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

Lecture – 61
Cerebellum Part – 10

So, welcome to this class on Neuroscience of Human Movements.

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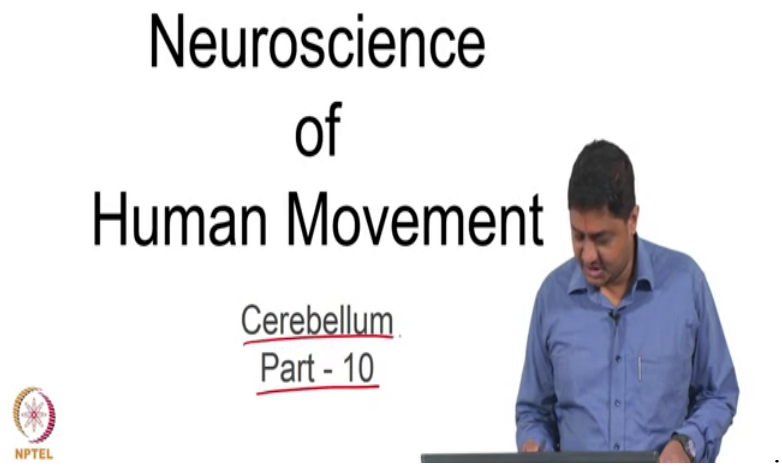

This is part 10 of our discussion on Cerebellum.

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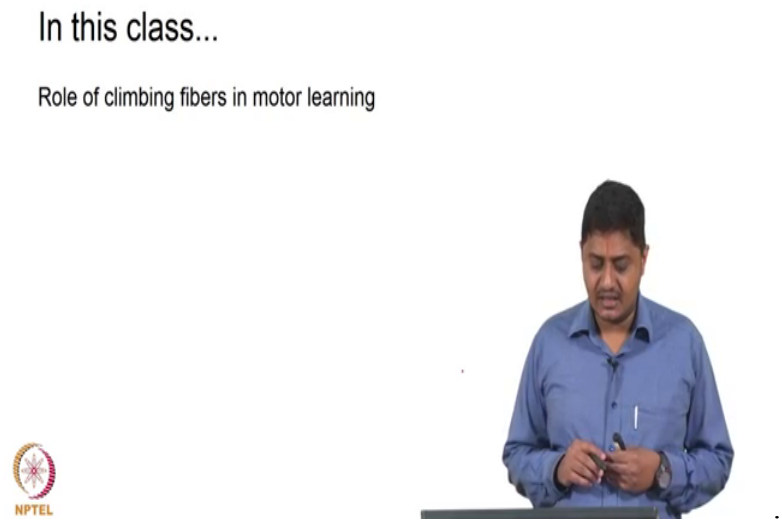

So, in this class we will be discussing the possible role of climbing fibers in motor learning.

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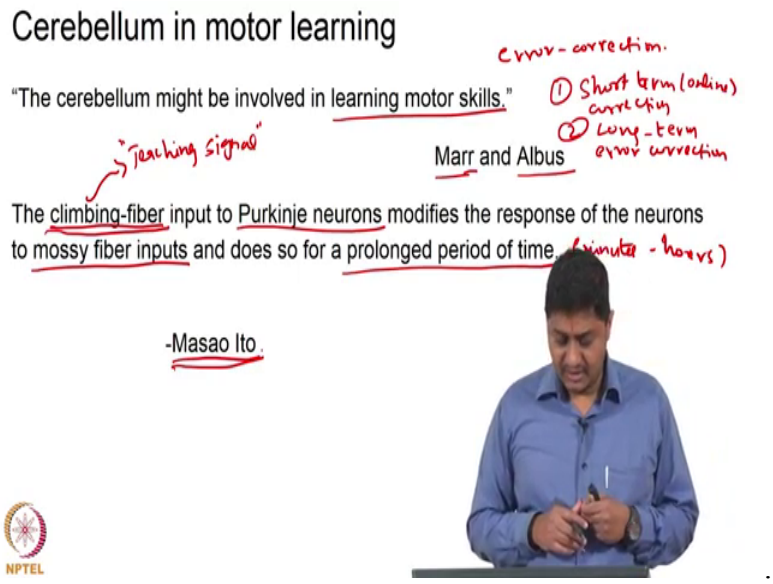

For a long time since the 1950s and 60s, probably the 70s, it was believed that the cerebellum might be involved in the learning of motor skills. Independently Marr and Albus proposed this, their theories and these theories continued to dominate the notion that cerebellum forms an important part where motor skills might be learnt. What is the basis behind this hypothesis? It turns out that cerebellum has relatively regular structure unlike the cerebral cortex as we have discussed previously.

