Bioinspired Design Engn/Biol 267: Octopus Optics (and Squid too!) Unit

Required Reading

1. Mäthger, L. M., & Hanlon, R. T. (2007). Malleable skin coloration in cephalopods: selective reflectance, transmission and absorbance of light by chromatophores and iridophores. *Cell and tissue research*, *329*(1), 179-186. [www]

Classic article describing basic optical structures and properties in the skin of cephalopods (octopus, squid, cuttlefish, etc.). Take particular note of differences between chromatophores and iridophores. We'll focus our study on the latter.

2. Xu C., Stiubianu G.T., and Gorodetsky, A.A. (2018). Adaptive infrared-reflecting systems inspired by cephalopods. *Science,* 359, 1495-1500. [www]. Supplemental Information here.

How do you go from squid and octopus to IR-reflecting systems for energy conserving structures, spacecraft components, and camouflage applications? This paper describes a clever design to do just that. What principle found in the marine world was incorporated into human design and build? What promise does this hold for various real world applications? What are current limitations that must be overcome to actually make this clever design a viable product for real world applications?

3. Kreit, E. et al (2013). Biological versus electronic adaptive coloration: how can one inform the other? *J R Soc Interface* 10: 20120601. [www]

Brilliant article that compares and contrasts human made and biological optical technology for application to e-paper (aka Amazon kindle). The biological optics will be familiar to you (after we study it); try your best to grapple with the human-made technologies.

Further Reading:

1. Xu C., Escobar M.C., and Gorodetsky A.A. Stretchable Cephalopod-Inpsired Multimodal Camouflage Systems. (2020), *Advanced Materials*, 1906717. [www]

The latest and greatest camouflage system that was inspired by cephalopods. State of the art camouflage system. They manipulate light in both IR and human-visible regions.

2. Yu C. et al. Adaptive optoelectronic camouflage system with designs inspired by cephalopod skins. (2014) *PNAS*, 111(36), 12998-13003.

3. Rossiter, J., Yap, B., & Conn, A. (2012). Biomimetic chromatophores for camouflage and soft active surfaces. *Bioinspiration & biomimetics*, *7*(3), 036009.

Soft material chromatophore based camoflague! They made an elegant system. None of their technology seems so advanced as to be outside the realm of a potential capstone project inspired by this work.

4. 5. Kang, Y., Walish, J. J., Gorishnyy, T., & Thomas, E. L. (2007). Broad-wavelength-range chemically tunable block-copolymer photonic gels. *Nature Materials*, *6*(12), 957-960.

Brief article describing a clever chemical-reaction based method for optically tunable gels.

5. DeMartini, D. G., Krogstad, D. V., & Morse, D. E. (2013). Membrane invaginations facilitate reversible water flux driving tunable iridescence in a dynamic biophotonic system. *Proceedings of the National Academy of Sciences*, *110*(7), 2552-2556.

Really brilliant little article that clarifies the mechanism and neurochemistry that drives changes in iridophore material and optical properties. Also, see a very well-written summary of this work here: http://www.ia.ucsb.edu/pa/display.aspx?pkey=3076

6. Mäthger, L. M., Bell, G. R., Kuzirian, A. M., Allen, J. J., & Hanlon, R. T. (2012). How does the blue-ringed octopus (Hapalochlaena lunulata) flash its blue rings?. *The Journal of experimental biology*, *215*(21), 3752-3757.

Fun paper that describes a novel and unexpected mechanism for how low frequency wavelengths can be flashed so fast. Might be fun to think about integrating this mechanism into a biomimetic device.

7. Ghoshal, A., DeMartini, D. G., Eck, E., & Morse, D. E. (2013). Optical parameters of the tunable Bragg reflectors in squid. *Journal of The Royal Society Interface*, *10*(85), 20130386.

The most detailed description of the material properties and construction of iridocytes. The main text is very readable. Be aware that the supplemental information contains a lot of the details on how the study was actually done. You can even download the authors' MATLAB code from the journal's website (look under "Figures and Data"):
http://rsif.royalsocietypublishing.org/content/10/85/20130386.short

8. Miller W.H. and Bernard, G.D. (1968) Butterfly Glow, *J. Ultrastructural Research*, 24, 286-294.

This paper was way ahead of its time in terms of biological optics. It describes the repeating unit structures in butterfly eyes that make them glow red or yellow. 50 years later, humans are realizing the same pattern in butterfly eyes can be integrated into human designs for cameras that help detect cancer.