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

Lecture - 28
Monosynaptic Reflexes - Part 2

Welcome to this class on Monosynaptic Reflexes this is part 2.

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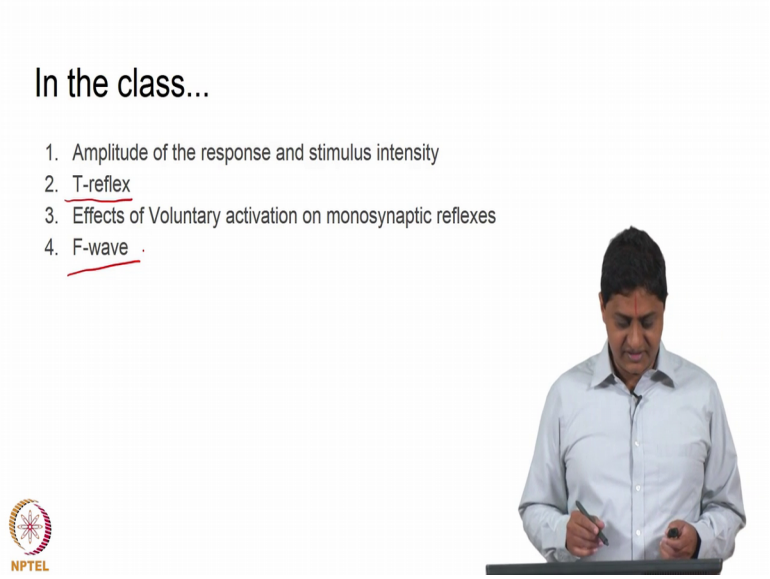

We were talking about in the previous class: the relationship between the stimulus amplitude and the response amplitude for the two different cases of the responses that we saw the H reflex and the M response or the M. Why does this happen we did not discuss why it happens? We need to discuss why it happens.

And then the mechanical analog of the H reflex are more precisely H reflex is the electrical analog of the mechanical response or the tendon tap reflex, which is also called as the T reflex. And then what happens to monosynaptic reflexes especially the H reflex, when there is voluntary muscle activation. So, is reflex amplitude always the same is that how is that affected, how is it modulated and why is that important, that is the third topic.

When we will talk about a very very special case, where an action potential backfire has an produce has a another action potential from alpha motoneuron are the F wave we will discuss these kind of things.

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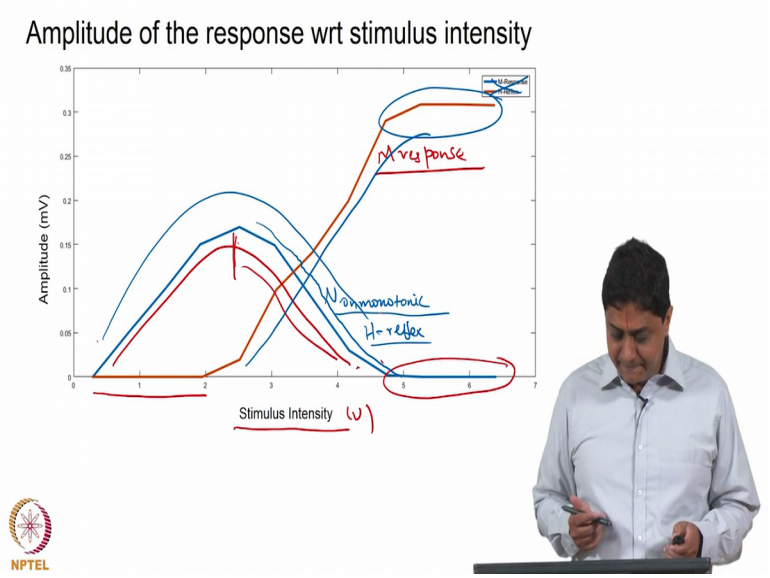

So, we saw in the previous class what we saw was that as the stimulus amplitude increased H reflex amplitude continued to increase and some point it started reducing. And we said that is the nonmonotonic case, is it not that is the nonmonotonic case of the H reflex, this is wrong.

