ANATOMY

☑ Sheet ○ Slide ○ Handout

Number

1

Subject

Anatomy

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Price:

بسم الله الرحمن الرحيم وبه دوماً نستعين

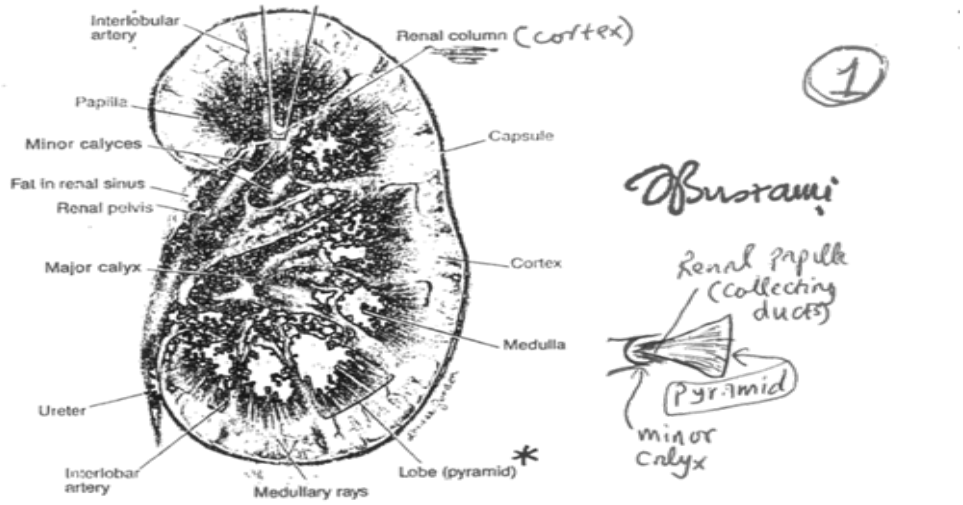
Correction notes before we start:

1- We have all to forget about the Habal we went through in the first, second years, the previous semester and the CNS, so study well.
2- You will read repeated info too many times through this sheet, I've put them because I believe in التكرار بيعلم الشطار, if you don't just forgive me.

This sheet was written based on section's (1) record.

<u>We are going to start with the Urinary System:</u>

• If you look at a longitudinal section in the kidney, you can differentiate The Outer Cortex and Inner Medulla, here the medulla looks darker than the cortex because it is stained, but in a fresh sample the medulla will be pale and the cortex will be dark. The Medulla is made up from a lot of pyramids (on average around 10 pyramids), if you look at a fresh state of a kidney the **pyramids** will look striated and the Cortex is granular (for reasons discussed later). The Pyramid has an apex and a base. The apex is called **Renal papilla** which projects in something called **Minor Calyces**, While the base has a horizontal line called **medullary base**.

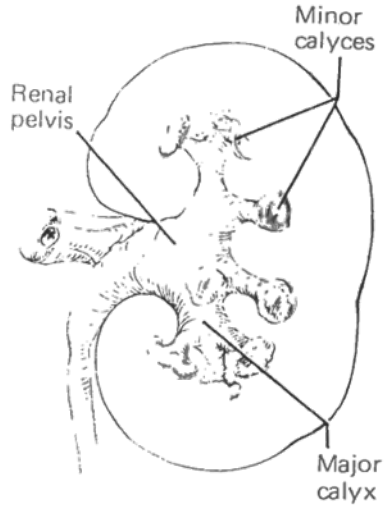


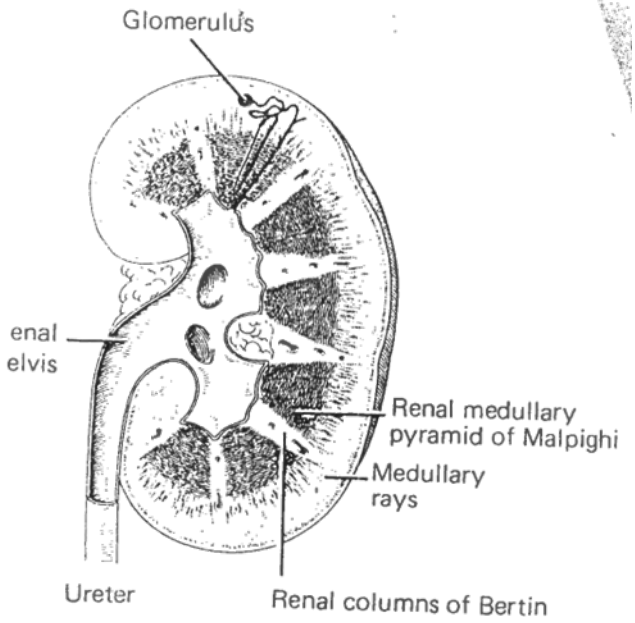
Again; by looking to the figure above we find the Outer cortex, the Inner medulla which has on average 10 pyramids (some books states that they are 7-12 pyramids but we are concerned with the average). Parts of the cortex run between the pyramids and they are called The Renal Columns.

