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A Reaction-Diffusion Model for Synapse Growth and Long-Term Memory[1] KANG LIU, JOHN LISMAN, MICHAEL HAGAN, Brandeis University — Memory storage involves strengthening of synaptic transmission known as long-term potentiation (LTP). The late phase of LTP is associated with structural processes that enlarge the synapse. Yet, synapses must be stable, despite continual subunit turnover, over the lifetime of an encoded memory. These considerations suggest that synapses are variable-size stable structure (VSSS), meaning they can switch between multiple metastable structures with different sizes. The mechanisms underlying VSSS are poorly understood. While experiments and theory have suggested that the interplay between diffusion and receptor-scaffold interactions can lead to a preferred stable size for synaptic domains, such a mechanism cannot explain how synapses adopt widely different sizes. Here we develop a minimal reaction-diffusion model of VSSS for synapse growth, incorporating the recent observation from super-resolution microscopy that neural activity can build compositional heterogeneities within synaptic domains. We find that introducing such heterogeneities can change the stable domain size in a controlled manner. We discuss a potential connection between this model and experimental data on synapse sizes, and how it provides a possible mechanism to structurally encode graded long-term memory.

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