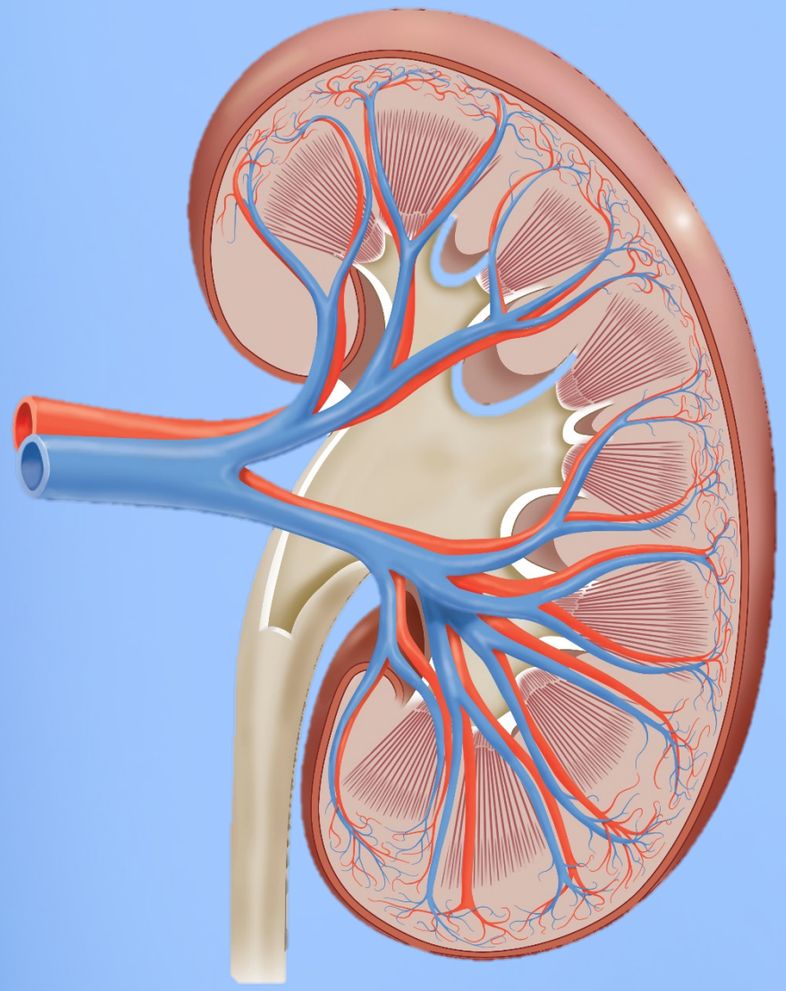
RENAL FUNCTIONS & GFR



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Renal Block

Objectives

- Enumerate general functions of the kidney
- Identify and describe that the nephron is the structural and function Unit of the kidney
- Explain glomerular filtration membrane & filtration forces
- Describe mechanism of filtration & composition of the glomerular filtrate
- Calculate the net filtration pressure using parameters of Starling forces

Key Words

nephron, glomerular filtration, tubular reabsorption and tubular secretion, capillary hydrostatic pressure, glomerular filtration membrane, filtrate.