It is actually blue is actually H reflex and red is a M response ok. This is M response, we saw that as a increase the amplitude of the stimulus So, this is the stimulus amplitude, this is in volts actually. This is the response this is the response is it not. And what we see is that as I increase the stimulus amplitude, the response continues to increase until some point and after some point it starts to decrease is it not. Actually, it is a relatively more smooth curve here we have drawn with a fewer points, which is where you are seeing a non smooth curve here, but one what happens is a smooth response like that.

So, this is the relationship between stimulus amplitude and response amplitude whereas, in the case of M response for a while around until that point the response does not start there is no M response. And then M response starts and when it starts to increase it keeps increasing monotonically at some point it saturates. Of course, at some point it must saturate, but it does not go back that is the most important point like in H reflex.

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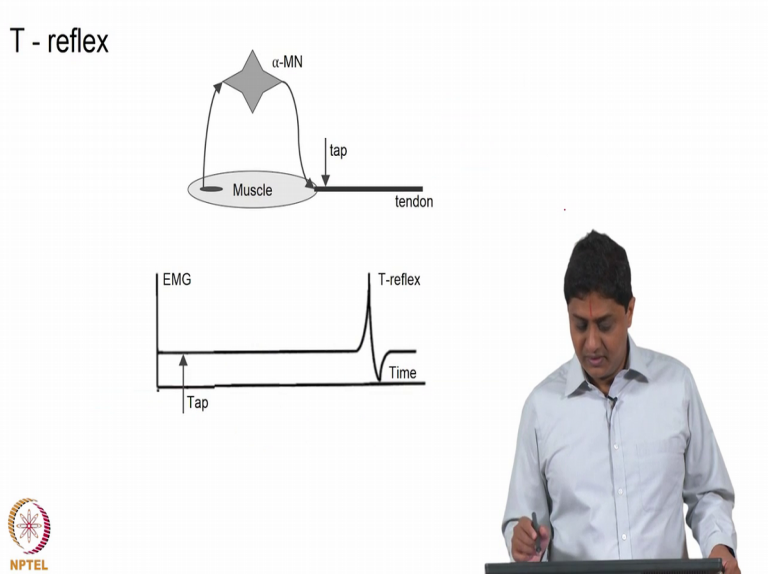

The question is why H reflex amplitude starts reducing after that point it starts reducing and at some point it becomes 0 for all these cases, H reflex amplitude is 0 why? Let us go back to the case of what happens how these H reflex is produced and remained ourselves of the mechanism the physiological mechanism. That is probably the reason why let us try to discuss that in a bit.

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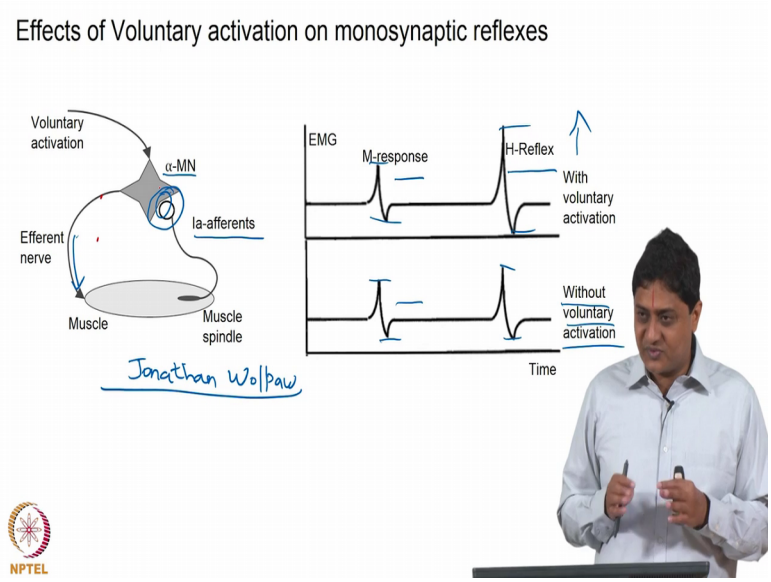

