Foundations of Cognitive Robotics
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Lecture – 06

Good morning students. Welcome to the Foundations of Cognitive Robotics. In my last lecture, I told you about the top part of the human brain. Now, today I am going to take a look inside what is there in a human brain. Some of the things that are hidden from the top we are going to find out that what is their inside it.

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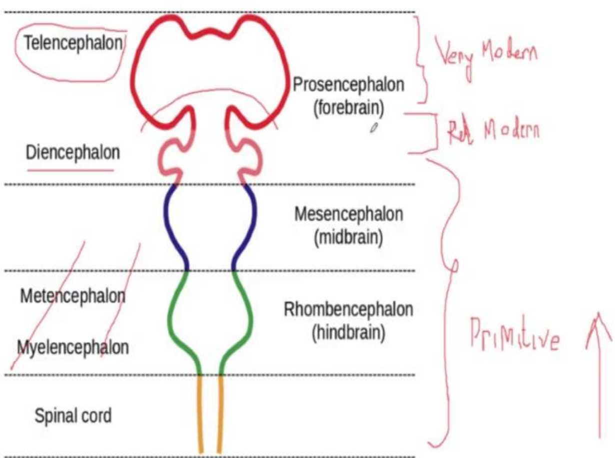

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To begin with I will first talk about how this entire brain system has evolved. There are some parts of the brain which are quite primitive part, some parts which are relatively more modern and some parts which are very modern. Generally, it is considered that this part of the brain this is more or less the primitive part of the brain. So, this is the primitive part, very primitive part you can even see it in some of the very primitive organisms also. So, this is this is the primitive part, ok. So, this is the primitive part.

Whereas, there is some part which is somewhere here you may say that which is relatively in the middle phase of development, so it is not very modern, but it is something which has developed after the primitive part. So, this is relatively modern I say and just I had just put it as relatively modern, relatively modern. And there is some part which is very modern. So, this is the part which is very modern. So, we can just call it to be a very modern part of the brain.

Now, when I have discussed about the brain structure in my last class, I have mostly focus on this very modern part of the brain that is the telencephalon part of the brain. Now, of course, if I look at it from the other way that is from the primitive side then there is this important part which we will be calling as the brain stem part of it which includes these you know these areas like the hind brain, the mid brain, so that is the brain stem part of it this is what we will be focusing more today.

So, the area which is above the spinal cord, and then on top of that the brain stem part there are also areas which are like diencephalons, and also there are some parts on top of that which are you know some part of the telencephalons which also we will be discussing today which are all relatively modern, ok. So, that also we will be discussing today.

So, these are the three things, one by one we will start from the very primitive part. We will talk about the brainstem part where we have this rhombencephalon part of the hindbrain, and the mesencephalon part of the midbrain, then the diencephalon. And then we will gradually go towards the top where we have the basal ganglia and we have cingulate cortex and such areas. So, we will talk about them next.

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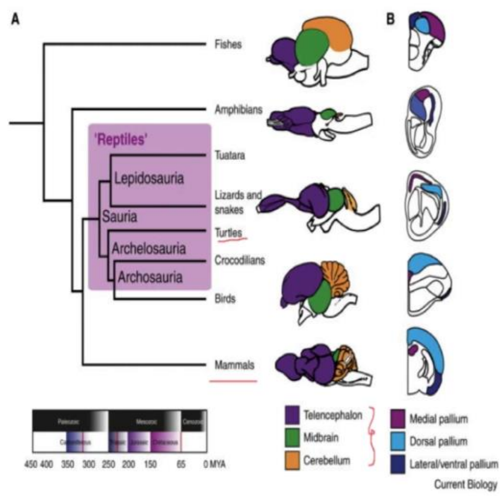

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Now, if I actually look into the different brains if I try to compare the brains of say something like the very higher order animals, like say the mammals, and compare it with reptiles, like say turtles. Now, you would see that these three important parts of the brain that is this telencephalon midbrain, and the cerebellum part of it they are mostly present in almost all of these, ok.

So, it is not that the mammals are only having telencephalon. The same is also present in birds, is also present in turtles, is also present in amphibians and in fishes. And the same thing is true for the midbrain and the cerebellum part. Only thing is that the proportion of each one of them is quite different from species to species. So, that is something that we have to be very careful about when we look into it.

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If we look at how a turtle responds and also if you look at that how for example, a mammal like a monkey is responding.

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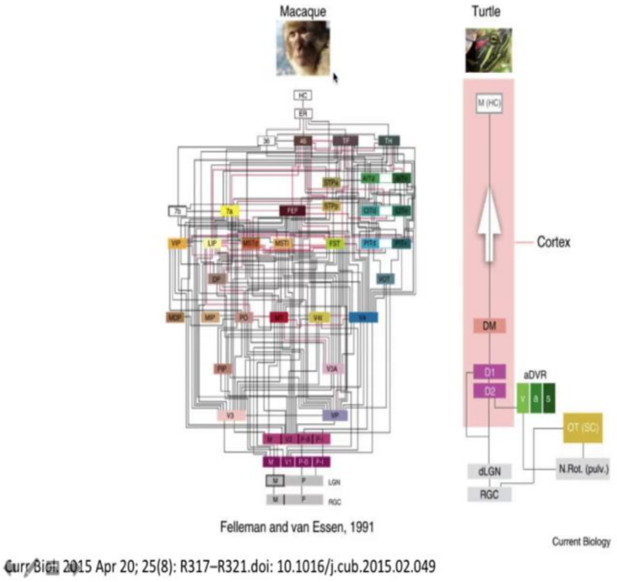

If you compare between the two you would see that in case of a turtle and in case of a macaque the common part is that both takes let us say the input from the vision both take it towards the hippocampus. So, that is common between both of them.

However, whenever we are talking about a monkey it goes through so many different regions in the brain. So, the path of the signal is quite complicated. On the other hand, if you look at the turtle that path is very simple and straightforward relatively in comparison with the macaque.

So, that is when you may say that even if both of them are having the same elements like say the telencephalon where the hippocampus is there or does that these you know sensory organs. But in one case they actually go through a vast many regions of the brain different ganglia’s or ganglia like you know nuclei’s are involved in it, whereas, in the turtle’s case that is not involved. So, the visual association is much less that is what possibly is the major difference between the way the signals are processed by the turtle and the signals are processed by the macaque.

Now, all these things have very important consequences as far as the behavior of different types of animals are concerned. They are cognitively different because of that they have different ratios or proportions of the brain areas and also they have different associations of networks in the brain areas.

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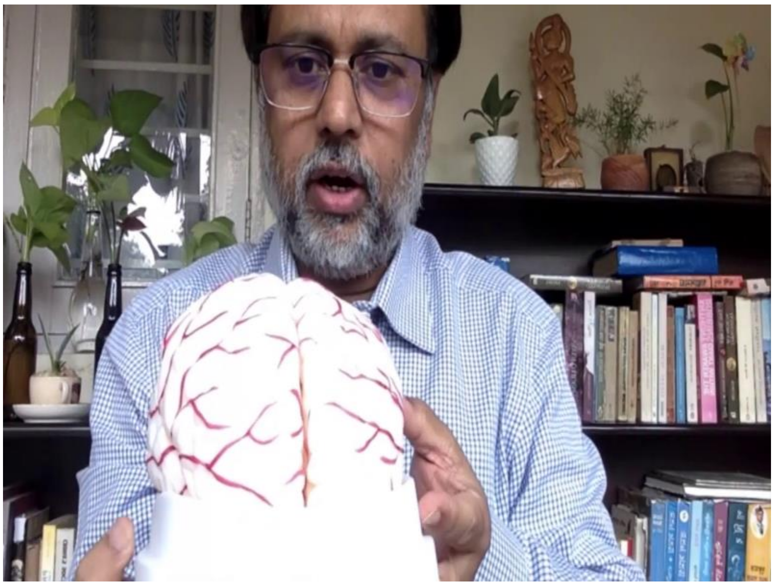

Now, let us look into the brain structure and let us see that what are the hidden elements, and then we will go back to the slides and we will see how we can correlate between the two. If I look at the brain structure, this is what if you remember we have discussed in the last class also.

Then you can see that if you try to remember that this was the prefrontal cortex and this is the frontal lobe part and then you can see the back side we have the parietal lobe and at the very back we have the cerebellum part of it, ok. This is all as far as if you take the brain, if you look at it from the top this is what you are going to see.

Now, let us try to remove it and let us see what is there inside. So, let us try to do that very carefully. And let us try to separate through the longitudinal fissure. You remember this is the longitudinal fissure let us try to separate one brain out at least, so that is what I would be trying to do and I will keep the rest out.

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Now, if you look at this part which is you know you can still remember that this is where was our frontal cortex areas, and you can still remember that in the back side we had this temporal lobe part of it. And what is there inside which is hidden is actually the brain stem part of it. So, you can see that in the brain stem. We have these areas which is known as medulla oblongata, then we have this area which is known as the pons area, then we have the midbrain here.

