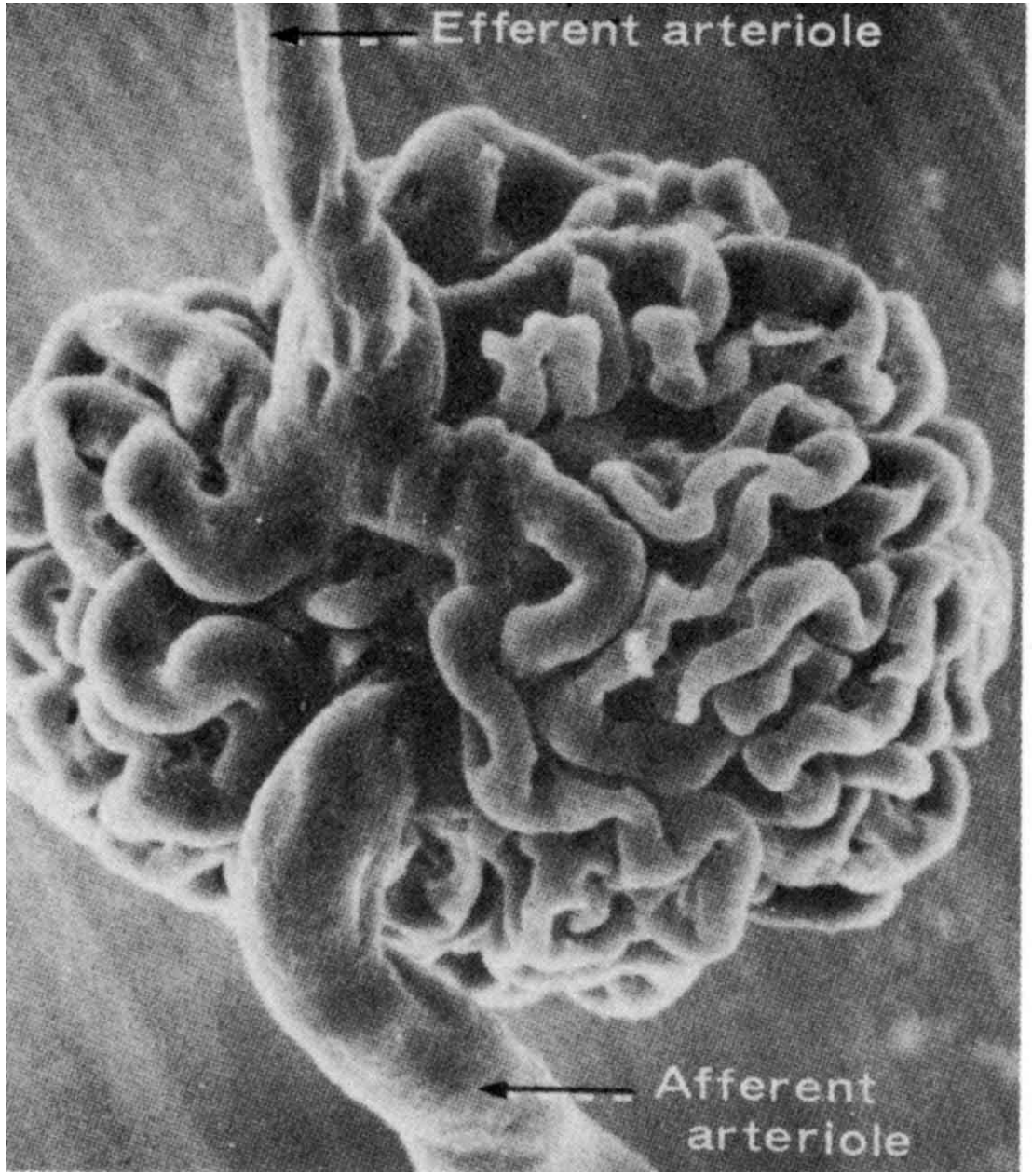
Renal corpuscle contains capillaries surrounded by epithelial cells. This arrangement is the basis of the kidney‘s filtration barrier.

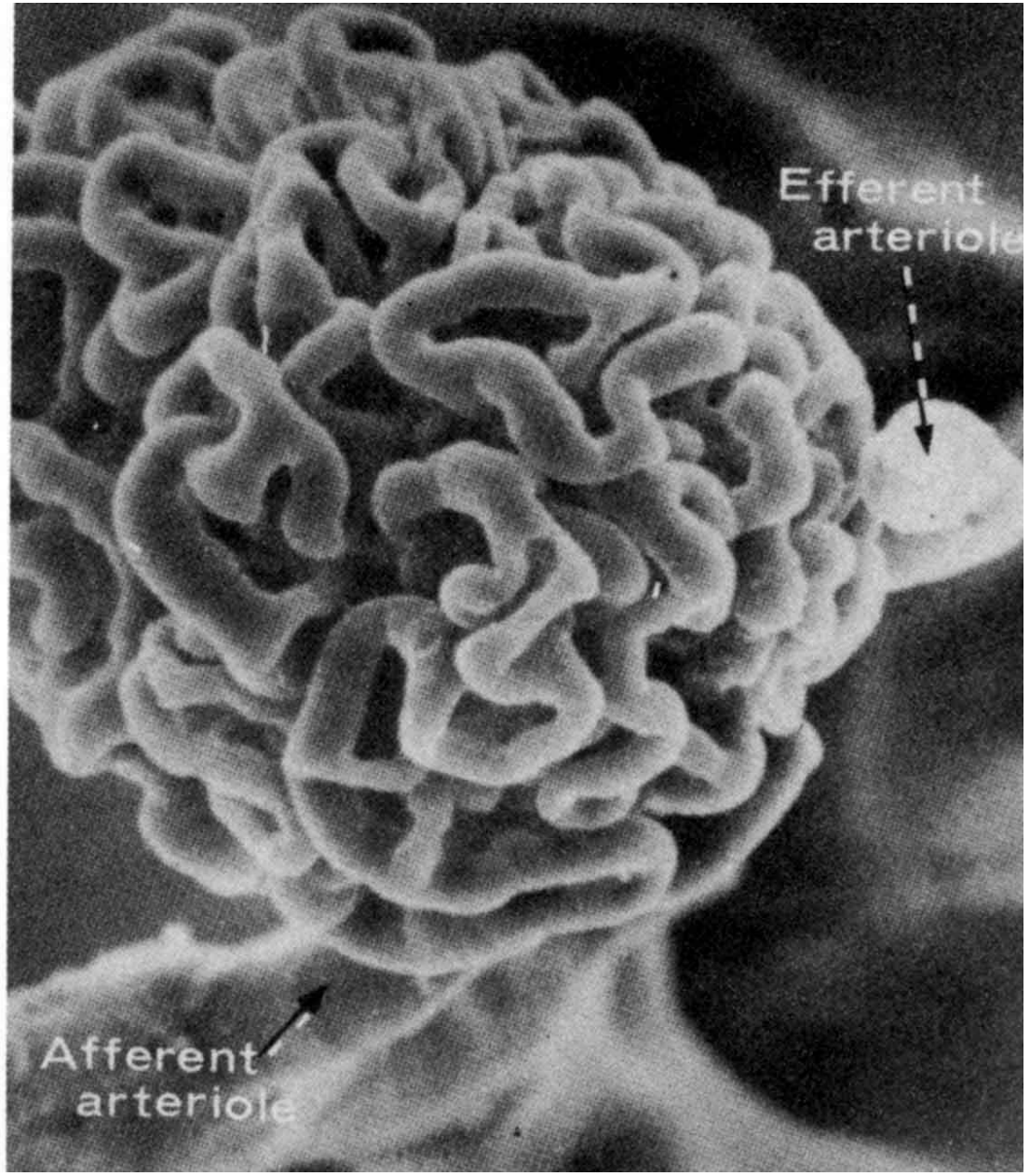




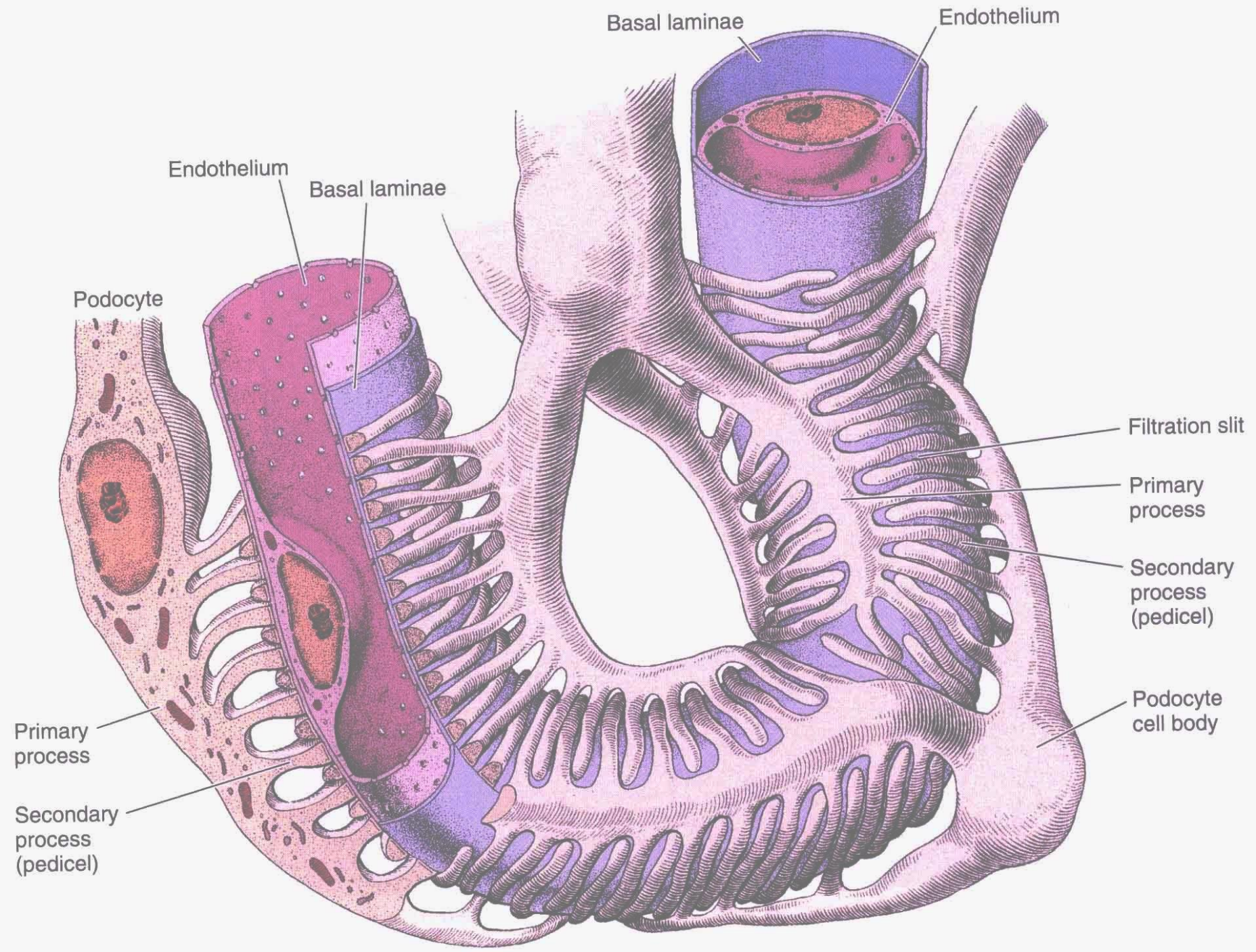



TP
US
BC
EA
AA
a

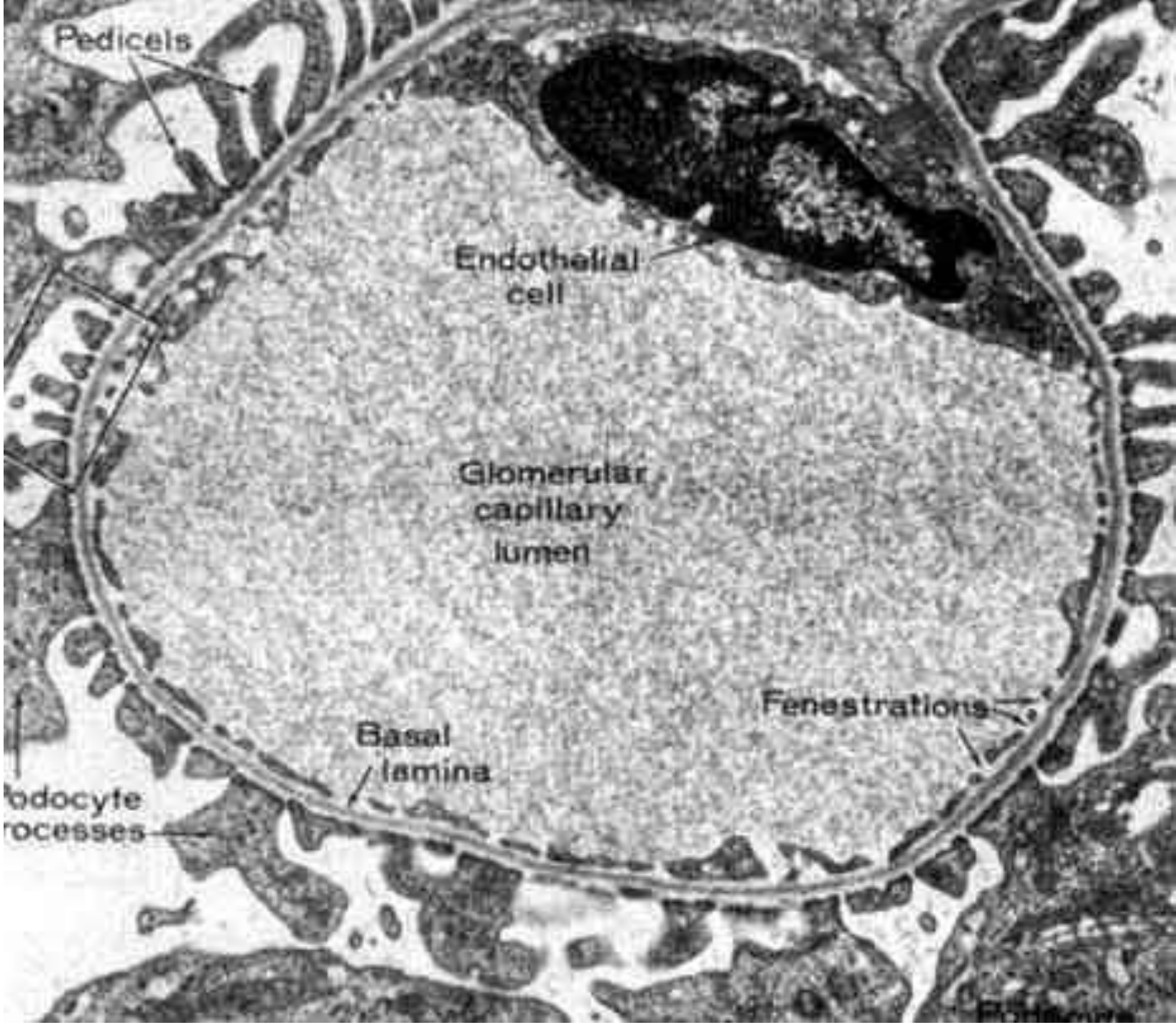

Efferent arteriole
Afferent arteriole


Efferent arteriole
Afferent arteriole

In the glomerulus, capillary endothelia are surrounded by epithelial cells with multiple processes – the podocytes.

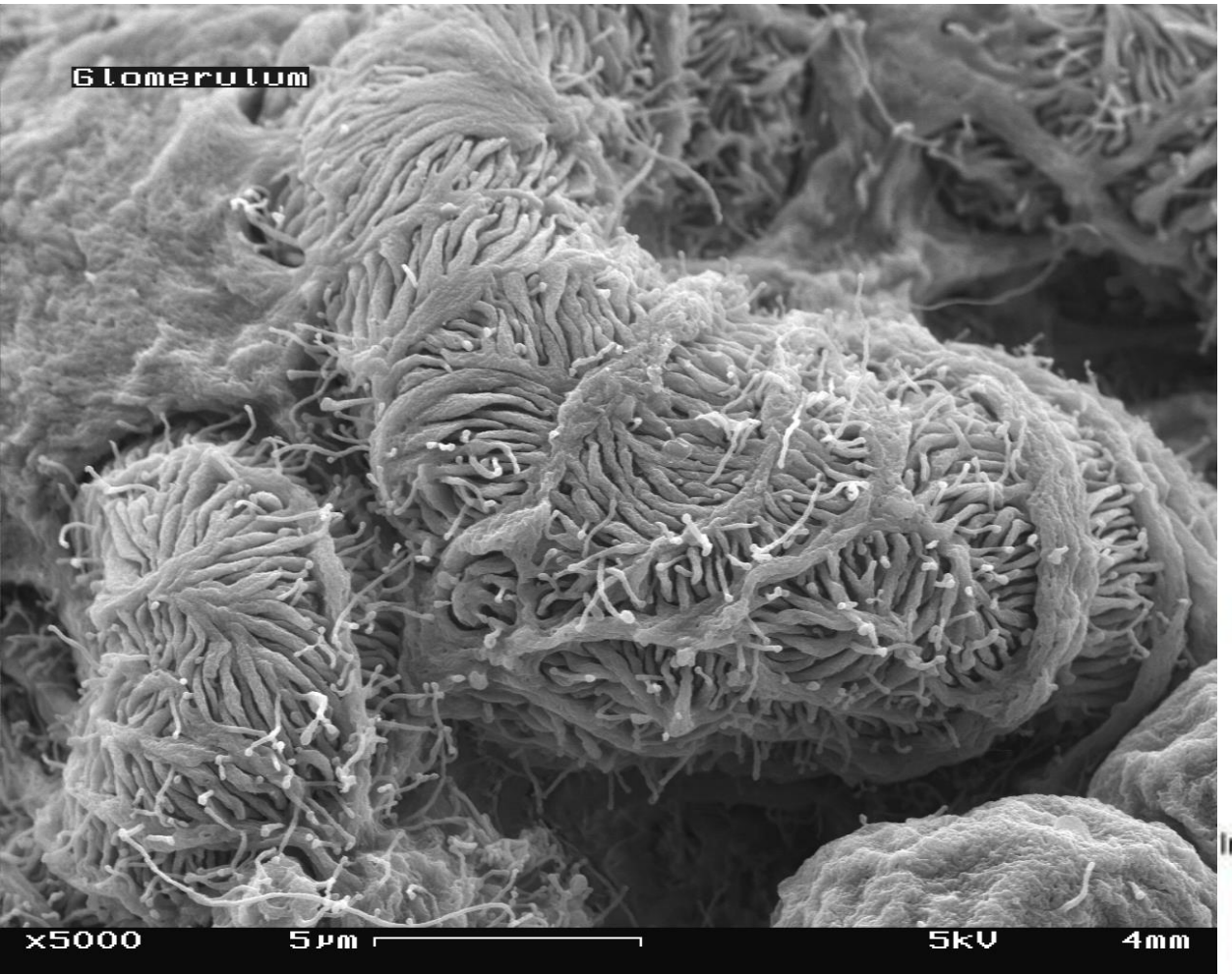


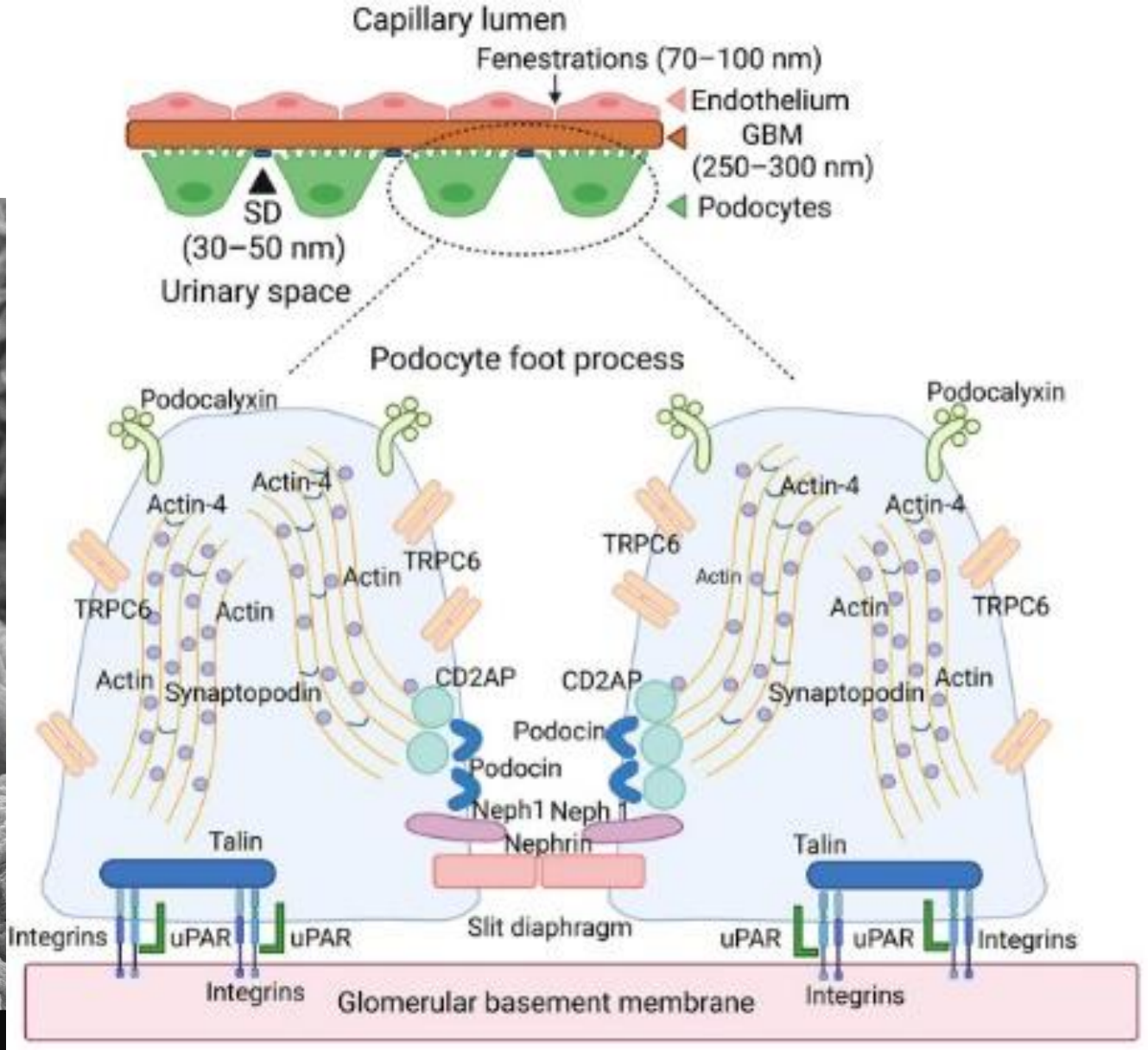
Pores in glomerular capillaries lack the diaphragm. They are about 70 – 90 nm in diameter.

