Neural Science for Engineers
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Lecture - 26
Reflexes: Introduction

So, I would like to start this topic with demonstration. I have requested Rathin to help me out with the demonstration. I needed to start it out with the demonstration rather than with the theory because you see the process and then understand how it is seen in real life. And we will work back into the theory part of it and why it is a very fundamental topic in motor control, that is the control of all motions within the body.

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So, what I am about to demonstrate here is something which some of you who have gone to a neurologist would be familiar. So, this is something called as the demonstration of a reflex and anybody from a MBBS background would realize how difficult it is to show this to an examiner in particular.

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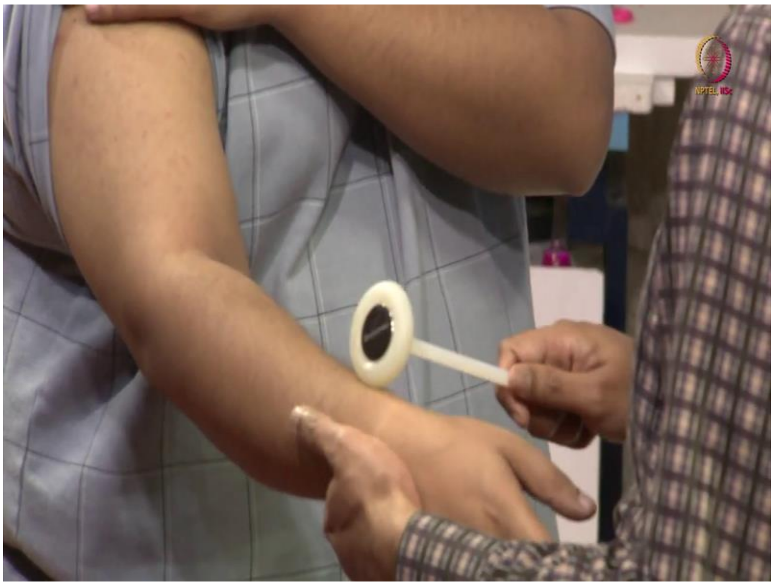

So, what is being shown is a tap and that is causing the limb to move. A similar kind of movement, not very obvious is the supinator reflex.

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And this you can see is the triceps reflex.

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So, for better viewing and for continuity I think I will demonstrate on the opposite side. So, this is the biceps yeah. So, Rathin I want you to do one thing, you try to hold your hand stiff, yes. Note the difference, it is just almost disappeared ok.

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So, we will do the same thing in true scientific methodology, repeatability. So, Rathin is focused on the triceps. So, I am not able to get the triceps as well as it is on the opposite side.

So, these are called reflexes. These are part of the clinical evaluation of patients and people when they check for their neurological status. But for the purpose of our discussion, it is important that you understand that this is universal. I demonstrated it on Rathin, it is would be very easy for him to demonstrate on me and vice versa and for any given person in the population.

A couple of these reflexes and I showed it to you on both sides of the body because it is a universal phenomenon. So, starting from that I think we will go on to the theory of how these reflexes form the fundamental mechanism of control and movement within the nervous system.

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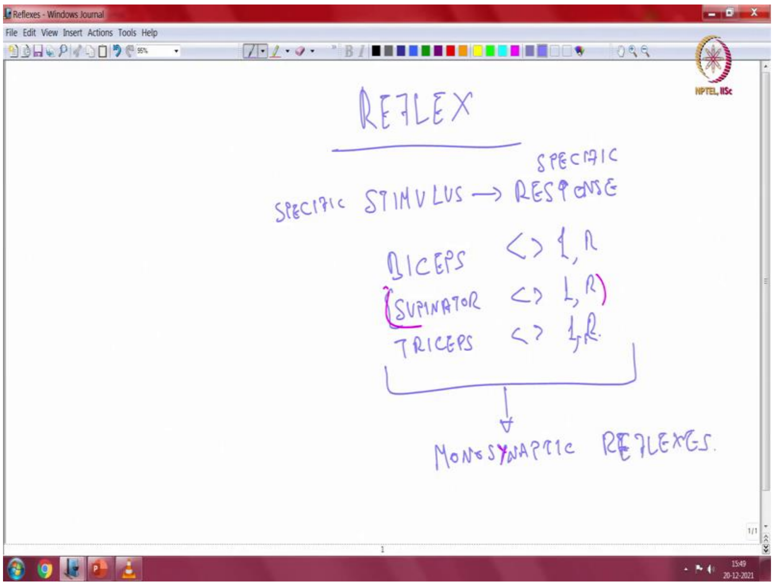