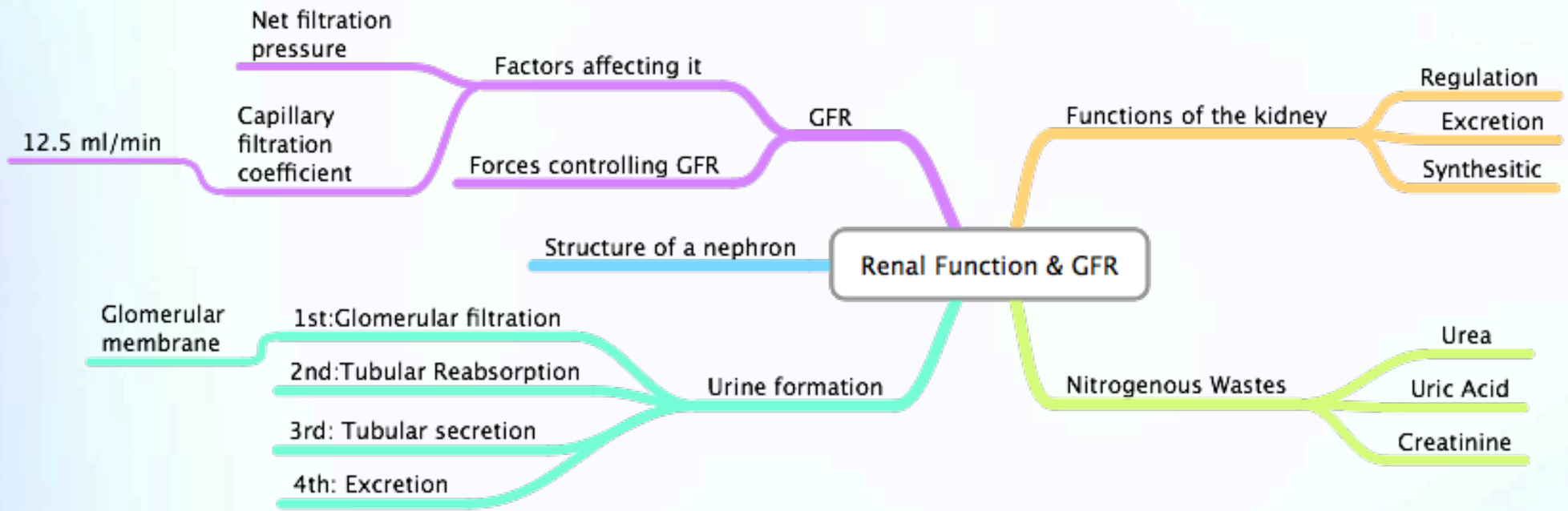
Color index

What was written with gray is less important

Abbreviations

RBF= Renal Blood Flow
GFR= Glomerular Filtration Rate
JGA=Juxtaglomerular apparatus

MIND MAP



THE FUNCTIONS OF THE KIDNEY

1-Regulation of…

- water and electrolyte balance
- body fluid osmolality & electrolytes
- acid/base balance
- arterial blood pressure.

2-Excretion of…

- waste products (UREA, CREATININE, URIC ACID).
- Detoxification and excretion of drugs.

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

3-Biosythesis

- activation of vitamin D(1)
- Erythropoietin production(2)
- Renin formation(3)
- glucose from amino acids during prolonged fasting. (gluconeogenesis)

NOTE

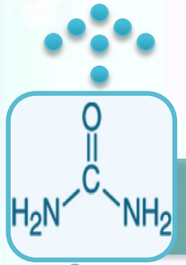
(1) Therefore, the patients who have renal failure will have recurrent fractures due to decrease synthesis of Vit D (treatment by : injection Vit D)

(2) Therefore, the patients who have renal failure will have anemia (treatment by : injection erythropoietin)

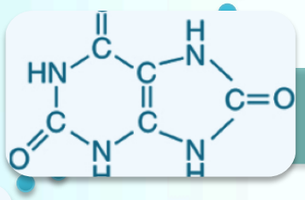
(3) Released by Juxtaglomerular apparatus

NITROGENOUS WASTES

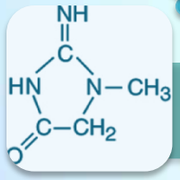
Measurement of nitrogen wastes within serum help to assess the kidney function



Urea



Uric acid



Creatinine

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

THE FUNCTIONAL & STRUCTURAL UNIT OF THE KIDNEY:

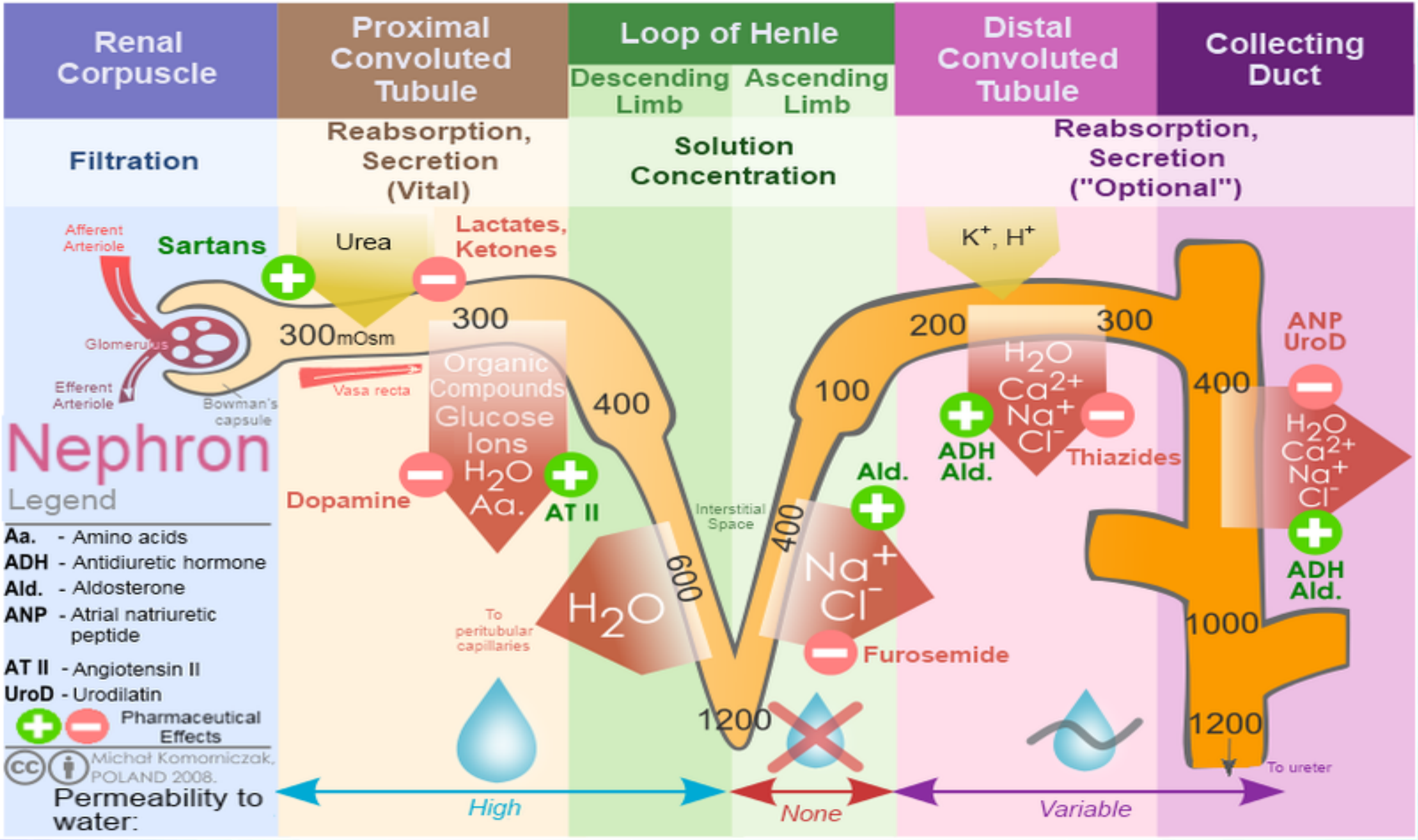
The nephron

- **Each kidney has 1 million nephrons, each nephron is capable of urine formation.**
- **Located in both the cortex and medullary areas**

URINE FORMATION STEPS

1. **Glomerular filtration:** Filtration of fluid from glomerular capillaries into the renal tubules.
2. **Tubular reabsorption**
3. **Tubular secretion.**
4. **Excretion**

