McCormick School of Engineering and Applied Science

NORTHWESTERN ENGINEERING

SPRING 2016

BETTER DESIGN THROUGH HUMANITY

HEAT-SENSING SCIENCE

Tito Fernández's LED array can sense when warm-bodied creatures are in its midst. Presented at the annual Design Expo and now on permanent display in The Garage, the device detects and mirrors heat radiating from objects within its field of view. This mimics the sensing ability of the black ghost knifefish, except using temperature gradients instead of electric gradients. A senior in mechanical engineering and manufacturing and design engineering, Fernández (not pictured) created the LED array in collaboration with Professor Malcolm MacIver, who studies the fish to learn how animal mechanics and sensory abilities fit together.

Photograph by Sally Ryan

"DESIGN INNOVATION EMPOWERS LEADERS TO DEVELOP MEANINGFUL SOLUTIONS, CREATE NEW VALUE, AND ENVISION NEW POSSIBILITIES. AT THE HIGHEST LEVEL, DESIGN UNLOCKS CREATIVITY AND THE ABILITY TO IMAGINE A NEW FUTURE."

GREETINGS FROM NORTHWESTERN ENGINEERING

Design is having a moment. The process of identifying a user's needs, prototyping and iterating ideas, observing user testing, and getting feedback has become a buzz-worthy approach across industries. One of our most prominent alumni, IBM CEO Virginia Rometty, was recently featured in a *New York Times* article on the company's new strategy. "Design thinking is at the center," she was quoted as saying.

At Northwestern Engineering, we have been teaching design thinking as an essential skill for 20 years. Design puts humans at the center of the process. What do users want? What do they need? What is the real problem behind the perceived problem?

It begins at the beginning with our first-year students: Every engineering student must enroll in Design Thinking and Communication, a two-quarter course in which they work in teams to design solutions for real clients. Many projects involve clients at the Rehabilitation Institute of Chicago. One patient, for example, needed a way for his walker-leg gliders to slide more easily. Another patient wanted a way to crochet with one hand.

These projects, and our design-thinking approach, were highlighted by *The Wall Street Journal* in February. The article underscored how these problems teach our students resiliency: how to observe the problem in action, brainstorm several solutions, prototype their ideas, conduct user testing, fail, reframe their approach, and try again.

I am pleased to feature our approach to design innovation in this issue of the magazine. Through the Segal Design Institute, we teach these skills across undergraduate and graduate programs, and, increasingly, across the University. Design innovation empowers leaders to develop meaningful solutions, create new value, and envision new possibilities. At the highest level, design unlocks creativity and the ability to imagine a new future.

Another skill our undergraduates are increasingly seeking is proficiency in computer science. Programming skills have become necessary in every field, and students from across Northwestern are taking computer science courses to prepare for a multitude of careers. Our Fundamentals of Computer Programming class enrolls students from nearly every school at the university and fills our biggest classroom. This is an area of increasing focus for us, and we will continue to revamp courses and broaden our offerings.

This issue also features ways our faculty are working toward energy sustainability. Sossina Haile, who we welcomed as a new materials science and engineering professor in 2015, is working to make liquid solar fuels a reality. Civil and environmental engineering professor Kimberly Gray's vision for a living city involves an entirely redesigned system that reimagines how energy, water, and information should flow. This issue shows this is an exciting time to be an engineer. I hope you agree.

As always, I welcome your feedback.

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

On the Cover

Students ideate content for an aviation experience design opportunity. See story, page 14. Photo by Sally Ryan.

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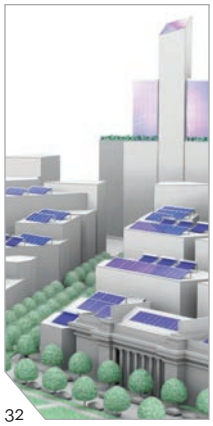
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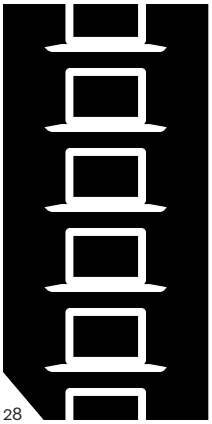
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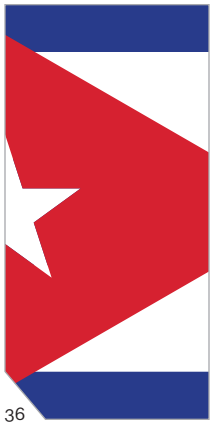
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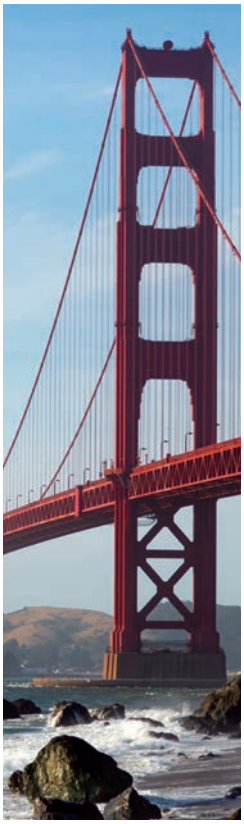
NORTHWESTERN ENGINEERING
SPRING 2016

NEWS



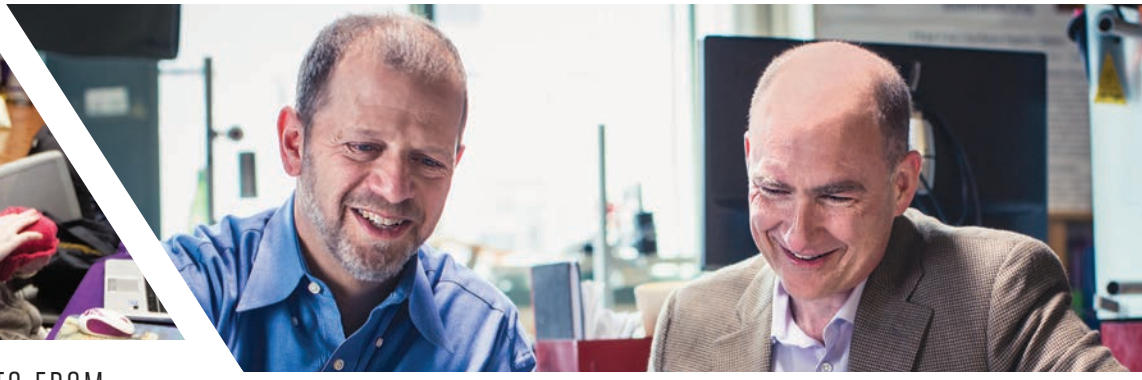
Northwestern Opens San Francisco Space

Northwestern is opening a new space in San Francisco to further enhance the University's leadership at the intersection of engineering, computer science, journalism, and integrated marketing communications.

Located in the heart of the Bay Area, Northwestern's newest educational space is anchored by Northwestern Engineering and the Medill School of Journalism, Media, Integrated Marketing Communications. Featuring a state-of-the-art presentation area, collaborative classrooms, and a flexible design studio, it will be used for quarter-long residencies, short immersion experiences, and events for alumni and collaborators.

Northwestern's westward expansion comes at a time of rapid change in the media and tech industries. The San Francisco programs will enable increasingly important collaboration between journalists and technology specialists in areas such as software development, digital design, and entrepreneurship where the interests of Medill and Northwestern Engineering intersect. The two schools already partner in the NUvention: Web+Media entrepreneurship class, in which students design, plan, and run web-based businesses, and in the Knight Lab, which builds technologies for publishers, journalists, and media consumers. Knight Lab technology has been used in Pulitzer Prize-winning stories in two of the last three years.

"THE MOST EXCITING AND UNEXPECTED BREAKTHROUGHS HAPPEN AT THE INTERSECTIONS BETWEEN DISCIPLINES." DEAN JULIO M. OTTINO



WILDHACKS DRAWS STUDENTS FROM ACROSS NORTH AMERICA

More than 450 college students from all over the United States and Canada converged on Northwestern's campus in November 2015 for the 24-hour WildHacks hackathon. The event challenged teams to create web, desktop, and mobile computer projects. Completely free of charge, the event was the University's largest intercollegiate hackathon to date.

At the end of the event, teams submitted their projects for scoring by the judges based on four criteria: originality, technicality, design, and usefulness. A team from the University of Illinois won first place and $2,000 with scavAR, a multi-player, augmented reality scavenger hunt.

