Overview of the Nervous System

Every minute of every day, your nervous system is sending and receiving countless messages about what is happening both inside and around your body. Right now, your nervous system is receiving sensory input from your eyes about the words on the screen, from your ears about the sound of the computer, from your skin about the feel of your clothes, etc. At the same time, your brain is receiving information from sensors that monitor your heart rate, blood pressure, levels of oxygen and the contents of your stomach and intestines. Your brain then interprets all of these signals, which allows for an understanding of the words on the screen, the recognition of the noise as computer noise, and the development of motor responses such as moving your eyeballs, changing positions in your chair, and decreasing or increasing your heart rate and digestion. In short, your nervous system coordinates all the activities of your body. This module will provide a general overview of the nervous system as a whole. A word of caution: A system capable of so many sophisticated and complicated functions has to be extremely complex. One module cannot possibly present all the information about the nervous system, and it will probably take a few trips through the nervous system before the pieces fall into place, so don't despair if you're a bit confused.
In a very general sense, the nervous system can be thought of as having 3 essential roles: sensing, integrating, and responding. The components of the nervous system responsible for carrying out those roles are the sensory component, the integrative component and the motor component. The sensory component of the nervous system detects changes that occur both outside and inside the body. The integrative component of the nervous system interprets and processes the information that arrives from the sensory component. The motor component carries out changes based on the interpretation by the integrative component of the nervous system. For example, when the sensory component detects an increase in external light level, the integrative component processes the information, and the motor component is activated to constrict the pupils of the eyes. The sensory, integrative and motor components of the nervous system interact to allow us to respond appropriately to the constantly changing conditions inside and around our bodies. While this is a very simplified picture of the nervous system, keeping this general scheme in mind will help to sort out the details that come later.
Before discussing the details of the nervous system, it is helpful to have a basic understanding of the cellular building blocks of the nervous system. The business cell in the nervous system is the neuron. In addition to neurons, there are also numerous support cells that will be covered in detail in other courses. Here, we will focus on neurons. A neuron's job is basically to pass messages from one part of the body to another. There are several types of neurons based on their structure and function, but all have certain common characteristics. First, they have a cell body with nucleus and organelles to provide for general metabolism and cellular maintenance. Second, they have processes specialized to receive (dendrites) and transmit (axons) signals. They have one to many dendrites, some of which have special endings that receive specific types of stimuli, such as pressure or temperature. Other dendrites may receive signals from other neurons. Neurons have only one axon process, which has one to several terminal endings that release neurotransmitters. Only the axon is capable of transmitting a signal to another neuron or to a cell of an effector organ through its neurotransmitter. In the nervous system axon terminals usually end on other neurons, most commonly on the dendrites of another neuron, but also on the cell body and rarely on an axon. The contact point between the neurons is called a synapse. A neuron's axon may be very long, such as an axon that runs all the way from the spinal cord to the big toe, or it may be very short, staying within a spinal cord segment. Signals that travel along axons are essentially electrical and consequently processes and neurons have to be insulated from one another like electrical wires. This is accomplished by supporting cells that encapsulate the neurons (except at synapses and axon terminals) or form sheaths around the processes. The sheath cells around some processes produce a lipid and protein material that is whitish in appearance called myelin. The myelin insulates the processes and greatly increases the speed of signal transmission. Neurons or processes that have myelin sheaths are said to be myelinated. Some neurons have processes that have a cellular sheath but lack myelin and they are said to be unmyelinated. The vast majority of axons in the nervous system are myelinated and accumulations of them appear whitish. Cell bodies never have myelin and accumulations of them have a grayish appearance. The nervous system is composed of billions of neurons that make billions of connections. This complexity gives us the ability to do everything from walk, to feel emotion, to learn, to constrict blood vessels, make us breathe and all of the other things that make us human.
How do individual neurons relate to the nerves that can be seen grossly? The structures that are visible in the body are not axons from single neurons, but rather groups of axons from many neurons bundled together. Individual axons, called nerve fibers, are grouped into fascicles, which are wrapped in perineurium. Fascicles are then bundled into groups and wrapped in epineurium. It is actually a bundle of fascicles surrounded by epineurium that is observed grossly and called a nerve. Realizing that what we call nerves are actually collections of many nerve fibers makes it easier to understand several very important characteristics of the nervous system. Firstly, it is easier to understand how some nerves can be much larger than other nerves. For example, the sciatic nerve, a very large nerve found in the posterior hip, has many more nerve fibers and many more fascicles than an intercostal nerve, which is much smaller. Secondly, it is easier to understand how a nerve can be a "mixed" nerve, carrying motor information to the periphery and sensory information to the spinal cord. Mixed nerves have both motor and sensory nerve fibers bundled in fascicles, allowing one nerve to have information traveling in both directions. It may be helpful to think of a nerve as a telephone cord with an outer coating around a collection of wires. Within the outside coating, some wires carry information to the earpiece and some wires carry information from the mouthpiece.
