The role of the dorsal abdominal artery in providing elastic recoil of the heart of the American lobster

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The cardiac neuromuscular system of *Homarus americanus* is a widely studied and relatively well-understood model system. The neurogenic lobster heart consists of a single ventricle suspended by an array of arteries and ligaments within the heart cavity. During systole (contraction), the lobster heart supplies hemolymph to seven different arteries, then fills passively by means of valved openings (ostia) during diastole (relaxation).

One of the main questions posed by the Johnson-Dickinson lab is: How do biological systems maintain stability and still allow for change? Using the cardiac neuromuscular system of the American lobster, *H. americanus,* as a model, I ask more specifically: How is lobster cardiac output (e.g., heart rate, volume flow rate, contraction force and amplitude) regulated by stretch due to pull from ligaments and arteries during natural contractions and stretches? While contraction of the decapod heart has been well studied, the mechanisms contributing to its relaxation component remain unclear. It is currently assumed that the arteries, with their elastic properties, contribute to this recovery from the force of the heartbeat and thereby determine the diastolic volume; however, no quantitative data on this have yet been reported.

For my summer research, I focused on one specific artery, the dorsal abdominal artery (DAA) and studied its role during diastole. The DAA runs from the posterior end of the heart to the tip of the lobster's tail fin, with five pairs of lateral arterial branches along its longitudinal length. Introducing a new experimental method to the lab allowed for manipulation and closer observation of the lobster cardiovascular system *in vivo.* By testing each of the five segments of the DAA, both intact (*in vivo*) and relaxed (*in vitro*), I was able to measure its force output relative to different tensions imposed by length changes. One of three measurements I recorded involves a "work loop" which measures hysteresis, or the energy that is lost to heat during extension as a result of viscous energy loss, and resilience, or the material's capacity to recover from a cyclic strain test.

$$R = \frac{(W/V)_{return}}{(W/V)_{extend}}; \qquad Hysteresis = 1 - R$$

Calculating the resilience of a "whole system" (intact heart + the 1st segment of the DAA) from one of my recordings, results in 78.35% resilience, while an "isolated" recording (the 1st segment of the DAA) results in 85.75% resilience. This tells us that the DAA itself has a higher resilience than does the whole system, and therefore, there is greater hysteresis in the whole system than there is in the isolated artery (see *Figure 1*). This also reveals that elastic recoil is more reliant on the artery than on the heart alone, which leads us to conclude the mechanical relaxation of the lobster heart is indeed influenced by stretch-elastic properties of the *intact* ligaments and arteries that were discarded in previous studies. Further analysis remains to be done; however, these findings lead me to predict that the whole system would also exhibit more "stress relaxation", or the ability to relieve stress when stretched or put under constant strain.

Additionally, after literature research and collaboration with other members of my team, I was able to identify small muscle fibers along the lateral sides of the DAA, which contributes to the artery's rubber band like structure. However, the varying force measurements obtained from each individual segment of the artery might give evidence to the DAA being a spectrum in terms of elasticity and tension. Future research will involve similar mechanical tests of the three pairs of alary ligaments and six other individual arteries stemming from the heart. This is needed in order to help quantify how each component of the heart system contributes to anisotropies in the relaxation and stretch of the lobster heart, and then compare them in terms of recoil contribution.

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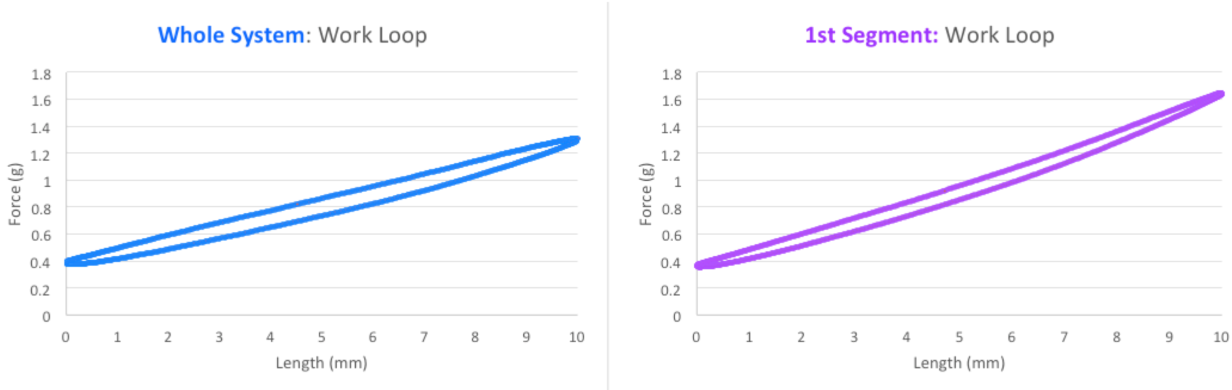

Figure 1. The area inside a work loop indicates the amount of energy lost as heat due to extension (hysteresis). The curve generated by experimental tests of force on the "whole system" demonstrates greater hysteresis when compared to that generated from the isolated 1st segment of the dorsal abdominal artery. Therefore, the elastic recoil of the lobster heart is more reliant on the DAA than on the heart alone.