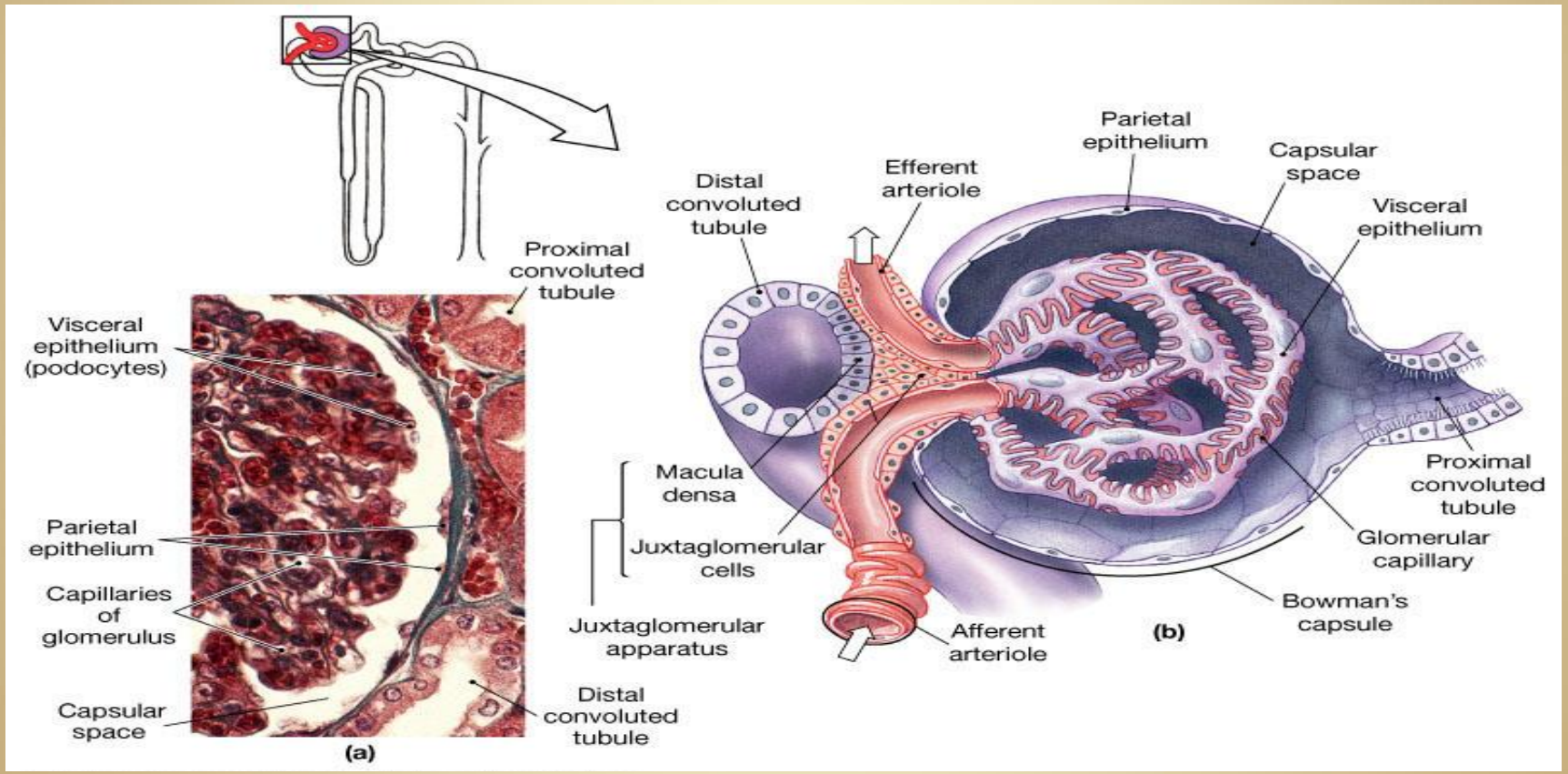
(endocrine function of kidney) the juxtaglomerular apparatus(JGA)



(endocrine function of kidney) the juxtaglomerular apparatus(JGA)

1-Definition :-

It is a secretary structure located at the area of contact between the distal convoluted tubules and the afferent and efferent of the glomerulus of the same nephron

2-The structure of the juxtaglomerular apparatus consists of 3 cells:- .

