The University of Texas at Austin
Department of Physics
College of Natural Sciences

Colloquium

Wednesday, January 24, 2024
John Archibald Wheeler Lecture Hall
PMA 4.102, 4:00pm

The Viscoelastic Mechanics and Microstructures of Biofilm Infections Help Them Resist Immune Clearance

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Abstract

Biofilms are communities of single-celled organisms that are bound together in a matrix of polymers and proteins. They are the primary cause of chronic bacterial infection, failure of medical devices, and a wide range of very harmful and expensive health outcomes, because biofilms are largely intractable to both the immune system and antibiotics.

The intercellular cohesion conferred by the matrix means that microbes in a biofilm have both mechanical and microstructural properties that do not exist for an equivalent population of microbes not in a biofilm. Mechanically, biofilms are viscoelastic materials, combining properties of both elastic solids and viscous fluids. Biofilm mechanics can be measured in bulk, using conventional rheology to measure the stress response to sinusoidal strain and strain rate, and at the local microscale using microrheology, in which thermally-driven fluctuations in the positions of probe particles are interpreted via Einstein's Fluctuation-Dissipation theorem. The microstructure of biofilms can be assessed using both light and electron microscopy.

Phagocytosis is a process used by the immune system to clear infection, whereby infecting pathogens are engulfed ("eaten") by a white blood cell. The primary "first responder" of the immune system is the neutrophil, which is a type of white blood cell that can use phagocytosis and other mechanisms to clear pathogens. Neutrophils easily engulf microbes that are not in a biofilm. However, since biofilms are an order of magnitude larger in size than neutrophils, one to a few microbes must be removed from the biofilm before they can be phagocytosed. This is a mechanical process that must be impacted by the mechanical characteristics of the biofilm, yet (apart from our own recent work) essentially nothing is known about how this works.

Here, I will discuss our recent work showing that biofilm mechanics and microstructure depend both on the activity of constituent microbes and on the environment in which the biofilm is grown - in the case of infection, this would be host tissue. Cations and cationic proteins made by the host can interact with bacteria and bacteria-produced materials, likely through electrostatic interactions and potentially through specific binding as well. These interactions can change both biofilm mechanics and biofilm microstructure, in ways that increase the solid-like elasticity of the biofilm and enhance the biofilm's resistance to phagocytic clearance. Intelligent disruption of key biofilm matrix components can compromise their mechanics and microstructure and make them more susceptible to clearance by phagocytic immune cells.

This perspective points the way toward a new approach to treating nominally-intractable biofilm infections, which could have significant benefit to human and animal health in a wide range of disease scenarios.

Dr. Gordon has been on faculty at UT Austin since 2010. She got her PhD from Harvard University in soft-matter physics in 2003. She became a Fellow of the American Physical Society in 2023. She hopes that she will have completed the 2024 3M half-marathon before she gives this colloquium.