Human Physiology
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Lecture - 04

Welcome to another new class on human physiology. In this class, we will discuss the structure of the neuron, the structure of nerves, and also the functions of the neuron. So, hopefully you like that you are following the classes. In the last few classes, we discussed the nervous system, including the brain and spinal cord. Also, we discussed different components of the spinal cord, including various nerves such as cranial nerves and spinal nerves. So, let us see that nerves are basically the smallest coiled unit of repetitive units and coiled units of neurons.

So, neurons are a very important component because they are the primary cells present in our nervous system. So, let us stay with it; let us see how these things, like neurons and their structure and function, work. So, one different concept will be covered for this class; we will discuss basic neuron anatomy and its structure, and then we will also discuss different components, for example, dendrites, cell bodies, axons, and axonal terminals. Then we would also like to have a brief classification of different types of neurons, and we will also discuss nerve structure.

In the last class, we gave different examples of cranial and spinal nerves, but in this class, we will see how the structure of nerves and different types of membranes of nerves work as well. So, what is a neuron basically? Neuron, as you know, is like a messenger of the body, right? So, basically, a neuron is like a fundamental unit or the fundamental cell of the nervous system, and it is the responsible component of the nervous system that receives different types of sensory signals; it also helps to guide or transmit those signals. To our brain or spinal cord, once the signals get processed, eventually from the brain or spinal cord, the efferent signals also get transmitted via the neurons. So, basically, neurons eventually form electrical and chemical signals to connect our whole body system in terms of various sensory and motor applications. So, one neuron sends its impulses to the following neuron, which is basically called a synapse.

So, as you can see, there is a connection of neurons where this is the first neuron and this is the second neuron. So, what it does is, if this neuron is receiving some sensory signal, it transmits the sensory signal from its axonal part to the axonal terminal area, and maybe some sort of neurotransmitter will be secreted from the axonal terminal area. This neurotransmitter molecule will eventually go and affect the next neuron, the second neuron, right? So, you can basically say that this number 1 will be like the presynaptic neuron and this number 2 would be the postsynaptic neuron. And what type of responses can the presynaptic neuron send to the postsynaptic neuron? Either it can send a stimulatory signal or it can send an inhibitory signal. And you have to remember that mostly two types of signal cascades happen; either it can be through different types of electrical signals that occur via ion transport channels, or it can be through different neurotransmitters or chemical signals as well.

For example, there is an important neurotransmitter, if you remember, that we discussed, which is like acetylcholine. There can be other types of neurotransmitters that have an important role in various functions, such as sensory or motor functions. So, in terms of the anatomy of a neuron, you mostly know, but let us see what the different components are. So, basically, a neuron has different components, including the dendrites, right? So, basically, these dendrites, as you see, are like branch-like extensions that receive signals from another neuron. So, basically, if I think there is one more neuron here.

So, these dendrites will basically receive signals from other neurons. In the from the axonal terminal area to this neuron, right? And then we have this cell body where you will see the nucleus, and as it has a nucleus, it will have mitochondria, Golgi bodies, etc. So, this part of the cell body, or the soma, of the overall neuron can actually produce different types of proteins and different types of growth factors. Right, and these proteins and growth factors can eventually transmit via this axonal area. So, then next you can see there is this whole region which is called the axon area.

This is like a long projection that transmits different types of electrical signals; it can also send different types of chemical neurotransmitters from the soma or the cell body terminal, or the axonal terminal area. So, all these signals, either the electrical signals or the neurotransmitters, basically carry through this area from the cell body to the axonal terminal. Then you see there is an area where we also have an axon hillock; mostly this is present in this case, the axon hillock. So, this is the axon hillock. So, this region is where action basically originates from the cell body, and it is also kind of a site where the action potential initiates.

