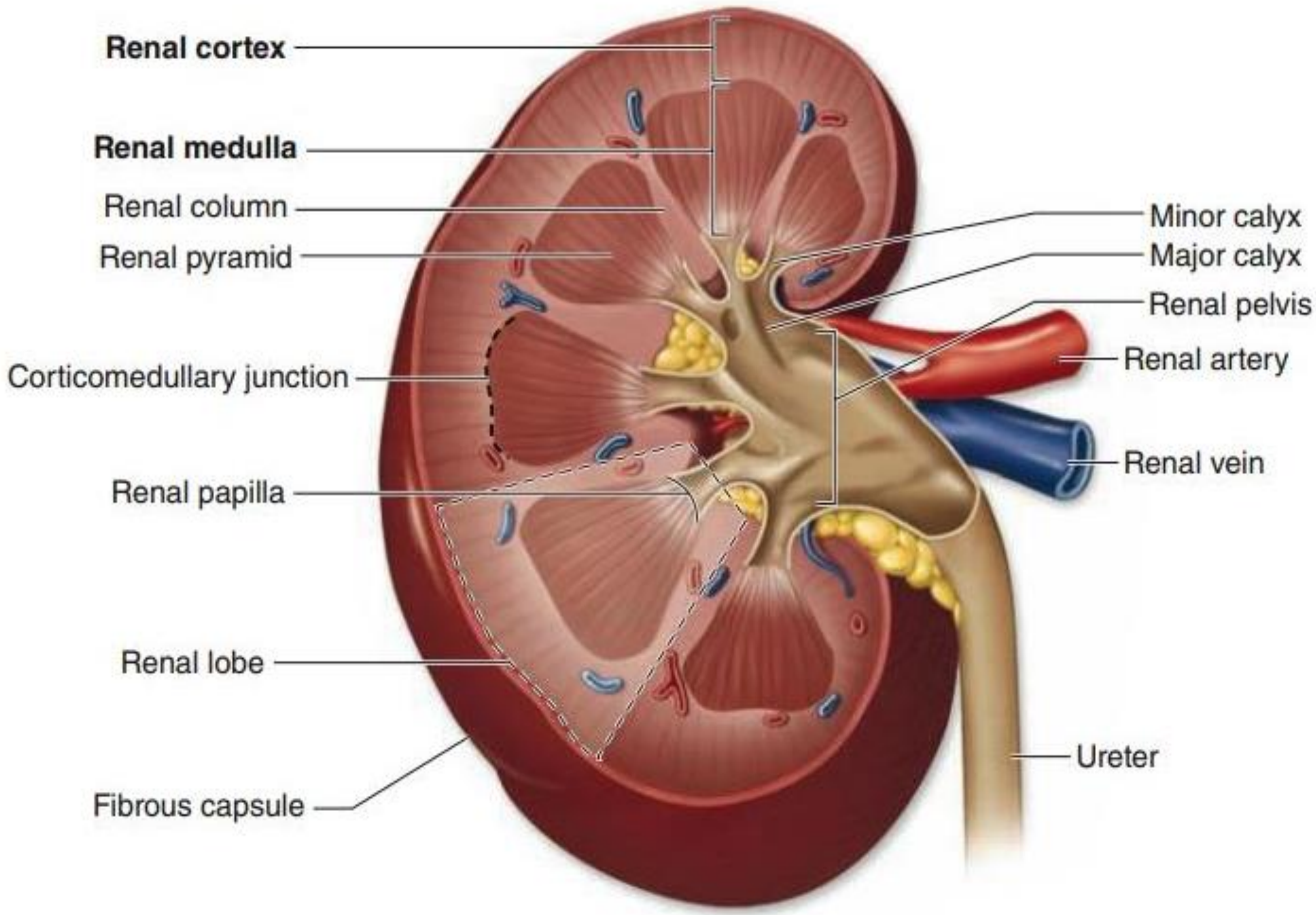
URINARY SYSTEM

DR. NASSAM EMAD DAIM

Kidney.



Each kidney is bean-shaped, with a concave **hilum** where the ureter and the renal artery and vein enter. The ureter divides and subdivides into several **major and minor calyces**, around which is located the renal sinus containing adipose tissue.

Attached to each minor calyx is a **renal pyramid**, a conical region of medulla delimited by extensions of **cortex**. The cortex and hilum are covered with a fibrous capsule.

The urinary organs are:

- A pair of kidneys
- A pair of ureters
- The urinary bladder
- The urethra.

Urine production, and the control of its composition, is exclusively the function of the kidneys. The urinary bladder is responsible for storage of urine until it is voided. The ureter and urethra are simple passages for transport of urine.

Functions

- The urinary organs are responsible for the production, storage, and passing of urine. Many harmful waste products (that result from metabolism) are removed from blood through urine. These include urea and creatinine that are end products of protein metabolism.
- Many drugs, or their breakdown products, are also excreted in urine.
- Considerable amount of water is excreted through urine. The quantity is strictly controlled being greatest when there is heavy intake of water, and least when intake is low or when there is substantial water loss in some other way (for example by perspiration in hot weather). This enables the water content of plasma and tissues to remain fairly constant.

Note: In diseased conditions urine can contain glucose (as in diabetes mellitus), or proteins (in kidney disease), the excretion of which is normally prevented.

THE KIDNEYS

Each kidney has a characteristic bean-like shape. A thin layer of fibrous tissue, which constitutes the capsule, intimately covers kidney tissue. The capsule of a healthy kidney can be easily stripped off, but it becomes adherent in some diseases.

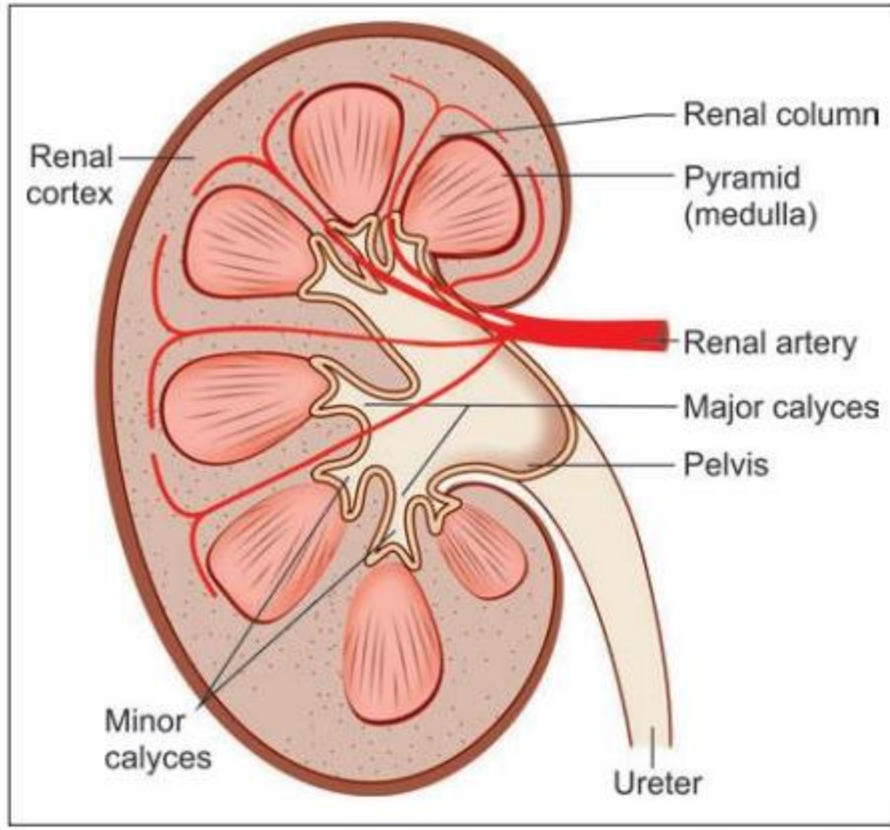
The kidney has a convex lateral margin; and a concavity on the medial side that is called the ***hilum***. The hilum leads into a space called the ***renal sinus***. The renal sinus is occupied by the upper expanded part of the ureter called the ***renal pelvis***.

Within the renal sinus the pelvis divides into two (or three) parts called ***major calyces***. Each major calyx divides into a number of ***minor calyces*** . The end of each minor calyx is shaped like a cup. A projection of kidney tissue, called a ***papilla*** fits into the cup.

Kidney tissue consists of an outer part called the ***cortex***, and an inner part called the ***medulla***

Medulla

The medulla is made up of triangular areas of renal tissue that are called the ***renal pyramids*** . Each pyramid has a base directed towards the cortex; and an apex (or papilla) that is directed towards the renal pelvis, and fits into a minor calyx. Pyramids show striations that pass radially towards the apex.



Some features to be seen in a coronal section through the kidney (Schematic representation)

Cortex

The renal cortex consists of the following:

- Tissue lying between the bases of the pyramids and the surface of the kidney, forming the ***cortical arches*** or ***cortical lobules***. This part of the cortex shows light and dark striations. The light lines are called ***medullary rays***
- Tissue lying between adjacent pyramids is also a part of the cortex. This part constitutes the ***renal columns***.
- In this way each pyramid comes to be surrounded by a 'shell' of cortex. The pyramid and the cortex around it constitute a lobe of the kidney. This lobulation is obvious in the fetal kidney.

Added Information

Interstitial Tissue of the Kidney

Most of the interstitial space in the renal cortex is occupied by blood vessels and lymphatics. In the medulla the interstitium is composed mainly of a matrix containing proteins and glycosaminoglycans. Collagen fibres and interstitial cells are present.

It has been held that interstitial cells produce prostaglandins, but it now appears that prostaglandins are produced by epithelial cells of collecting ducts.

The Uriniferous Tubules

From a functional point of view the kidney may be regarded as a collection of numerous ***uriniferous tubules*** that are specialised for the excretion of urine. Each uriniferous tubule consists of an excretory part called the ***nephron***, and of a ***collecting tubule***. The collecting tubules draining different nephrons join to form larger tubules called the ***papillary ducts*** (of Bellini), each of which opens into a minor calyx at the apex of a renal papilla. Each kidney contains one to two million nephrons.

Urinary tubules are held together by scanty connective tissue. Blood vessels, lymphatics and nerves lie in this connective tissue.

