Biophysics and biochemistry at low temperatures

Freeze, freeze, thou bitter sky,
That dost not bite so nigh
  As benefits forgot:
Though thou the waters warp,
Thy sting is not so sharp
  As friend remember'd not.

As You Like It
William Shakespeare

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Foreword

Cold is the fiercest enemy of many forms of life. This is due partly to the general slowing down of physiological processes at suboptimal temperatures, but mainly to the fact that the essential chemical of life – water – happens to freeze at a temperature which is widespread in the ecosphere. The freezing of tissue water and the resulting freeze concentration of all soluble matter can have devastating consequences, unless the organism is properly prepared to resist the physiological stresses.

There exists a vast literature describing the symptoms of cold injury and the metabolic and morphological changes which various forms of life undergo during the cold hardening period. The connection between injury and survival on the one hand, and the temperature induced changes in the aqueous substrate on the other, is seldom considered. The physical properties of water are extremely sensitive to changes in temperature and changes in the concentrations of dissolved solute species. Such sensitivity may well be amplified in the responses of biological structures and life processes to changes in the hydrogen bonding patterns that exist in water.

During the past six years my colleagues and I have been engaged in studying the responses of *in vitro* and *in vivo* systems to low temperatures, and we have come to realize the interplay of a wide range of principles and disciplines: the mysteries of undercooled water, the *in vivo* nucleation and propagation of ice, both spontaneous and catalysed, cold labile proteins, the properties of concentrated aqueous solutions, especially those of carbohydrate origin, cryobiochemistry, biological antifreezes and biogenic nucleation catalysts, cold hardening mechanisms, laboratory cryobiology, cell membrane energetics and dynamics, and others.

I thank the cloud physicists who taught me about undercooled water, the metallurgists who taught me about nucleation in condensed systems, the haematologists who explained the intricacies of the red cell membrane,

the insect physiologists who cleared up my misconceptions about the developmental stages of insects and the many others who helped me to synthesize my own ideas about causes and effects in low temperature injury and resistance. I thank them all.

The approach adopted in this book is that of one trained as a physical scientist who drifted into the life sciences fairly late in life and never received any formal teaching in biological dogma. The vocabulary is hard to assimilate and even harder to memorize. The book developed from a lecture course which I gave in the Department of Botany several years ago. It is by no means a comprehensive account of the subject. Its purpose is to sketch out the overlapping areas and disciplines where the interested student must search for solutions to the many unresolved problems.

Cambridge, 1985