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Stochastic model of CPEB3 oligomerization for synaptic facilitation and LTM formation

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CPEB3 is a mammalian prion-like protein of the CPEB family, which has been shown to mediate local protein synthesis in the synaptic facilitation
and Long Term Memory (LTM) formation both in vitro and in vivo.
Moreover, it has been observed that SUMOYlayion of CPEB3 regulates its oligomerization and activity. In the basal state, SUMOylated CPEB3
is the most abundant among CPEB3 forms, while deSUMOylation occurs when there is a synaptic activity.
From these information we built a simple stochastic model for LTM formation under external stimulus, assuming that CPEB3 oligomers represent the active form of the protein.
Our model considers a closed three-state chemical process, named SC (SUMOy-lated CPEB3 monomers),C_deol (pure CPEB3 monomers) and C_ol (oligomerized CPEB3 monomers). A synapse with no LTM will have mainly SC monomers, whilst the presence of LTM is correlated with a relevant number of oligomerized (C_ol) monomers. The transition from one state to another is regulated by the presence of an external stimulus, which increases of several orders of magnitude the transition probability from state SC to C_deol.
The fluctuations are relevant due to the small number of protein involved at synaptic scale.
We discuss the dynamics of this system analyzing the Laplacian Matrix properties of the Master Equation.
Since oligomers tend to aggregate more easily in presence an aggregation seed, we model the nonlinear character of the transition rates from C_deol to C_ol by an exponential law depending on a threshold parameter n_th, which represents the dimension of the aggregation seed. According to empirical observations, We consider a small number of total Monomers (form 8 to 15) and search for bistability behavior and transitions from an initial state SC and C_deol, as n_th varies in presence of an eternal stimulus.

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