General Functions of the Kidney

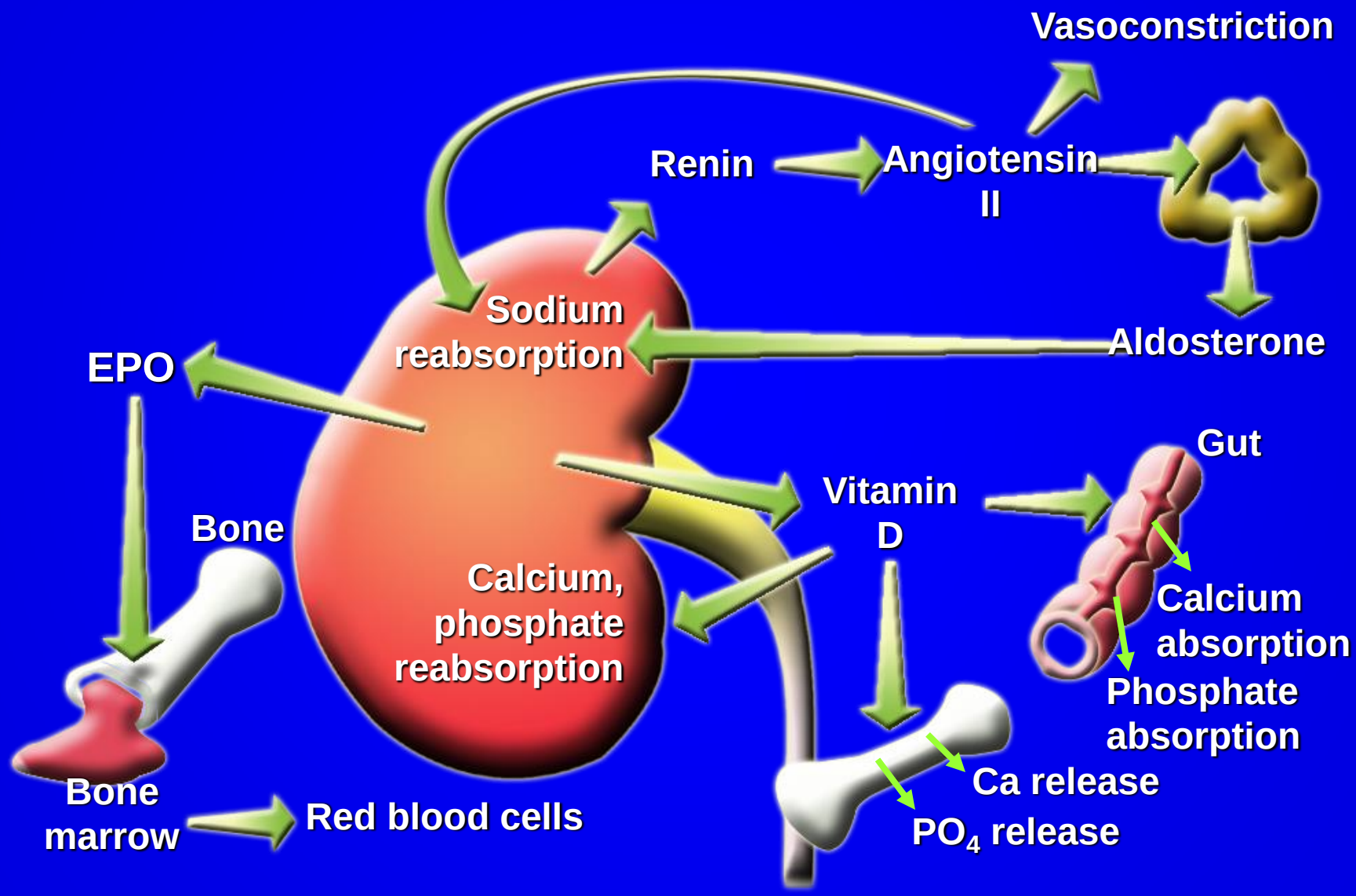
Major Functions of the Kidney

1. **Regulation of:**
   - body fluid osmolality and volume
   - electrolyte balance
   - acid-base balance
   - blood pressure

2. **Excretion of:**
   - metabolic products (urea, creatinine, uric acid)
   - foreign substances (pesticides, chemicals, toxins etc.)
   - excess substance (water, etc)

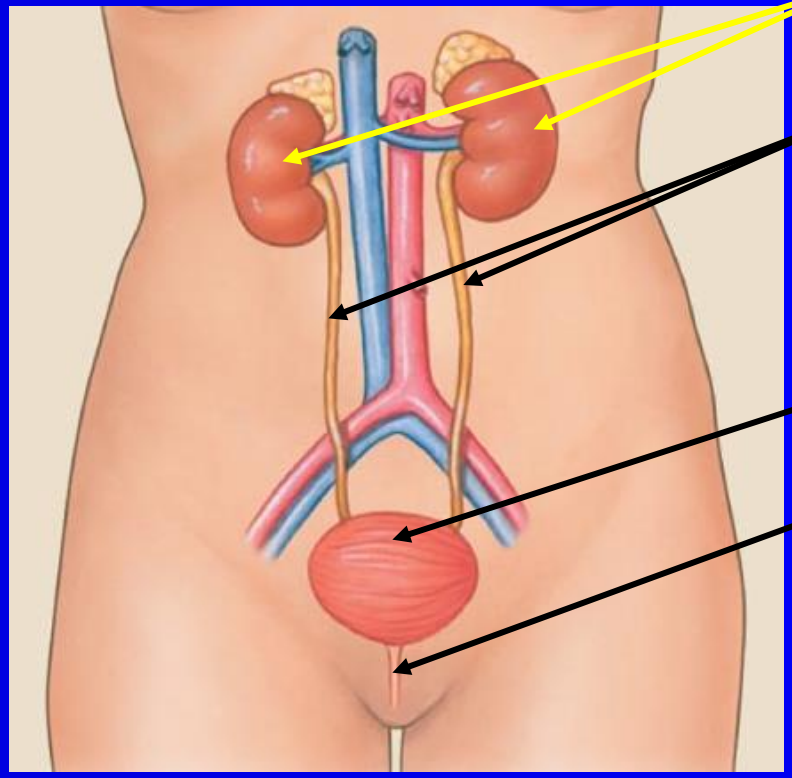
3. **Biosynthesis of:**
   - Erythropoietin
   - 1,25-dihydroxy vitamin D_3 (vitamin D activation)
   - Renin
   - Prostaglandin
   - Glucose (gluconeogenesis)
   - Angiotensinogen
   - Ammonia

Renal effects on other systems



KIDNEY STRUCTURE

Urinary system consists of:



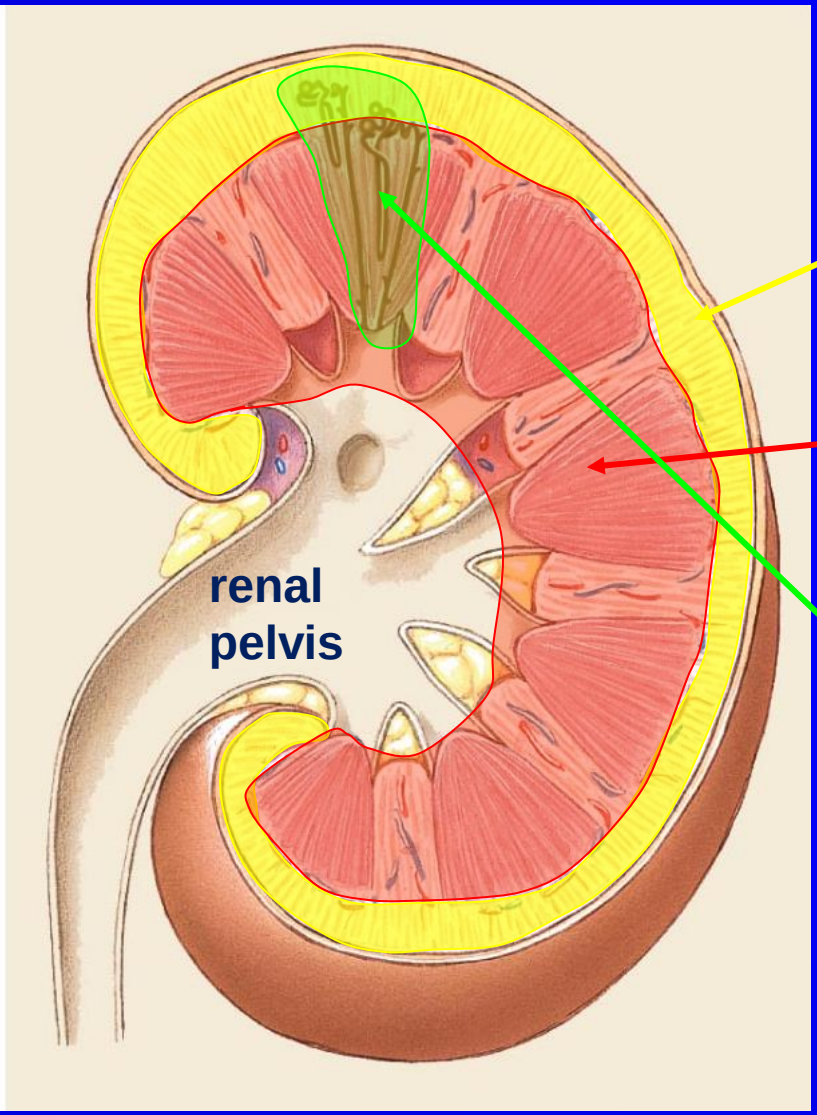
Kidneys – The functional unit of the system

