

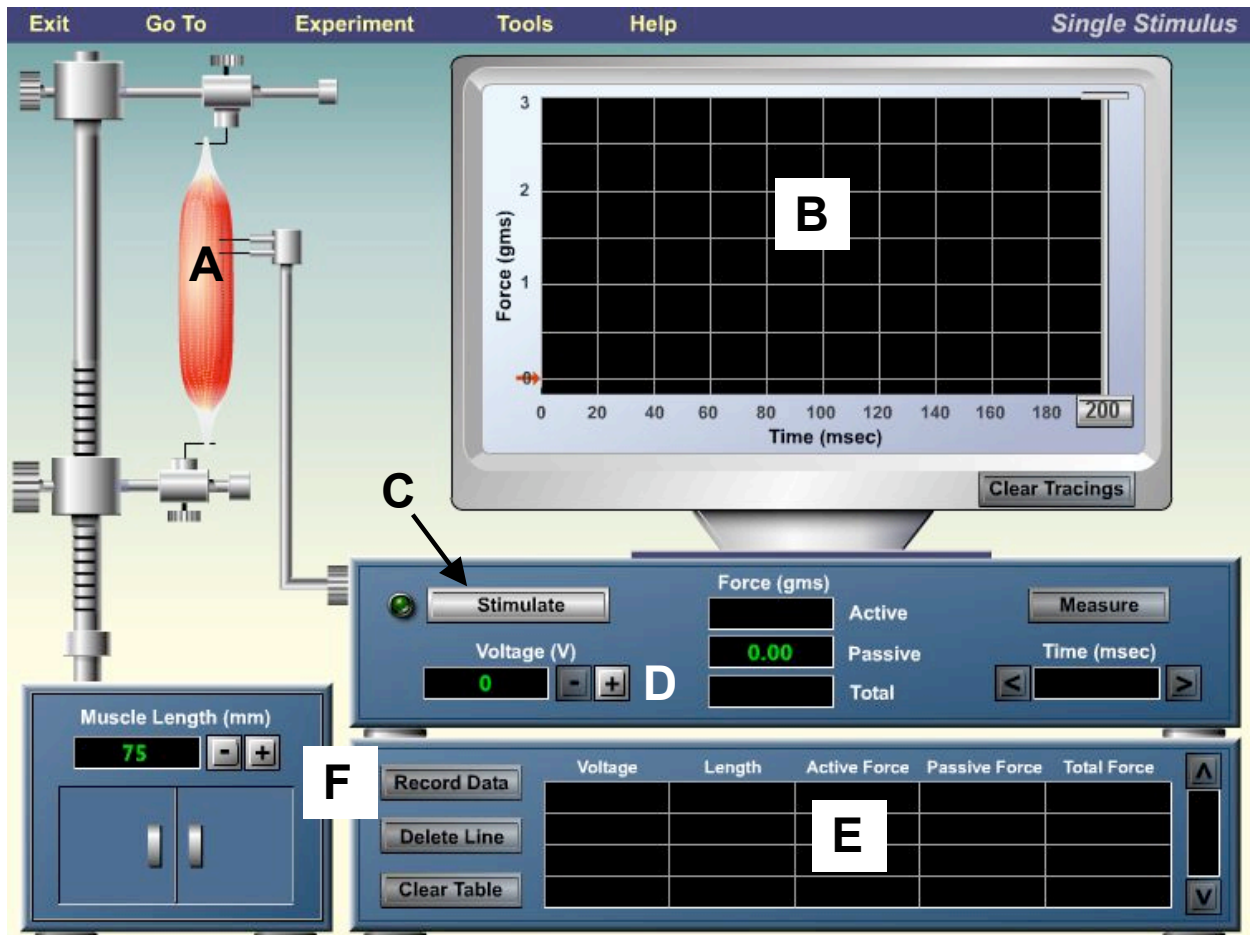
**Objectives:**

- Use a simulation of skeletal muscle experiments to investigate the concepts of the **latent period, threshold stimulus, maximal stimulus, recruitment** (also known as multiple motor unit summation), **wave summation** and **tetanus**.
- Develop and test hypotheses related to muscle contraction.
- Practice graphing data from an experiment.
- Practice interpreting a graph and drawing conclusions from data.

**Setting Up PhysioEx on lab laptops:**

Note: If you are using your own computer, insert your CD and proceed directly to step 7.

1. Plug in the laptop and the mouse provided.
2. Open the laptop and press the power button to turn it on.
3. When the Windows XP window appears, press **Ctrl-Alt-Del**.
4. At the login screen:
  - Make sure the login field is set to *user*.
  - No password is needed.
5. When the desktop has loaded, press the button on the CD tray on the righthand side of the laptop. The tray will pop open.
6. Snap the CD onto the tray and close the tray. (The CD is packaged in the back cover of your lab manual.)
7. The software will boot up automatically. It should take you to a screen with a clockface. The red second hand on the clockface should be moving.
8. Click on **Proceed**.
9. On the license agreement screen, press **Agree**.
10. Click on the **Main Menu** button.
11. Click on **Skeletal Muscle Physiology**.
12. You should see a screen that resembles the figure on the following page.