This you can see this, this is the mid brain area and then you can see this beak here. This is the area which contains the hypothalamus that is the easiest way to note down the hypothalamus. And, this is always indicating towards a gland here which is so very important pituitary gland which actually controls the behavior you know in terms of the hormonal behaviors.

Now, and on top of these hypothalamus we have the thalamus here and in this side we have the pineal gland, which contains the melatonin's. So, this is a very primitive structure of the brain, ok. And beyond this we will be getting more and more relatively modern structures. I will talk about them one by one. But this is something that we have to keep in our mind that the brain stem and the cerebellum which was somewhere in this side. This are some of the very early developments of the brain.

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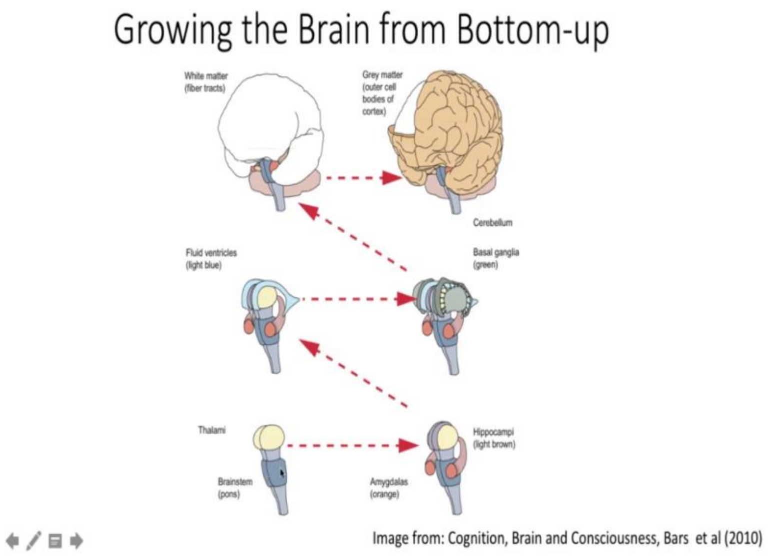

If you look at the brain then from bottom up then as I told you that this is the brain stem part which starts with the pons you know pons is somewhere here pons means a bridge, so that is somewhere here. So, below that you have this medulla oblongata. So, medulla oblongata then pons and then the midbrain and then the thalamus; so, that is the very primitive part.

Now, from there if you look at these slight something more we have added here. What we have added here is the hippocampus and the amygdala's. And then from here if you go further up you can see the fluid ventricles, fluid ventricles are needed to supply the nutrition to the brain that is added. Then, if we further go here what we can see that from the fluid ventricles we are actually coming to the basal ganglia part of it, ok.

So, once we are in the basal ganglia, we are nearly reaching towards the modern part of the brain and then from basal ganglia on top of it we have the white matters. As I told you earlier that these are highly myelinated nerves and then above the white matter we have the gray matter the cortex part of it and you can see the cerebellum in the bottom. So, the best way to actually keep an idea about the brain structure is thus you can practice it that how to grow it from the bottom till the top.

Now, once you practice that how this entire brain from the lower part which is connected to the peripheral nervous system through the spinal cord, how from there at the brain stem pons mid brains etcetera and then beyond that how it is connected once you know you have got an overall idea about it. Then we can actually let us try to go one by one inside this element. So, let us first focus on the brainstem itself on different parts of the brainstem different components and what is their functionalities.

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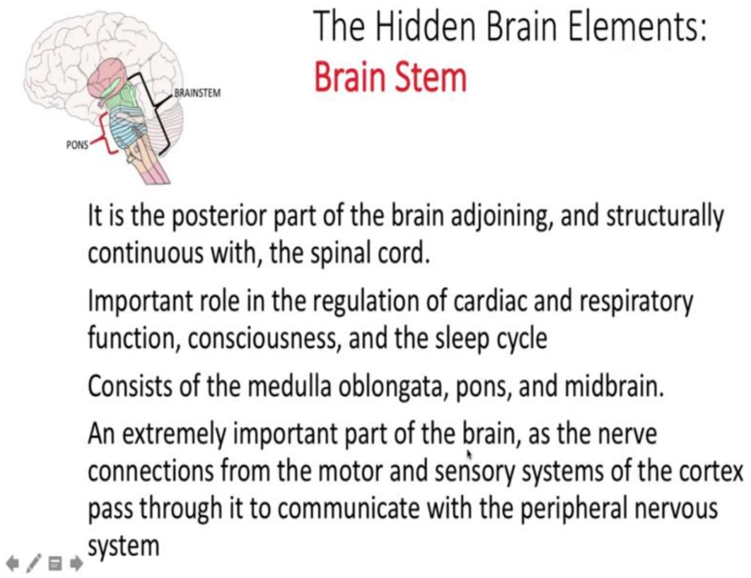

If I look at the brainstem we can see that this is the area that we are referring to and a very important area here is pons and also the medulla oblongata is somewhere here and the midbrain. So, that is the part that we are talking about which is basically posterior or the you know the back-side part of the brain adjoining and structurally continuous with the spinal cord.

Now, this part, the entire brainstem part has important relay you know roles in terms of the regulation of cardiac and respiratory function, consciousness and the sleep cycle. So, all these things you know whatever is the autonomous part of the nervous system, they are definitely controlled from here.

So, it consists of the three regions as I told you medulla oblongata, pons, and the midbrain. And this is indeed, even if it is very primitive this is indeed a very important part of the brain as all the nerve connections from the motor and sensory systems of the cortex from the top that also passes through it to communicate with the peripheral nervous system.

Apart from the fact that it controls many of the voluntary movements of the nerves, but also you have to, also make it a point to see that all the sensory nerves, the somatosensory connections they are actually coming through this medulla oblongata. And, then the pons and the midbrain, and then they are coming to the different regions through the thalamus to the different regions of the cortex.

So, essentially you know everything that is happening in the top part of the brain they are all getting connected through this area. So, some of the sensor signals this part itself processes, and for some it works like the passage, the connectors from which this all the signals will be going towards the top part of the brain. That is something we have to keep in our mind.

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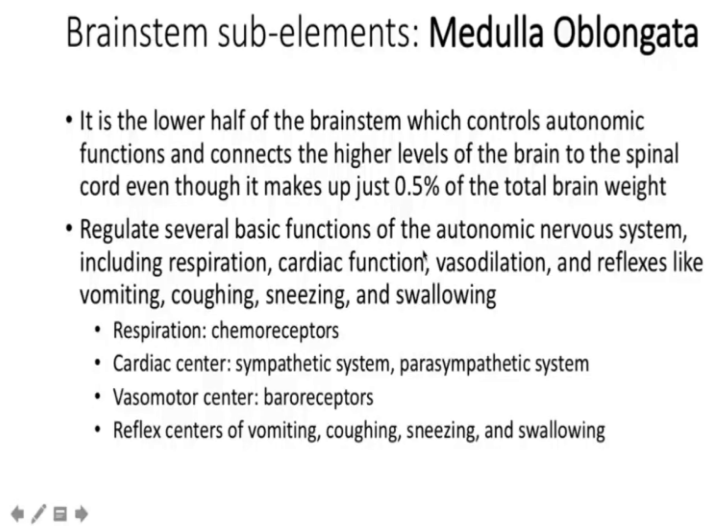

The first important sub element of the brainstem is the medulla oblongata. It is the lower half of the brainstem which controls the autonomic functions and connects the higher levels of the brain to the spinal cord even though it makes up just 0.5 percent of the total brain weight, but yet it has a very important role.

So, it regulates some of the very basic functions that is needed to leave the autonomic nervous systems, which includes respiration, cardiac function, vasodilation and all natural reflexes like vomiting, coughing, sneezing and swallowing. Say for example, respiration is carried out by the you know these kind of with the help of chemoreceptors. Cardiac centers are actually controlled through sympathetic and parasympathetic systems which these medulla controls. Vasomotor through the pressure receptors, baroreceptors the blood pressure and the reflex centers through the they control these all these reflex actions that I was talking about.

