1. Renal Functions & Glomerular Filtration

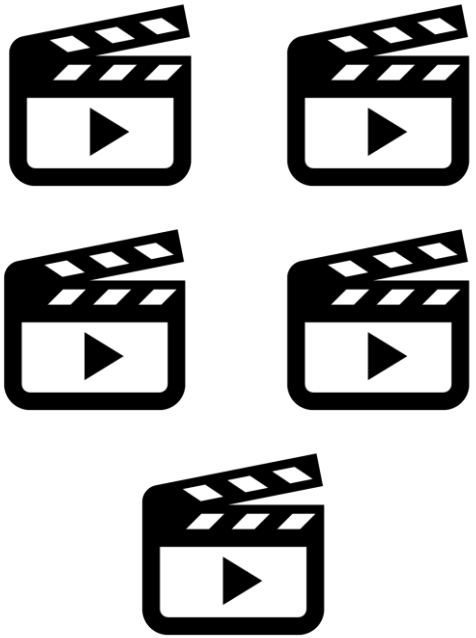
Color index

- Important
- Further Explanation

Physiology Team 434
contact us : physiology434@gmail.com

Contents

Recommended Videos!



Please check out this link before viewing the file to know if there are any additions/changes or corrections. The same link will be used for all of our work Physiology Edit

Kidney Functions

- **Filter** 200 liters of blood daily, from toxins, metabolic wastes
- **Regulation of :**
  - ✓ Water and electrolyte balance.
  - ✓ Arterial blood pressure.
  - ✓ Body fluid osmolality & electrolytes.
  - ✓ Acid/base balance
- **Excretion of :**
  - ✓ Waste products : O Urea O Creatinine O Uric Acid
  - ✓ Bioactive substances such as hormones and many foreign substances, especially drugs.
- **Synthetic Functions :**
  - ✓ Active form of vit D = 1,25 dihydroxychlicalciferol
  - ✓ Erythropoietin production
  - ✓ Renin formation
  - ✓ Synthesis of glucose from amino acids during prolonged fasting

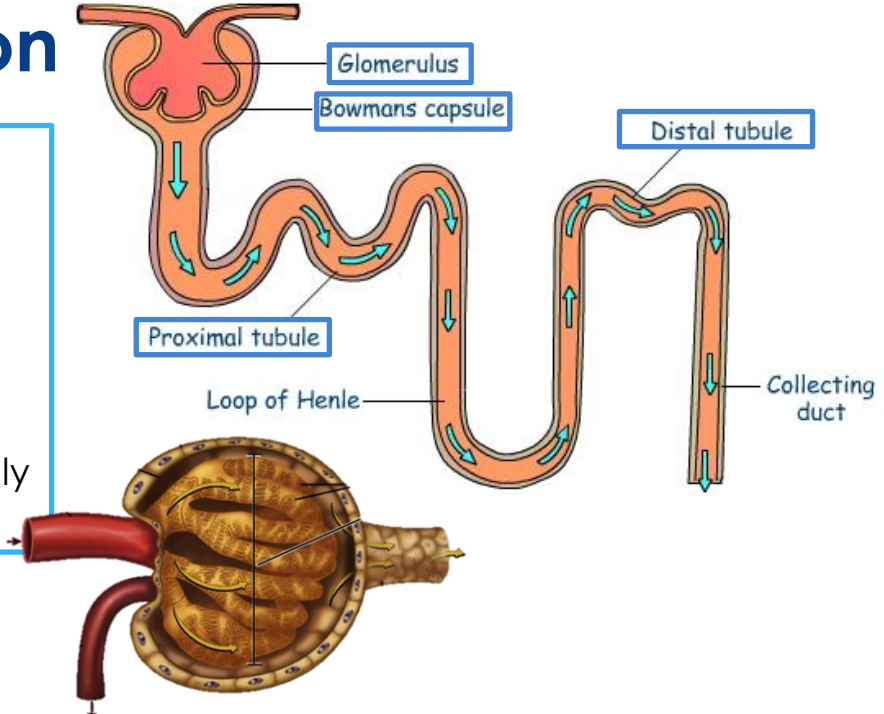
What is The Functional & structural Unit of The Kidney?

The Nephron

- Each kidney has 1 million nephrons, each nephron is capable of urine formation.

Structure of a Nephron

- **The Glomerulus:** which is the 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.



✧ Renal Tubules

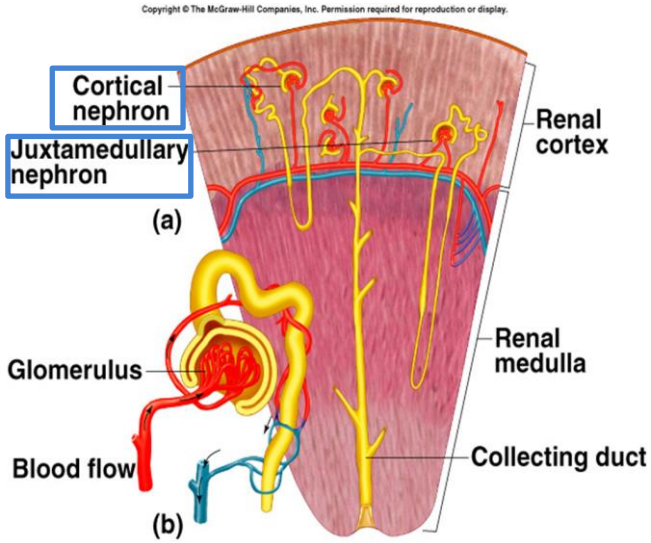
Proximal convoluted tubule (in cortex) **composed of** 1- microvilli 2-cobodial cells and mitocndia
Function : Reabsorbs water and solutes from filtrate and secretes substances into it

