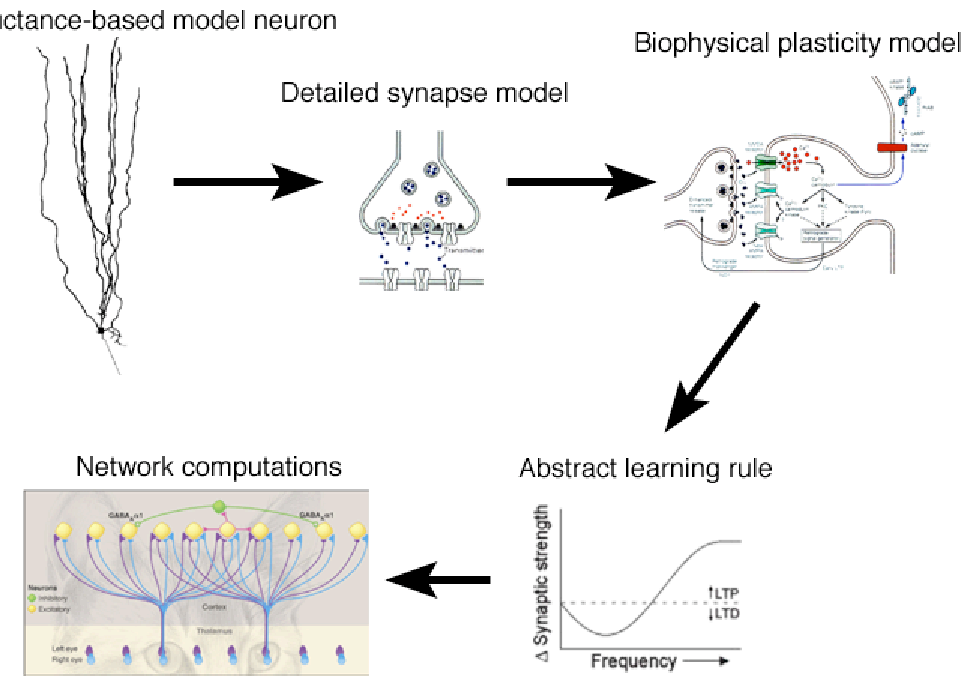
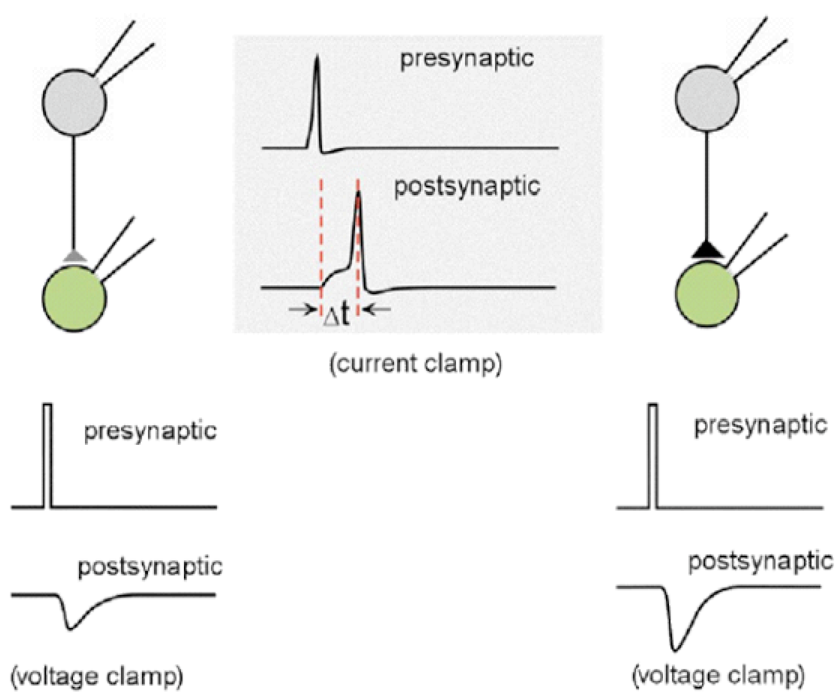
Simplified models of synaptic plasticity



Course website: http://www.bme.ogi.edu/BME665/

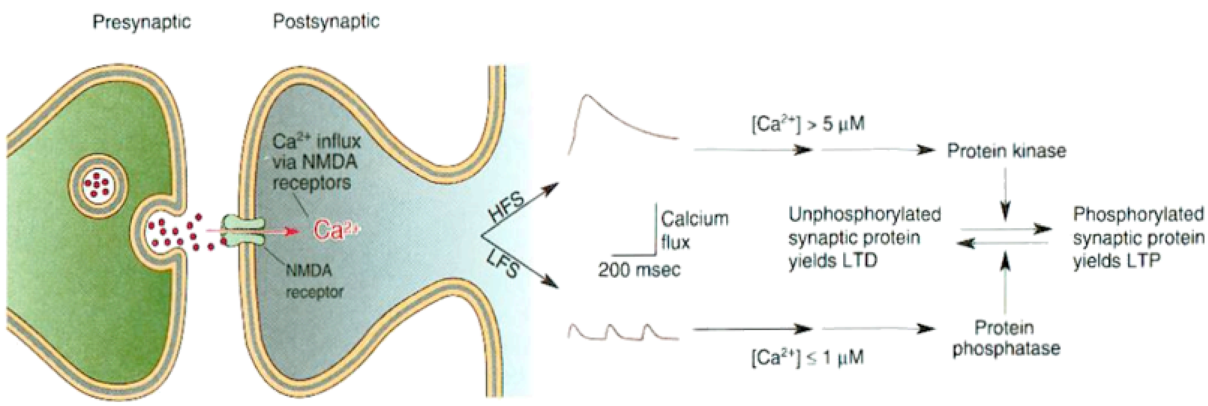
00_title.psd

Spike-Timing Dependent Plasticity (STDP)



00a_stdp_induct.psd

Calcium Concentration Determines Direction of Synaptic Plasticity

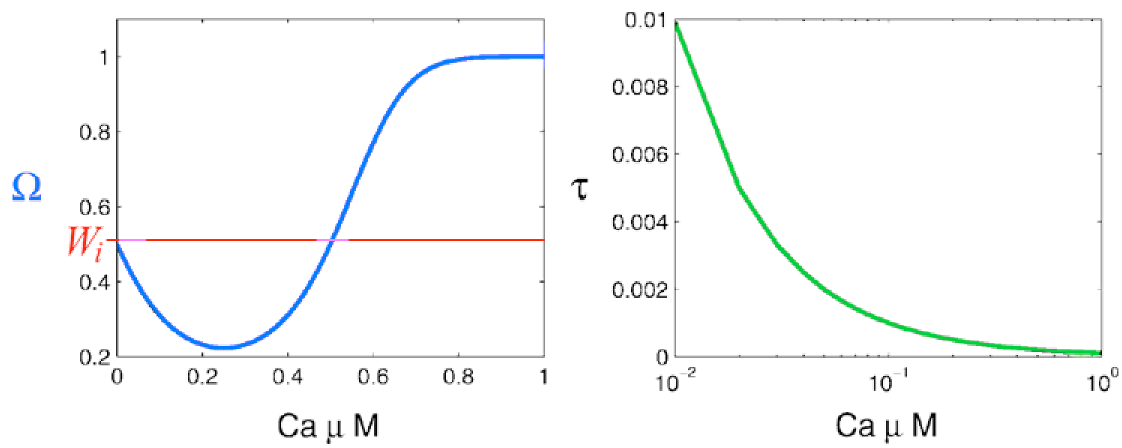


High Ca^{2+} => LTP
Low Ca^{2+} => LTD

01_caDepPlast.psd

Simplified Model of Calcium-Dependent Plasticity

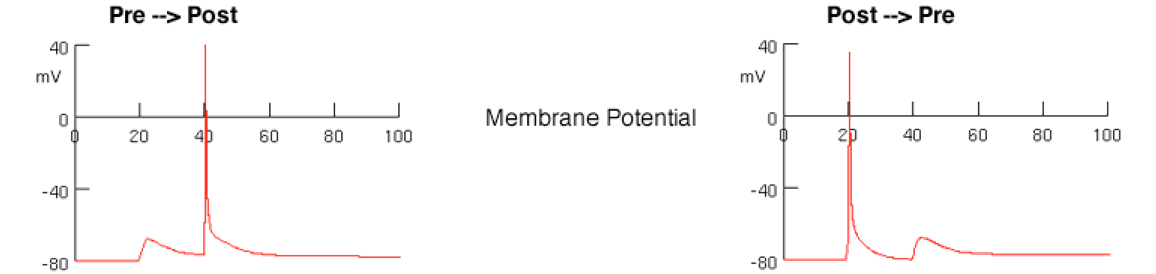
$$\dot{W}_i(t) = \frac{1}{\tau([Ca]_i)}\left(\Omega([Ca]_i) - W_i\right)$$



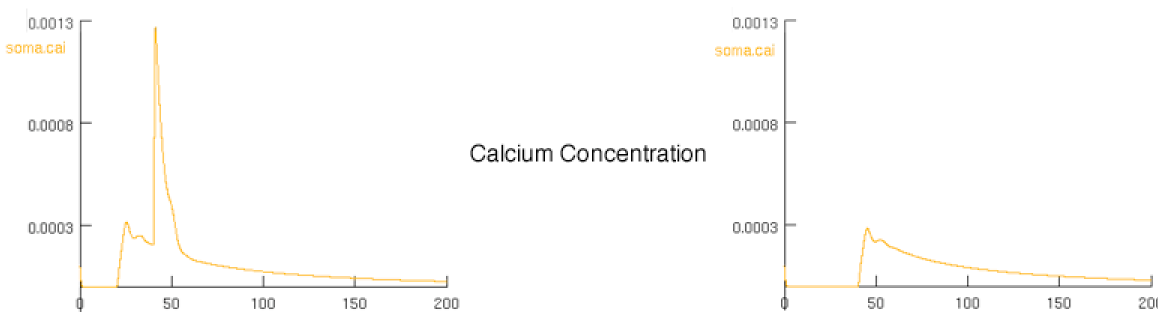
Lisman (1989), Shouval (2002)

