Cognition and its Computation
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Lecture - 52
Neurophysiology of Emotions - Limbic System

Hello and welcome back to this class on Emotions. In today's class we are going to talk about the Neurophysiology of Emotions and discuss the Limbic System in brief. So, we had seen in our last class the theories of emotions way back from Darwin who tried to explain emotions as a cultural through evolutionary and cultural context and he said that expressions emotional expressions are irrespective of culture.

And then again we saw James Lange theory which was opposed to the common sense view saying that the physiological responses had to happen first to feel an emotion.

So, gradually the theories they took different approaches we saw it and either it was a physiological point of view or the peripheral point of view or it was a central or a cognitive point of view.

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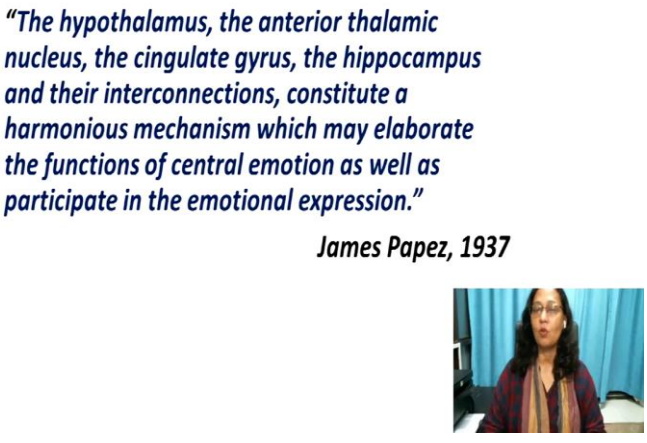

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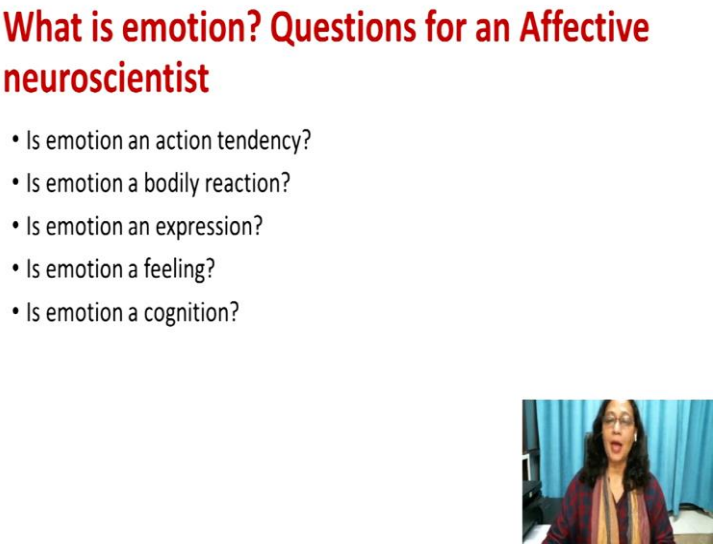

And the neuroscientists over time have tried to explain the neuro anatomics, the physiologist and now the neuroscientists have tried to explain emotions from a physiological standpoint. And this leads back to way early to Broca and then Papez. So, they have tried to the neuroscientists. So, the effective science neuroscientists today tries to question whether the emotion is an action tendency, is it a bodily reaction, is it an expression, is it a feeling or a cognition.

And they have seen that the emotion that is felt is and involves or engages multiple areas of the brain. Initially these were thought of as you know unitary areas that were responsible for emotion the feeling of emotion. And unitary areas isolated areas that were supposedly responsible for the elicitation of the expression and the arousal. But this gave rise to gradually gave rise to circuitry and now we know that there are multiple areas of the brain, multiple circuits that are in action to feel an emotion.

And it as with all other aspects all other cognitive functions all other effective functions and all other functions of the brain the it is an integration of the functionality of multiple areas.