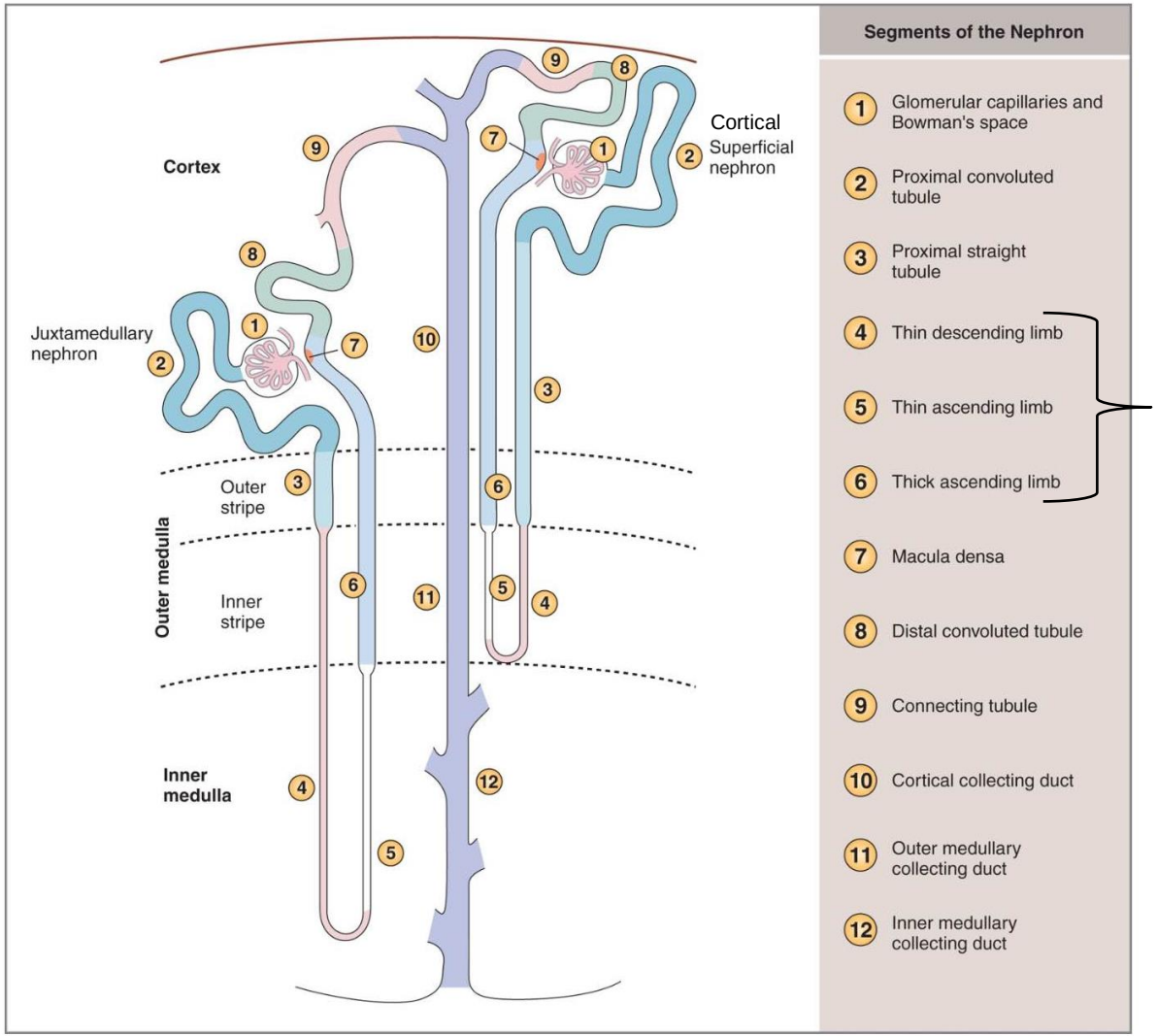
Loop of Henle smellier to Proximal convoluted tubule

Distal convoluted tubule (in renal cortex) **composed of** cuboidal cells without microvilli
Function : more in secretion than reabsorption

✧ Types of Nephrons

Cortical nephrons (85%)
Located in the cortex – Short loop of Henle.
Juxtamedullary nephrons: (15%)
Located in the cortex-medulla junction
Long loops of Henle that deeply invade the medulla.
Maintain salt gradient, help conserve water.

