**Introduction to Brain and Behaviour**
**Professor Ark Verma**
**Department of Humanities and Social Sciences**
**Indian Institute of Technology, Kanpur**
**Lecture 03**
**Neurons**

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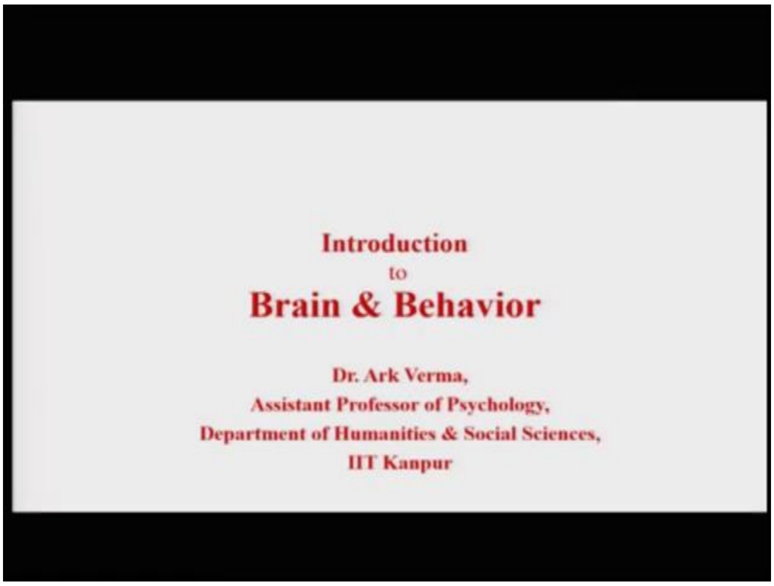


Hello, and welcome to the third lecture of the course introduction to Brain and Behaviour. I am Ark Verma I am an assistant professor. Hello, and welcome to the third lecture of the course introduction to Brain and Behaviour. I am Ark Verma I am an assistant professor of psychology at the Department of Humanities and Social Sciences in IIT Kanpur. I am also attached to the interdisciplinary program and cognitive sciences at the Institute.

In the last two lectures, we have talked very briefly about some of the background developments that led to formation of this interesting field called Cognitive Neuroscience. In the first lecture, we talked a little bit about the developments in neuroscience specifically, then we talked a little bit about some of the developments in psychology and eventually we also talked a little bit about some of the rudimentary earlier methods that were used or would be used in Cognitive Neuroscience.

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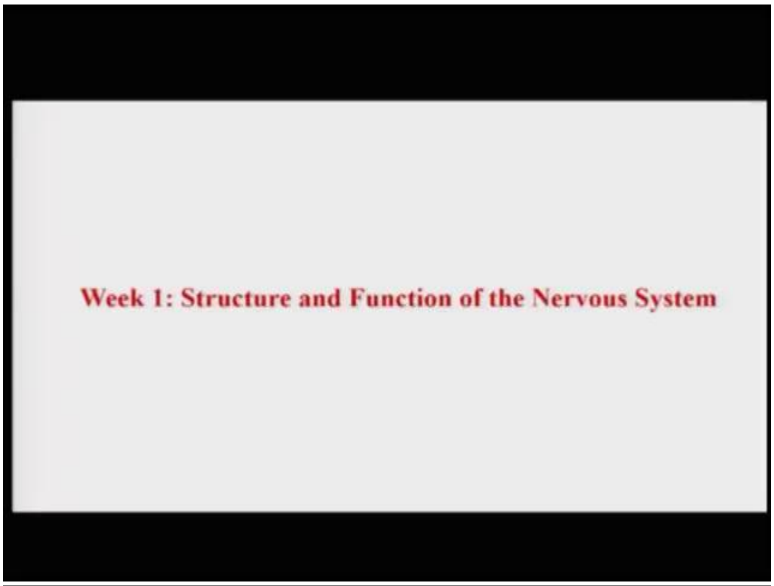


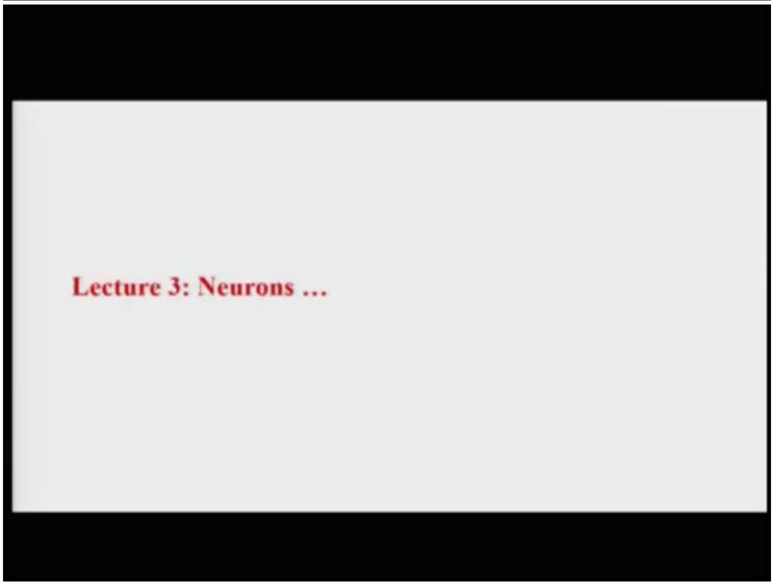


And today's lecture onwards, we will already start talking a little bit in detail in very short pieces although about the structure and the function of how the nervous system is organized. So, the first lecture in this series is the third lecture of the week, and it will basically talk a little bit about neurons. So, I immediately jumped to what neurons are?