Nephron

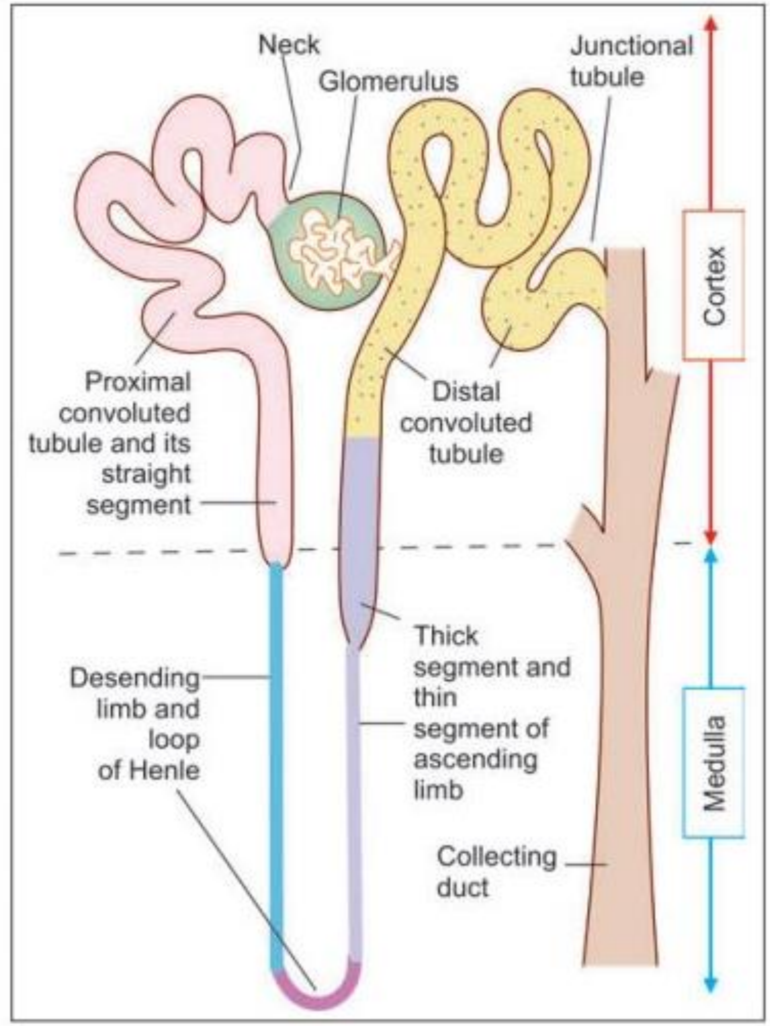
Nephron is the structural and functional unit of kidney and there are about 1-4 million nephrons in each kidney. The nephron consists of a ***renal corpuscle*** (or ***Malpighian corpuscle***), and a long complicated ***renal tubule***. Renal tubule is made up of three parts:

- The proximal convoluted tubule
- Loop of Henle
- The distal convoluted tubule

Renal corpuscle is situated in the cortex of the kidney either near the periphery or near the medulla. Based on the situation of renal corpuscle, the nephrons are classified into two types:

- Cortical nephrons or superficial nephrons (which have their corpuscles in the outer cortex).
- Juxtamedullary nephrons (which have their corpuscles in the inner cortex near medulla or corticomedullary junction).

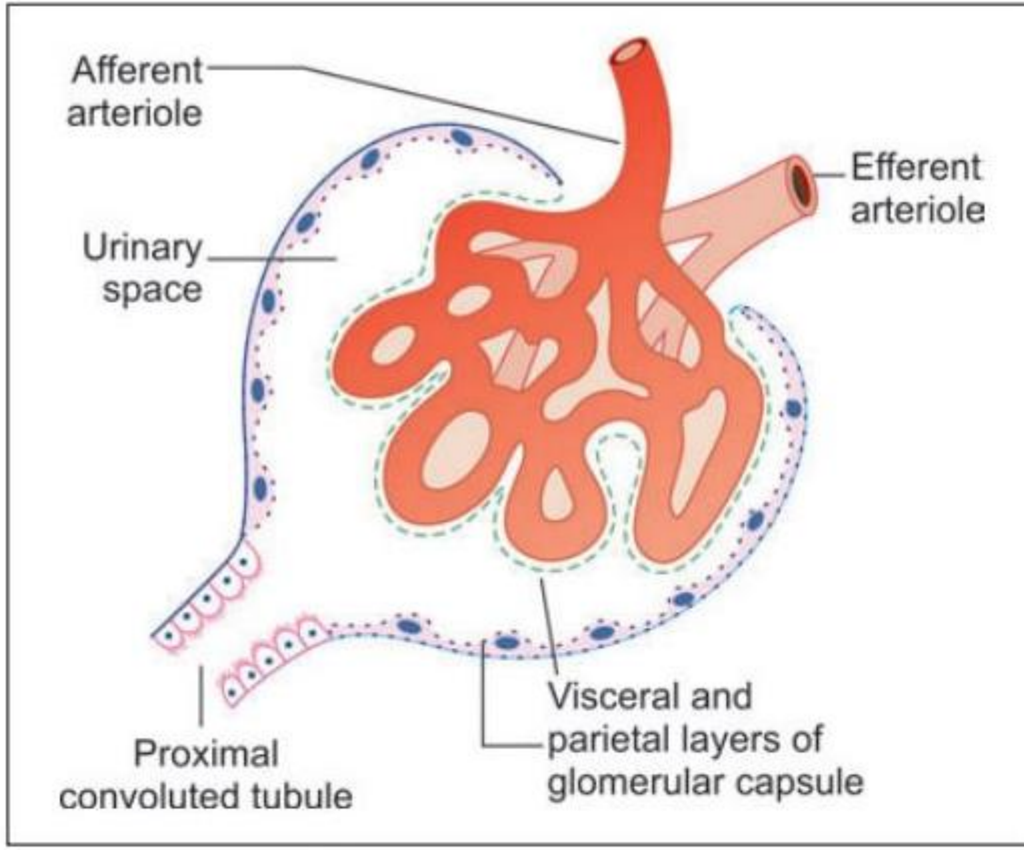
Renal corpuscles, and (the greater parts of) the proximal and distal convoluted tubules are located in the cortex of the kidney. The loops of Henle and the collecting ducts lie in the medullary rays and in the substance of the pyramids.



Parts of a nephron. A collecting duct is also shown (Schematic representation)

The Renal Corpuscle

The renal corpuscle is a rounded structure consisting of (a) a rounded tuft of blood capillaries called the ***glomerulus***; and (b) a cup-like, double layered covering for the glomerulus called the ***glomerular capsule*** (or ***Bowman's capsule***) The glomerular capsule represents the cup-shaped blind beginning of the renal tubule. Between the two layers of the capsule there is a ***urinary space*** that is continuous with the lumen of the renal tubule.

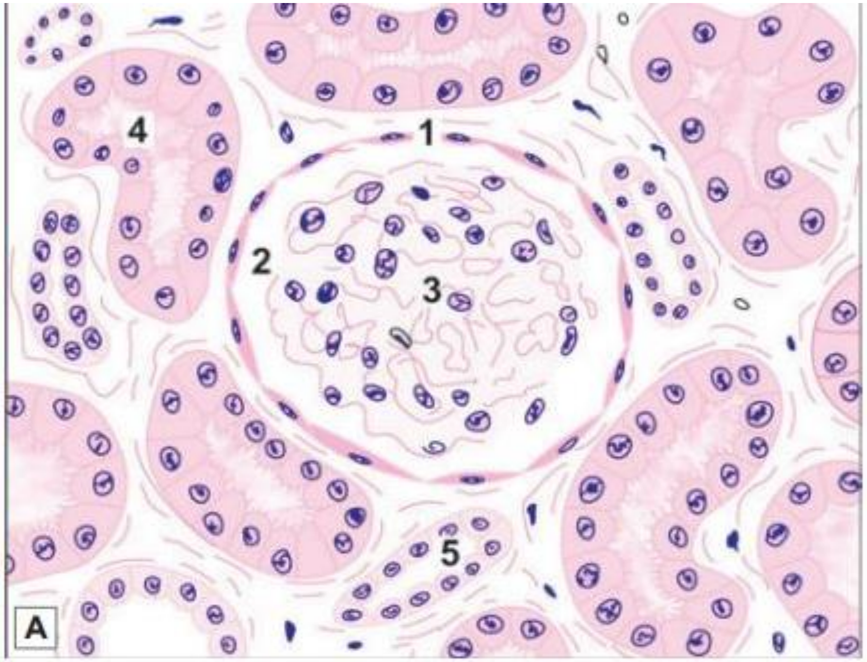


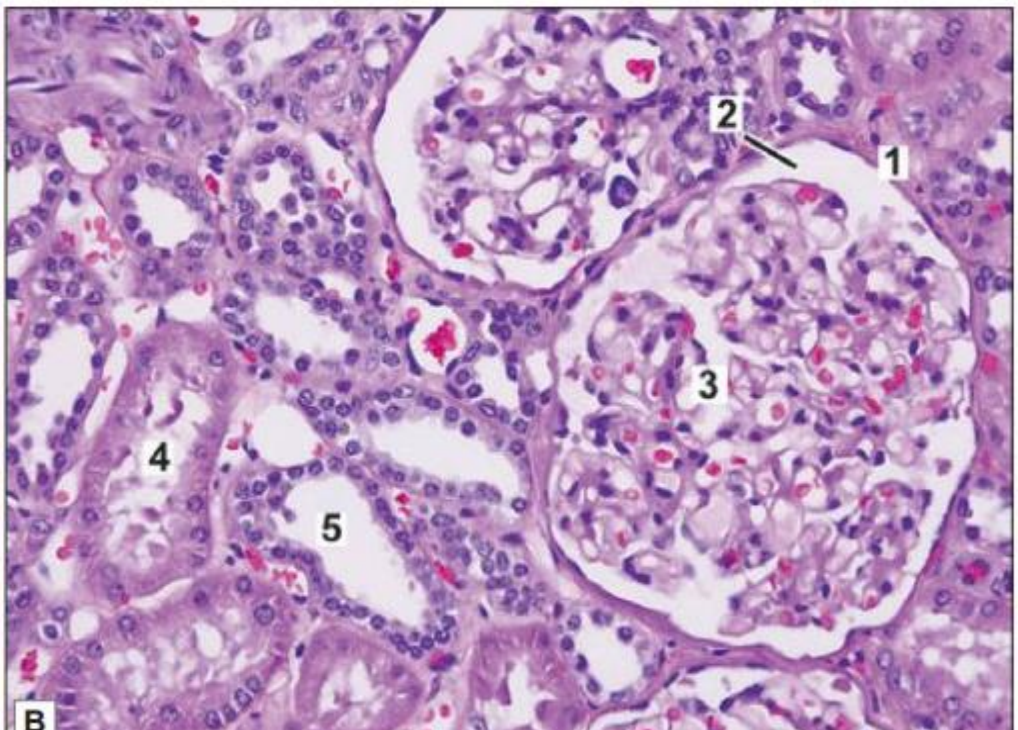
Basic structure of a renal corpuscle (Schematic representation)

Glomerulus

The glomerulus is a rounded tuft of anastomosing capillaries .Blood enters the tuft through an afferent arteriole and leaves it through an efferent arteriole (Note that the efferent vessel is an arteriole, and not a venule. It again breaks up into capillaries).

The afferent and efferent arterioles lie close together at a point that is referred to as the ***vascular pole*** of the renal corpuscle





- In the high power view of renal cortex large renal corpuscles can be identified
- The renal corpuscle consists of a tuft of capillaries that form a rounded glomerulus, and an outer wall, the glomerular capsule (Bowman's capsule)
- A urinary space between the glomerulus and the capsule is seen
- Proximal convoluted tubules are dark staining. They are lined by cuboidal cells with a prominent brush border. Their lumen is indistinct
- Distal convoluted tubules are lighter staining. The cuboidal cells lining them do not have a brush border. Their lumen is distinct.

Key

1. Bowman's capsule
2. Urinary space
3. Glomerulus
4. Proximal convoluted tubule
5. Distal convoluted tubule

The Mesangium

On entering the glomerulus the afferent arteriole divides (usually) into five branches, each branch leading into an independent capillary network. The glomerular circulation can, therefore, be divided into a number of lobules or segments.

Glomerular capillaries are supported by the ***mesangium*** that is made up of mesangial cells surrounded by a non-cellular mesangial matrix. The mesangium forms a mesentery-like fold over the capillary loop. Mesangial cells give off processes that run through the matrix. Mesangium intervenes between the capillaries of the glomerular segments.

