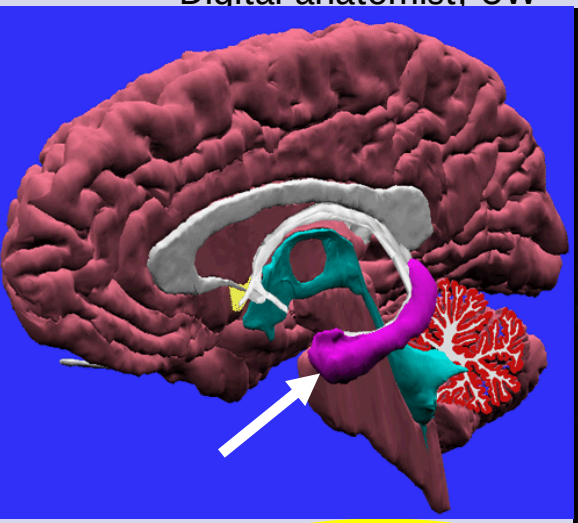
Neuromorphic VLSI Tutorial

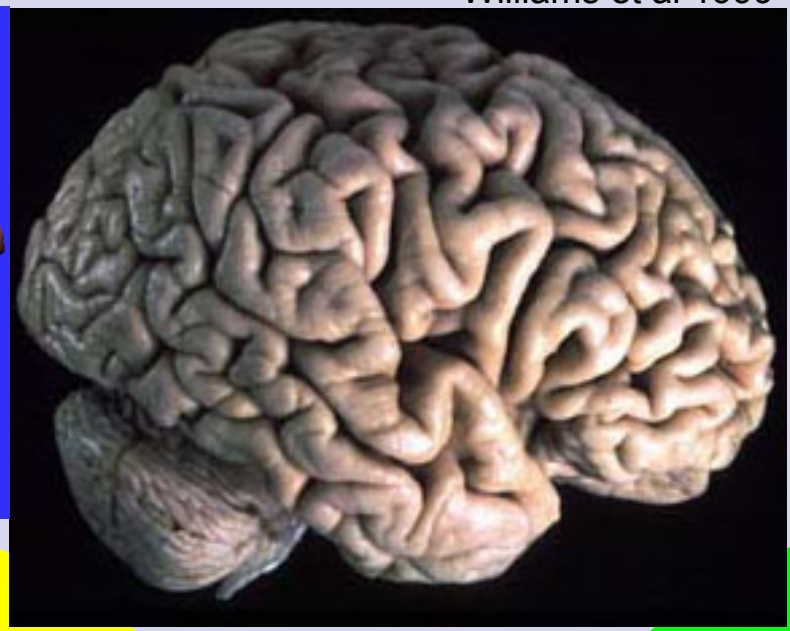
john arthur

Studying the brain

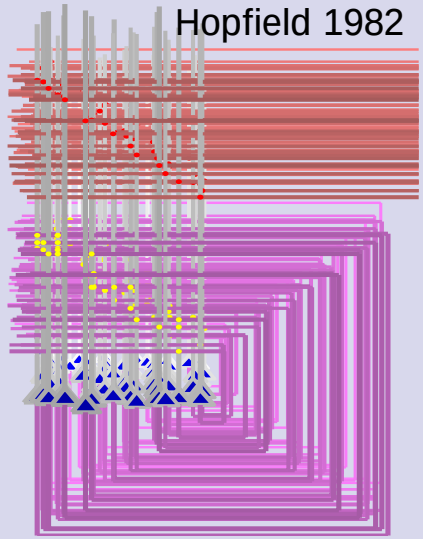
Digital anatomist, UW



Williams et al 1999



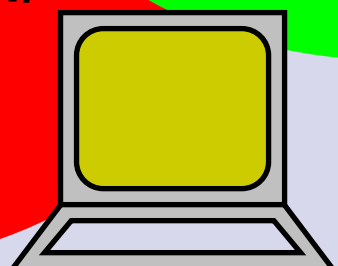
Hopfield 1982



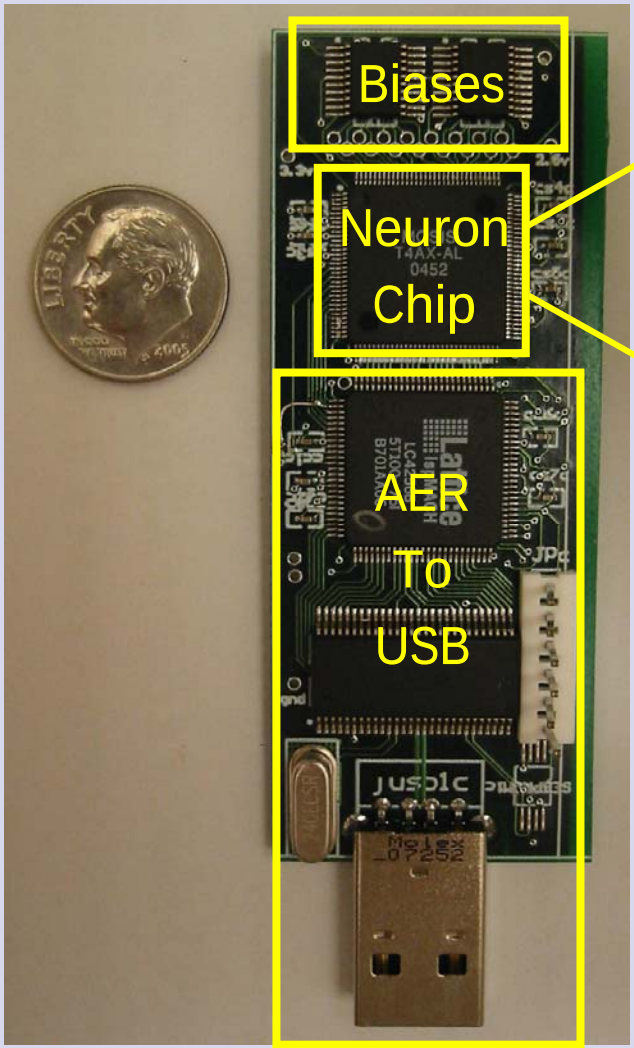
Experiment

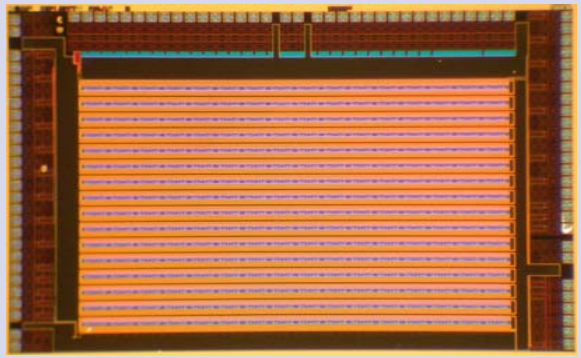
Theory

Simulation/
Emulation



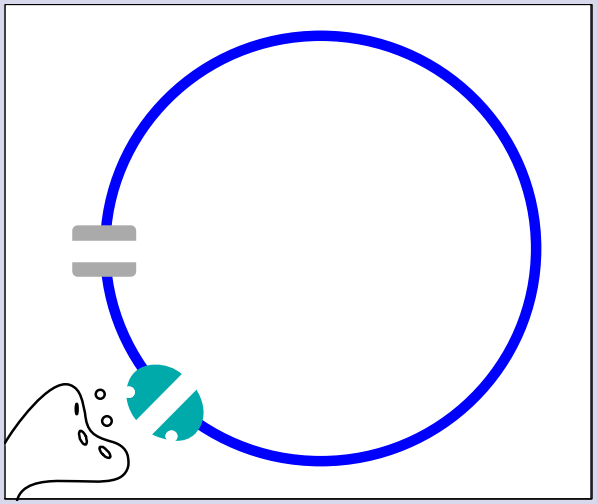
A Neuron Chip





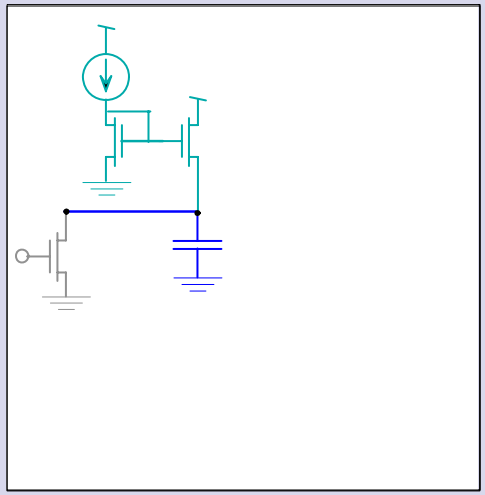
- 256 inhibitory neurons
- 1024 excitatory neurons
  - 21 plastic synapses each
- ~750,000 transistors
- 1-5mW

