Bio-inspired Ice-Control Materials for Cryopreservation of Cells and Tissues

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Cryopreservation is the process of preserving biological samples, such as cells, tissues, and organs, at ultra-low temperatures to halt metabolic activity, enabling long-term storage and recovery upon thawing. It plays a critical role in cell therapy, regenerative medicine, and organ transplantation. However, the high-water content (70%-90%) in biological samples makes them susceptible to damage during cooling and thawing due to ice crystal formation, osmotic imbalance, and excessive solute accumulation. Traditional methods rely on organic cryoprotectants like dimethyl sulfoxide (DMSO) to prevent ice formation, but these are cytotoxic and unsuitable for preserving tissues and organs. Ice-binding proteins (IBPs) from cold-adapted organisms offer a promising alternative by preventing freezing damage through precise control of ice nucleation and growth. Understanding the mechanisms of IBPs has inspired the development of biomimetic ice-control materials as safer and more effective cryopreservatives. My lecture will present our recent findings on IBPs, the design of biomimetic ice-control materials, and their application in cryopreservation, along with future strategies for improving preservation outcomes.