Demystifying the Brain
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Lecture – 09
Organization of the Central Nervous System Segment I-Cortex

Welcome to lecture 5 segment one, this lecture is about Organization of the Central Nervous System. And the more specifically a part of the central nervous system called the cortex. So, before we get into the details of the central nervous system and it is parts and so on and so, forth. Let us start with a small story.

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So, this story about this book a very delightful book called vehicles written by Valentino Braitenberg; who is a neuroanatomist and although the title says vehicles is not about, you know vehicles like cars and trucks it is about brains basically this book visualizes human bodies as vehicles with the brains as drivers of these vehicles.

So in fact, Braitenberg creates a simple thought experiments. So, this thought toys right which look like simple vehicles and which respond to the external world and make interesting movements and he compares the movements of these vehicles to those of real bodies are driven by in the nervous systems. So, in this book in chapter after chapter he defines these interesting vehicles and describes it is prop their properties.

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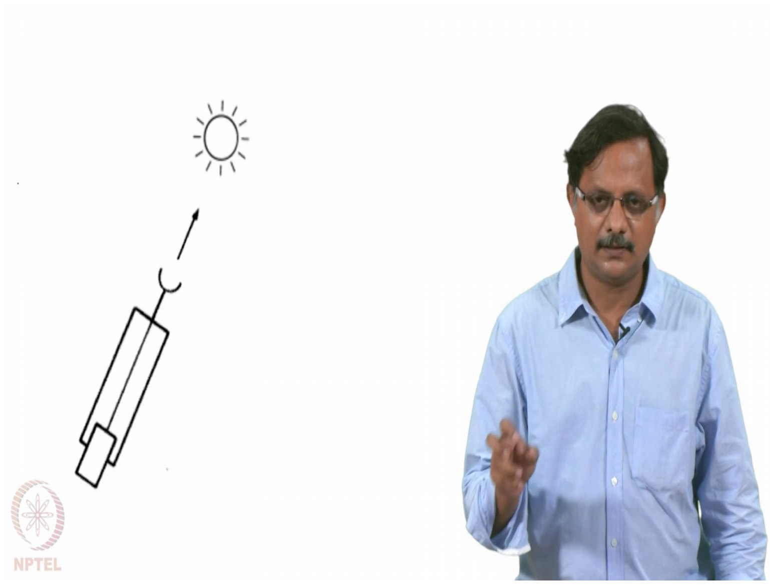

So, for example, let us start with a very simple vehicle. So, each of these vehicles actually has a bunch of sensors and these sensors are connected to the wheels of the vehicle and drive them. So, in this case it is a very simple vehicle it has only one sensor it is a photo photoreceptor it phototive right it responds to light and the sensor is connected to the and there is only one wheel to the vehicle and the sensor is directly connected connected to the wheel and if the intensity of the light picked up by the sensor is strong then the wheel is not turned as a higher velocity higher rate.

So, it is actually very simple vehicle it does not do much that is interesting. So, if there is a light source in front of it will simply go towards light source you know. So, show some kind of a phototaxis. So, nothing interesting happens here. So, let us take a slightly more complicated vehicle unlike the previous vehicle.

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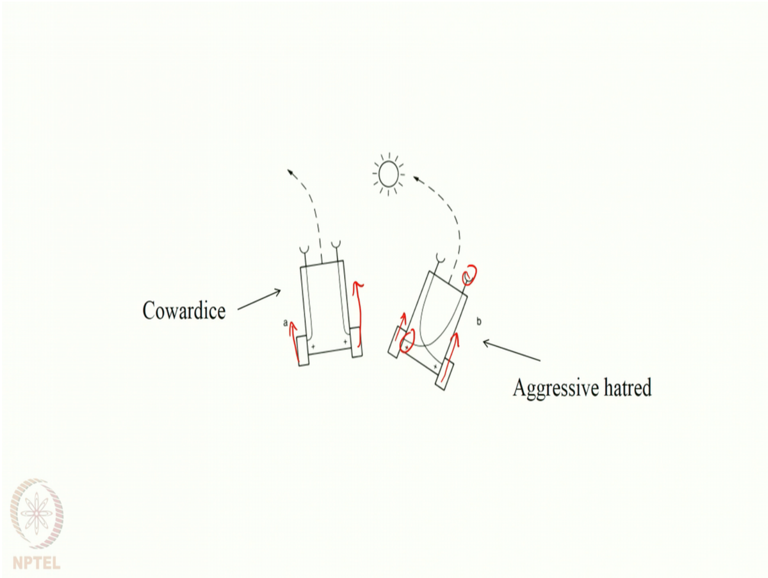

This has this vehicle has two sides. So, there are two photoreceptors in the front, and then the two wheels one is right and one on either side.

So, and then the photoreceptors are connected to the wheels through wires and on in the vehicle on the left side a vehicle number a of this photoreceptor on the right side is connected to the wheel on the right side and vice versa for the other side. So, whereas, on the vehicle on the right and the photoreceptor on the right side is connected to the left vehicle and vice versa.

So, let us take the left vehicle. So, you see that this photoreceptor on the right side and then light source is also in the towards the right. So, the sensor on the right side will pick up a stronger signal like therefore, it turns the corresponding wheel which is a right wheel at higher rate right whereas, a sensor on the left side picks up a weaker signal therefore, it turns the wheel on the left at a lower rate. So, therefore, you see that the wheel here right moves at a higher velocity and then the wheel here. So, therefore, you can easily see that the vehicle turns to the left ok.

So, somebody looking at this vehicle the response of the vehicle to the light might say that this vehicle is afraid of light right it is expression the emotion of cover disc ok. So, then let us look at the right vehicle the vehicle number a, but in this case the sensor on the right side is connected to the left vehicle and vice versa. So, the left sensor picks up a stronger signal therefore, the right wheel moves at a higher velocity than the left wheel. So, therefore, the vehicle turns towards the left towards the light source, but the thing is.

So, the since the connection between the sensor and the sensor in the wheel is a positive connection right as sensor picks up stronger and stronger signals. The wheel turns the wheel turns faster and faster therefore, as the vehicle approaches a light right the signal gets stronger and stronger and the wheel. So, and faster and faster and the vehicle simply rams into the light source right.

And if you look at it as some kind of a right living organism right moving towards right source, then you would say that it hates light and it is trying it is trying to aggressively dash towards light and destroy that light source right you can give this kind of an emotional commentary on what the vehicles are doing in this word Valentino Bbraitenberg does in his book.

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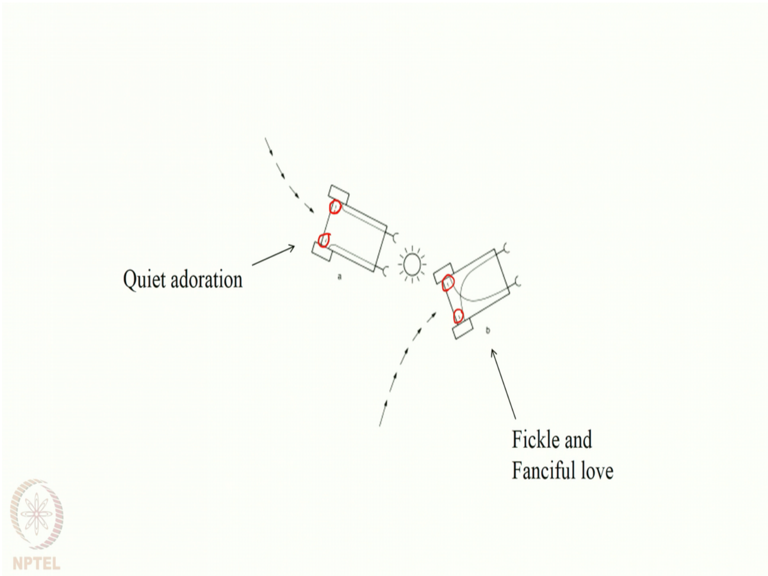

Now, let us change the wiring pattern slightly in the same vehicles and look at the radical change in behavior. So, in this case the wiring pattern is actually very similar to the previous case, but only difference is the connections in this case are negative connections ok. So, the as the pic as a sensor picks up stronger and stronger signals, it turns a corresponding wheel slower and slower ok. So, the response is slightly different interestingly different compared to previous case. So, in this case when the wiring patterns are on the same side that is the sensor connects to the wheels on the same side;

then the vehicle actually goes towards the light source right unlike in the previous case where when the wires are on the same side connect to the wheels on the same side the vehicle turns away from this light source in the previous case. Now the vehicle turns towards light source.

But, unlike before since the connections signs are negative as the vehicle approaches. The light source and gets closer and closer the intensity of the light picked up a sensors get stronger and stronger and correspondingly the wheels turn slower and slower. So, the vehicle actually slows down as it approaches the light source all right.

Whereas the other vehicle the right the connections signs are still negative, but the wires connected the wheels on the opposite side. So, in this case unlike the you know the vehicle on the previous slide it actually turns away from the light source, but since the connections since here are negative as approaches as the vehicle approaches the light source it gets slower and it is actually slower and slows down as it approaches vehicle and turns away.

So, Braitenberg gives a very interesting amusing description or commentary on this kind of behavior he says that the vehicle on the left that is the vehicle a displays a kind of a quiet adoration of the light source because it wherever it is it moves towards light source and gently approaches light source and stop said, when it comes vehicles light source and just sits there you know closer light source as though it is adoring that light source.

Whereas in the second case in vehicle b right; the vehicle charges ahead you know when it is far away and as, but as it comes very close to the light source it I do not know it gets cold feet or you know it got scared and gently wears way and he says it kind of expresses a fickle and fanciful love it is scared of commitment therefore, once it gets too close a light source it kind of wears away from the light source.

So, you can make these kinds of commentaries on very simple models of vehicles in the models which not a metaphor for the brains and the bodies. So, what the important?

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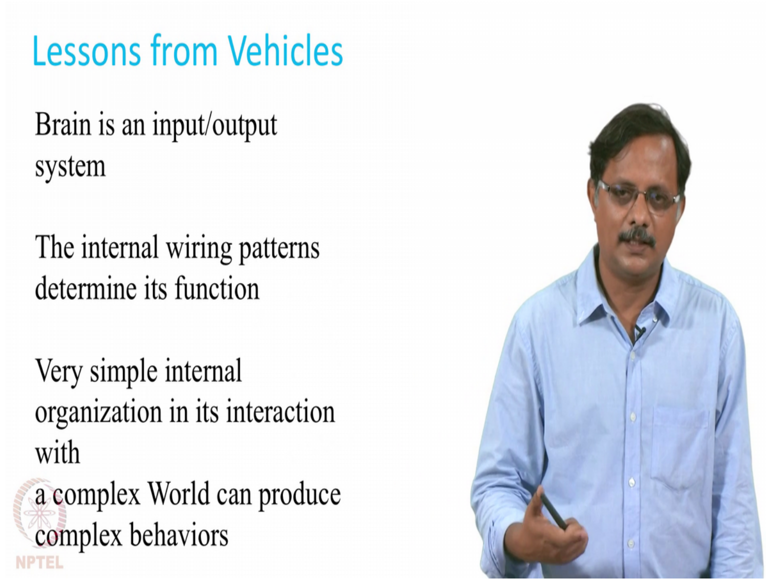

Take home lesson from Braitenberg book is that brain is an input/output system. Basically it has all these sensors the sense organs right, which receive the inputs from the external world and this sensory information flows through certain pathways. The nerves and the pathways of the brain and activate the outputs which is the motor system.

So, in this case in the case of the vehicle it. So, it is a wheels the internal wiring patterns determines a function determines, how the vehicle responds to the world outside, but what is very interesting about these vehicles is even these kinds of extremely simple wiring patterns I mean; is actually quite revealed there is two wires and going from a sensor to the one of the wheels all right can give very rich and interesting and even amusing behavior to the vehicles.

So, what Braitenberg concludes is that? You do not need a very complex brain in an in an organism to produce a very complex behavior even very simple organ internal organization of a nervous system right; I can produce very complex behaviors simply by virtue of the interaction of the organism with a very complex world it is a world that is world that is complex, but even the brain is simple the organism can produce complex behaviors ok.

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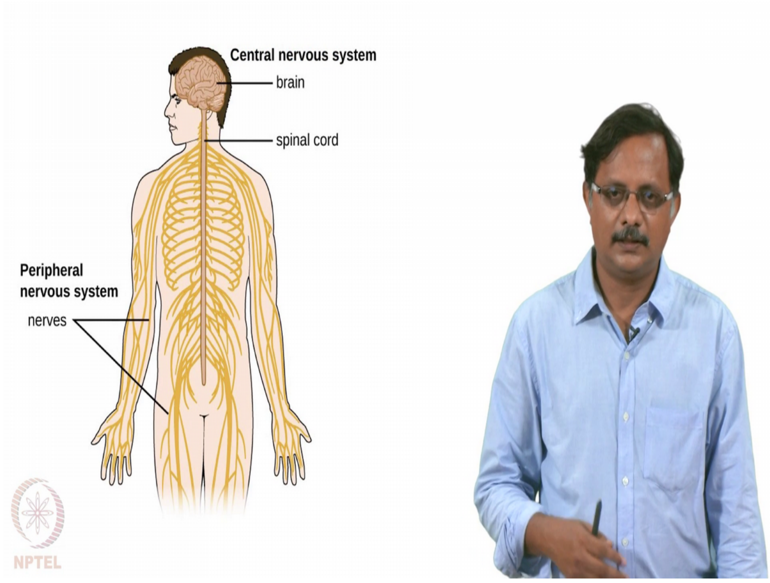

With that background; now let us now look at the body and the nervous system right. Now system also so actually it has two parts. We have talked about this once before. So, there is a part of the nervous system, which is housed within the bony vault the cranial vault and these vertebral column right that is called a central nervous system. And then there is there is external wires which go out from the central nervous system and permeate the entire body. They innervate the entire body and that is called the peripheral nervous system.

