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

Lecture – 52
Cerebellum Part-1

So, welcome to this class on Neuroscience of Human Movement. From this class onwards we start discussion on a new topic Cerebellum. So, this is part- 1 of what I presume is going to be a long series of lectures on this topic.

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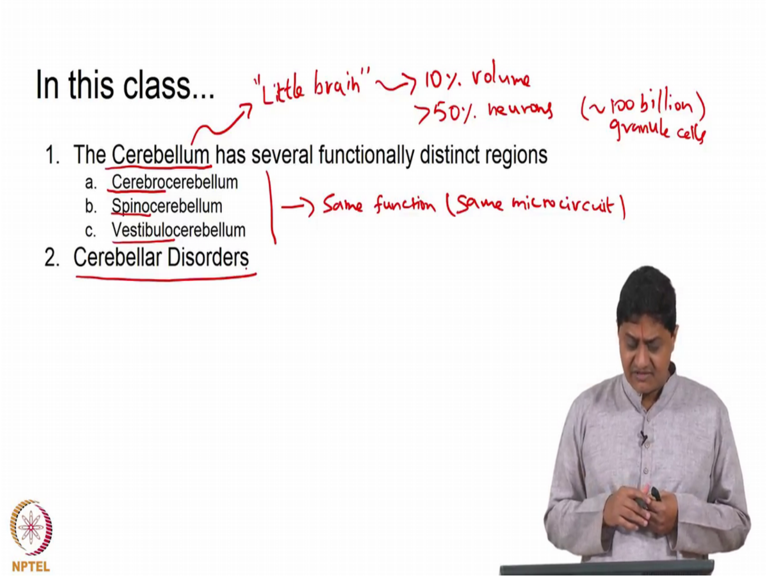

So, in this class we will discuss functionally distinct regions of the cerebellum these are called as variedly as cerebrocerebellum, cerebrocerebellum; spinocerebellum and vestibulocerebellum. What this means is that that part of the cerebellum that connects with the cerebral cortex is called as the cerebrocerebellum basically it receives inputs from the cerebral cortex and it outputs to the cerebral cortex mostly. This is called a cerebrocerebellum.

Spinocerebellum actually receives inputs from the spinal cord mainly and outputs not to the spinal cord but indirectly through other structures controls or sends output to the spinal cord. So, the output is not directly to the spinal cord. And vestibulocerebellum receives inputs from the vestibular system and outputs to the vestibular system, right.

So, what is cerebellum? Cerebellum quite literally means the little brain, this little brain but also the brain within the brain or the brain of the brain. Why this is called like that? Because it is a relatively small structure 10 percent by volume, so if the total volume of the brain is 100 units, 10 units or less of the volume is occupied by the cerebellum. But has greater than 50 percent of the neurons in the entire central nervous system.

So, if the central nervous system has 100 neurons, 50 of these are more than that are actually from the cerebellum not just that there is more actually, one type of cells within the cerebellum alone constitute more than 50 percent of the neurons in the central nervous system. These are the granule cells these cells alone constitute more than 50 percent of the neurons, so that gives you see an idea that this has to be a very dense structure, is it not. In 10 percent volume you are hosting more than 50 percent of the neurons.

The granule cells are believed to be several billions several tens of billions, close to 100 billion granule cells that is a large number, lots of these. And it turns out that although this is a very dense structure what is different, what differentiates it from the cerebral cortex where we saw that the picture is relatively muddled, there is a that is a more (Refer Time: 03:59) representations, there is convergence and divergence and different there are into strict boundaries etcetera. This is what we learned in the cerebral cortex or during the discussion of motor cortex and promoter supplemental motor areas we discussed this.

It turns out that the structure of the cerebellum is relatively regular. So, that is a particular micro circuit which we will discuss in a future class. And this micro circuit is repeated thousands and thousands of times, so same circle, regardless of whether the this is receiving input or output to the see from one to the cerebral cortex are from and to the spinal cord from one to the vestibular system. In all the cases the micro circuit remains the same giving us an idea that the fundamental function that is performed by all these regions, by all these 3 regions is expected to be the same; the fundamental function we can hypothesize immediately that they must perform the same function because they have the same micro circuit. This micro circuit is of paramount importance in the discussion of cerebellar function we will discuss that in future class.

We will also introduce the cerebellar disorders and the classic science of the cellular disorders giving us an idea of the functions of the cerebellum, ok. So, let us get started.

