

Neurobiology

Dr. Nitin Gupta

Department of Biological Sciences and Bioengineering

IIT Kanpur

Week - 01

Lecture 1.6: Parts of Nervous System

Hi everyone. In the last video we looked at what the brain is made of. So we saw different cell types, neurons, glia and we also saw how they connect to each other. In this video we are going to see how small circuits of cells are formed and then we will see how the brain, what are the different parts that the brain is made of and the broader nervous system is made of. So let's get started. When many neurons connect together at synapses they can form small circuits.

Can you think of a simple nerve circuit that goes from the sensory layer to the motor layer? So let me show you an example here. We are talking about the knee jerk reflex here and we will look at the circuit that is involved in causing this reflex. So those of you who are not familiar with this reflex let me explain it very quickly. Suppose you are sitting on a chair with your knee bent at about 90 degrees.

Now in this position if I hit your knee just below the knee with a sharp object like a small hammer what happens is that as soon as I hit your leg will move forward in this direction. So forward and upside and this will happen automatically without you even thinking about it. That's why it's called a reflex. So now let's try to understand why this happens or how this happens. When I hit this part of the knee it is connected to the quadricep muscles that are present in the front part of your thigh and at the back part of your thigh you have the hamstring muscles.

So there are sensory neurons and motor neurons that are embedded in the muscle. When the quadricep muscle is extended the sensory neuron is activated and the axon of the sensory neuron goes to the spinal cord and in the spinal cord it makes a contact with a motor neuron that comes back to the same muscle the quadricep muscle. So basically when the muscle is extended the sensory neuron is activated then the motor neuron is activated and this activates the quadricep muscle. The activation of a muscle makes it contract makes it become tight so it contracts and therefore this quadricep that had extended initially because of the hitting now actually contracts suddenly. The same sensory neuron also connects to an inhibitory neuron in the spinal cord shown here in green and this inhibitory neuron is connected to another motor neuron that is going to the opposing muscle the hamstring muscle.

So because the sensory neuron is activated the inhibitory neuron is also activated it reduces the activity in the second motor neuron and therefore that reduces the activity in the hamstring muscle and as the activity in the hamstring muscle is reduced it relaxes. So essentially the quadricep muscle is now suddenly contracting and the hamstring muscle is suddenly relaxing or extending and as a result the thigh will contract on the upside and extend on the lower side which will make the leg move in front and upside direction like this. So this small circuit with this sensory neuron and these motor neurons and one inhibitory neuron causes this sudden reflex. This is probably as simple as a circuit can get all the way from the sensory side to the motor side. Can you think of a reason why we have this knee jerk reflex? What can be the advantage of it that evolution allowed this reflex to arise and be maintained in the first place? There are a few theories about it.

One explanation says that suppose you are standing on the ground and you suddenly happen to lean backwards without even noticing. That backward leaning will cause an extension in the quadricep muscle which is in the front of the thigh and that will trigger this knee jerk reflex and now because your leg is on the ground you cannot really jerk it forward but rather your body will come forward because of the same contraction of the quadricep muscle and extension of the hamstring muscle. So it will make you become straight again as opposed to falling backwards. The other explanation is that suppose you jump from a height on the ground in that case also your quadricep muscle would extend suddenly and that would trigger the reflex and as the reflex is triggered you would spring back up. There are other possible explanations as well.

I would encourage you to go online and look for various theories for why we have this reflex and see which one you find most convincing. On this slide you also see these terms gray matter and white matter. Let's see what these mean. These terms gray matter and white matter are commonly used in English language when talking about the brain. There are even debates about whether gray matter is more important or white matter is more important.

So let's try to understand what these are referring to. This is the cross-section of a brain and here if you look carefully you can see there are two kinds of shades in the brain. There is this darker shade which is called the gray matter and then there is a lighter shade here and these areas can be called the white matter. So what produces these two colors or shades? The white matter here is actually made up of myelinated axons. So parts contain a lot of myelinated axons appear lighter in color and that is what is commonly referred to as the white matter and these other parts contain the cell bodies and the dendrites of neurons.

