McCormick School of Engineering and Applied Science

NORTHWESTERN ENGINEERING

SPRING 2022




Transforming Computer Science Education





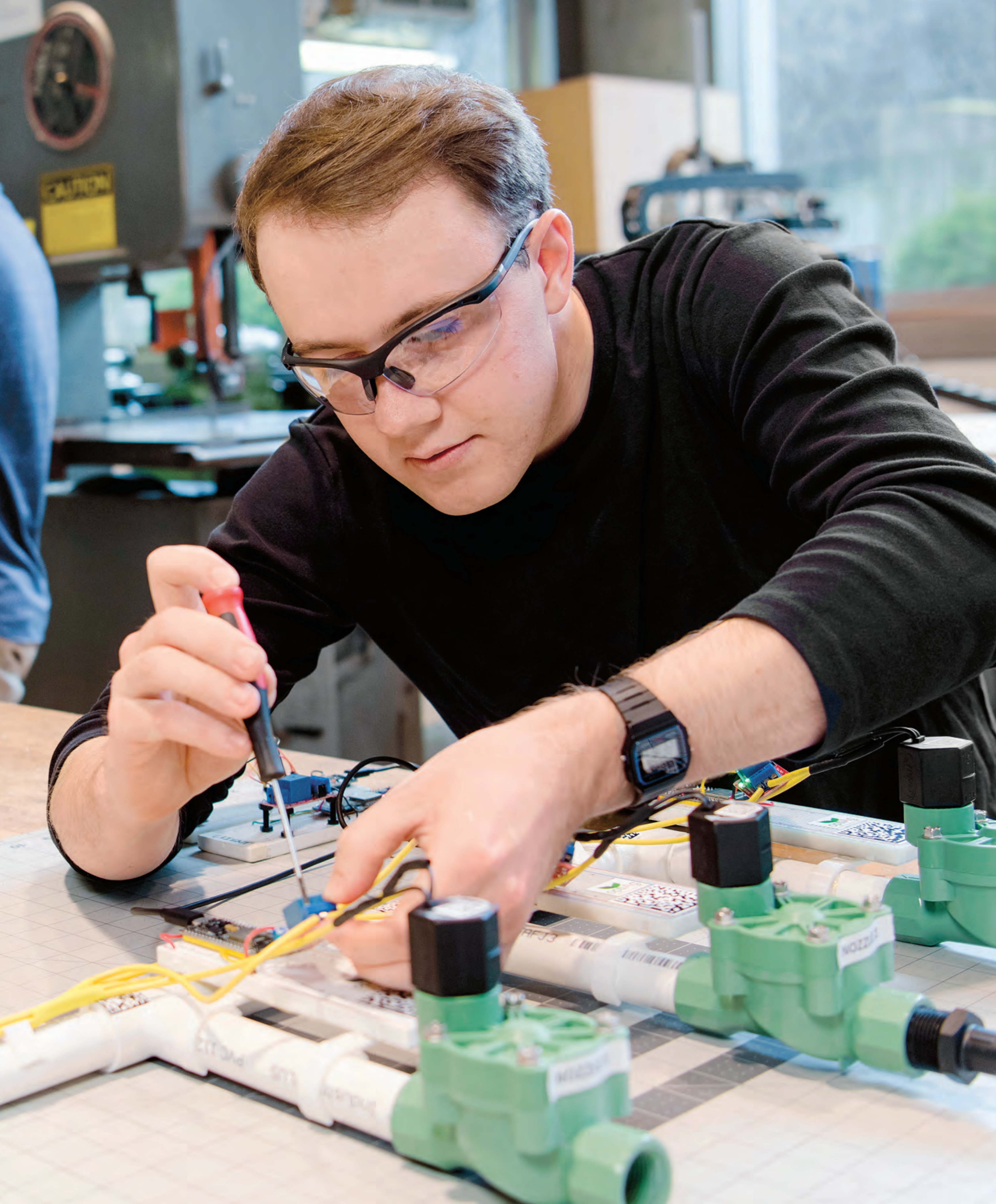
A MORE PRECISE WAY TO WATER

Senior mechanical engineering student Shane Dolan refines a prototype of his independent study project in the Segal Design Institute's Prototyping and Fabrication Lab. His device, called OptiAg, is an internet-of-things-enabled intelligent sprinkler controller for large agricultural operations. The system uses satellite imagery and sensor data to evaluate the health of crops in a field. Specially designed nozzles disperse optimal portions of water where needed, helping avoid resource waste and costs associated with overwatering.

Advised by Professor Michael Peshkin and supported by a Northwestern Academic Year Research Grant, Dolan developed a software model to test his system and found potential water savings between 10 and 13 percent.

Dolan, who will join Tesla's battery design team following graduation, hopes to field-test his prototype system this year.

Photography by Jason Brown


CAUTION

Spring is always a time of celebration, especially considering recent events, but as this issue shows, our students and faculty are also excited to work toward developing the new knowledge and solutions needed to confront our challenges.

GREETINGS FROM NORTHWESTERN ENGINEERING

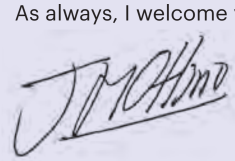
Over the past decade, the number of students studying computer science at Northwestern Engineering has grown exponentially. Additionally, students from across Northwestern are adding CS as part of their own plans of study. The field touches nearly every component of society and industry, and computational thinking has become an essential skill in many jobs. Because of this influx, our Department of Computer Science faculty continually reexamine how we teach computer science courses and how to expand the reach of our courses to students from all backgrounds. In this issue, you can read about their efforts and the new courses that have been developed to reach across disciplines. Current and future students will benefit greatly from their work.

In academia, the idea of collaborating across disciplines has gone from novel to necessary. One way to formalize these collaborations is by hiring faculty who share appointments across disciplines; this now accounts for 20 percent of our faculty. Another is through the development of interdisciplinary centers. At the McCormick School of Engineering, we are fortunate to be home to more than two dozen academic centers, which bring together researchers from across the University and industry to create new knowledge and tackle society's grand challenges. Some, like the Northwestern University Transportation Center, have been around for decades and have provided lasting leadership in the field, while others, like the Center for Advancing Safety of Machine Intelligence, are just launching and charting new ways of collaboration.

Also in this issue, you will find stories about innovative solutions our faculty are finding for problems such as counterfeit medicines, kidney allocation, and the pervasiveness of polymers and plastics in our environment. We also feature our colleague Jian Cao, who was recently elected to the National Academy of Engineering. It is wonderful to celebrate her achievements.

Spring is always a time of celebration, especially considering recent events, but as this issue shows, our students and faculty are also excited to work toward developing the new knowledge and solutions needed to confront our challenges.

As always, I welcome your feedback.



JULIO M. OTTINO
Dean, McCormick School of Engineering and Applied Science

On the Cover Capitalizing on the rapid growth of computer science, Northwestern CS teaching faculty are reimagining curricula while strengthening the department's inclusive community. Read more on page 14.

Photography by Jason Brown and Rob Hart

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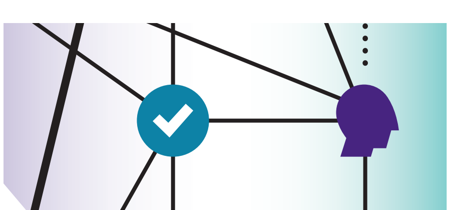
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NORTHWESTERN ENGINEERING
SPRING 2022

NEWS

"We want to give students hands-on, practical knowledge with the models and techniques used for collecting, cleaning, integrating, and analyzing data for reproducible results."

JILL WILSON
Codirector of data science program, Assistant Chair of Industrial Engineering and Management Sciences

NEW DATA SCIENCE AND ENGINEERING MINOR

Northwestern Engineering's Department of Computer Science and Department of Industrial Engineering and Management Sciences have launched a data science and engineering minor to provide students a practical foundation in data science.

Students in the program will build skills to develop comprehensive data science pipelines using computational data analysis to estimate, predict, design, and control engineering systems. The curriculum emphasizes fundamental statistical and computational methods. Students will gain experience with a variety of data models and learn how to engineer the data science pipeline to answer questions about data and think critically about the construction and implications of analysis and models for data-driven decision-making.

The data science and engineering minor program is managed by codirectors Jennie Rogers and Jill Wilson. "The minor will help students learn how to generalize engineering principles to the data science life cycle with an emphasis on real-world use cases," Rogers says.

Undergraduate Develops Course-Planning App

Navigating a collegiate course load isn't easy. With dozens of major and minor requirements and general electives to take, students spend hours mapping out their college experience to ensure they register for the right classes to earn their degrees.

To help, Dilan Nair, a second-year computer science student, developed Plan Northwestern, an open-source, online tool that allows students to search for and drag-and-drop courses into a four-year interface organized by academic quarter. Users cans save and share their plans via a URL.

Nair designed and developed Plan Northwestern over the course of a few weeks, leveraging his prior knowledge of web design and researching online how similar tools were built. Since the web application's launch in December 2021, thousands of Northwestern students have used it.

★★★★★ **10**

Students invited to present research during Northwestern CS's inaugural Undergraduate Research Showcase

↓ **36**

Percent fewer new projects pursued by scientists in 2020 compared to 2019, among those who did not pursue COVID-19-related research, according to research by Dashun Wang

TRUSTEE, ALUMNUS, AND BENEFACTOR LOUIS SIMPSON DIES

Louis A. Simpson, one of Northwestern University's foremost champions, passed away on January 8, 2022, following a prolonged illness. He was 85.

Known across campus as a great and generous friend of Northwestern, Simpson and his wife, Kimberly Querrey, have supported the University in countless ways for the past two decades, including with a $92 million gift in 2015 for bio-medical research.

Simpson and Querrey, a current Charter Trustee, have made widespread contributions totaling more than $250 million in giving to areas at Northwestern. In 2019, they gifted funding to create the Querrey Simpson Institute for Bioelectronics, the hub of Northwestern's research thrust and innovation in this area.

$15 Million NSF Institute to Focus on Novel Materials Discovery

Scientists and engineers often harness the power of data science to discover novel materials and structures that combine valuable properties in new ways.

A new $15 million interdisciplinary research institute co-led by Professor Sossina Haile aims to help such discovery by enabling researchers to create new theoretically grounded and experimentally validated approaches and tools for designing and discovering dynamical materials and structures.

The National Science Foundation's Institute for Data Driven Dynamical Design is one of five new Harnessing the Data Revolution Institutes funded through a $75 million investment announced in September by the foundation.

4

Number of students serving as mentors in the Farley Center's new student ambassador program

754

Microbes collected by Erica Hartmann and colleagues at Shedd Aquarium

IBM HONORS GINNI ROMETTY WITH $5 MILLION GIFT TO HER ALMA MATER

A $5 million gift from IBM will endow two Northwestern Engineering computer science professorships in honor of the first woman to lead the company, Virginia M. "Ginni" Rometty '79, '15 H.

A Northwestern alumna and vice chair of the University's Board of Trustees, Rometty retired as executive chairman of IBM in December 2020, having previously served as chairman, president, and chief executive officer.

The two Ginni Rometty Professorships of Computer Science will support research and teaching related to artificial intelligence (AI) and machine learning. The first professorship will be awarded to Jessica Hullman, associate professor of computer science and journalism. The second will fund the recruitment of a senior scholar who has attained distinction in AI and/or machine learning, with a preference for candidates who have demonstrated a commitment to diversity and inclusion in computer science.

"THE NOTION THAT WE CAN HARNESS THE DATA REVOLUTION TO TACKLE THESE VERY HARD PROBLEMS IS EXHILARATING. I'M ALSO DELIGHTED THAT OUR CENTER WILL HAVE A STRONG FOCUS ON SCIENCE OUTREACH TO UNDERSERVED COMMUNITIES." **SOSSINA HAILE** Walter P. Murphy Professor of Materials Science and Engineering

Theory and Practice in Design Thinking Leads to InstaShield PPE Face Shield

Clinical professor Dan Brown's professional life has been about identifying a real problem, designing a solution that seeks a competitive advantage, and getting it to the market in a socially responsible way.

At the outset of the pandemic, Brown and son Dan Jr. used that process to design InstaShield, a medical-grade clear plastic face guard that can be attached to the brim of any baseball cap. The duo also co-designed the manufacturing process for mass-producing the product rapidly. Northwestern head football coach Pat Fitzgerald wore one during the 2020 season.

The father/son team used Brown's trademarked Differentiation by Design process, which he teaches at the Segal Design Institute. "You have to get deep into the researching aspect of the design cycle, completely understanding and benchmarking where the existing knowledge is falling short, focus on these knowledge gaps and their metrics, followed by iterative, strategically focused design in the pursuit of competitively advantaged new knowledge solutions," Brown says.

Northwestern Engineering Senior on Jeopardy!

Senior Yejun Kim competed in the Jeopardy! National College Championship in February, finishing second in the quarterfinals.

Growing up in suburban Naperville, Illinois, Kim watched Jeopardy! with her family, but stopped when she got busy in high school and never imagined this scenario. "It was a surreal experience," Kim says. "I love Jeopardy! I love the show. But I never thought I'd get the chance to be on it."

When she came to Northwestern, Kim started to watch again with her roommate. In November 2020, she took the qualifying test on a whim. After being asked back for two rounds of tests in early 2021, a call later in the year informed her she'd made it to College Jeopardy!

When studying for the show, she noted her strong suits were also her favorite categories: classical music and general science. In taping the show, she said her favorite part was meeting people who worked on the set and her fellow contestants.

"I'm really glad I had this experience," she says. "Getting to meet the other students from all over the country just made it all so much fun."

"I LOVE JEOPARDY! I LOVE THE SHOW. BUT I NEVER THOUGHT I'D GET THE CHANCE TO BE ON IT."

YEJUN KIM
Chemical Engineering '22

5

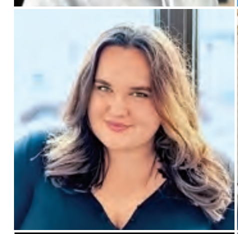
Startup companies involving Northwestern Engineering faculty that have moved into the University's new Querrey InQbation Lab technology accelerator

Expert Warns Policy Makers Against AI Threats

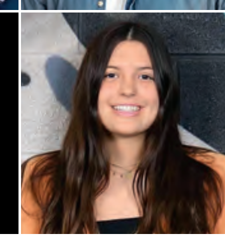
When it comes to protecting against cybersecurity threats via artificial intelligence, "policy makers are way behind the curve," says computer science professor V. S. Subrahmanian, a faculty fellow at the Northwestern Roberta Buffett Institute for Global Affairs.

Speaking at *FP*'s Tech Forum in November, he said policy makers in the United States and elsewhere are woefully unprepared for the challenges posed by advances in artificial intelligence, and that the current legislative framework is "not anywhere near where we need it to be."






Students, Alumni Featured in "25 Under 25" List



Five Northwestern Engineering students and alumni were featured in *Chicago Inno*'s 2021 "25 Under 25" list, which recognizes Chicago-area entrepreneurs and innovators age 25 or younger who are "working their way up the ladder at fast-growing firms and helping shape the future of Chicago's tech scene."

