DEPARTMENT OF BIOLOGY | UNIVERSITY *of* WASHINGTON

Biology Seminar

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https://sponberg.gatech.edu/ & https://sites.gatech.edu/flap-muri/

Transitions and tradeoffs in the fast, high-powered flight strategies of insects

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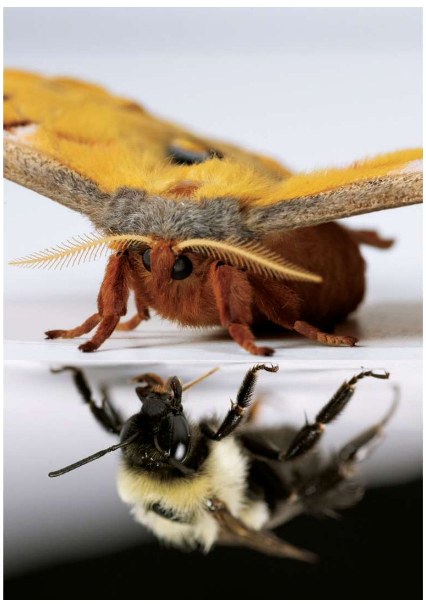

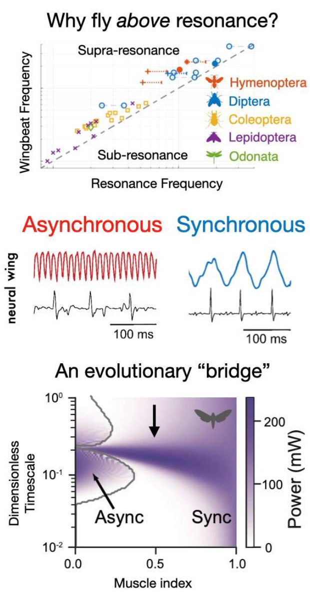

Flapping flight has played a key role in the diversification and success of insects. Yet there is no one singular answer to how insects fly. To reduce the extreme energetic costs of flapping flight at small scales, many insects operate as resonant biomechanical systems. That is, they store and return energy in their elastic exoskeletons to help accelerate their wings back and forth at high speeds. I will first discuss how, despite these advantages, most insects actually operate above their optimal resonant frequency because of muscular constraints and biomechanical tradeoffs. We then explore how insects have evolved two different strategies for powering this supra-resonant flight. Moths, locusts, and many other flying insects neurally activate their flight muscles synchronized to each wingstroke. But flies, beetles, and many bees, produce many wingstrokes for each pulse of neural activation. This "asynchronous" strategy utilizes stretch-activation in the flight muscle physiology to break the speed limit of synchronous muscle and allows for the very high wingbeat frequencies needed in small flying insects. However, our reconstruction of the evolutionary transitions between these two well-known modes of flight shows that the four major clades of asynchronous fliers likely evolved from a single common origin of asynchrony. This means groups like moths and butterflies would have secondarily lost ultra-fast asynchronous flight. We test this prediction by examining the muscle physiology of a synchronous hawkmoth, *Manduca sexta*, and find that it preserves the stretch-activated properties typical of asynchronous species. We then unify the two strategies into a single biophysics framework that shows how major evolutionary transitions reflect transitions in dynamics and why it was relatively easy to switch back and forth. We embody this model in a single flapping wing robot that can recapitulate this transition between the two strategies of flight with springy wings. Finally, we put isolated moth flight muscle into a mechanical virtual reality environment that lets us modify its physiological properties. This "physiological dynamic clamp" allows us to transition moth muscle back to an asynchronous flight strategy with a simple parameter change in its muscle behavior.

Seminar Speaker Bing Brunton