Introduction to Brain and Behavior
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Lecture - 21
Memory

Hello and welcome to the course, Introduction to Brain and Behavior. I am Doctor Ark Verma from IIT Kanpur. As you know I work at the department of Humanities and Social Sciences and also the interdisciplinary program in cognitive sciences at the institute. This is week 5 of the course and in this week we will talk about the neural basis and neural mechanisms behind memory. The one of the most fascinating aspects of being alive is the change one goes through almost every passing moment or at any span of time.

What causes these changes in our experience and what causes these changes in our sense of knowledge, in our view of the world or even our view of ourselves. While a part of this changes definitely comes from our genetic makeup and the processes of growth and maturation of the brain and the body, a lot of these changes are rooted in our experiences that we have since we are born. Everyday we come across something new, something unique.

Every day we come across maybe say for example even a repeated experience of the same thing and new insights are gained from that new realities. New truth kind of dawn upon us and we pick up something from each of these things. That is basically what experiences we are talking about.

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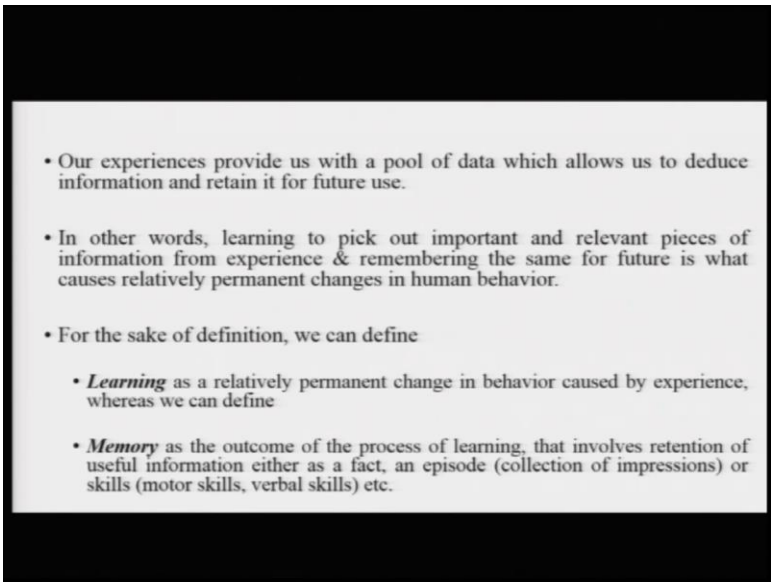

Now, experiences provide us with a pool of data which allow us to deduce information and retain it for future use. Say for example, I have given this example earlier as well. Say for example if there is very young child and the mother brings a cup of milk and the child impatiently just grabs on to the cup of milk but just to realize that it is too hot and it is not supposed to be touched immediately. That experience once it happens at least even once for that matter the child will learn that whenever the mother is going to bring that cup of milk you have to be patient and only touch it when asked to do so.

So, everything say for example if you come to class on a particular day and anything that you kind of learn that is new it gives you some more information and gives you some data using which you can say sort of deduce, this is what happens when I do not sleep well at night. It causes certain degree of fatigue. It causes certain degree of problem with the cognitive processes. So, maybe I should make it a point to you know sleep adequately at night, things like that.

So, every all of these experiences that we go through, all of these experiences actually in some way or the other provide us a pool of data from which we can deduce information and then retain it for our future use. So, in other words learning to pick out important and relevant pieces of information from experience and then remembering the same for the future is what causes the relatively permanent changes in behavior.

Now, this relatively permanent change in behavior is basically something that we are going to be concerned with and in this chapter or in this week let us say we will talk about what are the neural mechanisms that facilitate these relatively permanent changes in behavior and how are these changes let us say manifested in the brain.

Now, for the sake of definition we can define learning as a relatively permanent change in behavior caused by experiences whereas we can define memory as the outcome of the processes of learning, that involves the retention of useful information either as a fact here as I say you know Sun rises in the East, the prime minister of India is Mr. Narendra Modi, things like that or as an episode. This is where I went for my vacations. I stayed at that particular hotel.

We had this for breakfast that for lunch and we went out to see these important memorable places or even say for example skills. Say for example I went to practice or I went to the swimming school to learn swimming. After going there for several days now I can swim and the best stroke that I know let us say the butterfly stroke or something like that.

So, each of these experiences sort of if they are retained, the way they are retained, the manner in which they are organized and retained in our cognitive systems can be referred to as memory and as we said this could be either as a fact as an episode or say for example basically a skill.