Not all the cortex is located at the outer layer, part of it enters the medulla forming **Renal Columns** between the pyramids.

The **Ureter** is coming out from the kidney. Inside the kidney, once the ureter enters it forms Renal Pelvis OR Pelvis of ureter then it divides into (2-3) **Major Calyx** (تجويف).

Each major calyx divides into number of Minor Calyces (around 10), and each minor calyx receives the projections from the apex of the pyramid (renal papilla), this is the end station of the urine pathway (later on we will study the formation of urine, and we will see that the last step will be that the urine will pass through the apex of the pyramid> to the minor calyces> to the major calyces> then to the ureter and then downwards to the urinary bladder).





Remember that the area of the ureter which is found inside the kidney is called The **Pelvis** of ureter and its part of the Ureter, in the past it was named as The Renal pelvis (حوض الكلية), stating that its part of the kidney and that's WRONG as its part of the ureter. The Renal pelvis or as the doctor prefers The Pelvis of ureter divides into 2-3 major calyces and each major calix divides into a number of minor calyces, and each one of these minor calyces receives from the apex of the pyramid which is the end station of the urine pathway.

Each kidney is formed of around 1 million of microscopic structure called **Uniniferous tubules**.

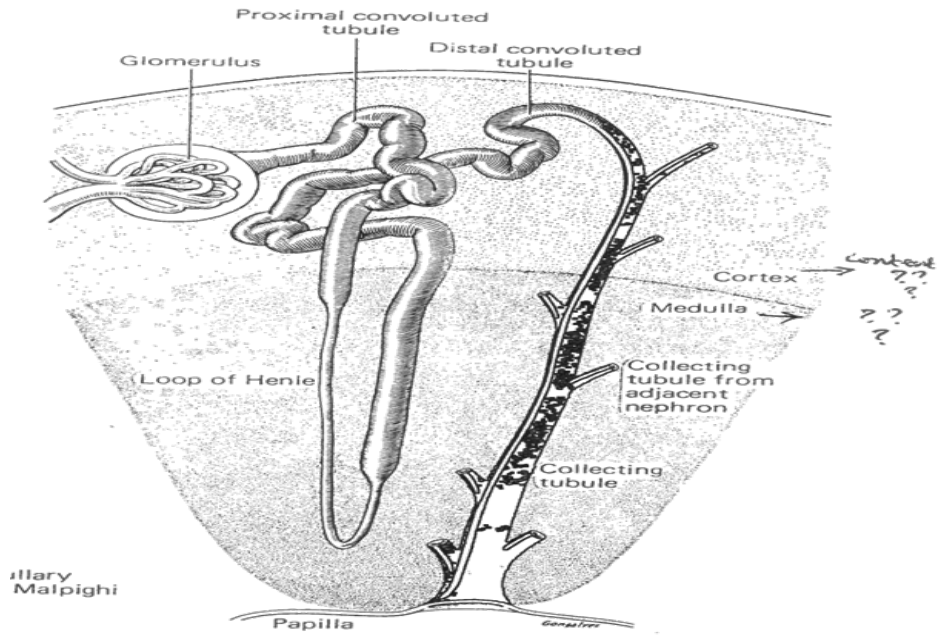
- Parts of the **Uniniferous tubules**:
  Nephrons and collecting tubules and Duct (functionally they are related to each other but developmentally they are of different origins, The Collecting duct is not part from the nephron).

- Parts of the **Nephron**:

Renal corpuscle: A network of capillaries receiving the blood through Afferent arterioles and sending it through efferent arterioles.

(Afferent arterioles > Capillary (glomerulus) > Efferent arterioles)

*Whenever we hear about the Glomerulus we remember the FILTRAITION of the plasma.



The main function of the kidney is filtration. The Filtrates (which is going to form urine) = plasma - plasma proteins, meaning that everything in the plasma (glucose, amino acids, Na+, K+, bicarbonate…) will filtrate except Plasma Protein in a healthy Kidney.

Not all The filtrates will become Urine as we will Absorb back most of the Vital elements; Glucose for example will be absorbed completely, 99.5% of Na+ will be absorbed, and 99% of the water too. So each filtration process will be followed by Reabsorption.

This **Renal corpuscle** is a group of capillaries responsible for Filtration of Plasma Not Blood (meaning that there is no WBC and RBC in the filtrate).

Around these Capillaries/Glomerulus there is a space called **Bowmen's Space of Bowmen's Capsule**. At the beginning of the filtration process the filtrates will accumulate in Bowmen's space, then Bowmen's capsule will link to the second part of the nephron which is called **Proximal convoluted tubule**.

