

# ACMS Grad & Postdoc Seminar



**Sanchita Chakraborty**  
**University of Notre Dame**  
**Wednesday, Feb. 25, 2026**  
**154 Hurley Hall**  
**3:30 PM – 4:30 PM**

## **Orientation-Sensitive Mean First Passage Time on Fly Muscle Cell Geometries: Green's Functions and Elliptical-Nucleus Optimization**

Diffusive first-passage processes play a central role in cellular transport, including signaling to nuclei in multinucleated muscle fibers, yet classical narrow capture theory typically models targets as isotropic disks. Motivated by microscopy data from fly muscle cells showing strongly anisotropic nuclear geometries, this talk develops a data-driven framework for mean first passage time (MFPT) problems with small, absorbing elliptical targets embedded in bounded two-dimensional domains. Using matched asymptotic analysis as the target size parameter  $\varepsilon \rightarrow 0^+$ , I derive a two-term expansion for the MFPT that reveals how target orientation enters at  $O(\varepsilon^2)$  through polarization tensors and derivatives of the regular part of the Neumann Green's function, yielding an explicit  $\cos(2\phi)$  dependence and predicting orientation-driven bifurcations in optimal alignment. These predictions are validated against high-order finite element simulations in canonical geometries. I then extend the theory to configurations of many small elliptical targets, deriving leading-order linear systems for capture strengths and nuclear fluxes together with orientation-sensitive corrections. To enable computation on irregular geometries extracted from fly muscle cell datasets, I use boundary integral methods (via chunkIE) to compute Neumann Green's functions and their derivatives directly on cell outlines. The resulting asymptotic surrogate supports a fast optimization pipeline for refining nuclear positions, sizes, and orientations on experimental geometries, providing a quantitative link between cell shape, nuclear anisotropy, and transport efficiency.

The Department of Applied and Computational  
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