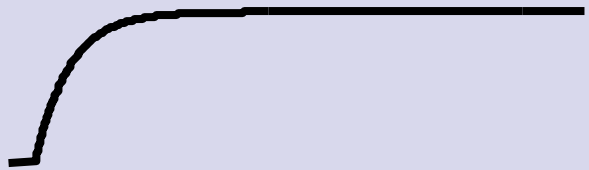
Neuron engineering



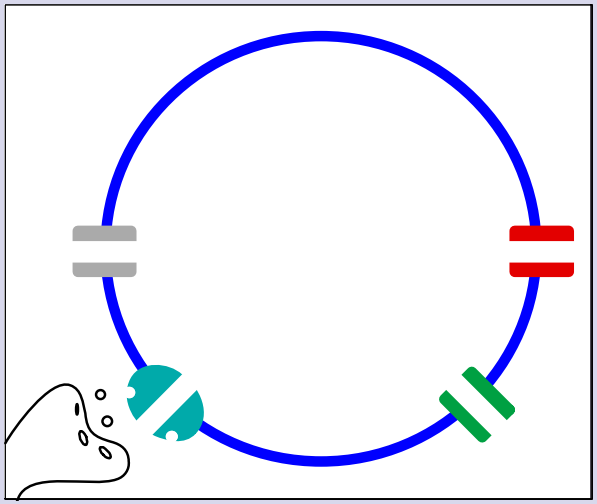
Leak channels

AMPA channels





Neuron engineering

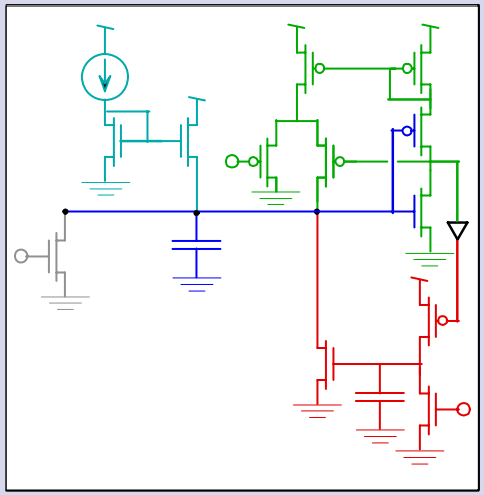


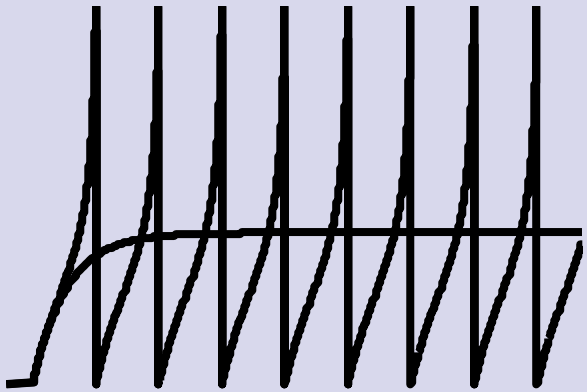
Leak channels

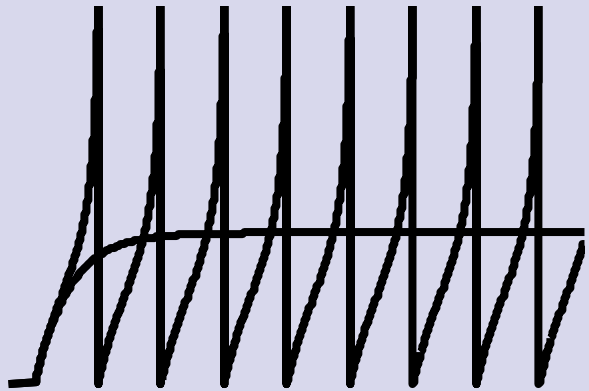
AMPA channels

Na channels

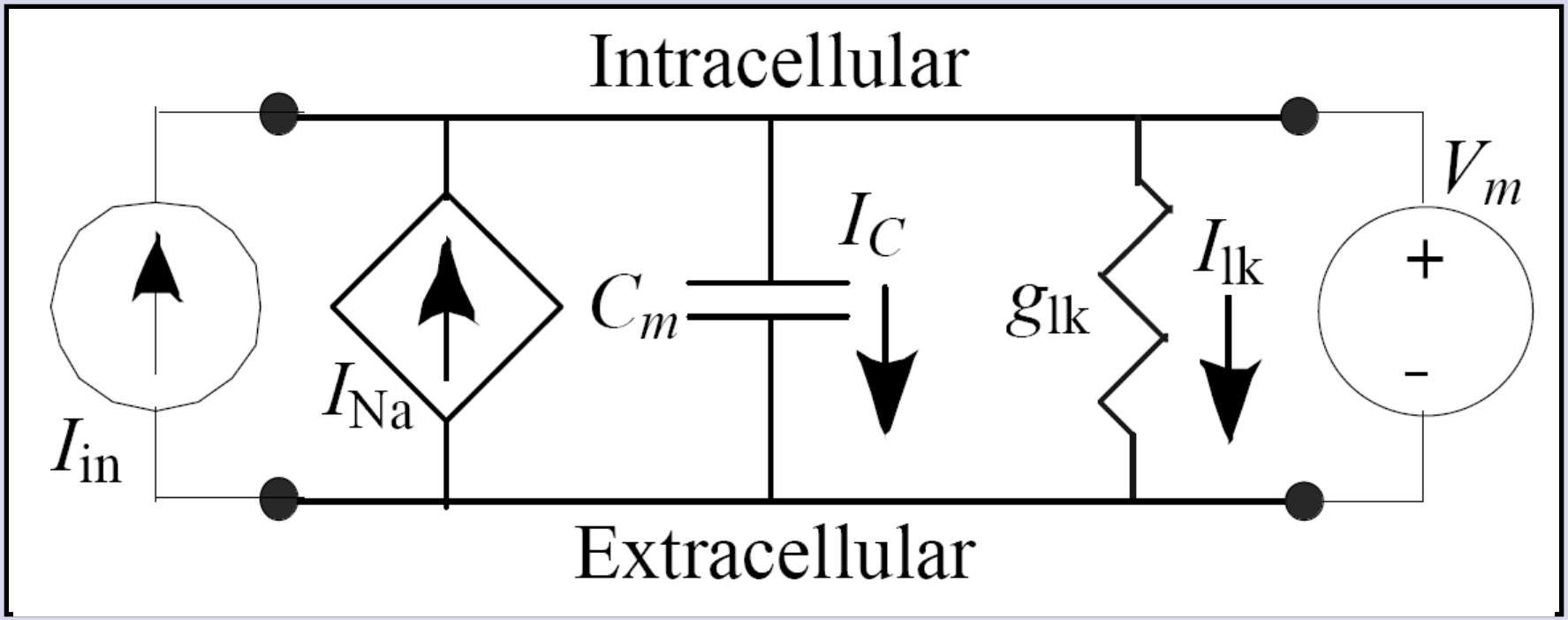
K channels

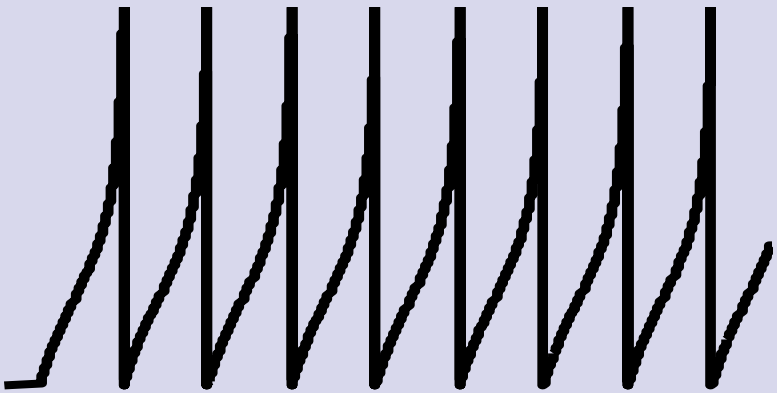