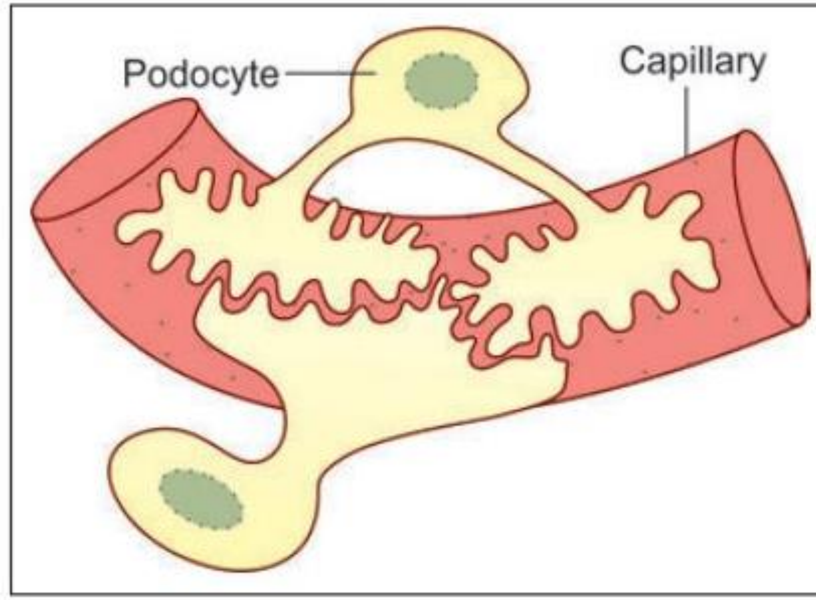
Mesangial cells contain filaments similar to myosin. They bear angiotensin II receptors. It is believed that stimulation by angiotensin causes the fibrils to contract. In this way mesangial cells may play a role in controlling blood flow through the glomerulus. Other functions attributed to mesangial cells include phagocytosis, and maintenance of glomerular basement membrane. The mesangium becomes prominent in a disease called glomerulonephritis.

Glomerular Capsule

The glomerular capsule is a double-layered cup, the two layers of which are separated by the urinary space. The outer layer is lined by squamous cells. With the light microscope the inner wall also appears to be lined by squamous cells, but the EM shows that these cells, called ***podocytes***, have a highly specialised structure. The urinary space becomes continuous with the lumen of the renal tubule at the ***urinary pole*** of the renal corpuscle. This pole lies diametrically opposite the vascular pole.

Podocytes

The ***podocytes*** are so called because they possess foot-like processes. Each podocyte has a few ***primary processes*** that give the cell a star-shaped appearance . These processes are wrapped around glomerular capillaries and interdigitate with those of neighbouring podocytes. Each primary process terminates in numerous ***secondary processes*** also called ***pedicels*** (or end feet) that rest on the basal lamina. The cell body of the podocyte comes in contact with the basal lamina only through the pedicels.

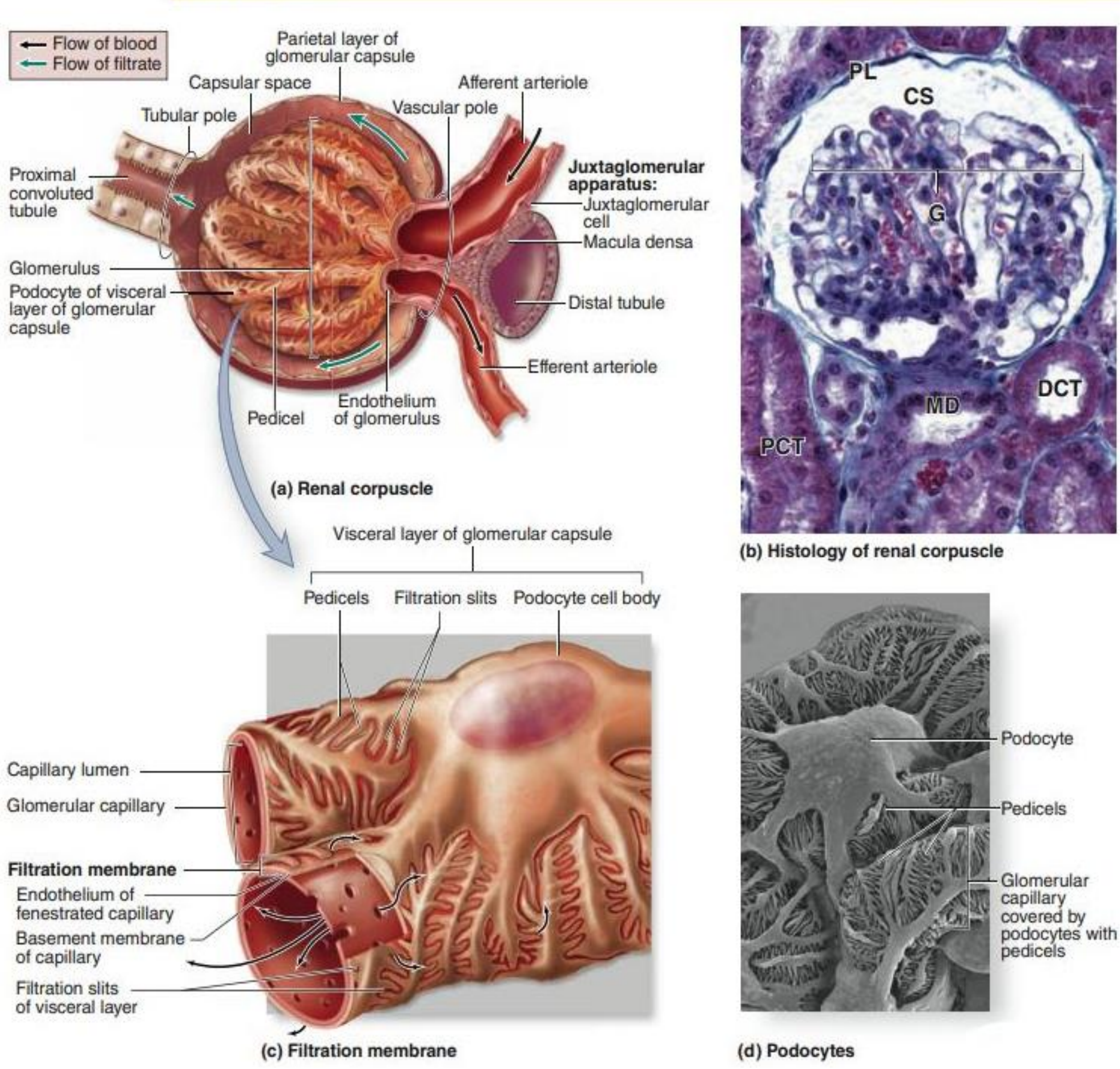


Relationship of podocytes to a glomerular capillary. Note that the entire surface of the capillary is covered by processes of podocytes, the bare areas being shown only for sake of clarity (Schematic representation)

Glomerular Basement Membrane

As compared to typical membranes the glomerular basement membrane is very thick (about 300 nm). It is made up of three layers. There is a central electron dense layer (***lamina densa***), and inner and outer electron lucent layers (***lamina rara interna*** and ***externa***). The lamina densa contains a network of collagen (type IV) fibrils, and thus acts as a physical barrier. The electron lucent layers contain the glycosaminoglycan heparan sulphate. This bears the negative charges referred to above. The glomerular basement membrane is, therefore, both a physical barrier and an electrical barrier to the passage of large molecules.

Renal corpuscles.



(a) The renal corpuscle is a small mass of capillaries called the glomerulus housed within a bulbous glomerular capsule. The internal lining of the capsule is composed of complex epithelial cells called podocytes, which cover each capillary, forming slit-like spaces between interdigitating processes called pedicels. Blood enters and leaves the glomerulus through the afferent and efferent arterioles, respectively

(b) The micrograph shows the major histologic features of a renal corpuscle. The glomerulus (G) of capillaries is surrounded by the capsular space (CS) covered by the simple squamous parietal layer (PL) of Bowman capsule. Near the corpuscle is that nephron’s macula densa (MD) and sections of proximal convoluted tubules (PCT) and distal convoluted tubules (DCT). (H&E; X300)

(c) Filtrate is produced in the corpuscle when blood plasma is forced under pressure through the capillary fenestrations, across the filtration membrane or GBM surrounding the capillary, and through the filtration slit diaphragms located between the podocyte pedicels

(d) The scanning electron microscopy (SEM) shows the distinctive appearance of podocytes and their pedicel processes that cover glomerular capillaries. (X800)

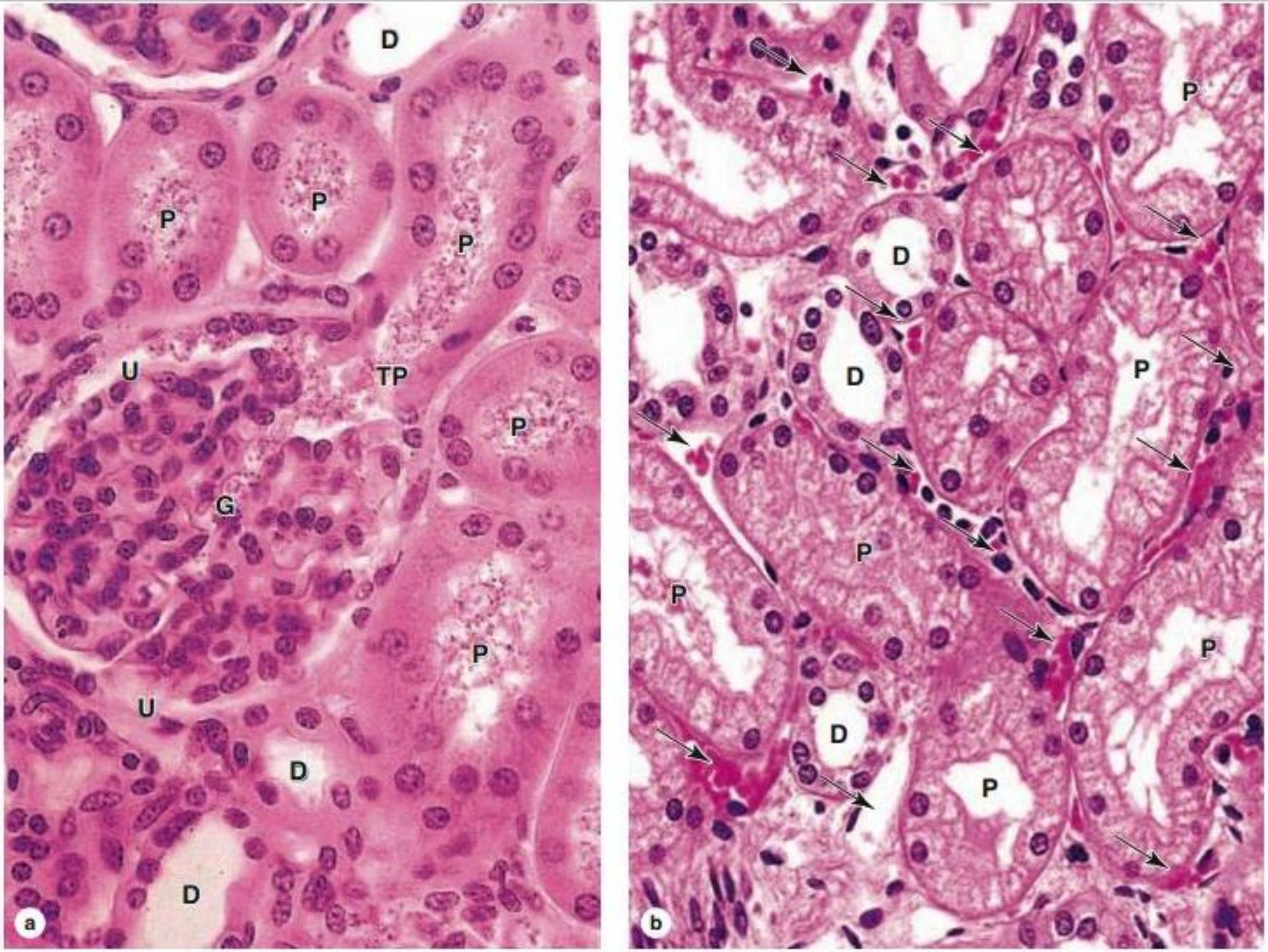
The Renal Tubule

The renal tubule is divisible into several parts that are shown in Figure
Starting from the glomerular capsule (in proximodistal sequence). They are: (**a**) the ***proximal convoluted tubule***; (**b**) the ***loop of Henle*** consisting of a ***descending limb***, a ***loop***, and an ***ascending limb***; and (**c**) the ***distal convoluted tubule***, which ends by joining a collecting tubule. Along its entire length the renal tubule is lined by a single layer of epithelial cells that are supported on a basal lamina.