Review of the Structure of a nephron

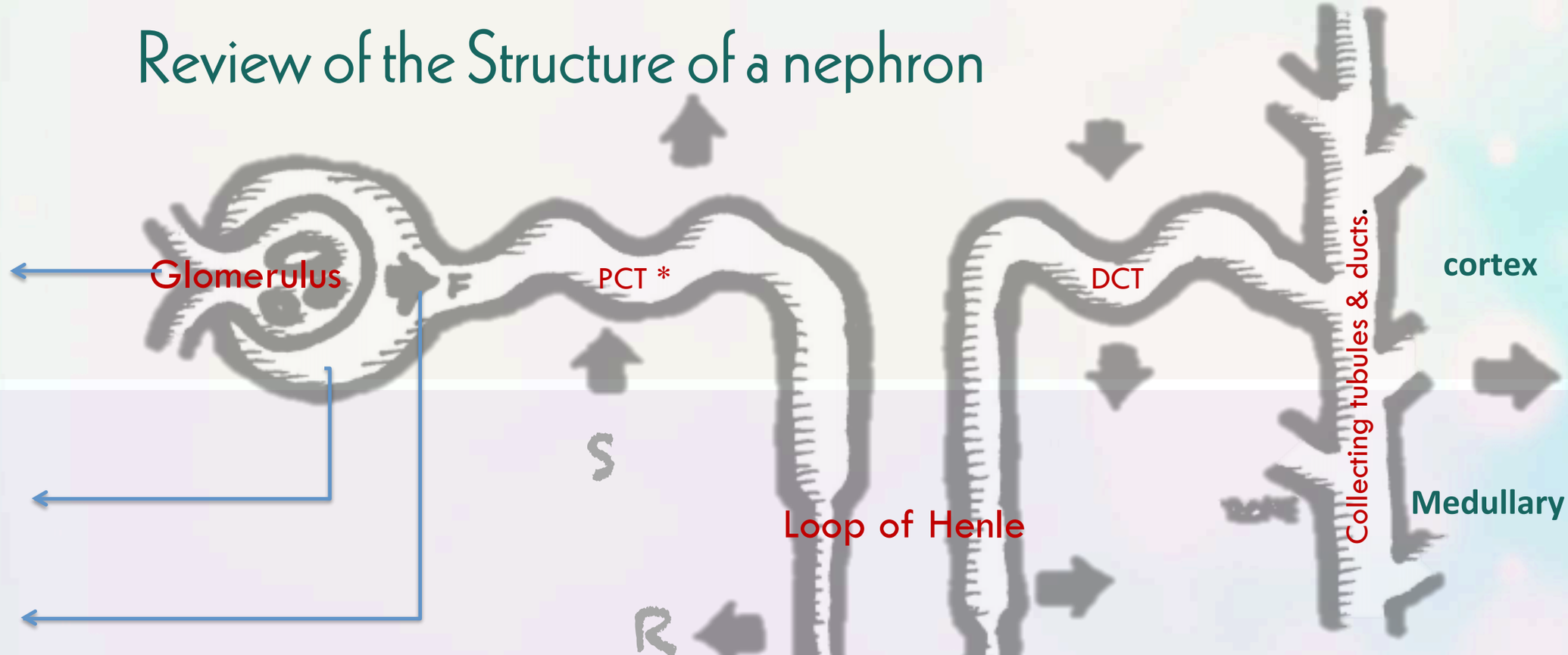


Review of the Structure of a nephron

Glomerulus: capillary tuft: in which large amount of fluid is filtered from blood.

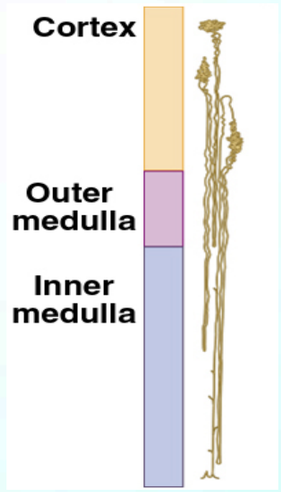
Bwaman's capsule: Around the glomerulus and receives the filtrate.

Glomerular filtrate collects in capsular space, flows into renal tubule



Tubules: in which filtered fluid eventually is converted into urine.

Types of nephrons:		Cortical nephrons:	Juxtamedullary nephrons
	Presence	85%	15%
	glomeruli loc.	in the outer portion of cortex	in inner part of the cortex
	loops of Henle.	Short loop	long loops extended into the medulla.
	Conc. Of urine	Diluted urine	Concentrated urine (because it Maintain salt gradient, helps conserve water)



* Proximal convoluted tubules has blind end that forms the Bowman's capsule

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:
High blood flow rate (1200 ml/min).
Presence of two capillary beds: 1. **Glomerular:** take place in filtration of fluid and solutes. 2. **Peritubular** take place in reabsorption and secretion
Efferent and **afferent** arterioles are major sites of renal resistance.(1)

NOTE

(1) because they have vascular smooth muscle cells which constricted and vasodilated in response to change in blood pressure

Glomerular filtration creates a plasmalike filtrate of the blood

Tubular reabsorption removes useful solutes from the filtrate, returns them to the blood

Tubular secretion removes additional wastes from the blood , adds them to the filtrate

Water conservation, removes water from the urine and returns it to blood. Concentrate wastes

Urinary excretion rate = Filtration rate – (reabsorption + secretion)。

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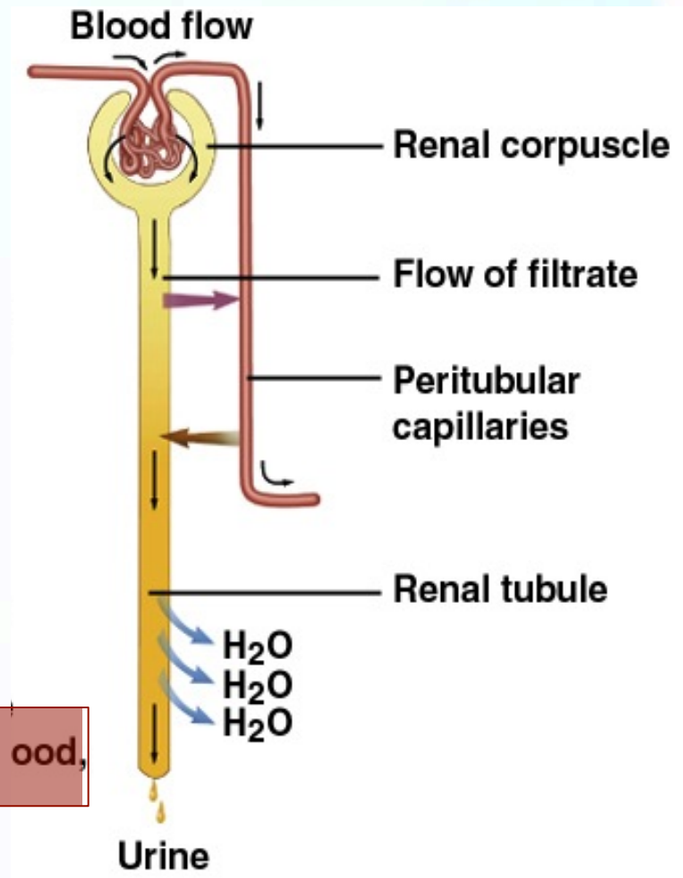


