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

Lecture - 69
Basal Ganglia – Motor Functions

Welcome to this class on Neuroscience of Human Movement. So, in this class we will continue our discussion on Basal Ganglia, specifically motor functions of.

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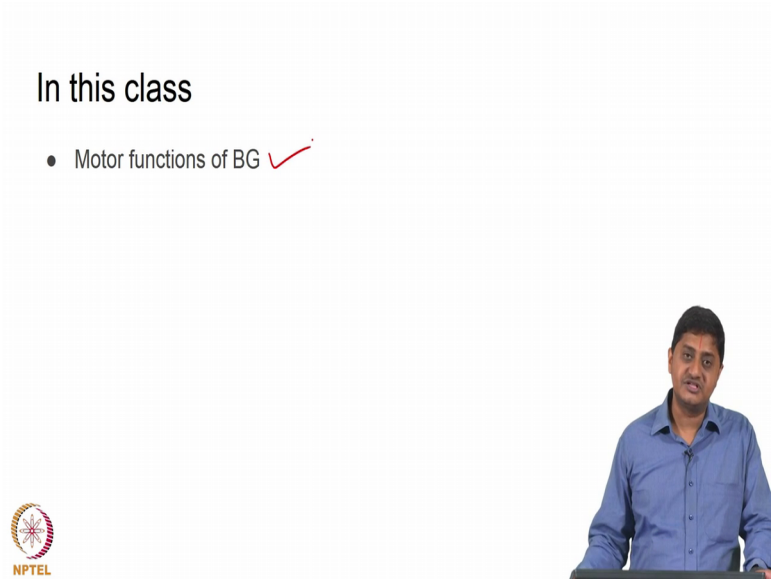

This class we will be focusing or we will start our discussion on motor functions of Basal Ganglia.

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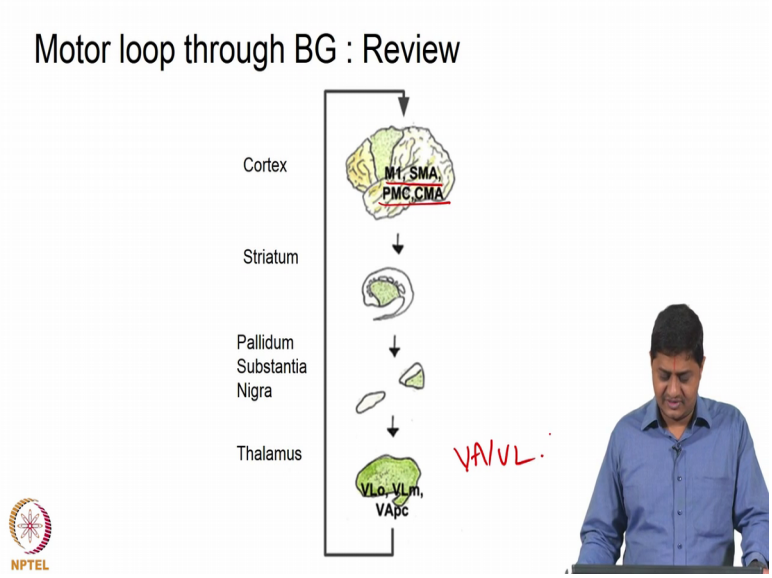

We discussed this in the previous class. So, in the cortex areas responsible for motor functions, these are primary motor cortex, supplementary motor area, premotor cortex and cingulate motor area. So, these areas that is projection onto Basal Ganglia, specifically the striatum or in most cases putamen right, from there the output goes to the pallidum and from there to the thalamus, where within the thalamus the motor areas project to ultimately the V A V L thalamus or ventroanterior and ventrolateral thalamus.