Charbel Bourjas ('19) Product manager at DoorDash, graduated with a bachelor's degree in computer science and a minor in entrepreneurship

Pitawat (Eng) Mahawattanangul ('19) Product development lead at NanoGraf, graduated with a bachelor's degree in materials science and engineering

Regina Morfin ('22) Studying manufacturing and design engineering, cofounder of Lura, a fashion brand that promotes access to sustainable textiles

Charlotte Oxnam ('23) Pursuing a bachelor's degree in industrial engineering, founder of Cue the Curves, an online platform designed to support and build a community for young, plus-size women and clothing brands

Sreya Parakala ('22) Pursuing a bachelor's degree in industrial engineering and management sciences and an entrepreneurship minor, founder of Iris Education, a web app that focuses on centralizing authentic insights on US college culture for international students.

Interdisciplinary Teams Finish Strong at Optimization Competition

Two multi-institutional teams featuring faculty, students, and alumni from Northwestern Engineering's Department of Industrial Engineering and Management Sciences and Department of Electrical and Computer Engineering earned top-tier placements at the US Department of Energy's global Grid Optimization (GO) Competition Challenge 2.

GO challenges teams to develop software management solutions for difficult power grid problems. Through a series of challenge-based competitions, GO seeks to accelerate the development of transformational and disruptive methods to create a more reliable, resilient, and secure US electricity grid.

Teams placing in the top shared a $2.4 million prize, to be used to develop their approaches further and pursue industry adoption of their technologies.

Challenge 2 expanded upon 2019's Challenge 1, which tasked teams with designing an algorithm for security-constrained optimal power flow, an ongoing issue in the electric power sector to determine optimal generator settings that best enable power to be routed to customers across a complex grid in a reliable and cost-effective manner.

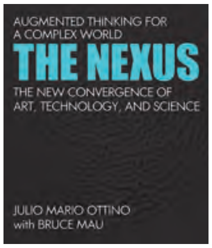
LACK OF NON-ENGLISH LANGUAGES IN STEM PUBLICATIONS HURTS DIVERSITY

With translators trained in technical subject matter in short supply, most science and engineering researchers choose to publish their research in English, the dominant language.

A team of graduate students at Northwestern aims to change that. In a paper published in the *Journal of Science Policy & Governance*, members of the University's Science Policy Outreach Taskforce called for new government policy measures to create a path to linguistic diversity in STEM publications with the goal of improving scientific communication and ending disparities between English and non-English STEM writing worldwide.

79

Bacterial isolates sequenced and phenotyped by Madhav Mani to mathematically relate the dynamics of their metabolic activity to their gene content



NAVIGATING THE NEXUS OF ART, TECHNOLOGY, AND SCIENCE

Dean Julio M. Ottino has published a new book that offers a guide for navigating the intersections of art, technology, and science. Published by MIT Press, *The Nexus: Augmented Thinking for a Complex World—The New Convergence of Art, Technology, and Science* was co-authored by renowned designer Bruce Mau, a distinguished fellow at Northwestern Engineering's Segal Design Institute and cofounder and CEO of Massive Change Network.

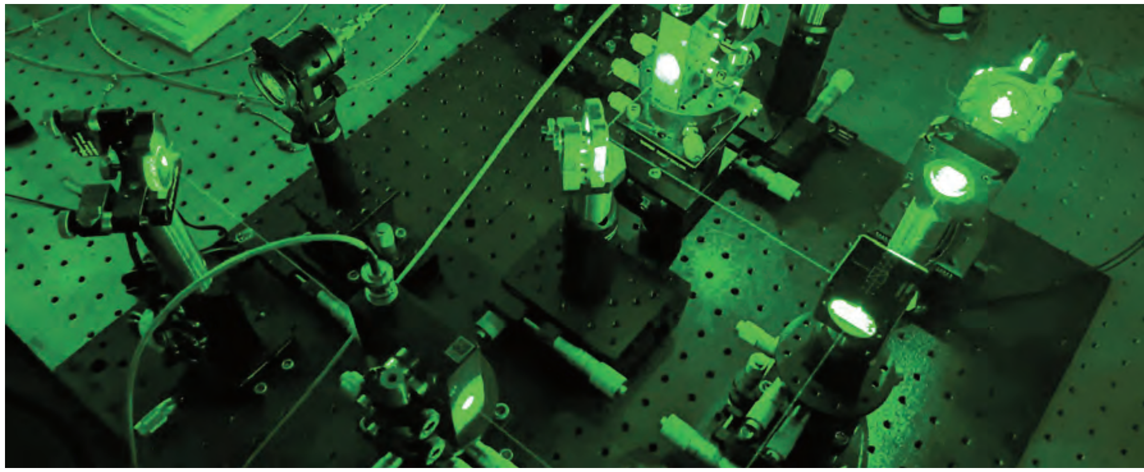
The ethos of looking at the world with different perspectives is a driving force behind the whole-brain engineering method employed at the McCormick School of Engineering. The authors contend that in today's challenging world, it's important to be able to hold conflicting viewpoints. "Nexus thinking is about different ways to see the world," Ottino says.

PhD and Master's Graduates Recognized at December Ceremony

In December, the PhD Hooding and Master's Recognition Ceremony recognized 111 master's and 13 PhD candidates. In total, 243 master's students and 88 PhD candidates graduated during the summer or fall of 2021.

Tim Stojka ('89), CEO and cofounder of Agentis Energy, spoke at the ceremony. "Relationships and people in your life are what is most important," he said. "Your success will be forgotten. Just remember, the impact you make on others will live on for generations. Humility is not thinking about yourself less but about thinking more about others."

LAB NOTES



NEW HOLOGRAPHIC CAMERA SEES THE UNSEEN WITH HIGH PRECISION

"It's like we can plant a virtual computational camera on every remote surface to see the world from the surface's perspective."

FLORIAN WILLOMITZER
Research Assistant Professor of Electrical and Computer Engineering

Researchers have invented a new, high-resolution camera that can see the unseen—including around corners and through scattering media, such as skin and fog, or potentially even through the human skull.

Called synthetic wavelength holography, the new method works by indirectly scattering coherent light onto hidden objects, which in turn scatters again and travels back to a camera. From there, an algorithm reconstructs the scattered light signal to reveal the hidden objects. Because of its high temporal resolution, the method has the potential to image fast-moving objects, such as a beating heart inside a chest or a speeding car around a street corner.

The relatively new research field of imaging objects behind occlusions or scattering media is called non-line-of-sight (NLOS) imaging. Compared to related NLOS imaging technologies, the Northwestern method can rapidly capture full-field images of large areas with submillimeter precision. With this level of resolution, the computational camera might be able to image through the skin to see even the tiniest capillaries at work.

While the method has obvious potential for noninvasive medical imaging, early-warning navigation systems for automobiles, and industrial inspection in tightly confined spaces, the researchers believe the possibilities are countless. The work was led by Professor Florian Willomitzer and Professor Oliver Cossairt.

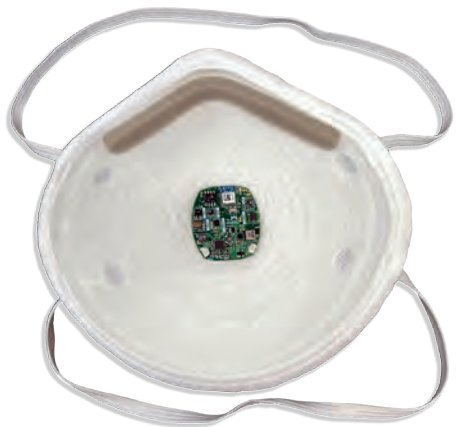
Rapid PCR Test Receives FDA Authorization

A new, highly sensitive, easy-to-use test for COVID-19 that requires a single swab and 15 minutes has received emergency use authorization status from the US Food and Drug Administration. Developed at Northwestern Engineering's Center for Innovation in Global Health Technologies, the test is being commercialized by spinoff company Minute Molecular Diagnostics.

Called DASH (Diagnostic Analyzer for Specific Hybridization), the device is small enough to sit on a countertop or desk. The user performs a simple nasal swab, places the swab in a chamber within a small cartridge, and then inserts the cartridge into the testing unit. After 15 minutes, an easy-to-read positive or negative result appears on the unit's touchscreen. The test uses a polymerase chain reaction (PCR) technique that amplifies DNA, increasing incredibly small virus samples to detectable levels.

"FACEBIT PROVIDES A FIRST STEP TOWARD PRACTICAL ON-FACE SENSING AND INFERENCE AND PROVIDES A SUSTAINABLE, CONVENIENT, COMFORTABLE OPTION FOR GENERAL HEALTH MONITORING FOR COVID-19 FRONTLINE WORKERS AND BEYOND."

JOSIAH HESTER Assistant Professor of Computer Science and Electrical and Computer Engineering; Breed Junior Professor of Design



"Fitbit for the Face" Can Turn Any Face Mask into Smart Monitoring Device

Researchers have developed what they're calling a "Fitbit for the face," a new smart-sensor platform for face masks. Named FaceBit, the lightweight, quarter-sized sensor attaches to any N95, cloth, or surgical face mask using a magnet.

Not only can FaceBit sense the user's real-time respiration rate, heart rate, and mask wear-time, it also may replace more cumbersome tests by measuring mask fit. FaceBit wirelessly transmits the information it gathers to a smartphone app with a dashboard for real-time health monitoring.

5TH GRADERS

Students at Dawes Elementary who are beta testing a new curriculum developed by Marcelo Worsley that teaches them how to code wearable devices to track steps

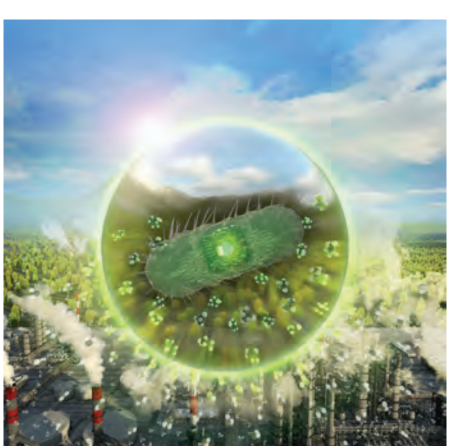
7

Novel techniques developed by John Torkelson to transform tires and other similar thermoset polymers into recyclable materials

WHAT IS THE SECRET BEHIND ARTISTIC SUCCESS?

Before developing his famed "drip technique," abstract artist Jackson Pollock dabbled in drawing, printmaking, and surrealist paintings of humans, animals, and nature.

According to a study led by Professor Dashun Wang, this period of exploration followed by exploitation of his drip technique set up Pollock for a "hot streak," or a burst of high-impact works clustered together in close succession. In Pollock's case, this was a three-year period from 1947 to 1950, during which he created the drippy, splattered masterpieces for which he is most famous. By using artificial intelligence to mine data related to artists, film directors, and scientists, the researchers discovered such a pattern is not uncommon but instead a repeated phenomenon. Hot streaks, they found, directly result from years of exploration.



Creating Value out of Carbon Waste

Most people know bacteria can break down lactose to make yogurt and sugar to make beer. Now, researchers led by Professor Michael Jewett and LanzaTech have harnessed bacteria to break down waste carbon dioxide (CO_2) to make valuable industrial chemicals. In a new pilot study, the researchers selected, engineered, and optimized a bacteria strain and then successfully demonstrated its ability to convert CO_2 into acetone and isopropanol (IPA).

This new gas fermentation process not only removes greenhouse gases from the atmosphere, it also avoids using fossil fuels, which are typically needed to generate acetone and IPA. After performing life-cycle analysis, the team found that the carbon-negative platform, if widely adopted, could reduce greenhouse gas emissions by 160 percent compared to conventional processes.

NEW TOOL TO GUIDE SUSTAINABLE BUILDING

Industry experts expect the green building materials market to sky-rocket in the next five years. But until now, there hasn't been a way to compare different basic materials and understand the impact of using them. Northwestern and World Wildlife Fund have partnered to develop an international tool that supports construction industry professionals in making environmentally responsible decisions as they select, source, use, and dispose of construction materials.

Originally created for disaster recovery and reconstruction guidance, *Building Material Selection and Use: An Environmental Guide* examines environmental impacts, material alternatives, and design and construction best practices. The guide consists of a database covering more than 50 building materials and their mechanical, thermal, electrical, and durability properties.

"We're developing a versatile computational tool that uses mathematical optimization and detailed building models and allows for rapid comparisons of options in the decision-making process."

ANDREAS WÄCHTER
Professor of Industrial Engineering and Management Sciences

$7.75 MILLION

U54 grant over five years that will support the Northwestern University Center for Chromatin NanoImaging in Cancer

60

Middle school and high school students who attended the 51st annual Career Day for Girls

42

Companies that recruited engineering students at the 2022 STEM Career Fair

First-of-its-Kind Live Imaging Leads to Major Discovery in How Cells Pattern in Tissues

The ability of cells to self-organize into specific functional patterns in tissues—the stripes of a zebra, the spiral of seeds in a sunflower—is a universal feature of life. Another well-known and much-studied pattern is the compound eye of the fruit fly, a highly patterned hexagonal lattice of 800 clusters of photoreceptor cells. How does an amorphous blob of cells develop into this precise and familiar pattern?

Professor Madhav Mani and his colleagues have discovered that the formation of this eye pattern involves mechanical forces, not just chemical signals transmitted between cells.

Using first-of-its-kind live imaging, the researchers saw cells moving into position as the eye developed; the cells were not static as previously believed. This major discovery establishes principles that should extend to other pattern systems. "This work helps us better understand how life builds itself," says Mani, a quantitative biologist.

DNA Computer Assesses Water Quality

A team of synthetic biologists led by Professor Julius Lucks has developed a low-cost, easy-to-use, handheld device that can let users know—within minutes—if their water is safe to drink.

The device works by using powerful and programmable genetic networks, which mimic electronic circuits, to perform a range of logic functions. Among the DNA-based circuits, for example, the researchers engineered cell-free molecules into an analog-to-digital converter (ADC), a ubiquitous circuit type found in nearly all electronic devices. In the water-quality device, the ADC circuit processes an analog input (contaminants) and generates a digital output (a visual signal to inform the user).

Equipped with a series of eight small test tubes, the device glows green when it detects a contaminant. The number of tubes that glow depends on how much contamination is present. If only one tube glows, the water sample has a trace level of contamination. If all eight tubes glow, the water is severely contaminated. In other words, the higher concentration of contamination leads to a higher signal.

Making Bioelectronics More Effective and Compact

Bioelectronic devices can help diagnose disease by sensing chemical biomarkers and can assist in treating ailments such as epilepsy and diabetes. Recent work by Professor Jonathan Rivnay could pave the way for less invasive and even more powerful bioelectronic devices.

Recorded signals produced by human tissues can be susceptible to added noise or distortion when transmitted from implanted or wearable bioelectronics. This can make it difficult for devices to properly analyze signals and perform effectively.