So, there is a micro circuit that we have discussed and this micro circuit is repeated many many times. So, in the cerebellum, so that means it becomes easier for people with modeling skills to model the activity of this. So, what they need to do is, if they can model the activity of one micro circuit, then they have practically modeled the activity of entire cell.

They will have to repeat this multiple times. So, this gave rise to a movement are almost large body of work that involved modeling of cerebellar function. That started out with the seminal work or the seminal contributions of Marr and Albus, where they claimed that motor learning is mediated by the cerebellum or at least error based motor learning what is meant here is error correction.

So, there are multiple roles for cerebellum. Let us list some of this. One is short term error correction. This is short term or online error correction as soon as there is an error that has to be corrected. The other is long term error correction. This is also called as motor learning or you make a mistake and you realize that, that is a mistake. For example, I wrote error correction, I wrote make and then, I corrected it right, but that is a short term error correction, but you make a mistake and then, you realize that is a mistake and you keep correcting it over successive repetitions of the same moment, then you become more and more skilled at performing at least at that moment, right. Later Masao Ito proposed that the claiming fiber input to the purkinje neurons contains important information in the sense that it modifies the response of the purkinje neuron to future mossy fiber inputs and it does.

So, for relatively prolonged period of time, this might be several minutes to several hours. Prolonged period of time means the response of the mossy fibers or of specific mossy fibers. Let us remember there are there is a great divergence from the mossy fiber system to the parallel fiber system. Is it not? So, response to specific massive fiber input is modified or is modulated by climbing fiber activity; in that sense climbing fiber activity can be called as some form of teaching signal. It teaches what is the correct way of doing things and what is at least the mistake, what is the wrong way of doing this if maybe it does not teach how to do things, but at least it teaches how not to do it. So, we will discuss the detail in this class.

So, the climbing fiber input modulates the response of the purkinje cells to mossy fiber inputs for relatively long periods of time lasting from several minutes to several hours, right. So, this is the idea propagated by Masao Ito and this was well supported in several experimental studies later on. Let us see some of this, ok.

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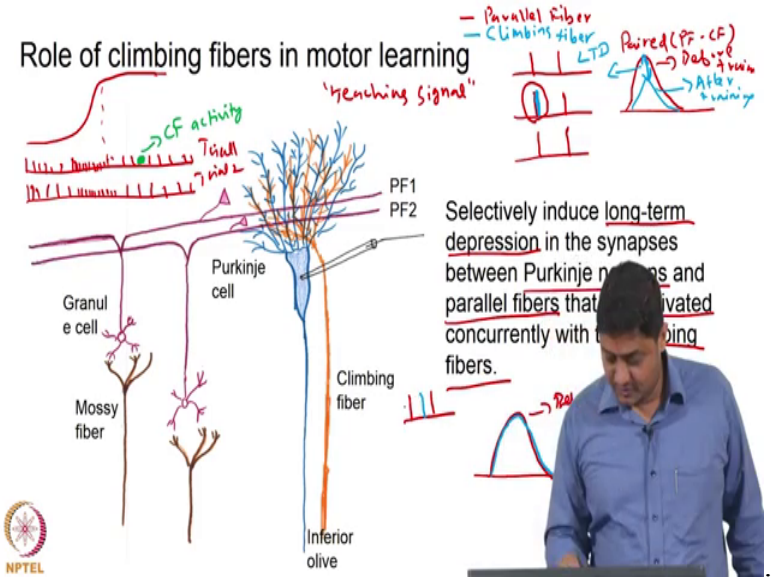

So, here you have stimulation of selectively purkinje cells by simultaneous stimulation of multiple parallel fibers and climbing fibers. When this is done and activity of purkinje cells are measured, what happens? So, this what is done is selectively induced long term depression and we will discuss what this is in a bit. In the synapses between purkinje neurons and parallel fibers that are activated concurrently with climbing fibers.