1ST step in urine formation

Glomerular filtration

Definition

It is the filtration of fluid from the glomerular capillaries into the renal tubules.

filtration of body fluid and blood from high molecular weight and negatively charged through glomerular capillaries to renal tubules.

GFR (Glomerular filtration rate)

normally

125 ml/min

=

20% renal plasma flow.

substances

It contains all substances present in plasma except RBC's & proteins .

Albumin does not normally pass as they are repelled by the negative charge of the proteneaceuos material of basement membrane

Example of proteins: fibrinogen and albumin

consisting of three layers:

Single layer of capillary endothelium.

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

Basement membrane between endothelium and epithelium.

Molecular size

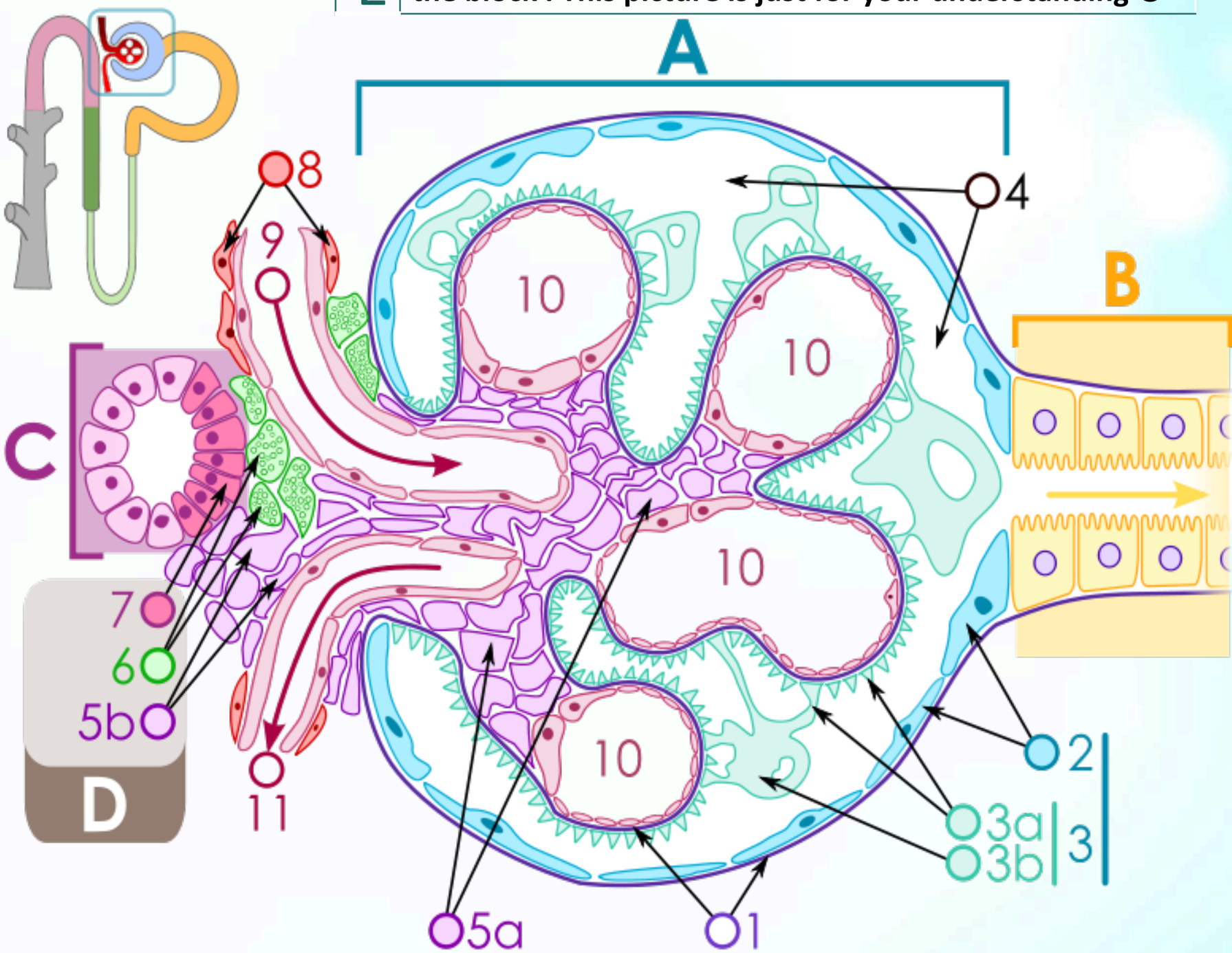
Allow passage of molecules up to 70,000 diameter

