Northwestern | McCORMICK SCHOOL OF ENGINEERING

FALL 2016

CHEMICAL AND BIOLOGICAL ENGINEERING

REINVENTING THE WHEEL: NORTHWESTERN RESEARCHERS DEVELOP RECYCLABLE RUBBER

John M. Torkelson's discovery could one day lead to recyclable car tires

by Monika Wnuk

Professor John M. Torkelson has found a solution to a common problem with rubber: it can't be recycled.

Separating recyclables from the waste stream has become routine behavior. Paper, plastics, glass, and metals are collected and converted into reusable products, reducing landfill diversion and minimizing its ecological footprint.

The ability of a non-paper material to be recycled depends largely on the way its polymers are linked. When rubber — which is made of permanent cross-linked chains — is heated, it strengthens and can't be remolded into a usable product that retains its original durability and elasticity.

Torkelson, Walter P. Murphy Professor of Chemical and Biological Engineering and materials science and engineering at Northwestern, and two of his PhD students have developed a simple, one-step strategy to solve this problem by modifying the way the polymers in rubber are linked.

"Our approach can be used for any rubber applications that require elasticity and durability – from common products like shoes, to aerospace materials," said Torkelson.

Torkelson sees particular impact for the tire industry. The Rubber Manufacturers Association estimates that of the 244 million scrap tires the US disposed of in 2013, 50 percent were simply burned for fuel. Nearly 10 percent — 20 million tires — were landfilled.

The team's approach would allow tires to be made using conventional polymers, maintaining the properties that make tires effective, but modifying the way the polymers are cross-linked. Currently, the resulting material has shown full retention of properties after two cycles of the process, with further trials to come.

The one-step synthesis approach separates the cross-links in rubber at high temperatures, making it possible for them to reform and retain their properties in a cooled state.

To successfully reform, the individual electrons that remain when a cross-link

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Torkelson

"MY GROUP WILL DEDICATE THE COMING DECADE TO THIS NEW LINE OF RESEARCH... IT HAS THAT MUCH POTENTIAL."

NEW CENTER FOR SYNTHETIC BIOLOGY LAUNCHES

The Center will solidify Northwestern's leadership in the field

Northwestern University is solidifying its place in the exciting field of synthetic biology.

Launching last February, the new Center for Synthetic Biology will make Northwestern one of the top destinations in the field for research and education in the country.

"This Center will rapidly raise our leadership profile in the field," said Milan Mrksich, director of the center. "It will create a community where the best faculty, students, and postdoctoral fellows find an intellectual home with partners from diverse backgrounds, a suite of technologies that allow research to be performed at the highest level, and a vibrant program for visitors from both within and outside Northwestern. This will create an ecosystem for synthetic biology that is second to none."

Synthetic biology uses tools and concepts from physics, engineering, and computer science to build new biological systems. Much of this research focuses on reprogramming cells by changing their DNA to take on new, specialized purposes, such as creating sustainable chemicals, next generation materials, or targeted therapies.

The Center for Synthetic Biology is led by Mrksich, Henry Wade Rogers Professor of Biomedical Engineering, chemistry, and cell and molecular biology, and co-director Michael Jewett, associate professor of chemical and biological engineering.

"The Center will focus on research that lies at the intersection of science and technology, creating opportunities for technology transfer, clinical translation, and commercialization," said Jewett. "Our educational priorities will help create a tightknit community that further enhances this field."

From left: Joshua Leonard, Neda Bagheri, Keith Tyo, Dean Julio M. Ottino, Julius Lucks, Milan Mrksich, Michael Jewett

The Center's advisory board includes three internationally renowned scientists and engineers: Frances Arnold, the Dick and Barbara Dickinson Professor of Chemical Engineering, Bioengineering, and Biochemistry at the California Institute of Technology; James J. Collins, the Termeer Professor of Bioengineering at the Massachusetts Institute of Technology; and Wendell Lim, professor of cellular and molecular pharmacology at the University of California at San Francisco.

"This new Center will help us attract some of the best minds and researchers as we continue to grow in this field," said Julio M. Ottino, dean of Northwestern's McCormick School of Engineering. "With a strong core in chemical and biological engineering and connections to many other disciplines, our faculty have already established themselves as an emerging area of strength."

