Foundations of Cognitive Robotics
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Lecture – 05

Good morning students, welcome to the course on Foundations of Cognitive Robotics. We have reached week-2 of this course now. Now, before I start the lectures of week-2, let us quickly summarize what we have learned in week-1.

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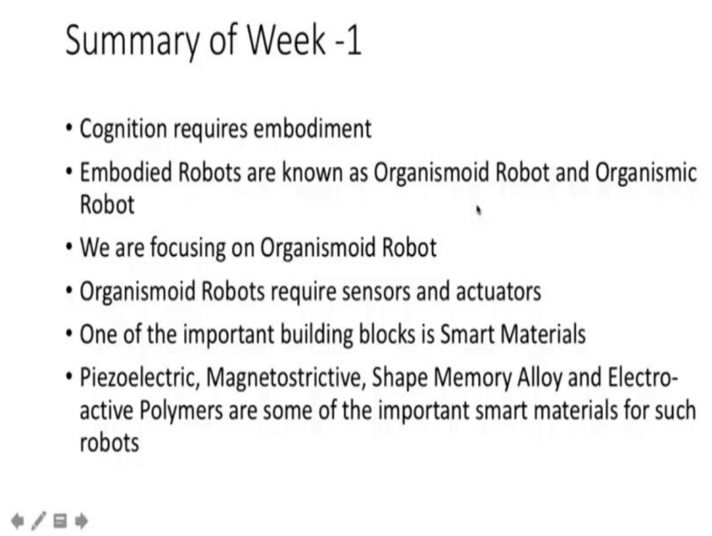

Summary of our learning of week-1. The first point that we have learned is that cognition requires embodiment we have told you, I have told you about the difference between strong AI and weak AI system. And the cognitive robots belong to the weak AI class for which embodiment is essential.

Now, embodied robots are classified into two categories; organismoid robot and organismic robot. So, these are the two categories you would see organismoid and oganismic robot. We will be focusing on organismoid robot. As I told you that organismic robot is still far ahead in the future. So, we will first, we will start to think of how to materialize an organismoid robot.

Now, organismoid robots, you know because they try to simulate like a biological system. In order to do that, they would require sensors and actuators. These sensors and actuators we have seen that in some of the traditional robots they are based on, like the actuators are based on motors or servo motors, and the sensors can be different types of off the shelf standalone sensors.

But if embodiment is unfocused, then one of the important building blocks of these sensors and actuators could be based on smart materials; that is why I told you about four different types of smart materials which can be used for sensors as well as actuators. Piezoelectric smart materials, magnetostrictive smart materials, shape memory alloys and electroactive polymers.

But if you remember that the last two shape memory alloys and electroactive polymers can be actually developed in terms of developing artificial muscles which can have agonist-antagonist structure. So, with this building block that we have discussed in the summary of week-1, now we will go to week-2 of our lecture.

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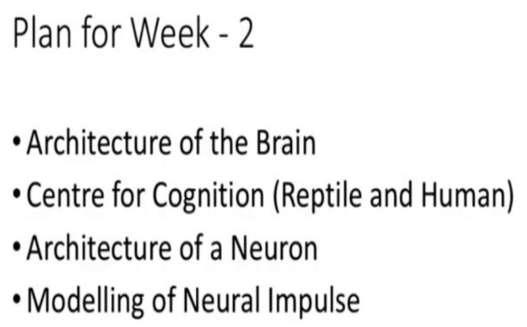

Let us now look into our learning goals of week-2. My plan for week-2 is that now because the cognition is into the picture, I will first discuss about the architecture of the brain, and the center for cognition for reptile and human by looking into the specific areas of brain. And then from brain, I would go to even in a top-down approach to the architecture of a neuron, and we will also talk about how to model the neural impulse.

Now, let us look into the cognitive perspective which we will be having with us, because when will be talking about the biological systems like the brain and the other nervous systems, then there can be a biological perspective towards it, but our focus will always remain towards cognition. So, let us look into that what do we mean by cognition, and from that point of view how we can look into a biological system.

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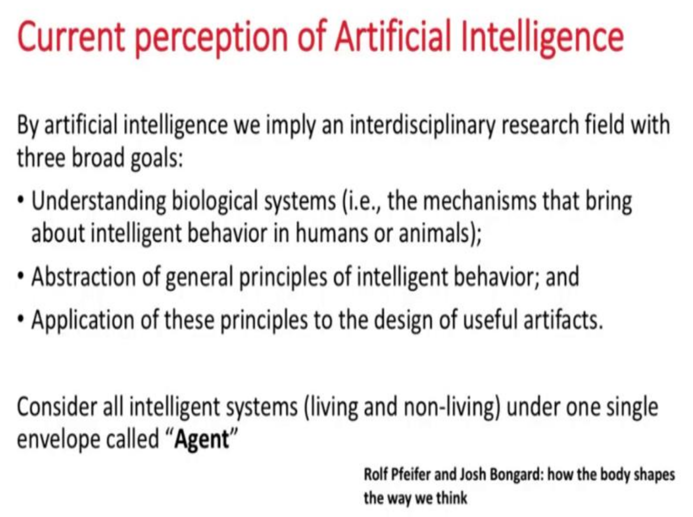

Our current perception of artificial intelligence actually touches three broad goals; the first one is the understanding of the biological system. For example, we will be trying to understand the nervous system today, and the mechanisms that bring about this intelligent behavior in humans or animals that is our first goal. The second goal is some of the abstraction of general principles of intelligent behavior.

As we will be talking about the biological systems, we will try to make these abstractions. And then further as the final goal is application of these principles to the design of useful artifacts. Now, we would consider all intelligent systems both living and non-living under one single envelop which is called agent. This is the direction that you will see in Rolf Pfeifer and Josh Bongard's book on how the body shapes the way we think.

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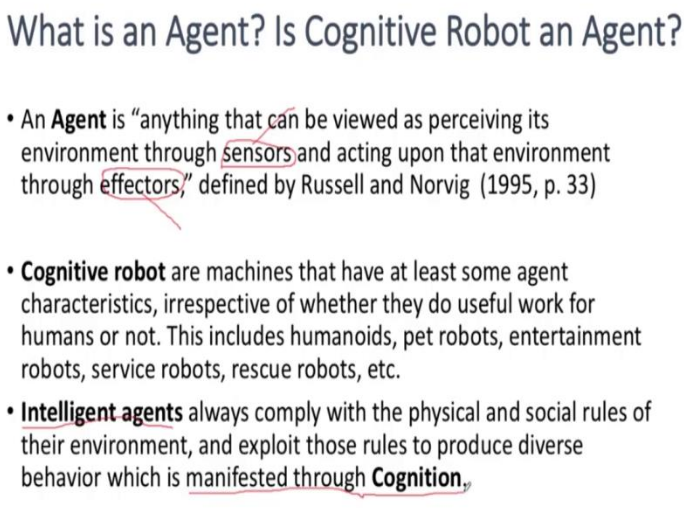

So, let us think into these agents. What we mean by this agent? So, what is an agent, and is cognitive robot an agent? Well, an agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors. So, there are two important points here. One is perceiving the environment through sensors, and another is acting upon the environment through the effectors. Both of them are important from an agent's point of view.