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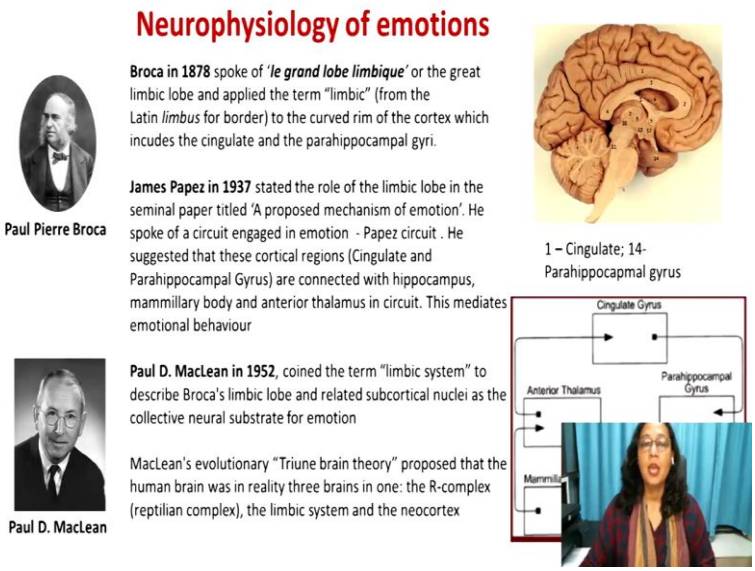

But to look at the history of these studies, neurophysiological studies of emotion it started way back by Broca in 1878 and he is the first one who spoke about the limbic or he said the le grand lobe limbique the grate limbique lobe. And he was the first one to apply the term limbic in Latin which means limbus or border. And why did he say that? Because he says that a certain area of the brain that is the curved rim of the cortex which includes the this is the area of the brain.

The one you will see on the anatomical image that is given and that is the cingulate and the 14 that is the parahippocampal gyrus he thought that these two areas were the seat of emotion. Today we know that there are multiple more structures that are engaged and may multiple more circuits, but this is way back in 1878. We are familiar with Broca because of his work on memory and language.

So, we know of Broca's area for the production of speech, but he has also been engaged in the study of emotions from the you know and coining the term limbic. After him Papez took up the study and Papez stated the role of the limbic lobe in his seminal paper which was titled a proposed mechanism of emotion and he spoke of a circuit engaged in emotion which was finally, named as the Papez circuit.

So, the Papez circuit which is actually an explanation of the limbic system as it goes engages multiple structures. So, it has from Broca we have moved to more structures and these include the cortical regions that would be the cingulate and the parahippocampal

gyrus as Broca suggested, but also was connected to the hippocampus the mammilary body and anterior thalamus that were a part of the Papez circuit.

And he said Papez said that these actually these this circuitry or these interconnections between these anatomical areas anatomical structures is what mediate emotional behavior. There are still there have been several other researchers who worked on emotion, but we move on to Paul MacLean in 1952 and his theory is of importance because he coined the term limbic system and a limbic system. So, now Broca's limbic role lobe he related it to other subcortical nuclei and he said that this collective was the neural substrate for emotion.

So, we are familiar with MacLean for another reason MacLean gave a brain theory or evolutionary brain theory known as triune brain theory and you may be familiar with this.

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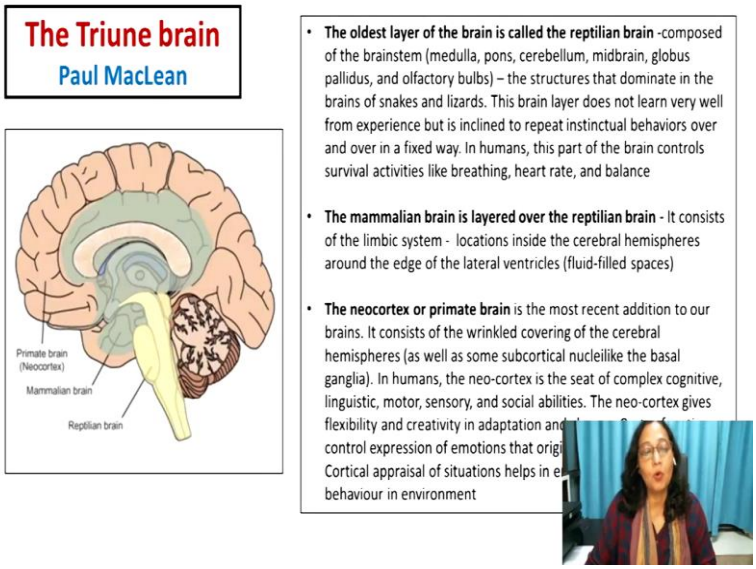

So, he said if you look at this anatomical image of the triune brain that MacLean spoke up he said that the oldest layer of the brain is a reptilian brain. And this is composed of the brain stem that is the medulla pons cerebellum globus pallidus and olfactory bulbs and these are the basic structures that are engaged for you know survival.

