Exploring New Boundaries in Nonequilibrium Biophysics

University of Michigan Graduate Student Gabriela Fernandes Martins and Professor Jordan M. Horowitz have made significant strides in exploring thermodynamic nonequilibrium, a foundational issue in biophysical science. In October 2023, they published their article “Topologically constrained fluctuations and thermodynamics regulate nonequilibrium response” in the journal Physical Review E garnering them special recognition as an Editors’ suggestion article.

Professor Horowitz’s lab has been investigating topics in biophysical research, focusing on understanding the general principles governing nonequilibrium behavior. Horowitz describes the biophysical phenomena his lab researches by explaining equilibrium as similar to common objects you might imagine such as “a glass of water, the air in this room, and a sheet of metal are all systems at thermodynamic equilibrium - they are motionless, static and lifeless.”

Professor Horowitz investigates the opposite, instead exploring how “much of the world around us is out of equilibrium, especially living organisms.” While we have macroscopic ideas of what these objects look like and how they feel, scientists complement this with the molecular underpinnings of matter, which drives many of the overarching questions explored in the biophysics program. Honing in on how this connects to the Horowitz lab’s research, Jordan continues:

“Today, after nearly a century of research into the physics of nonequilibrium systems, we have uncovered a rich diversity of structures and functions not possible in thermodynamic equilibrium. The processes that underpin life are probably the most dramatic, from subcellular processes like signal transduction and cytoskeletal reorganization to the swirling patterns that can occur in bacterial fluids. The possibilities are vast and the complexity seems unlimited. To rationalize this diversity of phenomena, we are in need of a theoretical framework that can guide our investigations and help us build models that describe our observations.”

In simpler terms, Professor Horowitz and his lab explore what happens when life happens – things may not be stable or predictable, but this holds the possibility for uniqueness and diversity. This goal of developing a theoretical framework to guide future investigations and the creation of new knowledge and visualizations to understand the world around us connects with the cutting-edge research in the University of Michigan Biophysics Program.

The paper at the center of this spotlight is Martins and Horowitz’s approach to understanding and elucidating the biochemical mechanisms of responding to small chemical changes, which is vitally important for living things’ ability to perform key functions, such as sensing or DNA replication. Horowitz describes their addition to the field as making this observation mathematically precise by proving inequalities that quantify the limits of biophysical sensitivity due to finite energy availability. Further, Martins and Horowitz applied this finding to understand how energy improves sensitivity in simple models of gene transcription.

A key figure in their publication illustrates the elegance of their theory by showing the sensitivity of 15,000 random kinetic models of a simple biophysical process as a function of the maximum nonequilibrium driving force (gray dots). Within the figure, you may note that all points fall below Martins and Horowitz’ predicted theoretical bound (red line). This figure not only verifies that the predictions were correct but additionally highlights the generality of their predictions applying to a number of physical situations, emphasized by 15,000 randomly sampled models all limited by their predictions.

Their findings stand out in a sea of submissions, with Physical Review E selecting their work as an Editors’ Suggestion due to its clarity, importance, and broad appeal. This distinction positions their study among a select few, placing Horowitz’s research group at the forefront of biophysical research and vision.

The University of Michigan Biophysics Program prides itself on fostering such innovative work, and Horowitz’s probing inquiries exemplify the unit’s drive to unlock the secrets of biological matter. By bridging the gap between complex scientific theories and the tangible world around us, this research paves the way for more discoveries that could have profound implications for how we understand and interact with life at its most fundamental level.
Welcome from the Director

Greetings Alumni, Friends, and Prospective Students:

I hope this message finds you well. Once again, I am delighted to speak to you in the latest edition of the Biophysics Newsletter. We are very grateful for your continued support of the Program in Biophysics. Many of you have watched the unit transform from a Research Unit within the Office of Research to a unique graduate and undergraduate program within the College of Literature, Science, and the Arts. I am excited to share the recent news and events from Biophysics.

Significant activities and happenings in Biophysics continue to involve our undergraduate and graduate students, postdoctoral coworkers, faculty, and staff. This May, we graduated the second largest class of undergraduates in the program’s history with 11; last year was the largest, and we saw 15 students moving onto the next phase of their lives and careers. It was amazing to hear from them about their plans and note their accomplishments during their studies in Biophysics at our graduation reception. We wish them all the best as they move to graduate schools, medical schools, and into the workforce.

