Northwestern | McCORMICK SCHOOL OF ENGINEERING

SUMMER 2017

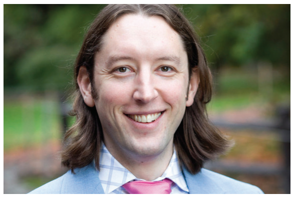
CHEMICAL AND BIOLOGICAL ENGINEERING

FACULTY WIN MAJOR AWARDS

Dean Julio M. Ottino receives NAE's Gordon Prize

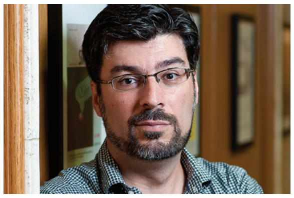

Julio M. Ottino


Neda Bagheri


Julius Lucks


Michael Jewett


Linda Broadbelt


Luis Amaral

Department of Chemical and Biological Engineering faculty received several notable awards during the 2016-17 year.

Julio M. Ottino, dean of Northwestern Engineering, received the prestigious 2017 Bernard M. Gordon Prize for Innovation in Engineering and Technology Education from the National Academy of Engineering (NAE). Established in 2001, the Gordon Prize is the nation's highest honor for engineering education. The award honored Ottino's development and implementation of Whole-Brain Engineering, the McCormick School of Engineering's principal guiding strategy for more than a decade.

Ottino received the award on Tuesday, May 30 in the Ford Motor Company Engineering Design Center in a ceremony with students, alumni, faculty, friends, NAE members, and members of the McCormick Advisory Council. NAE president Dan Mote, BMG Charitable Trust officer Ross Brown, and Northwestern president Morton O. Schapiro presented the award on behalf of the National Academy of Engineering.

"Receiving this award is a great honor, and I share it with many, many people," Ottino said during his acceptance speech. "Northwestern is a place that is full of good partners who have stretched my thinking in many directions."

Other major awards include:

Assistant Professor **Neda Bagheri** received a Faculty Early Career Development Program (CAREER) award from the National Science Foundation, the foundation's most prestigious honor for junior faculty members.

Associate Professor **Julius Lucks** received the 2016 Synthetic Biology Young Investigator Award from the American Chemical Society and was among 13 young faculty members nationwide to receive a 2017 Camille Dreyfus Teacher-Scholar Award.

Associate Professor **Michael Jewett** was honored with a 2017 Charles Deering McCormick Professor of Teaching Excellence Award, recognizing his dedication to high-quality education and passion for advancing his discipline through teaching.

Professor **Linda Broadbelt** was named the 12th recipient of the Dorothy Ann and Clarence L. Ver Steeg Distinguished Research Fellowship Award. The fellowship supports research and scholarship by a tenured Northwestern professor whose work enhances the national and international reputation of the University.

Professor **Luis Amaral** was named Erastus Otis Haven Professor of Chemical and Biological Engineering. The award will support his research which provides insight into the emergence, evolution, and stability of complex social and biological systems.

More faculty news can be found on page 7.

RANDALL Q. SNURR NAMED DEPARTMENT CHAIR

Snurr will succeed Linda Broadbelt on September 1

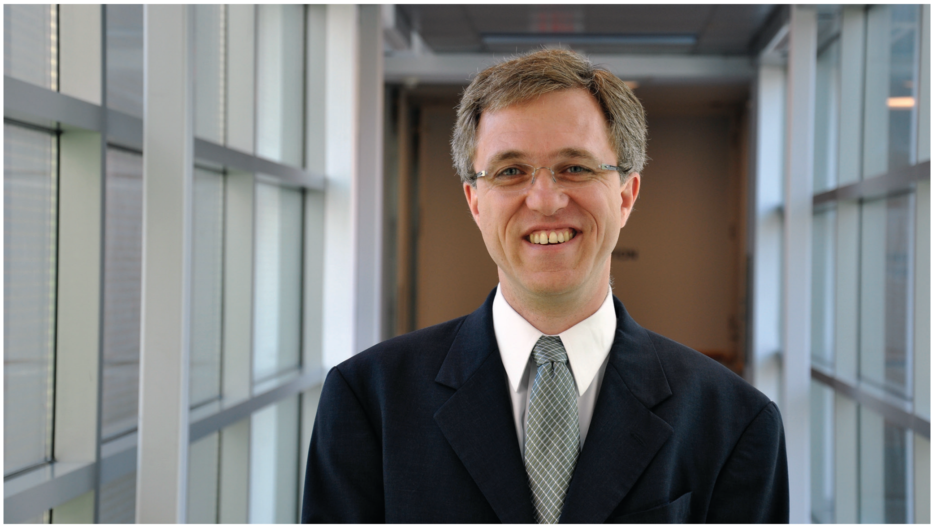
Randall Q. Snurr, the John G. Searle Professor of Chemical and Biological Engineering, has been named chair of the Department of Chemical and Biological Engineering. On September 1, he will succeed current chair Linda Broadbelt, who will become an associate dean for research.