So, these are the areas that these areas of the reptilian brain are responsible for involuntary action or involuntary functions like breathing, heart rate, balance, body

balance, you know respiratory the reticular activating system in this area is responsible for regulation of sleep and so on. And he said that after this reptilian area over evolution they developed the mammalian brain and this is a layer over the reptilian brain and it consists of the subcortical structures that engage in emotion.

And this is where the limbic system lies and the location is inside the cerebral hemisphere. As I said it is the sub cortical areas and around the edge of the lateral ventricles. And finally, the most recent development in evolution is the neocortex of the primate brain. So, this is where our evolution the human evolution has improved and we have a larger sample lobe and this area of the brain.

So, this whole neo cortex area is a recent addition to the brain and this is this has a wrinkled covering of cerebral hemispheres and as well as some subcortical nuclei the basal ganglia. So, the neocortex is not only the neocortex, but the basal ganglia along with this which forms the primate brain. And the basal ganglia as you know is a responsible for directed motor movement. So, in humans the neocortex is the seat for complex linguistic cognitive motor sensory and social abilities.

And it gives us what we know as cognitive flexibility what we know as imagination creativity and it also provides us with the ability to adapt to new changing environment. The cortical functions control and express the expression of emotion. Mind you the emotion areas that the areas that where the emotions are created or you know the arousal and the feeling of emotion is created is in the subcortical areas.

But the cortical areas give is the expression and also this at expression as per MacLean is because of how one is in relationship with the environment. So, how one appreciates the environment or rather how one evaluates the environment based on that the response the emotional response is given. So, this also implies a sense of emotional regulation and this is a controlled by the cortical regions of the brain. So, from the MacLean we move on to the limbic system.

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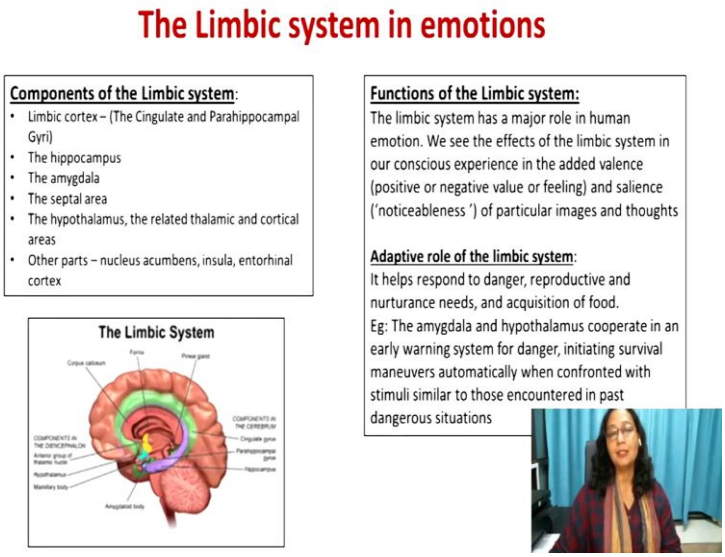

And as I told you earlier that several people had been thinking of multiple structures that are responsible for emotion, but there is a controversy as to which are the specific structures that are engaged in emotion and there are you know many theories as to what we should consider as emotion and what should as a limbic system and what can structure should not be.

But through the Papez circuit we know that there are certain specific structures that are absolutely engaged in emotions and was a part of the limbic system. So, we are going to discuss just the basic structures in the limbic system. So, the components of the limbic system primarily have these structures. So, that is the limbic cortex as suggested way back in the 1800s by Broca that includes the cingulate and the para hippocampal gyri.

So, and the hippocampus the amygdala the septal area the hypothalamus this is a the hypothalamus is a coordinating area we will talk a little more in details about the role they play and the hypothalamus related thalamic and cortical areas and other parts of the brain like the nucleus accumbens insula and the entorhinal cortex. The roles of the nucleus acumbens has been has been depicted very well in the reward circuit of the brain.

