Introduction to Neural Engineering
& Ethical Implications

A Curriculum Unit for Grades 6-12 STEM Classes

CENTER FOR
SENSORIMOTOR NEURAL
ENGINEERING

Research Experience for Teachers (RET) Program

Draft for Piloting, September 2015

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About the RET Program & the CSNE

About the Research Experience for Teachers (RET) Program

The Research Experience for Teachers (RET) program is a seven week research experience for middle and high school STEM teachers, hosted by the Center for Sensorimotor Neural Engineering (CSNE) on the University of Washington's Seattle campus. Each summer cohort is selected through a competitive application process. Accepted teachers work in a CSNE lab alongside a team of researchers conducting cutting-edge neural engineering research. They enhance their understanding of lab safety, bioethics, engineering education, and curriculum design. Together, the teachers work to develop innovative neural engineering curriculum materials, which are then pilot-tested in their own classrooms the following academic year.

About the Center for Sensorimotor Neural Engineering (CSNE)

The Center for Sensorimotor Neural Engineering (CSNE) develops innovative modes of human-computer interaction by connecting brains with technology. We study signals from the brain, use that information to cause an action—such as moving a prosthetic hand or computer cursor—and provide useful information back to the brain. Our research is aimed at significantly improving the quality of life for people with spinal cord injury, stroke, Parkinson's disease, and other disabilities. By designing closed-loop, bi-directional brain-computer interfaces, we hope to help restore mobility as well as sensory and motor functions.

Neural Engineering Skill Sets

The CSNE has identified the following skill sets as essential for students to achieve neural engineering competency. All education activities supported by the CSNE are designed to teach one or more of these skills.

1. **Fundamentals of neuroscience, neural engineering, and neuroethics research:** Knowledge of core concepts in neuroscience and neural engineering, designing and conducting experiments, analysis and interpretation of results, problem solving, understanding primary scientific literature, building scientific knowledge, and ethical and responsible conduct of research.
2. **Neural engineering best practices:** Oral and written communication of neural engineering knowledge and research, confidence, working independently, working on a team, participating in a learning community, innovation, and persistence.
3. **Connections to neural engineering industry and careers:** Awareness of career options in neural engineering and pathways

Funding

The Research Experience for Teachers program is supported by National Science Foundation Award EEC-1028725.

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Acknowledgements:
We acknowledge the support of the following individuals: Rajesh Rao, PhD; Eric Chudler, PhD; Chet Moritz, PhD; Lise Johnson, PhD; Kristi Morgansen, PhD; Sara Goering, PhD; Laura Specker Sullivan, PhD; Hale Soloff; Deb Harper; Josh Patrick; Mary Guiden; and Daphne Struck. Our gratitude is extended to the following people and organizations that granted the use of their educational materials: CSNE Neuroethics Thrust and Neuroscience for Kids.

Unit Overview

Using neuroethics as a common theme throughout, this unit will give an overview of a broad range of neural engineering topics including the human nervous system, electrophysiology, the history of neural engineering, medical devices, and the ethical implications of these emerging technologies.

Learning Outcomes

Unit-level learning outcomes are presented in this section. Each lesson plan highlights the learning outcomes aligned to the particular activities incorporated into that lesson.

Big Ideas & Enduring Understandings

- **Sensorimotor Neural Engineering:** The field of Sensorimotor Neural Engineering works to create devices to restore or augment the body's capabilities for sensation and movement.
- **Neuroethics:** There are major ethical points to consider when designing neuroprosthetics.

Essential Questions:

- What is sensorimotor neural engineering?
- How does the human nervous system work?
- What is the history of the scientific advances in this field?
- What are some examples of current neuroprosthetics and how do they differ from other medical devices?
- What are the ethical implications of designing and using neuroprosthetics?

Knowledge and Skills (Outcomes):

Students will know…

- Neural engineering uses engineering techniques to solve problems involving the nervous system.
- The nervous system transmits, stores and processes information.
- The nervous system involves both sensory input and motor activity.
- The anatomy of a neuron, and how the action potentials and synapses work.
- The historical background and current innovations of neural engineering.
- Many of the currently used neural biomedical devices.

- There are ethical considerations in the research and application of neural biomedical devices.

Students will be able to…

- Evaluate a case study and discuss the ethical implications involved.
- Model how a nerve impulse travels through the nervous system.
- Participate in a neural engineering design challenge with a deep understanding of the background needed to succeed in the process.

Knowledge and Skills (Prerequisite):

Helpful prerequisite knowledge and skills include: Familiarity with some biology and chemistry concepts including knowledge of cells, tissues, body systems, atoms, ions, and electromagnetism at a very basic level.

Key Vocabulary:

Neuron, nervous system, synapse, postsynaptic, presynaptic, vesicle, neurotransmitter, sodium potassium pump, action potential, axon, dendrite, cell body, myelin, neural engineering, neuroprosthetic, biomedical device, lobotomy, deep brain stimulation, brain computer interface, sensorimotor, closed and open loop.

Alignment to National Learning Standards

This unit is aligned to the Next Generation Science Standards (NGSS) and the Common Core State Standards (CCSS) in English Language Arts. Alignment to NGSS Performance Expectations and the three dimensions of science and engineering education (Disciplinary Core Ideas, Crosscutting Concepts, and Practices) are outlined in the tables below.

Next Generation Science Standards: Performance Expectations

Next Generation Science Standards: Middle School (Grades 6-8)

	1: History of Neural Engineering	2: Neuroethics Case Studies	3: The Nervous System	4: Neuroprosthetics	5: Robotic Arm
Life Sciences					
MS-LS1-8 Structure, Function, and Information Processing: Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.					

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS.

Next Generation Science Standards: High School (Grades 9-12)

	1: History of Neural Engineering	2: Neuroethics Case Studies	3: The Nervous System	4: Neuroprosthetics	5: Robotic Arm
Life Sciences					
HS-LS1-2 Structure and Function: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.					

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS.

Next Generation Science Standards: Crosscutting Concepts

	1: History of Neural Engineering	2: Neuroethics Case Studies	3: The Nervous System	4: Neuroprosthetics	5: Robotic Arm
Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.					
Structure and Function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.					

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS.

Next Generation Science Standards: Science & Engineering Practices

	1: History of Neural Engineering	2: Neuroethics Case Studies	3: The Nervous System	4: Neuroprosthetics	5: Robotic Arm
Engaging in argument from evidence.					
Obtaining, evaluating, and communicating information.					

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS.

Common Core State Standards—Literacy in History/Social Studies, Science, & Technical Subjects: High School (Grades 9-12)

	1: History of Neural Engineering	2: Neuroethics Case Studies	3: The Nervous System	4: Neuroprosthetics	5: Robotic Arm
RST.9-10.2 Key Ideas & Details: Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.		🧠			
RST.9-10.4 Craft & Structure: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 9-12 texts and topics*.		🧠			
RST.9-10.7 Integration of Knowledge & Ideas: Integrate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g. in an equation) into words.			🧠	🧠	🧠
RH.9-10.3 Reading History: Analyze in detail a series of events described in a text; determine whether earlier events caused later ones or simply preceded them.	🧠	🧠			
RH.9-10.4 Reading History: Determine the meaning of words and phrases as they are used in a text, including vocabulary describing political, social, or economic aspects of history/social science.	🧠		🧠	🧠	🧠
WHST.9-10.8 Research to Build and Present Knowledge: Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.			🧠	🧠	🧠
WHST.9-10.9 Research to Build and Present Knowledge: Determine the meaning of words and phrases as they are used in a text, including vocabulary describing political, social, or economic aspects of history/social science.			🧠	🧠	🧠

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards for English Language Arts and Literacy in History/Social Studies, Science, and Technical Subjects*. Washington, DC: Common Core State Standards Initiative.

Lesson One: History of Neural Engineering

Center for Sensorimotor Neural Engineering

Lesson Plan Authors: Alison Farrell and Micheala Ranz, Attic Learning Community

LESSON OVERVIEW

Activity Time: One 50 minute class period. Additional time for homework.

Lesson Plan Summary: In this lesson, students will be introduced to the unit on sensorimotor neural engineering and neuroprosthetics. Students will explore some historical background relating to animal and human research, neural anatomy and physiology, technology and prosthetics. Students will create a timeline of events related to neural engineering from the topics of research/ethics, anatomy and physiology, prosthetics, and technology.

STUDENT UNDERSTANDINGS

Big Idea & Enduring Understanding:

Students will understand that…

- **The History of Neural Engineering**: What happened in the past that will help students understand how the current innovations in neural engineering came to be.

Essential Question:

- What historical events have led to the current state of the field of neuroengineering?

Learning Objectives:

Students will know…

- A wide variety of interesting inventions, people and circumstances contributed to the current state of the field of neuroengineering.

Students will be able to…

- Appreciate the range of discoveries as well as notice patterns and connections between the events that contributed to the current state of the neural engineering field. Students will be able to research historical events in a variety of topic areas that relate to neuroengineering.

Vocabulary:

- Neural engineering
- Sensorimotor neural engineering

Standards Alignment: This lesson addresses the following Next Generation Science Standards (NGSS) and Common Core State Standards (CCSS).

NGSS Disciplinary Core Ideas (DCIs)

- **MS-LS1-8 Structure, Function, and Information Processing:** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

NGSS Crosscutting Concepts

- **Patterns:** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

NGSS Basic Understandings about the Nature of Science and Cross-Cutting Concepts

- Science is a Way of Knowing
- Science is a Human Endeavor
- Science Addresses Questions about the Natural and Material World

NGSS Basic Understandings about the Nature of Science and Practices

- Scientific Knowledge is Based on Empirical Evidence
- Scientific Knowledge is Open to Revision in Light of New Evidence

Common Core State Standards

- **CCSS.ELA-LITERACY.RH.9-10.3:** Analyze in detail a series of events described in a text; determine whether earlier events caused later ones or simply preceded them.
- **CCSS.ELA-LITERACY.RH.9-10.4:** Determine the meaning of words and phrases as they are used in a text, including vocabulary describing political, social, or economic aspects of history/social science.

MATERIALS

Material	Description	Quantity
Science Notebook	Any bound notebook students can dedicate to this unit or class	1 per student
Timeline Wall Chart Headings	Headings for class timeline with the name of each category	1 set per class
Student Handout 1.1: *Timeline Game Directions*	Game directions	1 per group
Student Handout 1.2: *Timeline Game Cards*	80 double sided cards describing historical events	1 set per 16 students
Student Handout 1.3: *Blank Timeline Game Cards*	Blank Timeline cards - 4 cards	1 per student
Tape	Anything that will attach timeline cards and headings to the wall	1 roll per group

TEACHER PREPARATION

1. Make copies of the Timeline Cards. The cards should be printed double-sided on card stock using a different color for each topic. A full set of cards is enough for about 16 students in groups of 4. Each student should also have one set of 4 blank timeline cards.

2. Plan to divide students into groups of 3-4. Each group needs 20 timeline cards. Teachers will be passing out a single category of cards to each group. So each group will only have one of the four topics (ethics/research, anatomy/physiology, prosthetics or technology).

3. Make a set of Class Timeline Wall Chart Headings. Set up the Class Timeline Wall Chart headings on a large blank wall (2 feet by 6 feet) using the layout shown here:

Topic	Earliest Events	Middle Events	Current Events
Ethics/Research			
Anatomy/Physiology			
Prosthetics			
Technology			

4. Teachers should consider leaving the timeline up for the rest of this unit and other neural engineering units. Students can reference the timeline and add additional information to it as they explore future lessons.

PROCEDURE

Engage: (5 mins)

1. Write the warm up on the board: *"What do you think the term 'Sensorimotor Neural Engineering' means?"*

2. Have student write individually in their science notebooks then take a few volunteer responses.

3. Discuss what "sensorimotor neural engineering" is with the class. (See *Background Information*).

Explore: (20 mins)

4. Break students into groups of 3-4.

5. Pass out a set of 20 timeline cards to each group. There are four tracks of cards: technology, ethics, prosthetics, and anatomy. Each track has 20 cards and a group of students should be given all 20 cards from the same track.

6. Give each group one copy of ***Student Handout 1.1:*** *Timeline Game Directions*. Alternatively, the teacher can explain the game to class.

7. Play Timeline Game. (See ***Student Handout 1.1:*** *Timeline Game Directions).* If there is time have groups trade card sets and play again with a new track of cards.

Explain: (5 mins)

8. Challenge students to create class timeline on the wall:
    a. Have students take turns, one student per group at a time, bringing an event they found interesting up to the timeline wall and posting it with tape.
    b. Instruct students to try and not post duplicate cards on the timeline. Provide a spot for students to leave duplicate cards near the timeline.

Elaborate: (10 mins)

9. Have student do a Gallery Walk looking at the class timeline. Instruct them to look for interesting connections and patterns.

10. After students are finished looking through the class timeline, have students answer the following prompts in their science notebooks (written on the board):
    a. "What do you notice about the timeline events? What patterns occur within topics and what connections do you see between topics?"
    b. "What questions came up for you during the gallery walk? What do you wonder and what would you like to learn more about?"

11. Pair Share - have students turn and talk to the person next to them about their responses to the questions on the board.

Evaluate: (10 mins)

12. Lead a class debrief of the connections and patterns that students observed in the class timeline. Make a class list of observations and questions that came up during the Gallery Walk and Pair Share. For more discussion prompts, ask the following questions and take volunteer answers:
    a. *"What are some examples of the ways that research on humans and animals led to breakthrough understandings about anatomy and physiology?"*
    b. *"What were some key technological breakthroughs that allowed for new neuroprosthetics to be developed?"*

13. Assign homework—Find 3-4 events to add to the timeline. Pass out ***Student Handout 1.2:*** *Blank Timeline Game Cards.* Instruct students to find events from at least two different tracks (anatomy, ethics, technology, prosthetics) and include a few sentences on their cards describing the event and how it is related to the field of neuroengineering.

STUDENT ASSESSMENT

Assessment Opportunities:

- At the end of the unit, teachers will collect science notebooks and use the contents to assess the students' learning. In this lesson, the following writing prompts will be included in the science notebook:
    - Warm up prompt
    - Gallery walk prompts
- Also, the homework is for students to complete ***Handout 1.2****: Blank Timeline Game Cards*, which will show that they were able to find and explain an interesting event in history related to neural engineering.

Student Metacognition:

- The prompts, written and discussion based, given during this lesson provide opportunities for students to reflect on their understanding on the topics addressed.

Scoring Guide:

- Student work will not be "scored" for correctness in any of these introductory activities. Instead, it can be graded for completion or just used for formative assessment purposes (i.e., what did students understand from the activity).

EXTENSION ACTIVITIES

Extension Activities:

- The cards students create could be mixed in and the game played again with the new cards.
- Have students choose a particular technological advancement and research medical devices that were invented or improved upon using their chosen technology.

Adaptations:

- The timeline game could be modified into a cooperative group activity. All 20 cards in a category are spread out with the date side down and as a group students work to put them in the correct order, checking the dates after they have lined up the cards with their best prediction.