So this is what is referred to as the gray matter and now you can see both of these are actually parts of the neurons and the neurons are not going to function if either the cell bodies or dendrites are absent or the myelinated axons are absent. So both are equally important for the functioning of the brain and therefore these debates about whether gray matter is more important

for intelligence or white matter are kind of meaningless. Now let's look at some other terminology as well. One common term that is used is nerves and nerves basically refers to a bundle of axons that are found in the body. So the bundle of axons that are going from the brain to different parts of the body can be called nerves.

You can have sensory nerves or motor nerves. We may also have bundles of axons within the brain like this white matter parts visible here. These can be called tracts. So both nerves and tracts are bundles of axons. It's just that when these bundles are present within the brain we commonly call them as tracts and when they go out of the brain to different parts of the body they are called nerves.

Another term that is used is ganglion. So ganglion refers to a group or a cluster of cell bodies that may be present in the body and similarly a nucleus may represent a cluster of cell bodies that are present within the brain. So the cell bodies are not uniformly distributed throughout the brain. They are packed in clusters or groups and these groups within the brain can be called nucleus or nuclei for plural and when they're present in the rest of the body like in the spinal cord or other parts of the body they can be called ganglion or ganglion. Just a caution here this term nucleus that we are using for clusters of cell bodies within the brain is different from the cell nucleus which is the part or which is the cell organelle that contains the DNA that is present in every cell but this nucleus we are using for clusters of cell bodies.

Now let's take a look at the organization of the vertebrate nervous system. This organization is broadly similar in humans and various other vertebrates. The nervous system can be broadly divided into two parts the central nervous system and the peripheral nervous system. Central nervous system is also abbreviated as CNS and peripheral nervous system can be abbreviated as PNS. So central nervous system basically includes the two main parts of the nervous system the brain and the spinal cord and the peripheral nervous system includes various nerves that are going from the brain or the spinal cord to various parts of the body like in the hands in the legs at the back and so on.

The peripheral nervous system can be further subdivided into two components the sensory part and the motor part. The sensory division basically includes those nerves that are collecting information from different parts of the body and relaying it to the spinal cord and the brain. So the information is flowing from the body towards the brain and this is also called as afferent division and these nerves that are carrying information to the brain are called afferent nerves and the other part is the motor division where the brain is sending signal to various muscles in the body to control their movement. So the signal is going from the brain and the spinal cord to various parts of the body. So this is also called as the afferent division.

Now within the sensory part we can distinguish two components those nerves that are collecting information from the external environment for example through the eyes or the ears or the skin and there are also nerves that are collecting information from within the body for instance sensing of your hunger or thirst or as we saw in the knee jerk reflex there are sensory neurons that are embedded in the muscles which are sensing the stretch or the relaxation of the muscles. So these kinds of sensory nerves can be called as sensing the internal environment of the body. The peripheral motor division can also be divided into two parts the autonomic nervous system and the somatic nervous system. The somatic nervous system includes those nerves that are connected to various muscles of the body that you can control voluntarily like your biceps or your leg muscles or your neck and so on and the autonomic nervous system includes those muscles in the body that are being controlled by the brain automatically without even conscious control for instance your heart or your lungs. There are a lot of organs in the body that are functioning without us consciously controlling them.

The heart is pumping the blood and it is changing the blood flow depending on the requirements of the body. If you are running the blood flow increases if you are sitting it may reduce. Similarly your lungs, your digestive system, your bladder a lot of these things are functioning under the control of the brain without us consciously controlling them. So they're all part of the autonomic nervous system. The autonomic nervous system is traditionally divided into two categories called the parasympathetic nervous system and the sympathetic nervous system.

There are informal words for these that are more popular. Sympathetic nervous system is also called the fight-or-flight nervous system. It controls whether you are ready to fight or run away from a predator for instance and the parasympathetic nervous system is the opposite. It controls your rest and digest responses. When you are ready to fight an animal a lot of things need to happen.

