Human Physiology
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Lecture – 24
Excretory system : Kidney - Part 1

I will now move on to, it is a complete, we are changing the gear and we are moving now to the excretory system. Okay, I will ask you a very simple question, what is the, if I ask you what is the main function of kidney, you will say that it is very important organ for, For what? Removal of what? Nitrogenous waste. Nitrogenous waste. Removal of what? Nitrogenous waste. Nitrogenous waste. I put this slide just to remind you that removal of nitrogenous waste is one of the, one of the six very important functions it performs.

One, okay, so let us briefly, okay, to fully, to fully realize the importance of the kidneys. Let us see what are the other important things which the kidney does. One very important function is the, is the amount of water in our body, okay, amount of water, okay. So, it has to, the kidney has to make sure that if you, if there is an excessive intake of water, that water be thrown out and if there is, if there is reduction in water intake and there is more loss of water through the, through the skin or any other source, you make sure that the loss of water through the urine is reduced.

So, it is very important. Another very important role is in sodium and potassium ion concentration, okay. It has to, go back to, go back to our homeostasis, okay, make sure that the amount of sodium ion concentration in the blood is always, always under, always guarded within very, very, very narrow limits. So, sodium ion concentration, potassium ion is very important. Then, yet another very important function is, you see, every time an amino acid is broken down, some H+ ions are released and if those H+ ions are allowed to remain, it will, it will, it will what, it will, it will alter the pH, okay.

So as far as, so okay, in one sentence, kidney plays a very important role in acid-base balance. What did I say? Acid. Acid. Acid. Acid. So, you have to make sure, okay, therefore, therefore, acid-base balance, acid-base balance is very important.

Then you have, then of course, we have seen that kidneys and endocrine organ, okay. And we already know the name of one hormone, what is it? Renin. Renin, okay. There are two more, I will tell you, I will tell you by and by. And there is another important hormone, erythropoietin, I will talk about it in, okay.

And then urea, we have seen creatinine, okay. What is creatinine? It is very interesting. Well, let us wait for two, three slides, I will talk. Creatinine is a very interesting topic.

Uric acid. Uric acid. Do we generate uric acid as an excretory product? We know that birds and reptiles do it. Uric acid as an excretory product. Do we do it? Yeah, we do. We do because when the DNA, RNA, adenosine, okay, these are all purines, okay.

And when they break down, okay, their ultimate product of excretion is uric acid, okay. So is urea an excretive product? Yes, largely. But uric acid, it is also there. We will talk about it eventually. And then bilirubin, you see when the, it is a product and product of the hemoglobin breakdown and the breakdown of hormones and drugs that we take, they all need to be.

So this is a very interesting slide that tells us about the enormous capability of our kidney to handle sodium. Let us take an example of sodium. What you are doing is look at the upper graph. And every day your intake of common salt is about how much? It is about 30 milli Eq/ day.

I am here. I am here. How much it is? 30 milli Eq. Okay, presume. Okay, 30 milli Eq. Your daily intake of common salt.

Now suddenly you decide to test, put your kidney to test, okay, and start ingesting 10 times more sodium chloride. So your intake has gone up, okay, you are experimenting on your physiology. And so from 30 you have gone to 300, okay. And the moment you start on a particular day, on day 0 you have done it. So intake has gone from 30 to 300.

And then what you keep on doing is you keep on collecting the urine sample, okay, and subjecting that sample to the analysis of amount of sodium in it. And you find that after a few hours, the urine contains almost 10 times more sodium. Are you with me? So your system that, so you have receptors for sodium, okay, and those receptors sense, okay, and the system suddenly tells you that no, no, there is too much sodium. And then kidney is instructed, okay, to make sure that what all of sodium chloride, sodium that you have taken is in excess, continue as long as you keep on. So on day 2, day 3 or day 4, you keep on taking 300, 300, 300 and you keep on excreting lot amount of sodium.