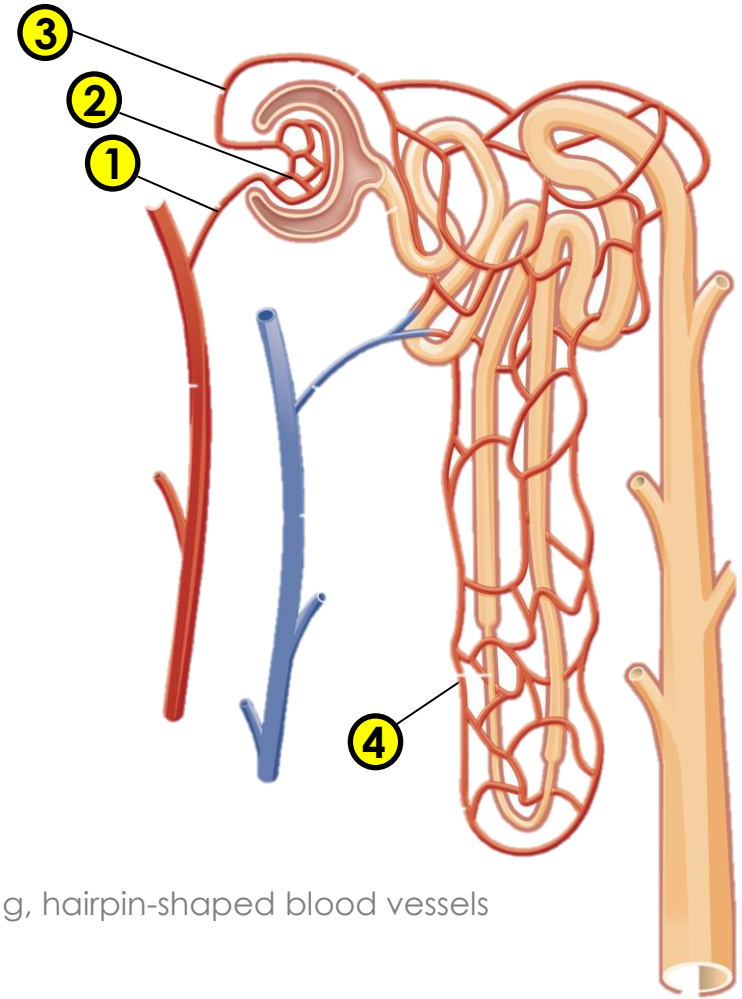




Loop on Henle

Renal Blood Vessels

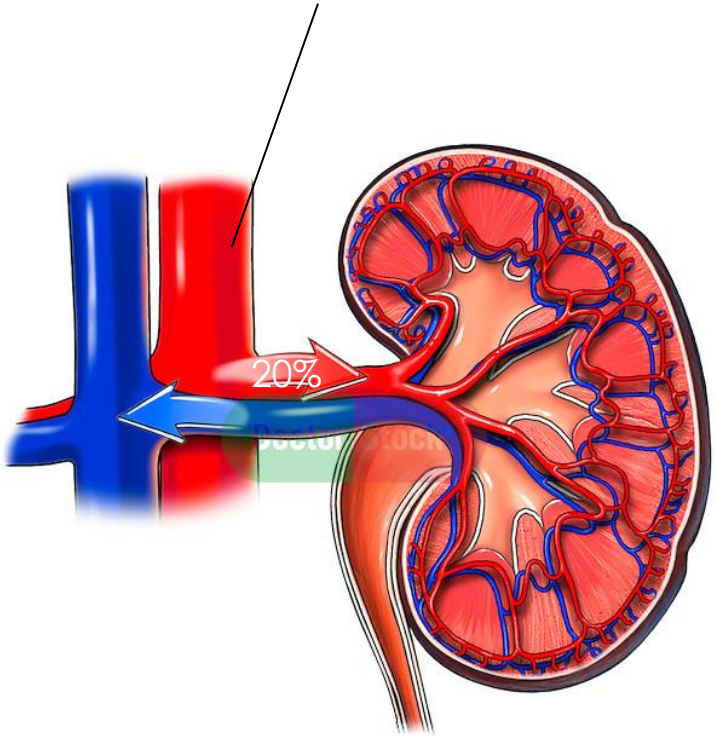
1. **Afferent Arteriole** — Deliveries blood into glomeruli
   - AS IN ARRIVING
2. **Glomerular Capillaries** — Produces filtrate that enters the tubules
3. **Efferent Arteriole** — Deliveries blood from glomeruli to peritubular capillaries
   - AS IN EXITING
4. **Peritubular Capillaries** — Vasa recta — Which are long, hairpin-shaped blood vessels



Mentioned in Males' Slides of Lecture 2

Renal Blood Flow

Renal blood flow to the kidney represents **20%** of cardiac output
The blood flow to each kidney through a renal artery