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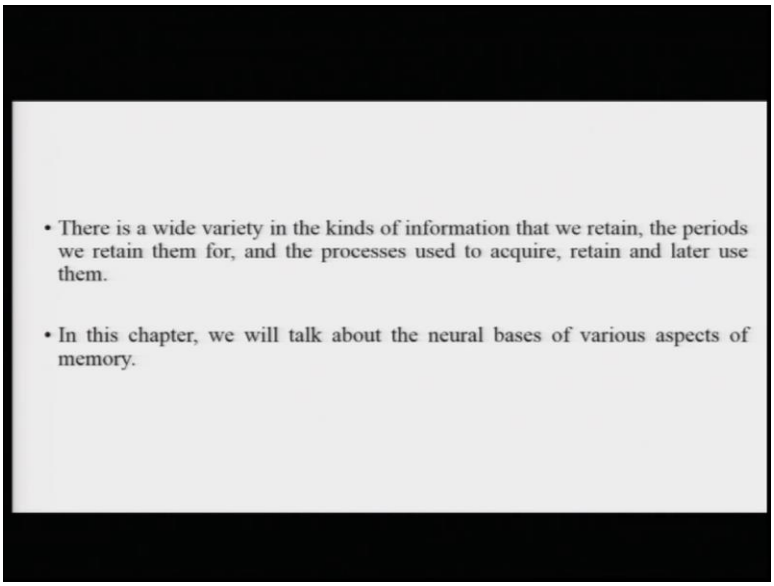

Now, there is a wide variety in the kinds of information that we retain, the period that we retain them for and the processes used to acquire, retain and later use them. In this chapter we will talk about the neural basis of various aspects of memory as I have been saying.

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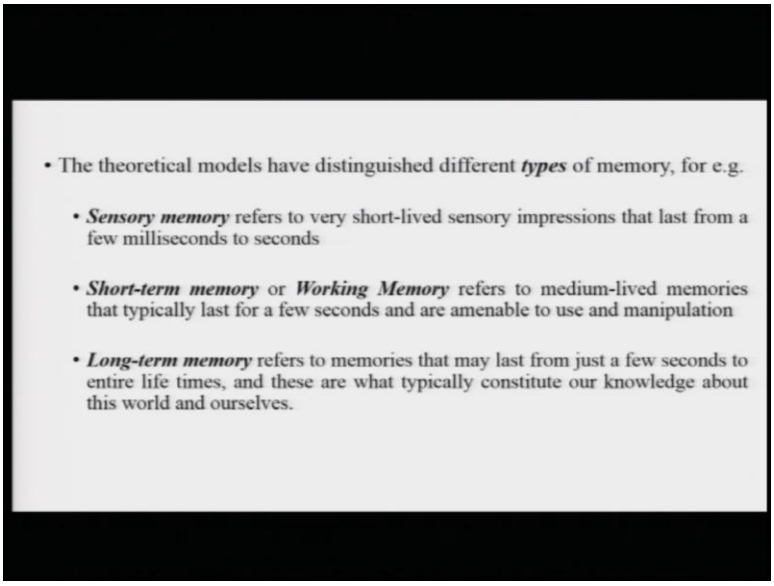

Now, I am sure you would know this from an earlier psychology class or let me just revise this for you. Theoretically models of memory have distinguished basically 3 kinds of memory or 3 stages in memory. First is Sensory memory which basically refers to very very short lived sensory impressions that last from a few milliseconds to maximum a second. This basically refers to all the informations that is impinging upon your senses.

Say for example, you can talk about auditory information, visual information, information about particular kind of odors, tastes, touches etc. All of this information that is impinging on your sensory apparatus, on your sensory modalities can be basically the initial part of the information can be considered as being part of sensory memory.

The other kind of memory is even your can call it Short-term memory. If you would say for example going by the older model of it Atkinson and Shiffrin or you can call it working memory basically going by more recent models given by Alan Baddeley and colleagues. Now, Short-term memory or working memory basically refers to medium lived memories that typically lasts from a few seconds to sometimes minute and are amenable to use and manipulation.

So, you can use this information, you can recall this information, maintain this and be conscious of it or manipulate this information. Say for example 2 plus 2 equals to 4 is basically something that has done in your working memory. You retrieve the concept of the number 2. You retrieve the concept of addition. You add 2 to itself and then you come up with the answer that 2 plus 2 equals to 4.

Finally, Long-term memory basically refers to the memories that may last from just a very few seconds to sometimes entire lifetimes if they are so important and these are typically what constitute our knowledge about this world, our courses of action and even our view of ourselves. So, for all practically purposes when we talking about his memory is too sharp, his memory is bad, his memory is good or say for example I remembered where I went to school in my childhood, I remember the teachers, I remember the friends, I remember the classroom, all of these typically comes under your long-term memory.

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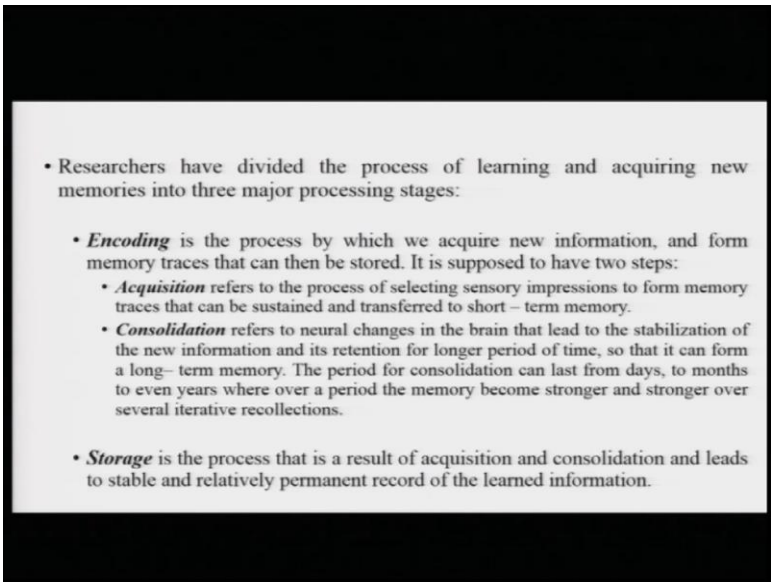

Now, researchers have divided the process of learning and acquiring new memories into three major stages. So, the first stage is called encoding. What is encoding? Encoding is simply the process by which you are acquiring new information and forming new memory traces so that they can be stored.

