Hebbian and non-Hebbian plasticity orchestrated to form and retrieve memories in spiking networks

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Simulated using the
Auryn simulator
github.com/fzenke/auryn

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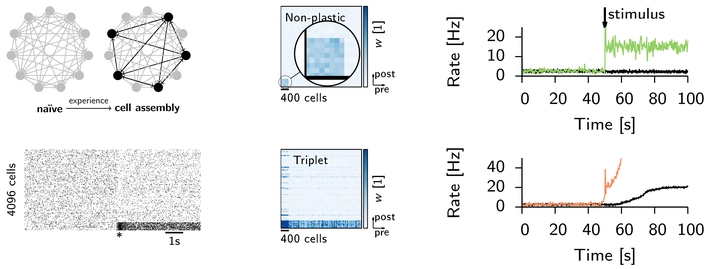
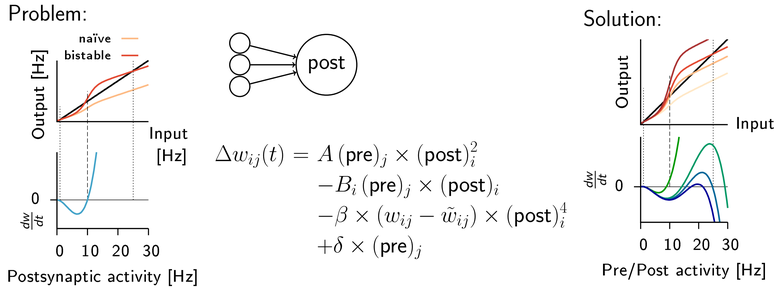
Classic learning rules fail to maintain memories



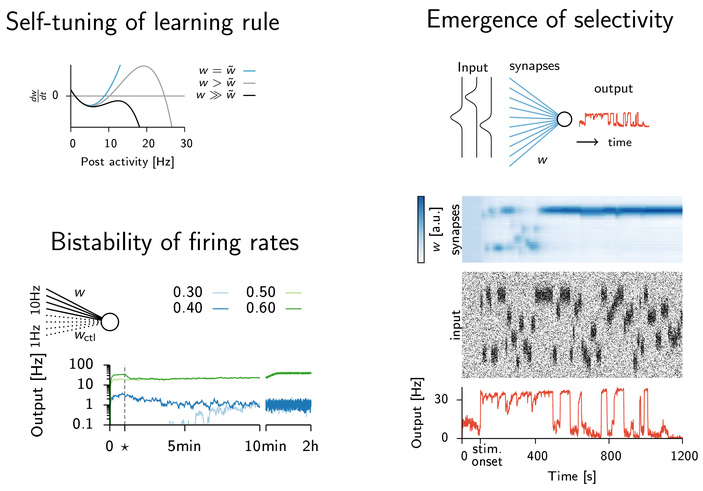
Learning rule: Triplet STDP (Pfister & Gerstner, 2006).

Problems: **Run-away activity** and **crosstalk** between memories.

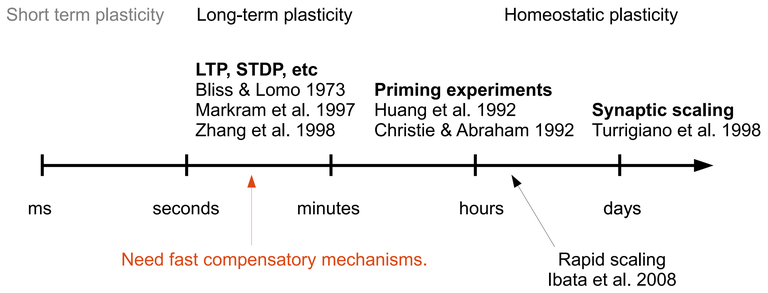
Orchestrated plasticity



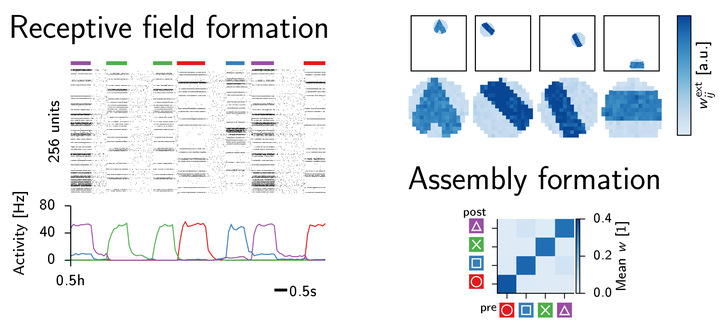
Interplay of firing rate and weight dynamics



