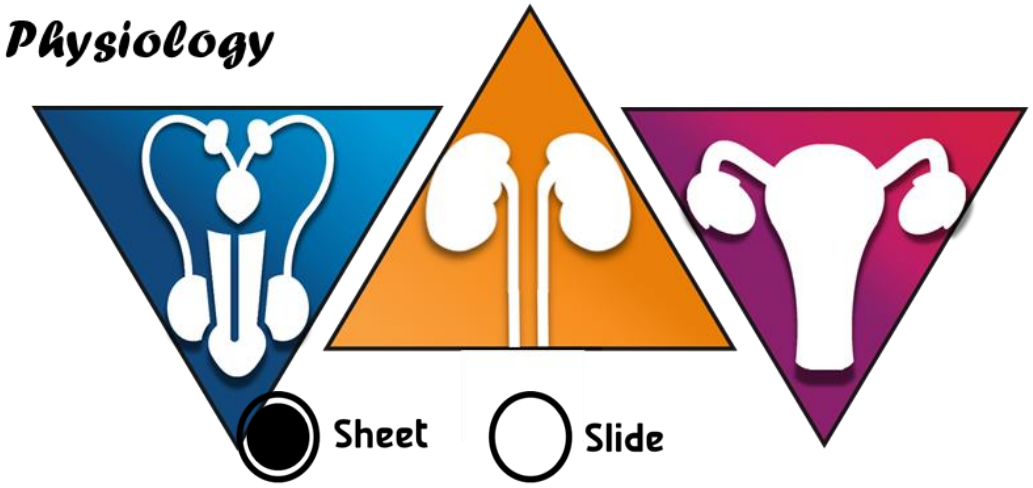
Urogenital system



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Since most lectures are repeated from the last year, I copied the included topics from 2015 1st sheet and modified it according to section 2 record. Sorry for any mistakes or missed information though I tried my best to include everything.

In this lecture we are going to talk about the following topics:

-Kidney is an essential organ for life.

-Renal circulation.

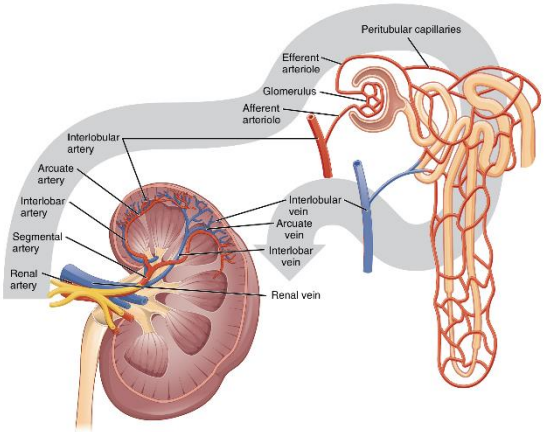
-Kidney composition.

-Renal blood flow vs renal plasma flow.

-Urine formation processes.

-GFR.

-Starling forces.



So, let's start our discussion, ***<u>kidney is essential for life</u>*** due to several reasons:

-Homeostasis of the electrolytes: one of them is potassium, so kidney failure causes hyperkalaemia which causes severe cardiac arrhythmias.

- Remove waste products and foreign chemicals like urea, creatinine and uric acid

- Acid-base balance (Hydrogen homeostasis)]: Kidney failure causes acidosis (accumulation of Hydrogen).

- Regulate fluids volume of the body, and thus, blood pressure: Kidney failure causes retention of fluid and thus high blood pressure which causes edema (pulmonary edema is fatal).

- Secrete hormones such as erythropoietin, which is important for erythropoiesis; Kidney failure causes anemia.

- Convert 25-hydroxycholecalciferol into 1,25-dihydroxycholecalciferol (calcitriol), the most active form of vitamin D; Kidney failure causes Calcium disturbances

- Gluconeogenesis (conversion of non-sugar sources, particularly amino acids, into glucose).

- Secretes renin, which is important for controlling blood pressure, through angiotensin- aldosterone system.

