Animal Physiology
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Lecture - 19

Welcome back to the NPTEL series of animal physiology lectures. Today, we will be starting a new unit; endocrinology and reproduction. This unit, just to give an overview, body is controlled by three sets of systems; one is the nervous system which we have completely covered, and you must have appreciated it that at different levels of our body control system, how the nervous system plays a very important role. The second line of command which dictates a lot of our physiological activities especially, the way the autonomic nervous system controls. So many functions are regulated by the endocrine system. The third system in that line, which we have not touched it, we will be coming is the immune system. Now, we will be talking about the endocrine.

What really is endocrine? Technically speaking, there are different modes of information transfer within the body. One of the modes, which we have studied, very extensively, is the synaptic mode, where you have a pre synaptic neuron, and then, there is a post synaptic neuron.

When the pre synaptic neurons secretes a neurotransmitter, post synaptic neuron accepts it, and then, conveys the message or transmit the message to the next, like if you consider them as node; from one node to anther node; to the third node; to the fourth node; likewise, along the nodes the information travels. This is one mode of transport or one mode of control route. The second mode of transport is the endocrine mode, where you have to do very long term transmission.

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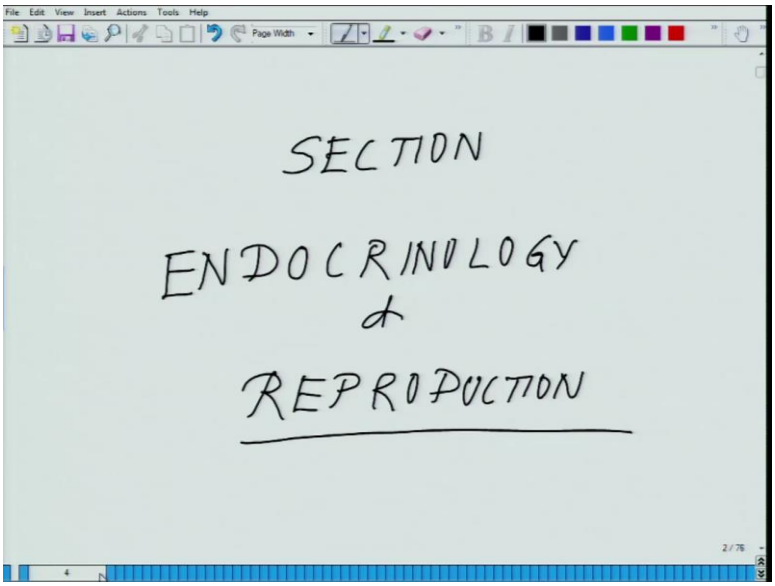

Let us formally start it. We are in this section. This section is basically, endocrinology and reproduction. This is our first lecture in that series; endocrinology and reproduction. In this section, one second.

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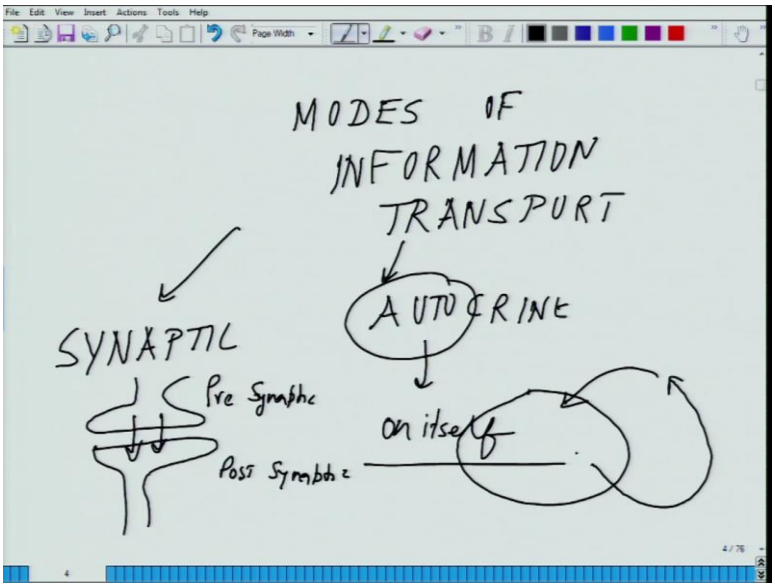

There are different modes of information transport. Let us enumerate all the different modes. One of them, I just now discussed with you is called synaptic mode, where you have a pre synaptic neuron. This is pre synaptic and here, you have a post synaptic neuron, and you have the neurotransmitters which are sending the signal from pre to

post. Then, there is another mode which is called autocrine mode. Autocrine mode means; here, you have a cell. This cell secretes certain chemicals, which act on the cell itself or too; it means on itself. So, this is the second mode of transport.