The Proximal tubule is found on the cortex then descends downwards to the medulla (pyramid) forming **loop of Henle** (has thin segment and thick segment) then ascends up to the cortex again forming Distal Convoluted Tubule Then The distal tubule opens in The Collecting tubules and ducts.

- What are the contents of The Renal Cortex?

1. Renal Corpuscle (by gross looking at the renal cortex it appears as granular, those granules are Renal Corpuscle).

2. Convoluted tubules (proximal and distal tubules).

3. Medullary Rays (extension of collecting tubules in the cortex that receives the distal tubules from different nephrons).

- What are the contents of The Medulla?

1. Renal medulla (renal pyramid).

2. Loop pf Henle (thin segments and thick segments, both differ in their functions).

3. Collecting tubules (small) and ducts (large). Once the filtrates reach the collecting tubule it is Called Urine, and as we said NOT all the filtrate become urine and we absorb most of it, because without the absorption the person will have

severe dehydration within few hours. The more absorption of water from the filtrate, the more concentrated urine will be produced. So the main function of the collecting tubules is Concentration of urine.

Remember that the hormone responsible for the reabsorption of water from the urine and increasing the permeability of the collecting tubules to water is the ADH (antidiuretic hormone).

4. Vasa recta (blood vessels).

HOW we can produce a concentrated urine (preserving body fluids) ? this requires 4 important factors:

1- Loop of Henle that helps in reabsorption of water by making a Hypertonic/ Hyperosmolar medium around collecting tubule by concentrating the salts over there, so the water will move by osmosis out from the collecting tubule back to the blood.

2- Collecting tubule.

3- Vasa recta.

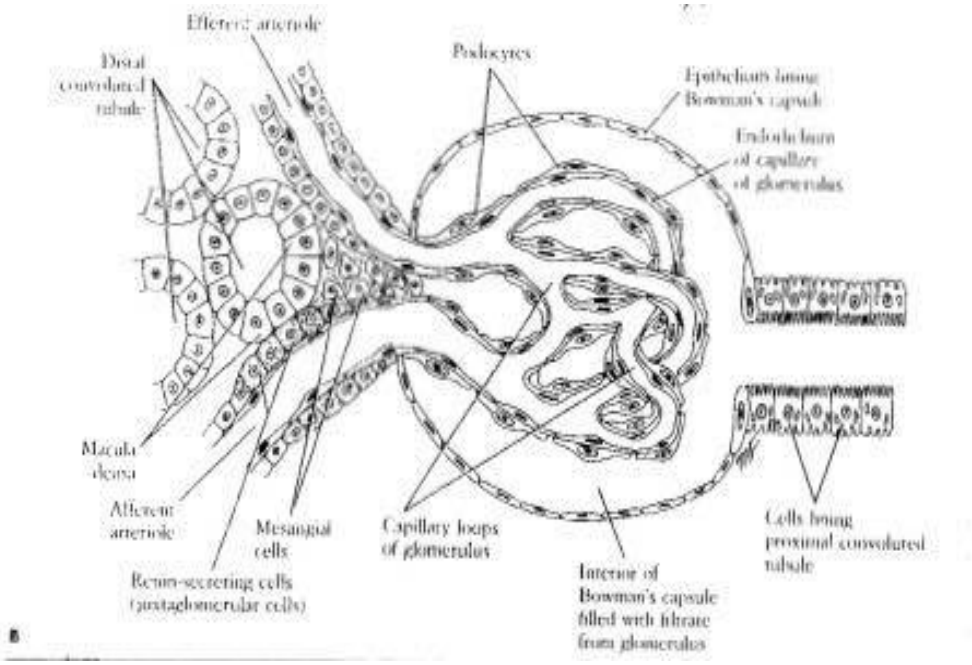
4- ADH (anti-diuretic hormone) that increase the permeability of collecting tubules to water, thus increasing the reabsorption of water and getting It back to the blood.

Now, let's define certain terms:

- **Renal Lobe**: The Renal pyramid with the cortical tissue that overlies its base and lying along its side (renal columns).
- **Renal Lobule**: Is the medullary ray (collecting tubule in the cortex) associated with the distal tubules opening in it (the end of the nephrons). Each renal lobule is separated from its neighbor by an Interlobular artery.

Wiki definition The renal lobule consists of the nephrons grouped around a single medullary ray, and draining into a single collecting duct.

By looking to the figure below, we can see the renal corpuscle (the glomerulus surrounded by Bowman's space): we said that the blood enters the kidneys through large afferent arteries then through the glomerulus (a group of capillaries responsible for filtration) and then leaves thorough efferent arteries. Each glomerulus is surround by bowmen's capsule and once the filtrate emerges from the capillary it accumulates in Bowmen's space.