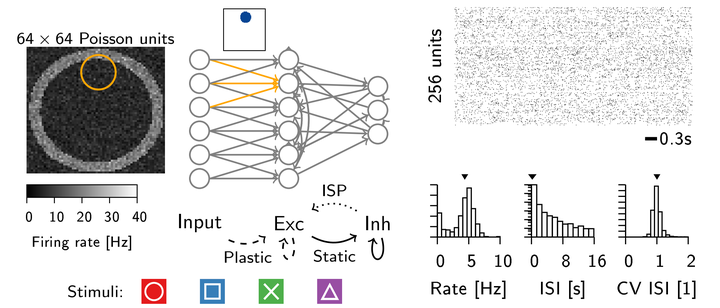
Induction timescales of plasticity



Online learning of repeating stimuli



Spiking network model



Network details: 4096 excitatory adapting integrate and fire neurons, 1024 inhibitory integrate and fire neurons, conductance based synapses with short-term plasticity, random sparse recurrent connections, pre-structured input connections (yellow circle above), spiking input from 4096 Poisson neurons, asynchronous irregular activity **Plasticity:** Triplet STDP Pfister & Gerstner (2006) with heterosynaptic and transmitter induced non-Hebbian plasticity.

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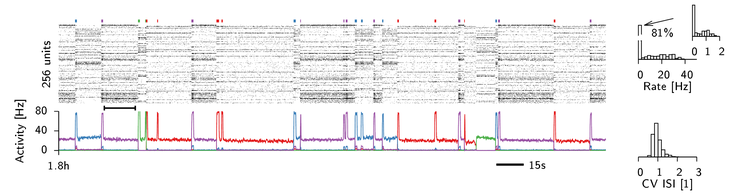
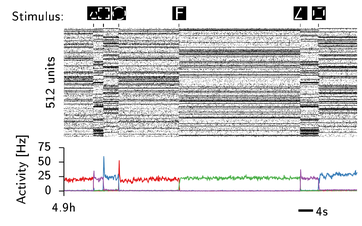
Memory recall and working memory

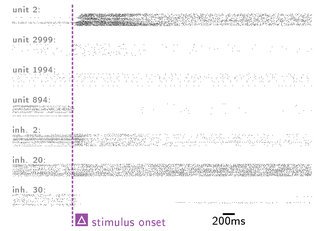
Stable selective delay activity despite ongoing plasticity



Associative memory recall

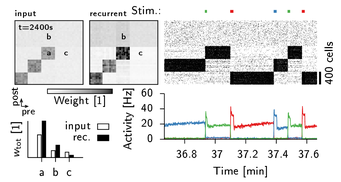


High trial-by-trial variability

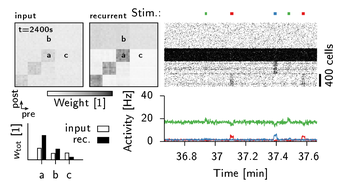


Synaptic consolidation

With consolidation



No consolidation

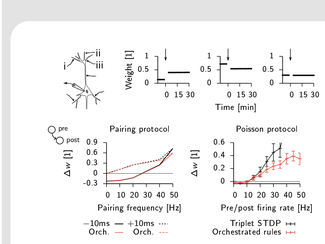


Consolidation model

$$\tau^{\text{cons}} \frac{d}{dt}\tilde{w}_{ij}(t) = w_{ij}(t) - \tilde{w}_{ij}(t) + f(\tilde{w}_{ij})$$

Reference weight $\tilde{w}$ follows w on long timescale τ^{cons} under the influence of the gradient f. Here we used a shallow double well potential for shown simulations, but other (and more complex) forms are possible.

Plasticity induction



Model qualitatively reproduces results from postsynaptic tetanization protocols in Chen *et al.* (2013). Effect on pairing protocols is small.

Summary

- Local Hebbian and non-Hebbian learning rules interact on a short timescale to stabilize plasticity
- Multiple stable equilibrium points stabilize background and recall states respectively
- Consolidation key to heterosynaptic plasticity without overwriting of memories
- Homeostasis acts on much longer timescales and establishes fine-tuning