Sowing the Seeds of Neuroscience

SpikerBox:

Listening in on the Neural Activity of Cockroaches

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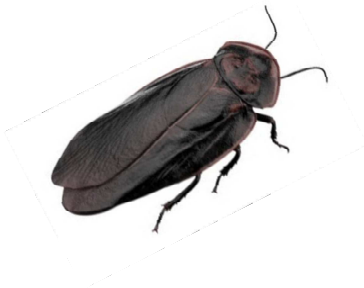
Activity Time: Two 50 minute class periods plus additional time for homework.



Lesson Summary:

In this lab, students will investigate if cayenne pepper extract affects the electrical communication in the cockroach nervous system. They will use a SpikerBox, a "bioamplifier" that allows them to hear the spikes (action potentials) of live neurons in a cockroach's leg.

STUDENT UNDERSTANDINGS

Big Ideas & Enduring Understandings

- **Neural Activity:** Neurons communicate using neurotransmitters and action potentials (or "spikes") that we can see/hear in a cockroach leg.
- **Neuroactive Properties of Plants:** Some plants, like cayenne pepper, can affect the electrical communication in the cockroach nervous system.

Essential Questions

- How do neurons communicate?
- How can I use technology help me see and hear this communication?
- How does cayenne pepper affect electrical communication in the nervous system?

Neuroscience Core Concepts

- The nervous system controls and responds to body functions and directs behavior.
- Each neuron communicates with many other neurons to share information.
- The nervous system influences and is influenced by all other body systems.
- Humans have a complex nervous system that evolved from a simpler one.
- Neurons communicate using electrical and chemical signals.
- Sensory stimuli are converted into electrical signals.
- Action potentials are electrical signals carried along neurons.
- Electrical signals in muscles cause contraction and movement.
- Synapses are small gaps between neurons that allow electrical signals to pass from neurons to other cells.
- Neurotransmitters are chemicals that send information from one nerve cell to another.
- Neuroscience research must be done in an ethical manner.

- Testing chemicals or plant extracts on animals is a way to determine their likely effect on humans.
- Plants and herbs have been used around the world for millennia to alter brain function

Learning Objectives

Students will know…

- Neurons communicate using both electrical and chemical signals.
- The sounds heard on the SpikerBox are electrical signals being sent through a neuron.
- Testing chemical or plant extracts on animals is a way to determine their likely effect on humans.

Students will be able to…

- Demonstrate safe lab procedures.
- Follow the procedures to successfully conduct an investigation of the effect of cayenne pepper extract on the nervous system of a cockroach.
- Evaluate their data to understand and explain the effects of cayenne pepper extract on a cockroach's neural activity.
- Define action potential.

Standards Alignment

Washington State Essential Academic Learning Requirements (EALRs): Science
Science EALR 1: Systems • 6-8 SYSA Science EALR 2: Inquiry • 6-8 INQA—Question • 6-8 INQB—Question • 6-8 INQE—Model • 6-8 INQF—Explain • 6-8 INQI—Consider Ethics Science EALR 3: Application • 6-8 APPC
Next Generation Science Standards (NGSS)
From Molecules to Organisms: Structures and Processes • MS-LS1D-3 • MS-LS1D-8
Common Core Standards: English Language Arts (ELA)
Reading Standard for Literacy in Science and Technical Subjects: Key Ideas & Details • CCSS.ELA-Literacy.RST.6-8.1 • CCSS.ELA-Literacy.RST.6-8.3 Writing Standard for Literacy in Science and Technical Subjects: Text Types & Purposes • CCSS.ELA-Literacy.WHST.6-8.2d • CCSS.ELA-Literacy.WHST.6-8.2f Language Standard 4c & 6: Vocabulary Acquisition & Use • CCSS.ELA-Literacy.L.6.4c • CCSS.ELA-Literacy.L.6.6

TEACHER PREPARATION

Materials

Classroom Materials

Item	Quantity
Copies of *SpikerBox Background Reading—Student Handout*	1 per student
Copies of *Ethics of Research with Animals—Student Handout* (located in *Appendix*)	1 per student
Copies of *SpikerBox Lab Observations—Student Handout*	1 per student
Copies of *SpikerBox Lab Procedure—Student Handout*	1 per student
Copies of *SpikerBox Results & Conclusions—Student Handout*	1 per student
Copies of *SpikerBox Vocabulary Activity—Student Handout*	1 per student
Student lab notebook	1 per student
Pen	1 per student
Classroom computer with projector to show video	1 per class
Classroom laptop, iPad, iPhone, or Android phone to show "spikes"	1 per class