And the reward circuit is also a part of you know researchers saw that the reward circuit could also explain the response the emotional response towards pleasure seeking behaviors or reward seeking behaviors and how that circuitry is formed in addiction we

will see that a little later. So, you know coming back to the limbic system, the functions of the limbic system mind you are not only emotional arousal and emotional expression.

The limbic system is engaged in multiple other functions and one of them is sleep one of them the other is social cognition, the other is sexual behavior, emotion limbic system is also related to memory. But we will look here look at the also involved in motivation, but we will look at the specific emotion related functions of the limbic system. So, coming back to this again.

So, the limbic system has a major role in human emotion and we see the effects of the limbic system in our conscious experience in the added balance. So, how whether we appreciate a stimulus in the environment or we have aversion to it. So, whether we give a positive or a negative value or feeling and whether it is noticed by us whether we approach it whether we avoid it in the case of particular images or thoughts it is you know in all these environmental interactions we find the role of the limbic system.

The limbic system also has an adaptive role it helps us to respond to danger as I said it is responsible for sexual activity reproduction and nurturance needs in the acquisition of food. So, also in search behavior and we just to give you an example the amygdala and the hippocampus coordinate to form an early warning signal for danger. How does it do it? The sorry amygdala and the hypo thalamus, so how does it do? It the it initiates the survival maneuvers automatically when confronted with stimulus that the individual has face faced in the past.

So, dangerous stimuli that the individual has faced in the past has triggered some kind of a memory and that memory is brought back or elicited when facing a novel stimuli that is similar to that dangerous stimuli and this creates a warning signal that is taken up by the amygdala. And when it is the fear response is created the hypothalamus brings about the associated endophrenal changes that require for the individual to fight or flight.

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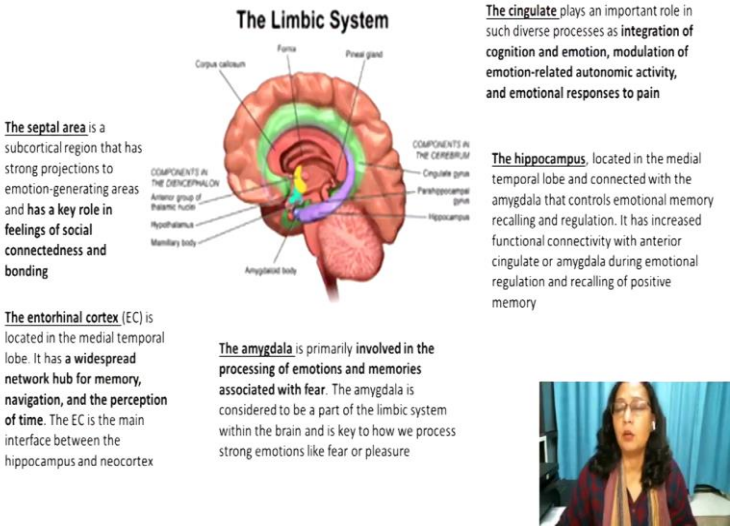

So, we will look into the multiple anatomical areas in the limbic system. As I said the cingulate is a very important area in the limbic system and if you look at this green area this is the cingulate gyrus. And the cingulate plays an important role in the integration and cognition of cognition and emotion, why? Because it is the central it is a communicative area between the subcortical areas and the new cortex to the cortical areas. And so, it modulates emotion related autonomic activity and emotional responses to pain.

The next important area is the hippocampus and we spoke about the para hippocampus gyri earlier the hippocampus is located in the medial temporal lobe. So, if you if you see over here the hippocampus actually gets its name from the sea horse. So, it is a Latin name for the seahorse and somehow anatomys early anatomys thought that it look like a seahorse. So, the hippocampus is in the medial temporal lobe and it is connected with the amygdala. So, just below this you can see the amygdaloic body or the amygdala.

The amygdala is like an has gets its name from its shape. So, it looks it is like an almond shaped small body and this is closely related to the hippo campus now the hippo campus is the seat for declarative memory, so and especially the long term declarative memory. So, the it has increased functional connectivity with the anterior cingulate or amygdala during emotion regulation and recalling of falsed memory it can it also you know. So, it

is it pairs with the amygdala when the imagery of yesterday I in the last day I was talking about a sad day or a happy day.

