Large-scale neural modeling

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Goal: Link structure to function through multi-level computational models.

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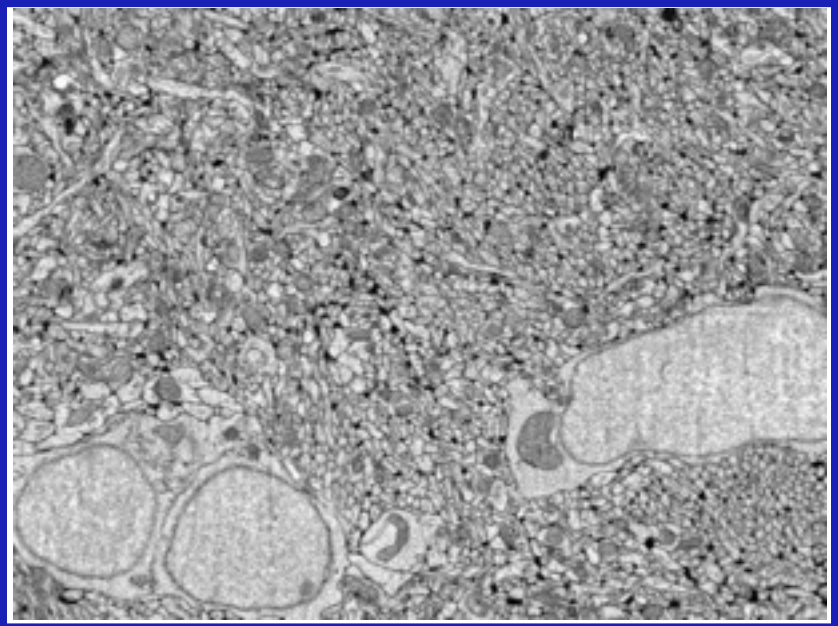
We're acquiring brain data at an unprecedented rate

Dendritic recording

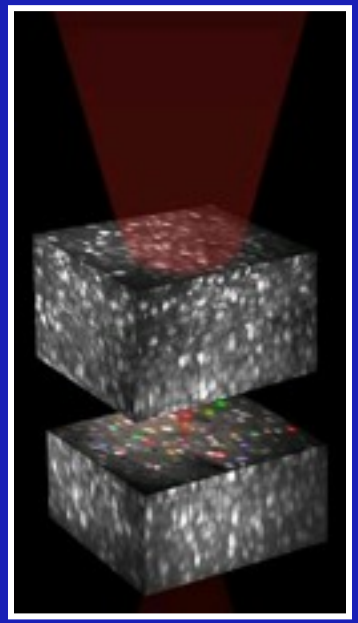
Hausser et al 1997

Serial Scanning EM



Denk et al 2005

Ca^{++} imaging



Reid et al 2005

Now all we have to is connect the dots…

Computational primitives + Microcircuitry = Functional behavior

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Multi-level modeling

The problem is one of scale

- 7 levels of investigation
- 10 orders of magnitude

Option 1: **Experiment**

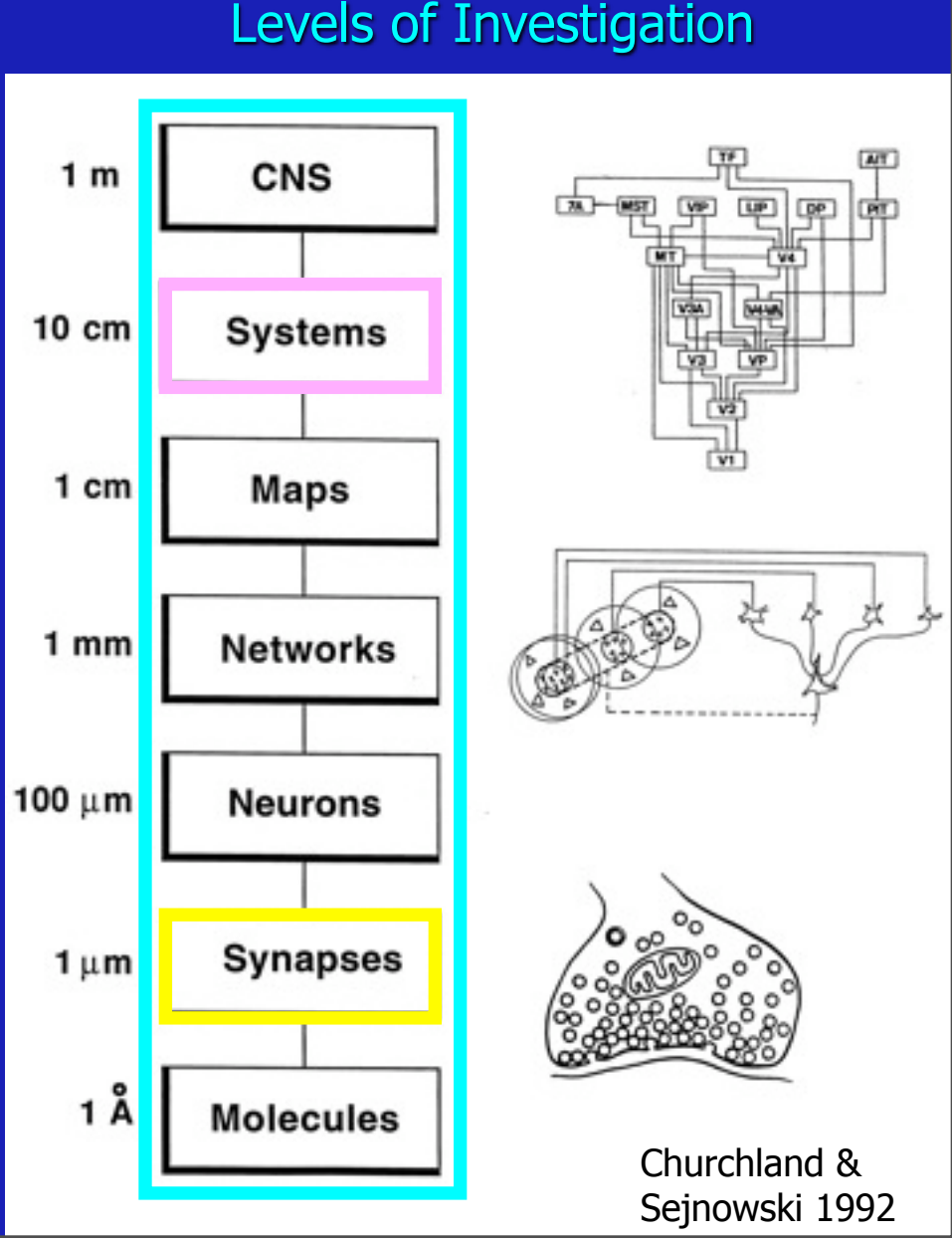
- Difficult to control

Option 2: **Theory**

- Ignores details

Option 3: **Simulation**

- Include all details
  - Complements theory
- Control all parameters
  - Complements experiment



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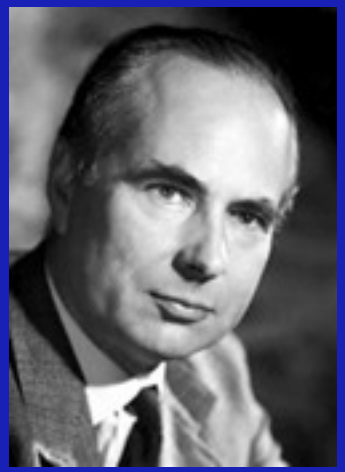

J. Physiol. (1952) 117, 500–544

A QUANTITATIVE DESCRIPTION OF MEMBRANE CURRENT AND ITS APPLICATION TO CONDUCTION AND EXCITATION IN NERVE

By A. L. HODGKIN and A. F. HUXLEY

From the Physiological Laboratory, University of Cambridge

(*Received* 10 *March* 1952)

This article concludes a series of papers concerned with the flow of electric cur
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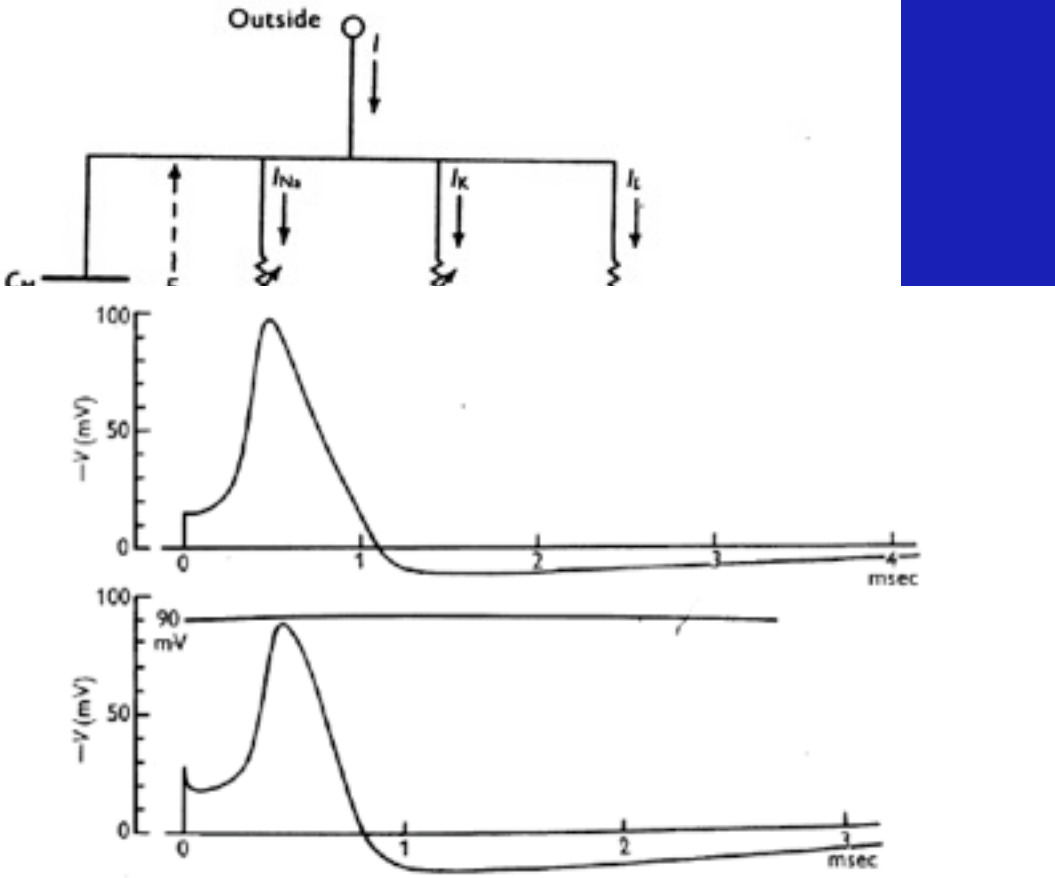

Fig. 1. E
R_K

Fig. 14. Upper curve: solution of eqn. (26) for initial depolarization of 15 mV, calculated for 18·5° C. Lower curve: tracing of membrane action potential recorded at 20·5° C (axon 11). Vertical scales are similar. Horizontal scales differ by a factor appropriate to the temperature difference.

