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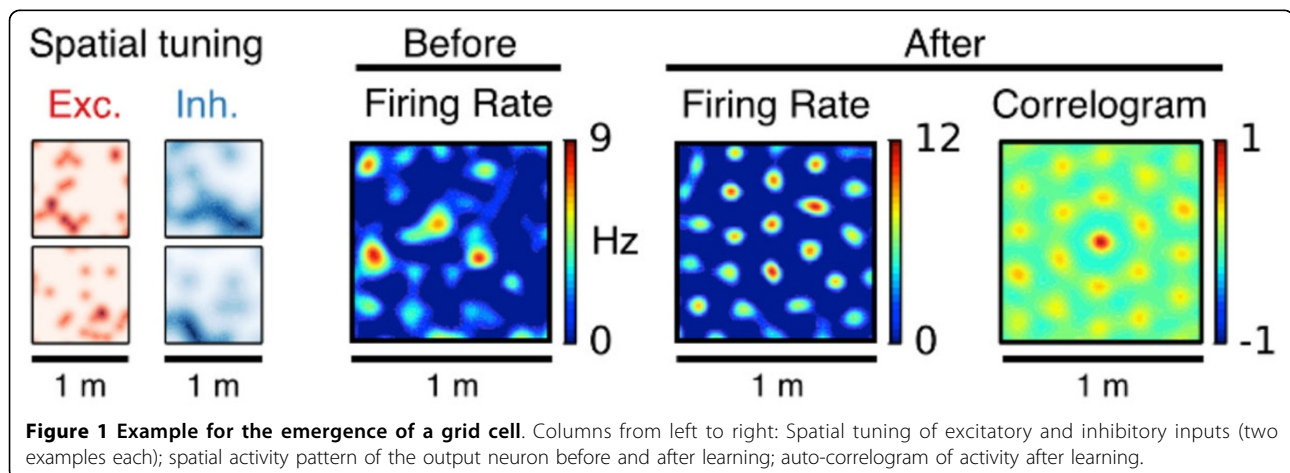
# A model for spatially periodic firing in the hippocampal formation based on interacting excitatory and inhibitory plasticity

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Neurons in the hippocampal formation exhibit a variety of spatially tuned firing patterns. The mechanisms by which these different patterns emerge are not fully resolved, although competing computational models exist for several of them. Here we present a new model that can generate all observed spatial firing patterns by a single mechanism. The model consists of a feedforward network with a single output neuron. Its essential ingredients are i) spatially tuned excitatory and inhibitory inputs [e.g., 1] and ii) interacting excitatory and inhibitory Hebbian plasticity. The inhibitory plasticity homeostatically controls the output firing rate by balancing excitation and inhibition [2]. We show in simulations and by a mathematical analysis that the output neuron

develops periodic firing patterns along a stimulus dimension if inhibitory inputs are more broadly tuned than excitatory inputs along this dimension. More generally, depending on the relative spatial auto-correlation length of the excitatory and inhibitory inputs, the model exhibits firing patterns that are similar to those of place cells, grid cells (see Figure 1) or band cells (neurons that fire on spatially periodic bands [3]). For inputs with combined spatial and head direction tuning, the same mechanism leads to output firing patterns reminiscent of head direction cells and conjunctive cells (neurons that fire like grid cells in space but only at a particular head direction). A linear stability analysis of the homogeneous steady state accurately predicts the spatial



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periodicity obtained from simulations. The model combines the robust pattern formation of attractor models [e.g., 4], with the spatial (rather than neural) structure formation of models based on synaptic plasticity [5]. In contrast to attractor models [6], our model predicts that the grid spacing should be robust to global modifications in inhibitory synaptic strength, a distinction which could be experimentally verified.

In conclusion, we propose a feedforward network model that generates all known spatial firing patterns in the hippocampal formation through a single self-organizing mechanism.

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