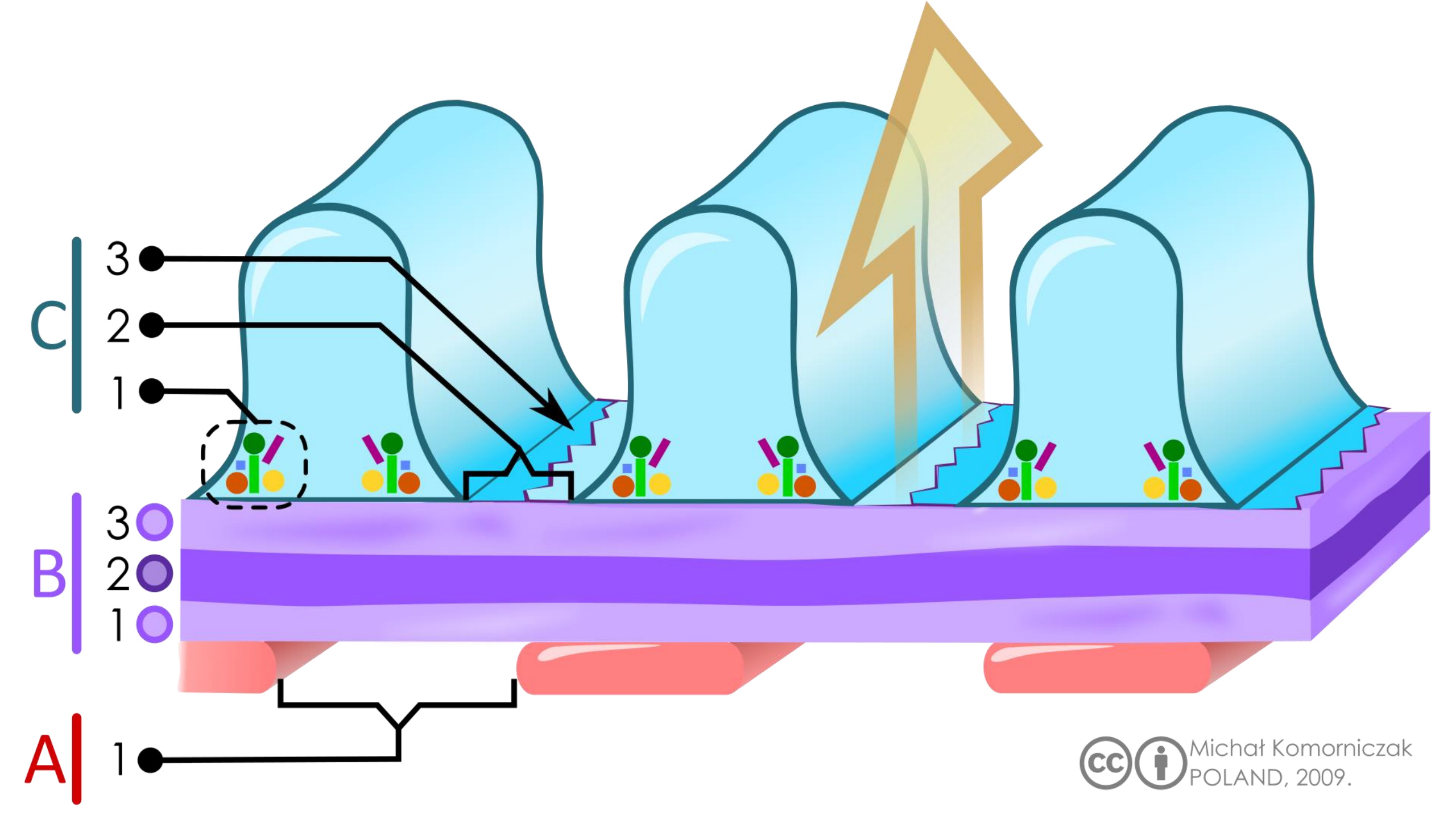


Glomerular basement membrane is thick (300 – 370 nm). It contains type IV collagen, proteoglycans and multiple other proteins.

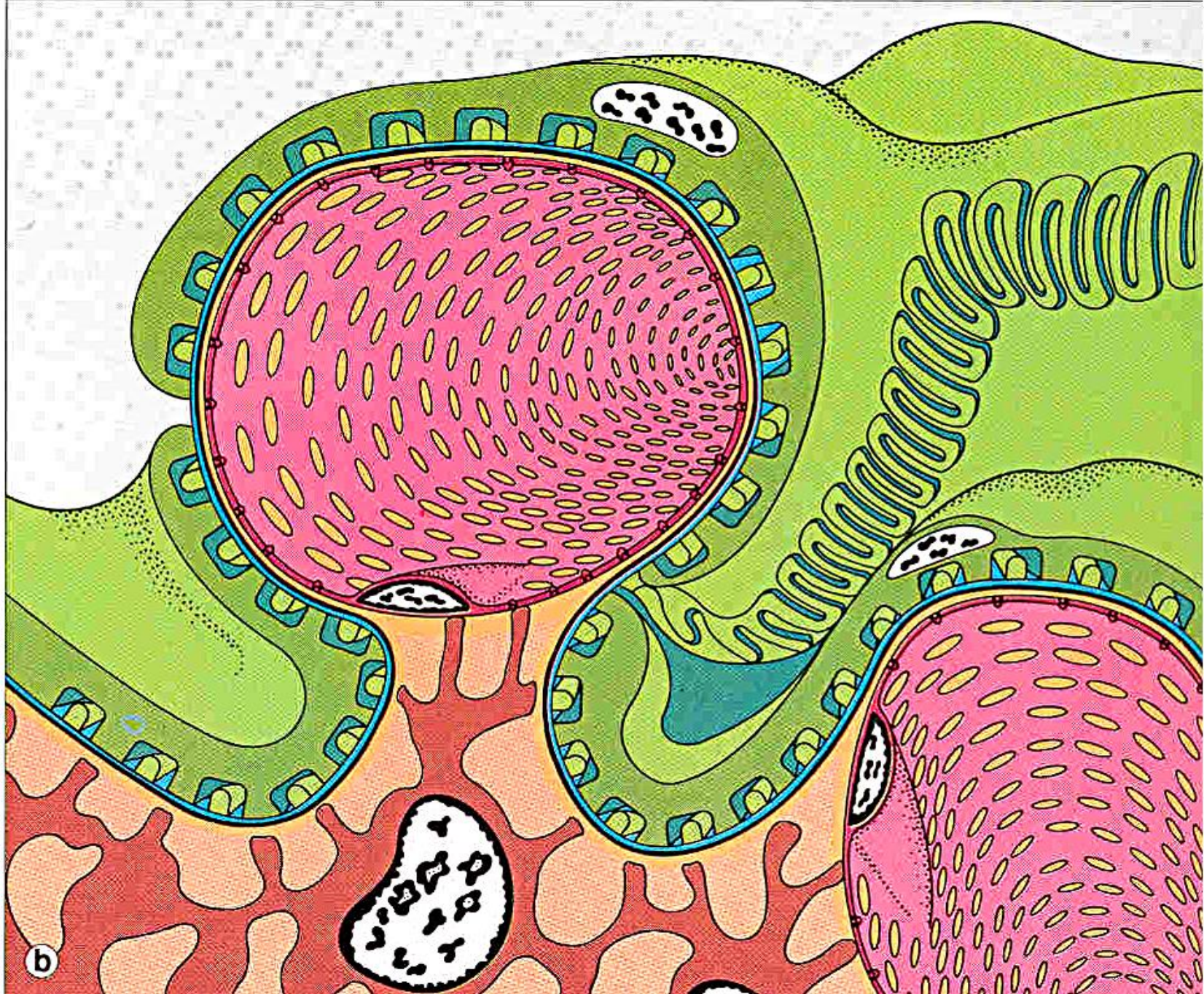
Podocytes interdigitate, the spaces between the pedicels, called filtration slits, are about 40 nm wide. There is a diaphragm in these slits.



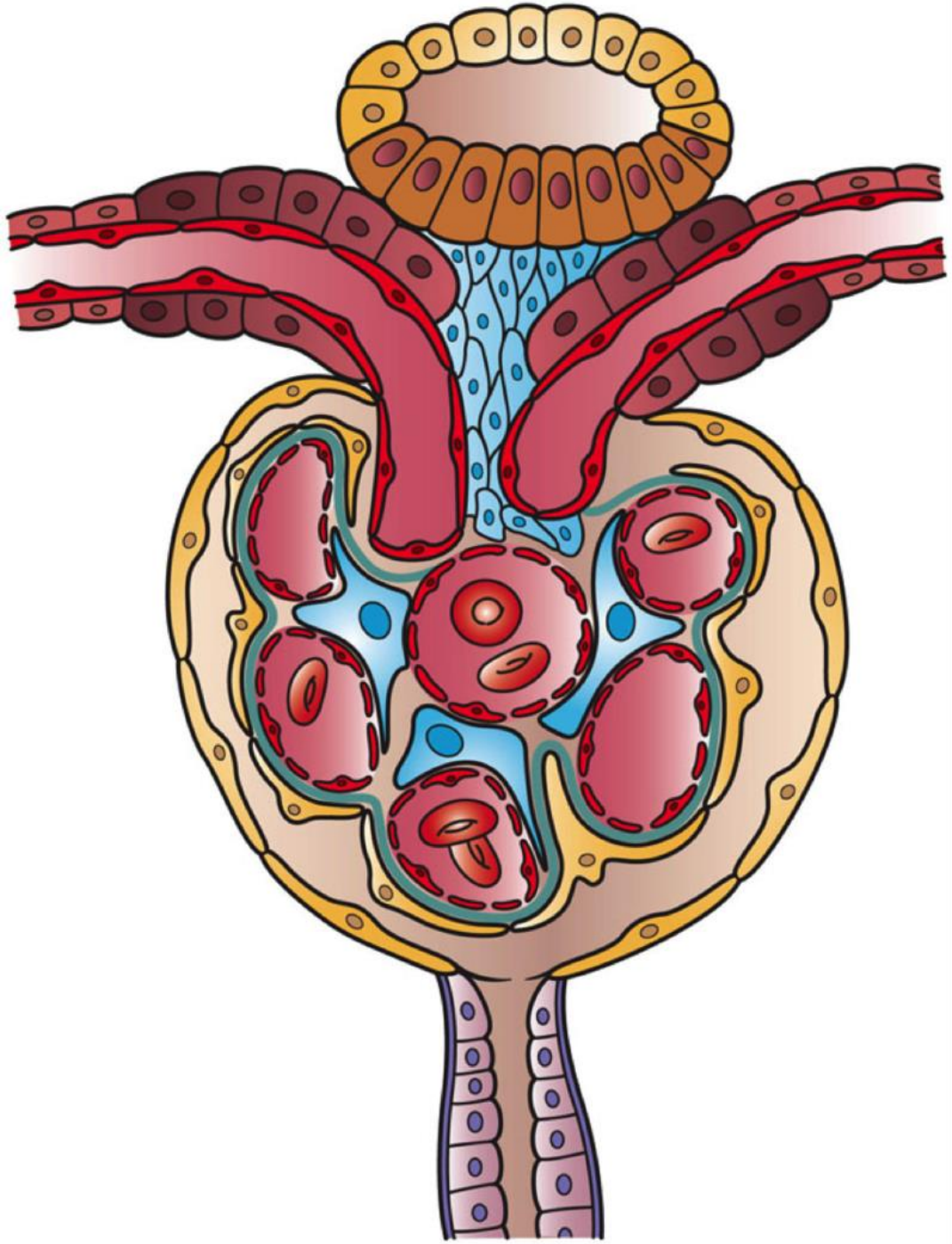


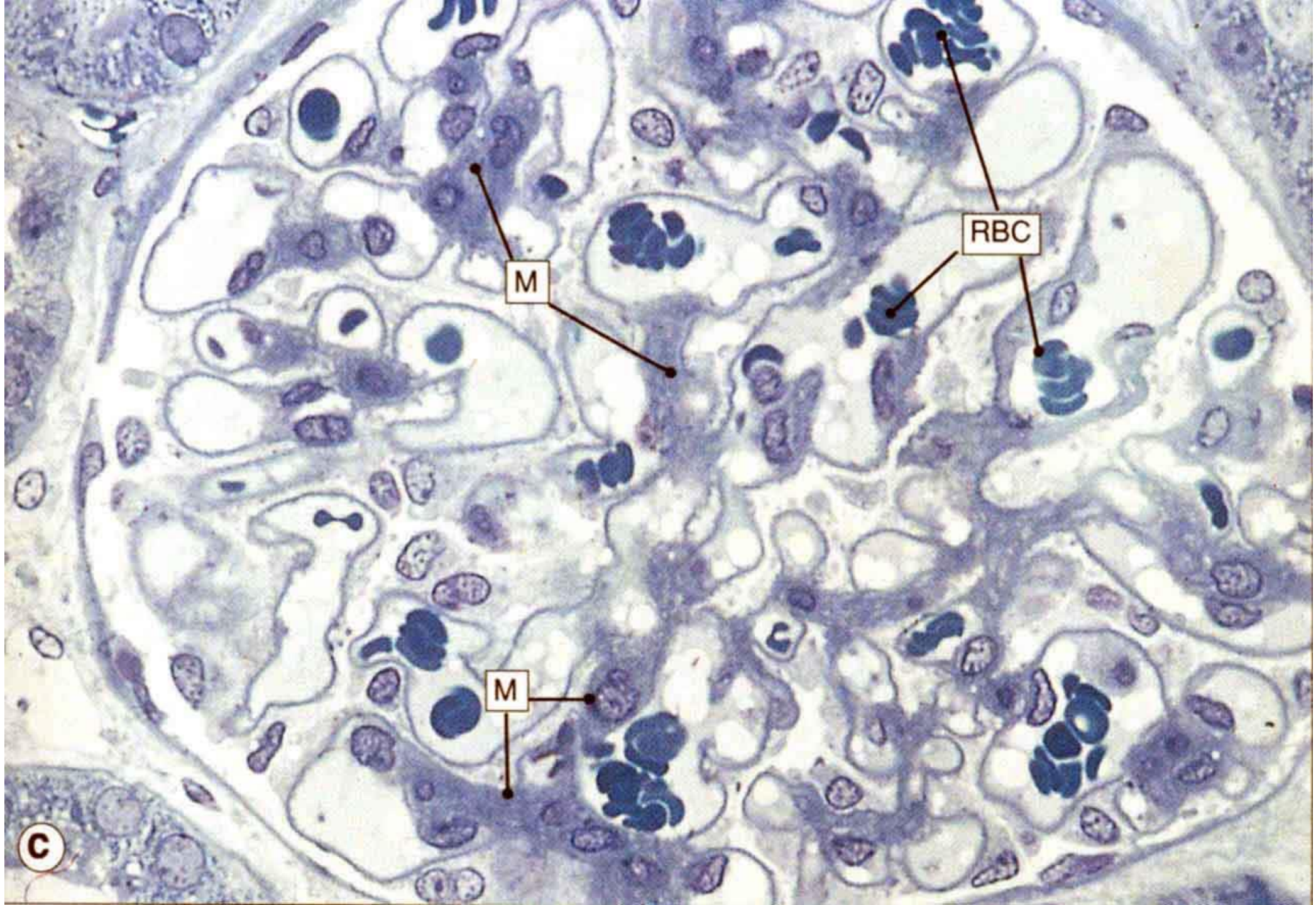


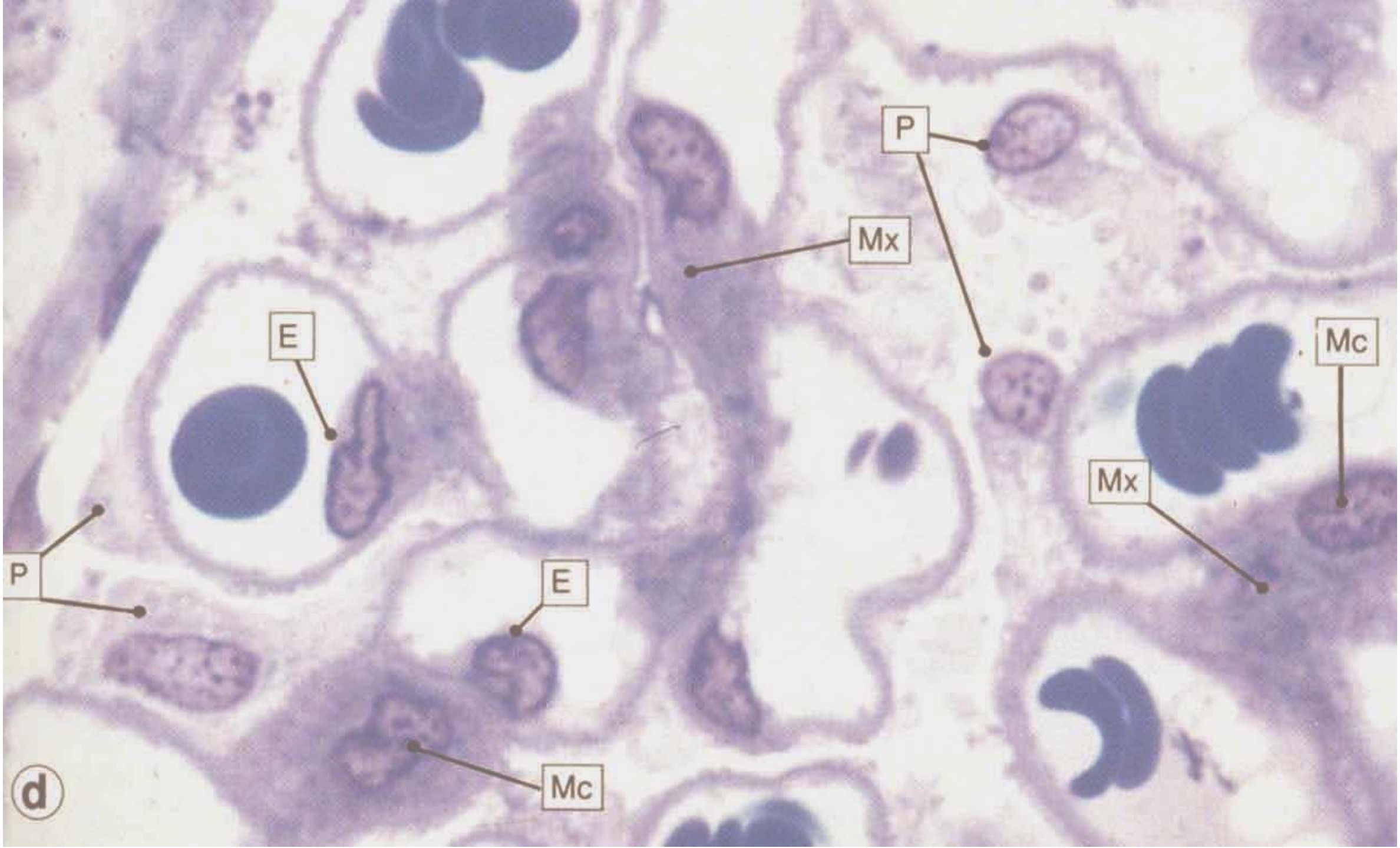

GC
EnC
BM
MM
M
a

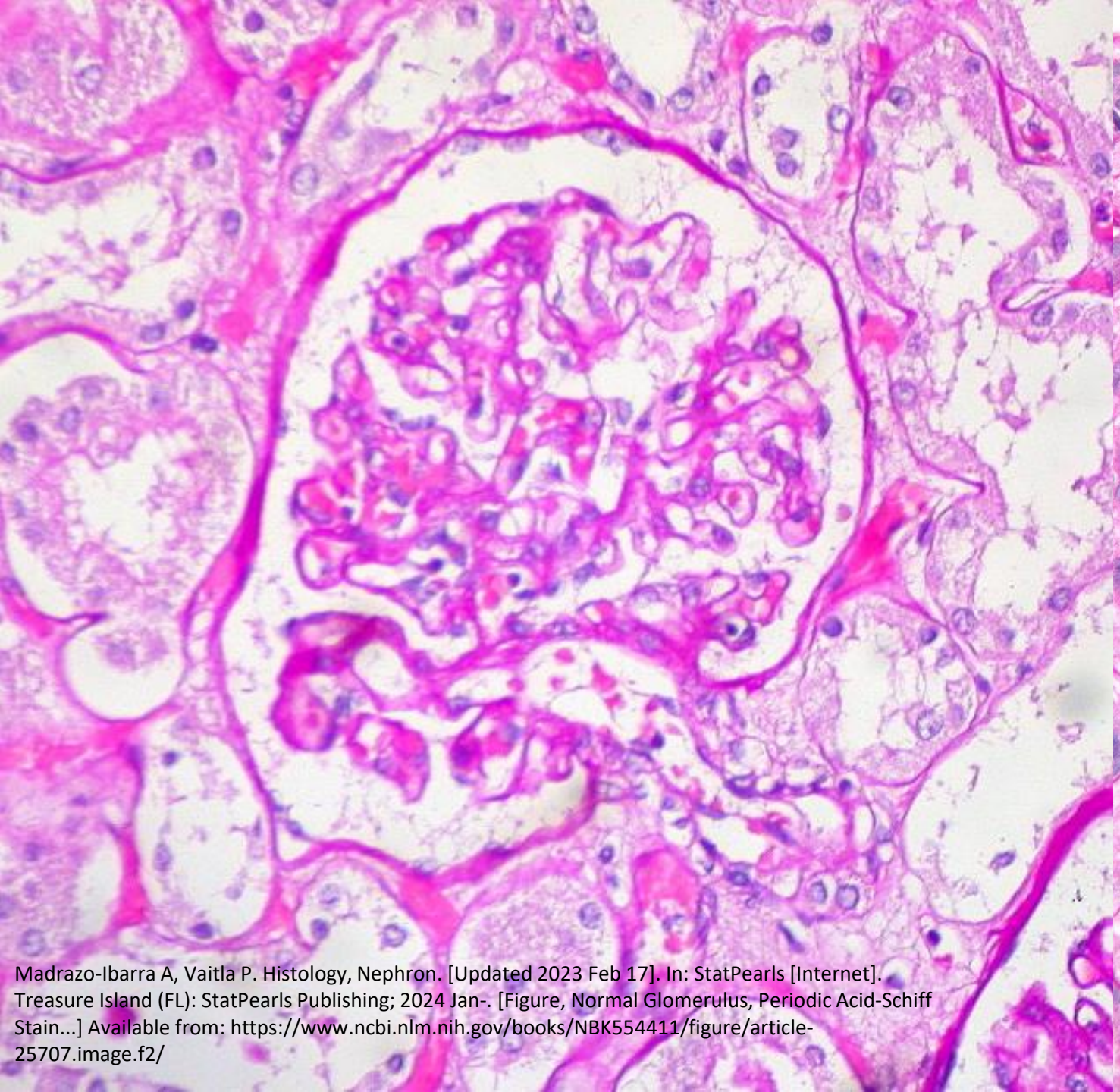

b

Mesangial cells (blue) proliferate in a variety of glomerular diseases. They can also be located outside of the glomerulus (extraglomerular MCs).

