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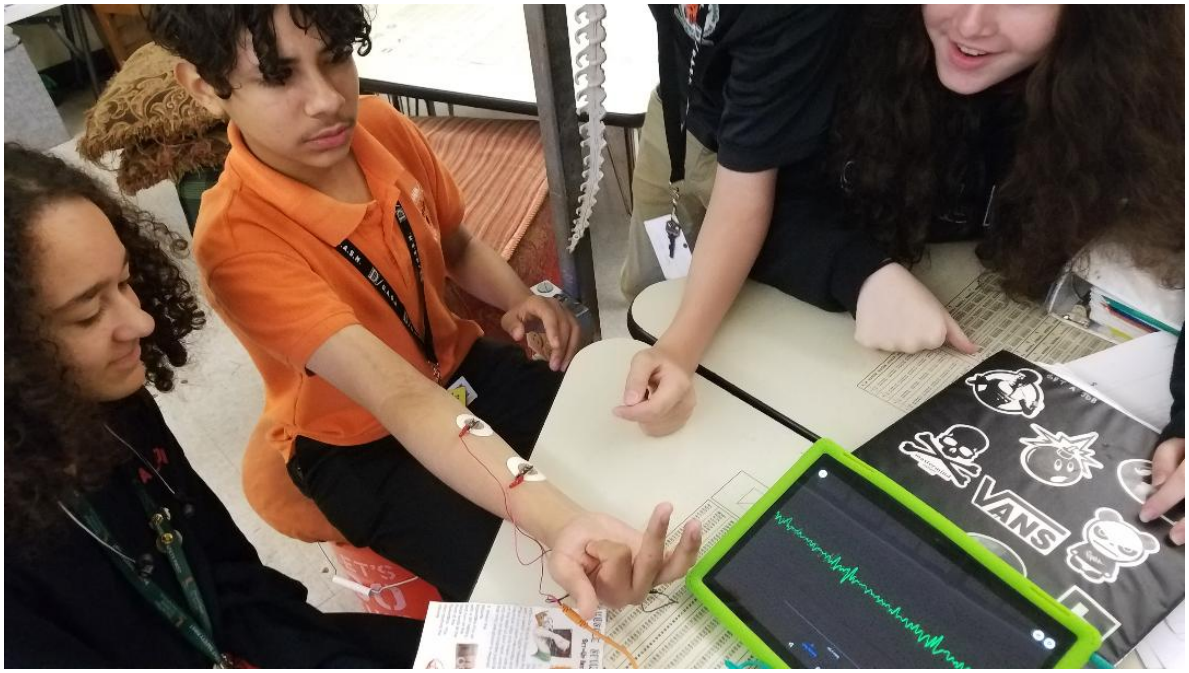
Neuroscience in a (Spiker)Box