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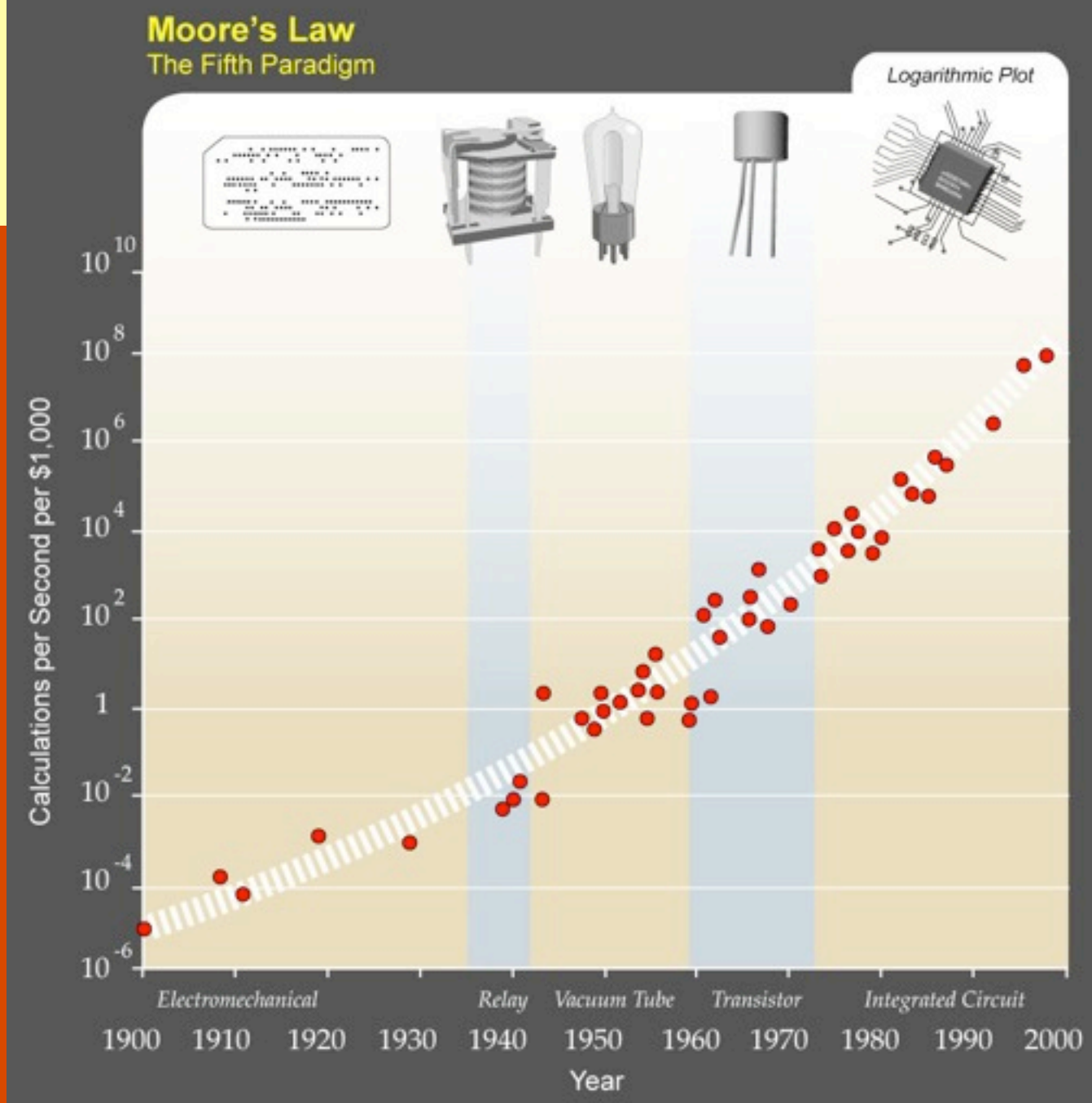

Ray Kurzweil 2001

3GHz Dell Precision

100Mz Compaq Presario

Brunsviga Model 20

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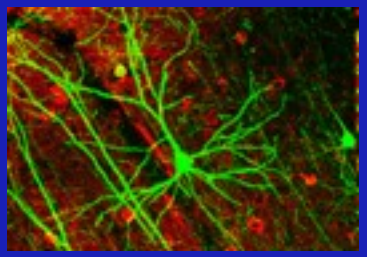

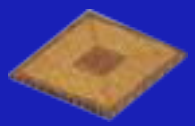

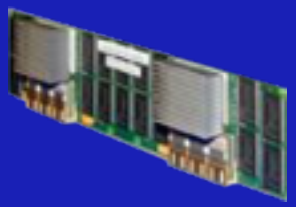

2 Processors

4 Processors

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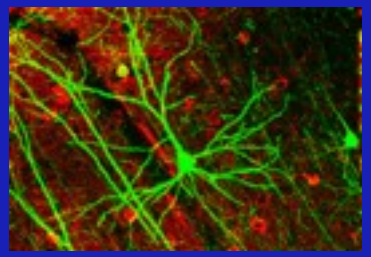

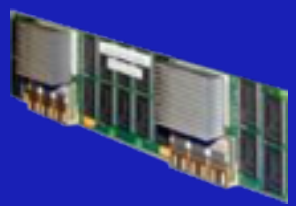

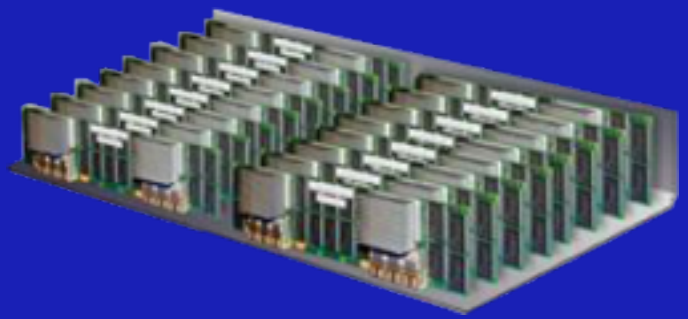

4 Processors

64 Processors

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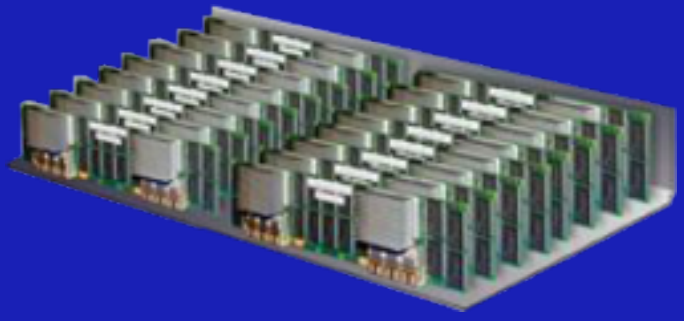

64 Processors

2,048 Processors

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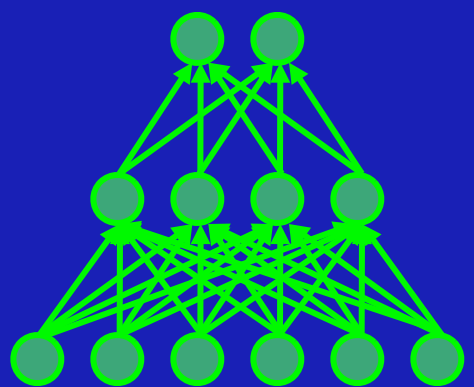
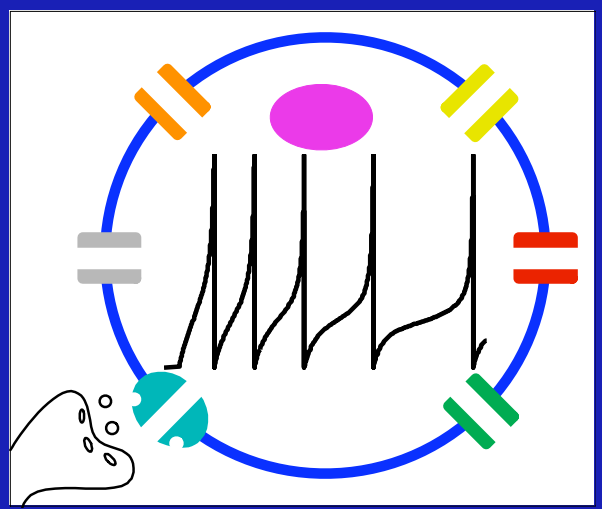
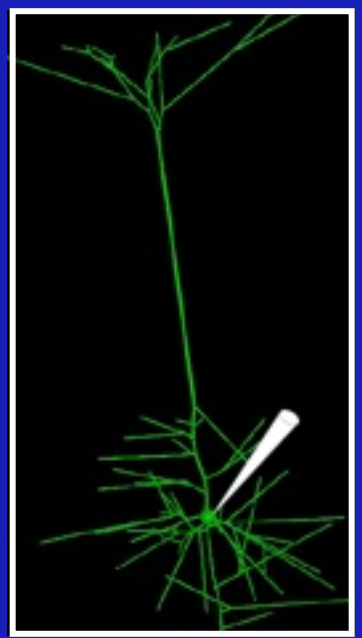
Neural abstractions