Ureters

Urinary Bladder

Urethra

Conducting & Storage components



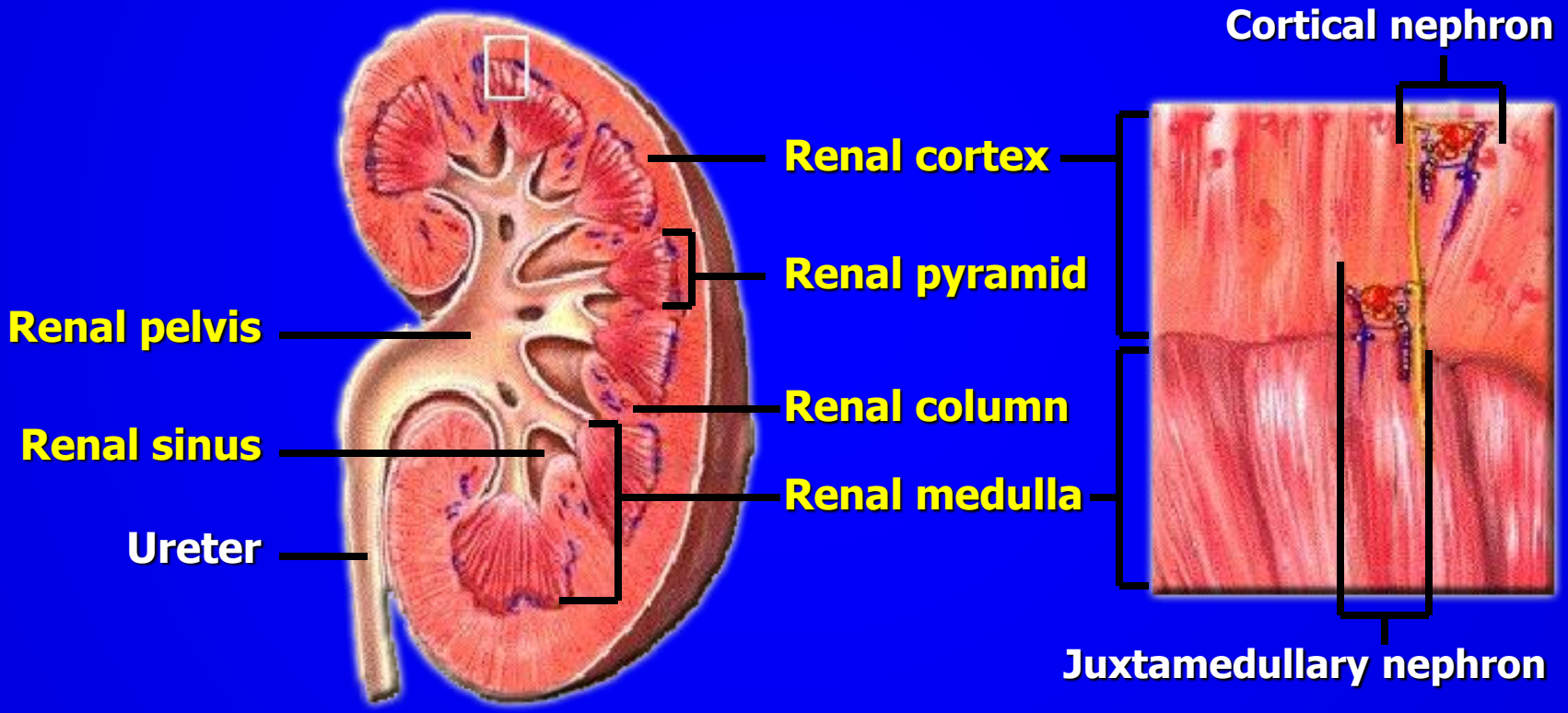
Divided into an outer cortex

And an inner medulla

The functional unit of this kidney is the nephron which is located in both the cortex and medullary areas

Macroscopic Structure of the Kidney

Internally, the human kidney is composed of three distinct regions: the renal cortex, medulla, and pelvis.



Nephrons in the cortex are cortical nephrons; those in both the cortex and the medulla are juxtamedullary nephrons.

Microscopic structure

The basic unit of the kidney is the nephron
Nephron consists of the:

* Glomerulus
* Proximal convoluted tubule
* Loop of Henle
* Distal convoluted tubule
* Collecting duct
* Juxtaglomerular apparatus

Nephron

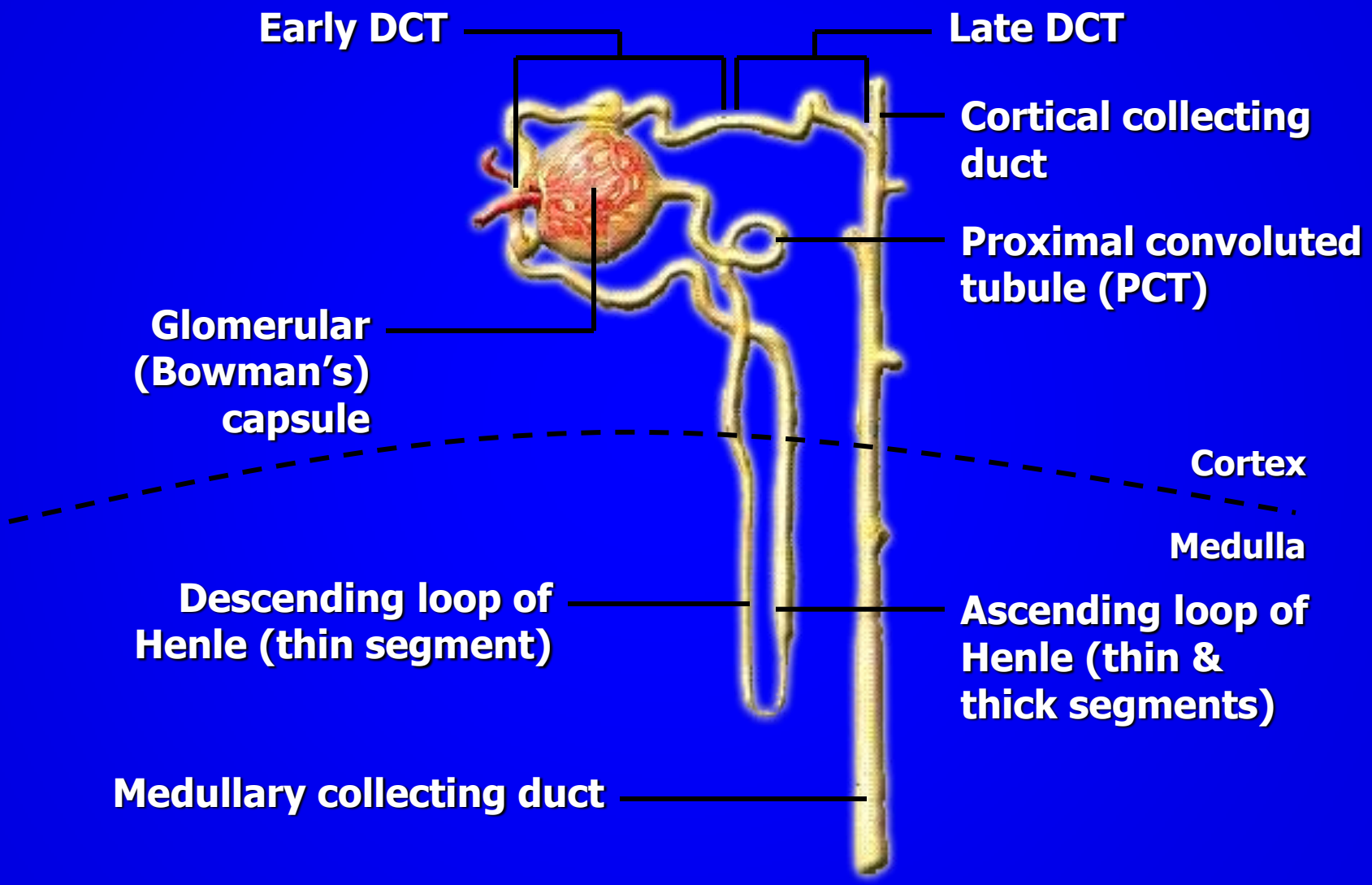
Size of the nephron = 200µm diameter
Number of nephrons = 2.6 millions in both kidneys.