"I am confident that Randy will lead the department to great heights," said Julio M. Ottino, dean of Northwestern Engineering.

A highly cited researcher, Snurr has received many awards throughout his career, including the 2011 Institute Award for Excellence in Industrial Gases Technology from the American Institute of Chemical Engineers, the Leibniz Professorship from the University of Leipzig, and a CAREER Award from the National Science Foundation. He also served as senior editor for the *Journal of Physical Chemistry* and is currently on the editorial boards of *Adsorption*, *Adsorption Science and Technology*, *Chemistry of Materials*, *Current Nanoscience*, and the *Journal of Molecular Catalysis A*.

"I am fortunate to take over the position of department chair at a time when the department is in such a strong position," Snurr said. "I am very grateful to Linda for her leadership as chair over the past eight years. The department has never been in better shape."

With an interest in developing materials to address environmental and energy problems, Snurr focuses on adsorption, diffusion, and catalysis in nanoporous materials. In collaboration with chemistry professor Joseph Hupp, Snurr has developed novel crystalline nanostructures known as metal-organic frameworks (MOFs), which are highly porous compounds that show promise for the storage of gases.



Randall Snurr

In recent years, MOFs have emerged as a promising material for carbon capture in power plants. But finding the optimal MOF to do the best job can be difficult. "People are really excited about these materials because we can make a huge variety and really tune them," Snurr said. "But there's a flip side to that. If you have an application in mind, there are thousands of existing MOFs and millions of potential MOFs you could make. How do you find the best one for a given application?"

In new work published by *Scientific Advances*, Snurr discovered a new way to rapidly identify top candidates for carbon capture — using just 1 percent of the computational effort that was previously required. By applying a genetic algorithm, his group rapidly searched through a database of 55,000 MOFs.

One of the identified top candidates, a variant of NOTT-101, has a higher capacity for carbon dioxide (CO_2) than any MOF reported in scientific literature for the relevant conditions. This information could lead to designs for newly commissioned, cleaner power plants.

> "I AM FORTUNATE TO TAKE OVER THE POSITION OF DEPARTMENT CHAIR AT A TIME WHEN THE DEPARTMENT IS IN SUCH A STRONG POSITION."
>
> RANDALL SNURR

"The percentage of carbon dioxide that the MOF can absorb depends on the process," Snurr said. "The Department of Energy target is to remove 90 percent of carbon dioxide from a power plant; it's likely that a process using this material could meet that target."

MITCHELL WANG JOINS NORTHWESTERN

Wang studies nanostructured polymers and soft materials

Many nanostructured polymers self-assemble, but little is known about this assembly process. Muzhou (Mitchell) Wang's work seeks to better understand this mysterious activity.

Mitchell Wang

"Some materials have no features at the nanoscale and then attain a certain morphology," Wang said. "My overall motivation is to understand how materials achieve their final structures and be able to predict those structures."

Wang brought this work to Northwestern in January 2017, when he joined the Department of Chemical and Biological Engineering as an assistant professor. After earning his PhD in chemical engineering from the Massachusetts Institute of Technology, he served as a National Research Council postdoctoral fellow at the National Institute of Standards and Technology (NIST).

