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

Lecture – 27
Monosynaptic Reflexes Part 1

Good morning, welcome to this class on a Monosynaptic Reflexes this part 1.

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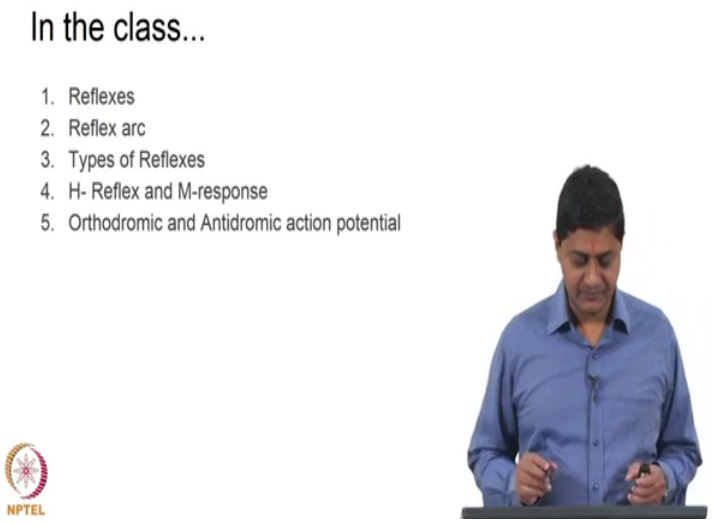

So, in this class we will define or at least we will come up with the working definition of reflexes, and define what is called as the reflex arc and types of reflexes, how do we classify reflexes. And two specific classes two specific cases of reflexes the H-reflex and the M-response critical the role of orthodromic and antidromic action potential travel. You have seen what these are in previous classes, I will remind them what it is today's class and we will proceed ok.

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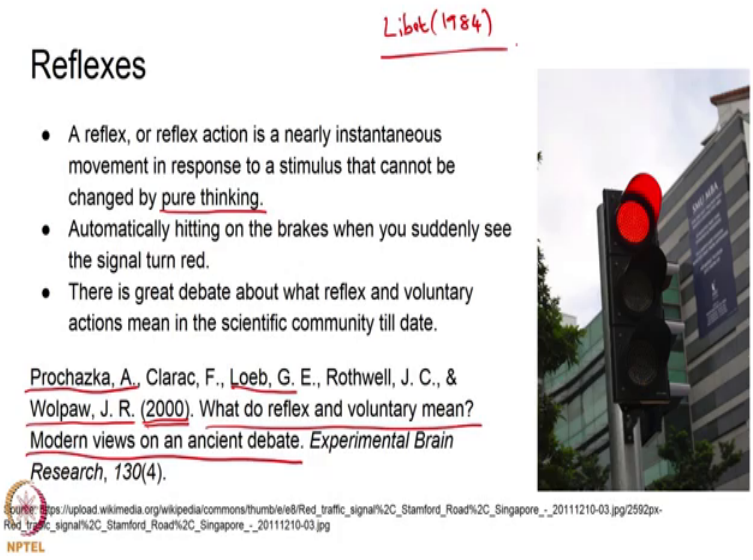

So, there are multiple definitions that are available for this word reflex, we need to agree on what is a working definition if we have to teach this class if we have to learn about this topic we need to agree, what do you mean by a reflex. For now for the purpose of this class today's class alone. We will call that that action or that movement that is nearly instantaneous to a stimulus, which I cannot modulate by pure thinking pure volition. I cannot control purely by thinking that the response has to be different, I cannot change that response let us take some example.

So, the common reflex that you will see for example: in physiological test if you go to a doctor they do a physiological test. So, what they do is you know reflex test is they tap with a little hammer on the near the knee is it not this is also we call the knee jerk response. Regardless of what the person wants to do there is a response that response he cannot control by pure thinking I do not want to move my leg.

If you have that this it is possible that you know some of the amplitude may change, but the response may not disappear. So, for the purpose of this class we will say that the response I that I cannot control by pure thinking will called as reflex, and everything else is non-reflex. And again you know within non reflex there are several things.