So, how does it relate? The image or the reconstruction of a day is done by the hippocampus. But the expression the matched paring of emotion is done by the amygdala and all this is coordinated by the medial temporal lobe. We have already seen that earlier the amygdala is involved in the processing of emotions and memories primarily associated with fear it is also responsible for other emotions, but primarily with fear. And it is; so, the it is the main major part of the limbic system and it is a key to how we process strong emotions like fear or pleasure.

So, in general the amygdala assigns emotional significance to sensory experiences. So, if there if there is a visual sensation along with that the it is a pairing as I said of a of an with an emotional weightage and the limbic system directs the hypothalamus to express the motor and endocrine components of emotional state. So, the role of the hypothalamus is to we will just look at the role of the hypothalamus.

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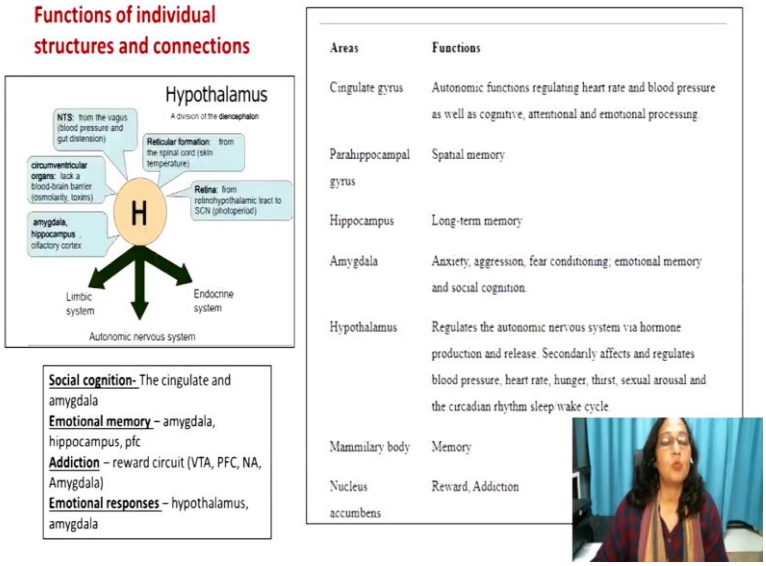

So, the role of the hypothalamus is to coordinate the endocrinal endocrine system and also the autonomic system. So, from the endocrine system it helps with the secretion of hormones and neurotransmitters and you know this is activated this is activated by the sympathic activation. So, now, this the hypothalamus especially like in stress the hypothalamus it directs the pituitary gland to a secrete certain hormones.

So, for response to which is sent to the adrenal gland for the secretion of cortisol to you know for the fight or flight response in stress. So, that actually involves the hypothalamic pituitary and adrenal access HPA access is known as I am not going to get into the details of HPA access, but coming back to this again. So, the hypothalamus has multiple functions I will come back to it, but before that.

So, the amygdala coordinates with the hypothalamus which again direct endophrenal component for the emotional state and emotion emotional experiences and expressions are accompanied and even initiated by body responses. So, many times an increase in heart rate or the increase in respiratory rate can initiate you know are initiated by the experience and these responses gradually wane with habituation

So, as we get used to say the classical example is a loud sound being perceived as a threat. So, you know there is an increase in the. So, the fear system is activated and increase in the stress response or the heart and the respiratory rate and the blood pressure they get increased, but if the loud sound continues there is an adaptation to that sensory stimulation and we become familiar and there is a habituation.

So, the amygdala is seen to be important in processing these experiences. So, first the initiation of response and also the adaptation. So, now the another area which is important in the limbic system is the septal area the septal area is a sub cortical region and it has strong projections. So, it is like a it is a bundle of fibers that have a projections to emotion generating areas and this is it has a key role in social cognition and especially for connectedness interpersonal connectedness and bonding.

The final one that we are going to talk of area that we are going to talk of is the entorhinal cortex and it is located again in the medial central lobe. And it has as you already know that the medial temporal lobe is very closely related to memory. So, it has a widespread network hub for memory navigation and perception of time. So, the e c or the entorhinal cortex is the main interface between the hippocampus and the neocortex.