So, what is meant here is the following. Let us consider 2-3 cases suppose there is a case when I am going to drop parallel fiber activity in red. So, red indicates parallel fiber activity or stimulation of parallel fibers and blue indicates climbing fiber stimulation, right. So, suppose there is a case where the parallel fiber is stimulated here and then, is stimulated there. Just the parallel fibers are stimulated, but not the climbing fibers, right. So, this is at the, then in further trials in further trails I am activating the parallel fibers in approximately the same sequence, but in one case along with the activation of a climbing fiber cell; that is climbing fiber stimulation.

Let us remember the, let us remind ourselves of these two things. Climbing fiber stimulation provides a relatively strong input to purkinje cell activity this we know from previous discussions. Climbing fiber stimulation causes what are called as complex spice due to protracted calcium conductance. This we have discussed in previous classes. So, due to this protracted calcium conductance, there is what is called as a complex spike activity. There is an observed in the purkinje cells.

Now, whenever climbing fibers are firing in tandem with parallel fibers, then what happens is the activity of these parallel fibers in future. So, then you stimulate parallel fibers. For example, what is the response of the purkinje cells that is what we need to discuss. What is the response of the purkinje cell when there is paired activity of parallel fibers along with.

So, paired means paired activity of parallel fiber and climbing fiber. When the parallel fiber activity and climbing fiber activity is pad as in that case for example, the response of the purkinje neuron I am going to draw it. Before training it was like this and after training I am going to draw in blue. It is like this at depression in its activity, right. So, this is after training; red is before training.

What will happen if climbing fiber activity is not paired along with the parallel fiber activity or in other words, if you have climbing cyber activity independent of parallel fiber activity, what you will see is that so, there is an activity. This is before training and then, I have a case where there is parallel fiber activity and independent without any relation to the parallel fiber activity, there is an independent climbing fiber activation.

So, these two are not happening simultaneously separately. Then, after training also you will see is very similar response. So, what does this tell us? This tells us that what is happening here is when climbing fiber activity accompanies parallel fiber activity, it tells the system, it tells the purkinje cell that what has happened is a mistake reduce your activity. That reduction is what you are seeing as this difference. This is a relatively long term depression of the synaptic strength between that parallel fiber and that purkinje cell or in other words, what these parallel fibers are telling you is wrong is the information that is given by the climbing fiber.

So, the climbing fiber in this sense acts as a teaching signal. The climbing fiber I am writing in code because this is an interesting hypothesis. So, the climbing fiber input therefore acts as a teaching signal telling the purkinje cell that the information from parallel fibers whose activity accompanies its own activity at the climbing fibers, own activity is wrong and their activation or their stimulation in future should be responded to with a lesser effect so to that extent. That means, whenever there is an error right, parallel fibers activity that caused that error will not be responded to in future at least for the near future for the next few minutes to next few hours.

So, that is in when this is repeated over several days, when this is repeated over multiple iterations, what happens is that this becomes solidified. In some sense, this becomes the trend that these parallel fiber activities will no longer cause that moment why, because these movements are the ones that cause the error that has been taught to us earlier by the climbing fiber activity.

So, what is what will be the activity of the climbing fibers and parallel fibers in learning? For example, let us take one or two cases. Suppose in accurate wrist movements first before training before an adaptation, suppose that is the activity. So, toward picture try to improve that not much improvement suppose that is the actual displacement trajectory and you see that the activity of purkinje cells is this, right something or I mean it rather something and then, there is close to the moment.

There is a lot of activity and then there is a different amount of activity after the moment, right. In some cases, this may be accompanied by climbing fiber activity marked in green. For example, in some trials there is a climbing fiber activity or firing of a climbing fiber, in some cases this is in regular moments. Only in some cases, this climbing fiber activity will be there and in other cases, this will not be that in other trails for example there will be no climbing fiber activity. This is trial 1 for example and this is trial 2, ok. Suppose you have to make these movements as adaptations, so I will erase this, suppose there is an adaptation, right.