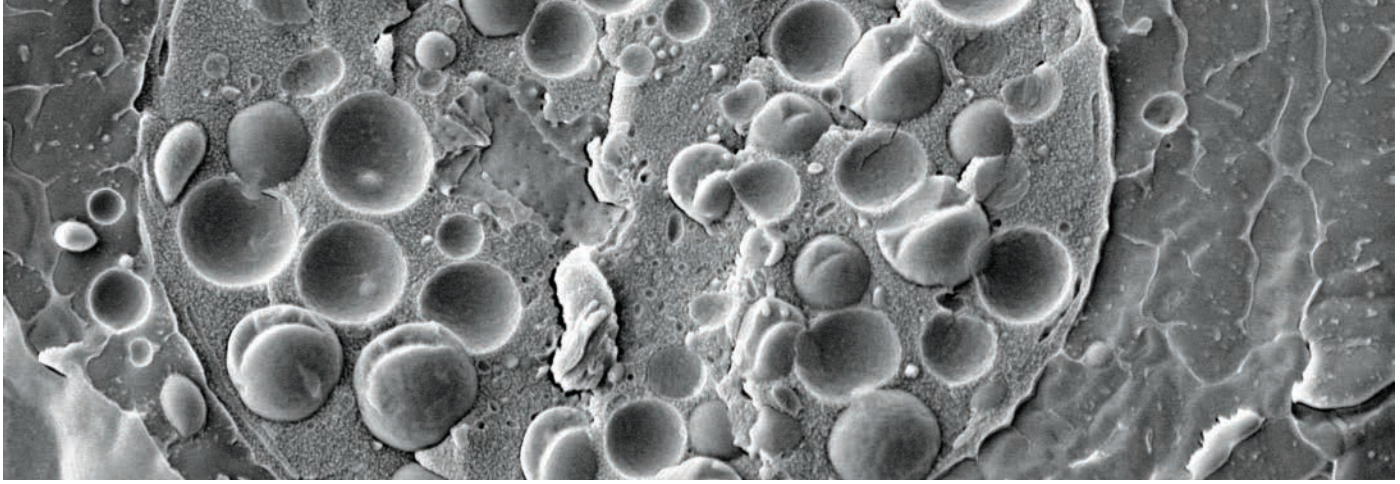
"WildHacks is a great example of what can result from student passion and effort," said Michael Marasco, director of the Farley Center for Entrepreneurship and Innovation.

THREE NORTHWESTERN STARTUPS RECEIVE INNOVATION AWARDS

Tanvas, AMPY, and Coapt were among the 24 enterprises honored at this year's Chicago Innovation Awards. All three have Northwestern Engineering ties.

Tanvas, which allows users to feel textures on flat, glass touchscreens, and AMPY, a wearable device that transforms kinetic energy into battery power, received two of the ten "Up-and-Comer" Awards. Coapt received the competition's sole Collaboration Award for its new technology that enables prosthetics to perform complex and natural motions.

The Chicago Innovation Awards program recognizes the most innovative new products or services brought to market or public service in the Chicago region. Winners are invited to ring the NASDAQ closing bell in New York.



Northwestern Receives $5 Million for Nanoscale Research

Northwestern received a five-year, $5 million grant from the National Science Foundation to establish, in collaboration with the University of Chicago, a new national resource to provide academic, small business, and industry researchers access to cutting-edge nanotechnology facilities and expertise.

The Soft and Hybrid Nanotechnology Experimental (SHyNE) Resource ensures the integration of biological nanostructures with the backbone of hard materials, for applications such as microfluidic molecules for biosensors and synthetic scaffolds for tissue regeneration, among others.

"SHyNE Resource streamlines our nanotechnology facilities, providing unique and integrated capabilities for internal Northwestern and University of Chicago researchers as well as external users, especially small and medium enterprises and startup companies," said Professor Vinayak P. Dravid, SHyNE director. "This award further cements our leadership in nanotechnology and related advanced materials research, education, and outreach."

The new resource deepens existing collaborations and is expected to draw a variety of researchers from the Chicago area, the greater Midwest, and nationally. SHyNE also offers regional colleges and public institutions, including museums, the opportunity to access research and training instrumentation under one umbrella.

SHyNE is one of 16 user-facility sites nationwide that the National Science Foundation is funding with $81 million of support as part of a new National Nanotechnology Coordinated Infrastructure.

200

Students who interviewed with companies for internships and jobs at the annual McCormick Interview Day on Jan. 29

HOWARD TULLMAN PREDICTS TECH TRENDS

In January 2016, serial entrepreneur and CEO of startup hub 1871 Howard Tullman addressed wide-ranging technology trends of the future before a packed audience at the Dean's Seminar Series. He predicts that the world will see more products and services that save time, are customized, mine personal data, leverage the sharing economy, and treat attention as currency.

The Wall Street Journal Highlights Design Thinking and Communication

In the Segal Design Institute's Design Thinking and Communication (DTC) course, student teams take on design challenges that have been submitted by real clients and that have no correct answers. The February 24 edition of *The Wall Street Journal* highlighted how those projects lay the foundation for future success in engineering.

The article showcased some of the most recent DTC projects that students tackled on behalf of patients at the Rehabilitation Institute of Chicago. By working with clients directly, teams experience first-hand the challenge of empathizing with their client's unique needs, managing team dynamics, and in some cases, realizing the need to start over. In doing so, students learn valuable lessons in teamwork, resiliency, and creativity.

"It's obviously not a good feeling when people say 'no, I really don't like this idea,'" said Robert Bell, a DTC student. "At the same time, I feel like our entire group was pretty good at overcoming those kinds of setbacks ... we just moved forward with a different part of our plan."

"IT WAS ONLY WHEN WE PUT ON OUR DESIGNER HATS AND REALLY DOVE INTO THE WORLD OF LAUNDRY THAT WE WERE ABLE TO PIN-POINT PROBLEMS WE COULD SOLVE."

KRISTINE OAK EDI STUDENT

EDI Class Helps Reimagine Laundry

Students in the Engineering Design and Innovation (EDI) program recently worked with Procter & Gamble to help design Tide Spin, an app-based service that outsources the mundane chore of doing laundry to professional cleaners at Tide laundry facilities.

Two student teams used human-centered design to evaluate the process through which consumers could schedule a time for their laundry to be picked up and then washed and returned. The teams observed people doing their laundry, interviewed potential users, studied the interpersonal dynamics of people doing others' laundry, prototyped potential environments, and tested logistics.

In the end, the teams recommended a professional business model. The first laundry service backed by a national brand, Tide Spin sends the laundry to its own facilities staffed by Tide-trained professionals.

24

Students who will go to San Francisco this winter for the new Bay Area Immersion Experience

275

Girls who participated in the annual Career Day for Girls at Northwestern Engineering

DATA AS ART SHOWCASES COLLABORATIVE PROJECTS

This fall, for the third year in a row, artists and engineers teamed up in Data as Art, a collaborative class that brings together students from Northwestern and the School of the Art Institute of Chicago to fuse analytics and aesthetics by representing data sets through visual arts. The overarching goal is to have artists and engineers work together, sharing thought patterns, cultures, and work styles.

Projects used data from the Addgene database, a plasmid repository, and drew on information from Chicago transportation, crime, education, income, and Superfund sites to create visualizations and soundscapes. One project, called The Moving Class, visualized the movements of people from different socioeconomic statuses and their transportation methods within the city.

ETOPiA PLAY EXAMINES GALILEO'S CONTROVERSIAL LIFE

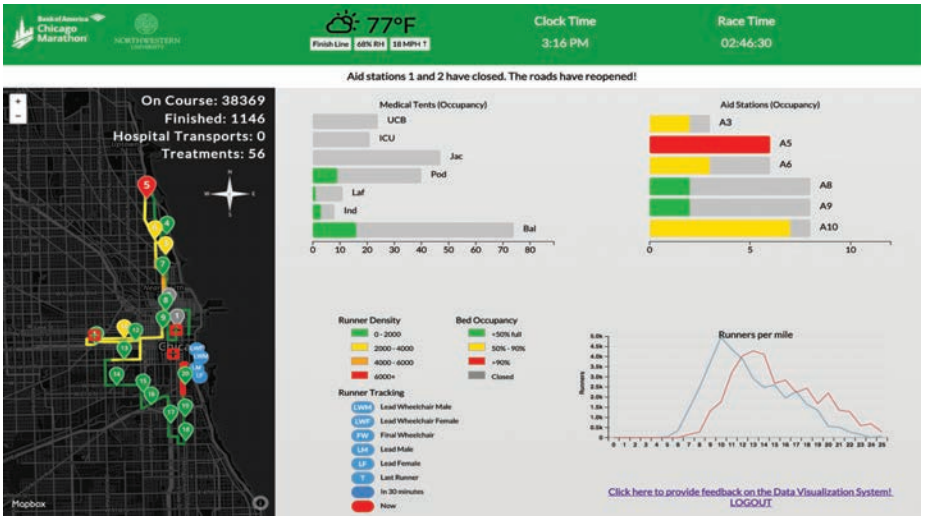
When scientist Galileo Galilei created the first telescope, he opened the world's eyes to a universe of planets, moons, and stars, which led to a new view that threatened long-held tenets of the Roman Catholic Church. The eighth season of ETOPiA presented Bertolt Brecht's *A Life of Galileo*, a play examining the struggles and controversy between evolving scientific knowledge and conservative social norms. ETOPiA: Engineering Transdisciplinary Outreach Project in the Arts inspires dialogue about the roles of science and technology in society.

