SPIKE MODEL NEURAL NETWORKS

Listening for Tones

MARKERS

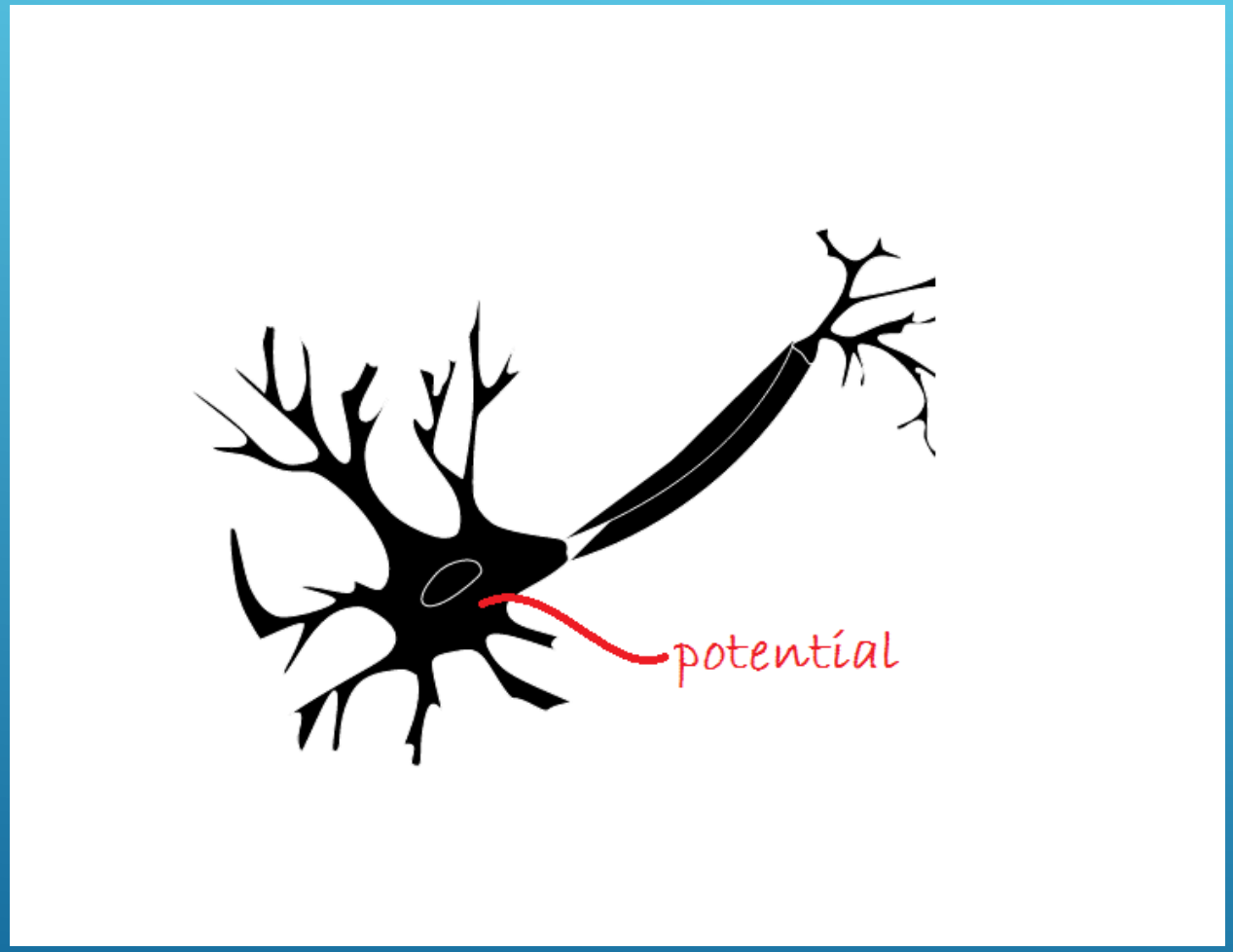
STRUCTURE

Inputs

Weights

Potentials

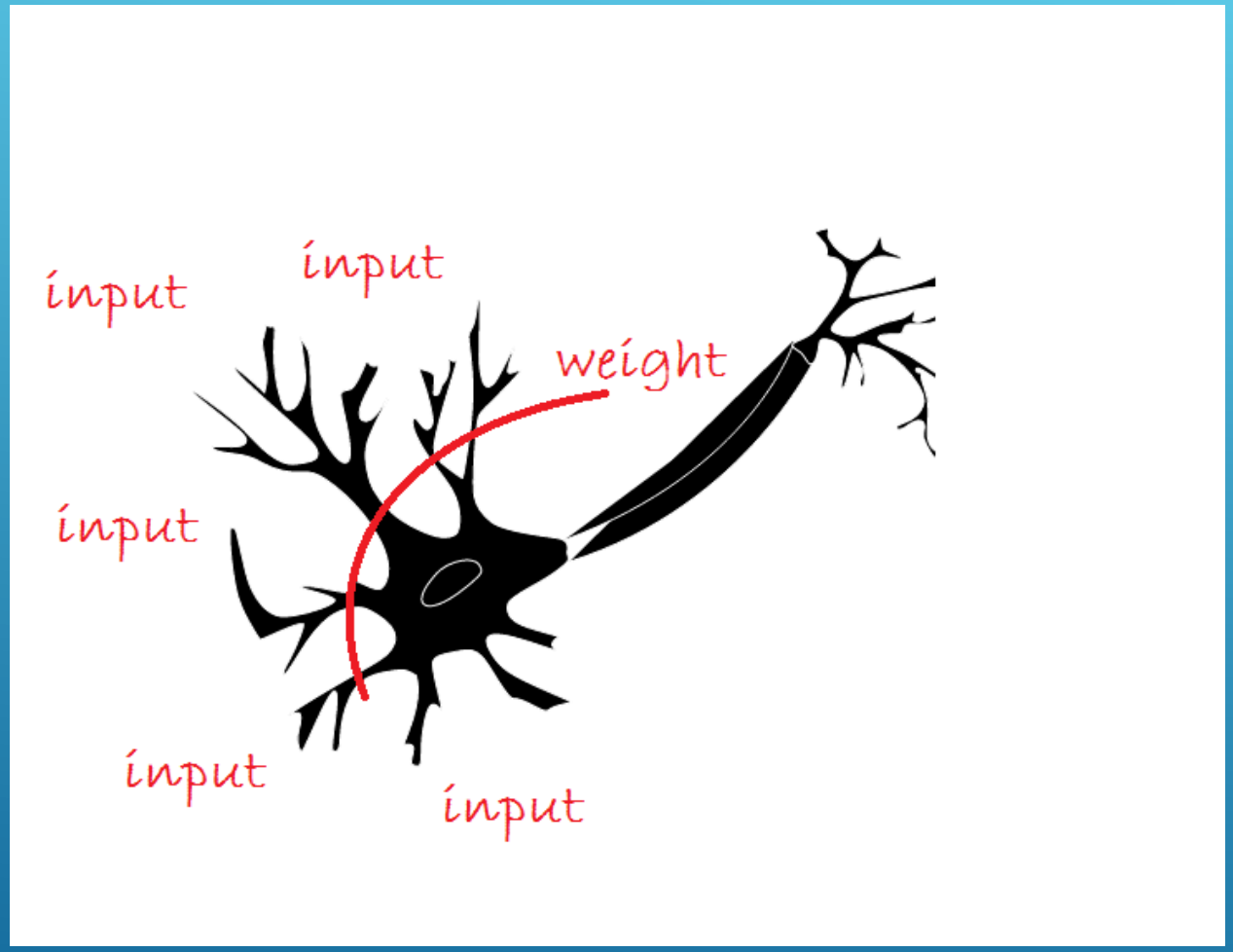
Outputs



STRUCTURE

The potential is the neuron's internal electrical pressure. It can be positive or negative. When the potential surpasses the threshold the neuron will spike.