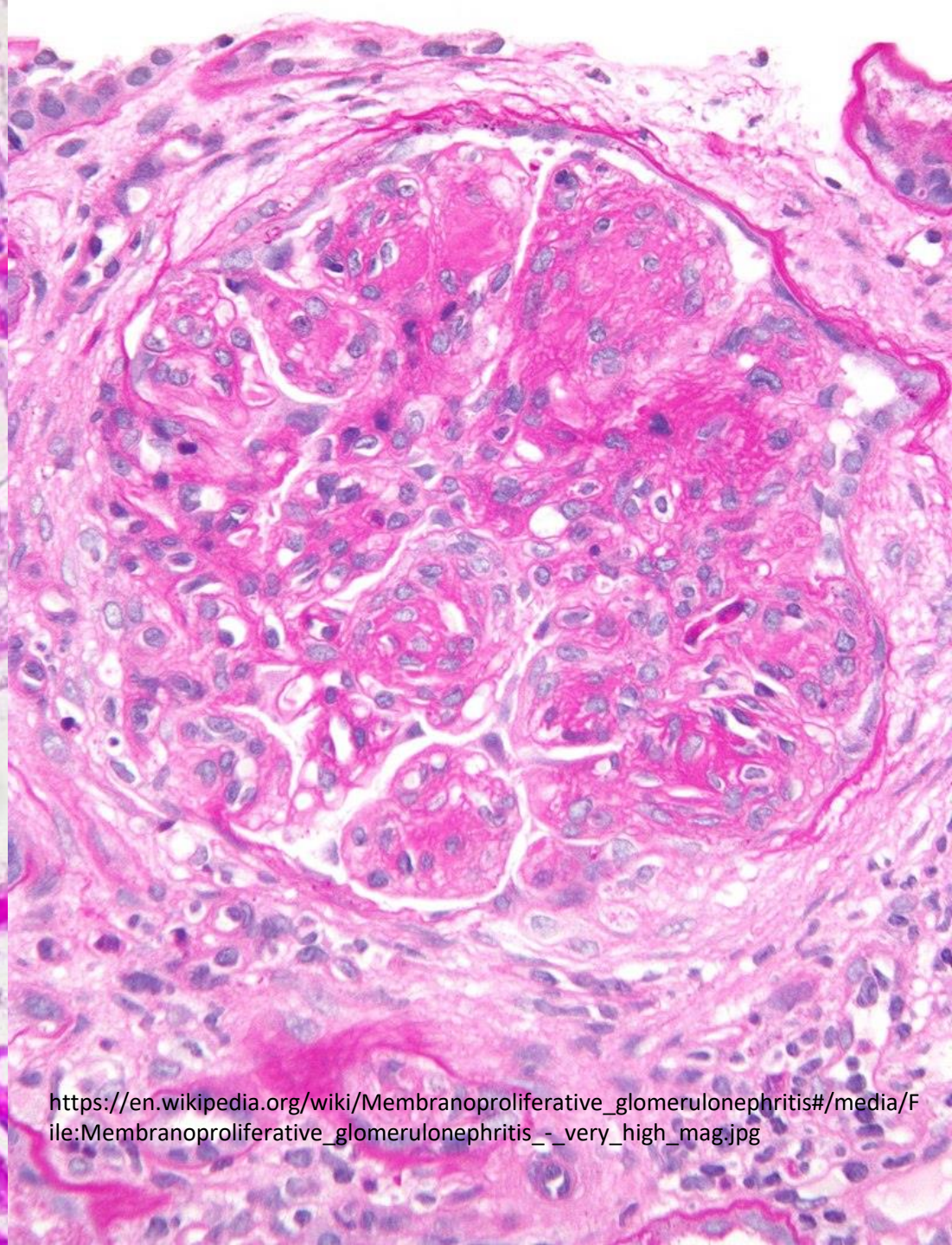



M
RBC
M
C


P
Mx
E
Mc
Mx
P
E
Mc
d



Madrazo-Ibarra A, Vaitla P. Histology, Nephron. [Updated 2023 Feb 17]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. [Figure, Normal Glomerulus, Periodic Acid-Schiff Stain...] Available from: https://www.ncbi.nlm.nih.gov/books/NBK554411/figure/article-25707.image.f2/



https://en.wikipedia.org/wiki/Membranoproliferative_glomerulonephritis#/media/File:Membranoproliferative_glomerulonephritis_-_very_high_mag.jpg

The renal corpuscle

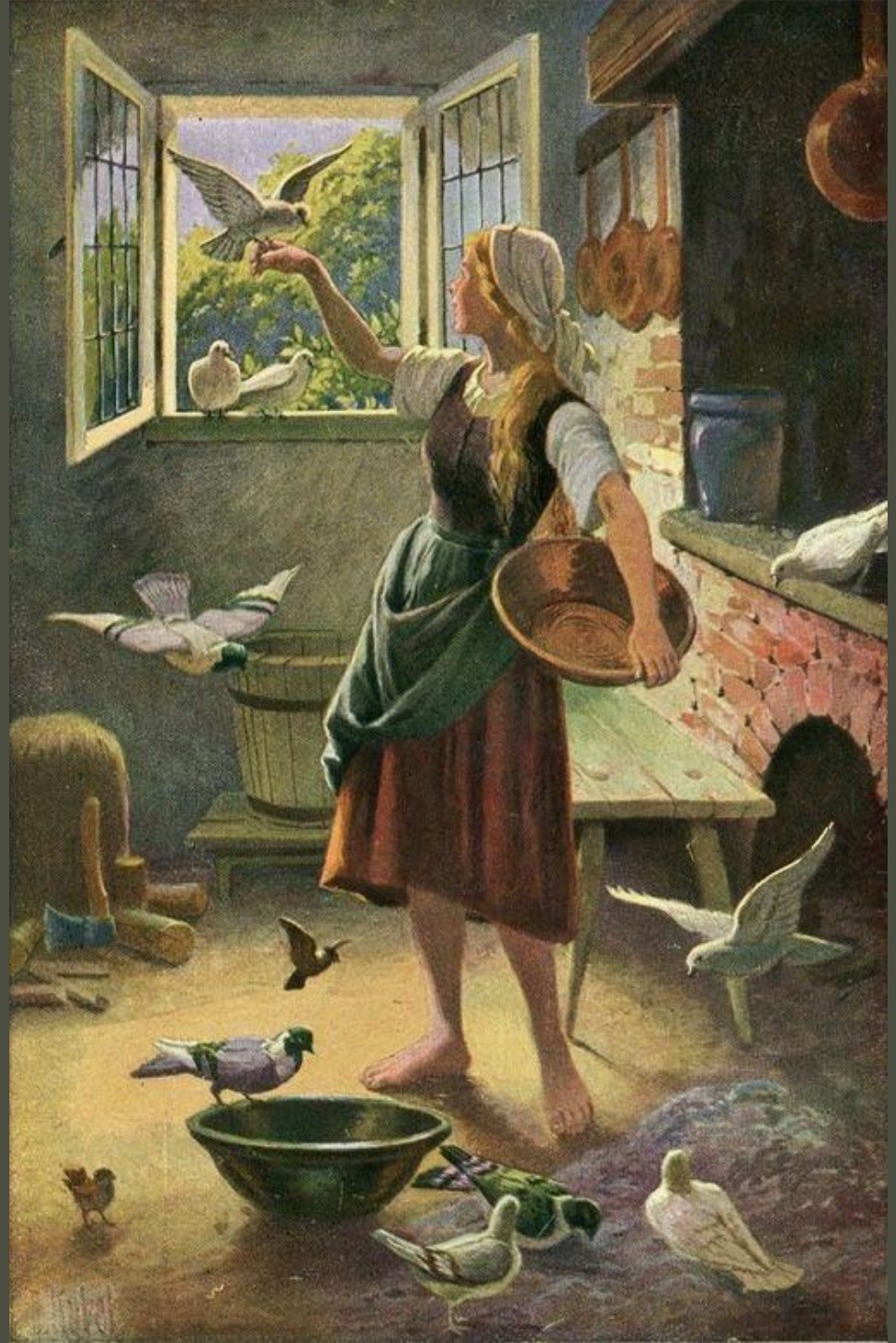
- Convoluted capillaries of the glomerulus are supplied by afferent arteriole and drained by an efferent arteriole – portal system of the kidney
- The filtration membrane consists of porous endothelial cells, glomerular basement membrane and podocytes
- Podocytes have primary processes that branch into secondary processes - pedicels, between the pedicels there is a filtration slit covered by a very thin diaphragm
- Its job is to filter blood, the cells and large proteins cannot pass
- Mesangial cells provide structural support, secrete several signal molecules, phagocytose and also have contactile properties

How does the kidney know the substances that should be eliminated?

„die guten ins Töpfchen,
die schlechten ins Kröpfchen!“

„the good ones in the pot,
the bad ones in the crop!“

Brothers Grimm, Cinderella
(1819)



Painting by Otto Kubel
(1930)

https://upload.wikimedia.org
/wikipedia/commons/b/bd/C
endrillon.jpg

Blood plasma

Blood cells

Larger proteins over 70 kDa

Lipoproteins

Small proteins and peptides

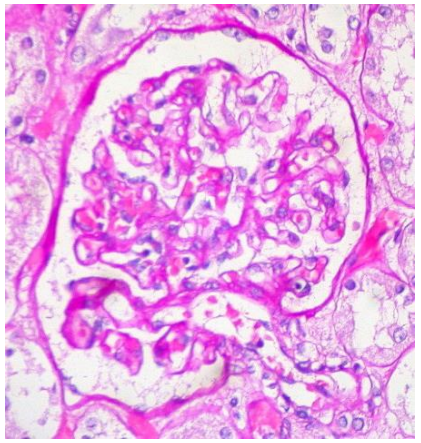
Aminoacids

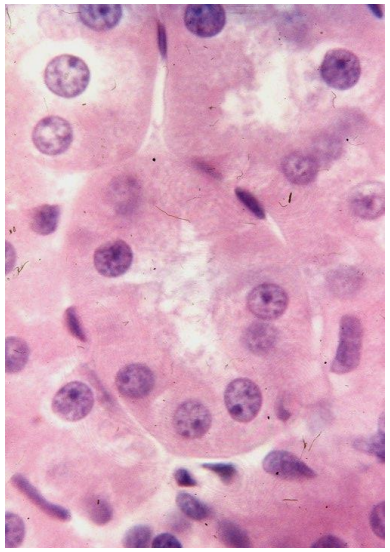
Glucose

Urea

Ions

Various small molecules

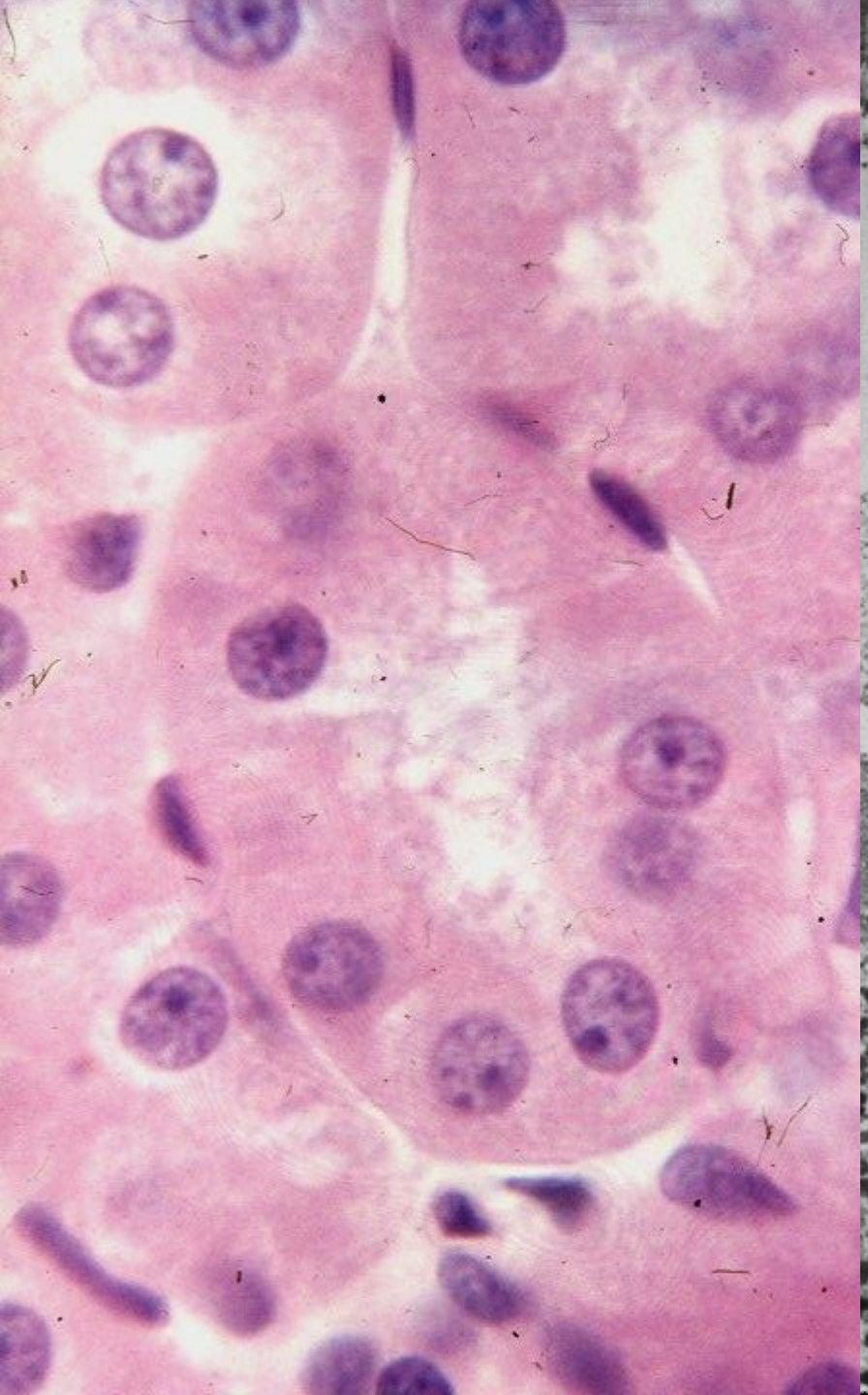


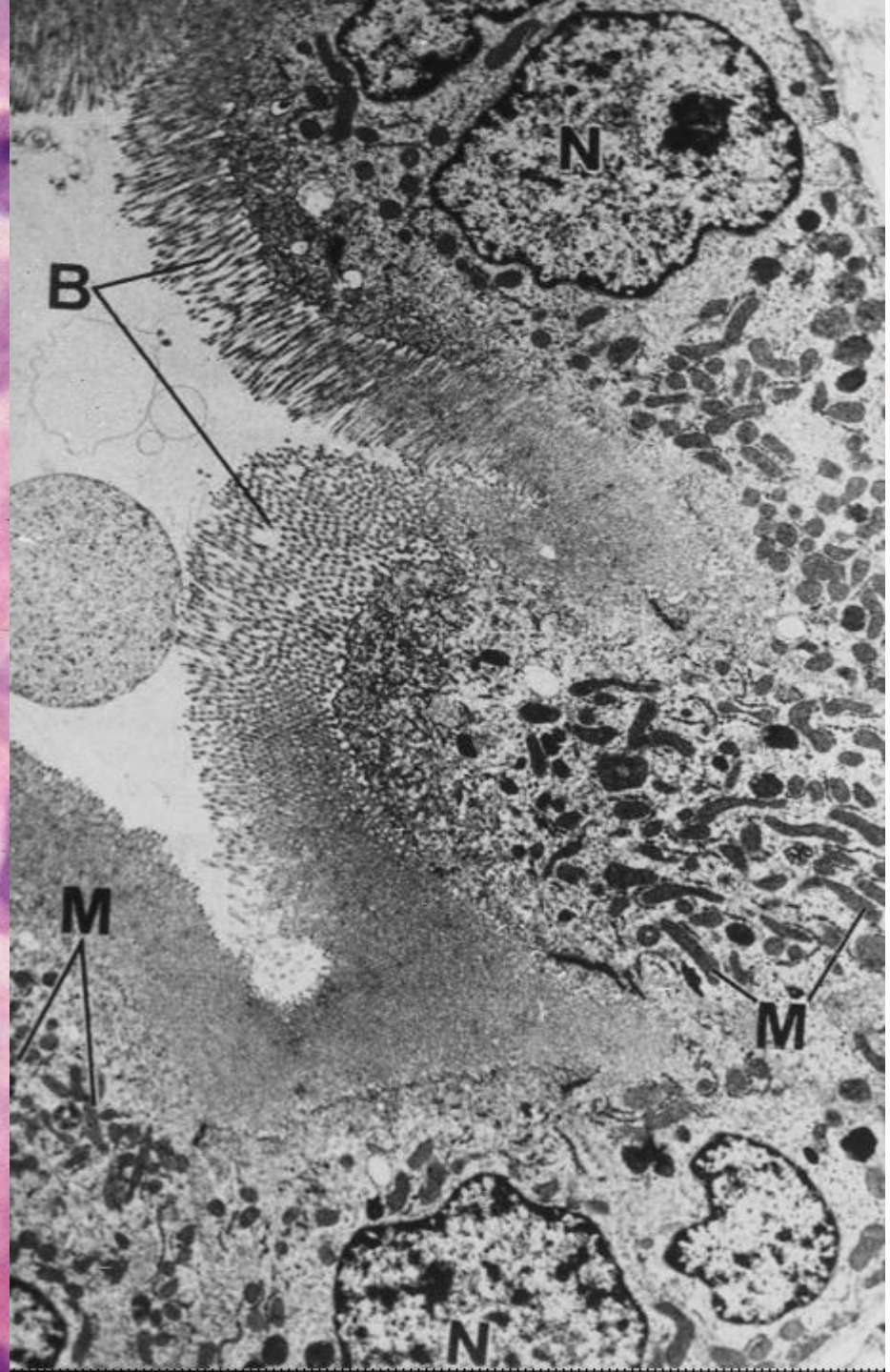


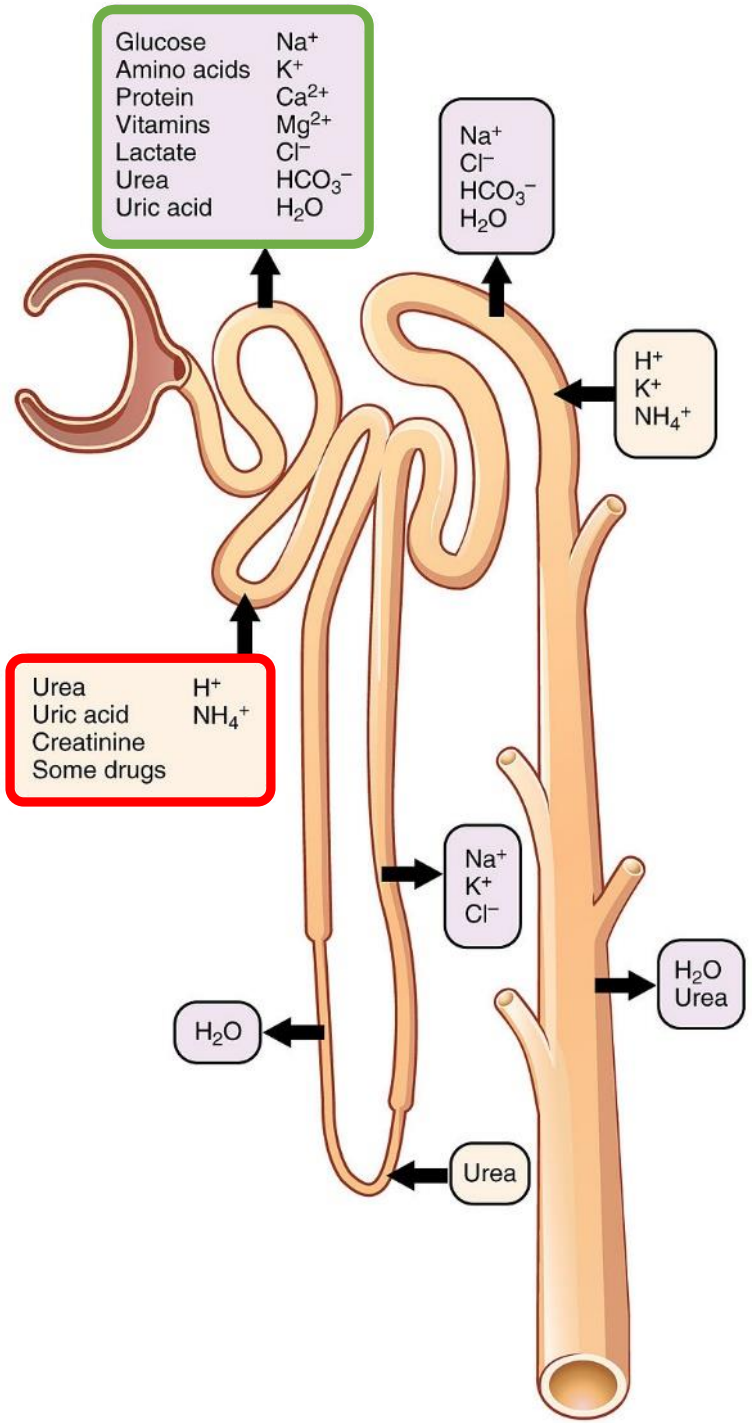
Case 1

A girl (9 years) has a urinary dipstick positive for hemoglobin. Microscopy of urine has revealed the following picture.

1. What is the differential diagnosis of a positive dipstick?
2. What additional information is supplied by microscopy?

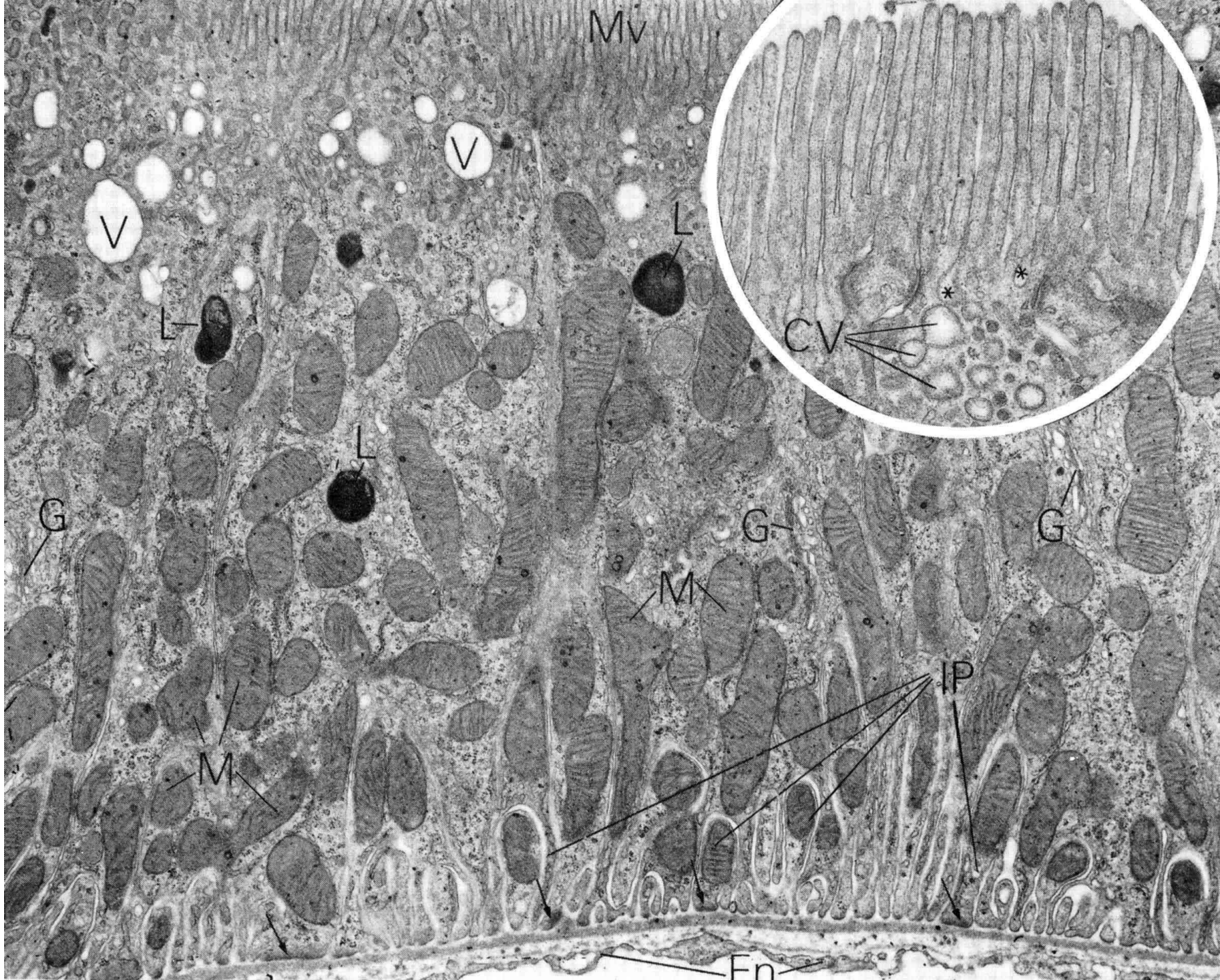



N
B
M
M
N


Glucose
Amino acids
Protein
Vitamins
Lactate
Urea
Uric acid
Na+
K+
Ca2+
Mg2+
Cl−
HCO3−
H2O
Na+
Cl−
HCO3−
H2O
H+
K+
NH4+
Urea
Uric acid
Creatinine
Some drugs
H+
NH4+
Na+
K+
Cl−
H2O
H2O
Urea
Urea

