HISTOLOGY Of the Kidney

Lecture (35)

Prepared by

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Learning objectives (ILOs) and contents

After this lecture, students should be able to:

1- Describe the histological organization of the kidney; cortical and medullary organization .

2- **Describe the structural units ; uriniferous tubules .**

3-Discriminate the different parts of functional units; the nephrons .

4- Describe the histological structure of the renal corpuscles and correlate the histological structure and functions of these corpuscles .

5- Describe the histological structure of The glomerular filtration barrier.

Structure of the kidney with L.M.:

The stroma is formed by a thin fibrous connective tissue capsule .*The interstitial connective tissue is scanty.*

The parenchyma of the kidney:

-The kidney is a compound tubular gland formed of the uriniferous tubules. Each uriniferous tubule is formed of 2 parts of different origin and function; A: The nephron. B: Collecting tubules. Nephrons are the functional units of the kidney.

-Each kidney contains 1–1.3 million nephrons. The nephron is a tube about 55 mm in length in the human kidney. It starts at one end with Bowman's capsule, which is the enlarged blind end of the nephron. Bowman's capsule has been invaginated by a tuft of capillaries (glomerulus) so that, it has 2 layers: the visceral layer is in direct contact with the capillary endothelium, and the parietal layer surrounds an approximately spherical urinary space. Bowman's capsule and glomerulus of capillaries form a renal corpuscle.

-Nephrons connect to collecting ducts .The nephron and the collecting duct form the uriniferous tubule.

- The parenchyma is arranged in two zones: An outer darker reddish brown granular tissue; cortex and an inner lighter tissue; medulla.The outer renal cortex consists of many round corpuscles and tubule cross sections, whereas the inner renal medulla consists mostly of aligned linear tubules and ducts.

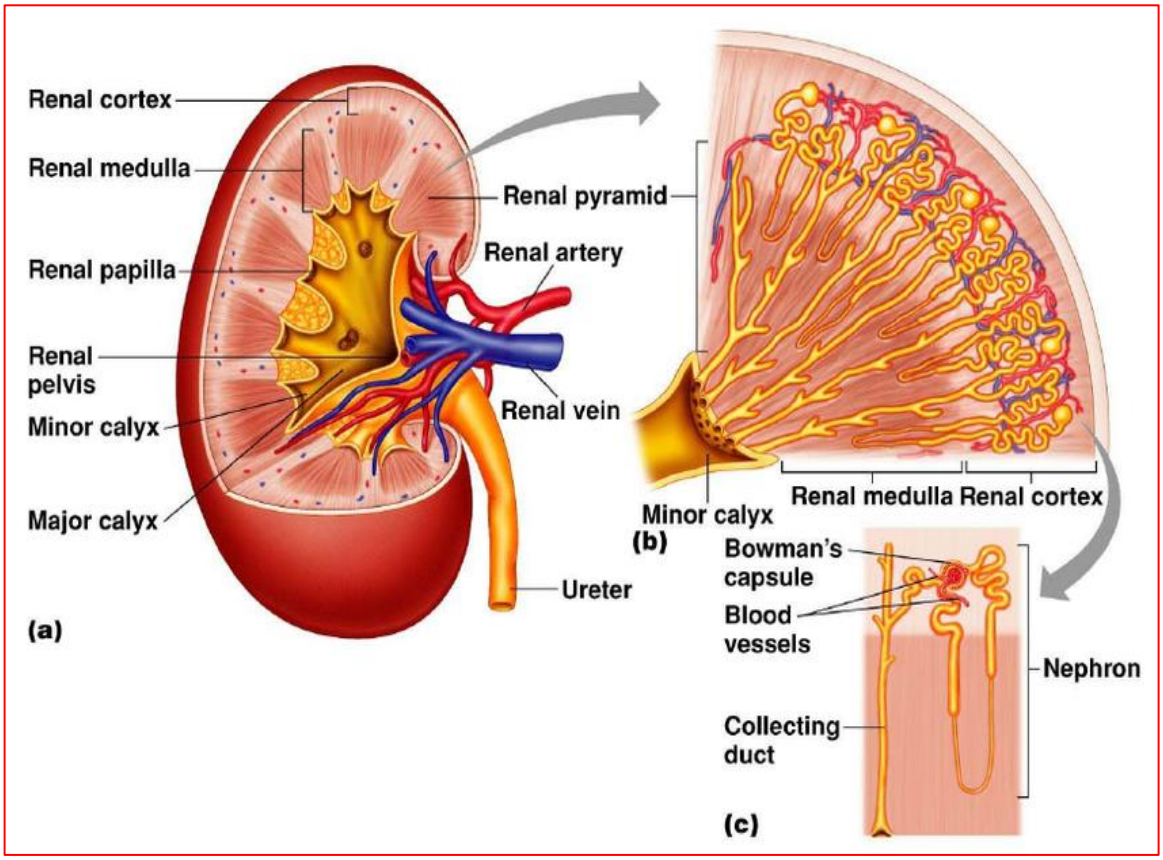
- Renal pelvis, the expanded upper portion of the ureter sends to the substance of the medulla 2 or 3 major calyces which divide into smaller divisions called minor calyces.

