Developers:

The Neuron Cookie was originally developed in partial fulfillment of the requirements of OTH 341, Neuroanatomy, in the Bachelor of Occupational Therapy degree program at Creighton University by the following students: Jennifer Tangeman; Michele Skinner; Karen Louie; Abby Nolting; Linda Miller; and Linda Willmore.

Neuron Cookie

Introduction

In this activity, students will construct a neuron and learn about dendrites and axons as unique structures associated with this cell. Each organelle and its function are explained as the individual or pair of students constructs the neuron, the basic structural unit of the nervous system. Neurons are found in the brain, the spinal cord, in ganglia (pl., ganglion, singular, meaning "little brain"), and in the walls of the gut.
Nervous tissue is considered one of the four basic types of tissue. These four basic types combine to form organs; organs performing a like function comprise organ systems. Within cells of the four basic types, including neurons, small functioning units known as organelles perform various functions critical to development, growth, maintenance, and activity of cells.
The neuron is unique among cells because of its structure, through which the ability to receive and conduct electrical is conferred. While certain organelles present within the neuron are common to many types of cells (such as the nucleus and mitochondria), the cellular extensions (dendrites and axons) are not.
Within the central and peripheral nervous system, there are supporting and nutritive cells. In the central nervous system these are known as glia, from the Greek word for "glue". There are three types of glial cells: astrocytes, oligodendrocytes, and microglia. Astrocytes are important in "mopping up" potassium that leaks out into the extracellular space after the neurons fire electrical currents, and are also a critical element in the formation of the "blood-brain barrier". They play a role in guiding the axons of developing neurons to their proper targets, and after brain injury, become active in "scar formation".
Oligodendrocytes wrap axonal processes in myelin, a fatty substance. This acts much like insulation around an electrical cord and prevents leakage of current. Through this insulation, the speed of conduction of the electrical current down the axon is increased dramatically. Microglial cells are the phagocytes of the nervous system and have been implicated in the spread of HIV within the brain.

Background

The discovery by Ramon Cajal and Santiago Golgi (who shared the Nobel Prize in 1906) that neurons have these processes began the era of modern neuroscience. Golgi developed a technique of staining neurons that involved depositing silver on the processes (now called the Golgi technique), but despite the fact that he developed the technique, even in his hands it was capricious. Ramon Cajal, an eclectic medical doctor - scientist was able to exploit the technique maximally. He stained nervous tissue from a variety of species, and had the rare artistic gift of being able to reproduce through detailed drawings what he observed through the microscope. To this day, many of the drawings continue to be reproduced in neuroscience textbooks. In addition, he was the first to develop the technique of taking pictures through

the microscope, thus becoming the "father of photomicroscopy".
Cajal's extensive observations on brains from many types of animals led him to formulate the neuron doctrine. He hypothesized that the processes emanating from the stained neurons were in fact connected in a circuit like pattern. It was through these connections that neurons functioned. It was not until the advent of electron microscopy that neuroanatomists were able to discern why the Golgi technique was effective in staining neuronal processes. It is now known that the silver was attracted to the cellular "skeleton" (neurofilaments) within dendrites and axons.

Science Standards

Guiding Documents

National Science Education Standards

Life Science Content Standard C: As a result of their activities in grades 5-8, all students should develop understanding of structure and function in living systems. Principles that underlie this standard include structure and functions of cells, tissues, organs, systems for movement, control, and coordination. A behavioral response requires coordination and communication at many levels, including cells, organ systems, and whole organisms. (pp. 155-157).

AAAS Benchmarks

By the end of 5th grade, students should know that the brain gets signals from all parts of the body telling what is going on there. The brain also sends signals to parts of the body to influence what they do. (p. 136)

Human Identity Grades 6-8: By the end of the 8th grade, students should know that human beings have body systems for providing coordination of body systems. (p. 129) "Students can now develop more sophisticated understandings of how organs and organ systems work together." This includes the carrying of messages by nerves to help the organism respond to its environment. "Asking 'What if?' questions such as 'What might happen if some other parts weren't there or weren't working?' can stimulate students to reflect on connections among organs." (p. 137) By the end of the 8th grade, students should know that interactions among the senses, nerves, and brain make possible the learning that enables human beings to cope with changes in their environment.

