

## Urinary System

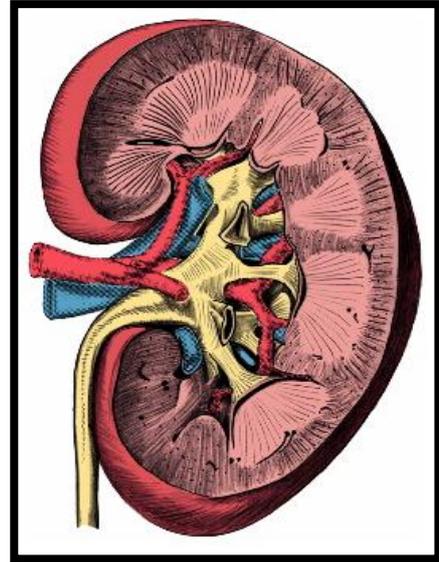
The main components of the urinary system are the kidneys, ureters, urinary bladder and urethra.

### Functions of the urinary system:

- Excretion of the waste products and elimination of foreign substances from the body.
- Regulation of the amount of water in the body.
- Control of the concentration of most compounds in the extracellular fluid .

Functionally these processes can be divided into two steps, each of which have their anatomical correlate:

- Filtration: in the glomeruli of the kidney.
- Selective reabsorption and excretion: in the tubular system of the kidney.



In addition, the kidney also functions as an endocrine organ:

- Fibrocytes in the cortex release the hormone erythropoietin, which stimulates the formation of red blood cells.
- Modified fibrocytes of the medulla secrete prostaglandins which are able to decrease blood pressure.
- The Juxtaglomerular cells produce and secrete rennin, which activates angiotensinogen into angiotensin (potent vasoconstrictor).
- Juxtaglomerular cells It also stimulates the secretion of aldosterone.

Kidney is formed of multiple lobes, each lobe made up of a renal pyramid (base in the cortex and the apex in medulla).

**Capsule:** fibrous CT. covering the cortex, and continuous at hilum with supporting tissue.

**Renal Cortex:** extends between medullary pyramids, cortical components of lobes fuse forming outer zone that contains renal corpuscles as well as convoluted tubules.

**Renal medulla:** contains multiple medullary pyramids separated by regions of cortex.

## Cortex and medulla

- Millions of nephrons are packed into each kidney.
- The cortex consists of convoluted tubules (distal & proximal) together with the renal corpuscles (glomeruli).
- The medulla consists of loops of Henle and collecting ducts.
- The cortex and medulla surround and drain into the hollow pelvis, which is lined by transitional epithelium.