Every new interaction you have with the world sort of is a way to encode say for example unknown aspects or unknown facts about this world and you sort of can retain them. You form

memory traces and you can retain them. Encoding is basically supposed to have two steps. First is acquisition.

Acquisition basically refers to the process of selecting the sensory impressions to form memory traces that can be sustained and transferred to short-term memory. What is this need of selecting sensory impressions? If you remember from the last chapter when we were talking about attention, we were talking about the fact that at any point in time the amount of stimulation that has received at our sensory modality is huge. We need to select some of that in order to be able to process this. Acquisition is very much like that.

Which sensory experiences you are having at any point of time need to be sustained revised, rehearsed and send to short-term memory is basically one of the aspects that acquisition controls. Once you selected that then comes consolidation. Consolidation basically refers to the changes in the brain that lead to stabilization of this new information and its retention for a longer period of time. Now, how do you store? How do you select?

How do you stabilize any source of information? You basically need the activity in the brain to sort of register this experience and not only just register this to stabilize it by having some changes in the brain corresponding to some changes in the environment. So, that is the idea behind consolidation.

So, basically the period for consolidation can last from days to months to even years where over a period a particular memory could become stronger and stronger due to several iterative recollections or say for example several repetitive experiences. Suppose say for example you are going to learn a particular skill.

I was talking about swimming. The first time you put your feet into water, the first time you sort of lie horizontal and try to flap your arms and legs that is the first experience. There is something corresponding to that experience that will be changing in the brain. If that is just a one of thing, it is one way.

But suppose you go there every day and you try the same kind of skills everyday there are bound to be some changes in the brain that will register that experience, analyze that experience for you

and will basically stabilize and consolidate the experiences from that particular activity. Eventually that will basically form the basis of learning the skill of swimming.

So, encoding basically comes in 2 steps. Acquisition, selecting what you need to pick up from the environment and consolidation basically having corresponding changes in the brain basically which will establish those experiences. Once you have learned something, once you have acquired something, encoded something let us say the other step is storage. Storage basically refers to, it is basically a result of acquisition and consolidation and leads to more stable and relatively permanent record of the learned information.

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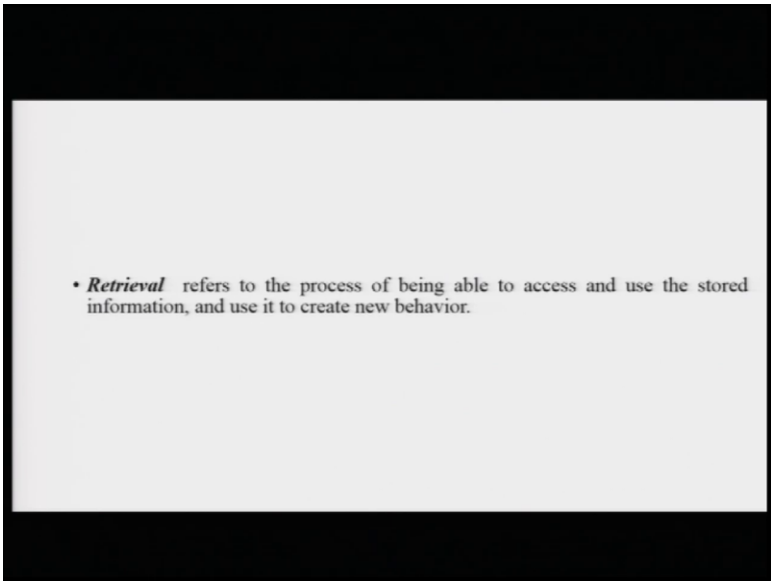

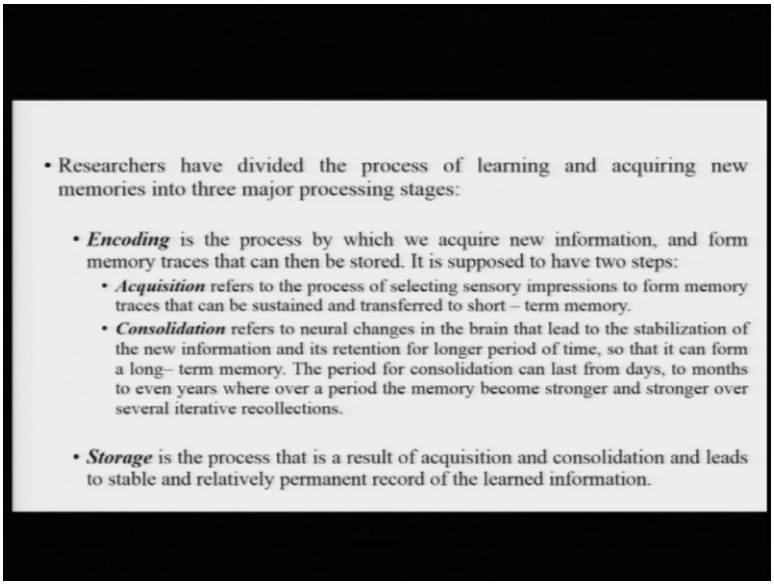

Now, after you have encoded and you stored the other thing is just to use this information which now a very well placed in our indexed in your brain. Now, retrieval basically refers to this process of being able to access and use the stored information to create new behavior. So, that is basically what is retrieval. So, I hope this is clear. We are talking about encoding, storage and retrieval which are the basic processing mechanisms in order to acquire memory.

