Matthew Leighton

Curriculum Vitae

Education

2020–Present **Ph.D. in Physics**, *Simon Fraser University*, Burnaby, Canada

2016–2020 **B.Sc. Honours in Physics and Mathematics**, *Dalhousie University*, Halifax, Canada
- **Honours Thesis:** *Modelling the Formation of Cross-Linked Collagen Fibrils*, supervised by Prof. Andrew Rutenberg.
- Middle-Distance Runner with the Varsity Track Team (2016-2018)
- Choral Scholar with the University of King's College Chapel Choir (2016-2020)

2019 **Exchange Program, Mathematics, Statistics, and Finance**, *Chalmers University of Technology*, Göteborg, Sweden

Experience

Research

2020–Present **Graduate Researcher**, *Sivak Group*, Simon Fraser University
Working under the supervision of professor David Sivak, analyzing biological molecular machine systems using the theory of nonequilibrium statistical mechanics. Projects include exploring performance trade-offs in intracellular transport systems, and investigating information thermodynamics in multipartite stochastic systems.

2018–2020 **Undergraduate Researcher**, *Rutenberg Group*, Dalhousie University
Worked with professor Andrew Rutenberg on various research projects in theoretical biophysics using computational and mathematical methods. Projects included modelling stochastic effects in the process of host cell invation by *S. Typhimurium* bacteria, developing a theoretical model for the thermodynamics of *in vivo* Collagen fibril growth, and studying the mechanics of double-twist liquid crystal elastomer systems under deformation.

Teaching and Outreach

Fall 2022 **Teaching Assistant**, *PHYS 801: Grad Student Seminar*, Simon Fraser University
- Responsibilities running peer review sessions and providing feedback on graduate student research presentations.

Spring 2022 **Organizer**, *Frontiers in Biophysics 2022*, Vancouver, Canada
- Member of the organizing committee for Frontiers in Biophysics 2022, a conference run by and for graduate students in biophysics and related areas in the Pacific Northwest.
- Conference was held in person in downtown Vancouver, with 85 attendees.

Fall 2021 **Teaching Assistant**, *PHYS 132: Physics Laboratory I*, Simon Fraser University
- Responsibilities included helping to run the lab sessions and grading lab reports.
- Received the Fall 2021 Physics TA Teaching Award for outstanding teaching efforts.

Fall 2021 **Teaching Assistant**, *PHYS 344: Thermal Physics*, Simon Fraser University
- Responsibilities included leading tutorials and grading assignments.

Summer 2018,2019 **Science Outreach**, *Dalhousie University*, Halifax, Canada
- Led interactive physics experiment demonstrations as part of the Discovery Days outreach program for elementary and high school students.

Other

2017–2018 **Business Analyst**, *Inetco Systems LTD*, Vancouver, Canada
Responsibilities included:
- Financial modelling and analysis,
- Managing marketing campaigns, and
- Communicating product requirements to the software development team.

Started as a summer co-op student, and stayed on as a part time consultant over the next year.

Summer 2015,2016 **Bicycle Instructor**, *Pedalheads*, Vancouver, Canada
- Taught children aged 4-13 beginner to advanced biking skills.

Volunteer Coach
- Head coach for a Vancouver Hawks youth field hockey team (Spring 2015/16/17)
- Assistant coach for Kitsilano Secondary School's junior ice hockey team (2015-2016)

Publications and Manuscripts

M.P. Leighton, D.A. Sivak, "Dynamic and Thermodynamic Bounds for Collective Motor-Driven Transport", *Physical Review Letters,* **129**:118102, 2022

M.P. Leighton, D.A. Sivak, "Performance Scaling and Trade-offs in Collective Motor-Driven Transport", *New Journal of Physics*, **24**:013009, 2022

M.P. Leighton, A.D. Rutenberg, and L. Kreplak, "D-Band Strain Underestimates Fibril Strain for Twisted Collagen Fibrils at Low Strains", *Journal of the Mechanical Behavior of Biomedical Materials*, **124**:104854, 2021

M.P. Leighton, L. Kreplak, and A.D. Rutenberg, "Chiral Phase-Coexistence in Compressed Double-Twist Elastomers", *Soft Matter*, **17**:5018, 2021

M.P. Leighton, L. Kreplak, and A.D. Rutenberg, "Nonequilibrium Growth and Twist of Cross-Linked Collagen Fibrils", *Soft Matter*, **17**:1415, 2021

Selected Talks and Posters

Talks

June 2022 **Dynamic and Thermodynamic Bounds for Collective Motor-Driven Transport**, *Frontiers in Biophysics 2022*

May 2022 **Dynamic and Thermodynamic Bounds for Collective Motor-Driven Transport**, *Workshop on Stochastic Thermodynamics III*

June 2021 **Scaling Laws and Performance Trade-offs for Collective Transport**, *Frontiers in Biophysics 2021*

November 2020 **Structural Phase Transitions in Double-Twist Elastomers**, *Collagen Cafe II*

July 2020 **Nonequilibrium Growth of Cross-Linked Collagen Fibrils**, *Collagen Cafe I*

June 2020 **Elastomeric Properties of Double-Twist Collagen Fibrils**, *Soft Matter Canada Symposium*

March 2020 **Modelling Cross-Linking in Collagen Fibrils**, *APS March Meeting (via DSOFT Virtual Meeting)*

