**Computational Neuroscience**

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**Week – 01**

**Lecture - 01**

Welcome to the Computational Neuroscience course. So we are at the first week and we will begin in the first week with introduction to neuron structure or some basic structures of the brain, how the neural systems are organized in the brain in the central nervous system. And we will then go into, as we have discussed in the intro video, we will go into how action potentials are generated. So let us first begin today in our first lecture with the neuron structure. And so there is a long history behind the study of structure of neurons and the name neuron originated back in the 19th century long ago and it was finally shown to be a unit structure by, as you can see in the slide, the sections that are present in terms of the direction in which the slices are made from the brain. So if you have a horizontal section like so, that is what we call a transverse section and so sections that are parallel to this plane are made from the brain and we get a a different view of the different regions compared to what we would get when there is a vertical section vertical plane and then a section is created which is what is known as the coronal section And now if we go along the midline plane, parallel to the midline plane which is this, the last one and that is called the sagittal section.

So if we get a sagittal section or mid-sagittal section of the human brain then it looks somewhat like this inside the skull where you can see the various structures that are present. The outside as we have said is the layered cortical structure at the top with a variety of different lobes with different functions which we will talk about in the brain structures section in the course lecture. And as you can see there is the midbrain structure and cerebellum and then brain stem followed by the spinal cord which connects to the peripheral nervous system down in the body. So if we take sections of the brain as we were saying a particular part of it and then we can do staining with appropriate stains to mark out the different cell bodies present in the brain then it would look somewhat like this.

This particular one is what we call a nasal section which has to do with staining nasal bodies But what the main point is that it allows us to visualize the cell bodies or the

neurons present within the layer or within the section that we are going to observe. So a neuron I mean if we get a section here as you can see if we blow up this region it is a layered structure in the cortex which starts from the layer 1, layer 2, 3, 4, 5, 6, 5a, 5b, 6 and then white matter. What we mean by this is that these different layers - layer 1, 2, 3, 4, 5 and 6 they have been named in that way because of the different types of neurons or different morphologies of neurons that are present, the different kinds of connectivities that are present between the layers and so on. So the nomenclature is based on the morphology as well as function of neurons in that layer. And we will gradually see later on that layer 4 generally serves as the input layer, where the inputs from subcortical structures mainly the thalamus comes in into this layer and then hierarchically different processing stages are present in the cortex.

So now if we look into one particular neuron from here we will see that, so when we look at only one neuron we will see a variety of morphologies and these morphologies were first studied by I mean a number of people but the most important contributions although contradictory in terms of the overall picture were done by a physician from Italy, Camillo Golgi and a pathologist from Spain, Santiago Ramon y Cajal and both of them together got the Nobel Prize in 1906 because of their work on the structure of the nervous system. They were very strong in their neuroanatomical work and their contributions are extensive in terms of our understanding today of the nervous system. So they did painstaking work in order to understand by visualization and then drawing by hand what neurons look like and then made discoveries based on those observations. And so Golgi on the one hand was of the group, which propounded the idea of the reticular or a network like nervous system more like the circulatory system that everything is connected within itself. Whereas Ramón y Cajal and others based on their observations and experiments, came up with the neuron doctrine.

They propounded the theory that neuron is a single entity by itself and there are many different neurons, many types of neurons and they are connected to each other not like a net in a continuous manner but more like a contiguous manner. So that is what Ramón y Cajal showed that in his lecture about the neuron doctrine in his Nobel lecture. Later we know that indeed Ramón y Cajal was correct but that took a lot of work finally with electron microscopy, when we could look at separate synapses between neurons, which is the points at which neurons connect to each other. Only then was the idea of the neuron doctrine clearly established. So we will go on to look at how the morphology of neurons look like.

So here are number of examples of the structure of neurons. So what we are seeing here are in the center are cell bodies. So this is the cell soma. Like so like any in all neurons there will be a cell soma And that contains the nucleus and all the processes that go on in

terms of maintenance of the cell. that happens in the Soma.

