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Bio-Inspired Energy-Converting Materials

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Ionic gradients across biological membranes are critical to maintaining physiological homeostasis. These systems serve to regulate the concentrations of ions within each cell while providing a robust platform for energy storage and release. In humans, this energy transduction facilitates ATP production, neuronal signaling and muscular contraction. The motif of gradients across membranes is present across all forms of life; due to the selective pressures of their environments, various organisms evolved to use their gradients in unique and powerful ways. This dissertation presents the development and study of three artificial systems that mimic the strategies of maintaining and using ionic gradients found in nature.

The first study presents a power source that used ionic gradients stored within hydrogels to generate electricity. This work was inspired by the electric eel, which uses the precise organization of ionic gradients within its electric organ to produce external discharges of up to 860 V.

The second study elevated this eel-inspired power source from a proof-of-concept to a practical power source for real world electronic devices. This work was inspired by the electric rays of the *Torpedo* family, which can generate approximately 10-fold higher power output than electric eels from their thin, disc-shaped electric organ.

The third study developed a temperature-controlled assay for extracting the proton permeability coefficient through lipid membranes of individual liposomes using fluorescence microscopy. This work focused on the unique lipid structures found in the membranes of extremophile archaea, which contribute to their ability to survive adverse conditions by maintaining large gradients of ions.

Evolution has produced organisms with highly specialized and powerful systems for maintaining and using ionic gradients across cell membranes. The works presented in this dissertation demonstrate how nature's examples can provide a template for the design of artificial systems. With further development, the systems described here may offer power generation and drug delivery strategies that are ideally suited for integration into the human body.

Jury:
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