CHEMICAL AND BIOLOGICAL ENGINEERING

NEW ENGINEERING CENTER HOSTS SUSTAINABLE URBAN SYSTEMS WORKSHOP

Nearly 150 stakeholders attended the SUSPIRE workshop on Northwestern's downtown campus

Chicago area community members and stakeholders from a range of industries gathered for the Sustainable Urban Systems: Predictive, Interconnected, Resilient, and Evolving (SUSPIRE) workshop on July 16-17.

Hosted by Northwestern Engineering's new Center for Engineering Sustainability and Resilience (CESR), alongside Argonne National Laboratory, the University of Chicago, and the Illinois Center for Urban Resilience and Environmental Sustainability, the workshop discussed ways to improve sustainability and quality of life within the Chicago region by addressing how climate, natural, technological, and societal disruptions will transform urban systems. SUSPIRE is part of a series of workshops on sustainable urban systems sponsored by the National Science Foundation.

Bill Miller

"NSF has charged these workshops with charting a research agenda," said CESR director **Bill Miller**, professor of chemical and biological engineering. "We're really interested in identifying activities that bring together people from diverse perspectives. Do all the science you want, but if you're not connected with the community early in the process to see what they need and what works for them, it's not going to work."

The two-day conference included participants from academia, community organizations, and government entities, discussing new strategies to advance a sustainable urban systems research network that not only addresses science and engineering topics, but also social, behavioral, and economic considerations.

Pete Beckman, senior computer scientist at Argonne National Laboratory and codirector of the Northwestern Argonne Institute of Science and Engineering; Susan Popkin, Institute Fellow and director of the Housing Opportunities and Services Together Initiative at The Urban Institute; William Abolt, vice president, energy at AECOM; and Sarah Murdock, director of US climate resilience and water policy at the Nature Conservancy, delivered keynote addresses at the event.

Northwestern Engineering alumna Kyra Woods ('13), now a member of the Sierra Club Illinois Chapter, talks with an attendee at the SUSPIRE workshop.

The workshop included panel discussions with representatives from diverse institutions, including the Chicago Metropolitan Agency for Planning, the Metropolitan Water Reclamation District of Greater Chicago, Chicago Community Trust, Bronzeville Urban Development, SURGE Institute, The Plant, Calumet Collaborative, and the Center for Neighborhood Technology.

To encourage continued engagement after the workshop, participants collaborated during breakout sessions to discuss diverse urban systems and create near-term plans to promote a sustainable and resilient Chicago.

TEACHING CRISPR AND ANTIBIOTIC RESISTANCE TO HIGH SCHOOL STUDENTS

BioBits Health brings hands-on, low-cost, high-tech synthetic biology into the classroom

Professor Michael Jewett (right) and former PhD student Jessica Stark (center) test the BioBits education kit with high school students.

How can high school students learn about a technology as complex and abstract as CRISPR? It's simple: just add water.

A Northwestern University-led team has developed BioBits, a suite of hands-on educational kits that enable students to perform a range of biological experiments by adding water and simple reagents to activate freeze-dried cell-free reactions. The kits link complex biological concepts to visual, fluorescent readouts, so students know — after a few hours and with a single glance — the results of their experiments.

After launching BioBits in summer 2018, the researchers are now expanding the kit to include modules for CRISPR and antibiotic resistance. A small group of Chicago-area teachers and high school students have completed the first pilot study for these new modules, which include interactive experiments and supplementary materials exploring ethics and strategies.

"After we unveiled the first kits, we next wanted to tackle current topics that are important for society. That led us to two areas: antibiotic resistance and gene editing," said **Michael Jewett**, professor of chemical and biological engineering and codirector of Northwestern's Center for Synthetic Biology. He was the principal investigator of the study published in the journal *ACS Synthetic Biology*.

Instead of using live cells, the BioBits team removed the essential cellular machinery from inside the cells and freeze-dried them for shelf stability. Keeping cells alive and contained for an extended period of time involves several complicated, time-consuming preparation and processing steps as well as expensive equipment. Freeze-dried cell-free reactions bypass those complications and costs.

"These are essentially test-tube biological reactions," said **Jessica Stark** (PhD '19), a former student in Jewett's laboratory, who led the study. "We break the cells open and use their guts, which still contain all of the necessary biological machinery to carry out a reaction. We no longer need living cells to demonstrate biology."

BioBits Health uses three components required for CRISPR: an enzyme called the Cas9 protein, a target DNA sequence encoding a fluorescent protein, and an RNA molecule that targets the fluorescent protein gene. When students add all three components — and water — to the freeze-dried cell-free system, it creates a reaction that edits, or cuts, the DNA for the fluorescent protein. If the DNA is cut, the system does not glow. If the DNA is not cut, the fluorescent protein is made, and the system glows fluorescent.