Reflexes that are falling at the edge between voluntary and non voluntary what is voluntary and what is reflex? We do not know the answers to this question, we still do not know here is a paper by brilliant scientists are to Prochazka Jerry Loeb John

Rothwell and Jonathan Wolpaw who are experts in this field, as late as 2000 year 2000 they are discussing what do reflex and voluntary mean modern views on ancient debate. Those who are interested in this terminology, and the nuances that come with this terminology what baggage do term does terminology carry in this must definitely consider reading this paper, definitely worthwhile.

It is at least a good philosophical introduction to the notion of reflexes in voluntary. What if I know; that at least if I say that you know I know that I am going to do this, actually there is data from I think that was a Libet 1984. It is a paper by Libet where he shows that you know before you even know that something is going to happen, the response for that action are the sequence of even for that action has already been started, only after that you realize that you this is going to happen.

So, in other words the action is already initiated and only after that you come to know that this is the action that is going to happen. So, in that case if that particular action voluntary or not, no answers to those questions I leave you with questions than with answers, but for now for the purpose of this class will only say that if I cannot modulate response by pure thinking, that response is a reflex. For the purpose of today's class and suddenly you are realizing you are on the road suddenly you are realizing that as a red light what you do? Is on it is it is not the conscious process the light has turned red now I must hit the brakes. It is like you know you are automatically hitting on the brakes when you see that red light here right as soon as you do that right.

By the way let us remember that you know there are drivers with good reflexes and then there are drivers with bad reflexes. Let us take the case of a you know a person who is putting the finger and a source of on a hot body on a hot object right when you do that reflex.

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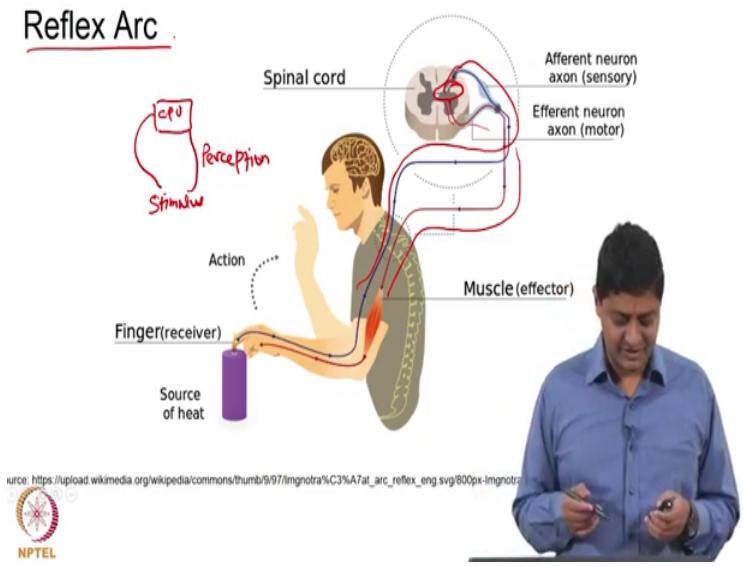

Actually what happens is that you know there are pain and temperature sensitive receptors, we saw this in one of the previous classes there are more receptors and nociceptors. Not these detect the presence of heat or painful stimuli, and cause some sort of not necessarily in a simple manner some sort of response by the muscle you want to withdraw your fingers from the source of are your hand from the source of heat or danger right.

This need not necessarily happened in a relatively simple loop, it may involve several processing loops and it need not involve the brain also, it need not involve conscious thinking also it may it may be that it is happening at the level of spinal cord ok. So, what happens is that there is the receptor information of the perceptual information that goes in blue, that is shown in blue here that goes to the spinal cord and some processing is happening not shown here, is some processing of this information.

And some command to withdraw is given that is coming in red here, and a muscle to withdraw the muscle responsible for withdrawal of the arm is activated and then the arm is withdrawn. So, this is function that involves a perception part and an action part with the processing unit included. So, let us say this is the stimulus, there is the perceptual part our perception, then there is some sort of processing or I am going to call the entire thing as a CPU and there is an action ok. This loop is also called as a reflex arc frequently in literature ok.