So, if within the central nervous system there is a cerebral cerebrum which is this which consists of these two large hemispheres on either side and there is cerebellum.

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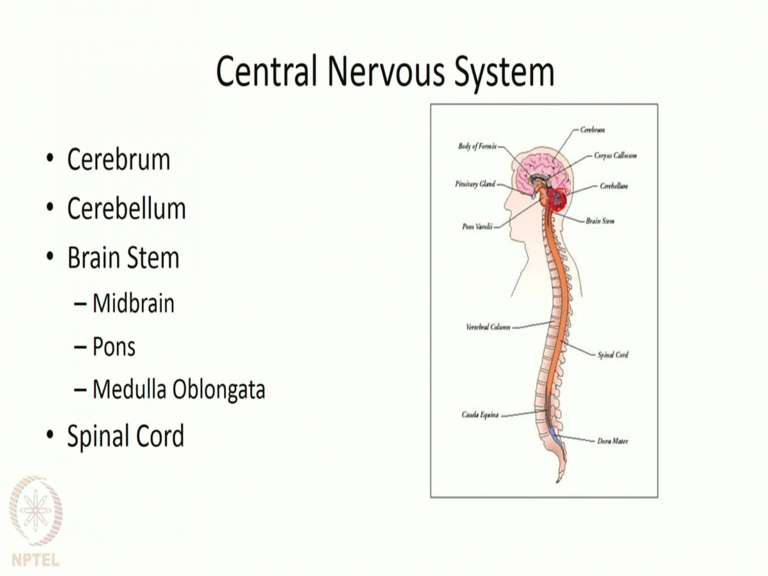

Which is this organ in the back right of the brain and then there is a spinal cord ok. Which extends from here to all the way to here ok? And between spinal cord and these you know cerebrum there is brain stem which can be more clearly seen in this picture.

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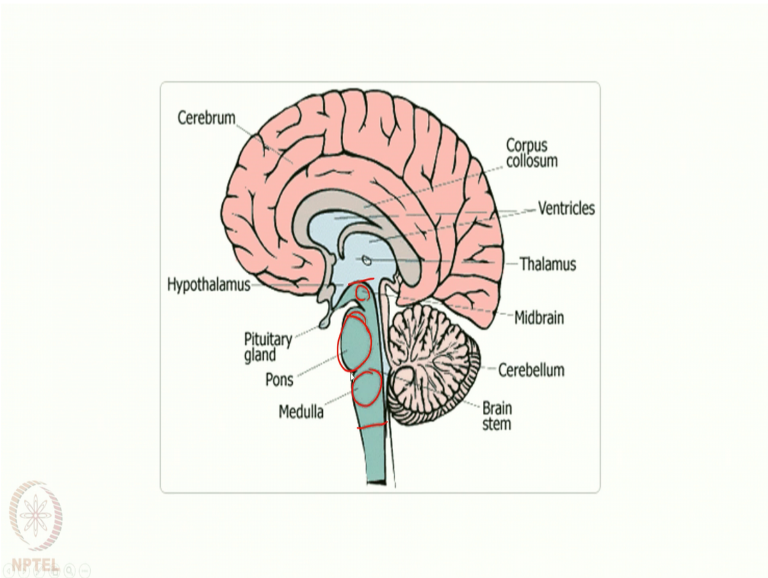

So, so, between so, from here to here it is ok. So, the brainstem, which consists of again three regions, the midbrain which is here and the pons which is this whole structure in the medulla oblongata ok.

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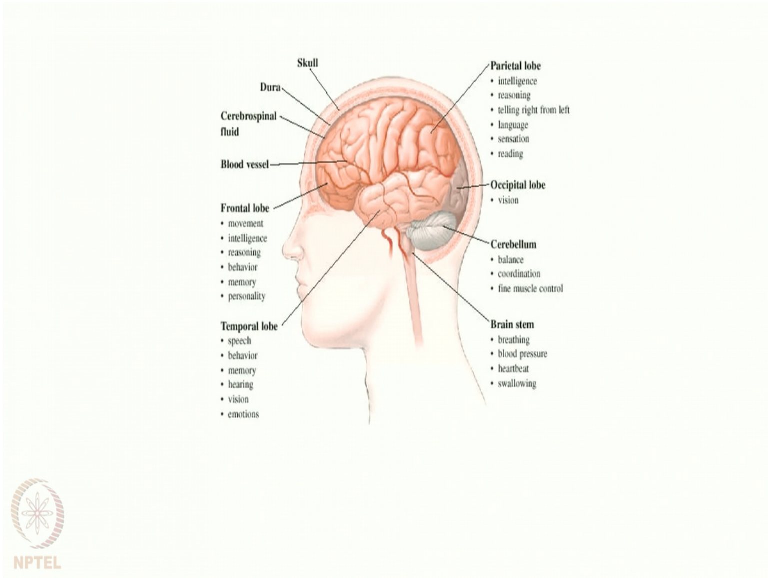

So, if generally if you are looking at if you are taking a typical medical course on nervous like a course on neurophysiology, but very quickly you would see pictures like this you know you would there are there are maps which tell you which part of the brain does? What and once you are introduced to basic anatomy of the brain you are taught? Which parts of the brain do? What kind of a function?

For example, in this picture you can see that in the parietal lobe it controls you know this parietal lobe is here there are seeds of intelligence and reasoning and language and sensation and. So, on and in the in the frontal lobe again you can see that is right here right you can see again there are seeds of intelligence and reasoning and behavior, but then you would wonder what is the difference between the reasoning as it is conducted by parietal lobe? And as it is conducted by frontal lobe and it is pretty confusing.

So, these kinds of approaches are where you give you are given a bucket list of brain of brain areas and their corresponding functions right. Probably they are good for writing exams and where you mug up a bunch of terms and you know regurgitate them in exams, but I feel they do not really give much inside into how brain function is organized in the brain? Ok. So, for that, this problem is very similar to understanding poetry or trying to read poetry in this strange format.

So, I am going to tell you read a poem to you, but in a very weird format and you need to figure out what this poem is?

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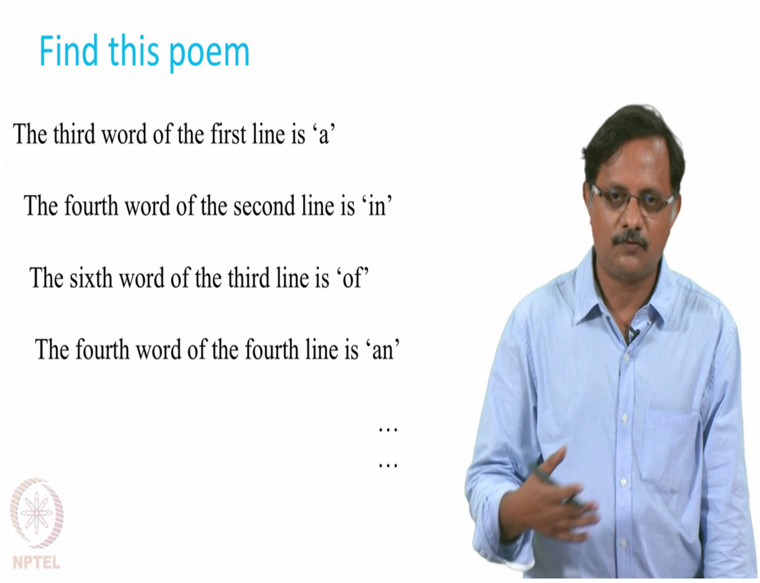

So, the poem has 4 lines and the third word of the first line is a and the fourth word of the second line is in the sixth word of the third line is off and the fourth word of the fourth line is and so on so, forth. I am going to give you right you know the positions of various words and by describing them over many sentences; I mean it is a it is a nightmare to figure out what this whole poem is by reconstructing all this you know all these instructions.

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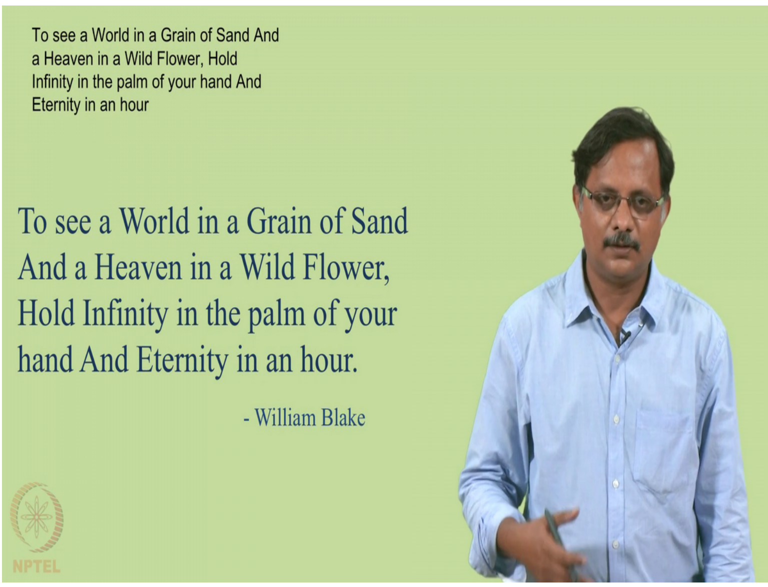

Whereas right if I give the poem like this you now to see a world in a grain of sand and it is a famous poem from William Blake ok. So, it is much easier much more comfortable if you have the words are present in a sequence and not like a bucket list, but even if you give them give their coordinates

So, that, but this is the kind of pattern that people follow when they describe you know brain functions as maps like this. So, where is what we will do? We will present the brain areas in a sequence and then their function becomes more logical more obvious which is what we have began to.

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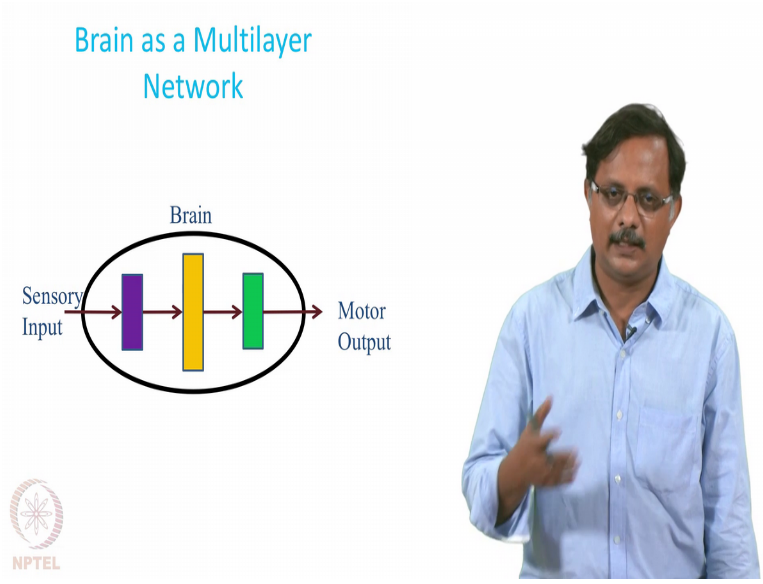

Do in the last lecture where we looked at, now multilayer networks where the networks connect to each other in a feed forward in a unidirectional fashion.

Where in the input layer you give the sensory input right. Whether in the output layer pick up the motor output looked examples of you know past tense learning and look at net talk or how network learns to convert text into speech and all that. So, there is input layer and then there is output layer between the two there is one hidden layer like this is standard format of a three layered multilayer perceptron, but brain is; obviously, more complicated. So, we can add more layers. So, you can have lots of layer.

