Demystifying the Brain
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Lecture - 05
Neurons and Neural Signaling: Outline Segment-I

Hello, this is lecture three of the course diversifying the brain. In the last lecture we talked about brain structure, we talked about the relationship between brain structure intelligence we began with the study of Einstein's brain, and we found that the study was inconclusive, and the results were like not very interesting not very significant. So, then we looked at other aspects of brain structure probably wiring diagrams, wiring patterns, and we found that wiring patterns are important, because that can the wiring patterns can optimize the delays involved in transmission of signals from one part of the brain to another.

So, we note this principle called save wire principle, and with that we were also able to account some of the gross features of brains anatomy right, through evolution starting from simple creatures like hydra or two more complex brains like human brain, but if you really understand want to understand the question of brains in intelligence, and brain function you cannot go very far by just studying brain structural properties, you need to get into signaling you need to get into the neurons function. So, that is what this lecture is about. So, in this lecture we will talk about neurons and neural activity or neuron function.

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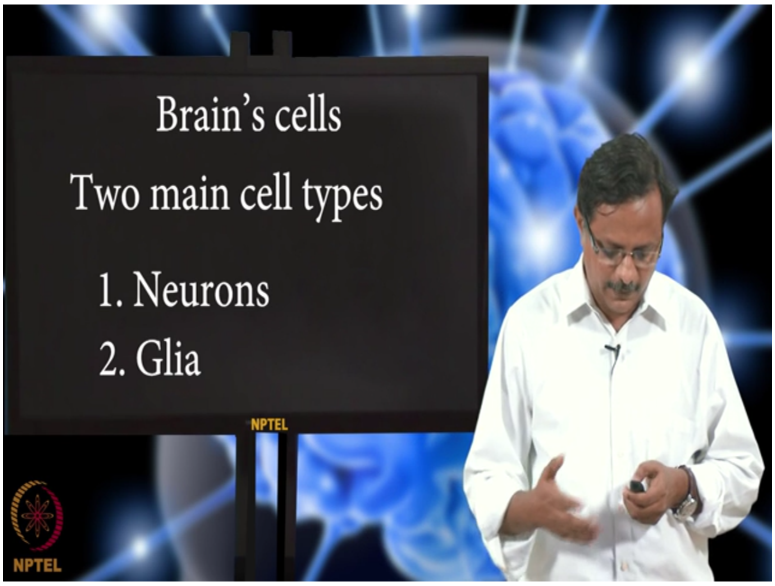

Now, traditionally it is been thought that brains function is brains information processing, functions are basically you know implemented by neurons, these first cells called neurons, but work done over the last couple of decades, has shown that there is a second class of cells called glia cells. Which also are in or deeply in brains information processing activities. So, we will talk about these two kinds of cells neurons and glia.

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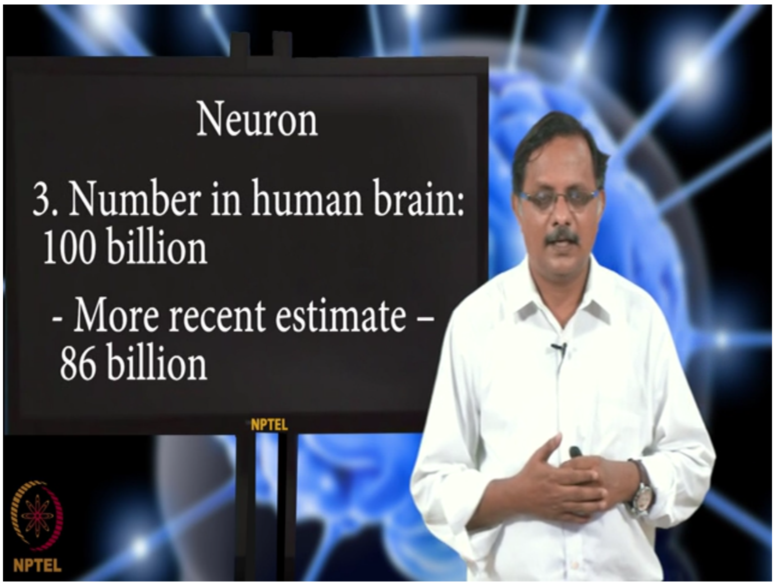

Now, neuron is a special kind of cell it is electrically active cell. So, it become belongs to a class of cells called excitable cells, or excitable tissues. So, they are relatively active and they also have this interesting wiring structure, wiry structures which project out of the cell body, this arboreal projections. And the number of neurons in human brain is a 100 billion although the number has been revised there is new estimate, which says idle brain has about 86 billion neurons.

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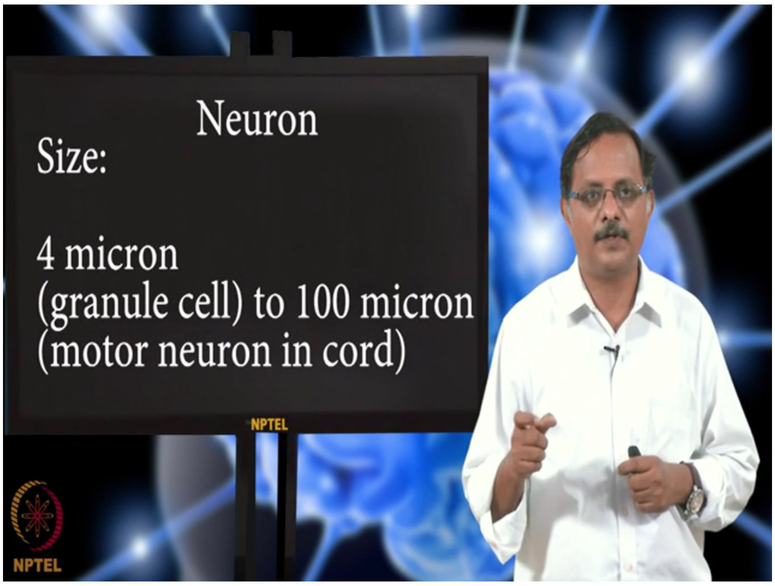

In terms of size the cell body of a neuron or which is called soma can range, anywhere between 100 microns in case of a motor neuron. The spinal cord or a small neuron like grain granule cells, it has only four micron thick soma, but we will talk about size of a neuron we should also can if you consider the entire arbore, then neurons can be very big for example, neuron sitting in your spinal cord.

In the lumbar area of the spinal cord somewhere here, it can send a projection wall the way toward toe which means this single cell is like you know, as long as a couple of feet right. So, neuron size can vary a lot. So, now let us get some intuitive understanding of what is special about neuron shape.

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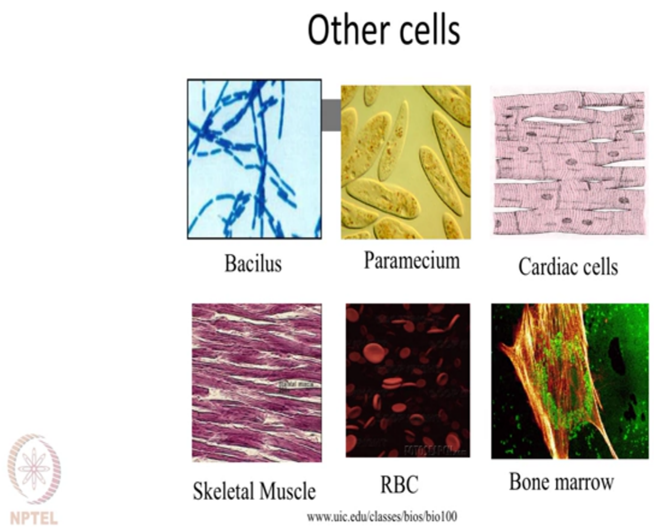

So, here in this picture you are looking at a bunch of cells, you can see some bacteria like in a bacillus and paramecium, you can see the cardiac cells, you see this connection between cardiac cells. And the cardiac cells talk to rarest neighbors you know they have what are called a shoulder to shoulder contacts by which they communicate with nearby neighbors, then there is skeletal muscle, then there is red blood cells there is doughnut shaped red blood cells, and bone marrow cells and all that.

So, typically the shape of these cells is nothing very interesting, I mean the typical cell is like a fluid filled shapeless blob, but just look at some pictures of neurons.

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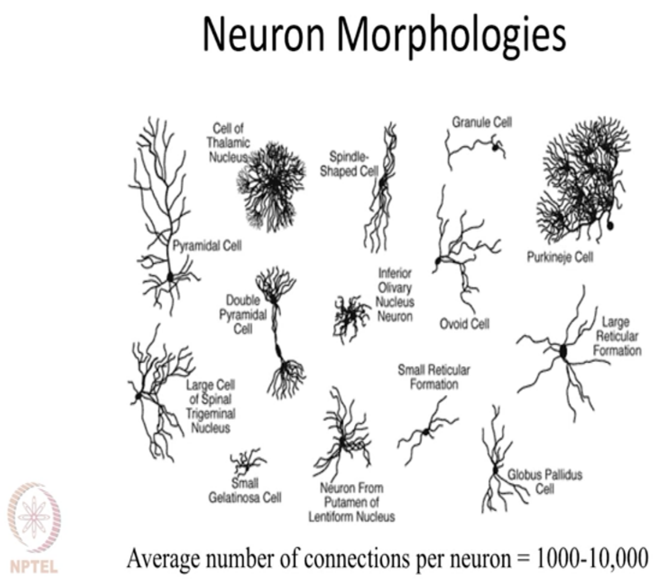

Neurons 1 thing that is liking is similar or distinct about a neuron is these wiry structures at seek out of the soma. In fact, in this picture it is very hard to find the soma right, soma is like a little dot somewhere in the middle of this you know in a complex tree and then, so, this neurons that this picture show a variety of different kinds of neurons, there is this pyramidal cell you know on the top left, then you have a small gelatinous cell, and then there is on the top right you see this complex cell with very rich harbors it is called a purkinje cell is located in the cerebellum structure towards the back of your brain.

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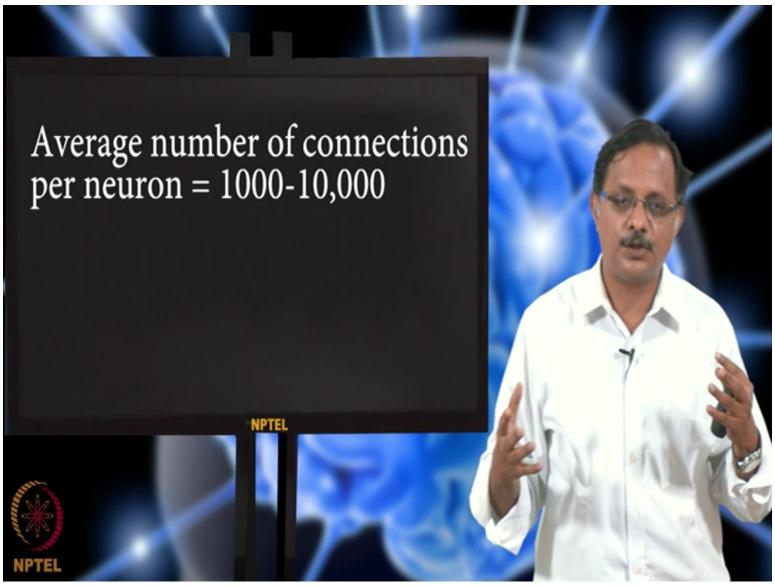

And it an average neuron has about 1000 10000 connections whereas, a purkinje cell has about 1 or 2 lac connections. And so, 100, 2000, 8000 connections.

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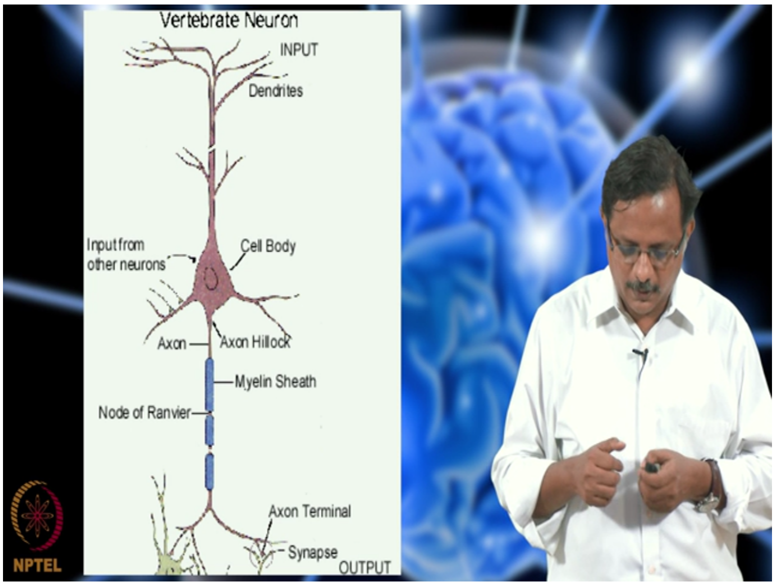

So, that is what is special about a neuron, and here you see a typical neuron actually it is a pyramidal neuron. The neuron has all these wires, but these wires are typically grouped into 2 sections.

So, there are this shorter section the short set of wire which are called the dendrites, you see in the upper part of the figure, and then typically you have a long wire called the axon, which towards the end it branches out in to a many branches these are called the axon collaterals. And at the end of the collateral you have an axon terminal. So, between these 2 you have the cell body.

So, you can see that unlike in other cells the cell body is only a small part of a bigger structure called a neuron, in cell bodies called soma in case of a neuron, and so the on the axonal side you also have some neurons have this kind of a myelin sheath provided by you know certain other cells, they are a class of glial cells. Because of myelin sheath the connection speeds on the axon are faster, and this conduction is more reliable, because the wave shape is more reliable, and we will talk more about this later on in this course.

So, the neuron so actually takes inputs from other neurons on the dendritic side, and the upper side, and processes and combines all these inputs that it receives from various neurons, in the soma. And at the soma generates new signals, which are propagated on the axon, and these signals run down the axon at to the end of the axon to the axon terminal.

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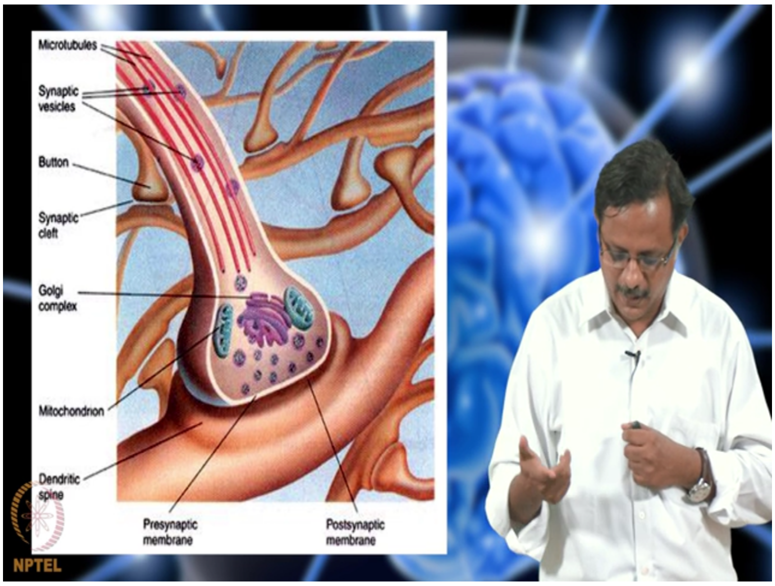

And at the synapse, which you see at the bottom of the figure right you see kind of contact between a presynaptic neuron, and the postsynaptic neuron at the synapse. And this is where the signal jumps from presynaptic neuron to the postsynaptic neuron to another neuron, and then this cycle continues. So, let us take a closer look at the synapse.

So, at the synapse in this picture you see 1 structure coming from the top, and this is actually a presynaptic terminal the tip of an axon of a certain neuron, and it makes contact with a dendrite of another neuron, and you see that the point of the contact which is actually the synapse, there is a very the presynaptic side has a kind of a swollen structure, which is called a button which is fringed for button, and on the postsynaptic side the dendrite is although it is like a cylinder you know it is a it is a tube, they become it becomes a flat structure like a flat elevated structure. And the tip of the button is also flattened out it is a flat surface.

So, these 2 flat surfaces now meet at the at the point of synapse, making a you know coming into sharp opposition. So, that you have a lot of surface area at the point of contact, and that is necessary because we remember from our first lecture. The signal that goes from the presynaptic side to the postsynaptic side is a chemical signal.

So, the presynaptic side releases a chemical which is called neurotransmitter, and we will talk more about this later on in the course. So, this chemical diffuses through this narrow gap of about 20 nanometers across, the what is called the synaptic cleft to the dendritic side, and then it you know axon genetic side and then input other electrical responses on a dendritic side. So, you need this kind of special geometric arrangement at the synaptic at the point of synapse right to enable this kind of signaling to occur in the synapse.