✧ Features of Renal Circulation

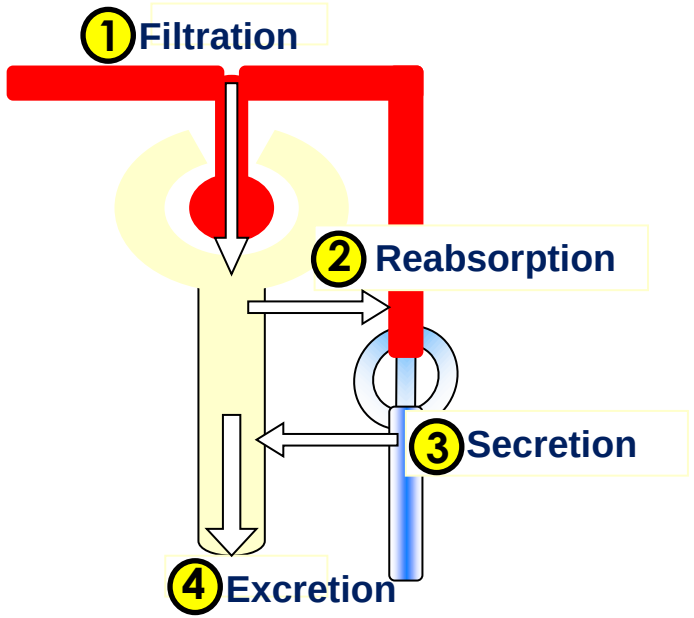
- ✓ High blood flow (1200 ml/min)
  Such high rate of RBF are not surprising in light of the central role the kidneys play in maintaining the volume and composition of fluids!
- ✓ Presence of 2 capillary beds: Glomerular & Peritubular.
- ✓ Efferent and afferent arterioles are major sites of resistance Due to the high pressure in those 2 arterioles.

Urine Formation

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

Steps of Urine Formation (Renal Processes)

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



Urinary Excretion Rate = Filtration Rate – Reabsorption + Secretion

Mentioned in Males' Slides of Lecture 2

Urine Formation cont.

① Glomerular Filtration	② Tubular Reabsorption	③ Tubular Secretion	④ Urine Excretion
✧ The first step in urine formation ✧ Blood flows through the glomerulus, allowing protein-free plasma to be filtered through the glomerular capillaries into the Bowman's capsule.	✧ Movement of substances from tubular lumen back into the blood ✧ Reabsorbed substances not lost in the urine, but are carried by the peritubular capillaries to the venous system ✧ Most of the filtered plasma is reabsorbed	The selective transfer of substances from the peritubular capillary into the tubular lumen	"The end product" The elimination of substances from the body in the urine
✧ 20% of plasma entering the glomerulus is filtered ✧ 125 ml/min filtered fluid	**Types** ○ **Transcellular** (across the cell) ○ **Paracellular** (between cells) ○ **Active** substances that are needed by the body (via primary active transport based on ATP hydrolysis (e.g. Na+) or secondary active transport based on an ion gradient (e.g. glucose) ○ **Passive** Bulk flow results from the imbalance of osmotic or hydrostatic forces at the peritubular capillary. Exactly the same as at the peripheral capillary or the glomerulus	Allows for rapid elimination of substances from the plasma via extraction of the 80% of unfiltered plasma in peritubular capillaries and adding it to the substances already in tubule as result of filtration	All plasma constituents filtered or secreted, but not reabsorbed remain in the tubules and pass into the renal pelvis to be excreted as urine and eliminated from the body

Only in Males' Slides of Lecture 2

Glomerular Membrane

It's where the first step in renal processing occur which involves the filtration of plasma in the glomerulus

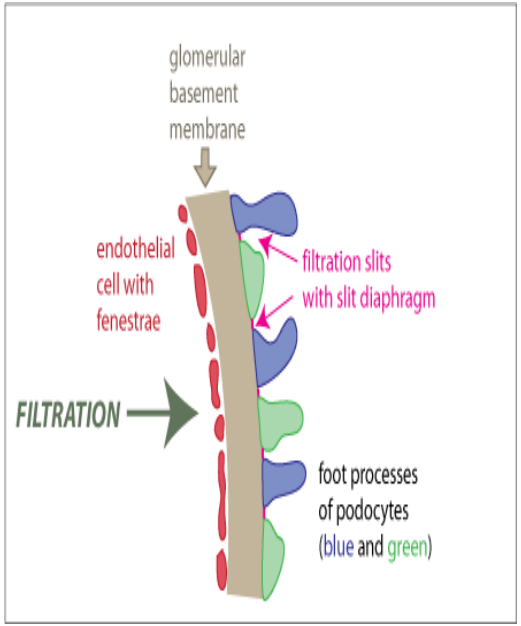
Composed of three layers :

1- Endothelium of the glomerular capillaries : it is fenestrated and the pores are about 50 – 100 nm in diameter.

2- Basement membrane : composed of fused basal laminae of the other layers.

3- Epithelial membrane : visceral membrane of glomerular capsule **(podocytes).**

Filtration Membrane : Filter that lies between the blood and the interior of the glomerular capsule.



Glomerular Membrane cont.

