

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



**Lecture - 53**  
**Cerebellum Part – 2**

So, welcome to the class on Neuroscience of Humour Movement. We are continuing with our discussion on a Cerebellum.

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In this class...

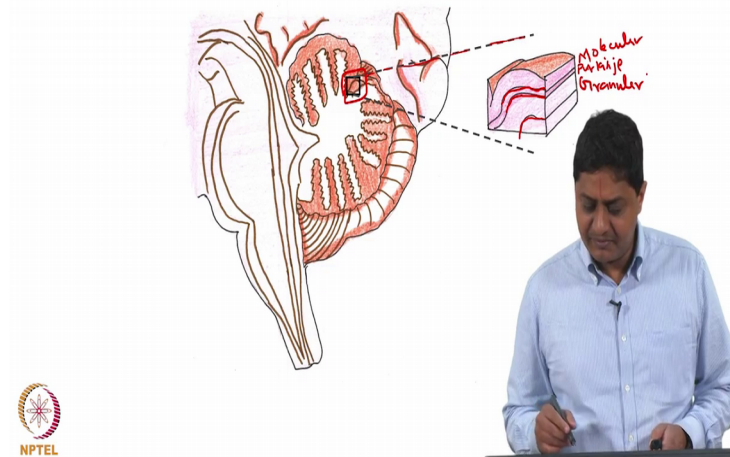
1. Cerebellar cortex
2. Layers of cerebellar cortex
3. Types of afferents into cerebellum
  - a. Mossy Fibers
  - b. Climbing Fibers
  - c. Purkinje Fibers



So, this is part 2 of our discussion on cerebellum. So, in this class will be talking about cerebellar cortex different from cerebral cortex. So, this is cerebellar cortex and the different layers of cerebellar cortex and the types of inputs that are received by the cerebellum and the type of output in the cerebellum ok.

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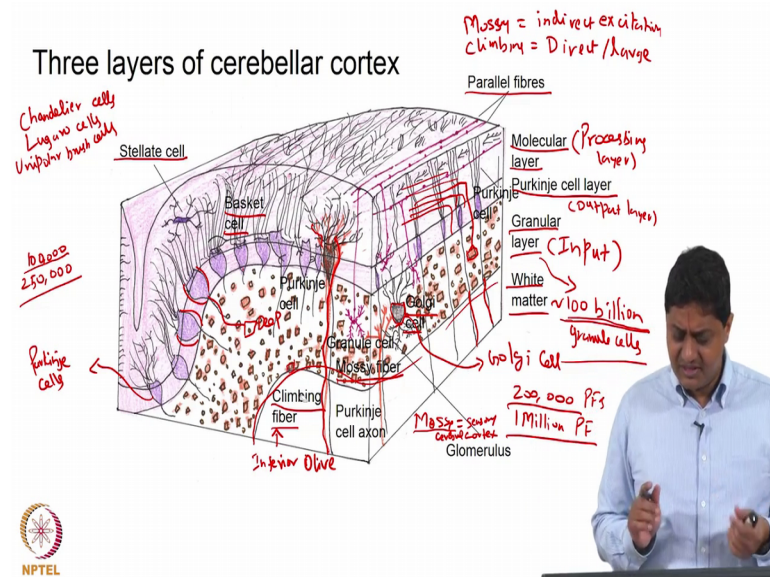
## Cerebellar cortex



So, we said that the cerebellum is located inferior and posterior to the brain stem and inferior to the cortex. So, if you take a particular area a relatively small area of its context of the cerebellar cortex is going to show, it is going to have this unique three layer structure, so there is one layer there and the relatively thin layer there and as and a thicker layer at the bottom.

So, these layers are called as M, the thinner layer is called as P, and the deeper layer is called as G. What are these? It is not miles per gallon, but these are rather molecular layer, Purkinje layer, and the granular layer ok. So, these are the three layers of the cerebellum. And of this so bigger picture is slide.