TEACHER BACKGROUND & RESOURCES

Background Information:

Teachers should know sensorimotor neural engineering is a field of engineering focused on making devices which interact with the nervous system and can restore or augment a person's capability for sensation and movement. Neural engineers study the nervous system, working to understand how to repair, replace, enhance and exploit the system. The fields of engineering and science overlap but engineers tend to focus more on application while scientists explore fundamental concepts.

For additional information see the following links

- Center for Sensorimotor Neural Engineering http://www.csne-erc.org/
- What is Neural Engineering? http://www.csne-erc.org/braintech-journal/post/what-neural-engineering

Citations:

Content Credits

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Student Handout 1.1: Timeline Game Directions

Name:_______________________________ Date:_________________ Period:__________

1. Each group of players (2-4 students) needs one set of 20 timeline cards and a pile of tokens or pen and paper to keep track of the score. Cards are divided into four categories, ethics of research, anatomy and physiology, prosthetics, and technology and each group will receive cards from only one category.

2. Each card represents a historical event which is described on both sides of the card. One side includes the date and the other side does not. Do not look at the date side of the cards.

3. Make sure all cards are stacked up with the date side down. Shuffle your cards and pass out an equal number to each player. Players do NOT pick up their cards or turn them over. If there is an unequal number of cards put the extra card(s) into the middle date side up. If there is an equal number of cards each player puts one card into the middle date side up.

4. Arrange the cards in the middle from oldest on the left to youngest on the right. It is fine if there is only one card in the middle, just remember older cards to the left and younger cards to the right.

5. Choose a player to go first. The first players adds her top card to the timeline whenever she think it fits, right, left or in between existing cards. The player turns her card over to check her placement. If their card is in the correct spot she leave it date side up and play passes clockwise. If her card is in the wrong location she moves the card to the correct spot in the timeline, leaves it there and receives one point (use tokens or paper to keep track of the score).

6. Play continues until all the cards have been added to the timeline.

7. The player with the fewest points wins.

.

Student Handout 1.1: Timeline Game Cards

Student Handout 1.3: Blank Timeline Game Cards

Both of these handouts can be found as separate Word documents (in order to keep formatting intact).

Animal and Human Research Ethics (S-1)	**Anatomy and Physiology (S-1)**
Innovations in Prosthetics (S-1)	**Technology (S-1)**

Anatomy and Physiology (S-1)	Animal and Human Research Ethics (S-2)
Technology (S-2)	**Innovations in Prosthetics (S-2)**

Animal and Human Research Ethics (S-1) At the medical school in Alexandria, Egypt, humans and animals were vivisected. Vivisection is surgery conducted for experimental purposes on a living organism to view living internal structures. Historians believe that more than 600 criminals were subjected to vivisection while they were alive. Human dissection and vivisection were generally forbidden throughout the rest of Egypt and in the Roman Empire due to moral concerns.	**Animal and Human Research Ethics (S-1)** French philosopher François-Marie Arouet de Voltaire noted that vivisection uncovered organs of feeling in animals, proving that animals were not machines, but feeling beings. Vivisection is surgery conducted for experimental purposes on a living organism to view living internal structures. Later in the century, British philosopher Jeremy Bentham summarized his thoughts on the subject: "The question is not, can they reason? Nor, can they talk? but, can they suffer?"
Animal and Human Research Ethics (S-1) The American Society for the Prevention of Cruelty to Animals (ASPCA) was the first humane society to be established in North America. Humane treatment means treating animals with respect and care. A law to prevent the beating of horses came about through early action from ASPCA. Later, this law was used to prosecute a parent who was beating her child, as there were no laws at the time preventing the abuse of children. Nine years later the American Society for the Prevention of Cruelty to Children was founded.	**Animal and Human Research Ethics (S-1)** Harvard University founded one of the first vivisection laboratories in the country, despite opposition from the Massachusetts Society for the Prevention of Cruelty to Animals (MSPCA). Vivisection is surgery conducted for experimental purposes on a living organism to view living internal structures. Various anti-vivisection groups were founded, including the American Anti-Vivisection Society (AAVS) and the New England Anti-Vivisection Society (NEAVS). The new anti-vivisection groups tried, unsuccessfully, to outlaw the practice of vivisection.
Animal and Human Research Ethics (S-1) French scientist Louis Pasteur proved the controversial theory that diseases were caused by microscopic organisms ("germs"). Using yeast, silkworms, and sheep, Pasteur found that microbes could travel through the air and that the spread of disease could be controlled by sterilization, which includes the use of heat, chemicals, pressure, irradiation, or filtration to remove or kill microbes. This discovery had wide application to surgical techniques and medicine.	**Animal and Human Research Ethics (S-1)** The U.S. Congress passed the Pure Food and Drug Act (PFDA) which made it against the law to use false or misleading claims about a food or drug. As it applied to "man and other animals," it also covered animal feed and veterinary drugs. The act did not, however, require any type of testing to ensure that a product was safe or effective.

Animal and Human Research Ethics (S-2) French philosopher François-Marie Arouet de Voltaire noted that vivisection uncovered organs of feeling in animals, proving that animals were not machines, but feeling beings. Vivisection is surgery conducted for experimental purposes on a living organism to view living internal structures. Later in the century, British philosopher Jeremy Bentham summarized his thoughts on the subject: "The question is not, can they reason? Nor, can they talk? but, can they suffer?" **(1764)**	**Animal and Human Research Ethics (S-2)** At the medical school in Alexandria, Egypt, humans and animals were vivisected. Vivisection is surgery conducted for experimental purposes on a living organism to view living internal structures. Historians believe that more than 600 criminals were subjected to vivisection while they were alive. Human dissection and vivisection were generally forbidden throughout the rest of Egypt and in the Roman Empire due to moral concerns. **(3rd and 2nd Centuries B.C.E.)**
Animal and Human Research Ethics (S-2) Harvard University founded one of the first vivisection laboratories in the country, despite opposition from the Massachusetts Society for the Prevention of Cruelty to Animals (MSPCA). Vivisection is surgery conducted for experimental purposes on a living organism to view living internal structures. Various anti-vivisection groups were founded, including the American Anti-Vivisection Society (AAVS) and the New England Anti-Vivisection Society (NEAVS). The new anti-vivisection groups tried, unsuccessfully, to outlaw the practice of vivisection. **(1871)**	**Animal and Human Research Ethics (S-2)** The American Society for the Prevention of Cruelty to Animals (ASPCA) was the first humane society to be established in North America. Humane treatment means treating animals with respect and care. A law to prevent the beating of horses came about through early action from ASPCA. Later, this law was used to prosecute a parent who was beating her child, as there were no laws at the time preventing the abuse of children. Nine years later the American Society for the Prevention of Cruelty to Children was founded. **(1866)**
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Animal and Human Research Ethics (S-1) The American Medical Association started to advocate for the benefits of research with animals and developed regulations for the humane treatment of animals used in medical schools. Humane treatment means treating animals with respect and care.	**Animal and Human Research Ethics (S-1)** Once known as the "strangling angel of children," diphtheria is a highly contagious childhood illness caused by a bacteria. The dreaded disease would begin with cold-like symptoms and lead to death in as little as a week. Death rates for diphtheria were high, and the need for a vaccine was clear. German scientist Emil von Behring found that low doses of modified toxin (a damaging substance naturally produced by diphtheria bacteria) injected into rats, mice, or rabbits appeared to protect them from the illness. After more than 15 years of research, von Behring produced long-lasting immunity in guinea pigs, monkeys, and donkeys. This research was used in the first vaccination studies on humans.
Animal and Human Research Ethics (S-1) For 150 years, doctors had been researching ways to treat diabetes, a disease in which a person has high blood sugar levels. Juvenile diabetics would usually fall into a coma and die a year or two after symptoms of the disease first appeared. Through studies with dogs, it was known that the pancreas produced an important substance ("insulin") that regulated blood sugar. Canadian doctor Frederick Banting extracted insulin from beef pancreases and used it to successfully treat a 14-year old boy dying of diabetes, who at the time weighed only 65 pounds. Families with diabetic children rushed to Toronto for treatment. The Toronto Star called the extract "one of the greatest achievements in modern medicine." Banting and colleagues won the Nobel Prize for their work.	**Animal and Human Research Ethics (S-1)** During World War II, German Nazi doctors performed gruesome experiments on prisoners who were Jewish, homosexual, mentally disabled, physically disabled, or children. These prisoners were forced into being test subjects. Several tens of thousands of people died in these experiments, and many of those who survived were disfigured. In response, the "Nuremberg Code" was developed to describe ethical conduct in human research. The Code was widely adopted in scientific research communities. One of the ten points of the code stated a requirement for animal research before human research to minimize the harm to humans.
Animal and Human Research Ethics (S-1) Members of the research community published The Principles of Humane Experimental Technique. One of its core messages, the 3 Rs (Replacement, Reduction, and Refinement), became widely accepted by scientific communities. In many countries, the 3 Rs are the principles currently guiding the use of animals in research.	**Animal and Human Research Ethics (S-1)** After World War II, the Federal government began supporting biomedical research in ways it never had before, increasing the budget of the National Institutes of Health (NIH) 150-fold between 1945 and 1961. Additional research money created a demand for more research animals. Dogs, which had played a large part in animal research in the past, were especially sought after. People's fears of dog-napping are reflected in the 1961 Disney movie 101 Dalmatians, which tells the story of pet dogs stolen by a cruel villain.

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Animal and Human Research Ethics (S-2)

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Animal and Human Research Ethics (S-2)

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Animal and Human Research Ethics (S-1) The federal Food, Drug, and Cosmetic Act (FDC Act) was amended to require that all drugs not only be safe but effective. This amendment did not distinguish between medicines for humans and animals. Regulations for animal drugs, medicated feed, and veterinary food additives were strengthened.	**Animal and Human Research Ethics (S-1)** Pepper, a Dalmatian dog, disappeared from her family's backyard in Pennsylvania. The family tracked the dog to an animal dealer who had sold her to a hospital in New York City that conducted a pace-maker experiment on her heart, which she did not survive. Pepper's story was widely publicized and an outraged public demanded more accountability in animal research, especially research using dogs.
Animal and Human Research Ethics (S-1) Lesley and John Brown, a young English couple, had been unable to conceive a child for nine years. Lesley Brown had blocked fallopian tubes. Having gone from doctor to doctor for help to no avail, she was referred to Dr. Patrick Steptoe. In 1977, Lesley Brown underwent the very experimental in vitro ("in glass") fertilization procedure in which an egg was extracted from one of her ovaries and fertilized outside her body with John's sperm. The two-day-old embryo was placed back into Lesley's uterus and the pregnancy resulted in the first successful "test tube baby." This work was made possible by decades of research with mice, rabbits, and hamsters. Dr. Steptoe's colleague won the Nobel Prize.	**Animal and Human Research Ethics (S-1)** Animal activists brought awareness to the testing of cosmetics on animals, particularly the Draize test, in which chemicals were put into the eyes of rabbits. In full-page advertisements in major newspapers, major cosmetics companies were accused of being cruel to animals. Public response was immediate. Several companies, including Revlon and Avon, announced their intention to cease animal testing.
Animal and Human Research Ethics (S-1) The first transgenic mouse is created. A transgenic organism is a living organism in which genes, or gene regulatory regions, have been added, removed, or modified. The change in DNA will cause the organism to exhibit a new property (immune system change, genetic disorder, etc.) which can be passed to its offspring. Scientists create mice with human genes. To more effectively study human diseases and cures, these transgenic mice become the research subject of choice. Currently, more than 90% of animals used in research are mice.	**Animal and Human Research Ethics (S-1)** A little-known organization called People for the Ethical Treatment of Animals (PETA) gained national prominence with an exposé on research that involved depriving monkeys of sensory input into their spinal cords to give them numbed arms. The monkeys gnawed and licked their arms, producing wounds. A co-founder of PETA worked as a laboratory assistant, photographed the monkeys, then reported the lab to authorities. A subsequent raid led to the filing of animal cruelty charges, loss of funding, and the end of the research. The incident came to be known as the Silver Springs Monkey Case.

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Animal and Human Research Ethics (S-1)

Scientists search for a vertebrate (having a backbone) animal that could function as a model organism because it is easier to study rather than humans and higher organisms, making it a more ethical research subject. A model organism tends to be small, able to reproduce rapidly with many offspring, inexpensive to house and maintain, able to be manipulated genetically on the molecular level, and well-studied by other scientists. Many scientists advocate for the use of zebrafish as a model organism. Zebrafish are commonly found in pet shops and home aquaria. They are small, hardy, breed readily, lay many eggs, and have genes more closely related to humans than fruit flies or worms. Their eggs are fertilized externally and embryos develop quickly, are transparent, and can be genetically manipulated. Zebrafish were therefore particularly attractive for studying developmental biology and modeling human disease. Currently, there are at least 600 laboratories around the world that use zebrafish, and several researchers use only zebrafish in their research.

Animal and Human Research Ethics (S-1)

The European Union (EU) bans the use of animals to test cosmetic ingredients. They also implement a “marketing ban” that prohibits the sale of products from outside the EU that contain ingredients tested on animals. The marketing ban will be implemented slowly, with some animal tests allowed until 2013. The European Union is uncertain whether the 2013 deadline can be met because replacement tests have not yet been fully developed. The ban also contradicts laws requiring safety testing of certain chemicals.

Anatomy and Physiology (S-1)

The Edwin Smith Papyrus was written. This ancient Egyptian medical text was purchased from an antiquities dealer by Edwin Smith in 1862. The papyrus describes 48 cases involving injury, fractures, wounds, dislocations and tumors. These surgical descriptions of trauma are the first known written record describing the nervous system.

Anatomy and Physiology (S-1)

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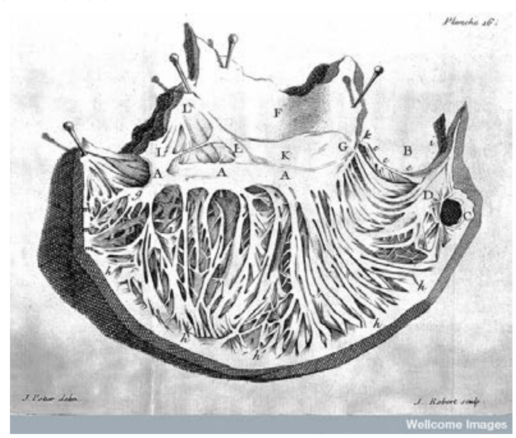
Hippocrates teaches that the brain is related to sensation and is the location of intelligence.

Anatomy and Physiology (S-1)

Leonardo da Vinci creates wax casts of human ventricles.



