

# RENAL FUNCTIONS & GFR

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من سلك طريقا يلتمس فيه علما سهل الله له به طريقا إلى الجنة □



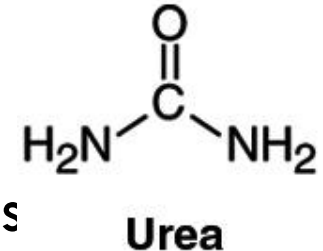
# What are the functions of the kidney?

- 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 dihydroxycholecalciferol.
  - 2- Erythropoietin production.
  - 3- Renin formation.
  - 4- Synthesis of glucose from amino acids during prolonged fasting.

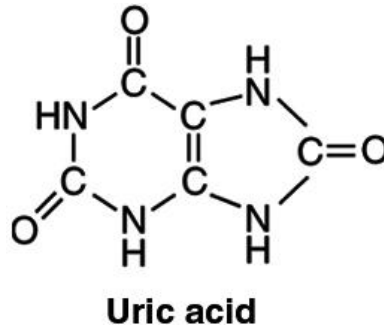
# Nitrogenous Wastes

## □ Urea

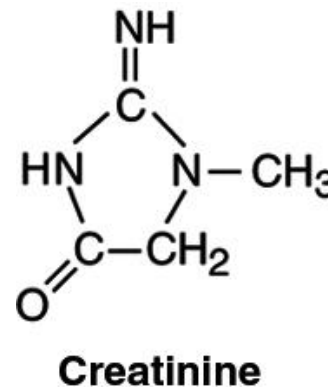
- proteins → amino acids →  $\text{NH}_2$  removed → forms ammonia, liver converts to urea