5

US Science Envoys announced this year, which include Mark Hersam

GRADUATE STUDENTS CELEBRATE COMMENCEMENT

Northwestern Engineering recognized 167 master's degree students and 13 PhD students during its December commencement ceremony. Held in the Technological Institute's Ryan Family Auditorium, the ceremony featured speaker William White ('61), professor of industrial engineering and management sciences and former CEO and chairman of the board at Bell & Howell.



"Working together as a team, we have developed a dashboard that has all the important data in one place, enabling information-based decision making."

KAREN SMILOWITZ
PROFESSOR OF INDUSTRIAL ENGINEERING AND MANAGEMENT SCIENCES

ENGINEERS GIVE TECHNOLOGY ASSIST TO BANK OF AMERICA CHICAGO MARATHON

In October 2015, a Northwestern and Chicago Marathon research team used big data—both historic and real-time—to supply a comprehensive picture of the Bank of America Chicago Marathon as the race unfolded.

Logistics expert and professor Karen Smilowitz and her team of four engineering students custom-designed a new data visualization system that provided a computer simulation of the 26.2-mile race, forecasting where large concentrations of participants would be 20 minutes later and helping race officials plan accordingly.

Two large, one-stop "dashboards" in the busy forward command tent simultaneously displayed the race simulation and important course conditions onscreen: location of lead runners, runner density on the course, medical tent and aid station capacity, current temperature, any issues on the course, and much more.

NORTHWESTERN ENGINEERS FEATURED AMONG *FORBES*' "30 UNDER 30" LIST

Forbes' annual "30 Under 30" series recognizes the year's best and brightest under-30-year-olds from across 20 categories. Selected from a pool of 15,000 candidates, the 2016 list included two members of the Northwestern Engineering community: Cary Hayner and Anoop Jain.

A PhD candidate in chemical and biological engineering, Hayner was recognized as cofounder of SiNode Systems, a startup that is building faster-charging, longer-lasting batteries through the development of silicon-graphene composites. Jain ('09) earned a spot on the list for his work as founding director of Sanitation and Health Rights in India, which builds energy efficient toilet facilities in Indian communities.

GRADUATE WINS SECOND PLACE IN ACM STUDENT RESEARCH COMPETITION

Recent graduate Leesha Maliakal's research poster beat out 117 other contenders to take second place in the Association for Computing Machinery (ACM) Student Research Competition. Her project, CrowdCheer, studied the effects of crowd-sourced and targeted motivation for marathon runners in an attempt to understand how to leverage existing crowds to improve runners' performances. Her work sprung from Professor Haoqi Zhang's Social Computing and Crowdsourcing class and continued in Zhang's undergraduate research group.

SENIOR MAGDALENA OLEWINSKA NAMED CO-OP STUDENT OF THE YEAR

Computer engineering senior Magdalena Olewinska was selected as Northwestern Engineering's 2016 Walter P. Murphy Cooperative Engineering Education Student of the Year. Olewinska completed her co-op with Siemens Medical Solutions, Inc., where she joined a diverse team of engineers on the embedded systems software team. Specifically, she worked on the motion control of molecular imaging cameras and contributed to multiple projects as well as community service at Siemens. She will join the embedded systems software team full-time after graduation.

LAB NOTES

"TYPICAL SULFUR CONCRETE USES SAND, WHICH IS INERT. IT'S JUST FILLER. IN OUR MARTIAN CONCRETE, THE SULFUR IS NOT JUST GLUE. IT REACTS WITH THE MINERALS IN THE MARTIAN SOIL. THAT COMPLETELY CHANGES THE PICTURE."

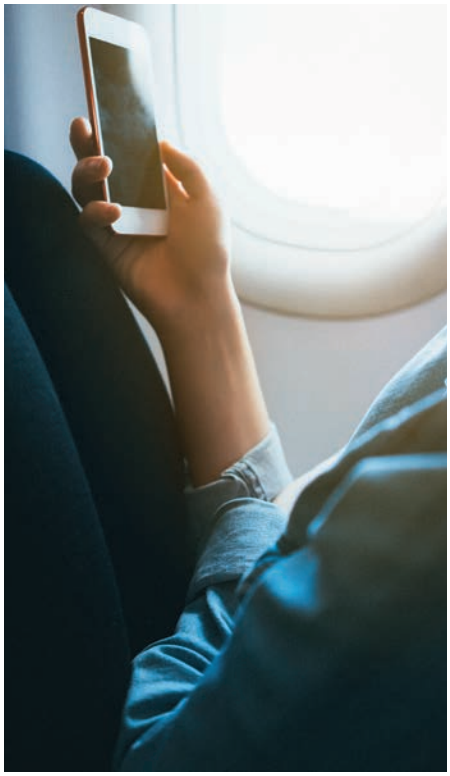
GIANLUCA CUSATIS ASSOCIATE PROFESSOR OF CIVIL AND ENVIRONMENTAL ENGINEERING

BUILDING CONCRETE SHELTERS ON MARS

Professor Gianluca Cusatis and his team have developed a Martian concrete using materials naturally found on the Red Planet. This high-strength concrete, which can be created quickly, is durable enough to withstand meteorite impacts—key to creating viable shelters for humans.

Usually, concrete is made of gravel, cement, and water. Cusatis, however, used a different approach. Instead of gravel, he used a Martian soil simulant created by NASA, and instead of water, he used molten sulfur, which is abundant on Mars.

After testing his concrete's mechanical properties, Cusatis found that it was more than two times stronger than other sulfur-based concretes. In fact, after adjusting for gravity on Mars, the material's strength is equivalent to that of concrete used to build skyscrapers on Earth.



Why Does Inflight Wi-Fi Perform So Poorly?

While the idea of inflight Wi-Fi has grown popular quite quickly, complaints about the quality of the service have also mounted. To probe this issue, Professor Fabián Bustamante's team built Wi-Fly, an application to measure inflight Internet connectivity. Using the app, they found that inflight Wi-Fi is, in fact, slower than using a dial-up modem.

To help crowdsource data to gain a deeper understanding of customers' primary problems and potential solutions, the team is encouraging others to use its app during flights. You can participate during your next flight by visiting wifly.aqualab.cs.northwestern.edu.

$500,000

Top prize won at the Clean Energy Trust Challenge by Hazel Technologies, a student startup

$10 MILLION

Amount of the new N.XT fund for Northwestern faculty and students to support early-stage innovations

Detecting Hidden Malicious Ads in Apps

Most people are accustomed to seeing ads while using apps on their mobile devices. Some pop up during games; others sit quietly in the sidebars. Mostly harmless, ads generate income for developers, who often offer their apps for free. But as smartphone use grows, the number of malicious ads hidden in apps is also increasing—tripling in just the past year.

To curb attacks from hidden malicious ads, Professor Yan Chen and his team are working to better understand where these ads originate and how they operate. Their research has resulted in a dynamic system for Android that detects malicious ads and locates and identifies the parties that intentionally or unintentionally allow them to reach the end user.

In 2015, Chen's team tested about one million apps in two months and found that while the percentage of malicious ads is actually quite small (0.1 percent), the absolute number is still large considering that two billion people own smartphones.

Ad networks could potentially use Chen's system to prevent malicious ads from sneaking into the ad exchange. Ad networks buy space in the app through developers, and then advertisers bid for that space to display their ads. Ad networks use sophisticated algorithms for targeting and inventory management, but have no tools available to check the safety of each ad.

"It's very hard for the ad networks," Chen said. "They get millions of ads from different sources. Even if they had the resources to check each ad, those ads could change."

"NO MATTER WHAT APP YOU USE, YOU ARE NOT IMMUNE TO MALICIOUS ADS."

YAN CHEN PROFESSOR OF COMPUTER SCIENCE

USING FM TO IMPROVE WIRELESS NETWORK PERFORMANCE

How much can your neighbor's Internet network interfere with the speed and performance of yours? You may be surprised. Unless a home is located in the middle of nowhere, it's likely neighboring homes' Wi-Fi networks will bump into each other and prevent data from getting through. This is particularly true in large, urban apartment buildings where many people reside within a smaller area.

Professor Aleksandar Kuzmanovic and his PhD students have found that problems caused by competing networks can be mitigated by using an already existing, extremely cheap medium: FM radio. Because wireless networks are completely separate from each other, they have no way to communicate. The team developed a communication technique to fix this problem.

