# Urinary system

Excretion is the process by which the unwanted substances and metabolic wastes are eliminated from the body. Although various organs such as GI tract, liver, skin and lungs are involved in removal of wastes from the body, their excretory capacity is limited. But, the renal system or urinary system has maximum capacity of excretory function.

**Renal system includes:**

1. A pair of kidneys
2. Ureters
3. Urinary bladder
4. Urethra. Kidneys produce the urine.

Ureters transport the urine to urinary bladder. Urinary bladder stores urine until it is voided (emptied). Urine is voided from bladder through urethra**.**

## FUNCTIONS OF KIDNEY

Kidneys perform several vital functions besides formation of urine. By excreting urine, kidneys play the principal role in homeostasis. Thus, the functions of kidneys are:

1. **ROLE IN HOMEOSTASIS**

   The primary function of kidneys is homeostasis. It is accomplished by the formation of urine. During the formation of urine, kidneys regulate various activities in the body, which are concerned with homeostasis such as:

   i. Excretion of Waste Products Kidneys excrete the unwanted waste products which are formed during metabolic activities:

   a. Urea – end product of amino acid metabolism

   b. Uric acid – end product of nucleic acid metabolism

   c. Creatinine – end product of metabolism in muscles

   d. Bilirubin – end product of hemoglobin degradation

   e. Products of metabolism of other substances f. Harmful foreign chemical substances like toxins, drugs, heavy metals, pesticides, etc.

ii. Maintenance of Water Balance Kidneys maintain the water balance in the body by conserving water when it is decreased and excreting water when it is excess in the body.

iii. Maintenance of Electrolyte Balance Maintenance of electrolyte balance, especially sodium is in relation to water balance. Kidneys retain sodium if the osmolarity of body water decreases and eliminate sodium when osmolarity increases.

iv. Maintenance of Acid–Base Balance The pH of the blood and body fluids should be maintained within narrow range for healthy living. It is achieved by the function of kidneys. Body is under constant threat to develop acidosis, because of production of lot of acids during metabolic activities. However, it is prevented by kidneys, lungs and blood buffers, which eliminate these acids. Among these organs, kidneys play major role in preventing acidosis.

2. **HEMOPOIETIC FUNCTION Kidneys** stimulate the production of erythrocytes by secreting erythropoietin. Erythropoietin is the important stimulating factor for erythropoiesis. Kidney also secretes another factor called thrombopoietin, which stimulates the production of thrombocytes

**4. REGULATION OF BLOOD PRESSURE**

Kidneys play an important role in long-term regulation of arterial blood pressure by two ways: by regulating ECF volume and through renin-angiotensin mechanism.

**5. REGULATION OF BLOOD CALCIUM LEVEL**

Kidneys play a role in the regulation of blood calcium level by activating 1, 25-dihydroxycholecalciferol into vitamin D. Vitamin D is necessary for the absorption of calcium from intestine.

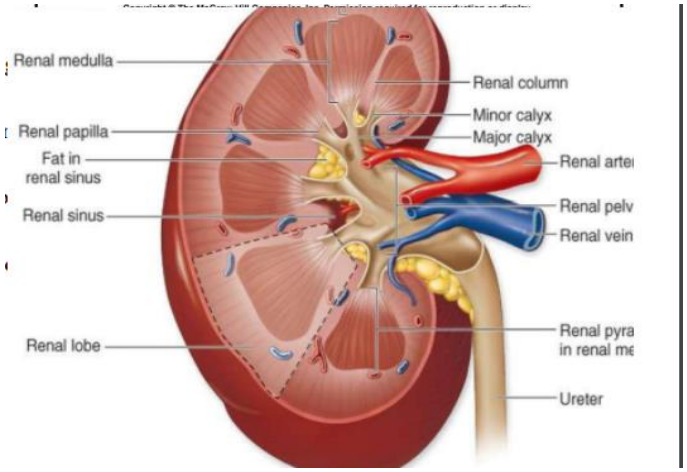
**FUNCTIONAL ANATOMY OF KIDNEY**

Kidney is a compound tubular gland covered by a connective tissue capsule. There is a depression on the medial border of kidney called

hilum, through which renal artery, renal veins, nerves and ureter pass.

## DIFFERENT LAYERS OF KIDNEY

The components of kidney are arranged in three layers




1. Outer cortex
2. Inner medulla
3. Renal sinus.

1. Outer Cortex Cortex is dark and granular in appearance. It contains renal corpuscles and convoluted tubules. At intervals, cortical tissue penetrates medulla in the form of columns, which are called renal columns or columns of Bertini.

2. Inner Medulla Medulla contains tubular and vascular structures arranged in parallel radial lines. It is divided into 8 to 18 medullary or Malpighian pyramids.

