THE RENAL SYSTEM (L1)

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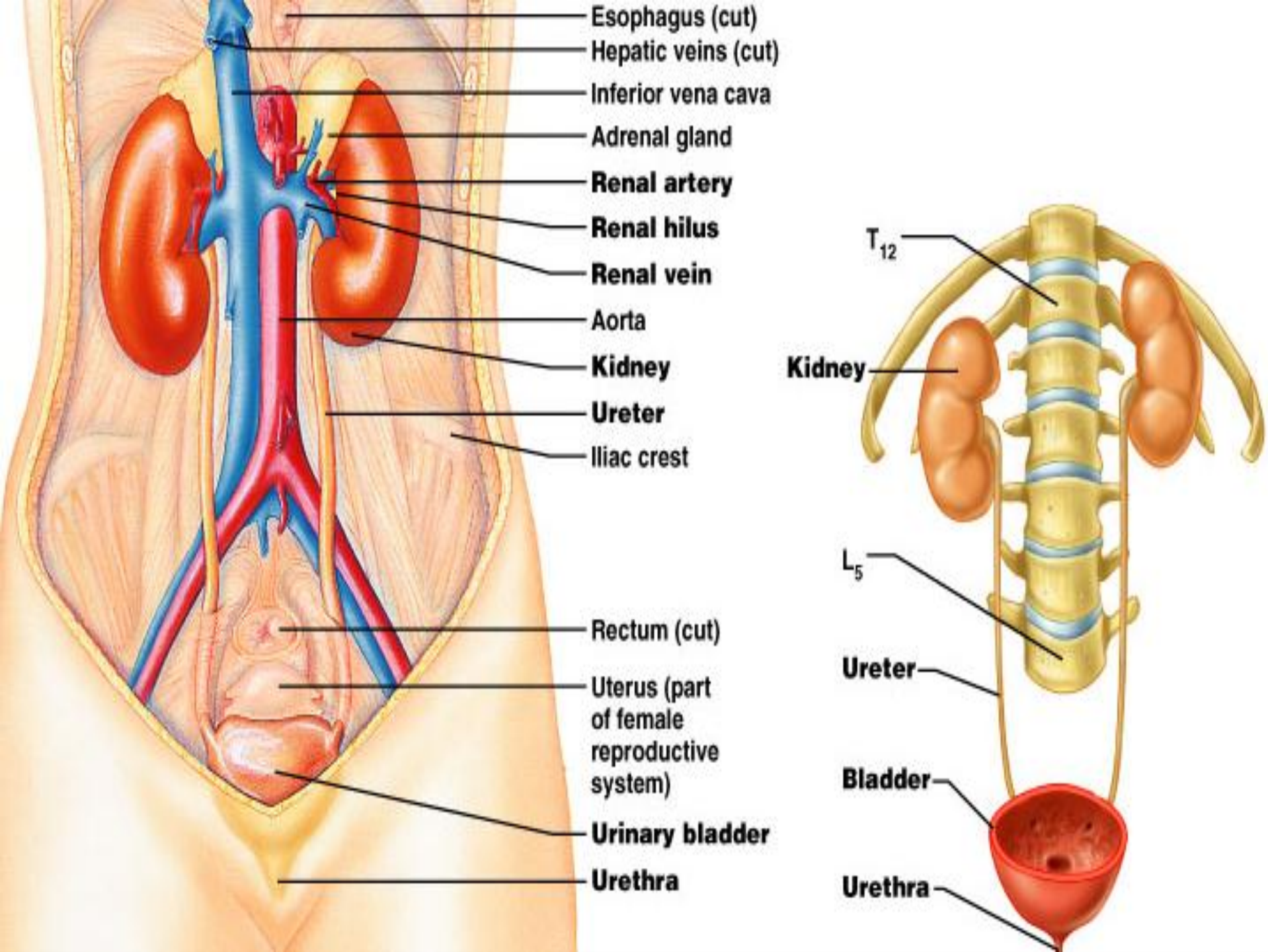
2nd stage

PHYSIOLOGY #II
University of Basra

Urinary system

Overview

- The urinary system consists of **two kidneys** , a single midline **urinary bladder, two ureters** which carry the urine from the kidney to the urinary bladder and **a single urethra** which carries the urine from the bladder to the outside of the body.
- The kidneys make up the main purification system of the body. They control the composition of the blood by removing the waste products and conserving the useful substances.
- The kidneys are the major excretory organ among other excretory organs of the body :skin ,liver, lungs and intestine.