In addition to Center leadership, faculty members Neda Bagheri, Joshua Leonard, and Keith Tyo have already put Northwestern on the map as a national leader in this growing area of study.

"We have grown in an organic, patchwork way," Mrksich said. "Our students know each other, but they don't recognize the entirety of the community. The Center will solidify their experience, so that we can all come together and attack the real challenges in the field."

Northwestern Presence Felt at Synthetic Biology Conference

Established in 2014, the Synthetic Biology: Engineering, Evolution, and Design (SEED) conference focuses on the top cutting-edge advances in science and technology from the field of synthetic biology. Chaired by Jewett, SEED 2016 focused on designing, harnessing, and expanding the capabilities of biological systems. The event took place in July in Chicago.

"This was a terrific event for Northwestern," Jewett said. "We were able to showcase our new faculty and the recent launch of the Center. There was a lot of excitement for what we are doing here. I think we are quickly becoming one of the top three US destinations for research and education in the field of synthetic biology."

The conference featured stimulating presentations and discussions of recent work in the field, with many highlights from Center for Synthetic Biology faculty and students.

SYNTHETIC BIOLOGISTS JOIN NORTHWESTERN

Julius Lucks and Danielle Tullman-Ercek join the Department of Chemical and Biological Engineering this fall

Northwestern Engineering's growing synthetic biology team is expanding to include two new faculty.

This fall Julius Lucks from Cornell University and Danielle Tullman-Ercek from the University of California at Berkeley will join Northwestern's Department of Chemical and Biological Engineering and Center for Synthetic Biology.

Lucks' work combines experiment and theory to ask fundamental questions about the design principles that govern how RNA folds and functions in living organisms. He then explores how these principles can be used to engineer biomolecular systems to open doors to new medical therapeutics.

Lucks has received several awards and honors, including an NSF CAREER Award, NIH New Innovator Award, Office of Naval Research Young Investigator Award, Alfred P. Sloan Research Fellowship, and DARPA Young Faculty Award. He earned his bachelor of science in chemistry from the University of North Carolina at Chapel Hill, where he received a Barry M. Goldwater Scholarship, and then earned an MPhil in chemical physics from Cambridge University, where he received a Winston Churchill Scholarship. He has a PhD in chemical physics from Harvard University.

Tullman-Ercek, formerly Berkeley's Merck Chair in Biochemical Engineering, seeks to control the transport of all types of materials, from electrons to macromolecules, across cellular membranes. Her work has broad applications, including the production of biofuels and chemicals as well as the development of living batteries.

Lucks

Tullman-Ercek

Tullman-Ercek's awards and honors include the Exxon Knowledge Build Award, NSF CAREER Award, Charles Wilke Endowed Chair in Chemical Engineering, and paper of the year from the Journal of the Taiwan Institute of Chemical Engineers. She earned her bachelor of science from the Illinois Institute of Technology and PhD in chemical engineering from the University of Texas at Austin, where she was a NSF Graduate Research Fellow.

Recyclable Rubber, continued

John M. Torkelson's simple, one-step strategy to recycle rubber could one day impact the tire industry.

comes apart at high temperatures, called radicals, must find each other upon cooling. The team needed to find a molecule that had both a stable (reforming) radical, as well as a carbon-carbon double bond, which they found in a molecule called TEMPO methacrylate.

The research builds on more than 15 years of work in the area by various researchers. Limitations of prior approaches included processes that were costly, chemically-intensive, and required many reaction steps under specific conditions. These processes were also characterized by low recovery of cross-links and material properties, according to Torkelson.

"Our approach requires only one round of chemical synthesis, uses all commercially-available components, which are also inexpensive and easy to synthesize, and is adaptable to a large fraction of cross-linked polymers out there," said Torkelson.

The team's next steps will include iterations to improve the methodology, and searching for industry partners to help bring the technology to market. They will also explore new applications.

"My group will dedicate the coming decade to this new line of research," said Torkelson. "It has that much potential."

MASANET USES SABBATICAL TO COMBAT CLIMATE CHANGE

Masanet leads International Energy Agency's Energy Demand Technology Unit

Climate change is one of the world's biggest problems. Northwestern Engineering's Eric Masanet is working to be part of the solution.

