# RENAL SYSTEM GFR

By

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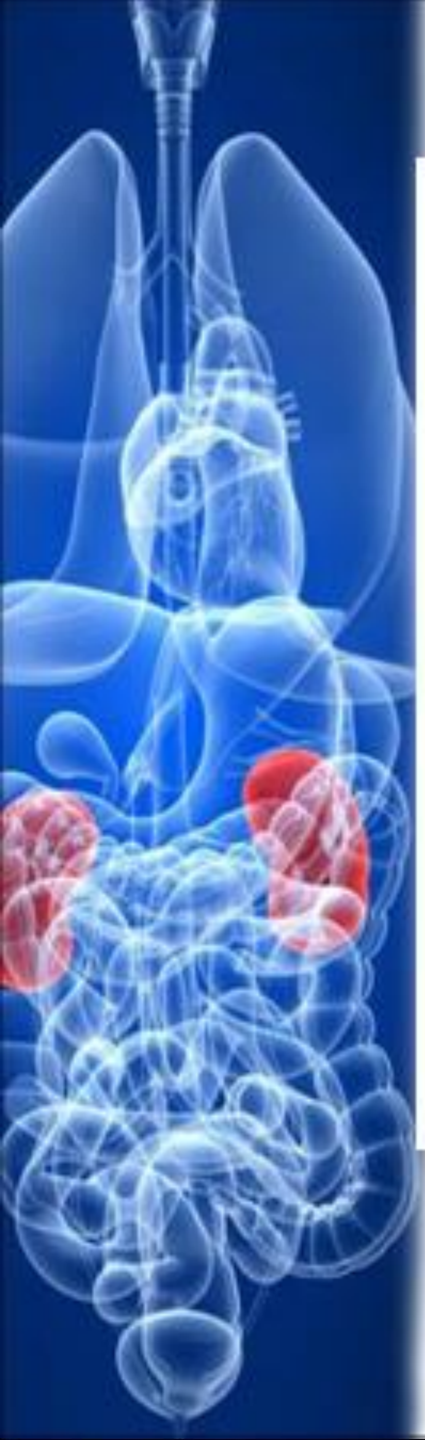
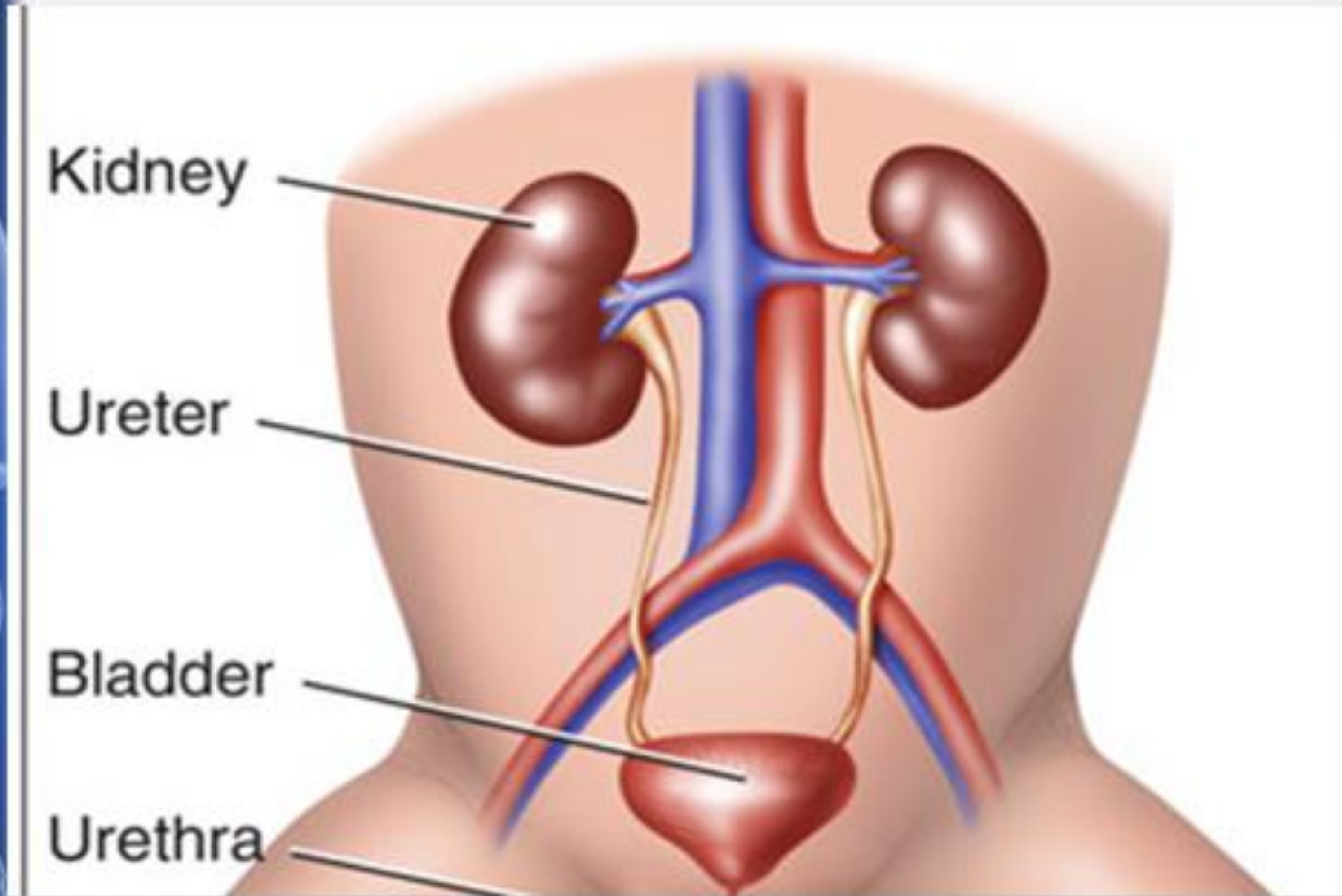
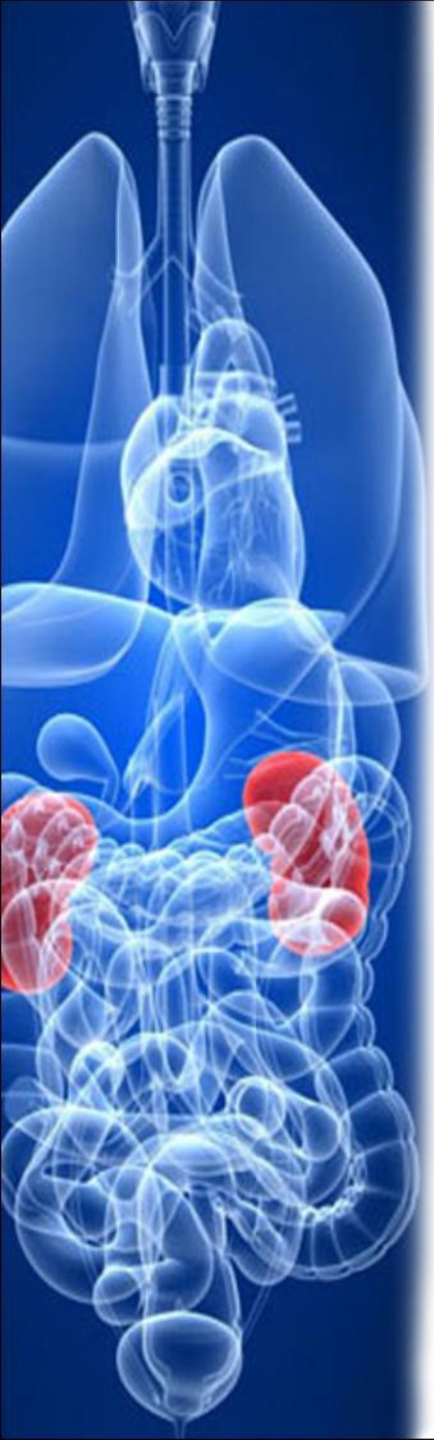
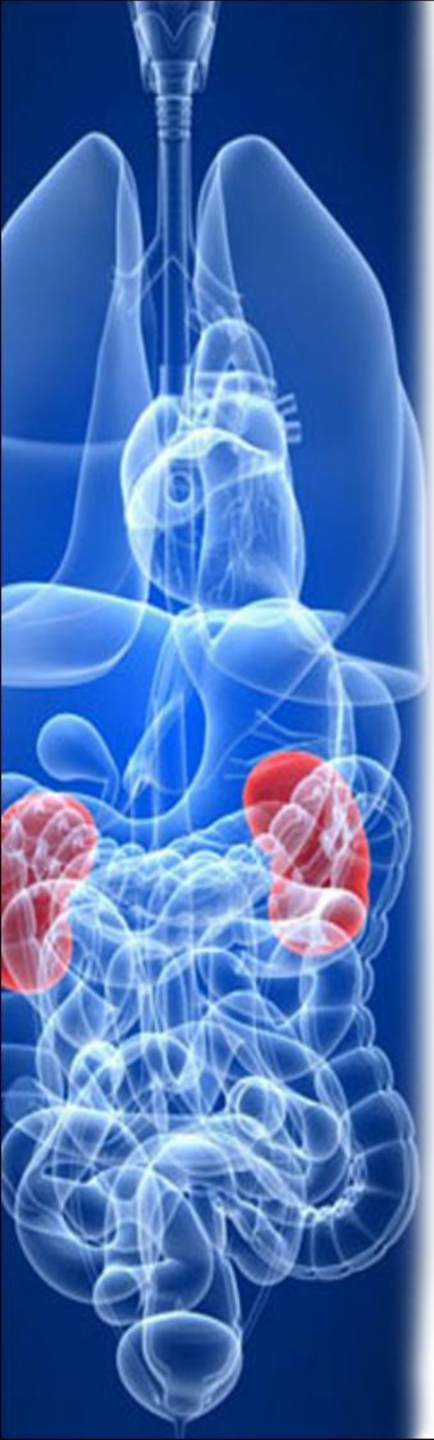



