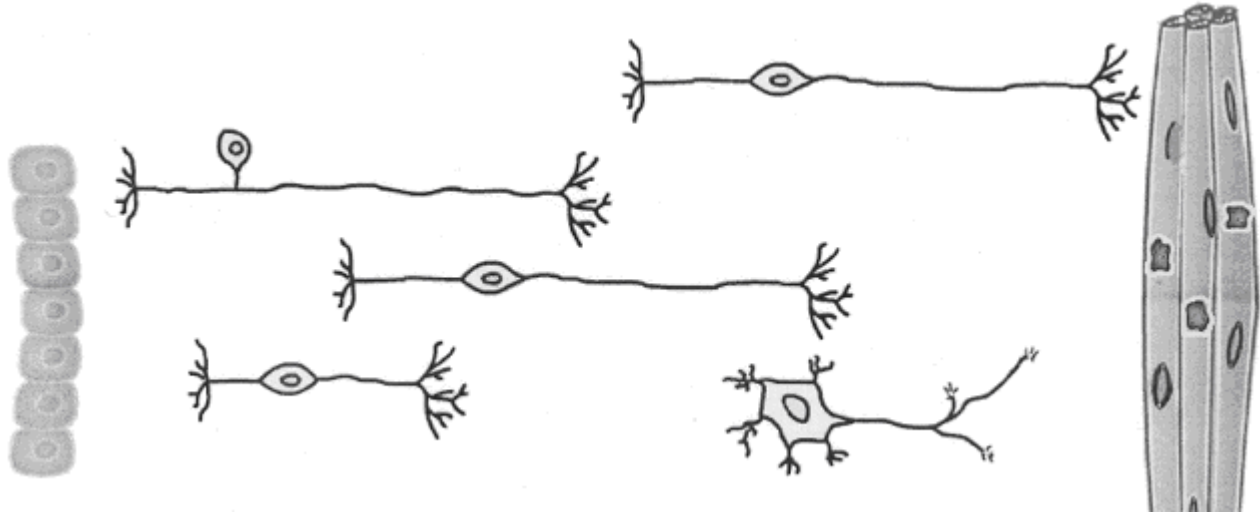


To begin, follow your teacher's directions to open the Virtual Neurons software.

On the left side of the screen is a group of skin cells. On the right side of the screen is a group of muscle fibers. In the middle are different types of neurons.



**Part 1 – Making the initial neuron connection**

**Your Mission:** to get a message from the skin cells to the muscle fibers using any or all of the neurons, causing the muscle fibers to twitch

**How to accomplish your mission:**

1. Arrange the neurons to get a message from the skin cells to the muscle fibers.
2. After arranging the neurons, press the Start button in the upper left-hand corner of your screen to test whether the arrangement makes the muscle fiber twitch.

**NOTE Neurons cannot be moved once the circuit is started.**

If the neurons are activated (firing action potentials) and you want to rearrange them, press the Stop button in the upper left-hand corner of the screen.

Draw a neuron that connects to the muscle fiber. What do you think is the name of this neuron?

Draw a neuron that receives information from the outside world (like from skin). What do you think is the name of this neuron?

Draw a connector neuron. What do you think is the name of this neuron?

**Part 2 – Changing neuron connections**

Once you have successfully made the muscle twitch, more tests can be conducted. Try the following suggestions and write down the names of the neurons you used.

Make the muscle twitch using two neurons. \_\_\_\_\_

Make the muscle twitch using three neurons. \_\_\_\_\_

Make the muscle twitch using four neurons. \_\_\_\_\_

Identify which neuron type would be MOST likely to...

- a. be connected to the skin of your finger: \_\_\_\_\_
- b. have its axons and dendrites in the spinal cord: \_\_\_\_\_
- c. be connected to your bicep: \_\_\_\_\_
- d. be connected to a taste bud: \_\_\_\_\_

Set up a series of three neurons, one of each neuron type, so that the muscle twitches.

- a. Press the Start button. Let the circuit run for 15 seconds. Click on the Stop button RIGHT AWAY when the time reaches 15 seconds. How many twitches happened? \_\_\_\_\_
- b. Calculate the “rate” of twitching. “Rate” means the number of times something happens in a certain period of time. To calculate the twitch rate, you divide the number of twitches by the number of seconds.

**Calculation**

$$\text{Twitch Rate} = \frac{\text{\# of Twitches}}{\text{\# of Seconds}}$$

$$\text{Your Twitch Rate} = \frac{\text{_____ Twitches}}{\text{_____ Seconds}} = \text{_____ twitches/second}$$

- c. Based on your calculated twitch rate, how many twitches do you think will happen in a minute (60 seconds)? \_\_\_\_\_ twitches
- d. Test your prediction by letting the circuit run for a minute.
  - How many twitches really happened in a minute? \_\_\_\_\_
  - Was your estimate correct? \_\_\_\_\_
  - If not, what might explain the difference in the number of twitches?