1)Juxtaglomerular cells

These are especial granular cells present in the wall of the afferent arteriole

2)Macula densa

Modified cells because more crowded & more dense than other cells present in the wall of the initial part of the DCT.

3)lacis cells

these are non granular tall thin cells that fill the space between the juxtaglomerular cells and the macula densa

Function of the juxtaglomerular apparatus

secretion of the hormones (endocrine function):-

1. secretion of the renal erythropoietin hormone in regulation of the RBCs production

2.secretion of the renin for autoregulation of the GFR and RBF.

3.secretion of prostaglandins for autoregulation of the GFR and RBF.

Hormones produced by the kidney:

1-Renin is a glycoprotein produced by epithelial cells of the juxtaglomerular apparatus. Renin is regulated by:

a. Hypotension due to hypovolemia causing a decrease in renal blood flow, low sodium in tubular fluid results from hyponatremia stimulate beta-adrenergic receptors in juxtaglomerular cells to release renin.

b. Prostaglandin (PGIz) stimulates renin secretion.

Action of renin:

Angiotensinogen (plasma glycoprotein produced by liver) is converted to active angiotensin I by renin. Angiotensin I is converted to angiotensin II by angiotensin-converting enzyme present in the lungs and kidneys causes the following actions :

a. Stimulates production of aldosterone and ADH.

b. Contraction of vascular smooth muscle causing vasoconstriction.

c. Hypertension.

d. Thirst.

e. Regulate the glomerular filteration rate through tubuloglomerular neuroendocrine feedback because lack of the chloride in the tubular fluid detected by the macula dense which causes afferent arteriolar dilatation and efferent constriction to increase the filteration and blood flow in the glomerulus

3- Erythropoietin :

Erythropoietin, a glycoprotein originating in the glomerulus. It derives from a profactor (32-globulin), synthesized in the liver and transported to the kidneys. In the glomerular tuft, the profactor is converted to the active erythropoietin by a renal enzyme(renal erythropoietic factor)

Secretion of erythropoietin is stimulated by altitude, androgen, cobalt salt, renal hypoxia and hemorrhage. Erythropoietin controls the proliferative sequence of erythrocytes in the bone marrow.

4- Prostaglandins:

Cells of the interstitium, the collecting ducts and the arterial wall of the kidneys can synthesize prostaglandins (PGS).

Prostaglandins play role in autoregulation of renal blood flow, glomerular filtration rate (PGs causing vasodilation and improve renal circulation).

2- 1.25. Dihydroxycholecalciferol:

The kidneys are responsible for the final step in the transformation of vitamin D_3 (cholecalciferol) into a biologically active form (1,25-dihydroxycholecalciferol) under the stimulation of PTH. The most important function of the dihydroxy vitamin D_3 is the formation of calcium-binding proteins in the renal tubules and intestinal cells. Calcium-binding protein facilitates the calcium reabsorption through these cells.

Calcitonin inhibits the activation of 25-hydroxy vitamin D_3 (formed in liver) to 1,25-dihydroxy vitamin D_3 in the proximal tubules.

Glomerular filtration

Definition :-filtration of plasma from metabolic waste products as urea, creatinine and uric acid as well as many foreign substance and toxins by glomerular capillaries filtration

Mechanism of filtration:-

The glomerular filtration is performed through the glomerular filtration membrane :-

-the glomerular filtration membrane consists of the 3 layers :-

1-the capillary endothelial cells

These are separated from each other by large pores called fenestrae.

