Dendritic Computation and Plasticity in Neuromorphic Circuits

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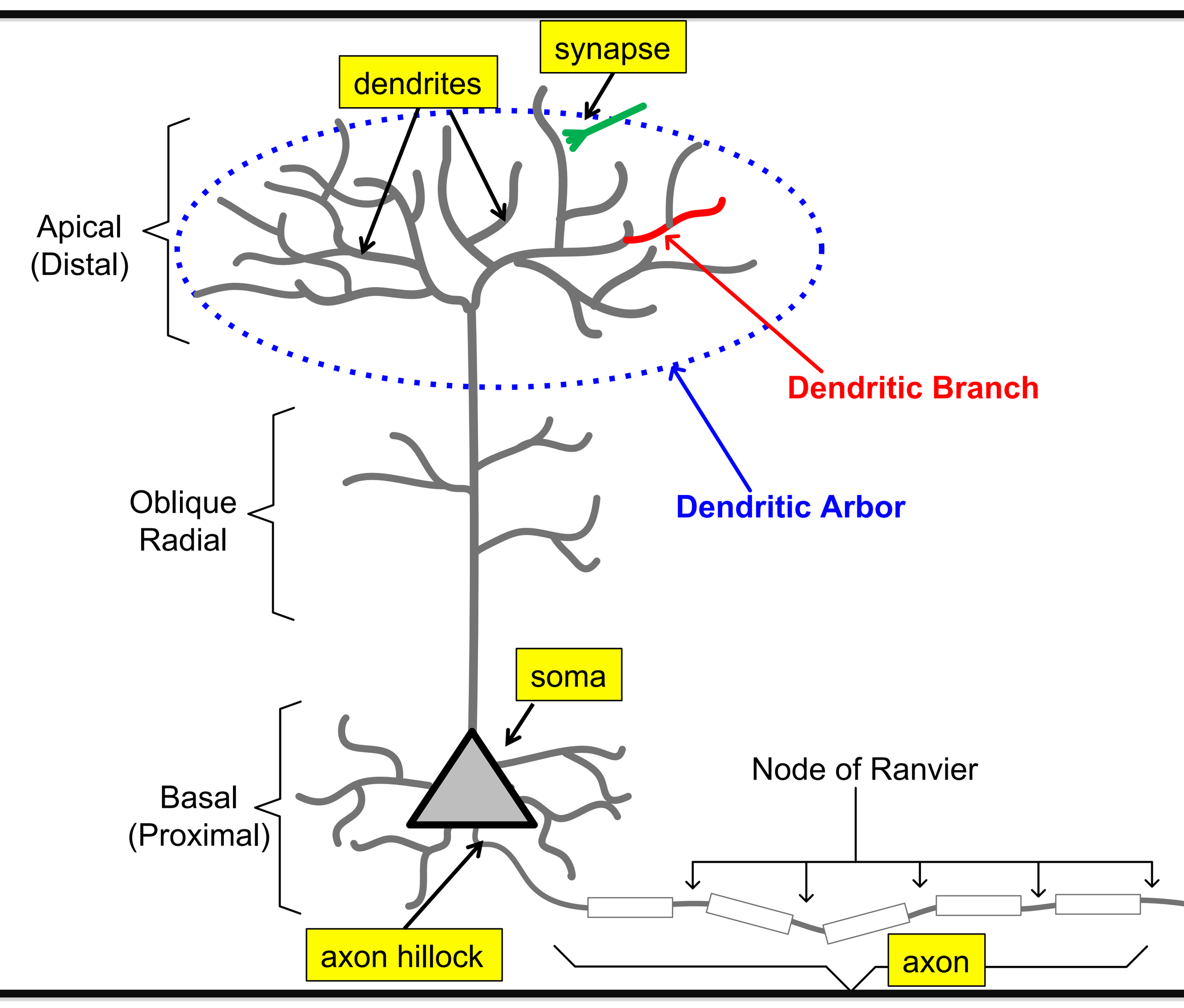
Motivation & Introduction