"AFTER WE UNVEILED THE FIRST KITS, WE NEXT WANTED TO TACKLE CURRENT TOPICS THAT ARE IMPORTANT FOR SOCIETY."

MICHAEL JEWETT

EXPLORING THE ETHICS OF EMERGING SCIENCE

The event "Exploring Ethics: Across Art, Humanities, and Science" was held at the Block Museum

From new ways to fight disease to managing natural resources, scientists working at the forefront of technological innovation are driven to profoundly influence life as we know it.

Yet coinciding with the arrival of these new advances are ethical questions that consider the foreseen — and unforeseen — impact these technologies could have on individual relationships, communities, and society.

How do ethical considerations impact decisions that scientists and researchers make every day? How can engineers adapt science to social needs? What is the public's role in technologies that redefine fundamental aspects of life itself?

Those questions guided "Exploring Ethics: Across Art, Humanities, and Science," a public forum held in May at the Block Museum of Art. Sponsored by the McCormick School of Engineering and the Block Museum, the event brought together engineers, artists, and researchers from Northwestern to discuss how leaders in science and the humanities are raising new ethical questions emerging from innovative scientific research.

Transdisciplinary artist and Northwestern Artist-at-Large Dario Robleto guided the discussion. With a deep appreciation for science, Robleto perceives a growing gap between public awareness and scientific developments, one he feels is contributing to a lack of ethical oversight in scientific innovation. He said working across disciplines is vital to fostering a conversation that leads to new levels of moral understanding.

Professor Josh Leonard answers a question from the audience during "Exploring Ethics: Across Art, Humanities, and Science."

Professor **Josh Leonard**, one of three speakers from the Department of Chemical and Biological Engineering and the Center for Synthetic Biology, expanded on the promise of the growing field — and the ethical considerations that coincide with it. By reprogramming cells at the DNA-level, synthetic biologists are developing new ways to create targeted therapeutics or next-generation materials or chemicals.

Leonard explained that many ethical considerations in synthetic biology stem from the "dual-use" nature of the field. He noted, for example, that synthetic biologists can now create fully synthetic viruses from scratch. While such capability "sounds scary," he showcased a model specifically designed to respond to pandemic influenza within a week.

Professor **Danielle Tullman-Ercek** discussed how to ensure technological advances reach those who need them most. An expert in engineering microbes, she created a novel protein secretion pump that achieved a 20-fold increase in the amount of protein that could be made with bacteria. It marked a breakthrough that could dramatically reduce the cost of medicines like insulin, impacting countless lives.

"We made this wonderful thing, but how do we do make people aware of it so it can be used to make proteins more efficiently for the common good?" Tullman-Ercek said.

For Professor **Julius Lucks**, scientists and artists travel a similar path to discover, analyze, and communicate the world around them, a mindset that has informed his work developing technology to tackle a growing public concern — clean water.

While Lucks's technology could help empower countless people, discussions with Robleto revealed thought-provoking consequences: If anyone could test the health of their water, for example, how might that impart trust in, and provoke action toward, their local governments?

"This is a very real possibility," Lucks said. "As scientists, it's unanticipated. We didn't think we would face these questions when we first started this project."

Electron-behaving Nanoparticles Rock Current Understanding of Matter

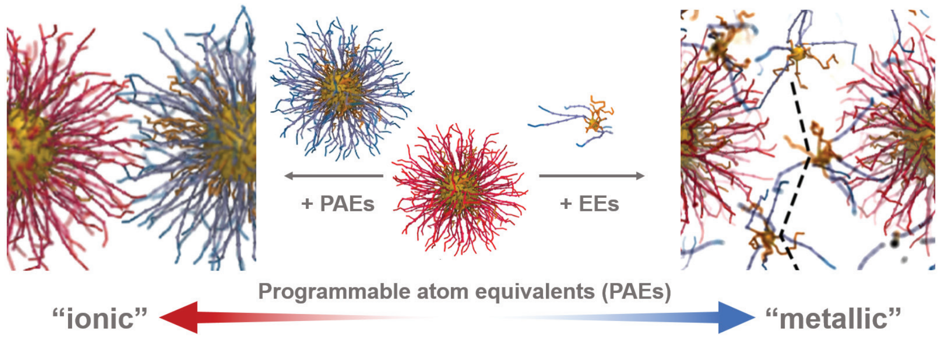
Discovery will lead to new methods for materials design

Professors **Monica Olvera de la Cruz** and **Chad Mirkin** have made a strange and startling discovery that nanoparticles engineered with DNA in colloidal crystals — when extremely small — behave just like electrons. Not only has this finding upended the current, accepted notion of matter, it also opens the door for new possibilities in materials design.