Bowmen's capsule is made up from two layers (between them we find the Bowman's space):

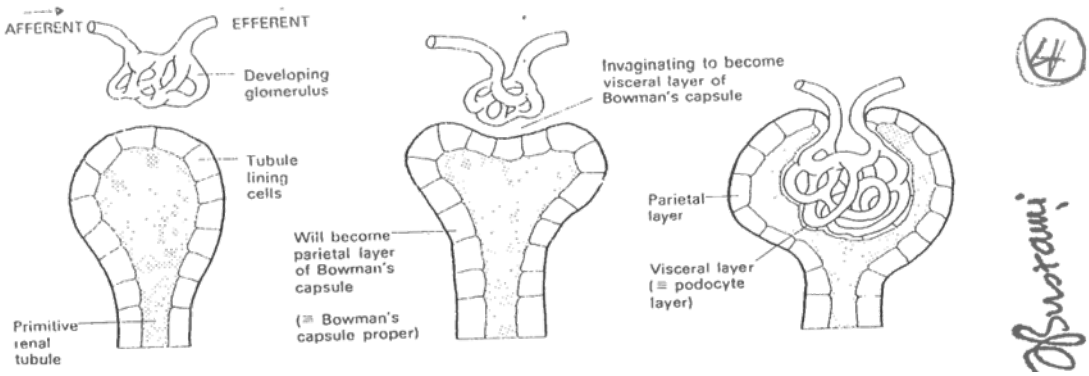
1- Parietal layer (which is simple squamous epithelium, then it changes to Cuboidal at the beginning of The Proximal convoluted tubule).
2- Visceral layer (Podocytes, star-shaped cell) aids in the formation of The Filtration layer.

Filtrates (plasma - plasma proteins) pass through several layer to reach the bowmen's space which are:

1) The **endothelium** of the capillary (glomerulus) which is fenestrated epithelium resting on the basement membrane.

2) **Visceral layer (Podocytes)** of bowmen's capsule. Those layers together are Called the Filtration barrier. Specific part of the afferent artery has a role in the renin-angiotensin system, this part is called Juxtaglomerular apparatus responsible for the release of Renin that converts Angiotensinogen into Angiotensin1 (the rest of the story will be discussed later on). Also, the part of the distal tubule which is found between the afferent and the efferent is called the Macula Densa (also will be discussed later on).

- **In the early stages of development:**



A network of capillaries will be pushed into the bowmen's capsule, the layer of the Bowmen's capsule that covered the capillaries is called visceral layer (Podocytes) and the remaining outer one which doesn't come in contact with anything is The Parietal layer, in between them there is the Bowmen's space.

زي لما تفعص ايدك في بلون، البلون هو عبارة عن الBowman's capsule و إيدك هي الcapillaries، الجزء من البلون اللي غطى ايدك رح يكون الvisceral layer والجزء المتبقي هو الparietal layer والفراغ اللي بينهم هو الBowman's space.

The Podocytes (visceral layer) hanging on the wall of the capillary (fenestrated endothelium and basement membrane) have extensions radiating from the cell body called the primary processes which further branch to secondary processes (foot processes).

The capillary's wall from inside is made up from fenestrated endothelium (fenestrated = spaces helping in filtration) laying on basement membrane, then the Podocytes which have primary and secondary processes, between the secondary processes (Foot processes) there is spaces closed by a diaphragm.

All of these layers are called The **Filtration barrier**. [Filtration barrier = fenestrated endothelium + basement membrane + the diaphragm between the

foot process]. This filtration barrier allows all the components of the plasma to pass except the plasma proteins.