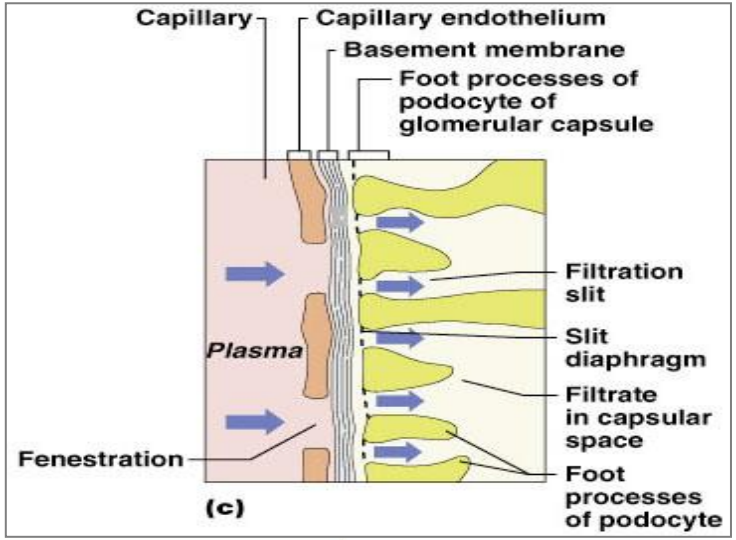
- Glomerular filtration membrane is highly permeable to water and small molecules (less than 10.000 MW).

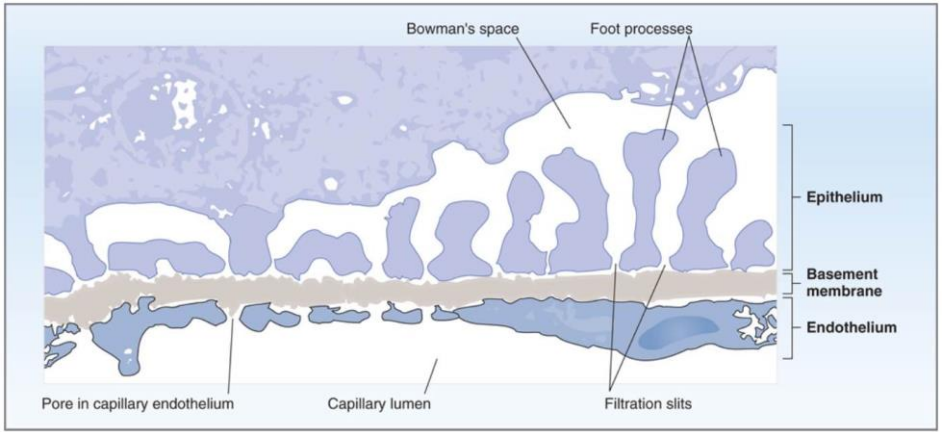
- Large molecules (more than 70.000 MW especially proteins are not filtered due to:

1- Their large size.

2- Negative electrical charge, because their passage is repulsed by negatively charged glycoproteins present on endothelial pores, basement membrane and podocytes.

(they will be repelled by negative charge in the membrane)





Glomerular Filtration Rate (GFR)

The rate of production of filtrate at the glomeruli from plasma per minute = 20% of RPF*

99% of filtrate **reabsorbed**, **1 to 2 L** urine **excreted**

GFR is determined by:

NFP = 10

1: The Net Filtration Pressure across the glomerular capillaries

Starling's Forces

NORMAL VALUES

K_f = 12.5

2: The glomerular capillary filtration coefficient

Surface Area

Permeability

GFR = NFP^1 x K_f^2

NORMAL GFR WILL BE :

GFR = 10 x 12.5

= 125 ml/min = 180 L/Day

* Renal Plasma Flow

Mentioned in Males' Slides of Lecture 2

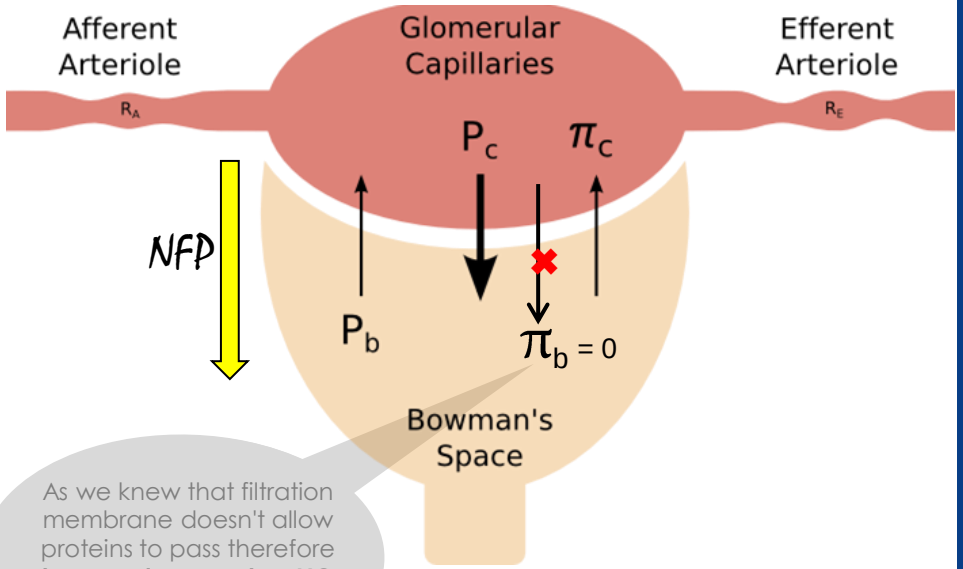
Forces Controlling GFR
Starling's Forces