So, what happens? So here is a case, this is a slide for voluntary activation, but will just discuss H reflex here we are stimulating the muscle nerve and the first neurons to get

stimulated are the largest 1 a afferents, stimulation intensity as I increase the stimulation voltage the smaller 1 a afferents are also going to be responding and after some time there going to be muscle response right.

So, that that muscle response is what is recorded here; this is H reflex response we said this is actually an EMG this is muscle activity that is and the stimulus is applied approximately here is it not. So, the stimulus is applied here they keep increasing the stimulus amplitude what happens is as I keep increasing the stimulus amplitude more and more 1 a afferents start getting recruited right. After some time what happens the alpha motoneuron so this is the alpha motoneuron their axons start getting recruited their axons are stimulated.

And the response if the stimulation is given here the response travels in two directions the action potential travels in that direction, as well as in that direction. This distance is shorter there is going to be smaller delay for the muscle response that is what you see as the M response here this is what we discussed in the previous class.

Now I am I am continuing to increase the amplitude, because then the response is not going to the delay in the response is not going to change because this distance is going to be the same unless I move the stimulating point. This just this distance is going to be the same so this delay will be the same, but I say increase the amplitude more and more of this alpha motoneuronal axons will start getting recruited.

And so, the response amplitude will keep increasing the M response amplitude will keep increasing monotonically the smallest alpha motoneuron are the alpha motoneuron. With the smallest diameter until it gets recruited the amplitude can be increased and as the stimulus amplitude keeps increasing the response will keep increase, which is what you see the red plot here, which is what you see as that plot this response also relatively monotonic response this is what happens with M response. The question is not that the question is what happens with H reflex why does it show a nonmonotonic response after that point that is a reduction in amplitude and the actually at around that point it becomes 0 why does this happen.

Let us remind ourselves one more time what happens here; there is this is monosynaptic response H reflex is monosynaptic, M response does not involve any synapse other than the neuromuscular synapse, because it directly this is direct response at the direct

stimulation, direct response case this is M response here that involves one synapse which is we call it as the monosynaptic case.

So, as and when we stimulate this afferent this is what get stimulated, then whenever we say synapse there are several things that are involved immediately is it not. Let us remind ourselves the case of the synapse how synapse have works, there is a neurotransmitter that is packed in a vesicle and this neurotransmitter will need to be released and that release is governed by the membrane around the synaptic end bulb and its property.

So, if that membrane goes to depolarization calcium channels are going to open and calcium is going to enter and then that is going to be detected. And then the vesicles are going to move and exocytose the neurotransmitter are send the neurotransmitter molecules into the synaptic cleft after which it this chemical diffuses, through the through the cleft, which was a small gap and reaches the receptor. And then the receptor detects and then opens and sodium enters this is the story of the synapse is it not.

So that means, there is a relatively small delay associated with the chemical synapses, this delay is about 0.5 milliseconds, but it is not just the delay there are several things that control the how much can this be pushed to what action you can push this the other thing that could happen. Several 1 a afferents are this motoneuron can receive inputs from several sources is it not it could have multiple dendrites and there could be both temporal and spatial summation.

If for example, there is action potential traveling in two directions, if I am stimulating here. We said this is orthodromic conduction and there is antidromic conduction, but what also happens is that there is action potential that is generated due to this synapse that is traveling in that direction. If they meet with appropriate phase or out of phase it is possible that they could extinguish each other, what happens you said there is an absolute refractory period for channels.

So, when let us now take I am going to zoom out that zone for you to see there ok, now that is the membrane there ok. In this membrane one action potential is traveling due to this is the alpha motoneuronal axon one more action potential is traveling on the alpha motoneuronal axon other action potential is traveling on the alpha motoneuronal soma for example, for example, in two different directions, suppose that is a sodium channel voltage gated sodium channel ok.