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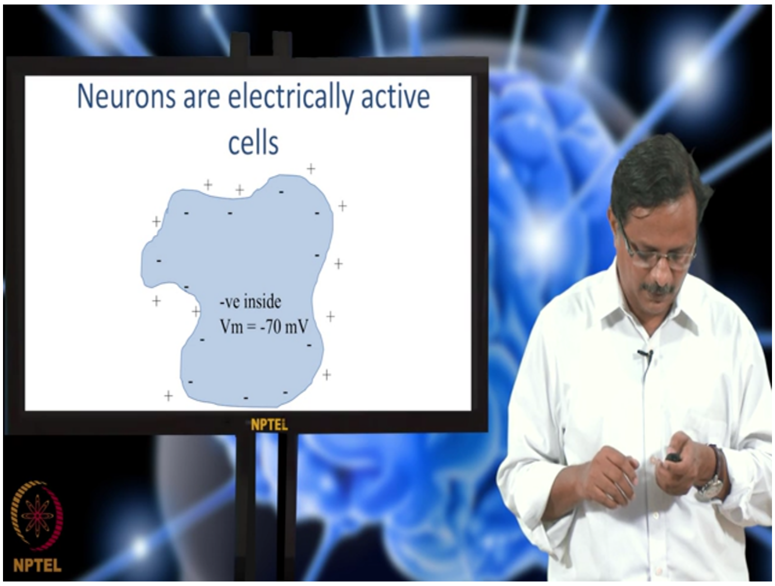

Now, so that is something about the structural aspects on neurons, now let us come to this function aspects in the right. So, neurons like I said already there's a electrically active cells.

Now, any cell has a certain potential electrical potential inside it, with respect to outside the cellular environment. So, if you take the outside as ground potential. Inside in a neuron in typical neuron it is about minus seventy millivolts, this number can vary depending upon the neuron type you are talking about, can be anywhere between minus 80 or minus 60, and depending upon the cell type, but minus 70 millivolts is a reasonable typical figure.

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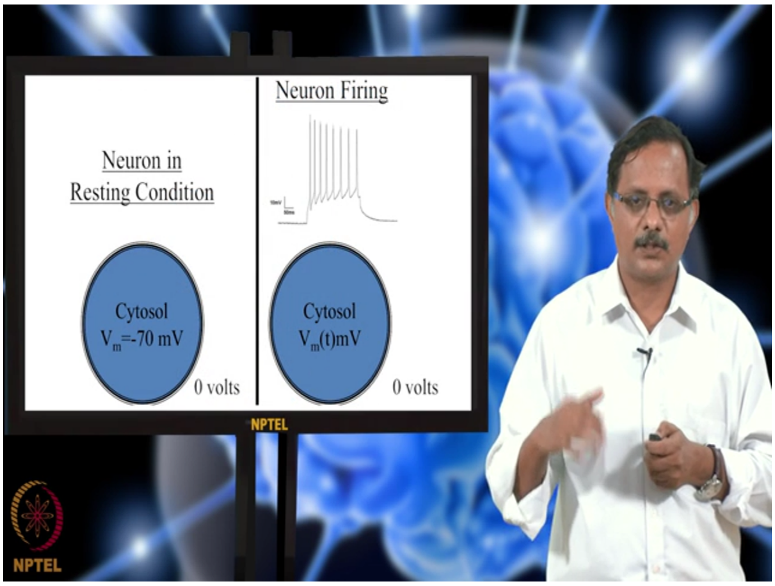

And this figure is not always constant. So, the neuron can remain in 2 states, there's a resting state which is what it normally in, and the resting state the voltage of the neuron inside the neuron is about minus seventy millivolts. This is called the membrane potential because this is a potential that exists across the membrane of the neuron. So, between inside and outside. So, the what is separates what separates inside to the with the outside is the membrane of the neuron.

Now, so resting condition this membrane potential is constant, but when the neuron gets excited due to certain factors, we will talk more about that later in the course right, then this what was constant this voltage shows very rapid fluctuations, as you can see in the figure on the graph on the top that you can see consisting of these sharp spikes, are actually these sharp voltage fluctuations.

And these are nothing, but the action potentials, which we discussed in the very first lecture. So, that is when you said neuron is active and all or the neuron is firing. So, the neuron can stay in 2 states resting state where the membrane (Refer Time: 08:31) is constant the active state are exited state, where then membrane potential shows a sharp spikes called action potentials.

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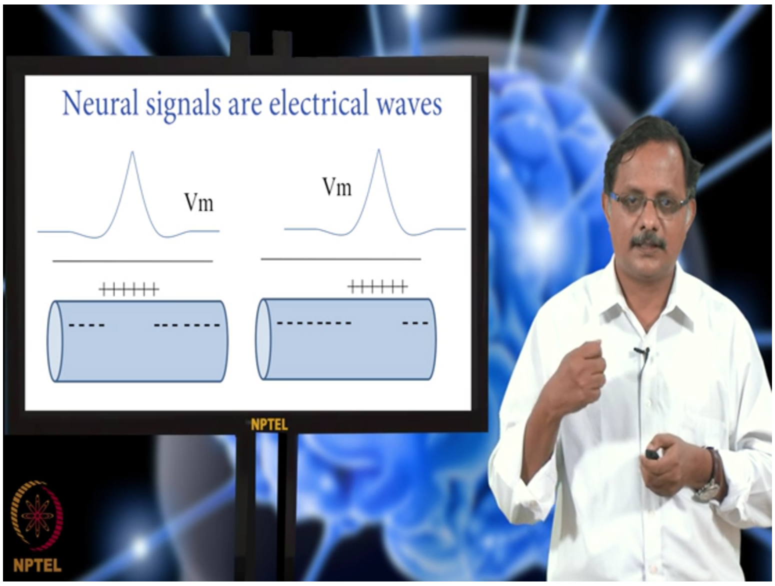

Now, these electrical signals are generated by the neuron, travel along the wires of the neuron along the end the axons and dendrites. And that is the signals that neuron communicates.

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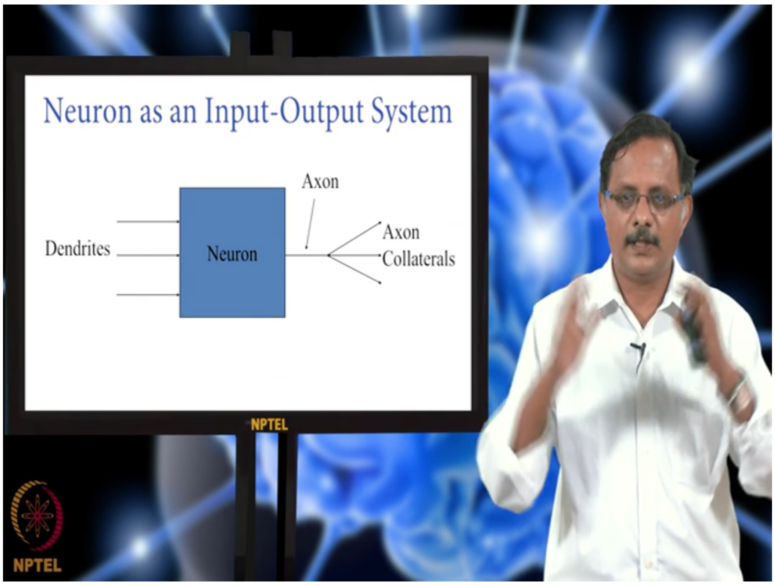

Now, if you look at the you know complete picture of the neuron. So, you think of neuron soma is a black box some kind of a black box, and dendrites carry inputs from other neurons. So, those are the input lines into the black box, and then all these signals are combined by the neuron, and new signal is generated by the neuron, the cell body, and this new signal single that is generated travels down the axon, to the axon collaterals and goes with other neurons.

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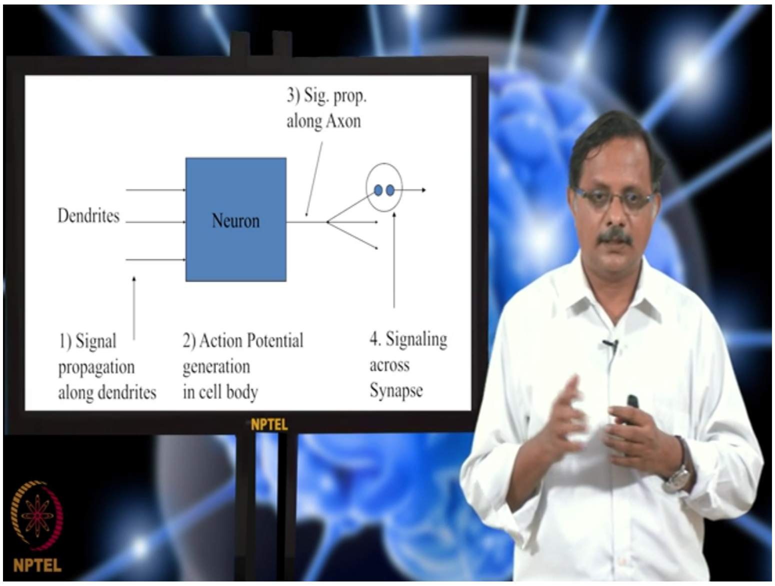

So, you see that in this process there are 4 signaling components in a neuron. So, on the entry point of the neuron in the dendritic tree all the signals propagate down a dendritic tree. So, that is the first component of signaling, or the signal processing along dendritic dendrites, then all these signals come to the neuron, and then they get added up and an action potential or a plane of action potentials is generated in the cell body.

That is a second component action potential generation cell body, then these signals which are generated at that at the end of the soma over or at the meeting point of the soma, and the axon, which is called the axon hillock these travel down. The axon and that is the third component second propagation along the axon, and finally when the signal gets to the synapse to the presynaptic terminal, at the it is converted into a chemical signal, which crosses the synapse. So, this signal across synapse is the fourth component ok.

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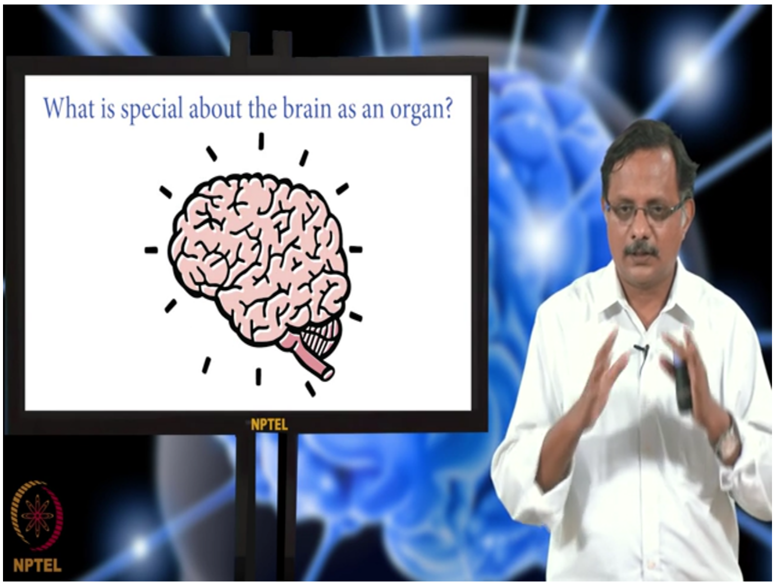

So, that is broadly the signaling components in a neuron. Now, let us kind of try to learn that is important lesson out of what we have just discussed, what is special about the brain is an organ, because this was the question that is been repeating through the all the previous lectures, what is so, special about brain. The question might sound somewhat in nave, because you can just say that you know brain is designed to be special, and brain is designed to be intelligent.

But it is not as simple as that because brain like any other organ is a bunch of cells, it is a mass of cells. Now any cell in the body has the standard you know infrastructure like it has a nucleus it is all these organelles like you know (Refer Time: 10:39) bodies endoplasmic reticulum, and then it has a cell membrane, in little bit lipid bilayer, and there's nucleolus and all these things.

So, whether it is a neuron or a cardiac cell, or a skin cell, they all have the same structures internally. So, what is special about the brain? This so, the answer to that because you do not say pancreas is intelligent or you know heart is intelligent, you say brain is intelligent.

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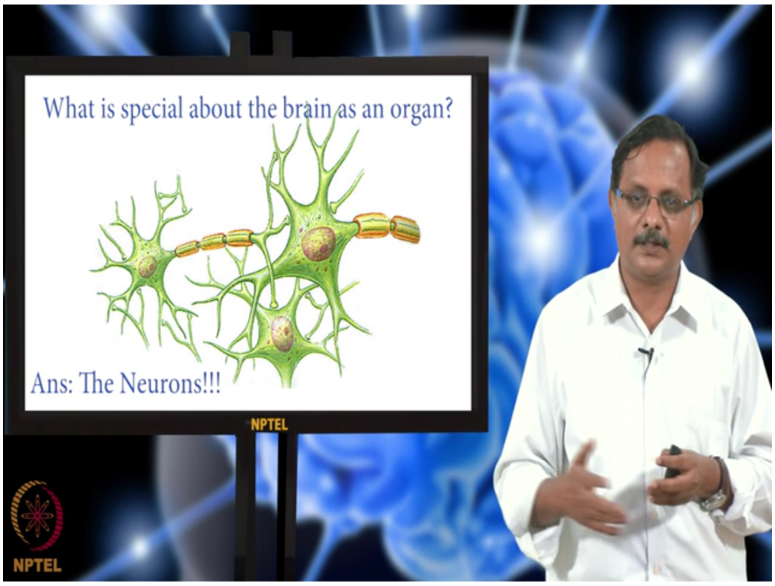

What is the reason well the simple answer to that is in neurons, there is something special about neurons, and that is what makes a brain special.

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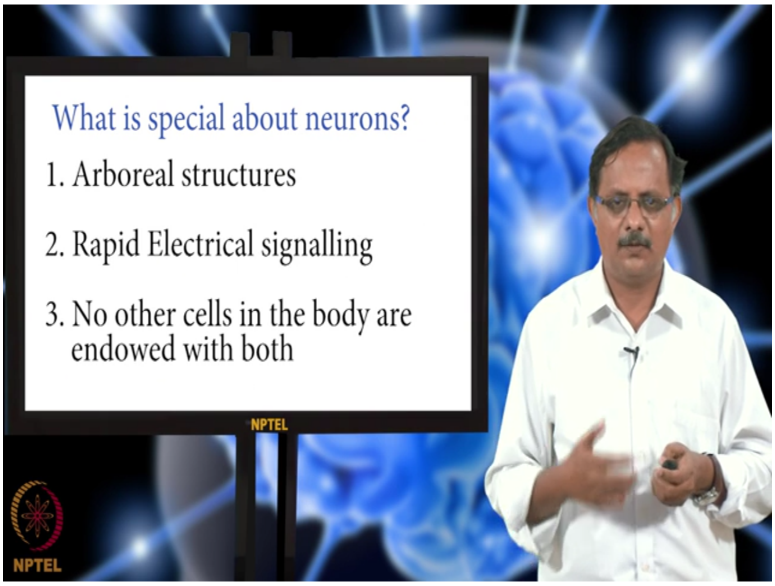

But then what is so special about neurons well there are 2 main distinguishing features of a neuron compared to other cells, they have these arboreal structures, they have these wires sticking out of them, and then they can exhibit rapid electrical signaling. So, we have seen that they sharp action potentials right which are the sharp elliptical spikes are so the each spike is only about 1 millisecond wide.

So, these signals are very rapid. So, no other cell in the body can display both these properties, no other cell in the body has such a rich arboreal branching structures. Secondly, no other cell in the body can exhibit such a rapid electrical signaling. Even cardiac cells have elliptical signaling, means that is why you know heart is a electro mechanical pump, but those signals are much smaller, much slower for example, a cardiac cell fires an action potential of a cardiac cell is about half a second, that is very slow, compared to a neuron which where the action potentials are like a millisecond.

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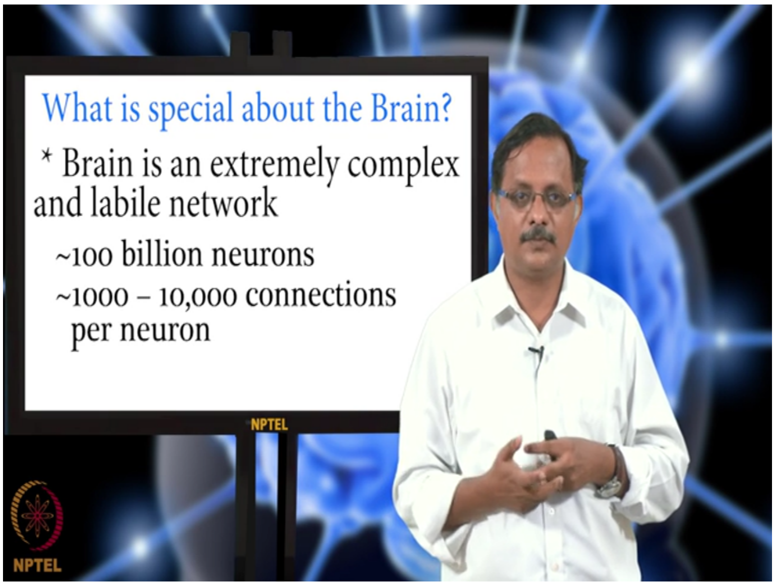

So, basically what is special about brain is it is a complex network is a network consisting of 100 billion units, and each of these units the neurons is connected to a 1000 10000 other connections, and other neurons so, these there and it is also this network is a dynamical network it is sending these signals rapidly, you know at the rate of you know sometimes hundreds of hertz.

