Modeling Plasticity: from Single Cell Axonal Trafficking to Neural Networks

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The role of individual neurons in neural plasticity is affected by both its underlying compartmentalized infrastructure of axons and dendrites as well as by communication between neurons and neural regulating cells. We present two models to address plasticity from alternate perspectives. Mathematically neuron axon structure has largely been ignored in terms of its nano to microscale components that impact macroscale outcomes. The first model demonstrates the ability of integrated roles of the axonal microtubule network and trafficking to internally define a neuronal 'barcode'. This model establishes a mechanism by which individual neurons of a given type have expanded diversity and opportunity for functional plasticity. We apply a totally asymmetric simple exclusion process (TASEP) and Langmuir kinetics combined modified model to track equilibrium and non-equilibrium dynamics of kinesin motors on the staggered infrastructure of the axonal microtubule network and partial differential equations for the motor density profile. The second model presents a neural network simulation for the transfer of impulses between the post-synaptic and pre-synaptic compartments for digital implementation. For calcium dynamics we consider the lipophilic retrograde signaling model. The Hebbian learning rule for synaptic plasticity is used including the antisymmetry Tsodyks and Markram proposed form where the time interval of potentiation and depression are comparably similar. The model reproduces relevant biological behaviors with more limited but appropriate feedback control. The system architectures and simulation outcomes are presented for both models.