So, the topic of discussion is something called as reflexes. So, reflex is medical term in which you find stimulus which produces a specific response. Now the response is specific that is important it is not just any kind of response. So, there is a specific stimulus, and that way produces specific response. In the video I have demonstrated something called biceps supinator and triceps both left and right.

And I showed something about how it is universal. So, there are couple of such reflexes all throughout the body and they form a class of reflexes called monosynaptic reflexes. So, we will see what actually happened during the process and then how it is very important that we understand the process.

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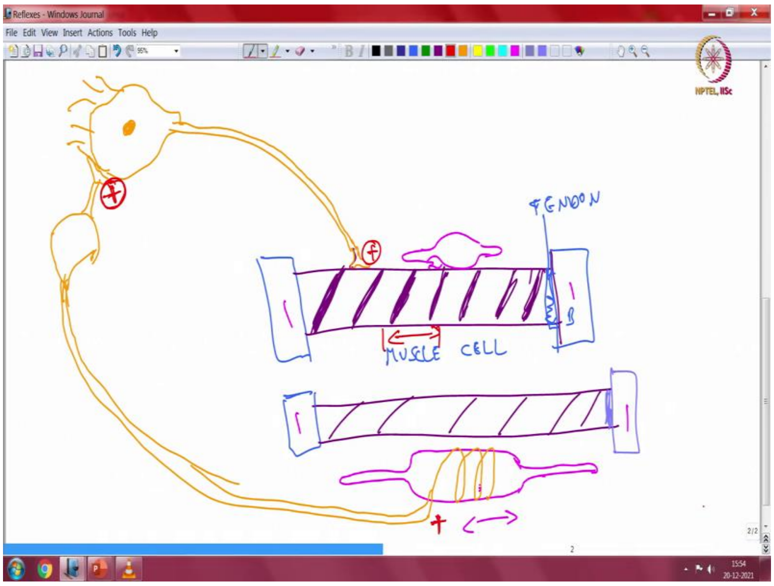

So, going back to our very old discussions we understand that you know there are muscle cells which can contract. And so, this is general notation for a muscle cell. So, how a muscle cell acts is because it has got a synapse and the synapse has got axon which comes all the way from the spinal cord. So, the cell body of the synapse is in the spinal cord.

Now, this is one part of the story. So, what actually happened during the process is muscle cells are attached to the bones. And this is a representation of a bone and when you tap that hammer. So, this is through tendons; so, this is a tendon muscle. Muscle, cell, tendon and bone. So, when you use that hammer and tap, what happens is there is a sudden increase in the length of this muscle cell.

Now, it results in the activation of something called as a muscle spindle. Now muscle spindles are sensor systems. I call the term systems instead of a cell because we will subsequently try to understand what complete functions are. So, the muscle spindles are located in muscle fibres and they are these kind of spindly structures which is present in a muscle cell and they are parallel.

So, what I mean by parallel is, when there is a change in length of the muscle cell, there is a change in length of the muscle in the spindle also. So, muscle spindle also gets increased. Now the muscle spindle is not so simple, there are fibres which come along the surface here and these fibres in turn go all the way to the spinal cord through the sensory part of the nerve.

But the axonal part of the neuron would go and synapse on to this muscle cell. And the more interesting part is, it gives a positive stimulation. So, let us analyze what has happened. So, we have a basic resting muscle spindle, sudden tap causing an increase in the length of the muscle, that length causes an increase in the length of the muscle spindle that in turn activates these fibre.

So, basically these contain sodium receptors which are sensitive to stretch. So, there is an increase in length, this cell gets activated and by default it is synapsing to the muscle cell of the same muscle, the neurons supplying the same muscle there is a positive activation and what actually happens is it stimulates. Now what does stimulation result in? Stimulation results in decrease of the muscle cell.