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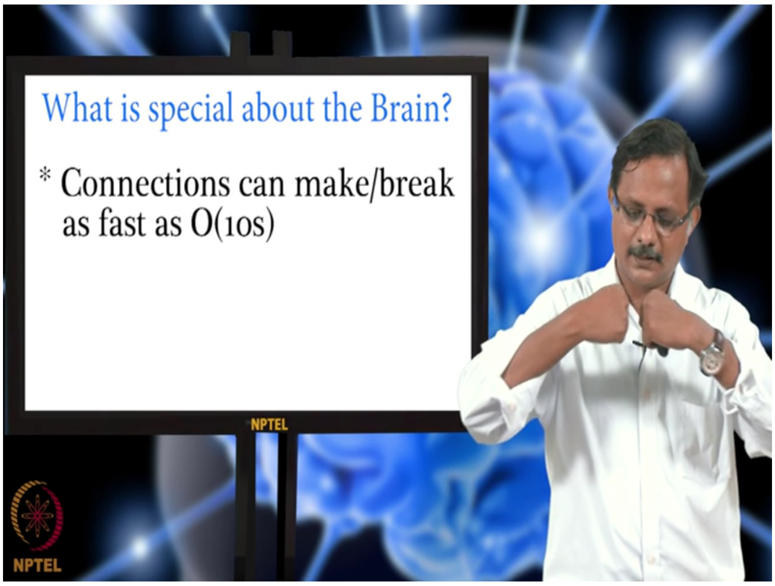

And also these connections are not fixed it is not a fixed network, this is labile network it is a variable network for example, the connections in your brain before the lecture quite different from the connections in your brain after the lecture. So, at the fastest timescales the connections among neurons can vary at the scale of like, order of 10 seconds as is that is that is very fast. So, you are looking at a very complex network, and a very labile variable network, and no other organ in the body can be described in these terms.

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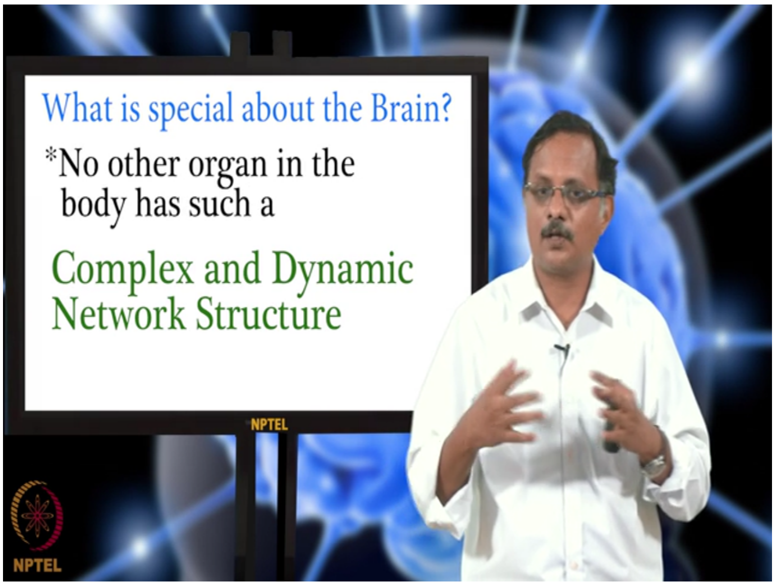

So, brain is a complex and dynamic network structure, and no other organ in the body has a same network structure, because even if you take an organ like heart which is capable of you know very complex dynamics, in the very complex beat patterns. In the heart the network is very simple because each cell only talks to its nearest neighbors.

So, that is very simple and that is it is fixed and there's no change in the network and whereas, in the brain and neuron can send projections to very far remote parts of the brain, and talk to it and this connectivity keeps varying internal internally although the gross section of the brain looks about the same it does not change like rapidly on scale up for days or weeks, microstructure is changing constantly. So, that is what makes brain very special

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In this respect you can compare the brain with the entire mobile network of the world.

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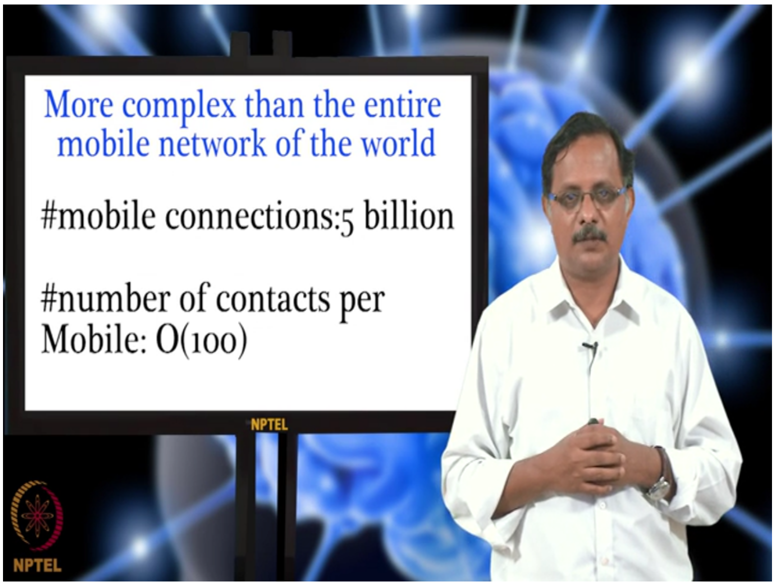

I mean we have a planet has about 7.5 billion population, among them about 5 billion people are supposed to have mobile connections. And let us assume that each person has on the mobile like about few 100 contacts, I mean that network is nothing compared to the network that you have here know inside your cranium. So, in nutshell that is what is special about the brain, and is really an amazing organ in for this for these reasons. Now like I said this is a second class of cells called the glial cells, which also participate in the brains information processing in it in addition to neurons, and that is becoming more and more clear only over the last couple of decades.

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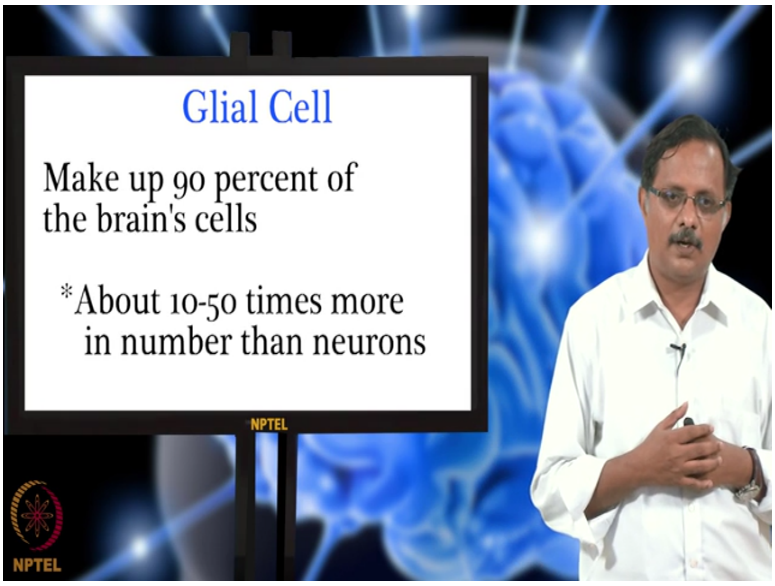

Glial cells have always been thought there about 90 percent of the brain cells, but actually these that means there are about 10 to 50 times more in more numerous than neurons.

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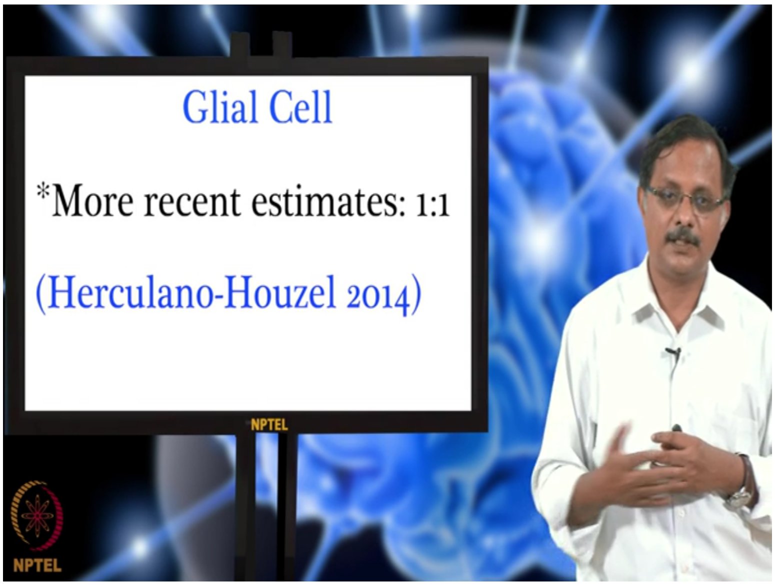

But more recent estimates downsizes these numbers looks like now, people start thinking that there for every 1 neuron there is a 1 glial cell of so, the ratios are like more 1 to 1 and not 1 is to 10.

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But glial cells do not carry nerve impulses they are not electrically very active, but they show other signals by which they seem to be responding to signals coming from outside, and also using these other signals they can talk to neurons.

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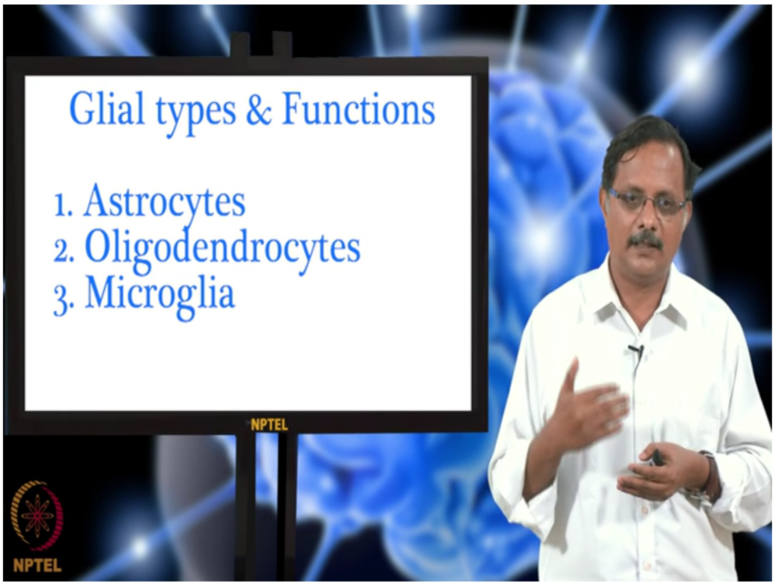

So, there are glial cells found both in central nervous system, and the peripheral nervous system central nerve system I think we have discussed it, in the very first lecture is the part of nerve system that is located safely housed within this bony vault of your cranium, that is a skull, and the vertebral column.

So, that is like brain inside the skull, and the spinal cord inside the vertebral column both these structures together is called the central nervous system. And then there is a peripheral nerve system consists of all the wires that go out of this bony vault, and innervate the body and spread all over the body, and innervate say you know send signals all over the body that is called the peripheral nervous system, or PNS in the CNS there are 3 kinds of glial cells, there is the astrocytes they are the oligodendrocytes and microglia.

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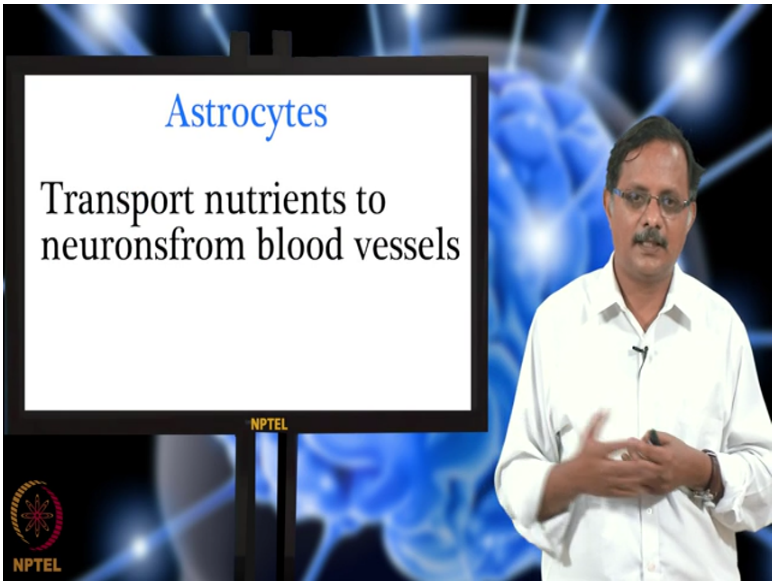

Now, astrocytes like transport nutrients to neurons from blood vessels. So, for example, I mean any cell in the body needs energy, and that energy comes from the bloodstream in the form of glucose and oxygen. The thing is a typical cell like for example, a skin cell, or a muscle cell, schedule muscle cell, when it is active it spends energy and so, when it wants energy sends out certain hunger signals.

Which act on the nearby blood vessels, and the results dilate, and then release oxygen and glucose which is picked up by the tissue, but brain is different I mean. So, neurons are different because they do not have some of the molecular machinery to process energy that comes on the blood vessels.

So, they depend upon this kind of glial cells the astrocytes. So, astrocytes act as intermediaries between the blood vessels and the neurons. So, you have astrocytes holding onto a blood vessel on one side, and making contact with neuron on the other side. And so, it takes picks up the energy in the form of glucose from blood vessels. The glucose enters astrocytes, now where it gets converted into lactate the lactate is supplied to the neuron where it is picked up by the neuron, and then converted to ATP and this ATP is used for the for driving the activities of the neuron.

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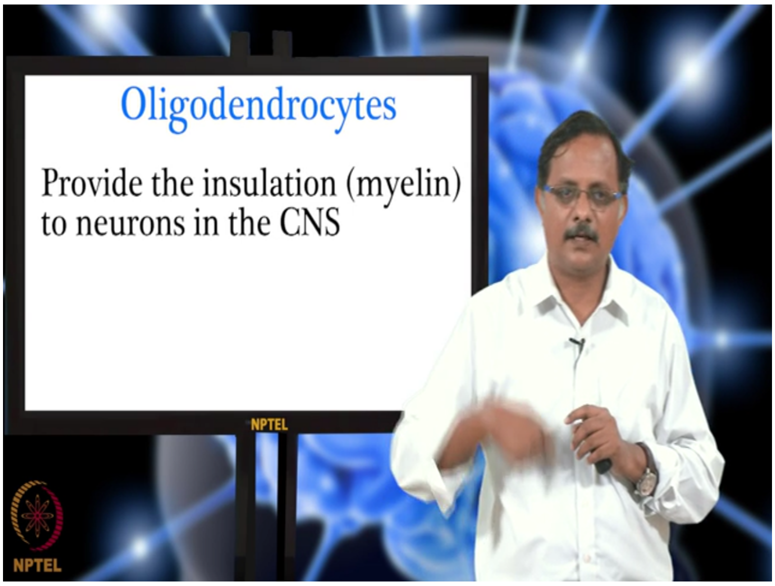

Now, then there are oligodendrocytes these are the cells which wrap around the axons of neurons and provide the myelin sheath. So, as the speed of conduction I think we talked about some of these you know aspects in the last class, because we said that the myelinated axon fibers, are faster than unmyelinated once, and this myelin sheath actually comes from oligodendrocytes in the CNS.

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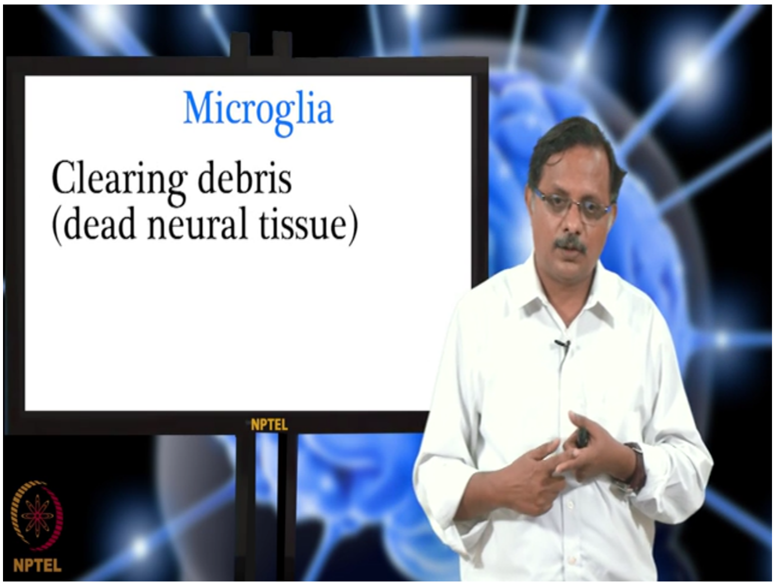

Then there are microglia these are like you know scavenger cells in the brain, and they clear the debris of dead neural tissue.

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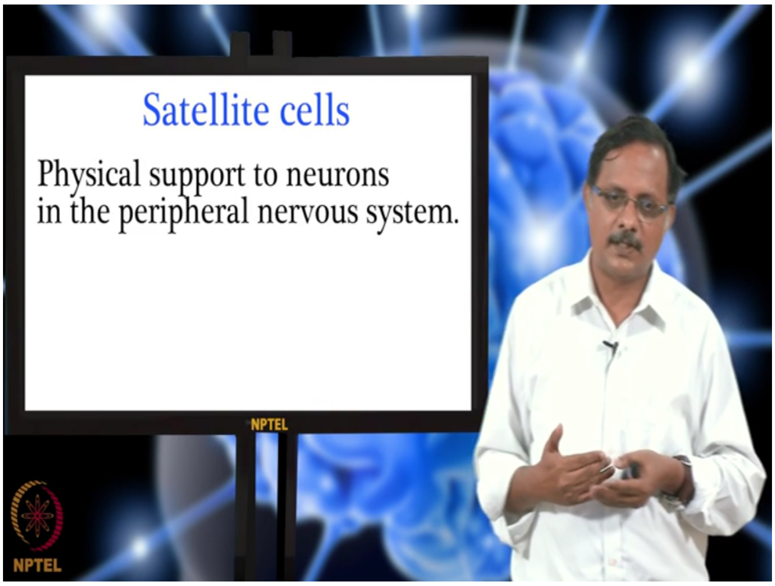

So, the peripheral nervous system you have the satellite cells which act like, the provides physical support to the neurons.

