

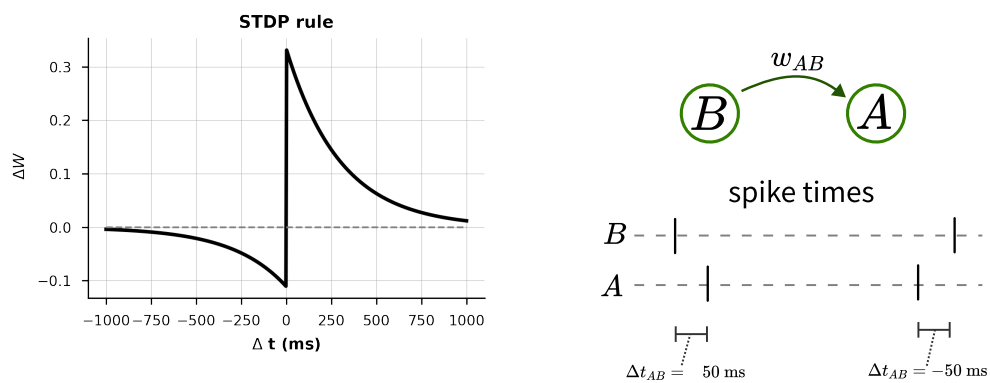
# Mathematical Models of Neural Systems and Cognitive Functions - Exercise Gjorgjieva I

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## 1 Exercise 1

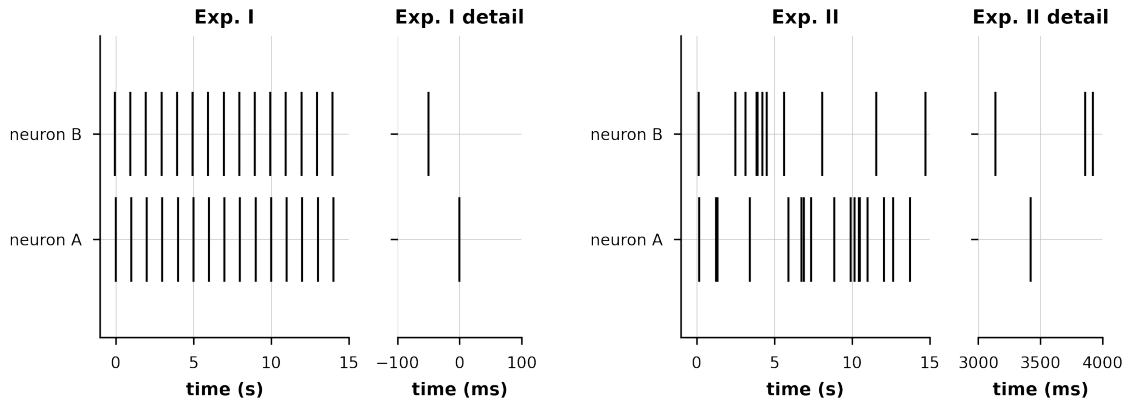
A. Consider the symmetric spiking-time dependent plasticity (STDP) rule, represented in the plot below.



Imagine that this rule governs the weight  $w_{AB}$  of a synapse that goes **from** neuron  $B$  **to** neuron  $A$ .

- (a) What is the change in synaptic weight when neuron  $B$  fires shortly before neuron  $A$ , for example with  $\Delta t_{AB} \approx 50$  ms? And what happens when the two neurons fire in the opposite order?
- (b) What is the change in synaptic weight when neuron  $i$  and neuron  $j$  fire nearly at the same time, for example with  $\Delta t \lesssim 100$ ms? And what happens when the two neurons fire with a larger time delay, such as  $\Delta t \gtrsim 300$ ms?

- B. The neurons  $A$  and  $B$ , still subject to the same STDP rule shown above, are forced to spike by an external source at two different regimes, as shown in the figure below.



In experiment A, as in the previous question, spikes are paired so that  $\Delta t_{AB} = 100$  ms, with a rate of 1 Hz for each neuron. In experiment B the rates are also 1Hz, but the spiking is highly variable and uncorrelated (independent Poisson processes), therefore any value of  $\Delta t_{AB}$ , positive or negative, is equally likely to occur. After a sufficiently long time, the final synaptic weight  $w_{AB,end}$  is measured.

- For each experiment, using the STDP rule shown above, predict whether the synaptic weight will increase, decrease or remain unchanged compared to the initial value  $w_{AB,0}$ . Explain your reasoning.
- Assuming that the average firing rate of neurons is the same in both experiments,  $\nu^B$  and  $\nu^A$ , explain analytically your previous response. Hint: Express the weight update in terms of contributions from the pre-synaptic and post-synaptic neurons and in terms of all pre-post spike pairs, and consider separation of time scales.

## 2 Exercise 2

Open the notebook 'notebook.STDP.ipynb'. Execute the code and complete the parts of the code that are missing.