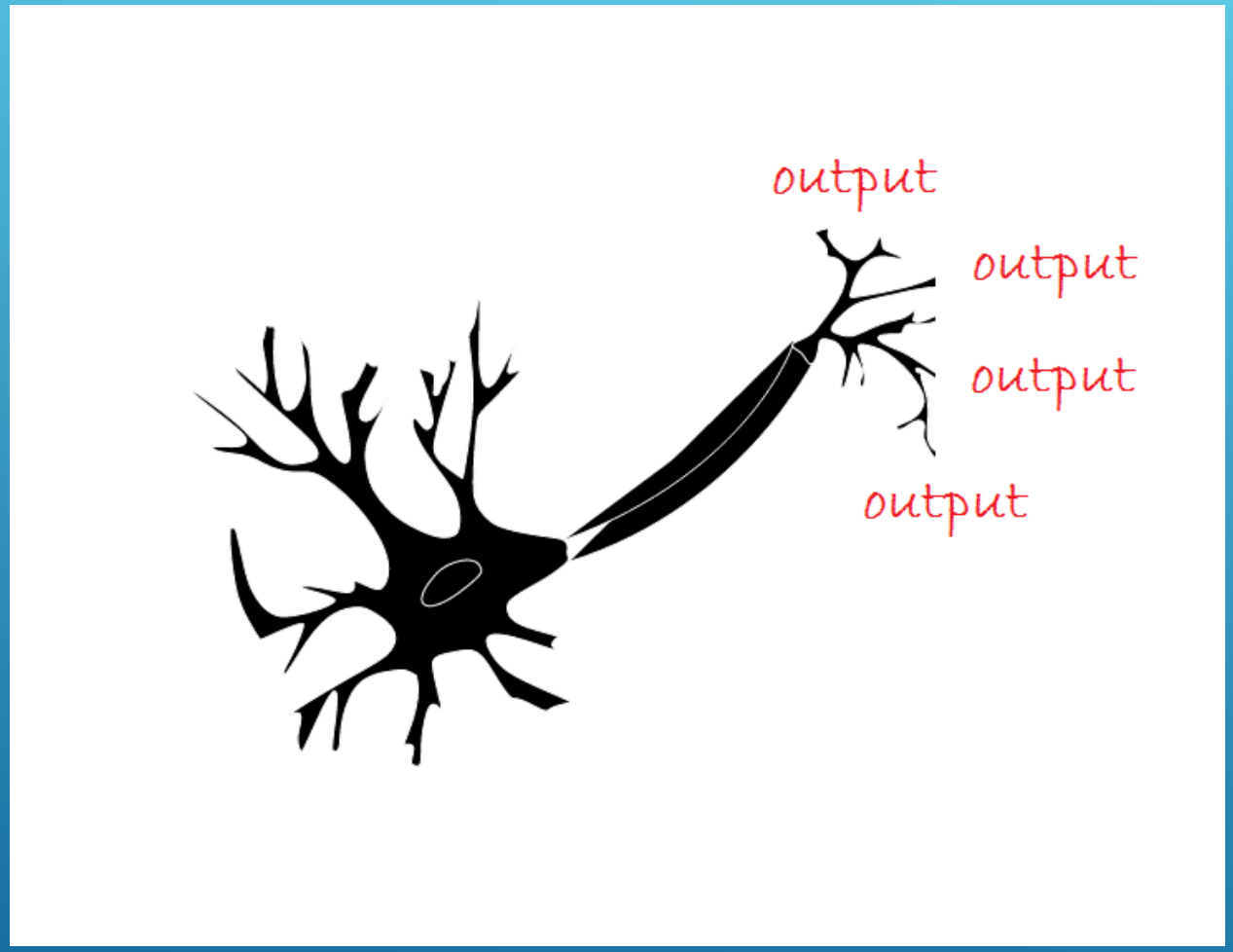
The electric potential "leaks" across the cell body. It will therefore decay toward zero over time.



STRUCTURE

Inputs can come from other neurons or from sensory input.

Weights determine how much each input influences the neuron's potential and can also flip the input's sign.



STRUCTURE

Output from the neuron is simply a spike. It has a positive or negative direction, but does not contain amplitude information.

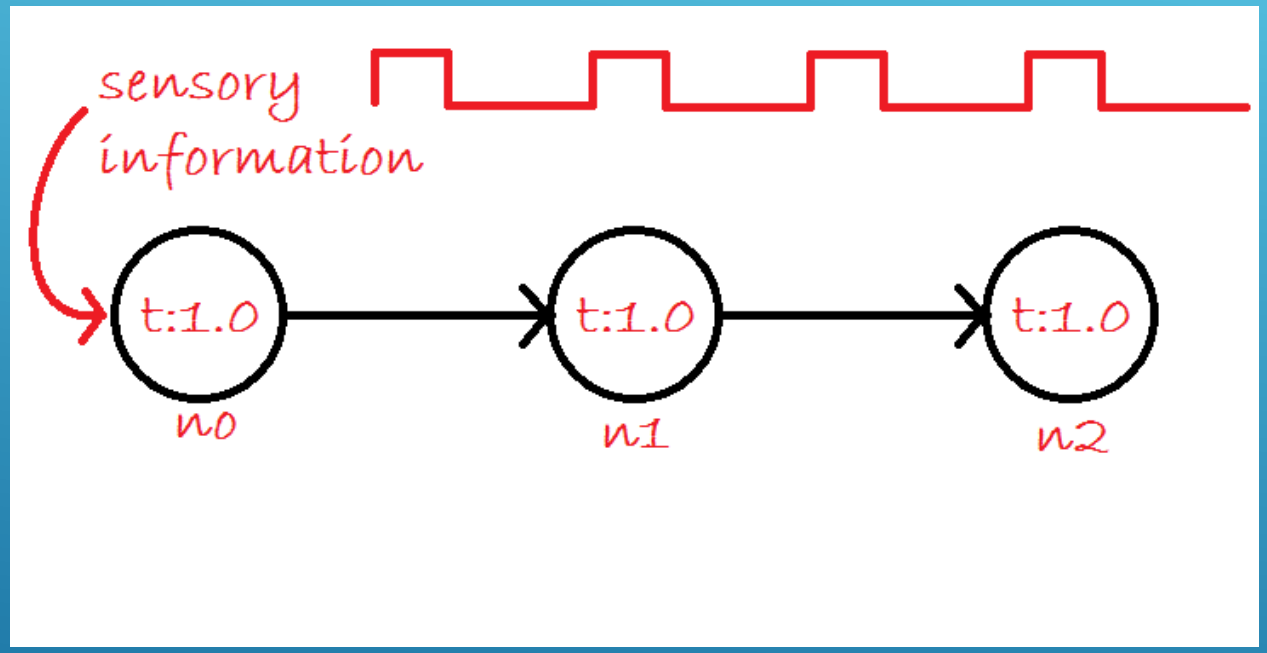
After a spike, a neuron will return to a restful state with zero potential.

SIMPLE EXAMPLES

Chain of length Three

Chain of Length Four

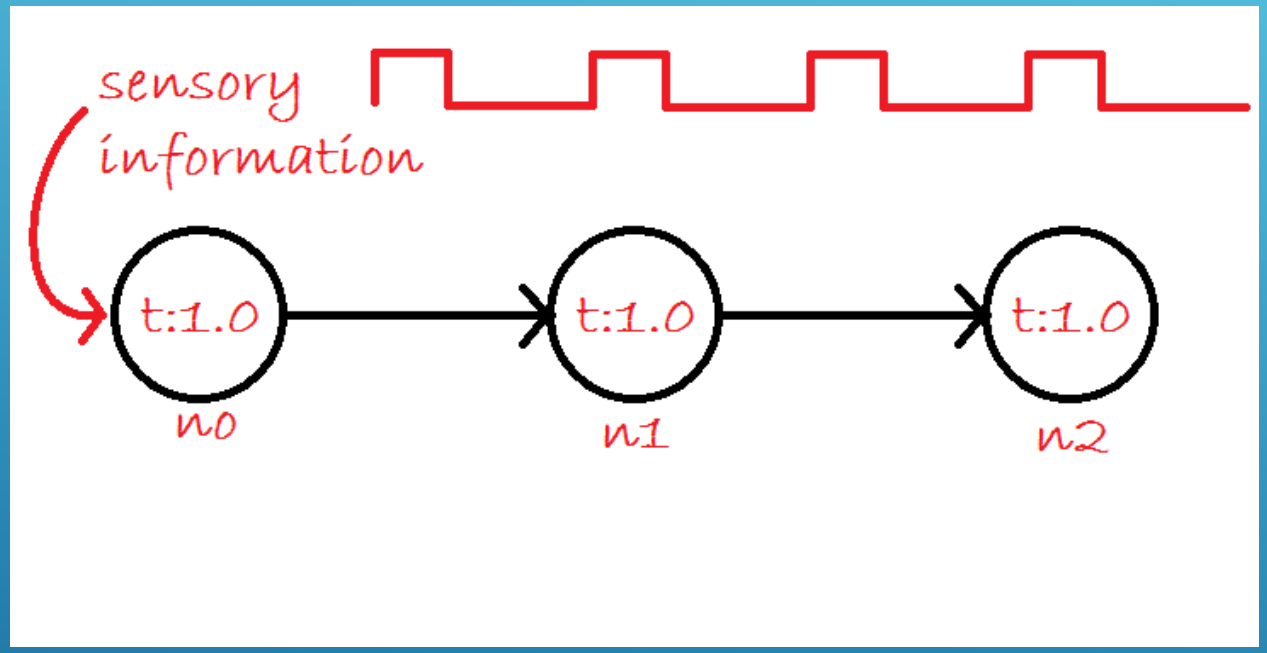
SIMPLE EXAMPLE



Consider the simple example on the left.