Now, when we talk about cognitive robot, we are talking about machines that have at least some agent like characteristics, irrespective of whether they do any useful work for humans or not. This would include humanoids, pet robots, entertainment robots, service robots, rescue robots, etcetera. So, they should have some agent like characteristics in the sense that they should have some sensors and they should have some effectors associated with them.

Now, in this same spirit, we will talk about intelligent agents as you can see. These are the agents which always comply with the physical and social rules of their environment. So, it is not only essential to have some sensors and some effectors, but also, they should comply with the physical and social rules of their environment and exploit those rules to produce diverse behavior. Now, whenever they are doing these the intelligent agents, this is generally manifested through cognition. So, this is what is important, that this is manifested through cognition. So, let us then look into that how exactly this manifestation happens in the system.

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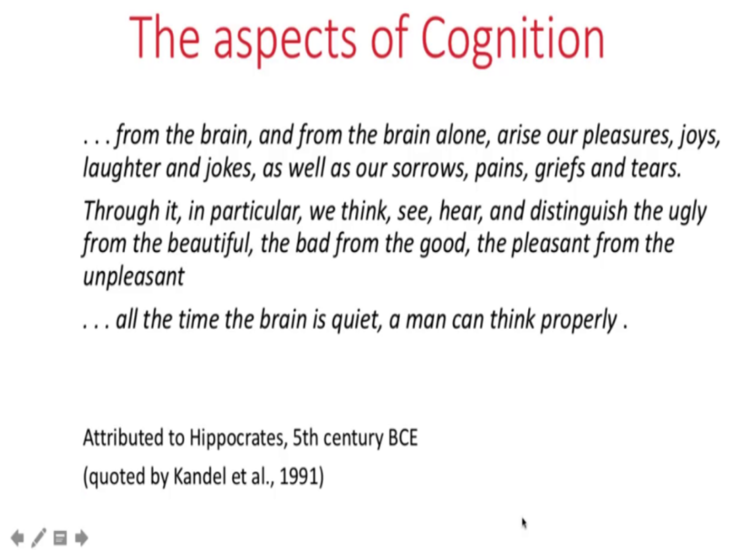

Now, whenever these cognition would come into our purview, we would always remember these very interesting quotation by Hippocrates in the 5th century BCE, when he said that from the brain and from the brain alone, arise our pleasures, joys, laughter and jokes, as well as our sorrows, pains, griefs and tears. Through it, in particular, we think, see, hear, and distinguish the ugly from the beautiful, the bad from the good, the pleasant from the unpleasant. All the time the brain is quite, a man can think properly.

So, even in the 5th century BCE, people understood that when we talk about the cognition, there is somewhere in the brain that the center for cognition lies. And they have understood that when we talk about cognition, we are talking about emotions, it can be both good emotions as well as bad emotions. It can be related to our thought process; it can be related to our, you know, capacity of judgment, capacity of identifying what is beautiful, differentiating bad from the good, and pleasant from the unpleasant. So, that is essentially what we want to impart to a cognitive robot as well. And in the biological system, by and large, this is controlled by nothing but the brain.

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How does brain activity relate to Cognition?

That’s a long story!

Let’s just begin with the basic architecture of the Human Sensory and Processing System.

So, the question is how does brain activity relate to cognition? Well, that is a long story. Let us just begin with the basic architecture of the human sensory and processing system. We will first look into the human sensory and the processing system; through that you will be able to appreciate what a complex architecture is required to get the level of cognition that Homosapiens are having. Let us look into the human nervous system.

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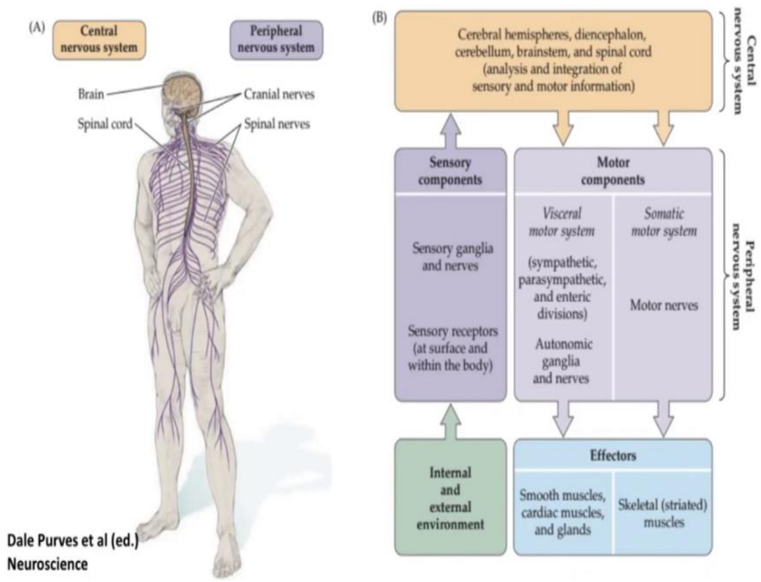

The human nervous system is essentially divided into two parts; central nervous system and peripheral nervous system. Now, central nervous system would consist of the brain, and the spinal cord, whereas the peripheral nervous system would have the cranial nerves and the spinal nerves. Function wise, the central nervous system is having the cerebral hemispheres, diencephalon, cerebellum, brainstem. So, this all the three or four important parts, they are all inside the brain when we actually look into the brain, we look into all these things.

In addition to that, the central nervous system also consists of the spinal cord. So, they basically take part in the analysis, and integration of sensory and motor information. Now, whenever you have some internal or external environmental change, your sensory receptors at the surface and within the body if it is external, then the outside you know thinks of the sensory receptors at the surface. And if it is inside the body, then it is a visceral one. So, those sensory receptors, they actually collect the information of the environment, and they add it up in the sensory ganglias. And from there, the sensory components are actually accessed by the central nervous system.

On the other hand, that is the input for the central nervous system, then the central nervous system what it gives back to the peripheral nervous system is in terms of different motor components. We can divide it into two parts; one is the visceral motor system; another is the somatic motor system. The visceral motor system which would consist of sympathetic, parasympathetic and enteric divisions, they have autonomic ganglia and the nerves, and they control things like for example, our heart rate, our digestions and our all other internal organs that is controlled by the visceral motor system.

On the other hand, the somatic motor system controls the motor nerves, and they control the effectors like the skeletal muscles, so that is where the somatic motor system would work. And the visceral motor system would work on cardiac muscles, glands and the smooth muscles which occurs in the in large intestine regions etcetera. So, that is the overall you know circuitries architecture of the nervous system in a human body.