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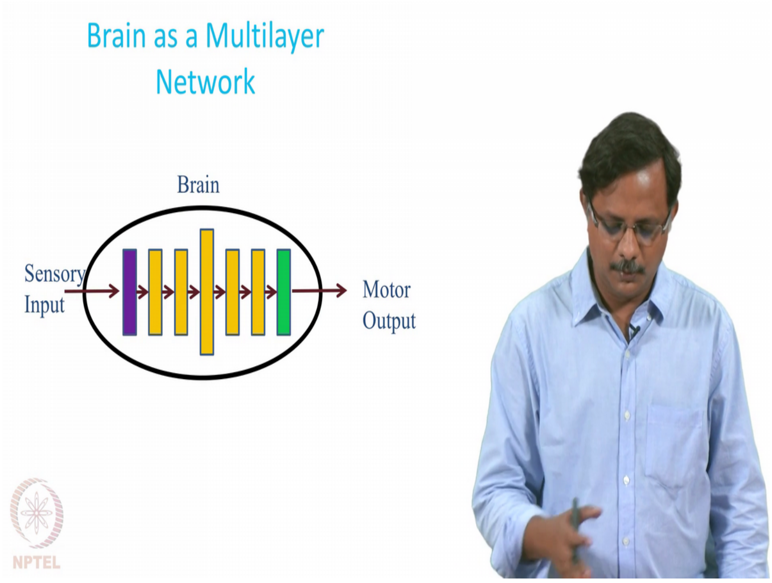

Between the input layer and output layer, in the sensory layer and the motor layer or you can even make it even more complex by having multiple sensory regions and multiple motor regions.

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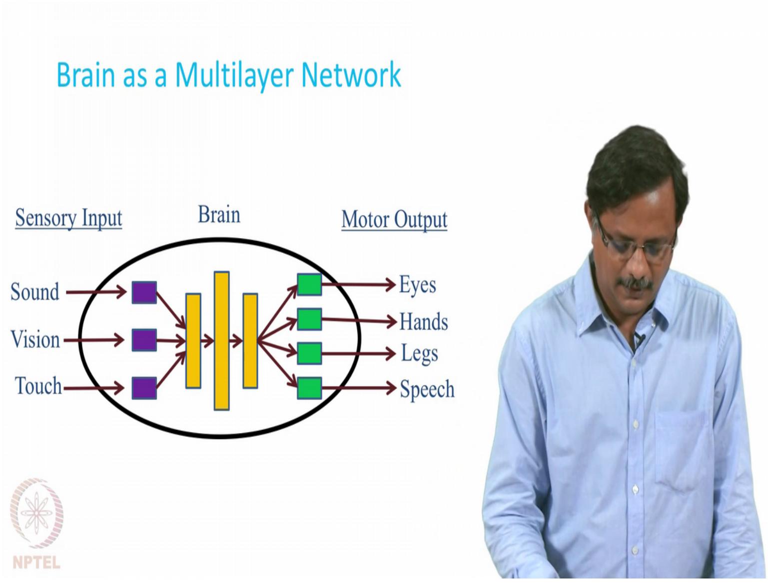

So, for example, you can have an input layer which only receives sounds another input layer which receives vision or another which receives.

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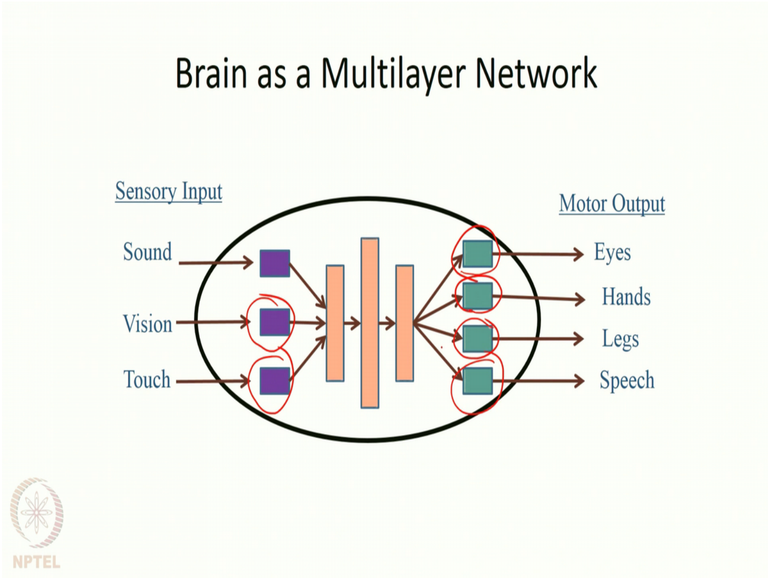

A touch information from your skin and the outputs can also be multiple output layer output regions. So, you can have one region which controls your eye movements. So, here eyes does not mean like you know vision you are seeing, but eyes here refers to your motor output where you move your eyes around and then hand says you know controlling hands and then you have legs which the area controls legs and speech area which controls your in a vocal apparatuses.

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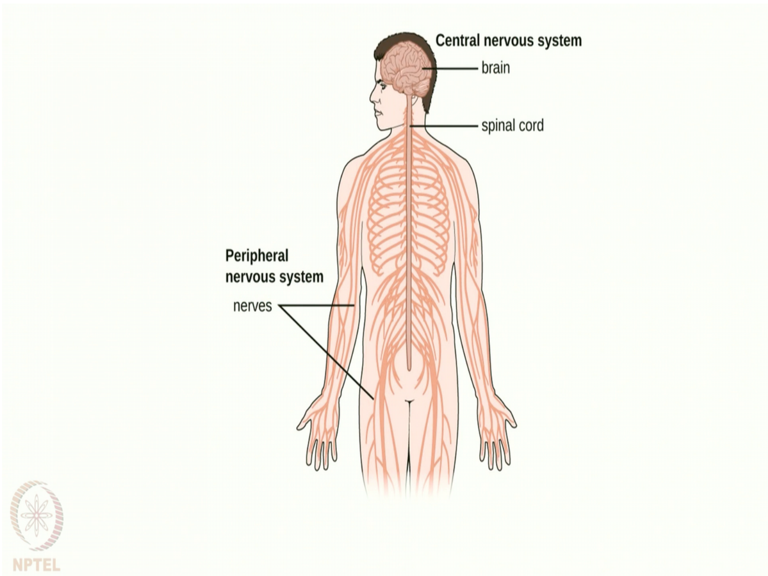

So, you can now superimpose this kind of a high level picture on the on a picture of the nervous system. And see how you can apply this picture onto nervous system? So, suppose I am looking at an object and there is a cup on the table and I want to reach out to the cup. So, information comes through the eyes and goes to the visual areas and then goes to the motor areas.

Then comes down to the spinal cord it goes to the nerves of the hand and reaches the hand and activates the hand and hand moves and grabs a cup or you are getting a strange smell from some point in the someplace in the room and that smell goes through the nostrils and goes to olfactible right and then you it goes to the motor cortices and goes onto the spinal cord and activates. The nose of your legs and you walk towards right the source of the smell and maybe you discover a dead rat.

So, you see in both these examples here; you have any input in from you know source of sensory information which goes through multiple stages within the; now system both peripheral and central and then output to activate some kind of a mo motor apparatus and I know you produce some kind of a movement.

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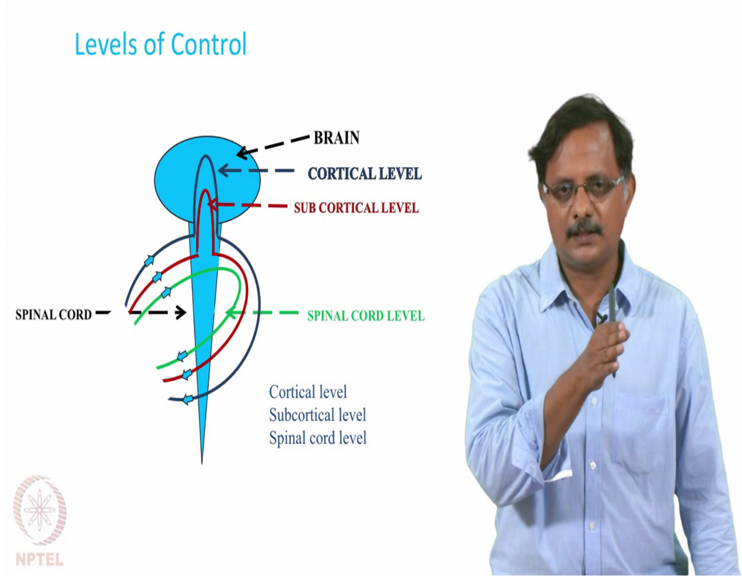

So, this pathway from sensory to motor actually is organized at a multiple at multiple levels. There are multiple levels of control like the; you know the levels of management in a large in a company. You can have in upper management low in a middle management and the lower team you know team leaders and so on. So, and then you have vice presidents at the top there is a single hierarchy in the way brain controls you know it is output. So, there is a lowest level which is called the spinal cord level. So, for example, you have information coming from outside which goes to the spinal cord, then there is this immediate pathway which goes back to the same site of origin of this sensory information this is called a spinal cord level a good example of this is your reflexes.

For example, when you go to a doctor very often right when you go to neurologists, but sometime neurologists test your knee reflex by tapping on your knee with a rubber hammer; while do that you know you just kind of gently jerk your knee. So, in this case the sensory information is going from your knee to the spinal cord and thus a return signal comes back to the same knee joint and activates the muscles. So, so you produce this flick of the joint.

Then there is a next higher level where sensory information goes all the way to the you know subcortical area the lots of you know I i will just define what is cortex and subcortex very soon, but let us just say for now that cortex is surface of the brain and subcortex is a structures which are located deep inside the brain. So, you go all the way to the subcortex and come back and produce movement with a subcortical level and the cortical level consists of a much longer pathway where you receive input from outside it goes all the way to the brain surface and comes down and cortex goes out producing movements.

So, these are the three broad levels of control in the brain if you think of the brain function as simply a long pathway from the sensory to the motor areas ok.

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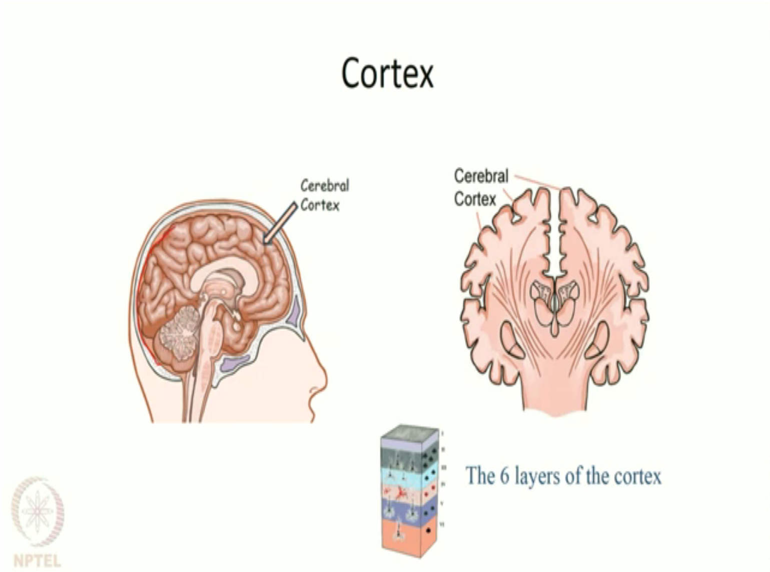

So, that shows the cortical level subcortical level and the spinal cord level. So, let us begin with cortex like, I just have like I said just a moment ago cortex is this you know the surface of the brain which is which consists of ich sheets of neurons. So, it is like an imagine you know covering the entire brain with a sheet of cells right and you can see and this sheet is about 2 to 5 millimeters in thickness it consists of 6 layers of neurons.

So, in this picture you can see the sheet it covering the co you know the brain and in actually in this picture. You can this is a coronal section of the brain you can see that brownish outline of; of this section and this outline is a cor is the cortex and if in the picture below you can see further blow of a small part of this outline this cortex you can see that there are 6 layers numbered from 1, 2, 3, 4, 5, 6 will talk about the connectivities of these layers and so, on later on in the course.

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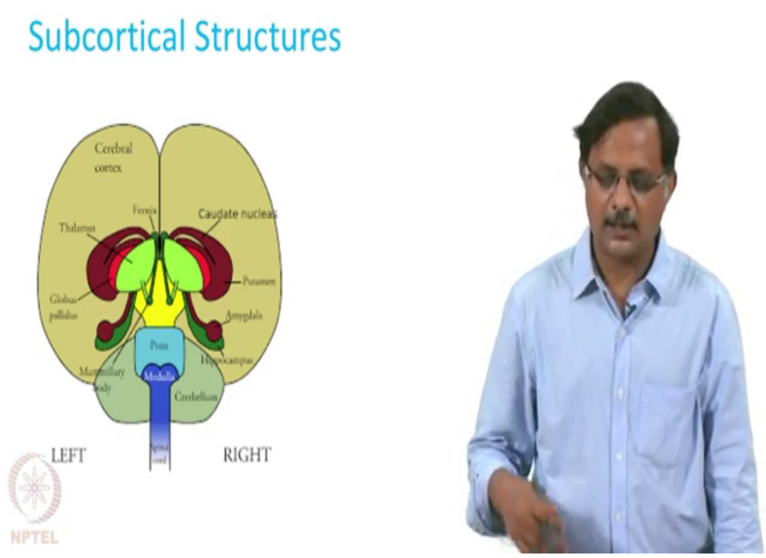

So, then there are subcortical structures. So, the surface of the brain and this sheet of neurons is called the cortex and deep inside the brain. There are lots of again neural masses these are the subcortical structures.

