

BIOMEDICAL ENGINEERING

DEPARTMENT WELCOMES
NEW FACULTY

Neha Kamat and Jonathan Rivnay join in 2016-17

The Department of Biomedical Engineering is excited to welcome two new faculty members during the 2016-17 year. Both assistant professors, Neha Kamat will join in January, and Jonathan Rivnay will join in February.

"Northwestern continues to invest in biomedical engineering," said Eric J. Perreault, professor and department chair. "This year, two exceptional young scientists join our faculty."

Kamat joins Northwestern from Harvard University, where she served as a NASA Postdoctoral Research Fellow. She integrates materials science and synthetic biology to design artificial cells, which act as tools to understand and recreate targeted cellular behaviors. These artificial systems have tremendous potential for medicinal and biotechnological applications, including targeted drug delivery, novel sensors for mechanical stress, and as an approach to studying fundamental signaling processes within cells and systems of cells.



Neha Kamat



Jonathan Rivnay

"NORTHWESTERN CONTINUES TO INVEST IN BIOMEDICAL ENGINEERING. THIS YEAR, TWO EXCEPTIONAL YOUNG SCIENTISTS JOIN OUR FACULTY."

ERIC J. PERREAUULT

In 2012, Kamat received her PhD in bioengineering from the University of Pennsylvania, where she received a National Science Foundation Graduate Research Fellowship.

Rivnay currently works as a staff research scientist at PARC, a research and development company owned by Xerox. Before joining PARC, Rivnay was a postdoctoral fellow in the bioelectronics laboratory at the Centre Microelectronique

de Provence in France, where he was funded by a prestigious Marie Curie Fellowship. He received his PhD from Stanford University in 2012.

Rivnay's research integrates organic ionic/electronic mixed conductor materials into novel bioelectronics devices for diagnostics and therapies. He will continue this work at Northwestern, collaborating with researchers in neural engineering, biomaterials, and medicine.

FROM THE CHAIR

Dear friends,

Before celebrating our recent successes, I would like to take a moment to reflect on some of the reasons behind them. This year marked the passing of **Christina Enroth-Cugell**, emerita professor of biomedical engineering and neurobiology; she was 96. Christina was a founding member of our department, an early champion for women in science, and a celebrated researcher. Her research, which integrated engineering analyses and physiology, was an inspiration for the then-nascent field of biomedical engineering. She made Northwestern a renowned center for vision research and attracted prominent researchers who continue to contribute to our department. We are forever grateful for her contributions to biomedical engineering at Northwestern.

Once again, we had a year filled with accomplishments. Our continued achievements were reflected in our entry into the top ten graduate programs in the nation, as ranked

by *US News and World Report*. This ranking reflects contributions from all facets of our department.

Our faculty continue to attract large amounts of external funding to support their fundamental research endeavors. Many of our laboratories also continue to pursue translational work, which is modernizing discovery and delivery in our healthcare system. These accomplishments provide a fertile training ground for our students at all levels, who have opportunities to work in our diverse group of laboratories and make fundamental contributions to their success. In this newsletter, you will see some recent examples of our research and entrepreneurship, how our students are benefitting from and contributing to these endeavors, and how our faculty and students continue to receive prestigious awards recognizing their achievements.

Northwestern continues to invest in biomedical engineering. As noted on page one, this year two

exceptional young scientists will join our faculty. **Neha Kamat** works on artificial cells to understand and recreate targeted cellular behaviors. Her research has applications in medicine and biotechnology including targeted drug delivery, sensors for mechanical stress, and for fundamental research on signaling processes within cells and systems of cells. Neha complements our expertise in biomaterials and synthetic biology. **Jonathan Rivnay**'s research integrates organic ionic and electronic mixed conductor materials into novel bioelectronic devices. Some of the many applications include novel interfaces for recording and stimulating within the human nervous system, and for controlled biomolecule delivery. Jonathan's unique expertise positions him at the interface of our existing strengths in neural engineering and biomaterials.

This coming year, we are searching for additional faculty in the areas of neuroimaging and cancer research. This growth is made possible through our continued collaborations with Northwestern

Medicine, and by substantial University investments in space on both the Evanston and Chicago campuses. These investments will provide biomedical engineering with approximately 15,000 square feet of new space in the coming years to support current and future needs.