Now that we have discussed the essential roles of the nervous system (sensing, integrating, and generating a motor response), and the basic structure of neurons and nerves, we can move on to discuss the organization of the nervous system. For the sake of description, the nervous system is divided structurally into the central nervous system and the peripheral nervous system, and functionally into the autonomic nervous system and the somatic nervous system. These can be thought of as two different methods for thinking about the nervous system; they are not exclusive of one another. There are autonomic and somatic components of both the central and peripheral nervous systems, and the central and peripheral nervous systems are both involved in somatic and autonomic nervous system processes. It is important to recognize that the "divisions" of the nervous system exist for the purposes of description, discussion and study. They are not actual divisions in the nervous system itself. There is significant communication between all parts of the nervous system, and the different divisions of the nervous system are very highly interrelated.
We will first discuss the structural divisions of the nervous system: the central nervous system and the peripheral nervous system. These divisions are often abbreviated CNS and PNS, respectively. The central nervous system consists of the brain and the spinal cord, while the peripheral nervous system consists of the nerves outside the central nervous system. A couple of useful terms to define at this point are nucleus and ganglion. In the central nervous system, a collection of neuron cell bodies is called a nucleus. In the peripheral nervous system, a collection of neuron cell bodies is called a ganglion (plural: ganglia). The one exception to this rule that you may have encountered is the basal ganglia in the brain. Indeed, the basal ganglia technically should be called the basal nuclei, but they were named prior to the terms being defined and the name has stuck. Remembering the difference between a nucleus and a ganglion, and that both are simply collections of nerve cell bodies, will help you as we add more information onto the nervous system. In the image, the red structures depict the central nervous system, and the blue structures depict the peripheral nervous system. While these branches are called "nervous systems," they are not actually separate systems. The central and peripheral nervous systems differ structurally and are therefore considered separately, but they work together and are both part of the same overall system.
The central nervous system comprises the brain and the spinal cord. In general, the central nervous system is responsible for the integrative functions of the nervous system. Information about internal structures and the world around us is carried to the spinal cord, where it is subsequently carried to the brain. Our brains receive the information, send it to many different locations in the brain for interpretation, make decisions about the information, and then put together a response that is shipped down the spinal cord and back out to the periphery. In addition to forming motor responses to the information that reaches the brain, the brain also uses the information to perform our most complicated human functions: intellect, emotion, behavior, memory, learning, etc. The spinal cord acts primarily as a highway for information from the brain to the periphery; however, it also performs some basic integrative functions such as reflexes.

Structurally speaking, the central nervous system is unique from the rest of the body in that it consists only of blood vessels and nervous tissue. You may have heard the brain referred to as "gray matter". This term comes from the appearance of cell bodies and unmyelinated axons in the nervous system. The exterior surface of the brain (the part that touches the inside of the skull) is composed of many millions of neuron cell bodies, which have a grayish color and is thus called "gray matter". Streaming out from those cell bodies and into the center of the brain are myelinated axons, which have a whitish color, and are called "white matter". The spinal cord is arranged in reverse - the myelinated axons (white matter) are on the outside of the spinal cord and the cell bodies (gray matter) are on the inside. The concept of white and gray matter will be revisited in the future, but it is useful now to remember that the brain and spinal cord are opposite in their arrangement of gray and white matter.
The peripheral nervous system is generally responsible for delivering messages from the CNS to the periphery and from the periphery to the CNS. The peripheral nervous system consists of 12 pairs of cranial nerves that originate from the brain, and 31 pairs of spinal nerves that originate from the spinal cord, and many branches of those nerves. Cranial nerves and spinal nerves together are called peripheral nerves. These nerves will be discussed in detail in other modules. Nerve fibers carrying information from the periphery to the CNS carry sensory information and are referred to as afferent nerves (these are really nerve fibers, but you will often hear them called nerves). Afferent nerves have receptors that detect different types of information, for example light, sound, touch, temperature, pain and stretch. These receptors are located primarily on the skin, but are also located in muscles, joints, and some organs to allow the brain to receive information about the location of various body parts (called proprioception) and the function of internal organs. Nerve fibers carrying information from the CNS to the periphery carry motor information to various effectors and are referred to as efferent nerves. Effectors are the structures that are altered by incoming information. The major effectors of the peripheral nervous system are skeletal muscle, cardiac muscle, smooth muscle of blood vessels and organs, and glands. Most nerves in the body carry both afferent and efferent nerve fibers, but some are exclusively motor or exclusively sensory. As soon as a nerve has entered the spinal cord, it is no longer considered part of the peripheral nervous system. Remember, the peripheral and central nervous systems are not actually separate systems, but rather two parts of one system.