Neuroscience in a SpikerBox



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BACKYARD BRAINS

Table of Contents

Goals …3

Florida Standards ….4

Materials … .4

Initial Activity: Understanding Where the Nerves Are and How they work….. 5

Activity 1 Record Electricity from Your Muscles! ….7-8

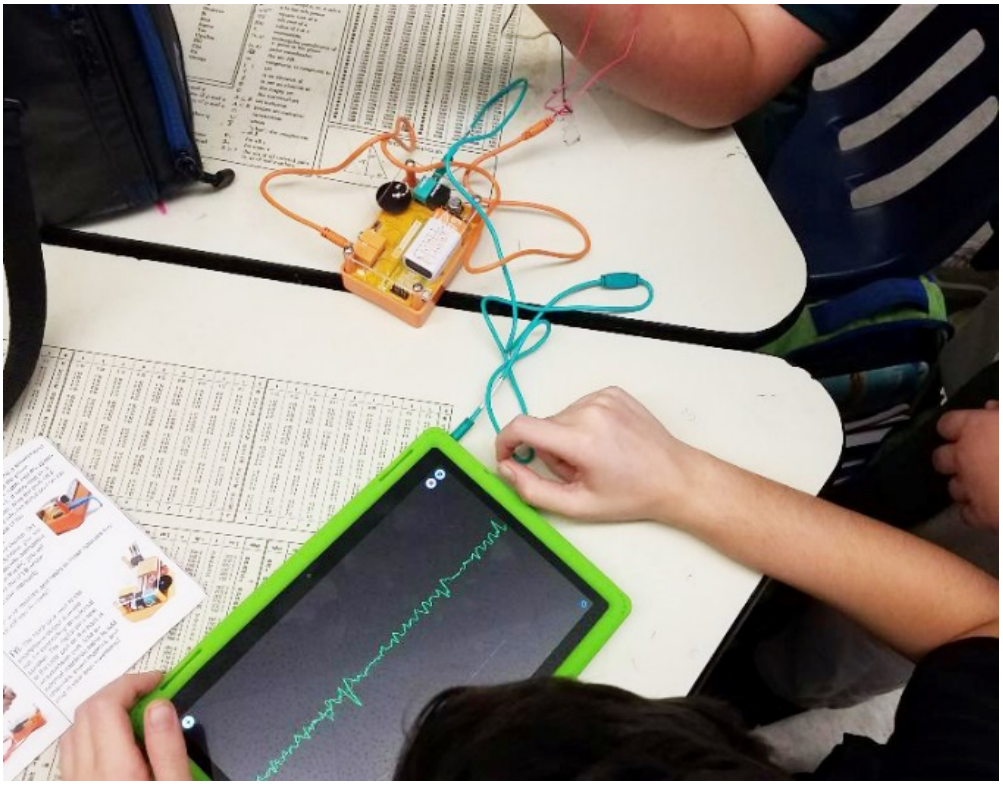
Activity 2: Controlling the Claw …9-10

Other Activities: …

- **Human to Human Interface …p11**
- **Muscle Fatigue …p12**
- **Detail Muscle Action Potential …. P13**

Evaluation Plan … p15

Resource List:



Goals

To develop a greater understanding of the neuroscience of human physiology. Student understanding of the neuroscience of muscles through "seeing" the electricity of muscle movement.

With every step you take, every turn of your head, and every time you pick up a pencil, electricity courses through the muscles involved. Electricity acts as both a signal telling your muscles to move and is produced by them when your brain tells them to contract. Before now, seeing or listening to your bioelectricity was often a costly and complex process. That's changed, however, thanks to the Backyard Brains Muscle SpikerBox. Using the device students can easily begin to listen to and record their own muscle action potentials and display them live on their smartphone or tablet. They will use the Muscle SpikerBox to record their bicep or forearm muscles while doing isometric muscle contractions until fatigue/failure occurs. They will measure the EMG amplitude during the contractions to learn about changes in muscle cells & neural signals. Then they will learn how to control a robotic hand (prosthetic hand) or control each other.

The easy to use kit allows students to record EMG signals, giving them the power to perform human physiology experiments. It's perfect for education of all ages-nobody is too old to be delighted by spikes! For students interested in experimenting further, it's also fun and great for projects, and neuroscience makes an impressive show at a science fair. The Muscle Spikerbox can be used to non-invasively detect the electrical activity of human muscles with simple skin surface electrodes. With time students can even identify individual motor units (that's one muscle fiber!) & see single muscle spikes. The Muscle Spikerbox comes with 2 types of electrodes. One type is a sticker electrode that is aimed for broad recordings of several muscles in the arm or leg. The second type are our homemade brass tipped popsicle stick electrodes used for small muscles like eyeblink & finger muscles. The device readily interfaces with a smartphone, tablet, and computer.

Florida Standards

SS.912.P.3.13 Describe advances made in neuroscience.

SS.912.P.3.14 Discuss issues related to scientific advances in neuroscience and genetics.

SC.912.L.14.17 List the steps involved in the sliding filament of muscle contraction.

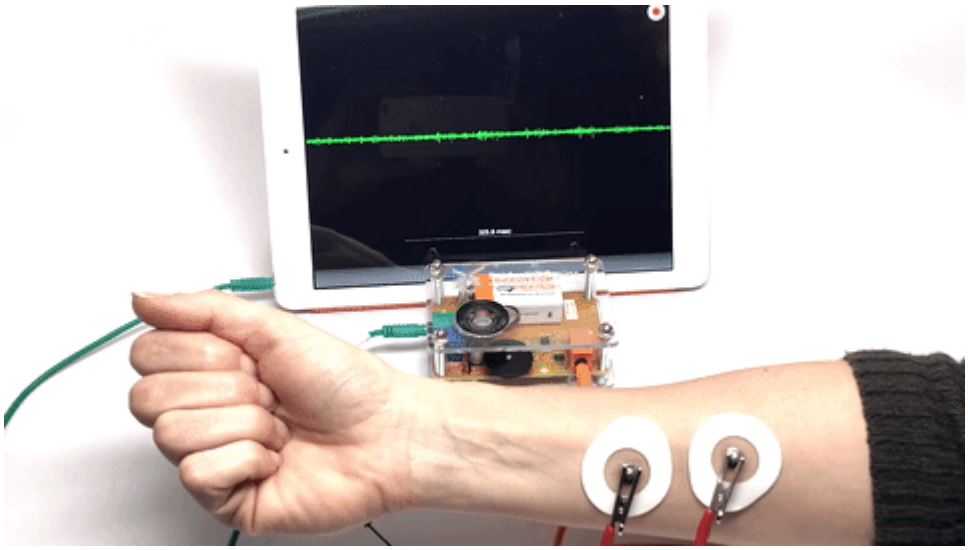
Materials

BackYard Brains

- Muscle Spiker Box Pro,
- The Claw.

