Neuroscience of Human Movement
Department of Multidisciplinary
Indian Institute of Technology, Madras

Lecture – 26
Excitation and Inhibition within Spinal Cord Part - 2

So, welcome to this class on Excitation and Inhibition within the Spinal Cord Part 2.

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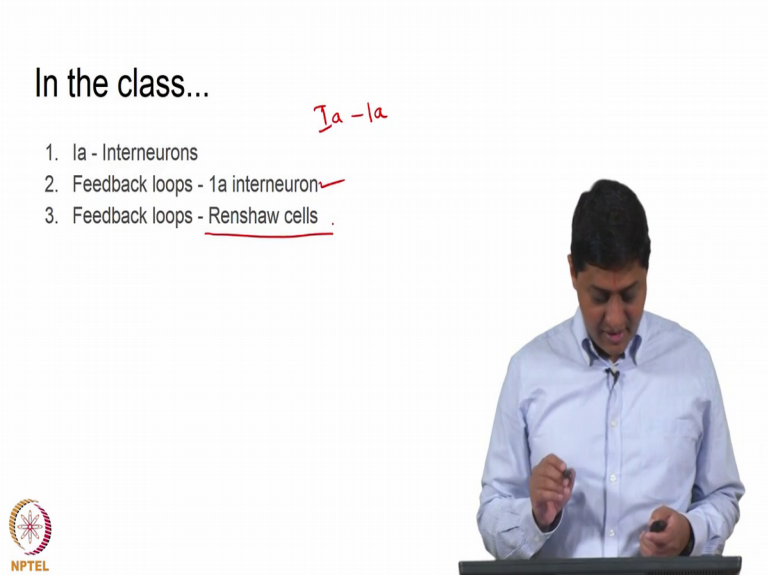

In this class we will be talking about 1a interneurons and its function. So, it is written with Roman numeral 1. But for clarity in this class, I am going to call this as 1a with numeral 1 and a ok. Otherwise, some students read it as I a interneuron. So, that is actually 1a inter neurons and the feedback loops that are involved by 1a inter neurons and those that involve a combination of 1a inter neurons Renshaw cells. We saw the case of Renshaw cells yesterday. Let us remind ourselves what it is.

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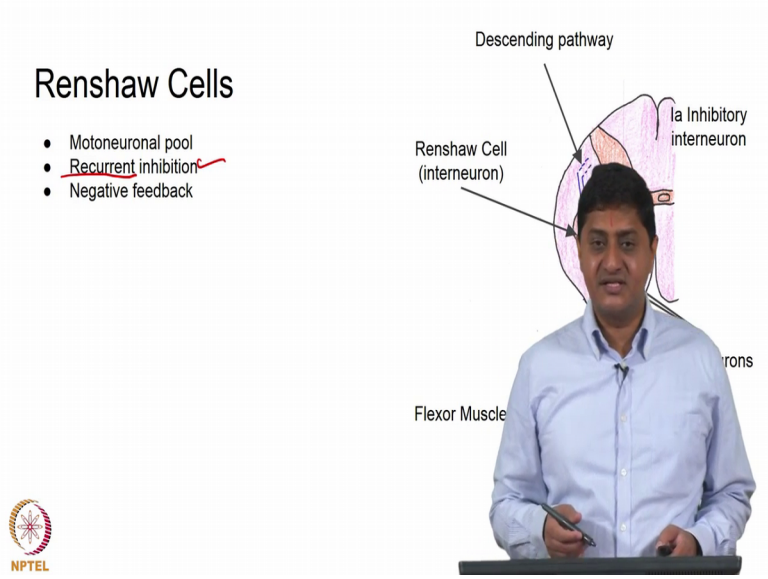

So, Renshaw cells are activated by motor neurons and they inhibit the motor neuronal pool that excites it. A farm of negative feedback is what we say phenomenon also called recurrent inhibition. That is more to that. It just this is just one part of a relatively larger feedback loop. We will see the remaining parts and we saw that are Renshaw cell is a inhibitory interneuron. But there is one more inhibitory interneuron which we will call as one a inter neurons.