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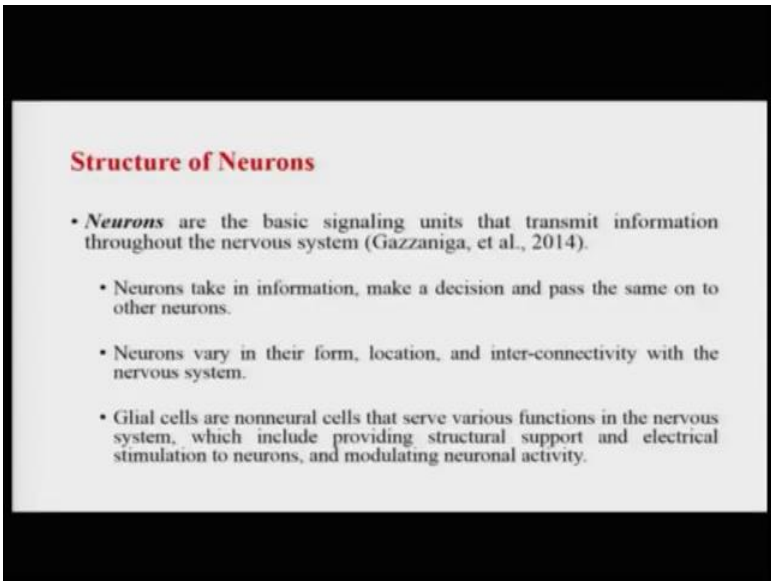


Now, neurons are these basic signaling units or the simple cells that that combined to form the brain, but we will talked about them as a signaling units that transmit information throughout the nervous system. So, they are the cells that are mainly responsible for generating and transmitting information in reaction to any kind of physical or chemical stimulation that is that may be available.

So, neurons take in information, they make a decision about whether this information has to be passed further or not pass further and so on, they make a decision and then they pass the same on to the other neurons. We will talk about them in these things in detail going further, but I am just giving you a brief idea.

So, neurons also vary in their form, in their location where all they are existing, and the patterns of interconnectivity within the nervous system. So, there are probably, you know, neurons of different kinds and shapes across different parts of the brain and the entire nervous system.

Another interesting kind of cells that are available within the nervous systems are Glial cells, although which are non-neural cells, but there is a very important functions like providing structural support and electrical stimulation to these neurons, and also sometimes modulating the electrical activity throughout these neurons.

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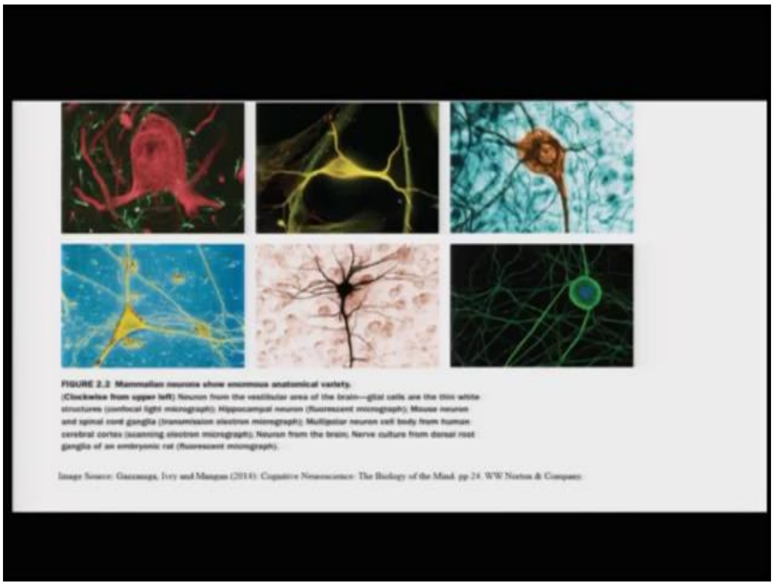

Let us move further. This is just a bit of an idea of different kinds of mammalian neurons that have been documented, you can say for example, see on the top left as hippocampal neurons, mouse neurons, spinal cord ganglia, and so on. So, this is this is something which is just as a bit of a demonstration source from Gazania’s book.

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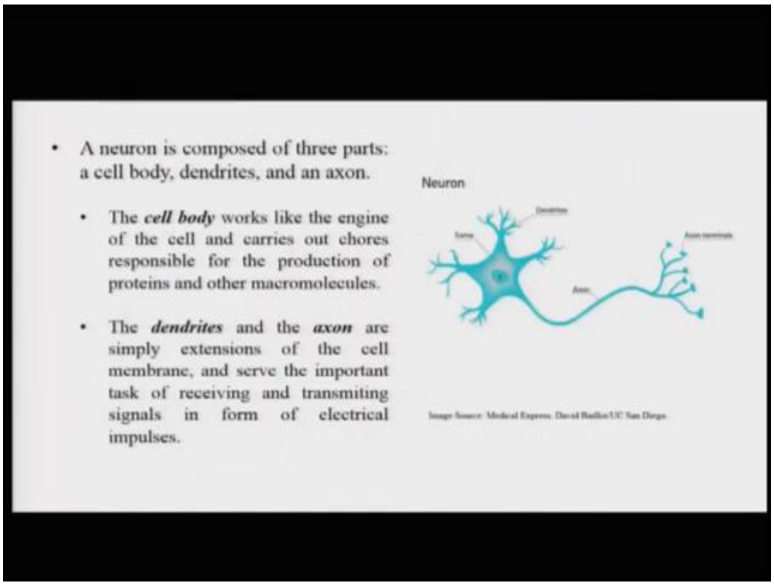


Now, just in keeping things slightly simple. A neuron has basically 3 very important parts. One is the cell body that you can see in the center, it is called cell body or Soma. Then you can see these projections around the cell body which are called dendrites, you can see this long fibre which is called the axon at the end of this long fibre are these terminals, which are called the axon terminals. I will talk to you about, what each of these do now?

So, the cell body is like the engine of the cell of any cell for that matter, which carries out chores like the ribs, you know, right the production of different kinds of proteins, and other macromolecules which are responsible for the metabolism that is carried out in the cells. The dendrites and the axons are just extensions of the cell membrane, but they serve very important functions of receiving and then transmitting this electrical signal throughout the body of the neuron or to the other neurons.