Laboratory Materials

Review the materials with your students. It will be helpful to show them each piece of lab equipment and mention how it will be used in this activity. Most lab materials are provided in the *Sowing the Seeds of Neuroscience* classroom kit. The starred (*) items below are provided in your kit only if you requested them. There are enough materials in the classroom kits for ten groups to do this laboratory. Depending on class size, groups should be made of two to three students.

Item	Quantity
250 ml or larger beaker filled with ice	1 per cockroach
Dissection scissors	1 per group
Toothpick	1 per group
SpikerBox	1 per group
SpikerBox sound cable and/or iPhone cable	1 per class
Cayenne pepper extract	10 ml per group
Cockroach	1 leg per group (~2 roaches per class)
Push pins	2 per group
3 mm by 3 mm square of Parafilm	1 per group
3 mm by 3 mm square of cardboard*	1 per group
Pipette	1 per group
Timer	1 per group

Safety Materials

Item	Quantity
Safety goggles*	1 per student
Gloves*	1 pair per student

*Safety materials are provided in the classroom kit only if you requested them.

Lab Safety

- Students must not eat or drink anything in the lab.
- When working with cockroaches, always wear gloves.
- Students should wear gloves and goggles during this lab to protect skin and eyes from the cayenne pepper extract. When the lab is complete, students should wash their hands with soap.

Preparation

- It is important for students to complete the *Neuroscience 101* lesson before embarking on this lab investigation. *Neuroscience 101* provides critical background information on the nervous system, including electrical and chemical transmission and action potential.
- Photocopy Student Handouts.
- Assign the reading on the *SpikerBox Background Reading—Student Handout* as homework; this reading should be completed before students begin this lab.
- Plan your timing: It will work well to deliver this lab activity over two full class periods, with additional time for homework.
    - On Day One, introduce the activity using the *Engage* activities, review the background reading, and guide students through a review of the learning goals and vocabulary. Students should complete the lab investigation using a cockroach leg and cayenne pepper extract, as described in the *Explore* section. It is important to spend time discussing what the spikes are, ensuring that students really understand that they are hearing action potentials.
    - On Day Two, students can complete the *Explain*, *Elaborate*, and *Evaluate* sections of the lesson plan.
- Determine how best to set up your classroom for the lab: Most lab materials are provided in the *Sowing the Seeds of Neuroscience* classroom kit. There are enough materials in the classroom

kits for ten groups to do this laboratory. Depending on class size, groups should be made of two to three students.

- Cut the parafilm (provided) and the cardboard (not provided) into 3 mm by 3 mm squares. Each group will need one square each of parafilm and cardboard—this is to protect the cork of the SpikerBox when students use the cayenne pepper extract.

- If you have an iPad, iPhone, or Android phone and would like to use this to show students the spikes, download the "Backyard Brains" app. This free app is available from iTunes at https://itunes.apple.com/us/app/backyard-brains/id367151200?mt=8 or wherever you download apps for your Android phone. You will need to plug the three banded end of the "SmartPhone cable" into your SmartPhone and the other end into the SpikerBox for this to work.

- If you have a laptop and would like to use this to show students the spikes, download the free sound editing program AUDACITY from this site: http://audacity.sourceforge.net/. You will need to plug one end of the "laptop data cable" into your laptop microphone port and one into the SpikerBox for this to work. **Note:** Due to electrical interference, you cannot see the spikes well on a desktop computer, so it is important to use a laptop.

- If you haven't already discussed the ethics of using animals in research—including the use of animals in the science classroom—please do so before delivering this lesson. If students haven't already read the *Ethics of Research with Animals—Student Handout*, assign this now. In addition, please refer to the *Teacher Background & Resources* section of this lesson plan for a list of helpful teaching resources on this topic.

  Emphasize the importance of respect for animals, and the gentle and respectful handling of the cockroaches during this investigation. Explain that the cockroaches will be anesthetized in ice water before the "surgery" and euthanized in a freezer after the lab investigation

- Consider an alternate activity that can be provided for students who have an ethical objection to the use of animals in the science laboratory. A list of activities is included in the *Appendix* to this curriculum. For example, a student may opt to observe the lab activities but opt out of being the person who actually removes and handles the cockroach leg.