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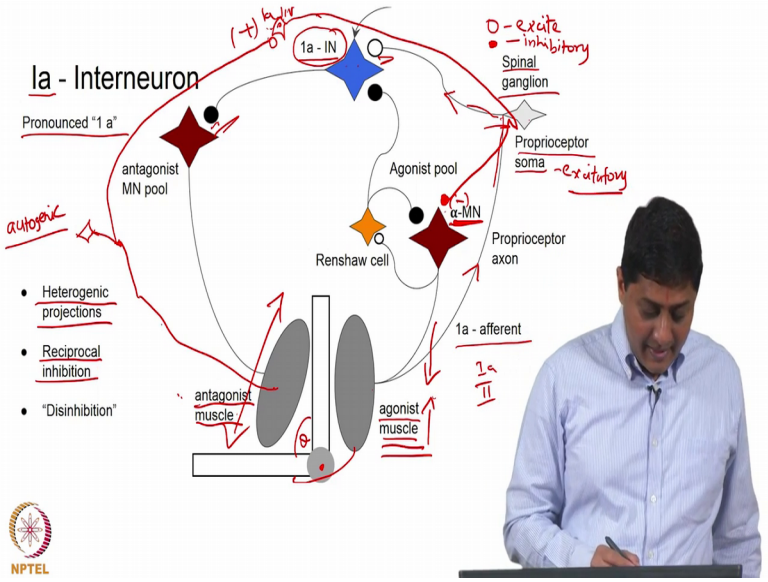

So, pronounced 1a, but usually in textbooks it is written like that. It is not i a interneuron, but rather 1a interneuron. These are excited by the proprioceptive neurons of the other muscle of the agonist muscle. Let us consider a simple case. Here is a one joint. So, that

is one joint that is spanned by only two muscles. Let us consider the theoretical case. There are only two muscles: one is the agonist, the other is the antagonist for the purpose of this discussion.

Let us suppose that this antagonist muscle is contracting or is trying to reduce that angle theta ; that angle is trying to reduce. When that happens, what will happen is it because this muscle is connected to both bones like that and this muscle is connected to both bones like this. Because of this reason as this reason muscle shortens, this muscle is going to reduce size.

As this message is going to shorten, this muscle is going to be stretched. It is going to be elongated. When this muscle is elongated, we saw earlier a case of linked sensor which are muscle spindles right. So, these are these are of two types: primary spindle and secondary spindle are 1a afferent, 1a afferent are two afferent is it not; 1a we saw is responsible for detection of both length and velocity, two is responsible just for the detection of length 1a can depending on the sensitivity of the dynamic and static gamma motor neuron. Depending on that it will act either as a length sensor or as a velocity sensor. This is what we saw.

So, when this muscle when the antagonist is contracting, the agonist will stretch and then the sensor will start firing will start sending an input that is proportional to the amount of stretch, is it not ? So, it is a length sensor. So, as soon as the length becomes increased, this is going to start sending information. So, in the sensory part of this proprioceptive neuron is here intertwined with the intra fusel fibers; actually in the center right, intertwined with the intra fusel fiber here like that. Cell body or the soma is in the spinal ganglion and we said it has a characteristic T shaped axon right like that

So, conduction happens antidromically in that direction towards that. There is a little bit of processing, very little bit of processing and then auto dromically in that direction. Then what happens? So, this proprioceptor neuron is exciting and inhibitory interneuron which is called 1a inter neuron. So, this 1a inter neuron is activated, what it will do is it will inhibit. So, here the open circles are excitatory. Those that are you know filled empty circles are excitatory; those that are filled are inhibitory.

