1. Parts of the Nervous System

You hear a loud noise behind you. You jump. Your heart begins to beat faster and you breathe more rapidly. When you turn around, you realize that the loud noise was caused by someone dropping a heavy book on the floor. In this example, the circulatory, respiratory, muscular, and skeletal systems in your body have worked together to respond to a change in the environment. How were all of these systems able to respond at the same time, immediately after hearing the noise?

The nervous system is the body system that collects and responds to information from inside and outside of the body. It sends instructions to the rest of the body about what to do. Signals are sent within the brain as well as between the brain and the rest of the body constantly. Like the other body systems, the nervous system is composed of organs that are made up of tissues, which are, in turn, made of cells.

Cells of the Nervous System The main cells of the nervous system that transfer signals to, from, and within the brain are called neurons A typical neuron has three parts: a cell body, a long axon, and dendrites. The structure of a neuron is very important for its function of transferring signals. You can think of a signal passing from one neuron to the next like a relay race. The dendrites of one neuron receive signals from other neurons. The signals move through the cell body and axon, then on to the neighboring neurons through the ends of the axon. The many branched axon endings allow a neuron to pass a signal to several other neurons at once, so the signal can travel multiple places at once. For example, when you are startled by a loud noise, signals go from the brain to your muscles, to your heart, and to your lungs at the same time so that you react to the noise in several ways.

Tissues of the Nervous System Nervous tissue is made up of different kinds of neurons, as well as other cells that support neuron function. The axons of neurons are often bundled up next to each other and covered in connective tissue forming tracks, like highways, for signals to pass between the brain and the body.

Remember that there are four kinds of tissues: nervous, connective, epithelial, and muscle. All the parts of the nervous system are made of nervous tissue and other tissues. The spinal cord is an organ that transfers information between the brain and other parts of the body. The spinal cord is made of nervous tissue that is surrounded by a thin layer of connective tissue and blood vessels.

Organs of the Nervous System The organs of the nervous system are the brain, the spinal cord, and the nerves. The brain is an organ that processes information received from both outside and inside of the body. It is protected by the skull and is the control center for the entire body. It is also the most complex organ in the human body, consisting of almost 100 billion neurons.

The spinal cord runs down a person's back, protected by the backbone. Most information passes through the spinal cord on the way to the brain. Signals from the responding brain also pass through the spinal cord on the way to the rest of the body.

Nerves are organs that transmit information toward and away from the brain and spinal cord. They are made up of the axons of neurons bundled together. Almost every part of the body has nerves interacting with it. To get to the various body parts at and below the neck, pairs of nerves branch off from either side of the spinal cord and into the other organs of the body. For example, nerve branches near your shoulders travel down your arms and into your hands. One side connects to your left hand and the other side to your right hand.

2. Stimuli to and from the Brain

Your stomach "growls" and you know that you are hungry. Besides the grumbling sound, you actually might feel an ache inside your belly. Or, when you eat too much, you can feel the fullness in your stomach. How does that happen? How do you know what your stomach is feeling?

Nerves in your stomach are sending information to your brain and the brain is interpreting that information as hunger or fullness. A grumbling stomach is an example of a stimulus in your internal environment. A stimulus is a change in the internal or external environment that causes the nervous system to react. An example of an external stimulus is the sound that was made when the heavy book was dropped behind you. Lights, odors, or the flavors of foods are other examples of stimuli (plural of stimulus).

Nerves are found inside and all around most of the organs in the body. If something about the organ changes, the nerve responds by sending a signal to the brain through the spinal cord. Nerves that transport signals toward the brain are called sensory nerves. Sensory nerves receive and transmit sensory information such as sounds or pressure from the other body systems and from the external environment. Motor nerves are the nerves that transmit information from the brain toward the rest of the body. Together, sensory and motor nerves relay information to and from the brain.

When the brain receives information about the change, it makes a decision and then sends information to the other body systems telling them how to respond. For example, your stomach expands when it is full. Sensory nerves around the stomach detect this change in size. This information is sent to the spinal cord, which relays it to the brain. The brain interprets this information as the feeling of fullness and decides that it is time to stop eating. The brain then sends signals back through the spinal cord to your arm muscles, telling them to contract and put down your fork. The relaying of all this information to and from the brain usually happens in less than a second. The process of receiving a signal and interpreting it for a response is called information processing.

A response to a stimulus can also be the formation of a thought or a memory. For example, you might be excited that school is ending when you hear the bell ring. Or you might form a memory of what the bell sounds like so that you recognize it the next day.

3. Voluntary and Involuntary Responses

If you have been to a check-up at the doctor's office, the doctor might have used a small rubber hammer to hit below your knee. Then, to your surprise, your lower leg probably kicked forward. What caused your leg to act like it had "a mind of its own"?

