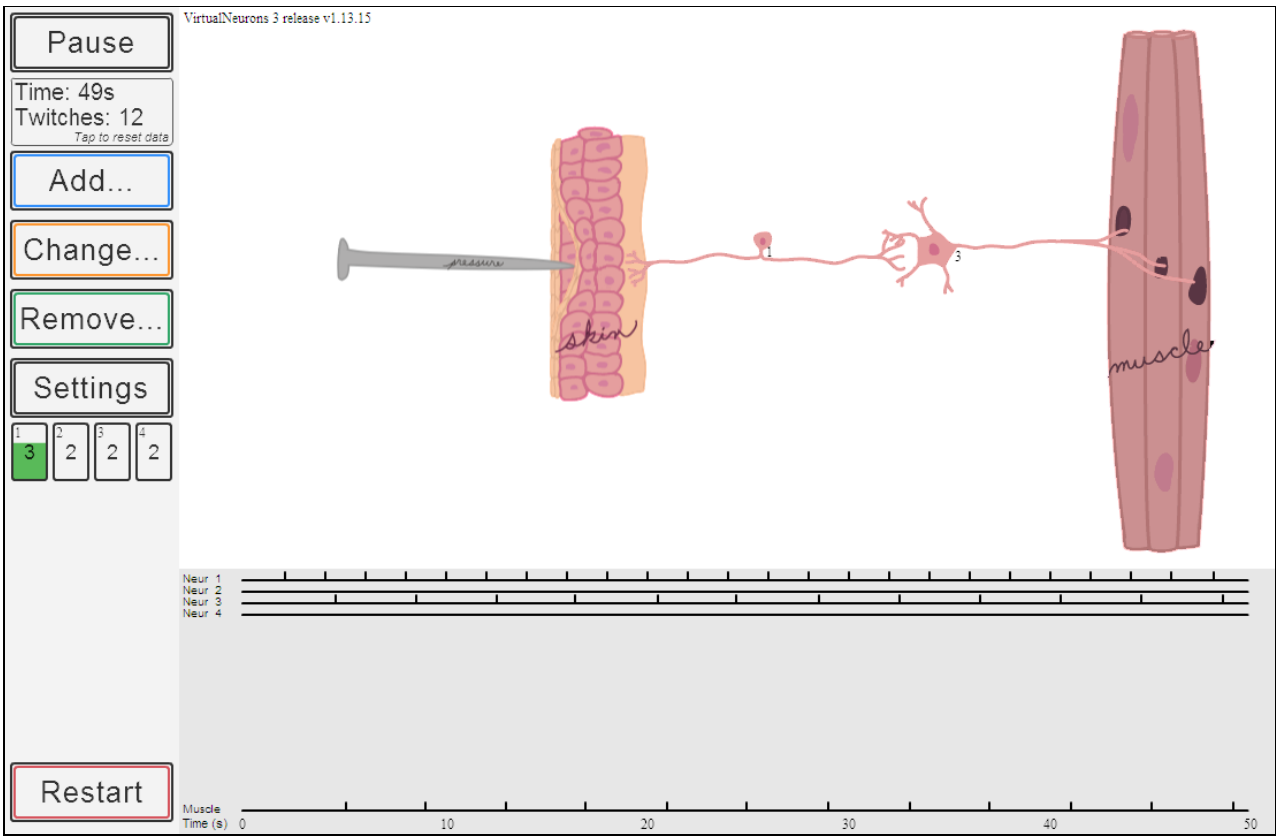
Circuits in this document are suggested variations on circuits illustrated in the teacher guide. When examining any of these circuits, remember to calculate individual neuron firing rates and muscle contraction rates. Quantitative comparisons may yield subtle differences.