So, again so, in the neo cortex this is the prefrontal cortex that is very important also for the perception of emotion, but though it is not considered as a part of the limbic system. I forgot to mention that you know if there is a earlier studies which show that emotion sorry amygdala was responsible for emotion was done by Kluver Bucy. And Kluver

Bucy they saw some patients in whom the amygdala and the amygdala had the amygdalaic lesions.

And they saw that there was a stark change in the behavior patterns of animals with amygdalaic lesion. So, the animals showed no fear no anger and hyper sexuality and they would engage in sex with almost any member of the species or with even objects. So, this was named as the Kluver Bucy syndrome and we still know it by the name of the Kluver Bucy syndrome and it has this gave us an extra input about the role of amygdala in the limbic system or in emotion per say.

So, now coming back to the hypothalamus I spoke of multiple structures and with their functions I have in the limbic system I have provided a chart over here a table over here that I have taken from the Rajmohan Mohan das in their from their paper in journal of Indian psychiatry Indian Journal of Psychiatry in 2007. And here along with this coming to hypothalamus we already know that it regulates the autonomic nervous system via hormone production and release. Actually it simulates the pituitary gland for the and we all know that pituitary is the master gland for secretion of multiple hormone.

Along with it has secondary effects for blood pressure heart rate hunger or sexual arrivals circadian rhythm etcetera we already know that now what else does it do? One very important thing is that it gets input from the retino hypothalamic track or the SCM and this is also important for how we where we look what we do during a threat perception.

So, we already spoke about the reticular formation and the reticular formation is important for skin temperature along with seat wake cycles and from the hypothalamus coordinates with the vegus for blood pressure and gut distension. So, in an emotional state one may have you know gut issues. So, circumventricular organ and that osmolarity and increase of secretion of toxins and of course, we know that it coordinates the hypothalamus coordinates with the amygdala and hippocampus and the olfactory cortex.

So, now looking at the limbic structures and the functions now if you look at. So, the limbic structures have multiple functions and many functions are integrated by the coordination of or many functions are happen because of the integration and coordination of multiple structures. So, we know that social cognition again is regulated by the cingulate and the amygdala.

Emotional memory we have already spoken about the amygdala and the hippocampus it is also the role of the pre frontal cortex here as to the for the working memory as well as decision making. And so, how much value do you put to this situation today, how much of an emotional expression will happen?

It is not only the elicitation of emotion, but emotion as a cognition that takes into that takes into consideration the role of pre frontal cortex, but mind you prefrontal cortex or the frontal lobe per say is not considered as a part of the limbic system. In addiction I already spoke of the reward circuit the structures of the limbic system are engaged and one of them being the amygdala and the ventral segmental area.

Actually, in the reward circuit what happens is the ventral tegmental area is secretes there are dopamine secretions during a pleasure elicitation and the dopamine secretions are tend to multiple areas. So, there is a circuit that the pathway is from the VTA to the nucleus abundance for the action the for the search behavior to the prefrontal cortex for the pleasure sense pleasure feeling to the amygdala or the emotional emotion of pleasure emotion of joy happiness to the amygdala. And the memory of this event that has caused pleasure to the hippocampus.

So, these pathways get activated together very easily in addiction. So, this is known as the reward circuit I will not get into the details of the reward circuit right now. So, now, we have spoken about the limbic system and we seen that. Now this is an old hm you know what should I say a presentation of emotion and emotion circuitry, but the very notion of the limbic system as being a unitary basis of the emotional brain has been strongly questioned in recent years.

And the, so you know there are more brain based models of emotion that have come into being and these have a critical influence on effective neuroscience in the regions here.