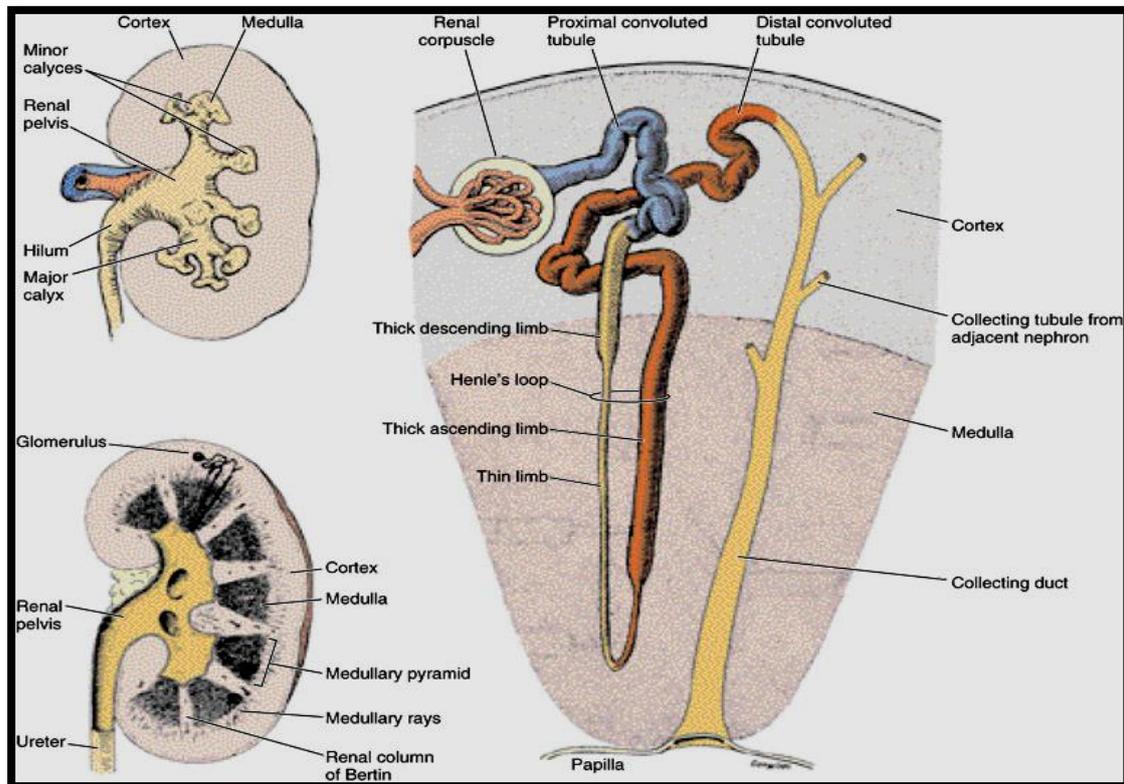


Illustration showing renal cortex, medulla, and renal pelvis with their content

**The Nephron;** the basic functional unit of the kidney, is formed of glomerulus and the tubular system.

**The Glomerulus** (renal corpuscle) is a round (~200µm in diameter) blind beginning of the nephron.

- It is invaginated by a tuft of capillaries at its vascular pole and is enclosed by two layers of epithelium (Bowman's capsule).
- Cells of the outer layer of Bowman's capsule formed of simple squamous epithelium.

- Cells of the inner or visceral layer (podocytes) have small foot-like processes (pedicles) of their cytoplasm form a fenestrated epithelium around the fenestrated capillaries of the glomerulus.
- The openings between the pedicles (filtration slits) covered by a thin membrane, the filtration slit membrane.
- There is a thick basal lamina between the podocytes and the endothelial cells of the capillaries.
- The basal lamina and the slit membranes form the glomerular filtration barrier, which prevents some large molecules from entering the capsular space.
- Mesangial cells in the glomerulus form the connective tissue that gives structural support to podocytes and vessels.

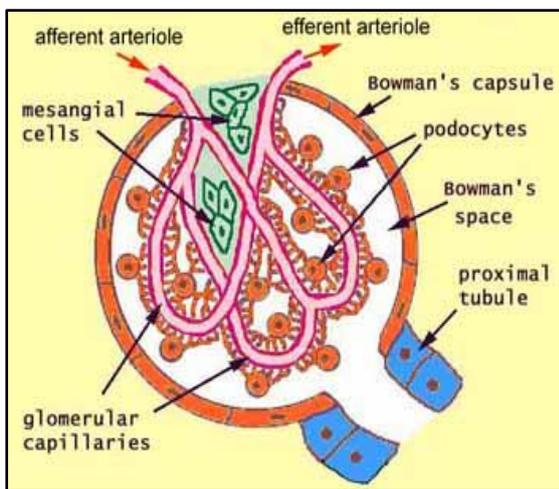
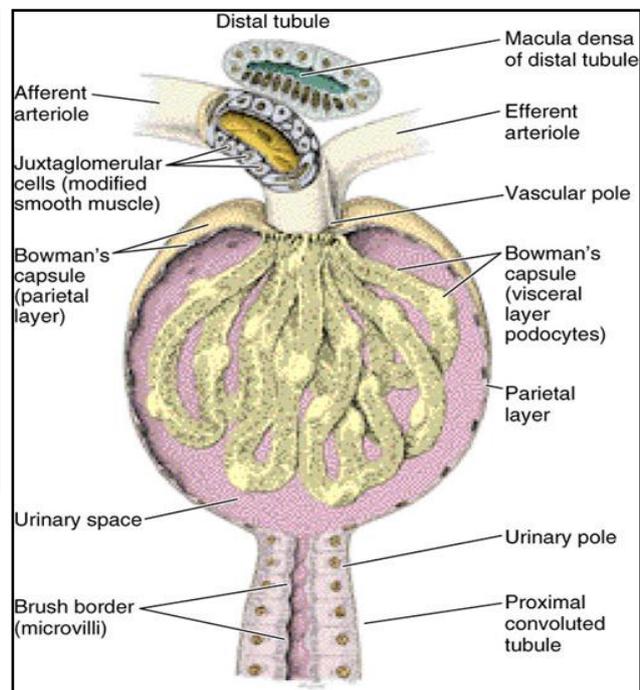


Illustration showing the glomerular structure



### The Juxtaglomerular Apparatus

The distal tubule contacts the glomerulus forming a specialized tubular epithelium, the macula densa. At the point of contact with the glomerulus, the distal tubule is in close contact with the endothelial cells of the efferent and afferent arterioles of the glomerulus.

