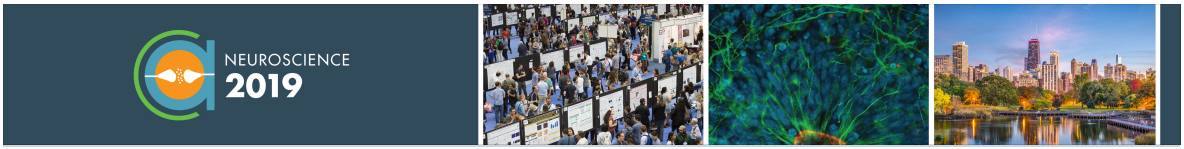

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Session 789 - Intrinsic Hippocampal Circuits: Spatial Navigation

Add to Itinerary

789.16 / BB43 - Robust emergence of sharply tuned place cell responses in hippocampal neurons with structural and biophysical heterogeneities

October 23, 2019, 1:00 PM - 5:00 PM | Hall A

Presenter at Poster
Wed, Oct. 23, 2019 4:00 PM - 5:00 PM

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Abstract
Place cells in the hippocampal CA1 region are endowed with complex dendritic arborization, exhibiting heterogeneity in structural features such as length, diameter and branching patterns. These neurons are electrotonically non-compact structures effectuating immense bidirectional attenuation to signal propagation, and are capable of sustaining the generation and active propagation of dendritic spikes. We recently showed that synapses that are randomly dispersed across the dendritic arbor of such neurons endowed with disparate ion channel distributions yield sharply tuned place cell responses through dendritic spike initiation [1]. Although our analyses had demonstrated that sharp place-cell tuning could emerge in the presence of expansive heterogeneities in synaptic and channel profiles, the impact of morphological heterogeneities on place-cell tuning has remained unexplored. In this study, we asked if sharply tuned place-cell responses mediated by dendritic spikes would emerge in different CA1 pyramidal neuron morphologies, each expressing heterogeneities in channel expression and synaptic localization as well. To do this, we performed independent stochastic searches of a 21-parameter space (covering passive and active properties involving 6 somato-dendritic channels) in 5 distinct morphologies, each endowed with randomly dispersed synapses (100 synapses carrying place-field information), and found models that manifested sharp place-field tuning. Next, we validated this subset of sharply-tuned models against 12 electrophysiological measurements (input resistance, resonance frequency, total inductive phase and backpropagating action potential amplitude at 3 locations each) from CA1 pyramidal neurons. This two-step validation process from stochastic searches spanning thousands of parametric combinations yielded several models that were both sharply tuned and intrinsically valid, independently for each of the five morphologies, with disparate profiles of synaptic localization and parametric combinations. Mechanistically, employing virtual knockouts of NMDA receptors or dendritic sodium channels, we found the initiation of dendritic spikes to be a critical contributor to sharpness of place-cell responses in all morphologies. From the functional standpoint of achieving sharply-tuned feature encoding and concomitantly maintaining homeostasis of intrinsic excitability, our results point to ion channel degeneracy and suggest neuronal morphology to be a "sloppy" parameter even in electrotonically non-compact structures.
1. Basak R. and Narayanan R., J. Physiol., 2018 (http://dx.doi.org/10.1113/JP275310)

Abstract Citation