**Advanced Methods in Neuroscience**

**Topic: Neuroscience Introduction and Methods used in research**

**Developed by:** CUNO graduate students

**Grades:** High School

**Vocabulary words:** neurophysiology, immunohistochemistry hippocampus, optogenetics

**Materials:** Powerpoint slides of presentation

**Time needed: ~1 hour**

**Introduction (10 min)**

What does the brain do? (5 min)

How do we study the brain (5 min)

**Old methods of studying the brain (15min)**

Lesioning the brain (5 min)

Visualizing the brain (5 min)

Immunohistochemistry (5min)

**New Methods: How do neurons communicate? (25 min)**

Neurophysiology: recording activity (15min)

Optogenetics: manipulating activity(10min)

**Summary:** This lesion teaches students about the history of neuroscience research through the lens of the various techniques used. These techniques start with old methods of study (lesions, anatomy) and the new methods (neurophysiology, immunohistochemistry, optogenetics). The lesson starts with understanding that brains are used to take in information through your senses, do various computations so that you can think, behave, and learn.

**Prerequisites for Students:** Basic understanding that the brain is made up of neurons that communicate through action potentials.

**Learning Goals:**

* Gain a perspective of what the brain can do
* Understand the old and new techniques scientists use to understand the brain in their own research

**Background for instructor:**

* Everyone can be a scientist, introduce yourself as a regular person!
* Refresh basic knowledge of the brain and that the brain is made up of a network of cells called neurons.
* Make sure you have the brain bank to look at after the presentation is over.

**Set-up:** Setup a projector and computer for the slides, and brain bank to the side.

**Lesson Outline:** Introduce yourselves and start by asking the students what they know about the brain. What does the brain do? Explain that the brain works to take in information from the world around you, and uses that information allowing you to think internally, behave with, and learn about the world around you.

Segway into questions of How do we know what the brain does? How do we study the brain??

Starting with old techniques: Introduce that some of the first neuroscience studies came from lesioning experiments. In the 1820’s, some of the first neuroscience research was done by poking holes in the brains of rabbits and pigeons and seeing the various deficits the animals had.

Dr. Broca was a doctor who had many patients who could understand language, but not speak themselves. After these patients passed away, he discovered that these patients has lesions in their brains in one specific area—the left frontal lobe. This is now known as Broca’s Area!

Besides knowing some general facts about what areas help with specific behaviors, neuroscientists want to look at something more specific: the cells that make up the brain. How do we know the structure of neurons?

The Golgi stain is one of the oldest techniques developed by Golgi in the 19th century. This randomly stains neurons with silver, and allowed early neuroscientists examine neurons. Ramon y Cajal famously used Golgi stains, and went on to postulate that the long axons of cells carried information to other cells. Golgi and Cajal got the Nobel prize for this work in 1906.

Even though this was impressive, we can now do specific staining in the brain. Instead of randomly labeling cells, like with Golgi stains, we can now stain for specific cell types within the brain—this is a technique called immunohistochemistry.

So we know broadly what some brain areas are sued for, and we know what cells look like, but how do we know how neurons communicate? We use a technique called neurophysiology to see how neurons communicate with each other. With this, we record the electrical potentials from neurons with metal wires—electrodes. By recording the activity of specific neurons, we can see how they speak and communicate with other neurons! You can see that different cells peak with different languages (different spike forms). We can do these recordings in behaving animals, and ask ourselves which neurons are active during different behaviors?

Going into the hippocampus study of place cells using neural-recordings. In this study, the researchers wondering how neural activity in the hippocampus helps the rat remember where it is in space? They found that different cells will only fire when the rat is in a specific place—naming these cells *place cells*!

Now, we can record the activity in behaving animals, but we can also manipulate the activity using a technique called optogenetics. Using a ion channel, channelrhodopsin, we can activate neurons with light. This channel is found in green algae! We can genetically engineer an animal to express channel rhodopsin in specific neurons, and activate those neurons with blue light.

Summary and Questions follow!

**Wrap-up, final thoughts**: There is a lot that is introduced here, but reinforce the idea that the brain is a complex machine that we are still figuring out! Remember that new techniques are always developing and allowing us to explore new parts of the brain.