Components

Vascular part
(glomerulus)

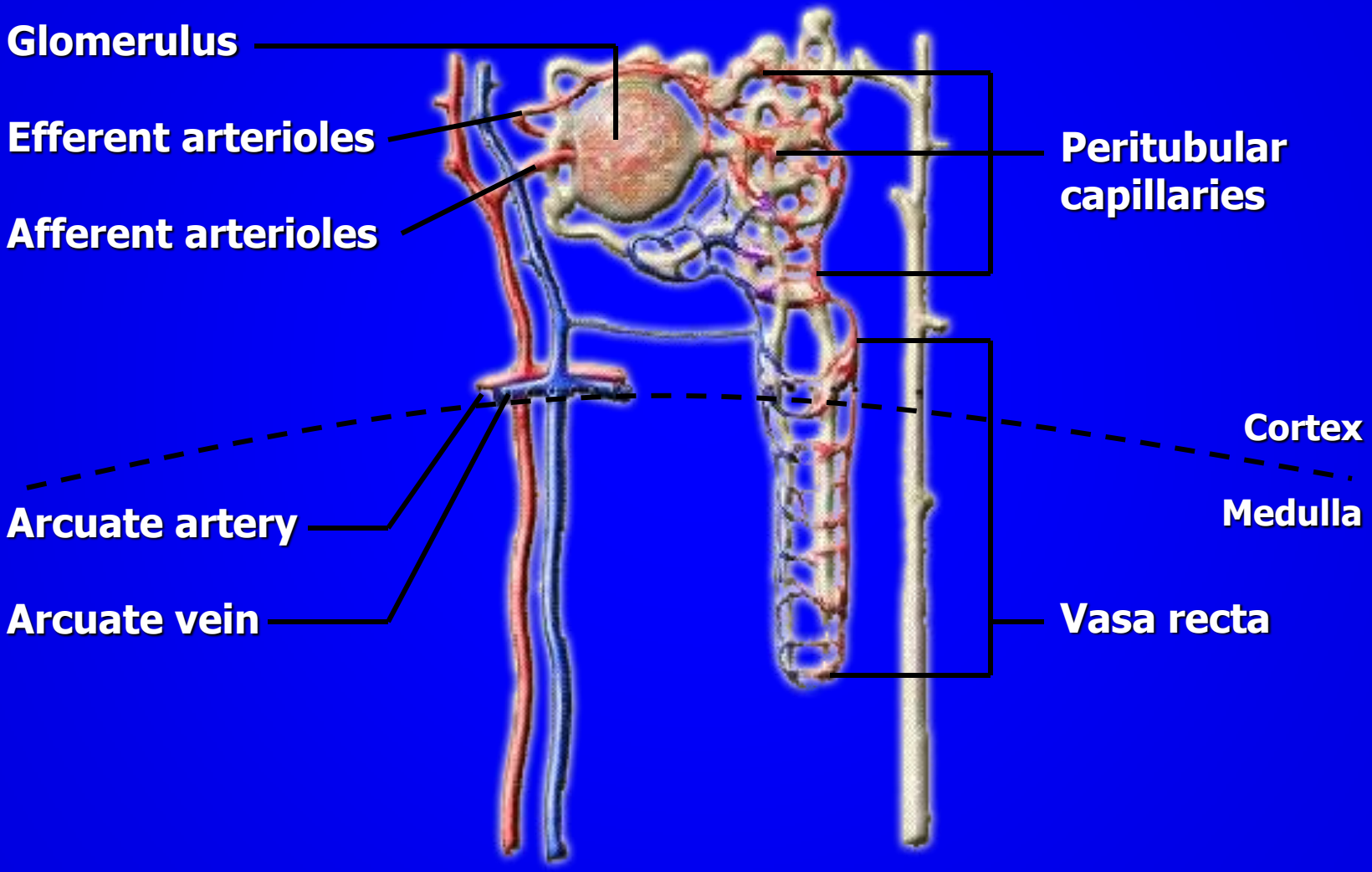
Tubular part
(tubules)

Nephron Structure: Tubular Segments



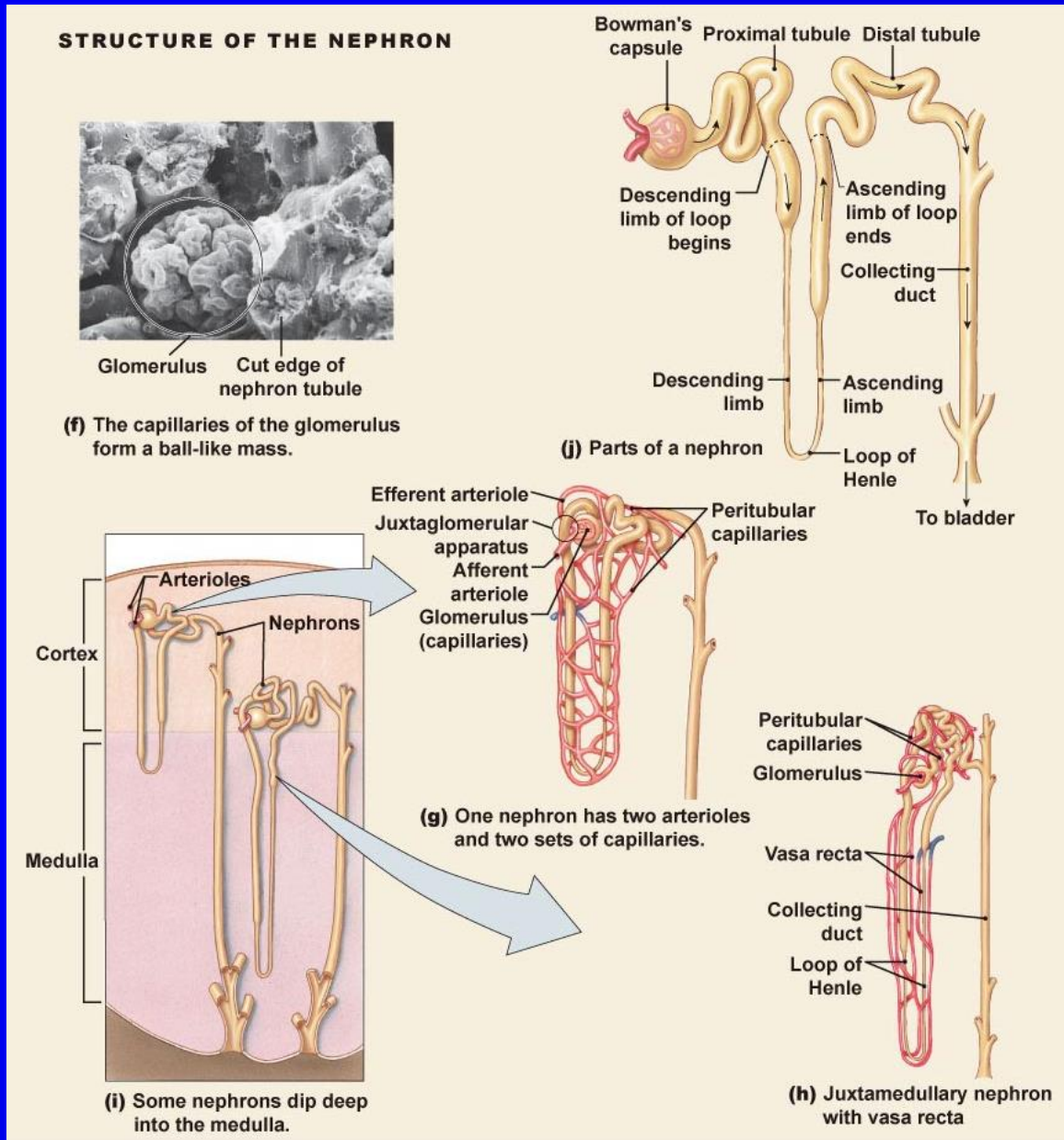
DCT - Distal convulated tubule

Nephron Structure: Associated Blood Vessels



The nephron consists of:

- **Vascular components**
  - Afferent & efferent arterioles
  - Glomerulus
  - Peritubular capillaries
  - Vasa recta
- **Tubular components**
  - Proximal convoluted tubule
  - Distal convoluted tubule
  - Nephron loop (loop of Henle)
  - Collecting duct
- **Tubovascular component**
  - Juxtaglomerular apparatus



Types of nephrons

Cortical	Juxtamedullary
Glomerulus in upper cortex	Glomerulus in inner part of the cortex
85%	15%
Short loop of Henle	Long loop of Henle and vasa recta
Diluted urine	Concentrated urine

Juxtaglomerular apparatus

- The juxtaglomerular cells are cells that synthesize, store, and secrete the enzyme renin.

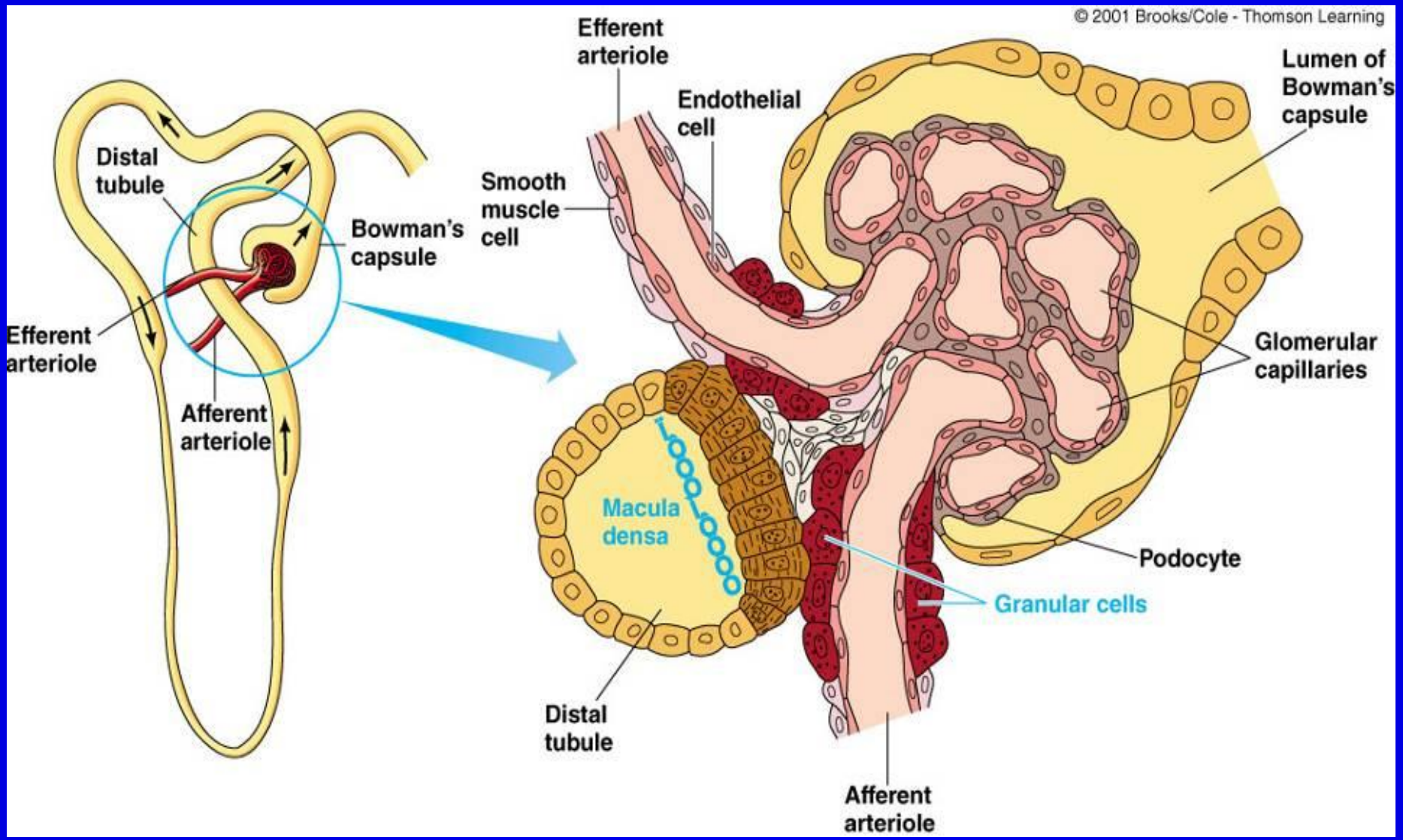
- Specialized smooth muscle cells in the wall of the afferent arteriole (Granular cells) have mechano-receptors for blood pressure.

- The macula densa is an area of closely packed specialized cells lining the distal convoluted tubule.
- Sensitive to the concentration of sodium ions in the fluid.

Where these structures are in contact they form the monitoring structure called the juxtaglomerular apparatus (JGA), which is composed of macula densa and granular cells.