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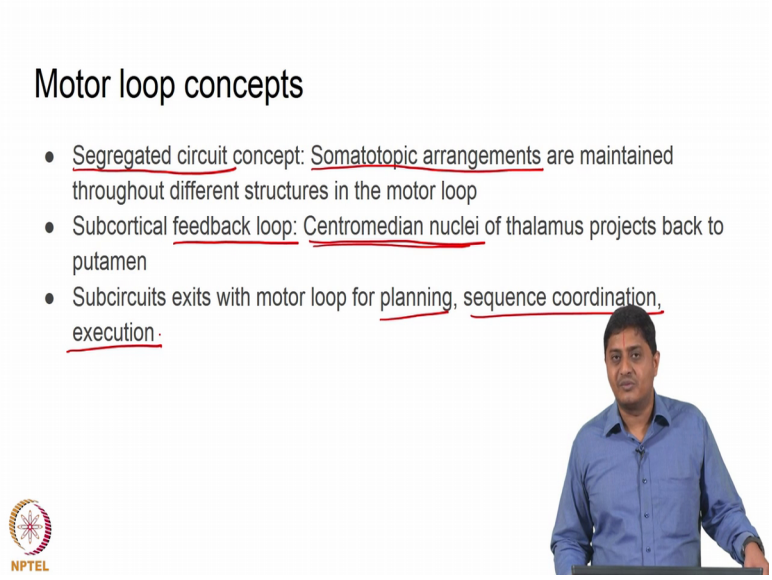

And important principle is the concept of segregated circuits in this inputs, received from different areas of the motor cortex, say for example, the hand and leg are kept separate in the striatum, are kept separate in the pallidum, are kept separate in the thalamus. So, essentially there is some sort of somatotopic, unlike the somatotopic in the primary motor cortex or unlike the somatotopic in the cerebellum. This somatotopic is not so profound or so, well studied; however, there is this separation or segregation of different areas. So, somatotopic arrangement are maintained throughout different structures within the motor loop.

So, within the Basal Ganglia, so there is this separate arrangement; that is maintained for different areas right. This again within the motor loop; of course, note different functions are differently maintained, in other words motor, the function is separately maintained from a executive function, which is separately maintain from limbic function etcetera. So, that is different within the motor loop different areas of the frontal cortex, different areas of the motor cortex, project to different areas in the striatum and the connections from the striatum to the palladium, and to from the palladium to the thalamus and from the thalamus back to the cortex are maintained separately throughout there is not mixing of this.

And not just that the thalamus projects to the cortex; that is the major output of the thalamus, but a particular region of the thalamus, the centromedian nuclei of the thalamus actually projects back to the striatum right. So, essentially acting as a feedback loop; so, that means, the striatum is receiving input not just from the cortex, but also from the thalamus. We discussed this in the previous class, we said that the cortical inputs received by the striatum medial spinning neurons are located in more distal dendrites when compared with the inputs coming in, say from the thalamus or say from the local inter neurons of the striatum right.

So, the dopaminergic inputs coming in from the substantianatic grapers compactor and the cortical inputs coming in from various regions in the cortex, are actually projecting to the distal dendrites right. Whereas thalamus and the local circuit neurons actually project close to the soma; that means, they have any ability to nicely moderate, finely modulate the output of the striatum medial spinning neurons right. So, where does that thalamus neuron originate in the centromedian nucleus of the thalamus alright. Also it has been

noted that different sub loops or different sub circuits exists within the motor loop for planning sequence coordination and execution.

So; that means, depending on for what function I am going to use a particular limb or a particular organ of the body. So, depending on whether I want to pick up the pen or whether I want to push the pen out right or whether I want to perform a cyclic movement like that, or whether I want to write. For example, depending on that these are different functions, but essentially we are using the same limb and the same effector for that right. So, essentially these functions are different, it turns out that Basal Ganglia has different loops for different aspects of this moment rated behaviour right. So, essential for planning, there is a different loop for sequence related function or sequencing of actions, there is a different loop and for execution of action there is a different loop.