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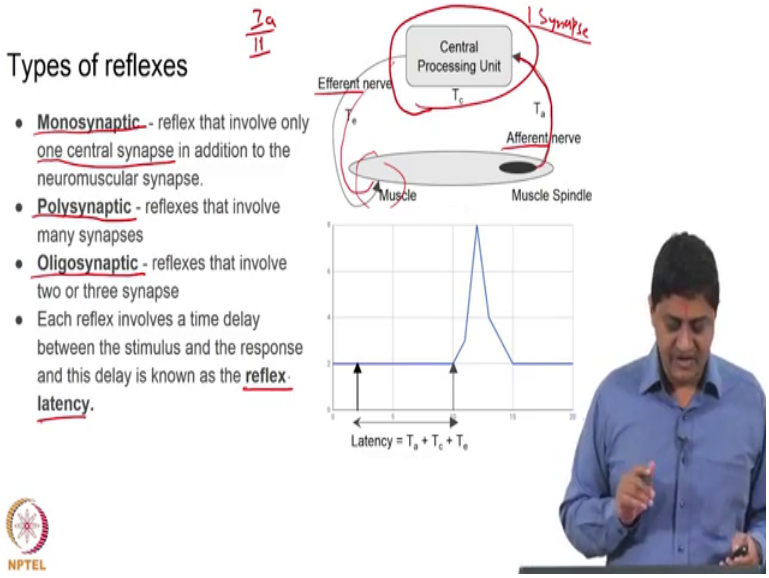

So, that is what is shown here again for example, there is a, but with a particular example of the muscle getting lengthened when the muscle gets lengthened when the muscle gets stretched what happens? We saw what will happen. There are one a afferents and two afferents this 1 a afferents are responsible for detection of velocity and length 2 is responsible for detection of length alone.

So, as this muscle is getting stretched, this information goes where are one a to or two a afferents to a central processing unit, afferent means perception sensory efferent means motor action ok. This central processing unit gives command to that muscle our other muscles to perform an action. Those the reflexes that involve only one synapse at the central processing unit only one synapse; at the at the central processing unit please note what; that means, is the one synapse is at the central processing unit there is. Obviously, a synapse between the efferent neuron and the muscle that is a neuromuscular junction of the neuromascular synapse that this not considered as part of this discussion, that is there in all the cases. That if there in reflexes that is there in voluntary actions that is there in non-reflexes that is there everywhere so, that synapse is not considered.

If there is only one synapse in the central processing unit, then the reflex is called as monosynaptic reflex that involves only one central synapse that is a key word. So, actually there are two synapses one between the perceptual neuron and the action neuronal between the alpha motor neuron and the one a afferent right. And one more

between the alpha motor neuron and the muscle fiber, that is a neuromuscular synapse, there are actually two, but there is only one central synapse these reflexes are called as monosynaptic reflexes.

Those cases in which there are either two or three synapses, they are called as oligosynaptic reflexes. And there are reflexes that involve many synapses more than 3, but can still be called as reflexes these are called as polysynaptic reflexes. And note usually there is a time delay how do you know how many synapses are there, you actually do not know when you are measuring from the outside you do not know how many synapses are there.

But it turns out that the delay between the stimulus arrival, and the response arrival scales as a function of the number of synapses, as the number of synapses increases the latency the time delay between the stimulus arrival and the response beginning increases. So, that means, if there is a greater latency, latency means is the delay between the stimulus and the response just called latency sometimes called reflex latency most specific more precisely right.

If this latency is greater; that means, that there must be a greater number of synapses, it usually scales nicely with the number of synapses. As the number of synapses increases the latency increases to a great level. As if the latency is less; that means, that the number of synapses must be less because why is this? Let us remind ourselves what our synapses whenever we say synapses by default we are talking about chemical synapses. These synapses involve release of a neurotransmitter response by a receptor to that neurotransmitter etcetera is it not.

So; that means, there is a chemical transport that is involved from the outside from the synaptic end bulb of one neuron, to the receptor part of the other neuron in the middle there is extracellular space, through in which this chemical moves purely by diffusion. This is not a controlled process, this may take a finite amount it is not you know it it is not going to take 0 time it is going to take a finite amount of time and that is not the same in all cases.

So, there is some uncertainty involved in that so, but one thing is clear that as a latency increases a number of synapses increases. So, that is very well known and the well documented.

