Reliable information processing through self-organising synfire chains

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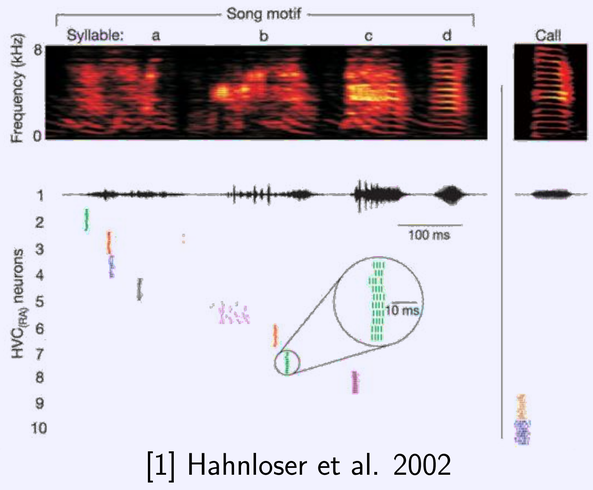
Precise spatiotemporal neuronal activation patterns are observed in nature



[1] Hahnloser et al. 2002

Precise, sequential patterns of activity linked with:

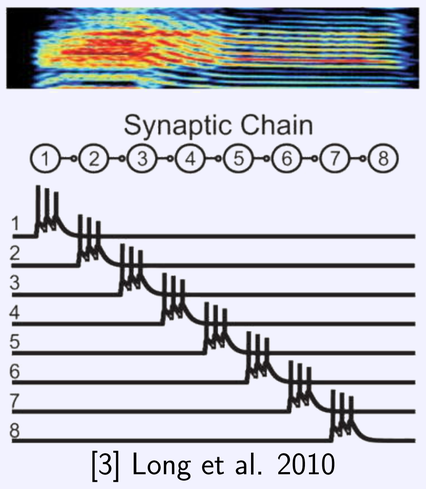
- Song vocalisation in song birds.
- Visual input, reaching and drawing in monkeys.
- Behavioural response to auditory clues in rats.

What is the underlying structure responsible?

One model to explain the appearance of these patterns is synfire chains.

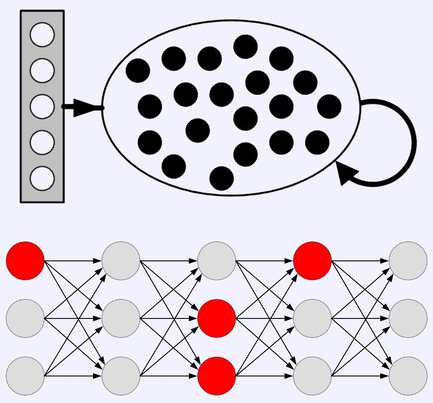
- First proposed by M. Abeles in 1991 [2].
- Theoretically stable and robust feed-forward structures.
- Some experimental evidence to support existence.

How can these chains develop?

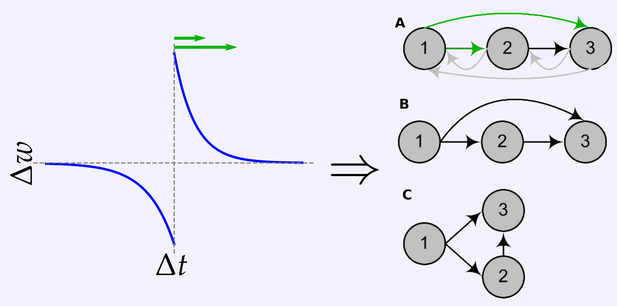


[3] Long et al. 2010

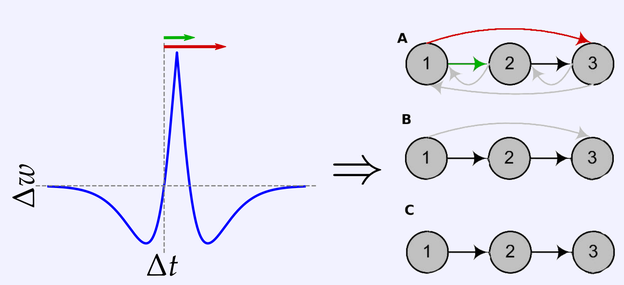
Synaptic plasticity rules can lead to the self-organisation of synfire chains but stability requires network constraints



