Demystifying the Brain
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Lecture – 10
Organization of the Central Nervous System Segment 2-Subcortical Structures

So, in this segment we will talk about the Subcortical Structures. So, we said last time that the cortex is the sheet of neurons that covers the entire in a cerebral surface.

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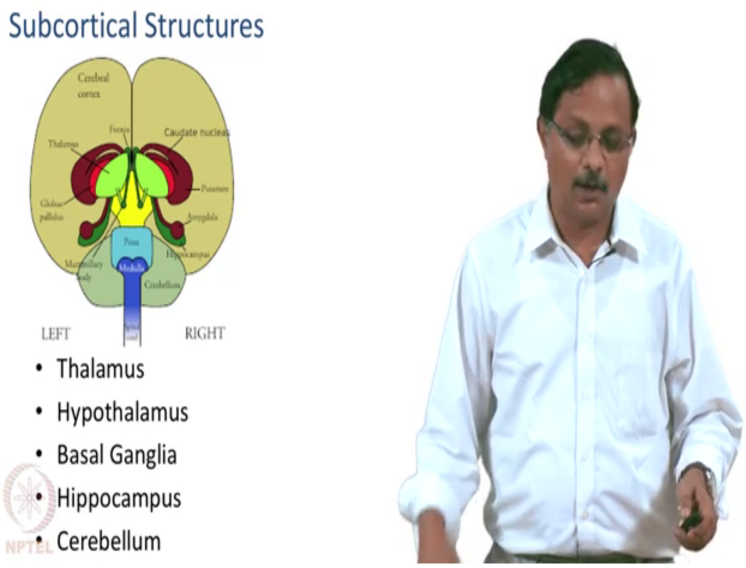

Subcortical structures are basically those that lie under the cortex or the the sub cortex. So, here some of them main subcortical structures which we will be talking about are the thalamus hypothalamus basically and it is not one structure, but it is a whole circuit there, where several modules together are called the basal ganglia.

And then there is hippocampus or the hippocampal complex which again ca consists of lots of 4 neural clusters or the hippocampal fields. Then we will also talk about cerebellum is not exactly a subcortical structure, because it is not located under the cortex it is outside the brain located ventral to the occipital lobe so, but we will also it is a it is not cortex. So, we will talk about this also in the same category.

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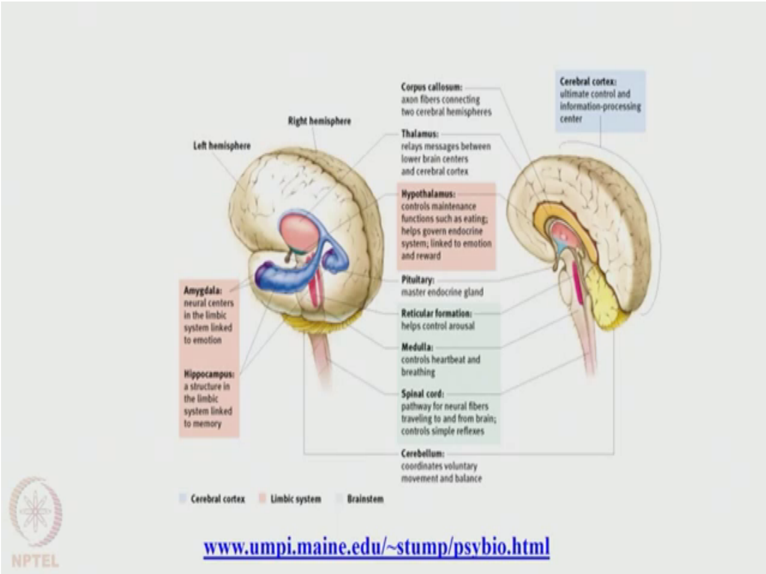

So, in this figure you can see thalamus it is this egg shaped pink structure . So, thalamus is a major important gateway to the cortex.

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Most sensory information that goes to the cortex goes through the thalamus. So, sensory information and also motor integration occurs through thalamus. So, for example, the motor output from the motor cortex does not go through thalamus, but the motor cortex is influenced and in it is motor in it is moment decision making by other structures like; you know basal ganglia or cerebellum and these influences reach the motor cortex via the thalamus. So, both on the motor side and sensory side inform a lot of information has to go through the thalamus and thalamus consists of 50 nuclei this nucleus here is basically a cluster of neurons it is a compartment within the thalamus.

There are 50 of them approximately and here there are two kinds of nuclei, there are: specific nuclei which make point to point connections to the cortex and they also receive feedback connections extensive, feedback connections from the cortex. Then there are these nonspecific nuclei which send diffuse projections to the cortex.

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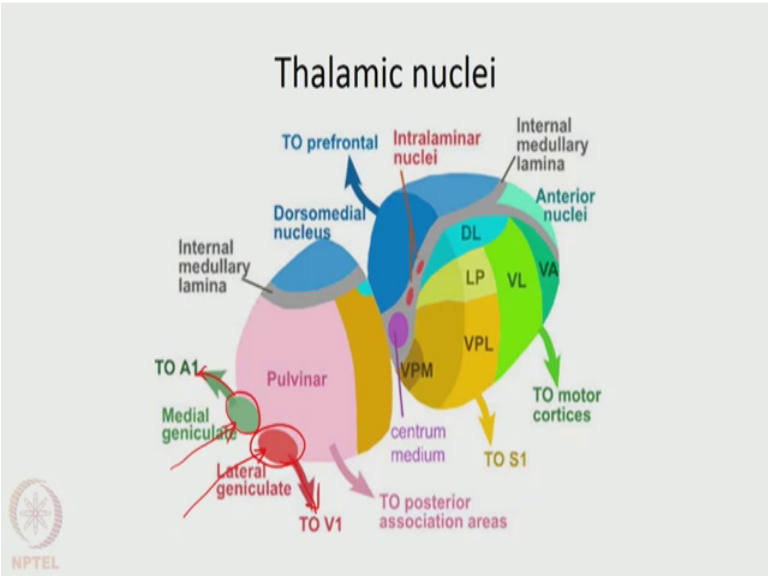

So, let us talk about both these kinds of nuclei. So, this fi picture actually shows some of the connections to the cortex from the sensory organs and you know and then the connections from the co from the thalamus to the cortex. So, we talked about lateral geniculate nucleus right. So, visual information from the eyes comes to lateral geniculate nucleus and then from there it goes to the primary visual cortex.

So, similarly medial geniculate nucleus comes from the information to this structure comes from the ears and from there it goes to the primary auditory cortex and so, on. So, these are some of the examples of point to point connections.

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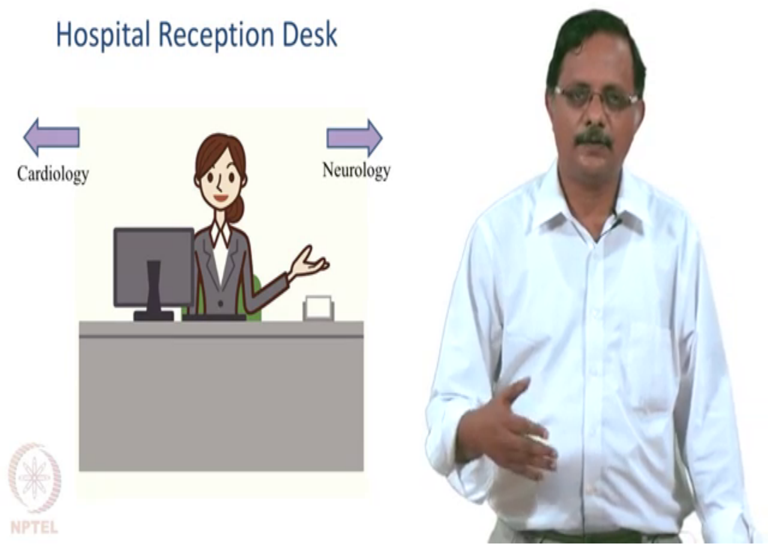

So, you can think of the thalamus has some kind of a hospital reception desk where our patients come into the hospital; and they do not directly go to different divisions or different departments of the hospital, they go to the receptionist desk and then the receptionist directs them to you know which division they have to they are supposed to go to.

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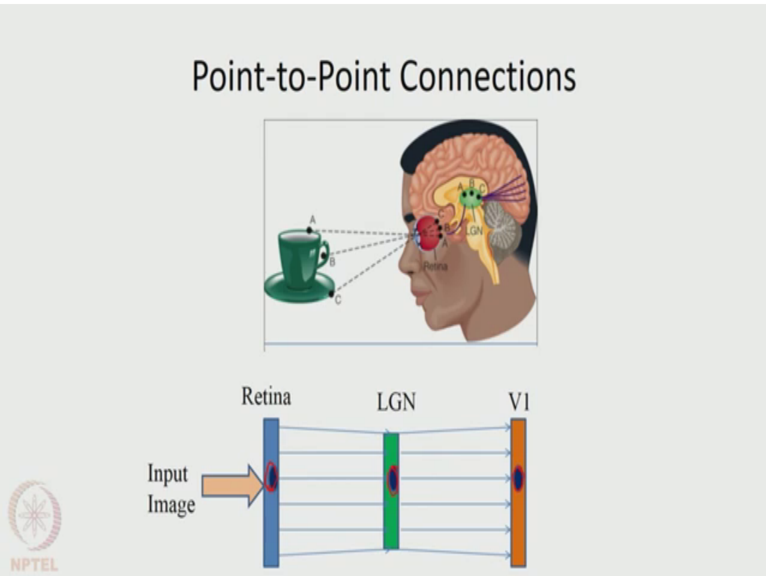

So, let us talk about point to point connections. So, you take as an example consider retina on which the input image falls and information from retinal goes to Aegean and then from there it goes to V 1 . So, what we mean by point to point connections is say if you place a small dot of light on the retina right that produces a very specific image on the LGN, that is; a small local cluster of neurons get activated in response of this dot. And then when the LGN projects to V 1 then another local cluster of neurons in V 1 get activated.

So, what; that means, every point on the retina gets mapped onto very specific a very specific point on the LGN, which in turn gets mapped onto a specific point on V 1 so, there is a point to point mapping between retina and V 1 and which is mediated through LGN. So, this is what we mean by point to point connections have from a thalamic nuclei.

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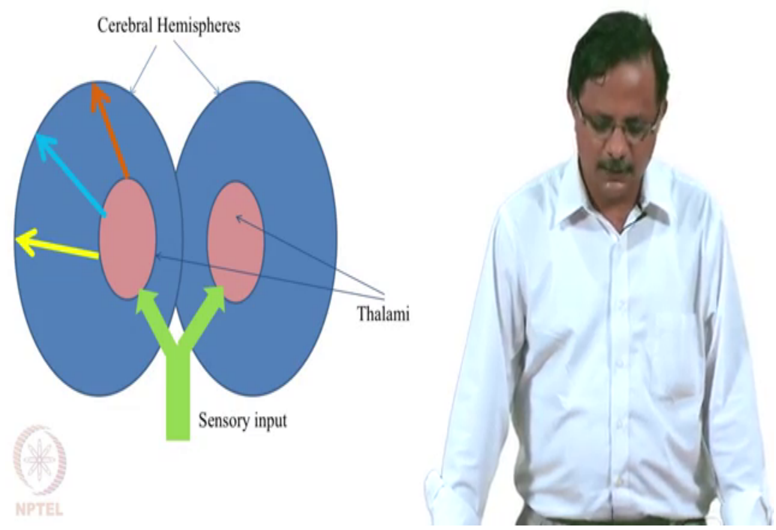

So, as you can see in this cartoon picture a sensory input comes to both the thalami. There are two thala thalamuses or thalami plural right; on either side in either hemisphere and information from sensory sources comes to the thalamus and then it is outed to a various cortical areas. Now one logical question; we can ask at this point is why do you need the thalamus? Why cannot the sensory fibers directly go to the corresponding cortical area right why this stopover because.

In fact, some of the older textbooks on you neuroscience simply describe the thalamic function as if it is a rely nucleus; that means, it just simply takes the input and passes it on to a to a target structure, but why do you need this intermediary nucleus.