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This is relatively confusing, but we will take a step by step understand what is going on. So, the inputs come from the bottom, so this is white matter. So, at the granular layer which starts around here, this layer is the major input layer of the cerebellum. This is a major input layer of the cerebellum.

What this has is a large number of granule cells. What is this number? We mentioned in the previous class this is about 100 billion granule cells, that is an RF cells, 100 billion approximately 100 billion granule cells are there in the granular layer. So, there called as this is called granular layer because, it contains a large number of granule cells.

The next layer is called as the Purkinje cell layer, it contains cell bodies shown in purple here. These cell bodies of the unique and distinct cells that are cells that are unique and distinct to the cerebellum. These cells are called as Purkinje cells, and also highlighted elsewhere example there, their cell bodies are located in the Purkinje layer, or Purkinje cell layer.

So, what does mean? When I say there cell bodies are located in Purkinje cell layer, it means their dendrites an axons are elsewhere, their dendrites extend in to the molecular layer actually they have too many dendrites not shown in this picture. Each Purkinje cell can have dendrites from anywhere from 100000 to above 250000 dendrites that is a large number of dendrites.

So, each Purkinje cell has about 100000 to 25000 dendrites. And these dendrites are in the layer above the Purkinje cell layer are the molecular layer and the axons the axons of these Purkinje cells project on two nuclei embedded within the cerebellar cortex is nuclei are called as the deep cerebellar nuclei. So, these are the major output structure of the cerebellum.

So, the Purkinje cell layer in some sense can be considered to be an output layer. In the molecular layer what you have are dendrites of the Purkinje cells and it turns out that the axon of the granules cells. So, the granule cells is said are a very large number that I am going to be throwing out such large numbers.

So, please be cautious in interpreting them and please verify read them and understand and make sure that you know you get the numbers correct. These granules cells their axons ascend upwards and then proceed perpendicular to the dendrites of the Purkinje cells. But then we have 100000 billion granular cells, it turns out that these granules cell axons when they go and there are several of these that go like this right.

(Refer Time: 06:08) each Purkinje cell they all go parallel to each other. But, perpendicular to the dendritic tree of Purkinje cells right. It is because they are parallel to each other these are called as parallel fibres. For illustration only a few of these are shown; obviously, what is there is a more complicated picture.

But what we are showing here is only a few only like a few 10's or few less than 10 parallel fibres are a little more than 10 Purkinje cells. What is actually happening is it there are 100000 million granules cells. And each Purkinje cells is innervated anywhere between 200000 parallel fibres to 1 million parallel fibre's. 1 Purkinje cells receive input from 200000 to 1 million parallel fibres that is a large number.

So, all these are not shown for illustration purpose only we are showing a small number of this connections, it turns out that this interaction between the input layer, or the granules cells and the output layer which is are arguably that is the Purkinje cell layer happens at the molecular layer. So, this is the major processing layer with a cerebellum.

So, what is going on? Let us remind ourselves one more time. So, what is going on is that the major inputs are received at the granule cell level, at the granule cell layer, or the granular layer. These input proceed further to other layers by the granule cells and it is

parallel fibres. The Purkinje cell layer contains cell bodies of the Purkinje cells, where as their axons project to the deep nuclei and their dendrites are in the molecular layer. And these dendrites contacted by 100s of 1000s of parallel fibres, 100s of 1000s of parallel fibres.

So, the molecular cell layer they are the molecular layer is the major processing layer of the cerebellum. Purkinje cell layer is the major output layer of cerebellum where as the granular layer is the input layer right, so this what is not discussed is that the cerebellum also contains other cells such as basket cells, and interneuron inhibitory inter neurons shown here that is the we will write this here for clarity that is the Golgi cell, and at different type of inter neurons, these are the inter neurons, this star shape inter neurons.

So, they are called as the stellate cells. What is the not shown in this picture or other type of cells these are chandelier cells, or Lugaro cells, and unipolar breast cells. There are several other cell types, but for the purpose of this cause and discussion it is enough if we understand the functions of the granule cell.