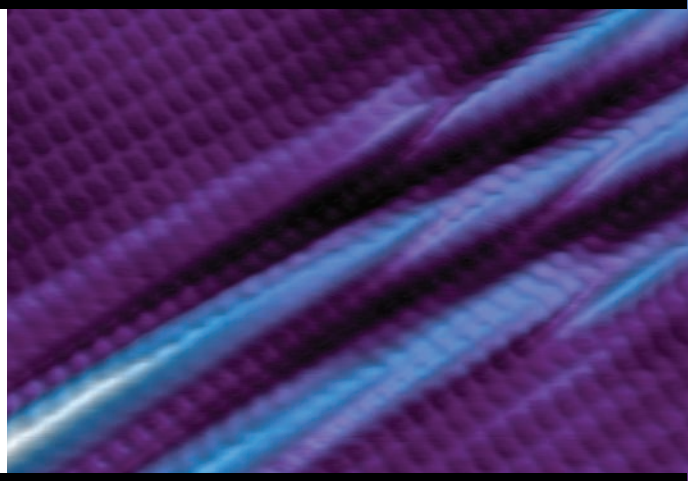
Called "Wi-FM," the new technique enables existing wireless networks to communicate through ambient FM radio signals, preventing one person's network data from fighting with a neighbor's data. When network data are sent at the same time, they bump into each other. Then both data packets back off and stop moving toward their destinations. This is what causes those unexpectedly slow Internet speeds. Wi-FM works by allowing a device to "listen" to the network and select the quietest time slots according to FM radio signals.

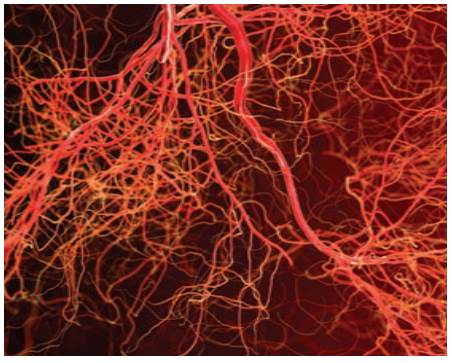
Engineering Touch

Because touch involves a complicated chorus of sensors, skin, muscles, and the nervous system, incorporating touch into modern electronics and robotics has proven difficult. Now, engineers and scientists in the Neuroscience and Robotics Lab have taken up the challenge. One group builds technology that produces tactile feedback through forces and vibrations, making flat touchscreens feel bumpy and textured. Another is working to give robots the same manipulation skills as humans. Watch a video about their work at bit.ly/robotictouch.

Scientists Create Atomically Thin Metallic Boron

A team of scientists from Northwestern Engineering, Argonne National Laboratory, and Stony Brook University created the first two-dimensional sheet of boron—a material known as borophene. This new material differs from three-dimensional boron, which is nonmetallic and semiconducting, because it shows many metallic properties at the nanoscale. The researchers, including Professor Mark Hersam, found that borophene has unusual ridges that look like corrugated cardboard and a higher tensile strength than any other known material.



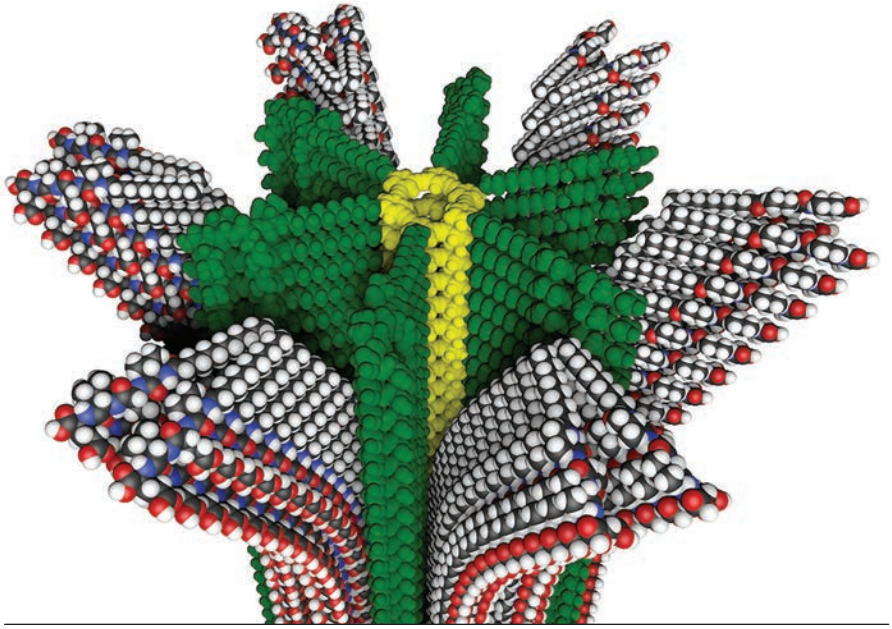


NEW MATERIAL WITH BUILT-IN VITAMIN A MAY REDUCE SCARRING

While scarring is a natural part of the healing process, scar formation within blood vessels after surgery can block blood flow to a dangerous degree. To prevent such complications, Professor Guillermo Ameer developed a new biodegradable material with built-in vitamin A, which has been shown to reduce scarring. The soft elastic material can be used to treat injured vessels or to make medical devices, such as stents, with intrinsic healing properties.

316

Coral sites represented in a new coral bleaching response index created by Northwestern researchers



"WE HAVE CREATED A SURPRISING NEW POLYMER WITH NANO-SIZED COMPARTMENTS THAT CAN BE REMOVED AND CHEMICALLY REGENERATED MULTIPLE TIMES."

SAMUEL I. STUPP BOARD OF TRUSTEES PROFESSOR

RESEARCHERS DEVELOP NEW HYBRID POLYMER

Led by Professor Samuel Stupp, Northwestern scientists created a completely new hybrid polymer that could lead to new concepts in self-repairing materials, drug delivery, and artificial muscles. The polymer has both rigid and soft nano-sized compartments that have extremely different properties and are organized in specific ways. These compartments can break off to deliver something to an environment and then chemically regenerate to function again.

The hybrid polymer works by cleverly combining two types of known polymers: those formed with strong covalent bonds and those formed with weak non-covalent bonds. "We can create active or responsive materials not known previously by taking advantage of the compartments with weak non-covalent bonds, which should be highly dynamic, like living things," Stupp said.

"WE'RE TALKING ABOUT A DIFFERENCE SO SMALL THAT IT'S INCREDIBLE THAT PEOPLE CAN EVEN THINK ABOUT MEASURING IT NOW."

SELIM SHAHRIAR

PROFESSOR OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Shahriar Participates in Discovering Gravitational Waves

At 5:51 a.m. Eastern Daylight Time on September 14, 2015, two L-shaped antennae located on opposite sides of the United States blipped out of place. The displacement lasted just 0.2 seconds and moved a distance that is 1,000 times smaller than a proton. But this tiny event carried an enormous amount of information about the birth and nature of the universe. The event confirmed the existence of gravitational waves, a major prediction of Albert Einstein's 1915 theory of general relativity.

Professor Selim Shahriar took part in the team that measured the displacement. He leads the experimental portion of Northwestern's chapter of the LIGO (Laser Interferometer Gravitational-Wave Observatory) Scientific Collaboration, the international consortium that made the groundbreaking discovery.

Shahriar searches for ways to improve the sensitivity of the LIGO detectors and broaden the spectrum over which the detectors are sensitive. His group has identified a technique that improves sensitivity by a factor of nearly 20; a tweak could allow the instrument to probe a volume that is about 8,000 times larger than now possible.

Previously, astronomers could only explore the universe using light. Detecting gravitational waves provides another tool for astronomical exploration, which could potentially reveal what happened within the very moments that the universe was born.

DOPING POWERS NEW THERMOELECTRIC MATERIAL

In the production of electrical power, nearly two-thirds of energy input from fossil fuels is wasted as heat. Industry is hungry for materials that can convert this heat to useful electricity. Finding a good thermoelectric material is the challenge.

Professor Christopher Wolverton calculated the electronic structure of tin selenide, finding that the electrical properties could be improved by adding a doping material. A team, including Professors Vinayak Dravid and Jeffrey Snyder, found that doping tin selenide with sodium boosts its performance as a thermoelectric material, pushing it toward usefulness. The doped material produces a significantly greater amount of electricity than the un-doped material, given the same amount of heat input.