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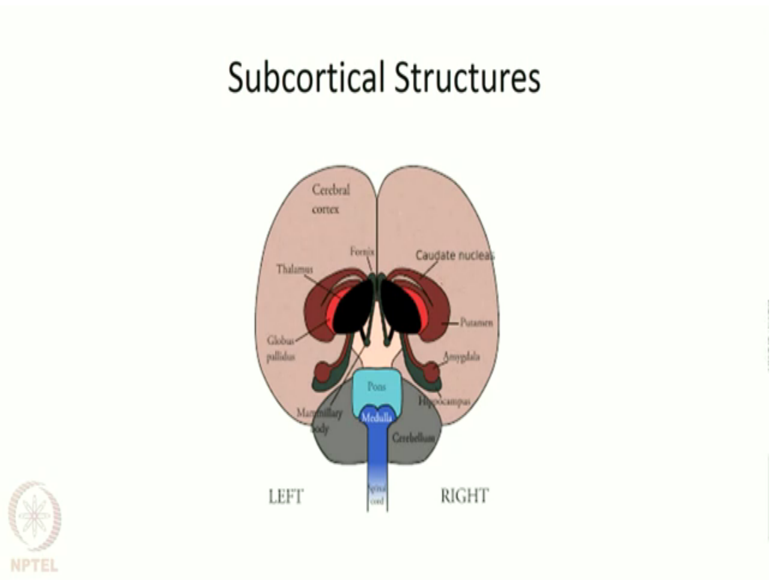

So, for example, there is the caudate nucleus or you know putamen and amygdala and hippocampus and all these structures are subcortical structures.

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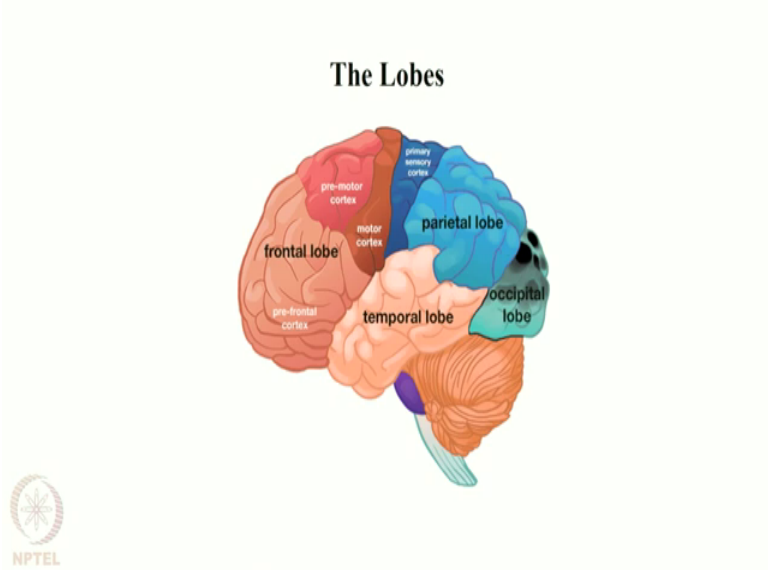

So, let us begin with the cortex for that you know. Let us quickly recall that, there are these lobes of the brain, because lobes are superficial and this cortex is also superficial. So, there is occipital lobe and then there is a parietal and temporal and frontal lobe within the brain surface in the cortex. There are many different cortical areas I am not going to know again coming to these cortical areas.

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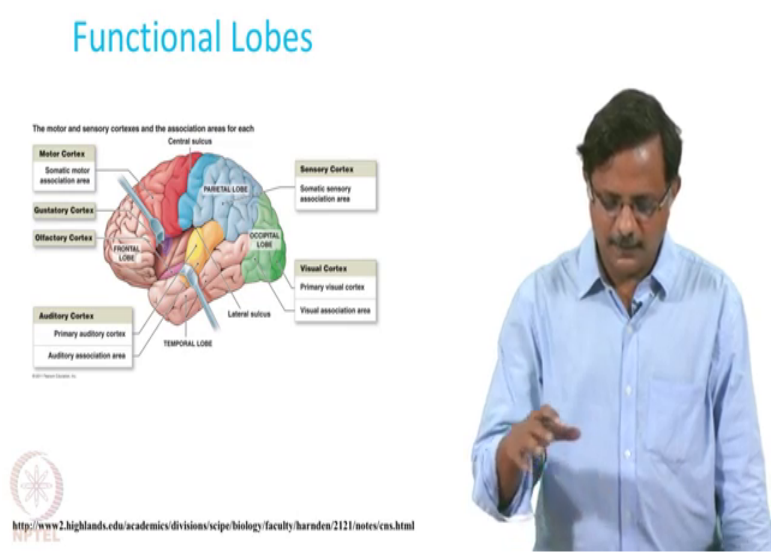

Because let us again like going back to a bucket list of functions kind of approach and besides that is not very helpful. So, let us now go through certain important sensory cortical areas.

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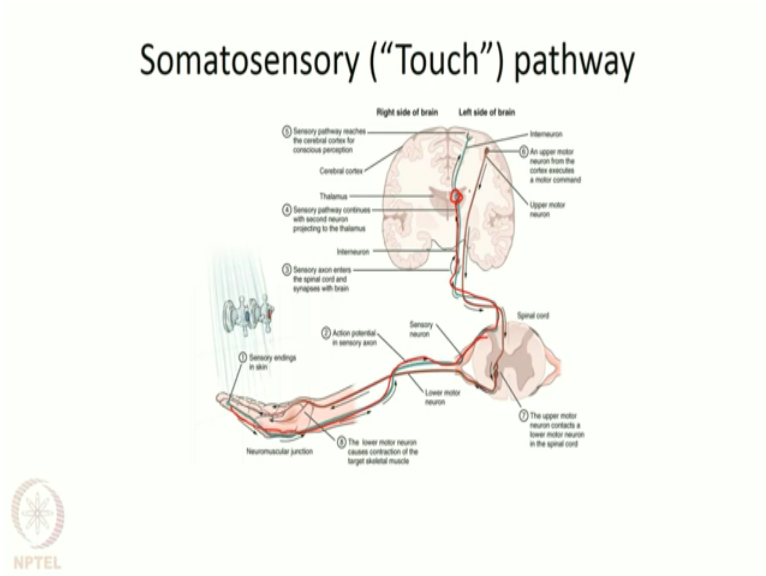

So, if you look at touch right, how touch is process right you touch something with your hand and there are these touch receptors. So, in the tips of your fingers which convert the pressure information or you know other properties like temperature tickle each and all these other touch related information right into electrical signals and this information climbs up along this pathway.

You see this blue line which goes to the spinal cord first and then claims up right, there is a first stopper here and climbs it climbs further up goes to the thalamus. Now thalamus is a very important sensory hub right it is like most sensory information going to the brain. First goes through this big junction box right called thalamus, and from there it goes upwards to the cortex to the appropriate cortical area which specializes in processing that form of sensory input.

So, in case of for touch input or what is called somatosensory input right? The coret corresponding cortical area is called as a somatosensory cortex. So, this is located right here.

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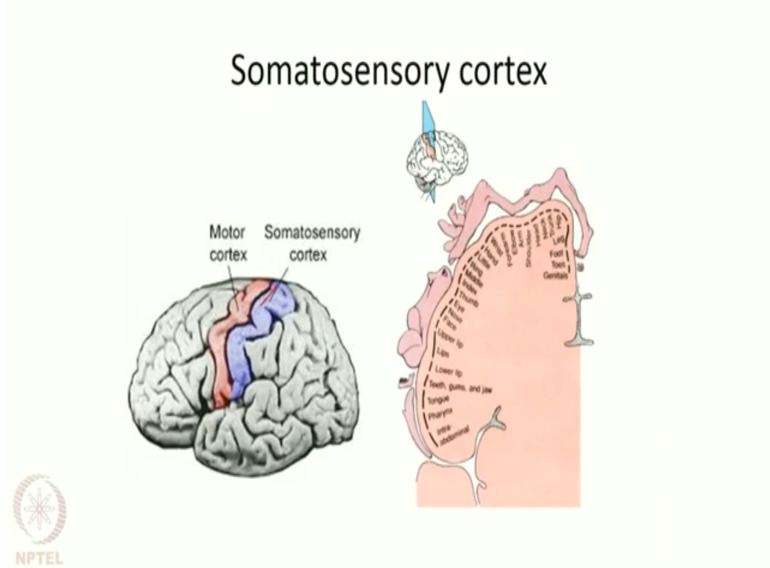

And so, this purple region and. In fact, you see this dark groove that is called a central sulcus. And before that you have the precentral gyrus which is this pink area and then behind that you have the post central gyrus; which is the purple area and the somatosensory cortex is located inside the post central gyrus.

So, we have just used the terms gyrus and you know our sulcus ok. So, you see you can see that brain surface is made up of this convolution this folding patterns which can be compared to hills and valleys and gyrus are like hills and sulci are like valleys or grooves. In fact, it is a very simple mnemonic for memorizing this. So, the Sanskrit word for mountain is giri. So, gyri are like giri or mountains and you know sulci are grooves.

So, on the right side you know look at a side view or a section of this somatosensory cortex and you can see that different body parts are mapped onto different areas in the sometimes in the somatosensory of cortex. So, for example, you can see the lip region here and; that means, if you touch the lower lip it will activate the corresponding neurons in that part of the somatosensory cortex or if you maybe touch your toes right it will activate the foot area in somatosensory cortex and so on so forth, but you can see that the brain surface is really distorted right in it is map on the somatosensory cortex we will talk about this later on in more detail in this course.

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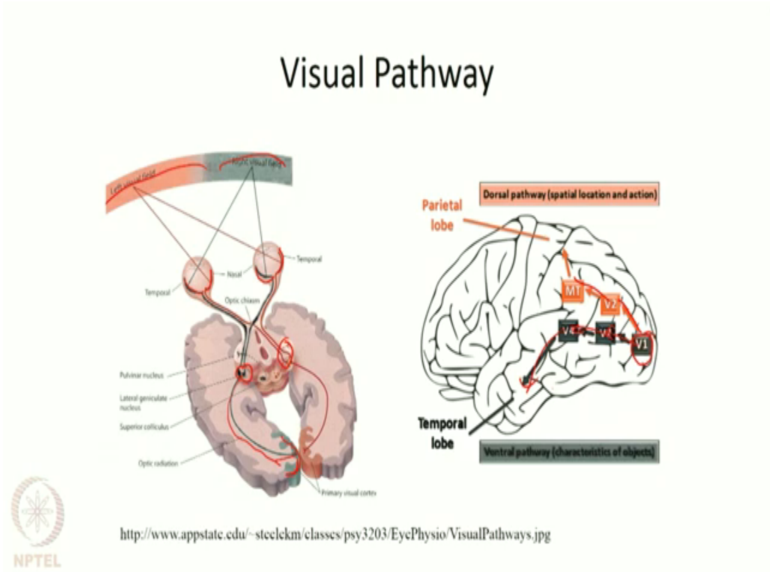

Then if you look at visual system; now the visual information goes into the eyes and then it is it is sent to the thalamus. And then further to the cortex, let us see how that works out. So, information from your right visual field which is shown here that is all that you see on the right of your you know in the of your fixation point and all that you see on the left side that is your left visual field both of them go to both the eyes right you can see that at visual field is seen in this part of the eye end and also in this part of the eye on the right eye. And similarly visual field is seen in this part of the left eye in this part of the right eye.

Now, both these information's are you know broadcasts or sent upwards to thalami right there are. So, in thalamus there is a part of thalamus called later geniculate nucleus; where this information goes this is like a first stop over and from there it is sent further up right into the cortex to the primary visual cortex which is inside the occipital lobe.

So, from the primary visual cortex which is called v 1 right? Now you see the side view of the same picture from v 1 it goes to v 2 and then to mt and so on this called the dorsal pathway or the where pathway we talked about this a little bit before and and also it goes to v 2 and v 4 and and lower down into the temporal lobe in the inferior temporal lobe right right. So, which is called; the what pathway? Because when once you once you come to the inferior temporal lobe there are neurons which respond to complex objects.

So, so it basically that part of the brain tells you what the object is and therefore, it is called the pathway.

And whereas, in the other pathway the dorsal pathway it tells you where the object is therefore, it is called the where pathway.

