Neuroanatomy 3

[00:00:00.68] This is the third segment of the neuroanatomy and neurophysiology lecture. In this segment, we're going to be concentrating on neurophysiology or the structure and function of individual neurons. This is a neuron. It has dendrites, which receive information from other neurons in the form of neurotransmitters being released; the cell body or soma, which has all of the organelles that are usually found in cells, including the nucleus.

[00:00:30.05] The axon projects from the cell body. It's wrapped in myelin, which is a fatty sheath produced by glia, other non-neuron cells in the brain, and has gaps in it called Nodes of Ranvier. The myelin and the nodes of Ranvier help signals travel down the length of the axon, where they end up at axon terminals. And at the axon terminal, neurotransmitters are released on to the next neuron.

[00:00:58.91] There are several different structures of different neurons. On the left, we have a multipolar cell. This is the most common type of neuron. It has multiple groups of dendrites and then a single axon leaving from the cell body directly.

[00:01:13.91] In the middle, we have a bipolar cell, which has a single axon leaving directly from the cell body and a single group of dendrites, also leaving directly from the cell body. Bipolar cells are most commonly found in the retina. And on the right, we have a unipolar cell, which has a single projection leaving the cell body, which branches to become both dendrites and an axon. These are found throughout the body in both sensory and motor systems.

[00:01:44.86] Neurons connect with each other at synapses. On the left side of this diagram, you can see a synapse where the presynaptic cell, the cell that is sending a signal into the synapse, is represented by a little triangle. This is the axon terminal. And in the axon terminal, there are vesicles or little bubbles of membrane that are full of neurotransmitters.

[00:02:09.59] And when the signal arrives down the axon to release the vesicle, the membranes merge with the edge of the cell and it releases the neurotransmitter, which drifts across a tiny gap between the cells. And on the postsynaptic cell, the cell receiving the signal at the dendrite, those neurotransmitters bind to the receptors that are marked here on this diagram. If enough receptors are activated, then a signal will be generated in the second cell.

[00:02:39.79] This signal is called an action potential. And it looks exactly the same every single time it happens. An action potential is an all-or-nothing signal. Either it happens in full, as shown in this diagram, or it doesn't happen at all.

[00:02:55.87] The membrane has a potential that's maintained by charged ions, primarily sodium, potassium, and calcium, being concentrated on one side of the cell at higher or lower concentrations than on the other side of the membrane. In the first part of the action potential, when the receptors are triggered, the sodium channels in the membrane of the cell will open and sodium will flow into the cell. And the membrane potential or the electrical charge of the neuron will increase.

[00:03:35.11] At the peak of this curve here, the sodium channels will close and potassium channels open and potassium exits the cell. You can remember that sodium enters the cell and potassium exits the cell because neurons first developed in seawater. And the sodium in seawater is very high, but it's much lower inside of a neuron.

[00:03:57.40] And then once the potassium channels open, the membrane starts to re-polarize as the positive charge exits the cell. And then eventually, the potassium channels close and everything returns back to rest. This entire process takes about five milliseconds.

[00:04:21.52] So as we talk about groups of neurons and their activity, remember that within a single neuron, signals are generated electrically. It's technically a chemical signal caused by an ion gradient of charged ions moving across the membrane to generate a voltage, but you can think of this as being an electrical signal. And when neurons communicate with each other, they do so via neurotransmitters. So the signal between different cells is chemical.

[00:04:53.11] Chemical signaling between neurons is done with neurotransmitters. Depending on how you count, there's anywhere between a few dozen and over 100 different types of neurotransmitter. A few of them are shown here.

[00:05:06.19] Each cell releases only one type of neurotransmitter. And there are multiple types of receptor for each neurotransmitter that are different in their level of sensitivity and how much response they generate in the neuron that's receiving the signal. All of the communication between different neurons and between neurons and muscles is accomplished by releasing these molecules.

[00:05:32.96] Myelin helps signals travel more efficiently within a neuron. When our neuron here receives enough neurotransmitter from the presynaptic cells that are sending it information, an action potential occurs. And that action potential travels along the membrane of this cell.

[00:05:51.46] And ions continue to flow in and out of the cell every time it reaches an ion channel. The action potential is then renewed as the signal travels along the surface of the neuron. Myelin acts as an insulator that means that the signal doesn't have to be renewed as often by the flow of ions in and out of the cell. So the signal can travel farther and faster without degrading.

[00:06:19.39] Many, but not all, neurons per myelinated. Myelin is expensive for the cells to produce. It's generated by helper ourselves called glia. And it's not needed in all cases. If the signal doesn't need to travel very fast, as many pain signals don't need to travel very fast, or if it doesn't have to travel very far, then the neuron might not be myelinated.

[00:06:44.32] We have to be able to change the strength and structure of different synapses depending on learning, new stimuli in the environment, or any other things that we need to change. This is called syntactic plasticity. We can increase or decrease the strength of a synapse. And this might be accomplished through changing the amount of neurotransmitter released, the number of locations where neurotransmitter is released, the threshold where a neurotransmitter is

released-- so getting over the threshold is easier or harder-- the sensitivity of the receptors on the postsynaptic cell, the number of receptors or the type of receptors.

[00:07:25.84] We might generate an entirely new synapse that wasn't there before, connecting neurons that weren't previously connected, or losing a synapse so neurons that were connected are no longer connected. But we won't grow an entirely new neuron. Adults don't grow new neurons except under very special circumstances. This generally happens only in a couple of areas in the brain, along the lining of the lateral ventricle, which is a drainage system throughout the center of the brain; in the hippocampus, which is an area of the brain that is responsible for forming new memories; the dentate gyrus, which is next to the hippocampus and supports many of the hippocampus' functions; and the olfactory epithelium, which is located inside of the nose.

[00:08:13.15] Finally, I want to review glia, which support and defend neurons. Neurons are kind of helpless. And there's a lot of things that they can't do for themselves. Plus, they're vulnerable to damage and infections.

[00:08:24.70] The brain doesn't heal itself like other cell types do. So it's very important to defend the brain whenever possible. Glia help defend the brain from infections. They feed neurons.

[00:08:35.68] They clear away waste products. They protect the brain against foreign bodies. And they form the blood-brain barrier, which is a special physical barrier where a type of glia called astrocytes surround the blood vessels in the brain and prevent any molecules or bacteria that aren't supposed to be there from getting through.

[00:08:56.42] But on the downside, they can block helpful drugs. While some drugs, psychoactive drugs, can get through to the brain, many other drugs can't, especially antibiotics. The brain still requires a constant blood supply and an interruption due to a stroke, aneurysm, or other emergency can cause neurons to die very quickly.

[00:09:16.12] And for neural engineers, the fact that glia form scars and tissue blockades around any foreign bodies in the brain, like helpful electrodes that we might be using for our neural engineering device, can be a problem, even though it's usually a good thing. Glia have many consequences in neural engineering because they can interfere with all of the helpful things that we're trying to do because from a glia's perspective, they're not helpful. So we have to make sure that we take them into account whenever we're designing something that would physically intrude on the brain so that we can evade the brain's natural defenses.