Animal Physiology
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Lecture – 37

Welcome back to the NPTEL lecture series on animal physiology. So, we are in section 12, the lecture 3, this is basically in the gastrointestinal physiology. So, we talked about the, in the first lecture we talked about the overall architecture of the digestive system, we talked about how the nervous innervations of sympathetic and parasympathetic systems are kind of controlling the whole system, the whole architecture. And then on in the second lecture, we talked about the first part, where the one second, where the first intake of food takes place, that is in the mouth, and the saliva, the function of the saliva, how saliva secretion is being regulated, and how the first phase of the food is being broken down into pieces, before through bowless movement in the form of peristaltic movement, it moves to the stomach.

A stomach is the, I should say the first after the mouth, it is the first station through the esophagus it reaches the stomach. Stomach is the first station, where the food is exposed to one of the most acidic environment in it is whole track, all the way excuse me. All the way from mouth to excretion from anus, this particular structure is the most acidic, where the p h almost hits upon 1 and even possible less.

And that is because of hydrochloric acid, which is being produced, by their different cells they are parietal cells, chief cells and everything. So, the way we are dividing this particular classes. We will talk about the anatomical feature of a stomach from there, we will move on to the different cellular structure, and how they regulate the movement of h plus and c l minus ions, which leads to the formation of hydrochloric acid. And then we will talk about the different phases, which regulate the whole digestion process.

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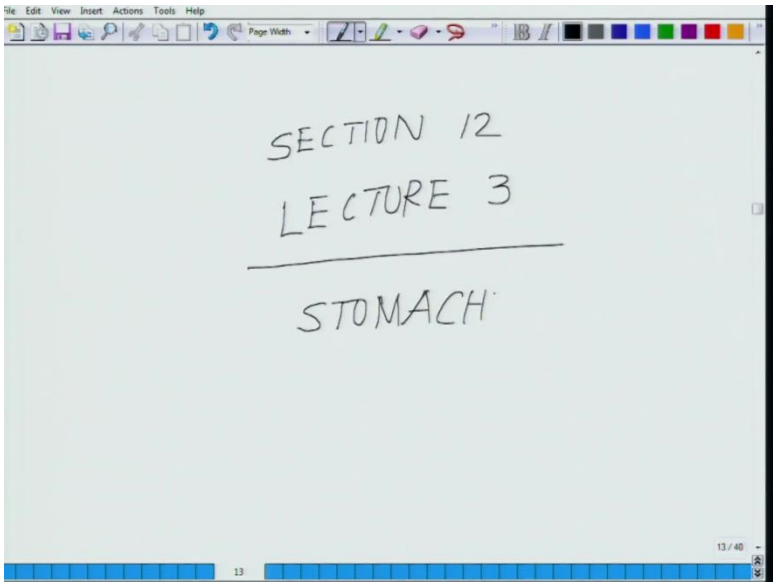

So, anatomically speaking, so if you look at the structure ((Refer Time: 02:25)) get back to the section 12, lecture 3 stomach.

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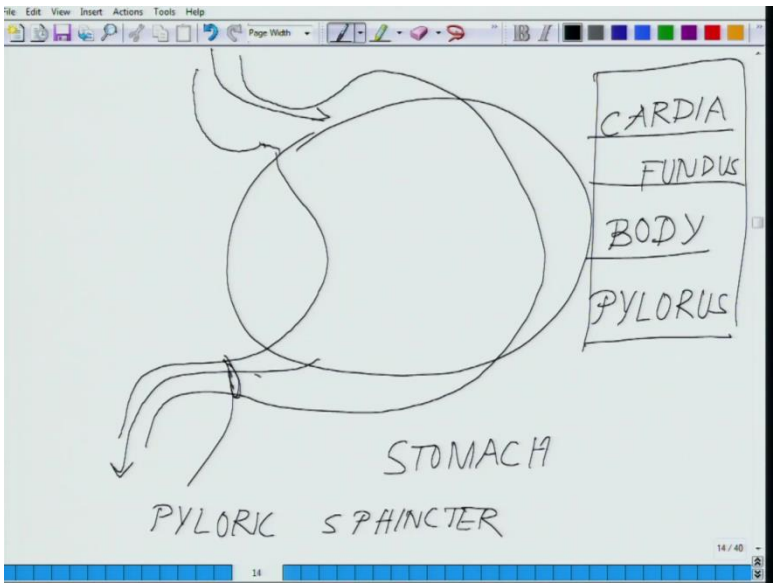

So, the overall structure, if you look at the stomach the way it looks like it is a structure, is physically looks something like this. And of course, not this one second, let me just redraw it, something like where the food moves to the whole path wait this is wrong way to put it to the, let me redraw it, something like this. So, the food is coming, I am showing you the arrow, this is how the food is entering, and this is where the food moves

to this small intestine. And what is ever happen, everything happens in this zone. So, if you look at the very basic structure of it, it is divided into four different parts, parts are named as cardia, fundus, the body and the pylorus.

These are the four anatomical feature of stomach, and each one of them has their own function. And what I will do and they something called pyloric sphincter, which is present somewhere out here, which ensures this pyloric sphincter ensures that the, when the food should be sent to the intestine. Till so it is kind of a control mechanism by which food is being ensured that the all the gurgitation, ((Refer Time: 04:44)) all the chemical reactions takes place, in such a way that the food is now ready, to be transported to the small intestine. For further absorption and all other metabolic, metabolism related events.

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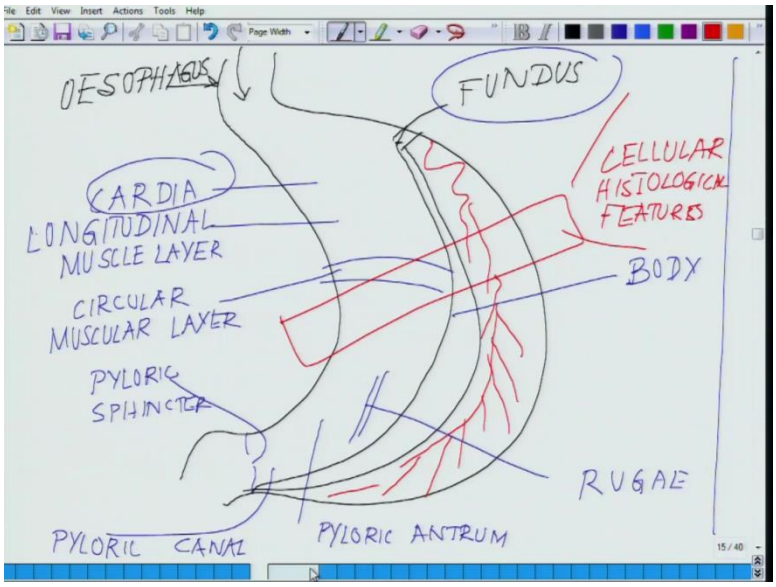

So now, coming back to the structure, anatomical feature of the structure, so let me redraw this. So that, I can label all it for you people, so fine. So, this is the entry port of the food, so this is esophagus. So, then the food is entering, this is the fundus region and this whole vessel, if I have to hat trick a cross section of this something like this, if you see cross, if I take the upper view of it. You will see lot of blood vessels all over the place like likewise, it is completely inner weighted with blood vessels likewise. So, this is just the kind of a cross view, what I am trying to draw for you people.