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So, let us try to argue the role for a structure like, thalamus by looking at this picture. So, when you look at this picture and you can see that there are 5 horses in it and each horse has is being driven by a horseman right. And they are like moving at a high velocity and you as you can see from their gait and from there the inclination and so, on. And you can also notice the colors of the jackets worn by the horsemen and then that colors of the caps right and the colors of the horses, there are black one the brown ones and so, on and so, forth.

So, you look at this picture; obviously, you do not take in the entire picture as a whole right you shift your attention from point to point on this picture and whenever your eyes fixate on a given point. They gather information about the about the part of the image in the neighborhood of the point very fixated right, because if you want to process the entire image as a whole that requires a lot of computation resources in the brain.

So, for example, if you are looking at this image it is processed by your visual system right your color is processed in say V 4 a part of the visual system and here the fact that the horses are moving. Suppose you are looking at the real video of the horses you can see that horses are moving and that is recognized by motion areas like no mt and mst.

And the fact that there are people in this picture and their horses right that is recognized by some of these object recognition areas of the inferior temporal area right. And then in the lower areas we simply look at patches of color and you know local lines or edges and things and primitive information like this. So, so, to process to apply all this machinery all this visual processing machinery on every part of the image simultaneously is expensive and not economical.

So, brain figure out a way of doing it piecemeal, you know you apply the entire machinery of visual processing. On one part of the image at a time and complete the processing and once you are done there you shift your focus or attention to another part right.

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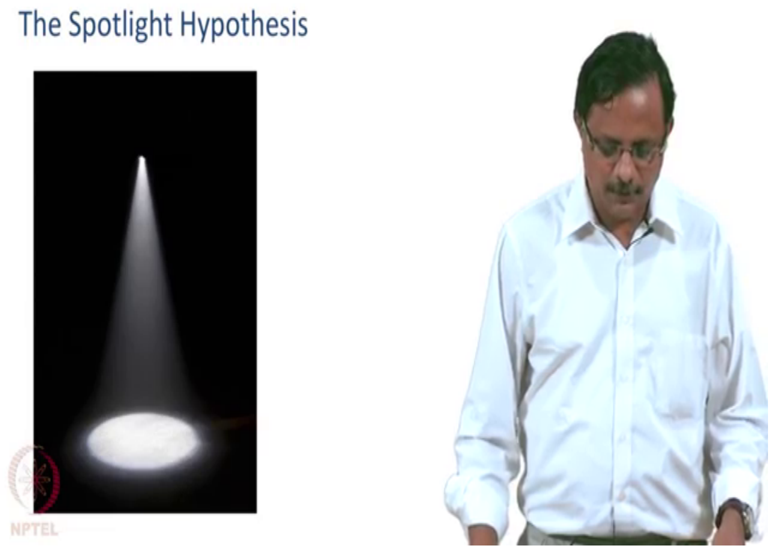

So, you so, you are basically you apply some kind of a spot right and a spotlight basically highlights a part of the stage right which is important at that moment.

And, once it is done the spotlight moves over to another part of the stage which is of interest at that moment.

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There are theories which propose that thalamus plays the role of this kind of a spotlight an attentional spotlight. So, although the wiring is fixed there is some kind of a missionary that goes on inside the thalamus right, this missionary essentially does what you are loo seeing in this picture. So, in this picture you are highlighting a path of the image and whereas, the surrounding area is blurred.

So, you do not have much information coming in surround surrounding area you are trying to access as much information as possible from the central area and by applying some kind of a spotlight in the center the thalamus applies this kind of a spotlight alright.

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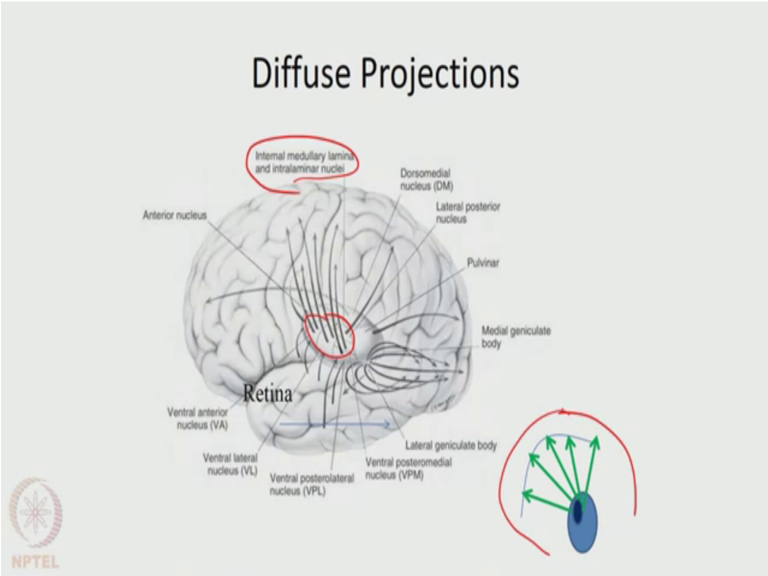

And now let us compute diffuse projections of thalamus. So, like I said there are this point to point connections and from some of the nuclei thalamus nuclei like; L G N and m g n there are other nuclei like for example, the internal medullary, lamina and the inter lamina nuclei right here which can be seen here and these project to extensive parts of cortex. So, like you can see in this cartoon picture here ok.

So, what is the purpose of these kinds of nuclei right? One example that you can give the mini nuclei within you know very diverse functions, but one next example you can give is the effect the action of the esa the another structure called the reticular activating system or RAS.

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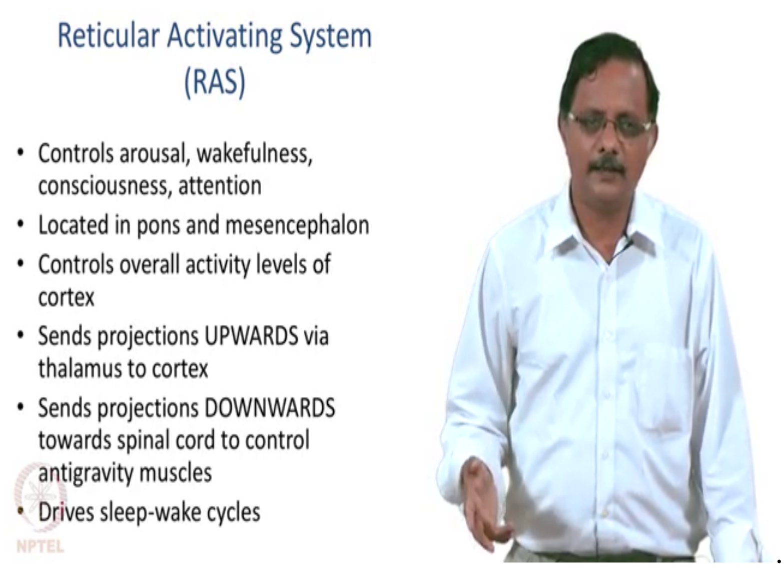

The RAS controls your arousal and wakefulness, some of the systems we have seen before are specific systems you know for example, sensory for processing sensory and you know motor function.

Whereas the array simply controls the overall global state of the brain, because if you want to process sensory information to become aware of sensory information or produce movement; the brain should first be conscious it needs to be in a waking state right in sleep you cannot move much I mean you know you can some people have suffered from a condition called somnambulism where even in sleep they can walk around.

But I mean that is an abnormal condition, but in normal condition you are you know your (Refer Time: 09:04) muscles of your body and the legs are deactivated in sleep in sleep state. So, you do not get to move much during your sleep other than rolling around.

So, so, brain undergoes a global change in state between waking and sleep and this change in state is triggered by the reticle controlled by a reticular activating system and since it is a global change right.

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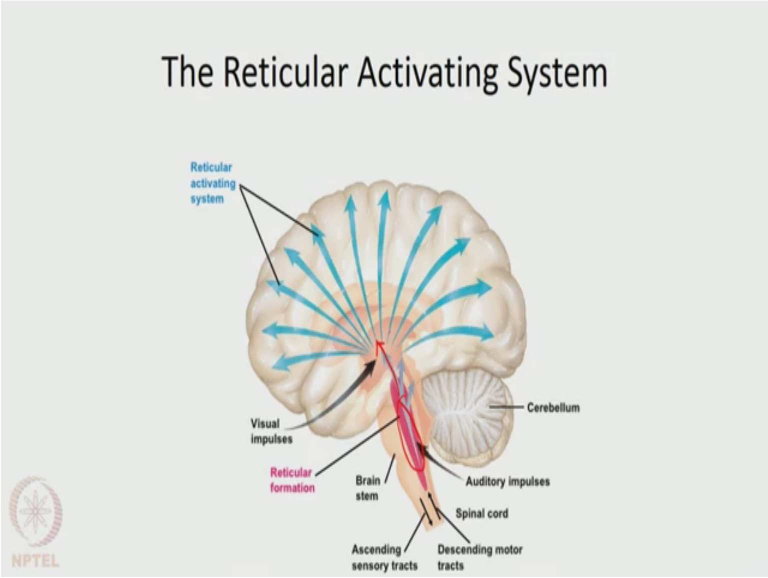

The RAS actually projects to the thalamus and; So, like you see in this picture they RAS is located here it projects the thalamus right and through the diffuse projecting nuclei of the thalamus, they activate and access large parts of the cortex.

So, here there again are two kinds of connections from RAS to from RAS. So, there are the upward connections from RAS to thalamus and from thalamus up and onwards to the cortex then the RAS also sends downward connections to spinal cord. And onward to muscles which control the antigravity muscles these are the muscles which keep us you know erect or you know in a stad standing position working against a gravity therefore, they are called anti gravity muscles.

So, these downward signals also go to control the antigravity muscles. So, in sleep state the antigravity muscles are you know deactivated. So, you do not get to move you do not you do not be would not be able to stand where as in waking state articular are activated or enabled. So, that you know you can stand erect.

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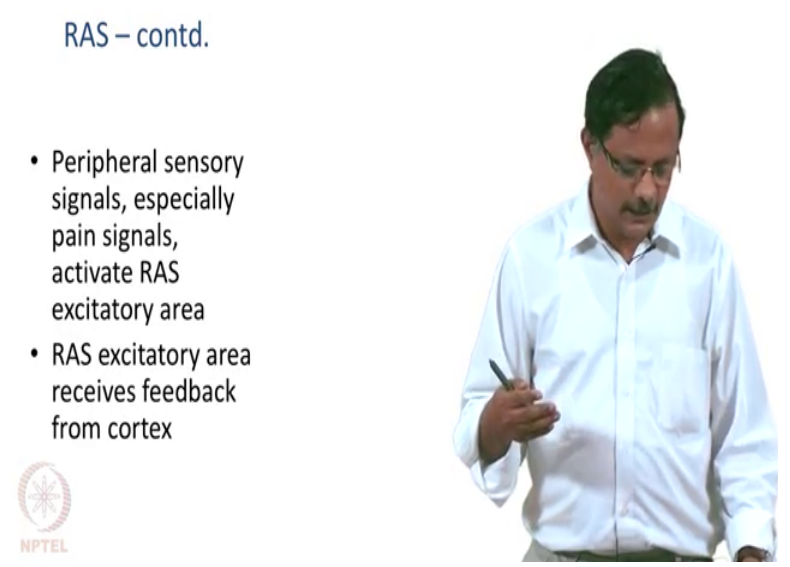

So, these signals from RAS control and through thalamus which through the diffuse collection of the simple thalamus, they control the cortex and change it between the waking and a sleep states.

The RAS intern is also a ca can be activated by the peripheral sensory signals, especially brain signals and that kind of is input you know this feature you can even verify in your personal experience. Suppose you are very sleepy right and you can kind of counter that by simply pinching yourself or rubbing your eyes and no things like that by giving slightly painful stimuli you can act on your RAS and RAS in turn sends signal to the cortex increasing the level of arousal. So, in the cortex, therefore, RAS area a RAS also receives feedback in the cortex. So, when you pinch yourself this signal goes to the soma to sensory cortex and then that sends feedback to the RAS and that in turn changes a arousal.