Kidney
Ureter
Bladder
Urethra



# General kidney functions

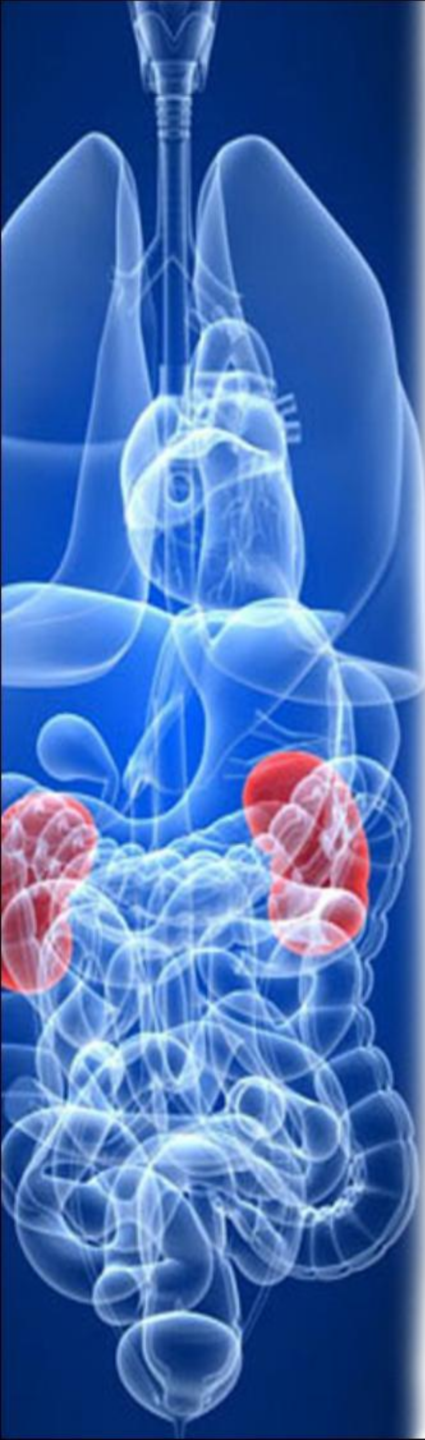
1. Urine formation
2. Excretion of waste products as urea and creatinine, while conserves important substances as glucose and amino acids.



3. **Water and electrolyte homeostasis e.g., $Na^+$, $K^+$, $Ca^{2+}$, $CL^-$,and $HCO_3^-$.**

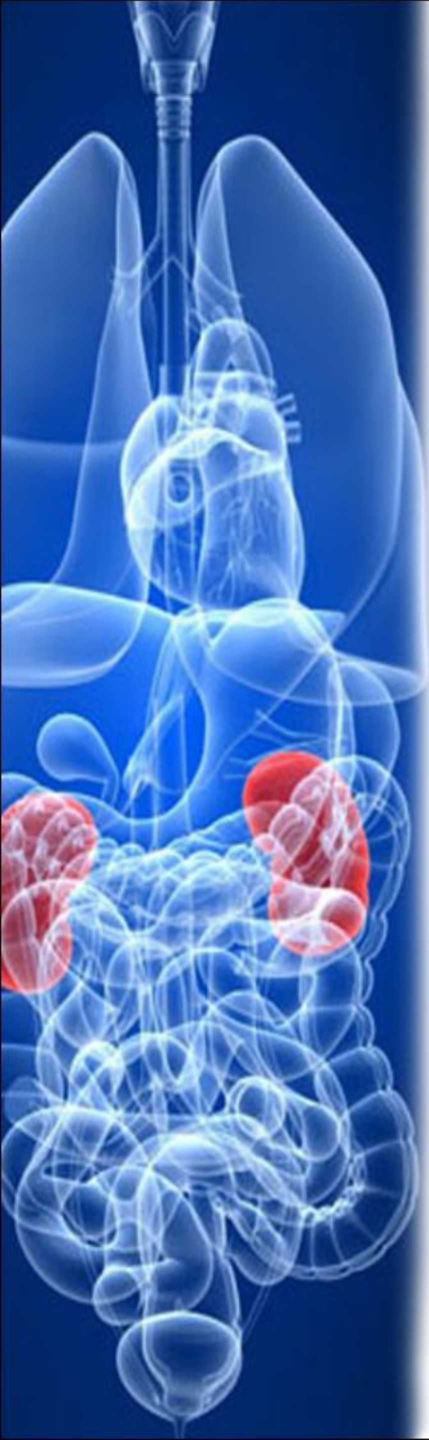
4. **$H^+$ homeostasis : adjusts pH of the body within normal limits.**