2-the basement membrane

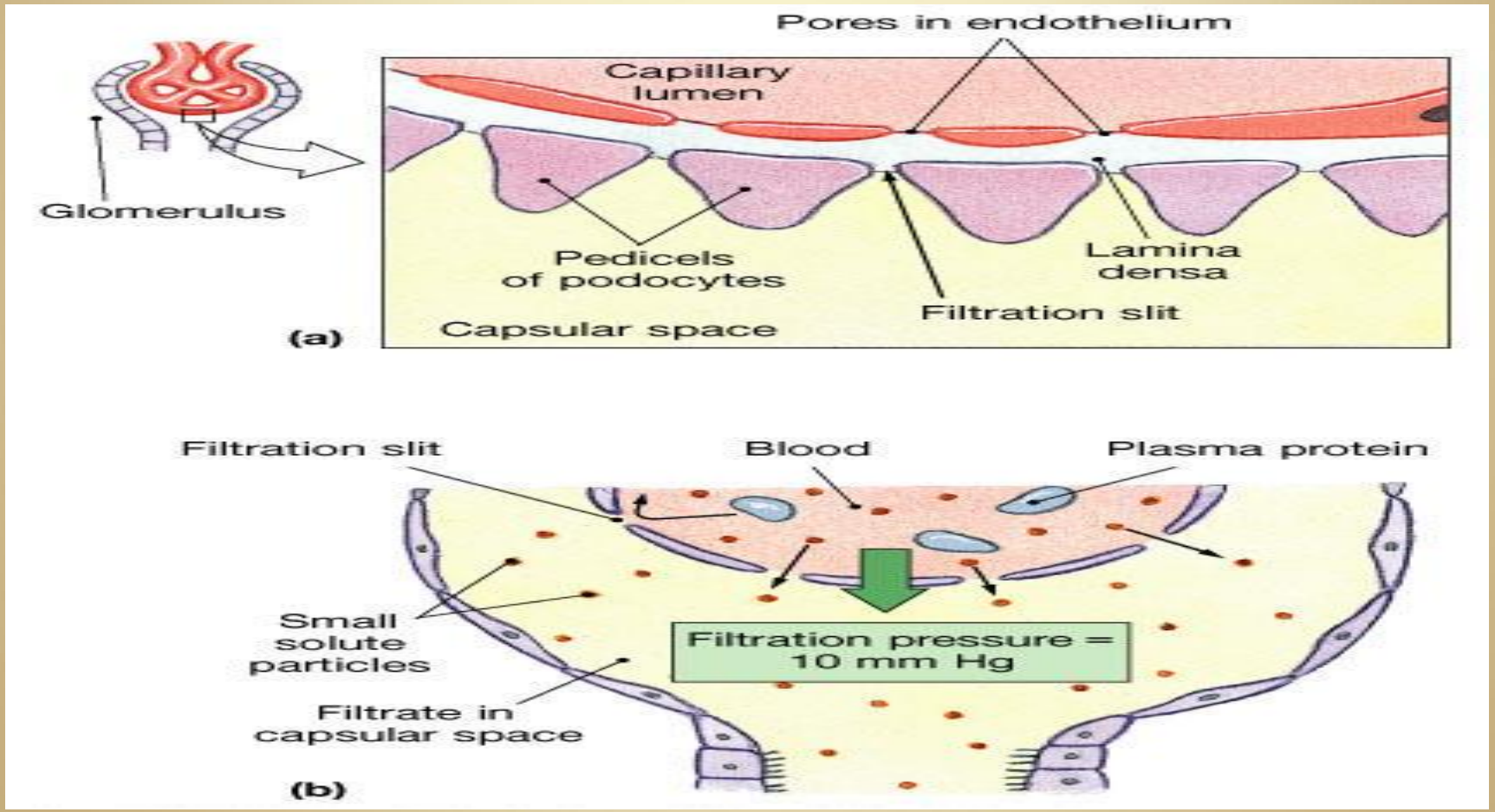
This is a protein layer.

It appear pore less but in fact it contain spaces through the fluid can filter .

3-the epithelial cells from the Bowman's capsule = podocytes

-they have numerous finger- like projections(pseudopodia) that interdigitate forming slits called slit pores.

