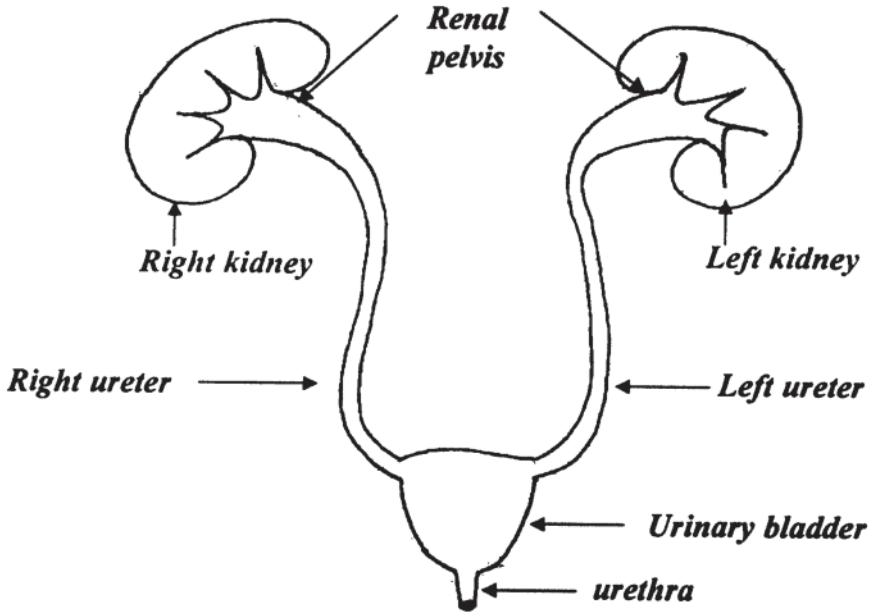
# Renal physiology

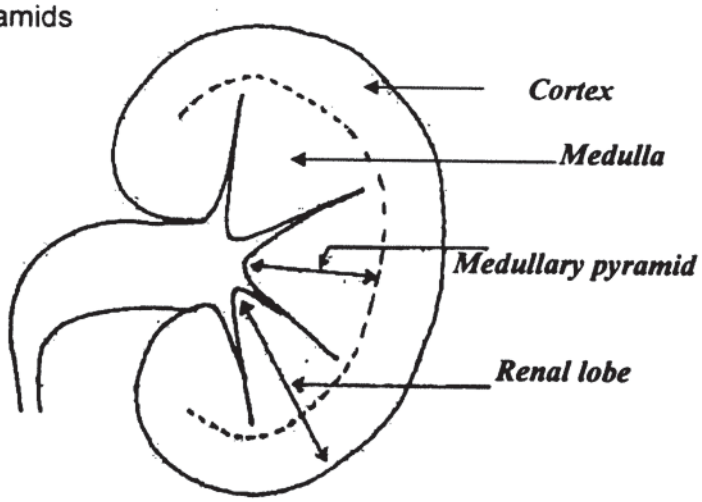
## General composition of the urinary system: -