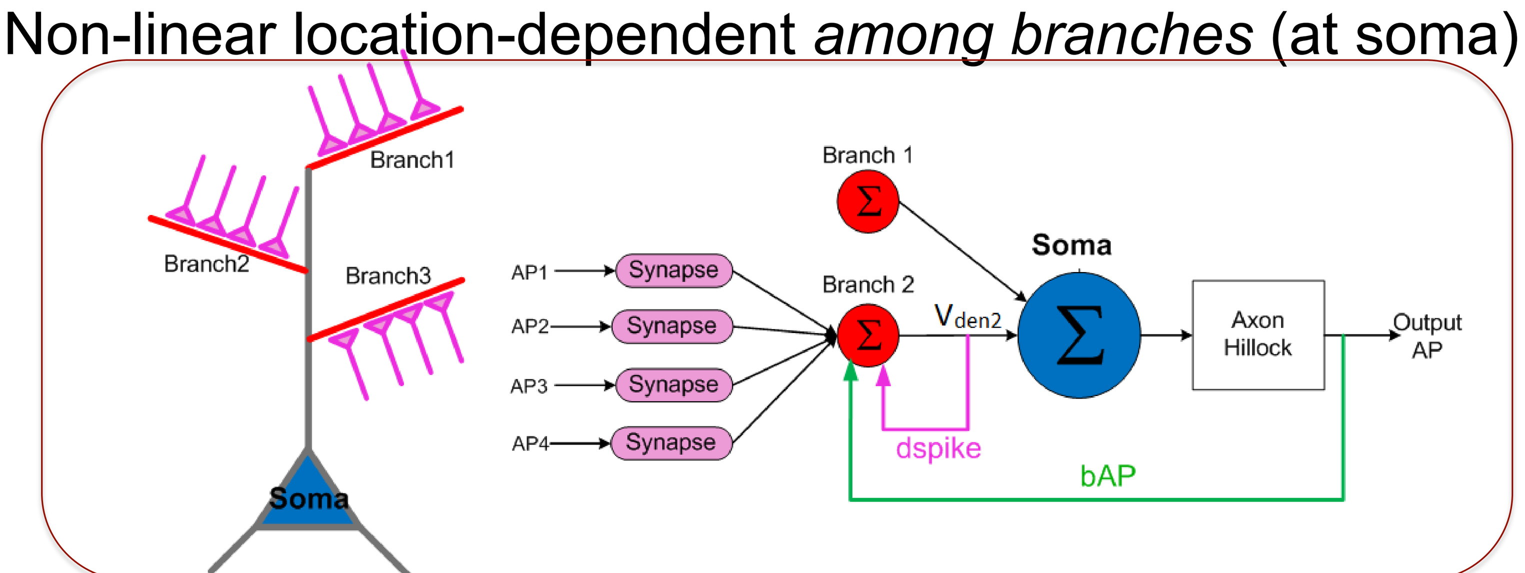
- ***Pyramidal neurons*** are principle neurons in the ***cortex*** where information processing, learning, and memory formation taking place in the ***brain***
- They have unique **dendritic structure** that contributes to complex computations
- It is essential to include these complex **intra-neuron computations** in neuromorphic circuits to mimic neural signaling, learning and memory formation
- These computations include **non-linear integration**, **spiking mechanism** and **plasticity**
  - Dendritic spikes are results of spatio-temporal clustered input activation
  - Dendritic spikes and action potentials can reset the dendritic excitability locally and globally respectively