To understand the fundamental processes that govern the self-assembly of nanostructured polymers and other soft materials, Wang uses recent innovations in advanced optical microscopy. These techniques allow Wang and his team to directly monitor the dynamic evolution of polymer morphology in real time.

"I was always jealous of biologists because they could watch cells evolve under the microscope," Wang said. "Things are harder to discern at the nanoscale. Now optical microscopy techniques allow us to observe materials below the optical resolution limit."

Born in China, Wang grew up in Ohio. He earned his bachelor's degree in chemical engineering from the California Institute of Technology in 2009, where he worked with Professor Julia Kornfield to design tissue adhesives for corneal wound repair. At MIT, Wang used experiments and simulations to understand the dynamics of rod-coil block co-polymers, a class of polymers that combines multiple functionalities into a single self-assembled nanomaterial. This work helped uncover the effect of shape and geometry on the mechanisms of polymer motion in entangled systems.

While at NIST, Wang worked on super-resolution optical microscopy of nanofabricated materials and became more familiar with Northwestern through the Center for Hierarchical Materials Design (CHiMaD). CHiMaD is a NIST-sponsored center for advanced materials research aimed at developing the next generation of computational tools, databases, and experimental techniques to enable the accelerated design of novel materials. The Chicago-based consortium includes Northwestern as the lead, along with University of Chicago and Argonne National Laboratory. Now at Northwestern, Wang is involved with CHiMaD and the Materials Genome Initiative.

Wang has received several awards and honors, including a National Defense Science and Engineering Graduate Fellowship and National Science Foundation Graduate Research Fellowship. He was also a finalist for the American Physical Society's Padden Award.

At Northwestern, he looks forward to continuing his research and becoming a mentor for students. "Starting a research group from the ground up is an exciting experience," Wang said. "I'm excited to see my students grow into scientists."

TO UNDERSTAND THE FUNDAMENTAL PROCESSES THAT GOVERN THE SELF-ASSEMBLY OF NANOSTRUCTURED POLYMERS AND OTHER SOFT MATERIALS, WANG USES RECENT INNOVATIONS IN ADVANCED OPTICAL MICROSCOPY.

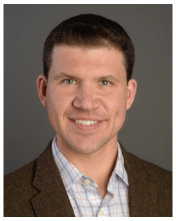
RESEARCH HIGHLIGHTS

'REWIRED' CELLS SHOW PROMISE FOR TARGETED CANCER THERAPY

Human immune cells rationally engineered to sense and respond to tumor signal

A major challenge in truly targeted cancer therapy is cancer's suppression of the immune system. Northwestern synthetic biologists now have developed a general method for "rewiring" immune cells to flip this action around.

"Right now, one of the most promising frontiers in cancer treatment is immunotherapy — harnessing the immune system to combat a wide range of cancers," said Associate Professor **Joshua N. Leonard**, the senior author of the study.



"The simple cell rewiring we've done ultimately could help overcome immunosuppression at the tumor site, one of the most intransigent barriers to making progress in this field."

When cancer is present, molecules secreted at tumor sites render many immune cells inactive. The researchers genetically engineered human immune cells to sense the tumor-derived molecules in the immediate environment and to respond by becoming more active, not less.

This customized function, which is not observed in nature, is clinically attractive and relevant to cancer immunotherapy. The general approach for rewiring cellular input and output functions should be useful in fighting other diseases, not just cancer.

"This work is motivated by clinical observations, in which we may know why something goes wrong in the body, and how this may be corrected, but we lack the tools to translate those insights into a therapy," said Leonard. "With the technology we have developed, we can first imagine a cell function we wish existed, and then our approach enables us to build — by design — a cell that carries out that function."

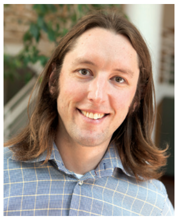
Currently, scientists and engineers lack the ability to program cells to exhibit all the functions that, from a clinical standpoint, physicians might wish them to exhibit, such as becoming active only when next to a tumor. This study addresses that gap, Leonard said.

Published on December 12 in the journal *Nature Chemical Biology*, the study provides details of the first synthetic biology technology enabling researchers to rewire how mammalian cells sense and respond to a broad class of physiologically relevant cues. Kelly A. Schwarz, a graduate student in Leonard's research group, is the study's first author.

