Basics of Mental Health and Clinical Psychiatry
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Lecture 08
Limbic system

Hello everyone. So, today we will start our next topic that is Limbic System.

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Now, the concepts we will cover in this limbic system - what are the components of limbic system, what are the neural circuits, functions of limbic system and applied aspects.

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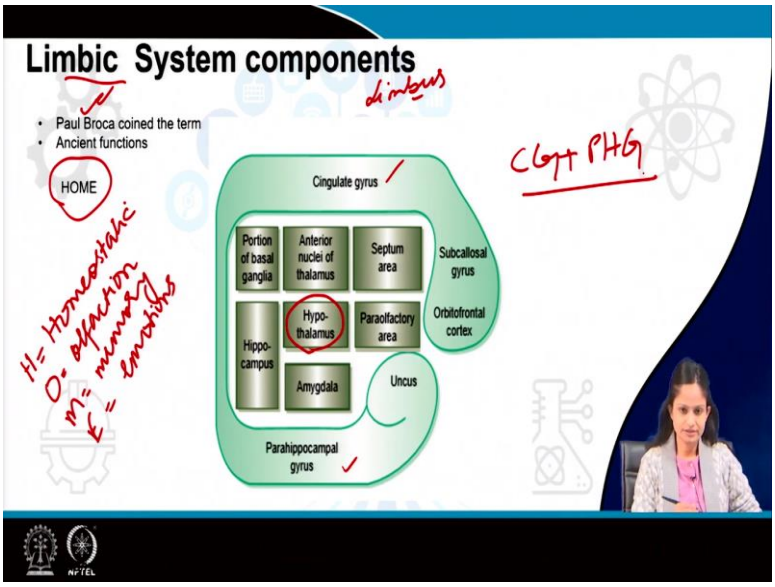

Now, limbic system components before going on to the components, this limbic system has been termed by Paul Broca. Now, the word limbic came from the word limbus, limbus means border. This limbic system is usually concerned with the ancient functions. Now, what are the ancient functions? A very short note I have given, home, home means, H stands for homeostatic functions. Homeostatic functions means what are the autonomic functions been done in our body.

O is mainly for olfaction, olfactory function, that means smell. Then M of course, memory, E is emotions. So, these are the four important functions you have to remember of limbic system. These are the ancient functions, phylogenetically this is a old structure that is limbic system. So, it is mainly concerned with the ancient functions H, O, M, E - Homeostatic, Olfactory, Memory and the Emotions. Now, this is a generalized structures given what are the components of the limbic system.

Few components you have to remember, every components you do not have to remember. What you have to remember is the subcortical structure which are present in the limbic system, the most important the center of the limbic system is hypothalamus. The cingulate gyrus, the parahippocampal gyrus, these two mainly forms the what we call as limbic cortex, cingulate gyrus and the parahippocampal gyrus. Now, other structures subcortical structures we will discuss later.

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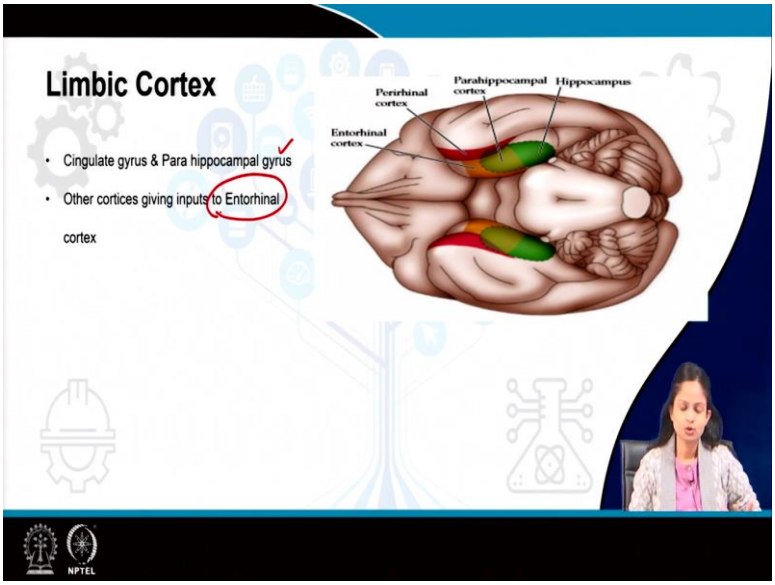

Now, what happens in this limbic cortex? As I told you, the cingulate gyrus and parahippocampal gyrus forms the limbic cortex mainly, besides that whatever informations

are present in the other cortical surfaces, whether it is temporal lobes or orbitofrontal cortex, perirhinal cortex, parahippocampal cortex, these are all relayed to the entorhinal cortex. So, entorhinal cortex forms a very important structure in the limbic system which usually sends or perceives very important informations from all the cortices of our brain and sends the final information to the hippocampus, it receives as well as it sends the information. So, entorhinal cortex is very important.