Opposes Filtration

Promotes Filtration

The Net Filtration Pressure (NFP) is the sum of

- P_c — Glomerular Hydrostatic Pressure = **60 mmHg**
- π_c — Colloid Osmotic Pressure of Glomerular plasma proteins = **32 mmHg**
- P_b — Bowman's Hydrostatic Pressure = **18 mmHg**
- π_b — Colloid Osmotic Pressure of Bowman's proteins = **0 mmHg**



As we knew that filtration membrane doesn't allow proteins to pass therefore **bowman's space has NO proteins** which means oncotic pressure = 0

$$NFP = (P_C - P_b) - (\pi_c - \pi_b)$$

$NFP = (60 - 18) - (32 - 0) =$ 10 mmHg

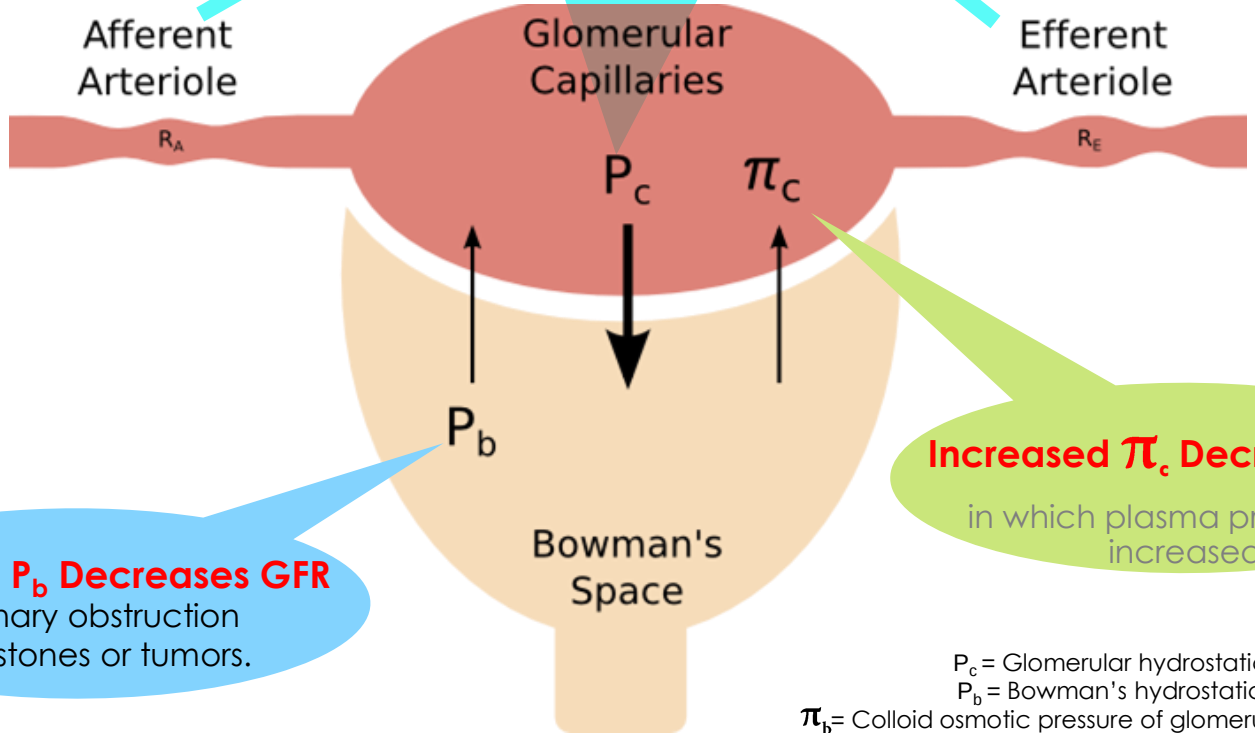
Recall!

$$GFR = NFP \times K_f = 10 \times 12.5 = 125\ ml/min$$

Mentioned in Males' Slides of Lecture 2

Changes in Forces & Affection of GFR

Increased P_c Increases GFR.
This pressure is affected by:
ABP, Afferent & Efferent arteriolar resistance'
': Constriction or dilation



Increased P_b Decreases GFR
In urinary obstruction
e.g. stones or tumors.