So, that seems to be some segregation that is maintained in terms of function also, not just in terms of areas right. So, of course, hand and leg areas are maintained separately, but within the hand depending upon what I am going to do, depending on whether there is a planning that is required, so that is also segregated.

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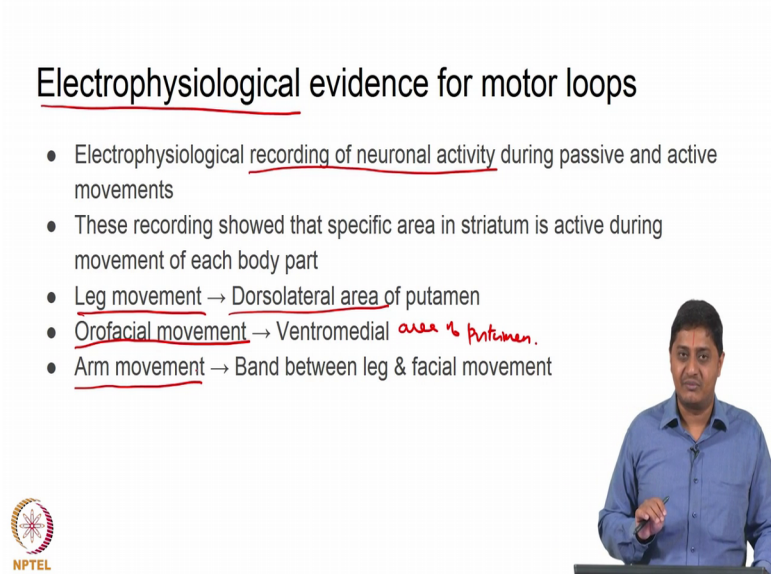

How do we know these things essentially? So, I am speaking as if we know everything. How do you know these things? Actually our knowledge of Basal Ganglia function is limited, but still it has improved tremendously in the last few decades right.

Importantly this has come from two sources; one is electrophysiological recordings. So, what it involves is, either stimulating electrophysiologically specific areas in the striatum or specific areas in the Basal Ganglia and observing the output in terms of behaviour, or of course, recording from specific regions of the Basal Ganglia during natural everyday behaviour for example, or natural lab related behaviour so whatever. So this is one way of doing it, this is basically electrophysiology. The other way of doing it is to use anatomical principles that something that we will discuss the next slide right. So, what is done here in electrophysiology, is recording of neural activity during passive and active moments right.

So, when the monkeys arm is moved passively, if I say a robot, what is the response in the Basal Ganglia or when the monkey itself is volitionally making the same movement, what is the activity in specific region within the Basal Ganglia right. What this has shown is that specific area in the striatum is active during movement of specific part of the body. So, essentially for example, leg movements, during leg movements dorsolateral area of the putamen or neurones in the dorsolateral area of the putamen are active and during facial moments ventromedial or a different region of putamen are active. And during arm moment a specific band or a specific area that lies between the dorsolateral and ventromedial region of the putamen was used for arm movments.

Once again you do not have to remember all the little details, how this is dorsolateral, this is ventromedial and this is the band between the other two or this, but it is important to remember the concept, it is important to grasp the concept that the leg movement areas in the striatum is different from the facial movement areas in the striatum, which is different from the hand movement areas of the striatum. You may not be able to remember dorsolateral ventromedial right, but it is necessary to remember that these are maintained separately.