In closing, I encourage you to remain engaged in our department and to participate in our future. Contributions from our alumni support many of our student initiatives. This year and next year, we are focused on increasing experiential learning opportunities for our students — in research, design, entrepreneurship, and industry. Just let us know how you would like to be engaged.



Eric J. Perreault
Department Chair

NEW OPPORTUNITY FOR VISITING SCHOLARS

The Department of Biomedical Engineering is excited to announce new six-month and twelve-month positions for visiting scholars. With substantial support from Northwestern, visiting scholars will collaborate with a biomedical engineering faculty member.

We are now accepting applications until January 15, 2017. Decisions will be made in mid-February 2017.

For more details, visit mccormick.northwestern.edu/biomedical/visiting-scholar-program.

Stay Connected

Join the Northwestern Biomedical Engineering group on LinkedIn— a private group for Northwestern alumni and current students. It's a great way to stay connected with fellow alumni, interact with current students, and stay informed about upcoming BME events. To join the more than 800 Northwestern BME alumni on LinkedIn, visit [linkedin.com/groups/3299815](https://www.linkedin.com/groups/3299815).

START-UP SPOTLIGHT



Milan Mrksich in his lab

SAMDI Tech

Over the past decade, advances in genetic mapping tools have provided great insight into how DNA influences cell behavior. But genetics is only half the equation; much of cells' behavior is the result of post-transcriptional processes, events that occur after DNA is transcribed, carried out by complex enzyme interactions within the cell. The roles that enzymes play in regulating cell behavior are not completely understood, largely because researchers have lacked the proper tools to measure the many simultaneous reactions in a cell.

Professor **Milan Mrksich** has developed a new technique for profiling enzyme activities in cell lysate, a fluid containing the internal contents of cells. The process uses surfaces that present an array of

SAMDI TECH OFFERS LABEL-FREE BIOCHEMICAL TESTING FOR HIGH-THROUGHPUT SCREENING AND PEPTIDE SUBSTRATE DISCOVERY.

peptides that each interact with enzymes in a lysate. The changes the enzymes make to the peptides can be directly read using a laser to determine the changes in mass of those peptides.

Called SAMDI (self-assembled monolayers desorption ionization) mass spectrometry, the technique is a super-fast, low-cost, and label-free method of measuring biochemical activities on a surface. Not only does the technology enable researchers to identify patterns of enzyme activities in cell lysates, but it could lead to a better understanding of biological functions in general and aid in the discovery of early stage modulators of enzymes involved in human disease.

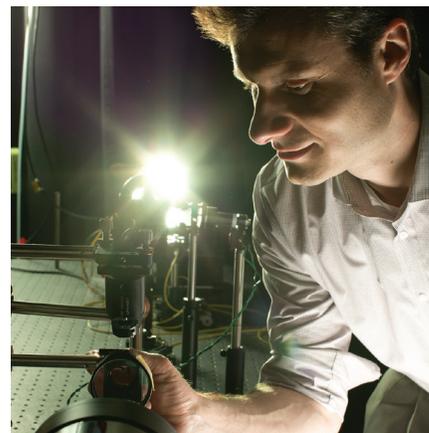
Mrksich and his partners spun out the technology into SAMDI Tech, a company offering label-free biochemical testing for high-throughput screening and peptide substrate discovery. In addition to eliminating labels, the approach reduces the rates of false positives and negatives, shortens assay development times, and easily translates to a high-throughput format.

During its short time as a startup, SAMDI Tech has already garnered several accolades. It was recently selected as 1 of 15 specialized centers for the Chemical Biology Consortium, the discovery engine for the National Cancer Institute's Experimental Therapeutics (NExT) program.

Preora Diagnostics

Someday doctors might diagnose lung cancer by shining a light inside of their patient's cheek. Professor **Vadim Backman's** company Preora Diagnostics is working to make this type of non-invasive test a reality.