Your blood flow has to increase, your breathing rate has to increase, your liver needs to release more energy so more glycogen converts to glucose in the liver and you need to release adrenaline while you can reduce the activity of your digestive system. So you don't need to spend energy on digesting the food while you are fighting an animal and similarly you can reduce the activity of your bladder or anus. So this is controlled by the sympathetic nervous system which activates your body in a high energy state to be able to fight or run and when you realize that the animal, the dangerous animal has gone away or the danger has gone away then you can relax. So at that time the heartbeat can slow down, the breathing rate can decrease and your liver instead of releasing glucose can focus on releasing bile for digestion of food. The peristalsis movement of the stomach and the intestine could increase and your bladder can be more active.

So this is controlled by the parasympathetic nervous system. There are different nerves that control, that activate the body through the sympathetic nervous system and different set of nerves

like the vagus nerve that are controlling the parasympathetic part of the nervous system. In the common life in the modern world it is often felt that the balance between the activity of sympathetic and parasympathetic nervous system can be thrown off. So even though we are rarely in situations where facing a dangerous animal and therefore there is rarely a need for fight and flight responses, we still tend to activate it more frequently than required and therefore our body remains in this kind of over excited state and is not able to digest the food properly and is not able to get enough rest. And therefore these approaches like meditation or yoga or music therapy sometimes help in activating the parasympathetic nervous system to relax the body.

Most of the nerves that go from the brain to the body go through the spinal cord but there are some nerves that bypass the spinal cord and they go directly from the brain to different parts of the body. So these are called the cranial nerves and there are 12 of them. So these ones are shown here. Some of them are sensory in nature, some of them are motor nerves. For instance the olfactory nerve gets signal from the nose and takes it directly to the brain.

The optic nerve takes signal from the retina and takes it to the brain. And then there are some motor nerves for instance the vagus nerve. This is one of the parasympathetic nerves that is controlling the activity of the heart and the lungs and so on. So it is obvious that the brain is really important. It is not only controlling our movements and our sensation, it's even controlling all the internal organs in the body.

And therefore we need a lot of protection for the brain to prevent it against any kind of injury. And evolution has come up with six protective layers for the brain for this purpose. Of course we have the skull, the bony structure that is surrounding the brain. So that provides protection against any physical impact. And then of course you have the skin on top above the skull.

And between the skin and the skull there is another protective layer called the periosteum. Now below the skull there are another three layers that are covering the brain. These are called the dura mater, the arachnoid and the pia mater. They are also shown in this picture here on the right. So in this picture you can see there is this layer that has been peeled off, that is indicated by number one.

This is called the dura mater. So this is a fibrous layer that is just below the skull and it is covering the brain. And then below the dura mater you have another layer called the arachnoid. It is also a fibrous layer that is covering the whole brain. And then below the arachnoid there is another layer, the third layer called the pia mater. And this layer is covering the whole brain and it is even tightly sticking to the brain so that it is going through all the grooves and all these peaks and valleys of the brain.

So it is tightly covering the brain. It has vasculature, so blood vessels go through it into the brain. All these three layers together, the dura mater, the arachnoid and the pia mater are called meninges. So these three meninges are the three internal protective layers of the brain. You may have heard of the term meningitis. That is basically referring to the situation where any of these meninges becomes infected with some virus or bacteria.

And that is a serious problem for the brain. The brain receives nutrients and oxygen through the blood. But in addition to blood vessels there is another type of fluid that is present in the brain that is called the cerebrospinal fluid. This fluid is present only in the brain in the spinal cord and not in other parts of the body. If you look at a cross-section of the brain you can find that there are certain cavities or ventricles through which the cerebrospinal fluid flows and it also goes throughout the brain. It is present between the arachnoid and the pia mater, the last two layers that are covering the brain.

The functions of the cerebrospinal fluid include providing protection against impact by acting as a cushion. And it also has protective roles. So it plays role in the immune response and it also regulates the blood flow in the brain.