Esophagus (cut)
Hepatic veins (cut)
Inferior vena cava
Adrenal gland
Renal artery
Renal hilus
Renal vein
Aorta
Kidney
Ureter
Iliac crest
Rectum (cut)
Uterus (part of female reproductive system)
Urinary bladder
Urethra
T12
Kidney
L5
Ureter
Bladder
Urethra

Functions of the kidneys

Excretory functions

- Kidneys filter blood producing large volume of large molecules (proteins , RBCs)are retained in the blood ,small molecules and ions enter the filtrate.(produce filtrate)
- Most of filtrate volume is reabsorbed back into the blood.
- Metabolic waste, toxic materials and excess ions remain in a small volume of filtrate.
- Additional waste products are secreted into the filtrate resulting urine formation.

Regulatory function

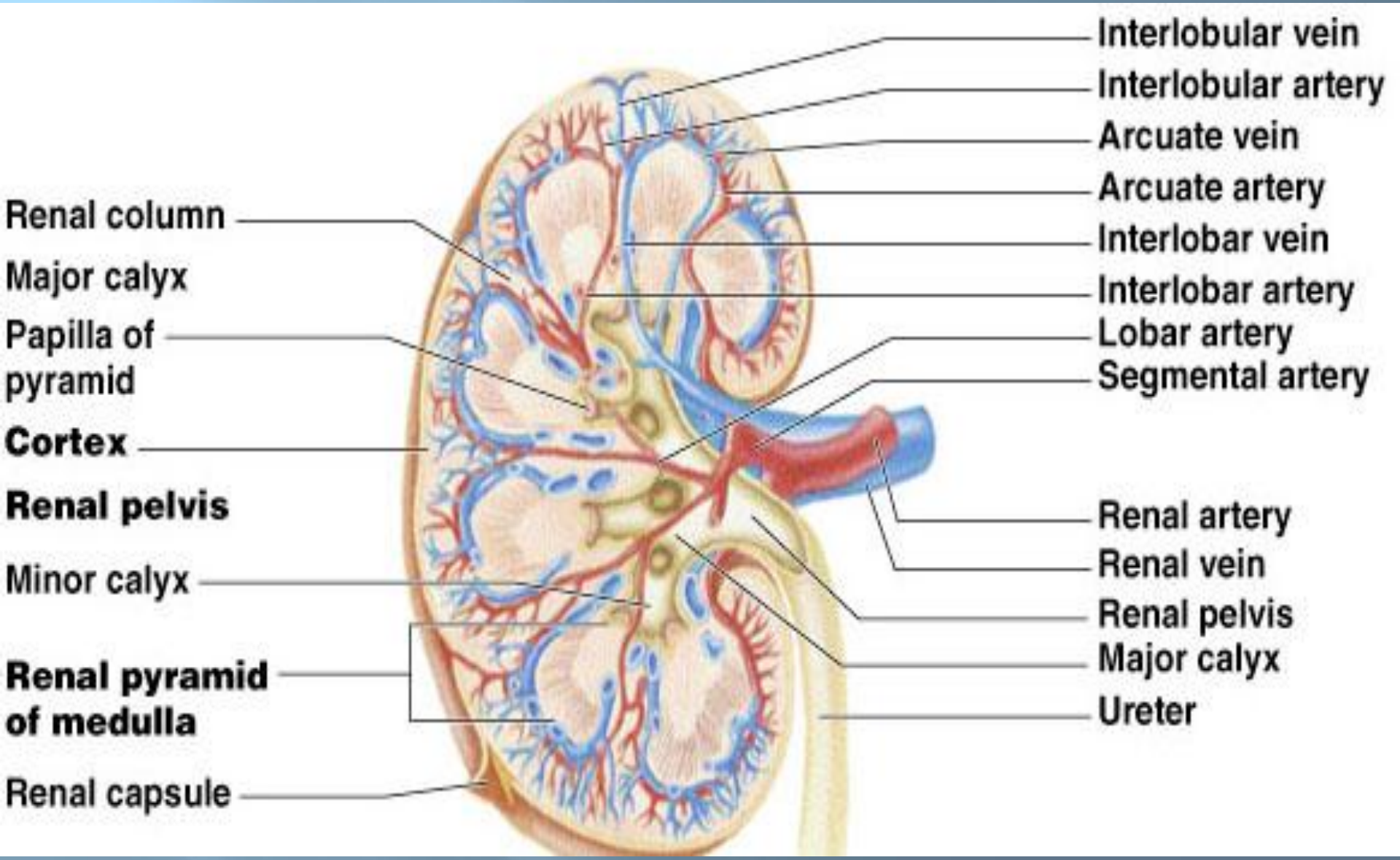
- Regulation of blood volume and pressure by controlling the extracellular fluid volume (ECF) in the body by producing either a large volume of diluted urine or a small volume of concentrated urine.
- Regulation of concentration of solutes in the blood by regulation of concentration of major ions (Na^+,Cl^-,$HCO3^-$,$HPO4^{2-}$).
- Regulation of PH of ECF by secreting variable amounts of H^+ .
- Regulation the synthesis of RBCs by secreting of erythropoietin hormone.
- Vitamin D synthesis, therefore regulates Ca2+ blood level.