02_CaPlastEq.psd

Spike Order Controls Calcium Concentration

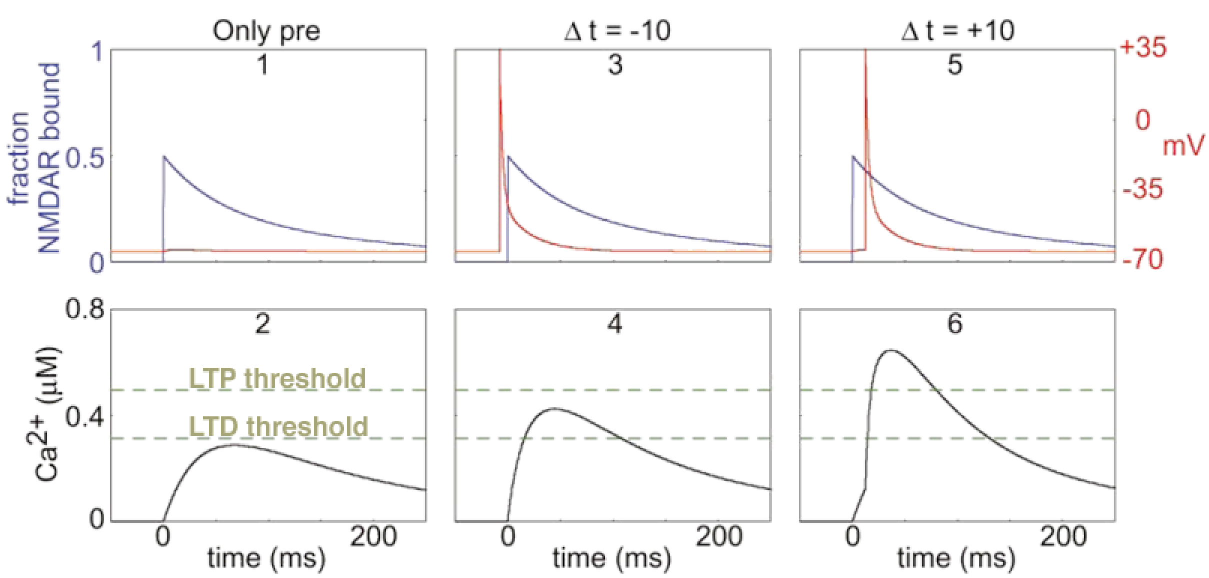


$$\frac{d[Ca(t)]}{dt} = I_{NMDA}(t) - (1/\tau_{Ca})[Ca(t)]$$



03_order.psd

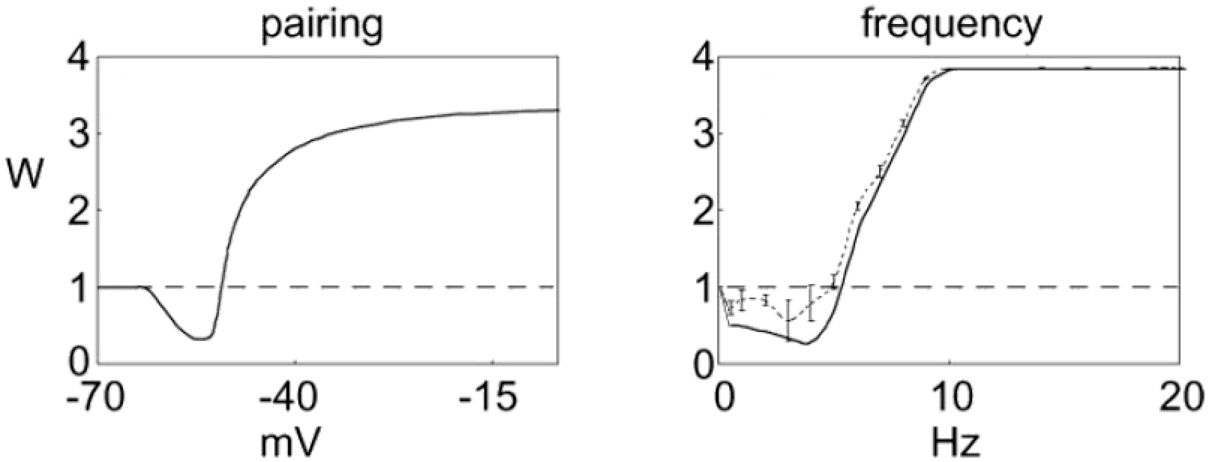
Calcium Threshold for Synaptic Plasticity Can Predict Effects of Spike-Pairing



Shouval (2002)

04_Ca_LTP.psd

Calcium Model Prediction of Frequency Dependency

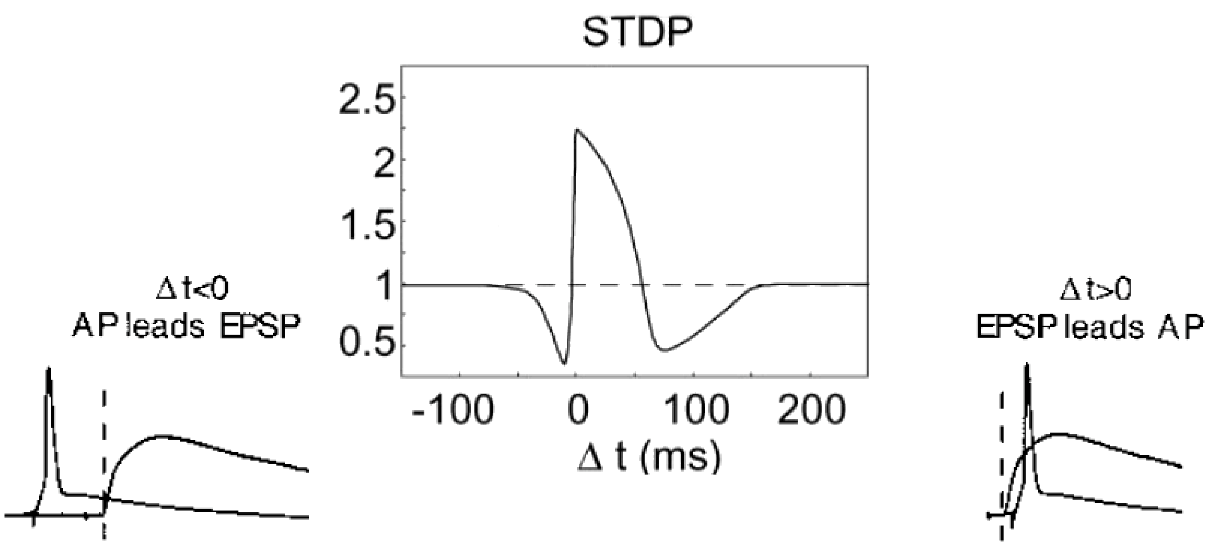


Consistent with the BCM model

Shouval (2002)