Then somewhere here, somewhere here, you stop, you go back to your 30 and you find that the excretion from the urine also stops. But then it comes down to the basal level, it comes down to the basal level and then it does not go beyond that. Are you with me? Okay, so you take more, okay, you get, you lose more. Okay, what are we talking? We

are talking of homeostasis of sodium with reference to blood and who is playing the key role? The kidney is playing the key role, okay. Now there is a, the author has shown there is a slide, you see extra, extracellular fluid volume, your volume has gone up.

Just see, extracellular volume is what, what am I talking about? We are talking about the volume of the fluid, okay, entire volume of the fluid in your body, I divide it into extracellular, extracellular, the extracellular fluid volume has gone up. Why has it gone up? Because you have taken more sodium, okay, it is increasing the, is increasing the osmotic value of your biological fluids. To reduce that your body is now conserving water. When there is more water, okay, the osmolarity will be, the osmolarity will be, so this just is slightly increase in the, in the, in the volume of the, okay. So you know where the kidneys are, you know that the kidneys, okay, this, you know what is this red large vessel here? It is what, very good, what is it? Descending aorta.

This is descending aorta, you know, you know, okay, I will go back to the left ventricle, hello, left ventricle, oxygenated blood pumps, okay, during systole, it goes into aorta, aorta comes around and there it goes, okay, and enroute somewhere in your back, it gives rise to, it goes to one branch, goes to this kidney, one goes to another kidney, okay, and the blood, and the blood after having undergone ultrafiltration will be returned through the venous system, it will go and then this way the blood will go back to the, to the heart via one of the vena cava and then you have here you have a tube which you call as the ureters, the product of filtration, okay, the formation of urine will go via this tube which you call as ureter, it will go to ureter bladder and then finally it will be discharged to the outside and sitting somewhere on the kidney are, these are the two organs on the left and right and what are they? They are adrenal glands and we will talk about it in due course of time. Okay, this is the, this is the human model, you can see those things, that is the actual human cadaver, okay, you can see the two kidneys, the ureters and you can see the urinary bladder there, okay. We divide the, so what are we doing? We take a section, vertical section through the kidney. Are you with me? So you can see the dorsal pole, you can see the ventral pole and then you have the outer part which we call as the cortex, the cortex and then this is the inner part which is called as medulla, the outer medulla, the inner medulla and this is huge space here, this is a huge space here and that the function of that space is to keep on continuously receiving the filtered products, okay, which will be taken down into the, taken down via the ureter and taken to the urinary bladder. This is a, this is an enlarged view to show you the organization of a nephron.

What are we talking about? A nephron. When I say nephron, what do I mean? Okay, I mean Bowman's capsule, okay, I mean Bowman's capsule. And in the Bowman's capsule, there is an artery, okay, and there is a tuft of glomeruli and then the blood will flow into the efferent, okay, and the Bowman's capsule will give rise to the the proximal

convoluted tubule, it goes down. There is a purpose for that. The tube goes curves several times and then it goes straight, straight into the medulla.

So you can see that it goes, it goes into the medulla and then it comes up, so descending limb, loop of Henle, come up ascending limb, okay, then distal convoluted tubule, okay, and then collecting duct, okay, and then finally it will go. Now, organization of one, nephron, one unit, we have about a million or so. Both kidneys put together, how much? A million or so, okay, huge number of, okay. And please remember, if they degenerate, they cannot regenerate, okay. Are you with me? There is no question, whatever, whatever, so whatever nephrons we have, okay, as we age, you will have less nephrons and by the time you are 60, 70, okay, the number has been reduced to 40 or 50 percent, okay, but that does not matter because there is enough compensation there and okay.

So, okay, so the point that I want to make here is that it is in the cortex, cortical areas that you have the Bowman's capsule, where are all the Bowman's capsules located? In the cortical area, okay. In this image, we are again looking at the kidney and author shows us two different types of nephrons. Can you see one nephron here? Can you see one nephron here? Can you see the nephron here? We are talking about the cortex. Can you see this nephron here and then it goes, this proximal convoluted tubule, it goes down as far as the upper layer of the medulla, this is the thin segment of the loop of Henle, then ascending limb, ascending limb and then there is something very interesting is happening there. What is happening there? Can you see? The tubule, you are right, the tubule as it goes down and then it comes up, it talks to the same Bowman's capsule.