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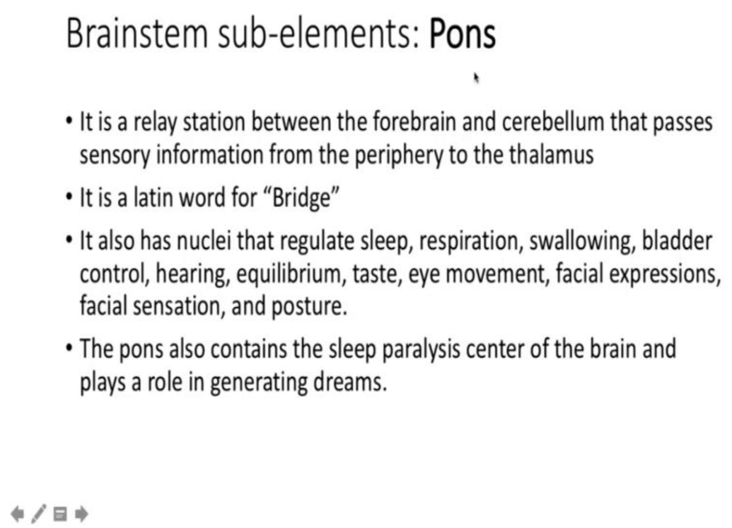

On the top of the medulla oblongata, we have the pons region which is a relay station between the forebrain and cerebellum that passes the sensory information from the periphery to the thalamus. And it is a Latin word of bridge because it is joining between the thalamus area midbrain thalamus area and the area below that is the medulla oblongata and the spinal cord.

Now, it also has nuclei that regulate sleep for example, respiration, swallowing, bladder control, hearing, equilibrium, taste, eye movement, facial expressions, facial sensation and posture. So, here the pons control some of the non-autonomous sensory systems also, not just the autonomous sensory systems. And it also contains the sleep paralysis center of the brain and plays a role in generating the dreams. So, that is about the pons.

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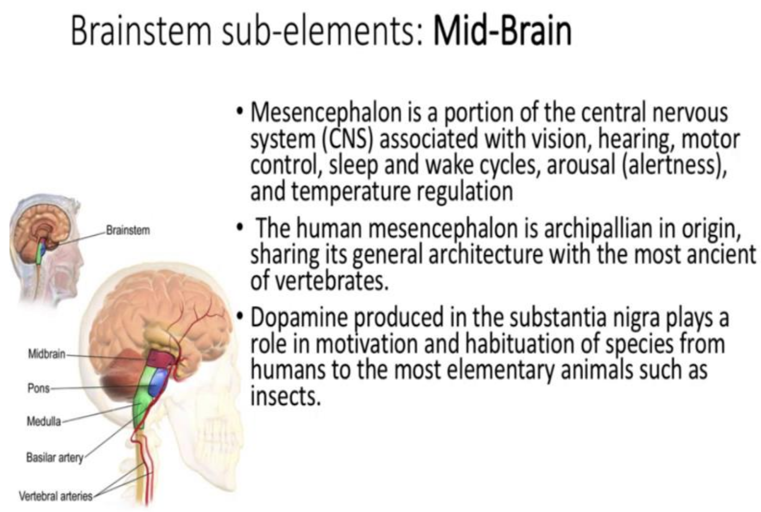

Now, we come to the midbrain region. So, we have talked about the medulla, we have talked about the pons and now we are in the midbrain region. Midbrain or so called mesencephalon is a portion of the central nervous system which is associated with things like vision, hearing, motor control, sleep and wake system, arousal and of course, the temperature regulation.

In fact, this a system is one of the most archipallian in origin, sharing its general architecture not only with our other primate you know other groups of primate species, but also with many of the vertebrates also. And a very important region in the midbrain where we have the substantia nigra, they actually create dopamine and that plays a role in motivation and habituation of species from humans to the most elementary animals such as insects. So, that is one of the important source from midbrain onwards the dopamine production. So, that is the importance of the midbrain.

We have talked about the midbrain part which is somewhere here. And now we will be going to the thalamus part of the brain which plays a very important role, I will tell you later on in terms of cognitive processes. So, it is in the top of the midbrain and it is below the you know the cortex areas etcetera. So, somewhere in between which connects between the lower part of the brain and the upper part of the brain that is where is the thalamus is coming into the picture.

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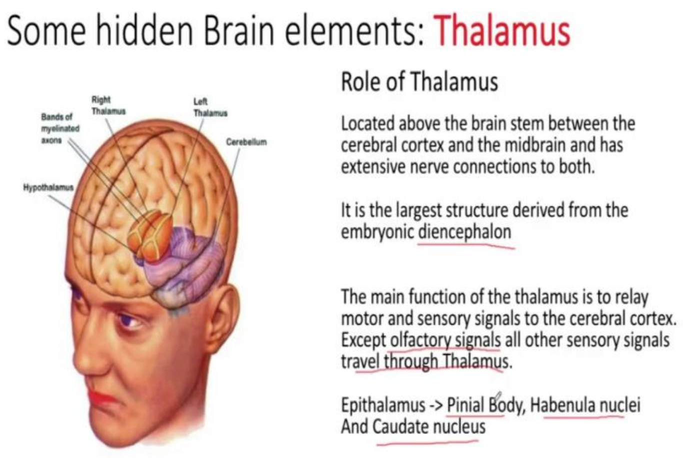

The thalamus as you can see that it has two parts in it, the right thalamus and the left thalamus. And it is just in the middle part, it is just at the central part which connects between the cortex part, and the cerebellum and the on the other hand the brain stem and everything.

So, it is located above the brain stem and between the cerebral cortex and midbrain which has extensive nerve connections to both that is what is thalamus. And it is the largest structure which is in fact, derived from the embryonic diencephalon part of it. You remember I have talked about that just below telencephalon, we have the diencephalon. So, this is the diencephalon part from which actually these you know the thalamus is actually derived.

Now, the main function of the thalamus is to relay motor and sensory signals to the cerebral cortex of course. As I told you that it works like a junction station and except the olfactory signals. Olfactory signals are directly connected to the brain or the cortex part, but except that all other sensory signals actually travel through the, they have to travel through the thalamus that is very important.

Now, this thalamus also has some additional parts outside that is the epithalamus region and the most important thing is the Pinial body and the Habenula nuclei and Caudate nucleus. Out of that I will just only talk about the pinial body which is a very important one in terms of course, reptiles it plays a very important role, in terms of the color change, for example, for the higher order animals also pinial body has some important functions.

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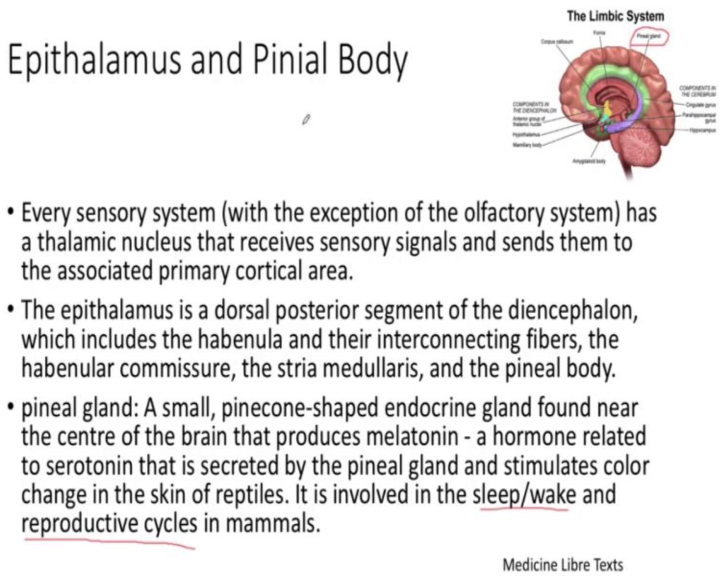

Now, you can see the position let us say in that entire picture you can see that the this this particular gland the pineal gland is somewhere here. You can always see that it is opposite to the hypothalamus that big bird’s beak and the opposite to it you can see the small region here that is where it is the pineal gland.

Now, this is part of what you call epithalamus and it is a dorsal posterior segment of the diencephalon. So, it is the posterior the back side of diencephalon and that includes the habenula and other interconnecting fibers also.

So, the pineal gland which is a very small pinecone shaped endocrine gland and these actually controls the you know hormone called melatonin, and this hormone related to you know serotonin it is secreted by the pineal gland and it stimulates color change in the skin of reptiles. In case of mammals, the same gland is actually involved in terms of the sleep wake, and the reproductive cycles in mammals. They have a pineal gland has a very important role to play. So, this is in one of the epithalamus systems that this pineal gland comes into picture.

We have seen the thalamus part of the brain. Now, let us look into this bird’s beak part of it which is known as hypothalamus. All our well-being our homeostasis, that is controlled by the hypothalamus. It is also one of the very primitive parts of the brain. So, let us look into the functions of the hypothalamus. And as I told you that in from close very close to the beak we have this pituitary gland which is actually controls. So, hypothalamus controls the pituitary glands, they actually secrete the hormones and that is actually controls many of our organic behavior.