A 2 neuron simple circuit



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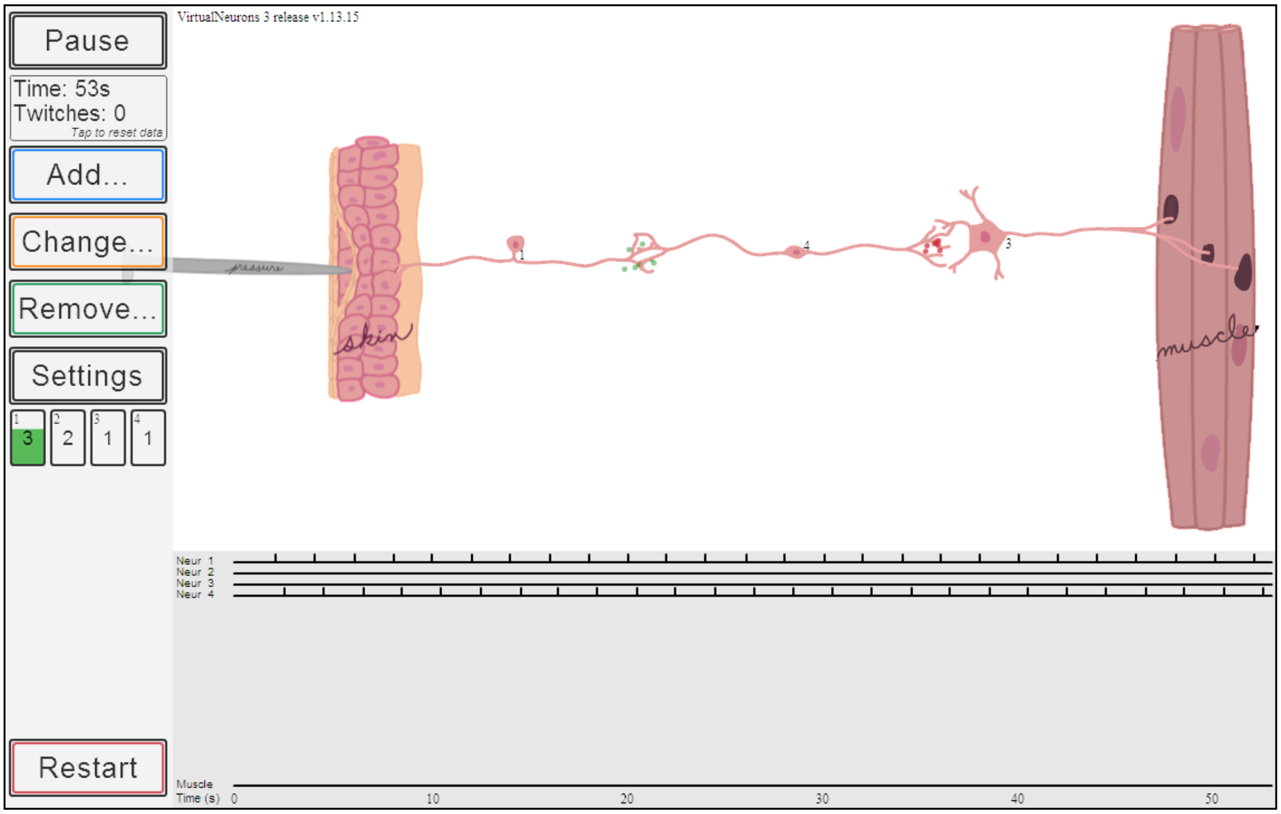
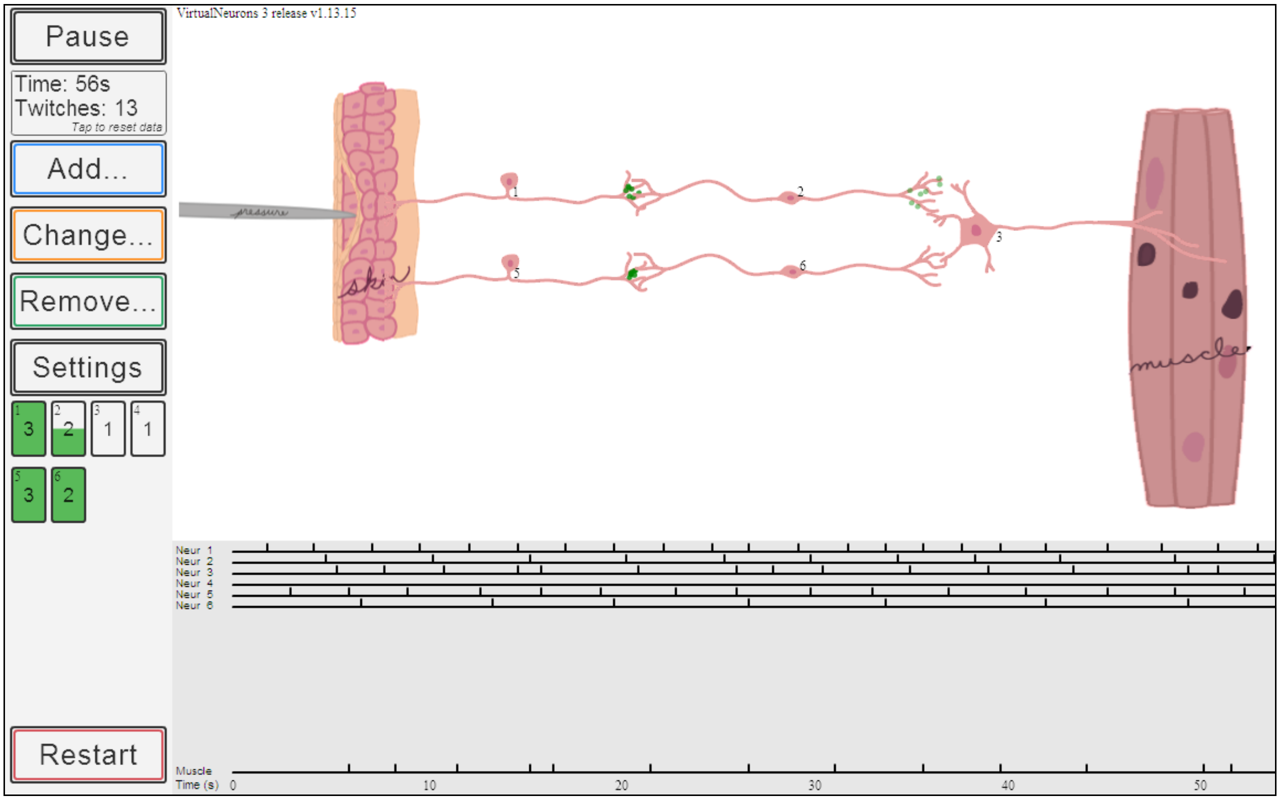
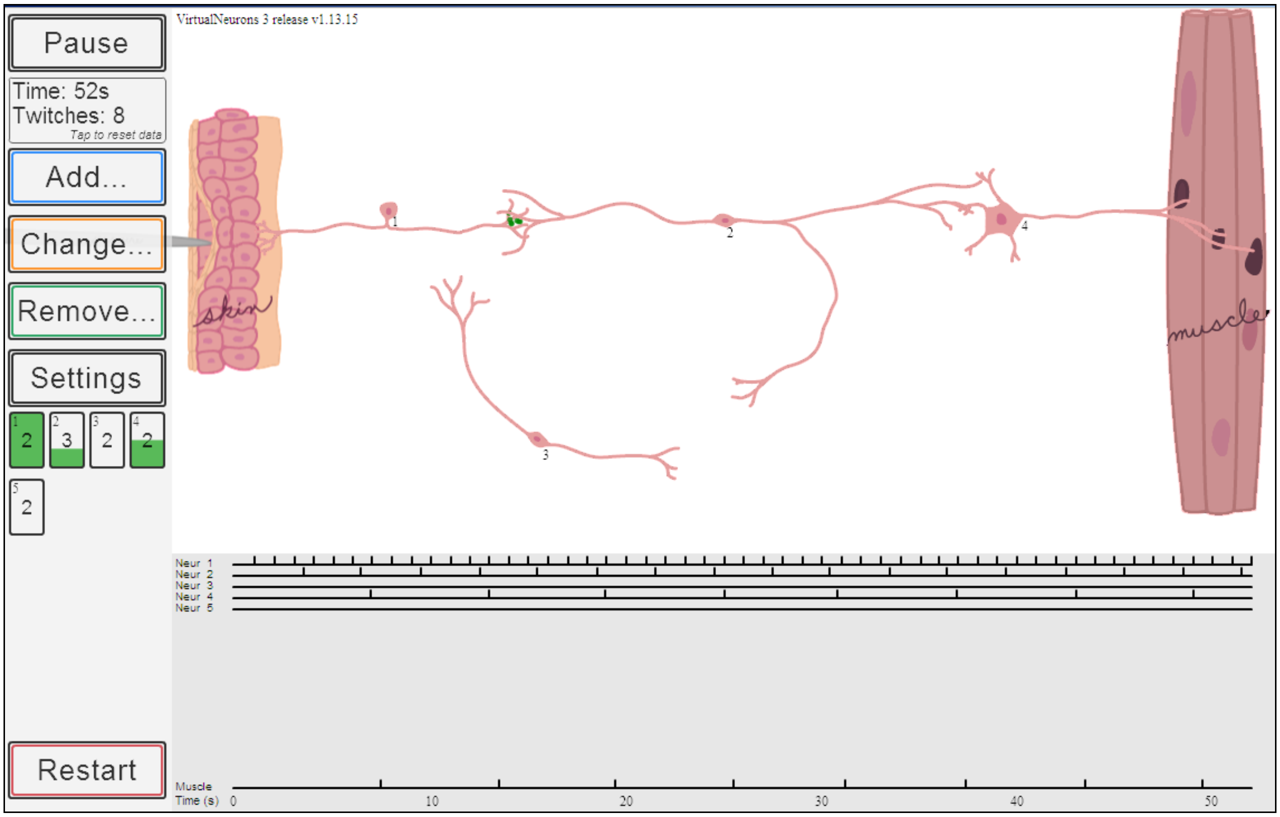
3 neuron circuit with inhibitory interneuron



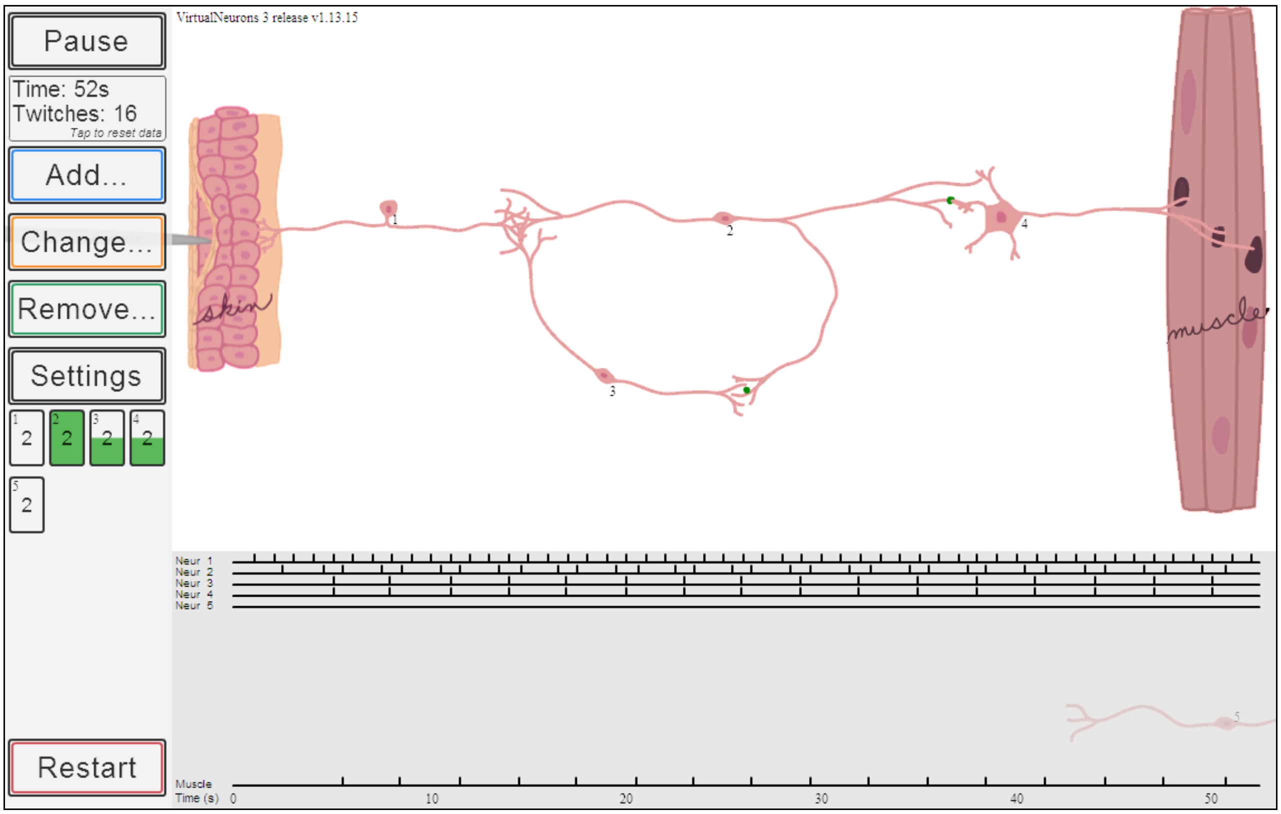
Two sensory neurons with excitatory connections to the motor neuron



