Learning

Computational Cognitive Neuroscience
Randall O'Reilly

Overview of Learning

- Biology: synaptic plasticity
- Computation:
  - Self organizing – soaking up statistics
  - Error-driven – getting the right answers

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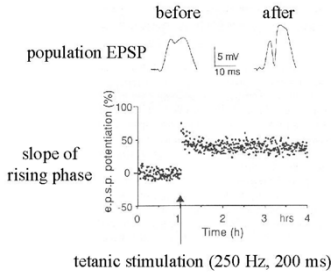
Synapses Change Strength
(in response to patterns of activity)



tetanic stimulation (250 Hz, 200 ms)

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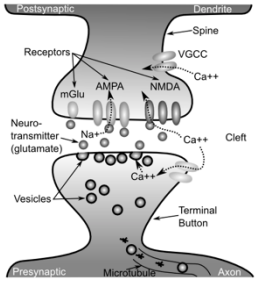
What Changes??



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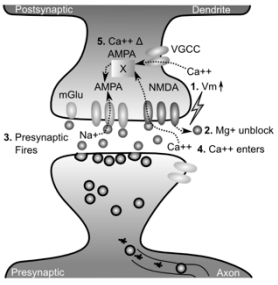
Gettin' AMPA'd



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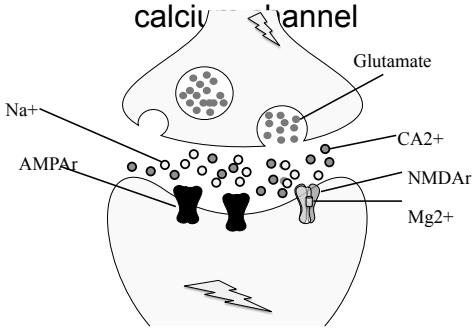
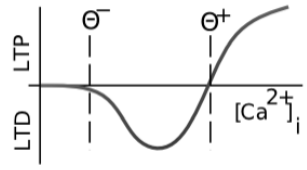
Opening the NMDA receptor calcium channel



Which Way?



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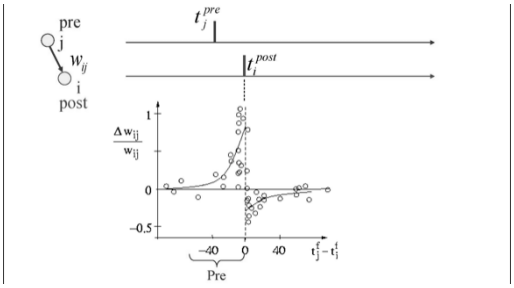
Causal Way?



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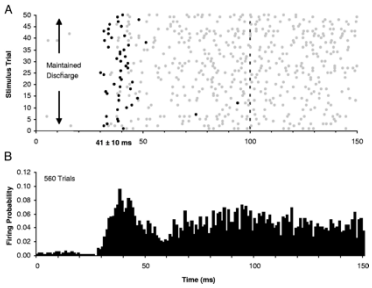
Let's Get Real..



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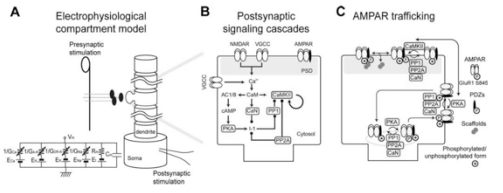
Urakubo et al, 2008 Model

- Highly detailed combination of 3 existing strongly-validated models:



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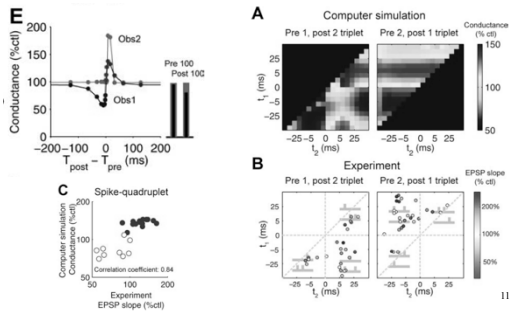
"Allosteric" NMDA Captures STDP

(including higher-order and time integration effects)



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What About Real Spike Trains?