***The main functioning organ in the urinary system is the kidney***

## Functional anatomy of the kidney: -

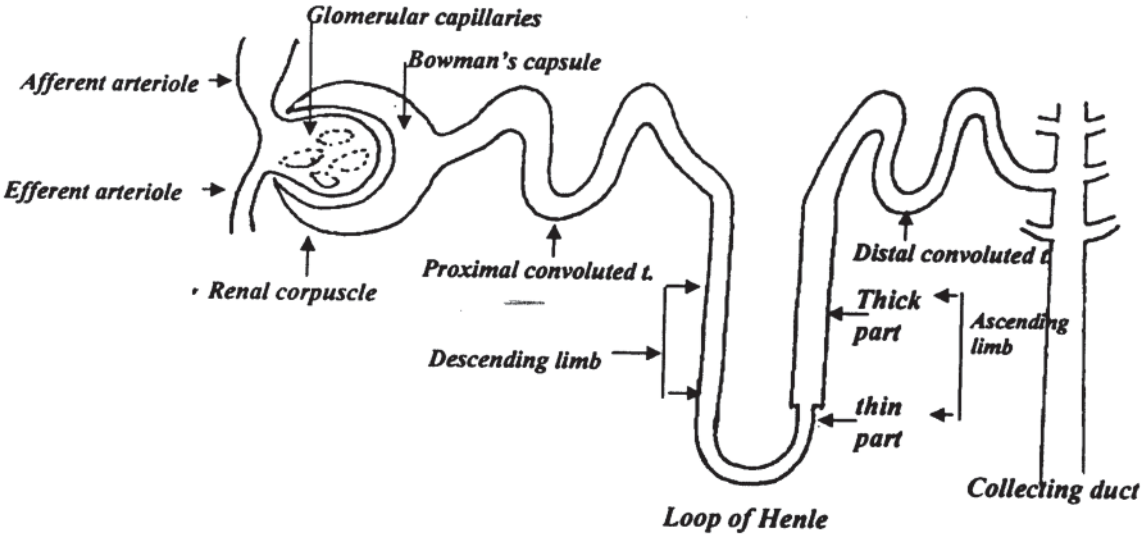
- **The kidney is composed of: -**
  1- Outer cortex
  2- Inner medulla: - Made up of a number of cone shaped masses called medullary pyramids




***Each medullary pyramid and the overlying part of the cortex is called renal lobe.***

# Nephron

It is the functional unit of the kidney. Each human kidney is composed of 1 million nephrons. The nephron is composed of :-



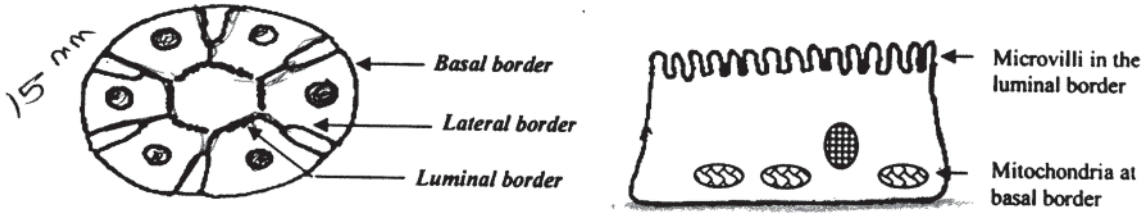

## A- Renal corpuscle (the glomerulus):- formed of

1- **Glomerular capillaries**

2- **Bowman's capsule:** It is the expanded proximal end of renal tubules forming a double walled cup, inner wall covering the glomerular capillaries and outer wall.

## B-Renal tubules:- formed of

### *1. Proximal convoluted tubule:-*




- It is about 15 mm long.
- Lined by single layer of cuboidal cells.
- These cells show brush luminal border due to presence of microvilli that increase the surface area of luminal exposure 20-folds.
- Near the basal border of the cells there are numerous mitochondria which provide energy for active transport.
- Between the lateral borders of the cells there are spaces called lateral intercellular spaces.
- Tubular cells rest on a basement membrane.

## 2. Loop of Henle:-

- Composed of descending limb and ascending limb.
- The wall of the descending limb and lower part of ascending limb is thin (made up of flattened cells) and is called thin segment of loop of Henle. It varies from 2-14 mm in length.
- The remaining part of the ascending limb is thick (made up of cubiodal cells, like other parts of the nephron) and is called thick part of the ascending limb. It is about 12 mm in length.

