Specific Learning Objectives

Middle School (6^{th} –8^{th} grades)

- Students will learn about the exciting field of neuromorphic engineering.
- Students will understand how a neuron sends electrochemical impulses as they build and then witness the phenomena in a electronic model
- Students will identify the basic structures of a neuron, (i.e. Pre synaptic terminal, Dendrites, Nucleus, Axon, Cell Body (Soma), Axon Hillock, Myelin insulation) and describe their function.
- While studying the design and structure of the Tritonia sea slug and the SlugBug robot, students will compare and contrast the physical and neurological structures of each.
- Students will attach a brain to a self-built robot and witness a neural network generating locomotion in a walking robot.

High School (9^{th}-12^{th} grades)

- Students will learn about the exciting field of neuromorphic engineering.
- Through hands on activities and using discrete electronic components students will build a **functioning neuron, synapse, a neural network and a neural muscular junction.**
- Students will attach a brain to a self-built robot and witness a neural network generating locomotion in a walking robot.

Outline of SlugBug Curriculum

Middle School SlugBug Unit

The Middle School Slug Bug Science unit is a standards based, multidisciplinary unit in which students learn about neuroscience, mechanical engineering, neuromorphic engineering, robotics, biology and electronics as they design and construct a real walking robot. The six or seven middle school lessons are presented at the introductory level and can be modified to fit the teaching style of the individual teacher or the curriculum of the school. Complete with lab sheets and supplementary teacher lecture information, this science unit is flexible and easy to implement. Teachers can expand or combine lessons to meet their students' needs and the time available.

This curriculum was pilot tested on 21 6^{th} graders from Edison Middle School, Champaign, IL. The test population was a from the school's enrichment program consisted of 9 girls and 12 boys.

Lesson One: "Introduction to neuromorphic engineering" After a brief teacher lecture introducing the field of Neuromorphic Engineering, students went into the computer lab

and performed a prepared WebQuest activity on the topic. A WebQuest is a guided Internet search with five parts: Introduction, Task, Process, Evaluation and Conclusion.
Lesson Two: "**Introduction to neurons and how they function"** After they examined a model of a brain made out of jello, students labeled the parts of a neuron and learned how neurons function. Next the teacher assisted the students as they built a neural network with their own bodies and created a model of a neuron out of pipe cleaners.
Lesson Three: "Basic components of electronics" In order to perform the modeling tasks later in the unit, students were instructed on the function and properties of resistors and capacitors. The teacher described the concept of electricity as " a flow of particles or energy." Using a river/dam analogy resistance and capacitance were discussed**.**
Lesson Four: "Build a neuron with electronic components" While learning about parallel/series connections and breadboard use, students each built an electronic model of a neuron. With an oscilloscope students were able to then probe their neuron and see "spikes." Analogies between electric and biological parts will be made throughout the lesson.
Lesson Five: "Build a SlugBug" Students assembled their SlugBug Robots and considered leg shape and attractiveness in their final design.
Lesson Six: "Tritonia sea slug… it walks" The teacher explained how the brain of the SlugBug was designed after the simple brain of the Tritonia Sea Slug. In a Venn diagram the students compared and contrasted the biological and mechanical "Slugs." Finally, the students were allowed to perform "brain surgery" as the SlugBugs were hooked up to their brains and allowed to walk.

High School SlugBug Unit

The High School level Slug Bug/build a brain lessons will teach about neuroscience in a hands on way, while focusing on the analogies between a robot and a biological brain. Students will delve deeper into the world of neuromorphic engineering when they actually build a robot brain using electronic components. Once they fully understand the workings of their robot brain it is mounted on the Slug Bug body and used to create walking locomotion. This unit is still under development.

Lesson One: "Introduction to Neuromorphic Engineering" After a brief teacher lecture, students will analyze and discuss the field of Neuromorphic engineering and how robot technology can be used in the modeling of biological systems.
Lesson Two: "Build a SlugBug body" Students will assemble their SlugBug Robots and considered leg shape and attractiveness in their final design.
Lesson Three: "Build a neuron" While learning about parallel/series connections and breadboard use, students will each built an electronic model of a neuron. With an oscilloscope students will then probe their neuron and see "spikes." Analogies between electric components and biological parts will be made throughout the lesson.
Lesson Four: "Build a synapse" Students will use electronic components to build a model of a working synapse. The teacher will point out analogies between sending messages with chemical and electric methods of delivery.
Lesson Five: "Build a neural network" Students will connect a series of neurons to demonstrate a neural network. Then they will use the constructed model to demonstrate lateral inhibition.

Lesson Six: "Connect neuron to muscle" Students will connect their neural network to a muscle (servo motor) to see how it creates motion.
Lesson Seven: "It walks" During this final lesson the students will become "neurosurgeons" as they connect the brain to the Slug Bug robot body and create locomotion.