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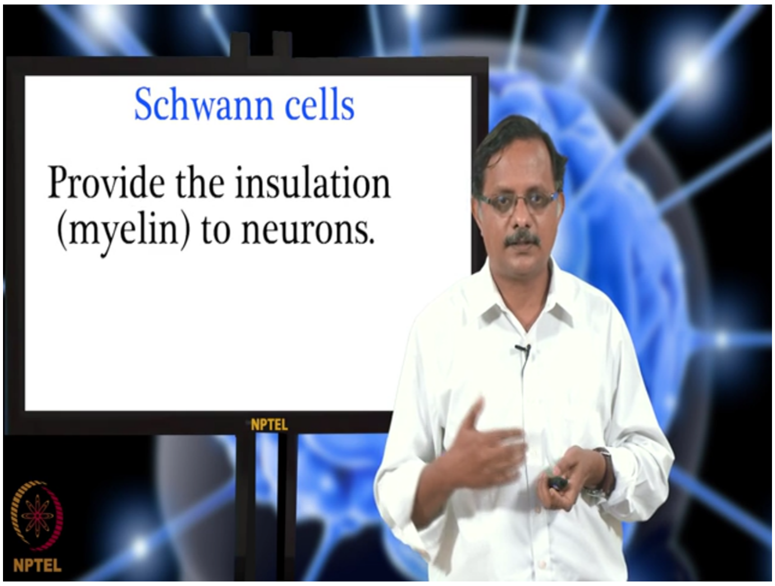

And the Schwann cells which also provide myelin sheath to neurons.

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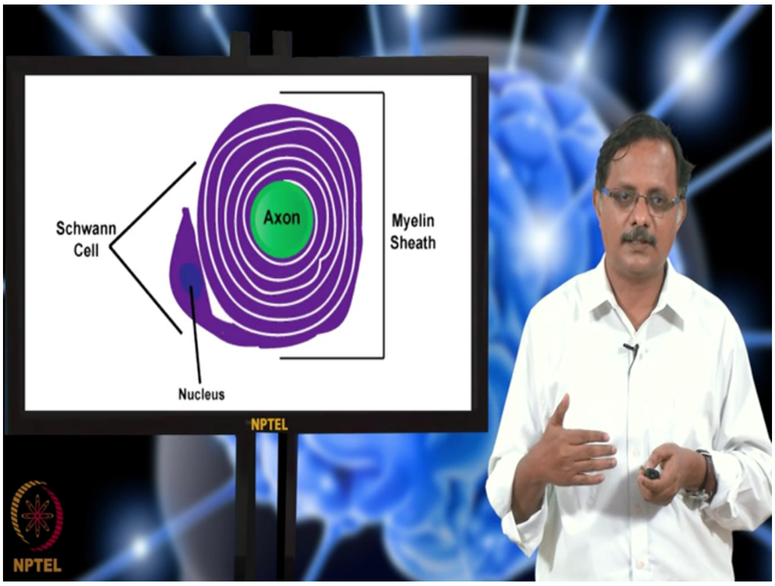

And Schwann cells are like equivalent to oligodendrocytes, in the peripheral nervous system. So, here is a simple cartoon picture of how a Schwann cell wraps around the axon over and over other providing a thick myelin sheath, and thereby increasing conduction velocity.

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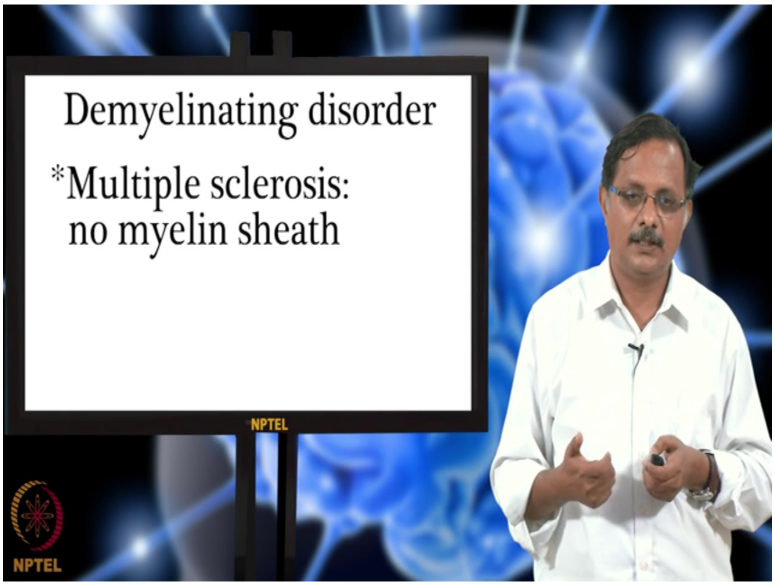

So, there is a disorder called demyelinating disorder or called multiple sclerosis, where patients do not have myelin sheath.

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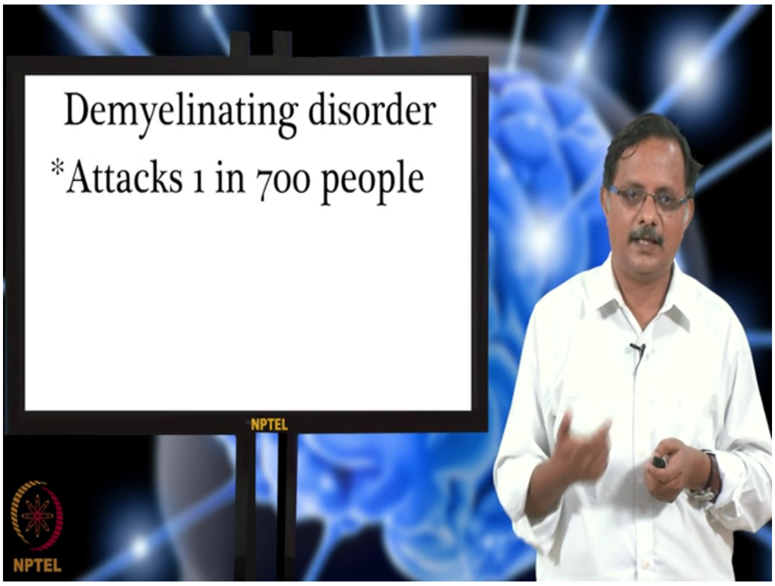

These attacks 1 in 700 people.

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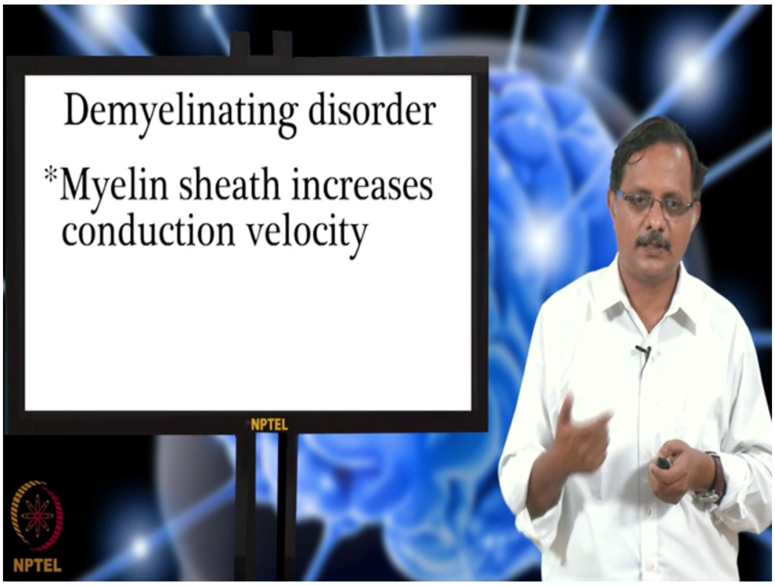

And because the sheath increases connection velocity loss of sheath reduces conduction velocity.

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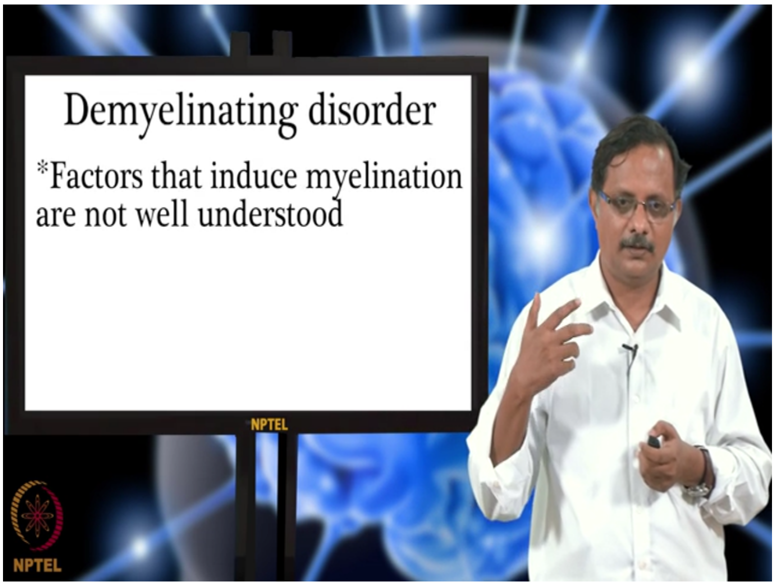

And therefore, these people have trouble, and in with movement with the perception, and cognitive functions and so on so forth.

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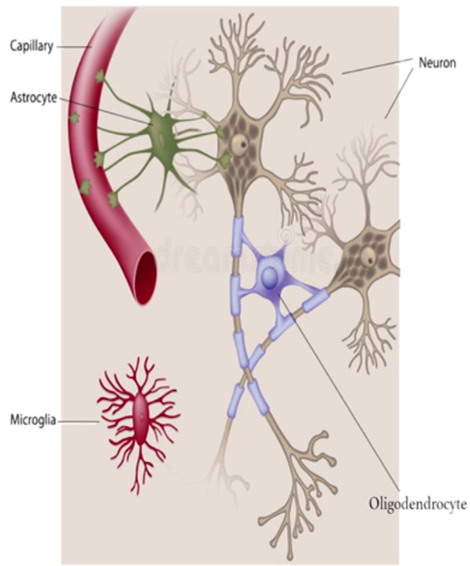

To summarize the relationship between neurons and glia, in this picture is a simple cartoon picture that shows how the neurons are distributed or located with respect to the glial cells. So, you can see that astrocyte the green cell over there, which makes contact with the blood vessel on one side, and makes a contact with neuron and other side right. And shuttling energy molecules from bloodstream to the neuron, and then there is this purple cell which wraps around the axons of neurons, there's a oligodendrocyte the this sheath is a myelin sheath, and that gives you increased conduction connection velocity on the axon.

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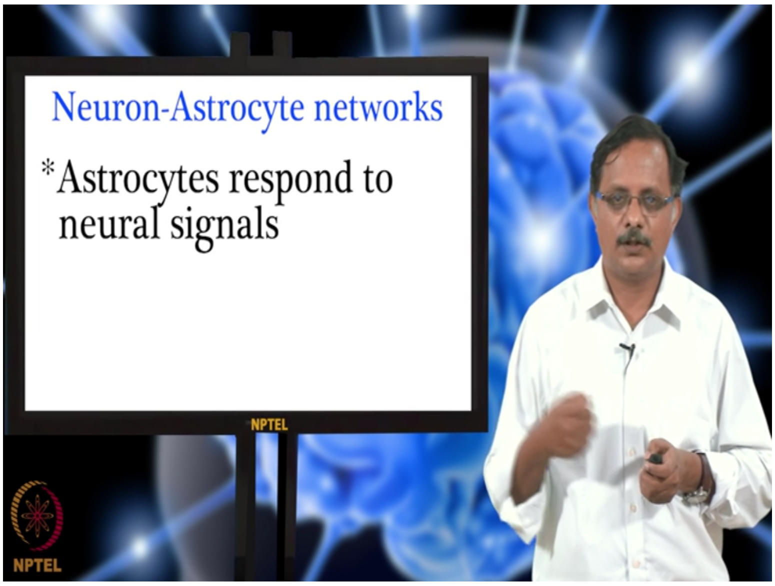

So, neurons and astrocytes talk to each other. So, for a long time like I said people thought that glial cells do some kind of a secondary or insignificant functions.

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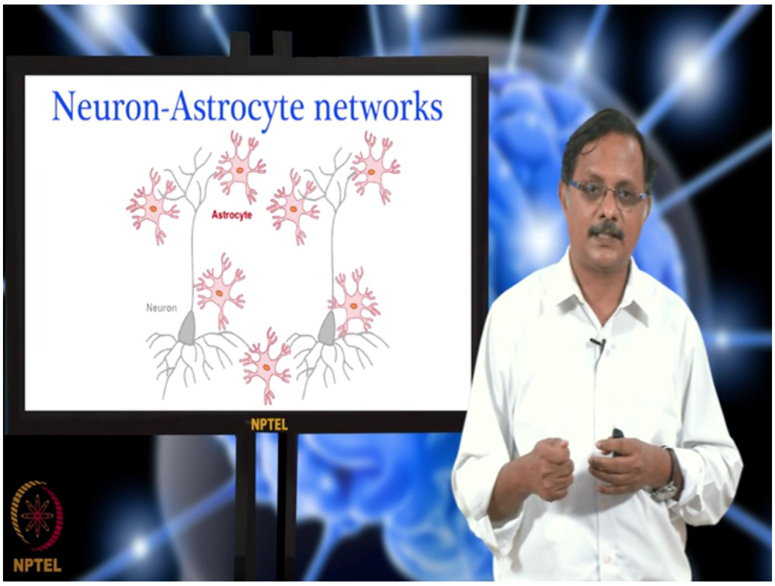

In fact, the word glia itself comes from Latin which means glue. So, people thought glial cells are just like glue that whose purpose is to keep the neurons in place, but actually people found that every active cells, they participate in neural signaling for example, it is been now known that astrocyte respond neuron signals.

Neurons can talk to each other by exchanging chemicals, but interestingly it is been found that astrocyte can also respond to those chemicals, they have receptors for these chemicals, and then they can process these signals, and they can also release chemicals which can act on neurons. So, they kind of get in to the loop of neuron communication cycles.

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So, astrocyte also regulates signaling across neurons. So, we have slits at 2 neurons a neuron A, and neuron B talking to each other across synapse. And astrocyte can send its sent foot, or what is called the presynaptic process, to wrap around the synapse and an eavesdrop on what neuron a is telling neuron B ok.

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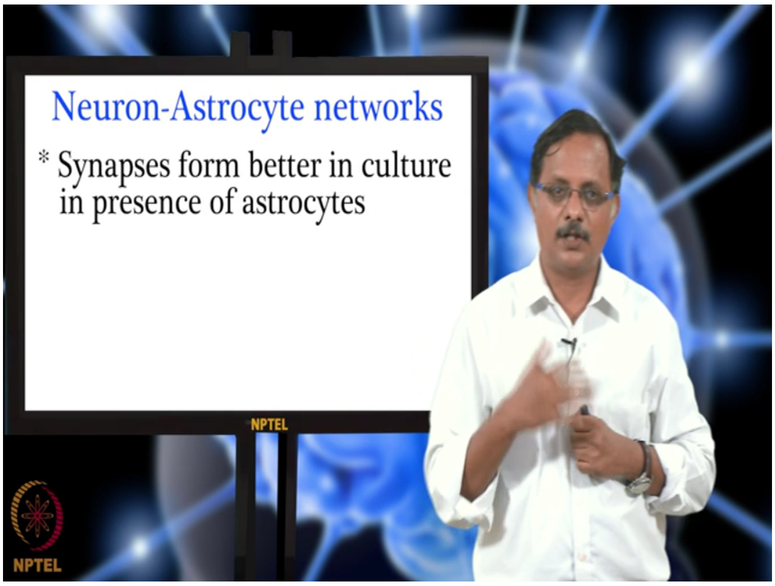

So, and also it is been found that synapses form between cultures in presence of astrocytes. So, acids are very deeply involved in both the development, and function of neurons and neural networks.

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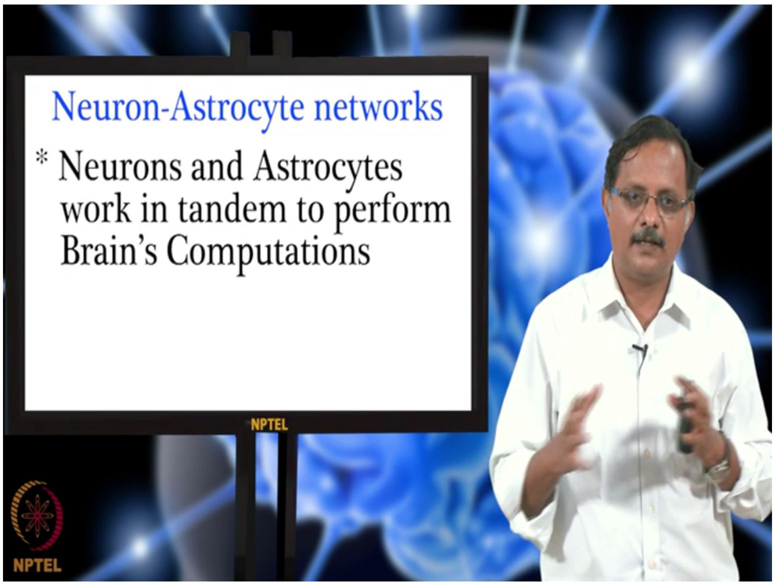

So now, the current thinking is in the field is that neurons, and astrocyte form in tandem work in tandem to perform brains computations. And neurons are not the so solitary heroes the red that are doing all the brains computations, neurons are working along with astrocytes right to perform brains computations. So, we have talked a little bit about the brain cellular constituents. Now let us talk about neural signal.