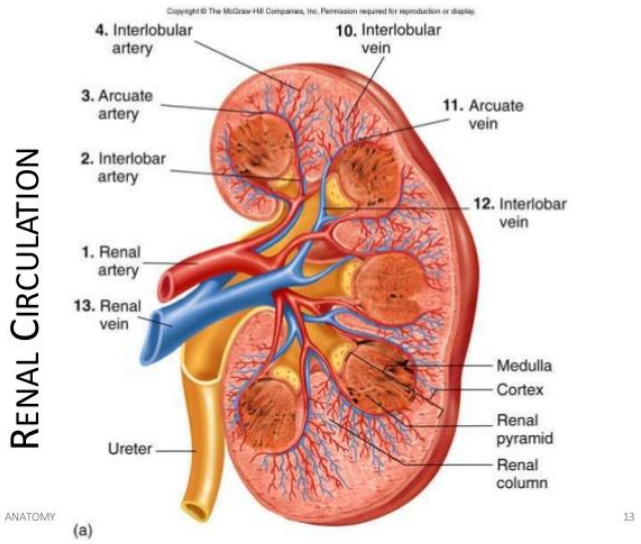
* Another evidence on the importance of the kidney: it is a target for many hormones such as Aldosteron and ADH.

Kidney is **a reconditioner organ** which means that kidney receives blood not only for the supply of oxygen and nutrition, but it also changes in the composition of the

blood, and there for it receives **too much blood flow** it receives 25% of the cardiac output through renal arteries.

Renal circulation:

• The renal artery (the fifth branch of the aorta) enters the kidney through its hilum and divides many times to form segmental arteries (five in number) → interlobar arteries → arcuate arteries → interlobular arteries (cortical radiate arteries).

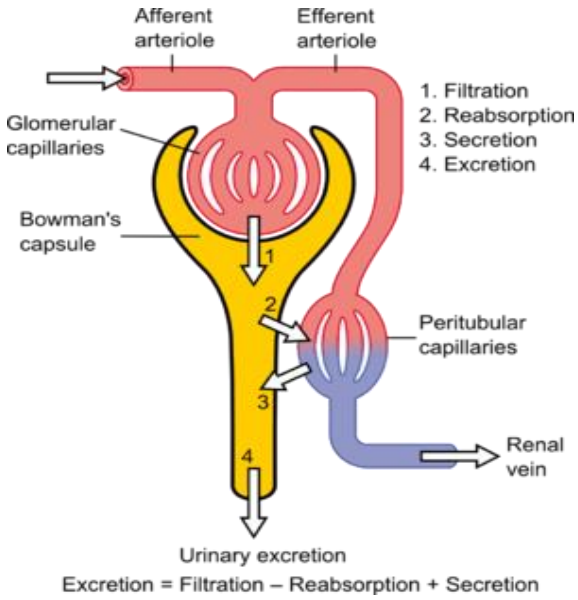


• Interlobular arteries divide again into many afferent arterioles.

• Each afferent arteriole enters a glomerulus and divides to form the glomerular capillaries.

• The capillaries converge again to form efferent arterioles

• Efferent arterioles leave the glomerulus and divide, once again, to form peritubular capillaries.



• Peritubular capillaries re-join to form interlobular veins → arcuate veins → interlobar veins.

• Interlobar veins join to form the renal vein which leaves the kidney through its hilum.

** Note that the glomerular capillaries did not form venules, but instead efferent arterioles, which divide again (instead of converging) to form other capillaries.

This is known as the portal circulation.

Renal composition:

Kidney is composed histologically of two regions:

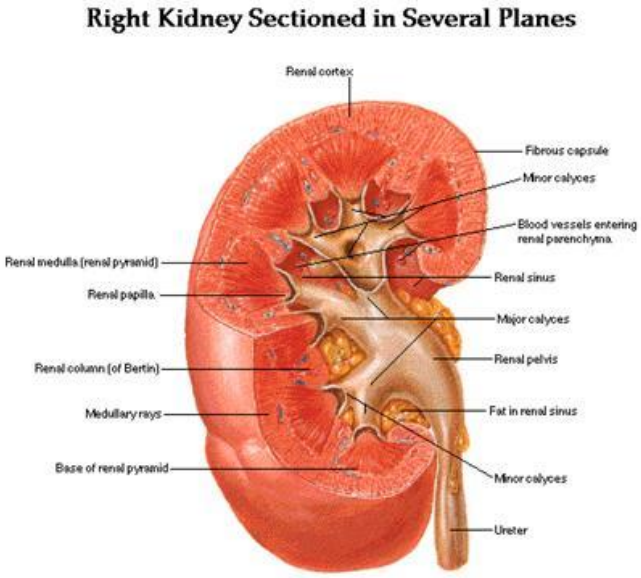
1-cortex: granular, contains glomeruli (million), darker in colour since it has a rich blood supply. "cortical atrophy means kidney damage"

2-medulla: striated, contains tubules.

