Effects of two related amines, octopamine and tyramine, on the heartbeat of *Homarus americanus,* the American lobster

Anthony Yanez, Class of 2022

Central pattern generators, or CPGs, are neural circuits that control rhythmic behaviors. These rhythmic behaviors are essential to life—think walking, running, and breathing. All organisms, humans and mollusks included, rely on these behaviors to survive. It follows that CPGs must be both robust and flexible. They must be able to adapt their output to respond to environmental stresses and physiological demands.

The lobster cardiac system, which is controlled by a simple CPG, provides a good model circuit for study. The cardiac ganglion, or CG, is a simple neural circuit of 9 neurons found in the lobster heart. The lobster heart is neurogenic; it relies on bursts from the CG to contract regularly (Cooke, 2002). To modulate the action of the heart, the lobster relies on various neuromodulators. Among the neuromodulators used are octopamine and tyramine.

Octopamine and tyramine are monoamines that are central neurotransmitters in invertebrates. They have been widely studied in insects. In *Drosophila melanogaster*, many varieties of octopamine and tyramine receptors are expressed in muscle and in the nervous system (Pauls, Blechschmidt, Frantzmann, el Jundi, & Selcho, 2018). Some accept tyramine only, some octopamine only, and one, the octopamine/tyramine receptor, accepts both. Where these receptors are located, and how they are expressed relative to one another in a system, is key to understanding how these amines modulate said system. Recent analysis by a collaborator has shown that some octopamine specific receptors and an octopamine/tyramine receptor are expressed in the CG. The CG also expresses the gene that encodes for the enzyme that synthesizes tyramine and octopamine, suggesting local release of amines. Since it is already known that these amines affect lobster heart output, and we see expression of an octopamine/tyramine receptor, we predicted that the presence of both at the same time would have additive or nonlinear effects.

This summer we tested this prediction by experimenting primarily on whole lobster hearts. We recorded heartbeat contraction amplitude and frequency, first recording with a control solution then with an amine solution. We then compared percent change in contraction amplitude and frequency. We used three different amine conditions: octopamine alone at 10^{-6} M and 10^{-5} M, tyramine alone at 10^{-6} M and 10^{-5} M, and a mix of octopamine and tyramine, each at 10^{-6} M and 10^{-5} M.

We found that our prediction was incorrect. There was no significant difference between the effects of octopamine alone and those of the octopamine and tyramine mix, at any concentration, on percent change in contraction amplitude and frequency. Among our next steps in this project are to examine the isolated CG. Any discrepancies between the isolated CG experiments and whole heart experiments may be attributed to phenomena at the muscle. We intend to mine the CG and muscle tissue transcriptome to discover specific receptor expression in the lobster cardiac system.

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