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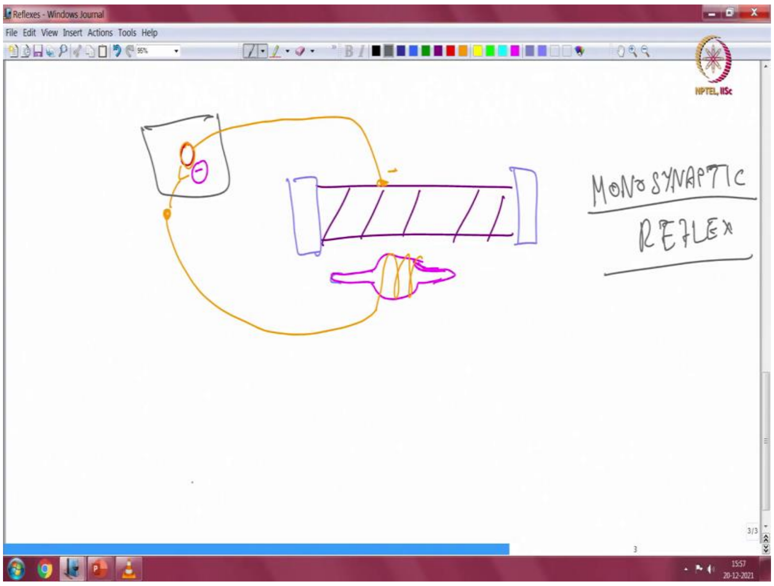

So, what happens is, contraction of the muscle cell. What happens to the muscle spindle? Muscle spindle also reduces its size and what happens to the neuronal stimulation? Nothing happens to the muscle cell. So, you have negative output here and that in turn produces negative. So, this is the theoretical demonstration. So, we will reiterate the whole stuff again.

Sudden increase in length of the muscle causes increase in length of the sensor, it is a stretch sensor, the sensor gives an output to a neuron, the neuron gives an output to the commanding neuron of the same muscle cell.

And that reduces the size of the muscle cell and then it contracts. Once the length comes down the output from the receptor sensor comes down, the neuron which is supplying the sensor reduces its activity and the muscle cell activation comes down because the neuron coming to the muscle cell reduces its activity. So, that is what we actually saw.

The key step here is this. So, we see that in the entire exercise. There is only one synapse. So, the single synapse is what makes it called a mono synaptic reflex. So, it looks very interesting, it looks very novel, but what is so fundamental about it? There is nothing fundamental about this right.

So, what I have told you is only part of the story. So, the remaining part of the story is what makes this system very interesting. So, muscle spindle is not just about, there is still one more entity which needs to be considered.

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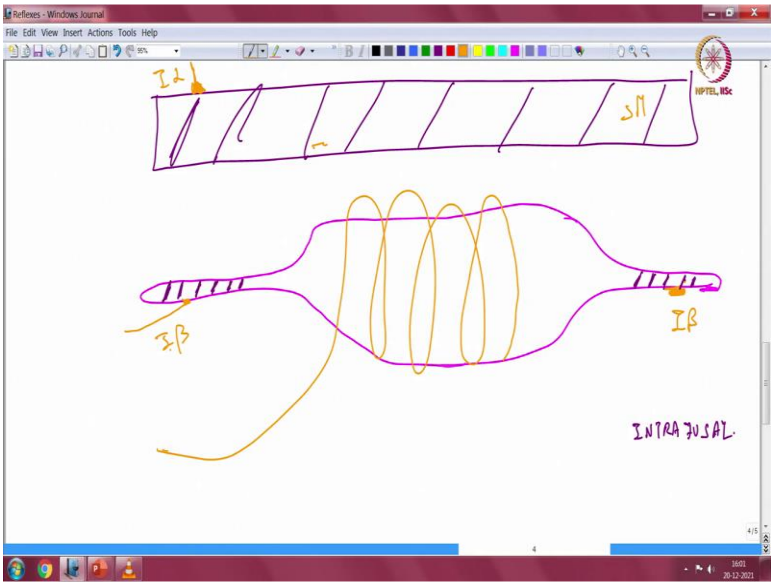

So, muscle spindle I drew it like this spindle. So, spindle is shaped like this, apart from having this, there are muscle fibres in this part of the spindle, that is what makes it interesting. So, you have something called as intrafusal fibres.

