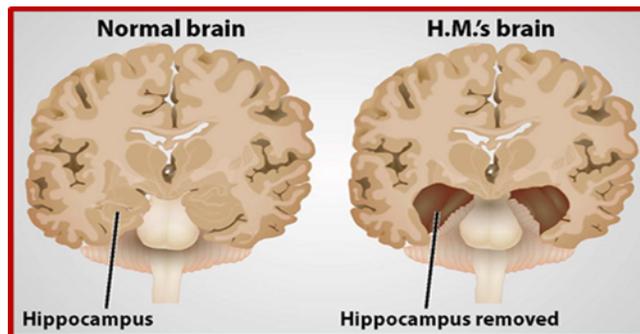


Memory
Prof. Manish Kumar Asthana
Department of Psychology
Indian Institute of Technology Roorkee

Lecture - 6
Neuropsychology of Memory, Research Methods in Memory

Hello, I welcome you all in the lecture series of memory. Today we are going to have a lecture 6 and we are entering with this lecture to week 2. In this lecture, week 2 lectures, we are going to cover the topics neuropsychology of memory, research methods in memory. Let us start with these case studies. There are two case studies what you see on your screen.

First case study is the famous case study of Henry Mollison. And the second case study is the SM woman with the fearless brain. The first case study, the era of 1950, till that period, we were, the researchers were sure enough that the memory is not localized in a specific brain region, but it is scattered and consolidated during the consolidation process in the entire brain. But the Henry Molson case, when it came to 1953, researchers understood that there is a site for the memory localization. And how?



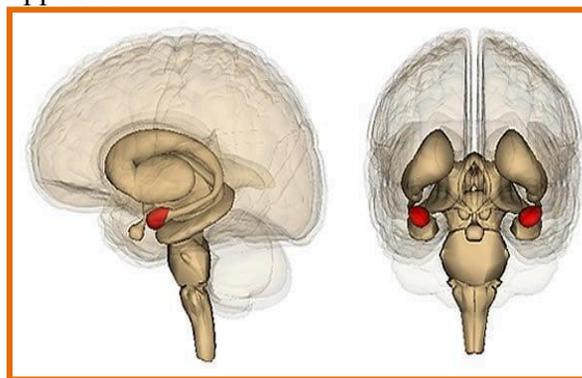
Source: [Davis \(2017\)](#); [Halber, 2018](#); [Dan et al. \(2021\)](#); [Neuroscience News \(2010\)](#)

Because the Henry Molson, at the age of 27, where he was having a lot of seizures, a lot of blackouts, and researchers were wondering that how this seizures and blackouts are such higher number is there. So, as a recommendation they suggested that the site of campus and parahippocampal area can be removed to lower the seizures and blackouts. After doing the surgery, these brain regions were being removed, the seizures and blackout got reduced. However, the patient Henry Mollison started to have a problem

with the loss of memory, amnesia. The specific type of amnesia which he was facing with is the anterograde amnesia which means formation of new memory was a challenge for him.

Before the surgery, he was able to recall each and everything but after the surgery he was having difficulty to form a new memory. So the challenge to form a new memory we call it as anterograde amnesia. So if you see the brain structures of a normal healthy human being you see the site of hippocampus is intact and very well preserved and an individual is having not having a problem. So we are having a normal healthy human brain with a normal and healthy functioning of hippocampus. But, in the case of the Henry Mollison, this brain region was being removed as a treatment towards the blackouts and seizures.

