RENAL FUNCTIONS & GFR

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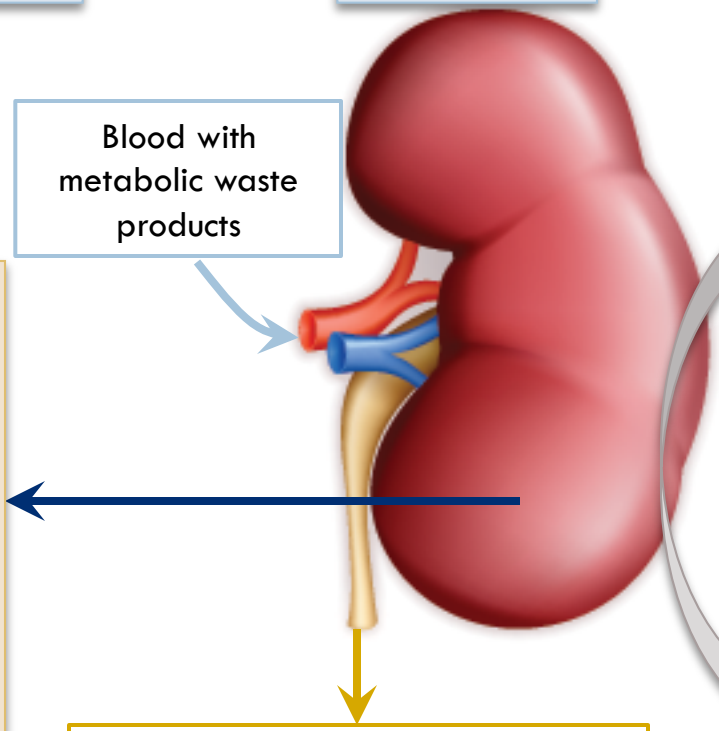
Functions of the Kidney

Synthetic function

Excretion

Regulation

Blood with metabolic waste products

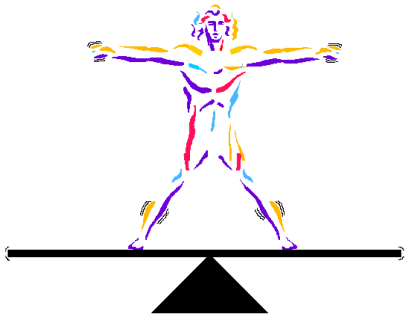


Glucose (gluconeogenesis)

Erythropoietin

1,25-dihydroxy vitamin D3 (calcitriol)

Renin



Metabolic waste products:
Urea
Creatinine
Uric acid
Bilirubin
Ingested toxins:
Drugs
Pesticides

Water & electrolytes
Acid-base
Arterial BP

What are the functions of the kidney?

- Regulation of water and electrolyte balance.
- Regulation of body fluid osmolality & electrolytes.
- Excretion of waste products (UREA, CREATININE, URIC ACID).
- Regulation of arterial blood pressure (RAS, excretion of excess salt and water).
- Regulation of acid/base balance.
- Detoxification and excretion of drugs.
- **Synthesitic function:**

1- active form of vit D (D3)= 1,25 dihydroxycholicalciferol.

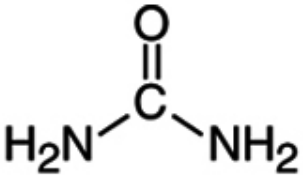
2- Erythropoietin production.

3- Renin formation.

4- Synthesis of glucose from amino acids during prolonged fasting.

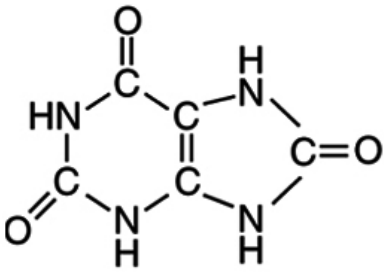
Nitrogenous Wastes

- Urea
  - proteins→amino acids →NH_2 removed →forms ammonia, liver converts to urea



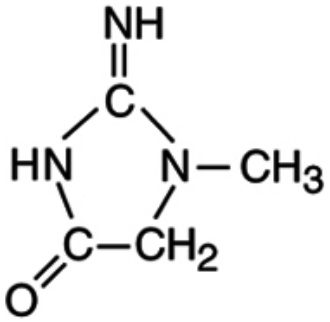
Urea

- Uric acid



Uric acid

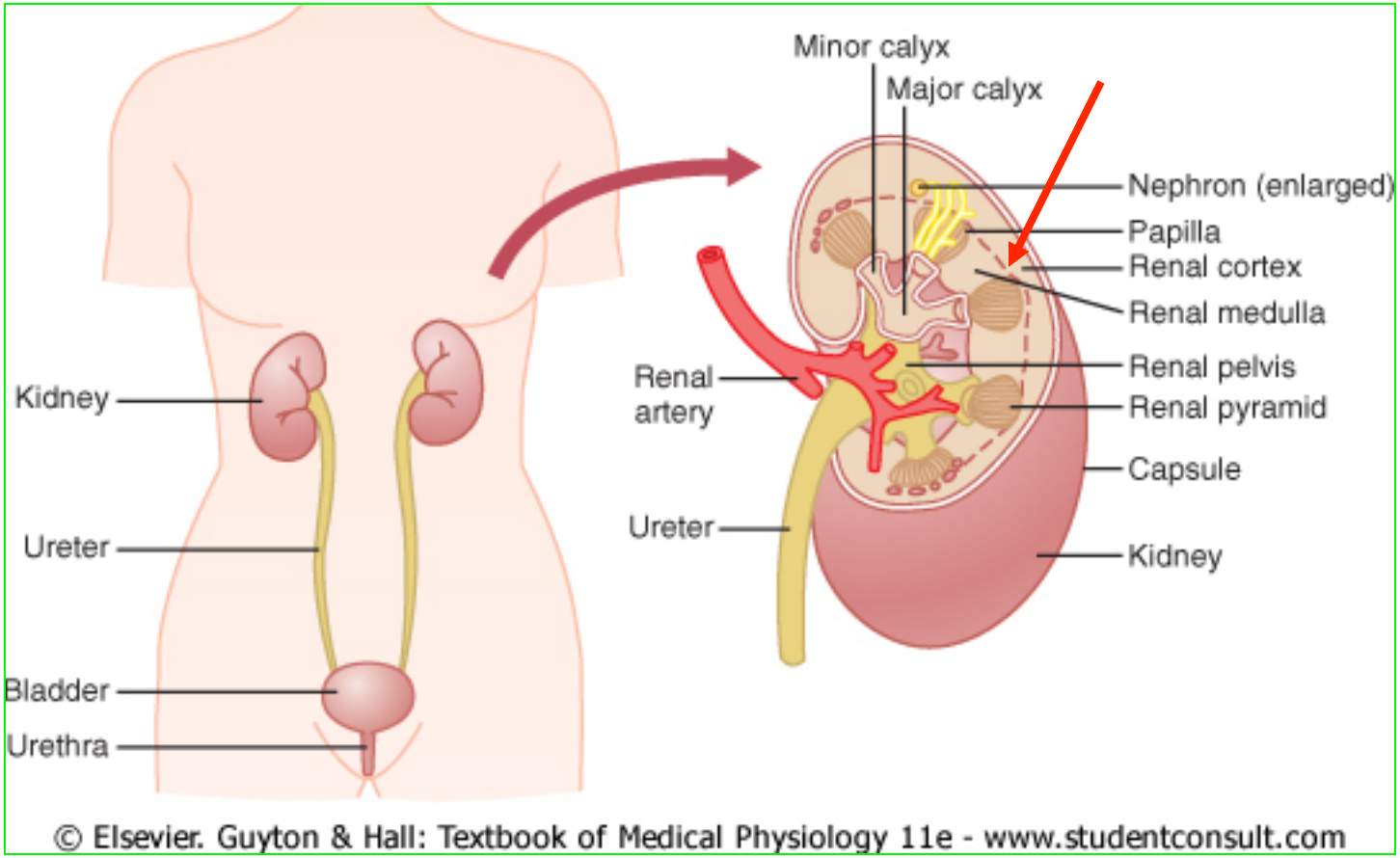
- Creatinine



Creatinine

PHYSIOLOGIC ANATOMY OF KIDNEYS

- **Size Clenched Fist**
- **Weight 150 grams**



What is the functional unit of the kidney?

- The nephron is the functional and structural unit of the kidney.
- Each kidney has 1 million nephrons, each nephron is capable of urine formation.

Structure of a nephron

- The Glomerulus: capillary tuft: in which large amount of fluid is filtered from blood.
- Bwaman's capsule: Around the glomerulus and receives the filtrate.
- Tubules: in which filtered fluid eventually is converted into urine.