3. Renal Sinus Renal sinus consists of the following structures:
i. Upper expanded part of ureter called renal pelvis
ii. Subdivisions of pelvis – 2 or 3 major calyces and about 8 minor calyces
iii. Branches of nerves and arteries and tributaries of veins
iv. Loose connective tissues and fat.

## PARENCHYMA OF KIDNEY

Parenchyma of kidney is made up of tubular structures called uriniferous tubules. The uriniferous tubules are of two types:

1. Terminal or secretary tubules called nephrons, which are concerned with formation of urine
2. Collecting ducts or tubules which are concerned with transport of urine from nephrons to pelvis of ureter. The collecting ducts unite to form ducts of Belini, which open into minor calyces through papilla.

## Nephron and Juxtaglomerular Apparatus

Nephron is defined as the structural and functional unit of kidney. Each kidney consists of 1 to 1.3 million of nephrons. The number of nephrons decreases in old age. Each nephron is formed by two parts:

1. A blind end called renal corpuscle or Malpighian corpuscle
2. A tubular portion called renal tubule.

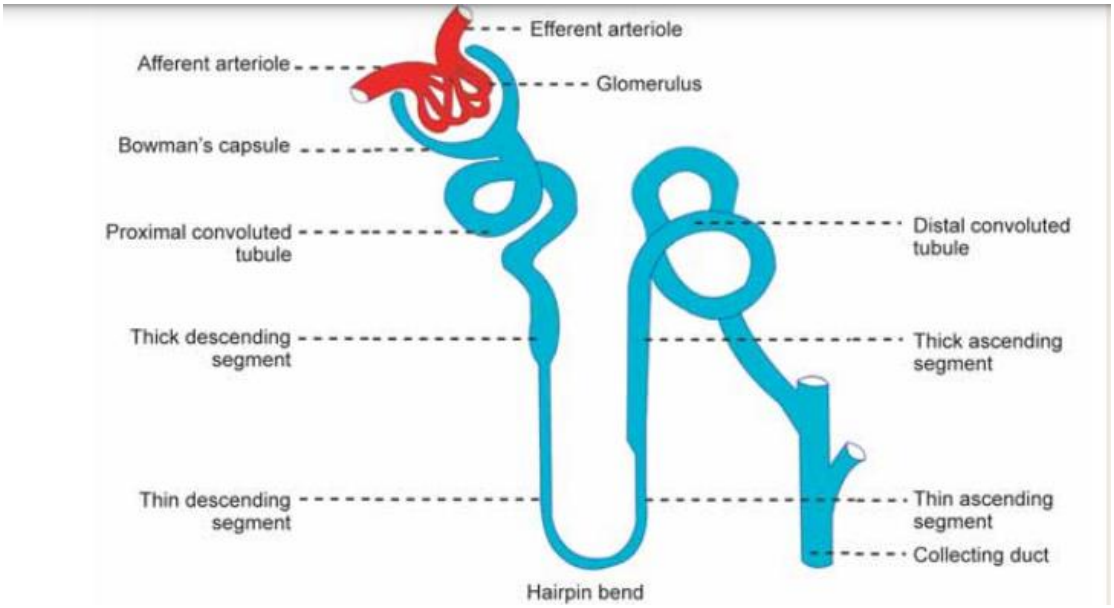
### RENAL CORPUSCLE

The renal corpuscle is also known as Malpighian corpuscle. It is a spheroidal and slightly flattened structure with a diameter of about 200 μ. The function of the renal corpuscle is the filtration of blood which forms the first phase of urine formation.

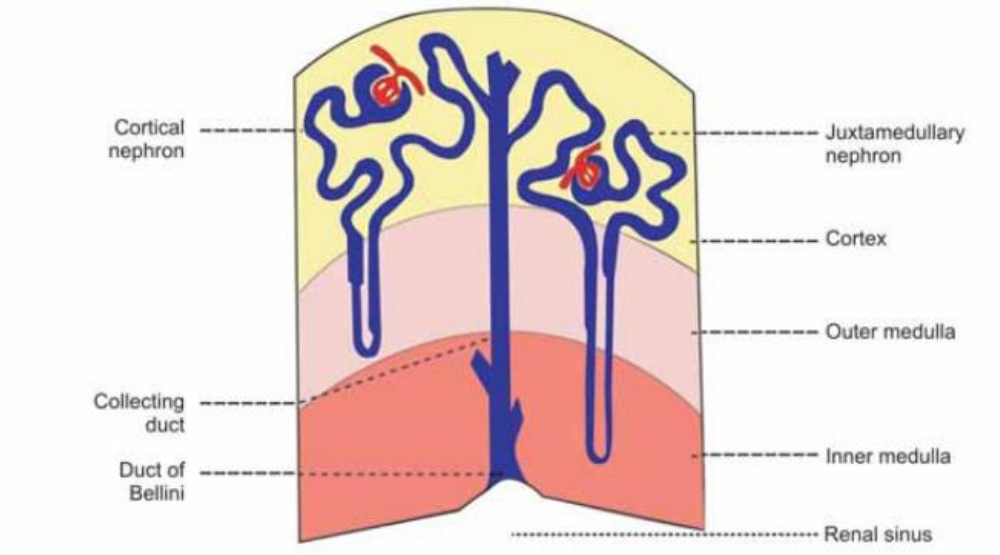
### SITUATION OF RENAL CORPUSCLE AND TYPES OF NEPHRON