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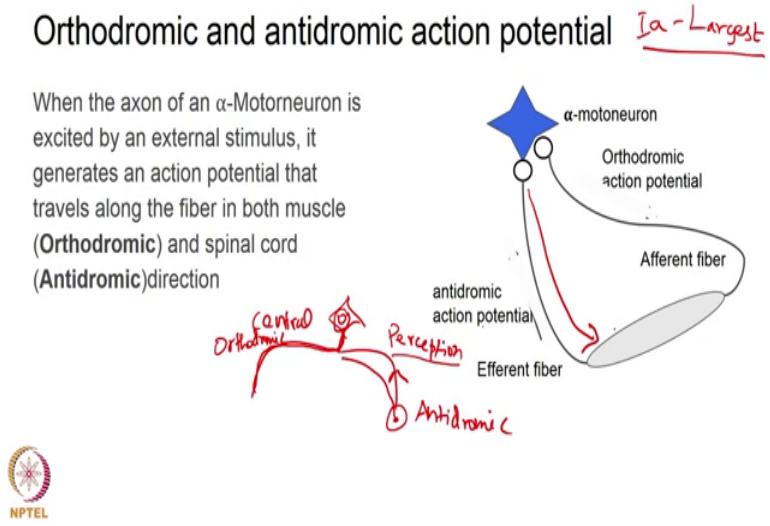

So, and there is a particular case of a reflect that we need to discuss, we will just discuss it now I will just introduce some terminology are just remind ourselves of this terminology. We said a case in which information moves from the cell body to the periphery through in the axon right that is called as orthodromic action potential ok. And in the case where the information moves from the periphery to the cell body right is called as antidromic action potential. A better example is the case of the proprioceptive neuron we have seen that earlier right not these neurons have a characteristic t shaped axon, one of this branch is the perception branch the other branch is the central branch.

This branch in the perception branch there is a sensor at the end this may be a Golgi Tendon organ, this may be a receptor, this may be a muscle spindle one a two whatever one of these. So, there is a sensor in the end and the information travels from the periphery to the neuronal cell body. In that case the movement that the conduction is called antidromic conduction in this case it is antidromic. Then there is a little bit of processing of very little processing here at the cell body, and then conduction happens from the cell body through the central axle in the reaching the spinal part, from there it goes elsewhere right this is called as orthodromic.

This can also be seen elsewhere in the case of the reflex arc, this can also be seen there. So, now, information about the muscle stretch for example, is taken out by the one a afferent for example, right. In that case first the information goes antidromically and

reaches the central synapse. And actually what it does it synapses with the alpha motor neuron and activates the alpha motor neuron that innervates the same muscle.

So, let us try to analyze this situation what happens is, information goes about. So, the muscle is getting stretched the muscle does not want to get stretched, somebody is stretching my muscle I do not want to get that muscle to be stretched for example.

Then the information about the muscle stretch goes to the proprioceptor neuron, this proprioceptor neuron activates are excites and alpha motor neuron that will contract to reduce the amount of stress. We saw several cases of negative feedback here is one case of negative feedback in which the proprioceptive neuron is directly requesting directly commanding the alpha motor neuron to contract right. When that happens right this there is a reflex there is a response.

So, that obviously, involves both orthodromic and antidromic conduction etcetera ok. Other thing that is possible is the following I could electrically stimulate these neurons and check response. Why is this necessary? I will discuss in future slides the applications of this modality why this becomes necessary.

Suppose I electrically stimulate neurons from the outside using a stimulator, basically applying an electrical pulse, then what happens because of this reason actually there are multiple things that could happen. If the neuron that I would like to stimulate is superficial, then the chances that I then the probability that I am going to be able to excite that are relatively high, but it could be deep also and I do not know I do not control how at what depth outside the inside the body this particular neuron is. So, we do not control that. But one other thing that is there is the thickness of the neuron.

The thickness as the diameter of the neuron increases, if I apply a larger stimulus it will first fire then in comparison with the smaller ones. So, this is for a pulse. So, when I apply a pulse, the largest neurons first fire and it turns out that the largest neurons in this case are the one a efferents. These are the thickest the first fire. So, as soon as they fire what happens is that, even though there is no length change in the muscle the one a afferents starts firing as soon as it fires it excites the alpha motor neuron, and the alpha motor neuron causes a contraction in the muscle.

