Structural Engineering Seminar Series

CEE 595 S & CEE 595 SO

Pattern formation in biological systems via mechanical instabilities and phase separation

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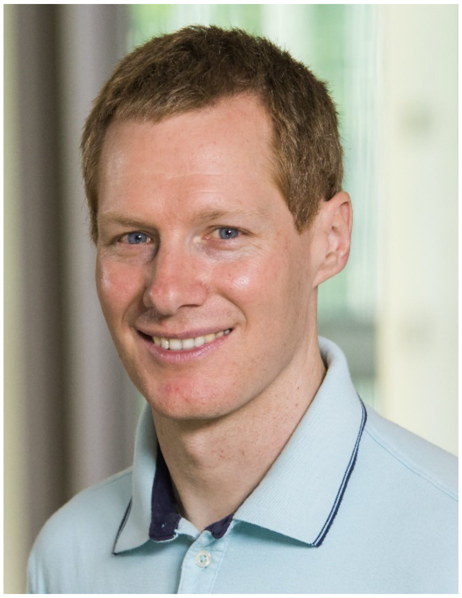
Abstract:

Pattern formation is ubiquitous in biological systems. While pattern formations are often associated with Turing-like reaction-diffusion systems, biology also exploits many other mechanisms such as mechanical instabilities and phase separation. In this talk, I will discuss how mechanical instabilities cause the wrinkling of bacterial biofilms and branching in developing lungs, and how phase separation is exploited to achieve the target morphology of intracellular condensates. Bacterial biofilms grown on substrates form wrinkled patterns that can be manipulated by modifying the substrate stiffness. We showed that the wavelength of wrinkles is consistent with the mechanical stability of compressed films on soft substrates. Furthermore, we demonstrated that the spatiotemporal pattern of wrinkles can be predicted by a continuum chemo-mechanical model that incorporates diffusion of nutrients and their uptake by bacteria, growth of the biofilm, surface friction, and the ensuing mechanical stresses and deformations of the biofilm. In the second part, I will discuss the branching morphogenesis of lungs. By combining experiments and modeling we showed that the patterned formation of stiff smooth muscles and their contractions physically sculpt new branches of growing epithelium. I will also comment on how we are going to use these insights to design an optogenetic system to engineer artificial lung organoids. In the last part, I will discuss, how interfacial energies between separated phases in multicomponent liquid mixtures regulate the morphology of intracellular condensates. We developed a graph theory approach to predict the morphology of coexisting phases from a given set of interfacial energies (forward problem), enumerate all topologically distinct morphologies, and reverse engineer conditions for interfacial energies that produce the target morphology (inverse problem).



Bio:

Andrej Košmrlj is an assistant professor of Mechanical and Aerospace Engineering at Princeton University. Andrej Košmrlj received his Ph.D. in Physics from the Massachusetts Institute of Technology in 2011, and his postdoctoral training at Harvard University. He joined Princeton University in 2015, where his group is doing theoretical and computational research of complex systems ranging from materials science to the physics of living systems. For his research achievements, Andrej Košmrlj has received the NSF Career Award and the Alfred Rheinstein Faculty Award. For his teaching efforts, Andrej Košmrlj has received the Excellence in Teaching Award from the School of Engineering and Applied Science.

Monday, December 6th, 2021 4:00 – 5:20 p.m.

1310 Yeh Student Center