The Golgi cell and Purkinje cell basket cell and stellate cell for the purpose of this class because otherwise class becomes a too detailed. It turns out that the granules cells receives inputs from the major from one of the major sources of a input to the cerebellum, these are called as mossy fibres ok. These mossy fibres service input to the granules cells.

So, each granule cell receives input from a few mossy fibres, but one mossy fibre innovates several 1000 granular cells that must be true right. Because it turns out that the total number of granules cells is 1000 billion and; that means, and also we said earlier in the previous class that that is greater than the sum total of all the neurones in the central nervous system and the rest of the cerebellum right.

So, that is more than 50 percent of the neurones are in the granular cell are composed of basically the granule cells is it not. So, each mossy fibre possible then innovates 1000s of granule cells, but one given granule cells this is input only from a few mossy fibres right.

So, these what are these mossy fibres? We say mossy fibres. What are these? These are sensory information from the spinal cord, and other information from the cerebral cortex. So for clarity if I say cortex now it is confusing whether it is cerebellar cortex or whether

it is cerebral cortex? Mossy fibres are input neurons that arise from spinal cord and other input regions of the cerebellum. And from the cerebral cortex through the point a nuclear ok.

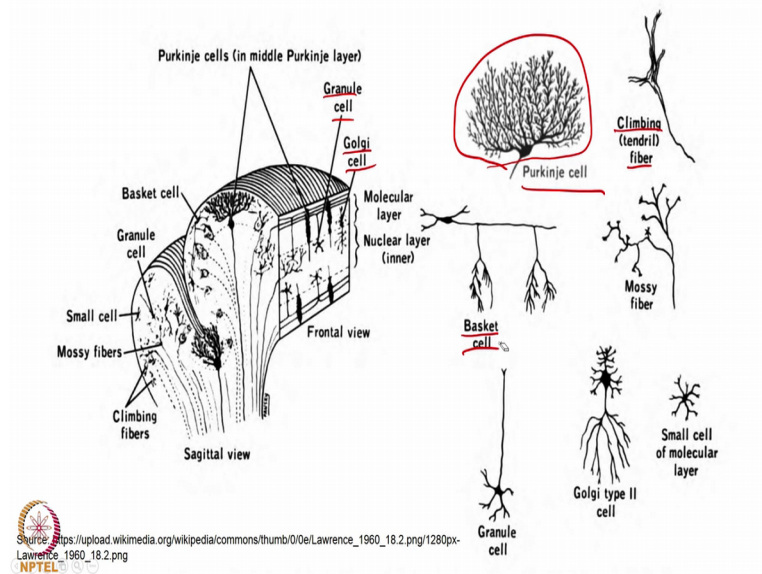
So, mainly from these two sources and maybe from other sources also, from for example, from the vestibular system, for example from visual system from other systems also, but mainly from the cortex and the spinal cord for example so that is sensory information. And the other information that come from the cortex these are called as these cells that bring this information into the cerebellum are called as mossy fibres. And then there is a special fibre that arises that arises from the inferior olive that arises from the inferior olive. These type of fibres are called as climbing fibres.

Because these fibres climb through the granular cell layer they do not projects to the granules cells, but rather they directly control the action of the Purkinje cells by connecting, or by innervating by making synapses with multiple dendrites of Purkinje cells like it has been shown in this picture. So, they climb over the Purkinje cell body cell dendrites and they make multiple connections and they do not project to the granules cells. So, where as the mossy fibres project to the granular cells and through the granule cell controller modulate the function of the Purkinje cells. So, let us remember the differences.

So, mossy fibres are indirect excitation they provide mossy fibre provide indirect excitation to the Purkinje cells. Whereas climbing fibres provide direct and relatively large excitation of the Purkinje cells ok. So, we will discuss the details in future classes, but it suffices to know for now that the climbing fibre directly and in a greater manner influences the function of Purkinje cells. Whereas the mossy fibres first synapse with the granule cells, actually they also synapse with the deep cerebellar nuclei not shown in this picture.