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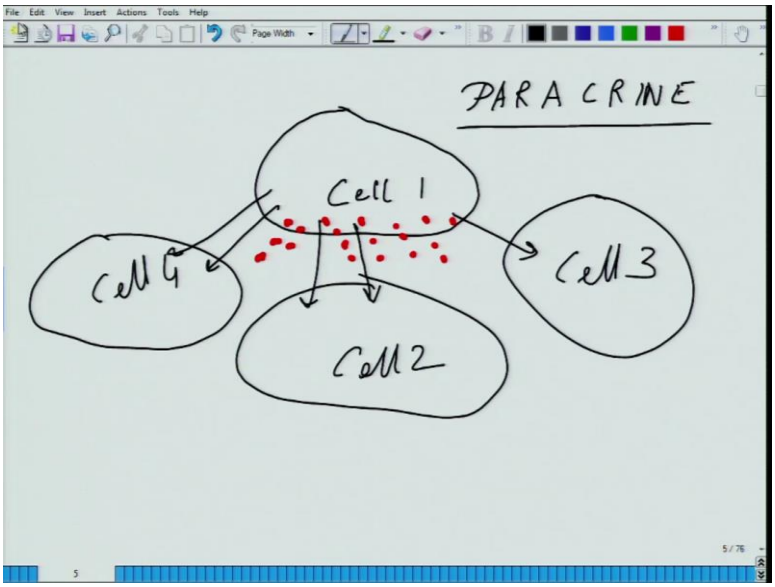

The third mode of transport in that line is something, called a paracrine mode. This is cell 1 and this is cell 2. Just for simplicity sake, it could be here as cell 3 or there could be nth number of cell; cell n, in a close proximity, but always remember, it is in a close proximity. If these cells secrete some information, say for example, from this cell, there is secretion of some kind of compounds; it is secreted by this. These compounds are being received by these cells, likewise; from one to b; from 1 to 2; from 1 to 3; from 1 to 4. So, this mode of transport is called paracrine mode of transport. Now, there is a third mode of transport, which is called endocrine mode of transport, which is also called, in other words, it is called a long distance transport.

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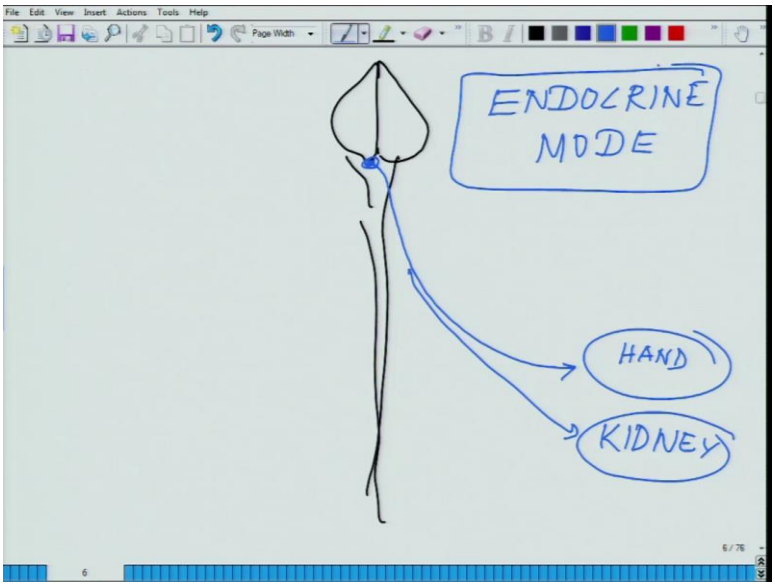

Something like, say for example, imagine, let me just, one second, some of the brain and this is the spinal cord. Say for example, from somewhere out here; this location. From here, some signal has to reach all the way to say, somewhere in your hand, or somewhere in your kidney, and which is not following the neural route, which is not following under unit, so long distance transport. This kind of long distance transport is exclusively carried by the blood vessel, and that falls under endocrine mode. If I have to give an outline of the endocrine mode, it pretty much, looks like this.

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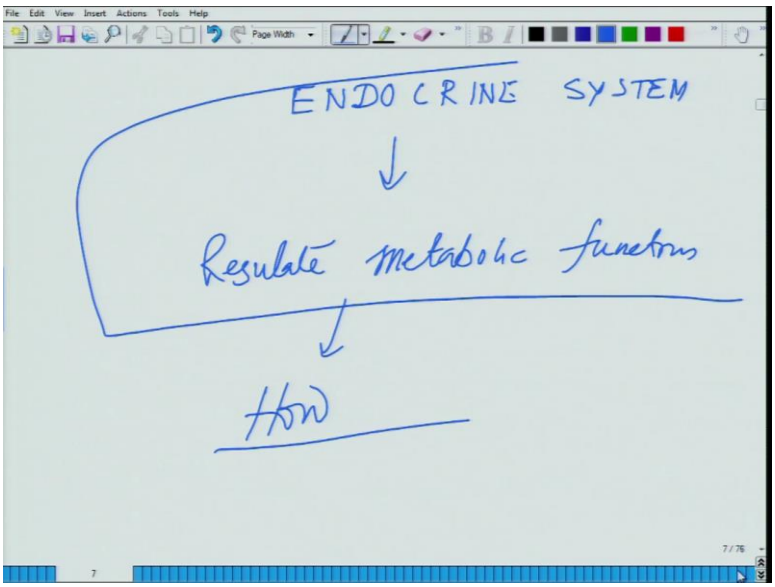

There is an endocrine system which consists of, I will be enumerating them, endocrine system. The major function of the endocrine system is to regulate the metabolic function. A wide range of metabolic functions are being regulated by the endocrine mode. How it does so? The way it does is they secrete hormones. These are series; they are different kind of hormones, we will come to that, into the blood. These hormones have specific receptors. For example, something let us give you a simple example that will help you to understand.

