Stomatogastric and Cardiac Ganglionic Sheaths as a Means of Passive Control of Neuromodulation in the Lobster, Homarus americanus

Rhythmic motor movements, which are controlled by hard-wired neuronal networks, must be flexible in order to respond to environmental changes. Neuropeptides, which can either be released locally within the nervous system or hormonally from endocrine-secreting organs, provide one source of this flexibility. In the American lobster, Homarus americanus, neuropeptides have been shown to elicit effects on both the stomatogastric ganglion (STG) and the cardiac ganglion (CG). In order for the hormonally released neuropeptides to be able to access the ganglia, though, they must permeate the connective tissue sheaths encasing these ganglia. However, little is known about what function these sheaths serve, especially in relation to neuromodulation.

Previous research in the Dickinson lab has demonstrated that the STG sheath is selectively permeable to different neuropeptides found in vivo in the lobster; red pigment concentrating hormone could permeate the sheath whereas Cancer borealis tachykinin-related peptide Ia could not pass through the sheath as efficiently. Because size and hydrophobicity were implicated in determining this selective permeability, the first goal of this project was to elucidate whether larger and more hydrophilic peptides could permeate the sheath at all. Two hydrophilic peptides, GYS (GYSDRNYLRFamide) and calcitonin-like diuretic hormone (CLDH; GLDLGLGRGFSGQAAKHLMGLAAANFAGGPamide), were superfused at a range of concentrations over the STG while the pyloric pattern was recorded extracellularly. The threshold concentration for activation and the intensity of activation for each peptide were compared with the sheath intact and after its removal. For both GYS and CLDH, the peptides had similar thresholds of activation in the sheathed and desheathed conditions but the levels of excitation in these two conditions at a given concentration were significantly different. Thus, it appeared that the STG sheath did serve as a substantial barrier to the permeation of large, hydrophilic peptides like GYS and CLDH.

To further understand the effects that CLDH has on the STG, as its bioactivity in the STG and the CG have not been previously characterized, we examined the effects of CLDH in both nervous systems. Data collected from the STG suggest that CLDH can either increase the burst frequency of the pyloric system or induce tonic firing in the PD and/or LPG neurons of the pyloric system. Further analysis will be performed to elucidate how CLDH is eliciting this dichotomous effect. In the CG, however, CLDH induces a very regular increase in burst frequency and decrease in the number of spikes per burst. In addition to examining the bioactivity of this peptide, we also investigated whether CLDH is localized in the nervous tissue and endocrine-secreting organs via immunohistochemistry. The peptide was found in the STG and commissural ganglia of the stomatogastric nervous system, the cardiac ganglion, and the eyestalk but not in the two primary endocrine-secreting glands, the sinus gland and the pericardial organs. These results suggest that CLDH can only be released locally within the nervous systems to effect the aforementioned changes in the STG and the CG, and thus its ability to permeate the STG and CG sheaths might not be physiologically relevant.

Given that both GYS and CLDH had difficulty permeating the STG sheath, the third goal was to determine whether the CG sheath also might serve as a passive barrier to neuromodulation via these two peptides. Using methods almost identical to those in STG electrophysiology, both GYS and CLDH appeared to be able to permeate the CG sheath with relative ease. For both peptides, the threshold of activation and the extent of excitation at each concentration was the same in both the sheathed and desheathed conditions. These results corroborate previous electron microscopy of the ultrastructure of the STG and CG sheaths, which suggested that the CG sheath contains lacunae and sinuses that the STG sheath did not. Consequently, these potential hemolymph channels might allow for larger, hydrophilic peptides like GYS and CLDH to permeate the CG sheath but not the STG sheath.