If pulsed sensory information was presented to n0, then it would spike when/if that sensory sum had surpassed the internal threshold of 1.0.

It would then send a spike to n1 which would spike to n2 if the internal potential surpassed the threshold of 1.0.



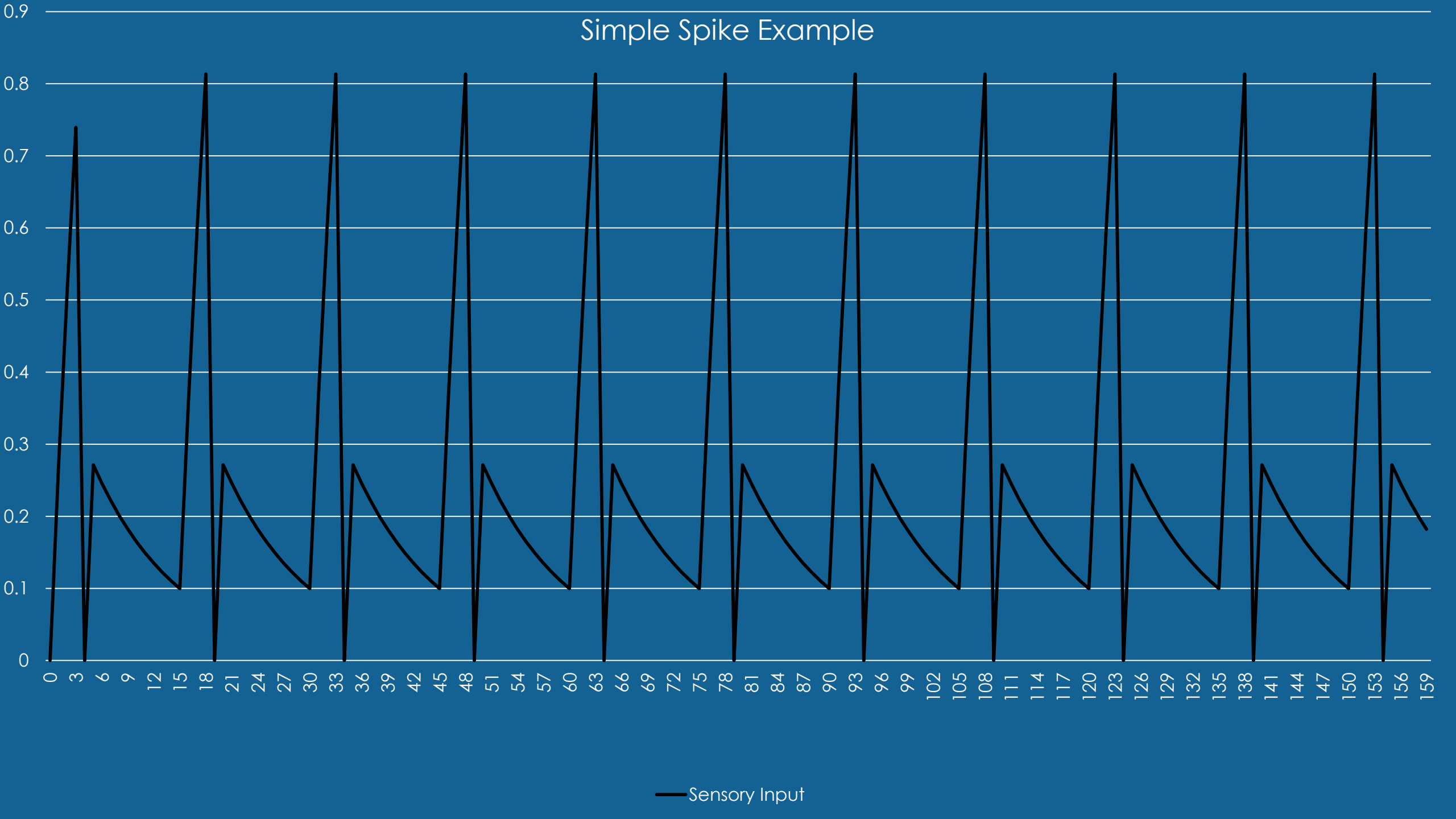
SIMPLE EXAMPLE

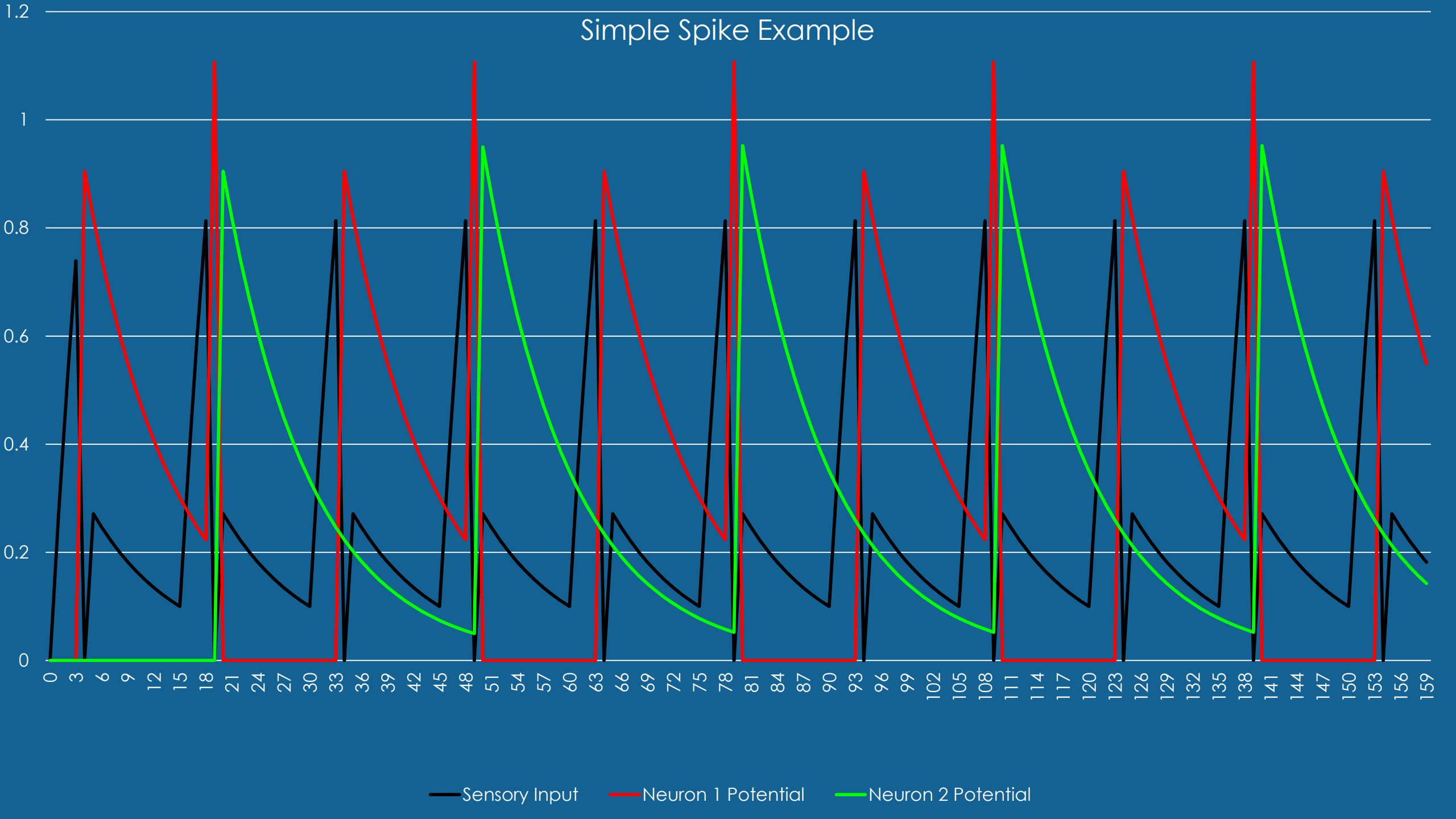
For this example, let the sensory input cycle on for 5 samples, then off for 10 samples.