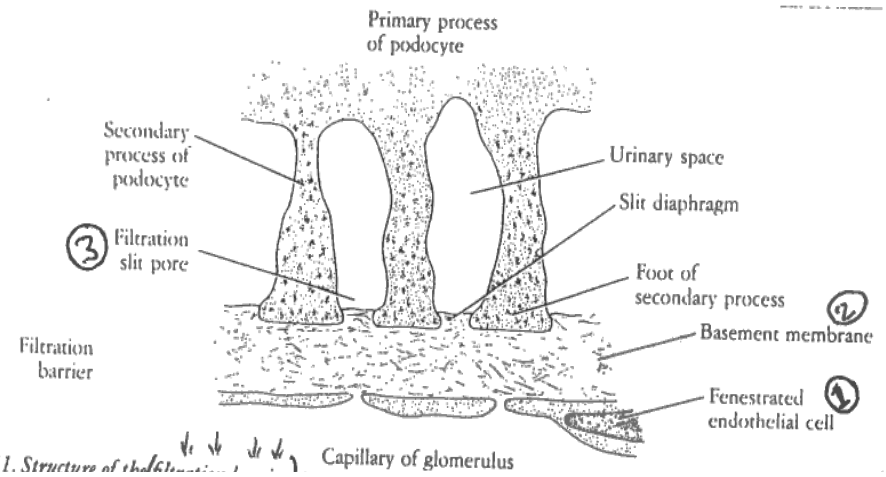


Fig. 13-11. Structure of the

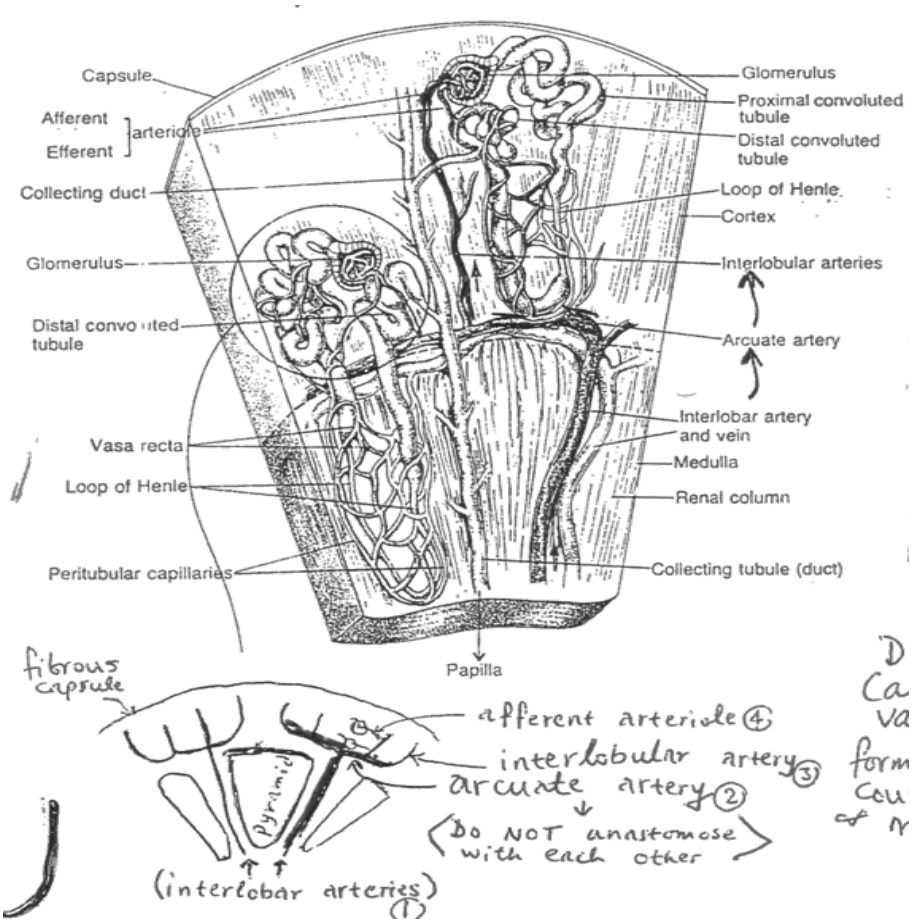
We should know that the filtration process doesn't depend only on the molecular weight of the molecule, the albumin's molecular weight for example allows it to pass but because of its negative charge it will not pass through the filtration barrier. So the Filtration Process Depends on the Molecular weight (size of the filtrate) and the Charge of the molecule. -We have said that the glomerulus/ renal corpuscle is a network of capillaries surrounded by Bowmen's capsule, between the capillaries there is connective tissue called **intra-glomerular Mesangium**; it's function is to support the wall of the capillary. Also, there is Phagocytic cells. If proteins passed through the capillaries due to a certain pathological condition, it will be phagocytosed by those phagocytic cells.

The Blood Supply OF the Kidney:

Blood supply of kidney is important for the filtration process. Renal Artery originate from the abdominal aorta at the Right Angle (at High blood Pressure), once the renal artery reaches the kidney it divides into: anterior division and posterior division. Then the anterior division gives four segmental arteries, and the posterior division gives one segmental artery. [Those segmental arteries are **Anatomical Ends Artery** meaning that there is no anastomosis between them. If one segmental artery got occluded by a thrombus for example, the part of the kidney supplied by it will dye].

Now, each Segmental artery gives two lobar arteries (the total number of lobar arteries = 10), then those lobar arteries go towards the lobe/pyramid giving Inter-Lobar arteries that go to Renal lobe (continuing on the margins of the pyramid-على الجوانب). This inter-lobar artery reaches the base of the pyramid and divides in a T-shape manner giving the Arcuate arteries, which further divide into Inter-lobular arteries. Each inter-lobular artery forms a large afferent artery that forms capillary plexuses (glomerulus) and comes out as a small efferent artery. The efferent artery forms a capillary plexus around the convoluted tubules (proximal and distal) called the peritubular capillary plexuses or Vasa recta (will be explained later on through this sheet).

So, in the kidney there are two capillary plexuses: **Glomerulus for filtration** and **Peritubular plexuses for reabsorption**.



