Electrostriction, capacitive susceptibility, and neuromorphic computing in droplet interface bilayers.

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Biomembranes are essentially ultrathin capacitors that provide barriers needed to maintain differences in electrical and chemical potentials in cells. It is generally believed that ion channels and other pore-forming proteins embedded in biomembranes act as electrical resistors that completely control transport across the membrane, which would otherwise be impermeable to the flow of water, ions and molecules. In this picture, the biomembrane can be characterized with an equivalent *RC* circuit, with ionic currents solely controlled by the conductance (resistance) of ion channels. However, in the presence of electric fields, charges exert forces on the membrane that can significantly change membrane area and thickness and hence, capacitance in a process known as electrostriction. This results in a capacitive susceptibility that replaces the more familiar concept of constant capacitance, which, up to now, has dominated electro-physiological descriptions and characterizations of biomembranes. Electrostriction is an electro-mechanical phenomenon that encompasses both electrowetting and electrocompression, and results in large capacitive currents for small voltage inputs that can be utilized in the development of neuromorphic computing elements exhibiting both short-term and long-term synaptic plasticity.

Up to now, neuromorphic elements have been predominantly devices which simulate the resistive and capacitive behaviors needed for neural networks and brain-inspired computing, but in non-brain-like ways. We are integrating droplet interface bilayer and polymer interface technologies with micro- and nanofabrication to develop fundamentally new types of neuromorphic elements that have the composition (biomolecules), structure (biomembranes), and switching mechanism (voltage-sensitive ion channels) of real biological synapses, and operate at lower power than the current state-of-the-art. Our devices consist of insulating, nm-thick lipid bilayer or polymer-based membranes that can assemble at the interfaces of two or more aqueous droplets in oil, and that have demonstrated both memristive and memcapacitive behaviors, including memory resistance, synaptic functions such as paired-pulse facilitation and depression, and charging hysteresis.