So, you can see that after the axon, the prolonged extension of the axon, this part, which is called the axon hillock, and in this area, basically the action potential originates, and how it originates we will discuss in the next classes. We thoroughly discuss how all this electrical signaling actually happens and how the different types of neurotransmitters move from the cell body to the axonal terminal. So, let us stay with it in our next classes; we will thoroughly discuss that process. So, after that axonal hillock area, you see this is the terminal area, which is the axonal terminal area or synaptic terminal area. These are the endpoint or the end terminal of the axon or the whole neuron, where one neuron, or the presynaptic neuron, sends the signal to the second neuron or another neuron.

See this through this terminal area only if they remove different types of neurotransmitter proteins, and then this signal eventually passes to the postsynaptic neuron. Lastly, you can see there is a fatty type of layer in the insulating layer which is called the myelin sheath. It basically acts to speed up the entire transformation process. So, basically this transmission or the signal, like kind of signals due to the insulation, can jump from one side to another side, reducing the time of the transmission. So, now let us discuss a little bit in detail, one by one.

So, as you see, the dendrites are short, branch-like extensions of the neuron, and they also have a very high surface area. And what these dendrites do is basically function like an antenna, right? So, basically they function as an antenna. So, they receive signals right. So, these dendrites receive different types of signals; either they can be stimulatory signals or inhibitory signals from the presynaptic neuron. So, if I consider that there is one more neuron over here.

So, if I consider there is one more that is like a presynaptic neuron, and if I consider this is a postsynaptic neuron. So, these dendrites basically add as antennas to receive these signals, and there are a lot of channels or ion transporters present. In the next classes, we will discuss in thorough detail these ion transporters, but briefly here you can see different ligand-gated ion channels, for example, sodium ion channels and chloride ion channels. Apart from that, there are a lot of G coupled protein receptors also present here, right? You can see there are a lot of

G-coupled protein receptors also present. They also influence different types of intercellular signaling pathways, such as neurotransmitter binding, which often leads to slower and more prolonged postsynaptic effects.

After the dendrites, as we said, another important component is the cell body, where we have the nucleus; that also means we have ribosomes and the Golgi body. So, by all this, cell organelles are mostly present in the cell body or the soma area, and they carry genetic information; apart from that, protein production actually happens here. So, different types of proteins, including enzymes, neurotransmitters, different membrane proteins, and various growth factors, all undergo synthesis here. So, let us see slowly how protein synthesis happens. So, basically, as you see inside the neuronal cell body, this is the primary site of protein synthesis.

So, as you see inside the nucleus, nuclear DNA contains different genes that serve as templates for protein production. So, basically, initially, replication happens, as you all know. After the replication, once the mRNA comes to this ribosome in the rough endoplasmic reticulum, it creates the translation step, right? So, basically, once the replication happens, then via transcription, the mRNA gets produced, and this mRNA comes to the endoplasmic reticulum where the ribosomes are present, and via the process of translation, eventually, protein synthesis takes place. As you know, all three steps involve replication and transcription, where, most importantly, the mRNA molecule, or messenger RNA, is transcribed. This eventually carries the genetic code to the rough endoplasmic reticulum or the ribosome, where the process of translation, or protein synthesis, happens.

And once the protein synthesis happens, these proteins can be either neurotransmitters or different enzymes or growth factors. They eventually go to the Golgi body where protein packaging or protein repackaging happens. Basically, it creates a packed protein, and these packed proteins eventually get transmitted via the motor proteins that are present in the axon. So, basically, this is the nucleus area where protein synthesis takes place. Then, in the action area, as you can see, we have already discussed the starting point of the action origination area.

This is called the action hillock, and mostly here the action potential is generated. After that, there is this insulating myelin sheath, and through this long axonal part, what basically happens is that either an electrical signal or different types of chemical molecules, like neurotransmitters or growth factors, are transmitted from the cell body to the axonal terminal area. And as we said, because this myelin sheath contains a lot of lipid and high fat, it basically creates an insulating layer. And with this insulating layer in between, you can see there are certain gaps that are called nodes of Ranvier. So, basically, the signals can eventually jump from one node to another by bypassing those fat insulating layers.