- **Disposal instructions:** Cockroaches and their legs should be placed into a doubled plastic bag, placed in the freezer for 24 hours (which euthanizes these insects), and then thrown away in the garbage.

- Care instructions for cockroaches will be included with your cockroaches.

TEACHER PROCEDURE

Day One

Engage

1. Explain the purpose of the lesson and review the *Big Ideas, Enduring Understandings,* and *Essential Questions.*

2. If students did not read the *Background Reading* as homework, they should do so now. Review the background reading and vocabulary terms.

3. Distribute copies of the *SpikerBox Lab Observations—Student Handout*. Ask students to develop and record their hypothesis for the lab investigation, as prompted in Question #1 of the handout. The rest of the handout will be used for students to record their observations during the lab.

4. As the background reading explains, students will be using cockroaches for this investigation. Emphasize the importance of respect for animals and the gentle handling of the cockroaches during this investigation. Specifically, it is important to discuss that this lab will require students to cut a leg off of an anesthetized cockroach, soak the leg in a plant extract, and run an electrical current through the leg using a device called a SpikerBox. Like any animals used in the laboratory, we must treat the cockroaches carefully and respectfully.

5. Using the classroom computer and projector, share with students this short video by TED Fellow and neuroscientist Greg Gage (the creator of the SpikerBox). Alternatively, you can assign the video viewing as homework. The video is a great demonstration of the SpikerBox activity and explains the science in an engaging manner.

   "The Cockroach Beatbox" Video (6:16 mins)
   TED ED
   http://ed.ted.com/lessons/the-cockroach-beatbox

6. Hand out copies of the *SpikerBox Lab Procedure—Student Handout,* one per student. Review the lab procedures.

Explore

7. One cockroach will be shared by 5-6 groups. Each group will need 1 leg. Provide instruction to the class on how you would like students to obtain the cockroach legs. You may choose to do the snipping or have a student volunteer from each group snip one leg. Some general instructions are provided below:

    - Place your cockroach in a beaker of ice water. This is to **anesthetize** (numb) your cockroach so that it doesn't feel any pain when you remove its leg.

    - Once the cockroach stops moving, remove it from the ice water and use the dissection scissors to cut off one of its legs near the body. The closer you cut to the body, the better.

8. Encourage students to work through the procedures and to record their observations on the *SpikerBox Lab Observations—Student Handout*.

9. When all groups have completed the lab, provide instruction on how you would like students to clean up their lab stations and put away lab equipment. Students should wash their hands with soap after cleaning up their stations.

Day Two

Explain

10. Distribute copies of the *SpikerBox Results & Conclusions—Student Handout*, one per student. Allow time for students, in their lab groups, to respond to the questions in the "Results" section of the handout. (A scoring guide for this learning task has been provided at the end of this lesson plan).

11. Bring the class back together to discuss the results of their investigations.

12. Connect the lab investigation back to the concept of human health. Testing chemical or plant extracts on animals is a way to determine their likely effect on humans. What can our understanding of the effect of cayenne pepper extract on the neural activity of a cockroach tell us about its potential medical use?

Elaborate

13. Students were introduced to neuroscientist Gregg Gage in the "Cockroach Beat Box" TedTalk video viewed at the beginning of the lesson. Invite your students to take a deeper look at the person who invented the SpikerBox that they used in the lab.

    Share with students a segment of Sanjay Gupta's show, "The Next List," which provides an inside look at "DIY neuroscientist" Greg Gage and his company Backyard Brains. Greg's company produces and sells SpikerBox DIY kits.

    "The Next List" Video Segment (21:10 mins)
    Backyard Brains
    https://backyardbrains.com/about/press

14. Initiate a class discussion about Greg's educational mission. What resonates with students? What do they think of the "DIY science" concept? In what ways is Gregg different from your idea of a neuroscientist?

15. Discuss how Greg took a scientific topic, an educational mission, a technological invention, and an entrepreneurial spirit and turned it into a company. What were the steps taken to form, fund, and grow the company? What problems is the company attempting to solve related to: neuroscience education, people with neurological disorders, and the community of Detroit?

