UC Irvine Samueli
Department of Chemical and Biomolecular Engineering

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Multiscale Dynamics of Neuronal Bioelectricity

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Abstract: Electrical signaling in nerve cells underlies the formation of thoughts, the control of movement, and the storage of memories. Classical mechanistic models, most notably the equivalent circuit framework pioneered by Hodgkin and Huxley, have been central to our understanding of bioelectricity. However, these models treat the living membrane as composed of lumped electrical elements, missing key physics: the localized (nanoscale) nature of ion transport through specialized channels and pumps; diffuse charge reorganization at membrane interfaces; and the deformable nature of the lipid bilayer, which enables coupling of electrical and mechanical effects.

In this seminar, I will present recent and ongoing work in collaboration with Prof. Kranthi Mandadapu and our junior colleagues, which explores the electrochemical response of neuronal membranes with diverse geometries under localized ionic currents and applied electric fields. I will describe how dielectric mismatch, capacitive effects, and membrane geometry can shape long-range signal propagation, complex spatiotemporal dynamics, and mechanically induced instabilities resulting from ion channel currents. By combining analytical theory with multiscale simulations, we are attempting to develop a mechanistic framework for the coupled electrochemical and mechanical behavior of neuronal membranes at the nano and microscale. These insights open new avenues for predicting, interpreting, and potentially controlling membrane dynamics in both natural and engineered excitable systems.

Bio: Karthik Shekhar is the John F. Heil Jr Assistant Professor in the Department of Chemical and Biomolecular Engineering at the UC Berkeley. His undergraduate (IIT Bombay) and graduate (MIT) degrees are also in chemical engineering. His research as a postdoc was at the intersection of single-cell genomics and neuroscience (Broad Institute). At UC Berkeley, Karthik leads an interdisciplinary group comprising engineers, physicists, and biologists working at the crossroads of neuroscience and biophysics, combining theoretical and computational analyses with genomic and molecular biological techniques. The Shekhar group's research has been recognized by fellowships from the McKnight Foundation, Hellman Foundation, and the Glaucoma Research Foundation. He received the Douglas H. Johnson award from the BrightFocus foundation. He has received multiple teaching awards at Berkeley, including the Donald E. Noyce Prize for university-wide excellence in undergraduate teaching.

Hosted by: *Prof. Elizabeth Read*