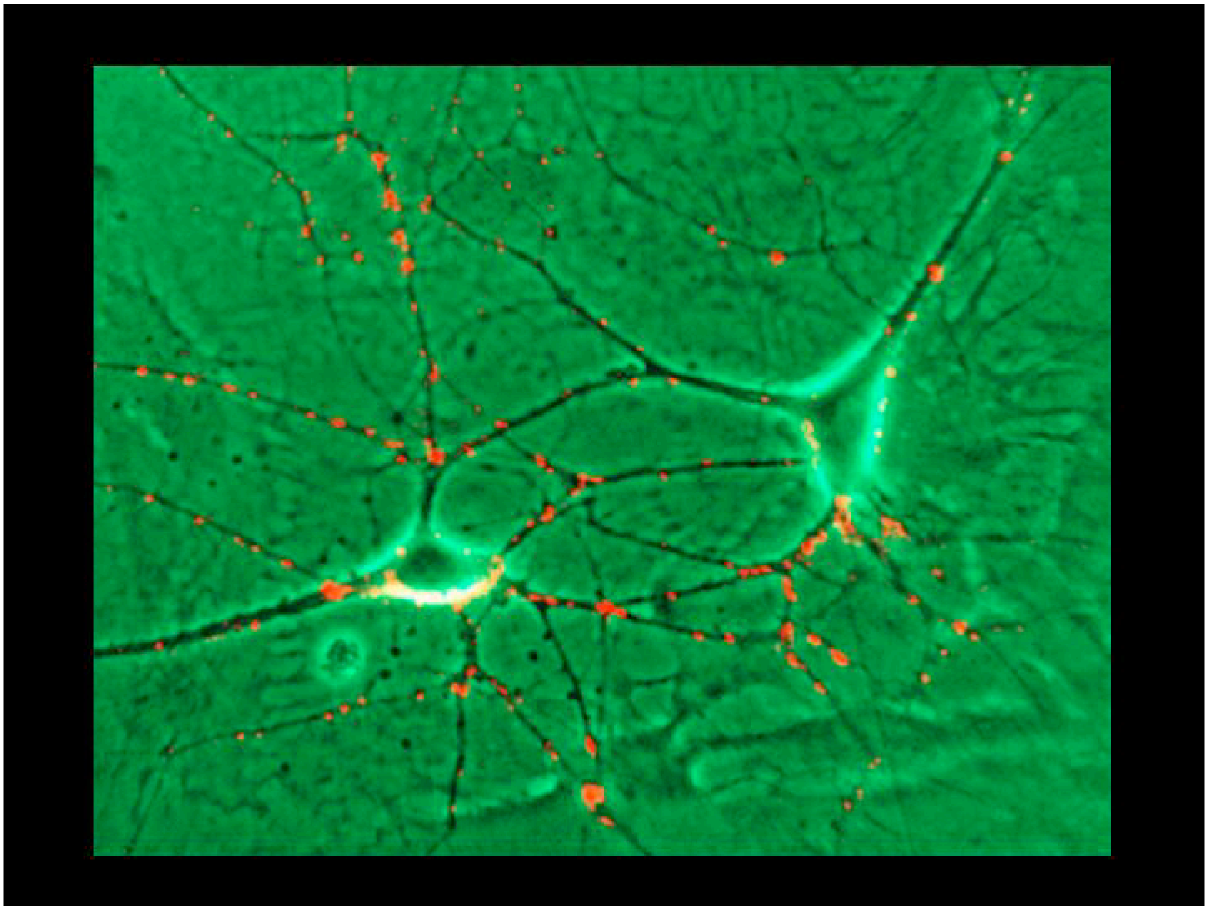
05_freqDep.psd

Calcium Model Prediction of Spike-Timing Dependent Plasticity

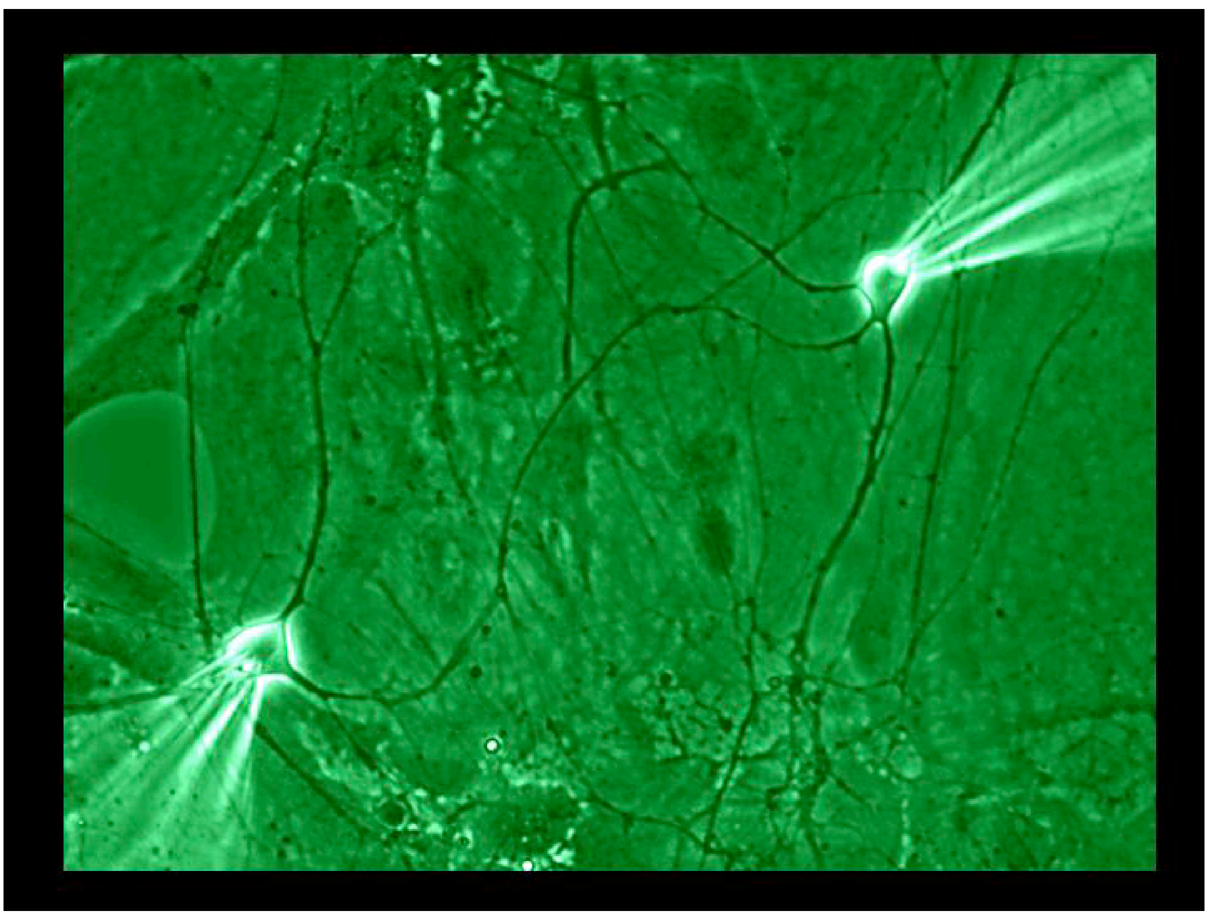


Shouval (2002)

06_Ca_stdp.psd

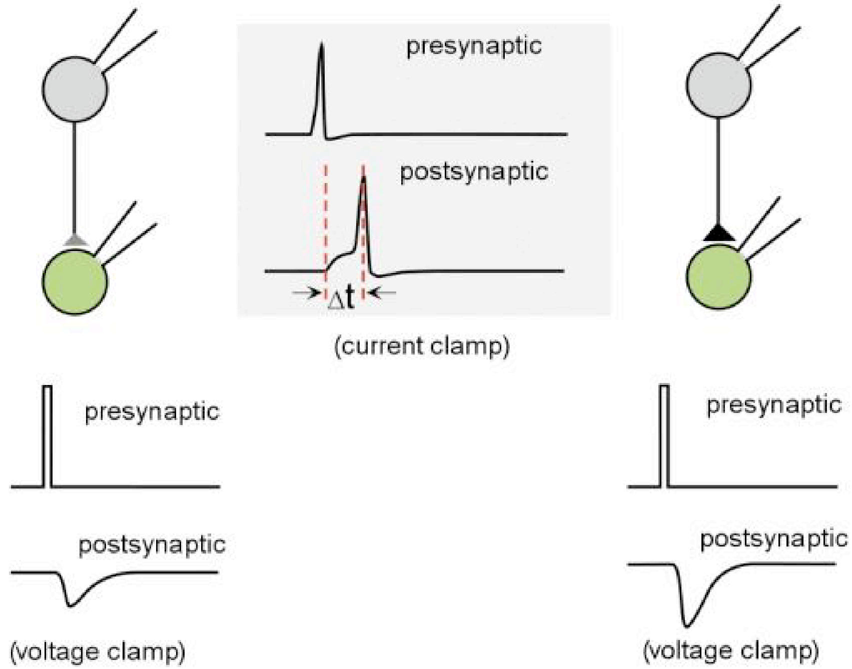


07a.jpg

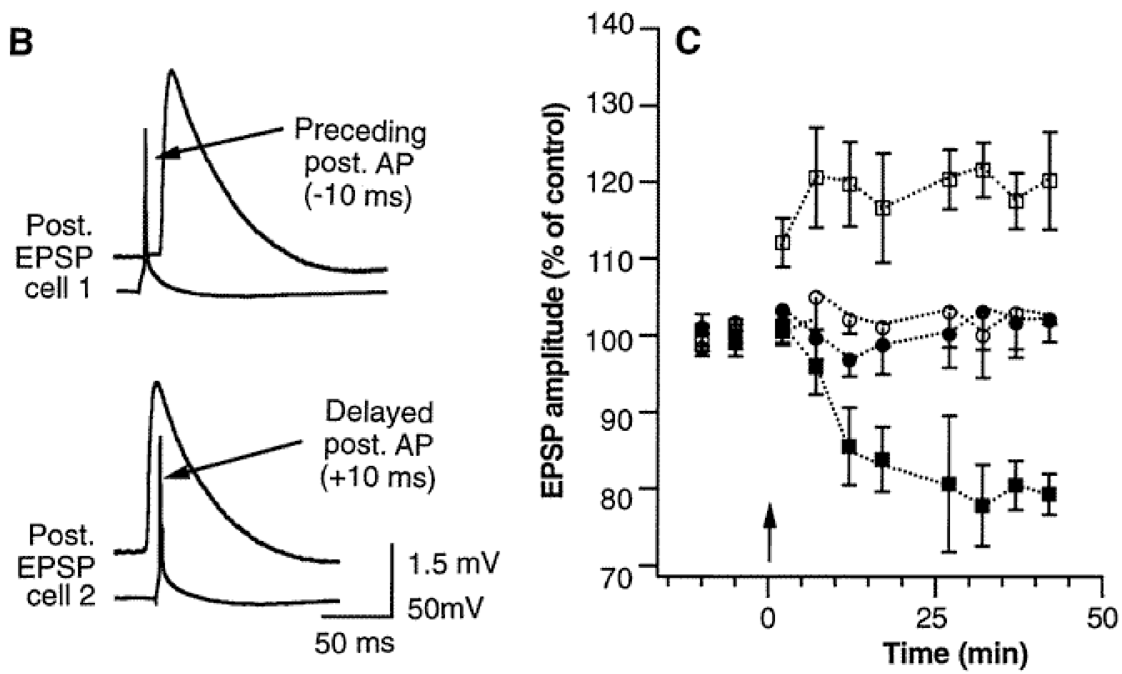


07b.jpg

Experimental paradigm -- correlated pre- and postsynaptic spiking



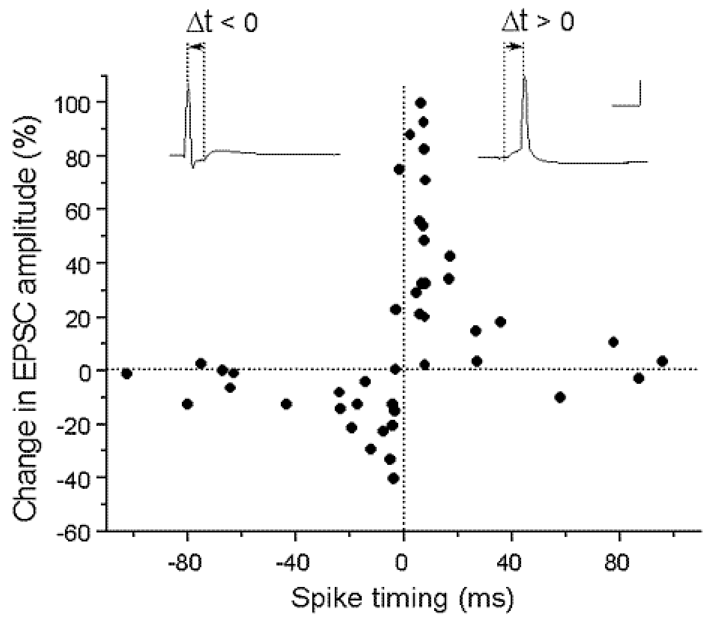
08.jpg



Markram et al. 1997

09.gif

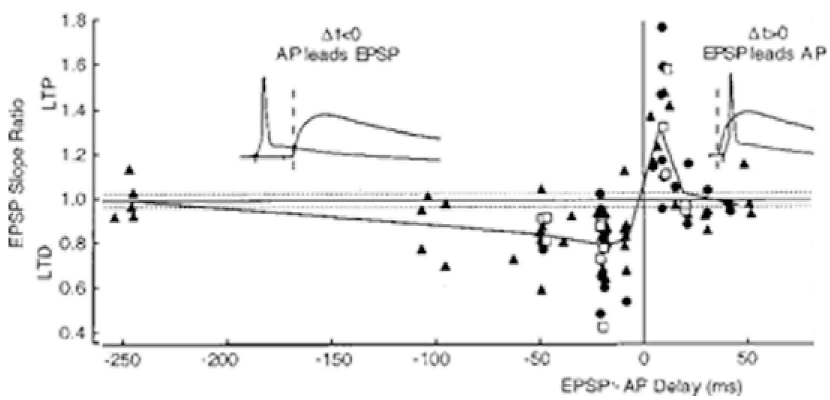
Anti-Symmetric STDP Learning Rule



Bi (1998)

10_BiRule.psd

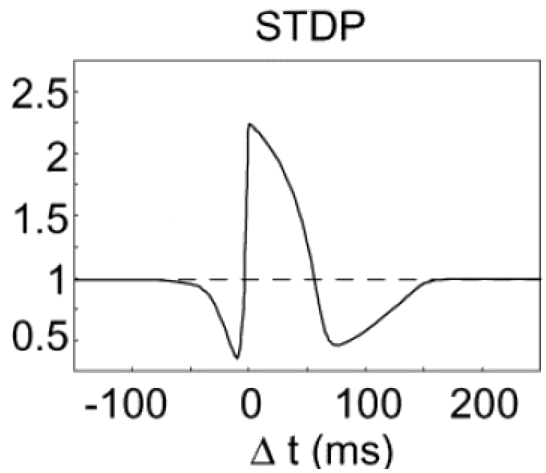
Long Interval of LTD



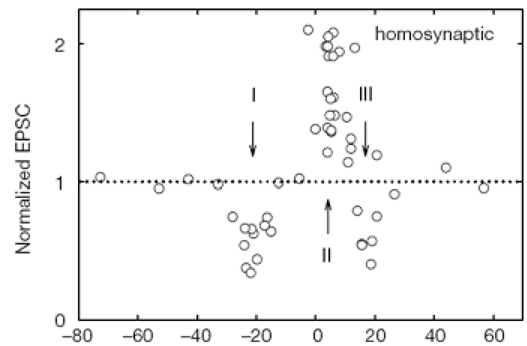
Feldman (2000)

11_feldmanRule.psd

Empirical Agreement with Calcium Model Prediction?