Rate	Spiking	Compartmental
		
Inaccurate	Compromise	Accurate
Tractable	Theory of Dynamical Systems	Intractable

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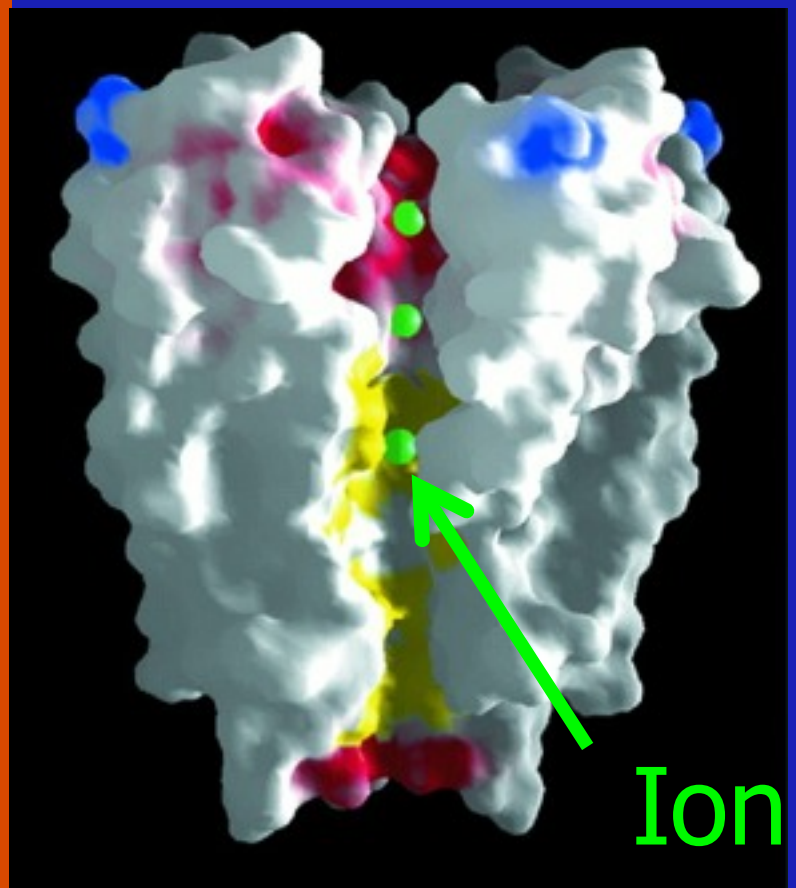
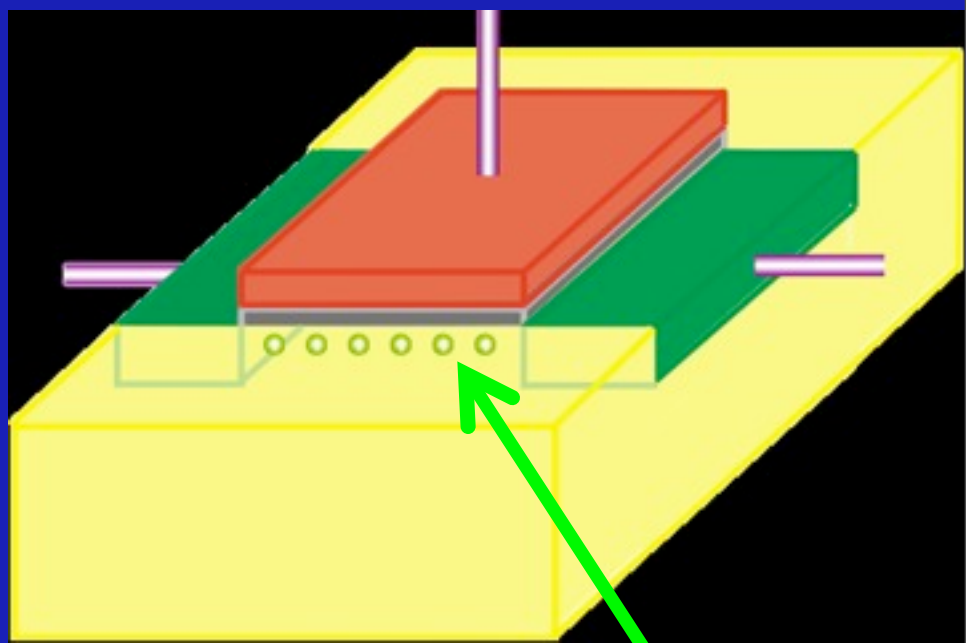
Analog computing—our secret weapon





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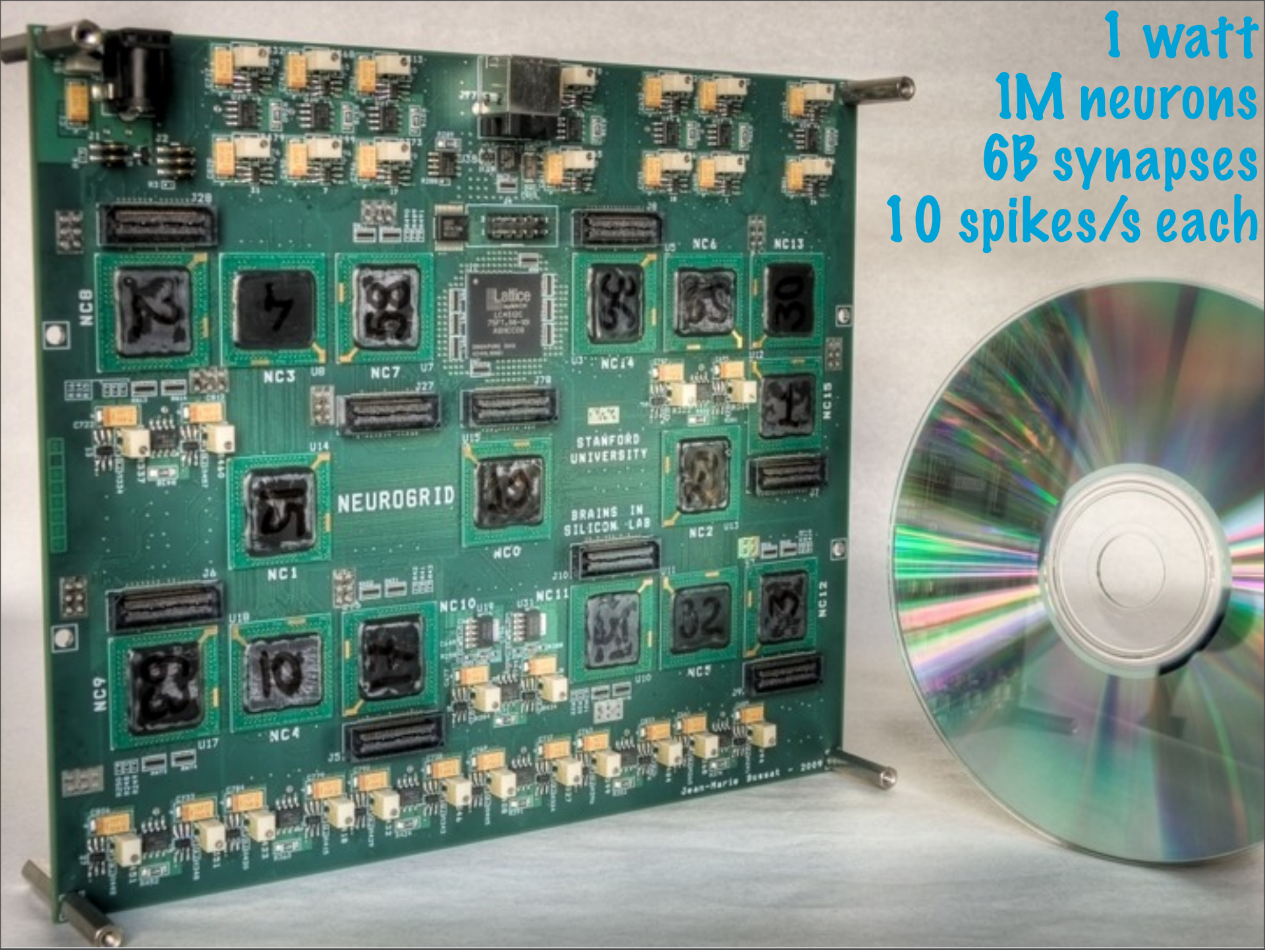
1 watt
1M neurons
6B synapses
10 spikes/s each
NEUROGRID
STANFORD UNIVERSITY
BRAINS IN SILICON LAB
NC0
NC1
NC2
NC3
NC4
NC5
NC6
NC7
NC8
NC9
NC10
NC11
NC12
NC13
NC14
NC15

John Arthur

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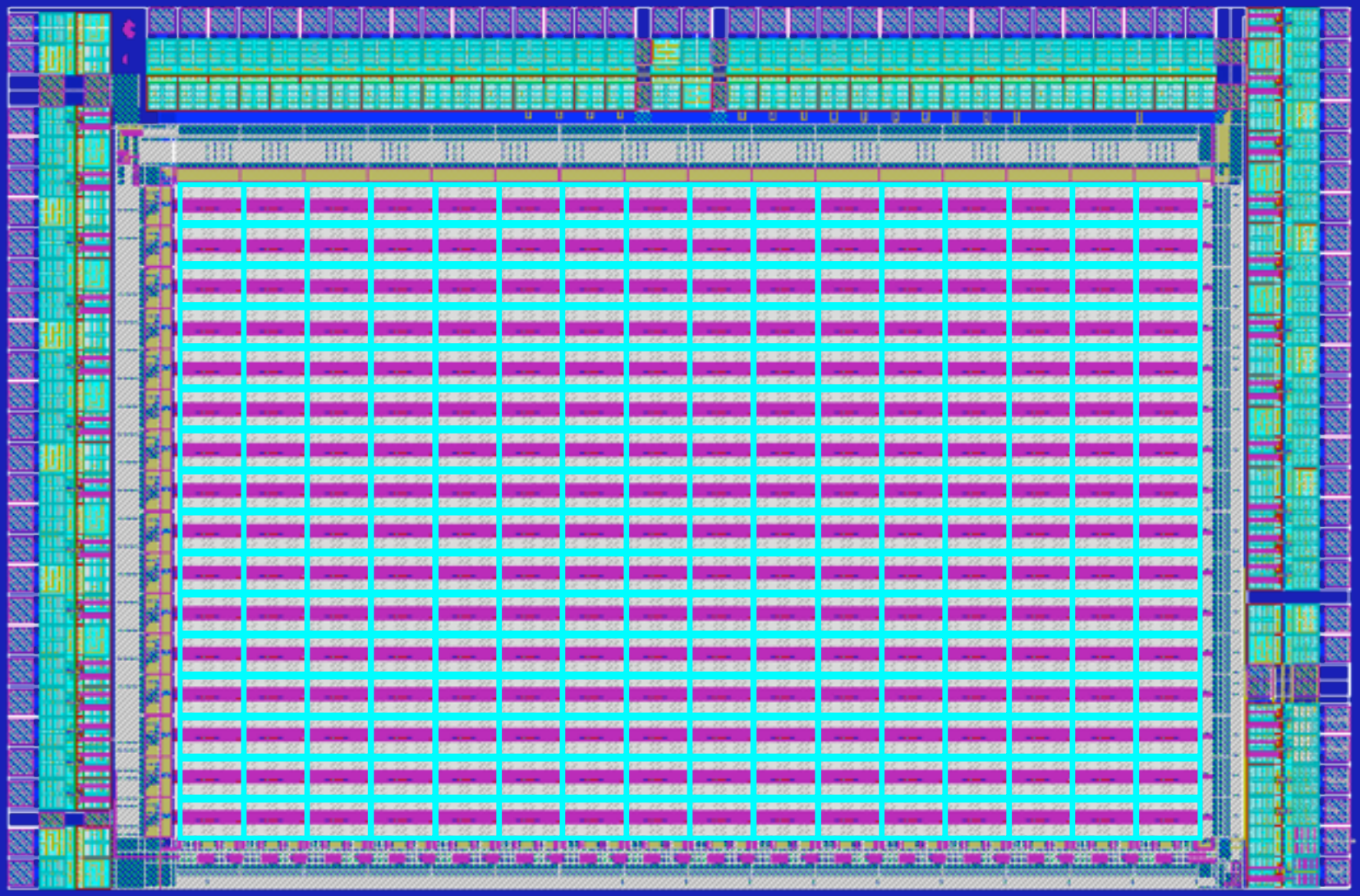