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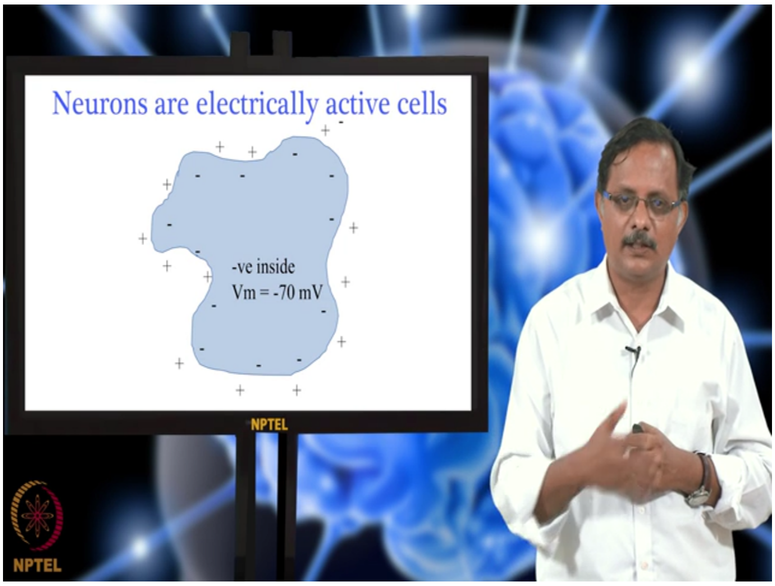

So, like I said already the neurons electrically active cells, and this signals are you know propagate along.

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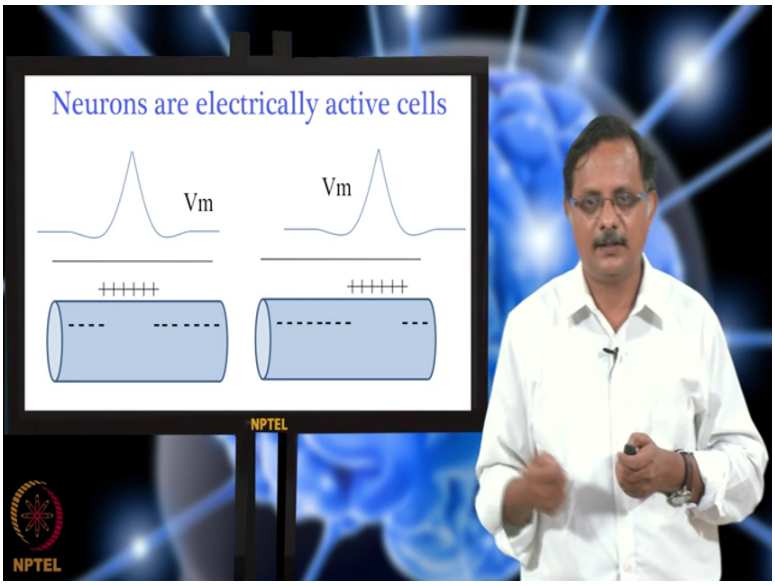

The fibers of the neurons as electrical waves.

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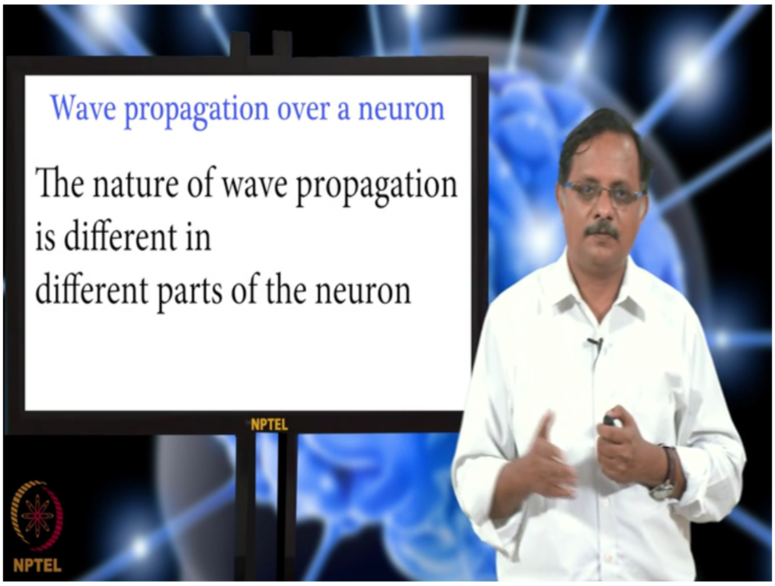

Now, here there's a little difference in the manner in which these waves propagate on the dendritic side, as opposed to axonal side.

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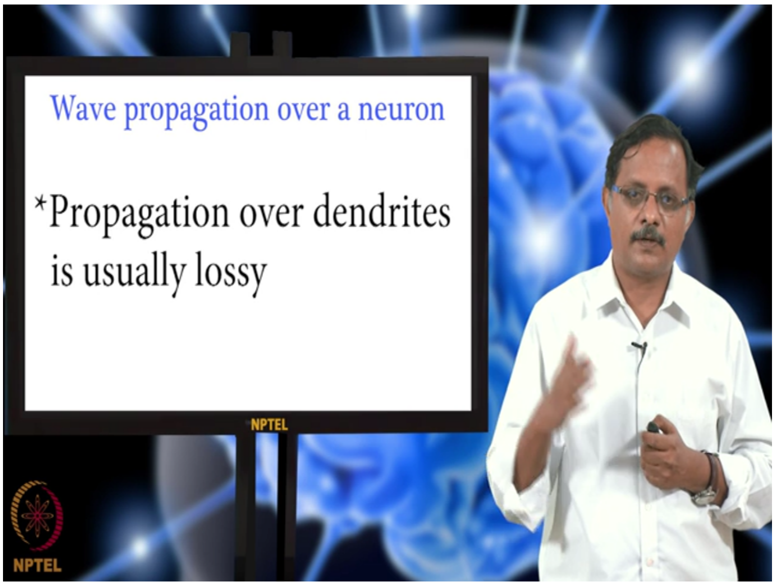

So, propagation over indeed dendrites is usually lossy that is you know you lose, and their signals lose energy as they run along their dendrites.

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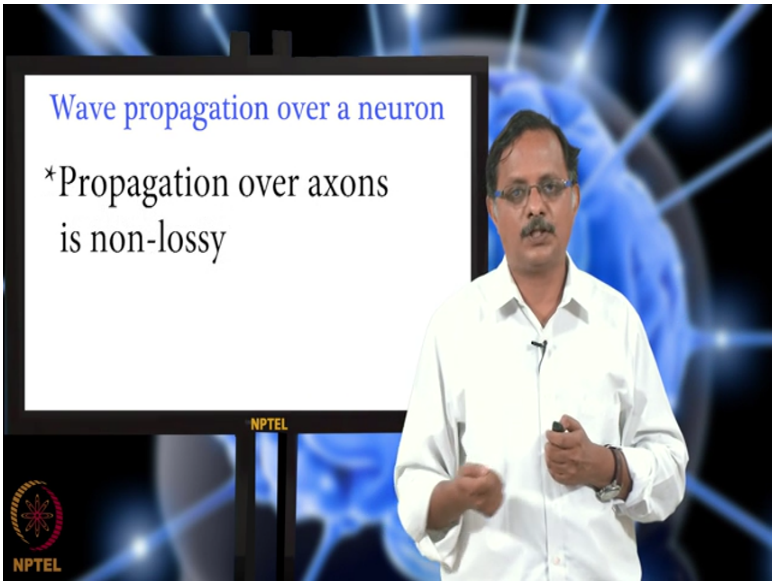

Whereas propagation over axons is non lossy. So, let us look at that.

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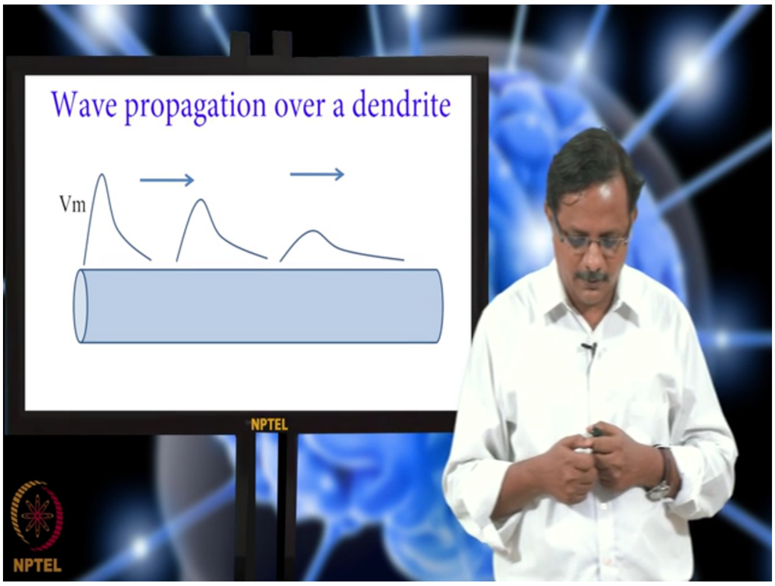

So, here is a cotton picture which shows a dendrite as a pipe, and then if you have a voltage wave. So, starting at the leftmost tip of this pipe.

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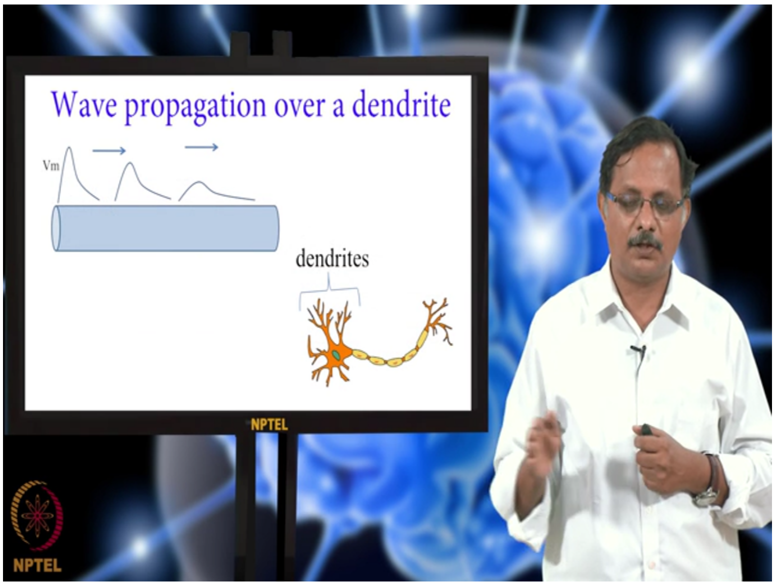

As it propagates on board is lose amplitude lose steam, and lose energy this will lose amplitude. And also it widens in time, because that is why it is lossy, and this kind of a propagation happens in the dendritic side ok.

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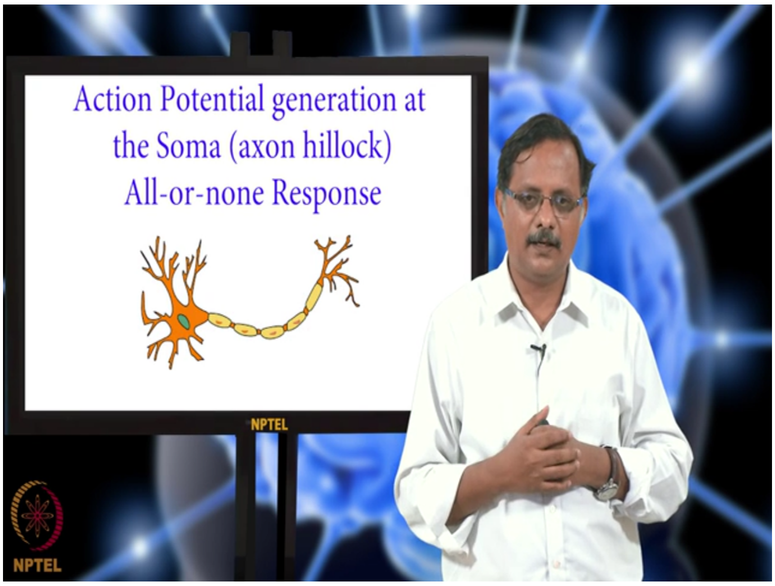

So, now let us see what happens on the in the cell body proper. So, to understand that let us imagine that you are injecting some current into the cell body.

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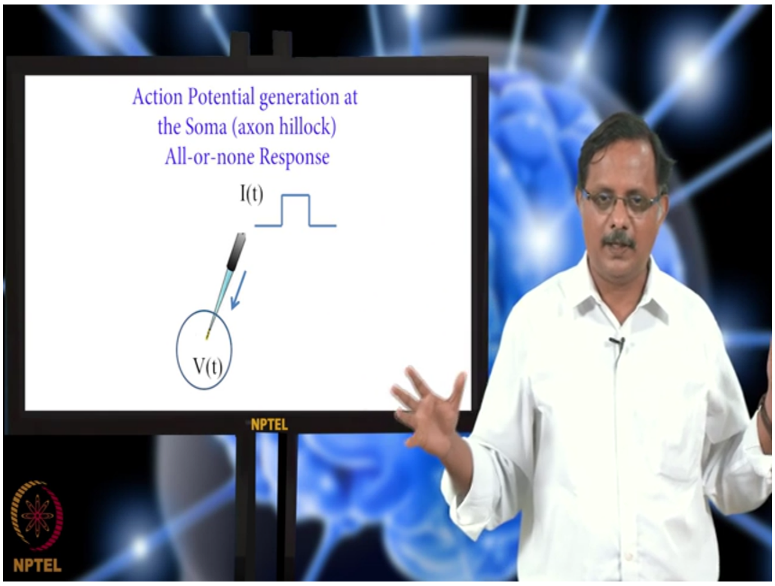

So, imagine that the so, forget about the arbors for a moment, and imagine cell bodies like a sphere like a little ball, and then you poke it with a micro electrode alright, and inject some current interior and let us say the current is a the current pulse. So, the I of t here is a pulse

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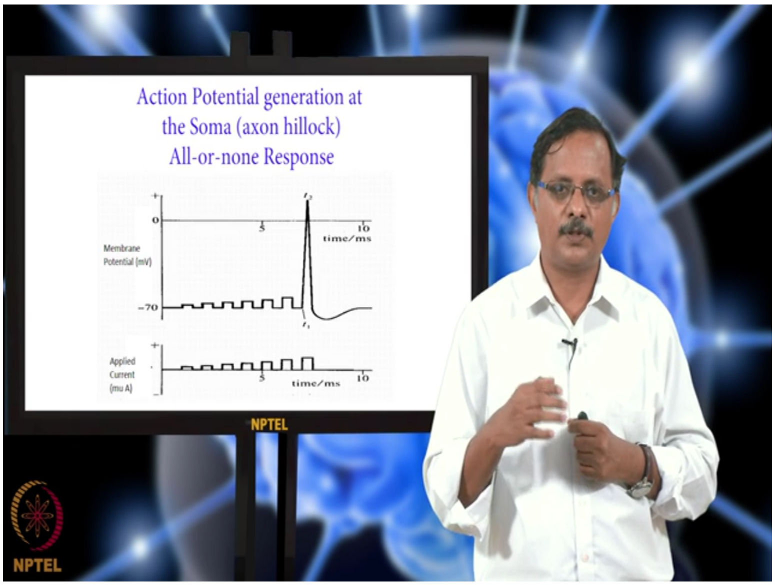

Now, what people have found is on something very special about a neuron is that when you give a current pulse that radial current pulse produces a small voltage response, in the membrane potential the injecting current you are injecting charge into the cell. So, that increases the voltage. So, when your pulse current pulse is small that produces a small upward deflection of the voltage as you can see in this graph.

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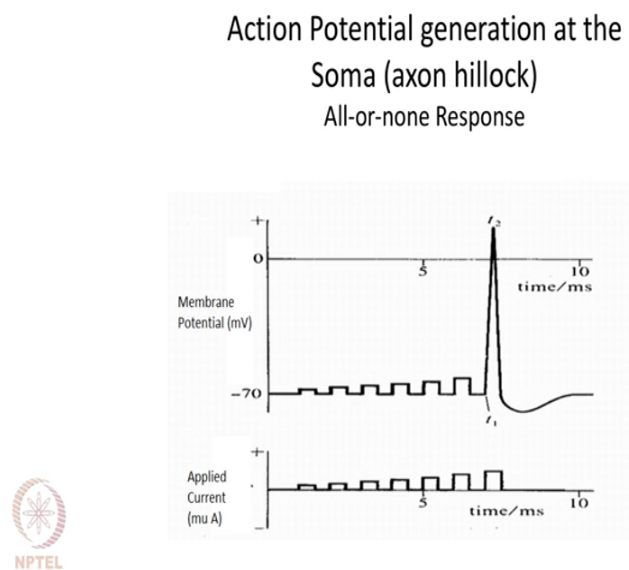

Whereas now you keep on increasing your you know current pulse amplitude as your amplitude increases the upward deviation of the membrane potential also increases progressively up to a point, but beyond a point when the current pulse x exceeds certain threshold value you see that the voltage also suddenly shows this large upward swing and that is action potential.

So, therefore, this kind of response is called an all or none response, because it is like as a current is increased until a point there is not much response or very little response in a neuron, but beyond a point when the current causes a threshold, suddenly it shows a you know huge explosive response, but therefore it is called an all or none response, and so the what we call action potential is actually a kind of an all or none response.