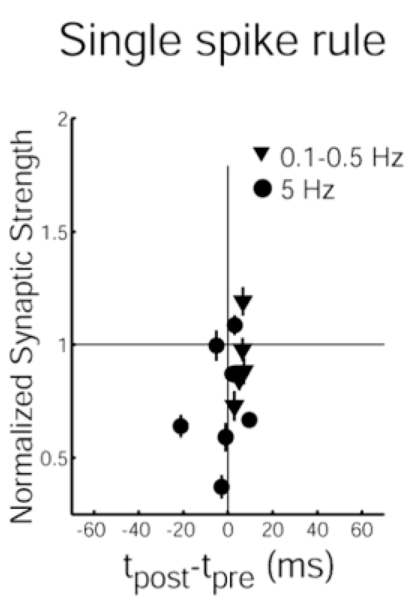
Shouval (2002)

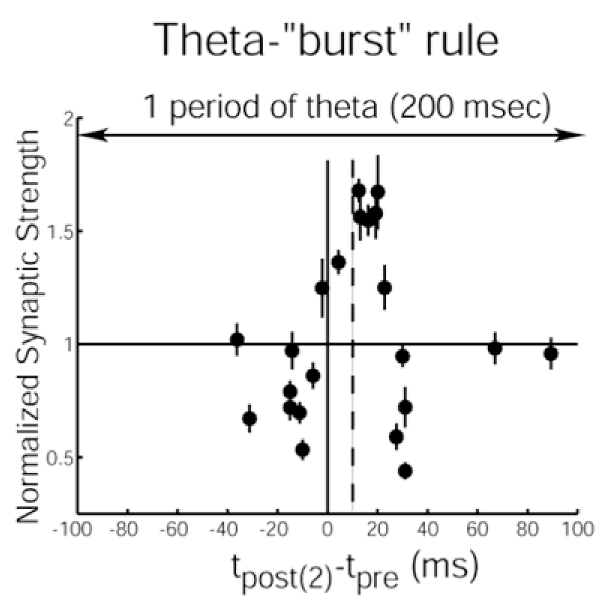


Nishiyama (2000)
Hippocampus slice

12_Ca_stdp2.psd

Hippocampus Slice STDP with Burst-Pairing



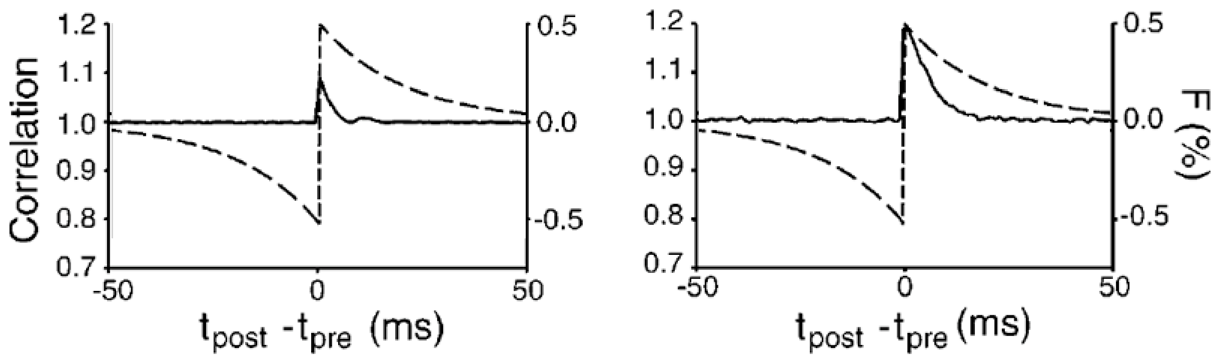


SS Wang, et al. (2004)

13_burstSTDP.psd

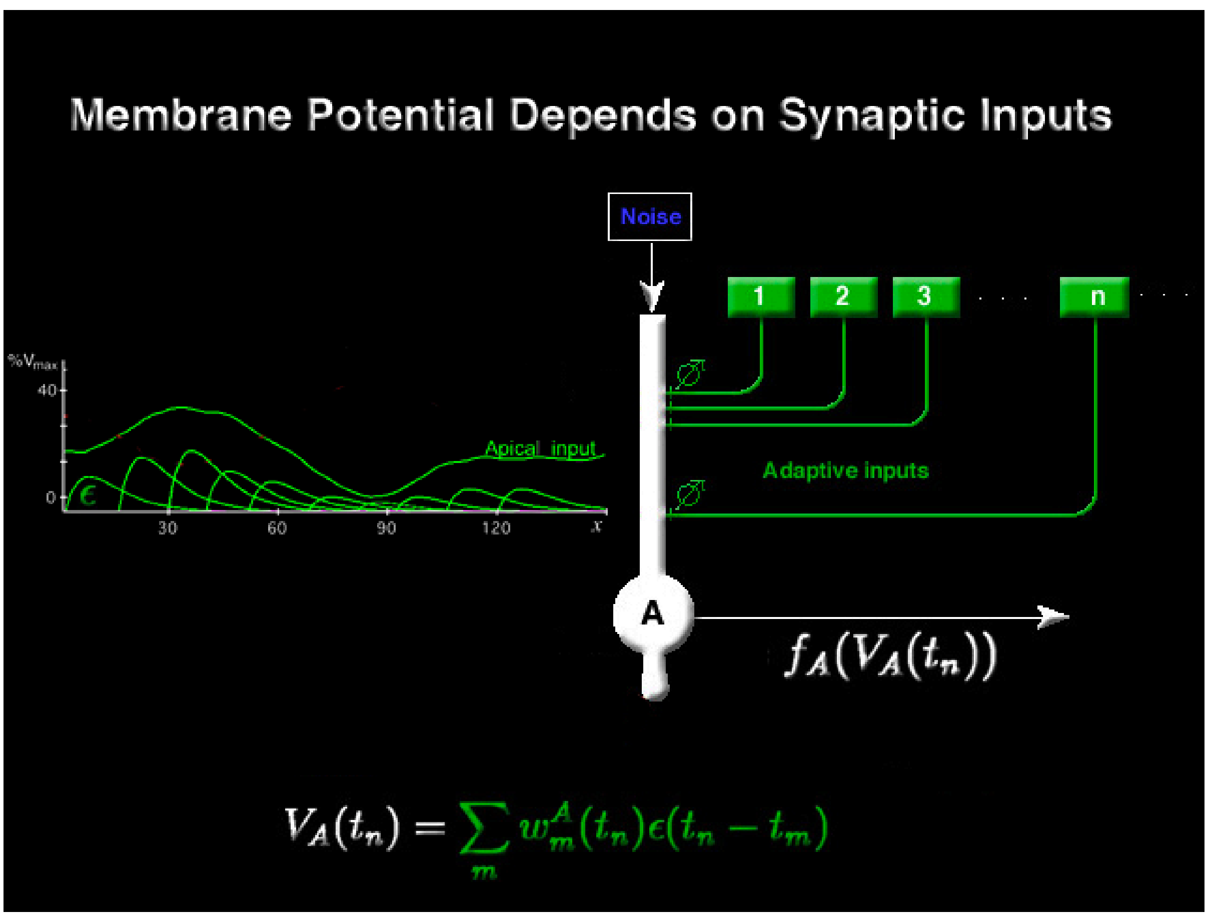
Competitive STDP Model

$$F(\Delta t) = \begin{cases} c_P e^{-|\Delta t|/\tau_P} & if \quad \Delta t > 0 \\ -c_D e^{-|\Delta t|/\tau_D} & if \quad \Delta t < 0 \end{cases}$$

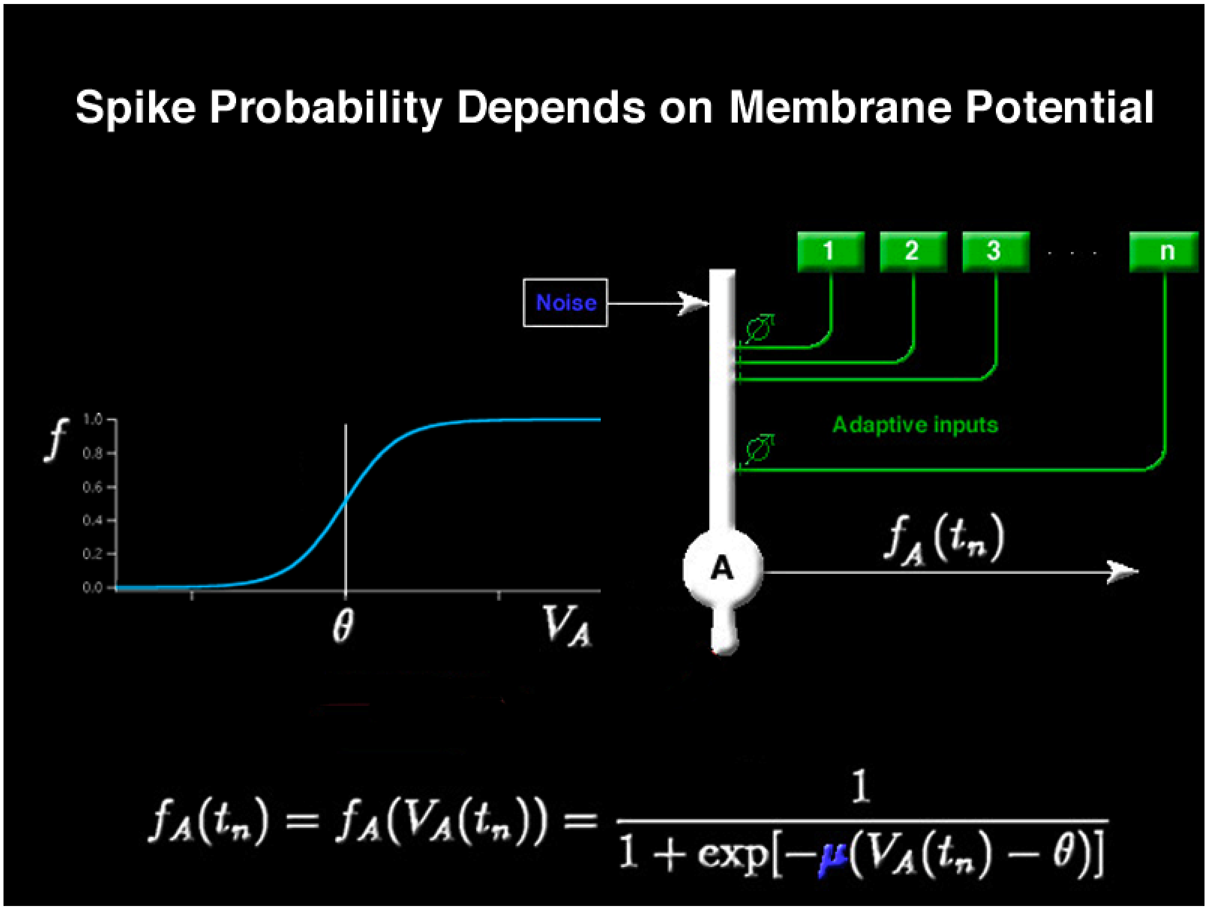


Song & Abbott (2000)

