**Animal Physiology**
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**Module - 1**
**Lecture – 27**

Welcome back to the animal physiology course in NPTEL. So, today we will be starting a new section which is digestion. So, before I really give you an overview on digestion, let us talk little bit about how this whole thing works. So, body needs energy and for the energy, it has to process the food what we eat. So, in order to process the food, there is a complex channel through which the food moves through. It is just like processing plant where you take the raw food, raw or cooked whatever. So, you take the net food and this food is broken down into small particles. There is basically in other words what you are doing the way you process minerals, you take it, bring down the size of it.

So, the reaction takes place better after that this passes through different stages and channels, where different components of the food. So, food basically consists of four components. If you look at food carbohydrates, which is the major source of energy includes your glucose, galactos, mannose and lactose. These all we have discussed in the first section. Then, the food contains the lipids which we have talked about the major constituents of the membrane, lipids, fatty acids, cholesterol and all other things. Then, food contains a huge chunk of proteins, the building block which includes, which consists of 21 different amino acids, the permutations and combinations of acids and apart from it, food contains a lot of minerals which are essential.

As you could see the whole communication in the body is because of minerals, sodium chlorides and the ionic sates, potassium, magnesium, calcium and apart from it, there are few other small components which include your vitamins and some hormones which are derived from outside the system, vitamins like molecules and all those things. So, overall if you have to classify, you have the food. It could be classified as carbohydrates, lipids or fats, proteins, minerals, vitamins and few other accessory compounds similar to hormones, those kinds of growth boosters and all those things. So, all these different components have to be absorbed in a different fashion. They cannot be absorbed and they have to be regulated in a different fashion.

So, this whole process by which the food initially what we in take in the mouth, basically using our teeth, we grind it. So, this is the first thing is to grind the food. In other words, you are increasing its surface to volume ratio because as you are going down, the particle size, basically what is happening, whatsoever chemical within the body is going to act upon it to break it down further will get more surface area. What you basically do in nanotechnology, where you reduce the size of surface to volume ratio of a particle and then a part of it, then there are whole range of secretion of different hormones and different chemicals all along the path way, and at times the food is exposed to these particles are exposed to very acidic condition.

Then, they are exposed to basic conditions, and then they are action of different kinds of molecules which dissolve the lipids. For that you require lipid dissolving solutions, then you need absorption protein and then you need special absorption of other minerals. This whole thing takes place along the GI tract or gastrointestinal tracts. So, all of you must have seen some pictures of the gastrointestinal tracts here and there or in some advertisement or in doctors clinic or at least at one time, in all these years you must have seen one picture. At time it may sound to you a very complex picture. You know how this whole thing works.

So, what I will try to do in this class, I will give you over all topology that how in a simple blocked diagram which will clarify all your confusion, and I am not going to exactly draw the way anatomy is. I will just follow; I will just breakup the anatomical features into blocked diagram that will help you to appreciate how this whole structure looks like. What I will do? The first thing is that I will give you a topological idea, the second thing what I will do is that if you remember while we were talking about the nervous system, I told you most of the digestive system is under the control of the sympathetic and parasympathetic system.

So, what I will do, I will draw the connectivity of the sympathetic and parasympathetic system, where all these are connected and this will help you to appreciate that how these different opposing nervous signal helps the food to travel all along the GI tract from the mouth all the way down, and the processed and the rest of the food which cannot be used is defecated out from our body as a fecal matter. So, there is a next aspect of anatomy which I am going to share, and the third thing what we will do is will draw the cross-section of the GI tract to give you an idea how this whole tract is designed by nature over

millions of years of evolution which helps it to absorb with extreme efficiency all the different things, and how that structure is being harmed when we take like you know we take excessive liquor or some other kind of agents that are not healthy for our body when taken at higher concentration. So, what I will do is, I will just summarize what I have just now told you and then we will move onto the blocked diagram of the digestive system.

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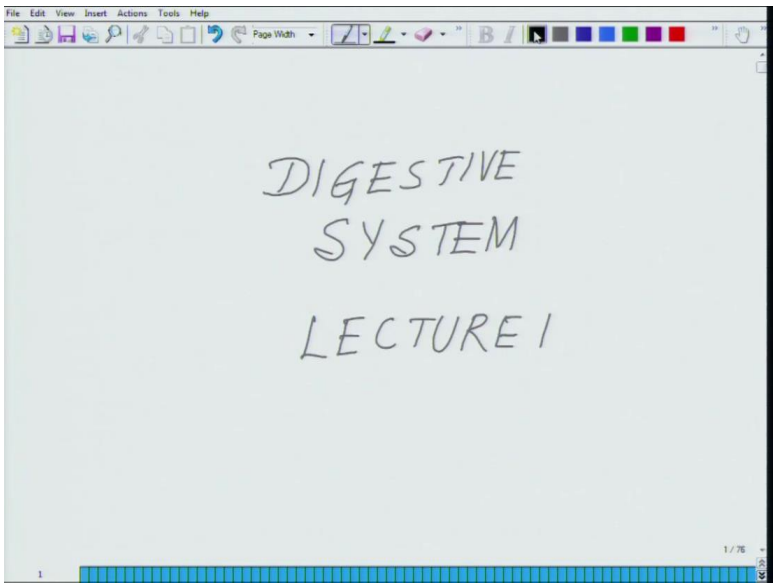


So, this is our digestive system that what we are dealing with in our lecture 1.