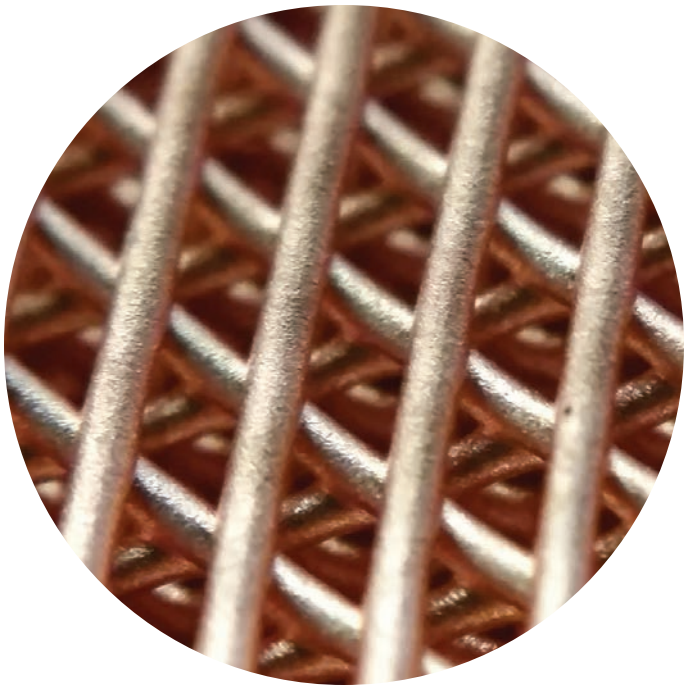
2.5 MILLION

People worldwide on dialysis who could benefit from MATUBand, a device from NUvention: Medical that allows doctors to control patients' blood flow

GRAPHENE BALLS IMPROVE OIL'S PERFORMANCE

Researches have long sought for additives to enhance oil's ability to reduce friction between automotive gears. Professors Jiaxing Huang, Yip-Wah Chung, and Q. Jane Wang discovered a top contender: graphene balls. In a series of tests, oil modified with crumpled graphene balls outperformed commercial lubricants by 15 percent in reducing friction and the degree of wear on steel surfaces.

Huang discovered crumpled graphene balls about five years ago. He made this novel type of ultrafine particle by drying tiny water droplets with graphene-based sheets inside. Their crumpled, irregular shapes make them self-disperse well in oil.



Cheaper, Faster Way to Print 3-D Metals and Alloys

Professors Ramille Shah and David Dunand have created a new way to print three-dimensional metallic objects using rust and metal powders. Instead of relying on vast metal powder beds and expensive lasers or electron beams, their new technique uses liquid inks and common furnaces, resulting in a cheaper, faster, and more uniform process. The researchers have also demonstrated that the new method works for an extensive variety of metals, metal mixtures, alloys, and metal oxides and compounds.

Their unique 3-D inks and process open doors for architectures that are more sophisticated and uniform, faster to create, and easier to scale up. The new method could be used for printing batteries, solid-oxide fuel cells, medical implants, and mechanical parts for larger structures, such as rockets and airplanes. It could also be used for on-site manufacturing that bypasses the sometimes slow-moving supply chain.

NEW SLANT ON SEMICONDUCTOR CHARACTERIZATION

With so many applications for semiconductor materials, it's important to characterize them carefully and accurately. Otherwise, computer chips could fail and lasers burn out. Professor Matthew Grayson's research team has created a new mathematical method that makes semiconductor characterization more efficient, more precise, and simple.

"Up until now, everyone would take separate pieces of the material, measure each piece, and compare differences to quantify non-uniformity," Grayson said. "That means you need more time to make several different measurements and extra material dedicated for diagnostics."

By flipping the magnetic field and repeating one measurement, Grayson's method quantifies whether or not electrical conductivity is uniform across the entire material—a quality required for high-performance semiconductors.

2,000

Age of the mummy portraits that Northwestern scientist Marc Walton studied to understand ancient pigments

NEWLY DEVELOPED MICROFLUIDIC DEVICE SORTS STEM CELLS

Professors Horacio Espinosa and Cheng Sun developed a microfluidic device that could lead to a better understanding of how stem cells function and bring the world one step closer to fighting debilitating neurological diseases. The new tool sorts neural stem cell populations, making them easier to study.

As fluid containing the neural stem cells flows through the spiral-shaped device, inertial forces arrange and sort the cells by size, with smaller cells moving toward the inner wall of the device while the larger clusters move toward the middle.

ENGINEERING FLOW IN MUSIC PRODUCTION

Professor Bryan Pardo and his Interactive Audio Lab researchers are replacing today's complicated, hard-to-use interfaces in audio production software with easy-to-understand interfaces crowd-sourced from the public.

Tools from his lab include Reverbalize, a reverberation tool with a control interface that employs a word map of regular terms that people use to describe reverberation, and SocialEQ, an equalizer that lets users achieve a desired effect by listening to the sound and rating alternatives. Watch a video to learn more about his work at bit.ly/engineeringflow.

Mark Hersam

Chad Mirkin

Lee Miller

Brenna Argall

Samuel Stupp

Todd Murphey

Bruce Wessels

Richard Van Duyne

Elizabeth Gerber

James Rondinelli

Todd Kuiken

Bruce Lindvall

Faculty Awards

MARK HERSAM NAMED US SCIENCE ENVOY

One of five scientists to receive this year's honor from the US Department of State, Hersam will focus on emerging technologies in Eastern Europe.

BRENNA ARGALL RECEIVES FACULTY EARLY CAREER DEVELOPMENT (CAREER) AWARD

The five-year, $525,000 National Science Foundation grant will help Argall develop autonomous devices for people with disabilities.

BRUCE WESSELS RECEIVES TMS FELLOW AWARD

The Minerals, Metals, and Materials Society recognized Wessels with its highest award for his seminal contributions to the field.

TWO AWARDS FOR JAMES RONDINELLI

Rondinelli received the National Science Foundation's Presidential Early Career Award for Scientists and Engineers and a prestigious Sloan Research Fellowship.

CHAD MIRKIN RECEIVES PRESTIGIOUS INTERNATIONAL DAN DAVID PRIZE

Mirkin was recognized for his groundbreaking research coupling human DNA and nanotechnology.

FIVE NAMED ELITE MEDICAL AND BIOLOGICAL ENGINEERING FELLOWS

Chad Mirkin, Samuel Stupp, Richard Van Duyne, Todd Kuiken, and Lee Miller were named to the American Institute for Medical and Biological Engineering's College of Fellows for their contributions in teaching, research, and innovation.

FACULTY RECEIVE 2015 COLE-HIGGINS AWARDS

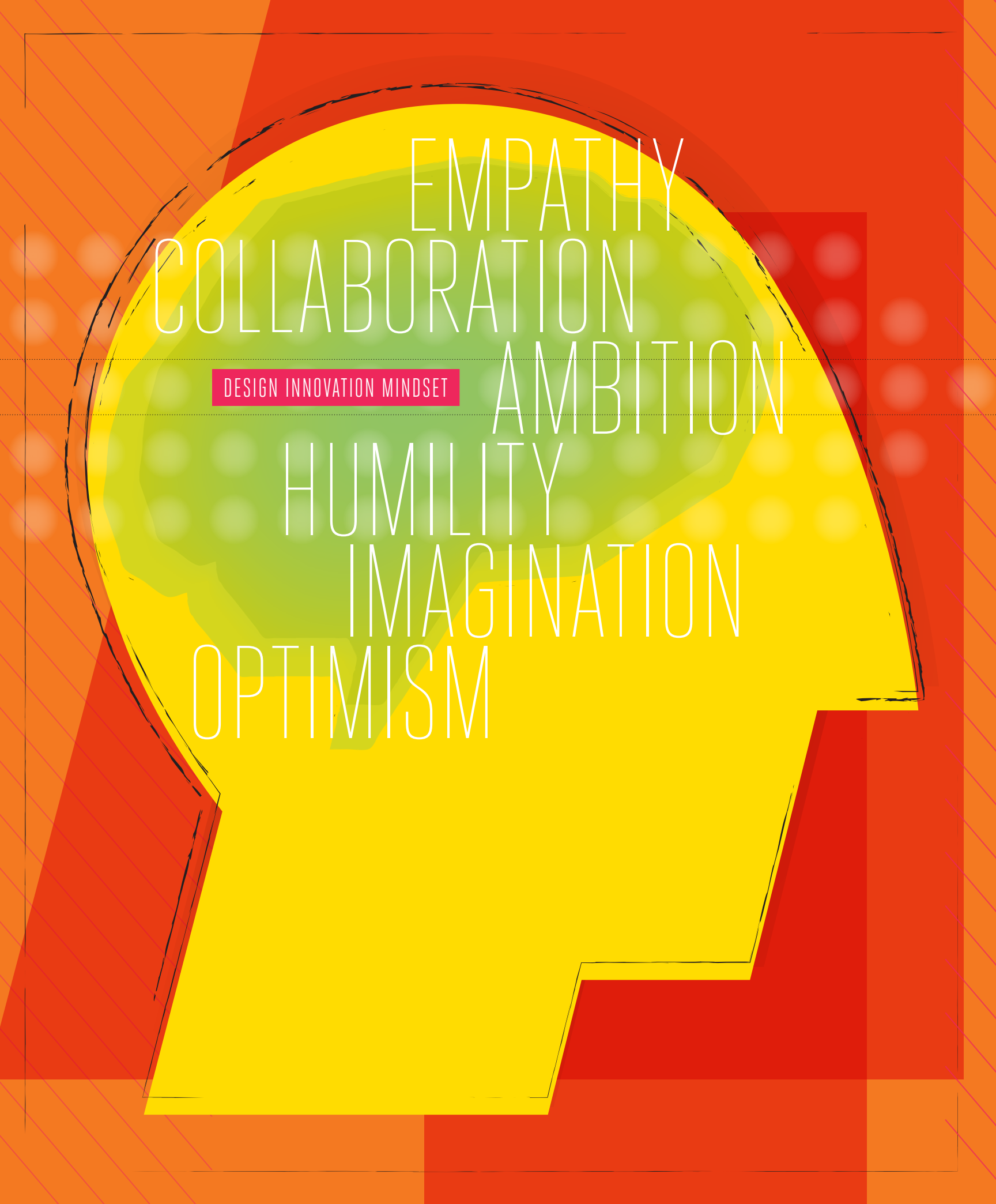
Northwestern Engineering recognized Todd Murphey with the Cole-Higgins Award for Excellence in Teaching and Igal Szleifer with the Cole-Higgins Award for Excellence in Advising.