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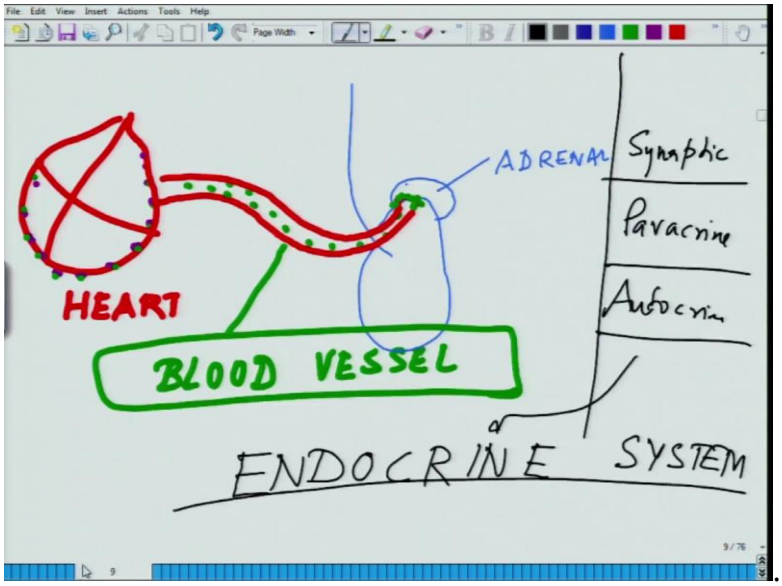

Say for example, in your kidney, something is secreted. Kidney has one of the endocrine glands, which is called adrenal. So, this is the adrenal; just on top of kidney. For example, adrenal secrete some specific, say some specific hormone. This hormone; what this hormone will do is essentially, this hormone; let me let me put this in green, it will be easy to show you blood vessel. This particular hormone from here, along the blood vessel will travel to; say for example, it has to go to your heart. Say for example, it has to do something in your heart. So, this is your heart. What will happen is that, along the blood vessel, this compound will travel. But, while it is travelling along this blood vessel, it is crossing through several other systems. It is not that, this is exclusively, in this compound. There is a separate channel from the adrenal, along the kidney to reach to the heart. It is travelling all along the body, because the blood is circulating.

But then, how it identifies that it has to reach to the heart. It is just like, say for example, you have, how the postman identifies? Think of it. How a postman identifies is that, this is your address; this is where I have to deliver; house number, say 23 and say [fl] number this or street number this; and the city x y z; and then, the state and then, the country. Then, there is a something called, say the pin code or a zip code; a six digit number by which you identify. So, there is several level of identification.

Same way, in the biological system, there are kind of zip code or pin code, in the form of, this heart has specific receptors for this particular molecule, all along, wherever it has the target . Whenever, this receptor identifies the molecule out here, it binds on them and then, it shows its action. This kind of transport which is completely dependent on the blood vessel, except one region; I will come to that where, it is not blood vessel dependent; it is neural dependent. Other than that, it is all blood vessel dependent. So, this mode of transport of information transfer falls under endocrine system.

So, this is the broad overview of the endocrine system. To summarize up till now, I told you about synaptic mode, paracrine mode, autocrine mode and here, you have the endocrine mode. Next, what we will do, we will enumerate all the different endocrine systems which are present in our body, one second, save it.

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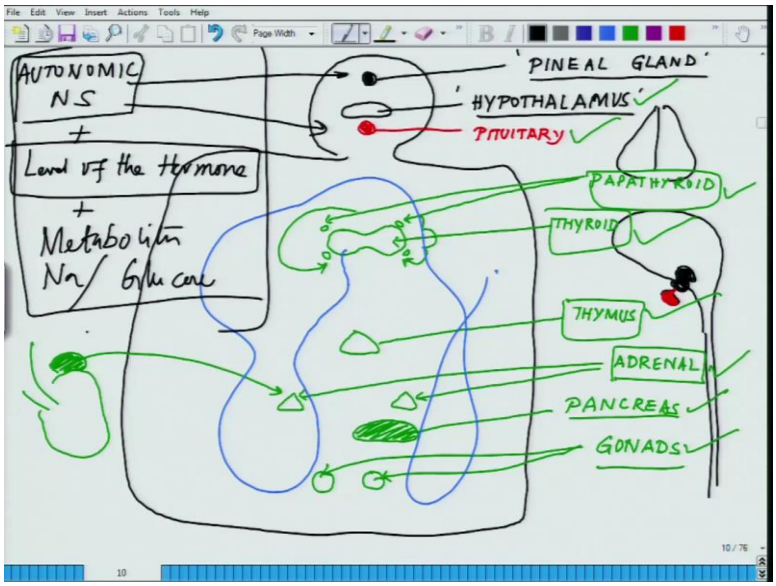

Broadly speaking, now, I am just showing you a cartoon and give you an idea where, each one of these endocrine systems is located. So, up in the brain out here, there is an

organ called, it is not very well developed in human though, and I will come to that. It is called pineal gland. This is very well developed in birds and other avian systems, and some of the migratory animals, where they have to understand the biological claw very right. They have to understand the seasonal variation very correctly. Based on that, their migratory routes are being dictated.

So, pineal is very well developed in those kinds of systems, where there is a lot of inter play of circadian rhythm, or the biological clock and all these things. This is up in the brain; somewhere located, and is called a pineal gland. This is one of the endocrine systems. The next one in the line is, just if I have to draw the brain like this, or let me draw it sidewise. Then it is easy for me. If this is the sidewise view; somewhere out here, there is a; I am just trying the cartoon out here, called hypothalamus. Just never confuse with hippocampus because, many of times I used to do that, as the two words are fairly close. Underneath the hypothalamus, just attached to it underneath, if any one of you or those of you have the dissection facilities, we used to do this dissection. Just underneath, it is a small gland. It is pretty much just underneath out here, is called pituitary. These are all in very close proximity of the vein, or almost within the brain. Underneath, along the tricia, you have a very major organ sitting like this, which is called thyroid and parathyroid.

