Stochastic Resonance in Attractor Neural Networks with Triple Well Synapses

Antony Bertolin
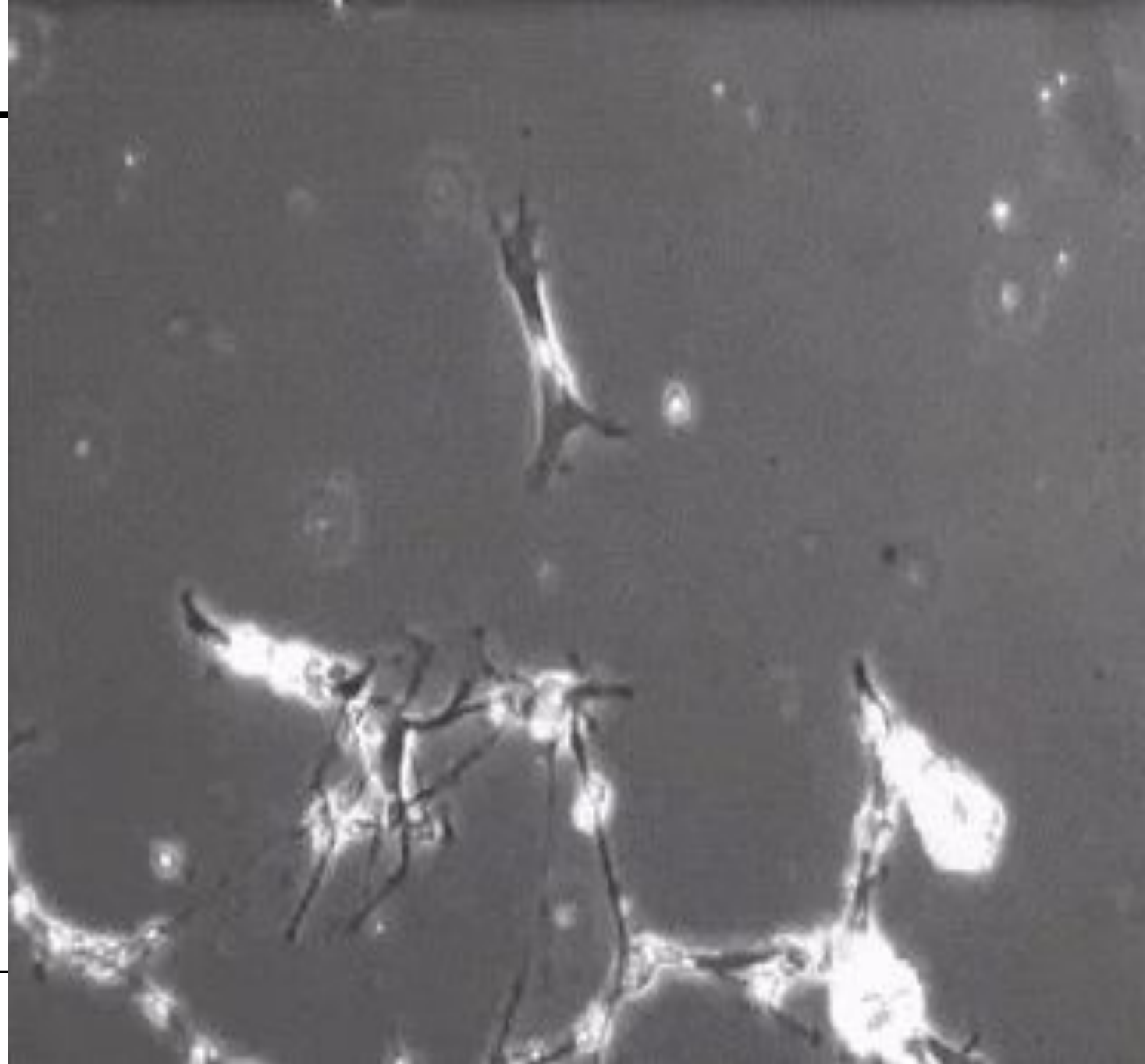
Geisa Salles

Wolf De Wulf
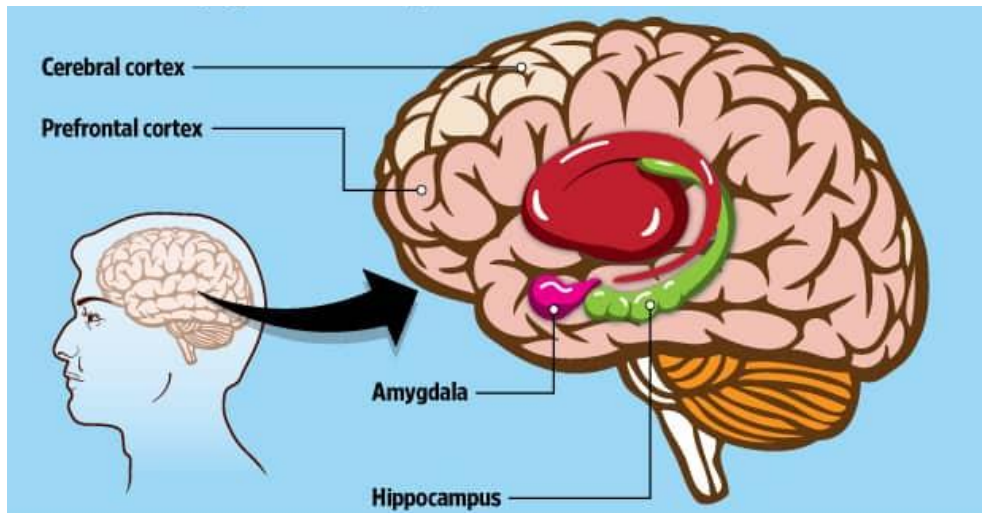
To develop a complete mind:
Study the science of art;
Study the art of science.
Learn how to see.
Realize that everything
connects to everything else.