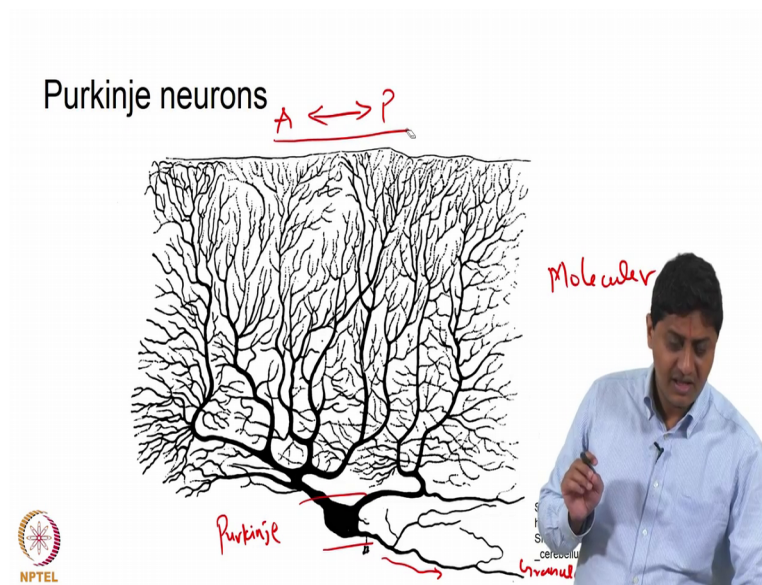
So, the mossy fibres synapse with the granular cell and these granule cells take information act. After they become parallel fibres they innervate multiple Purkinje cells and modulate action of Purkinje cells in an indirect and less with less amplitude when compared with (Refer Time: 15:24). So fundamentally different mechanisms, so we will continue this discussion of this theme. We will continue throughout our discussion of cerebellum.

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Is here is another pictures showing a one more time the Purkinje cells, Golgi cell, granule cells. So, this is a granule cell and these are this is a Golgi cell, this is a granule cell. And a see the distinct tree like structure of the Purkinje cell and compared with the other cells and how climbing fibres. And there different types of Golgi cells, a Golgi cell type one, type two, and there are basket cells. And right these are the various cells within the cerebellar cortex, some of them are not shown but many of them are shown.

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So, one more time here is a the view of the Purkinje cells it. So, their full body is in the Purkinje layer, this is in the Purkinje layer. Where axon is going to the granular layer, the granular cell layer and their dendrites are in the molecule layer. Look at the dendritic tree structure this is a relatively small Purkinje cells with a small number of dendrites.

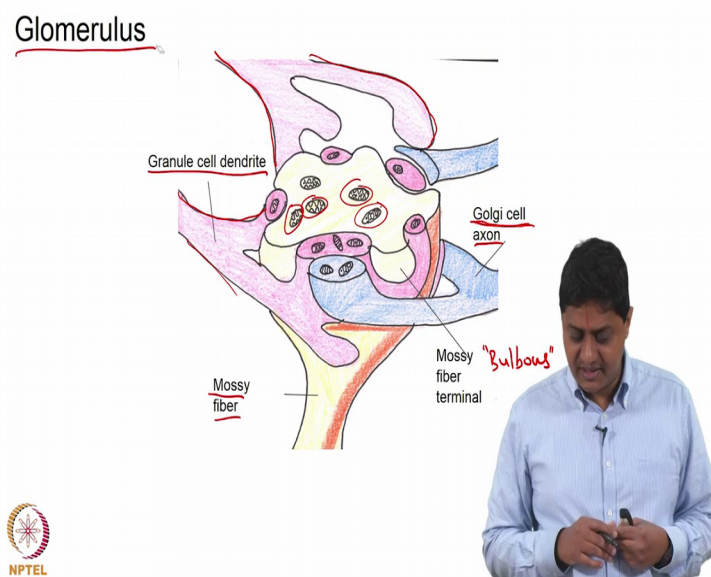
I said that the are at least a smaller representation for illustration purposes we said that this has relatively large number of dendrites anywhere between 100000 250000 dendrites and important point to note is that the Purkinje cells are thick. Or one would think when you are viewing that this is like a tree you would think that this is 3D structure just like a real banyan tree for example.