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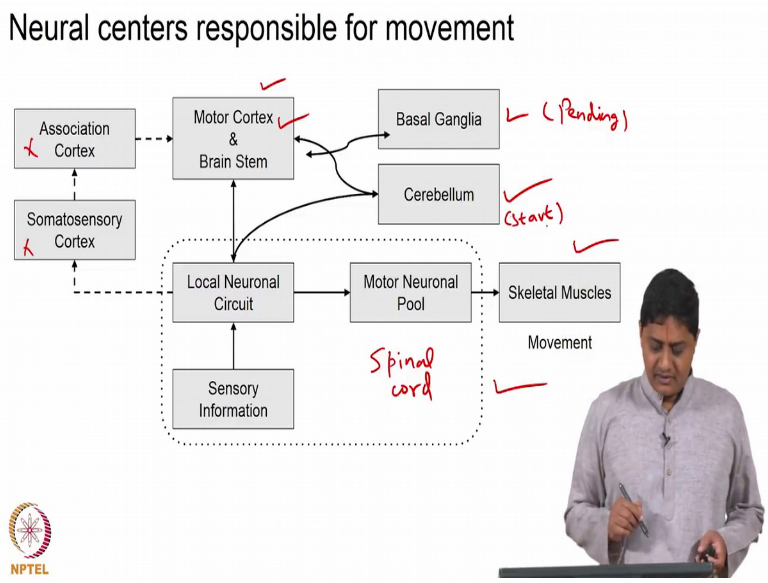

Before we move on let us discuss the status of this course. This is a course on movement neuroscience. We have discussed skeletal muscles and their physiology of skeletal muscles. We have discussed this is the spinal cord is it not, this is the spinal cord, spinal function reflexes, monosynaptic reflexes, pollyali gerson application fluxes, pre-programmed reactions have discussed. You have discussed the cortical regions maybe not the brainstem that is pending but we have we have at least discussed the motor cortex supplementary motor cortex, premotor cortex and promoter areas etcetera we are yet to discuss these two.

So, today we will get started with our discussion of cerebellum. We will follow that up next by our discussion of basal ganglia. These two topics are of course, not going to be discussed as part of this course, right. This is pending. So, we are getting started with this. This is starting today, right. So, let us proceed. So that means, the next two topic after cerebellum is 4 over after we discuss cerebellum the next two topic is Basal Ganglia, ok. That is what next.

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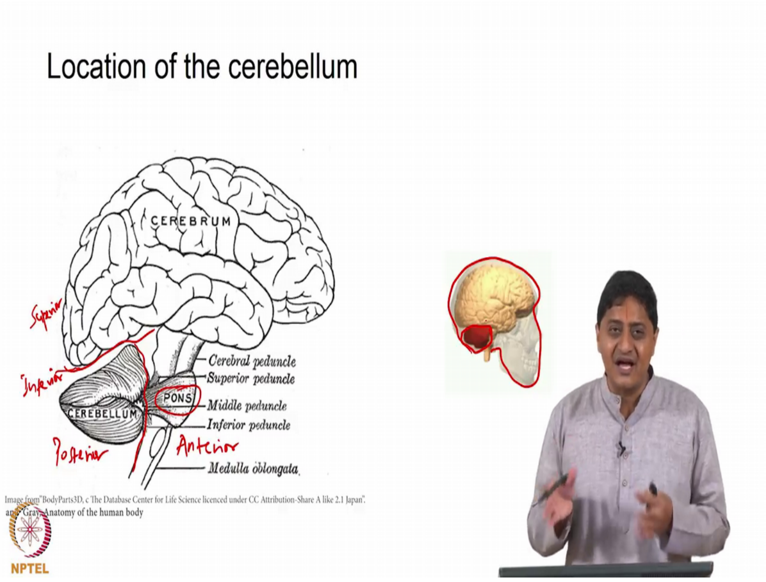

So, where is the cerebellum? The cerebellum is located inferior, so this is superior going up and his inferior. Inferior to the to the inferior to the cortex; you have the cerebellum here and also it is posterior (Refer Time: 07:29), also the cerebellum is located posterior to the brainstem just behind pons. So, that is the human skull that is shown here, it is a human skull. And the area that is highlighted in red there is this cerebellum so, inferior to the cortex posterior to the brainstem and the parts.

So, its function is dependent on its anatomy. So, we are again once again back to the good old problem of structure function relationships or anatomical and physiological relationships. It turns out that understanding its function are we are interested in the movement signs, we are interested in the motor part. It turns out that entire cerebellum can be considered to be a mortal part of the brain entire cerebellum most of its function is motor. So, its function is dependent on its structure. So, we are going to continue this line of discussion. So, most of the lectures on cerebellum is going to be on cerebellar neurophysiology, ok.