Other parts of the juxtaglomerular apparatus are extraglomerular mesangial cells and the juxtaglomerular cells surrounding the afferent arteriole (modified smooth muscle cells), which produce and secrete renin. Renin activates angiotensinogen, into angiotensin I, which

in turn converts into angiotensin II. Angiotensin II is the most potent vasoconstrictor known. It also stimulates the secretion of aldosterone.

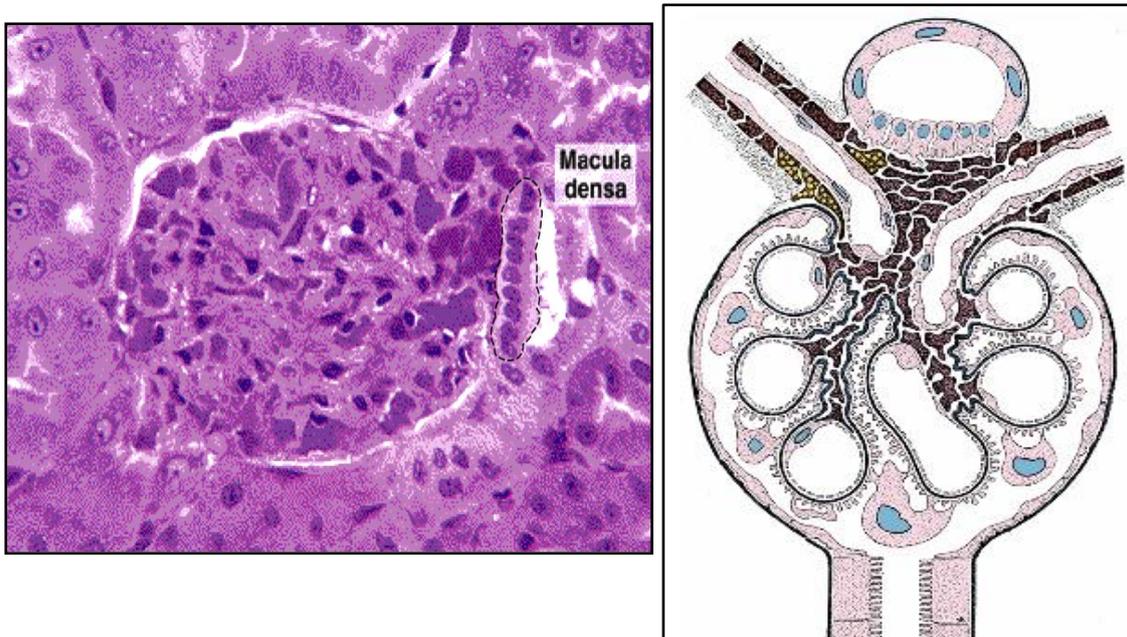


Illustration showing the macula densa

### **Glomerular capillary endothelium**

In the kidney, the endothelium of glomerular capillaries is fenestrated. The fenestrations are too small to allow blood cells through, but plasma can pass freely out of the holes and into the filtration membrane.

The capillaries of renal glomeruli are leaky. Although the filtration membrane holds back cells and plasma proteins, the remaining fluid (water, mineral ions, and small molecules) passes freely into Bowman's space and hence along the renal tubule.

### **The glomerulus**

The glomerulus is a small knot of capillaries and supporting structures suspended within Bowman's capsule. The glomerulus is the source of the initial filtrate of plasma that is eventually processed into urine. With this function, the glomerulus is the most significant component of the nephron.

### **Several elements comprise the glomerulus:-**

#### **- Cells**

- Capillary endothelial cells line the fenestrated glomerular capillaries.
- Podocytes stand upon pedicels on the outer side of the glomerular capillaries.
- Mesangial cells concentrated between capillaries at the vascular pole of the corpuscle. They are respond to Angiotensin II and reduce blood flow. There are two types:
  - Extra-glomerular (**lacis cells**) at vascular pole
  - Intra-glomerular; **phagocytic cells**

#### **- Extracellular materials**

- The filtration membrane is a sheet of porous material between capillary endothelium and podocyte pedicels, composed of endothelial and podocyte (epithelial) basement membranes
- Mesangial matrix is a local variation on connective tissue matrix.

### **Tubules of the Nephron**

- The renal tubule receives plasma filtrate from the glomerulus and processes it into urine.
- The tubular system can be divided into proximal and distal tubules, which in turn have convoluted and straight portions.
- The loop of Henle, intermediate tubules connect the proximal and distal tubules. Running from the cortex of the kidney towards the medulla (descending), then turning and running back towards the cortex (ascending).