The juxtaglomerular apparatus

Including macula densa, and juxtaglomerular (granular cells) cells



The Nephron

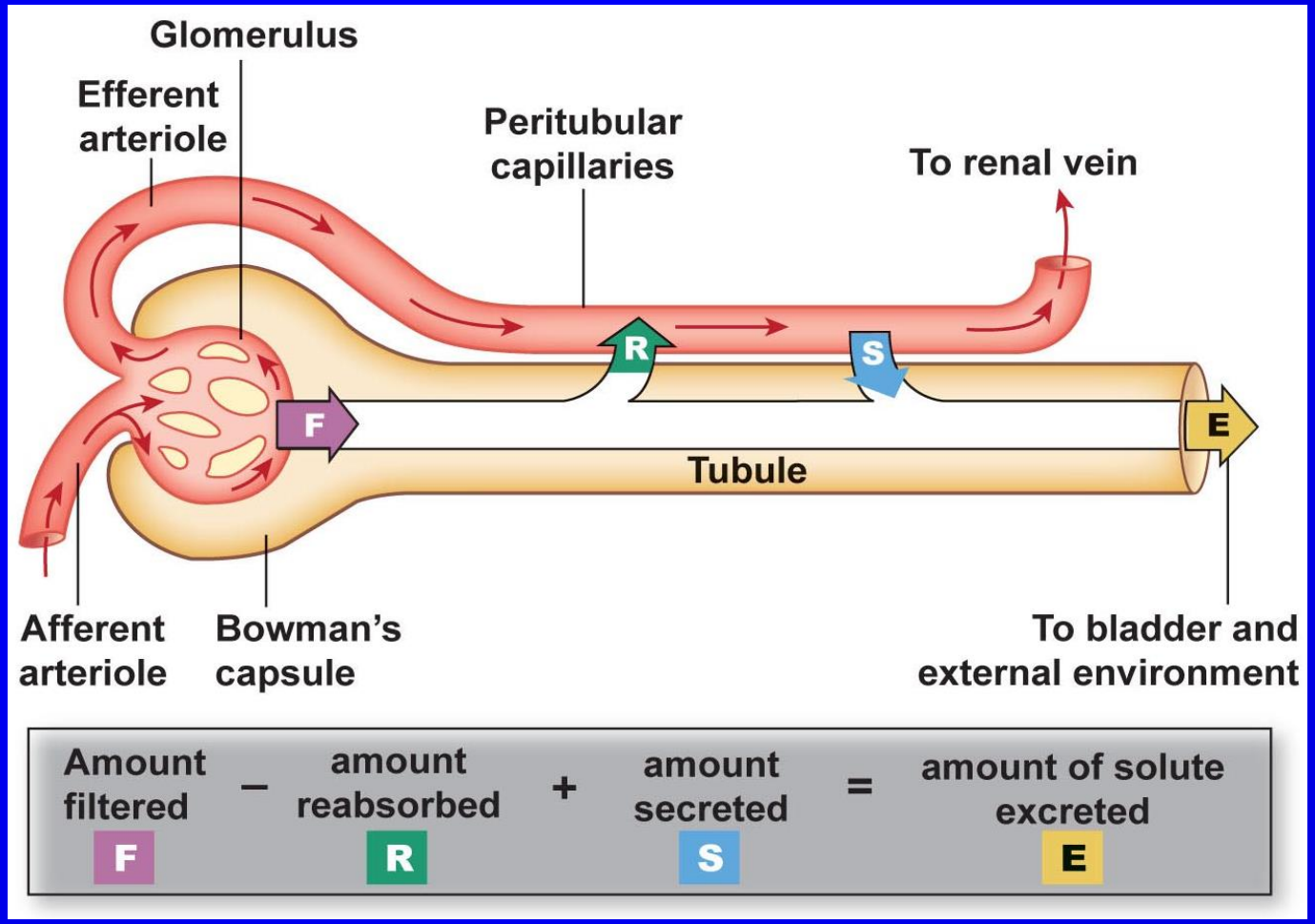
Simplified view of its functions

1- Glomerular Filtration

2- Tubular Reabsorption

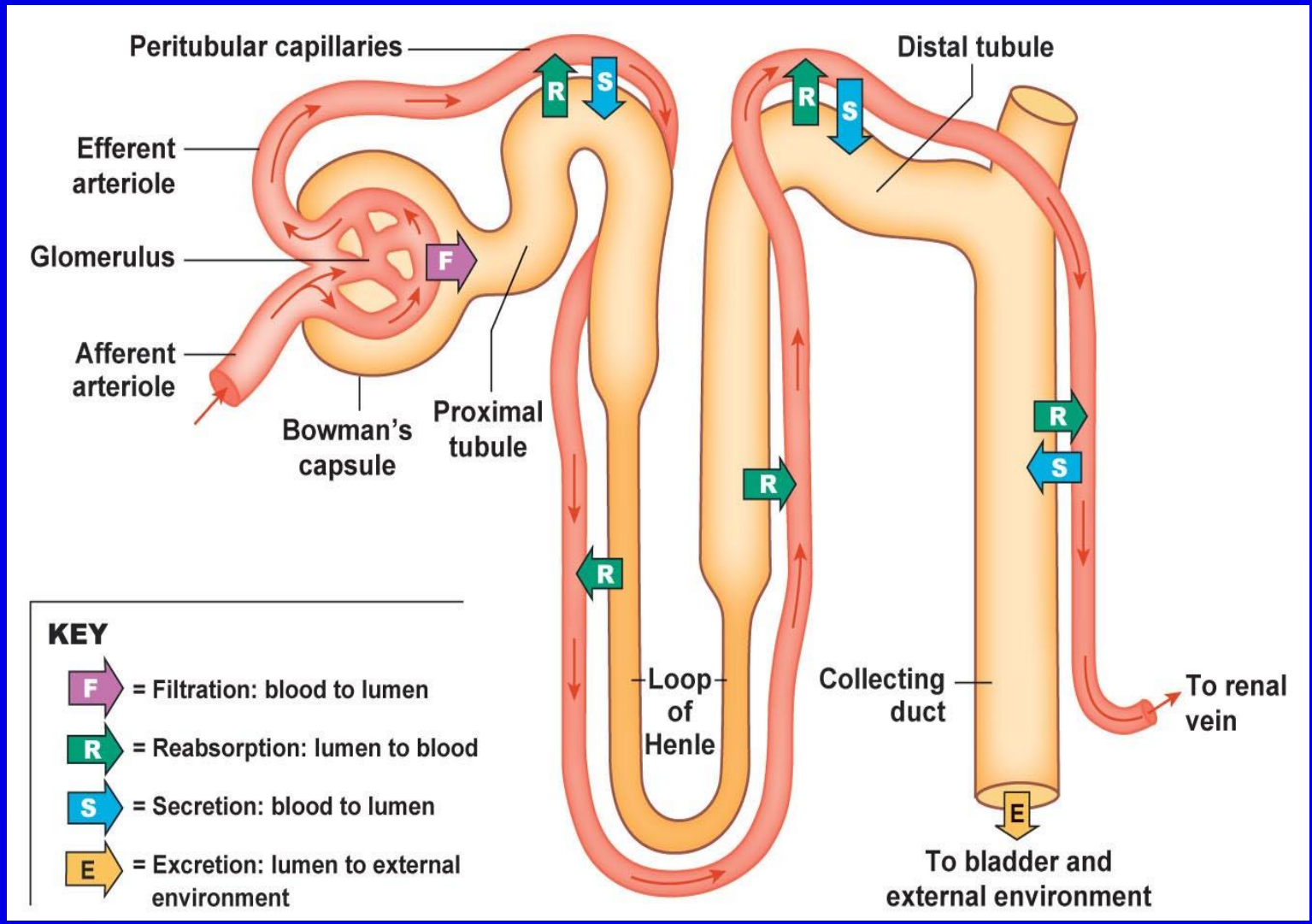
3- Tubular Secretion

4- Excretion



The Nephron

Locations for filtration, reabsorption, secretion & excretion



Renal Blood Flow

Renal Artery

Cortex

- **Branches to "afferent arterioles" (similar to pre-capillary arteriole)**
- **Surround network in glomerulus**
- **Leave glomerulus as "efferent arteriole" (similar to post-capillary arteriole)**
- **Efferent arteriole enters another capillary system called the peritubular capillaries**

Medulla

- Blood supply to medulla comes from "efferent arterioles" of Juxtamedullary nephrons and from vasa recta (straight capillaries into medulla)

- In inner medulla both descending and ascending vasa recta are close to each other – helps with exchange of substances flowing into and out of medulla

- In resting condition (adult) kidney receives 1.2 L of blood /min (25% of CO).