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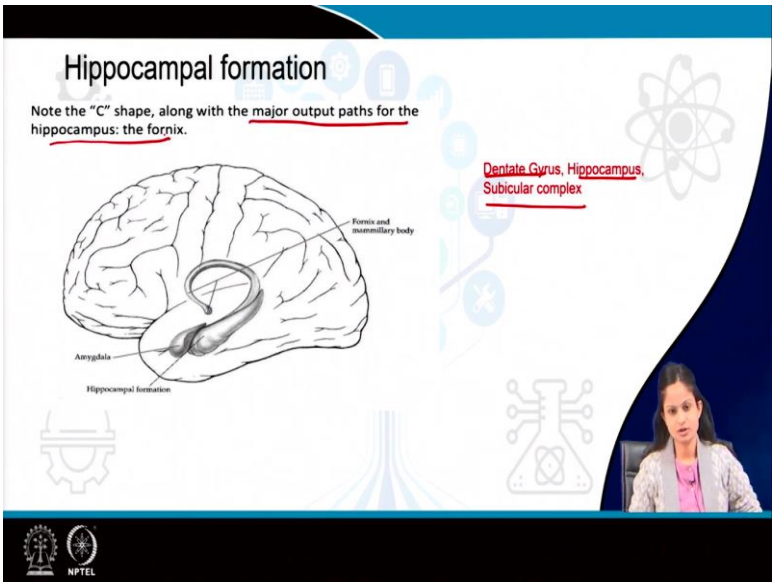

Besides this, the hippocampal anatomy is very important. Hippocampal anatomy means it consists of dentate gyrus, hippocampus and subicular complex or the subiculum. This three each having their own cytoarchitectural structures, means they have different types of cells. We are not going to go details in those cells, but what we have to remember is hippocampus is a C-shaped grey body. It has got these three structures - dentate gyrus, hippocampus and subiculum in terms of folds and these folds they finally you can see it makes a C-shaped structure with amygdala attached to it and the major output paths for the hippocampus is via fornix and the mammillary body.

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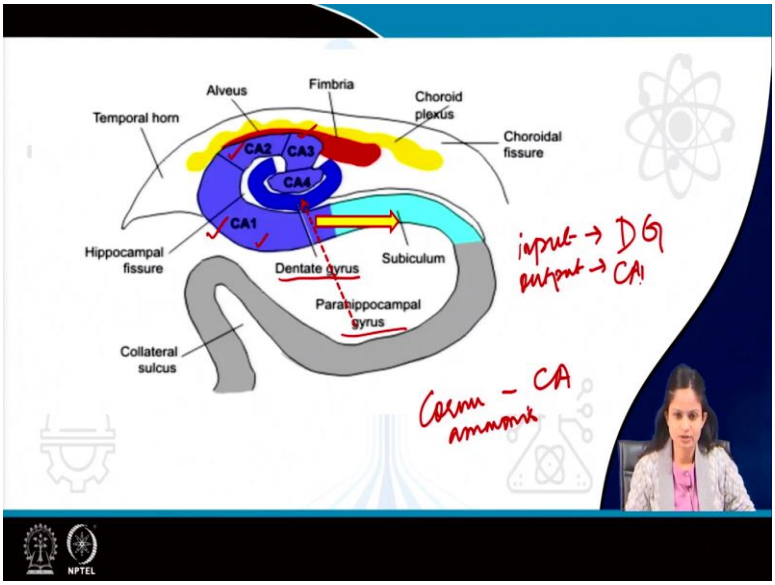

Now, we will see what is the hippocampus? In the hippocampus and the dentate the few cells which are present. Mainly we have C1, CA1, CA2 and CA3. CA4 if you do not remember also it is okay, but CA1, CA2 and CA3 cornu ammonis. CA is the word which has been discovered from cornu ammonis. So, in this way we have CA1, CA2, CA3. 1, 2, 3 is because of the difference in the cytoarchitectural structure as I told you. So, these are present in the hippocampus.

So, what is important is? From the parahippocampal gyrus this is the parahippocampal gyrus of the parahippocampal cortex, the information goes to the entorhinal cortex and then from the entorhinal cortex the major input is through the dentate gyrus. So, the input is to the dentate gyrus and the output, the major output is from the CA1 region of the hippocampus. So, input is to the dentate gyrus and the output is from the CA1 region of the hippocampus region. So, this much you have to remember.

