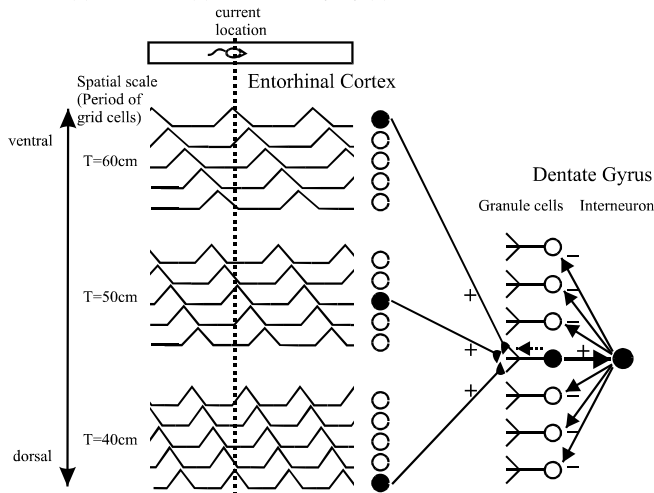


How Do Small Cells Code Large Spaces? From Entorhinal Grid Cell to Hippocampal Place Cell

Recent discovery of entorhinal grid cells raised a question how their small-scale periodic firing can lead to representation of large spaces via hippocampal place cells. Anatoli Gorchetchnikov and Stephen Grossberg of the NSF Center of Excellence for Learning in Education, Science, and Technology developed a model that explains how projections from several different spatial scales of the entorhinal grid cells can undergo self-organization and create a representation of space that spans many meters. The approach of the model is similar to the previously developed *spectral timing model* (Grossberg and Merrill, 1992, *Cognitive Brain Research*, 1). that proposed how a spectrum of cells tuned to brief but different delays are combined and modulated by learning to create a population code for controlling goal-oriented timed behaviors that span hundreds of milliseconds or even seconds. Furthermore, the new model proposes that hippocampal spatial and temporal processing (spectral spacing and timing) are carried out by parallel circuits within entorhinal cortex, dentate gyrus (DG), and CA3 that are variations of the same circuit design. In particular, interactions between these brain regions transform fine spatial and temporal scales into population codes that are capable of representing the much larger spatial and temporal scales that are needed to control adaptive behaviors. The suggested homology between spatial and temporal processing may clarify how spatial and temporal information are integrated into an episodic memory.

In the model, as in the data, entorhinal grid cell activity for each spatial scale is a periodic process (Figure 1). The only difference between the scales is the period of this activity, and therefore, of the inputs to DG. Thus DG cells add several periodic processes

$$a_1x_1(t) + a_2x_2(t) + \dots + a_nx_n(t)$$



through synaptic integration. The period of the resulting process is equal to their *least common multiple*. As a result, the total space that can be covered by unique input combinations, and therefore unique representations, within a transversal DG slice is predicted to have the size of the least common multiple of the incoming grid periods.

Figure. Model for place cell learning involves three populations of entorhinal grid cells with different spatial scales that are aligned along the dorso-ventral gradient in entorhinal cortex. Their firing profiles are represented as peaks of activity. The current location of the animal causes the corresponding grid cells to fire (filled circles). A dentate gyrus granule cell that receives strong projections from all three active grid cells fires (filled circle) and suppresses other granule cells. Back-propagating action potentials from this granule cell (dotted arrow) trigger learning within the pathways from the active entorhinal grid cells. For clarity, only currently active projections are shown.