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Dynamics and pattern formation of synaptic learning: Why do we profit from slow learning?[1]

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Neuronal dynamics is the dynamics of the brain. It is highly nonlinear because neurons are elements responding to a membrane potential that needs to exceed a threshold in order to generate an action potential or 'spike'. Neuronal dynamics occurs on at least two different levels: that of the neurons themselves (on a millisecond timescale) and a much slower one at the synapses, where learning takes place. Synapses are situated on a neuron, receive spikes emitted by other neurons, and are located at the end of an axon transmitting spikes with a finite delay. This talk will concentrate on many fascinating questions such as: What do synaptic representations (maps) of the outside sensory world look like, how do they develop as a consequence of synaptic learning, and is their development compatible with chaos or is it governed by totally different principles? In so doing, we focus on universal principles underlying both the rich diversity of neuronal dynamics of many interacting neurons and the corresponding, adiabatic, learning dynamics at the synapses in conjunction with pattern formation in large systems of synapses. The timescale of the latter is, in general, at least five orders of magnitude slower than that of the neurons. Not only does this "slow" synaptic learning lead to an adiabatic principle and, hence, to analytical insight into the learning process itself but it also allows for robustness of learning as compared to the much more fragile neuronal dynamics.

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