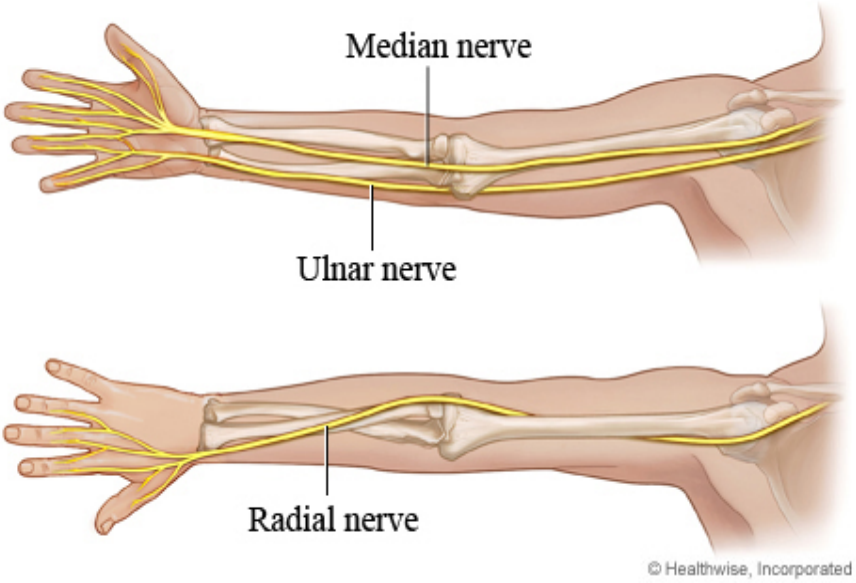
Shown on a smartphone or tablet.

Tables used in groups to allow small group 3-4 to work together



Initial Activity

Before the students can investigate the neuroscience of muscle action, they need to get a basic understanding of where the nerves are in the forearm and what they do. The image shows the nerves and their placement in relationship to the bone. Basic information also is provided on how each nerve works



Three main nerves run past the elbow and wrist to the hand.

- **Median nerve.** This nerve passes down the inside of the arm and crosses the front of the elbow. At the wrist it goes through a "tunnel"-called the carpal tunnel-made up of the wrist bones and a tough band of connective tissue (ligament). The median nerve supplies muscles that help bend the wrist and fingers. It is a main nerve for the muscles that bend the thumb. The median nerve also gives feeling to the skin on much of the hand around the palm, the thumb, and the index and middle fingers. When the median nerve is compressed over a long period, it can cause carpal tunnel syndrome.
- **Ulnar nerve.** This nerve passes down the inside of the arm. It then passes behind the elbow, where it lies in a groove between two bony points on the back and inner side of the elbow. The ulnar nerve supplies muscles that help bend the wrist and fingers, and that help move the fingers from side to side. It also gives feeling to the skin of the outer part of the hand, including the little finger and the outer half of the back of the hand, palm, and ring finger. When the elbow is bumped over the ulnar nerve, it's often called hitting the "funny bone."
- **Radial nerve.** This nerve passes down the back and outside of the upper arm. The radial nerve supplies muscles that straighten the elbow, and lift and straighten the wrist, thumb, and fingers. The radial nerve gives feeling to the skin on the outside of the thumb and on the back of the hand and the index finger, middle finger, and half of the ring finger.

Current as of: September 20, 2018 **Author:** Healthwise Staff
Medical Review: William H. Blahd, Jr., MD, FACEP - Emergency Medicine& Adam Husney, MD - Family Medicine & Kathleen Romito, MD - Family Medicine