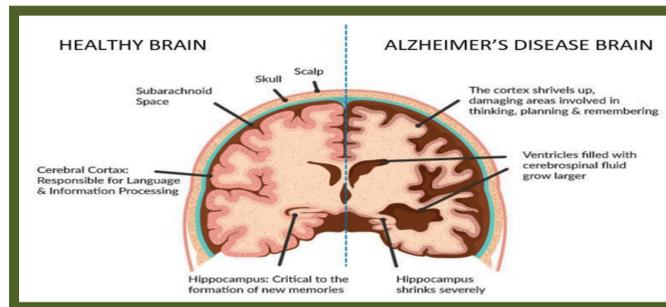
What we saw is that he was having memory loss problem, amnesia. He was not able to form a new memory. With this case, we understood one thing that the brain regions are very important for the initial formation of memory. However, when the memory is becoming old then brain structures are not required and that is why in the case of HM, he was able to remember the event and information which happened before the surgery which means that before the surgery the information and memory and the consolidated knowledge and experience has become independent of the structure that is hippocampus but the initial formation we require this memory. Then another unique case came is the SM case study where the almond sized organ was being calcified, means hypercalcification happened.



Source: [Davis \(2017\)](#); [Halber, 2018](#); [Dan et al. \(2021\)](#); [Neuroscience News \(2010\)](#)

It's a rare genetic disorder and this woman suffered with this rare genetic disorder by the age of 13 and 14. Her whole amygdala just got vanished away from the brain because of too much calcium in her brain. But this is a very rare genetic disorder. We do also have high calcium in our brain, but that doesn't impact our this thing. But this was a genetic disorder.

So, this entire amygdala was gone. So she lost the information about the threat memory, fear memory. And this was a very particular and unique case here that the memory was being lost but very specific memory was being lost that is the emotional memory, but in emotional memory also the specificity was about the threat memory she got lost. Now these two important cases it is why we are showing you is to reflect upon the two different sides of the memory structures and their contribution and role in the memory formation and learning. Talking about this thing the last cartoon what you see on your screen is the how the healthy normal human brain looks like so this is the how the normal healthy human brain looks like but when a person age enters into an elderly becomes an elderly then we see that the brain starts to deteriorate brain starts to change a lot of neurological problems lot of you know neural disconnections dysfunctioning starts to happen and what we see here you can see that how the healthy brain looks like but here the shrinkage starts, the cortex is trying to shrink the connectivity you know the sulci the gyri also changes and deforms themselves changes themselves as a result, the direct effect comes over the memory part. Alzheimer is a broad umbrella term under Alzheimer, there is frontotemporal dementia, dementia, and a lot of other memory problems start to arise due to neurological problem. Now, this leads towards also the shrinkage of the hippocampus, the site of memory formation for the fresh memories or initial memories. So, when the hippocampus is shrinking severely, compared to the healthy brain then we can understand that the formation of new memory becomes a very challenging task in an healthy individual. And this is what we have seen with our grandfather and grandmother memories and interaction that somehow they lose information they lose to form new memories but at the same time they do remember the events which has occurred 10 years back 20 years back or 30 years back vividly, detailed way, and very clearly.



Source: [Davis \(2017\)](#); [Halber, 2018](#); [Dan et al. \(2021\)](#); [Neuroscience News \(2010\)](#)

Okay, so what we see is that the why the amygdala could be an important part we could see that it is just sitting on top of the hippocampus which is our site for the storage of memory okay, so the three important brain regions which as a memory researcher an individual has to always remember first is the hippocampus, second is the amygdala, and third is the frontal cortex. And in the frontal cortex also, the dorsolateral prefrontal cortex behaves differently, ventromedial prefrontal cortex and medial prefrontal cortex. When we talk about the dorsolateral prefrontal cortex, ventromedial prefrontal cortex and medial prefrontal cortex, we have to also talk about the left side of dorsolateral prefrontal cortex or right side of the dorsolateral prefrontal, left side of ventromedial prefrontal cortex or right side of ventromedial prefrontal cortex, left side of medial prefrontal cortex or right side of medial prefrontal cortex. Out of two hippocampal structures are there, left side and right side. Behave, mimic, imitate, respond equally.