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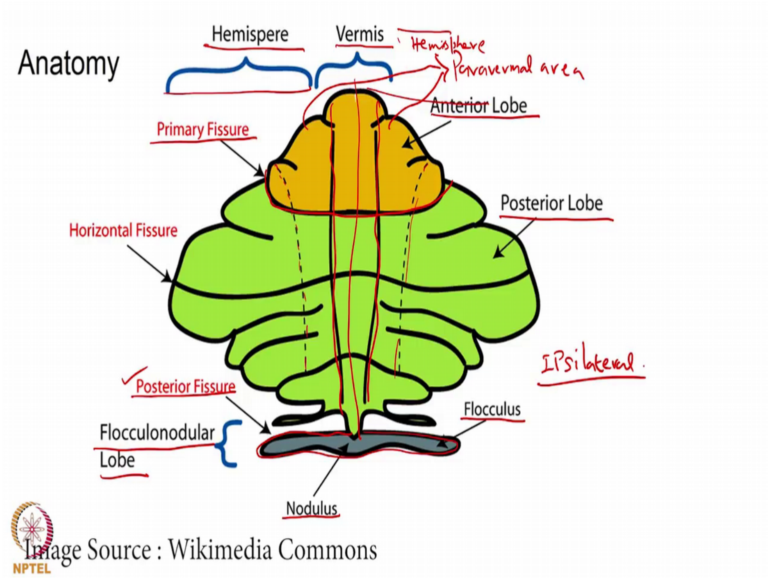

There are two lobes this is the anterior lobe that which is located on top that is the anterior lobe and the one that is located in the bottom is the posterior lobe here. And these two are divided by a fissure and that fissure is called as a primary fissure. It turns out that there is a relatively phylogenetically old region of the cerebellum called as a flocculonodular lobe this contains two nuclei or two regions called as floccules notice. This is phylogenetically old are the primitive part of the cerebellum. This primitive part of the cerebellum is divided from the from the other parts through the posterior fissure.

The more medial region is called as vermis. So, that is that area. And the areas shown here by dotted lines, that area and that area are called as the paravermal area, ok. And these two basically there are two halves this is one hemisphere. So, this half is one hemisphere and that is the other hemisphere that is the other these are cerebellar hemispheres, right. We have discussed we have seen cerebral hemisphere lay earlier; these are cerebellar hemispheres.

Important to note is that cerebellar control unlike cerebral control is (Refer Time: 10:43). What do I mean by that? The left side of the motor cortex controls the right side of the body we have seen this earlier projections to the contralateral side of the bodies how we would this. Why is that? You have seen that earlier there is the pyramidal decussation where about 90 percent of the neurons from the pyramidal tract cross over to the other side of the body. We have discussed this in previous classes.

It turns out in the cerebellum the left side of the body is controlled by the left side of the cerebellum and the right side of the body is controlled by the, right side of the cerebrum or in other words the same side not control lateral but ipsilateral the same side. But that does not of course, mean that there is direct projections from the cerebellum to the spinal cord that does not happen, ok. So that means, area is controlling the left side of the body receive inputs from the left cerebellar hemisphere. So, that is what we should remember, ok.

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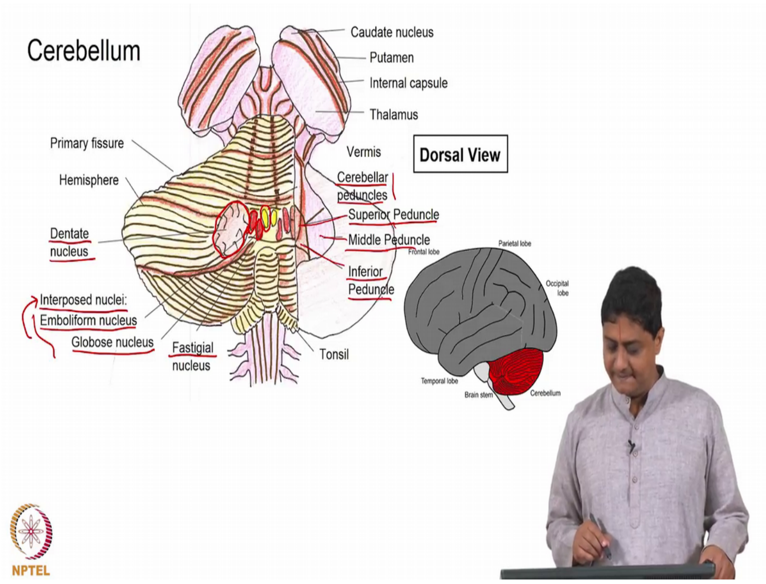

So, another view this is dorsal view what is of interest for us is the pedicles here, what is shown clearly is the cerebellar peduncles. These are the major input structures to the cerebellum they bring inputs from various sources or outputs they also send outputs. So, these are the major input output structure. So, these are the bundles of neurons that take the input from various sources and send to the cerebellum or take the output from the cerebellum and send to other parts of the brain. So, these are divided into 3 peduncles, one is the superior potential, there is a middle peduncle other is inferior potential. These are shown here. That that is the superior peduncle, that is the middle production that is the inferior peduncle, ok.