Spiking neuron

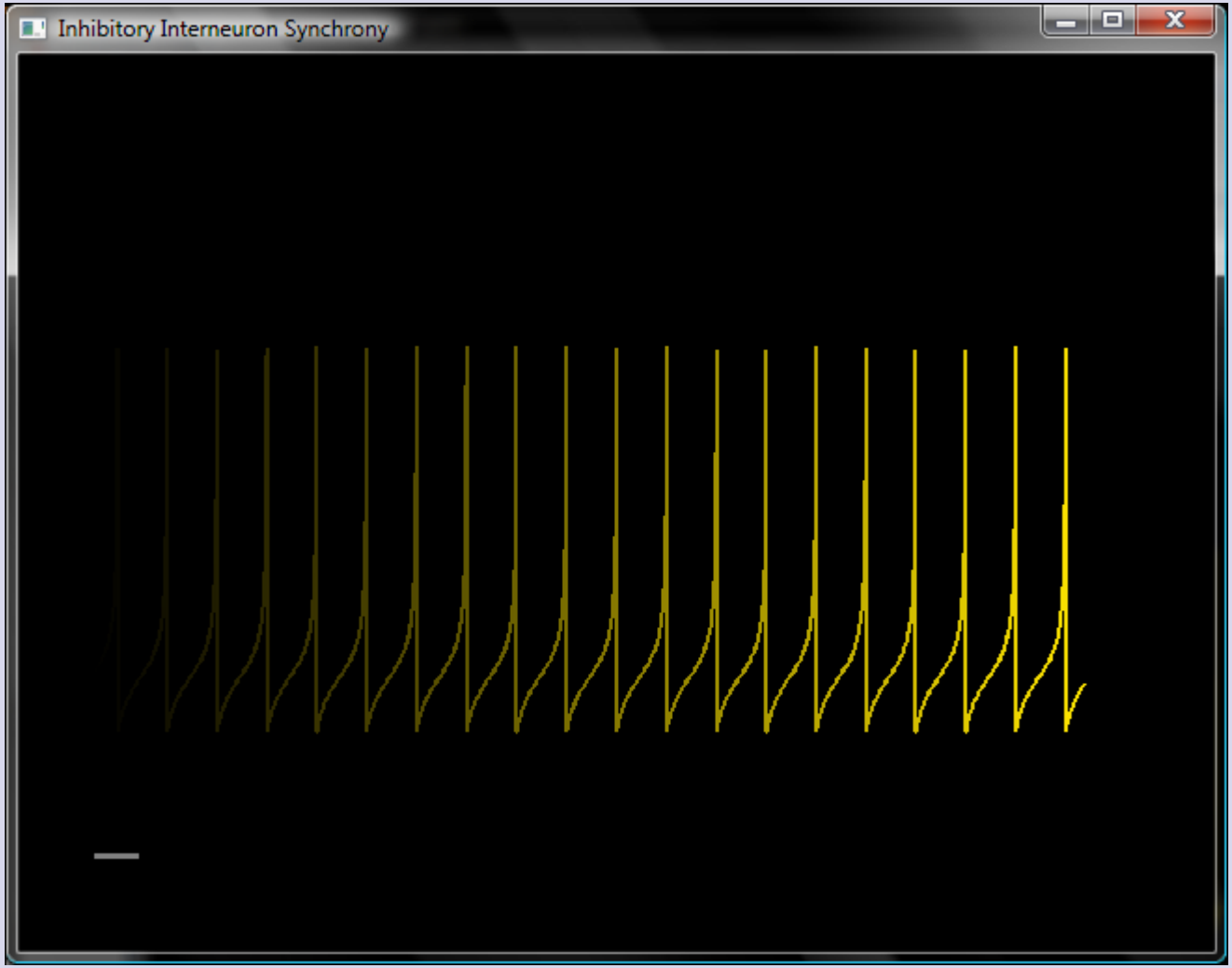




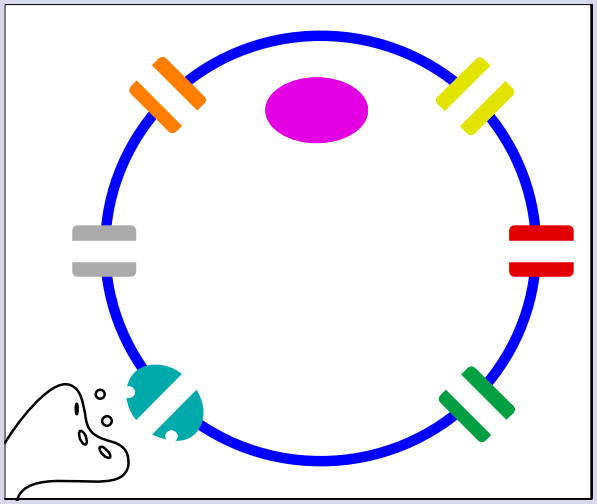
$$\tau \frac{dv}{dt} = -v + r + \frac{v^3}{3}$$

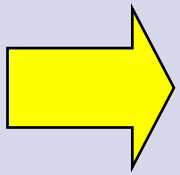
Run Neuron Lab – neuron.exe

- ‘r’ key increases current to neuron
- ‘shift’ + ‘r’ decreases current
- ‘t’ key increases neuron time constant
- ‘shift’ + ‘t’ decreases time constant
- Try ‘f4’ if nothing happens (big board)