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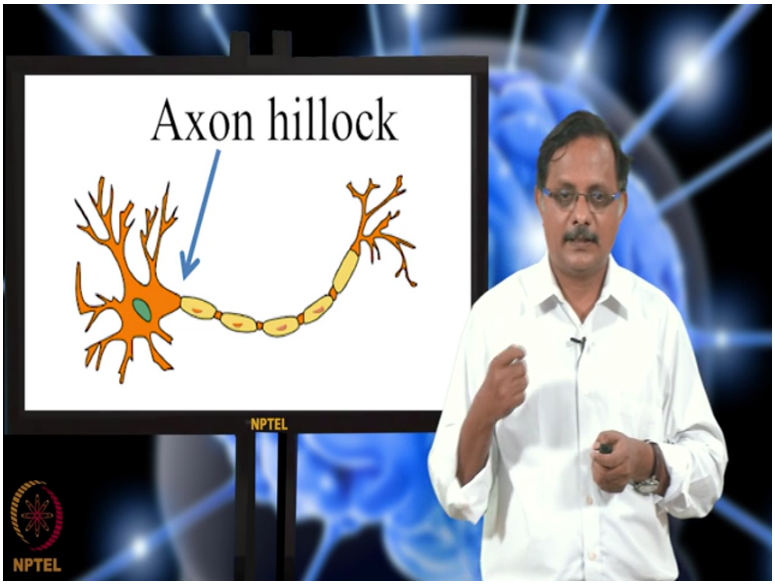

So, this all or none response is actually produce at the meeting point of the soma, and the axon that is the what is called the axon hillock, as you can see in this figure.

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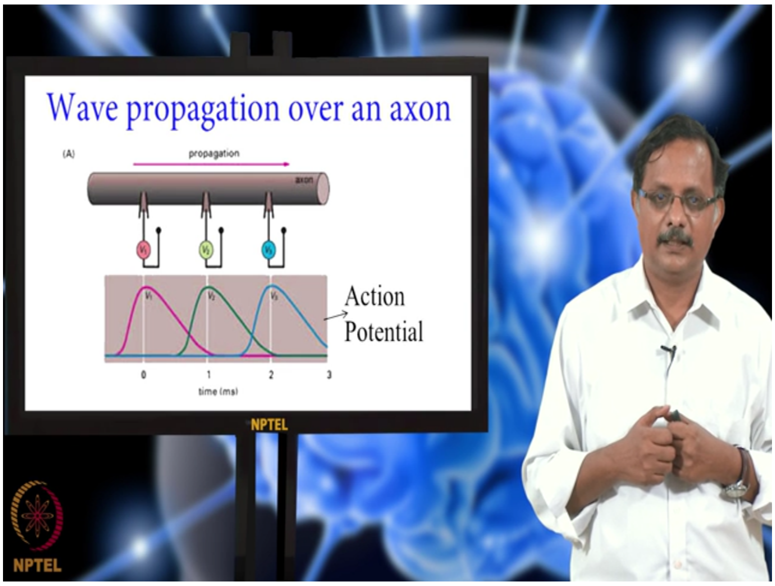

So, once the action potential is generated at this meeting point in the action, in the axon hillock it then propagates along the axon, as you can see in the cartoon picture at the bottom of this slide. And this action potential you know propagates along the axon, and in the top of the slide you can see this little in a kind of pipe along which the acceleration is propagating

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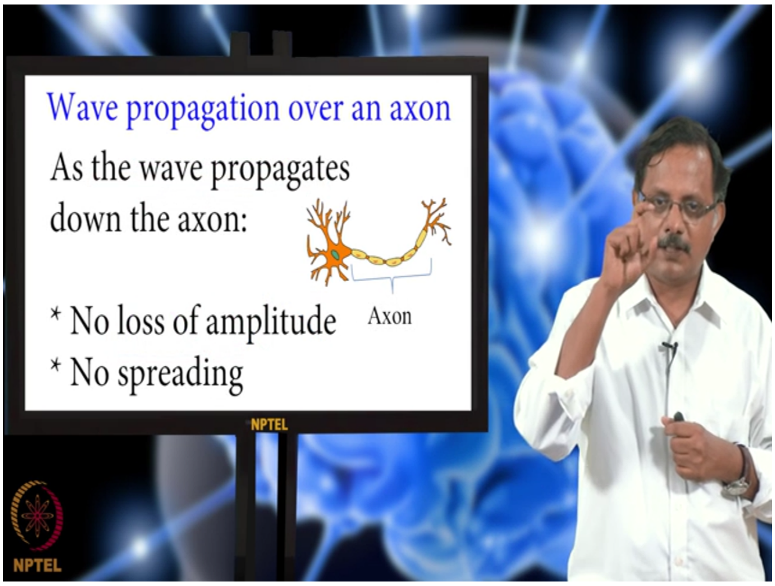

So, if you measure the voltage at various points along the axon, at every point the axon the action potential or the voltage wave has a fixed amplitude and width in time. So, therefore as the action potential propagates along the axon its shape is intact there is no loss of amplitude, and there is no spreading in time, but what happens on the dendritic side is totally different, and as it propagates on the dendritic side it lose amplitude, and spreads in time whereas, on the axonal side it is intact all right it does not lose amplitude or there's no spreading in time. We will see why this happens later on what kind of machinery that axon has and why does it happen all that will see in the next segment of this lecture.

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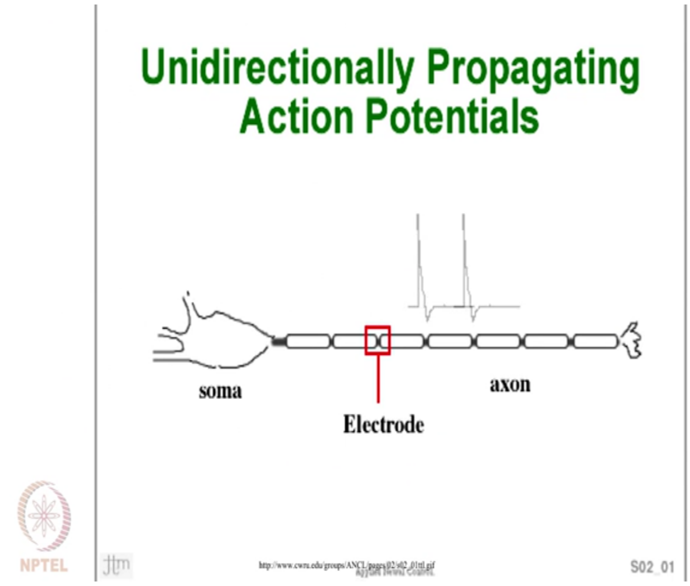

So, it is simple animation which shows how the action potential propagates along the axon. So, now we have come to the end of the axon at the meeting point of one cell, and the other cell and at this synapse.

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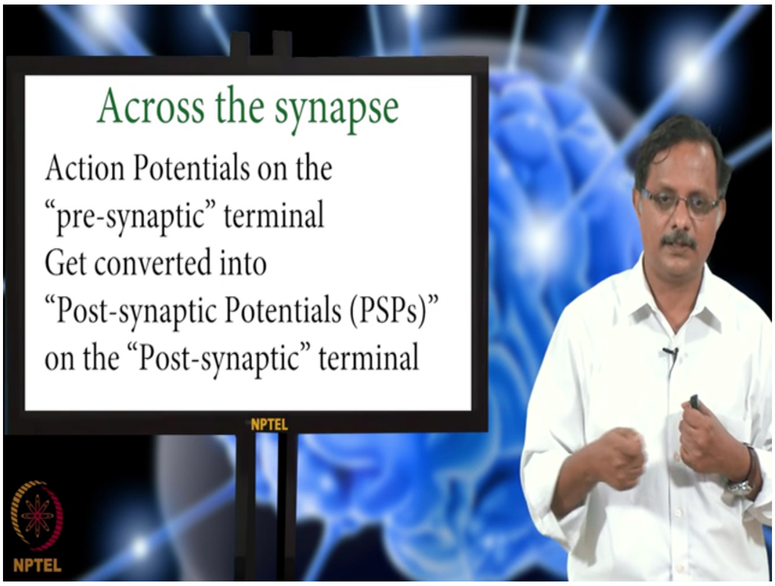

So, if you remember from our very first lecture, we said that the signal that goes from the presynaptic side to the postsynaptic side is a chemical signal. So, this signaling step which consists of transmission of a signal from presynaptic neuron to the postsynaptic neuron it is called neurotransmission.

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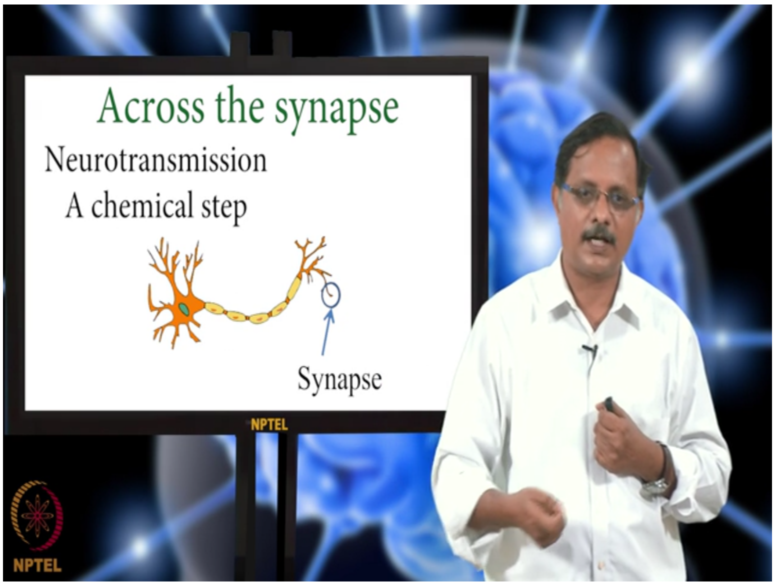

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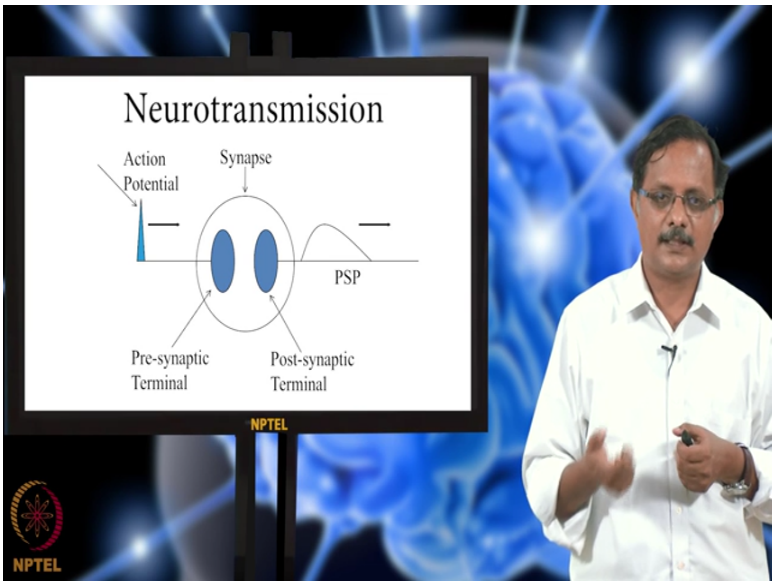

And it is a chemical step. So, in this step basically what happens is you have the presynaptic side of a neuron that is a called the presynaptic terminal, and then the postsynaptic side of a neuron called a post synaptic terminal these 2 come together at the synapse.

Now, on the presynaptic side right you have an action potential which marches down the axon, and arrives at the presynaptic terminal. So, at that point some chemistry takes place and will discuss that later on in the second segment of this lecture. So, chemistry takes place, and then the chemical is released by the presynaptic terminal.

And this chemical arrives at the post synaptic terminal by diffusing across this narrow gap of the synaptic cleft, and the chemical acts on the postsynaptic as terminal, and produces a voltage response. And this voltage response is called the postsynaptic potential for you know for obvious reasons, it is which is called PSP. So, the electrical signal on the presynaptic side the action potential comes to the synapse, it gets converted to a chemical signal, and the chemical signal is again converted to an electrical signal on the postsynaptic side, where it becomes another voltage wave which is called a postsynaptic potential.

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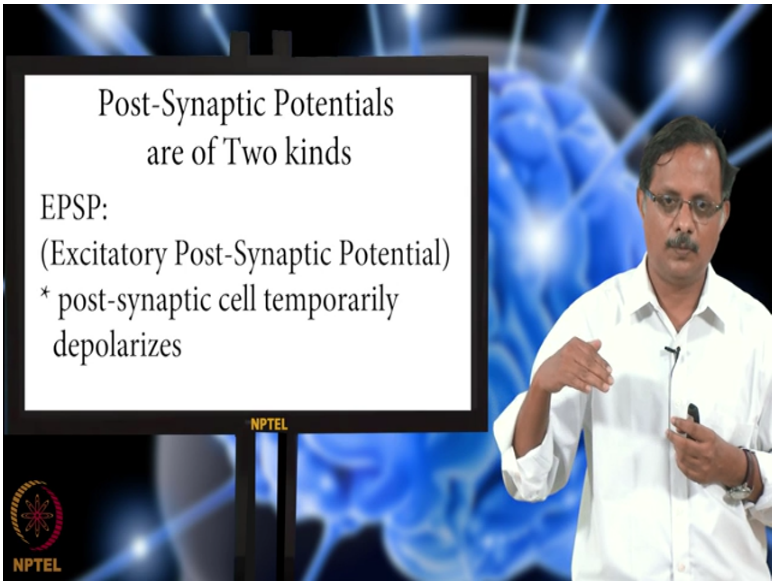

Now, these postsynaptic potentials are of two kinds, there are what are called excitatory postsynaptic potentials, where the postsynaptic brain becomes more positive than what it normally is that is it comes grows higher than minus 70 millivolts, or what is called it depolarizes and there is the IPSP or the inhibitory postsynaptic potential, where the postsynaptic cell temporarily hyperpolarizes; that means, its potential goes below the normal value of minus 70. So, let us see how that looks.

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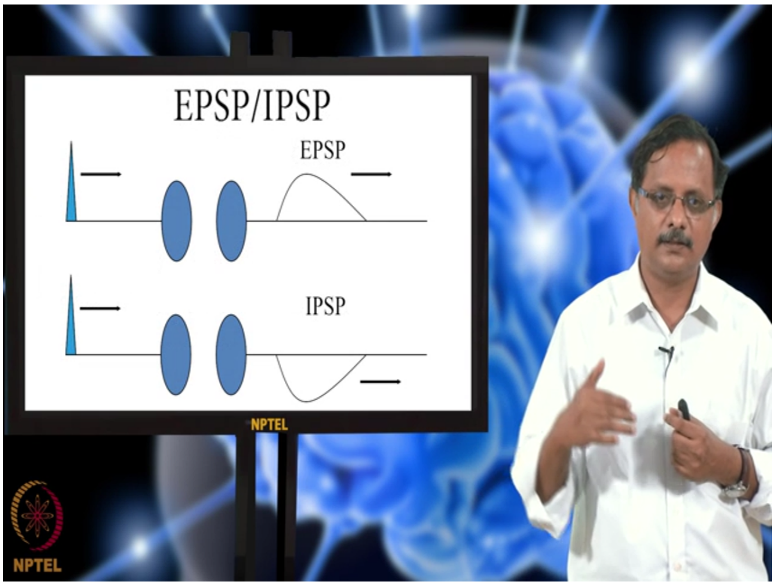

So, you have the two cases here. So, in the in the case shown in the top that the action potential comes in and which produces a PSP which is positive right above the baseline value of minus 70 millivolts, it is called the EPSP excitatory postsynaptic potential.

In the figure below you have the action potential coming in which gives converted into again a chemicals step, and then the response on a postsynaptic side, where the EPSP this time is negative therefore, it is called the IPSP or inhibitory postsynaptic potential.

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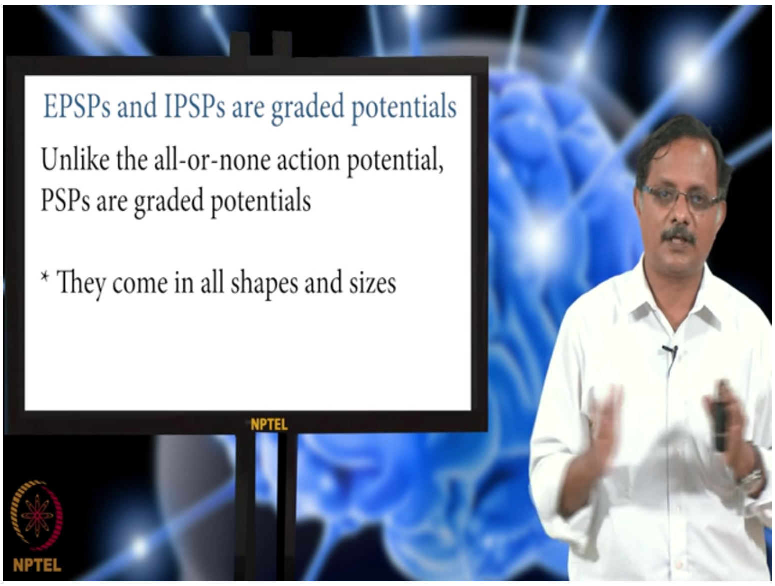

Now, the PSPs both EPSPs, and IPSPs are graded potentials; that means, unlike the action potentials, which have a fixed size and shape the EPSPs come in all sizes shapes, and sizes they can be positive or negative.