## □ Uric acid

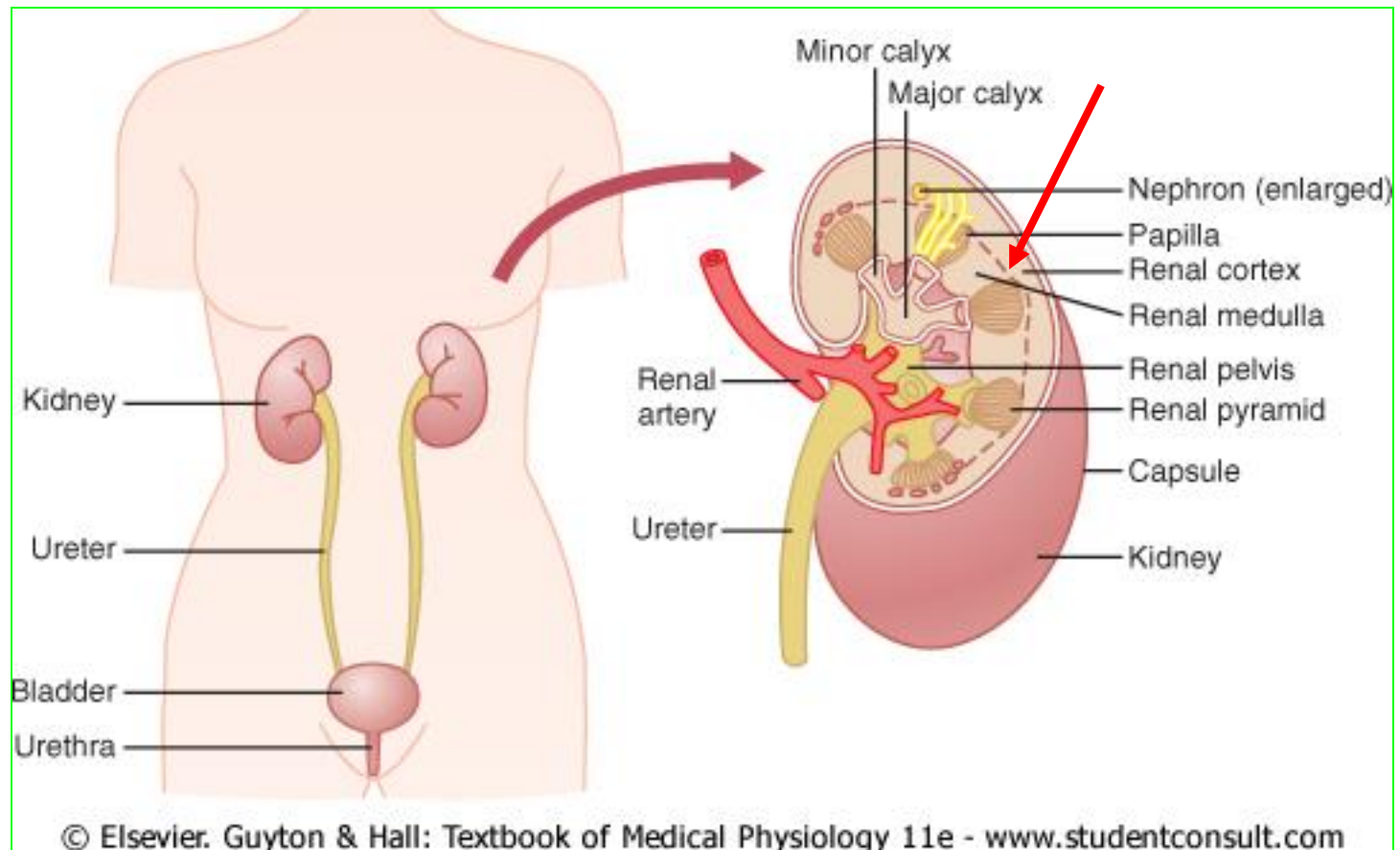


## □ Creatinine



# PHYSIOLOGIC ANATOMY OF KIDNEYS

- Size Clenched Fist
- Weight 150 grams

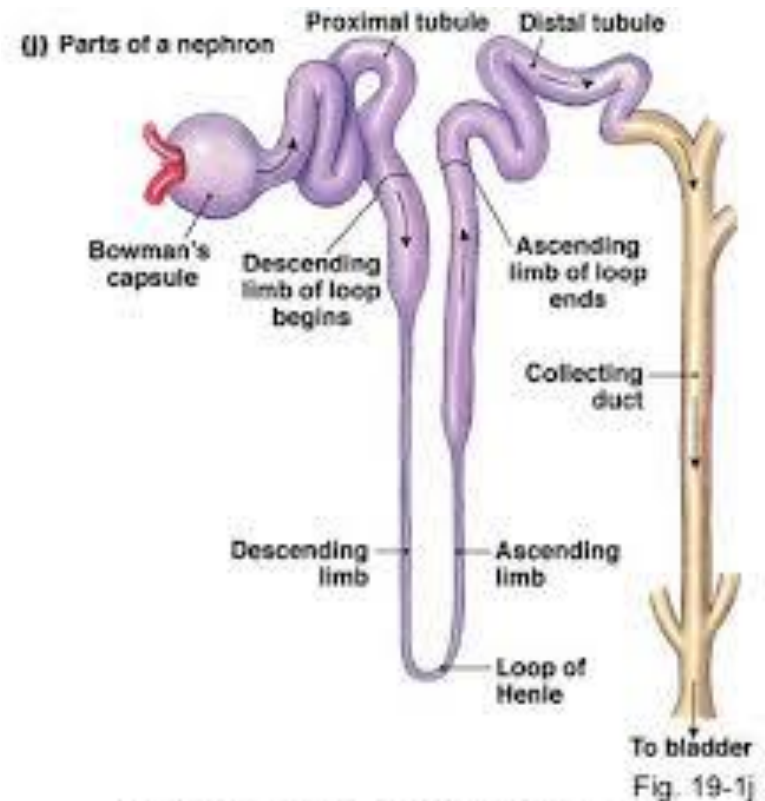


# What is the functional unit of the kidney?

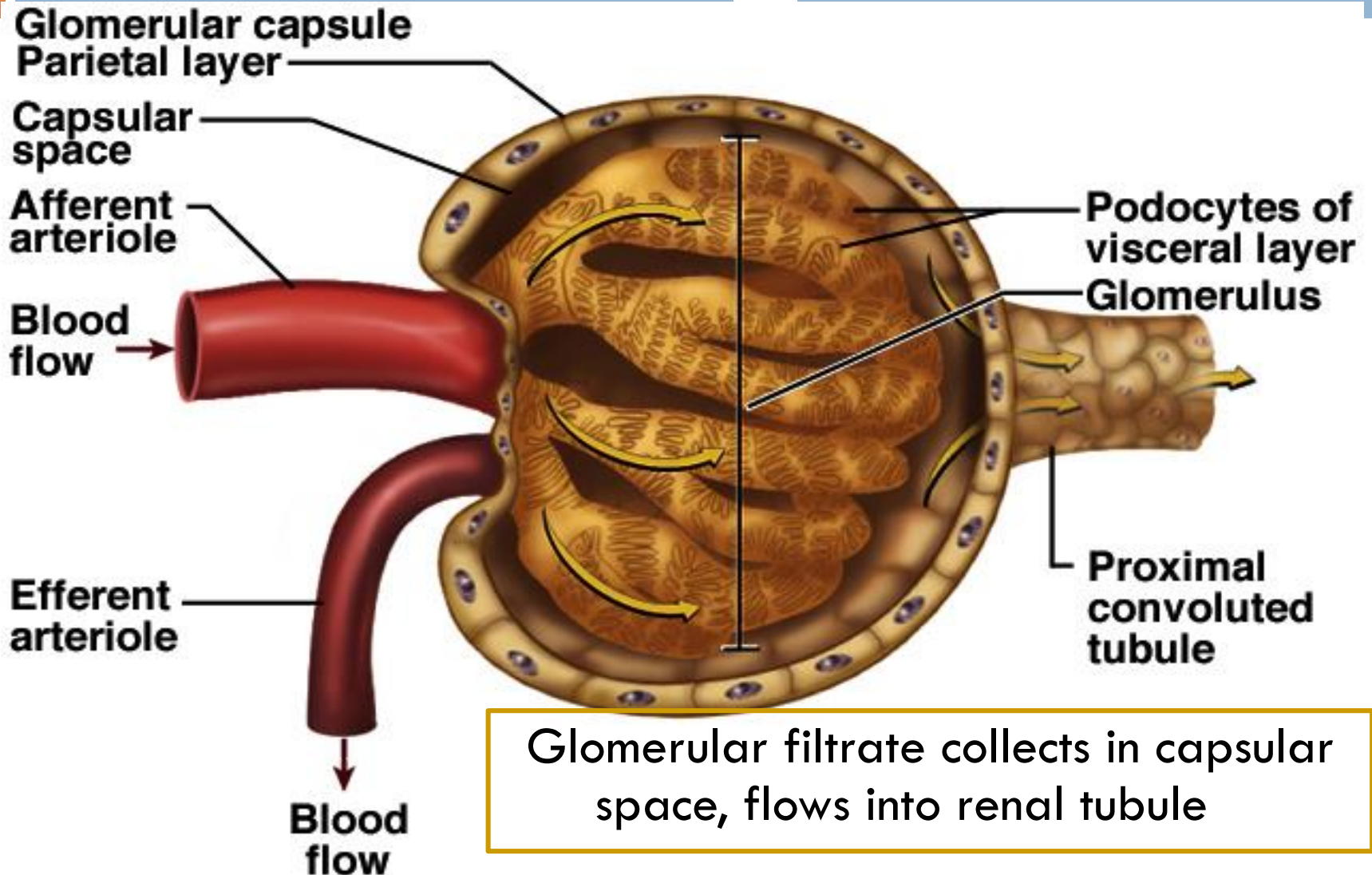
- The nephron is the functional and structural unit of the kidney.
- Each kidney has 1 million nephrons, each nephron is capable of urine formation.

# 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.

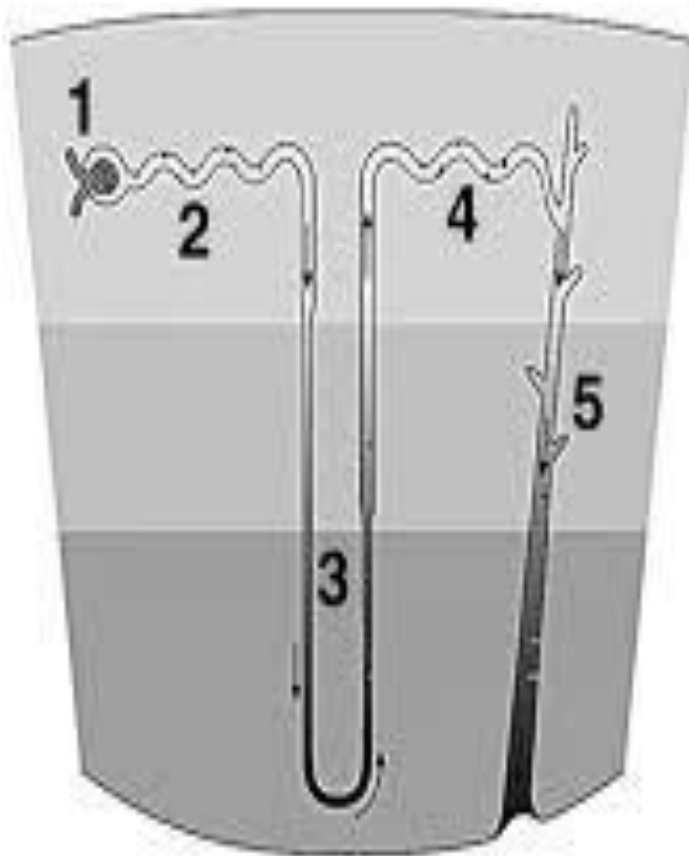


# The Glomerulus





# Structure of a Nephron



- 1- Glomerulus
- 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.

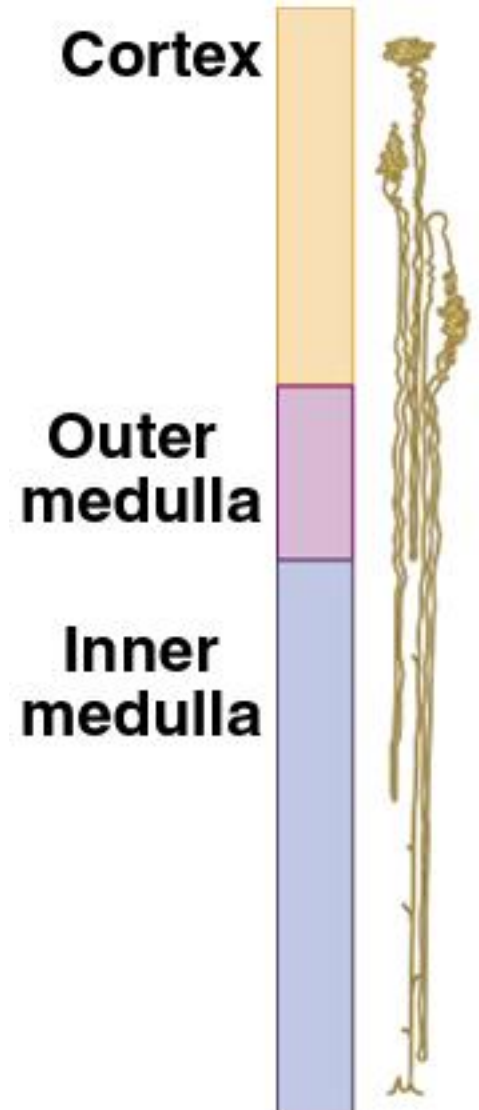
. Peritubular capelaries

2-Juxtamedullary nephrons: (15%):

Have long loops extended into the medulla.