It turns out the deep within the cerebellar cortices there are nuclei that are embedded these nuclei are the output nuclei of the cerebellum, this output nuclei of the cerebellum are the dentate nucleus that is the big nucleus there. That is the dentate nucleus. And then there are two other nuclei in red marked in red there that one and that one these are the emboliform nucleus and globose nucleus together they are called as the interposed nuclei. And then the one that is marked in yellow there is the fastigial nucleus, right

So, these are the deep cerebellar nuclei which form major output structures of the cerebellum, ok. So, the major output structures of the cerebellum are the dentate nucleus, emboliform nucleus, globals nucleus and fastigial nucleus. And the emboliform and globose together are called as the interposed in nuclei, ok. The major input output neuronal branches are called as cerebellar peduncles and these are divided into superior, middle and inferior triangles, ok.

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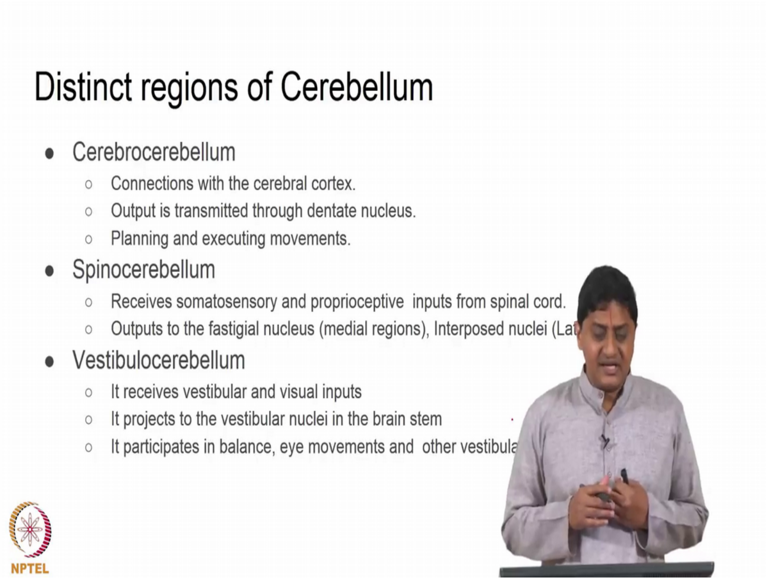

There are distinct regions of the cerebellum.

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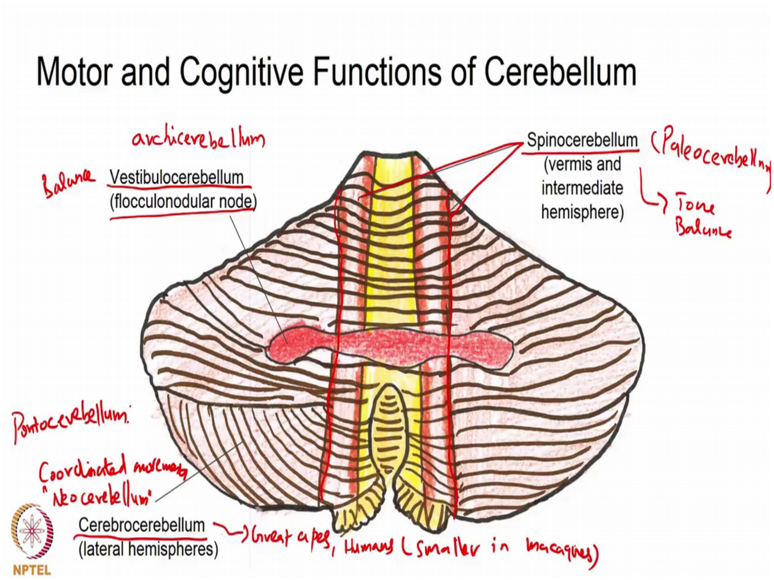

We call this, so this region is called as the lizard. This region is called as the cerebrocerebellum. And the vermal and paravermal area together are called as the vermis and paravermallayer together are called as the spinocerebellum. And we said that the flocculonodular an nodelars nuclei are the flocculonodular lobe is called as a vestibulocerebellum.

Turns out that the phylogenetically oldest nucleus or the phylogenetically oldest structure of the cerebellum is the vestibular cerebellum, this is also called as archicerebellum. Various textbooks, various names, there are many names archicerebellum. That mean this is present even in lower vertebrates such as fishes but not in but not in lower animals, animals lower than fishes for example.

This is present even in fishes but fishes do not have spinal and cerebrocerebellum. Higher animal such as mammals you are going to have you are going to have spinocerebellum this is also considered relatively old but not too old that is why it is called a paleocerebellum, ok. Relatively old structures this is responsible for maintenance of tone balance of the more medial parts of the body. We will discuss that in future classes; responsible for balance.

The most recent development of the cerebellum is the cerebrocerebellum which is found or whose size is much larger in great apes. They are present in other primates but the size is much larger in play great apes and humans; believed to be responsible for coordinated movements, well coordinated movements are probably the function of cerebrocerebellum. So, called as neo cerebellum; neo means new. So, this is a newest part of the cerebellum.

