Princeton University – Department of Physics Graduate Program Personal Statement

I strive to use the analytical tools of physics to gain a new perspective on problems in the life sciences. I have pursued this at McGill by complementing my research experiences in the life sciences with a rigorous and quantitative approach to science through a Joint Honors degree in Mathematics and Physics. With research experiences in both theory and experiment, I now aim to strengthen my foundation by tackling a challenging puzzle at the interface of physics and biochemistry at the graduate level.

My fascination with the epigenetic principle, namely that our traits are not fixed by our DNA and can be heritably altered by our environment through methylation, landed me in Professor Moshe Szyf's lab at McGill in freshman year. Under conditions of environmental stress and diseases such as cancer, methyl groups bound to DNA nucleotides serve as an additional layer of gene regulation. Thus, efficient detection of DNA methylation sites will prove to be a crucial component of personalized medicine. Professor Szyf's proposal to combine Professor Walter Reisner's expertise in single-molecule DNA manipulation with his methylation analysis techniques gave me the opportunity to work in both of their labs simultaneously after my sophomore year. In Professor Szyf's lab, I purified our protein of interest, then optimized and imaged its binding to methylated DNA using Total Internal Reflection Fluorescence microscopy in the Reisner Lab. I submitted this work for my Honors Research Thesis and presented at three conferences, receiving a departmental award and nomination to the Canadian Undergraduate Physics Conference. Working in two labs, four city blocks apart, highlighted to me the importance of collaborative, interdisciplinary research. I want to challenge myself with even more demanding opportunities in graduate school.

This past summer, I worked with Professor Michel Gingras at the University of Waterloo on spin ice physics. When cooled to absolute zero, both water ice and spin ice exhibit Pauling's residual entropy. The Kycia group in Waterloo had previously measured the specific heat of a spin ice – dysprosium titanate – using extremely long relaxation times and found this entropy to be eliminated, contradicting the 'spin ice' moniker of the material. We sought to explain their unusual results with the generalized Dipolar Spin Ice Model. My role was in developing a cumulant expansion technique to accelerate Monte Carlo simulation times and test a wide range of parameter values. We concluded that the model could not account for this new experimental data, leading us to propose a stuffing mechanism in which some dysprosium ions replace titanium ions. This would lift the ground state degeneracy, enabling entropy to be eliminated, consistent with Kycia's observations. In the autumn, I presented this work through talks and posters, receiving prizes at departmental, faculty-wide, and national conferences (including First Prize at the Canadian Undergraduate Physics Conference). Collaborators at McMaster University and Cornell University are currently planning a follow-up experiment to test whether our model of the stuffing mechanism accurately describes spin ice structure. This interplay between theory and experiment demonstrated to me the importance of constructing experimentally verifiable theories. The judicious application of quantitative tools to physical systems has an intrinsic elegance and value, and I want to continue my training in such approaches.

Currently, I am working on the problem of protein-protein interaction over long distances. I became interested in this when my former supervisor, Professor Jürgen Sygusch at the University of Montreal, alerted me to an improbable candidate for a solution – the Resonant Recognition Model. Surprisingly, assigning ionization potentials to amino acid sequences and computing their cross-Fourier transforms is an extremely accurate method of predicting protein-protein interactions at the level of side-chain 'handshakes'. However, there exists no physical explanation for why this should work. As with Professor Szyf's proposal, I could not resist the opportunity to return to the Sygusch Lab, having honed my skills in physics, to work on a highly relevant problem in biochemistry for my senior-year Honors Research Project. At present, we have verified the model's prediction accuracy for both structured and unstructured proteins, and I am applying the transition dipole coupling theory of long-range interaction to establish a solid physical basis for this model. Applying my training in quantum mechanics and electrodynamics to address this rich biophysical problem both motivates and affirms my enthusiasm for graduate research in this field. I have been selected to receive full funding to present my results-to-date at an international conference at the King Abdullah University of Science and Technology in January 2013, and look forward to verifying our predictions through experimentation next semester.

As I am pursuing a career in academia, graduate school is a natural next step. I also thoroughly enjoyed my role as a teaching assistant for an Honors Complex Variables course this year, and graduate studies will further develop my teaching and communication skills. Ultimately, I am eager to focus my research efforts on an outstanding problem, and the Princeton University Graduate Program in Physics offers many such opportunities. I have already contacted Professor Robert Austin to see how best to apply my experience with single-molecule techniques and theoretical physics to unravel the mechanics of cancerous cells. I have also contacted Professor William Bialek, whose work on genetic and neural networks directly aligns with my research interests. Finally, Professor Joshua Shaevitz's Lab presents exciting opportunities to do experimental and theoretical studies of collective cellular behavior. Probing fundamental questions with balanced prongs of theory and experiment is what fascinates and motivates me. Such a scientific journey in Biophysics at Princeton is compelling.

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