WORKSHOP
Mathematical Neuroscience
September 16 – 19, 2007

Control of synchrony by distal dendritic gap junctions

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Abstract

Gap junctions allow direct electrical communication between neurons. From theoretical and modeling studies it is well-known that although gap junctions can act to synchronize network output, they can also give rise to many other dynamic patterns including antiphase and other phase-locked states. The particular network pattern that arises depends on cellular, intrinsic properties which affect firing frequencies, as well as the strength and location of the gap junctions. Interneurons or GABAergic neurons in hippocampus are diverse in their cellular characteristics, and have been shown to have active dendrites. Furthermore, parvalbumin-positive GABAergic neurons, also known as basket cells, often contact one another via gap junctions on their distal dendrites. Using compartmental representations for the individual cells, we perform simulations of two-cell network models to explore how distal electrical connections affect network output, and we apply weakly coupled oscillator theory to reduced model versions to understand and predict their network dynamics. Our work suggests that distally located gap junctions not only significantly expand the range of phase-locking properties of these networks in general, but can also function to decrease network synchrony with increases in gap junction coupling strengths. This occurs if the individual cells have particular intrinsic properties that can be revealed from characteristics in their phase response curves.