Rivnay and his team addressed this challenge by bringing some of the function from "back-end" electronics to the actual recording site. This breakthrough may result in a higher level of amplification and will enable more integrated, multifunctional, and potentially more power-efficient devices.

NEW APPROACH TO SHRINKING TUMORS

A new tool developed by Northwestern researchers harnesses immune cells from tumors to fight cancer rapidly and effectively and has produced a dramatic shrinkage in tumors in mice compared to traditional cell therapy methods.

With a novel microfluidic device that could be 3D printed, the team multiplied, sorted through, and harvested hundreds of millions of cells, recovering 400 percent more tumor-infiltrating lymphocytes (TIL)—natural immune cells that invade tumor tissue—than current approaches.

Led by Professor Shana O. Kelley, the team's approach—recovering the TIL cells and injecting them back into mice—produced a large improvement in survival rates in mice with tumors compared to more traditional methods of TIL recovery.

2 TIMES

Scientists who formed collaborations at virtual conferences interacted two times more than those who did not, according to research by Daniel Abrams

Is the Coronavirus on Airplane Air Filters?

Researchers led by Professor Erica Hartmann have launched a new project to explore what, exactly, airplane cabin filters actually capture. The researchers will specifically look for evidence of pathogens, including SARS-CoV-2, on used filters collected from airplanes. If viruses can be found, the filters from international flights could be used as a new way to track when and where viruses enter a country. Rather than test travelers individually, it might be possible to monitor entire flights with one test.

"Nature is good at copying DNA, but we really wanted to be able to write DNA from scratch."

KEITH E. J. TYO Associate Professor of Chemical and Biological Engineering

OUR DNA IS BECOMING THE WORLD'S TINIEST HARD DRIVE

The human genetic code is millions of times more efficient at storing data than existing solutions, which are costly and use immense amounts of energy and space. In fact, a couple hundred pounds of DNA could store all the digital data on the planet and totally eliminate the need for hard drives.

Using DNA as a high-density data storage medium holds the potential to forge breakthroughs in biosensing and biorecording technology and next-generation digital storage. Certain inefficiencies, however, prevent using the technology at scale.

Researchers led by Professor Keith E. J. Tyo have proposed a new method for recording information to DNA that takes minutes, rather than hours or days, to complete. The team used a novel enzymatic system to synthesize new DNA that records rapidly changing environmental signals directly into DNA sequences, a method that could change the way scientists study and record neurons inside the brain. Tyo says his lab is interested in leveraging DNA's natural abilities to create a new solution for storing data.

Metallization May Lead to Safer, More Efficient Batteries

Suitable solid-state ionic conductors are a key to producing new safe, efficient batteries. Candidate materials for these solid-state batteries are superionics, which show a transition from an insulating state to a conducting state in which one ionic species is mobile.

Recent research could make it easier to study properties of these superionic materials. Led by Professor Monica Olvera de la Cruz, a team observed a classical system that exhibits a transition between insulating and conducting states—called "metallization" because the mobile ions in the compound behave like electrons in metals. The group hopes this will accelerate the development of safe solid-state batteries.

UNDERSTANDING COBALT'S HUMAN COST

Although electric cars have fewer environmental impacts than gasoline-powered vehicles, producing the parts necessary for such green technologies can have dire impacts on human well-being.

After studying the effects of mining cobalt—a common ingredient in lithium-ion batteries—on communities in the Democratic Republic of the Congo, an interdisciplinary team of researchers led by Northwestern engineers is calling for more data on how emerging technologies affect human health and livelihoods.

Such data can inform policy makers, industry leaders, and consumers, enabling them to make more socially and ethically responsible decisions when developing, funding, and using green technologies.

"We hope that policy makers recognize the urgency of the human costs of cobalt mining sooner rather than later."

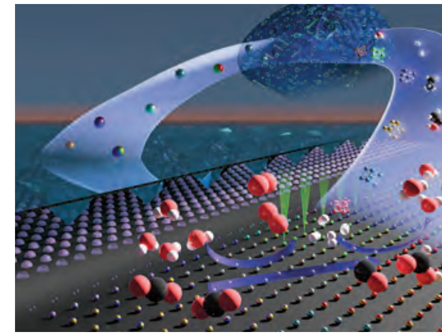
JENNIFER DUNN Associate Professor of Chemical and Biological Engineering

17

Northwestern Engineering faculty named in the Highly Cited Researchers 2021 List by Clarivate

3

New, never-before synthesized crystalline phases of low-symmetry colloidal crystals created by Chad Mirkin

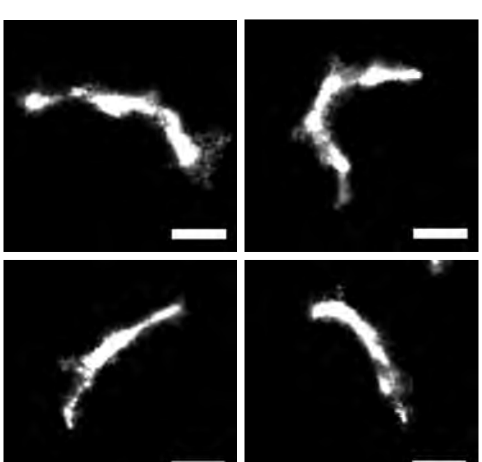


Machine Learning Guides New Nanomaterials Development

Nanoparticles have already found their way into applications ranging from energy storage and conversion to quantum computing and therapeutics. Given the vast tunability that nanochemistry enables, identifying new materials only through experiments limits discovery.

Researchers from Northwestern and the Toyota Research Institute have successfully applied machine learning to guide the synthesis of new nanomaterials. Their highly trained algorithm combed through a defined dataset to accurately predict new structures that could fuel processes in clean energy, chemical, and automotive industries.

"We asked the model to tell us which mixtures of up to seven elements would make something that hasn't been made before," says Professor Chad Mirkin, who led the research. "The machine predicted 19 possibilities, and after testing each experimentally, we found 18 of the predictions were correct."



FIRST TO VISUALIZE POLYMERS IN ACTUAL MATERIAL

The structure of polymers was first hypothesized around a century ago, but researchers had not directly seen what they look like in an actual material.

Professor Muzhou Wang and his team are among the first to directly image individual polymers in a bulk polymer environment. To show the first clear images of single-polymer molecules in a solid material, the researchers used super-resolution optical microscopy, which can highlight individual molecules and provide contrast against a dark background.

Historically used primarily in the biological community, Wang's group is pioneering super-resolution microscopy's adoption in polymer science to study the conformation and flexibility of the polymers in their materials directly.


Guillermo Ameer


Samuel Stupp


Julius Lucks


Wei Chen


John Rogers


Hao Zhang


Josiah Hester


Alessandro Rotta Loria


Neha Kamat


Muzhou Wang


Ryan Truby


Linsey Seitz

Faculty Awards

Guillermo Ameer Named to National Academy of Medicine

Election to the Academy is considered one of the highest honors in the fields of health and medicine.

Wei Chen Selected for 2022 Engineering Science Medal

The award from the Society of Engineering Science was presented for her seminal contributions to design under uncertainty.

Josiah Hester, Muzhou Wang Named Sloan Research Fellows

The two-year, $75,000 fellowship is one of the most competitive and prestigious awards available to young researchers.

Samuel Stupp Receives Hirschmann Award in Peptide Chemistry

The award from the American Chemical Society recognizes and encourages outstanding achievements in the chemistry, biochemistry, and biophysics of peptides.

John Rogers Honored with Prestigious Washington Award

Given by the Western Society of Engineers and the Washington Award Commission, this award is conferred annually upon an engineer whose professional attainments have preeminently promoted the happiness, comfort, and well-being of humanity.

Alessandro Rotta Loria Selected for 2022 Curriculum Innovation Award

Rotta Loria will use the funding from the Alumnae of Northwestern University toward creating massive datasets that allow students to realize virtual geothermal energy projects with potential to impact cities.

Ryan Truby Receives Air Force Young Investigator Research Program Award

The program enhances early-career development of outstanding young investigators and will fund his research at the intersection of multifunctional materials, mechanics, manufacturing, and robotics.

Four Faculty Named to Medical and Biological Engineering Elite

Julius Lucks, Evan Scott, Hao Zhang, and Teri Odom are among 153 engineers who make up the American Institute for Medical and Biological Engineering's College of Fellows Class of 2022.

Neha Kamat, Josiah Hester, and Linsey Seitz Recognized with NSF CAREER Awards

The Faculty Early Career Development (CAREER) Program offers the National Science Foundation's most prestigious awards in support of early-career faculty who have the potential to serve as academic role models in research and education and to lead advances in the mission of their department or organization. The three Northwestern Engineering faculty recipients will each receive more than $600,000 over five years.




Transforming Computer



Capitalizing on the rapid growth of computer science, Northwestern CS teaching faculty are reimagining curricula while strengthening the department's inclusive community.

Science Education

In the interconnected world of big data, it's no secret the field of computer science is booming.

At Northwestern, the number of computer science majors has grown more than 600 percent since 2011, making CS the third most popular major at the University.

But basic computer science knowledge is also becoming more essential to fields outside of tech. Currently, more than 50 percent of all Northwestern undergraduates take a computer science class before they graduate—a threefold increase since 2010.

"Computer science education is more and more important," says Huiling Hu, assistant professor of instruction at Northwestern Engineering. "Many areas and jobs now require basic skills in computational thinking, including writing programs, processing and understanding data, conducting efficient simulations, and making intensive calculations."

Over the past several years, the Department of Computer Science has responded to this growth by adding faculty and staff and by taking strides to develop new courses based on emerging ideas and student demand, all while fostering a broad community.

Photography by Jason Brown and Rob Hart

"As we look at growth in undergraduate enrollment, the most important thing for us is to continue our focus on community, to continue to make this a place where people feel support and belonging."

SARA OWSLEY SOOD
Chookaszian Family Teaching Professor and Associate Chair for Undergraduate Education

"Our ongoing challenge is determining the best way to cater to students with different life goals and different interests in what they want out of a CS degree," says Samir Khuller, the inaugural Peter and Adrienne Barris Chair of Computer Science. "One CS student plans to get a PhD and research compilers and computer architecture. Another has a plan to work as a consultant on Wall Street. The goals of those two students and what training they need are different."

Meeting the needs of students with divergent goals results in a more inclusive environment, one that meets students where they are and works to create cohesiveness within a seemingly disparate student population.

"As we look at growth in undergraduate enrollment, the most important thing for us is to continue our focus on community, to continue to make this a place where people feel support and belonging," says Sara Owsley Sood, Chookaszian Family Teaching Professor and associate chair for undergraduate education.

Leveling the playing field

The first stop for many students is enrolling in the Northwestern CS introductory course sequence. Historically, the mandatory sequence began with Fundamentals of Computer Programming I (CS 111) followed directly by Fundamentals of Computer Programming II (CS 211).

In the past few years, however, faculty have found that students who had already learned to program in high school had a big advantage in this sequence. In fall 2020, Sood launched Fundamentals of Computer Programming 1.5 to serve as a bridge between the first two courses.

"We found that the gap between 111 and 211 was a difficult leap for people who had not programmed before," Sood says, "and that really hurt us in terms of serving students who didn't program in high school. This new course helps the transition for students starting CS studies their first year of college."

The department also recognized that non-CS majors might need a different entry point altogether. Sarah Van Wart, assistant professor of instruction, revamped Intro to Computer Programming as a beginning course for non-majors with no prior programming knowledge.

"The difference between the CS majors and non-majors is a history of technical experience with code," Van Wart says. "Some students have been programming since elementary or middle school, some are just starting. Some students have a humanities and social science focus, some are STEM all the way. It's very hard to pin down the typical student, and that's great."

The course uses familiar applications like art and music to engage students in the creative problem-solving, such as producing animation, that programming can support. It also emphasizes the idea of computational thinking, the process of formulating and solving problems by breaking them down into simple steps.

"Non-major students usually have not yet established a computational way of thinking," Hu says. "I find it essential to reinforce computational thinking in non-major classes. I also spend more time ensuring that students can get their questions answered quickly."

Other non-majors, including journalism and music students, regularly enroll in the Tools and Technology of the World Wide Web course Van Wart launched as an introduction to both computer programming and basic information design. Students practice building interfaces and work on projects relevant to their interests, including portfolios, interactive photo galleries, and infographics.

"Aside from offering the introductory classes to help students bring up their experience level, I think one of the best things we can do at the instructor level for the CS major classes is acknowledge that everyone comes from different backgrounds, everyone has a skill set they are bringing to the table, and everyone proceeds at a different pace," says Sruti Bhagavatula, assistant professor of instruction. "We're here to work with the students and figure out how to ensure everyone is learning effectively, and to give them the resources they need to continue."

Northwestern CS Faculty of Instruction
Back row (*left to right*): Zach Wood-Doughty, teaching postdoctoral fellow (assistant professor of instruction in September 2022); Sara Owsley Sood, Chookaszian Family Teaching Professor of Computer Science; Katherine Compton, assistant professor of instruction; Mohammed Alam, assistant professor of instruction; Connor Bain, assistant professor of instruction

Front row (*left to right*): Huiling Hu, assistant professor of instruction; Sarah Van Wart, assistant professor of instruction; Vincent St-Amour, assistant professor of instruction; Branden Ghena, assistant professor of instruction; Sruti Bhagavatula, assistant professor of instruction; Shravas Rao, teaching postdoctoral fellow

Interdisciplinary Course Offerings

Northwestern CS faculty have introduced several new courses in recent years to promote collaborations with other Northwestern schools and offer hands-on opportunities to explore the field's expanding reach. These include:

Communicating Computer Science Designed by Connor Bain, the course explores the cultural, practical, and policy-related roles of computer science communication throughout society. Students learn communications skills for building awareness of CS through public outreach, communicating research outcomes in both academic and non-academic settings, and informing policy makers of the cultural and legal significance of CS issues.

Generative Methods Designed by Katherine Compton as an exploration of the intersection of programming and art, this course exposes students to modern applications of creative coding. One collaboration with theater design students in the School of Communication led to the creation of virtual costumes that overlay graphic masks on video and track body and facial movements.

Inclusive Making Developed by Marcelo Worsley, the course explores making—a form of computing that connects digital and physical technologies—as a practice that promotes broader participation in digital fabrication. Students from computer science, communication, learning sciences, and design study maker literature and technologies while working together to build their own tools to solve an accessibility problem in the maker space.

Innovation Lab: Building Technologies for the Law Multidisciplinary teams of Northwestern students, faculty, and professionals explore the innovation process in the legal profession—understanding stakeholders' needs, brainstorming ideas, and prototyping and testing them. Designed by Kristian Hammond and Daniel W. Linna Jr., the course facilitates team-based, cooperative lab experiences for students who want to create new tools, stories, story forms, and physical devices at the intersection of computer science and law.

CS Student Groups

Northwestern CS student groups foster community while offering leadership opportunities and personal growth across many areas of computer science. Some groups include:

CodeID: Code for Inclusion and Diversity Seeks to improve access to programming resources for all students.