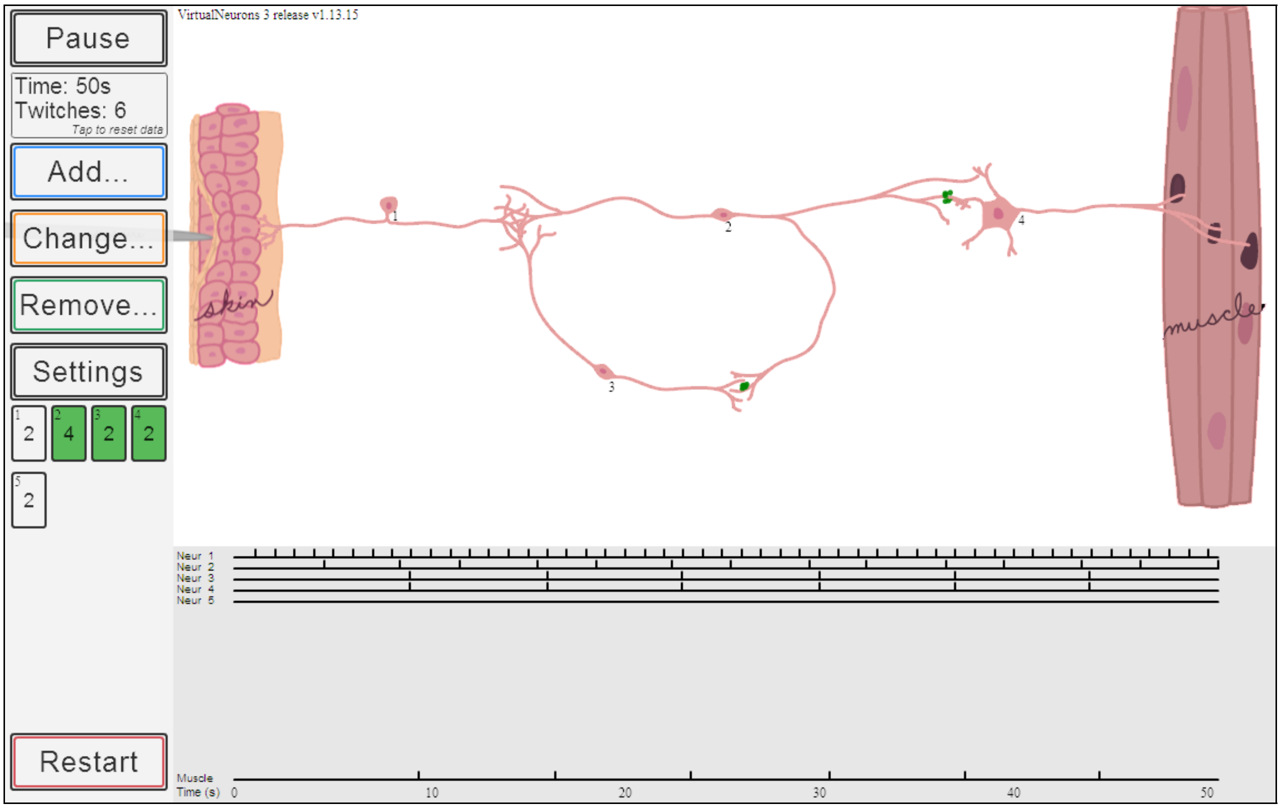
Feedback loop with feedback neuron removed



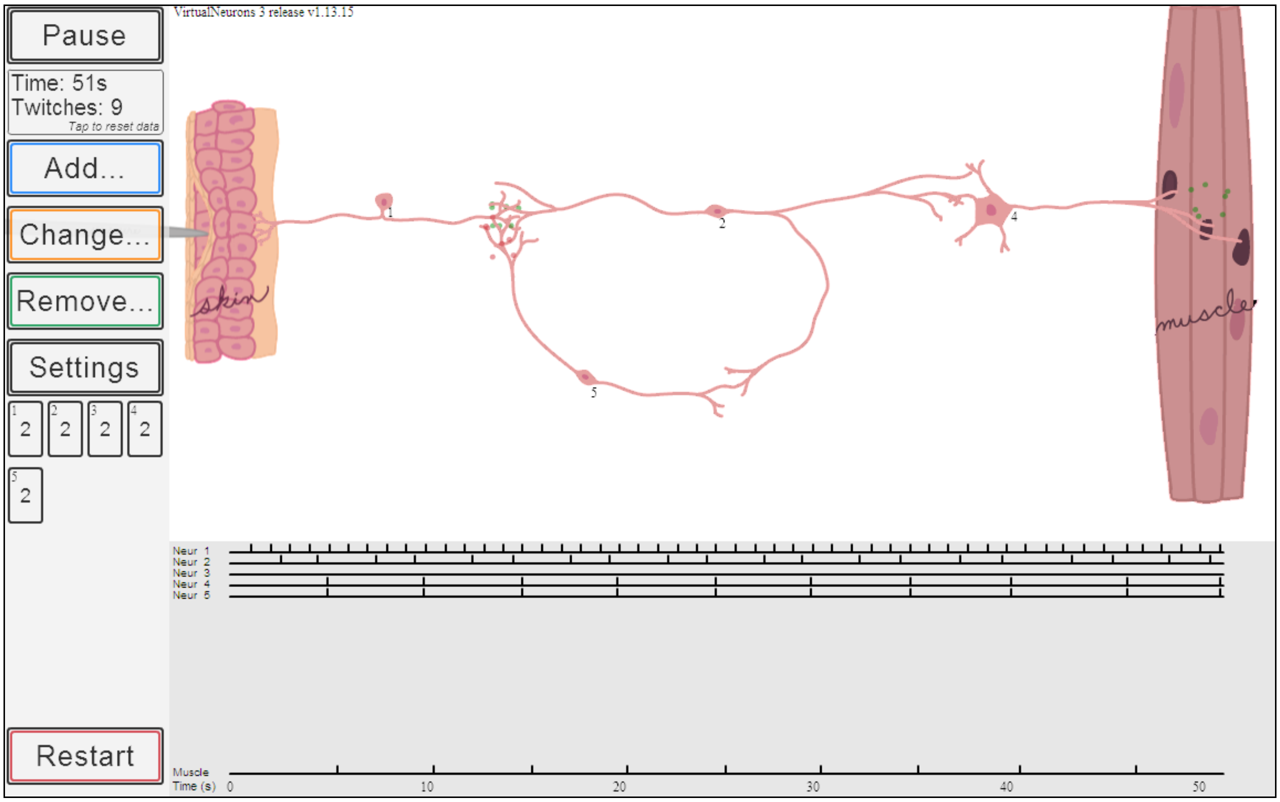
Positive feedback loop with the threshold for neuron 2 set too low to see any effect of the feedback