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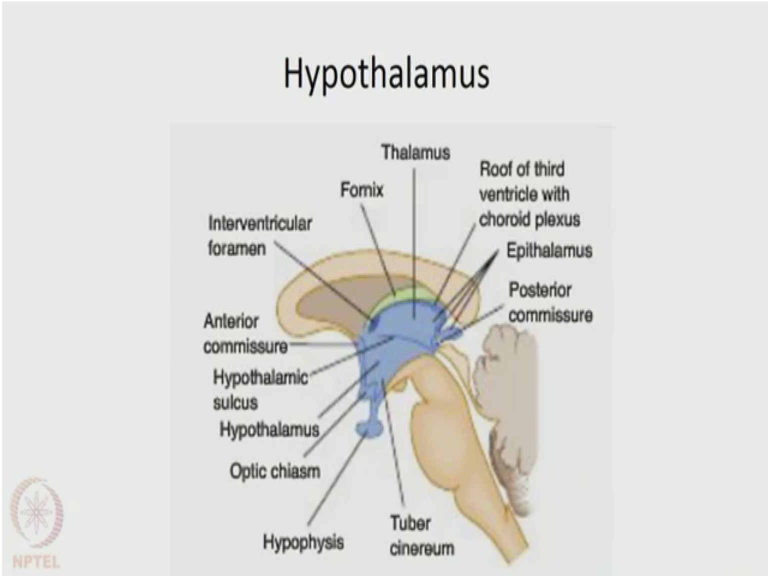

So, another structure which is located ventral to the you know thalamus is the hypothalamus. Now just as the thalamus can be considered as a as a junction point between the world and the brain you can think of hypothalamus has junction point between the brain in the body right; because brain is not just you know receive information information from the world and acting upon the world it is also 7 times receive information from the body and in turn controlling various body type processes.

So, a lot of that control from the brain to the body they runs through hypothalamus.

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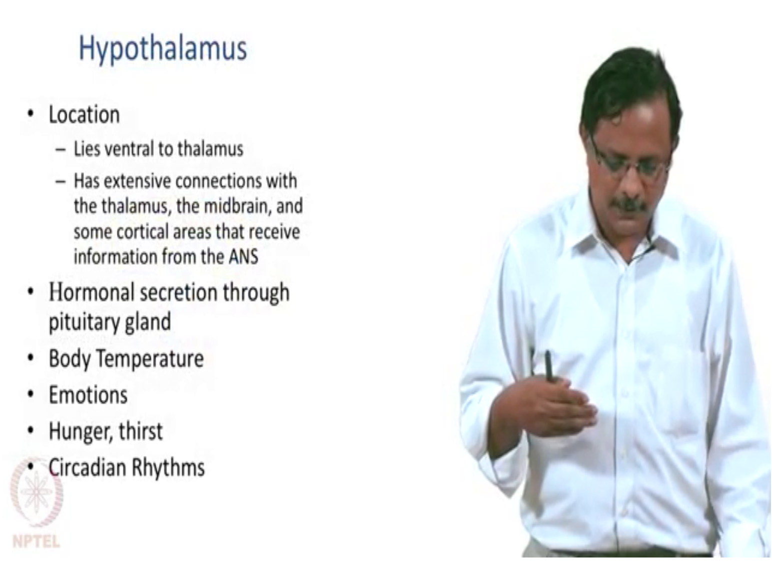

So, hypothalamus is a extensive connections to the thalamus and to the midbrain and other cortical areas, which receive input from the autonomic nervous system this is a part of no system which is responsible for controlling the bodily organs and it is also in involved in hormonal secretion through pituitary gland and know thing you can see this picture here pituitary gland is not shown here it is somewhere in front of you know here in hypothalamus. So, this gland is the master gland. So, the gland system of the body is called the endocrine system and pituitary gland is the master gland which controls the other glands. So, the hypothalamus controls the pituitary gland it also controls other bodily parameters like you know body temperature emotions hunger thirst activities and circadian rhythms.

So, circadian rhythms are inter intrinsic bodily rhythms which are roughly a 24 hours long. So, we know that a lot of you know the process that you see in the world are driven by the day and night cycle right; that is driven by the external you know some movements of the sun and all that, but there are internal processes also which are roughly 24 hour hours long . So, that is why they are called circadian rhythms the separate brain structure called the suprachiasmatic nucleus which controls the internal bodily circadian rhythms and. So, the super suprachiasmatic nucleus also know talks to hypothalamus and also the RAS to control the sleep wake cycles.

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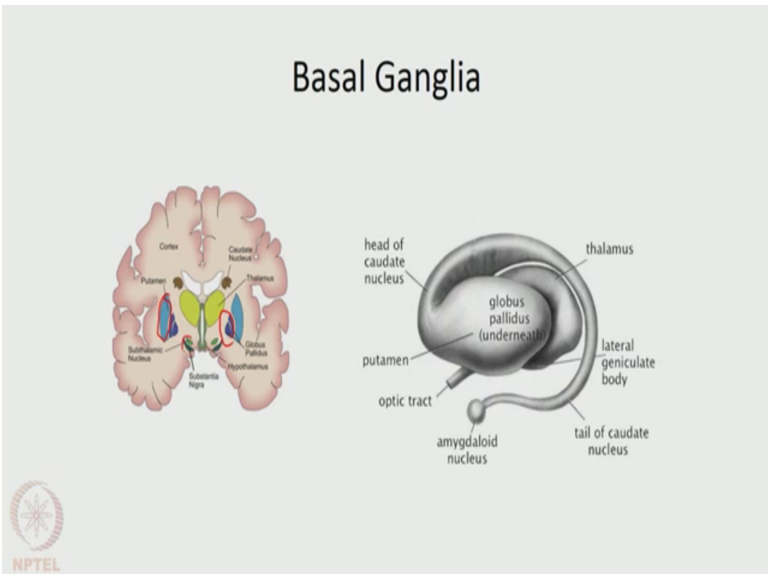

So, then there is a structure called basal ganglia which is also subcortical structure it is actually a circuit of several nuclei you can see some of them here in this coronal section. So, the globus pallidus and the putamen and the light blue region then the substantia nigra then there are two of them there are and the subthalamic nucleus here the green structure right and all these structures together are called basal ganglia.

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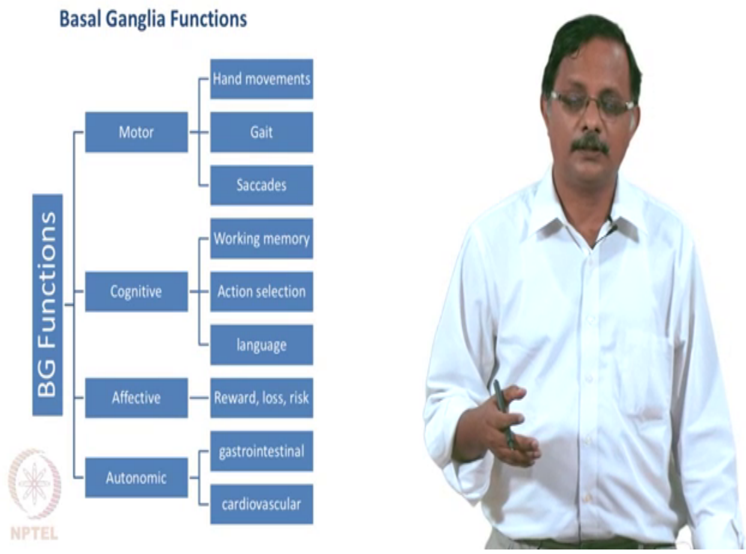

And so, they these this circuit right is involved in a lots of functions. In fact, it is they are involved in pretty much the all the four major functions of the brain, that is; motor cognitive affective or an emotional and also autonomic or which is related to the functions of the autonomic nervous system.

In motor again they control a variety of motor functions like for example, movements of the hand or movements of the legs or gait movements of the eyes or circuits and so, on. So, in cognitive the control working memory or action selection. So, if you have multiple actions among which you have to choose the best action right; how do you choose that based on which action is going to be most rewarding ok. So, this function is strongly controlled by basal ganglia and then language also.

Then effective it controls the reward a loss and risk in autonomic it controls gastrointestinal processes and in a cardiovascular activity.

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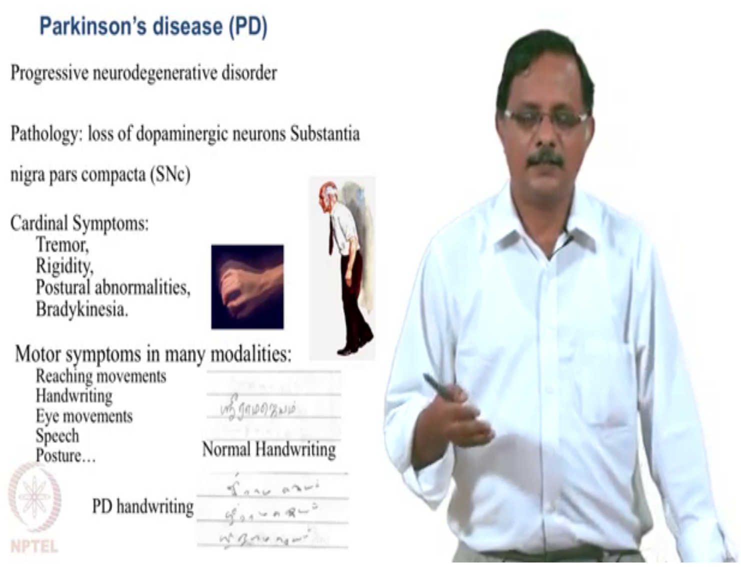

So, one of the diseases which associated with the function of basal ganglia is the parkinsons disease it is a progressive neurodegenerative disorder it is characterized by loss of a cells. In this one of the best linear structures are called the substantia nigra pars compacta or SNc and there is no cure for the disease there is only management you can slaughter them to slaughter the disease by use of drugs or you know brain stimulation and other methods, but today there is no way of stopping this loss of cells in this part of the brain and loss of cells in this tiny part of the brain can have a very substantial or dramatic effects on symptoms there are four major symptoms called the cardinal symptoms of parkinsons they are tremor the this in a shaking of your hands and other extremities there is digit of the joints and postures abnormalities.

So, very often you see pd patients walking with the little stoop that is a postural abnormality and bradykinesia refers to slow movements slowness of movements. So, they move slowly. In fact, this slowness in movement is also sometimes extended to slowness in thought right they think slowly they react slowly . So, the this is which is called bradyphrenia. So, brady is slower and phrenia is mine. So, like I was mentioning before motor symptoms in pd can be linked to moments of reaching moments of handwriting like pd patients have this kind of a peculiar handwriting where they write very small letters it is called micrographia.

Ah they also have problems with eye movements and problems in speech and posture and. So, on. So, within motor that pretty much all the forms of motor out of motor modalities can in principle be affected in this disease in a given patient all the you may not see all the symptoms, but in principle all these symptoms can be seen in pretty patients just because of loss of cells in this tiny little part of basal ganglia the SNc.

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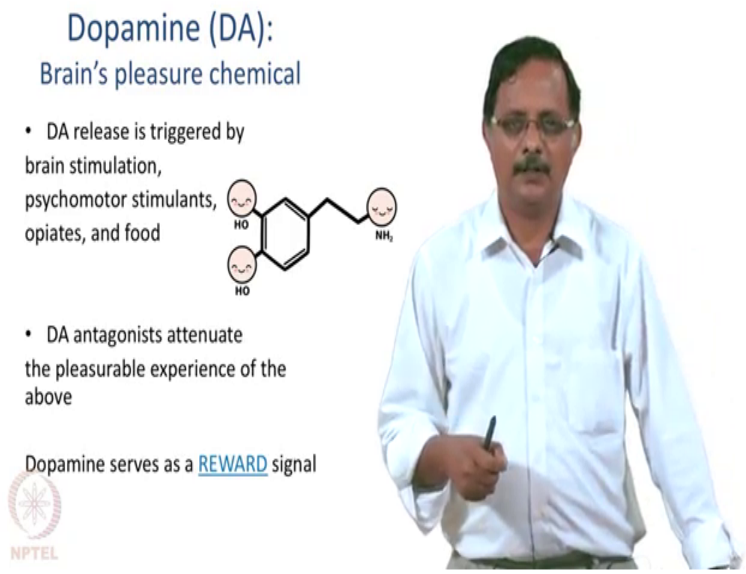

So, an important chemical which plays a lot of coordinating role in the process of basal ganglia is dopamine it is called the brains pleasure chemical it is released by brain stimulation. For example, there are this pleasure centers in the brain right which; when stimulated electrically by placing the electrode can give a sense of pleasure you know the person feels happy if we know if you can somehow place a wire electrical electrode in that part of the brain and pass current in that part of the brain.