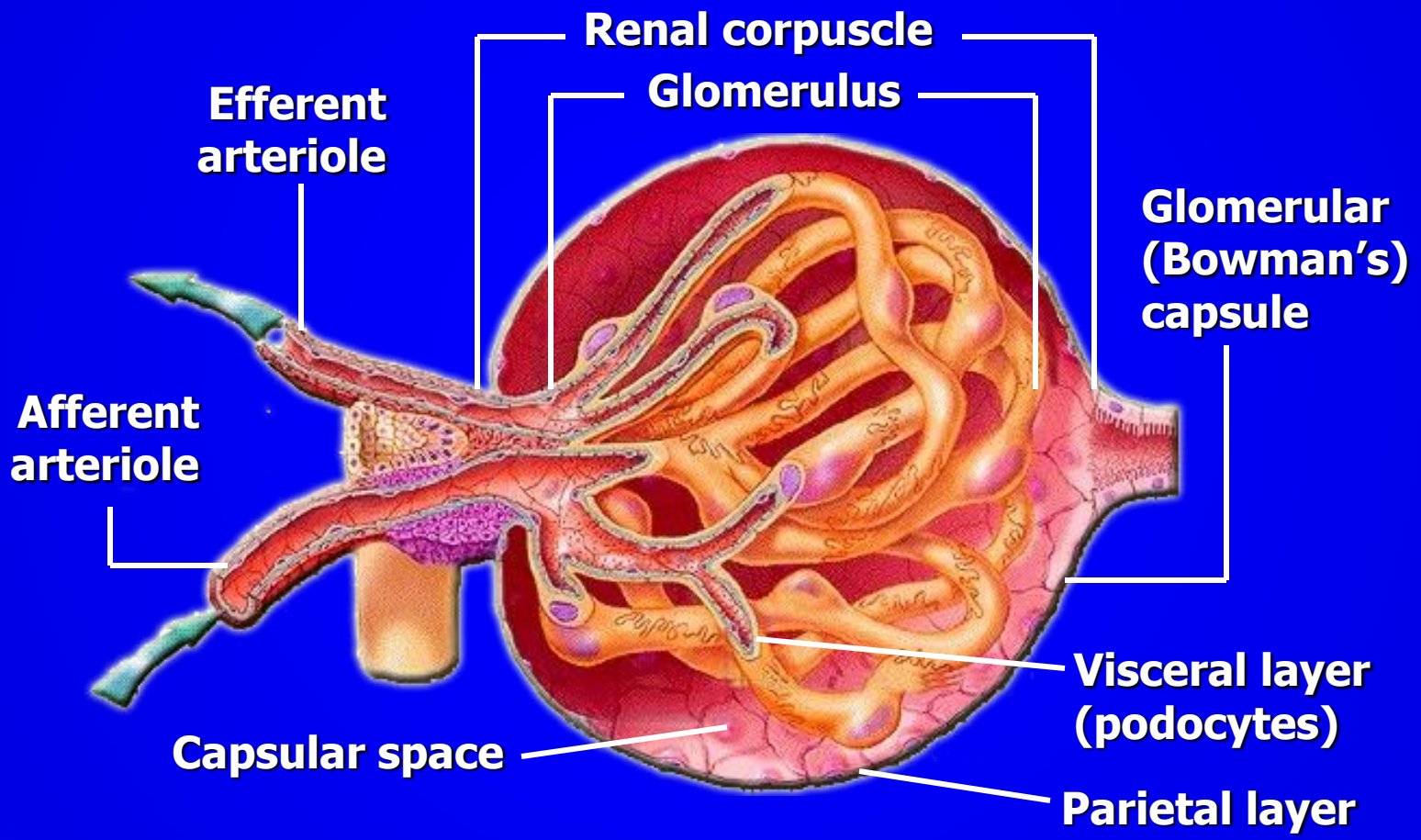
ULTRASTRUCTURE OF THE NEPHRON

Glomerulus

- The glomerulus has several characteristics that differ from the features of most other capillaries of the body.
  - the endothelial cells of the glomerulus contain numerous pores (fenestrae).
  - glomerular endothelium sits on a very thick basement membrane.
  - On the surface of the basement membrane are negatively charged glycosaminoglycans such as heparan sulfate.
  - The negatively-charged basement membrane repels negatively-charged molecules from the blood, like proteins helping to prevent their passage into Bowman's space.

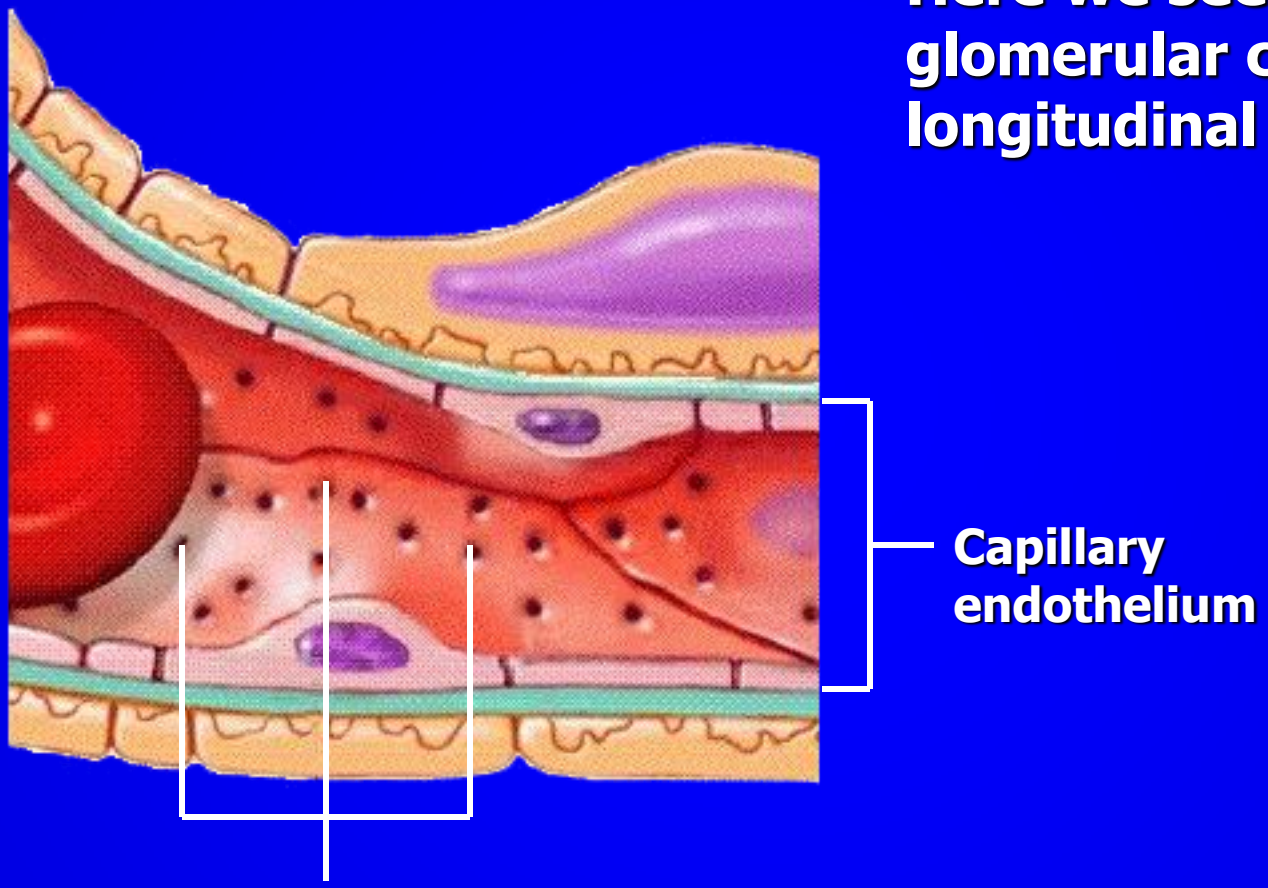
Cellular Features of the Renal Corpuscle