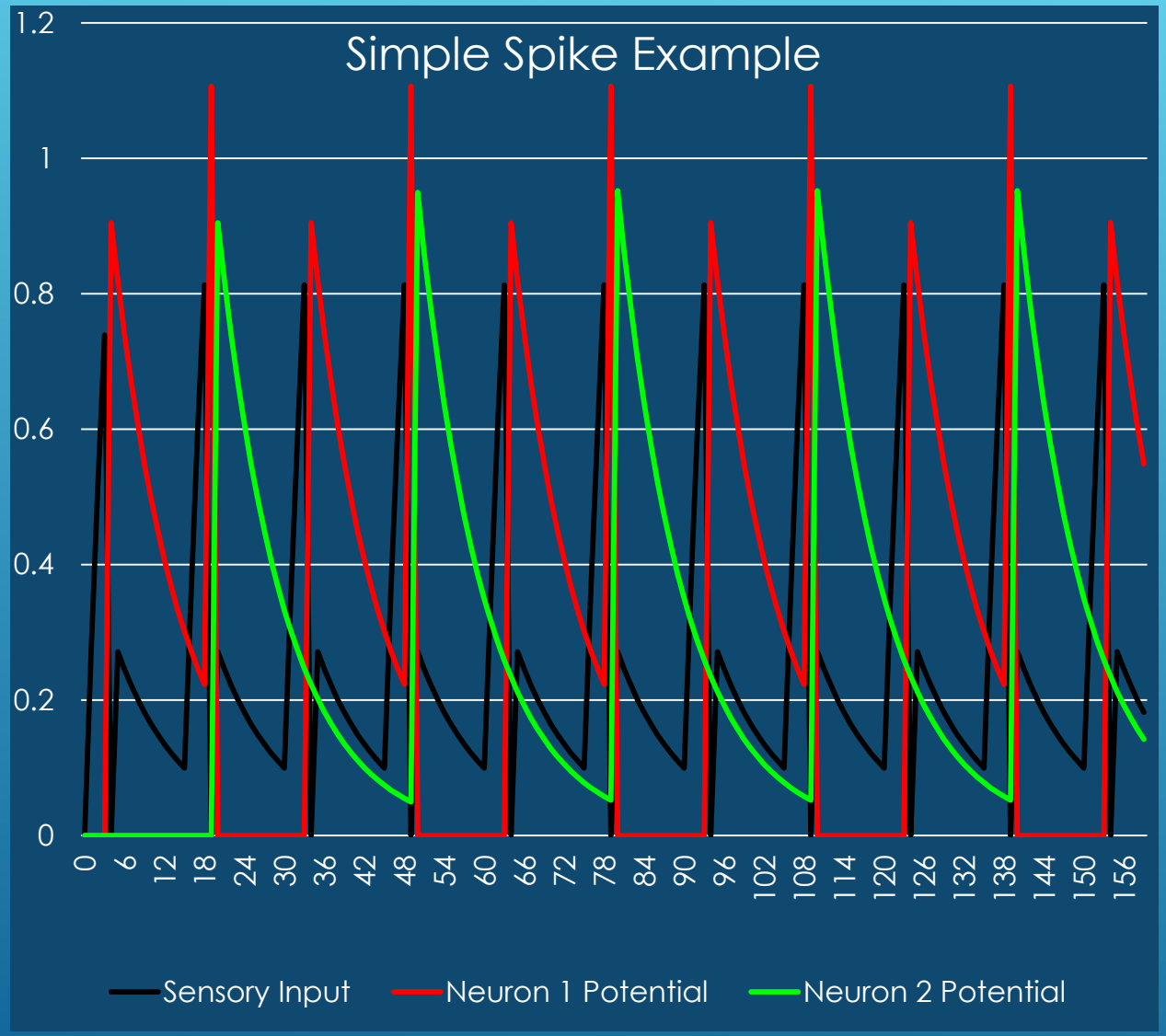
It will be easy to see how the potential in the sensory neuron climbs during the on cycle.

As the sensory potential surpasses the 1.0 threshold, it will spike to n1 and the potential of n0 will return to 0.

A further sensory stimulus will again increase the potential, but this will not be sufficient to have n0 spike and it will decay during the off cycle.


Simple Spike Example
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99 102 105 108 111 114 117 120 123 126 129 132 135 138 141 144 147 150 153 156 159
Sensory Input


Simple Spike Example
1.2
1
0.8
0.6
0.4
0.2
0
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99 102 105 108 111 114 117 120 123 126 129 132 135 138 141 144 147 150 153 156 159
Sensory Input
Neuron 1 Potential
Neuron 2 Potential

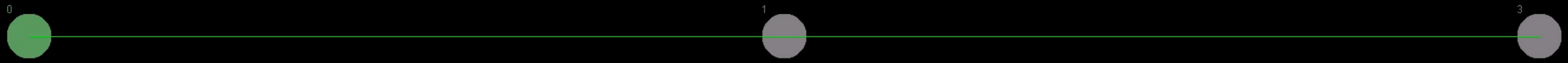


SIMPLE EXAMPLE

We can see the black sensory potential go through cycles of increase, spike, return to zero, increase, decay, and repeat.

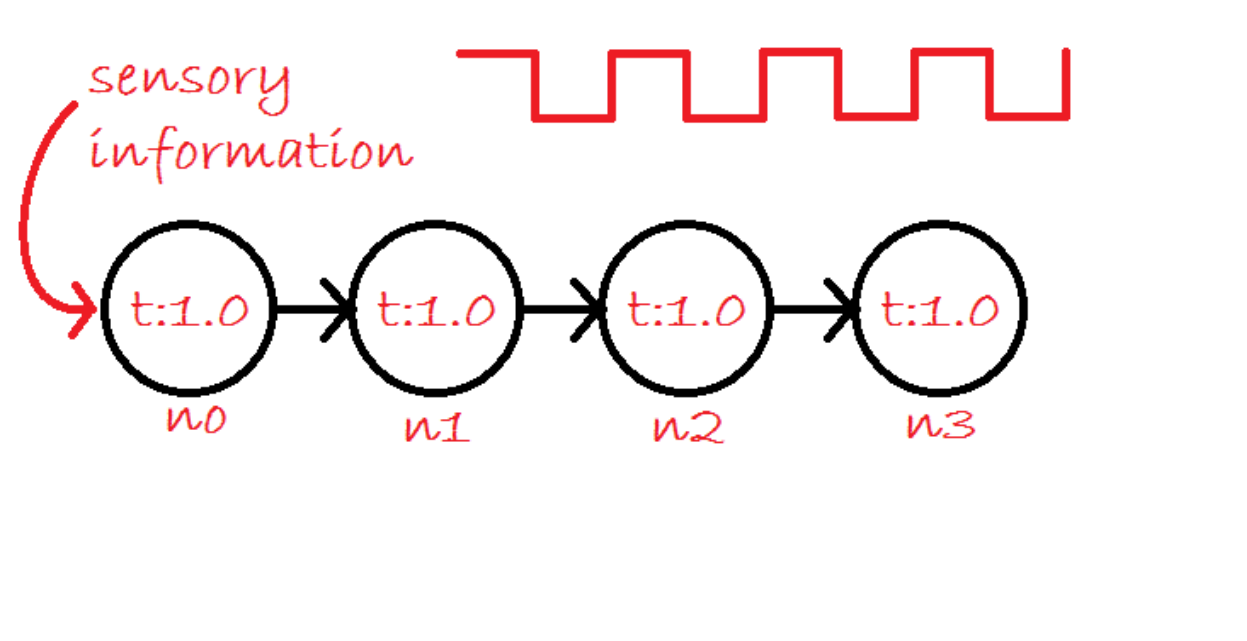
The n1 (red) line spikes almost immediately after n0 spikes.