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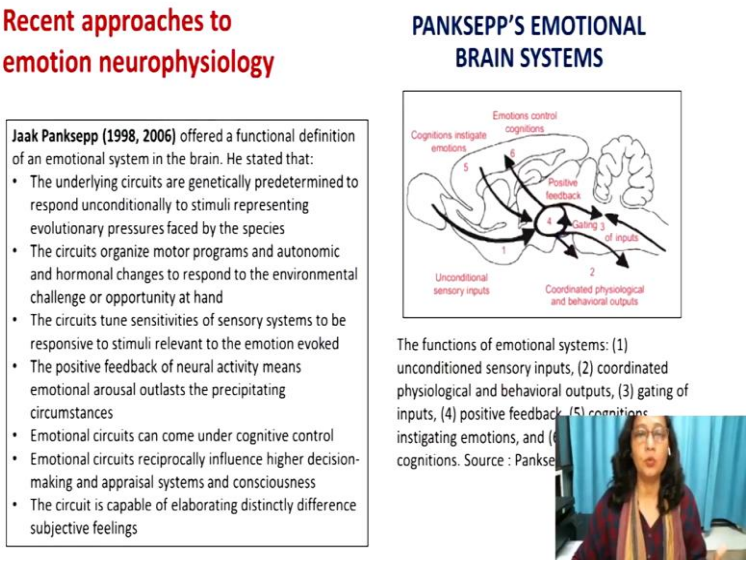

So, in today's section we are going to talk about a little about the recent approaches to emotional physiology and that brings out brings us to Panksepp emotional brain systems where Panksepp offers definition of the emotional systems in the brain. And his basic tenets are that there are underlying circuits that are genetically predetermined to respond unconditionally to stimuli representing evolutionary pressures.

So, now this so, what it what it is trying to say is that you know there these over evolution there are some genetically invites circuitry that we have created. And these circuits organized motor programs and autonomic and hormonal changes to respond to environmental challenges or opportunities. And the circuits tune the sensory systems to be responsive to stimuli relevant to the emotional arousal.

So, there is a; there is a memory of the novel event that gets added to the circuitry and to the past circuitry and it the this stimuli is you know tuned to create a an emotion a specific emotion. And this positive feedback of neural activity actually leads to emotional arousal that may outlast the precipitating circumstance. So, it may go beyond the event and may continue the emotional arousal and these emotional circuits come under cognitive control and are reciprocally they influence the higher order thinking or our appraisal systems and consciousness.

And these circuits are capable of elaborating distinctly different subjective feelings. Now, if you just look back or think back about the theory of the emotional theory classes that we did. You will see that this is very very similar to Lazarus appraisal theory.

So, that was one of the large appraisal theories you know cognitive theories that were developed and Lazarus's theory has speaks about an appraisal before the you know physiological change comes through. So, this appraisal system is what a Panksepp have Panksepp will other researchers have tried to explain through neural circuitry.

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PANKSEPP'S EMOTIONAL BRAIN SYSTEMS

Basic Emotional Systems	Key Brain Areas	Key Neuromodulators
General + Motivation SEEKING/Expectancy	Nucleus Accumbens—VTA Mesolimbic and mesocortical outputs Lateral hypothalamus—PAG	DA (+), glutamate (+), many neuropeptides, opioids (+) neurotensin (+)
RAGE/Anger	Medial amygdala to Bed Nucleus of Stria Terminalis (BNST), medial and perifornical hypothalamic to dorsal PAG	Substance P (+), ACh (+), glutamate (+)
FEAR/Anxiety	Central & lateral amygdala to medial hypothalamus and dorsal PAG	Glutamate (+), many, neuropeptides, DBI, CRF, CCK, alpha-MSH, NPY
LUST/Sexuality	Cortico-medial amygdala, Bed nucleus of stria terminalis (BNST) Preoptic and ventromedial hypothalamus Lateral and ventral PAG	Steroids (+), vasopressin, & oxytocin, LH-RH., CCK.
CARE/Nurturance	Anterior cingulate, BNST Preoptic Area, VTA, PAG	oxytocin (+), prolactin (+) dopamine (+), opioids (+/–)
PANIC/Separation	Anterior Cingulate, BNST & Preoptic Area Dorsomedial Thalamus Dorsal PAG	opiods(–), oxytocin (–) prolactin (–) CRF (+) glutamate (+)
PLAY/Joy	Dorso-medial diencephalon Parafascicular Area Dorsal PAG, Tectum	opioids (+/–), glutamate (+) ACh (+), Any agent that promotes emotions reduces play

Now, Panksepp's emotional brain system talks about the four negative emotions or four primary emotions rather and three additional emotions. So, the four primary emotions being motivation or search and along with expectancy, then rage, anger, fear, anxiety and last sexuality. And the positive emotions additional positive emotions that he talks of are care nurturance panic or separation and play and joy and he speaks about key brain areas.