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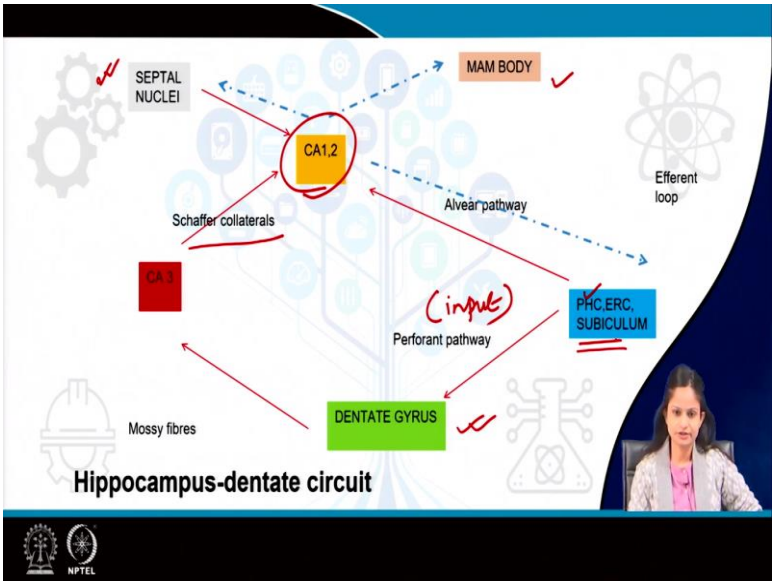

Now, coming to the circuits. The first circuit is the hippocampus dentate circuit because if you do not understand the circuits you would not be understanding what the functions, the roles played by each of the structures of the limbic system. So, first I told you, the input should be from the entorhinal cortex. So, parahippocampal gyrus or the parahippocampal cortex, perirhinal cortex or vitofrontal cortex, every region of the cortex, they send the information to the entorhinal cortex.

From entorhinal cortex the information will traverse in two ways. The first it will go to the CA1 region with the help of alvear pathway which is also important, but the main pathway which you have to remember is the perforant pathway, that is to the dentate gyrus because I told you the major input, this is the major input to the hippocampus from entorhinal cortex via perforant pathway to dentate gyrus. The other pathway is also there, that is alvear pathway to the CA1 region.

Now, in the dentate gyrus we have different types of cells. The axons of the dentate gyrus, those are the mossy fibers, they will relay the information to the CA3 region. The CA3 region, there also we have different types of cells from the CA3 regions the information will be relayed to the CA1 region. CA2 region is also there, but most important you have to remember CA1 region. So, CA3 to CA1 region, the information which is traversed by the axon fibers they are mainly known as Schaffer collaterals.

So, this Schaffer collaterals is important over here, they will take the information from CA3 region to the CA1 region of the hippocampus. So, you can see entorhinal cortex is giving

input to the dentate gyrus as well as to the CA1 region. From dentate gyrus, that is the perforin pathway; through the mossy fibers the information will be taken to the CA3 region. From CA3 region with the help of scraper collaterals the information will be taken to the CA1 region.

Now, also CA1 region receives inputs from the septal nuclei. Now, these are all the afferents we have seen or the inputs we have seen to the hippocampus. Now, we will see the efferent. From CA1, the afferents are mainly back to the septal nuclei back to the entorhinal cortex and the mammillary body. As I told you, the major output is from the CA1 region. So, CA1 region after taking all the information it will give output to back to the septal nuclei, mammillary body as well as to the entorhinal cortex and this will finally completes the circuit of the efferent loop. So, this is hippocampus dentate circuit.

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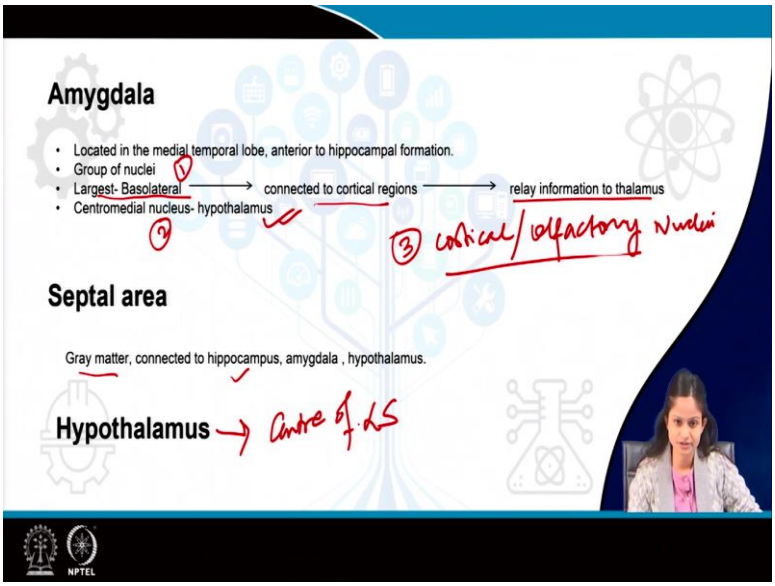

Now, coming to the other structures, that is amygdala the subcortical structures present in the limbic system. Now, we know amygdala is located in the medial temporal lobe which is anterior to the hippocampal formations we had seen in the last picture. So, amygdala the group of nuclei there are mainly three groups of nuclei present in the amygdala the central median group of nuclei which is concerned with all the autonomic and the endocrine functions.

That means, they relay the information to the hypothalamus. We have another nuclei that is for the cortical nuclei or olfactory nuclei. Amygdala plays an important role in olfaction also. So, the first nuclei which is the largest nuclei is basolateral nuclei which is connected to the

other cortical regions and hence they relay information to the thalamus. This is mainly for the sensory information. So, basolateral nuclei is the one, the centromedial nuclei that is for the autonomic endocrine functions, they relay the information to the hypothalamus and the third is the olfactory nuclei.