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:

1. Cortical Nephrons Cortical nephrons are the nephrons, which have their corpuscles in the outer cortex of the kidney near the periphery. In human kidneys 85% nephrons are cortical nephrons.
2. Juxtamedullary Nephrons Juxtamedullary nephrons are the nephrons which have their corpuscles in the inner cortex**.**



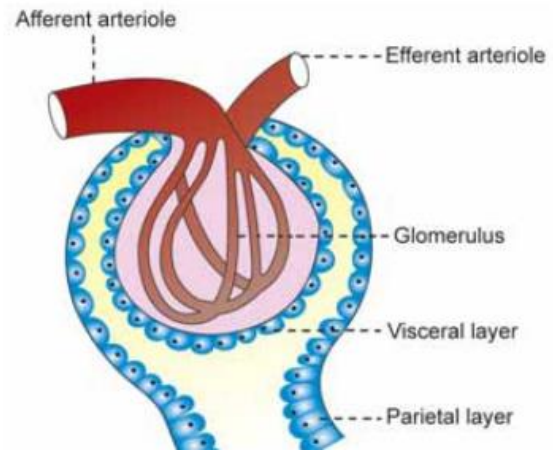

**Structure of nephron**




**Types of nephron**

## Features of types nephron

| Features | Cortical nephron | Juxtamedullary nephrons |
|---|---|---|
| Situation of renal corpuscle | Outer cortex near the periphery | Inner cortex near medulla |
| Loop of Henle | Short | Long |
| | Hairpin bend penetrates only up to outer zone of medulla | Hairpin bend penetrates up to the tip of papilla |
| Blood supply to tubule | Peritubular capillaries | Vasa recta |
| Function | Formation of urine | Mainly the concentration of urine and formation of urine |




**Renal corpuscle**

## STRUCTURE OF RENAL CORPUSCLE

The renal corpuscle is formed by two portions:

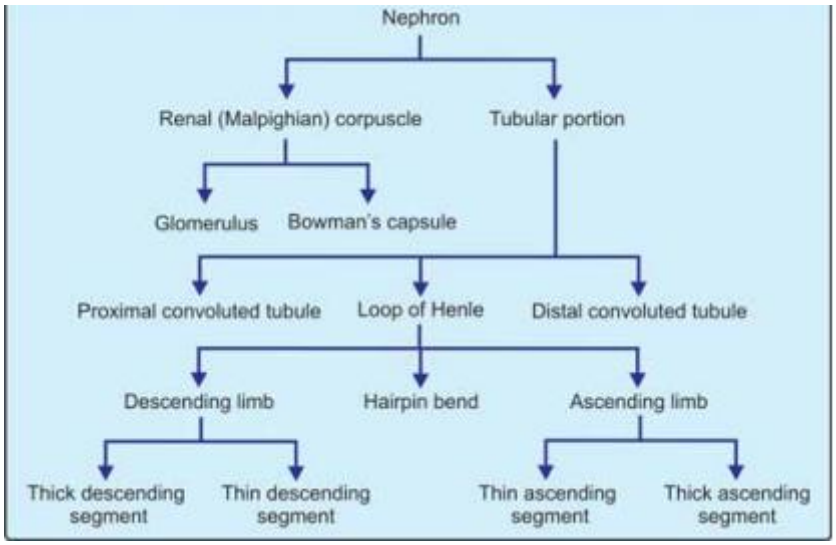
**1. Glomerulus**

Glomerulus is a tuft of capillaries enclosed by Bowman's capsule. These capillaries are disposed between afferent arteriole and efferent arteriole. Thus, the vascular system in the glomerulus is purely arterial.

**2. Bowman's Capsule Bowman's capsule encloses the glomerulus.**
The structure of Bowman's capsule is like a funnel with filter paper.

**TUBULAR PORTION OF NEPHRON**
The tubular portion of nephron is the continuation of Bowman's capsule. It is made up of three parts:
1. The proximal convoluted tubule
2. Loop of Henle
3. The distal convoluted tubule.

**PROXIMAL CONVOLUTED TUBULE**
It is the coiled portion arising from Bowman's capsule. It is situated in the cortex. It is continued as descending limb of loop of Henle.