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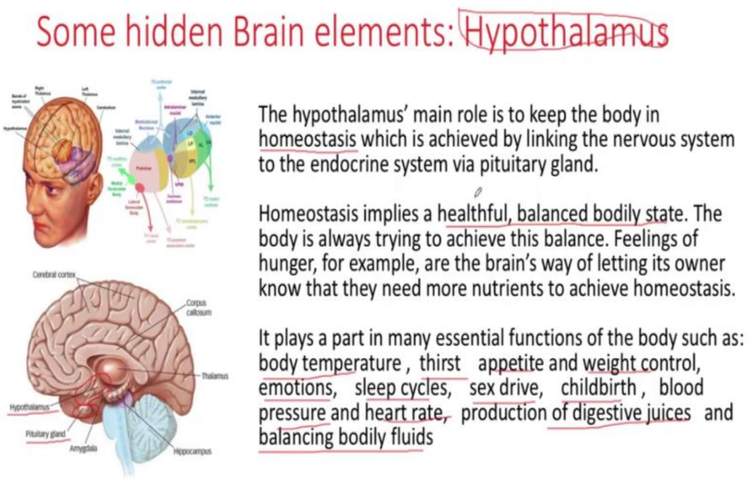

So, let us look into the hypothalamus. Hypothalamus is as I told you the main role is to keep the body in homeostasis condition. So, this is a homeostasis condition. That means, you know that your body temperature, for example, appetite, heart rate, blood pressure, everything it is kept under control by the homeostasis.

So, it actually gives you a sort of healthful balanced bodily state. That is the role of the hypothalamus. So, it has a very important role. And as you can see I told you that this is the big region that is where you have the hypothalamus and it is so close to the pituitary gland that is what it controls directly.

So, it is a part of the part where you know many essential functions of the body such as the body temperature, the thirst, appetite, weight control, emotions, sleep cycles, sex drive, childbirth, BP, heart rate, production of digestive juices and the balancing of body fluids. These are all the role of the hypothalamus. So, it has a very important role to play.

Now, hypothalamus has actually it is not a single monolithic thing, it has many important what you call nuclei’s inside the hypothalamus.

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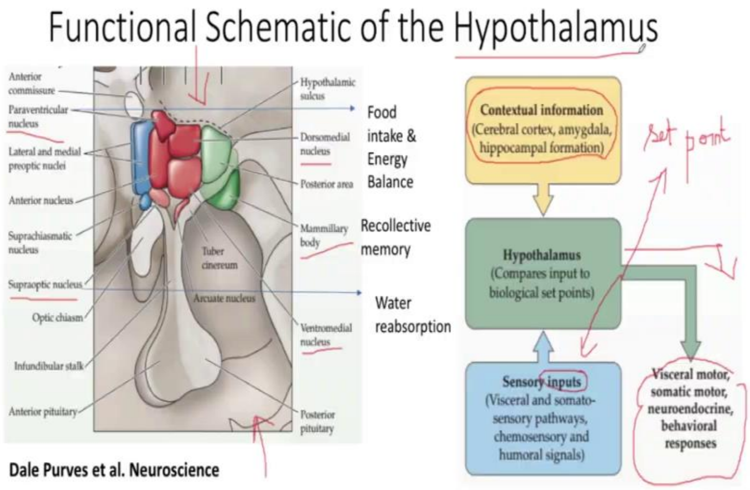

Let us look into these nuclei. So, some of the important nuclei for example: this nucleus paraventricular nucleus. So, this is one of the important nucleus paraventricular nucleus. Then also you have dorsomedial nucleus, mammillary body, then there is a ventromedial nucleus. So, and here there is a supraoptic nucleus.

So, all these they play different important roles. For example, whatever you know information, the contextual information that comes through your cerebral cortex, amygdala and the hippocampal region that actually comes to the hypothalamus.

And these different regions that I have talked about, they actually also get input from the sensory inputs. The sensory inputs are coming from the bottom side, ok. So, sensory inputs are coming towards the hypothalamus and from the cortex you are getting the input.

So, from both the sides you are getting the inputs. Based on it you are actually taking a decision and that what is this state tells me that, what will be my set point. For example, set point I will call it and so let us just try to keep this in our mind that this is the part which will be part of the set point and this is the part which are going to give us the inputs.

So, we compare between the set point and the input that is what the hypothalamus is going to do. And then it takes the actions. And these actions go to the visceral motor, somatic motors, neuroendocrine, behavioral responses or some actions goes towards the motors, and towards the muscles, and some towards the secretions of different types of hormones that further controls the organs. So, that is the role that is played by the hypothalamus.

We have talked about thalamus and the hypothalamus. Now, we will gradually enter towards the cortical region, the cerebral cortex region of the brain and we will be just at the base of the cerebral cortex region of the brain. So, if you look at it what I am talking about we have covered all these regions and now we will be talking about this region where just at the base we are having some people call it as a limbic system, the border system.

But a very important part some of the very important parts of the border systems will be the three things, one is that we will talk about here the basal ganglia part. And we will also talk about here the hippocampus part somewhere here, and we will talk about on top of it just below corpus callosum we have actually what you call the cingulate, particularly the anterior cingulate, ok.

So, the entire cingulate cortex that is the part beyond which the actually all other cortex that I had already discussed the frontal, prefrontal, parietal cortex etcetera is there. So, we have just then reached the cortex part of the brain. Let us look into their functions and their you know characteristics.

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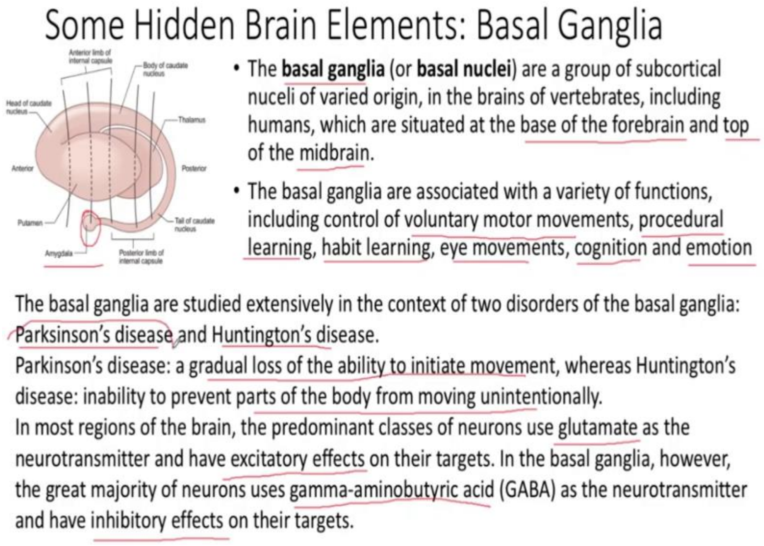

One of the most important part here is the basal ganglia part which is essentially a group of subcortical nuclei of varied origin and you will find generally in the brains of vertebrates including the humans and this is situated at the base of the forebrain and at the top, at the top of the midbrain that is where is the basal ganglia part of it.

Now, this is associated with a variety of functions. It controls for example, the voluntary motor movements. You will see that if this is lost in many of our voluntary actions that are lost procedural learning for example, ok, habit learning, eye movements, some people say good bit of cognition and emotion.

These are the things, particularly there is an area which is adjacent to the basal ganglia is the amygdala that controls many of our emotions. So, what happens if the basal ganglia do not work? Then you get two different types of disorders like the Parkinson's disease and the Huntington's disease.

Now, in the case of Parkinson's disease you will be having a gradual loss of the ability to initiate the movement, whereas in case of Huntington's disease you will be unable to prevent parts of the body from moving unintentionally. So, that is what is the Huntington's disease. This is in fact, a very fatal disease.

Now, in most regions of the brain the predominant classes of neurons actually use glutamate as the neurotransmitter and it actually have an excitatory effect. On the other hand, in basal ganglia great majority of neurons in basal ganglia actually use something called GABA, gamma aminobutyric acid and that works like a neurotransmitter that have inhibitory effects on their target. So, by nature this is somewhat different because it works on the GABA.

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So, if you just see some of these basic disease for example, what happens in the Parkinson's disease. So, you can see it in a very small video. Parkinson's disease or PD is the second most common neurodegenerative disorder after Alzheimer's disease and affects 1 percent of individuals over the age of 65.

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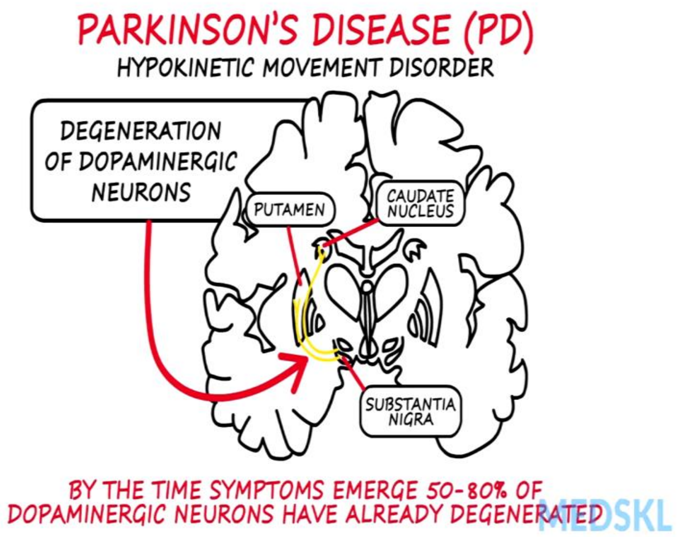

It is classified as a hypokinetic movement disorder and occurs due to degeneration of dopaminergic neurons that project from the substantia nigra in the midbrain to the basal ganglia. The initial precipitant of neuronal death is unknown and by the time symptoms emerge between 50 to 80 percent of dopaminergic neurons have already died.