So, this is the role played by amygdala. The septal area or the septal nucleus which I told that is a gray matter which is connected to the hippocampus, amygdala and hypothalamus. And the center of the limbic system is hypothalamus and regarding hypothalamus we had already taken a separate chapter.

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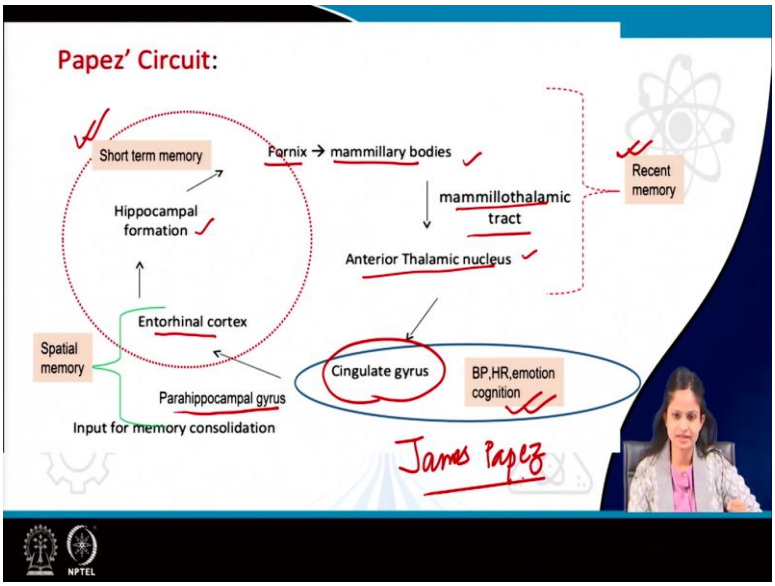

Now, we will see what is a papez' circuit. So, in the papez' circuit we can see this much I had already discussed, that means the information coming to the entorhinal cortex from every other cortical areas, then it is moving to the hippocampal formation. Hippocampal formation the processing occurs with the help of dented gyrus, CA3 neurons and CA1 neurons. Then the information is taken out with the help of fornix to the mammillary bodies. Now, this portion is known as the papez' circuit.

Now, this portion of the papez' circuit is mainly important for short term memory. This much you have to remember, this is very important for short term memory, that means the consolidations, the hippocampal formation is mainly responsible for the short-term memory. If any destruction occurs to this path, there will be loss of short-term memory. Now, from mammillary bodies the information with the help of mammillothalamic tract it traverses or it ends in the anterior nucleus of the thalamus.

If you could remember the anterior nucleus of the thalamus as I already told in the thalamus chapter, it plays a very important role in memory formation. So, anterior nucleus of the thalamus and the mammillothalamic tract is very important for the recent memory. Then from anterior thalamus nucleus the information is traversed or information is taken to the cingulate cortex or the cingulate gyrus. The cingulate gyrus is very important for cognitive functions besides emotions and blood pressure regulations and heart rate regulations.

From cingulate gyrus with the help of parahippocampal gyrus again the information is taken to the entorhinal cortex. So, this forms a total closed loop or circuit. And this entorhinal cortex and parahippocampal gyrus, this is mainly important for spatial memory. Spatial memory means 3D structure of the memory. Suppose I am walking in a road. So, I should know the 3D dimensions of the road. So, that is spatial memory. So, all this type of memories and the learning process and emotional behavior and cognitive process are destroyed in neurodegenerative, various neurodegenerative disorders.

So, papez' circuit is mainly the entorhinal cortex, hippocampal formations, mammillary bodies, anterior nucleus of the thalamus, then cingulate gyrus. This forms a closed circuit known as papez' circuit. It is named after James papez'. It is named after James papez'. So, this is very important circuit for input for memory consolidation.

Now, since we are talking about the neural circuits, we are going from inside to outside. This we had learnt; first we saw the hippocampus dentate circuits, then we moved out of the hippocampus and we saw how the anterior nucleus of the thalamus and the cortical areas are involved. So, this is papez' circuit.

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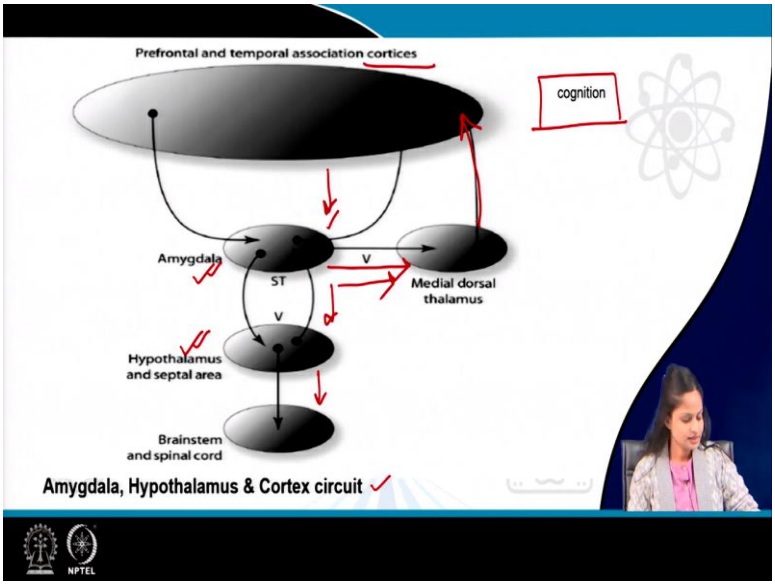

