Small step from single neurons to networks

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Outline

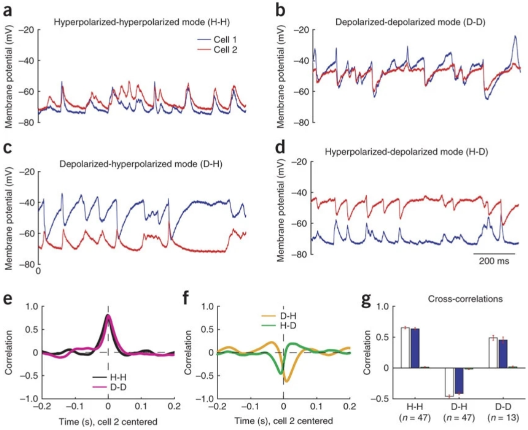
Information from inside a cell is valuable!
- E/I balance
- Spatial representations

Modeling can help when intracellular recordings are not available

A synapse is not a number

Information from inside the cell helps us understand **balance of excitation and inhibition**

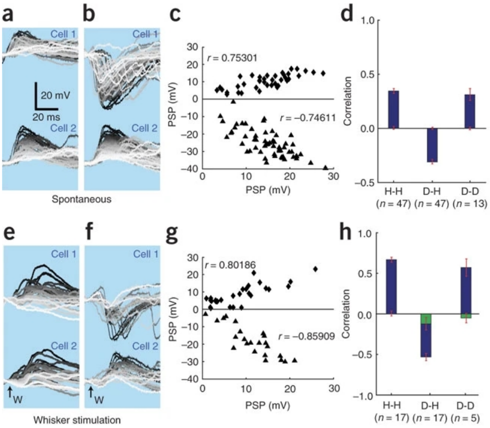
... during spontaneous activity



Okun, Lampl, 2008

Information from inside the cell helps us understand **balance of excitation and inhibition**

… and also during evoked activity



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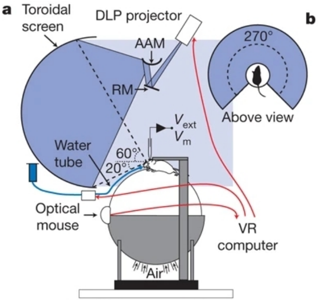
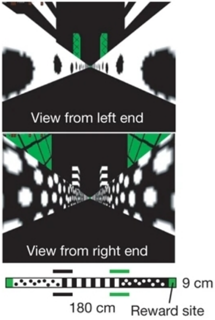
Information from inside the cell helps us understand **formation of spatial representations**





Harvey et al. 2009

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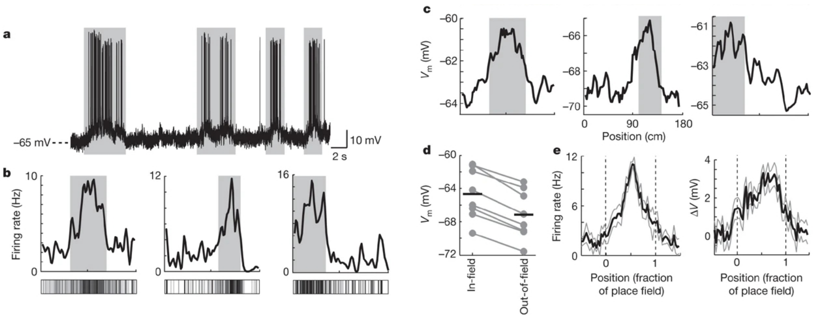

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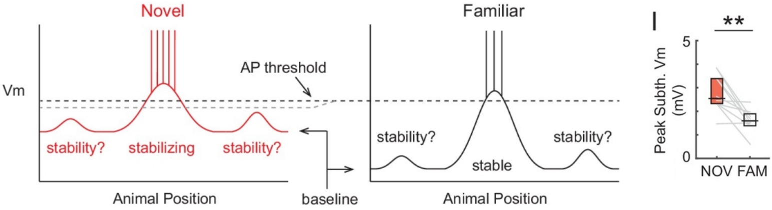

Cohen et al. 2017

When intracellular recording impossible, a model can help

To get some intuition, we start with the LIF neuron

$$\begin{aligned}\frac{\mathrm{d}V}{\mathrm{d}t} &= -V + I, \qquad \text{(with constant input } I\text{)}\\ V &= 0 \quad \text{if} \quad V > \theta\end{aligned}$$

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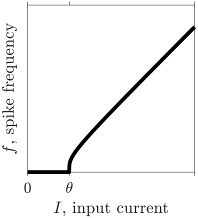
$$f(I) = \frac{1}{T} = \begin{cases} 0 & I \le \theta \\ \frac{1}{\log\left(\frac{I}{I-\theta}\right)} & I > \theta \end{cases}$$

What does the f-I curve tell us?



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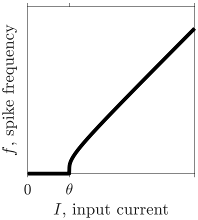

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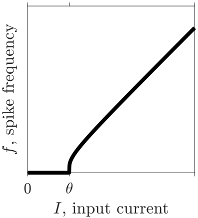

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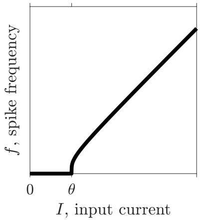

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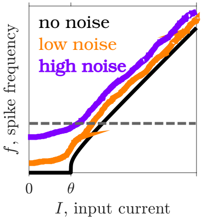
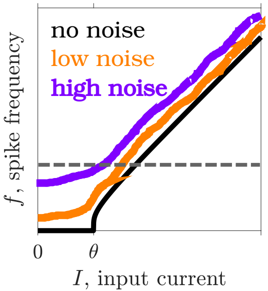


