Ice Shaping in Solutions of Ice-Binding Proteins – Melting vs. Growing Morphologies

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A fundamental property of ice-binding proteins (IBP) is their ability to shape ice crystals in distinguishable forms characteristic of the particular protein type. IBPs with moderate thermal hysteresis activities induce elongated bipyramidal crystals – often with well-defined facets - while hyperactive IBPs produce more varied crystal shapes, such as the "lemon-like" crystals typically observed with *Tenebrio molitor* IBP. These unique morphologies are frequently considered to be growth shapes. We conducted a systematic study of ice shaping in solutions containing a wide range of IBPs. Ice crystals in solutions of moderate IBPs do indeed grow into their faceted shapes, but in the presence of most hyperactive IBPs, ice melts into its final crystal shape. We suggest that these melting shapes result from the affinity of the hyperactive IBPs for the basal plane of ice. The ability of most hyperactive IBPs to block growth in all directions precludes the possibility of controlling crystal shape during growth. Nevertheless, IBPs influence the melting velocity of ice surfaces, and therefore these proteins dictate the final shape of the melted crystal. To confirm that ice shaping can be obtained during melting, a simulation of a melting process was performed using a 3D geometric model and a velocity profile that reflects slow growth or melting perpendicular to the basal plane. The shape of the final crystal obtained in this simulation indeed resembles the experimental observations. Our results show a clear difference in the ice shaping mechanisms of moderate and hyperactive IBPs. This study implies that growth and melting patterns of ice in IBP solutions provides essential insights on the process of ice recognition by these proteins.

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