[4] Waddington et al. 2012



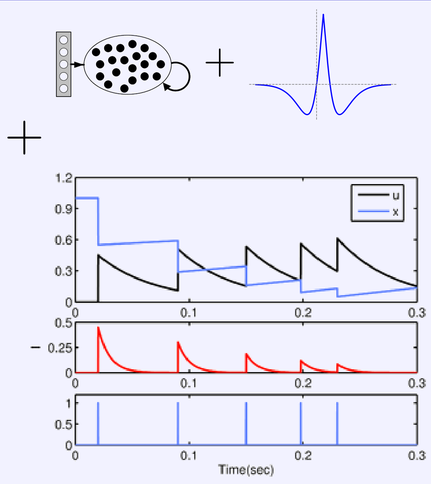
STDP can be used to develop synfire chains in a pool of neurons, but **requires strong topological constraints** to avoid collapse.



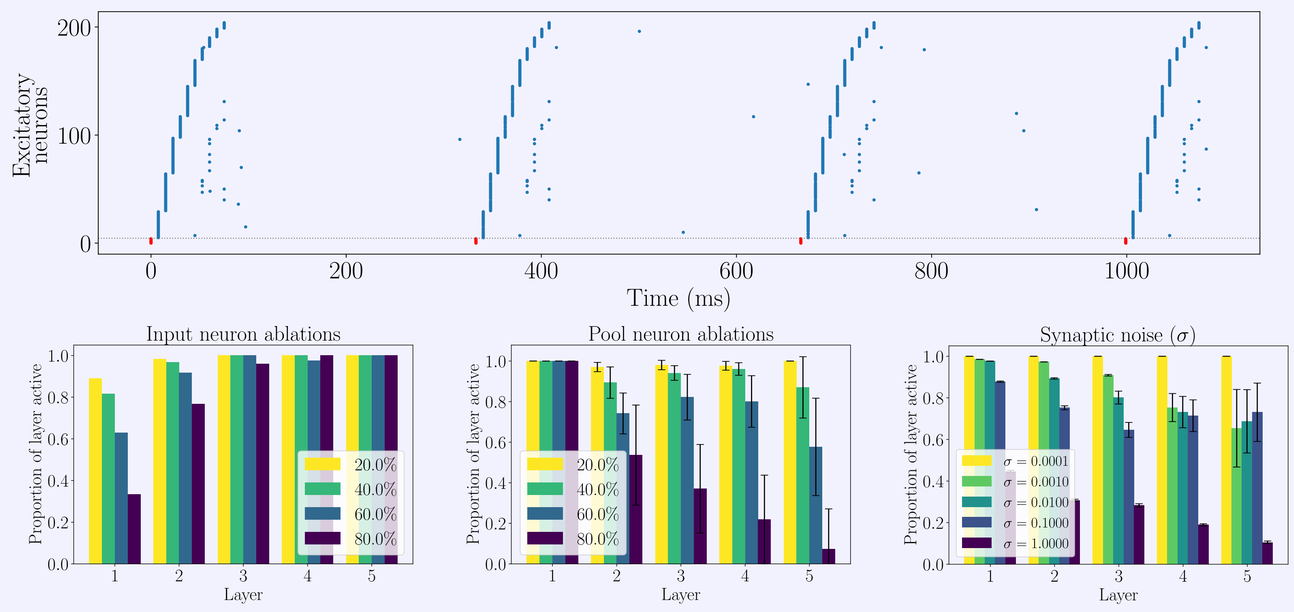
Triphasic-STDP does not require topological constraints but still **requires suppression of ongoing spontaneous neuronal activity**.