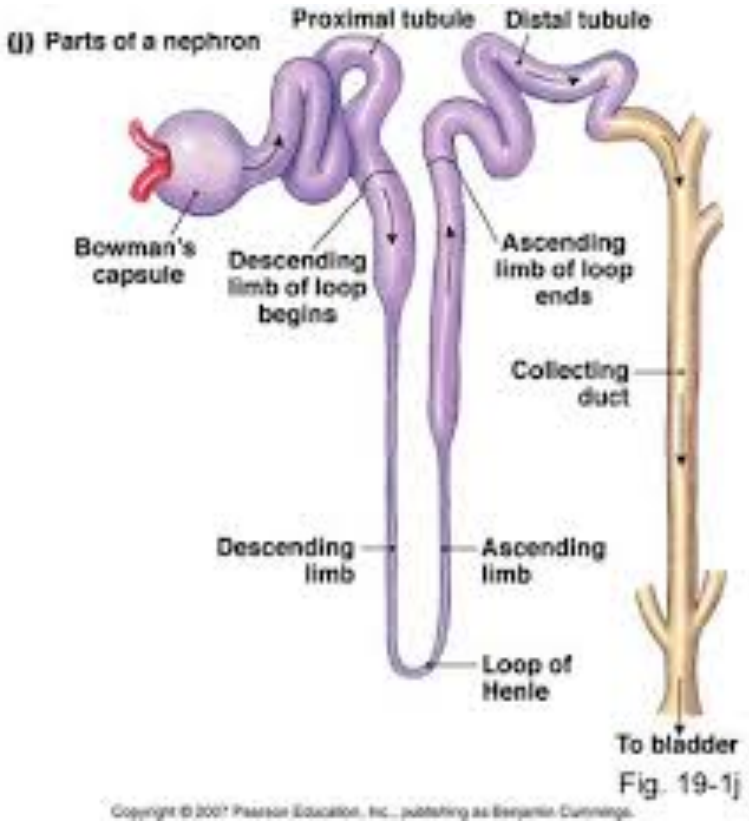
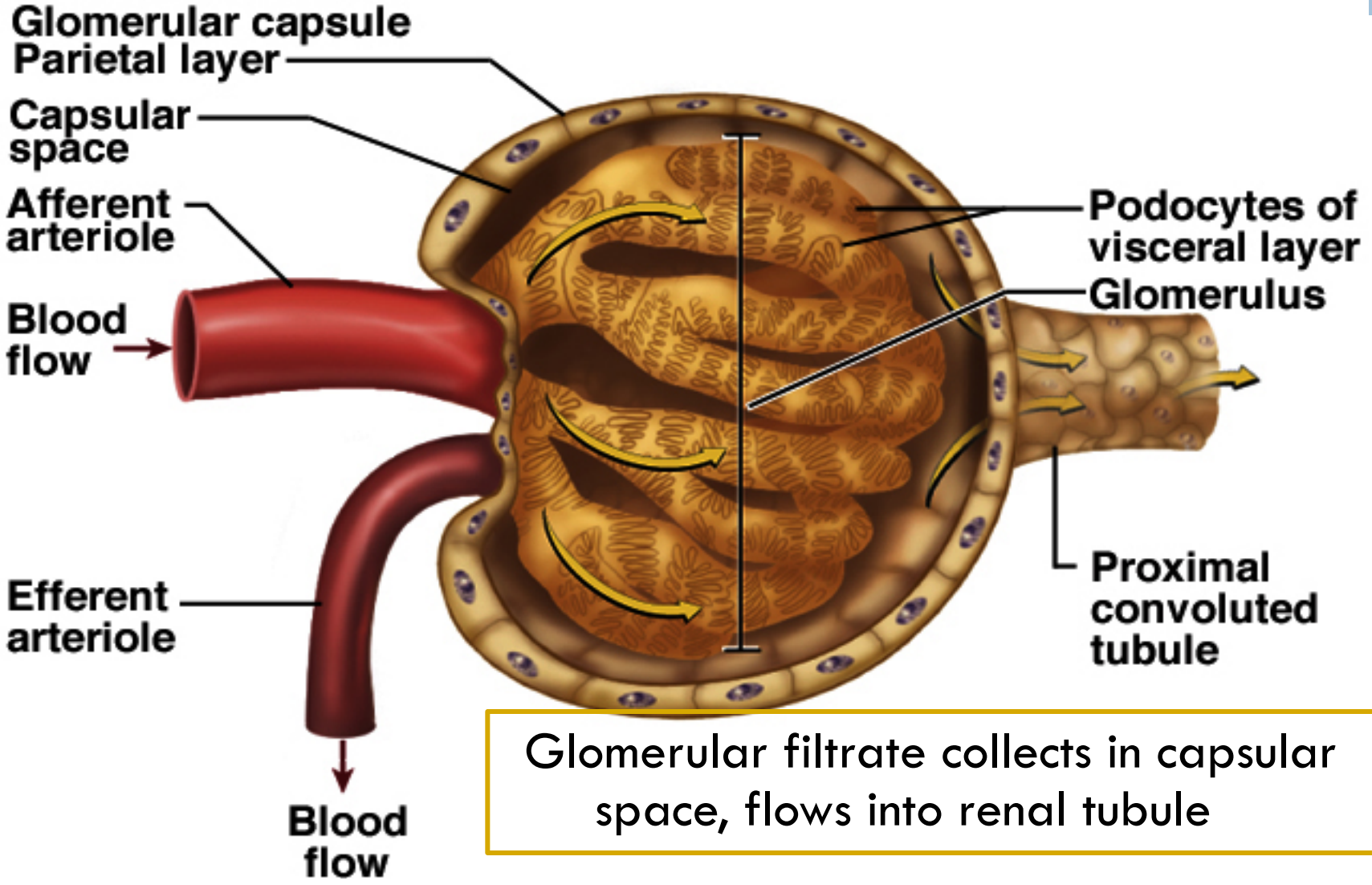


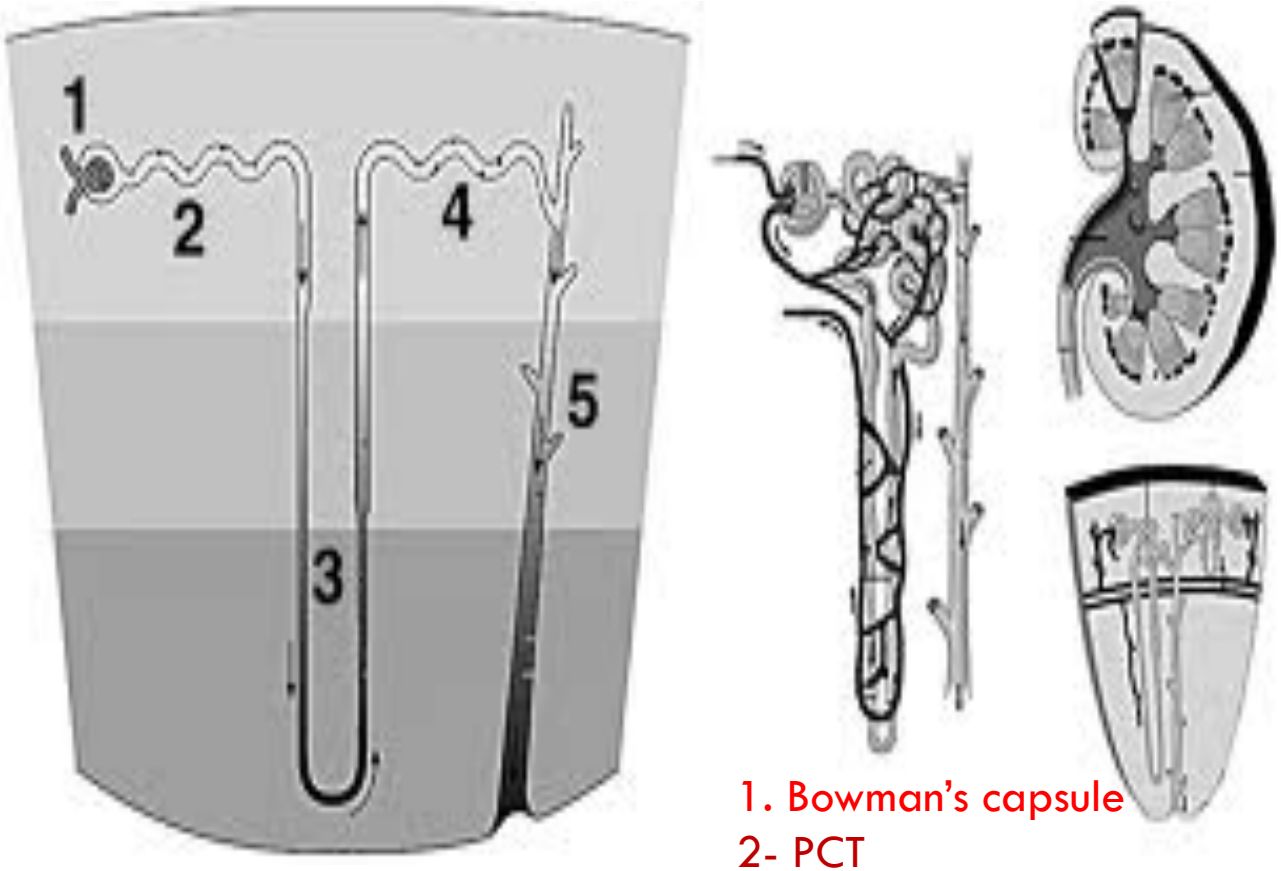
Fig. 19-1j

The Glomerulus



Glomerular filtrate collects in capsular space, flows into renal tubule

Structure of a Nephrone



1. Bowman's capsule
2- PCT
3- Loop of Henle.
4- DCT
5- Collecting tubules & ducts.

Structure of a nephron, cont……

- The renal tubule is divided into different sections with different structural and functional characteristics:
- Proximal tubules (in the cortex).
- Loop of Henle.
- Distal tubule (in the renal cortex).
- Connecting tubule, cortical collecting, and the cortical collecting ducts, which run downward in the medulla and become:
- Medullary collecting ducts.

RENAL BLOOD VESSELS

- **AFFERENT ARTERIOLE:**
  - DELIVERS BLOOD INTO THE GLOMERULI.
- **GLOMERULI:**
  - CAPILLARY NETWORK THAT PRODUCES FILTRATE THAT ENTERS THE URINARY TUBULES.
- **EFFERENT ARTERIOLE:**
  - DELIVERS BLOOD FROM GLOMERULI TO PERITUBULAR CAPILLARIES.
- **PERITUBULAR CAPILLARIES:**
  - VASA RECTA.

Structure of a nephron, cont…..

Types of nephrons:

1- Cortical nephrons: (85%):

Their glomeruli in the outer portion of cortex and have short loops of Henle.

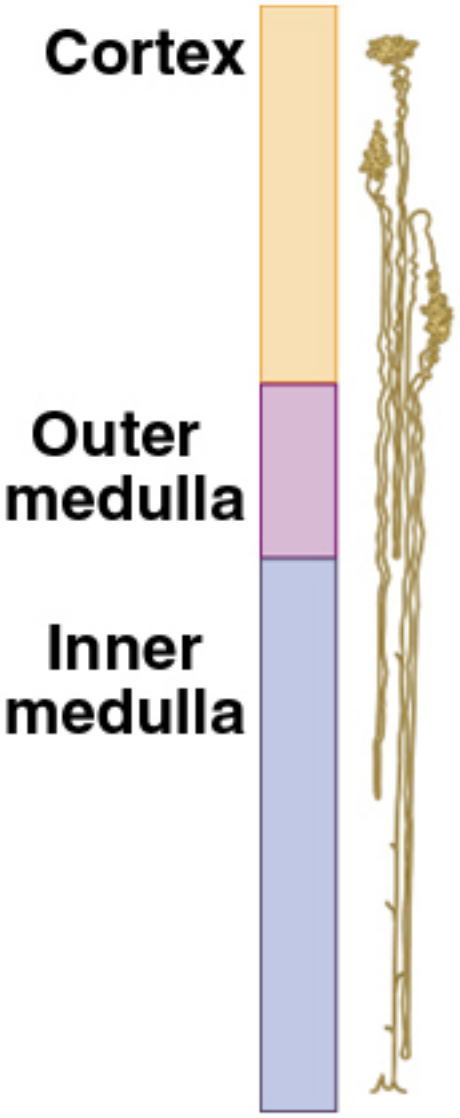
. Peritubular capelaries

2-Juxtamedullary nephrons: (15%):

Have long loops extended into the medulla.

