Cognition and its Computation
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Lecture - 04
Anatomical Structures of the Brain

Hello and welcome back to this class on Cognition and Computation. Today we will be talking about the primary seat of cognition, that is the brain and its anatomical structures.

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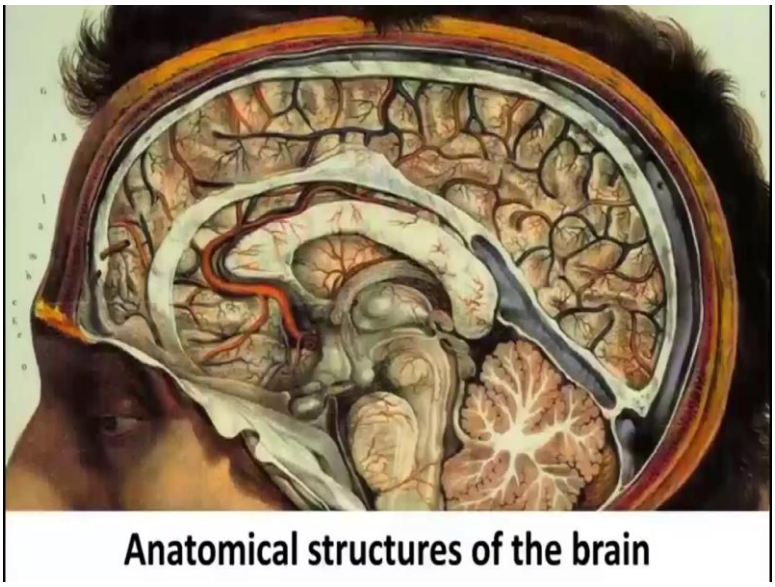

When we talk about the brain, it does not it is just part of the nervous system or the information processing system.

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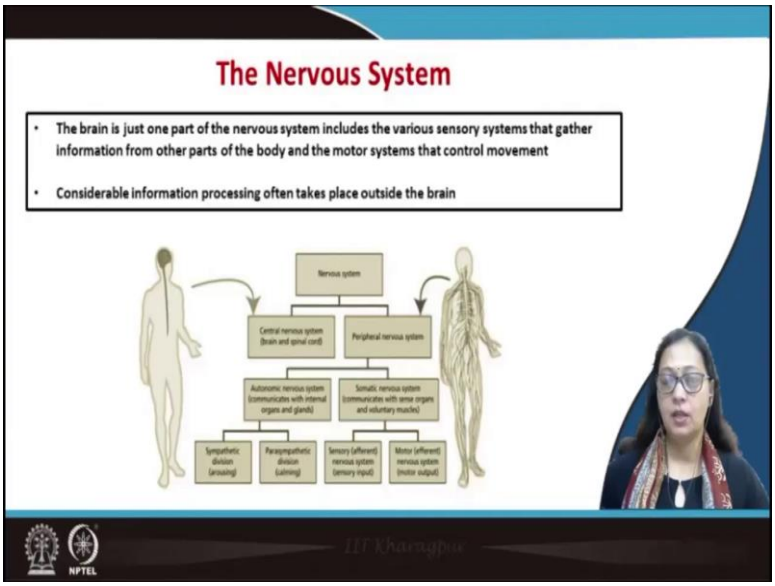

The nervous system in details if we talk about it is divided into two types of nervous system; one is the central nervous system and the other is the peripheral nervous system. The central nervous system consists of the brain and the spinal cord, while the peripheral nervous system consists of the autonomic nervous system and the somatic nervous system.

The autonomic nervous system communicates with the internal organs and glands and it is very very important for the expression and the feeling of emotion. So, the arousal system and the calming system or the sympathetic activation system and the parasympathetic activation system are a part of the autonomic nervous system.

The somatic nervous system on the other hand communicates with the sense organs and voluntary muscles and these are actually a bundle of nerve fibers that are divided into the sensory nervous system or the afferent nervous system, that is the sensory input and the motor or efferent nervous system which is for the motor output.

As I mentioned earlier the brain is just one part of the nervous system and it includes the information from the sensory systems and the motor systems. And it actually gathers information from all across the body and controls our thoughts and movements. It must it is important to understand that a considerable amount of information processing is actually done outside the brain; but still we consider the brain as the seat of cognition and that is why we are going to talk about the brain today.

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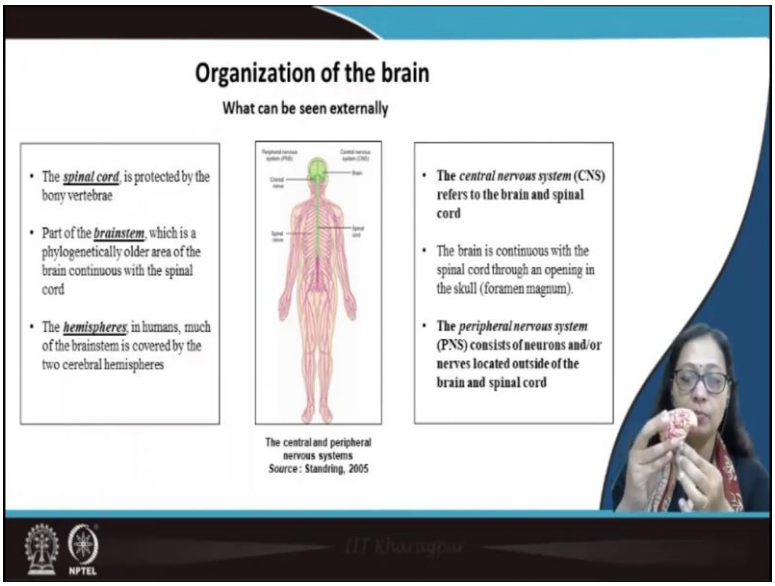

So, when we talk about the organization of the brain what can we see externally. So, for the brain we see the hemispheres. So, here we see the cerebral cortex, that is the upper layer of the brain; we see the brain stem which is a phylogenetically an older area of the brain and it continues to the spinal cord.

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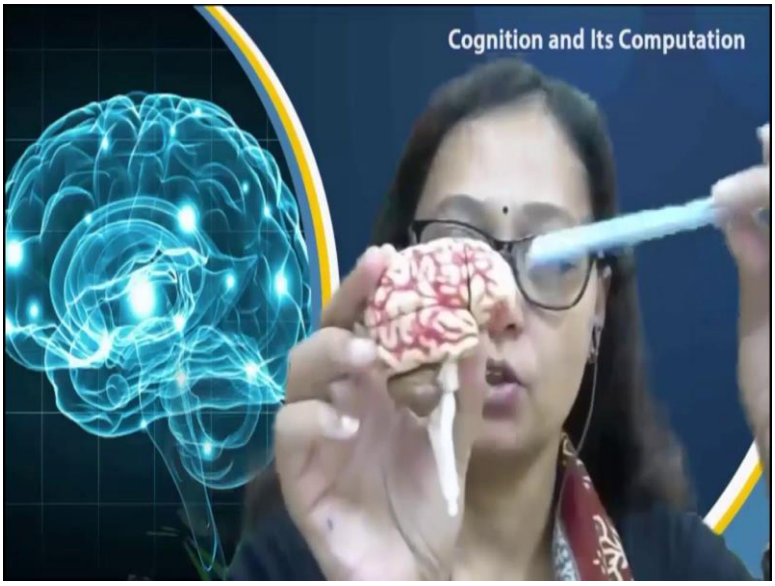

The central nervous system as I already mentioned refers to the brain and the spinal cord and the brain is continuous with the spinal cord. So, there is no break between the brain and the spinal cord and there is an opening through which in the skull through which it

enters the spinal cord, this is known as the foramen magnum. And this structure we are going to explain now in a little details.