Positive feedback loop with neuron 2 threshold raised

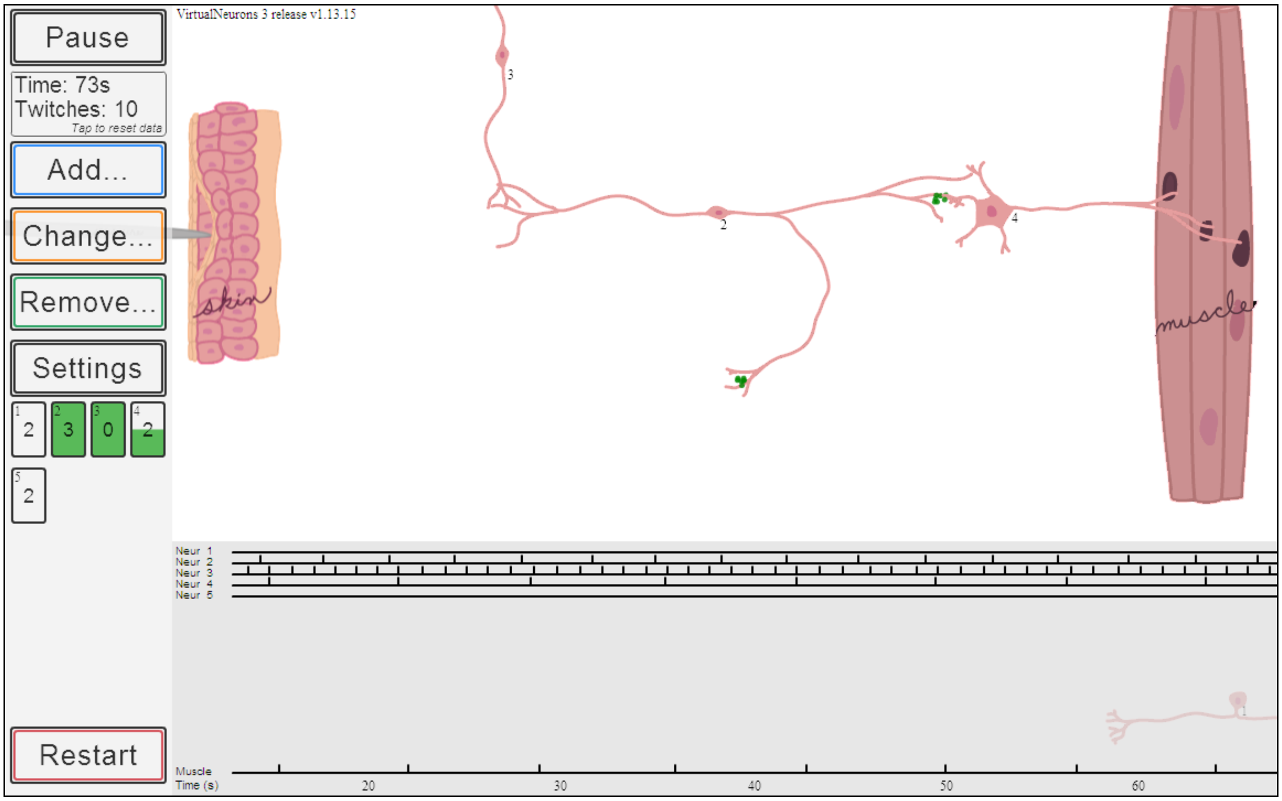


Negative feedback loop with neuron 2 threshhold lowered



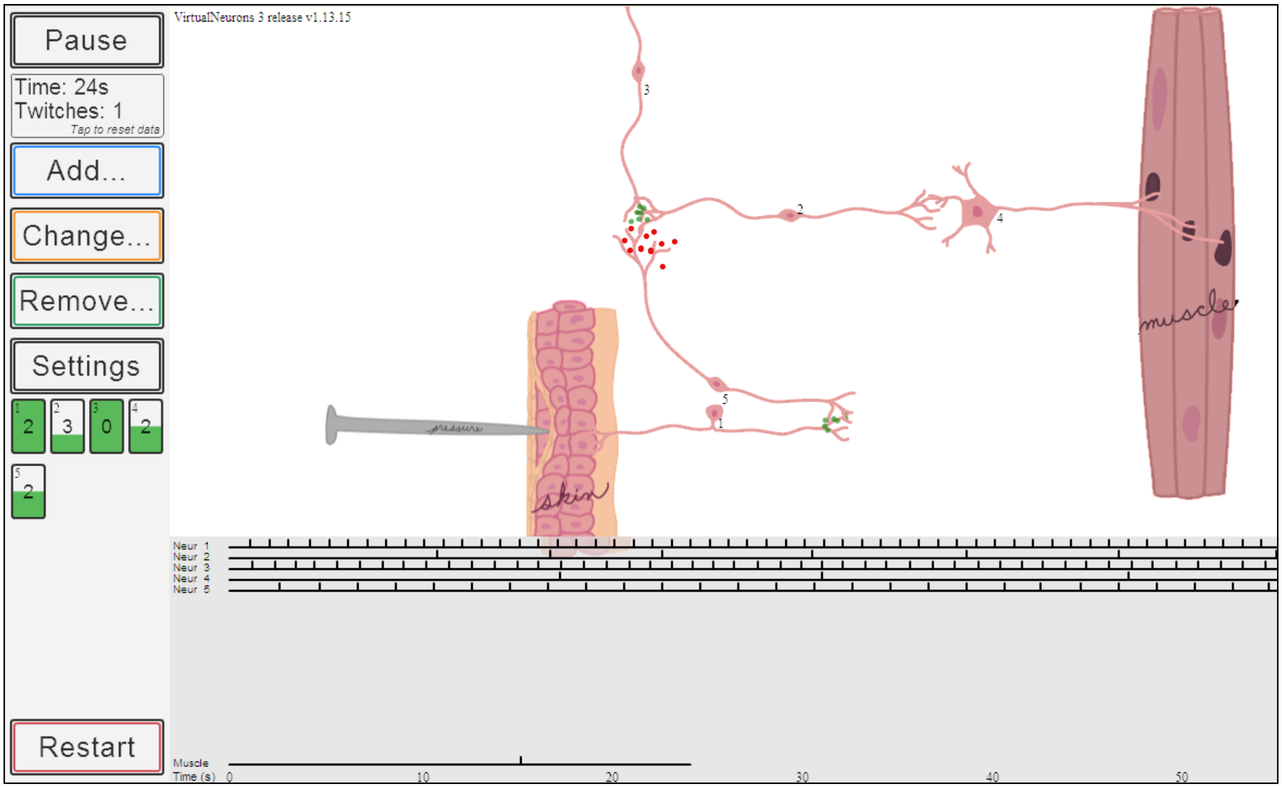
One way to make a muscle contract without any sensory input

Note threshold on neuron 3.