January 2020	**Coarse-Grained Structure of Double-Twist Liquid Crystals**, *Atlantic Undergraduate Physics Conference* **Selected for award – top theory talk.**
November 2019	**Modelling Cross-Linking in Collagen Fibrils**, *Canadian Undergraduate Physics Conference*
August 2018	**Stochastic Modelling of Cellular *Salmonella* Infection**, *Dalhousie Bioblast Symposium*

Posters

April 2022	**Dynamic and Thermodynamic Bounds for Collective Motor-Driven Transport**, *SFU Physics Department Poster Session*
May 2021	**Scaling Laws and Performance Trade-offs for Collective Transport**, *Biophysical Society of Canada Annual Meeting* **Selected for poster award.**
February 2021	**Performance Trade-offs in Cooperative Intracellular Transport**, *SFU Physics Department Poster Session*

Selected Awards

2022	**Hargreaves Scholarship**, *Simon Fraser University*
2022	**Howard Malm Graduate Scholarship**, *Simon Fraser University*
2022-2025	**NSERC CGS-D**, *Simon Fraser University*
2021	**TA Teaching Award (PHYS 132)**, *SFU Physics*
2021	**Kirk H. Michaelian Graduate Scholarship**, *Simon Fraser University*
2021	**Poster Award**, *Canadian Biophysical Society*
2020–2021	**NSERC CGS-M**, *Simon Fraser University*
2020–2021	**BC Graduate Scholarship**, *Simon Fraser University*
2020	**NSERC USRA**, *Dalhousie University*
2020	**Top Theory Talk**, *Atlantic Undergraduate Physics Conference*
2018	**NSERC USRA**, *Dalhousie University*
2016–2020	**Chancellor's Scholarship**, *Dalhousie University*
2016–2020	**Helen Roby Choral Scholarship**, *University of King's College*
2017–2018	**USports Academic All-Canadian**, *Dalhousie University*
2016–2017	**USports Academic All-Canadian**, *Dalhousie University*
2016–2020	**Dean's List**, *Dalhousie University*

Languages and Technical Skills

- **Languages:** English (Native), French (Fluent)
- Extensive experience with scientific programming and numerical optimization in Python
- Experienced in the use of Compute Canada computing clusters
- Working knowledge of MATLAB, Mathematica, and HTML

Miscellaneous Qualifications

Grade 8 Piano, Advanced Music Theory, *Royal Conservatory of Music*

DELF B2, *French language Certification*
CSIA Level 1 Ski Instructor, *Canadian Ski Instructors Alliance*
AST 1 Avalanche Skills, *Avalanche Canada*
Emergency First Aid, CPR-C, and Bronze Cross, *Canadian Lifesaving Society*
Cansail 4, *Sail Canada*

Overview of Research

My research is focused on understanding the behaviour and performance of *molecular machines*, nanometer-scale protein complexes which carry out important functions within cells. Countless molecular machines are in constant motion within each cell of every plant and animal on earth. They convert between different types of energy (e.g., chemical, electrical, and mechanical), transport materials, and assemble complex structures. Molecular machines are wildly different from the everyday machines we're used to interacting with: they have no inertia (can't coast), and their movements are dominated by random fluctuations – they do useful work only on average.

Despite their bewildering differences from human-scale machines, we can nonetheless study them using the framework provided by the laws of physics. Macroscopic machines like engines and refrigerators are governed by the theory of classical thermodynamics, which describes how energy flows through these machines in the form of work and heat, and gives insight into how to best design optimal versions. The theory of *stochastic thermodynamics* has been built up over the last 20 years to bring these same concepts of work, heat, and energy to randomly fluctuating nanoscale objects like molecular machines. Within the theoretical framework of stochastic thermodynamics, we aim to understand both how existing biological molecular machines have evolved to optimize their performance, and to uncover design principles for the future development of synthetic nanoscale machines. We then ground our theoretical ideas with computer simulations as well as frequent comparisons with *in vivo* experiments.

In addition to the unique features described above, biological molecular machines frequently coordinate their actions and work collectively to achieve larger common goals. Most important tasks within cells are accomplished by many molecular machines working together, with numbers ranging from only a handful to several hundred molecular machines. The main thrust of my research is to better understand how molecular machines interact with each other to optimize their collective performance. As an example, my supervisor David Sivak and I recently published a paper outlining a mathematical framework for modelling the collective operation of molecular *transport motors*, a class of molecular machines that burn chemical "fuel" to move important cargo within cells. We found that the number of motors used to transport a given cargo can be tuned to optimize their performance, either maximizing their efficiency or speed of operation depending on the context.

The main applications of my research are twofold. First, we aim to improve our basic understanding of existing biological molecular machines that work constantly to accomplish a wide range of tasks within the human body. The malfunctioning of these machines, in particular failures of coordination between collections of molecular machines that are supposed to work together, has been linked to a number of different human diseases including various cardiomyopathies, mitochondrial disorders, and neurodegenerative diseases like Alzheimers. I believe that a better understanding of the inner workings of molecular machines will help lead to new insights on how to treat these diseases. Secondly, I believe that nanotechnology will play an increasingly large role in clinical medicine in the coming decades. Swarms of nanoscale machines may be well-suited to complex-yet-critical tasks such as drug delivery and tissue repair. My work takes a first step towards understanding how nanoscale machines can work together to achieve a common goal, ultimately uncovering design principles that will be essential for the future engineering of such medical nanomachines.