Modeling the output of a central pattern generator

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Experimental analysis in our lab has provided a quantitative description of the spatiotemporal pattern of inhibitory synaptic input from the heartbeat central pattern generator (CPG) to segmental motor neurons that drive heartbeat in the medicinal leech. To begin the process of elucidating the relative roles of this pattern of input and motor neuron intrinsic properties and electrical coupling in the elaboration of the heartbeat fictive motor pattern, we constructed a conductance-based ensemble model of all the segmental heart motor neurons and their known synaptic inputs. Our focus was intersegmental and side-to-side coordination of the asymmetric motor pattern: motor neurons on one side fire nearly in synchrony (synchronous coordination), while on the other they fire in a rear-to-front progression (peristaltic coordination). The model reproduces the general trends of the two intersegmental phase relations among motor neurons, but the match with the living system is quantitatively poor, particularly for the peristaltic coordination mode where the phase progression among the segmental motor neurons in the model is only half that observed in the living system. Thus the realistic inputs (experimentally determined) do not produce similarly realistic output in our model.

Modeling experiments, indicate that the most important determinant of the intersegmental and side-to-side phase relations among the heart motor neurons in the model was the spatiotemporal pattern of synaptic inputs, yet phasing was influenced by electrical coupling between the motor neurons in each segment, intersegmental conduction delays in the premotor interneurons, intra-burst synaptic plasticity, and intrinsic membrane currents of the motor neurons.

Understanding the shortcomings of the model required that we establish experimentally the precise timing of motor neuron activity in each segment with respect to CPG activity. This analysis show quantitatively how motor neurons in the model fail to fire at the appropriate time with respect to their synaptic inputs and suggest that the intrinsic properties of the model motor neuron are simplistic.