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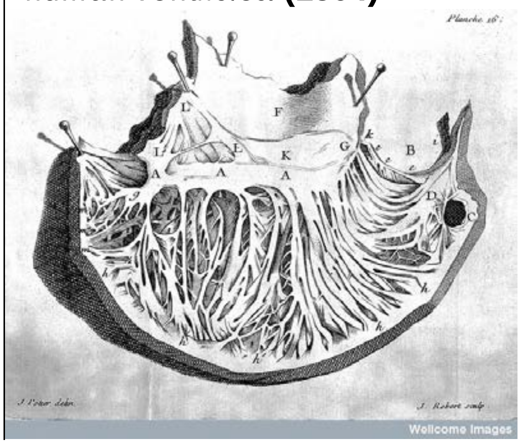
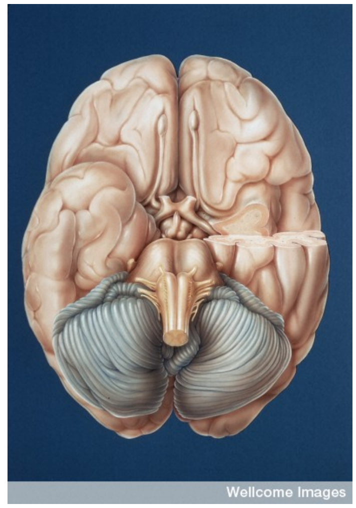
Anatomy and Physiology (S-2) Leonardo da Vinci creates wax casts of human ventricles. **(1504)**  	**Anatomy and Physiology (S-2)** Hippocrates teaches that the brain is related to sensation and is the location of intelligence. **(400 B.C.E.)**

Anatomy and Physiology (S-1)

Johannes Kepler discovered retinal images are inverted by the lens of the eye.

Anatomy and Physiology (S-1)



The modern classification of the twelve cranial nerves is created by Samuel von Soemmerring.

Anatomy and Physiology (S-1)

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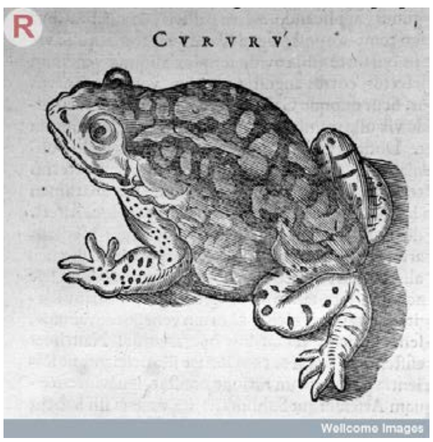


frog's leg muscles proving that nerve action is electrical.

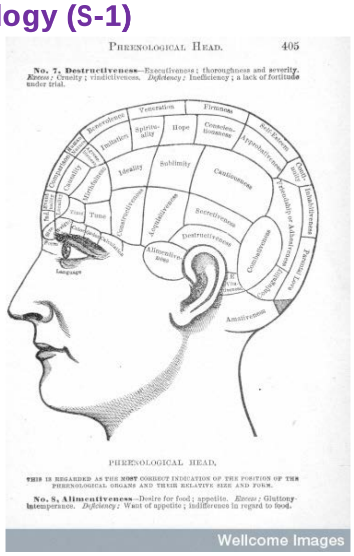
Anatomy and Physiology (S-1)

Experimental evidence for neuroplasticity (physical changes to neurons) in animals is presented by the Italian anatomist Michele Vicenzo Malacarne. He paired animals and then trained one of the pair extensively for

years. After dissection he noticed the cerebellums of the trained animals were larger.

Anatomy and Physiology (S-1)

Franz Gall theorizes that specific functions are controlled by specific regions in the brain and founds the field of phrenology.

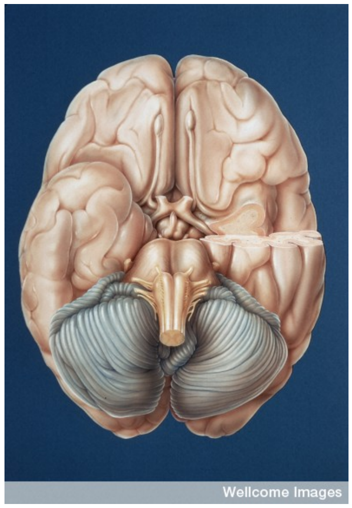


Anatomy and Physiology (S-1)

Marie-Jean-Pierre Flourens notes the cerebellum regulates motor activity and that the mind is in the brain, not the heart. He was a major founder in the fields of brain research and anesthesia.

Anatomy and Physiology (S-2)

The modern classification of the twelve cranial nerves is created by Samuel von Soemmerring. **(1778)**



Anatomy and Physiology (S-2)

Johannes Kepler discovered retinal images are inverted by the lens of the eye. **(1604)**

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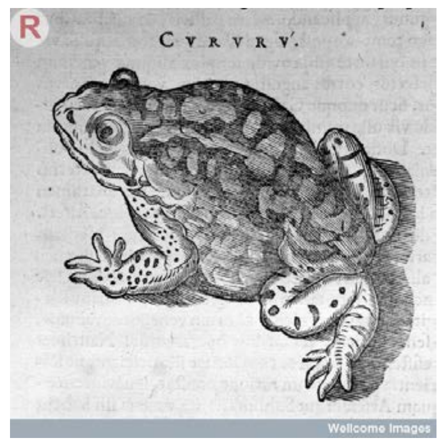
Anatomy and Physiology (S-2)

Luigi Galvani stimulates nerves in a frog's leg muscles proving that nerve action is electrical. **(1791)**



Anatomy and Physiology (S-2)

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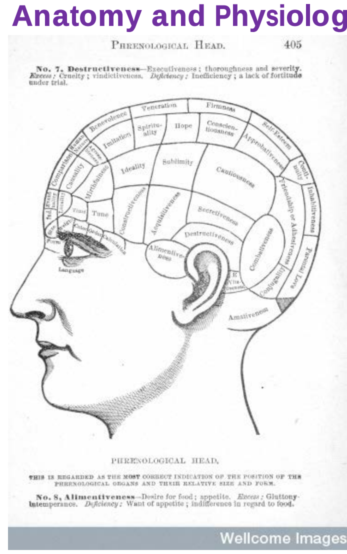
Anatomy and Physiology (S-2)



Franz Gall theorizes that specific functions are controlled by specific regions in the brain and founds the field of phrenology. **(1808)**

Anatomy and Physiology (S-1)

Johannes Evangelista Purkinje was the first to observe neurons (nerve cells) in brain tissue. He sliced brain tissue into thin sections using a metronome which allowed him to see the neuron cell bodies and surrounding dendrites.

Anatomy and Physiology (S-1)

Hermann von Helmholtz determined the speed of a nerve impulse travelling along the sciatic nerve in a frog. Before his research scientists thought the nerve impulse was almost instantaneous and too fast to measure.

(Pictured: Helmholtz Pendulum)

Anatomy and Physiology (S-1)

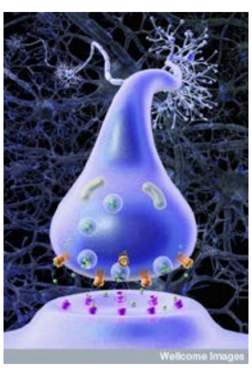
Wilhelm von Waldeyer-Hartz synthesized the current knowledge about neurons into a general neural theory describing how the nervous system is organized and coining the term “neuron”.

Anatomy and Physiology (S-1)

Charles Sherrington coins the term synapse. He went on to describe how the nervous system coordinated different body areas and the basic parts of a reflex arc.

Anatomy and Physiology (S-1)

German pharmacologist Otto Loewi proved that neurons communicate across synapses by releasing chemicals. He went on to discover the first known neurotransmitter, acetylcholine.



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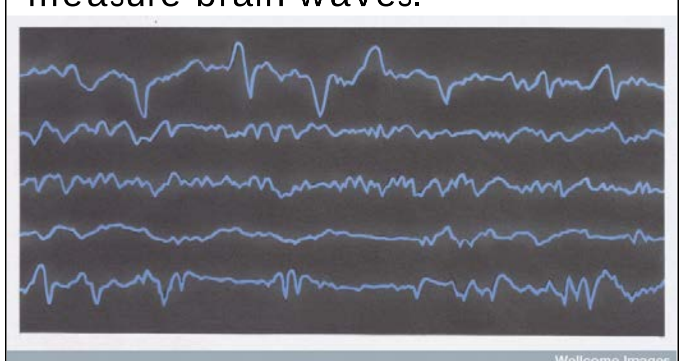
Hans Berger invented the electroencephalogram which can measure brain waves.



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(Pictured: Helmholtz Pendulum)

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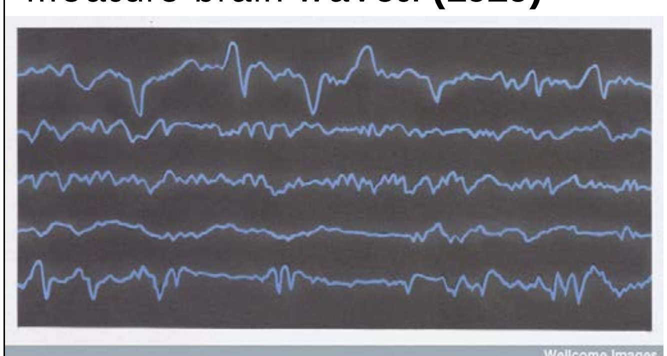

Anatomy and Physiology (S-2)

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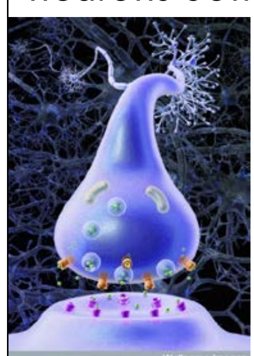


synapses by releasing chemicals. He went on to discover the first known neurotransmitter, acetylcholine. **(1921)**

Anatomy and Physiology (S-1)

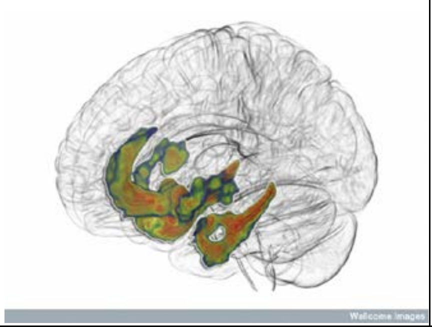
Rita Levi-Montalcini discovered nerve growth factor. She isolated the nerve growth factor from cancerous tumors that stimulated the growth of nerve cells.

Anatomy and Physiology (S-1)

Brenda Milner discovered the connection between the medial temporal lobe and memory. The temporal lobe plays an important role in hearing, memory, speech and emotional response. Milner was instrumental in helping neurosurgeons avoid causing additional damage to important areas of the brain.

Anatomy and Physiology (S-1)

M.E. Phelps, E.J. Hoffman and M.M. Ter Pogossian develop first PET (positron emission tomography) scanner. The PET can produce three dimensional images of the body areas and is used extensively in research and treatment into the human brain.



Anatomy and Physiology (S-1)

Human Brain Project, a 10-year scientific research project whose goal is to develop a thorough understanding of brain function and structure, is founded. The Human Brain Project is based in Switzerland and primarily funded by the European Union.

Innovations in Prosthetics (S-1)

An Egyptian wooden toe is the oldest known prosthetic. It was found in 2000 in a tomb near the ancient city of Thebes.

Innovations in Prosthetics (S-1)

Oldest known artificial leg. This early Roman prosthetic was made of bronze and discovered in 1858 in Capua, Italy.

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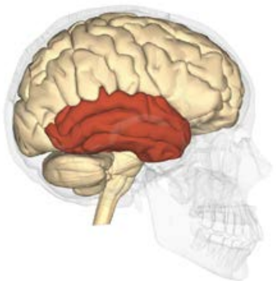

Anatomy and Physiology (S-2)

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Innovations in Prosthetics (S-2)

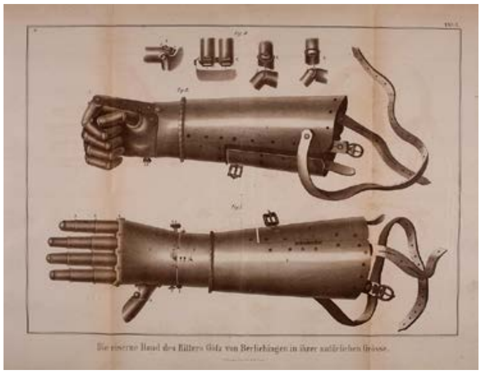
Oldest known artificial leg. This early Roman prosthetic was made of bronze and discovered in 1858 in Capua, Italy. **(300 B.C.E)**

Innovations in Prosthetics (S-2)

An Egyptian wooden toe is the oldest known prosthetic. It was found in 2000 in a tomb near the ancient city of Thebes. **(800 B.C.E)**

Innovations in Prosthetics (S-1)

Gotz von Berlichingen was a German Imperial knight, mercenary and poet. After losing his right arm in a siege he had a pair of technologically advanced artificial iron hands crafted that could move by relaxing springs and was suspended by leather straps.



Innovations in Prosthetics (S-1)

Modern amputation surgery practices are introduced by French Army surgeon Ambroise Pare. He applied the scientific method to battlefield surgery, experimenting with different treatments and observing results.

Innovations in Prosthetics (S-1)

Giovanni Battista Porta publishes Magia Naturalis. This collection of scientific information covered a range of topics including geology, optics, hidden writing, cooking, metallurgy and more. Magia Naturalis included a description of an early hearing aid made of wood and shaped like animal ears.

Innovations in Prosthetics (S-1)

James Potts improved on leg prosthesis by building a wooden shank and socket leg prosthesis with a steel knee joint and articulated foot controlled by catgut tendon. The leg he developed was worn by the Marquess of Anglesey after he lost his leg in the Battle of Waterloo and eventually became known as the Anglesey leg.

Innovations in Prosthetics (S-1)

Alphonsus William Webster was issued the first known British patent for a hearing aid. His device consisted of a curved earpiece worn behind the ear to assist in hearing.

Innovations in Prosthetics (S-1)

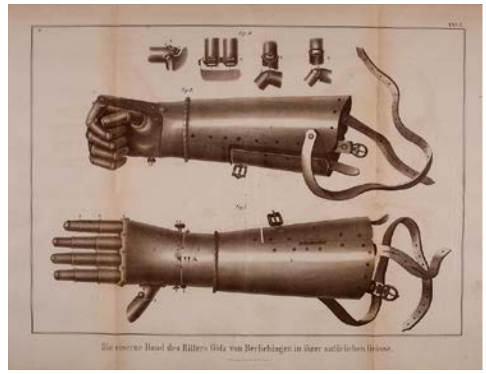
Benjamin Palmer received the first patent for an artificial leg. He designed a more natural looking prosthesis by adding anterior springs, a smooth appearance and concealed metal tendons.