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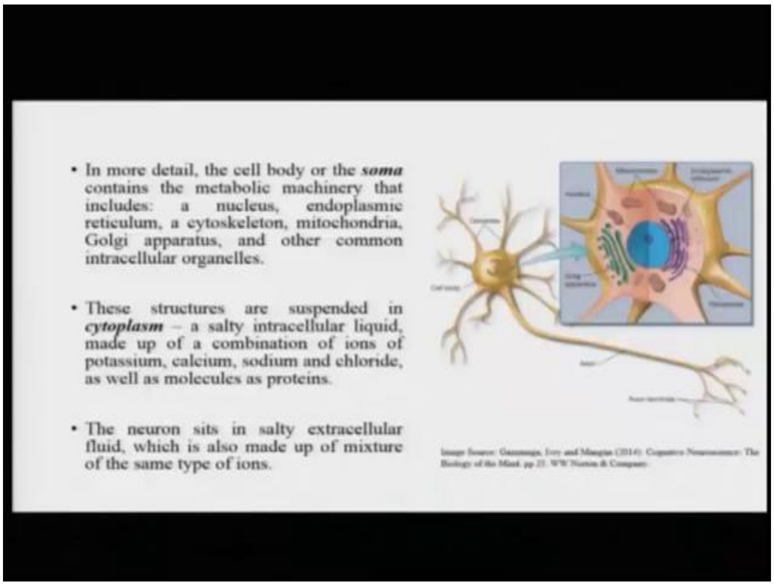


Let us go in a little bit. Let us go in a little bit of more detail. The cell body or the soma as they call it, contains the metabolic machinery of the of the cells, so it includes nucleus, the endoplasmic reticulum, cytoskeleton, mitochondria, and the Golgi apparatus and other kind of common intra cellular organelles that you might already be aware of from your biology class.

Now, these structures are suspended in this salty intracellular liquid called a cytoplasm, which is composed of ions of three main kinds of molecules as some proteins as well, these three molecules are very, very important you should remember them. They are calcium molecules, sodium molecules, potassium molecules and chloride ions. So, all of these ions combined to form this intracellular liquid called the cytoplasm.

Now, the neuron also is resting in this extracellular environment or in this extracellular fluid, which is also made up of a mixture of the same type of ions. So, inside and outside is very similar material is the same fluid material, which is composed of these ions which are of potassium, sodium, calcium and chloride.

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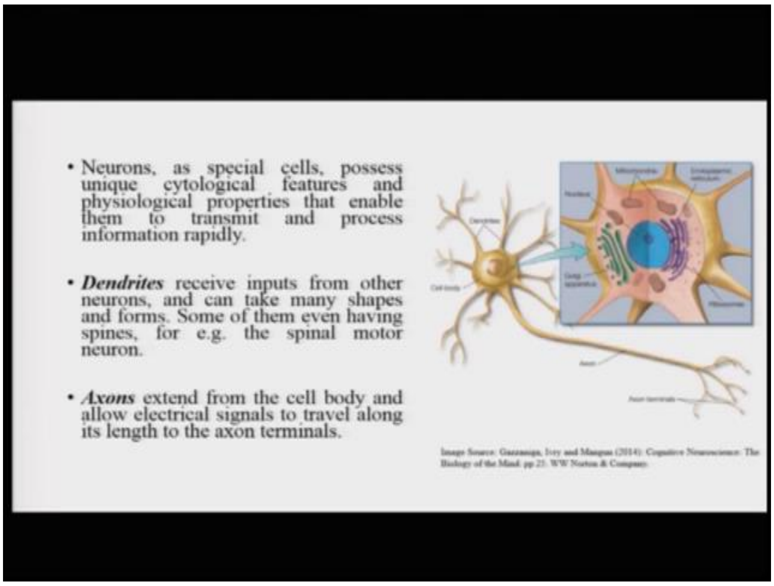


Now, neurons, as they are very important they are special cells, they possess unique cytological and physiological properties that enable them to transmit and process information rapidly. Now, when I am saying information at this point, you should just make a mental note that I am talking about information in terms of chemical and electrical activity, how how does that really play out, we will see in detail moving further.

The dendrites, these projections that you can see on top of the cell body are basically responsible for receiving inputs from other neurons. And they receive these inputs and because they have to receive these inputs, they can take any kind of shape you basically if you look into, if you go on Google and just you know try and find out different types of shapes that dendrites take you will be amazed.

And then similarly, there is this this long fibre the axon that you are seeing, the idea of… the responsibility of the axon is to sort of allow the electrical signals that are generated or received from other neurons to you know, to let those electrical signals travel along the cell body and then transmit them to other neurons.

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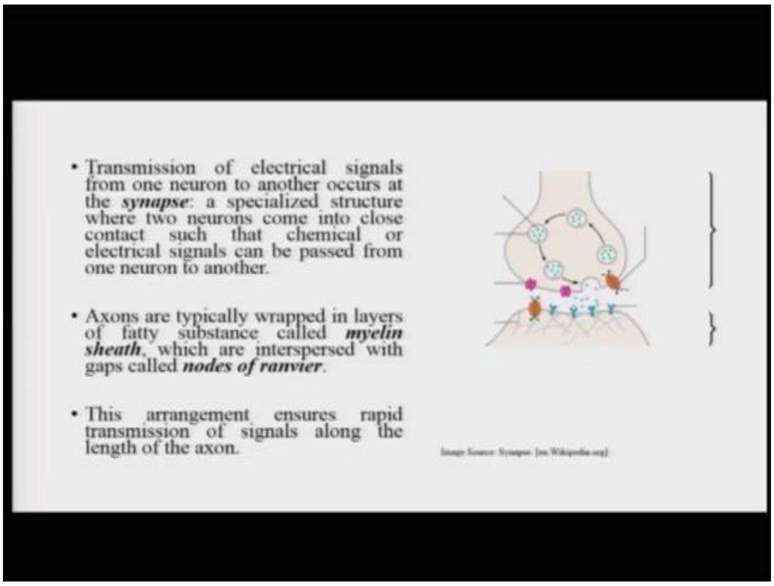


Now, this now the transmission of these electrical signals from one neuron to the other happens at a particular site called the synapse and you can see this here in the figure the synapse is a specialized structure, is a specialized place where two neurons come close enough to each other such that any kind of chemical or electrical messages or signals can be passed to and to and fro.

So, the idea is typically there is the organization is like one of the neurons that is passing the signal is referred to as the pre-synaptic neuron and the other neuron that is receiving a signal is called post-synaptic neuron. But we will talk about that, as we move further on, for now, you have to just remember that synapse is the place where this transmission of electrical or chemical signal from one neuron to the other is going to take place.