.Vasa recta

Maintain salt gradient, helps conserve water

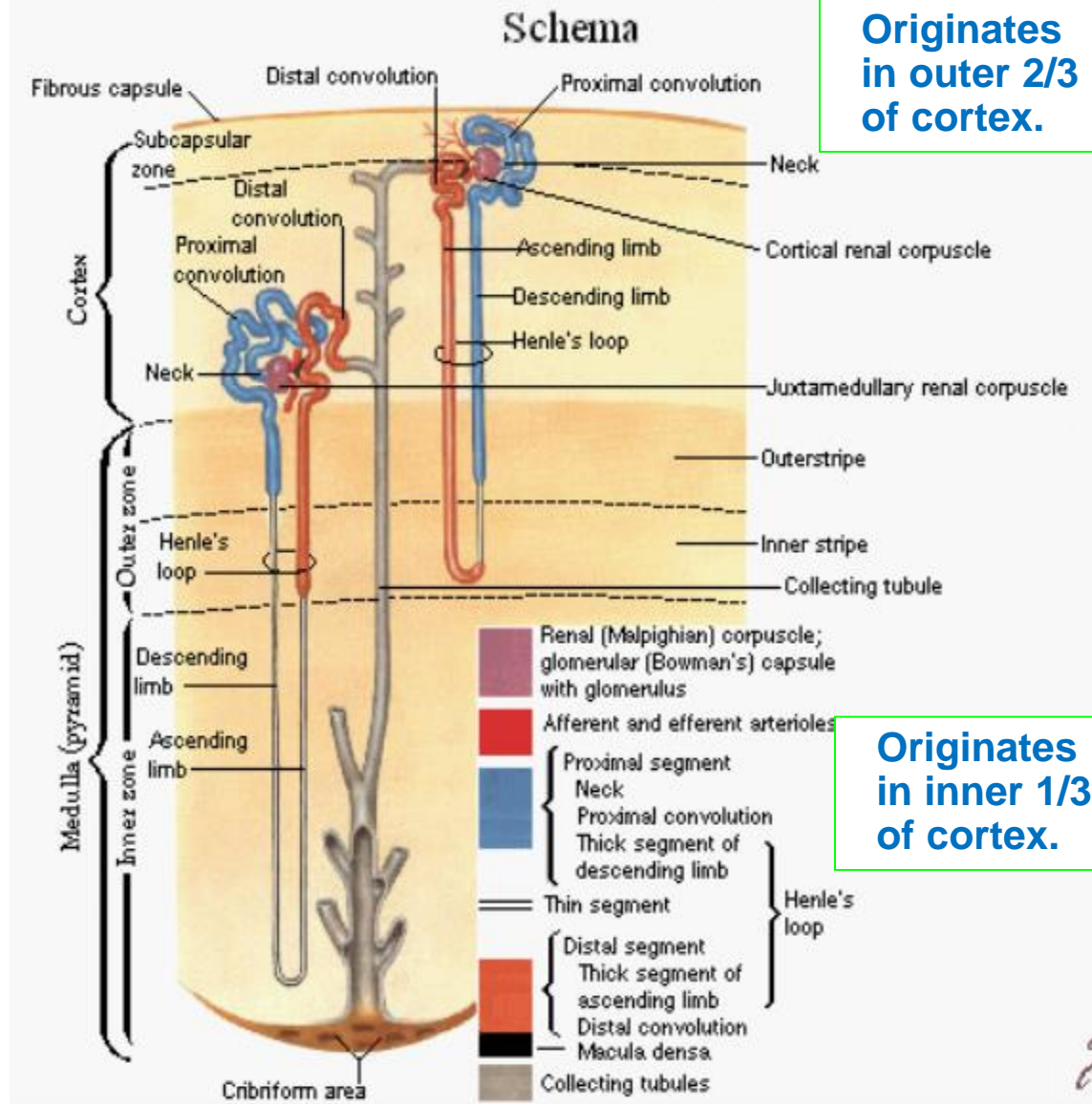


# NEPHRON TYPES

## Cortical and Juxtamedullary Nephrons

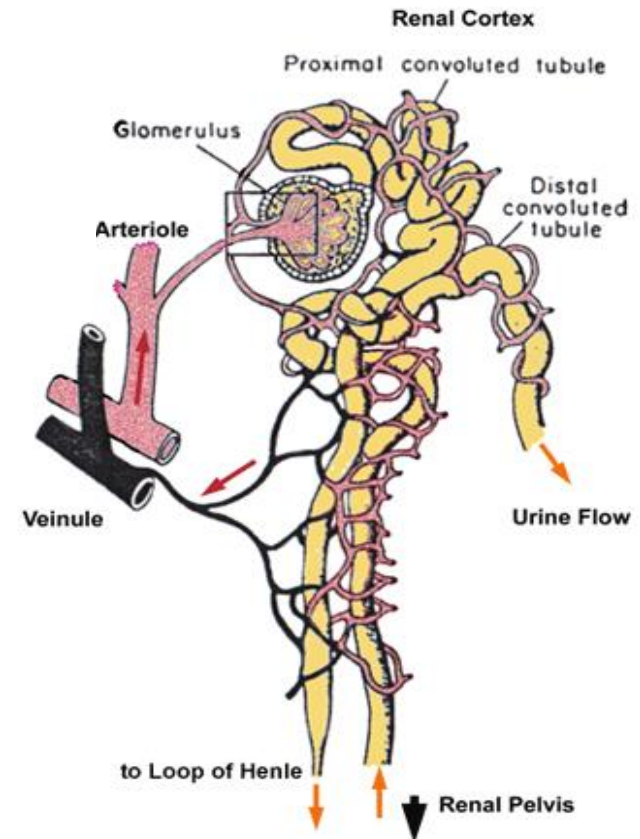
1-2 % Blood Flows Through Juxta Medullary Nephrons