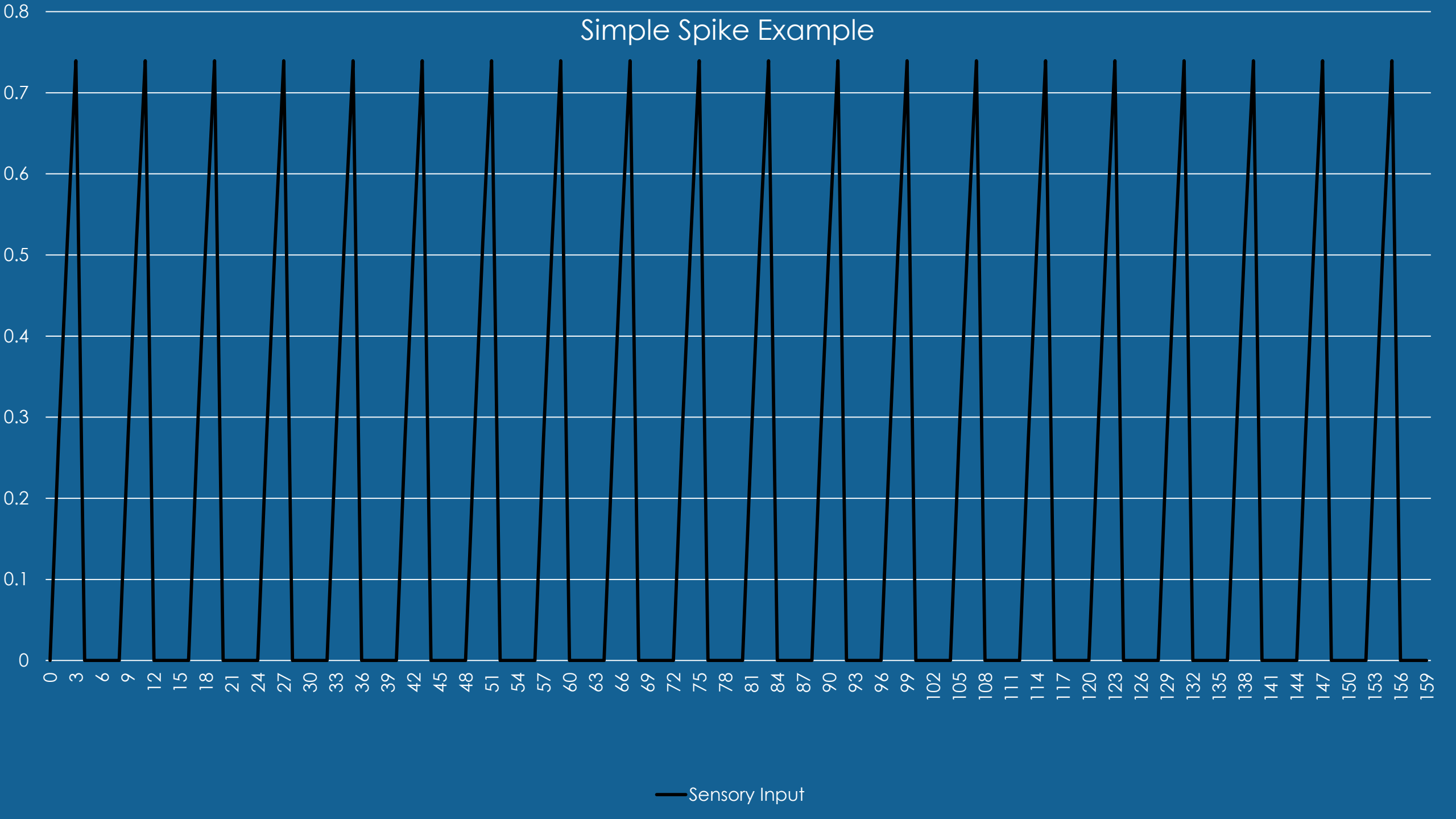
The n2 neuron only spikes every other time n0 spikes. This indicates the diminishing value as information spikes travel through the network.

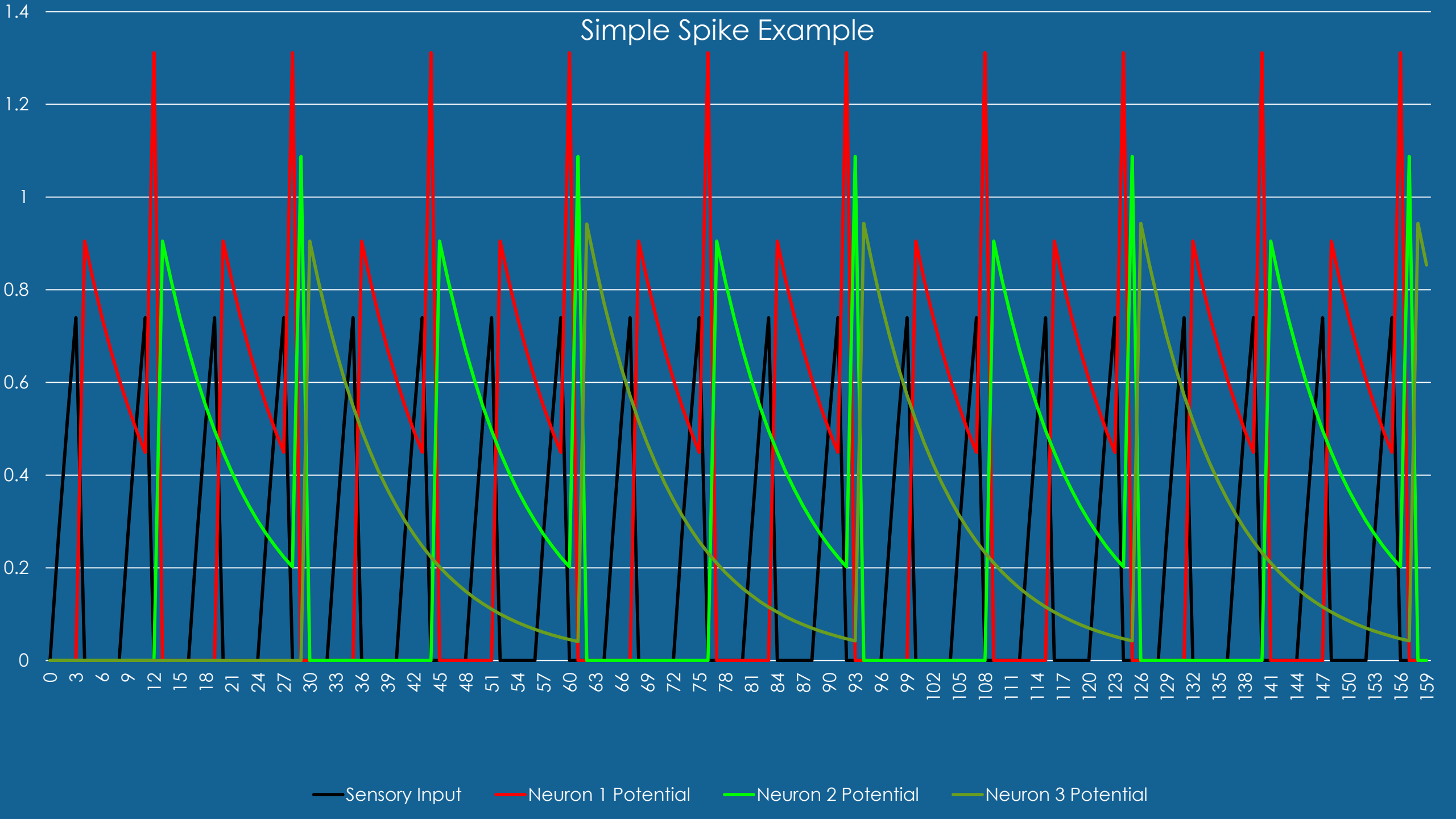

0
1
3

SIMPLE EXAMPLE 2

As a second example, we add a fourth neuron to the end and change the duty cycle to one half (4 on, 4 off) for the sensory neuron.