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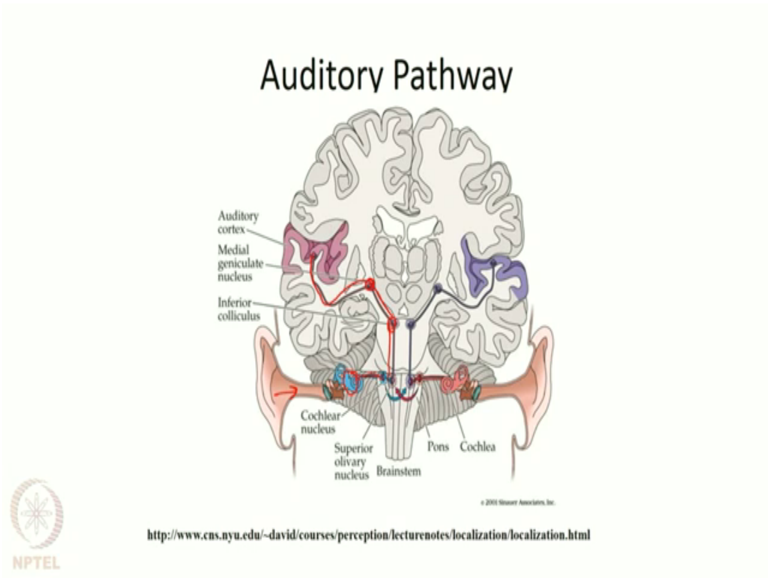

Then if you look at audition or the auditory pathway you process sounds and then you convert them into electrical signals. So, the sound vibrations of the air which enter the ear external ear act on the tympanum and then produce can produce vibrations in the tympanum and we know some of this stuff from our high school biology right. So, these vibrations are converted into electrical signals inside the and cochlea and cochlea actually analyzes the frequencies cons that consists inside the sound signals that we listen to and convert these frequencies into electrical signals.

So, it does some kind of a Fourier transform you know if you have done any engineering courses on Fourier transform you can relate to what the cochlea does? So, it it breaks up the in the in the frequencies present in input signal and perform some kind of Fourier transform of this signal. And these signals are sent from the cochlea to the next stopper or which is the cochlear nucleus. And then the superior olivary nucleus from there it goes up to inferior colliculus and from there it goes to a part of the thalamus again now called a medial geniculate nucleus and like I mentioned once before thalamus is like this big junction box through which most sensory input going to the brain has to pass through this it is in fact, called the gateway to the cortex.

So, beyond the thalamus it goes to the appropriate part of the cortex which is called the auditory cortex or the primary auditory cortex.

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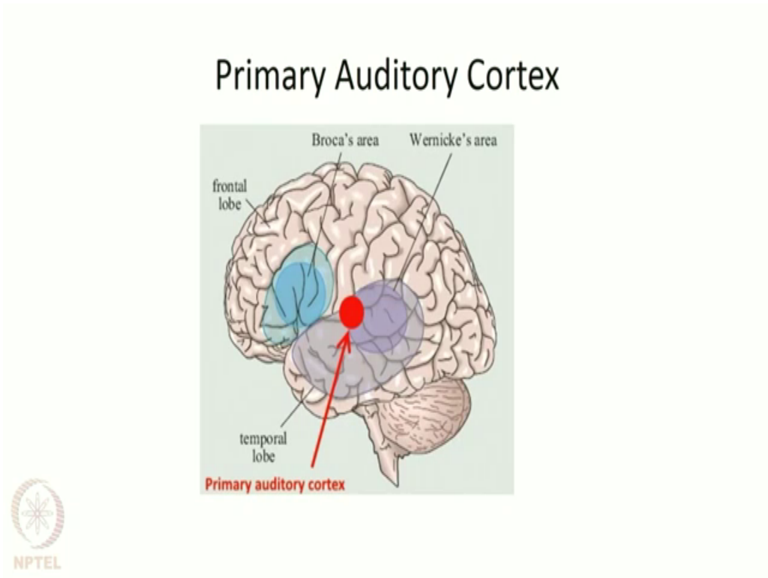

And in a side view you can see that somewhere here ok, in the superior temporal lobe then let us look at all factors that is how do you process smells?

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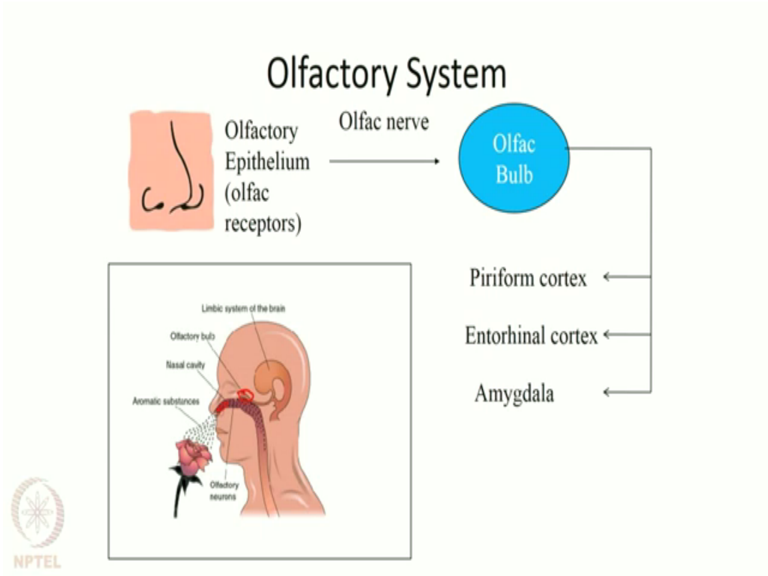

Now, for the smell is based on your inhalation right, you inhale the when you inhale the smell molecules. The chemical that produces smell right are taken into the into the nostrils and here these molecules interact with the olfactory receptors which are there inside the nostrils and from there this information which is converted into electrical signals are transmitted by an by an olfactory nerve to a structure called olfactory bulb, which can be seen here and from there it is sent to various cortical regions called the piriform cortex internal cortex. These are all in the base of the brain underneath the you know in the lower part of the temporal lobe and then also to amygdala ok.

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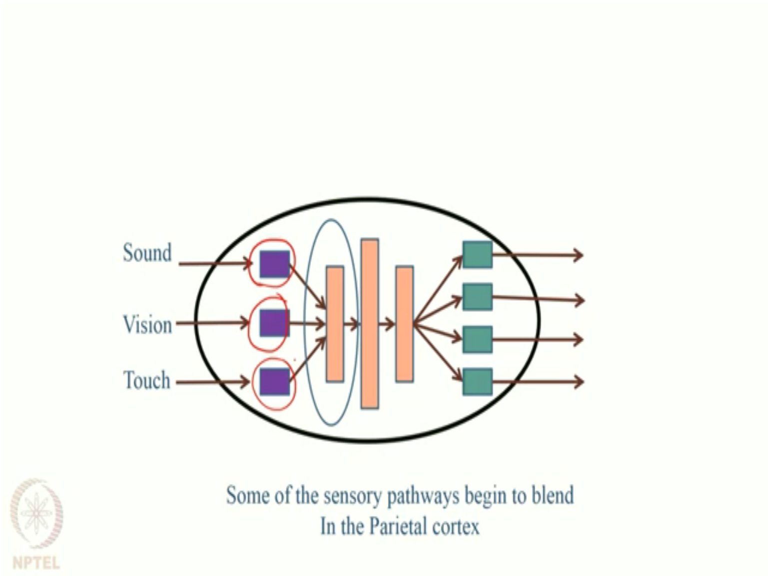

So, so, far we have seen how different the sensory inform? Transfer information enters the brain and have you know and reach different cortical areas, but beyond a point this sensory information’s begin to blend, because when you are looking at sensory information you very often you do not treat it in it is pure form you combine vision with sound and you combine you know vision with touch and so, on so forth. So, suppose you are reading some text aloud, now you look at the sound of it you look at the; you know the visual appearance of the text and so, on so forth. So, you tend to combine different density modalities and this combination occurs in the next stage which is in the parietal lobe. So, let us look at that.

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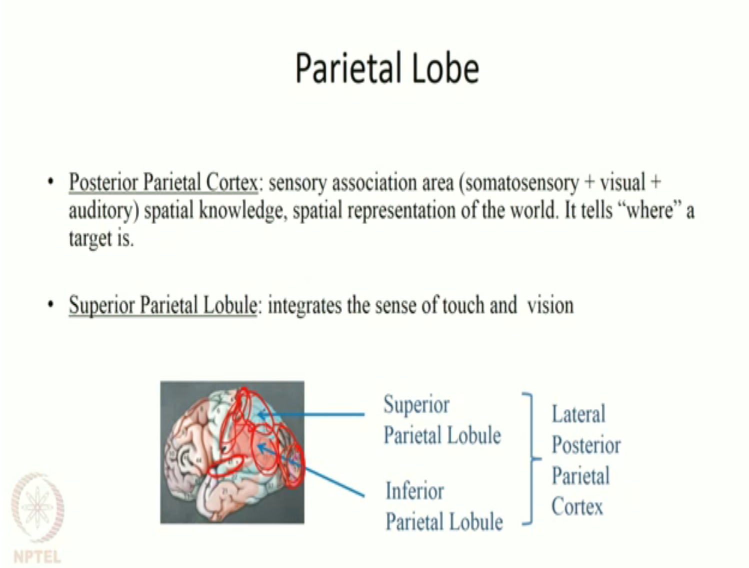

So, parietal lobe is this whole region is called a parietal lobe. So, within this there is the lateral side. So, it show side of the brain and then the medial side which is in the center in the midst which is the center in the midst you can see it in the midsagittal section. We are not talking about the medial side medial side for the moment, within the lateral side, the lateral posterior parietal because in the front in anterior parietal you have the somatosensory areas.

But, if you go back a little that you have the posterior parietal cortex within this there are two regions one above and one below. The one above is called superior parietal lobule and the one below is called the inferior parietal lobule. And the superior parietal lobule which is here right he you can see that it is very conveniently located between the touch processing areas here and the vision processing areas which are you know all over here.

So, it is located exactly in the middle of these two regions. So, it is only natural that the neurons seems to be in parietal lobe right, they integrate the sense of touch and vision and they respond to both touch information and the visual information. So, which is necessary if I want to operate a pen like this I am looking at it and I am touching it I am feeling it. So, I need to combine both these information informations that to be able to manipulate the pen effectively.

So, similarly if you go posture parietal cortex you go back a little right you have what is called a sensory association areas which combine both all the three modes of you know sensory information that is a touch visual and auditory. So, that is back way back a little bit in parietal area. So, you can see that this area is located if I let me clean up this a little bit. So, this area is located very strategically between among three areas you have artery system here you have visual system here you have touch soma to sensory system, here this area is located right in the middle right some kind of a triple point in this theory these three sensory areas

So, you can see that it come it is capable of combining information from a touch visual and auditory as. So, the kinds of sensory information, this is the area which also tells where the target is.

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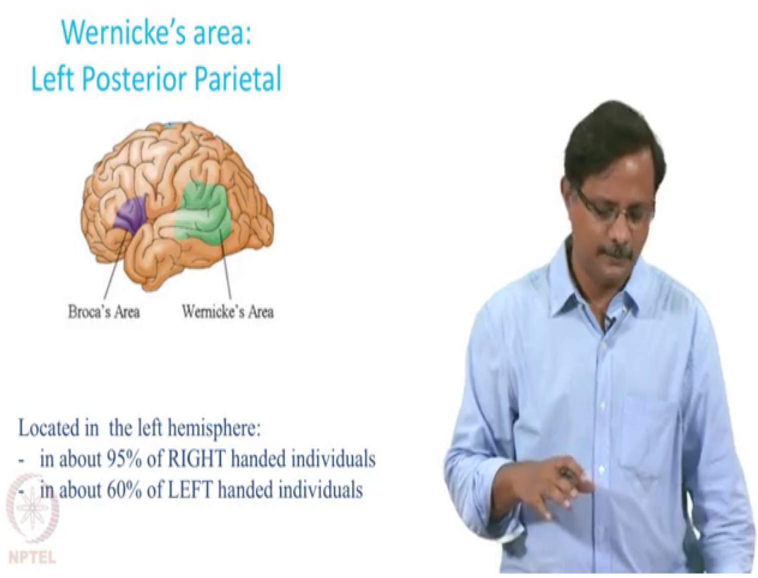

Then there is wernickes area is area which is also located in the posterior parietal on left and this is typically located in the left posterior parietal. We have seen in our very first lecture or maybe the second lecture that wernickes area is responsible for language understanding or the comprehension of language and that this is located in the left hemisphere in most people who are right handed. So, 95 percent of right handed individuals have the this area wernickes area located in the left brain and in about 60 percent of the left hand individuals it is also located in the left brain ok.

So, on the so, until now the basic sensory processing occurs in both sides of the brain in both hemispheres, but language processing seems to become unilateral it is only on one side it occurs say that in the mostly in the left side of the brain on the right posterior parietal.