– leonardo da vinci

Fetal neurons making connections *in vitro*, Oxford University Scientific Society
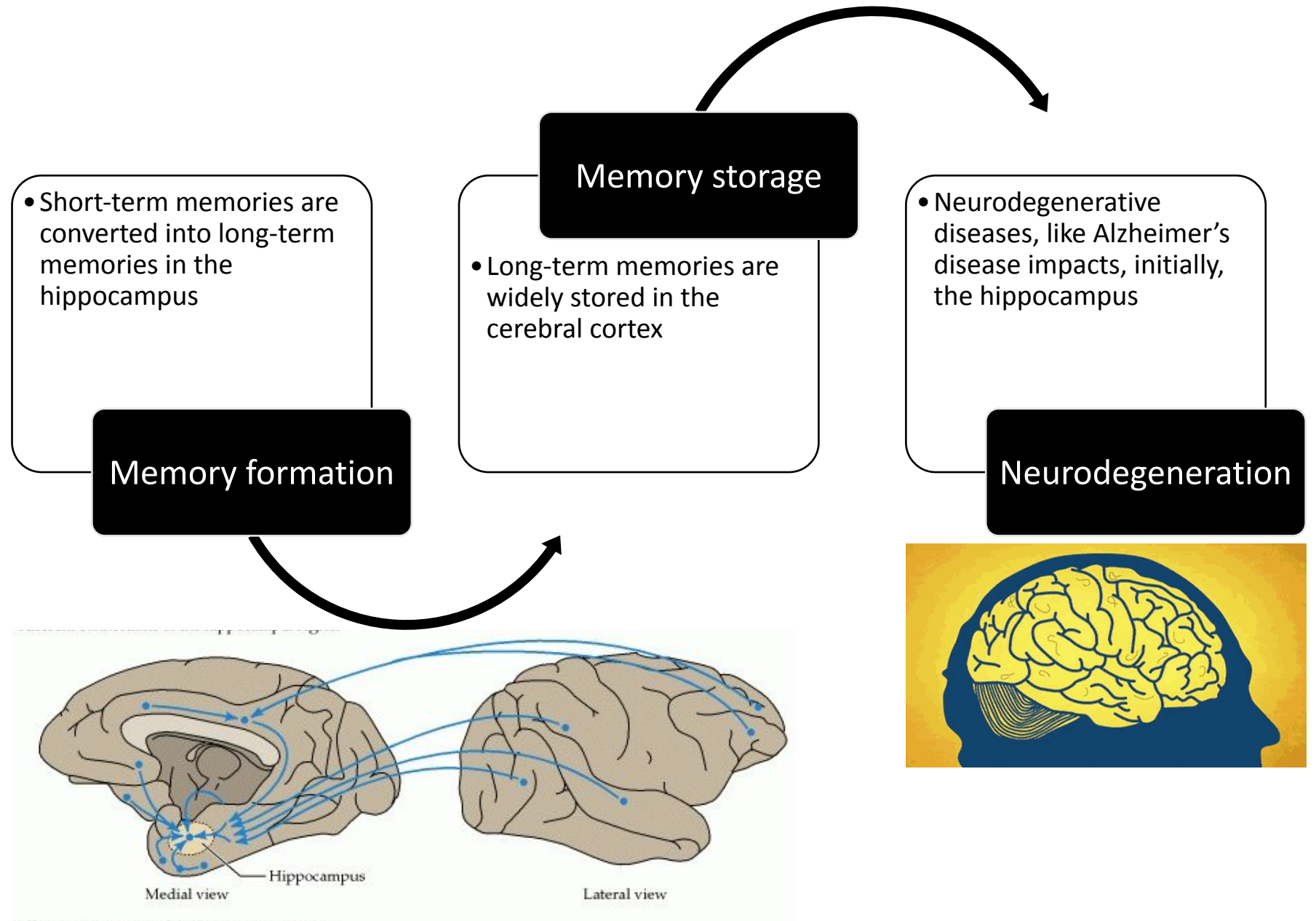
STM and LTM

Short-term memory

- Brain stores information temporarily so that it can be repeated, such as remembering a phone number you see on TV

Long-term memory

- The hippocampus retrieves information from the short-term memory and begins to change the brain's physical neural wiring.
- These new connections between neurons and synapses stay as long as they remain in use. Information stored in long-term memory can stay in the brain for a short while (a day, a week) or last as long as a lifetime.