Biophysics has continued to evolve in undergraduate education, and the program has seen an increase in the number of majors. I’m happy to report that the innovations in the Physics for the Life Sciences curriculum we were involved in with our Physics partners continue to grow. Kudos to Professors Meiners, Wood, and Yang, who contribute to teaching our students in the course. Also new in our curricular activities has been the transitioning of our pioneering Introduction to Programming in the Sciences course to become a template and core of the Program for Computing in the Arts and Sciences (PCAS) within the college that is bringing experience and learning of computer skills to the Arts, Social, and Natural Sciences. Professor Veatch has been integral to developing and teaching this new undergraduate curriculum. Equally noteworthy is the launch of our new entry-level course in the emerging major in Quantitative Biology, Introduction to Quantitative and Computational Biology. Professor Wood led this development and will serve as a bridge into courses that emphasize our strong focus on quantitative approaches in biology.

We strive to provide undergraduate students with experiential learning through research and internships beyond the research opportunities in our laboratories. This summer, we will host seven undergraduate students for 10 weeks of research experience at Michigan through the NSF-sponsored summer REU program, co-directed by Professors Zachowski and Wood, with staff support from Sara Grosky.

The Biophysics graduate students are at the core of the outstanding research taking place in our laboratories, and they continue to receive recognition for their accomplishments. In our efforts to maintain a strong and diverse graduate program, Biophysics continues to host its “Preview Program” for prospective graduate students with diverse experiences to explore Michigan Biophysics as they move toward applying for graduate school. Last fall, we hosted an excellent group of students during our annual retreat at Matthaei Botanical Gardens and Nichols Arboretum to learn about our program and the process of applying for graduate school and to network with our students, faculty, postdocs, and staff. The event was a great success. We are all excited about our incoming class of 9 new graduate students and expect to be reporting on their accomplishments in a future newsletter.

I continue to be awed by the work of the Biophysics faculty. They are addressing biophysical questions across scales – from the holistic system level, examining cells and their mutual interactions, to the molecular level, querying the structure-function relationships that govern cellular processes. Our faculty continues to be prosperous in their research and teaching endeavors and are being recognized for these efforts within the university, nationally and internationally, with awards, grants, and speaking invitations. We congratulate Professor Veatch for her induction as a Fellow of the American Physical Society and provide a shout-out yoo-hoo to Professor Horowitz, who will be promoted to Associate Professor with tenure in the fall. Affiliate Professor Bitem received the Rackham Faculty Recognition Award for her contributions to the University and scholarly endeavors, and I was honored to receive the Rackham Distinguished Faculty Achievement Award. We are pleased to welcome two new Affiliated Faculty into Biophysics, Professors Idse Heemsperker and Terra Sztain. We also note the retirement of our long-time colleague, Professor Ramamoorthy, and wish him the best in his new ventures at the National Magnet Laboratory and Florida State University. Other advances and achievements by our faculty are highlighted throughout the newsletter, and I urge you to read about our amazing faculty.

We are excited to welcome a new Biophysics Manager, Ms Alex Franklin, who is already making her mark on Biophysics with her organizational skills and experience. We are pleased she joined us and look forward to her assistance in moving Biophysics forward. We will miss Ms Sandra Moing, who retired after 54 years of service to the university and nine years of service with Biophysics. I will greatly miss her always cheerful hello!

In closing, I want to express my deep gratitude for the opportunity to serve as the Director of our Biophysics Program. I am constantly amazed by the developments of my faculty colleagues and their coworkers and the achievements of our students. Your support and engagement are invaluable, and we encourage you to continue sharing your work with us.

We look forward to a new year that surpasses our expectations from the last. If you find yourselves in Ann Arbor, please take a few minutes to visit us.

Charles L. Brooks III
Director and Professor of Biophysics
Cyrus Levinthal Distinguished University Professor of Chemistry and Biophysics
Warner-Lambert/Parke-Davis Professor of Chemistry

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This year’s Annual Biophysics Retreat was held at the Matthaei Botanical Gardens on October 20, 2023. The day’s programming comprised of six presentations from the Vecchiarelli, Walter, Aucius, Sept, Wood, and Horowitz labs, followed by a trivia game conducted by the Graduate Student Council. There were also interactive activities, such as potted plant crafting, pressed flower bookmark making, and nature walks, run by the Matthaei Botanical Gardens staff. The day concluded with an engaging poster session.