There are extended structures along protruding from the Soma either in one direction or in multiple directions as you can see here in the different examples that are shown in this slide they are called these protrusions are called Dendrites and there is a single very thin output like structure that goes out from the neuron and is called the Axon. So in this, in these diagrams, the Axon is not visible in that sense because it is not stained for the Axon itself except in some of them where it is marked with an "A" here are the axons which is a thin much thinner structure and is called the output layer. So what we have in general is a neuron with its cell soma like so and there are structures protruding from it in multiple direction with variety of morphologies possible these are called the dendrites and there is a particular structure that goes out from the neuron which is called the axon and this axon goes and makes connections can make connections with multiple neurons if not just one neuron. So they can branch off into many groups and make connections with many different neurons dendrites and that connection point is what we will call synapses. But in terms of the structure what we know is that the axon has different components in it which we will discuss a little later and similarly the dendrite can have many different properties involved in terms of processing and so those details we will go into when we talk more about the computational side of how these neurons compute information that is coming in or rather process information that is coming in from the previous structures.

So if we look at it more closely with in a cartoon form what we see here is this is the axon where the beginning of the axon from the soma is through what we call the axon hillock or where what we will see the action potential or the currency of computation that we will discuss later is actually initiated from there and that action potential or a particular form in the membrane potential that is the membrane potential inside the potential inside and outside the neuron that travels along this axon as an output. And generally the axon is covered with what we call myelin sheath and that allows the action potential to travel very fast. And as we discussed so here are the axon terminals where multiple different neurons can be connected or rather projected onto by the neuron here. On the other side as we said these are the dendrites with intricate morphology and these dendrites are the sites where there are inputs coming into the neuron from the previous neurons. So that is the axons here will be projecting onto possibly dendrites of the next neuron.

So if we have dendrites here they are projecting onto this dendrite here and that axon can proceed further and so on and that neuron's axon can proceed further and so on taking the information away to the next stage of neurons. A particularly important aspect that we need to mention here is that there can be neurons that actually do not have even

any axon thus just dendrites and so these are exceptional cases. And they make dendro-dendritic connections or synapses. So what is the neuron like I mean in terms of what in terms of it being a cell what are the special properties that it has in its structure. So as we said there is one input side so this is not a physical input side it is a functional input side which are the dendrites.

And there is an output side and that is the axon and this axon then provides an input to the input side of next neurons which are the dendrites. And the structure of the neuron the cell body that is the membrane that membrane is like any other neuron. So if we consider the cell membrane here if we take a patch of the membrane and look into its cross section what we will see is that it is made up of like any cell lipid bilayer structure like so. So these are phospholipids that form the entire that make the entire membrane of the neuron from the dendrites up to the axons the whole structure is covered with a lipid bilayer where this circular structure is more polar or hydrophilic part and these chains are the hydrophobic parts which make up the inside of the membrane. So as we know that in other cells also this membrane acts as an insulator electrically as an insulator between the outside and inside and later on we will see the correct way to represent the membrane is like a capacitor.

And the inside of the neuron and the outside of the neuron are both aqueous mediums and so this will be the basis of our understanding of action potentials or how the membrane potential is generated in a neuron. So this aqueous medium outside and inside are made up of different types of ions at different concentrations. So we will look at this in more detail in a later lecture when we talk about the excitable membranes and ion flow through membranes. So primarily the ions that are at play are sodium ions, potassium ions, calcium ions, chloride ions, magnesium ions. So and there are more but these are the sort of main players in terms of the function of the neuron in terms of its electrical properties and the membrane with its insulating heavy chains of the phospholipid bilayer in the middle acts as a separator or something that separates the outside and inside and insulates them to create the membrane potential by acting like a capacitor.

So as you can see here the cell in this particular diagram this is an example where we have the soma in a cultured neuron and there are multiple dendrites that have projected from the neuron body cell body. And these dendrites have protrusions on them which are called the dendritic spines. And we will talk about this because these are the sites of where connections are made between the previous stage neurons and the current stage neuron to provide input to the neuron. So that will be taken up in the next lecture on neuron structure in the network and synapses lecture after today. Thank you.