16. Ask students: How might you be able to use the knowledge and skills gained through the *Sowing the Seeds of Neurscience* curriculum to make positive change in your own community?

Evaluate

17. In this lesson, students have investigated the effects of cayenne pepper extract on the neural activity of cockroaches. Challenge them to think about how this information could be used to develop ideas for new drug therapies to treat neurological disorders or pain associated with other diseases. Allow time for students to respond to the questions in the "Conclusions" section of the *SpikerBox Results & Conclusions—Student Handout*. (A scoring guide for this learning task has been provided at the end of this lesson plan).

18. Bring the class back together to discuss the conclusions of their investigations. In particular, talk about the different types of neurological disorders that students identified as potentially being treated with drug therapies that are chemically similar to cayenne pepper extract. What additional information would be needed? How might a pharmacologist go about gathering that information?

19. ***Optional:*** Assign a vocabulary quiz using the terms introduced on the Student Handouts. Hand out copies of *SpikerBox Vocabulary Quiz—Student Handout* and administer it like a quiz, with no peeking at lab notebooks or the Background Reading. An answer key is provided in the *Scoring* Guides section below.

SCORING GUIDES

Answer Key for Vocabulary Quiz Handout

13 possible points.

Clue Puzzles:

- Electrical Transmission
- Nervous System
- Anesthetize
- Chemical Transmission
- Substance P
- Neuron
- Synaptic Gap
- Capsaicin
- Neurotransmitter
- Sensory Stimuli
- Electrode
- Spike

Final Scramble: Action Potential.

Scoring Rubric for Lab Observations Handout

12 possible points.

Dimension	Needs Work (0 Points)	Basic (1 Point)	Proficient (3 Points)	Advanced (5 Points)
Hypothesis Development	Needed adult assistance to develop hypotheses.	Independently developed a hypothesis somewhat substantiated by previous observation of similar phenomena. Did not use the "If, Then" format.	Independently developed a hypothesis somewhat substantiated by previous observation of similar phenomena. Used the "If, Then" format.	Independently developed a hypothesis well-substantiated by previous observation of similar phenomena. Used the "If, Then" format. Hypothesis clearly communicated the predicted effect that cayenne pepper extract will have on the spikes (action potentials) of a cockroach leg attached to a SpikerBox.
Observations of Initial Experiment	Incomplete or incorrect.	Recorded observations where prompted **(1 point per response, 3 points possible).**	N/A	N/A
Observations of Cayenne Experiment	Incomplete or incorrect.	Recorded observations where prompted **(1 point per response, 4 points possible).**	N/A	N/A

Scoring Rubric for Questions from Results & Conclusions Handout

17 possible points.

Results

Dimension	Needs Work (0 Points)	Basic (1 Point)	Proficient (3 Points)	Advanced (5 Points)
Describes how the pattern of spikes changed when you touched the cockroach leg with a toothpick.	Incomplete or incorrect.	Provides a clear summary of observations.	N/A	N/A
Describes how the addition of the cayenne pepper extract affected the spikes, both with and without touching the leg with the toothpick.	Incomplete or incorrect.	Provides a clear summary of observations.	N/A	N/A
States whether observations supported or refuted hypothesis. Supports this statement with evidence.	No conclusion provided.	Student states whether observations supported or refuted hypothesis for the effect of cayenne extract on the cockroach leg.	Student states whether observations supported or refuted hypothesis.	Student clearly states whether observations supported or refuted hypothesis. Conclusion clearly based on the data.
Using terms from the vocabulary list, explain what is happening within the cockroach's nervous system when the leg is exposed to the	No explanation provided.	Explanation is provided, but is not based on student's own observations, is unclear, and/or doesn't correctly use vocabulary terms.	Explanation clearly describes the chain of events occurring within the cockroach's nervous system, including the concepts of:	Explanation clearly describes the chain of events occurring within the cockroach's nervous system, including the concepts of:

cayenne pepper extract.			-Chemical transmission of neurotransmitters -Electrical transmission -Action potential Explanation is based on student's own observations as well as *Background Reading*. Correctly uses two or more vocabulary terms.	-Chemical transmission of neurotransmitters -Electrical transmission -Action potential -Capsaicin or substance P Explanation is based on student's own observations as well as *Background Reading*. Correctly uses three or more vocabulary terms.