New Staff Profile

Alex Franklin, Biophysics Manager

Welcome to Alex Franklin, who joined Biophysics as the new Program Manager in January 2024! With prior experience as U-M Chemistry’s Executive Coordinator, Alex brings expertise in Faculty Academic Affairs and Human Resources, along with a tremendous amount of volunteer work to increase diversity, equity, and inclusion at U-M. We’re excited for her contributions to our unit.

Discover U-M Biophysics Video

Last June, UM Biophysics had a video produced overviewing the field of biophysics and what makes our program here at University of Michigan unique.

Scan this QR code to watch!

2023 - 24 Biophysics Seminar Series

Min Wu
Yale School of Medicine

Wade Zeno
University of Southern California

Janice Robertson
Washington University in St. Louis

Lydia Kisley
Case Western Reserve University

Steven Damo
Fisk University

Greg Alushin
The Rockefeller University

Olivier Lichtarge
Baylor College of Medicine

Katie Geiger-Schuller
Genentech Research

Angela Gronenborn
University of Pittsburgh

Melike Lakadamyali
University of Pennsylvania

Brandt Eichman
Vanderbilt University
Core Faculty News

Core Faculty Highlights & Awards

Charles L. Brooks III is the Recipient of 2023 Rackham Distinguished Faculty Achievement Award. This award honors senior faculty who have consistently demonstrated outstanding achievements in the areas of scholarly research and/or creative endeavors, teaching and mentoring of students and junior faculty, service and related activities that have brought distinction to themselves and to the University of Michigan. Only five faculty members across the University are selected for this award each year.

The Qiong Yang lab, notably enthusiastic biophysics students Sung, Kadiyala, Blanchard, and Puls, initiated new directions in embryo mechanobiology and organization. Their work, spans cell-free reconstitution, aggregated cells, pescods, and embryos, dissecting biomechanics and spatiotemporal dynamics in mitotic waves, epiboly, and somitogenesis. Kadiyala’s recent HHMI Janelia visit yielded 3D single-cell tracking data with light-sheet microscopy, pivotal for studying embryo growth and patterning. The lab acknowledges funding from the Margaret and Herman Sokol Faculty Awards through the Associate Professor Support Fund.

Sarah Veatch has been elected a Fellow of the American Physical Society for “foundational work in understanding the miscibility phase transition and associated critical phenomena in membranes, and for rigorously applying these physical concepts to biological processes.” This lifetime honor recognizes significant contributions in fundamental research, applications, education and public outreach, or service. Each year, no more than 0.5% of the APS membership may be selected as Fellows.

Retirement

Ayyalusamy “Rams” Ramamoorthy, Robert W. Parry Collegiate Professor of Chemistry and Biophysics, Professor of Chemistry, and Professor of Biophysics in the College of Literature, Science, and the Arts, and Professor of Macromolecular Science and Engineering in the College of Engineering, retired from active faculty status on July 31, 2023. Professor Ramamoorthy joined the University of Michigan faculty as an assistant professor in 1996, and was promoted to associate professor, with tenure, in 2002, and professor in 2008. His research career has brought him to prominence and recognition as a leading world expert in solid-state NMR. His research foci include the development and use of lipid-nanodiscs to study membrane proteins, amyloidosis-related protein aggregation, and anticancer peptides. Professor Ramamoorthy has taught courses in chemistry and biophysics, and developed courses in NMR spectroscopy. He served as the co-director of the Biomolecular NMR Facility (2000–2016) and the associate chair of biophysics (2012–2014). His service to the community includes a long-running online seminar series on proteinopathies and membrane proteins, begun during the COVID-19 pandemic and continuing today.

Promotion

Jordan Horowitz has been promoted to the Associate Professor with tenure ranking, effective September 1, 2024. Professor Horowitz joined our faculty in Biophysics and Complex Systems at the University of Michigan in January 2019. His independent work is in the theory of non-equilibrium statistical physics with a focus on living systems far from equilibrium and the establishment of bounds and limits on the accuracy and speed with which these processes can occur. His promotion seminar was titled “Energy and function in biophysical processes.”
Julie Biteen is the Recipient of 2023 Rackham Faculty Recognition Award. These awards are for mid-career faculty who have demonstrated remarkable contributions to the University through outstanding achievements in scholarly research and/or creative endeavors; excellence as a teacher, advisor and mentor; and distinguished participation in the service activities of the university and elsewhere. Only five faculty members across the University are selected for this award each year.