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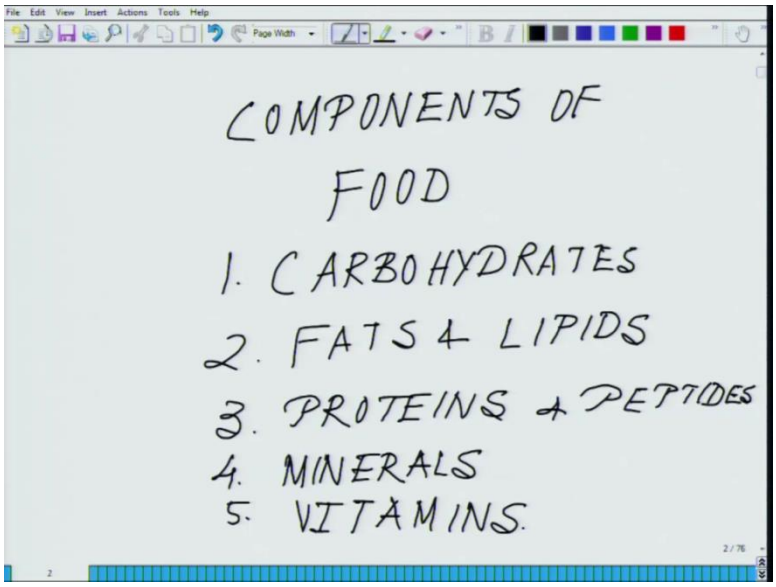

So back to next slide we have talked about the components of food which includes your carbohydrates, fats and lipids, proteins and peptides, then you have minerals, then you have vitamins. These are the components.

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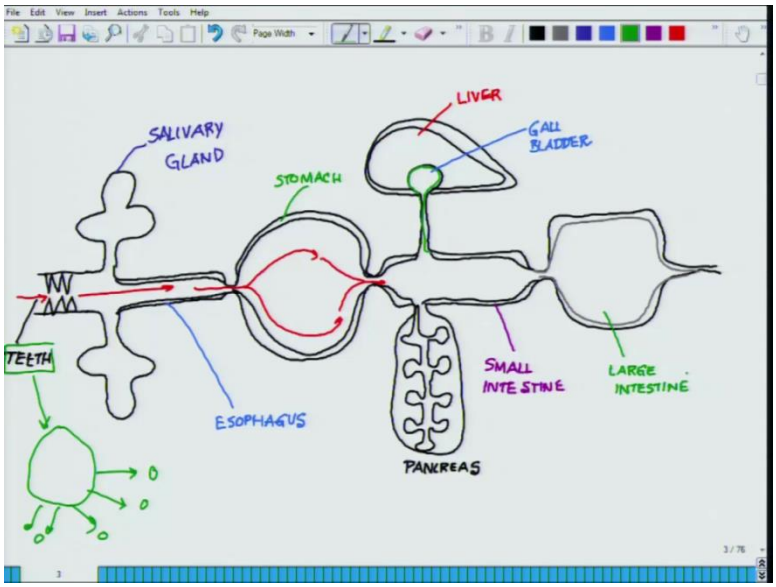


Now, what I will do? We will talk about the whole geometry or the topology of the digestive system. Let us start drawing it. I am drawing it horizontally instead of drawing it vertically because that way I will get more space to draw everything. So, I will just put the label as soon as I am done with the drawing, ok. So, this is the teeth where food intake is taking place. So, food is entering here, and this is the zone where food is broken down into small pieces. Now, you will reach a canal called as esophagus come to that, then we enter into stomach like this and the stomach is exceptionally acidic come to that, and this is the part where food experiences extreme acidic environment, and this is. Because of this environment whatsoever drug, which has to be administrated to our body through the digestive system have to be ensured that this could with stand the extreme acidic environment.

Now, start labeling all of it one by one. So, the first one is the teeth, where basically the bulk amount of food, smaller component breaking down into pieces. Step 1, this is the function of the teeth. Now comes the second which is called the salivary gland. So, all of you are well versed with this one definitely because salivary gland, this is in your mouth and if you see some good food, you will start salivating. You know you will start feeling

bit you know if I could get that food. So, this is completely driven by your brain when the saliva started to come or you are about to eat and you are getting saliva. So, it is that salivary gland that regulates it, and it is regulated by the higher centers of the brain through a series of sympathetic and parasympathetic secret module.

Now, from here comes this canal which is this whole part and mind it, these are all double walled structures and we will come in-depth on this thing likewise. So, this is your oesophaegus. From esophagus, the food enters into a completely acidic environment stomach which has pH around one stomach. This is the next stage. Next stage is stoppage for the food. Here the food gets kind of you know and now it is reaching stomach. Now, here there are two organs which come to the play. The biggest organ of the body which is here is the liver. So, this is your liver and inside this you see this structure, this one which is present almost embedded in to this structure. This is gall bladder.