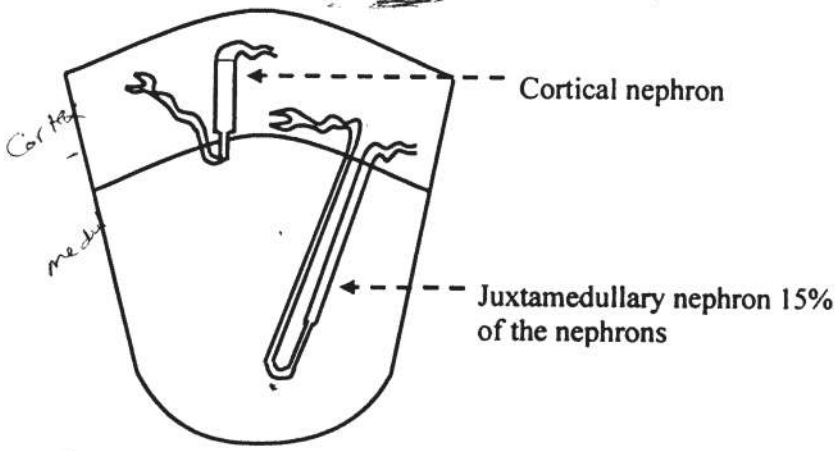
- **There are 2 types of nephrons:-**

**a- Cortical nephrons: - They have 2 characters.**

1. They have their glomeruli in the outher cortex.
2. Their loop of Henle is short (short thin segment) that penetrate only a short distance in the outer medulla.

**b- Juxtamedullary nephrons:- They have 2 characters.**

1. They have their glomeruli in the deep cortex (juxtamedullary region).
2. They have long loops of Henle (long thin segment) that penetrate deeply in the medulla, many of them reach the tips of the medullary pyramids. They constitute only about 15% of the whole nephrons.




## 3. Distal convoluted tubules:-

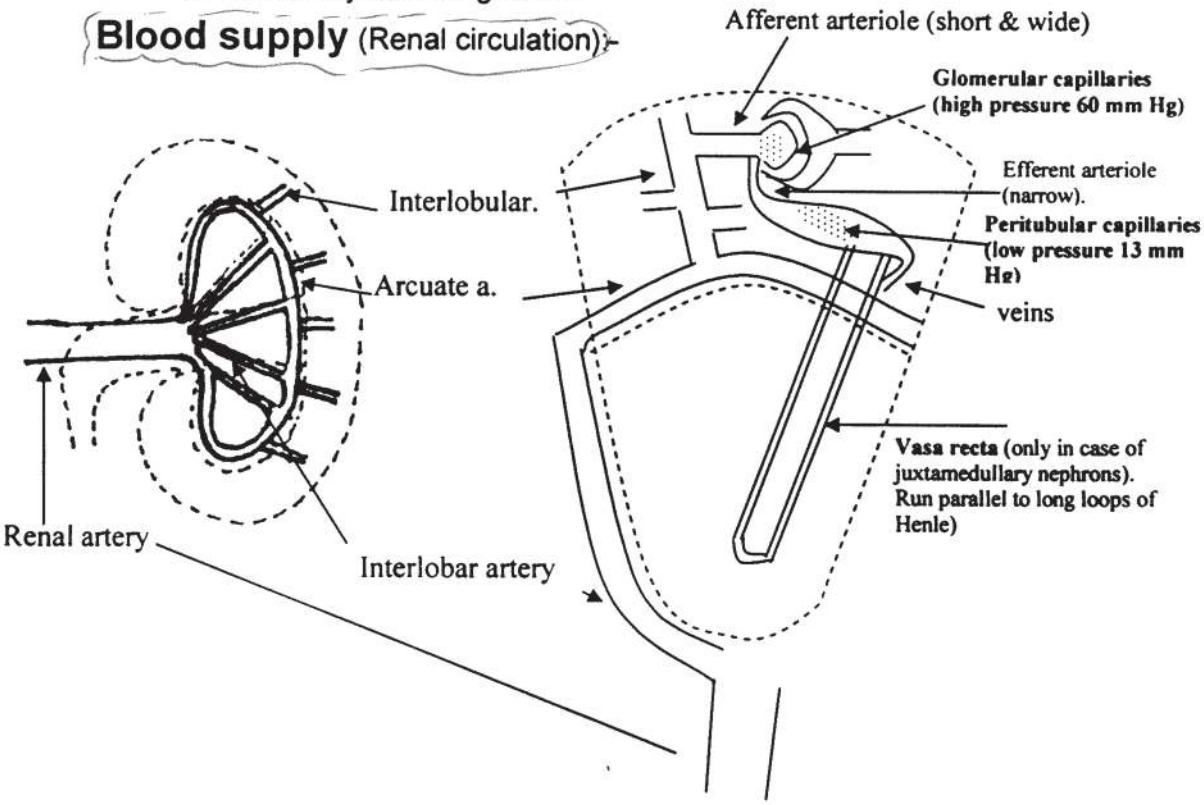
- It is about 5mm in length.
- Its epithelium is lower than that of proximal tubules and has fewer microvilli.
- **It is divided functionally into:-**
  1. **First half:-** similar in structure and function to the thick part of the ascending limb of loop of Henle and is called **the diluting segment of distal tubule**.
  2. **Late distal tubule**: the second half.