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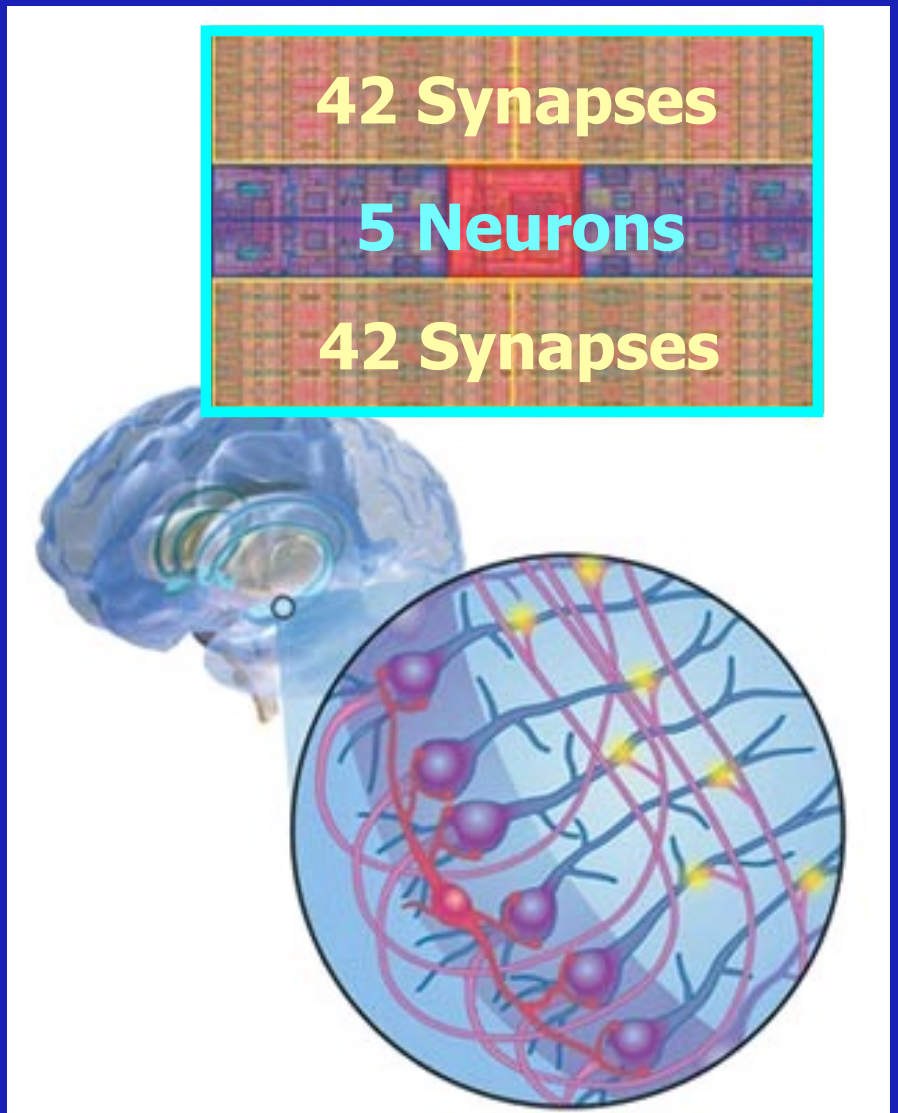