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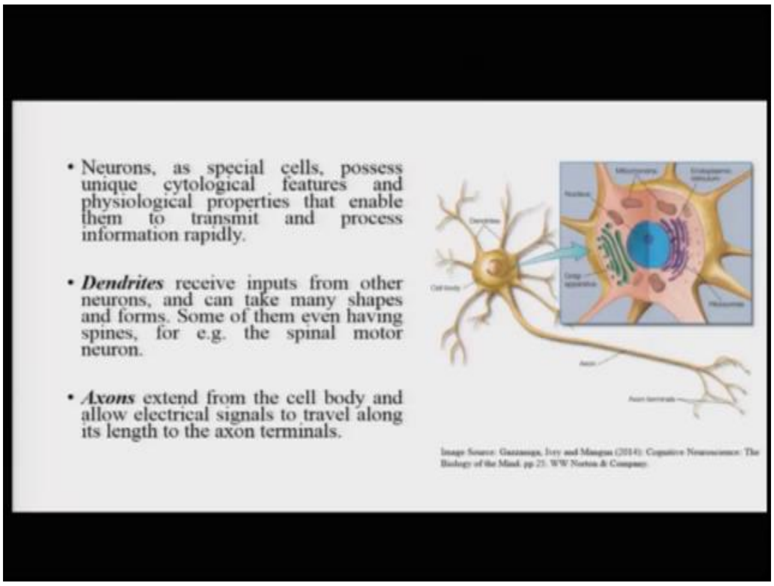


Now, there is a very important property of these axons that we sort of want I sort of wanted to mention is that this layer of axon is covered with a fatty substance with a layer of a fatty substance, which is called myelin. And this layer is called the myelin sheath and this myelin is basically there are, there are these gaps at regular intervals in this myelin sheath, which basically, what it does is?

It ensures the rapid transmission of the electrical signal along the body of the axon, this sort of an insulating material that that allows the electrical signal to fast to pass very quickly from the top of the axon to its bottom to where the axon terminals lie. So, this is this is something again, which is something that you should remember. Now, let us come and start discussing a little bit about the signaling that I have been talking about.

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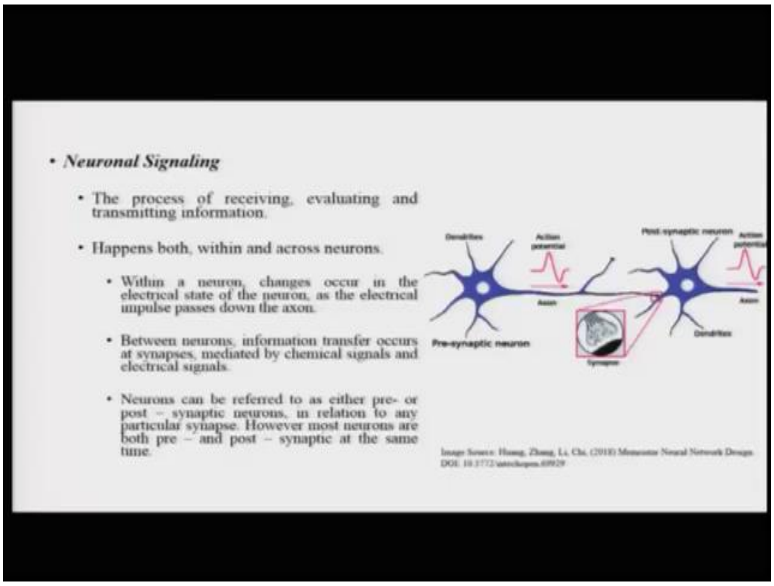


Now, the process of receiving, evaluating and transmitting information is referred to as neuronal signaling. And it happens both within neurons and across neurons. So, for example, a signal could be generated within the cell body within neuron and then it could be passed on to other neurons via transmission throughout the length of the axon. And it could basically be just received from another neuron and passed on along the cell body, along the axon to other neurons. So, it can happen across neurons as well as within neurons.

Now, when this has to happen within the neuron the changes in the electrical state of the neuron will have to happen and will create a sort of an electrical impulse that would then pass down the length of the axon. So, this is when the transmission is happening within the neuron. However, mostly this electrical activity needs to be communicated with other neurons as well.

So, when it when this neuronal signaling is supposed to happen between the neurons, what happens is? Information or this signal transfers, basically across at the synapse, and is mediated by chemical and or electrical signals.

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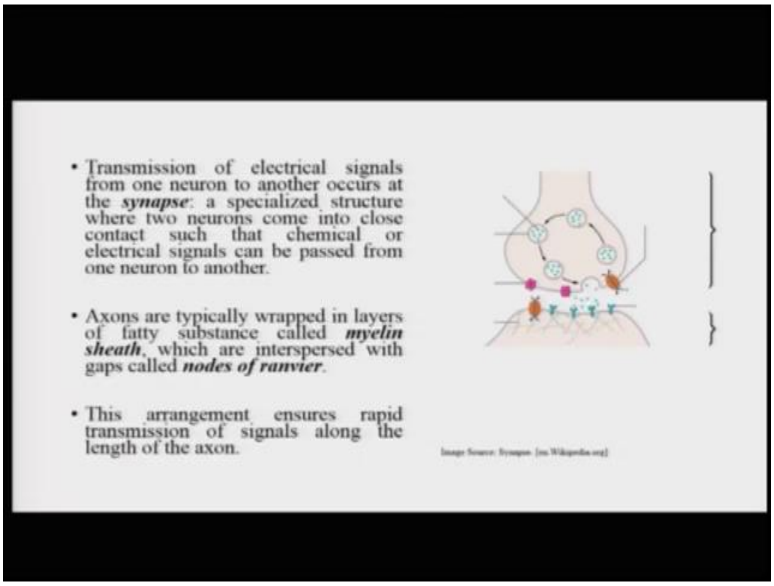


So basically, the exchange of information that we saw in the figure in here, this is basically an example of some kind of information exchange chemical or electrical happening at the synapse between couple of neurons.

