Plastic Neural Network Simulations

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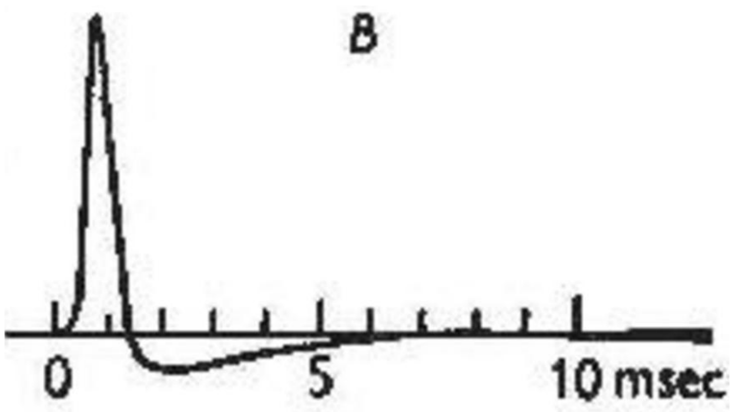
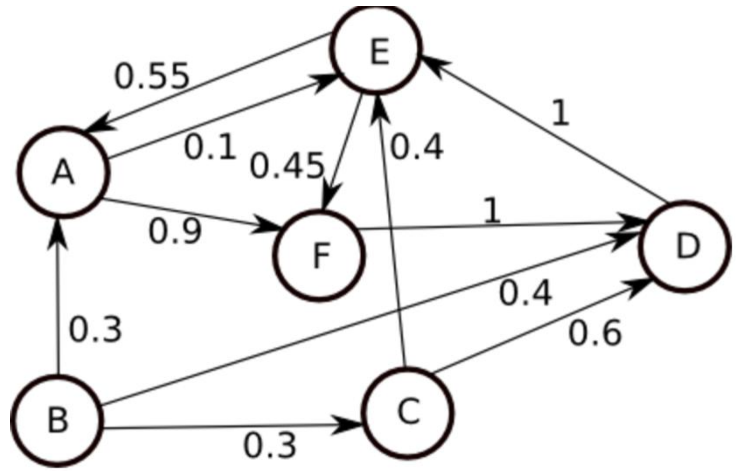
Neuron Dynamics

Excitatory Refractory Leaky Integrate & Fire





$$\tau_m \frac{dV}{dt} = -V + I(t)$$

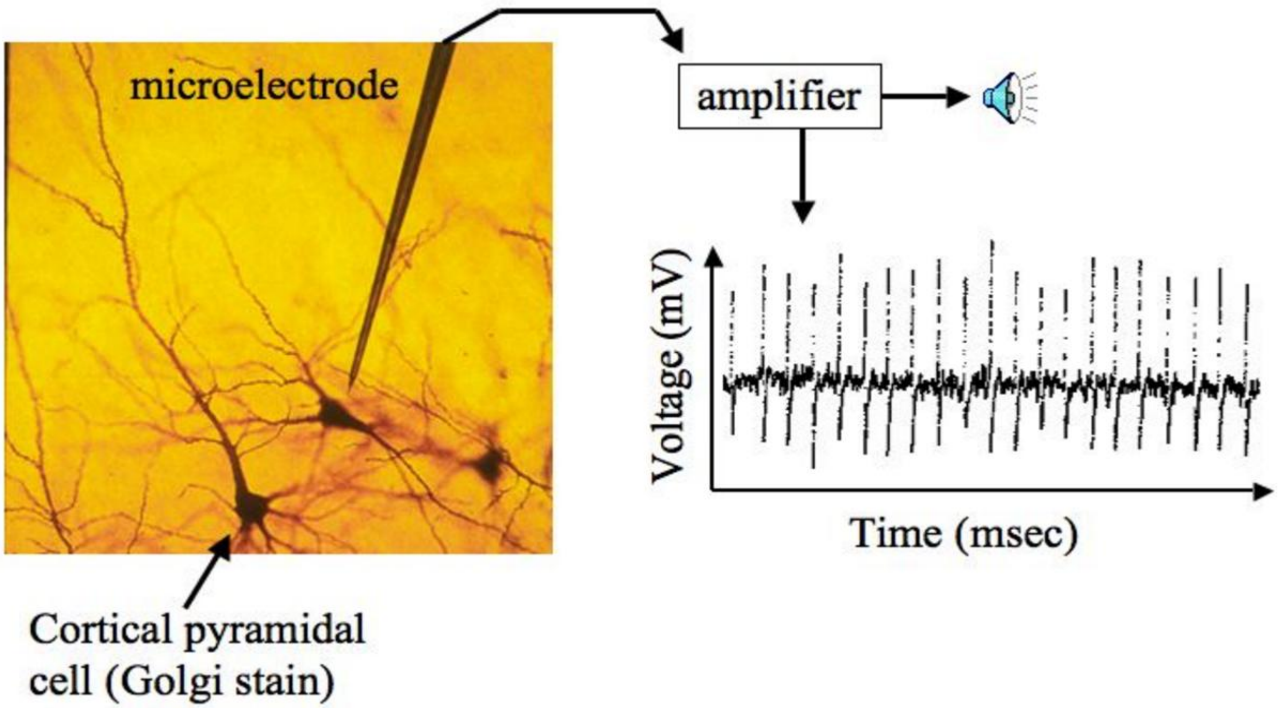
I(t) = random noise + weighted input from spiking neighbors