Now, we will see the amygdala, hypothalamus and cortex circuit. Now, we can see the prefrontal and the various temporal association cortices. The various cortices as I told you they will take the information to the entorhinal cortex. Now, from there the information is traversed to the amygdala. Now, amygdala sends two of its pathway. One is the ventral amygdala fugal fibres and another one is the ST fibres. These fibres sends information to the dorsomedial nucleus of thalamus and to the hypothalamic area, hypothalamus and the septal area.

Though hypothalamus and the dorsomedial nucleus of thalamus also has a one on one relations with the help of ventral amygdala fugal fibres. So, from cortices to the amygdala, then from amygdala to the thalamus as well as to the hypothalamus and from the hypothalamus all the information goes to the brain stem and spinal cord.

So, this circuit is mainly important for the cognition or plays an important role in cognitive pathway because amygdala plays an important role in cognition. From amygdala all the sensory informations are going to the thalamus dorsomedial nucleus of thalamus and again it is moving back to the cortex. This is the pathway which is already taken back to the cortical areas. So, this is another circuit.

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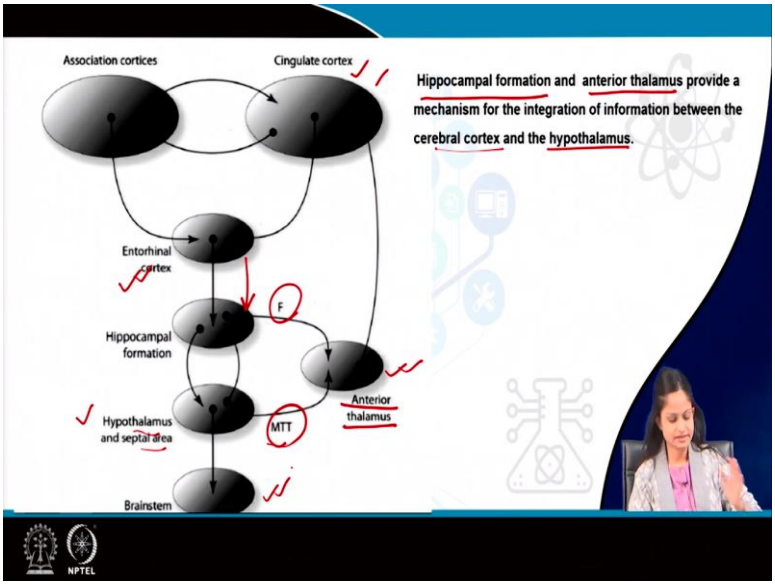

The next circuit which is important this is the association cortex circuits. What every cortices I told you, they take the information from the cingulate cortex and other association cortices to the entorhinal cortex. From the entorhinal cortex, the information is sent to the hippocampal formations. From the hippocampal formations the information is taken out with the help of fornix. This is nothing but the papez' circuit which I am talking about.

So, from the fornix it moves to the anterior nucleus of the thalamus. From anterior nucleus of the thalamus with the help of mammillothalamic tract, it moves to the hypo, also the information comes from the hypothalamus and septal area through mammillothalamic tract to the anterior nucleus of the thalamus. So, from anterior nucleus of the thalamus information again gets traversed to the cingulate cortex. So, what we can see and again the information from hypothalamus comes to the brain stem.

So, there is an coordinated circuit which is present between the hippocampal formation, anterior thalamus and cerebral cortex and hypothalamus. So, this hippocampal formation and anterior thalamus provides a mechanism for integration of information, whatever information, sensory information's between the cerebral cortex and hypothalamus. These are the cortical surface, this is the hypothalamus.

Every information is getting traversed through the cortex, hippocampal formation where processing occurs output through fornix to the anterior nucleus of thalamus; further it again convey back the information to the cortex; anterior thalamus also receives information from the hypothalamus which also receives information from the hippocampal formations and

finally, sends back the information for action to the brain stem or spinal cord. So, this is the integration mechanism which is present between the cortex level, amygdala hippocampus and hypothalamus and brain stem level.