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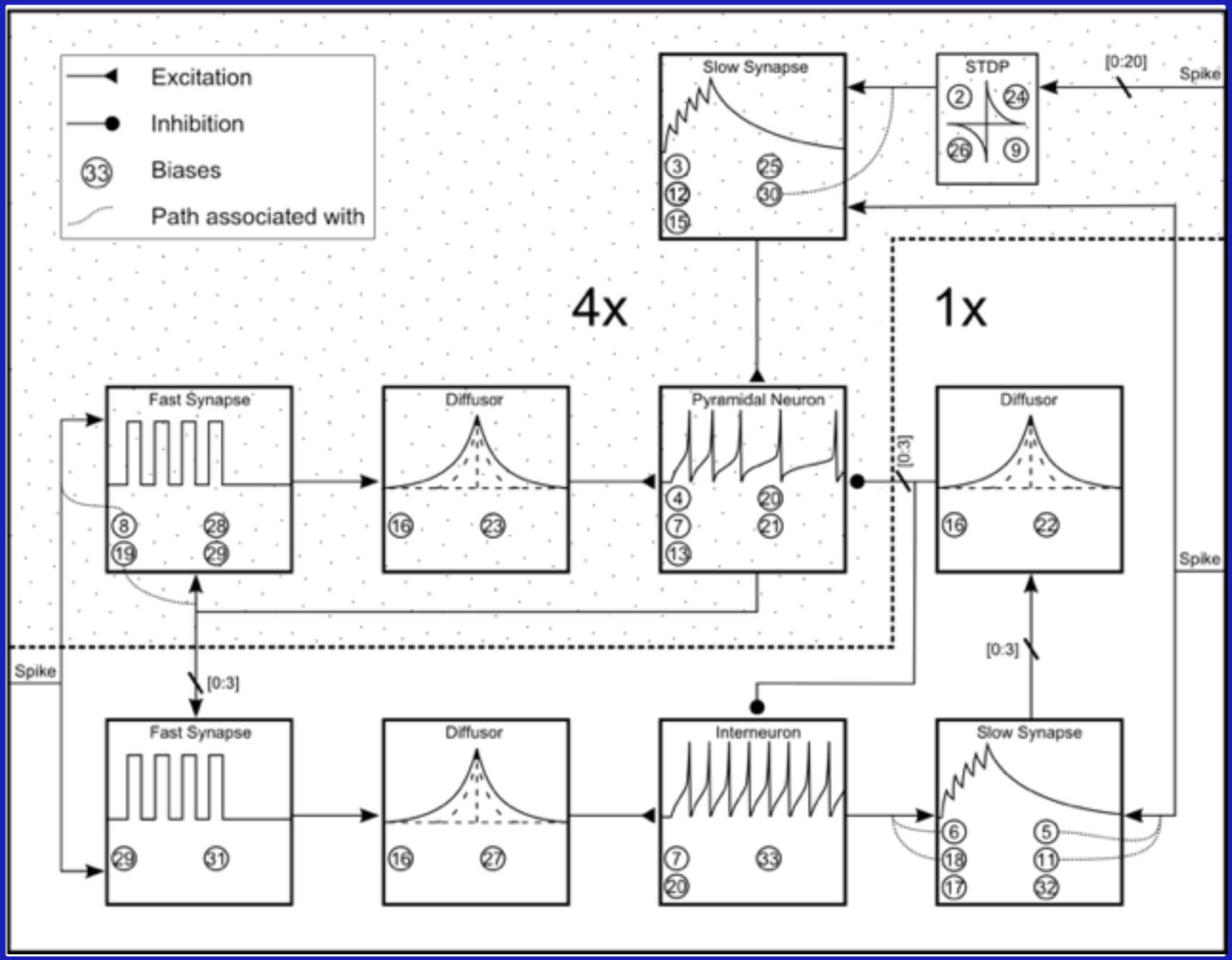
Excitation
Inhibition
33 Biases
Path associated with
Slow Synapse
STDP
[0:20]
Spike
2
24
26
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Fast Synapse
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Pyramidal Neuron
Diffusor
8
19
28
29
16
23
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Spike
Spike
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[0:3]
Fast Synapse
Diffusor
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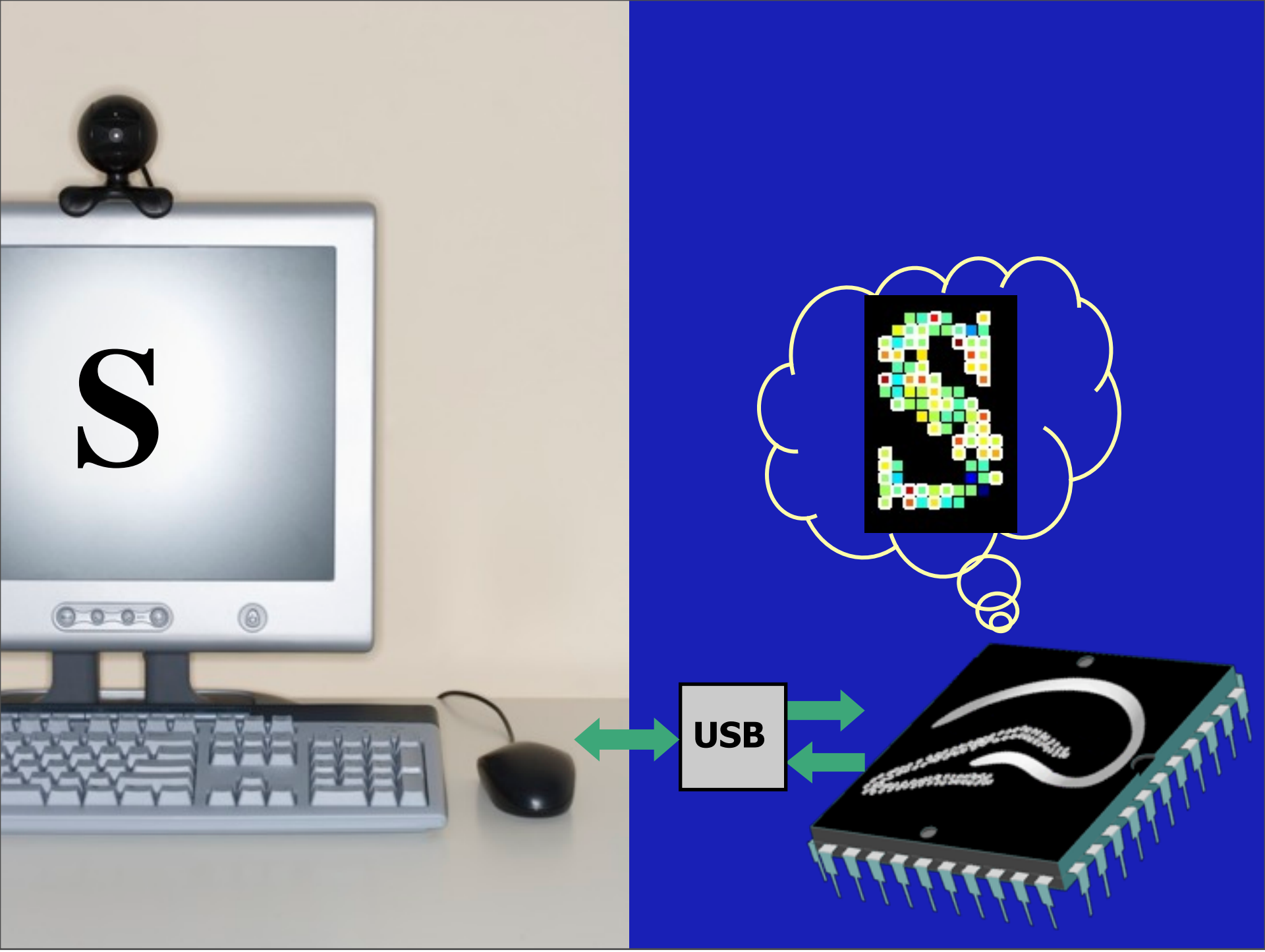
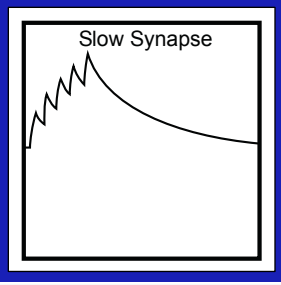
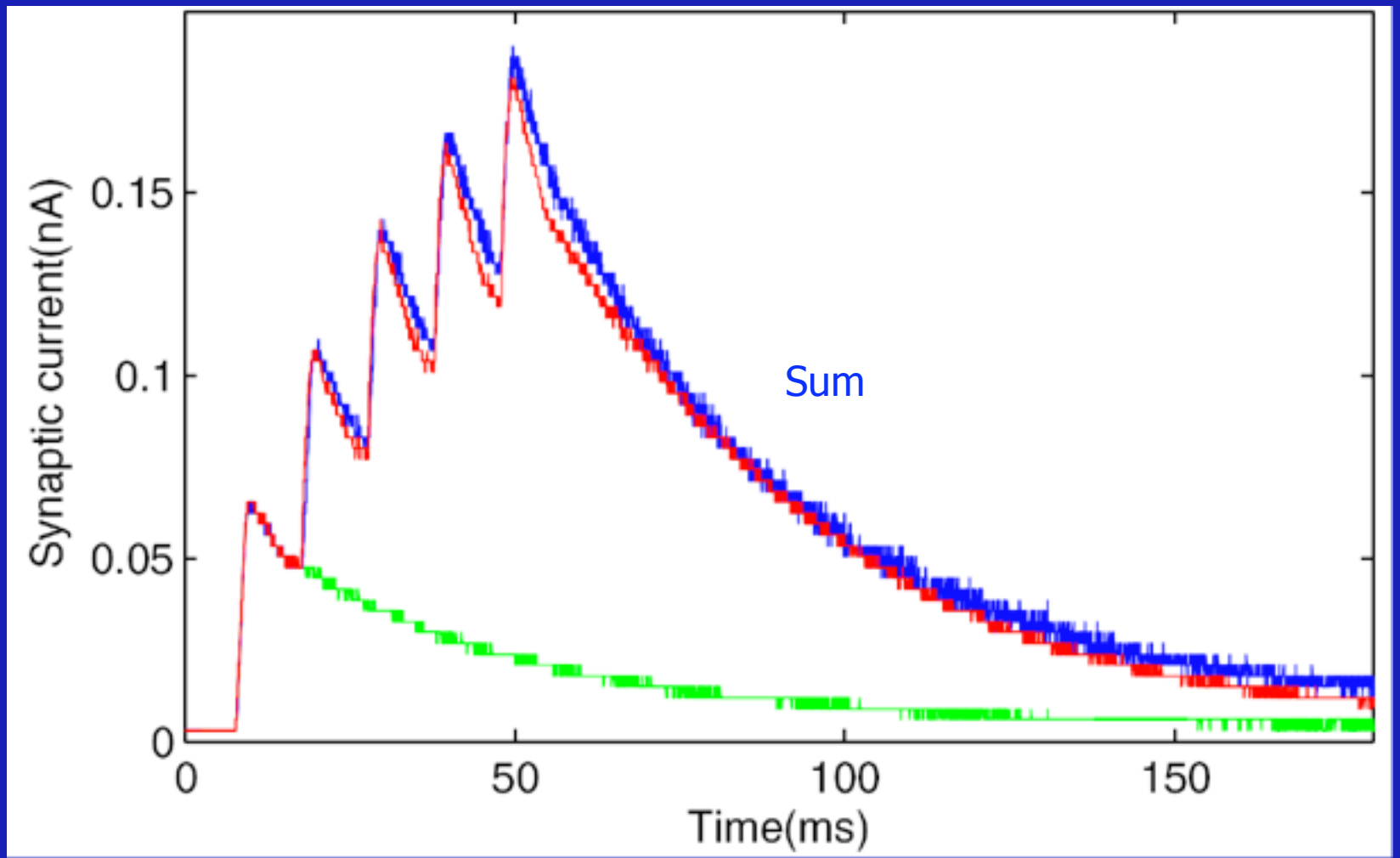

S
USB

Lab 1: Synapse Model





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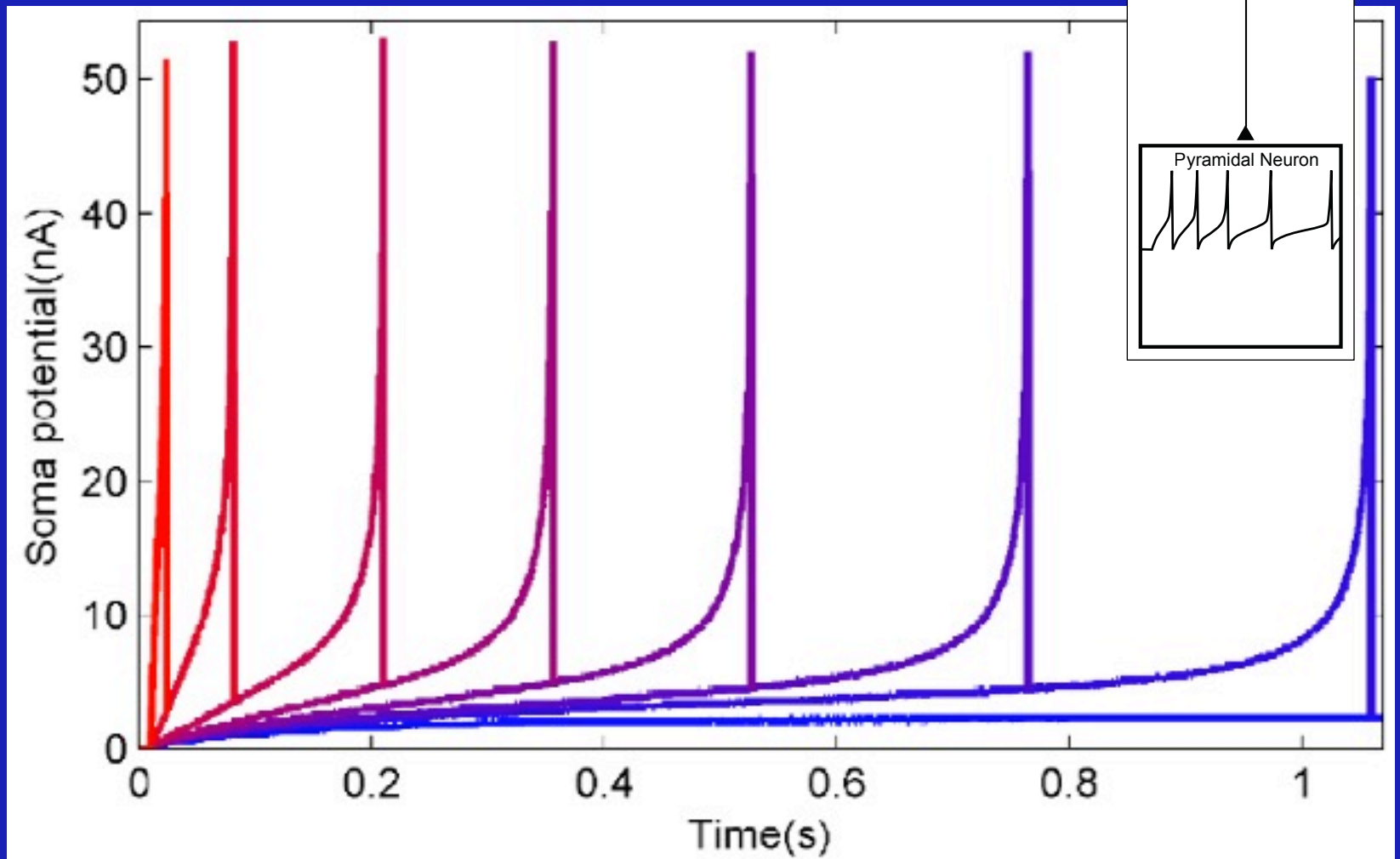
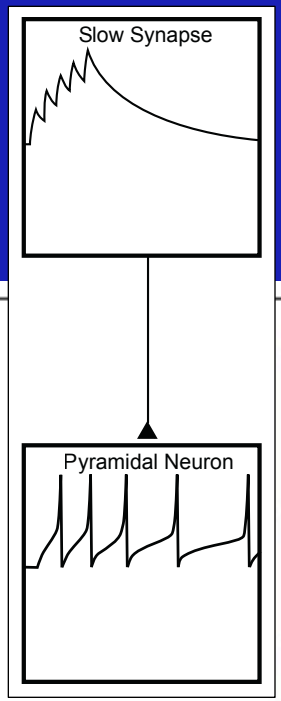
Lab 2: Neuron Model