Proximal convoluted tubule (PCT)

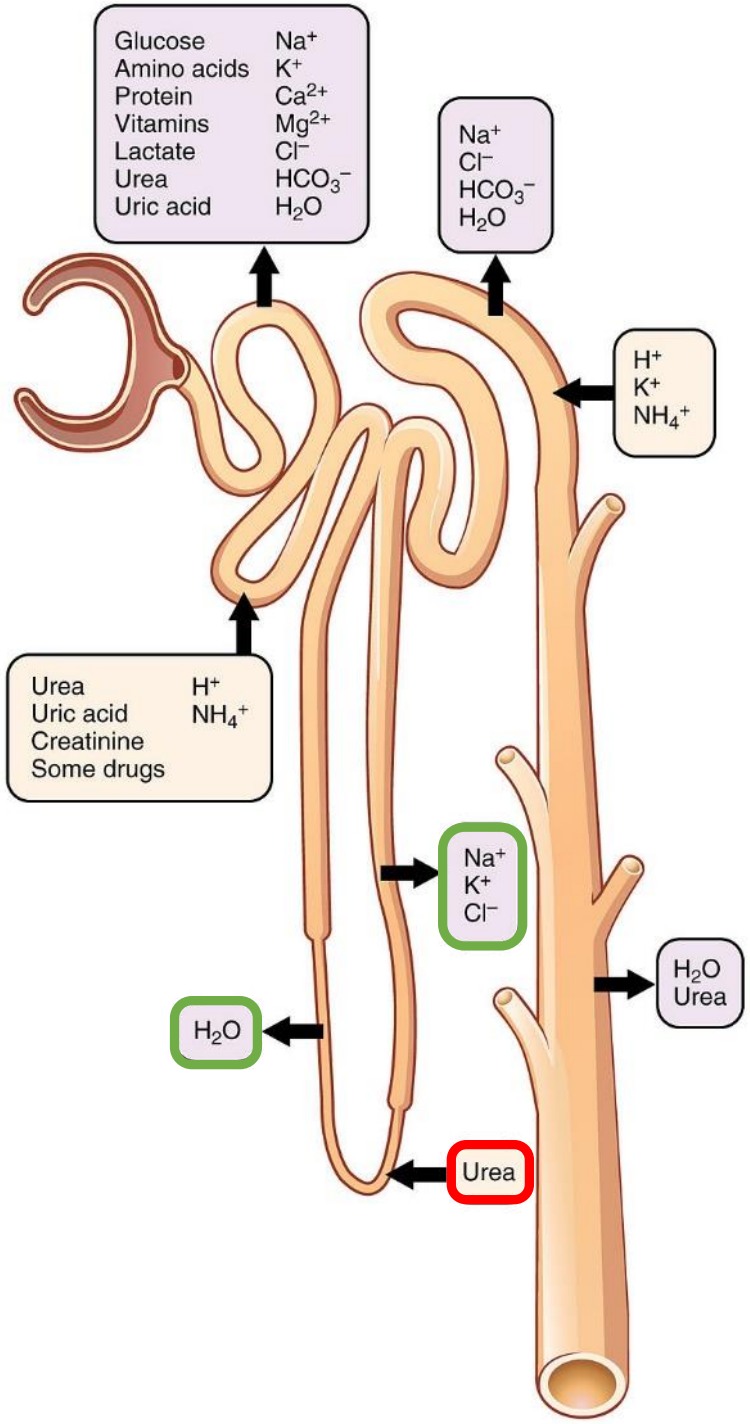
Have you already seen similar cells?



Basal labyrinth (striations)

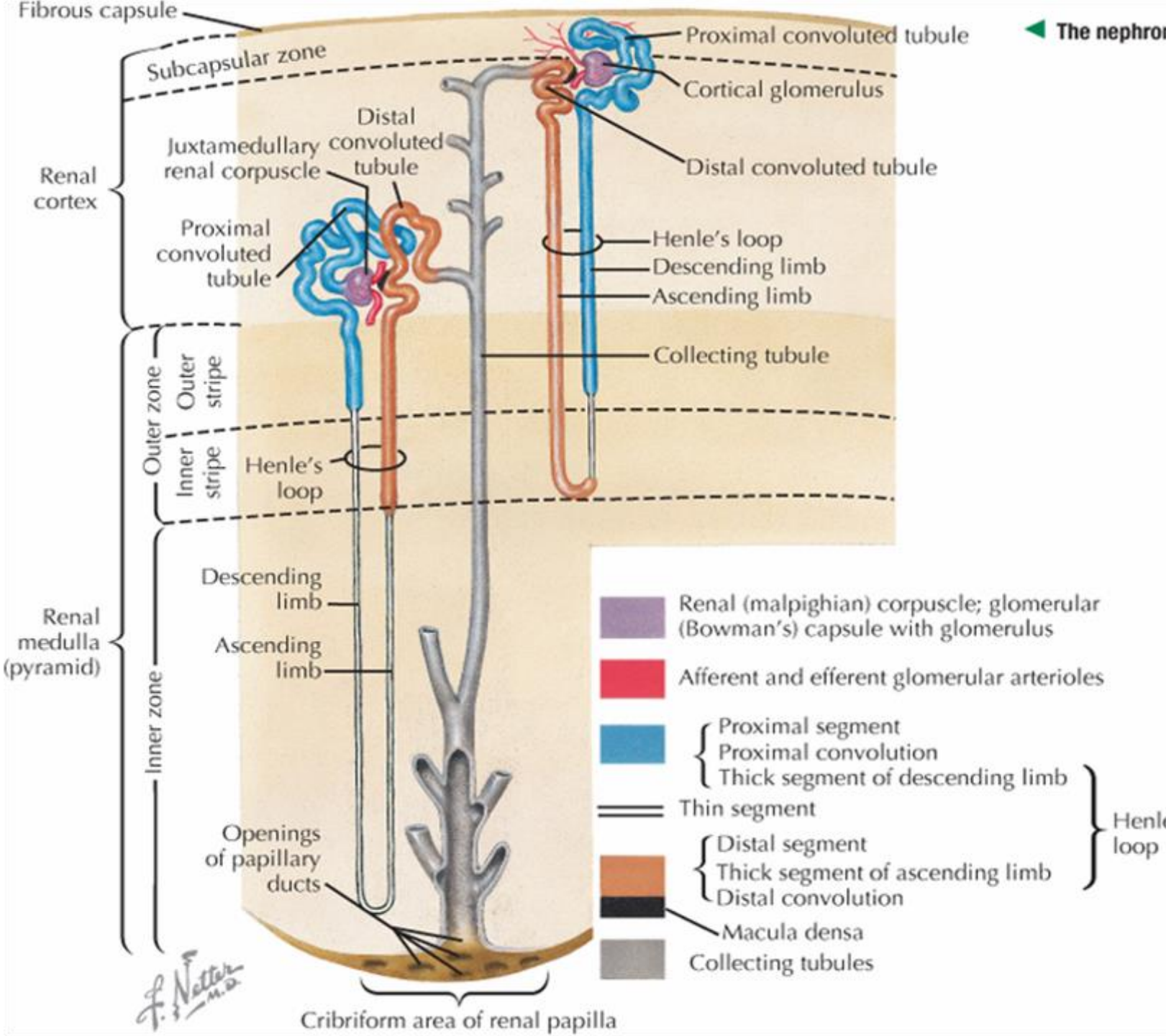
PT absorbs about 70% of water and sodium and 100% of glucose, proteins, AAs.

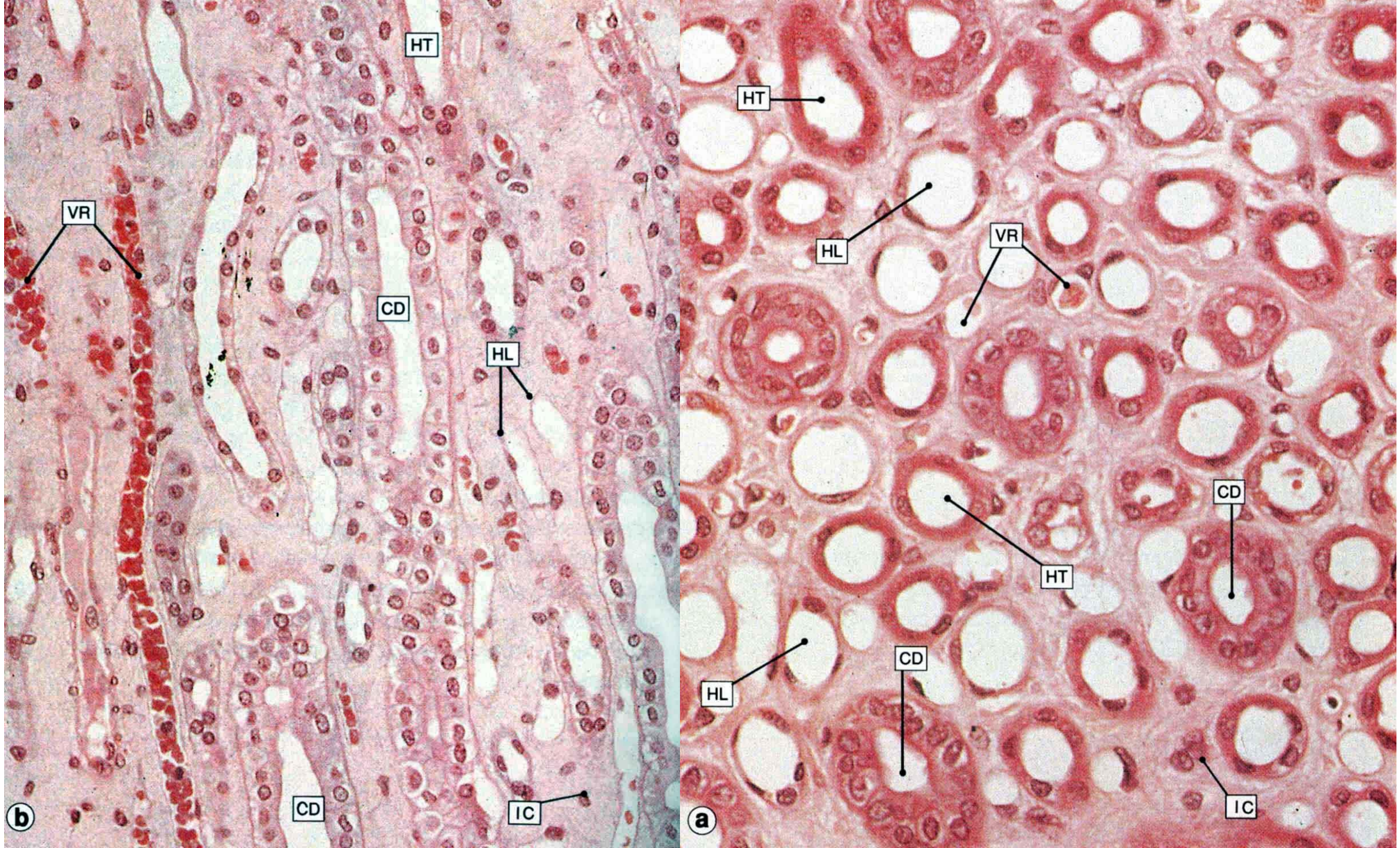
LoH – medulla ECF concentration (up to 1200 mOsm/l in humans, 9000 mOsm/l in this mouse).

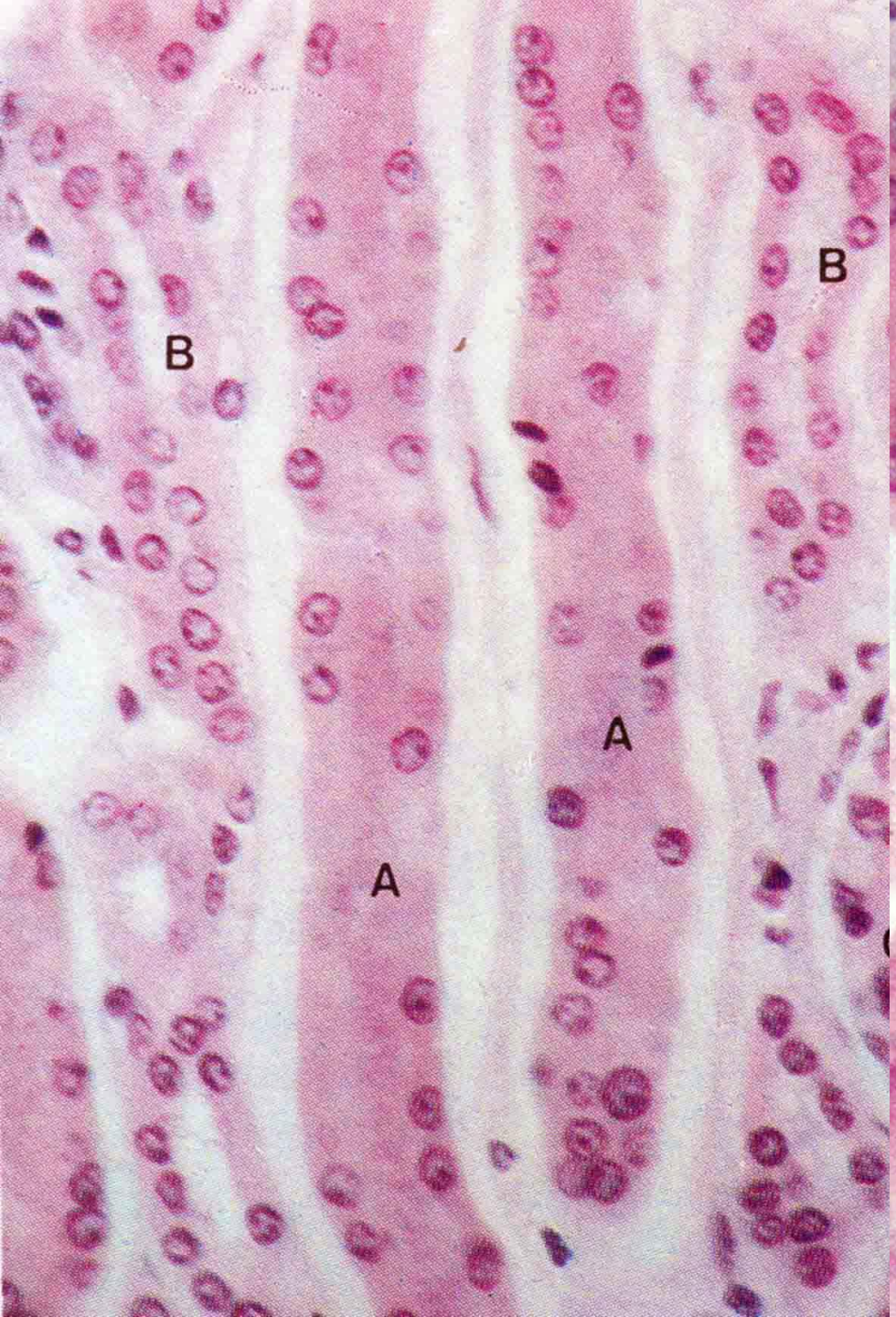


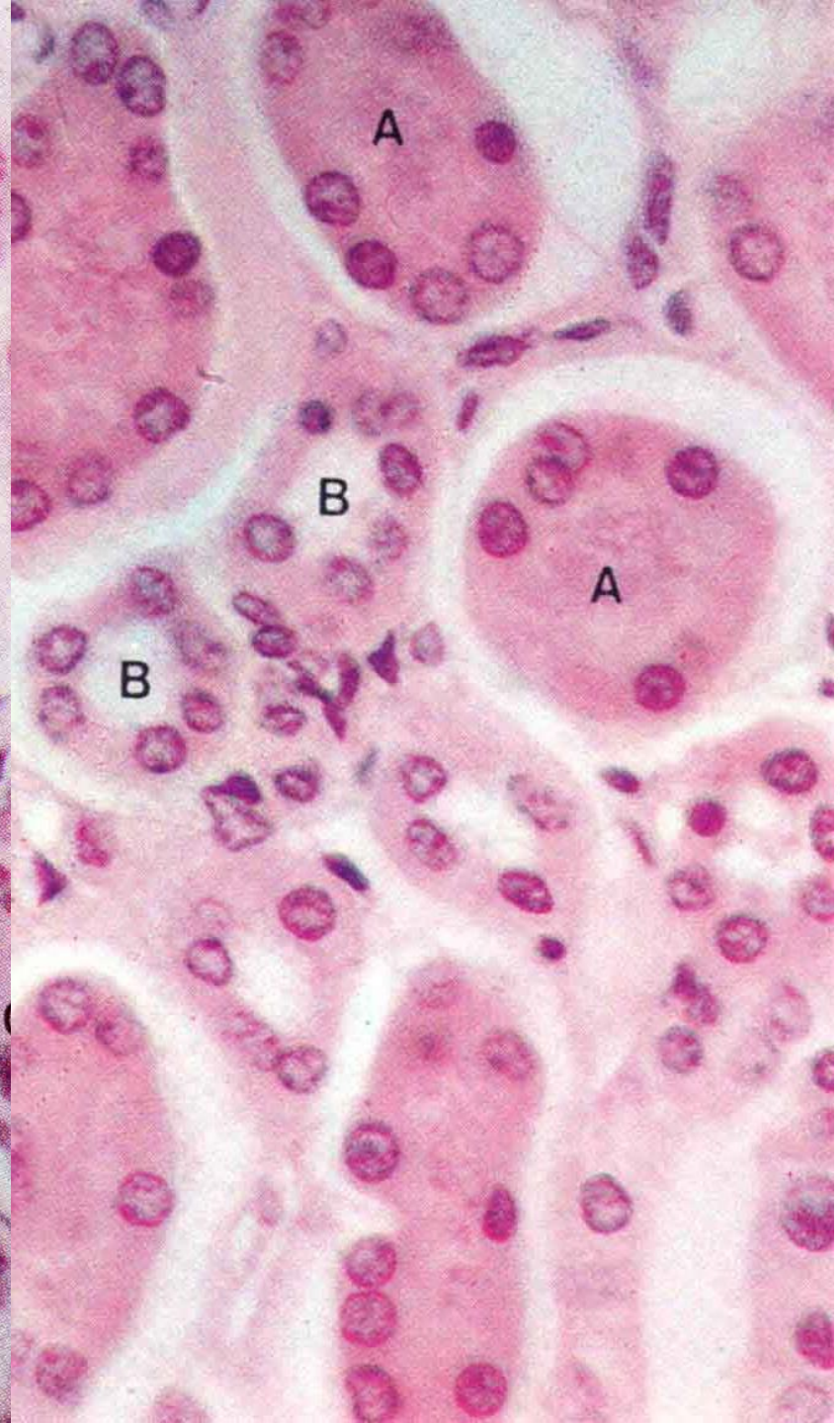
The **loop of Henle** is longer in juxtamedullary nephrons.

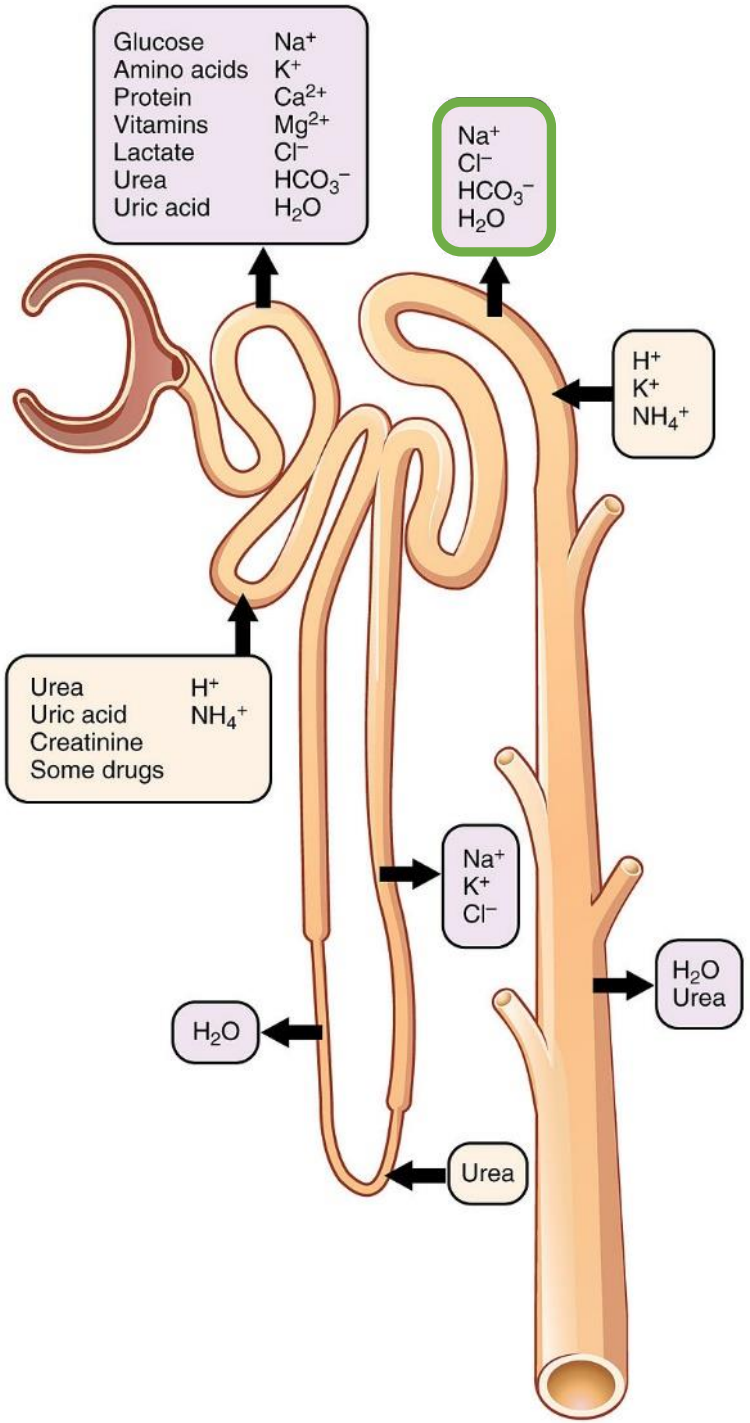
proximal straight tubule = thick descending limb of the loop of Henle
thin descending limb + thin ascending limb = ductus intermedius
thick ascending limb = distal straight tubule