There is a reason many a times whenever you see the picture of the digestive system anatomically, it is being drawn it becomes really challenging for those who have not seen the physical digestive system. Under who has not done the dissection at times find it difficult for them to understand exactly what is connected to what. That is the whole reason. Why I decided that I will give you flow chart diagram that will clarify all you know what the anatomical location is. From now on wherever you look into real anatomical image, you will be able to figure out the connectivity between the different organs which constitute this whole GI tract. Coming back to this, this is the gall bladder and this is where you can see another organ on the other side. I have not drawn the organ full. It looks more like this, and this is your pancreases. You might have heard people suffer from pancreatitis and all these things.

So, this is where your pancreas lies and we will be talking more about this because this is the seat of a hormone secretion of the body. Then, here the food enters into small intestine, the huge area where there is a lot of absorption taking place which is very well nicely supplied with blood vessel, so that they can absorb as much food particle or the different components of the food particle. So, this is a very well vascularised structure in the body. So, then comes the small intestine and then comes the structure where you called the colon or large intestine. It is out here. Basically, the major job is to absorb a lot of residual matter. So, this is the GI tract intestine and in terms of anatomical perspective

if I draw it, if I look it, so you are using the picture horizontally. If I draw it anatomically, then this is how it will look like.

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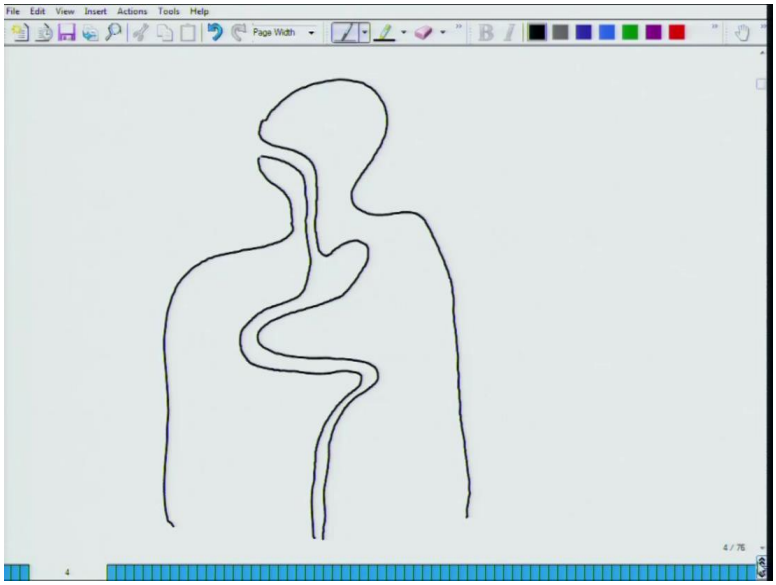

This is the head and this is the rest of the body. Then, it is something like this. So, this is how it will look like. This is where you are taking your food. So, this is same structure previous slide. So, this is what is happening. So, food is entering from the mouth.

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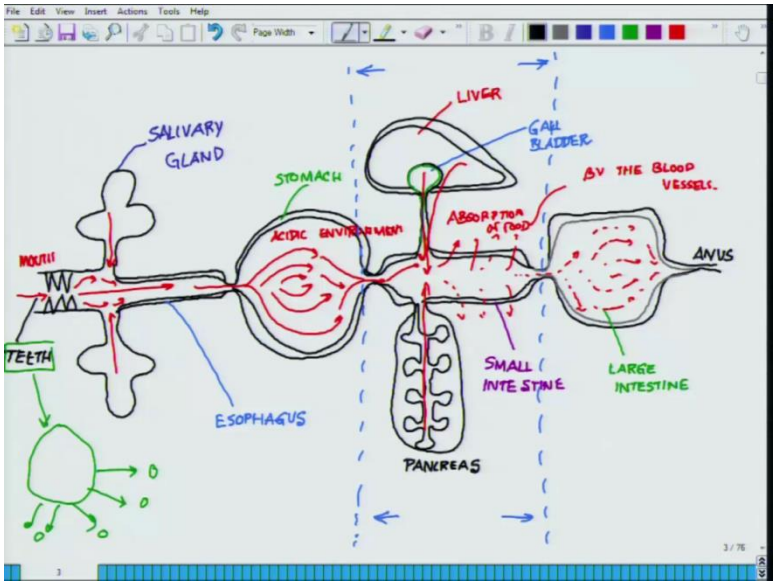


Then, there is a series of secretion which are taking place here from the salivary gland. After that the food moves through the esophagus and then it moves into the stomach. In

the stomach, it is exposed to a lot of acidic environment. So, the reason what I am trying to highlight is that say for example, this is a very application oriented situation. So, say for example, you have to take a drug through an oral root. So, the first thing that happens is that you take that drug. This drug experiences a very acidic environment in the stomach. So, if this drug has to be absorbed somewhere as I told you, it is in the small where the maximum absorption is taking place because it is very well vascularized supplies with lot of blood vessels, that is if that has to happen, one has to ensure that drug in the intestine, sorry in the stomach survives the heavy acidic environment.

