The Mathematics of Biological Fluid Dynamics

Friday, August 8, 2:00 p.m. - 4:50 p.m., Hilton Portland, Plaza Level, Pavilion East

One exciting area of mathematical research within Mathematical Biology is “biological fluid dynamics,” which consists of explaining and understanding the interaction of fluids and living organisms. This includes the motion of microorganisms such as bacteria and algae, cell motion, the fluid flow in the respiratory and cardiovascular systems, flying and swimming, and much more. The research problems are inspired by the need to understand basic functions of life, such as reproduction, growth, feeding, and locomotion.

The mathematics of biological fluid dynamics involves developing theory, creating models, and designing computational methods for numerical simulations of the systems being investigated. This is typically done in collaboration with experimentalists and other scientists. This expository session highlights a variety of applications of the mathematics behind biological fluid dynamics and identifies current research questions in this area.

Ricardo Cortez, *Tulane University*

Neuromechanics and Fluid Dynamics of an Undulatory Swimmer

2:00 p.m. - 2:20 p.m.

The swimming of a simple vertebrate, the lamprey, can shed light on the coupling of neural signals to muscle mechanics and passive body dynamics in animal locomotion. We will present recent progress in the development of a multiscale computational model of the lamprey that examines the emergent swimming behavior of the coupled fluid-muscle-body system.

Lisa Fauci, *Tulane University*

Mathematical Modeling of Sperm Motility and Mucociliary Transport

2:30 p.m. - 2:50 p.m.

The motility of sperm flagella and cilia are based on a common physiological structure capable of generating a wide range of dynamical behavior. We describe a fluid-mechanical model for sperm and cilia coupling the internal force generation of dynein molecular motors through the passive elastic axonemal structure with the external fluid mechanics. As shown in numerical simulations for motile sperm, the model's flagellar waveform depends strongly on viscosity as well as dynein strength. We will also show numerical simulations of multiciliary interaction.

Robert Dillon, *Washington State University*

Modeling E. Coli Aspartate Chemotaxis in a Stokes Flow

3:00 p.m. - 3:20 p.m.

For certain bacteria such as *Escherichia coli*, bidirectional propeller-like rotary motion of flagellar filaments results in the net movement of the cell through gradients of chemoattractant molecules toward areas of higher attractant concentrations. Directional switching of the flagellar motor is governed by a phosphorelay circuit that transfers phosphoryl groups from donor to acceptor proteins; and protein phosphorylation state is controlled by binding of chemoattractants to specific receptors. The three-dimensional hydrodynamics of cell motility is modelled by coupling the chemotaxis equations of a simplified phosphorylation cascade with the method of regularized Stokeslets of the fluid motion through cell transport and external forcing from the flagellar motor. The results demonstrate how the phosphorylation affects the run and tumble mechanism of swimming bacteria. This work is in collaboration with Robert Bierman (Biology student), Jordan Bush (Math student), and Frank Healy (Biology faculty).

Hoa Nguyen, *Trinity University*

Modeling Interactions between Tumor Cells, Interstitial Fluid and Drug Particles

3:30 p.m. - 3:50 p.m.

The interactions between tumor cells and their microenvironment are complex, and this complexity is leveraged when both tumor and stromal cells are exposed to anticancer therapeutic agents. We will present a model based on fluid-structure interaction techniques that allows us to explore the role of the interstitial fluid flow and tumor tissue architecture on the extent of drug penetration into the tissue. We show how this model can be parameterized using available data from laboratory experiments, and how it can be applied to test various properties of anti-cancer agents.

Katarzyna A. Rejniak, *H. Lee Moffitt Cancer Center & Research Institute and University of South Florida*

Sperm Motility and Cooperativity in Epithelial Detachment

4:00 p.m. - 4:20 p.m.

On their way to fertilize the oocyte, mammalian sperm must undergo drastic changes in their behavior and biochemistry. Along this journey, sperm have been shown to bind to cilia lining the oviductal epithelium and break these bonds near the time of ovulation. It has been hypothesized that changes in motility enable sperm to break free of the surface and progress through the oviduct. Using the method of regularized Stokeslets, we explore the separate roles that surfaces and binding have upon swimming in the viscous environment that sperm encounter. We also investigate whether nearby sperm will effectively cooperate to escape a surface.

Julie Simons, *Tulane University*

Swimming through Heterogeneous Viscoelastic Media

4:30 p.m. - 4:50 p.m.

Elastic polymers and filamentous networks immersed in a fluid environment are common in biology. Those biological fluids are often inhabited by microorganisms whose motility depends on the surroundings. We consider a simple model of a free microswimmer in a highly heterogeneous, viscoelastic medium. An effect of viscoelasticity is modeled by immersing viscoelastic structures in viscous environment. Varying complexity of those structures allows medium to exhibit different viscoelastic properties. Regions of higher structural density can significantly change a swimming pattern of a microorganism.

Jacek Wrobel, *Tulane University*