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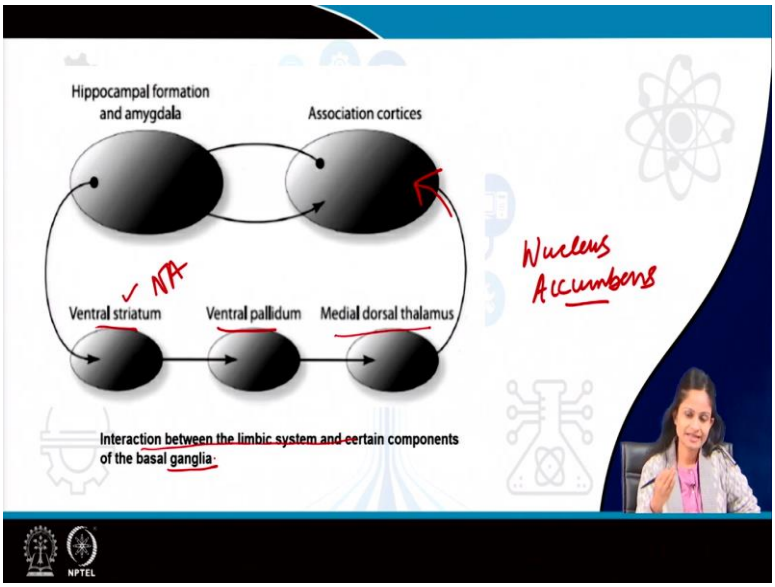

So, the last circuit which is very important, this shows the interaction of the limbic system with the basal ganglia. Now, this is the pathway which is mainly occurring through ventral striatum which contains the nucleus-nucleus accumbens. Nucleus accumbens is a nucleus which plays an important role in addictive behavior in case of addiction. So, in any information from the cortical areas and hippocampus there is an integrated information which happens between hippocampus and cortex we have seen.

Then, with the help of ventral amygdala fugal fibers, the fiber sends information to the ventral striatum; from there it moves to the ventral pallidum; then dorsomedial nucleus of thalamus which conveys the information back to the cortical surfaces. So, this is the interaction or the circuit shows the information of the limbic system and the basal ganglia. In this way, the basal ganglias, cortex, hypothalamus, hippocampus, amygdala, these all are integrated or related in such a way that there is integration of information at every level.

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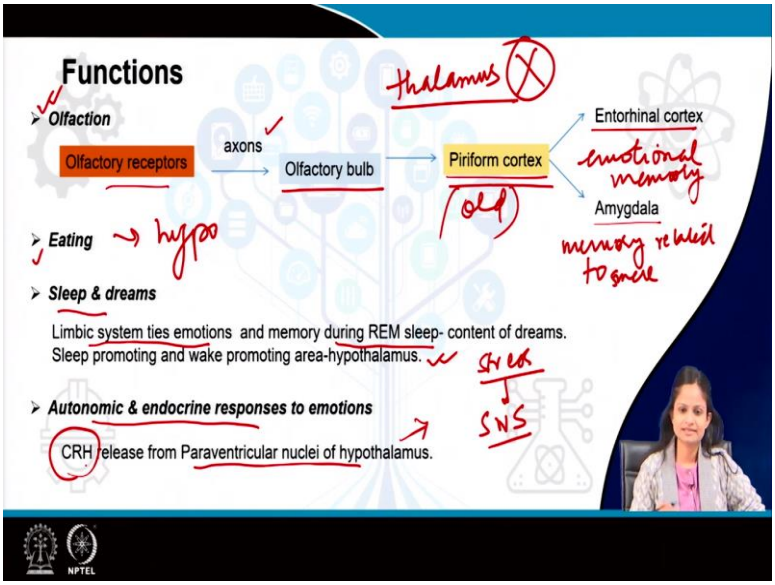

So, completion on of the circuits now we will talk about the functions of limbic system. The first function is olfaction as we have noted about home. So, O is for olfaction. Now, olfaction you can see the olfactory receptors are present, olfactory receptors; from the olfactory receptors, axons of the olfactory neurons they travel the information to the olfactory bulb. From olfactory bulb, the information is taken to the piriform cortex this is a very old or primitive cortical area.

From piriform cortex information is taken to the entorhinal cortex and amygdala. So, entorhinal cortex and amygdala plays an important role in case of emotional memory. And amygdala also plays an important role in respect to memory related to smell. That means, if I smell something and if it the smell is known to me then I could recall that okay this smell is of that substance. So, that is these olfactory memories. So, olfactory receptors conveying the information to olfactory bulb; then from olfactory bulb to the piriform cortex; from piriform cortex to entorhinal cortex and amygdala.

Now, what is very important to see over here? There is no thalamus involved. This is the only sensory pathway where thalamus is not involved. So, the next function is eating. Now, in eating I had already described in the my last lecture of hypothalamus there is a feeding center, there is a satiety center; the lateral nucleus of the hypothalamus is the feeding center; the satiety center is the ventromedial nucleus of the hypothalamus. How ventromedial nucleus keeps and check on the lateral nucleus of the hypothalamus with the help of plasma glucose levels and there is also the mechanism of arcuate nucleus of the hypothalamus with the help of proprio melanocortin levels and neuropeptide Y levels.