### Nephron and Collecting Tubule



# 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 (1 200 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.

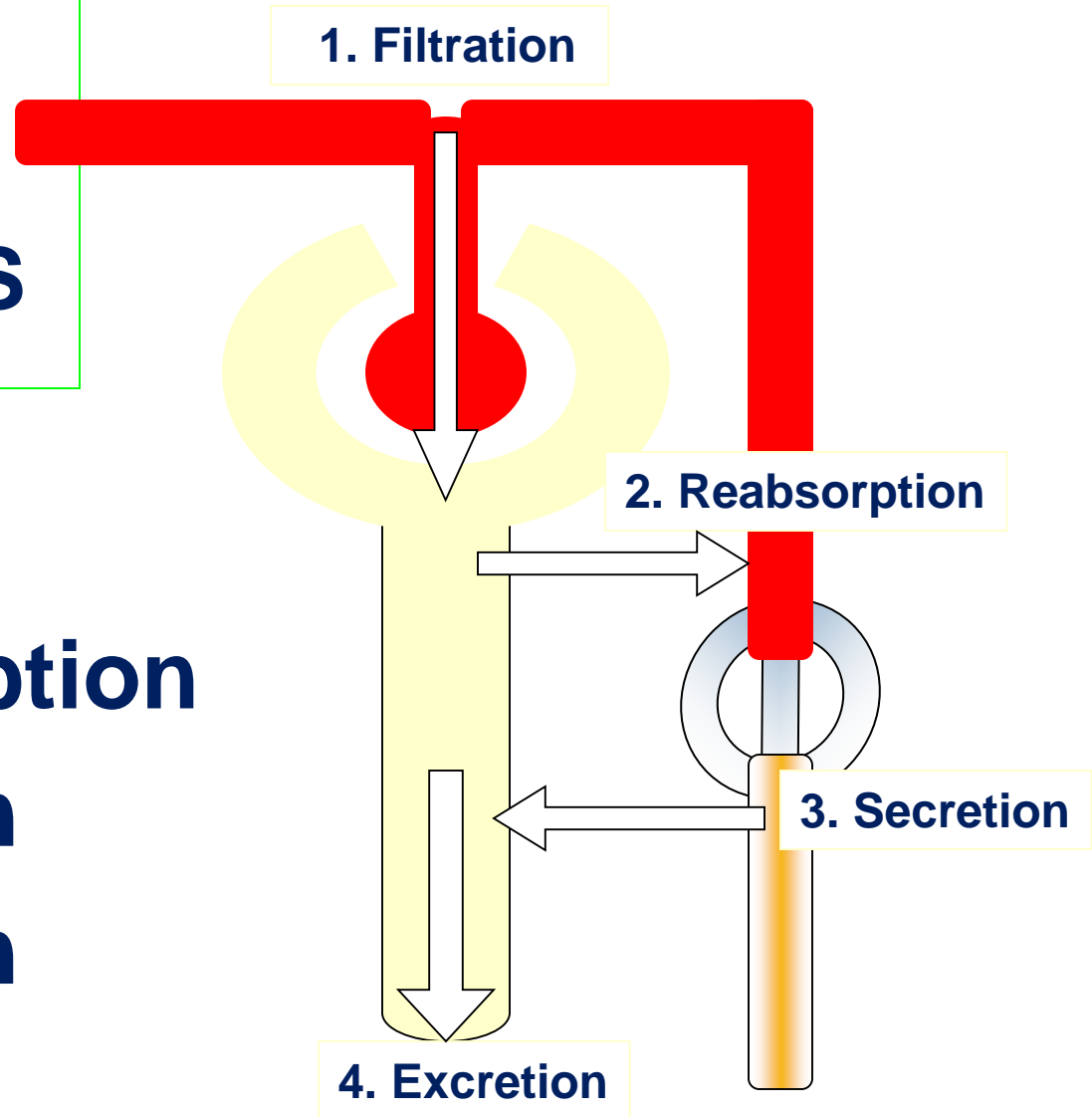
Steps of urine formation (basic renal processes):

- 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.**

# 4 RENAL PROCESSES

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

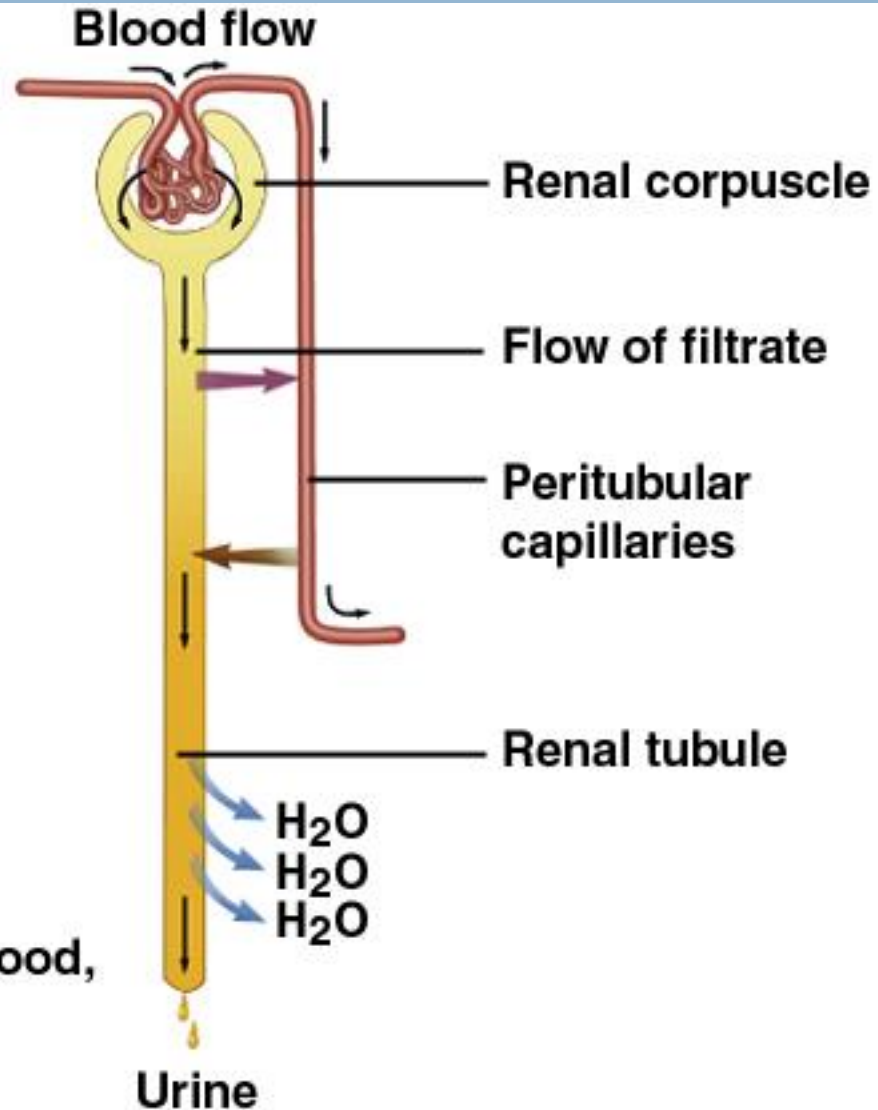


$$\text{Urinary Excretion Rate} = \text{Filtration Rate} - \text{Reabsorption Rate} + \text{Secretion Rate}$$




# Urine Formation Preview

- ① **Glomerular filtration**  
Creates a plasma-like 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  $125 \text{ ml/min} = 20\%$  renal plasma flow.

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- What is glomerular membrane?
  - What controls passage of molecules through this membrane?
  - What are the forces responsible for passage of fluid (filtrate) through this membrane?

