Human Physiology
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Lecture – 45
Secretory functions of alimentary tract- Part 1

In the previous class we talked about - we were interested in understanding the overall anatomy of the digestive system. We talked a lot about the smooth muscles which form the bulk of the system and their role in propelling the food. We did a bit on the peristalsis movement and then we also talked about what? About the regulation of the peristalsis by way of the enteric nervous system and the two components and the control of the enteric nervous system by way of the autonomous nervous system, sympathetic and parasympathetic. So, we did a bit of that and we will move on. Actually when we talk about the entire system we can safely divide into three components, the one that we have already done, just the anatomy of it and how the food is propelled along the length, and the second point we can talk about is the secretions. Continuously there are, the food has to, the food has to be digested, it has to be mixed with, mixed with enzymes, the proper enzymes and proper quantity and the enzymes keep on changing as the food keeps on changing and then the most important part is depending, you need to provide a proper environment for an enzyme to act which means the pH.

So you have to keep on changing the pH and this is, this would be the second component and the third and the last component would be absorption. So right now, another, this or maybe next lecture we will talk about how the secretions, what are the secretions, why are they secreted, when are they secreted and how are they regulated. How does a particular enzyme come when it comes and how does a particular acid or alkali is discharged into the system as and when required.

Of course you want to keep everything wet, everything wet, I mean just as we need to keep our trachea and the entire passage moist, so we need to actually, so how do we manage that? We keep it by way by what you call as the mucus, so right from your mouth, so the entire length of the alimentary canal throughout you will have a very large number of what you call as goblet cells, what do you call them as? Goblet cells. Goblet cells and those goblet cells they are mucus secreting and mucus it is a watery fluid which is very rich in polysaccharides and little amount of proteins are also there. I mean not that the mucus from beginning to the end is same, no, even the quality of the mucus keeps on changing. It is slightly different but it does many important functions. Like it does not allow the food to directly come in contact with the inner wall of the alimentary canal, no that is a bad idea. So it protects it, it mechanically protects the stomach and then it is a great lubricant so that the food can just pass along, it allows the formation of chime. Very important it is a buffer and it will move food. So let us talk, let us begin at the level of the jaw, you see you cannot really chew the food without saliva, saliva is very important. Why saliva is important because it is only when we chew the food and it is broken into smaller fragments and then it is dissolved in the saliva then only your taste buds can have access to the food. So your taste buds by which you can taste, taste hello, salt, sweet what else, bitter what else, sour very good, spicy is not a taste, it is not a taste, bitter, bitter, bitter, bitter, have you heard the word umami, umami what is it, umami ok, we will talk about this sometime later.

So we are talking about parotid glands, sublingual glands, submandibular glands. They are in the upper jaw, they are in the lower jaw and they secrete a lot of substances and they contain one enzyme called as alpha-amylase and then it has some lysosomes which will protect us from the bacteria that we might ingest and you know something, the salt concentration of the saliva - sodium chloride is relatively very low, very low, can you guess why? Can you guess why, answer is very elegant. The answer is if it were as salty - it means the saliva were as salty as blood, blood is very salty, do you agree with me, blood is very salty. If that were so then our taste buds for salt would get habituated, if you expose a particular receptor to the same stimulus continuously for a very long time the receptors gets habituated. And if the salt receptors, receptors for salt on our tongue were to get habituated we will not get the taste of salt when we are eating it. So as to make sure that your sensory system for salt remain sensitive to salt you make sure that the saliva is poor in salt. So that when you take salt you immediately realize no, no the salt is too little or too much or whatever and salt is so important, sodium chloride, it is so important that nature has made sure that we are very particular, our sensory systems are very particular about the ingestion of salt. Get the point, so what is the point author is trying to make is that the sodium chloride is important for the osmolality. So what is it, osmolality of fluid 300. Am I okay there? hello, 300 okay, extracellular fluid 300. blood 300, lymph 300, intracellular 300 as the saliva is being secreted in the salivary gland 300, okay. But as it is being processed by the duct, I will show you how it happens, as it is being processed by the duct and lot of ions are reabsorbed, okay, so here we have the salivary gland, can you appreciate those glands there, each component there, each unit there is called as an acinus. The same word we will also use for the secretory component of the pancreas. We will talk about it later, so can you see that, so this is a cup, that is a cup and the cup is made of single layer of cells and the moment there is a single layer of cell, there is apical side, hello and there is a basal side, okay. Are you with me? And on the basal side you will have a capillary somewhere there and these are ducted glands, so the secretions are poured into this duct. There are a hundreds of thousands of them and then the secretion will finally be brought into the, brought into the mouth and then okay. Now the saliva as it is being formed, okay. So these cells will secret saliva, how they secrete - we will see in 5 minutes. They secrete the is juice which contains certain amount of bicarbonate ions, sodium, chloride, enzymes, amylase, etc and as it goes, so as it is being secreted right in this pocket, osmolality is still 300, how much it is? 300. We will call it as primary saliva, what do we call it as? Primary saliva. By the time the primary saliva flows into the ducts, okay. A lot of sodium, okay, and chloride is absorbed back and osmolality is almost reduced to 100, reduced to what? 100.