Conclusions

Dimension	Needs Work (0 Points)	Basic (1 Point)	Proficient (3 Points)	Advanced (5 Points)
What types of disorders do you think could possibly be treated with cayenne pepper? What evidence do you have?	No disorder named.	One disorder or type of disorder named, but lacking explanation or evidence. *For example: A pharmacologist might try using cayenne pepper in a throat spray to reduce sore throat pain.*	One disorder or type of disorder named, specifically pain disorders. Includes some explanation and supporting evidence. *For example: Cayenne pepper extract at first increased, but after five minutes, then decreased the neural activity in the cockroach leg. This means*	One or more disorders or types of disorder named, specifically pain disorders. Includes detailed explanation and supporting evidence. *For example: We observed that there was a decrease in action potentials after the cayenne extract had been on the cockroach*

			that it could no longer send pain messages. Cayenne might have the same effect in humans.	*leg for five minutes. This may be because the capsaicin in the cayenne pepper caused a release of the neurotransmitter substance P. When the body ran low on substance P, it couldn't continue to send a pain message.* *If cockroaches are a model organism for understanding about pain, this suggests that humans may have less pain if they rub cayenne pepper extract on their bodies.*

EXTENSIONS

- While you have a SpikerBox at your disposal, try some different investigations into the neural activity of cockroaches, crickets, or worms. The Backyard Brains project has over 20 different experiments to try, including some that don't require a SpikerBox. Some experiments can even be done with humans!

  Backyard Brains Neuroscience Experiments
  https://www.backyardbrains.com/experiments/

- Students can learn more about the structures of the nervous system by coloring one or more of these pages:

  Neuroscience Coloring Books
  Neuroscience for Kids
  http://faculty.washington.edu/chudler/colorbook.html

- If your students are looking for more information and activities related to neuroscience, check out this website:

  Neuroscience Experiments & More
  Neuroscience for Kids
  http://faculty.washington.edu/chudler/experi.html

- Challenge students to choose one of the careers listed in the *Career Connections* section of this lesson plan and to consider how a person in that career might use plant extracts, conduct research on animals, or research new drug therapies.

TEACHER BACKGROUND & RESOURCES

Resources

The Science and Ethics of Animal Research
A curriculum for grades 6-12 from the Northwest Association for Biomedical Research about the ethics of using animals in scientific and medical research.
http://nwabr.org/curriculum/animals-research

Speaking Honestly – Animal Research Education (SHARE)
A program designed to guide educators in leading a discussion-based classroom activity on the different views on the use of animals in research. The activity requires a single class period of 50-75 minutes.
http://sharehappens.org/

Backyard Brains: Neuroscience for Everyone
Extensive information on the SpikerBox device, including additional lab investigations.
http://www.backyardbrains.com/

Arduino Uno Microcontroller Circuit Board & the SpikerBox
Sowing the Seeds of Neuroscience
http://www.neuroseeds.org/links/arduino

Lights, Camera, Action Potential
Neuroscience for Kids
http://faculty.washington.edu/chudler/ap.html

The Chile Story
Sowing the Seeds of Neuroscience
http://www.neuroseeds.org/links/chili-pepper

Cayenne
University of Maryland Medical Center
http://umm.edu/health/medical/altmed/herb/cayenne

Career Connections

Biologist: A scientist that studies living organisms and their environments. Biologists may specialize in botany (the study of plants), zoology (the study of animals), or many other specialties.

Bioengineer: Also called biomedical engineers. These scientists apply their knowledge of biology, medicine, and engineering to design solutions to health and medical problems—such as new devices, instruments, or procedures. They may work in research facilities, universities, or manufacturing within the medical industry.

Entomologist: A zoologist (biologist that focuses on animals) that specializes in the study of insects. There are a wide variety of careers within entomology, including using insects to study disease transmission in humans.

Neuroscientist: A scientist that studies the brain and nervous system. Neuroscientists are primarily concerned with research.

Pharmacologist: A biomedical scientist that studies the interactions between drugs and cells, tissues, organs, or entire organisms. Pharmacologists are primarily concerned with research.

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Chili Pepper Photograph. Courtesy of Microsoft Clipart.

Laboratory Procedures Photographs. Photos taken by Eric Chudler and Kristi Straus. 2013.

Bibliographic Credits

"Cayenne." University of Maryland Medical Center, 2010. Web. 23 January 2013. <http://umm.edu/health/medical/altmed/herb/cayenne>.