So, some of these earlier studies were in about done in the 60s and on exposed animals; in some extra extra means animals were hooked up by an electrode like this and there was a set up by which the animal can just press a lever and which will activate his electrode and the electrode passes current in the pressure center. So, the animal kept on choosing you know and this pressing the le kept on pressing the lever and activating it is it is pressure centers and at the cost of forgoing food. So, the animal literally stopped itself right it just simulated simulated cell through this electrode, but in did not take any food. So, it is a kind of addictive process which which is triggered by stimulation of these pleasure centers.

Now, when this similar pleasure centers are simulated dopamine is also released in addition if you take psychomotor stimulants you know drugs opioids all these addictive substances also cause release of dopa dopamine and even food can be addictive food is also a pleasurable kind of stimulus. So, therefore, food also causes a release of dopamine and contrarily application of dopamine antagonists. So, that is substances which counter the effect of dopamine right attenuate or suppress the pleasurable experience of the own kind of miserable stimulating.

Therefore, it is thought that dopamine cells serves as a reward signal; it represents reward right in the brain and there is lot of evidence to support that.

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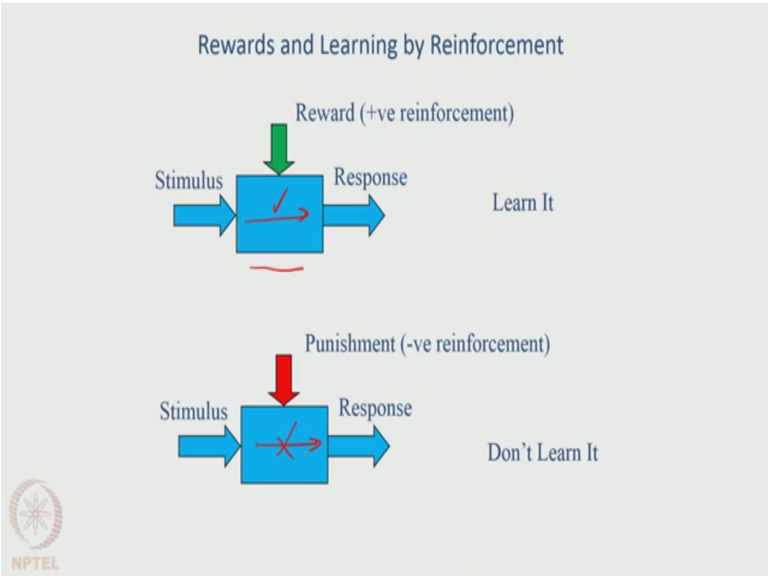

So, the fact that dopamine represents reward right has been linked to a certain form of learning called reinforcement learning. So, which has been observed in animal psychology for a long time, an enforcement training basically the animal or the agent right tries to learn the correct response to a given stimulus by taking the reward or punishment feedback from the environment.

So, to take an example; let us say and say this is an animal which looks at a little say a yellow thing and thinks it is a some kind of food item and grabs it and eats it it turns out that it is a good food item very nutritive and all that and tasty. So, next time when the animal sees the same stimulus same object it will, but you know exhibit the same response and eats it.

So, that is what you see in this upper block diagram. So, you have the agent or the animal which looks at the stimulus. In this case the yellow object and produces a response and that gave a reward to the animal, because which is probably represented in the form of 4 dopamine signals and, because of that reward the stimulus response connection is strengthened. Further, right and next time around for the same stimulus animal produced the same response it learns that relationship.

Whereas, imagine another case where the animals saw some and a brown or a red object and grabs it and it gets bitten right. Now stung by that say bug right and next time around when they sees when the animal sees the same object it stays away from it or avoids it. So, in this case for a given stimulus when the animal produces a response which has lead to a punishment or negative reward or negative reinforcement and therefore, next time around the animal does not produce a response the same response and in this case the connection between the stimulus and response is attenuated or suppressed.

So, this kind of learning is called enforcement learning and there is a lot of evidence that the base layer system exactly is involved in implementing this kind of reinforcement learning.

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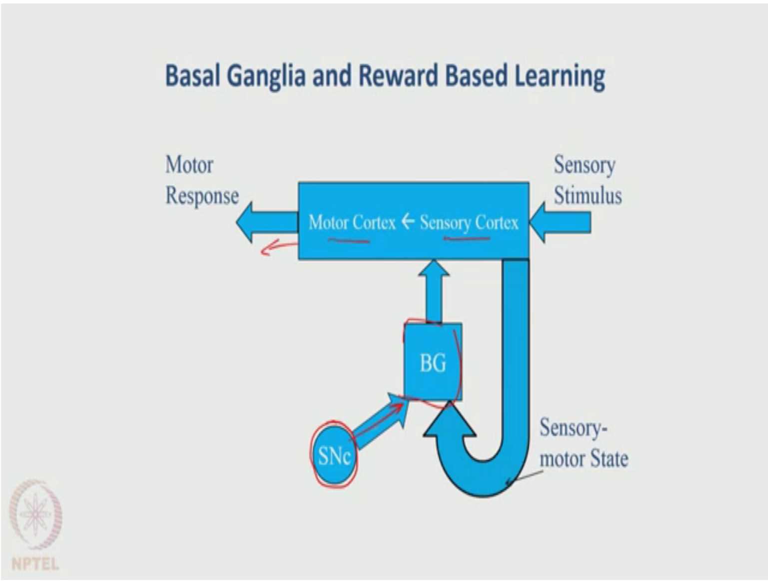

So, if you look at the anatomical position of the basal ganglia it, basically takes input from the sensory and motor cortices and. So, if you apply the previous you refer to the previous slide where there is an agent which takes the stimulus and produce a response right within the brain you can imagine that the stimulus information goes to the sensory cortex right, and then the sensory areas project the motor areas and the motor areas produce this commands necessary for movement.

So, this like the main pathway and the information from sensory and motor cortices is also project at the basal ganglia and basal ganglia also receives information from substantia nigra at which is where there are dopamine cells and dopamine is released here. So, when you have a pleasurable experience dopamine is released from the substantia nigra neurons and also other dopamine clusters also. So, there also dopamine is released.

So, dopamine from substantia nigra goes to a basal ganglia. So, you can see that just like in this in a schematic where this box like has access the stimulus information response information and the reward information basal ganglia has access here to the to the stimulus and response, that is; motor and sensory areas coming from the cortex it also has access to the reward information which is coming from the sensory you can combine these three forms of information. And then send its output back to the motor cortex and recommending it to strengthen the connection. So, that it produces the same response next time around or recommending it to attenuate the connection. So, that you know asking it not to produce same response next time around when it sees the same stimulus ok.

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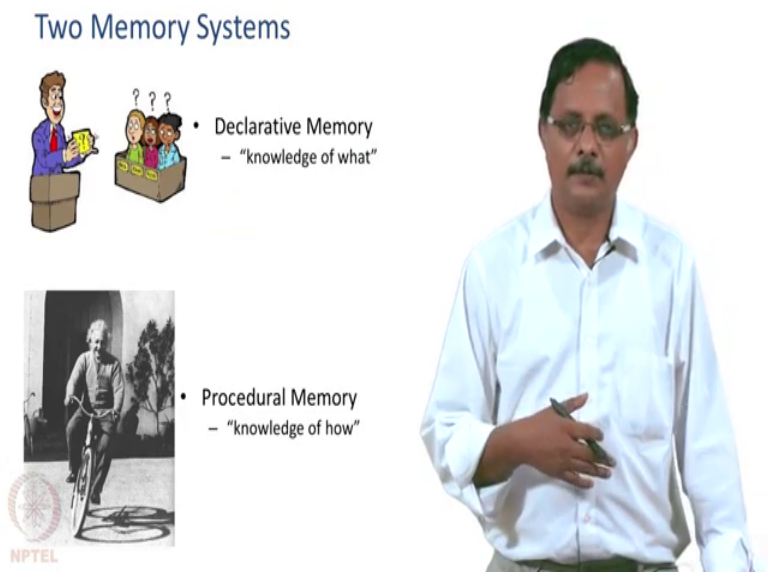

So, that is what basal ganglia does? So, when we talk about basal ganglia we should mention that there are two kinds of memory systems in the brain. So, first is called the declarative memory which is referred to the knowledge of what right here it is called declarative, because this is a kind of knowledge which you can express like for example, what is the capital of India or what color is a typical leaf right and so, on..

So, so this is this is a kind of these are factual information right and the other kind of information is procedural memory; this is a here this is described as knowledge of how this is the first memory of motor skills. So, for example, are riding a bike that something cannot declare you just know it is in your motor system you can do it, but it is hard to define it precisely.

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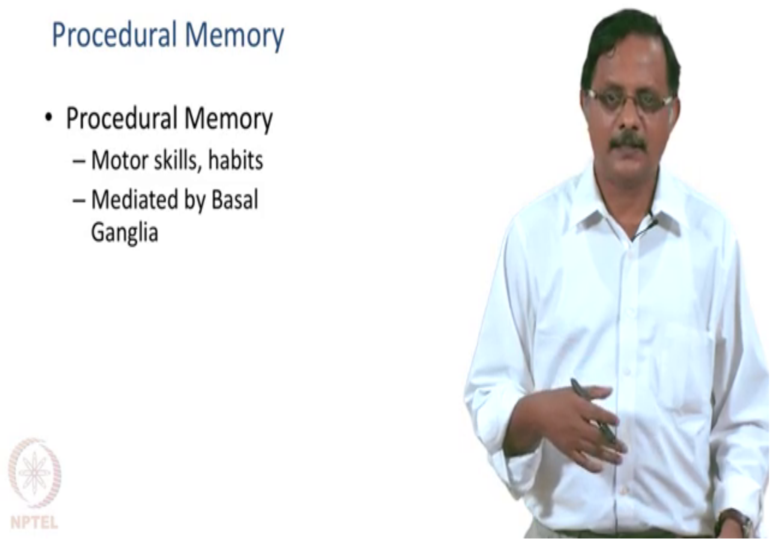

So,. So, so the basal ganglia is involved in the memory of motors you know motor skills or habits are which is the procedural memory whereas, for the other kind of memory the declarative memory is a different structure.

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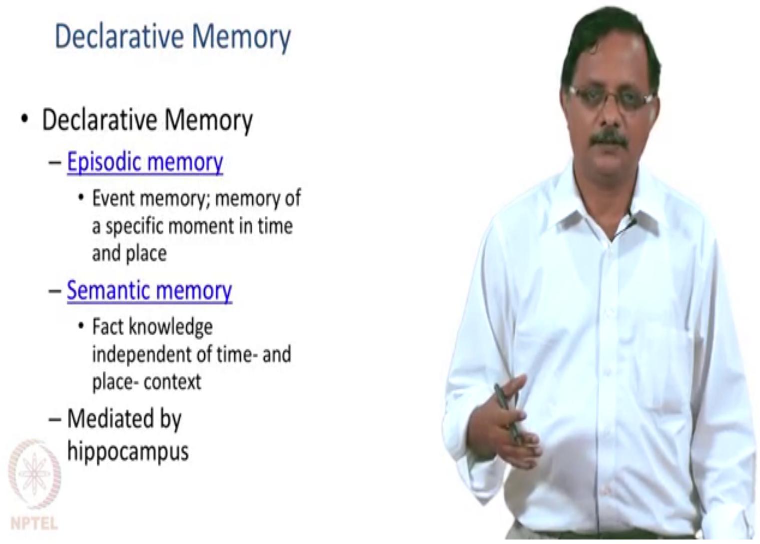

Which is involved and that is called hippocampus ok.

And within declarative memory there are two subcategories; which you know refer to the memory of events and, that is episodic memory and our memory of facts right which is called semantic or word memory or I refers to the memory of names of you know things and places and things like that.