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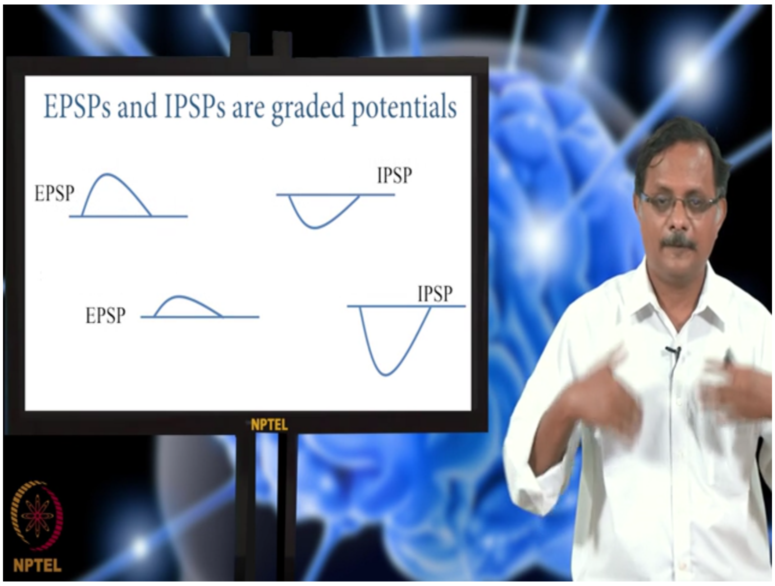

They can be small or big as you can see some of these cartoon diagrams on this slide ok.

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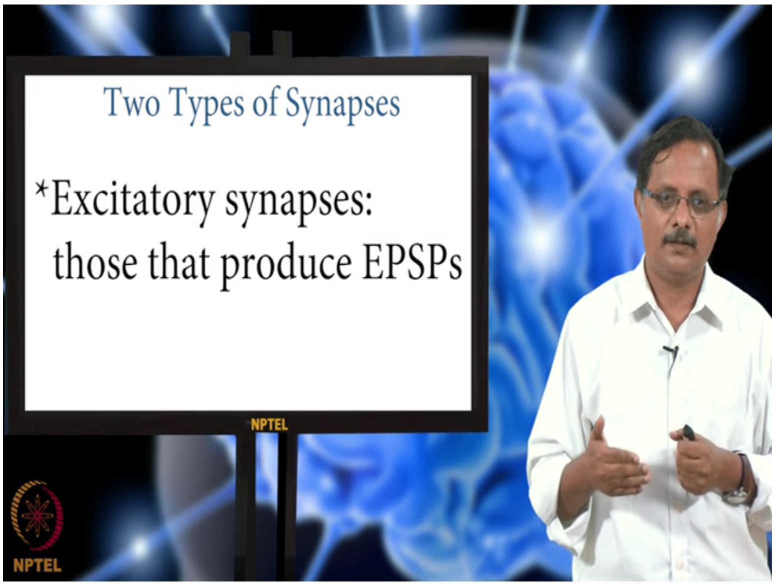

Now, when do you have an EPSP and when do you have an IPSP. So, that depends upon the nature of the synapse. So, there are two kinds of synapses, there these excitatory synapses where when you get an action potential on the input side, you get a EPSP on the output side, or in the postsynaptic side.

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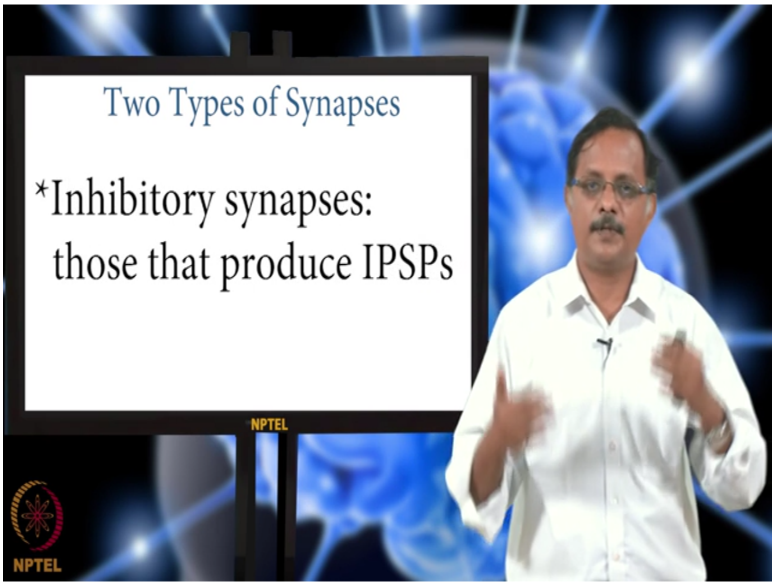

And there are these inhibitory synapses, where you get an IPSP on the postsynaptic side.

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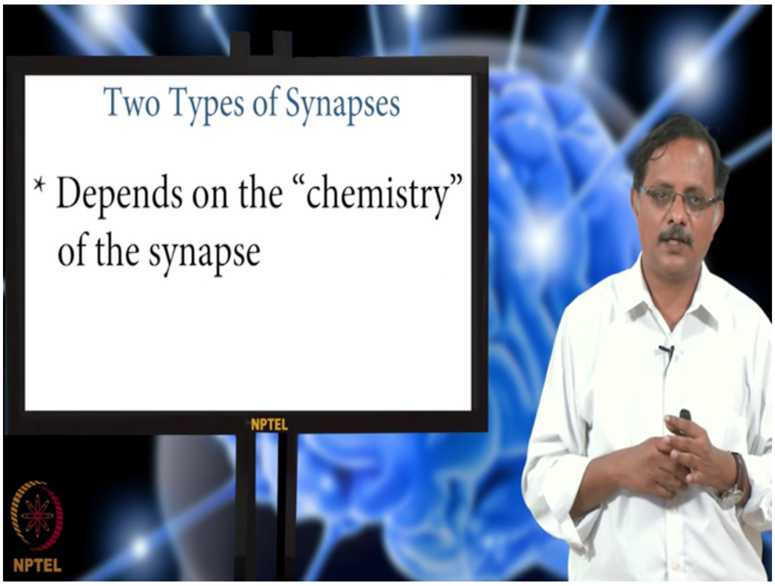

So, please remember that the signal on the presynaptic side is always the same.

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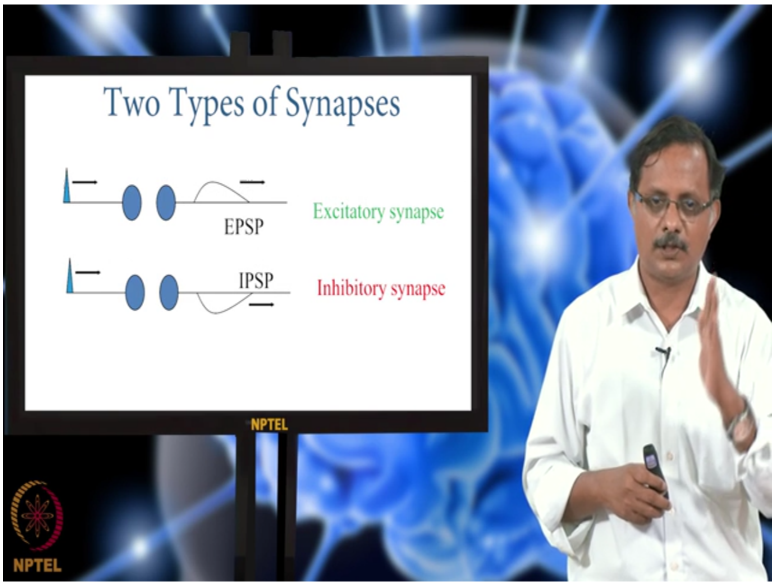

The action potential is always positive it is an upward deviation from the baseline voltage, but on the postsynaptic side things are different, the voltage though if the PSP can be positive or negative that can be EPSP or IPSP. So, in case of excitatory synapse in EPSP in case of inhibitory, synapse you have an IPSP.

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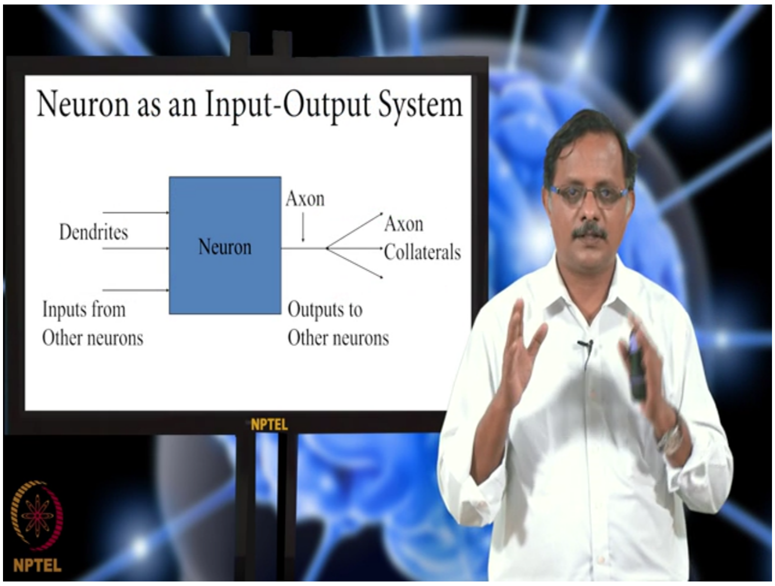

So, now if you want to summarize this. We said neuron is like an input output system. So, the neuron somas like a black box, this is input from dendrites all, in the form of PSPs which are obtained at the which are generated at the level of synapses, and all these

PSPs propagated downwards, towards the neuron and that is at the pointer at the level of neuron, you have action potential generated, and in which propagates down the axon to the axon collaterals. And at the synapse it jumps to the other neuron.

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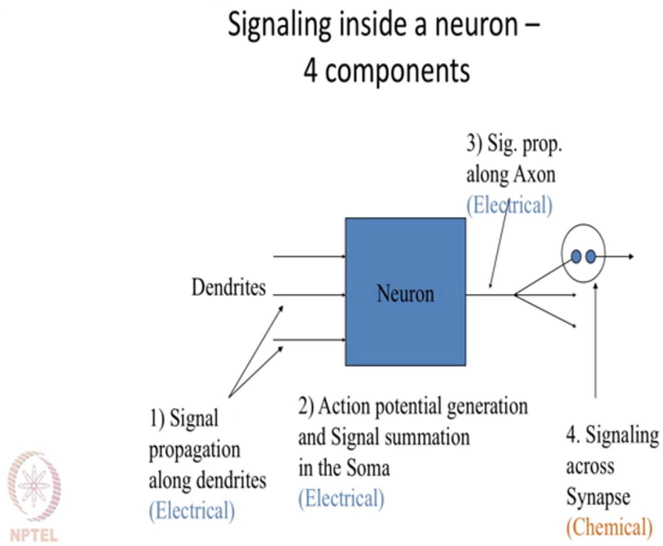

So, you see that the of these 4 signaling components 3 components are electrical components for example, signal propagation learn propagation along dendrites is completely electrical, then the summation of all these signals in the soma is also electrical, then signal propagation along the axon which is in form of action potentials is also electrical only the 4th step, well signal jumps across synapse is chemical.

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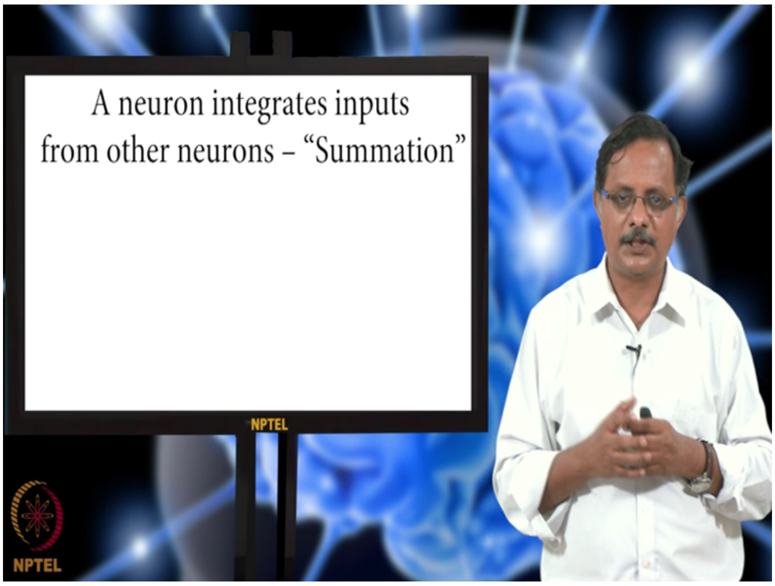

I just briefly mentioned before the neurons summate different inputs coming from different neurons.

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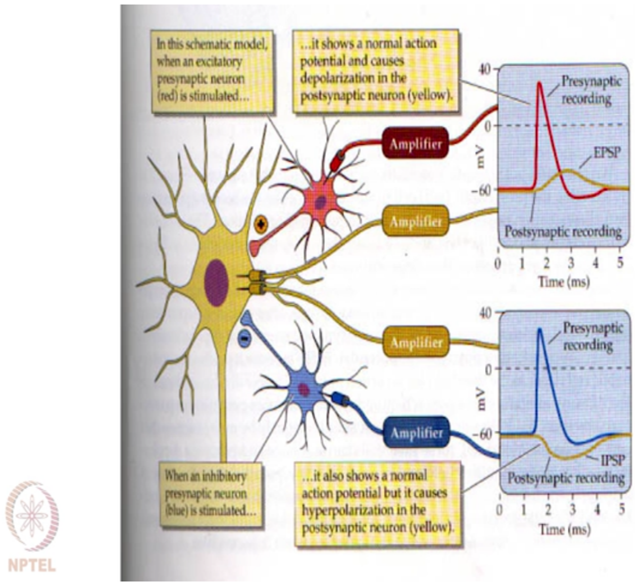

For example in this picture you see that large yellow neuron, it is input from the red neuron and which is which happens in a excitatory neuron. So, the synapse should be in the red neuron, and the yellow neuron is an excitatory synapse. So, it is indicated by the plus sign over there, and synapse between the blue neurons which is inhibitory neuron, and the yellow neuron, is inhibitory synapse, which is indicated by the negative sign over there.

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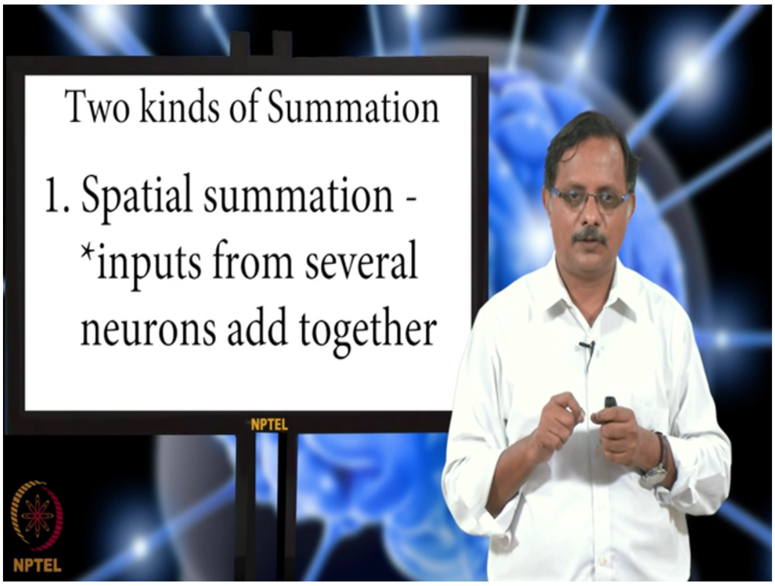

So, this summation that we are talking about in the in the soma is of two kinds, there is special summation. Where it adds up signals coming for a cross or mini dendrites.

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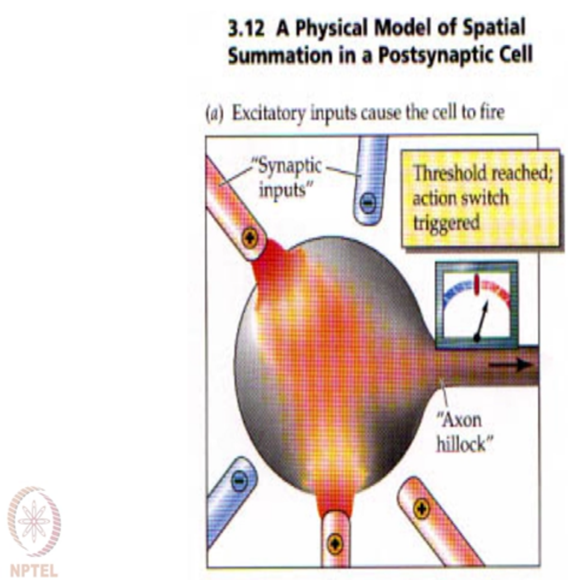

So, how does that work let us look at these simple schematics? So, you have this big red region which is the soma of a given neuron, and it receives input from many other cells. So, you see that the red input lines are like you know excitatory inputs, and the blue input lines are inhibitory inputs. So, in this case 2 of the excitatory inputs are active, and they are injecting you know currents, and increasing the voltage of the soma.

So, therefore, on the whole the soma membrane potential is higher, and probably this neutron will become excited, and send action potentials.

