Human Physiology
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Lecture – 44
Physiology of smooth muscles and digestive system - Part 4

Now let us briefly take a look at the autonomous nervous system. I will give you some thumb rules okay which will hopefully make your life simple. One thumb rule is that parasympathetic nervous system with generally postganglionic fibers release acetylcholine. Acetylcholine postganglionic of course in parasympathetic. Several of the neurons of the myenteric plexus also, neurotransmitters are same. There is acetylcholine, there is epinephrine, there is norepinephrine, there is serotonin, there is bradykinin, there is dozens of them.

And then there are peptides about which I am not talking. But my point at the moment is, I am here to give you some thumb rules. One thumb rule is that acetylcholine generally stimulates the smooth muscles of the alimentary canal, exactly opposite to the cardiac muscle. And it works at extremely low concentrations, 10 raised to the power of minus 5M.

Are you with me? If you prepare acetylcholine solution and then if you drop, just drop on the smooth muscle of the alimentary canal, it contracts. I am saying this because I have done it. And you know something and then what experiment? We make a solution 10 raised to minus 5M and then see how much is the contraction. Then 10 raised to minus 4M which is 10 times concentrated and then see whether you get, and then 10 raised to minus 3M and then draw a dose response curve.

When you are a student in pharmacology, this is standard practical. Then what you are really doing is you are assaying acetylcholine. It is a bioassay, get the language. It is a bioassay of acetylcholine in your given unknown solution. That is your problem.

And you can find out the concentration using a biological method because a chemical method may not be as sensitive and a biological method is because that acetylcholine is really working. So here we are looking at the spinal cord, central nervous system, here is the medulla oblongata and from medulla oblongata you are getting a parasympathetic nerve and I do not have to tell you. We are talking about vagus. What we are talking about? Vagus. So this is vagus author has not shown.

It will be pre-ganglionic, post-ganglionic and it acts on here, here. Just sees where it acts, all the way. Vagus, vagus, vagus, vagus, branches of vagus. Done so far? What is the other name of parasympathetic nervous system? Cranio-sacral, you are forgetting. What do you call it as? Cranio- sacral.

What do you call it as? Cranio-sacral. Don't forget. Cranio-sacral. So from the vertebral column, what did I say? Say that again.

Vertebral column. Say that again. From the vertebral column at the level of sacral vertebra, at the level of 3rd vertebra, at the level of sacral 4 vertebra, the nerves will come out. And those nerves will go where? Those nerves will go to the horizontal colon, to the descending colon and to the rectum.

Okay. So this is the parasympathetic nerve supply to the alimentary canal and if that system is activated, if this system is activated, it will promote peristalsis. Okay. It is excitatory. It is actually excitatory and not only it excites the smooth muscles, it also excites the various glands because you will need, you will need to secrete juices, you will need to secrete juices containing enzymes.

Okay. So it is not only, the smooth muscles but also the glands. Okay. Now I am going to ask you a question. Okay. And let me see how smart you are.

Before operating on a patient, okay, a doctor or an anesthetist may inject, okay, an agent which will block the action of acetylcholine or a substance that will block the parasympathetic nervous system for a few hours. Why? To prevent the secretions whether they are in the air passage or you want to prevent the secretion because when you are awake, you see secretions we do not realize but we take care of secretions, we make sure that our passages are clean and open. The patient in general anesthesia may not be able to do that. Are you with me? Yes or no? You see we do not realize if something I will swallow, okay, I will clear my throat. The patient an anesthetist may not be able to do that.

So one way is to overall reduce the secretion. How do you reduce the secretion? Block the parasympathetic nervous system temporarily, okay. So I will take you now to the next slide and here we talk about these sympathetic nervous system. So where are we? We are looking at the vertebral column from what level to what level please? Say that again. T1 - L 2, these are the preganglionic fibers, these fibers which go to the alimentary canal, they generally do not synapse in the ganglionic chain, the fibers just pass through and they enter into a ganglia which we call as what? They are all sympathetic ganglia, these are all sympathetic ganglia.