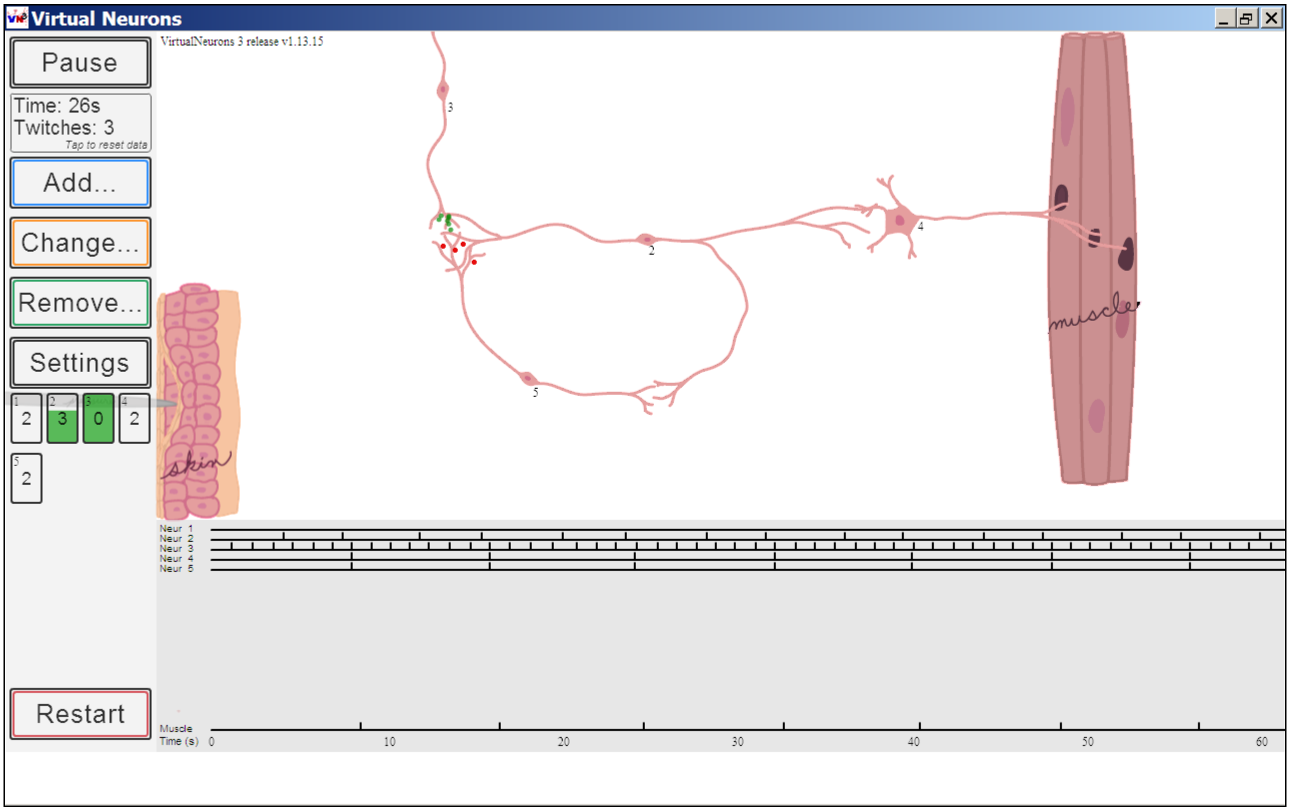
Spontaneously driven muscle contraction modified by sensory input

Is neuron 5 excitatory or inhibitory? Why?



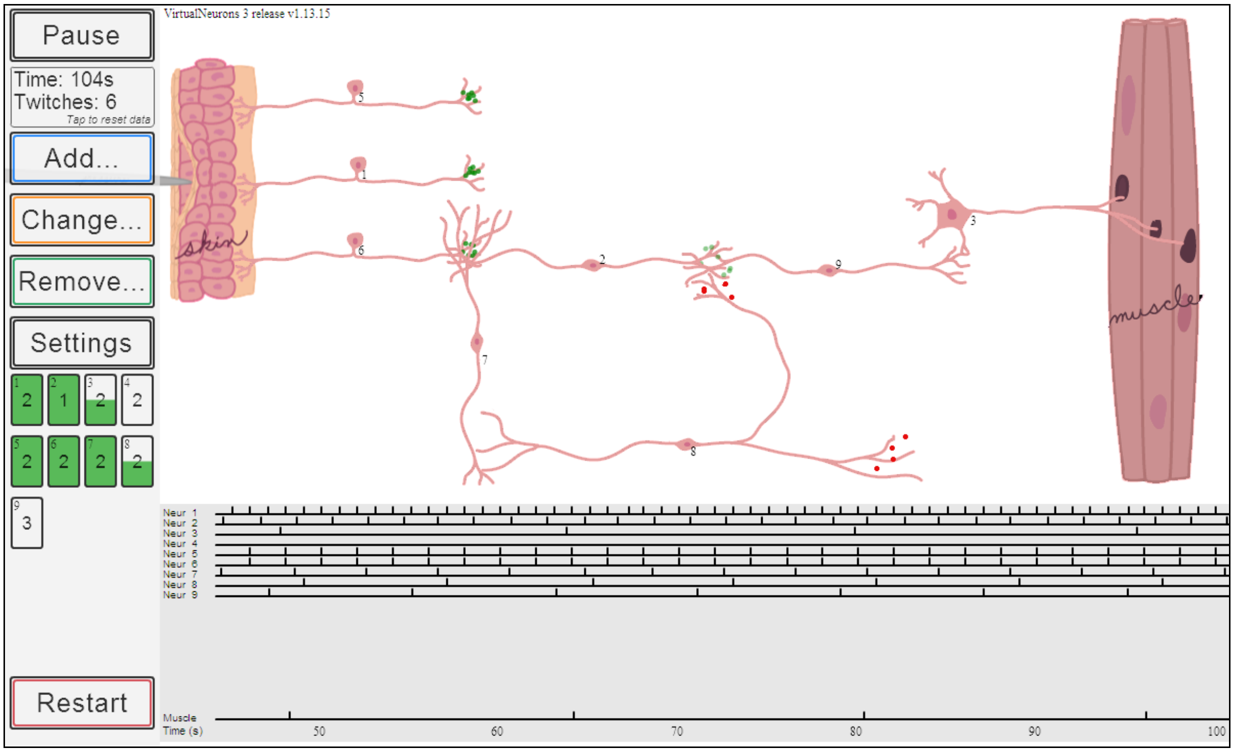
Spontaneously driven muscle contraction modified by a feedback loop

Is neuron 5 excitatory or inhibitory? Why?



The next sequence of screen shots demonstrates a series of related circuits.

An example of a feed-forward loop formed from multiple neurons

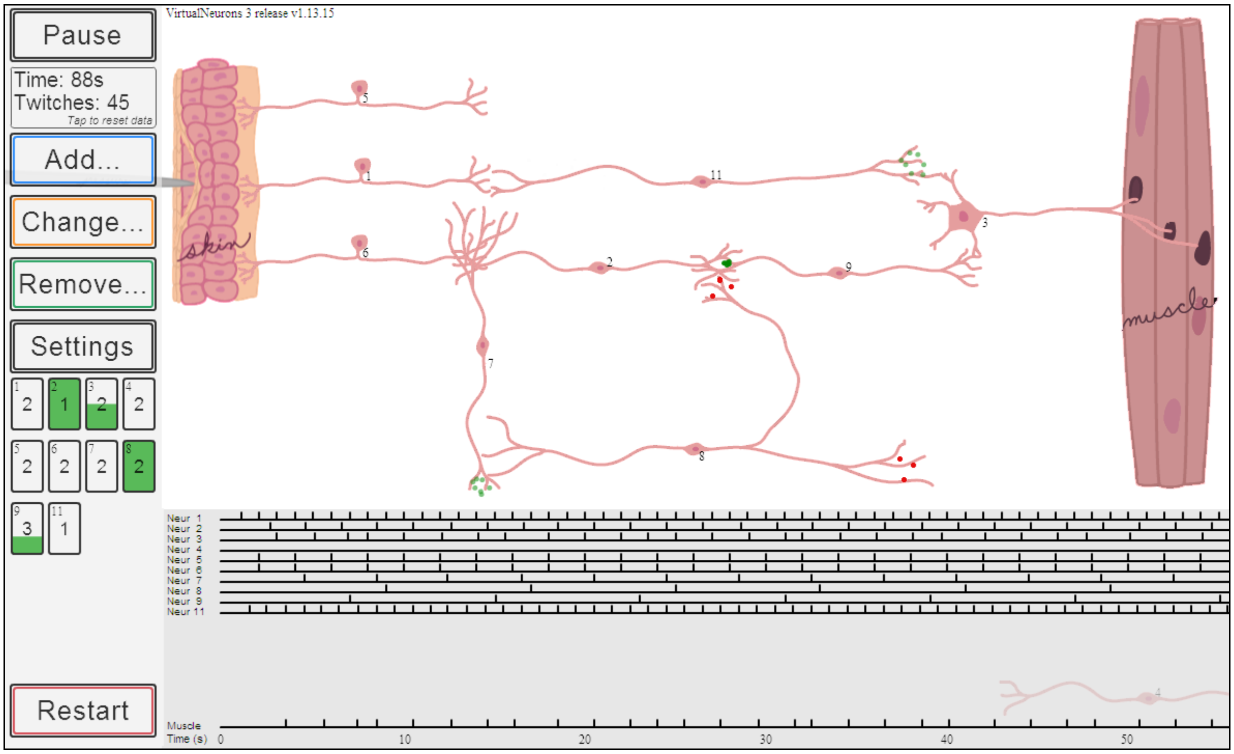


Which neuron is the inhibitory one?