WATCHING RNA FOLD

New technology takes a nucleotide-resolution snapshot of RNA folding during synthesis

By the time you reach the end of this sentence, RNA folding will have taken place in your body more than 10 quadrillion times. The folding of RNA is essential to life, yet because it happens so rapidly, researchers have difficulty studying the process.



"RNA folding during transcription is one of the biggest, most essential pieces of biology that we know comparatively nothing about," said Associate Professor **Julius B. Lucks**. "It's an extremely ancient process, and it happens every single time a gene is expressed in a cell. But we have never been able to shine sufficient light on this process at all."

Lucks's group may finally be able to put the mystery to rest. Many years of research in Lucks's laboratory have culminated in a technology platform that provides a super high-resolution representation of RNA folding right as it is being synthesized. Allowing researchers to view this crucial biological process could potentially lead to future discoveries in basic biology, gene expression, RNA viruses, and disease.

Lucks and his team have already used the technology to view the folding of a riboswitch, a segment of RNA that acts as a genetic "light switch" to turn protein expression on or off in response to a molecular signal, in this case fluoride. Supported by the National Institutes of Health, the research was published online on October 31 in *Nature Structural and Molecular Biology*. Postdoctoral scholar Eric J. Strobel and graduate student Kyle E. Watters, both in Lucks's group, were co-first authors of the paper.

Lucks's technology combines two existing components: a next-generation sequencing technique, which is typically used for sequencing human genomes, and a chemistry technique to turn RNA structure measurements into big data. "Instead of treating it like a genome sequencer, we're treating it like a molecular microscope to get a massive snapshot," Lucks said.

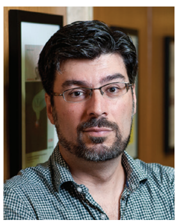
The technique captures the RNA folding pathway in a massive dataset. Lucks's group uses computational tools to mine and organize the data, which reveals points where the RNA folds and what happens after it folds. From the structural information they gather, they can reconstruct a movie of the RNA folding process. The team plans to make the data-analysis component open source, so researchers anywhere can download and run the program.

The technology can be applied to many questions pertaining to RNA, such as how it plays a role in disease. Several notable human diseases, including Ebola, hepatitis C, and measles, are caused by RNA viruses, which are viruses that have RNA as their genetic material. And just as misfolded proteins can cause diseases, such as Alzheimer's and Parkinson's, RNA misfolding could also play a role in human illnesses.

STUDY FINDS FEMALE FACULTY ARE UNDERREPRESENTED IN GENOMICS

Playing field for female faculty in STEM disciplines not always as level as it appears

Succeeding in the male-dominated science, technology, engineering and mathematics (STEM) disciplines can be challenging for female faculty. Now, a Northwestern study of the collaboration patterns of STEM faculty has found that the playing fields in some disciplines are not as level as they first appear.



"Our findings in molecular biology, particularly genomics, are what surprised us the most," said Professor **Luís Amaral**. "There is a lot of research money in this high-profile area, and women are not represented proportionally. This raises all sorts of questions as to what kind of cultural environment has been created in the field."

Knowing that collaboration is critical to the scientific enterprise, Amaral and Teresa K. Woodruff, professor of biomedical engineering and a Northwestern Medicine reproductive biologist, focused on this factor in their study of the underrepresented group of female faculty in STEM. The data analysis of the complete publication records of nearly 4,000 faculty members in six STEM disciplines at top research universities across the country produced a number of findings.

The researchers found that, broadly speaking, female faculty (for the six different disciplines in the study) have as many collaborators, or co-authors, as male faculty and that female faculty tend to return to the same collaborators a little less than males. Previous research by Amaral had shown that novel collaborations have a greater likelihood of producing work of higher impact.

However, those aggregate patterns have to be interpreted with care, Amaral cautioned, because the situation can change within subdisciplines. By digging deeper, the researchers found that females are underrepresented in large teams in genomics (a subdiscipline of molecular biology). This could be an indication of a negative cultural milieu in this particular subfield, the researchers said.