So, this 1a interneuron inhibits the antigonish motor neuronal pool. This antagonist motor neuronal pool is the one that is activating and causing contraction. So, in a way as

soon as it is realized that this muscle is stretching that the agonist muscle is stretching, the proprioceptive information goes via 1a interneuron and inhibits the motor neuronal pool that and prevents contraction of this muscle. What will then happen? Then this contraction will reduce right. So, the stretching will reduce; a way of a method in which I am implementing negative feedback. Let us let us assume I am the agonist muscle somebody is pulling me the antagonist muscle is pulling me. I am trying to you know ensure and minimize the amount of you know that antagonist activation. So, I will not be pull too much.

So, that information goes why are the proprioceptive neuron to through the 1a interneuron. Note the information from the proprioceptive neuron is always excitatory. This is always excitatory. Information from the proprioceptive neuron is always excitatory, as the length increases. The excitation amount is going to increase the rate of firing is going to increase. This is true for all proprioceptive neuron. In this case this is 1a afferent this is true of two afferents is two of 1b. What is 1b? 1b is the afferent associated with Golgi Tendon organs, a different case does not matter. All the proprioceptive neuron says are excitatory.

So, this the probability that the 1a inter neuron is going to increase its firing is increased when proprioceptive proprioceptive neuron sends and excitatory command to this 1a inter neuron. As soon as this is getting exciting; however, this 1a interneuron inhibits since inhibitory neurotransmitters, inhibits this alpha motor neuronal pool. Thus preventing any further contraction or at least to some extent it is reducing the probability that the contraction is going to continue sustained or keep on increasing. Why is this needed? Otherwise this muscle can keep on contracting and this the otherwise the antagonist muscle can keep on contacting and the agonist muscle can keep on stretching.

At some point it could cause damage and it are to create a balance in the amount of contraction and contraction and stretching between these two muscles. Also we are not just interested in achieving a particular posture which is theta. So, and I am saying that is the theta I want; it is not just that we are interested in achieving the particular theta. I am also interested in achieving that with a relative sense of ease or smoothness humans like this.

So, we like to you know achieve this with some smoothness. So, to ensure that there is some amount of moment to moment control at least to some extent. There are some delays associated with this; obviously, there is some delay here. There is some delay here, there is some delay here and some delay here. So, there is definitely some delay, but despite those delays there is some amount of control that is exerted on the antagonist muscles, alpha motor neurons to ensure that the probability that they will contract is at least slightly reduced due to this.

Also one thing to note is that it is not necessary that the agonist muscle will contra will stretch only when the agonist muscle is contracting. It is also possible that the agonist muscle will stretch due to an external load. An external load could cause stretching even at in those cases, because it is not like the proprioceptors neuron can know who is causing the stretch. The proprioceptive neuron just detects the amount of stretch. So, as soon as the stretch comes, so, it sends the excitatory information to one interneuron which further sends an inhibitory information to the antagonist motor neuronal pool.

So regardless of what the source of stretching is the antagonist motor neuronal pool will get inhibited to some extent. Also we must realize one more thing, what is not shown in this picture just to prevent the complications that may it arise is the following.

Let us suppose the following the opposite is happening. It is supposed that it is the agonist muscle that is contracting. In other words that muscle is reducing in its length that muscle is getting stretched, then what will happen? As soon as this muscle is getting stretched, what is not shown in this picture? Now I will draw that that is a proprioceptive axon here whose cell body is laying in the spinal ganglion. Let us say that is the spinal ganglion and there is a T shaped axon having both orthodromic and antidromic conduction

And that is one more there is one more neuron here. This is the 1a interneuron. So, this is exciting a different 1a inter neuron and that one inter neuron is going to inhibit this alpha motor neuron, that alpha motor neuron, why? That alpha motor neuron is the one or that pool of alpha motor neurons is the one that is causing this contraction. I want to prevent or minimize or reduce slightly to some extent or control the amount of contraction that is happening in this alpha motor neuronal pool. So, I am so, there is reciprocal inhibition.

So, in other words the projection is going to the opposite muscle. So, this is true for all muscles; this is true for all the muscles then have counterparts. So, in every case that is somebody else. So, in this case, so when this is getting when this agonists is getting stretched, it is going to excite this one there is a different 1a interneuron here. That 1a inter neuron is going to be excited and that guy is going to come or that 1a inter neuron is going to inhibit the alpha motor neuronal pool that is causing the contraction of this muscle.

