**Lesson 1:** Introduction to Neurons and Action Potential

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**LESSON OVERVIEW**

**Activity Time:**

One 50 minute class period. Additional time for homework.

**Lesson Plan Summary:**

In this lesson, students will first watch the video about a girl with the rare autosomal disorder CIPA (Congenital insensitivity to pain with anhidrosis) and who cannot perceive pain. Students will brainstorm as to how we react to sensory information and how neurons communicate. Students will learn about action potentials and the molecular interplay in the neuronal cell and its surrounding via different ion channels and pumps. Students will learn about how positive ions such as Na+ and K+ entering the neuron depolarizes the cell. This information is built upon in Lesson 3 in which optogenetics technology is introduced. Students will end the lesson by learning about synapses, briefly recirculating back to the beginning of the lesson - how many different types of neurons interact leading to our response/reaction to various stimuli. This lesson lays the foundation for Lesson 2 which explores various technologies used to study the function of this complex structure - the brain.

**STUDENT UNDERSTANDINGS**

**Investigative Phenomenon/Problem:**

* **Description of Phenomenon/Problem:** News report on a girl with a rare genetic disorder who cannot perceive pain.
* **Driving Questions:** 
  + How do neurons function and transmit information through an action potential helping us to perceive and process sensory information?
  + What is your reaction when you accidentally touch a very hot pan or step on a sharp object?
  + What are the changes happening in neurons which help them communicate information received from various receptors in our body which help us perceive sensory information such as pain or malodorous substances or changes in physiological pH?

**Learning Objectives:**

*Students will know…*

* The mechanism of action potential and how information is transmitted through a neuron.
* The role of different ions and ion channels and the Na+/K+ pump
* The importance of the myelin sheath in speeding up the transmission of action potential - saltatory conduction. *(This is optional)*

*Students will be able to…*

* Identify and understand the structure of a neuron - cells which transmit nerve impulses.
* Analyze and correlate the role of each ion channel and pump to the different parts of the action potential.
* Understand how action potential from one neuron leads to release of neurotransmitters in synapse triggering communication with the adjacent neurons.

**Note:** There are 2 types of synapses; chemical (common) and electrical synapses. Only chemical synapses are highlighted here.

**Vocabulary**:

* **Action potential:** The nervous system’s communication method is via action potentials, which are electrochemical changes that originate in neurons, are propagated down their axons, and elicit a corresponding response in the adjacent neurons.
* **Axon:** The part of a neuron that takes information away from the cell body.
* **Brain:** An organ contained in the skull that functions as the body’s command center. The brain, along with the spinal cord, is part of the central nervous system. It controls movement, functions, sensations, memory, and thoughts.
* **Dendrite:** The part of a neuron that brings information to the cell body.
* **Feedback:** The process in which the output of a system is used to make changes in the operation of the system.
* **Nervous system:** Consists of the central nervous system (brain and spinal cord) and peripheral nervous system (all nerves throughout the body not part of the brain or spinal cord).
* **Neuron:** A specialized cell within the nervous system that transmits information. It is characterized by the axon and dendrite. Also called a nerve cell.

**Next Generation Science Standards:**

This lesson builds toward the following Performance Expectation (PE) and its integrated three dimensions of learning. Additional dimensions are denoted with an asterisk (\*).

| **High School Performance Expectations** | | |
| --- | --- | --- |
| [**HS-LS1-1**](https://www.nextgenscience.org/pe/hs-ls1-1-molecules-organisms-structures-and-processes) **From Molecules to Organisms: Structures and Processes**  Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.  [**HS-LS1-2**](https://www.nextgenscience.org/pe/hs-ls1-2-molecules-organisms-structures-and-processes) **From Molecules to Organisms: Structures and Processes**  Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. | | |
| **Science and Engineering Practices (SEPs)** | **Disciplinary Core Idea(s)** | **Crosscutting Concepts (CCCs)** |
| Constructing Explanations and Designing Solutions    Developing and Using Models | LS1.A: Structure and Function  \*LS1.B: Growth and Development of Organisms | Structure and Function  Systems and System Models  \*Cause and Effect  \*Patterns  \*Stability and Change  (Feedback, whether negative or positive, can  stabilize or destabilize a system) |

**Common Core State Standards:**

* **CCSS.ELA-LITERACY.RST.11-12.7:** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
* **CCSS.ELA-LITERACY.RST.11-12.9:** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
* **CCSS.ELA-LITERACY.RST.11-12.10:** By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.
* **CCSS.MATH.PRACTICE.MP4:** Model with mathematics. (They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas.)

**TEACHER PREPARATION**

**Materials:**

| **Material** | **Description** | **Quantity** |
| --- | --- | --- |
| Classroom Computer | Teacher computer with projector, speakers, and internet connection to project slideshow and videos | 1 |
| Supplies | Large whiteboards and whiteboard markers  OR student notebooks | 1 set per lab group |
| Documents | Slidedeck for Lesson 1.  Student Handouts for HW: Can be adapted from many online sources. For example, <https://www.interactivephysiology.com/demo/misc/assignmentfiles/nervous/Action_Potential.pdf> OR  <https://commons.wikimedia.org/wiki/File:1222_Action_Potential_Labels.jpg> (label free action potential diagram)  Teacher Resources: See any of the following: the handout above, <https://faculty.washington.edu/chudler/ap.html>, OR <https://www.ncbi.nlm.nih.gov/books/NBK21668/> | 1 per student |

**Preparation:**

1. Create and make copies of the teacher-designed *Student Handout for HW* one per student. See the materials section above.
2. Review the slide deck and modify it if needed.