3-corticomedullary border.

Microscopic features:

Each kidney contains one million nephrons (tubule) which consists of a renal corpuscle and a renal tubule; and a renal corpuscle consists of Bowman's capsule surrounding a network of glomerular capillaries (glomerulus) which receives blood through the afferent arteriole and then the blood leaves through efferent arteriole. the renal tubule consists of a proximal tubule, loop of Henle, distal tubule and a collecting duct. The tubule is 6cm long. We divide it into two parts; one is for ultra-filtration and one for modification (secretion and reabsorption) and then the urine is excreted. So, Excretion= Filtration + Secretion – reabsorption.



** an abnormality in the kidneys is either in the glomerulus responsible for filtration (glomerulonephritis) or in the tubules responsible for modification (tubulonephritis).

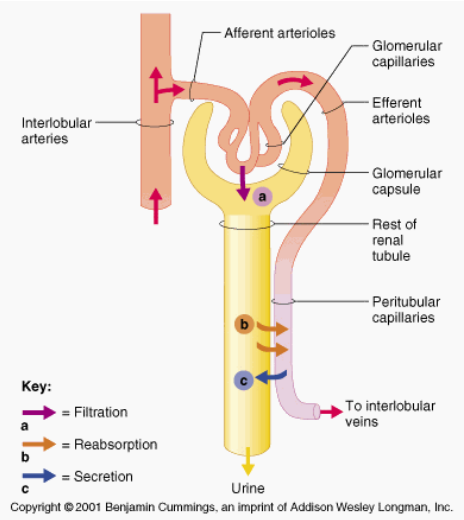
** Also, Renal atrophy is a kidney disorder where the kidneys are relatively small in comparison to the gender, age and body weight of the patient

So, ***Renal formation processes*** are:

1-glomeruler filtration: movement of fluid (plasma) from the glomerular capillaries to bowman's capsule, this process is **passive**.

2-tubular reabsorption: movement of substances from tubules to the peritubular capillaries.

3-tubular secretion: movement of substances from peritubular capillaries to tubules.



Urine = glomerular filtration+ tubular secretion – tubular reabsorption.

Renal blood flow vs renal plasma flow

Renal Blood Flow (RBF): Defined as the volume of blood entering both kidneys per unit time.

Kidneys are small (150gm each), yet they receive the highest blood supply in the body; out of the 5L/m cardiac output, 1250 ml goes to both kidneys (renal arterial blood flow) that is 25% of the cardiac output However, unlike other tissues, O2 and nutrients concentrations do not decrease significantly as the blood leaves the kidneys.

Renal Plasma Flow (RPF) which is volume of blood plasma delivered to the kidneys per unit time. And it equals 55% of the blood flow (assuming that hematocrit is 45%) this equals 650 ml roughly, so 650 ml of plasma enters the kidney every minute and 649 ml leaves the kidney and only 1 ml is extracted as urine each minute So urine output is 1ml/minute = 60ml/hr = almost 1.5 liters per day.

Although 650 ml/m of plasma enters the glomerulus → only 125 ml/m is filtered, so the filtration fraction is 20%.

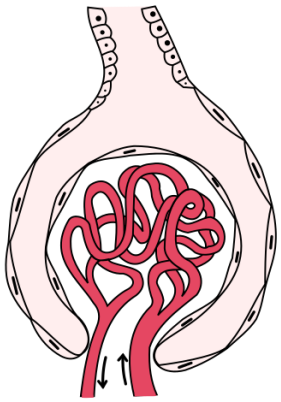
Hence that the kidney has two outputs:

1) The renal venous blood flow (1249 ml per min)
2) Urine output (1ml per min)

Glomerular filtration rate (GFR):

Glomerular Filtration Rate (GFR) is the volume of plasma filtered from the glomerular capillaries to Bowman's capsules per unit time which equals 125 ml/m in male adults. We use GFR as a tool to tell us how much kidney function we have, and we classify kidney failure into 4 stages according to GFR:- - 50-100% decrease renal reserve (homeostasis is perfectly controlled, so 1 million nephrons are enough) - 20-49% Renal insufficiency - 5-19% Renal failure (survive with some modifications and medicines) - >5% End stage renal failure (without transplantation or hemodialysis the patient cannot survive) ** 100% equals 125ml per minute.