So, let us suppose that I am able to sync the time of a stimulus application to the response, the response I am measuring using electrodes using emg say using say using surface emg using surface electrodes ok. Let us say that measurement or the measurement of the output and the stimulus our sinked properly. In that case I will get delay between when the stimulus was applied and when the responses are not.

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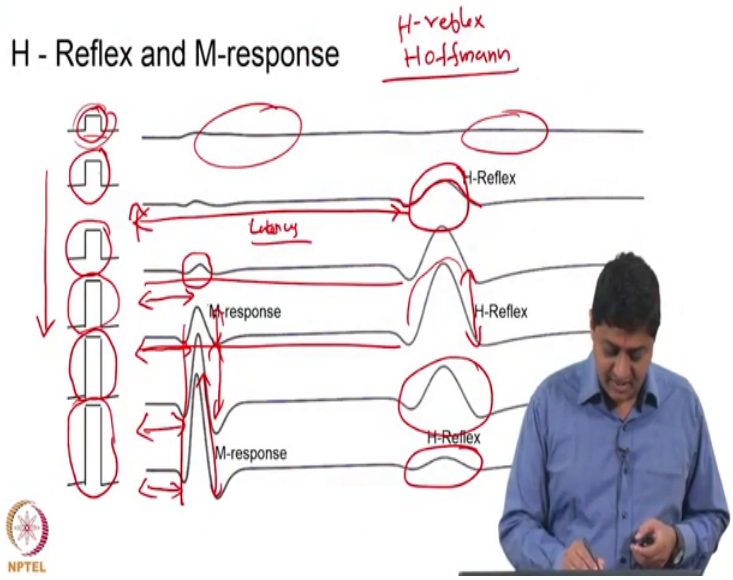

I can then start studying the relationship between the characteristic of the stimulus and the characteristic of the response. Why is this important? I will soon say before the end of the class. Suppose there is a small stimulus that is applied of some strength that stimulus no response, nothing happens and it is like. Then I increase the stimulus strength like that right you see the second one that one is a taller building when compared with that one is it not.

So, increase the stimulus strength then what happens is a response is seen at that latency say for example, here is when the stimulus is applied, the latency is so much. And what is this response? This response how is this caused? This is due to the firing of one a afferent that car that activates our excites the alpha motor neuron, and the alpha motor neuron causes a muscle contraction which whose electrical activity are the local field potential of that muscle contraction is measured here ok. So, this isn't actually measured at the neuron, this is measured at the muscle level. So, this is the output the net output of

the system and that is measured at the muscle level that happens at so much delay some latency ok.

Now this reflex that is induced due to electrical stimulation is called as H reflex attributed to a scientist called Hoffmann's nobody calls this as Hoffmann reflex anymore, everybody calls it as H reflex. H reflex means is that reflex that is elicited through electrical stimulation of Amazon no monosynaptic one alone monosynaptic one alone, because you will soon see what happens later on there are other things that come into the picture.

The monosynaptic one that involves the one a afferents activation of the one a afferent is called H reflex and I increase the stimulus strength. So, this building is bigger than the previous building then the response increases. And I increase the similar strength further then the response increases for them. So, you see that the that the amplitude is different and not in all these cases the latency remains approximately the same is it not the latency is approximately the same in all the cases so; that means what? That means, all these reflexes have same pathways, because the latency does not change it involves the same neurons, but the amplitude changes.

So; that means, something else was gone why? Because the number of one a afferents that get recruited increases as a function of the stimulus strength; as I increase the stimulus strength in that way the number of one a afferent that get recruited increases. So, the thickest one is the thickest one a afferent is the first one to get recruited, the next thicker one is the second one to get recruited the next thicker one is the third one to get recruited and so on and so forth right.

The smaller diameter fibers are actually the ones corresponding to the motor neurons, those are relatively smaller when compared with the afferents. There must be some reason why the afferent information is carried in large diameter fibers when compared with the efferent information. And also we said in the previous class that, comparison between alpha motor neuron and gamma motor neuron alpha motor neurons are thicker and gamma motor neurons are thinner we said that earlier ok.

So, here these as the number of one a afferent that I am getting recruited increases, the response keeps increasing. Note the response is the total sum of the muscle activity. So, the total muscle activity keeps increasing. So, what is measured is not an individual

neurons response, but rather muscles response ok. But can it go forever can it can it go up forever that is the question. The answer you will you can see from the picture at some point I keep increasing the stimulus, the response decreases the response reduces and actually at some point if it is further increased actually at some point becomes 0, there is no more response why is this the case we need to check why this is the case?