Can we grow stable synfire chains without topological constraint nor suppressing spontaneous activity?

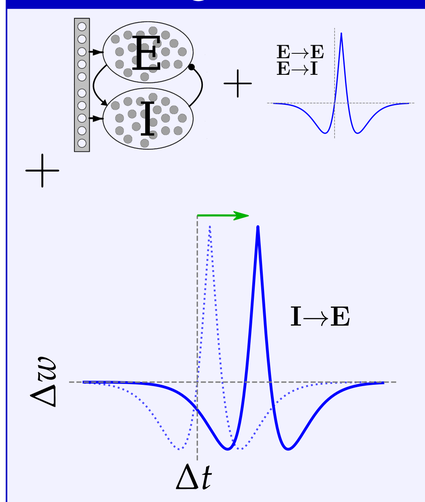
Long self-organised synfire chains can be robustly stabilised through the use of depressing synapses



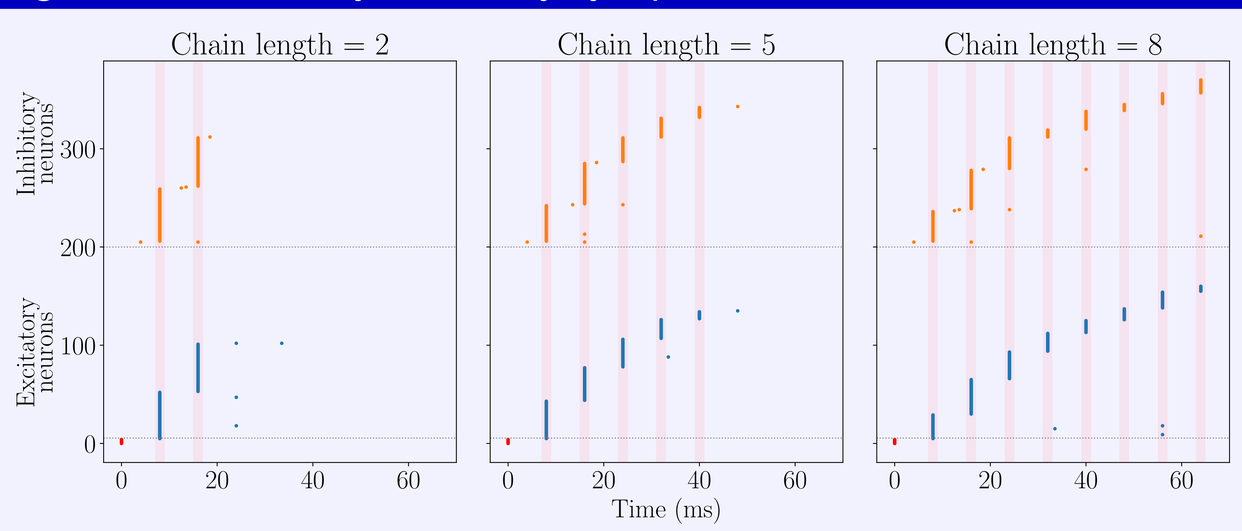
- Short term plasticity models the depletion and recovery of neurotransmitter at each synapse.
- Increased activity at a depressing synapse decreases EPSP magnitude.
- This causes the chain to resist cycles and stabilises long chains.
- Model is robust to ablations of input neurons, pool neurons and to synaptic noise.