HT
VR
CD
HL
CD
IC
b
HT
HL
VR
CD
HT
HL
CD
IC
a

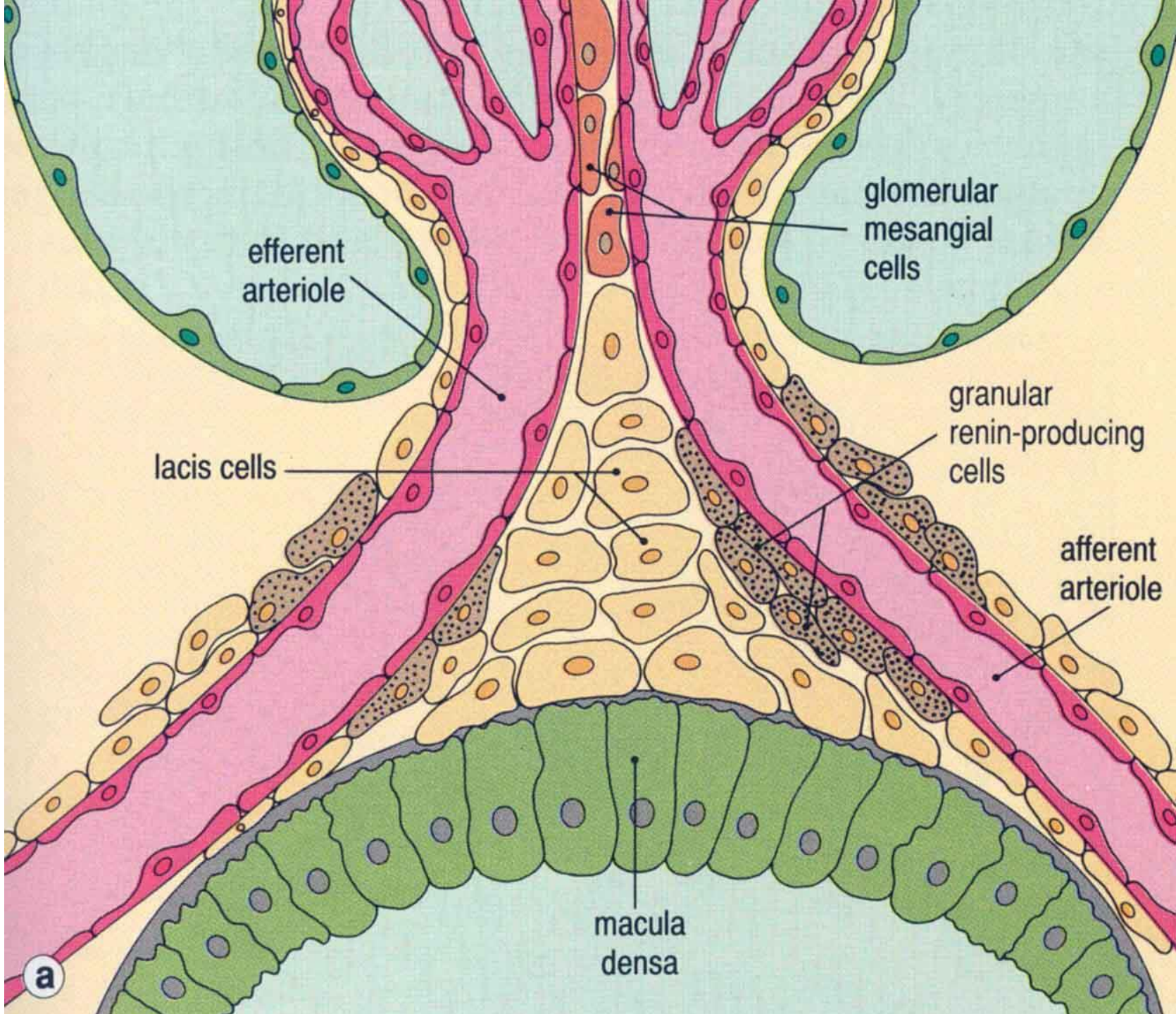

B
B
A
A


A
B
A
B

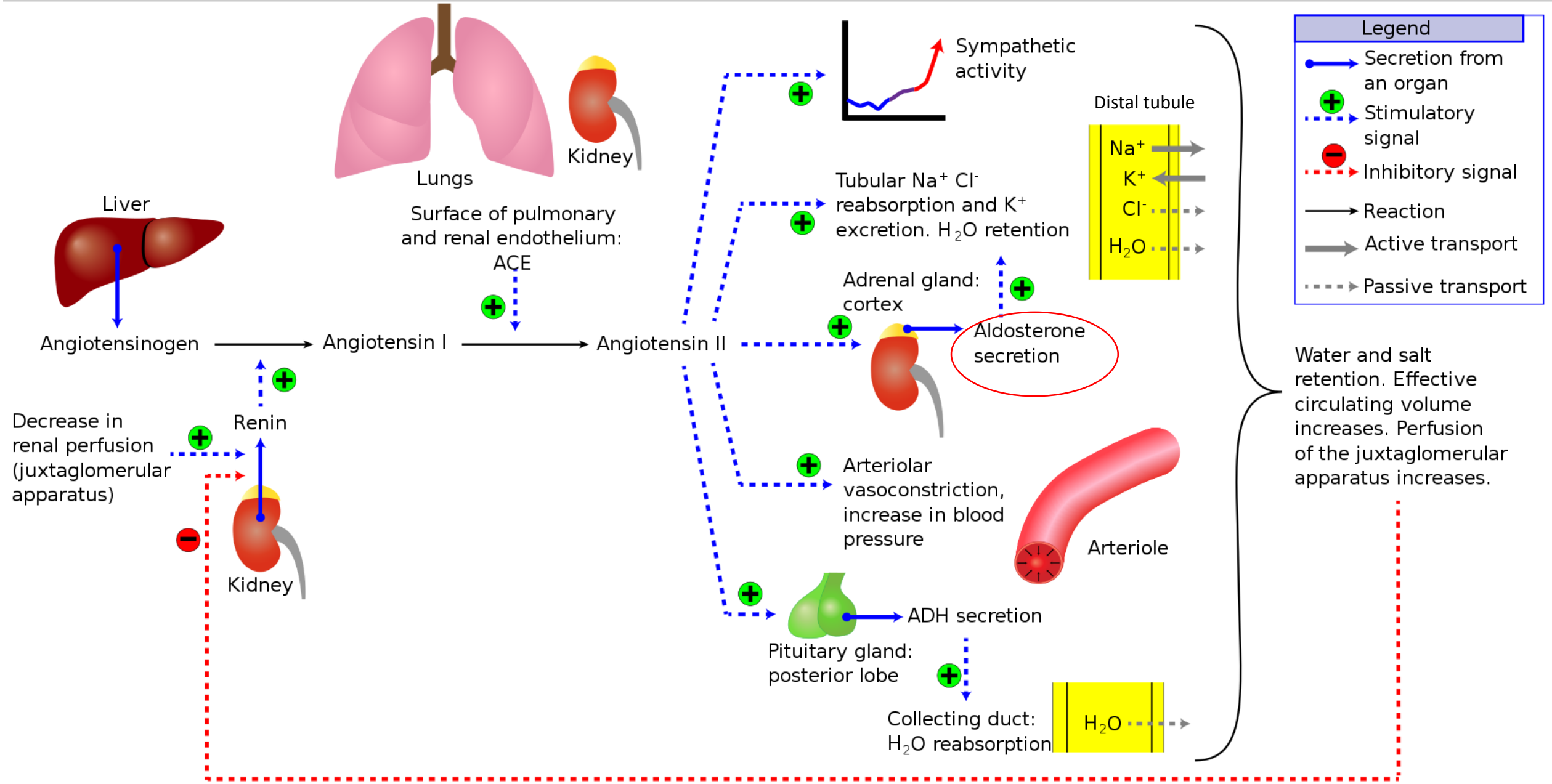

Glucose
Amino acids
Protein
Vitamins
Lactate
Urea
Uric acid
Na+
K+
Ca2+
Mg2+
Cl−
HCO3−
H2O
Na+
Cl−
HCO3−
H2O
H+
K+
NH4+
Urea
Uric acid
Creatinine
Some drugs
H+
NH4+
Na+
K+
Cl−
H2O
H2O
Urea
Urea

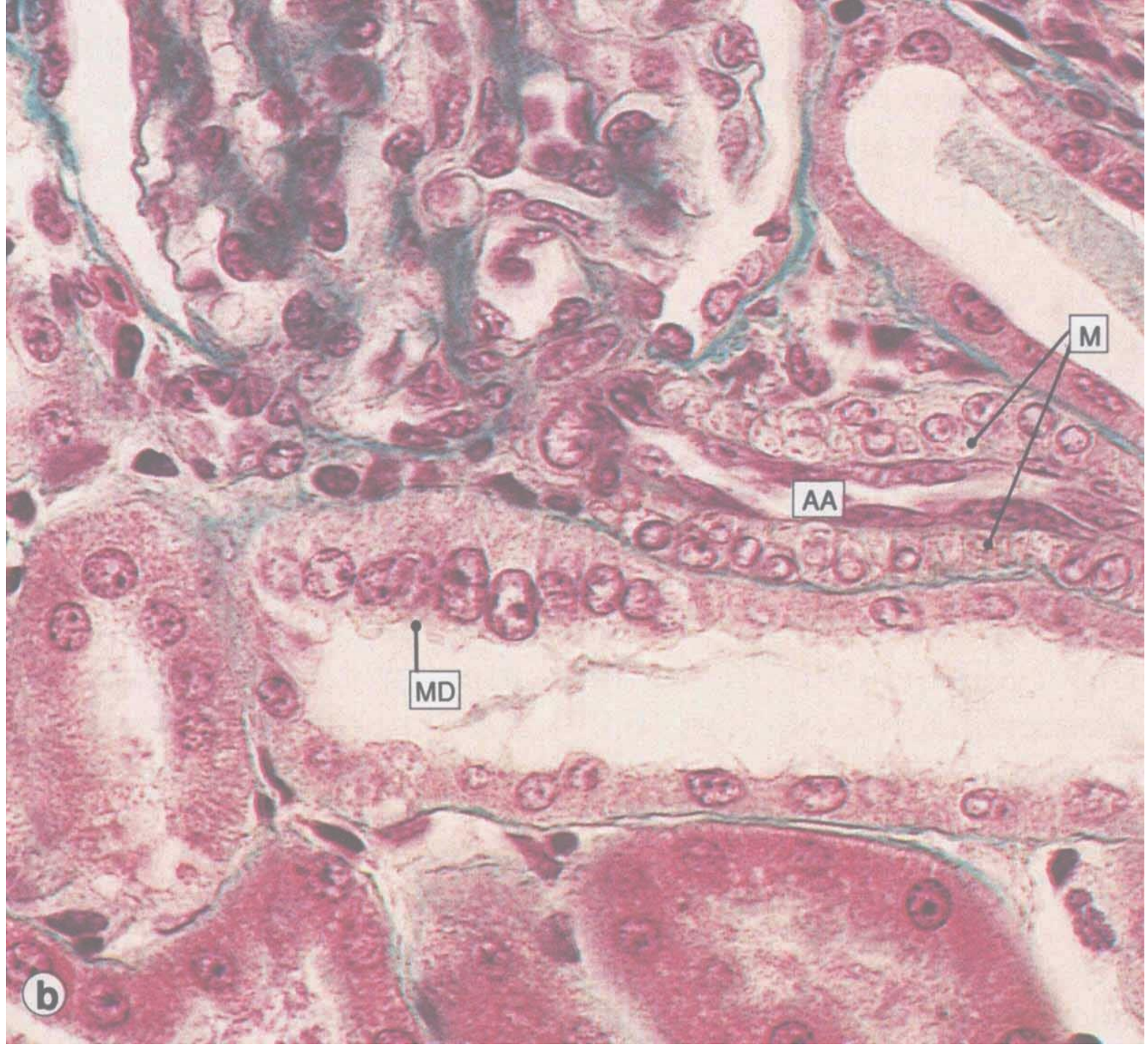

NOOTRY

Juxtaglomerular apparatus senses the amount of fluid and sodium in the distal tubule through macula densa. The release of renin increases when the concentration of sodium is low. It also increases the resistance of the afferent arteriole.

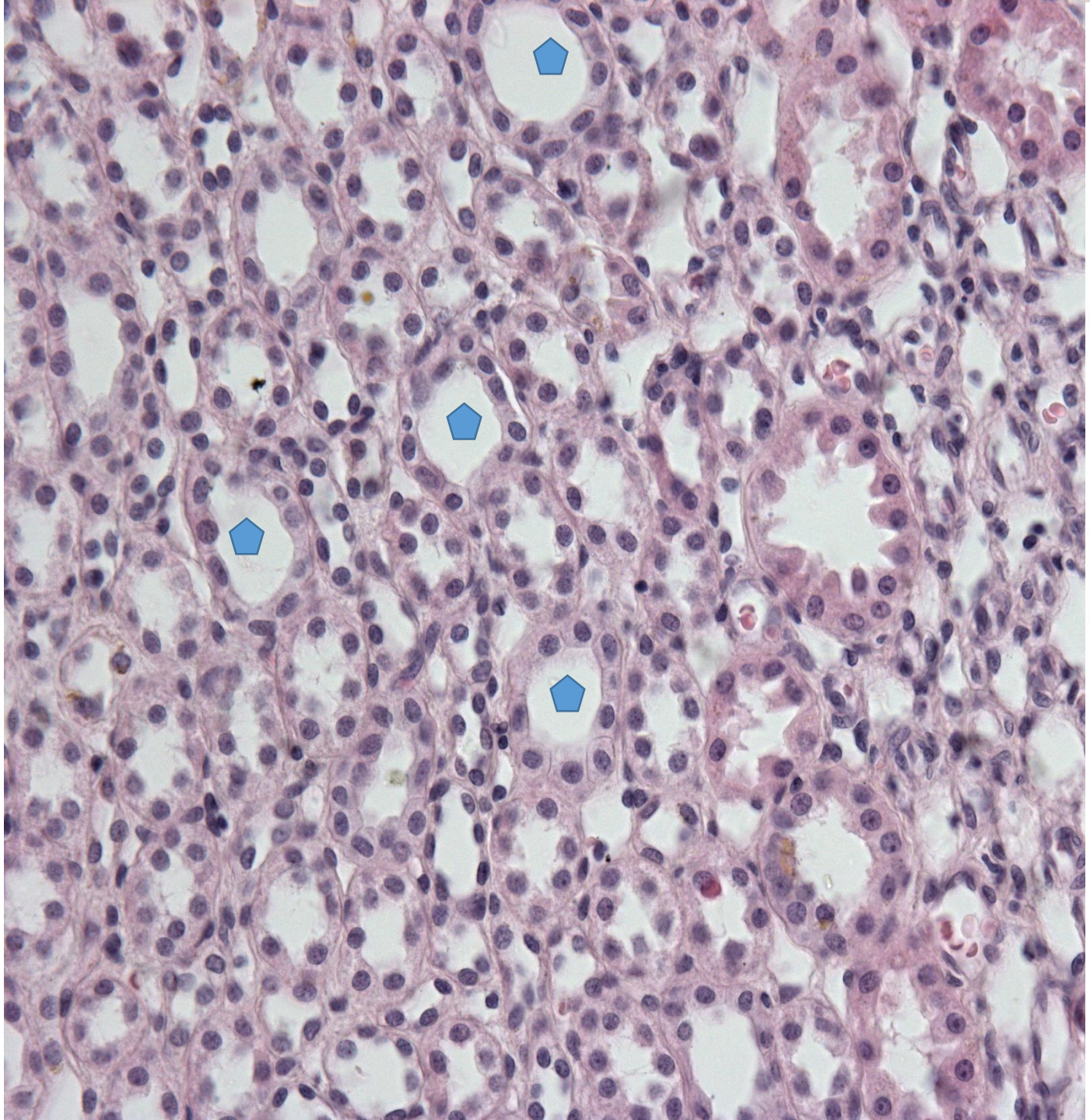


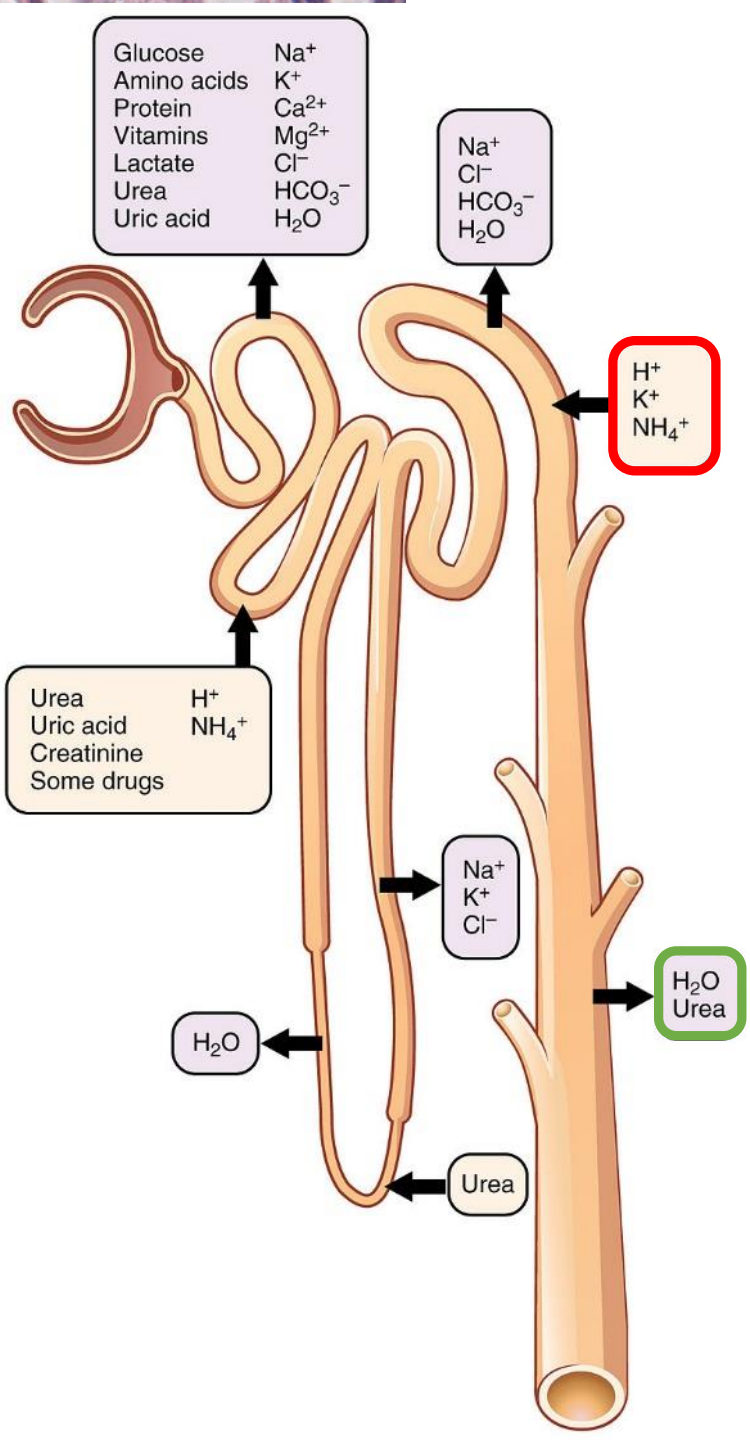
Renin–angiotensin–aldosterone system



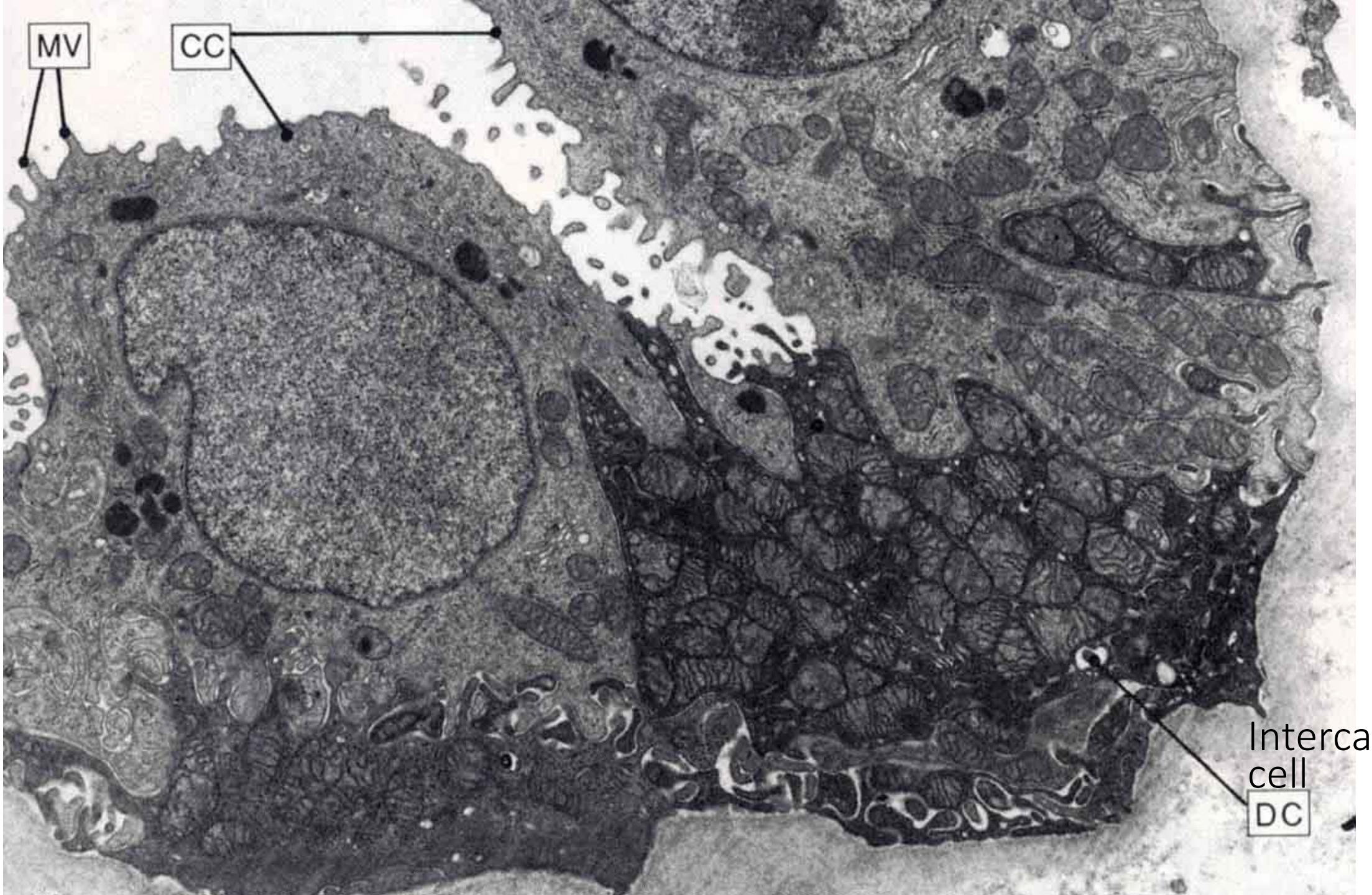

M
AA
MD
b

Section of medulla, some collecting ducts marked





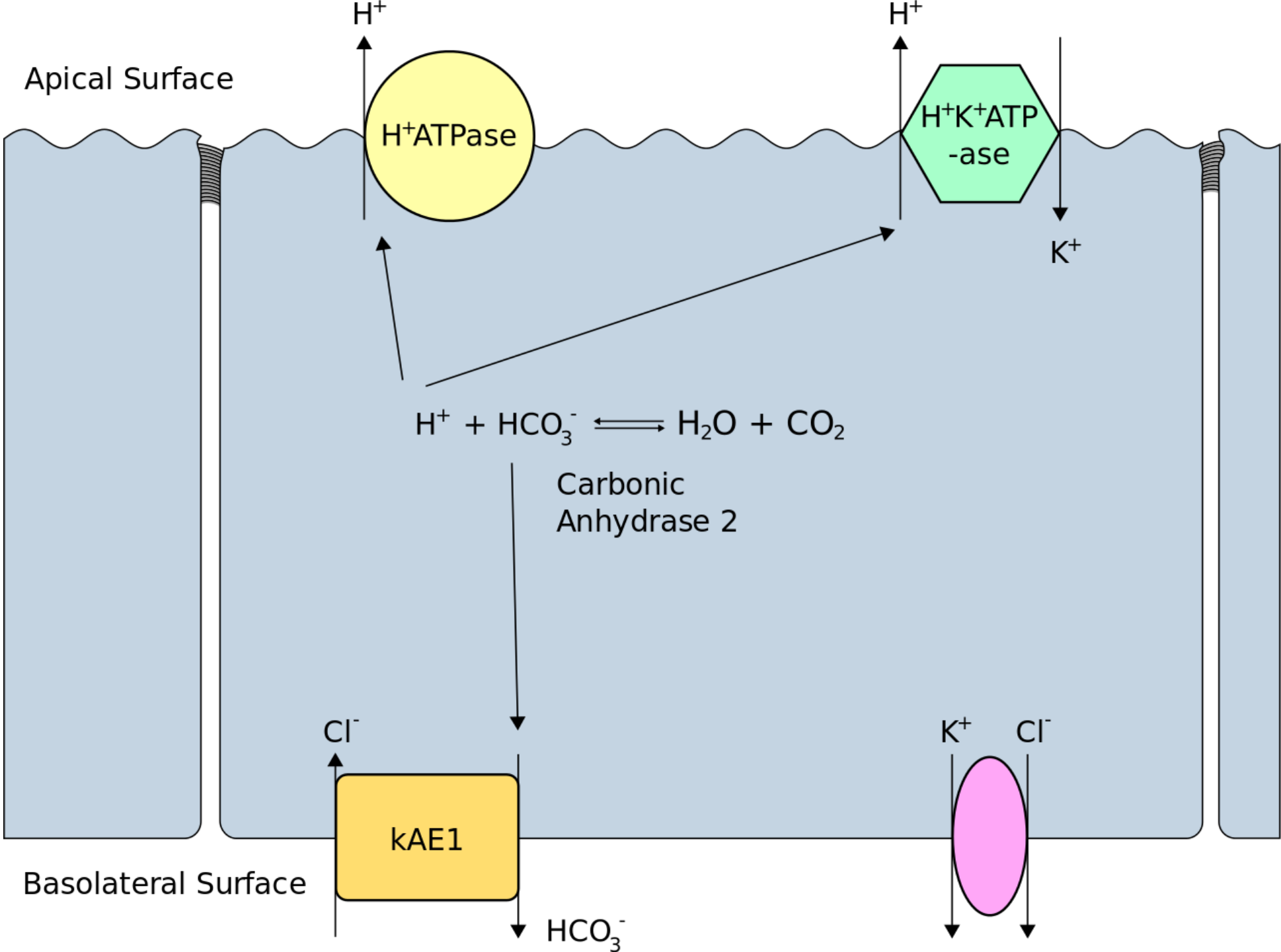
Principal cells of the collecting system contain aquaporin.