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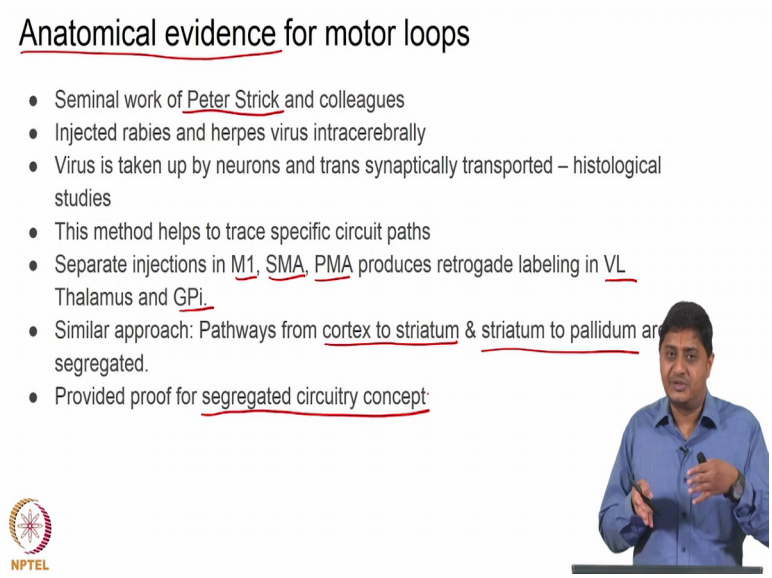

The other way of studying this of course, is anatomical evidence right, how is this done? This kind of work was pioneered by Doctor Peter Strick and his colleagues. So, what they do is they inject rabies and herpes viruses intracerebrally and it turns out that these virus, these viruses can be transported across synopses right. So, this virus is taken up by neurons and transinoptically transported; that means, that they can cross the synopsis so, but it takes time, it does not happen instantaneously of course.

So, as soon as the injection is given, it takes anywhere between hours to days for this viruses to be transported right and it turns out that this viruses show up in specific manner in anatomical slicing. So, what happens is that, these viruses are injected intracerebrally. So, basically using injections these viruses are injected into specific regions within the Basal Ganglia. Once again you have to know to which area you are injecting it into and then what you can do is, after say 1 day or after 2 days, after a specific time line right, you sacrifice animal and perform histological analysis. Basically you take specific slices of the Basal Ganglia circuit and then identify which areas of the Basal Ganglia actually show staining for this particular virus right.

Showing then, using that you can actually identify which areas of the Basal Ganglia are connected to which areas of the Basal Ganglia once again. So, this method helps us to trace the path ways right, specific circuit path. This is a revolutionary concept, this is also used to trace pathways from other regions to other regions. In other words this is also

used to trace path ways from the spinal cord to the cortex and vice versa etcetera right. Of course, separate injections in primary motor cortex, supplementary motor area, premotor area produces labelling in ventrolateral thalamus and the GPi right using a similar approach pathways from the cortex to striatum and from striatum to pallidum have also been found and have been found to be segregated right.

So, essentially once again this provides strong evidence for the concept of segregated circuitry. So, again this concept that this idea, that different regions sending inputs to the Basal Ganglia, there is not mixing of inputs from multiple regions. These regions and these input are maintained separately and the outputs are also sent separately. So, there is segregation, but importantly and important part to note, but an important point to note is that, a large number of cortical neurones project to a relatively smaller number of neurones in the striatum right.

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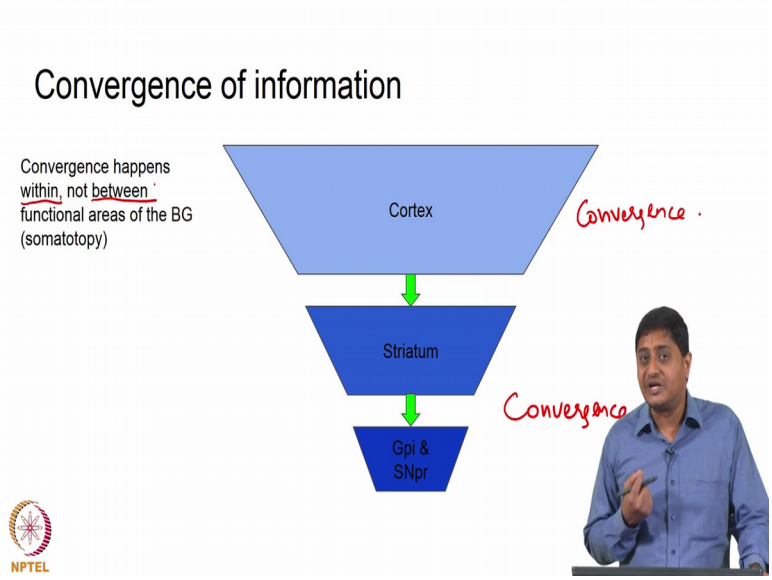