Are they part of the chain? No, they are not a part of the chain. They are not a part of the chain. So every sympathetic preganglionic fiber does not enter, it does not end into the chain. It can just pass through and it enters into these three ganglia, celiac, superior mesenteric and inferior mesenteric ganglia. And here you have the preganglionic fiber and the postganglionic fiber which supply and again what is the neurotransmitter being used here? Acetylcholine, excellent, excellent, everybody should know.

What is it? Preganglionic is what? Postganglionic is what? Norepinephrine. What is it? Norepinephrine. So norepinephrine is being released at its target. Now where is the target is

an interesting question. It is going to the myentric and submucosal plexus.

Let me talk about this diagram. This is the epithelial cells of the alimentary canal. Okay, so far here you have the lumen, here the food will pass this way. Okay, so far. And the author shows one network of neurons and I will call this network of neurons as what you already know the name, say that again. Where is this located? Where is this located? Just outside there is a layer of longitudinal muscles and just inside there is a layer of circular muscles.

Okay, and these muscles by the way we saw them, right? Yes or no? I have shown it to you. Okay, we have seen alimentary canal? Okay, there we did not see the plexuses because you need to use %-%%a specific stain. Okay, they are there, we do not see them because we did not use the proper neuronal stains but they are there. Okay, so there is a myentric plexus and there is a submucosal plexus here. And can you see your author has a very interesting way? Just see sympathetic there, mainly postganglionic. Okay, mainly postganglionic means if I take you to the previous slide, if I take you to this slide, see these are the preganglionic and these are the postganglionic.

So can you see these red fibres here? Now keep this in your mind, and these are the ones which are terminating on what? On the neurons of the submucosal plexus. Are you with me? Yes or no? It is ending there. Okay, so this is how the sympathetic nervous system is innervating the neurons of the enteric nervous system. Which component of the enteric nervous system? Submucosal plexus.

Done. At the same time there is also input from the parasympathetic nervous system, they are preganglionic. The fibres are what? So those fibres which are coming right over there, okay okay okay okay okay. Those fibres you know, these fibres are preganglionic. Okay, they are coming via vagus. The cell bodies of these neurons is located in the medulla oblongata, maybe in the vagal nucleus.

Those neurons sitting in the medulla oblongata, they give rise to axons which come out of the brain by way of the vagus, tenth cranial nerve, travel all the way to the alimentary canal. Which part of the alimentary canal that we have seen in one of the previous slides. And then they come all the way and they innervate, what neurons? Neurons of the? Myenteric plexus. Okay, so this is how sympathetic and parasympathetic nervous system is. And then eventually it is these neurons which will release acetylcholine and this is postganglionic is going to release norepinephrine. These neurons, these neurons myenteric and this, I told you once I will tell you again, dozens of different neuropeptides, neurotransmitters.

So they can have glutamate, they can have GABA, they can have acylcholine, they can have n number of. So the control of smooth muscles of the alimentary canal is extremely complicated. It is very delicate control. Okay, and it has to continuously get the signal. It has to perform a mechanical function of pushing the food.

Okay, so it has to know whether the bolus of the food is there or it is yet to arrive or it i, it