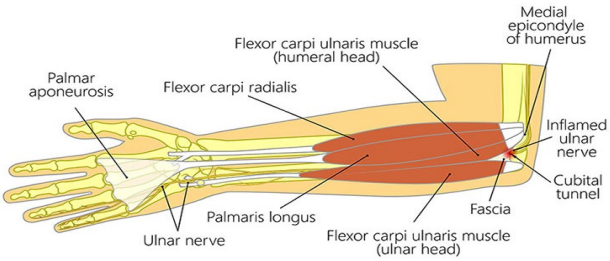
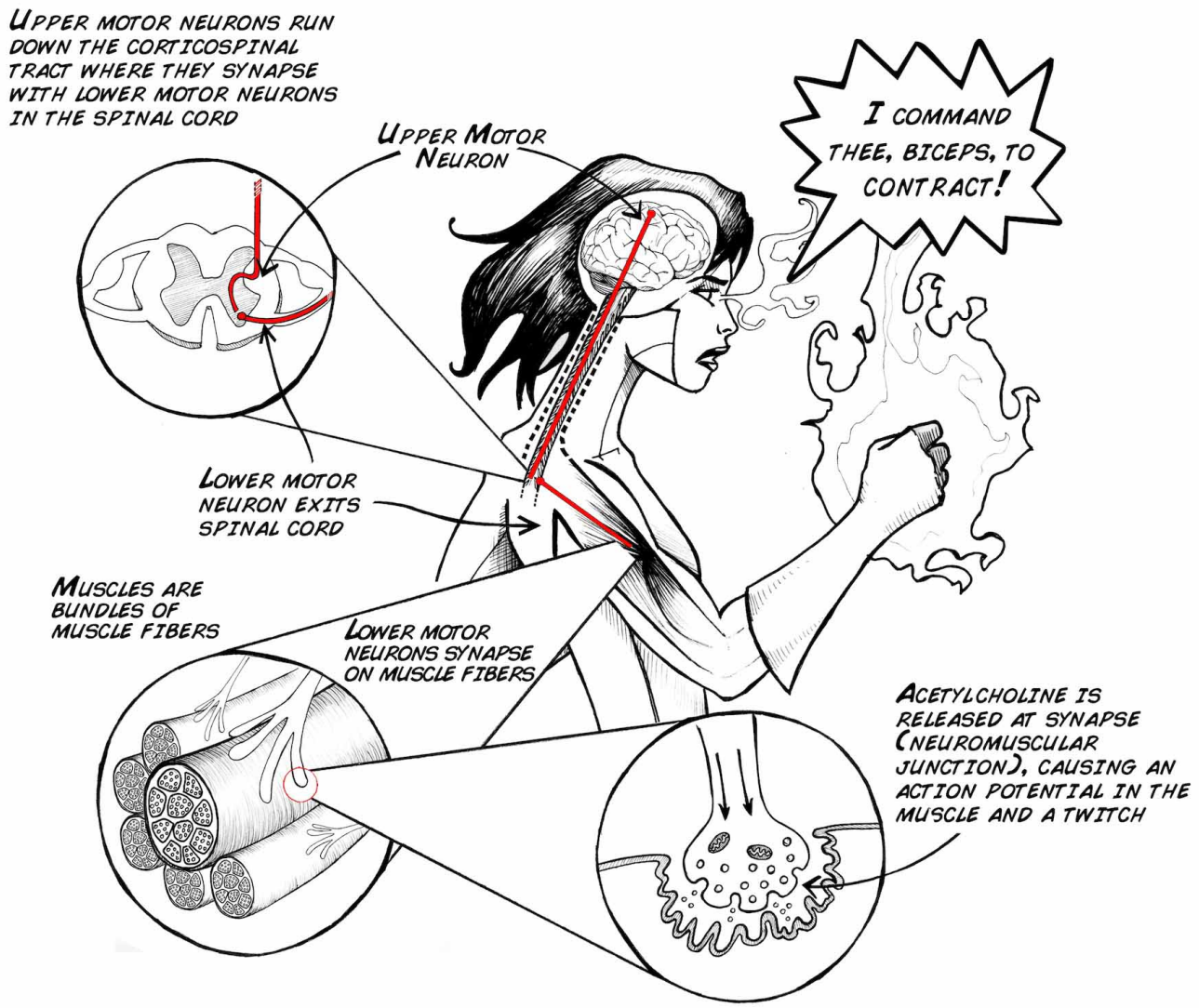


Figure 1 This is detail image of the bones, muscles and tendons also in the hand and forearm

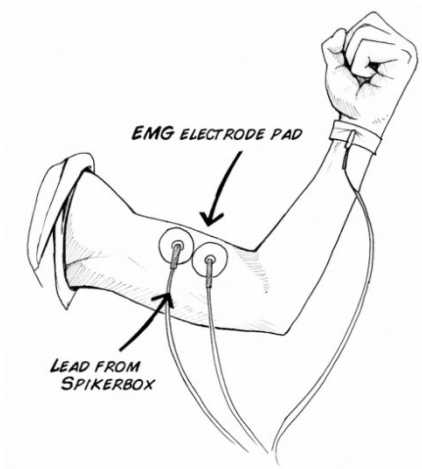
Activity 1 Record Electricity from Your Muscles!

You may have heard and seen spikes from invertebrates. But what about yourself? Your body uses electricity to communicate and control parts of the body. Though all cells have ionic gradients across their membranes, the most well-known organ systems that use electricity are the brain, the muscles, and the heart. Your neurons and muscles work together to allow your body to move quickly.



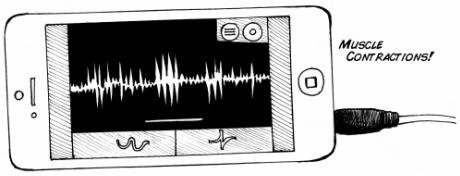
Now let's try to record muscle action potentials in humans! This muscle physiology lab activity is great for students of all ages.

In this experiment, we are going to record the group activity of 1000's of muscle fibers within the bicep muscle.



1. Remove the sticky backing from your Large Muscle electrodes and place these surface electrodes close to each other on your bicep.
2. Hook up the Muscle SpikerBox leads (the 2 red alligator clips) to the two surface electrodes on your bicep.
3. Place the reference electrode (Black) anywhere on the body. In the figure above we show it attached to a metal bracelet near the wrist. You can also use another surface electrode placed anywhere on the back of your hand (like in the movie above), or if you have any metal rings on your fingers, you can clip the reference electrode to your ring.
4. Turn on the Muscle SpikerBox and listen for changes in activity. Do you notice a difference when you flex your muscles?