Structural considerations

- The kidneys are paired of bean shaped organs that lie behind peritoneal lining of the abdominal cavity.
- Each kidney is surrounded by a thin capsule to resist stretch and limit the swelling .
- The renal artery ,renal vein ,renal lymphatics and ureter enter and leave the kidney through a **helium** on the midline concave surface of the kidney.

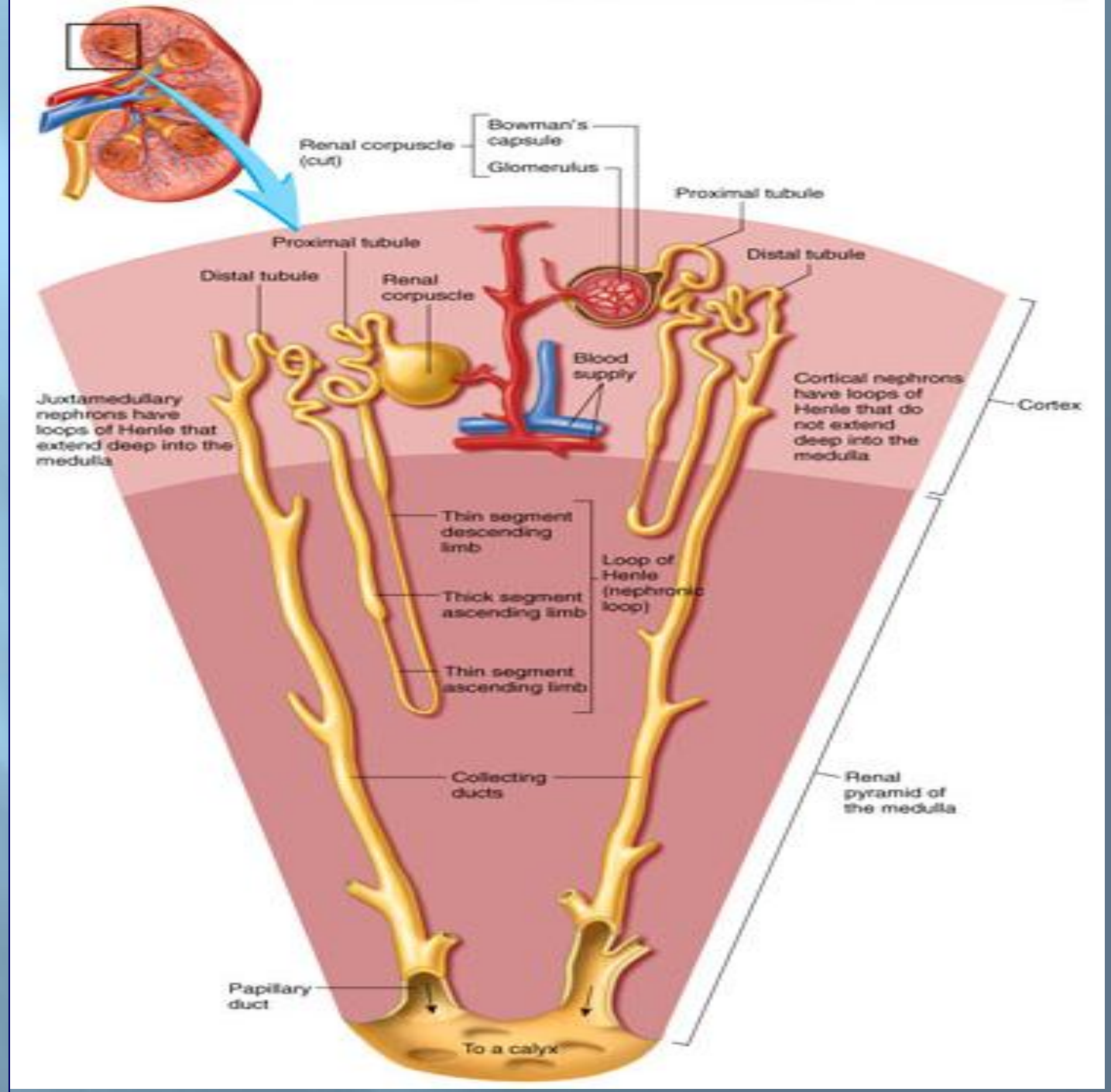
Internal structure of the kidneys

- There are two distinguished layers inside the longitudinal section of the kidney .The outer layer the **cortex** and the inner layer the **medulla**.
- The medulla is made up of series of cone shape **pyramids** which project to the **minor calyces**.
- Minor calyces open into **major calyces** which open into **renal pelvis**.
- The renal pelvis leads to the ureter which drains into the bladder.