Amygdala also does the same. But frontal cortex doesn't do the same way. Frontal cortex, left dorsolateral prefrontal cortex behave differently than the right dorsolateral prefrontal cortex. Though they have a compensatory mechanism, however, still the functioning is very, very different. So, as a memory researcher, when an individual is working towards the learning and memory, it should be very clear which side of the brain an individual is

targeting and which side of the brain an individual is taking into consideration for the neurostimulation study, TMS, TDCS, etc.,

Also, at the time of EEG, which side of the neuroimaging studies, which side of the brain is being recorded for more clarity and for more specificity. Taking you forward the other case studies which people have been paying lot of attention is the traumatic brain injuries. Traumatic brain injuries brain if you can see here the cartoon is there from the Bigler's 2016 study there is a mild TBI traumatic brain injury is there mild in nature and then the severe traumatic brain injury is there. Now traumatic brain injuries can be seen in your childhood. Most of the time we move around as a kid and we bang our head.

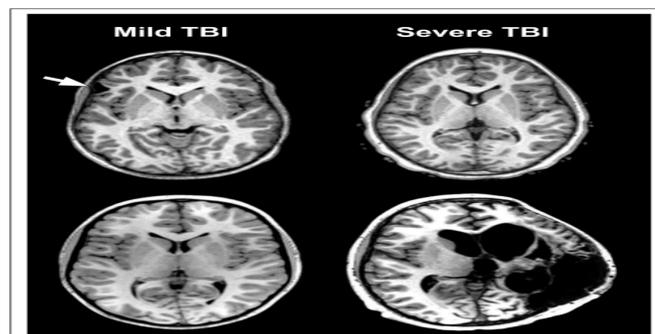
Some banging is fine. The jerk is being compensated and this shock is being neutralized with the cerebrospinal fluid. However, when the cerebrospinal fluid is not efficient enough, when the jerk hit from the wall or hit from the ground is very strong, then it affects the brain. But if the shock to the brain is very mild in nature, then compensatory mechanism is always there. The evolution of the brain has provided that aid to the human kind that the compensatory mechanism is there.

Left side is not working, right side will come. So you have seen that the brain is being, you know, are in two sections, you know, left side and right side of the brain, which is very easy. So based on the left and right side of the brain, we have to we have understood that, you know, the functioning, the classification, the cognitive deficit, the behavior deficit, the neural deficit can be studied easily. So here you can see the traumatic severe traumatic brain injury patient and you can if you divide then you could see that the right you know side of the severe TBI seems to be affected largely you know so this this section can is indicating something is really severely something is bad. And as you know from literature, right side of the brain is an emotional brain. So one could see that the change in personality might be common here, change in emotional aspect and emotion regulation, emotion deregulation, then bipolar disorder, schizophrenia, many other emotional type disorders or related disorders could be easily predicted with this, seeing this cartoon on your screen. So examination of performance in memory task is very easy.

Such patients have been given a task. Now when we talk about such individuals, then lot of coordination is required. One has to understand the brain may be divided into four different lobe, frontal lobe, parietal lobe, occipital lobe, and temporal lobe but these different types of lobe and even when we talk about the memory then we say hippocampus frontal cortex amygdala is responsible. But the projection from all these different brain regions are so dense in nature that any damage to your visual area or right side of the brain may effect the projections at the frontal cortex as a result, your decision making reasoning everything is going to be compromised you know and such decision making problem solving method are requiring less time they are happening at less than a second. So, when an individual has to work in this, we see that they perform worse and impairment is very common.

Neuroimaging studies have also highlighted that individual with brain damaged and the intact brains. They perform differently, you know. So, cognitive deficit, behavioral deficit, neural deficit can easily be seen in these individuals. So, mild TBI, they perform, they compensate, there is projection. Some network is still intact.

However, in severe TBI, we see impairment is there. And when the impairment is there, then individual face lot of challenges and trouble in doing so. When such traumatic brain injury happens then the size of the brain, the volume of the brain everything you know seems to be changing you know the shape the length the thickness and even the sulcus and gyri you know sulcus and gyri also pay the price. And as a result, the folding, the connectivity, the assembly of the neurons, all these things get compromised. As a result, the individual with the severe TBI has to pay a more price than the person with the mild TBI.