5. Plug in your SmartPhone Cable (with our free Android or iPhone apps installed) or computer (using our Backyard Brains PC app and a USB cable if you have the Muscle SpikerBox Pro).



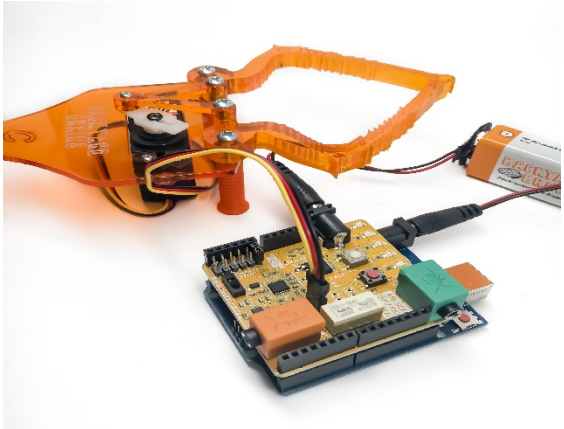
6. Pick up something heavy. Do you see and hear a difference? The "Whoosh" is the sound of many action potentials occurring in your muscles as the muscles contract. You are listening to the conversation between your brain and muscle!

Activity 2: Controlling the Claw

Make your first anthropomorphic Neuroprosthetic, in which you control a robotic claw with the signal of your muscles.

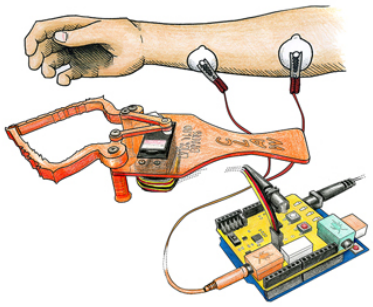
What will you learn?

In the following experiment you will learn to control the Claw with the EMG signal of your muscles. The Claw will open and close depending on the strength of the signal you make when contracting the muscles of your hand; you can perform this experiment to impress your friends, for a school science fair, or just to dive into the study of Neuroprosthetics!



