

Educator's Guide and Script For
The Human Body: The Nervous System

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INTRODUCTION

The goal of this program is to present an upper level high school or introductory pre-med or pre-nursing school overview of the anatomy and physiology of the nervous system. Using the latest in 3-D graphics, medical imaging and for the first time detailed cadaver dissection. This program is designed to maximize student learning. Beginning with the evolution of the brain, the program looks at the most intricate and advanced neural network in the world – the human nervous system. The three components of the nervous system are systematically laid out: the brain and spinal cord; the peripheral nervous system; and the autonomic nervous system. The program ends with an examination of nervous system diseases and an in depth look at the spinal cord through dissection.

ADVANCED VOCABULARY DEFINITIONS

- **Autonomic nervous system:** The part of the nervous system of vertebrates that controls involuntary actions of the smooth muscles and heart and glands
- **Axon:** The long, hair-like extension of a nerve cell that carries information to other cells
- **Central nervous system:** The portion of the vertebrate nervous system consisting of the brain and spinal cord
- **Cerebral cortex:** The gray, folded, outermost layer of the cerebrum that is responsible for higher brain processes such as sensation, voluntary muscle movement, thought, reasoning, and memory
- **Cerebral hemispheres:** The two halves of the brain (right and left)
- **Cerebrum Meninges:** The meninges is the system of membranes which envelops the central nervous system
- **Corpus callosum:** The large bundle of nerve fibers linking the left and right cerebral hemispheres
- **Dendrites:** The branched projections of a neuron that conduct the electrochemical stimulation received from other neural cells to the cell body
- **Dura mater:** The tough fibrous membrane covering the brain and the spinal cord
- **Electroencephalogram:** A recording of the brain-wave patterns or electrical impulses of the brain from electrodes placed on the scalp; EEG

- **Frontal lobe:** The part of the cerebral cortex in either hemisphere of the brain lying directly behind the forehead
- **Ganglion:** An encapsulated neural structure consisting of a collection of cell bodies or neurons
- **Left hemisphere:** The hemisphere specialized for speech, writing, language, and calculation
- **Nerve fibers:** The slender projection of a nerve cell, or neuron, that conducts electrical impulses away from the neuron's cell
- **Nerve impulse:** A wave of physical and chemical excitation along a nerve fiber in response to a stimulus, accompanied by a transient change in electric potential in the membrane of the fiber
- **Nervous system:** The system of nerves, ganglia, the spinal cord and brain that regulates and coordinates all the body's activities
- **Neural pathways:** A neural pathway, or neural tract, connects one part of the nervous system with another
- **Neurons:** A nerve cell: a cell that is specialized to conduct nerve impulses
- **Occipital lobe:** The part of the cerebral cortex in either hemisphere of the brain lying in the back of the head
- **Parietal lobe:** The part of the cerebral cortex in either hemisphere of the brain lying below the crown of the head
- **Peripheral nervous system:** The nervous system which links the spine and brain to the skin, muscles, blood vessels and other sensory organs
- **Reflex action:** Also known as a reflex, it is an involuntary and nearly instantaneous movement in response to a stimulus
- **Right hemisphere:** The hemisphere specialized for spatial abilities, face recognition in vision, and some aspects of music perception and production
- **Spinal cord:** The longitudinal cord of nerve tissue that is enclosed in the spinal canal. It serves not only as a pathway for nerve impulses to and from the brain, but also as a center for carrying out and coordinating reflex actions independently of the brain
- **Spinal ganglion:** Any of the sensory ganglia situated on the dorsal root of each spinal nerve
- **Spinous ganglion:** See spinal ganglion
- **Spinous processes:** The bony projections at the back of the vertebrae
- **Temporal lobe:** The part of the cerebral cortex in either hemisphere of the brain lying inside the temples of the head
- **Vertebral bodies:** The bones that make up the spine
- **Vertebral column:** spinal column: the series of vertebrae forming the axis of the skeleton and protecting the spinal cord
- **Visual cortex:** se cortical areas primarily concerned with the processing of visual information. The visual areas of the cortex are primarily located in the occipital lobe: the rear, lower part of the cortex

SCRIPT

HUMAN BODY: THE NERVOUS SYSTEM

The miracle of all miracles on this planet is the human body. Now see it in a way never revealed before.