They maintain the body metabolism, they regulate the body metabolism and hence urge the person either to eat or not to eat. In this way, the eating or the food behavior is maintained by hypothalamus. Now, sleep and dreams. The limbic system ties emotions and memory during REM sleep, REM sleep - rapid eye movement sleep, this we will discuss later in the sleep physiology chapter in details. So, the content of dreams is usually maintained by the limbic system with the help of emotions and memory.

And besides that, we have the sleep promoting area and the wake promoting area in the hypothalamus which secretes GABA and histamine simultaneously respectively from its region - sleep promoting and wake promoting area which induces sleep and wake cycle. Then the autonomic and the endocrine responses to emotions are mainly done with the help of corticotropin releasing hormone. Now, this corticotropin releasing hormones and is again released from the paraventricular nuclei of hypothalamus.

As I told you, hypothalamus plays in a very important role in limbic system because it forms the core of the limbic system or center part of the limbic system. So, whenever there is stress in our body our sympathetic system will get activated. So, whenever there is stress in our body our sympathetic system will get activated; the corticolimbic system will get activated, that will cause release of corticotropin releasing hormones from hypothalamus and with this releasing hormones there will be differences in the cortisol level secretions and various hormones adrenaline, non-adrenaline secretions and that will finally, cater the actions of autonomic responses and the endocrine responses to emotions.

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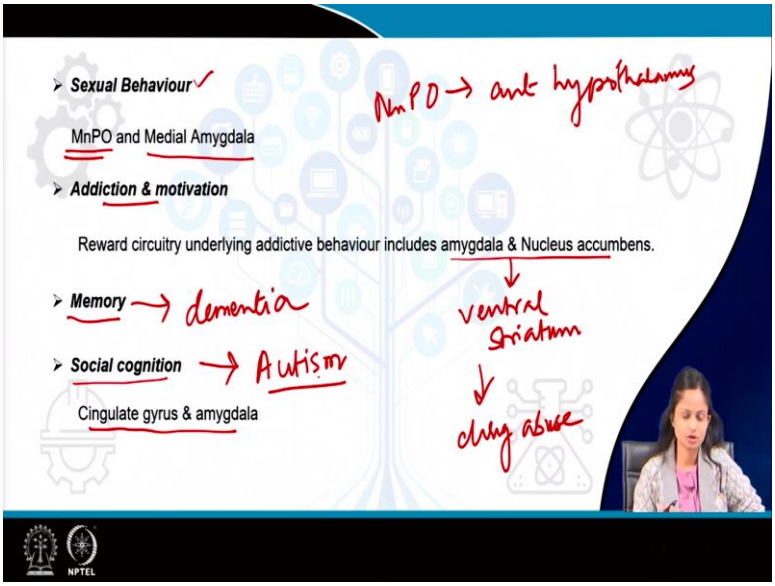

Then the sexual behavior. The sexual behavior is usually maintained by median preoptic nucleus of anterior hypothalamus and median amygdala. This median preoptic nucleus is of anterior hypothalamus and median amygdala. These are the two structures you have to remember which is important for sexual behavior. Addiction and motivations, I had already told, amygdala and nucleus accumbens; the ventral it plays a very important role through the ventral amygdala fugal fibers via ventral striatum.

The pathway, the circuit has already been discussed. With that, reward circuitry mechanisms underlying addictive behavior includes amygdala and nucleus accumbens. If this nucleus accumbens or this circuit gets disturbed this finally, results in drug abuse. That means, urge to take more drugs. The memory, I had already discussed about the memory, various forms of memory - short term memory, recent memory, spatial memory cognitive memory, olfactory memory, these are all important and it plays an important role in the limbic system.

Now, whatever papez', whether it is papez' circuit or other circuits if they get destroyed what happens in neurodegenerative disorders what results in dementia. Dementia means loss of memory along with the loss of cognitive functions. Amnesia means only loss of memory, but along with loss of memory, gradual loss of memory if there is loss of the cognitive functions also that means, you are not able to learn, you are not able to do your daily activities, routine activities, you are not able to perceive the various sensations, you are having problem in emotions, feeling, behavior.

So, these are all cognitive functions, if they also get destroyed with your memory then that could results in dementia. So, the next is the social cognition. The social cognitions means how we behave with our surroundings, how we behave, how our behavior is attributed or how our behavior is affected with the people, how we mix socially with the people. So, that is mainly done by the cingulate gyrus and amygdala, these are the two structures which are mainly important for social cognitions and this social cognition is mainly affected in case of autistic disorder.

Whenever there is autism, a person suffering from autism they do not know how to behave socially. If you ask them to smile, then their cognitive or affective behavior gets destroyed. So, social cognition is very much affected in case of destruction of cingulate gyrus and amygdala.