This is the big challenge. Whenever you have to take a drug directly through the oral route because the drug goes through a whole range of modification pH changing environment, it has to be stable at different pH. So, it has to finally be absorbed in the right place which is the small intestine. That is why I have put that acidic environment. From this acidic environment of the stomach, it moves to the large intestine which I told you the zone where there is a lot of absorption taking place which I am showing by the arrow. Enormous amount of absorption is taking place, absorption by the blood vessels.

So, after this whatsoever it is that it is in this particular zone, where you have secretions from the liver, gall bladder and pancreases. So, all those secretion which are there are taking place at this zone, and all the absorption are taking place, it is here where glucose is being regulated. Islet cells of langerhams are regulating your glucose level and all other things. It is here, where any defect in this zone leads to a person being diabetic or some kind of you know liver problem or something. It is the critical zone of pathway which is essentially this is the zone, where major problem arises. It can be in the liver cancer, it could be in the form of pancreatitis, it could be a form of some kind of in the gall bladder burst out.

So, this is a very critical zone of the anatomy where lot of absorption takes place, and lot of very critical functions are being regulated here. So, most of the gastro intestinal pathologies in terms of liver or billary problems, liver problems, pancreatic problem, they are all concentrated in the very critical part of the anatomical structure, a chuck of it. As a matter of fact if you look at the institutes on NIAH or in India, we have specific institutes for nation institute for liver likewise. This is so very important, very interesting zone especially we are passing through an interesting time. When people are you know

de-tissuing liver, there is a problem in the liver, they could you know replace a part of it or they are trying to de-tissuing pancreases some part of it if they could put it back.

So, these are some of the very critical zones where there is enormous amount of studies going on across the world, where people are trying to ensure that you know how we could reduce the pain, and the problems of the people who suffer from liver disorders. Here these things are commonly fatty livers or liver cancer or liver damage because taking excessive wine or some form of liquor, there is liver has a problem or same way in the pancreases. You hear this you have pancreatitis. Many celebrities die of this particular problem. So, this is a very critical zone of the whole g tract. Then, after that whatsoever absorbing takes place in the small intestine, rest of the food which is not absorbed now moves to the large intestine. Large intestine is another zone. It is fairly huge zone and it is not that this whole zone is very functional. So, the major idea of the large intestine is to absorb the residual minerals and all other things which have not been absorbed in the small intestine.

So, this is the last frontier and after that through the anus here, we have the anus, you defecate. Whenever the concentration in the material is to be thrown out of the body goes beyond a concentration, you feel you have to defecate out, throw away the food. So, this is an open channel.

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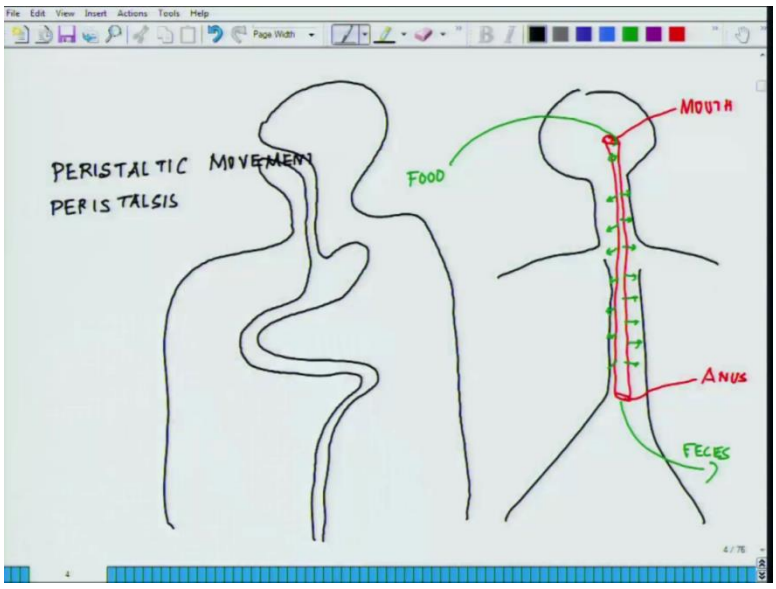

So, if you look at it from the mouth through an anus, this is an open channel which is running through the body along the cross-section of the body. If I had to give another analogy, it is something like this. This is a cartoon of a human being if you look at it like this. So, basically what is happening here is channel which is moving like this if this is the mouth and this is the anus. So, here the anus, here you have the mouth along this kind of tube you take any amount of food out here. This is getting the energy important material of the food is getting absorbed all along this tract after processing. Of course, it is getting processed inside and this is the food material.

So, it is getting absorbed and rest of it is being defecated out. So, this is both side open ended channel. It opens one at the mouth, one at the anus and along that tract, all these phenomenal events are taking place and this is what I wish you people to appreciate that how it looks. So, simple, but it is really a marvel of nature how the food enters and goes through all these different structures and in those structures, it goes through a different process and different components of the food, carbohydrate, your fat, proteins, vitamins, minerals, water. Water needs a specific absorption process. There are specific water channels which help the water to be absorbed slowly.