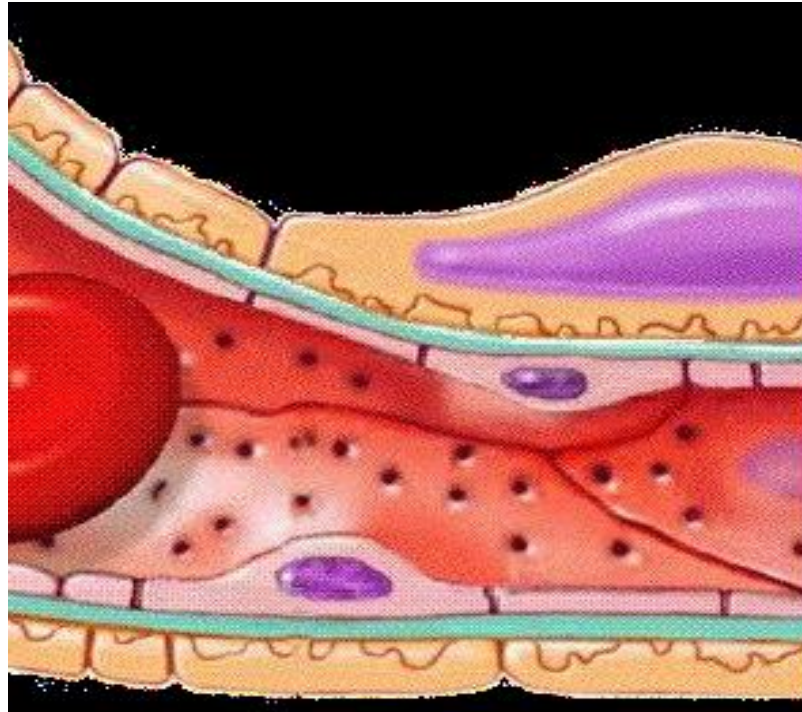
# Glomerular membrane

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.