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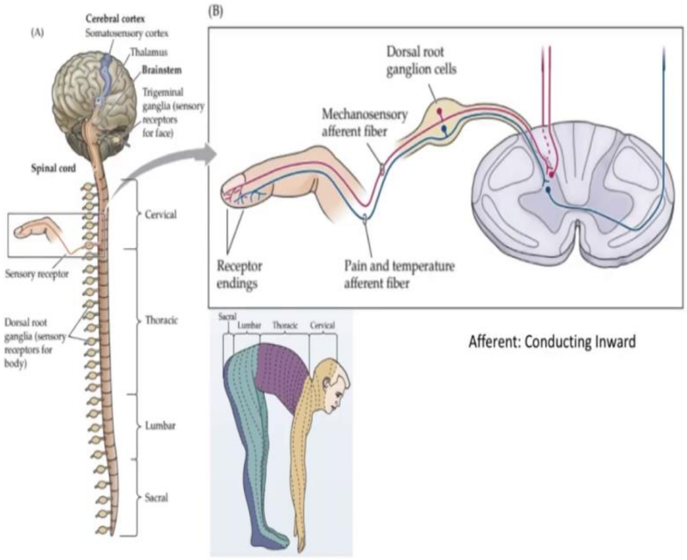

Now, let us look into some of the sub elements of it. Well, if we look at the central nervous system, you can see how it looks like, the top you have the brain. And the brain itself you can see is having different parts what we can see from here is the cerebral cortex; we can see also the thalamus here. And below the thalamus, we can see the brainstem; and below that we can see the spinal cord. So, this is this entire thing is the central nervous system.

How does it work? Well, look at one sensory receptor let us say we are considering one finger. Now, here are the receptor ends. And you have two different kinds of this red and blue denotes two different kinds of nerve fibers. One group in the red group is the mechanosensory afferent fibers. Afferent means something which is conducting the signal inward towards the spinal cord, and then towards the brain.

Now, mechanosensory afferent fiber is one which senses the changes in the mechanical forces, stresses, deformations etcetera. And the other one is the pain and temperature afferent fiber which senses the if there is some cutting bruise so the pain or if there is a temperature, so this is what carries it and they need the blue ones also goes towards through both of them goes through the dorsal root of the ganglion cells. And you can see this dorsal root of the ganglion cells here.

Now, this is the part of the central nervous system. And here the spinal cord itself is divided into four important parts, cervical, thoracic, lumbar and sacral. As you can see that the cervical region, you can clearly see up to the shoulder level, then the thoracic part, the body part, then the lumbar part and then, so it is the belly and the bottom part and then the sacral the bottom most part. So, that is what is the region of the spinal cord.

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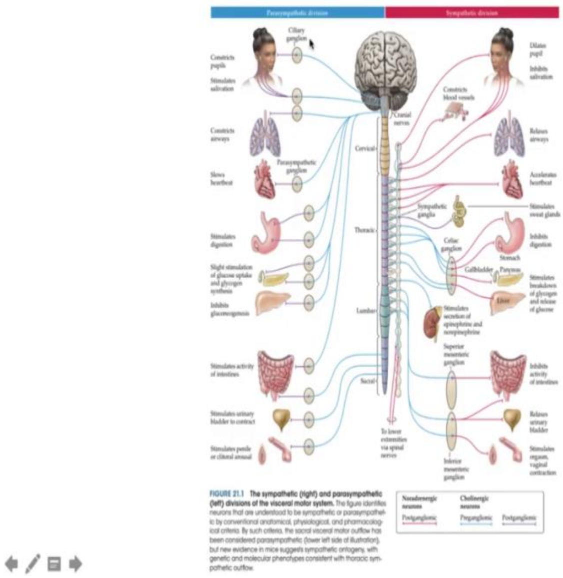

Now, let us look into the other part that is the peripheral nervous system. As I told you that it has two parts in it parasympathetic and the sympathetic divisions. Now, if you look at these very carefully, sympathetic division which is with the red bar is what is always required whenever it urgency, you need to do something immediately. For example, you are exclaimed it dilates the pupil.

It will inhibit the salivation; it will constrict the blood vessels; it will relax the airways, accelerate the heartbeat, and there will be stimulation of the sweet gland, sweat glands, inhibition of the digestion, stimulation breakdown of glycogen and the other release of the glucose – you need energy, inhibits activity of things like intestines, relaxes the urinary bladder, stimulates sometimes orgasms etcetera. So, this is all in terms of the sympathetic division.

Now, I told you that in the peripheral nervous system that these sympathetic jones, they actually the nervous systems they have the role of taking care of all the emergencies of the body. But our body is not always in an emergency mode it is also having the relaxation modes. So, it is at that mode when we will be having the other group of nerves of the peripheral nervous system that is the parasympathetic nerves, they will be playing an important role.

Let us look into their role. And in fact, what you will notice is that just like when we have discussed the muscles that you have agonists and antagonists, similarly there is always contradictions in the architecture. There is one group which excites it and there is another group which actually inhibits the process. So, during relaxation, it is the parasympathetic nerve which will come into picture. Let us look into their actions.

If you look at the parasympathetic division, you would see that here it is constricting the pupils so much so that in ultimate stage of relaxation you may simply sleep, it will stimulate salivation. It will constrict the airways you do not need too much of oxygen anymore; it will slow the heartbeat, because you are relaxing. It will stimulate the digestion process now. There will be a slight stimulation of glucose uptake and glycogen synthesis. It will inhibit the gluconeogenesis.

Stimulate the activity of the intestine, stimulate urinary bladder, stimulate peniles of clitoral arousal. So, these are all under the parasympathetic division. So, the peripheral nerve system always works between the two. Sometimes these is important when you have to survive, and sometimes this is important when you have to maintain the condition, the homeostatic condition.

Now, what you will see is that many of them are having you know the sympathy nerves, for example, are having either they are directly coming to these you know the roots – the ganglia roots, otherwise they may have some sort of you know they are ganglias closer to the organs itself. So, that is also possible in some of these groups.

Now, in the other hand in these case for the parasympathetic ones, you would see that here some of them are coming to the parasympathetic ganglions. And from there they are actually going to the directly you know this group is going to the brain stem area. Whereas, the other group here these last three of them, you would see that they are going to the sacral area. And from the sacral area, the signal goes to if required it goes to the brain stem. So, this is about the peripheral nervous system.

Why this cognitive architecture is important for us? Because we have to think of it when we will be developing the robotic cognitive architecture, some sort of a similarity is needed in terms of developing intelligent agents. So, that is why it is important for us to study the biological system to make abstraction of these systems, and then try to implement it.

We will now go into the central nervous system and the core of the central nervous system that is the brain. Now, we will look into one of the most sophisticated central nervous system, the core of the central nervous system that has been developed by nature. We look into the human brain. Now, let us look into a model of the human brain fast, and then I will describe the system to you one by one, sometimes going deep inside the system.

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Here is with us a model of the human brain. Now, as you can see here that this human brain is divided into two parts; the left and the right. And there is a fissure between the two, so that is what is called the longitudinal fissure. So, we have the left part of the brain, and the right part of the brain and that is from the top when we are looking at. And this very top part of the brain, the top part is actually is the frontal lobe of the brain; we will talk about it when you will see the diagram.

Now, if I look at a side view of the brain, you see we are looking we are now taking it towards the side, now let me just tell you that the eyes will be towards this direction the frontal side ok, and the ears will be in this direction. Now, as you can see that there is a deep fissure here, this deep fissure is known as the lateral fissure which actually separates the frontal lobe from the temporal lobe. So, the temporal lobe is here.

We can also see in the top another fissure that is visible ok, and this fissure is known as the sulky the central sulky, and that actually divides the frontal lobe and the parietal lobe. So, this is where from the central sulky, the front part is the frontal lobe part and the back part is the parietal lobe part.