Last December, representatives from 195 countries converged at the United Nation's Conference on Climate Change (COP21) in Paris. There, they reached a landmark agreement that is believed to be a historic turning point for combating climate change.

Called the "Paris Agreement," it is the most significant international deal to reduce global warming since the issue first emerged.

The agreement's arguably most ambitious goal is to limit the global temperature rise to well below 2 degrees Celsius. Associate professor Eric Masanet's modeling team is crunching numbers to help governments explore ways of getting there.

Currently spending his sabbatical with the International Energy Agency (IEA) in Paris, Masanet leads the IEA's Energy Demand Technology Unit, which is addressing some of society's most pressing challenges by identifying clean energy technology pathways and policies that can help limit global temperature rise.

"The Paris Agreement will require major shifts in energy systems, behavior, and development pathways over the next two-to-three decades in all world regions," said Masanet, Morris E. Fine Junior Professor in Materials and Manufacturing.

Masanet is no stranger to modeling complex systems. At Northwestern, he develops mathematical models that quantify opportunities for reducing society's energy and resource use over different scales of time and space. Manufacturers, consumers, and policymakers use such models to identify technological, behavioral, and policy pathways toward more sustainable products and processes.

Although he has dedicated his life to sustainability, Masanet said his IEA experience has "redoubled" his passion for using models to guide effective technology and policy decisions.

"Having sound data on how transitions to more sustainable energy systems can meet multiple societal goals — and at what cost — is imperative for accelerating policy action, and this is where modeling can make a real difference," Masanet said.

Masanet

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>
> ERIC MASANET

When he returns to Northwestern, Masanet plans to leverage the experience and knowledge he gained abroad in his laboratory's modeling work. His time in Paris, he said, has given him a more global perspective on how different countries deal with climate challenges and solutions.

"The optimal mix of technologies and their rates of adoption in one country might look very different from those in another," Masanet said. "I've developed a greater appreciation of how local factors influence the shape of energy policy and for how such nuances must be reflected in analyses for technology guidance."

DATA SCIENCE, COMPLEX SYSTEMS AT THE CENTER OF 'ONE BOOK ONE NORTHWESTERN' SELECTION

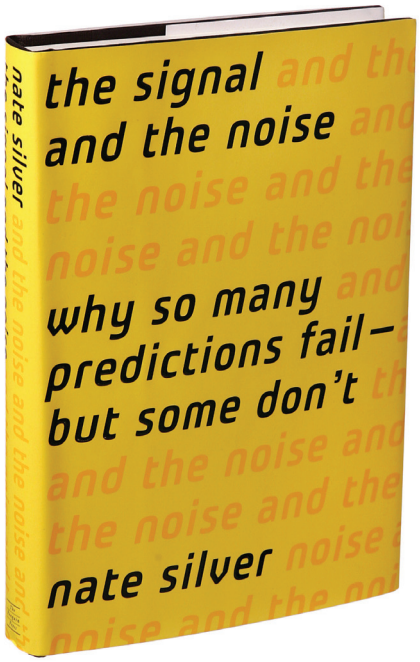
Nate Silver's *The Signal and the Noise* chosen for University discussion throughout academic year

Every year, Northwestern chooses a book with the intention of providing a theme for common discourse throughout the University community.

Dubbed One Book One Northwestern, the program's selection for the 2016-17 academic year is Nate Silver's *The Signal and the Noise (Penguin Books, 2012)*. Silver, a statistician and founder of fivethirtyeight.com, examines statistical analyses and how they allow people to extract understanding from data, as well as analytics' role at the heart of predicting outcomes in areas like athletics, elections, health, weather, the markets, and more.

First-year students were mailed a copy of *The Signal and the Noise* over the summer and encouraged to read it before arriving on campus so they could participate in a University-wide discussion of its themes. Highlighted by a keynote talk delivered by Silver himself on October 6, the Northwestern community will have opportunities throughout the academic year to contribute to lectures, panel discussions, exhibitions, performances, and off-campus excursions related to the book. Students were even able to download an app to make statistical predictions before and during Northwestern's September 17 football game against Duke.

Stephen Carr, who chairs the steering committee that helps organize One Book One Northwestern events, believes the book effectively communicates how predictions of outcomes based on sound methodologies can affect everyone's lives, even if they don't have a statistical background.



Nate Silver's The Signal and the Noise examines how people extract understanding from data.