However the presence of the 3 layers, the permeability of the glomerular capillaries is much greater than that of other capillaries present in the body


Pores in endothelium
Capillary lumen
Glomerulus
Pedicels of podocytes
Lamina densa
Filtration slit
Capsular space
(a)
Filtration slit
Blood
Plasma protein
Small solute particles
Filtration pressure = 10 mm Hg
Filtrate in capsular space
(b)

The permeability of the glomerular filtration membrane :-

-The great volume of the filtrate is formed daily

As 125 ml/minute at 180 L/day.

The dynamics of the glomerular filtration :-

The glomerular filtration is a passive process = not require energy that involve the interaction between the following forces :-

1-filtration forces:

(1) hydroststic glomerular capillary pressure (GCP)=

-The pressure of the blood in afferent arterioles glomerular capillaries

-this force filter the plasma from the glomerular capillaries into the Bowman's capsule

-these force pressure is normally 80 mmHg

(2) Colloid osmotic pressure in Bowman's capsule:
Practically zero.

2-opposing forces:

-These forces antagonize the filtration forces

(1) Glomerular colloid osmotic (oncotic) pressure in the glomerular capillaries (GOP)

-these pressure is due to the plasma proteins in the **glomerular capillaries**

-this force antagonize filtration of the fluid from the glomerular capillaries into the Bowman's capsule

-these force pressure is normally 30 mmHg

(2) Intracapsular hydrostatic pressure (CP) :-

- this pressure is due to the pressure of the fluid in Bowman's capsule.

-this force antagonize filteration of the fluid from the glomerular capillaries into the Bowman's capsule

-these force pressure is normally 10 mmHg.

The net filtration pressure(NFP):-

=20 mmHg

Glomerular filtration rate (GFR) :

Definition :- It is the quantity of glomerular filtrate formed in all the nephrons of both kidneys in each minute.

In the normal person GFR is about 125ml/min. The amount formed in the day 180 litres, about 99% of this filtrate is reabsorbed by renal tubules.

1-glomeular filtration

(1) normally, the glomerulus receive about 700 ml/plasma/minute (RPF)

(2)only 1/5 of the RPF (125 ml/ filtrate/minute)

filtrated in the glomerulus=in bowman's capsules

(3)the remaining 4/5 of the plasma with the blood (80%) pass to the efferent arteriole then to the peritubular capillaries to the interlobular veins to the arcuate veins then to the interlobar artery then to the renal vein to the body

(4)the glomerular filtrate (GF):

the plasma without plasma proteins because of their high molecular weight and other factors and the blood cells due to their molecular diameter.

Factors affecting on the GFR:-

1-the renal blood flow

The GFR is directly proportional to the RBF.

2-the glomerular capillary pressure (GCP):-

The GFR is directly to The GCP.

The GCP is affected by the following factors:-

(1)afferent arteriole diameter :-

V.C decrease both the RBF & GCP, so the GFR is reduced so decrease the urine volume.

V.D increase both the RBF & GCP, so the GFR is increased so increase the urine volume .

(2)efferent arteriole diameter :-

V.D decrease the GCP, so the GFR is reduced so decrease the urine volume (although the RBF increased).

The mild V.C

Mild constriction of the efferent arteriole causing increase of the glomerular pressure due to increase the resistance to flow in the glomeruli so increase the filtration rate .

The sever V.C :-

Sever vasoconstriction of the efferent arteriole at the beginning increase the GFR due to increase the glomerular pressure then after that the GFR will decrease due to increase the colloidal osmotic pressure cause marked decrease in the so the GFR is reduced so decrease the urine volume .

3-sympathetic stimulation :-

-strong stimulation of the sympathetic cause marked vasoconstriction of the glomerular arterioles leading to reduction of both RBF & GFR.

4-arterial blood pressure

The variation of range 80_160 mmHg affect the GFR slightly because the autoregulation mechanism

-the increase in the arterial blood pressure=hypertension cause increase the glomerular capillary pressure so increase the pressure inside the nephron causing increase the GFR and urine formation .

-the decrease in the arterial blood pressure=hypotension cause decrease the glomerular capillary pressure so decrease the pressure inside the nephron causing decrease the GFR and urine formation and the filtration process completely stop when the ABP up to 60 mmHg .