ELIZABETH GERBER RECEIVES WELLS FARGO FOUNDATION AWARD

Gerber received a grant as part of the award to use toward developing a scalable, open-source innovation curriculum.

BRUCE LINDVALL RECEIVES SERVICE AWARD

Assistant Dean Lindvall received the Penny Warren Honorary Service Award from Northwestern's Black Graduate Student Association.


EMPATHY
COLLABORATION
AMBITION
DESIGN INNOVATION MINDSET
HUMILITY
IMAGINATION
OPTIMISM

BETTER DESIGN THROUGH HUMANITY

EQUIPPED WITH A DESIGN INNOVATION MINDSET AND TOOLBOX, NORTHWESTERN STUDENTS LEAVE READY TO CONFRONT SOCIETY'S PRESSING PROBLEMS.

NOW THAT THE WORLD IS DEEP INTO THE DATA AGE, it can seem as if "the numbers" have replaced once highly valuable human qualities. When trying to solve some of the world's biggest problems, people tend to consult the numbers rather than the most affected people.

Northwestern engineers believe they can harness some of the non-quantifiable qualities—LIKE EMPATHY AND DEEP HUMAN UNDERSTANDING—to solve seemingly unsolvable problems. Not only can this HUMAN-CENTERED APPROACH identify the underlying issues with the greatest impact and meaning, IT CAN ALSO PRODUCE FAST, THOROUGH, TRANSFORMATIVE SOLUTIONS THAT HAVE THE POWER TO CHANGE LIVES.

WHAT WOULD HAPPEN IF WE PUT HUMANS BACK INTO THE FOREGROUND?

THIS CONCEPT IS CALLED **DESIGN INNOVATION.**

AND AT NORTHWESTERN, IT'S BOOMING.

For the past 20 years, Northwestern students have learned design innovation skills to uncover richer insights that lead to more meaningful products, services, and systems.

"WE ARE COUPLING THE WORD **'DESIGN' WITH 'INNOVATION'** BECAUSE WE ARE SEEKING TO INNOVATE IN A VARIETY OF SPACES. BUT WE'RE USING DESIGN-CENTRIC TOOLS BOTH **TO FIND** AND **TO FRAME THE PROBLEM** AND **IDEATE** AND **ITERATE** SOLUTIONS."

GREG HOLDERFIELD Director of the Segal Design Institute

Ironically, as an approach to solving big problems, design innovation appears **smaller**, **more personalized**, **more specific**,

MORE HUMAN.

WHAT IS DESIGN INNOVATION?

DESIGN INNOVATION CREATES VALUE USING DESIGN-CENTRIC TOOLS AND FRAMEWORKS, SUCH AS

EMPATHY, VISUALIZATION, PROTOTYPING, AND **ITERATION.**

By acquiring design innovation skills, students are prepared to **find and frame problems**, **identify opportunities**, and **innovate across a variety of spaces**.

THEY ARE READY TO BRING THEIR IDEAS TO LIFE.

The results of design innovation benefit all stakeholders. The end goal does not have to be a product.

It can be a **service**, **system**, **business plan**, or **experience**.

"**Innovation is creativity that is implemented**," says ELIZABETH GERBER, associate professor of mechanical engineering and director of the Segal Design Cluster. "**It could just impact one person's life. It could impact a thousand people's lives. But it must influence what we do and how we experience our lives**."

DESIGN INNOVATION REQUIRES A TYPE OF THINKING THAT IS **TRULY WHOLE-BRAIN**. Innovators must augment their analytical thinking with creativity, which results in a human-centered, holistic perspective.

DESIGN RESEARCH

FOR DESIGN INNOVATION TO WORK,

THE DESIGNER MUST UNDERSTAND THE USERS IN THE CONTEXT OF THEIR EVERYDAY LIVES, WHICH HELPS SHED LIGHT ON OFTEN UNARTICULATED NEEDS.

ELIZABETH GERBER says,

"WE WANT TO KNOW WHAT KEEPS OUR USERS UP AT NIGHT AND WHAT GETS THEM UP IN THE MORNING."

FINDING THAT ANSWER REQUIRES **A VERY DIFFERENT METHOD** THAN OTHER TYPES OF RESEARCH.

1. DESIGN RESEARCH OFTEN RELIES ON SMALL SAMPLE SIZES
2. IT DOESN'T JUST ASK WHAT, IT ASKS WHY
3. IT REQUIRES UNDERSTANDING AND LEARNING, NOT PROVING OR JUSTIFYING

"WE ARE NOT ASSERTING THAT DESIGN RESEARCH IS BETTER THAN OTHER TYPES OF RESEARCH. ALL TYPES SERVE DIFFERENT PURPOSES, AND THEY OFTEN ALL COME TOGETHER TO INFORM DECISION MAKING." **GREG HOLDERFIELD** Director of the Segal Design Institute

A HISTORY OF INNOVATION

It all started in 1997 when the singular first-year class now called Design Thinking and Communication (DTC) debuted. Now a cornerstone of the Northwestern Engineering experience, DTC, co-taught by faculty from the Cook Family Writing Program, challenges students to use design thinking to attack potentially unsolvable problems.

The Segal Design Institute was founded in 2007 and initially offered a small, engineering-focused curriculum. Now design innovation has exploded to include a wide variety of programs, course offerings, degrees, and students from eight schools across Northwestern University.

Segal Design Institute Degree Programs

- **BACHELOR OF SCIENCE IN MANUFACTURING AND DESIGN ENGINEERING (MADE)** FOCUSES ON PROCESS AND PRODUCT DESIGN AS WELL AS MANUFACTURING SYSTEMS AND MANAGEMENT.
- **SEGAL DESIGN CERTIFICATE** OFFERS UNDERGRADUATES THE OPPORTUNITY TO BUILD DESIGN KNOWLEDGE AND SKILLS.
- **MASTER OF SCIENCE IN ENGINEERING DESIGN AND INNOVATION (EDI)**, A FULL-TIME GRADUATE PROGRAM, TEACHES ENGINEERS HOW TO ADDRESS DESIGN PROBLEMS USING A HUMAN-CENTERED APPROACH.
- **MASTER OF PRODUCT DESIGN AND DEVELOPMENT MANAGEMENT (MPD2)** TEACHES PRACTICING PROFESSIONALS THE CONCEPTS AND TOOLS OF PRODUCT DESIGN AND DEVELOPMENT.
- **MMM PROGRAM**, A DUAL-DEGREE PROGRAM AT THE INTERSECTION OF BUSINESS, TECH, AND DESIGN INNOVATION WHERE STUDENTS EARN AN MBA AND AN MS IN DESIGN INNOVATION.
- **PHD IN THE DESIGN CLUSTER** OFFERS AN INTERDISCIPLINARY PROGRAM WHERE STUDENTS PRACTICE AND RESEARCH THE PRINCIPLES AND TECHNIQUES OF DESIGN.

MINDSET. PROCESS. TOOLS.

NORTHWESTERN ENGINEERING TAKES A THREEFOLD APPROACH TO TEACHING DESIGN INNOVATION:

1 **ESTABLISH A MINDSET**

2 **FOLLOW A PROCESS**

3 **DEVELOP A TOOLBOX**

"THERE ARE A LOT OF SUBJECTS THAT I COULD READ ABOUT IN A BOOK AND UNDERSTAND MOST OF THE CONTENT. BUT I CAN'T JUST PICK UP A BOOK AND UNDERSTAND DESIGN INNOVATION. THAT'S THE REASON I'M HERE. AND THAT'S WHY NORTHWESTERN ENGINEERING'S HANDS-ON APPROACH IS ESSENTIAL."

DIXON YU Junior, Industrial Engineering and Manufacturing and Design Engineering (MaDE)

FROM THE START,

successful design requires an optimistic **MINDSET** focused on the future. Students begin with **EMPATHY** to best understand the end users' needs and **HUMILITY** to acknowledge that they don't have all the right answers.

"**EMPATHY is the foundation of design thinking**," HOLDERFIELD says. "**We're not looking at big data or insights from a thousand people. We're deeply mining the stories of a few people. We want to find needs that are often unarticulated and might be different from what the data show**."