Innovations in Prosthetics (S-2)

Modern amputation surgery practices are introduced by French Army surgeon Ambroise Pare. He applied the scientific method to battlefield surgery, experimenting with different treatments and observing results. **(1529)**

Innovations in Prosthetics (S-2)

Gotz von Berlichingen was a German Imperial knight, mercenary and poet. After losing his right arm in a siege he had a pair of technologically advanced artificial iron hands crafted that



could move by relaxing springs and was suspended by leather straps. **(1508)**

Innovations in Prosthetics (S-2)

James Potts improved on leg prosthesis by building a wooden shank and socket leg prosthesis with a steel knee joint and articulated foot controlled by catgut tendon. The leg he developed was worn by the Marquess of Anglesey after he lost his leg in the Battle of Waterloo and eventually became known as the Anglesey leg. **(1800)**

Innovations in Prosthetics (S-2)

Giovanni Battista Porta publishes Magia Naturalis. This collection of scientific information covered a range of topics including geology, optics, hidden writing, cooking, metallurgy and more. Magia Naturalis included a description of an early hearing aid made of wood and shaped like animal ears. **(1588)**

Innovations in Prosthetics (S-2)

Benjamin Palmer received the first patent for an artificial leg. He designed a more natural looking prosthesis by adding anterior springs, a smooth appearance and concealed metal tendons. **(1846)**

Innovations in Prosthetics (S-2)

Alphonsus William Webster was issued the first known British patent for a hearing aid. His device consisted of a curved earpiece worn behind the ear to assist in hearing. **(1836)**

Innovations in Prosthetics (S-1)

Edward G Hyde was awarded the first US patent for a hearing aid for his ear scoops.

Innovations in Prosthetics (S-1)

Douglas Bly invented and patented an anatomical leg which he called “the most complete and successful invention ever attained in artificial limbs”. His leg included an ivory ball and rubber socket ankle that provided a more natural gait.

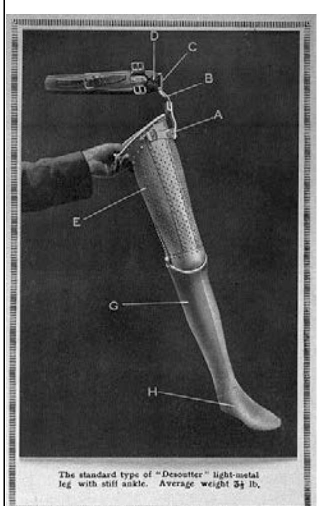
Innovations in Prosthetics (S-1)

The Civil War ends with over 70,000 amputees and ushers in a new interest in prosthetics. The introduction of the Minnie ball rifle bullet resulted in large slow healing wounds and greatly increased the number of amputations during the war.

Innovations in Prosthetics (S-1)

Alonzo E Miltimore issued the first US patent for an electric hearing aid. The device was never produced.

Innovations in Prosthetics (S-1)



The standard type of “Desoutter” light-metal leg with stiff ankle. Average weight 3½ lb.

Marcel Desoutter lost his leg in an airplane accident and made the first aluminum prosthesis. He and his brother went on to form a company that manufactured artificial legs. The company expanded during and after The Great War, increasing production of artificial legs and also producing pneumatic tools.

Innovations in Prosthetics (S-1)

Globe Ear-Phone Company introduces the first electric hearing aid with a volume control. The device weighed just over 8 oz without the battery.

Innovations in Prosthetics (S-2)

Douglas Bly invented and patented an anatomical leg which he called "the most complete and successful invention ever attained in artificial limbs". His leg included an ivory ball and rubber socket ankle that provided a more natural gait. **(1858)**

Innovations in Prosthetics (S-2)

Edward G Hyde was awarded the first US patent for a hearing aid for his ear scoops. **(1855)**

Innovations in Prosthetics (S-2)

Alonzo E Miltimore issued the first US patent for an electric hearing aid. The device was never produced. **(1892)**

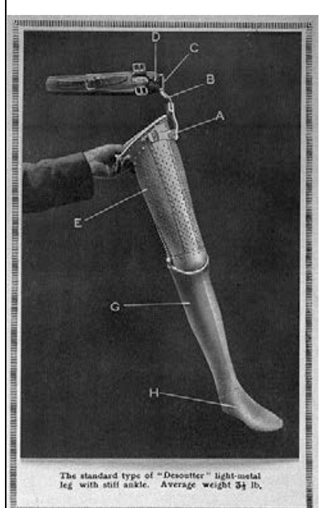
Innovations in Prosthetics (S-2)

The Civil War ends with over 70,000 amputees and ushers in a new interest in prosthetics. The introduction of the Minnie ball rifle bullet resulted in large slow healing wounds and greatly increased the number of amputations during the war. **(1865)**

Innovations in Prosthetics (S-2)

Globe Ear-Phone Company introduces the first electric hearing aid with a volume control. The device weighed just over 8 oz without the battery. **(1912)**

Innovations in Prosthetics (S-2)



The standard type of "Desoutter" light-metal leg with stiff ankle. Average weight 3½ lb.

Marcel Desoutter lost his leg in an airplane accident and made the first aluminum prosthesis. He and his brother went on to form a company that manufactured artificial legs. The company expanded during and after The Great War, increasing production of artificial legs and also producing pneumatic tools. **(1913)**

Innovations in Prosthetics (S-1)

Allen-Howe Electronics Corp introduces the first hearing aid with a printed circuit.

Innovations in Prosthetics (S-1)

André Djourno and Charles Eyriès designed and implanted the first electrical auditory prosthesis device. They successfully stimulated the auditory nerve using the device.

Innovations in Prosthetics (S-1)

Drs. Brindley and Lewin were the first to implant a stimulation device for vision restoration. They implanted an electrode array with 80 possible stimulating points into the visual cortex. Their test subject was eventually able to recognize simple patterns and letters.

Innovations in Prosthetics (S-1)

Paul Bach-y-Rita conducted the first studies on sensory substitution and neuroplasticity. He added four hundred vibrating plates to the back of a chair. Blind subjects learned to recognize vibrations that were activated in connection with a camera. Bach-y-Rita believed subjects were processing the vibrations in the visual cortex and some learned to differentiate between a variety of images.

Innovations in Prosthetics (S-1)

The deep brain stimulation (DBS) device is approved by the Food and Drug Administration for the treatment of essential tremors. The DBS is a device implanted in the brain that sends electrical impulses to specific parts of the brain and provides a last resort option when tremors have not decreased with other treatments.

Innovations in Prosthetics (S-1)

The Argus II retinal implant is approved in the USA as a medical device to improve vision in patients whose retinal receptors are not functioning properly due to diseases such as macular degeneration or retinitis pigmentosa.

Innovations in Prosthetics (S-2)

André Djourno and Charles Eyriès designed and implanted the first electrical auditory prosthesis device. They successfully stimulated the auditory nerve using the device. **(1957)**

Innovations in Prosthetics (S-2)

Allen-Howe Electronics Corp introduces the first hearing aid with a printed circuit. **(1948)**

Innovations in Prosthetics (S-2)

Paul Bach-y-Rita conducted the first studies on sensory substitution and neuroplasticity. He added four hundred vibrating plates to the back of a chair. Blind subjects learned to recognize vibrations that were activated in connection with a camera. Bach-y-Rita believed subjects were processing the vibrations in the visual cortex and some learned to differentiate between a variety of images. **(1969)**

Innovations in Prosthetics (S-2)

Drs. Brindley and Lewin were the first to implant a stimulation device for vision restoration. They implanted an electrode array with 80 possible stimulating points into the visual cortex. Their test subject was eventually able to recognize simple patterns and letters. **(1968)**

Innovations in Prosthetics (S-2)

The Argus II retinal implant is approved in the USA as a medical device to improve vision in patients whose retinal receptors are not functioning properly due to diseases such as macular degeneration or retinitis pigmentosa. **(2013)**

Innovations in Prosthetics (S-2)

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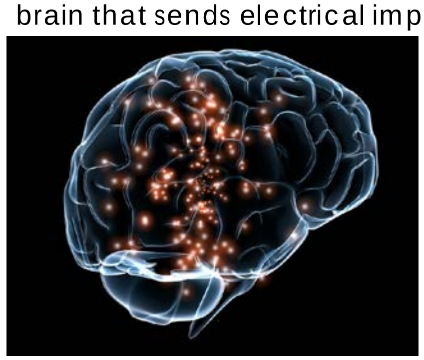


parts of the brain and provides a last resort option when tremors have not decreased with other treatments. **(1997)**

Technology (S-1)

Charles Babbage & Ada Lovelace, frustrated with the many errors in the current printed calculation tables, begin work on programmable mechanical calculating machines (the Babbage Difference Engine). After 10 years and £17,000 (enough money to buy 5 steam engines) the project was halted. Babbage went on to design other mechanical calculating machines and built a number of prototypes.

Technology (S-1)

The impure form of aluminum is produced for the first time by Danish physicist and chemist Hans Christian Ørsted. Aluminum is soft, durable, lightweight, easy to work with and resistant to corrosion.

Technology (S-1)

With the financial backing of Alfred E. Hunt, the large-scale production of aluminum starts at the Pittsburgh Reduction Company. The company is later renamed The Aluminum Company of America and then Alcoa.

Technology (S-1)

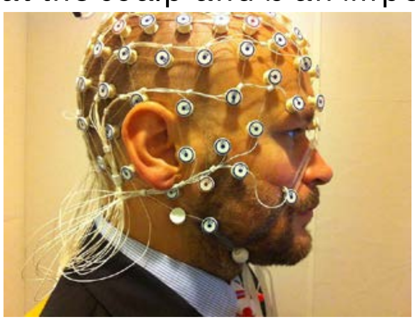
Hans Berger invents electroencephalography (EEG) and records human brain activity for the first time. An EEG measures electrical activity at the scalp and is an important diagnostic and research tool used to study brain activity.

Technology (S-1)

British mathematician Alan Turing publishes his paper "On Computable Numbers, With an Application to the Entscheidungs Problem" describing a hypothetical device able to solve any mathematical equation written as an algorithm.

Technology (S-1)

Austrian engineer Paul Eisler invented the printed circuit. He held a variety of jobs, eliminating radio interference for an audio recording firm as well as working as a journalist and printer. His engineering training and experiences with radio and printing were critical as he worked on his own to design the first printed circuits.

Technology (S-2) The impure form of aluminum is produced for the first time by Danish physicist and chemist Hans Christian Ørsted. Aluminum is soft, durable, lightweight, easy to work with and resistant to corrosion. **(1825)**	**Technology (S-2)** Charles Babbage & Ada Lovelace, frustrated with the many errors in the current printed calculation tables, begin work on programmable mechanical calculating machines (the Babbage Difference Engine). After 10 years and £17,000 (enough money to buy 5 steam engines) the project was halted. Babbage went on to design other mechanical calculating machines and built a number of prototypes. **(1822)**
Technology (S-2) Hans Berger invented electroencephalography (EEG) and records human brain activity for the first time. An EEG measures electrical activity at the scalp and is an important  diagnostic and research tool used to study brain activity. **(1924)**	**Technology (S-2)** With the financial backing of Alfred E. Hunt, the large-scale production of aluminum starts at the Pittsburgh Reduction Company. The company is later renamed The Aluminum Company of America and then Alcoa. **(1888)**
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Technology (S-1)

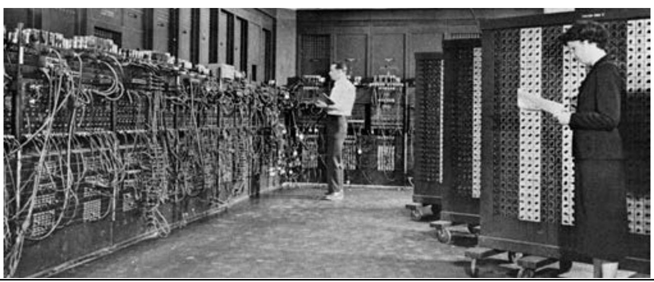
The USA used printed circuits on a large scale to make proximity fuses which can be set to detonate when the explosive device is a particular distance from the target.

Technology (S-1)

Warren McCulloch and Walter Pitts published their landmark paper "A Logical Calculus of Ideas Immanent in Nervous Activity". The paper described the first neural network mathematical model.

Technology (S-1)

The first general purpose programmable electronic computer the Electronic Numerical Integrator And Computer (ENIAC) was built by J. Presper Eckert and John V. Mauchly at the University of Pennsylvania. ENIAC was designed to calculate ballistic tables for the armed forces and was also used to study the hydrogen bomb.



Technology (S-1)

Alan Turing proposes the Turing Test as a measure of machine's ability to mimic human intelligence. He proposed if a human carrying on a text-only conversation with a machine and another human can't tell the difference between the machine and the human the machine has passed the Turing Test.

Technology (S-1)

The first artificially intelligent computer programs are written. A checkers-playing program was written by Christopher Strachey and a chess-playing program was written by Dietrich Prinz.

Technology (S-1)

The first industrial robot was installed in a factory. The robot was named Unimate and took over the dangerous job of moving parts off a conveyor belt and welding them onto an automobile at the General Motors assembly plant in New Jersey.

Technology (S-2)

Warren McCulloch and Walter Pitts published their landmark paper "A Logical Calculus of Ideas Immanent in Nervous Activity". The paper described the first neural network mathematical model. **(1943)**

Technology (S-2)

The USA used printed circuits on a large scale to make proximity fuses which can be set to detonate when the explosive device is a particular distance from the target. **(1943)**

Technology (S-2)

Alan Turing proposes the Turing Test as a measure of machine's ability to mimic human intelligence. He proposed if a human carrying on a text-only conversation with a machine and another human can't tell the difference between the machine and the human the machine has passed the Turing Test. **(1950)**

Technology (S-2)

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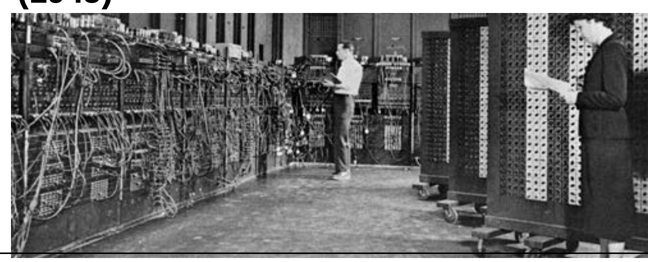


Technology (S-2)

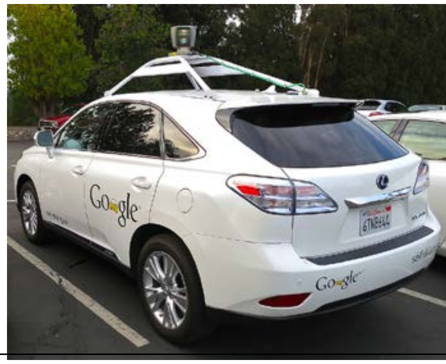
The first industrial robot was installed in a factory. The robot was named Unimate and took over the dangerous job of moving parts off a conveyor belt and welding them onto an automobile at the General Motors assembly plant in New Jersey. **(1961)**

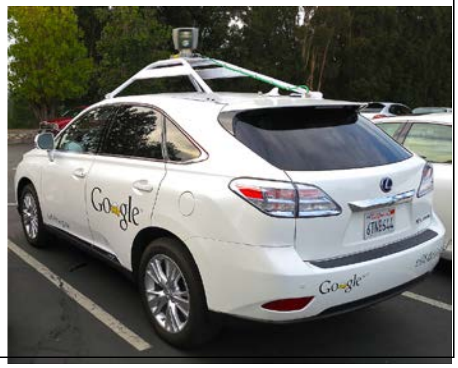
Technology (S-2)

The first artificially intelligent computer programs are written. A checkers-playing program was written by Christopher Strachey and a chess-playing program was written by Dietrich Prinz. **(1951)**

Technology (S-1) Professor Jacques Vidal coined the term Brain Computer Interface to describe a direct connection between a brain and an electrical device.	**Technology (S-1)** Dean Pomerleau at Carnegie Mellon University creates ALVINN (An Autonomous Land Vehicle in a Neural Network). The vehicle was designed to learn how to follow roads using a neural network.
Technology (S-1) Ian Horswill invents the robot Polly at the Massachusetts Institute of Technology (MIT). Polly was an early example of a behavior based robot. The robot used computer vision and could move at animal like-speeds (1m per second).	**Technology (S-1)** The Deep Blue chess machine (IBM) defeats the (then) world chess champion, Garry Kasparov. The pair played six games. They each won a game and then went on to play three games that were draws. Deep Blue won the sixth game in 43 moves.
Technology (S-1) The Nomad robot explores remote regions of Antarctica looking for meteorite samples. Nomad was programmed for robotic searching and automated on-site sample testing. The robot found five meteorites and also sampled a variety to terrestrial rocks.	**Technology (S-1)** The Blue Brain Project is initiated in Switzerland. The project's goal is to study the brain's architectural and functional principles, eventually learning enough reverse engineer the mammalian brain and build a synthetic brain.