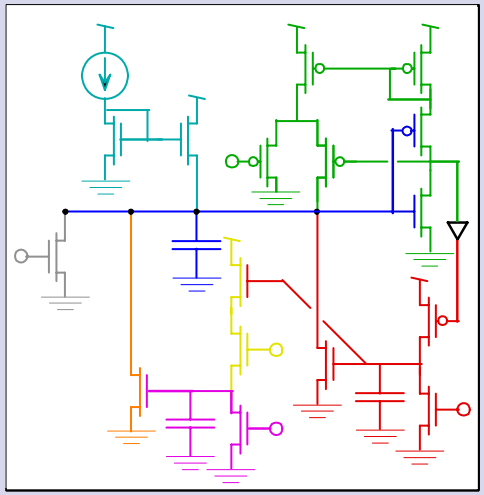

Inhibitory Interneuron Synchrony

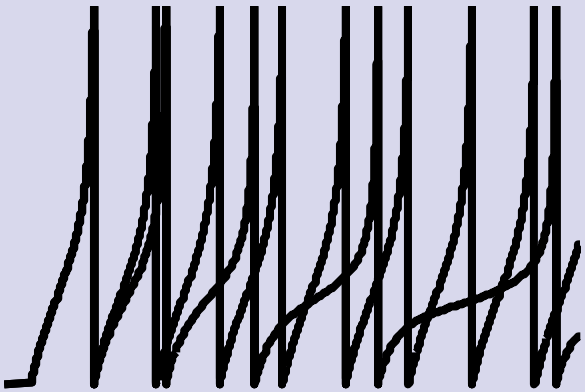
Neuron engineering

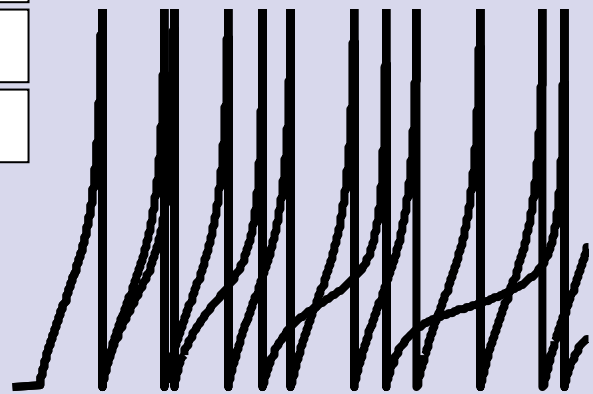




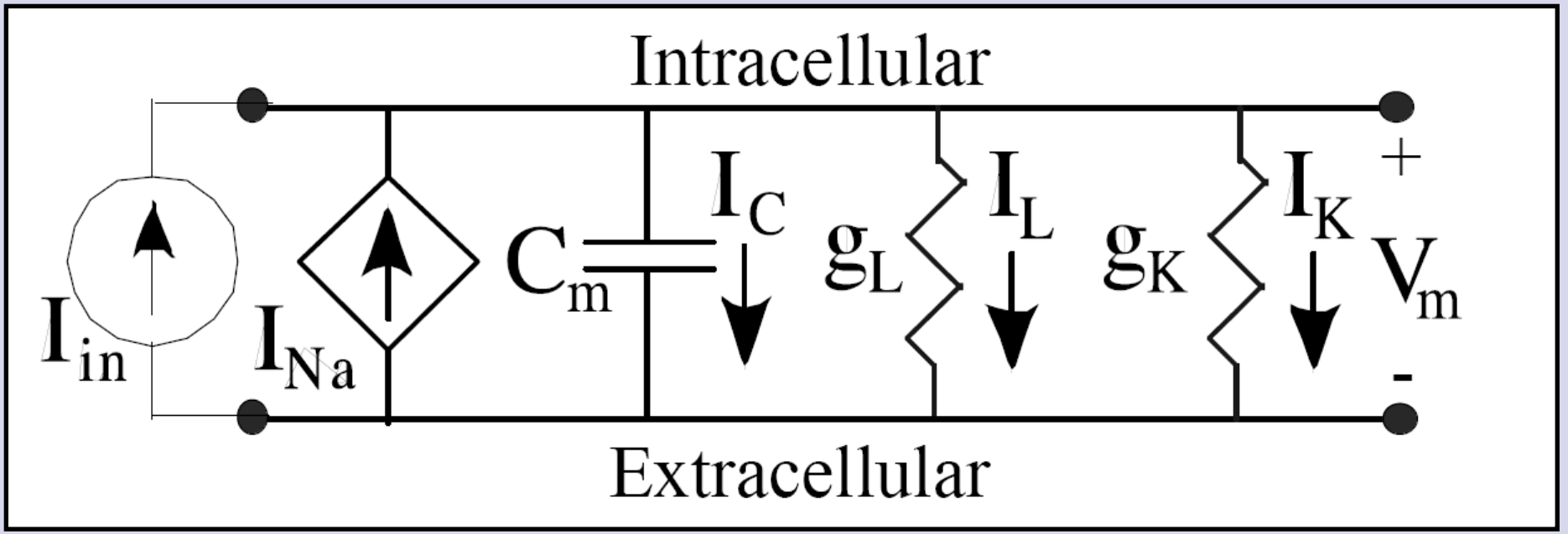
- Leak channels
- AMPA channels
- Na channels
- K channels
- Ca channels
- Ca buffers
- K(Ca) channels

