26th Annual Interdisciplinary Symposium

May 31 - June 2, 2024
About the Symposium
The Miller Institute’s Annual Interdisciplinary Symposium samples broadly across the full spectrum of basic sciences by bringing together members of our scientific community over a weekend of talks and activities. We hope you find the sessions to be informative, enjoyable, and productive with new research collaborations emerging from discussions sparked by the presentations. This is also an opportunity for participants to meet and interact with the Miller Research Fellows, some of the brightest researchers now entering the sciences.

Your presence is especially valued as a distinguished “discussant” that is, an experienced scientist who can help facilitate discussions between the disciplines. We have put as much effort into choosing our invited guests as into choosing our speakers, because we believe that each participant contributes to the success of the Symposium. Thank you for joining us!

About the Institute
The Miller Institute for Basic Research in Science at the University of California, Berkeley is dedicated to the encouragement of creative research and investigation in the pure and applied sciences. Learn more about our programs for postdocs (left), Berkeley professors (middle), and visiting professors (right) below.
2024 Symposium Committee

Anna Barth, Miller Fellow 2021-2024, EPS
Michael Celentano, Miller Fellow 2021-2024, Statistics *
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Shashank Gandhi, Miller Fellow 2021-2024, MCB
Boryana Hadzhiyska, Miller Fellow 2022-2025, Physics
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George Varnavides, Miller Fellow 2022-2025, MSE & Physics
Elena Zavala, Miller Fellow 2022-2025, MCB

* indicates a fellow has since completed their term

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Miller Institute
Interdisciplinary Symposium
2024 Guest Speakers

**Harmit Malik**
Fred Hutchinson
Basic Sciences

**Eric Neuscamman**
UC Berkeley
Chemistry

**Dianne Newman**
Caltech
Biology and Geobiology

**Jonas Peters**
Caltech
Chemistry

**Mikhail Shapiro**
Caltech
Chemical and Medical Engineering

**Nicholas Swanson-Hysell**
UC Berkeley
Earth and Planetary Science

**Rachel Pepper**
University of Puget Sound
Physics and Biophysics

**Special Presenter:**
**Mike Bostock**
CEO & co-founder, Observable

Representative articles can be found here:
Abstract: “Rules of engagement: molecular arms races between host and viral genomes.”

The evolutionary battle between viruses and the immune system is a high-stakes arms race. The immune system makes antiviral proteins, called restriction factors, which can stop the virus from replicating. In response, viruses evolve to evade the effects of restriction factors. To counter this, restriction factors evolve too, and the cycle continues, in which both sides rapidly evolve at interaction interfaces to gain or evade immune defense. For example, primate TRIM5α uses its rapidly evolving ‘v1’ loop to bind retroviral capsids whereas the MxA antiviral protein uses its rapidly evolving Loop L4 domain to recognize viruses such as influenza; single mutations in these loops can dramatically improve viral restriction. The challenge for the immune system is that mammals do not evolve as fast as viruses. How then, in the face of this disadvantage, can the immune system hope to keep pace with viral evolution? Using deep mutational scanning, we comprehensively measured how single mutations in the TRIM5α v1 loop affect restriction of divergent retroviruses. Unexpectedly, we found that most mutations increase weak antiviral function. Moreover, most random mutations do not disrupt potent viral restriction, even when it is newly acquired via a single adaptive substitution. Our results indicate that TRIM5α’s adaptive landscape is remarkably broad and mutationally resilient, maximizing its chances of success in evolutionary arms races with retroviruses. We also exploit combinatorial mutagenesis at rapidly evolving positions to dissect and enhance the antiviral properties of MxA antiviral proteins, revealing unprecedented capacity for antiviral adaptation and a ‘breath versus specificity’ tradeoff that constrains their natural evolution.
Eric Neuscamman
Department of Chemistry
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Eric got started towards theoretical chemistry unknowingly by initially trying to pursue chemical engineering, which his parents thought would be a good practical amalgamation of his interests in chemistry and mathematics. As an undergraduate at UCLA, however, Eric got hooked on quantum mechanics and has pursued increasingly less practical directions ever since.

At Cornell, he completed a PhD under Garnet Chan studying electronic structure theory, an interest he carried forward into postdoctoral stints as a Miller Fellow at Berkeley and a Lawrence Fellow at Livermore. Since joining the Berkeley faculty, he has continued to enjoy the development of mathematical models for how electrons behave within molecules. Eric’s current pursuits include modeling excited states and sneaking increasingly sophisticated concepts into the freshman chemistry curriculum.

