NANOPHYSICAL APPROACHES TO BIOLOGICAL SYSTEMS

In perusing this special issue of *Physics in Canada*, you may wonder *"what is biology doing in a physics journal?"* To answer this question, one must realize that the field of biology is undergoing a revolution in which emergent collective behaviours of *molecules* take center stage. A major thrust of twenty-first century physics is to achieve a deep understanding of the form and function of these molecular collectives and to address fundamental questions such as *"what is life?"*. These challenges run as deep as those about the origin of the universe, and are as fundamental as those about the indistinguishable nature of quantum particles.

While biological and biochemical assays have traditionally been used to identify biomolecules and binding between biomolecules, theoretical and experimental tools from the domain of *nanoscale physics* can provide new insights into our understanding of the structure, dynamics and self-assembly of biological molecules and systems. In the wet, squishy, and highly fluctuating interior of the living cell, entropic confinement plays a key role in determining molecular motions and shapes. The precise and robust nature of cell division can be understood using the languages of out-of-equilibrium statistical mechanics and phase-transition theory. The stochastic playgrounds of biological molecules are qualitatively estranged from the land of Newton's cannonballs and inclined planes and Carnot's heat engines, and are typically missing from introductory physics curricula.

We hope that this issue reveals how the field of biological physics is rich with new paths in statistical mechanics, polymer physics, and soft matter. Pioneering work in these areas of physics depends on multiple perspectives offered by physical, biological and health scientists. These multidisciplinary collaborations integrate directly with the diagnostics, biotechnology and pharmaceutical industries.

This issue features articles from just a small subset of the excellent Canadian researchers applying nanoscale physics to biological systems. Some of the articles address questions of understanding this nanoscale world in terms of thermodynamic concepts: the importance of entropy and confinement (Sabrina Leslie and colleagues); mapping free energy surfaces of unfolding proteins and nucleic acids (Michael Woodside); and developing theoretical tools and experimental approaches to understanding the operation of nanoscale machines (Aidan Brown and David Sivak, and Chapin Korosec and Nancy Forde, respectively). Others demonstrate how new imaging technologies are pushing our understanding of molecular dynamics and organization within cells (Joshua Milstein and colleagues) and are providing insight into nanoscale mechanics of assembled protein materials (Laurent Kreplak and colleagues). Finally, three articles explore the transition of nanoscale biophysics from the research laboratory to "real-world" applications: the use of solid-state nanopores for sequencing nucleotides (Vincent Tabbard-Cossa and colleagues); the discovery, development and commercialization of a unique plant-based biomolecule for personal care and biomedical applications (John Dutcher and colleagues); and advice on commercializing research technology in Canada (Andre Marziali).

The message of this issue, especially to the youngest and most curious physicists into whose hands this issue has fallen, is that there is *plenty of work to be done by physicists – theoretical, experimental and technological – to get to the bottom of life's mysteries*. There is an abundance of fascinating physical principles and tools to explore, develop, and use in the context of open biological questions and open biotechnology challenges. Squeezing, pulling and probing single molecules can create paradigm shifts of understanding, which can open up new directions in biotechnology, a thrust which is supported by the growing Canadian entrepreneurial scene. To educators, we hope that the research and education articles in this issue will lead to more focus in our classrooms and laboratories on these exciting new areas of physics research.

We invite you to read the articles in this issue written by Canadian leaders in different areas of biological physics. We hope that they will inspire and inform the next generation of scientists and technologists, and help you to see how nanoscale physics can be used to advance our understanding of the richness and complexities of life.

Sincerely,

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Guest Editors

Comments from readers on this Foreword are more than welcome.

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