So, this kind of projections that go to the other muscles or afferent projections that go to neurons that innervate; innervate other muscles are called as heterogenic projections. Those projections that go to the neurons innervating the same muscle are called as autogenic projections.

In this case, these projections are heterogenic and when the agonist muscle is getting contracted, the antagonist will inhibit the agonist motor neuronal pool. When the antagonist muscle is getting contracted, the agonist will inhibit the motor neuronal pool of the antagonist are more simply because this terminology is a little confusing. We can use biceps and triceps. If biceps is contracting, then triceps will get stretched, then triceps will inhibit the motor neuronal pool that innervates biceps because it is do a that motor neuronal pool that is causing this contraction.

So, I want to minimize that or if triceps is contacting, then biceps will get stretched, and it will send inhibitory information through 1a inter neuron to reduce minimize or balance the amount of contraction in the triceps. So, we do not want the triceps to keep contracting forever. So, I want to minimize it. So, this kind so, that is this balance that is achieved that is achieved between agonist and antagonist. So, that is inhibition reciprocally between these two cases.

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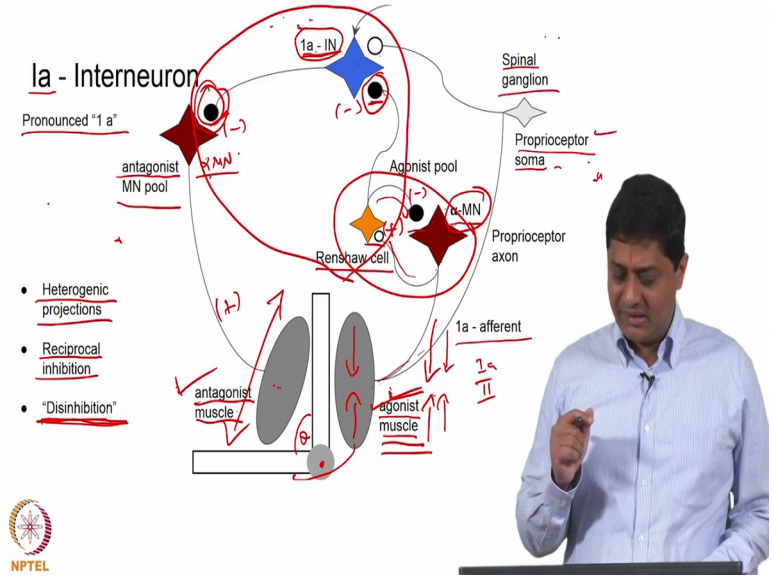

Now, we have Renshaw cell is activated by alpha motor neuron right. This is what we saw in the previous classes, what we saw in the previously. So, whenever this alpha motor neuron is firing, it is going to activate this Renshaw cell. What this Renshaw cell does? One part of what we saw yesterday was that it inhibits the same alpha and gamma motor neuronal pool for that agonist and its and its agonist; so for that muscle and its agonist all the muscles that perform approximately the same function.

So, it is going to not just inhibit one muscle, it is on it may also inhibit other muscles. It will also inhibit not just alpha motor neuron, it will also inhibit gamma motor neurons. This is the function of this is one function of Renshaw cell. One other function that it does is, it also sends an inhibitory connection innervation to 1a inter neuron that innervates the antagonist. Let us straight analyze this situation. What this does is. So, let us this alpha motor neuron sends a command, the Renshaw cell becomes activated or gets excited and since inhibitory command to 1a interneuron

So, what will that do? That let us let us straight analyze what will be the action of the alpha motor neuron itself. This alpha motor neuron when it is firing will cause a contraction of this muscle ash as has been shown previously. It will cause a contraction of that muscle. It will cause a contraction which will cause a stretching in this muscle, is it not? This is what this alpha motor neuronal activation will do.