5. **Regulation of arterial blood pressure through:**
   a. Renin- angiotensin system.
   b. Controlling blood volume.

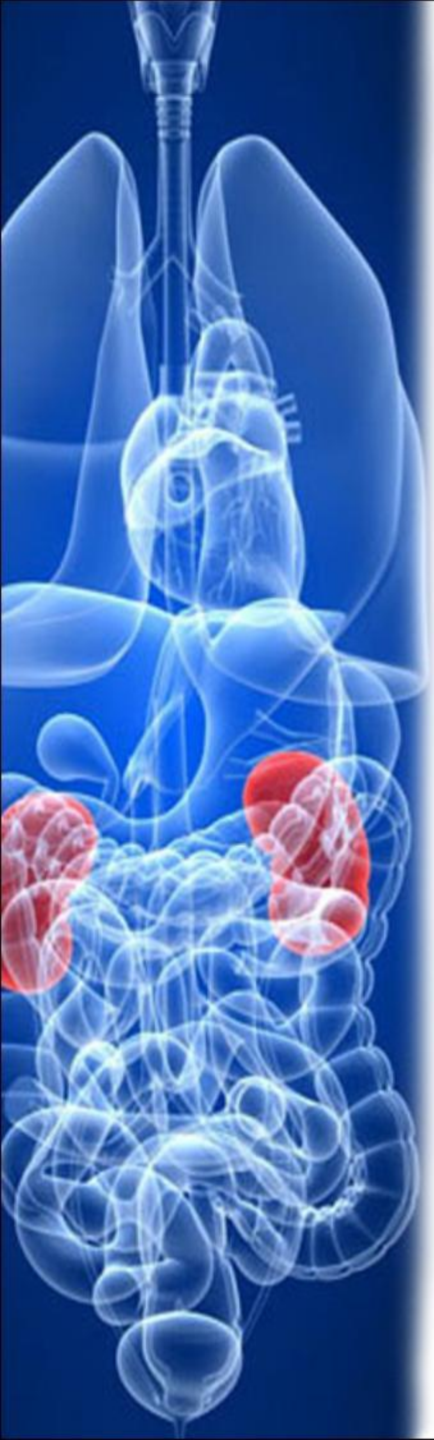


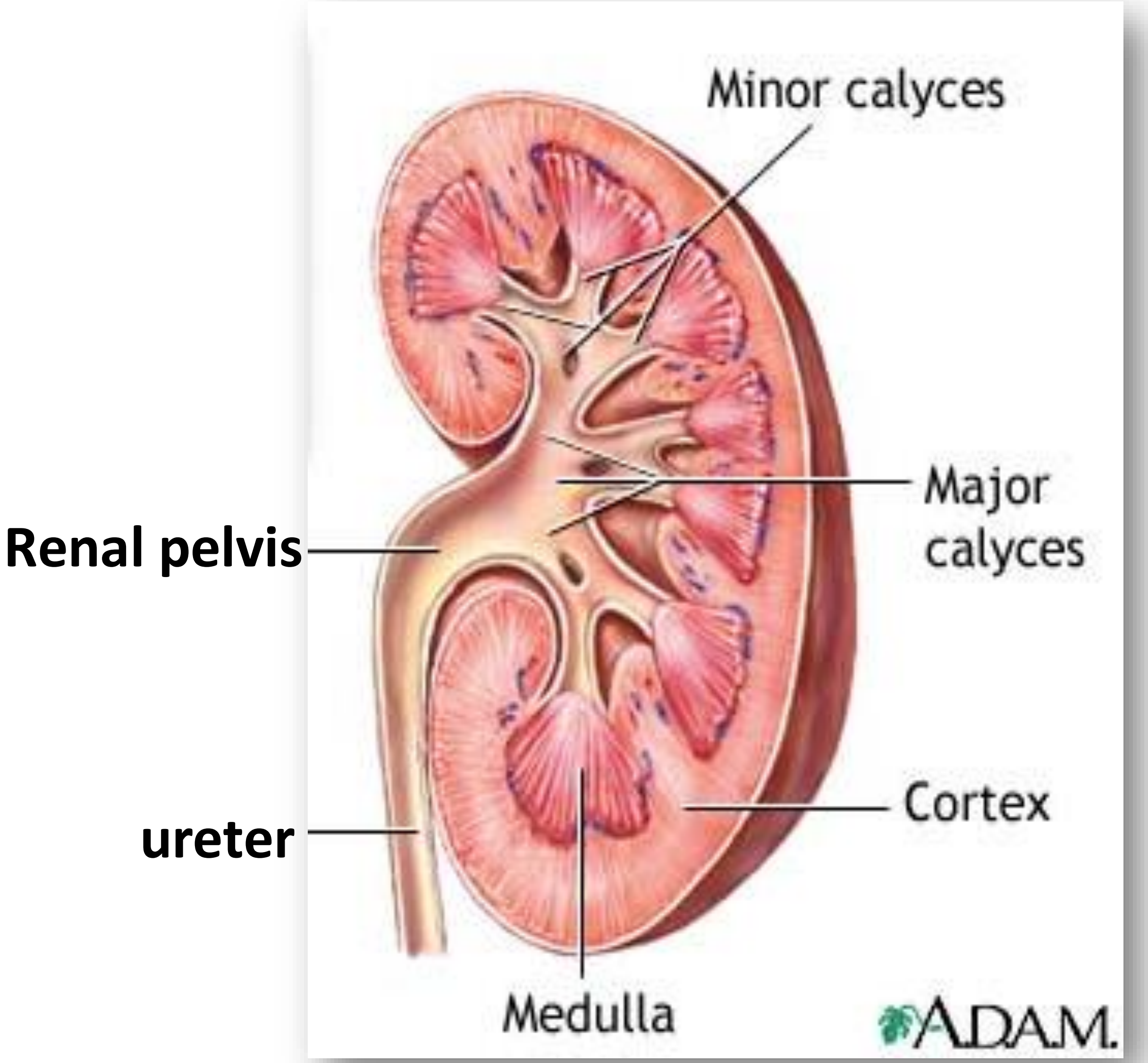
6. Endocrine function:-The kidney secretes:

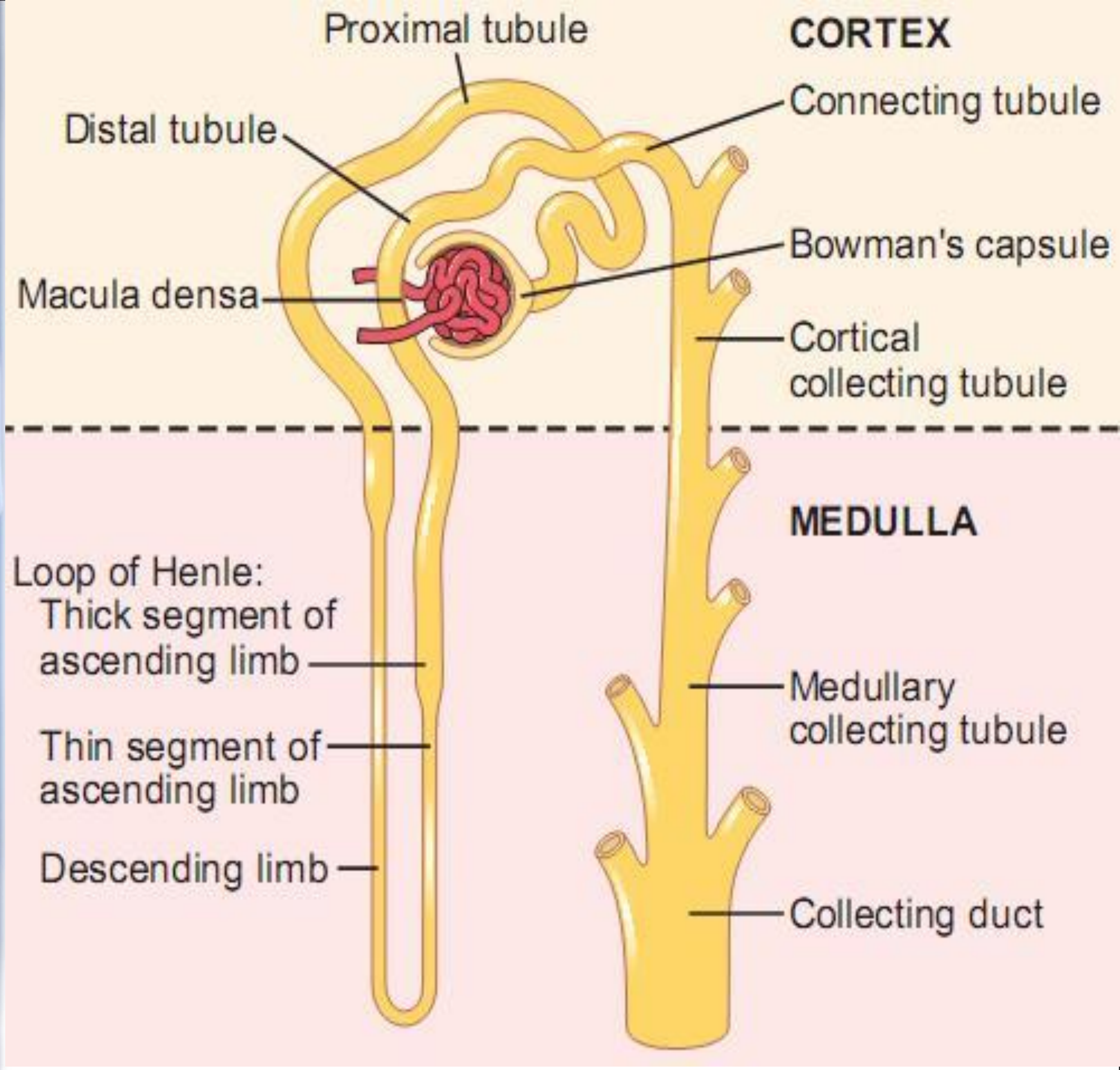
a. Erythropoietin, which stimulate RBC s formation.
b. 1,25 dihydroxy cholecalciferol which is essential for bone formation and $Ca^{2+}$homeostasis.
c. Renin, which converts angiotensinogen to angiotensin I.

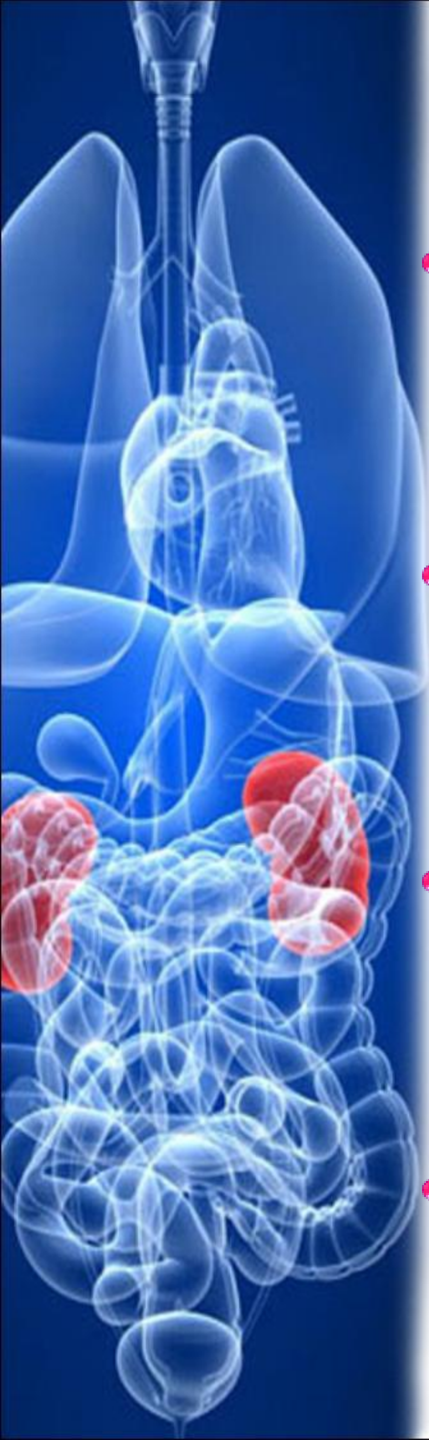


- the kidney has a cortex and a medulla and each lobe of it consists of pyramid of medulla covered by cortical tissues.
- The cortex has a granular appearance and consists primarily of glomeruli, convoluted tubules, cortical collecting tubules and blood vessels.
- the medulla has a striated appearance due to the parallel arrangement of Henle's loop, collecting ducts and blood vessels.