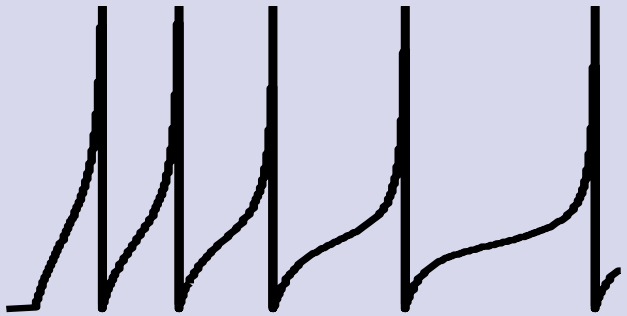






Adaptive neuron



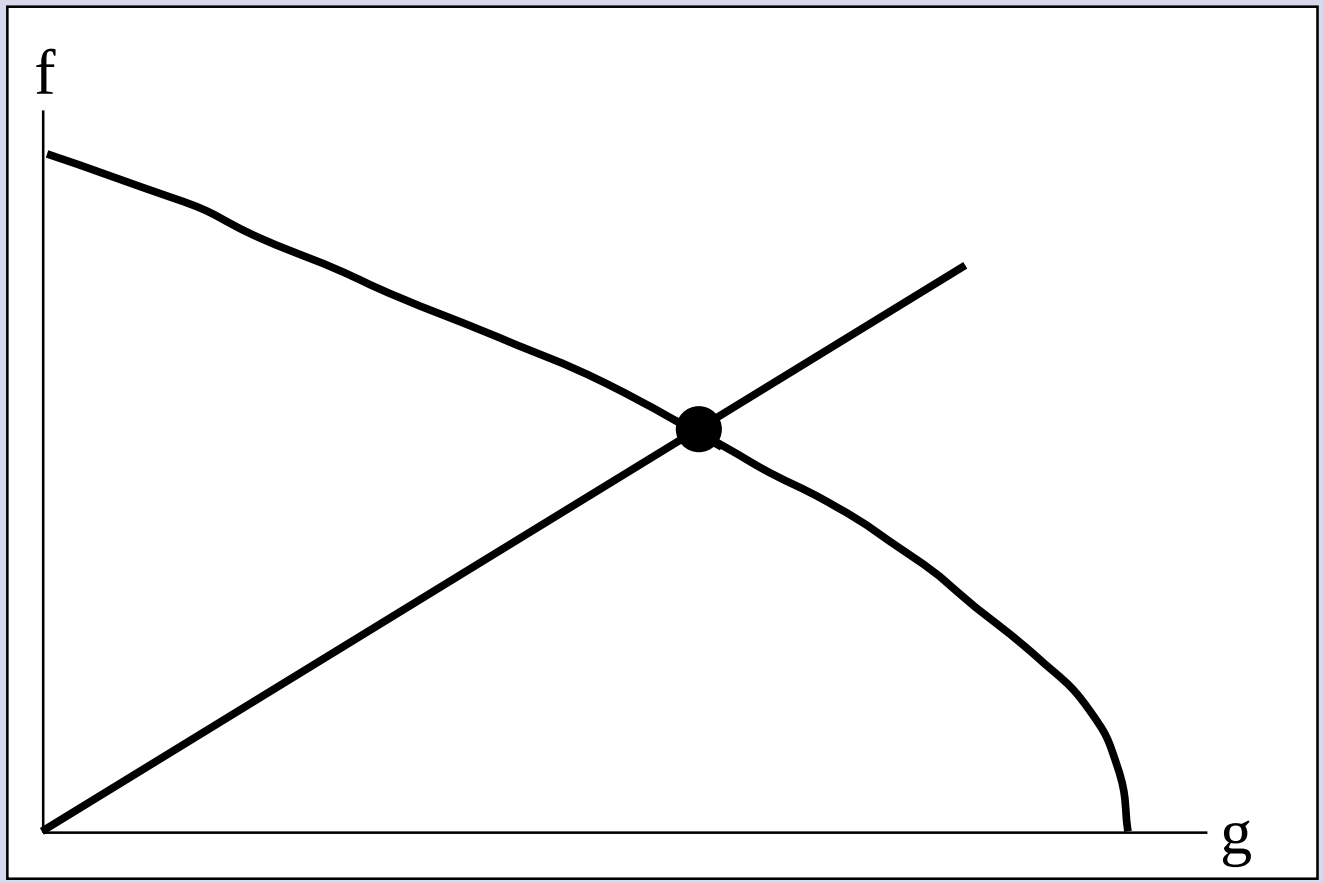


$$\tau_g \frac{dg}{dt} = -g$$

$$\tau \frac{dv}{dt} = -v(1+g) + r + \frac{v^3}{3}$$

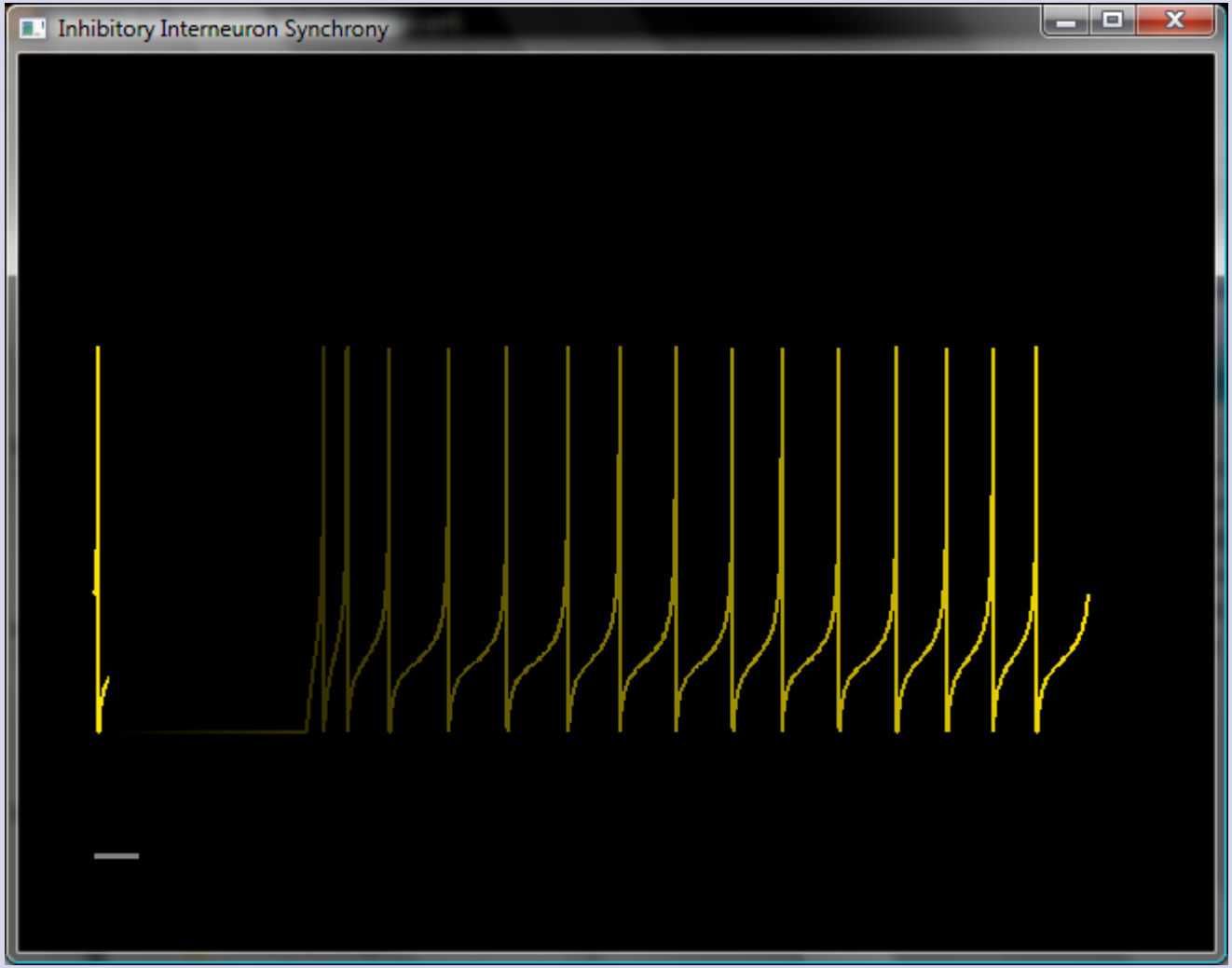
$$g \to g + \Delta g, t \to t_{spk}$$

Adaptive neuron frequency

