

# CHEMICAL AND BIOLOGICAL ENGINEERING

## ALUMNA EARNS A SPOT ON AICHE'S '35 UNDER 35' LIST

**N**ot even a decade removed from her studies at Northwestern, alumna **Beth Carter** ('08) has firmly established her presence in the chemical engineering field.

In August 2017, the American Institute of Chemical Engineers (AIChE) announced it had named Carter among the recipients of its first "35 Under 35 Award," which salutes the industry's brightest young minds.

As a lead development specialist in the Refining Development Group at Honeywell UOP, Carter heads R&D teams cultivating novel process, equipment, and catalyst technology solutions in oil refining. According to Carter, it's an opportunity to address real customer needs with innovative technologies, such as a new process that will replace sulfuric acid and hydrofluoric acid with an ionic liquid catalyst to bring heightened efficiency and environmental value to the current petroleum refining process.

Carter answered some questions to provide more insight into her career since graduation and what the award means to her.

### **How did you react when you learned about the AIChE award?**

I was excited. People often receive awards at the end of their careers when they have a long laundry list of accomplishments. I didn't think that was me, but receiving the award helped me realize that I've had a real impact on energy technology development.

### **What do you most enjoy about your work at UOP?**

I enjoy working with a diverse team of really smart people. Plus, UOP has the resources for tech development — pilot plant, analytical capabilities, process design, commercialization resources, and more — that allow us to bring impactful technologies to market.

### **Did you always have engineering on your career radar?**

I decided to become an engineer largely to avoid having to do a lot of writing. I learned in my first-year Design Thinking and Communication course that wouldn't be the case. McCormick was always consistent in educating technically competent engineers. The school also taught us how to write, present, and collaborate, all skills I'm applying regularly today.

### **What experiences and people at Northwestern propelled you to where you are today?**

I got my job at UOP through Northwestern adjunct professor Gavin Towler. I met him my freshman year, and he helped me land an internship with UOP that summer.



Beth Carter

He showed me the possibilities of a career in chemical engineering and how it could lead to having an impact on the world.

Northwestern also gave me an opportunity to get involved in novel projects like the autonomous robot competition. Sometimes it's hard to be a young engineer. People tend to think that the good engineers all have gray hair. That competition taught me that it's not the gray hair, but rather the approach to problem-solving and bringing ideas to life that makes an engineer successful.

# MASANET USES SABBATICAL TO COMBAT CLIMATE CHANGE

## Eric Masanet led International Energy Agency's Energy Demand Technology Unit

Climate change is one of the world's biggest problems. Professor **Eric**

**Masanet** is working to be part of the solution.

In December 2015, 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. Masanet spent his two-year sabbatical with the International Energy Agency (IEA) in Paris, exploring ways to help governments reach this goal. He also led 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 sets very ambitious goals," Masanet said. "It will require major shifts in energy systems, behavior, and development pathways over the next two-to-three decades in all world regions."

Masanet 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



Eric Masanet

**"THE PARIS AGREEMENT WILL REQUIRE MAJOR SHIFTS IN ENERGY SYSTEMS, BEHAVIOR, AND DEVELOPMENT PATHWAYS."**

### ERIC MASANET

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 "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. "The world needs such analyses and numbers urgently, given the decisions and investments being made in many countries related to clean energy deployment and climate change mitigation."

After returning to Northwestern this quarter, 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, depending on local factors, such as energy supplies, economic structure, and local resources," 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."

# UNDERGRADUATE RECEIVES 2018 MARSHALL SCHOLARSHIP

## Lucia Brunel will attend the University of Cambridge

Senior **Lucia Brunel** has received a 2018 Marshall Scholarship, which will send her to the United Kingdom this fall. She will spend a year at the University of Cambridge to obtain a master of philosophy in materials science and metallurgy.

Designed to train future leaders, the Marshall Scholarship promotes partnerships, peace, and greater understanding among Britain, Ireland, and the United States.

Established in 1953 as a British gesture of thanks to the United States for assistance Britain received under the Marshall Plan after World War II, the Marshall Scholarship aims to strengthen the relationship between the British and American citizens, their governments and institutions. Beginning in September 2018, 43 scholar winners — the largest cohort of scholars since 2007 — will begin degrees at leading British institutions.

Brunel has conducted research since 2013, when she was a high school senior working in a biomaterials lab at the University of Texas at Austin. At Northwestern, she continued her research path as a member of Professor John Torkelson's laboratory and through a series of three summer research projects.

Brunel missed the initial call from the Marshall committee while on the flight to Chicago from her Marshall interview in Houston. The committee didn't leave a message, so she called the number right back and got the good news, to cheers from nearby passengers she had chatted with on the plane.