So, these are intrafusal fibres and the others are extrafusal fibres, extrafusal fibres or outside of this spindle. So, we are looking at it from this spindle point of view. So, this is the larger muscle cell, and these have synapse over here. These have synopsis over here and then there is an entire sensor system sitting over here.

And you have two muscle cells which can be activated independent of each other. So, this is called 1 beta, 1 beta and 1 alpha they have rates of transmission which are very different. Now we have set up the discussion and we will see how things work from here. So, what actually happens if we send a stimulation to 1 beta?

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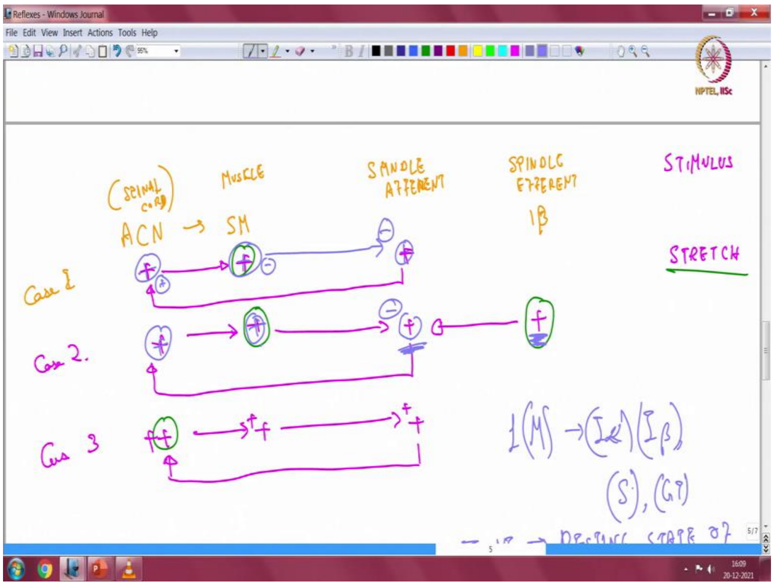

So, 1 alpha, 1 beta, then spindle muscle cell or maybe I think I should make it a little more detail and we look from top down. So, anterior cell neuron this is in the spinal cord, this goes to skeletal muscle cell, then we have spindle cell with spindle afferent; afferent is towards the spinal cord.

So, this will be a smaller fiber; spindle afferent then spindle efferent, 1 beta ok. So, we will revise the whole stuff, this is skeletal muscle, this is 1 alpha fibre which synapses onto the muscle cell, the huge spindle which is disproportionate.

The spindle has got muscle cells on both sides, each muscle cell is fed by a one beta fibre on both sides. The muscle cell itself gives an output to the spinal cord through this spindle cell fibre. So, what we first thought case 1 is I have put a stimulus, stimulus is stretch. So, that produces spindle afferent that causes anterior cell activation that causes skeletal muscle activation. So, spindle afferent results in ACN and then that results in muscle cell. So, clear about that.

Case 2; we give spindle efferent. Now what happens with spindle efferent is it causes spindle afferent activation, why? Because there is stretch in the spindle. So, both the peripheries contract spindle gets stretched. Muscle is not stretched, spindle is stretched, what does this do? It causes ACN activation and that causes smooth muscle activation.

So, that is the other way of doing it. Now case 3, say ACN is activated, smooth muscle is activated, spindle afferent is also activated because spindle afferent is activated. So, it goes in this direction, it goes in this direction, and it goes in this direction and you have plus. So, you have more contraction happening over here, but this does not cause it indefinitely.

So, what will happen is an increase in this one, causes further this in turn activates something else, another reflex by which the contraction comes down. So, I think that need not be mentioned here. So, this is a beautiful loop which happens within the muscle, the nervous system is able to control muscle activity through this mechanism. Please note that each one of these three things are different.