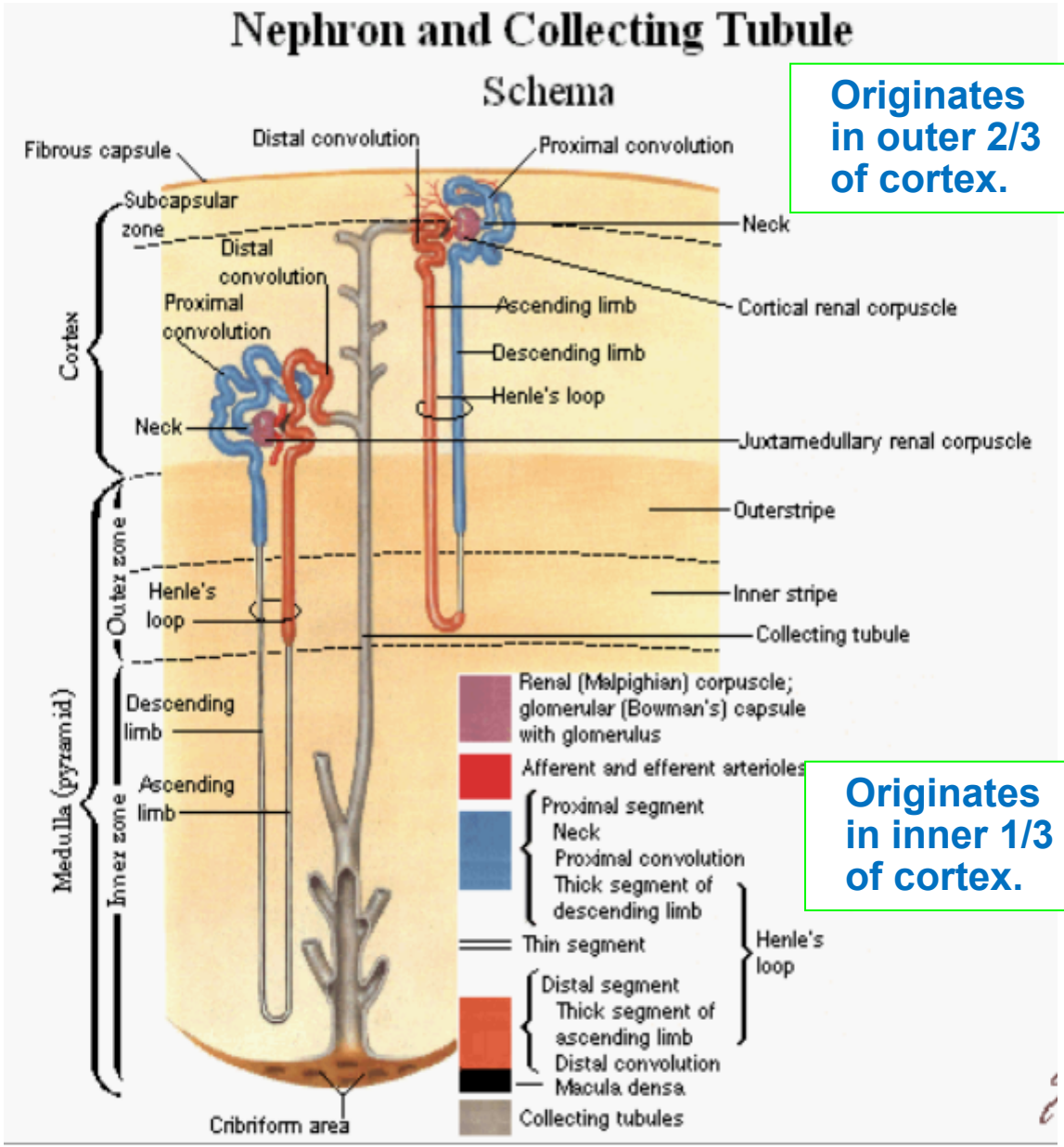
.Vasa recta

Maintain salt gradient, helps conserve water



NEPHRON TYPES
Cortical and Juxtamedullary Nephrons

1-2 % Blood Flows Through Juxta Medullary Nephrons



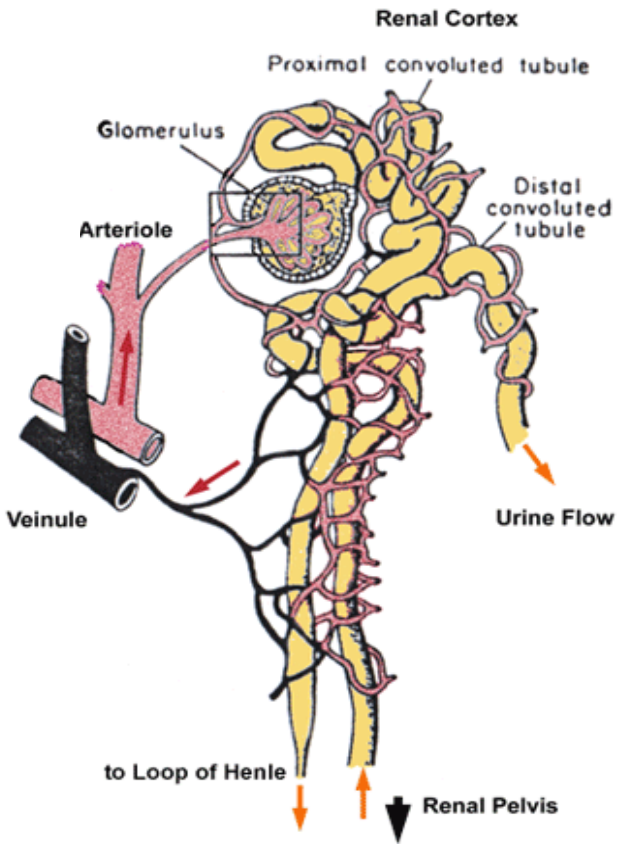
Renal blood flow:

- Renal blood flow to the kidney represents 20% of cardiac output.
- The blood flows to each kidney through a renal artery.
- Features of renal circulation:

1- High blood flow rate (1200 ml/min).

2- Presence of two capillary beds: glomerular and peritubular.

Efferent and afferent arterioles are major sites of renal resistance.



Urine formation

The primary function of the kidney is to 'clear' unneeded substances from the blood to be excreted in urine.

Steps of urine formation (basic renal processes):

1- Glomerular filtration: Filtration of fluid from glomerular capillaries into the renal tubules.

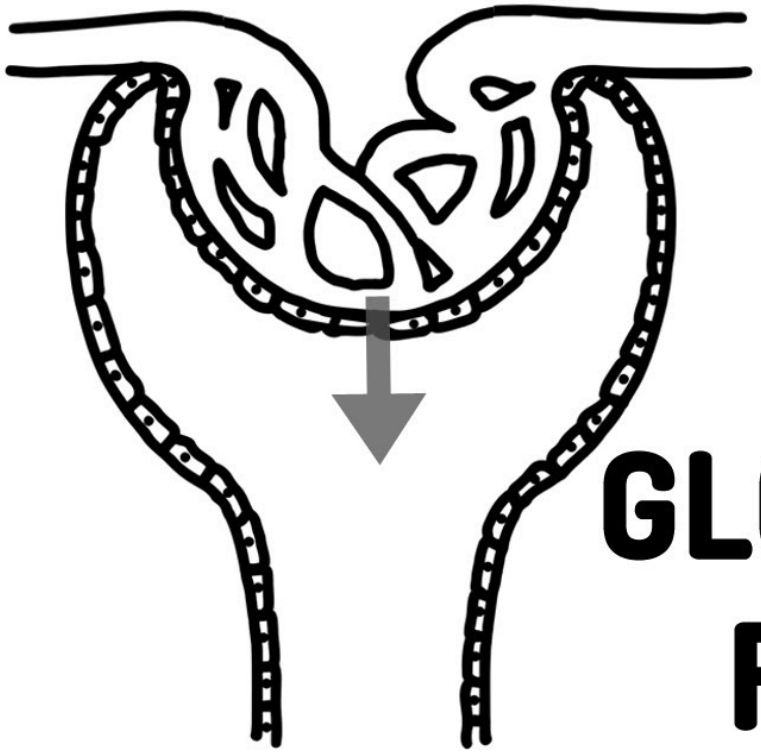
2- Tubular reabsorption

3- Tubular secretion.

4- Excretion.

Urinary excretion rate = Filtration rate- reabsorption +secretion.