How fast would the muscle contract in this circuit if neurons 7 and 8 were not in it?

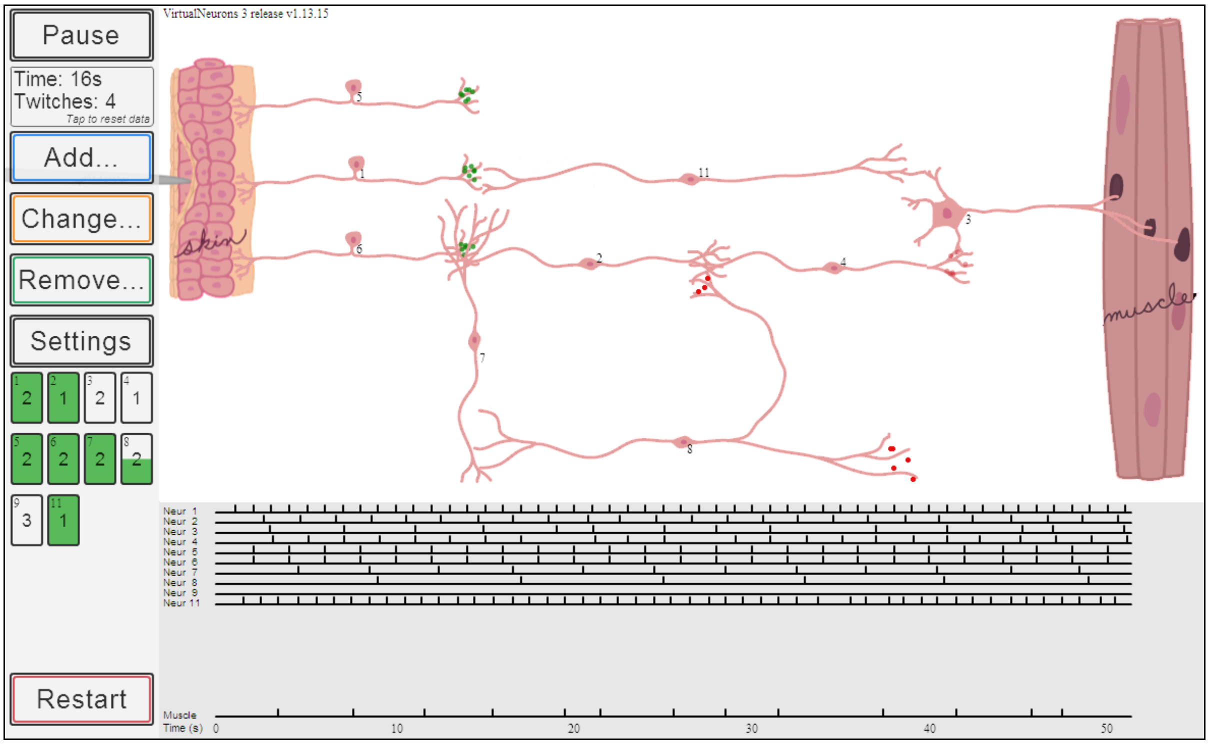
What is the effect of the feed forward loop? How does this differ from feedback?

The muscle is now driven by two different input rates.



When will the muscle contract next?

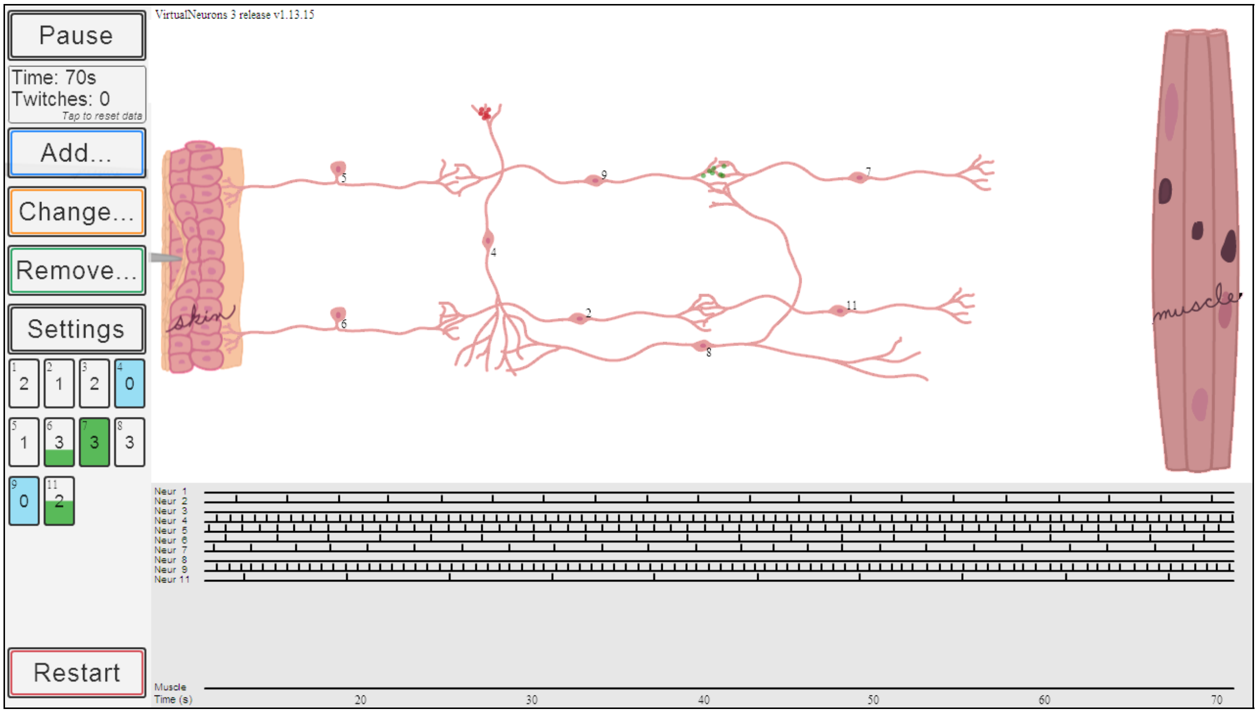
The same circuit as on the previous page, but with the excitatory neuron 9 changed to an inhibitory neuron 4.



Compare the muscle contraction rates between these 2 circuits.

The following circuit demonstrates how 2 separate inputs (neurons 5 and 6) can generate oscillating or rhythmic outputs (neurons 7 and 11) through cross inhibition. Neurons 4 and 8 are inhibitory. The thresholds have been adjusted to make the circuit work.