Source: [Bigler \(2016\)](#)

Now, TBI is a very common method which individual has studied. Just like in previous lecture, week one lecture, we understood different animal models are being used. Researchers have used different species having different type of nervous system. Some species are having a very, very simple nervous system. Some species have a very complex nervous system.

This species is nothing but we humans, have a very very complex nervous system so when we are studying the nervous system it could be simpler in nature and then it could be complex in nature. Definitely, the complex nervous system requires lot of understanding, lot of insights, lot of perspective and multi-measure assessment and multi-model assessment is required. While with the simpler, you know, nervous system model, it is very easy to understand how an individual respond to it and that is why researchers, you know, have been trying to use it. So, you can see on your screen that the B model or the octopus or the worms, the starfish or hydra or zebrafish as we saw earlier and the rodents models are being used. The idea to use such model is to understand when signal is being sent, how the projection of the neurons are happening, how the neurons are interacting with each other, how they are coordinating with each other.

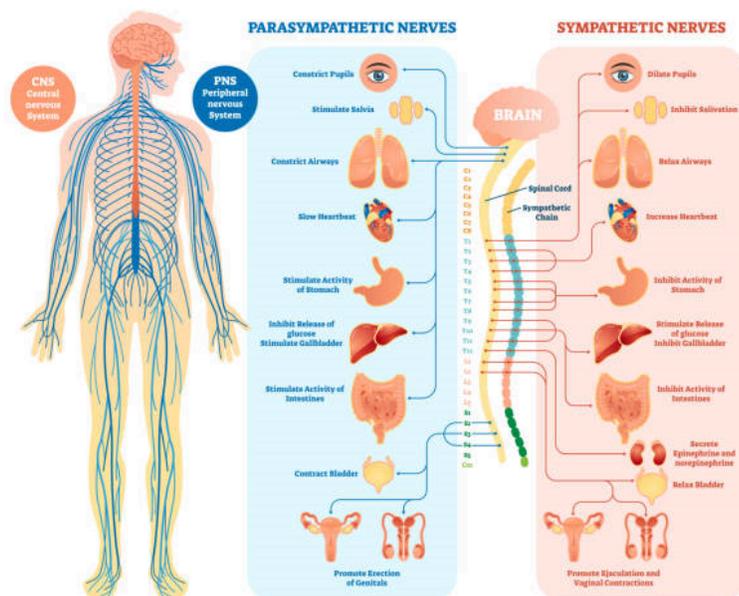
In humans, there are more than one type of neurons are there, lot and lot of neurons are there. While in many other species, some species they just have one symbol and single neuron and these single neurons are so visible that you do not even require a sophisticated analysis or high and visual methods to understand. These systems, these nervous systems are very very simple in nature and one can easily understand. So, that is why the cross-cultural species are being paid more attention towards it. But one should be note, it should be noteworthy here that only few species individual have studied in the nervous system.

Many more species are there where individuals have been trying an effort to understand their nervous system. Because we are talking about the human memory system, let us talk about the human nervous system. We cannot talk about the due to time constraint, we

cannot talk about the other nervous system. But human nervous system has been divided into the two parts. So one is the central nervous system part and then the peripheral nervous system part.

The central nervous system part is composed of brain and then the spinal cord. The spinal cord is nothing but it is the medulla oblongata with what you can see is the brain stem and this brain stem is coming down to the body. And this brain stem, It is just coming down, bringing the information from the brain to the rest part of the body. This is the interface. This is the interface collecting the central nervous system with the peripheral nervous system in between. But together they are being seen as the central nervous system part. Peripheral nervous system, the word itself is at the periphery.

So, something which is at the periphery. So, you know, these nerves, nerve endings can be seen as the peripheral nervous system. This peripheral nervous system, if you see, are having the, you know, collects the sensory information from the receptors and sends down to the central nervous system. So, you know, if you feel pain here, at your toe then the pain will travel up and then through medulla oblongata it reaches to your central nervous system. Similarly, if you feel pain or you know if you touch a hot coffee mug with your hand then the signal from your fingers you know travel back together to this peripheral nervous system to the brain stem and then from the brain stem it reaches to your central nervous system.