This is there in higher mammals and the size of the cerebrocerebellum is much bigger in great apes and humans when compared with say even monkeys, say even smaller in it is smaller in macaques for example, right. So, this gives us an idea that which part of the cerebellum is going to be responsible for what function, and which functions are considered to be most crucial or for the existence of different species, right. So, as you go up the phylogeny you realize the appearance of more coordinated movements are more finely controlled movements. This is you know probably in some sense modulated by inputs from the neo cerebellum are the cerebrocerebellum. How exactly does this do that is the content for the future classes.

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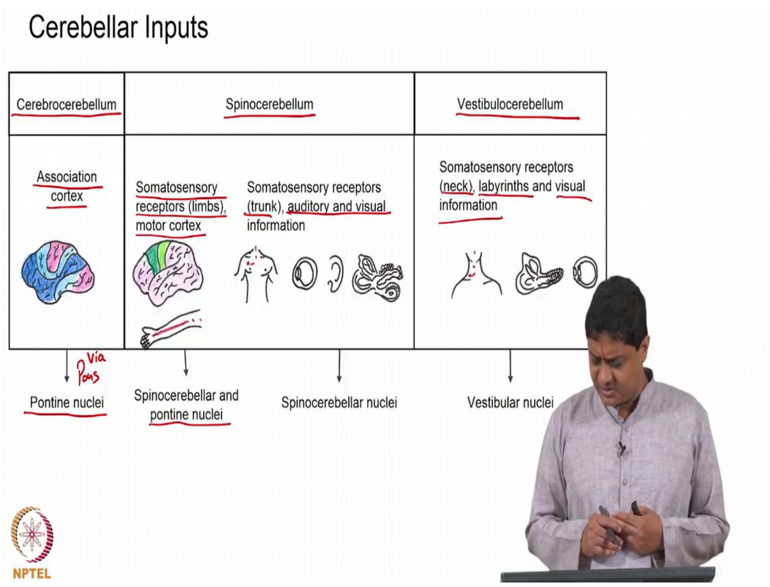

So, major inputs to the cerebellum. So, fundamentally we are divided that into 3 cerebrocerebellum, spinocerebellum and vestibularcerebellum, right. Cerebrocerebellum mainly sensing you know receives inputs from association cortices and its it is it will not it does not project directly to the cerebellum but rather via pons which is also the reason this cerebrocerebellum because it receives inputs from the ponte nucleate it is also sometimes called as the ponto cerebellum, so many names, too many names, ponte cerebellum is another name for cerebrocerebellum, neo cerebellum is another name for cerebrocerebellum, ok. So, the cerebrocerebellum receives inputs from association cortices via pons.

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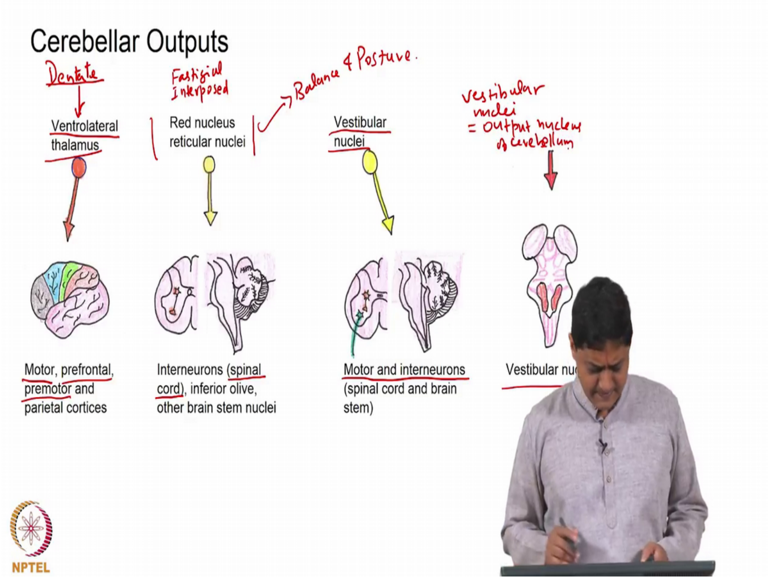

After processing that is happening in the cerebellum it outputs via the dentate nucleus to the ventrolateral thalamus. I think some details are missing we will give the details in future classes; through the ventral lateral thallamus to motor prefrontal promoter and periodic courtesies. So, important regions that are responsible for decision making and control of movements receive the outputs through from the dentate nucleus. So, dentate nucleus mainly projects to the cortex via the ventral lateral thallamus. So, the thalamus is the relation. So, it is going to receive the inputs from the dentate nucleus and pass it on to the cortex or multiple areas within cortex, prefrontal cortex, premotor cortex, parietal and motor areas of the of the cerebral cortex, ok.

