Intra membrane molecular phototransducers for muscle cell stimulation

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Abstract
Life-machine interfacing holds broad potential in regenerative and therapeutic medicine, robotics, and life-enhancing technologies. Several approaches have been explored to develop functional abiotic/biotic interfaces responsive to external stimuli. In this communication, I present intra-membrane molecular transducers as a promising alternative to both genetic strategies and covalent engineering for cell opto-stimulation. Specifically, I introduce a class of molecular phototransducers based on photochromic molecules and discuss their working mechanisms in detail. Owing to their amphiphilic nature, these molecules exhibit a natural affinity for the plasma membrane, allowing their spontaneous incorporation. Upon light absorption, the phototransducers convert optical energy into an electrical signal, thereby stimulating the host cells. Through chemical engineering, we have developed distinct phototransducers capable of modulating various membrane electrical properties, including capacitance, conductance, and surface charge. Experimental results obtained in muscle cell models will be presented, alongside a simplified mechanistic model. Furthermore, a proof-of-concept actuator based on a quasi-three-dimensional electrospun scaffold seeded with C2C12 skeletal muscle cells will be demonstrated. These findings offer a new design rationale for photo-responsive systems that operate via non-covalent targeting of biological membranes, potentially advancing future life-machine integration technologies.