There is external stretch resulting in muscle contraction, there is efferent contraction 1 beta contraction which causes activation which causes muscle contraction and then there is this one alpha stimulation which is causing further muscle loop. So, the fine tuning of muscle activity happens to a large extent in the spinal cord. Now what are the implications? Implications are, I have not completed the loop.

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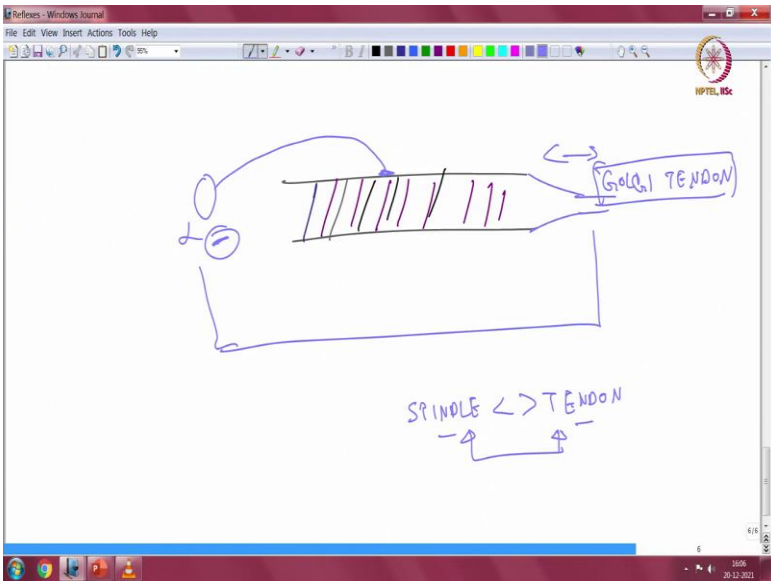

So, why does not this continue indefinitively? So, in the skeletal muscle design which I spoke about the tendon which is this one. So, when there is stretch in the tendon this reduces the alpha activity. So, alpha activity, which is coming to the neuron, so this is negative.

So, when this is negative. There is a balance between the spindle activity vis a vis tendon, this is from the Golgi tendon. So, Golgi tendon, spindle cancel out each other. So, you cannot have indefinitive contraction happening.

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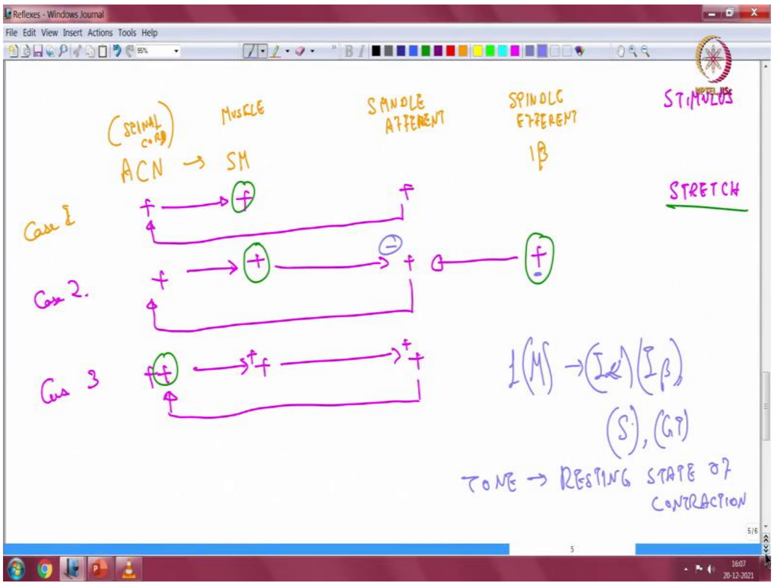

On the other hand, what is more what is more interesting is there is this positive feedback which is there and if you have just spindle afferent coming without any other activity you notice that there is a feedback cycle of a muscle contraction which is happening over here.

I think I did not complete this. So, that completes the loop. So, in effect what is happening is you have two or three different control mechanisms by which length of the muscle cell is controlled.