has to be pushed? How quickly? How far and then as it is being pushed, has it been properly digested, has it been - depending on the content of the bolus of food, depending on the type of the food that you have taken. Okay, more in protein, more in carbohydrate, you need to give the enzyme, you need to give the right enzyme and most important. How it does, I still do not know. But you have to give the right enzyme in right amount. Hello, how do you decide the amount? Okay, I mean you have taken, you have taken 25 grams of a particular type of protein today and 25 grams of another type of protein day after tomorrow. Are you with me? So the stomach has to decide as to which enzyme I am going to release, in what proportion? And day after tomorrow if you take 50 grams of, then I have to release more enzyme. Okay, so for n number of computations which the system has to do, okay, therefore the system has, therefore the gut has been provided with the independent nervous system with extremely complicated neurons which I do not understand.
Okay, so that the nervous system can deal with these extremely fine computations with reference to how to the type of food, what enzyme, how much of enzyme and at the same time sensing the environment. Hello, sensing the environment means what? After all, how will the system know whether the pH is okay or not? Hello, and the stomach has so much pH, okay, and then the chime which is there at a certain pH which may be too strongly acidic into the stomach, then as it goes into the duodenum you need to neutralize it, make sure that you bring the pH to 7, okay, of the food. I mean for doing that how much of alkali you have to release as bicarbonate ions, how much of bicarbonate ion are you going to release? I mean it is very easy for me, how much? Okay, and you have to just release enough bicarbonate so that the pH goes to 7, not that it goes to 7.2 or 7.4, so you have to release bicarbonate so much, we have to have a system by which you keep on carefully monitoring the pH of the stomach so that you can titrate it to the right level.

Are you with me? What I am doing is I am not giving you any clear concepts because my concepts are also not clear. What I am trying to tell you is to give you an essence of the complexity of the situation, okay. So that you will be able to broadly appreciate, accurately it is very difficult, broadly appreciate the importance of the enteric nervous system - which many people also like to call as gut brain, what do you call it as? Gut brain. Gut brain because it is very large and it is roughly estimated that the number of neurons that you would encounter in the spinal cord, so your spinal cord has a large number of neurons, almost an equivalent number of neurons you will find in the gut brain, okay. How my alimental canal is able to identify what kind of food I am taking? Okay, we are looking at the same thing, okay. I put this slide because it tells us more about the sensation, okay.

So there are, so let us see this is a secretory cell. What secretory cell? It might be secreting acid in the stomach, it might be secreting bicarbonate in the duodenum or it may be secreting a particular enzyme, okay so far. And it is being controlled by what? It is being controlled by this neuron, okay. This neuron is, it is being controlled by this sympathetic neuron, okay. Then it is also being controlled by this neuron.

Where is this neuron? This neuron is of the submucosal plexus, okay. And then the author

tells us there are sensory terminals, okay. The sensory terminals they will pick up the information about what enzyme, what product of enzyme, okay. All that information, it takes to this neuron.

From this neuron it goes to this neuron. From this neuron, this neuron it goes, the information goes over the vagus, okay. And over the vagus it will go to the medulla. Now medulla knows, okay as to what kind of food is where and what is the pH and then it will again give back information over the motor fibers over the vagus which will bring about the suitable motor output.

The information will go to the smooth muscles or to the secretory tissue and the system will respond accordingly. Can I go ahead now? I need to. They regularly come from the vagus? Oh yeah, yeah, yeah, yeah, yeah, it does.

Do not form a ganglion. No, no, no, they do not form. They, the answer to your question is here, okay. This is a preganglionic. This fiber is preganglionic. Preganglionic means what? Its cell body is in the medulla oblongata and it is terminating on these neurons.

This is something like a postganglionic fiber. We do not call it a postganglionic fiber. We call it a neuron of the enteric nervous system. But this particular neuron will have receptors for acetylcholine, okay, and what neurotransmitter this particular neuron contains? I do not know, but author gives us a rough idea. Is there any significance of it being preganglionic or postganglionic because whatever, anyway only acetylcholine is going to get released.

Okay. No, no, no. Let us not over simplify. Ask your question again. I do not know, I can try. Yeah. What is, is there any significance like being a preganglionic fiber as opposed to postganglionic because either way acetylcholine is what is going to get released.

Okay, okay. Oh, no, no. It is not a question of only the neurotransmitter. It is a major question of processing. A lot of processing is happening in the ganglion, okay, which is necessary for autonomic regulation.