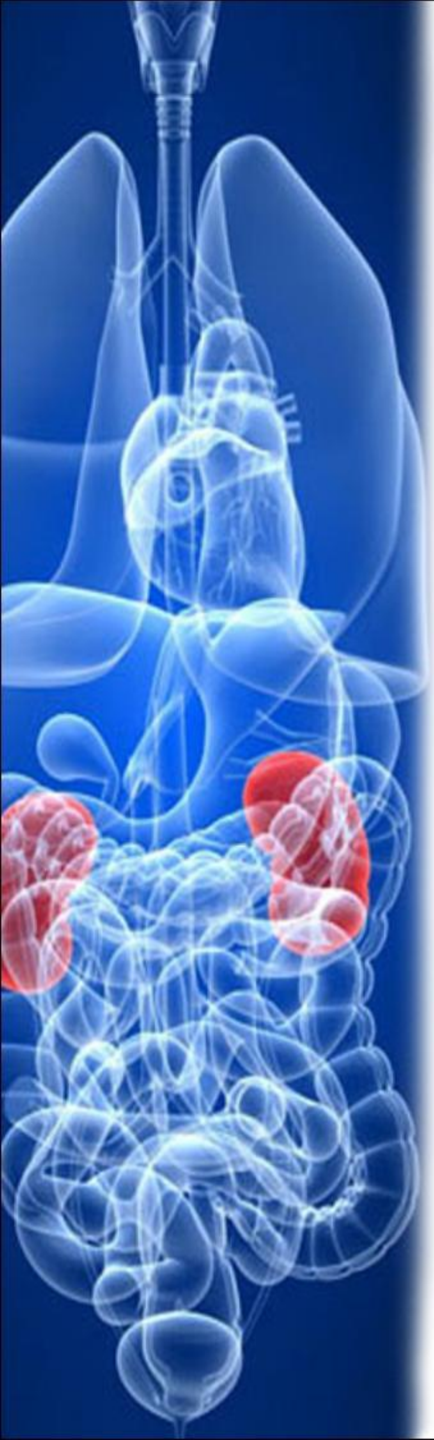

Minor calyces
Major calyces
Renal pelvis
Cortex
ureter
Medulla
A.D.A.M.


Proximal tubule
CORTEX
Connecting tubule
Distal tubule
Bowman's capsule
Macula densa
Cortical
collecting tubule
MEDULLA
Loop of Henle:
Thick segment of
ascending limb
Medullary
collecting tubule
Thin segment of
ascending limb
Descending limb
Collecting duct



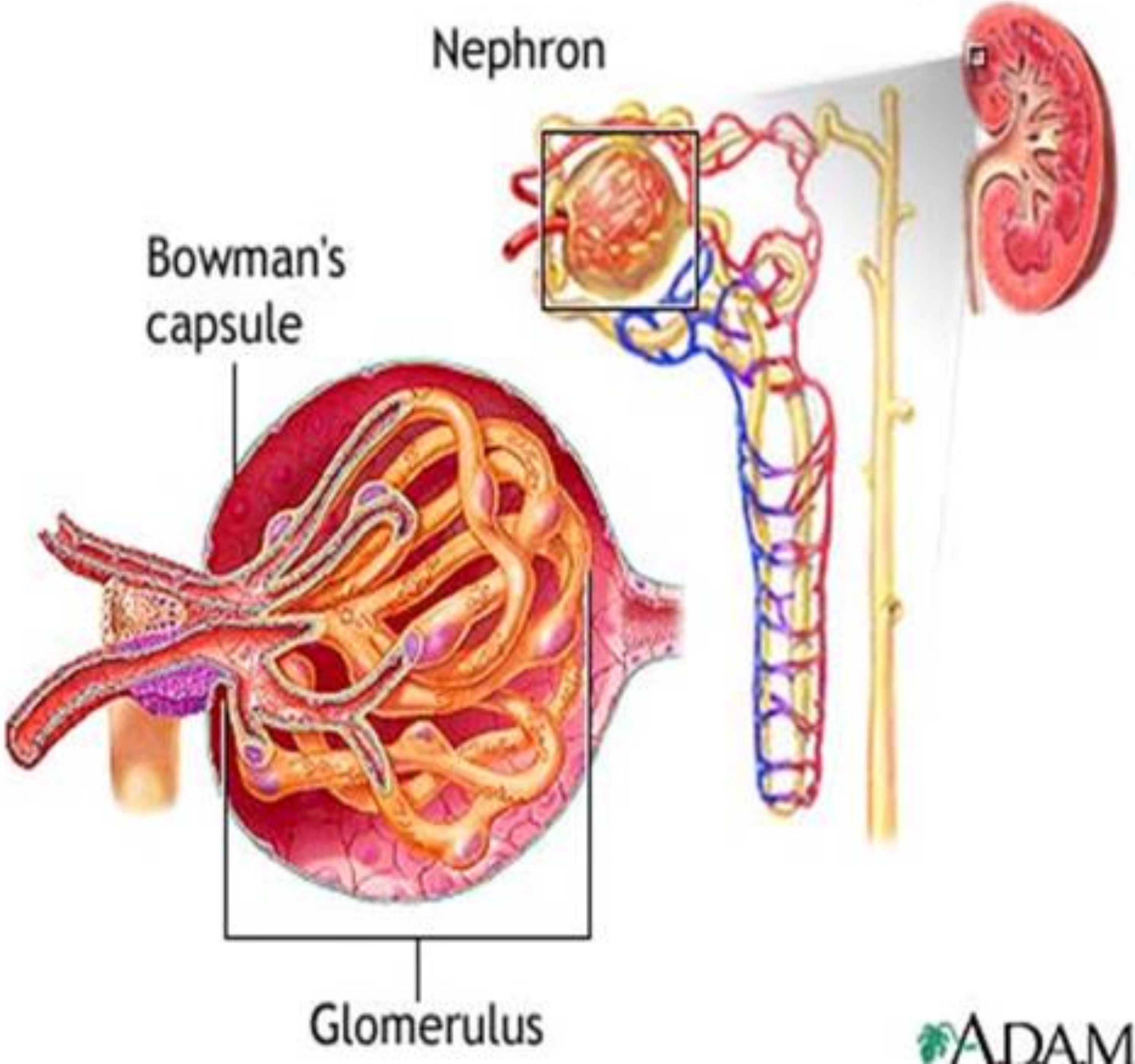
# The Nephron

- The nephron is the functional unit of the kidney, which can perform nearly all the functions of the organ.
- Each kidney contains from 1 to 1.2 million nephrons in the young adults but with age there is progressive decrease in number.
- this decrease does not affect the normal function due to the great reserve in the kidney tissue.
- The nephrons like the neurons never regenerate again after pathological degeneration.



