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Making a Mesh of Things: Using Network Models to Understand the Mechanics of Heterogeneous Tissues

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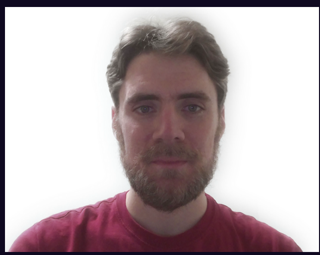
Abstract:

Networks of stiff biopolymers are an omnipresent structural motif in cells and tissues. A prominent modeling framework for describing biopolymer network mechanics is rigidity percolation theory. This theory describes model networks as nodes joined by randomly placed, springlike bonds. Increasing the amount of bonds in a network results in an abrupt, dramatic increase in elastic moduli above a certain threshold – an example of a mechanical phase transition. While homogeneous networks are well studied, many tissues are made of disparate components and exhibit spatial fluctuations in the concentrations of their constituents. In this talk, I will first discuss recent work in which we explained the structural basis of the shear mechanics of healthy and chemically degraded cartilage by coupling a rigidity percolation framework with a background gel. Our model takes into account collagen concentration, as well as the concentration of peptidoglycans in the surrounding polyelectrolyte gel, to produce a structure-property relationship that describes the shear mechanics of both sound and diseased cartilage. I will next discuss the introduction of structural correlation in constructing networks, such that sparse and dense patches emerge. I find moderate correlation allows a network to become rigid with fewer bonds, while this benefit is partly erased by excessive correlation. We explain this phenomenon through analysis of the spatial fluctuations in strained networks' displacement fields. Finally, I will address our work's implications for non-invasive diagnosis of pathology, as well as rational design of prostheses and novel soft materials.

Date:
04/04/2022

Time:
9:00 AM-10:15 AM (PT)
12:00 PM-1:15 PM (ET)

About the speaker:



Dr. Jonathan Michel is a post-doctoral research associate in the group of Moumita Das at the Rochester Institute of Technology. He is broadly interested in the mechanics and dynamics of biopolymer networks, with a particular focus on the role of hierarchical structure and heterogeneity both of constituents and spatial arrangement in determining structure-property relations.

Dr. Michel's current work is focused on experiment-driven modeling of ex-vivo tissue samples and reconstituted in-vitro networks. Prior to joining RIT, he earned a Bachelor of Science at Carnegie Mellon University, and a doctorate at the Georgia Institute of Technology, where he performed computational research on the mechanics of fiber networks with hierarchical spatial organization.

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