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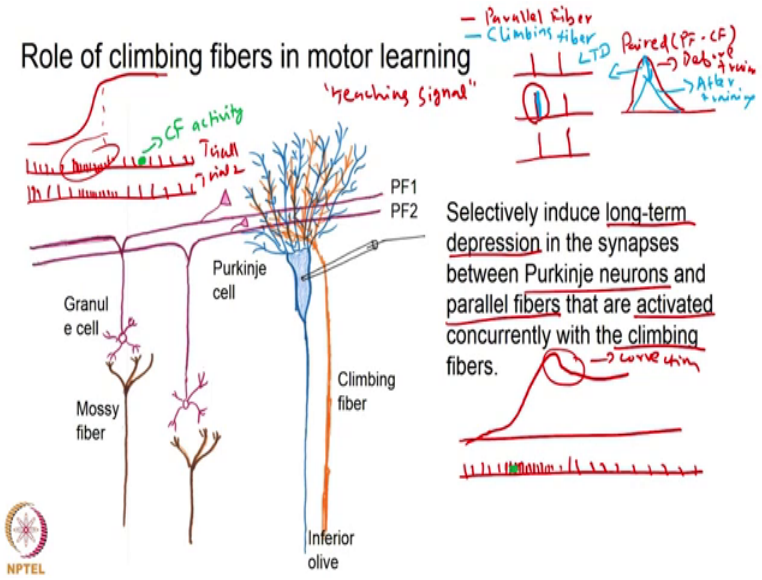

Suppose there is a perturbation to which there must be an adaptation right, so that is the displacement profile. Note there is a correction that is happening here. At this time what happens if we draw the climbing fiber activity? Sorry if we draw the purkinje cell activity, you will find that there is as usual as you saw here there is going to be similar activity here, but what you also note that is that in these cases, there is also going to be climbing fiber activity around here or here for example, there is going to be climbing fiber activity now after adaptation, this is during adaptation

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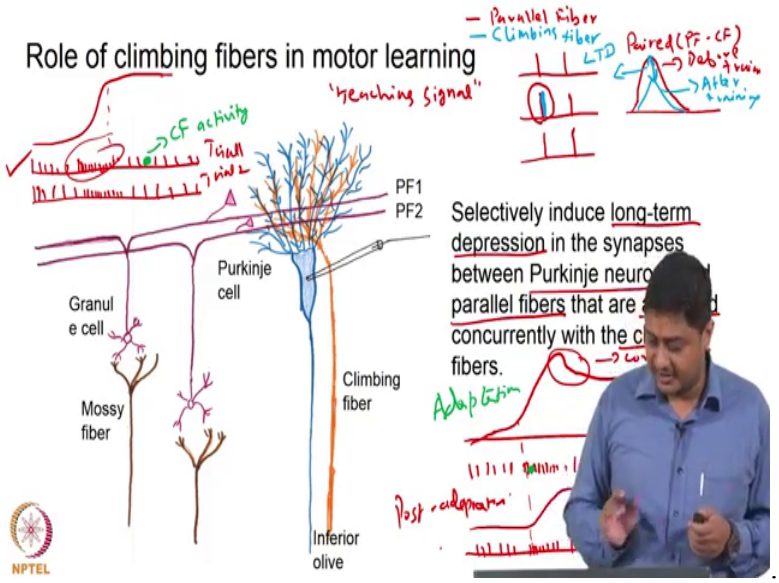

After adaptation what you observe is that the movement becomes relatively smooth. So, people have learnt and the activity of the purkinje cell is similar to the activity before learning similar to that, right this is post adaptation. So this means that the climbing fiber is teaching the mossy fibers or the climbing fiber is teaching the purkinje cell how to respond to errors, right.