When V = Vth (spike), set V → 0 and hold for duration R (refractory period)

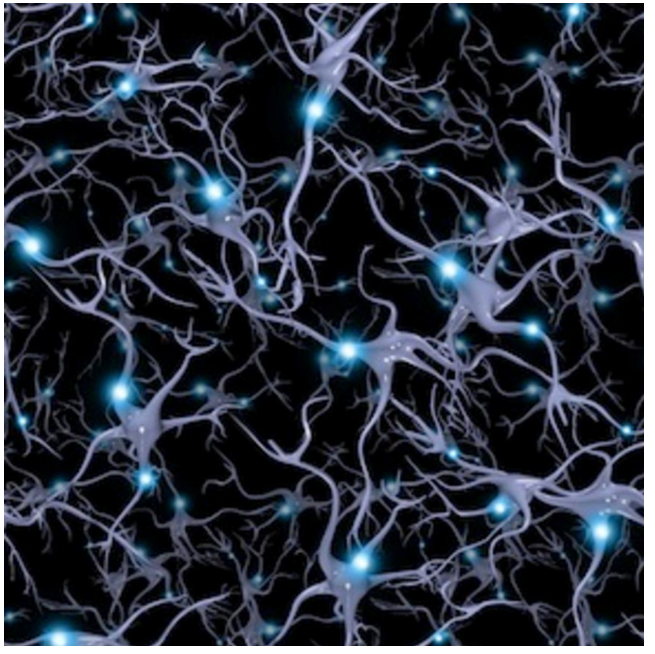
Weights between 0 and 1; weighted input = weight * Vth

Stimulus

Each stimulated neuron spikes every p milliseconds
(assuming not in refractory period)

