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Nanoscale electromanipulation of cell membranes — Perturbation, reorganization, restoration

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Abstract

We are immersed in electric fields. Every sensation, every motion, every thought arises from a coordinated network of electrical signals — our nervous system. Electricity can kill us, it can restart our heart, it can control and energize our paralyzed limbs. Yet we know surprisingly little about the details of the interactions between electric fields and living cells. Most of what we have learned is centered on the cell membrane, the primary transducer of the energy of externally applied electric fields, and the mediator of intercellular signaling.

Of great interest are the effects of electric pulses that are intense enough to affect membranes, but brief enough that they do not cause permanent damage. This is the regime of electropermeabilization (electroporation), where we use pulsed electric fields to modify the barrier function of the membrane to allow normally impermeant pharmacological agents or genetic material to gain access to the cell interior. Applications of electroporation technology include cancer therapy, genetic engineering, and bio-industrial processing. Our investigations of electropermeabilization on the nanoscale, with the tools of molecular modeling and quantitative fluorescence microscopy, reveals an amazing biomolecular complexity, even within a few nanometers, a few nanoseconds.

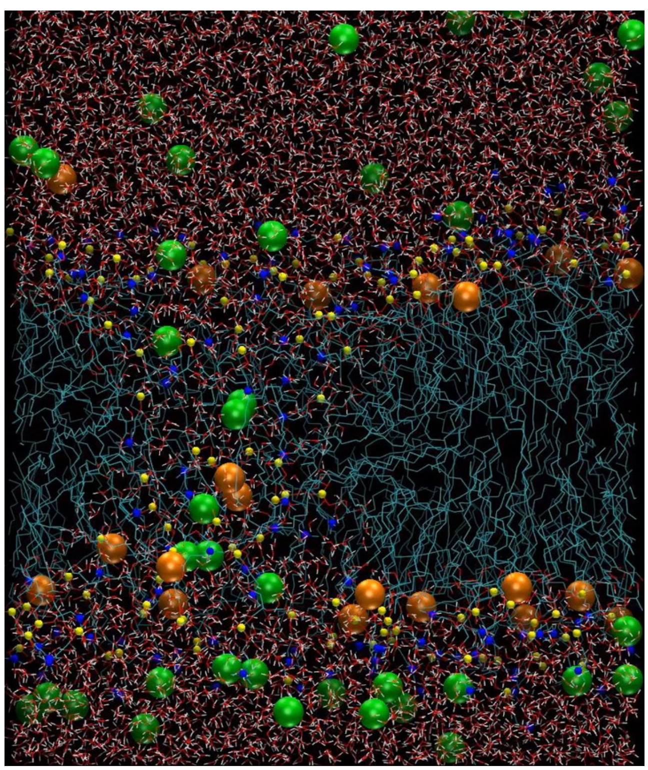

Figure 1. Calcium chloride transport through a molecular model of a lipid electropore.