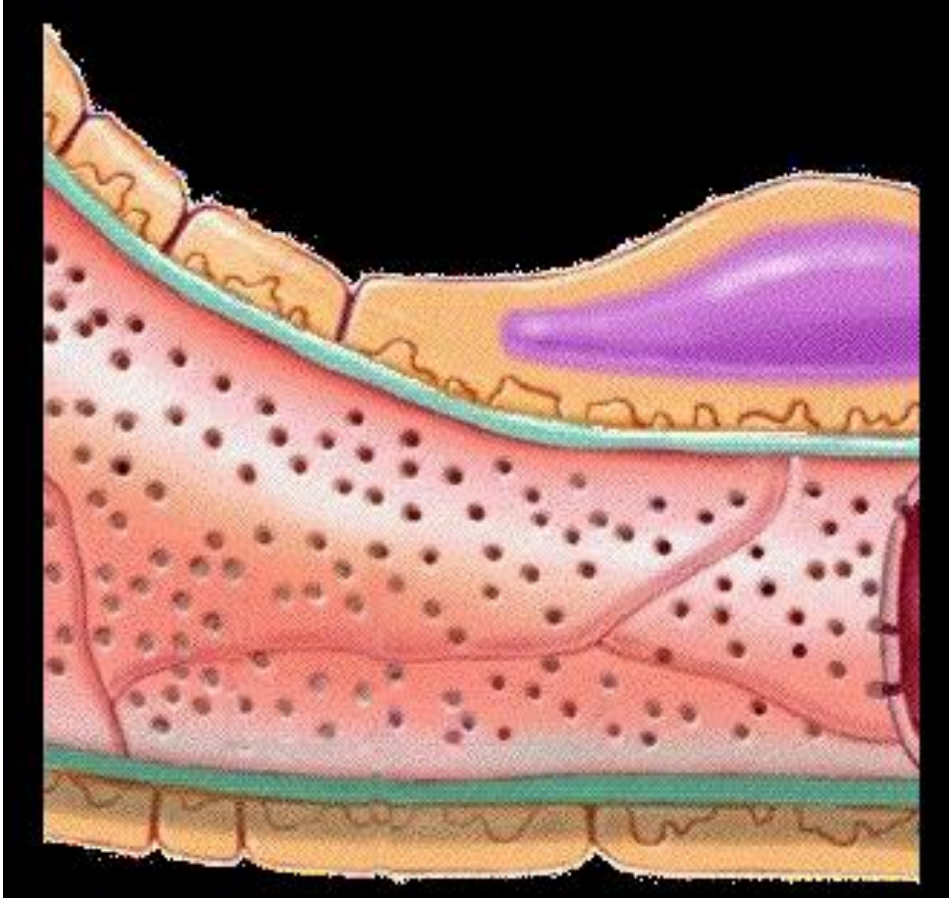
# Glomerular membrane

Here we see a glomerular capillary in longitudinal section



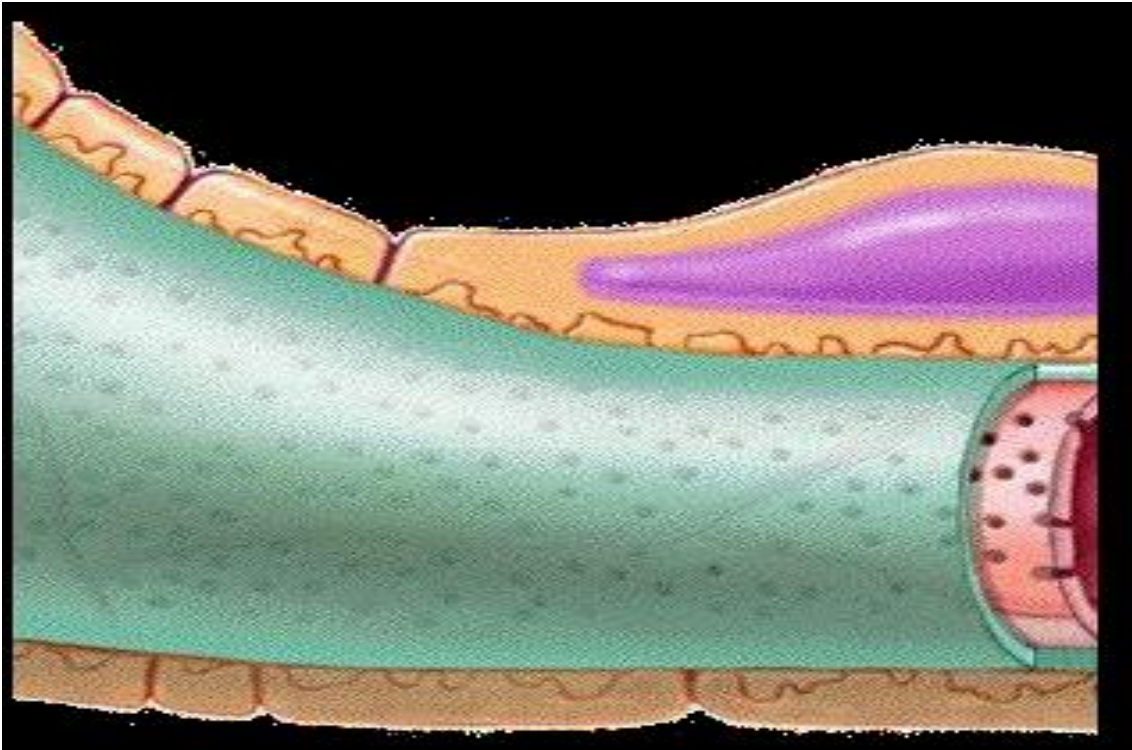
Capillary  
endothelium

# Glomerular membrane



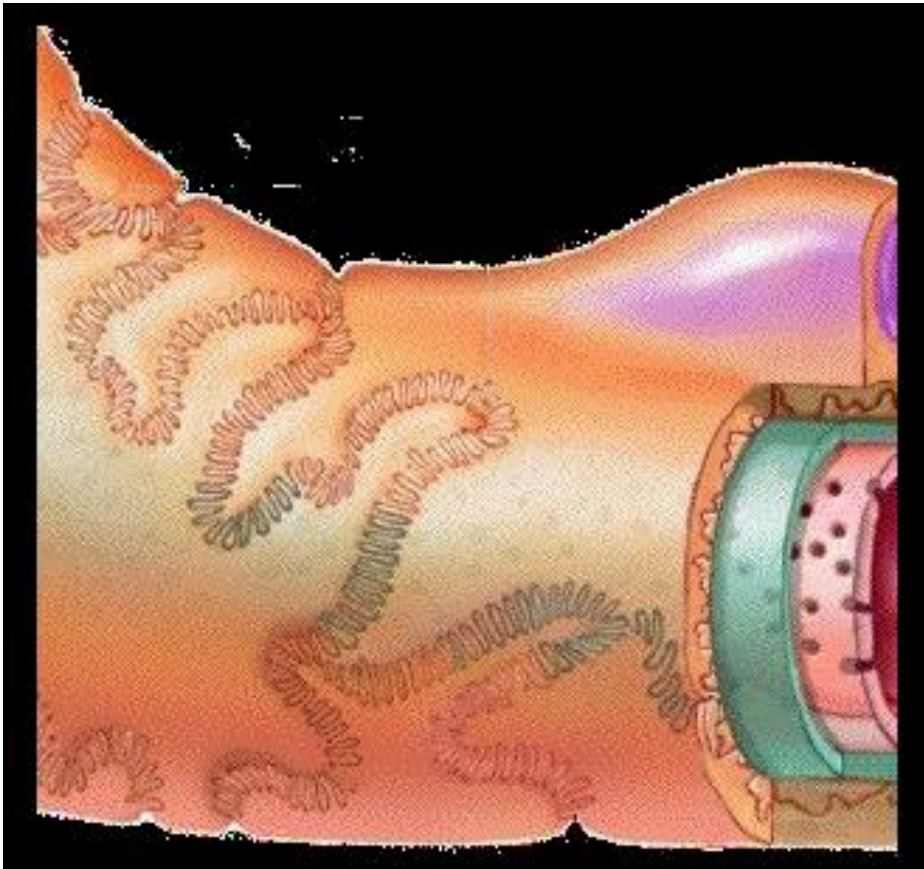
**Capillary  
endothelium**

# Glomerular membrane



**Basement  
membrane**

# Glomerular membrane

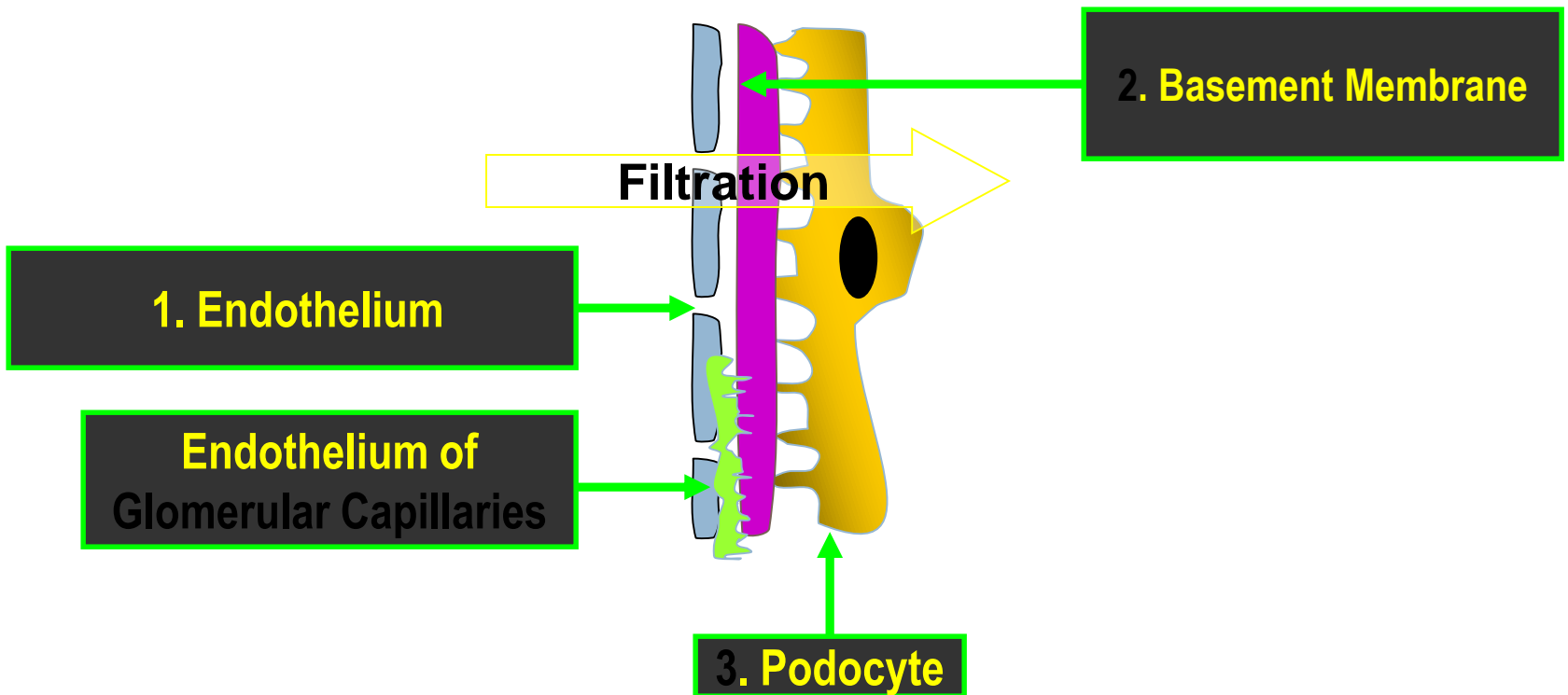