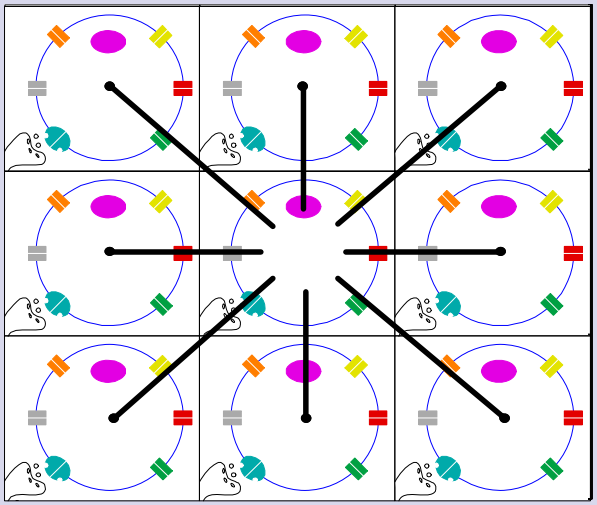


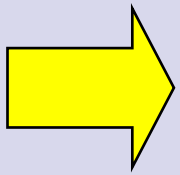
Run Adapting Lab – adapting.exe

- ‘s’ key turns on current step to neuron
- ‘shift’ + ‘s’ turns off current
- ‘g’ key increases K+ strength
- ‘shift’ + ‘g’ key decreases K+
- Try ‘f4’ if nothing happens (big board)