In many ways the human brain is like the world's fastest high speed computer, executing 100 million operations per second – impressive. However, the human brain with a trillion cells – 50 to 100 billion neurons - can handle over 10 quadrillion instructions per second. The human brain with its intricate neural network is also the most advanced structure in the universe, a structure that has reshaped the plane. A structure that has become aware of itself. Welcome to the awesome world of the human nervous system. I'm Dr. Mark Reisman.

Evolution of the Brain

Jim is a climate scientist working in his office. At the moment, he is working on design refinements for measuring CO₂. Suddenly the fire alarm goes off. He's startled. His heart starts racing. Blood pressure goes up. He feels weak. Within a few seconds somehow it all comes back to normal. His sense of smell picks up the acrid odor of smoke. He knows this isn't a drill. He begins gathering up important papers and transfers data to his thumb drive. The siren from the approaching truck alerts him to impending danger and he races out of the room. For Jim what just happened was a demonstration of the many facets and brilliance of his nervous system.

It is a nervous system that began evolving in the oceans hundreds of millions of years ago. At one time the animal world consisted of many invertebrates, animals without backbones, such as worms, cephalopods, and arthropods, to name a few. Animals without backbones, but not without nerve tissue and sense organs. Among these creatures were the first neo-chordates - the first animals to build a backbone.

From these evolved fish, and eventually amphibians - animals such as salamanders. Salamanders were the first to move about on the land surface. These were joined by crocodilians and reptiles, lizards and snakes. Shortly thereafter, dinosaurs appeared. All of these animals had very distinct backbones and skulls containing ever larger brains. During the age of dinosaurs, two more major groups of vertebrates appeared - birds and mammals. Both with even greater brainpower, brain power that reached its highest level with a group of mammals known as primates, of which we humans have the greatest brainpower of all. A brainpower that gives us the capacity to invent and use tools, tools that we use to transform the world, to create the post-modern, information rich world we live in today.

But just as important was that the large complex human brain allowed for the development of language and the use of symbols. By the time these children have reached the age of two, they can already speak, understand stories, count and use

numbers. They are on their way to investigating the world around them, eventually using their brain to study itself.

The Three Components of the Nervous System

It is a study that begins by dividing the nervous system into three components, components that can be defined by both anatomy and function. Let's start with the central nervous system. It is made up of the brain and the spinal cord, a bundle of nerve fibers that runs along and inside of the backbone, the vertebral column.

Now we come to the second component of the central nervous system: the peripheral nervous system. Branching from the central nervous system are 43 pairs of nerves, 31 from the spinal cord like these, and 12 from the brain itself. These pairs of nerves extend even further.

The nerves branch and snake their way into every nook and cranny of the body. The end result is a network - an information highway, carrying information from the senses to the brain, and the brain sending instructions back to the muscles. This is the peripheral nervous system.

Let me show you a classic demonstration of the peripheral nervous system. The knee reflex test.

The third component, the autonomic nervous system, controls such functions as heart rate and blood pressure. This system has its own chain of nerves along the spinal cord. But it also uses parts of the other two components - the peripheral nervous system and the central nervous system.

Brain Anatomy

The central nervous system, as we noted, has two main parts: the spinal cord and brain. The brain is quite delicate and needs maximum protection. The body does this by encasing it in a bony hard skull. Additional protection is provided by three layers of surrounding tissue known as the meninges, tissues that hold fluid like a water balloon, a fluid that is the third line of defense for the brain from blows to the head.

Now as we look at the brain from the outside, we can see a great deal of structure, structure that separates the brain into numerous parts. The largest part? - the cerebrum. The cerebrum is divided into two halves: the left and right cerebral hemispheres, connected by the corpus callosum.

Just as people are left-handed or right-handed, play tennis left-handed or right-handed, people seem to be predominantly left brained or right brained. Brain research has shown that the right hemisphere is more visual and processes decisions intuitively, holistically, and randomly, while the left hemisphere, the faster hemisphere, is the seat of language and processes information in a logical and sequential order. However, both sides of the

brain are involved in nearly all human activities.

The outer surface of the cerebrum is made up of a layer of gray matter called the cerebral cortex. This is where all the action takes place.

So the human brain needs as much gray matter as is possible and with a pretty much fixed skull size, the human body has come up with an ingenious solution to the problem of more gray matter, the solution of how to get more gray matter into the relatively small size of the skull. That's how the brain fits more gray matter into the skull and why the surface of the brain is so folded. By the way, if I do this with a second piece of paper, each time the result is different. So each human's brain folds are just like a fingerprint, unique to that individual.