This one is the thyroid, and the one which you see like this, the bottom two also, is called parathyroid. Underneath this, you have, once I will independently talk about this, I will talk about where exactly these are located. Thymus, this has immense role in your immune mechanism, which is the third control which you are going to deal with, one second, just, so that you do not have a confusion; the arrows right.

These two are adrenal which is on top of the; adrenal is mostly located, if this is the kidney, on top of the kidney is your adrenal gland and underneath along, it is just behind it actually, is the pancreas which is also an endocrine gland, as well as a digestive system; a major part of the digestive system. Then, you have the gonads or the sex organs, which are involved in all the endocrine regulation, of puberty and reproduction and all these things.

So, these are the major endocrine systems in your body; starting from hypothalamus, pituitary, parathyroid, thyroid, thymus, adrenal, pancreas and gonads. They are all linked

with rich blood vessels. Whatsoever the secretion takes place, under the influence of different control; we will come to those different controls. They travel through these conduit tubes of blood vessels to the different organs, and wherever they have their receptors, they act accordingly.

In other words, what I was trying to make you understand, say for example, if something is secreted out here and it is travelling all over the body. So, it will only reach to the place, where it has the receptors. It will not bind, but it will reach everywhere; it will not bind at any place, till it finds its own receptor. This is very important for you to understand because; it is travelling all over the body, because it is in the blood vessel. But then, it will only find its, wherever it will find its receptor; it will bind there only. Other than that, it is not going to bind anywhere else, and this is very important and fundamental understanding, is very essential for this system.

Now, coming back to, who are the systems who are controlling these different units? Who are the control partners in this game? This is being controlled by one of the one, which you have already studied, is autonomic nervous system. This is one of the major controllers. Then, there is another controller. It is the level of the hormone itself. This is very important.

If the level of the hormone exceeds certain limits, which body does not need, then it has a feedback loop or a negative feedback loop to say; do not secrete more. It is just like, say for example, I say I need 20 molecules; the body needs 20 molecules. But, if it exceeds 20 molecules, then what will happen? There will be an auto inhibitory effect. In other words, there will be a negative feedback loop, which will say; please do not secrete more; I have sufficient; I have 20 with me and I do not need anymore.

So, anything exceeding 20, I will say no; shutdown. That is another way. There is a third way. Third way is, it is being controlled by different metabolites. Say for example, glucose; if there is a decrease in the glucose level in the body, you are running out of energy molecule because, glucose is all major energy molecule. So, you will feel tired. Then, this endocrine system comes into play. Then, it will say; I need more energy. So, I need to breakdown the reserve; it is just like you are running out of money; you go to the bank and tell; withdraw money, or you go to an ATM machine and you withdraw money. Exactly, the same way, I am running out of energy.

So, there are storage molecules, which break down and release energy. Those kinds of regulations are taken care by endocrine. Basically, what is happening? If the metabolite level goes down then they get triggered and vice versa, if the metabolic metabolite level goes up, say for example; sodium goes up in the body, and you have ensure that there is no excess sodium. There are systems which come into play, and which you will be talking about it, or say for example, the glucose level goes up. There is a system which ensures that the glucose is being filled out, from the blood vessels, because otherwise, the viscosity and everything will get affected.

Same way, if the blood glucose level goes down, body is running out of energy. We have to ensure that the body gets sufficient amount of energy molecules, there should be a mechanism by which, you can regulate this process. So, the metabolites is the third level of control; here are the metabolites. These are the three levels of control; which maybe sodium; it could be glucose; or it may be 1000 and other things which control. So, these are the different control units, which regulate all these different 7 or 8, which I have enumerated for you people; pituitary, hypothalamus, adrenal and all these things.

From here, we will move on to the next one. What is the mechanism of action? This is very important. This is something before I draw, I will give you an overall idea; how they function? The endocrine function in the time window could be classified into two groups. Some actions maybe, very immediate, say for example, body needs energy; there is a shortage of glucose. Immediately, I have to ensure within your liver, you have glycogen molecules, which are kind of, I mean thick polymer molecules; thick big polymer molecules, which could be broken down to glucose.

This is an instantaneous process; it has to be done now. Because, body cannot wait, say for example, you are feeling thirsty. Now, you have to drink water. Now, you cannot wait till the evening to drink water, or body is running out of energy now; body immediately needs energy. This is one, which is short term effect and it has to be very fast; very quick.

If there are certain changes, say for example, one of the changes is that while I was young, I was not having the moustache. The moustache developed over a period of time; as I was in my adolescent. So, these are long term effect. They take time; it does not happen in a day. Slowly, I see my moustache starts coming and I become young, and I

become a youthful person, or vice versa. Some of these hair colors or some of these changes, which are taking place; they are changing; they are becoming white and getting old. These are long processes. These are not something instantaneous. I need energy and I will get it.

So, these are the two broad classifications in our endocrine system; one is a short term instantaneous effect; the other one is a long term and prolong persistent effect. For this kind of two pathways, the body follows two different molecular routes, and depending on the end result; what has to be achieved by the body, it decides what kind of route it is going to follow. Based on that, the identities of the molecules are being determined by nature; where it is going to act? How it is going to act?