Inhibitory Interneuron Synchrony

Neuron engineering





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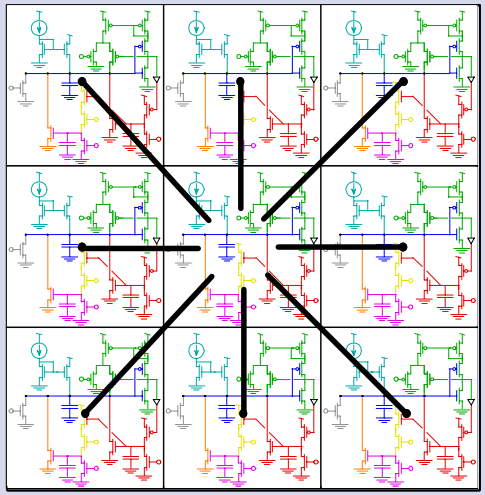
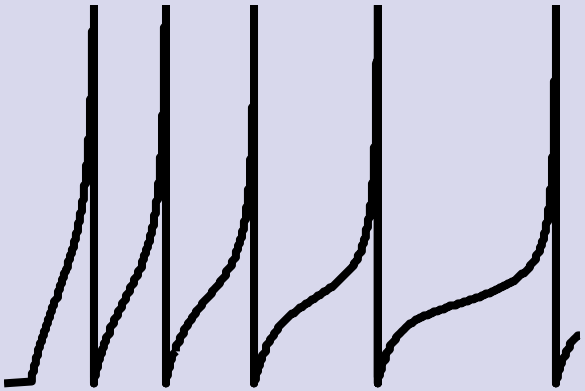
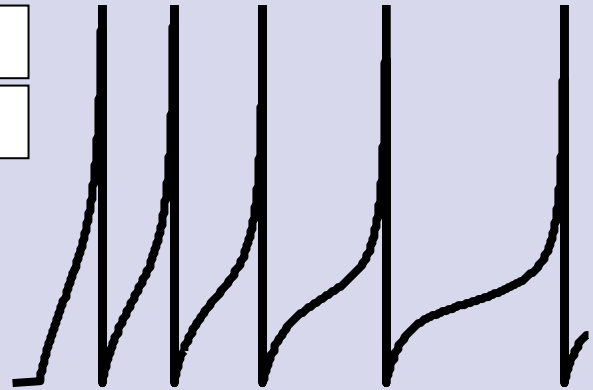
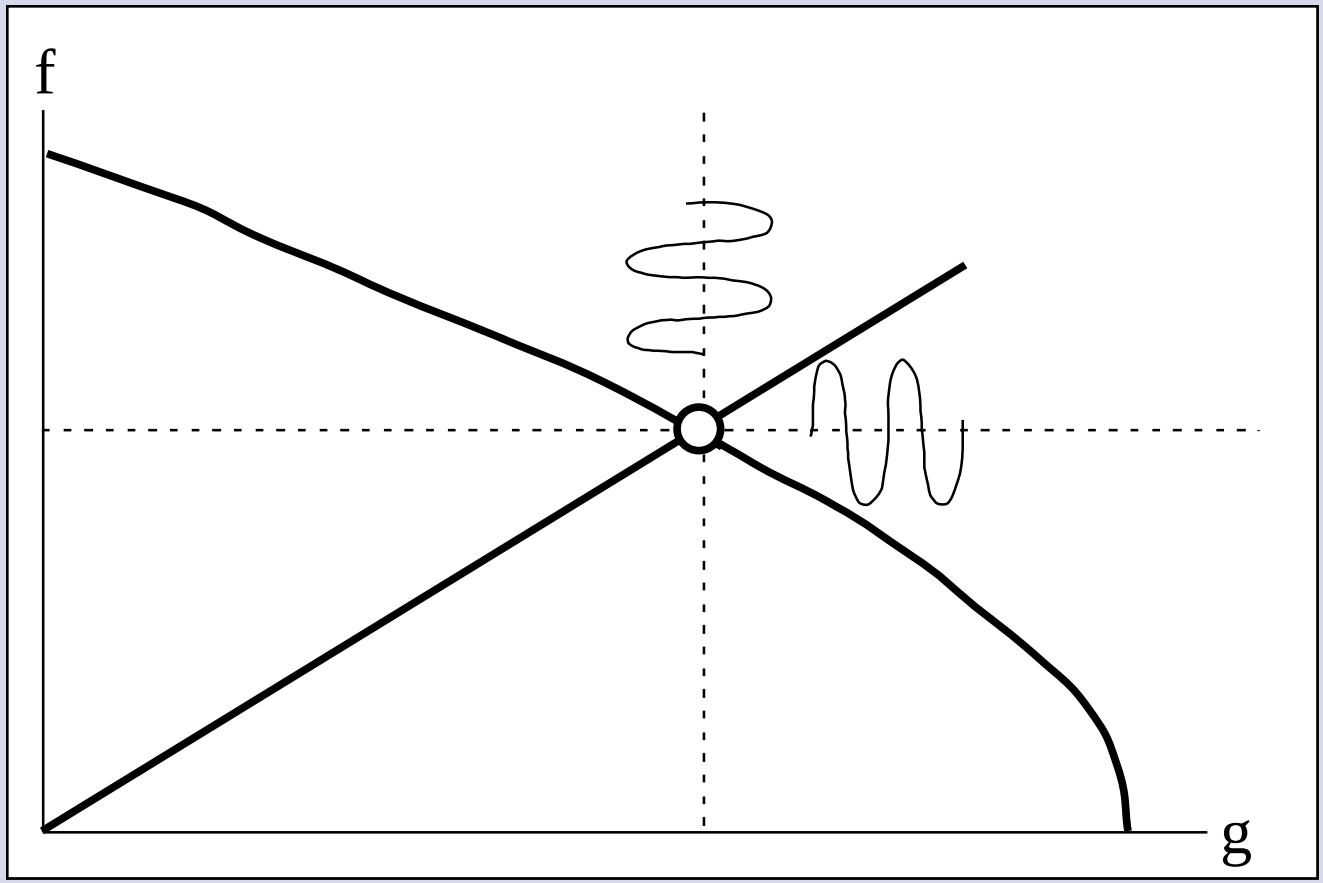