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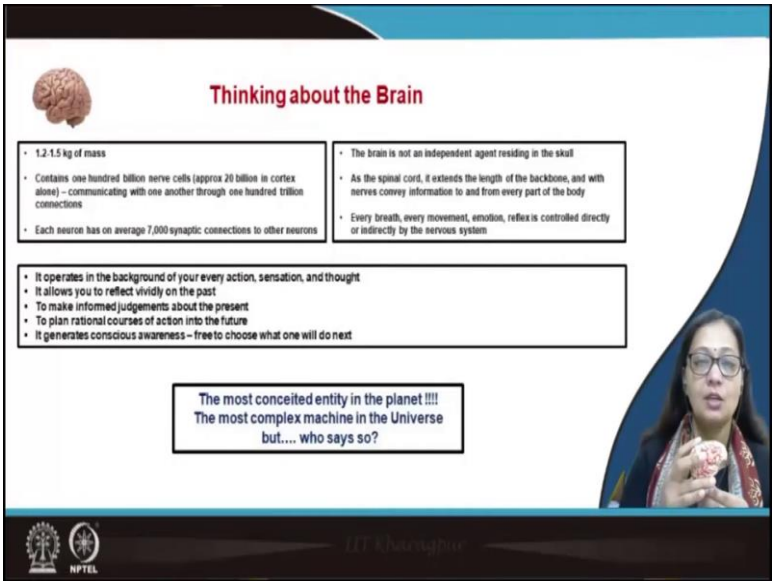

So, before we get on with it, let us understand what is the size and weight of the brain. So, it is the brain itself is around 1.2 to 1.5 kilograms of mass and contains more than one hundred billion nerve cells with approximately 20 billion within the cortex itself and it communicates with one another through more than one hundred trillion connections. The brain is not an independent agent residing in the skull; as we discussed it connects for every breath for every movement, every emotion reflex, it connects directly or indirectly with other parts of the nervous system.

But it operates in the background for every action, every thought, every sensation that we feel and it allows us to reflect on our past, assess our present and contemplate and plan our future. So, it generates a conscious awareness and in fact it is said that the brain is the most conceited entity in the planet. Why? Because it says so, it thinks that I am superior. And who is saying it? It is again the human brain saying it.

So, when we talk of the brain and especially when we are trying to understand the anatomical structures, we must understand a few details for getting on further.

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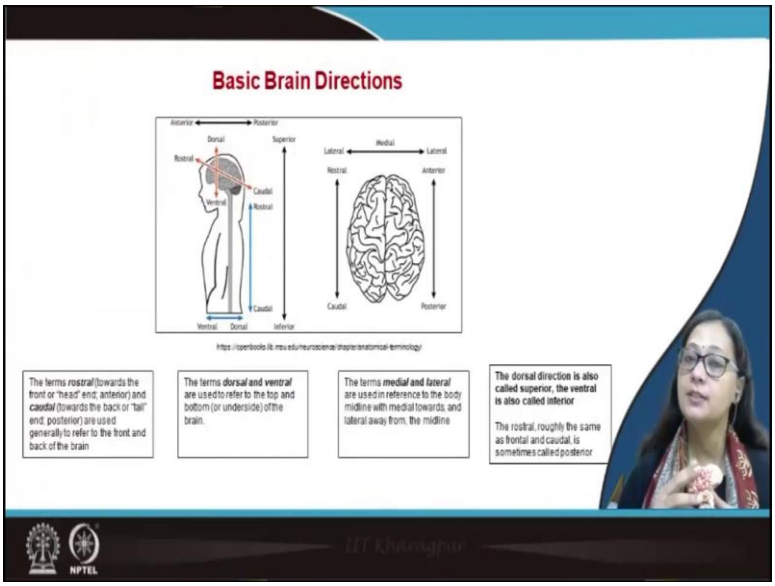

So, first and foremost let us see what the brain directions means. So, while studying the brain, we talk about the rostral and the caudal end. So, what exactly is when we talk about the rostral direction? So, the rostral is the front part of the brain, the caudal as the term suggests is the back or the tail end.

So, when we talk about the spinal cord, in the spinal cord the caudal end is at the lower end that is the tail. And because the brain folds itself like this, so through evolution the forebrain has folded like this. So, that is why we say that this part it is not the top, but this part is the rostral section. So, it is anatomically like this. So, this part is the rostral section of the brain and this part is the caudal section of the brain.

Now, the dorsal section is this top part and the ventral is referred to the underside or the bottom part of the brain. The term medial and lateral are used in reference to the midline. So, say if I slice my brain from here and just take out one part. So, if the brain is like this and I slice it from the center; this part is the medial section of the brain and this side or this side is the lateral section of the brain.

So, lateral is moving away from the midline. So, if this is the midline, moving away from the midline is the lateral section of the brain. Now, when we talk of the brain more often than not especially if you are looking at images, you will see that they talk of the anatomical planes. Now, what exactly does it mean?

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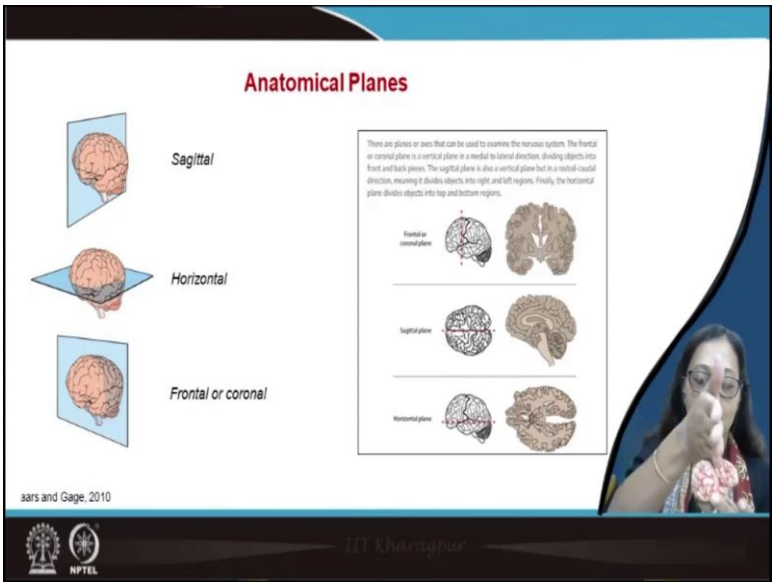

So, if you slide the brain from the center as we said from the mid line, then that becomes a sagittal section. So, from the midline if I slice the brain like this; so this is the medial sagittal plane from the center and these are the other parasite sagittal areas. The a horizontal section of the brain would be to slice the brain from the center like this horizontally. And the frontal and the caudal sections would be, if we sliced it like a sausage, so this is the frontal section and if we slice it like this, so this is the coronal section of the brain, because it represents more like a crown, ok.