Now, you can see that just like the frontal lobe divided between left and right. Similarly, if I just turn it you will see that the parietal lobe is also divided between left and right. And not only that below that we have two different parts also here, these are parts of the cerebella. So, this is when we look into the brain from the top.

Now, I am going to even open it up from you in order to know that where this brain is connected with the so called you know the spinal cord. So, let us look into that. Now, if I actually try to open it up, this will be visible to you.

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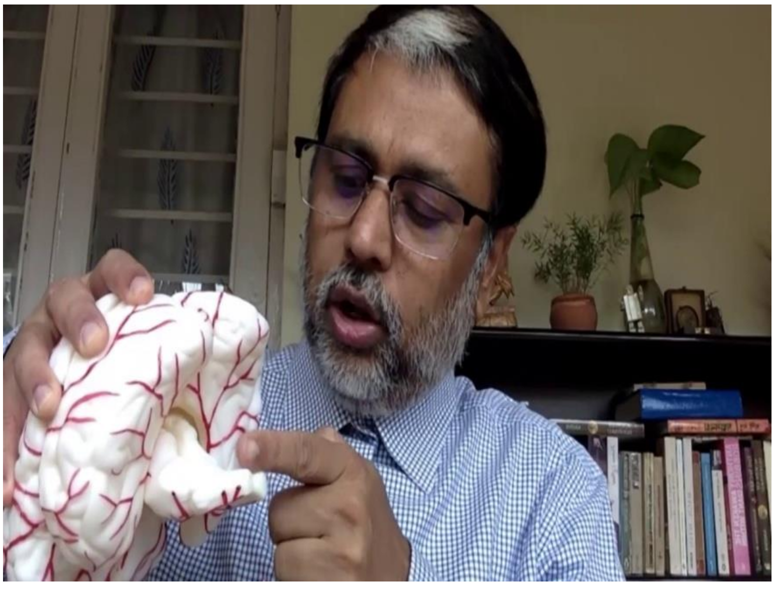

So, let us take keep these other parts away. Now, we are deep inside the brain and we are looking at the brain from inside. As you can see that from the spinal cord, this is where we are actually getting all the nerves inside the brain region that is the brainstem as you can see. Now, this brainstem, this part is what is called the medulla oblongata, and then you have the pons area, and then you have the midbrain.

And even deep inside you are going to have the other parts which we will discuss later on the thalamus and hypothalamus and all these regions, but this is where the brain gets connected with the these you know peripheral nervous system through the spinal cord. So, this is what is the overall view. So, we have to keep in mind once again the basic important part is the frontal lobe, the temporal lobe and the parietal lobe, this is the cortex area of the brain. And also I have shown you the cerebellum.

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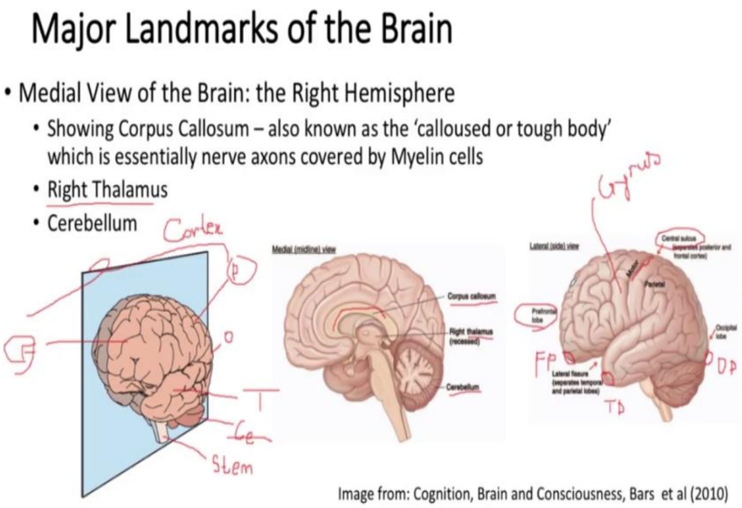

Now, let us look into the details of this brain structure into the major landmarks of the brain. If I take a medial view of the brain, then we will see the right hemisphere. So, if I take the medial view, you will see the right hemisphere part of it ok. And just keep your mind that this is what is the frontal lobe.

So, this is the frontal part, this is the frontal part ok. I will just write F here, so that you understand that. This is the frontal part. And this is what is the parietal part, so I will just write P here, so that you would understand. This is the parietal part. So, eyes are here in this direction. And this is what is the temporal lobe, so that is the T, I will put here that is the T part. And deep below the parietal part, we have the occipital part here. So, I will just write it as O which will say that this is the occipital part here.

And if you remember that this is what I have shown you a few minutes before so that is the brain stem. So, this is the stem part of it ok. So, I will just try to write here that this is the stem part of the brain. So, you know you can get the bearing of it ok. And of course, this is the cerebellum part, so that is what is the C I put. So, I will keep it as Ce, so that you know this is the cerebellum. On the other hand, this top area these frontal and parietal and all these things together that is the cortex part ok, so that is the cortex. So, this is the cortex part of the brain. So, this is just to give you an overall bearing of when you are looking at the brain. And in this case we are looking into the right hemisphere ok.

Now, if I actually open up from the longitudinal fissure, if I open up the brain, then inside you will see this region and that is what is known as corpus callosum. The corpus callosum is actually white, because it is myelinated. Myelinated means here there is a fatty layer over all the nerves, whereas this area is the gray area the top part is the gray area.

Now, inside that I told you that in from the brainstem if you go up you can see the cerebellum here that is what is the cerebellum part that I was telling you. And then if I you can see also here the pons area and the you can also see the midbrain, and on the top of it you can see the thalamus part of it. In fact, the thalamus is also having the right thalamus and the left thalamus; here it is the right hub. So, you are going to see the right thalamus here ok.

And if you look at the whole brain system again you see the frontal lobe the most important part is the prefrontal lobe part of the frontal lobe. And there is a pole here this is also known as the frontal pole. So, this is the frontal pole, I can call it shortly as FP that means, this is the frontal pole ok. So, this is the frontal pole area. Then you also have similarly one pole here that is the ultimate culmination point of the temporal pole, so I can call it as Tp which is below the lateral fissure ok. And similarly you have the occipital lobe here and this is where you have the occipital pole. So, this is where you have the occipital pole ok. So, these are three important poles.

Now, another thing I want to show you from this diagram that you can see that some region seems like they are actually going up bulging up the hill regions ok. So, these are the regions which are like we will call them to be gyrus. So, this is what will be the gyrus region, that means, here you are getting the bulging or the hill like situation. So, these are gyrus region gyrus region ok, ok.

Now, you can see the other part that is the valleys you can see and valleys are called the sulcus. And it is the central sulcus that I have shown you earlier, so that is the central sulcus region ok. So, central sulcus essentially divide the cortex into two part that is the frontal cortex the F the frontal cortex part and the parietal cortex part, this is where it is dividing between the two. So, this is when you are actually getting a medial view of the brain.

