Bioinspired Design (Engn/Biol 267) Jellyfish Propulsion Unit

Required Reading

1. **Colin, S. P., & Costello, J. H. (2002)**. Morphology, swimming performance and propulsive mode of six co-occurring hydromedusae. *Journal of experimental biology*, *205*(3), 427-437. [www]

This article compares actual measurements of jellyfish propulsion to a jet propulsion model. Spoiler alert: jellyfish are way more efficient than the jet propulsion model predicts.

2. **Villanueva, A., Smith, C., & Priya, S. (2011).** A biomimetic robotic jellyfish (Robojelly) actuated by shape memory alloy composite actuators. *Bioinspiration & Biomimetics*, *6*(3), 036004. [www]

This article describes design, development, testing of a bioinspired jellyfish robot. Take particular note of shape memory alloy (SMA) + metal composite technology used to build the robot (hint: these are well within your reach!). Also note how small details, such as inclusion of flaps, made a huge difference in swimming performance.

3. **Frame, J., Lopez, N., Curet, O., and Engeberg E. (2018)**. Thrust force characterization for free-swimming soft robotic jellyfish. *Bioinspiration & Biomimetics*, *13*, 064001. [www]

This article details design optimization of free-swimming jellyfish robots using pneumatic-network actuators cast from silicone rubber. In what ways is this design successful? How could it be improve? Think about (dis)advantages of pneumatic net vs. SMA actuators. What biological elements are (not) well-integrated into this clever design?

4. **Hammond, C., Glavy, J. and Sorenson, J. (2013).** A biomimetic Jellyfish with Solenoid Circular Actuator: *Mastigias bellis* (Daisy). Washington and Lee University, Bioengineering and Bioinspired Design, fall 2013.

This report describes the work of a BioE student group from last year who sought to mimic the circular muscles in jellyfish for propulsion, more similar to the actual biological model. This article also serves as a first introduction to the nature of the capstone project you will tackle during the second half of the course (not necessarily on this topic).

Further Reading:

1. Colin, S. P., Costello, J. H., Dabiri, J. O., Villanueva, A., Blottman, J. B., Gemmell, B. J., & Priya, S. (2012). Biomimetic and live medusae reveal the mechanistic advantages of a flexible bell margin. *PloS one*, *7*(11), e48909.

Brilliant article (though heavy on fluid mechanics) showcasing biology and engineering and self-reinforcing in their principles of design and understanding.

2. Villanueva, A. A., Joshi, K. B., Blottman, J. B., & Priya, S. (2010). A bio-inspired shape memory alloy composite (BISMAC) actuator. *Smart Materials and Structures*, *19*(2), 025013.

This paper further describes the very clever BISMAC technology that was later integrated into Robojelly.

3. Dabiri, J. O., Colin, S. P., Costello, J. H., & Gharib, M. (2005). Flow patterns generated by oblate medusan jellyfish: field measurements and laboratory analyses. *The Journal of Experimental Biology*, *208*(7), 1257-1265.

First-ever visualization of vortex ring formation in jellyfish. Until this paper, it was presumed jellyfish just squirt out a jet of fluid.

4. Dabiri, J. O., Colin, S. P., & Costello, J. H. (2007). Morphological diversity of medusan lineages constrained by animal–fluid interactions. *Journal of Experimental Biology*, *210*(11), 1868-1873.

Contains some more details on math modeling of force generation in jellyfish. Also details how many jellyfish have shapes ("bell geometry") that makes them near optimal for propulsion energy efficiency (even if they are slow).

5. Gemmell, B. J., Costello, J. H., Colin, S. P., Stewart, C. J., Dabiri, J. O., Tafti, D., & Priya, S. (2013). Passive energy recapture in jellyfish contributes to propulsive advantage over other metazoans. *Proceedings of the National Academy of Sciences*, *110*(44), 17904-17909.

Turns out that the jellyfish musculature and material properties are arranged to give an added boost during the relaxation phase of swimming making yet even more efficient than previously thought!