Some responses to a stimulus are voluntary, and others are involuntary. Responses that you have to think about to control are voluntary responses.

For example, moving your body to stand up from your chair after you hear the bell ring at the end of the school day is a voluntary response to the bell. Responses that you do not have to think about, such as your breathing, heartbeat, and digestion, are involuntary.

A reflex is an involuntary response. Some reflexes, like blinking in response to something coming toward your face, are controlled by the brain. But some reflexes are processed in the spinal cord and do not even require the brain for a response. The knee-jerk in response to the rubber hammer is a spinal cord reflex. Spinal cord reflexes occur quickly because the information is processed in the spinal cord and a reaction occurs before the brain even receives the information about a stimulus. In a knee-jerk reflex, information passes from the knee to the spinal cord and then to the leg muscles. Your leg moves even before your brain recognizes the hit of the hammer. These reflexes have a very predictable cause-and-effect pattern, so any change to that pattern indicates that something is wrong. This is why the hammer test is one good test for checking how well the nervous system is responding to signals.

4. Sense Receptors

You are surrounded by stimuli in both your internal and external environments—hunger, thirst, sounds, images, odors, and objects to touch and feel. Many of these stimuli are harmless, but some may be dangerous. How does your body handle all these stimuli to ensure that you survive?

Sense receptors are specific kinds of sensory neurons that detect and are activated by stimuli from outside or inside of the body. Being activated means that they initiate the signal that is sent to the brain in response to the stimulus. They are found in and around almost every organ in the body.

Some sense receptors monitor internal conditions. For example, heat and cold receptors throughout the body detect changes in temperature. Other sense receptors in blood vessels detect changes in blood pressure. Receptors all over the body even detect changes in the body's position or pressure and pain in different regions of the body.

Other sense receptors detect changes in the external environment such as light, sound, and temperature. Humans gather information from the many stimuli in the external environment through their senses of sight, hearing, smell, taste, and touch. Although these stimuli are different, the body responds to them in a similar way. First, a stimulus is detected by a sense receptor. Second, a signal is sent to the brain. Third, the brain responds. It can respond by sending a signal to trigger a behavior, thought, emotion, and/or the creation of a new memory.

Mechanical Receptors There are many kinds of sense receptors, and each kind responds to a different kind of stimulus. A mechanical receptor is a sense receptor that detects and is activated by movement.

Mechanical receptors are found all over the body. Mechanical receptors in the stomach detect how much food is inside by how stretched the tissue in the stomach is. Mechanical receptors in the inner ear allow you to hear, using the movement of tiny hairs in the inner ear in response to sounds. Mechanical receptors in the skin are able to interpret different kinds of pressure as different kinds of touch, like soft touch or vibration.

Chemical Receptors Sense receptors that detect and are activated by chemical substances are called chemical receptors. Chemical receptors are found in the mouth and nose. Taste buds are structures on the tongue that contain chemical receptors. The receptors are activated by chemical substances you put in your mouth, such as sugars in foods and beverages. Chemical receptors send signals to the brain that are interpreted as taste or smell. Chemical receptors are important for survival. The ability to smell and taste allows animals to distinguish fresh food from a toxic substance. Smell and taste keep many animals, including you, from poisoning themselves.

Light Receptors Light receptors are sense receptors that detect and are activated by light. Light receptors are part of a category of receptors called electromagnetic receptors. Light receptors in the eye absorb light and trigger nerve signals that result in sight. Light hitting your eye is a stimulus. You see when light reflects off an object, enters the eye, and activates the light receptors at the back of the eye. The information is sent to the brain through sensory nerves and processed to form an image. Without these receptors, you would not be able to see.

The human eye contains two kinds of light receptors with different functions—rods and cones. Rods respond to dim light and to motion, but they cannot detect color. Cones help to interpret light of different colors. Humans have three kinds of cones. One responds to red light, one responds to blue, and the third responds to green. All of the colors you see result from the interaction of signals sent to the brain from these three kinds of cones.

5. Memory, Learning, Thoughts, and Emotions

You walk into a room and smell a familiar scent. It reminds you of your best friend and one day that you couldn't stop laughing together. This memory makes you happy. How does the nervous system do this?

You have learned that behaviors, like moving your leg, are the result of information processing. Thoughts, feelings, learning, and memory can also be the result of information processing. In the example you just read, the stimulus was the smell and the response was a series of thoughts, memories, and feelings that all happened within your brain.

Memory Some types of information processing result in the formation of new memories or recalling old memories. For example, you have formed a memory of your favorite food because your brain processed the information from the chemical receptors in your tongue when you ate and enjoyed that food. Now you can remember what it tastes like without even having to eat it.