It is the processing. Is the word processing clear to all of you? Okay. And the information goes to neurons and then the neurons process and tells, okay, I am going to control, I am going to control that particular muscle, I am going to control that particular secretory gland and that one and not that and all that processing happens in the ganglia, okay. That does not happen in the case of our somatic system. But in the autonomous nervous system you need a lot of, means as if in the autonomous nervous system, this is my language, that the nervous system says that - I am not going to take the responsibility of controlling everything at the level of the center, okay. I delegate that responsibility to the ganglia. Are you with me? So the ganglia use the neurotransmitters. So neurotransmitters is only a tool, okay. But the importance of the ganglia is a huge amount of processing.

It is to tell ultimately at the end organ how much of neurotransmitter is being released and where it will be released and all that processing happens in the autonomic ganglia. Let us see. Here is this catalogue, let us see, what is it, number 1, acetylcholine, number 2 what, norepinephrine, number 3 what, we have done this, Adenosine, they are very familiar. What is fourth one, fifth one, sixth one, cholecystokinin, seventh one, substance P, what is eighth, ninth somatostatin, leu-enkephalin-, met-enkephalin and the list is incomplete. This goes on and on and on, okay, and then there are the author raises his hands.

What is the last sentence? The specific functions of many of these are not known. This is just a different preparation of the smooth muscles where the people have used different antibodies against different, different neurotransmitters and you can see the beauty. At least they are showing, the author is showing endorphin, enkephalin and dynorphin and these are some of the signalling molecules, okay. This is peristalsis, okay. So obviously this is the bolus, the bolus - immediately behind that, now please remember, see whenever we have to look at these images and we look at the motor component and we understand immediately and we feel happy about it, okay, okay. But that is only 20% of the truth, 80% of the truth is you should ask yourself how does the system know and for that then you must ask where is the sensory component? And then how does the sensory component know and then you will know how hard it is to figure out everything.

Are you with me? When the food is here, these muscles in front of the food need to relax, particularly the circular muscles need to relax whereas these guys need to contract, okay. And it is amazing. How do you know with how much force to contract? Are you with me? Whenever we push a thing, you know we push or lift anything we immediately get an approximate judgment as to how much strength am I going to need and exactly I just apply the necessary amount of force, okay. So obviously those muscles also need to, okay, you cannot overdo it, you just have to do it at the right pace, okay. And for instructing those smooth muscles you have to have a sensory input, where is the sensory input come from? Okay, I am not giving you the answer, I do not know the answer, okay. I am just sensitizing you to this component of the physiology, okay. So very interesting slide look at this, very interesting, very interesting slide, I will tell you why.

Here author uses his imagination to tell us as to how actually peristalsis may happen, okay so far. For our convenience author has removed everything, only kept the longitudinal muscle layer, the circular muscle layer and the myentric plexus. Everything else is removed for our understanding, okay. So far, we are good with the story. Now the next thing author does is, author has drawn different neurons and given them different colors and here is the legend, okay. And the green one is the sensory neuron. So there is a neuron, where is it? It is there. This particular neuron as long as the food was here, y the food was here, the food was here, the food is being pushed here, here, here, here, it will go here, look at the big arrow, we will call this as the bolus of food.

So as long as the bolus was here, okay, this neuron was under stretch, are you with me? Okay, now as the food moves forward, the stretch has gone. As a result of that, this now

neuron is taking a signal along with the arrow. This neuron excites this blue neuron which is an interneuron, this blue neuron talks to this brown neuron, okay, brown is all my artificial colors, okay. That brown neuron has one branch which goes and stimulates the longitudinal muscle and it has another branch that goes and stimulates the circular muscles which are immediately behind the bolus. And when they are excited, ook at these arrows, they will press and they will push the bolus in one direction.

Are you with me? So this is how perhaps the signaling is happening. I want you to spend more time and try to understand what are the different functions that might be undertaken by this slide. I will stop now and we will see about this in the next class.