Diagram of renal corpuscle structure:

	Name of the structure
A	Renal corpuscle
B	Proximal tubule
C	Distal convoluted tubule
D	Juxtaglomerular apparatus
1.	Basement membrane (Basal lamina)
2.	Bowman's capsule – parietal layer
3.	Bowman's capsule – visceral layer
3a	Pedicels (Foot processes from podocytes)
3b	Podocyte
4.	Bowman's space (urinary space)
5a.	Mesangium – Intraglomerular cell
5b.	Mesangium – Extraglomerular cell
6.	Granular cells (Juxtaglomerular cells)
7.	Macula densa
8.	Myocytes (smooth muscle)
9.	Afferent arteriole
10.	Glomerulus Capillaries
11.	Efferent arteriole

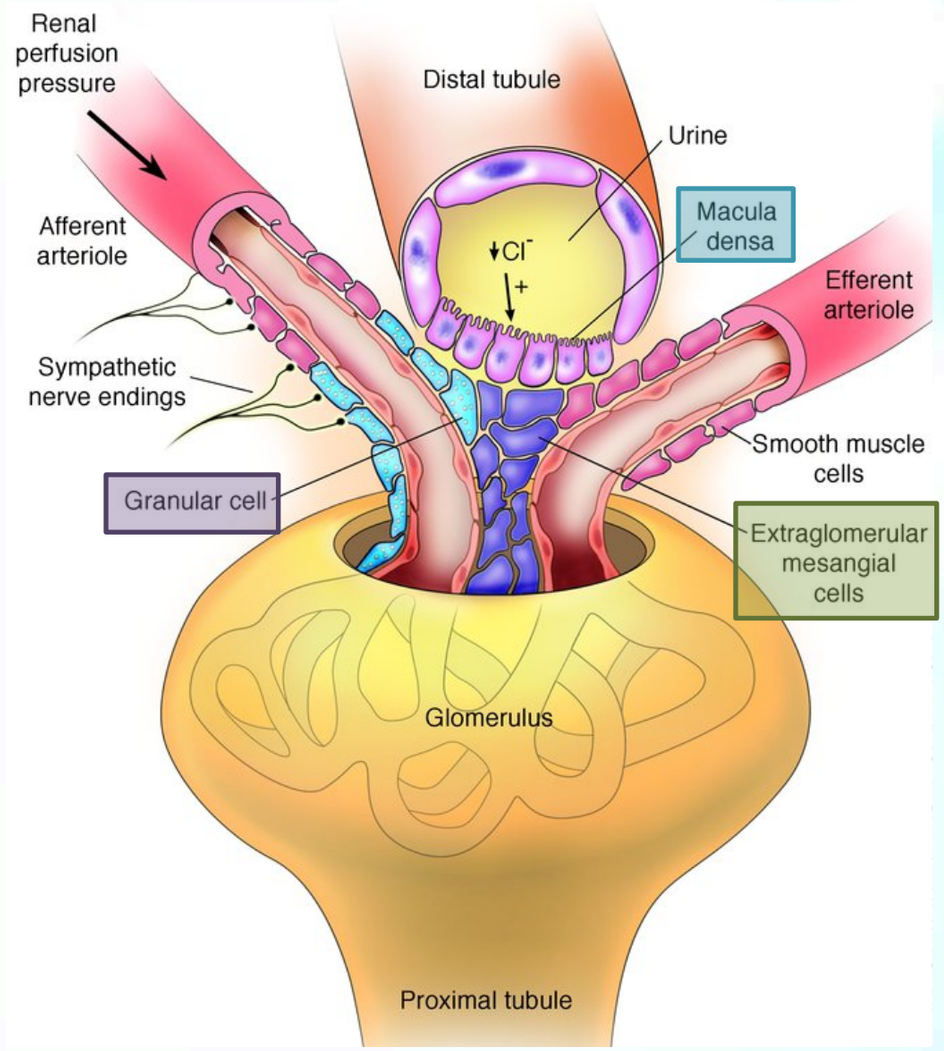
NOTE

Hopefully this illustration will help you to understand the Glomerular membrane and will help you throughout the block . This picture is just for your understanding ☺