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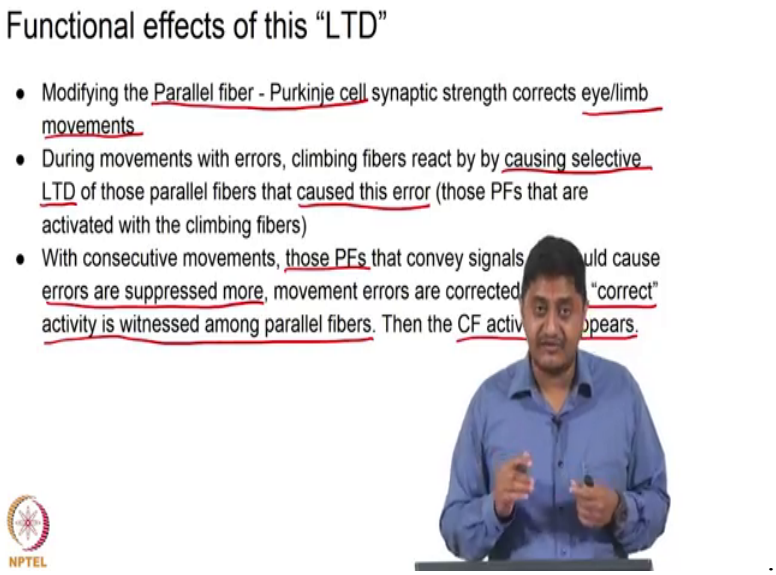

So, basically it modifies the parallel fiber purkinje cells in optic strength to correct. For example, multiple movement errors especially in eye and limb movements during movements with errors climbing fibers react basically by causing selective long term depression. So, it does not happen every time; only in cases when there is an error climbing fiber reacts.

So, whenever the climbing fiber reacts, you know that those parallel fibers and their activity should be responded to less in future. So, parallel fibers that caused this error will not be responded to in future because they cause errors and consecutive repetitions of this multi with successive moments. Those parallel fibers that convey error that convey signals which could cause movement errors suppress their activity, suppress more and more and movement errors are corrected more and more.

Thus, reducing the movement errors, also reducing the activity of these parallel fibers causing a more correct or more appropriate simple spike activity; simple spike activity means activity of parallel fibers. So, more correct or more appropriate activity of parallel fibers is taught by the climbing fibers by around that time climbing fiber activity itself disappears.

So, climbing fiber activity when it accompanies a parallel fiber activity, it means that parallel fiber is causing an error. We have to reduce the effect of that parallel fibers in future and that is selectively done through multiple iterations and later on the climbing

favorite activity disappears, but parallel fiber activity are those parallel fibers are not responded to in future trials, right.

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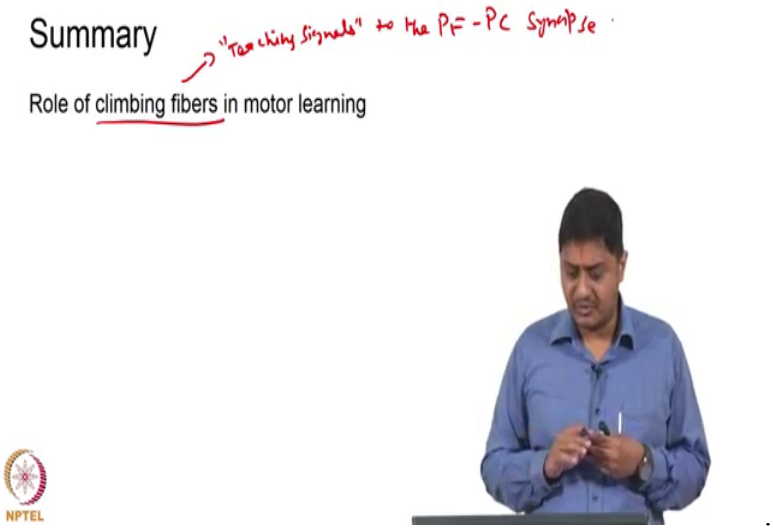

So, in summary what we have learnt is the crucial role of climbing fibers. What is this crucial role? Climbing fibers act as teaching signals to the parallel fiber purkinje cell synapse are they selectively modify the synaptic strength of a parallel fibers and purkinje cells and thus, it contributes to motor learning. This is a dominant hypothesis in motor learning. We will continue our discussion on motor learning in the next class.

Thank you very much for your attention.