THE PROCESS FOR SOLVING THE PROBLEM

OFTEN BEGINS WITH MESSY, AMBIGUOUS NEEDS, WHICH ARE EXAMINED THROUGH IMMERSIVE OBSERVATIONS AND INTERVIEWS.

STUDENTS LEARN HOW TO

- IDENTIFY THE RIGHT PROBLEM,
- GENERATE MANY IDEAS FOR SOLVING IT,
- ITERATE ON THOSE IDEAS, AND
- IMPLEMENT THE OPTIMAL SOLUTION.

FINALLY, **STUDENTS DEVELOP A TOOLBOX** that helps them frame problems and bring concepts to life. THIS INCLUDES:

- BRAINSTORMING,
- PROTOTYPING,
- STORYTELLING,
- USER TESTING,
- RAPID ITERATION,
- AND GIVING AND RECEIVING FEEDBACK.

THE IMPORTANCE OF BEING EMPATHETIC

To establish successful, long-term solutions, designers must first understand the people they aim to serve. For one group of freshmen in DTC, this meant navigating campus in a wheelchair while researching how to build a better ramp.

"We went out multiple times with a wheelchair to test different bumps, curbs, steps, and ramps," says Nathan Miller, freshman in mechanical engineering. "Even when ramps exist, it was so difficult to roll up them."

"From that, we could understand how the ramp affects the user," adds William Barron, a freshman in computer science. "We better understood which angles are climbable and which are not."

Miller, Barron, and their teammates now say that they can't walk anywhere without noticing steep curbs and broken sidewalks that might be difficult for people in wheelchairs.

"It opened my mind up to the world," Barron says. "It gave me a broader understanding of the world and the problems that exist outside of my own experience."

Read more about the team's ultimate solution on page 22.

MISCONCEPTIONS ABOUT DESIGN

Walter Herbst, director of the Master of Product Design and Development Management program, has dedicated his life to design, and his more than 125 patents prove it. During his time in the industry and academia, he's noticed that many people have misconceptions about design innovation.

FALSE: *Design is purely aesthetic.*
TRUE: While aesthetics are often a component of design, design is a process and an outcome that holds meaning for the end user.

FALSE: *Design is only used to make attractive products.*
TRUE: Design can be used to create a product, service, business model, or experience.

FALSE: *Innovation is synonymous with creativity.*
TRUE: Creativity is the conception of something new. Innovation is the implementation of something new.

"STUDENTS HAVE TO REALIZE THAT THEY DO NOT AND WILL NOT ALWAYS HAVE THE RIGHT ANSWERS. THEY CAN ALSO FIND PURPOSE AND MEANING IN THE SETBACKS." **BRUCE ANKENMAN** Co-director of the Segal Design Institute

RISK. FAIL. REPEAT.

AS STUDENTS ADAPT TO DESIGN THINKING, THEY OFTEN FEEL APPREHENSIVE.

EVEN THOUGH THE WORLD IS A MESSY, COMPLICATED PLACE, BRIMMING WITH AMBIGUITY AND UNCERTAINTY, CHILDREN LEARN TO SOLVE NEAT EQUATIONS AND TO SEEK THE ONE CORRECT ANSWER.

They are urged to color within the lines and follow a prescribed path to success. That leaves little room to explore the uncomfortable boundaries of the unknown.

When Northwestern Engineering students experience **their first design course**, **Design Thinking and Communication (DTC)**, during freshman year, they balk at the idea that there can be many right answers. They also soon learn that finding the answer isn't the only challenge—the problem itself is often ambiguous.

"AMBIGUITY IS NOT ALWAYS A COMFORTABLE PLACE TO BE. DESIGN INNOVATORS ARE NOT NECESSARILY FOCUSED ON WHAT IS PROBABLE. INSTEAD, THEY WORK IN SPACES THAT ARE UNKNOWN, OFTEN MINING UNARTICULATED NEEDS OF USERS. THEY HAVE TO USE INTUITION TO MAKE A LEAP FORWARD INTO THE REALM OF POSSIBLE."

GREG HOLDERFIELD Director of the Segal Design Institute

If embracing ambiguity is difficult for students, then accepting failure can seem incomprehensible. The best way to find the right problem and an optimal solution requires taking risks, testing many iterations, and failing over and over again. Most Northwestern students are high achievers who finished at the top of their classes in high school. Lifelong perfectionists accustomed to straight A's, they often experience a deep fear of failure and recoil at the very thought of it.

"**The educational ecosystem at large bemoans failure**," says Ahren Alexander, a senior studying manufacturing and design engineering. "**But it's extremely important to realize that failure is necessary. Failing helps you understand what you could be doing better**."

Students benefit from failure in ways that extend beyond the design process and their final projects. They also develop resilience and humility, both key to working and living in the world outside the academic experience.

LESSONS FROM FAILURE

Accepting failure isn't always easy for anyone. Imagine how hard it can be for students accustomed to being at the top of their class. But FAILURE IS NOT ONLY INHERENT IN THE DESIGN PROCESS—IT'S CELEBRATED.

"It's really valuable to get comfortable with failing. If you're not failing, then you're not trying something that takes risks."
BETSY CHOU
Junior in mechanical engineering who is pursuing the Segal Certificate

"Every failure is a push toward a solution."
WILLIAM BARRON Freshman in computer science

"From the beginning, our professors told us to do as many things as possible and expect most of them to fail. We've been through a lot of failure, so we're prepared. Even if things don't go smoother in future design classes, we will cope with the failures better than we did the first time."
PAUL KLATT Freshman in mechanical engineering

"It's always disappointing when something fails. But you learn a lot more from what's wrong than what's right."
MILLIE ROSEN Freshman in chemical engineering

opposite Photograph by Sally Ryan

THE DESIGN PROCESS AT WORK

FRESHMAN: WHEELCHAIR RAMP

PROBLEM: Wheelchair users have difficulty navigating curbs and broken sidewalks.

SOLUTION: Portable, dual-telescoping wheelchair ramp.

CHALLENGES: The ramp needed to be sturdy enough to hold a wheelchair but lightweight enough to be portable. The DTC team developed a ramp with a telescoping structure, allowing it to extend in length from two feet to six feet. A locking mechanism secures the sections of the ramp in place for stability.

LESSON LEARNED: Early prototypes often fail. "**Near the end of the project, we tested the prototype, and the walls buckled under very little weight**," says Nathan Miller, freshman in mechanical engineering. "**That wasn't exactly ideal**."

GRADUATE: EDUCATION STARTUP

PROBLEM: Preschools in some areas of India lack adequate learning resources.

SOLUTION: SharEd, a startup that leverages the sharing economy for early childhood education.

HOW IT WORKS: Preschool children need a variety of books, toys, and games for the best learning environment, but these materials can be expensive. SharEd develops theme-based curricula and corresponding materials. "**We put eight different schools together**," explains Kate Geremia, MMM student and chief marketing officer of SharEd. "**Each school receives one of the units. Every month, they come together and rotate units**."

LESSONS LEARNED: User observation is important—even when the users are on the other side of the world. SharEd's chief financial officer and MMM student Nihar Shah visited Pune, India over winter break to observe students and teachers in the classroom. "**Observational research and becoming immersed into the environment is so much more valuable than relying on pure numbers or intuition**," Geremia says. "**It allows you to gain different insights**."

UNDERGRADUATE: BREADFRUIT PEELER

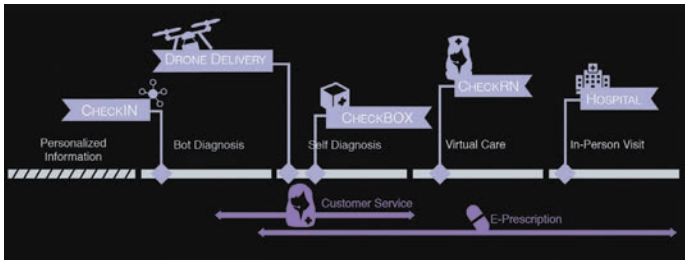
PROBLEM: Breadfruit is a staple food in Haiti and Jamaica, but its tough, stiff exterior and dense, starchy interior make peeling it difficult.

SOLUTION: A bicycle-powered device that rotates the breadfruit for the person peeling it, preventing the arm from overwork.

CHALLENGES: The peeler needs to be safe, easy, and economically viable. "**It needs to be manual because electricity is unreliable in Haiti and very expensive in Jamaica**," says Betsy Chou, a junior in the Segal Design Certificate program.

LESSONS LEARNED: If the intended user cannot realistically use a product, then it does not matter if it's well engineered. "**This made me think more about what people actually need**," says Dixon Yu, a junior in MaDE. "**I pursued engineering because I wanted to understand how things work. Design combines that curiosity with serving humans**."

GRADUATE: VIRTUAL HEALTH SYSTEM



PROBLEM: Northwestern Medicine needed a virtual care system that could serve 10 times more patients per primary care physician.