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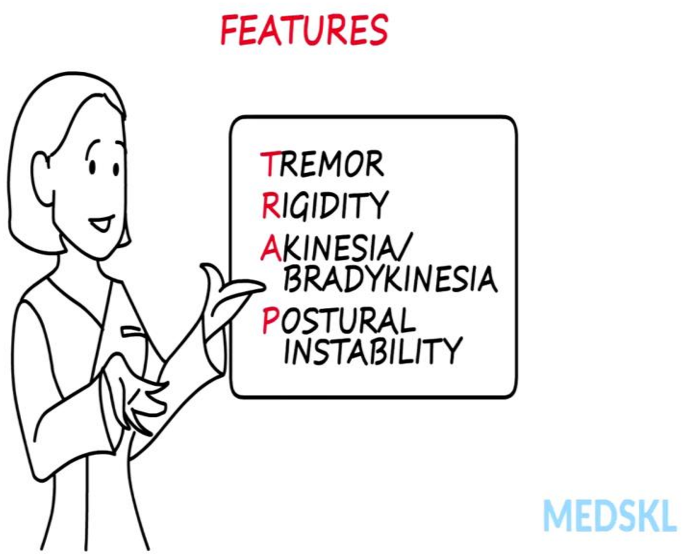

The cardinal features of PDR, tremor, rigidity, akinesia or bradykinesia and postural instability easily remembered with the mnemonic trap.

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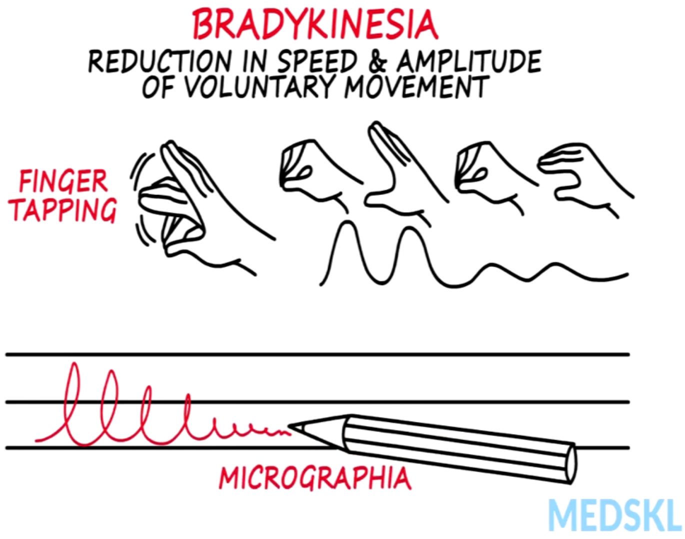

The most essential feature for diagnosis of PD is bradykinesia which is characterized by a reduction in both speed and amplitude of voluntary movement. This is most striking during repetitive movements like finger tapping, where tabs are slowed and become progressively smaller in amplitude or writing where letter size decreases across the page also known as micrographia.

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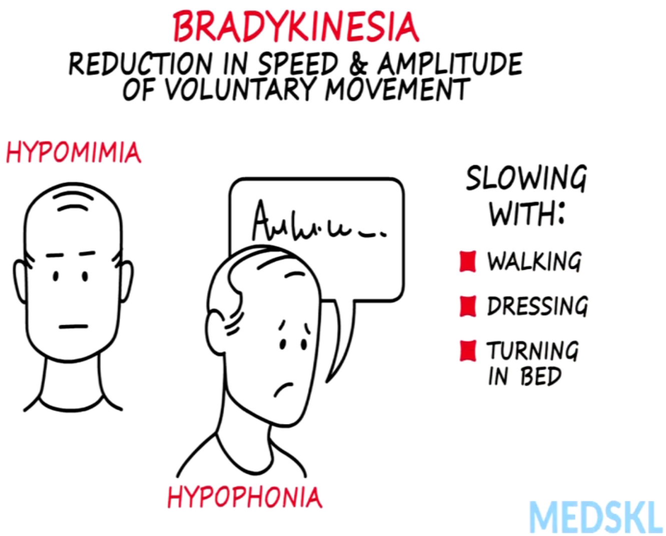

Bradykinesia is also manifested as a loss of facial expression or hypomimia, reduced vocal volume or hypophonia and slowing with a variety of other activities including walking, dressing and turning in bed.

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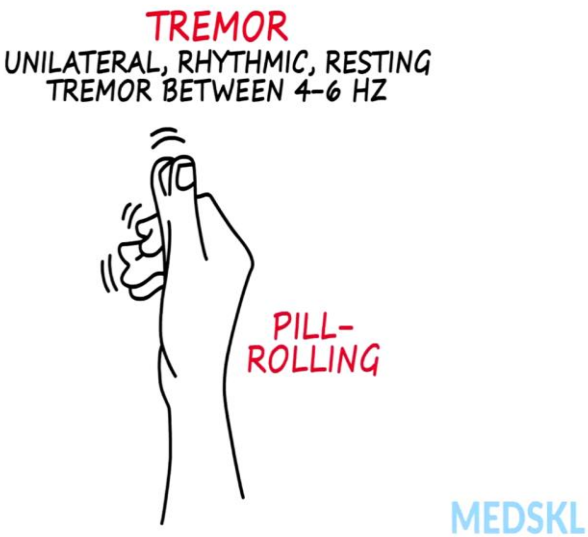

The tremor in PD is typically a unilateral, rhythmic, resting tremor between 4 to 6 Hertz and can classically start as a pill rolling tremor of the thumb and forefinger.

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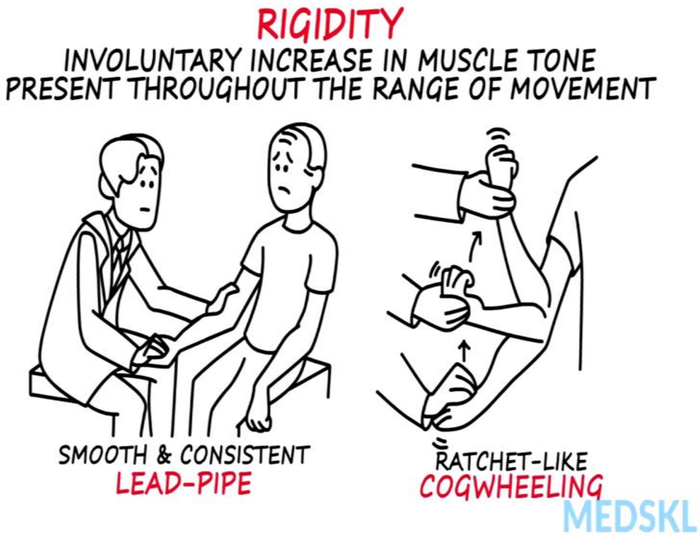

Rigidity is an involuntary increase in muscle tone present throughout the range of movement and can be tested by passively moving the arm, neck or leg. If rigidity is smooth and consistent throughout it is called lead pipe rigidity. If however, there is a ratchet like quality it is called cogwheeling, which is thought to be due to rigidity superimposed on an underlying tremor.

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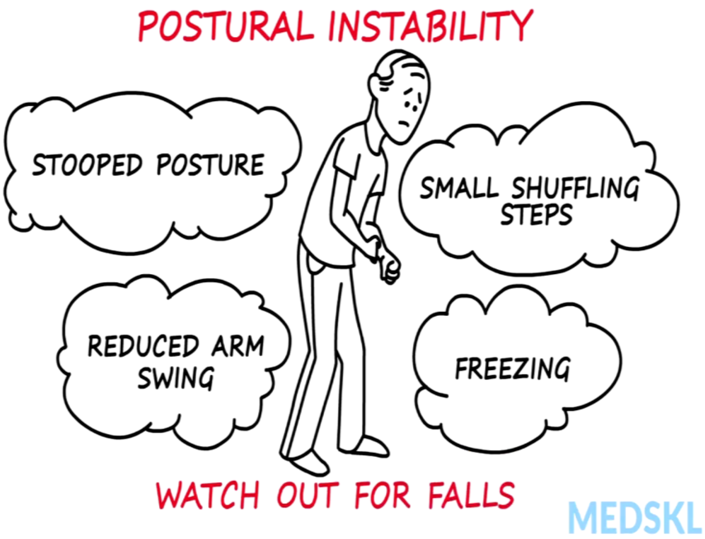

Parkinsonism also causes characteristic gait abnormalities like stooped posture, small shuffling steps, reduced arm swing and freezing. So, make sure to ask your patients and watch out for falls.