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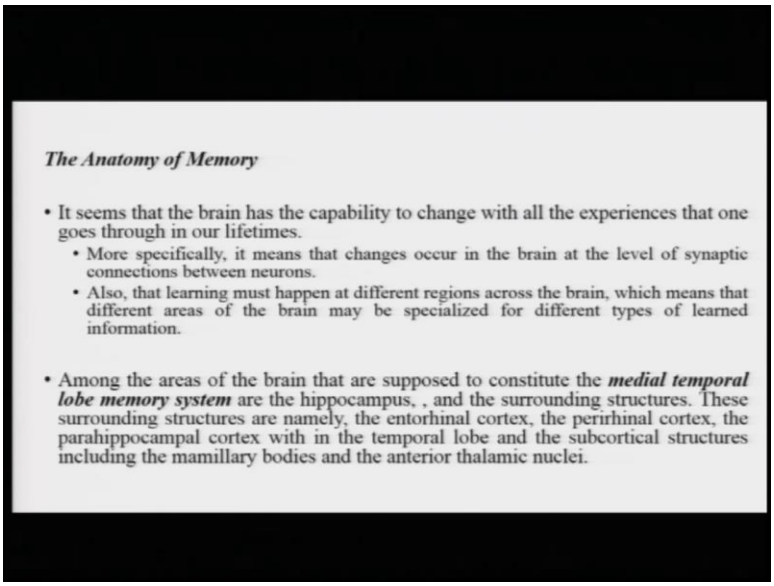

Now, let us look at the anatomy of the memory. Let us look at very grossly the neural structures that support memory. Now, it seems that the brain does have the capability to change with all the experiences and that one goes through in our lifetimes. Everything that you do is in some way or

the other is registered in the brain. So, it basically mean that changes occur in the brain at the level of synaptic connections between neurons.

So, there are assemblies of neurons if you remember we have talked about Donald Hebb and his idea of you know neuron that fire together wire together that kind of concept. So, the idea is that assemblies of neurons, networks of neurons will basically through synaptic connections fire in a manner so as suited.

Just are the changes that are going on in the environment so as to register the new experiences that you are having. So, at is basically what is the physical registry or the physical recording of your experiences in the brain. Now, given that we are talking about not single neurons at isolated regions of the brain. We are talking about networks which sort of means that learning can happen or must be happening at different regions across the brain which basically would also translate into the fact that different areas of the brain would eventually get specialized for different types of learned information.

So, that is something that basically leads to physical registry of information and experiences in the brain. Now, among the areas of the brain that are supposed to constitute the major temporal lobe memory system there are these very very important areas, the hippocampus and the surrounding structures. These surrounding structures are namely, the entorhinal cortex, the perirhinal cortex, the parahippocampal cortex within the temporal lobe and the subcortical structures including the mamillary bodies and the anterior thalamic nuclei.

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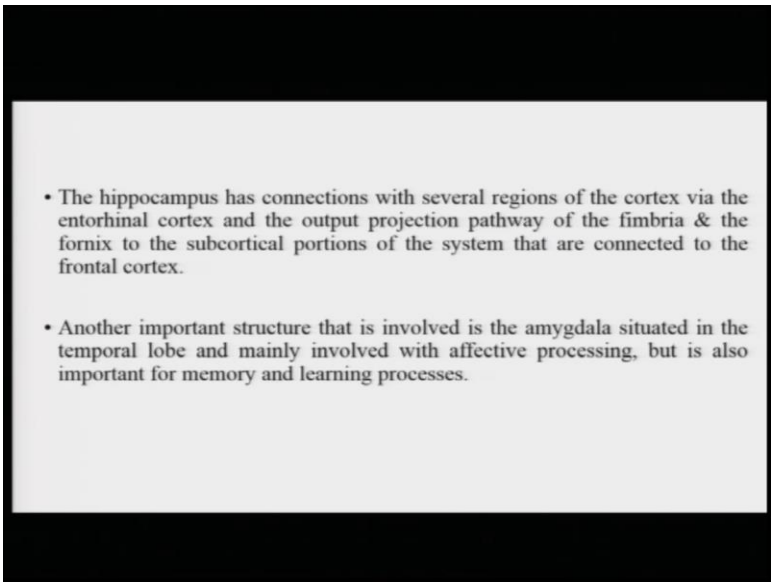

So, the hippocampus basically is a very very important region. We will see and will talk about this in much more detail going further. But the hippocampus has connections with several regions of the cortex via the entorhinal cortex and also the output projection pathway of the fimbria and the fornix to the subcortical portions of the system that are connected to the frontal cortex.

Now, another important structure that involved or is deemed to be involved in memory is the amygdala which is situated in the temporal lobe and is mainly involved with affective processing but amygdala is also been deemed as very important for process of learning and memory and we will see how is this actually implicated in the future lectures.