So, you will be gradually you will be familiar with these sections if you study more about the anatomical images about the brain slices.

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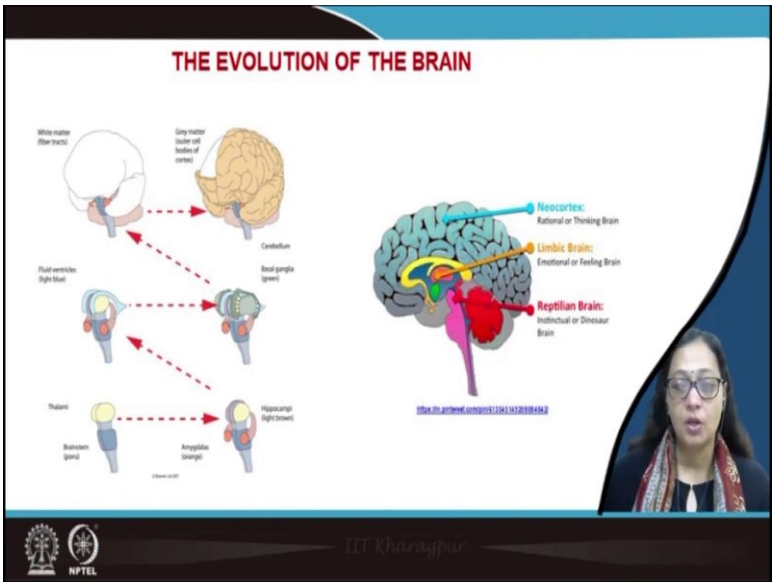

Now, how did the brain evolve?.

So, when we talk of the human brain, in fact for all mammalian brains; the reptilian brain was the first part to evolve. Now, what is the reptilian brain?

So, it is the brain stem. So, the lower parts of the brain. So, that is the brain stem or the pons and the amygdalas that is how it evolved and from there to the ventricles, we will talk in details about the different parts of the brain, so you will understand about the ventricles.

And then, so first the reptilian brain developed, from there came the limbic brain, so that would be more of the subcortical structures. So, the structures that are within this framework, ok. And then finally, came in the neocortex or the thinking brain, so that would be the development of the cerebrum.

So, this part this is how the brain evolved over time. So, the rudimentary structures that developed were more for survival. So, for, so they are primarily responsible for the involuntary functions of our you know like breathing, like reflexes, so that the lower part of the brain they control these involuntary physiological functions. And the more of the brain has evolved, the more we are in control of our conscious processes.

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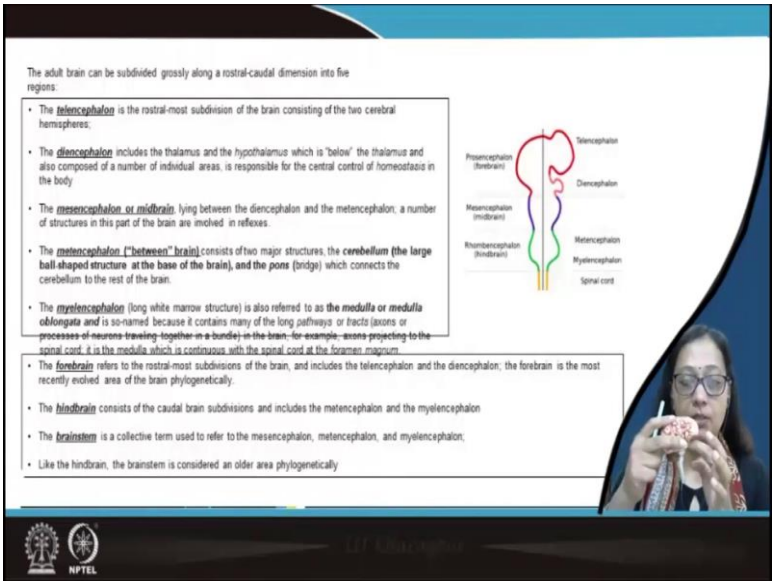

Now, the adult brain many times you come across terms like the telencephalon, diencephalon.

So, this is another way of dividing the brain adult brain into a rostral caudal dimension. So, what is the rostral caudal again? So, this is the rostral section of the brain, this is the caudal section of the brain, ok.

So, on a rostral caudal dimension again the brain is divided into five regions and the first is the telencephalon that consists of it is the major rostral subdivision of the brain and it consists of the two hemispheres, so these two hemispheres. Then comes the diencephalon and it includes the thalamus and the hypothalamus. So, that is the structure that is within, I will open this up to show you; so the subcortical structures, that is within, ok. And the these are primarily responsible for the control of homeostasis, that is body balance and also with the integration of the functioning.

The third comes the mesencephalon or midbrain lying between the diencephalon and the metencephalon and it consist of a number of structures that are involved in the reflexes.

So, first is this structure, then we have within the diencephalon, then comes the mesencephalon and the or the midbrain and then comes the metencephalon. It consists of two major structures, the cerebellum; so this is the cerebellum, it is a large bell shaped structure at the base of the brain and the pons. So, here is the pons ok; this is the pons and that is the bridge which could connects the cerebellum to the rest of the brain.

And finally, you have the myelencephalon or the white long white narrow structure nanostructure that is known as the medulla oblongata and it is so named, because it contains many of the long pathways or tracts. So, that is why it has this, it is a bundle of fibers and it has this white look and it projects, it has axons that project into the spinal cord and it is continuous with the spinal cord.

So, the these structures now again the brain. So, we know that primarily the brain we have the forebrain; if we divide it more simply, then we have the forebrain, the hindbrain and the brainstem, ok. So, like the hindbrain, the brainstem is also an older area phylogenetically, that is it has evolved earlier.

So, the human brain is bilaterally symmetrical.