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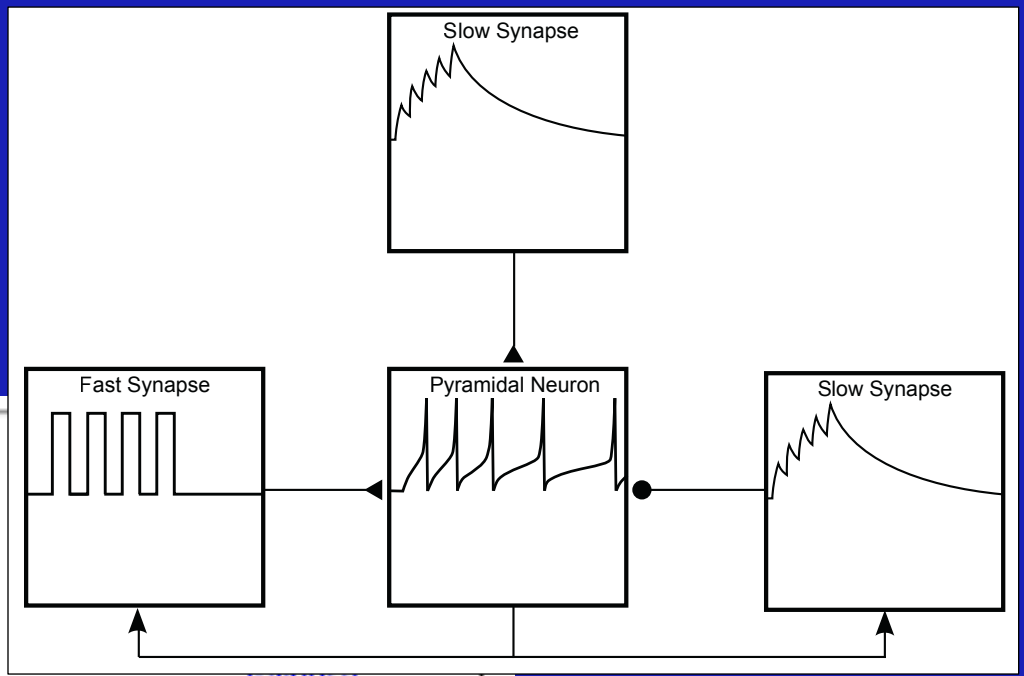
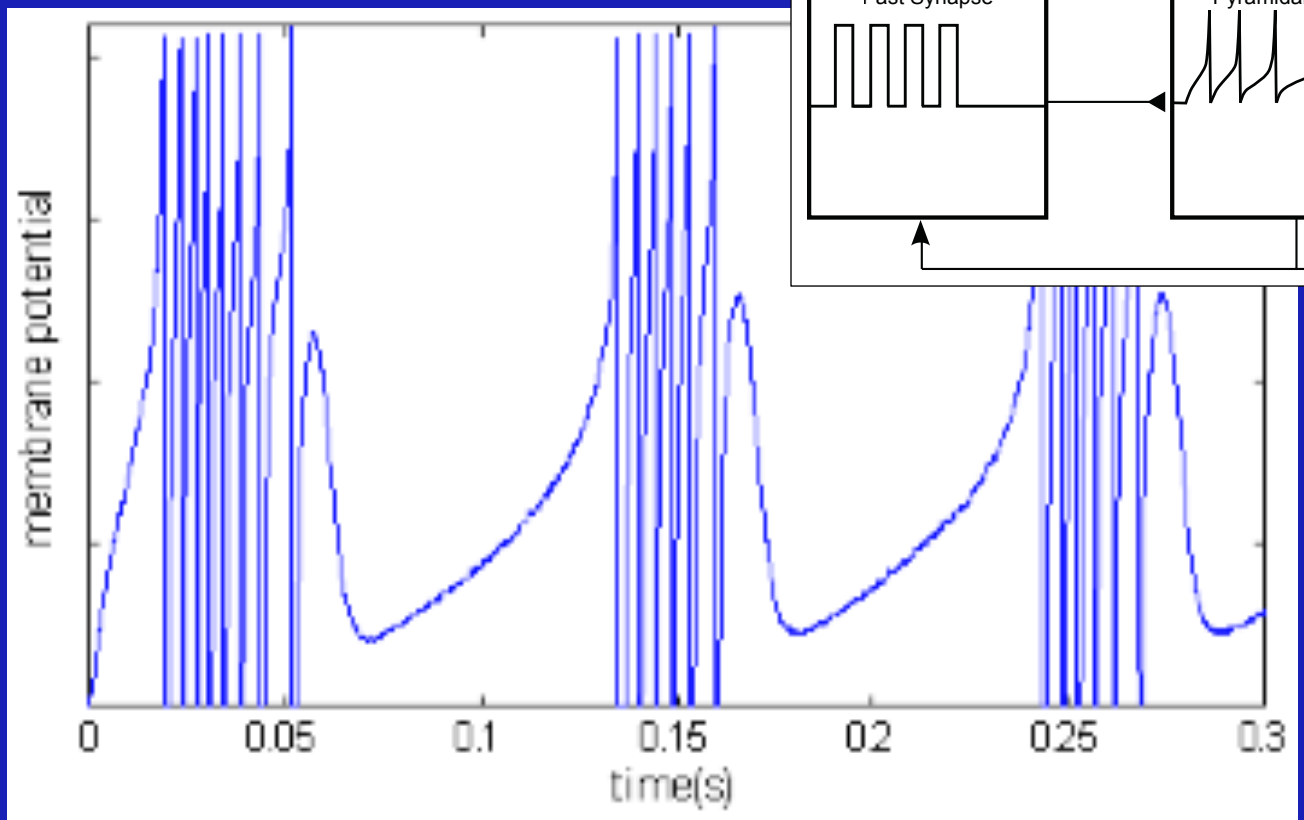
Lab 3: Adaptation and Bursting





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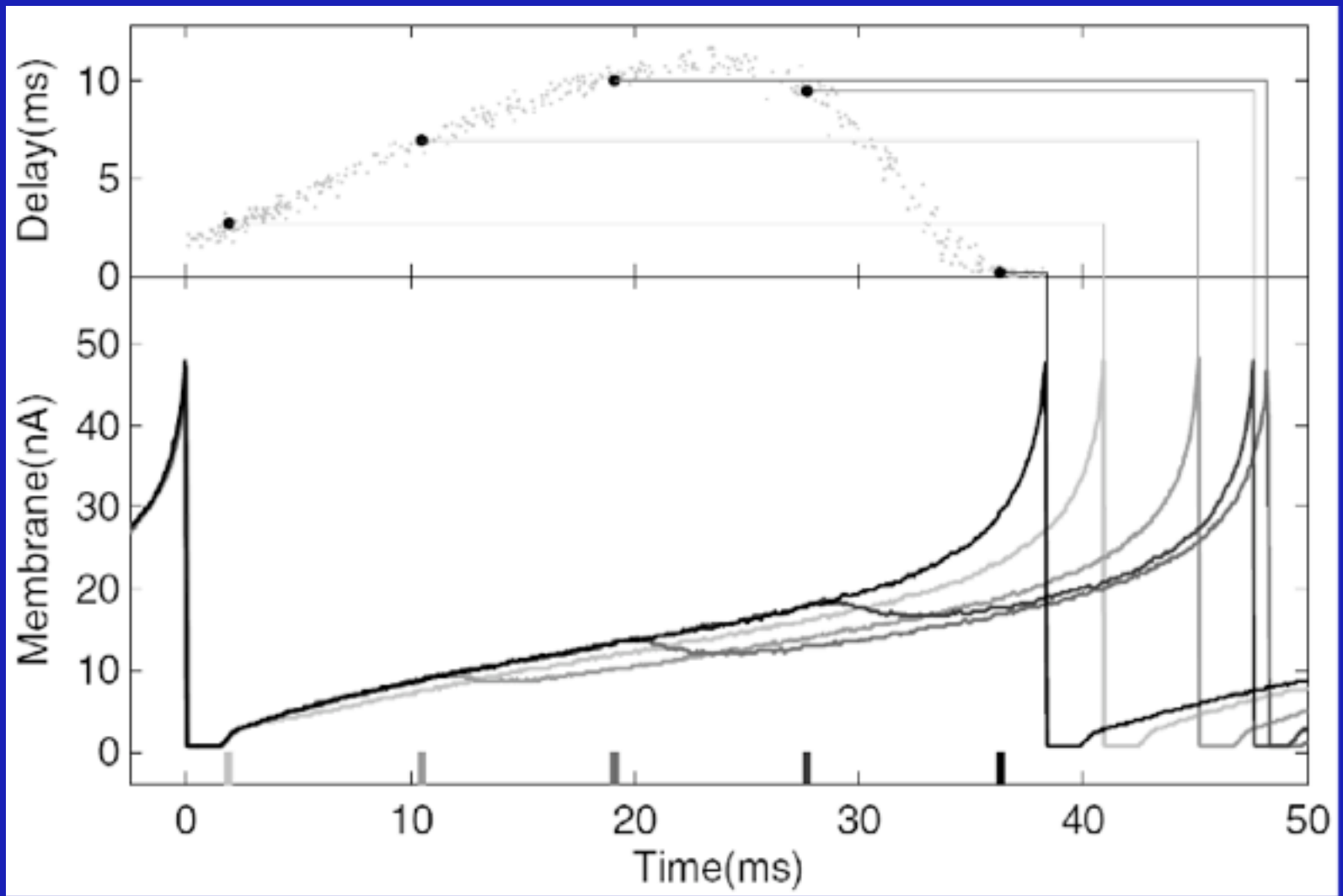
Lab 4: Phase Response