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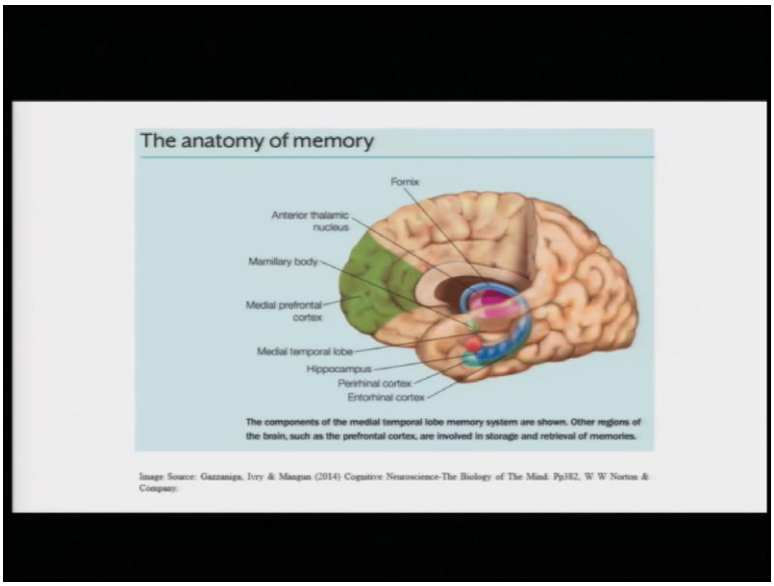

Now, this is basically diagram representation borrowed from Gazzaniga. You can see that these are the areas. So, these are the mamillary bodies, the anterior thalamic nuclei, the fornix. This is the medial prefrontal cortex that we talking about is the medial temporal lobe this area. You can see the hippocampus. You can see the perirhinal cortex, entorhinal cortex.

This is basically the medial temporal lobe memory system which we will be talking about again and again and which is basically the system of neural structures that are deemed to be superiorly important, that are deemed to be very very important in the acquisition of memories.

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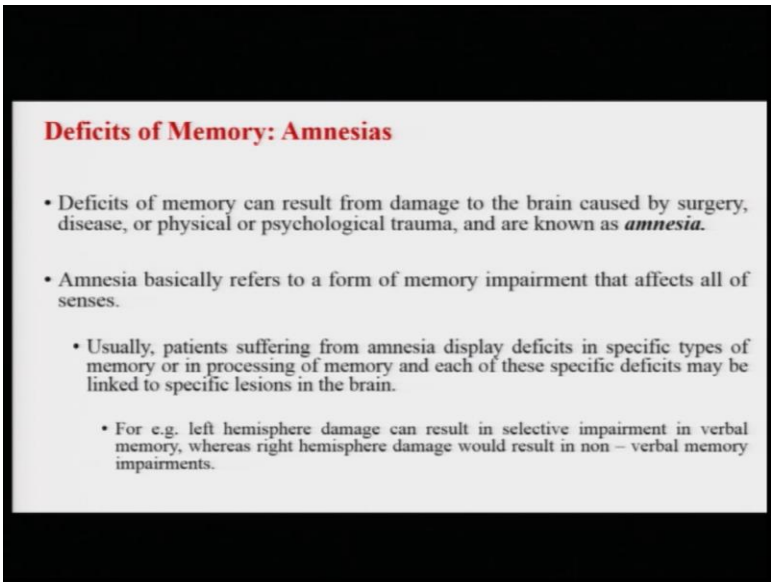

Now, let us move further. Let us talk a little bit about the deficits of memory that are possible. Let us talk about amnesias. Now, deficits of memory can result from various causes. Say for example, they can result from damage to the brain caused by surgery, disease, physical or psychological trauma and these deficits of memory from various causes a lump to be there can called as amnesias.

Now, amnesia is basically refers to a form of a memory impairment that would affect all of your senses. It is not something that will just affect one aspect of memory. Now, usually what happens is that patients who are suffering from amnesia would display deficits in specific types of memory or in specific aspects of processing that lead to memory and then each of these deficits may be linked to the specific lesions that these people have in their brain.

Let us take an example. The left hemisphere damage can selectively impair verbal memory, memory about verbal materials words etc. whereas right hemisphere damage can and would result in say for example deficits in memory for nonverbal items. Say for example images and colours and those kind of things. Now, this is again we have talked at a gross level. We kind of you know zoom in a little bit further when we go ahead.