Proximal Convoluted Tubule

The junction of the proximal convoluted tubule with the glomerular capsule is narrow and is referred to as the ***neck***. The proximal convoluted tubule is made up of an initial part having many convolutions (lying in the cortex), and of a terminal straight part that descends into the medulla to become continuous with the descending limb of the loop of Henle.

The ***neck*** is lined by simple squamous epithelium continuous with that of the glomerular capsule (Some texts refer to the neck as part of the glomerulus).



(a) The micrograph shows the continuity at a renal corpuscle's tubular pole (**TP**) between the simple cuboidal epithelium of a proximal convoluted tubule (**P**) and the simple squamous epithelium of the capsule's parietal layer. The urinary space (**U**) between the parietal layer and the glomerulus (**G**) drains into the lumen of the proximal tubule. The lumens of the proximal tubules appear filled, because of the long microvilli of the brush border and aggregates of small plasma proteins bound to this structure. By contrast, the lumens of distal convoluted tubules (**D**) appear empty, lacking a brush border and protein.

(b) Here the abundant peritubular capillaries and draining venules (arrows) that surround the proximal (**P**) and distal (**D**) convoluted tubules are clearly seen. (Both X400; H&E)

The ***proximal convoluted tubules*** are 40–60 μm in diameter. They have a relatively small lumen. They are lined by cuboidal (or columnar) cells having a prominent brush border. The nuclei are central and euchromatic. The cytoplasm stains pink (with haematoxylin and eosin). The basal part of the cell shows a vertical striation.

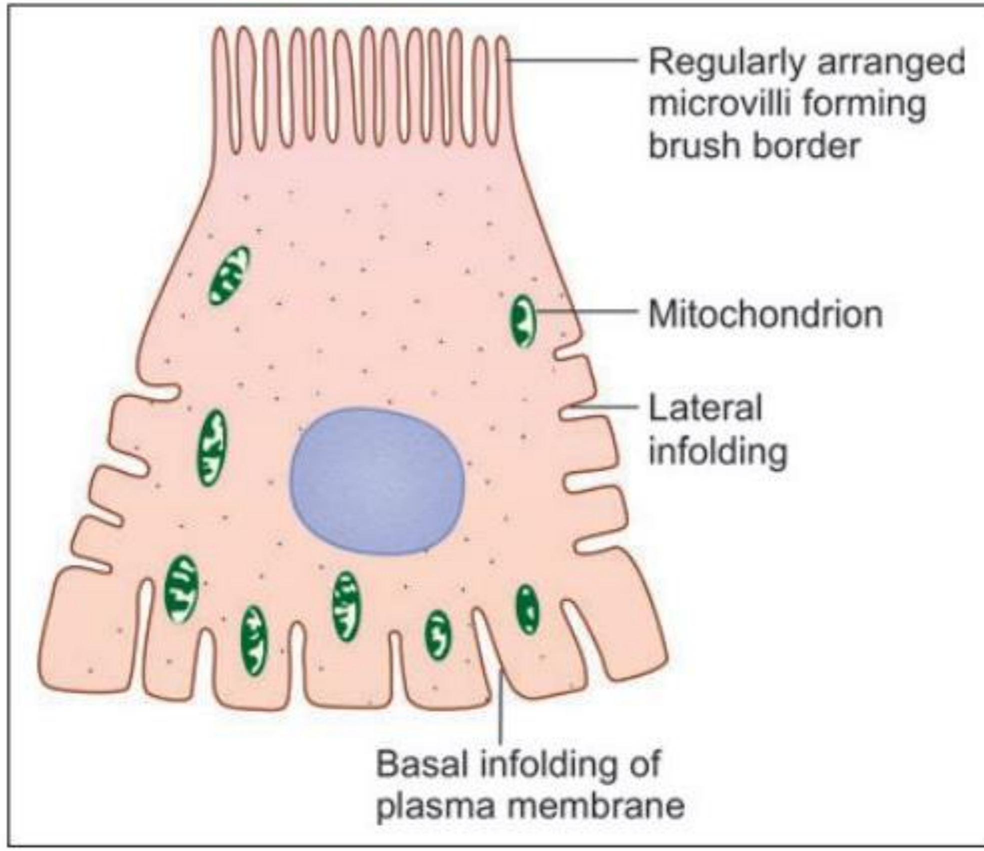
With the EM the lining cells of the proximal convoluted tubules show microvilli on their luminal surfaces. The striae, seen with the light microscope near the base of each cell, are shown by EM to be produced by infoldings of the basal plasma membrane, and by numerous mitochondria that lie longitudinally in the cytoplasm intervening between the folds . The presence of microvilli, and of the basal infoldings greatly increases the surface area available for transport. Adjacent cells show some lateral interdigitations. Numerous enzymes associated with ionic transport are present in the cytoplasm.

Loop of Henle

The descending limb, the loop itself, and part of the ascending limb of the loop of Henle are narrow and thin walled. They constitute the ***thin segment*** of the loop. The upper part of the ascending limb has a larger diameter and thicker wall and is called the ***thick segment***.

The thin segment of the loop of Henle is about 15–30 μm in diameter. It is lined by low cuboidal or squamous cells. The thick segment of the loop is lined by cuboidal cells.

The loop of Henle is also called the ***ansa nephroni***. With the EM the flat cells lining the thin segment of the loop of Henle show very few organelles indicating that the cells play only a passive role in ionic movements across them. In some areas the lining epithelium may show short microvilli, and some basal and lateral infoldings.



Some features of the ultrastructure of a cell lining a proximal convoluted tubule (Schematic representation)

The length of the thin segment of the loop of Henle is variable. The loops of nephrons having glomeruli lying deep in the cortex (juxtamedullary glomeruli) pass deep into the medulla. Those associated with glomeruli lying in the middle of the cortical thickness extend into the medulla to a lesser degree, so that part of the loop of Henle lies in the cortex. Some loops (associated with glomeruli placed in the superficial part of the cortex) may lie entirely within the cortex.

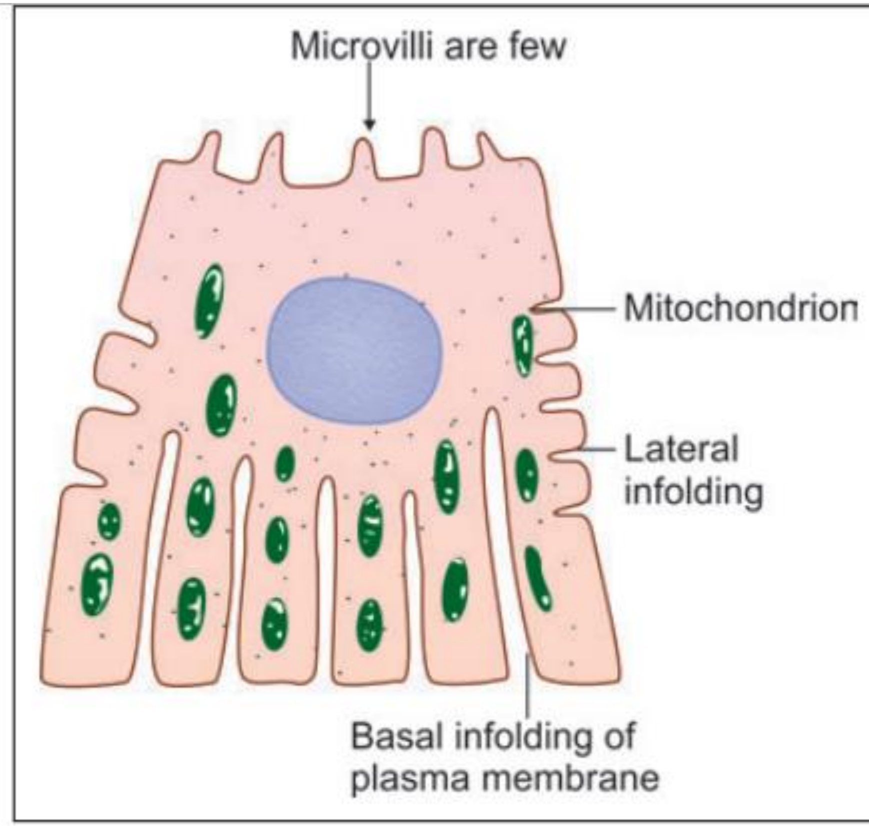
Distal Convoluted Tubule

The distal convoluted tubule has a straight part continuous with the ascending limb of the loop of Henle, and a convoluted part lying in the cortex. At the junction between the two parts, the distal tubule lies very close to the renal corpuscle of the nephron to which it belongs.

The distal convoluted tubules are 20–50 μm in diameter.

They can be distinguished (in sections) from the proximal tubules as

- They have a much larger lumen
- The cuboidal cells lining them do not have a brush border
- They stain less intensely pink (with eosin).



Some features of ultrastructure of a cell lining a distal convoluted tubule (Schematic representation)

The structure of the (ascending) thick segment of the loop of Henle is similar to that of distal convoluted tubules. The cells of the distal convoluted tubules resemble those of the proximal convoluted tubules with the following differences.

- They have only a few small microvilli.
- The basal infoldings of plasma membrane are very prominent and reach almost to the luminal surface of the cell. This feature is characteristic of cells involved in the active transport of ions. Enzymes concerned with active transport of ions are present in the cells.

At the junction of the straight and convoluted parts of the distal convoluted tubules, the cells show specialisations that are described below in connection with the juxtaglomerular apparatus.

Note: Students may be confused by somewhat different terminology used in some books. The straight part of the proximal convoluted tubule is sometimes described as part of the loop of Henle, and is termed the ***descending thick segment,*** in distinction to the (ascending) thick segment. Some workers regard the thin segment alone to be the loop of Henle. They include the descending and ascending thick segments with the proximal and distal convoluted tubules respectively.