National Science Teachers Association Scope Sequence and Coordination

"At the 6-8 grade level, the curriculum should emphasize the human organism." (p. 48) Students should explore the different systems.

Nebraska Science Standards

"Grades 5-8 At the middle school level, students expand their scientific inquiry skills through knowledge, observations, ideas, and questions. Middle school students will begin to recognize the relationships

between explanation and evidence. They understand that background knowledge and theories guide the design of investigations, the types of observations made, and the interpretation of data. Student investigations will shape and modify students' background knowledge. (p. 24)

"8.1 Unifying Concepts and Processes

"8.1.1 By the end of eighth grade, students will develop an understanding of systems, order, and organization.

Student demonstrations:

- Recognize and describe integral parts and functions of any system.
- Analyze and predict the interactions within a system and between systems.
- Create and use classification schemes.
- "Interpret cause and effect relationships within and between systems."
  p. 25

"8.4 Life Science

8.4.1 By the end of eighth grade, students will develop an understanding of the structure and function in living systems.

Student demonstrations:

- Investigate and describe the levels of organizations: cells, tissues, organs, organ systems, whole organisms, and ecosystems.
- Investigate and describe the specialized function performed by specialized cells, such as muscular and skeletal, in multicellular organisms.
- Investigate and describe the internal human body systems.
- Investigate and explain how disease affects the structure and/or function of an organism."

Objectives

Students will

- Construct a neuron and learn that within the neuron there are different organelles and with specific functions
- Complete a simple neuronal circuit which concretely demonstrates how neurons are wired in a functional unit
- Participate in a learning module to reiterate the key points and apply what they have just learned

Science Content

- Neurons are the structural building blocks of the nervous system
- Through specialized processes, neurons are "hard-wired" to each other to form functional circuits
- In these circuits neurons communicate with each other through electrical and chemical signaling

Science Process Skills

- Making Connections
- Communicating
- Modeling
- Predicting
- Reasoning

Hands-On Activity

Safety

Use sanitary procedures and be aware of allergic or dietary considerations before consuming the edible representations!

Materials:

- Paper plates (one per student or team)
- Hand wipes or paper towels
- Sugar cookies (best if ordered from a grocery bakery) - these will represent the cell body
- White icing - to represent the cytoplasm
- Plastic spreaders
- Various candies for organelles (number per student):
  1 green candy - represents the nucleus
  3 banana shaped sugar candies - represents the Golgi apparatus
  3-5 chocolate covered rice bits - represents the rough endoplasmic reticulum
  3- 6 plain candy coated chocolate circles - represent mitochondria
- Pull-apart red string licorice - represents dendrites and axons
- Mini-marshmallows for myelin
- Plastic bags for students to take neuron model home (optional, but highly recommended)

Procedure

The students begin with the cell body (the cookie), putting it on a plate. Review the biochemical components of the cell membrane, recalling that the cell membrane carries an electrical charge. The cookie is then iced to represent the cytoplasm. Cytoplasm, consisting of water, ions, and sugar, has a jelly-like consistency. The organelles "float" within the cytoplasm.

The nucleus can be described as the place where the directions to make stuff for the cell resides (it is where deoxyribonucleic acid, or DNA, is located). Through DNA, genetic directions for protein synthesis are relayed to other cell organelles where the protein will be constructed. (Help the students relate to the function of DNA by recalling that in the movie "Jurassic Park", the dinosaurs are brought to life through the use of DNA found in a preserved mosquito that sucked the blood of the dinosaur.)

Over the course of a lifetime (and some neurons can be around as long as one hundred years) the neuron will need to replace worn out organelles and membrane. Proteins are made up of amino acids strung together. Some short protein chains - peptides- also act as neurotransmitters, or chemical messengers, in the nervous system. Thus, the ability to synthesize protein is extremely important in maintaining the structural integrity, and function, of the neuron. The green runt- representing the nucleus- gives the "go signal" for the cell to make proteins (thus, green = go).