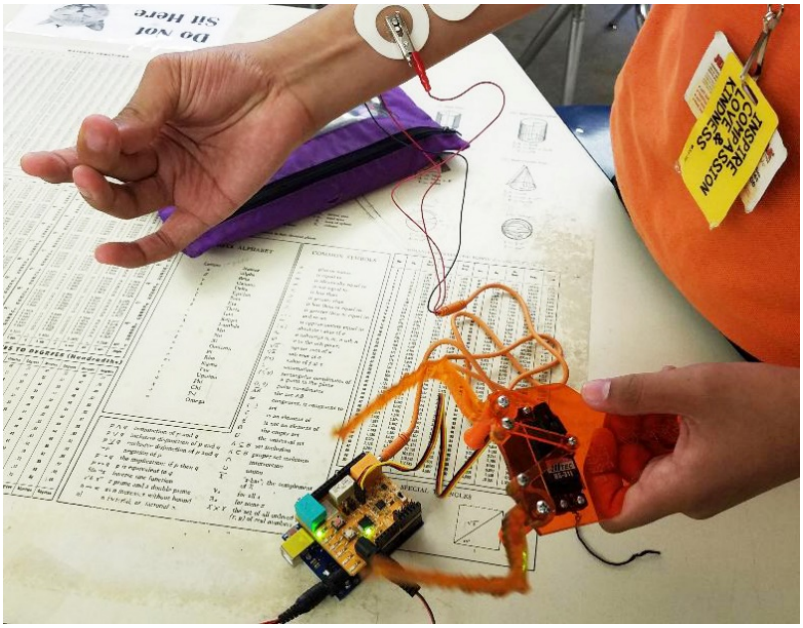
Procedure

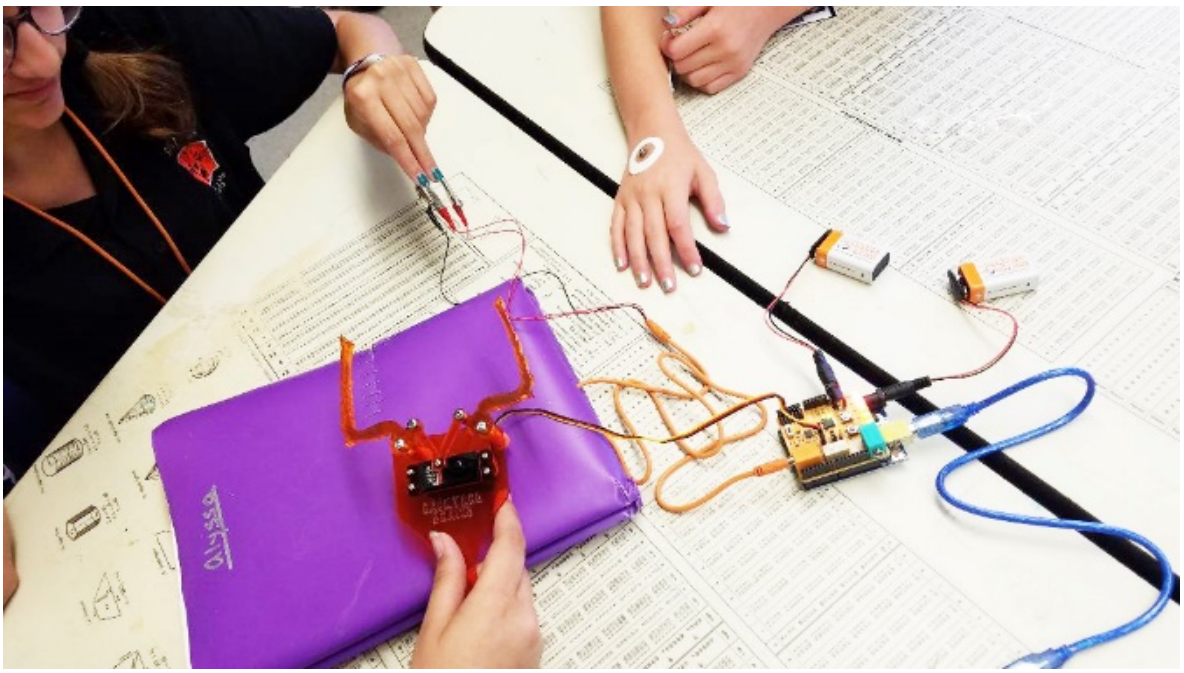
1. Your Robotic Claw has a three-wire servomotor cable that you plug into your Muscle SpikerShield. The Cable has a black, red, and a yellow wire. The yellow is the control wire, red is power (9V), and black is ground.
2. Plug the Servomotor cable into the three pin header on your Muscle SpikerShield. Order is important! The yellow side goes toward the center of the board.
3. Your Claw is power hungry and needs its own power supply. Plug the two 9V batteries into the barrel connectors on the Muscle SpikerShield Board and the Arduino.



4. Place three sticker electrodes on your own, two on your forearm and one on the back of your palm.
5. Taking your orange electrode cable, connect the two red alligator clips on the electrodes on your forearm (order does not matter) and the black alligator clip on the ground on the back of your hand. Plug the orange cable into the orange port on your Muscle SpikerShield.

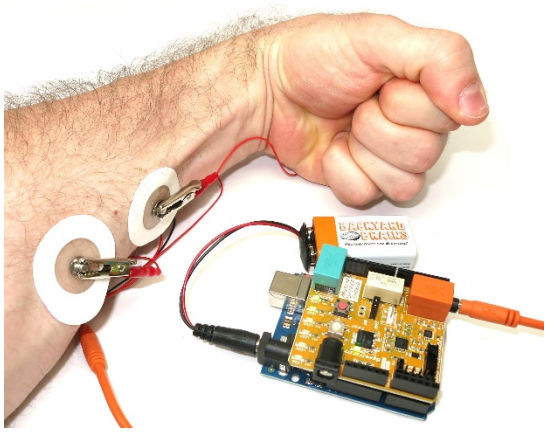
6. Plug the additional battery into the barrel connector on the blue Arduino board to power up the system.
7. Now flex your arm! You should see the Claw move as well. You can push the white button to change between high and low threshold modes, and you can push the red button to switch between default open or default closing.





Other Activities

1) Control Machines with your Brain

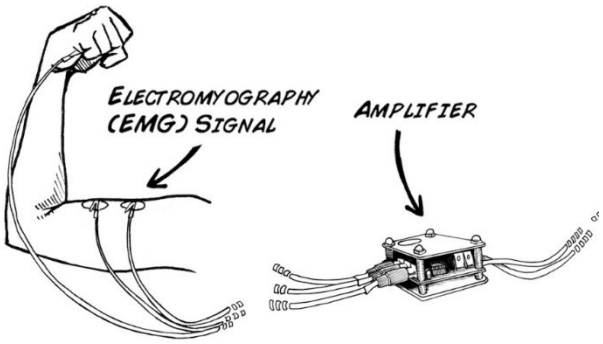


Now that you have your EMG Signal, can you use it to drive another system? Neural Engineering continues, using the popular Arduino microcontroller.

Background

In the Muscle SpikerBox experiment we learned about how motor neurons activate muscles with electrical signals, and we learned how to record that electrical activity using the BYB Spike Recorder App. These EMG signals are powerful tools for doctors and scientists who study human physiology, but they are also powerful tools for us biohackers! By using our EMG signals as an input, we can begin to create human-machine interfaces.

Procedure

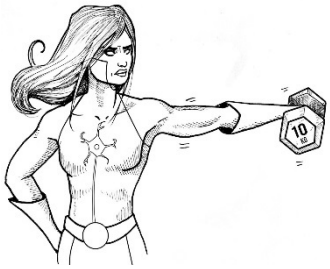


Let's get started! If you purchased the SpikerShield Bundle, everything is ready to go out of the box!