In this way, it basically increases the speed of transmission. So, what the function of the node of Ranvier is, is that the node of Ranvier is basically the gaps in between the myelin sheath, and it helps in jumping the signal from one point to another, basically speeding up the neurotransmission process. In terms of transport in the action, it has two different types of protein. So, you can see that the two important proteins, one of them being kinesin, or the anterograde, is an important motor protein that basically takes the molecules, enzymes, or neurotransmitters from the cell body. So, on this side, we have a cell body, and on this side, we have the axon terminal area.

So, what happens is basically this kinesin protein carries either neurotransmitters or enzymes from the cell body to the axonal terminal area. In the same way, there is one more type of motor protein, which is a retrograde transport protein, also called dynein. They carry like the leftover vesicles without the neurotransmitter or maybe with the leftover neurotransmitter. So, once the neurotransmitter gets processed in the axonal terminal area, the leftover neurotransmitter can come back to the cell body via the retrograde transport protein, which is a dynein. This interestingly different type of dynein can also come and affect the nucleus of the neuron.

So, we will discuss it, but mostly try to remember that there are two types of motor proteins: one is kinesin, which carries the molecule or neurotransmitter from the cell body to the axonal terminal area. And then there is a retrograde protein, which is also called dynein; it carries leftover vesicles or different types of viruses, and sometimes it can carry them, taking those to the cell body from the axonal terminal area. So, as you see, like the kinesin, in this case, let us consider a condition where there is a neuronal or nerve injury. So, for example, let us consider that the nerves are like a coiled combination of a lot of neurons. So, let us consider that there is a nerve injury that has occurred.

So, to heal this nerve injury, we need certain growth factors or certain molecules, right? So, what happens basically during nerve injury is that different growth factors are being secreted. So, different growth factors, like neuronal growth factors. They are secreted from this injured area. And what happens to this neuronal growth factor if I consider here the injuries this neuronal growth factor, with the help of the dynein type of protein, basically transmits or transports from the injured area to the cell body area? So, if the injury happens here, it secretes certain neuronal growth factors, and these neuronal growth factors are carried by the dynein type of protein or the retrograde protein, and eventually, they take the protein to the cell body area. And once it goes to the cell body area, it eventually stimulates the cell nucleus to produce different healing proteins, okay.

Eventually, different healing signals stimulate the nucleus, and then replication, transcription, and translation occur to produce various healing proteins. And with the help of kinesin, this healing protein gets transported to the injured areas. So, basically, this healing protein eventually, with the help of dynein, gets transported to the healing area from axonal through this axonal part from the cell body to the neuronal injury area. So, in this way, once the injury response has been initiated, this injury response can eventually stimulate the neuron nucleus to synthesize a particular type of healing protein that can eventually be transported to the healing injury area to heal that injury. Okay, in the same way as we said that certain cases of bacteria or viruses, especially viruses like rabies, polio, or herpes, can eventually infect our neurons with the help of dynein.

So, basically, initially what happens is that the viruses can come inside the neuron from the terminal area or from another area, and eventually, when they enter that neuron area, this virus, with the help of the dynein protein, can carry the viruses and affect the nucleus. So, once this virus can go and fuse inside the nucleus, it changes the genetic pattern of the cell, and eventually, slowly, with the help of this host cell, the virus starts to replicate. And with the number of viruses increasing, eventually the neuro signals and the neuro signaling process fall apart. So, in this way, as you know, rabies is a very deadly virus, and it can come from a dog bite or a monkey bite. So, eventually this virus can affect our neurosignal process, and in that way, patients can basically lose all their motor neuron activity, as they will have significant difficulty swallowing any water or food, and slowly their cardiac muscles, lung muscles, and all muscle function will stop because the entire neurosignaling process will eventually be affected, as the virus will directly affect the nucleus of all the neurons.

Hopefully you understand how this process of kinesin and dynein happens. So, just remember that kinesin will take the molecule from the cell body to the terminal area, to the axonal terminal area. So, if the transport is from the cell body to the terminal area, it will help kinesin, and once the transport is needed in the retrograde direction, it will help dynein. So, it is clear to you. As we said, like the myelin sheath, which is a fatty or lipid-rich insulating layer, this basically surrounds the axons, and as we said, there are small gaps called nodes of Ranvier.