### 4. *Collecting ducts:-*

The distal tubules coalesce to form collecting ducts that are about 20 mm long and pass through the renal cortex and medulla to empty into the pelvis of the kidney at the apices of the medullary pyramids. They are functionally divided into:-

1. Cortical collecting ducts.
2. Medullary collecting ducts.

## Blood supply (Renal circulation):-




### Special aspects of renal circulation:-

### 1)There are 2 capillary beds:-

#### *1- Glomerular capillaries:-*

- It is high-pressure capillaries (60 mm Hg) because blood comes to it through the wide afferent arteriole and leaves it through the narrow efferent arteriole.
- Shows continuous filtration of fluid into Bowman's capsule i.e. it functions as the arterial end of the usual tissue capillaries.

#### *2-Peri tubular capillaries:-*

- It is a low pressure capillaries (13 mm Hg) because it receives the blood from the narrow efferent arteriole.
- Shows continuous reabsorption of fluid from the tubular lumen i.e. functions as the venous end of the usual tissue capillaries.

**2) The blood supply to the medulla:** is derived from the vasa recta (long straight capillary loops). Thus the blood flow to the medulla is slow and little in amount (only 1-2% of the total renal blood flow) compared with that of the cortex.

## Renal blood flow:-

Renal blood flow = 1200 ml blood / minute (650 ml plasma /minute)

Renal fraction = the fraction of cardiac output that passes through the kidney

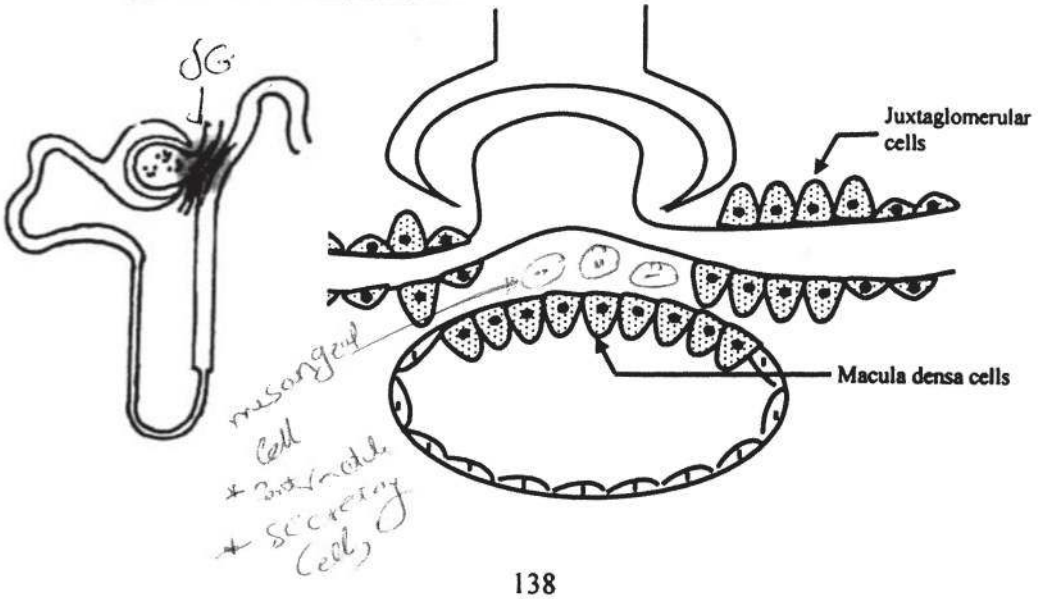
$$= \frac{\text{Renal blood flow (1200)}}{\text{Cardiac output (5000)}} = 20 - 25\%$$