Some features of the simulation:

- A. the muscle that you will be testing
- B. the oscilloscope display, which will display your muscle tracings
- C. the **Stimulate** button; this will deliver stimulus to the muscle
- D. the **Voltage** adjustment (0-10.0 V)
- E. the spreadsheet that you will use to collect your data
- F. the **Record Data** button, which saves muscle data in the spreadsheet

**Note:** You have the option to change the length of the muscle. For this activity, there is no reason to change the muscle's length. It should remain constant at 75 mm.

\* Furthermore, muscle length will **not** be an answer to any question in this activity!

## Part 1: Generating a tracing.

1. Click on the **Stimulate** button. Because the voltage is set to 0 V, the muscle will not contract. You should see a blue line move across the display. This line represents the force of muscle contraction during the experiment.
2. Click and hold the **[+]** button beneath the Stimulate button until the voltage window reads 3.0 V. Click the **Stimulate** button once and you should see the

muscle react to the stimulation. On the display window, a new yellow line will appear on the screen. (The colors of the tracings will alternate between blue and yellow throughout the simulation.)

3. Practice recording your data in the spreadsheet by clicking on the **Record Data** button. Your simulation data are now saved in the spreadsheet. Notice that the spreadsheet saves both active and passive force. For our purposes, we are only interested in total force (saved in the last column). However, active and total force will always be the same throughout the simulation.
  4. Practice changing the stimulus strength one more time. Press and hold the **[+]** button to change the voltage to 5.0 V. Press the **Stimulate** button once and observe how increasing the strength of the stimulus changes the tracing.
  5. Press the **Record Data** button to save your new data in the spreadsheet. You need to press **Record Data** after each stimulation in order to record the data. If you forget to save the data, it will be lost.
  6. To clear the oscilloscope display, click the **Clear Tracings** button. To clear the contents of the spreadsheet, click the **Clear Table** button. The software will ask you if you really want to delete the data. Click **Yes**.
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## Part 2: Determining the latent period.

1. With the voltage set at 5.0 V, stimulate the muscle.
2. Notice the latent period towards the lefthand part of the tracing.
3. To measure the length of the latent period, click on the **Measure** button. This puts a vertical yellow line on the display screen. You can move this yellow line to the left or right with the arrow keys associated with the Time (msec) window (below the Measure button). Practice moving the line to the right, and then to the left. Notice that, as the yellow line moves, it provides you with a time reading (in msec) in the Time window. By moving the yellow line to a specific event in the tracing, you can determine the time that this event occurs.
4. Return the yellow line to the lefthand margin of the display using the **[-]** button.
5. To determine the length of the latent period, slowly move the yellow line across the tracing until the latent period has ended.

► **Question 1:** Record the length of the latent period: (2 pts) \_\_\_\_\_ msec.

► **Question 2:** Describe what is happening inside the muscle fibers during the latent period (2 pts).

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**Part 3: Obtaining graded contractions by increasing stimulus strength.**

1. Clear any tracings in the display window and clear the spreadsheet (if there are data in it).
2. Reset the voltage to 0 V.
3. Click **Stimulate**.
4. Record the data in the spreadsheet.
5. Repeat steps 3 and 4, increasing the stimulus strength by 0.5 V each time. Make sure to record the data in the spreadsheet after each stimulus.
6. Continue until you reach a stimulus of 10 V.

► **Question 3:** What is the threshold stimulus? (1 pt) \_\_\_\_\_ V

► **Question 4:** What is the maximal stimulus? (1 pt) \_\_\_\_\_ V

► **Question 5:** When you increase the voltage, what is happening in the muscle tissue to cause the increase in force that you observe? (2 pts)

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► **Question 6:** What variable did you hold constant in this experiment? (1 pt) \_\_\_\_\_

► **Question 7:** What variable did you change? (1 pt) \_\_\_\_\_

► **Question 8:** What term that describes this phenomenon? (2 pts) \_\_\_\_\_

7. Select **Print Data** under the **Tools** menu.
8. In the pop-up window, give the document a name that you will recognize when it comes off of the printer.
9. Click the **Print** button. The document will print to the laser printer in the back prep room (S-545). Print enough copies for everyone in your lab group.
10. On the graph paper provided, graph the data. Place total force (in grams) on the Y-axis and voltage (in volts) on the X-axis. Make sure you label the axes clearly and include the units (5 pts).
11. Along the X-axis, label the threshold stimulus and the maximal stimulus (1 pt each).
12. Give the graph an original, meaningful, descriptive title. Example: "The effect of increasing voltage on the force of skeletal muscle contraction." Don't steal my title! (1 pt)
13. Think about how you determined the threshold stimulus and then devise an experiment to determine a more accurate threshold stimulus.