In addition to dividing the nervous system structurally, the nervous system can be divided functionally into the somatic nervous system and the autonomic nervous system. Again, remember that these are not actually separate nervous systems, just different components of one system.
The somatic nervous system can be thought of as the branch of the nervous system of which we are conscious. The somatic nervous system provides sensory and motor innervation to all body parts except organs, smooth muscles, and glands. It is involved in our voluntary movements - jumping, walking, speaking; reflexive movements; and the sensations that we are aware of such as pain and light.
The autonomic nervous system is the branch of the nervous system of which we are unconscious. It involves the unconscious regulation of the visceral (organ) functions that maintain homeostasis within the body. The autonomic nervous system is a module by itself, but suffice it to say here that this is the branch of the nervous system that manages all of the body's internal functions. This includes regulating heartrate, blood pressure, digestion, etc. The autonomic nervous system has two components: sympathetic and parasympathetic. The sympathetic branch of the autonomic nervous system prepares the body to fight or flee in stressful situations, while the parasympathetic branch of the autonomic nervous system prepares the body to rest and digest in relaxing situations. These systems both innervate each structure and balance one another's actions. We can be thankful that we are unconscious of the workings of the autonomic nervous system because it would be nearly impossible to remember to digest on top of everything else we think about on a daily basis.
A good example of how the various components of the nervous system come together is the reflex arc. A reflex is a very specific response to a very specific stimulus that involves only neurons in the spinal cord and peripheral nerves. Let us consider the reflex that occurs when you touch something sharp. The pain receptors in your skin are activated and carry the pain message to the spinal cord on a sensory neuron. The axon terminal of the sensory nerve synapses in the gray matter of the spinal cord where the signal is interpreted. The neurons in the spinal cord then send a motor signal to your arm to withdraw from the painful stimulus. This entire pathway takes only milliseconds and effectively prevents you from damaging your finger. This is a particularly simple example because the generation of the motor signal occurs in the spinal cord and not in the brain. The brain would eventually receive information about what occurred, but the information would not be processed by the brain until after the signal had already been sent to the muscles of the arm to contract and withdraw the finger.
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Injuries: In this course we pose many nerve lesion or injury questions in order to test understanding of nerve innervation and pathways. Injuries to the nervous system are common and may occur through disease processes or trauma (crushing or cutting). The effect or the power of the body to repair or compensate for the disease or injury depends upon the site and nature of the injury. Injuries or diseases may destroy neurons or interrupt nerves leading to an identifiable loss of function affecting sensory, motor or integrative functions. Little or no regeneration or repair occurs in the central nervous system, although there may be compensation for some injuries. When a neuron dies it is not replaced. When injured, particularly when cut, peripheral nerves may regenerate by the growing of new axons down the remaining nerve sheath. Regrowth occurs at about 1 mm/day and the amount of functional restoration depends upon how well the cut nerves are reapproximated.
At this point, you should have a basic picture of the organization of the nervous system in your mind. To recap, the nervous system is responsible for all the activities of your body from digestion to emotion. The nervous system is built from a network of neurons with billions of synapses allowing all the parts of your body to communicate. We divide the nervous system structurally into the central nervous system and the peripheral nervous system. The central nervous system consists of the brain and spinal cord, and the peripheral nervous system consists of the nerves outside the brain and spinal cord (12 pairs of cranial nerves, 31 pairs of spinal nerves and all their branches). We also divide the nervous system functionally into somatic and autonomic systems. The somatic nervous system consists of those functions of which we are aware, and the autonomic nervous system consists of those functions of which we are unconscious. The autonomic nervous system may be divided further into sympathetic and parasympathetic components that interact to regulate homeostasis.

All the components of the nervous system interact to allow us to do all the things that make us uniquely human, from speaking to feeling emotions to learning complex information. You will go on to learn many more details about how the nervous system functions, but maintaining a general picture about its organization will go a long way towards making the details of the nervous system clearer.