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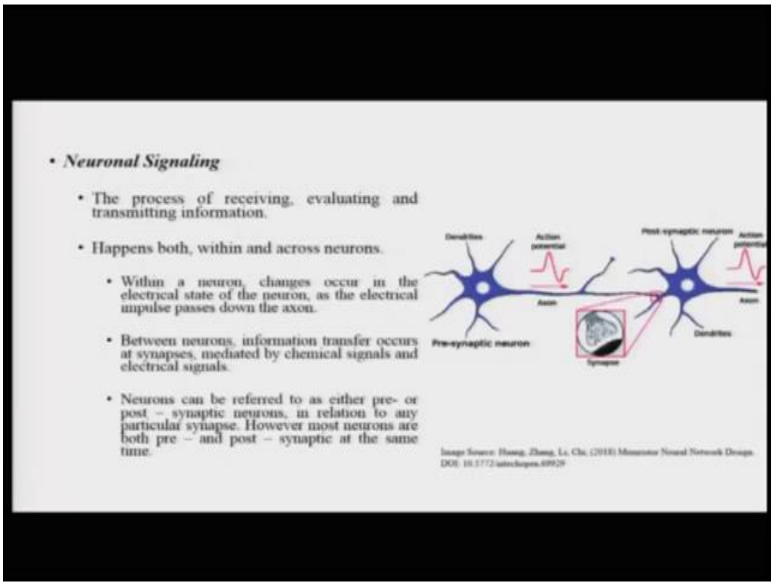


Neurons can be therefore as I was saying can be referred to as either presynaptic or postsynaptic neurons. But again, as I would like you to note is that the neurons are do not just have single connections, I mean they might be connected to many neurons at the same time. And in that sense every neuron can be looked at as both pre and postsynaptic neurons at once because it is probably receiving a signal from another neuron through its dendrites and then passing on the same signal to another neuron through its axon terminal.

It is presynaptic neuron for one case, and a postsynaptic neuron in the other case, so it is basically relative to what signal processing you are talking about, a neuron can be considered pre or postsynaptic here. Now, how is this signal generated? This thing that I have been talking about what is this whole concept electrical and chemical signal being generated. Let us start talking about it. And over the first concepts we can sort of discuss here, is this whole concept of the membrane potential.

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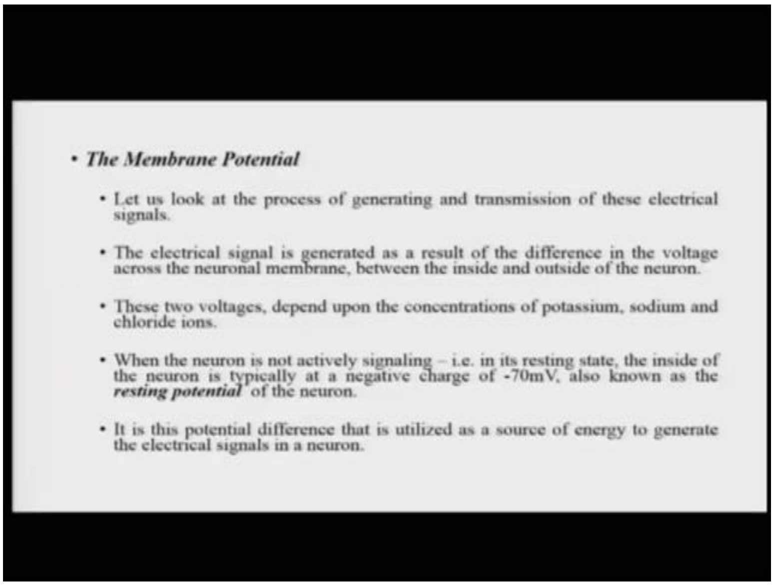


So, let us look a little bit more closely at the generation and transmission of this of these electrical signals that we are talking about. Look at some of the basic facts that we have to begin with. So, an electrical signal is generated as a result of the difference in the voltage across the neuronal membrane.

So, this neuronal body there is a voltage difference across this body and also between the inside and outside of the neuron. So, if you remember the extracellular material is also cytoplasm like material inside is the cytoplasm material, which is both of these are constructed with the same kind of ions.

So, these two voltages basically and this creation of these voltages, the inside voltage and outside voltage depend upon the concentration of the kind of ions potassium, sodium, calcium and chloride ions, the different they exist in different concentrations inside and outside of the neuron and this difference in concentrations basically leads to build up of these voltages.

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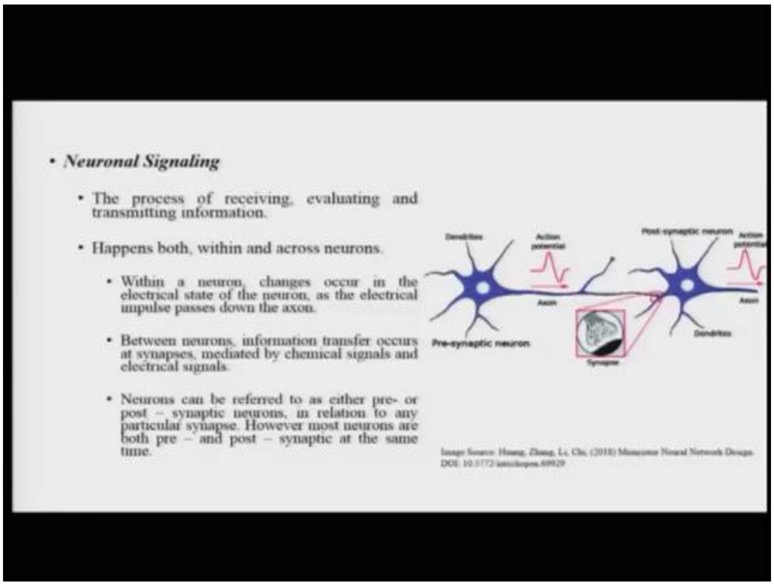


Now, when a neuron is not actively signaling or passing information from itself to the other neuron or electrical signals.