"We have never seen anything like this before," said Olvera de la Cruz, who made the initial observation through computational work. "In our simulations, the particles look just like orbiting electrons."

With this discovery, the researchers introduced a new term called "metallicity," which refers to the mobility of electrons in a metal. In colloidal crystals, tiny nanoparticles roam similarly to electrons and act as a glue that holds the material together.

"This is going to get people to think about matter in a new way," said Mirkin, who led the experimental work. "It's going to lead to all sorts of materials that have potentially spectacular properties that have never been observed before. Properties that could lead to a variety of new technologies in the fields of optics, electronics, and even catalysis."



Researchers developed a new term, "metallicity," referring to the mobility of electrons in metal.

"THIS IS GOING TO GET PEOPLE TO THINK ABOUT MATTER IN A NEW WAY."

CHAD MIRKIN

Successful Research Papers Cite Young References

Analysis of scientific citations reveals previously unknown patterns

When it comes to publishing the most impactful scientific research and identifying the best up-and-coming research paths, it takes one to know one.

That's what Professor **Luís Amaral** and collaborators found when they analyzed nearly 6 million citations among more than 156,000 published scientific papers.

While most researchers cite older, well-established papers in their field, highly cited papers — papers that other published papers cite the most often and therefore are considered successful — also cite more work that has been published relatively recently.

In fact, the study found that cited work goes on to become highly cited itself, showing that top scientists and engineers are adept at betting on good prospects.

"You could say the best researchers also have the best scientific taste," said Amaral, Erastus Otis Haven Professor of Chemical and Biological Engineering and lead author of the research published in the journal *Nature Human Behavior*.

To better understand the context in which papers are cited, Amaral and his team examined more than 156,000 papers in PLOS journals between 2005 and 2016. He found that highly cited papers did not uniformly cite just the classic papers in the field. Instead, they cited papers that were much younger — two to four years younger on average, depending on the paper section. That means authors of top scientific papers are generally up-to-date on the latest scientific literature in their field.

Professor Luís Amaral and collaborators analyzed nearly 6 million citations in the study.

Northwestern Launches Program on Plastics, Ecosystems, and Public Health

Network of researchers convene to focus on plastic waste impacts and solutions

The Institute for Sustainability and Energy at Northwestern University (ISEN) is spearheading a new Program on Plastics, Ecosystems, and Public Health. The program's ultimate goal is to establish comprehensive scientific understanding of the uncertain environmental and human health impacts resulting from the unprecedented use and accumulation of plastics worldwide, while accelerating the discovery of scalable solutions to mitigate such impacts.

Rooted in Northwestern's renowned multidisciplinary team science culture, the program is designed to link experts from across the University in fields of materials science, chemistry, engineering, law, and public health to the complementary research of the program's targeted network of members from academic, civic, government, and industrial partner institutions.

Today, the world produces more plastic waste than ever, adding about 300 million additional tons per year — nearly equivalent to the weight of the entire human population.

"The scientific community recognizes the problem of plastic pollution, but more research must be done to understand how it moves through the environment and the extent of its impacts, and to discover deployable, cost-competitive solutions," said **John Torkelson**, Walter P. Murphy Professor of Chemical and Biological Engineering and Materials Science and Engineering at Northwestern Engineering. Torkelson is a program network member who has been working on the recyclability of plastics for two decades.

The new Program on Plastics, Ecosystems, and Public Health will bring together experts from across Northwestern to gain a scientific understanding of the impacts of plastics use and accumulation worldwide.

New Structured Map of Mixing Geometries

Connecting different ways of cutting and shuffling leads to new ways of thinking about the mathematics of mixing

To mix cream into coffee, you can take several different approaches, according to the principles of physics: let the cream diffuse throughout the coffee by itself, gently stir it, or put a lid on the cup and shake it up.

Engineers often think about mixing according to those three approaches (diffusion, chaotic advection, and turbulence). But another approach called cutting and shuffling — think of cutting a deck of cards and shuffling it — offers another way to think about mixing.

Northwestern Engineering researchers have studied the mathematics behind such mixing and have come up with a new conceptual map to show how this approach works in different dimensions. They also introduced the concept of time-continuous piecewise isometries, a mathematical concept describing the way that the cut pieces can be rearranged to reform the original domain.