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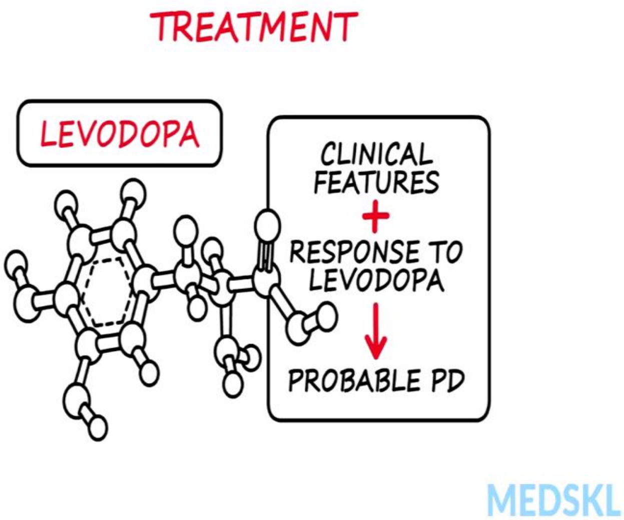

PD is treated with levodopa which is a precursor of dopamine. The neurotransmitter that is deficient in PD. An excellent response to levodopa in a patient with asymmetric tremor predominant Parkinsonism is supportive of the diagnosis of PD.

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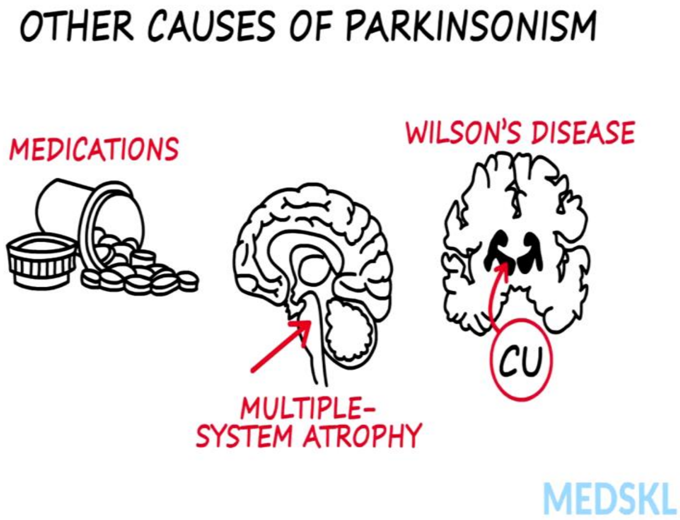

It is important to keep in mind that PD is the most common form of Parkinsonism, but patients may develop Parkinsonism from other causes including medications, such as antipsychotics. Other degenerative disorders such as multiple system atrophy or progressive supranuclear palsy, and Wilson's disease which causes copper deposition in the basal ganglia, alright.

So, we have reached up to the basal ganglia which is at the base of the cortex. Now, in the cortex particularly a near the you know temporal lobe we have a very important region called hippocampus which is very important in terms of the memory of the brain system. So, let us look into the hippocampus region.

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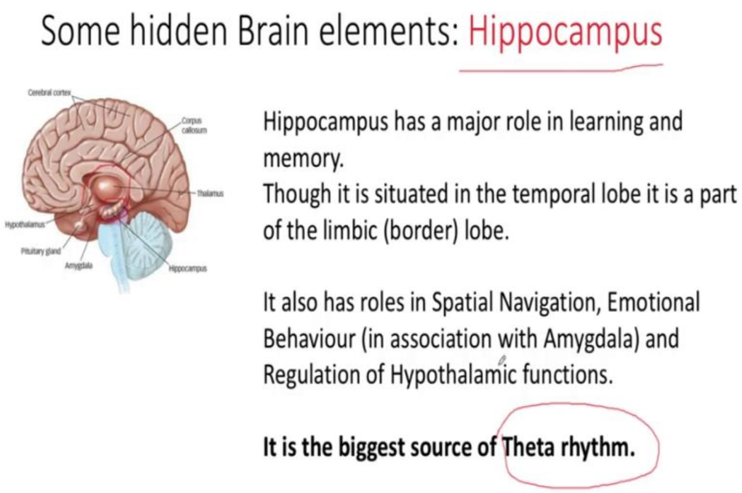

Now, look into the hippocampus region which has a major role in learning and memory, and though even though it is situated in the temporal lobe it is essentially a part of the border part of the brain in the limbic lobe.

And it has also roles in terms of spatial navigation, emotional behavior, so not just the memory and regulation of some of the hypothalamic functions. And it is the biggest source of the theta rhythm. This is important. You have to keep in your mind; at a later stage we would see in terms of the origin of the theta rhythm and its use, hippocampus is one of the biggest source in terms of the theta rhythm.

You can see the position of the hippocampus here. So, it is you know that is the hypothalamus region and then on top of it you can see the hippocampus. So, that is the way. So, it is in this is it has connections with thalamus and also with the hypothalamus this entire region, together you have the hippocampus.

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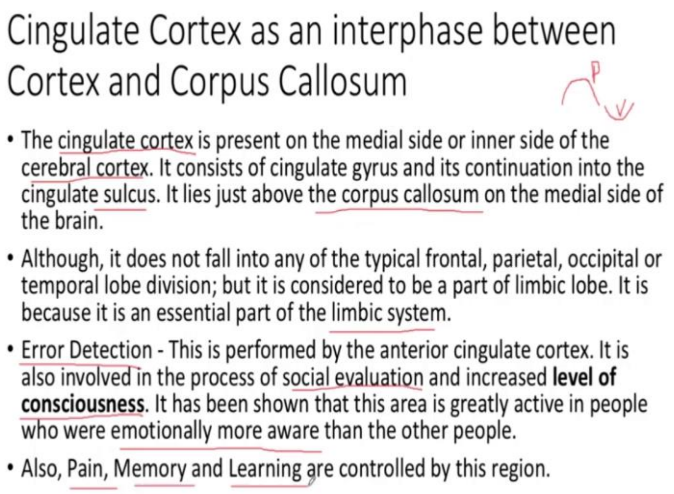

Well, the next important one is actually the cingulate cortex without which we cannot in fact; develop the cognitive model of brain. So, cingulate cortex plays a very important role in developing the cognitive model of brain.

Now, this is on the medial side or inner side of the cerebral cortex, as I told you that it is in inner side. And it consists of cingulate gyrus that is the topper upper part of the peaks and its continuation into the cingulate sulcus. So, you remember I hope that the gyrus and the sulcus, the peak and the valleys, the peak and the valleys. So, both of them you know you will see the cingulate cortex.

Now, this is just above the corpus callosum on the medial side of the brain and although it does not fall into any of these typically frontal parietal occipital part, because it is just above the corpus callosum. Corpus callosum, if you remember actually joins the left and the right side of the brain etcetera, but it is an essential part of this limbic system. It is used in for example, things like error detection, ok.

Also, it has a very important role in social evaluation; that means, you know what is our role in the society, it continuously testing. Increased level of consciousness that is what without singular cingulate cortex you can think of it. And, it has been shown that this area is greatly active in people who are emotionally more aware than other people. This part is also responsible for things like pain, memory and learning which are controlled in this region.

We have talked about some of the hidden brain elements; we have also earlier talked about the cortex, now it is the combination of all of these things together that actually makes the whole brain function. Towards this direction different people have tried to develop different models.

There are some very early models in 1960 where people try to actually you know call it is the MacLean model, where it is developed in terms of the brain is developed as a triune model of three parts, that is a reptile part of the brain. Then the paleo mammal part of the brain and that is the very early mammal part of the brain and then the primate part of the neo mammal part of the brain.

However, today we know that these are not exactly the same. But we can still say as I told you earlier that like the brain stem part and the midbrain part this is the part which is like you can consider it to be the primitive part of the brain, ok. Then, you have the more and more as the evolution progress, you get more and more developed part on the top side of it. But still this model gives us some important behavioral matching, ok.

So, even historically and it is a useful concept to begin with let us look into this model, and then we will see what are the some of the more advanced model towards this direction.