If you get an over upper view, then this zone is called cardia, and here you have a bunch of longitudinal muscle layer. There are two kinds of muscle arrangement here, longitude these are all smooth muscles, longitudinal muscle layer and second one is series of circular muscle layer. And these longitudinal and circular muscle layers, helps in the movement of the stomach, circular muscular layer, a muscle layer. And then we have, this is the fundus; this is cardia and here is the body.

So, body part and this surface is called rugae surface; and this zone is called pyloric antrum; and here is the pyloric sphincter; and this part is called pyloric canal. So, this is the overall geometry of the stomach. So, all these organs, most of these digestive organs or any of the secretary organs needs a site or needs a geometry or anatomy by which it can secrete. So, think of it, you have so and you have to, if you think of a pipe, what happens a pipe, it is hose and the it is started dumping out that fluid. So, what kind of pipe like structure, this stomach has, so there we are entering after giving you this whole, overall anatomical idea of it.

I will move on to the cellular structure, how the cellular structure of a stomach looks like. Let us move on to the cellular structure, and how this histology and this and where all these different cells are so, basically what we will be doing. We will take up a cross section of this and we will move on to the, cellular histological feature. So, the cellular structure, the way it looks like if you go through your cross section of the cellular structure, it looks something like this. So, bit of a complex drawing, but there with me, eventually to look very straight forward.

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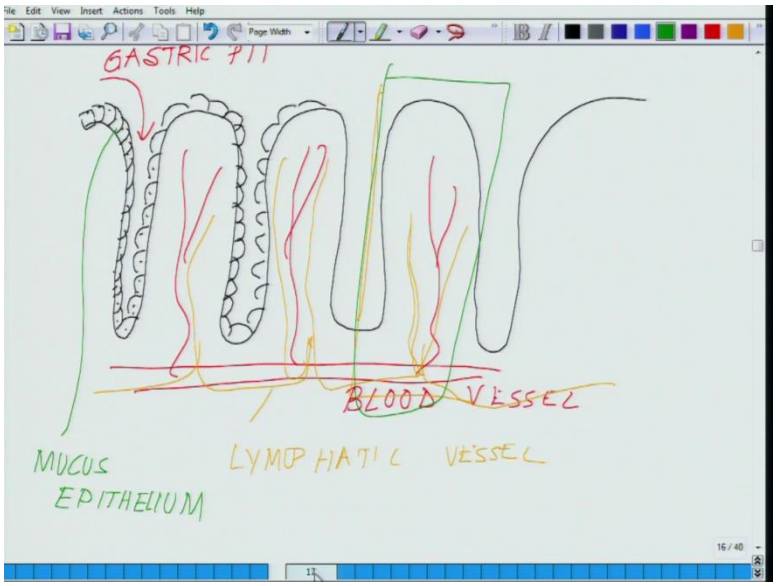

So, something like this, this is how the structure looks like, and even if you make a cross section, it will look this only. So, and these are, line by different cells like this and I will get the different nomenclature, so imagine it, if you reverse it, it looks more like a pipe. So, I am just drawing one of them, and I will leave the rest for you to for your imagination to take over, these are the different cells, which are forming the structure, these are the nucleus, I am putting.

So, these are called, these structures are called, this gap what you see is called the gastric pit fine. And these cells are called mucus cell lining, mucus epithelium, and within the mucus epithelium, you have some series of cells, and underneath it. And I will come in depth, after I will just give you the overall underneath this, you have the, all the blood vessels which are moving through all this, likewise these are the blood vessels, you see. And along with the lymphatic vessels, which are running along.

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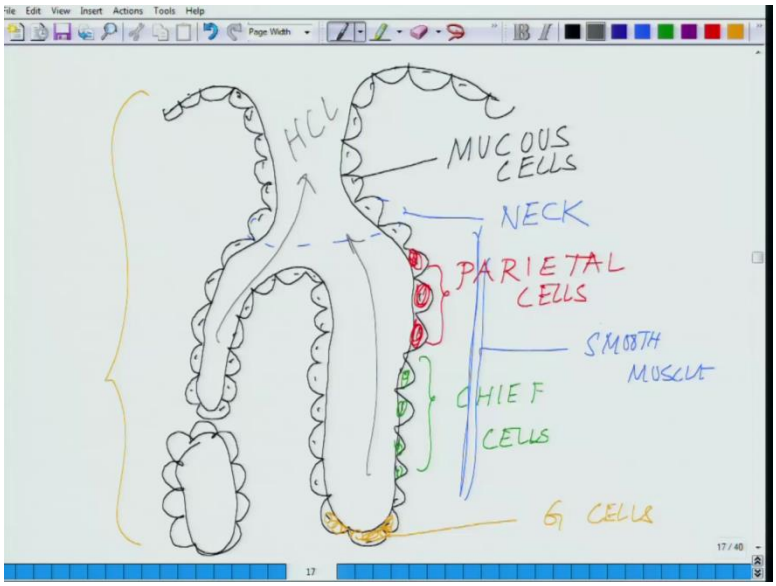

Now, if I take a complete cross section of this, something like this and redraw it, how that will look like, so where I will be talking about the different cell types which are involved in it. So that will look like more like this, again redraw that, one small fragment, that will help you to realize it better, I just picked up one of those gastric pits. Now, let put all the cell, which are present in the gastric pit, I am just doing ((Refer Time: 12:01)) reverse site drawing the cells, that makes life little bit easier.

So, these are the cellular lining, which are forming, the gastric pits and underneath the gastric pits you have another series of cells, which are forming, the supporting cell to the gastric pits and so these are the nucleus. So, in this, so I told you that these are the mucus cells and this zone what you see here, is called the neck of the pit and within a neck of the pit underneath that, you have some cells which I am ((Refer Time: 13:14)) now putting in red, these are called parietal cells and underneath that, I am putting them in green.

And the series of cells which are called chief cells and you have series of smooth muscles around it, and very, very underneath out here, you have certain cells which are called G cells. So, each one of these, are formed of, each one of those pits what I have drawn, formed out of chief cells, parietal cells and the G cells. So, we started with the overall architecture, we talked about the position of the pylorus, fundus, body and the

connecting tube. And then we talked about the basic cellular anatomy, and we showed you location of the gastric pit.

So, through these gastric pits, what I have drawn, basically through this pits, you see the secretion of hydrochloric acid, how that happens? Now, we will move on to the production of hydrochloric acid, none of this the cells which are involved in it, they do not produce hydrochloric acid, they produces tell let me give you the way they do it. They produce h plus ion and c l minus ion and they secreted, and then they interact and form hydrochloric acid.

So, if a cell in a cytoplasm starts producing hydrochloric acid, then that is cell it is very difficult for that individual cell to survive. So, they do not, do it like that and it is mucus cell lining, which prevents these cells from getting destroyed. So now, what we will do, will pick up the individual cell here. And then we will talk about, how it is forming the… How it is helping in the formation of the hydrochloric acid, it is going back to cellular geometry of it.