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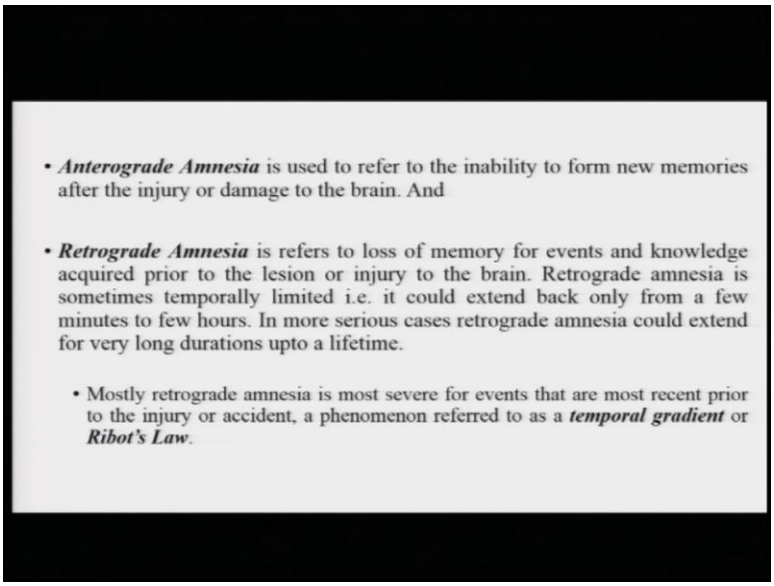

Now, a very important type of amnesia is anterograde amnesia. Now, anterograde amnesia is basically used to refer to the inability to form new memories after injury or damage to the brain. Suppose somebody has suffered a stroke which has damaged a particular area of the brain. We will talk about that specific area more in further but it has damaged a particular area in the brain that is let us say responsible for formation of new memories.

What could happen then is because that area that was responsible for formation of new memories the person will not be able to form any new memories, remember anything post that injury, stroke, accident, surgery whatsoever. The other kind of amnesia that people are sometimes suffer with is called retrograde amnesia and retrograde amnesia is basically what refers to the loss of memory for events and knowledge that is acquired prior to the lesion or injury to the brain. Retrograde amnesia is sometimes temporarily limited.

So, sometimes you can say for example, forget everything behind the point there where the injury was supposed to happen or sometimes it could be temporarily limited. Say for example, you will just forget stuff extending around to only a few minutes or a few hours. Say for example, sometimes people suffered with accidents and sometimes even though the injury is not so much but the shock is such that the person does not remember the entire 48 hour, 24 hour prior to that accident. Sometimes it could extend to months. Sometimes it could extend to even a couple of years or maybe a few more years.

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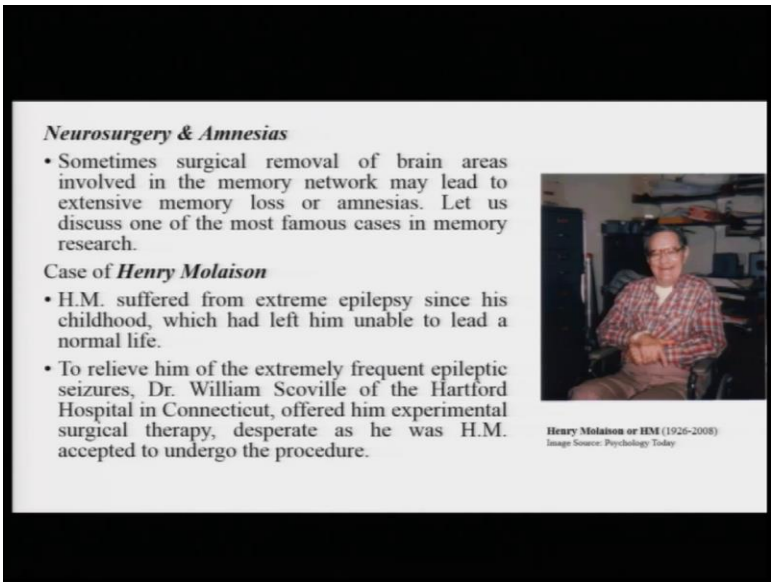

So, mostly one of the things that is important to know for retrograde amnesia is that mostly retrograde amnesia is most severe for events that are most recent prior to the injury or accident and this phenomena is referred to as a temporal gradient or the Ribot's Law. So, that is something you have to sort of remember. Now, sometimes amnesias can be brought upon by surgical removal of the brain areas.

Now, this is something that has happened many a times in the past and basically one of the most important individuals or one of the most important cases that were of the same kind was one of this gentleman called Henry Molaison and what happened was let us talk about little bit about his story.

Now Henry Molaison suffered from extreme epilepsy since his childhood and this epilepsy left him debilitated unable to lead a normal life around 20-25 years of age. Now, to relief him of the extremely frequent epileptic seizures that he was having Doctor Willium Scoville of the Hartford Hospital in Connecticut offered him a treatment which was experimental surgical therapy.

Now, this treatment basically involves surgical removal of the supposed sources of these epileptic seizures. Now, for H.M because he was so desperate that to I need to just get rid of so many of these seizures that are happening to me. He agreed to undergo this particular procedure. So, let us see what happens.

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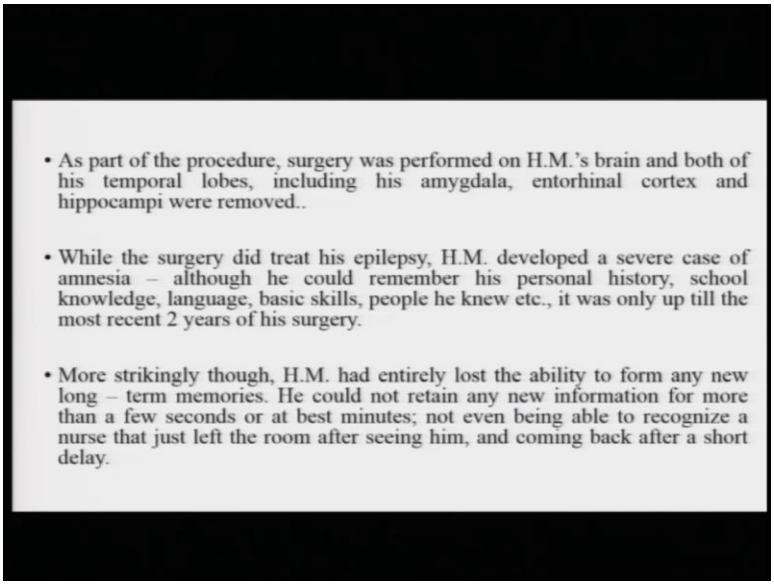