Juxtaglomerular apparatus JGA

Structures make JGA	Description	Function in the apparatus
1- juxtaglomerular cells (Granular cells)	Specialized smooth muscle cells in the wall of the afferent arteriole have mechano-receptors for blood pressure.	Synthesize, store, and secrete the enzyme renin.
2-Macula densa	an area of closely packed specialized cells lining the distal convoluted tubule.	Sensitive to the concentration of sodium ions in the fluid.
3-extraglomerular mesangial cells	outside the glomerulus, between the macula densa and the afferent arteriole	The specific function of mesangial cells is not well understood, although it has been associated with the secretion of erythropoietin
these structures are in contact they form the monitoring structure called the juxtaglomerular apparatus		



Glomerular Filtration Rate (GFR) + Forces controlling GFR: Starling's forces

Determined by :

- The glomerular capillary filtration coefficient (Kf)=12.5
- The net filtration pressure across the glomerular capillaries.

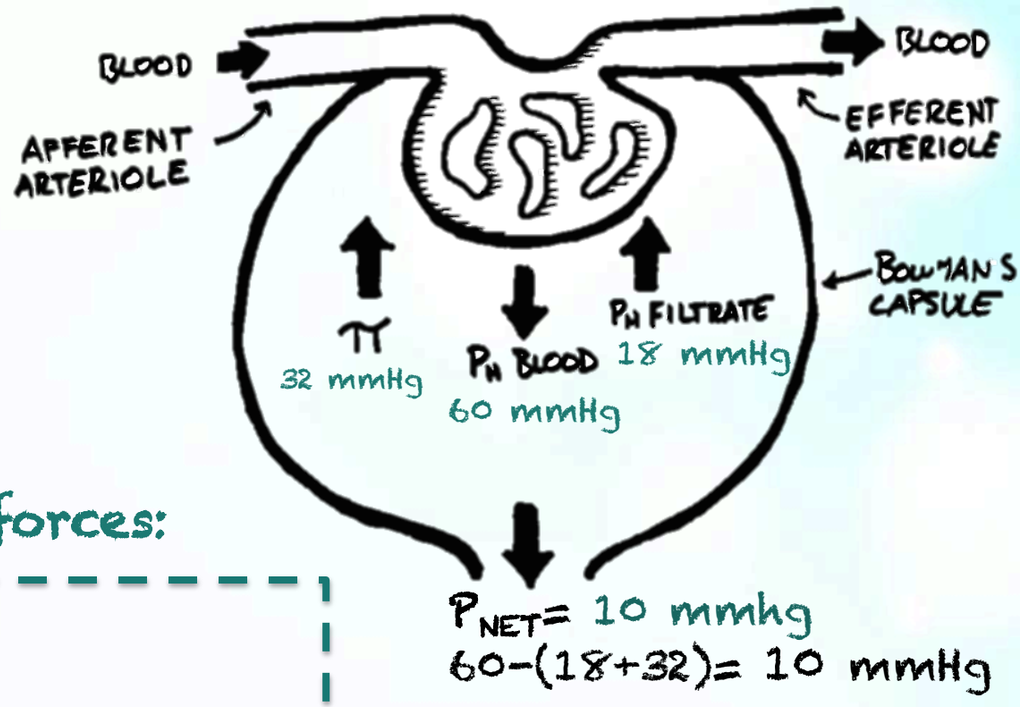
99% of filtrate reabsorbed

1 to 2 L urine excreted

GFR = Kf x Net filtration pressure.
= 12.5 X 10 = 125 ml/min
or 180 L/day

depends on

1. permeability
2. surface area of filtration barrier

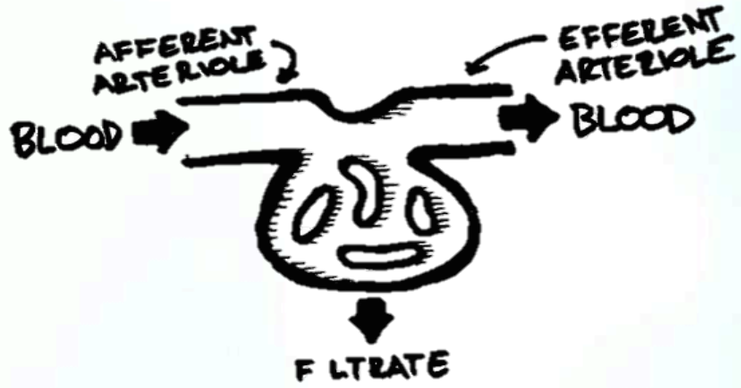


Starling's forces:

glomerular hydrostatic pressure	P_H BLOOD	= 60 mmHg	It promotes filtration.
hydrostatic pressure in Bowman's capsule	P_H FILUTRATE	=18 mmHg	It opposes filtration.
colloid osmotic pressure of glomerular plasma proteins	π	= 32 mmHg	
net filtration pressure	P_{NET}	60-(18+32)= 10 mmHg	

1ST step in urine formation

How changes in Forces determining GFR affect GFR?



Changes in Glomerular pressure

INCREASE IN…

A- **Bowman's capsule pressure** which happen in urinary obstruction:

1. Stones
2. Tumors

B-**Glomerular capillary colloid osmotic pressure**

INCREASE IN…

C- glomerular capillary hydrostatic pressure

Which is affected by:

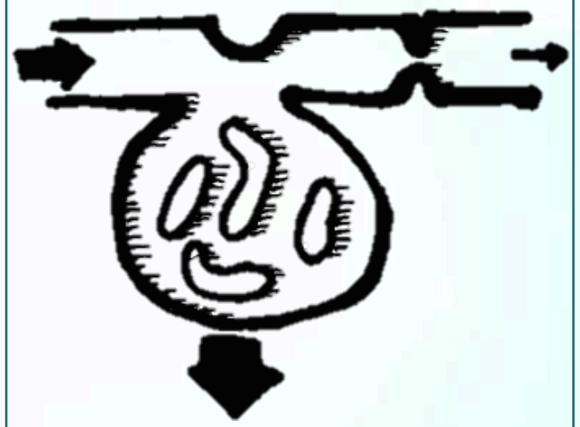
1. ABP.
2. Afferent arteriolar resistance. (DECRESE filtration)
3. Efferent arteriolar resistance(increase filtration)

How GFR is affected ?

⬇GFR

⬆GFR

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).

Afferent vasoconstriction	Efferent vasoconstriction
	
⬆ Resistance ⬇RBF ⬇GFR	⬆Resistance ⬇RBF ⬆GFR

Factors affecting Renal blood flow and GFR

↑ RBF & GFR

1. Hyperglycemia
2. Fever

↓ RBF & GFR

1. Sympathetic stimulation of renal arterioles
2. Norepinephrine
3. Aging

↑ ONLY GFR

High protein diet → ↑ amino acids → ↑ filtrate

↓ ONLY RBF

Angiotensin II (. It constricts efferent arteriole more than afferent)

Multiple choice Questions

Question	Choices	Question	Choices
Q1: The pressure in the glomerular capillaries is high because of the resistance to flow provided by the	a. Afferent vasoconstriction b. Efferent vasoconstriction c. Both A&B	**Q5:** In response to hemorrhage, which of the following is activated to decrease GFR?	a. ANP Secretion b. Renal autoregulation c. Proteinuria d. Sympathetic nervous system
Q2: A blockage in urine outflow (perhaps due to nephrolithiasis) causes an increase in the pressure in Bowman's space. How would this affect net glomerular filtration pressure and GFR?	a. Decrease b. Increase c. Nothing changes	**Q6:** Which ONE of the following cause an increase in GFR only ?	a. High protein diet b. Hyperglycemia c. Angiotensin II
Q3: The mean arterial pressure increases from 90 mmHg to 110 mmHg. What happens to **prevent** an increase in the pressure in the glomerular capillaries?	a. Constriction of afferent arteriole b. Constriction of efferent arteriole c. Dilation of efferent arteriole d. Both A or C	**Q7:** If the hydrostatic pressure in Bowman's capsule is 18 mmHg and glomerular hydrostatic pressure is 70 mmHg while the colloid osmotic pressure is 32 mmHg . How much is the net filtration pressure across the glomerular capillaries?	a. 10 mmHg b. 20 mmHg c. 30 mmHg
Q4: Renal blood flow to the kidney represents how much of cardiac output?	a. 12% b. 15% c. 20%	**Q8:**From the previous question , knowing the net filtration pressure across the glomerular capillaries, how much is the GFR ?	a. 125 ml/min b. 250 ml/min c. 375 ml/min
Answers: Q1-b ….. Q2-a ….. Q3-d ….. Q4-C		Answers: Q5-d ….. Q6-a ….. Q7-b ….. Q8-b	