Remember from the CVS that the main factor in the reabsorption process is the **Blood pressure/Hydrostatic pressure** in the capillaries (القوة الدافعة) which is responsible for filtration, opposed by the **oncotic pressure of plasma proteins** which is constant in healthy individuals and responsible for reabsorption.

How is that?

When the blood reaches the glomerulus through large afferent arteries, filtration will occur due to the High blood pressure in comparisons with oncotic pressure, now the filtrates are in the Bowmen's capsule and what remained in the blood are plasma proteins, so oncotic pressure will become higher than blood hydrostatic pressure in the peritubular capillary plexuses so reabsorption will occur rather than filtration.

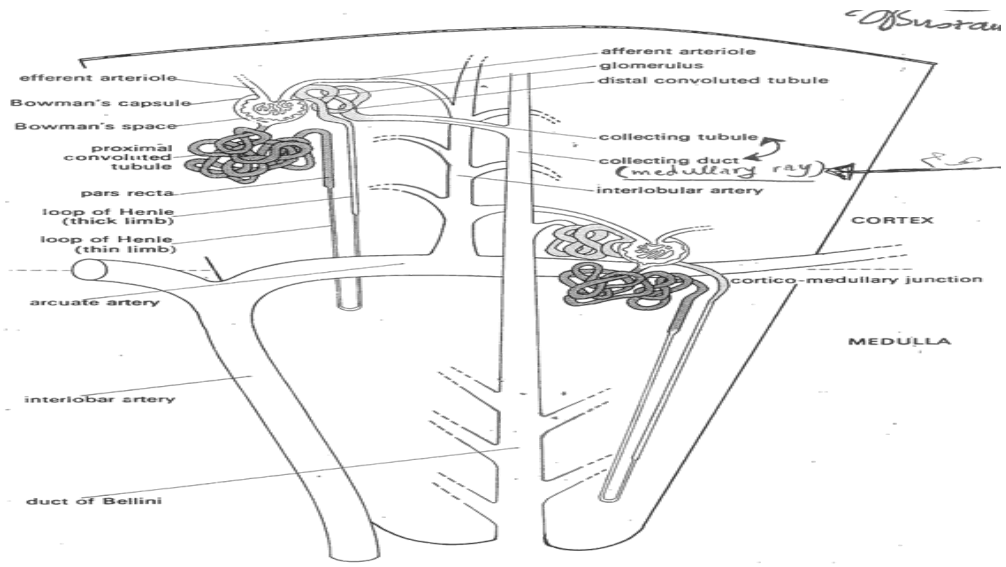
- **There are two types of nephrons:**

1. **Cortical nephron** (in the outer part of the cortex).
2. **Juxtamedullary nephron** (near to the medulla).

Juxtamedullary nephrons form 15% of all nephrons in the kidney, their loop of Henle goes deep down in the medulla and its mainly responsible for the formation of Concentrated Urine = conservation of body fluids. This process avoids severe dehydration from occurring as in diabetes insipidus patients. The efferent artery emerges from the glomerulus forming capillary plexuses that surround the convoluted tubule and loop of Henle called Vasa Recta which has descending and ascending limbs, it’s function will be discussed later.

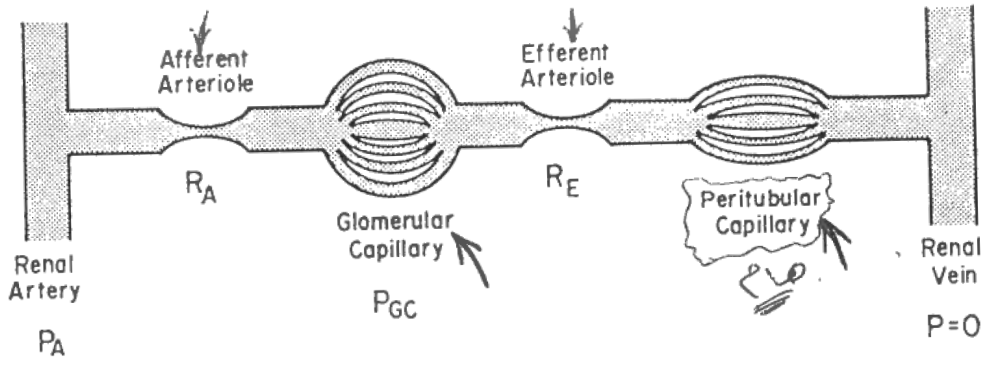
On the other hand, the loop of Henle of the cortical nephron barley reaches the medulla, and the capillary plexuses that form from the efferent artery which surrounds the conventional tubule is called the peritubular capillary plexus and it functions in reabsorption.

The Vasa recta in the medulla meets Peritubular capillary plexuses in the cortex.