5-the size of the glomerular capillary bed (the filtrating surface area)

-the GFR is reduced if the glomerular surface area available for filtration is decreased .these occurs due to decrease the functioning of kidney mass= the number of the nephrons

-as chronic renal failure

-as after nephrectomy

6-the glomerular capillary permeability= pores :-

The GFR is directly proportional to the glomerular capillary permeability .

The glomerular capillary permeability is altered by:-

(1)renal diseases as nephritis due to damage of the capillary wall & reduction of the negativity charges .

(2) fever & hypoxia

7-the plasma oncotic pressure

-These forces antagonize the filtration forces

-these force pressure is normally 30 mmHg .

-THE GFR is inversely proportional to the plasma oncotic pressure in the glomerular capillaries

-the false increase in the plasma proteins as dehydration reduce the GFR

- decrease in the plasma proteins as hypoproteinemia increase the GFR

8-the intracapsular hydrostatic pressure (CP) :-

-this force antagonize filtration of the fluid from the glomerular capillaries into the Bowman's capsule

-these force pressure is normally 10 mmHg

-The GFR is inversely proportional to the intracapsular pressure in the Bowman's capsule

-the increase in the intracapsular pressure as sticture or stone in the ureters reduce the GFR

-The filtration process completely stop if the capsular pressure increase to 20 mmHg because the filtration process will be balanced by the opposing forces .

The autoregulation mechanism of the renal blood flow

1-This is intrinsic mechanism in the kidneys that keep the RBF constant (1200 ml/minute) despite changes in the arterial blood pressure changes.

2-there is a direct relationship between the

(1)arterial blood pressure

(2)the renal blood flow

(3)glomerular filtration rate

(4)urine output

1-when the arterial blood pressure rise from 100 to 160 mmHg:-

1-The increase in the blood pressure leads to :-

(1)increase arterial blood pressure

(2) increase the renal blood flow

(3) increase glomerular filtration rate

(4) increase urine output

In spite these increase in the arterial blood pressure will increase the RBF that not occur due to the vasoconstriction of the afferent arterioles so lead to :-

(1)decrease arterial blood pressure

(2) decrease the renal blood flow

(3) decrease glomerular filtration rate

The vasoconstriction of the afferent arterioles occur by intrinsic mechanism by the following 2 mechanisms :-

1-myogenic theory :- rise of the blood pressure stretches the afferent arteriole lead to vasoconstriction of the afferent arteriole by the direct contractile response of the smooth muscle in their wall to stretch .

2-tubuloglomerular feedback regulation :-

The rise of the blood pressure increase the glomerular filtration so the rate of flow through the ascending limb of LH and the 1st part of the DCT increase so increase the concentration of the Na , K concentration due to decrease reabsorption of salts. These initiate a signal from the macula dense give **Thromboxane A2** for the vasoconstriction of the afferent arterioles.

1-when the arterial blood pressure falls from 80 to 100 mmHg:-

1-The decrease in the blood pressure leads to :-

(1)decrease arterial blood pressure

(2) decrease the renal blood flow

(3) decrease glomerular filtration rate

(4) increase urine output

Despite these decrease in the arterial blood pressure will decrease the RBF that not occur due to the vasodilatation of the afferent arterioles so lead to :-

(1)increase arterial blood pressure

(2) increase the renal blood flow

(3) increase glomerular filtration rate

The vasodilatation of the afferent arterioles occur by intrinsic mechanism by the following 2 mechanisms :-

1-myogenic theory:- fall of the blood pressure lead to vasodilatation of the afferent arteriole.

2-tubuloglomerular feedback regulation :-

The fall of the blood pressure decrease the glomerular filtration so decrease the rate of flow through the ascending limb of LH and the 1st part of the DCT so decrease the concentration of the Na , K concentration due to increase reabsorption of salts. These initiate a signal from the macula dense give **prostaglandin I2 and renin** which cause vasodilatation of the afferent arterioles and vasoconstriction of efferent arterioles.