"Those who have had coursework in mathematics, science, or engineering may find what the book teaches fairly obvious," said Carr, professor of chemical and biological engineering and materials science and engineering. "But it's compelling to discuss its themes with those of different backgrounds who see the world in less-quantitative terms."

According to Carr, many research areas embraced by chemical and biological engineering faculty connect to *The Signal and the Noise*'s guiding principles. Professor Luís Amaral uses data science to achieve a better understanding of nature's complex networks as co-director of Northwestern's Institute on Complex Systems (NICO). Professor and associate dean of undergraduate engineering Wesley Burghardt studies the complex flow behavior of ordered polymeric and self-assembled fluids to gain new insights into its structural origins. Like Silver's book, their work applies analytics to large data sets in order to separate confounding factors (the "noise") from the essential values they have acquired (the "signal").

To learn more about One Book One Northwestern and the events planned for *The Signal and the Noise*, visit northwestern.edu/onebook.

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>
> STEPHEN CARR

MASTER OF BIOTECHNOLOGY PROGRAM WELCOMES NEW COHORT, LAB SPACE

The program's latest class of students will enjoy a larger, modern lab space

This fall, the Department of Chemical and Biological Engineering's Master of Biotechnology Program (MBP) welcomes its 13th cohort of matriculates.

Featuring students from across the United States and five other countries around the world, this year's class offers an impressive range of backgrounds in biotechnology, pharmacy, molecular biology, and chemical engineering. The class also features a nearly even split among male and female students, who are joining the program after completing their undergraduate degrees, working in industry, or serving in the military.

In addition to a new cohort of students, MBP is pleased to open a new, larger laboratory space located within the Technological Institute. Students will experience lab courses using the same sophisticated equipment found in the biotechnology industry.

"The new lab facilities allow us to dedicate separate rooms for microbial and animal cell experiments," said Arthur Felse, program lecturer and MBP assistant director of research. "More importantly, the additional space and program resources have allowed us to add state-of-the-art process analytical equipment that MBP graduates use in industry, including a flow cytometer, automated Western blot, metabolite analyzer, and off-gas analyzers for our bioreactors."

The program will also host its annual Biotechnology Day on November 10, a life sciences festival designed to inspire and inform students and scientists interested in learning more about the field. The day's events will feature community outreach activities, tours of facilities, career panels, a keynote speaker from the MBP Industrial Advisory Board, and an open networking session.

MBP's new lab space includes state-of-the-art equipment that program graduates use in industry.

"Biotechnology Day is a great opportunity to promote the Master of Biotechnology Program and the biotechnology industry as a whole," said Natalie Champagne, assistant director of external relations and career management for MBP. "The MBP team believes in collaborating with community partners and sharing knowledge with the younger generation, which is why we invite nearly 100 high school students each year to take part in the day's events."

Since its founding in 2003, MBP has graduated more than 300 students while earing its status as one of the nation's top biotechnology programs. Featuring a unique curriculum that blends engineering, biology, and business, the program also includes 1,000 hours of intense research to grow students' hands-on skills, as well as an optional industrial internship where students gain valuable experience in the challenging environment of the biopharmaceutical industry.

MBP ALUMNI HAVE PURSUED SUCCESSFUL CAREERS AS SCIENTISTS, ENGINEERS, CONSULTANTS, AND PHD CANDIDATES IN INDUSTRY AND ACADEMIA

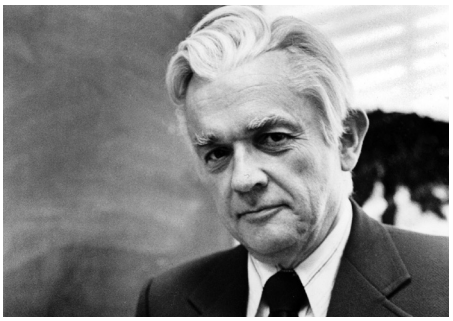
MBP alumni have pursued successful careers as scientists, engineers, consultants, and PhD candidates in industry and academia, including at organizations like AbbVie, Amgen, Deloitte, Genentech, Johnson & Johnson, MedImmune, and Pfizer.

William F. Stevens, Emeritus Professor, Passes Away

William F. Stevens, emeritus professor of chemical and biological engineering, passed away on December 5, 2015.