And then we call it as secondary saliva, what do you call it as? We call it as secondary saliva. Now this is interesting, there is a basal rate at which the saliva is being secreted by our salivary glands and that keeps on flowing in our mouth, keeps on flowing, the rate may go slightly up or down but it keeps on flowing - and that is of course the reason why our mouth is always wet, okay. It may go up when we start eating or when we smell food, particularly when I am hungry, all that would happen but there is a basal rate, okay. Now that basal rate happens to be very important because if the basal rate goes down, it is still there, saliva is there, if the basal rate goes down then you start experiencing dryness of your mouth and throat, okay. And then that dryness is conveyed to the brain and that is expressed as thirst. Are you getting the entire story now? It is beautiful, it does not mean that saliva has stopped being secreted, no. That is very bad. Saliva has to, even the rate at which the saliva is being secreted if that goes down, okay, dryness of the mouth, dryness of the mouth means generation of thirst which means behavior. You start looking for water, okay. I hope this image is clear to you, we are okay, so what am I doing here? I am okay, this is a single acinus, can you see that dark brown patch there on the other side, that is a smooth muscle cell, a bundle of smooth muscle cells, what would be the significance of these cells? So you are right, so they will contract and push, eject, eject, okay, suddenly to make sure that if you suddenly require, you see they will, okay. Now let us go for the most important part. So what I will do is I will pick up a cell from here and I will blow up the cell here and the cell has a luminal side, therefore as usual we have done this 100 times. This is the apical side and this is the basal side and the moment I said basal side you should immediately look for, for sodium-potassium pump, done, okay. We are very familiar with that, okay. Sodium-potassium pump and then every time there are 3 ions of sodium that go in, 2 ions of potassium that come in. And actually the potassium ion keeps on circulating because there is a channel for, there is a channel for potassium, it keeps on circulating, okay. And what is the purpose of this? The purpose is to make sure that there is excess of sodium there, as a result of that you need to make sure that this import system, what is import system? Look at it and tell me what is the name of the system, it is there, NKCC. What it is so familiar, look at the beauty of the nature, same protein system from here, here, it is same, NKCC keeps on working and that keeps on driving, one potassium and chloride and chloride, okay.

Now so we have excess of chloride and then that excess of chloride is delivered on the apical side or on the luminal side by way of a channel, by way of a chloride channel, by way of what? A chloride channel. Now a quick word on chloride channels, okay. They are all proteins, if you look at the entire, it is a big family, big family of proteins, chloride channels. You can broadly divide that family into 1 and 2 groups, okay. One of them is CFTR, hello, CFTR. Do not give that strange look. CFTR I talked about the CFTR in this class or I have not - cystic fibrosis transmembrane conductance regulator, okay - sorry, I keep on mixing the classes, I will explain it to you, there are 2 types, okay, there are 2 types of channels, one of them are called as transmembrane, one of these is very smart, good, anyway, so one family is called as, you get that type of channel and that type of channel is abundantly present in your respiratory channel and called as CFTR and cystic fibrosis and the other one is, this is of the other type. What would be the difference between this chloride and this chloride transport system and this chloride transport system? This chloride system - work goes in a cycle, with one cycle, one protein molecule will take in 1 sodium, 1 potassium, chloride and chloride -

take it from outside and put it inside. Again it will go through a cycle. But this guy here is a window, is a window, is it always open, no, it is not always open, it is not always open, only when you are either ingesting food or thinking of food and when the salivary glands are excited, okay. And then it starts secreting, then this chloride channel will open like a window and it will allow - I do not know - maybe 15,000 ions of chloride to pass through every second, huge amount, huge amount, okay. So this is a channel is a voltage gated channel. It is a voltage gated channel which means what? When this cell is excited, why excited? Well, it is excited because autonomous nervous system, it is excited because the parasympathetic nervous system input comes. So parasympathetic nervous system input comes, it is excited, once it is excited there is change in the voltage of the plasma membrane. As a result these voltage gated chloride ion channels opens and they allows the flood of chloride ions from the inside to go towards the luminal side and why is it negative? It is because of this.

