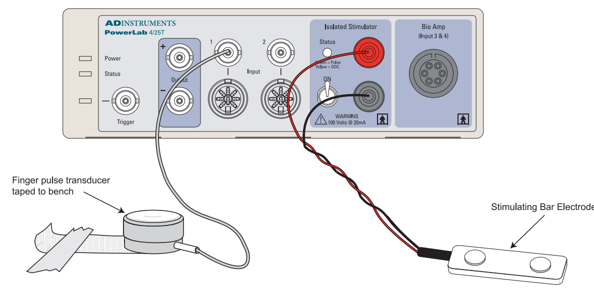
<u>**LAB COPY**</u>

Muscle Physiology

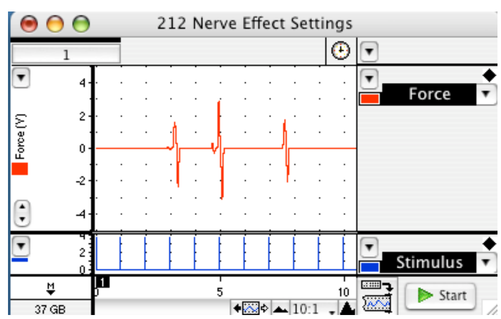
Warning. These exercises involve application of electrical stimulation to muscle through electrodes placed on the skin. PowerLab's isolated stimulator blocks connection between the stimulus electrodes and AC power, and limits stimulus current to levels that are safe, but people who have cardiac pacemakers or who suffer from neurological or cardiac disorders should not volunteer for these exercises. If the volunteer feels major discomfort during the exercises, discontinue the exercise and consult your instructor.

Set up and equipment calibration

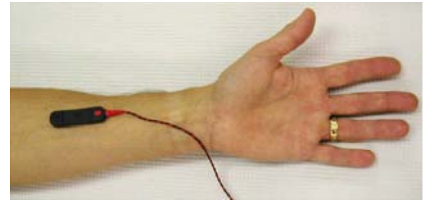
1. Make sure the PowerLab is connected and computer is turned on.
2. Connect the finger pulse transducer to the BNC socket on Input 1 of the PowerLab.
3. Have a volunteer sit at the table, with their elbow and forearm on the table top. Attach the pulse transducer, velcro side down, to the tabletop so the volunteer can place a fingertip on the transducer without lifting their arm. Your lab instructor will tell you how to attach the transducer.
4. Connect the bar stimulus electrode to the isolated stimulator output of the PowerLab. The leads are color-coded; plug the red lead into the red socket and the black lead into the black socket (Figure 1).



5. Turn on the PowerLab.
6. Make sure the Isolated Stimulator switch on the front of the PowerLab is turned off (down).
7. Locate Chart on the computer and launch the program.
   If the *Experiments Gallery* dialog window does not appear in front of the *Chart* window, choose the *Experiments Gallery…* command from the *File* menu.
8. In the Experiments Gallery dialog window, select the settings file “212 Nerve Effect Settings” in the right-hand list and click the **Open** button to apply those settings.
9. A *Chart* window with two channels will appear. The upper graph will show force measured by the pulse transducer and the lower graph will show electrical stimuli.
10. Click ***Start***. You should see one stimulus per second on the lower graph. Tap on the pulse transducer to see the effect of a change in force. The *Chart* Window should look like the figure at right.



Locating a motor point.



Motor points are locations on the body surface where nerves controlling skeletal muscles lie close to the skin. If a stimulating electrical current is given at a motor point, the nerve is stimulated and the muscle will contract in response. In this part of the lab, you will locate a motor point for the **median nerve**, which controls the **flexor digitorum superficialis**, a muscle responsible for fast flexing of the fingers.

1. One member of each group should volunteer as subject. Anyone who has a cardiac pacemaker or suffers from neurological or cardiac disorders should not volunteer. If the volunteer feels major discomfort during the exercises, discontinue the exercise and consult your instructor.