There are two kinds of memory: short-term and long-term. Short-term memory, often called working memory, acts as temporary storage for information that is being processed at a given point in time. In order to solve a math word problem, for example, you need to keep in mind the beginning of the problem while you read the rest of the problem, but you don't need to remember it five days later. Long-term memory is used to store information in the brain over long periods of time, sometimes your entire life. The building of a long-term memory involves permanent changes to the connections between different neurons in the brain. Short-term memory often becomes long-term memory as these changes occur.

Forming new memories generally requires a part of the brain called the hippocampus. The hippocampus is located deep inside the brain. Once these memories are made, they are stored as long-term memories all over the brain.

Learning Learning is also a result of information processing. Learning and memory are closely related. Learning is the process for making new memories, and remembering what you have previously learned is important for learning new things. For example, when you learned how to read, your brain had to store the relationship between letters and words and what they meant. If it weren't for memory, you would have to relearn these things every time you pick up a book. Also, like memory, learning causes structural changes in the brain, changing the connections between different neurons.

Some behaviors change as we age, but learning is a behavior that lasts a lifetime. What we learn can and does change as we get older. For example, you probably learned to talk and walk as a toddler. Young people will often learn brand new ideas faster than older people. But older people can often connect different ideas together better because they have more memories of similar information to connect with the new information.

Thoughts and Emotions Thoughts and emotions can also occur as a result of information processing. How you think about and feel toward a stimulus can change how you interact with that stimulus. For example, if it makes you happy when you ride a bike or skateboard, you might try to do it more often. But if you have negative feelings toward these things, you will likely avoid them.

6. Regions of the Brain

In the 1950s a man known as H.M. underwent surgery to remove a part of his brain that was causing seizures, a condition in which a person can lose consciousness or suddenly shake all over his or her body. He had a normal memory before the surgery, but afterwards, he could not form new memories. He was still able to walk, talk, and perform short tasks. He could even recall things from childhood, but he could not learn any new information. From H.M.'s surgery, scientists realized that the parts of H.M.'s brain that were removed, including part of the hippocampus, were needed for forming new memories. Why did his surgery only affect his memory but not other things that the brain controls? How is it possible to remove portions of a person's brain and the person remains alive after the surgery?

Evidence from studying H.M. and the brains of other patients has supported the claim that different regions of the brain are important for processing different kinds of signals. For example, vision is processed by a region near the back of your brain known as the visual cortex. This is because the eye's sense receptors connect to the visual cortex. Odors, tastes, and sounds are all processed in different regions of the brain. As scientists learned from H.M., even something as complicated as making new memories happens mostly in one part of the brain. However, some signals are processed in more than one region, like the process of painting. The visual cortex of the brain is used to analyze the shapes and colors on the canvas and the motor region of the brain is used to move your hand.

Scientists have learned that an injury to a particular region of the brain results in a loss of a specific function rather than a loss of all functions. For example, if someone has had an injury to the vision section of their brain, it will not injure their hearing. This predictable cause and effect pattern also works for understanding diseases. Alzheimer's disease affects the creation of new memories. Predictably, neurons in the hippocampus are some of the first cells to be affected by this disease. Similarly, Lou Gehrig's disease, also known as amyotrophic lateral sclerosis (ALS), injures motor neurons, especially in the motor control region of the brain.

Scientists now have techniques for studying brain regions in non injured brains. Imaging technologies are used to see which regions of the brain are being used when certain types of information are being processed. Functional magnetic resonance imaging (fMRI) devices are used to see, in real time, which regions are sending or receiving signals in response to a stimulus.

7. Lesson Summery

Parts of the Nervous System The nervous system includes the brain, spinal cord, and nerves. The parts of the nervous system are made of nervous tissue, which is made of neurons and other kinds of cells.

Stimuli to and from the Brain The brain processes signals from stimuli in both the internal and external environments and responds to it. Sensory nerves receive signals from the environment and transmit them to the brain. Motor nerves send signals from the brain to the other organs.

Voluntary and Involuntary Responses There are two kinds of responses to a stimulus, voluntary and involuntary. A reflex is an involuntary, rapid, automatic response to a stimulus. Spinal cord reflexes are processed in the spinal cord.

Sense Receptors Sense receptors detect stimuli from the environment. When a stimulus is detected, the sense receptor sends a signal to the brain. The brain either sends a returning signal resulting in an immediate behavior or a memory forming.

Memory, Learning, Thoughts, and Emotions Memory, learning, thoughts, and emotions also result from information processing by the brain. Short-term memory acts as temporary storage of information that is being processed. Long-term memory stores information in the brain over long periods of time.

Regions of the Brain Signals travel from various parts of the body to specific regions of the brain. Scientists have gathered evidence for this understanding through various methods.