"THROUGH MY INVOLVEMENT IN SWE, I AM WORKING TO OVERCOME REFLEXIVE QUESTIONING OF THE ABILITIES OF WOMEN IN STEM."

LUCIA BRUNEL



Lucia Brunel

"I am fortunate to have family and friends who supported me through the long application process and fabulous mentors and professors at Northwestern University who guided me through revisions of my application materials and mock interviews over the past several months," she said.

A winner of the Goldwater Scholarship for the 2017-18 academic year, Brunel will work in the Cambridge Centre for Medical Materials, where her research will focus on improving the performance of bioactive "scaffolds" used in tissue engineering.

Brunel's drive started at a young age. In elementary school, "nobody believed that I — a girl — could have won the Math Olympiad," she recalled. She has served on

the executive board of the Northwestern chapter of the Society of Women Engineering (SWE) for the past three years and has taken honors engineering classes.

Her placement in the laboratory of Cambridge professors Ruth Cameron and Serena Best, leading female researchers in materials science — a field in which women are underrepresented in academic roles — is a perfect fit.

"Through my involvement in SWE, I am working to overcome reflexive questioning of the abilities of women in STEM," Brunel said.

Brunel will graduate in June with a joint bachelor's and master's degree in chemical and biological engineering.



# RESEARCH HIGHLIGHTS

## NORTHWESTERN JOINS NSF CENTER TO PRODUCE FUELS AND CHEMICALS

Center will develop new technologies to produce fuels and chemicals from US shale-gas deposits

Northwestern is a key partner in the new Center for Innovative and Strategic Transformation of Alkane Resources (CISTAR). Funded by the National Science Foundation (NSF) and led by Purdue University, the engineering research center will develop new technologies to produce fuels from US shale-gas deposits that could inject \$20 billion annually into the economy.

The new approach proposes to convert light hydrocarbons from shale gas into chemicals and transportation fuels using a network of portable, modular processing plants. It is estimated that there is enough



Linda Broadbelt

energy in shale to provide all of the nation's transportation fuels for 100 years.

CISTAR has received the highly competitive NSF engineering research center designation. It is one of only 19 currently active ERCs in the United States and one of four new ERCs announced this year.

The NSF will provide \$19.75 million over five years for the center. Industrial and university partners will contribute additional funding and critical resources. In addition to researchers from Northwestern and Purdue, the center includes lead academic teams from the University of New Mexico, the University of Notre Dame, and the University of Texas at Austin, as well as partners from industry, national laboratories, and national and international research organizations.

Northwestern faculty members who are involved with the center include **Linda Broadbelt, Jennifer Cole, Jennifer Dunn, Tobin Marks, Justin Notestein, and Peter Stair.**

## CREATING A BETTER RNA SWITCH

Newly developed switch activates genes thousands of times better than nature

Professor **Julius Lucks** and his team have developed a powerful and versatile tool that achieves gene activation thousands of times better than nature. The research was published in *Nature Communications*.

Using a computational design approach, Lucks created the switch by molecularly



Julius Lucks

programming an RNA molecule called Small Transcription Activating RNA, or STAR, that his group had previously discovered. He uses an algorithm — developed by Northwestern

alumnus Joe Zadeh ('03) — to optimize the STAR for specific applications. An outside company uses the algorithm's results to construct a physical piece of RNA, which Lucks then uses in experiments.

Lucks likens STARs to a light switch. "For anything to happen in biology, the 'light' has to be turned on," Lucks said. "We're always interested in turning things

"WE'RE ALWAYS INTERESTED IN TURNING THINGS ON, SO WE FOUND A WAY TO ENGINEER SOME REALLY GOOD LIGHT SWITCHES."

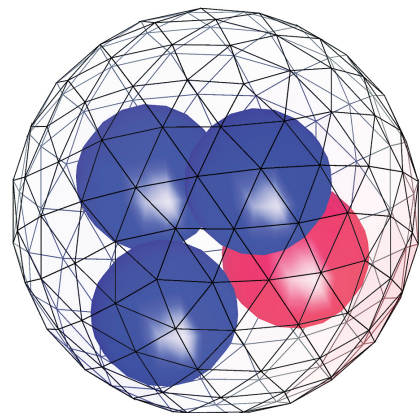
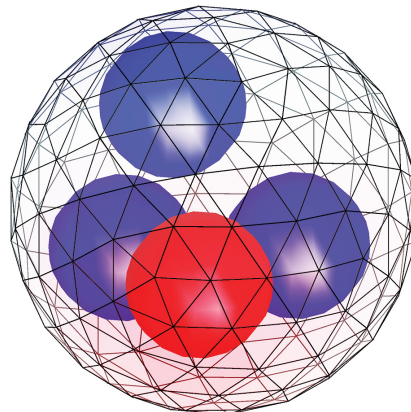
JULIUS LUCKS

on, so we found a way to engineer some really good light switches."

