A Universal Cell Fate Control Platform Leveraging Extrinsic Photobiomodulation and Engineered Topographical Cues

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ABSTRACT

Regenerative medicine requires the precise control of cell fate to construct functional tissues *in vitro*, offering an alternative to organ transplantation. My background in Biomedical Engineering provided the foundation for addressing the challenge of cell differentiation control, a core requirement for tissue assembly. I joined this lab due to its pioneering work on using physical cues, specifically the synergistic effect of Extrinsic Photobiomodulation (EPM) and topographical cues, to direct stem cell differentiation without relying on specialized chemical factors.

Our preliminary data demonstrated that this novel, chemical-free method effectively induces Human Umbilical Cord Wharton's Jelly Mesenchymal Stem Cell (WJ-MSC) differentiation, with the shape of the collagen microisland dictating the lineage (e.g., adipogenic, neurogenic, osteogenic). However, all prior reports were confined to MSCs. The motivation of this project is to validate this platform as a universal method applicable across the entire cell lineage map.

The current study will test this universality by applying the EPM-micropattern method to Mouse Embryonic Stem Cells (mESC) for germ layer induction and Mouse Cardiac Progenitor Cells (CPC) for generating specific cardiac cell types. To achieve this, I will develop new technical components: 1) Universal Microwells featuring selective cell-attracting and repelling coatings for enhanced cell affinity and confinement across various cell types. 2) Incorporate organ-specific collagen (extracted from porcine heart) to enhance lineage fidelity. 3) Investigate temporal modulation in the EPM protocol, based on our finding that EPM-induced differentiation is mediated by intracellular calcium redistribution, to promote cardiac maturation. Successful control over differentiation at both the pluripotent (mESC) and progenitor (CPC) levels will establish this as a potent, universal tool for generating any cell type, signifying a major breakthrough for both tissue engineering and developmental biology.

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