Abstract: “Losing electrons in crowds to predict a molecule’s color.”

How do we predict a molecule’s color from basic physical principles? Can we use the molecular orbital diagrams of freshman chemistry, or do we need something more? What are those diagrams really telling us, anyway? In this talk, we will explore how ideas like molecular orbital theory allow us to accurately approximate electrons’ intricate interactions by simpler group behavior. In particular, we will discuss recent progress in generalizing these approaches so that they can be used to model the “excited” states that molecules adopt when they absorb light.
Dianne Newman’s interdisciplinary research focuses on elucidating mechanisms of bacterial energy conservation and survival when oxygen is scarce. Her training combines molecular microbiology and environmental science, giving her an appreciation for the importance of accurately characterizing the microenvironments that surround microbial populations and communities to understand the activities of cells within them. Dr. Newman started her independent career at Caltech in 2000 and is currently the Binder/Amgen Professor of Biology and Geobiology. Her honors include the National Academy of Science’s Award in Molecular Biology and a MacArthur Fellowship, but she is most proud of her trainees, who have gone on to lead successful scientific careers in academia, industry, government, and the nonprofit sector. Dr. Newman is a member of the National Academy of Sciences and the American Academy of Arts and Sciences, and a Fellow of the American Academy of Microbiology and the American Geophysical Union.

Abstract: “Phenazines power an extremely slow bacterial maintenance state near life’s metabolic edge.”

Microbial metabolism is breathtaking in its diversity, yet is unified by a core bioenergetic principle: electrons must flow in a manner that enables energy to be conserved. Bacteria are creative geniuses when it comes to implementing this principle, having invented ways to conserve energy by coupling the oxidation of a wide array of substrates—including gases, minerals, and sugars—to the reduction of many others. Their metabolic inventions have transformed the Earth and continue to sustain it and its inhabitants. While we understand in exquisite detail how certain metabolisms such as aerobic respiration and oxygenic photosynthesis work, most of our knowledge of these processes comes from studying bacteria growing quickly under nutrient-replete conditions. Yet the majority of microbes in nature are metabolically attenuated, a vital state about which we know far less. In this talk, I will explain how the opportunistic pathogen Pseudomonas aeruginosa fuels an extremely low power lifestyle by recycling self-generated redox-active “antibiotics” called phenazines. I will close with a discussion of how recent conceptual and technical advances have positioned us to better understand life in the slow lane, and the practical importance of this knowledge.
Rachel Pepper
Departments of Physics & Biophysics
University of Puget Sound
rpepper@pugetsound.edu

Dr. Rachel Pepper is a Professor of Physics and the William D. and Flora McCormick Chair in Biophysics at the University of Puget Sound where she studies problems at the intersection of fluid mechanics and biology.

Rachel received her Ph.D. in Physics from Harvard University. Rachel completed a postdoctoral fellowship at the University of Colorado at Boulder Department of Physics working in the Physics Education Research Group and was a Miller Fellow at UC Berkeley. At the University of Colorado, she studied student learning difficulties and helped transform upper-division physics courses. At UC Berkeley, she examined the interaction of marine larvae with Turbulence.