Technology (S-2) Dean Pomerleau at Carnegie Mellon University creates ALVINN (An Autonomous Land Vehicle in a Neural Network). The vehicle was designed to learn how to follow roads using a neural network. **(1989)**	**Technology (S-2)** Professor Jacques Vidal coined the term Brain Computer Interface to describe a direct connection between a brain and an electrical device. **(1971)**
Technology (S-2) The Deep Blue chess machine (IBM) defeats the (then) world chess champion, Garry Kasparov. The pair played six games. They each won a game and then went on to play three games that were draws. Deep Blue won the sixth game in 43 moves. **(1997)**	**Technology (S-2)** Ian Horswill invents the robot Polly at the Massachusetts Institute of Technology (MIT). Polly was an early example of a behavior based robot. The robot used computer vision and could move at animal like-speeds (1m per second). **(1993)**
Technology (S-2) The Blue Brain Project is initiated in Switzerland. The project's goal is to study the brain’s architectural and functional principles, eventually learning enough reverse engineer the mammalian brain and build a synthetic brain. **(2005)**	**Technology (S-2)** The Nomad robot explores remote regions of Antarctica looking for meteorite samples. Nomad was programmed for robotic searching and automated on-site sample testing. The robot found five meteorites and also sampled a variety to terrestrial rocks. **(2000)**

Technology (S-1) Google builds the first self-driving car. Tests are currently underway and Google hopes to have the cars in production and available to the public by 2020. 	**Technology (S-1)** Apple's Siri is included as a regular feature for the first time in this year's release of the Apple iPhone. 

Technology (S-2) Apple's Siri is included as a regular feature for the first time in this year's release of the Apple iPhone. **(2011)** 	**Technology (S-2)** Google builds the first self-driving car. Tests are currently underway and Google hopes to have the cars in production and available to the public by 2020. **(2009)** 

Lesson Two: Neuroethics Case Studies

Center for Sensorimotor Neural Engineering

Lesson Plan Authors: Alison Farrell and Micheala Ranz, Attic Learning Community

LESSON OVERVIEW

Activity Time: One 50 minute class period. Additional time for homework.

Lesson Plan Summary: In this lesson, students will read, reflect, and discuss a neuroethics case study as part of an introduction to a unit on the history of sensorimotor neural engineering, anatomy and physiology of the nervous system, and current innovations in neuroprosthetics.

STUDENT UNDERSTANDINGS

Big Idea & Enduring Understanding:

- **Neuroethics:** There are important unanswered ethical questions related to the use of neuroprosthetics and related technology.

Essential Question:

- What are the ethical implications of using neuroprosthetics?

Learning Objectives:

Students will know…

- That a variety of different neuroprosthetics exist and that there are ethical implications to their use by patients.

Students will be able to…

- Articulate and discuss the ethical questions related to neuroprosthetics.

Vocabulary:

- Brain-Computer Interface (BCI)
- Deep Brain Stimulator
- Ethics
- fMRI
- Neural implant
- Neuroethics

- Neuroprosthetic
- Parkinson's Disease

Standards Alignment: This lesson addresses the following Next Generation Science Standards (NGSS) and Common Core State Standards (CCSS).

NGSS Basic Understandings about the Nature of Science and Cross-Cutting Concepts

- Science Addresses Questions about the Natural and Material World

NGSS Science & Engineering Practices

- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

Common Core State Standards

- **CCSS.ELA-LITERACY.RST.9-10.2:** Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
- **CCSS.ELA-LITERACY.RH.9-10.3:** Analyze in detail a series of events described in a text; determine whether earlier events caused later ones or simply preceded them.
- **CCSS.ELA-LITERACY.RH.9-10.4:** Determine the meaning of words and phrases as they are used in a text, including vocabulary describing political, social, or economic aspects of history/social science.

MATERIALS

Material	Description	Quantity
Science Notebook	Any bound notebook students can dedicate to this unit or class	1 per student
Student Handouts 2.1 - 2.9: *Case Studies #1-9 in Neuroethics*	Various short case study descriptions with questions	1 copy of one of the handouts per student (see *Preparation* notes)
Teacher Handout 2.1	Nervous System Review Topic Cards	1 for every 4 students (1 card per student)
Teacher Handout 2.2	Online Resources for Research	1 per student or provide as an online resource

TEACHER PREPARATION

1. Make copies of Case Studies. There are a variety of case studies included in this lesson plan (***Student Handout 2.1*** to ***Student Handout 2.9***). The teacher may choose to pick one for the whole class, or use different case studies for each group. Consider choosing case studies that are applicable to future units. Make copies so that each group of 3 or 4 students has one case study, and each individual student has their own copy.

2. Determine preassigned student groups (3-4 students).

3. Make copies of ***Teacher Handout 2.2*** on card stock paper. Make one copy for every four students so that each student has one card. Cut out the four cards from each handout and stack them so they are ready to pass out at the end of class.

PROCEDURE

Engage: (8 mins)

1. The homework from *Lesson One* was for students to create three or more timeline cards by researching the history of at least two of our four timeline topics from *Lesson One*, and filling in a blank timeline card with an event that fits into our class timeline. As students enter, have them attach their timeline cards to the class timeline.

2. Write the warm up on the board: "What do you think a neuroprosthetic is? What are some examples?"

3. Have student write individually in their science notebooks then take a few volunteer responses.

Explore: (7 mins)

4. Arrange students into groups of 3 or 4, these will be their discussion groups.

5. Pass out various case studies (***Student Handout 2.1*** to ***Student Handout 2.9***), one set to each group, and have each student read the case study silently to themselves. Tell them to wait to read the questions included with the case study until instructed to do so.

6. As the groups are silently reading, write the following prompts on the board:
    a. *"Write a brief personal reflection about your initial response to the case study."*
    b. *"Write 2-3 questions to ponder that came up for you after reading the case study."*

Explain: (20 mins)

7. When students finish reading the case study, have them write their responses to the prompts in their science notebooks.

8. Have students share the questions they generated with the group. Read one questions at a time, and have each student share their thoughts on the question. Continue until all questions have been asked and discussed. When a group is finished discussing student generated questions, groups may read the questions included with the case studies and continue their discussion.

9. If a group finished early and time allows, have the group read a second case study and repeat Steps #5 through 8.

Elaborate: (5 mins)

10. As the groups are discussing their case studies, write the following prompts on the board:
    - *a. "What is ethics?"*
    - *b. "What are some specific ethical concerns that came up during your small group discussion?"*

11. When the students are done with their discussions, have them answer the prompts in their science notebooks.

Evaluate: (10 mins)

12. Bring the whole class back together and lead a discussion on the prompts. Take volunteer answers from the class.
    - a. List ideas for what ethics is.
    - b. List student generated ethical concerns on the board.

13. The following are possible reasonable answers to class discussion prompts:
    - a. What is ethics? (one possible answer)
        - i. Moral principles that govern a person's or group's behavior.
    - b. What are some of the ethical concerns that came up during your small group discussion? (possible answers include)
        - i. Security
        - ii. Privacy
        - iii. Enhancement
        - iv. Normality
        - v. Identity
        - vi. Responsibility vs. Freedom

14. Give each student a card with one of the following nervous system topics on it: The Brain, The Spinal Cord, The Neuron, or Nerve Signals (See ***Teacher Handout 2.1***). Each card includes a list of vocabulary to help guide their research. For homework, students

will research their given topic and write notes, important information, and define the vocabulary in their science notebooks. This step is in *Preparation* for *Lesson Three: The Nervous System*. ***Teacher Handout 2.2*** includes a list of URLs that link to basic nervous system information. Teachers may include this information for students or let them research on their own.

STUDENT ASSESSMENT

Assessment Opportunities:

- At the end of the unit, teachers will collect science notebooks and use the contents to assess the students' learning. In this lesson, the following writing prompts will be included in the Science Notebook:
  - Warm up prompt
  - Case study prompts
  - Ethics prompts
  - Research notes on The Nervous System (Homework)
- Also, the homework is for students to research parts of the nervous system, which will show that they were able to conduct content research and use it in the following class activity.

Student Metacognition:

- The prompts, written and discussion based, given during this lesson provide opportunities for students to reflect on their understanding on the topics addressed.

Scoring Guide:

- Student work will not be "scored" for correctness in any of these introductory activities. Instead, it can be graded for completion or just used for formative assessment purposes (i.e., what did students understand from the activity).

EXTENSION ACTIVITIES

Extension Activities:

- This lesson could be extended out to a whole unit on neuroethics or science ethics in general. Using case studies, teachers can guide students through a series of rich discussions, engaging them in the science material while helping them understand the human concerns related to the content. Here is a helpful website for teaching lessons with case studies: http://sciencecases.lib.buffalo.edu/cs/. Additional link are provided under the *Teacher Background & Resources* section.

Adaptations:

TEACHER BACKGROUND & RESOURCES

Background Information:

It is important to have a basic understanding of the definition of ethics. The following resource provides information on neuroethics.

- "Neuroethics: A Modern Context for Ethics in Neuroscience." Illes and Bird, 2006. Trends Neurosci, Sep 2006; 29(9): 511-517. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1656950/

Resources:

- General Neuroethics Overview: Judy Illes and Stephanie Bird, "Neuroethics: a modern context for ethics in neuroscience" (*TRENDS in Neuroscience* 2006, 29(9):511-517).
- Authenticity: Felicitas Kraemer, "Me, Myself, and My Brain Implant: Deep Brain Stimulation Raises Questions of Personal Authenticity and Alienation" (*Neuroethics* 2013, 6:483-497).
- Enhancement: Maartje Schermer, "Health, Happiness, and Human Enhancement – Dealing with Unexpected Effects of Deep Brain Stimulation" (*Neuroethics* 2013, 6:435-445).
- Cyborgs: Grant Gillett, "Cyborgs and Moral Identity" (*Journal of Medical Ethics* 2006, 32:79-83).
- Agency: Pim Haselager, "Did I Do That? Brain-Computer Interfacing and the Sense of Agency" (*Minds and Machines* 2013, 23:405-418).
- Physical/Psychological tradeoffs: Walter Glannon, "Stimulating Brains, Altering Minds" (*British Medical Journal* 2009, 35:289-292).
- Privacy/Security: Tamara Bonaci, Ryan Calo, and Howard Jay Chizeck, "App Stores for the Brain: Privacy and Security in Brain Computer Interfaces" (*IEEE Technology and Society Magazine* June 2015, 32-39).
- The National Center for Case Study Teaching in Science provides a case collection and a variety of teaching resources, including information on teaching and assessment methods. http://sciencecases.lib.buffalo.edu/cs/teaching/

Citations:

Felicitas Kraemer, 2013. “Authenticity or Autonomy? When Deep Brain Stimulation Causes a Dilemma.” *Journal of Medical Ethics* 39:757-760.

G. Gillett, 2006. “Cyborgs and Moral Identity.” *Journal of Medical Ethics* 32(2): 79-83.

Tamara Bonaci, Ryan Calo, and Howard Chizeck, 2015. “App Stores for the Brain.” *IEEE Technology and Society Magazine* June 2015: 32-39.

Walter Glannon, 2009. “Stimulating Brains, Altering Minds.” *Journal of Medical Ethics* 35: 289-292.

Student Handout 2.1: Case Studies in Neuroethics

Name:________________________________ Date:__________________ Period:__________

Developed by the CSNE Neuroethics Thrust at the University of Washington, **October 2014**

Case 1: DBS at the Dinner Table

Written by Tim Brown and CSNE Ethics Thrust

Harold has an overeating problem and a sedentary lifestyle. As a result, he is morbidly obese and, as a result, he is headed for many health complications: cardiovascular disease, diabetes, and mild depression. His physician warns him that his symptoms will worsen if he does not change his eating habits. He has tried several diets, exercise regiments, and even an appetite suppressant (Lorcaserin) with no results. Due to prior abdominal surgery, gastric bypass surgery is not an option for him. Harold's physician learns of an experimental treatment for impulse control disorder (ICD) available at a local hospital: a deep brain stimulation (DBS) device can be used off-label to control Harold's cravings. Harold is referred to the local surgeon and after a long discussion agrees to have the device surgically implanted. His results are substantial: he no longer craves food the way he once did, and he's able to control his portions. He slowly begins to lose weight.

Harold has noticed that he no longer desires food the way he once did and mealtimes have become more like a chore than anything else. The food tastes the same, but he no longer looks forward to it. He misses the excitement of looking forward to a good meal and despite his weight loss begins to regret his choice of DBS. He is afraid to admit any of these sentiments to his family or friends; they have stigmatized obesity before, and he is afraid of provoking any more criticisms of his relationship to food. He doubts that they will understand that he now feels like he has given up something intimately connected with his sense of self – his identity. He wonders if he should discontinue the DBS and try to "get his old self back".

Questions:

1. *Is Harold merely experiencing a conflict between two things he wants (i.e., to be thin and to enjoy food) that are incompatible for him or is he experiencing something more fundamental – a loss of identity. What does it mean for something to be a threat to identity and how important is this?*

2. *Is Harold's problem mostly just a "weakness of the will" that he should take responsibility for, rather than seeking treatment? If Harold was addicted to heroin, would we be open to his concerns about losing a part of his identity (as someone that enjoys drugs). Why or why not?*

3. *Do you worry that Harold feels undue pressure (by family, friends, his provider, society) to undergo and continue treatment? Could his decision to keep or discontinue the DBS be autonomous despite feeling pressure from people who care about him?*

Student Handout 2.2: Case Studies in Neuroethics

Name:________________________________ Date:__________________ Period:__________

Developed by the CSNE Neuroethics Thrust at the University of Washington, **October 2014**

Case 2: A Little Help Here?