Code'n'Color Supports Black, Indigenous, and other people of color who are doctoral students in computing and coding-related disciplines.

Develop + Innovate for Social Change (DISC) Pairs teams of Northwestern students with local nonprofits to build websites and apps and participate in other tech projects.

Entrepreneurship in Action (EPIC) Facilitates involvement in the startup ecosystem at Northwestern.

Latin@CS Attracts current and prospective students in computing fields who identify as Latin American, Latinx, and Hispanic.

Responsible AI Student Organization (RAISO) Examines the impact of technology on the world and the burden on developers, engineers, programmers, and others responsible for helping to ensure the safety of their technology.

Developing advanced interdisciplinary courses

Upper-level courses have also shifted, thanks to an expanding faculty. In 2016, the University announced a growth initiative committed to adding 10 new faculty appointments in core computer science areas and 10 collaborative CS+X appointments jointly with units outside the McCormick School of Engineering. Since then, Northwestern CS has added 16 new tenure-track faculty members and plans to hire nine additional faculty in the coming years.

During this time, the department has also added 10 fully integrated teaching-track faculty, all of whom hold doctorate degrees, advise undergraduate research projects, and pursue their own research specialties. The bolstered breadth of research interests among the expanded faculty team combined with their energy and passion has led to a host of new advanced, interdisciplinary courses. A common theme among several new classes is an emphasis on the social implications of technology.

In response to a specific request for an ethics course, Van Wart joined forces with Sepehr Vakil, assistant professor of learning sciences at the Northwestern School of Education and Social Policy, to launch Computing, Ethics, and Society.

The interactive course examines computing through the lens of social theories. Students assess how computing technologies both benefit and harm lives individually, culturally, and politically and examine critically the values, ideologies, and contexts through which computing technologies emerge.

Composed primarily of undergraduate students majoring in computer science, learning sciences, sociology, or legal studies, the course also draws graduate students, including those in the Master of Science in Artificial Intelligence program.

"Students from different disciplines with different backgrounds and experiences bring valuable insights to class around how technology and society mutually shape one another," Van Wart says.

“Students have a vision of trying to build the world they want to live in. It makes me very hopeful.”

SARAH VAN WART Assistant Professor of Instruction

Artificial intelligence and machine learning

The rapidly expanding field of artificial intelligence (AI) also draws students from across disciplines. Mohammed Alam, assistant professor of instruction and deputy director of the Master of Science in Artificial Intelligence program, now teaches the first course he took as a graduate student in the department: Intro to Artificial Intelligence.

Back then, there were 15 or so students in his class. Now, he caps the course at 100.

With the expansion in class size and the lightning-speed progression and evolution of AI, Alam focuses on delivering course material in an absorbable manner so students—who come from engineering disciplines as well as behavioral sciences, learning sciences, linguistics, psychology, and cognitive science—can retain the information and build on the core techniques and applications in subsequent courses.

His teaching style gravitates toward the philosophical aspects of AI, with an intuitive approach to computer science. In spring 2021, he launched a course, AI Perspectives: Symbolic Reasoning to Deep Learning, devoted to creating space for unstructured discussion and interdisciplinary perspectives.

He recalls, “In the weekly writing assignment, a student reflected, ‘I thought I had this intelligence thing figured out, and now I am completely confused.’ And that is exactly what I want—for students to break free of all their preconceived notions about intelligence and artificial intelligence, then build up their knowledge again.”

Students building community

Creating a supportive, inclusive community goes beyond offering new courses. Northwestern CS students also connect and build relationships through student groups and the peer mentor program.

Launched in 2015 by Professor Ian Horswill, the Northwestern CS undergraduate peer mentor program helps ensure that students representing a range of computing backgrounds receive individual attention and real-time feedback. Peer mentors aid students in courses at all levels. During regular “office hours,” they serve as positive role models, encouraging progress, answering questions, and providing instruction on course material.

Each quarter, Northwestern CS hires more than 150 undergraduates for the program. “Peer mentors are well-versed in the subject material and are familiar with the common errors students make because they went through the same themselves,” says Abigail Coneeny, a fourth-year computer science student and mentor.

“Peer mentors have helped me in my CS classes more times than I can count, and I’m glad to give back,” says Chase Duvall, a mentor pursuing a combined bachelor of arts and master of science in computer science degree. “One-on-one support from other undergraduates who understand the student experience really makes a difference. Whether in office hours, on class forums, or in tutorial sessions, it’s always gratifying to help someone have an aha moment.”

Outside of the classroom, students have created several CS-focused student groups, including Women in Computing, CodeID: Code for Inclusion and Diversity, and Code’n’Color, a doctoral student support group for Black, Indigenous, and other people of color in computing and coding-related disciplines.

Van Wart, a faculty adviser for student groups, says they provide support, friendship, and an encouraging view of a CS future, adding, “Students have a vision of trying to build the world they want to live in. It makes me very hopeful.”

MICHELLE MOHNEY

Leveraging the whole-brain network

Research centers empower interdisciplinary collaboration to confront global challenges

Climate change. Cancer. Public health. Working across more than two dozen research centers, Northwestern Engineering faculty stand at the forefront of finding solutions to society's toughest challenges. While these centers vary in size, scope, and focus, they all cultivate talent, collaboration, and innovation at the intersection of disciplines.

"Learning from each other and seeing ourselves as both contributors and beneficiaries of a dynamic and ever-evolving whole-brain network is at the center of McCormick's culture," says McCormick School of Engineering Dean Julio M. Ottino. "Increasingly, our centers serve as a catalyst for interdisciplinary research at McCormick, complementing the strong foundation provided by our departments and linking us to other schools."

Five centers led by Northwestern Engineering faculty have achieved recent notable success. Their stories offer insight into the world-changing potential of Northwestern research across the broad spectrum of engineering disciplines.

ALEX GERAGE

Center for Physical Genomics and Engineering

Leading a new frontier in engineering living systems

Since its founding in 2019, the Center for Physical Genomics and Engineering (CPGE) has pioneered research in physical genomics—a burgeoning field of study bridging molecular biology, bioengineering, and physics—that seeks to reprogram the genome by controlling the structure of chromatin, a complex of protein and DNA that regulates gene expression. The approach opens the door to fundamentally new methods to treat diseases such as cancer and Alzheimer's and to engineer living systems to overcome environmental challenges such as climate change.

Emphasizing integration across disciplines

CPGE's 14 core faculty members, many of whom maintain multiple appointments or lead their own research centers, come from 11 departments across Northwestern Engineering and Northwestern's Weinberg College of Arts and Sciences and Feinberg School of Medicine. The center roster also includes 11 external members from other universities, a group that continues to grow thanks to CPGE's annual Symposium on Physical Genomics.

$7.75 MILLION

Grant supporting CPGE's new NCI Cellular Cancer Biology Imaging Research Center

Recent accomplishments

CPGE leads a National Cancer Institute (NCI) Cellular Cancer Biology Imaging Research Center to develop and test nano-imaging technologies, used in conjunction with molecular and computational methods, to study the origin of cancer stem cells and their ability to adapt to chemotherapies. The project brings together researchers in optics, imaging analysis, electron microscopy, computational genomics, and cancer biology to close existing knowledge and technology gaps in this area of cancer research, potentially leading to strategies for preventing tumor resistance to therapeutics.

The center's Physical Genomics Training Program, supported by a National Institutes of Health T32 training grant, welcomed its first cohort of six graduate students last fall. Students participated in transdisciplinary coursework, lab-based training, career development, and research seminars while also receiving mentorship from faculty across 17 departments at the University.

Leadership

Vadim Backman

Director and Sachs Family Professor of Biomedical Engineering and Medicine

"It's easy to become compartmentalized in your own field, but we're trying to bring in fantastic people with unique areas of expertise—engineers, biologists, molecular modelers, mathematicians, physicists, AI experts—and show them how to find a common language. If you bring together people who really want to make change, good things are going to happen."

VADIM BACKMAN

Center for Advanced Regenerative Engineering

Unlocking the human body's healing potential

Tissue loss and dysfunction from injury or disease can lead to significant morbidity and billions of dollars in economic losses from decreased productivity. Launched in 2018, the Center for Advanced Regenerative Engineering (CARE) supports research, technology development, and clinical expertise at the convergence of engineering, medicine, and biological sciences to improve the repair and regeneration of blood vessels, skin, nerves, bones, and other tissues and organs.

Building an ecosystem

Central to CARE's mission is forging an ecosystem of research, education, and clinical translation to help bring reliable and scalable technologies from the research bench to operating rooms. To accomplish this, CARE has partnered with two dozen academic and industry partners—from Northwestern's Feinberg School of Medicine to the US Army Institute of Surgical Research to Medline Industries—to jumpstart research and testing collaborations while addressing regulatory approval processes and user adoption challenges.

Recent accomplishments

In 2021, spinout startup Acuitive Technologies brought CITREGEN, a biomaterial created in the center, to market for use in musculoskeletal surgeries. Stryker Corporation employs this biomaterial in Citrelock, an implantable device used to attach soft tissue grafts to bone in reconstruction surgeries. Comparable in strength to cortical bone, Citrelock maintains structural integrity during healing while allowing host tissue to remodel the implant over time.

Also in 2021, CARE was awarded a National Institutes of Health T32 graduate student training grant, one of the first two T32 grants awarded in the field of regenerative engineering. Called RE-Training, the program will educate regenerative engineers through faculty mentorship, hands-on industry internships, and clinical experiences through CARE's partners.

Leadership

Guillermo Ameer

Director and Daniel Hale Williams Professor of Biomedical Engineering

"Clinical translation—bringing our innovations from the research lab to patients to improve their care—is very important to our goals."

GUILLERMO AMEER

47

Number of CARE-affiliated faculty, which include members from Shirley Ryan AbilityLab, University of Chicago, and Lurie Children's Hospital

Northwestern University Transportation Center

Transportation solutions for industry, government, and the public

From climate change to supply chains, transportation plays an integral role in some of the biggest challenges facing society. The Northwestern University Transportation Center (NUTC) brings together experts from academia, government, and private and nonprofit corporations to develop new policy, operations, and technology to improve the movement of goods, people, energy, and information.

Enduring collaborations with industry leaders

NUTC is widely recognized for its close collaborations with companies representing all facets of transportation: shipping and carrier firms, freight forwarders and third-party logistics providers, financial institutions, consulting firms, and trade associations. The center's Business Advisory Council is composed of senior leaders from more than 60 companies, including FedEx, UPS, IBM, Boeing, and United Airlines, who provide guidance to faculty, support research initiatives, and help foster NUTC-hosted outreach programs and special events.

Recent accomplishments

Beginning in April 2020, NUTC hosted nine weekly virtual roundtable seminars that covered the COVID-19 pandemic's impact on the global supply chain. Once lockdown restrictions were lifted, the focus pivoted to the changing transportation landscape in cities.

These roundtables helped NUTC secure a $1 million grant from the US Department of Transportation to further explore the effects of communications technology and e-commerce on travel demand in wake of the pandemic.

The center is also expanding its research in autonomous, electric, connected, and shared mobility systems. NUTC researchers are collaborating with researchers at the University of Illinois Urbana-Champaign to build a test-track facility to study autonomous freight trucks.

Leadership

Hani Mahmassani

Director, William A. Patterson Distinguished Chair in Transportation, and professor of civil and environmental engineering

"Many centers work with their state and federal transportation departments, but very few have established an enduring relationship with the transportation industry." HANI MAHMASSANI

1954

NUTC's founding, making it the country's oldest university center for multidisciplinary transportation research

Center for Human-Computer Interaction + Design

Developing the future of human and computer interaction at home, work, and play

Society's relationship with technology has evolved beyond simply sitting in front of a computer. Modern human-computer interaction reflects a dramatically different landscape—pervasive, multi-modal, and inclusive.

Launched in 2020 as a joint venture between Northwestern Engineering and Northwestern's School of Communication, the Center for Human-Computer Interaction + Design (HCI+D) studies the future of human-computer interaction and creates next-generation technologies to support a more collaborative, sustainable, and equitable society.

Bringing together diverse disciplines

HCI+D faculty includes experts in communication, computer science, design, learning sciences, mechanical engineering, medicine, organizational behavior, journalism, economics, and psychology who study how computing can enhance people's lives through seven core research areas:

- Better Health
- Collaborative Computing
- Data Visualization
- Human-Centered Artificial Intelligence (AI)
- Inclusive Computing
- Interactive Computing
- Revitalizing Communities

27

HCI+D faculty affiliates represent seven of Northwestern's nine schools

Recent accomplishments

By studying algorithms supporting online marketplaces and crowdfunding platforms, HCI+D researchers pinpointed changes to improve equity and access to fundraising. Another project developed AI-driven, inclusive audio-editing interfaces for sound engineers, musicians, and podcasters with blindness or visual impairment.

The center also launched the Human-Computer Interaction Certificate. Open to all Northwestern undergraduate students, the program builds knowledge in designing, evaluating, and implementing interactive computing systems for human use.

Leadership

Elizabeth Gerber
Codirector and professor of mechanical engineering and of communication studies

Bryan Pardo
Codirector and professor of computer science and of radio, television, and film

Darren Gergle
Codirector and professor of communication studies

"We are experiencing an unprecedented time in computing technology that isn't just influencing how we work, but what we do at home and in the classroom. HCI+D provides an important interdisciplinary perspective of the evolving relationship between these pervasive technologies and our society."

ELIZABETH GERBER

Center for Innovation in Global Health Technologies

Creating context-appropriate healthcare for the developing world

Through education and training, research, and product development, the Center for Innovation in Global Health Technologies (CIGHT) develops and brings to market on-demand healthcare technologies that integrate seamlessly with the lives of patients and medical practitioners in the developing world.

From classroom ideas to global implementation

Since its founding in 2005, many of CIGHT's ideas for diagnostic devices were developed through student projects in senior biomedical design courses. CIGHT faculty and student researchers travel annually to Cape Town, South Africa, to collaborate with faculty from the University of Cape Town to test and implement the devices in the region's resource-poor townships. Past innovations include a phototherapy blanket to treat jaundice in neonates, a digital x-ray system, and a specimen cup to test for tuberculosis.

Recent accomplishments

CIGHT leveraged its expertise in point-of-care diagnostics to develop a highly sensitive, easy-to-use test device for COVID-19. Called DASH (Diagnostic Analyzer for Specific Hybridization), the device uses a polymerase chain reaction—PCR—technique to detect the virus. Users place a nasal swab into a chamber within a small cartridge, and then insert the cartridge into the testing unit. Results appear on the unit's touchscreen within 15 minutes.

In March 2022, DASH received emergency use authorization from the US Food and Drug Administration. The device is produced through Minute Molecular Diagnostics, a startup company spun out of CIGHT and cofounded by David Kelso, clinical professor of biomedical engineering and CIGHT founder, and Sally McFall, research professor of biomedical engineering.

Leadership

Matthew Glucksberg
Codirector and professor of biomedical engineering

Sally McFall
Codirector and research professor of biomedical engineering

"Unlike many university centers, we do product development. And we do it directly in our labs."