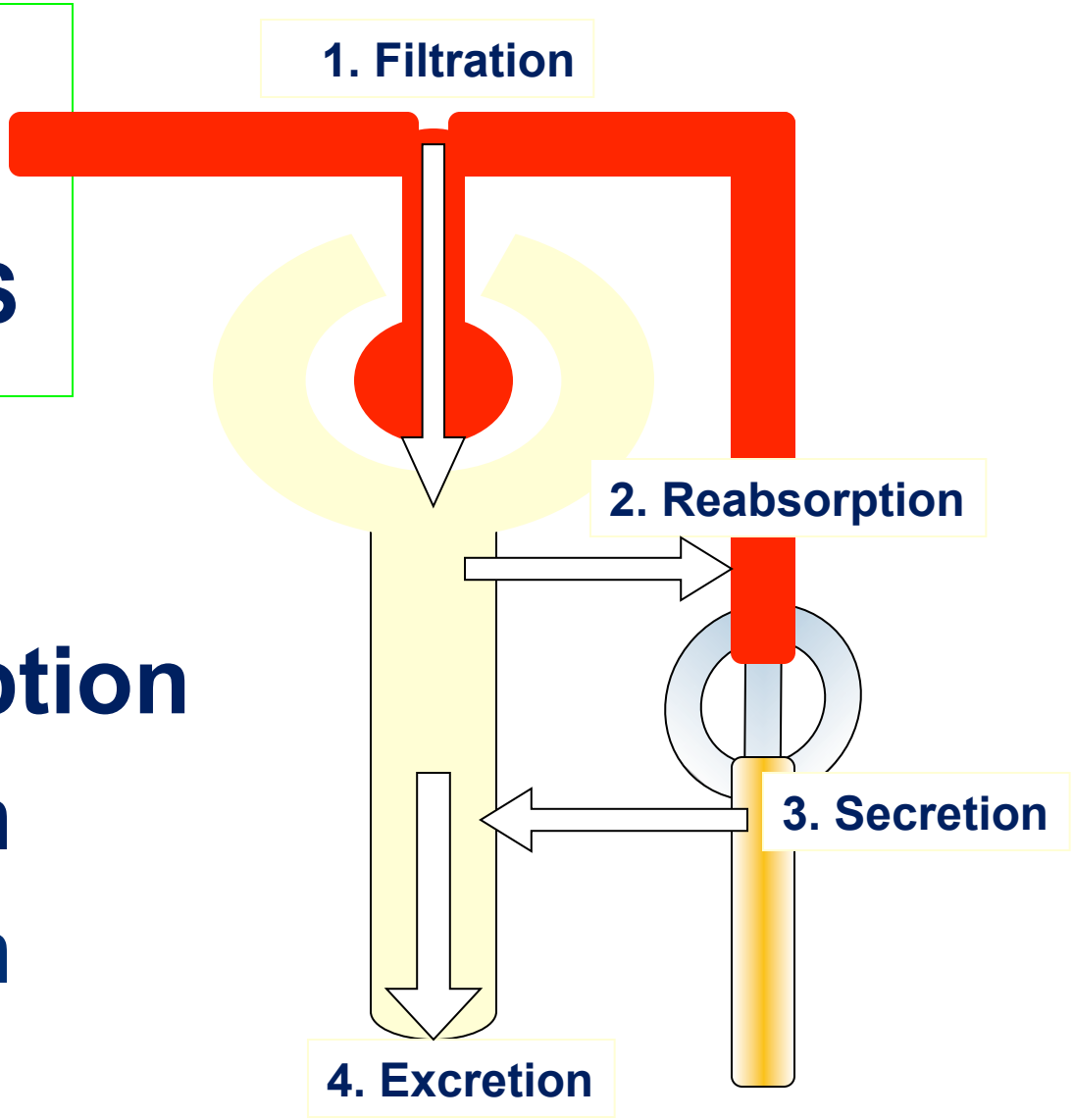
1st Step in Urine Formation



GLOMERULAR FILTRATION

4 RENAL PROCESSES

1. Filtration
2. Reabsorption
3. Secretion
4. Excretion



Urinary Excretion Rate = Filtration Rate – Reabsorption Rate + Secretion Rate

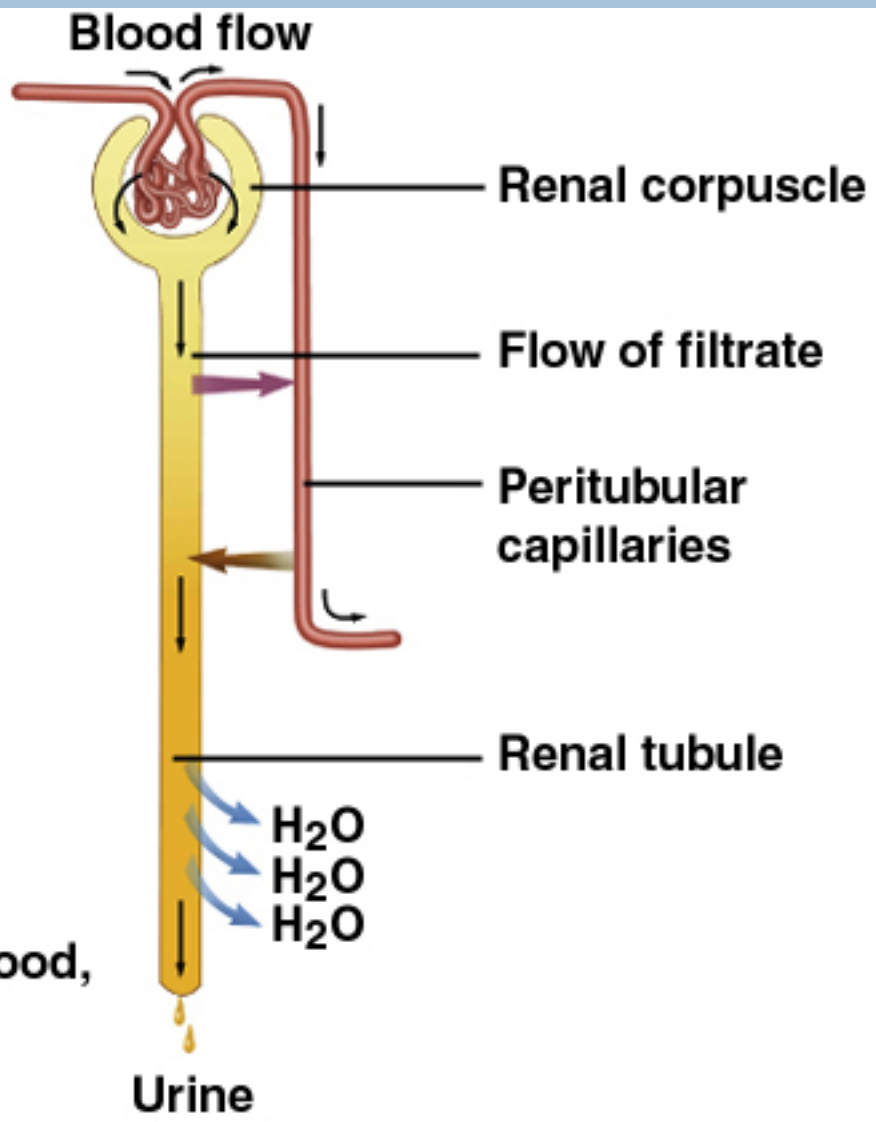
Urine Formation Preview

① **Glomerular filtration**
Creates a plasmalike filtrate of the blood

② **Tubular reabsorption**
Removes useful solutes from the filtrate, returns them to the blood

③ **Tubular secretion**
Removes additional wastes from the blood, adds them to the filtrate

④ **Water conservation**
Removes water from the urine and returns it to blood, concentrates wastes



Glomerular filtration rate (GFR)

- The first step in urine formation is glomerular filtration.
- It is the filtration of fluid from the glomerular capillaries into the renal tubules.
- It contains all substances present in plasma except proteins.
- GFR is normally 125 ml/min = 20% renal plasma flow.

- What is glomerular membrane?
- What will filter? (composition of filtrate)
- What determineGFR?
- What are the forces responsible for passage of fluid (filtrate) through this membrane?
- Regulation of GFR

Glomerular membrane

Blood in the glomerulus is separated from the fluid in the Bowman's space by a filtration barrier (glomerular membrane) consisting of three layers:

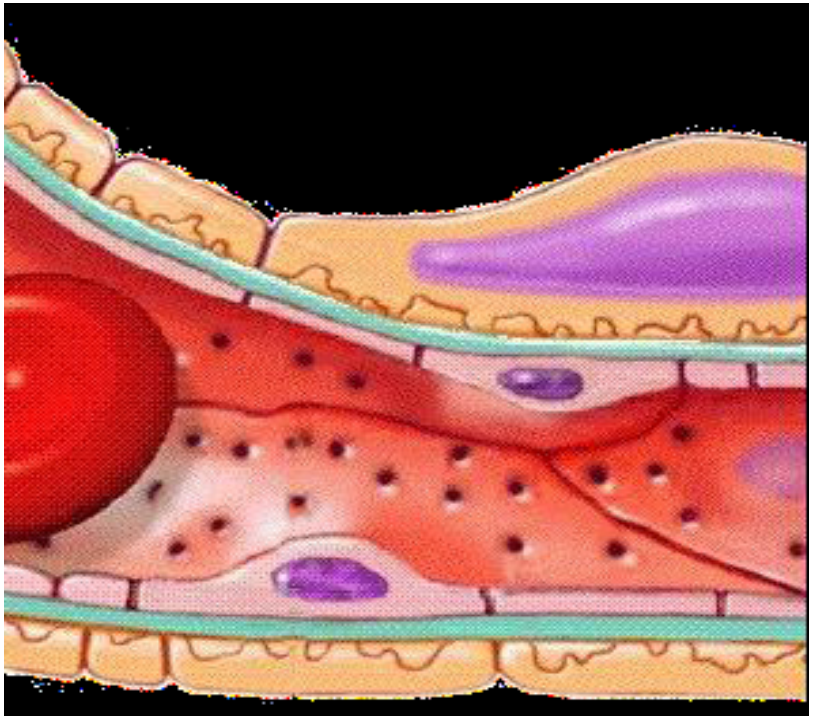
1- Single layer of capillary endothelium.

2- Single epithelial lining of Bowman's capsule (Podocytes) During filtration the fluid moves between their foot processes (psudopodia).

3- Basement membrane between endothelium and epithelium.

