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A mathematical framework for developing freezing protocols in cryopreservation MOHIT DALWADI, SARAH WATERS, HELEN BYRNE, IAN HEWITT, University of Oxford — Cryopreservation is the process of preserving biological constructs by cooling to temperatures low enough to halt biochemical processes, such as metabolism. This allows biomaterials to be kept in 'suspended animation', with important applications in tissue engineering, fertility, and food security. However, many freezing protocols have low recovery rates. In general, cooling too quickly results in the formation of lethal intracellular ice, while cooling too slowly amplifies the toxic effects of the cryoprotective agents (CPA) added to limit ice formation.

In this talk, we present a mathematical model for cryopreservation to understand and quantify these observations. We consider a system consisting of three different regions: ice, extracellular liquid, and intracellular liquid. The two interfacial boundaries separating the three phases can move and must be determined as part of the solution. The presence of CPA lowers the freezing point of the system, and the cell membrane moves due to the osmotic pressure difference across the membrane. We introduce two metrics to characterize the cell damage caused by freezing, accounting for supercooling and CPA toxicity. Given cell properties, we show how these damage metrics can be used to predict an optimal cooling rate.

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