The company develops novel, highly accurate, non-invasive tests to diagnose lung, prostate, colon, pancreatic, and ovarian cancers. Backman's tools seek to diagnose cancer at its earliest, most treatable stages, when cancer rarely exhibits symptoms.



Vadim Backman diagnoses disease by analyzing patterns in scattered light.

PREORA DEVELOPS NOVEL, HIGHLY ACCURATE, NON-INVASIVE TESTS TO DIAGNOSE LUNG, PROSTATE, COLON, PANCREATIC, AND OVARIAN CANCERS.

Backman's potentially life-saving technology, called nanocytology, works by harnessing the power of light to examine cells from easily accessible areas of the body. A simple swab of cells from one area, such as the inside of a cheek, can uncover malignancies in a nearby organ, such as the lungs.

When researchers shine light onto the harvested cells, photons bounce off the nanostructures within them. The different angles of scattered light tell a story about the health of cells, which upon analysis can lead to an accurate diagnosis at even the very earliest stages of cancer formation. Using these bio-optic techniques, Backman can detect details indicative of "pre" pre-cancer, something that formerly could not be done with conventional microscopes.

In June, Preora Diagnostics initiated a 600-patient validation study for its lung cancer screening test, which will be launched commercially next year. Development of its other tests will be funded by the National Institutes of Health grants and private early stage investors.

RESEARCH HIGHLIGHTS

UNDERSTANDING CHROMATIN'S CANCER CONNECTION

Imaging technique allows researchers to study chromatin in live cells

Professor **Vadim Backman** has developed a new way to image chromatin, a complex of macromolecules — including DNA, RNA, and proteins — within living cells that house genetic information and determines which genes get expressed.

The structures within chromatin span from nucleosomal (10 nanometers) to chromosomal (longer than 200



nanometers) length scales.

Little is known about chromatin's dynamics between these length scales due to lack of imaging techniques. Because they require toxic fluorescent dyes to enhance contrast, previous techniques could not image chromatin in living cells without killing or perturbing the cells. Understanding this missing length scale is crucial, however, because it is the exact area where chromatin undergoes a transformation when cancer is formed.

"Changes in chromatin's structure have been linked to the regulation in genes often implicated in cancer," Backman said.

Backman's new imaging technique allows researchers to peer inside of chromatin at the missing, mysterious length scale (20-200 nanometers). Not only is the technique label-free, allowing researchers to study chromatin within unharmed, living cells, but it does so with high-throughput and at very low cost.

The work was published in October in the *Proceedings of the National Academy of Sciences*. Professor **Igal Szleifer** was also an author on the paper.

IMAGING STROKE RISK IN 4D

New MRI technique detects blood flow velocity

Affecting 33.5 million patients worldwide, atrial fibrillation is the most common form of cardiac arrhythmia and a major risk factor for stroke.

Michael Markl, who is a professor of biomedical engineering and radiology, has developed a new imaging technique that can help predict who is most at risk for stroke. This breakthrough could lead to better treatment and outcomes for patients with atrial fibrillation.



Atrial fibrillation is linked to stroke because it slows the patient's blood flow. The slow, sluggish blood flow can lead to blood clots, which can then travel to the brain and initiate stroke. Markl's cardiac magnetic resonance (CMR) imaging test can detect the blood's velocity through the heart and body. Called "atrial 4D flow CMR," the technique is non-invasive and does not require contrast agents. The imaging program, which images blood flow dynamically and in the three spatial dimensions, comes in the form of software that can also be integrated into current MRI equipment.

"We simply programmed the scanner to generate information differently — in a way that wasn't previously available," Markl said. "It allows you to measure flow, diffusion of molecules, and tissue elasticity. You can interrogate the human body in a very detailed manner."

Supported by the American Heart Association and the National Institutes of Health, the research was described online in October in the journal *Circulation: Cardiovascular Imaging*.

WHISKERS HELP ANIMALS SENSE WIND'S DIRECTION

First-ever study shows that rats use whiskers to locate source of airflow

Published in the August 24 issue of *Science Advances*, a paper by Professor **Mitra Hartmann** reported that rats use their whiskers to help locate airflow sources, giving them the ability to find food, avoid predators, and connect with potential mates.