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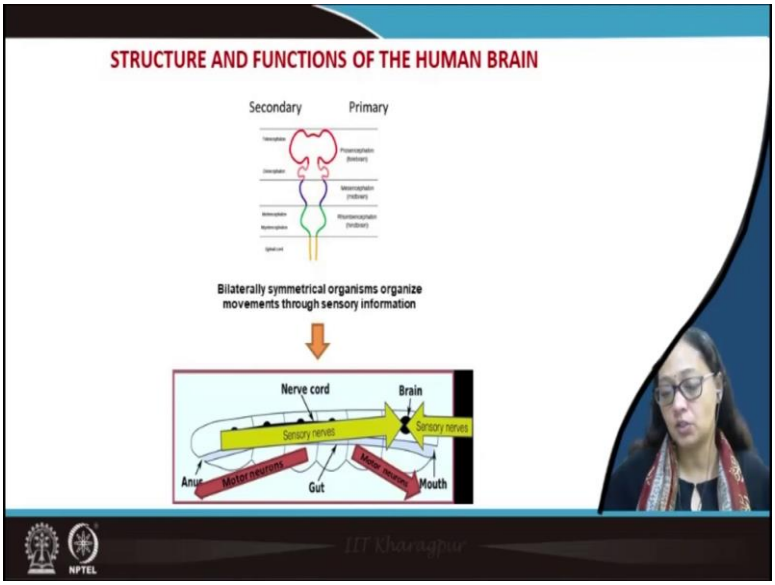

And in fact that is how it is in most of the mammalian structure, mammalian species. And these organisms, these biologic bilaterally symmetrical organisms they organize movements through sensory information. So, what does it do? It from all parts, from the different parts of the body; that is from the head from the top of the head to the toes to the anus, there are the sensory input system or the sensory nerves carry information to the brain and from the brain, the motor nerve neurons they carry the instructions for the actions to again the different parts of the body.

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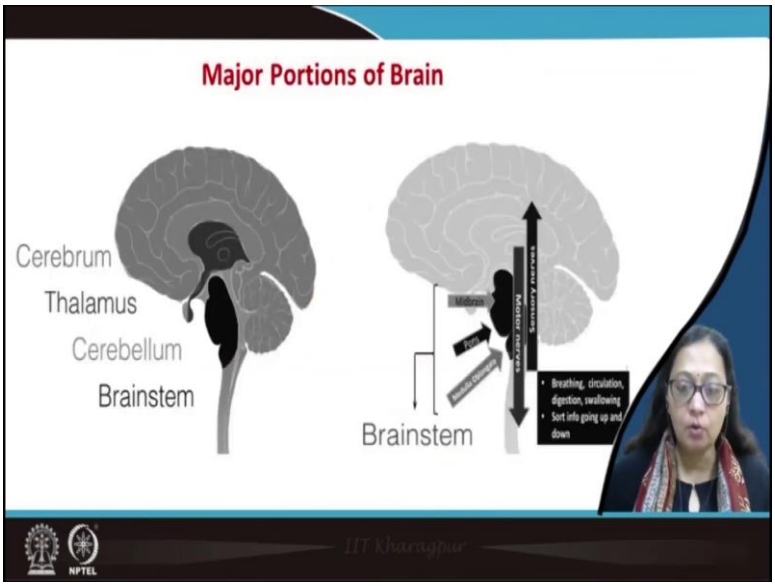

So, as we spoke about a little earlier about the forebrain, the midbrain, hindbrain; here we will talk about some of the specific structures that are important to understand cognition. So, we will start with the, so the primary structures to be discussed are cerebrum, thalamus, cerebellum and the brain stem.

So, the brain stem to start with the brain stem; the brain stem consists of the midbrain, the pons. So, yes here is the midbrain, the pons and the medulla oblongata, ok. And what does it do? It is responsible, as I said for the lower areas of the brain are responsible for more of the involuntary processes for survival.

So, the brainstem is responsible for breathing, circulation, digestive activities, swallowing and it sorts the information that is moved up and down to the forebrain. So, with the help of the sensory nerves, information is sent to the forebrain and the motor nerves they carry the information from the forebrain to the different parts of the body; the brainstem helps to integrate this.

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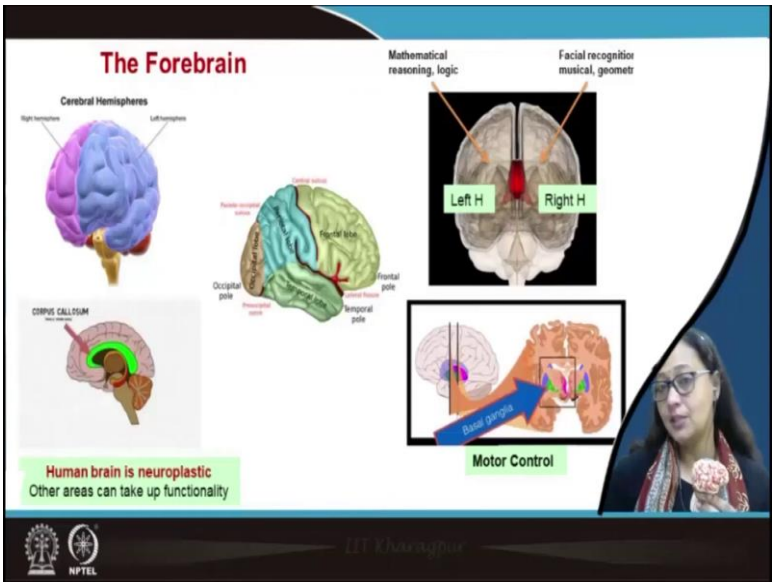

Now, coming to the forebrain, the forebrain is divided into the two hemispheres; but before that it has it is the max larger part of the brain, that is consists of the forebrain. And it is filled with the upper outer structure has a wrinkly appearance and is known as the cerebral cortex. The forebrain is divided into two hemispheres, the two cerebral hemispheres, that is the right hemisphere and the left hemisphere.

And some of the cognitive functions are specific to certain hemispheres, like mathematical reasoning, logic these are more with the left hemisphere; while facial recognition, musical recognition, geometrical understanding is more with the right hemisphere. You will see later that language functions are also specific to a certain hemisphere.

Now, the forebrain is the human brain is neuroplastic and as you will see later when we discuss the other chapters; that it means that it the near areas can take up the functionality of these specific structures.

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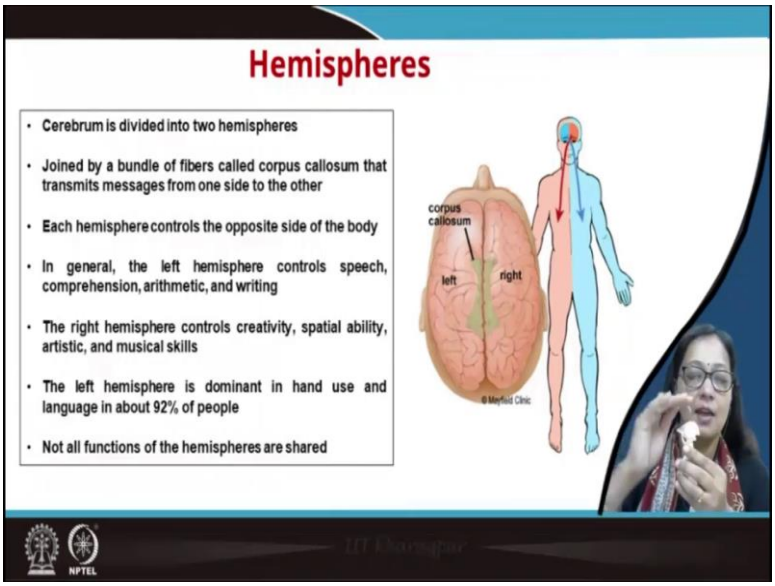

So, as I was mentioning the forebrain is divided into two hemispheres and the forebrain is the primary part of the forebrain is the cerebrum. And the cerebrum again the two hemispheres are connected or joined by a bundle of fibers known as the corpus callosum.

