Human Physiology
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Week - 08
Lecture - 01

Welcome everyone to another brand new class of human physiology. In the last few classes, you remember we discussed our skeletal systems, bones, muscles, and various bone-related diseases. From this week onwards, we will discuss excretory systems, with the kidney being the main part of the excretory system. We will thoroughly discuss various aspects of the kidney, including its structure, functions, and how urine formation occurs, as well as how acid balance regulation happens. So, hopefully, we will enjoy the excretory classes. So, what are the different contents for today's class that we will try to cover? The first thing we will discuss is our general excretory system, then we will see what the different types of excretory organs are; mostly, we will also discuss different metabolic wastes, what the different types of metabolic waste compounds present are, and how they are synthesized or generated in our body.

We will discuss the urinary system, the structure of the kidney, and briefly the function of the kidney. The detailed function of the kidney will be discussed in consecutive classes where we will thoroughly try to dissect each area of the kidney and examine how urine formation and other regulations occur, but in this class, it will mostly be an introductory part. So, what is the excretory system? Excretion is the process by which metabolic waste and other excess substances are removed from our body, right? So, what are the different types of organs that generally contribute to the removal of excess substances or excretory compounds like the lungs, skin, kidneys, or liver? These are all different components of excretory organs. These organs work together with the circulatory, nervous, and endocrine systems to keep our body under homeostatic conditions.

Do you remember what homeostasis is? It is about maintaining the right balance. In these cases, if a lot of excretory waste products get synthesized and deposited in our body, our body will be full of toxic compounds that can significantly damage our physical and physiological balances; it can cause toxicity to our cells and tissues, and significant hampering can disrupt our normal body systems. So, it is very important that these excretory organs, like the lungs, skin, kidneys, and liver, can rapidly remove metabolic waste or other excess substances from our body. So, let us see what the different types of excretory organs are and what types of molecules or excretory wastes they remove from the body. So, the lung is an important excretory organ, right? It functions by removing carbon dioxide.

This is also a waste product; it is not a metabolic waste, of course, but is a respiratory-related waste, right? So, what we do is our lungs initially consume oxygen from the air, and that oxygen is supplied or delivered to the cells by hemoglobin, which is present in the RBCs. So, once the oxygen is delivered to different parts of our body, mostly the inside of the cells, the cells use it for the cellular respiration process, and after having undergone cellular respiration, it removes it and produces carbon dioxide as a byproduct. So, this is a byproduct type of waste product, and the same carbon dioxide can again move from the cells to the tissue, where it can get to the blood, and the blood can again carry the carbon dioxide back to the lungs, where, through the breathing out process or expiratory process, you can remove the carbon dioxide from the body. Then, skin is another excretory organ; what can skin generally help to remove? It helps to

remove excess water from the body, excess salt from the body, and a small amount of urea as well. How does it? We have a lot of sweat glands, you know, right? We have a lot of sweat glands that produce sweat.

So, with the sweat excess amount of salt, little bit urea and of course with the skin excess heat also can disappear okay so lungs and skin are two important excretory organ then next the very most and the major excretory organ which is the kidney right how kidney function kidney helps in form a kind of to generate or form the urine Through the urine process, it filters out all the toxic components like ammonia, urea, uric acid, creatinine, excess water, and excess salt, and they are removed by the process of urination. This way, the kidneys filter our blood and keep it pure, and excess toxins can be easily removed. The final excreted organ is the liver, which produces bile, which contains bilirubin, a byproduct of hemoglobin. You remember we discussed this in our blood class. So, bilirubin, once formed, is also a toxic excess product, right? Excess amounts of bilirubin are not good.

Why? Because this also contributes to a condition like jaundice, right? So, the liver in this production of bile and through our hepatobiliary route removes the physis material. So, you can see that all these lungs, skin, kidneys, and liver are very important organs that are part of our excretory system; they either remove excess substances like water or can also remove excess salt. Apart from that, they can secrete or excrete carbon dioxide, ammonia, urea, uric acid, bile, or bilirubin. So, what are the different major metabolic wastes present in our body? Primary is carbon dioxide; it is formed during cellular metabolism. Then water, of course; like our body, 90 percent of our body is made of water.

