Contribution ID: **234** Type: **Talk (17 + 3 min)**

Understanding membrane damage during freezing using neutron scattering

Wednesday 22 March 2023 17:20 (20 minutes)

The removal of water from biological tissue by desiccation or freezing is associated with dramatic changes to membrane structure, often leading to cellular (and organismal) death. We now understand that much of the damage to under these conditions is physical, rather than biochemical. The maintenance of membrane structure is vital for cellular function, but these structures can be affected by relatively small changes in temperature and/or hydration, leading to phase transitions, loss of semi-permeability and cell death. In nature, some organisms have evolved methods to reduce damage, including accumulation of small sugars which can reduce dehydration and encourage glass formation. By contrast, artificial cryopreservation relies on the addition of membrane penetrating cryoprotectants such as DMSO. Both types of molecules affect membrane structure, but the interactions, and therefore cryoprotective mechanisms, are different. Over the past two decades we have applied a range of scattering techniques, including SAXS, SANS and neutron membrane diffraction, to understand the interactions between cryoprotective molecules and lipid membranes. In this paper we present an overview of this research and use this to contrast the different modes of action of the two classes of cryoprotective molecules. The wider implications for our understanding of cryopreservation will be discussed.

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Session Classification: Bio-inspired Soft Matter Systems

Track Classification: Soft Condensed Matter