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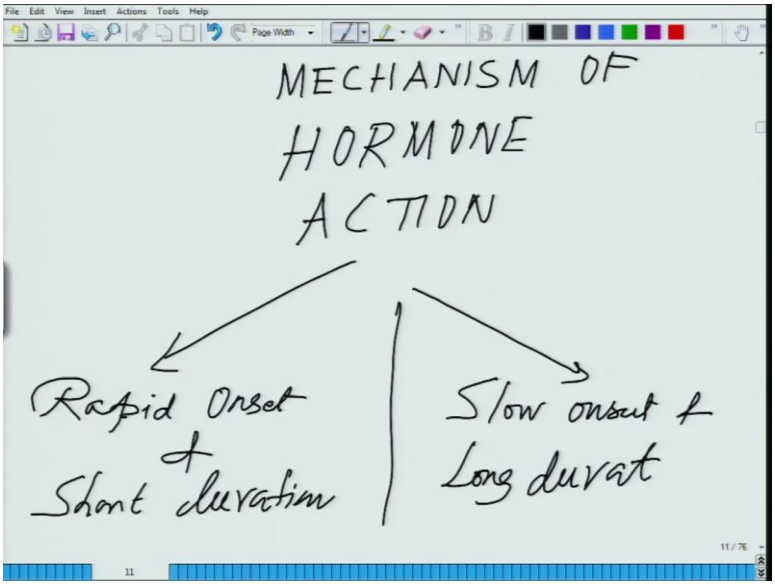

So, broadly speaking in terms of time frame, if I had to classify, I will classify them as under the heading of, this falls under mechanism of hormone action. Within the mechanism, I have rapid onset and short duration. This is one route. The other one is slow onset and long duration. Based on that you have the two classifications.

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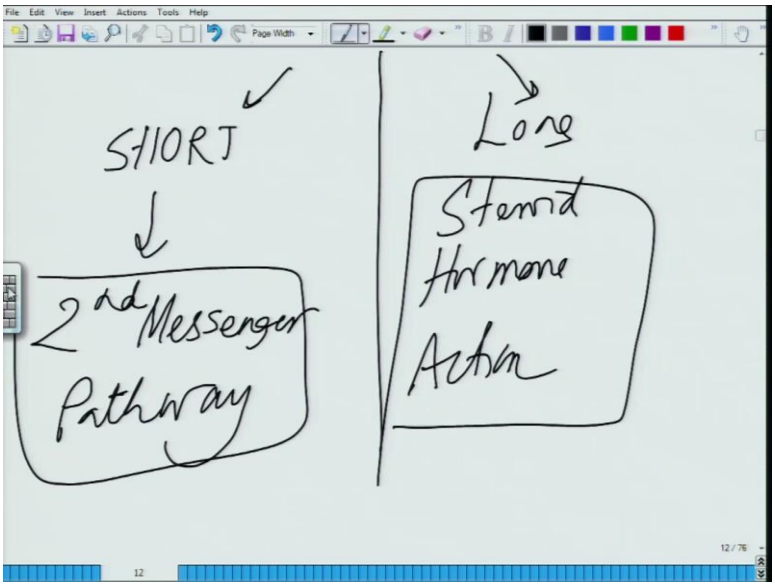

The short one, which falls under second messenger pathway. This is the biochemical route which we will be talking about, and the long lasting effect; the other one, right hand side. This falls under steroid hormone action. What exactly, that means? Let us discuss this and then, I will draw the flow chart for your better understanding; graphical understanding of the situation. What is the second messenger system really? Now, how that word all came together? Say for example, let us go back to the diagram, where I was drawing that along the blood vessel, the hormones are travelling. This hormone has two options. First of all, the first and the major thing is that, it should have receptor on the surface of the target cell.

Imagine like, if this is the one which is secreting hormone, and this is the one which is the target; this pen is the target. The molecules which are travelling here, should have a receptor on them. First of all, they have to bind with the receptors. Once it binds to the receptors, it has two options; it either gets inside the cell, or it acts from outside. If it acts from outside, then in that situation, the hormone itself is the first messenger. So, it is just like a postman comes to your door, and put the letter in your letter box. Postman is a messenger; just like hormone is a messenger. And it binds to the surface of the cell; the target cell.

Now, within the target cell, there are series of action which take place, which are carried out by another set of messenger. And that messenger, if the first messenger was the

hormone itself, and the second messenger all goes downstream, which are inside the cell, which are taking care of the other action. The final result resultant thing is being seen, falls under the second messenger. With this background, I will draw it. That will make you to appreciate it better.

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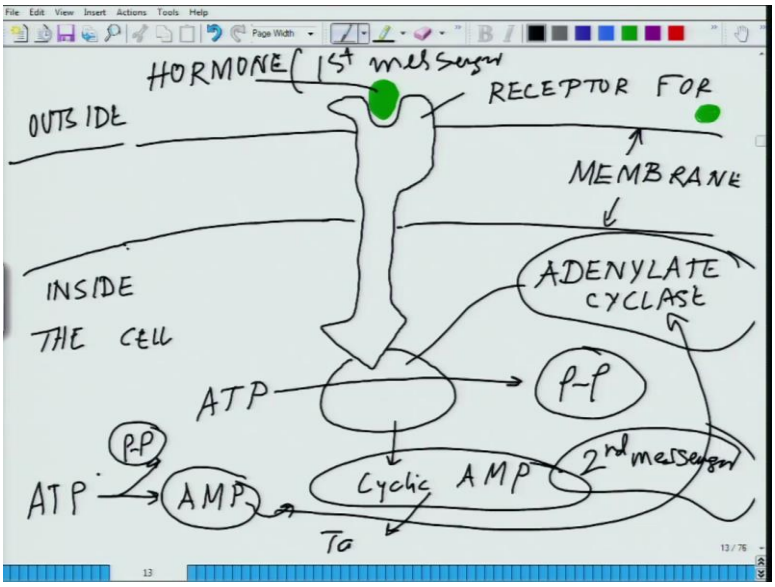