- The structure of the nephron consists of two main Parts:

1. Renal corpuscle, formed of a "glomerulus" and "Bowman's capsule."
2. Renal tubules which include proximal convoluted tubule, loop of Henle, distal convoluted tubules and the collecting ducts.


Nephron
Bowman's capsule
Glomerulus
ADAM

# The glomerular membrane has 4 layers:

A. Endothelial walls of capillaries, which is perforated by thousands of small holes called "fenestrae" (70-100nm in diameter).

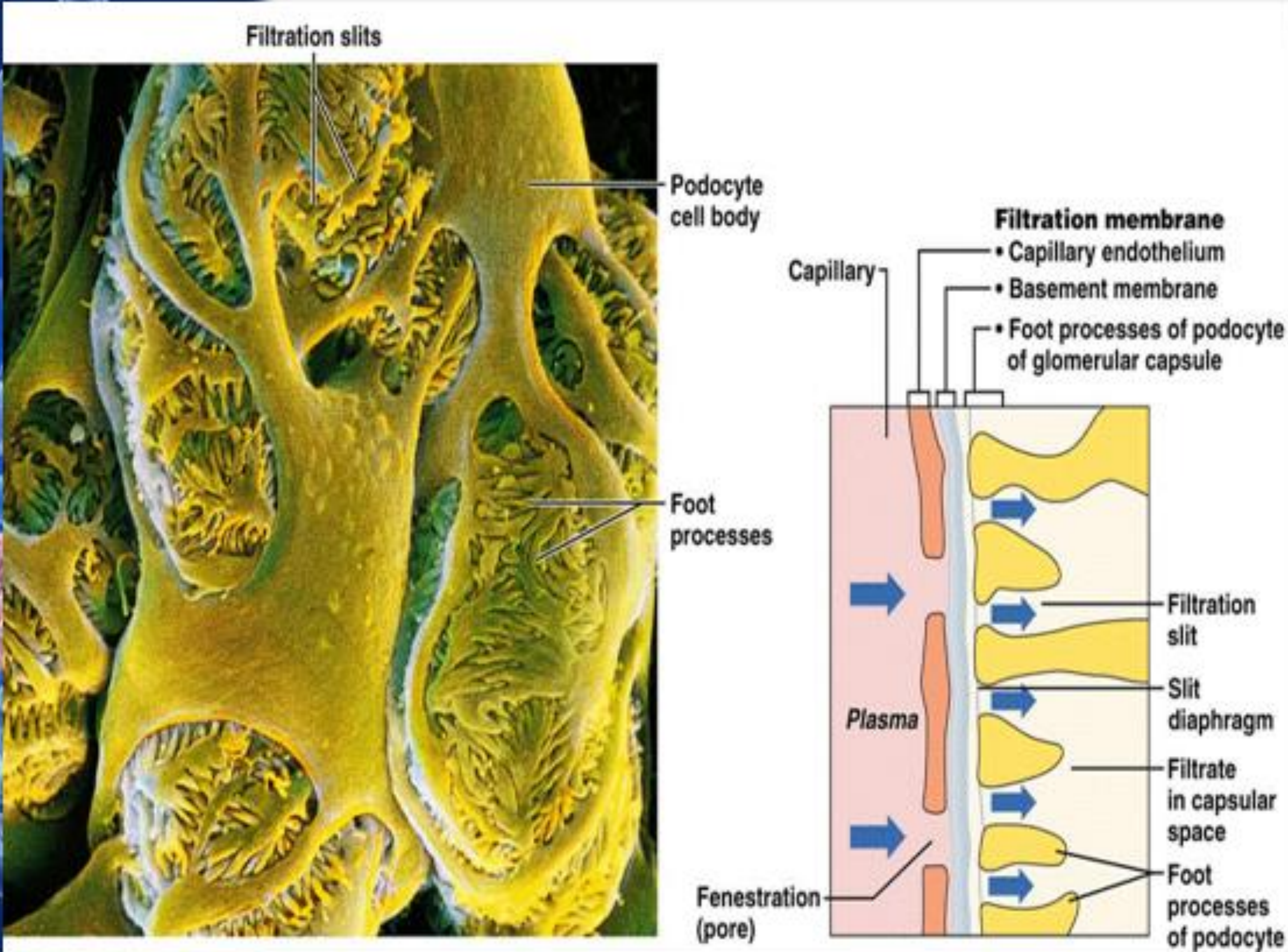
B. Basement membrane of those capillaries (basal lamina), which is formed of loose collagen bundles and proteoglycan filament with wide large spaces in between. The basal lamina does not contain visible gaps.

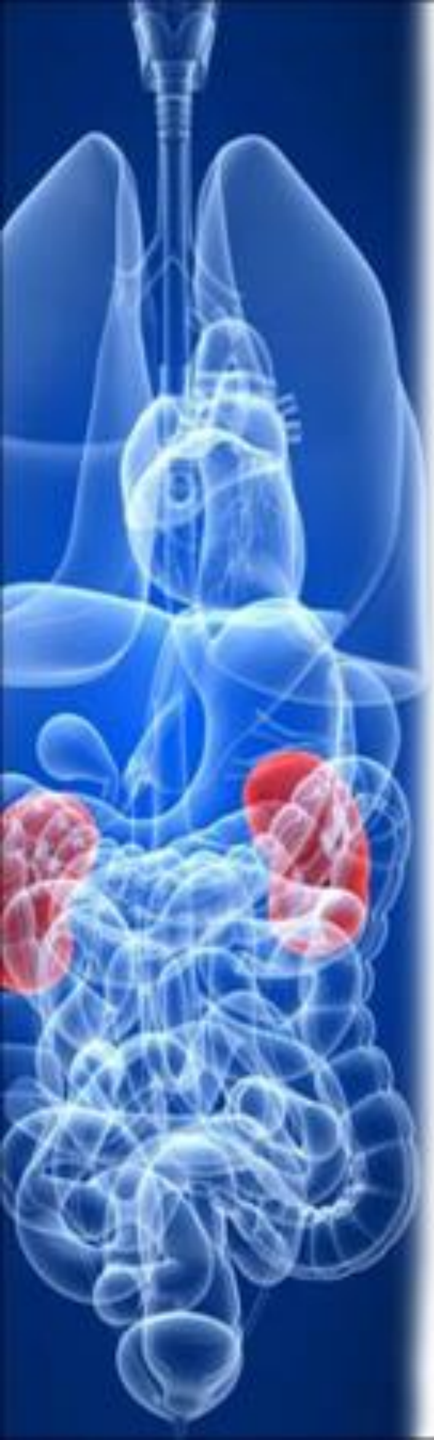
**C. Epithelial cells of Bowman's capsules (called podocytes) with its filtration slits.**

**It is the most outer layer of interrupted epithelial cells arranged in a finger like projections (pseudopodia) forming slits called "filtration slit pores" (25nm in diameter) through which filtrate passes.**

**D. Filtration slit diaphragm:-** It is a specific basement membrane of the podocytes, which is the second layer of the Bowman's capsule and considered as the fourth layer of the glomerular membrane.

