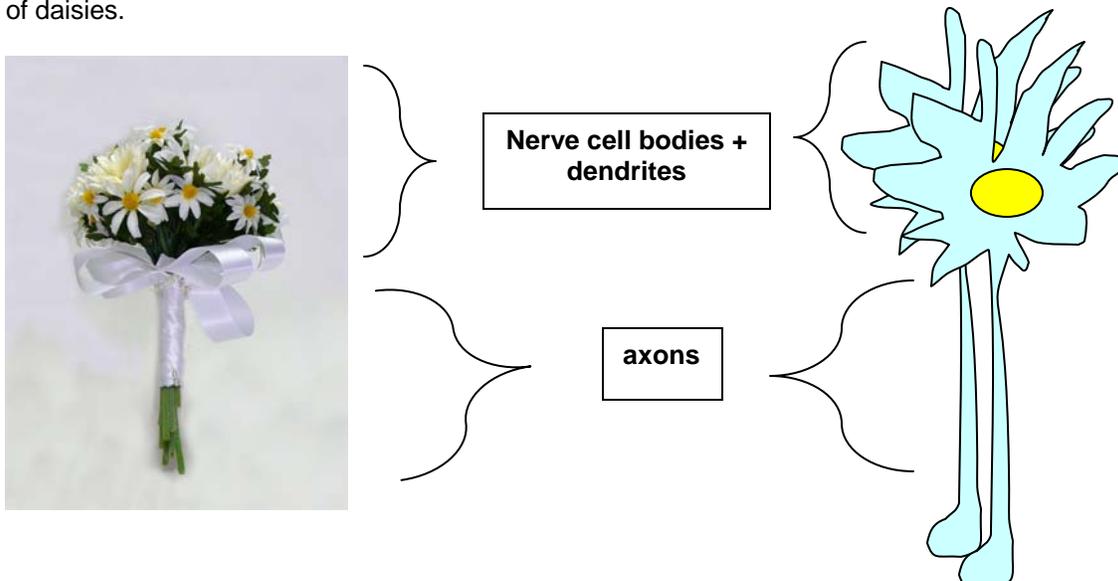


The Nervous System, Part I....Unlecture

Review basic nervous system anatomy before you begin this lecture. The lecture touches on a few of the major characteristics, but you are expected to have already been exposed to this topic in anatomy.

Slide #1: The nervous system is an intricate extrinsic control system that is fast acting. It has a variety of functions. One of the most important of these is **sensory detection**, which involves the ability to sense change. The greatest opportunity for change exists at the interface between the external environment and your body, which occurs at your skin. Therefore a large number of sensory receptors are dedicated to that region of your body, so that you are able to constantly detect changes that might affect your well being and that might require immediate action in order to maintain homeostasis. Sensory receptors also exist within your body, but because your internal environment is “relatively constant”, fewer sensory receptors are required. Once the information is detected by the sensory receptors, it must be processed. **Processing information** includes converting the signal received at the receptor to a signal that can be transmitted to the central nervous system. When that information arrives in the central nervous system, it is integrated (**neural integration**) by considering all of the information coming in at that time from a variety of receptors. Some information has future applications and must be stored (such as the information you learned in anatomy about the nervous system 😊), and as you all know, it isn't very useful to store the information if you can't retrieve it when you need it. How we think (**process thought**) and how we perceive things are also part of the nervous system function. Have you ever listened to music and thought it was the best, while the person sitting next to you thought it was awful? Or perhaps a particular perfume is your favorite, but another person thinks it stinks! These are issues of perception. The concept of **learning** occurs in the central nervous system and is related to information storage, retrieval, and memory. Your nervous system is also that part of your body involved in **emotion**. Why do some things make you happy or sad? Why do you get angry, etc? All of these emotions arise in the deeper regions of your brain. Once you have integrated information, and considered all of the input you have received, your brain must decide...is this something that needs to be changed? What are we going to do about this? This is the function of **motor output**, planning and implementing motor commands.