Simple Spike Example
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99 102 105 108 111 114 117 120 123 126 129 132 135 138 141 144 147 150 153 156 159
Sensory Input


Simple Spike Example
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99 102 105 108 111 114 117 120 123 126 129 132 135 138 141 144 147 150 153 156 159
Sensory Input
Neuron 1 Potential
Neuron 2 Potential
Neuron 3 Potential


0
1
3
3

LEARNING

What learning means

Propagation of lessons learned

Switching Signs

One phase of learning

The learning cycle

LEARNING

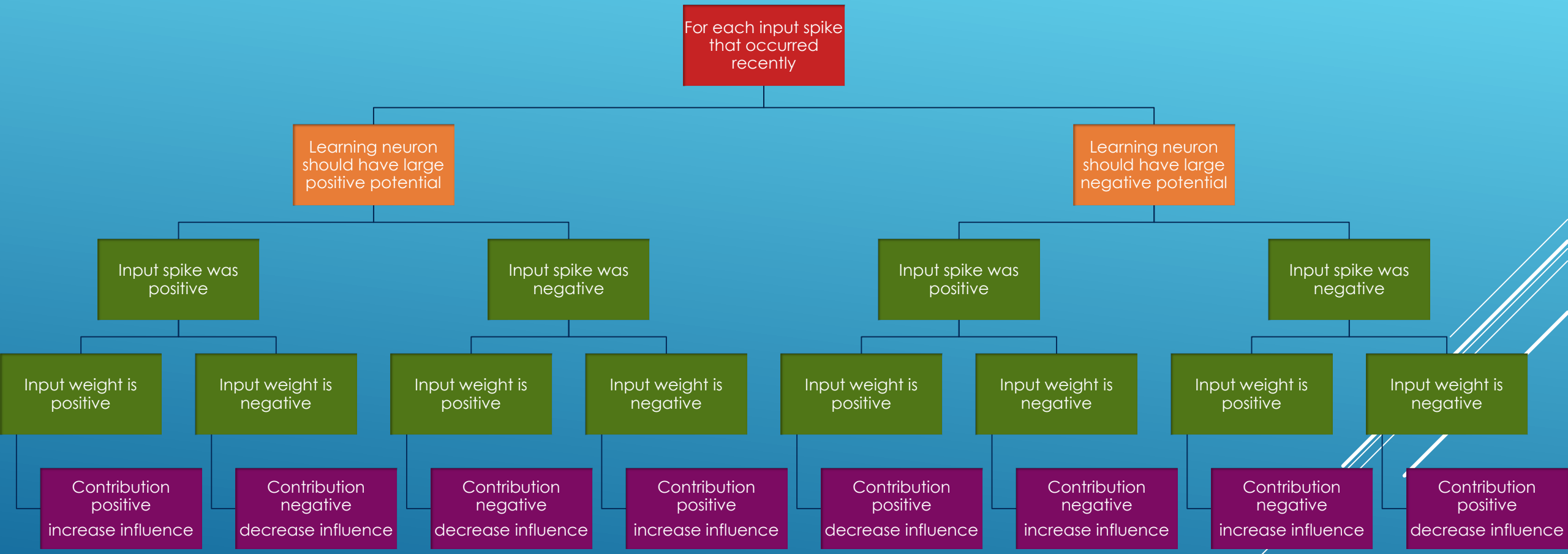
- We want to be able to identify input data presented to the neural network.
- This means that when we present the neural network with some particular input time data, it should excite particular neurons.
- Given random input connections, input weights, and thresholds, it is unlikely the neural network will perform the task
- The network must be taught how to respond to the input we determine as interesting.

LEARNING

- One way to achieve this learning is to have an outside mechanism repeatedly present input data and tell the neuron(s) that should be excited to get excited.
- If a neuron should be excited, then it should increase the influence of neurons that would have recently helped contribute to the desired excited state.
- If an input neighbor neuron recently had a spike that contributed to the desired response of the learning neuron, then that neighbor's influence should increase.
- Similarly, if an input neighbor neuron recently had a spike that was counter to the desired response of the learning neuron, then that neighbor's influence should decrease.

LEARNING

- If an input neighbor recently had a positive spike and the learning neuron has a positive input weight associated with that neighbor, then the neighbor had a positive (not necessarily good) influence on the learning neuron.
  - If the learning neuron should be having a positive spike (or at least a large positive potential) then this input spike was helpful, and the neighbor neuron's influence (weight) should increase.
  - If the learning neuron should be having a negative spike (or at least a large negative potential) then this input spike was harmful, and the neighbor neuron's influence (weight) should decrease.

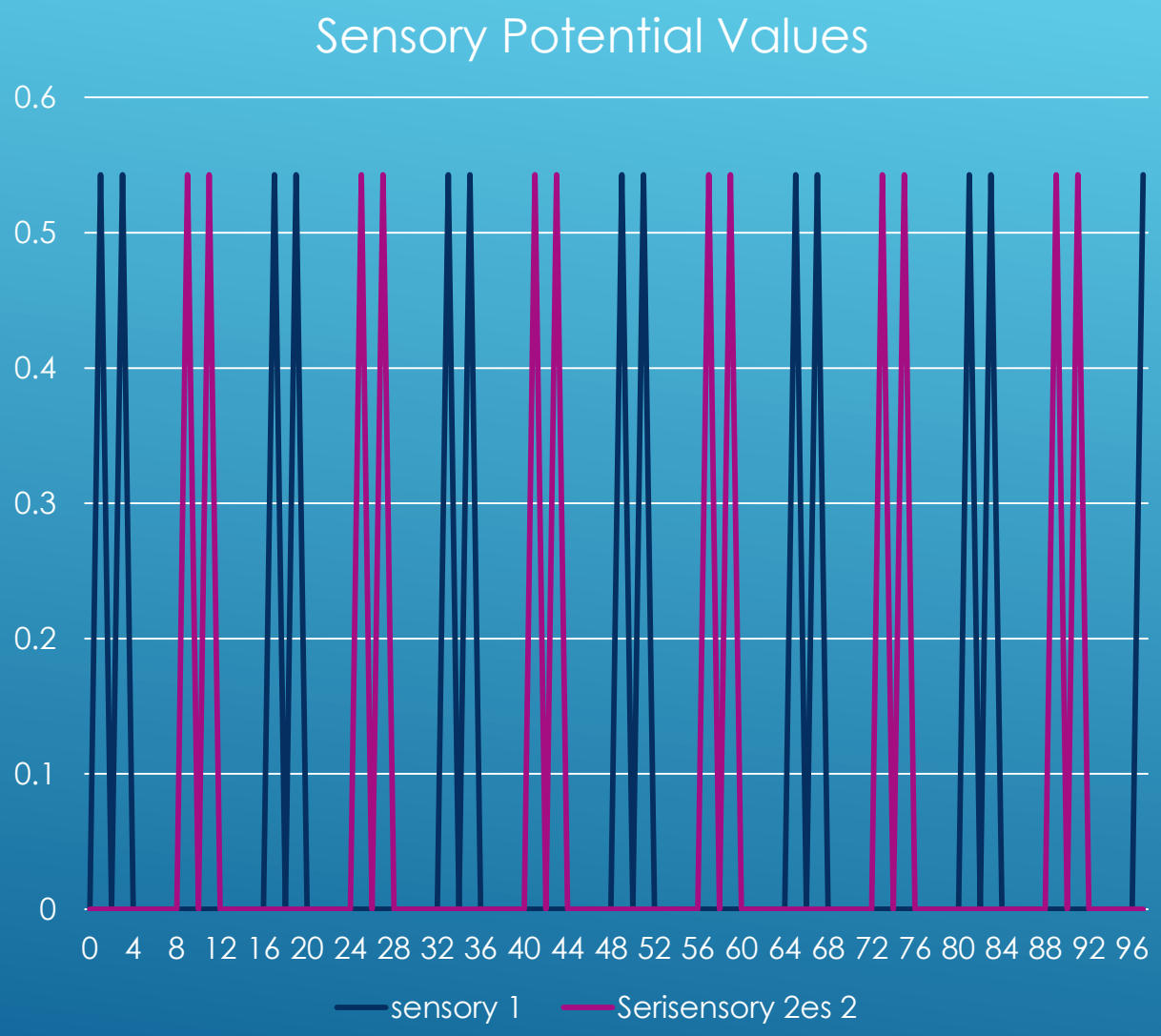

For each input spike that occurred recently
Learning neuron should have large positive potential
Learning neuron should have large negative potential
Input spike was positive
Input spike was negative
Input spike was positive
Input spike was negative
Input weight is positive
Input weight is negative
Input weight is positive
Input weight is negative
Input weight is positive
Input weight is negative
Input weight is positive
Input weight is negative
Contribution positive increase influence
Contribution negative decrease influence
Contribution negative decrease influence
Contribution positive increase influence
Contribution positive decrease influence
Contribution negative increase influence
Contribution negative increase influence
Contribution positive decrease influence

LEARNING ADDITIONAL RULES

- Switching the sign of an input weight if it goes too low. For example, if a neighbor was consistently sending spikes that were bad for the learning neuron (given its current weight), than switching the sign would be good for the learning neuron, and that harmful neighbor that became a very quiet neighbor could then become a helpful neighbor.
- Propagation of learning. If a neighbor has been helpful in achieving the desired state in the learning neuron, let the neighbor know! "I was able to correctly spike (pos/neg) because of your help! Please keep up the good spiking!" This allows the neighbor to also learn how to be better at what it was doing. For efficiency, this propagation should not go more than a few layers deep, especially when cycles are introduced.