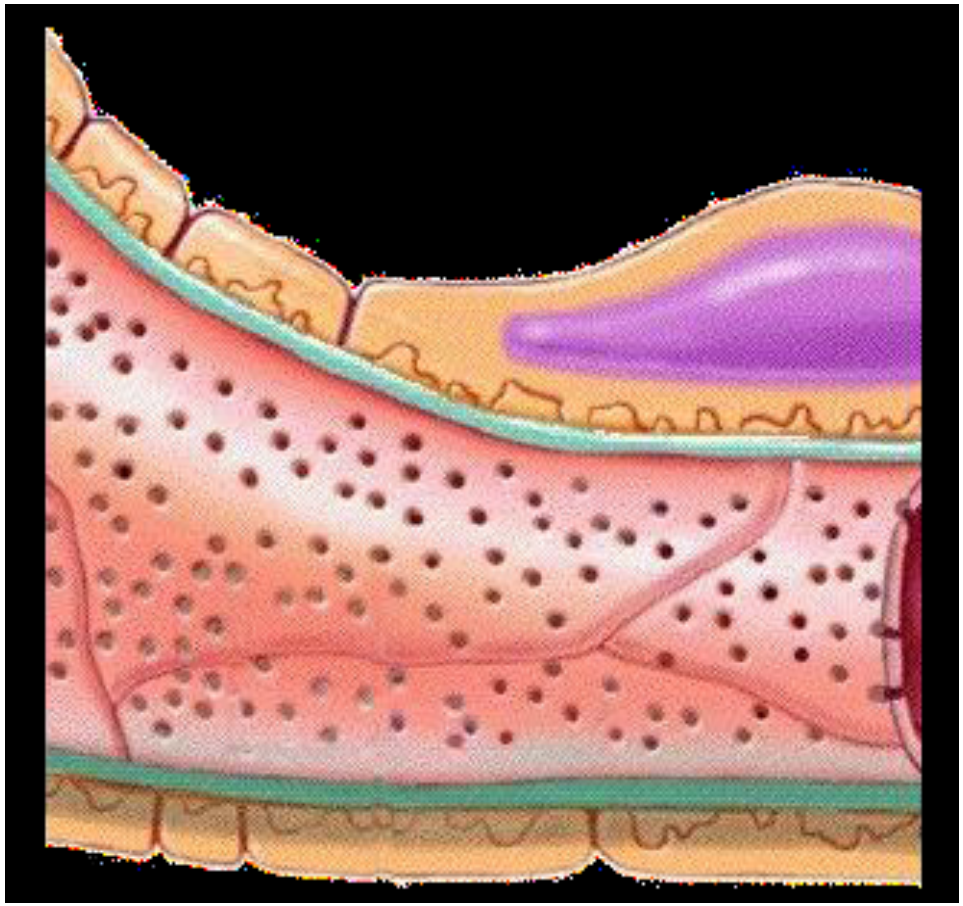
Glomerular membrane

Here we see a glomerular capillary in longitudinal section



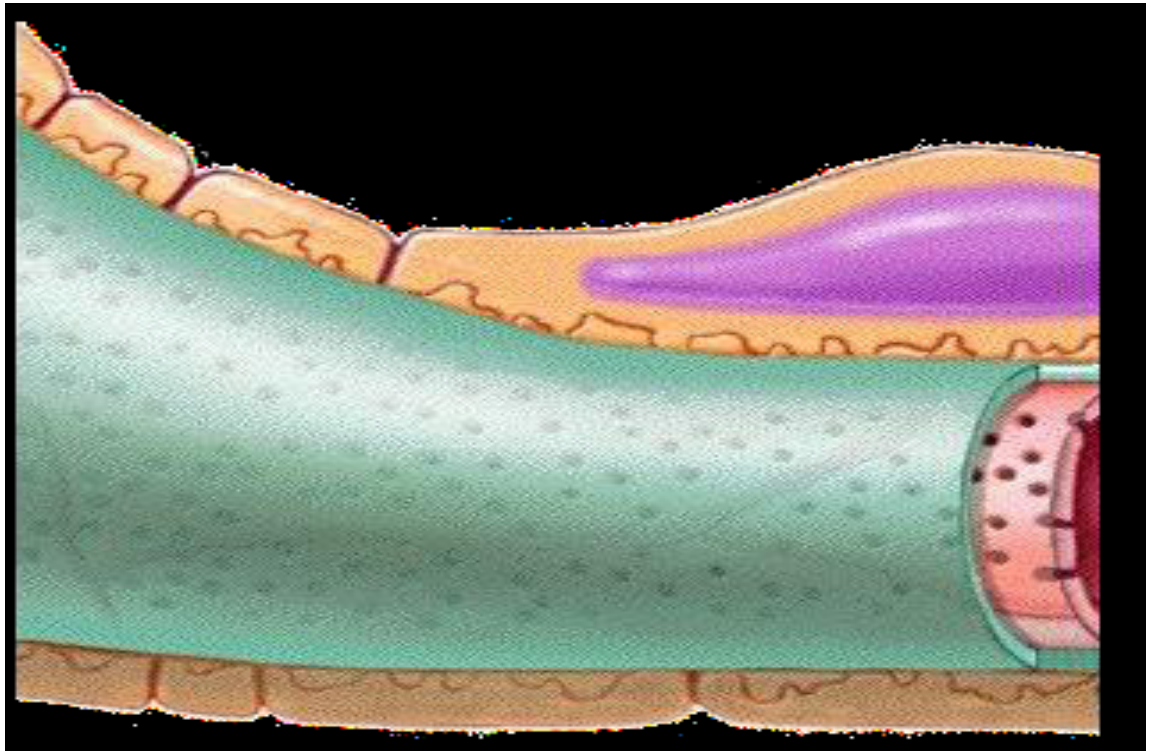
Capillary endothelium

Glomerular membrane



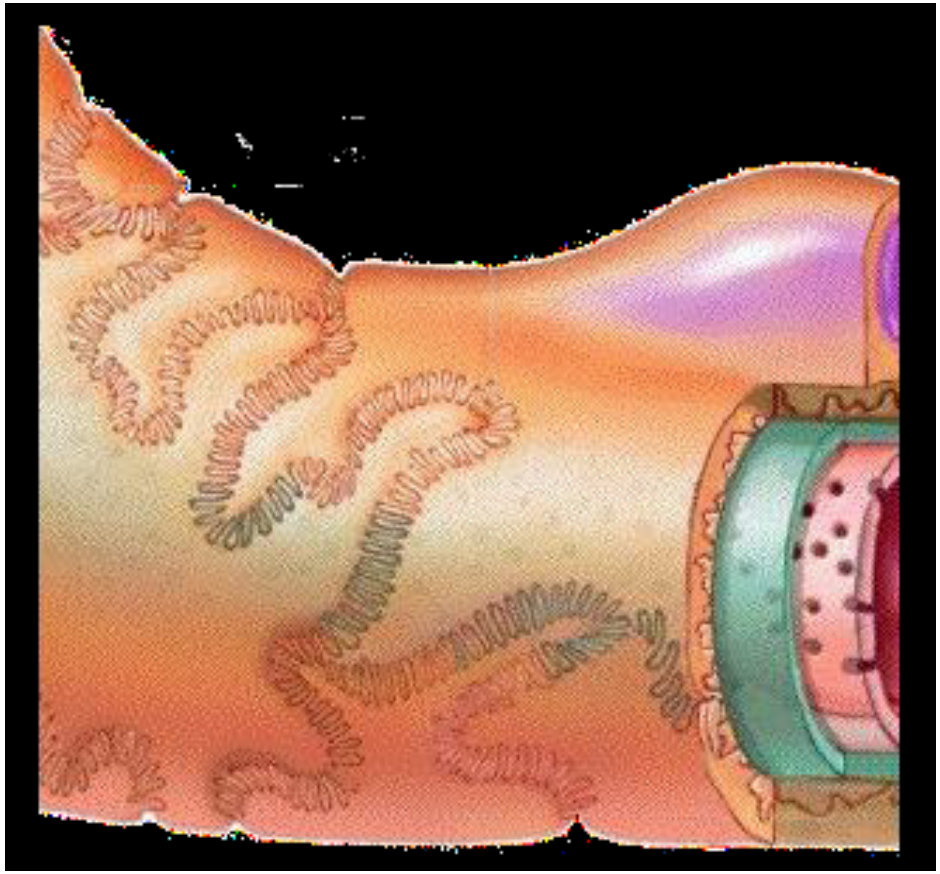
Capillary endothelium

Glomerular membrane



Basement membrane

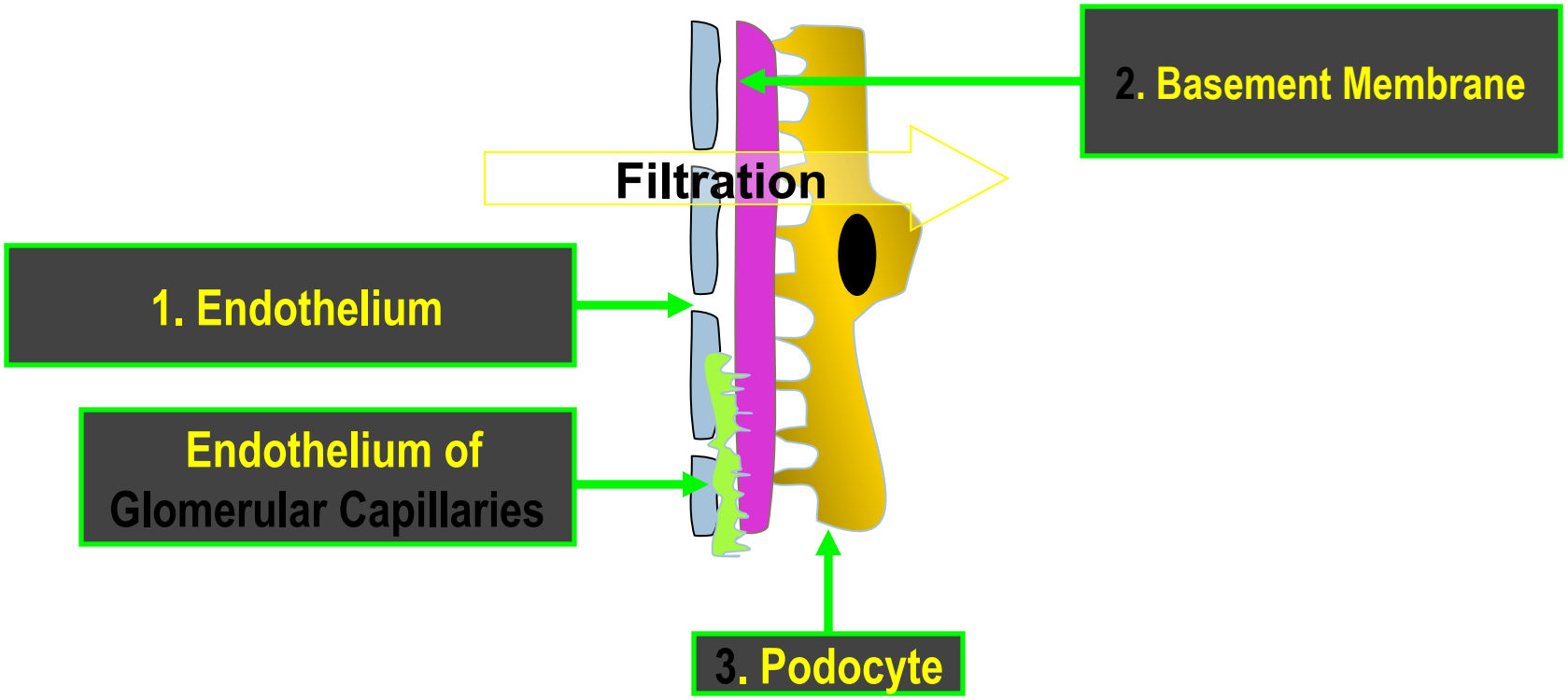
Glomerular membrane



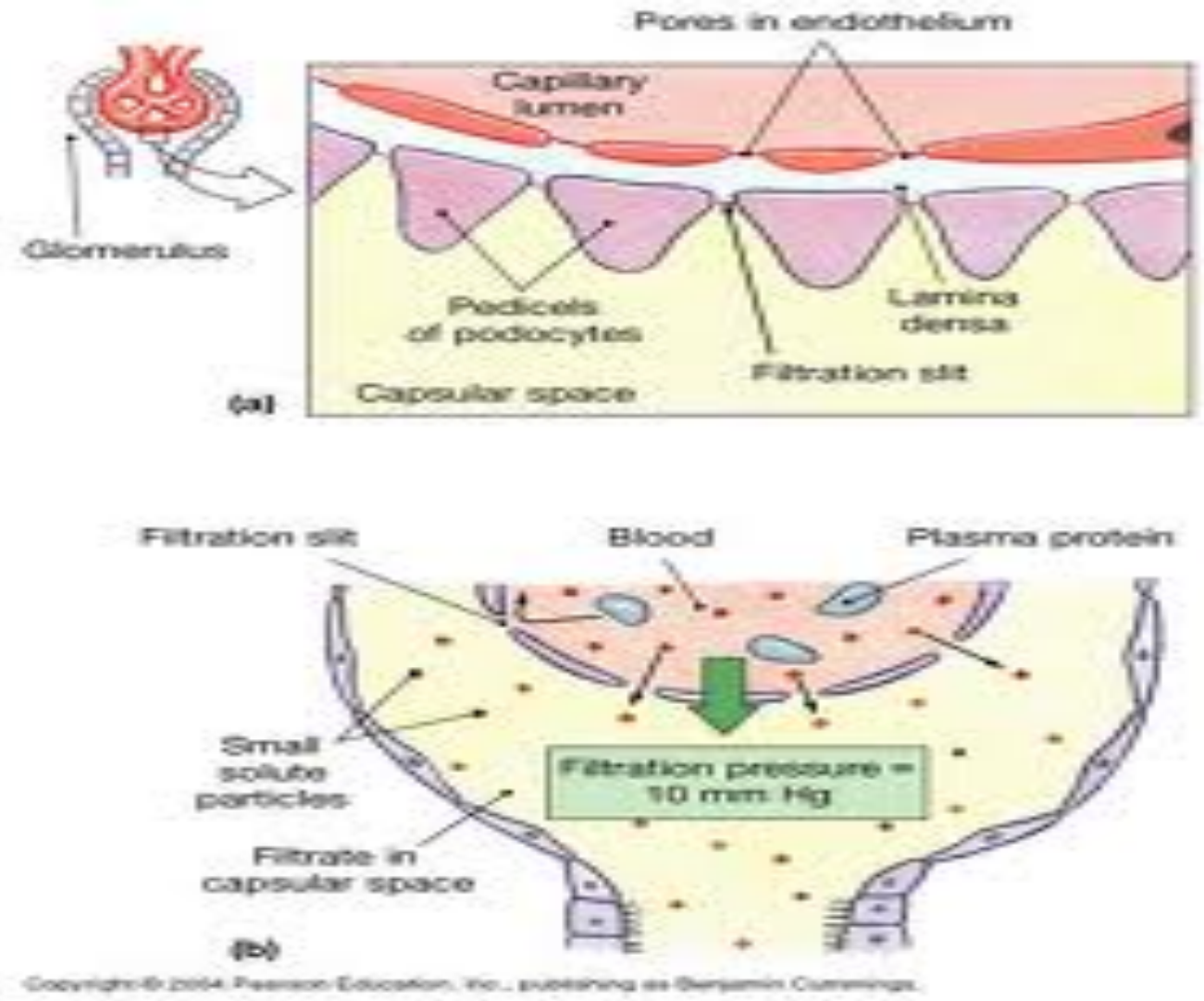
Podocytes (cell body with nucleus)

