Emergent Mechanics and Origins of Behavior in Simple Non-Neuronal Systems

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Maeder Hall, ACEE

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The tradeoff between stability of form and sensitivity to environment is central to the emergent dynamics of living systems. In metazoan tree of life, one of the most successful strategies for addressing this challenge is the integration of a nervous system and muscle architecture enabling complex signal processing capabilities. Informed by the perspective of a living fossil, we study the physical constraints on multicellular collectives which existed before the evolution of the nervous system. Through joint experimental study of the phylum placozoa – an early diverging sister group to all animals with no muscles or neurons – and agent based numerical work, we investigate the delicate interplay between sensitivity and stability in a parsimonious model (an active elastic sheet) calling upon concepts from active matter and embodied computation. First we explore locomotory behavior in this animal driven by “walking” cilia in ventral epithelium. We find that through local rules alone multicellular collectives can generate long-wavelength stability without compromising organism-wide sensitivity to local inputs. We describe a low-dimensional representation of organism scale dynamics in the form of a simple quasi-particle description. Finally, we demonstrate the utility of these results in the context of behaviorally relevant settings including: local-global foraging, tribotaxis (ascending frictional gradients) and phototaxis. Next, we report the discovery of ultra-fast epithelial contractions (50% cell area in 1 second, an order of magnitude faster) and associated contractile dynamics in dorsal epithelium of Trichoplax adherence. Live in-toto imaging of the whole animal reveals emerging contraction patterns, including propagating waves. We hypothesize a new role of cellular contractions in epithelium - enabling resilience to rupture via "active cohesion". Finally, we reveal the role of tissue fracture dynamics in organism scale morphogenesis. Time permitting, I will also share snippets of our work on ultra fast morphological dynamics in single cells and frugal science for global health.

Manu Prakash, Ph.D. is Assistant Professor of Bioengineering at Stanford University and runs a curiosity driven lab in organismic biophysics. He is also passionate about frugal science; developing ultra-affordable and accessible technologies that can be used for science education, research, and public health in resource poor settings globally. He is a 2016 recipient of the MacArthur Fellowship, an HHMI-Gates Faculty Scholar, and 2015 National Geographic Emerging Explorer and the NIH Director’s New Innovator Award and CZ BioHub Investigator.

There will be a social period following the talk outside of Maeder Hall.

All are welcome.

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