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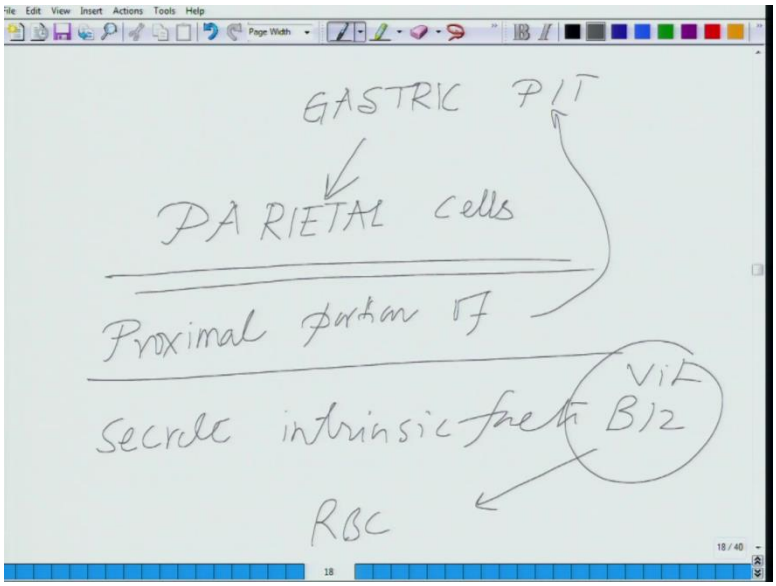

So we talked about the parietal cells. So, we in the gastric pit, now inside the gastric pit, so within the gastric pit, you have two types of secretary cells. So, first one is the parietal cells, these parietal cells are especially common along the proximal portion or you must have seen that in the picture or so these are the proximal section, where they are fairly common, they are along the proximal portion of the gastric pit portion, of gastric pit.

And they secrete intrinsic factors like vitamin B 12, if you remember that, this was helpful in vitamin B 12 is in full in the R B C production.

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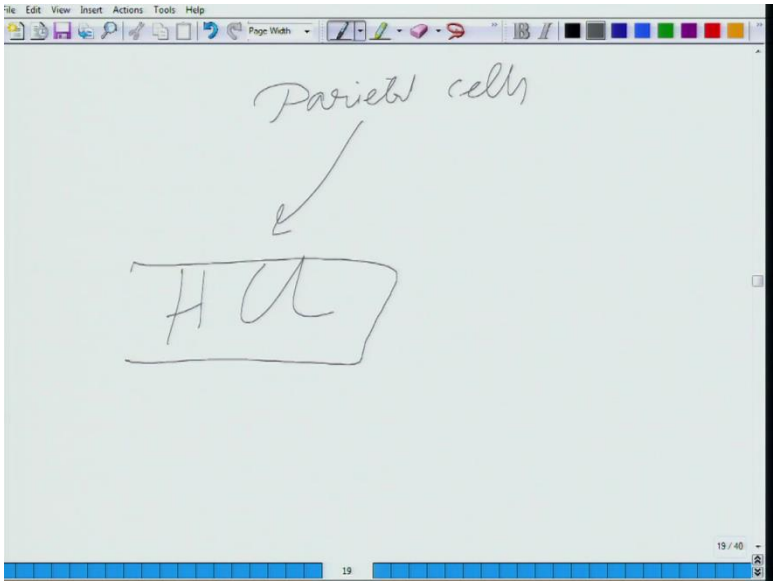

So, parietal cells, the other function of parietal cells are HCL production. So, how it does so?

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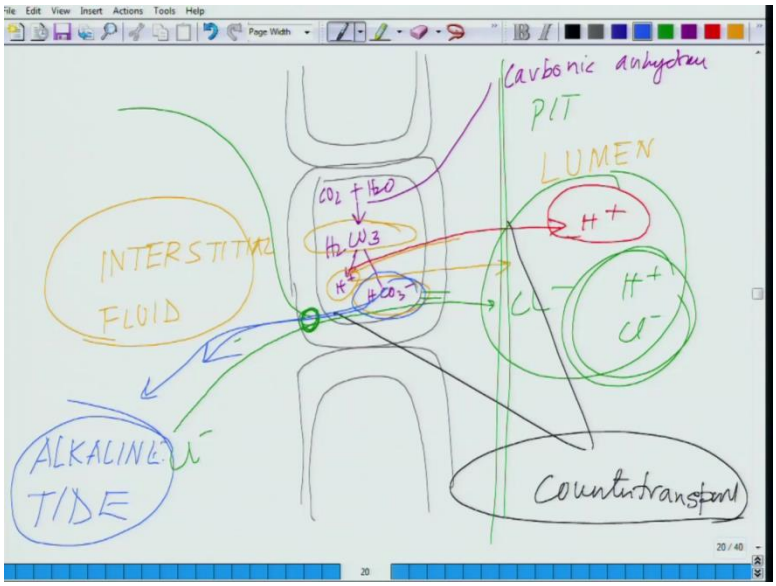

So, let us look at the geometry of the parietal cells they… So I am now at the cellular level, what I have drawn the just before this, now I am talking about the individual cells. So, let us take up this section that is happening is that. We have talked about this reaction

C o 2 plus H 2 o in the presence of carbonic and hydres, carbonic anhydres enzyme, it forms H 2 C o 3, H 2 C o 3 immediately dissociates into H plus and H C o 3 minus ions. Then what happens, once this gets dissociated, so this bicarbonate ion, which is released here.

So, there is, these ions here two three things happen, this H plus ion through transporter moves inside. So, this side is the lumen side of it, and this side is interstitial fluid. So, essentially what is happening is that, these two ions are transported independently by a mechanism. So, hydrogen ion generated inside the parietal cell has the enzyme carbonic anhydres converts the carbon dioxide in water to carbonic acid, which is H 2 C o 3 what you could see here. Then the carbonic acid, promptly dissociates into H plus and H C o 3 minus, the hydrogen are actively transported into the lumen.

So, this hydrogen is actively transported into the one second, into the lumen area. And whereas, the bicarbonate ion, which are produced here, H C o 3 is transported into the interstitial fluid. So, they follow a two different, so there is a counter transport mechanism. So, this is a classic case of between these two, this one and this one, there is a counter transport. So, after this what happens this H plus which is being moved out there, from outside. From the interstitial fluid, the chloride is being transported like this and this chloride transport and H C o 3 ejection is a reversible.

So, one direction what is happening is that, the bicarbonate is being released out of the cell, and chloride is being taken up the cell. So, it is the, it is a kind of a, so there is a mechanism by which there are two reverse processes which are happening. So, carbon dioxide, chloride is getting inside the cell and bicarbonate is sent out of the cell, counter transport, there is a co transport there is a counter transport taking place. So, after this what happen is that, once this chloride is being sent here, then this chloride the diffusion process moves inside the lumen.

So now, you have the source of H plus and c l minus and this side what you are seeing, this side is the pit. So, this is where, they are throwing out these two. And whereas, when this H C o 3 is coming on this side, this leads to a event, which is called alkaline tide, this makes the interstitial fluid fairly alkaline, there is a sudden influx of the bicarbonate ion.