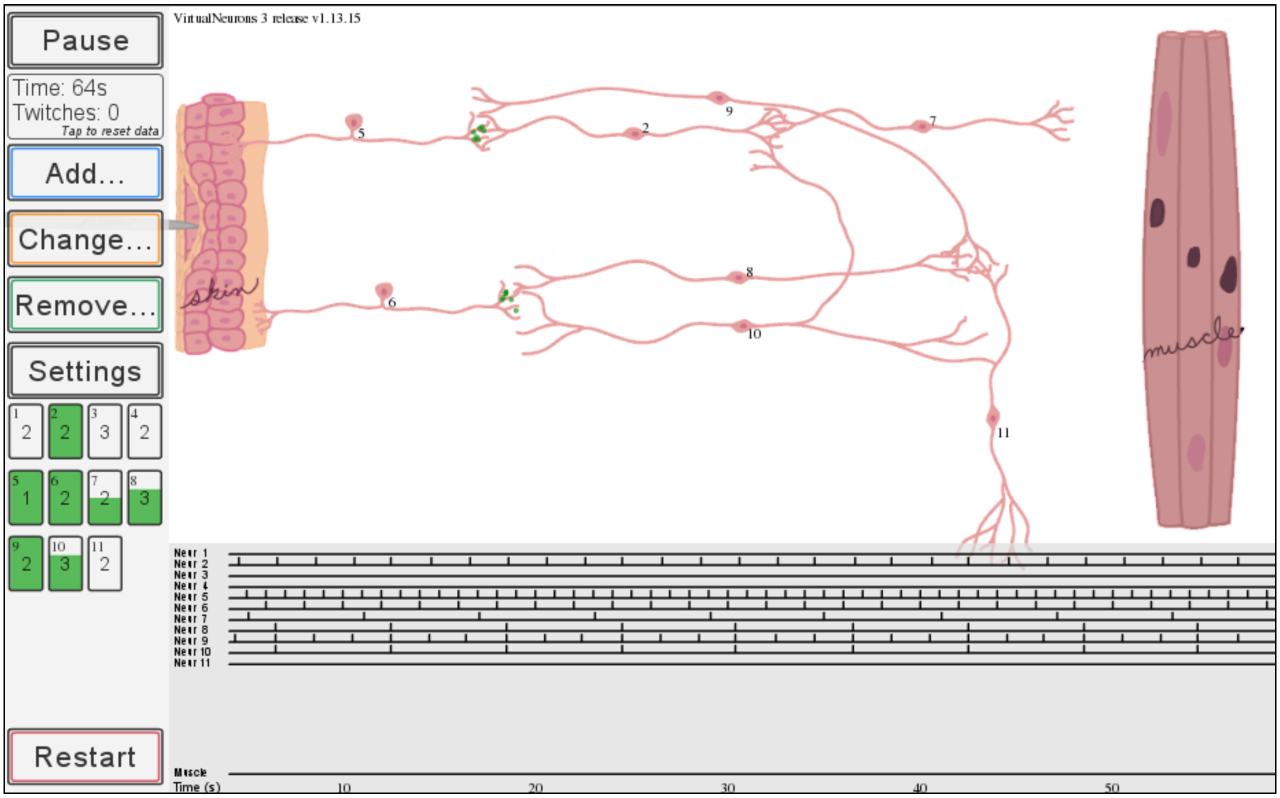
Rhythmic outputs generated by 2 separate inputs through cross inhibition



This circuit models the kinds of neuronal circuits that drive alternating motor behaviors in many animals; crawling in insects, swimming in fish, or walking. Since the program only has one fixed muscle, you have to pretend that neurons 11 and 7 would each go on to stimulate a motor neuron that causes muscles to contract on opposite sides of the body, producing alternating movements like swimming or walking. The different inputs can be sensory information from the internal stretch of muscles (not the skin illustrated here) or spontaneously firing pacemaker neurons in the central nervous system.

Another cross-inhibition circuit with less regular outputs

Can you figure out why?



(Probably because the inputs are not identical and are somewhat in sync with each other.)

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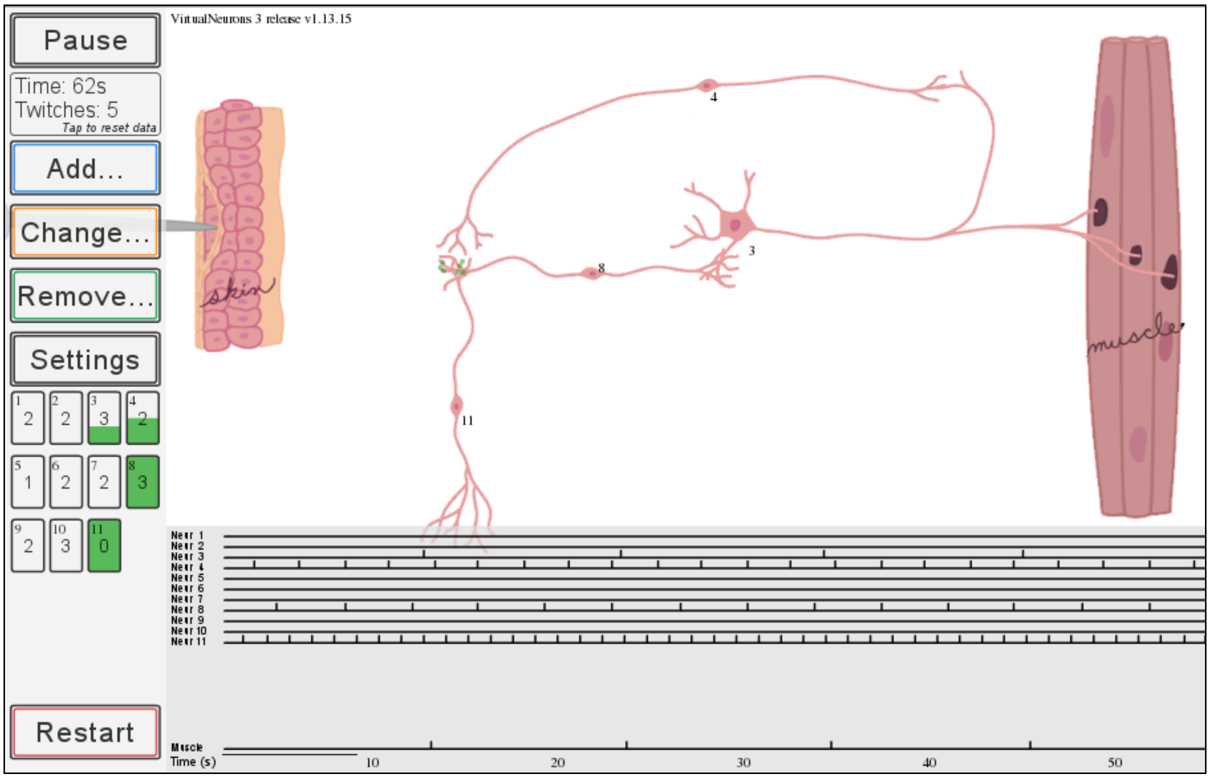
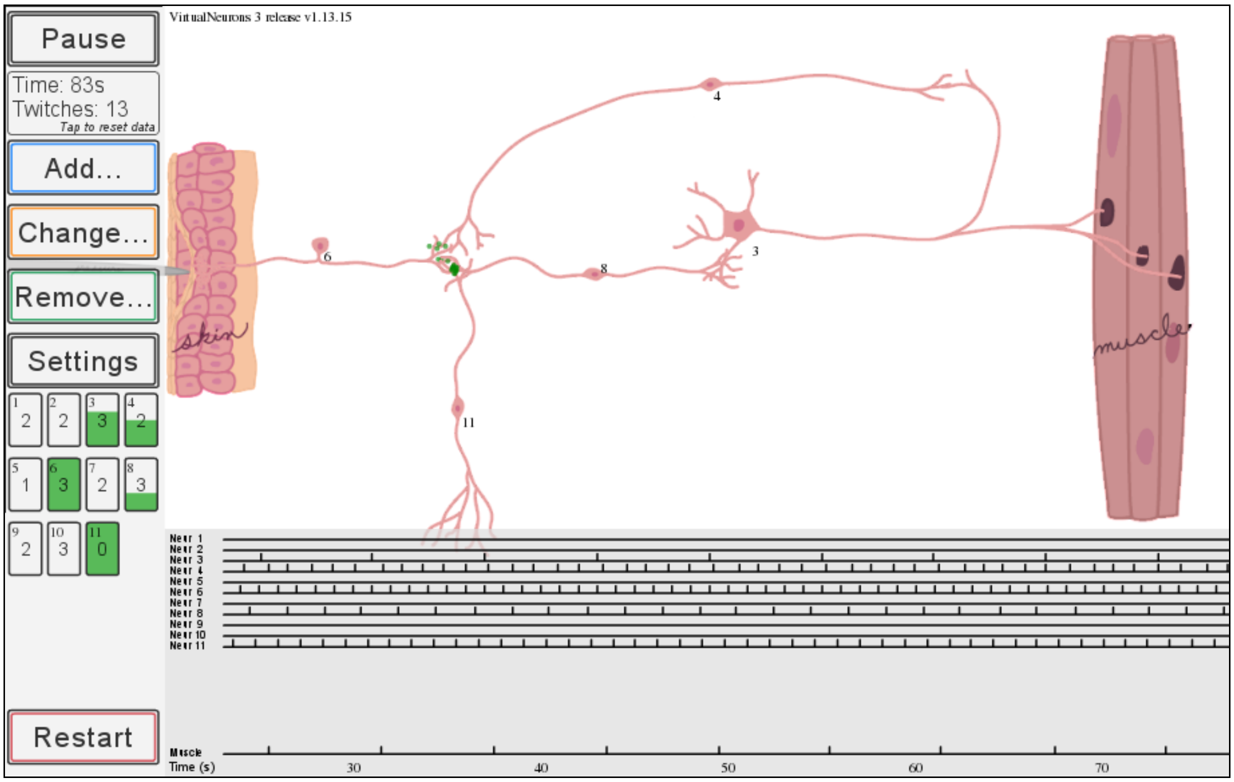
A circuit that activates muscle contraction from a pacemaker interneuron (neuron 11) with negative feedback (neuron 4)



