COLLOQUIUM
MECHANICAL ENGINEERING

The Department of Mechanical Engineering presents:

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11:10AM-12:00PM
Bourns Hall A265

The Solid Mechanics of Fluid Shells: Understanding Structure and Organization in Cell Membranes

Abstract: Cellular membranes are heterogeneous 2-dimensional fluids of lipids, proteins and other small molecules. The use of cryo-electron tomography and confocal microscopy is producing an ever growing database of detailed 3-dimensional membrane conformations capturing the structure and molecular organization of biomembranes in cellular processes ranging from viral budding and organelle maintenance to signaling and trafficking. This wealth of experimental data demands generic, quantitative methods for interpretation of the physical mechanisms that produce and maintain the structure and order in cellular membranes.

In this talk I will present a computational framework for quantitative analysis of the mechanics of biomembranes, built on Lagrangian finite-element discretization of continuum mechanics models based on large deformation shell theory, employing artificial viscosity techniques for r-adaptive remeshing for robust simulation of external loadings and large membrane deformations. I will then focus on two applications of the framework for understanding cellular membrane structure. First, I will discuss a systematic method for using membrane shape (as determined by microscopy or tomography) as a reporter for applied forces. By modeling observed biomembrane shapes as fluid lipid bilayers in mechanical equilibrium, the externally applied forces as well as the pressure, tension, and spontaneous curvature can be computed directly from the shape alone. To illustrate the potential power of this technique, I will present the results of experimental application of an axial force with optical tweezers to vesicles, explicitly demonstrating that the applied force is equal to the force computed from the membrane conformation. Next I will turn attention toward understanding mechanical stability and interactions for phase-separated membrane domains, known as “lipid rafts.” Presenting results of a combination of mechanical modeling and in vitro experiments, I will show how lipid domains can buckle into a dimpled morphology, which facilitates a repulsive interaction that slows coalescence and helps regulate domain size and tends to laterally organize domains in the membrane.

Bio: William Klug is an Associate Professor in the Mechanical and Aerospace Engineering Department at UCLA, where he has been since 2003. He received a B.S. in Engineering Physics from Westmont College in 1997, a M.S. in Civil Engineering from UCLA in 1999, and a Ph.D. from Caltech in 2003. He is the recipient of a 2007 NSF CAREER award. Professor Klug's primary scientific background is in continuum and computational modeling of the mechanics of solids and structures. He has particular experience and interest in the development of numerical methods for modeling thin beam- and shell-like structures, and in the application of those methods to multi-scale and multi-physics problems in biology, including mechanics and assembly of viruses, mechanics of cell membranes, mechanics of DNA, mechanics of cytoskeletal networks, and electro-mechanics of the heart.