MATTHEW GLUCKSBERG

1 MILLION
COVID-19 test cartridges per month produced by CIGHT spinoff company Minute Molecular Diagnostics

Practical Solutions for a Healthier World

NORTHWESTERN INDUSTRIAL ENGINEERS WORK TO MAKE HEALTHCARE DELIVERY MORE EFFICIENT, MORE RELIABLE, AND SAFER.

Time can mean life or death when receiving the life-saving organ gift from a deceased donor. Within a very narrow window, the medical team must preserve, transport, and match the organ with a compatible recipient. Any glitch in the system could lead to a wasted kidney or worse yet, a tragic outcome for the intended recipient.

Faced with an optimization issue like this, medical professionals can turn to the experts: faculty from Northwestern Engineering's Department of Industrial Engineering and Management Sciences, who use data science to make complex processes more efficient and reliable.

Transplantation optimization is only one of many healthcare delivery challenges that faculty and students at the McCormick School of Engineering work to solve. These researchers also develop new ways to disrupt supply chains for counterfeit medications in low- and middle-income countries. The results of that effort could save lives and lead to new policies to protect the most vulnerable.

"WE NEED TO FIGURE OUT QUICKLY WHO WOULD BENEFIT THE MOST FROM THE KIDNEY BECAUSE ANY DELAY COULD BE DANGEROUS FOR THE PATIENTS."

SANJAY MEHROTRA
Professor of Industrial Engineering and Management Sciences, Director of the Center for Engineering and Health

Optimizing transplantation systems

To produce optimal outcomes, kidney transplantation systems require a complex mix of medical and logistical procedures to be completed quickly, efficiently, and skillfully. With the greatest speed possible, a medical team must harvest the organ, determine how suitable it is for transplant, find the right donor, and deliver it there—a process mired in protocols and hampered by geography.

The potential implications for improving the process are big. In 2021, according to OrganDonor.gov, 90,483 people needed a kidney transplant. Only 24,670 received one.

Professor Sanjay Mehrotra uses analytical modeling, data science, and machine learning to optimize kidney transplantation systems by creating new processes to determine which organs are suitable for transplant and who the best recipient will be. With colleagues from Northwestern Feinberg School of Medicine, the RAND Corporation, Duke University, and Yale University, he hopes to change the transplant system in the United States, making it more efficient while wasting fewer donated organs.

In an effort funded by the National Institute of Diabetes and Digestive and Kidney Diseases, Mehrotra collaborates closely with individuals who have held leadership roles at the United Network for Organ Sharing (UNOS), the national organization that seeks to develop policies and procedures that improve the organ transplant and donation process. The final deliverable of this patient-centered project will be a scientifically validated policy structure that over five years could save 5,000 to 7,500 lives from among the nearly 100,000 patients on dialysis waiting for a kidney transplant.

"You cannot pass every kidney that is donated through the same protocol, because that results in delays that would be unfair to the patients," says Mehrotra, professor of industrial engineering and management sciences and director of the Center for Engineering and Health. "We need to figure out quickly who would benefit the most from the kidney because any delay could be dangerous for the patients."

The research will help guide discussions at UNOS. The project has also aided in identifying some deeply hidden scientific problems on which no prior modeling or mathematical research has taken place. For example, machine learning could help healthcare professionals find ways to identify kidneys that will get discarded due to system inefficiencies, and optimize the life of the kidneys once they are harvested. Using the information gleaned from past transplants, scientists could determine which donor characteristics are most associated with successful procedures, the ideal temperature for storing the kidney after harvesting, the maximum time and distance a kidney can travel before implantation, and other key considerations.

Mehrotra is uniquely equipped for this kind of work. An expert in methodologies for decision-making under uncertainty and their application to problems in health systems engineering and other operations research applications, he can approach issues with an analytical grounding while looking for a way to optimize a crucial process.

"Kidneys are a finite resource that we need to maximize," he says.

"WE NEED TO BE CERTAIN OUR APPROACHES ARE USEFUL FOR PRACTICAL IMPLEMENTATION. THESE STATISTICAL TECHNIQUES CAN HELP REGULATORS EXTRACT MORE UTILITY FROM LIMITED RESOURCES."

EUGENE WICKETT
PhD student in industrial engineering and management sciences

Disrupting potentially lethal supply chains

While industrial engineers often focus on efficiently moving goods to where they are needed, those same engineers can work to halt movement when necessary.

The World Health Organization estimated in 2017 that at least one in 10 pharmaceuticals consumed in low- and middle-income countries is either substandard or falsified, resulting in mortality estimates ranging from the hundreds of thousands to millions. One example of a vulnerable population is young children in sub-Saharan Africa in areas with high malaria prevalence.

As a PhD student in industrial engineering and management sciences, Eugene Wickett has taken to tackling this problem. After graduating in industrial engineering from Georgia Institute of Technology, he was building local health data infrastructure in Liberia when he saw the potential for more impact. He joined the PhD program at Northwestern in 2017 to study operations research for social good. Wickett has been designing methodology to solve these problems under the guidance of Karen Smilowitz, James N. and Margie M. Krebs Professor in Industrial Engineering and Management Sciences, and Matthew Plumlee, assistant professor in industrial engineering and management sciences.

Wickett's research focuses on ways to disrupt the flow of degraded, poor-quality, or counterfeit versions of medications such as amoxicillin and antimalarials to hospitals and pharmacies. While on a related visit to Liberia in 2019, he spoke with regulators, pharmacy owners, and other stakeholders. Wickett began thinking about modeling the generation of poor-quality medicines in supply chains.

Several low- and middle-income countries conduct post-market surveillance. Through this process, products can be labeled as "substandard" if they have less than the usual amount of an active ingredient, or "falsified" if they are fake. Wickett has found that it is critical to understand the interaction between supply chains, which determines how the product arrived at a location, and post-market surveillance. This can help regulators to determine whether medicines have degraded under suboptimal storage conditions, were manufactured poorly, or were damaged somewhere between the manufacturer or point of use.

"Using supply-chain information, we can narrow down likely explanations for where products degraded, which aids regulators in targeting their intervention resources," Wickett says.

Wickett is working to improve this process by combining on-the-ground pharmaceutical regulation with scientific procedures. That involves determining strategic priorities, deciding on when and where to sample medications, and identifying how best to analyze what was found.

"We need to be certain our approaches are useful for practical implementation," Wickett says. "These statistical techniques can help regulators extract more utility from limited resources."

BRIAN SANDALOW

Photography by Jason Brown (*opposite*) and Matthew Allen (*above*)

CONFRONTING OUR PLANET'S POLYMER PROBLEM

Northwestern researchers seek solutions to the plastics pollution dilemma with new ideas on polymer design and upcycling.

MANY POLYMERS—including plastics used to manufacture the plethora of products used only once and thrown away—don't degrade easily and consequently pack our landfills and pollute our waterways.

The statistics are dismal. Something as simple and ubiquitous as a plastic shopping bag can take 1,000 years to decompose. Researchers find tiny pieces of these materials in fish, table salt, human organs, and even breast milk.

Though not every polymer ends up in the environment, the prospect of reusing these materials remains dim. At best, less than 10 percent of plastics are recycled.

Still, there is reason for hope: Northwestern Engineering professors are working to quantify just how much of these materials plague our environment and, at the same time, are developing new polymer designs and upcycling processes to help ensure a cleaner, greener future.

TAKING ON MICROPLASTIC POLLUTION

Experts say that microplastics—small plastic pieces less than five millimeters long—linger in rivers for years before entering the world's oceans, which are estimated to contain millions of tons of them. It's a global pollution problem that scientists worldwide are studying.

Because rivers are in near-constant motion, researchers previously assumed lightweight microplastics quickly flowed through them, rarely interacting with riverbed sediments. To the contrary, a team led by the McCormick School of Engineering and the University of Birmingham in England has found that these plastics can deposit and linger within riverbeds for as long as seven years before washing into the ocean.

The research revealed that hyporheic exchange—a process in which surface water mixes with water in the riverbed—can trap lightweight microplastics that otherwise might be expected to float. The study is the first assessment of microplastic accumulation and residence times within freshwater systems, evaluating plastic pollution at its source and as it travels through the entire water stream.

"Most of what we know about plastics pollution we've learned from the oceans, because it's very visible there," says Aaron Packman, professor of civil and environmental engineering and one of the study's senior authors. "Now, we know that small plastic particles, fragments, and fibers can be found nearly everywhere. However, we still don't know what happens to the particles discharged from cities and wastewater.

"Most of the work thus far has been to document where plastic particles can be found and how much is reaching the ocean. Our work shows that a lot of microplastics from urban wastewater end up depositing near a river's source and take a long time to be transported downstream to oceans."

"These deposited microplastics cause ecological damage, and the large amount of deposited particles means that it will take a very long time for all of them to be washed out of our freshwater ecosystems."

AARON PACKMAN Professor of Civil and Environmental Engineering

To conduct the study, Packman, his former student Jennifer Drummond (now at the University of Birmingham), and their team developed a new model to simulate how individual particles enter freshwater systems, settle, and then later remobilize and redistribute. The model—which used global data on urban wastewater discharges and river flow conditions—is the first to include hyporheic exchange processes, which play a significant role in retaining microplastics within rivers.

Researchers found microplastic pollution resides the longest at headwaters, the source of a river or stream. In headwaters, microplastic particles moved at an average rate of one kilometer every five hours. But during low-flow conditions, this movement slowed to a creep—taking up to seven years to move the same distance. In these areas, organisms are more likely to ingest microplastics in the water, potentially degrading ecosystem health.

The residence time decreased as microplastics moved away from the headwaters, farther downstream. Residence times were shortest in large creeks that frequently flood.

Environmental scientists and engineers can use these findings to better assess and understand the long-term impacts of microplastic pollution on freshwater systems. "These deposited microplastics cause ecological damage, and the large amount of deposited particles means that it will take a very long time for all of them to be washed out of our freshwater ecosystems," he says. "This information points us to consider whether we need solutions to remove these plastics to restore freshwater ecosystems."

RELEGATING DUMPS TO HISTORY

Despite research and policy efforts, recycling initiatives have struggled with complex materials like tires and mattresses, leading to tons of unnecessary trash in dumps and landfills across the country.

Soon, that could change. Thanks to efforts by Professor John Torkelson, such dumps could become little more than a bad memory. Torkelson is using simple chemistry to address long-standing barriers associated with recycling about a quarter of today's plastics.

He and his team have developed new techniques to transform tires and other similar thermoset polymers into recyclable materials by changing their structure at the molecular level. The breakthrough research builds excitement in the sustainability field and could help mitigate fires, pollution, and the lost economic value associated with synthetic polymer waste.

"This is a case of our looking at a class of materials that were considered hopeless in terms of recycling," says Torkelson, Walter P. Murphy Professor of Chemical and Biological Engineering and Materials Science and Engineering. "We are using one- or two-step chemistry to transform them into recyclable material with full recovery of properties to see how that can really help address sustainability."

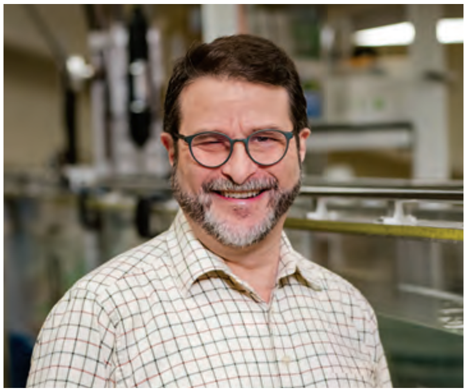
Synthetic polymers and plastics come from chemical reactions of monomers (molecules made up of single units). For example, ethylene makes polyethylene, which could be used to manufacture a milk jug. Termed thermoplastics, these materials can be recycled and melted down to create new products.

But tires and many other polymers constitute a class of materials called thermosets, made of long polymer chains that are permanently cross-linked. Cross-linked rubbers cannot be melted down and recycled into new products because of these permanent cross-links.

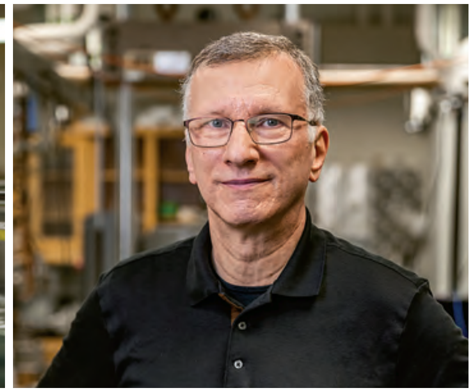
The Torkelson research group has found several ways to create a new type called dynamic covalent cross-links. These create robust cross-linking under conditions in which they are typically used, yet allow the materials to melt at a much hotter temperature.

For example, a tire made of such material would melt at 280 degrees Fahrenheit, a temperature it would never reach under normal conditions of use. Then, when the recycled polymer is cooled again, the cross-links come back together just as strong, with the same properties as before.

"We've been able to effectively transform the thermosets into thermoplastics for recycling," Torkelson says. "We can make cross-links that are just as robust as regular cross-links at use temperatures, but at high temperatures, they come apart temporarily."



Aaron Packman



John Torkelson

Monica Olvera de la Cruz

Researchers face an uphill battle when trying to address problems with entirely new materials, including trying to convince manufacturers to reinvent their literal and figurative wheels by adopting practices that may not balance out until years later. However, Torkelson's solutions involve chemical reactions to existing materials, taking many steps—and years of development and implementation—out of the equation.

His work highlights success in synthesizing addition-type polymers, which are used to make car tires; step-growth-type polymers, with applications including foam mattresses and insulation; and sister cross-linked polymers, which can be made without toxic compounds, resulting in a highly viable material for recycling.

"My group has been dedicated to this work because it has so much potential," Torkelson says. "We're tackling problems that are important to saving the environment, while also doing well by the economy."

UPCYCLING TO REDUCE PLASTIC WASTE

Instead of renewing a commitment to recycling techniques that can only be used once on certain plastics, researchers have looked to other solutions to reduce plastic waste. Plastic upcycling, the process of efficiently deconstructing and rebuilding polymers—the essential building blocks of plastic—has become a major area of focus.

In contrast to recycling, where plastic is heated up, broken down, and then rebuilt into weaker, poorer quality plastics, upcycling breaks polymers down into their fundamental components, which sometimes allows them to become even sturdier plastics than they were before.

A team led by Monica Olvera de la Cruz, Lawyer Taylor Professor of Materials Science and Engineering and Chemistry, has provided the basis for a technique to enhance the effects of an enzyme that breaks down the plastic used to make soda bottles and inexpensive clothing—commercially termed PET—into its fundamental parts.

Olvera de la Cruz's team hoped to create as green an upcycling process as possible—one that didn't create pollutants but instead removed them. Using an enzyme that can be synthesized in a lab, the researchers developed a process that can be used repeatedly without using other solvents.