So; that means, there is convergence; there is convergence here and also we said that a relatively large number of the striatal medium spinning neurons project to a relatively smaller number of neurones, in the output nuclei basically globus pallidus internal and substantial pars reticulata right. So, essentially what is happening is one more level of convergence here. So, this would make us believe that. So, from multiple areas it is projecting to smaller area so; that means, integration of information from multiple areas in the cortex, happens in the striatum.

Actually this is not what happens, what happens is that convergence happens within, is very important concept. Convergence happens within functional and anatomical areas within the basal ganglia not between. So, essentially this is done while maintaining segregation, there is convergence.

So, a lot of cortical neurones come say from, supplementary motor area and they project to a smaller number of neurones in the striatum and those neurones in the striatum project to a smaller number of neurones in the output circuitry basically, the pallidum right. Now, if you take similarly a different area say the cingulated motor area right, a large number of cingulated motor area neurons project to a smaller number striatal neurons.

And relatively large number of striatal neurons project to a smaller number pallidal neurons, segregation is maintained while at the same time convergences happen. So, this is an important point to remember. So, convergences happen within, but not between functional areas of the, basal ganglia. Thus, maintaining the segregation, maintaining the somatotopic integrity.

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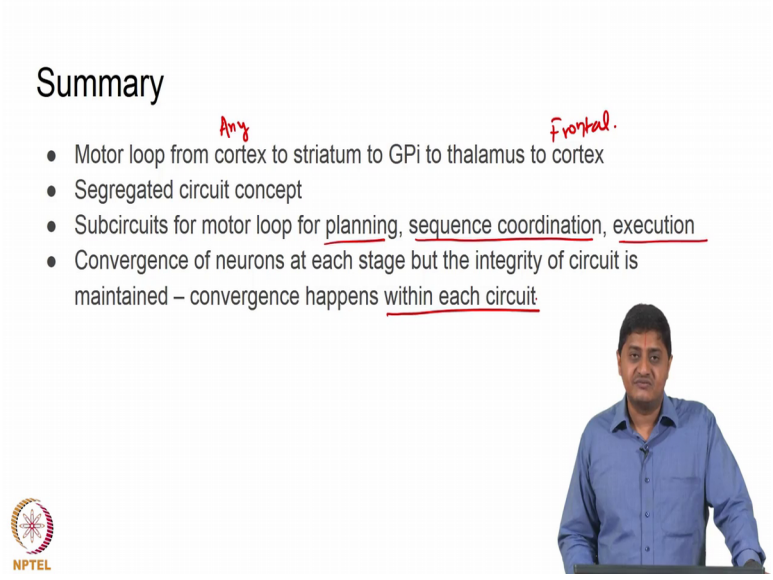

So, in summary essentially, motor loop is the loop from the cortex to the striatum back to the G P i, back to the cortex. So, in summary motor loop is the loop that starts or that originates in the cortex and projects to the straitum and from there it projects to the

palladium and from there it projects to the thalamus and back to the cortex. Note this cortex can be any cortex except the primary visual and the primary auditory cortex.

This cortex is always the frontal cortex, something to remember and there is segregation of input and pathways right and there is separate sub circuits for planning sequence coordination and execution. And there is feedback coming in from the centromedian nucleus and there is feedback coming in from the centromedian nuclei of the thalamus back to the striatum and there is convergence from the cortex to the striatum and from the striatum to the palladium right and convergence happens within the circuit, but not between circuits. So, with this we come to the end of this lecture. We will continue this discussion in a future class.

Thank you very much.