Intercalated cell

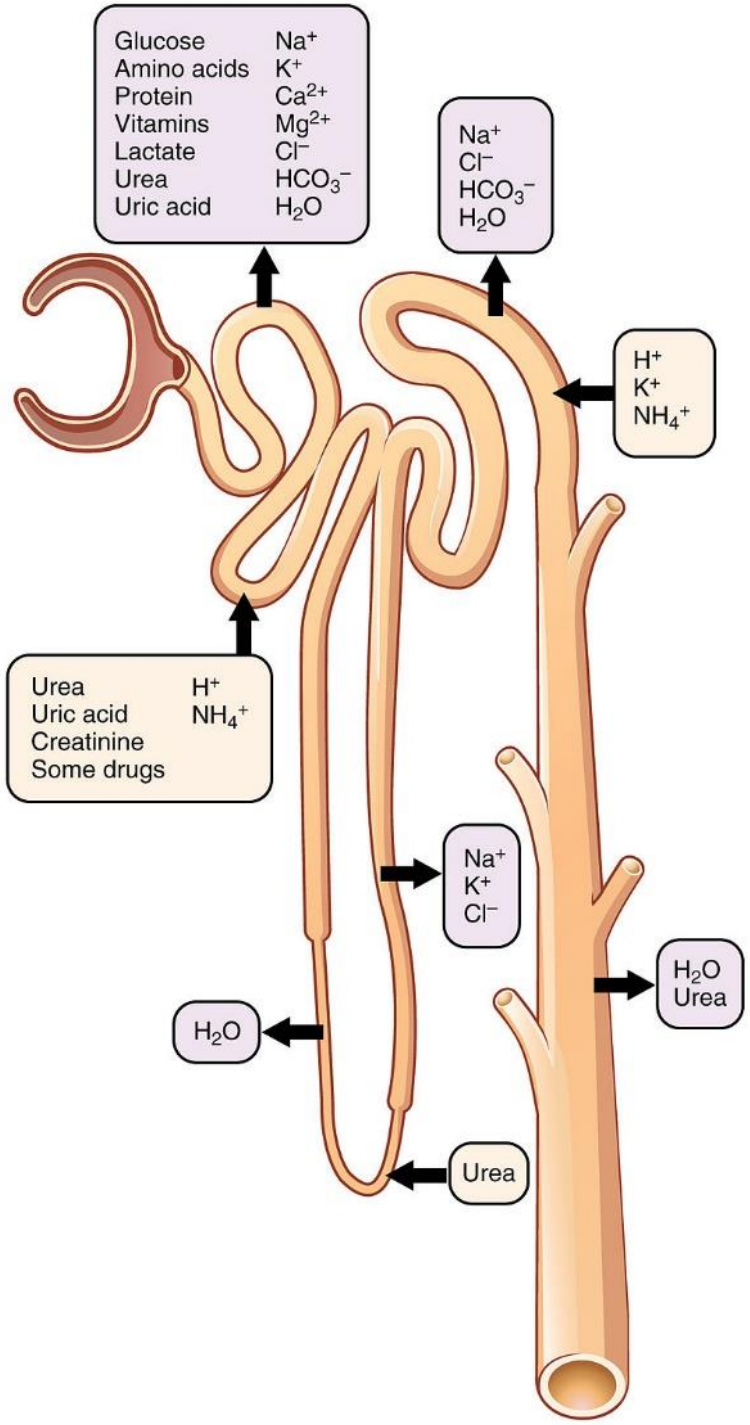
Intercalated cell

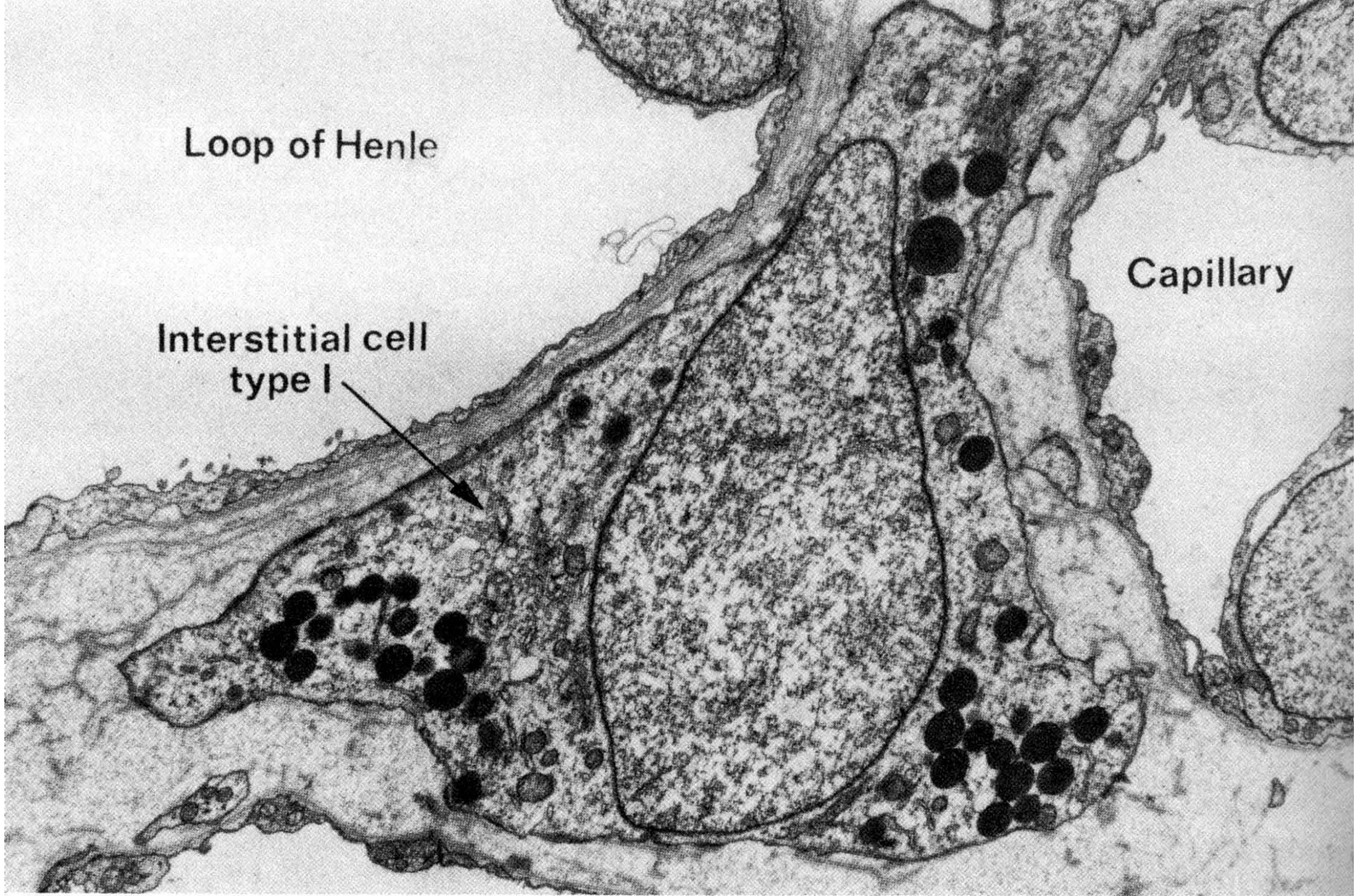
Have you already seen similar cells?



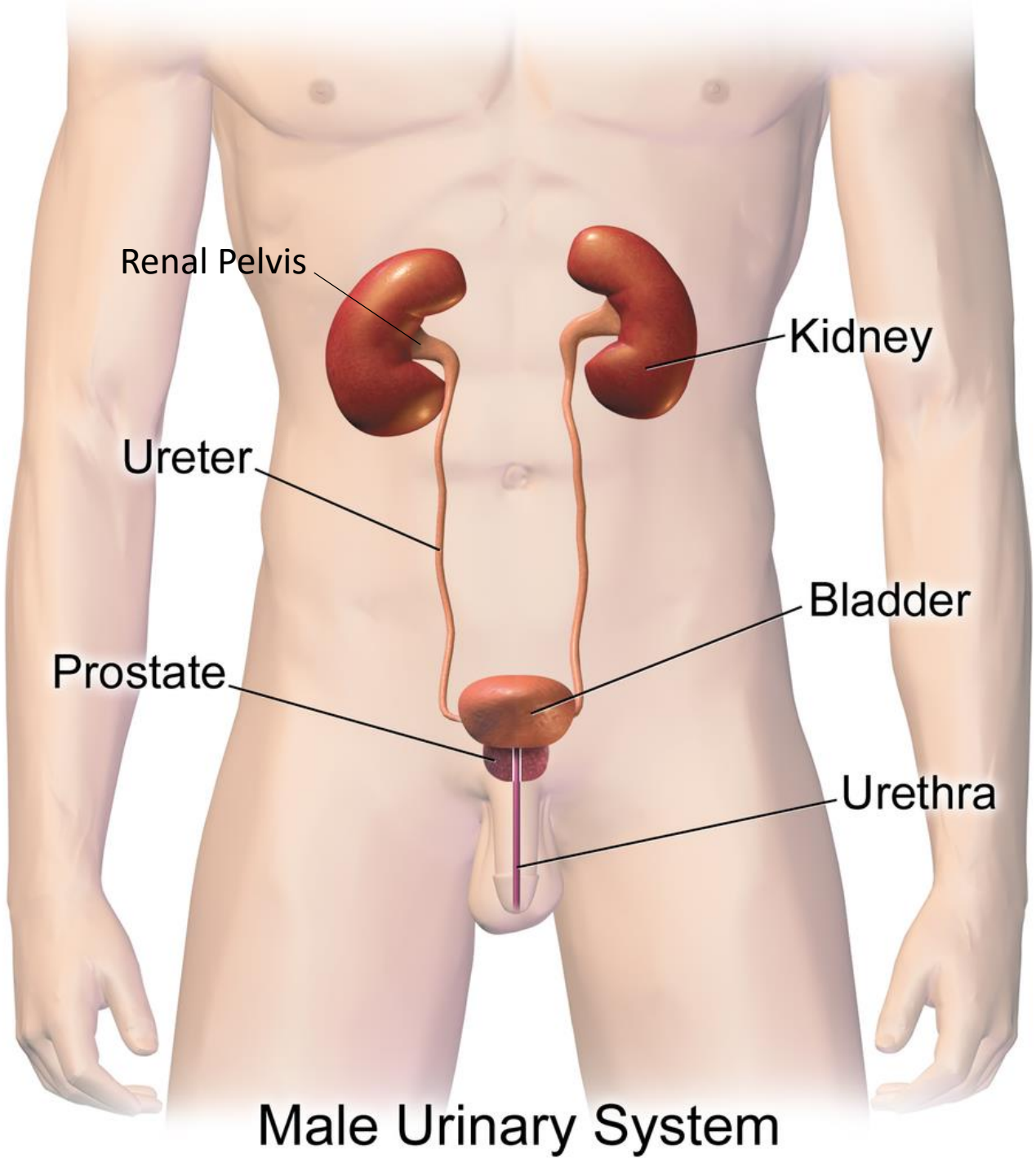
Functional arrangement of the kidney

- Renal corpuscle
  - Glomerulus (convoluted porous capillaries), Bowman‘s capsule with podocytes in its visceral layer and simple squamous epithelium in its parietal layer
- Tubules
  - Proximal tubules (most absorption)
  - Loop of Henle (concentration of medullary ECF)
  - Distal tubule (ion absorption) regulated by aldosteron
- Collecting tubules and ducts (not a part of a nephron)
  - CDs (water absorption, urine acidity) regulated by ADH

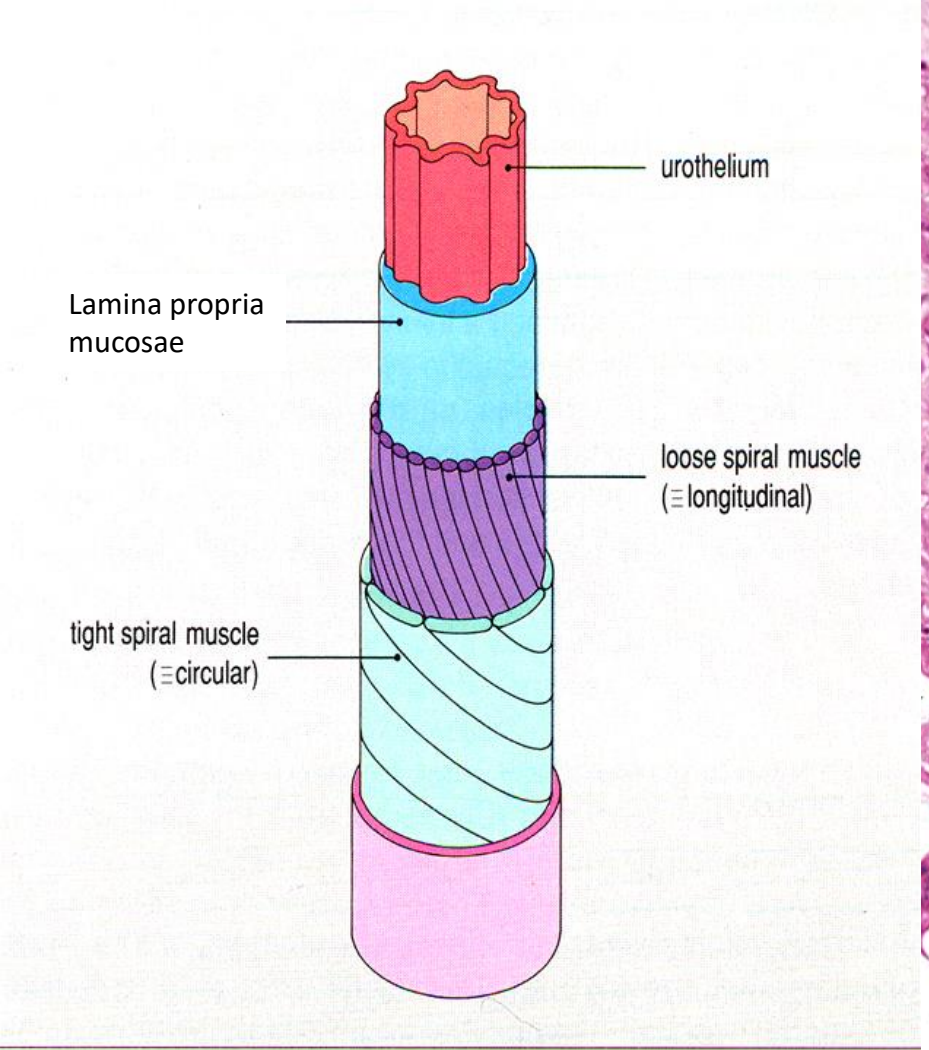



Loop of Henle
Capillary
Interstitial cell
type I

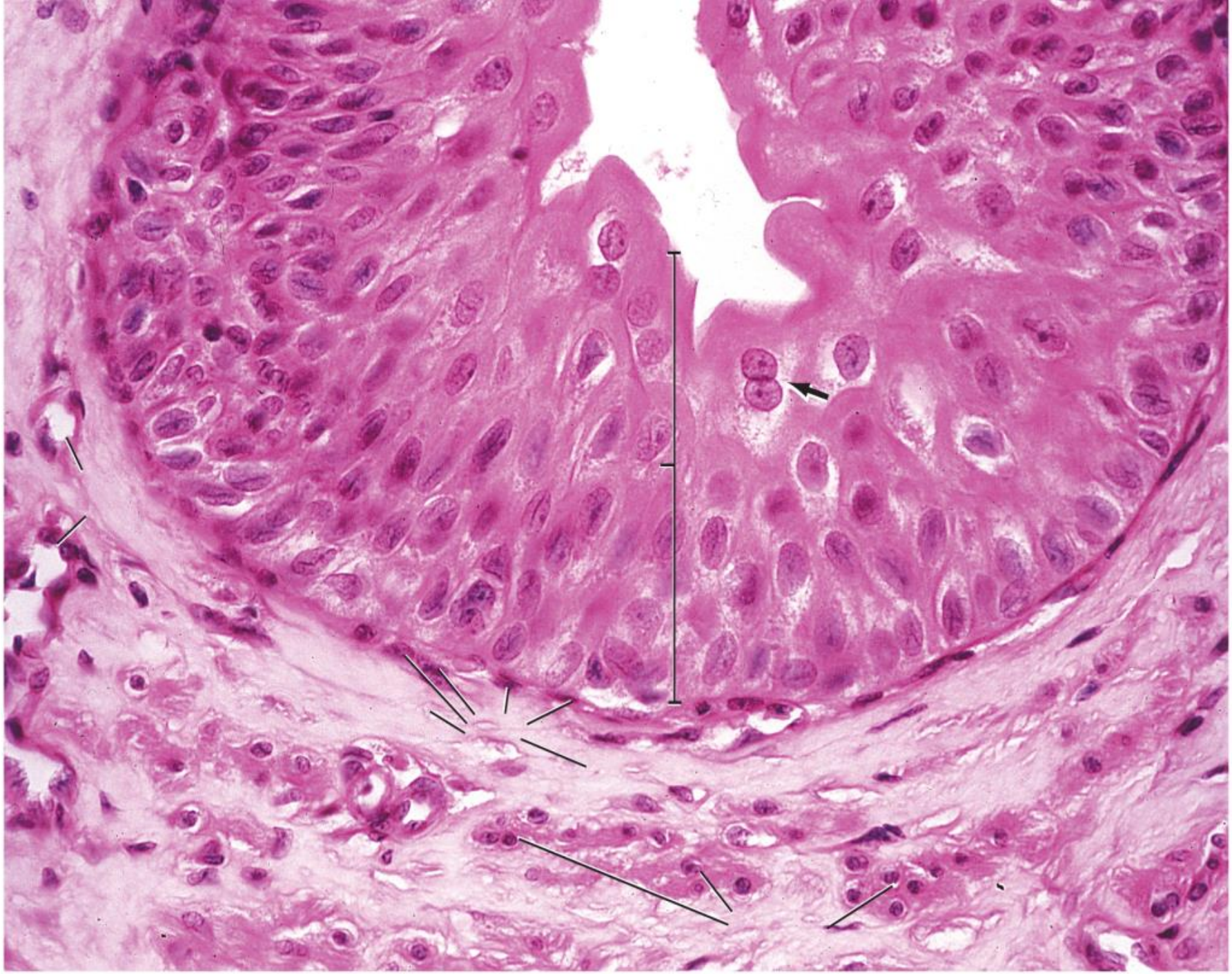
Excretory pathways: calyx minor, calyx maior, pelvis renalis, ureter, vesica urinaria, urethra