Interlobular vein
Interlobular artery
Arcuate vein
Arcuate artery
Interlobar vein
Interlobar artery
Lobar artery
Segmental artery
Renal artery
Renal vein
Renal pelvis
Major calyx
Ureter
Renal column
Major calyx
Papilla of pyramid
Cortex
Renal pelvis
Minor calyx
Renal pyramid of medulla
Renal capsule

Structure of the nephron

- The functional unit of the kidney is the **nephron** (where the blood is filtrated)
- Nepheron is blind end tubules running from the **Bowman's capsule** into the renal pelvis.
- There are about one million nephron in each kidney .
- The nephron begins at the **glomerulus** *(comprises a tuft of glomerular capillaries with the Bowman's capsule*
- The capillaries are derived from the **afferent arterioles** and drain into the **efferent arterioles.**
- Many branches of capillaries form cluster that invaginates into the Bowman's capsule
- The glomerulus and the Bowman's capsule form the **renal corpuscle.**


Renal corpuscle (cut)
Bowman's capsule
Glomerulus
Proximal tubule
Distal tubule
Proximal tubule
Distal tubule
Renal corpuscle
Blood supply
Juxtamedullary nephrons have loops of Henle that extend deep into the medulla
Cortical nephrons have loops of Henle that do not extend deep into the medulla
Cortex
Thin segment descending limb
Loop of Henle (nephronic loop)
Thick segment ascending limb
Thin segment ascending limb
Collecting ducts
Renal pyramid of the medulla
Papillary duct
To a calyx

- The materials leave the blood in the glomerulus and enter the Bowman,s capsule through the **filtration membrane**.
- Fluids from Bowman,s capsule flows into the coiled segment (**proximal convoluted tubule)**,then into **loop of Henle** ,down into the medulla.

There are two types of nephrons:

1-Cortical nephrons :

The glomeruli are in the two thirds of the cortex.

Short loop of Henle ,that dip into the outer medulla.

2-Juxtamedullary nephrons

Glomeruli in the inner cortex.

Long loop of Henle extends deeply into the medulla

- **Proximal convoluted tubule** is about 14 mm long ,60 µm in diameter .It is composed of simple cuboidal epithelial cells ,made up the wall.

- **Loops of Henle** are continuous of proximal convoluted tubule .Each loop has two limbs : **descending and ascending.**

  The ascending limb of loop of Henle leads into a second coil section: **the distal convoluted tubule.**
- **Distal convoluted tubule** begins at a special structure: the **juxtaglomerular apparatus.**
- **Collecting duct: The** cells of collecting duct have some microvilli and numerous mitochondria. The absorb Na^+ , K^+ and Cl^- actively.

Juxtaglomerular apparatus.

- The tubule passes between the afferent arteriole that supplies blood to the glomerulus and the efferent arteriole that drains it. This short section of the tubular cells is known as **macula densa**
- Juxtaglomeruler apparatus secretes enzyme **rennin** , and play an important role in the regulation of **filtrate formation** and **blood pressure.**
- The distal tubules of several nephrons join to form a **collecting duct** that passes through the medulla to the **papilla.**