However, excess accumulation of water in certain situations can cause edema, and excess water needs to be removed. A lot of nitrogenous waste products we have, or they can also be synthesized or developed during various metabolic processes. These are some of them: ammonia, urea, uric acid, or creatinine. Apart from that, some mineral salts like sodium chloride and potassium sulfate can also form, and an excess amount of these can also cause certain damage. For example, sodium chloride or other types of salt can cause our pressure to build, like blood pressure increasing.

So, having excess salt in our body is also not good, and a certain mechanism of excretion is needed to remove the excess amount of salt. So, let us see what those are one by one. So, ammonia, right? We all know what it is. It is NH3, and it is a very dangerous kind of toxic product; ammonia is hugely toxic to our cells. It can be produced only by our cells, but of course, the cells are not producing it in large amounts.

But in certain dysregulations, if this ammonia is not removed by the excretory system, small amounts of ammonia can build up, and it can significantly change the acid pH balance of our body; it can significantly create poisonous toxins like urea and uric acid. Which, further in turn, can damage our kidney cells; it can damage our other cells also, causing a significant condition of necrosis or other sorts of genetic changes. So, ammonia is a kind of significant toxic metabolic waste, and the excretion of ammonia requires a high amount of water. Although ammonia is highly soluble, excretion of ammonia requires a high amount of water. Most aquatic animals can excrete ammonia directly.

Next is urea, right? So, with the ammonia and carbon dioxide from this urea cycle, urea generally forms. Urea is also a significantly toxic element, but this is a little bit lower than

ammonia. So, basically, ammonia is more toxic than urea. And urea is also less soluble in water. Urea is relatively less toxic, but it also takes less water to remove from the body.

So, it is produced by the urea cycle in the liver; try to remember that urea is produced by this urea cycle, where ammonia and carbon dioxide can form urea after a series of reactions. This is a type of metabolic product that occurs in the liver; an excess amount of urea is, of course, toxic for our body, and our kidneys remove the excess urea from the body through the process of urination. Then third is the uric acid; it is insoluble in water. So, try to remember that while ammonia, uric ammonia, and urea are soluble in water, uric acid is completely insoluble in water. So, uric acid is mostly synthesized or formed by the ammonia metabolism in the body.

That means in cases where a high amount of ammonia is forming in the body, it can quickly metabolize to form more uric acid, and the problem is that uric acids, although slightly less toxic compared to ammonia, are almost insoluble in water. Okay, that means there can be a chance of the formation of uric acid crystals, and these crystals can get deposited in the kidneys or maybe even in the bones and joints, causing significant damage and pain. But the removal of uric acid requires less water compared to urea and ammonia. Although uric acid is less toxic compared to ammonia, all of these are excretory compounds. So, if they kind of build in the body for a longer term with a higher amount, they can significantly damage it.

And kidneys, mostly in the process of urination and urine formation, remove all three different types of excretory compounds. Then creatinine is also another breakdown product of creatine phosphate. This is also an excretory compound. This can also get crystallized, and whenever there is crystal formation, it can get deposited in kidney cells, causing further damage, right? So, serum creatinine is a blood measurement by which you can monitor your kidney health. So, in cases of high serum creatinine in your blood, there might be a signal that your kidneys are having some sort of issue.

This should not be the only parameter right. Serum creatinine should not be the only parameter to judge your kidney health because there might be situations where those who are bodybuilders, due to their high muscle mass, may have a higher amount of creatinine as well. So, if there is a detection of a higher amount of serum creatinine, the doctor should do another type of test, for example, the BUN, or blood urea nitrogen. So, those tests should also be performed apart from the serum creatinine to confirm whether the situation is due to kidney failure. The situation may be exactly normal just because of consuming too much animal protein or having too much muscle mass.