**Podocytes (cell body with nucleus)**

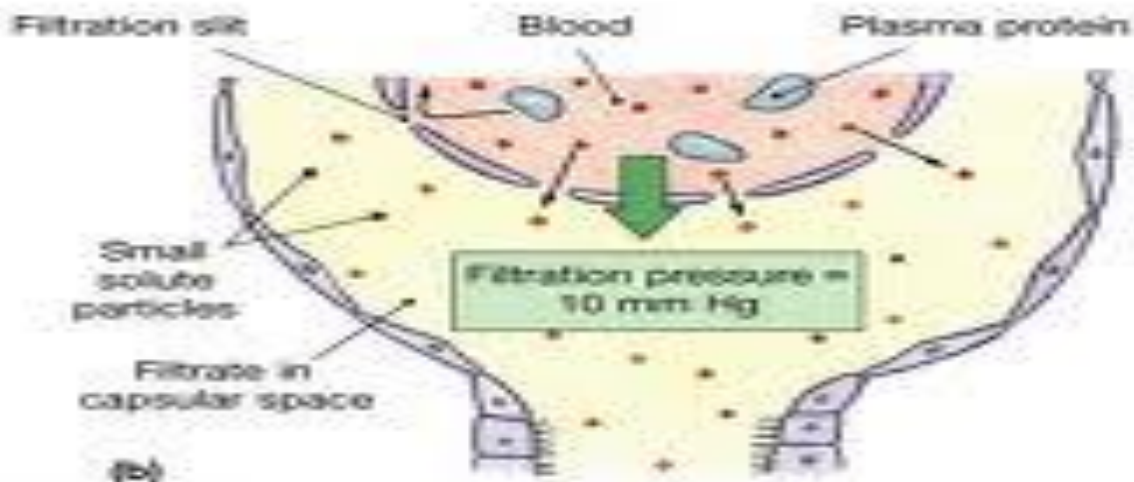
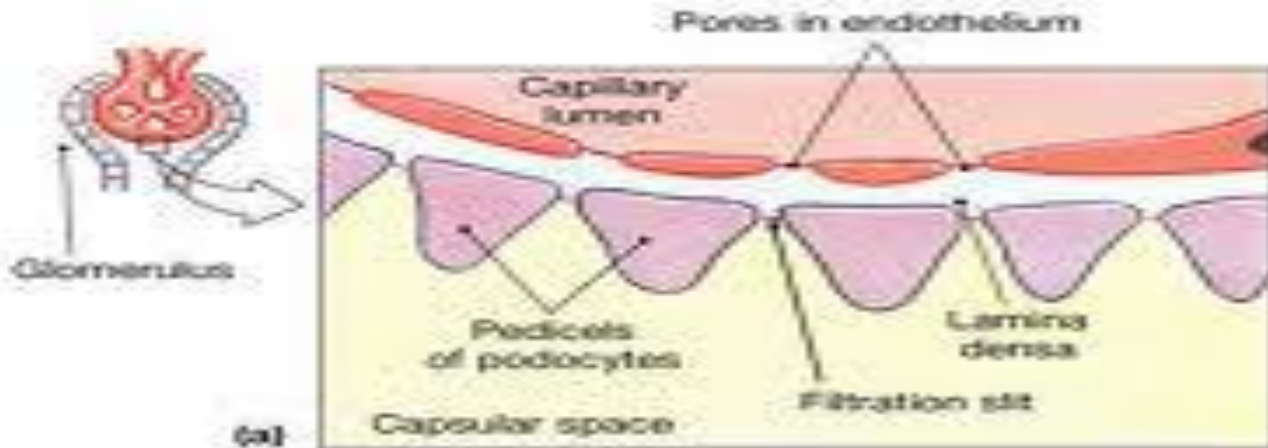
**Filtration slits**



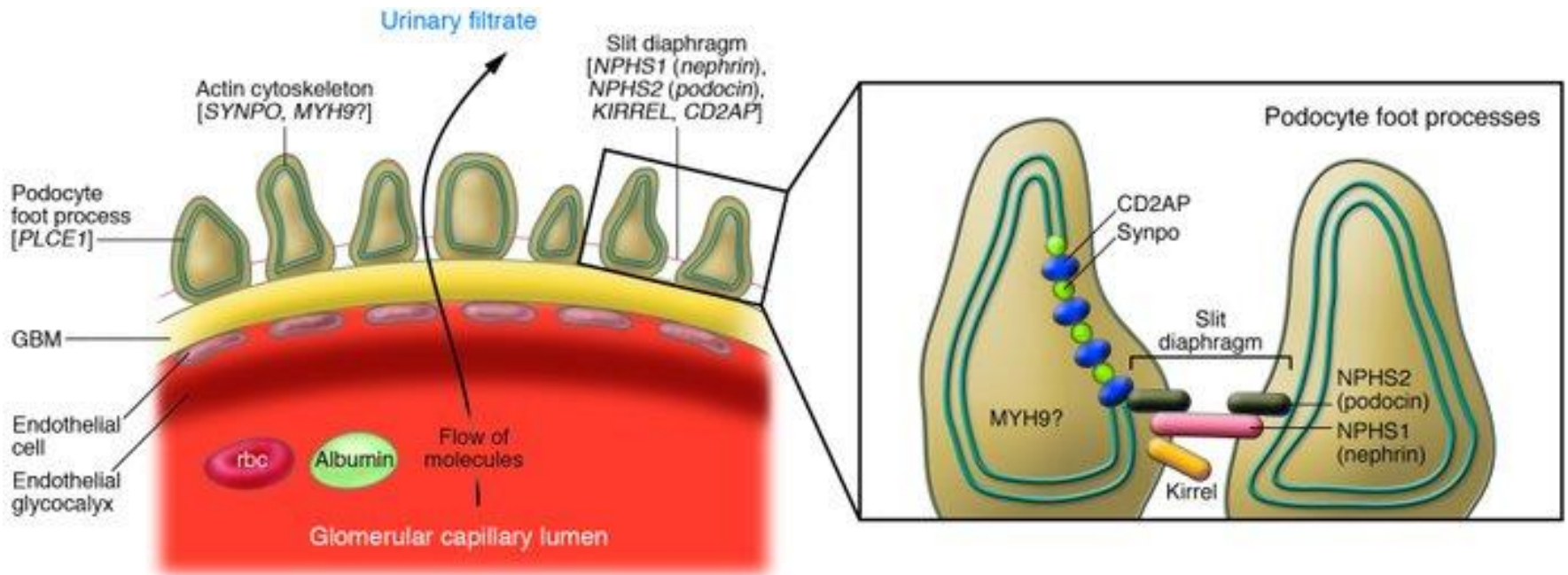
# FILTRATION MEMBRANE



# 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 Filtration Rate (GFR)

□ The GFR is determined by:

1- the net filtration pressure across the glomerular capillaries.

2- the glomerular capillary filtration coefficient (Kf)