Juxtaglomerular (JG) cells

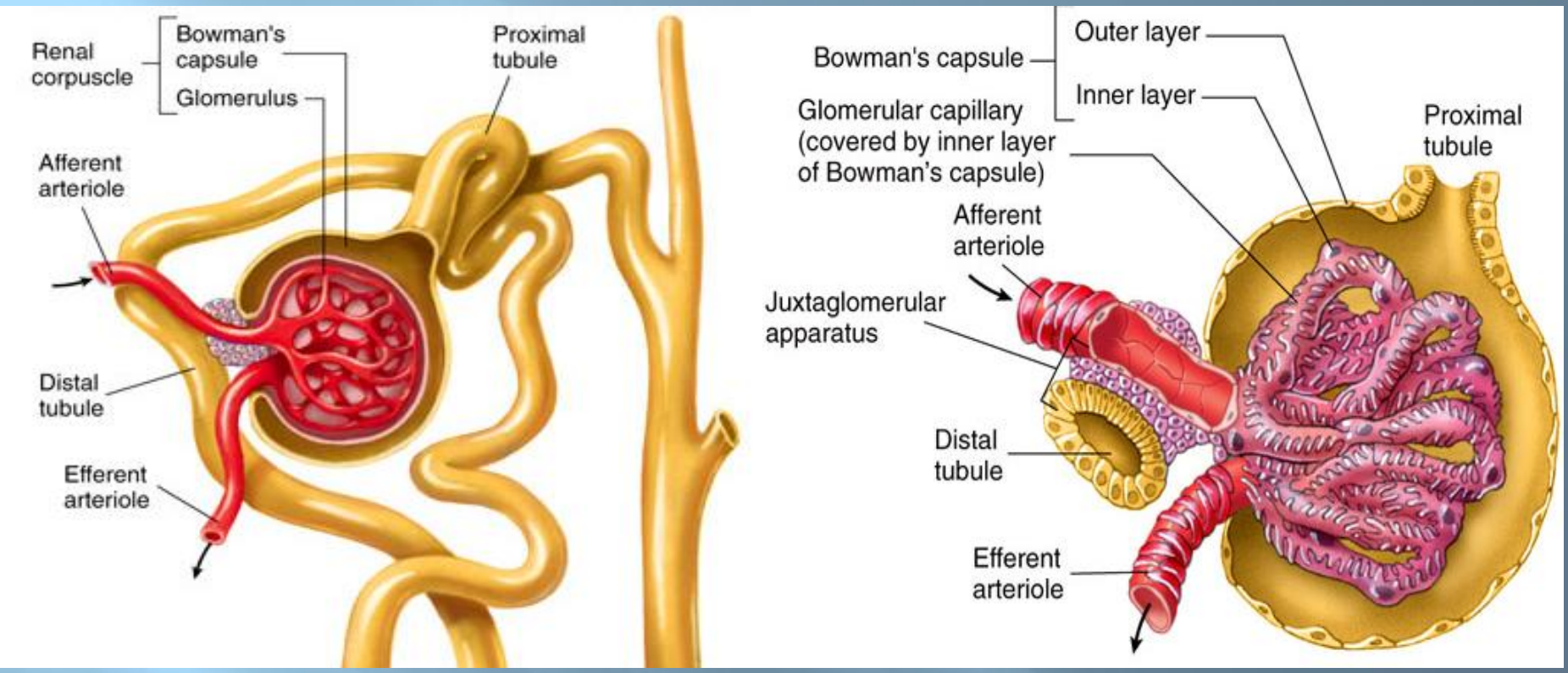
- They are modified smooth muscle cells in afferent arteriole wall detect changes in blood pressure (a stretch reflex) ,
- Secrete enzyme renin to trigger Renin-Angiotensin system if blood pressure falls
- Distal tubule contacts afferent arteriole at renal corpuscle

Macula Densa (MD) cells

- Special cells in the wall of the distal tubule in this area monitor the osmotic potential in the filtrate in the distal tubule
- They stimulate JG cells to release renin if filtrate is too dilute, indicating insufficient filtration and/or low blood pressure/low blood volume
- Both JG and MD cells work together to regulate blood pressure and blood volume

Renin-Angiotensin System

- Hepatocytes secrete inactive precursor Angiotensinogen into the bloodstream
- Juxtaglomerular (JG) cells secrete the enzyme renin to convert Angiotensinogen to Angiotensin I in the bloodstream
- Angiotensin I is transported to the lungs where Angiotensin Converting Enzyme (ACE) converts Angiotensin I to Angiotensin II
- Both Angiotensin I and Angiotensin II act as circulating hormones to increase blood pressure and blood volume.



a b

a: The renal corpuscle consists of Bowman's capsule and glomerulus, **b:**Bowman,s capsule covers the glomerular capillaries. Juxtaglomerular apparatus consists of cells from the wall of the afferent arteriole and the distal convoluted tubule.