Collecting Tubule

The terminal part of the distal convoluted tubule is again straight. This part is called the ***junctional tubule*** or ***connecting tubule***, and ends by joining a collecting duct.

The smallest collecting tubules are 40-50 μm in diameter, and the largest as much as 200 μm. They are lined by a simple cuboidal, or columnar, epithelium. Collecting tubules can be easily distinguished from convoluted tubules as follows.

- Collecting tubules have larger lumina. In transverse sections their profiles are circular in contrast to the irregular shapes of convoluted tubules.
- The lining cells have clear, lightly staining cytoplasm, and the cell outlines are usually distinct. They do not have a brush border.

The walls of collecting tubules (in the proximal part of the collecting system) are lined by two types of cells. The majority of cells (called ***clear cells***) have very few organelles, a few microvilli and some basal infoldings. The lining epithelium also contains some ***dark cells*** (or ***intercalated cells***). These have microvilli, but basal infoldings are not seen. They contain numerous mitochondria.

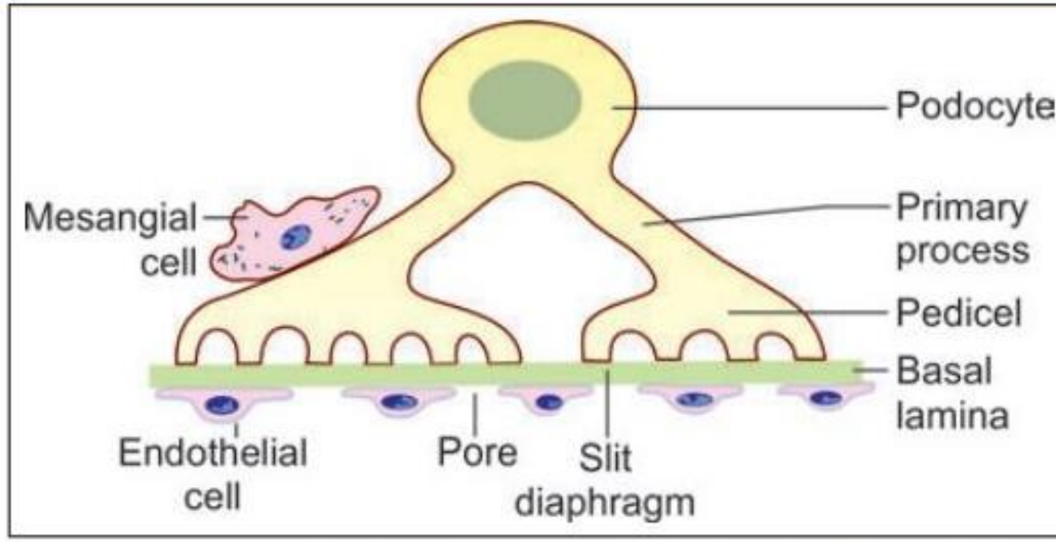
The cells of the collecting ducts do not have microvilli, or lateral infoldings of plasma membrane. Very few organelles are present in the cytoplasm.

Glomerular Filtration Barrier

In the renal corpuscle water and various small molecules pass, by filtration, from blood (in the glomerular capillaries) to the urinary space of the glomerular capsule. Theoretically the barrier across which the filtration would have to occur is constituted by (a) the capillary endothelium, (b) by the cells (podocytes) forming the glomerular (or visceral) layer of the glomerular capsule, and (c) by a ***glomerular basement membrane*** that intervenes between the two layers of cells named above, and represents the fused basal laminae of the two layers. In fact, however, the barrier is modified as follows.

- Firstly, the endothelial cells show numerous fenestrae or pores that are larger than pores in many other situations. The fenestrae are not closed by membrane. As a result filtrate passes easily through the pores, and the endothelial cells do not form an effective barrier.
- Between the areas of attachment of individual pedicels there are gaps in which the basal lamina is not covered by podocyte cytoplasm. Filtration takes place through the basal lamina at these gaps that are, therefore, called ***filtration slits*** or ***slit pores*** . These slits are covered by a layer of fine filaments that constitute the ***glomerular slit diaphragm***. From what has been said above it will be clear that the filtrate does not have to pass through podocyte cytoplasm.

It follows, therefore, that the only real barrier across which filtration occurs is the basal lamina (or the glomerular basement membrane) that is thickened at the filtration slits by the glomerular slit diaphragm. The efficacy of the barrier is greatly enhanced by the presence of a high negative charge in the basement membrane and in podocyte processes. (Loss of this charge, in some diseases, leads to excessive leakage of protein through the barrier).



Filtration slits (Schematic representation)

Defects in the glomerular basement membrane are responsible for the nephrotic syndrome in which large amounts of protein are lost through urine. The regular arrangement of podocyte processes is also disorganised in this condition.

Juxtaglomerular Apparatus

Juxtaglomerular apparatus is a specialised organ situated near the glomerulus of each nephron (juxta = near). The juxtaglomerular apparatus is formed by three different structures.

- Juxtaglomerular cells
- Macula densa
- Lacis cells

Juxtaglomerular Cells

A part of the distal convoluted tubule (at the junction of its straight and convoluted parts) lies close to the vascular pole of the renal corpuscle, between the afferent and efferent arterioles. In this region the muscle cells in the wall of the afferent arteriole are modified. They are large and rounded (epithelioid) and have spherical nuclei. Their cytoplasm contains granules that can be stained with special methods. These are ***juxtaglomerular cells***. They are innervated by unmyelinated adrenergic nerve fibres. Juxtamedullary cells are regarded, by some, as highly modified myoepithelial cells as they contain contractile filaments in the cytoplasm.

The granules of the juxtaglomerular cells are seen by EM to be membrane bound secretory granules. They contain an enzyme called ***renin***.

The juxtaglomerular cells also probably act as baroreceptors reacting to a fall in blood pressure by release of renin. Secretion of renin is also stimulated by low sodium blood levels and by sympathetic stimulation.

Note: In addition to renin the kidney produces the hormone erythropoietin (which stimulates erythrocyte production). Some workers have claimed that erythropoietin is produced by juxtaglomerular cells, but the site of production of the hormone is uncertain.

Macula Densa

The wall of the distal convoluted tubule is also modified at the site of contact with the arteriole. Here the cells lining it are densely packed together, and are columnar (rather than cuboidal as in the rest of the tubule). These cells form the ***macula densa***. The cells of the macula densa lie in close contact with the juxtaglomerular cells.

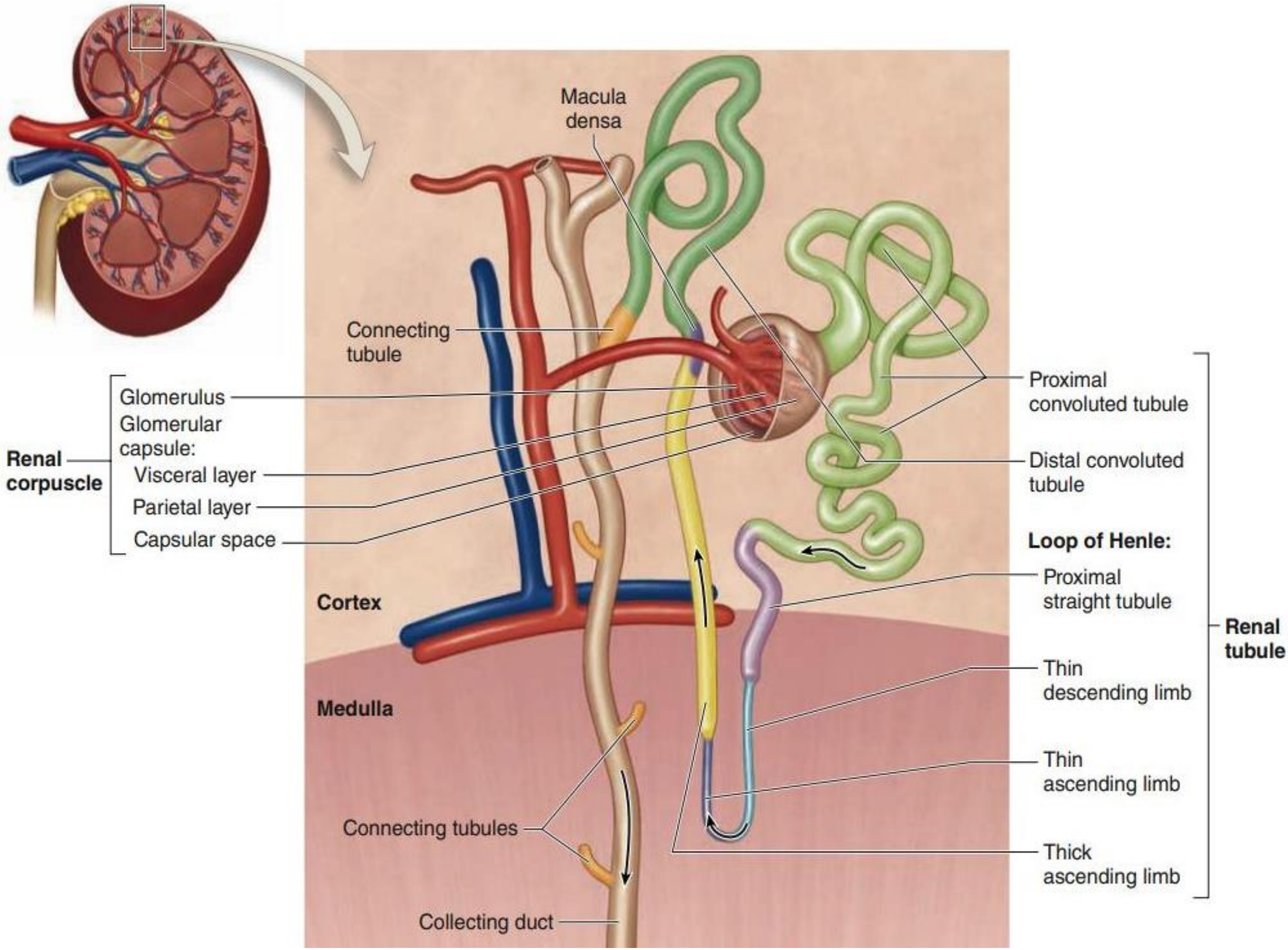
Lacis Cells

In addition to the renin producing cells, and the macula densa, the juxtaglomerular apparatus has a third component: these are ***lacis cells***. These cells are so called as they bear processes that form a lace-like network. They are located in the interval between the macula densa and the afferent and efferent arterioles. The function of lacis cells is unknown.

Mode of Action of Juxtaglomerular Apparatus

The juxtaglomerular apparatus is a mechanism that controls the degree of resorption of ions by the renal tubule. It appears likely that cells of the macula densa monitor the ionic constitution of the fluid passing across them (within the tubule). The cells of the macula densa appear to influence the release of renin by the juxtaglomerular cells.