And it is what do the, what does the corpus callosum do? It is the it connects the two hemispheres together and it is like a fiber bridge flowing from the right to the left hemisphere. And when the corpus callosum it is cut, it looks like a white structure. Now, let us open this, you will see I am just removing the different structures of the brain; this is the corpus callosum. So, this green part that you see here, this part is the corpus callosum, ok.

So, it bridges the right and the left hemisphere. So, these are actually the subcortical structures that you can see, I will l explain it a little later. And this the corpus callosum looks, it is actually white in color; because it consists of nerve axons with white myelination myelin cells and it is it connects, it is a bundle of fibers, it connects the as I said and carries information from one hemisphere to the other.

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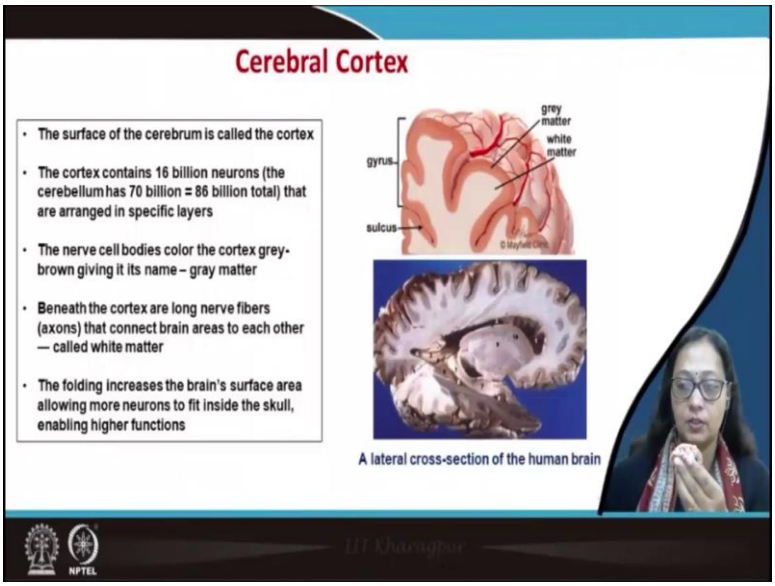

Now, so coming back to the cerebral cortex; the cerebral cortex as I mentioned is again if you I have just separated it. Now, if you look at this is just a part of the cerebral cortex; if you look at this part of the cerebral cortex, you will see that it has multiple folds, ok.

And so there are crests and troughs ok and these are known as the gyrus and the sulcus. And the these ridges are the gyri and the folds are the sulci or the sulcus in singular. And these are, so the cerebral cortex is filled with gray matter. So, the upper part is the gray matter and the internal part inside is the white matter, ok.

So, the nerve cell bodies colored the cortex brown and gives it the name gray matter. So, and the cortex has the long fiber ends or the axons that connect the brain with each other; so that is inside and that is why it is known as the white matter. The folding's of the cerebral cortex increases the brain surface area allowing more neurons to be concentrated to fit inside the skull.

And these we already know that the single unit of functioning information processing is a neuron. And the human brain is so efficient because of the closely packed number of neurons within such a small framework of the brain. So, the to fit in more neurons, we have these multiple folds within the cerebral cortex.

Now, the brain can be divided into, again the forebrain can be separated into three important areas, ok. And these areas or I should say these important folds and troughs

that need to be talked off when we are talking about the brain. So, if we if we divide the two hemispheres. So, if we if we divide the two hemispheres, we see a deep structure or fissure; this is that it is a sulcus, so it is a trough. So, it is a sulcus that divides the two hemispheres and this is known as the medial longitudinal fissure.

So, if you slice the human brain from the nose backwards, so into two hemispheres; that is the medial that is the longitudinal fissure that you got. The next is a fold that runs forward on the slide of the brain and that is known as the lateral sulcus; the lateral sulcus divides the a temporal lobe, ok. And so, you can cut it from here, so this is where you find the lateral sulcus, ok. It divides the arm of the temporal lobe from the body of the main cortex, ok.

And then we have the central sulcus here, that divides the rare half of the brain, that is the posterior part of the brain. So, if you look at this, you think of this as the brain; so the posterior part of the brain, it divides the posterior part of the brain from the frontal lobe. So, these are the three important structures that you must understand when we are talking about the brain.

The reason is, because it helps to understand; it helps to identify different lobes of the brain, especially some of this other structures as well.

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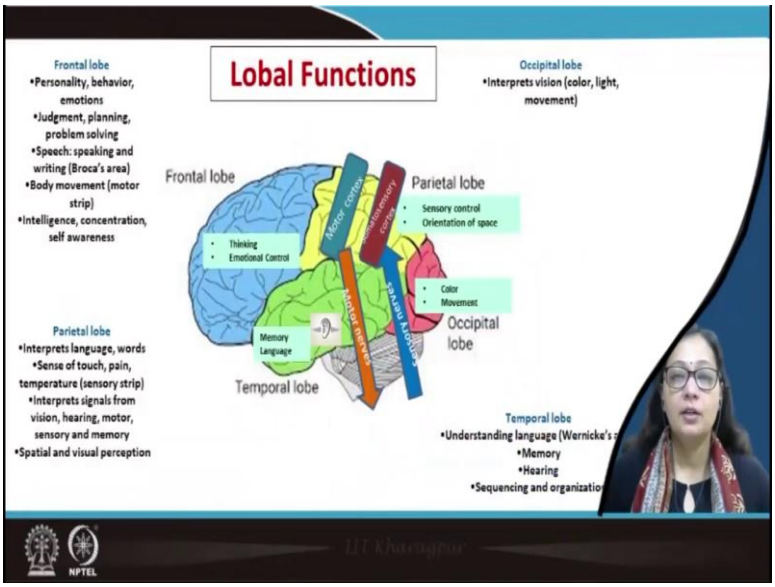

So, the cerebral cortex again is divided into four lobes; the frontal lobe, the parietal lobe, the occipital lobe, and the temporal lobe. So, the frontal lobe is the frontal part of the brain, the parietal lobe is here at the back of the brain and that is the central sulcus divides the frontal lobe and the parietal lobe. And we have the occipital lobe at the back lower back of the brain just above the cerebellum and the temporal lobe is at the sides.

So, what are the functions? These the lobes of the brain are very important for multiple number of cognitive functions, because it is the seat of a group of neurons that are related to specific cognitive functions. So, the frontal lobe is responsible for personality, behavior, emotions, judgment, planning, problem solving.

So, if you see we are talking of mainly the cognitive or the thinking related functions, the frontal lobe also has; it is actually we will talk in details about the frontal lobe in the next class, but we must understand that the frontal lobe has two more important areas related to motor functioning.

So, one is a premotor area, where the thinking and planning of action is done and then we have the motor cortex that is on the top of the frontal lobe. So, or I should say at the caudal part of the frontal lobe, posterior part of the frontal lobe, which the motor cortex sends out information to the motor nerves to carry out the actions.