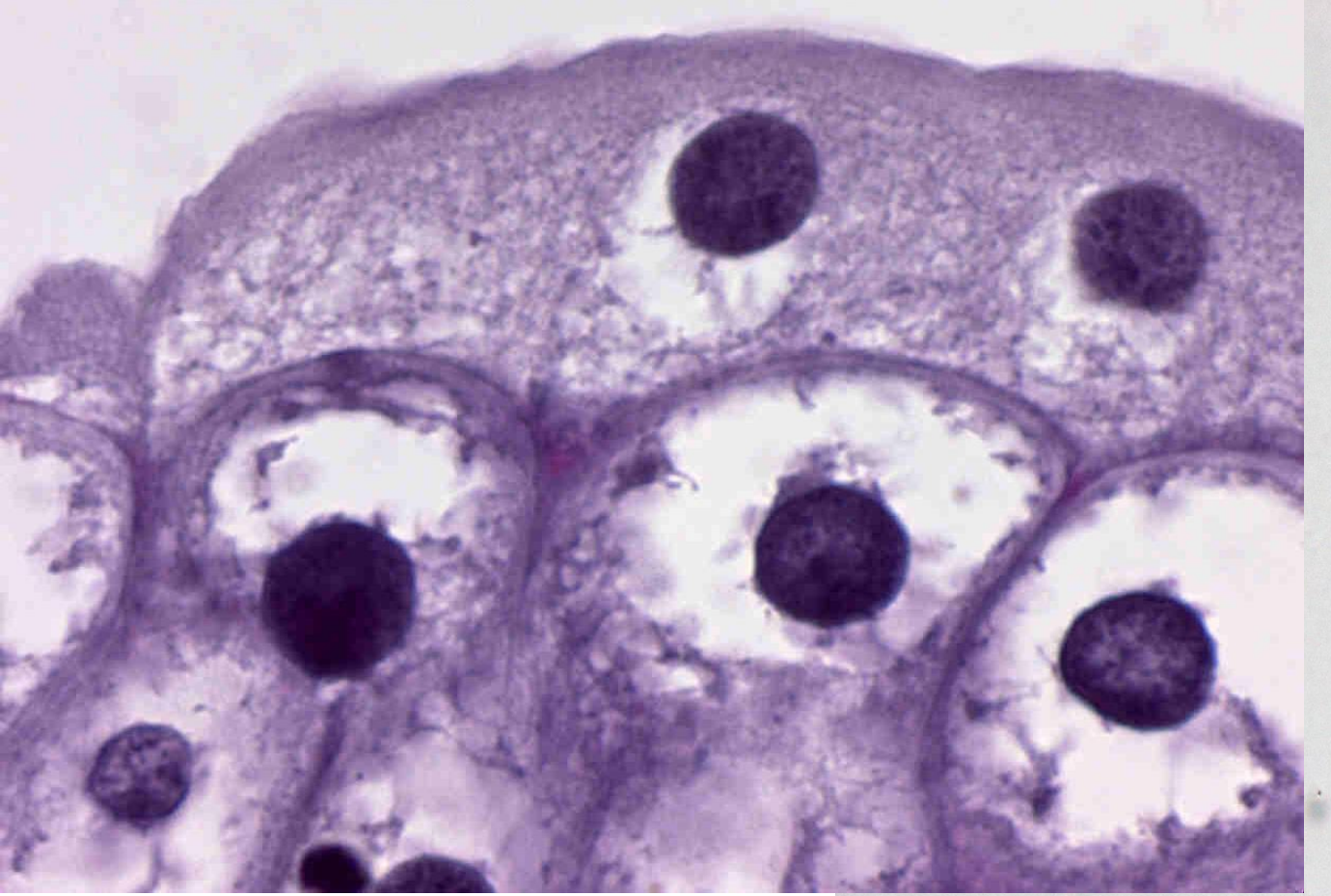


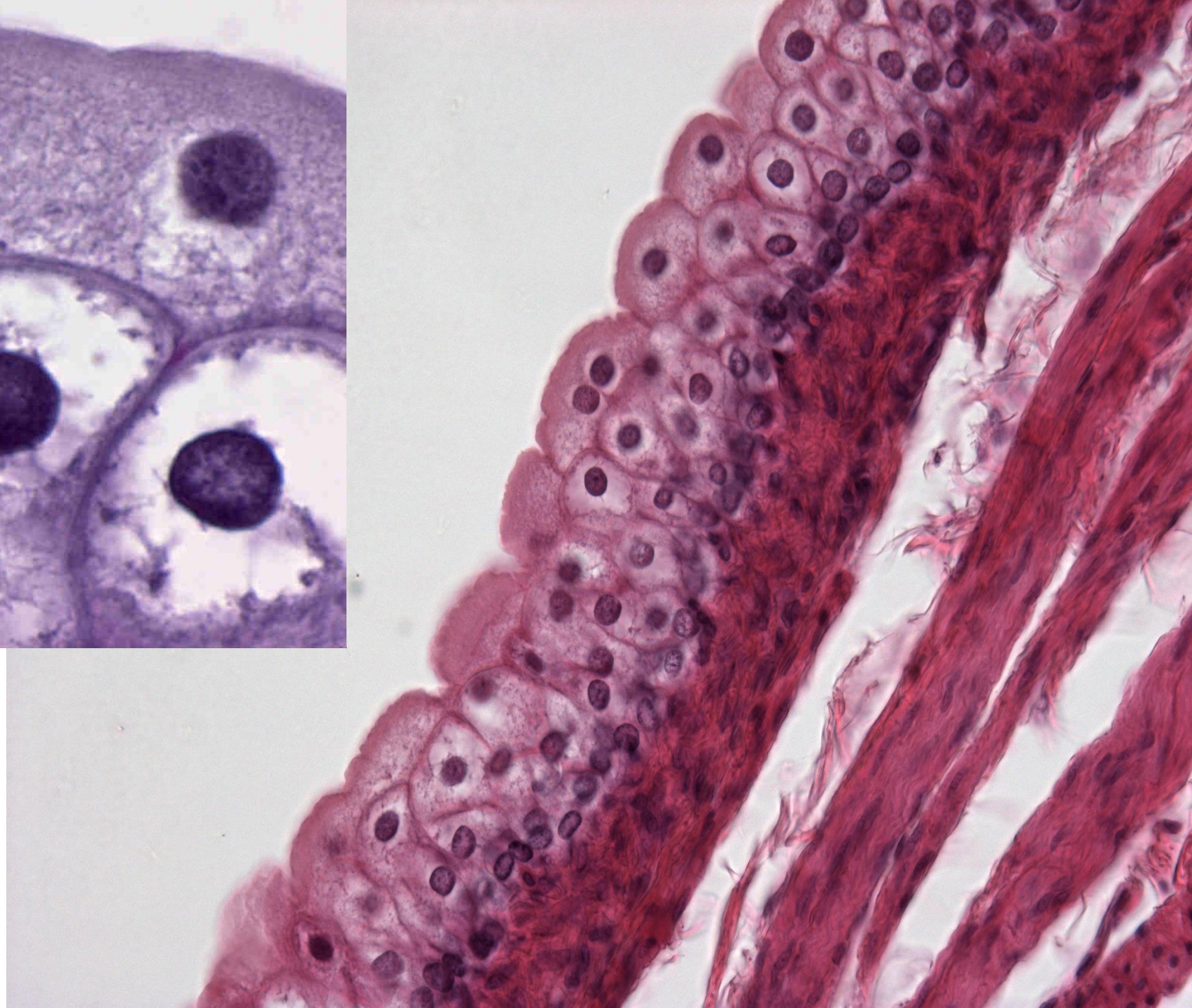
Excretory passages



Transitional epithelium (urothelium)

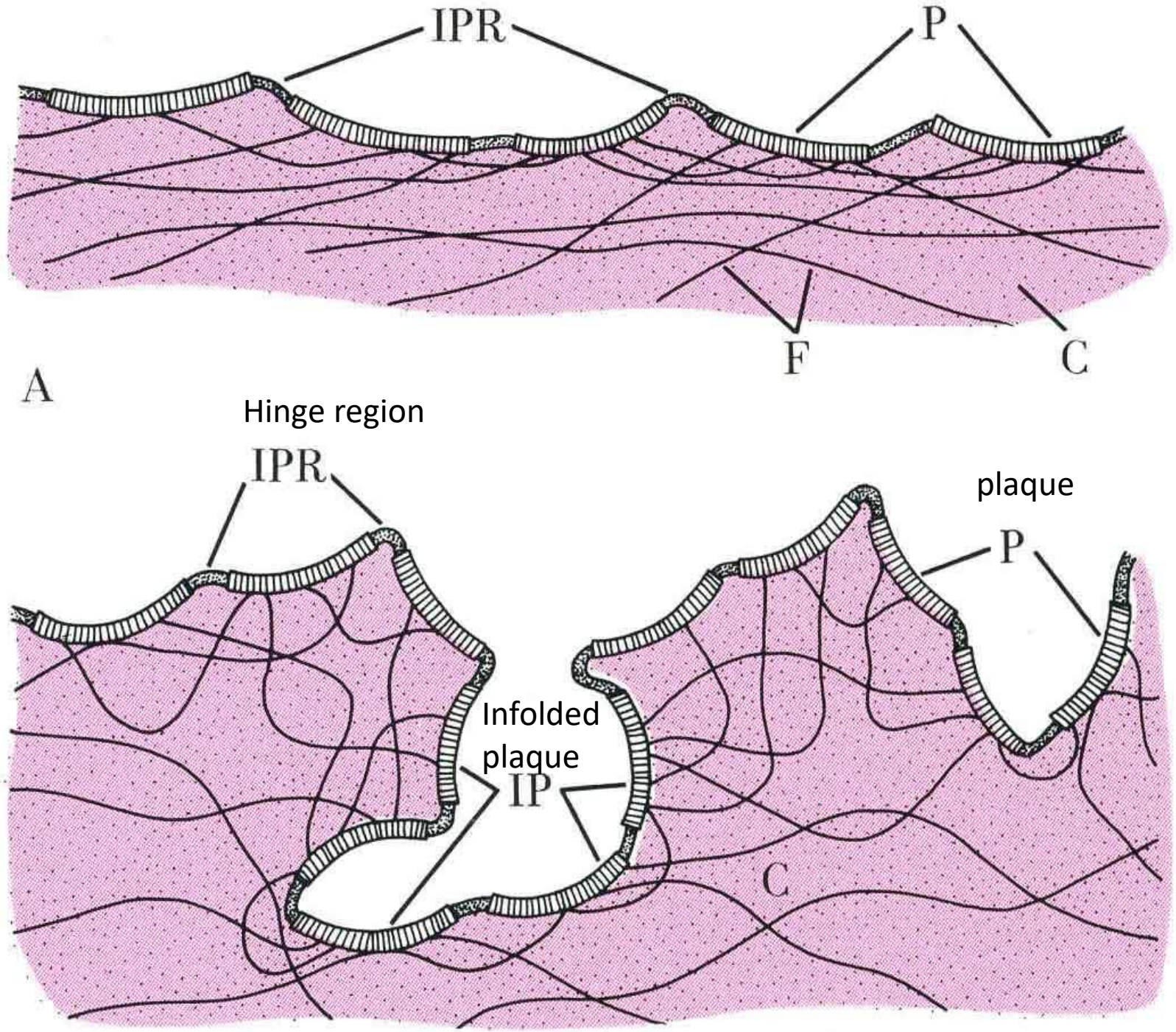




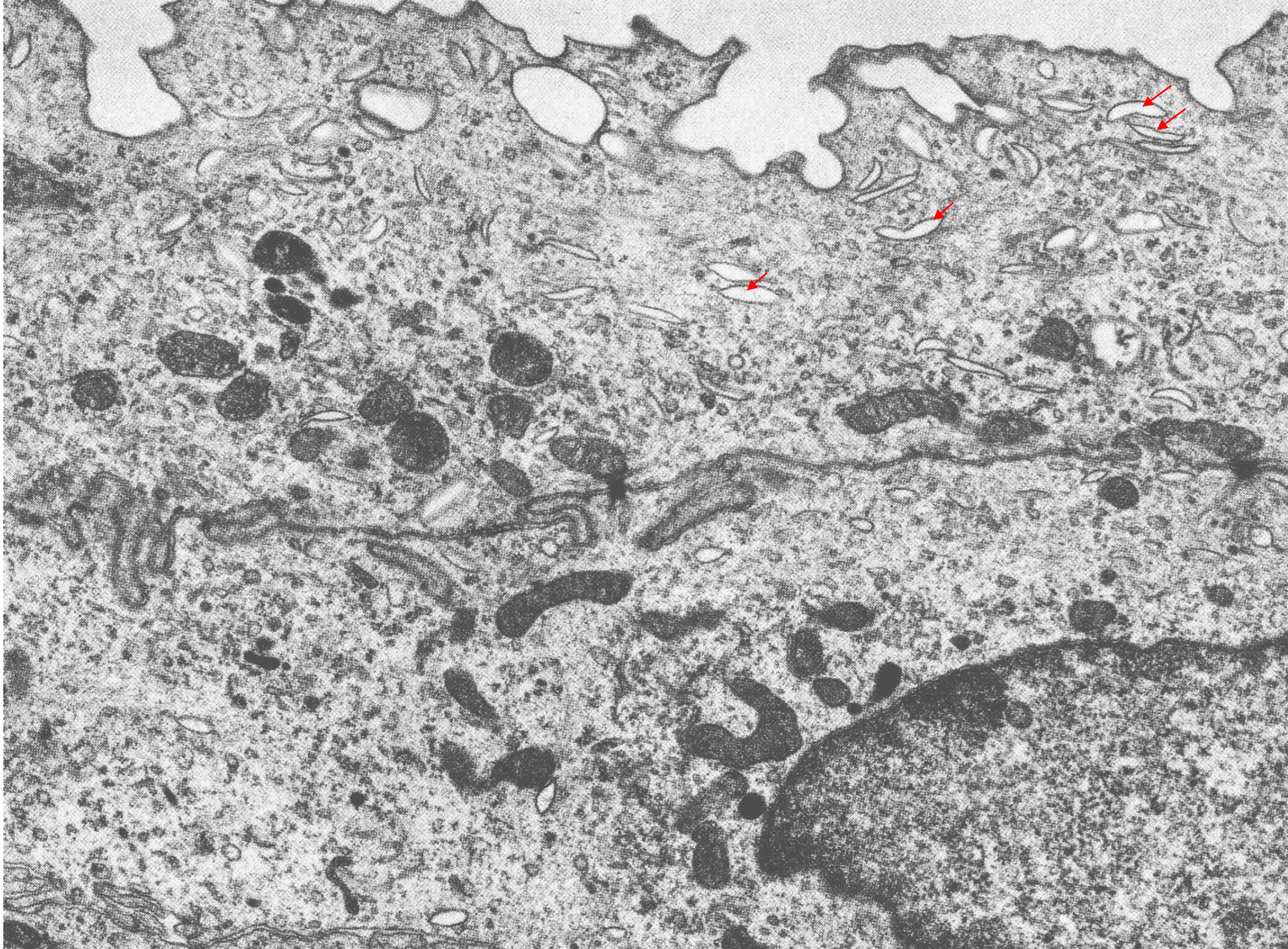


Transitional epithelium (urothelium) – umbrella cells

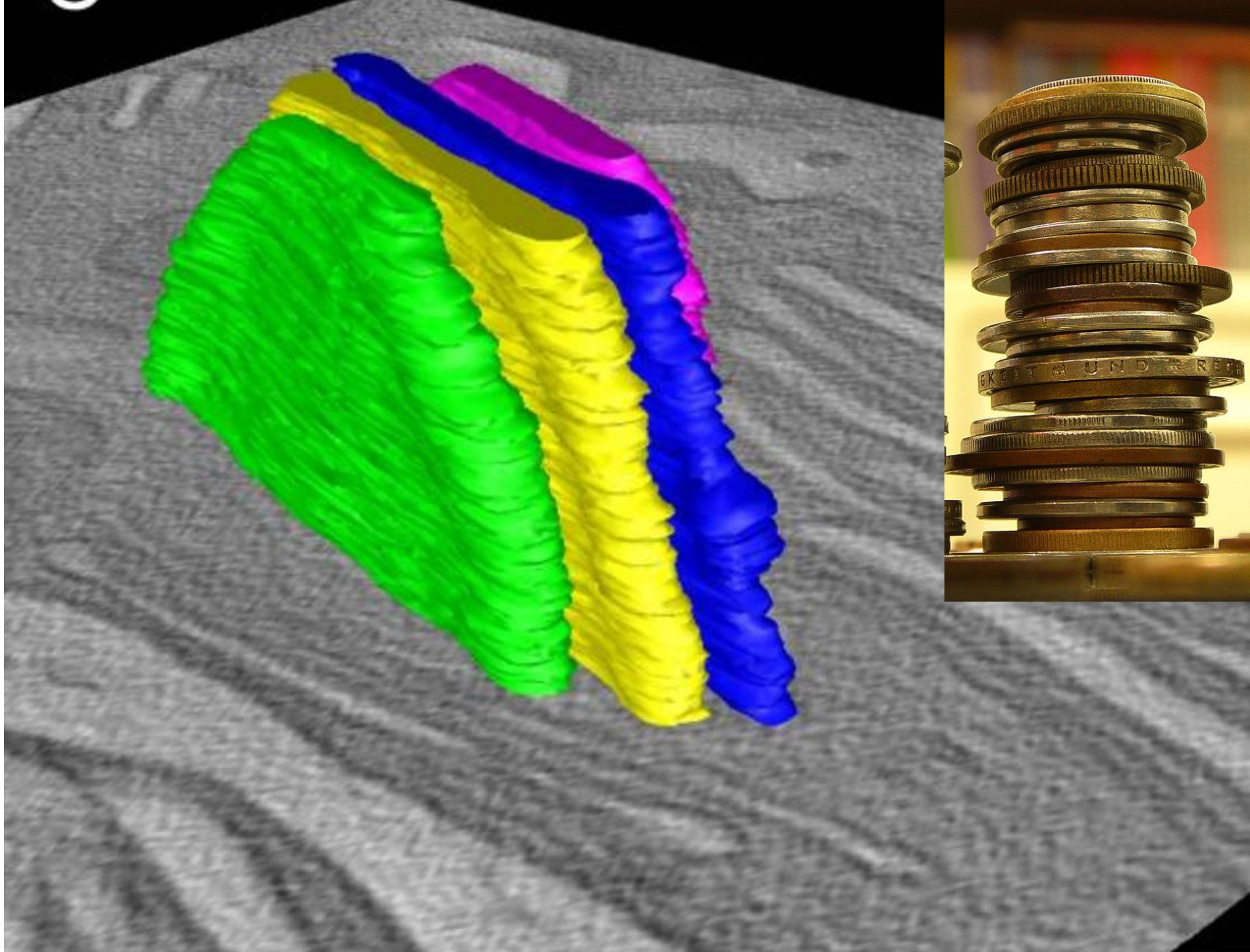
Transitional epithelium (urothelium) – plaques containing uroplakins. Their infolding can appear as a fusiform vesicle. These vesicles serve as a reserve to increase the membrane surface area during distension.



Uroplakins cause the unusual shape of the apical membrane. Note multiple fusiform vesicles (red arrows).



3D imaging of the fusiform vesicles

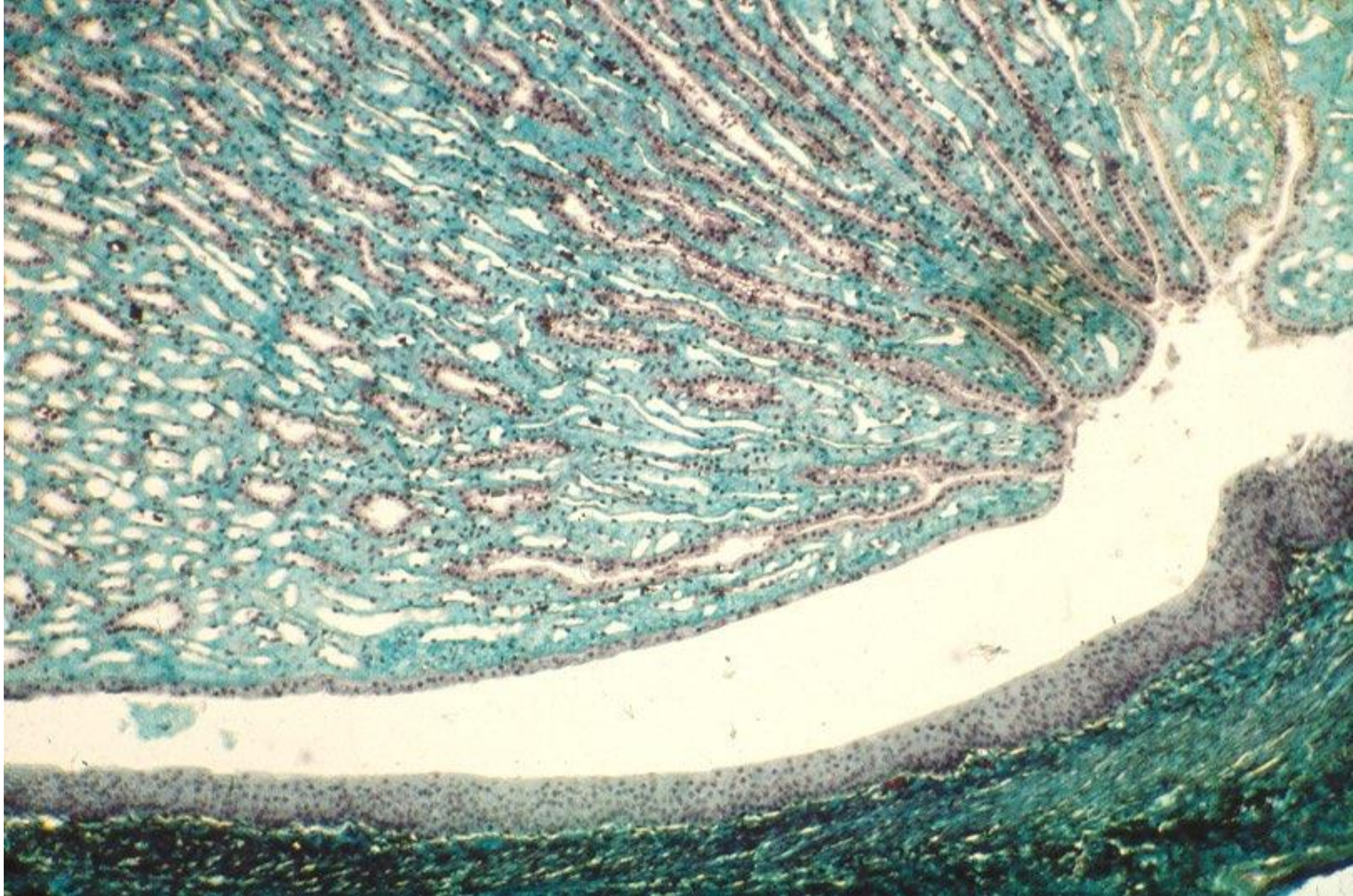


Hudoklin S, Jezernik K, Neumüller J, Pavelka M, Romih R. Electron tomography of fusiform vesicles and their organization in urothelial cells. PLoS One. 2012;7(3):e32935. doi: 10.1371/journal.pone.0032935. Epub 2012 Mar 12. PMID: 22427911; PMCID: PMC3299716.