Special thank you to **Backyard Brains: Neuroscience for Everyone** for **e**xtensive information on the SpikerBox device, including additional lab investigations. <http://www.backyardbrains.com/>.

SPIKERBOX BACKGROUND READING
STUDENT HANDOUT

Name:_____ Date:_____ Period:_____

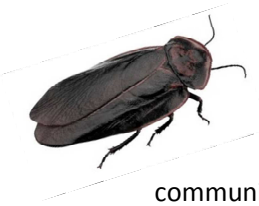
What part of your body makes the most noise? Your mouth? Clapping your hands or stomping your feet? Imagine that we plugged your body into a stereo or speaker system; would we hear anything? Where would we plug the cord in? Today you will learn how your nervous system can actually make a sound if you "plugged it in."

It's Electric!

The **nervous system** controls and responds to body functions and directs behavior. Each **neuron** (nerve cell) communicates with many other neurons to share information. The brain is a key component of the nervous system and is the body's most complex organ—it contains a hundred billion nerve cells and we use them all! Your brain is a network of neurons that need to communicate with each other in order for your brain to function. The brain influences and is influenced by all other body systems so it needs to be able to communicate with the nerves in the rest of your body. When you stub your toe, do you feel it right away? How do nerves communicate so quickly?

Neurons communicate using electrical and chemical signals. **Chemical transmission** occurs when **neurotransmitters** pass between nerve cells. Neurotransmitters are chemicals that send information from one nerve cell to another. The **synaptic gap** is an area between neurons that allows neurotransmitters to pass between neurons**.**

Inside of a single neuron, the body uses another method as well: **electrical transmission**. **Sensory stimuli** are converted into electrical signals and electrical signals in muscles cause contraction and movement. Neurons use electrical signals called **action potentials** to send information within a cell. Action potentials are electrical signals carried along neurons. These electrical signals cause neurotransmitters to be released at the end of a neuron, which cross the synapse to the next neuron.



Do you think it is possible to hear the nervous system's electrical signals from a speaker? Turns out you can! In this lab investigation, you are going to learn about communication within the nervous system by seeing and hearing action potentials ("spikes") in a cockroach. Humans have a complex nervous system that evolved from a simpler one. We can learn about the human nervous system by studying simpler animals, including cockroaches.

Hot & Spicy Cayenne Pepper

Plants and herbs have been used around the world for millennia to alter brain function—think about how people drink coffee or tea to wake up in the morning. This happens because the chemicals in the plants are similar to chemicals that our body uses and can affect the body's interactions with those chemicals.

Does your family cook with cayenne pepper or do you enjoy sprinkling red pepper flakes on your pizza? The hot and spicy taste in cayenne pepper comes from a chemical called **capsaicin**. Capsaicin is found in all chili peppers and it is a human irritant—it causes a burning sensation. Some people enjoy this burning sensation in the mouth. In fact, chili peppers have been used for at least 9,000 years by Native Americans as both food and medicine.

Although capsaicin is an irritant that causes a burning sensation, interestingly, over time it appears to reduce pain. Capsaicin is currently used as an ingredient in skin ointments and creams to relieve pain, such as that associated with arthritis and shingles. Scientists are also researching capsaicin as a key ingredient for an experimental drug to treat arthritis pain. It would be injected by a doctor and may be able to relieve pain for weeks or even months.

The pain relief caused by capsaicin seems to be connected to the burning sensation. When neurons in the body are exposed to capsaicin, they release **substance P**, a neurotransmitter that sends information about pain and heat. If the capsaicin remains on the body for an extended period of time, the body runs low on substance P and can't continue to respond. The body is unable to send a pain message! In other words, when you leave capsaicin on the skin, the neurons are depleted of the neurotransmitter substance P and this reduces pain sensations.

Current research also suggests that capsaicin is able to kill cancer cells—this is another amazing chemical derived from a plant!

Electrical Communication in the Cockroach Nervous System

As part of this activity, you will see if cayenne pepper affects the electrical communication in the cockroach nervous system. You will use a device called a SpikerBox. A SpikerBox is a "bioamplifier" that allows you to hear the spikes (action potentials) of live neurons in a cockroach's leg.