Written by Tim Brown and CSNE Ethics Thrust

Janet is a high school student in her junior year. Her advisors and mentors have warned her to prepare for college as early as possible, and Janet is not one to procrastinate: she's signed up to take her ACTs and SATs, she tries doubly hard to earn high marks in all of her classes, and she is signed up to volunteer for a local charity organization. Lately, however, she is finding it difficult to keep up: she has trouble focusing on her studies, and (once she focuses) she finds that she takes longer than she'd like to comprehend the material she studies. One of her classmates recommends that she try a device — a transcranial direct current stimulation (tDCS) headset. The device's website and advertising materials claim that it will help her concentrate on her work for longer and think more efficiently. The device works by applying a weak electrical current to the user's prefrontal cortex for a period of time determined by the user. Janet's classmate is willing to lend Janet her device for a few weeks.

Questions:

1. *Is it fair for Janet (or her classmate) to use this device? The price of the device is fairly high—$249. Do Janet and her classmate have an unfair advantage over their peers?*

2. *Is using a device like this any different from other ways of changing brain function, for instance drinking coffee or taking prescription drugs like Adderall?*

3. *Should the device be considered a "medical" device or an non-medical enhancement? What if it ALSO can be used by people with dementia to help their memory?*

4. *Would you think less of someone who used such a device to accomplish something important (e.g., make a medical discovery)?*

5. *Some people who have used tDCS have experienced headaches, brief loss of consciousness, and even temporary blindness. How should the potential benefits of tDCS treatment be balanced against the risks?*

Student Handout 2.3: Case Studies in Neuroethics

Name:________________________________ Date:__________________ Period:__________

Developed by the CSNE Neuroethics Thrust at the University of Washington, **October 2014**

Case 3: Hacking the Presidency

Written by Katrina Lane and CSNE Ethics Thrust

Eric Jones disclosed his diagnosis of mild early Parkinson's Disease during his first presidential run 7 years ago. Now, in the middle of his second term as president his tremors and slow walking have been getting worse. Medications have ameliorated his symptoms well in the past, but are increasingly less effective. Jones' doctors recommend DBS for treatment of his worsening motor symptoms. Jones consults his family and top advisors. His wife wants him to undergo DBS now to improve his motor functioning while in office. She is particularly worried about stigma associated with Parkinson's symptoms and what effect this may have on his legacy as a strong leader. The Secretary of Defense is adamantly opposed to DBS, citing security issues. She is concerned that the device could be hacked, putting the President's health, and in turn the country's security, at risk. Jones' doctor tells him that it would be possible to do the procedure without informing the media.

Questions:

1. *Should Jones have to disclose whether he is getting a DBS? Why or why not?*

2. *Sometimes DBS can have side effects, such as causing depression or obsessive behavior (e.g., gambling). Does this change your view of whether Jones should be allowed to get a DBS? Does it change your view of what Jones should have to disclose to the public?*

3. *What if Jones were an airline pilot? Neurosurgeon? Truck driver? Teacher? Should the level or type of responsibility of one's job influence whether one can get a DBS (or other biomedical device that might be "hack-able") or what has to be disclosed and to whom?*

Student Handout 2.4: Case Studies in Neuroethics

Name:________________________________ Date:__________________ Period:__________

Developed by the CSNE Neuroethics Thrust at the University of Washington, October 2014

Case 4: The Power of Memory

Written by Sami Ayele and CSNE Ethics Thrust

Dawit, a 53 year-old Ethiopian immigrant, is visiting a hospital on the behest of his employer, a taxi company. Recently, he has shown symptoms of PTSD — flashbacks, depression, and hypervigilance. Once triggered, he hyperventilates and feels “paralyzed” by fear —as if frozen in time. As a taxi driver, he is liable for any damages upon the car and patrons; because of this, his concerned employer connects him with a free consultation at the local university hospital’s immigrant trauma unit.

At the consultation, Dawit reveals a history of trauma – severe experiences at the start of a civil war in his home country, time spent in refugee camps and a move to Seattle in 1994. He has already tried various treatments for PTSD, including several families of medications, but they were not effective. The hospital is running a study that tests deep brain stimulation for treatment-resistant PTSD. The DBS research team stresses that his memories will not be erased, but their impact may be “softened”.

His wife encourages him to enroll. His son, Ilyas, however does not support the DBS study. Not only is he is concerned for his father’s well-being, he is also worried that the implant may alter his memories of the traumatic events, as his memories are an important part of his life narrative. Ilyas works as an activist, and has often brought his father along to meetings to share his story. His son is worried that Dawit’s ability to communicate the devastation wrought by the civil war and its aftermath will be lost if his memories of the events are “softened”. As with their relatives in Ethiopia, Ilyas also fears that his father may lose the power of his memories to fight for change, even as his mental health improves.

With his family split in this decision, Dawit takes a three-day break from work to consider his options.

Questions:

1. *Should Dawit undergo DBS treatment? Why or why not?*

2. *Is there a difference between erasing a memory and taking away the “sting” of a memory? Do Dawit’s memories give him the ability to motivate others the way Ilyas claims they do?*

3. *Should we be able to adjust our memories using technology? Are there other ways to adjust our memories, and are these any more (or less) problematic?*

Student Handout 2.5: Case Studies in Neuroethics

Name:________________________________ Date:__________________ Period:__________

Developed by the CSNE Neuroethics Thrust at the University of Washington, October 2014

Case 5: Imaging or Imagining the Future

Written by Sami Ayele and CSNE Ethics Thrust

Advances in neurotechnology provide governments with new methods of selecting employees. Imagine the following hypothetical case. A certain government spy agency has found that adding fMRI to its interview process is an efficient and effective way to screen individuals for high level security clearance. All candidates are informed that fMRI will be part of their interview. Several potential candidates for an array of positions at the agency have concerns regarding this level of inspection – including Tara - but proceed with the testing as this is the only way to her dream job. The agency has developed an fMRI algorithm to determine each individual's "brain fingerprint" for true and for false answers. Tara "passes" the exam and is offered her sought after job as a field agent trainee.

Unbeknownst to Tara, the agency is working on enhanced algorithms based on the "brain fingerprint" obtained from its fMRI screening. The agency hopes to be able to use data from the original screening test to "guide" the careers of its employees (e.g., leadership potential, ability to handle high stress situations, likelihood of challenging authority, and so on). Tara finishes her field training but finds that when she applies to many of the positions within the agency she is told that she is "not a good fit for these" based on the output of the brain fingerprint algorithms. She is frustrated and feels like her "brain is being used against her."

Questions:

1. *Do we have a right to keep our signals private?*

2. *What are the concerns over knowing behavioral correlations in the brain?*

Student Handout 2.6: Case Studies in Neuroethics

Name:________________________________ Date:__________________ Period:__________

Developed by the CSNE Neuroethics Thrust at the University of Washington, **October 2014**

Case 6: It Wasn't Me!

Written by Matthew Sample and CSNE Ethics Thrust

Fiona was involved in a car accident that resulted in a complete lower spinal cord injury: she has lost control of both of her legs. She has agreed to participate in a clinical trial of a device that links implants in her brain to the nerves in her legs, allowing information from her brain to bypass her spinal cord injury and control her limbs directly. Instead of just moving her legs as she wishes, her legs are controlled by thinking in different ways (like trying to have the thought "now I will move my right leg forward").

The brain activity she generates is picked up by the implants in her brain, interpreted by a computer, and sent down to move her legs. Getting the device to work well requires Fiona to endure long training sessions (2-4 hours, almost daily) for months. Over time, she begins to have success with the device, though her walking isn't as easy or fluid as it once was.

After a year of using the device, Fiona opts to upgrade. A new operating system for the device is available, one that is able to predict when and how she wants to move her legs. This is useful because sometimes Fiona gets tired or distracted and generates brain activity that isn't easily or accurately translated into smooth motion of her legs. The new operating system will be "smarter" – it will extrapolate what she intends to do – like a text messaging or internet search site "autocompleting" terms or phrases.

Fiona hopes that her limbs would be more responsive (that she would be able to control them with less attention) after the upgrade, and so she spends relatively little time training with the new software. But shortly after the upgrade, Fiona has an accident. Her left leg responds too slowly and it causes her to stumble into a shop display. She claims that the new software is not as reliable as the previous version, and blames the software's designer for the fall.

Questions:

1. *Is Fiona right to blame the new adaptive software and/or its designer?*
2. *How could we tell who is responsible? What evidence could help us decide?*
3. *Would it make a difference if her accident occurred before the upgrade? Why?*
4. *Can she be responsible for an accident even if she didn't plan or mean to do it?*

Student Handout 2.7: Case Studies in Neuroethics

Name:________________________________ Date:__________________ Period:__________

Developed by the CSNE Neuroethics Thrust at the University of Washington, October 2014

Case 7: Cyborgs and Moral Identity

From: G. Gillett, 2006. "Cyborgs and Moral Identity." *Journal of Medical Ethics* 32(2): 79-83.

A three-year-old boy, James, has a severe brain injury and does not have long to live. His parents are distraught until they meet a specialist in "neuroreconstruction," who tells them about a technique that uses enzymes, growth hormones, and microelectrical stimulation guided by a computer to restore injured brains to functioning states. However, during the reconstruction James will lose all of his memories, his personality may change, and his development will be delayed. James' parents decide to go ahead with the treatment in order to give their son a chance at a longer life.

Jessica has a similar brain injury to James. A specialist also recommends neuroreconstruction to her parents. However, her neuroreconstruction is slightly different from James'. Rather than restoring her brain to its normal functioning by repairing the neural tissue itself, her method of reconstruction would require implantation of microchips into her brain to replace the functions of damaged neural tissue. Essentially, these microchips would work like neural tissue, but would not be neural tissue.

Questions:

1. *Do you think that James post-treatment will be the same person as James pre-treatment?*

2. *Should we allow James' parents, and the specialist they consult, to change James in this way? Would it be better to forbid this kind of treatment?*

3. *Do you think that Jessica post-treatment will be the same person as Jessica pre-treatment?*

4. *Can we expect that Jessica will act differently from a "normal" human?*

5. *If Jessica acts differently, should we treat her differently?*

Student Handout 2.8: Case Studies in Neuroethics

Name:_______________________________ Date:_________________ Period:__________

Developed by the CSNE Neuroethics Thrust at the University of Washington, October 2014

Case 8: Privacy and Security

From: Tamara Bonaci, Ryan Calo, and Howard Chizeck, 2015. "App Stores for the Brain." *IEEE Technology and Society Magazine* June 2015: 32-39.

Brain computer interfaces (BCIs) that allow users to interface with computers through carefully trained thought procedures are now a reality. To work with this BCI technology, software companies are developing applications so that users can control a computer mouse or keyboard, play an arcade game, or exercise their memory and attention. However, not all these applications are beneficial. Some companies have developed "brain spyware" – applications for BCIs that can extract personal data such as credit card PINs, addresses, and birthdates. Companies have also proposed using neural signals to create "brain fingerprints" that would determine whether information about a person is true, while others have suggested studying neural responses to marketing to develop "neuromarketing" techniques.

Questions:

1. *What are some ways in which genetic information can be used unethically or illegally? Could neural signals be used in the same ways?*

2. *How is studying a BCI user's neural signals different from studying someone's genome? Should people have the right to keep their neural signals private? Why or why not?*

3. *How can we protect people from "brain spyware"?*

4. *Should we allow companies to pursue "neuromarketing" techniques?*

Student Handout 2.9: Case Studies in Neuroethics

Name:________________________________ Date:__________________ Period:__________

Developed by the CSNE Neuroethics Thrust at the University of Washington, October 2014

Case 9: Authenticity and Autonomy

From: Felicitas Kraemer, 2013. "Authenticity or Autonomy? When Deep Brain Stimulation Causes a Dilemma." *Journal of Medical Ethics* 39:757-760. Also: Walter Glannon, 2009. "Stimulating Brains, Altering Minds." *Journal of Medical Ethics* 35: 289-292.

A 62-year-old patient with Parkinson's disease had a brain pace-marker (a Deep Brain Stimulator, or DBS) implanted as treatment for his motor symptoms, which at times became so severe that he was bedridden. However, after the DBS was turned on, he developed a manic state that was not responsive to medication and which soon led to financial and personal chaos. When the DBS was turned off, the manic state disappeared and he began to act as he had before. However, his motor symptoms also returned. The patient and his physicians had to choose one of two options: turn on the DBS and admit the patient to a chronic psychiatric ward because of his manic state, or turn off the DBS and admit the patient to a nursing home because of the physical disability caused by his motor symptoms. After much deliberation, the physicians decided to turn off the DBS (so that his cognitive capacities would be intact) and ask the patient which option he wanted to choose. The patient chose the first option: to have the DBS turned on and be admitted to a psychiatric ward.

Questions:

1. *What would you choose? Would you rather have full cognitive capacity and lose some motor control, or have full motor control yet experience an ongoing manic state? Why would you make this choice?*

2. *Do you think the physicians were right to ask the patient to make his choice with the DBS turned off? What might be the problem with asking him to choose with the DBS turned on?*

3. *Given the possibility of side effects like mania, do you think DBS should be used as medical treatment?*

4. *Do you think the DBS changed the patient's identity? Why or why not?*

Teacher Resource 2.1: Nervous System Review Topic Cards

The Brain: Cerebrum Cerebral cortex Corpus callosum Frontal lobes Parietal lobe Temporal lobe Occipital lobe Limbic System Cerebellum Brain Stem	The Spinal Cord: Vertebrae Gray matter White matter Cervical spine Thoracic spine Lumbar spine Sacrum Coccyx Spinal nerve Reflex arc
The Neuron: Cell body Axon Dendrite Glia cells Myelin Node of Ranvier Schwann cell Neural network Motor nerve Sensory nerve	Nerve Signals: Resting potential Action potential All or None principle Ion Voltage gradient Synapse Neurotransmitter Excitatory signal Inhibitory signal

Teacher Resource 2.2: Online Resources for Research

"Your Brain & Nervous System" article
http://kidshealth.org/kid/htbw/brain.html

Brain Basics
http://science.nationalgeographic.com/science/health-and-human-body/human-body/brain-article/

https://www.headway.org.uk/About-the-brain.aspx

Neuroscience for Kids
http://faculty.washington.edu/chudler/neurok.html

Kahn Academy/Crash Course Nervous System
https://www.khanacademy.org/partner-content/crash-course1/partner-topic-crash-course-bio-ecology/crash-course-biology/v/crash-course-biology-125

Lesson Three: The Nervous System

Center for Sensorimotor Neural Engineering

Lesson Plan Authors: Alison Farrell and Micheala Ranz, Attic Learning Community

LESSON OVERVIEW

Activity Time: One 50 minute class period. Additional time for homework.

Lesson Plan Summary: In this lesson, the class will use their homework research notes on the nervous system assigned at the end of *Lesson Two* to perform a jigsaw exercise to review a neurobiology topic. Groups of two or three students will model one of four topics (brain, spinal cord, neurons, nerve signals). Small groups will then combine to form a larger group that contains students modeling at least one of each of the four topics. Each small group will then share their model with their larger group.