So, how these all wonderful things are happening along that channel, this is exceptionally important for you people to appreciate and understand. With this what I will do, I will highlight one interesting thing which is called peristaltic movement. So, it is basically the word is this peristaltic or it is also called peristalsis movement. What really is peristaltic movement? So, excuse me. So, whenever we take food, what happens? How the food really moves through this channel? I draw the channel for you. Now, the food moves in the ball of bolus. So, when you take a food, it is just like we chew the food. Once we chew the food, it forms a bolus or a ball like structure. In that ball moves imagine you have a flexible tube like this, and you drop a ball. How the ball will move? So, the ball will move like this if you look at it.

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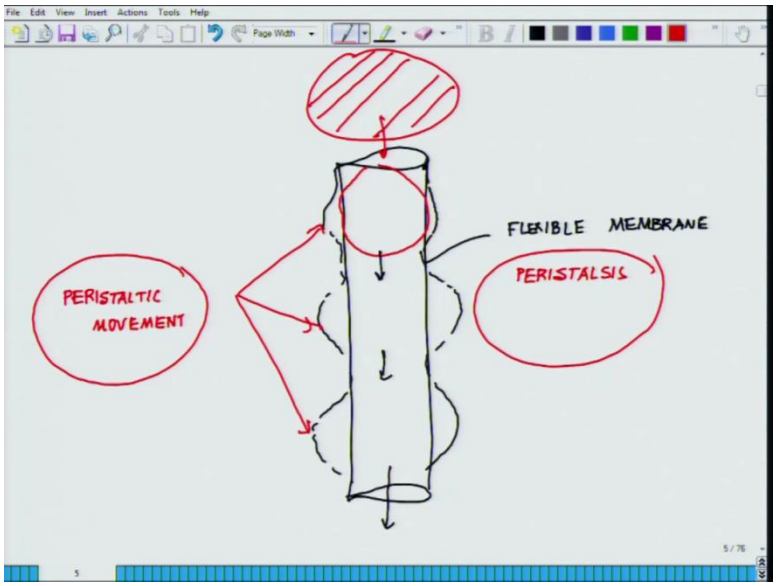


This is a flexible tube you have likewise and here, I have a ball something like let me redraw this. I have a ball like this. Now, this ball has to get through this is very flexible. So, what will happen when the ball will be here? Stage 1, ball will be here, this wall. It gets inflated like this to accommodate this. Then, once this ball will move here, and then this part will get inflated. Then, as the ball will move here, this part will get inflated to accommodate that big ball and eventually once it comes out and this is a flexible membrane. So, this whole motion of the ball is moving through the digestive tract like that is called peristalses and this whole motion is called peristaltic movement, ok.

So, this is how the food moves through this narrow tube in the form of bolus. It goes through like this and this whole peristaltic movement is governed not only by the nature of this muscle, the smooth muscle, but along with it there are nerve signals which regulate this process. This is very important. This is one of the areas of research which is currently lot of attention has been put that how the nerve signals are regulating this motion of food like this. So, like this if you follow my hand likewise, it is moving like this and this is very important this whole motion of the food along the path way.

So, what I will do? Now, as I told you I will draw the connectivity because it is a complex tube. So, every point of it you people have to understand. You know there is lot of connectivity issues here. Who is what and how these connections are taking place. So, what I will do now? I will add on that the component of the parasympathetic and

sympathetic, where they are regulating the whole process. So, let me see if I could do it in this diagram. It is a bit tricky. So, I will redraw it. That is easier. So, I will again redraw the whole structure.

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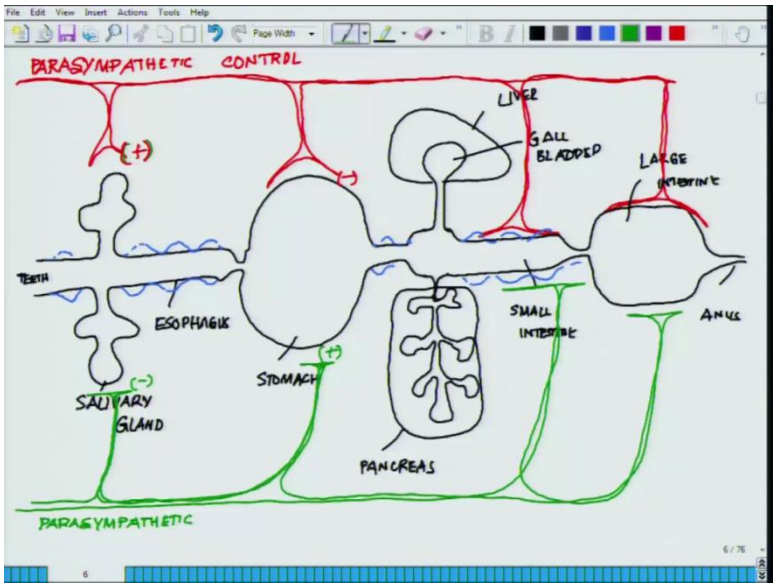


So, here you have the salivary gland, then you have the stomach coming through, then you have the small intestine, then you have the large intestine and then you have the anus. Here you have the salivary gland, salivary gland leading through the stomach. From the stomach it moves through here pancreas and liver connection and this is the large intestine and here you have the anus, here on this side you have the gall bladder and here you have the liver, and on this side you have the pancreases, ok. So, let me just put the nomenclature. So, here you have the teeth, then you have the salivary gland, esophagus, you have the stomach, liver, gall bladder, small intestine, pancreases, seat of endocrine system, the large intestine and anus.