**Abstract: “Hydrodynamic interactions of microscopic sessile suspension feeders with their environment.”**

Microscopic sessile suspension feeders live attached to surfaces and, by consuming bacteria-sized prey and by being consumed, they form an important part of aquatic ecosystems. Their impact is mediated by their feeding rate, which depends on a self-generated feeding current. Here I discuss two stories related to these feeding currents. First, I will discuss the interaction of organisms with ambient flow from the environment. Most previous work on feeding currents focused on organism in still water. However, ambient flow is nearly always present in their natural habitats. I will show that feeding rates depend on the interplay of ambient environmental flows and the orientation of the organism relative to the surface of attachment. I will then discuss work where my lab measured the full 3D orientations for Vorticella Convallaria, to determine if they avoid orientations found to be unfavorable for feeding. Next, I will discuss the impact of microscopic sessile suspension feeders on flow around sinking biological aggregates. Sedimentation of these aggregates plays a critical role in carbon sequestration in the ocean and in waste-water treatment plants. In both these contexts, the sinking aggregates are “active”, since they are hot-spots of biological activity and are densely colonized by microorganisms, including sessile suspension feeders.
Electrons, and the protons with which they associate to make hydrogen atoms, are the fuel currency of life. They are the basis by which biology stores up food (photosynthesis), provides the world with high density energy (oil), and generates key ingredients we need to make biomolecules like protein and DNA (fertilizer). Simply put, hydrogen atoms decorate the key molecular building blocks of our world. Hydrogen gas (H2) is readily made by combining protons and electrons, in fact so easily that it’s hard to avoid. While this is great news if hydrogen is what you want (water electrolysis for the hydrogen economy), avoiding it presents a daunting challenge if you want other chemical products instead. Indeed, among the most fascinating challenges in catalysis today is to control proton/electron currency in a manner that avoids, or at least heavily mitigates, the production of hydrogen and efficiently directs it towards the reduction of other substrates (nitrogen, carbon dioxide, organic molecules) to make the hydrogen-rich molecules (ammonia, ethylene, alkanes) we need to feed and fuel the planet. As society aspires to shift to an increasingly renewably sourced energy supply, this challenge in catalytic selectivity becomes an exciting opportunity; if we can devise ways to manage hydrogen atoms, for example by shifting them from water (H2O) to nitrogen or carbon dioxide, we will be able to feed and fuel the planet more sustainably. To build the fundamental science needed to address this challenge, our lab at Caltech, inspired by Nature, is devising new catalytic approaches for managing proton and electron currency. My lecture will walk you through our master plan, from the bottom up.
Mikhail Shapiro is the Max Delbrück Professor of Chemical Engineering and Medical Engineering, an HHMI Investigator, and Director of the Center for Molecular and Cellular Medicine at Caltech. The Shapiro laboratory develops biomolecular technologies allowing cells to be imaged and controlled inside the body using noninvasive methods such as ultrasound. These technologies enable the study of biological function in vivo and the development of cell-based and gene-based diagnostic and therapeutic agents. Mikhail received his PhD in Biological Engineering from MIT and his BSc in Neuroscience from Brown. He conducted post-doctoral research at the University of Chicago and the University of California, Berkeley, where he was a Miller Fellow. Mikhail’s awards include the NIH Pioneer Award, the Packard Fellowship, the Pew Scholarship, the Vilcek Prize for Creative Promise, the Sontag Foundation Distinguished Scientist Award, the Mark Foundation Emerging Leader Award, the Camille Dreyfus Teacher-Scholar Award, the Carl Hellmuth Hertz Ultrasonics Award and the Roger Tsien Award for Excellence in Chemical Biology.

Abstract: "Talking to cells: biomolecular ultrasound for deep tissue cellular imaging and control."

The study of biological function in intact organisms and the development of targeted cellular therapeutics necessitate methods to image and control cellular function in vivo. Technologies such as fluorescent proteins and optogenetics serve this purpose in small, translucent specimens, but are limited by the poor penetration of light into deeper tissues. In contrast, most non-invasive techniques such as ultrasound and magnetic resonance imaging – while based on energy forms that penetrate tissue effectively – are not effectively coupled to cellular function. Our work attempts to bridge this gap by engineering biomolecules with the appropriate physical properties to interact with magnetic fields and sound waves. In this talk, I will describe our recent development of biomolecular reporters and actuators for ultrasound. The reporters are based on gas vesicles – a unique class of gas-filled protein nanostructures from buoyant photosynthetic microbes. These proteins produce nonlinear scattering of sound waves, enabling their detection with ultrasound. I will describe our recent progress in understanding the biophysical and acoustic properties of these biomolecules, engineering their mechanics and targeting at the genetic level, developing methods to enhance their detection in vivo, expressing them heterologously as reporter genes, and turning them into dynamic sensors of intracellular molecular signals. In addition to their applications in imaging, gas vesicles can be used to control cellular location and function by serving as receivers of acoustic radiation force or seeding localized bubble cavitation. Additional remote control is provided by thermal bioswitches – biomolecules that provide switch-like control of gene expression in response to small changes in temperature. This allows us to use focused ultrasound to remote-control engineered cells in vivo.
May 31 - June 2, 2024
Symposium Agenda

Friday, May 31

3 - 6 pm  Arrival and Registration  Lobby/Reception
4:30 - 6 pm  Welcome Reception  Redwood Dining Hall
6 - 7 pm  Dinner  Redwood Dining Hall
7:30 - 11 pm  Miller Fellow Posters + visual aids ; social time  Buck Hall