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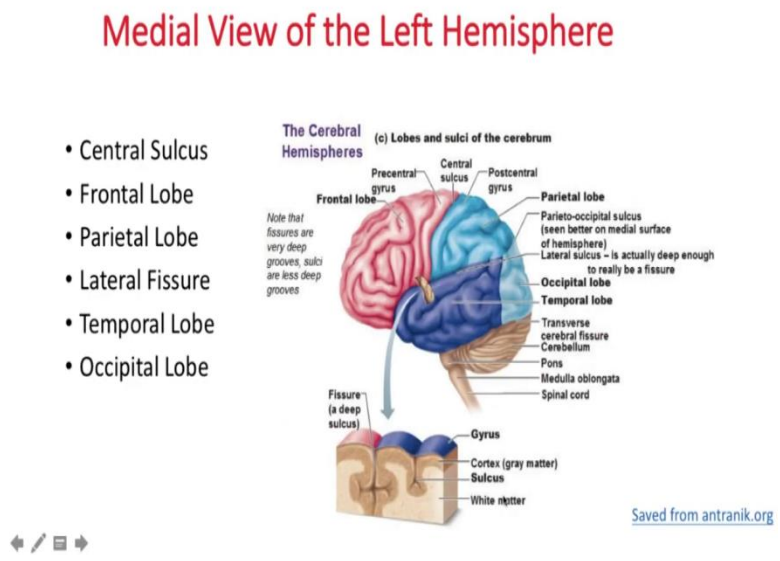

Now, let us look into just very similar to the right hemisphere. If I look into the left hemisphere, you can again see the central sulcus here. And you can see that the central sulcus is having two hills in between these central sulcus valley is there. The hill in the front part is called precentral gyrus, and hill in the backside part is the post central gyrus. This precentral gyrus and postcentral gyrus, they are very important you know somatosensory actions; I will talk about it soon

Now, you can see also the other parts in the frontal lobe and this is where is the prefrontal region of it. So, you can see the frontal lobe, you can see the parietal lobe as I told you here that is the parietal lobe. Parietal lobe itself is having two parts this is the parietal the frontal part and that is the somatosensory part, and this is what is the occipital part of it that is where is the occipital lobe.

And in the side where the ear is there let us say we have the temporal lobe as you can see the temporal lobe is here. And below the cerebellum is actually visible, and that is where you see transverse cerebral fissure, below which the cerebellum is there. Also you can see this slightly bulged pons and the medulla oblongata below which the spinal cord is there.

Now, anything slice here you would see that the top part that is where is a gyrus part, and below that up to certain level you have the cortex gray matter where you do not have any myelin cover. And if you go deep inside the sulcus, you will get the white matter like the corpus callosum I showed you earlier. So, this is what is the structure of the left hemisphere which you can see that it is very much of a similar structure like the right hemisphere.

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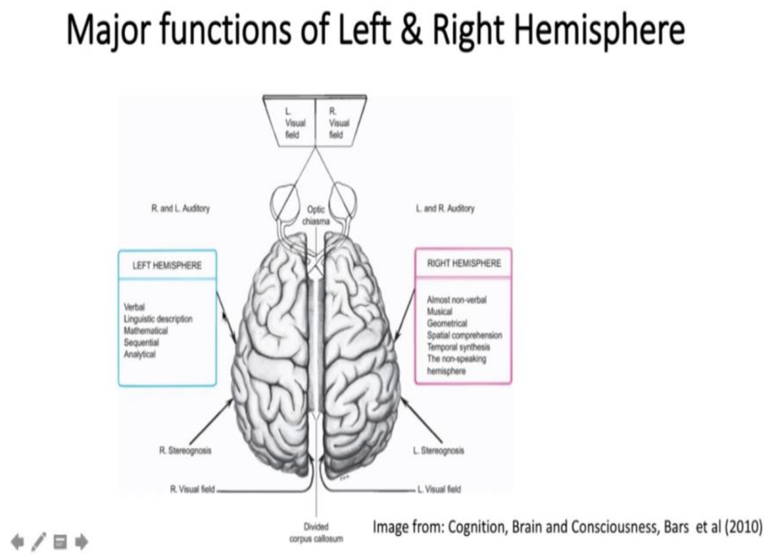

Now, what are the functions of this left and the right hemisphere. Let us look into that. The major functions of left and right hemisphere is in terms of that the left hemisphere takes care of the verbal, linguistic description, mathematical and sequential analytical activities here. The back part there is this stereognosis the depth sensing part, and even in the back side you have the right visual field here.

So, you can see that whatever you are watching from the eyes they are getting criss-cross connected. So, the right visual field is coming here in this region the left in the left hemisphere, whereas the left visual field getting criss-crossed is coming here in this in the right hemisphere in the right in the you will get the left visual field.

Now, in the right hemisphere, there are non-verbal things – musical, geometrical, spatial comprehension, temporal synthesis, non-speaking hemisphere, these are the right hemisphere part and behind that you have this left depth left side depth perception. The depth perception of the left side is coming in the back side of it. Now, one thing is very important here that these in today’s definition you cannot very distinctly always say that left does this and right does this because there are lot of coordination between both of them that happens.

Important thing here is that you can see in the middle the presence of this corpus callosum. In fact, these two views are very intermittently mixed. So, the left and the right there you know very intermittently mixed. So, if I actually cut the two parts of the brain, you would see that there will be kind of a delay of the signals of something like 1 millisecond or so. But they are you know very highly connected that is why I told you that many works of the left are also influenced by the right and vice versa through the corpus callosum part of it.

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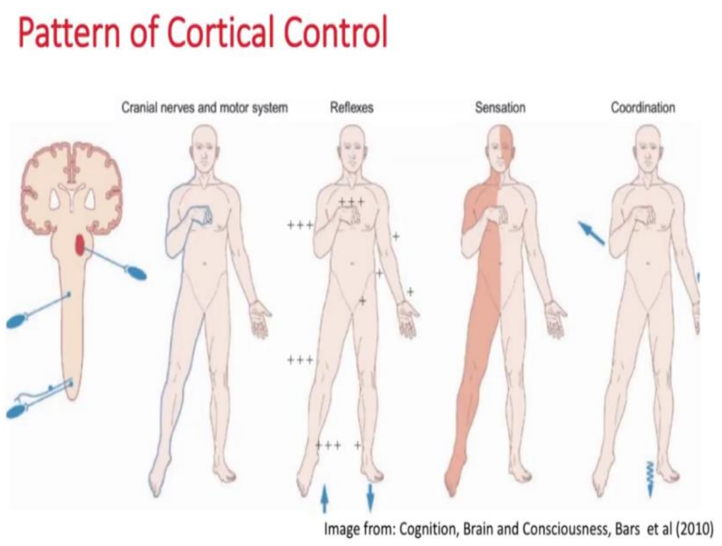

Some of the important points of the cortical control we have to keep in our mind that there are three important point here. One is that we have some actions which are locally resolved these are called reflexes like you can see, the reflex here, the reflex on the wrist area ok, the reflex here, the reflex on the knee is a very popular reflex area the reflex here. So, these are local reflexes for which the central nervous system is not associated directly this happens.

Now, the in terms of the sensation, all the somatosensory sensation of the left side goes to the right side of the brain and vice versa that is the right side goes to the left side of the brain. However, when we talk about coordination then right side has to work with the left. So, then they actually crossed on both the sides together; otherwise left goes to the right and right goes to the left that is the usual pattern of the cortical control.

