

Key Invited

Electromagnetism of Functional Biomaterials

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The multidisciplinary field of electro-mechano-biology (EMB) requires the combined efforts of biologists, material scientists, physicists, and engineers. This is in part due to the great morphological complexity of the cellular system. The emergence of EMB was boosted by numerical simulations, which allow envisioning both fundamental discoveries for cell migration and deformation in microfluidic constrictions over a broad range of time and length scales, and technologies for cancer treatment and drug delivery vehicles. Although a few mechanisms by which cells can be electrodeformed are identified, a few recent papers highlight the potential of multiscale and multiphysics simulations that contain elements of stochasticity in heterogeneous systems to analyze the role of forces and deformation in biological systems [1-2]. These considerations make an exploration of the theoretical and phenomenological aspects of electromagnetism of functional bionanomaterials a well-motivated direction to pursue. In the EMB of cells and tissues, what matters is the range of characteristic timescales of delayed motion, which limits the applicability of electromagnetic fields. In [3], we have recently considered the role of these short- and long-term timescales in building spring-dashpot network models of cell architecture to provide a framework for studying the creep and strain relaxation of a single nucleated cell.

With this motivation, in this talk, we want to review the recent efforts of my lab and others on a very old problem, namely, how to use electricity to study and control the mechanical properties of functional biomaterials. We first briefly review results from the literature on the basic core-shell model of an individual cell as an integrated whole, and then shift the focus to relevant equations for computing the Maxwell stress tensor to interpret the cross-properties between electrical and mechanical phenomena of materials. After a brief overview of the constraints and limitations imposed by the continuum EMB analysis of cells, we report on several recent advances in EMB development for characterizing the electric behavior of two organelles depending on the scale length, for discussing prolate-oblate morphology change of a reference cell as a function of the electromagnetic frequency, and for modeling the electromechanically induced cell membrane and nuclear envelope rupture. Some other interrelated purposes are to discuss the key successes and limitations of this versatile approach to analyzing cell electromechanics. Next, we identify several subjects in EMB that are significant for the scientific community, to deepen the electromechanical analysis in each of these areas.

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References

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