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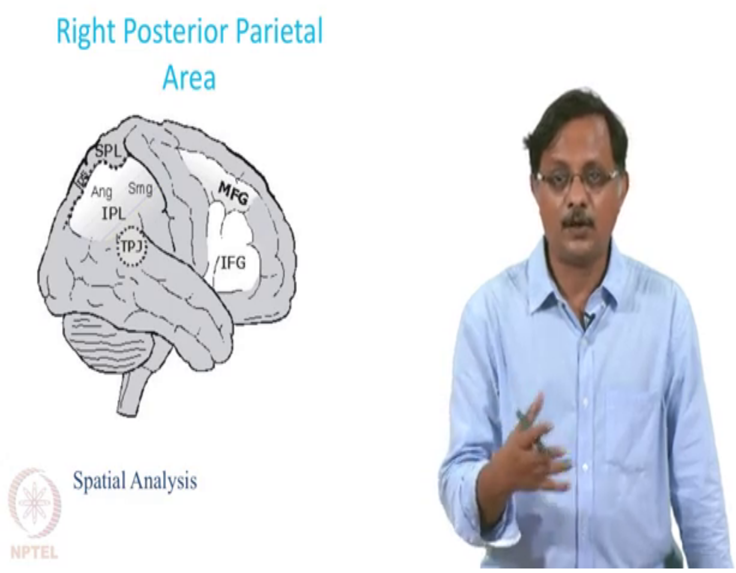

Then there is a kind of a complimentary area which is you know responsible for large scale spatial analysis. So, so, damage to this area can give rise to problems related to understanding space. So, for example, all right if there is a lesion in the right posterior parietal cortex. So, since the right brain processes left part of the world and the right part of the world. So, damage to the right posterior cortex gives rise to difficulties in handling the left part of the world.

So in fact, the difficulty in this case is. So, profound that the patients simply fail to recognize or acknowledge the left part of the world.

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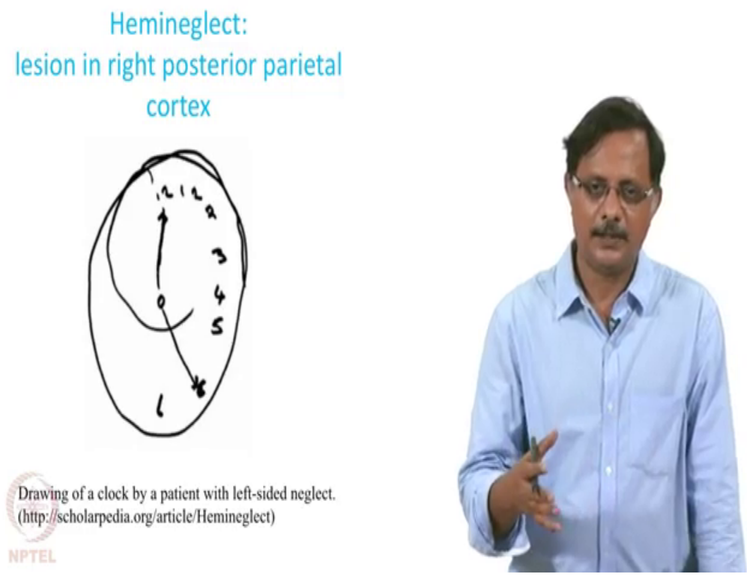

So, here is a picture of a clock and drawn by a patient who suffers from a lesion or a damage to that right posterior parietal cortex. And in this case the person has drawn the clock only on the left on the right side the person has completely omitted the details of the clock on the left side maybe it is as low the left side of the space while left side of the world does not exist right for this patient.

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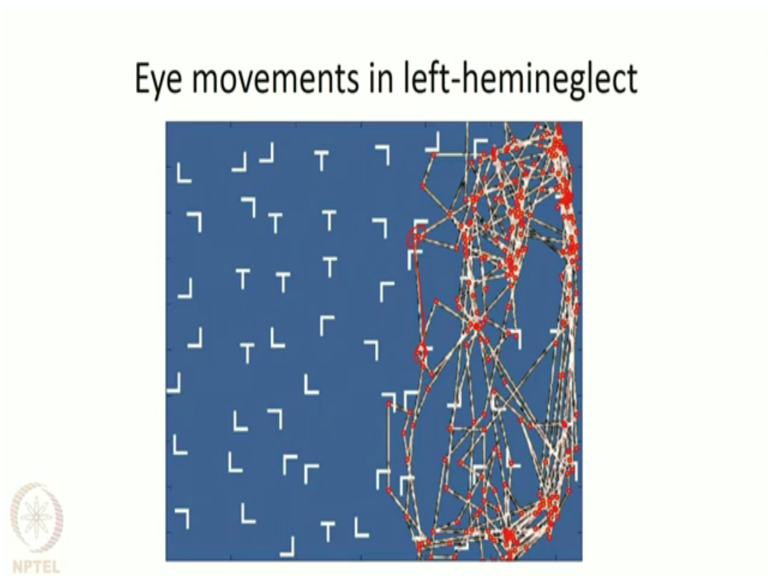

Similarly, a patient suffering from this left hemineglect which is; what this condition is called? That was asked to search or visually scan a certain image which has these regular features consisting of right angles and inner t junctions.

So, normal person would scan the entire image, but the Hemineglect person seems to be scanning only the right half of the image right. These dots show and the lines here show the scan path the lines show the path that is travels by your you know eyes has scanned the image and the dot show where the eyes are fixated temporarily. So, in this case also the patients have no fail to acknowledge or look at the left part of the image.

There is another interesting experiment done by Hemineglect patients.

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So, this will people were taken into a famous cathedral in the city of Milan in Italy this catheter is called piazza del duomo. So, in one case the patients were asked to face the cathedral and describe the cathedral in the other case the patients were asked to turn that back on the cathedral and described the street that is in front of the cathedral in both cases, the patients only described the left part of the scene as though momentarily the right part of the scene disappeared or simply became nonexistent right.

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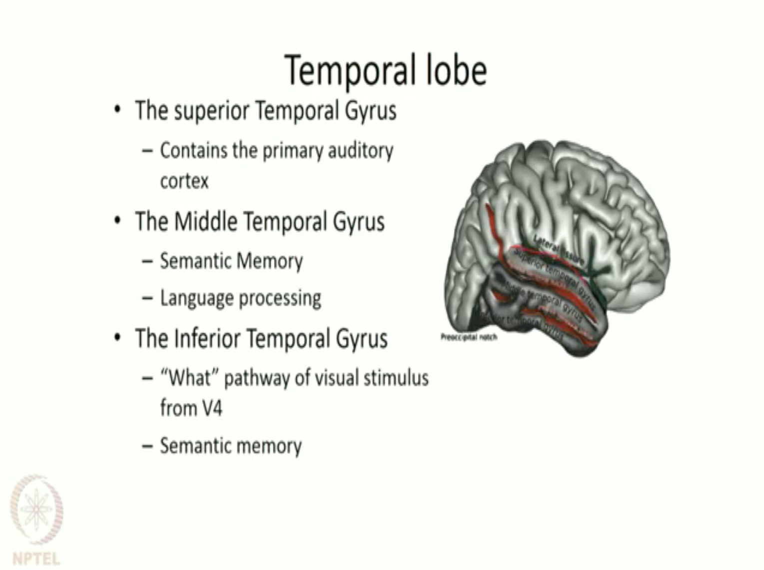

So, for the patients then let us go to temporal lobe. Temporal lobe again has three different regions: there is a the superior temporal gyrus, the middle temporal gyrus and the inferior temporal gyrus. So, superior temporal gyrus that we have already mentioned that it has a area which the process sounds it is called the primary auditory cortex and middle temporal gyrus has areas, which process a semantic memory or memory of words or naming or names of objects all right. The verbal names of objects. So, it is also involved in language processing the inferior temporal gyrus which is a part of the what pathway as you mentioned before that deals with representing all objects all right it is also related to names of objects. So, there is where you store wa names of objects

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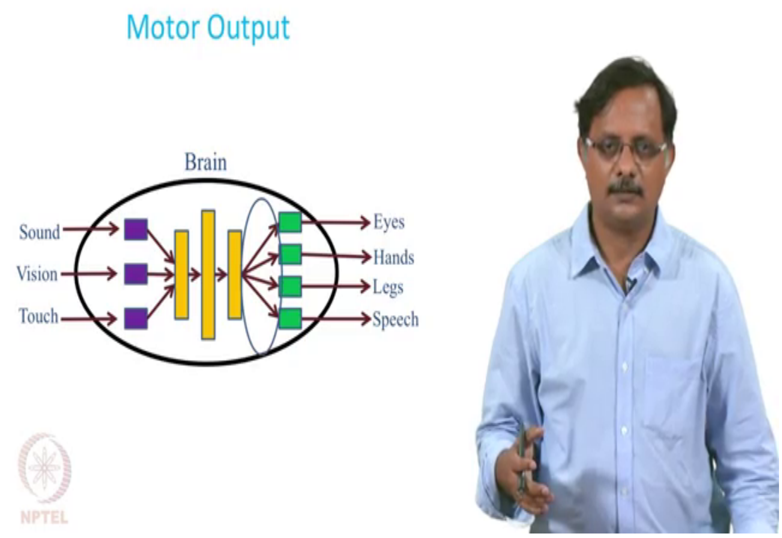

So, we talked about sensory input, we talked about combining sensory input. Then let us go to the motor side and look at different forms of motor output. So, there is motor output you know there is map is represented in the frontal part of the brain in the frontal lobe.

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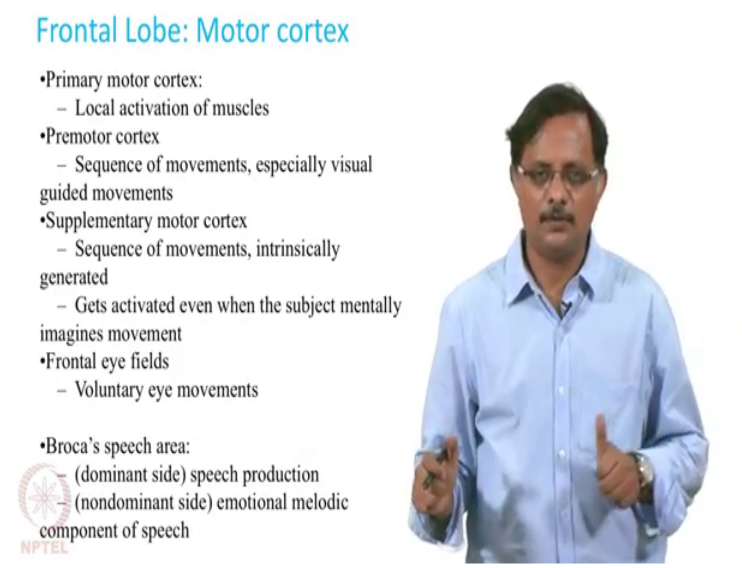

So in fact, a very broad thumb rule for organizational function in the brain is a posterior brain or the brain behind this central sulcus right is mostly about sensory processing about crossing inputs whereas, the anterior brain or the brain.

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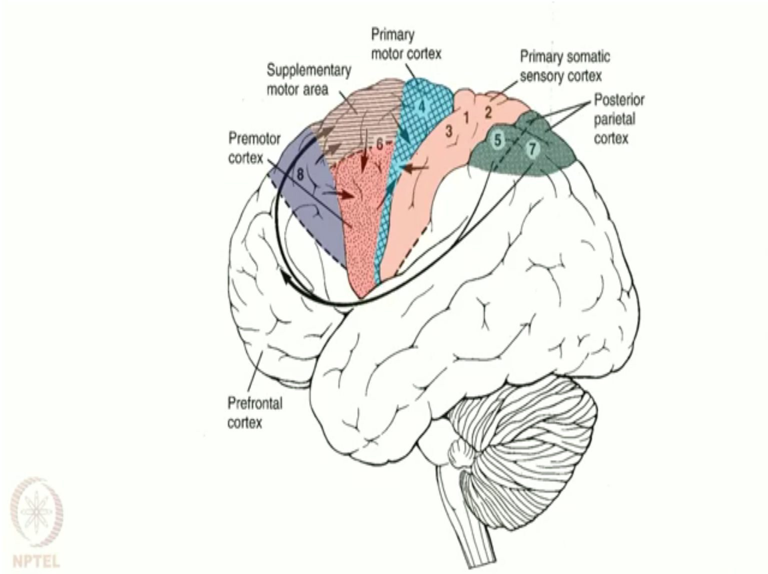

In the front in the front of the central sulcus is mostly about action that was output or output are planning or before you perform some action you plan to know for it, and you have a strategy for it, and all these all the strategizing and decision making and actions all that occurs in the anterior brain before this inter circus ok.

So, there are lots of areas which control movement the so called motor areas in the frontal lobe. So, for example, there is a primary motor cortex right, where if you activate neurons. So, the blue region here is the primary motor cortex which is right in front of the central sulcus. Now in the precentral gyrus so, here if you activate neurons they produce activation of you know some specific muscle or a part of a muscle.

Whereas, if you activate the supplementary motor cortex which is at a higher level in the hierarchy. Then the primary motor cortex will produce a whole you know complex sequence of movements there for example, say waving the hand alright and what is interesting is a supplementary motor cortex gets activated even when you are not moving, but you are only imagining moment right. So, suppose you are imagining that you are playing on a piano and you guys you can see the sublimity motor cortex is active, but when you are actually playing the piano that is when the primary motor cortex also join that joins activity.