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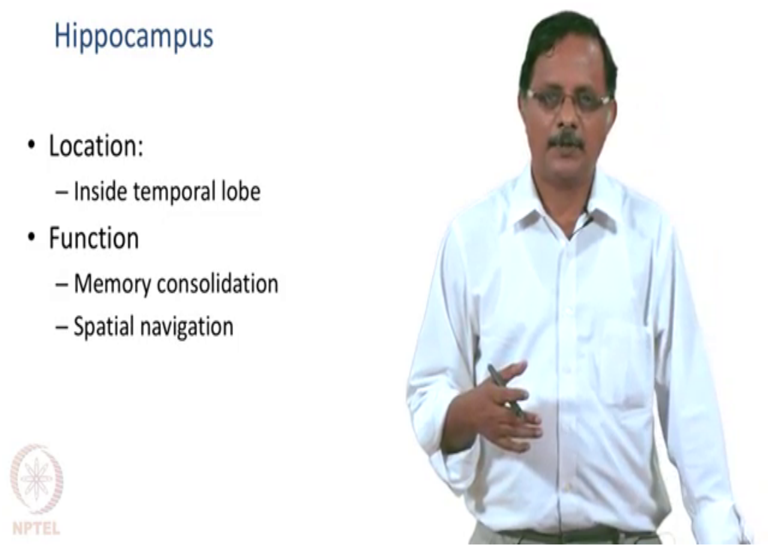

So, hippocampus is located inside the temporal lobe as you can see in this figure say this long structure is the hippocampus.

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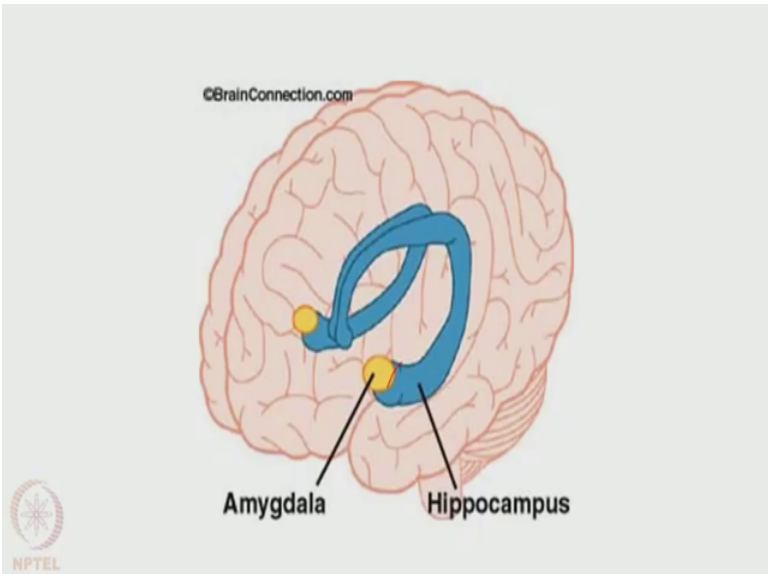

Its function that two na important functions it does memory consolidation, that is; when you receive information from outside through sensory apparatus and through sensory systems this information is thought to be stored for a short time in the hippocampus and then from there it is thought to be passed on to long term stores in the cortex. So, therefore, it is it is it will place a major role in mem memory consolidation.

In addition it is also plays a role in (Refer Time: 24:42) case. How do you find a way around in this three dimensional world and navigate the three dimensional space. So, let us look at that first of all.

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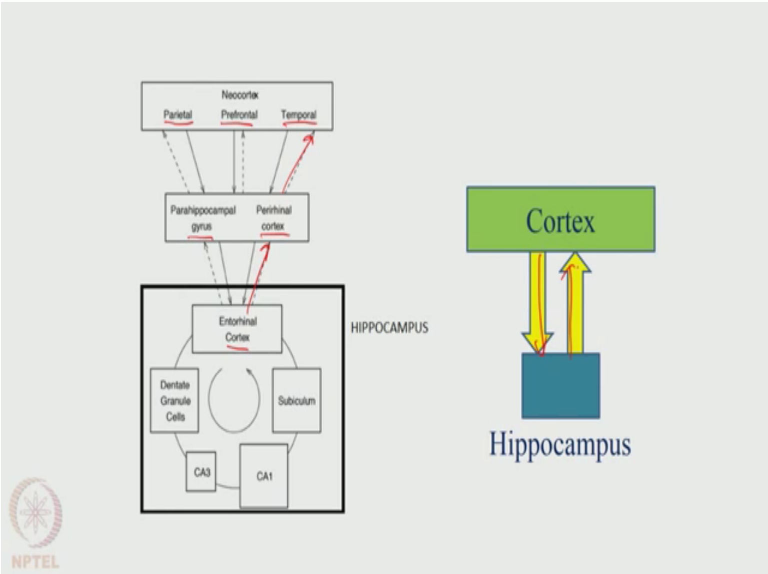

Let us look at the anatomical position of hippocampus. So, hippocampus receives information from widespread cortical sources. So, here you can see that it receives infor information for parietal areas the prefrontal areas and the temporal areas I mean; that is pretty much you know the whole of the cortex and these projections go to two smaller cortical areas called the parahippocampal gyrus and peritoneal cortex and from there these two areas further project to one cortical area called the entorhinal cortex.

So, these are located below the temporal lobe and they are not visible in this view and . So, this at this entorhinal cortex is called is the gateway to the hippocampal complex. So, from here information goes to the dentate gyrus here and then a field called CA 3. Another field called CA 1 and subiculum and comes back to the entorhinal cortex and from here it is projected back via the same pathways back to the cortex. So, in a simple schematic this anatomical relationship can be represented like this. So, you have cortex which projects to hippocampus and then hippocampus projects back to the cortex.

So, this is you can see that there is a huge reduction right in the in the size of the number of the number of dimensions involved in this representation. So, hippocampus also thought to do some kind of a data compression right when it receives inputs from the cortex. Let us think you know present a simple schematic right by which we can explain; what kind of a compression the hippocampus does? And what is really does it represent right about the sensory state in the sensory cortices?

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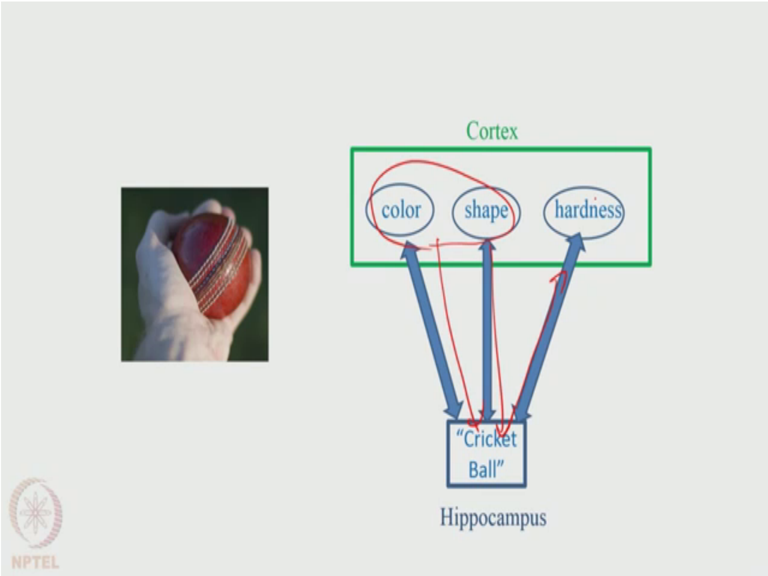

Let us say you are holding a cricket ball right in your hand and when you are doing this right in your brain and sensory areas of the brain many areas are activated. So, you see this large patch of red color right and you see then in response to that some of the color neurons of your V 4 area are likely to be activated. Then you see that the ball is round right the circular in this view and therefore, you see some others are neurons which they represents shape right in, in both in V 1 and V 2 and also higher up in it area that these neurons will get activated.

Then since you are holding it you can touch it and feel it. So, you can also recognize that it is a hard object. So, hardness is also represented in some of the neurons of your somatosensory either primary or secondary somatosensory areas. Now all these areas are representing the same object and all these areas through higher a higher cortical areas through higher sensory association areas project hippocampus after a few stages.

So, in hippocampus there are neurons which respond to this whole combination of sensory inputs. In this whole sensory pattern right and then, probably there are neurons which represent this who was firing activity represents this cricket ball. So, if you see this color and this shape. For example, right that activates this cricket ball in a neuron. So, to speak and once the cricket ball neurons are activated and then they send feedback to the again to the cortex and then that will activate the other parts of the cortex also.

For example, even though you are not holding the ball if you are even, if you are just looking at the ball in the right and the visual features of the ball and activate the cricket ball neurons of the hippocampus and these neurons. When they activate the cortical areas back they might activate the somatosensory areas also.

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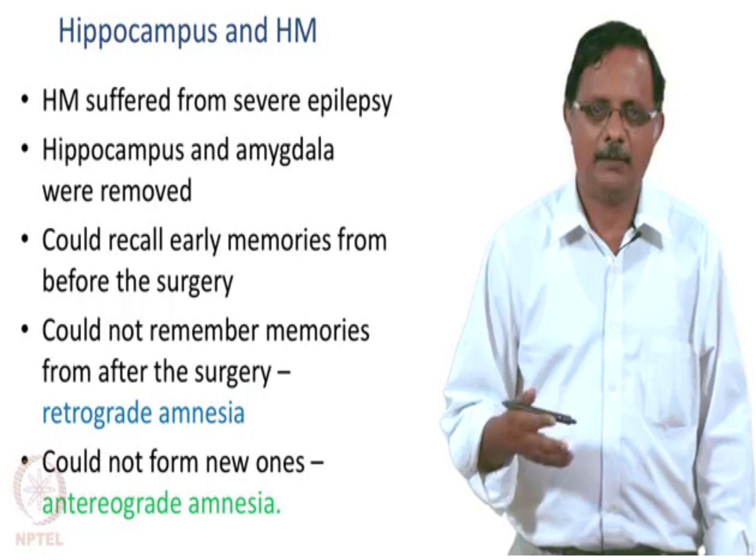

So, we when you are looking at the ball you have a kind of a sensation or a feeling or a memory that the ball is a hard object. So, a lot of data about hippocampus has come right in the earlier studies by this patient called right. These are the initials of his name and this suffered from severe epilepsy and. So, an epilepsy is a kind of disorder where there is abnormal electrical activity that spreads from point to point in the brain and usually this activity start from some one point and spreads to. Typically the whole of the whole of the brain whole of the cortex and starting point this trigger point is very often in the temporal lobe . So, this please points are called the epileptic foci.

So, a surgical treatment for this kind of a condition is identification of the focus and you know and surgically loosening the surrounding area in some cases in the earliest surgeries that were performed as a treatment for this condition about somewhat crude and then the surgeons would remove the entire temporal lobe. So, as soon as surgery was performed on and along with temporal lobe his hippocampus and amygdala were also removed right.

So, because of this initially they the family members and the surgeons did not find anything wrong with the patient, but very soon they notice that he had very serious memory problems. So, for example, he could not recall memories from events that occurred after the surgery and that is called retrograde amnesia

He also could not memorize new things . So, that is called anterograde amnesia he could only memorize things for a short window after the event has occurred like for ago 10, 15 minutes, but after that the memory is gone. So, for example, if the doctor came to meet him right in the hospital ward the patient would talk to him introduce himself and so, on. And then the doctor came back again in the afternoon or maybe the following day it was like a new experience the patient had did not have any memory of meeting the doctor on the previous day. So, that is retrograde amnesia and then the inability to and to form new memories is anterograde amnesia right.

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So, that is something about the memory consolidation functions or hippocampus. I just mentioned that hippocampus is also involved in spatial navigation that is; how do you find your way around that in a city or you know in the spatial in the spatial three dimensional spatial worlds.

A lot of this work was also done on rats because lights are known for their excellent spatial navigation capabilities. For example, you can leave a rat in a maze like this what you are seeing on this slide and you know after some experience after some running around in the maze the rat very often finds the way out. In this case the motivation of other rat is a piece of cheese that is located outside a maze and it can find its way around and find the find the cheese ok.