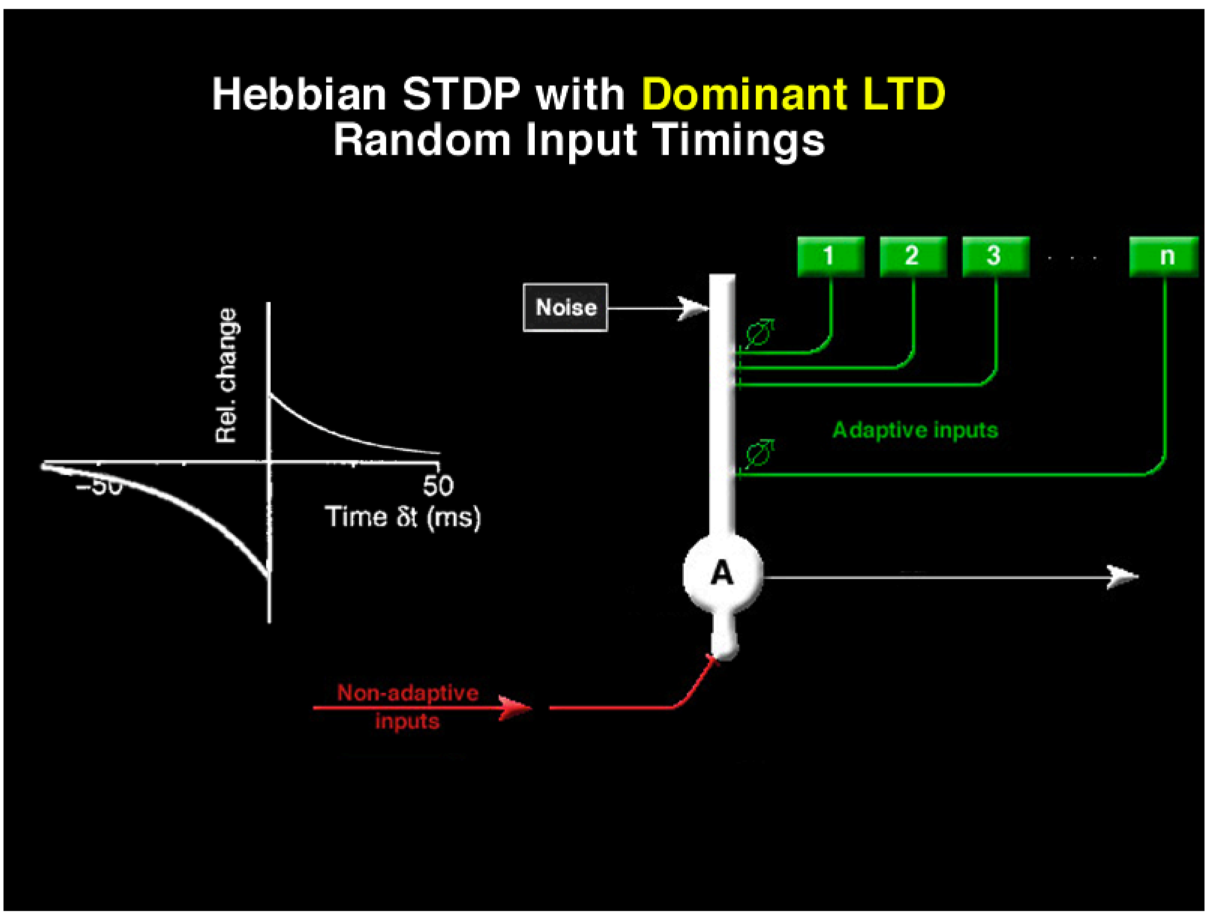
14_songRule.psd



15_Module.psd

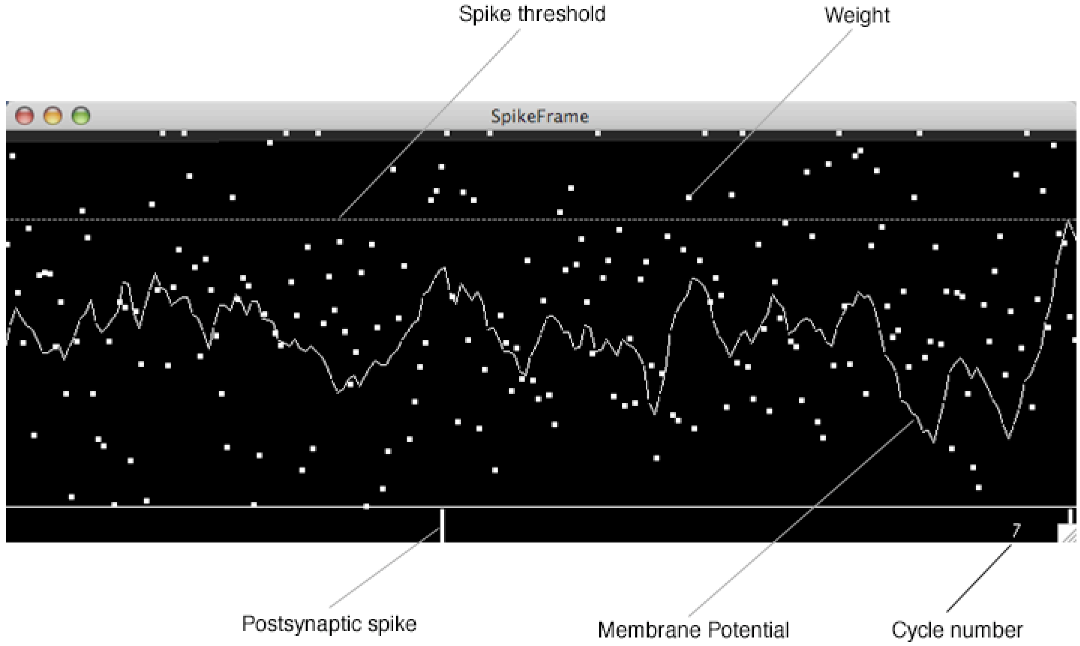


15b_Module.psd



17_feldmanSimul.psd

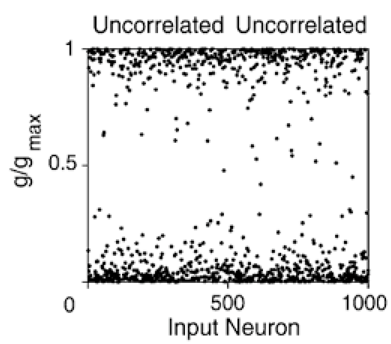
STDP Simulation

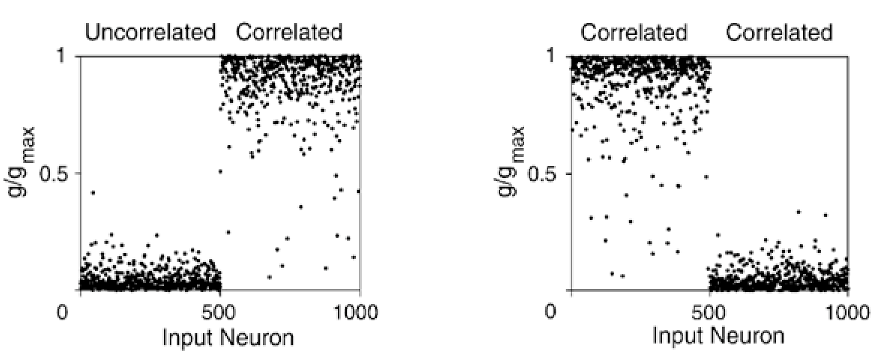


16_sim.psd

Competitive STDP Model

$$F(\Delta t) = \begin{cases} c_P e^{-|\Delta t|/\tau_P} & if \quad \Delta t > 0 \\ -c_D e^{-|\Delta t|/\tau_D} & if \quad \Delta t < 0 \end{cases}$$

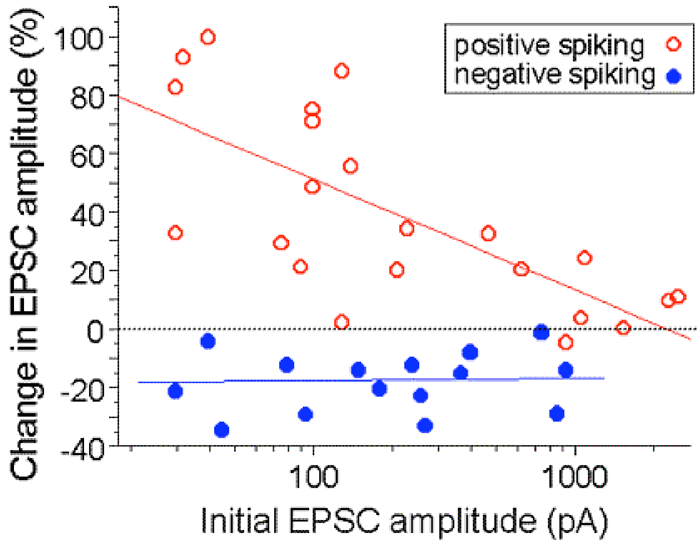




Song & Abbott (2000)