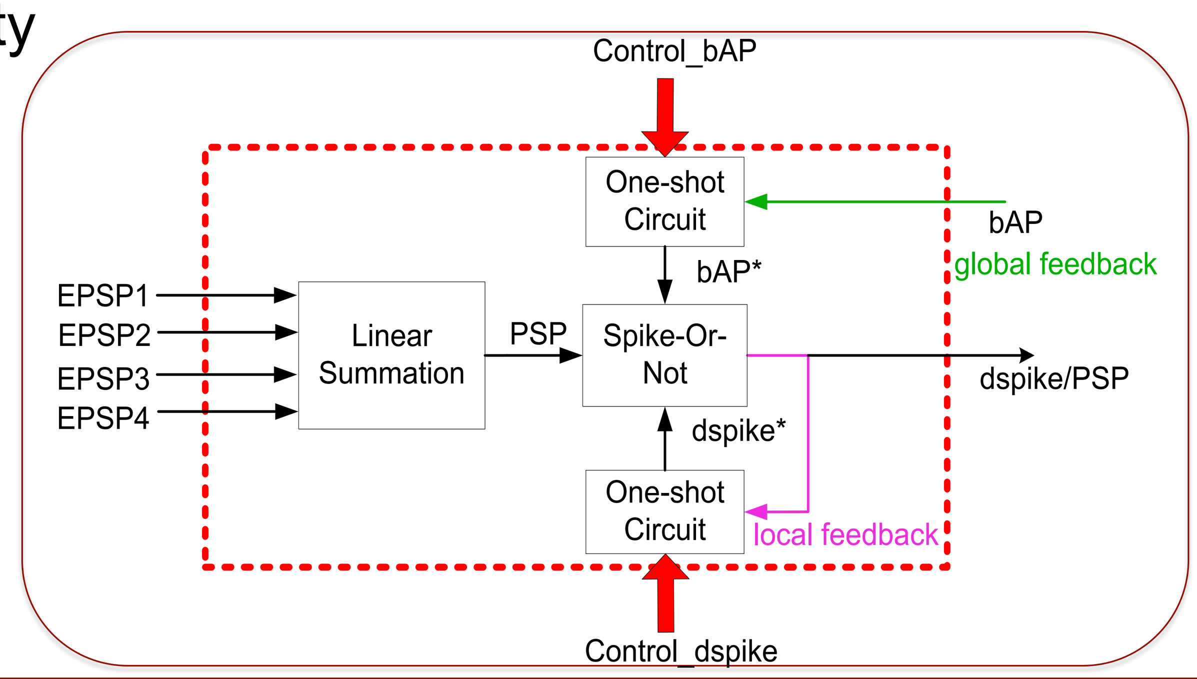
Neuron Module Setup

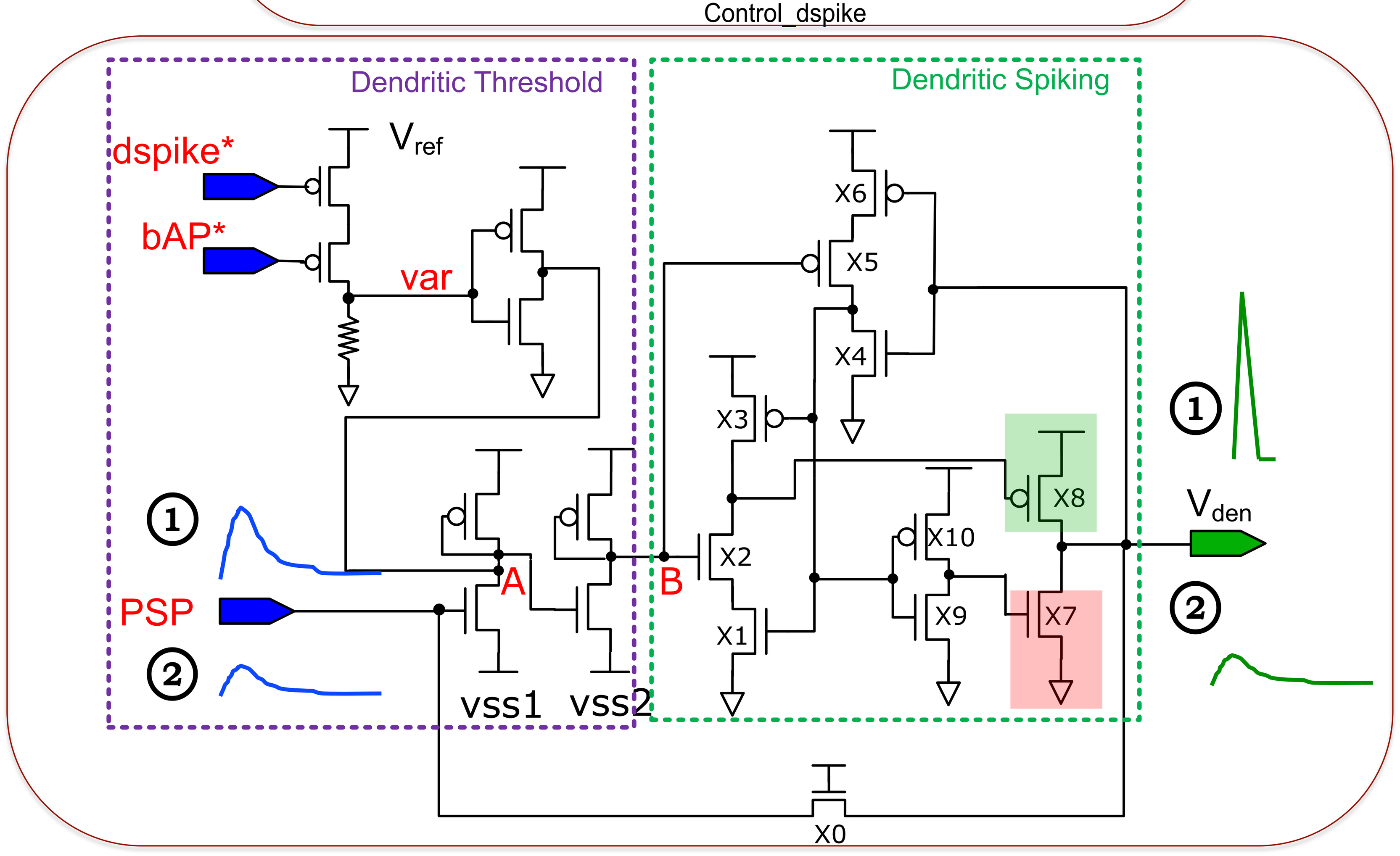
- Each neuron module has circuit components: synapses, dendritic branches, soma, and axon hillock
- Circuit designed using CNFET (carbon nanotube field-effect transistor) SPICE model
- Two-layer active dendritic arbor constructed:

1. Super-linear integration *within branch* (spiking mechanism)
2. Non-linear location-dependent *among branches* (at soma)



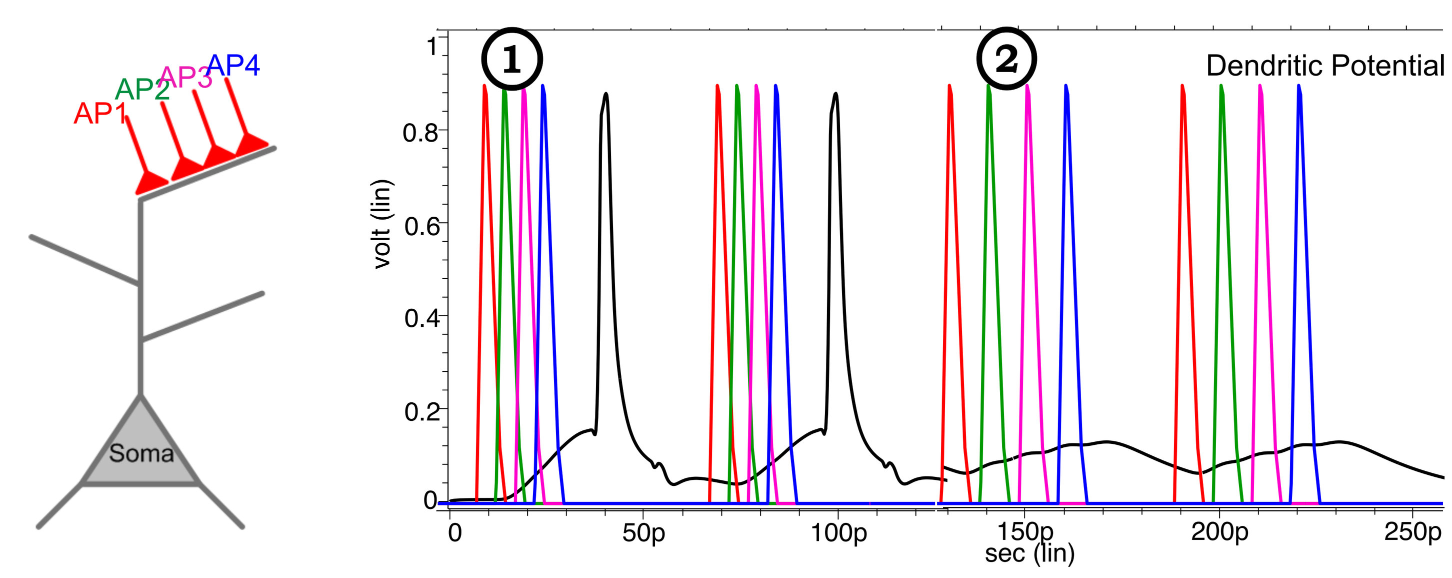
- Two feedback pathways control a short-term dendritic plasticity