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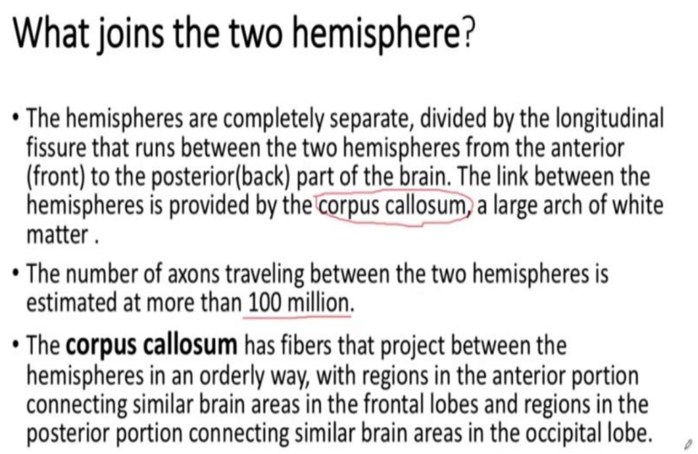

So, the question as I told you that what joins the two hemisphere? So, the hemispheres are completely separate individualistic divided by the longitudinal fissure that runs between the two hemisphere from the anterior or the frontal part to the posterior or the back part of the brain. The link between the hemisphere is provided by the corpus callosum. So, this we have to keep in our mind this is a very important thing that this corpus callosum which actually joins the left and the right.

Now, it is like a large arch of white matter. The number of actions that travel between the two hemisphere is estimated to be more than 100 million. So, it is a huge number of nerves which criss-crosses to the corpus callosum. It has fibers that project between the hemispheres in an orderly way with regions in the anterior portion connecting similar brain areas, the frontal areas, frontal lobes as well as in the posterior portion connecting similar brain areas in the occipital lobe. So, corpus callosum connects both the frontal parts as well as the occipital parietal parts of the left and right sub parts of the brain.

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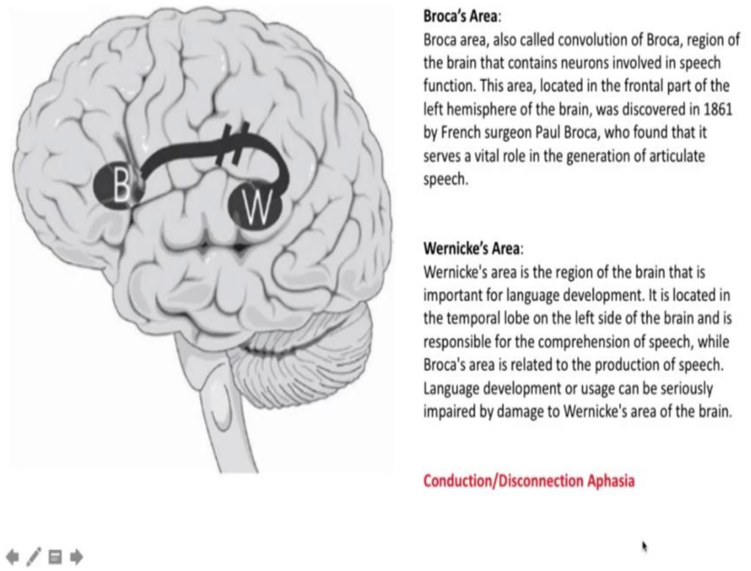

Here there is an important consideration I would like to tell you that is there that the function of the brain is localized or is it that every area works on everything. Now, even though there are associations between different areas, but it was found for 100s of years through surgeries, neurosurgeons mostly and through other scientific endeavors that there are indeed specific areas of the brain which are associated with specific activities.

Like the Broca's area of the brain also called the convolution of broca; this is the region of the brain that contains neurons involved in the speech function. So, this area is located as you can see in the frontal lobe part of the left hemisphere of the brain, and it was discovered in 1861 by a French surgeon named Paul Broca who found that it serves a vital role in the generation of articulate speech. So, the Broca's area actually is needed in terms of speech generation.

On the other hand, how do you know that what you are talking about is making sense that comes you know that was discovered after nearly about 50 years after Broca's discovery that is by the Wernicke's area. So, Wernicke's area is the region of the brain as you can see that it is coming on the temporal lobe backside of the temporal lobe of the left temporal lobe of course. And this is where it is important for the language development, and it is responsible for the comprehension of the speech while broca area is related to the production of the speech. So, language development or usage can be seriously impaired if there is a damage to Wernicke's area.

Now, sometimes there can be a good language development, but suddenly the connectivity may get lost, in that case you will get a disconnection lack of conduction and that is known as a typical disease called aphasia. Let us look into the case where this Broca's area loses contact with the Wernicke's area. So, I have gathered two small YouTube videos in order to you know you to in order for you to appreciate that what happens if this connection gets lost.

My final intention is to tell you through these that indeed there are parts in the brain which are specifically trained for specific activities. Let us look into it what kind of aphasia happens if this Broca's area and Wernicke's area lost touch with they lose touch with each other. Let us look into that.

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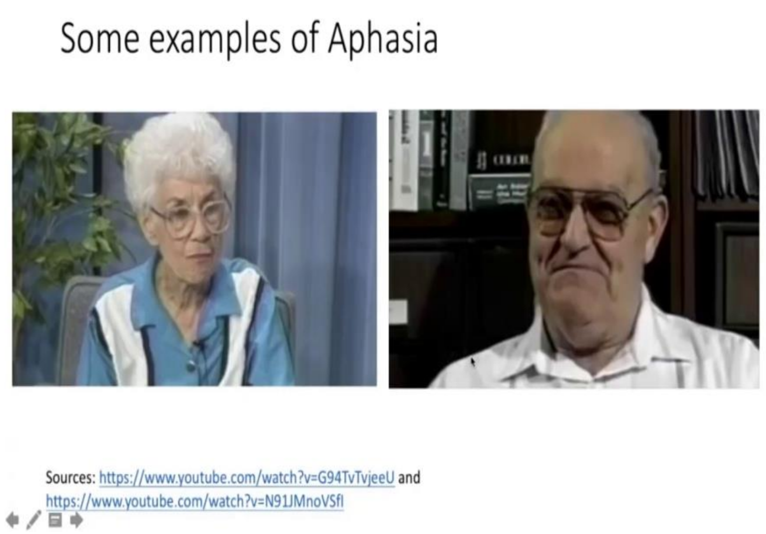

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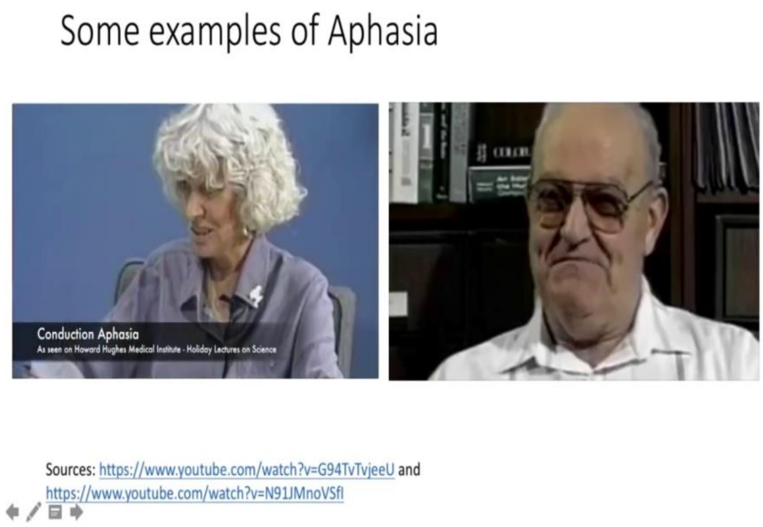

What is so interesting about this lady, she clearly is very intelligent and she clearly understands the instructions and she clean can express herself in a very good way, but you could see how after a while she completely disconnects; the what she wants to do, what she is heard she should do and what she actually does.

