A natural example of different circuit architectures for analogous behaviors in different species

Akira Sakurai and Paul S. Katz
Neuroscience Institute, Georgia State University

Recent modeling studies have shown that neuronal circuits with considerably different membrane and synaptic parameters might produce relatively similar network outputs. However, there is still a general assumption that similar behaviors in related animal species originate from a common neural architecture. In this study, we show that two species produce similar behaviors using homologous neurons connected in circuits having distinct architectures and dynamics.

The nudibranch molluscs *Melibe leonina* and *Dendronotus iris* exhibit swimming behaviors consisting of rhythmic left-right body flexions. It was previously shown in *Melibe* that the central pattern generator (CPG) for swimming consists of two bilaterally symmetric neurons, Swim Interneuron 1 ($Si1_{Mel}$) and Swim Interneuron 2 ($Si2_{Mel}$). $Si1_{Mel}$ and $Si2_{Mel}$ are electrically coupled ipsilaterally and mutually inhibitory with both contralateral counterparts. Their homologues ($Si1_{Den}$ and $Si2_{Den}$) have been identified in *Dendronotus* but their synaptic connections are fundamentally different. The $Si1_{Den}$ neurons do not form mutual inhibitory synapses but are electrically coupled to all other swim interneurons. $Si1_{Den}$ does not function as the member of the swim CPG; rather its tonic firing initiates and accelerates the swim motor program.

In addition to Si1 and Si2, we recently found an additional bilateral pair of neurons, Si3, in both species. The Si3 pair forms another half-center oscillator element that is interconnected with the Si1/2 complex. In *Melibe*, $Si3_{Mel}$ receives excitatory input from the ipsilateral $Si1_{Mel}$, and makes inhibitory synapses onto the contralateral $Si1_{Mel}$. This causes $Si3_{Mel}$ bursts to be approximately 25% phase delayed from the contralateral Si1/2 bursts. Injecting hyperpolarization current into $Si3_{Mel}$ slowed down but did not stop the rhythm, suggesting that $Si3_{Mel}$ plays an important role in pattern generation, but is not critically necessary for rhythm generation. In contrast, in *Dendronotus*, each $Si3_{Den}$ drives the contralateral $Si2_{Den}$ via strong electrical and chemical excitatory synapses, making the $Si3_{Den}$ burst slightly phase-advanced to the contralateral $Si2_{Den}$ burst. A hyperpolarizing current injection into $Si3_{Den}$ suppressed the rhythm, suggesting their critical role in the rhythm generation. Thus, despite having homologous neurons producing similar two-phase motor outputs, there are substantial differences in network architecture, phase relationships, and internal dynamics between these two CPGs.

Supported by NSF- IOS-1120950, 0814411