**LOOP OF HENLE**
Loop of Henle consists of:
**i. Descending Limb**
Descending limb of loop of Henle is made up of thick descending segment and thin descending segment. The thick descending segment is the direct continuation of the proximal convoluted tubule. It descends down into medulla. The thick descending segment of Henle's loop is continued as thin descending segment.

### ii. Hairpin Bend

The thin descending segment is continued as hairpin bend of the loop. The hairpin bend is continued as the ascending segment of loop of Henle.

### iii. Ascending Limb

Ascending limb of Henle's loop has two parts, thin ascending segment and thick ascending segment. Thin ascending segment is the continuation of hairpin bend. The thin ascending segment is continued as thick ascending segment. Thick ascending segment ascends to the cortex and continues as distal convoluted tubule.

## DISTAL CONVOLUTED TUBULE

It is the continuation of thick ascending segment and occupies the cortex of kidney. It is continued as collecting duct.

## COLLECTING DUCT

The distal convoluted tubule continues as the initial or arched collecting duct, which is in cortex. The lower part of the collecting duct lies in medulla. Seven to ten initial collecting ducts unite to form the straight collecting duct, which passes through medulla.

## JUXTAGLOMERULAR APPARATUS

Juxtaglomerular apparatus is a specialized organ situated near the glomerulus of each nephron (juxta = near).

**STRUCTURE OF JUXTAGLOMERULAR APPARATUS** The juxtaglomerular apparatus is formed by three different structures:

### 1. Macula Densa

Macula densa is the terminal portion of thick ascending segment of Henle's loop that runs in between afferent and efferent arterioles of the same nephron. Actually, it is very close to afferent arteriole. In this part of thick ascending segment, the cuboidal epithelial cells are tightly packed.

**2. Extraglomerular Mesangial**

Cells These cells are situated in the triangular region bound by afferent arteriole, efferent arteriole and macula densa. These cells are also called agranular cells, lacis cells. Glomerular mesangial cells Glomerular mesangial cells or intraglomerular mesangial cells are situated in between the glomerular capillaries and form a cellular network which supports the capillary loops. These cells are contractile in nature and play an important role in regulating the glomerular filtration. The glomerular mesangial cells are also phagocytic and secrete matrix of glomerular interstitium, prostaglandins and cytokines.

**3. Juxtaglomerular Cells**

Juxtaglomerular cells are specialized smooth muscle cells situated in the wall of afferent arteriole just before it enters the Bowman's capsule. This part of the afferent arteriole is thickened like a cuff and it is called polar cushion or polkissen. Because of the presence of secretary granules in their cytoplasm, the juxtaglomerular cells are also called granular cells.

**FUNCTIONS OF JUXTAGLOMERULAR APPARATUS**

The primary function of juxtaglomerular apparatus is the secretion of hormonal substances. It also regulates the glomerular blood flow and glomerular filtration rate.

**1. Secretion of Renin**

The juxtaglomerular cells secrete renin. Renin is a peptide with 340 amino acids. Along with angiotensins, renin forms the renin – angiotensin system which is a hormone system that plays an important role in the maintenance of blood pressure.

Renin–Angiotensin system When renin is released into the blood, it acts on angiotensinogen and converts it into angiotensin I. Angiotensin I is converted into angiotensin II by the activity of angiotensin converting enzyme (ACE) secreted from lungs. Most of the conversion of angiotensin I into angiotensin II takes place in lungs. Angiotensin II has a short half-life of about 1-2 minutes. Then it is degraded into angiotensin III by angiotensinases which are present in RBCs and vascular beds in many tissues.

Angiotensin II Angiotensin II is the most active form. Its actions are:

1. Angiotensin II increases arterial blood pressure by causing vasoconstriction and inhibiting baroreceptor reflex
2. It stimulates zona glomerulosa of adrenal cortex to secrete aldosterone
3. Angiotensin II regulates glomerular filtration
4. It increases sodium reabsorption from renal tubules
5. It increases water intake by stimulating the thirst center
6. It increases secretion of antidiuretic hormone (ADH) from hypothalamus. Angiotensin III Angiotensin III increases the blood pressure and stimulates aldosterone secretion from adrenal cortex.

**2. Secretion of Other Substances**

The extraglomerular mesangial cells of juxtaglomerular apparatus secrete prostaglandin. In vitro secretion of cytokines like IL-2 and TNF by the mesangial cells is observed recently. Macula densa secretes thromboxane A2.

**3. Regulation of Glomerular Blood Flow and Glomerular Filtration Rate**

Macula densa of juxtaglomerular apparatus plays an important role in the feedback mechanism called tubuloglomerular feedback mechanism, which regulates the renal blood flow and glomerular filtration rate.