So have you understood the steps by which a huge amount of chloride is suddenly being released only when the cell is excited. And the cell will be excited when the food will arrive in the stomach. I am sorry not in the stomach. Okay good good good good. Yes. So the saliva has a 100 milli mole Osmolality. Osmolality and your cells is 300 so won't the water move. You are forgetting important step that is the primary that is happening at the primary saliva where the osmolality is 300. So when that phenomenon is happening, in the previous slide that we saw that at 300 milli osmos. So these are the primary secretory cells and these are the cells of the duct.

So here it is 300 here and by the time the saliva travels down the duct it is processed and in the process what happens - to make this simple - the author has taken one cell here and he has blown up the cell here and again in the cell on the basal side you have the pump and on this side you are absorbing lot of sodium okay. And so the logic is here you are reabsorbing sodium and this thick arrow and you are also releasing some potassium - but look at the thickness of the arrow. The author is trying to codify what? This is much more prominent than this and as a result the saliva goes, the osmolality is reduced, but that happens much later at the level of the duct. Does it answer your question? No, this is 300 by 200 100 100 100 and because released in the mouth 100 that is the point already made - that sodium has to be less. Water has to be there but sodium has to be less and because water has to be there because water is not there then it will create the dryness. so the volume of the water has to be same and osmolality has to be less. That is that is your final formation of saliva. Yes. Yeah I now I understand your question and I will give you the answer. The answer to that question is the cells that are lining the mouth within them they have 300 milliohms - that is absolutely correct and there are no aquaponics anywhere okay. No good you ask otherwise I would have forgotten to mention this point. There are no aquaponics so water does not go across the cells okay. So now let us see this. I am sure you can immediately see the human face there. On the human face there can you see the nose there okay - so in the nose these are the olfactory receptors in your nose and on your tongue and the author has given the code for sensory fibres which is what orange colour. So the nervous information that is coming either from your nose or from your tongue it is going to the olfactory gustatory systems and hello are you good? Then it is going to the hypothalamus - so hypothalamus knows how by way of your smell and by way of your taste and then the hypothalamus will send the information to certain groups of nuclei which are again sitting in the medulla oblongata. And those centres - I will call as what? What are they? They are neurons okay - what is the peculiarity of these neurons? They are getting information from the hypothalamus what kind of information the hypothalamus has already processed the information with reference to taste and smell. So the hypothalamus is getting information from where tongue okay - which is over fifth cranial nerve - information over the nose first cranial nerve. Hypothalamus is integrating that information okay. It also goes to the memory centres - so you already know that this smell means this particular food. Are you with me okay. And then then that information will go to the salivary centres. These are the neurons - look at the green line - they are innervating the salivary glands is the picture very clear to you. I am trying to make it as simplistic as possible okay. yes or no? We are good so far. Then this information is going over the sympathetic and parasympathetic activation. Now see when we talked about heart and sympathetic and parasympathetic okay we gave an impression that the heart is there and sympathetic nervous system. It can push it up make it fast - make it strong and the parasympathetic nervous okay - if it goes and then maintain it within a reasonable limit okay. That is true for heart - but there are many places where the sympathetic and parasympathetic nervous system work hand in hand - you get my point not in opposite direction but in hand in hand. Together in the same direction and I put this slide because this is a classic example of that. How it operates - let us let us see - very briefly again. We are looking at the same cell what cell is this? This is the cell of the salivary gland are you with me so far? But this is interesting because on the on the basal side the author has clearly shown two different types of receptors okay. And what kind of receptor is this M1 what does M stand for? Muscarinic type 1 there are M1, M2, M3, M4, M5. Let us stop there M5 - out of that M1 and they are all G protein coupled - so they will go how many times it will go up and down? 7 times how many times? 7 Times. What is this fiber? This fiber is post ganglionic parasympathetic and therefore it contains acetylcholine are you okay with my flow of thought okay. Preganglion is also acetylcholine post ganglion is also acetylcholine and that acetylcholine neurotransmitter which is coming via here as well. I mean this is something like this. You are sitting in the middle of medulla oblongata in the middle of medulla oblongata - you have group of neurons - I will call it as salivatory center okay. That neuron will talk to those cells which will give rise to axons which will go over the vagus hello, go over the vagus yes or no? yes go over the vagus - they will go to the salivary glands - but they will have a ganglia and the post ganglion are also cholinergic. And this is releasing acetylcholine. Now can somebody tell me what is the meaning of this part on the smooth muscles. That we have seen in the previous slide on smooth muscles - on the plasma membrane have another protein. That protein is M3. What does M3 mean? Muscarinic - but it is not M1 - it is M3, okay. And when it is stimulated - those smooth muscle cells will contract. And then there is also norepinephrine. Now this is a part of sympathetic nervous system it will act by what kind of receptor? Beta 2 adrenergic receptors and whereas the muscarinic receptor it acts on endoplasmic reticulum that endoplasmic reticulum will have calcium. When it acts by IP3 mechanism. It will release calcium okay. Now that calcium is driving these vesicles and these are secretory vesicles - what do they contain? You remember alpha-amylase is a enzyme okay. And then the liquid part - what are all the components of the saliva - they are being released - so beta-adrenergic mechanisms - G protein coupled mechanism - it will act by cyclic AMP mechanism - cyclic cyclic AMP mechanism. It will drive the proteins and the mucin okay what which is the component of the saliva will be released into the into the into the cup and then it will be driven to the mouth.

