Neural Science for Engineers
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Module - 02
Lecture - 09
Neuro Muscular Junction

So, previous class, we had a discussion on how synapses function and what method the information is modulated through a synapse. Now, Synapse is a very important entity within a nervous system, and it is through synapses that a lot of computation happens as you have seen. One of the important things which happens in a synapse is Amplification.

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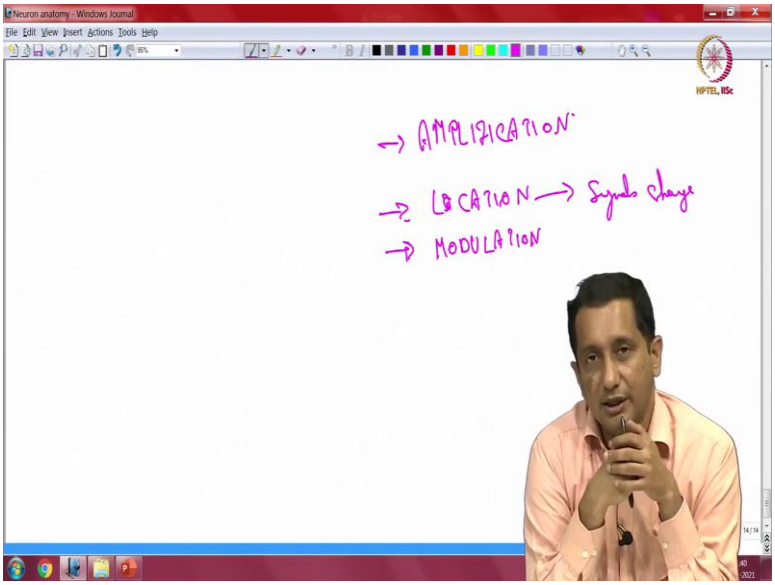

So, synapse amplification happens then based on location, we have seen how signals change either in terms of frequency, whether in terms of occurrence and then, we have also seen how modulation can be done with synapses. So, modulation is you can change the output frequency of the postsynaptic neuron.

So, all these are functions which can happen just because of the synapse and it is interestingly, electrochemical reaction. So, electrical activity converting into chemical activity, organic chemicals and then, going back to electrical activity and that is seamlessly integrated. It looks very inefficient.

For all its beauty, you would think that if you just put an electrical synapse between two cells, it should be much more interesting to compute. But for whatever reason, nature thought best to do it like this through an elaborate system of calcium, neurotransmitters, combining of vesicles, quantized vesicles and then amplification at the postsynaptic.

I did not speak about the postsynaptic receptor amplification and that is how synaptic transmission is to be understood. Why it happens? Yeah, I have no clue as to why it happens like that. It happens like that. So, in the discussion on synapses, I think it is also right to mention something about the muscular system because it is relevant for some discussions downstream. So, I should introduce the mechanism of synaptic transmission across a neuromuscular junction.

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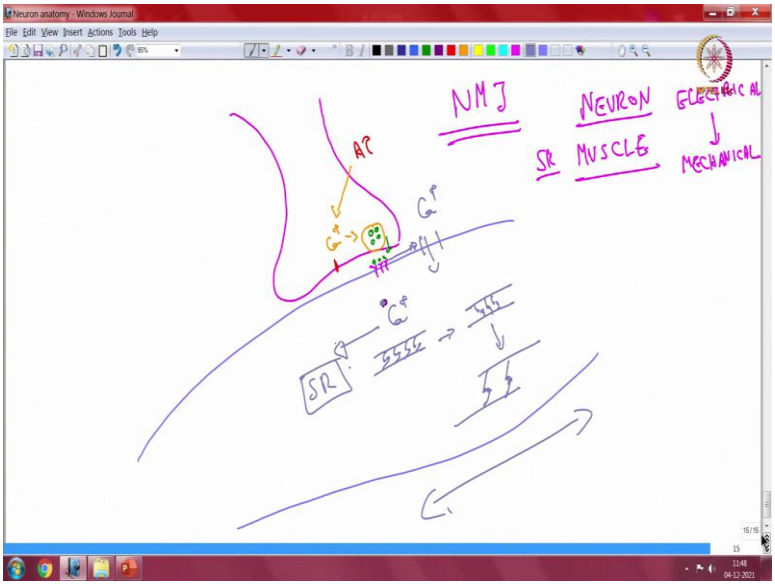

And that is for this thing. So, when we think of a neuromuscular junction, you have two funny cells interacting. So, you have a neuron, and you have muscle. So, we will put it as skeletal muscle. So, you have neuron and skeletal muscle cell. So, how is electrical activity converted into mechanical? So, that is something which we will see here. So, again, the players are the same.