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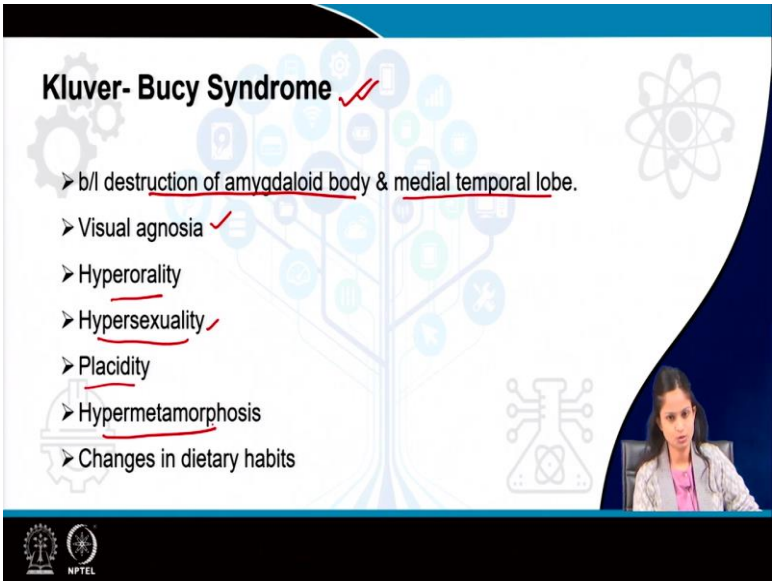

So, these are the structures or these are the components of limbic system a very important disorder we should come across in case of Kluver-Bucy syndrome. Now, Kluver-Bucy syndrome occurs whenever there is a bilateral destruction of amygdaloid body and medial temporal lobe. Now, amygdala as already been told you, it plays a very important role in memory functions and emotional behavior and social cognitions; besides that, temporal lobe also plays an important role because all the cortical information's are taken up by the entorhinal cortex for further processing.

So, hence whenever there is a destruction of the inferior or the medial temporal lobe along with the bilateral destructions of amygdaloid body that results in Kluver-Bucy syndrome. Now, we will see what are the symptoms - the first symptom is visual agnosia. Visual agnosia means I will show something to the patient who is suffering from Kluver-Bucy syndrome, but even after seeing, the person will not be able to recognize or interpret what he or she is seeing. So, that is known as visual agnosia.

Then hyperorality. As the name suggests, anything the person whatever he sees, he will try to take into his mouth. So, the urge of feeding behavior is affected or the feeding behavior is affected over here. So, that is hyperorality. Again hypersexuality, the sexual behavior is affected over here. Placidity, that means there is no emotions, there is no feelings present in that person, there is no emotions or behavior changes you can see in that persons; whether you are poking the person, there is no anger, there is no happiness seen on the face of the person.

Hypermetamorphosis means whenever the person sees anything there is a tendency to touch those whatever the person is seeing. So, that is hypermetamorphosis. There is also changes in the dietary habits. These are the main symptoms of Kluver-Bucy syndrome when there is bilateral destruction of amygdala body and medial temporal lobe. So, this much you have to remember in Kluver-Bucy syndrome and the limbic system.

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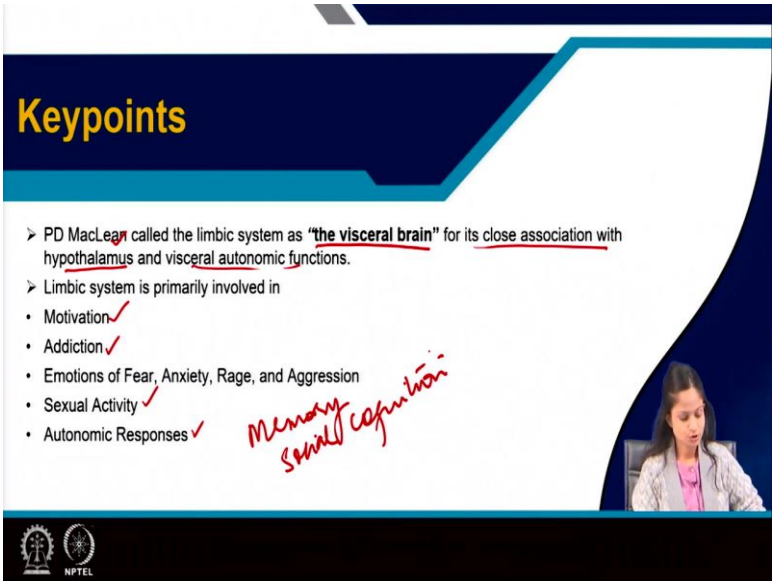

So, the key points what you have to remember is Maclean called the limbic system as the visceral brain. As the name suggests, visceral brain, why? Because whatever the visceral functions, that means H is mainly for the homeostatic functions. These are mainly done with the help of hypothalamus. So, it has got its close association with hypothalamus and various

autonomic functions. That is why the scientist has given the name as visceral brain to the limbic system.

And the main important functions where limbic system is primarily involved, that is motivation, addictions, emotions of fear, anxiety, rage, aggression, sexual activity, autonomic responses. Besides that, there is memory formations and social cognitions or affective behavior. So, this much you have to remember in limbic system. Thank you.