But before that there is one more thing that we need to discuss that one more thing is, something else also happens it seems. As the stimulus strain keeps increasing and I am beginning to see a response at that latency, a smaller latency. I said earlier that the H reflex is the monosynaptic reflex monosynaptic pathway and that latency is so much.

If I see a response at the lower latency then there is only one possibility that is there is no synapse in that pathway what could be that path way is the question. As in that the response keeps increasing as I keep increasing the stimulus, you see that the latency remains the same the amplitude keeps increasing is it not; very large amplitude responses, that happen at a much lower latency when compared with the H reflex.

It is not clear what is the physiological what is the mechanism of this what happens is I am stimulating here at this point stimulation is applied at that point I said the first ones to get activated are these one a afferent. This is the alpha motor neuron this is the motor neuronal axon. At some point the motor neuronal axon starts are one motor neuronal axon starts getting stimulated, and it conducts causes a small contraction.

Note these responses again all these responses are EMGs are muscle responses these are all muscle responses the net response of the muscle not an individual fiber. So, it is getting stimulated in the middle of the axon in the center of the axon. So, we said early on when we discussed action potential propagation that if it is stimulate the neuron in the middle action potential will travel in both directions that is what happens.

So, action potential travels antidromically as well as orthodromically from the alpha motor neuron. So, this orthodromic action potential causes contraction of the muscle which is what you are seeing here, which is what is seen here. What happens to the antidromic action potential we need to check something must happen to this antidromic action potential that reaches the alpha motor neuron.

So, I am stimulating in the middle, it causes action potential to travel in two directions. The one that reaches the muscle causes a contraction that is observed of this response and obviously, since this distance is much greater then say that distance is it not? That the line in blue is much shorter than the line in red that; I have drawn or I am going to draw with for the sake of clarity the line in black that is the loop for the H reflex the black line is the loop for the H reflex. We said early on that the latency is actually due to multiple reasons is it not? There is a latency that is involved in the perception loop, there is a latency that is involved in the action loop and there is a latency that is involved in the central processing loop.

The sum of all these thing is the total latency that is what you are observing here. So, that is this is the total latency this is the total latency whereas, here the blue line is much shorter; so the line. So, the latency is also much shorter the blue line is much shorter. So, the latency is much shorter, that is the reason you are having the response are a pretty quickly in comparison with H reflex importantly. And the I keep increasing the stimulus; I keep increasing the stimulus the response I keeps increasing.

A question is, why does the H reflex the response go down this we have not discussed. I seems it seems like this is increasing until some point and then decreasing in the case of H reflex why is this happen why would this happen? And what happens to the antidromic action potential that is reaching to the alpha motor neuron. You see an alpha motor neuron is an efferent neuron that only keeps giving command, it is not used to receiving command at the at the command giving pathway is it not. So, this is the pathway through which command is given for the first time some information is you know arriving at the alpha motor neuron.

And usually there is not any response that arrives because this alpha this action potential arrives and gets extinguished at the axon hillock at around that area nothing happens, usually in the at least in the initial stimulation state. But it could it is possible that at some point this action potential could go and cause a new action potential to be generated in the alpha motor neuron; what will have when that happens what is the response that is another thing that will have to see.

So, there are a few things that we need to discuss, one is the relationship between the size of the stimulus and the size of the H reflex there is not a monotonic response as you see

here, here I keep increasing the stimulus the response size increases a relatively monotonic response. Here, it first increases and then decreases and non-monotonic response of the H reflex amplitude this is the other thing that we need to say ok.