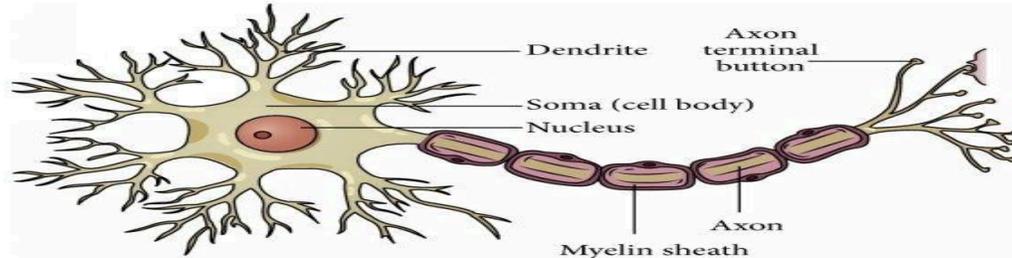
Source:

<https://organismalbio.biosci.gatech.edu/chemical-and-electrical-signals/nervous-systems/>

These motor neurons that carry the information from the CNS to the body part and motor neurons are there so you know motor neurons help when I am lifting this you know object in my hand then the motor system has to coordinate the information is coming from my central nervous system that you have to hold this thing in your hand for some period of time then you put it down so putting it down holding it in the hand is the information being given from the central nervous system and then holding it for too long or something when the pain starts then also that information travels back from the peripheral nervous system to the central nervous system. Now, this entire system is being divided into parasympathetic and sympathetic nervous system. Parasympathetic nervous system starts to function when a person is in a calm state in a very relaxed state think about a situation when you are doing a meditation, that time, parasympathetic nervous system gets activated. However, when you face a threat, when you face a danger, when you are crossing a road, a highway with a heavy traffic, with a fast moving cars, or you are walking through a jungle, or you are meeting your supervisor, then in that case, your sympathetic nervous system gets activated. Because sympathetic nervous system gets activated for two reasons, either you have to fight or either you have to flight and fight or flight in both cases you know the body parts require energy as a result these bodily functions start to you know heart starts to pump blood, breathing starts to happen faster, the blood rushes in those parts of the body where the defense system is required like in the case of fight the fist and energy is required in your hand while in running your legs has to move faster so the energy rushes in your

legs and arms and you know body part in doing so because the blood is pumping the blood the and it is moving in the body part so fast it increases the body temperature to cool down the body temperature different type of you know these sweat glands are there which starts to secrete the sweat to cool off the body so as a result skin temperature you know also varies under the sympathetic system. In the parasympathetic system, skin responses are generally at the baseline. So, when we are talking about these motor neurons, sensory neurons and how the peripheral nervous system is sending back the

information to the central nervous system and central nervous system is sending back to the peripheral nervous system, we have to understand how the neurons and what neurons are because the central nervous system is having a basic unit. What is this basic unit of central nervous system? It is the neuron, and these neurons can be seen as a basic unit of nervous system.

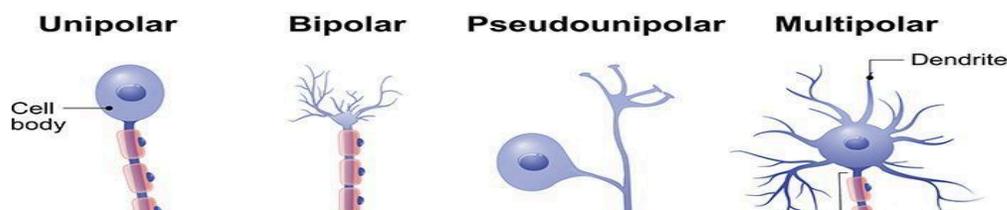


Source: Pu et al. (2012)

So, nervous system is comprised of two parts, central nervous system, peripheral nervous system and neurons are the basic unit of it. So, neurons could be motor neurons, sensory neurons, you know, different types of neurons can be there. So, on your screen, you are seeing the neurons, which is having one pole. One pole is there. So, unipolar is there.