**PROCEDURE**

*Use the Lesson 1 slide deck as you progress through the lesson procedure.*

**Activity 1: Introducing the Puzzling Phenomenon (5 minutes)**

1. As the Do Now activity as students come into the room, have them independently watch the [video](https://www.youtube.com/watch?v=n6iOUW523BE) regarding a girl who cannot perceive pain due to a rare autosomal genetic disorder CIPA. (4m12s) Alternatively, you may choose to show this to all students at once. Closed captioning is available through YouTube.

**Young Girl Cannot Feel Pain, Battles Rare Medical Condition CIPA**

ABC News, July 5, 2012 | YouTube 4:12 minutes

<https://www.youtube.com/watch?v=n6iOUW523BE>

**Activity 2: Brainstorm About the Phenomenon (30 minutes)**

1. After watching the video, ask students to brainstorm with their partners about the following question: *How do we react to different sensory information around us?* (see ppt for details). Share and discuss with the class. (5 minutes)
2. Using the slide deck, discuss the generalized structure of a neuron.
   1. *Optional:* Teacher can include saltatory conduction and a mention about diseases where myelin sheath is destroyed such as multiple sclerosis.
   2. Resources: <https://faculty.washington.edu/chudler/salt.html> OR <https://www.khanacademy.org/science/biology/human-biology/neuron-nervous-system/v/saltatory-conduction-neurons>
   3. See additional resources mentioned in the Teacher background section.
3. Using the slide deck, introduce action potentials. Ask students to come up with a hypothesis as to what is happening in the neuronal cells with the positive and negative charges.
4. Steer the class discussion towards ions such as Na+, K+ and Cl- . Discuss the typical events in a neuronal action potential and add the molecular events due to different ion channels and pumps. **(25 mins)**

**Activity 3: Conceptual Models (15 minutes)**

1. Challenge students to practice drawing out the action potential and explaining the concepts of different molecular events to their partners. (10 minutes)
2. Ask students how their models of action potentials relate to the story of the girl with CIPA?
3. Wrap up the lesson with a quick review and answer any student questions. (5 mins)

**STUDENT ASSESSMENT**

**Assessment Opportunities:**

* Student participation in class discussion and teacher observation during various activities.
* Students practice concepts learned in class and also finish HW.

**Scoring Guide:**

* Grade HW and ‘do now’ question or review next class based on concepts learned in Lesson 1.

**DIFFERENTIATION FOR INCLUSIVE INSTRUCTION**

**Adaptations for Remote Learning Environments:**

| **Name of Activity** | **Remote Adaptations** |
| --- | --- |
| **Activity 1** | [Video](https://www.youtube.com/watch?v=n6iOUW523BE) played by teacher on Zoom/Google Meet |
| **Activity 2** | Student discussion in breakout rooms and shared remote whiteboard |
| **Activity 3** | Student discussion on breakout rooms and shared remote whiteboard |

**Adaptations for Learners’ Needs:**

For younger students, neurons and the concept of action potential can be introduced using:

**How Do Nerves Work - Elliot Krane**

Ted-Ed August 9, 2012 | YouTube (4:59 minutes)

Closed Captioning available

<https://www.youtube.com/watch?v=uU_4uA6-zcE&t=8s>

**Lights, Camera, Action Potential**

Neuroscience for Kids

<https://faculty.washington.edu/chudler/ap.html>

**Make a Neuron Model**

Neuroscience for Kids

<https://faculty.washington.edu/chudler/chmodel.html>

**Extension Activities to Build on Student Interest and Expertise:**

Students can learn about different types of neurons, different types of neurotransmitters, or can compare cardiac and neuronal action potentials using the following resources and others found online.

Chapter 1: Basics of Neuroscience & Neural Engineering <https://uw.pressbooks.pub/yspreach2020/chapter/chapter-1/>

Chapter 3: Brain and Spinal Cord Stimulation <https://uw.pressbooks.pub/yspreach2020/chapter/day-3-brain-and-spinal-cord-stimulation/> (for students to explore more in neuroscience)

**TEACHER BACKGROUND & RESOURCES**

**Background Information:**

* **ebook Chapter 1: Basics of Neuroscience & Neural Engineering** <https://uw.pressbooks.pub/yspreach2020/chapter/chapter-1/>
* **ebook Chapter 2: Brain and Spinal Cord Stimulation** <https://uw.pressbooks.pub/yspreach2020/chapter/day-3-brain-and-spinal-cord-stimulation/> (for students to explore more in neuroscience)
* **Molecular Cell Biology.** 4th edition. Section 21.1 Overview of Neuron Structure and Function <https://www.ncbi.nlm.nih.gov/books/NBK21535/>

**Additional Resources:**

* Free online course: [Fundamentals of Neuroscience, Part 1: The Electrical Properties of the Neuron](https://online-learning.harvard.edu/course/fundamentals-neuroscience-part-1-electrical-properties-neuron?delta=2)

**Citations:**

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