In the study, the team designed a polymer and created the conditions needed to effectively protect the enzyme (called PETase), so that when the structure was heated, the PETase wouldn't unravel and become ineffective. The polymer consists of a hydrophobic (water-repelling) backbone and highly specific concentrations of its three components, calculated by PhD student Curt Waltmann, to specifically interact with active sites on the enzyme.

"We found that if you put the complex of the polymer with the enzyme together, and near a plastic, and then you heat it up slightly, the enzyme was able to break it down into small, monomeric units," Olvera de la Cruz says. "In addition to operating in an environment where it could clean microplastics, our method has protected against high temperature degradation."

By finding a way to protect the enzyme from heat, the team opened many doors for the research community. For example, it could help engineers find solutions for removing microplastics from rivers and oceans.

The team, which includes John Torkelson and Danielle Tullman-Ercek, professor of chemical and biological engineering, has its sights set on encapsulating entire microplastics in the structure, then making an aggregate of microplastics with these enzymes.

"You can make a new polymer with the monomeric units," Olvera de la Cruz says. "These are dangerous things that are bad for our health. We don't need to make more. You can reuse the ones already here to make an equally good plastic—or better."

AMANDA MORRIS AND WIN REYNOLDS

Photography by Jason Brown and Matthew Allen

LAB TOUR

QUERREY SIMPSON INSTITUTE FOR BIOELECTRONICS

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2

A wearable sensor that tracks COVID-19 symptoms and recovery. A wireless, flexible respiratory monitor for patients with sleep apnea. An implant that senses fatal levels of ingested opioids and then delivers life-saving naloxone.

These are just a few of the biocompatible electronic, photonic, and microfluidic technologies developed for the human body by scientists and engineers in the Querrey Simpson Institute for Bioelectronics (QSIB).

With broad applications across medicine, rehabilitation, and sports, QSIB supports the entire ecosystem of translational science—from fundamental materials development to device and component engineering to system prototyping—all under one roof. These systems are then deployed in clinical research settings within the institute's medical partners, including Northwestern University Feinberg School of Medicine and Shirley Ryan AbilityLab.

"We designed the lab to provide an educational experience for the students that's almost impossible to gain any other way," says John Rogers, Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering, Biomedical Engineering, and Neurological Surgery and QSIB director. "They gain an understanding of all steps in the process, and ultimately, how their work impacts patients."

Supported by a gift from Northwestern University trustee Kimberly K. Querrey ('24 P) and the late Louis A. Simpson '58 ('96 P), who joined the Board of Trustees in 2006 and became a life trustee in 2010, the two-floor, 24-hour facility in the Technological Institute's AB wing features a wealth of state-of-the-art research spaces, testing rigs, and manufacturing tools.

Special thanks to Anthony Banks, director of engineering research at the Querrey Simpson Institute for Bioelectronics, for supporting contributions on this story.

QSIB's third-floor lab is configured to support new device development, from initial concepts to scaled prototype manufacturing.

1. PUBLIC ENTRYWAY QSIB's museum-like entrance displays some of its biggest achievements, from a skin-mounted microfluidic device for sweat analysis to a wireless monitoring sensor worn by premature babies in the neonatal intensive care unit.

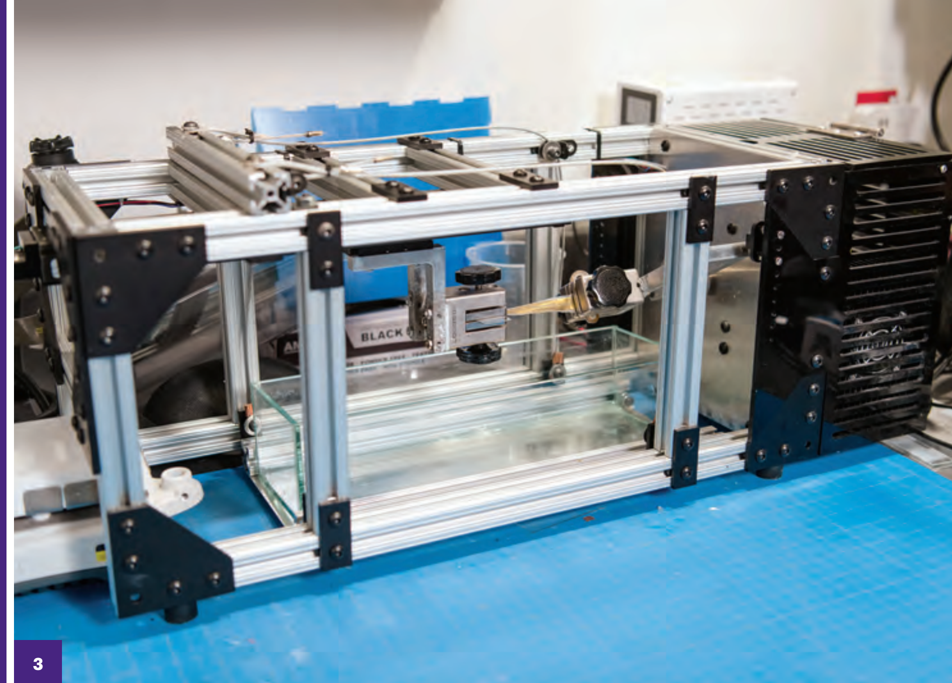
2. PROTOTYPING AREA Overlooking the AB wing atrium, students populate the circuits in their prototype electronic devices using microscopes and soldering equipment. Overhanging fume extractors capture rising solder smoke. Project benches—each devoted to specific research—provide students a dedicated space to iterate their devices.

3. CYCLIC TESTER To test the structural integrity of implanted bioelectronic devices—such as the lab's battery-free, dissolvable transient pacemaker—students turn to a cyclic tester, which recreates natural conditions inside the human body. Device prototypes are submerged into a saline solution—heated to the same temperature as the body's natural biofluids—then twisted and contorted to replicate the changes and stresses that come with human movement.

4. MANUFACTURING AREA Laser cutters, milling machines, and 3D printers support scaled manufacturing techniques that combine different components developed in the lab into fully realized devices that can be tested in clinical settings.

The space's flagship equipment is a Manncorp Autotronik surface-mount technology (SMT) component placement system (4A), a robotic assembly tool that applies surface-mount technologies onto printed circuit boards. The machine can dispense more than 5,000 SMT components per hour, with the smallest components just 0.2 by 0.4 millimeters in size.

Photography by Jason Brown



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4A

5A

6

5B

QSIB's fourth-floor space supports new materials development and processing and fabrication for individual electronic device components. When complete, these materials transition to the third floor where they are further developed and combined to create functioning systems.

5. ISO 6 CLEANROOM QSIB's cleanroom features three sections devoted to semiconductor materials development: a microlithography room (5A), which uses light-based tools to define geometric patterns on thin film samples (blue light is filtered to avoid contaminating the samples, giving the space a yellow appearance); a wet chemistry lab (5B), used to etch and clean the patterns; and a deposition room, where metals are placed onto the finished sample.

6. FLUIDICS LABORATORY Students use microfluidics technologies, mechanical instrumentation, and chemical synthesis tools, such as colorimetric assays, to build device components for systems that aid in drug delivery or sweat analysis. Past projects in this area have included a personalized system for nutrient balance, composed of a skin-interfaced microfluidic sensor for monitoring essential nutrients in sweat and an integrated transdermal patch that delivers needed vitamins through the skin.

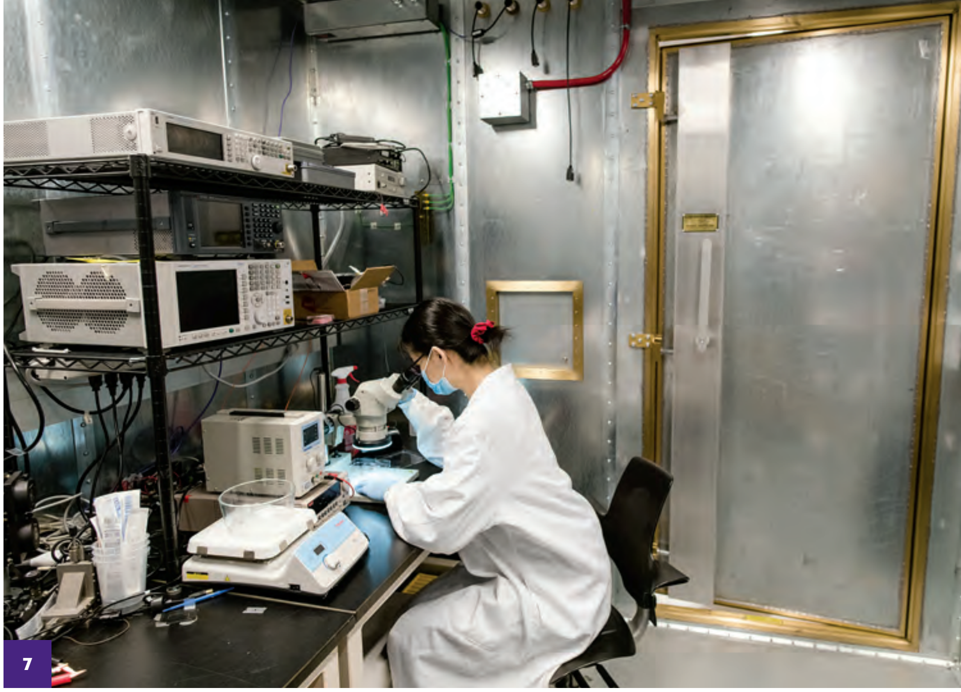
7. RADIO FREQUENCY DEVICE TESTING LABORATORY Also known as a Faraday cage, this room blocks out all electromagnetic signals, providing an interference-free space to test the power output of wireless electronic devices developed in the lab. This necessary step ensures devices meet Federal Communications Commission regulations before they are tested on patients in hospitals.

8. ELECTRONICS LABORATORY Featuring four project-specific testing stations, this lab was designed for bench-testing electronic, thermal, flow, and temperature characteristics on devices with medical applications.

9. PROJECT LOCKERS Resembling elementary school cubbies, these storage spaces provide an efficient way for QSIB's approximately 150 undergraduate, graduate, and postdoctoral students to hand off samples to collaborators or to restart their work when returning to the lab.

ALEX GERAGE

Photography by Jason Brown



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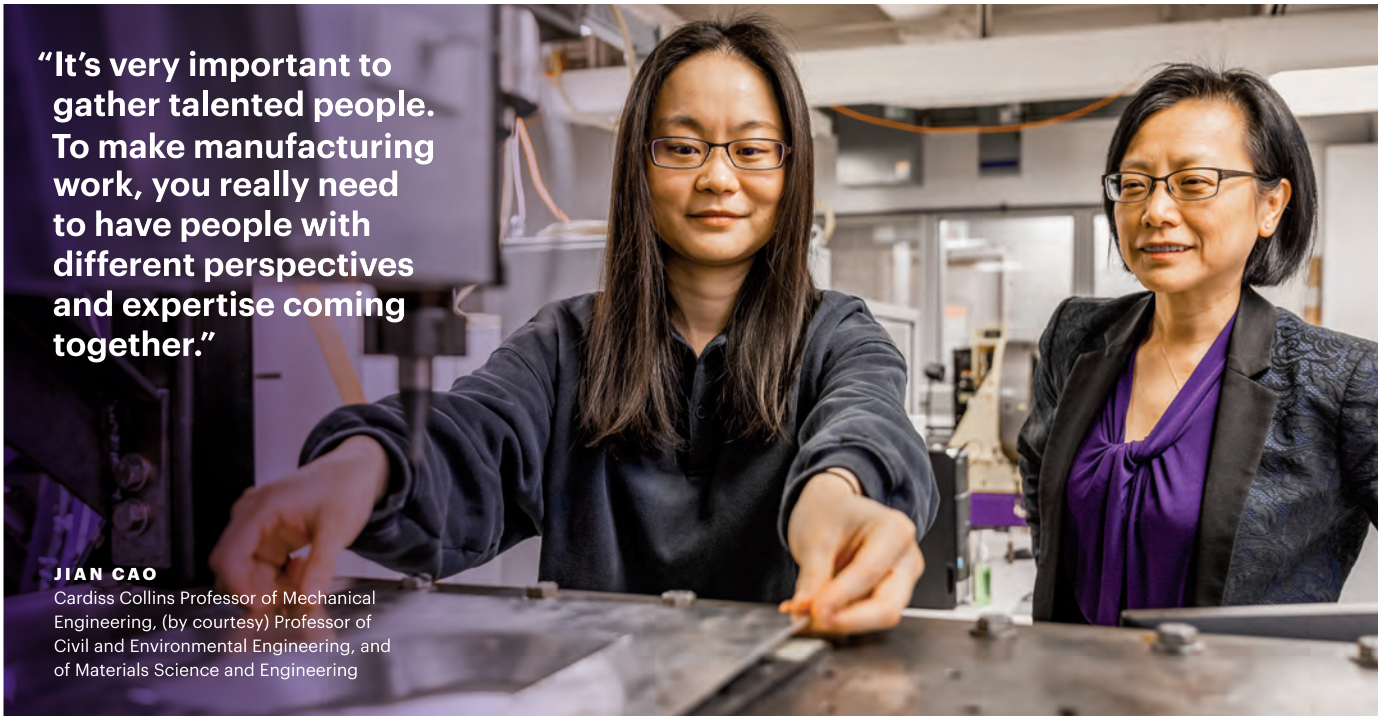
BREAKING THE MOLD

Jian Cao is shaping the future of manufacturing with her pioneering efforts in mechanical engineering.



"If you look at the advancement of human societies, most of it is technology driven," says Jian Cao, Cardiss Collins Professor of Mechanical Engineering and (by courtesy) professor of civil and environmental engineering and of materials science and engineering.

The opportunity to improve human existence, she explains, is what drew her to the field. "For so many different applications—from transportation to medicine—you always need a mechanical engineer," she says.

Cao's innovations, which include a pioneering flexible sheet-forming system, are transforming the way the world makes things. For her work, Cao has received numerous accolades, including the American Society of Mechanical Engineers' Milton C. Shaw Manufacturing Research Medal and her recent election to the National Academy of Engineering, among the highest honors in the field.

CHANGING THE GAME

In manufacturing, there's always a traditional way of doing things, Cao says. Looking at old processes in new ways fuels her work.

"In the Henry Ford age, manufacturing had a one-product-fits-all approach," she says. "Today, we like more personalized products and rapid development, so we need manufacturing processes that can change the product to a new form very quickly."

Cao's work has led to innovative manufacturing processes and systems that have increased material manufacturability and resulted in more flexible, energy-efficient manufacturing. At the material level, she has made fundamental contributions in characterizing the forming behavior of metals and woven composites.

Her research group has designed unique equipment for forming and additive manufacturing. One of the group's major modernizations is dieless sheet forming, which eliminates the need for a geometry-specific solid die.

"The solid die is a tooling that sometimes can weigh over a ton," Cao says. "Traditionally, you have to make the die to form the sheets. But we said, 'We don't need that. We just need a simple tool that can move around using a computer control to form the part.' That totally changed the game."