Imagine, this is the cell. This is the membrane, I am drawing. So, this is the cell membrane and here, you have a receptor for a specific hormone. Here, it is like and then, from here, is the hormone molecule, fine. This is the receptor; the cell surface, receptor for this thing; this hormone and here, you have the hormone molecule. So, hormone comes along the blood vessels, and it binds to the receptor. Once it binds to the receptor, what happens inside the cell? This is outside the cell and this is inside the cell.

Once it binds there, then it leads to a cascade of reaction inside, thereby one of major reaction which takes place, which is I talked about adenosine phosphate. This, under the action of an enzyme called adenylate cyclase. What it does is basically, it removes the two phosphate group from ATP. So, it becomes AMP. What is happening essentially is that adenosine tri phosphate, there are three phosphate moieties attached to it. This becomes AMP, and in that process, the two phosphates are being thrown out and that phosphate, which is out here, is cyclised. It forms something called a molecule, called cyclic AMP.

It is a cyclic reaction, which takes place, within this molecule. This is done by this enzyme called cyclase; adenylate cyclase. At the ATP binding site in it, it removes the two phosphates and what it does; it makes a cyclic molecule of AMP; either it could be AMP or innocent mono phosphate, with a single phosphate moiety, or it is a cyclic molecule cord; cyclic AMP. The cyclic AMP is, if this is your hormone, is your first messenger and this cyclic AMP is your second messenger. This is the second messenger system and then, this particular second messenger goes to the target tissue, and shows its action.

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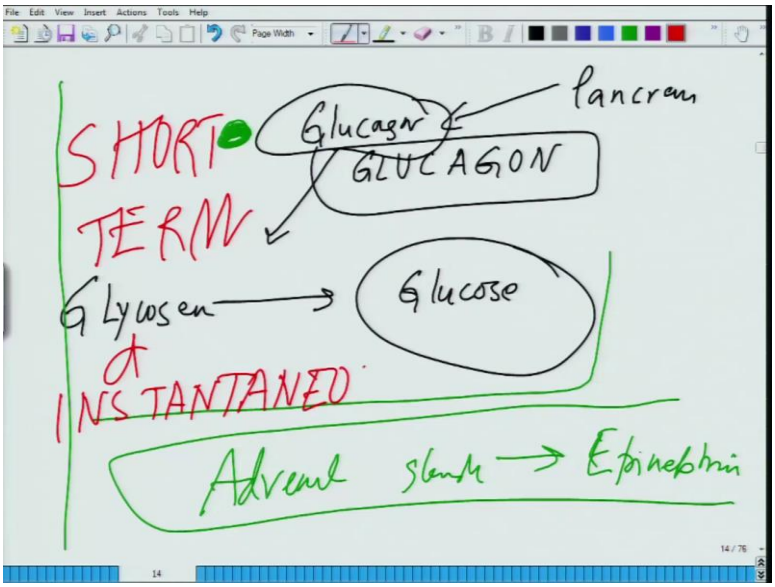

One such classic example, which is being followed by the body, using a second messenger system is by glucagon. Glucagon is secreted by pancreas and this glucagon goes to the liver; let me get the spelling right, glucagon. This goes to the liver and there, it converts the glycogen to glucose. That is exactly, it is the glucagon. Now, think of it, if this glucagon is this thing; this moiety, and let me go back to the previous slide. Here is glucagon binding; glucagon binds follows a cascade of reactions; cyclic AMP and everything. This cyclic AMP then involved in breaking line of the glycogen to glucose.

So, this is one of the classic examples. Other than that, you have the adrenal. The other hormone which follows this is the adrenal gland, secreting the epinephrine. This also follows the same routine as followed by the glucagon. This is one mode, where the first messenger or the hormone is not entering inside the cell; it just binds and the rest is all

cascade of reactions, which is taking inside the cells. Now, we will move on to the second one, which is the hormone is entering. This is, one second, this is all about your short term, always remember, this second messenger is a short term effect and instantaneous effect.

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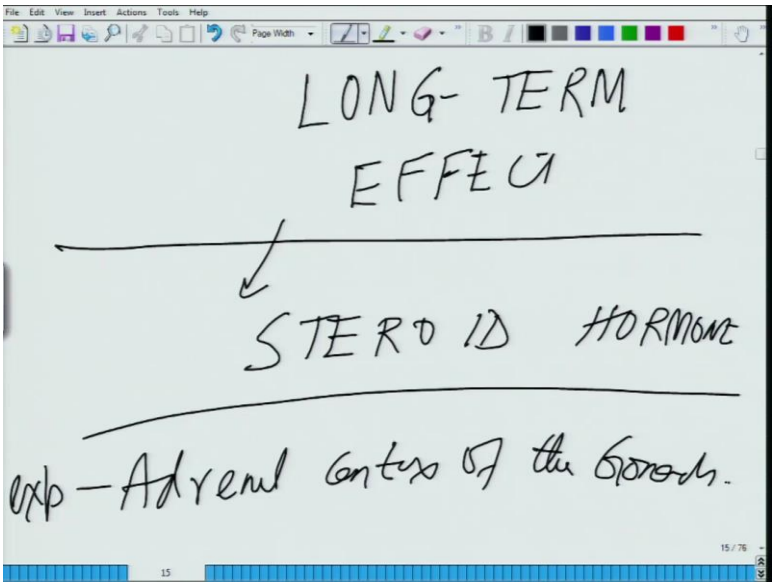

Now, we will move on to the long term effect. What are the long term effects and how they work? The long term effects are dictated by the steroid hormone. And how they work? Most of these long term, if you look at them; they are mostly in the adrenal cortex. This is an example of long term effect; then adrenal cortex of the gonads follow the long term route.