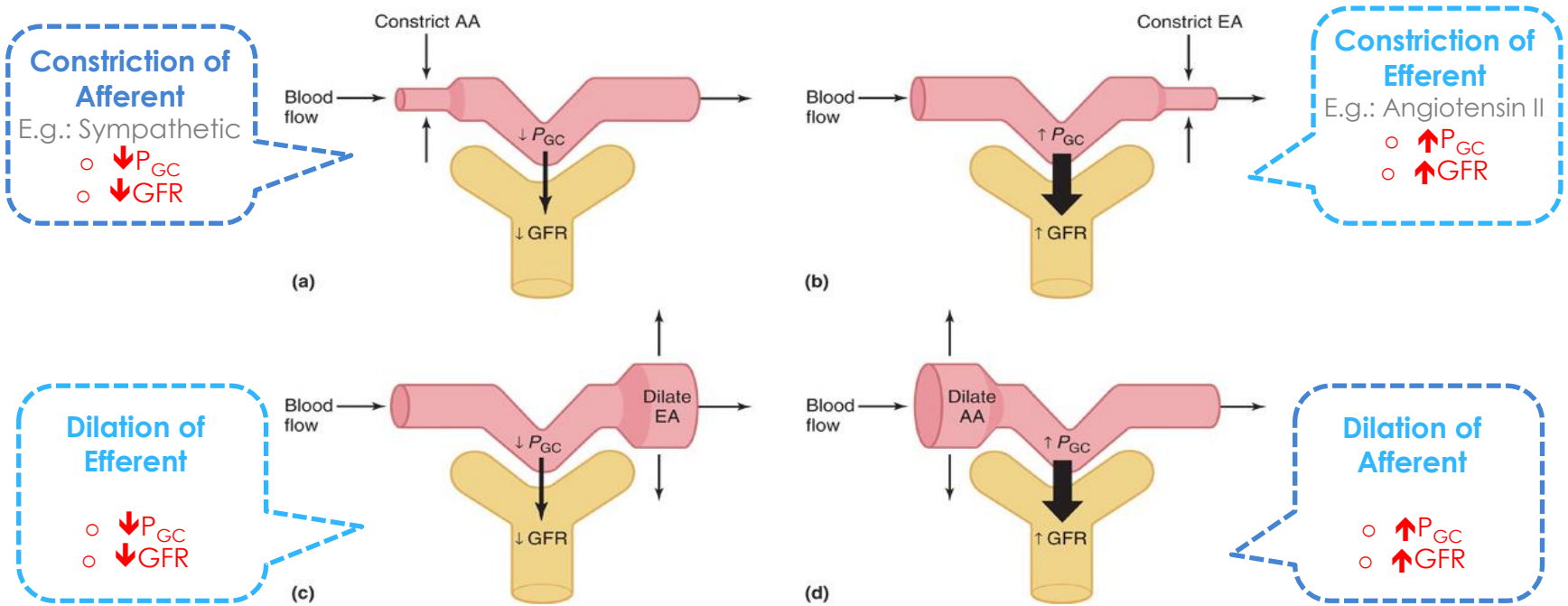
Increased π_c Decreases GFR
in which plasma proteins are increased.

P_c = Glomerular hydrostatic pressure
P_b = Bowman's hydrostatic pressure
π_b= Colloid osmotic pressure of glomerular plasma proteins

Mentioned in Males' Slides of Lecture 2

Afferent & Efferent Arteriolar Resistance Affect

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).



P_{GC} = Glomerular Hydrostatic Pressure

Mentioned in Males' Slides of Lecture 2

Cont.

To **sum up** the previous discussion on the changes which occur to RBF and GFR under different parameters..

Parameter	RPF	P_c	π_c	GFR
Afferent Constriction	↓	↓	NC	↓
Afferent Dilation	↑	↑	NC	↑
Moderate Efferent Constriction	↓	↑	NC	↑
Severe Efferent Constriction	↓	-	↑↑	↓
Efferent Dilation	↑	↓	NC	↓
↑Total Plasma Proteins	NC	NC	↑	↓
↓Total Plasma Proteins	NC	NC	↓	↑

Note: if severe vasoconstriction occur to the efferent the blood moves so slowly where GFR increases and the blood is almost completely filtered and the remaining plasma proteins will increase the oncotic pressure therefore GFR decreases

RBF = Renal Blood Flow P_C = Glomerular Hydrostatic Pressure π_c = Glomerular Oncotic Pressure NC = No Change

Additional

Factors Affecting Renal Blood Flow & GFR

Factor	GFR	RBF	Explanation
Sympathetic Stimulation of Renal Arterioles	↓	↓	It causes constriction of kidney's blood vessels. Moderate or mild sympathetic stimulation has little influence on renal blood flow and GFR. While severe stimulation - in case of severe hemorrhage, brain ischemia - influences GFR a lot that it can lead to ARF
Norepinephrine	↓	↓	Released during sympathetic stimulation
Angiotensin II **(Constricts efferent arteriole more than afferent)**	↑	↓	Angiotensin II is released in special conditions such as reduced renal perfusion pressure due to renal artery stenosis, to protect the kidney
Aging	↓	↓	After age 40, GFR decreases progressively with age, by about 0.4 - 1.2 mL/min per year. The exact mechanism is yet unclear.

Factors Affecting Renal Blood Flow & GFR cont.

Factor	GFR	RBF	Explanation
High Protein Diet	↑	↑	1- High-protein meal increases the release of amino acids into the blood. 2- Amino acids are reabsorbed in the proximal tubule with sodium. 3- Increased amino acid reabsorption also stimulates sodium reabsorption. 4- This decreases sodium delivery to the macula densa —> its feedback causes decrease in resistance of the afferent arterioles —> raises renal blood flow and GFR. 5- This increased GFR allows sodium excretion to be maintained at a nearly normal level while increasing the excretion of the waste products of protein metabolism, such as urea **This mechanism will be more clear if we take the tubular reabsorption lecture ☺**
Hyperglycemia	↑	↑	(e.x: Diabetes mellitus) same cause as high protein diet
Fever	↑	↑	-

Mentioned in Males' Slides of Lecture 2

Composition of Glomerular Filtration :

Glomerular Filtration has almost the same composition as that of plasma, except that it has no significant amount of proteins (it has about 0.003%).