Nicolai Lehnert is part of a team of U-M researchers that has been awarded $2.1 million dollars by the National Institutes of Health to develop safer intravascular (IV) catheters. Professor Lehnert and Chemistry professor Mark Meyerhoff, working with Michigan Medicine research scientist Alvaro Rojas-Pena, are developing the technology that will incorporate a nitric oxide (NO) generating system in the catheters. Nitric oxide is naturally produced in our arteries and used by our bodies to suppress blood clotting and fight infections. The team aims to greatly reduce the number of fatalities related to blood clots and infection that occur with regular catheters.

Kristen Verhey was named as American Association for the Advancement of Science fellow for contributions to the fields of cell biology and biophysics in understanding microtubules and motors, and development of the tubulin code. Only twelve U-M faculty and staff members have been recognized by the American Association for the Advancement of Science as 2023 fellows in recognition of their extraordinary achievements. AAAS, the world’s largest general scientific society, announced that 502 scientists, engineers, and innovators have been chosen for the lifetime honor for their scientifically and socially distinguished achievements.

Terra Sztain has joined our ranks as Biophysics Affiliated Faculty. Her research integrates approaches from chemistry, biophysics, mathematics, and computer science to develop strategies for understanding dynamic biochemical systems. These methods are applied in the design of novel molecules targeted towards environmental and medical challenges. She presented her research to Biophysics faculty, students, and postdocs in a seminar titled “Dynamics and computer-aided molecular design.”

Idso Hoenskork has joined our ranks as Biophysics Affiliated Faculty. His research is focused in understanding how human pluripotent stem cells generate and interpreting the chemical and physical signals that allow them to self-organize into spatial structures consisting of multiple cell types in vitro, and, by extension to the embryo, in vivo. He presented his research to Biophysics faculty, students, and postdocs in a seminar titled “Modeling development with pluripotent stem cells.”

Annual Student Symposium in Biophysics “Seeing the Unseen: Advancing Scientific Visualization”
Friday, May 31, 2024 - Rackham Amphitheatre and Assembly Hall (4th Floor)
Graduate Program News

The Biophysics Graduate program currently has 36 students who are doing research in 15 different labs within the departments of Chemistry, Physics, MCDB, CDB, Mechanical Engineering, Life Science Institute (LSI) and Medicinal Chemistry. This year we welcomed a first-year graduate student cohort of 4 new students. These students join us with a variety of scientific backgrounds, including Physics and Chemistry.

Rackham Predoctoral Awardees

Congratulations to Biophysics Graduate Students Grace Arhin and Chia-Yu Kang for being awarded Rackham Predoctoral Fellowships in this year’s competition! This fellowship supports outstanding doctoral students who have achieved candidacy and are actively working on unusually creative, ambitious, impactful dissertation research and writing. It is one of the most prestigious awards granted by Rackham Graduate School.

The Krimm Exceptional Awards Winners

The Krimm Exceptional Dissertation Award recognizes a graduate student who defended their dissertation within the past two academic years. The 2024 Krimm Exceptional Dissertation award goes to Ziyuan Chen for his dissertation titled "Single-Molecule Mapping and Heterogeneous Dynamics of Epigenetic Modifications in Live Microbes." Ziyuan made impressive inroads as a student in Julie Biteen's lab while actively contributing to the graduate program.

The Krimm Exceptional Graduate Student Award recognizes mid-career graduate students who are actively working on dissertation projects.

The 2023 Krimm Exceptional Graduate student award goes to Sicong Ma. Sicong’s work in the Keane lab is focused on identifying structure-function relationships in microRNAs with a particular emphasis on the role that base pair mismatches play in their function. Sicong has a great start on his career path as an biophysicist with one published paper and another available via bioRxiv.

The 2024 Krimm Exceptional Graduate student award goes to Eilidh McClain. Eilidh’s work in the Sension and Penner-Han labs is focused on understanding the ways in which the organometallic coenzyme adenosyl cobalamin (vitamin B12) interacts with the protein CarH (a DNA regulatory protein) in order to modulate the reactivity of CarH. Eilidh is a co-author on three papers with a fourth paper being submitted soon.

“Molecules of Life” Student Showcase at the Museum of Natural History

Discover the connection between form and function as you explore the molecular building blocks of life. In the realm of biological macromolecules such as proteins and nucleic acids, form determines function, so visualizing the three-dimensional structures of molecules is key in researching the ‘tiny’ macromolecules that perform vital functions in our cells.