LEARNING VIDEO NOTES

- The sensory neurons are receiving:
  - 4 cycles on and 12 cycles off
  - The top (n0) is "on" 0, 1, 2, 3
  - The bottom (n1) is "on" 8, 9, 10, 11
- The right neurons are trying to
  - Spike positive when n0 is on
  - Spike negative when n0 is on
  - Spike positive when n1 is on
  - Spike negative when n1 is on
- The neurons that are trying to spike negative still started with positive input weights. Those weights will need to decay toward zero, and then flip sign before the neuron learns how to properly spike.
  - Around frame 180,
  - 8 seconds into the video
  - After the 12th time of seeing n0 "on"
- After they flip sign, they QUICKLY learn how to negatively signal that n0/n1 respectively are on. And from around 25 seconds on, they appear to fire as hard as the positive neurons.

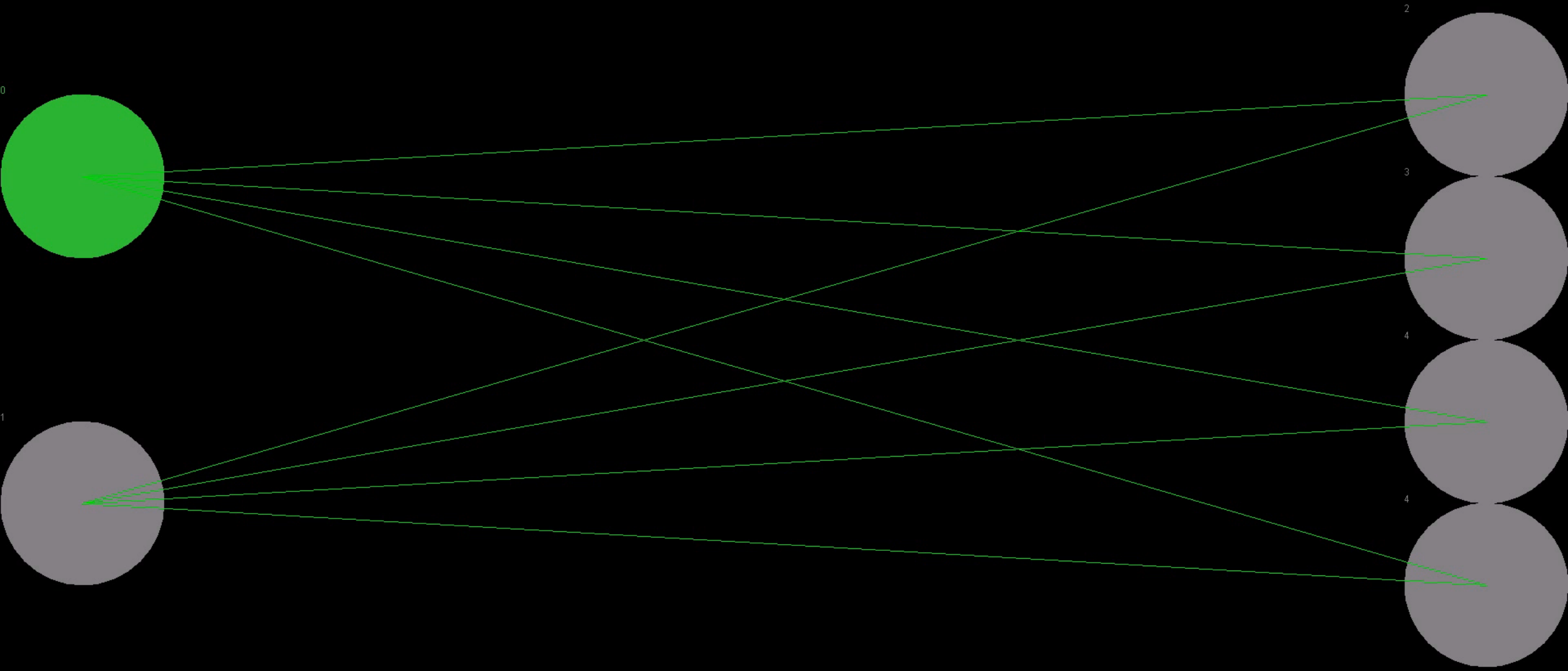


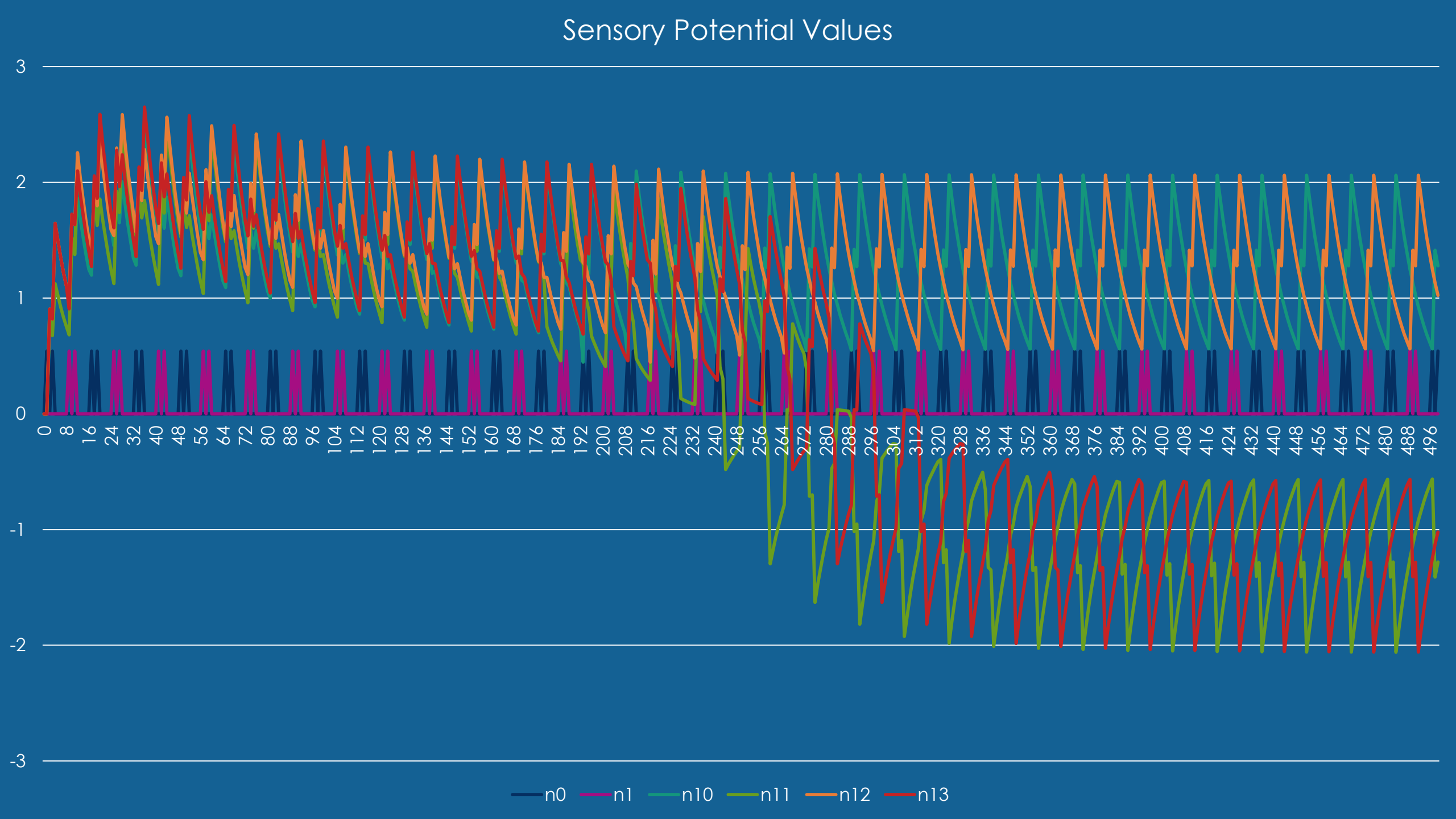
LEARNING

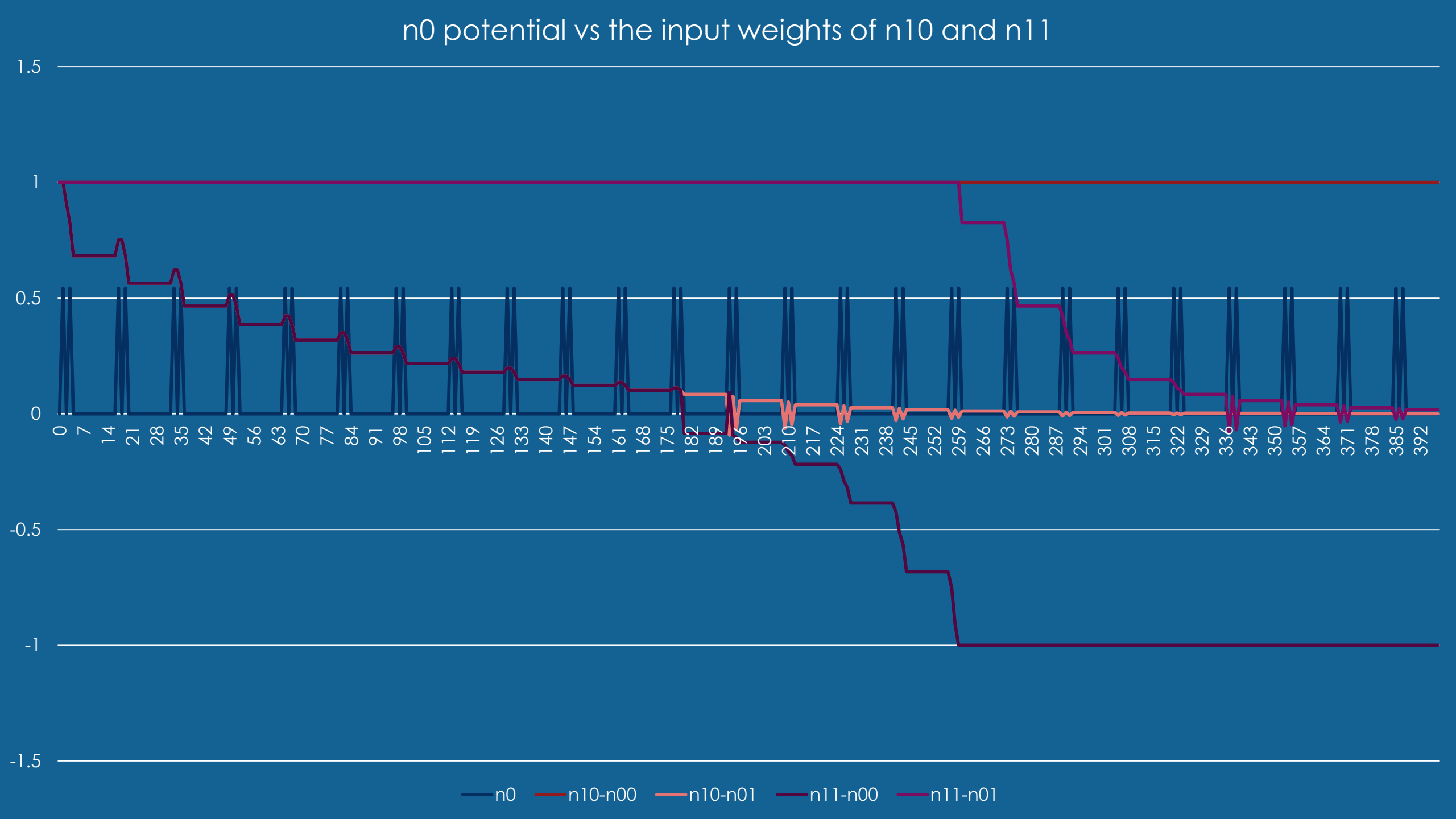
The potential values of the input sensory neurons for 100 frames.

Each frame the neuron is “on” it receives an input of 0.6. This allows them to spike twice in the 4 frames that they are on.