Composed of Glomerulus and Bowman's capsule



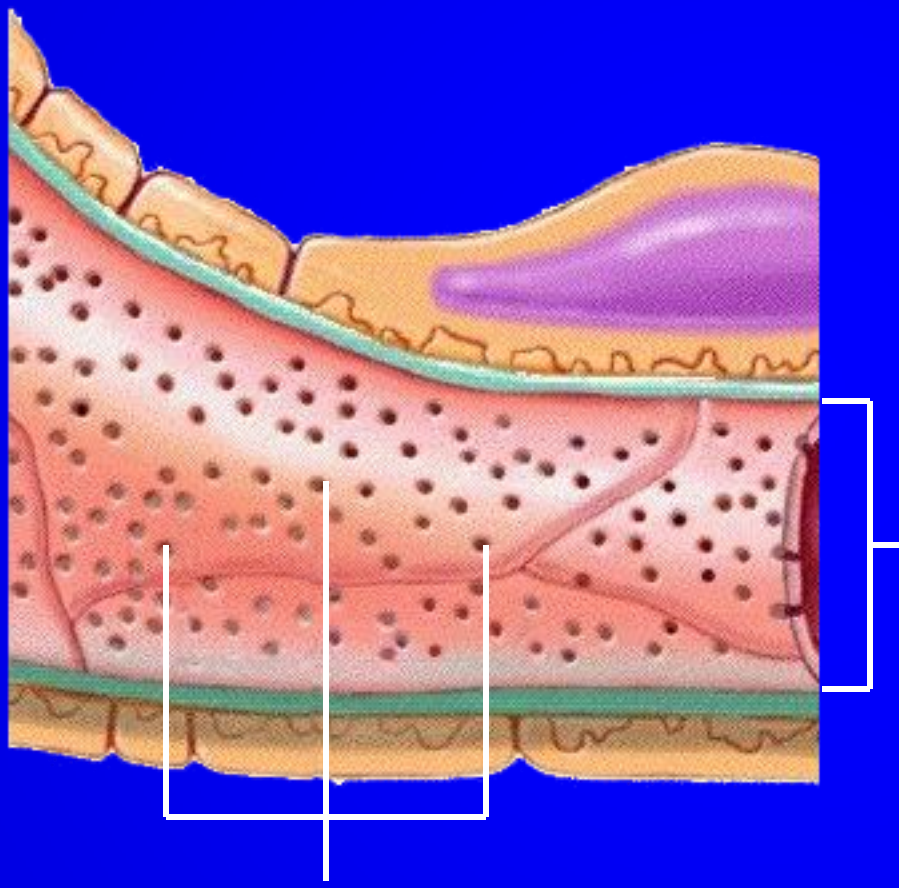
Glomerulus

Cellular Features of the Renal Corpuscle



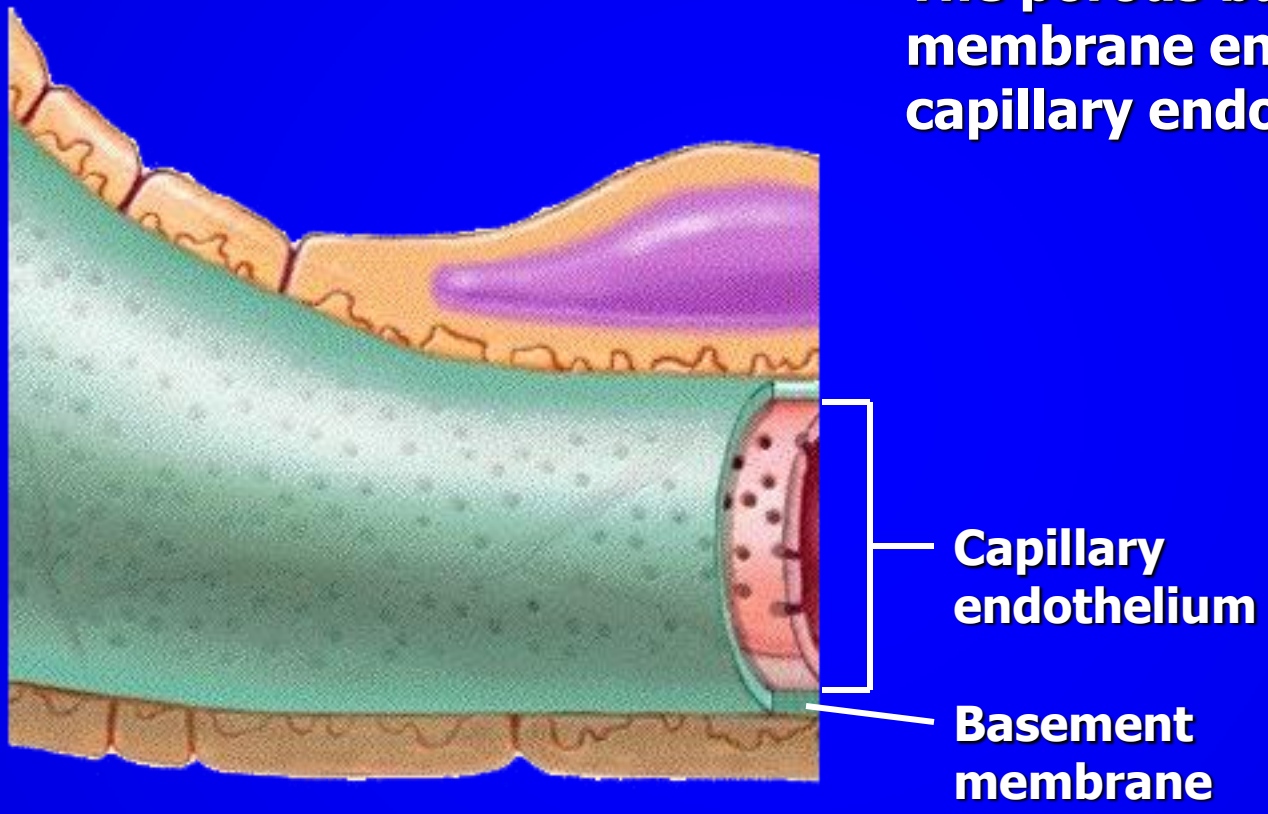
Here we see a glomerular capillary in longitudinal section.

Cellular Features of the Renal Corpuscle



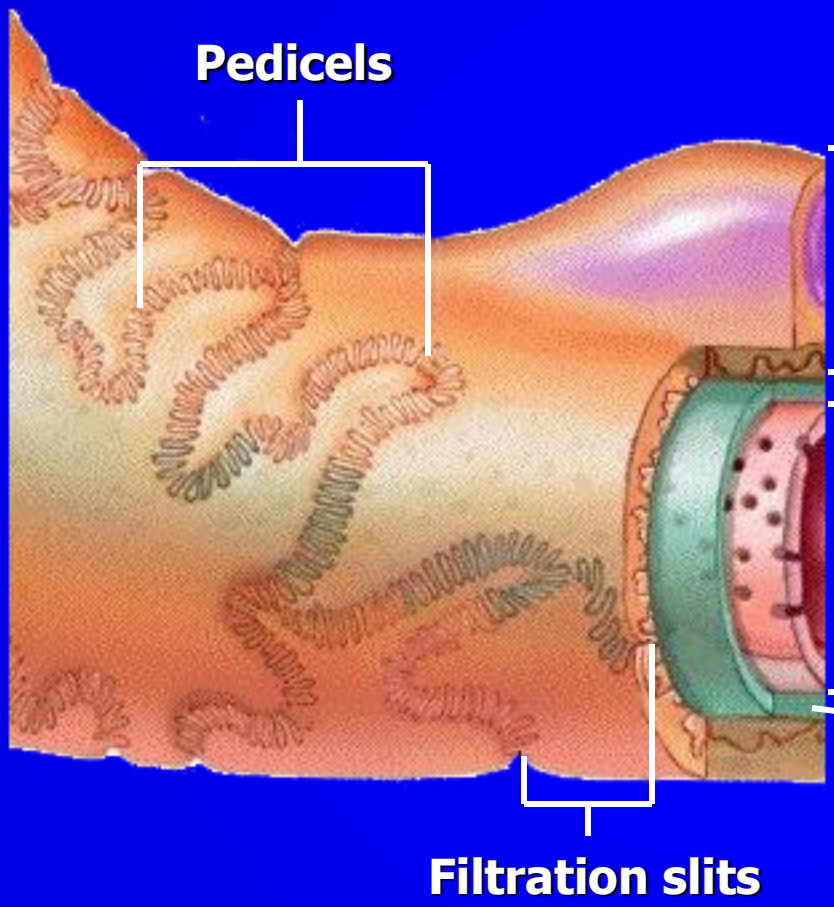
Now completing the capillary endothelium, you can see the fenestrations more clearly.

Cellular Features of the Renal Corpuscle



The porous basement membrane encloses the capillary endothelium.

Cellular Features of the Renal Corpuscle



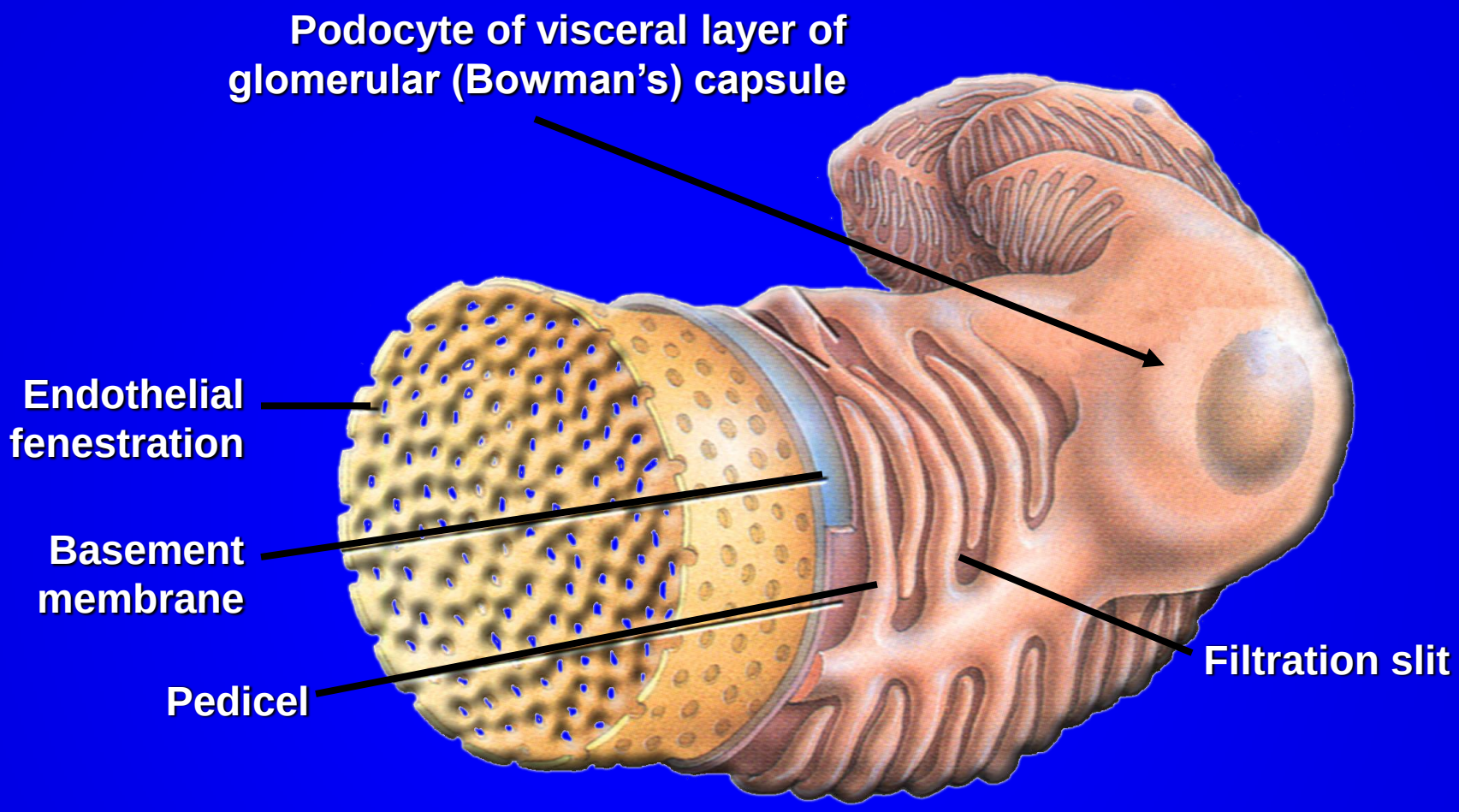
Surrounding the basement membrane is a layer of **podocytes**.