Whenever there is a nerve impulse that travels through this myelinated axon area, the depolarization step, or during the depolarization and repolarization, these signals can eventually jump from one node to another node. So, in this way, this basically speeds up the process of transmission, which is also called saltatory conduction. This is also called the saltatory conduction process. So, how is this way like this; it basically increases the speed. So, you can see that the myelinated axons can conduct nerve impulses much faster.

So, almost like 120 meters per second compared to the unmyelinated axons, which are around 0.5 to 10 m/s. So, basically, these myelinated actions, as you can see, are like once the node of Ranvier where the signals can jump from one node to another node of Ranvier, helping in terms of increased speed, right? So, as you can see, myelinated axons can conduct nerve impulses much faster. So, this rapid transmission is ultimately highly essential for quick reflexes and efficient communication with the nervous system. Then finally, we have the axonal terminal area; you can see this is the axonal terminal area where basically all these neurotransmitters, proteins, or different other molecules eventually get removed.

And how it happens is that there are different calcium ion channels present here, and when calcium binds to two different proteins, which are snare proteins present on the vesicles, it occurs here. So, once this calcium ion binds to this different type of bridging protein. They fuse these vesicles together with it, and eventually, after the exocytosis type of mechanism, these fused vesicles will release the neurotransmitter from the presynaptic neuron to the postsynaptic neuron. And again, the neurotransmitter, with the help of the ligand-gated voltage channel, will be taken up via the dendrites. So, this post-synaptic region, or the axonal terminal area, has the main function of basically releasing the neurotransmitter to the next neuron, and eventually some of the unused neurotransmitter gets reuptaken.

In the presynaptic neuron, these unused neurotransmitters, even with the help of the dynein protein, can go to the cell body where the lysosome can eventually degrade those leftover neurotransmitters to the amino acids. So, here a lot of reuptake and enzymatic degradation mechanisms also happen. So, this is the overall kind of diagram of a neuron. So, we will quickly summarize; as you can see, there is this antenna or dendrite-type molecule, then we have this cell body, right? We have a cell body where different types of proteins and other neurotransmitter synthesis happen, and then we have this long axonal area, right? We have a long axonal area. Where different types of electrical voltage-like signals or neurotransmitter molecule movements happen, either from the cell body to the axonal terminal area.

And even inside the axonal terminal area, this neurotransmitter, with the help of calcium ions, is basically removed in the postsynapse. So, this is the postsynaptic area. And once the neurotransmitter is basically consumed by another neuron, There might be some leftover neurotransmitter that can still be present; it will eventually be reuptaken by the previous presynaptic neuron. So, this is basically the whole structure of the neuron, and briefly, we gave you what the components of the neuron are and how they play an important role in various transmission processes. But the exact processes of neurotransmission will be discussed in the next few classes, where we will see how these different types of electrical signals are generated, the different processes of action potential, how it is generated, and how these signals eventually transmit.

by various ion transport pathways. So, please stay with it, and hopefully after all the classes on neurotransmission, everything will be much clearer. But in this class, hopefully, you understood how different components of the neurons are responsible for various important functions. Lastly, there are different classifications of neurons. For example, it can be a multipolar neuron where it possesses a single action but multiple dendrites extending from the cell body. So, you can see it has a single action, but it can have multiple dendrites.

So, basically their function is that the multiple dendrites allow them to receive inputs from different other neurons. And then it can be a bipolar neuron; you can see the bipolar neuron where it has only a single axon and a single dendrite. So, extending on the opposite side of the cell body. So, you can see there might be a single action and signal dendrite extending to the opposite side of the cell body, and it is primarily involved in sensory perception, acting as relay neurons for specific senses. Where you can see this type of bipolar neuron is in the retina of our eye, and then there can be unipolar neurons.