In the way if I inhibit this 1a inter neuron, if I inhibit this. This 1a inter neuron is already inhibiting this antagonist pool. In other words there is one minus here; there is one more

minus here. So, effectively what I am doing is I am increasing the probability that an excitatory command is going to be center to this antagonist muscle. Or in other words, there is a contraction here and want to increase the probability that the antagonist; there is a contraction in the agonist I want to increase the probability. That the antagonist will also contract; so as to balance the contraction provided by the agonist.

So, as soon as this as soon as this agonist is contracting I want to contract the antagonist or at least increase the probability that it will contract right. That is going to happen only if I excite this alpha motor neuronal pool. This is the alpha motor neuronal pool, did not. This I want the excite, but what the Renshaw cell is doing is it inhibits the 1a interneuron which is inhibiting; it inhibits the 1a interneuron which is inhibiting the alpha motor neuronal pool or in other words it is increasing slightly the probability that this alpha motor neuronal pool is going to reach threshold or is going to get activated and going to contract; thus, providing one more level of negative feedback.

So, there are at least two three levels that we have levels of negative feedback that we have seen. One is this itself this loop is it not? So, the alpha motor neuronal pool excites and that is negative feedback here. The alpha motor neuronal pool excites a Renshaw cell and their Renshaw cell inhibits the alpha motor neuronal pool that is one level. Two the muscle the agonist muscle contracts or the or the antagonist muscle contracts that causes a stretching of this muscle, the agonist muscle which is inhibiting which inhibits the contraction of the antagonist through the 1a inter neuron. That is that loop, is it not? That is the bigger loop.

Then there is the loop that covers that. So, toward in this case the first two are cases of inhibition against an excitation. Whenever there is an excitation that is going to be an inhibition. So, excitation happens in the Renshaw cell, inhibition happens. Inhibition is provided by the Renshaw cell that is first. Second is excitation happens in this alpha motor neuronal pool, inhibition is provided by the 1a interneuron through the mediated obviously by the proprioceptors neuron; these are two.

The third is a different case in which an excitation is provided or an inhibition to inhibition or that that. These two are provided through the activation of Renshaw cell as soon as this alpha motor neuron is getting excited. It is exciting not inhibiting, it is inhibiting the inhibition of the other opponent other pool are. So, it is a very fine design.

So, depending on the case, inhibition or excitation could happen and in this particular case an inhibition of inhibition are at this inhibition, it is a very very important terminology this. This inhibition will discuss this in great detail when we discuss brain structures especially basal ganglia. This terminology this inhibition is performed at this is happening in the spinal cord, but this also happens at several levels within the brain especially in the basal ganglia. We will discuss this in greater detail later.

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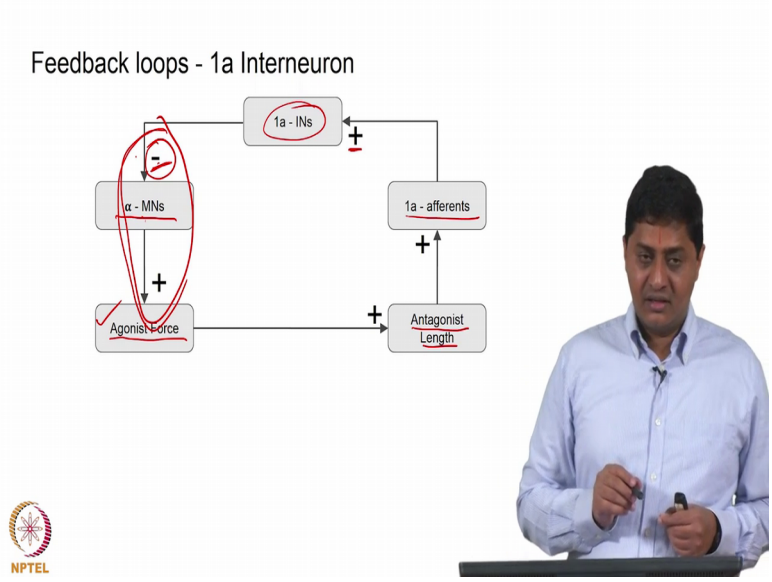