## Nerve supply:-

- The kidneys are richly innervated by sympathetic nerves which originate from 4th thoracic to the 3rd lumber spinal segments. Its stimulation leads to:-
  1. Vasoconstriction of renal blood vessels (the main action).
  2. Stimulation of renin secretion via $B_1$ receptors.
  3. Stimulation of $Na^+$ and $H_2o$ reabsorption from renal tubules.
- There also appears to be a cholinergic innervation via the vagus nerve, but its function is uncertain.

## Juxtaglomerular apparatus:-

- The initial portion of the distal convoluted tubule passes in the angle between the afferent and efferent arterioles of the same nephron. The juxtaglomerular apparatus lies at the area of contact between the distal convoluted tubule and afferent and efferent arterioles and is composed of:-
  1- **Macula densa cells:-** The cells lining the DCT at this area are denser than other tubular cells and are called macula densa cells. They function as **receptor cells responding to changes in Na Cl concentration in the tubular fluid.**



2- **Juxtaglomerular(JG)cells:-** The smooth muscle cells of the arterioles, mainly those of the afferent, are swollen and contain dark granules and are called juxtaglomerular(JG)cells. They secrete renin,

## General functions of the kidney:-

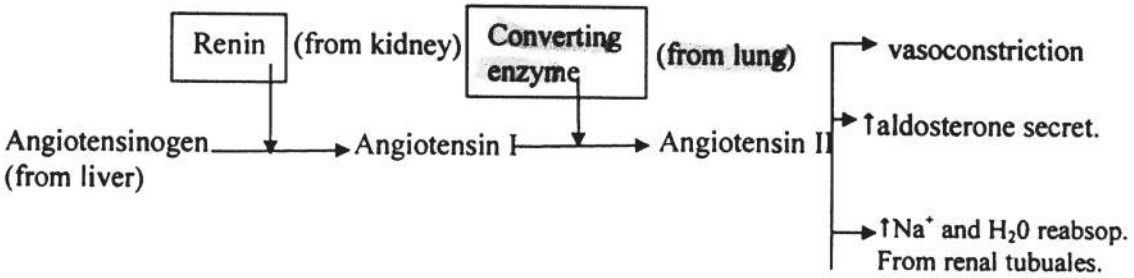
### 1-Homeostatic function:-

- It is the most important function. The kidney plays the major role in homeostasis.
- The kidney regulates volume, ionic composition and H+ concentration of the plasma.
- The kidney performs this important function through urine formation.

**2-Secretory function (endocrinal function):-** It produces:-

***1- Renin: -***

- It is secreted from the JG cells.
- It has an important role in the regulation of arterial blood pressure.



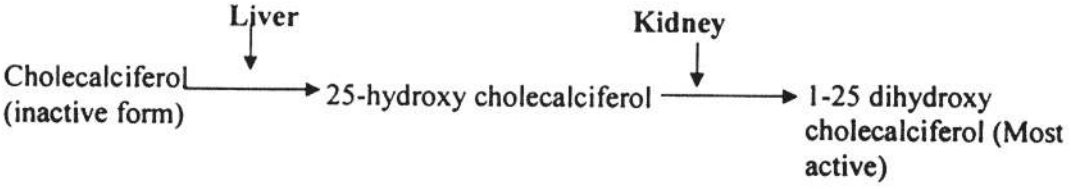

- Factors that increase renin secretion:-
  1- ↓NaCl concentration in the tubular fluid → stimulation of macula densa cells →↑JG to secrete renin.
  2- ↓Blood pressure in the afferent arteriole →↑JG cells to secrete renin (JG cells act as intra renal baroreceptors).
  3- Sympathetic stimulation → direct stimulation of JG cells.