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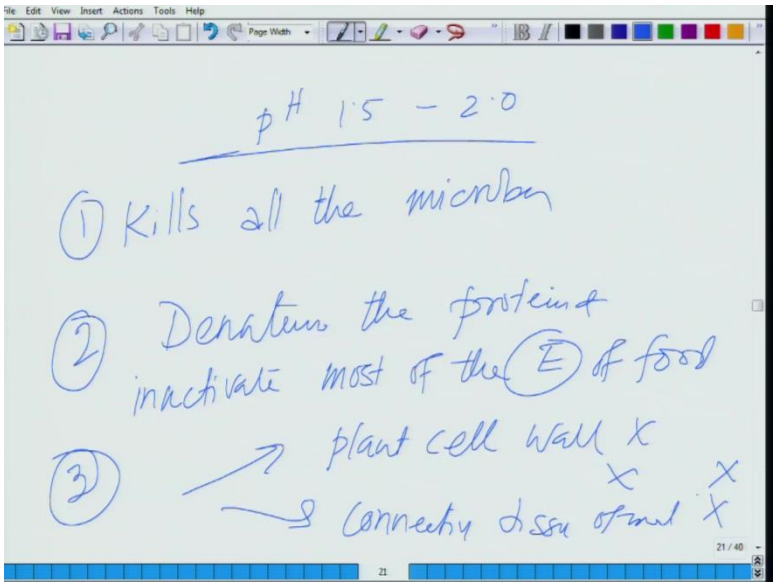

So, what this HCL does. So, the P H goes to 1.5 to 2 and what it essentially does, it kills all the microbes, this is the major job it does. Second thing is does, it denatures the protein and inactivate most of the enzyme of the food, most of the enzymes of food. And the third important thing it does is that, it also breaks down the plant cell wall and a connective tissue in the meat. So, plant cell because we have a lot of vegetarian diet plant cell wall breakage, and connective tissue of meat is being broken down.

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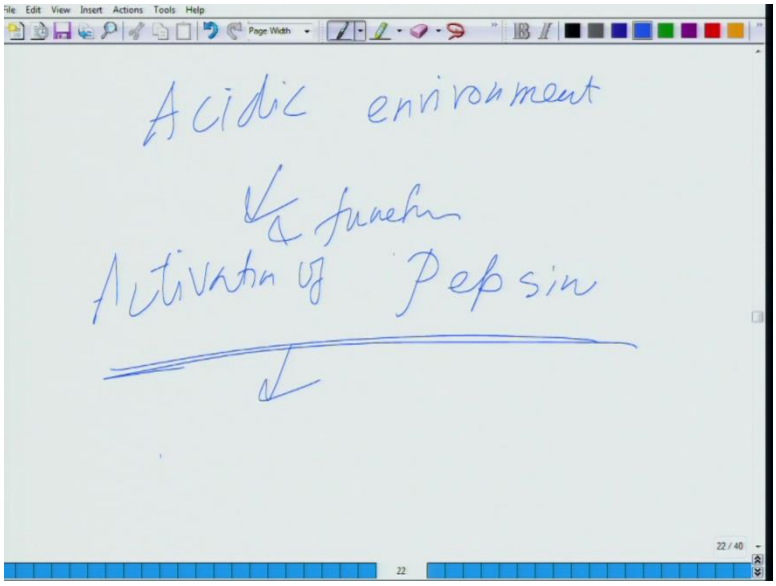

And lastly this acidic environment does a second set of job, acidic environment this to the activation of ((Refer Time: 22:13)) the activation and function of pepsin, which is basically a protein digesting enzyme secreted by the chief cells, which are just underneath it. So, it follows four actions, once it creates an acidic environment by which most of the microbes are being killed.

The second thing it does it, denatures all the proteins and the enzymes present in the food. Third thing it does, it gets rid of, it breaks down chops down the plant cell walls, and the connective tissue of the non vegetarian part of the food. And lastly what it does, it promotes a secretion of pepsin, which is secreted where the chief cells. So, you talked about the parietal cells underneath you have the chief cells.

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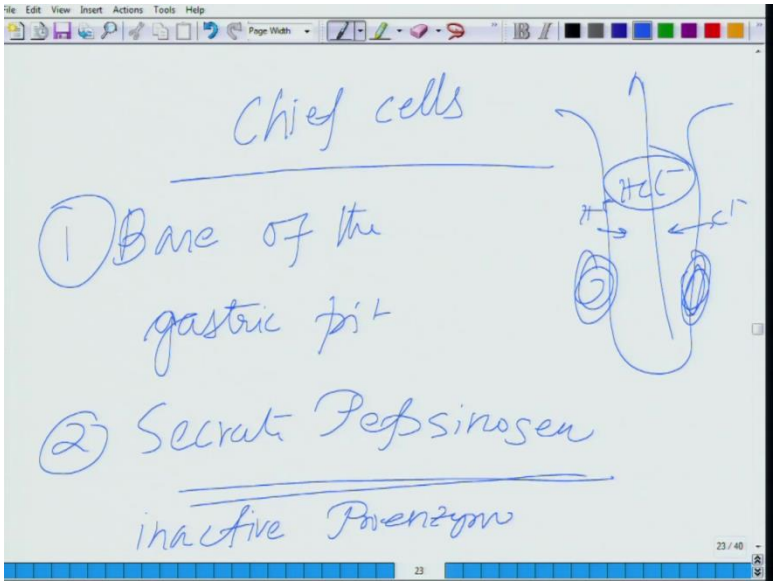

So, now, we will talk about, what the chief cells are doing out there. So, coming to the chief cells, so what the chief cells are essentially doing is that, they are more abundant near the base. As you must remember like I was when I was drawing the pit like this, they are mostly concentrated out here, along the pit and this is the pit. Where all the H plus and C l minus are falling, so this is the H C L pit. So, they are more towards the base of the gastric pit, this immediate location of it. And these cells secrete pepsinogen and which is an inactive pro enzyme, and it has inactive pro enzyme.

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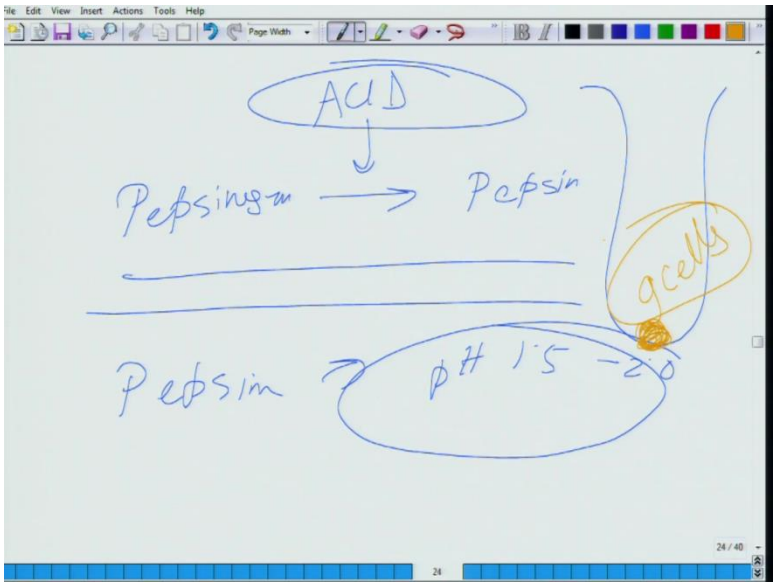

And this pepsinogen is converted, pepsinogen is converted to pepsin, presence of the acid and this acid is being supplied by the parietal cells, which have present there. So essentially, this pepsin is most functions most effectively at the P H of 1.5 to 2 that is the zone, where it acts, it is activity is maximum. So, we talked about the parietal cells, we talked about the chief cells, still there is one more cell at the bottom of the pit, if you remember well I was drawing it, I showed you that they are certain cells, which are present here, which I call the G cells.