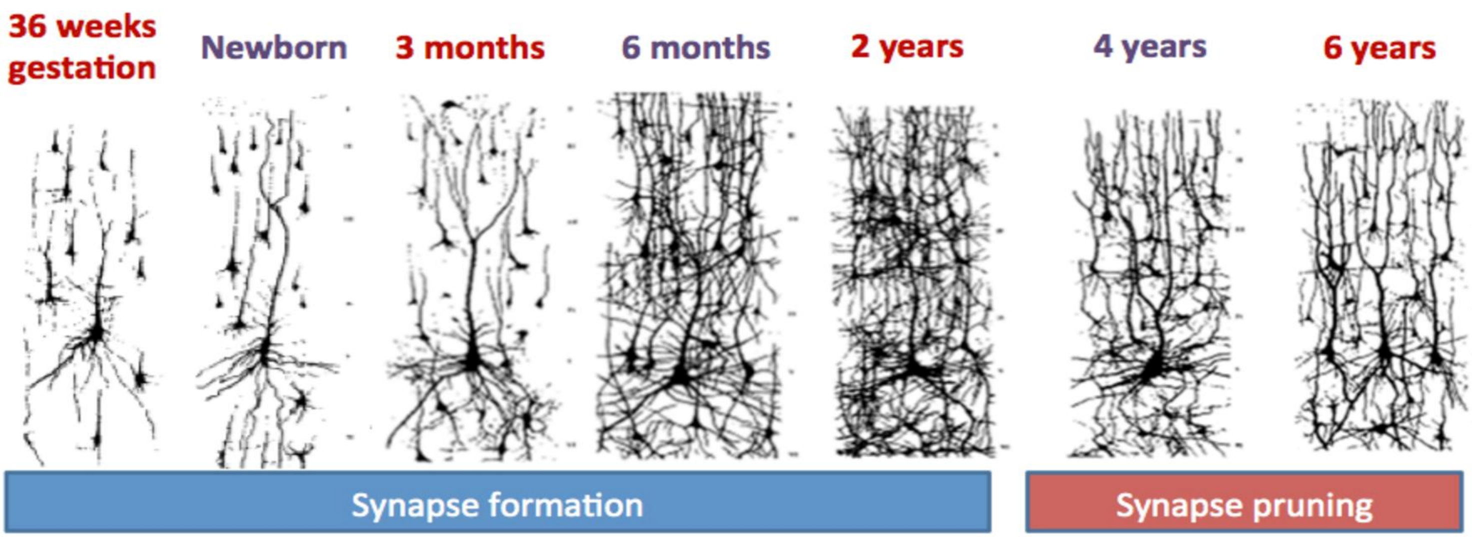


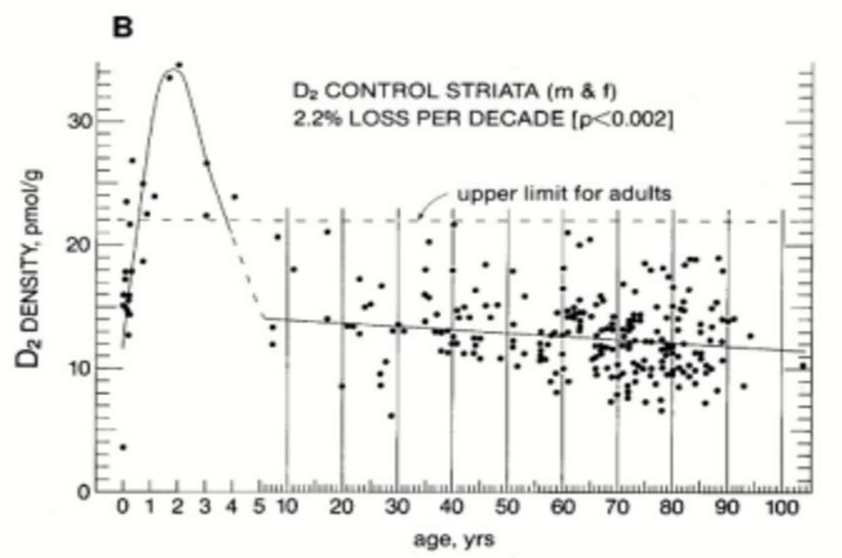
We have a biologically-plausible spiking network.



But it’s boring because its connectivity is fixed.

Developmental Plasticity



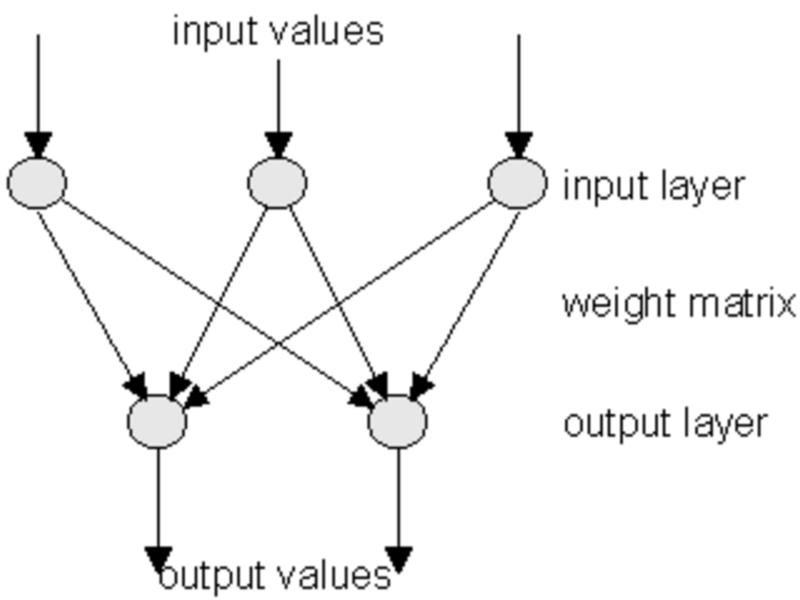


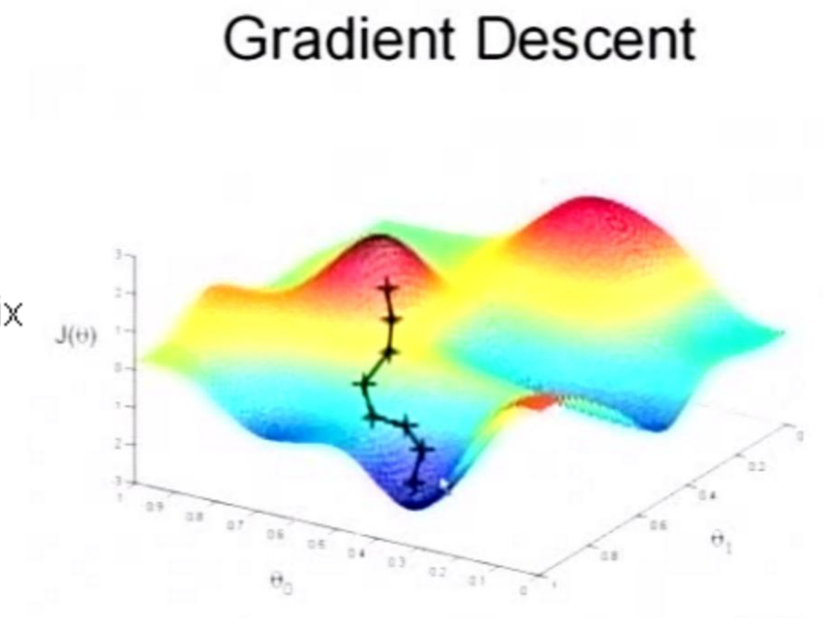
Rate of synapse formation skyrockets during infancy.