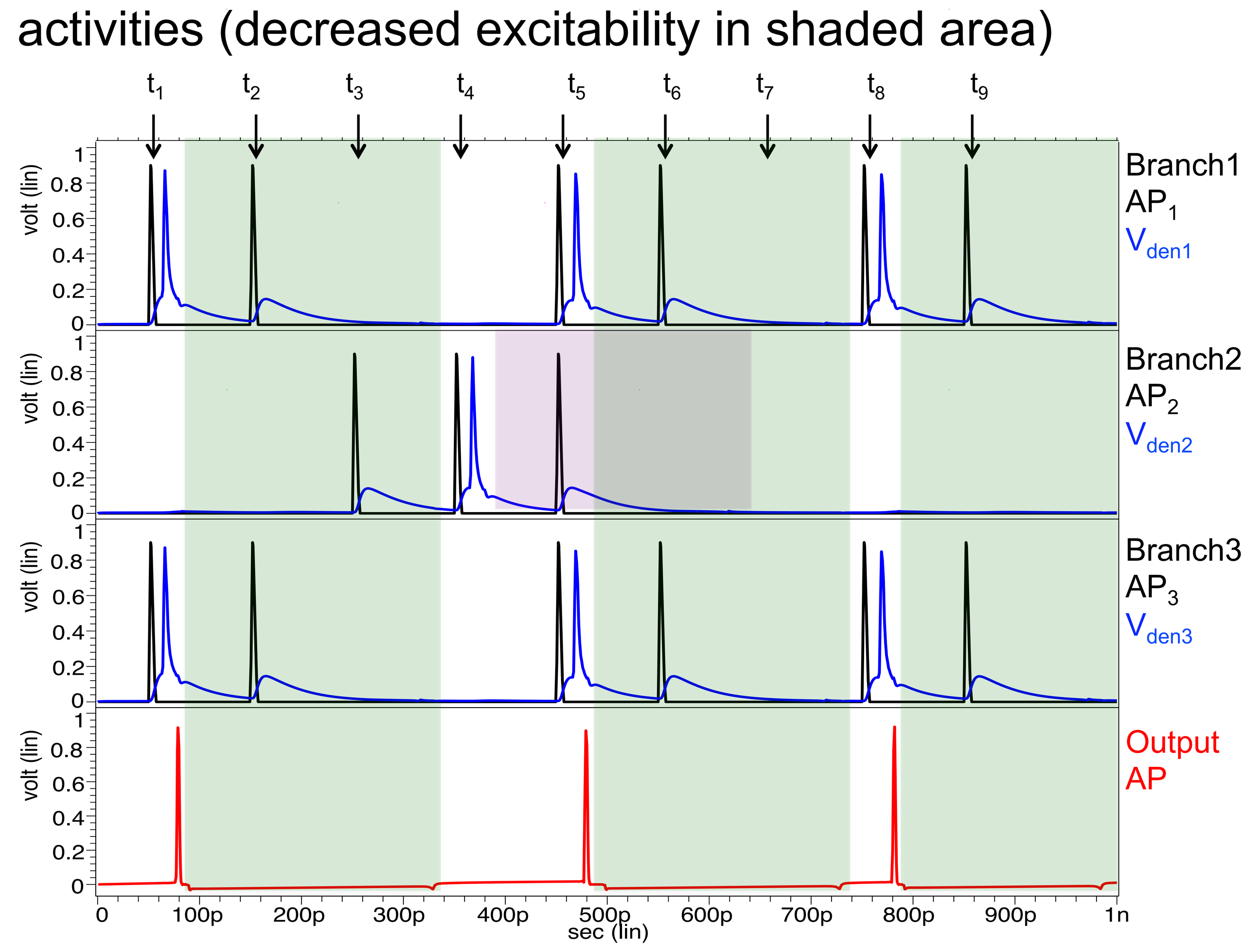


Simulation Results

- It requires both spatially- and temporally-clustered inputs in our prototype dendritic branch to initiate spikes



- Branch excitability suppressed by both local and global activities (decreased excitability in shaded area)



Discussion

- The global and local reset mechanism (short-term plasticity) imposes the limit on how fast the stored information can be retrieved
- The excitability of the dendrite can be up-regulated to emulate branch potentiation (long-term plasticity) which interacts with synaptic plasticity and makes the memory retention more robust