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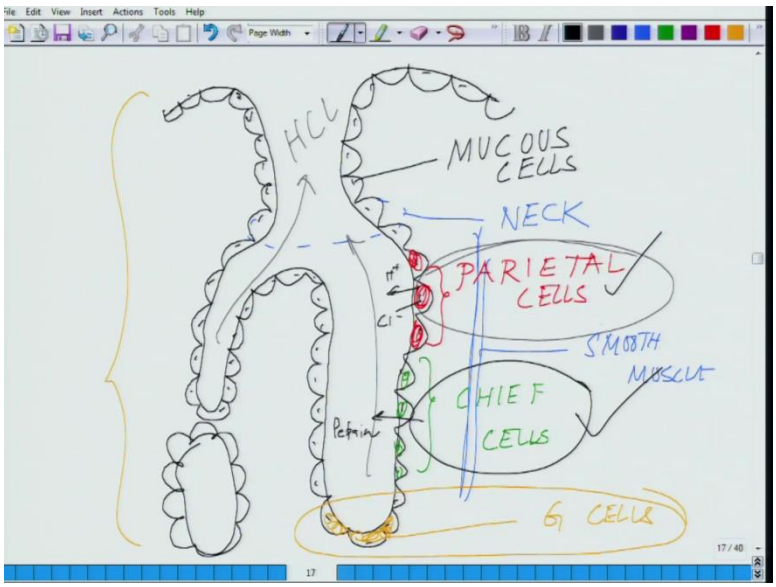

If I go back, you will see that next one; these are the cells, we have not talked about cells. So, we have talked about this, we have talked about this, so this is the one. So, if I, so from here, coming H plus and C l minus and these are the once which are secreting pepsin.

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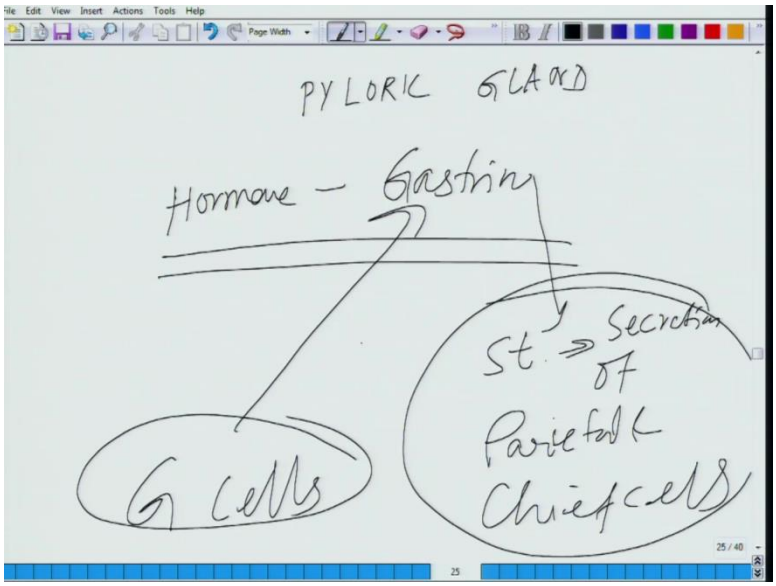

Now, let us talk about the third one in the line, which is the, one second, which have the G cells. So, pyloric gland, which is secreting the… So these are basically, they secrete a hormone called gastrin, which is produced by the G cells and what gastrin does. So, basically gastrin is produced by the G cells and G cells are most abundant in the gastric pit of the pyloric antrum. And gastrin is stimulates, there this is what gastrin does. So, function of gastrin is that, it is stimulates a level of things, it stimulates the secretion of a parietal and the chief cells. So, secretion of parietal and chief cells this is it is major function, this is one of the function of it.

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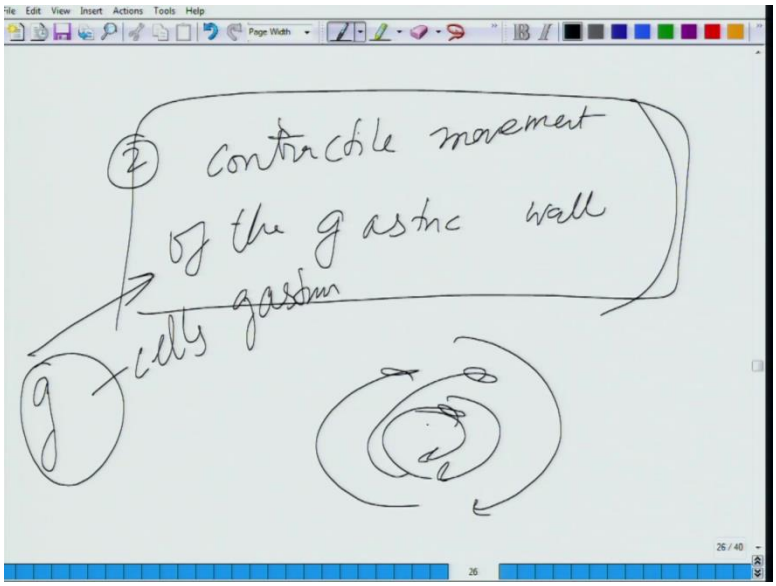

And it has a second function; second function is that, so there is along this, there is a contractile moment which is essential. So, contractile moment of the gastric wall, this contractile moment is being supported by this gastrin, and this is extremely essential it is something like this. The food has to be continuously in motion, it is just like you are, you take you know, how you mix the dough do, while you are making bread, it is just you have to mix it so mash it up you have to really you know, push it through. So, it has to go through this whole motion, that motion is being promoted by this hormone called gastrin, which is secreted by those G cells, which are at the base of the gastric pit, so that is the function of it.

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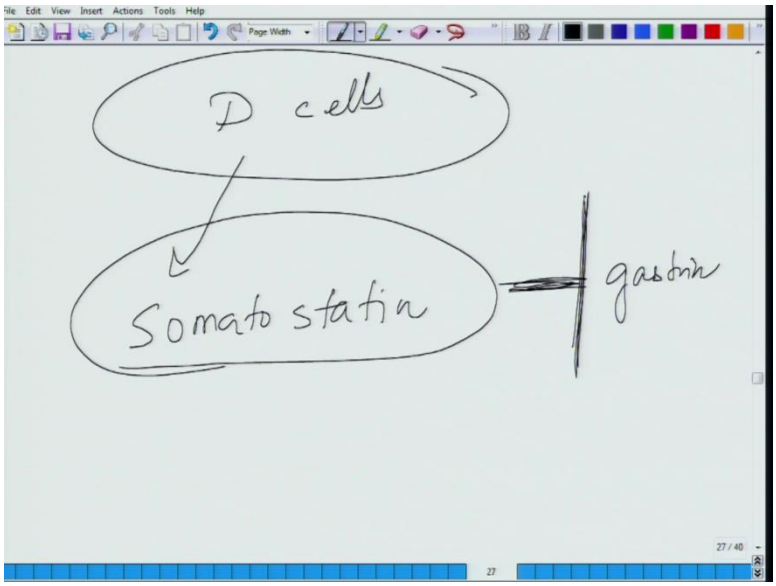

So, now we have pretty much enumerated, there is couple of more small details which, so this pyloric gland also contain there is something called D cells, which I have not mentioned in the picture, they are very few in numbers. And they release something called somato statin, which is a hormone that inhibits gastrin release. So, this is kind of a, if this is the inhibitory signal I am drawing gastrin. So, in other word, the D cells which are present in the gastric pit are regulating the secretion of the G cells, which are secreting gastrin.