HOWEVER, synapses continue to form across entire lifespan.

Learning = modified connectivity

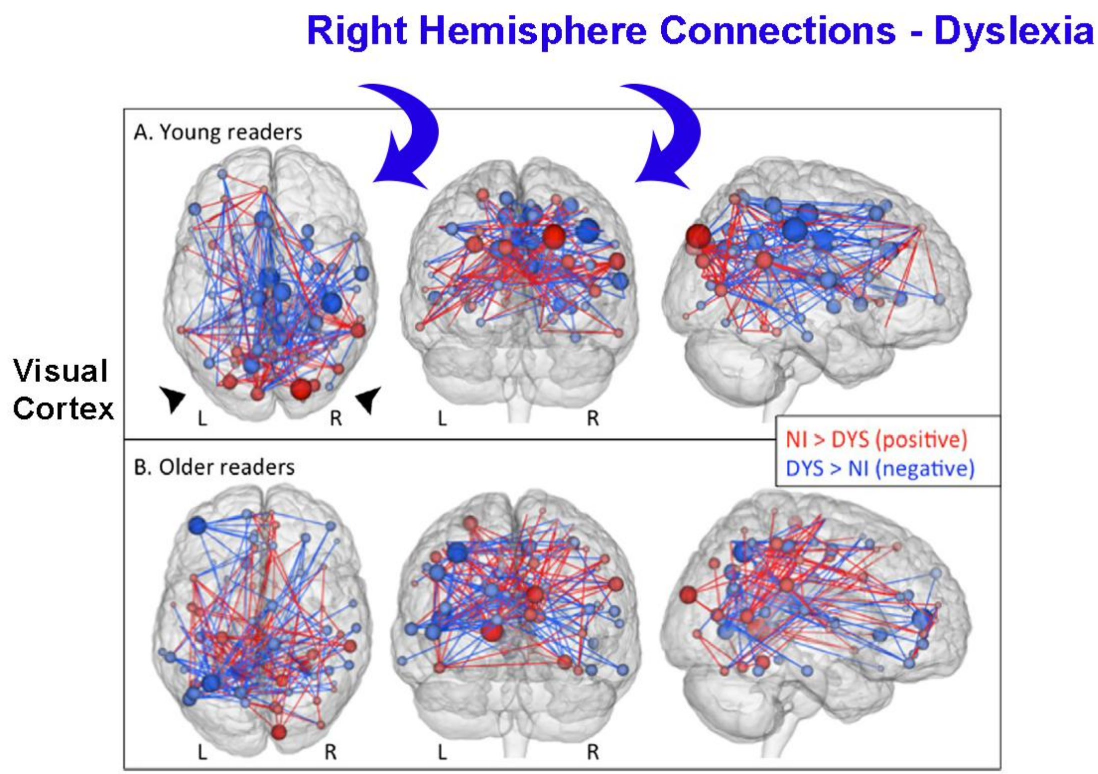
Weight modification can implement gradient descent on feed-forward artificial neural networks





Common artificial learning rule: backpropagation
(can be extended to recurrent ANNs as well – “backpropagation through time”)