Saturday, June 1

7:30 - 8:30 am  Breakfast  Redwood Dining Hall

8:40 - 9:20 am  Mikhail Shapiro, “Talking to cells: biomolecular ultrasound for deep tissue cellular imaging and control.”  Buck Hall
9:20 - 9:50 am  Discussion
9:50 - 10:10 am  Break

10:10 - 10:50 am  Dianne Newman, “Phenazines power an extremely slow bacterial maintenance state near life’s metabolic edge.”  Buck Hall
10:50 - 11:20 am  Discussion

11:20 - 12:30 pm  Group Photo followed by Lunch  Redwood Dining Hall

1 - 1:40 pm  Jonas Peters, “Avoiding Hydrogen and Getting Protons and Electrons to Where we Want Them Instead.”  Buck Hall
1:40 - 2:10 pm  Discussion
2:10 - 2:40 pm  Break

May 31 - June 2, 2024
Symposium Agenda Continued

3:20 - 3:50 pm  Discussion  
Buck Hall

3:50 - 4:20 pm  Break

4:20 - 5 pm  Nicholas Swanson-Hysell, "The onset of Neoproterozoic Snowball Earth and the drivers of long-term climate change."  
Buck Hall

5 - 5:30 pm  Discussion

5:30 - 6 pm  Free Time

6 - 7 pm  Dinner  
Redwood Dining Hall

7:30 - 8:30 pm  Special Presentation: Mike Bostock, "Never the right abstraction."  
Buck Hall

8:30 - 11 pm  Stargazing and social time  
Buck Hall

Sunday, June 2

7:30 - 8:30 am  Breakfast  
Redwood Dining Hall

9 - 9:40 am  Rachel Pepper, "Hydrodynamic interactions of microscopic sessile suspension feeders with their environment."  
Buck Hall

9:40 - 10:10 am  Discussion

10:10 - 10:30 am  Break

10:30 - 11:10 am  Eric Neuscamman, "Losing electrons in crowds to predict a molecule’s color."  
Buck Hall

11:10 - 11:40 am  Discussion

12 pm - 1 pm  Lunch and close of Symposium  
Redwood Dining Hall
Nicholas Swanson-Hysell is an Associate Professor of Earth and Planetary Science at UC Berkeley. He is a geologist with a field-based research program focused on integrating geological, geophysical, and geochemical data to reconstruct long-term global change. A major focus of his research program is leveraging the remanent magnetization of rocks to reconstruct ancient plate tectonic motions. These Earth history investigations have led him to conduct field research on all seven continents.

Abstract: “The onset of Neoproterozoic Snowball Earth and the drivers of long-term climate change.”

Earth’s climate has transitioned between intervals of non-glacial climate with no significant land ice on Earth, glacial climates like today with polar ice caps, and snowball Earth climates when ice extends to all latitudes. I will highlight our ever improving constraints on two snowball Earth episodes that resulted in ice sheets extending into the tropics during the Cryogenian Period between 717 and 635 million years ago. Subsequent to Cryogenian global glaciation, there have been three major non-glacial to glacial transitions over the past 500 million years with ice sheets restricted to high latitudes. The most recent transition resulted in Earth being in its current glacial climate regime with ice caps in both hemispheres. While we understand long-term climate change to be controlled by sources of CO2 from the solid Earth and CO2 sinks through the weathering of silicate rocks and organic carbon burial, reconstructing how changes in these sources and sinks have resulted in climatic shifts is a major challenge of Earth science. I will present our work developing and evaluating the hypothesis that the process of arc-continent collision is a major lever for cooling Earth’s climate on long timescales when it occurs near the equator. Such mountain building leads to the uplift of rocks with a high potential to sequester carbon particularly when they are located in the warm-wet tropics. These mountains can lower atmospheric CO2 concentrations on million-year timescales and enable the onset of glacial climate states.
Mike Bostock is the co-CEO and founder of Observable, a data app and computational notebook platform. Mike is also the creator of D3.js and Observable Plot, popular open-source libraries for interactive data visualization. Mike was formerly a graphics editor for The New York Times, studied information visualization as a PhD student at Stanford, and earned a BSE in computer science from Princeton.

Abstract: “Never the right abstraction.”