As part of the procedure surgery was performed on H.M's brain and both of his temporal lobes, including his amygdale, entorhinal cortex and the hippocampi on from both the hemispheres were removed. Now, what did surgery does? As it treats his epilepsy. He does not really suffers from any epileptic seizures post the surgery but the side effects of the surgery and removal of those specific organs of the brain was that H.M developed a severe case of amnesia of anterograde amnesia.

So, although he could remember his personal history, he could remember parts of his school knowledge, language, basic skills, people he knew and so on but it was only up till the most recent 2 years of his surgery. Most strikingly though H.M. had entirely lost the ability to form any new long term memories. So, what could happen was once he is been having an experience for a few seconds or few minutes it probably retains something for a few seconds maybe a minute or so but he would not be able retain it beyond few minutes.

So, he could not retain any new information for more than a few seconds or at best minutes. Even say for example, not being able to recognize a nurse that had just left the room after seeing him or a doctor that has been treating him for so long. So, this is basically something that is very very interesting and you know it handed while the surgery relived H.M. of a surgery it

handed him a life that was in a sense never had that sense of continuity after a particular point of time.

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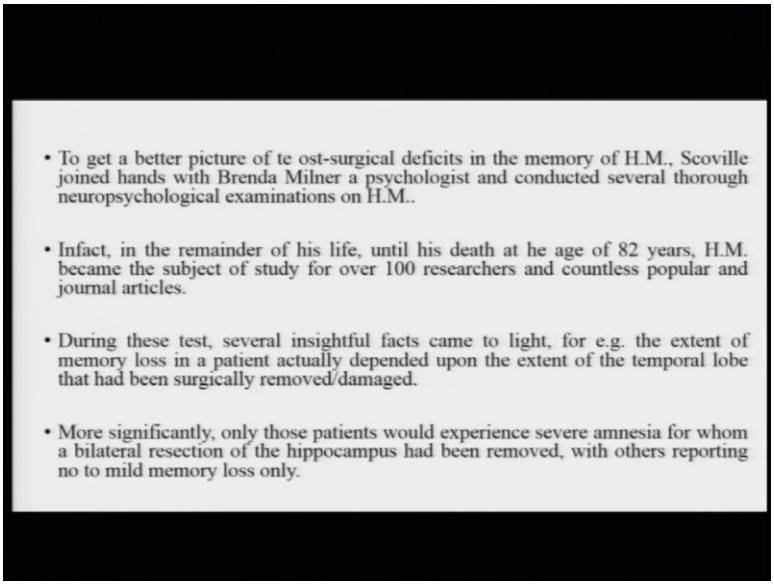

Now, to get a better picture of the post surgical deficits in the memory of H.M. Doctor Scoville joined hands with Brenda Milner who was a psychologist and conducted several thorough neuropsychological examinations on H.M. Now, what are neuropsychological examinations? They are just tests or batteries of tests that basically test you for specific cognitive abilities and specific cognitive deficits for that matter.

Now, in the remainder of his life until his death at the age of 82 years H.M had become the subject of study for over 100 researchers and the subject for countless journal articles and popular stories. During these tests which Scoville and Milner giving him, several insightful facts came to light.

It is about the nature of memory etc. For example the extent of memory loss in a patient actually dependent upon the extent of the temporal lobe that was removed. So, it sort of established that the temporal lobe is the structure that is very very important for acquiring and retention of memories. More significantly only those patients would experience severe amnesia for whom a bilateral resection of the hippocampus was done or bilaterally both the hippocampi were

removed. Other patients for whom only one part of the hippocampus was removed basically suffered only mild memory loss.

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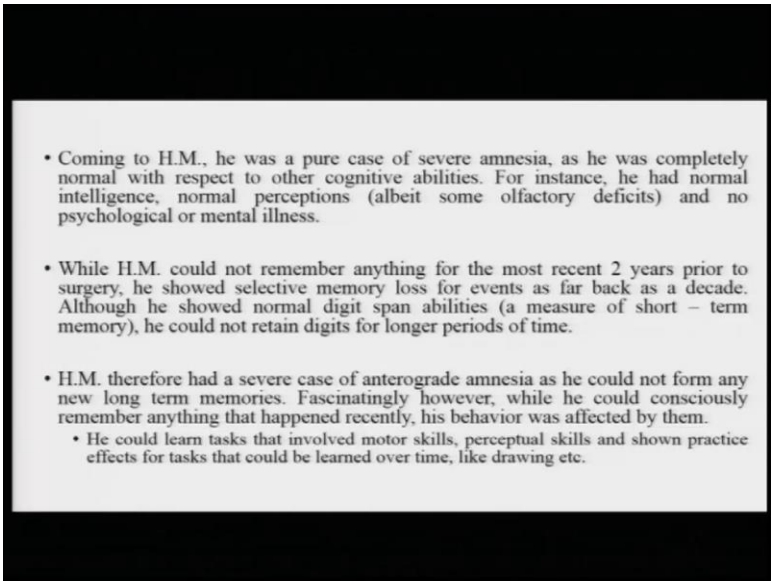

Now, let us come back to H.M. H.M was one of the first pure cases of severe amnesia as he was completely normal with respect to other cognitive abilities. For instance he had normal intelligence, normal perception albeit a little bit of problems with olfactory perceptions which by the way as you would know from the last chapter that is located around middle temporal lobes.