Connectivity often implicated in brain disorders



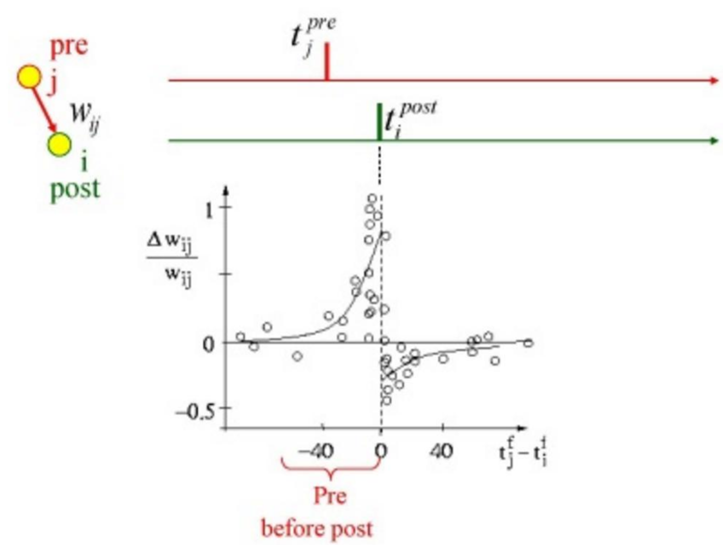
Biological Synapse Modification

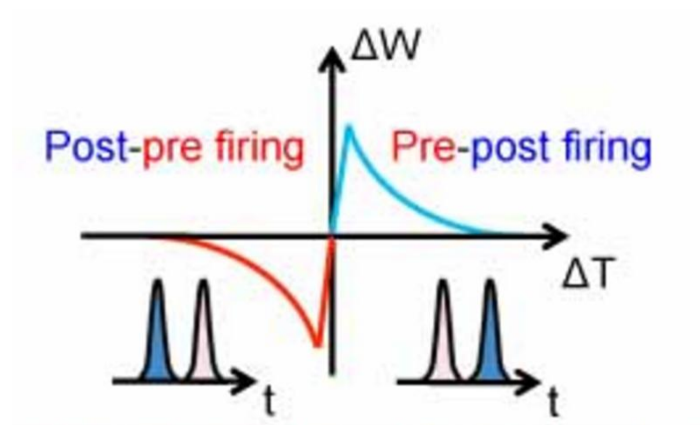
Spike-Timing Dependent Plasticity

Hebbian learning: "Neurons that fire together wire together"

STDP learning: like Hebbian, but depends on order of spiking

If I predict you, I'll strengthen my weight to you.
But if you predict me, I'll weaken my weight to you.