Filtration slits

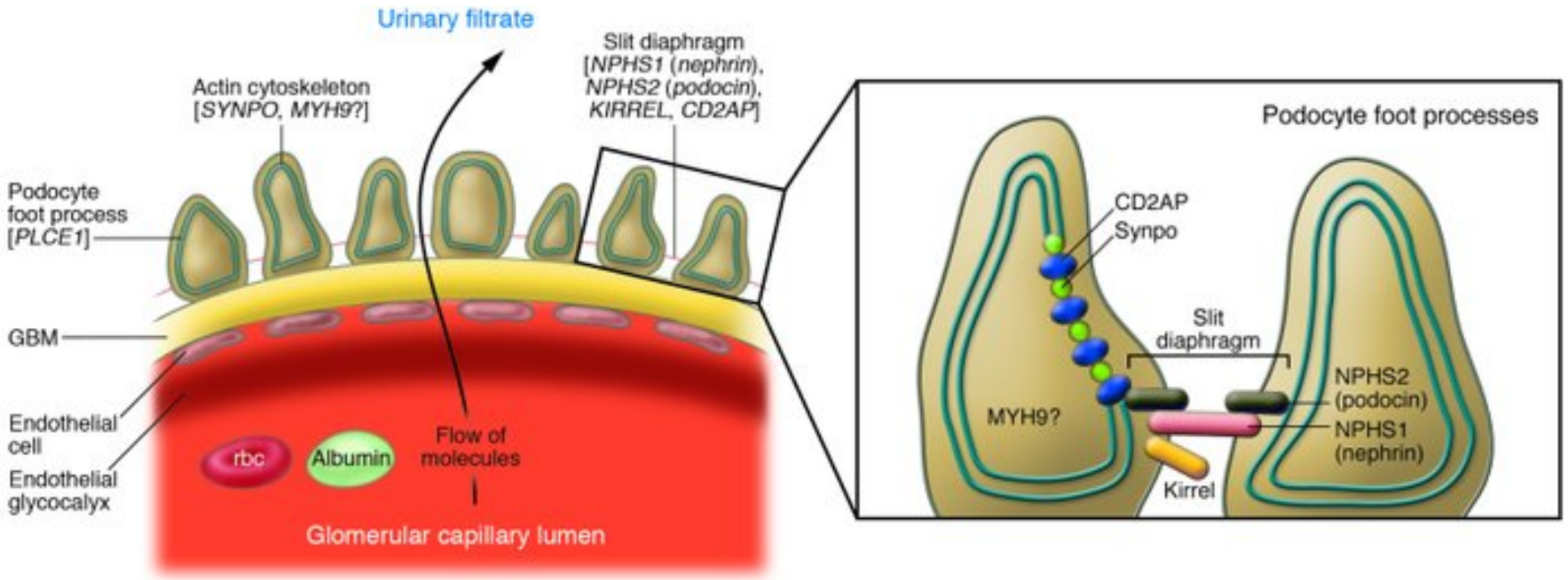
FILTRATION MEMBRANE



Glomerular membrane



Glomerular membrane



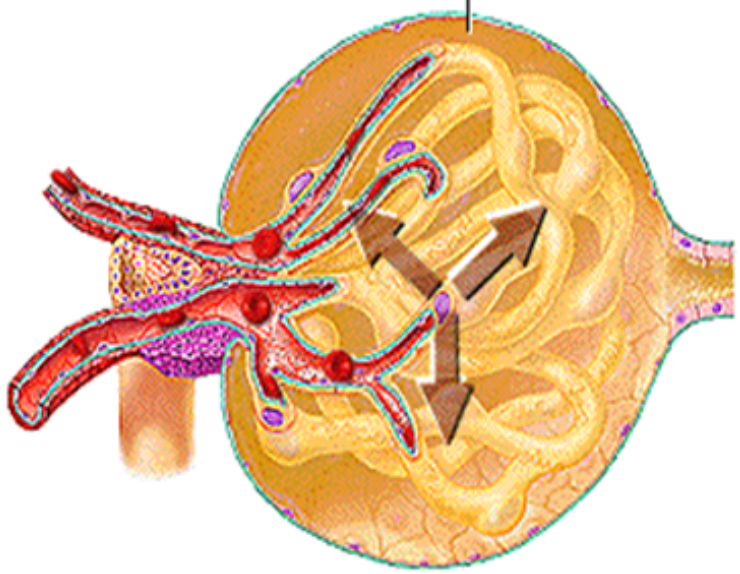
Characteristics of glomerular membrane:

- Allow passage of molecules up to 70,000 D
- Albumin does not normally pass as they are repelled by the negative charge of the

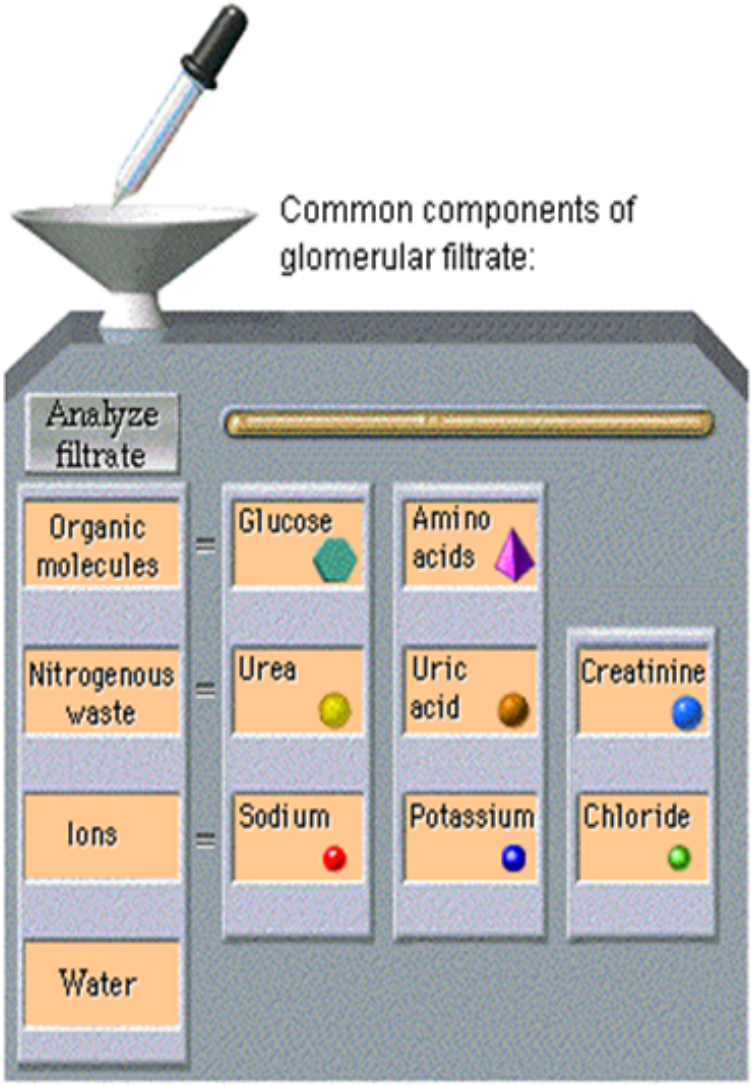
glycoproteins material of basement membrane.