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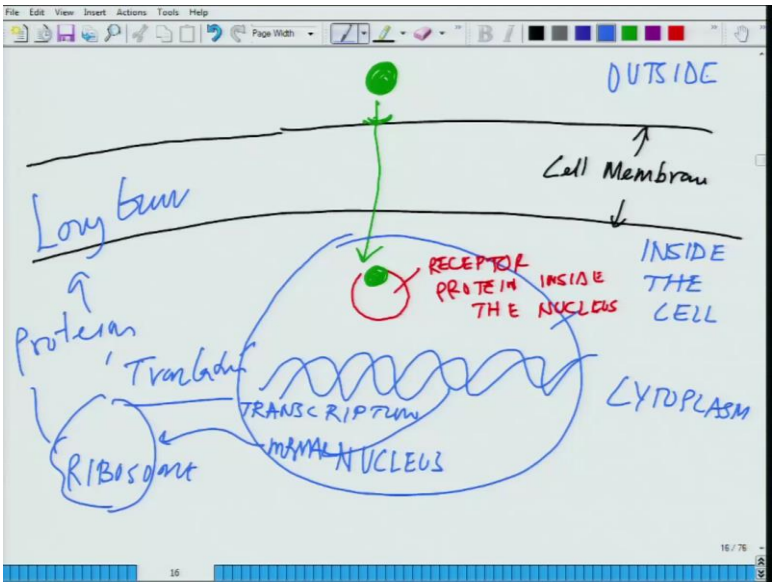

Coming back, again, we will draw the cell to explain this. This is the cell membrane and here, you have the hormone molecule. It binds to its receptor and directly enters inside the cell. Once it enters inside the cell, most of them add directly inside the nucleus. This is the nucleus inside the cell. So, this is inside the cell and, this whole area is the cytoplasm; this is outside the cell and this is where, you have the nucleus.

Now, once it enters inside the cell, inside the nucleus; it binds to the receptor protein in the nucleus. This red color is the receptor protein inside the nucleus. Then, this complex of steroid hormone and receptor protein, then binds to the DNA out here and then, leading to the transcription and generation of MRNA, and the same RNA comes, and from the ribosomes, the proteins are being secreted; proteins are being formed. These proteins then, show their long term effect. This full process is also called the translation process.

So, this is essentially, how a steroid hormone functions. So, a long term effect, a short term effect. A short term effect, where you have the second messenger; a long term effect, where the steroid molecule directly enters inside the cell, to the nucleus and there, it has specific receptor protein molecules. It binds to them; binds to the DNA and leads to specific expression of the genes, which leads to the specific expression of the certain kind of specific proteins, which are needed by the body for a long term action. Just I showed you; development of the moustache; development of the sexual behavior; all

these kinds of things are a very long term changes. They do not happen in a day. They take over a period of time it happens. So, these are the two broader ways by which the classification of, the action of the endocrine system is being regulated.

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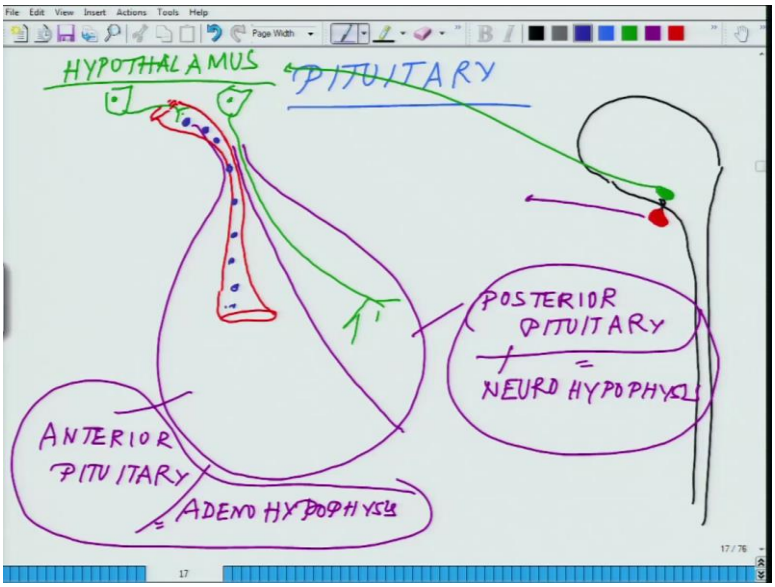

From here, what we will do, we will move on to the first system, which will be talking about the basic architecture of the pituitary. First, if you remember pituitary, I showed you the location of the pituitary on one of the beginning slides. It is somewhere, if this is spinal cord and it is sitting somewhere out here, this small piece of small red color almond shaped organ is called pituitary. So, pituitary, if you have to draw it; it is something like this.