Hello. It is a peculiarity of mammals. The tubule, the tubule as it goes down, goes down into the medulla and then comes up and then talks to. Why am I using the word talk to? I will tell you a little later. There is a signaling happening. There is a signaling happening here and then the rest of the urine goes here, here and then this collecting duct will receive it from hundreds and hundreds of the, what am I talking about? I am talking about a nephron, about a nephron and now author tells us something interesting.

Author tells us that the nephrons are divided into two types, okay and both the types of nephrons are in front of you. Can you identify the differences between the two nephrons? The second one is at a slightly lower level, deeper into the cortex and the second one gives rise to, second one gives rise to a descending limb which goes deep into the medulla, okay. I will call this as the cortical nephron. What will I call this as? It is cortex, cortical neuron and I will call this one as the juxtamedullary nephron. It is a nephron in the cortex but it is close to the medulla.

So what do I call it as? Juxtamedullary nephron, okay, please remember and whereas this

is about, I do not know, about 80-80 percent of the nephrons belong to this type, about 15-20 percent belong to the what type? Juxtamedullary. Juxtamedullary nephrons are of the different types and functionally they are distinct, okay and we will come to that eventually when we talk about reabsorption of the fluid. In the last slide, here I think we have the renal cortex. Which one? I just want to conclude between the two.

Okay. Renal cortex, renal medulla. Yeah, yeah, that is mammalian and it plays a very important role in concentrating the urine. Actually concentrating the urine because, you see why mammalian kidney is so special? That is still adapted.

You are absolutely correct. Let me explain. The osmolality of our blood is about 300 milliosmoles. How much, what did I say? 300 milliosmoles. Now this number you have to learn by heart, remember and never forget, okay.

What did I say? 300 milliosmoles. 300 milliosmoles, okay. And if you are dehydrated, okay, you are capable of absorbing enough water when during the formation of the urine so that the urine can be as concentrated as 1200 to 400 milliosmoles. What are you doing? You are concentrating the urine. Hello. Concentrating, how do you concentrate? How do you concentrate? Okay, I will not give you the answer now, but I will leave you with a very interesting question, okay.

Our, the mammalian physiology is capable of concentrating the urine, not that you are interested in concentrating the urine, but you are interested in absorbing as much as water as possible and in the process, the urine gets concentrated, but the very mechanism, look, your biological fluid is 300 milliosmoles. Are you with me? Your blood is 300 milliosmoles, your lymph is 300 milliosmoles, all intracellular fluid is 300 milliosmoles. And how is it that in a particular compartment of your body, you are able to generate a fluid that is 1400 milliosmoles. Are you with me? Okay, just hang on to this very interesting question, think about it. Eventually, I will tell you one or two lectures down, I will tell you, okay.

So here we have the, you remember we had that renal artery that enters into the kidney and then branches and branches and we have a renal artery and then these are the different branches that you can see and those branches will finally and here we will have afferent arteriole that arteriole is entering into where? Into the into the Bowman's capsule you will call this as glomerulus, we will call this as afferent arteriole, we will call this a efferent arteriole and different arteriole, now this is something interesting, different arteriole branches again. So here is a very interesting situation in which a blood vessel comes, goes to the glomerulus, branches, then branches get together, come out of the Bowmen's capsule and again branch. Are you with me? Hello, that is interesting. Okay,

so I will call this as the afferent arteriole and you can see the red is oxygenated blood and then it is giving away its oxygen taking carbon dioxide becoming deoxygenated to the vein and finally by the renal vein it will be taken to the vena cava. Is the whole picture clear so far? By the time the blood reaches here, means where it is about to enter into the Bowmen's capsule.

Okay, now by the time the, okay, let us go to the dorsal aorta, aorta, okay, 80 - 120, hello, 80 120 or average is 100, let us go by the average, okay. By the time it enters into the renal artery it is still about 100, by the time it enters, by the time the blood enters into these vessels, these vessels as they branch, branch, branch, branch and as they go into the smaller vessels as the resistance increases, the blood pressure here is about 60 mmHg, how much is it? 60 mmHg. And by the time it comes out of the glomerulus there is very little loss because the tuft is very small, it is about 59 mmHg. So there is loss of how much? 1 mmHg. 1 mmHg and then by the time and then by the time blood goes into what you call as a peritubular capillary network, what do you call it as? Peritubular capillary network.