So, what have we seen? Let us reminder ourselves, this is a schematic of what is going on; what is going on is this. So, suppose the agonist is contracting and producing a force right that causes that increases the length. So, the agonist is contracting, its length is reducing; then the antagonist is getting stretched. But the antagonist getting stretched, what will happen? The 1a afferents will become active and they will send excitatory recommends to 1a interneurons which will inhibit the alpha motor neurons of the agonist. So, that is the negative feedback loop that we are talking about.

As soon as this alpha motor neuron fires, then there is a then there is a balance that is brought about by the action of 1a inter neuron sending this negative information. This is the first negative feedback loop that you see, then what else?

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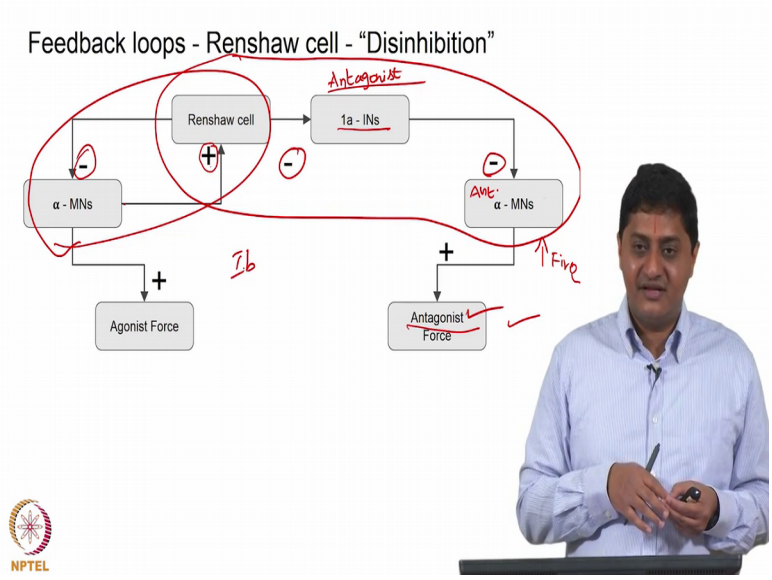

Then we saw the case where the alpha motor neuronal pool activates the Renshaw cell which further inhibits the same alpha motor neuronal pool that loop. That is a second feedback loop. Then what we also saw was that this Renshaw cell not only inhibits the alpha motor neuronal pool, but also inhibits the 1a interneuron of the antagonist. This is which 1a interneuron. This is antagonist 1a interneuron. This antagonist 1a inter neuron is inhibiting the alpha motor neuronal pool of the antagonist of this. This is alpha motor neuronal pool of the antagonist that is getting inhibited by the 1a interneuron its activity itself is inhibited. So, that is minus into minus plus. In other words effectively increasing the probability that this alpha motor neuronal pool will fire or increasing that probability.

So, what we have seen is there is one more loop that involves that. In this case this is negative because this is this might appear as plus minus into minus is plus. This is what it would appear as this is negative because it is activating the antagonist; in that sense it is negative.

So, one more level, one more level of hierarchy in which negative feedback appears in this. So, balance in this system appears or manifest at multiple levels. By the way we are not done there is more to the story. With this at least we are able to realize that there are two or three levels at which at least it is happening within the spinal cord, then there are other levels of spinal you know hierarchy. Actually there are other things within the spinal cord that is 1b information. Information that comes from Golgi Tendon organs. It is not like it is unused, it must be used somewhere, how is it used and other things that are not discussed so far.

So, we will discuss all those things and other such. So, we will this is going to be a recurring theme in this course. So, this is going to come several times from time to time I am going to say. So, this neuron is inhibiting. So, this neuron is this inhibiting. By the way it might appear like what is this disinhibition? Inhibition of inhibition that is not it is not actually excitation. There is a difference between exciting somebody and not inhibiting somebody. There is a difference between these two, is it not um?