- Blood cells don not normally pass through the membrane.

Glomerular Filtrate



The concentration of each of these substances in the glomerular filtrate is similar to its concentration in **plasma**.



Glomerular Filtration Rate (GFR)

- The GFR is determined by:

1- the net filtration pressure across the glomerular capillaries.

2- the glomerular capillary filtration coefficient (Kf)

GFR = Kf x Net filtration pressure.

= 12.5 X 10 = 125 ml/min

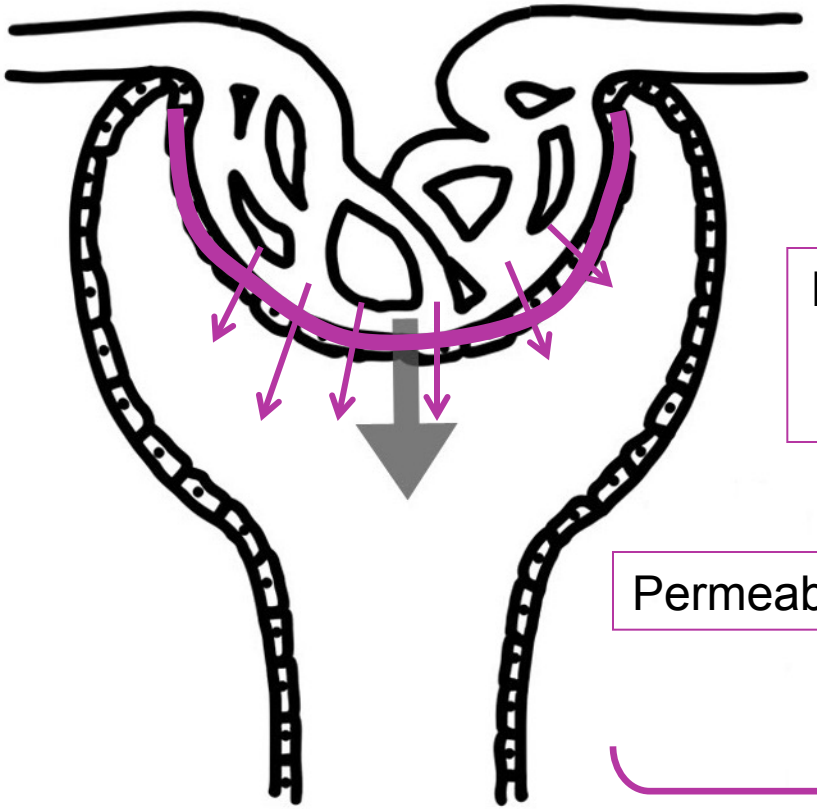
Glomerular Filtration Rate (GFR)

- Filtrate formed per minute
- Filtration coefficient (K_f) depends on permeability and surface area of filtration barrier
- GFR = NFP x K_f ≈ 125 ml/min or 180 L/day
- GFR = 10 X 12.5 = 125 ml/min
- 99% of filtrate reabsorbed, 1 to 2 L urine excreted

Forces controlling GFR: Starling's forces

- The net filtration pressure is the sum of:
- 1. glomerular hydrostatic pressure (= 60 mmHg). It promotes filtration.
- 2. hydrostatic pressure in Bowman's capsule (= 18 mmHg). It opposes filtration.
- 3. colloid osmotic pressure of glomerular plasma proteins (= 32 mmHg). It opposes filtration.
- So, net filtration pressure = 60-18-32= 10 mmHg.

Glomerular Filtration Rate (GFR)



What controls (determines) the GFR?

Factors related to the membrane itself

- Permeability
- Filtering surface area

The sum of the forces acting across the membrane (starling forces)

→ Net filtration pressure ***(NFP)***

Capillary filtration coefficient (Kf)

GFR = 125 ml/min
OR 180 L/day

GFR = Kf X NFP

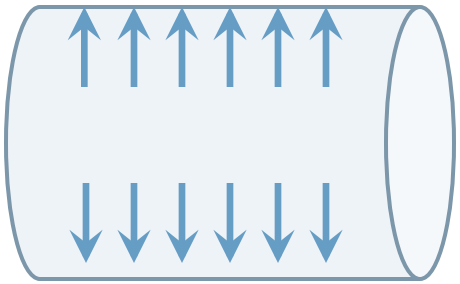
Cont. determinants of GFR- Starling Forces

Starling Forces

Forces that control movement of fluid in/out of a capillary

Hydrostatic pressure (P)

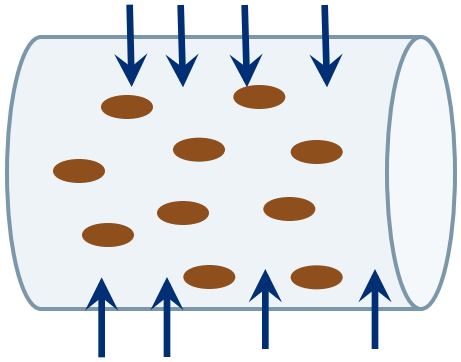
The pressure exerted by blood (water) on the walls of the blood vessel



Moves fluid ***OUTSIDE***

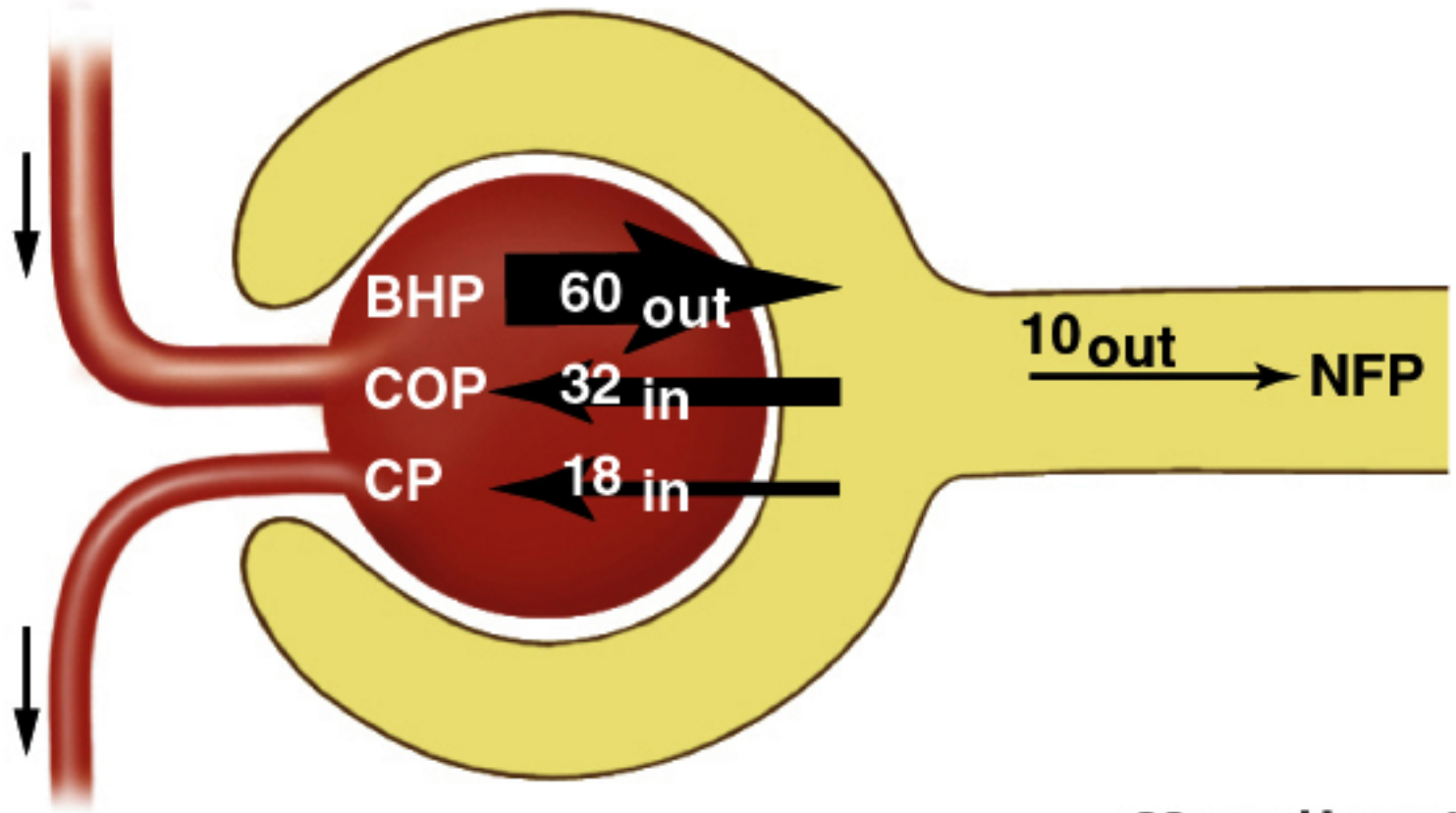
Colloid osmotic (oncotic) pressure ( )

The osmotic pressure created by the non-diffusible plasma proteins inside the blood vessel