Beyond the f-I curve



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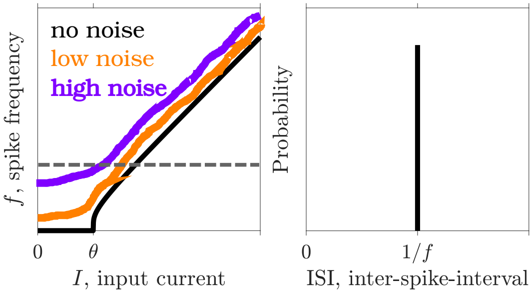

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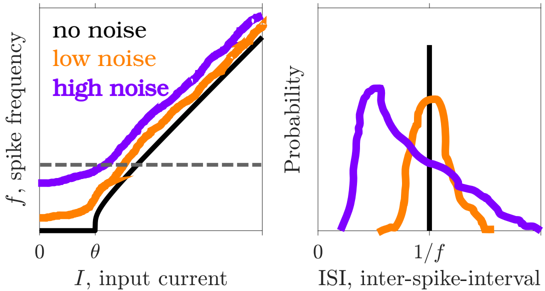

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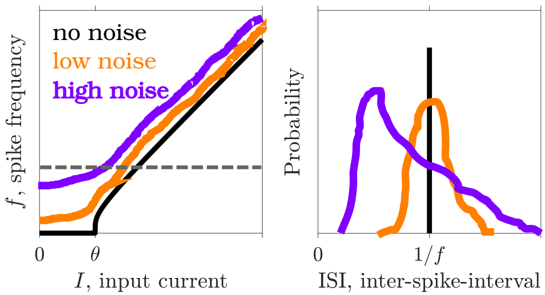

In today's exercise we'll explore the f-I curve and the ISI distribution for different types of inputs to a LIF neuron.

Is a synapse a number?

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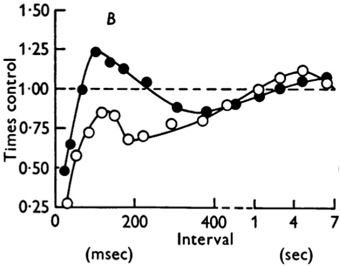
Alas, **short-term plasticity** (facilitation and depression) exists.



Hubbard, 1963

Synaptic model of short term plasticity, Tsodyks Markram

Dynamics of synaptic resources:

$$\text{recovered: } \frac{\mathrm{d}x}{\mathrm{d}t} = \frac{z}{\tau_{\mathrm{rec}}} - U_{\mathrm{SE}}\, x\, \delta(t - t_s)$$

$$\text{active: } \frac{\mathrm{d}y}{\mathrm{d}t} = -\frac{y}{\tau_{\mathrm{in}}} + U_{\mathrm{SE}}\, x\, \delta(t - t_s)$$

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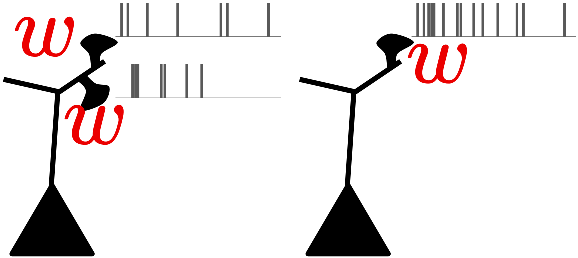
To model facilitation, U_{SE} also changes with time

$$\text{facilitation: } \frac{\mathrm{d}U_{\mathrm{SE}}^1}{\mathrm{d}t} = -\frac{U_{\mathrm{SE}}^1}{\tau_{\mathrm{facil}}} + U_{\mathrm{SE}}(1 - U_{\mathrm{SE}}^1)\delta(t - t_s)$$

A toy example where short term plasticity is important



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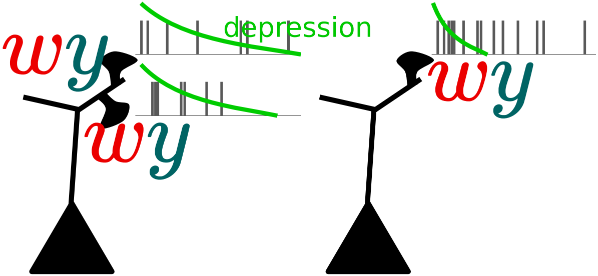

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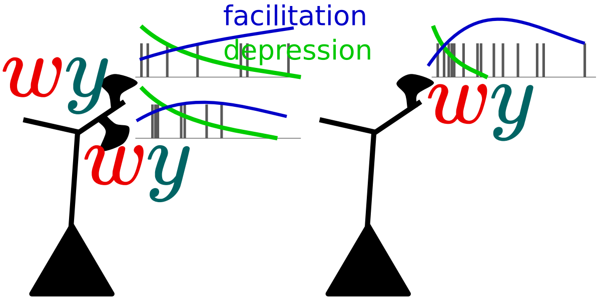

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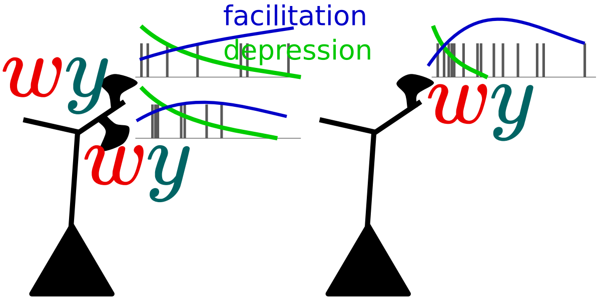

In today's exercise we will explore quantitatively the effects of short term plasticity on the input a neuron receives and on the response of a LIF neuron model.