► **Question 9:** Describe how you will conduct your experiment here (3 pts).

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14. Perform your experiment.

► **Question 10:** According to your experiment, what is a more accurate measure of the threshold stimulus? (2 pts) \_\_\_\_\_ V

**To continue:**

Select **Multiple Stimulus** from the Experiment menu at the top of the screen.

Notice that you now have a window that allows you to change the number of stimuli per second delivered to the muscle.

## Part 4: Investigating Wave Summation

1. Clear any tracings from the display and delete any data in the spreadsheet.
2. Set the voltage at 8.2 V and make sure that the muscle length is 75 mm.
3. Click **Single Stimulus**, and then click **Single Stimulus** again when the muscle has relaxed about halfway.

► **Question 11:** Is the force produced by the second stimulus greater than that produced by the first stimulus? (1 pt) \_\_\_\_\_

4. Clear the tracing.
5. Try step 3 again, but this time click the **Single Stimulus** button several times in rapid succession.

► **Question 12:** Does the total force continue to increase with subsequent stimulations? (1 pt)

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## Part 5: Investigating Tetanus

1. Clear any tracings from the display screen.
2. Check that the voltage is set to 8.2 V.
3. Click and hold the **[+]** button to set the stimulus rate to 30 stimuli/sec.
4. Click the **Multiple Stimulus** button. As you can see on the tracing, the muscle is now receiving a series of stimulations. When the tracing reaches the right side of the display, press **Stop Stimulus**.
5. Record the data in the spreadsheet.

► **Question 13:** Using non-scientific language, describe the appearance of the tracing. (2 pts)

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6. Increase the stimulation rate by 10 stimuli/sec incrementally up to 150 stimuli/sec. Record the data in the spreadsheet after each tracing.

► **Question 14:** What variable is being held constant? (1 pt) \_\_\_\_\_

➤ **Question 15:** What variable are you changing? (1 pt) \_\_\_\_\_

➤ **Question 16:** How does the appearance of the tracings change as the stimulation rate is increased? (2 pts)

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➤ **Question 17:** What happens to the total force over time as you increase the stimulation rate? (2 pts)

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➤ **Question 18:** Describe what happens to the muscle's ability to relax as you increase the stimulation rate. (2 pts)

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➤ **Question 19:** Why does increasing the frequency of stimulation produce a smoother response? (What is happening inside of the muscle fibers?) (2 pts)

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7. Select **Plot Data** under the **Tools** menu.
8. Click on the **Print Plot** option. It appears on the top of the graph window. Print enough copies for everyone in your lab group.
9. Attach your graph to this handout (2 pts).
10. By looking at your graph, estimate the stimulation rate at which there appears to be no significant increase in force. **Circle this data point on your graph.**
11. Clear the tracings from the display window and delete the data from the spreadsheet.
12. Look at your current settings. You should have the voltage set at 8.2 V and the stimulation rate set at 150 stimuli/sec.
13. Click on the **Multiple Stimulus** button. When the tracing reaches 120-140 msec, press **Stop Stimulus**.
14. Think about what this tracing is showing you. Imagine that this is what your muscles are doing when you're lifting weights at the gym. Notice that there is a considerable amount of force being generated, but that the contraction is smooth and steady.

► **Question 20:** Your muscles need to generate a great deal of tension to lift the weights. What is the term given to the force generated by the weights that the muscles need to overcome in order to shorten? (1 pt) \_\_\_\_\_

15. After you leave the gym, you go to a fancy restaurant for dinner where you order an expensive bottle of Merlot. The waiter pours you a glass of wine. When you pick up the glass of wine, you want to contract your muscles in a smooth fashion, but you don't want to generate as much force as you did in the gym. (If you did, you would probably splash the wine in your face!)

► **Question 21:** Why is the force needed for picking up the glass of wine less than the force needed for lifting the weights? (2 pts)

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16. Devise an experiment that would decrease the muscle's force while maintaining a smooth contraction. While you're brainstorming, feel free to play around with the simulation to achieve your desired results. (Trial and error is one way to address this question, but here's a hint: think about what you learned in **Part 3** of this activity.)
17. When you've come up with a way to decrease the force while keeping the contractions smooth, continue with the exercise.

► **Question 22:** What variable will you change in your experiment? (1 pt) \_\_\_\_\_

► **Question 23:** Describe how you will perform your experiment (4 pts).

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18. Before beginning your experiment, clear any of your practice tracings. Start your experiment with the settings recommended in step 12.

19. Perform your experiment, changing your variable in regular increments. After each tracing, record your data in the spreadsheet.

20. Select **Plot Data** from the **Tools** menu. On the graph window, use the slider bars to plot total force on the Y-axis and your variable\* on the X-axis. (\*This would be your answer to Question 22 above.)

21. Click on **Print Plot** on the top of the graph window. Print copies for each lab group member. Attach your graph to this handout (2 pts).

► **Question 24:** Describe what is happening in the muscle to generate these smooth contractions of lesser force (4 pts).

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