And there is another several of this voltage you know strategically placed voltage gated sodium channel are present and which is what causes the propagation of action potential as we have seen right. So, as this reaches that point as this action potential reaches that point it is going to cause depolarization and the lot of sodium is going to coming. At around the same time if this reaches this point right lot of sodium is going to come in and depolarization is going to travel in that direction and depolarization from here is going to travel in that direction.

If for example, this guy reaches just slightly early then a lot of sodium will enter that is ok. After that the inactivation gate of this channel will close we saw that the activation gate and inactivation gate are simultaneously activated when the depolarization is reach. The activation gate opens immediately, because it is a rapid process the inactivation gate slowly closes, as the inactivation gate is closed at if this action potential reaches when the inactivation gate is closed are during the absolute refractory period it is not possible for this part of the membrane to go to depolarization anymore. This action potential will get extinguished at that point it will no longer travel.

So, these two actions potential: in other words say action potentials can meet each other and extinguish each other. Of course, there are conditions as to when or how this will happen? This will happen only when these two action potentials reach in each others are mutual refractory periods. If it causes refractory period and the other action potential is arriving during a refractory period is not possible for this action potential to add up or in other words these are out of phase and so they will subtract each other and could it could practically go to 0.

But this could happen only in a few of 1 a afferents in alpha motoneurons, but not others which is why what you will see is as the stimulus amplitude is increase in some of these 1 a afferents and alpha motoneurons. This will happen or this phenomenon that was just now explained will happen and the smaller amplitude responses seen. But the others will continue to respond, but soon as the amplitude of stimulation keeps increasing at some point this will happen in practically all the cases, because all of them will have two action potentials traveling in either direction almost all of them. Let us once again remember that the H reflex is the net response not an individual neurons response or an individual muscle fibers response. Is the response to stimulation. So I am stimulating with the given amplitude what is the response that is felt in the muscle that is the

response that is recorded? So, that is active response of several alpha motoneurons is it not, not just one alpha motoneuron.

So, depending on the amplitude of the stimulation the response characteristic will start reducing because of what was just now explain, because of this mechanism and after some time it will practically extinguish this is what happens here. So, that the response of the H reflex starts reducing here and it continues to reduce because of that same mechanism and at some point it becomes 0 there is no more this so there is no more fuel for this to happen as in no more sodium that there is present, because of these reason it is not possible for H reflex amplitude to keep on increasing there is a nonmonotonic response of the H reflex.

And at some point it becomes 0, there is the M you might ask why does this not happen in the M response case. In the case of M response the response is travelling in that direction is it not, there is no opposite action potential that is travelling in this direction from the muzzle that does not happen. So, the possibility that an M response is going to be extinguish it is close to 0 is it.

So, but why does it become; saturated, in other words why does that happen? Why does this happen, because at some point I have recruited practically all the alpha motoneurons I cannot increase the alpha motoneuronal response anymore I have recruited everybody all of them are firing the only thing that I can do after that is keep reducing the time between the stimuli for example. And we also saw what could happen; if I increase the frequency of stimulation, if I increase the frequency of stimulation; what happens is that you know the H reflex rate goes up the H reflex amplitude keeps reducing after some time right.

So, why because of similar phenomena because of similar mechanisms, please do read about this so may at least I have given you a start to read ok. So, this is why the M response has a monotonic increase with stimulus; intensity whereas, the H reflex shows a nonmonotonic response. This is critical difference between M response and H reflex because of the physiological basis why this happens.