To perform the experiment that led to this discovery, Hartmann's team placed



five, equally-spaced fans in a semicircle around the edge of a 6-foot circular table. In each trial, one of

the five fans was randomly selected to blow air toward a "start-door" located on the opposite side of the table. A rat had to run from the door toward the fan blowing air, and go down a rat-sized hole directly in front of that fan. Each of the five holes (one in front of each fan) led to a tunnel beneath the table, where the rat was rewarded for choosing the correct fan. Cameras positioned above the table recorded the rats' performance.

With five fans to choose from, rats could perform at a 20 percent correct level just by chance. After the rats had performed the task at a level of approximately 60 percent correct or higher for 10 days in a row, the researchers cut off the whiskers (a procedure as painless as a haircut) and looked for changes in behavior. Ultimately, the team's results showed that whisker removal decreased rats' performance by approximately 20 percent.

RESEARCH DAY



Winning images appear on the BME t-shirt (from left to right): Biliary epithelial cells cultured in a novel gel biomaterial, advanced control systems for powered prosthetic legs, 4D image of blood flow through the heart.

The Department of Biomedical Engineering celebrated the research and accomplishments of faculty, students, and alumni at its annual BME Research Day on May 19, 2016 at Prentice Women's Hospital in Chicago.

Keith Cook, alumnus and associate professor of biomedical engineering at Carnegie Mellon, delivered the keynote address: "Artificial Lungs for Destination Therapy." **Wenzhong Liu** received the dissertation award for his work on retinal oxygen metabolism in early diabetes. Graduate students **Kelly Jarvis**, **Phillip Lewis**, and **Maria Whitmore** received research awards for their accomplishments in each of the department's three main research areas. Each graduate student research award winner contributed an image that was then printed on a t-shirt for incoming BME freshmen.

This year's event included seven three-minute pop talks — high-level overviews of current research designed to highlight the diverse research in the department and to spark collaborations. These talks were well received and will be continued in future years. Find one three-minute talk presented by Hayley Belli here: <https://youtu.be/2wcOqJXWzsk>

The next BME Research Day will take place on May 18, 2017 at AbilityLab (the RIC's new building). Please join to hear about the department's research and to interact with current students and faculty at a poster/cocktail reception.

REGENERATIVE BANDAGE HEALS FASTER

Antioxidant bandage delivers healing protein to diabetic wounds

Professor **Guillermo Ameer** and his team have developed a new treatment for hard-to-treat diabetic foot ulcers. Called a "regenerative bandage," the novel material heals diabetic wounds four times faster than a standard bandage and has the added benefit of



promoting healing without side effects.

Ameer's laboratory previously created a thermo-responsive material — with intrinsic antioxidant properties to counter inflammation — that

is able to deliver therapeutic cells and proteins. His team used this material to slowly release into the wound a protein that hastens the body's ability to repair itself by recruiting stem cells to the wound and creating new blood vessels to increase blood circulation.

"We incorporated a protein that our body naturally uses to attract repair cells to an injury site," Ameer said. "When the protein is secreted, progenitor cells or stem cells come to the wound and make blood vessels, which is part of the repair process."

The thermo-responsive material is applied to the wound bed as a liquid and solidifies into a gel when exposed to body temperature. Ameer believes that the inherent antioxidant properties within the material also reduce oxidative stress to help the wound heal.

The research was published in August in the *Journal of Controlled Release*. Professor **Hao F. Zhang** also contributed to the work.

ENHANCING IMAGING WITH LIGHT

New technology platform increases spectroscopic resolution by four fold

Led by Professor **Hao F. Zhang**, a biomedical engineering team developed a new super-resolution optical imaging platform based on spectroscopy, a type of imaging that examines how matter responds to light. Called spectroscopic photon localization microscopy (SPLM), the platform can



analyze individual molecules with sub-nanometer resolution.

The novel technology

platform leverages photon localization microscopy (PLM), which captures inherent spectroscopic signatures of emitted photons, or light particles, to identify specific molecules. Current spectroscopic imaging and PLM technologies require multiple fluorescent dyes to enhance contrast in the resulting microscopic images. Unable to distinguish between dyes, these techniques record multiple images from different discrete wavelength bands.