Now, while H.M. could not remember anything for the most recent 2 years prior to his surgery, he showed selective memory loss for even sometimes as far back as decades. Although he showed normal digit span abilities so short-term memory is sort of alright, he could not retain the digits if he was asked to retain it for longer periods of time. Now, H.M. therefore had been a severe case of anterograde amnesia.

He had a severe case of anterograde amnesia as he is not able to form any new long term memories. Fascinatingly however while he could not consciously remember anything that happened recently his behavior was sometimes shown to be affected by that. For example, he could learn task that involved motor skills or procedural skills.

Say for example he could pick up things that he were made to practice every day for a period of time, things like drawing star, by looking at the mirror or something or tasks like that. Now, while H.M's case was fairly insightful about the nature of memory etc and we will come back and we will keep coming back to H.M. as while talking about memories.

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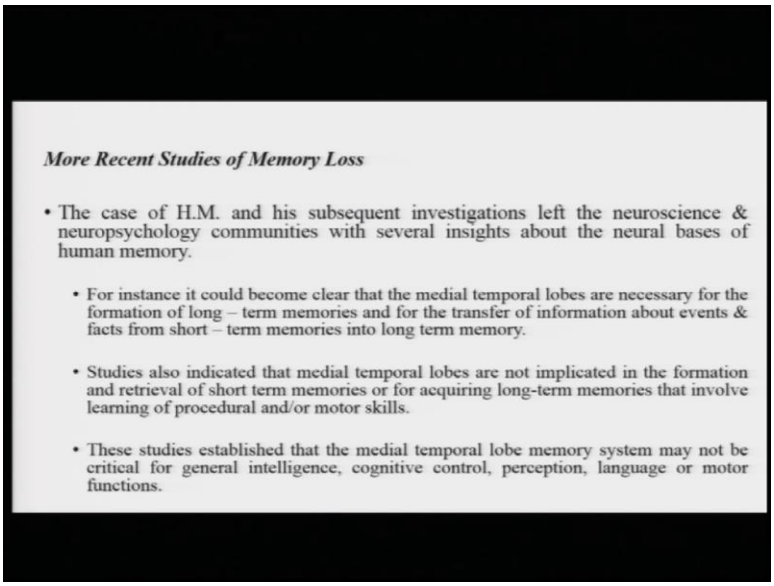

More recent studies of memory loss have also been fairly important. For instance it has become clear that the medial temporal lobes are necessary for the formation of long-term memories and for the transfer of information about events and facts from short-term memory into long term memory.

Secondly studies have also indicated that the medial temporal lobes are not implicated in the formation and retrieval of short term memories, memories that stay for just a few minutes or even for acquiring long term memories that involve learning of procedural or motor skills. Finally a lot of these more recent studies have established that the medial temporal lobe system may not be critical for things like general intelligence as for cognitive control, perception abilities, language or motor functions.

Because all of these functions are retained and are unaffected in individuals like H.M. who had undergone a medial temporal lobe lesions.

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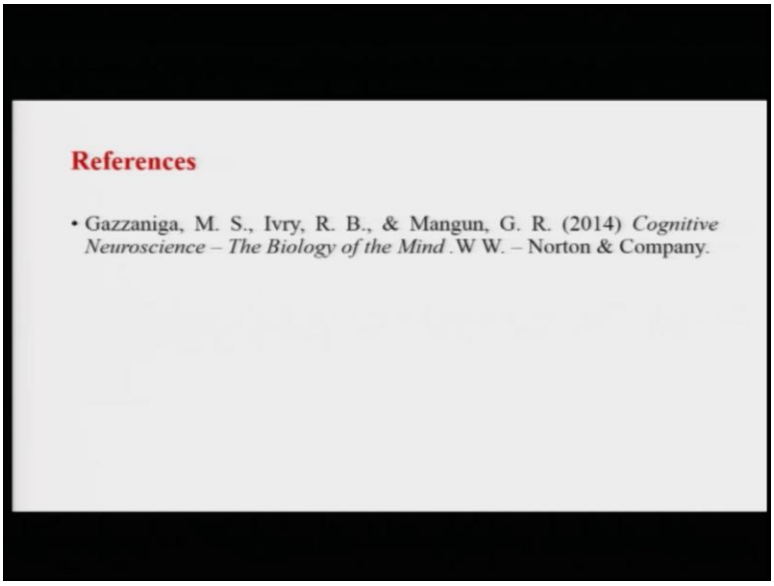

So, I think this is all I wanted to open this chapter with. This is just a bit of an introduction and what we will be talking about in the rest of the week. Thank you.