Julio M. Ottino

"THIS IS A NEW WAY OF LOOKING AT THESE MIXING MATERIALS THAT COULD OPEN UP RESEARCH IN THE FIELD."

JULIO M. OTTINO

Their results, published in the journal *Physics Reports*, connects together years of research by the team about this new paradigm for mixing.

"This is a new way of looking at these mixing materials that could open up research in the field," said **Julio M. Ottino**, Walter P. Murphy Professor of Chemical and Biological Engineering, who coauthored the research.

CONNECTING BIOTECHNOLOGY STUDENTS WITH INDUSTRY LEADERS

MBP's spring trip to San Diego introduced students to Gilead Sciences, Illumina, and Catalent

When students enroll in Northwestern's Master of Biotechnology Program (MBP), many enter with no work experience and few connections to the pharmaceutical or biotechnology industries.

That is why the program emphasizes building connections with industry professionals.

Site visit trips, in particular, introduce students to potential career paths within the biotechnology field and highlight similarities and differences between companies and industries.

"The site visit trips are arranged to provide networking and educational opportunity for students," said **Natalie Champagne**, MBP assistant director of external relations and career management. "It is my hope that students will get a glimpse of how the industry works by participating in a site visit trip."

The MBP spring 2019 site visit trip in April took 18 students to San Diego, where they learned about and connected with professionals from Gilead Sciences, Illumina, and Catalent. Each company provided tours to the students as well as opportunities to talk with and hear from current employees and researchers.

"This trip gives students direct access to the labs of some of the most progressive companies in the biotechnology and pharmaceutical field," Champagne said.

MBP students visited Illumina during their spring 2019 industry site visit trip.

Ruojia Shi, one of the MBP students who traveled to San Diego, said that as an international student, the trip served as "a rare opportunity for me to go inside some top pharma companies in the United States and build my connections with industry insiders."

The San Diego trip was the fifth site visit trip for MBP students in the past three years. Previous MBP students connected with industry professionals in San Francisco, Boston, North Carolina, San Diego, and New Jersey.

Alumni Profile: Nick Ruggero

Alumnus uses systems thinking to tackle some of the world's biggest problems

Nick Ruggero

Alumnus **Nick Ruggero** ('10) is shooting for the stars.

As a hardware engineer for X, the "moonshot factory" at Alphabet Inc., Google's parent company, he works to create radical new technologies to solve some of the world's hardest challenges.

"X is a very dynamic place to work, and as part of my job, I closely interface with software and hardware engineers, scientists, mathematicians, artificial intelligence experts, and business and strategy people," Ruggero said.

It's those people that help Ruggero enjoy his job working on an early stage team focused on the intersection of life sciences and computation.

"The people are really one of the best parts of X," he said. "They are, in my opinion, some of the most amazing, hardworking, creative, crazy, talented, and fun people to be around. It makes it a pleasure to go to 'work.'"

Ruggero earned his bachelor's degree in chemical engineering from Northwestern Engineering. He then worked in research and development at a materials science startup before pursuing his PhD in chemical engineering at Stanford University where he focused on studying systems biology.

"An undergraduate degree in chemical engineering gives you a broad background in systems thinking," he said. "It makes you comfortable reasoning at different scales and coming at a problem from both a bottom-up and top-down approach."

Lucks Lab Startup Selected for Argonne's 'Chain Reaction Innovations' Entrepreneurship Program

Postdoctoral fellow Khalid Alam will further develop his startup, Stemloop, during the two-year program

Khalid Alam, a postdoctoral fellow in Professor **Julius Lucks**'s lab, was among five science and engineering entrepreneurs selected by Argonne National Laboratory for its Chain Reaction Innovations entrepreneurship program (CRI).

Khalid Alam

The two-year program, which started in June, will support Alam's efforts to further develop and scale proprietary technologies while also refining the business strategies behind his startup, Stemloop. In addition to dedicated laboratory and office space, he will have access to Argonne's significant R&D resources, an advisory network of business mentors, and networking opportunities with commercial partners and investors.

Alam led the development of the core technologies behind Stemloop while working in Lucks's lab. He and Lucks are cofounders of the startup, which is using advances in cell-free synthetic biology and molecular engineering to create new biosensing platforms.

Stemloop was born out of the Lucks Lab's research mission to understand how cellular systems sense and respond to their environments and how that capacity can be harnessed for new applications. The company is working toward commercializing a platform of technologies developed within the Lucks Lab and the ecosystem of Northwestern's Center for Synthetic Biology and Center for Water Research, including one focused on environmental water quality monitoring.