Whereas now we see this system - which system parasympathetic? Whereas the parasympathetic nervous system plays this component - you need trafficking within the cell yes or no? You need trafficking you need trafficking. Trafficking will not happen without - this part being stimulated by by acetylcholine and this part by beta-adrenergic - sees to it that there is more mucin which is a very important component of the saliva because of the sympathetic stimulation. So the two systems working against one another – no, okay. Actually parasympathetic nervous system is making sure that the calcium is there so that the trafficking and release can happen acting via M1 acting via M3 it is acting on the smooth muscles to make sure that it is ejected. And the sympathetic nervous system is acting on the secretory cells so that the composition of the saliva is regulated. So they are working handing in hand to make sure that saliva in its right concentration with right ingredients is being released at the right time. You have a question you can ask. Yes - I do not really know. What I know is that as soon as you see the regulation at the level of the saliva center and once you either stop eating or why do you stop eating because there is a satiety mechanism - means your system tells the brain that okay I have had enough food and it is not a good idea to continue eating. So I have to stop eating okay. At that time - in that loop the salivatory centers are also inhibited okay. I do not know whether there is any GABA signaling happening there. But, at that stage, once that is inhibited - the whole system is inhibited means it stops function okay. So you have taken food you have chewed it - you have mixed it with saliva as a result of mastication and the food will go if you are particularly standing it is very easy the gravity will pull the food down the esophagus. And then food will go and at the junction of the esophagus and the stomach you have a sphincter muscle we have already seen the control - what mechanism was that latch mechanism. That word is familiar latch mechanism okay. So this will open and it will allow the passage of the food. What we are looking at is inside the stomach. The inner wall of the stomach is thrown into what you call as a Rugae. What is the word for this? It is called as Rugae. This is the esophageal sphincter and this is the pyloric sphincter - after the pyloric sphincter the stomach will communicate with duodenum Now listen this is going to become very interesting. When I say very interesting it is my gentle way of saying that it is going to be complicated, okay. So please be with me and do not miss a single word, okay. I will try to make as simple as possible okay. Okay so let us see. We will call this part of the stomach as the fundus. So the food arrives in the fundus part and later part which is towards duodenum. I will call it as the antrum. Have you observed these two words. Traditionally this is the fundus part - the bigger part and the later part is called as the antrum, okay. Remember now. Let us take a step forward, okay. This is a section through the wall of the stomach and we are familiar with the outermost layer is serosa, inner layer is longitudinal layer. In the inner layer is a circular muscle. Stomach is more complicated. There is one more layer which you do not get in other parts it is called as the oblique muscle layer. I mean it is very necessary to make sure that the stomach wall goes through rigorous contraction and relaxation so that the food is thoroughly mixed with the acid and the enzymes. Therefore the wall is really thick and then I will tell you what if you are walking on the inner wall of the stomach, okay there is a hole there and a hole there and a hole there and a hole there, okay. Are you with me and these are called as gastric pits. What you call them as gastric pits. So can you see that gastric pit there on the surface okay. They are very tiny okay - very narrow - and very deep. Very deep so they go as far as here are you with me? What do you call them as 'gastric pits'. Some people also like to call the whole thing as a gastric gland, okay. But the gastric gland is a.