Podocytes (cell body with nucleus)

Capillary endothelium

Basement membrane

Together, the fenestrated capillary endothelium, basement membrane, and podocytes make up the filtration membrane (3 layers).



Details of Filtration Membrane

Negative charge

Glomerular filter

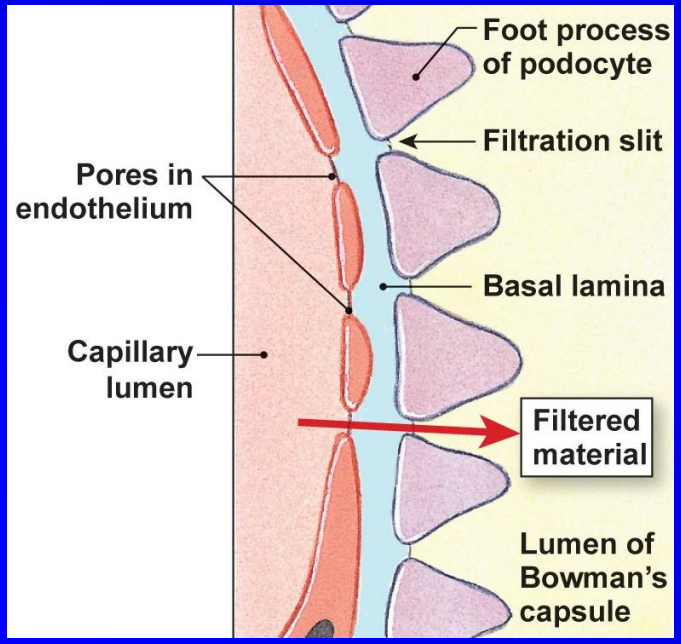
- The filtration surface is 1.5 square meter
- Amount of the solution, which is filtered in glomerular apparatus is around 180-200 L / day.
- The rest (97 %) has to be reabsorbed in the tubules back to the body, so the final volume of urine is around (1.5 - 2 L per day).

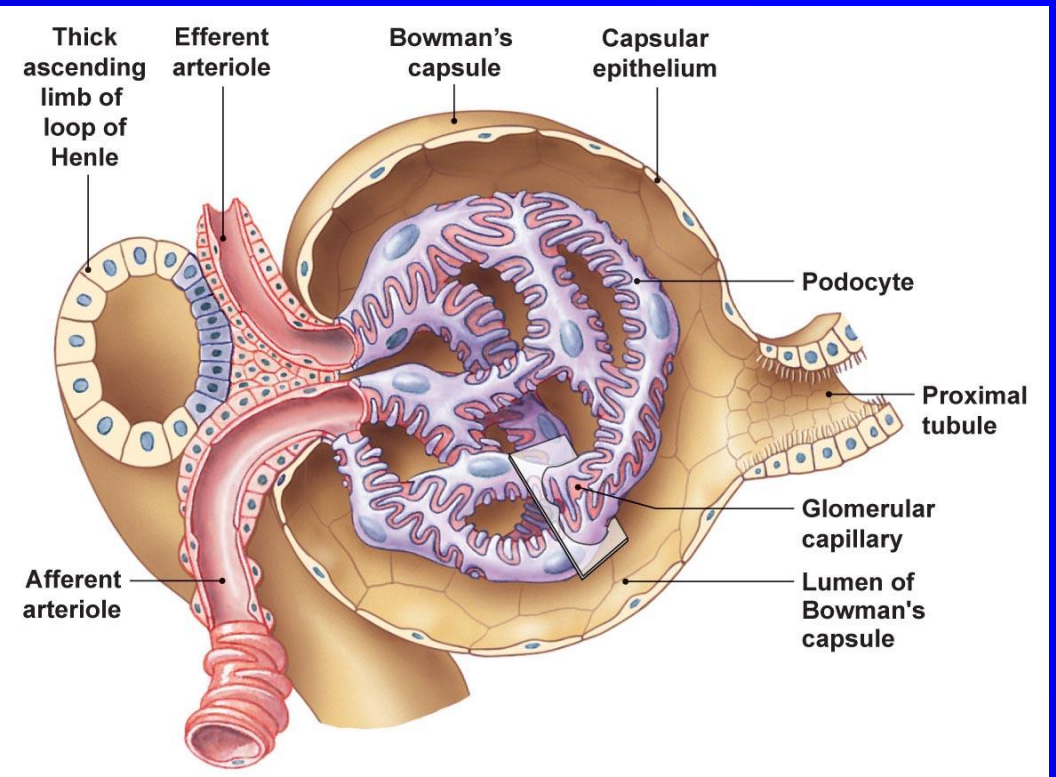
- **Glomerular filter:**
  - the capillary endothelium
  - basal membrane
  - epithelium of the Bowman's capsule (PODOCYTES)

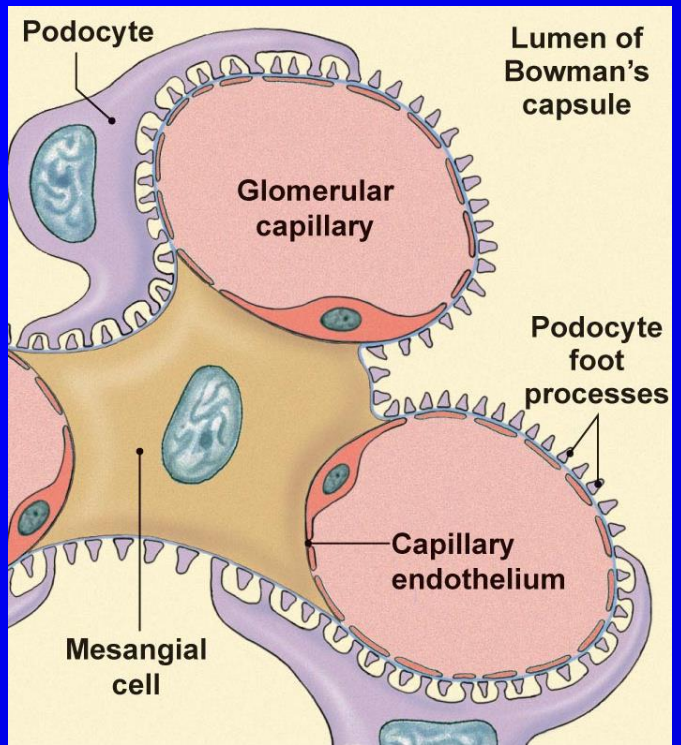
- **Podocytes:**
- Special cells which have numerous of pseudopodia (pedicles) that interdigitate to form filtration slits along the capillary wall.

Nephron
Filtration Membrane

- Capillaries are fenestrated
- Overlying podocytes with pedicels form filtration slits
- Basement membrane between the two







Nephron
Glomerular Filtration

Barriers:

1- Mesanglial cells can alter blood flow through capillaries.

2- Basal lamina alters filtration by:

Containing negatively charged glycoproteins which act to repel negatively charged plasma proteins.

3- Podocytes form the final barrier to filtration by forming "filtration slits"