Okay, by the time it goes the blood pressure falls to about 30, 25, 20, 15, okay, 12, it is really falls and then by the time the blood enters into the veins, it is about 8 mmHg, 6 mmHg, 4 mmHg, okay and then by the time it goes to the heart we know that the pressure is very low, but we will talk more about it, okay. I am going to talk about this very, can somebody make an essence of this image, you know this is scanning electron photomicrograph. This is called as, beautiful technique, this is called as a cast. What is this cast? They have a liquid, okay, synthetic liquid which can polymerize. What do you do? It is liquid now, but it can polymerize and it can polymerize within say 30 minutes or 40 minutes and once it polymerizes it solidifies.

Are you with me? So, what they have done is, in the case of a rat or a dog, hello, you open the animal and insert your that, it take your substance that say, take that special substance of yours in a syringe and inject it in the renal artery. Hello, inject it where? Renal artery. So, along with the renal artery it will spread everywhere, okay, it will go into the arteriole, it will go into the glomeruli, it will go everywhere, okay and then wait for a while and then remove the kidney, okay. Now that liquid has polymerized, that liquid has become solid, okay and now you put that kidney into, remove it from the animal, take that kidney and put it in dilute acid, wait for one day. So, all these biological part is now gone and what remains is that polymer, but that polymer has taken the shape of the capillary network.

Are you getting it? And then you take scanning electron photo micrograph of that. I appreciate the beauty of the technique there. So, otherwise I mean how would you know,

how is the entire capillary network, how is the 3D organization of the glomerulus within which you can appreciate it here. Can you see this network, can you see this, this, this, this? Are you getting it? Yes or no? Am I talking Greek and Latin? It is very simple, great. So, this is the histological section, you can see the glomerulus, the whole thing is the Bowman's capsule and this little space where the filtrate and then this again I am sure you can see the two nephrons here, okay.

What will I call this nephron as? And what will I call this as? Great, great. Now, okay, we are going to, we are looking at a Bowman's capsule and here we have the, so I am sure you can make out what it is afferent and efferent and glomerulus and this I will call as the, as the, so Bowman's capsule is a cup, is a double walled cup, is a double walled cup and the inner space of the cup you have the capillary network where the ultrafiltration will happen. So, I will call this as a parietal layer. Hello, this is a cup. Just see, I will draw the cup in air, parietal layer, parietal layer, parietal layer, visceral layer and in the visceral layer what do you have? What is glomeruli? Capillary, capillary, not of capillaries, okay, good, good, good.

Now the, here is a capillary, it is a capillary, it is extremely thin, okay and you have to use it as a, as a source to filter, okay, so you must give plenty of space for the fluid to come out. But the problem is, please appreciate, the blood is entering in that capillary at a pressure about 60 mm Hg. Hello, the capillary should burst. 60 mm Hg is pretty high, okay, it is very high, the capillary should burst. So that to prevent the capillary from bursting, okay, the capillary wall is supported by special type of cells, which are called as podocytes, which are called as what? Now podocytes.

Now imagine here is a tube, okay, there is a tube and in the tube there is, it is very thin because you have to allow the filtration to happen, it is made up of very thin capillary, very thin, but you also want to make sure that it does not burst. So I will, I will try to protect it, but if I try to protect it, my protective layer will inhibit the filtration. Okay, so how will you design it? The design is I will protect it not like this, but like this, are you with me? So there is still what? Space, there is still space, okay. So therefore, the word podocyte, a cell with feet and what are those feet doing? The feet are pressing on the outer wall of the capillary making sure that the capillary does not burst, but there is space between the feet, I am using the word feet to which the filtrate can come out, are you getting it? So these are, this is the capillary and what you see here, these are all the podocytes and there are spaces through which the ultrafiltrate can move out and here is a picture that explains everything to us. What do we have here? We have a capillary, okay and in the capillary, we have the endothelial cells here, this is the nucleus of the endothelial cell and the endothelial cell has many spaces which we call as fenestry or windows through which the fluid can freely open, come out and this is actually can you