Just behind the motor cortex, there is an area known as the somatosensory cortex, that is actually a part of the parietal lobe. The parietal lobe as you will see is responsible for sensory control and orientation of space, and the somatosensory cortex receives sensory inputs from the different parts of the body.

So, just look at the anatomical positioning of the these areas. So, you have the sensory information receiving system, that is the somatosensory cortex; just next to it is the motor cortex, whereas the where the action is planned action is instructions for the action is being sent out. And just before that is the premotor cortex, the premotor cortex sends out is the area that plans the actions and the information for the executive control; so all the thinking, planning, coordination is done in the prefrontal cortex, that is the frontal part of the frontal lobe.

So, coming back to the different functions of the lobe, the parietal lobe it interprets, language, words sense of touch. So, the sensations it has, as I said it has a sensory area

and it interprets signals from vision. So, from the sense organs vision, hearing, motor, sensory cortex and memory and especially it is responsible for spatial and visual perception, it is also responsible for spatial memory.

The occipital lobe lying at the back of the brain is responsible primarily for vision and it interprets vision that is for color, light, movement. And then comes the temporal lobe at the side of the brain and the temporal lobe is responsible primarily for understanding language.

We have the Broca's area that is responsible for language articulation in the frontal lobe and just close to it, we have the language understanding area or the Wernicke's area in the temporal lobe. The temporal lobe is also responsible for memory, hearing and sequencing and organization of information.

Now, coming back to another area of the brain, that is the cerebellum.

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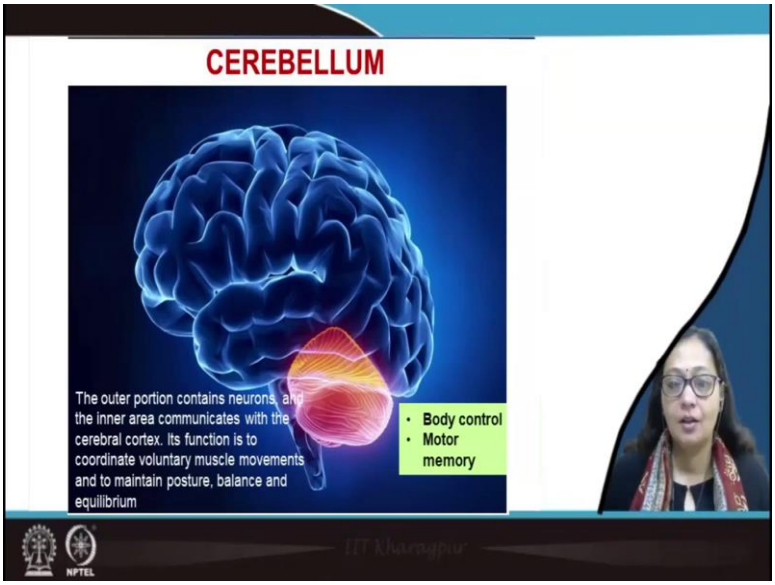

The cerebellum is I have distributed the different parts of the brain, so just to show you this is a structure; as you can see from the slide it is a structure at the lower part of the brain and the outer portion it contains neurons and the inner area communicates with the cerebral cortex. Its function is to coordinate with the voluntary muscle movements, to coordinate the voluntary muscle movements and to maintain posture balance and equilibrium.

So, it is primarily responsible for body control and motor memory. So, all the procedural learning that we have like muscle memory to put it simply like riding a bicycle to swimming, to you know balancing yourself on the scales all this is primarily coordinated by the cerebellum.

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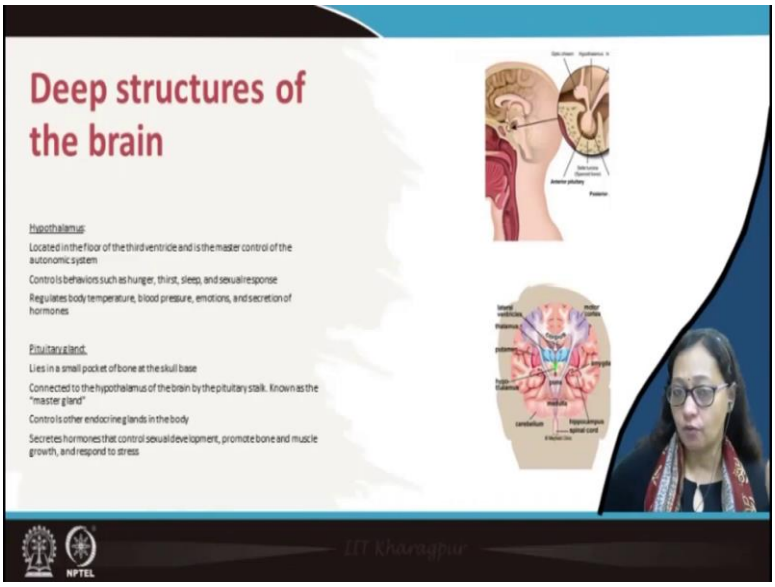

Now, coming to the deep structures of the brain. So, here I come back to the deep structures of the brain and as you can see this is the midbrain, this is the pons, this is the medulla; but here you can see these two units, these this is the thalamus, ok.

And here we have several other structures. So, here we have the putamen, as you can see from the picture rather less from the demonstration; you can see that there is a putamen, there are there is a hypothalamus, just below the thalamus we have the hypothalamus and this is the hypothalamus. Here at this end we have another very important structure that is the amygdala; the hypothalamus and the amygdala along with several other structures here, the basal ganglia, the putamen these are a part of the limbic system, that is these deep structures of the brain are more responsible for the emotional functioning.

Now, the coming to the thalamus and the hypothalamus; so thalamus is the integrating or center of the brain or the relay center of the brain. And it the links the system nervous system with the endocrine system it maintains. So, that the sorry that is the hypothalamus; the hypothalamus it lies just below the thalamus and it links the nervous

system with the endocrine system and maintains the secretion of multiple endocrine glands and it maintains homeostasis and primarily regulates the body temperature.

So, there is a small gland which is known as a master gland, the pituitary gland that regulates hormones and hypothalamus is responsible for coordinating the function of the pituitary gland to for the discharge of the hormones. And that is why the hypothalamus is a very important structure for arousal or you know especially emotional arousal.

Now, it is the hypothalamus is located at the floor of the third ventricle; we will talk about the ventricles a little later and it is the master control of the autonomic nervous system just as I mentioned right now. And it controls behaviors such as hunger, thirst, sleep and sexual response and regulates body temperature, blood pressure, emotions and the secretion of hormones by the coordination with the, by the regulation of the pituitary gland.

The pituitary gland lies in a small pocket of bone at the skull base and it is connected to the hypothalamus by the pituitary stock. And it controls the endocrine glands of the body and secretes the hormones for sexual development, promotes bone and muscle growth and responds to stress.