The RNA switches found in nature are unable to turn the "lights" fully on or off. Often times the room is consistently dim instead of completely dark or brilliantly light. But researchers have desired to have a tighter control of the system. Lucks' STAR can turn on the light — or activate a gene — 9,000 times brighter than without the STAR present, providing the completely dark or light room that researchers have lacked.

Lucks plans to use his new tool to explore diagnostic applications. Because RNA excels at detecting other strands of RNA, STARs could be useful in diagnosing RNA viruses. To do this, Lucks' switch could be engineered to turn on in the presence of one of these viruses.

Monica Olvera de la Cruz is working to understand why ions inside of water droplets (as shown here) are extremely difficult to separate.



## UNDERSTANDING RARE EARTH EMULSIONS

**Surface polarization in mixed media increases attraction among elements**

Rare earths are a set of 17 chemical elements along the bottom of the periodic table. Because most of the elements each have +3 charges in their ionic structures, they are notoriously difficult to separate.

Professor **Monica Olvera de la Cruz** and her team are working to better understand why rare earths are strongly attracted to each other across long distances, making separation and extraction tediously difficult. A series of molecular simulations suggest, for the first time, that the medium in which the elements are suspended — in addition to the elements themselves — is partially responsible for the strong attraction. Published in *Physical Review Letters*, this finding could potentially make rare earth recovery faster, easier, and less expensive.

The time-consuming and expensive separation process requires hundreds of steps and toxic chemical solvents. To separate the elements, engineers encapsulate them in self-assembled nanodroplets



Monica Olvera de la Cruz

of water immersed in oil. Engineers then use surfactants, which grab the elements from the water and pull them into the oil. But when the water droplets are suspended in oil, the droplets are strongly attracted to one another and aggregate. In a theoretical study, Olvera de la Cruz's team discovered that the mixed medium of oil and water plays a major role.

"A unique feature of these emulsions is that the interface between the two mediums gives rise to surface polarization," Olvera de la Cruz explained. "That surface polarization contributes to the inter-droplet interactions."



At waste-gas-to-fuel plants like this one in China, Jewett's collaborators at LanzaTech use clostridia to produce sustainable fuels.

In a surprising twist, the team also discovered that the finding only applies to water droplets in oil. When the reverse occurs — oil droplets suspended in water — the induced charge is repulsive and the attraction is reduced. This better understanding of emulsions can be applied to separating rare earths as well as other elements, including the removal of radioactive metals and nuclear waste.

## NEW CENTER TO ACCELERATE BIOLOGICAL DESIGN

**Northwestern-led center receives \$12 million grant from US DOE**

Northwestern will lead a new center dedicated to accelerating the production of sustainable, low-cost bio-fuels and chemicals. Called the Clostridia Foundry for Biosystems Design, the multi-institutional center has received a five-year, \$12 million grant from the US Department of Energy.

The center's researchers — from Northwestern, Oak Ridge National Laboratory, and clean-energy startup LanzaTech — will focus on clostridia, a bacterium that metabolizes carbon to produce fuel.



Michael Jewett

"Clostridia can fix carbon from carbon dioxide and carbon monoxide and use it to grow and make something useful," said Professor **Michael Jewett**, the center's principal investigator.

A waste-gas-to-fuel startup, LanzaTech houses a collection of clostridia strains. Michael Koepke, who leads LanzaTech's synthetic biology team, is a leading expert in genomically manipulating clostridia. He and Jewett have been collaborating for the past two years to engineer clostridia to produce sustainable fuels, but engineering microorganisms to perform new tasks is not without its challenges.

"We end up fighting a tug of war between what the cell wants to do and what we want it to do," Jewett said.

Jewett bypasses this problem by removing the cell from the equation. He and his team isolate and activate basic cellular processes outside of the live, intact microorganism. This accelerates testing from a handful of designs in three months to thousands of designs in three days.

Professors **Linda Broadbelt** and **Keith Tyo** are co-principal investigators on the grant.

# GREGORY MAHER RECEIVES COLE-HIGGINS AWARD

**Maher was selected for his dedication to students and valuable insights into engineering**

“NO PROFESSOR AT NORTHWESTERN HAS HAD SUCH A LARGE IMPACT ON MY EXPERIENCE AS PROFESSOR MAHER.”

CHBE UNDERGRADUATE



Adjunct professor **Gregory Maher** received the 2017 Cole-Higgins Award for Excellence in Teaching from the McCormick School of Engineering.