So, what about spinocerebellum? Spinocerebellum receives inputs as we have seen in one of the previous classes it receives inputs about for example, proprioception, right from somatosensory receptors or proprioceptive receptors etcetera and also from motor cortex. Others like you know from the trunk and other inputs auditory, visual information etcetera, right. And it receives input via mainly via the spinal spinocerebellar nuclei pontine nuclear in some cases. And where does it output to? It outputs via the fastigial nucleus and the interposed nucleus depending on the case, fastigial nuclei and the interposed muclei through the red nucleus and reticular formation oh. That is crucial for us what is what should be what would be its function; balance and posture

So, in outputs from the spinal cerebellum go to the red nucleus and reticular nuclei formation by are the fastigial and interposed nuclear depending on the specifics and note they then control the red nucleus and reticular formation then control the movements via the spinal cord. So, in a through inter neuron, right. Then the vestibular nuclei, in the vestibulocerebellum this is inputs from the labyrinths and visual information and proprioceptive information of the neck. Why is important? The head orientation and the head position is crucial, is a crucial input that is received by the vestibullar cerebellum and via the;

So where is this processing happening? We know where this processing is happening we said where that is happening that it is going to happen here the archicerebellum or in the flocculonodular node. From there the outputs go through the vestibular nuclei to the motor and inter neurons, and in some other cases directly to the vestibular nuclei. It turns out that the vestibular system or the vestibular nuclei acts similar to the cerebellar deep nuclei, in a sense vestibular nuclei can be considered is an output nucleus of the cerebellum in some sense. We will discuss this detail in a future class.

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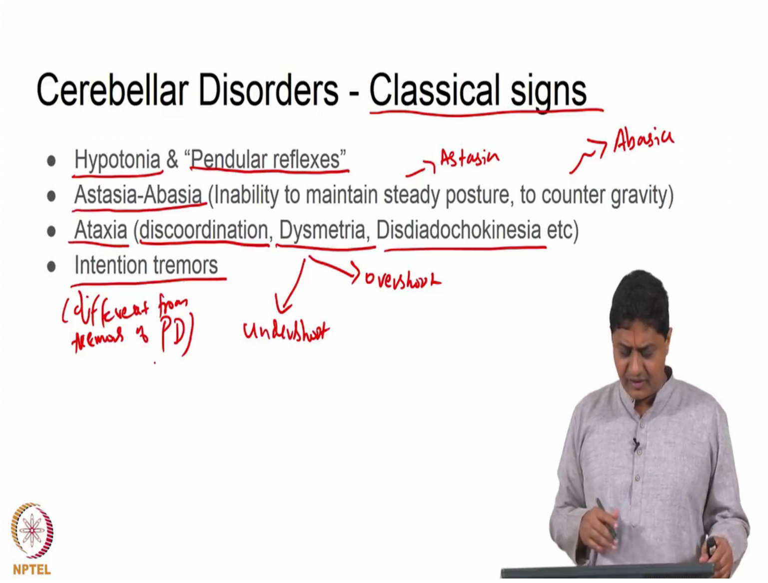

So, then what is the difference between other diseases and diseases of the cerebellum? Fundamental differences in the manifestations and in the clinical signs give us information about what could be the possible function of the cerebellum, ok.

The classical signs of cerebral lesions first, hypotonia; this is surprising because we have seen in previous classes what happens if the lesion is in the motor cortex for example; or in the cortical regions controlling the movements if there is a lesion we know immediately what happens. We have discussed that for several lecture. What will happen? Hypertonia that is preceded by a period of hypotonia are mainly or after the period of hypotonia is over the major manifestation of lesions of the motor areas of the cortex of the of the cerebral cortex lead to hypertonia and hyperreflexia we have seen this very clearly. For the cerebellum though it is hypotonia are an amount of reduced tone.

So, this gives us an idea that though maintenance of tone forms probably an important function of the cerebellum we have discussed this kind of conclusions coming to this kind of conclusions is dangerous I know. So, with caveats at least we could hypothesis that you know probably this is an important function. We will discuss the details in future classes. At least by looking at the signs you could hypothesis that cerebellum must be an, must play an important role in maintenance of tone. So, hypotonia is what happens when there is a lesion of the cerebellum or maintenance of minimal tone is not happening.

And also what happens he said if there is a tendon tap, right. In healthy humans, so a simple clinical test in healthy adults when there is a tendon tap for example, the regular knee jerk reaction is elicited, right. So, that is known and after that, what happens after the reflex is over? The knee comes to an immediate stop in healthy adults after the; so there is a tap and there is a jerk that is given after the jerk is over the knee comes back to its rest position and stays there whereas, if that same experiment is repeated with cerebellar patient or some of the cerebellar patients shows the following sense.

When there is in a tap there is a reflex but then the reflex does not stop immediately, there is going to be a pendulum like moment of the limb also called as the pendula reflexes classical sign associated with the cerebellar disorder. So, if there is this pendula reflex immediately you can say that there is a cerebellar problem.