The Renal Artery's blood flow is 1200 ml/min (equaling 1/4 cardiac output), this huge amount of blood doesn't enter to nourish the kidneys only, but it enters in order to be filtrated and get rid of toxic materials and other unwanted substances. Most of the blood entering the kidneys remain in the cortex (95% of blood), very minimal amount of it goes to the medulla (only 5 % of blood) because if large amounts of blood enter and leave the medulla (البحر الميت) continuously, it will reduce the hyperosmolar medium there through the removal of ions by the flowing blood, leading to a reduction in the reabsorption of water from the collecting tubules. While in the juxtamedullary nephron; the afferent entered and left as efferent, and this efferent forms something called vasa recta which descends in the medulla. So the vasa recta is the same as the peritubular capillaries in the cortex. We are going to learn later on that the vasa recta has both ascending and descending limbs (the descending limb forms the arteriole and the ascending forms the venule), those vasa recta surround the loop of Henle and surround the collecting ducts. (the function of the vasa recta will be discussed later on).

When we say that there are two capillary plexuses, means that kidney has **Portal Circulation**. [afferent artery > capillary plexuses (glomerulus) > efferent artery > peritubular capillary plexuses in cortical nephron/Vasa Recta in juxtamedullary nephron].



As we said that **loop of Henle** is the main structure in the medulla and has an important role in the formation of a hyperosmolar medium> for reabsorption of water, they function with the help of the **vasa recta**, and who get benefit from this are the **collecting tubules**. also, **ADH** has a role in the production of concentrated urine> conservation of body fluids (Those are the 4 main important factors). Rodents (القوارض) and animals living in the desert have very long loop of Henle in order to conserve their body fluids and produce highly concentrated urine as an adaptation to their environment.

As we said, we have cortical nephron and juxtamedullary nephron; Which one goes deeper in the medulla and has a very long loop of Henle? The juxtamedullary nephron. Which one has an important role in the concentration of urine? The juxtamedullary nephron.

Also we said that we have two sets of capillaries in the kidney:

1- glomerular capillaries, with a huge afferent arteriole and a tiny efferent arteriole to increase the pressure of the blood passing through them.
2- peritubular capillaries surrounding the convoluted tubules. Also, there are two opposing forces; the Hydrostatic pressure of blood within the capillary (the main driving force which is continuously changing) and the Oncotic pressure which is relatively constant. So when blood flows with a certain concentration of proteins and filtration of plasma contents except proteins occurs, the concentration of proteins in plasma will increase, then we reach

the peritubular capillaries with this high concentration of proteins which will oppose the hydrostatic pressure of the blood and reabsorption will occur.

The blood entering the kidney flows within two capillary beds:

1- glomerulus inside the Bowman's capsule, it is the main site for filtration.
2- peritubular capillaries in the cortical nephron for reabsorption, on the other hand in the juxtamedullary nephron they are called vasa recta with the same function. The vasa recta in the medulla receives very small amount of blood (5%) and 95% will stay in the cortex and this is important for the preservation of the hyperosmolar medium in the medulla.

The total amount of blood entering each capillary is 1100-1200 ml/min which is 1/4 cardiac output. The amount of plasma of this blood equals 57% (625 ml of plasma/min enters the kidneys). Only 20% of the plasma entering the kidney will undergo filtration (almost = 125 ml/min) and this is a huge amount so this filtration process should be followed by reabsorption. Now, 124 ml/min will be absorbed, so only 1 ml/min will become Urine (this number may vary between 0.5- 20 ml/min, for example a fasting person may produce 0.5ml/min urine, while a diabetes insipidus patient may produce 20ml/min). Again, the GFR (Glomerular Filtration Rate) = 125 ml/min and 1 ml/min only will form urine, in other words, 99% of the filtrate will be reabsorbed (99.5% of Na+ will be absorbed, 99% of water and all glucose and amino acids are absorbed).

***In conclusion**: 1 ml/min of filtrate will become urine> 1.5-liter urine everyday (average of urine formed each day).

Clinical Correlation: If you checked a urine analysis test for a patient and noticed high amounts of amino acids, this predicts a pathology (urine should be protein free), because 99% of the filtrate will be absorbed back as well as glucose, 99.5% of Na+ will be absorbed, amino acids are completely absorbed…etc.