- The renal medulla in humans consists of 8-15 conical structures called *renal pyramids,* all with their bases meeting the cortex (at the corticomedullary junction) and separated from each other by extensions of the cortex called *renal columns*.
-Each pyramid plus the cortical tissue at its base and extending along its sides constitutes a *renal lobe.*
-Parallel ducts and tubules extending from the medulla into the cortex comprise the medullary rays; these plus their associated cortical tissue are considered *renal lobules*.
-The tip of each pyramid, called the *renal papilla*, projects into a minor calyx that collects urine formed by tubules in one renal lobe.
-The number of nephrons decreases slightly in older adults, a process accelerated by high blood pressure.

If a kidney is donated for transplant (unilateral nephrectomy), the remaining kidney undergoes compensatory growth with cellular hypertrophy in the proximal parts of the nephron tubules and an increase in the rate of filtration, which allow normal renal function .

-The major divisions of each nephron are:

1- Renal corpuscle;
2- Proximal tubule, a long convoluted part, located entirely in the cortex, with a shorter straight part that enters the medulla;
3- Loop of Henle (or nephron loop), in the medulla, with a thin descending and a thin ascending limb;
4- Distal tubule, consisting of a thick straight part ascending from the loop of Henle back into the cortex and a convoluted part completely in the cortex; and
5- Connecting tubule, a short minor part linking the nephron to collecting duct .


Renal cortex
Renal medulla
Renal pyramid
Renal artery
Renal papilla
Renal pelvis
Renal vein
Minor calyx
Major calyx
Ureter
(a)
Minor calyx
(b)
Renal medulla
Renal cortex
Bowman's capsule
Blood vessels
Nephron
Collecting duct
(c)

Connecting tubules from several nephrons merge to form collecting tubules that then merge as larger collecting ducts. These converge in the renal papilla, where they deliver urine to *a minor calyx*.

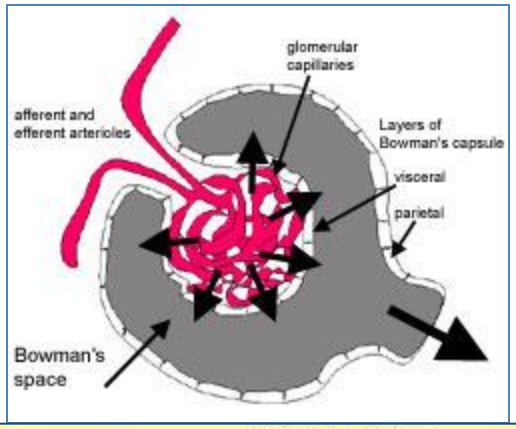
Cortical nephrons **are located almost completely in the cortex while** ***juxtamedullary nephrons*** **(about one-seventh of the total nephrons) lie close to the medulla and have long loops of Henle.**

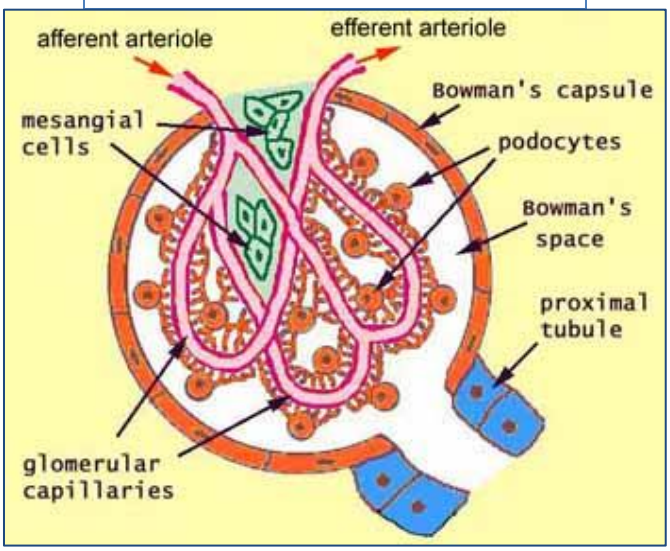
Renal Corpuscles

The renal corpuscle :It is the initial dilated part of the nephron enclosing a tuft of capillary loops. It is the site of blood filtration, always located in the cortex, about 200 µm in diameter. It consists of a tuft of glomerular capillaries, the glomerulus, surrounded by a double-walled epithelial capsule called the glomerular (Bowman) capsule. It has two poles; a vascular pole &a urinary one.

