

In this set of lab activities, we will explore neural circuits.

An individual neuron has a relatively simple set of signaling functions. Neurons receive input on their dendrites. They integrate this input, and when the total excitatory signal is over threshold, an action potential is generated. The action potential travels down the axon to release neurotransmitter on partner neurons. In general, the transmitter can either excite or inhibit these partners.

Although simple, these signaling functions enable neurons to form *circuits*, and circuits of even a few neurons can generate fascinating and complex behaviors. Our goal is to get a better feel for how amazing circuits are.

We will do this through exploration—the key in this set of labs is to *be curious*—that is, to try things, to make predictions, to change things, etc. The more you explore, the better sense you will get for how neural circuits can work.

### Part 1: Setting up the simulator

- Navigate to [https://github.com/rcalinjageman/cartoon\\_network](https://github.com/rcalinjageman/cartoon_network)
- Click the file “cartoon network.jar”, then click the download button.
- Save the file on your computer, find it, then double-click it to launch
- If you have a Finch robot connected to your computer, press “c” on the keyboard to connect it to the stimulator. The message on the screen should change from “No finch” to “Finch!” if the connection is made.
- If your Finch stops responding or the simulator starts acting strangely, simply close the program and then re-open it. Your work, unfortunately, will not be saved, but it should be relatively easy to re-create any network you were working on.

### Part 2: How the simulator works

The simulator lets you design circuits of neurons. If you have a Finch robot attached, it lets you connect these neurons to the sensors (sensory neuron) and actuators (motor neurons) of the robot.

The simulator uses a ‘mode’ system: you press a key to change the mode, and the mode determines what clicking the screen will do. The mode is always reported in the top left-hand of the screen. **If you click on the current mode, it will make a menu appear that enables you to select a mode using the mouse.**

### Designing the Network:

- ‘a’ –enters add mode; clicking the screen adds neurons
- ‘d’ –enters delete mode; clicking a neuron deletes it
- ‘g’ –enters grow mode; clicking a neuron stretches it length-wise
- ‘s’ –enters shrink mode; clicking a neuron shrinks it length-wise
- ‘r’ –enters rotate mode; clicking a neuron rotates it 20 degrees counter-clockwise
- ‘x’ –enters stimulation mode; clicking a neuron stimulates it

### Editing Neuron Properties:

- 'w' –enters transmitter mode; clicking a neuron brings up a dialog for selecting if the neuron will release glutamate (excitatory) or GABA (inhibitory)
- 't' –enters type mode; clicking a neuron brings up a dialog for selecting if the neuron will be Silent (no spontaneous activity), Spontaneously active (spikes even with no input), or Bursting (not yet implements, but the neuron fluctuates regularly between silent and active).
- 'l' – enters activity mode; clicking a neuron brings up a dialog for selecting the max firing rate of a neuron from 1 (slow) to 10 (rapid)
- 'q' –enters transmitter mode; clicking a neuron brings up a dialog to select how many molecules of neurotransmitter will be released with each AP—default is 10; options are from 1 to 40

*Note that, like real neurons, NT **anywhere** on the neuron causes an effect, not just on the dendrites. The only exception is NT the neuron itself released.*

