DATA-DRIVEN, BIOLOGICALLY CONSTRAINED COMPUTATIONAL MODELS OF HIPPOCAMPAL NEURONAL NETWORKS AT SCALE

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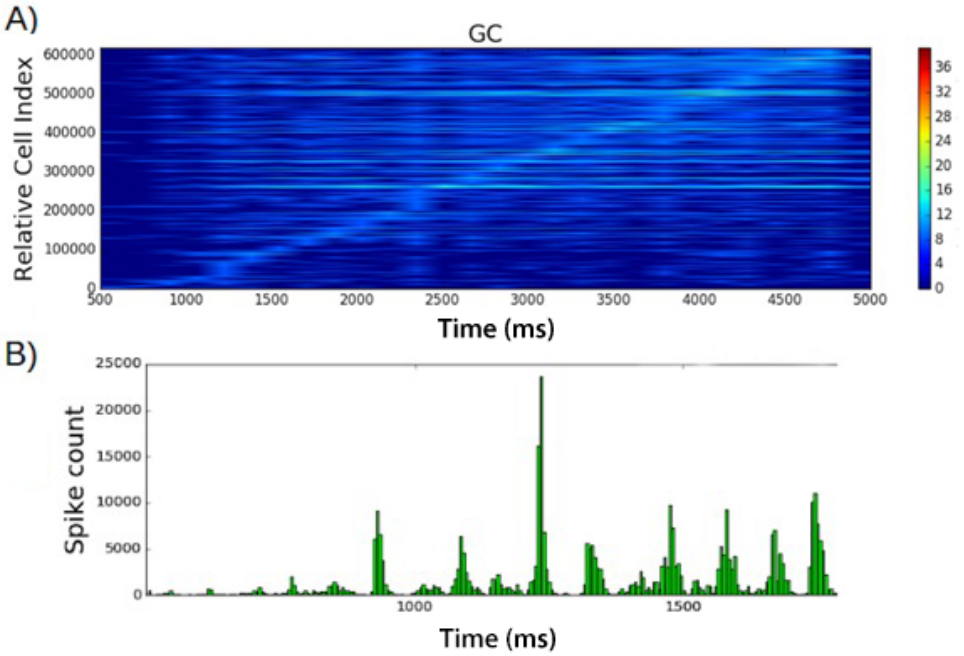
Research Challenge

Elucidating the mechanisms of sharp-wave ripples (SWRs), which are oscillatory events in the hippocampus required for consolidation of spatial and episodic memories. We are constructing large-scale, biophysically detailed computational models of the neural circuits that comprise the mammalian hippocampus. These models will help provide insight into the neural circuit mechanisms of sparse and selective memory representations, and oscillatory neuronal population dynamics.

Methods

- NEURON as the principal simulation environment, implemented in Python.
- Morphologically and biophysically detailed cell models of diverse cell types.
- High performance parallel computing tools for data I/O, specification, simulation, and analysis of large-scale network models containing > 1 million neurons running on up to 32,000 computer processors.
- New optimization algorithm, "population annealing," a parallelized multi-objective version of simulated annealing to efficiently tune large-scale network models to match experimental data.



(A) Activity of model hippocampal dentate granule cells during simulated spatial navigation, ordered by location of peak firing rate. (B) Rhythmic population activity of the major cell types in the network model.

Results and Impact

The hippocampal neural circuits involved in spatial memory storage and recall are comprised of numerous diverse cell types. Connections between cell types are highly selective, and each cell type exhibits distinct dynamics and selectivity. Large-scale models that contain the same elements that can be measured and perturbed in experimental systems can be used to explore candidate mechanisms, generate hypotheses, and inform the design and interpretation of experimental manipulations.

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