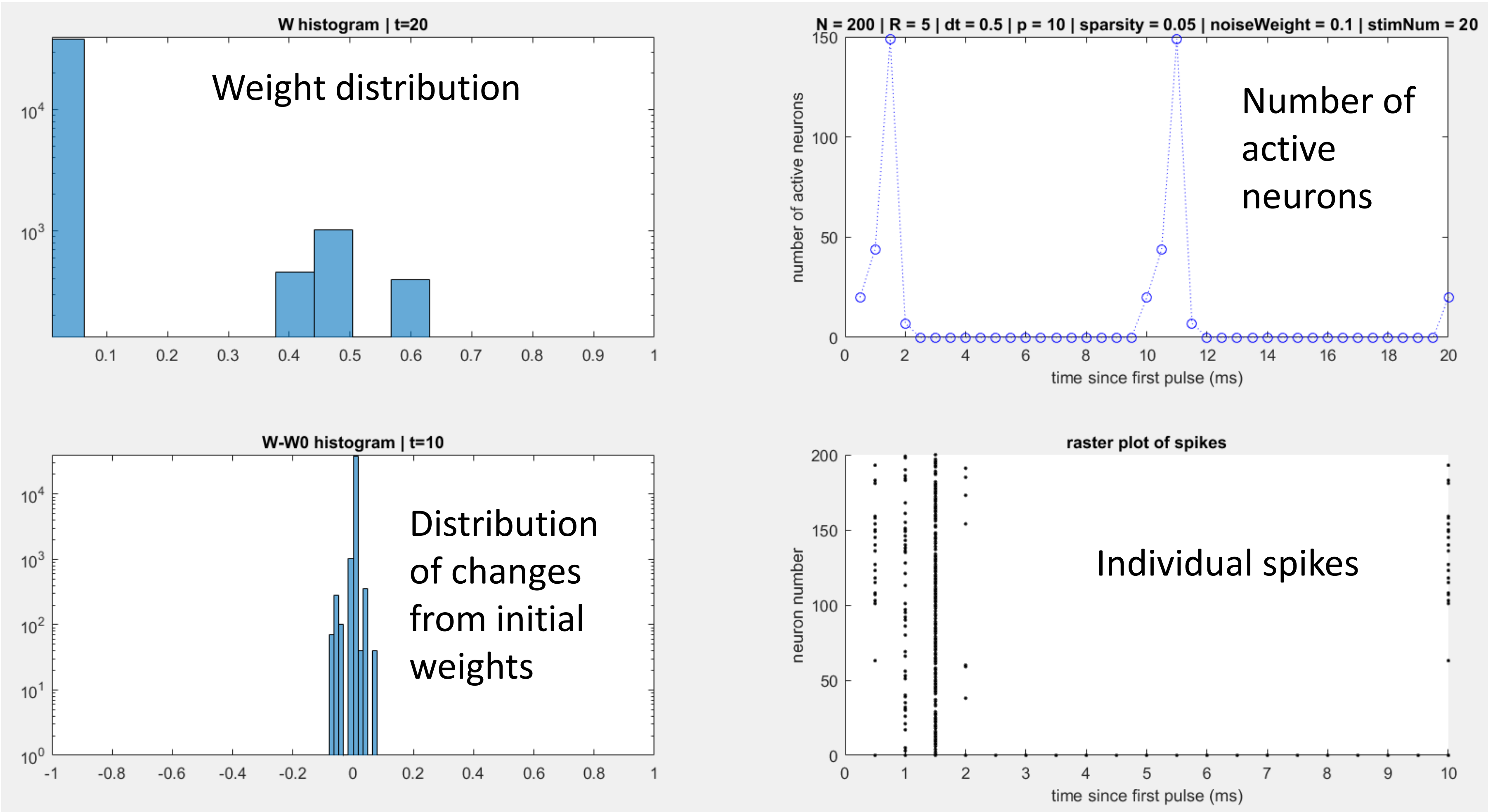


My simulations

1. Randomly select *sparsity%* of connections to exist (set their weight to 0.5)
2. Set all other weight to epsilon (~0.01)
3. Simulate network and see what happens to
   - Weight distribution
   - Network activity

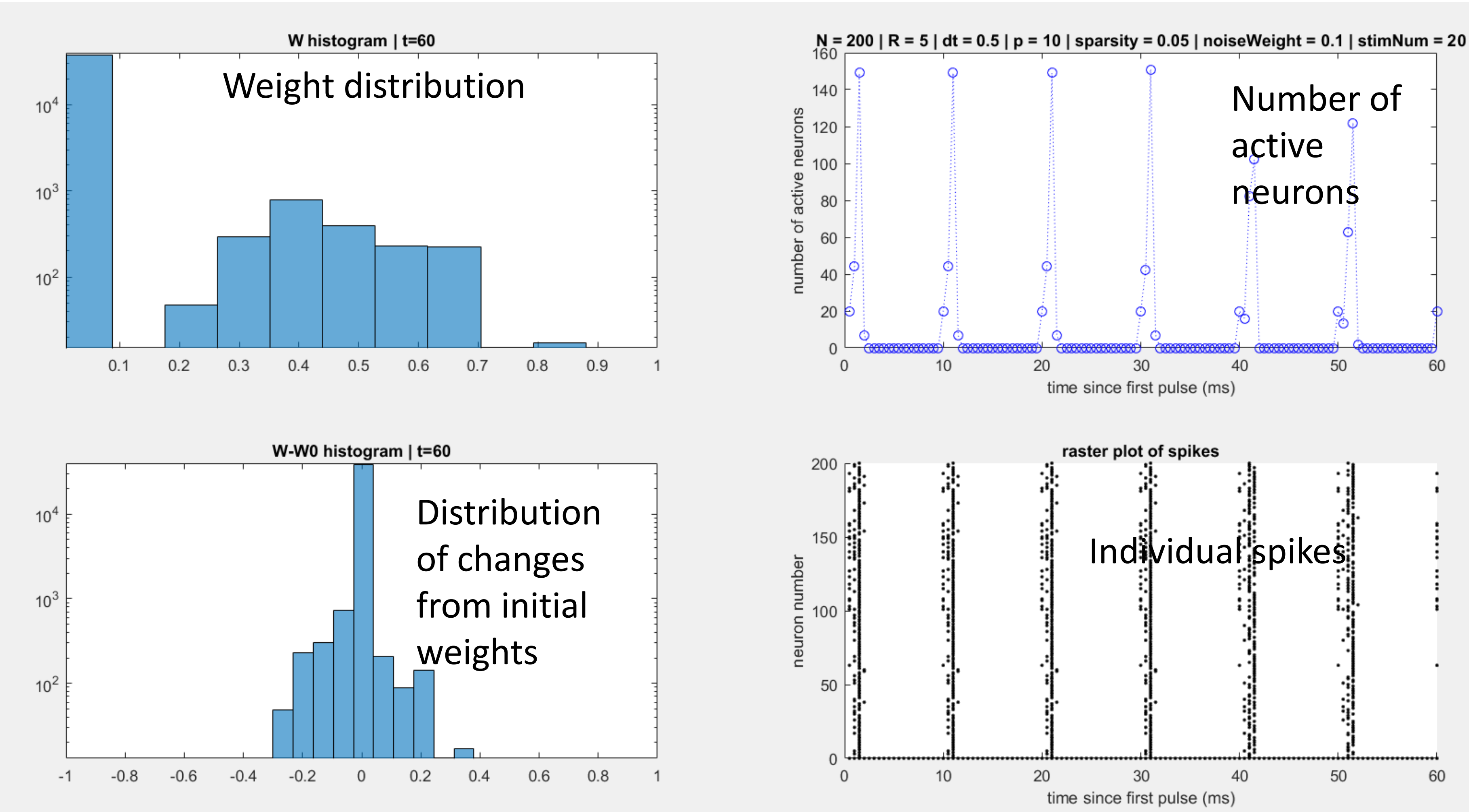
Normal result: *the network reorganizes itself so that only the neurons that are directly stimulated spike*