Then the other classicals in a second classical sign, astasia and abasia; what are these? The inability to maintain steady posture of the limbs is called as astacia, this is astasia, and inability to produce forces against gravity to counter the gravity is called as a abaisha. Also the other classical sign is ataxia. This comes in various forms I only stated a few here.

What this refers to is a group of symptoms that that could involve this coordination, very very poor coordination of the body parts and dysmetria or the size of the movement is either there is either there is an overshoot or there is an undershoot, there is dysmetria. And then the inability to perform rhythmic repetitive movements this is called us this doadchokiniesia. This is that this is the case where you are asked to perform movements like this, right. A normal human can do this with relatively stable steady rhythm but people with cerebellar disorders cannot this, right. So, these kind of coordination problems are called as, together they are called as (Refer Time: 28:28) there they come in many forms the details vary we will discuss the details in future.

And then intention tremors, hat this means is that if you are given a target if you have to reach say the tip of this pen and I am a healthy person I am reaching and reaching there again reaching few times. Suppose I have a problem with the cerebellum then the target is the same, reach there, then what happens. As I start moving closer to the target the amount of oscillation increases, I do not reach the tremor increases only when I have the target and when I want to reach when I have the intention to reach the target. It starts with a lower amplitude here and then as I go higher the amplitude of the of the oscillation increases its called a the intention tremors fundamentally different from other tremours.

So, there is a this is different from the tremors associated of Parkinson’s disease and the regular healthy physiological tremor. So, characteristic features are different from other tremors, so fundamental differences.

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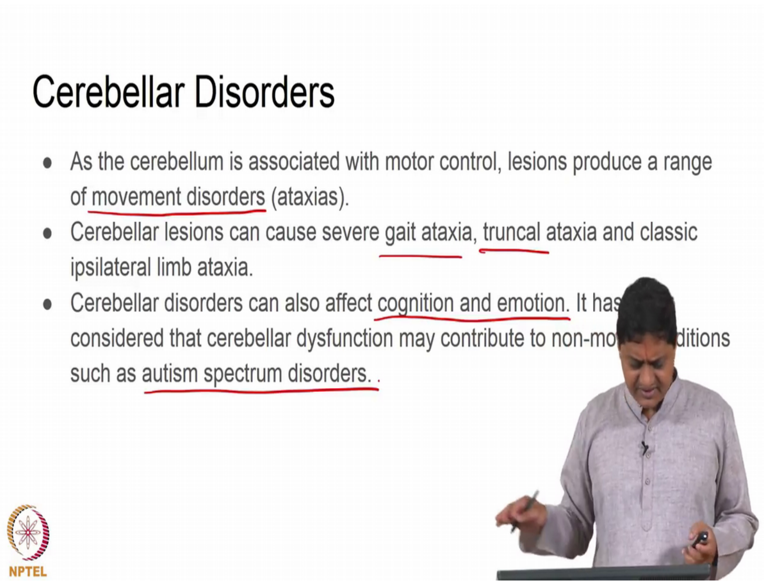

So, basically when the when lesions of the cerebellum happen basically there is a whole range of movement disorders that are seen because mainly cerebellum is a motor part of the brain. And also multiple, multiple examples are given gait ataxia truncal ataxia and other ipsilateral limb ataxia.

And they can also affect cognition and motion, actually this is less studied part it is believed that cerebellum also plays a role in cognition emotion. So, there are other disorders too which cerebellum may contribute her cerebellar dysfunction may contribute these are for example, hypothesis to be for example, autism spectrum disorders and other disorders. Also a crucial feature of cerebellar disorders is the following, that the ability to perform movements with less conscious effort is compromised. What do I mean by that? When you are performing a movement that is relatively familiar or when you have a patient whose one side of the cerebellum is compromised whereas, the other side remains intact these are classical cases, right.

In this case what happens suppose, let us consider the patient whose left side of the cerebellum is compromised and the right side of the cerebellum remains intact. Then what happens? Whenever he wants to perform a movement with the right hand he does not have to think much bird when he has to perform a movement with the left hand he has to try and do that with conscious effort. So, cerebellums function in intact systems are not well known there is no or in other words it appears as if cerebellums function is to remove the notion of conscious effort from the effort from the movement related effort that is being made.

So, in other words when the movement is being made there is need to have less conscious effort in familiar well learnt movements, right, in well learned movements. This, less conscious effort is present in healthy individuals but people with cerebellar lesions will have to make more conscious effort. So, this is an important detail that we will discuss probably in the future classes.