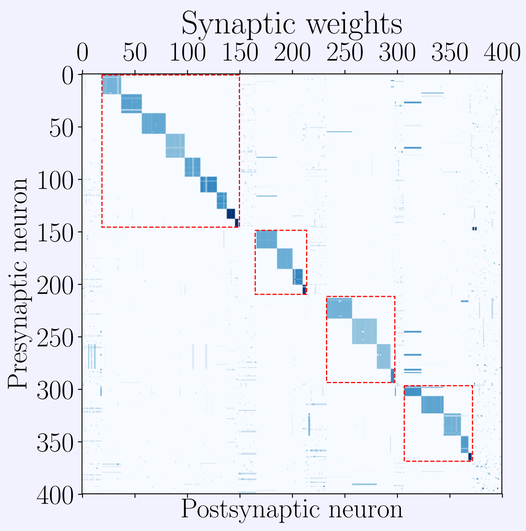
Chain length can be modulated by shifting the triphasic-STDP learning rule for inhibitory-excitatory synapses



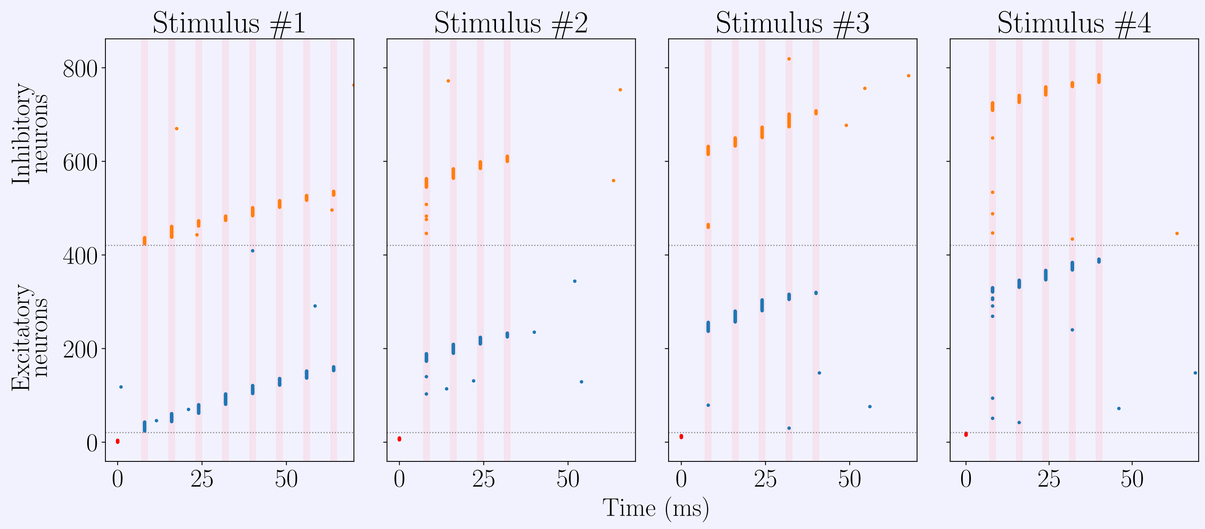
- Inhibitory-Excitatory synapses are learned using an offset Triphasic-STDP rule.
- The shift of the peak causes inhibitory neurons to potentiate synapses onto neurons which fire beyond the desired chain length.
- This offset restricts chain length and prevents the formation of cycles.



Multiple chains may be developed in a network by presenting different stimuli



- Stimulation with different inputs causes multiple chains to develop.
- These chains remain stable under ongoing activity using the techniques developed above.
- One chain tends to dominate over time.



[1] Hahnloser, Richard HR, Alexay A. Kozhevnikov, and Michale S. Fee. "An ultra-sparse code underliesthe generation of neural sequences in a songbird." Nature 419.6902 (2002): 65.
[2] M. Abeles. "Corticonics: Neuronal Circuits of the Cerebral Cortex." 1st. Cambridge, England: Cambridge University Press, 1991.
[3] Long, Michael A et al. "Support for a synaptic chain model of neuronal sequence generation." Nature vol. 468,7322 (2010): 394-9. doi:10.1038/nature09514
[4] Amelia Waddington et al. "Triphasic spike-timing-dependent plasticity organizes networks to produce robust sequences of neural activity." Frontiers in computational neuroscience 6, 2012.