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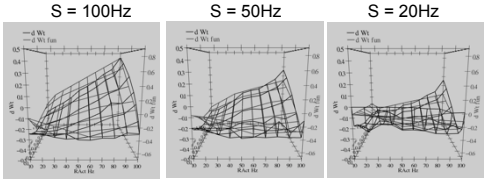
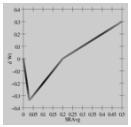
Extended Spike Trains = Emergent Simplicity

S = 100Hz S = 50Hz S = 20Hz



dW = f(send * recv) = (spike rate * duration)



r=.894

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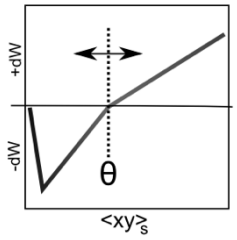
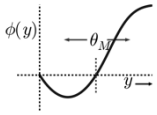
XCAL = Linearized BCM



- Bienenstock, Cooper & Munro (1982) – BCM:
- **adaptive threshold** Θ
  - Lower when less active
  - Higher when more.. (homeostatic)



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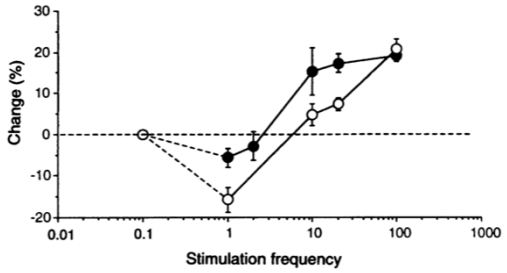
Threshold Does Adapt



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Computational: Self-Organizing and Error-Driven

- Self-organizing = learn general statistics of the world.
- Error-driven = learn from difference between expectation and outcome.
- Both can be achieved through XCAL.

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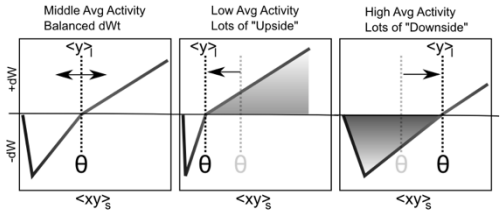
Floating Threshold = Long Term Average Activity (Self Org)



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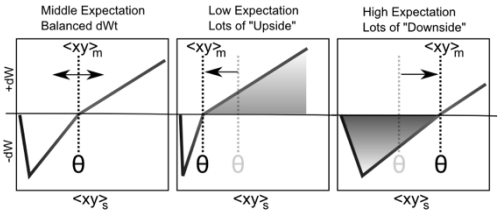
Floating Threshold = Medium Term Synaptic Activity (Error-Driven)



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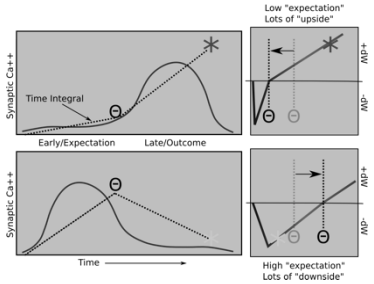
Fast Threshold Adaptation: Late Trains Early



Essence of Err-Driven: dW = outcome - expectation

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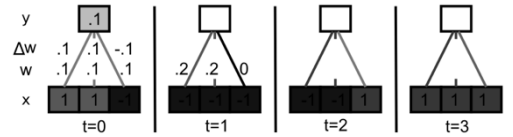
Hebbian Learns Correlations



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Self Organizing Learning

- Inhibitory Competition: only some get to learn
- Rich get richer: winners detect even better
  - But also get more selective (hopefully)
- Homeostasis: keeping things more evenly distributed (higher taxes for the rich!)

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Limitations of Self-Organizing

- Can't learn to solve challenging problems – driven by statistics, not error..

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