Pressure alters the stroke volume and heart rate of the American lobster

John Pietro 2018

Work in the Johnson lab has shown that the lobster heart is mechanically anisotropic, leading to the loading of muscles and tendons of the heart in a pattern of forces that differ in three-dimensional space (Dickinson *et al.*, 2016). Research on isolated (*in vitro*) lobster hearts, has shown that the cardiovascular system of the American lobster, *Homarus americanus*, responds to stretch by increasing heart rate and stroke volume, which in turn increases flow rate and blood circulation. Other research in the Johnson Lab, (Armiyaw *et al.*, 2016), demonstrated the importance of understanding three-dimensional loading of the heart during normal heartbeats, but did not connect those measurements to the internal pressures generated during contraction and relaxation of the heart. These pressures determine the ability of the heart to deliver oxygen to tissues at a rate sufficient to support their activity (Wilkens and McMahon, 1994).

As a first step in determining the relationship between pressure, heartbeat frequency and amplitude, a new dissection was introduced, where the heart was maintained without disturbing its surrounding ligaments or the connected circulatory system. After this, the heart was manipulated following the guidelines of the *in vitro* preparations to confirm that heart frequency and amplitude generally increased with stretch. Although the relationship of pressure to heart function is not well characterized in lobsters, Wilkens and McMahon (1994), demonstrated that heart rate and stroke volume showed little or no change in response to a change in afterload or perfusion pressure in the crab *Carcinus maenus*. To examine this in *H. americanus* the posterior artery of the dissected lobster was intubated and flow rate from the tube was measured. The tube's length was then changed to alter the afterload pressure of the system: with a greater tube length, came a greater resistance to flow.

I found that heart rate increased in response to stretch, which is similar to *in vitro* preparations described above. However, heart rate decreased in response to increased afterload (Fig. 1),which is different from the results for the crab *C. maenas* (Wilkens and McMahon, 1994). This response is similar to the baroreceptor response chiefly responsible for maintaining circulatory system blood in mammals (Figure 2; Souza et al., 2008). While well known in mammals, this response has only been mentioned in passing for crabs (Burggren et al.,1990).

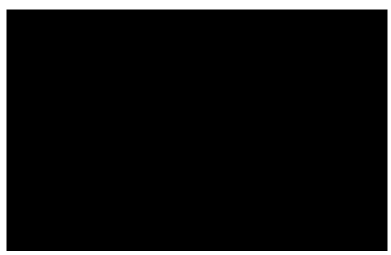

Figure 1. Lobster heart rate as a function of pipe length. Heart rate decreased with increasing afterload (pipe length), mimicking the baroreceptor response (Fig. 1).

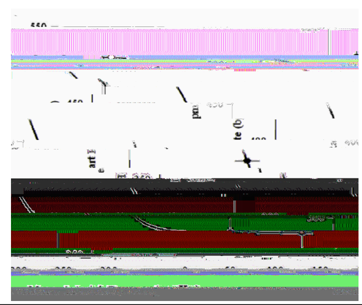

Figure 2. Example of baroreceptor response from rats (Souza et al., 2008). Heart rate decreases with increasing arterial pressure.

Faculty Mentors: Amy Johnson and Olaf Ellers
Funded by: Henry L. and Grace Doherty Charitable Foundation Coastal Studies Research Fellowship

References Cited

Armiyaw, A.L (2016) Influencing factors on the anisotropic mechanical responses of the cardiac muscles in the heart of the American lobster, *Homarus americanus* President's Summer Research Symposium poster presentation.

Burggren, W., Pinder, A., McMahon, B., Doyle, M., & Wheatly, M. (1990). Heart rate and hemolymph pressure responses to hemolymph volume changes in the land crab *Cardisoma guanhumi*: evidence for" baroreflex" regulation. *Physiological Zoology*, *63*, 167-181.

Dickinson, E.S., Johnson A.S**.,** Ellers, O., Dickinson, P.S. (2016). Forces generated during stretch in the heart of the lobster *Homarus americanus* a 1 (n) 1 T3 1 Tf β3cm BT 0 Tm /TT3 1 Tf ( ) 0 TlT43.2044 *Journal of Experimental Biology*, 219:1187-1202.

Souza, H. C., Martins-Pinge, M. C., da Silva, V. J. D., Borghi-Silva, A., Gastaldi, A. C., Blanco, J. H. D., & Tezini, G. C. (2008). Heart rate and arterial pressure variability in the experimental renovascular hypertension model in rats. *Autonomic Neuroscience*, *139*(1), 38-45.

Wilkens, J.L., McMahon, B.R. (1994). Cardiac performance in semi-isolated heart of the crab *Carcinus maenas*. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, *266*: R781-R789.