The cerebral cortex is estimated to contain hundreds of billions of cell bodies, networks of nerves that are impulse-collecting centers.

Incredibly the gray matter is only this thick two tenths of an inch.

Underneath the gray matter is white matter. It is made up of many nerve fibers that carry signals back and forth from the brain's interior to the surface.

Now back to the outer structure of each cerebral hemisphere.

The cerebral cortex can be divided into four sections, which are known as lobes. The frontal lobe, parietal lobe, occipital lobe and temporal lobe have been associated with different functions from reasoning to auditory perception.

The frontal lobe is located in the front of the brain and is associated with reasoning, motor skills, higher level of cognition, and expressive language. At the back of the frontal lobe, near the central sulcus, lies the motor cortex. This area of the brain receives information from various lobes of the brain and utilizes this information to carry out body movements.

The parietal lobe is located in the middle section of the brain and is associated with processing tactile sensory information such as pressure, touch, and pain. A portion of the brain known as the somatosensory cortex, or homunculus, is located in this lobe and is essential to the processing of the body's senses.

The occipital lobe is located at the back portion of the brain and is associated with interpreting visual stimuli and information. The primary visual cortex, which receives and interprets information from the retinas of the eyes, is located in the occipital lobe. The temporal lobe is located on the bottom of the brain. This lobe is also the location of the primary auditory cortex, which is important for interpreting sounds and the language we hear. The hippocampus is also located in the temporal lobe, which is why this portion of the brain is also heavily associated with the formation of memories.

Remember when Jim was startled by the fire alarm? His heart rate and blood pressure went up and then returned to normal.

Primitive Brain

Ever feel in times of crisis that some deep-seated feeling or instinct is welling up and taking over? Such events are the result of the primitive brain or what we doctors call the limbic system, a system located in the lower center of the brain. It is also a system with a number of components.

If we do a cross section of the brain here is the cerebral cortex with its gray matter and white matter, the corpus callosum, the fiber bundles that connect the two hemispheres, and at the lower back of the brain is the cerebellum - the part of the brain that controls posture and timing during movement. And then we come to our more primitive brain which has some very distinctive structures. Here's the thalamus. It relays nerve impulses from the rest of the nervous system to the cerebral cortex. Situated under the thalamus is a structure critically important for controlling many of our autonomic functions, including body temperature. It's called the hypothalamus. And here is the other regulator of autonomic functions such as heartbeat and respiration: the fairly large brain stem. Also situated in the brain complex is the pituitary gland, the master gland.

Brain Waves

The brain is constantly pulsing with electrical activity, an activity which shows a pattern. Here on this patient we are performing an electroencephalogram. Leads are being positioned on the surface of the head in order to pick up electrical signals from the brain. Stephanie will now perform what is known commonly as an EEG. Stephanie.

Stephanie speaks

Great. The wires are applied. And this is the patient brain wave. If you would close your eyes patient, we'll see over the occipital leads and the posterior head regions, we have alpha activity. The paper's speed of the machine is divided into one second periods of time, and the electroencephalographer will count how many waves per second occur. This is eye blinking artifact. Open your eyes patient. The eyes open and we see the blinks and the eye tremor movement goes away. Would you smile patient? Smiling causes muscle activity over the temporalis regions, which is why we ask the patients to be quiet and relaxed during their test.

So this procedure provides us tremendous information regarding the electrical activity of the brain. Thank you Stephanie.

That brings us to the basis of all that electrical activity, the neuron. Neurons are highly specialized cells, specialized in their structure, function, and how they are linked together.

What we see here is a time lapse of one neuron reaching out to another neuron. Neurons

are cells that form the functional basis of the nervous system. Structurally, they are different in significant ways from any of the body's other cells. However, at their core there like every other cell in the body, they contain cytoplasm and a nucleus with chromosomes. But what differentiates the nervous system cells are the branches that radiate out from the cell body. These branches carry nerve impulses. The many dendrites that we see here receive impulses from other neurons, and a single axon carries the electrical impulse from the neuron to a dendrite of an adjacent neuron. Neuroscientists have discovered that impulses travel in only one direction, a direction that, once formed, can act like a permanent pathway from one part of the body to another.