STM x LTM

Memory formation
- Short-term memories are converted into long-term memories in the hippocampus

Memory storage
- Long-term memories are widely stored in the cerebral cortex

Neurodegeneration
- Neurodegenerative diseases, like Alzheimer's disease impacts, initially, the hippocampus

Hippocampus

Medial view

Lateral view

https://www.ncbi.nlm.nih.gov/books/NBK10901/

Triple Well Potential

- Any model with 3-well synapses

- Simplest version:
  6th degree polynomial

$$a_2x^2 + a_4x^4 + a_6x^6$$
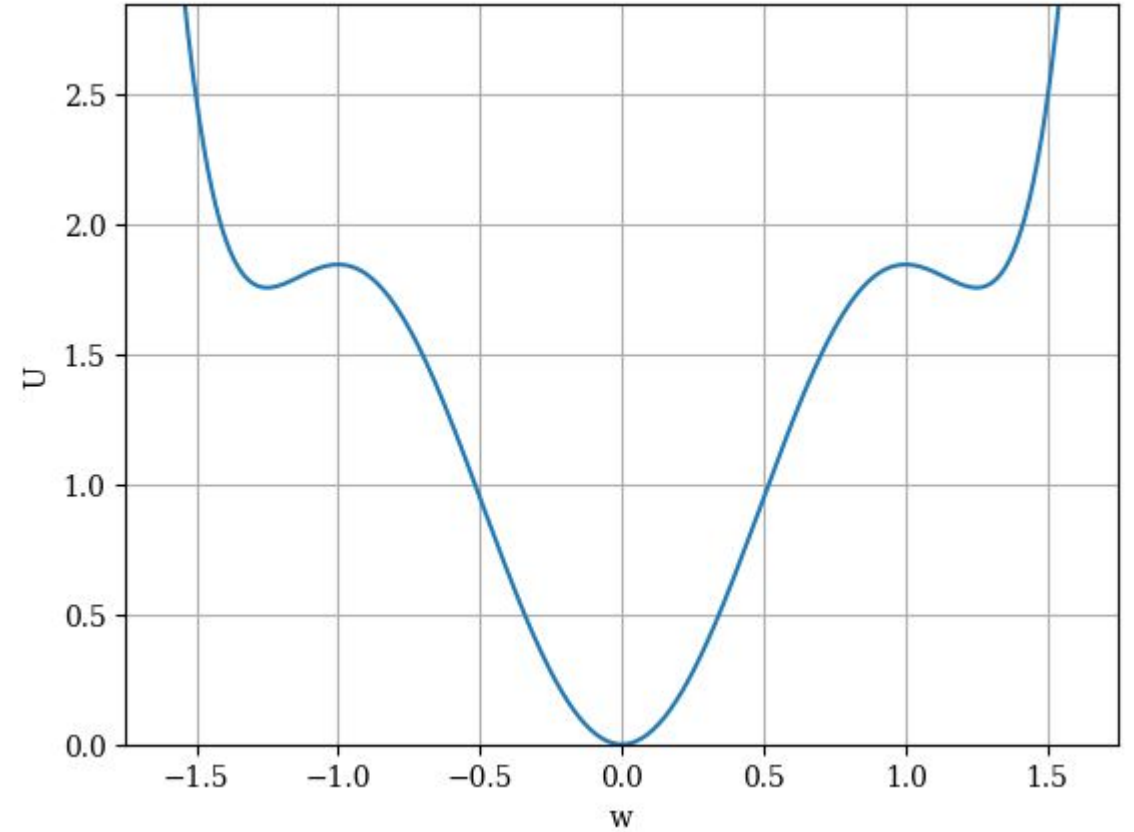
Stochastic Resonance
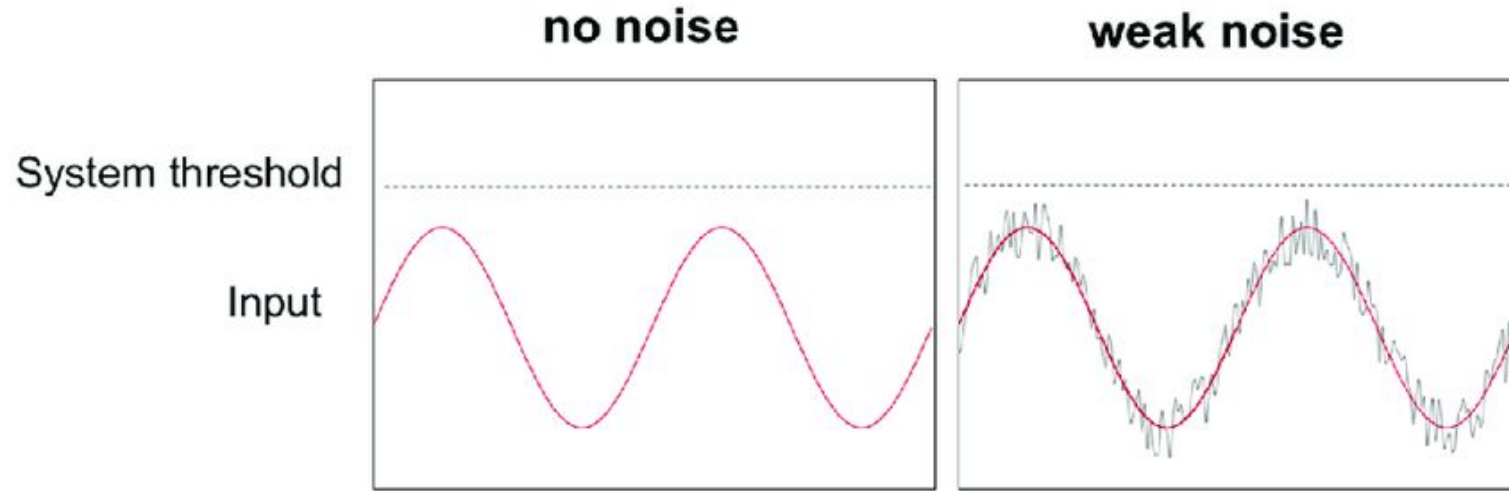
A phenomenon in which a very weak signal to be detected by a sensor can be boosted by adding white noise to the signal, which contains a wide spectrum of frequencies

