

**Barcoding of episodic memories in the hippocampus of a food-campus of a food-caching bird.** Chettih SN, Mackevicius EL, Hale S, Aronov D (2024). Cell. 187(8):1922–1935.e20. [Article](#)

### Re-interpretation based on the IPL mechanism

Hippocampal neurons in chickadees show patterns of activity of CA1 neurons that are specific to the locations of hidden food resulting from retrieval of specific memories but are independent of place fields (set of CA1 neurons that fire when the bird reaches a place) for the same locations. In other words, one set of CA1 neurons fire during memory retrieval associated with reaching a place and another set of CA1 neurons fire when the bird reaches a particular location. Authors call these different sets of CA1 neurons that fire as barcodes.

It was previously shown that place cells (hippocampal CA1 neurons) (O'Keefe and Dostrovsky, 1971) are also associated with different higher brain functions such as trajectory of motion (Frank et al., 2000); location and memory in different contexts (Pastalkova et al., 2008), reward (Gauthier and Tank, 2018), auditory frequency in cognitive maps (Aronov et al., 2017), and abstract learned variables (Schuck and Niv, 2019; Park et al., 2020). In humans, visual images led to firing of sparsely located hippocampal neurons among a larger population of non-responsive neurons (Waydo et al., 2006). Firing of different sets of sparse hippocampal pyramidal neurons during different brain functions necessitates a mechanistic explanation. There is a combinatorial mechanism operating at the input levels of these CA1 neurons. To arrive at this mechanism, it is possible to view the following.

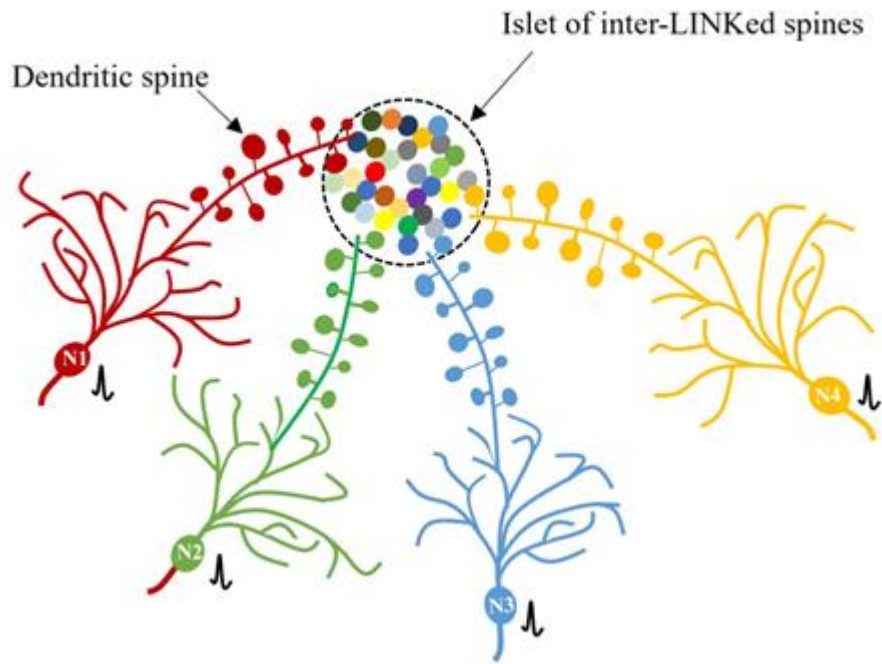
1. The different brain functions associated with separate operations operate at a lower level than the CA1 neurons – this can be at the synaptic levels between CA3 & CA1 &/or CA1 & CA3, &/or CA3 & granule neurons &/or CA3 & entorhinal neurons.
2. Since any set of nearly 140 input signals can fire a cortical pyramidal neuron, pyramidal neurons having thousands of input terminals can be

fired by a gigantic combination of input signals arriving through those input terminals (Palmer et al. 2014; Eyal et al., 2018).

3. Reaching a place is associated with first-person inner sensations of that place. Memory of food located in a specific place is associated with first-person inner sensation of food in a particular location.