2. Place a tiny amount of electrode cream on the two silver contacts of the stimulating bar.

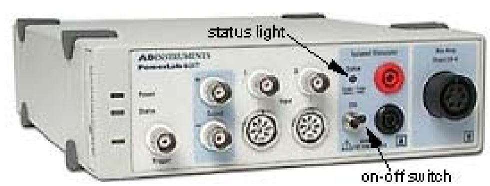
3. The volunteer should place one arm, palm up on the desktop, and position the stimulus electrodes as illustrated at right. The silver electrodes should face down and touch the skin. The electrode bar should be parallel to the long axis of the arm, with the wires pointing towards the hand. The volunteer can hold the electrode bar in place with the fingers of their other hand.

4. Turn the stimulator switch on the PowerLab unit to the **ON** position (up).

5. If the subject feels unacceptable discomfort, they can immediately stop stimulation by removing the stimulus electrode. You can also stop the stimuli by turning the PowerLab stimulator switch **Off**, or clicking the Chart's ***Stop*** button on the computer screen. Stimulation in most places gives rise to little discomfort. In some places, there is a substantial sensory effect: there may be a painful sensation in the forearm or hand, away from the site of stimulation (towards the fingers). At these places, a cutaneous sensory nerve is being stimulated.

6. The electrical stimuli should produce twitches of the fingers or thumb if you are near the motor point. Pick the electrode up and move it from place to place until you locate the position giving the largest twitches of one of the fingers. **Mark that electrode position on the subject's skin** with a marker or ballpoint pen.

   Pick the electrode up to move it – sliding it from place to place will leave a smear of electrode cream, and stimulating current may flow across the skin rather than stimulating the underlying nerves. Wipe any excess electrode cream off the skin.

   If no twitch occurs and the subject cannot feel the stimuli, check that the electrodes are connected to the PowerLab, and the Stimulator switch is **On**. The stimulator status light should flash orange when the electrode is not touching the skin, and green when it is on the skin. If the stimulus status light does not flash green when the electrode is on the skin, you may need to put more electrode cream on the contacts.

   You may need to increase stimulus strength to observe a twitch: do this by choosing ***Stimulator Panel*** from Chart's **Setup** menu. An **Isolated Stimulator Panel** window will appear, and you can increase the Stimulus Amplitude setting. Do not change the other settings.

7. Once you have located a motor point that produces flexion of a finger, click the *Stop* button to stop *Chart* monitoring, and turn the stimulator switch **OFF** on the PowerLab. Close the Chart window.

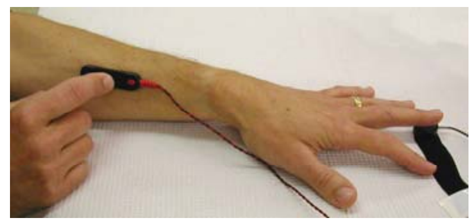
Determining Threshold Stimulus Amplitude and Observing Motor Unit Recruitment.

In this experiment you will gradually increase stimulus amplitude (measured in milliamps, mA), to determine the smallest stimulus that produces a detectable response (the **threshold stimulus amplitude**), and then examine the effect of increasing stimulus intensity above the threshold value.

1. Open the settings file **212 Muscle Stimulation Settings** from the **Experiments Gallery** in Chart's **File** menu. Each time you press the Start button, this file will record 4 seconds of data including four stimuli.

2. You should see a small floating Isolated Stimulator Panel below the Chart Window, where you can adjust the strength of the stimulus (Stimulus Amplitude, 0-20 mA) and stimulus frequency (0-20 Hz = 0-20 stimuli/sec). Make sure the settings in the Isolated Stimulator Panel match those in the illustration below. If you do not see the Isolated Stimulator Panel, choose **Stimulator Panel** from Chart's **Setup** menu.

3. The volunteer should place their hand as shown at right , with the finger that produced the greatest twitch response on the pulse transducer, and the bar electrode held on the motor point. Add more electrode cream before positioning the electrodes.