A) Bowman's capsule:

It is a double- walled cup, formed of a parietal and a visceral layers separated by Bowman's space or capsular space, which is continuous with the lumen of the renal tubule. The outer parietal layer of a glomerular capsule consists of a simple squamous epithelium supported externally by a basal lamina. At the tubular pole, this epithelium changes to the simple cuboidal epithelium that continues and forms the proximal tubule.





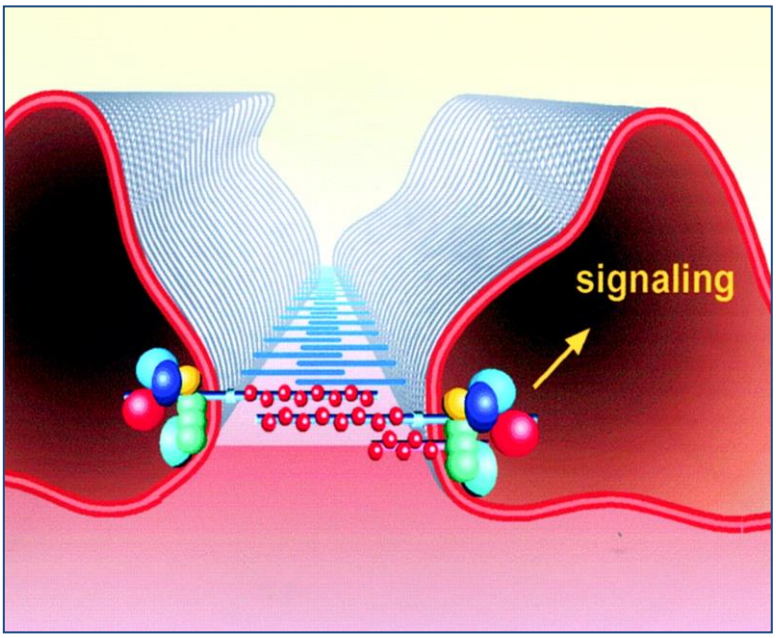
The visceral layer of the glomerular (Bowman) capsule consists of unusual stellate epithelial cells called podocytes , From the cell body of each podocyte several primary processes extend and curve around a length of glomerular capillary.

-Each primary process gives rise to many parallel, interdigitating *secondary processes or pedicels* (L. pediculus, little foot).

-The pedicels cover much of the capillary surface, in direct contact with the basal lamina. Between the interdigitating pedicels are elongated spaces, or filtration slit pores, 25- to 30-nm wide.

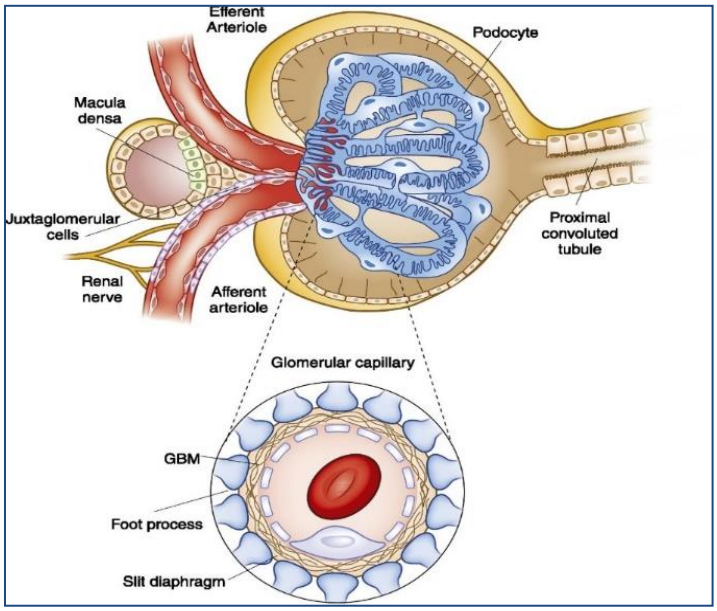
-Spanning adjacent pedicels and bridging the slit pores are zipper-like *Slit diaphragms* that are modified and specialized occluding or tight junctions composed of nephrons & other proteins, glycoproteins, and proteoglycans important for renal function. Projecting from the cell membrane on each side of the

filtration slit, these polyanionic glycoproteins and proteoglycans interact to form a series of openings within the slit diaphragm, with a surface that is negatively charged.