Objective of the project

In the provided triple-well model, the noise may facilitate the transitions of the STM to LTM, implying nonuniform dependence of the memory longevity on the noise level

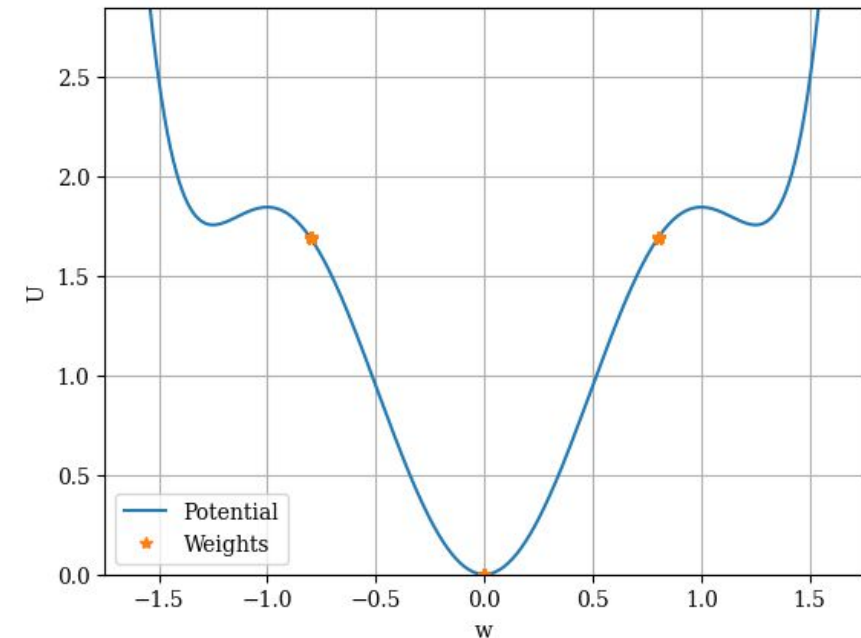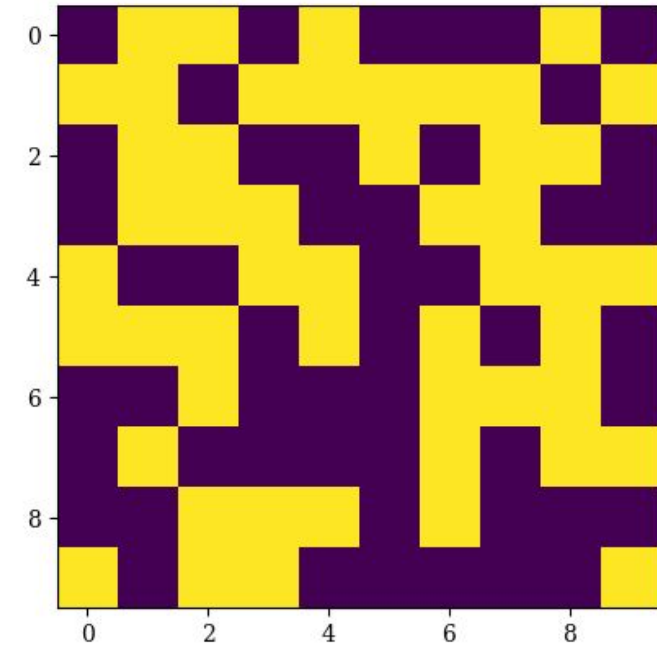Find the dependence of the memory lifetime on the noise level and see if this is indeed the case.