Born in Detroit, Michigan, Stevens received a BS in chemical engineering from Northwestern University in 1944 and a PhD in chemical engineering from the University of Wisconsin in 1949. After serving in the Navy, he worked in industry at BFGoodrich and consulted with a number of oil and chemical companies before joining Northwestern as a chemical engineering faculty member in 1951.

In addition to teaching hundreds of undergraduate and graduate students, Stevens served as chair



Stevens

of the Department of Chemical and Biological Engineering, as well as dean of The Graduate School at Northwestern. He was also credited with helping redesign Northwestern Engineering's freshman curriculum.

Stevens retired from teaching at Northwestern in 1987. In retirement, he continued his role as an active member of the Glenview Community Church, singing in the choir and serving on several committees. He also served as president of his town's library board. He enjoyed using computers and traveling with his wife Lillian.

A loving husband, father, grandfather, and devoted friend, Stevens is survived by his sister Sally Koepsell, his children Karin Friese, Martha Freeman, Alan Stevens, and Susan Pierce, as well as 11 grandchildren, and 13 great-grandchildren. He was predeceased by his wife Lillian in 2009 and daughter Fran Derby in 2015.

FACULTY NEWS

Michael Jewett received the highly competitive MURI grant to develop new types of electrical materials for battery storage and sophisticated lightweight electronics.

Julius Lucks received the 2016 ACS Synthetic Biology Young Investigator Award for his early contributions to the field.

William Miller was appointed to the Science Advisory Committee of The Nature Conservancy of Illinois.

Chad Mirkin received the prestigious 2016 Dan David Prize in the Future Time Dimension for his trail-blazing breakthroughs in nanoscience.

Randall Snurr received the 2015 Ernest W. Thiele Award from the Chicago Local Section of AIChE.

Igal Szleifer received the Cole-Higgins Award for Excellence in Advising for fostering learning and creativity in a positive environment.

STUDENT NEWS

Bola Adeniran (Tyo) was selected as a Presidential Fellow, the highest honor that Northwestern bestows upon its graduate student population. Adeniran is also an NSF Graduate Fellow and an HHMI Gilliam Fellow.

Erik Carlson (Jewett) received the grand prize at the Synthetic Biology: Engineering, Evolution, and Design (SEED) conference for his poster about repurposing ribosomes to expand the chemistry of life.

Alaksh Choudhury, a former student in the Master of Biotechnology Program, received the second place poster award at the Synthetic Biology: Engineering, Evolution, and Design (SEED) conference in the molecular systems biology category.

Taylor Dickman (Tullman-Ercek), **Jessica Yu** (Bagheri), **Do Soon Kim** (Jewett) and **Devin Stranford** (Leonard) received NSF Graduate Research Fellowships.

Jake Heggestad received a Summer Undergraduate Research Grant for his research in Michael Jewett's lab.

Hanyu Gao (Broadbelt) was awarded first prize in the poster competition at the 24th International Symposium on Chemical Reaction Engineering.

PhD students **Daniel Garcia** and **Jian Gong** had research featured on the cover of *ACS Sustainable Chemistry and Engineering*.

Ashty Karim (Jewett) earned the second place poster award at the Synthetic Biology: Engineering, Evolution, and Design (SEED) conference for his work on establishing a new paradigm to enable sustainable chemical synthesis in cell-free systems.

Matt Mendonca (Snurr) received an NDSEG Fellowship.

Nicholas Thornburg (Notestein) received the Gore Fellow Award, a prize for industry-bound graduate students sponsored by the W. L. Gore company. Mary Wang (Mirkin) received third prize.

Casey Whitford (Snurr) was awarded first prize in the poster competition at the Gordon Research Conference on Catalysis.

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Making the Most of Viruses

Viruses make useful devices for bionanotechnology applications, such as drug delivery, nanomaterial production, and biosensors. But researchers have been limited by the shapes and sizes of viruses found in nature. By making a single mutation at the nucleic acid level, Professor Danielle Tullman-Ercek's group altered the virus's shell in order to change its size and geometry. The finding shows that many more viral shapes and sizes may be within reach than previously thought, which could change the way scientists think about the natural evolution of viruses.

Read more about Danielle Tullman-Ercek joining the Department of Chemical and Biological Engineering on page 3.