SpikerBox Vocabulary List

Action potential: An electrical signal carried along a neuron. It is an "all-or-none" impulse that transmits information within the nervous system. The action potential is sometimes called a spike.

Anesthetize: To numb or reduce pain.

Capsaicin: The chemical found in hot peppers that makes them spicy. Capsaicin is also used as an ingredient in skin creams to reduce pain.

Chemical transmission: Neurons communicate using both electrical and chemical signals. Chemical transmission is when a neurotransmitter is received by a dendrite, causing an action potential to occur in that cell.

Electrical transmission: Neurons communicate using both electrical and chemical signals. Electrical transmission is the electrical signal that is carried along the receiving neuron after a chemical neurotransmitter is passed from one neuron to another.

Electrode: A conductor through which electricity enters or leaves an object. The electrodes in the SpikerBox are pins attached to wires.

Neuron: A nerve cell.

Neurotransmitter: Chemical that transmits information across the synapse to communicate from one neuron to another.

Nervous system: An organ system that controls and responds to body functions and directs behavior.

Sensory stimuli: Information from the senses. Sensory stimuli include anything you see, hear, taste, smell, or feel.

Spike: Another word for **action potential**. An electrical signal carried along a neuron. It is an "all-or-none" impulse that transmits information within the nervous system.

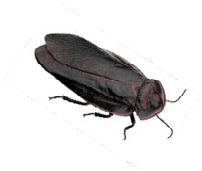
Substance P: A neurotransmitter that sends information about pain and heat.

Synaptic gap: The area between neurons that allows neurotransmitters to pass between neurons**.** It is the functional connection between an axon of one neuron and a dendrite of another.

SPIKERBOX LAB OBSERVATIONS
STUDENT HANDOUT

Name:_____ Date:_____ Period:_____

Observations and Notes on the SpikerBox Lab



Hypothesis Development

1. Develop a hypothesis for the effect that cayenne pepper extract will have on the spikes (action potentials) of a cockroach leg attached to a SpikerBox. Write down your hypothesis using the "If, Then" format.

Initial Experiment

2. After you first pin the electrodes to the cockroach leg, record your observations about the pattern/sound of these spikes.

3. After you touch the cockroach leg with a toothpick, record your observations about the pattern/sound of these spikes.

4. After your teacher has shown you the spikes on a laptop, iPad, or SmartPhone, record your observations about the pattern of these spikes.

Cayenne Extract Experiment

5. After you add cayenne extract and wait three minutes, record your observations about the pattern/sound of these spikes.

6. After you touch the cockroach leg with a toothpick, record your observations about the pattern/sound of these spikes.

7. While waiting five minutes without touching the cockroach leg, explain how the cayenne pepper seemed to change the spikes of the cockroach leg both with and without touching it with a toothpick.

8. After five minutes, listen carefully to the spikes again, both with and without touching the leg. Did anything change? What was different?

SPIKERBOX LAB PROCEDURE
STUDENT HANDOUT

Name:_____ **Date:**_____ **Period:**_____

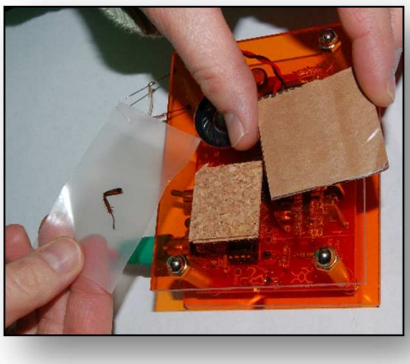
Lab Procedure for SpikerBox Activity

Your group will need the following laboratory materials:

Item	Quantity per Lab Group
Goggles and gloves	1 per student
Dissection scissors	1
Toothpick	1
SpikerBox	1
Cayenne pepper extract	10 ml
Push pins	2
3 mm by 3 mm square of Parafilm	1
3 mm by 3 mm square of cardboard	1
Pipette	1
Timer	1

Directions: Follow the procedures. Where indicated, record your observations and notes on the *SpikerBox Lab Observations—Student Handout*.

1. Pin the parafilm and cardboard to the cork on the SpikerBox. It should look like the photo—with the parafilm on top, the cardboard in between, and the cork on the bottom. This will protect the spiker box from getting wet when you use the cayenne extract.