So, it is a auto mechanism, which regulates when the gastrin has to secrete, because when the gastrin is secreting, when the G cells is secreting gastrin. So, that will stimulate the parietal cells and the chief cells. And eventually the secretion of acid, by the parietal cell will be enhanced and the secretion of pepsin by chief cells will be enhanced. So, somato statin is the one, which comes into play, and ensures the gastrin secretion is being regulated, and they are by preventing the excess secretion of acid.

So overall, if I have to summarize the cellular structure, so we talked about the anatomy, now we are at the cellular structure. So, there are three types of cells parietal cells, chief cells, G cells and D cells. Parietal cells are involved in hydrochloric acid formation; chief cells are involved in pepsin formation; and your G cells are involved in gastrin formation; and D cells are involved in somato statin formation, which regulates the gastrin secretion.

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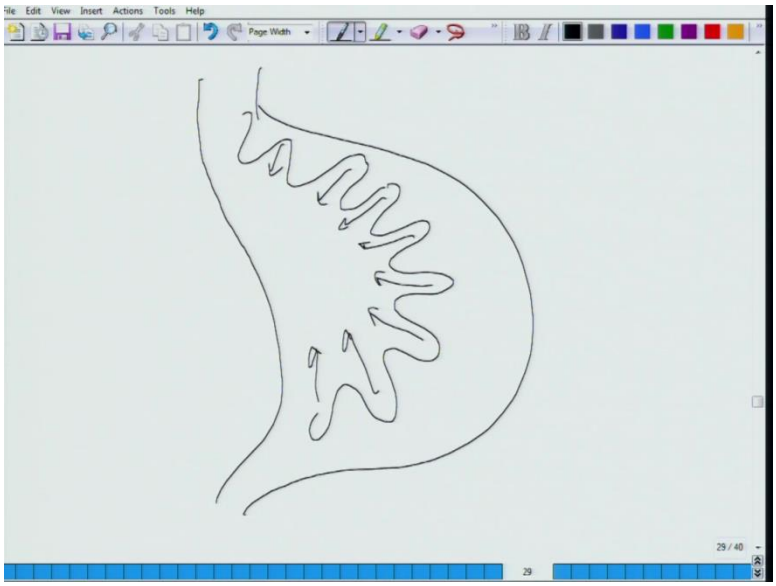

So now after this, after talking telling you the anatomy, overall anatomy, cellular anatomy and the structure of the gastric pit, it is just one more, just kind of a understanding sake. So, if you look at this is structure, which is more like this. So, this whole thing has pits like this, these are the pits where all the processes in a three dimension, just imagine this picture in a three dimension ((Refer Time: 30:14)) section I have drawn. So, from here, we will move on to the regulation of the gastric activity, and gastric activity is regulated at three different stages, they have three different stages. So, one of the stages called the cephalic stage and is called a intestinal stage, and in between there is another stage, we will which will be talking about soon.

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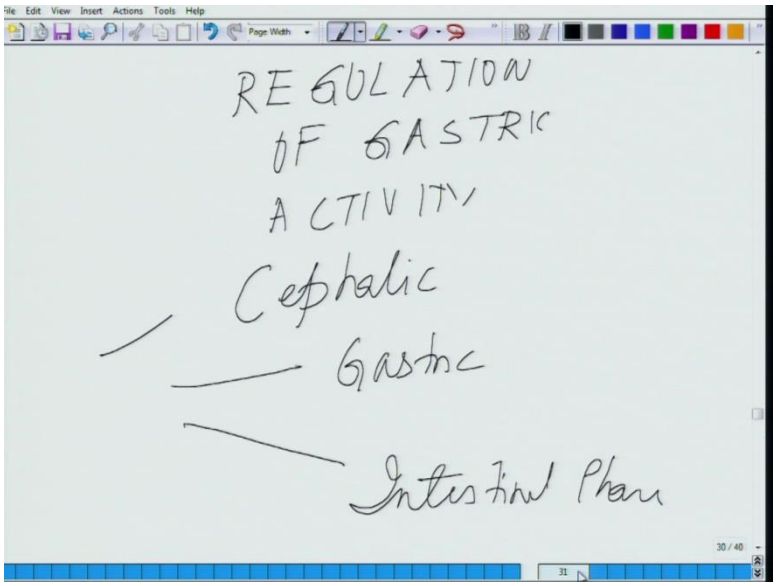

So, let us get back to the slide, so well one second, about the regulation of gastric activity, regulation of gastric activity. So, you have the, I was telling you, there are three phases by which it is being regulated, cephalic phase, gastric phase and intestinal phase. So, what is cephalic phase, it is very interesting, that this all this secretion process. If we talk about the cephalic phase, starts much before the food reaches the stomach, this you might wonder how that happens.

Because, whenever you smell a good food or some really nice something is frying, you get a temptation, wow I should eat that, by that time the nerve innervations along the stomach, leads to the secretion of a whole bunch of chemicals, and that is where the cephalic phase is initiated. So, the food has not reached their why the way, you just smelled something and you just taste maybe, do like this, you taste something.

And already your stomach is getting ready, something is coming, I have to secrete you know, hydrochloric acid, pepsin and all other things to ensure I can break the start. So, that is where, we are talking about the cephalic phase. And that is why in the first class, I was telling you, be very careful this is very well innervated network of neurons and blood vessels, they are continuously helping this system alike a autonomous unit, to do it is function.

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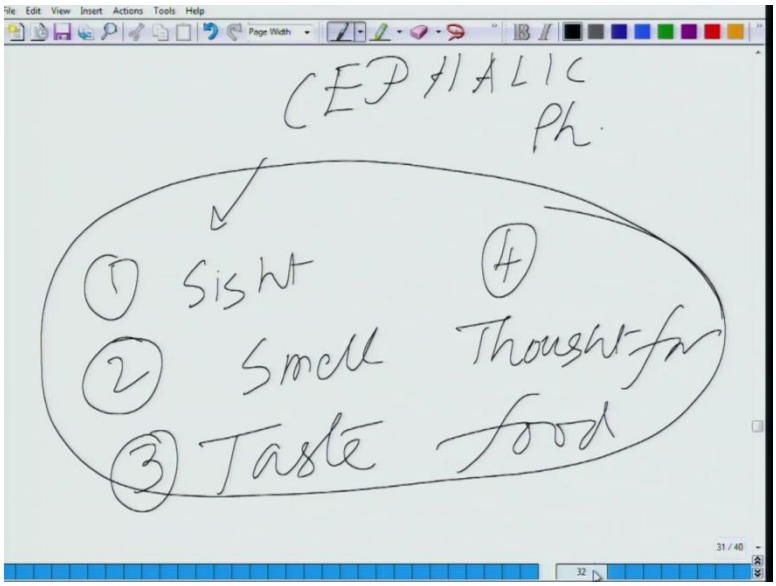

So, let us get, let us some of details of the cephalic phase. So, cephalic phase, so cephalic phase, starts with these are the stimulus, a site even the site of the food is smell, taste or the most important thought for food initiates, these are the signal, which initiates the cephalic phase.