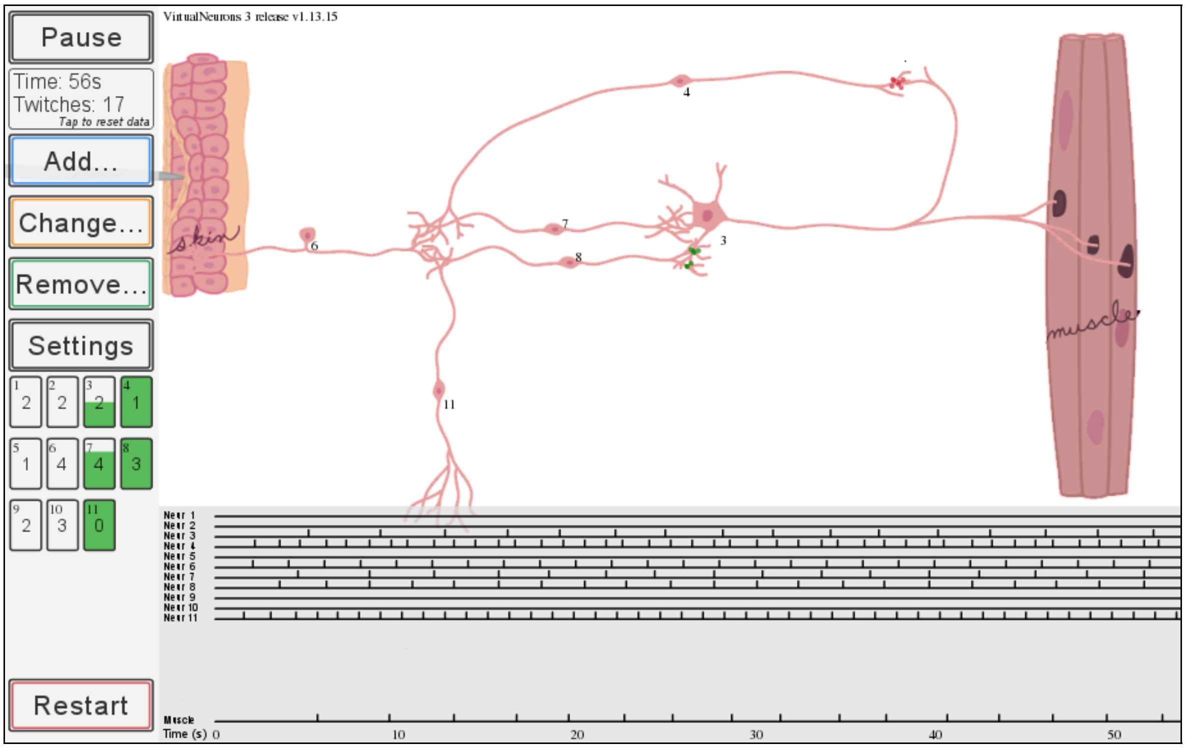
The negative feedback forms the basis for comparing the actual performance of the muscle with the pacemaker input, as would occur in a homeostatic system.

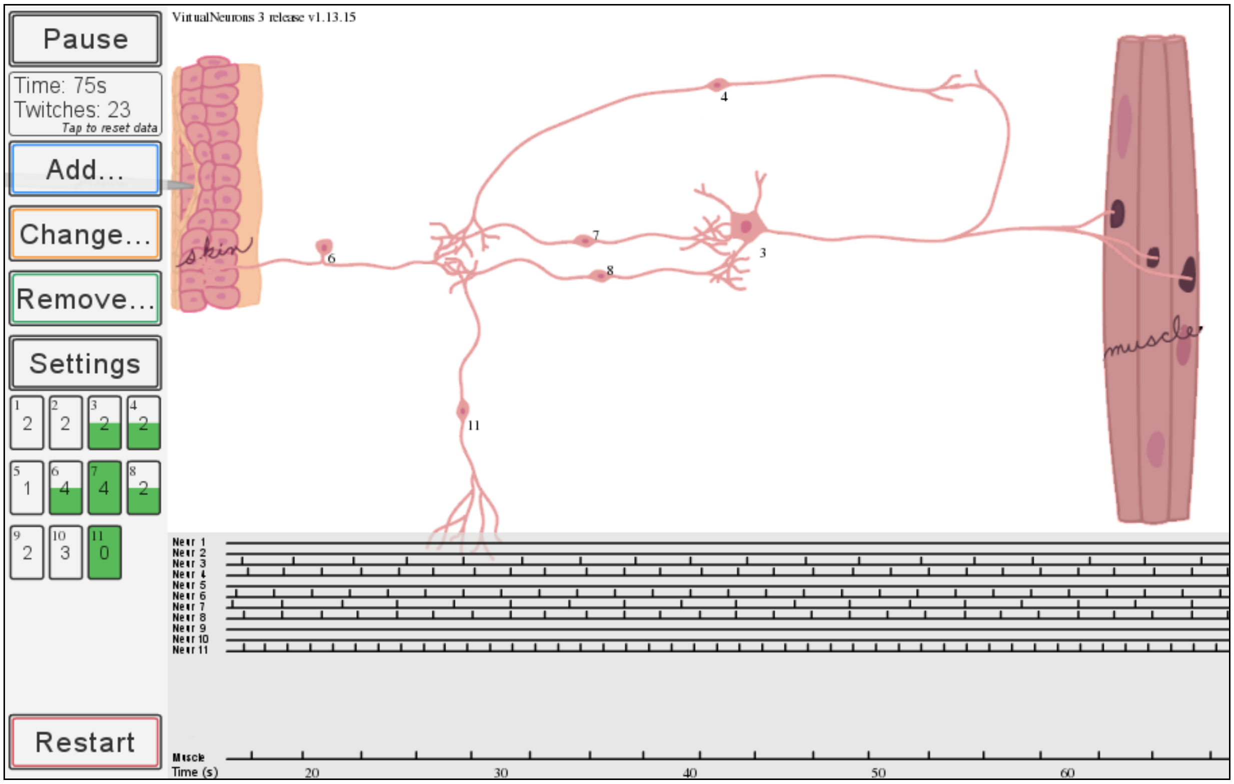
The same circuit as on the previous page plus sensory input

Neuron 8 compares all 3 inputs before causing the muscle to contract.



The addition of another interneuron (neuron 7) in parallel to neuron 5, but with a higher threshold, drives muscle contractions faster only when the input (neuron 6) is higher. Compare above with the next 2 circuits.


Pause
Time: 56s
Twitches: 17
Tap to reset data
Add...
Change...
Remove...
Settings
Restart
VirtualNeurons 3 release v1.13.15
skin
muscle
Time (s)
Muscle



So having multiple interneurons in parallel in this feedback loop circuit allows it to respond to the differences detected among the various inputs. This is an example of a system that responds in a homeostatic manner. Raising the threshold of the motor neuron (3) will give the system a greater dynamic range over which to detect changes in inputs.

Note the program has a very limited range of input firing rates for the sensory neurons. These can be varied by using the following conditions: spontaneous (zero threshold, no need to touch the skin), maximum when placed on the skin across from the pin, half maximum when moved away from the pin, or modulated slighty by changing the threshold when the neuron is on the skin. Some of these input rates are subtle. So you must calculate the rates of firing to be able to see the differences in both input rates and muscle contraction rates.

Play with changing the threshold on neuron 3. What happens?

Then vary the thresholds on neurons 7 and 8.

Add another excitatory interneuron with a third threshold level. What happens now?