Now, I will introduce the red and the sympathetic and parasympathetic connectivity. So, it works like this. So, this is the parasympathetic I am drawing. So, this is the parasympathetic moving through, then you have the parasympathetic connectivity as a whole structure out here, then you have the parasympathetic connectivity of the large intestine. So, this is your parasympathetic connection. So, if you look at parasympathetic connection carefully, you will have your salivary gland, your stomach, your small intestine, your large intestine under the parasympathetic control. So, this parasympathetic

control where synthetic control which I told I will show in green. So, the sympathetic control exactly moves in the same way. Here is the sympathetic control moving through along the stomach.

Then you have the sympathetic control exactly where you have the parasympathetic control and here you have this. So, this is basically the parasympathetic control. So, I told you there is the way the food moves. I will show it in green. The way the food moves is something like this along the path, and this is what we call as peristalsis. So, this whole peristalsis process along with is here also. The same thing happens. It moves like this, this peristalsis process along with the motion of the bolus along the muscle like you know changing the elasticity of the muscle as it moves through is also governed by sympathetic and parasympathetic.

So, if I say that this one gets a positive signal here for example, it gets simultaneously a negative signal from here or vice versa whichever we want to call it. If it gets a positive signal here, it will get a negative here. Similarly, if it gets a negative here, then you will get a positive here. There are always reverse signal which helps say for example, I say on off, on off, on off. So, this whole tube is being regulated by this on off switches, and this whole completely innervated with these sympathetic and parasympathetic neurons and apart from it, it is very well vascularised if we go back to the previous slide and if we look at this. So, this is under the complete. So, if I draw the vasculature like this in with the pink color.

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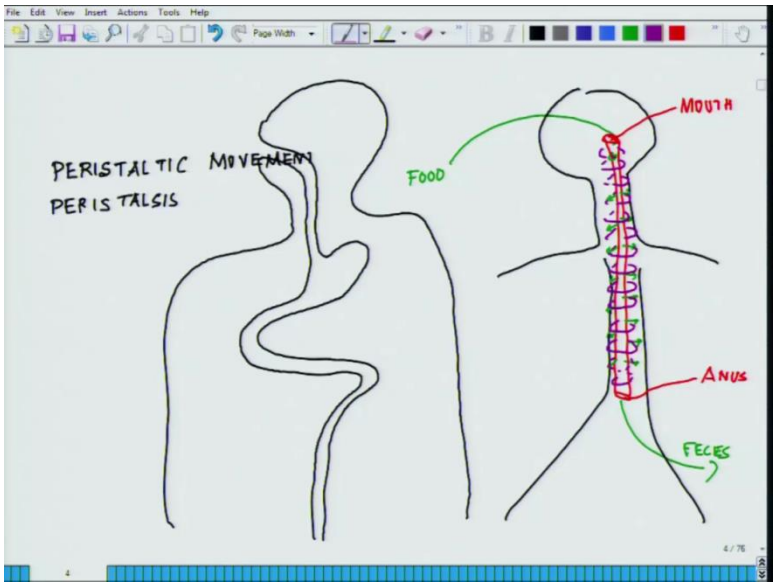


So, it is completely vascularized. There is a huge amount of blood vessel vascularising. It is here the body as to you know absorb all its nutrients. If you look at the cross-section of it, since I have drawn this, I will draw the sympathetic and parasympathetic control thing and I will draw the cross-section.

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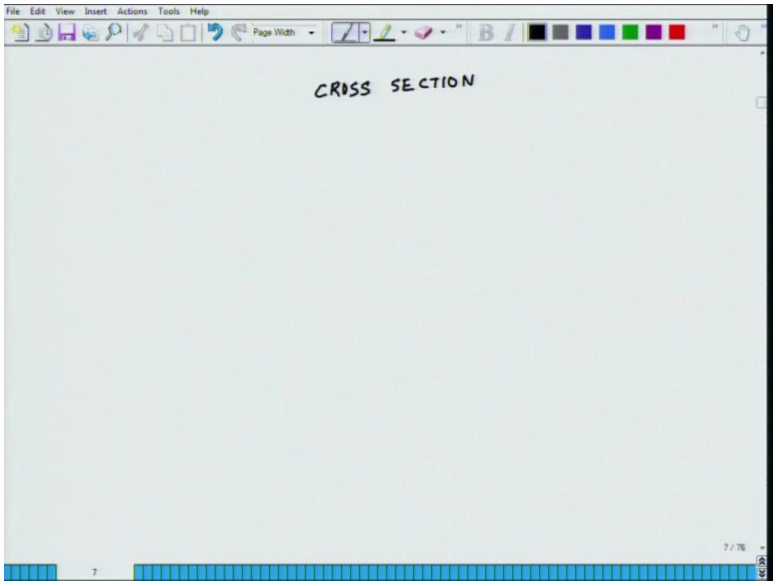


So, the cross-section is very interesting. It has multiple layers. So, basically what I am trying to show is this. What I am essentially drawing is the cross-section of this.