The findings were published November 4 in the journal *PLOS Biology*. The STEM disciplines included in the study are chemical engineering, chemistry, ecology, materials science, molecular biology and psychology.

"Much more progress needs to be made for underrepresented groups to feel welcomed in STEM disciplines," Amaral said. "In fact, the degree of progress is not even uniform within a single discipline, so one needs to make sure females are not being excluded from specific subdisciplines."

FIRST SPHERICAL NUCLEIC ACID DRUG INJECTED INTO HUMANS TARGETS BRAIN CANCER

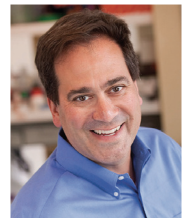
Drug approved by the FDA for use in clinical trial

The first drug using spherical nucleic acids to be systemically given to humans has been developed by Northwestern scientists and approved by the Food and Drug Administration as an investigational new drug for an early-stage clinical trial in the deadly brain cancer glioblastoma multiforme.

The new drug is able to cross the challenging blood-brain barrier to reach tumors in animals, where it turns down a critical cancer-causing gene. Now, the Phase 0 clinical trial will investigate the drug's ability to reach tumors in humans.

The glioblastoma drug represents a revolutionary new class of drugs. The novel spherical nucleic acid platform it is based on can be applied to other types of neurological diseases, such as Alzheimer's and Parkinson's, by similarly turning down the genes that lead to those diseases.

It's highly unusual for a drug to be developed in preclinical research at a university,



shepherded through FDA approval as an investigational new drug and studied in a clinical trial — all within the same university and without funding from a pharmaceutical company. In most cases, a drug is developed and licensed to a pharmaceutical company.

Chad A. Mirkin, the George B. Rathmann Professor of Chemistry, Materials Science and Engineering, and (by courtesy) Chemical and Biological Engineering and Biomedical Engineering, developed the drug with Alexander Stegh, assistant professor of neurology in Northwestern's Feinberg School of Medicine.

"If the spherical nucleic acids cross the barrier and localize in the brain, the implications go beyond glioblastoma," Mirkin said. "This would give us the ability to target diseases of the brain by targeting pathways that we know are associated with different diseases, including Huntington's, Parkinson's and Alzheimer's diseases."

The drug, which consists of short snippets of RNA densely arranged on the surface of spherical gold nanoparticles, changes the genetic makeup of the tumor cells and dampens their ability to divide. The drug targets the gene BCL2L12, which is involved in apoptosis, or programmed cell death. Mirkin and his group invented spherical nucleic acids, and Stegh identified the gene to target.

SENIOR MATTHEW AMROFELL NAMED CO-OP STUDENT OF THE YEAR

Amrofell completed his co-op with Baxter Healthcare

Chemical engineering senior Matthew Amrofell completed his co-op with Baxter Healthcare as a member of a research and development project team, and he attained the responsibilities of a supervisor. Selected as Northwestern Engineering's 2017 Walter P. Murphy Cooperative Engineering Education Student of the Year, Amrofell sat down with Engineering Career Development to talk about his experience.

How do you feel your co-op experience has shaped you as an engineer and person?

The co-op experience is a great way to see the practical side of engineering combined with the traditional classroom learning experience. As a student, I was able to get that practical experience as well as learn some of those soft skills, like how to be a leader in a corporate environment, how to delegate work, how to work with people who have very different work styles, and more.

Tell me what it was like to act as the interim replacement for your supervisor when she was out for three months on maternity leave.

It was a little nerve-racking at first, but I transitioned into the role well. Stepping into my supervisor's position for the interim was definitely more responsibility than my first co-op term. During my first co-op, I was a jack of all trades, completing a variety of tasks given to me by my team. However, in this new role, I had long term responsibility and knew what my work entailed for the entirety of my co-op stint. I was fitting into a niche rather than getting one-off, short-term projects. For an example, the research and development process I coordinated involved several moving parts. There were multiple companies involved in several aspects of the process, including manufacturing and product reliability.

What was it like to work alongside senior and seasoned engineers?

It was a great experience but also a bit complicated to manage what it meant to be a co-op while being in a position of authority. On the one hand, I was always trying to learn as much as I could from my team who were very experienced in the industry. On the other hand, I had to take on a leadership role. Although complicated, my manager was very impressed with how I handled it, and I got along well with all the other people on my team.

