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Mathematical Modeling of Multi-Species Motor-Cargo Transport

Intracellular transport of cargo, including macromolecules, vesicles and organelles, through the attachment to microtubules via molecular motors, such as kinesin and dynein, is a complex process that plays a significant role in neuronal function. Disruption of this transport has been linked to neurodegenerative diseases, such as Alzheimer's and Parkinson's diseases. Thus, studying the interactions among different types of cargo and molecular motors can lead to a better understanding of the complicated processes involved during intracellular transport.

Here, we will present a mathematical model based on traffic-like partial differential equations to describe coupled motor-cargo transport within the squid giant axon when two different types of cargo are present, competing for motors. Using parameters in the mathematical model that can be directly obtained from experimental measurements within the squid giant axon allows for predictions of the behavior of the cargo to be compared to and validated with experimental outcomes. When there is an excess of motors present, an analytical solution of the governing equations can be obtained, and in the long time limit agrees with the experimental results. However, when motors are scarce, the cargo transport is nonlinearly coupled. As a first step towards understanding this phenomenon, we analyze experiments in which the C-terminus of amyloid precursor protein (APP-C) is co-injected with APP-C coated nano-beads in the squid giant axon leading to competition for motors.