Energy minimization as an organizing principle for neural proteins

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Abstract

Dendritic spines carry thousands of synaptic spines and every spine harbours hundreds of protein species. Hereby, the necessary number of proteins must be maintained at all spines and times to keep synaptic homeostasis and to provide the molecular basis for synaptic plasticity. At the same time, the task to distribute molecules with limited lifespans along the widespread and complex dendritic morphologies is highly demanding. Today, it is not clear which rules determine how neurons approach this task. Here, we provide theoretical and experimental evidence showing that energy minimisation is a strong candidate for such a rule. To this end we use a diffusion reaction model to simulate the distribution of mRNAs and proteins at the soma, dendrites and spines. Our model allows us to calculate neuronal mRNA and protein numbers and to predict which mRNA species are more likely to localize in dendrites based on energetic efficiency. Our model predictions are supported by the experimentally measured neuronal translatomes and proteomes comprising tens of thousands of molecular species.