First, mate the Muscle SpikerShield on top of the Arduino, aligning all the pins on the shield to the female headers on the Arduino. In this experiment we are using the first Analog input (A0), so be sure to jumper the input select to 1. Note: your Arduino can run on an external USB power source or the included battery leash once your code has been uploaded,

Then connect the orange electrode cable wire from the Muscle SpikerShield to some electrodes on your arms. Hook the two red clips onto your arm and place the black one on the back of your wrist. You can also plug in a speaker to hear your muscle activity alongside the visual outputs!

2) **EMGs during Muscle Fatigue**:

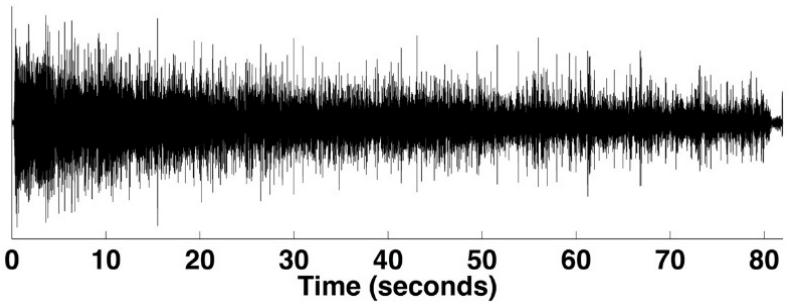


In this muscle fatigue lab students will be introduced to some more in-depth muscle physiology & why their muscles get tired. They will use the Muscle SpikerBox to record their bicep or forearm muscles while doing isometric muscle contractions until fatigue/failure occurs. They will measure the EMG amplitude during the contractions to learn about changes in muscle cells & neural signals during fatigue.

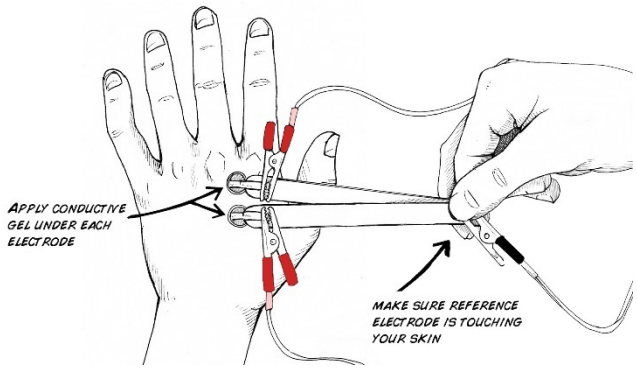
[Note: In truth you can use any muscle you like for this experiment, as long as you can figure out how to produce fatigue in that muscle in a controlled fashion.]

Isometric biceps hold

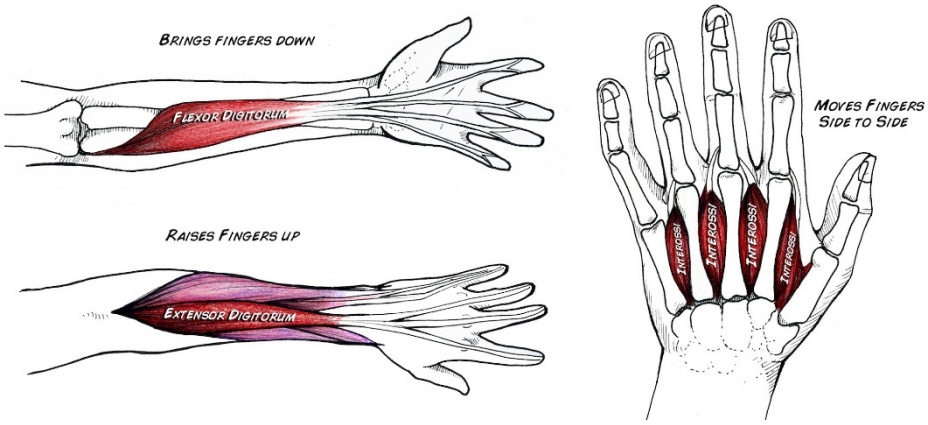
1. Hook up your EMG patch electrodes to your bicep, plug the electrodes into your Muscle SpikerBox, and hook up your SpikerBox to either your mobile software or PC.
2. Select a dumbbell that is at about 60% of your maximum lifting weight. Depending on your strength, this will be ~10-25 lbs (~5-12 kg). With your back to a wall to control your posture and arm position, hold the weight in your hand for as long as you can, with your elbow at a 90 degree angle. This is called an "**isometric**" contraction since your muscles are working, but your joints are not moving. [Note: you will probably find that your wrist gets tired faster than your bicep. You can avoid this problem by hanging a weight off your wrist rather than holding the dumbbell in your hand (see video above).]
3. Record your EMG during this task using SpikeRecorder on tablet/smartphone or your computer.
4. Observe the amplitude (height) and firing rate (number of impulses) in the EMG. What do you see over time? The gross signal may look similar to this:



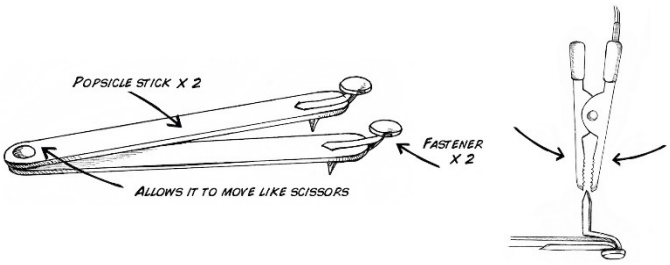
3) Muscle Action Potentials:

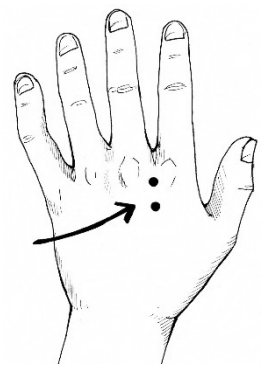


In this experiment students will look at EMG activity more closely. The muscle activity they saw in the previous experiment was the result of many muscle fibers contracting at once. When you add up the electrical activity from each fiber, you get a large distributed EMG signal that can be pick up using surface electrodes. But what about the signal to each fiber? This experiment will show students how to use the Muscle SpikerBox to record neural activity or motor units from the small interosseous muscles in your hand.



1. Using your orange electrode cable, attach the red alligator clips to each of the brass fasteners in our "popsicle stick electrode" that came with your SpikerBox. Attach the black alligator clip to the ground screw. See images below as a guide.

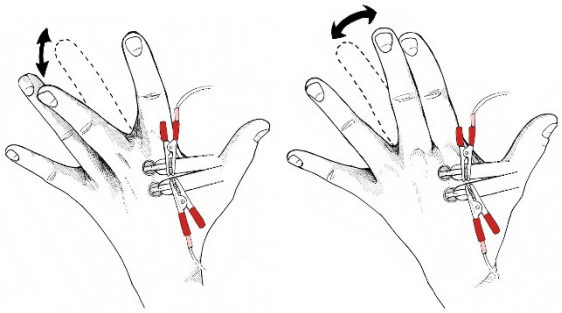


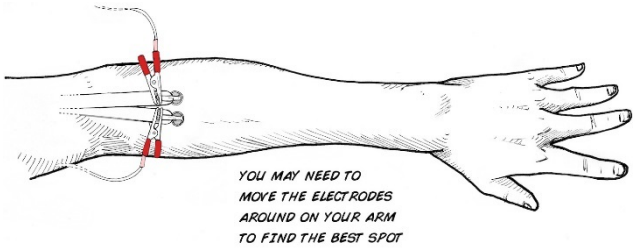


2. Locate an indent (valley) between knuckles on your hand.

3. Place the electrodes over the back of your hand between the knuckles as shown below. Make sure you put a dab of conductive gel in-between each electrode and your skin. This will increase your signal quality (without gel you will most likely just get noise).

4. Hook up the Muscle SpikerBox to the electrode cable (see video above as a guide).
5. Turn on the Muscle SpikerBox.
6. Plug in your SmartPhone Cable (with our free Android or iPhone apps installed) or computer (using our Backyard Brains PC app and a USB cable if you have the Muscle SpikerBox Pro).
7. Move your middle or ring finger either side to side or up and down. Do you notice a difference?





8. Now, try to isolate the muscles in your forearm responsible for up and down motion of your fingers! Can you find your *flexor digitorum superficialis*?

9. Observe your smartphone or computer screen to see if you can isolate single muscle action potentials. You may find you have to "think about moving" so that you only generate a single twitch and a single AP! See if you can do it!

Evaluation Plan

Student will be able to demonstrate an understanding of the neuroscience of muscles through:

1. The students will be able to observe the effects of these fatigue processes, albeit indirectly, by examining the amplitude of the EMG signal during a muscle contraction. As fatigue progresses, the students will come to understand:
    a. the firing rate of motor neurons drops, which in turn drops the number of action potentials the muscles themselves then fire, leading to a reduction in strength,
    b. muscles can often also continue generating action potentials due to neural drive, but the muscle is unable to contract due to molecular fatigue events in the muscle fibers, which in turn leads to a reduction in strength.
2. They will also be able to observe what do muscle Action Potentials look like on different muscles or different parts of the body.
3. Explain the impacts the amplitude of the muscle action potentials affecting fatigue or athleticism.
4. Students will demonstrate the ability to use this technique to pick up any neuronal action potentials of other activities.
5. They will also be able to see what the differences there is (if there is one) between an action potential coming from a reflex (like the patellar reflex) and the same motion happening voluntarily.

Student data sheets, images of the “sound” of muscles from the app, analysis and conclusions (CER) will be collected as well as reflections about what they learned and the process this inquiry methodology provided for their learning.

Resource List:

The web site www.backyardbrains.com provides lots of lesson, investigations and experiments as well as the equipment.