So, it its probabilistic the probability that this is going to fire. At least we should agree that the probability that a neuron is going to fire is increase when it is this inhibitor, when the inhibition on it is reduced. So, the probability that you know you are all going to perform well or you know or reach great heads is going to be increased. If the inhibitions on you is removed something of that are, but yet there must be other sources or it there may be other sources which may be spontaneous or control that may cause excitation. But at least we are preventing we are removing the obstacle to excitation in that sense.

So, it is not exactly excitation, but it can be considered to be a form of excitation or at least we are increasing the probability, it is going to be excited. Or consider that you know if inhibition is present, then the chance that it is going to become excited as at least lower in the presence of a inhibition versus in the presence of this inhibition. In that sense it is, it can be considered to be an excitation.

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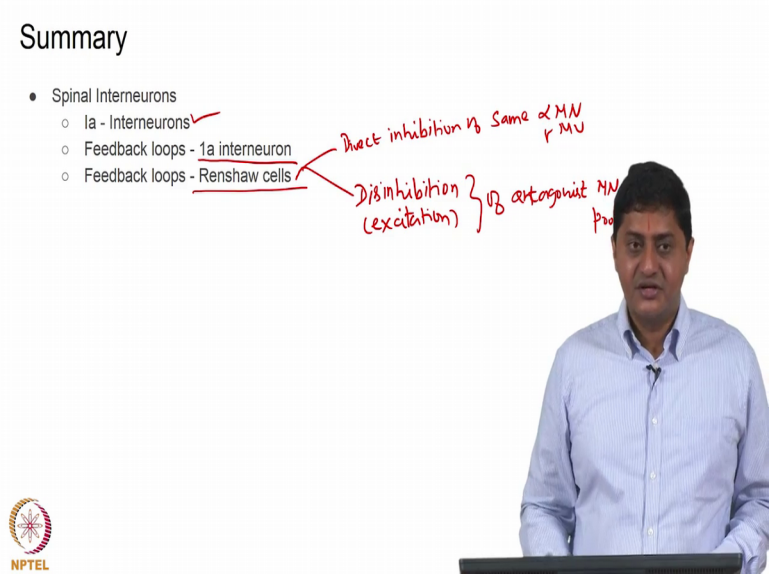

So, what we have seen in this class is the case of 1a interneuron, its important function in inhibiting the antagonist alpha motor neuronal pool; when the agonist muscle is contracted when the agonist sorry agonist muscle is stretched. When the agonist muscle is stretched the antagonist alpha motor neuronal pool is inhibited and we said that that is remember that this inhibition is going to happen regardless of what causes the stretching of this muscle. The stretching can happen, because of the contraction of the antagonist or it can happen because of an external load

Either way the alpha motor neuronal pool of the antagonist will get inhibited. Because 1a interneuron is just performing its function; 1a afferent is just performing its function. What is the function of 1a afferent? As soon as the length this increased fire and you know, till 1a interneuron to inhibit the antagonist alpha motor neuronal pool; that is the function. They do not know what is causing this stretch; that is a more fine information.

And feedback loops concerning 1a interneuron, there are there is one that involves reciprocal inhibition between two muscles for example, and this exists throughout the body in multiple muscles

And then feedback loops involving Renshaw cells. The one that involves a smaller feedback loop that involves; so, there are two of these. One involves direct inhibition of the same, alpha motor neuronal pool. That is what we saw alpha motor neuronal pool and gamma motor neuronal pool just a motor neuronal pool.

And within the Renshaw cells, there is one more that it in this inhibition or excitation; excitation of the antagonist motor neuronal pool. So, by this because I am activating the opponent because I am activating the antagonist negative feedback is achieved. So, you have seen these three cases. We will see more cases and those that involve reflexes and stuff from future classes in future classes.

So, with this we come to the end of this class.

Thank you very much.