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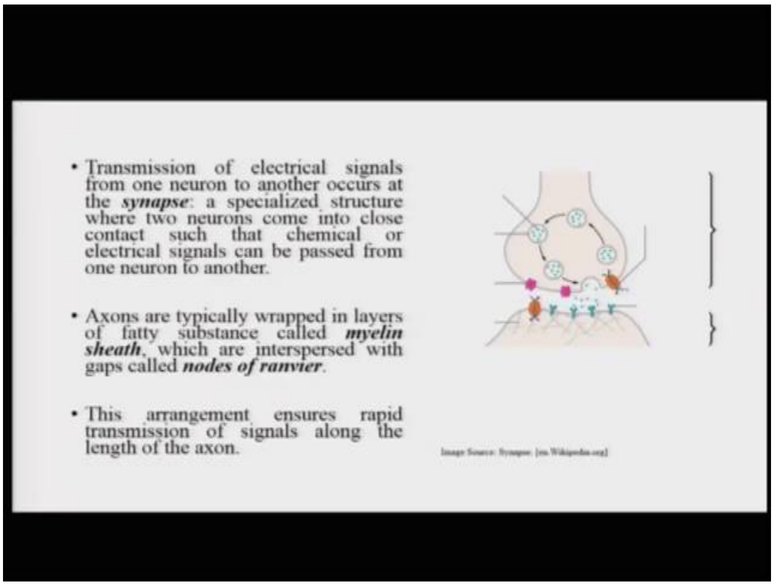


So, basically the exchange of information that we saw in the figure here, this is basically an example of some kind of information exchange chemical or electrical happening at the synapse between couple of neuros.

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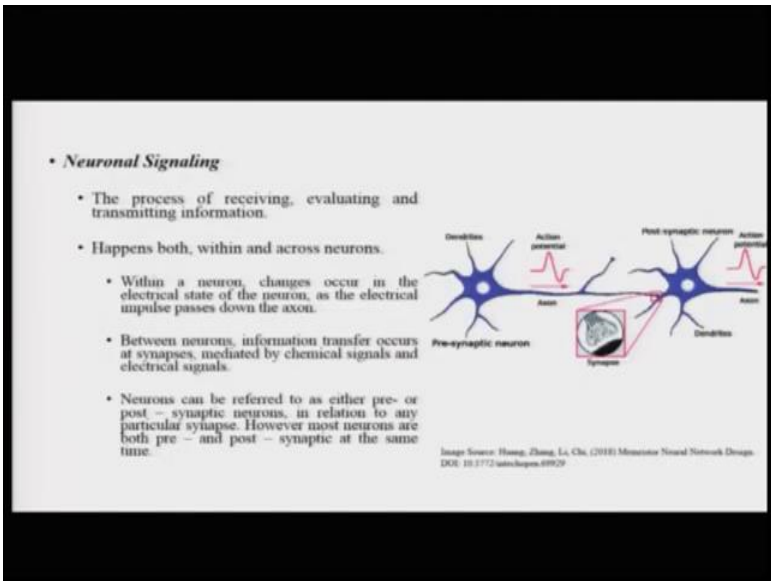


Neuros can be therefore, as I was saying, can be referred to as either presynaptic or postsynaptic neurons. But again, as I would like you to note is that the neurons are do not just have single connections, I mean they might be connected to many neurons at the at the same time.

And in that sense every neuron can be looked at as both pre and postsynaptic neurons at once, because it is probably receiving a signal from another neuron through its dendrites and then passing on the same signal to another neuron through its axon terminal. It is presynaptic neuron for one case, and a postsynaptic neuron in the other case, so it is basically relative to what signal processing you are talking about, a neuron can be considered pre or postsynaptic here.

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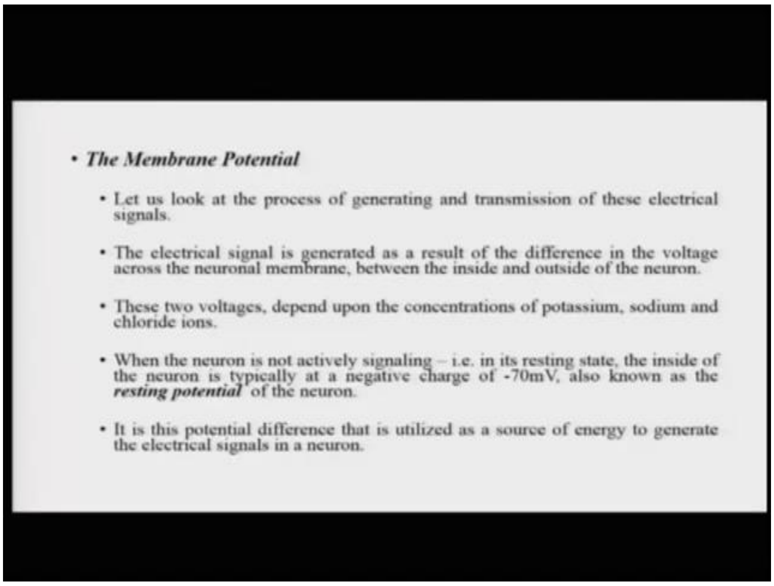


Now, how is this signal generated? This thing that I have been talking about what is this whole concept of electrical and chemical signal being generated, let us start talking about it. And over the first concepts we can sort of discuss here is this whole concept of the membrane potential.

So, let us look a little bit more closely at the generation and transmission of this of these electrical signals that we are talking about. Let us look at some of the basic facts that we have to begin with. So, an electrical signal is generated as a result of the difference in the voltage across the neuronal membrane.

So, this neuronal body there is of these electrical signals that we are talking about. Look at some of the basic facts we have to begin with. So, an electrical signal is generated as a result of the difference in the voltage across the neuronal membrane, so this neuronal body, there is a voltage difference across this body and also between the inside and outside of the neuron.

So, if you remember the extracellular material is also cytoplasm, like material the inside is the cytoplasm material, which is both of these are constructed with the same kind of ions. So, these two voltages basically and this creation of these voltages, the inside voltage and outside voltage depend upon the concentration of the kind of ions potassium, sodium, calcium, and chloride ions, the different they exist in different concentrations inside and outside of the neuron. And this difference in concentrations basically leads to build up of these voltages.

Now, when a neuron is not actively signaling or passing information from itself to the other neuron is the resting potential of the neuron. So, just quickly remember this. So, this is basically referred to as the resting potential of the neuron which is around minus 70 millivolts. It is this potential difference of minus 70 millivolts is what is utilized as a source of energy would generate an impulse and to pass on that impulse from one neuron to the other, we will talk about how that happens in much more detail as we go further.