Each tubule is differentiated into several specialized segments:-

#### **The proximal tubules:**

- The proximal tubule is the longest section of the nephron (about 14 mm), and the diameter is ~65  $\mu\text{m}$ .
- The convoluted part of the proximal tubules coils close to the glomerulus in the cortex.
- Their walls are formed by a low columnar epithelium with wide brush border (long microvilli) that are active in endocytosis.

- They almost completely resorb substances of nutritional value from the glomerular filtrate (glucose, amino acids, protein, vitamins etc.).
- In the proximal tubules the volume of the glomerular filtrate is reduced by about 75%.
- Sodium ions are actively resorbed from the glomerular filtrate.
- The straight portion of the proximal tubule merges with the intermediate tubule (thin segment of the loop of Henle), and descends towards the medulla.

### The loop of Henle:

- Dips into the medulla where it helps establish the hypertonic environment of medullary interstitial fluid.
- A flattened, only ~1-2  $\mu\text{m}$  high epithelium forms the intermediate tubule, which is only ~15  $\mu\text{m}$  wide.
- Descending parts of the straight proximal and intermediate tubules are permeable to water but not to solutes.

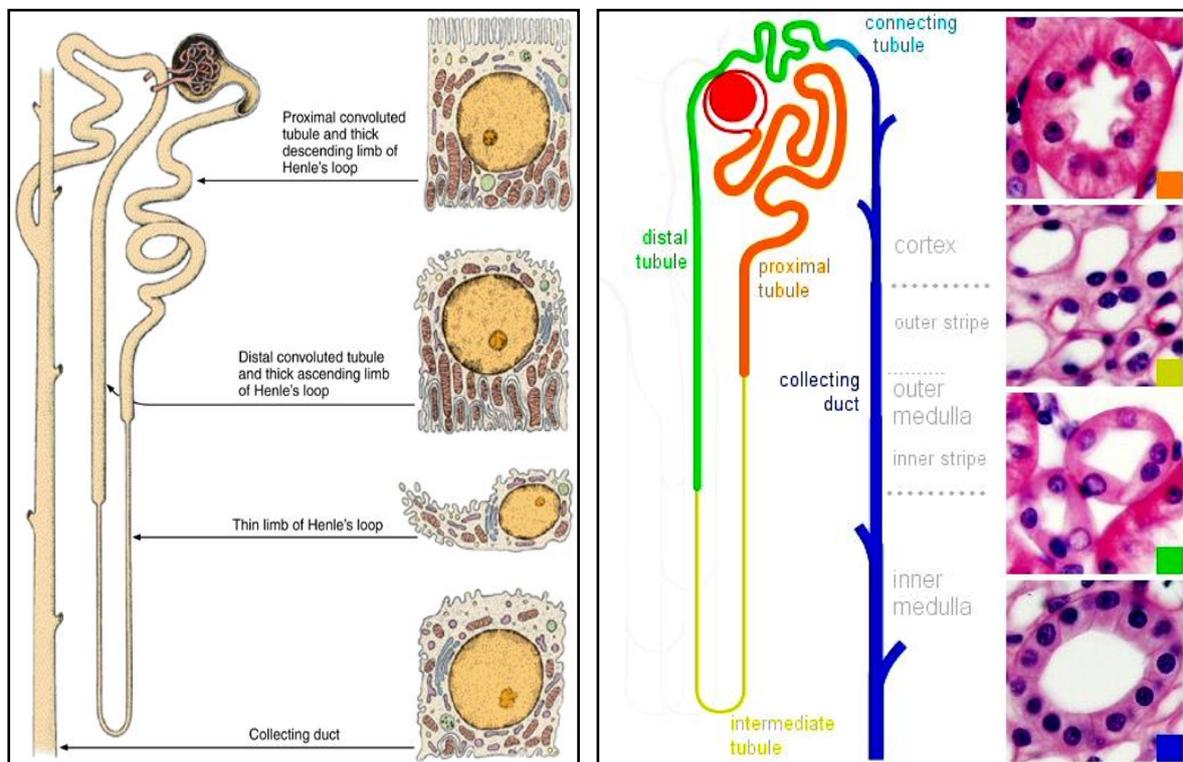


Illustration showing the different parts of renal tubules

## The distal tubule

- The **convoluted** part, returns to the macula densa (juxtaglomerular apparatus) from which the tubule arose, formed by tall and narrow cells.
- The thin segment of Henle's loop leads into the straight part of the distal tubule, which is formed by low cuboidal cells without a brush border (but with few short microvilli).
- The diameter of the tubule expands to ~35  $\mu\text{m}$ .
- Epithelial cells in the ascending parts of the intermediate and straight distal tubules cells transport chloride (active) and sodium ions (passive) out of the tubular lumen into the surrounding peritubular space.
- The epithelium is not permeable to water or urea. Consequently, the transport of ions over the epithelium sets up a gradient in osmotic pressure, which serves as driving force in the further concentration of the urine.
  - Transport  $\text{Cl}^-$  out of lumen; so salt concentration is low and urea is high
  - Aldosterone stimulates sodium/potassium pump in distal convoluted tubules and resorb sodium