It has two parts. One part is called posterior; posterior pituitary. The other part is called anterior pituitary. Both have different functions and different circuits. The other terminologies for them; is also called adenohypophysus; and this is called neurohypophysus. There is a reason for that. This is one of those, I was telling you all, rest of the places, it is all controlled by blood vessel. This posterior pituitary is not controlled by blood vessel.

So, pituitary is controlled by another higher center, within the brain, somewhere here, which is called hypothalamus. Here is hypothalamus. Hypothalamus has two modes of control. There are two ways by which hypothalamus can control pituitary. Hypothalamus is one of the master organs, and it is deeply embedded within the brain. So, one mode is

that hypothalamus secretes certain things in which, along a small local blood vessel reaches the pituitary. That is hypothalamus does for anterior pituitary. But for posterior pituitary, I told you, that there is one place within the endocrine system, which is directly under the nervous control. In the posterior pituitary, what happens is that posterior pituitary is in direct neural connection of the hypothalamus. That is why, sometime in the literature, it is also considered as an extinction of the hypothalamus. That is why it is called neurohypophysus.

After giving this idea, and I showed you how it works, if these are the neurons of the hypothalamus, they directly innervate within the posterior pituitary. Whereas, in the hypothalamus, there is another set of neurons, which are controlling anterior pituitary, they stimulate a local blood vessel out here. Whenever, the secretion takes place, these are the blood vessels, which come and dump the signal, which are sent by the hypothalamus. So, this is the basic anatomical architecture, what you have to appreciate about, and if these are the hormones, they are travelling like this. If I have to put this in whole perspective of the nervous system, then it is like this.

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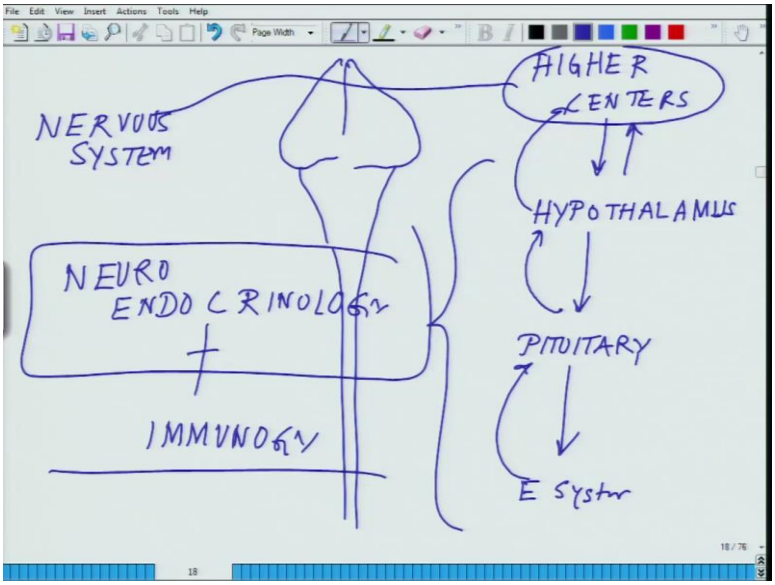

There are higher centers of the brains, which are cross talking with the hypothalamus; the double arrow showing the cross talk. Hypothalamus then, dictates the pituitary to act, which is one of the master endocrine systems, and we will appreciate that. Then, pituitary tells many other endocrine systems to act accordingly, and there are different

control mechanisms in every route; how they are being controlled and there is a cross talk.

If you look at it, these are the higher centers of the brain, which are part of the nervous system. This is where, the difference systems start converging. The area which falls under this whole interaction is called neuro endocrinology. This is the whole field which is developed over the years, is area of neuro endocrinology. Now, there is even more one addition into this, which is where, the immune system is cross talking with it. This falls under neuro immuno endocrinology. These are some of the future areas because, if you look at it, initially, we used to treat every system separately; this is digestive; this is endocrine; this is nervous; this is heart; or this is lungs; or this is the respiration; right. Now only, things are converging because, we are realizing there are multiple levels of control. There is an intricate control of nervous system, endocrine system, immune system, continuously at interplay. It is a very dynamic system.

Now, the way, we look at things are slowly changing. We are realizing that there are common molecules. We look at norepenephron, I told you, norepenephron is a neuro transmitter. Yet, norepenephron also functions as a hormone. So, the same molecule functioning as a hormone, as well as the neuro transmitter. So, there is nothing called like, very hard and fast, water type compartment. No, this is this and this. Biology is all mixed up out there, like chemical or the molecules, changes their duty based on the context. It is a very context dependent. The same molecule maybe, in a totally different way or follows a totally different route of action, as compared to when it functions as a part of the nervous system, as well as it is acting as a part of the endocrine system. They may convert; they may diverge.

So, these are some of the small things, which you people need to appreciate. Coming back, where I was in the previous slide, I just forgot to tell you something. This small local blood vessel which is present, which is sending from the hypothalamus, to the pituitary is also called hypothalamic pituitary; hypopayseal portal system. This is the direct name of the blood vessel, which are local blood vessels. One more thing [FL]. From here, one more thing I am going to show. So, these are the blood vessels which are carrying the hormones, which are secreted by. This is something, what you people have to appreciate is, that most of the hormones are carried by the venous blood. So, these are

veins which are basically receiving the hormones, and they are the ones, which carry it it all over the body.

So, this is something, that is why specifically, wrote that, venous blood vessels which are carrying these signals. So, I will end here and then, we will resume from the pituitary in the next class and then, we will go the pituitary and all the hormones secreted by the pituitary. Then, how the hypothalamus is controlling and then, we will go one by one and we will finish this section.

Thanks a lot.