Then, more than one pole is there. As you can see, this end is there. And then, this end is there. So, two poles are there. So, it is known as bipolar.

And then, the pseudounipolar is there, you know, pseudo-randomization bipolar. is there which is not defined where the pole will be, so you can see that this section and this section random section is there so pseudo monopolar is there and then the multipolar polar poles are there you know you can see that different different poles are there and this dendrite connections are there with that. So, one neuron if you talk about this one neuron is having a cell body and dendrites are there. Cell body is what you see on your screen this is cell body and then dendrites are there. As per our understanding and as per our knowledge, there are 100 billion neurons are there in the brain and 13.5 millions are there in the spinal cord itself.



Source: <https://qbi.uq.edu.au/brain/brain-anatomy/types-neurons>

As I was telling you earlier this medulla oblongata spinal cord what you are seeing on your screen this section you know the spinal cord this is having 13.5 million neurons are there in this spinal cord. Neurons are of various shapes, various sizes are there depending on the location and the functions of the brain. So, where they are there. So, in the brain also if we talk about you know when you draw a brain, then moving from you know this where the site of the hippocampus is there. So, from this layer, surface layer to the inside layer, you will see that different types of neurons you know are residing here, different sections different regions and different larynx are there in these regions. Okay.

Let us briefly talk about the structure of the neuron. So, neurons generally neurons are having one axon and one dendrite. So, you know one axon you can see this is the axons and then one dendrite is there and then the cell body is definitely there at the center. There are certain receptor sites are there you know from where they select the receptors. Not all receptor sites are functioning one and not all receptor sites are accepting the receptors also.

So, some receptor sites are empty, some receptor sites are there. Now, when we talk about the receptors then these are neuro you know receptors are there and neurotransmitters are there as for our understanding is there 100 types of neuro receptors are there out of which 30 neuro receptors are playing role in the memory more or less. Then, the neurons are generally resting state in order to you know be active, they need to have a certain potential and when they becoming inactive to active this potential we call it as action potential and because action potential is generating an impulse you know there is an impulse you know you are sitting on a couch and suddenly we give you a kick with a coffee strong coffee, then you know, you just get shocked and then you start becoming impulsive, active and responsive. Similarly, the neurons are there, neural impulse is there.



Source: <https://www.moleculardevices.com/applications/patch-clamp-electrophysiology/what-action-potential>

Entire process of this, if you see, you know, moving from resting state to the calcified state, you know, resting state to action potential, this is an electrical to chemical reaction is happening entirely. So, the electrical impulse is there due to the movement of, you know, the ions uptake and down regulation is happening and this changes entirely to makes the resting state neuron to fire and this changes in the you know micro volt minus 52 minus 80 millivolts is there which is generally the resting state of the neurons are there if you provide such potential if you provide this 80 millivolt potential then the neurons will shoot and they move from resting state to the action state and to study this in detail let us put some time here on the slide as you can see for the action state or for the neural impulse there are five stages are there and these five stages listed here so the first stage if you see the resting state is there so here the neurons are at resting state they are not doing anything you are just sitting in your couch and watching a beautiful movie and suddenly you know you come to know that your mother is arriving at the train station so you know you have to move from resting state you leave the remote control and then you have to go and you change to get your mother. But this state of excitation, we call it as depolarization, you know, where the neurons which are at resting state are now going to do an active state.

So, in depolarization, what happens? Rapid rise in the membrane potential is happening. which means that lot of positive ions you know opening of these sodium channels are there and lot of sodium ions start to rush in you know so there is an opening and then the cell which was negative initially you know which was negative initially at let's say minus 80 millivolt suddenly the doors starts to open up and lot of sodium ions start to rush in and when lot of sodium ions are rushing in, you know, this starts to become positive because it is there. And once it is getting this, so this is the depolarization.