Components are:

- Water.
- Electrolytes.
- Glucose.
- Urea.
- Creatinine.

It is less than 1/2000 protein as compared with plasma.

Innervation of the kidney

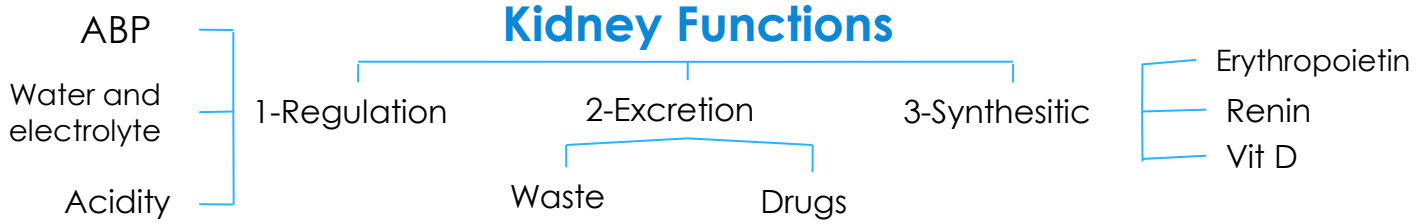
Sympathetic nerves

- supply renal blood vessels.
- regulate blood flow.
- Filtration.
- water reabsorption.
- rennin secretion.

↑ sympathetic = constriction, ↓ blood flow

"There is no parasympathetic innervation".

Only in Males' Slides



Renal tubule			
	PCT	Loop of Henle	DCT
component	Cuboidal cells microvilli	Cuboidal cells microvilli	Cuboidal cells
Function	Reabsorbtion Secretion	Reabsorbtion Secretion	Secretion

$$GFR = NFP \times K_f$$

$$NFP = (P_C - P_b) - (\pi_c - \pi_b)$$

Summary

Filter that lies between the blood and the interior of the glomerular capsule

Filtration Membrane

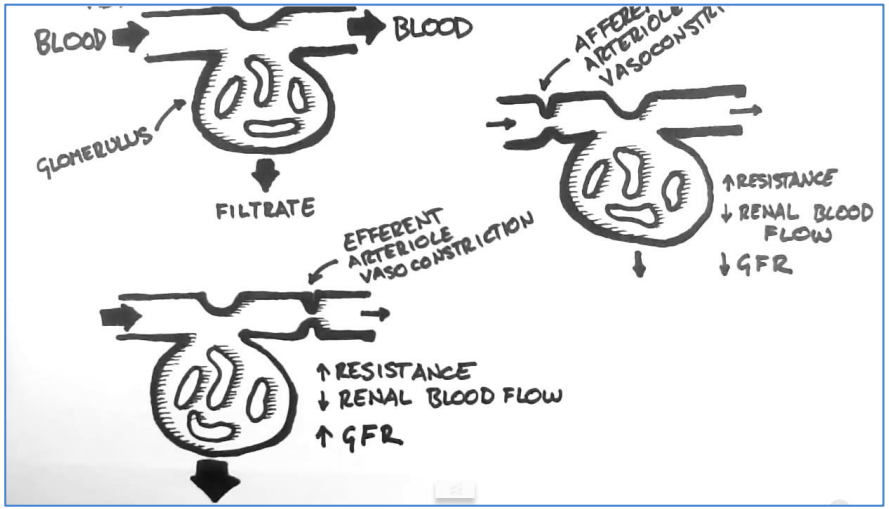
- Endothelium
- Basement Membrane
- Epithelial Membrane

Permeable to small molecule (less than 10.000 MW) *large molecule & negative charge molecule doesn't go throw

---

_

It has the same molecule as the plasma except it **no significant amount of proteins**



Summary

1- Which one of the following is a composition of distal convoluted tubule :

A. Microvilli
B. Podocyte
C. Cuboidal cells
D. A &C

2- Renin is released by

A.Podocyte
B. Juxtaglomerular apparatus
C. Microvilli
D. Juxtamedullary nephron

3- Which one of the following tubules is more in secretion than reabsorption :

A. Distal convuluted tubule
B. Proximal convuluted tubule
C. Loop of Henle
D. A & C

4-Mention 2 components secreted from the kidney :

1- renin 2- erythropoietin.

5- Proximal convoluted tubule composed of

1- Microvilli 2- cuboidal cells

6- Juxtamedullary nephron located in :

Cortex-medulla junction

7-Mention the 3 layers in filtration membrane :

1- Endothelium of glumerular capillary
2- Basement membrane
3- Epithelial membrane

8-Give 2 reason why proteins do not filtrated :

1- Their large size.
2- Negative electrical charge

9- Mention 3 components filters in glomerular filtration :

1- water 2- glucose 3- urea

1.C
2.B
3.A

Questions

THANK YOU FOR CHECKING OUR WORK!

BEST OF LUCK

Done By:

- Hussain alkaff
- Ahmad Alzahrani
- Abdullah Alfaleh
- Maha Alrabiah
- Reem Labani
- Hadeel Alsulami
- Nouf Almasoud