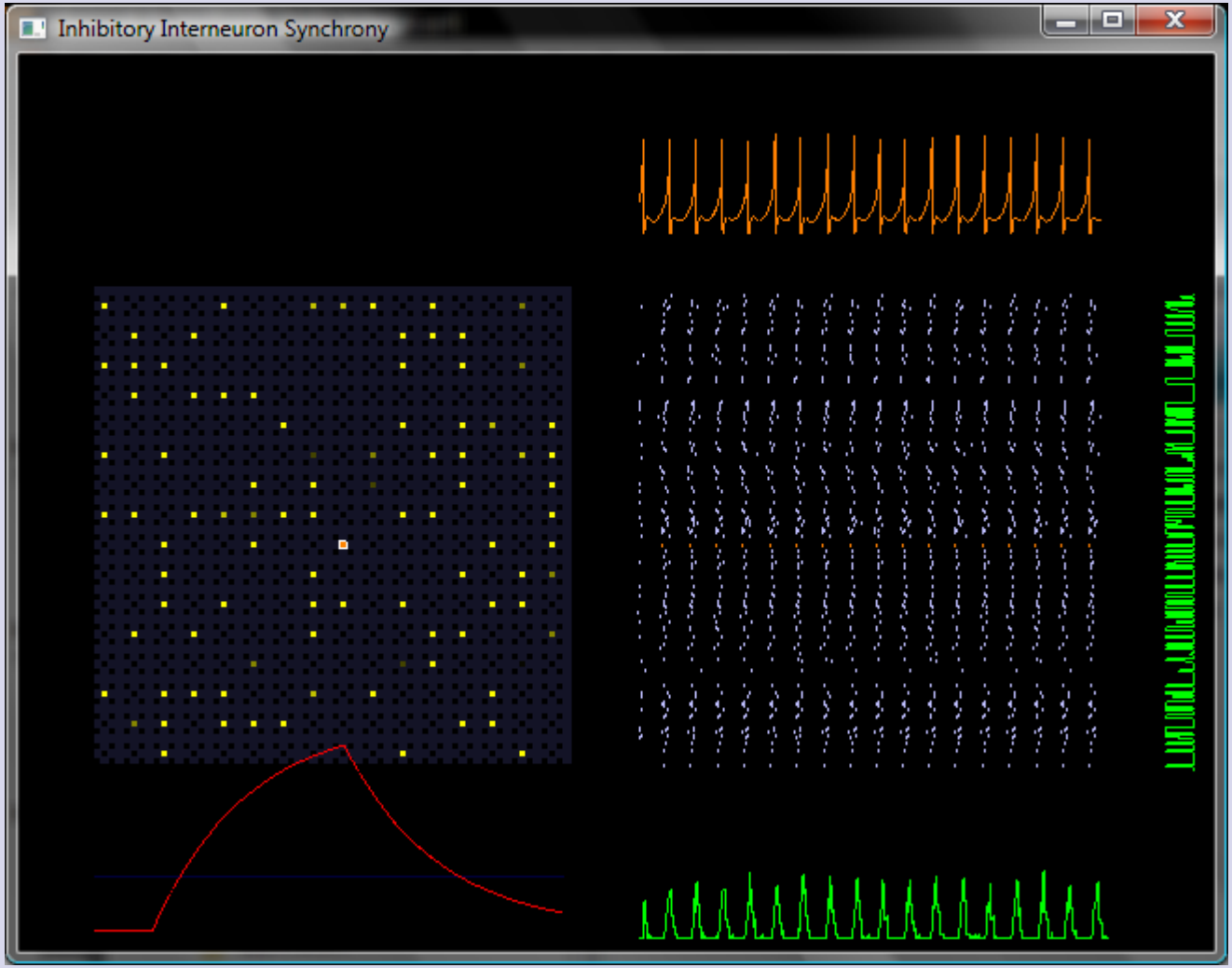
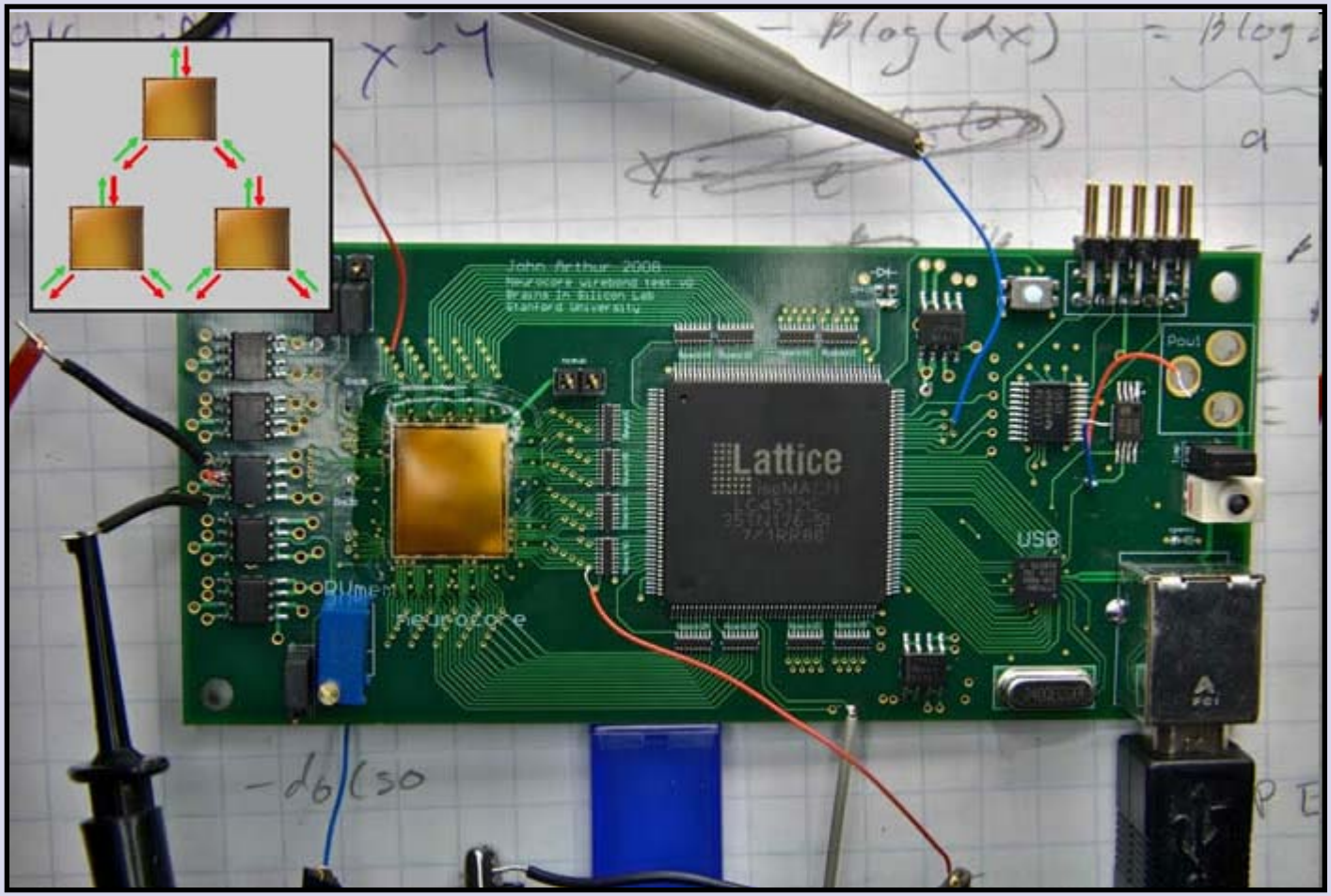


Synchrony



Run Synchrony Lab – synchrony.exe

- ‘+’ key turns up inhibition
- ‘-’ key turns downs inhibition
- ‘→’ key increases decay time
- ‘←’ key decreases decay time
- ‘↑’ key increases rise time
- ‘↓’ key decreases rise time


Inhibitory Interneuron Synchrony

A future chip: Neurogrid