Revision:

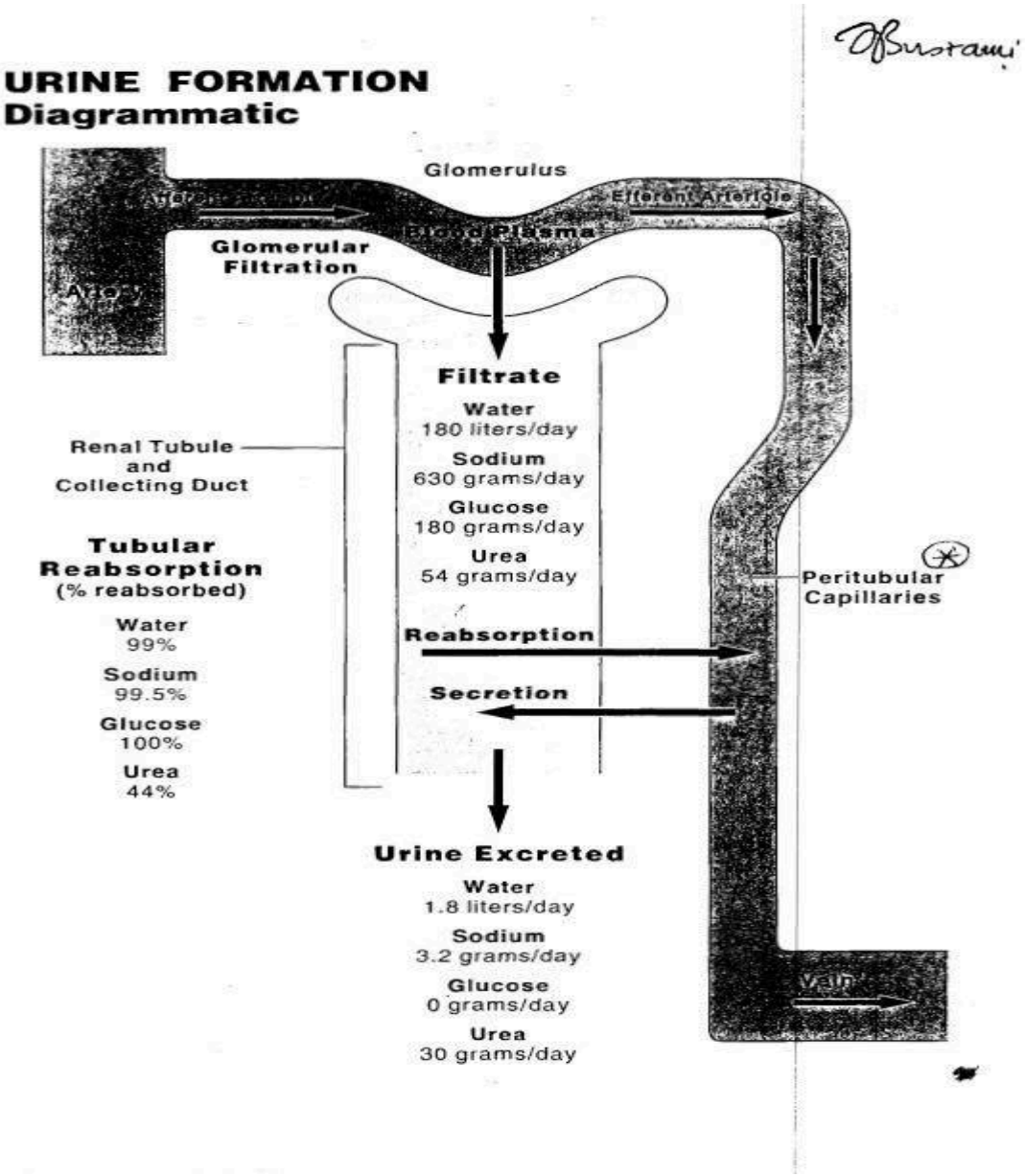
- Large afferent arteries enters the glomerulus and small efferent arteries so this will create high blood pressure aids in the filtration in the first beds of capillary in the kidney> Glomerulus.
- then that efferent artery form peritubular artery around convoluted tubule in the cortex aids in the reabsorption and secretion (due to the high oncotic pressure in comparison of hydrostatic pressure). While this efferent artery forms vasa recta in the medulla that surround convoluted tubule aids in the concentration of urine.
- There is two types of nephron: Juxtamedullary nephron> concentration of urine.

- Renal Lobe = pyramid and the cortex around it.
- Renal Lobule = medullary rye (a group of collecting ducts/ Tubules) +nephrons draining in it through its distal end.
- The Renal Lobule located between two interlobular arteries.
- Cortex contain parts from the collecting tubule in order to receive filtrate from distal artery but in this part of collecting tubule there is no concentration of urine because it is not surrounded by hyperosmolar medium, and it only collects the urine.

Urine Formation:

- The blood enters through the afferent arteriole forming capillary plexus/ glomerulus, then filtration occurs in the glomerulus and then the afferent arteriole emerges forming peritubular capillary in the cortical nephron :

1- filtration in glomerulus by the effect of the capillary's blood pressure (hydrostatic).
2- reabsorption in peritubular capillary plexuses due to the high oncotic pressure.
3- Secretion, which is another function to the peritubular plexuses. Things that doesn't filtrate in glomerulus will filtrate in the peritubular capillaries such as drugs (antibiotics).



This is all what we have for today's lecture, sorry for any mistakes and good luck ❤️