**Part 3 – Causing the Neurons to activate (or fire action potentials)**

1. Press SHIFT + S.
2. Enter the password your teacher provides.
3. The Neuron Setup window allows you to change the number of neurons to work with and allows you to activate new features.
  - a. Check the **Action Potential Meters** box.
  - b. Check the **Change Neuron Threshold** box.
  - c. Check the **Graph** box.
4. Click the **Save Setup and Start** button.
5. At the top of the screen, there are **Action Potential Meters** for each neuron.
  - An **action potential** is an electrical signal that travels along the axon, away from the cell body, to the axon terminal where it triggers the release of neurotransmitters.
  - The number of times an action potential triggers the release of neurotransmitter is recorded at the bottom right of each **Action Potential Meter**.
  - The green bar across the action potential represents the neurons' **threshold**, or the point at which a neuron produces an action potential.
  - The height of the red line indicates the membrane potential inside the neuron.
6. Set up a series of three neurons, one of each neuron type, so that the muscle twitches and let the circuit run for 10 seconds.
  - a. How many action potentials did the sensory neuron create? \_\_\_\_\_
  - b. How many action potentials did the interneuron create? \_\_\_\_\_
  - c. How many action potentials did the motor neuron create? \_\_\_\_\_
  - d. How many times did the muscle twitch? \_\_\_\_\_
  - e. Why is the number of times the muscle twitches different than the number of times the sensory neuron produces an action potential? If not, why not?
  - f. Click on GRAPH / SHOW to see a record of activity created when you ran your circuit. What does each red tick mark mean? If you are unsure, run your circuit again and turn the graph on immediately.
  - g. Use the graph to trace how many times each neuron fires and follow information flow through the circuit.

7. The green threshold bar can be moved up or down to change the set point at which the neuron produces an action potential. To change the threshold, click on the bar and slide it up or down.
- a. Increase the threshold, or move the bar up for the neurons.
    - How does this affect the number of times each neuron fires?
    - How does this affect the number of times the muscle twitches?
    - Can you see changes in the graph that reflect the changed thresholds?
    - Pretend you are the neuronal cell body adding up the incoming signals since the last time that neuron fired. When your count reaches the threshold level set by the green bar, does the neuron fire?
    - Make a table to record the thresholds and firing rates of the different neurons and muscle in the circuit. If you do this in a spreadsheet, use print screen to copy a picture of your circuit into the spreadsheet as well. Otherwise, make a sketch of your circuit to go with the table.

Neuron #	Sensory				Motor				Muscle	
Circuit sketch	Threshold	Firing Rate	Threshold	Firing Rate	Threshold	Firing Rate	Threshold	Firing Rate	Threshold	Firing Rate

- b. How do you think decreasing the threshold will affect when each neuron fires and the number of times the muscle twitches?
- c. Test your prediction using the graph to record what happens. Explain how your results compare with your prediction.

**Part 4 – Designing circuits**

Design a circuit to test how different arrangement of neurons (number and/or type) affects the muscle twitch rate. You will need to set up one circuit, test it, and then set up another circuit and test it. Continue to set up circuits and test them. You will not be able to set up two circuits at the same time. Turn on all the features of the Virtual Neurons program.

Using the setup menu (SHIFT + S + password), turn on Change Neuron Shapes and Advanced Neuron Shapes and choose how many neurons you want. Click Save setup and start. Click the Star Lollipop button and then click on the neuron whose shape you want to change. Click on the desired shape.

Design circuits to satisfy the following criteria or ones that your teacher gives you.

1. Design a circuit that sends information to the muscle through two different pathways.
2. What happens if a circuit has two inhibitory neurons in a row?
3. What happens when one of those circuits has an inhibitory neuron in it?
4. Design a circuit that makes the muscle twitch without any sensory input. Interneurons that fire spontaneously are called *pacemaker neurons*.
5. Design a circuit with a backward-going loop of excitatory neurons in it. How does the information in the loop change the firing rates of the other neurons and the muscle contraction rate?
6. Design a circuit with a backward-going loop with an inhibitory neuron in it. How does the information in the loop change the firing rates of the other neurons and the muscle contraction rate?
7. Can you take one of your circuits and get it to do the same thing with fewer neurons in it?

**Virtual Neurons Design Challenge**

Write this out on a separate sheet of paper.

**Problem Statement:** Write a set of design goals for a neuronal circuit you want to create.

**Prediction:** Write down how you think such a circuit might work and explain why you think so.

**Make and test your circuit:** The first version may not work as you intended. Capture the circuit performance with print screen and paste it into a document or spreadsheet. Calculate the rates of neuronal firing and muscle twitching. Analyze when and how information flows through each part of the circuit. Compare this performance with your design criteria.

**Data:** What information do you need to record to help you determine if your circuit is working properly? Make a table to record your data and create a graph to display it. Write a few sentences to summarize the data.

**Conclusion:** Put your conclusions together as a paragraph. Be sure to include the following information:

- Identify whether your prediction accurately described how the circuit really worked and why.
- How did you have to change your circuit to get the desired behavior?
- Explain what your data allows you to conclude about how the circuit works.
- Address whether or not your results agreed with your prediction.
- List ways the circuit could still become better.
- List any new problems you thought of while you were building the circuit or analyzing how it operated.