This is a conduction aphasia. So, in this case in this conduction aphasia what we will be actually getting is that the person will not be actually able to get all the you know numbers, that the person is asked. So, these ladies having conduction aphasia.

In this case, you will be getting another type of an aphasia and another type of an conduction aphasia, where this person will be actually losing the talk you know the capacities to actually comprehend what he is talking about ah.

Inputs for the Brain

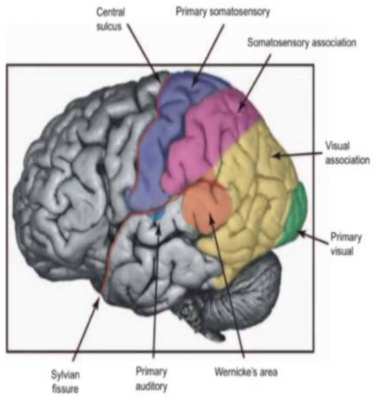

Image from: Cognition, Brain and Consciousness, Bars et al (2010)

Now, let us look into the brain from an input-output point of view; as I told you that the central sulcus, play a very important role. Behind the central sulcus we have the parietal lobe part of the brain, and on the parietal lobe I am showing here two regions; the primary somatosensory part, and a part of somatosensory associations.

So, primary somatosensory part they actually picks up all the signals from the thalamus region, which are related to somatosensory related senses. For example, you are touching something if you remember the finger example, then it comes to this primary somatosensory part. And this association part actually mixes these signal along with other signals that we get from; let us say from the visual association, let us say from the temporal association, all these things the association happens here, like you get the full understanding of the situation.

In the backside, the other input is coming from the in the occipital lobe that is where is the visual association is coming and here also the green part, this is where is the primary visual input comes and this is where the visual association comes. And similarly, you have the primary auditory input coming here and you can see the sylvian fissure of the lateral fissure, below which you can see the temporal lobe here. So, the primary auditory inputs are coming here, and then you have the brocas region somewhere here and the Wernick's area, they actually help in order to process the things and also to create the effector, so that you can speak you know something meaningful.

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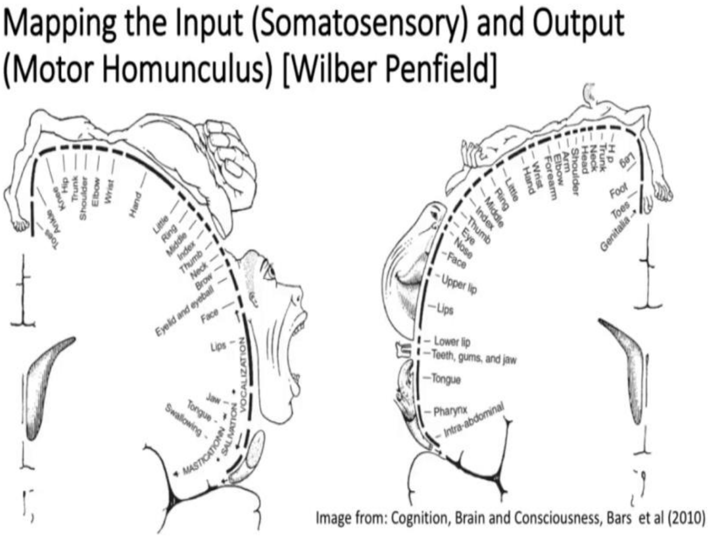

So, this is how all the inputs are coming in the back side of the brain. If you look at the mapping of it of the cortex on the left, you have the input coming on the back side of the brain. So, this is from the central sulcus onward in the parietal lobe part as you can see that it starts from the toes, hips and trance and all these regions, wriest and you can see that the hand plays such an important zone in large amount of cortex areas devoted towards understanding somatosensory activities from the hand. No wonder that you know, human beings they have evolved in a way that they have learned how to maximally use their hand in comparison to the leg.

And the next very important region is the face region; you can see that how each part of the face like sensing from the brow, from the eye read, from the face itself, the lips, their jaws, swallowing, everything comes in this big region. So, there is a large part of the parietal region which is devoted towards the somatosensory homunculus. Now, homunculus means a small homosapiens almost as if sitting here.

Now, just like that if you look at the frontal part, this is where I have shown the frontal part. In the frontal part, if frontal lobe you have the motor homunculus part and it was fast that Wilber Penfield actually denoted all these regions. Now, what you will see in the motor homunculus part, just like these somatosensory part it will start with these genitalia toes, foot, leg, hip, etcetera; then this is the effector part.

So, this is how you will be able to move your fingers, and you can see how large this index finger is taking the place in the brain. And then you can see the eye, the nose, face, upper lips, lower lips, teeth, tongue, pharynx, and the abdominal part; so there is a large part once again here.

So, you can see that this is the region through which we will actually control the movement of these lips, so that is the motor part of it and that is from the frontal cortex. And from the parietal cortex, this is the region where we are taking the senses the somatosensory senses of different parts of the body.

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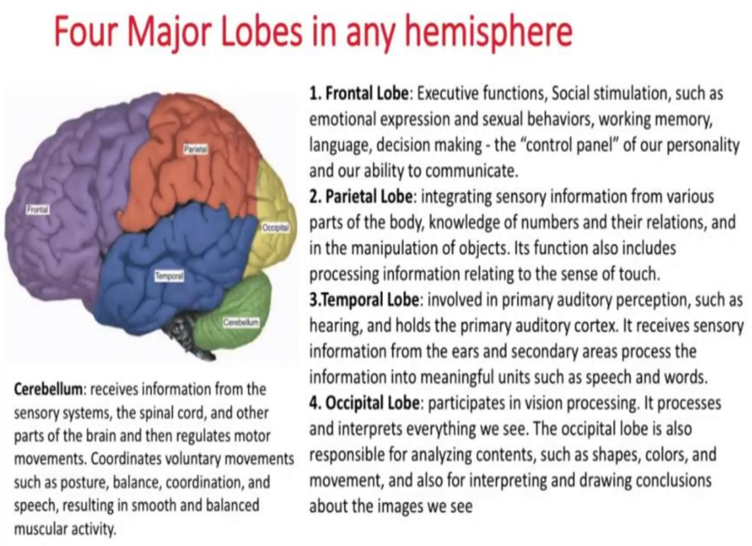

As I am giving you a lot of information, let us try to once again summarize them in terms of the major lobes of the brain. There are four major lobes in any hemisphere of the brain; these are the frontal lobe, the parietal lobe, the temporal lobe and the occipital lobe. The role of the frontal lobe is in terms of the executive functions, social stimulation. So, they are they call that the frontal lobe is what is the (Refer Time: 48:30) sign of homosapiens.