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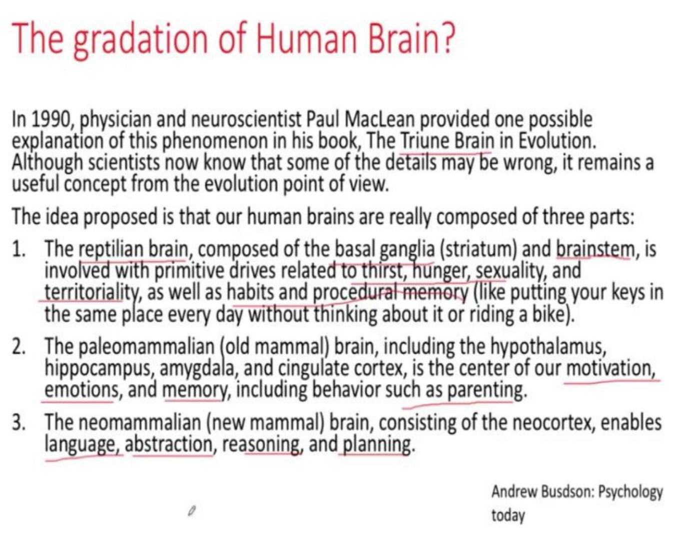

If you think of the gradation of human brain as I told you this MacLean's model and that talks about this a triune brain for example, ok, the triune brain part in evaluation. Now, it as I told you that they try to explain the brain in terms of three parts, the reptilian brain composed of the basal ganglia and the brainstem part which has the medulla oblongata, pons and midbrain, etcetera. And that is involved with all the primitive drives related to thirst, hunger, sexuality and territoriality as well as habits and procedural memory, ok.

So, that is the one-part reptilian brain. Then the paleo mammal brain which really includes the hypothalamus, hippocampus and amygdala, cingulate cortex etcetera which is the center of our motivation like you know emotions, memory, ok, dopamine's for example is motivation and behavior such as parenting that was one of the suggestion. Of course, today we know that it is not parenting is not only for the mammals, but also for the reptile birds for example, there are these parenting behaviors.

And, then this model said that there are new mammalian parts consists of the neocortex which enables higher order things, like language, abstraction, reasoning and planning. This is somewhat true that really the cortex for the top part that is involved with many of these important parts of the work. So, this was the first attempt to describe that how different parts of the brain are involved with different nature of works.

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Commonly studied conscious and unconscious Brain Events

	Conscious	Unconscious
1	Explicit cognition	Implicit cognition
2	Immediate memory	Longer term memory
3	Novel informative and significant events	Routine, predictable and non-significant events
4	Attended information	Unattended information
5	Focal contents	Fringe contents (e.g. familiarity)
6	Declarative memory (facts etc.)	Procedural memory (skills etc.)
7	Supraliminal stimulation	Subliminal stimulation
8	Effortful tasks	Spontaneous/automatic tasks
9	Remembering (recall)	Knowing (recognition)
10	Available memories	Unavailable memories
11	Strategic control	Automatic control
12	Grammatical strings	Implicit underlying grammars
13	Intact reticular formation and bilateral intralaminar thalamic nuclei	Lessened reticular formation or bilateral intralaminar nuclei
14	Rehearsed items in working memory	Unrehearsed items
15	Wakefulness and dreams (cortical arousal)	Deep sleep, coma, sedation (cortical slow waves)
16	Explicit inferences	Automatic inferences
17	Episodic memory (autobiographical)	Semantic memory (conceptual knowledge)
18	Automatic memory	Noetic memory
19	Intentional learning	Incidental learning
20	Normal vision	Blindsight (cortical blindness)

There are in fact, some commonly studied conscious and unconscious brain events on the basis of these. For example, you can see the whole list, I and you can just you read it for your reference. Some of the conscious brain events could be something like immediate memory, explicit cognition and things like you know strategic control, ok, things like the rehearsed items in working memory, wakefulness and dreams, ok, intentional learning, normal vision. So, these are all part of the conscious you know brain events.

Now, if you look at the unconscious brain events then longer term memory that is one of the unconscious brain. You do not know, but it is happening continuously. Procedural memory; the brain is keeping the procedural knowledge continuously in some areas even without discussing with you apparently, automatic control for example. For all the automatic nervous systems you know the parasima the sympathetic nervous systems for example.

Then the deep sleep coma sedation, ok. So, these are the some of the things which are controlled by the unconscious brain elements, so brain events. So, this is what you know we can keep in our mind and you can try to find out that what areas of the brain actually control the conscious versus the unconscious brain events as a sort of an exercise.

We will now talk about three of the greatest minds in brain science who have actually who have very important contributions in terms of developing the cognitive architecture of the brain. As I always told you that if you have to develop a cognitive robot, you have to understand that what is the cognitive architecture of the brain itself. So, this three people have you know phenomenal contribution in the field. Let us look into their proposed models and let us look into some of the modern views towards that.

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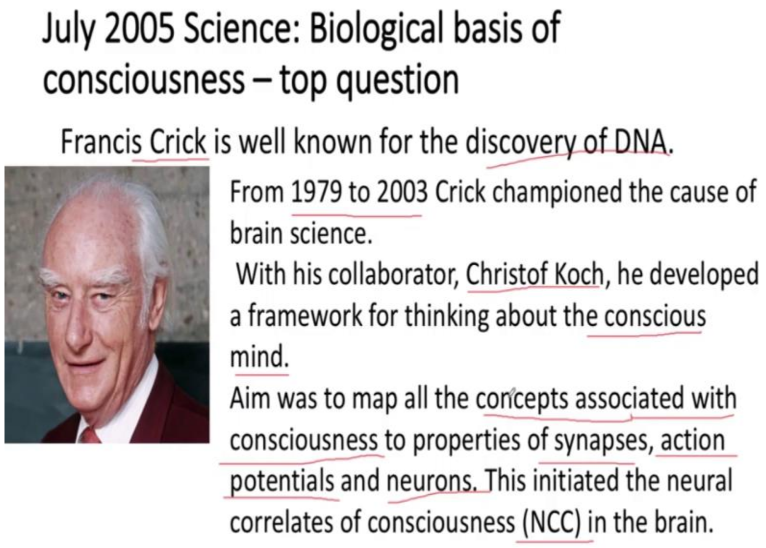

We will first begin our journey with Francis Crick. Many of you have heard of Francis Crick as the discoverer of DNA, he in fact got his Nobel Prize for this. But between 1979 to 2003 Crick championed something else. He worked with his collaborator Christof Koch and he developed a framework for thinking about the conscious mind, where from the consciousness rises.

His aim was to map all the concepts associated with the concepts associated with consciousness to properties of synapses to properties of action potentials, action potentials and neurons. So, in fact this is what is called NCC, neural correlates of consciousness in the brain.

So, he is the first person who started focusing on the fact that it is there is some biological connections between the consciousness and the biological elements. And in order to know that you have to start with the neuron itself, the neurons, action potentials, synapses and how the neural's network that was the first you know initiation towards this field.

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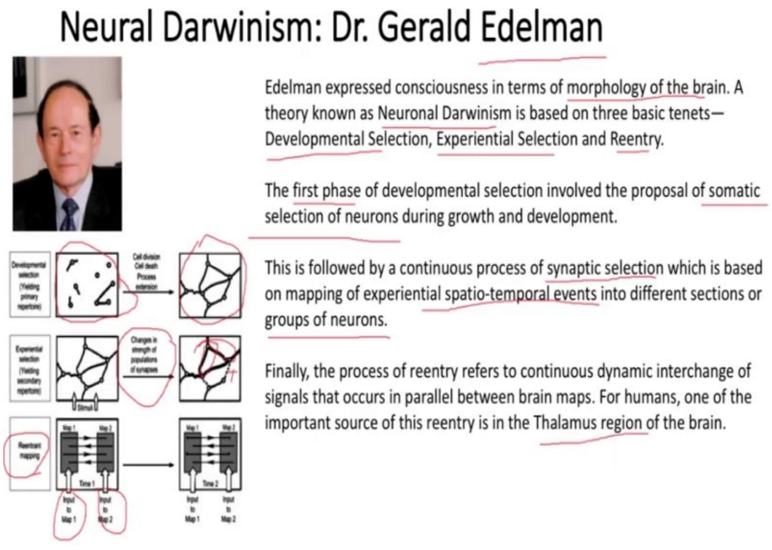

The next is also by another very famous Nobel laureate in neuroscience that is Gerald Edelman. Now, Edelman expressed consciousness in terms of the morphology of the brain. His theory is known as Neuronal Darwinism is based on three basic tenets that is you know it is based on the development of selection, experiential selection, and the reentry part of it.

Now, when a you know for example, a child is first developing, at that time the child is having billions of neurons in him, but at the first phase this is the first phase of developmental selection, it involves the somatic selection of neurons, ok, so during the growth and development. So, you can see that this is where the fast neurons are coming and at the developmental phase some of these neurons are selected and the networks are getting built and that is what is the somatic selection phase, that is what is the developmental phase.