So, what is the part of the urinary system? Let us see. So, our urinary system has two kidneys, one on the left side and one on the right side. From the kidneys, we have this nice tubular structure, the urethra, which carries the urine from the kidneys and delivers it to our urinary bladder. The urine will come out through the urethra. So, the renal system includes a pair of kidneys, ureters, urinary bladder, and urethra.

These, as a whole, generally help to remove the urine from the body, right? Then a little bit about the kidneys: we have how many kidneys, like 2 kidneys on both sides. These are mostly p-shaped, about 10 to 12 centimeters long, about 5 centimeters wide, 3 centimeters in thickness, and the mass of each kidney is around 135 to 150 grams. So, the kidney has a component like the outer cortex. So, these are basically, you can see these are like the outer cortex area, right? These are like the outer cortex area, the outer cortex, right? Then inside this, we have the inner

medulla. This is the middle part, right? And then it also has a renal sinus, and inside this medulla, there are a lot of these nephron-like structures, right? A lot of small nephrons.

What is a nephron? The nephron is the structural unit of the kidney. So, this is the microstructure or the single unit of cells that is called a nephron. So, as you see, what I said is that this inner medulla has a lot of structural units of cells. So, the nephron is the structural micro unit cell of the kidney, and do you know how many nephrons are present in each of our kidneys? As a whole, we have around 2 to 3 million nephron cells. So, in each kidney, we have roughly about 1 to 1.

5 million. The thing is that with this nephron, in cases of certain injury, although they may repair themselves, if the injuries are significant and if the nephrons are completely destroyed, they are unable to regenerate. So, we have only a fixed number of nephron micro unit structural cells in the kidney. And if, due to a lot of our bad habits, such as alcohol consumption, or maybe due to infection, or due to an immune disorder, or toxic buildup of excretory waste, the nephrons are completely damaged, irreversible damage occurs, then we will first lose this fixed number of nephrons, causing complete kidney damage. And once this complete kidney damage condition arises, there is no treatment available; we have to undergo hemodialysis, which means we have to purify our blood. Apart from that, there would be a condition that we can also transplant, like a kidney, in order to restore normal excretory function.

But, these processes are, of course, very complicated transplants, and there are not enough organ donations available. Also, you can imagine that another problem is that once a similar type of kidney is transplanted into our body, the body's immunity can reject it. So, there are a lot of complications. So, it is always preferable that we take care of our kidney health because the nephrons are limited in number. So, the structure of the kidney, as we said, if you go into a little bit of detail, you will see this outer cortex area and then the inner medulla area.

The inner medulla will have a lot of nephrons inside, right? Going through this detail of the kidney structure is, of course, important, but in our next consecutive classes. We will thoroughly discuss the function of the glomerulus and the nephron structure, where the glomerulus, the proximal convoluted tubule, and the distal convoluted tubule will be thoroughly covered; but this is just the gross anatomical structure of the kidney. So, in the kidney, we also have a renal sinus; you can see that the renal sinus consists of the following structures: it has a renal pelvis, 2 to 3 major calyces, and these also connect with branches of nerves, arteries, and veins. Sometimes, loose connective tissues and fats are also present to connect with the kidney. Then this is the tubular structure of the kidney because the kidney mostly has this nephronal tubular structure where you can see the places of the glomerulus; from the glomerulus, you can then observe the proximal convoluted tubule, then the Henle loop, and then the distal convoluted tubule.

So, as a whole, this tubular structure is part of the nephron, and the nephron, as I said, is a structural unit of the kidney. So, each nephron contributes to the filtration of urine, which basically helps the blood filter out all the toxic metabolic waste. The blood gets filtered and enters the circulation; the metabolic waste that comes out of that blood will combine with water to form urine and eventually be excreted from the urinary system. So, what are the different functions of the kidney? It plays an important role in homeostasis by reducing the excretory waste in our body, right? So, it excretes different types of waste products like urea, uric acid, creatinine, and bilirubin. It maintains the water balance; as I already said, excess water is also not good for our body.