Urothelium

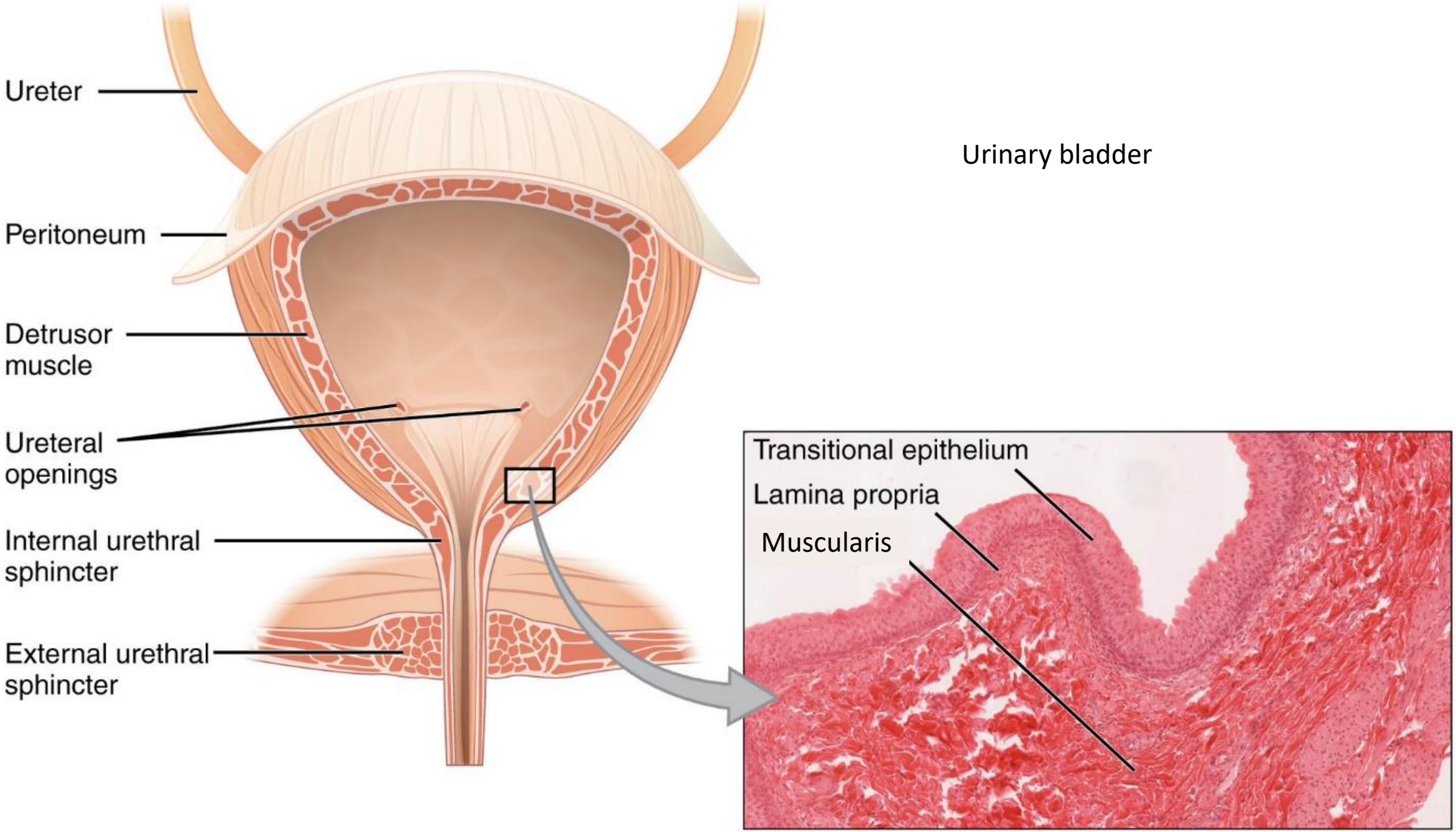
- Transitional epithelium (urothelium) is a type of epithelium specific for the excretory pathway of the urinary system
- In male urethra, it is only found in the two proximal parts (pars vesicalis, pars prostatica), in female urethra in proximal portion
- It is adapted for changes in volume of these organs
- The cells of the superficial layer are called the umbrella cells, they can change their shape and contain uroplakins, that contribute to a permeability barrier
- Fusiform vesicles with uroplakin-containing membrane can be used to expand apical cell membrane during distension

Minor calyx

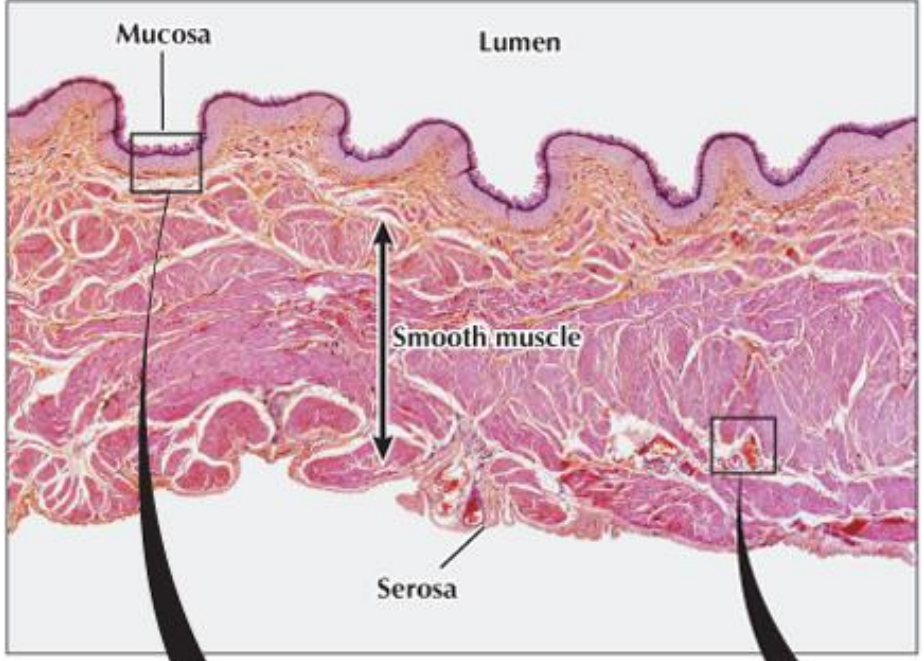


Urether has three layers of muscularis (l, c, l)

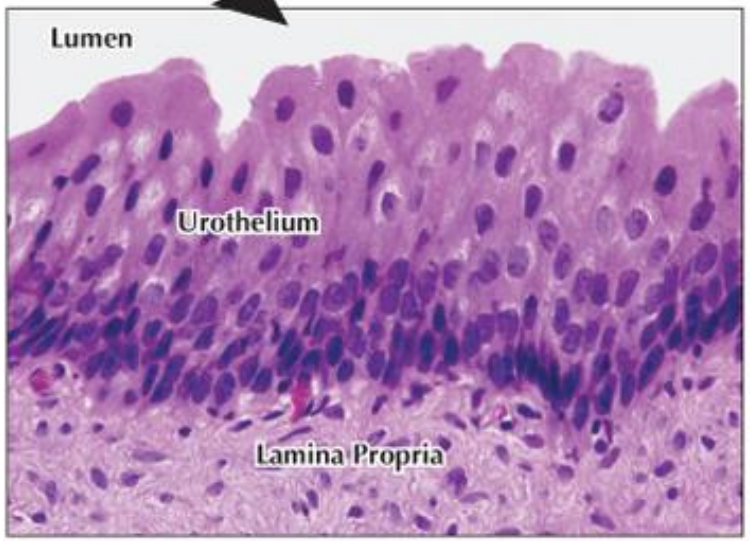
Urinary bladder



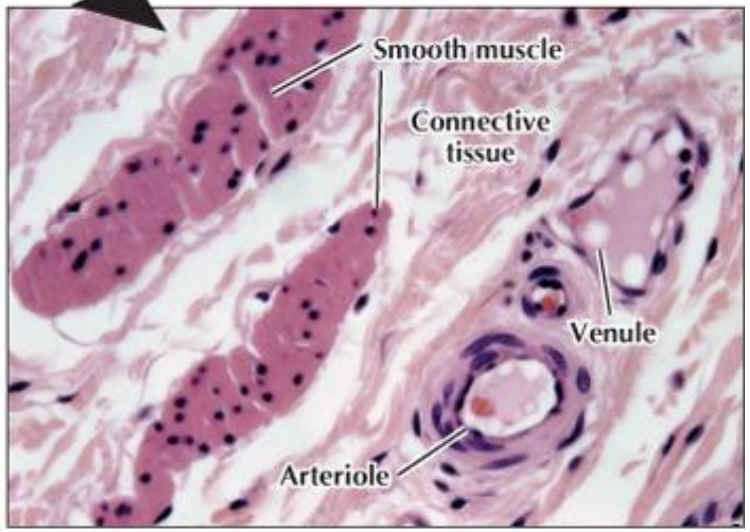
Urinary bladder



◀ **LM of the wall of the urinary bladder in transverse section.** The mucosa, according to the degree of distention, may look corrugated, with irregular longitudinal folds created by shape changes. Smooth muscle in the muscularis externa is thicker than that of the ureter. The superior bladder surface is covered externally by a serosa of peritoneum rather than by adventitia, the usual outer layer in the rest of the bladder. The serosa consists of connective tissue covered externally by thin, simple squamous epithelium made of a continuous layer of mesothelial cells (not seen at this magnification). 17×. *H&E.*

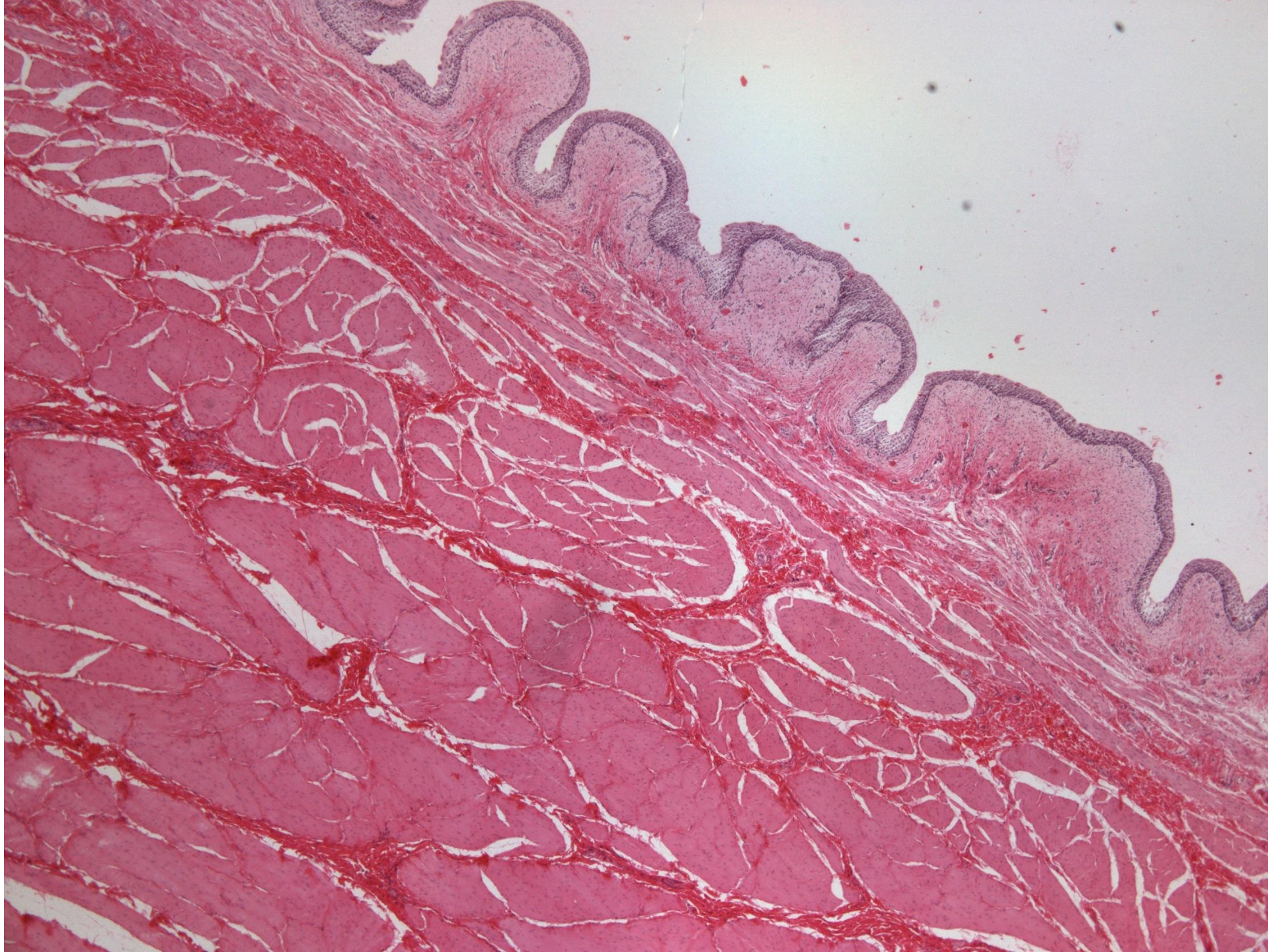


▲ **LM of the mucosa of the bladder at high magnification.** In the empty bladder the urothelium has an increased thickness—up to 8-10 cell layers. The lamina propria is highly fibrous with scattered connective tissue cells and a few capillaries. 420×. *H&E.*



▲ **LM of part of the muscularis externa of the bladder at high magnification.** Fibrous connective tissue surrounds irregular smooth muscle cell bundles. An arteriole and venule are in the area. 420×. *H&E.*

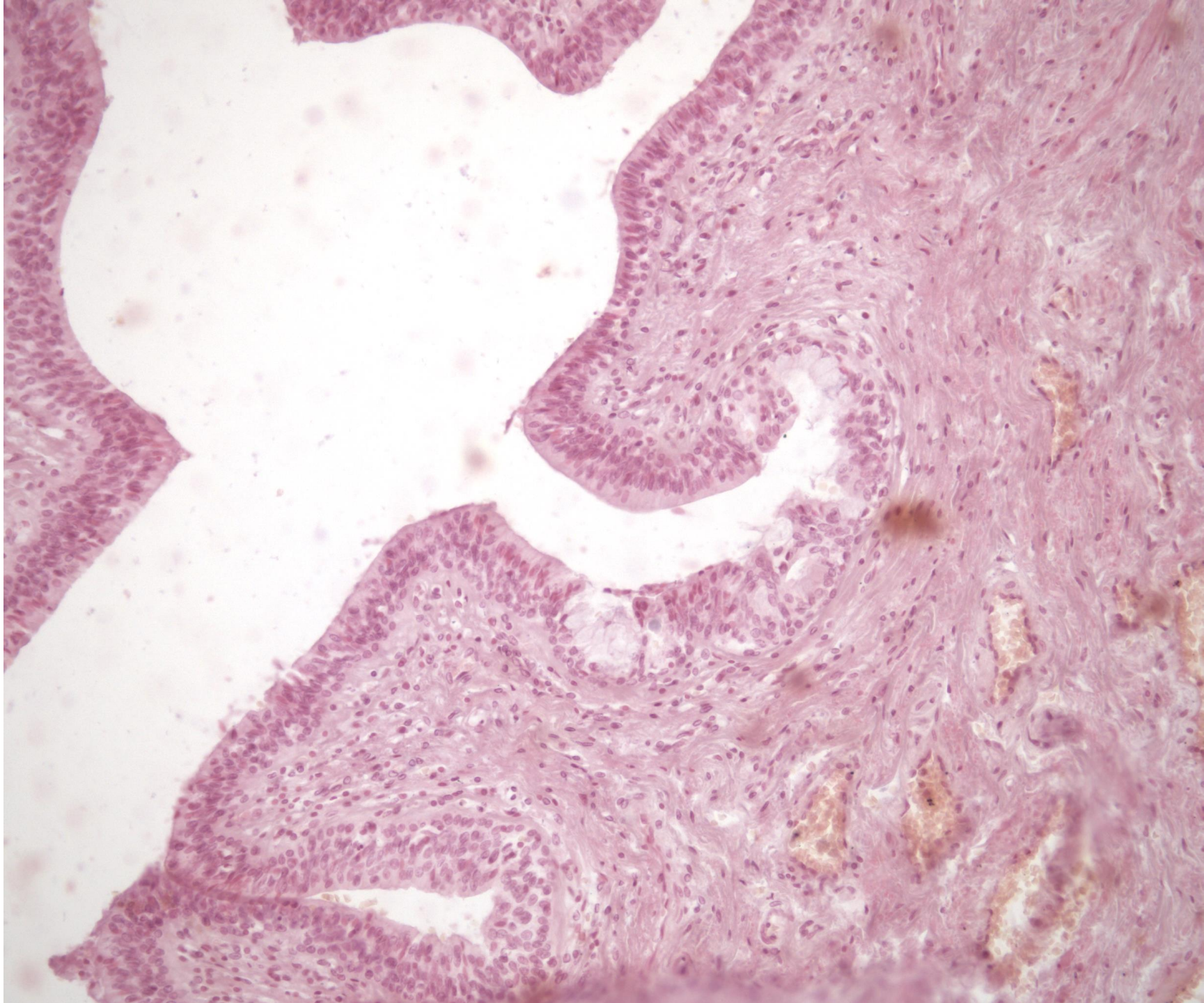
Urinary bladder



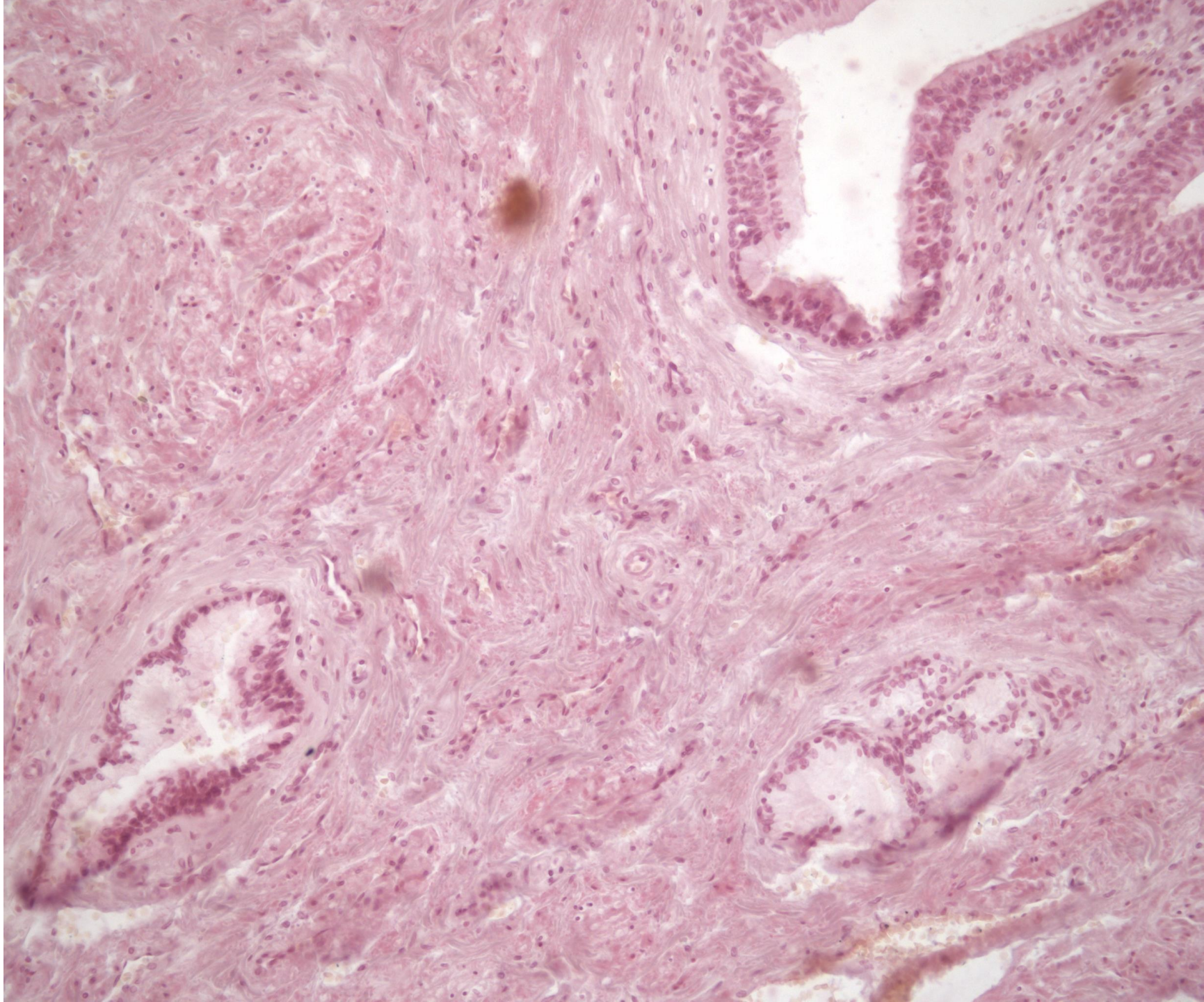
Uterer, urinary bladder

- Ureter
  - Mucosa with urothelium, three layers of smooth muscle, adventitia rich in adipose tissue, vessels, nerves
  - Outer longitudinal layer of smooth muscle is found in the terminal portion of ureter and is continuous with the musculature of the urinary bladder
- Urinary bladder
  - Trigone is relatively smooth and constant in thickness, it has a different embryologic origin from the rest of the bladder
  - The smooth muscle of the urinary bladder is less regularly arranged (in comparison with the ureter) forms the detrusor muscle and the sphincter urethrae internus
  - Similarly to ureter, the smooth muscle is mixed with connective tissue

Urethra – lacunae urethrales Morgagni



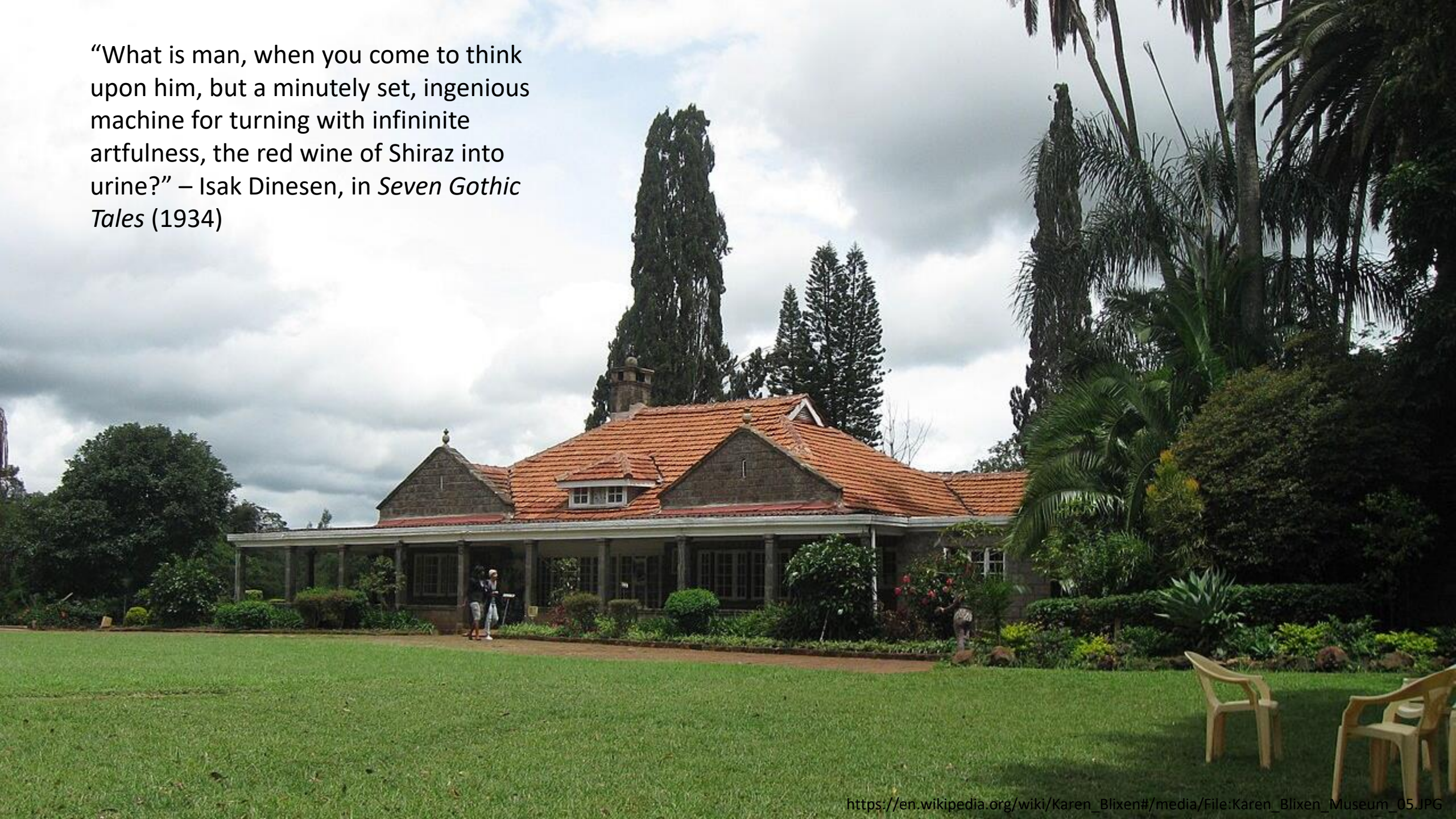
Glandula urethrales Littrei



Urethra

- Male urethra
  - Prostatic urethra lined by urothelium, ejaculatory duct joins at this point
  - Membranous urethra – (pseudo)stratified columnar epithelium, external sphincter
  - Penile (spongy) urethra runs through corpus spongiosum, lined by (pseudo)stratified columnar epithelium except at the distal end (fossa navicularis), where we find stratified squamous, glandulae urethrales and bulbourethrales empty to this part
- Female urethra
  - Initially urothelium, distally stratified squamous, glands of Skene analogous to male prostate
  - Lamina propria highly vascularized, external urinary sphincter

“What is man, when you come to think upon him, but a minutely set, ingenious machine for turning with infininite artfulness, the red wine of Shiraz into urine?” – Isak Dinesen, in *Seven Gothic Tales* (1934)



https://en.wikipedia.org/wiki/Karen_Blixen#/media/File:Karen_Blixen_Museum_05.JPG