In Biophysics 421, under the guidance of Markos Koutmos, Assistant Professor of Chemistry & Biophysics, and Liz Tidwell, PhD candidate (now graduate) in Biophysics, students created models with digital modeling software and brought them to life via 3D printing. This exhibit showcases the 3D printed molecules, scaled up to better reveal the structures that inform, make, break, modify, and move within the body.

The showcase is live at the U-M Museum of Natural History from August 2023 - July 2024.
Undergraduate Program News

Our Biophysics program is growing rapidly—in 2023, we taught more than 2400 total student credit hours, more than double the number from 2020—thanks to cross-department collaborations and growing interest in popular courses, including classes in structural biology and physics-based explorations of human physiology and medicine. We’re also seeing a rise in Biophysics Majors, including a growing number of students choosing Biophysics as a second major to complement their coursework in biology or chemistry. In addition, we’ve partnered with the Program in Biology to develop a new major in Quantitative and Computational Biology, which builds on several new introductory courses focused on computational and mathematical approaches for understanding, and predicting, the behavior of living systems. Most importantly, our students are excelling—as our recent graduation reception highlighted. It’s particularly exciting to see them going on to top-rated medical schools and PhD programs throughout the country to continue their careers. Overall, we believe the next few years offer opportunities to build on this growth and position Biophysics as a central hub for cross-disciplinary education at the interface of physics, chemistry, and the life sciences.

Graduating Seniors

In 2023, the U-M Biophysics program graduated our biggest undergraduate cohort since the inception of the biophysics major with 15 graduates. During the 2024 Graduation Reception, U-M Biophysics graduated 11 students.

2023 REU Program

The Summer REU Program in Biophysics provides selected non-University of Michigan undergraduate students from around the US an opportunity to conduct ten weeks of summer research with some of the country’s leading biophysicists in a range of biophysical fields. The program is conducted in concert with the NSF Research Experience for Undergraduates Program and is supported by funds from the National Science Foundation.

During the summer of 2023, we had seven REU students with us in Ann Arbor:

- Lily Bertemes: Physics major working in Markos Koutmos’s lab
- Colin Davidson: Biochemistry major working in Kevin Wood’s lab
- Jessica Dawson: Biophysics major working in Allen Liu’s lab
- Rachel Hendrickson: Biophysics major working in Jim Penner-Hahn’s lab
- Rachel Meeker: Physics major working in Tomek Cierpicki’s lab
- Bella Schaub: Biophysics major working in Dawen Cai’s lab
- Anna Shcherbakova: Physics major working in Julie Biteen’s Lab

New Undergrad Class Offering

BIO/BIOP 233: “Introduction to Quantitative and Computational Biology”

A new Biophysics course has been approved and is scheduled to debut in Winter 2025. This course introduces students to the basic computational and mathematical tools to model biological systems across length scales, from individual molecules to ecosystems, highlighting both the unity and breadth of quantitative approaches aimed at living systems. At the conclusion of this course, students should be positioned to pursue more specialized courses in quantitative biology, bioinformatics, and biophysics.
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New Online Merchandise Store!
U-M Biophysics has teamed up with Ann Arbor Tees to offer made-to-order Biophysics merchandise! Visit our store at www.gatwebstore.com/UMBP or scan the QR code below.

GIVING BLUEDAY
Thank you for supporting Giving Blueday!
Thank you to everyone who joined us for our 10th Giving Blueday, our annual day of giving! A decade of impact, driven by you. Your support will help to shape the next 10 years!

If you missed Giving Blueday, it’s never too late to support Biophysics. Visit https://myumi.ch/pkRMd or scan the QR code.

Biophysics Merch Store
Biophysics Giving Site

Congratulations on Your Retirement, Sandra!
Sandra Moing has announced her retirement after almost 9 years with Biophysics. Sandra has served as the Biophysics Program’s Executive Coordinator since October 2015 and has worked at the university for a total of 34 years. We thank her for her dedication to Biophysics and wish her well on her next chapter!

U-M Biophysics Program Newsletter

Director __________________________ Charles L. Brooks III
Associate Director for Graduate Studies _____________ Sarah Veatch
Associate Director for Undergraduate Studies _______ Kevin Wood

Program Manager __________________________ Alex Franklin
Executive Coordinator ______________________ Sandra Moing
Student Services Coordinator _____________ Sara Grosky
Events & Communications / Editor of Newsletter ______ Rebecca Dieker

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