So, thanks to the development of the electro physiological tools as well as you know other functional parameters measurement. We have a better idea also for the blood parameters we have better idea today about the key brain areas that are engaged in these basic emotional systems.

And we also know the key neuromodulators the excitators or the you know inhibitors that are responsible for the creation of a you know for the elicitation of an emotional

response and this response may be an expression or the feeling of or balance of emotion ok.

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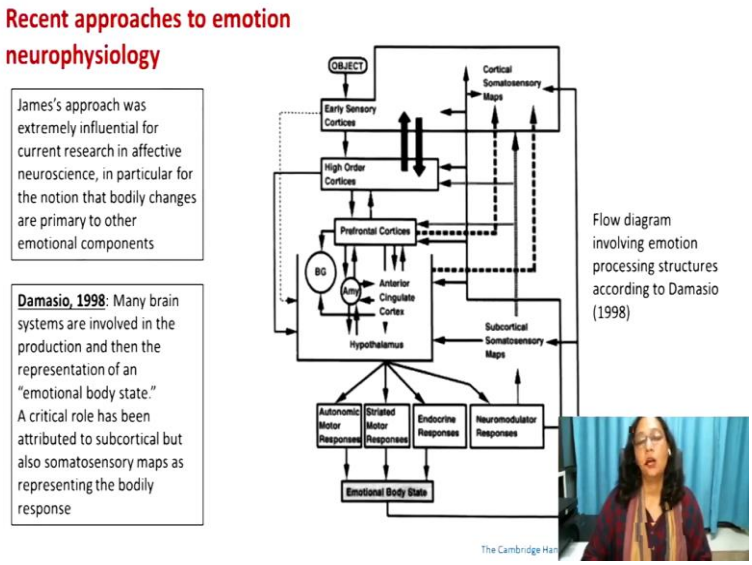

So, another recent approach to emotion neurophysiology has been explained has been given by the Damasio. And we know of Damasio because of his study on emotional decision making, where you know he spoke about one of his patients who could not decide due to a lesion. Now he speaks about the emotion being a very very important factor in decision making and he says that actually emotion gives weightage to a decision.

So, Damasio when he speaks about emotion he talks about multiple areas that are engaged in emotions. So, he talks about the early sensory cortices sending information to the higher order cortices to the prefrontal cortice where the evaluation is done and this information is sent back to the basal ganglia to the amygdala and to the hypothalamus from where again you know there is the autonomic motor response is generated the striated motor response is generated.

So, the tightening of muscles, the blood flow, the vascular, neuro modulator responses, the endocrine responses, so that you know release of hormones are all these are again regulated by the hypothalamus. And this feedback goes back to the cortical somatosensory map and it is again sent back to the sensory cortices. So, as you see in the previous theory also you see the role of learning and memory even in emotional response

and you know classical conditioning has been a very very important part of the emotional theories.

So, you know you get to understand that even emotional responses are learned and we categorize novel situations. So, the amygdala looks into a novel situation trying to match it with inputs from the hippocampus that you know if there is a if there is a declarative memory for a similar incident. And you know then send the information to the hypothalamus for the other responses elicitation of responses.

So, Damasio states that many brain systems are involved in the production and the representation of an emotional body state as you can see the cortical areas both the sensory cortex as well as the higher order cortexes that is the cognitive areas are engaged the amygdala the hypocampus the basal ganglia the hypothalamus the striated muscles the endocrine areas and. So, all these are responsible for the creation of an emotion.

So, Damasio talks of an emotional body state and he says that a critical role is attributed should be attributed to the subcortical areas, but also the somatosensory map as representing the bodily response. So, we may have a tingling sensation in our palms that may be interpreted as here. So, there is a map of you know this tingling sensation here it may mean something another tingling sensation somewhere else you know maybe mapped to some other emotional elicitation.

So, again this is very very idiosyncratic that is very specific to the individual though it may also have you know some evolutionary conduits to it. So, in a nutshell this is what I thought we should be discussing in the neurophysiology of emotions again. There is too much to discuss and probably this is too less a time to talk about the neurophysiology of emotions. Anyway catch you soon in the next talk.

Thank you.