Slide #2: Recall from anatomy that there are two major divisions of the nervous system; the Central nervous system (**CNS**), and the peripheral nervous system (**PNS**). The CNS includes the brain and spinal cord, while the PNS includes everything else. Notice that you have different terms used in the CNS and PNS for the same thing! Think of the neurons in the nervous system as flowers, with the nerve cell body looking kind of like a daisy, and the stems looking like an axon. Remember that the nervous system is like the body's wiring system, and when you have a bunch of wires, it is easier and neater to bundle them. So, neurons are arranged like a bouquet of daisies.



A cluster of nerve cell bodies (like you see in the picture of the daisies) would be called a **nucleus** in the CNS, and a **ganglion** in the PNS. A bundle of axons (like the bundle of stems you see in the picture of the daisies) would be called a **tract** in the CNS and a **nerve** in the PNS.

Slide #3: This slide shows the movement of information to and from the central nervous system. Information is detected by the sensory neurons, and sent from an **afferent** (incoming) axon to the central nervous system. In the CNS, it is sent through a series of interneurons to a motor neuron. The motor neuron sends efferent (outgoing) information to a muscle cell, gland, or another neuron in the peripheral nervous system. Notice that the cell bodies of the sensory neurons are located in the peripheral nervous system (in the **dorsal root ganglia**) and the cell bodies of the motor neurons are located in the **anterior gray horn** of the spinal cord in the CNS.

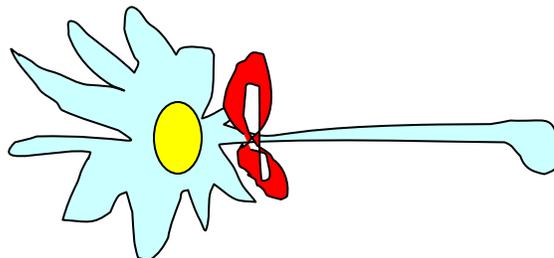
Slide #4: There are two major populations of cells in the nervous system; neurons, which conduct information, and neuroglia (“nerve glue”), which support the function of the neurons.

Slide #5: Neurons are the basic structural and functional unit of life. Currently we believe that all neurons are amitotic (they do not divide) after a certain stage in human development. Most scientists believe that mitosis stops in neurons for two reasons; 1) a neuron is very complex, compared to the average cell, with specialized regions (dendrites, axons, nerve cell body). This makes cell division more involved. 2) adding new neurons could alter or complicate important information pathways, making it difficult for people to function. Because these cells can’t divide, the pathways that are laid down during development are preserved.

Neurons, like other cells, respond to stimuli. They respond by producing and conducting electrochemical impulses. This is how information is sent from sensory neurons all the way through the central nervous system to the effector cells (muscle, nerve, gland). Because one neuron is not directly connected to the next neuron in a pathway, a “chemical bridge” is created by releasing chemical regulators called neurotransmitters. This is very clever, in that the “bridge” is only created by a cell when a message is being sent. When a message is not being sent, the neurotransmitter stays within vesicles in the neuron. As previously stated, the term “nerve” refers to a bundle of axons in the peripheral nervous system. These bundles are “mixed” in that they contain both afferent (sensory) and efferent (motor) fibers (=axons).

Slide #6: Anatomy of a neuron: A neuron is composed of a nerve cell body, also called a perikaryon (remember the term “eukaryotic”....karyon means “nut or kernel”, so perikaryon means “surrounding the nut or kernel”). This part of the cell is full of rough ER and is considered the nutrition center of the cell because all proteins and other products are produced in the nerve cell body and then transported to other regions in the neuron. We have already mentioned the clustering of nerve cell bodies in previous slides. The dendrites, which emanate from the nerve cell body like the petals of a daisy, receive incoming information. They transmit that information to the nerve cell body. Anatomically, a dendrite looks somewhat like a tree branch, thicker near the nerve cell body and thinner as it projects outward. The axon is the same diameter along its entire length. It transmits information away from the nerve cell body toward the next cell.

Slide #7: Neuron structure; Image shows a “standardized” neuron and its parts. Please note the **axon hillock**, where information received at the dendrites is “added up” or summated. If this neuron was a “Monster’s Inc” character, it would be right where you would put its bow tie.



Also, notice the **nodes of Ranvier** in the image. These are spaces between the myelin sheath that surrounds some axons. When an axon is myelinated, the message being sent moves faster because it is able to jump from one node of Ranvier to the next, instead of going one little step at a time. This process is called **salutatory conduction**.