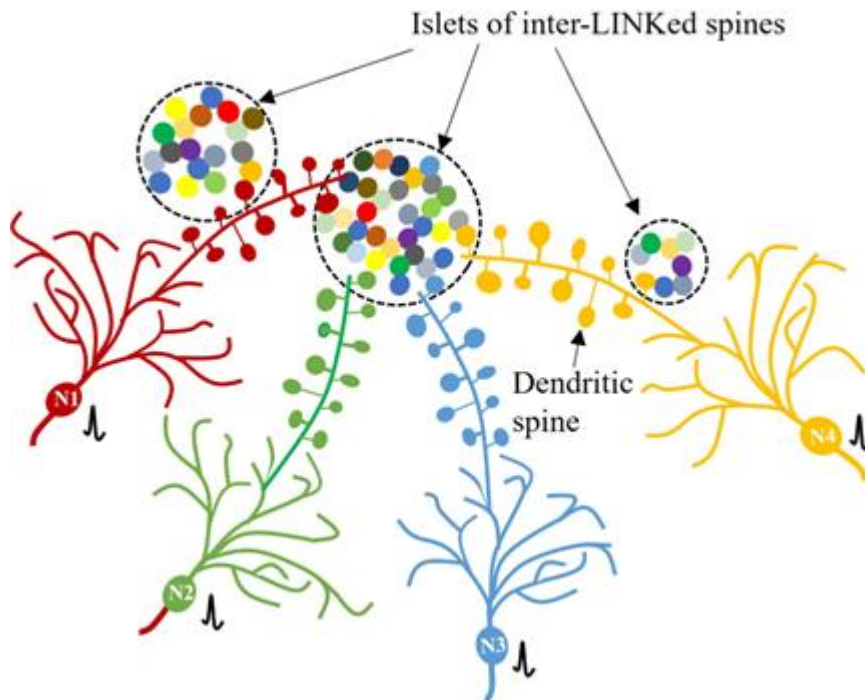
4. Firing of sets of sparsely located CA1 neurons indicates that specificity to any function is achieved by firing of certain CA1 neurons being held at subthreshold activation states.

These lead to the question, “What type of a mechanism occurring at the lower level, presumably at the input level of CA1 neurons that can generate both first-person inner sensations and firing of different sets of CA1 neurons?” Semblance hypothesis provides a solution to this. Semblance hypothesis describes an operational mechanism at the initial locations of the input terminals (see the FAQ section on the website). To summarize, according to the semblance hypothesis, learning generates inter-neuronal inter-spine LINKs between spines that belong to different neurons at the locations of convergence of pathways through which associatively learned stimuli propagate. Two inter-LINKed spines can inter-LINK with more spines of different neurons during additional associative learning events to form an islet of inter-LINKed spines (**Fig.1**).



**Figure 1.** One islet of inter-LINKed spines having 32 spines (dendritic spines) that belong to 32 different neurons are shown. Due to space limitations only neurons (N1, N2, N3 and N4) of 4 inter-LINKed spines are shown in the picture. Depending on the location of the inter-LINKed spine where the input signals from a cue stimulus arrive in an islet of inter-LINKed spine, its neighboring inter-LINKed spines will be depolarized. This also depends on whether the neighboring spines are receiving inhibitory inputs at the same time. Along with this, depolarization propagates from the inter-LINKed spines to their neurons. If the neuron is being held at sub-threshold activate level short of the potentials that are arriving, then the neuron will fire.

Note that spines of one neuron can be part of different islets of inter-LINKed spines (Fig.2). Chettih et al.,’s work (Chettih et al., 2024) shows that at the time of memory retrieval of a place or the location, different sets of neurons fire. According to semblance hypothesis, during different learning events, converging pathways of associated input signals from inter-LINKed spines. Different spines of a neuron can inter-LINK with spines that belong to different neurons. Since an inter-LINKed spine can inter-LINK with more than one spine, it leads to the formation of islets of inter-LINKed spines. When this continues, spines of a neuron will be part of different islets of inter-LINKed spines, which will give a picture shown in **Fig.2**.



**Figure 2.** Spines of a neuron are part of different islets of inter-LINKed spines. Here, three islets of inter-LINKed spines are shown. Note that one spine of the neuron N1 on the leftmost side is part of the leftmost islet of inter-LINKed spines (having 19 inter-LINKed spines). Also, another spine of the same neuron N1 is part of the middle islet of inter-LINKed spines (having 31 inter-LINKed spines). Similarly, neuron N4 has one spine as part of the middle islet of inter-LINKed spines. It also has another spine that is part of another inter-LINKed spines (with only 8 inter-LINKed spines). When a cue stimulus arrives at an inter-LINKed spine in an islet of inter-LINKed spines, then units of first-person inner sensations is expected to be generated. Along with this, potentials from the inter-LINKed spines reach their neurons. If addition of these potentials can allow the net potential to cross the threshold for firing an action potential, then that neuron fires.

According to the operational mechanism derived by the semblance hypothesis, first-person inner sensation of a memory of food or a place occurs at the inter-LINKed spines within the islets of inter-LINKed spines. Furthermore, firing of postsynaptic neurons depends on amount of depolarization arriving at these sub-threshold activated neurons. Based on these, findings in Chettih et al.,’s work (Chettih et al., 2024) can be explained in terms of specific sets of input signals arriving at different sets of islets of inter-LINKed spines leading to firing of

different sets of neurons that are being held at sub-threshold activation levels. Each higher brain function in which hippocampal CA1 neurons are involved, it leads to firing of different sets of neurons that in turn lead to the appearance of a barcoding of firing neurons.

## References

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