Methodology

- 100 neuron network

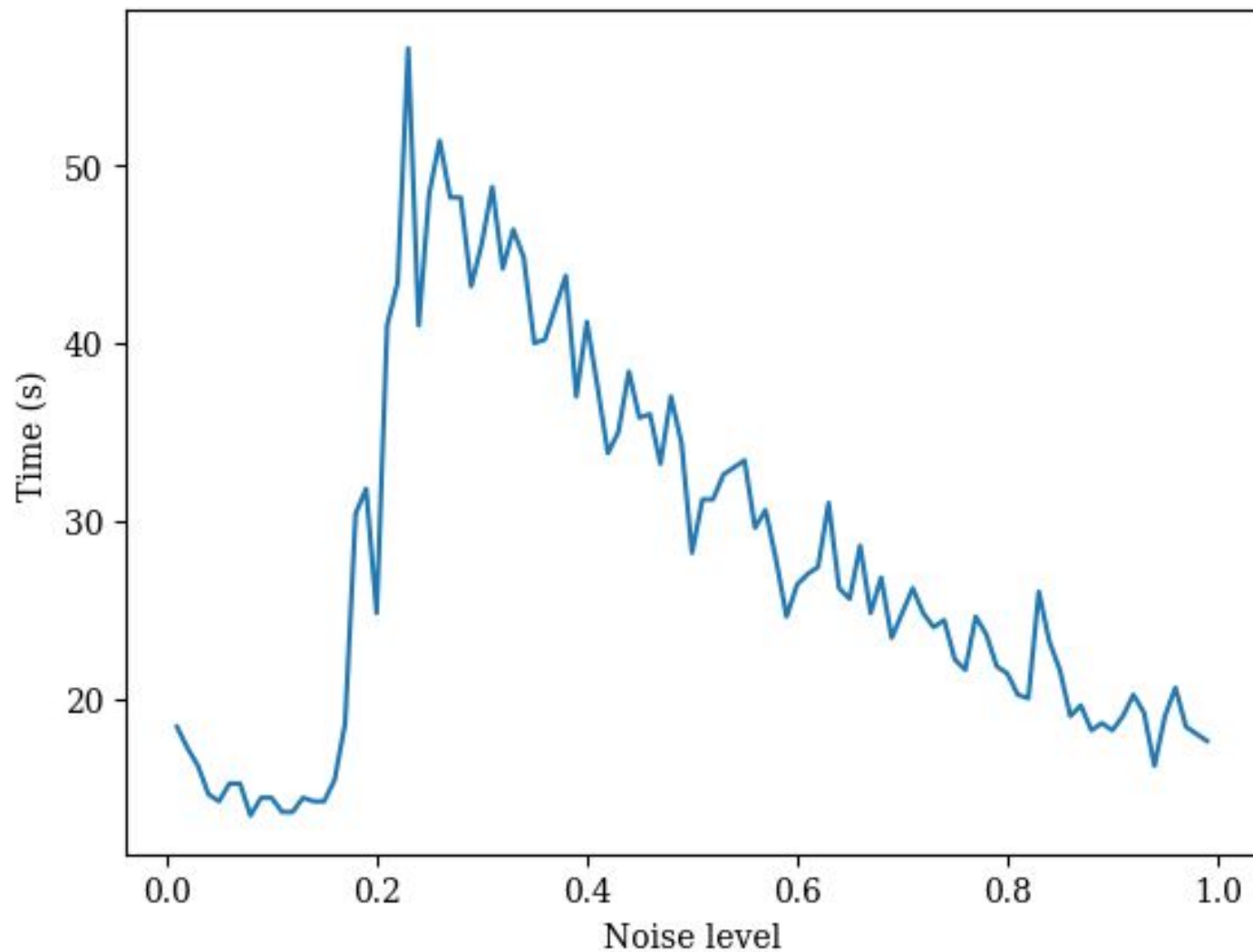- Exposure to maximum entropy pattern

- Hebbian learning rate (lambda) = 0.8

$$\frac{dw_{ij}}{dt} = \lambda \xi_i \xi_j$$