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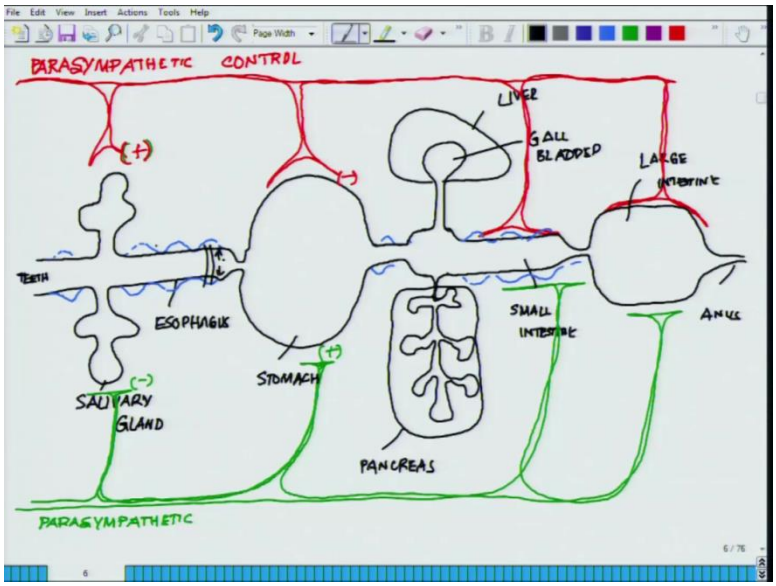


So, if you cut it like this, if I have the tube like this and I cut it like this, so this is the tube and this is the top part of the tube, where the food is travelling down the way and this is the anus. I am cutting in a cross-section like this, and this is what I am going to show you the cross-section shows like this.

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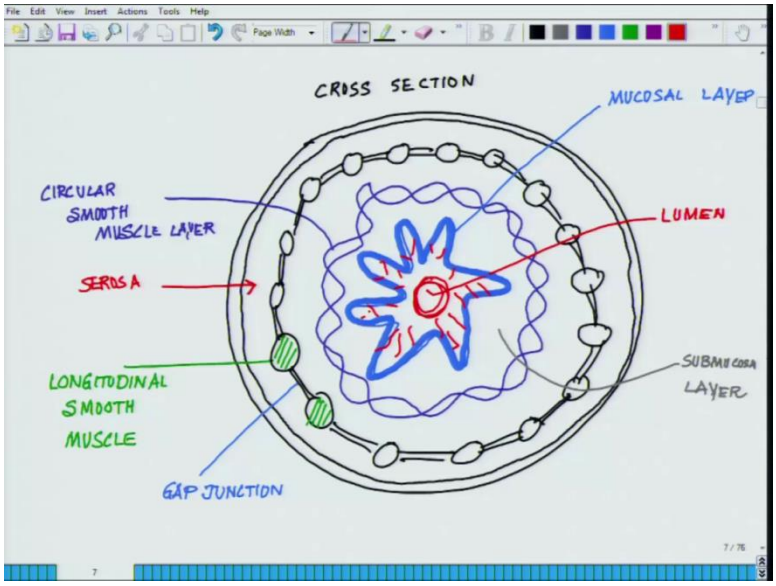


This is how the cross-section looks like. There are multiple layers and this is the outer most layers. What I am drawing now is the double layer looks like. Then, inside this layer, you have the next layer which is something like this. This is just for your

understanding sake I am doing like that because if you see an anatomy book, it is far more complex. I am just trying to draw a blocked diagram, so that you people may understand in a simple way how that looks like and appreciate this beauty of this channel which is pretty much our life line.

So, this is the next layer. So, the space between this and this is called serosa, and this is called you see this layer, this is called longitudinal smooth muscle. There are two different kinds of smooth muscles and I have already talked to you about the muscle physiology. Between the longitudinal smooth muscles, you see these structures. These important structures, these are called gap junctions. This is how the electrical impulse from one muscle is being shifted or transferred to the next muscle.

Then comes the next level. Let me draw this and then I will tell you. So, this layer what I have drawn now is called circular smooth muscle layer, and then within the circular smooth muscle layer, you have another layer which is this layer which is called the mucosal layer. This is of course double. Let me just change, ok. This is a double layered. All of them are pretty much double layered, thick double layered structure and this is called the mucosal layer, and the central cavity which you see here is called lumen. So, we talked about. In between there is a layer and these two are called sub-mucosal layer. So, if you look at it, you have the outer most covering and then you have the serosa layer which is here.

Then, you have longitudinal smooth muscle which is the next layer. It has gap junctions in it. Then, you have the next layer which is the circular smooth muscle layer, then you the mucosal layer, then of course the center which is the lumen through which the bolus passes. So, this kinds of cross-sectional view of the GI tract what we have just now discussed along these lines, these are cross-sectional view with a little bit of here and there. Some of them will have you know a brush border like this for enhancing absorption and all those things, these are further modifications, but over all geometry of the GI tract is like this.