So, length of the muscle cell can be controlled by 1 alpha afferent, 1 beta or by combinations of spindle cell and Golgi tendon activity. So, there are multiple things. Now the sum of all these things if we look at what actually happens with all of this is there is something called as tone. So, tone is a resting state of contraction.

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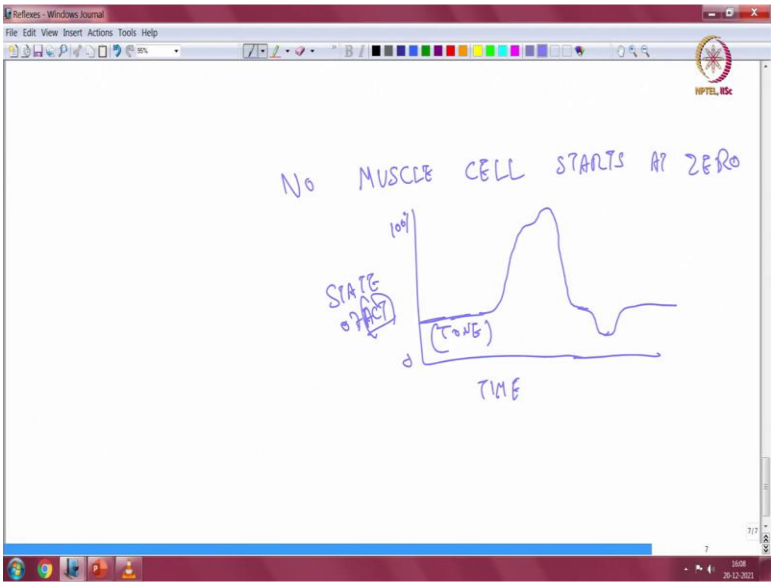

What it essentially means is that no muscle cell starts at zero. So, there is always a baseline activation. So, if we plot time and state of activation and 100 percent contraction and 0 percent, muscle cell is always at a distance. So, that that level of activation is called as tone.

So, when there is activity, there is increase in the activity to various extent based on the amount of stimulation and there is also a provision that if you have say some something happening on the opposite side you can reduce the tone a bit and you know that is responsible for a lot of functions which we go.

So, this is how the idea that the monosynaptic reflex is a fundamental entity in controlling muscle activity is depicted, let us revise. So, we start with stretch, stretch is spindle afferent, stretch spindle afferent stretch causes ACN activation that in turn causes smooth skeletal muscle activation. So, that contracts and that contraction results in negative and that in turn becomes negative.

Now, if we could look at the second in which spindle afferent. Spindle afferent which in turn activates the alpha motor and in turn produces this one, but in this case there is still persistent activation happening because the activation is not from the spindle cell as such, it is from the muscle cells on the spindle fibre.

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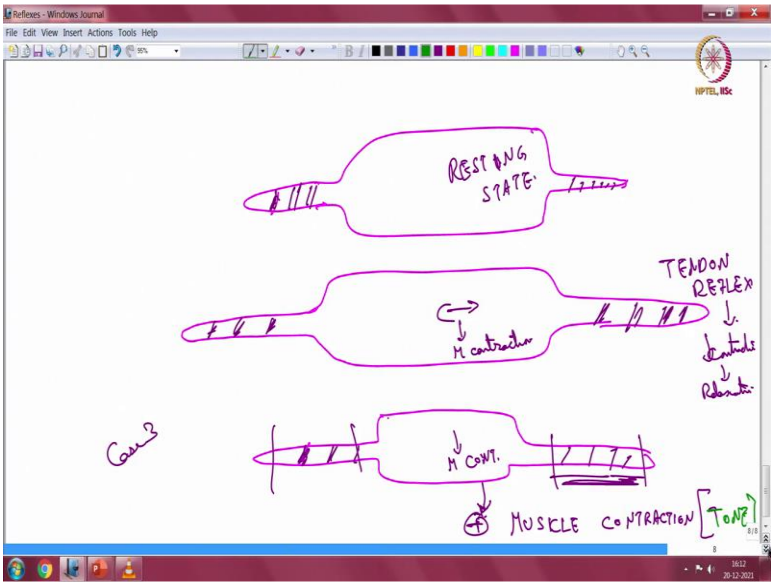

What do I mean by that? We will redraw the spindle. So, this is what happens with the tendon reflex, which results in decreased contraction followed by relaxation. Contraction because the length suddenly increases, stretch increases and that produces muscle contraction, this is a sort of resting state. On the other hand, when there is contraction in this two parts, this gets stimulated, muscle gets stimulated, muscle contracts, but the signal does not die out because the contraction is being manipulated over here.