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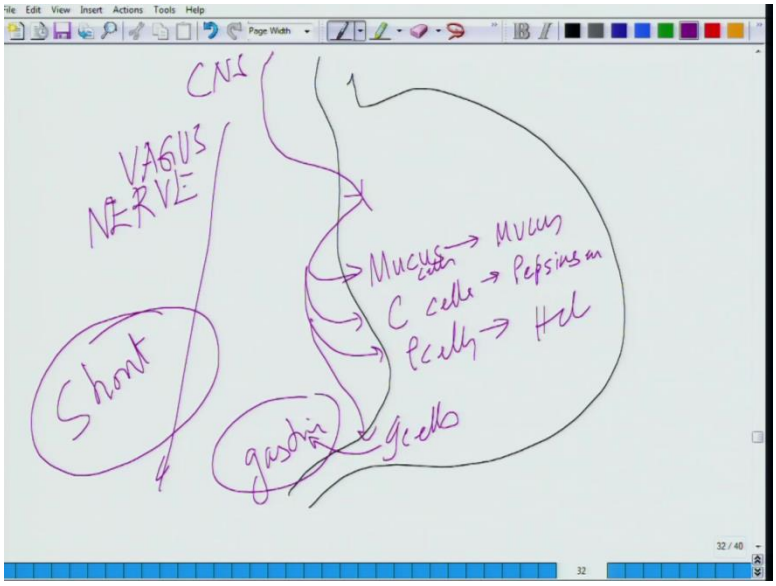

And interestingly, what is happening in the stomach during that time, these are the reactions which have taking place in your stomach. So, from this central of this system, I am putting them in the red, in maroon form this central of the system, these signals are

coming through the vagus nerves. And they are stimulating the mucus cells, chief cells, parietal cells and the G cells. And mucus starts secreting, these are mucus cells, mucus this chief cells start secreting pepsinogen, they start secreting H C L in the G cells you know, it starts secreting the gastrin.

So, this duration is very short, so short duration event. And essentially what is happening during this phase, the stomach is priming up itself that some food will be arriving and there is some degree of secretion. So, if you continuously think about food, they are will already be a secretion of hydrochloric acid, which you may not even be aware of, just by the sheer thinking of the food, it could you know, change your like you know, mill you within the stomach.

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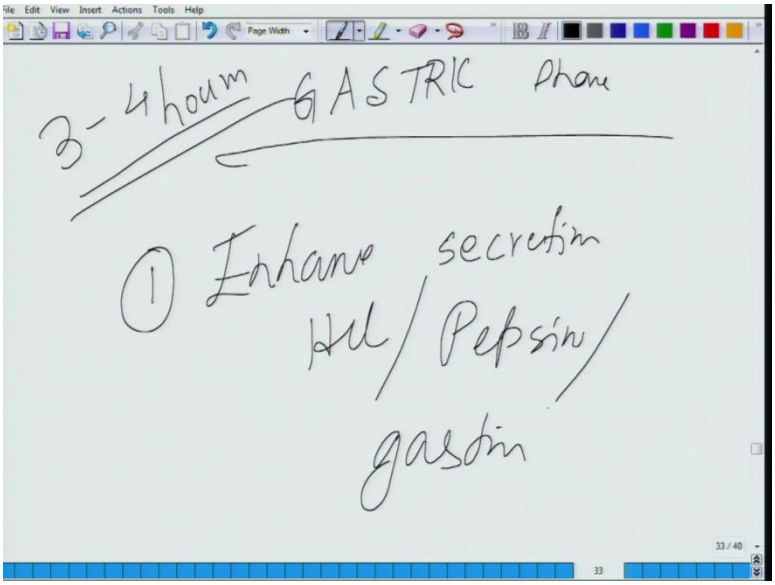

From here we move on to the phase two, which is slightly longer phase, which is the gastric phase. So, move on to the gastric phase, so gastric phase lasts for around 3 to 4 hours and gastric phase of course, 3 to 4 hours. And it basically what it does it enhance, the enhance secretion of H C L, pepsin and the gastrin and all other things, which are involved in it.

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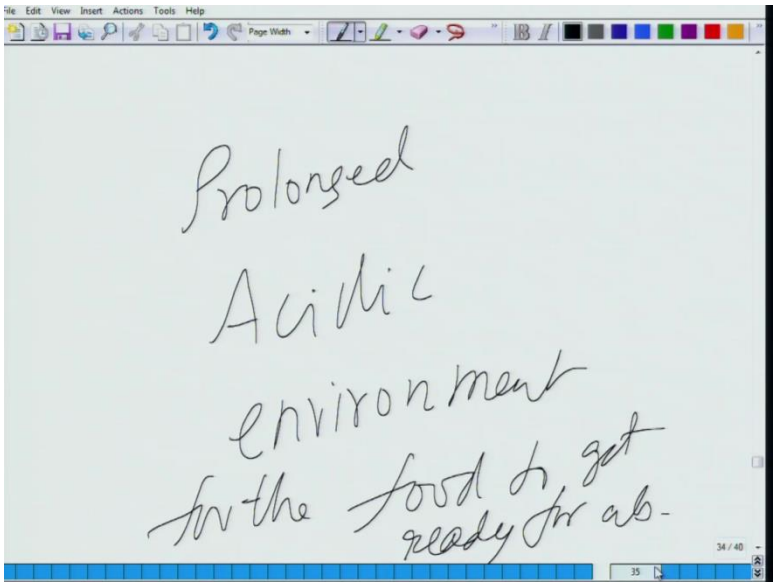

And it creates a prolonged acidic environment for the foods to you know kind of get ready for absorption in the stomach.

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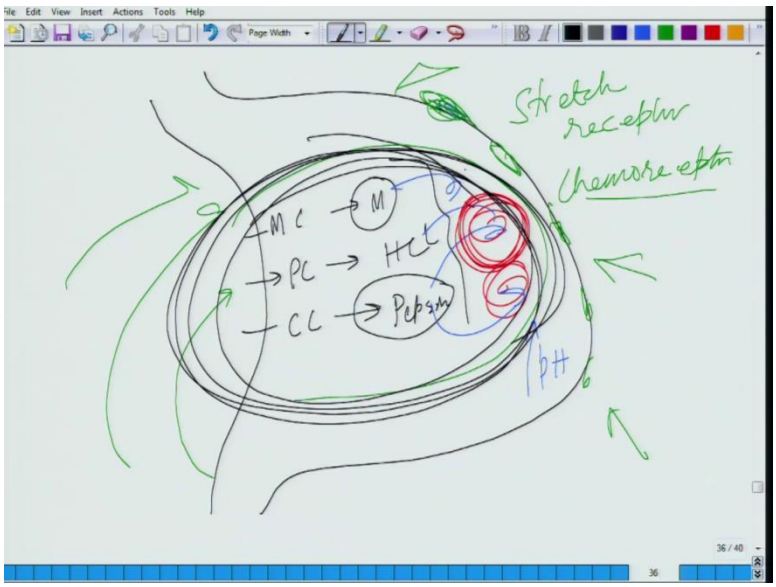

This is what it does and during that phase, there are few other receptors, which are getting activated. So, this is the stomach out here. So, from the central nervous system, we had talked about the mucus cells, I am just putting at m s M C mucus cells, secreting the mucus by M. And you have the parietal cells secreting H C L you have the chief cells C C secreting the pepsin. So, here this, all these are helping the food, I am just

representing by red ((Refer Time: 36:39)) food to mix. And apart from it, there is a huge rise of the P H in the situation, and the stretch receptors here.