Now, why are we talking about this pituitary gland in case of cognition and you know emotions? Again as I said the secretions are very very important for the autonomic arousal system and understanding feeling of emotion, expression of emotion, understanding the arousal system by the frontal structures is important for cognition; because the cognitive system and the affective system you can you cannot separate the two, ok.

As you will see there is a wonderful discussion on this by Antonio Di Maccio and he speaks about you know how emotions are very important for decision making, please go through it if you if it is possible.

Considering the other deep structures of the brain, comes the pineal gland.

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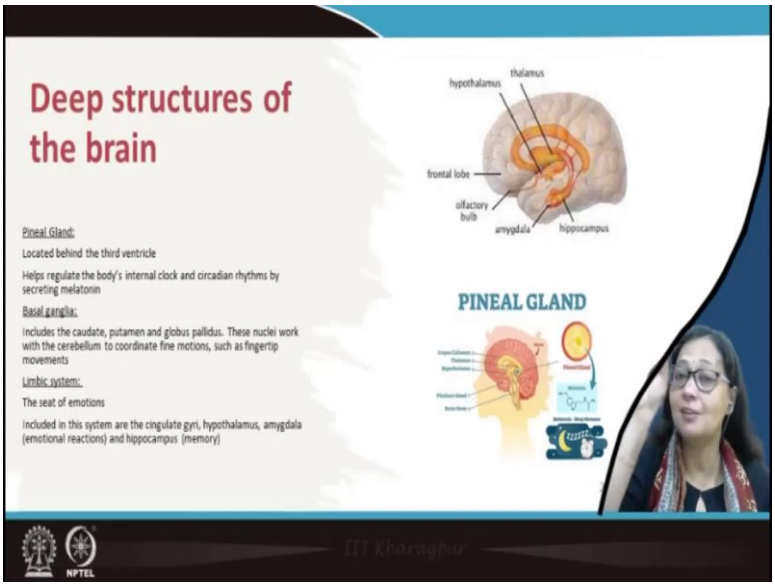

The pineal gland was historically spoken about by Descartes, Rene Descartes who thought that it was the because it is a single structure in the brain; while all the other structures that he found were you know were two in number on different hemispheres, so Descartes thought that the pineal gland was the connection between the mind, so that is the thought process and the body that is the mechanization process.

So, , but over the years with multiple amount of research, we know today that the pineal gland is not responsible for the mind body connection; but it is important for the body's internal clock and maintaining the circadian rhythms, because it secretes a hormone known as the melatonin and it is the which actually controls the body mechanisms or the body's internal clock.

Another very important structure in the brain a subcortical structure that is that lies below the cortex is the basal ganglia; sorry it includes I spoke about the putamen, but the basal ganglia includes the caudate, the putamen and the globus pallidus. And all these three are a bundle of nuclei which connect with the cerebellum to coordinate the fine motions and especially like fine motor movements or fingertip movements. These are also important as I said for the limbic system.

So, they are also responsible for the functioning of or they are the seat of the emotions. There is one very important structure that I did not mentioned here is the hippocampus. So, this is the hippocampus; if you look at this, the hippocampus is looks has got the

name from, because of its look it looks like a seorse. And the this is a very important structure for learning and memory, as you will gradually see that the with information with the neuroplasticity or the neuroplastic quality of the hippocampus and a wonderful study..

We will discuss this when we talk about memory is the study of the taxi drivers of London, who is due to their increase in the, due to their rehearsal of the streets of London the and the hippocampus is responsible for spatial memory. And this area of the size of the hippocampus changed in the London taxi drivers. You can go through this video on London taxi drivers online; but we will discuss about it later when we talk about memory.

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When we talk about the brain and its anatomical structures, we must also talk about the projection tracts. The projection tracts are the carriers of information, these are the fibers of the brain and primarily they are white matter tracts that connect the cortex with other areas of the central nervous system; like the deep nuclei, the brain stem, the cerebellum, and the spine. They may be these projection tracts they may be both sensory, that is the afferent tracts or motor that is the efferent tracts.

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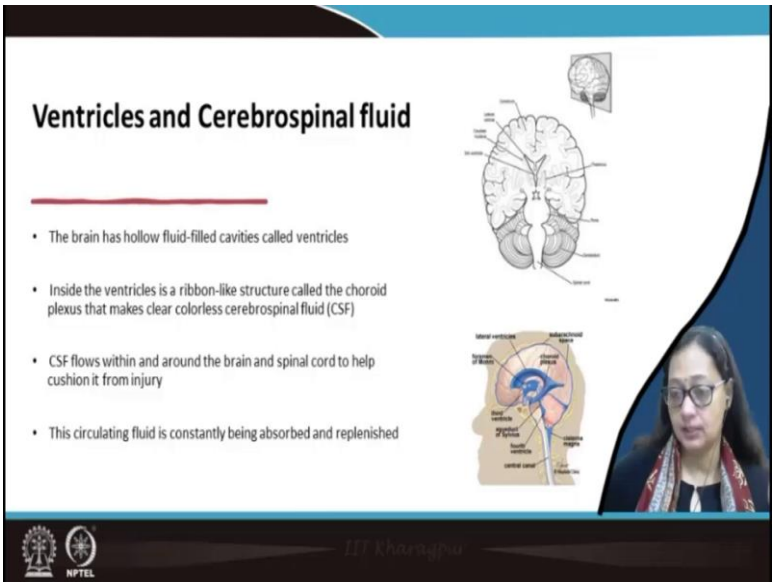

Now, we come to another very important some very important structures of the brain, these are the ventricles and we will also talk about the cerebrospinal fluid.

The brain has hollows fluid, fluid filled cavities and these are known as ventricles. Long back Leonardo da Vinci spoke about these cavities and he said that it is this is what actually carries the information to and from the human brain.

So, the ventricles, there are primarily four ventricles in the in our brain and it is composed of two lateral ventricles, the third ventricle and the fourth ventricle. The these ventricles have cavities are cavities within the brain that produce and store the cerebrospinal fluid. Now, inside the ventricles are is a ribbon like structure called the choroid plexus, that makes the colorless cerebrospinal fluid.

So, the work of the cerebrospinal fluid is to protect the brain or push on it from, protect the brain and the spinal cord from injury.

So, it the brain basically floats on the cerebrospinal fluid and this fluid constantly replenishes the brain. So, the there is another structure known as the cerebral aqueduct or the aqueduct of sylvius, which within the brainstem that connects the third ventricle with the fourth ventricle and it is located within the brain stem. And it is surrounded by the periaqueductal gray matter with the tectum of the midbrain located posteriorly and the tegmentum anteriorly, you can see this from the image.