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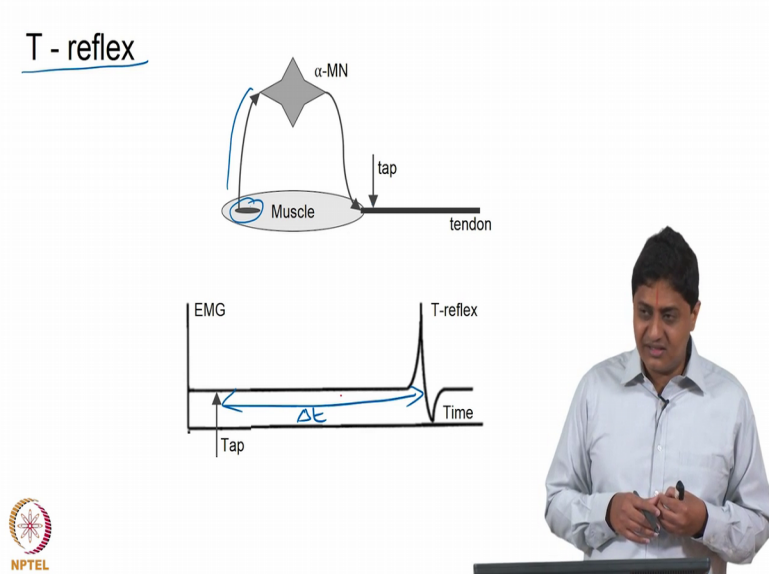

And note this is not going to affect the timing of the appearances, timing is going to be approximately the same, timing is not going to change there is an amplitude someone gone change. And we saw what is the we discuss at least introduced in the previous class what will happen if a tendon is stabbed with a small hammer, there is going to be a jerk or what is called as a knee jerk response right this is called as the tendon response have the T reflex.

The electrical analog of this T reflex is the H reflex or the T reflex is a monosynaptic reflex the discussed. So, if I tap the tendon, then the muscle spindle feels as if muscle spindle senses the stretch sudden stretch. And then immediately 1 a afferents that is the muscle spindle feel, that is there and immediately 1 a afferents will start firing and command the alpha motoneuron two contract that response is what is spelled as the knee jerk response.

So, and that response to and approximately that delay the delta t will be the same as the H reflex approximately the same as the H reflex response why? Because the pathway involved is the same is it not there is an 1 a afferent and there is a alpha motoneuronal pathway. So, all the since all that these things remain the same the timing remains the same ok.

Now, the question is what will happen if there is voluntary muscle activation or some voluntary moment is performed during what will happen to the amplitude of the reflexes

during voluntary movements, usually what happens is if there is voluntary activation the H reflex amplitude goes up the M response amplitude remains the same. In other words if there is voluntary activation of the muscle the H reflex amplitude increases when compared with the case of no voluntary activation without voluntary activation if the responses so much with voluntary activation the response is going to be much higher.

But that difference is not going to be seen in the M response. So, what does this mean why does this happen what is going to be the physiological mechanism behind this? Once again this is due to the pathways that are involved. Let us remember one more time the H reflex pathway involves the 1 a afferent and the synapse whereas, the m response pathway only involves the alpha motoneuronal axon or at least about half of it actually.

So, because of these differences, fundamental differences in the physiology the difference in the amplitude happens; please check what that difference is. So, another thing that could happen is what could happen in the case of; you know maneuvers this so called generous maneuver right.

So, this is the case where we keep the two hands clenched with each other and I am just pulling like that, any tightly I am trying to pull the two hands away from each other. In this case many muscles will be activated at that time if we test the H reflex response of the lower body or some other relatively distant muscles; what you will see that, is that an increase. Usually, an increase in the H reflex response or the amplitude of the H reflex will change right, why does this happen again you know. So, the question is out there why this happens at least what is known is it a this voluntary activation of multiple muscles are maneuver that activates many muscles usually causes an increase definitely causes a change in the H reflex usually causes an increase in the H reflex response again you need to check why.

Now, the other question is can I somehow modulate the H reflex response can I train people to change the amplitude. You see this is a monosynaptic reflects or in other words this involves just 2 neurons and 1 synapse are as in the 1 a afferent and alpha motoneuron these are the 2 neurons and just 1 synapse between them. This is what is involved here. Now again not counting the neuromuscular synapse not counting the neuromuscular synapse.