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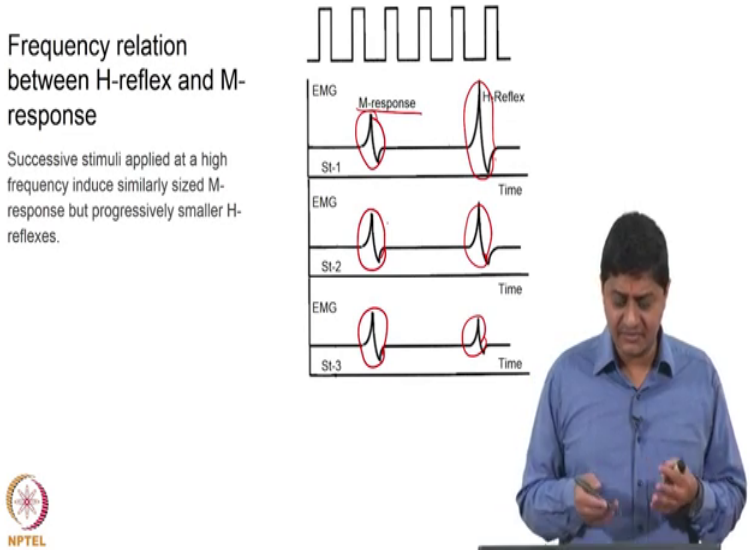

So, suppose I keep a playing successive stimulate at and I change the frequency at a relatively high frequency when I do that, then what happens is that all the m responses will be of the same size, but the H reflex you know size reduces ok. Actually, if I continue this business at some point h reflex will get extinguished the question is why does this happen.

So, but the M response amplitude remains the same that means, that the mechanism involved in these two processes are different fundamentally different, that is the reason why you are seeing that M response amplitude remains approximately a constant regardless of the stimulation frequency. I keep changing the stimulation you know the response M response remains approximately the same.

So; that means, something must something must be fundamentally different we need to check what this is.

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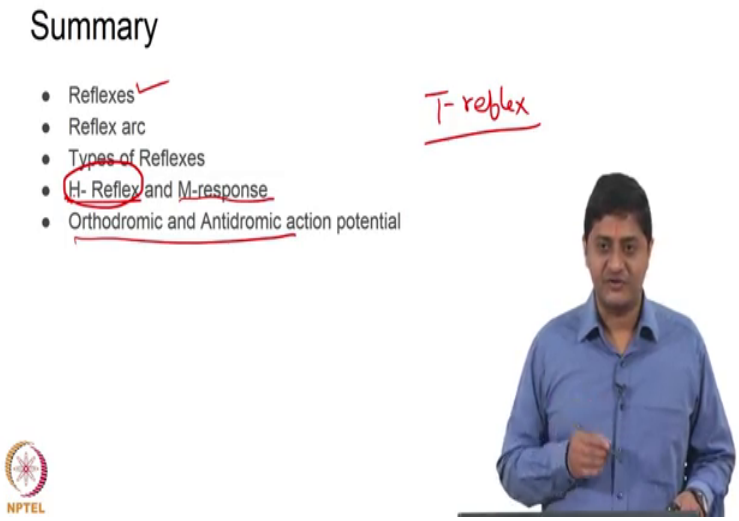

We will stop here for this class we will continue this discussion in future. So, what we have seen so far is the definition of reflex. We said that this is a response that is almost instantaneous that cannot be controlled by pure thinking; reflex an arc is one that involves a perception loop and action loop smaller bigger. So, a central processing unit and we defined weight when there is only one central synapse it is monosynaptic, when there are two or three central synapses its only cause synaptic, when there are many central synapses it is polysynaptic and we defined; what is H reflex. H reflex is this reflex that is elicited in response to electrical stimulation of muscle nerve and m response, and we reminded ourselves of what the orthodromic and antidromic action potential.

But before we finish we need to realize the relationship between H reflex and that the knee jerk response. So, what is a knee jerk response? We said what it is. So, a person is sitting on a chair and relatively small hammer is used to you know tap on tap near the persons knee and a jerk is caused is it not ot. This response involves a monosynaptic pathway and is called as the tendon response or the T reflex ok.

This response is elicited by mechanical perturbation of the system, I am mechanically perturb again I am I am hitting with a hammer. When the same is done when something similar is done by electrically stimulating I get H reflex so, there is a fundamental

difference. Otherwise the pathways are the same the pathways in all that the pathways of the one a afferents ok.

So, in the next class we will see the relationship between H reflex stimulus and the response, why it produces a non-monotonic, what will happen if the stimulus goes through the alpha motor neuron in the turns back arbitrarily you are return back. Questions like that will not does in future classes we will stop here.

Thank you very much for your attention.