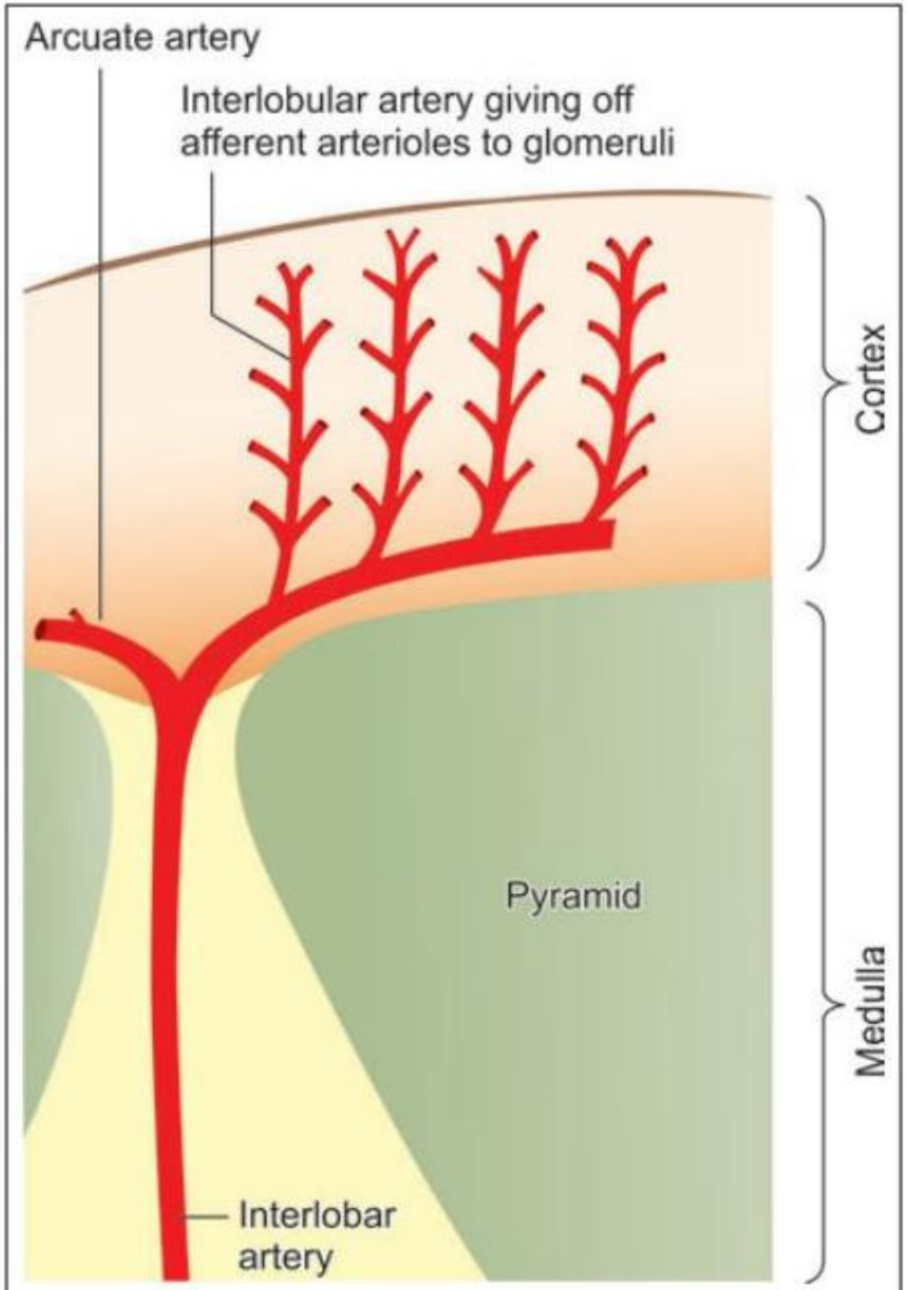
Renin acts on a substance called ***angiotensinogen*** present in blood and converts it into ***angiotensin I***. Another enzyme (present mainly in the lungs) converts angiotensin I into ***angiotensin II***. Angiotensin II increases blood pressure. It also stimulates the secretion of aldosterone by the adrenal cortex, thus influencing the reabsorption of sodium ions by the distal convoluted tubules, and that of water through the collecting ducts. In this way it helps to regulate plasma volume and blood pressure.



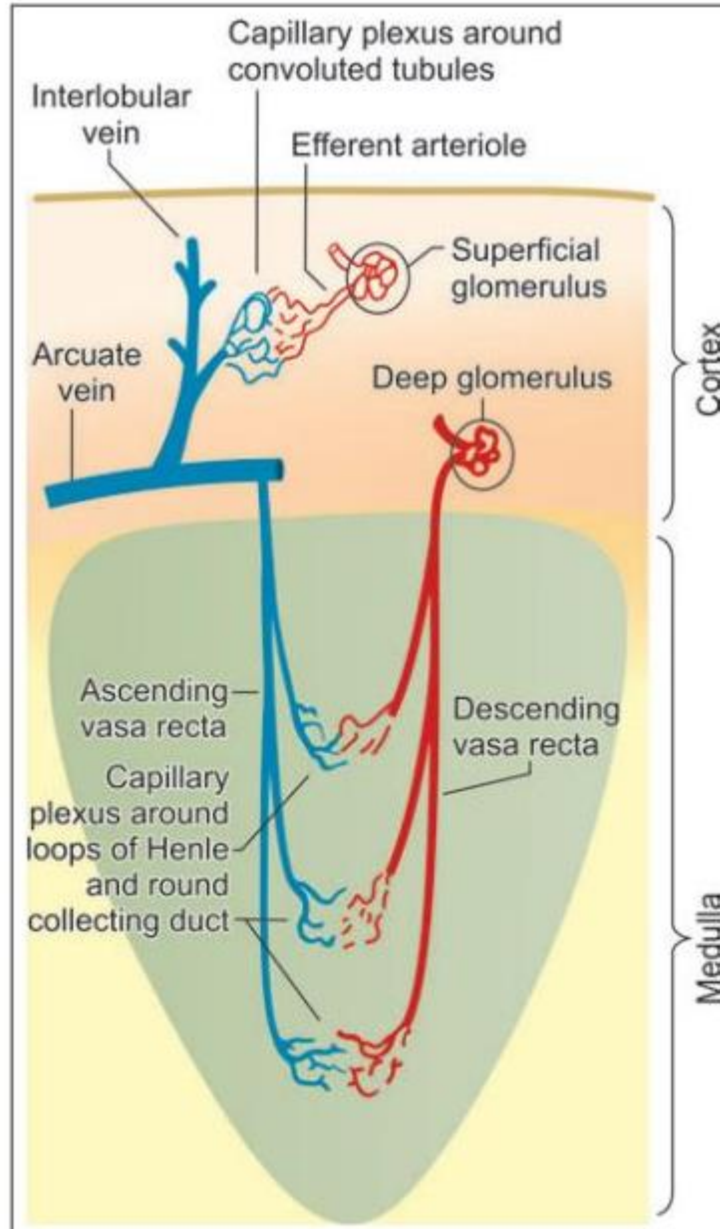
Macula
densa
Connecting
tubule
Glomerulus
Glomerular
capsule:
Visceral layer
Parietal layer
Capsular space
Renal
corpuscle
Proximal
convoluted tubule
Distal convoluted
tubule
Loop of Henle:
Proximal
straight tubule
Thin
descending limb
Thin
ascending limb
Thick
ascending limb
Renal
tubule
Cortex
Medulla
Connecting tubules
Collecting duct

Renal Blood Supply

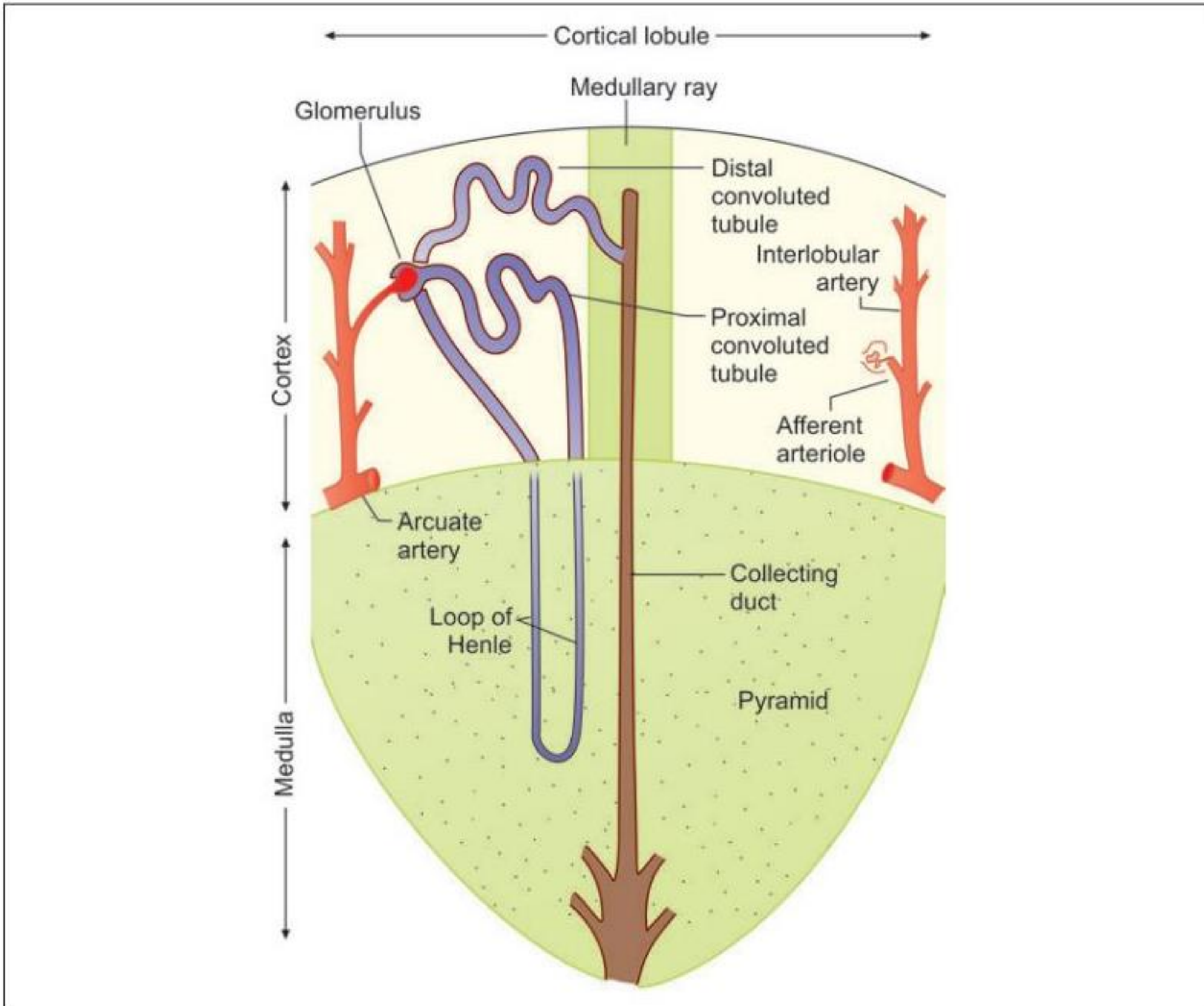
To understand the functional correlation of the kidney, it becomes important to understand the blood supply of the organ. Each kidney is supplied by a **renal artery** that divides in the hilus into several segmental branches, which branch into several **interlobar arteries**. The interlobar arteries continue in the kidney between the pyramids toward the cortex. At the corticomedullary junction, the interlobar arteries branch into **arcuate arteries**, which arch over the base of the pyramids and give rise to interlobular arteries. These branch further into the **afferent arterioles**, which give rise to the **capillaries** in the **glomeruli** of renal corpuscles. **Efferent arterioles** leave the renal corpuscles and form a complex **peritubular capillary network** around the tubules in the cortex and long, straight capillary vessels or **vasa recta** in the medulla that loops back to the corticomedullary region. The vasa recta form loops that are parallel to the loops of Henle. The interstitium is drained by interlobular veins that continue toward the arcuate veins.