The Northwestern team's SPLM, however, can characterize multiple dye molecules simultaneously, increasing the imaging speed in multi-stained samples. Removing the need for recording multiple images makes the imaging process simpler and less expensive. SPLM is also sensitive enough to distinguish minor differences from the same type of molecules.

The research was published in July in *Nature Communications*. Professors **Vadim Backman** and **Cheng Sun** served as co-authors on the paper.

In Memoriam: Christina Enroth-Cugell

Cristina Alma Elisabeth Enroth-Cugell,

emerita professor of biomedical engineering and neurobiology, passed away June 15 at age 96. She will



Christina Enroth-Cugell

be remembered as a renowned vision scientist, distinguished researcher, and compassionate colleague.

Arriving at Northwestern in 1955, Enroth-Cugell worked as a research fellow and instructor in the University's Department of Ophthalmology before transitioning to the role of faculty in the Department of Physiology. In 1968, she began a joint appointment between the Weinberg College of Arts and Sciences and the McCormick School of Engineering, where she was one of the first female faculty members to teach engineering at Northwestern. She was an early faculty member of what became McCormick's Department of Biomedical Engineering and Weinberg's Department of Neurobiology, and served as chair of the Department of Neurobiology from 1984 to 1986.

A celebrated researcher, Enroth-Cugell made several contributions to the areas of visual adaptation and the spatial and temporal aspects of receptive fields, and was at the center of the study of vision at Northwestern. Her lab, where she continued to play an active role well after her retirement in 1990, was a vital hub for producing many of today's vision scientists.

The Christina Enroth-Cugell Professor of Biomedical Engineering was named after her in 2008 and is currently held by professor **Igal Szeleifer**. Most recently, she served as an executive council member of the Northwestern Emeriti Organization from 2002 to 2004.

FACULTY HONORS

Guillermo Ameer received the 2016 MAC Eminent Chemical Engineers Award from the American Institute of Chemical Engineers.

Chad Mirkin received the International Dan David Prize in the Future Time Dimension and 2016 RUSNANOPRIZE.

Milan Mrksich received the iBIO iCON Innovator Award.

Wendy Murray was elected president of the American Society of Biomechanics.

Igal Szeleifer received the Cole-Higgins Award for Excellence in Advising.

Chad Mirkin, Samuel Stupp, Richard Van Duyne, Todd Kuiken, and Lee Miller were inducted into the American Institute for Medical and Biological Engineering's College of Fellows.

ADVISORY BOARD PROFILES



Michael Byun

A board-certified plastic surgeon, **Michael Byun, MD**, is the founder and director of Chicago Cosmetic Surgery and the BION Medica Skin Care Clinic. He has also developed anti-aging products, such as a cell biology-focused transformation growth factor beta, which is responsible for cell turnover. Now he is developing injectable serums that can either target bone, muscle, fat, or skin for cosmetic and reconstructive surgery.

Byun received his MD from Northwestern's Feinberg School of Medicine, where he completed his clinical fellowship in plastic surgery. He previously served as a research adviser at the University of California, Irvine Department of Neurobiology and at the National Institute of Neurological Disorders and Stroke Research.



Carson Thomas

Carson Thomas is the director of portfolio strategy for Baxter's renal business, which works to improve to lives of renal patients worldwide. Before joining Baxter, Thomas spent 15 years with GE Healthcare, working in marketing, strategy, and product development within the x-ray business and radiation dose tracking business. When he was hired at GE, he initially worked in clinical research and advanced clinical applications to introduce the first digital x-ray systems and several advanced applications that helped transition the x-ray modality into a digital modality.

Before leaving the x-ray business, Thomas managed all new product development globally for the radiography and fluoroscopy business and became segment manager of the radiography business. He earned his PhD in biomedical engineering from Northwestern.

STUDENT PROFILES



Hayley Belli

Belli's research uses statistics to quantify the geometry and mechanical properties of rat whiskers

Researchers have long known that rats use their whiskers to sense objects and spaces around them. But little is known how the whiskers then communicate that information to the brain.