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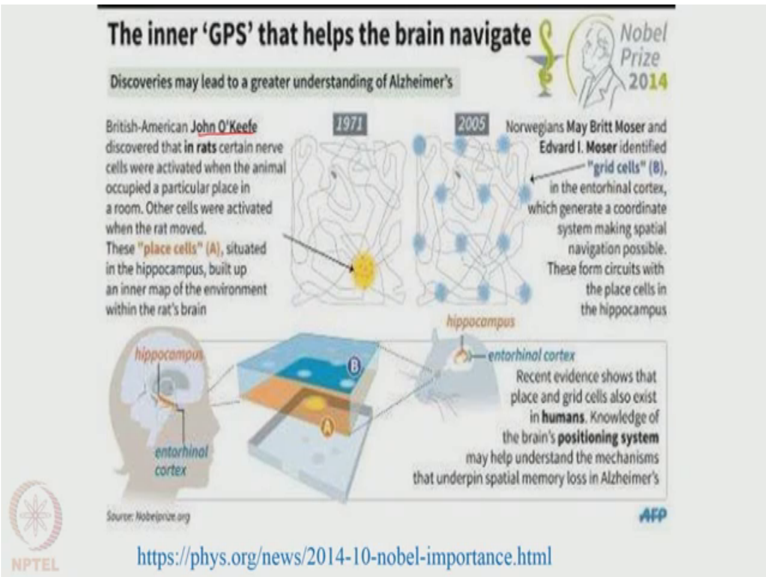

So, the spatial navigation properties of hippocampus you know became quite popular in the recent times, because of the Nobel prize that was given in 20, 14 to work done in this area. So, this popular article on the about that Nobel prize event talks about basically the hippocampus has inner GPS which is called the GPS of the brain which helps the brain to navigate in space. So, this was given to three people and one of them is John Okeefe who has worked on rats and found out that. So, within the hippocampus. So, in 1971 he has found that within the hippocampus there are cells which respond whenever the animal is in a certain location or certain place in the maze. So, in this case you can see this you know zig zag paths these are the parts of a rat moving around in a maze and whenever the rat comes to certain location the place cells fire; that means, that cell represents that location in the maze.

Ah similarly later on in 2005 the couple Mary Britt Moser and Edward Moser discovered new kinds of cells. So, these cells also fire in whenever the animal is at some location, but they do not fire only at one location they fire at multiple locations. So, same neuron fires when the animal is at any of these multiple locations and the what is very intriguing about these cells is all these areas form a very nice periodic spatial pattern and very often these patterns are hexagonal grids. So, therefore, these cells are called grid cells.

So, the grid cells are very intriguing it is really quite challenging to understand how a cell can respond to such you know patterns of such great spatial symmetry. So, these are called spac spatial cells which was found in different parts of different aspects of the surrounding space and. So, that they give some clues to how hippocampus represents the surrounding space and how it enables special navigation.

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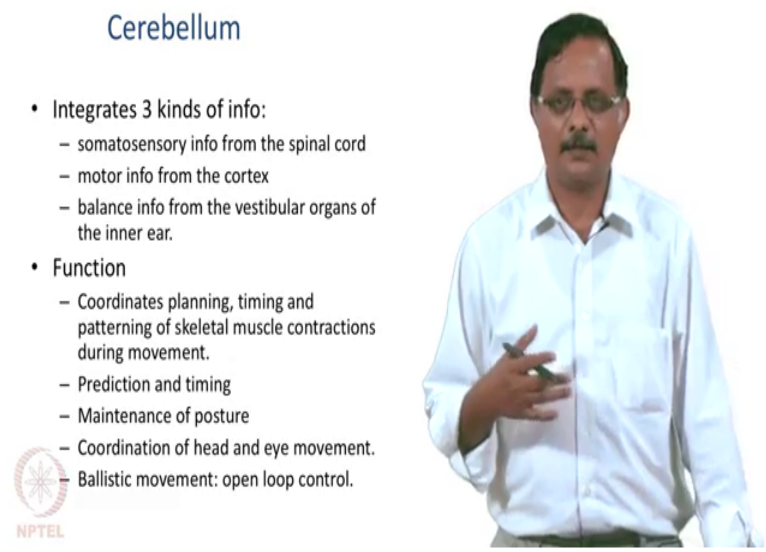

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Next let us come to cerebellum a cerebellum is the structure which is seen .

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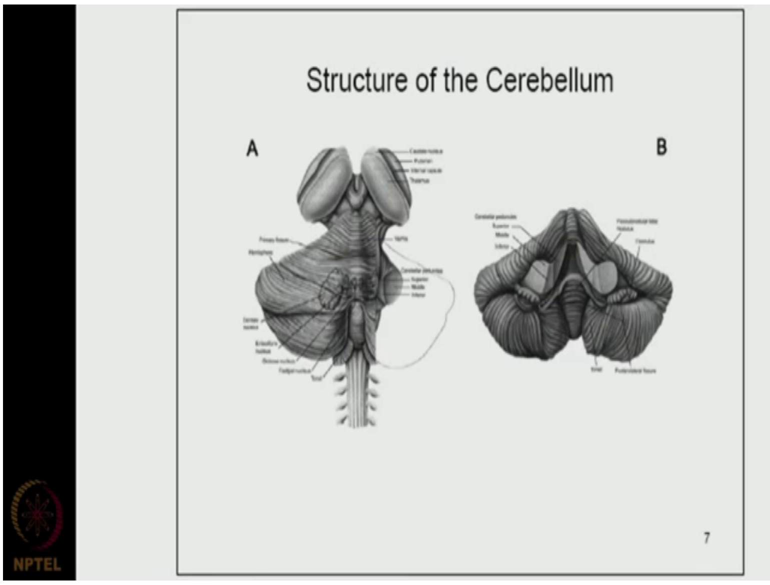

When tell to the occipital lobe it integrates three kinds of information; it receives information on the somatosensory information from the spinal cord receives motor information from the cortex and it also receives balance information from the vestibular organs of the inner ear it has diverse functions. So, for example, it integrates timing and patterning of a skeletal muscle contractions during moment and it is involved in prediction and timing that controls your posture maintenance of posture it also coordinates a head and eye movements its role in fast movements or open loop movements called ballistic movements.

So, because a lot of our movements are closed loop movements and for exam we want to hold a cup and I want to move my hand to hold a cup I am looking at the position of the hand at every instant right every point in this moment and I am looking at the position of the hand with respect to the cup and with that feedback right I adjust my hand position, but for certain kinds of moments you do not have the time to take a feedback for example, if you are jogging or sprinting right you are your steps are you are laying your steps. So, fast you do not have that time to wait for the feedback that comes from the footfall ok. So, such movements are called ballistic movements and the cerebellum is known is thought to be involved in ballistic moments and. So, it is necessary for making these fast movements.

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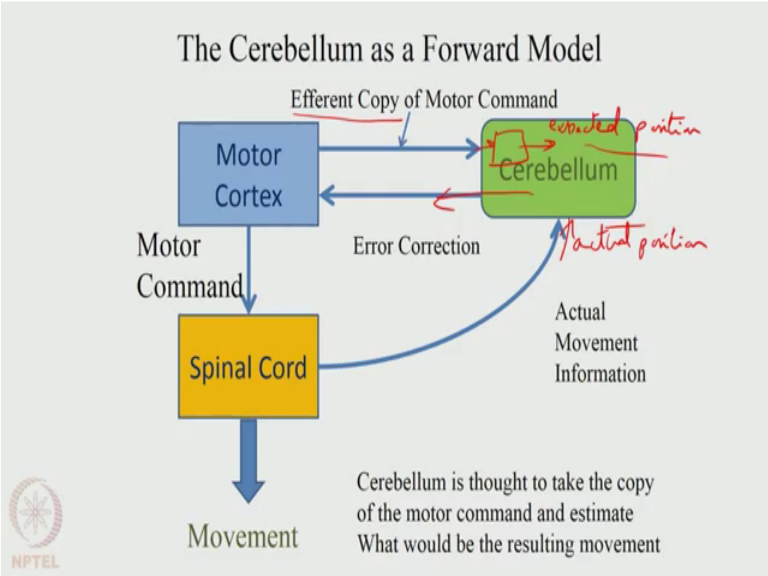

So, this schematic shows a one aspect of cerebellum function ah, but it does lot more than what is shown in the schematic. So, for example, when you are moving that your motor cortex sends a command and the motor command to the spinal cord and then spinal cord then sends commands to the muscles which produce the movement.

So, at the same time motor cortex also sends a sense a copy of the motor command to the cerebellum it is called the efferent copy right or the motor command which is sent to the cerebellum, when cerebellum takes this command and is thought to implement what is called an internal model or a forward model. So, basically it takes this command and inside cerebellum, there is machinery which takes this command and estimates what will be the; expected position of the hand or legs or whatever you know kind of factors which are being controlled by this motor command.

So, the spinal cord gets sensory input about the muscle position the muscle legs and basically the partial information or proprioceptive information from the body and sends it back to the back to cerebellum. Then cerebellum receives this motor camera and the copy of the motor command and using this internal model it estimates; what is the expected position of the of the of the body?

So, cerebellum compares the expected position and the actual position which comes from this spinal cord it compares this two and there is a mismatch between these two then the motor command did not succeed in producing; that in the correct configuration of the body which it is seeking to produce. So, therefore, this error between the expected position and the actual position right is sent back to the motor cortex right the therefore, the motor cortex adjusts its command and maybe it gives a stronger input or a weaker input. So, that to the high end (Refer Time: 36:57). So, that the expected position matches the actual position.

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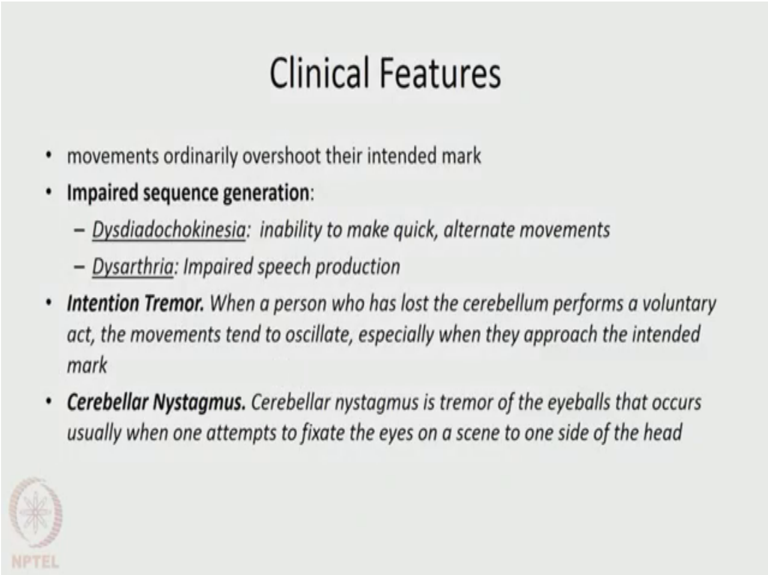

So, . So, damage to cerebellum has associated with can be seen in lots of symptoms. So, for example, since cerebellum is necessary for making fast moments right movements which are which involves fast moments umm right the patients will find difficulty in making such movements. So, one such clinical manifestation of this inability is called dysdiadochokinesia right which refers to making fast alternating movements something like this which is a kind of movement that you see in when karnatic musicians write sing .

Then this is also dysarthria which refers to impaired speech production. So, cerebellar lesions also give rise to intention tremor. So, it is a kind of a shaking which gets intensified. When the person reaches the intended goal position. So, you suppose you are trying to reach some object right and there is a cellular lesion right and the person suffering from intention tremor just; when the hand is approaching the object, then the tremor intensifies and stands and start shaking right now intensely.

There is also a problem it could be a problem with eye movement or what is called nystagmus? So, cerebellar nystagmus it which refers to the tremor of eyeballs right and this again is intensified this kind of tremor is intensified when the person tries to make fixate on a given point on the scene.