After the developmental phase then there comes a continuous process of synaptic selection; that means, the joint selections and the reinforcement. Like you can see that this particular region, this particular region, they are more reinforced, whereas this region is not reinforced. So, this reinforcement starts and that actually and develop a new spatial temporal event this new spatiotemporal map in terms of different sections or groups of neurons. That is the second phase. So, this is the phase where this experiential growth is happening.

And, finally there is a very interesting process of reentrant mapping that happens. And what it tells is that consciousness is essentially a dynamic process where this reentry has to happen. Reentry means a group of neurons which will continuously crosstalk between each other irrespective of what input is coming to one and or to the other.

It will continuously you know kind of in touch with each other and that actually this reentry would actually help it in terms of predicting what will be the output of the system. So, there are several reentric region. And what Edelman said is one of the important reentry region is possibly the thalamus region of the brain.

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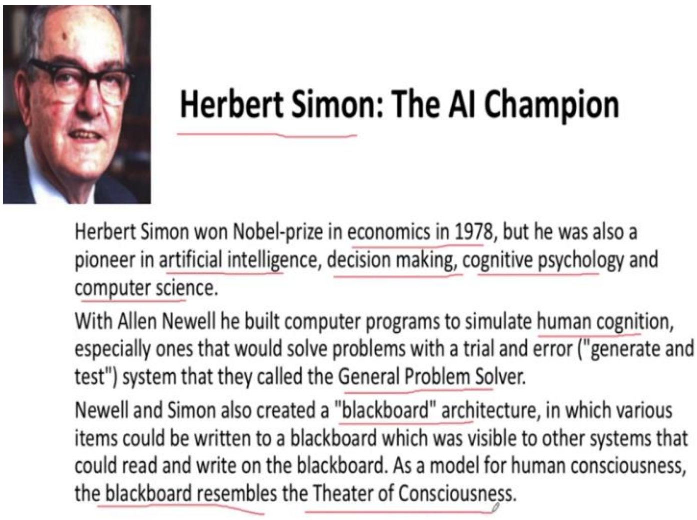

Beyond Edelman there is another person who had enormous contribution; his name is Herbert Simon, another Nobel Laureate. Of course, in a somewhat different area in economics in 1978, but he is considered to be a pioneer in artificial intelligence, in decision making, cognitive psychology and computer science.

So, together with Allen Newell he built actually computer programs which can simulate the human cognition, especially ones that would solve problems with a trial and error like a generate and test system. These are called general problem solver. He has proposed a concept of blackboard architecture, in which various items could be written to blackboard by different let us say group of neurons nuclei and it was visible to other systems that could read and write on the blackboard. As a model for human consciousness, this blackboard resembles the theater of consciousness. So, that was one of the important contribution.

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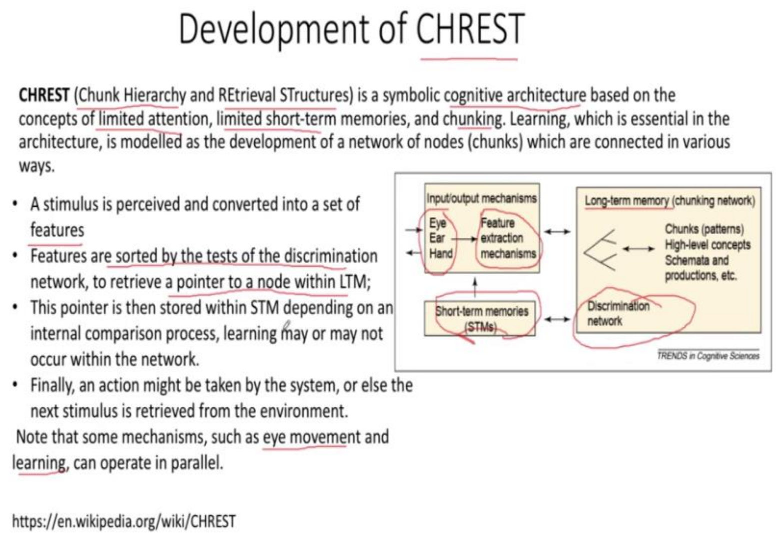

Herbert Simon has also contributed towards developing a very interesting algorithm suitable for AI, and this algorithm is also known as crest algorithm that is chunk hierarchy and retrieval structures.

Now, this is a symbolic cognitive architecture. For the first time somebody has talked about cognitive architecture, which is based on the concepts of limited attention, limited short term memories and chunking; so, sort of learning. It is essential in the architecture and it is a model as the development of network of nodes which are connected in various ways.

Let us say you consider this graph, that first of all you are getting inputs from all the different sensory organs, eye, ear, hands etcetera. Now, what in the CHREST model he proposed is that, there will be some feature which will be extracted from these mechanisms and then a very interesting thing happens. So, that is the first part a stimulus is perceived and converted into a set of features. Then these features are actually sorted by the tests of the discrimination.

So, there is a discrimination network which sorts these you know features and send them to pointers to a node within the, you know these limited term memories. So, then these are the long term memories. So, from this long term memory they actually send the indicators of this long term memories to the short term memory. So, that is what you know it actually goes here, to the short term memory. So, discrimination network thinks of what are the points where you have to connect it then from the address of those points comes to the short term memory.

And then finally, an action might be taken by the system you know if it is you know a new learning process or else you start a new you know feature to extract. And many of this process can be actually done parallel like eye movement and learning and many of the other process you can do it parallel.

So, that is what was the CHREST algorithm. This for the first time an algorithmic model had come up where you know you do first collect the features from the input, then you take them through a discrimination network, check whether you have already associated points, nodal points, with this experience and then those things where the associations are that is the only thing you declare to the short term memories. And, if it is new some new learning takes place and again you go ahead for the new inputs. That is the way you know he tried to simulate the brain.

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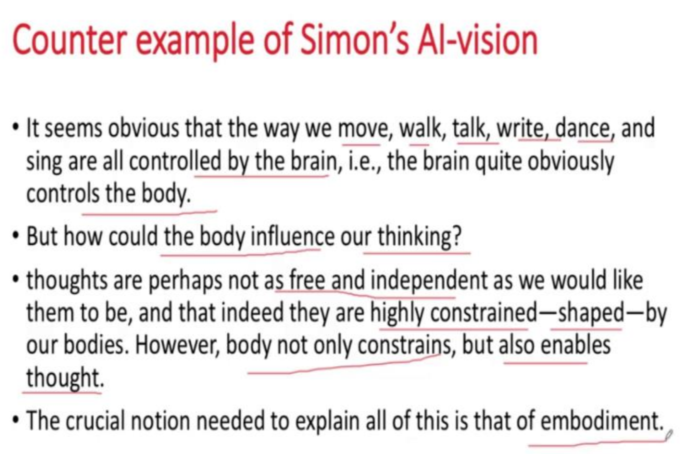

Now, there are counter examples of Simons this kind of a AI vision because there is no place of body in his vision. Now it seems, all right that when we move, we walk, we talk, we write, we dance; all these things are controlled by the brain. So, that is fine that the brain quite obviously, controls the body, but the question is how could the body influence our thinking. And it is something which is very important, because perhaps our thoughts are not as free and independent as we would like them to be they are indeed highly constrained shaped by our bodies.

So, body not only constrains, but also enables the thoughts in the way towards the which you know the body gets advantage out of it. So, the crucial notion is to explain this process of embodiment that is the counter to the Simon's AI logic.

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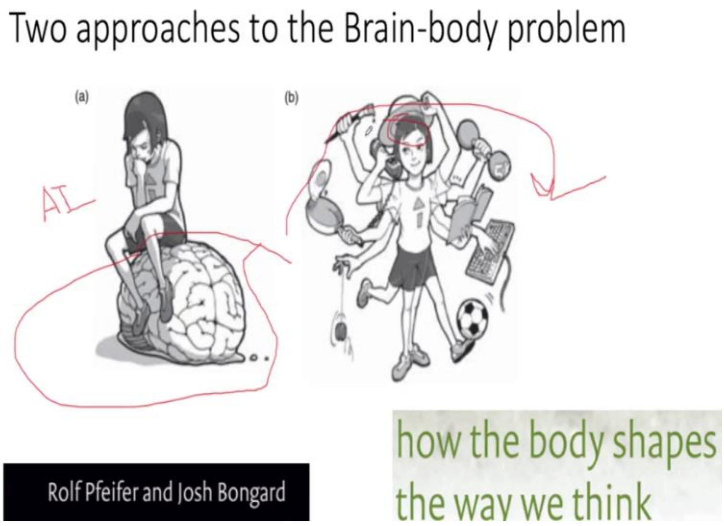

In fact, so there are these two logics, one group is these AI group. So, this is the AI group where the body is just a peripheral extension and the central part is the brain itself. Whereas, the other group for example, the Rolf Pfeifer and John Bongard's group, they talk about how our body, how our different somatosensory experiences as you can see all around us they actually shape our thought process in the brain. So, both the approaches we will actually try to cover while designing the cognitive robot.