Working with Professor **Mitra Hartmann**, PhD student **Hayley Belli** is helping to fill in this information gap. She studies the rat whisker-trigeminal system, which has been an important model in the neuroscience field since the early 1900s for studying the type of information encoded by neurons during tactile perception.

Belli's research uses statistics to quantify the geometry and mechanical properties of whiskers in order to develop a morphologically accurate 3D model of rat whisking behavior. With this model, her dissertation seeks to find patterns among the forces obtained by rats during active exploration that allows them to discriminate between objects of varying size and curvature.

In addition to being a sixth year graduate student in biomedical engineering, Belli completed her masters in engineering sciences and applied math at Northwestern. She also earned a graduate

certificate in clinical and translational research through the Searle Teaching Certificate Program and participated in the Kellogg Management for Scientists and Engineers Program.

"When I was studying applied math, I was interested in mathematical physiology," Belli said. "Then I started to learn about the large number of researchers in the field of computational neuroscience at Northwestern. When I looked into Mitra's research, it sounded really cool to be able to study how neurons encode information through the rat whisker model."

Outside of the lab, Belli remains active in the Northwestern community. She is assistant chair of Slivka Residential College, where she serves as an adviser and mentor for more than 140 undergraduate students in STEM disciplines.



Megan Burton

Undergraduate exercises creativity in the lab and abroad

Part biomedical engineer and part French student, **Megan Burton** is a living example of a whole-brain engineer.

As an undergraduate researcher, Burton works in Professor **Milan Mrksich**'s laboratory, where she uncovers activity patterns of phosphatases — an understudied class of enzymes that play

a vital role in more than 30 percent of all cellular processes. Mrksich's new SAMDI technology has made it easier to study these enzymes, potentially opening doors for discovery.

"Because phosphatases are so vital, if we understood how they are regulated, it could become a potential target for therapeutic drugs for a plethora of diseases," Burton said.

Outside of the lab, Burton is working toward French fluency and spent the summer abroad to help her polish her speaking and writing skills.

"Studying French has given me a more well-rounded education and helped get me out of the strict 'scientific' or 'hard engineering' mindset," Burton said. "It has added a different type of creativity to my engineering career."

Burton is also the vice president of fraternity development for Pi Beta Phi, a mentor in the Undergraduate Program for Advancing Learning, and active member of the Society of Women Engineers.

STUDENT AWARDS

Recipients of NSF fellowships:

Amy Adkins, Alejandro Azocar, Kiran Bhattacharyya, Raeed Chowdhury, Alya Eid, Samantha Huddleston, Alexandra Kolberg, Jacob Lewis, Adam Pluchinsky, and James Winkelman.

Recipients of NIH NSRA fellowships:

Adenike Adewuyi, Hayley Belli, Nicholas Bush, Matthew Perich, and Jon Thacker.

American Heart Association fellowship

recipients: **Adam Eshein, Yong Jeong, Brian Soetikno, Christopher Versteeg, and Jisheng Xiao.**

Science in Society 2016 Scientific

Images Contest winner: **Kelly Jarvis**

Technological Institute
2145 Sheridan Road
Evanston, Illinois 60208-3100

Nonprofit
Organization
U.S. POSTAGE PAID
Northwestern
University

Engage with Biomedical Engineering

As you have likely heard, Northwestern is in the midst of its We Will campaign. If you can give, we encourage you to direct your gifts to biomedical engineering. Thanks to your donations last year, we are busy renovating our undergraduate space for student collaborations. This year, we aim to enhance student research experiences through summer stipends and conference travel. (Read about undergraduate Megan Burton's research experiences on page 7.) If you would like to invest in our mission to increase experiential learning opportunities for our students, please direct your gift to mccormick.northwestern.edu/biomedical/donate.

We are also looking to improve industrial opportunities for our students. If you have internships or other opportunities available, please notify us. As you well know, our students are capable, hard-working, talented, and eager to get involved.

Finally, during winter and spring quarters, we plan to connect each freshman with one alumna or alumnus for an informational interview. To volunteer, visit the Northwestern Biomedical Engineering LinkedIn group: [linkedin.com/groups/3299815](https://www.linkedin.com/groups/3299815)