4. Turn the stimulator switch, located on the front of the PowerLab, to **ON** (the up position).

5. Click **Start**. Chart will record for a fixed duration of 5 seconds, then stop automatically.

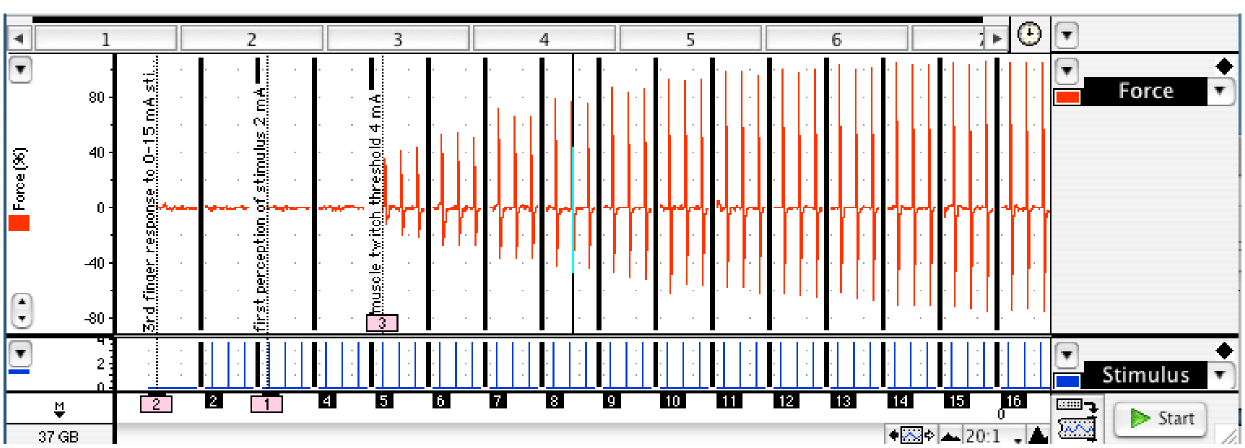
6. Increase the amplitude to **1.0 mA** and click **Start** again. Repeat until a twitch response is recorded on the **Force** graph. For most subjects, this ***threshold stimulus*** is in the range 3–8 mA.

7. When the first twitch response is seen on the **Force** graph, add a comment to the recording to note the stimulus amplitude used. To do this, choose **Add Commen**t from the **Commands** menu. Type your comment including the stimulus amplitude in mAmps in the **Comment** box of the resulting window, then click **OK**.

8. Continue to increase the stimulus amplitude in 1 mA steps until the response no longer increases. For most subjects, this ***maximal stimulus*** is in the range 6–15 mA.

9. Turn the stimulator switch **OFF** on the PowerLab.

10. Choose **Save** from the **File** menu to save the recording. Your data should resemble that in the figure below.



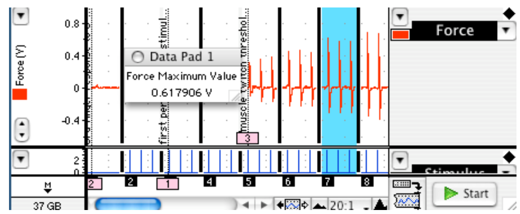
11. Measure the maximum force reading for each of the stimulus amplitudes you used as follows:

- Adjust the time axis scaling using the buttons near the bottom right of your Chart window 

so that all of your data are visible on the screen.

- Click on the  icon in the toolbar at the top of the Chart window to open a Data Pad miniwindow. The miniwindow will float wherever you position it on the screen and display the maximum Force in any selected subset of the data.

- Double-click in the time axis below the each section of your data. That should highlight that entire block of data, and the Miniwindow will display the maximum value of force for that experimental block. Write the stimulus intensity for that block and the corresponding maximum force on your data sheet.



12. Print a copy of your data as follows:

- Choose **Select All** from the **Edit** menu.
- Choose **Zoom Window** from the **Window** menu.
- Choose **Print Zoom** from the **File** menu.

13. Then close the **Zoom Window** by clicking the **Close** button in the upper left hand corner.Graph your data with Force on the Y-axis and Stimulus Amplitude on the X-axis.

Muscles are composed of many **motor units**. Each motor unit consists of a group of muscle cells all controlled by a single motor neuron, and the muscle cells in each motor unit contract in an all-or-none fashion. As additional motor units are stimulated the force of contraction increases (a process known as **recruitment**).

Can you use this information to account for the shape of your graph? Why is there a threshold? Why does contraction force increase with stimulus amplitude beyond this threshold? Why does contraction force reach a maximum, even though stimulus amplitude may continue to increase?