So, all social stimulations, emotional expression, sexual behaviors, working memory, language, decision making and the control panel of our personality, our ability to communicate, everything comes under the domain of the frontal lobe.

Parietal lobe mostly senses, it integrates the sensory information from various parts of the body, knowledge of numbers and their relations, in the manipulation of objects. Its function also includes processing information relating to the sense of touch. Then we have the temporal lobe which is having the primary auditory perception, such as hearing which holds the primary auditory cortex region; and also it receives sensory information from the ears, secondary areas process the information into meaningful units such as speech and words. Also the temporal lobe takes place in terms of as I told you that the speech recognition and stability, and also in some part the depth recognition.

Occipital lobe that is the very back side of these cortex area, it participates in vision processing. It processes and interrupts everything we see that is in the back side of the brain. The occipital lobe is also responsible for analyzing content, such as shapes, colors, and movement, and also for interpreting and drawing conclusions about the images we see.

Now, in the very back of course, this is not part of the you know the neomammalian part that is not of the part of the cortex, but an older part of the brain is the cerebellum part, but it is visible here. The role of the cerebellum is in terms of you know, receiving information from the sensory system, from spinal cord, other parts of the brain, and then regulate the motor movements.

We say sometimes that all these things that have to be learned first is learnt in the frontal cortex, parietal cortex; and then it is passed on to the cerebellum, so that helps us in terms of posture balance coordination, and balanced muscular activity that happens through the cerebellum. So, we have to keep these four important lobes in our mind allowing with the cerebellum and their functions.

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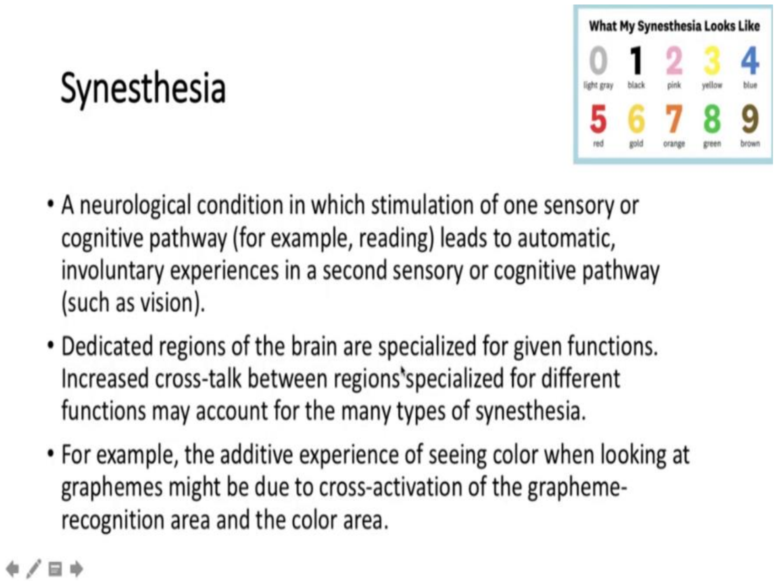

Now, what happens if we if some of these lobes in the sensing region, we have said that there are specific regions for each of the sensing; what if they get mixed that can create a problem called synesthesia. It is a neurological condition in which stimulation of one sensory or cognitive pathway may lead to automatic, involuntary experiences in a secondary sensory or cognitive pathway.

For example, when you are reading you can get a vision, like you are reading the numbers those who are having synesthesia will also see we call us, as they will be reading the numbers; even if the numbers are not colored that is the you know that is an interesting condition. So, this actually tells us once again that there are distinct regions and what happens if the distinct regions actually get somehow cross connected.

Now, we have seen different parts of the brain from the top. Now, you may wonder that where from the cognition the self identification, the perception, the thinking process, where from it finally comes; all these areas that we have seen, they are mostly like sensors and actuator controlling area. Deep inside the brain, deep inside the brain we have the areas which actually generates the sense of the perception of the self.

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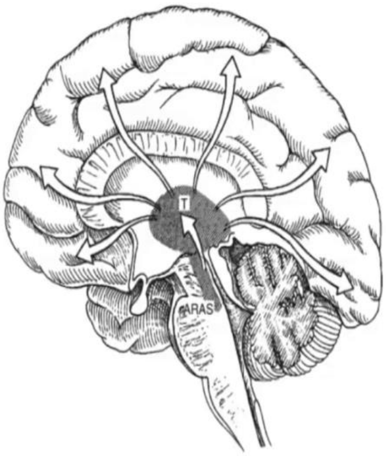

FIGURE 5.40 The ascending reticular activating system (ARAS) is found in the brainstem and thalamus, and sends projections throughout cortex. The ARAS is thought to be required for the normal conscious waking state. *Source*: Filley, 2002.

You can see that you have the cortex area here, and deep inside you can identify this region as the thalamus region. For example, and here you can see these ascending reticular activating system or ARAS; this is where the nerve signals are all going up. And this is where they are all you know, a there is a huge nerve junction that is happening here that junction of nerves is what is the reticular system, so there is this ascending reticular activating system. Now, it is a believed that this ARAS system is thought to be required for the normal conscious waking state of a homosapiens.

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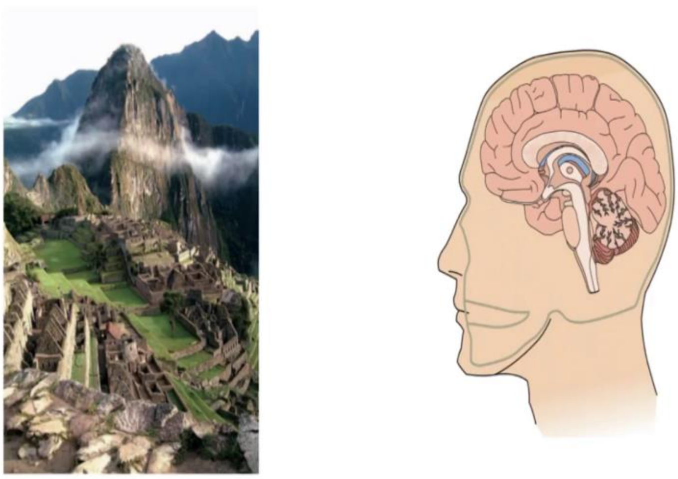

Brain Hierarchy: Analogous to Step Pyramid

Now, so far what we have seen in the human brain is from a top-down approach, it is like a analogous to a step pyramid of the Machu Picchu, it is a top-down approach as you can see that there are different divisions there. But the point is that even though it is a top-down, because also to say a bottom-up that is the way the brain actually a grew with respect to time in the evolutionary time rule, but they are all interconnected; in fact you can see here that they are all laterally connected.

So, even if it is having a kind of a top-down kind of an architecture, but there are lot of you know connections between different parts of the brain. So, it makes it as a fascinatingly integrating complex system. In the next talk, we will look into some of the deep brain structures and their roles.

Thank you.