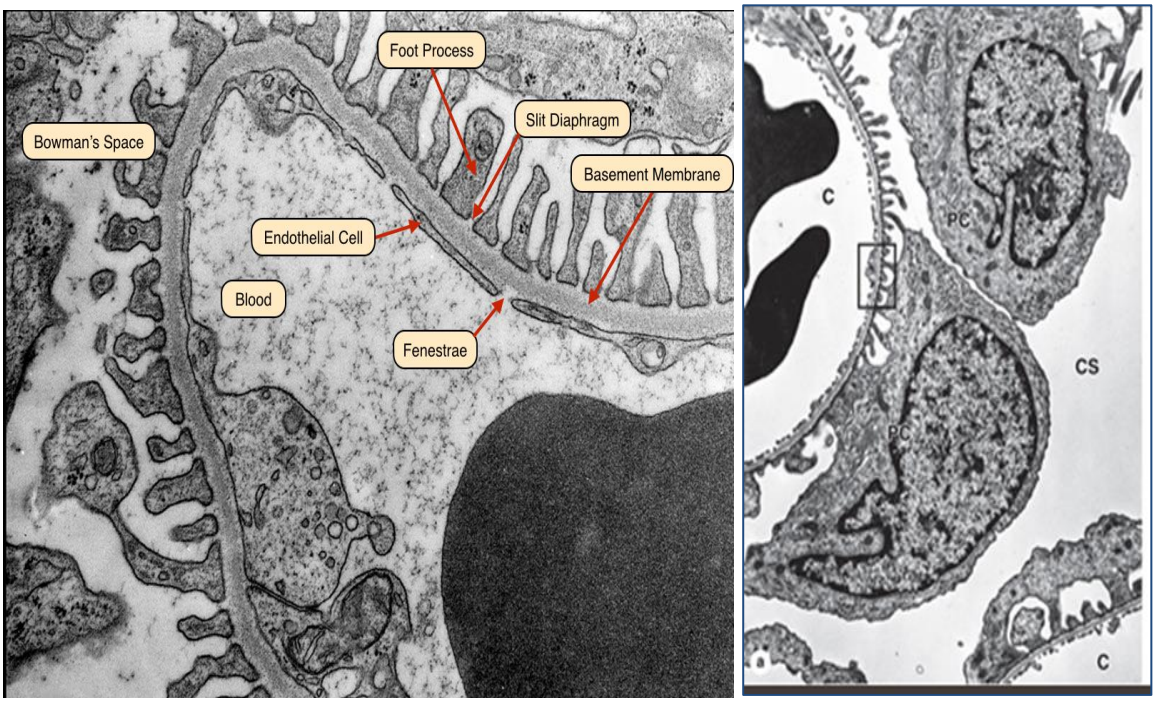
B) Glomerular capillaries:

Have highly fenestrated endothelial cells with a total length of approximately 1 cm and are uniquely situated between two arterioles—afferent and efferent—the muscle of which allows increased hydrostatic pressure in these vessels, favoring movement of plasma across the glomerular filter.



Between the endothelial cells of the capillaries and the covering podocytes is the thick (300-360 nm) glomerular basement membrane (GBM). This membrane is the most substantial part of the filtration barrier(that separates the blood in the capillary lumen from the capsular space) and is formed by fusion of the capillary- and podocyte- basal laminae. Laminin and fibronectin in this fused basement membrane bind integrins of both the podocyte and endothelial cell membranes, and the meshwork of cross-linked type IV collagen and large proteoglycans restricts passage of proteins larger than about 70 kDa.

The glomerular filtration barrier consists of three layered components:
1-The fenestrated capillary endothelium,
2-The glomerular basement membrane (GBM), the major component of the filter formed by fusion of the basal laminae of a podocyte and a capillary endothelial cell, and
3-filtration slit diaphragms between pedicels.



Glomerular filtration barrier.
Note: fenestrations in the endothelium of the capillary and the filtration slits , separating the pedicels , thick, fused basement membrane , and the thin slit diaphragms bridge the slits between pedicels.