So, if you want to train you are talking about training a specific set of neurons, just 2 neurons among billions. So, many neurons are there, but you want to train a specific set of or a specific pair of neurons. Training this is a very tedious process, but the question is not that the question is can the amplitude be changed based on training. That is the question, the answer is, yes; but with substantial training this kind of research is pioneered by Professor Jonathan Wolpaw; those who are interested in this topic can check this and other colleagues, do check the publications of a Professor Jonathan Wolpaw.

So, always published and how you could change even the response at of the monosynaptic reflex. Even that can be modulated can be changed deeper with substantial training not with a small amount of training; substantial training can be change. If the question is can this be trained the answer is yes, but not easy it is going to take substantial amount of training. Of course, what happens with you know voluntary activation we have seen it can be changed, but without voluntary activation for the same stimulus can I change the response that is that is the question, then that needs training because otherwise this response is going to be the same.

There must be sufficient time for this synapse to recover the mediator involved in a synapse is the neurotransmitter, it is packed in vesicles. And once all the neurotransmitter is finished it takes you know nonzero amount of time for that to be packed in vesicles one more time to be regenerated, is not like you can this is available instantaneously and in unlimited quantities no. So, because of this reason; there are other things that come into the picture into this please do read about this ok.

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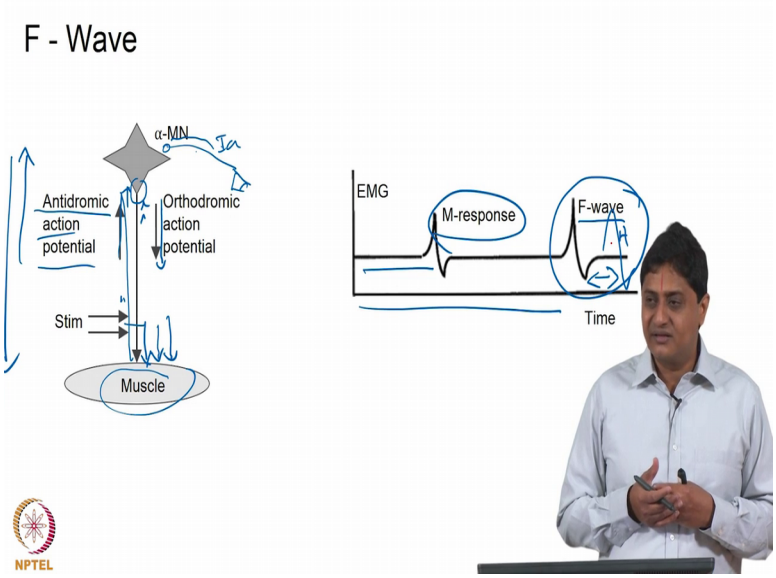

The other case is a very special case, we said what could happen with stimulation if I stimulate an alpha motoneuron in the middle, then there is going to be an antidromic conduction in that direction. And we said that could and it does extinguish the H reflex mediated response. So now, not shown here is the H reflex mediated response for to 1 a for example.

Now, that could extinguish then, but suppose I keep increasing the stimulus amplitude first what happens is; that if I stimulate there is going to be an orthodromic action potential that travels from the point of stimulation to the muscle. That is what is felt as the M response. But then there is also an antidromic action potential that travels from because, if I stimulate an axon in the middle: action potential is going to travel in both directions it. So, action potential will travel if I stimulate here action potential will travel in that direction as well as in this direction is it not and both directions.

Now, is it possible that this action potential could reach there and cause one more action potential here at the axon hillock? Again this due to the wager is due to the secularities involved in the generational action potential at the axon hillock this is purely dependent on the timing at which it arrives. At some in some cases what happens is this antidromic action potential reaches the axon hillock and causes a new action potential to be generated here. And that action potential will travel orthodromically in that direction and reach the muscle that is felt here. That is the F wave this response in other words so what

this means is that this antidromic action potential goes to the neuron and then the neuron backfires so neurons can backfire.