Slide #8: One-way conduction: Two different types of neurons are shown here to illustrate that information moves only in one direction, from the dendrites, through the nerve cell body, and down the axon.

Slide #9: Neuroglia: This is a list of neuroglia that we will be discussing in subsequent slides.

Slide #10: Astrocytes: The most numerous of all neuroglia (glial cells) is the astrocyte. The name astrocyte means “star-shaped cell”. These cells are found in the central nervous system and are very important in regulating the special environment in which the neurons function. You have already learned about the importance of maintaining pH in the body. Changes in pH can adversely affect the way in which neurons function and can even prevent them from sending any messages. One of the major functions of astrocytes is to buffer the extracellular environment of the neurons by breaking down the chemicals (neurotransmitters) that the neurons produce when they send messages. In addition, they take up K^+ that is released by the neurons during nerve cell signaling. Some astrocytes wrap around the capillaries in the brain to restrict the passage of harmful substances into the brain itself. This creates a “blood brain barrier” that protects the neurons and ensures their continued function. Because there are so many of these cells and because they are highly branched, the astrocytes also provide physical support (mechanical support) for the tissues of the CNS. Astrocytes can also help establish connections between neurons by triggering the formation of synapses. They do this by secreting signaling proteins called **thrombospondins**.

Slide #11: Astrocytes: Shows a histological image by compound light microscope of astrocytes, and a drawing showing how astrocytes use their projections to support neurons and form the blood brain barrier.

Slide #12: Blood Brain Barrier: Because the microenvironment of the brain is very critical, capillaries in the brain are not fenestrated. They are joined by tight junctions. This means that substances trying to get into the brain from the blood have to utilize transport mechanisms that involve the plasma membrane, such as diffusion, active transport, endocytosis and exocytosis. This creates an opportunity for cells to regulate what is entering the brain from the blood.

Slide #13: Ependymal Cells: Specialized epithelium lines the central nervous system that facilitates the production of cerebrospinal fluid. These cells are called ependymal cells. They are found throughout the CNS, lining the central canal and the ventricles. Specialized ependymal cells located in the choroid plexus (cluster of capillaries that hang from the roof of the ventricles) are responsible for producing some of the components that make up the cerebrospinal fluid (CSF). In addition, these cells are ciliated and the cilia helps to keep the cerebrospinal fluid moving. The ependymal cells are also only partially differentiated and can act as neural stem cells. They are able to divide, and the cells they produce can further differentiate to become specialized cells.

Slide #14: Microglia: These are stationary phagocytes (“big eaters”) that are located in the central nervous system. There are as many microglia as there are neurons. They are the sanitation department of the brain and are involved in keeping things “cleaned up”. They are also antigen presenting cells, which means that they ingest substances and present what they ingest to other immune cells. If the substance they are presenting is “recognized” by cells of the specific immune system, specialized cells are produced to eliminate that substance. They also have a regulatory function in the normal transmission of information that occurs at the synapse. I always

think of them primarily as the “janitors” of the central nervous system. So, if you have a dirty mind, you need lots of microglia!

Slide #15: Myelin sheath: The myelin sheath is a structure composed of cells that contain a high fat content. In the CNS, **oligodendrocytes** with long projections wrap around neurons to speed up the rate at which information moves down an axon. Remember that when axons are myelinated, the signal can move from one node of Ranvier to the next, without moving along bit by bit. Oligodendrocytes remind me of an octopus that got run over by a steam roller. In the PNS, Schwann cells perform this function. They are thin, flattened and wrapped around the axon like a jelly roll. The image on this page shows cross sections of nerves myelinated neurons. You can see the myelin wrapped around each neuron in these images.

Slide #16: Oligodendrocytes: Shows an image.