STEMLOOP

FACULTY NEWS

Michael Jewett was named a finalist for the 2019 Blavatnik National Awards for Young Scientists, one of 31 scientists and engineers recognized nationally this year and considered to be among America's most important young scientific researchers aged 42 years or younger.

Chad A. Mirkin received a 2019 Nakamura Award from the American Association for Advances in Functional Materials. He also earned the distinguished Harrison Howe Award from the Rochester Section of the American Chemical Society, recognizing scientists' outstanding contributions to chemistry.

Harold Kung received one of the Ten at Ten Awards from the US Department of Energy, recognizing two new electrode technologies for next-generation lithium-ion batteries developed based on research that was initiated in the Center for Electrochemical Energy Science.

Linsey Seitz was named a Scialog Fellow and will attend a program for early career rising stars interested in pursuing collaborative, high-risk, highly impactful discovery research on untested ideas applicable to creating breakthroughs in energy storage.

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Slowing Metabolic Rate Can Prevent Detrimental Effects of Genetic Mutations

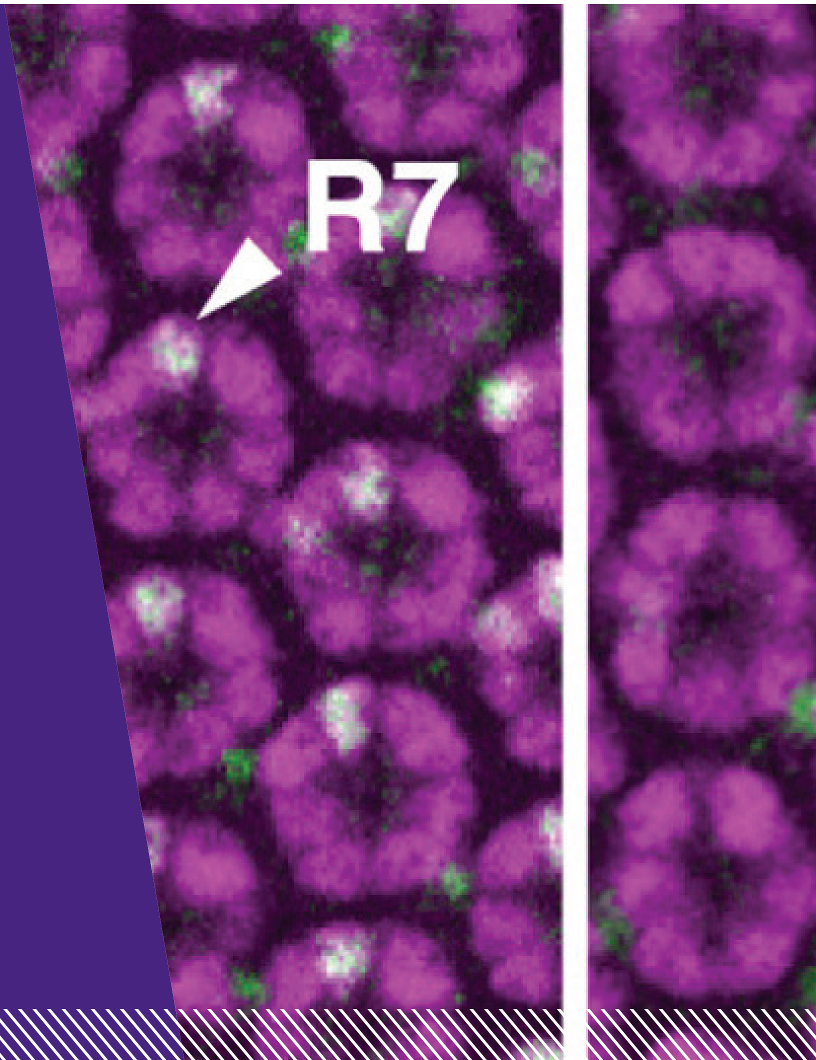
Just by slowing their metabolism, mutant fruit flies can go from zero to hero.

In a Northwestern University study, researchers slowed mutant fruit flies' metabolic rates by 50 percent, and the expected detrimental effects of many mutations never manifested. After experimentally testing fruit flies' many different genetic mutations, the researchers found the same result each time.

"This upends the paradigm of everything we know about development," said **Luís Amaral**, who led the computational research.

"We have always thought that if you 'break' some genes, there will be serious developmental consequences. It turns out that's not true for some genes — as long as you also slow the metabolism of the growing organism," he added.

The research could explain a number of factors, such as why factory-farmed chickens that are bred for hyper growth have more developmental problems or why caloric restriction is linked to longevity.



A common gene mutation damages R7 cells, which allow fruit flies to see ultraviolet light.