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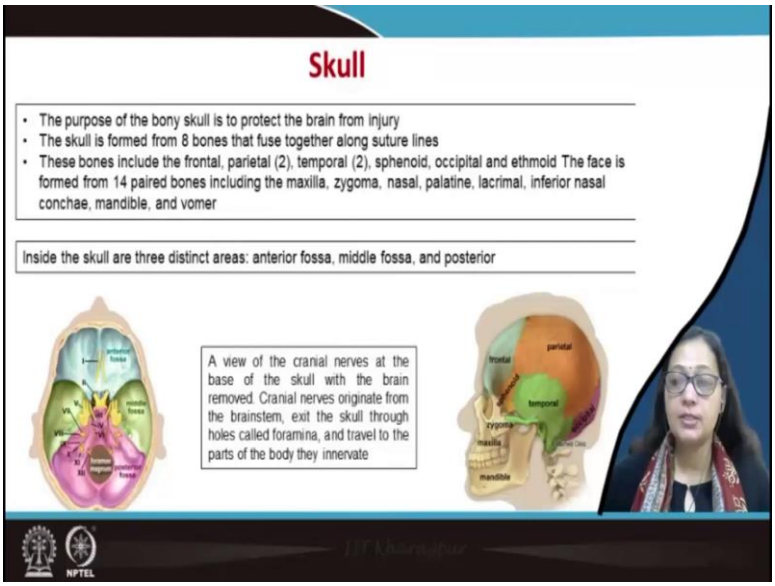

So, now coming back to the protecting mechanism of the brain; the brain is protected from external injury by a strong bony structure, a hard bony structure and this is the skull. The skull is formed of 8 bones that fuse together along this suture lines. As you can see from the slide, these bones include the frontal, parietal, temporal, sphenoid, occipital and ethmoid.

The face is formed from 14 pairs of bones and they include the maxilla, the zygomater, zygoma, the nasal, palatine, lacrimal, inferior nasal conchae, mandible and vomer. And the muscle groups along the face are based on these bone structures and that is why we have the zygomatic major as a very important part; it is a muscle group, that is responsible for the facial changes during a smile.

So, the inside the skull, there are three distinct areas and these are the anterior fossa, the middle fossa and the posterior. Now, what about the blood supply in the brain? How is the how do we get oxygenated blood into the brain for its functioning?

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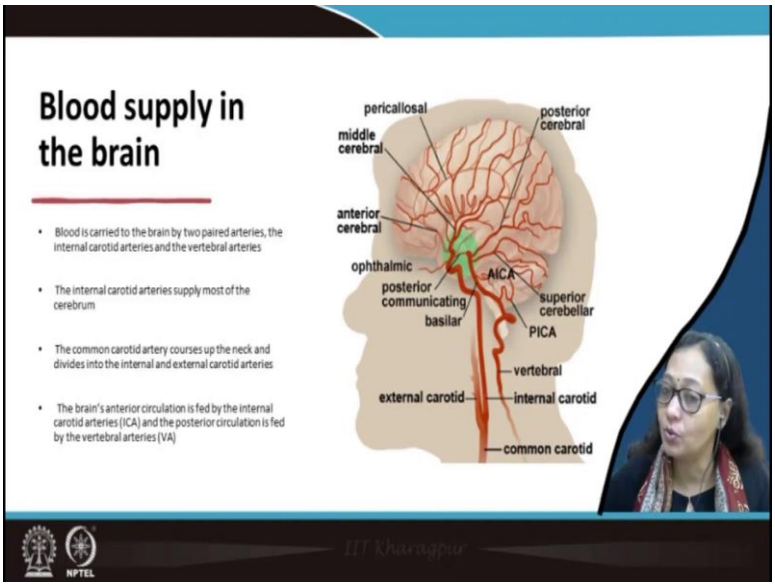

We already know that the brain requires a large amount of oxygenated blood to carry out its activities. And in fact, we require and this is what we try and measure through FMRI, you will see that later in one of the talks.

So, the blood is carried to the brain by two paired of arteries, the internal carotid arteries and the vertebral arteries. And the internal carotid arteries are the ones that supply most of the blood to the cerebrum.

The common carotid artery courses up the neck and divides into the internal and external carotid arteries. And the brains anterior circulation is fed by the internal carotid arteries and the posterior circulation, so the back of the brain is fed by the vertebral arteries. So, you know this is in a nutshell what we had to talk about the brain; in fact I have left out a lot many structures and especially the cranial nerves that also form a part of the central nervous system, that carries out that carries the information to the different parts of the body and sorry the nervous system, not the central nervous system.

So, the I have also left out various other specific areas related to cognitive functioning, which we will discuss in details; this was just a preliminary discussion to familiarize you with the brain, how brain studies are done.

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And in the last decades, a couple of decades we have seen that a large number of studies on the human brain have evolved. We have the human genome project, we have the human brain project and finally, we have the brain initiative.

And the objective of most of these studies was to plot the trillions of neural connections in the mouse and human brains. And the reason is so that we get a better understanding of the diseases. So, we have through these multiple number of studies, we have understood more about the functioning of different other kinds of cells; so which not only the brain is not only made up of the neurons, but the glial cells which are very important for cognitive functioning.

And we have through these researches on the brain and microscopic fractions of the brain bringing it to the single neuron study, the single unit of information processing; we have identified the contribution of different structures, different units to information processing and cognition. And this has helped us, we have identified the new roles of multiple such units; you know this has helped us to understand the circuits circuitry in the disorders like neurodegenerative disorders and the psychiatric disorders.

It has helped us to understand social cognition, how individuals process information in a social unit as an individual unit, how it has helped with decision making; in fact Kneman got his Nobel Prize on decision making with the study of neuroeconomics. So, there is a

large amount of study that has come over in the last couple of decades; but it is still limited when we talk of you know how much we know about the brain.

So, we a larger amount of studies are required and more explorations are required.

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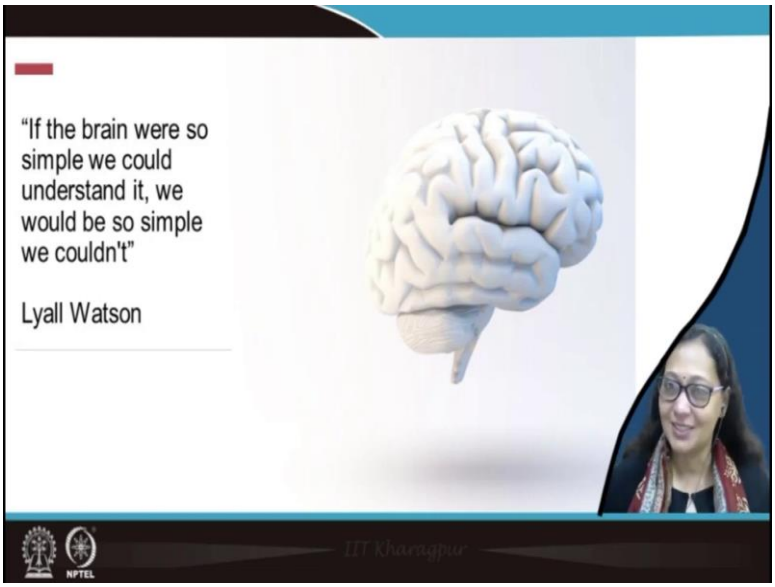

So, to end this lecture, I would like to end with this quote by Lyall Watson; he said that if the brain were so simple that we could understand it, we would be so simple that we would not. So, it is again the human brain that is trying to understand the brain and every time that we understand it completely it is one unit move one plus in the internal systems.

Thank you.