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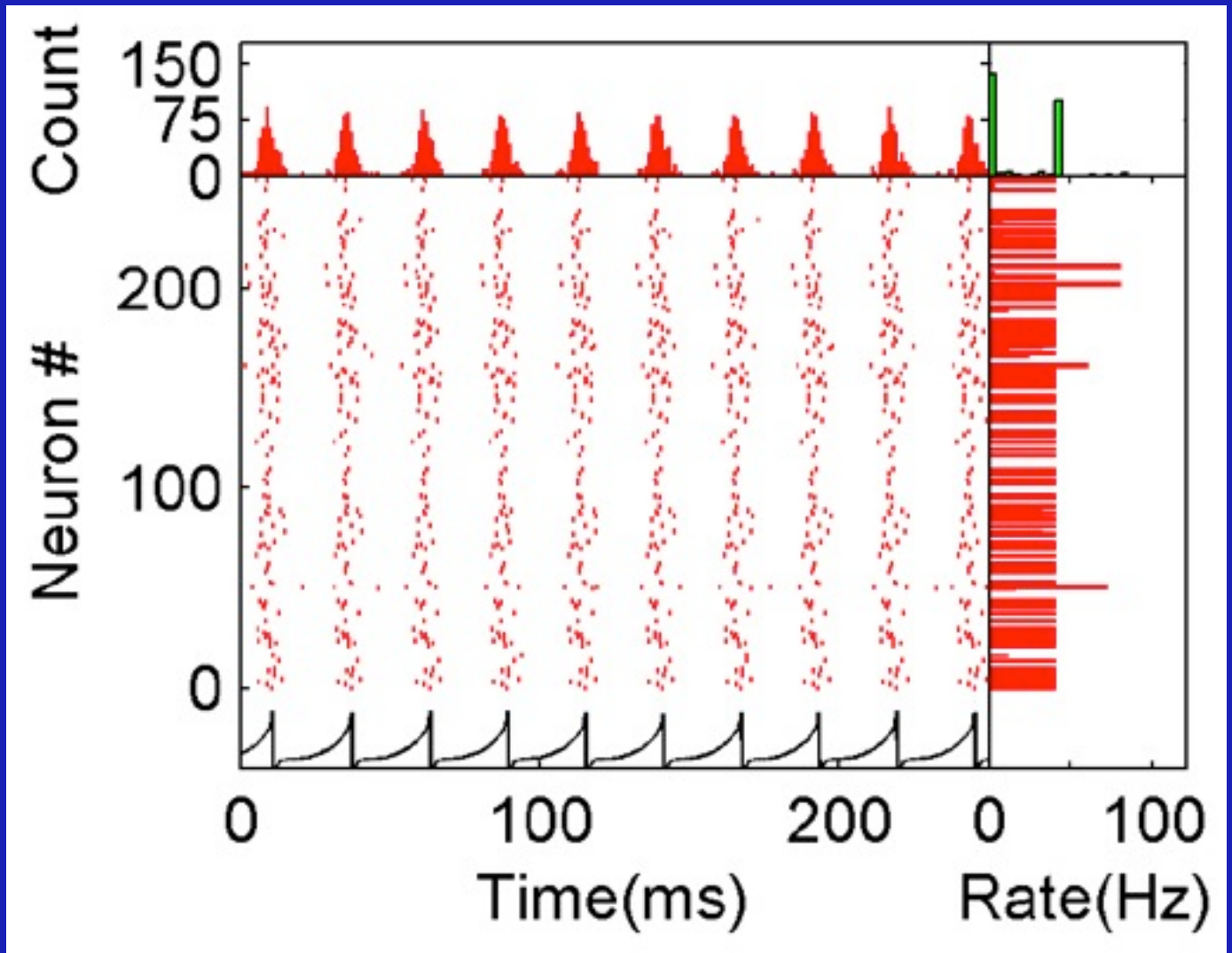
Lab 5: Synchrony



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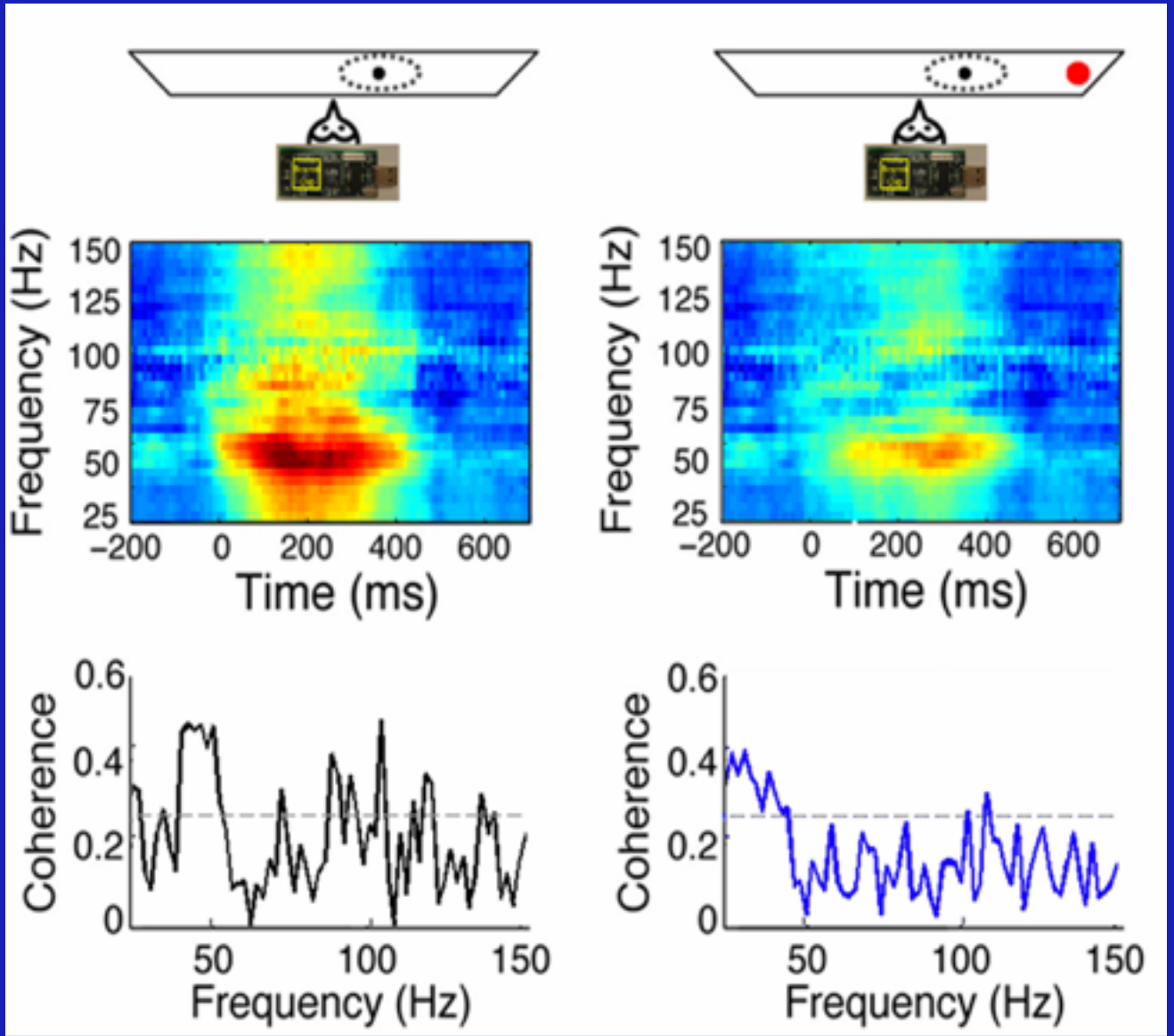
Lab 6: Attention



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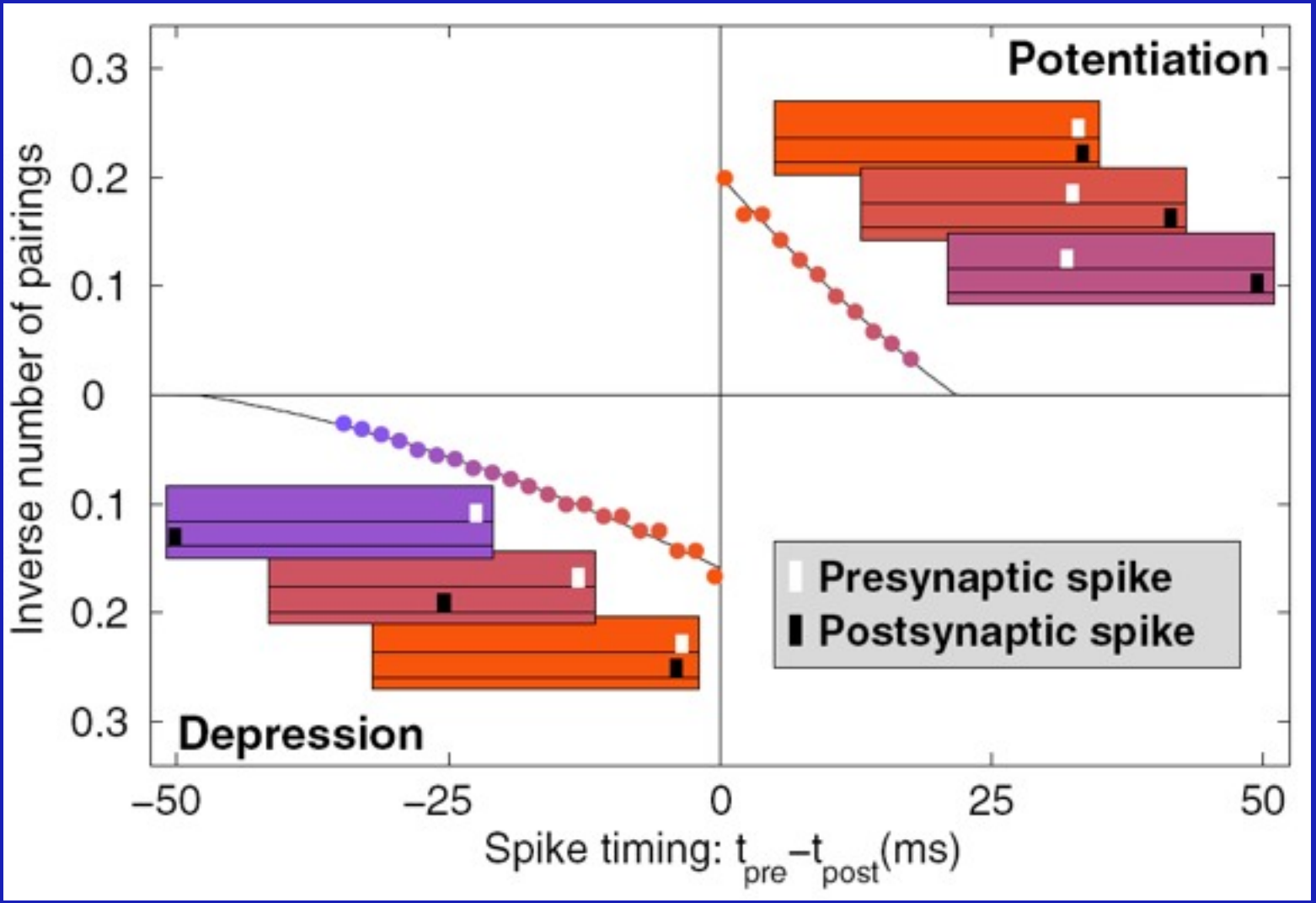
Lab 7: Synaptic Plasticity