Protein synthesis occurs at special sites out in the cytoplasm - special organelles, or little organs. The students then begin to construct the protein-making machinery in the cell. This includes the rough endoplasmic reticulum and the Golgi apparatus. We can explain it simply as the place where the proteins are put together and then packaged and addressed to use inside the neuron (replacing worn out parts) or outside the neuron (as a chemical messenger). Place the 3 banana shaped candies on top of one another for a convincing representation of the Golgi apparatus. If you have related history about Golgi, you can reinforce the information by asking the students who this organelle is named after. The reticulum, represented by the chocolate covered rice bits, has little bumps that represent the "stations" where the protein is made. The differences between the two types of endoplasmic reticulum (smooth and rough) and how it relates to function can be reviewed.
The last organelle placed in the cell is the mitochondria, the M & Ms. (We typically give each student a handful and allow them to choose how many to put in their neuron, as the extras invariably wind up in their mouth). Function of the mitochondria is explained with the classic label "Powerhouse of the cell". The process of oxidative respiration and the generation of ATP can be reviewed, or simply explain that oxygen is utilized here.

The students are then given 2 pieces of string licorice. They take the first and break it into 3-4 short pieces, placing the end of each into the cytoplasm (icing) at the top of the cookie (we usually explain this makes the neuron appear as though it is having a bad hair day). The other longer piece is placed at the bottom of the cookie with one end in the cytoplasm (icing) and the other extending off the plate. Definitions and explanations of each type of process are given. The analogy of a phone receiver works well. There is an earpiece to listen through (the receiving end, or dendrites) and a mouthpiece to speak into (the sending end - i.e., the axon). For more advanced students, the composition of the dendrites and axons can be elaborated, and the concept of the myelinated axon can be introduced. An insulated electrical cord works as a good visual or recall representation of specific glial cells wrapping a fatty-like substance, myelin, around the axons to keep the electrical current prorogating down the axon.

Students can make a simple circuit by connecting their axon to the dendrite of a neighboring student's cookie. Leave a gap between the axon and the dendrite, representing the synaptic space. This serves as a

launch point for a discussion of the synapse, transport of chemical neurotransmitters from the cell body down the axon to the synapse, and release of chemical neurotransmitters in response to a change in electrical potential of the membrane. The impact of drugs such as cocaine on this process, and the physical changes the neuron undergoes can be introduced, explained, or researched.
Neurons consume oxygen and glucose for fuel. The more challenging the brain's task, the more fuel it consumes. (Sousa, 2001). Snacks in moderate proportions can boost neuron function and reduce lethargy and sleepiness. Carbohydrates enhance the entry of tryptophan into our brain, elevating mood (Sylwester, 2000). So eat your neuron cookie!

WEB ACTVITY

Vocabulary

Neuron - basic structural unit of the nervous system; a cell with specialized processes that is electrically excitable

Mitochondria (pl.)- organelles within cells that function as the site of cellular respiration and through oxidative processes provide metabolic energy (the "powerhouse of the cell")

Endoplasmic reticulum - orgnaelle that is the site of protein assembly

Nucleus- the "control center" of the cell, location of DNA which gives "directions" for protein synthesis

Golgi apparatus - organelle that functions to "package and label" synthesized proteins for use either in or out of the cell

Dendrite- specialized process of the neuron that receives input from other neurons or receptors

Axon - the specialized process of the neuron that usually conveys signals form the neuron to other neurons or muscle. Axons may be myelinated or unmyelinated.

Myelin - a fatty, "insulating" substance that is essential to speeding up electrical conduction along the axon.

Reflex arc - the basic "functional" unit of the nervous system; may be as simple as two neurons connected to each other.

Resources and Links

More about Cajal and Golgi: see http://www.nobel.se/medicine/articles/cajal/

The story of how Golgi's slides were flown on the space shuttle Columbia: http://www.psu.edu/nasa/cajal2.htm

Interesting insights into the role of glia can be found in the studies of Dr. Marian Diamond, who compared the ratio of glial cells to neurons in Albert Einstein's brain (see her personal account in Neuroscience, Exploring the Brain). (In career exploration, Dr. Diamond can also serve as an excellent example of a successful female neuroscientist: http://ib.berkeley.edu/faculty/diamondm.html; http://www.newhorizons.org/blab_diamond1.html