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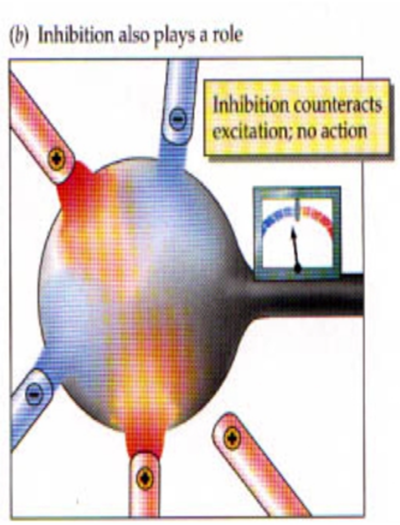

But suppose consider the case when the inhibitory synapses are also active. So, in this picture you see that 2 excitatory synapses are active, and also 2 inhibitors synapses are also active. So, 2 red's and 2 blues they all you know act you know, and the blues are counteract the reds, and therefore on the whole there is not much change in the voltage of the neuron. So, neuron may not fire.

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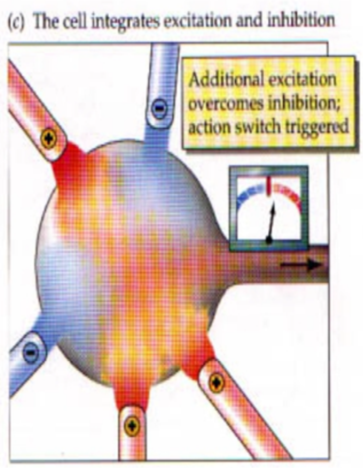

Look at the situation where there are 3 dendrites which excitatory are active and only 2 dendrites which are inhibitory they are also active. So, the on the whole you have you know 3 against 2 and so, the membrane potential of the soma, maybe it sufficiently increases to become excited, and then it produces action potentials, and these propagate down the axon.

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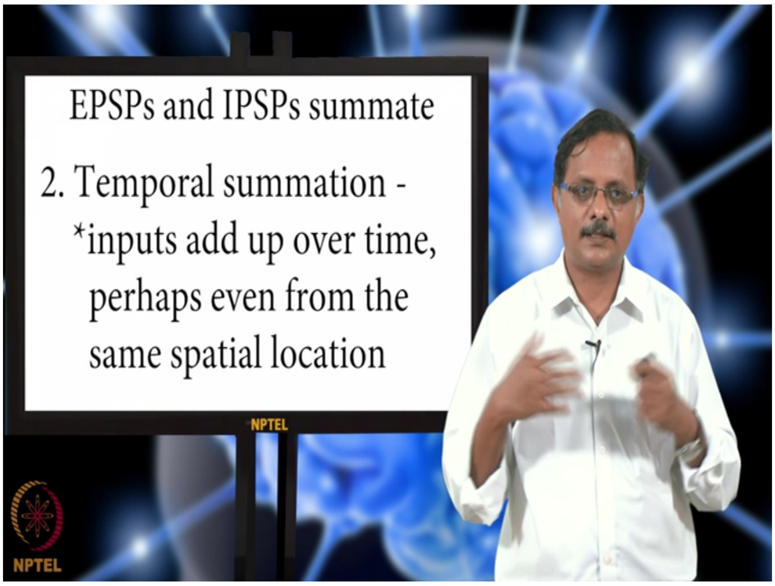

So, that is the kind of thing that that is called a spatial summation. Now there's a different kind of summation it also occurs, where summation occurs over time inputs add up over time, and I just save in the Spain same spatial location. How does that work?

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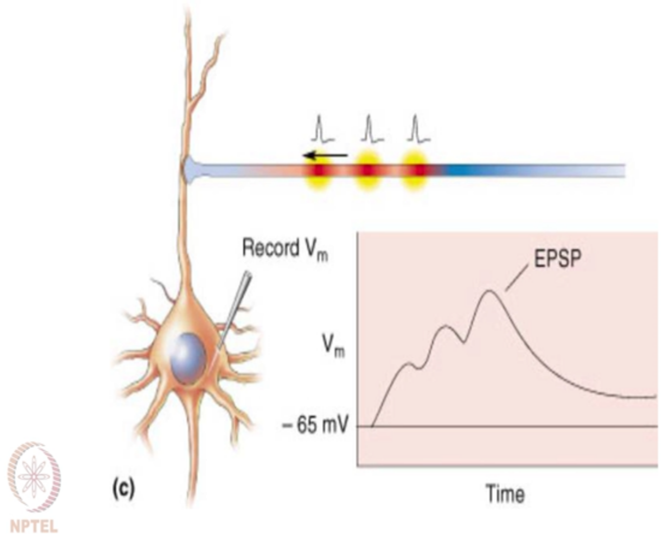

So, in this picture you see a neuron actually you can see the dendrite of a neuron vertical this, and there is the axon of another neuron the parallel horizontal line, which makes a contact with a dendrite of this neuron. Now the axon is carrying multiple action potentials a whole the whole train of action potentials are running along the axon, and each and all these action potentials arrive at the synapse, and produce a PSP on the postsynaptic side.

Now, we have seen that the axon potential is a very sharp spike, but the PSPs are much longer at running over like in maybe 100s of milliseconds. So, when the axon potential hits first axon potential hits, the dendrite it produces a long PSP, and by the time that PSP dies off completely this it is the dendrite is hit by the second action potential.

So, therefore, the PSP that is produced by a second action potential. Now builds up on top of the previous PSP, and then the dendrite is hit by the third action potential. So, by the time the second PSP is has died off right the third action potential has hit this synapse and therefore, the PSP that produced by it rides on top of the previous 2 PSPs. So, because of this the 3 PSPs add up to produce a huge very large EPSP. So, this kind of a submission which happens at the same synapse, but by integration or summation through time is called temporal summation ok.

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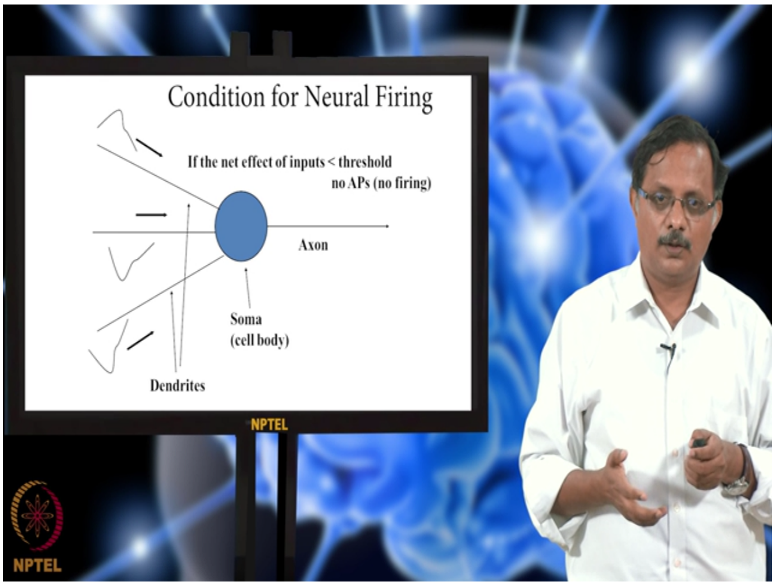

So, to wrap up what happens in a neuron is you have the cell body, and you have it has multiple input lines. In this schematic you can see there is only 1 PSP coming in there is a topmost line, and then so because what you seeing on the left side is of the dendrites. So, the there are multiple inputs lines, and multiple PSP is coming in the top 1 is an EPSP, and the bottom 2 are IPSPs. So, in this case the IPSPs dominate, and therefore the inhibit the neuron it does not get excited, and there is no action potentials that are released.

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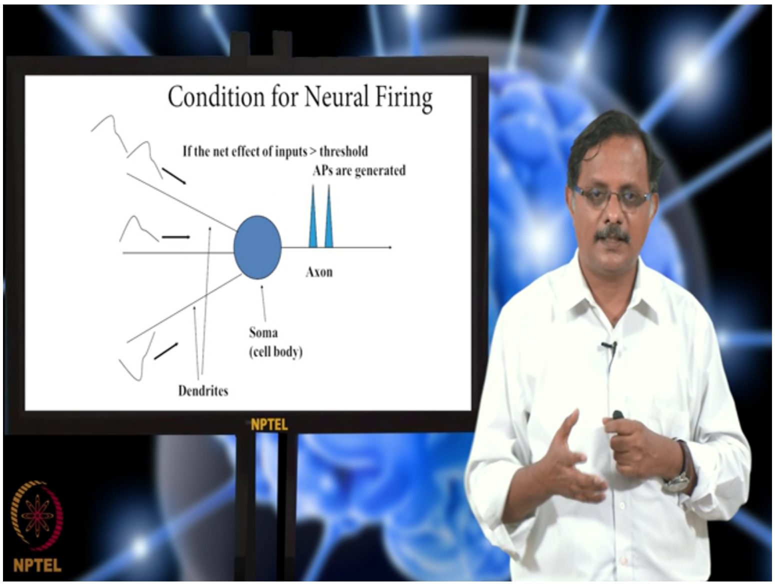

Whereas the second schematic you can see that the topmost line is carrying 2 waves to EPSP waves, and the middle line is carrying one EPSP wave, in the bottom was 1 is carrying like a single IPSP wave.

So, in this case the EPSP is dominate. So, all these waves when they arrive at the soma they tend to excite the neuron, and it produces action potentials which propagate along the axon. So, this is an in summary how a neuron functions, and how a neuron generate signals.

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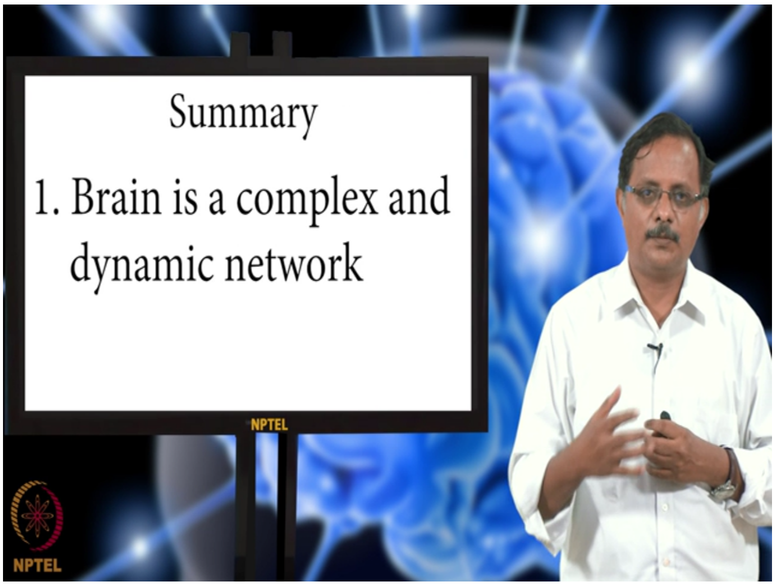

So, in summary we can say that brain is a complex and dynamic network, it is not only very large network the network is very complicate, it is very labile it is varying constantly.

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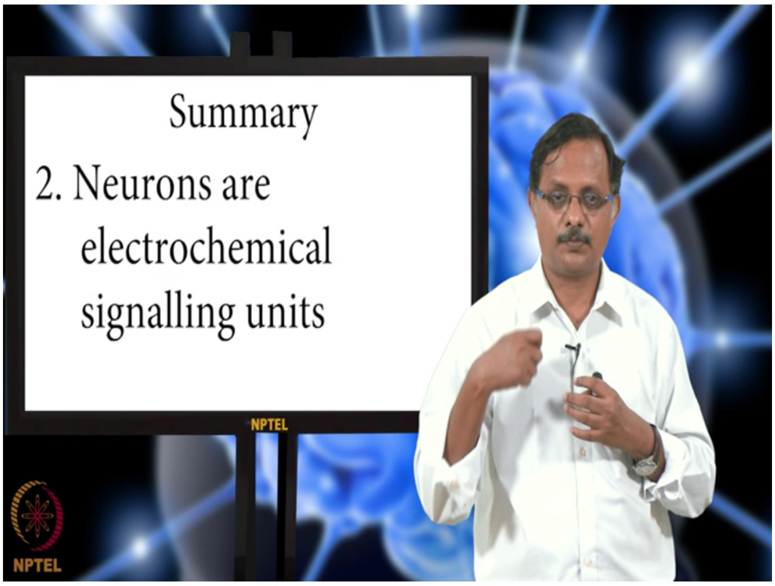

And also neurons produce signals. Now because neurons are electrochemical signals, they can generate and send signals both electrically and chemically.

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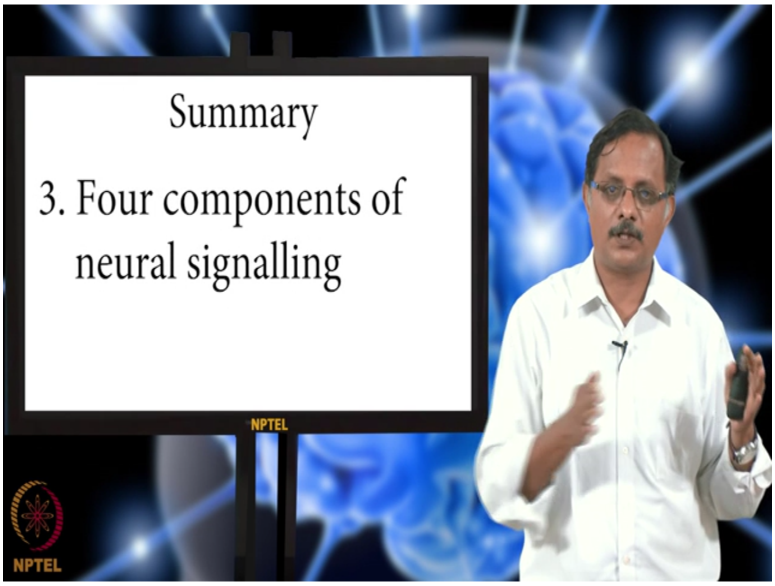

And there are four components of neuron signaling three of the components which occur within the neurons body are electrical signaling components. Whereas, a signal that jumps from one neuron to another is a chemical signaling step.

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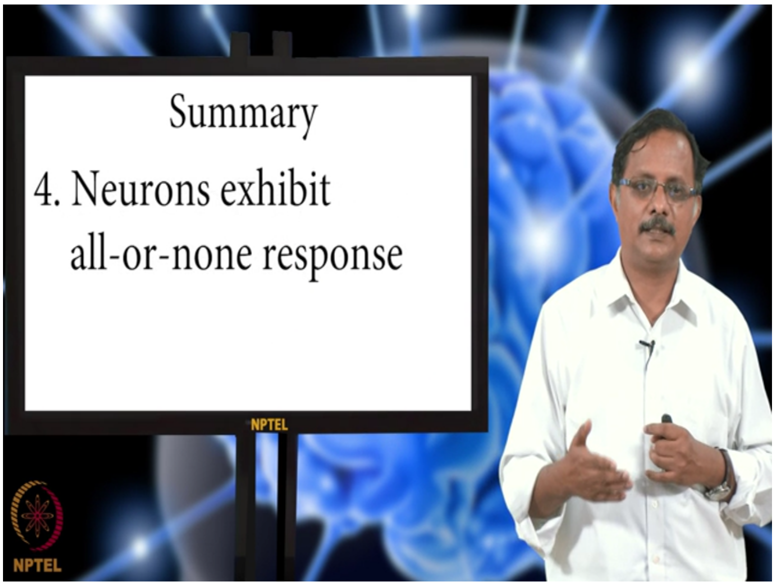

And neurons exhibit these all other than response, in the form of action potentials that is as a respond or not respond there is nothing this it is not a graded potential, it is not a graded response whereas, we have seen that the PSPs, both EPSPs and IPSPs are graded response.

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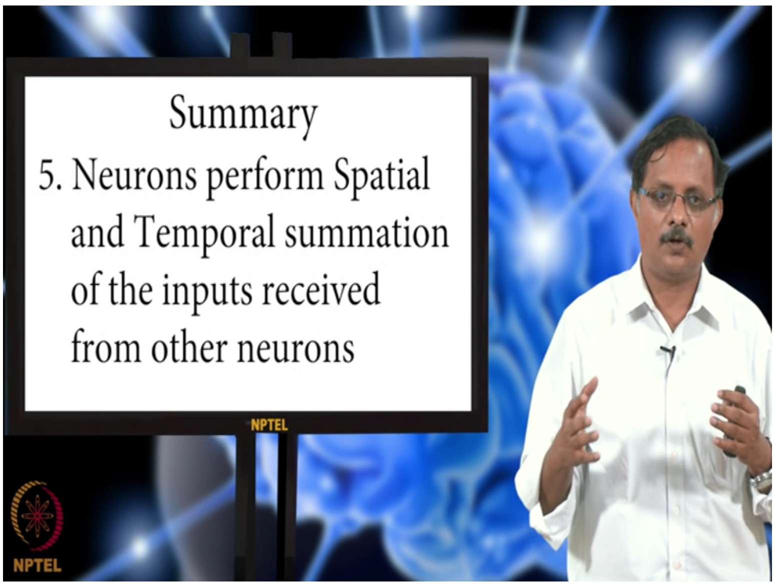

And neurons perform a temporal, and spatial summation of the inputs receive received from the other neurons. So, in this segment of the lecture, we have looked at a kind of a very simplified outline of what kind of signaling occurs in a neuron, but we did not discuss how these signals are generated what is the molecular, and (Refer Time: 34:00) machinery that generates these kinds of signals.

Because I thought it is it makes it easy if we just look at the outline first, and then go deeper into the various mechanisms, and see how this signals are generated. Now because neurons signaling is a very big subject. So, quite a complex subject if it straight away going to the molecular mechanism it looks all complicated you know it is the chance of getting lost. So, we thought that it is easier to look at the outline for us, and then go deeper into it the next segment of the lecture.

Thank you.