**The collecting duct** leads back through the medulla to drain into the pelvis.

- **The collecting ducts** are impermeable to water

### \*Cortical

1. principal cells
2. intercalated cells-secrete  $\text{H}^+$  ions against high-concentration gradients

\***Medullary**-several cortical tubules merging

\***Papillary** or Ducts of Bellini-several medullary tubules (principal cells)

## Excretory Passages

The minor calyces merge to form major calyces within the kidney, which in turn merge to form the renal pelvis (still within the kidney). The urine flows through these structures to the ureter and is channelled to the bladder. The bladder is finally emptied through the urethra.

- The basic structure of all these components is the same.
- The mucosa is lined with a transitional epithelium.

- The lamina propria consists mainly of dense connective tissue, with many bundles of coarse collagenous fibers.
- The muscularis usually consists of an inner longitudinal and outer circular layer of smooth muscle cells . In lower parts of the ureter and the bladder an additional outer longitudinal layer of muscles is added to the first two.
- Initially, the urethra is lined by a transitional epithelium in males and females. In males, it is replaced by a pseudostratified or stratified columnar epithelium below the openings of the ejaculatory ducts into the urethra. The distal parts of the female urethra and the distal end of the male urethra are lined by a stratified squamous epithelium.
- The lamina propria contains loose connective tissue.
- Smooth muscle cells in the muscularis are mainly oriented longitudinally. They are surrounded, in the middle part of the urethra (below the prostate in males), by striated muscle cells of the sphincter urethrae.

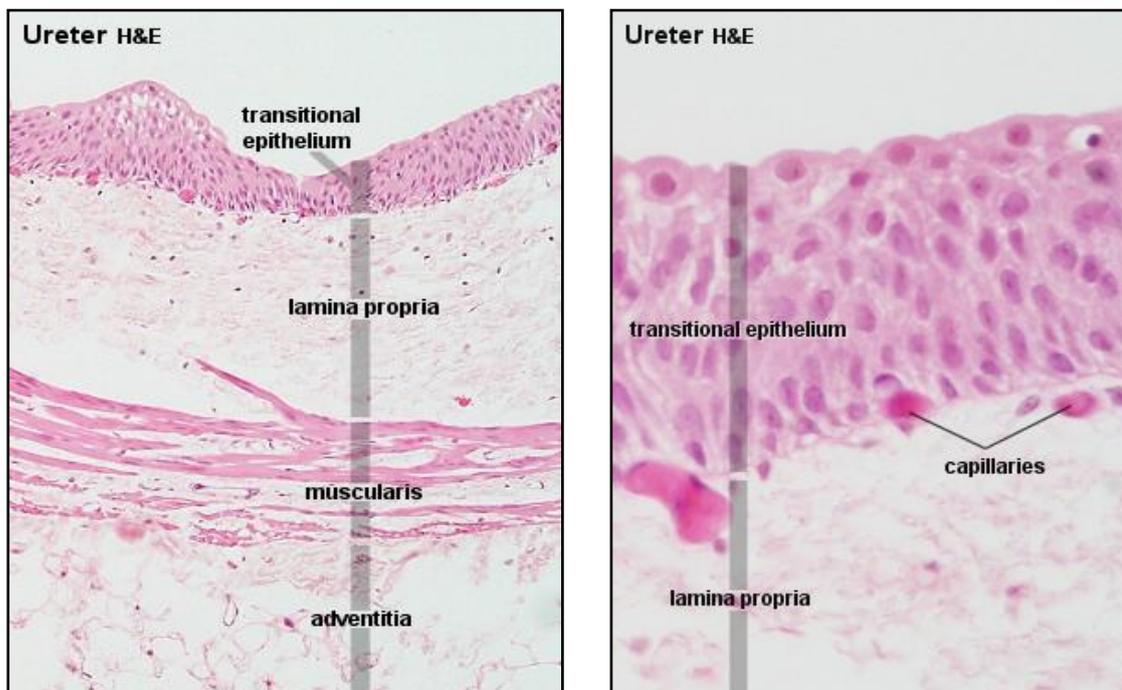


Illustration showing structure of the ureter