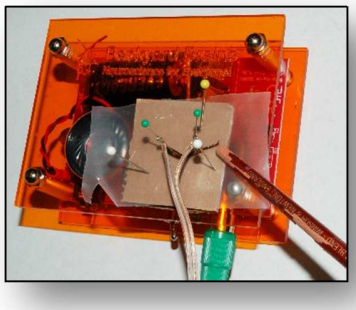


2. Follow your teacher's instructions on how to **anesthetize** (numb) a cockroach and remove a leg.

3. Place the cockroach leg on the parafilm that you placed on the SpikerBox cork.

4. Pin the **electrodes** into the cockroach leg, one on each side of the "knee" (see image). Use the electrodes to pierce the leg and pin it into the cardboard.

5. Turn on your SpikerBox. If you hear a popping sound, these are the spikes you are looking for! This popping is the action potentials—the electrical communication from neurons in the cockroach leg!



6. Although we don't have a way to count the spikes automatically, listen carefully and try to get a feel for how often the spikes are occurring—this way, when you add cayenne extract, you'll have a feel for whether any change occurs. ***Record your observations.***

7. Use the toothpick to touch the cockroach leg. Did anything change in the pattern of spikes? You can try this several times and try touching the leg in different locations. ***Record your observations.***

8. In addition to hearing the electrical communication, you can see the spikes too! Your teacher will plug a sound cable from the SpikerBox into a laptop, iPad, or SmartPhone so that you can ***see*** the spikes. ***Record your observations.***

9. Turn off your SpikerBox. Use a pipette to add ***a few drops*** of cayenne extract directly on top of the cockroach leg. Set your timer for three minutes and start it.

10. After three minutes, use a paper towel to gently soak up all of the cayenne extract, being careful not to touch the electrodes. It is very important to remove all of the cayenne extract.

11. Turn on your SpikerBox again and listen carefully. Do you notice any differences in the spikes? ***Record your observations.***

12. Use the toothpick to touch the cockroach leg. Did anything change in the pattern of spikes? You can try this several times and try touching the leg in different locations. ***Record your observations.***

13. Set your timer and wait five minutes without touching the SpikerBox. During this time, you can write about how the cayenne pepper seemed to change the spikes of the cockroach leg both with and without touching it with a toothpick.

14. After five minutes, listen carefully to the spikes again, both with and without touching the leg. Did anything change? ***Record your observations.***

15. Turn off your SpikerBox. Follow your teacher's instructions regarding how to clean up your lab station and put equipment away.

SPIKERBOX RESULTS & CONCLUSIONS
STUDENT HANDOUT

Name:_____ Date:_____ Period:_____

Results:

1. Summarize your observations of how the pattern of spikes changed when you touched the cockroach leg with a toothpick (before you added the cayenne pepper extract).

2. Summarize your observations of how the addition of the cayenne pepper extract affected the spikes, both with and without touching the leg with the toothpick.

3. Did your observations support or refute your hypothesis? Explain.

4. Using terms from the vocabulary list, explain what is happening within the cockroach's nervous system when the leg is exposed to the cayenne pepper extract.

Conclusions:

5. What types of disorders do you think could possibly be treated with cayenne pepper? What evidence do you have?

SPIKERBOX VOCABULARY ACTIVITY
STUDENT HANDOUT

Name:_____ Date:_____ Period:_____

SpikerBox Double Puzzle

Directions: Use the clues to help you unscramble each of the words. Solve the final puzzle by copying the letters in the numbered cells to other cells with the same number.

RAMRASCESICNNTLIISOTLE

VTSURSEMSONEY

NETHSEIZEAT

SOCIITSMELNAIMSHARCN

SUSNECPATB

NENURO

TAPSYGCINPA

NAISIAPCC

UTSARNEMTITNORRE

LYESOSSRNIUTMI

ERLDECTOE

PKEIS

Clues:

What do you call it when neurons communicate using electrical signals?

Which organ system controls and responds to body functions and directs behavior?

What is it called when you numb something?

What do you call it when neurons communicate using neurotransmitters?

Which neurotransmitter sends information about pain and heat?

What is a nerve cell called?

What is the area between neurons that allows neurotransmitters to pass between neurons?

Which chemical in hot peppers can reduce pain?

What is the name for a chemical that transmits information across the synapse?

What is the name for information gained from your senses?

This is a conductor through which electricity enters or leaves an object.

This is another word for action potential. It is an electrical signal carried along a neuron.