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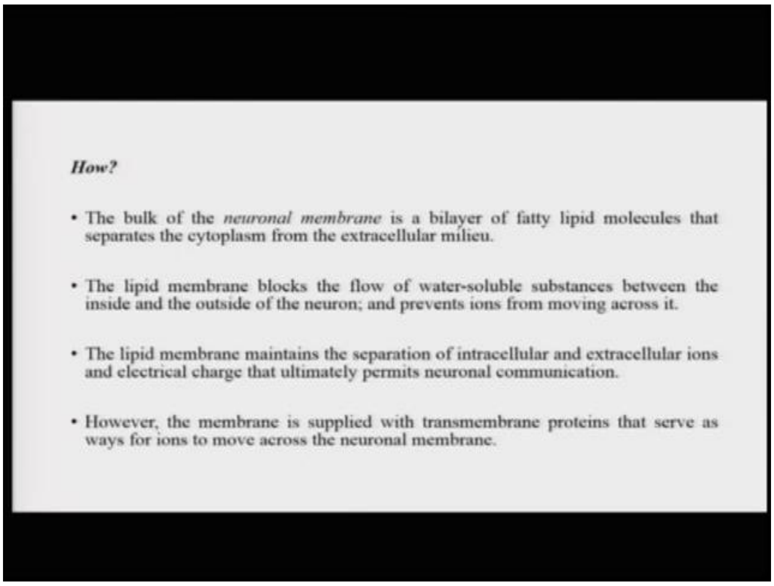


Now, how does this happen? How does this membrane potential built? So, let us look into this a little bit more deeply. Now, the bulk of this neuronal membrane that we are talking about this this voltage difference across this body and also between the inside and the outside of the neuron. So, if you remember the extracellular material is also cytoplasm, like material inside is the cytoplasm material, which is both of these are the constructed with the same kind of ions.

So, these two voltages basically and this creation of these voltages, the inside voltage and outside voltage depend upon the concentration of the kind of ions potassium, sodium, calcium and chloride ions, the different they exist in different concentrations inside and outside of the neuron. And this difference in concentrations basically leads to build up of these voltages.

Now, when the neuron is not actively signaling or passing information from itself to the other neuron. So, letting and it is not allowing exchange of either chemicals or electrical charge from inside and outside, but then there are avenues there are these things called transmembrane proteins, which are provided across this membrane, which basically serve as as ways or opportunities or avenues of movement of ions across this neuronal membrane, now this is this is a very, very important part which I would like you to remember and process in some more detail.

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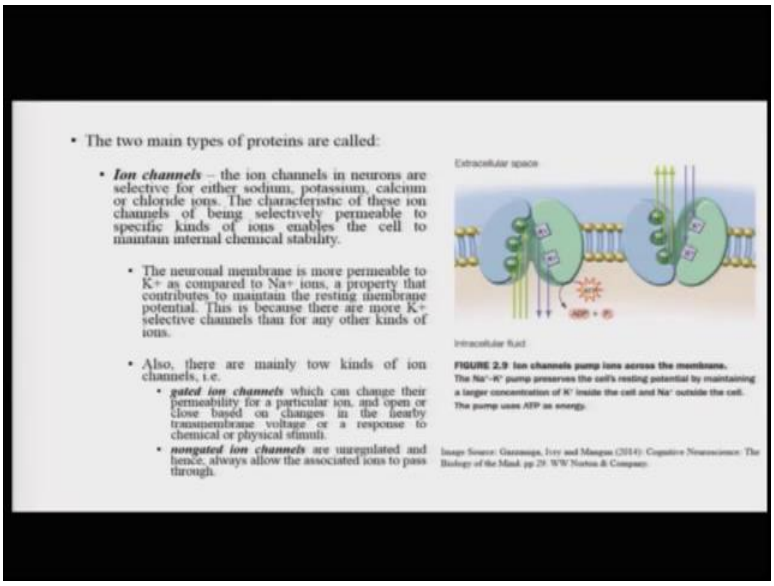


Now, there are two main types of proteins that allow for the crossing of ions from the inside to the outside, or from the outside to the inside of the neuron. First of them is called ion channels. Now, these ion channels basically in neurons are either selective or basically selective and they are selective for either sodium or potassium or calcium or chloride and so on. So, they are particular different kinds of ion channels which are sort of suited to allow specific kinds of ions to pass inwards or outwards from the neuronal membrane.

So, this characteristic of these ion channels being selectively permeable to specific kind of ions enables the neuron to maintain the internal chemical stability. So, for example, if some of the ions have gone out, which are disturbing this whole thing, a different channel will allow the same kind of ions to enter back in to restore this minus 70 millivolts that we have talked about earlier.

Now, this neuronal membrane, why is this more I mean, it has this unique property of being more permeable to potassium ions as opposed to sodium ions and this is this property that contributes to maintaining this resting potential. Because as you might be aware of your elementary chemistry that more of these potassium ions, basically they take out so, basically the more of these potassium ions, selective channels are there than for any other kind ions, more of these potassium ions are allowed to go outside as opposed to the other kind of ions.

Now, these channels can come in two kinds, one of them is called a gated ion channels. Now, these gated and channels are special channels which can change their permeability for a particular ion or open and closed on the basis of changes and the neuronal on the nearby transmembrane charge or if there is some kind of physical or electrical or chemical stimulation.

The other kind of ion channels are called non-gated ion channels which almost allow a free pass to ions of these specific kinds to go in and out through these particular channels. So, there is a combination of these channels, which basically allow for some time selective, sometimes unrestricted passage of ions from inside to outside of the neuron and vice versa.

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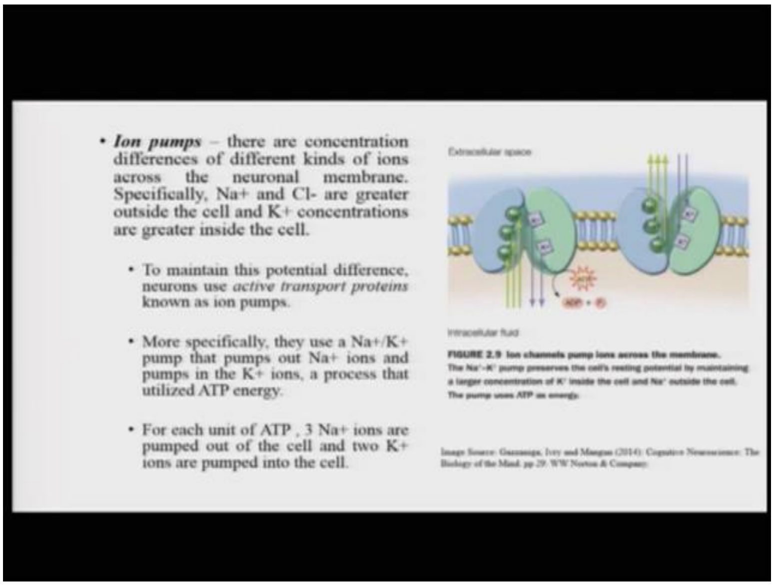


Another important another important kinds of transmembrane proteins are these ion pumps and these ion pumps basically are responsible for maintaining this the difference of the concentration of ions across the neural membrane. Specifically, it is observed that sodium and chloride ions are in greater concentration outside the cell, whereas potassium ions are in greater concentration inside the cell.

