

Improvement of dendritic signal transfer due to non-uniform membrane property

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In hippocampus, CA1 pyramidal neurons receive two distinct synaptic inputs: autoassociative memory inputs from CA3 and sensory inputs from entorhinal cortex (EC) (Fig. 1A). In fact, these inputs are known to be separately received in dendrites (Fig. 1B); inputs from CA3 are given to proximal dendrite, whereas inputs from the EC are to distal dendrite. Understanding manner of signal propagation and integration in dendrites of CA1 pyramidal neurons is important since CA1 is first stage of hippocampal output to neocortex.

A previous simulation study by Jarsky et al. [1] suggested that signal transfer from distal dendrite to soma is difficult and additional inputs (from CA3) to proximal dendrite are needed for somatic firing. On the other hand, experimental study by Nakazawa et al. showed that CA1 neurons of CA3-NMDAR knockout mice respond normally [2], suggesting that CA1 neuron can induce somatic firing without strong inputs to its proximal dendrite. These results [1,2] may be conflicting about possibility of somatic firing only by distal inputs. In our previous studies [3], we estimated distribution of membrane resistance in dendrite of CA1 pyramidal neurons. The estimated result was a step function (Fig.2A bottom); there is a steep decrease of membrane resistance. The estimated non-uniformity may concern behavior of dendritic signal propagation.

In this study, we investigate effects of non-uniform membrane property on dendritic signal transfer and discuss the possibility of somatic firing only by distal inputs. Assuming the estimated non-uniform distribution of membrane property [3], we analyze cable equations and perform numerical simulation of compartment models to clarify functional role of non-uniform membrane property. By analysis of cable equation, we find that when we give inputs to distal dendrite, somatic responses obtained for non-uniform model of membrane resistance were significantly stronger than those for uniform model (Fig. 2). Furthermore, using compartment models with active channels, we find that dendritic spike propagation is also improved by non-uniformity, and somatic firing can be obtained even just with distal inputs for non-uniform model. This result implies that the signal can be propagated from distal dendrite to soma without CA3 input, and may support the experimental results by Nakazawa et al. [2]. Moreover, our results suggest that the steep decrease of membrane resistance in distal dendrite realizes dendritic signal transfer from distal dendrite to soma.

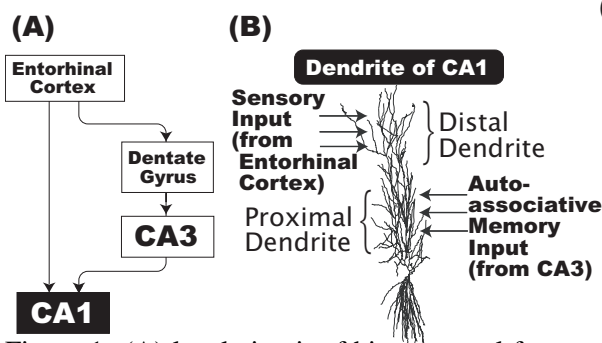


Figure 1: (A) local circuit of hippocampal formation; (B) dendrite of CA1 pyramidal neuron

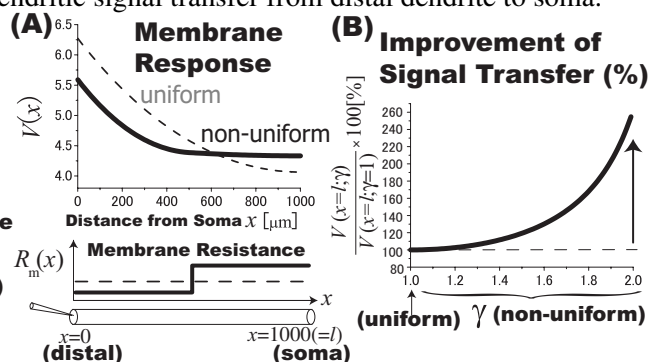


Figure 2: (A) membrane response to distal inputs; (B) improvement of dendritic signal transfer

References

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