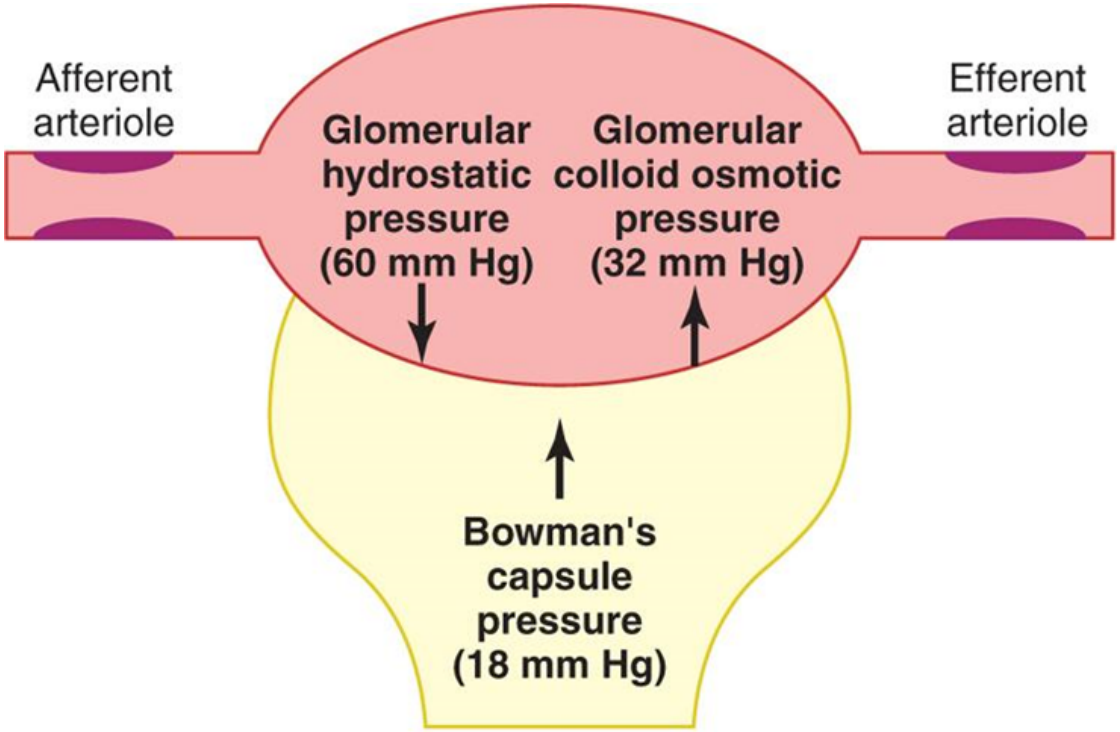


Pulls fluid ***INSIDE***

Net Filtration Pressure (NFP)



Blood hydrostatic pressure (BHP)	60 mmHg out
Colloid osmotic pressure (COP)	–32 mmHg in
Capsular pressure (CP)	–18 mmHg in
Net filtration pressure (NFP)	10 mmHg ou



Why is the glomerular hydrostatic pressure higher that the hydrostatic pressure seen in systemic capillary beds?

Net filtration pressure (10 mm Hg) = Glomerular hydrostatic pressure (60 mm Hg) − Bowman's capsule pressure (18 mm Hg) − Glomerular oncotic pressure (32 mm Hg)

CONTROL OF GFR

$$GFR = Kf \times [(P_G - P_B) - (\pi_G - \pi_B$$

$$GFR = Kf \times [(60 - 18) - (32 - 0)]$$

(1)Hydrostatic pressure inside the glomerular capillaries (glomerular hydrostatic pressure, PG), which promotes filtration

(2)The hydrostatic pressure in bowman's capsule (PB) outside the capillaries, which opposes filtration

(3)The colloid osmotic pressure of the glomerular capillary plasma proteins (πg), which opposes filtration

(4)The colloid osmotic pressure of the proteins in bowman's capsule (πb), which promotes filtration

REGULATION OF GFR

Regulation of GFR

$$GFR = Kf \times (P_G - \ _G - P_B + \ _B)$$

- Any factor that affect the parameters in the equation will affect the GFR.

- However, physiologic regulation of the GFR involves mechanisms that affect mainly the ***P_G***.

***P_G* depends on:**
- Arterial BP
- Afferent arteriolar resistance.
- Efferent arteriolar resistance.

Kf

$_G$

P_B

Can get affected in disease conditions causing changes in GFR

How changes in Forces determining GFR affect GFR?

- Increased Bowman's capsule pressure decreases GFR. It can happen in urinary obstruction e.g. stones , tumors..
- Increased glomerular capillary colloid osmotic pressure decreases GFR.
- Increased glomerular capillary hydrostatic pressure increases GFR. This pressure is affected by:

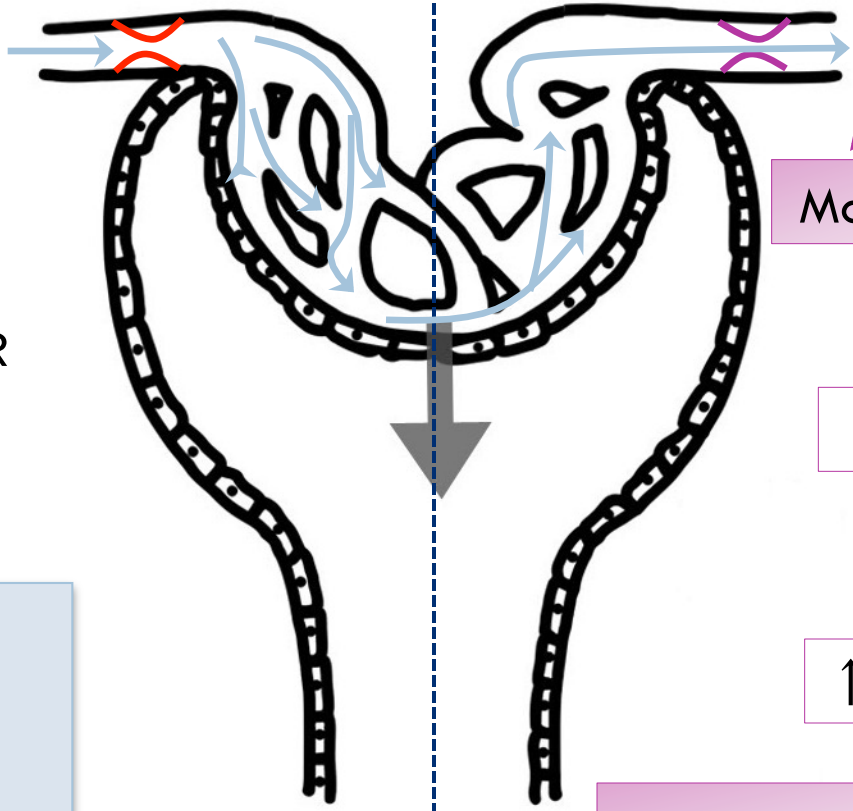
- ABP.
- Afferent arteriolar resistance.
- Efferent arteriolar resistance

Physiologic Regulation of GFR

Constriction of ***Afferent*** arteriole

↓ ↓ PG

↓ ↓ GFR



Constriction of ***Efferent*** arteriole

Moderate

↑ ↑ PG

↑ ↑ GFR

Severe

↓ ↓ PG

↓ ↓ GFR

Sympathetic stimulation
Epinephrine
Norepinephrine
Endothelin

Angiotensin II

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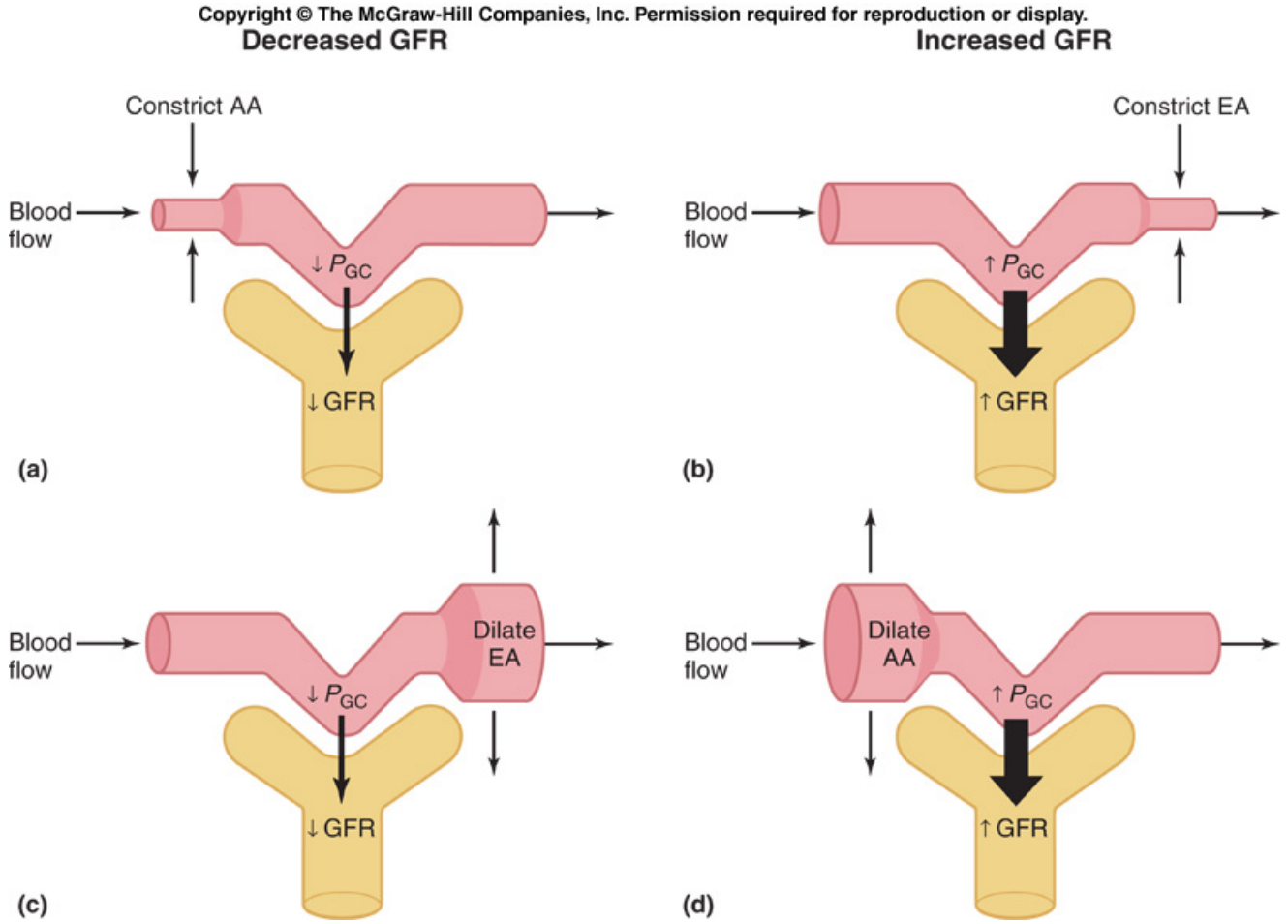

As vasodilation and vasoconstriction of the afferent and efferent arterioles alter the blood flow through the glomerular capillaries, there are corresponding alterations in the glomerular filtration rate (GFR).

Factors affecting Renal blood flow and GFR

- Sympathetic stimulation of renal arterioles decrease GFR & RBF.
- Norepinephrine decreases GFR & RBF.
- Angiotensin II decreases RBF. It constricts efferent arteriole more than afferent .
- High protein diet increases GFR.
- Hyperglycemia increases GFR & RBF.
- Fever increases GFR & RBF.
- Aging decreases RBF & GFR