Arrangement of arteries within the kidney



Behaviour of efferent arterioles of glomeruli in the superficial and deeper parts of the renal cortex (Schematic representation)

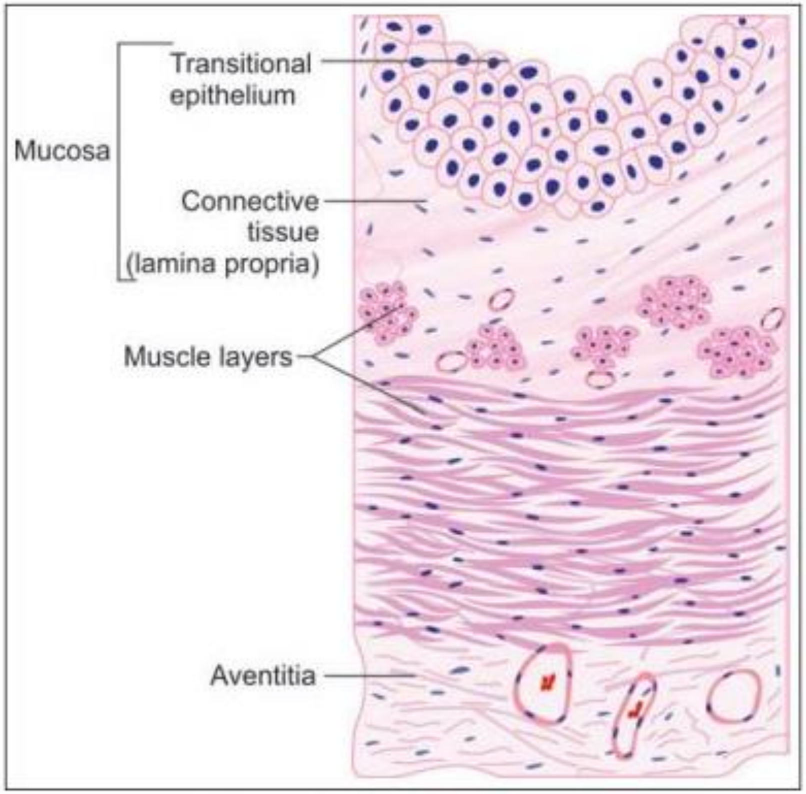


The concept of cortical lobules (Schematic representation)

THE URETERS

Ureters are muscular tubes that conduct urine from renal pelvis to the urinary bladder. The wall of the ureter has three layers:

- An inner lining of mucous membrane
- A middle layer of smooth muscle
- An outer fibrous coat: adventitia



Layers of ureter (Schematic representation)

Mucous Membrane

The mucous membrane has a lining of ***transitional epithelium*** that is 4 to 5 cells thick and an underlying connective tissue, ***lamina propria***.

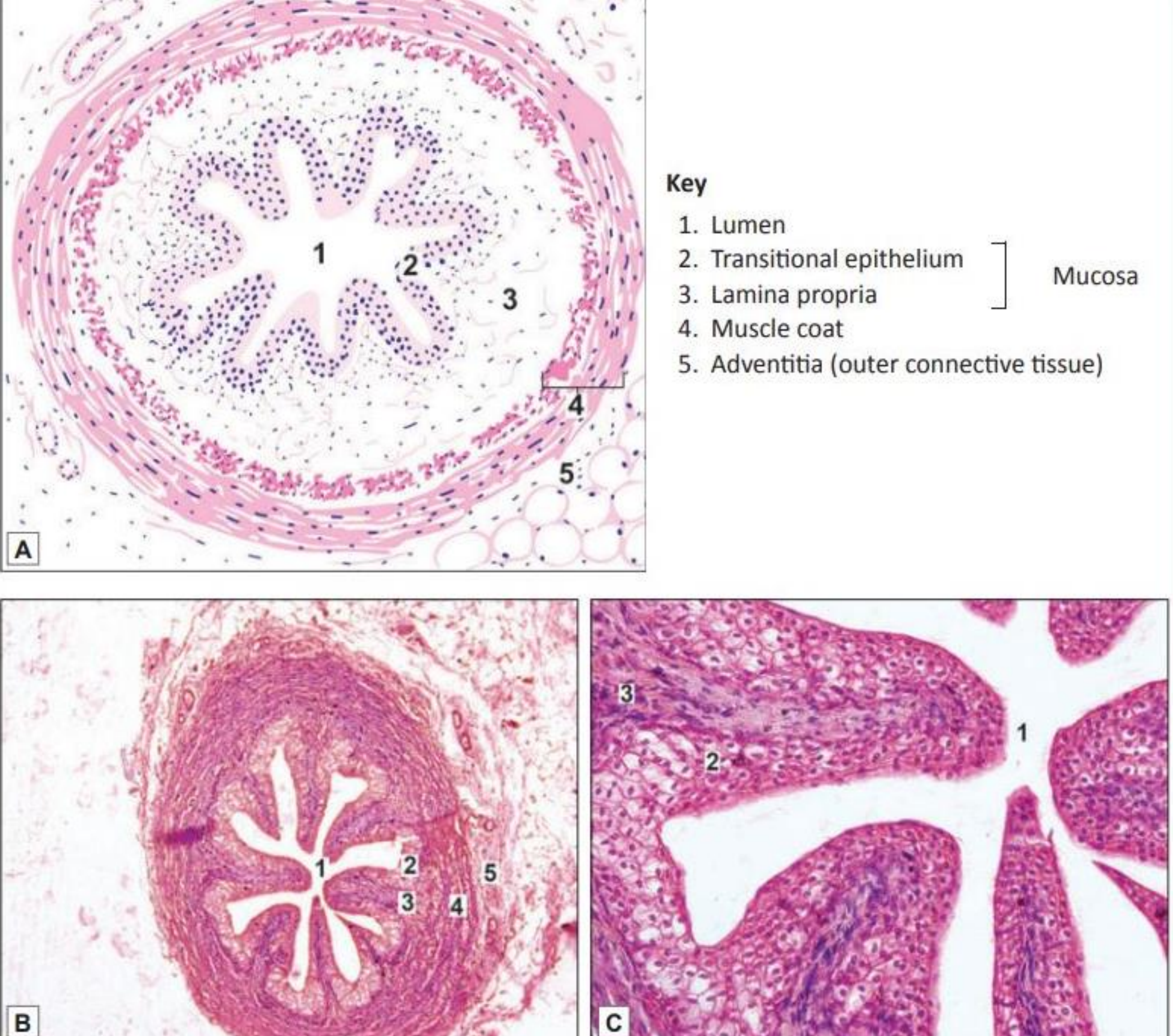
The mucosa shows a number of longitudinal folds that give the lumen a star-shaped appearance in transverse section. The folds disappear when the ureter is distended.

Muscle Coat

The muscle coat is usually described as having an inner longitudinal layer and an outer circular layer of smooth muscle. A third layer of longitudinal fibres is present outside the circular coat in the middle and lower parts of the ureter. The layers are not distinctly marked off from each other. Some workers have reported that the musculature of the ureter is really in the form of a meshwork formed by branching and anastomosing bundles of muscle fibres.

Adventitia

Adventitia is the outer fibrous coat consisting of loose connective tissue. It contains numerous blood vessels, nerves, lymphatics and some fat cells.



Ureter. A. As seen in drawing; B. Photomicrograph (low magnification); C. Photomicrograph (high magnification)

-The ureter can be recognized because it is tubular and its mucous membrane is lined by transitional

-The epithelium epithelium rests on a layer of connective tissue (lamina

The propria) mucosa shows folds that give the lumen a star-shaped

-The appearance muscle coat has an inner layer of longitudinal fibers and an outer layer of circular fibers. This arrangement is the reverse of that in the

The muscle coat gut is surrounded by connective tissue– adventitia in which blood vessels and fat cells are present

THE URINARY BLADDER

Urinary bladder is a muscular bag, where urine is stored temporarily and is discharged periodically via urethra during micturition.

The wall of the urinary bladder consists of three layers:

- An inner mucous membrane
- A thick coat of smooth muscle
- An outer serous layer

Mucous Membrane

The mucous membrane is lined by transitional epithelium. There is no muscularis mucosae.

In the empty bladder the mucous membrane is thrown into numerous folds that disappear when the bladder is distended. Some mucous glands may be present in the mucosa specially near the internal urethral orifice.

When the bladder is distended (with urine) the lining epithelium becomes thinner. This results from the ability of the epithelial cells to change shape and shift over one another.

Note: The transitional epithelium lining the urinary bladder (and the rest of the urinary passages) is capable of withstanding osmotic changes caused by variations in concentrations of urine. It is also resistant to toxic substances present in urine.

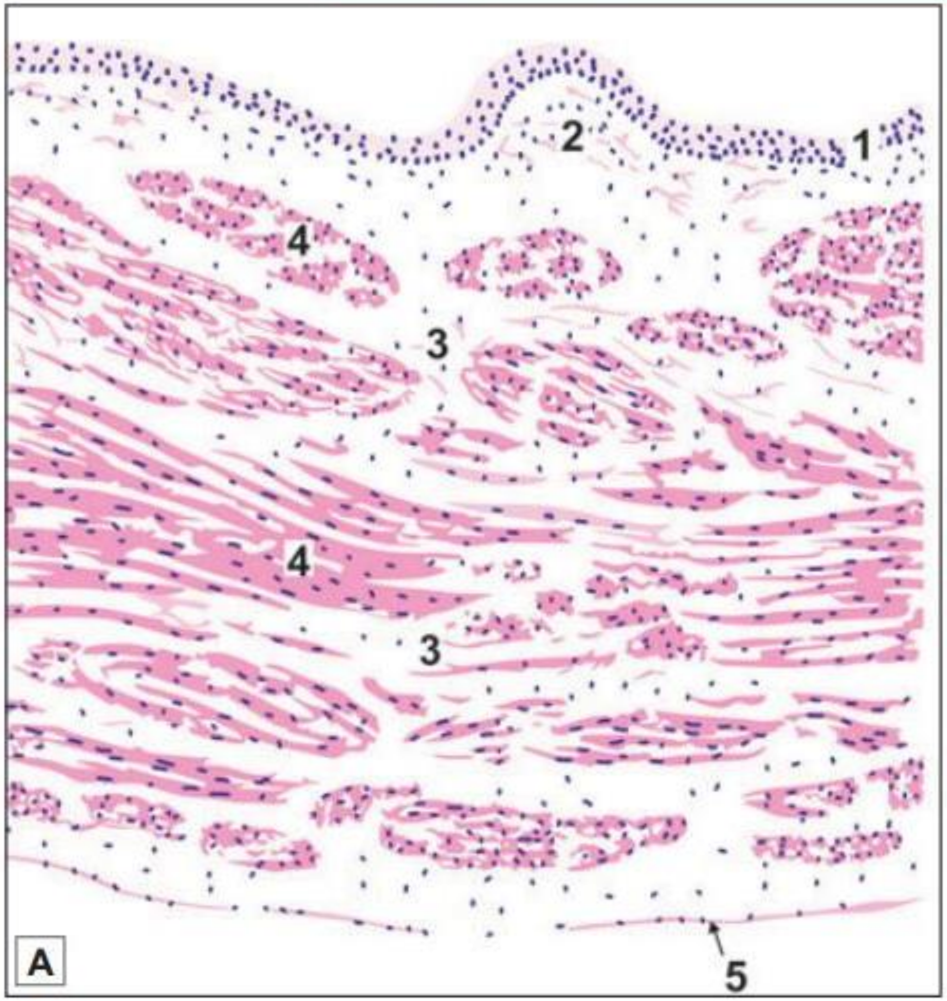
Muscle Coat

The muscle layer is thick. The smooth muscle in it forms a meshwork. Internally and externally the fibres tend to be longitudinal. In between them there is a thicker layer of circular (or oblique) fibres. Contraction of this muscle coat is responsible for emptying of the bladder. That is why it is called the ***detrusor muscle***. Just above the junction of the bladder with the urethra the circular fibres are thickened to form the ***sphincter vesicae***.