- The substances that pass from blood in the glomerular capillaries to reach renal tubules (glomerular filtrate) must pass through the capillary pores, then capillary basement membrane, then filtration slits of podocytes and finally slit diaphragm. This filtrate never cross the cell wall of the podocytes.


Filtration slits
Podocyte cell body
Foot processes
Filtration membrane
• Capillary endothelium
• Basement membrane
• Foot processes of podocyte of glomerular capsule
Capillary
Plasma
Filtration slit
Slit diaphragm
Filtrate in capsular space
Foot processes of podocyte
Fenestration (pore)



There are specific contractile cells between neighbouring capillaries "mesangial cells" that play a role in regulation of the glomerular filtration, as it contract and relax.

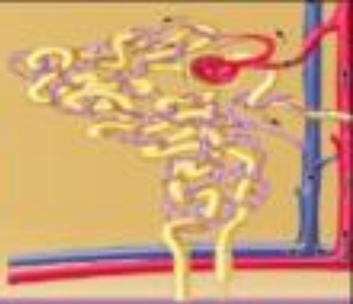
# Factors affecting mesangial cells

| Contraction | Relaxation |
|---|---|
| Endothelins | Atrial natriuretic peptide |
| Angiotensin II | Dopamine |
| Histamine | PGE2 |
| Vasopressin | |
| Noradrenalin | |
| Thromboxane $A_2$ | |
| PGF2 | |

- The charge on molecules as well as their diameters affect their passage into Bowman's capsule.
- The glomerular membrane permits the free passage of <u>neutral</u> substances
- any substance with molecular weight up to 5200 (100% filtered)

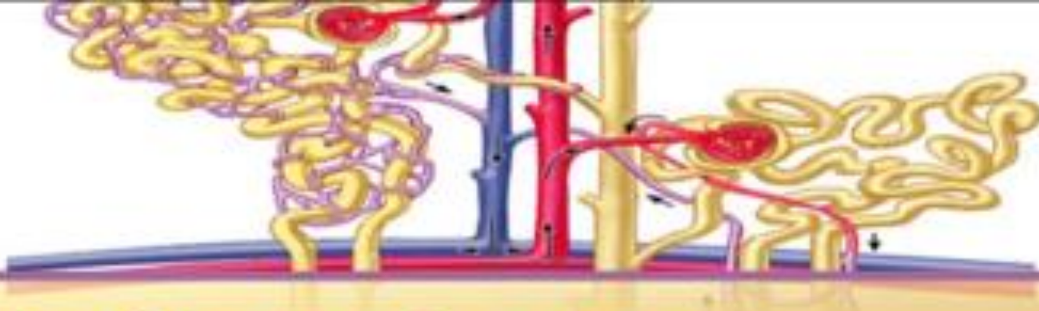
## *Q)Why proteins with small molecular weight (e.g., albumin) is only 0.5% filtered?*

- **Because the membranes of the pores are lined with proteoglycan that have very strong negative charge which repel strongly with the negative charge of the albumin.**



# Glomerular filtration rate (GFR)

- It is the amount of protein free plasma, which is filtered in both kidneys per minute across the glomerular membrane .
- It equals **125 ml/min** in normal 70 kg young adult.
- It is **about 10% less** in females than males.
- It is a passive process



## The filtration fraction: -

It is the percentage of GFR as regard the renal plasma flow.

= (GFR/Renal plasma flow) x 100

= (125/700) x 100

= 17.9% = approximately 20%.

**Dynamics of glomerular filtration:

a- The driving force for GF is the high hydrostatic pressure in glomerular capillaries (60mm Hg)

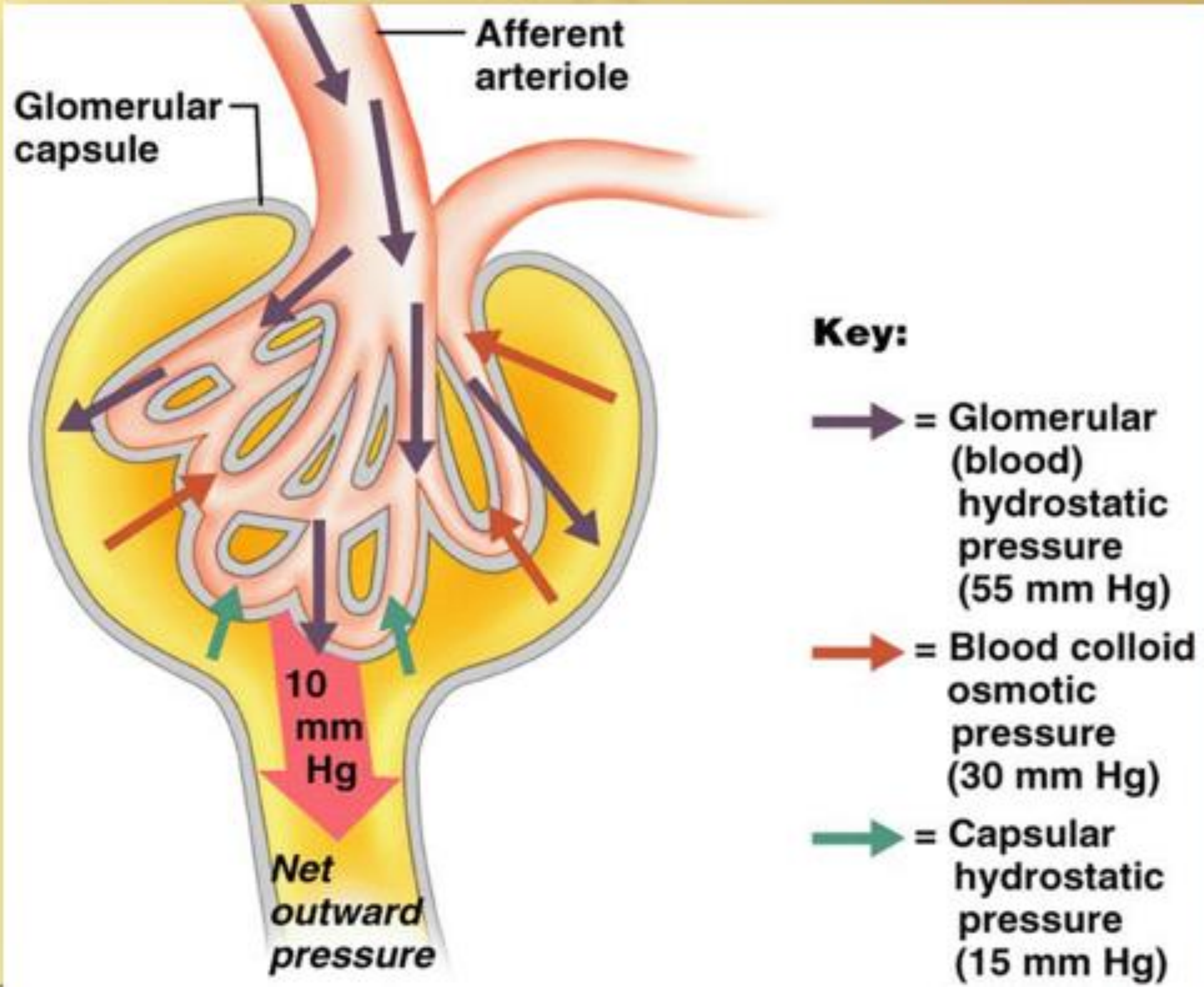
b-The forces which oppose the filtration, are:

1. Hydrostatic pressure in Bowman's capsule = 18 mm Hg.
2. Oncotic of plasma proteins = 32 mm Hg (here it is high because high concentration of plasma proteins)

Thus:

Net force of filtration (or Net filtration pressure)=
60 – (18 + 32) = 10 mm Hg.

# Dynamics of glomerular filtration



## **Composition of Glomerular Filtrate “Primary Urine”

The glomerular filtrate (GF) “Primary urine’ has the same properties as the plasma.

- Its pH is 7.4, specific gravity 1010 and osmolality 300 mosmol/litre.
- It is composed mainly of water and the freely filterable substances at same concentrations as plasma (e.g., glucose, urea, creatinine, electrolytes and amino acids).

However, it differs from the plasma in:

1. It contains a trace of proteins (0.03 gm/dl) particularly albumin.
2. The non-protein anions (e.g., $Cl^-$ & $HCO_3^-$) are about 5% greater than in the plasma, while the cations (e.g., $Na^+$ & $K^+$) are about 5% less.

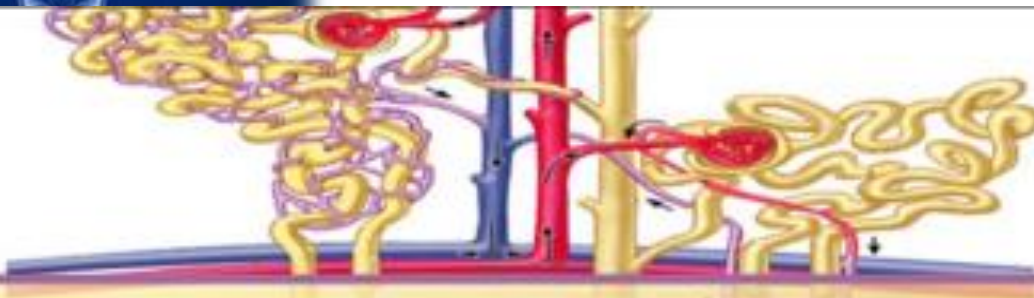
This is due to Donnan equilibrium

** Factors affecting GFR:

1. Hydrostatic pressure of the glomerular capillaries ( 60mm Hg) .
2. Hydrostatic pressure in Bowman's capsule (18 mmHg) .
3. Oncotic pressure of plasma proteins (32 mmHg).
4. Permeability of glomerular membrane .
5. Systemic blood pressure
6. Sympathetic stimulation

## 1- Hydrostatic pressure of the glomerular capillaries

- There are a direct relationship between glomerular capillary pressure and GFR.
- This pressure is affected by the diameter of afferent & efferent arterioles.
- constriction of affarent arterioles will diminish the glomerular capillary pressure that decreases GFR.
- dilatation of afferent arteriole increase the glomerular capillary pressure & GFR.
- Mild constriction of efferent arteriole increase the GFR, while severe constriction of efferent arteriole will decrease GFR due to diminish renal blood flow.

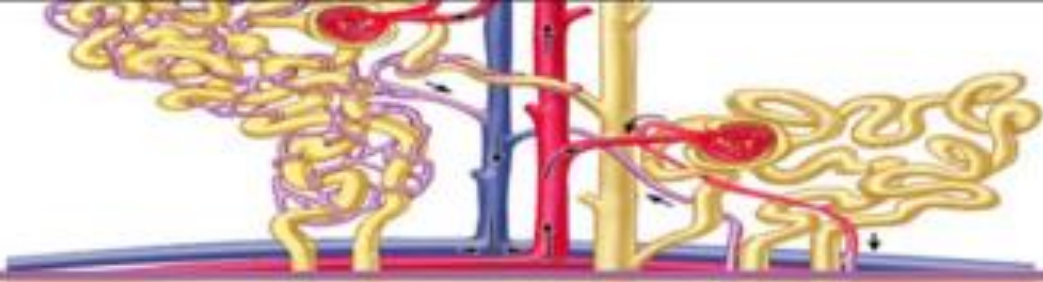


## 2– Hydrostatic pressure in Bowman's capsule

It is the antagonising force for filtration. Increase of this pressure by stone formation or any other obstruction in the urinary tract as tumours or fibrosis leads to marked diminish in filtration and if the obstruction is severe and maintained it will affect kidney function.

## 3 – Oncotic pressure of plasma proteins:

- It is also an antagonising force for filtration.
- Diminish formation of plasma proteins as in liver diseases or marked loss of it as in kidney disease increase GFR.
- The Oncotic pressure of plasma proteins is here high (32 instead of 28 mm Hg) because the filtered fluid is protein free filtrate which increases the concentration of plasma proteins.



## 4 – Permeability of glomerular membrane:

It is affected by:-

A. Total surface area of filtration (determined by total number of healthy nephrons)
B. The state of intra-glomerular mesangial cells (defensive cells). When contract decreases the effective filtration area with subsequent decrease in GFR while its relaxation increase the GFR.

This permeability is assessed by measuring what is called <u>Filtration Coefficient ($F_k$)</u> which is the volume of fluid filtered by all the nephrons in both kidney/minute/per 1 mm Hg net filtration pressure.

$$(F_k) = \frac{GFR}{Pressure} = \frac{125}{10} = 12.5 \text{ ml/minute/1 mm Hg.}$$

## 5 – Systemic blood pressure:

The GFR remains more or less constant between blood pressure 70 and 180 mmHg due to auto-regulation of renal blood flow. Yet in severe haemorrhage and shock when the ABP decrease below 70 mmHg there is marked decrease in GFR, and it may even stop in severe shock with subsequent acute renal failure. On the other hand, marked elevation of blood pressure above 210mmHg causes an increase in GFR and urine formation phenomena called “pressure diuresis”.

## 6 – Sympathetic stimulation:

Marked sympathetic stimulation as in severe exercise or intense emotional stress diminishes GFR by constricting the renal artery.