Eliminating the die also uses less raw material, which matters a great deal to Cao, whose driving goals are sustainability and energy efficiency. "The best way to conserve resources is to use less to start with," she says.

DIFFERING PERSPECTIVES

Cao, who joined Northwestern Engineering's faculty in 1995 and serves as director of the Northwestern Initiative for Manufacturing Science and Innovation, enjoys collaborating with colleagues, particularly Kornel Ehmann, professor of mechanical engineering. Her lab has nurtured doctoral students with diverse backgrounds, 43 percent of whom are either women or students from under-represented communities or first-generation families—a statistic Cao cites with pride.

"It's very important to gather talented people," she says. "To make manufacturing work, you really need to have people with different perspectives and expertise coming together."

SARA LANGEN

Photography by Matthew Allen

ADVANCING MEDICINE WITH NANOCARRIERS

With the mindset and discipline of an engineer, Professor Evan Scott seeks to improve drug therapy efficiency and effectiveness for a wide range of diseases.

> "WE LOOK AT THE BIOLOGY FIRST AND ASK, 'WHAT IS THE PROBLEM AND HOW DO WE ENGINEER A NANOPARTICLE TO ADDRESS THAT?' THEN WE TRY TO UNDERSTAND HOW THE IMMUNE SYSTEM RESPONDS TO THAT PARTICLE."
>
> **EVAN SCOTT**
> Kay Davis Professor and Associate Professor of Biomedical Engineering

Tiny, nanometer-scale particles, also known as nanocarriers, could represent the future of medicine. They can be programmed to travel inside the body and target disease sites, delivering high concentrations of drugs to specific areas while minimizing side effects.

Professor Evan Scott sees them as a valuable way to combat all kinds of disease, including cancer, infectious disease, glaucoma, and type 1 diabetes. He has spent much of his career solving medical problems with these tiny nanoparticles, using an engineer's mindset.

"We look at the biology first and ask, 'What is the problem and how do we engineer a nanoparticle to address that?'" says Scott, Kay Davis Professor and associate professor of biomedical engineering at Northwestern Engineering. "Then we try to understand how the immune system responds to that particle."

FROM CANCER TO DRUG DELIVERY

It's a problem-solving path he's followed for 20 years, starting as an undergraduate at Brown University. There, a course in immunology inspired him to learn more about how implanted materials interact with the immune system. That led him to Washington University in St. Louis, where he pursued his PhD, and then to École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland, where he focused on the development of nanoparticles for cancer immunotherapy and HIV vaccines.

Now, that work continues at Northwestern. Recently, he studied the interactions of nanoparticles with blood and how this impacts nanocarrier distributions within the immune system. By engineering nanocarrier surfaces to either stabilize or unravel albumin—a protein in the bloodstream—researchers could tune the nanocarrier's cellular interactions and circulation time.

That could help improve drug specificity, decrease dosage, and minimize adverse outcomes for patients receiving treatments for a variety of diseases, particularly those requiring intravenous drug administration.

A NEW TREATMENT FOR DIABETES

Along with Guillermo Ameer, Daniel Hale Williams Professor of Biomedical Engineering and Surgery, Scott developed a technique for using nanocarriers to re-engineer the commonly used immunosuppressant drug rapamycin to treat type 1 diabetes, potentially limiting or eliminating the need for daily insulin shots.

These nanocarriers may have broad utility for the treatment of a wide range of disorders. Scott is looking to realize that potential, investigating nanocarriers for pain management, endometriosis, and transplant tolerance.

In the near future, Scott hopes to continue his nanotherapy collaboration with Ameer to fight type 1 diabetes. More generally, Scott intends to study the mechanisms behind how nanocarriers target and stimulate cells of the immune system to discover new ways of controlling immune responses in the treatment of disease.

"This is going to be an ongoing field of research that will last for many years," Scott says.

BRIAN SANDALOW

Photography by Matthew Allen

MAKING **AI SAFETY** A PRIORITY

A collaboration between Northwestern Engineering and Underwriters Laboratories has spawned a new research hub that will focus on integrating safety into AI design.

Northwestern and Underwriters Laboratories (UL) Leadership
left to right Northwestern Engineering Dean Julio M. Ottino; Milan Mrksich, Northwestern vice president for research; Terrence R. Brady, UL CEO, president, and trustee; Timothy J. Rivelli, UL senior vice president and chief legal officer; Samir Khuller, Peter and Adrienne Barris Chair of Computer Science; Kristian Hammond, CASMI director and Bill and Cathy Osborn Professor of Computer Science; Christopher J. Cramer, UL senior vice president and chief research officer

From facial recognition to autonomous vehicles, the adoption of applications driven by artificial intelligence (AI) has exploded so quickly that it has outpaced efforts to understand how these machine-learning technologies affect human life.

To help examine AI systems and evaluate their impact, Northwestern Engineering and Underwriters Laboratories Inc. have created a research hub that seeks to better incorporate safety and equity into the fast-growing technology.

The McCormick School of Engineering will host—and the two institutions will jointly lead—the research and operations of the new hub, the Center for Advancing Safety of Machine Intelligence (CASMI). The Digital Intelligence Safety Research Institute (DISRI) at Underwriters Laboratories will support the research collaboration, committing expertise and resources as well as $7 million to the research hub over the next three years.

A DISTRIBUTED RESEARCH MODEL

The DISRI-CASMI partnership brings together and coordinates a wide-ranging research network focused on maximizing machine learning's benefits while recognizing and averting potential negative effects.

"Machine learning is among the most transformational forces in technology today, but we're only beginning as a society to genuinely understand and evaluate how it affects our lives," says Kristian Hammond, Bill and Cathy Osborn Professor of Computer Science at Northwestern Engineering and CASMI executive director. "Our partnership with Underwriters Laboratories will help us establish the clear understanding we need to develop these technologies safely and responsibly. Our goal is to go beyond platitudes and operationalize what it means for these technologies to be safe as they are used in the world."

The CASMI research hub extends a partnership that Northwestern Engineering and Underwriters Laboratories began in 2020 to map the extent of machine learning's current and potential impacts on human health and safety. Both organizations will build on that exploratory work as they refine a new framework to evaluate the impact of artificial intelligence and devise new ways to responsibly design and develop these technologies.

The "distributed research" model that CASMI will follow also calls for widely sharing ideas and research outcomes that address these issues. By developing connections and collaborations across multiple institutions and with researchers from different disciplines and backgrounds, the initiative will establish a research network capable of yielding results unlikely to be achieved by any one group in isolation.

THE HUMAN IMPACT

"Artificial intelligence informed by machine learning is increasingly ubiquitous in our everyday lives," says Christopher J. Cramer, Underwriters Laboratories' chief research officer and acting DISRI executive director. "It's imperative we get it right. We must develop approaches and tests that will incorporate equity into machine learning and hold it to standards guided by both safety and ethical considerations. I'm terrifically excited about this partnership, which will foster research aimed at integrating safety into machine-learning and artificial-intelligence design, development, and testing processes."

By the end of its first year, the collaboration aims to have funded and started sharing the results from an initial set of mission-driven research projects. The partnership will continue to expand its research initiatives during the hub's second and third years, while also exploring opportunities to connect the research network with industry partners.

"Underwriters Laboratories has been a longtime leader in advancing the safety of technologies that impact our everyday lives," says Julio M. Ottino, dean of Northwestern Engineering. "We are delighted to partner with them to advance the safe and ethical use of machine learning and artificial intelligence as these technologies continue to impact our society."

Photography by Jason Brown

CLASS NOTES

AGILITY AND RESILIENCE IN THE FACE OF CHALLENGE

ANDRES BARRY CREDITS HIS NORTHWESTERN EXPERIENCE FOR HIS ABILITY TO NAVIGATE COMPLEXITY AND UNCERTAINTY IN THE TRAVEL INDUSTRY.

"There are millions of ideas out there, but the winners end up being those who can execute best against them, and for that you need great people to come together."

As president of JetBlue Travel Products, ANDRES BARRY ('02) solves complex problems every day. The company, launched in 2018, handles the airline's travel packages, travel insurance, and car rentals, a crucial part of JetBlue's portfolio of offerings.

Barry acknowledges he has relished the challenge of building a new business, albeit one backed by an established brand, using data-driven decision-making, a skill he honed as an undergraduate in the Department of Industrial Engineering and Management Sciences.

"At Northwestern, I learned how to break down any challenge into discrete pieces and glue those particular bits together," Barry says. "The undergraduate program really built on our natural problem-solving skills as students to prepare a future generation of critical thinkers. As a result, I'm able to put together an end-to-end process combining creativity, invention, design, and implementation to tackle even the most challenging real-life business problems I encounter."

Barry, who previously served as managing director and partner of Boston Consulting Group, challenged his team to consider how to make their products easy to use while building on the trust and name recognition of the parent company. Then, in 2020, an unprecedented obstacle arose.

"Building a travel business when travel demand was wiped out by the pandemic was quite the challenge," Barry says, "but we had the resiliency to stick through it and come out on the other side with a winning business.

"Being flexible in an unpredictable market is key, and the most important thing is to build the right team," he adds. "There are millions of ideas out there, but the winners end up being those who can execute best against them, and for that you need great people to come together."

BUILDING OFF A NORTHWESTERN BASE

Agility and resiliency, traits Barry says he learned at Northwestern, have served him well during his career. His advice to incoming engineering students reflects that experience.

"Every skill I've developed since my time at Northwestern builds off the base I built during my time as a student. The analytical skills you develop are extremely valuable throughout your career, and your ability to understand and assess issues quickly enables better decision-making in the future," he says. "Get to know and appreciate the people around you. You have access to an incredibly talented and diverse group of classmates, many of whom will grow professionally with you. Take the time to build relationships. They can last you a lifetime."

BRIAN SANDALOW

Power Player

INVENERGY'S **MAGGIE PAKULA** IS BUILDING A BETTER FUTURE THROUGH SUSTAINABLE ENERGY SOLUTIONS.

MAGGIE PAKULA ('08) always wanted to work in the energy field, but she wasn't sure where to focus her studies. When her brother, David Pakula ('02), introduced her to Northwestern Engineering, she recognized it was the perfect fit.

Across disciplines, there were opportunities related to energy and climate change, which is exactly the direction Pakula wanted her career to take. "It felt like a hard-core engineering space," she says. "Tech was this awesome old building that had labs throughout, and I felt like I was getting a real world-class education."

> "TECH WAS THIS AWESOME OLD BUILDING THAT HAD LABS THROUGHOUT, AND I FELT LIKE I WAS GETTING A REAL WORLD-CLASS EDUCATION."

Today, Pakula serves on the Department of Civil and Environmental Engineering advisory board and talks to engineering students about her role as senior vice president of strategy at Invenergy, a privately held global developer and operator of sustainable energy solutions.

"I was always a high performer, but I don't think I had the natural inclination to accelerate up the corporate ladder," she says. "But here I am, and I think it's a good example to show students what they can do with their degrees."

THE LATITUDE TO LEARN

Pakula earned a master's degree in civil and environmental engineering at Stanford University and planned to go into academia until the opportunity to join Invenergy as a performance analysis engineer in 2010 set her on a new path.

"I liked that the company was small, but still a big player in the space—one of the top wind energy developers in the United States," Pakula says. "We had almost a gigawatt of wind turbines, and we had just started collecting data from all the assets. It was a blank slate, and that's why I stayed. It was an exciting opportunity to build something from the ground up."

In addition to establishing the company's Performance Analytics Program, which is responsible for large-scale analytical data processing to identify performance and operational anomalies in Invenergy's wind and solar assets, Pakula helped develop the commercial and market analytics group. She considers these achievements "a nice legacy to look back on."

Then, just as she began to look for a new challenge, the company offered her the chance to engage with market policy as director of regulatory affairs. That experience led to her position as senior vice president of strategy. In that role, she uses the analytical and collaborative lessons she learned at Northwestern to examine new market opportunities for advancing Invenergy's goals to build a sustainable world. She also serves on the board of Evergreen Climate Innovations (formerly Clean Energy Trust), a nonprofit supporting early-stage cleantech startups.

Invenergy has scaled considerably since she joined, from a staff of approximately 300 to more than 1,500, with 191 projects in wind, solar, and natural gas power generation, as well as advanced energy storage. Each time Pakula has sought a new challenge, the company has offered opportunities to expand her skills. "It's been great to be given the latitude and the trust to just go out and learn," she says.

SARA LANGEN

Using Technology to Strategic Advantage

At Accenture, **Annette Rippert** helps leading companies reimagine business through the power of technology and human ingenuity.

ANNETTE RIPPERT ('86, KSM '94) loves data—not just for data's sake, but for what it promises for tomorrow.

"Whether it's to inform product development, open new markets, or accelerate innovation, the power of data and insights is changing the future," she says.

As group chief executive of the Strategy & Consulting business at Accenture, the global professional services company, she oversees a 45,000-member team that helps Fortune 500 and leading technology clients apply data, analytics, artificial intelligence, assets, and innovation to deliver business outcomes.

Rippert credits Northwestern with teaching her the value of data back when she entered the field of electrical engineering and computer science as a student in the 1980s—and she has never forgotten the lesson.

In a 2021 *Fortune* op-ed, she said, "Business leaders need to break a lifelong habit of focusing on historical data and start learning from the future" by using new data sets processed by artificial intelligence to find patterns and anticipate trends.

"It's one of the reasons we've teamed with Northwestern to develop our workforce in the area of data and analytics," she says, referring to the custom executive education program in analytics and artificial intelligence that Northwestern developed in partnership with Accenture.

Transforming business through technology

Rippert, who credits the fast-paced, ever-changing nature of her work for keeping her at Accenture for nearly three decades, specializes in using emerging technologies to help clients accelerate growth.

"I have been fortunate to work with clients on groundbreaking industry shifts, such as the cable industry's move from analog to digital transmission and building the foundation for today's streaming services," she says. "Seeing the impact of this work has been immensely rewarding."

Rippert started as a technologist, architect, and leader of complex programs, then quickly moved on to lead major client accounts and global service lines at Accenture, eventually heading up its technology business in North America. Recently, she co-sponsored the launch of Accenture's $3 billion Cloud First initiative.

Her use of technology to transform business has earned her national recognition, including the Gold Stevie Award for Achievement in Management – Business and Professional Services. She was also ranked number one among the "Top Women Leaders in Consulting" for 2022 by *The Consulting Report*.

Balancing life's opportunities

Rippert's journey to the top of the consulting world wasn't a straight line. She joined Accenture (then Arthur Andersen) in 1986 because she wanted to apply her engineering skills to the broader business world.

"Northwestern helped shape me in so many ways and contributed to my success. It's important for me to pay it forward and do what I can to contribute to a thriving future for the University and its students."

"I could see technology was changing how business was done," she says. "And I realized that rather than build better circuits, I wanted to build better businesses."

After earning a master's of management degree from the Kellogg School of Management and working her way to senior leadership positions as a partner at Accenture, Rippert left the company in 2004. "I had achieved a great deal professionally and wanted to invest my full focus on raising my five sons," she says. "It was enormously fulfilling, but when my youngest son began school, I knew I had more to offer."