STUDENT UNDERSTANDINGS

Big Idea & Enduring Understanding:

- **Neural Engineering the Human Nervous System:** Neural engineers interface with the structure of the human nervous system to restore, improve, and enhance normal function. Solving neural engineering problems depends on a basic understanding of the nervous system.

Essential Question:

- What are the basic functions of the nervous system and the structures that support those functions?

Learning Objectives:

Students will know…

- Basic neurobiology necessary to understand the neuroprosthesis that will be studied in *Lesson Four*.

Students will be able to…

- Explain the relationship between function and structure in the nervous system in four areas: the brain, the spinal cord, the neuron, and the nerve signals.
- Use a model or create a skit to support teaching a small group of students about the nervous system.

Vocabulary:

- Action potential
- All or None principle
- Axon
- Brain Stem
- Cell body
- Cerebellum
- Cerebral cortex
- Cerebrum
- Cervical spine
- Coccyx
- Corpus callosum
- Dendrite
- Excitatory signal
- Frontal lobes
- Glia cells
- Gray matter
- Inhibitory signal
- Ion
- Limbic System
- Lumbar spine
- Motor nerve
- Myelin
- Neural network
- Neurotransmitter
- Node of Ranvier
- Occipital lobe
- Parietal lobe
- Reflex arc
- Resting potential
- Sacrum
- Schwann cell
- Sensory nerve
- Spinal nerve
- Synapse
- Temporal lobe
- Thoracic spine
- Vertebrae
- Voltage gradient
- White matter

Standards Alignment: This lesson addresses the following Next Generation Science Standards (NGSS) and Common Core State Standards (CCSS).

NGSSDisciplinary Core Ideas (DCIs)

- **MS-LS1-8.** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

NGSS Crosscutting Concepts

- **Structure and Function:** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

NGSS Science & Engineering Practices

- Obtaining, evaluating, and communicating information

Common Core State Standards

- **CCSS.ELA-LITERACY.RST.9-10.7:** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- **CCSS.ELA-LITERACY.RH.9-10.4:** Determine the meaning of words and phrases as they are used in a text, including vocabulary describing political, social, or economic aspects of history/social science.
- **CCSS.ELA-LITERACY.WHST.9-10.8:** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
- **CCSS.ELA-LITERACY.WHST.9-10.9:** Draw evidence from informational texts to support analysis, reflection, and research.

MATERIALS

Material	Description	Quantity
Science Notebook	Any bound notebook students can dedicate to this unit or class	1 per student
Modeling supplies	Clay, construction paper, yarn, packing material, pipe cleaners, beads, popsicle sticks, disposable plates and cups, etc.	Enough for class
Student Handout 3.1: *Nervous System Vocabulary List*	Checklist of vocab words for each nervous system topic; students use this during presentations to track vocab words	1 per student
Student Handout 3.2: *Nervous System Vocabulary Review*	Questions reviewing basic neurobiology to be answered in notebook	1 per student
Student Handout 3.3: *Neuroprosthetic Research Group Project*	Sign up sheet for Neuroprosthetic Research Homework	1 per group of 4 students
Student Handout 3.4: *Online Resources for Research*	Helpful links to research resources	1 per student

TEACHER PREPARATION

1. Gather modeling supplies, such as clay, construction paper, yarn, packing material, pipe cleaners, etc.

2. Photocopy handouts as described in the *Materials* table.

PROCEDURE

Engage: (5 mins)

1. The homework from *Lesson Two* was to research a neural biology topic (brain, spinal cord, neuron, or nerve impulse) and come to class with a list of vocabulary words defined. This information should be written in the students' science notebooks.

2. Write the warm-up on the board:
    a. *"What is the role of the nervous system?"*
    b. *"How are structure and function related in the nervous system (give examples)?"*

3. Have students write individually in their science notebooks and then discuss as a class. Make sure the idea of the nervous system as an input/processing/output system is discussed as well as the relationship between function and structure.

Explore: (25 mins)

4. Form groups of two (or three if needed) with a partner who had the same topic (brain, spinal cord, neuron, or nerve signal).

5. Small groups will build a model or create a skit incorporating and explaining all the vocabulary words on their neurobiology topic from *Lesson Two* (***Teacher Resource 2.1***).

6. Form large groups so that each group has at least one small group with each of the four topics (brain, spinal cord, neuron, or nerve impulse).

Explain: (10 mins)

7. Pass out ***Student Handout 3.1***, one to each student. Instruct students to use the handout during presentations to keep track of vocabulary word usage and as a tool to check their learning. Optionally this handout could be collected to assist in monitoring the skit/model sharing activity.

8. As a jigsaw activity each of the small groups will share their model or skit with their large group. The small group should be sure to include all vocabulary words, including explanations, while sharing. Some groups will have more than one of each topic, all

small groups should share even if they are repeating a topic within their large group. Alternatively if the class is small and there is time, small groups could share their models with the entire class.

Elaborate and Evaluate: (10 mins)

9. As groups finish sharing their models and skits pass out ***Student Handout 3.2:*** *Nervous System Vocabulary Review*. Each student should answer the questions in their science notebooks, with assistance from their larger group as needed. If time runs short students may finish the review questions at home.

10. Break the class into groups of four, give each group ***Student Handout 3.3:*** *Neuroprosthetic Research Handout*, and assign one of the following neuroprosthetics to each group: Cochlear Implant, Retinal Implant, Deep Brain Stimulator, or Spinal Cord Stimulator. Within each group, individual students will focus their research on one of four subtopics, have them decide as a group which student will research each of the subtopics.

11. Have students fill out the ***Student Handout 3.3:*** *Neuroprosthetic Research Handout* and return it to the teacher, making note of which subtopic and neuroprosthetic they are assigned to research. For homework, students should research their neuroprosthetic and subtopic and write notes and important information in their science notebooks.

12. Give students ***Student Handout 3.4*** (or send it in an email) including helpful websites to use for their online research.

STUDENT ASSESSMENT

Assessment Opportunities:

- At the end of the unit, teachers will collect science notebooks and use the contents to assess the students' learning. In this lesson, the following writing prompts will be included in the science notebook:
    - Warm-up prompt
    - Nervous system review questions (in class or homework)
    - Research notes on a neuroprosthetic (Homework)
- The student groups will be creating a model/skit of their specific part of the nervous system which will show the depth of knowledge gained from their research. An optional rubric is included to use with the model/skit presentation or the model/skit can simply be checked off as completed.

- Also, the homework is for students to research specific neuroprosthetics, which will show that they were able to conduct content research and use it in the following class activity.

Student Metacognition:

- The prompts, written and discussion based, given during this lesson provide opportunities for students to reflect on their understanding on the topics addressed.

Scoring Guide for the Model/Skit Assignment:

Criteria	High	Medium	Low
Model/Skit	The model or skit looks/feels finished. It is visually appealing, well thought out and easy to understand.	The model/skit is either unfinished **or** confusing.	The model/ skit is confusing **and** unfinished.
Topic Connection	There is a clear relationship between the skit/model and the topic.	There is some connection between the topic and the skit/model.	The relationship between the topic and skit/model is not clear.
Vocabulary	Topic vocabulary words are clearly explained and most words are incorporated into the skit/model.	Topic vocabulary words are mentioned but some are not clearly explained.	Two or more vocabulary words are not mentioned. Many vocabulary words are not clearly explained.
Presentation	Presentation of model/skit is enthusiastic, unrushed, and feels polished.	Presentation of model/skit a bit rushed at times. Presentation included a few mistakes but students quickly recover.	Presentation is disjointed and rushed. The presentation includes numerous mistakes and students often seem unsure what they are talking about.

EXTENSION ACTIVITIES

Extension Activities:

- Students could write short responses to each skit/model, describing the presentation and incorporating some of the vocabulary into their writing.

Adaptations:

- The number of vocabulary words could be shortened, leaving only the most critical four or five words in each list for younger learners.

TEACHER BACKGROUND & RESOURCES

Background Information:

Teachers should be familiar with basic nervous system biology.

Resources:

- The Neuroscience for Kids website provides a good resource for neurobiology review. http://faculty.washington.edu/chudler/chmodel.html
- Brain Overview. https://www.headway.org.uk/About-the-brain.aspx
- See ***Student Handout 3.4*** for resources on neuroprosthetics that students will need for homework assignment.

Student Handout 3.1: Nervous System Vocabulary List

Name:________________________________ Date:__________________ Period:__________

Write the names of the model/skit presenters for each category. Check off the vocabulary word as you hear it explained/defined. If there are words you don't know at the end of a presentation ask the presenters to review the terms again before moving on to the next presentation.

Presenters: **The Brain:** Cerebrum Cerebral cortex Corpus callosum Frontal lobes Parietal lobe Temporal lobe Occipital lobe Limbic System Cerebellum Brain Stem	**Presenters:** **The Spinal Cord:** Vertebrae Gray matter White matter Cervical spine Thoracic spine Lumbar spine Sacrum Coccyx Spinal nerve Reflex arc
Presenters: **The Neuron:** Cell body Axon Dendrite Glia cells Myelin Node of Ranvier Schwann cell Neural network Motor nerve Sensory nerve	**Presenters:** **Nerve Signals:** Resting potential Action potential All or None principle Ion Voltage gradient Synapse Neurotransmitter Excitatory signal Inhibitory signal

Student Handout 3.2: Nervous System Vocabulary Review

Name:________________________________ Date:__________________ Period:__________

Answer the following prompts in your science notebook.

The Brain:
Draw and label a picture of the brain. Next to each label briefly describe the function. (Include the following terms: Cerebral cortex, Frontal lobes , Parietal lobe, Temporal lobe, Occipital lobe, Cerebellum, and Brain Stem).

The Spine:
What is the difference between gray matter and white matter?

Draw and explain an example of a reflex arc.

The Neuron:
Draw and label a picture of the neuron, next to each label briefly describe the function (Include the following terms: Cell Body, Axon, Dendrite, Myelin).

Nerve Signals:
Briefly describe the two ways nerve impulses travel (electrical or chemical).

Student Handout 3.3: Neuroprosthetic Research Group Project

Name:________________________________ Date:__________________ Period:__________

Our Group's Neuroprosthetic is: ____

Subtopics - Write the name of each group member in one of the spaces below:

Anatomy and physiology: _____________________________

How the technology works: _____________________________

The history of the device: _____________________________

Ethical concerns: _____________________________

Student Handout 3.4: Online Resources for Research

Name:_________________________________ Date:__________________ Period:__________

General Helpful Websites:

Extreme-tech website with lots of BCI applications
http://www.extremetech.com/tag/brain-computer-interface

Brain-Computer Interface overview
http://www.braincomputerinterface.com/

The-Scientist.com - Search results for all things related to "neuroprosthetic"
http://www.the-scientist.com/?articles.search/searchTerm/neuroprosthetic/

MIT News: Creating Better Neural Implants
http://www.the-scientist.com/?articles.search/searchTerm/neuroprosthetic/

Medicine and Technology: Neuroprosthetics
http://www.uwomj.com/wp-content/uploads/2012/11/v79n2_8.pdf

Neuroprosthetics: Once More with Feelings
http://www.nature.com/news/neuroprosthetics-once-more-with-feeling-1.12938

Cochlear Implant

Building a Better Cochlear Implant, NPR.org
http://kuow.org/post/one-challenge-building-better-cochlear-implant-explaining-it

"Cochlear Implants" KidsHealth
http://kidshealth.org/parent/general/eyes/cochlear.html

Cochlear Implants, Navigating a Forest of Information... One Tree at a time
http://www.gallaudet.edu/documents/clerc/ci.pdf

Hearing Loss Simulator, Starkey Hearing Technologies
Explore mild, moderate, and severe hearing loss using this online simulator. http://www.starkey.com/hearing-loss-simulator

Retinal Implant

How the Artificial Retina Works—This graphic explains how a retinal implant works to restore some vision in people with certain kinds of blindness.
http://artificialretina.energy.gov/howartificialretinaworks.shtml

Biomedical Devices for the Eyes
This lesson plan provides background information on eye problems and vision deficiencies and then introduces students to a variety of biomedical devices, including retinal implants.
https://www.teachengineering.org/view_lesson.php?url=collection/cub_/lessons/cub_biomed/cub_biomed_lesson07.xml

The Bionic Eye - A series of short articles from *The Scientist* that provides a general overview to retinal implant devices.
http://www.the-scientist.com/?articles.view/articleNo/41052/title/The-Bionic-Eye/

Artificial Retinal Project
http://artificialretina.energy.gov/about.shtml

Deep Brain Stimulator
NINDS Deep Brain Stimulation for Parkinson's Disease Information Page
http://www.ninds.nih.gov/disorders/deep_brain_stimulation/deep_brain_stimulation.htm

Origin and Evolution of Deep Brain Stimulation
http://www.ninds.nih.gov/disorders/deep_brain_stimulation/deep_brain_stimulation.htm

Neuroscience: Tuning the Brain
http://www.nature.com/news/neuroscience-tuning-the-brain-1.14900

Spinal Cord Stimulator
Tame the Pain, Long-Term Spinal Cord Stimulation
http://www.tamethepain.com/chronic-pain/spinal-cord-stimulation-neurostimulation/long-term/

Spine-Health, Spinal Cord Stimulation for Chronic Pain
http://www.spine-health.com/treatment/back-surgery/spinal-cord-stimulation-chronic-pain

FDA Approves Spinal Cord Stimulation System that Treats Pain without Tingling System
http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm446354.htm

WebMD, Electrical Nerve Stimulation for Chronic Pain
http://www.webmd.com/back-pain/spinal-cord-stimulation-for-low-back-pain

Lesson Four: Neuroprosthetics

Center for Sensorimotor Neural Engineering

Lesson Plan Authors: Alison Farrell and Micheala Ranz, Attic Learning Community

LESSON OVERVIEW

Activity Time: One 50 minute class period. Additional time for homework.

Lesson Plan Summary: In this lesson, students will learn about four different specific types of neuroprosthetics, the history of the devices, how they work, and the ethical implications of their use. In groups they will create a poster that present all of the information that they learned.

STUDENT UNDERSTANDINGS

Big Idea & Enduring Understanding:

- **Neuroprosthetics:** Neuroprosthetics can be used to restore or enhance human function. There are a variety of different types of medical devices categorized as neuroprosthetics, each designed to help restore a specific neurological function.

Essential Question:

- What is a neuroprosthetic and how does it work?

Learning Objectives:

Students will know…

- What a neuroprosthetic is and a few examples of neuroprosthetics in use today.
- How each neuroprosthetic works with your brain, and how the technology works.

Students will be able to…

- Articulate the pro's and con's of using neuroprosthetics in human patients.
- Discuss the possible ethical implications of using specific neuroprosthetics.

Vocabulary:

- Cochlear Implant
- Deep Brain Stimulator
- Neuroprosthetic
- Retinal Implant
- Spinal Cord Stimulator

Standards Alignment: This lesson addresses the following Next Generation Science Standards (NGSS) and Common Core State Standards (CCSS).