### Connecting to the Finch robot

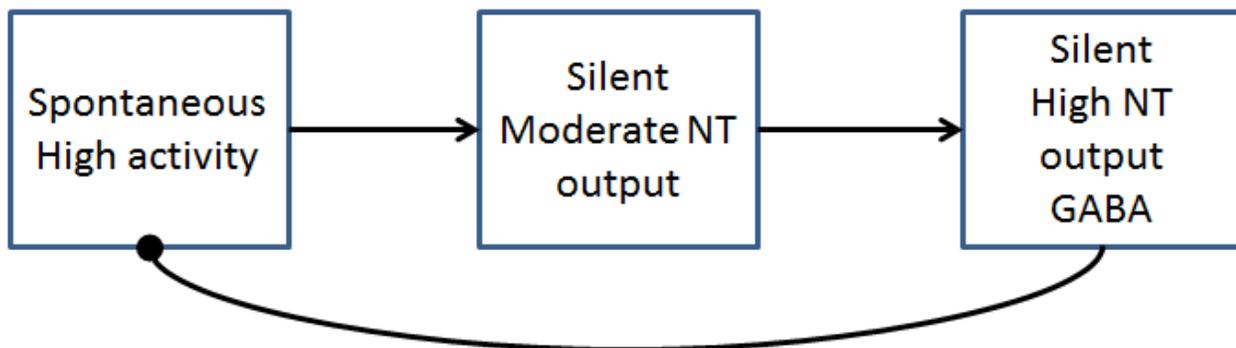
- 'c' –makes connection to Finch. Unfortunately, this causes a crash if the Finch is not connected (will fix this as soon as I know how)
- 'i' –enters input mode; clicking a neuron brings up a dialog that allows the neuron to become a sensory neuron that responds to sensors on the Finch. Options are:
  - 'None' –back to interneuron
  - 'Left hit' –fires if something is quite near to touching left infrared sensor
  - 'Right hit' –fires if something is quite near to touching the right infrared sensor
  - 'Left light' –increasing activity with increasing light levels on left light sensor
  - 'Right light' –increasing activity with increasing light levels on right light sensor
  - 'Temperature' –increasing activity with increasing temperature
- 'o' –enters output mode; clicking a neuron brings up a dialog that allows the neuron to become a motor neuron that responds to sensory on the Finch. Options are:
  - 'None' –back to an interneuron
  - 'Left forward' –each NT released temporarily drives the left motor forward
  - 'Left backward' –each NT released temporarily drives the left motor backward
  - 'Right forward' –each NT released temporarily drives the right motor forward
  - 'Right backward' –each NT released temporarily drives the right motor backward
  - 'Buzz' –each NT released temporarily increases the pitch of the Finch's buzzer
  - 'Red' –each NT released temporarily increases the brightness of the red LED
  - 'Blue' –each NT released temporarily increases the brightness of the blue LED
  - 'Green' –each NT released temporarily increases the brightness of the green LED
- '0' – brings up a dialog to adjust the threshold for light activity. This is used because we'd like the sensory neurons to fire when the light becomes brighter than normal, but what counts as 'normal' varies from room to room. The light sensor varies from 0-100; you set the threshold above which the sensory neuron should start to fire. It helps to have a light sensory neuron running so you can see what

the current light level is in the room. Set the threshold above the current reading to be able to detect light increases. Currently, the simulator only produces increased activity with increased light; there is not yet an option for decreased activity with decreased light.

- ‘-’ –brings up a dialog to adjust the threshold for temperature activity. The temperature sensor is in degrees Celsius. It helps to have a temperature sensory neuron running so you can see what the current temperature is. Set the threshold just above the current reading to be able to detect temperature increases. Currently, the simulator only produces increased activity with increased temperature; there is not yet an option for decreases activity with decreased temperature.

### Your challenges

- Make a simple reflex circuit where a touch to the left of the Finch causes it to rotate **towards** the touch? If you succeed, make it so a touch to the right also makes it rotate towards the touch.
- Can you make the Finch follow a light source? That is, it should go straight ahead when the light is straight ahead, but bend to the left when the light is to the left, etc.
- Make this common neural circuit:



Make the spontaneous neuron a motor neuron with red output; make the silent GABA neuron a motor neuron with green output.

What will this circuit do? Make predictions and then observe

- Time for a dance off!
  - Make a circuit that enables to Finch to ‘waggle’—to move left, then right, then left, then right. No input should be required. The circuit above might help you.
  - Now add some style—your Finch can buzz, light up, spin around in more complex ways.. design the most stylish dancer you can and we’ll have a dance off to end the lab.