***2- Erythropoietin:-***

- It regulates RBCs production from bone marrow.
- It is secreted in response to hypoxia.

***3- Active form of vitamin D:-***

- It ↑$Ca^{2+}$ absorption from GIT →↑ plasma $Ca^{2+}$. It also, enhances $ca^{2+}$ deposition in bone.



## Mechanism of urine formation:-

The urine is formed by 3 main processes:-

### 1-Glomerular filtration: -

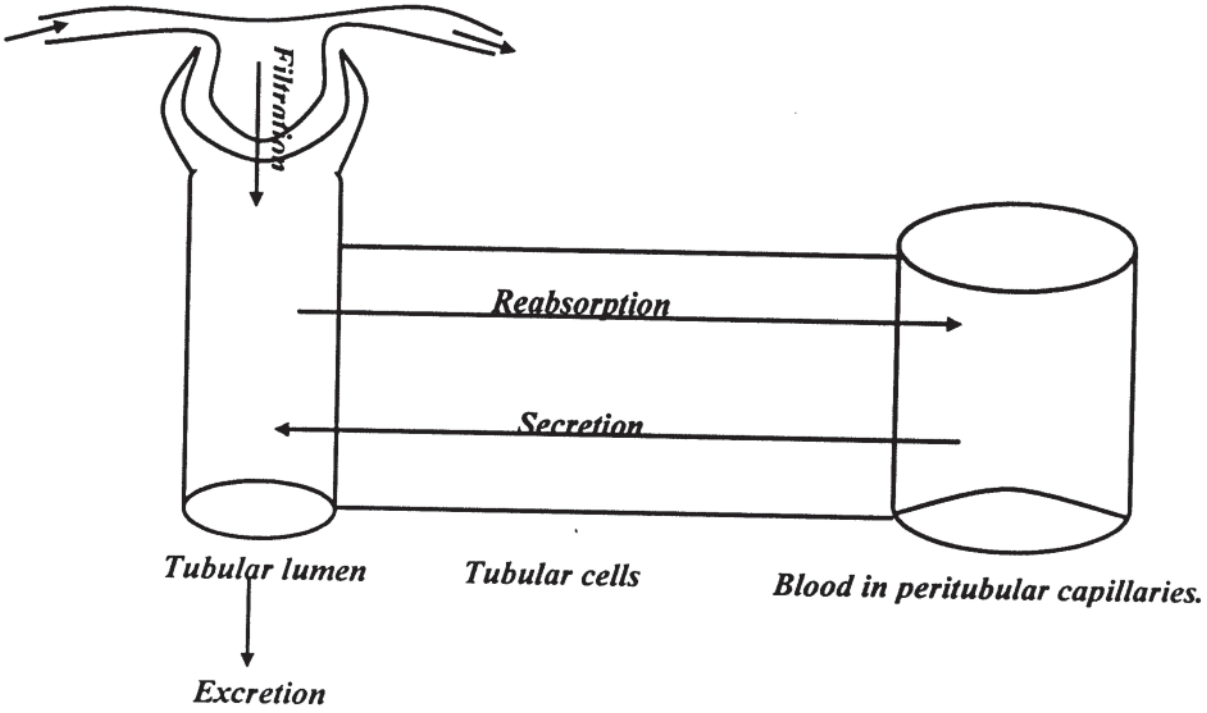
It is the filtration of fluid through the glomerular membrane into the Bowman's capsule. Usually 1/5 of the plasma flowing in the glomeruli filters.

### 2-Tubular reabsorption: -

It is the transport of substances from the tubular lumen to blood. The wanted substances, especially almost all of the water and many of the electrolytes are reabsorbed.

### 3-Tubular secrtion: -

It is the transport of substances from the blood to the tubular lumen.




***Note:-*** Excretion means substances that come out with the final urine