18_competition.psd

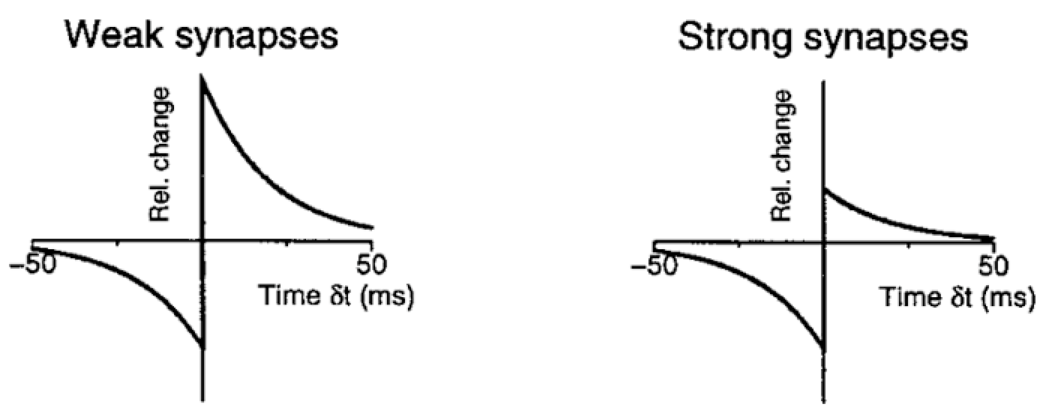
Dependence on initial synaptic strength



19.gif

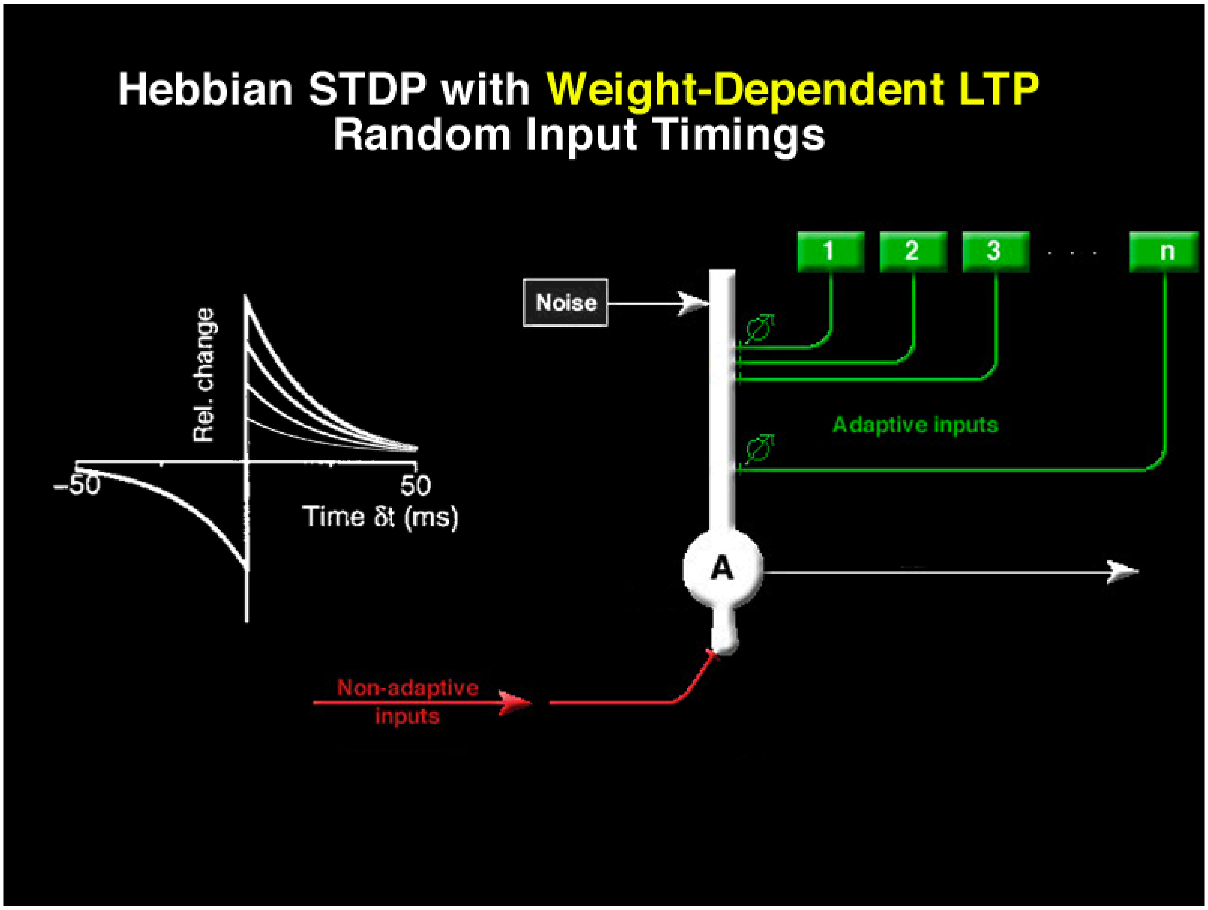
Stable STDP Model

$$F(\Delta t) = \begin{cases} c_P \; e^{-|\Delta t|/\tau_P} & if \quad \Delta t > 0 \\ -c_D w \, e^{-|\Delta t|/\tau_D} & if \quad \Delta t < 0 \end{cases}$$

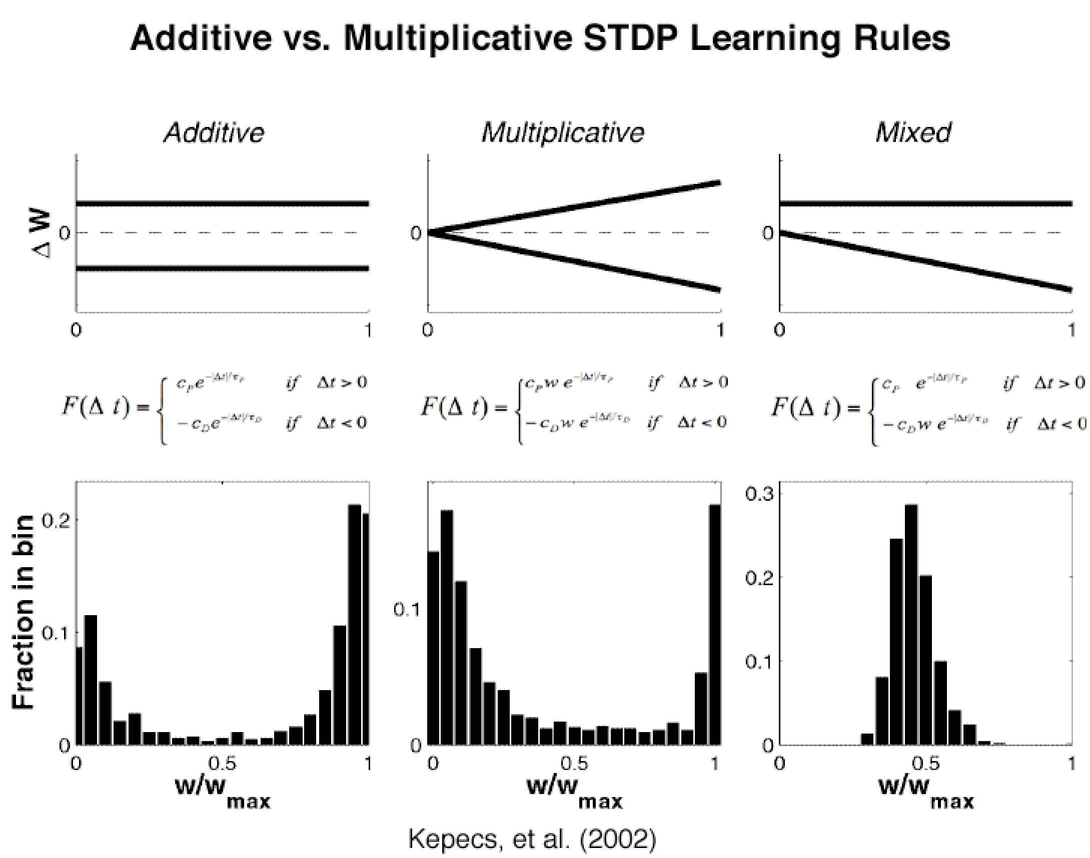


van Rossum et al. (2000)