$$\text{GFR} = \text{Kf} \times \text{Net filtration pressure.}$$

$$= 12.5 \times 10 = 125 \text{ ml/min}$$

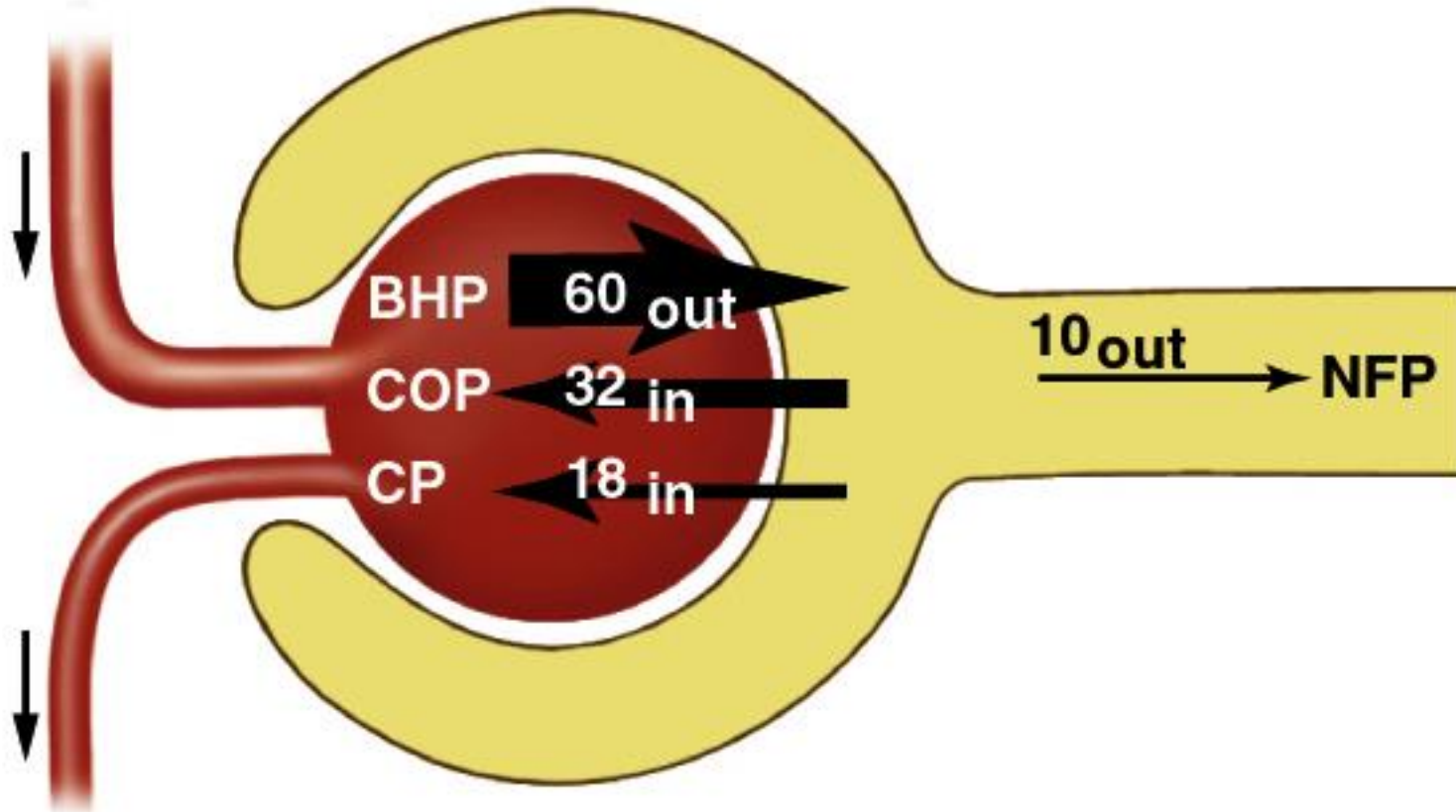
# Glomerular Filtration Rate (GFR)

- Filtrate formed per minute
- Filtration coefficient ( $K_f$ ) depends on permeability and surface area of filtration barrier
- $GFR = NFP \times K_f \approx 125 \text{ ml/min}$  or 180 L/day
- $GFR = 10 \times 12.5 = 125 \text{ ml/min}$
- 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.

# Net Filtration Pressure (NFP)



**Blood hydrostatic pressure (BHP)**  
**Colloid osmotic pressure (COP)**  
**Capsular pressure (CP)**  

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**Net filtration pressure (NFP)**

**60 mmHg out**  
**-32 mmHg in**  
**-18 mmHg in**  

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**10 mmHg out**



# CONTROL OF GFR

$$\text{GFR} = K_f \times [(P_G - P_B) - (\pi_G - \pi_B)]$$

$$\text{GFR} = K_f \times [(60 - 18) - (32 - 0)]$$

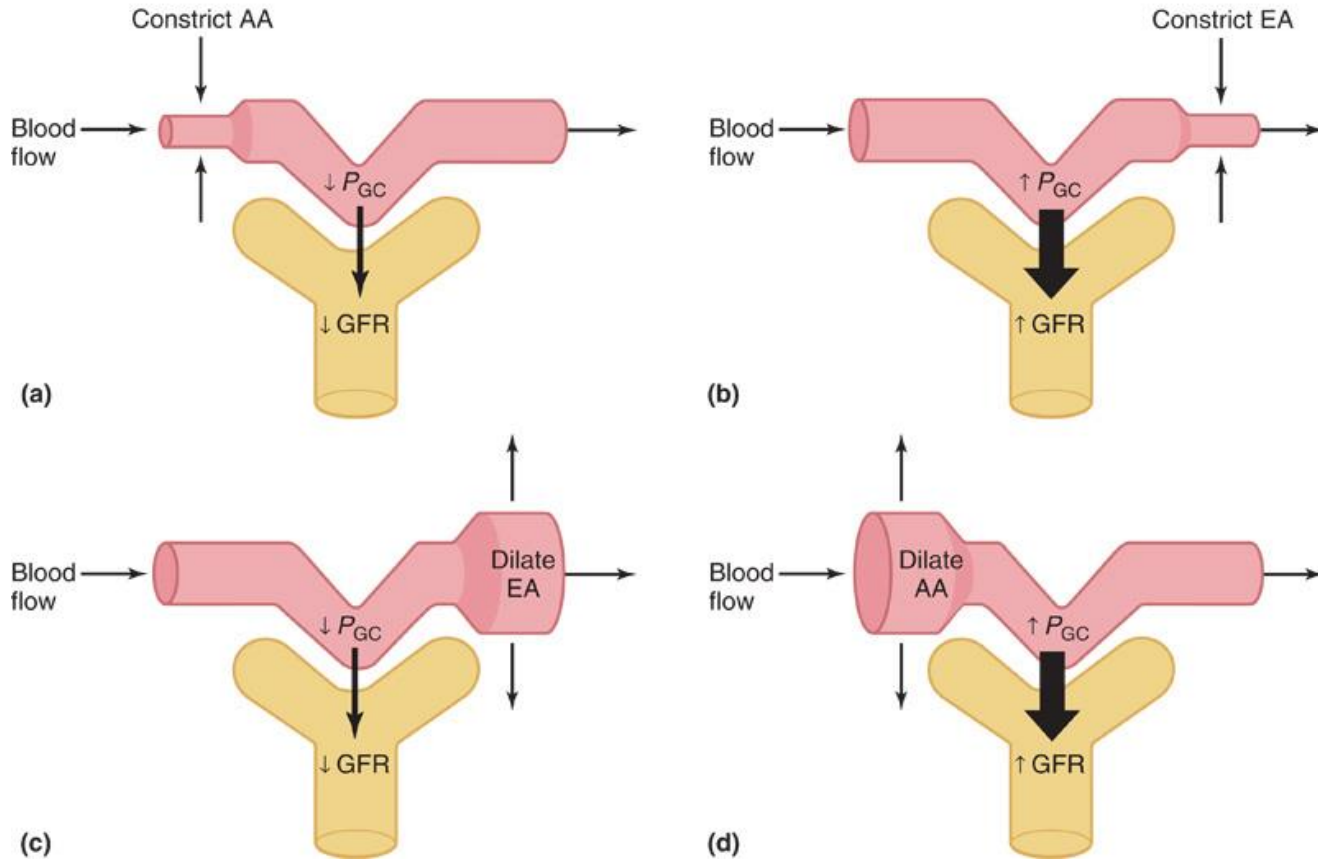
- (1) Hydrostatic pressure inside the glomerular capillaries (glomerular hydrostatic pressure,  $P_G$ ), which promotes filtration
- (2) The hydrostatic pressure in bowman's capsule ( $P_B$ ) outside the capillaries, which opposes filtration
- (3) The colloid osmotic pressure of the glomerular capillary plasma proteins ( $\pi_g$ ), which opposes filtration
- (4) The colloid osmotic pressure of the proteins in bowman's capsule ( $\pi_b$ ), which promotes filtration

# 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

Decreased GFR

Increased GFR



**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