There is a 4 frame cooldown period so that the sensory neurons don’t step on each other too much.


0
1
2
3
4
4


Sensory Potential Values
3
2
1
0
-1
-2
-3
0
8
16
24
32
40
48
56
64
72
80
88
96
104
112
120
128
136
144
152
160
168
176
184
192
200
208
216
224
232
240
248
256
264
272
280
288
296
304
312
320
328
336
344
352
360
368
376
384
392
400
408
416
424
432
440
448
456
464
472
480
488
496
n0
n1
n10
n11
n12
n13


n0 potential vs the input weights of n10 and n11
1.5
1
0.5
0
-0.5
-1
-1.5
0 7 14 21 28 35 42 49 56 63 70 77 84 91 98 105 112 119 126 133 140 147 154 161 168 175 182 189 196 203 210 217 224 231 238 245 252 259 266 273 280 287 294 301 308 315 322 329 336 343 350 357 364 371 378 385 392
n0
n10-n00
n10-n01
n11-n00
n11-n01

LEARNING TO IDENTIFY MUSIC NOTES

Simple 2 layer model

Three layer model with more difficult learning

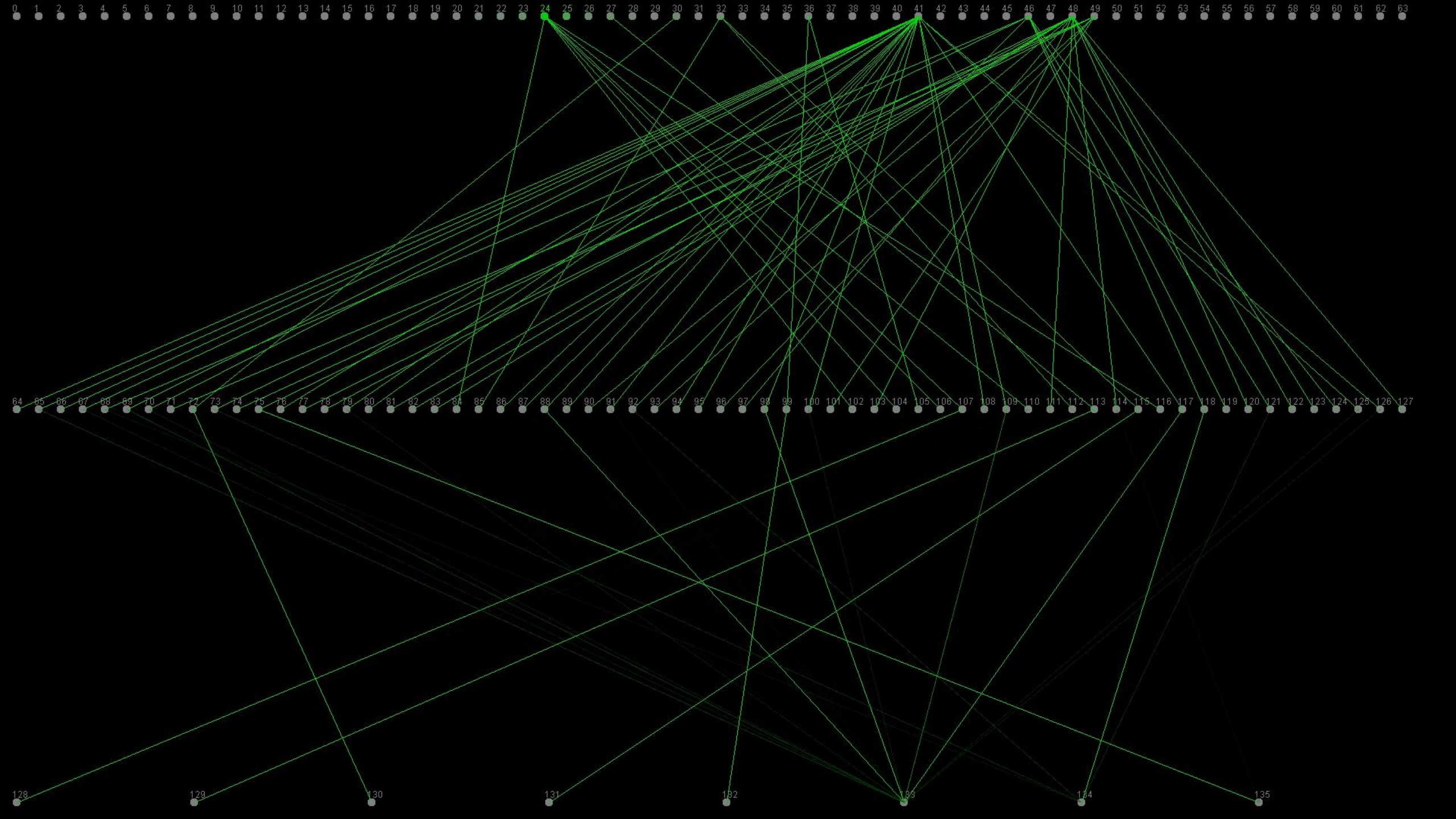

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63
64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127
128 129 130 131 132 133 134 135

IMAGE CREDITS

http://www.clker.com/clipart-neuron-in-progress-1.html

https://en.wikipedia.org/wiki/File:Gray921.png