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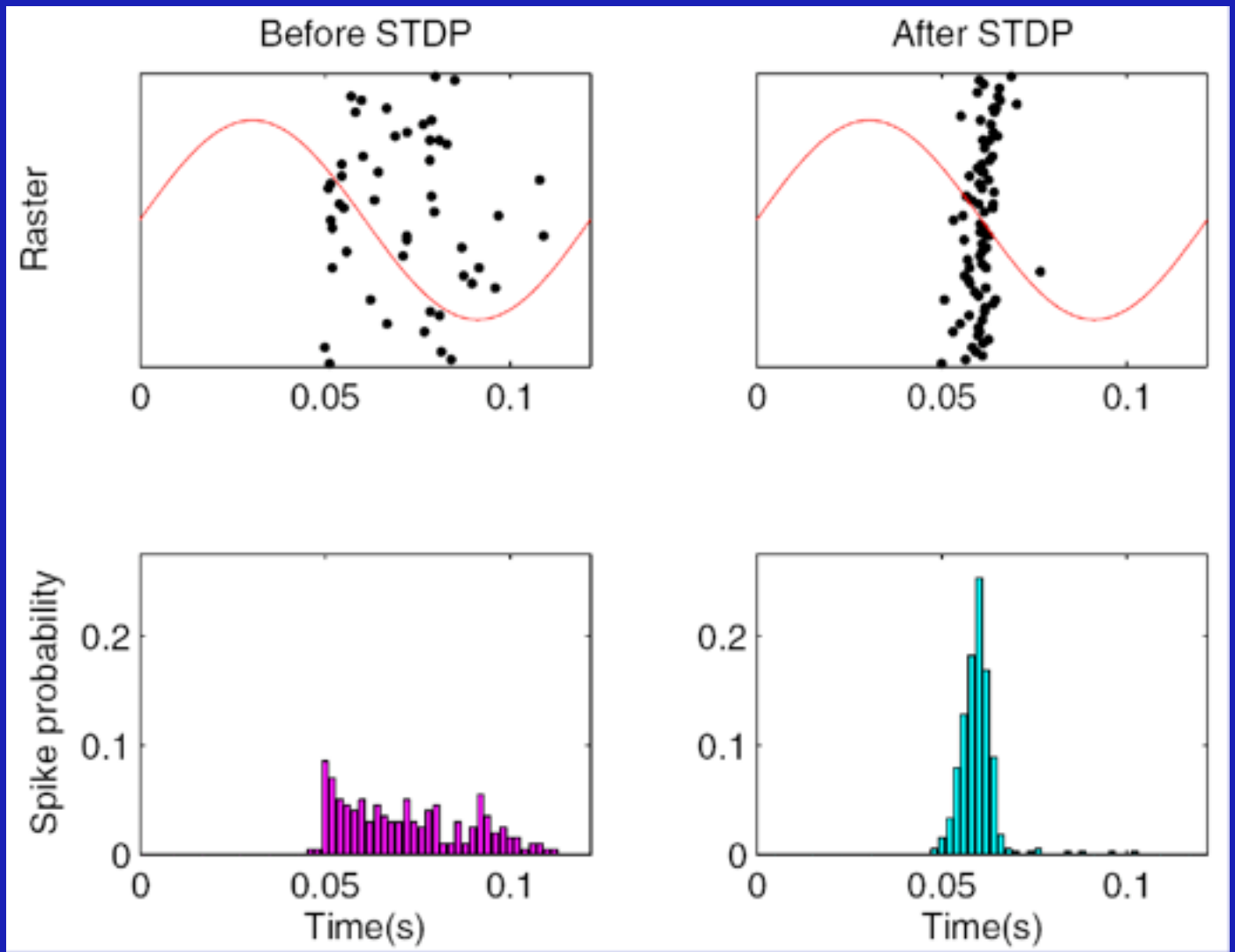
Lab 8: Plasticity and Synchrony



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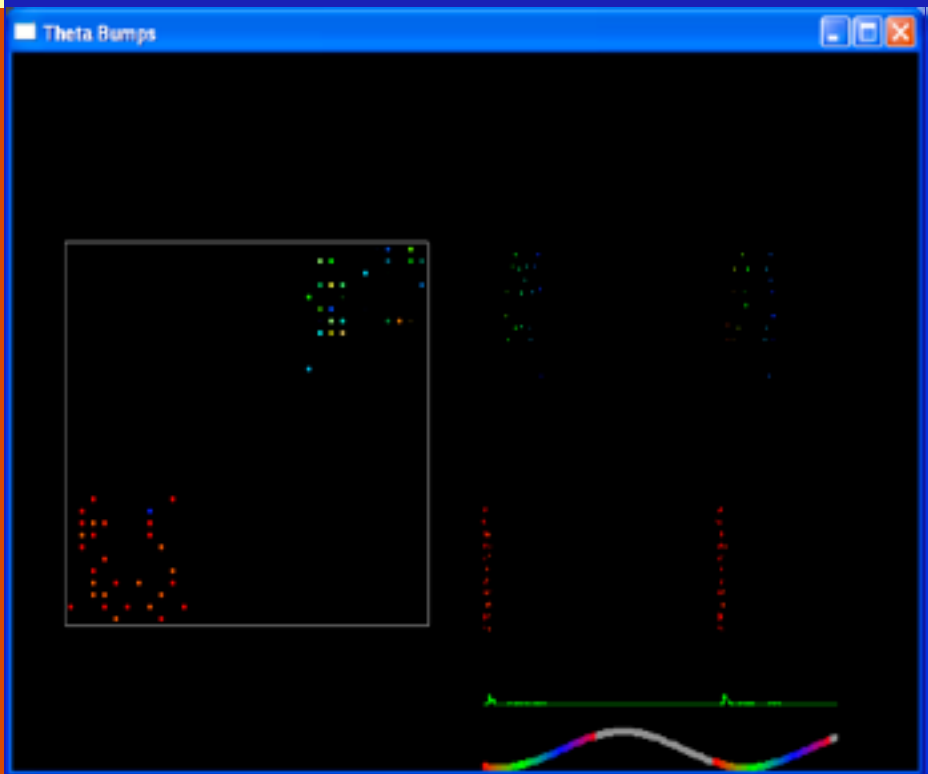
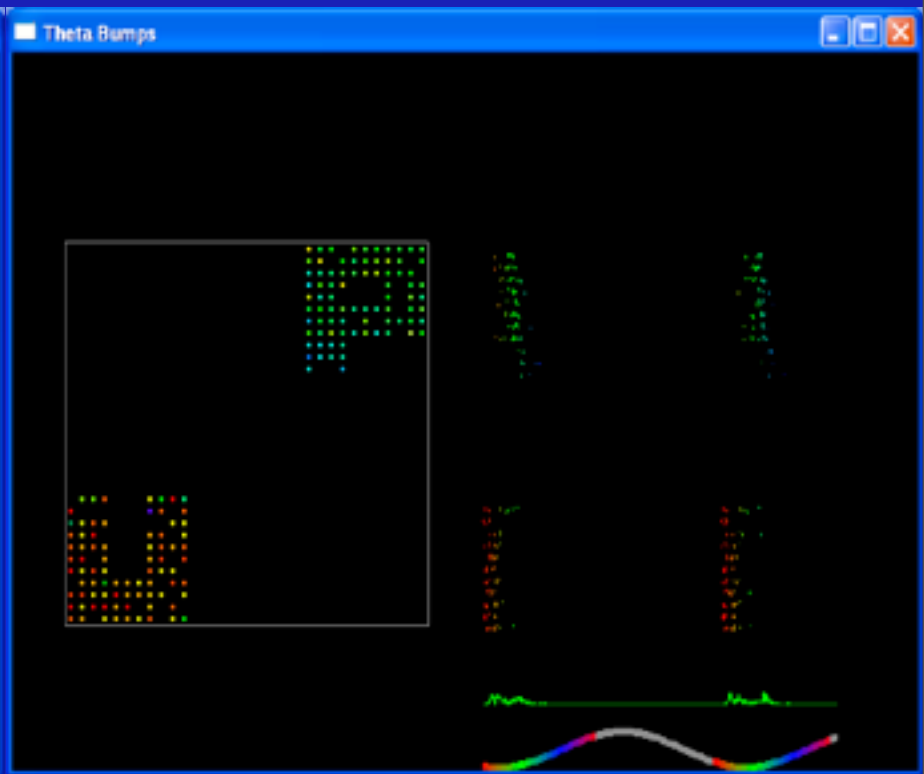
Lab 9: Associative memory



Before learning



After learning

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