Structure of the glomerulus

Glomerulus is composed of **fenestratedcapillaries.**

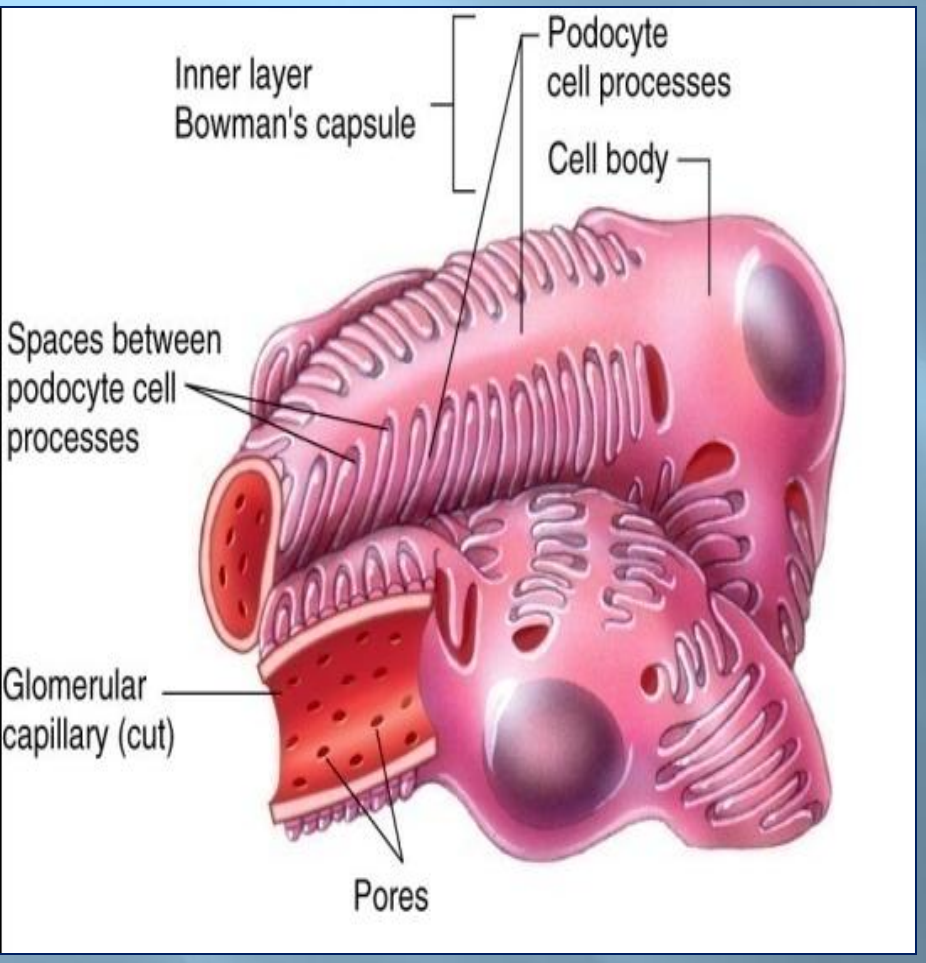
The filtrated fluid passes from the capillaries into the Bowman,s capsule through the **filtration membrane**.

The filtration membrane consists of:

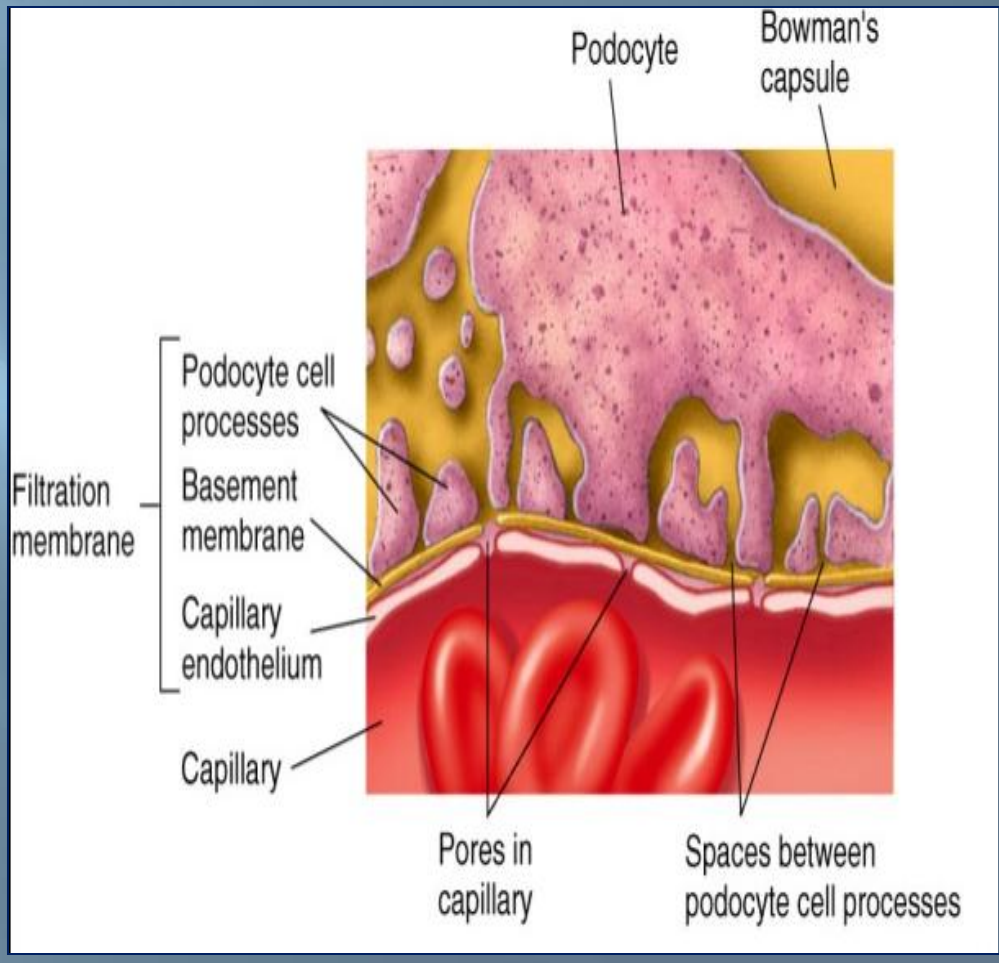
1-Fenestrated glomerular capillary endothelium.