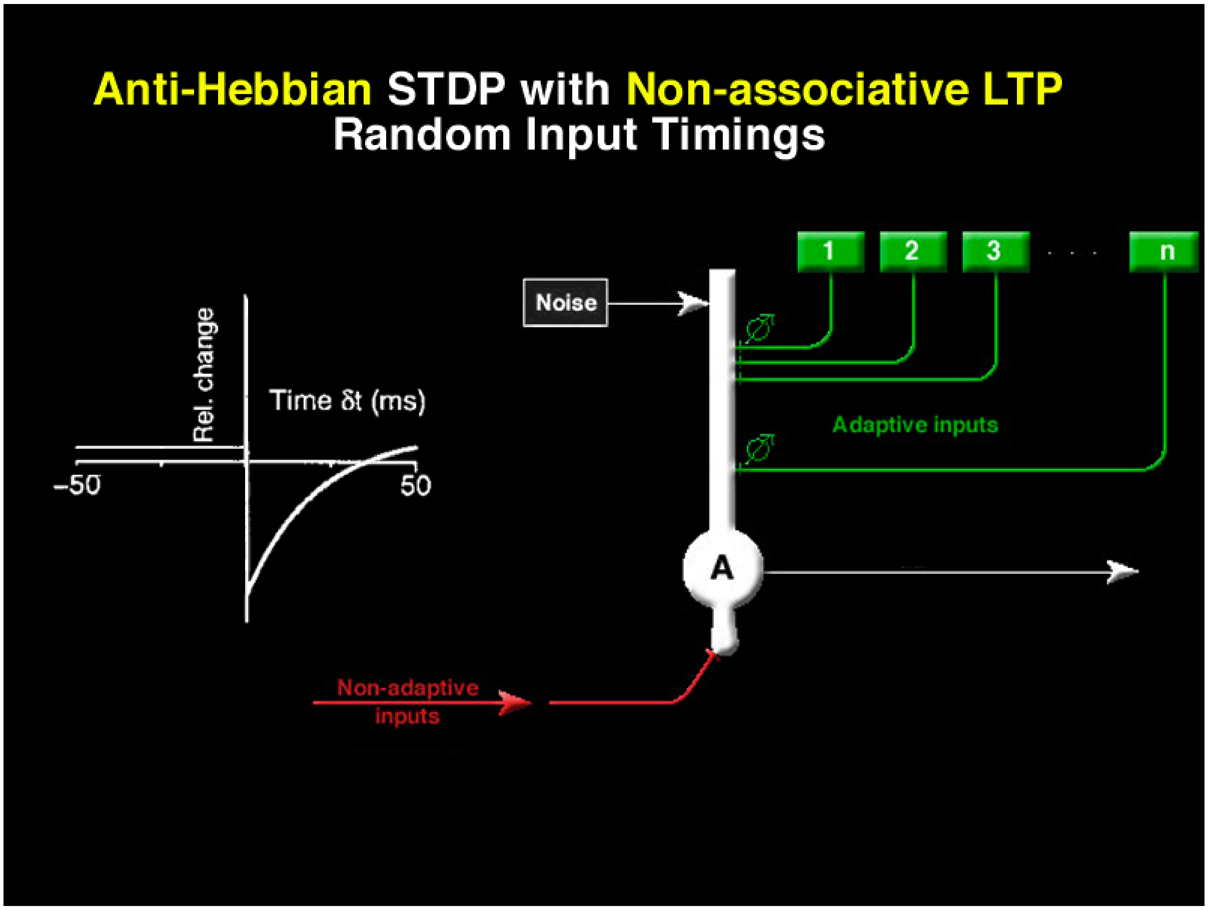
20_stableSTDP.psd



21_biSimul.psd

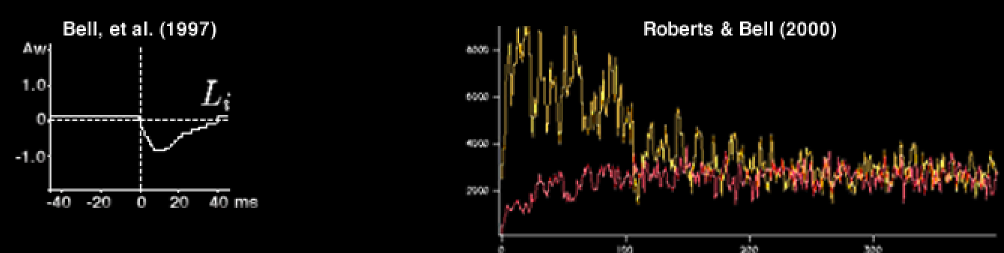


22_distrib.psd



23_bellSimul.psd

Learning Dynamics Have Fixed Points



$$< \Delta w_i(x_n, t) >= \alpha - \beta \sum_m L_i(x_m - x_n) f_b(x_m, t) \qquad \sum_n L(x_n) = 1$$

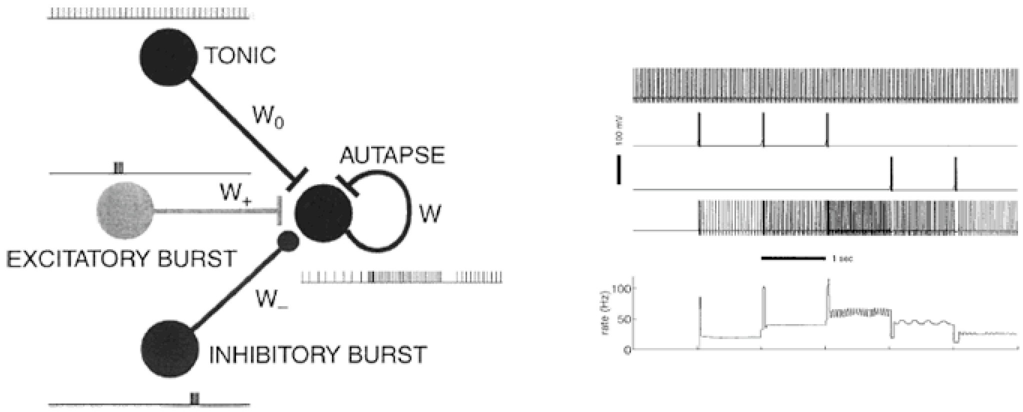
$$< \Delta w_i(x_n, t) >= 0 \quad \Rightarrow \quad 0 = \alpha - \beta \sum_m L_i(x_m - x_n) \hat{f}$$

$$\boxed{\hat{f} = \alpha / \beta}$$

$$f(x_n, t) \rightarrow \hat{f} = f(\hat{V}) \text{ as } t \rightarrow \infty$$

24_FixedPt.psd

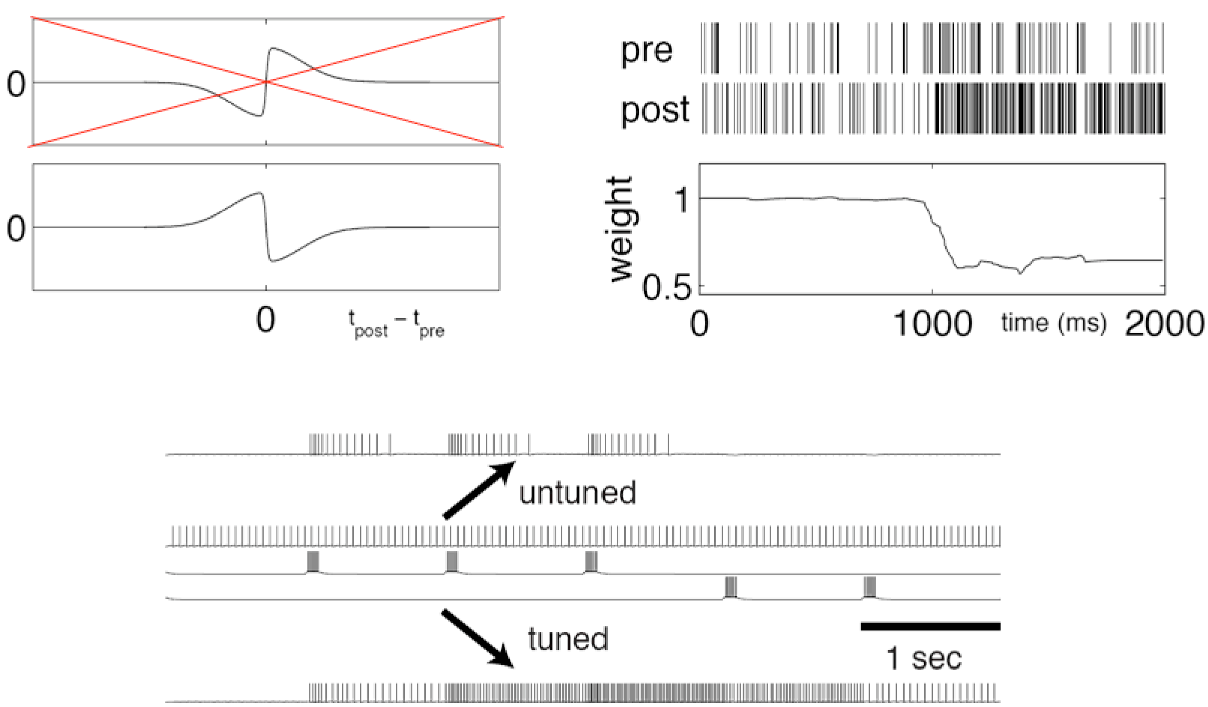
Neural Integrator



Seung, et al. (2000)