Maher, a process engineer with more than 30 years of experience in the design and operation of process units, was noted for his dedication to students and valuable insights into professional engineering.

“I can whole-heartedly say that there is no professor at Northwestern who better exemplifies what an engineer should be like,” one student said. “His years in industry make him an irreplaceable teacher, and I always feel like I am becoming a better engineer when working with him and learning from him.”

“No professor at Northwestern has had such a large impact on my experience as Professor Maher,” another student said. “He deserves every award the University has to offer.”

# LINDA BROADBELT RECEIVES E. V. MURPHREE AWARD

**Award honors Broadbelt’s outstanding research in chemical engineering**



Professor **Linda Broadbelt** received the E. V. Murphree Award in Industrial and Engineering Chemistry, awarded by the American Chemical Society (ACS) and sponsored by ExxonMobil Research & Engineering.

The award, which comes with a \$5,000 prize, recognizes one individual each year who has accomplished outstanding research of a theoretical or experimental nature in the fields of industrial chemistry or chemical engineering.

Broadbelt is the Sarah Rebecca Roland Professor in the Department of Chemical and Biological Engineering. She recently joined Northwestern Engineering’s senior

leadership team as associate dean for research after serving as the department’s chair since 2009.

Broadbelt’s research and teaching interests are in the areas of multiscale modeling, complex kinetics modeling, environmental catalysis, novel biochemical pathways, and polymerization/depolymerization kinetics. She is a member of the Robert H. Lurie Comprehensive Cancer Center of Northwestern University, the American Institute of Chemical Engineers (AIChE), the American Chemical Society, and the American Association for the Advancement of Science.



## FACULTY NEWS

**Linda Broadbelt** was named a fellow of the American Institute of Chemical Engineers.

**Jennifer Dunn** was appointed to a National Academy of Science committee on developing a research agenda for utilization of gaseous carbon waste streams.

**Omar Farha, Tobin Marks, Chad Mirkin, George Schatz,** and **Randy Snurr** were named 2017 highly cited researchers by Clarivate Analytics.



Omar Farha

**Omar Farha** was named fellow of the American Association of the Advancement of Science.

**Michael Jewett** and **Julius Lucks** were invited to join

the inaugural Leadership Council of Engineering Biology Research Consortium, the premier organization for engineering biology in the United States.

**Michael Jewett** joined the managing board of the Society of Biological Engineering within the American Institute of Chemical Engineering.



Josh Leonard

**Josh Leonard** was elected vice chair of the American Institute of Chemical Engineers' Food, Pharmaceutical, and Bioengineering Division and will ascend to chair next year.

He was also selected to join the scientific executive committee of GP-Write, a multinational synthetic biology project dedicated to realizing whole genome synthesis in order to understand, engineer, and test living systems.



Mitchell Wang

**Mitchell Wang** was selected as a fellow of the 2017-18 Searle Fellows program, which helps early career faculty develop expertise and knowledge about learning and teaching.

## STUDENT NEWS

**Anne d'Aquino** (Jewett) received a Ryan Fellowship.

**Tasfia Azim** (Jewett) and **Stephen Lillington** (Tyo) received poster prizes at the annual meeting of the American Institute of Chemical Engineers.

**Rey Martin** (Jewett) won the Best Presentation Award from the American Chemical Society BIOT Division at the ACS Annual Meeting.

**Do Soon Kim** (Jewett) received the 2017 Doh Wonsuk Memorial Award from the US Chapter of the Korean Institute of Chemical Engineers.

**Angela Yu** (Lucks) received the Best Talk Award at the regional Rust Belt RNA meeting. This is the second year in a row that a student in the Lucks group won the award.

## ALUMNI NEWS



Brian P. Chekal

**Brian P. Chekal** (PhD '02) will receive the 2018 ACS Award in Team Innovation, a national award that recognizes a multidisciplinary team for successfully moving an innovative idea to a product in commercial use. Chekal now works for Pfizer.



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One of the main things I've taken away from this experience is a sense of independence in solving problems and testing the solutions on my own.

UNDERGRADUATE JOSEPH DRAUT ('19), who spent his summer conducting research on Alzheimer's disease and synthetic biology in Josh Leonard's lab.

## How Low Can We Go?

Professor Eric Masanet spent his two-year sabbatical in Paris, where he worked to combat climate change. As head of the International Energy Agency's Energy Demand Technology Unit, Masanet led a modeling team that helped governments explore ways to limit the global temperature rise to well below 2 degrees Celsius — one of the Paris Agreement's most ambitious goals.

Masanet presented his work at multiple forums around the world, including a panel in Chicago called "Energy and Future Challenges in Environmental Regulation," organized by the World Steel Association.

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