So, players are you have action potential coming up to the dendritic end plate, you have calcium coming in because of the action potential and that in turn causes these vesicles to fuse and that in turn, produces to act on the receptors over here. So, the receptors are

very specific. So, acetylcholine acts only on acetylcholine receptors; serotonin only on serotonin receptors. That is a method of ensuring that there is some restriction.

To my understanding, a particular synapse is only one set of transmitters across, the protein content of the vesicles everything is predetermined. They do not change. So, it is not that today acetylcholine is in flavor and tomorrow it changes the serotonin. It is not like that. A particular synapse handles only one particular neurotransmitter. So, there is a lot of constraints which are put.

If you look at the constraints, action potential has uniform amplitude. The synaptic vesicle contains a specific amount of molecular load of acetylcholine. The acetylcholine goes to a specific number of post synaptic receptors. It in turn depends upon the number of receptors which are there on the postsynaptic membrane. So, if you have a lot of loss of proportion, you have issues in that. In fact, it is one of the mechanisms of diseases which are involved in neuromuscular junction especially.

So, you have receptor level problem. There are receptors which are lesser in the muscle cells, you have got lot of acetylcholine; but nothing happens on the post synaptic side. So, all of these are tightly controlled and genetically controlled. So, there is a large amount of screening mechanisms at the genetic level, protein level, the structural level which ensure that there is fidelity of information transfer from one part to the other.

So, coming back here, so acetylcholine triggers in the calcium. So, this is calcium; calcium from outside these channels act on calcium, now this calcium actually interacts on some proteins and these proteins in turn change their configuration. So, you have it like this and it is not like that its actually two set of.

So, the protein slides across because of availability of calcium. It is something similar to the channel opening stuff which I have told earlier. So, the entire molecule changes because of the because of the availability of calcium. Calcium binds to different parts of this in the protein and that protein, in turn, causes change in configuration of the muscle. So, that is how the entire muscle moves.

So, you have got millions of billions of these molecules. So, based on the calcium concentration, you can have varying grades of movement. So, higher the calcium concentration, the higher the sliding, the more the power generated within the muscle

and that is how muscle activity is generated. More interesting thing to happen is the calcium is sequestered back into the sarcoplasmic reticulum which is an entity.

So, it pumps out or rather pumps back into the sarcoplasm, reducing concentration of the calcium, which again results in the open configuration of these proteins. This is notational, I am not delving into the details of this. So, there is a cycle. So, this key ion is calcium, it is in the muscle. Like many other things, in fact, calcium is also important in the presynaptic part of the membrane.

Here again, the action potential is coupled through calcium into the synaptic vesicles. Postsynaptically, in a muscle cell especially the coupling is between acetylcholine acting on the receptors which open calcium channels from the outside to the inside of the muscle cell and that in turn causes a muscle activity. So, that is how muscle cells get activated and that is how movement happens in the body.

So, I included the muscle discussion into this because one, it is an integral part of the discussion which is going to happen. If we look at computers, you know you cannot discuss just the CPU right. You need to have an input, need to have processing and you need to have output and all three in biological systems have developed together.

So, there is never an entity in which the CNS developed, and the muscles did not develop, or the muscles developed and then thought that regulatory mechanisms need to exist. They all develop simultaneously at various parts of evolution, and they have been tightly linked. So, when you understand about function, it is important to understand it as a network, a closed loop network which elegantly behaves and works so well.

So, I have so far covered all these issues about information transfer across. So, myelinated fibers; how myelinated fibers transfer information fast when compared to unmyelinated fibers and the relevance of that. We have say for a 6-foot man, you should imagine that one the longest neurons would be from the tip of the toe up to the head and it is a single fiber.

So, myelination ensures that information from the tip of the toe goes into the head fast enough for you to actually integrate stuff which you are seeing. The distance between the eye and the optic pathway is somewhere about 6-7 centimeter; not 7, it is slightly longer. So, a beautiful system exists in information generation, processing and transmission.

So, I think we will take a break here and proceed on to an important concept in the next, where I highlight a lot more about neuronal processing and I think I should title it as something more interesting; ‘Analog versus Digital processing within the nervous system’. So, we’ll look into that in the next class.