Slide #17: Axonal transport: As we mentioned previously, the nerve cell body (also called the soma) is the place where all cellular products are made. They then have to be transported to all of the different spots in the nerve cell, some all the way down to the axon terminals (which in the case of really long nerves can be up to 1 meter away) Recall that 1 meter is about 3 feet! How is this accomplished? It involves the movement of products in vesicles by using the microtubule system (part of the cytoskeleton, remember?) and two type of motor proteins, kinesins and dyneins. **Kinesins** move substances from the nerve cell body toward the axon terminals. This direction is called **antegrade**. Kinesins move nutrients, enzymes, mitochondria, neurotransmitters, and organelles antegrade from the soma to the axon terminus. Dyneins move substances toward the cell body, or retrograde. This includes recycled membrane vesicles, left over from the release of neurotransmitter, and other things, such as rabies virus, polio virus, herpes simplex, and tetanus toxoid, along with other harmful substances. The recycled membrane vesicles are going back to the soma to be “refilled” with newly produced neurotransmitter.

Slide #18: Motor proteins: image shows dyneins and kinesins moving along microtubules..

Slide #19: Shows rabies virus moving retrograde up the axons toward the brain.

Slide #20: Three Classes of neurons: Neurons are classified in many ways. One way is the direction in which they send messages, to the CNS, from the CNS and within the CNS. Neurons that transmit messages to the CNS from sensory receptors are called **afferent neurons**. Neurons which transmit messages from the CNS to effector cells, such as muscles, glands, or other neurons, are called **efferent neurons**. Neurons that connect sensory and motor neurons, and act as integrators of information and modifiers of signals are called **interneurons** because they reside entirely within the CNS. 99% of all neurons are interneurons.

Slide #21: Presynaptic and postsynaptic neurons: The synapse is the space between two neurons. The neuron that conducts a signal toward a synapse is called the **presynaptic neuron**, because it comes before the synapse. The neuron that conducts the signal away from the synapse is called the **postsynaptic neuron**. The postsynaptic neuron is the second neuron in the chain.

Slide #22: Shows an image of synapses. The image in the extreme upper right hand is a transmission electron micrograph showing the axon terminus and the synaptic vesicles (which contain the neurotransmitter). The drawing shows the release of neurotransmitter by exocytosis from the terminal end bulb, or axon terminus, into the synaptic cleft.

Slide #23: Neural development: Like all other cells, neural cells arise from embryonic stem cells through differentiation. Because these cells are dividing during fetal development, and assuming their identity as neural cells (differentiation), these cells are extremely susceptible to drugs, alcohol, diseases, etc. This is a critical time in the development of a health fetus, and

much of the neural development occurs before some know for sure that you are pregnant. This underscores the need to restrict the use of alcohol, avoid unnecessary drugs, and take care of yourself during child bearing years, whether or not you are sexually active. During this time, the axon develops by extension of a growth cone from the nerve cell body. Neural pathways are directed by chemicals called **neurotrophic factors** and by the type of receptor located on cells. As the nervous system is established, 50-70% of the nerve cells that form through cell division are eliminated by programmed cell death (apoptosis). This occurs during fetal development. The precursors to the neurons that you have as an adult complete division before birth. In spite of this, new synaptic connections are formed and degenerate throughout life. In fact, studies on senior citizens determined that those who “exercised” their mind by doing puzzles, and reading continued to develop new connections within their brain.

Slide #24: Axonal Reaction: When an axon is transected (cut across in cross section), a special process of damage control and repair occur that involves increased protein synthesis in the nerve cell body. This process is referred to as chromatolysis. After the axon is transected, it disintegrates distal to the transaction. A sprout forms and a new growth cone develops, which gives rise to a new axon. This can only happen if the myelin sheath remains intact, and is possible in the PNS, though rare, but unlikely in the CNS.

Slide # 25: Chromatolysis and regeneration image. This image shows visually what is described in the text of Slide #24.

Slide #26: Role of Schwann cells: The Schwann cells are the cells that form the myelin sheath in the peripheral nervous system. However, they have additional roles when an axon is transected. First, they act as phagocytes and take up the debris generated by the destruction of the distal portion of the neuron. Also, in conjunction with a surrounding basement membrane, they form a regeneration tube that guides the direction of the newly developing axon. They do this by releasing chemicals that attract the growth cone. This directs the axon tip toward the appropriate destination.

Slide #27: Motor neuron cell body: This image depicts chromatolysis in a motor neuron. Notice the enlarged nerve cell body in the second image from the top due to increased protein synthesis.