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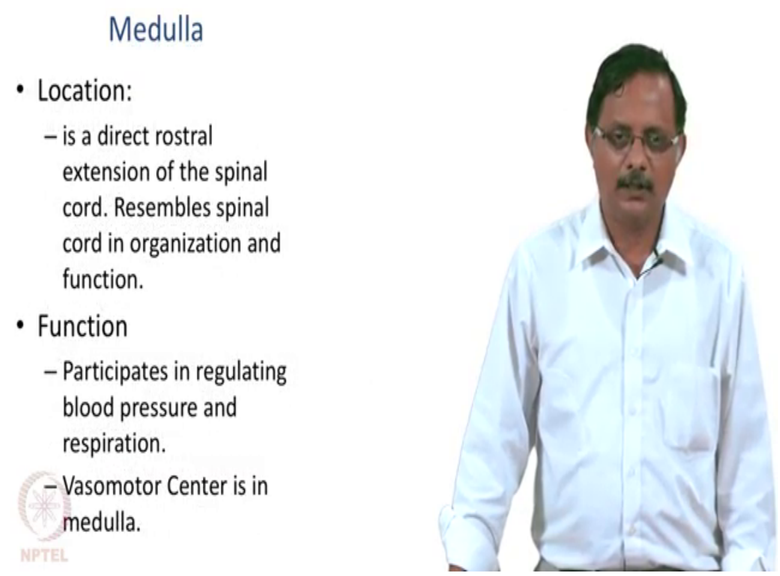

Then there is medulla which is located the rostral to the spinal cord and we talked about medulla and pons in the last lecture right and it is between the spa spinal cord and the cerebrum right. There are a lot of centers in medulla which control cardiac function and where is and which these are called vasomotor centers and it also participates in regulating blood pressure and respiration.

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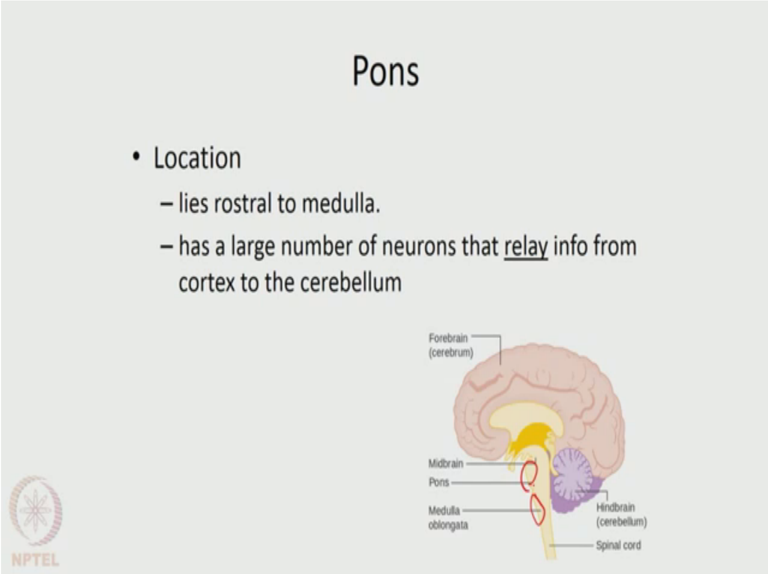

So, pons you can see in this picture pons is here and medulla is this is here and pons has lies rostral to the medulla that is; you know upwards to the medulla and it has a lots of neurons that relay information from the cortex to the cerebellum. So, this huge bundles of fibers called the peduncles right carry information from the cortex to the cerebellum.

So, so, so far we talked about lots of different components in the brain. So, we talked about sensory areas and motor areas in the last segment in this like; we talked about several subcortical structures, but you must remember that this kind of a bucket list kind of approach to brain structures is not a very convenient way of thinking about brain structures we should quickly refer to them as parts of systems, but then it then it seems more logical you. So, you can have more logical understanding of the function of these components.

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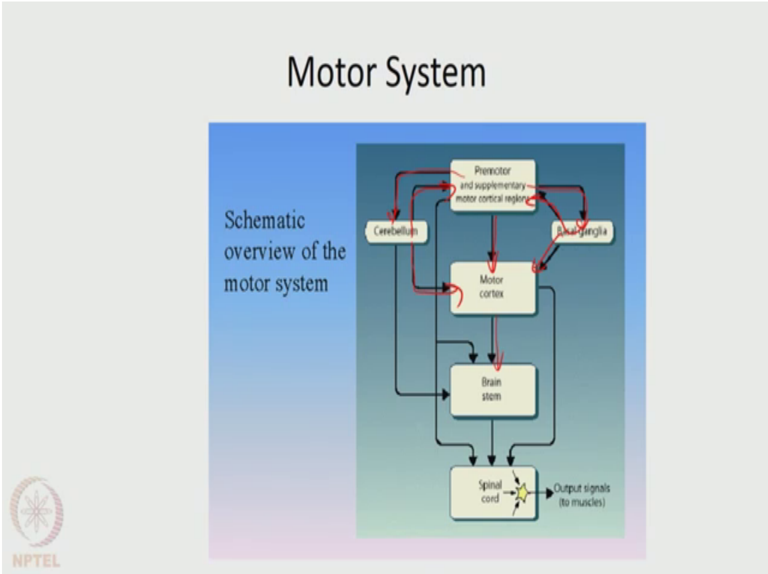

So, for example, now if you are talking about the entire motor system from the brain, then at the highest levels of this motor system you have the promoter areas the supplementary motor cortical area and. So, on and these then send projections down to the motor cortex, they are the primary motor cortex which in turn sends projections to the brainstem and then which in turn sends projections to a spinal cord. And spinal cord is called the final common pathway right through which all motor output should pass.

So, then when spinal cord neurons in the motor neurons of spinal cord send directly projections to the muscles and which muscles which when activated produce movement. So, in addition on the on the sides you have two loops. So, from promoter the supplementary motor area here projections to the basal ganglia and basal ganglia in turn projects backs to both the promoter and higher these higher motor cortical areas and also to the primary motor cortex.

On the ha other side similarly, you have cerebellum which receives input from these higher motor cortical areas, and then sends feedback right just like basal ganglia back to the same motor cortical areas. So, these whole networks of areas form the motor system of the brain.

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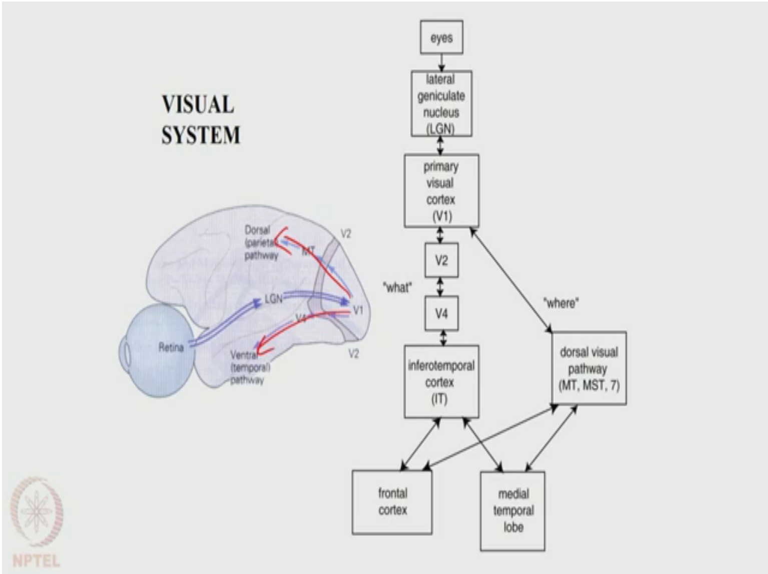

So, similarly we look at the visual system here also you have a huge network. So, you have the input from the eyes which goes to LGN which is a part of the thalamus. So, from there L G N projects to V 1 and then from there V 1 projects to V 2 and then you have the where pathway or the dorsal pathway and the what pathway are the ventral pathway?

So, there are actually lot ma lot more areas and this for example, the primate which is a sim alone has something like 100 and 20 visual cortical areas. So, it is a fairly complex system right. So, you can think of many such systems, but whatever system that we have discussed in the in these two segments of this lecture I have just tried to put them altogether in a simple cartoon picture I mean real one is a lot more complicated than this; obviously, I thought let us put all these structures in a in a logical framework right.

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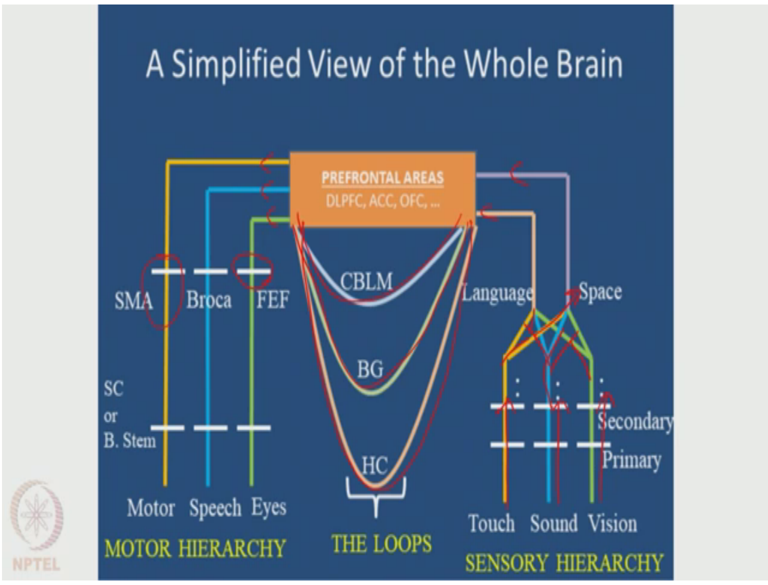

So, in this picture you can see that; there are three sensory hierarchies the touch this sound and the vision right.

So, here again you see the primary first and then secondary and so, on and so, forth. So, here neurons in the lower layers respond to more primitive features as you go higher and higher in the hierarchy, you find neurons respond to more and more complex features of that sensory modality.

At some point the sensory modalities starts blending starts mixing up right mixing with each other. And here you have sensory association areas or this kind of mixed areas as it go higher up then in the parietal areas in a post a parietal area, if you have seen in the last lecture that on the left side in most people all right you have a language understanding areas, that is; basically you are extracting language data information from these trees and three modalities.

On the right side, in most people right you also extract large scale spatial information which is what is processed in the posterior parietal. Now these abstract information which is extracted from sensory information then is sent to the prefrontal areas this where decision making is done, we thought of prefund areas some kind of a gait which decides what to do with information that comes from the sensory cortex and then based on the decision it sends out motor commands which go through multiple motor pathways..

So, you have the discursive motor pathway which is which is; what we normally call the motor pathway right which goes to the supplementary motor area and then through to the various motor cortical areas. And then it goes down to brain stem or you know spinal cord and produce movements of you know extremities and you know pa you know of the axial muscles and things like that.

And the other pathway is related to speech output and this activates a brocas area and produces speech the third pathway in this picture refers to the movement of eyes right or saccadic movements. So, here the cortical areas are like the frontal eye fields or supplementary eye fields or other higher motor cortical areas which are responsible for controlling eye movements.

So, these are this these are mainly the sensory and motor cortical pathways. In addition we have also talked about three loops right. So, we talked about the loop from the cortex hippocampus and back to the cortex. We talked about the loop from the cortex to the basal ganglia and back to the cortex. We also talked about the loop from cortex the cerebellum and back to the cortex. The only thing is cerebrum also he says feedback from the spinal cord which is not shown in this big picture. So, like I said this is a very simplified cartoon picture just to put everything that learned in the last two segments of this lecture right in a kind of a single framework right.

