A VIEW OF BIOHEAT TRANSFER THROUGH THE MICROSCOPE

Diller, Kenneth R.
Department of Biomedical Engineering
The University of Texas at Austin, USA

Abstract. Bioheat transfer is encountered in many medical situations, including trauma, surgery, disease diagnosis, and therapy. Heat transfer in living systems embodies novel features based on the unique physiological properties of cells and tissues. Processes such as convective transport with blood perfused through a vascular network, laser surgery, and tissue freezing require special approaches to analysis and solution. As the role played by heat transfer in dictating tissue response to temperature extremes is more full and accurately described it becomes possible to design process protocols to manipulate the state of living tissues to achieve medical objectives. A mechanistic understanding of these phenomena often must be gained at the level of the basic building blocks of living tissues: the individual cells and molecules. The light microscope can be adapted to allow real-time imaging of the dynamics of the cellular response to various forms of both high and low temperature thermal stress. Although the first attempts at using a microscope to investigate the response of cells to thermal stress were reported nearly two centuries ago, it was not until recent advances in instrumentation, control theory and engineering design that repeatable quantitative data could be obtained. Representative phenomena uniquely observed and measured at high and low temperatures include microvascular responses to burn injury, laser-tissue interaction mechanisms, heat shock protein production by gene expression, the thermal conditions prerequisite to intracellular ice formation, nucleation and crystallization of solid ice phases, transient volume alterations and shape deformation in cells during freezing and thawing, chemical segregation and phase interface morphology during solidification, and membrane transport of water and cryoprotective additives at subfreezing temperatures. Special microscopy techniques such as 3-D confocal and fluorescent imaging may be implemented to enhance the ability to visualize and measure key events. Examples will be shown of the application of this knowledge in medical practice.