**GFR is a rate = driving force = pressure difference/resistance or pressure difference x permeability.



Bowman's capsules: is a cup-like sack at the beginning of the tubular component of a nephron in the mammalian kidney that performs the first step in the filtration of blood to form urine. A *glomerulus is enclosed in the sac* to make sure that all the blood that gets out of the glomeruli goes to the tubule and nothing goes out.

Recap: The blood enters the kidney via the renal artery which is then divided into many parts forming eventually the glomerular capillary, the glomerular capillary is enclosed in bowman's capsule which is the beginning of the nephron and it marks the beginning of the **filtration** process. The glomerular filtration is **a passive process** meaning it is a bulk flow(الجمل بما حمل) . 1250 ml of blood goes to the kidney per min but the filtration is for the plasma not for the blood, as we said previously 55% of blood consists of plasma and 92% of plasma

consists of water, so we can conclude that filtration is mainly for water and some components of plasma, not all of them.

As you can see filtration occurs to the plasma not to the whole blood (we do not pay attention to the 45% of blood cells since they are not filtered), so it is more accurate to use the term **renal plasma flow** rather than renal blood flow.

Conclusion: The renal plasma flow as we said previously equals 650 ml per min, eventually it will reach the glomerular capillary and then it will be filtered but the filtration occurs without the proteins and that is why it is called ultrafiltration*.

* ultrafiltration occurs at the barrier between the blood and the filtrate in the glomerular capsule (Bowman's capsule) in the kidneys, the resulting fluid, virtually free of large proteins and blood cells, is referred to as glomerular filtrate, or ultrafiltrate.

Out of the 650 ml plasma that entered the glomeruli 125 will be filtered (filtration fraction= (125/650) \100% = 20%)→ as you can see 20% of the plasma is filtered per min which is too much!! Now how we are going to reduce this amount??

-Remember in the beginning of the lecture we said that urine formation requires 3 steps (step 1 glomerular filtration which we talked about previously) now we are going to talk about the other 2 steps:

As we said previously the nephron is composed of two parts capsular part (bowman's capsule) which is the ultrafiltration device and the tubular part (the rest of the nephron), the tubular part is composed of epithelial cells and it is the site where modification of the filtered plasma occurs, this modification is done either by adding or by removing to and from the filtered plasma, **the addition is called tubular secretion** (hence the name tubular since it occurs in the tube of the nephron and secretion since it is addition), and the removing process is called **tubular reabsorption.**

Keep in mind that this exchange (addition and removal) is between the peritubular capillaries (since they are around the tubule) and the nephron's tubule.

Now Let's go back to our topic which is urine formation:

As we have said previously the glomerular filtration rate is 125ml/min but we have also said that urine output is I ml/min, this huge difference is due to the tubular modification (tubular reabsorption and tubular secretion), 124 ml out of the 125 ml is reabsorbed back to the peritubular capillaries per min by tubular reabsorption so now we have an outcome of 1 ml of filtered plasma per min (which is what we want) so what is the importance of the tubular secretion process ??

Previously we defined the tubular secretion: movement of substances from peritubular capillaries to tubules, these substances include; potassium ions (K+) Hydrogen ions (H+) Ammonium ions (NH4+) Creatinine Urea, the mechanism by

which this secretion occurs is by passive diffusion or active transport (Not filtration).

> Note that there is a difference between diffusion and filtration:
>
> a) Diffusion is the movement of one specific molecule from a high concentration area to a low concentration one.
> b) Filtration is the movement of a fluid (mixture of several molecules) from a region of high pressure to a region of a low pressure.