So, this again depends purely on the timing: if there is sufficient time or if it arrives during a refractory period. Obviously, there is not going to be any backfiring, but if it does not happen and if there is sufficient fuel if there is sufficient probability that this could happen then it will happen.

So, it is not a sure case, but in some cases this does happen is it not, so this case is the case of F wave ok. If I were to compare the latency of the M response F wave and H reflex it is remind ourselves. The M response will arrive earlier why, because it travels a shorter distance; the F wave will arrive next why because it goes and come back.

When will the H reflex arrive if there is that anybody would guess an intelligent guess would be the following the H reflex would arrive after here, if at all it arrives why because. Or in other words F response timing is going to be slightly earlier than the H reflex is just slightly ahead of the H reflex it is timing, if at all there is an H reflex.

This is the H why this difference? You see the pathway involved in the H reflex is a longer pathway with 1 a afferent and a synaptic delay, but the pathway involved with the F response is the same alpha motoneuronal axon there is no synapse that is involved, because of this reason if at all that is going to be a H reflex that is going to arrive later in time. So, that is going to arrive after the F wave, if at all it is going to be there it is going to come later or in other words the latency of the F wave is going to be slightly smaller, slightly lesser than the H reflex latency.

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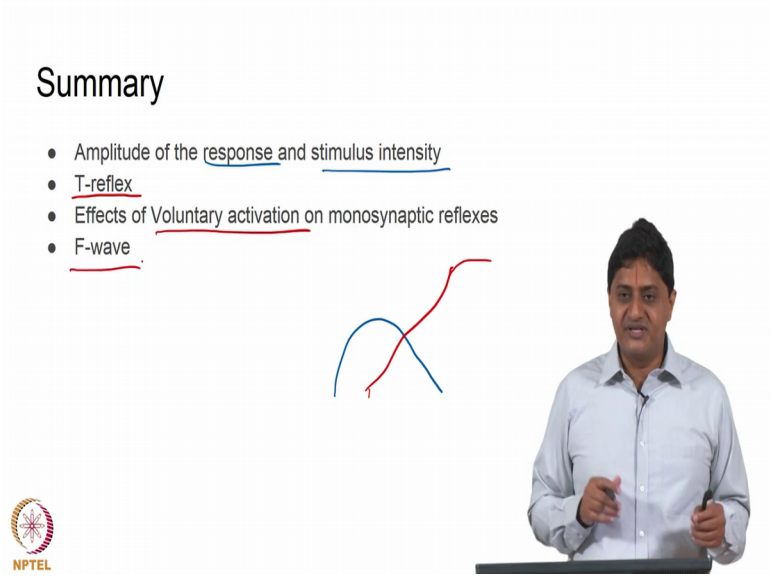

Of course, the M response latency will be much lesser. Of course so, in summary what we have seen is the relationship between the amplitude of the response and the amplitude of the stimulus or in other words, if I increase the stimulus amplitude H reflex shows that kind of a nonmonotonic response. Whereas, M response shows that kind of a monotonic response so and we saw why this happens? This happens because of the refractory periods involved or because of that reason the amplitude keeps reducing as I keep increasing the stimulus amplitude the response amplitude keeps reducing in the H reflex, but not in M response.

And we saw; what is the T reflex or the tendon tap reflex and we saw what happens with voluntary activation with voluntary activation there is going to be modulation that is usually an increase in the amplitude of the monosynaptic reflex without affecting the timing involved. And we saw; what is an F wave the peculiar case of a neuron backfiring, why do we do all these things that is the question. Finally, there must be reason why we do all these things, it turns out that this or these latencies and amplitudes are relatively comparable among individuals and also groups of individuals more importantly.

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

Thank you very much.