Double-click in the time axis to select one set of contractions as above, then choose **Zoom Window** from the **Window** menu. Did the muscle contraction start, or peak at the same time as the stimulus? How long was the delay (called latency) before contraction started? How long before it peaked? What do you think accounts for that delay? When you are finished with that analysis, close the **Zoom Window**.

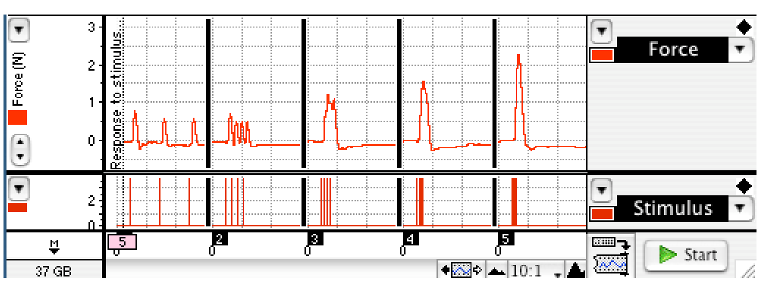
Did you save your data from the last experiment? Did you print the data and complete the graphical analysis? If so, continue with the next experiment.

Summation and tetanus

In this exercise, you will keep stimulus amplitude constant at a value that produced a maximal contraction in the preceding experiment, and examine the effects of changing the frequency with which the muscle is stimulated. With increasing frequency of stimulation, the muscle may not relax completely before the next stimulus arrives. As a result, a new contraction begins in a muscle fiber that is already partly contracted. What effect do you think this might have on the force of contraction of that muscle? State this as a hypothesis:

Then go on to test your hypothesis as follows.

1. Choose **Select All** from the **Edit** menu, then hit the **Delete** key, and **Delete** all of your data (you can get it back, if necessary, by reopening your saved data file).
2. Check the **Isolated Stimulator Panel** settings. **Frequency** should be **1 Hz**, and **Duration** should be **200 µsec**.
3. Set **Amplitude** at a **value that produced the maximal contraction force** in the preceding experiment.
4. Have your volunteer position their arm and the stimulating electrode in preparation for recording more data.
5. Turn the Stimulator switch on the PowerLab to **ON**.
6. Click **Start** to deliver a set of four stimuli. If that produces four large twitches continue with the next step. If your subject's finger does not twitch, they should reposition the electrode until pressing **Start** records a series of twitch contractions.
7. Increase the stimulus **Frequency** to **3 Hz** (3 stimuli/second) in the Isolated Stimulator Panel (do not change the Amplitude), and then click **Start** again.
8. Repeat the stimulation for the frequencies **5, 7**, **10**, **15** and **20 Hz**.
9. When you are finished, turn the stimulator switch on the front of the PowerLab to **OFF**.
10. Choose **Save** from the **File** menu to save the recording. Your data should resemble that in the figure below.



11. Print a copy of your data as follows:
    Choose **Select All** from the **Edit** menu.
    Choose **Zoom Window** from the **Window** menu.
    Choose **Print Zoom** from the **File** menu.
    Then close the **Zoom Window** by clicking the **Close** button in the upper left hand corner.
12. Measure the maximum force reading for **each** of the stimulus frequencies you used as follows:

    Adjust the time axis scaling using the buttons near the bottom right of your Chart window 

    so that all of your data are visible on the screen.

    If your Data Pad miniwindow is not already open, click on the  icon in the toolbar at the top of the Chart window to open a Data Pad miniwindow.

    Double-click in the time axis below the each section of your data. That should highlight that entire block of data, and the Miniwindow will display the maximum value of force for that experimental block. Write the **stimulus frequency** for that block and the corresponding **maximum force** on your data sheet.

13. Graph your data with **Force** on the **Y-axis** and **Stimulus Frequency** on the **X-axis**.

Do your results match your hypothesis?

The increase in force of contraction when stimulus frequency increases so that one stimulus follows another before the muscle is fully relaxed is called **temporal summation**. When the stimuli occur so frequently that the muscle does not relax at all, the sustained contraction is called **tetany**. In life, your nervous system often stimulates skeletal muscles with bursts of stimuli at high frequency, to take advantage of the resulting increase in force.

What evidence suggests that the mechanism of temporal summation is not the same recruitment mechanism that you saw in the preceding experiment?