So, it increases. But, after reaching to certain potential you know then the enough quantity is there inside the cell sodium potassium is there enough you reach at the train

station, you start to wonder have you reached on time, the train has arrived or not, then you realize the announcement is done the train is five minutes late so then you start to repolarize you calm down yourself so, there is a shoot there is a shoot and the positive ions you know because you have reached a transition at before time then you start to breathe out you relax. And this potassium starts to go out. Now, this sodium-potassium-sodium channel, which is there, you know, sodium is coming in, potassium is coming out. To balance the action potential or the potential of the cell, this repolarization happens.

So, repolarization, rapid sodium channel inactivation happens. A large influx of potassium ions happens. It starts to move out. The state of hyperpolarization which is where the lowered membrane potential is there due to potassium channel and unclosing the potassium channel. So you know when the potassiums are out then they start to close all the doors.

So no one comes in and no one goes out. And once this thing is happen, then so potassium keep on decreasing, decreasing, decreasing till it becomes negative again. So till it becomes reaches the minus 80 microvolt. So this is happening and then the cell becomes at resting state. You become calm.

Okay, I have reached on time at the train station. My mother train hasn't arrived. Now I am at resting state. Then the cell reaches that resting state and this resting state membrane potential returns to the voltage. Now, this hyperpolarization and depolarization can be studied.

Neurostimulation studies and magnetic stimulation studies have put lot of emphasis upon this understanding how the neurons are firing the potential. And this firing of potential, one neuron potential, one neuron is firing the potential and this is how it is happening. Imagine when thousands and thousands of neurons are firing together and thousands and thousands of neurons are moving from resting state to action potential. Then, you know, the underlying neural mechanism and cognitive functioning starts to happen in that regard. So, if we summarize this section of the lecture 6, we understood that the historical

perspective of memory, when the Henry Mollison case study came, HM case came, SM very recent case

came 10 years back and then the healthy brain versus the Alzheimer brain we studied. These case studies give us some insight that the initial idea and concept about memory getting consolidated across the brain was a misconception and myth. The initial formation of memory requires the brain region that is hippocampus, amygdala, frontal cortex. Initially, once the memory is becoming old, once memory is becoming old enough then it does not require hippocampus amygdala it becomes independent of brain structures. We also learn that traumatic brain injuries how the shape, size, gyri, sulci changes after the traumatic brain injuries and in traumatic brain injuries also there are different classification how the brain is undergoing shock if the brain is undergoing severe shock then it is a severe traumatic brain injury if the brain is not undergoing severe shock then it is a mild traumatic brain injuries

And the difference we have studied it. Then we also studied about the nervous system across the species. Different type of species are there. Some are having simpler nervous system. Some are having complex nervous system.

We human beings have a very complex nervous system and it is very difficult because lot and lot of different types of neurons are there. central nervous system is one functioning site, then the peripheral nervous system is the another functioning site. Both of their coordination, interface, interaction, integration results into, you know, the cognitive, behavioral or neural deficits. Then we talked about the neurons and the structure of neuron, how the neurons are there, we knew that, okay, one axon, one dendrite, one cell body is there.

But lot of projections are there. Neurons behave differently and how they behave, how they respond to it. Minus 50 to minus 80 microvolt is the resting state potential. And to move from this resting state potential to the action potential, this much potential is required. And this is what we studied in the action potential, how the depolarization is happening when the resting state of the neuron is there.

Lot of sodium ions start to rush in inside the cell body of the neurons and then suddenly the neurons are becoming positive and more positive in nature then the depolarization is happening after reaching the site when the too much positive potential is there then the potassium ion start to come out from it and it keep on coming out this is the repolarization or the hyperpolarization is happening. and then it keep on doing it till the cell becomes negative again reach the resting potential of minus 80 millivolt and once it reaches that then the cell becomes the stable again and this firing shooting of potential and reaching the resting state so action resting action resting keep on happening thousands and thousands of neurons are collectively doing the this task together and these action potentials are actually providing and giving an insight to us about the cognitive neural and behavioral deficits in an individual with respect to the memory processes. So we will stop here and in next lecture we will continue here from the further down the line from the action potential. Thank you.

Have a nice day.