This is not true what is actually true is that this Purkinje cells occupy a relatively large territory in the anterior posterior direction, in this is the A P direction. They occupy a relatively large territory in the anterior posterior direction. But when you are looking at it media later direction, when you are looking at it from that direction right it appears to you as if it is very thin. For example, the paper for example, is actually a 3D object right except that it is thickness is much smaller when compared with it is you know length and breadth as one would think.

So, there is as the length, that is the breadth, but it is thickness is very small it is actually a 3D object, but for one most practical purposes it can be considered to be 2D object is it not. So, for most analysis we could considered the likewise the Purkinje cell is actually very thick in the anterior posterior direction. But thin very thin in the medio lateral direction, and this is important for their function why we will see in the next class.



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And an important concept is the concept of Glomerulus. So, we said that there are Golgi cells, granule cells and mossy fiber. The mossy fiber axons are the bulbous axons of the mossy fibers that make connections with the dendrites of the granule cells here. So, these are the various dendrites from multiple dendrite cells right for simplicity only 2 or 3 granule cells are shown actually we said the number of granule cells contacted by each mossy fiber can be of the order of several thousand right.

So and the mossy fiber also connects with the axon of the Golgi cells. So, thus existing the Golgi cells, what is the function of these Golgi cells? We will see in the next class. So, these Golgi cells are also innervated by the mossy fiber not the number of mitochondria here the large number of mitochondria here.

There must be very critical or very high metabolic activity of this mossy granule cell, Golgi cell connection area are what is called as a glomerulus see. So, there must be high metabolic activity there must be happening at the glomerulus that is probably that is why there is great distribution of mitochondria in this region right.

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## Summary

- Cerebellar cortex
  - Layers of cerebellar cortex
  - Types of afferents into cerebellum
    - Mossy Fibers
    - Climbing Fibers
    - Purkinje Fibers
- Handwritten notes:*  
Molecular layer → Purkinje → Granular layer  
Climbing Fibers → outputs of cerebellum  
Purkinje Fibers → Deep nuclei



So in summary what you seen is that so the cerebellar cortex is compose of three layers, we said these are the molecular layer, Purkinje cell layer, and we and granular cell layer. And we described types of types cells in each of this, so we said that the granular cells layer context mainly the granular cell and some Golgi cells. The Purkinje cell layer contains cell body of Purkinje cells whereas, the molecular layer contains inhibitory interneuron's such as stellate cells, basket cells. And there are other cells also such as chandelier cells, luger cells, unipolar breast cells etcetera. So, we discussed the cerebellar cortex and the three layers of the cerebellar cortex.

What are these? This is molecular, Purkinje, and granular this is the new MPG. At molecular, Purkinje and granular cells; granular cell layers are three layers of cerebellar cortex and then we said there are different types of inputs and in to the cerebellar these are mossy fibers, and climbing fibers. And the Purkinje cells are the major output are at least modulate the output of the cerebellum or basically they project on to the these their axons, axons of Purkinje cell project on to the deep cerebellar nuclei.

Where are these deep cerebellar nuclei? We have not discuses that, we have not shown that in this picture. Actually the deep cerebellar nuclei are embedded within the cerebellar cortex. These are relatively dense structure that service independent nuclei to output information from the cerebellum. These are embedded within the cerebellar cortex, but was not shown in the picture that was discussed will discuss that and other

things in future classes. So, coming up next in the next class will be discussing about the microcircuitry involved with in the cerebellum.

Thank you very much.