T = 20



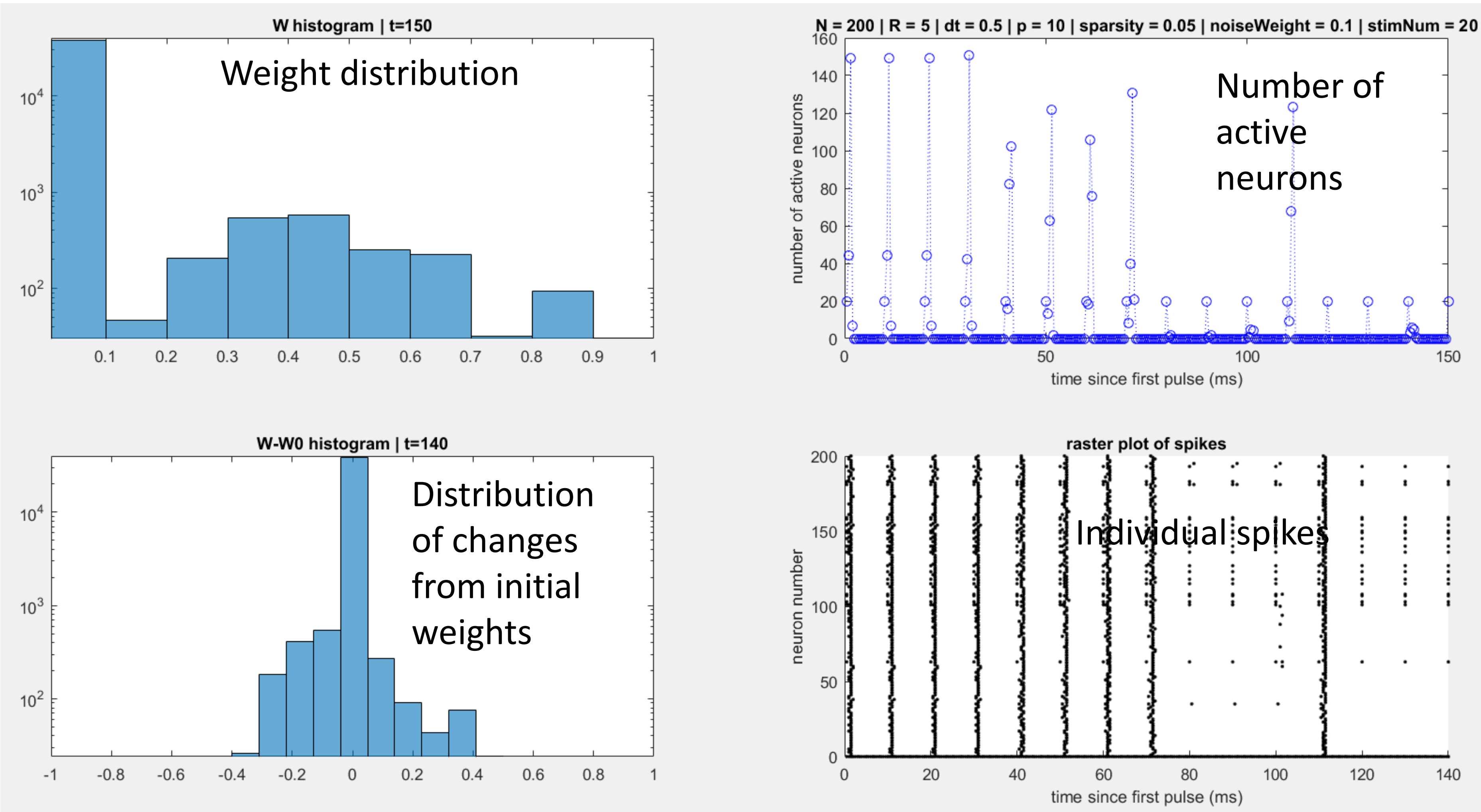
Normal result: *the network reorganizes itself so that only the neurons that are directly stimulated spike*