Then there is a premotor cortex which is located here right and this cortex is also above the primary motor cortex and here also if you activate neurons that produce sequence of moments, but what is interesting about promoter is that a neurons here also respond to visual inputs. So, they are this part is responsible for visually guided movements now suppose you are ready to catch a ball in the ball is coming towards you and you have to move your hand into the path of the ball and meet the ball and catch the ball to do that it is not enough to just activate your hand you should also process the visual information. As it is coming in and coordinate the movement of the hand with respect to the visual information. So, you need to have the corresponding area which controls your hand also respond to visual information. So, that is exactly what happens in the premotor cortex.

Then there are frontal eye fields because the. So, so your motor output right voluntary motor output is wrenches are either moving your hands are moving your trunk and moving your legs right all these consist of moments of skeletal muscle in addition to this your output consists of moving your eyes or moving your vocal cords activating your vocal cords. So, as to produce speech. So, moment of eyes is controlled by what are called frontal eye fields and they are located somewhere here ok.

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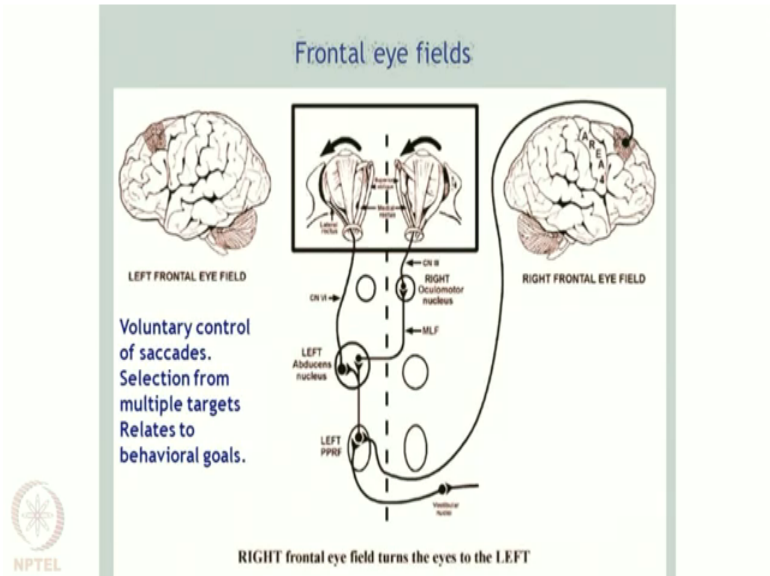

So, you can see that all these motor areas are all together they are nearby you know close to each other then brocas area we have seen before right is somewhere here and that control speech. We have talked about the sensory areas we have talked about the motor areas, but what happens in between the two right in this huge part of the brain which connects the sensory areas to the motor areas ok. So, so far we have been describing as if the sensory input simply goes on right crossing all these stages and you know getting translated into motor action it is as though there is no control there as though you are a kind of a helpless victim of your sensory inputs.

That is if you see some sensory input you have to produce right helplessly and without an inhibition the corresponding motor action.

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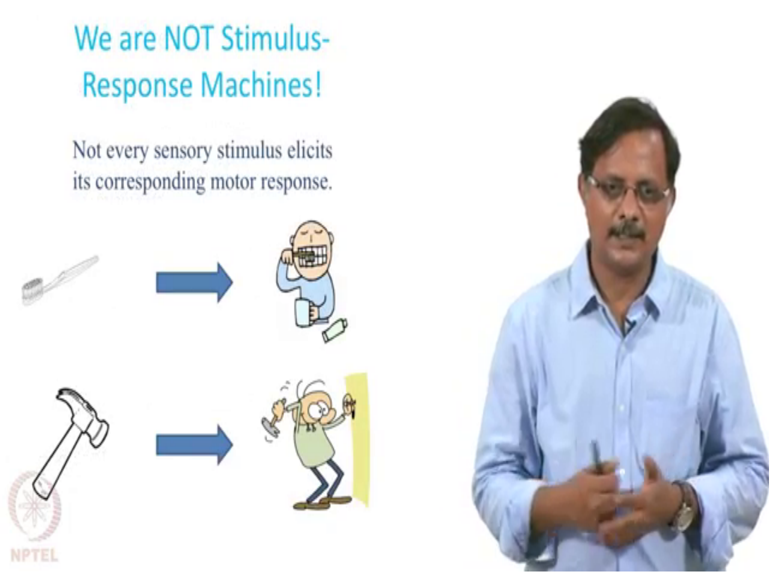

So, to give some example suppose you look at a brush a tooth brush right at logical function which you do with this toothbrush is brushing. So, immediately pick it up and brush yours or if you look at a hammer a logical function which you perform with the hammer is hammering a nail right you. So, pick up the hammer and keep performing right I mean so; obviously, that is not how we live and we do not respond to every object and immediately act on those objects as if you know we do not have any choice right of refraining from acting on that object.

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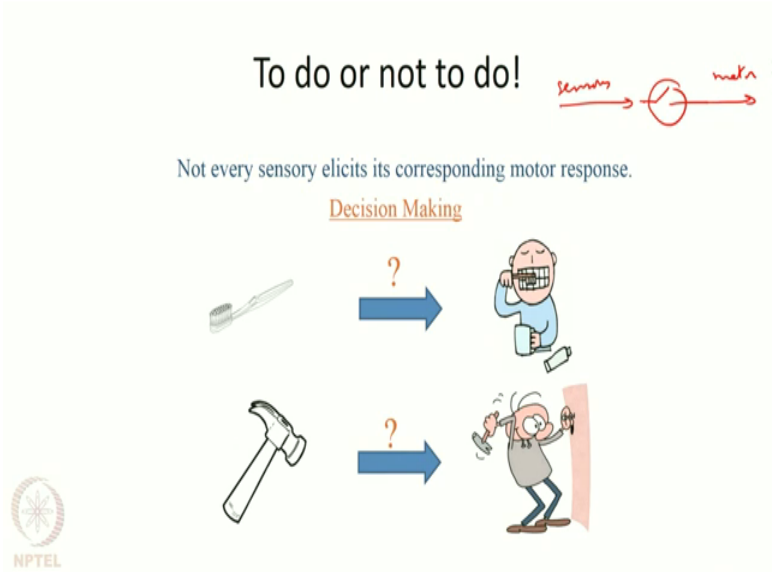

So; obviously, we have a choice we decide whether to perform the act on to perform the act right, because if you keep on acting or responding to the world like this. In fact, there is actually a there is a psychological condition called the environment dependency syndrome; where the person you know has no volition or will of his or her own is completely dependent on the environmental conditions. So, suppose you see a comb lying on the table right you immediately pick it up and comb your hair right or you see a pen that you immediately pick it up and start writing something alright.

So; obviously, I mean you cannot live like that, because you have your own objectives you have your own choices that you want to make and then the way you respond to a given input a given sensory input depends upon what you have in the mind alright. So, so it is that that is provided by the frontal lobe a part of frontal lobe which is called a prefrontal cortex.

So, this is what comes in between your input and output so. In fact, we can just make a simple cartoon picture here. So, this is your sensory input and this is a motor output and between these two you want to have a gate right which decides whether or not to go with this action that gate is located somewhere in this prefrontal cortex. In fact, there is not a single gate there are whole system of gates which are located inside the prefrontal cortex.

So, so, this is inside the frontal lobe whereas, you can see in this picture.

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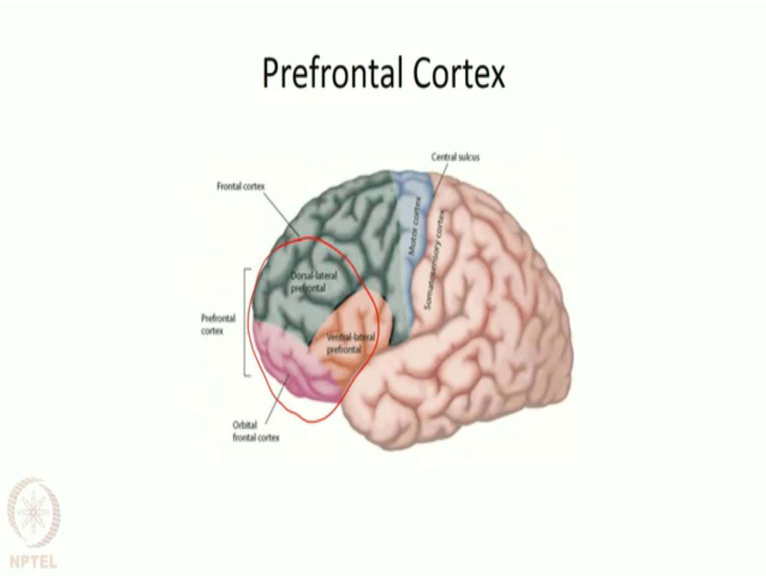

So, this is. So, this part is the prefrontal cortex and what you have seen before the where the motor here are located and there they are not they are in frontal lobe, but not in the prefrontal cortex.

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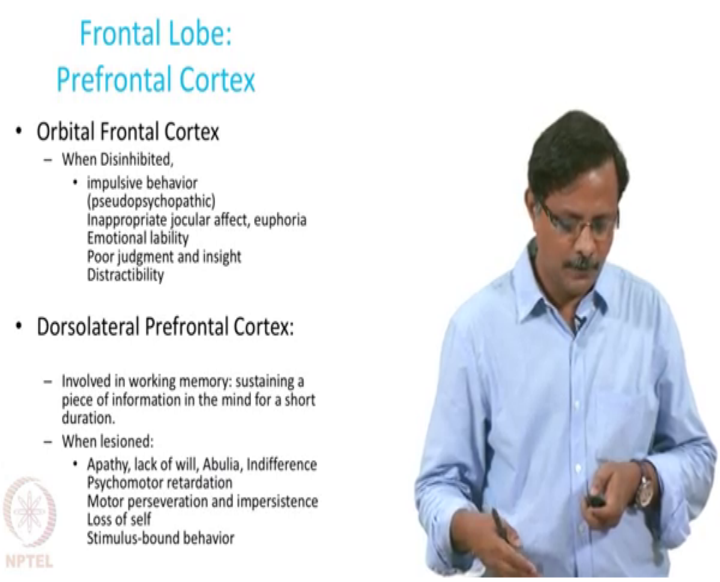

So, here again there are a couple of interesting important areas, in the prefrontal cortex there you see orbital frontal cortex which when disinhibited right produces impulsive behavior and poor you know their emotions are constantly shifting and fluctuating the poor judgment about; what is right and what is wrong and that quickly distracted in their plans and keep changing their plans and so, on so, forth.

Then there is a dorsal lateral prefrontal cortex which is involved in working memory and that is that refers to; how you store information for a short period of time? For example, if you are dialing a phone number you write you look at the number written on a piece of paper and keep it in your mind for a for a moment and then you dial it in. So, so this is the kind of memory that is called working memory. And the dorsal lateral prefrontal cortex which is part of a pre prefrontal cortex is involved in this kind of working memory.

So, therefore, when it is lesion or damaged people show apathy a lack of will and this condition called Apulia Abulia which denotes lack of will. So, person suffering from Abulia could be simply sitting there all day long you know without initiating any action and he has to be or she has been told what to do and on her own or the person may not have any will or motivation to do perform actions.

So, then there is a loss of self, because the sense of personality the sense of self is represented in the in this area and. So, damaged here right gives rise to loss of self and stimulus bound behavior, but a lot of our understanding of prefrontal cortex may be in the very first example of our understanding of prefrontal cortex has come with an accident to this person called phineas gage I think.

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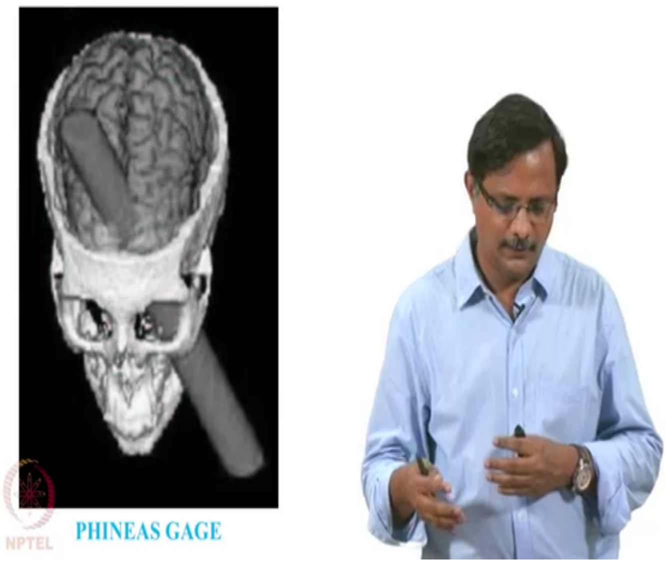

We talked about this story in an earlier lecture. So, gage was a road rail road railroad construction worker who worked in America in the late nineteenth century

His job was to pack ammunition right and then explode bombs and soften the soil. So, that you can lay down the railroads as he was doing that; once you know the bombs like kind of blew up on his face and the crowbar with which he was packing the ammunition went through his prefrontal cortex, damaging is orbitofrontal cortex and loss at the prefrontal cortex. So, after that he survived, but you know there was very perform personality changes right in this subject and the doctor who treated him this is how we would describe gages personality.