- Weight dynamics depend on synapse potential and Gaussian noise
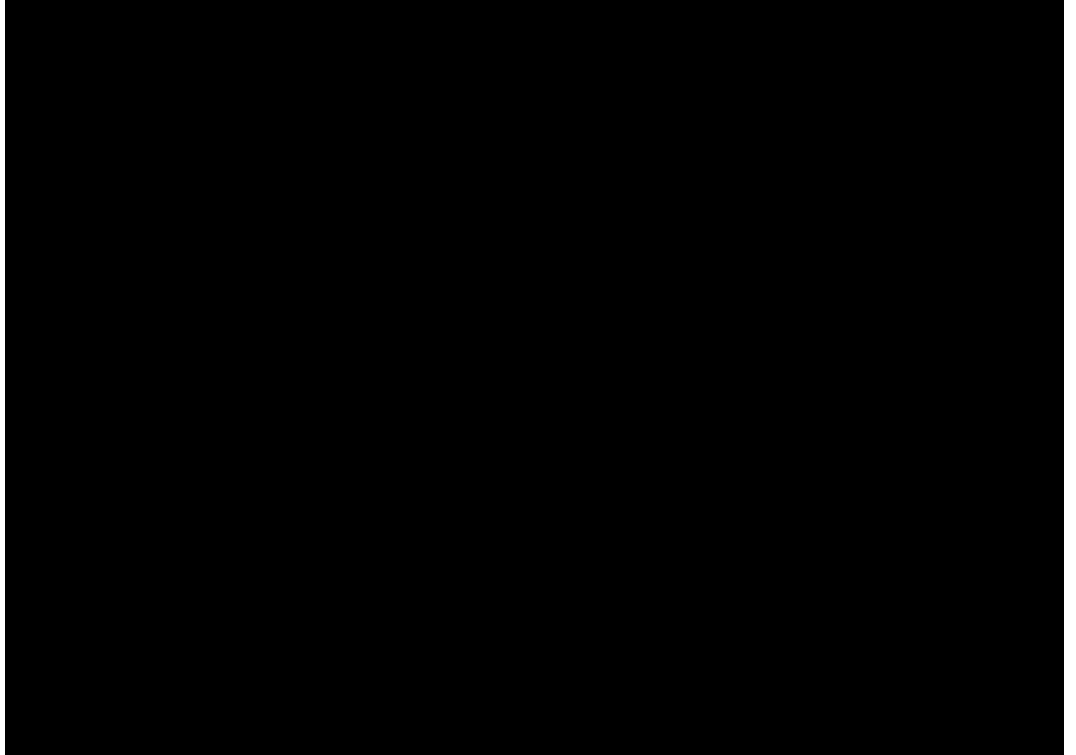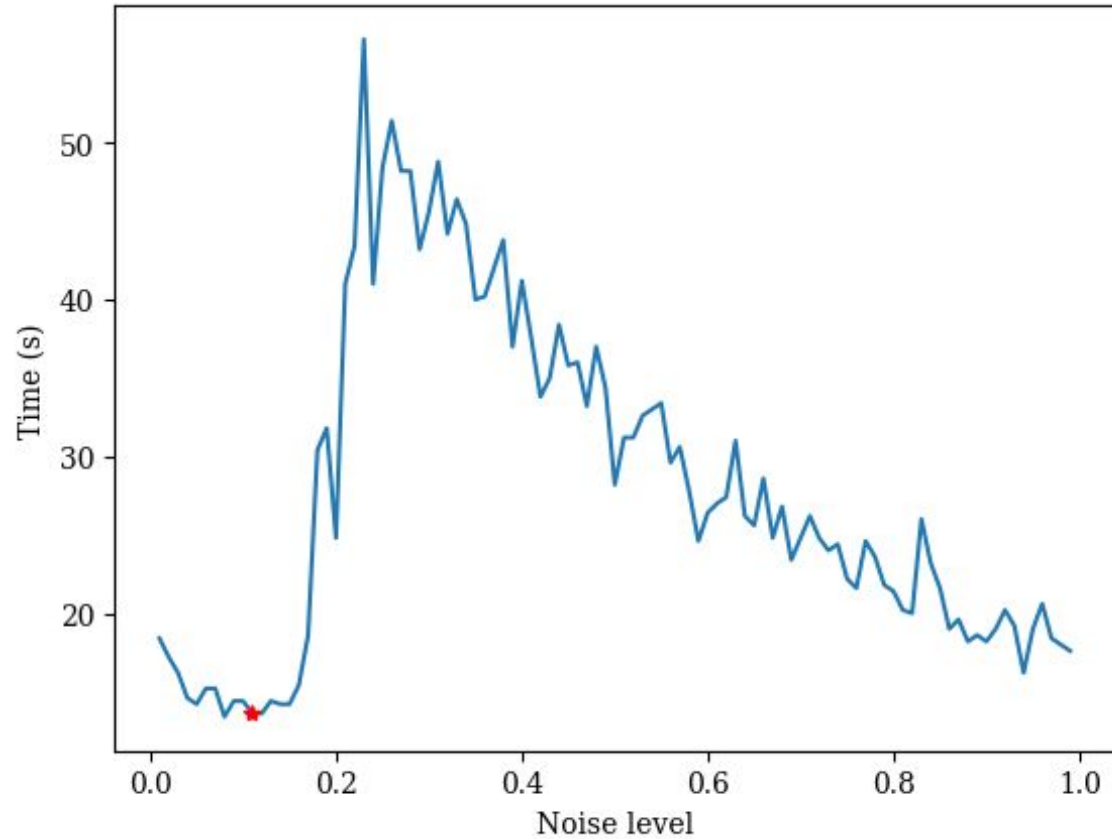
- Consider memory forgotten when: reconstruction accuracy < 0.5