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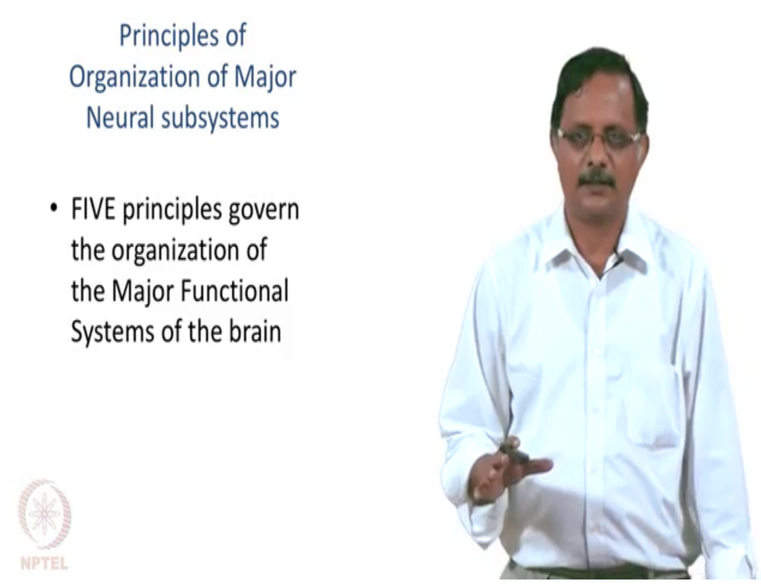

So, let us summarize some of these main organizational principles of the neural system that you find in the brain 5 principles have been desc have described typically where this one principles are as follows.

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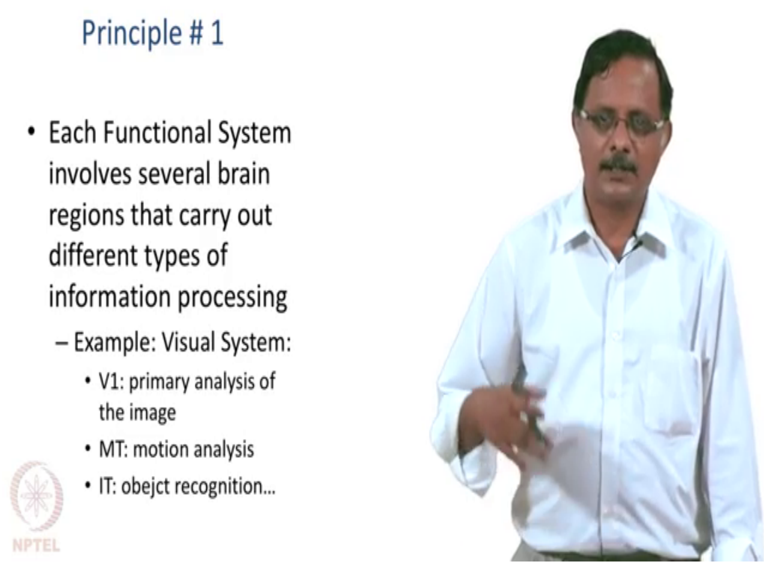

The first principle is that each functional system in the brain involves; our several brain regions that carry out different types of information processing. For example, if you take visual system there is a V 1 which does primary analysis of the image that it receives from on from the eyes then empty performs motion analysis I t does objective definition and so, on so, forth.

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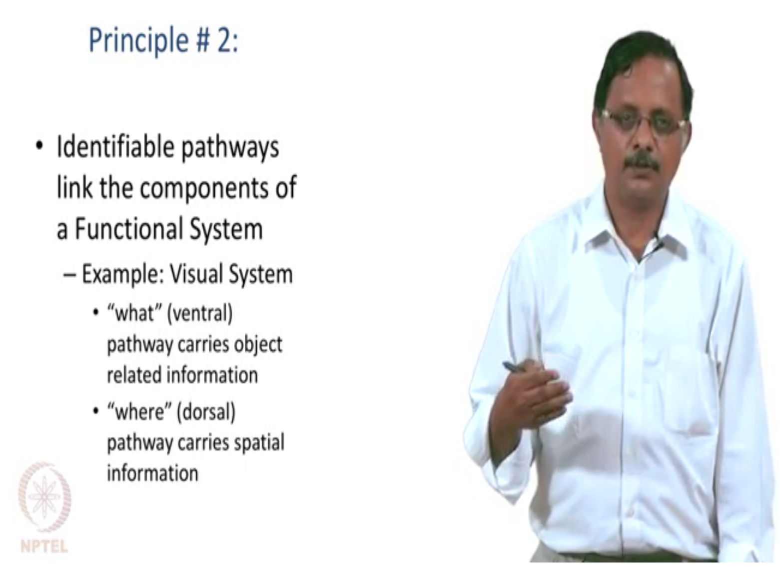

Then principle two says that; there are identical identifiable pathways that link the components of each function system. So, in the previous principal basically says there are distinct modules, where each module does something specific the second principle says there are specific pathways which connect these modules. Since in a logical order and the processing happens in that order. So, the so, for example, the, what and where pathways are examples of these kinds of identifiable pathways that link the various components.

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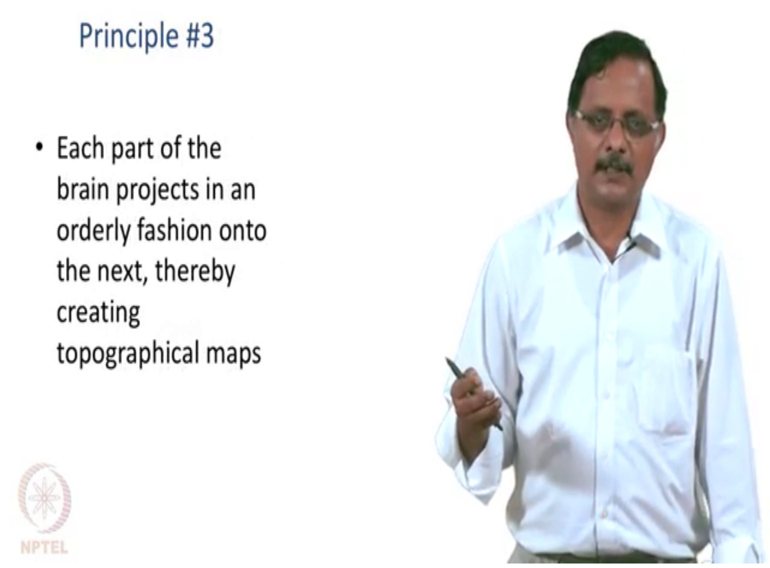

The third principle says that each part of the brain each of these modules projects to other modules. In a logical and orderly fashion, they will be creating topographical maps. So, we have talked about maps right brain maps and some of the earlier lectures. And next lecture we will talk about them in greater detail right this kind of orderly projection from one component; another through what we call point to point connections right. This is also spatial information right of the presentation in what one module and takes it forward to the next module.

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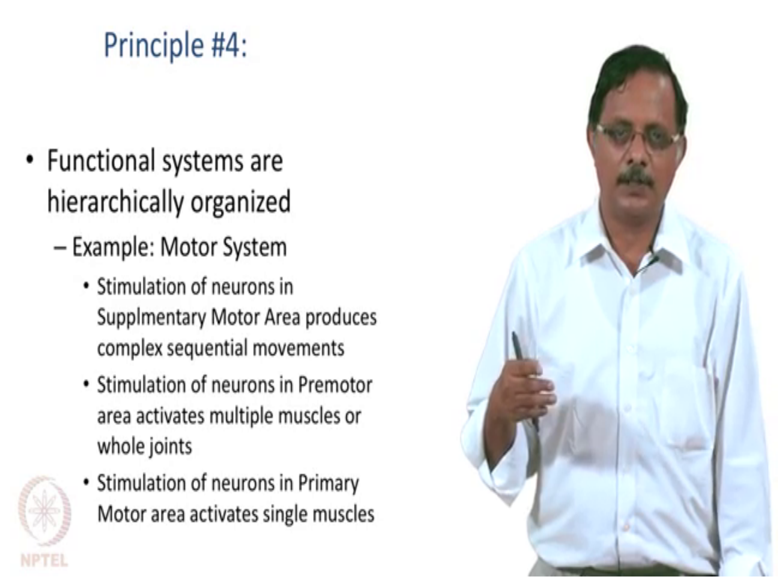

Then the 4th principal basically says that this intrinsic hierarchy right. In these functional systems like we discussed earlier, if you look at visual system the neurons of V 1 respond to only. So, lines or edges if you go to V 2 you find neurons which respond to curves alright or you know angles where multiple lines meet and if you go further, the inferior temporal area you will find neurons which respond to complex objects.

Similarly on in the motor side as you see in this slide, if you activate neurons of the supplementary motor area, it produces you know a complex sequential moment like for example, waving of hand on something like that or if you simulate your own. So, the promoter area it activates like maybe multiple muscles or a whole joint or if you come down. Further if you activate neurons of the primary motor area it might activate only single muscles. So, there is a hierarchy right in the control or in the motor system.

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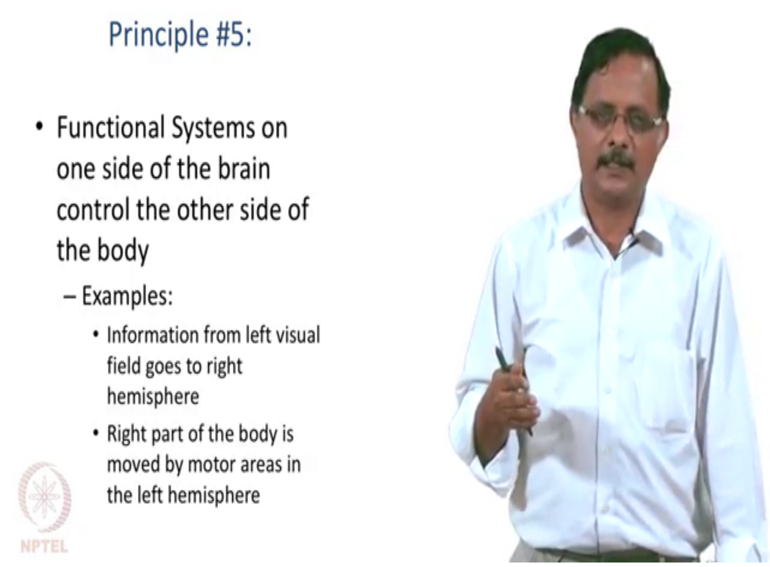

The 5th principle says that function systems on one side of the brain control the other side of the body. So, that is very peculiar pattern in which the functions are mapped onto the on to the brain and. So, if you look at the visual system the left part of the visual field is mapped onto the right brain on the right occipital lobe. So, similarly the left part of the body is controlled by the right motor cortical areas. So, there is a very interesting contra lateral mapping of body and the world or onto the brain surface.

So, information from for example, information on the left visual field goes to the right hemisphere and right party of the right part of the body is moved by motor areas in the left hemisphere.

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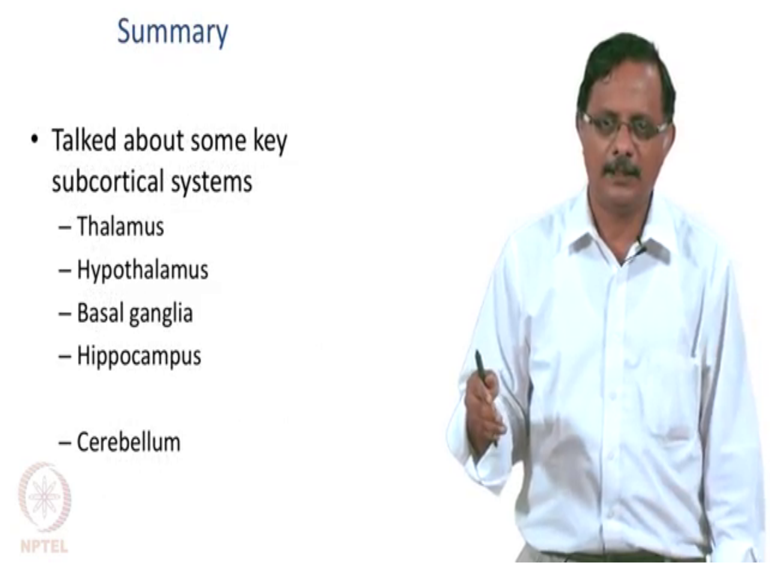

So, in summary in this segment; we talked about some of the keys of subcortical systems like thalamus hypothalamus, basal ganglia and hippocampus. We also talked about the cerebellum although it is not; what is a particle structure right?

And, we also tried to put all the brain components that we have discussed in this lecture into one grand framework and we also mentioned that it is more simplified picture and here one is not more complicated. So, the next lecture we will talk about the brain maps and some of the mechanisms by which these maps formed.

Thank you.