You have been involved with several community service initiatives and projects both in local communities and Northwestern's community. What made you decide to take on extra projects, and what did it add to your experience?

Initially, I wanted to give back to the Engineering Career Development office that had helped me secure my co-op, so I volunteered for an interview day. I really liked it, and I thought that everyone in the office got along really well, and it was a fun group. I liked it so much that I became the office's work-study student.

I also volunteered with a couple community service projects with Baxter during the summers. The teams picked local non-profit organizations that they wanted to work with and both summers we worked with Providing Advocacy, Dignity and Shelter or PADS, a resource for homeless people that provides temporary shelter as well as access to resources and services as they relate to finding a job.

I really appreciated how Baxter uses its people's specialized skills to then impact the greater community. This quality is something I have been looking for when pursuing full-time employment after graduation.

In Memoriam: Thomas Goldstick

Thomas Goldstick (center with white boutonnière) celebrates with colleagues at his retirement party.

Thomas K. Goldstick, emeritus professor of biomedical engineering and chemical and biological engineering, passed away on January 13 at age 82. A member of Northwestern's faculty for 32 years, Goldstick studied physiological oxygen transport in blood and tissue, specifically focusing on the arterial wall and the eye. His work with fellow Northwestern professor and former student Robert Linsenmeier produced a promising emulsified blood substitute that increased oxygen delivery to the eye and made national headlines in the 1990s.

In Memoriam: Wolfgang Sachtler

Wolfgang Sachtler (center)

Wolfgang M. H. Sachtler, emeritus professor of chemical and biological engineering and chemistry, passed away on January 8. Sachtler was internationally known for his scientific and technical contributions to the field of heterogeneous catalysis, an essential technology for the production of fuels and chemicals and for pollution control. He is perhaps best known for his research into the importance of available metal surface area dimensions on catalytic function, referred to as the "ensemble size effect."

FACULTY NEWS

Wes Burghardt was elected fellow of the Society of Rheology.

Michael Jewett was appointed to the editorial board of *Cell Systems*.

Danielle Tullman-Ercek became an editor of the journal *mSystems*.

STUDENT NEWS

Tasfia Azim (Jewett group) received an Undergraduate Research Grant.

Goliath Beniah and **Kailong Jin** (both Torkelson group) were among six finalists for the ACS Division of Materials Science and Engineering's Eastman Chemical Student Award in Applied Polymer Science.

Lucia Brunel (Torkelson group) received a Goldwater Scholarship.

Sam Davidson (Jewett group) received a Beckman Scholarship from the Arnold and Mabel Beckman Foundation.

Taylor Dolberg (Leonard group), **Ashty Karim** (Jewett group), and **Angela Yu** (Lucks group) received honorable mention at the Engineering Biology Research Consortium retreat's poster session.

Joseph Draut, **Amy Hong**, and **Cam McDonald** (all Leonard group) received summer research grants.

Jake Heggestad (Jewett group) received the Outstanding Poster Award in Engineering at the Chicago-Area Undergraduate Research Symposium.

Andrew Hunt (Jewett group) became a graduate fellow in the Brady Scholars program.

Andrew Hunt (Jewett group), **Andrew Rosen** (Snurr group), and **Jasmine Hershewe** (Jewett group) received NDSEG fellowships.

Scott Nauert (Notestein group) received a poster competition prize at the Catalysis Club of Chicago's spring symposium.

Peter Su (Tyo and Leonard groups) represented Northwestern at the Catalyzing Advocacy in Science and Engineering workshop.

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Synthesis Snapshot

This matrix of the RNA folding pathway shows how the transcription length and nucleotide positions change over time. (Nucleotide position is along the x-axis; transcription length is along the y-axis.) Each pixel in the matrix is a piece of information about the structure of the RNA molecules.

By pinpointing where RNA folds and what happens after it folds, Associate Professor Julius Lucks can reconstruct a movie of the RNA folding process. This could help his group understand questions pertaining to RNA, such as how it plays a role in disease.

Read more on page 4.