Accenture welcomed Rippert back after nearly seven years away. "The experience shaped my desire to help women balance life's opportunities and to sponsor programs to facilitate those who choose to leave and then return to the workforce," she says.

In search of role models

As an undergraduate, being one of few women in the engineering program wasn't easy, but the support of professors encouraged Rippert to excel.

She owes much to those who encouraged her at Northwestern, including Professor Emeritus Larry Henschen, who gave her the confidence to dive deeper into electrical engineering and computer science.

"That's one of the reasons being a mentor is so important to me today," she says. "I learned the necessity of advocating for myself, and my experiences spurred my passion for helping women in STEM fields."

Early in her career, Rippert was hard-pressed to find female mentors to help navigate her largely male-dominated professional path. And while today's women engineers have more resources and support systems, Rippert says a notable disparity and culture gap remains.

"Research shows it's critically important for girls and women to have visible role models," she notes, "which is why I participate in and advocate for programs such as the Grace Hopper Celebration, Girls Who Code, and Hour of Code."

Working together, giving back

Northwestern taught Rippert the importance of collaboration across disciplines. "The teams I lead work in this interdisciplinary fashion every day," she says. "The more we can develop whole-brain engineers and business leaders, the better off our collective future will be."

She gives back to the University today by serving on the McCormick Advisory Council and the Northwestern Board of Trustees, and she will deliver Northwestern Engineering's undergraduate convocation address in June.

"Northwestern helped shape me in so many ways and contributed to my success," she says. "It's important for me to pay it forward and do what I can to contribute to a thriving future for the University and its students."

SARA LANGEN

THE PERFECT SPRINGBOARD

MELISSA & DOUG CEO **FERNANDO MERCÉ** APPLIED HIS INDUSTRIAL ENGINEERING BACKGROUND TO ACHIEVE C-LEVEL SUCCESS IN THE BUSINESS WORLD.

"I APPRECIATED THE DIVERSE EXPOSURE TO DIFFERENT SUBJECTS, KNOWLEDGE, AND PEOPLE THAT NORTHWESTERN ALLOWED. TO ME, THAT'S WHAT THE NORTHWESTERN EXPERIENCE IS ALL ABOUT."

FOR FERNANDO MERCÉ ('92), being chief executive officer of global toy company Melissa & Doug is "like playing in a sandbox."

Spending his days working with toys is a dream job for an engineer, he says. From classic wooden toys and puzzles to crafts and pretend play, Melissa & Doug creates timeless, sustainable products that are designed to ignite children's imaginations.

Helping children succeed is a driving passion for Mercé, who also serves on the board of Domus, an organization that helps place struggling youth on a path toward health and opportunity. Melissa & Doug's 30-year commitment to fostering early brain development and championing the health benefits of open-ended play drew Mercé to the CEO position two years ago.

"This is a job that allows you to go back to your childhood and think as a child again," he says. "It's very hands on—our toys are physical toys, not software. Everyone is so passionate about the company's purpose to bring these incredible toys to children everywhere."

LEADING WITH PURPOSE

Purpose has remained a common thread throughout Mercé's career. Before joining Melissa & Doug, he served as president and CEO of Nestlé Waters North America, steering a $4.5-billion business and 9,000 associates at one of the largest healthy beverage companies in the United States. While there, he focused on improving the environmental sustainability of bottled water and increasing recycled plastic use in bottles. Prior to that role, the Brazilian-born Mercé served as president of Nestlé Purina, Latin America and Caribbean, where he managed 3,000 employees dedicated to bringing optimal nutrition to cats and dogs.

"Industrial engineering teaches the importance of each stage in the process of running a business. It helps you understand how to measure things quantitatively, as well as the softer skills that are necessary in order for everything to work together."

"It was amazing to see how that purpose impacted not only the consumer, but also attracted people with a lot of purpose to the business," he says. "It showed me that purpose helps drive performance and attracts people who are interested not just in the financials, but in the quality of the work."

Mercé joined Nestlé in 1992 as an industrial engineer after earning an undergraduate degree in the discipline from Northwestern Engineering. He says working as an internal consultant on a team that went from factory to factory helping each to become more efficient was "one of the coolest jobs an engineer could have." The experience felt like getting a practical master's degree in industrial engineering.

"At the time, I didn't want to go into an office; I wanted to be on the production floor experiencing what a factory looks and feels like and figuring out how to improve it," he says. "I could apply everything I studied at Northwestern almost immediately, which was very fulfilling. It gave my degree and the time I spent at Northwestern a real sense of purpose."

A LAUNCHPAD FOR SUCCESS

Mercé then earned an MBA from the University of Virginia Darden School of Business. He says his industrial engineering background became the perfect springboard into the business world.

"Industrial engineering teaches the importance of each stage in the process of running a business," he explains. "It helps you understand how to measure things quantitatively, as well as the softer skills that are necessary in order for everything to work together."

Mercé credits Northwestern's whole-brain engineering approach with helping him develop skills outside engineering courses that became pivotal to his success, such as the classes he took in interpersonal communications and economics. "I appreciated the diverse exposure to different subjects, knowledge, and people that Northwestern allowed," he says. "To me, that's what the Northwestern experience is all about."

A TRANSFORMATIVE TIME

It's an experience he'll be able to share with his son, who plans to study engineering at Northwestern next fall. When Mercé visited the campus with him, memories came flooding back.

"It's almost like moving back in time as you walk into the building," Mercé says. "There is that sense of wonder and constant learning. It was a transformative time for me."

Mercé's connection to Northwestern has remained strong. He supports the school with his philanthropy and with his time by serving on the advisory board of the Department of Industrial Engineering and Management Sciences. It's a way to give back that reaps its own rewards.

"I'm able to learn about this generation of students—what they're interested in and what's important to them—so that we can design our workplace to be more attractive and more fulfilling for them," he says. "There are knowledge gains on both sides. I love taking what I learn from those meetings back into my own businesses."

SARA LANGEN

IN MEMORIAM

Professor Emeritus Stephen Davis

Stephen Davis, Walter P. Murphy Professor Emeritus of Engineering Sciences and Applied Mathematics, passed away at age 82 on November 12, 2021. He will be remembered as a pioneer in fluid dynamics research and for his dedication to Northwestern Engineering.

Davis joined the McCormick School of Engineering in 1979 as a professor in the Department of Engineering Sciences and Applied Mathematics (ESAM) after previously working at Johns Hopkins University and Imperial College London. Early in his career, Davis also worked as a mathematician at RAND Corporation. Holding bachelor's, master's, and PhD degrees from Rensselaer Polytechnic Institute, Davis served as ESAM department chair from 1988 to 1991. When he retired in 2019, Davis also held courtesy appointments in the mechanical engineering and chemical and biological engineering departments.

Davis's research interests included theoretical fluid mechanics, hydrodynamic stability and interfacial phenomena, materials science, thin films and crystal growth, and asymptotic and variational methods.

"The McCormick School of Engineering wouldn't be what it is today without Stephen Davis," says Julio M. Ottino, dean of Northwestern Engineering. "He was not just a world-class researcher. What I admired was the elegance of his work. His style affected our culture; he will be sorely missed."

In 1994, Davis's work earned him election to the National Academy of Engineering, where he was recognized for contributions to the mathematics of hydrodynamic stability theory and interfacial phenomena. He was elected to the American Academy of Arts and Sciences in 1995 and to the National Academy of Sciences in 2004.

His other honors included the Fluid Dynamics Prize from the American Physical Society (1994), the G.I. Taylor Medal from the Society of Engineering Science (2001), the Royal Academy of Engineering Distinguished Visiting Fellowship, and election into the Academia Europaea.

"Steve's contributions to the ESAM department and McCormick as a whole cannot be overstated," says David Chopp, professor and chair of the Department of Engineering Sciences and Applied Mathematics. "His scientific work and leadership in the field is a major reason why ESAM is so highly regarded today. In addition to his scholarly work, he was also a wonderful colleague who was always friendly and approachable. It has been a tremendous privilege to have worked with him these many years."

An ISI Highly Cited Researcher whose work spanned six decades, Davis authored four books and more than 200 academic publications. He also delivered numerous special lectures, including at Imperial College London in 2014 and Massachusetts Institute of Technology in 2000.

In 2019, Northwestern Engineering held a daylong symposium in Davis's honor, featuring lectures by four international fluid mechanics and materials science experts. The lecture is now a yearly event.

"What Steve meant to Northwestern Engineering and to the fluid dynamics community cannot be summed up into words," says Michael Miksis, professor of engineering sciences and applied mathematics and (by courtesy) mechanical engineering. "Through his mentoring of students and postdocs, his collaborations, and his openness to talk about science and applied mathematics, he has impacted a generation of fluid dynamicists. His work and legacy will endure."

Leo J. O'Brien '43, '47, '49
Paul O. Grasse '46
Arthur W. Kleinrath '46
Robert F. Neunuebel '46
Wallace B. Behnke Jr. '47
Merle E. Kersten '48
Robert F. Olson '49
William C. Schumacher Jr. '50
William P. Birkemeier '51
Herbert J. Nelson Jr. '51
Philip T. Blair '53
Donald E. Amundson '54
Earl L. Hummell '54
Ronald G. Schultz '54
William S. Coleman '55
George S. Mavrogenes '55
Richard E. Wells '55
Clyde C. Yount '57, '59
William C. Laser '58
Patrick E. Milks '58, '67
William E. Nowers '58
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James D. Bargainer Jr. '59
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Richard A. Soderberg '62
Thomas B. Brown '63
John A. Dantico '63
Thomas E. Evans '64
Didier de Fontaine '67
Raj P. Khera '67
John Carl Ward '67
James W. Tingey '70
Nicholas Anthony Marra '79
Leon Zuckerman '79
William P. Pantos '80
C. Clair Claiborne '84
Richard A. Carlin '85
Mark Iserloth '85, '90
John Michael Siwula '86
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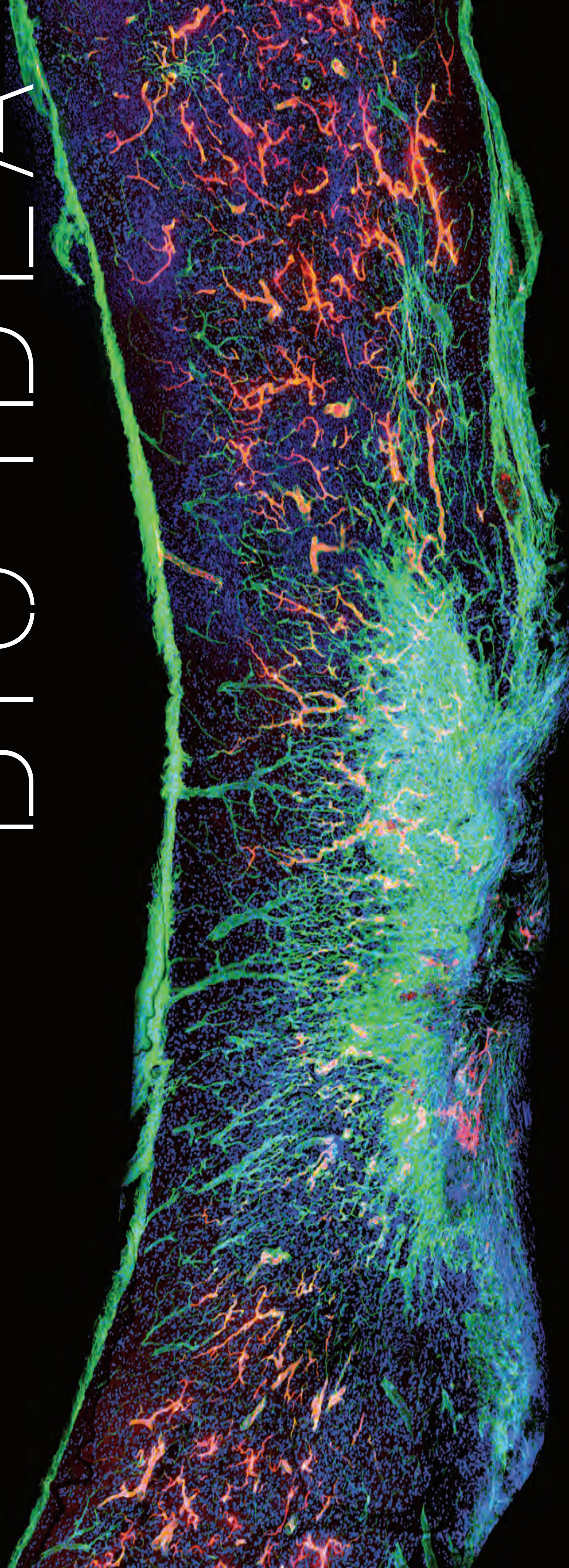
Warren W. Mowry '88
John J. Kennelly '91
Christopher A. Smolen '98
Michael Dundon '02
John P. Romankiewicz '06
Eric John Zimney '06
Richard Patrick Magrath III '14

BIG IDEA



"Dancing molecules" successfully repair severe spinal cord injuries

Nearly 300,000 people in the United States are living with a spinal cord injury. Less than 3 percent of people with complete injury ever recover basic physical functions. Currently, there are no therapeutics that trigger spinal cord regeneration.

Professor Samuel I. Stupp has developed a new injectable therapy that harnesses "dancing molecules" to reverse paralysis and repair tissue after severe spinal cord injuries. When researchers administered a single injection of these molecules to tissues surrounding the spinal cords of paralyzed mice, the animals regained the ability to walk just four weeks later.

By sending bioactive signals to trigger cells to repair and regenerate, the breakthrough therapy dramatically improved severely injured spinal cords in five key ways:

- The severed extensions of neurons, called axons, regenerated
- Scar tissue significantly diminished
- Myelin, the insulating layer of axons, which is important in transmitting electrical signals efficiently, reformed around cells
- Functional blood vessels formed to deliver nutrients to cells at the injury site
- More motor neurons survived

"The innovation in our research, which has never been done before, is to control the collective motion of more than 100,000 molecules within our nanofibers," Stupp says. "By making the molecules move, 'dance,' or even leap temporarily out of these structures, known as supramolecular polymers, they are able to connect more effectively with receptors." This is the first study in which researchers controlled the collective motion of molecules through changes in chemical structure to increase a therapeutic's efficacy.

Image by Samuel I. Stupp Laboratory/ Northwestern University

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UNCOVERING INSIGHTS BELOW WATER'S SURFACE

Professor Aaron Packman monitors a recirculating flume in the Environmental Transport Processes Laboratory. The 7.5-meter-long flume continuously recirculates water and sand, allowing Packman and collaborators to study flow and particle transport dynamics during extended periods of time—up to months in some experiments. Packman recently used the system to examine the mechanisms of long-term particle trapping in riverbeds. He found hyporheic exchange—a process in which surface water mixes with water in a riverbed—can trap lightweight microplastics that otherwise might be expected to float. Read more about his research on page 28.

Photography by Jason Brown