Mathematical modeling of energy transfer and mechanics in the heart

Summary

In heart muscle cells, energy used by most of the processes in the muscle cells is supplied in the form of ATP by mitochondria. Within this project, you would be designing state-of-the-art mathematical models to unravel mechanisms regulating ATP production in mitochondria, selection of energy transfer pathways between mitochondria and ATP consumers, as well as working on mechanistic models of chemical energy conversion into mechanical work by actomyosin. As you will be working in an interdisciplinary laboratory you will have access to the experimental data measured on-site and will be given the opportunity to design and participate in the experimental work to support your research.

Research field:	Applied physics and mathematics
Supervisors:	Prof. Dr. Marko Vendelin Dr. Martin Laasmaa
Availability:	This position is available.
Offered by:	School of Science Department of Cybernetics
Application deadline:	Applications are accepted between June 01, 2022 00:00 and June 30, 2022 23:59 (Europe/Zurich)

Description

In heart muscle cells, energy used by most of the processes in the muscle cells is supplied in the form of ATP by mitochondria. Within this project, you would be designing state-of-the-art mathematical models to unravel mechanisms regulating ATP production in mitochondria, selection of energy transfer pathways between mitochondria and ATP consumers, as well as working on mechanistic models of chemical energy conversion into mechanical work by actomyosin.

In the work related to mitochondrial ATP production and energy transfer, you will design a mathematical model of mitochondrial oxidative phosphorylation and take into account the known regulatory mechanisms of different processes involved. Using large datasets collected on wild-type and genetically modified animals, you will be able to pinpoint the changes in regulation of oxidative phosphorylation that would be consistent with the experimental data. We expect that through understanding energy transfer and mitochondrial regulation under different conditions, we can learn about possible adaptations of the related processes to the challenges induced by disease as well.

In the work related to actomyosin contraction and its use of chemical energy, you will engage in the development of mathematical modelsdescribing mechanical contraction and its ATP requirements. We expect to combine energy transfer and actomyosin models into one, allowing you to work on the interaction between mechanics and energetics in the heart. From this work, you would contribute to the field in multiple ways including mechanistic research of mechanical contraction and its regulation in health and disease.

Since you will be working in an interdisciplinary laboratory, you will have access to the experimental data measured on-site and will be given the opportunity to design and participate in the experimental work to support your research. We have an extensive range of equipment and well-established experimental protocols available in the laboratory, including biochemical and single-cell microscopy approaches.

Responsibilities and (foreseen) tasks:

- Development of mathematical models of
  - energy transfer, mitochondrial respiration
  - actomyosin mechanics and energy consumption
- Combining the developed mathematical models as required to answer research questions
- Data analysis and fitting by the models
- Design of new experiments required to distinguish between possible alternative hypotheses
- Writing academic papers

- Presenting the results in international meetings
- Supervision of junior students
- Participation in the teaching of the courses given by the laboratory

Applicants should fulfil the following requirements:

- a master’s degree in relevant field
- a clear interest in the topic of the position
- programming in Python or C++
- excellent command of English
- strong writing skills (English) that are compatible with doctoral-level requirements
- capacity to work both as an independent researcher and as part of an international team
- capacity and willingness to provide assistance in organizational tasks relevant to the project

The following experience is beneficial:

- Experience with development of mathematical models
- Experience with solving numerically ODEs and/or PDEs
- Working knowledge of SQL
- Working knowledge of statistics and statistical software
- Working with cells

We offer:

- Fully funded 4-year PhD position in one of the largest universities in Estonia
- The chance to do high-level interdisciplinary research in a supporting environment
- Great opportunities for self-development
- Opportunities for conference visits, research stays and networking with globally leading research centers in the field

About the department

The Laboratory of Systems Biology is a part of the Department of Cybernetics, School of Science, Tallinn University of Technology.

The main aim of the laboratory is to study regulation of intracellular processes and understand functional influences of intracellular interactions.

We use interdisciplinary approaches to tackle questions in cardiac physiology. For that, we have formed a team of researchers with backgrounds in biophysics, biology, and applied mathematics/physics. As a result, we are able to approach scientific questions on different scales, from organ to molecular level, using combinations of different experimental and theoretical techniques. When needed, we find new ways to characterize the data, develop new mathematical models, build new hardware, and program it to carry out novel experimental protocols.

Additional information

For further information, please contact Prof Marko Vendelin <markov@sysbio.ioc.ee> or Dr Martin Laasmaa <martin@sysbio.ioc.ee> or visit https://sysbio.ioc.ee.

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