So, there is a continued signal coming from this state. So, case 3 continued muscle contraction and that is called tone. The state of continued contraction which is there due to the muscle spindle and the muscle cells; muscle cell spindle extra fusal and intra fusal fibres both is responsible for this state of tone of the muscle.

So, this sort of gives an idea of the richness of the network and the control mechanism. So, remember this is just one of the most simple control mechanisms which are there in the human body, it is pretty conserved and you can notice that as I told you from the previous graph.

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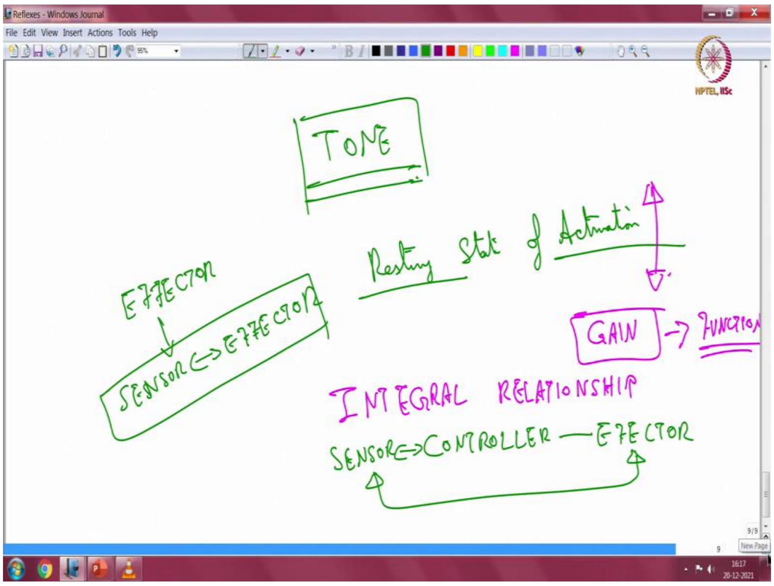

Tone is a fundamental property; the concept of tone I had already highlighted somewhere in the neural network discussion also because there is a resting state of activation. It means the opposite you know, but it is a very beautiful statement because it states that what we call rest already has some activity built into it. And what the nervous system does for control is to change the state of this activation.

So, you can either decrease the activation or increase the activation to produce some activity and that is a very fundamental property of all nervous system work see always start at a baseline including if you look at the resting membrane potential which is there in all excitable cells.

But this is one level above that you would always find that the state function is at a higher threshold than what is necessary. It expends energy but for whatever reason maybe for control smoothness or maybe there is a control theory which explains the whole stuff which I am not aware.

But the state of activation is what is changed. So, what actually gets changed is the gain of the system. So, the gain of the system results in function and that I think is a very profound statement when it comes to analyzing neuromuscular cell activity. The second thing which I want to say is the integral relationship between controller, effector and sensor.

So, the loop is there from the beginning. It is not that the loop is constructed or what I mean to say is, there was never a time when the nervous system developed independent of the muscle. So, you can see that the muscle has a sensor embedded within itself and it is that cell which is completely you know in tandem with the regular muscle cell and the control is not just at that level you have got even muscle cells present within that sensor.

So, you have a effector connected to a sensor effecter. So, sensor also has got another effector in it. So, that is that is another beauty. So, you have, and these are not just one there are literally millions of these cells and that is the kind of richness which biological systems have in their base control system. So, this is something which is present at the heart of the whole system and that is the reason I thought I should start my network analysis with the monosynaptic reflex.

There are polysynaptic reflexes in which multiple other neurons come in between those two effectors and the sensor dynamics and it gets modulated by various things, but I showed this in the demo at various muscles to say that it is universal.