Now, to maintain this potential difference, which we have been talking about. Neurons basically use active transport proteins known as ion pumps, so this is what these ion pumps are supposed to do. What they do? Is, they use a sodium potassium pump that pumps out sodium ions and pumps in the potassium ions, a process that is obviously it is basically where some kind of movement is happening, it will basically utilize some kind of energy and that energy comes out of the hydrolysis of the adenosine triphosphate molecules.

Now, for each molecule of adenosine triphosphate that is hydrolysed. The three sodium ions leave and two potassium ions are pumped inside the cell. So, you can see that three positive charges going inside but only two are coming inside, which is going to create this buildup of negative charge inside the neuron as opposed to the positive charge that is going to be outside the neuron.

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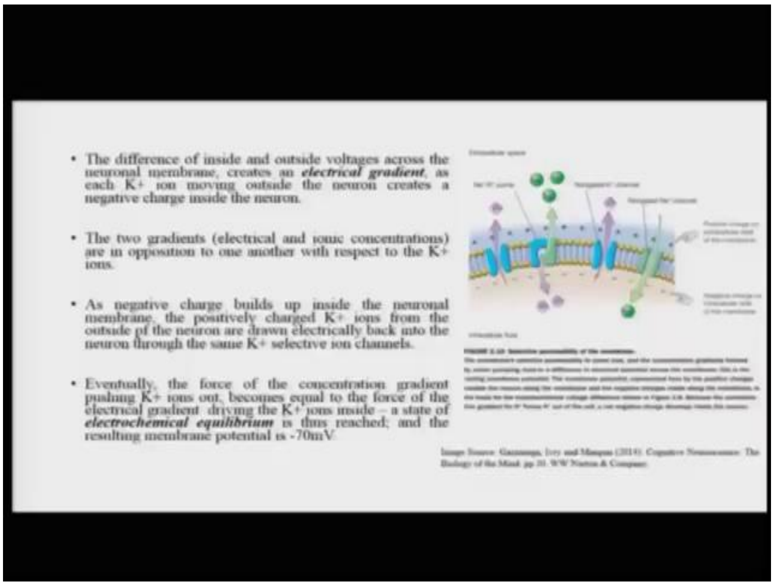


Now, there is difference that becomes created of the inside and the outside voltages across the neuronal membrane is referred to as or we can call it as an electricity gradient. Now, as each K plus sign moving outside creates a negative charges, I have already mentioned. Now, there are two kinds of gradients if you have noticed, there is this electrical gradient which is forming because of the difference in charge and there is the gradient which formed because of the difference in the concentration of these specific type of ions.

So, there are two gradient, electrical gradient and the ionic concentration gradient, which basically are sort of an opposition to each other. If the ionic gradient wants a sort of an equilibrium to be establish, the electrical gradient will get disturbed and so on. So, they both sort of in our work in opposition to each other, with respect to where these potassium ions should be. One sent these potassium ions outside, the other wants this potassium ions inside.

Now, as negative charge sort of keeps building up inside this neuronal membrane, the positively charged potassium ions from the outside of the neuron are drawn electrically back into the neuron through the same sodium selective ion channels. Eventually, what it leads to? Is the is that the force of you know the eventually what it sort of leads to? Because of the force of this concentration gradient, which pushes this sodium ions out is that this force, which is pushing the sodium ions out, becomes equal to the force of the electrical gradient which needs to push the potassium ions inside.

So, there are two kinds of gradients, one is pushing potassium ions out, the other is pushing this potassium ions in, and these two become sort of equal to each other. And in in a state where both of these forces are at an equal standing is referred to as the electro chemical equilibrium.

And this is where the charge that we are talking about of this membrane, the resulting membrane potential is minus 70 millivolts. So, this is this is sort of the first part of this you know the section of on neuronal signaling that I was supposed to be talking about, this is how this minus 70 millivolts charge is obtained.

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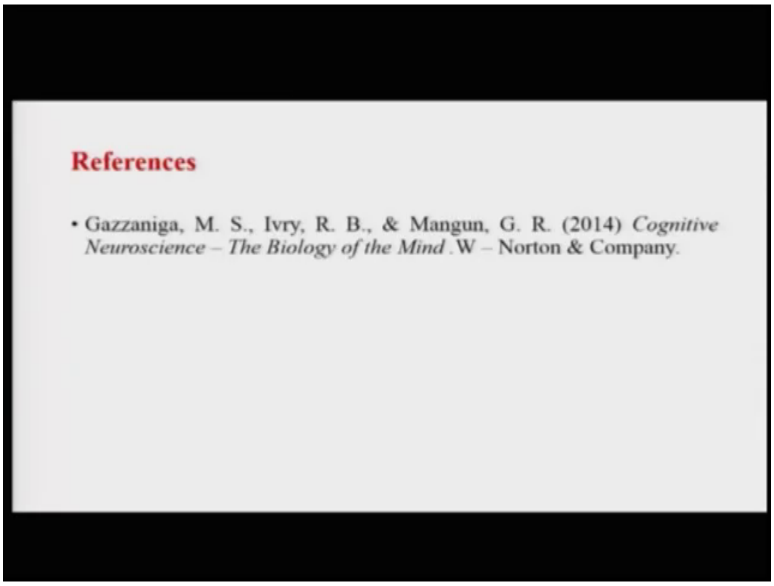


The next lecture, I will talked to you about the action potential and about the synapse which is basically how this charge is communicated through and across the neuron. Thank you.