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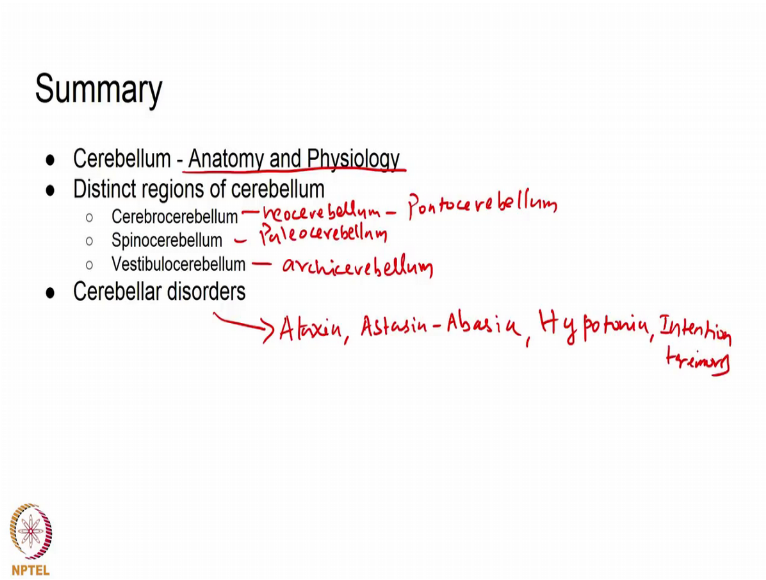

So, what we have seen in today's class is at least we have begun the discussion on the anatomy and physiology of the cerebellum. We have discussed the distinct regions of the cerebellum. There are also the other names of this, this is also called as a neo cerebellum and the pontocerebellum from time to time. Spinocerebellum is also called as a paleocerebellum the relatively older structure when compared to the cerebrocerebellum. And phylogenetically relatively oldest region of the cerebellum is the vestibular cerebellum this is also called as the archicerebellum.

And we have seen cerebellar disorders and we said there are 4 classical signs. What are the 4 classical signs? Not necessarily in the same order these are Ataxia, astasin-abasia. Ataxia may come in multiple forms this coordination dysmetria dysdiadochokinesia. Astacia is the ability to maintain posture. Abasia is the inability to counter gravity. Then hypotonia, then in tension tremors, it is not; fundamental difference from the cerebral cortex relations.

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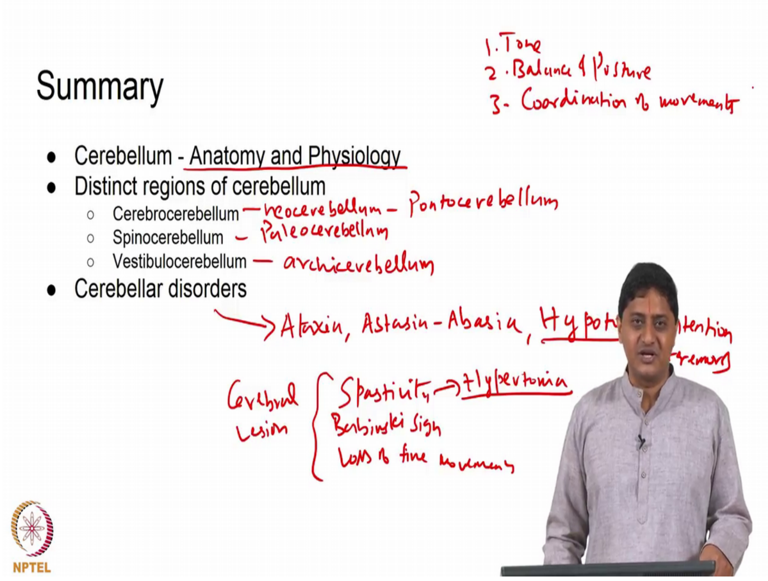

For example, if the lesion is in the cerebral cortex you are going to have what are the classical sense we saw that. What are the classical signs? These are spasticity, Babinski sign and lots of fine moments, is it not. (Refer Time: 34:27) is basically a form of hypertonia, spasticity is a form of hypotonia. This is a special form of hypertonia not general rigidity, but rather rate dependent rigidity we have seen this. So, this is cerebral lesions.

So, immediately you are able to distinguish the differences between lesions of the cerebellum and lesions of the cerebrum. When the lesions happen in the motor areas of the cerebral cortex you are going to have for example, hypertonia when it happens in the cerebrum you are going to have hypertonia fundamental difference. So, this means what are the major functions of the cerebrum, immediately we must be able to answer that is tone, balance and posture, and coordination of movements, coordination, control of moments. So, time the sequences of movements for example, it says.

By the way let us remember that all this is done through indirect projections to other motor areas of the brain not directly to the spinal cord this is what we have been saying from the beginning. Basal ganglia and cerebellum modulate motor outputs but do not directly control. In other words they do not project to the spinal cord they project to motor areas that control limbs our control the neurons in the spinal cord. So, the regions what are those regions these are the motor cortical regions and the brainstem regions of the motor are the motor regions of the potential.

So, with this we come to the end of this lecture. We will continue our discussion on the cerebellar physiology in the next lecture.

Thank you very much.