2- Basement membrane.

3-Podocytes processes



Figure(1):Fenesterated capillaries



Figure(2):Filtration membrane of the glomerulus.

Renal Blood Supply

The **renal artery** enters the kidneys at the **hilum.**

The renal artery branches to form **interlobar arteries,** which radiate out towards the cortex.

Interlobar arteries diverge near the base of the pyramid to form **arcuate.**

Interlobular arteries project from the arcuate.

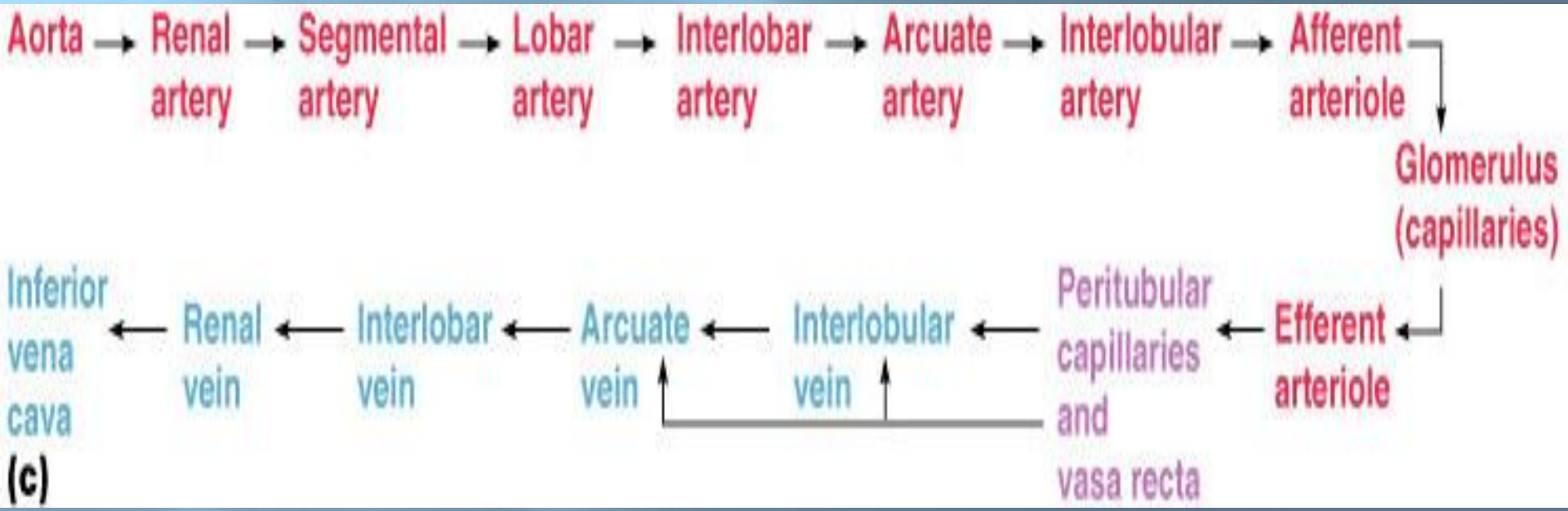
Interlobular arteries give rise to the **afferent arterioles** that supply the **glomerular capillaries.**