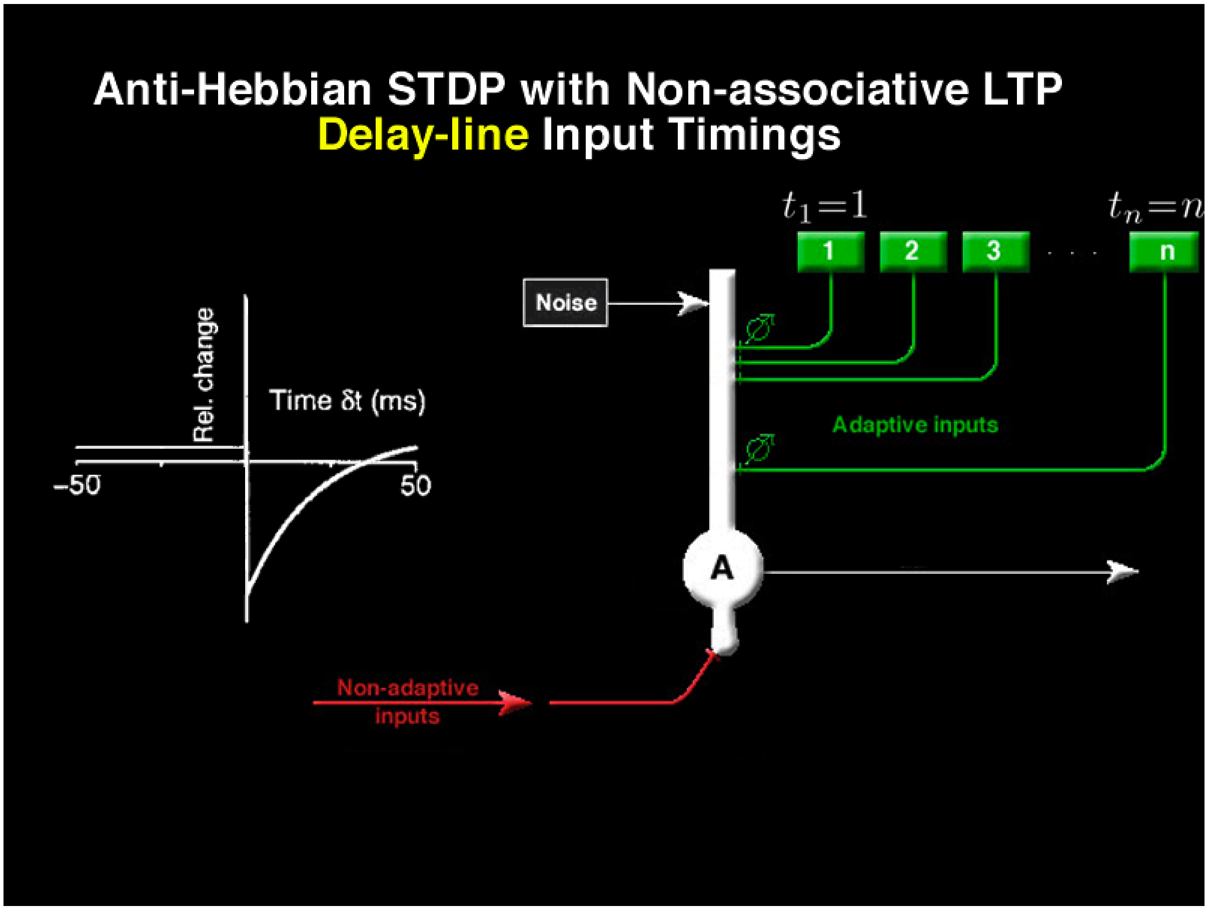
25_autopase.psd

Tuning the Neural Integrator

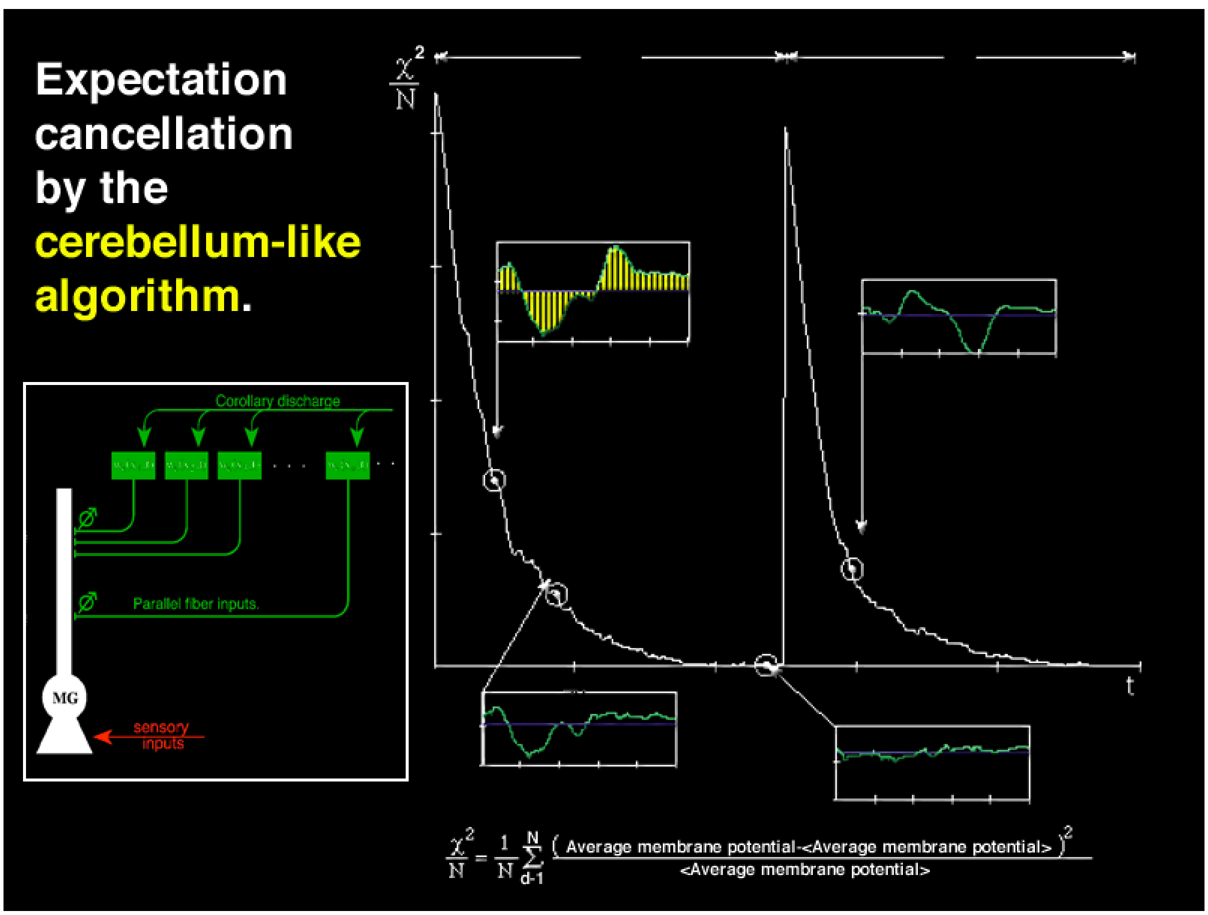


Xie & Seung (2000)

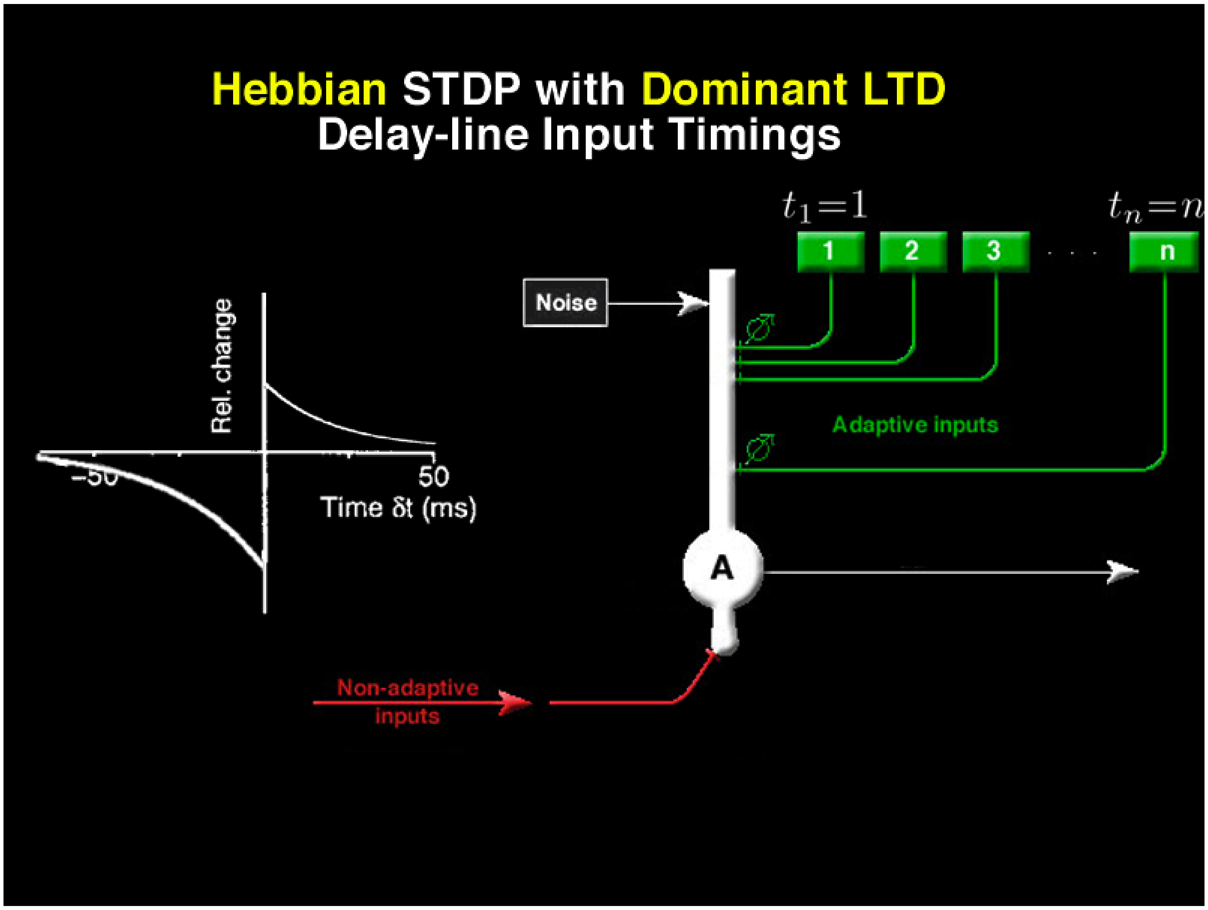
26_autopaseTune.psd



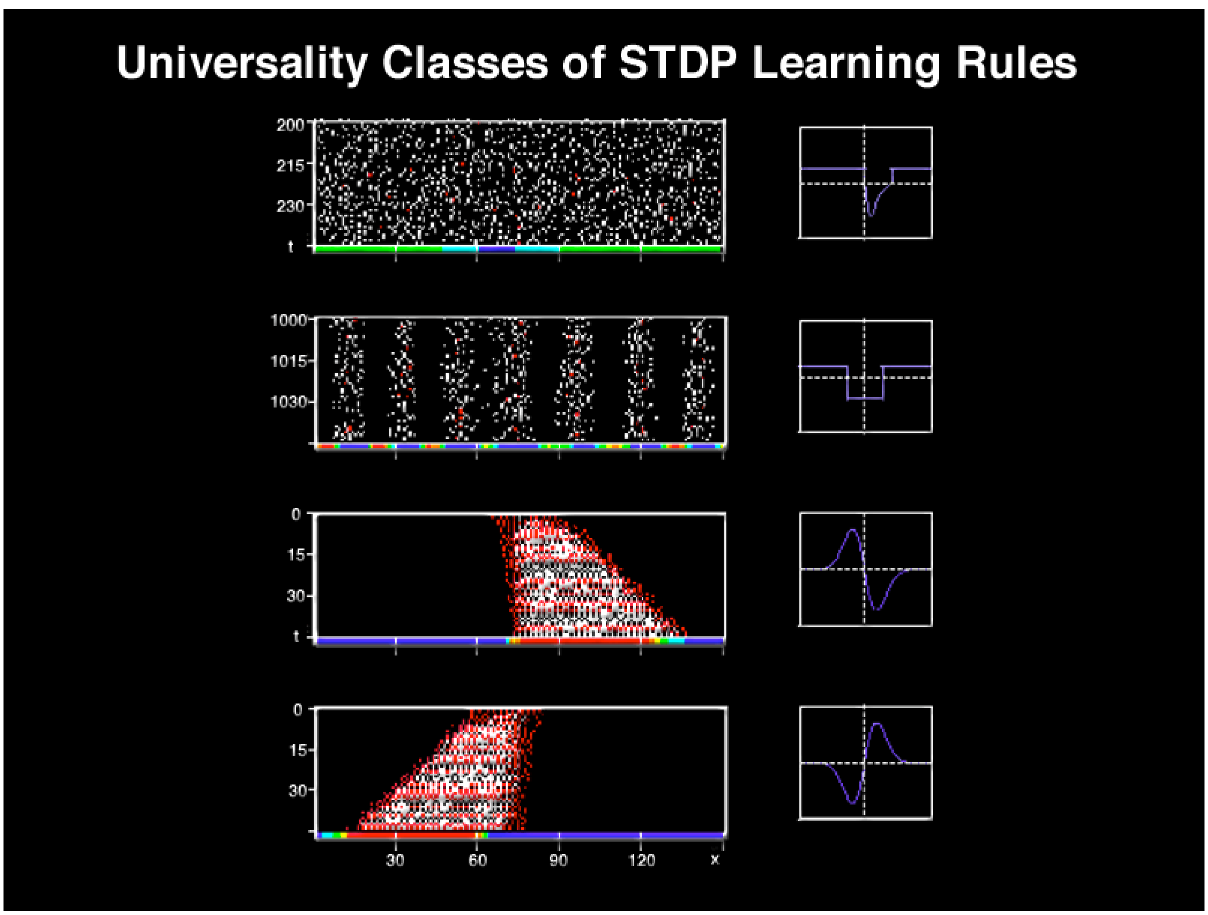
27_bellSimul2.psd



28_chi.psd



29_feldmanSimul2.psd



30_classesSTDP.psd