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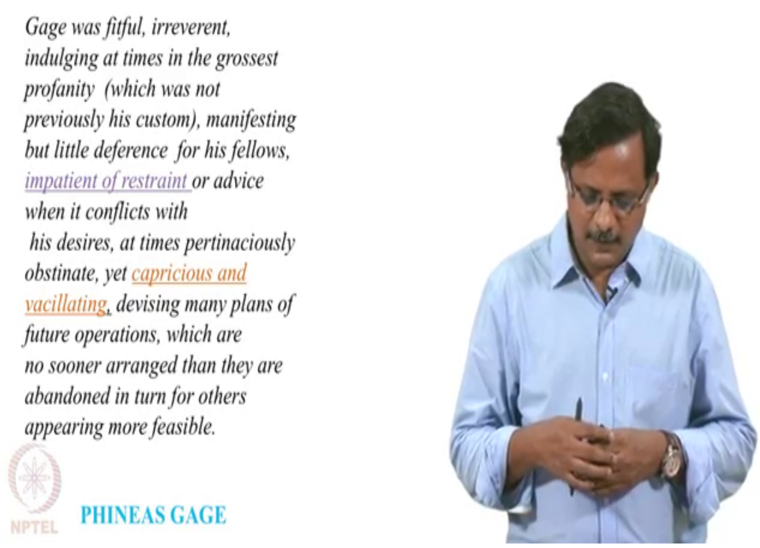

He says gage was fitful, irreverent, indulging at times in the grossest profanity he would swear and which was not his nature earlier which was not previously his custom, manifesting what little difference for his fellows, impatient of restraint or advice when it conflicts with his desires, at times pertenaciously obstinate, yet capricious and vacillating, devising many plans of future operations, which are no sooner arranged than they are abandoned in tone for others appearing more feasible.

So, basically he shows very highly variable and fluctuating emotional condition and is very impatient there is no restraint. And these are the kinds of capabilities that are given by a orbital frontal cortex and you cannot remember things. You know he cannot hang on to a goal and to be able to pursue a goal and hang on to a goal and show committed action towards too.

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And work towards the goal you need to have a strong memory.

So, for example, take the simple example of you know how you go to a kitchen or drink some water right, you go to the kitchen open your refrigerator and very often; when you go to the kitchen you forget or open the fridge that you forget, what you have come there for then you kind of use cut your head. And then you recall that you come there to drink some water and you pick up the bottle and drink.

So, to be able to pursue goal directed behavior you need to be able to keep the memory of the goal for a succinate period of time, and that is where prefunded function to picture and therefore, prefunded damage destroys that capability and. So, the person cannot hang on to a goal and pursue the goal for a long period. So, which is what you see in case of phineas gage right the heat he would devise many plans of future operations which are no sooner arranged and they are abandoned in turn for others appearing more feasible ok.

There is a typical prefrontal condition. So, prefrontal lobe is important for planning and working memory like we just said a goal or into behavior involves planning working memory and requires these prefrontal areas.

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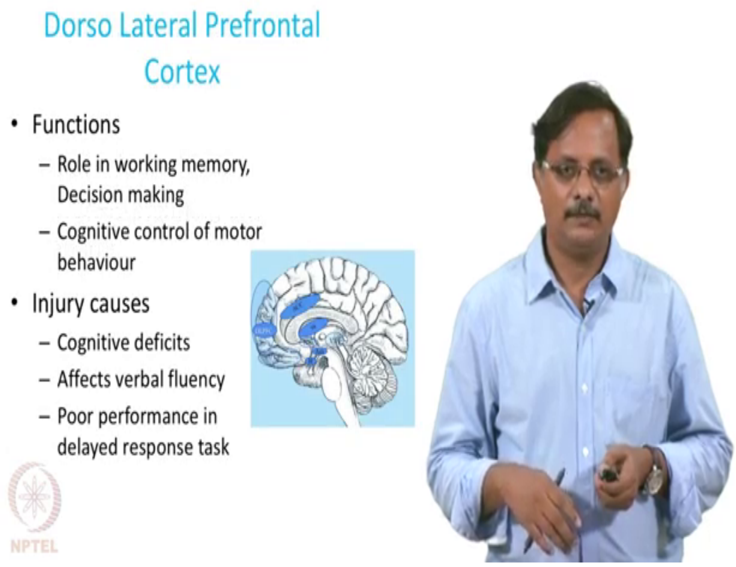

Then we also talked about dorsal to the frontal area which is it is involved in working memory and decision making.

So, injury to prefrontal cortex can give rise to cortical cognitive deficits like; we have seen just, now and it also affects the verbal fluency and shows poor performance in a working memory task called delayed response tasks. Let us see what this task is.

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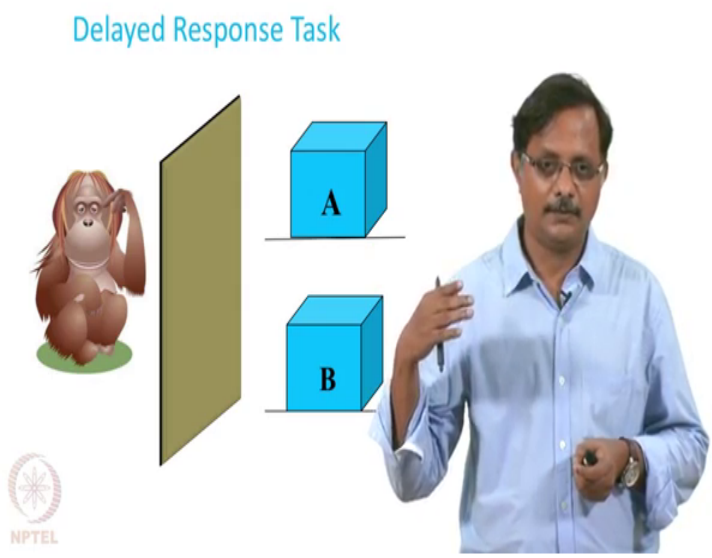

So, here you can see a chimp facing in two boxes a box A and box B.

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And one of the boxes hides a banana another box is empty. So, the chimp look gets to look at the 2 objects in 2 boxes and what is underneath these boxes first and then screen comes between the chimp and the boxes and the screen remains there for some time.

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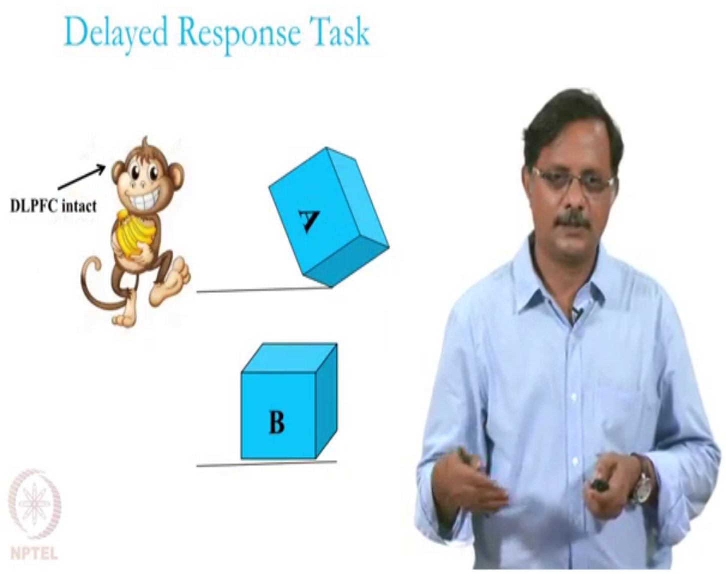

So, the meantime the chimp has to remember which box was hiding the banana, then the screen is removed the chimp had it is DLP FC. The selected prefrontal cortex intact that it remembers exactly which box has a banana I know picks up the opens the box and picks up the banana.

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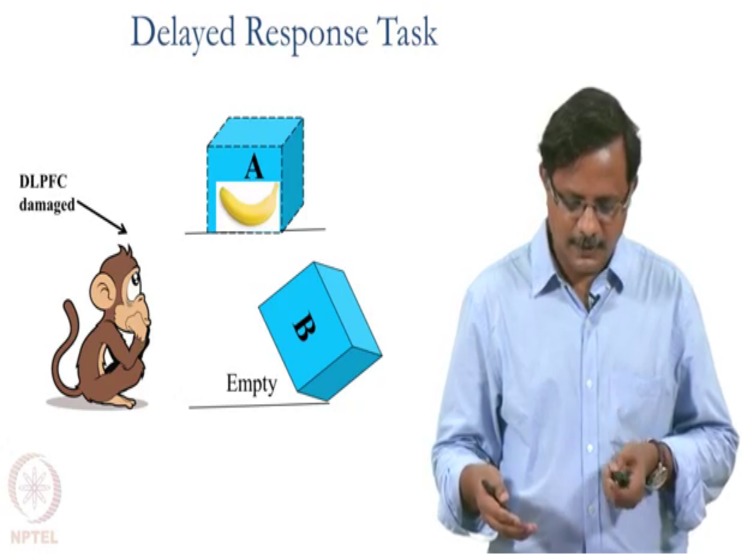

But, if the DLP FC is damaged and it does not remember, it has to right just by looking at the boxes in that cupboard from you would not be able to know, where the banana is and keeps wondering where the banana is.

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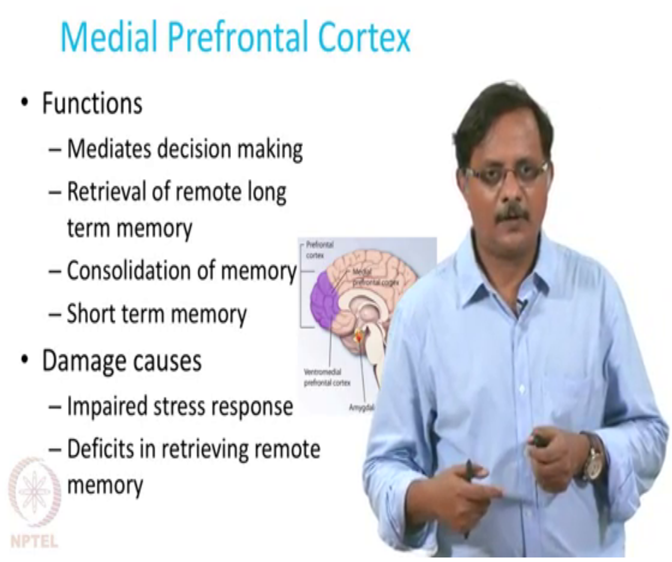

Then there is medial prefrontal pre frontal cortex which again has involvement in decision making it is involved in retail of a very strong much longer term memories.

So, DLP FC is into working memory which is a short term memory the order of seconds and minutes, but then we also need to have much longer memories sometimes. We pursue goals for you know years and decades through our lives right to do that, you need to have parts of the brain which can handle also information for much longer a term and medial prefrontal cortex is one such an important area in that circuit, Therefore, damage to medial prefrontal cortex can impair stress response and also have show deficits in retrieving remote memories ok.

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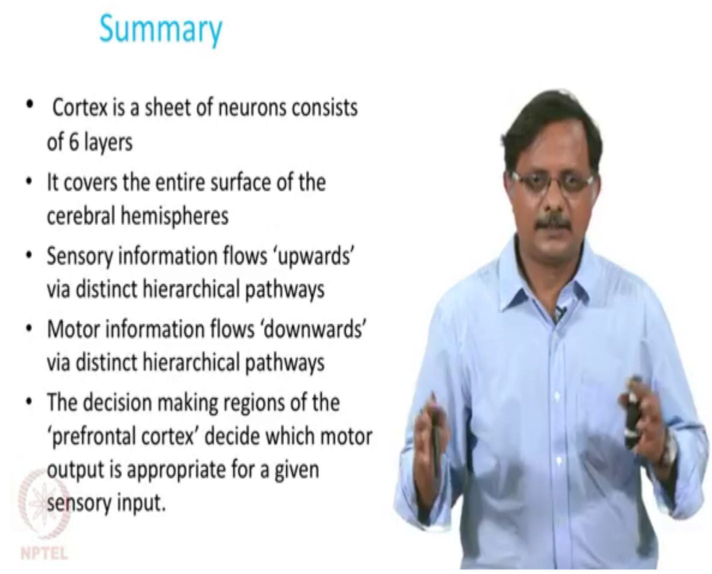

So, that completes the kind of a summary of some of the important cortical areas. And we have tried to put them together in a kind of a logical sequence. As if input comes to the sensory input and then flows through various intimate regions of the brain all right and flows upwards through distinct hierarchical pathways right.

And then after some point they blend they merge and then goes through various intermediate areas, the prefrontal cortex the decision making areas of prefrontal cortex and then they go to motor and motor areas where they flow downwards that where a distinct have a hierarchical pathways and produced various kinds of motor output.

So, these sensory input stream right, climbs upwards motor output stream climbs downwards ah, and then between the two this decision making regions of the prefrontal cortex which decide which motor action is appropriate for a given input; and it also decides whether or not to perform the motor action whether to perform the action or not perform a action whether to do it or not to do it.

Thank you.