see a feet here, a foot here, a foot here, please remember all these feet may belong to one cell, but in between the two feet, adjoining feet, can you see the space there? What is the importance of that space? Ultrafiltrate, there is room for ultrafiltrate, ultrafiltrate to come out and separating the two is a basement membrane, there is a, this is a capillary with a basement membrane, okay, but this basement, this, this, this basement membrane is very porous, okay, so whatever is filtrate, okay.

Now, again here comes another beauty of the biology. Listen to this, that basement membrane is made up of material which is negatively charged, which is what? Negatively charged. And since large protein molecules are invariably having a negative charge, they will not readily get, readily pass through that basement membrane, hello, hello, does it make sense? What statement did I make just now? Protein molecules, protein molecules, where are they in the blood, where are they, because the system does not want the protein molecules to flow out and it is under pressure, so there is very possibility that they will flow out, okay. So to make sure that ultra filtrates happens and small molecules go, no problem, but the protein you do not want to lose protein, to that end, this, this is, this is and there is a disease in which the membrane loses the charge, okay, are you with me? And in that particular case, if they take the urine sample and subject it to analysis, you will find that there is much more protein than what it is normally should be, normally there should be no protein, okay, are you with me? So this, this charge on this basement membrane, what kind of charge is sitting there please? Negatively charged. Okay, so, so I am sure you can, and then there are mesangial cells which have, which have smooth muscles, this is, this the blood is flowing here, this is the, this is the membrane and these are the podocytes, I am showing you the picture taken with, with an electron, electron microscope there, okay, this tells us everything actually, this is the plasma, these are the endothelial cells, this is the basement membrane and these are the different podocytes and the filtrate will, the filtrate will go from across from the capillary into the, let us see, see, this we are still talking about the same thing, this is the, this is the afferent vessel and efferent vessel, okay. So let us see, presuming there are 100 molecules of urea and it is passing, blood is passing, 100, just some figure I am taking, 100 molecules, what do you think all of them will be filtered? Some of them will be filtered, how, what do you think? Some of them will be filtered, it is not possible, you cannot, some of them will be filtered, some of them will not be filtered, then how do you deal with the problem of those which are not filtered? Are you getting the problem? You want to get rid of? How do you, how do you, say that again, you are right? You are there but you need to slightly improve, the answer is very simple, you filter the blood again, filter the blood again, filter the blood again and if you are, if you are at a time of 70 kg, okay, over a period of 24 hours, if I just monitor the amount of blood that is flowing through the kidney is 180 liters, how much the total amount of blood you have, 5 liters, are you with me? Okay, so the strategy which the kidney has is filter again, filter

again, filter again, filter again, as a result of that, if not in this term, in the next term, it will be filtered, are you getting the argument? Good, good, so, okay, then the second thing author wants to say is, whereas the smaller molecules are being filtered, the larger ones which are green, which are the protein molecules, they will remain within because the first of they are large and secondly, because the membrane is the membrane is what? The membrane is negatively charged, this gives us the filterability, the water has a molecular weight of about 18 and whatever the rate with what is very freely filtered, absolutely nothing to stop it therefore, we will call, I will call that filterability as how much? One and that is my standard.

So, I will compare it with sodium, what is my filterability? One and glucose is also one, inulin is a carbohydrate molecule, molecular weight about 5000, it is again one, so that but myoglobin, molecular weight is about how much? And then what is the filterability? 0.75, albumin is about how much? 69,000 and something, how it is a filterability? Not that, not that it cannot be filtered at all, okay, but very little, so this what does this table test tell us? Correlation between the size and the and of course, considering the charge, yeah. What about those proteins which are positively charged or something? They may be filtered, they may be filtered and to give you short answer, long answer will come eventually, they are taken back by the tubule by a process of pinocytosis, hang on to that question and answer, we will come to the answer of that question. Thank you.