Starling forces:

In some capillaries (like skeletal muscles) we have filtration at the arterial end and reabsorption at the venous end, in intestines we have only absorption while here in the glomerulus we have only filtration; this filtration is governed by Starling forces

Starling Forces:

1- Pc: the hydrostatic pressure generated by the pumping force of the heart. It averages 60 mm Hg in the glomerular capillaries. This force pushes the fluid outside.

**Note that Pc decreases markedly as blood passes through the arterioles, indicating high blood flow resistance in these vessels This force favors filtration

2- πc: the colloid osmotic pressure generated by the impermeable proteins in the plasma (not caused by the electrolytes as they are freely permeable). This force drives fluid inside.

Since 20% of plasma passing through the capillary is filtered, impermeable proteins concentration increases as they pass along the length of the capillaries from 28 mmHg to 36 mm Hg. Thus, the average πc is approximately 32 mm Hg. This force opposes filtration

3- Pi: the hydrostatic pressure generated by the interstitial fluid. It averages 18mm Hg in the Bowman's space. This force opposes filtration.

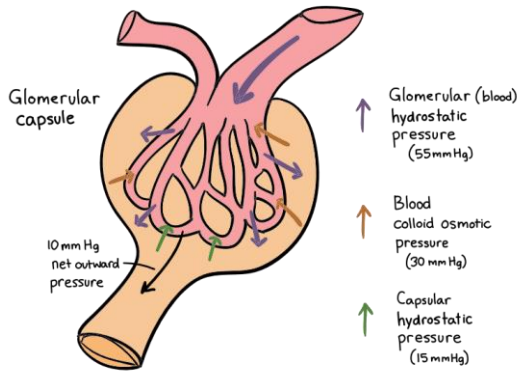
It depends on whether it is negative (it sucks the fluid outside) if it is positive it (pushes fluid inside).

4- πi: the colloid osmotic pressure of the interstitial fluid. Since filtered plasma is free of proteins, it equals zero.

For further understanding: https://www.youtube.com/watch?v=VMvD29-Agtg

The figure below shows both the afferent and the efferent arterioles of the kidney, notice that the afferent is larger in diameter than the efferent, because the efferent arteriole is smaller it makes the glomerular capillary pressure high 60 mmHg (the blood is getting in the glomeruli easily, but it is getting out of it with difficulty)

A hydrostatic pressure of 60 mmHg is so high compared to other parts of the body and this driving force makes the filtration rate here equals 10 times the filtration rate in all other capillary beds; in all other parts of the body 20L is filtered per day while in the kidney 180L is filtered per day. Also, the permeability is extremely high in the kidney; glomerular capillaries are 400 time more permeable than other capillaries.



It is important to remember that filtration is a flow (per time), and flow needs driving force opposed by resistance, the driving force is the pressure difference, and since resistance is a vague concept we replace it with permeability

At the end of the lecture the doctor asked a Question "the answer is from 2015 since the doctor hasn't answered it yet": In capillary beds of the body, why does the osmotic pressure does stay the same in arterial and the venous end although water is filtered which should increase the concentration of proteins in the venous end and thus the osmotic pressure?

The heart pumps 5 L/minute, 1 L is for the kidneys and the remaining 4L is for the rest of the body almost 2L is plasma being pumped. This equals about 4000L of plasma being pumped by the heart to the capillaries in the body (without kidneys), and only 20L is filtered per day (also some of them is reabsorbed) which too little to causes a difference in the concentration of the proteins between arterial and venous ends. However, in the kidney 20% of plasma is being filtered which is enough to cause a difference between the afferent and the efferent arterioles; that's why it starts with 28mmHg and increases to 36 mmHg (average is 32 mmHg).

**at a certain concentration of albumin in the blood, its relationship with the osmotic pressure stops being linear, but instead and further increase in the concentration will increase the osmotic pressure more than it is expected to do. The same happened here; when high filtration happened, we reached a high concentration of proteins which caused a higher than expected increase in the osmotic pressure.

Useful video : https://1drv.ms/v/s!AjMjAY3oGTNYhUqXRP9kDmcZdRhZ

Hope letter: Susses doesn't come alone; it's the result of infinite faults. The path is absolutely so hard but worth it! We are alive as soon as we keep going, ***"You never fail until you stop trying."*** So, stand up again and continue achieving because you live once!