Why are data visualization tools so hard to use? Some tools do too much, imposing constraints on how we solve problems and limiting the tool’s usefulness. Others seemingly do too little, offering endless possibilities but making even basic tasks a struggle. This talk will consider various approaches to designing visualization software, evaluating expressiveness and efficiency, and reflect on ways we can design tools that are easier to use and have lasting value.
Introducing the 2024 - 2027 Miller Research Fellows

Mark Carrington
Kathy Day Fellow
Chemistry
Host: F. Dean Toste
PhD: Univ. of Cambridge

Mohammad Farhat
Astronomy, EPS
Hosts: Eugene Chiang, Bruce Buffet
PhD: Sorbonne University

Katherine Fraser
Physics
Host: Benjamin Safdi
PhD: Harvard

Matthew Kustra
IB
Host: Christopher Martin
PhD: UCSC

Calvin Leung
Astronomy, Physics
Hosts: Aaron Parsons, Wenbin Lu and Liang Dai
PhD: MIT

Kate Reidy
MSE, Physics
Hosts: Andrew Minor, Michael Crommie
PhD: MIT

Ryan Unger
Mathematics
Host: Sung-Jin Oh
PhD: Princeton

Thuy-Duong (June) Vuong
EECS
Host: Alistair Sinclair
PhD: Stanford

Ian Waudby-Smith
Statistics
Host: Michael Jordan
PhD: Carnegie Mellon

Jonathan Wolf
EPS
Hosts: Weiqiang Zhu, Barbara Romanowicz
PhD: Yale

Sarah Zeichner
PMB
Host: Patrick Shih
PhD: Caltech
Miller Research Fellows

Anna Barth
2021-2024
EPS
Host: Michael Manga
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Lijie Chen
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Hosts: Avishay Tal, Umesh Vazirani
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Host: Evan Variano
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Miller Research Fellows Continued

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**Rohil Prasad**
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**Raul Ramos**
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**James Santangelo**
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**Carly Schissel**
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**Georgios Varnavides**
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Yuhan Yao  
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Hosts: Wenbin Lu, Raffaella Margutti  
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Lingfu Zhang  
2022-2025 
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Host: Shirshendu Ganguly  
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Mengshan Ye  
2022-2025 
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Xueyue (Sherry) Zhang  
2023-2026 
EECS/Physics  
Host: Alp Sipahigil  
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All current Miller Fellows and their detailed research descriptions can be found on the Institute’s website here:
The Miller Institute for Basic Research in Science at the University of California, Berkeley was established in 1955 after Adolph C. Miller and his wife, Mary Sprague Miller, donated just over $5 million dollars to the University. It was their wish that the donation be used to establish an institute “dedicated to the encouragement of creative thought and conduct of pure science.” The gift was made in 1943 but remained anonymous until after the death of the Millers.

Adolph Miller was born in San Francisco on January 7, 1866. He entered UC in 1883 and was active throughout his Cal years. After graduation he went to Harvard for Graduate School and then to study in Paris and Munich. He returned to the United States and taught Economics at Harvard until he was appointed Assistant Professor of Political Science in Berkeley in 1890. After just one year he moved to Cornell. A year later he moved on to Chicago as a full professor of Finance.

He married Mary Sprague in 1885. She was the eldest child of a prosperous Chicago businessman and perhaps the source of much of the Millers’ wealth. In 1902 Miller returned to Berkeley as Flood Professor of Economics and Commerce. He established the College of Commerce, which has grown into the Haas School of Business today.

After 11 years at UC, Miller resigned to become the US Assistant Secretary to the Interior. The following year the Federal Reserve system was established and President Wilson appointed Miller to its Board of Governors. He held that position for 22 years under 5 different presidents.

The Miller Institute has sponsored Miller Professors, Visiting Miller Professors and Miller Research Fellows at different times throughout its history. The first appointments of Miller Professors were made in January 1957. The first Fellows were appointed in 1960. Throughout its 65+ year history the Institute has hosted over 1,200 scientists in its programs.

In 2008 the Institute created the Miller Senior Fellowship Program and appointed its first recipient. Miller Senior Fellows serve as mentors to the Miller Fellows by leading discussions and participating in Institute events. They are awarded an annual research grant to use at their discretion in support of their research.

The Institute is governed by the Advisory Board, which is comprised of the Chancellor of the University, four outside members, and the Executive Committee. The Advisory Board meets once a year to assist the Executive Committee in selecting Miller Professors and the Visiting Miller Professors. The Executive Committee alone selects the Miller Fellows and the Miller Senior Fellows.

More at: miller.berkeley.edu
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