Blood plasma is filtered from the lumen of the capillary to the urinary space across the combined capillary endothelium-podocyte complex. Fenestrations in the endothelium are large (50–100 nm) and occupy 20% of the capillary surface. Fenestrations block the exit of cells, but allow free flow of plasma. The shared basal lamina of podocytes and endothelium constitutes the first, coarser filtration barrier; it blocks the passage of molecules larger than 70 kD. The thin diaphragms covering the slit openings between the podocyte foot processes constitute a more selective filter. The slits are composed of elongated proteins which arise from the surface of the adjacent foot process cell membranes and join in the center of the slit, in a zipper-like configuration. The width of the junction between 2 adjacent podocytes varies between 20 and 50 nm, possibly as a function of perfusion pressures of the glomerulus. Podocyte foot processes are motile (they contain actin and myosin). They are connected to each other by the slit diaphragm and to the basal lamina. The slit diaphragm molecular complex is associated with the actin cytoskeleton. Alterations in composition and/or arrangement of these complexes are found in many forms of human and experimental diseases.

addition to capillary endothelial cells and podocytes, renal corpuscles also contain mesangial cells (Gr. Mesos, in the midst + angion, vessel), most of which resemble vascular pericytes in having contractile properties and producing components of an external lamina. Mesangial cells are difficult to distinguish in routine sections from podocytes, but often stain more darkly.

-They and their surrounding matrix comprise the mesangium , which fills interstices between capillaries that lack podocytes.

-Mesangial cells extend contractile processes along capillaries that help regulate blood flow in the glomerulus. Some mesangial processes pass between endothelial cells (EC) into the capillary lumen where they may help remove or endocytose adherent proteinaggregates. Functions of the mesangium include the following:

1- Physical support of capillaries within the glomerulus.

2- Adjusted contractions in response to blood pressure changes, which help maintain an optimal filtration rate.

3- Phagocytosis of protein aggregates adhering to the glomerular filter, including antibody-antigen complexes abundant in many pathological conditions.

4- Secretion of several cytokines, prostaglandins, and other factors important for immune defense and repair in the glomerulus .

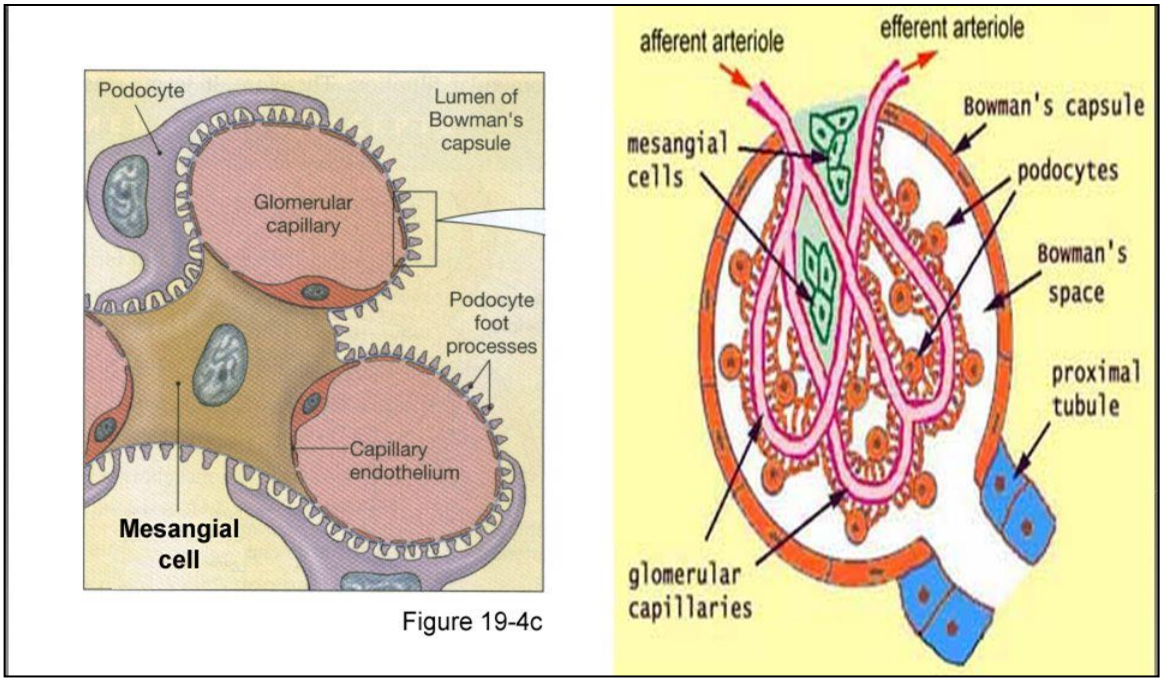


Figure 19-4c

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ºMEDICAL APPLICATION In diseases such as diabetes mellitus and glomerulonephritis, the glomerular filter is altered and becomes much more permeable to proteins, with the subsequent release of protein into the urine (proteinuria). Proteinuria is an indicator of many potential kidney disorders.