These are the stretch receptors, which I told you that, that they are longitudinal muscle and there are circular muscle, stretch receptor, chemo receptors, all gets activated. So, this is the zone, where there is huge amount of blood starts flowing into this, all this area and it is kind of action like this. If I took an action like this, there is a lot of movement, which is taking place, because of these different stretch receptors, which are there. So, this is the phase, where the food is kind of going through a just like imagine, when your mother in the kitchen, uses a grinder, the food is like you know churning, churning, churning, churning.

So, this is exactly the churning phase, when the food is kind of getting churned up, it is just like a mixi, there is a lot of movement, there is a circular motion like this, there is longitudinal motion like this. And it is kind of in different dimension it moves, and this is where your food is kind of getting all mixed up, with pepsin, hydrochloric acid, ensuring that it, every bit of molecule, the H C L and all other pepsin.

And other component reaches and ensures the food is broken down to, as much as smaller fragments as possible. Because, the smaller the fragment, it will be easier for the intestine, to absorb as much nutrient, it can afford to absorb from food. So, this is our gastric phase, from gastric phase we move on to the cephalic phase, which is the third and the final phase of it.

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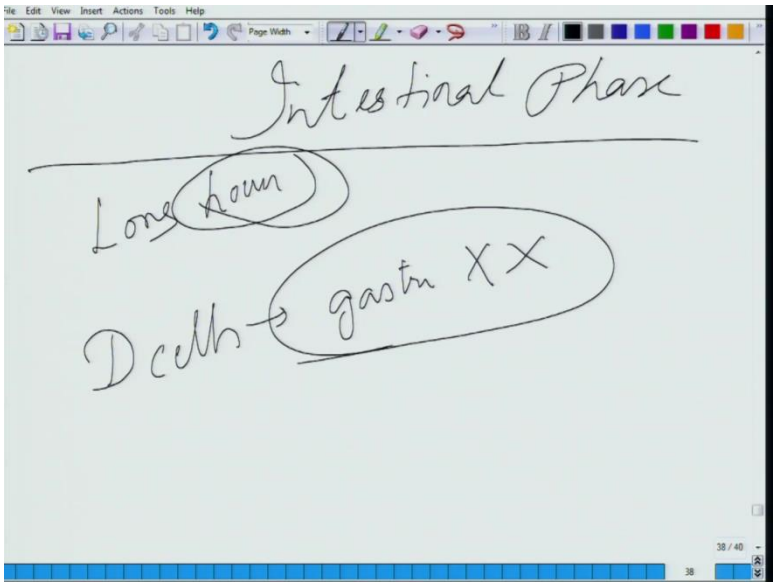

So the intestinal phase, I am just pardon me, intestinal phase this is just before entering the intestine. So, at this phase, there are basically what is happening? This is also a very long phase, this lasts for hours. The cephalic phase is the smallest one, then comes 3 to 4 hours phase of churning. And this phase is ran most of the other things, which are involved in circulation. So, this is the phase, when you, if you remember the D cells get activated, ensuring the gastrin secretion is being blocked, this is one thing which happens.

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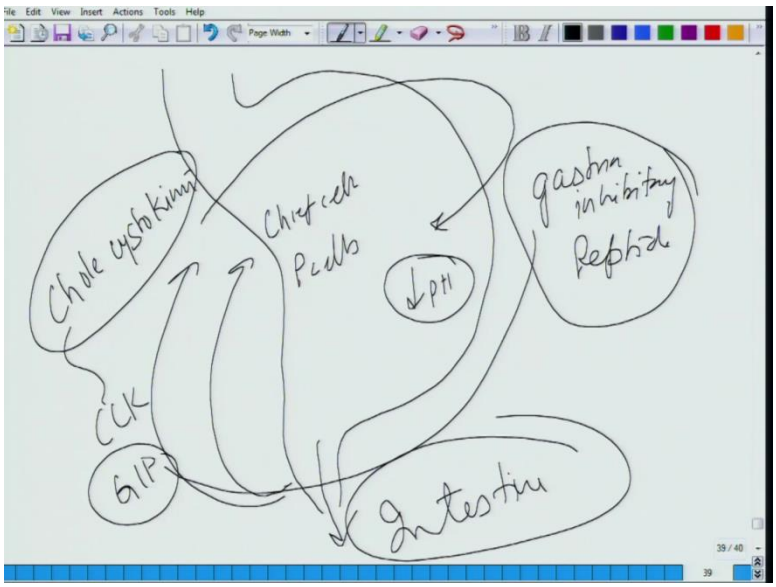

Then there are few other controllers, which come into play at this time from the blood vessel, which stops the different cells. So, via circulation you have, the chief cells, parietal cells, they are being ask to stop, by different factors like C C K, G I P. And C C K is basically chole cystokimi and G I P is basically gastrin inhibitory peptide. And you might itself self explanatory, this stop this chief cells, p cells and everything to you know stops secretion, the P H starts falling down or I means go start to go up out here.

And there is something called, mind to refluxes, which stops the movement, there is a huge amount of churning, which it is something like that, just before this I was telling you, there is a lot of churning, which is taking place like this. So now, it is just like a grinder or a food grinder is slowing down, it is now slowing down and the food is almost ready, through the pyloric sphincter to move to the intestine, for the next series of action. So, this is the overall function at the basic level what is happening in the intestine.

So, the food from esophagus enters the intestine, and it is exposed to the acid pits, which are formed by the gorge like structures of the cell like this, by the parietal cells, chief cells, G cells, D cells. And these parietal cells secreting hydrochloric acid or helps in the formation of hydrochloric acid, not the secrete hydrochloric acid, this secrete H plus ion and chloride ion. So, pardon me that statement is wrong, they actually secrete H plus ion and chloride ions, into the pit.

And the chief cells are secreting pepsin and this is being further enhanced by the gastrin secreted by the G cells, and then there is a lot of mixing of the food taking place. So, initially the first phase is the cephalic phase, when just by the thought of food or thinking about it, smelling about it or just tasting about it, leads to priming up the stomach. Next phase is the gastric phase, where there is a huge amount of movement of the longitudinal circular muscle of the stomach.

And the third phase is the intestinal phase, when the food everything in this things started slowing down, and food is almost ready as bowless, to move on to the next phase, which is the intestinal phase. So here, I will close in, so you people can go through, some of the very nice pictures given online. You can go through Google, and you can give and you will see the whole structure, what I have drawn, you can see much nice, three dimensional views of it and all this transporters are functioning.

Thanks a lot.