NGSS Disciplinary Core Ideas (DCIs)

- **MS-LS1-8:** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

NGSS Crosscutting Concepts

- **Structure and Function:** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

NGSS Science & Engineering Practices

- Obtaining, evaluating, and communicating information

Common Core State Standards

- **CCSS.ELA-LITERACY.RST.9-10.7:** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- **CCSS.ELA-LITERACY.RH.9-10.4:** Determine the meaning of words and phrases as they are used in a text, including vocabulary describing political, social, or economic aspects of history/social science.
- **CCSS.ELA-LITERACY.WHST.9-10.8:** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
- **CCSS.ELA-LITERACY.WHST.9-10.9:** Draw evidence from informational texts to support analysis, reflection, and research.

MATERIALS

Material	Description	Quantity
Science Notebook	Any bound notebook students can dedicate to this unit or class	1 per student
Media center	Computer, speakers, and projector/screen	1 per class
Poster paper	Large sheets of white or colored cardstock paper	1 set per group of 4 students
Poster markers	Various colors	1 set per group of 4 students
Sticky Notes	Pads of small sticky notes to use during Gallery Walk activity	Enough for each student to have several sticky notes
Student Handout 4.1: *Neuroprosthetic Poster Instructions*	Instructions on what to include in the poster on a neuroprosthetic	1 per group of 4 students

TEACHER PREPARATION

1. Make copies of ***Student Handout 4.1***.

PROCEDURE

Engage: (5 mins)

1. Write the warm up on the board: *"How would you define a neuroprosthetic?"*

2. Have student write individually in their science notebooks and then take a few volunteer responses. Provide the definition if needed.

Explore and Explain: (30 mins)

3. For homework the night before, students researched an aspect of a specific neuroprosthetic in their small groups. Have students get back together in their groups of four.

4. Each group will create a poster together including the four subtopics and at least one detailed diagram.

5. Lead a class discussion about what makes a good poster. Ask students what makes a poster clear, easy to understand, and informative. Create a class list of ideas that students can easily refer back to while creating their posters.

6. Give each group a copy of ***Student Handout 4.1*** to fill out. This handout includes information on what should be included in the poster.

7. Pass out poster paper and markers to each group.

Elaborate & Evaluate: (15 mins)

8. Hang neuroprosthetic posters on the wall and give students time to do a Gallery Walk to view the other posters. Give students sticky notes so they can write down responses and questions and stick them on the side of each poster.

9. For homework, each student will write a fictional case study involving one of the four neuroprosthetics that were explored in this lesson. They don't have to use the neuroprosthetic they researched. The case study must be typed and printed out so another student can read it.

STUDENT ASSESSMENT

Assessment Opportunities:

- At the end of the unit, teachers will collect science notebooks and use the contents to assess the students' learning. In this lesson, the following writing prompts will be included in the Science Notebook:
    - Warm up prompt
- The student groups will be creating a poster of their specific neuroprosthetic which will show the depth of knowledge gained from their research. See "Poster Checklist" below.
- Also, the homework is for students to create a fictional case study about a specific neuroprosthetic, which will show that they were able to creatively think about the use of a neuroprosthetic and the possible ethical implications of its use.

Student Metacognition:

- The prompts, written and discussion based, given during this lesson provide opportunities for students to reflect on their understanding on the topics addressed.

Scoring Guide—Neuroprosthetic Poster

Criteria	High	Medium	Low
Organization	Defined sections. Easy to follow layout. Lettering is neat and easy to read.	There are defined sections but organization scheme is not immediately clear.	Poster layout is confusing and difficult to follow.
Content - Check off each topic as appropriate Anatomy and Physiology Technology History Ethics	Content demonstrated in-depth, grade appropriate research was carried out. Anatomy and Physiology Technology History Ethics	Research information is complete but not in – depth. Anatomy and Physiology Technology History Ethics	Minimal effort put into research, information is sparse. Anatomy and Physiology Technology History Ethics
Diagram	Poster includes an informative detailed diagram that is clearly labeled and explained. Diagram shows evidence of students communicating with each other and making connections between their research areas.	Diagram is present with average labeling and explanation.	Diagram is absent or not labeled and explained

EXTENSION ACTIVITIES

Extension Activities:

- Design challenge: Create a working model of a neuroprosthetic. See the CSNE's 2014 RET curriculum unit, Introduction to Neuroprosthetics and Brain-Computer Interfaces for lesson plans related to this task. http://www.csne-erc.org/content/lesson-plans

Adaptations:

- Students could share their research verbally rather than creating a poster. The expectations around research can be adjusted to match different grade levels.

TEACHER BACKGROUND & RESOURCES

Background Information:

- It would be helpful to have general knowledge of prosthetics, neural engineering, and neuroprosthetics. Also, it is helpful to understand how neuroprosthetics work with human physiology.
- Teachers should refer to ***Student Handout 3.4:*** *Online Resources for Research* for background information on neuroprosthethics. Online resources of particular interest include:

    Cochlear Implants: Navigating a Forest of Information... One Tree at a time
    http://www.gallaudet.edu/documents/clerc/ci.pdf

    Retinal Implants: The Bionic Eye
    http://www.the-scientist.com/?articles.view/articleNo/41052/title/The-Bionic-Eye/

    Deep Brain Stimulator: Neuroscience—Tuning the Brain
    http://www.nature.com/news/neuroscience-tuning-the-brain-1.14900

    Spinal Cord Stimulator: WebMD, Electrical Nerve Stimulation for Chronic Pain
    http://www.webmd.com/back-pain/spinal-cord-stimulation-for-low-back-pain

Resources:

See list of resources provided in *Lesson Three,* ***Student Handout 3.4*****.**

Student Handout 4.1: Neuroprosthetic Poster Instructions

Name:_________________________________ Date:__________________ Period:__________

Our Group's Neuroprosthetic is: ____

Subtopics - Write the name of each group member in one of the spaces below:

Anatomy and physiology: ______________________________

How the technology works: ______________________________

The history of the device: ______________________________

Ethical concerns: ______________________________

Your Poster Should Include:

- ❑ A title
- ❑ The name of each group member
- ❑ At least one detailed diagram of the neuroprosthetic
- ❑ Information from all four subcategories:
    - ❑ Anatomy and Physiology
    - ❑ Technology
    - ❑ History
    - ❑ Ethics

Lesson Five: Robotic Arm

Center for Sensorimotor Neural Engineering

Lesson Plan Authors: Alison Farrell and Micheala Ranz, Attic Learning Community

LESSON OVERVIEW

Activity Time: One 50 minute class period. Additional time for homework.

Lesson Plan Summary: In this lesson, students will watch two video clips showing patients using neuroprosthetics, and then discuss the videos in groups and with the whole class.

STUDENT UNDERSTANDINGS

Big Idea & Enduring Understanding:

- **The Possibilities with Neuroprosthetics:** Neuroprosthetics can be used to restore or enhance human function. The future for the use of neuroprosthetics is promising and also brings up ethical concerns that are important to address.

Essential Question:

- Why do patients use neuroprosthetics and what are the possibly future innovations in this field?

Learning Objectives:

Students will know…

- How neuroprosthetics can improve or enhance the lives of the people who need them.

Students will be able to…

- Understand why patients use neuroprosthetics and predict future innovations in neural engineering.

Vocabulary:

- Cochlear Implant
- Ethics
- Neuroprosthetic

Standards Alignment: This lesson addresses the following Next Generation Science Standards (NGSS) and Common Core State Standards (CCSS).

NGSS Disciplinary Core Ideas (DCIs)

- **MS-LS1-8 Structure, Function, and Information Processing:** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

NGSS Cross-Cutting Concepts

- **Structure and function:** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

NGSS Science & Engineering Practices

- Obtaining, evaluating, and communicating information

Common Core State Standards:

- **CCSS.ELA-LITERACY.RST.9-10.7:** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- **CCSS.ELA-LITERACY.RH.9-10.4:** Determine the meaning of words and phrases as they are used in a text, including vocabulary describing political, social, or economic aspects of history/social science.
- **CCSS.ELA-LITERACY.WHST.9-10.8:** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
- **CCSS.ELA-LITERACY.WHST.9-10.9:** Draw evidence from informational texts to support analysis, reflection, and research.

MATERIALS

Material	Description	Quantity
Science Notebook	Any bound notebook students can dedicate to this unit or class	1 per student
Media center	Computer, speakers, and projector/screen	1 per class
Student Handout 5.1: *Unit Post-Assessment*	Post-assessment for the whole unit	1 per student
Teacher Resource 5.2: *Science Notebook Scoring Guide*	List of all student notebook prompts and assignments to use for scoring student notebooks throughout the unit	1

TEACHER PREPARATION

1. Set up media viewing (projector, screen, etc.).

2. Load both videos clips so they are ready to play.

3. Make copies of **Student Handout 5.1:** Unit Post-Assessment, one per student.

PROCEDURE

Engage: (10 mins)

1. Collect homework from *Lesson Four*—Student Generated Fictional Case Study. Teachers can look these over during the video for a quick proof-read before handing them out to students later in the lesson.

2. Show a short video clip "Eight Month Old Deaf Baby's Reaction to Cochlear Implant Being Activated" (0:49 minutes) https://www.youtube.com/watch?v=HTzTt1VnHRM

3. Write the warm up on the board: *"How can neuroprosthetics improve or enhance the lives of the people who need them?"*

4. Have student write individually in their science notebooks then take a few volunteer responses.

Explore: (15 mins)

5. Show the class the 60 Minutes video clip "Breakthrough: Robotic Limbs Moved by the Mind" (13:04 minutes). https://www.youtube.com/watch?v=Z3a5u6djGnE&feature=youtu.be

Explain: (10 mins)

6. Have students write responses to the following prompts in their science notebooks:
    a. *"Write a brief personal reflection about your initial response to the video clip."*
    b. *"What are some of the ethical concerns that could come up with this kind of technology?"*
    c. *"What do you predict will happen to this technology in the future?"*

7. Ask students to Pair-Share their responses to the prompts with a partner.

Elaborate: (10 mins)

8. Pass out the collected Fictional Case Studies students turned in as homework. Case Studies may be passed out to pairs or one per student.

9. While students are reading, write the following prompts on the board:
    a. *"Write a brief personal reflection about your initial response to the case study."*
    b. *"Write 2-3 questions to ponder that came up for you after reading the case study."*
    c. *"What are some of the ethical concerns that could come up in this situation?"*

10. Have students write their response to the prompts in their science notebooks.

Evaluate: (5 mins)

11. Collect the science notebooks and pass out ***Student Handout 5.1:*** *Unit Post-Assessment*. This Post-Assessment can be done as homework or in the next available class period.

STUDENT ASSESSMENT

Assessment Opportunities:

- At the end of the unit, teachers will collect science notebooks and use the contents to assess the students' learning. In this lesson, the following writing prompts will be included in the Science Notebook:
    - Warm up prompt
    - Robotic Arm Video prompts
    - Fictional Case Study reflection questions

- Also, the student will be completing a Unit Post-Assessment with short answer and essay questions covering the content and discussion topics in the unit.

Student Metacognition:

- The prompts, written and discussion based, given during this lesson provide opportunities for students to reflect on their understanding on the topics addressed.

Scoring Guide:

- Unit Post-Assessment Key included below.
- Science notebooks collected. A list of all prompts and assignments is included at the end of this lesson. Teachers may simply check off science journal notes as complete or grade based on thoroughness and quality of the responses.

EXTENSION ACTIVITIES

Extension Activities:

- Design challenge: Create a working model of a neuroprosthetic. See the CSNE's 2014 RET curriculum unit, Introduction to Neuroprosthetics and Brain-Computer Interfaces for lesson plans related to this task. http://www.csne-erc.org/content/lesson-plans

Adaptations:

TEACHER BACKGROUND & RESOURCES

Background Information:

- It would be helpful to have general knowledge of prosthetics, neural engineering, and neuroprosthetics. Also, to understand how neuroprosthetics work with human physiology. See the online resources provided in *Lesson Four.*

Resources:

- Refer to the online resources provided in *Lesson Four.*

Student Handout 5.1: Unit Post-Assessment

Name:________________________________ Date:__________________ Period:__________

1. List and describe three events you thought stood out from the timeline game. Why did you find these events interesting?

2. Come up with a hypothetical innovation in neuroprosthetics that you think might be developed in the next 20 years and describe how it works.

3. Define ethics.

4. From what we learned about ethics in neuroengineering, think of ethical concerns that might come up within a *different* scientific field of study? List that field of study and describe an ethical concern by writing a hypothetical case study.

5. How is a neuroprosthetic different than other medical devices?

6. Which neuroprosthetic would you be most likely to use if you needed it? Which would least likely to use even if you needed it? Why?

7. Give two examples relating form and function using your knowledge of the nervous system. Describe your examples in detail, using diagrams, labels, and sentences.

8. Explain in detail how a nerve impulse travels. Choose one: electrically or chemically.

Teacher Resource 5.1: Science Notebook Scoring Guide

To assess the student's learning over the course of the unit, collect science notebooks after the last activity and check to make sure they include all of the work assigned. Responses can be graded as complete/incomplete for each individual notebook entry.

At the end of the unit, students will have the following written responses in their science notebooks:

1. L1 - Timeline
   a. Warm up: What do you think the term 'Sensorimotor Neural Engineering' means?
   b. Class Timeline Prompts:
      i. What do you notice about the timeline events? What patterns occur within topics and what connections do you see between topics?
      ii. What questions came up for you during the gallery walk? What do you wonder and what would you like to learn more about?

2. L2 - Case Studies
   a. Warm up: What are the ethical implications for using neuroprosthetics?
   b. Case Study Prompts:
      i. Write a brief personal reflection about your initial response to the case study.
      ii. Write 2-3 questions to ponder that came up for you after reading the case study.
   c. Ethics prompts
      i. What is ethics?
      ii. What are some specific ethical concerns that came up during your small group discussion?
   d. Homework - Research notes on The Nervous System, including all vocabulary defined.

3. L3 - The Nervous System
   a. Warm up: What is the role of the nervous system? How are structure and function related in the nervous system (give examples)?
   b. Answers to Nervous System Review, Handout 3.1.
   c. Homework - Research notes on a Neuroprosthetic, specifically their subtopic.

4. L4 - Neuroprosthetics
   a. Warm up: How would you define a neuroprosthetic?

5. L5 - Robotic Arm
   a. Warm up: How can neuroprosthetics improve or enhance the lives of the people who need them?

b. Robotic Arm Video Prompts:
   i. Write a brief personal reflection about your initial response to the video clip.
   ii. What are some of the ethical concerns that could come up with this kind of technology?
   iii. What do you predict will happen to this technology in the future?
c. Student Written Fictional Case Study Reflection Questions:
   i. Write a brief personal reflection about your initial response to the case study.
   ii. Write 2-3 questions to ponder that came up for you after reading the case study.
   iii. What are some of the ethical concerns that could come up in this situation?