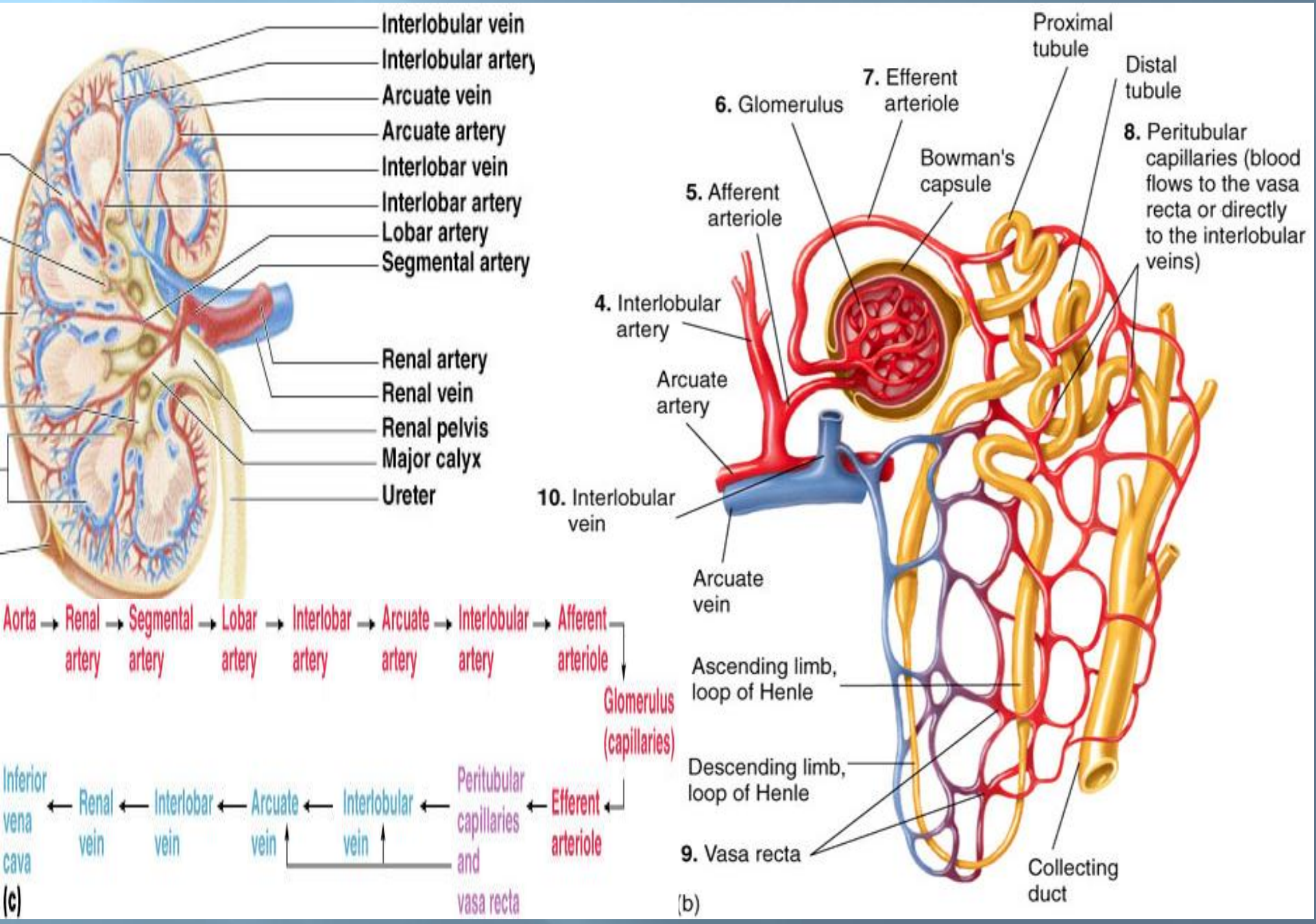
Efferent arterioles arise from the glomerular capillaries to carry the blood away from the glomeruli.

When the efferent arteriole exists the glomerulus ,it gives rise to plexus of capillaries, **peritubular capillaries** around the proximal and distal tubules.

- The efferent arteriole leaving the renal corpuscle enters the **peritubular capillaries** in the cortex (surrounding the proximal and distal tubules), which then flow in to the **vasa recta** capillaries in the medulla (around the loop of Henle and collecting ducts).
- Because of their arrangement ,the vasa recta perform differently from the peritubular capillaries

- **Vasa recta** is a specialized part of the peritubular capillaries course into the medulla along the loop of Henele of the juxtamedullary nephrons,then back toward the cortex.
- Veins form from peritubular capillaries are: **interlobular veins** to **arcuate vein** to **interlobar vein** to **renal vein.**




Interlobular vein
Interlobular artery
Arcuate vein
Arcuate artery
Interlobar vein
Interlobar artery
Lobar artery
Segmental artery
Renal artery
Renal vein
Renal pelvis
Major calyx
Ureter
Aorta → Renal artery → Segmental artery → Lobar artery → Interlobar artery → Arcuate artery → Interlobular artery → Afferent arteriole → Glomerulus (capillaries) → Efferent arteriole → Peritubular capillaries and vasa recta → Interlobular vein → Arcuate vein → Interlobar vein → Renal vein → Inferior vena cava
(c)
6. Glomerulus
7. Efferent arteriole
Proximal tubule
Distal tubule
8. Peritubular capillaries (blood flows to the vasa recta or directly to the interlobular veins)
Bowman's capsule
5. Afferent arteriole
4. Interlobular artery
Arcuate artery
10. Interlobular vein
Arcuate vein
Ascending limb, loop of Henle
Descending limb, loop of Henle
9. Vasa recta
Collecting duct
(b)

Renal nerve supply

- The kidney has rich **sympathetic nonadrenergic** innervations which supply renal artery and its branches, juxtaglomerular apparatus and renal tubules.

- Thanks