You can see that this is a very simple type of structure where it contains a single process extending from the cell body. So, there are no others like the dendrites that are present here; there is only a single type of process. which is called a unipolar neuron, and it basically functions in terms of primary sensory function, transmitting the sensory information from the periphery to the CNS. So, this type of unipolar neuron can be used for detecting touch, pain, temperature, and pressure in the skin. Finally, different functional classifications can also be done in terms of neurons, as we discussed in the last class regarding nerves.

So, there can be sensory neurons that transmit basically sensory information from sensory receptors in the peripheral nervous system to the CNS. Then there can be motor or FRN neurons which basically transmit the motor commands from the CNS to the effector organs and different types of muscles and glands. And there can be different interneurons or associative neurons. These are located entirely within the CNS, mostly in the brain and the spinal cord. They connect sensory and motor neurons and also have a very crucial role in terms of processing and integration of the signal.

Mostly, this type of interneurons is multipolar in nature. Finally, as we said, a nerve is basically a coiled and combined structure of neurons. So, you can see this is basically a very classic example of the nerve. So, we will discuss a little bit about the peripheral nerve. So, peripheral nerves are basically bundles of axons or nerve fibers. So, you can see these are like bundles, right? You can see there are several bundles of axions; neurons are present inside the nerve, and there are different layers also present.

So, this is like a whole nerve; this nerve can come from the spinal cord, and the layer of this nerve is called the epineurium. So, you see inside this epineurium layer, there are a lot of fascicle-like structures, which are basically a combination of many neurons, right? So, if you remove one fascicle, just think of it as pulling out one of these fascicles. So, you see, like, again, some coils of neurons are present here. So, this is like a large coil of neurons and this small coil of neurons is called a fascicle. So, if I pull out one fascicle, you will see that there are still a lot of different coils of neurons here.

So, this membrane layer of this second-like coil of nerves is called perineurium; this is mostly like the middle layer. And finally, you see that there are again small, small fascicles here. So, if I pull out one fascicle now, we will see that we will get a single neuron. And in this case, the membrane that basically covers the single neurons is called the endoneurium. So, basically, the epineurium, which is like the outermost layer of the nerve, has further coils of neurons in between; that middle layer of membrane is called the perineurium.

And finally, once we remove a single fascicle or a single neuron from this second layer of coil neurons, the membrane that covers the neuron is called endoneurium. So, the thing is that if any damages, for example, like any damages happen to the nerve, we will discuss in the next few classes how nerve injury and nerve repairs happen. Just remember that nerve injury can happen in any of these layers. But generally, if the nerve injury occurs in the endoneurium, it becomes very difficult to cure that nerve injury. If the intact perineurium is present, doctors generally try to connect this perineurium layer with another intact perineurium layer.

So, the doctor basically tries to connect one perineurium layer to another perineurium layer for the nerve regeneration process. So, in the case of any accident or any type of other injury where nerve damage occurs, the doctor tries to fuse one healthy perineurium to another healthy perineurium, and slowly, the nerve regeneration process happens. In the next class, we will discuss different types of nerve injuries that can happen to our body, and we will also thoroughly discuss the process of nerve regeneration. We will also see how complicated the process of nerve regeneration is; mostly, you have to remember that nerve regeneration happens in the peripheral nervous system. So, we will discuss why there is a difference between the central nervous system and its nerves, and we will also discuss how a peripheral nervous system injury can be repaired.

So do you know that the total length of all the neurons in your body, if laid end to end, could stretch for like 100 miles? It is like having an external and internal network of wires long enough to circle the Earth. So, you can imagine that if we tie all these total numbers of neurons together and create a circular path, it can cover enough distance to completely circle the earth. So, you can imagine how many times, how many neurons are eventually present, and finally, let us discuss these activity questions as well, such as which neuron sends the signal faster to the next neuron and why. So, can you tell me about this question? So, if you have any further questions, please send them to the email or you can also discuss them during the live session.

Thank you again for attending another class on human physiology. Hopefully, you are enjoying the neuroscience class. So, let us meet with another new class very soon. Thank you.