Serous Layer

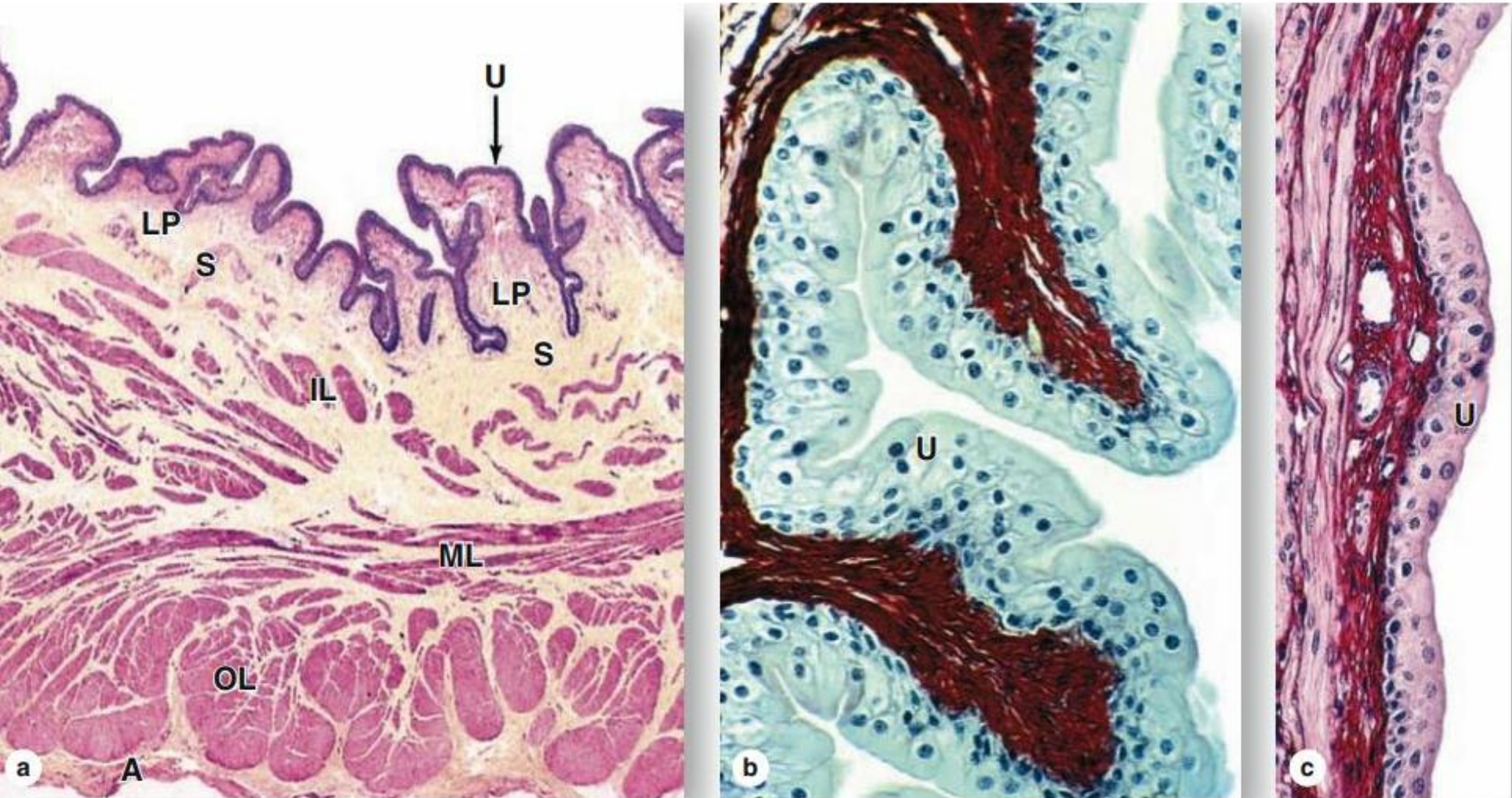
The superior surface of the bladder is covered by mesothelium of peritoneum, forming serous layer. The inferior part of the bladder is covered with adventitia which is made of fibroelastic connective tissue carrying blood vessels, nerves and lymphatics.

Urinary Bladder



- The urinary bladder is easily recognised because the mucous membrane is lined by transitional epithelium
- The epithelium rests on lamina propria
- The muscle layer is thick. It has inner and outer longitudinal layers between which there is a layer of circular or oblique fibres. The distinct muscle layers may not be distinguishable
- The outer surface is lined in parts by peritoneum (serosa) (not seen in the photomicrograph).

Bladder wall and urothelium.



(a) In the neck of the bladder, near the urethra, the wall shows four layers: the mucosa with urothelium (**U**) and lamina propria (**LP**); the thin submucosa (**S**); inner, middle, and outer layers of smooth muscle (**IL**, **ML**, and **OL**); and the adventitia (**A**). (X15; H&E)

(b) When the bladder is empty, the mucosa is highly folded and the urothelium (**U**) has bulbous umbrella cells. (X250; PSH)

(c) When the bladder is full, the mucosa is pulled smooth, the urothelium (**U**) is thinner, and the umbrella cells are flatter. (X250; H&E)

The Urethra

Urethra is a tube that carries urine from bladder to the exterior. In males, semen also passes through the urethra.

Although the male urethra is much longer than the female urethra, the structure of the two is the same. The wall of the urethra is composed of:

- Mucous membrane
- Submucosa
- Muscle layer.

In the case of the male, the prostatic urethra is surrounded by prostatic tissue; and the penile urethra by erectile tissue of the corpus spongiosum.

Mucous Membrane

The mucous membrane consists of a lining epithelium that rests on connective tissue. The epithelium varies in different parts of the urethra. Both in the male and female, the greater part of the urethra is lined by pseudostratified columnar epithelium. A short part adjoining the urinary bladder is lined by transitional epithelium, while the part near the external orifice is lined by stratified squamous epithelium.

The mucosa shows invaginations or recesses into which mucous glands open.

Submucosa

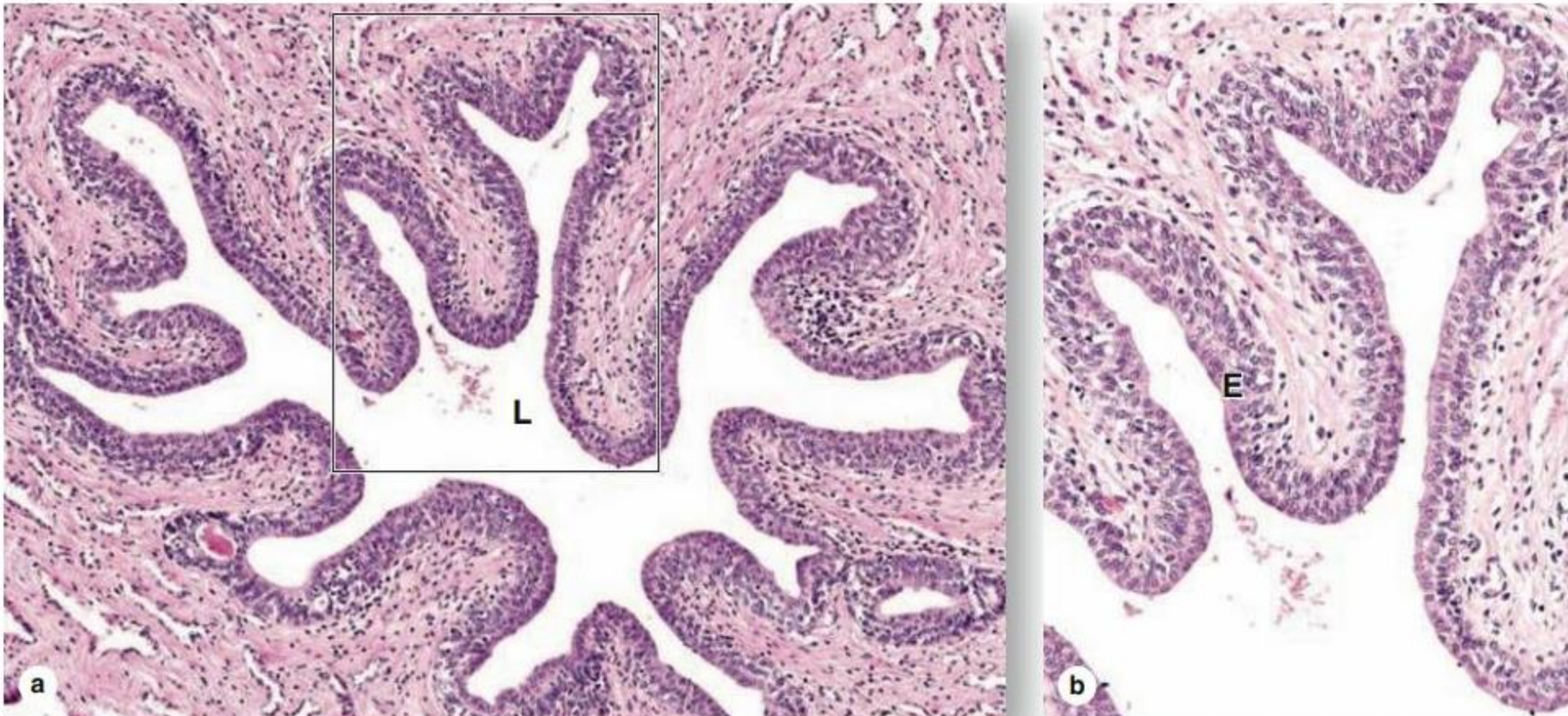
The submucosa consists of loose connective tissue.

Muscle Coat

The muscle coat consists of an inner longitudinal layer and an outer circular layer of smooth muscle. This coat is better defined in the female urethra. In the male urethra it is well defined only in the membranous and prostatic parts, the penile part being surrounded by occasional fibres only.

In addition to this smooth muscle the membranous part of the male urethra, and the corresponding part of the female urethra are surrounded by striated muscle that forms the ***external urethral sphincter***.

Urethra.



The urethra is a fibromuscular tube that carries urine from the bladder to the exterior of the body.

(a) A transverse section shows that the mucosa has large longitudinal folds around the lumen (**L**). (X50; H&E)

(b) A higher magnification of the enclosed area shows the unusual stratified columnar nature of the urethral epithelium (**E**). This thick epithelial lining varies between stratified columnar in some areas and pseudostratified columnar elsewhere, but it becomes stratified squamous at the distal end of the urethra. (X250; H&E)