Remember our Climate Scientist, Jim? When the fire alarm went off his sensory receptors originated electrical impulses, impulses which moved along neural pathways from the inner ear to the brain. Then interneurons relay more impulses to Jim's glands, organs, and muscles, producing his increased heartbeat, feelings of fear, and finally, action.

Interestingly, neural pathways are not like wires carrying electricity from the wall socket to your household and business appliances, but more like soccer players passing the ball from one player to another

Where the electrical impulse is passed on from one neuron to the next is called a synapse. Here the electrical charge jumps from an axon to a dendrite by electrical charge buildup involving sodium ions. Incredibly this process works millions of times a second, controlling all the precise actions of our soccer players.

Interestingly, the brain accounts for only 2% of the human body's weight. Yet, it needs 20% of the body's blood. Fortunately the brain has an ample supply of oxygen and glucose-sugar, brought to it by a vast network of blood vessels. But if that blood supply is interrupted, interrupted for only a few minutes, the consequences can be catastrophic.

Nervous System Diseases

Dr. Mark Reisman with patient

I understand that you've had some concerns and problems. What happened?

Well I don't know. A couple of weeks ago I started having numbness on the right side. My right arm especially, and some times the right side of my face.

Is that something new?

It is new, and it's been painful to touch at times. It's very sensitive.

Well, one of the major things we're concerned about is if you've had a stroke, and ultimately we'll get some imaging of your brain. But let me examine some of the blood vessels that go up to your brain to see if there are any blockages or potential narrowings. If you could just hold your breath, that would be terrific.

Well it doesn't sound like you have any blockages. The predominant reason for a stroke is generally a blockage in one of the blood vessels that go up to the head. Or a little piece of material breaks off from a blood vessel and goes into the brain. So we'll have to see if we can identify what the source of that might have been. But before we do that, let's get a clear diagnosis of whether or not you've had a stroke, and we'll do that by doing a scan of your brain to see if there are any areas with any damage.

All right.

We'll go from there.

Spinal Cord Anatomy

Moving on to the second part of the central nervous system we find the spinal cord running from the brain along the backbone. The nerve fibers of the spinal cord link the brain with the most of the body. Indeed, every part of the body not found in the head. In other words, most of the active parts of the body - organs, arms and legs. Most of the time, the spinal cord acts a passive conduit as the brain connects with the muscles, such as when playing tennis. Other times, when Sean has to suddenly duck, something else happens. The spinal cord nerve complex bypasses the brain and produces a reflex action: ducking.

Let's take a unique look at this part of the central nervous system.

Here we have a cadaver that is exposed from the back. The head is here. The legs are below here. And as you can see the back is exposed. And by removing the skin and various layers, we are able to expose the spinus processes of the vertebral column. You could actually feel these if you touch your back, these protrusions that come off of the vertebral bodies. These vertebral bodies are part of the thoracic portion of the vertebra, and basically, these connect going anteriorally to the ribs. As we go further down, you can see that we remove these spinus processes and the vertebra, and we've exposed the spinal cord. When we look at the spinal cord, you can see that there is a protective lining called the dura mater. This creates a very nice protection, and also provides some lubricity, and below the dura mater, you can actually see the fibers themselves in bundles as they go from above to below and on each intersection that being the vertebral bodies giving off nerves to the various parts of the body. When they initially come off, they come off in bundles called spinus ganglion or spinal ganglion, these very important processes. And you can see how it goes all the way down the body to the lower portion. This is the pelvic area here, and here again we left intact the sacrum of the body in order to show that very important bone below which is all fuse together.

Conclusion

There is no body system, no part of the body that the nervous system doesn't impact, even control. It is the great regulator, the system that keeps our heart correctly beating, our breathing regular, our body temperature constant, our digestive system working properly,

our body movements fluid and purposeful. Some control without even reaching our consciousness and others consciously direct. But the most remarkable aspect of the human brain is its correlation with all of our higher cognitive functions, starting with consciousness and the mind, a mind that is capable of abstract thought, reasoning, memory and use of symbols, symbols, which we use to form languages, which in turn have allowed us to build all of our great society, our modern economies filled with inventions and technologies that are beyond the wildest dreams of people living just a few hundred years ago.

Whether the brain is the source of consciousness and mind is open for debate. What is true is that for every mind activity there is a corresponding brain activity. Understanding and developing the full potential of the brain is the greatest uncharted territory facing man today. Thanks for joining me on this remarkable journey through the human nervous system, I'm Dr. Mark Reisman.

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