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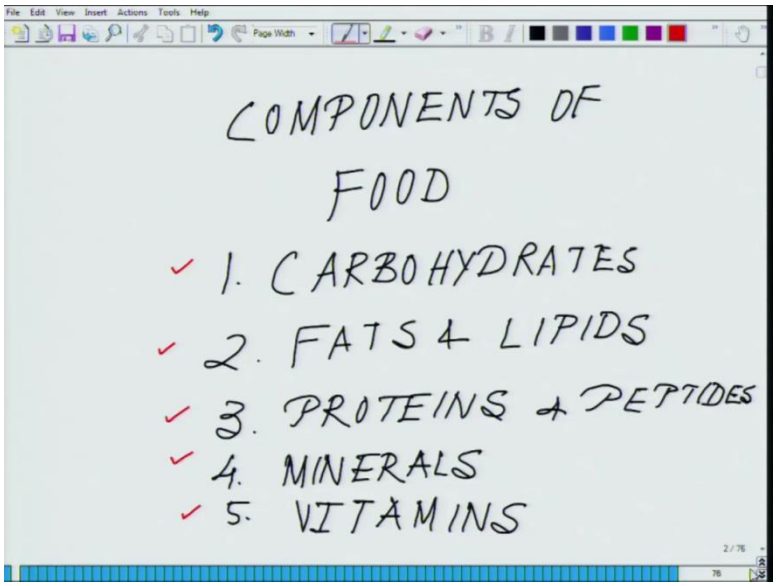


So, let us summarize what we have covered just now. We have talked about the components of the food, carbohydrates, lipids or fats, proteins, minerals and vitamins.

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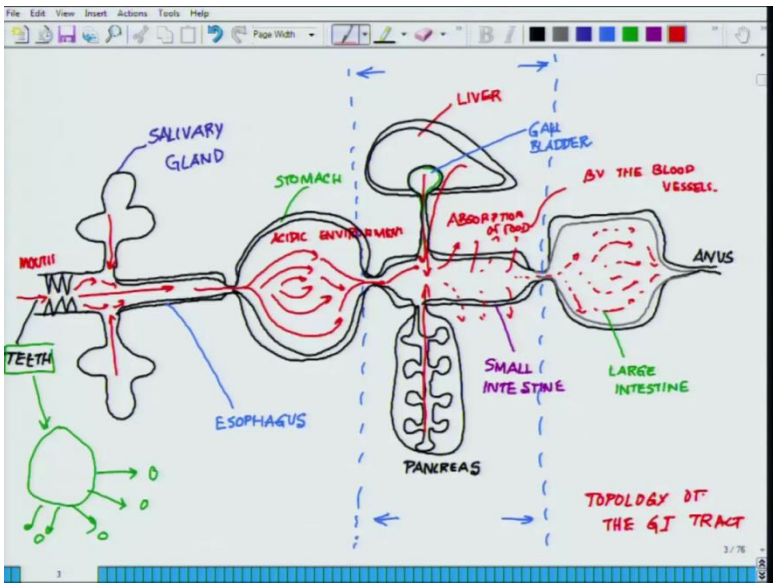


Then, we have talked about the overall typology of the GI tract, gastro intestinal tract with mouth, salivary glands, esophagus, stomach, liver, pancreases, small intestine, the large intestine and the anus.

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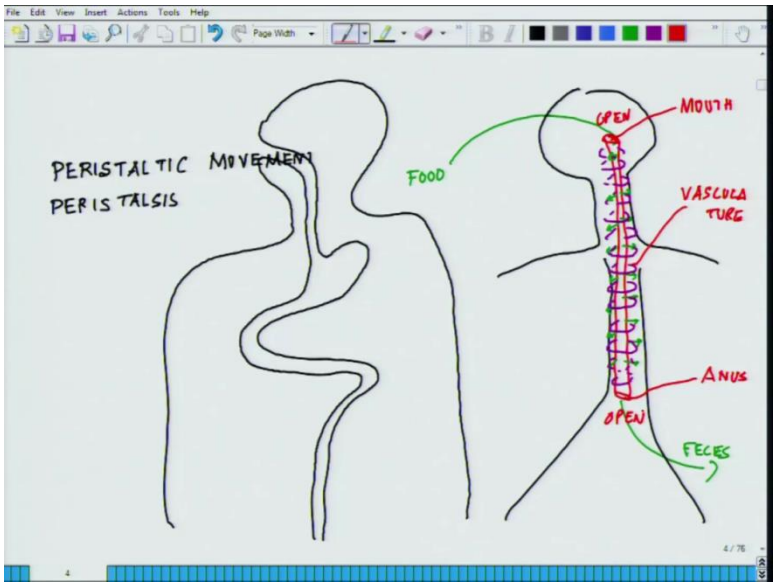


Then, we talked about giving you a feel how the vasculature is functioning. These are the vasculature or the blood vessels which are all along the open ended tube. So, this is open here and it opens here at the anus. So, this is open tube through which the food passes. It is getting absorbed and we talked about the peristaltic moment as how the food is moving through, and we talked about the parasympathetic and sympathetic control and then we talked about the cross-sectional view of the GI tract. With this over view, I will close this lecture. When we move onto the next lecture, we will be talking little bit more about the real process, where everything which aspect or which part of the food is getting absorbed and which part of the body.

Thank you.