So, when we discuss if you take a textbook of Medicine Physiology you would find that the reflex is discussed in very bland terms as a method by which you diagnose, a method by which you describe control within that. But more than it being an example of function, it is an example of the kind of hierarchical processing which happens. So, how does this reflex help in diagnosis a brief thing.

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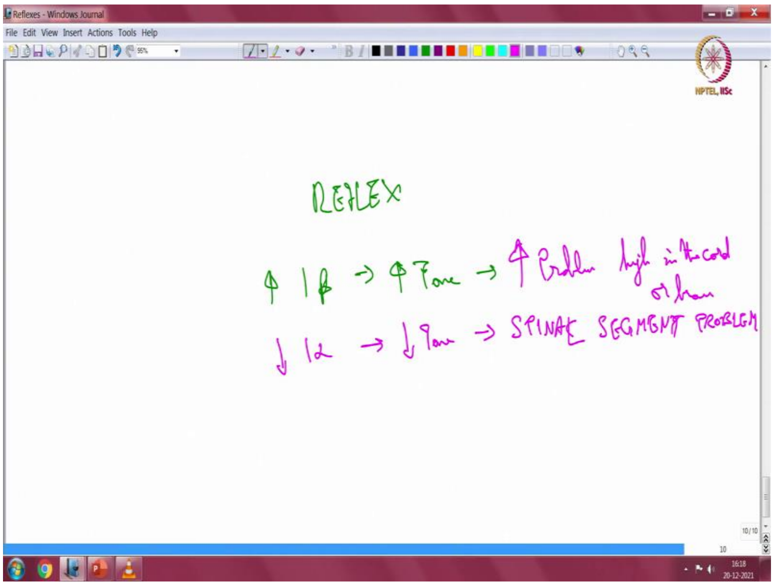

So, if there is increased 1 beta, it increases increase in tone which basically indicates that there is a problem high in the cord or brain. So, if there is a cut between; so, if it is decrease in 1 alpha it indicates decreased tone and spinal segment problem. So, that is that is a very crude way of describing how the medical interpretation is done, but the theory remains the same.

The theory remains the same whether it is discussed in medical terms or whether it is discussed in engineering terms. In engineering terms what I would like to highlight is the use of gain as a method of control, I think that is the mechanism of server controls, but the beauty of putting a sensor in the actuator with an actuator in the sensor I think that is something very unique.

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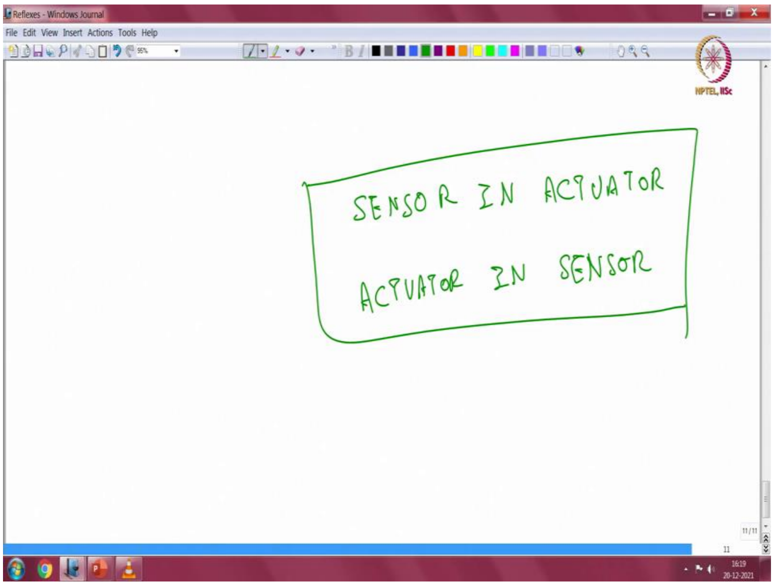

So, this is something for you to think about, something which is very beautiful and it is a very fundamental motion of the of control systems within the brain and spinal cord. So, with this I think I will stop my discussions over here and we will continue in next class.