T = 60



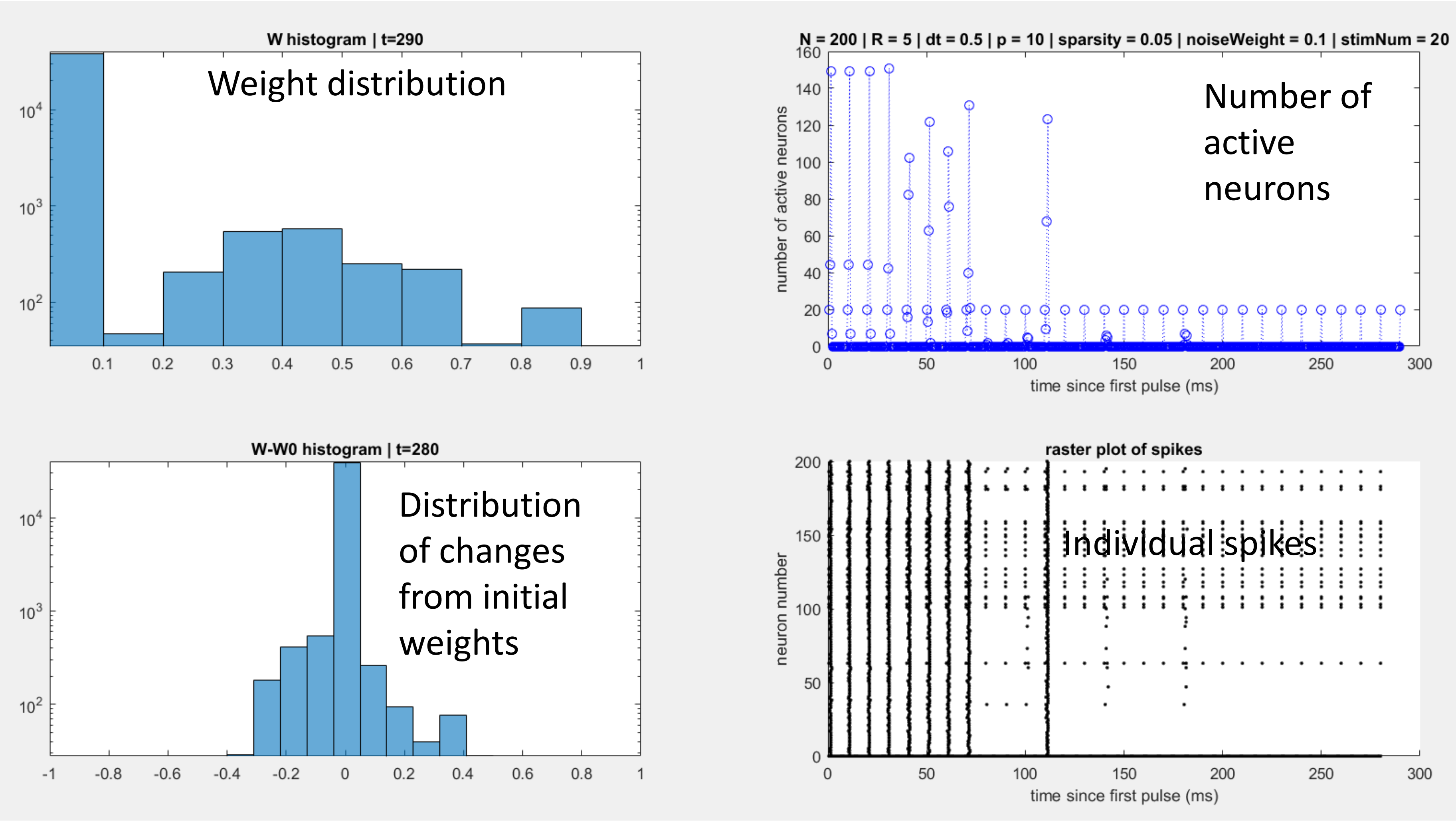
Normal result: *the network reorganizes itself so that only the neurons that are directly stimulated spike*

T = 150

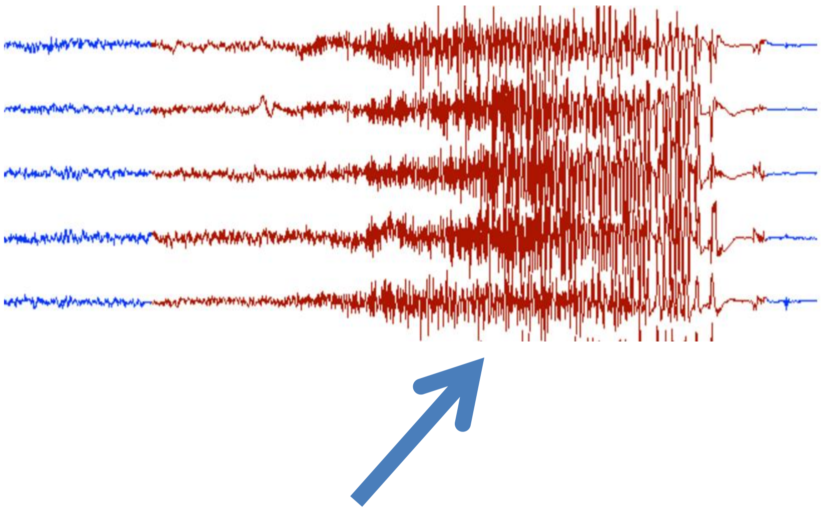


Normal result: *the network reorganizes itself so that only the neurons that are directly stimulated spike*

T = 150



Seizure?



EEG recording of seizure (multiple channels displayed)

Occurs sometimes when refractory period is low, but I've never seen it occur with normal refractory period