It maintains the electrolyte balance, and electrolyte balance is crucial for maintaining the osmolarity of our body, because if there is a change in the osmolarity, all these ion transport processes can be hampered. And as you remember, in our cellular transport class, we discussed that if, like all those ion transports, they participate directly in various functions of the organ. So, in cases of any imbalance all those organ functions will shut off. So, maintaining the osmolality and the electrolyte balance is very important; the kidney helps with that. It also maintains acid-base balance because in cases of acidic conditions in our blood or basic conditions, it can lead to situations such as acidosis or alkalosis.

So, it is not intended that our body's blood should have a neutral pH all the time. So, by removing excess H plus ions, the kidneys can help maintain the pH of the blood, right? Then it also has the hemopoietic function, right? You remember that whenever there is a situation of worn-out RBCs or damaged RBCs, the oxygen level will go down in the body, which will stimulate the secretion of erythropoietin, a type of hormone from the kidney. And these hormones will have a significant role in the activation of new RBC formation, and it also has an endocrine type of function that, in turn, regulates blood pressure. So, this is very important renin angiotensin mechanism we will discuss in later classes where renin angiotensin. Regulate our blood pressure properly because if it becomes high, it will create significant damage to the nephrons and the associated blood vessels related to the kidneys, which will completely shut off the proper excretory process.

So, maintaining proper blood pressure is very important. We have a misconception that having high blood pressure is only kind of detrimental to our heart. It is not right; high blood pressure is detrimental to all of our organs; it can damage our heart, our brain, and even our kidneys, because blood vessels and blood capillaries are present in all our tissues. Therefore, high blood pressure can cause significant damage, and renin-angiotensin from the kidney, which gets secreted from the kidney, can maintain the blood pressure in our body. Additionally, it can regulate the blood calcium level as well.

by activating like vitamin D. So, you can see like lot of very crucial important functions apart from excretion, maintaining the blood blood pressure, maintaining the calcium level, maintaining the acid base like level, maintaining like the water level or different type of ionic level. There are so many important roles of the kidneys, and they are so important for our overall homeostasis. So, I hope you enjoyed the kidney class; we have discussed that this is a primary introductory class on excretory systems. We thoroughly discuss different excretory products like carbon dioxide, water, different types of excess salt, and various nitrogenous excretory compounds or metabolic wastes like ammonia, urea, and uric acid. Also, we discussed different excretory organs, which are, if you remember, the lungs, our kidneys, and the liver.

So, some of the kidney structure we discussed also showed that the nephron is the structural unit of the kidney, which is limited in number, and in cases of nephron damage, we can have complete damage to the kidney because sometimes these damages are irreversible in nature. Due to the limited number of nephrons, it can cause a complete shutdown of our kidney-associated excretory system. which eventually results in mortality unless we can perform continuous hemodialysis or organ transplantation. So, I hope you enjoyed the class. So, do you know that the right kidney is slightly lower than the left kidney? This is very interesting.

Why? Because the liver occupies a considerable amount of space on the right side, and that is why the right kidney is a little bit lower than the left kidney. Right. And we are giving you a question that is not covered in class, but you should try to read the book, like Guyton or other similar materials, and you can also read internet resources. Can you tell us what the role of uromodulin in the kidney is? One interesting fact I will also share here is that our kidneys are mostly similar; about 60 to 70 percent of the genes in our body are common in the kidneys. Isn't it interesting? So, maybe our body has thousands and thousands of genes, right? So, out of that numerous number of genes, 60 to 70 percent of the genes are common in the kidney; only 30 to 40 percent are different.

And euromodulin, out of all those genes, is one of the most prevalent or common genes present in the kidney, and it has a very important role to play. Please read about it and try to let us know if you cannot find the answer. Thank you again for attending our excretory system class. I hope you enjoyed it. In the next few classes, as I said, we will thoroughly discuss urine formation and how blood filtration happens in the nephron, all different stages.

which happens in different parts of the nephron like the glomerulus, proximal convoluted tubule, and distal convoluted tubule. Hopefully, you will enjoy the next few consecutive classes. It will be a lot like an explanatory class, right? So, thank you again for attending. Let us meet with another new class next time.