Paper 10 - Supporting Material

Journal Club

January 2021

1 Overview

This document contains the supporting material for Paper 10 for the Journal club. Here, we explore a case-study of Biomimetics, and follow the thought process of engineers who learn from the biology of batoid fish like stingrays and eels to design a robot that swims efficiently.

Paper: Park, Sung-Jin, et al. "Phototactic guidance of a tissue-engineered soft-robotic ray." Science 353.6295 (2016): 158-162. DOI: 10.1126/science.aaf4292

1.1 Key Terms

- Phototactic: The ability of an organism to sense light ("photo") with it body, which automatically moves ("tactic") towards the stimulus of light. The motion of the organism is hence controlled by the direction and intensity of the light.
- Cardiomyocytes: The type of cells that comprise the heart ("cardiac") muscle in organisms. Its primary role is the contractile motion that enables the heart to pump blood.
- Optogenetics: A technique used to genetically modify neurons to express their light-sensitive ("opto") channels, enabling their activity to be controlled by light. Neurons are the cells of the nervous system that control our locomotive actions.
- Elastomer: Materials with rubbery consistency ("elastic") that are can return back to their original shape after being stretched or twisted.

2 Supporting Material

2.1 Nature's Swimming Hacks

The entire extract that follows in this section was taken from Ref.1:

There are four major types of swimmers: undulatory, oscillatory, pulsatile and drag-based, as illustrated in Figure 1. Undulatory swimmers are animals that generate a travelling wave along their body or propulsive fins to push fluid backwards. Examples include eels, lampreys and some rays. Oscillatory swimmers, such as salmon, tuna, dolphins and sharks, propel themselves primarily using a semi-rigid caudal fin or fluke that is oscillated periodically. Animals that periodically ingest a volume of water and then discharge it impulsively to produce thrust by reaction are called pulsatile swimmers, and examples include jellyfish, squid, frogfish and some molluscs. Finally, drag-based swimmers such as humans, turtles, seals and ducks propel a bluff body such as a rigid flipper through the water to generate thrust.

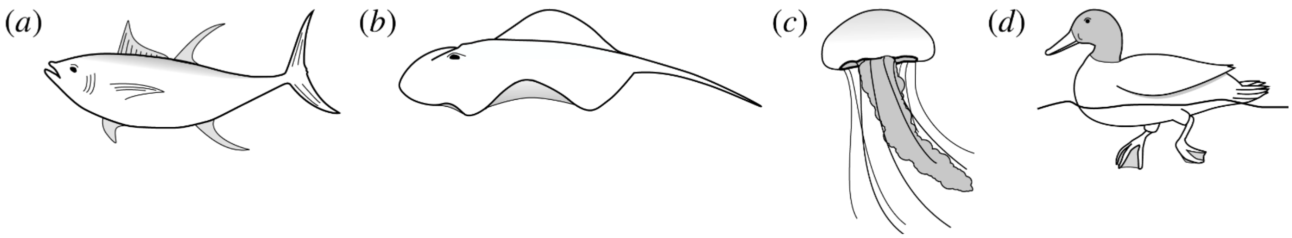

Figure 1: Examples of four swimming types: (a) oscillatory – tuna; (b) undulatory – ray; (c) pulsatile jet – jellyfish; and (d) drag based – duck. Image and caption were taken from Ref.1.

2.2 Videos of the Robotic Ray

Watch the swimming robotic ray in action in this short video by Wall Street Journal, which also summarizes the design of the robotic ray. You can learn more details from the engineers themselves in this video, which also conveys the inspiration for this biomimetic design, and includes clips of the laboratory assembling process.

3 Questions

1. Using what stimulus can the direction and speed of the robotic-ray motion be controlled?
2. What are each of the four layers of the robotic ray body made of?
3. Which of the layers in the answer to Qn.(2) responds to the stimulus that answers Qn.(1)?
4. What is the source of energy that powers the robotic ray?
5. A bit on design thinking: The authors note that real rays have two layers of muscles for downward and upward contractions respectively. However, to keep the design simple, their robotic ray has just one layer of muscle for downward contraction. What design feature did the engineers introduce to allow the robotic ray to perform upward contractions without a second muscle layer, and how does this feature work?
6. According to the paper, why are batoid fish ideal biological models for robotics? Do you agree or disagree with their reasons, and why?

4 References

1. Smits, A. (2019). Undulatory and oscillatory swimming. Journal of Fluid Mechanics, 874, P1. DOI: 10.1017/jfm.2019.284