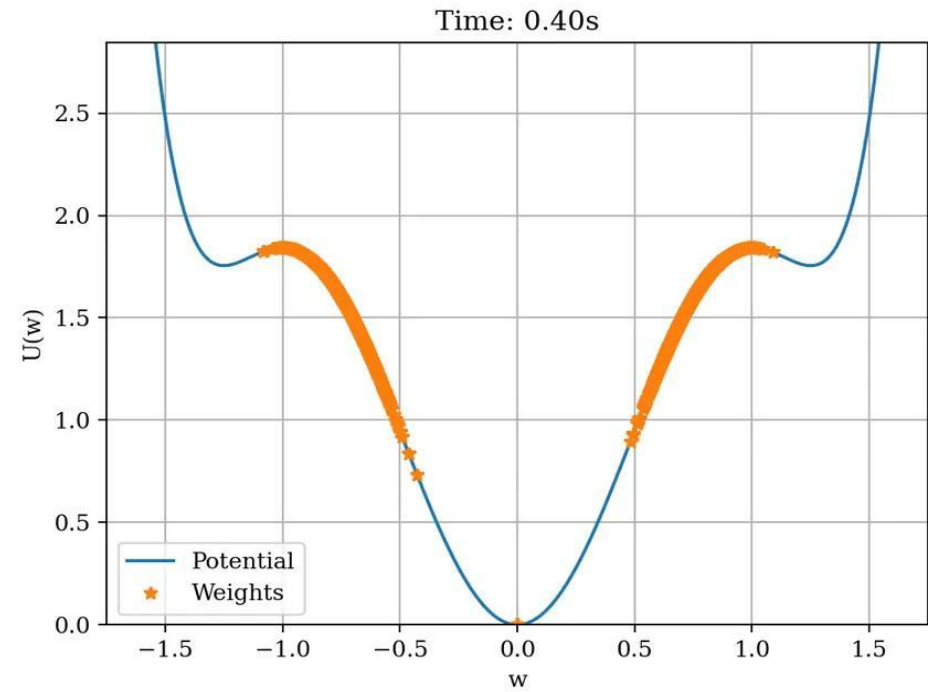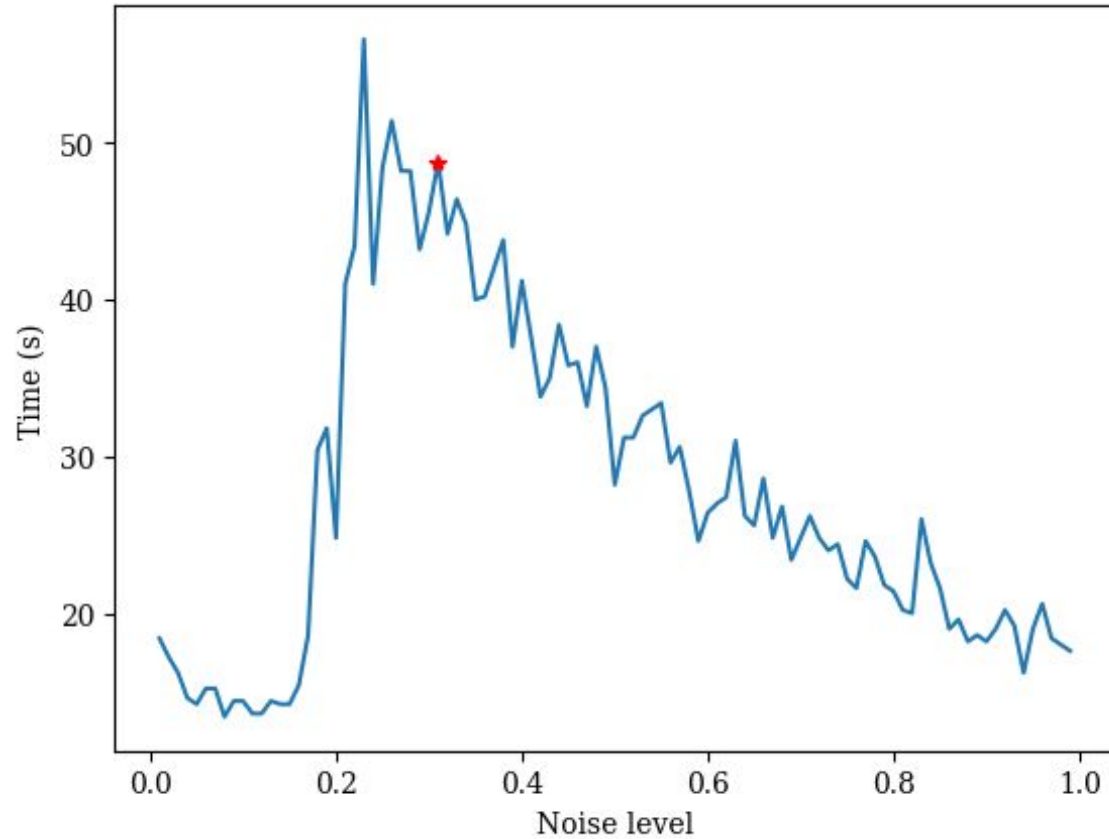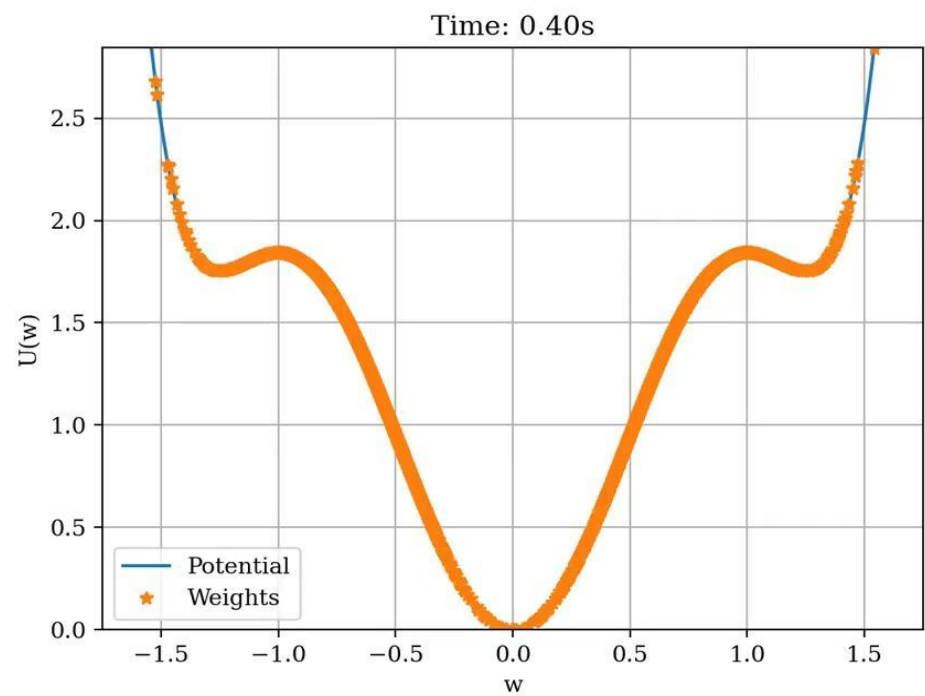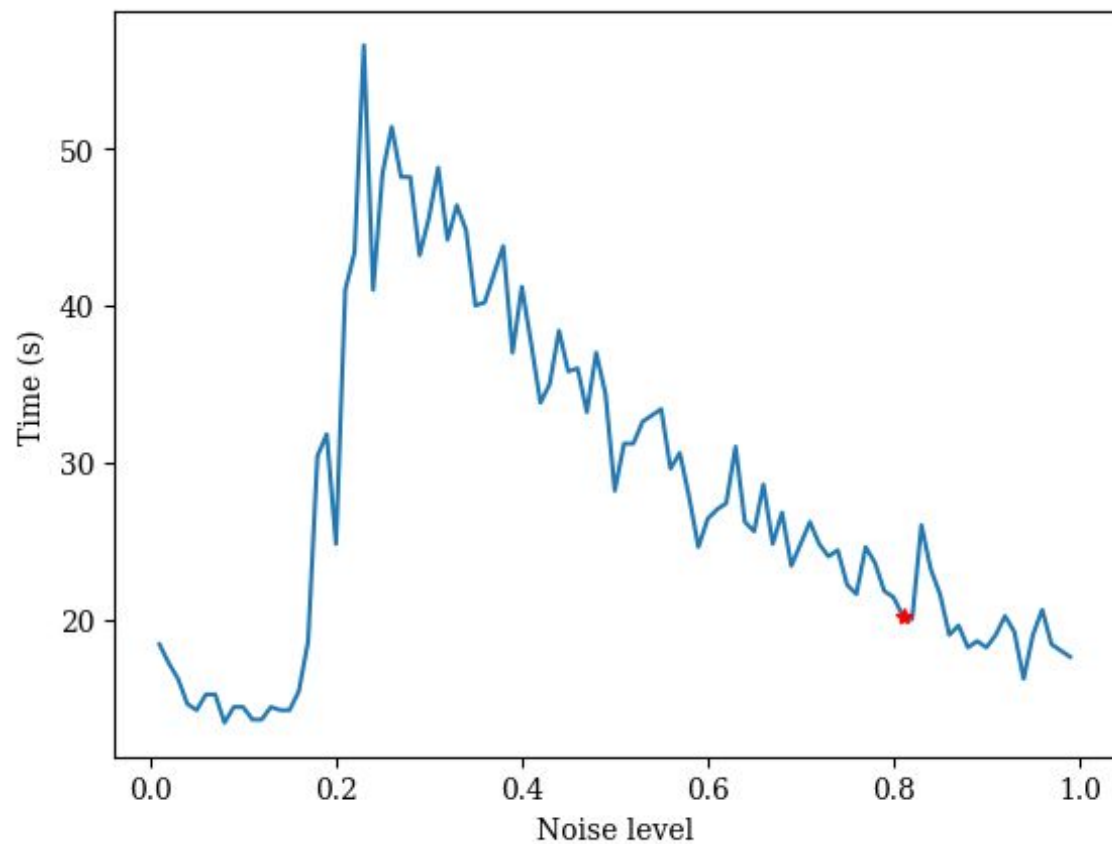
Results: time until forgetting

Results: case 1

Results: case 2

Results: case 3

Further Ideas

- Varying the Hebbian learning rate and making a 3D plot

- Changing the morphology of the synapse potential
  -> deeper wells
  -> wider wells

- …

Thanks for organising the Autumn School!

HAPPY NEUROWE'EN!!!