SOLUTION: Designed by students in the MS in Engineering Design and Innovation program, NM Check is a comprehensive virtual care system that brings healthcare to patients wherever and whenever they need it.

HOW IT WORKS: The system, targeted at millennials, consists of three main components: CheckIN, a web- and mobile-based health portal; CheckBOX, a system to deliver medical lab tests directly to patients; and CheckRN, a virtual care system for patients to interact with nurses via video conferencing.

LESSONS LEARNED: Design specifically for the targeted user. A system like this would work best for the generation that looks to WebMD and YouTube for their healthcare questions. The team found that the idea of entering a traditional healthcare environment is often too daunting for millennials, so they bypass the system altogether.

DESIGN BEYOND BORDERS

DESIGN INNOVATION AT NORTHWESTERN IS A COMPLEX STORY WITH MANY DIFFERENT PARTICIPANTS AND PROGRAMS.

THIS CONTINUOUSLY GROWING AND INCLUSIVE ENVIRONMENT MIRRORS THE DEMAND FOR DESIGN ON LOCAL, NATIONAL, AND INTERNATIONAL SCALES.

"**Segal was originally rooted in Northwestern Engineering**," HOLDERFIELD says. "**We hoped to give a human-centered design perspective to engineers. That's grown, morphed, and encompassed a variety of programs. To me, that's the beauty of it**."

"DESIGN THINKING ISN'T ABOUT GETTING TO QUICK SOLUTIONS; IT'S ABOUT EXPLORING WHAT'S POSSIBLE. THAT'S THE REAL POWER AND BENEFIT."

HUGH EKBERG (MMM '94)
President, Kitchen & Bath Americas at Kohler Co.

"THE DESIGN THINKING CURRICULUM HELPED ME HONE MY SKILLS INTO A POWERFUL DESIGN METHODOLOGY, WHICH I NOW LEVERAGE IN MY WORK TO CREATE IMPACTFUL AND PRACTICAL EXPERIENCES FOR PEOPLE." **ANTHONY JAKUBIAK (MS EDI '13)** Senior Experience Designer at SAP Labs

Northwestern Engineering is bringing diverse perspectives to design in many ways. HERE ARE A FEW EXAMPLES:

DESIGN THINKING AND DOING

The **new course**, similar to DTC, introduces non-engineers to the design process and is the first course that Northwestern Engineering has offered solely to students outside of the school.

MOOC

Northwestern Engineering offered a **massive open online course** (MOOC) called "Leadership through Design Innovation." More than 430 participants from around the globe enrolled in the MOOC, offered in winter quarter 2016, to learn more about the process and power of design.

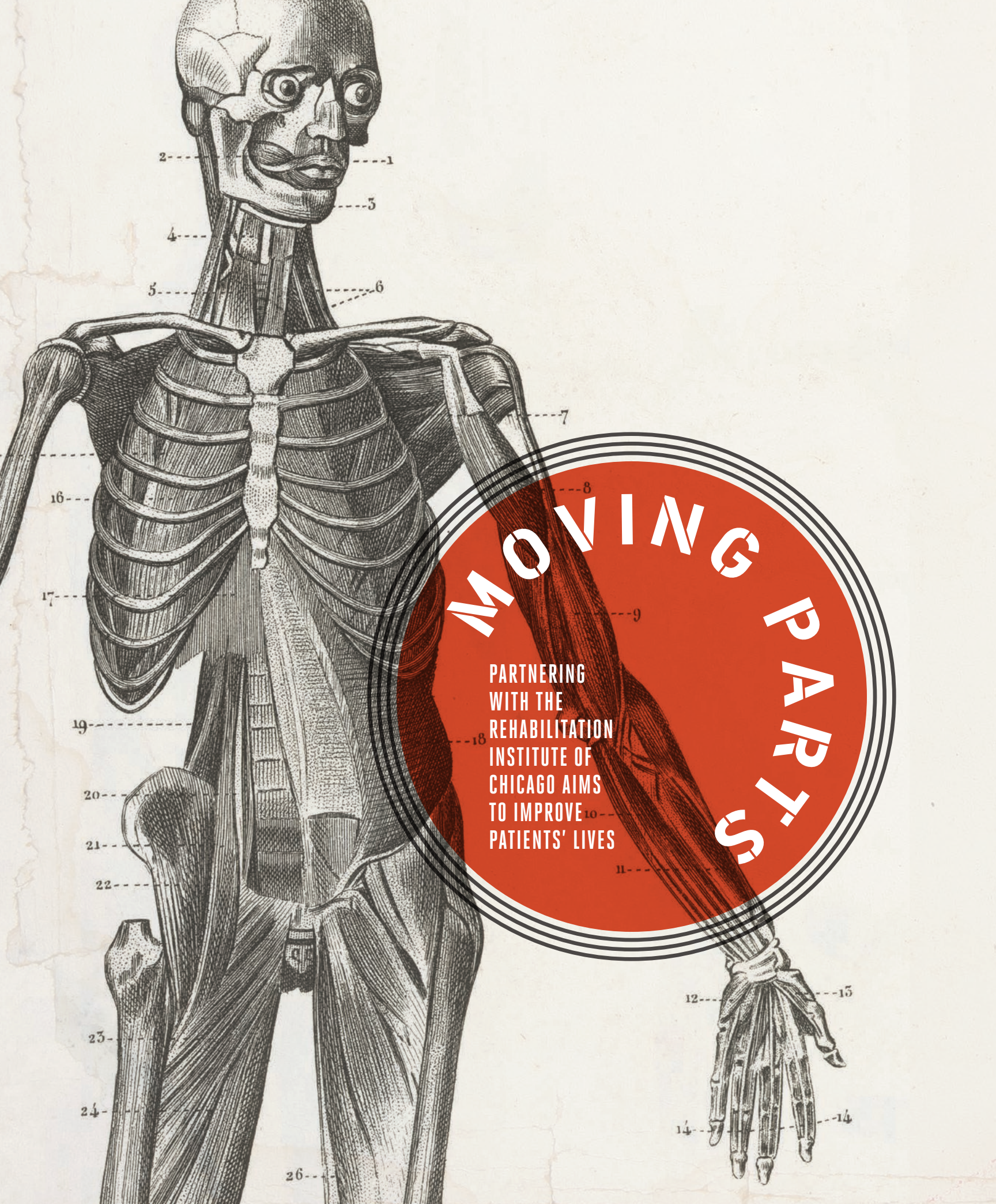
DESIGN FOR AMERICA

Founded at Northwestern in 2008, the **student-led network uses human-centered design to address social issues**. The organization has spread to several universities nationwide, including Stanford, MIT, Cornell, and Yale. More than 1,000 students are now involved, a number that grows each year.

"GOOD DESIGN PUTS USERS AT THE CENTER; SOLVES PROBLEMS LARGE AND SMALL, ARTICULATED AND TACIT; IMPROVES THE ART OF DAILY LIVING WITH SIMPLE ELEGANCE, IF NOT SURPRISE AND DELIGHT. THAT CAN TRANSLATE TO GOOD BUSINESS, YET TO QUOTE HERMAN MILLER FOUNDER D.J. DE PREE, 'GOOD DESIGN ISN'T JUST GOOD BUSINESS, IT'S A MORAL OBLIGATION.'"

GRETCHEN GSCHEIDLE (MPD2 '10) Director of Insight + Exploration at Herman Miller, Inc.

Written by Amanda Morris



MOVING PARTS

PARTNERING WITH THE REHABILITATION INSTITUTE OF CHICAGO AIMS TO IMPROVE PATIENTS' LIVES

EVERY YEAR, thousands of people from around the globe visit the Rehabilitation Institute of Chicago (RIC) in search of better outcomes. Many have debilitating diseases, spinal cord or brain injuries, limb amputations, or are recovering from stroke. Through research and innovative thinking, Northwestern Engineering faculty contribute directly and indirectly to helping these patients adapt, continually improve, and eventually recuperate.

STARTLING FINDINGS

Shaking someone's hand, waving hello, and dribbling a basketball might seem like similar activities. All require up-and-down motions in the arm, wrist, and hand, but that's where the similarities end. Each of these activities depends on very different mechanical properties within our arms, which can be modified by varying the signals to and from the nervous system.

"We change the mechanics of our limbs for different tasks," says Eric Perreault. "We do it often, but we don't usually think about it."

Perreault, however, does think about it—a lot.

With a joint appointment in the Department of Biomedical Engineering and at RIC, Perreault seeks to understand how humans use their limbs to interact with the physical world. He is particularly interested in how stroke, spinal cord injuries, and other motor deficits affect the musculoskeletal and nervous systems. As a researcher, his ultimate goal is to help others develop interventions that improve these individuals' lives.

"The interactions between the nervous system and the mechanical system are still poorly understood," says Perreault, professor and chair of biomedical engineering. "There are a lot of things we can't measure in humans because those critical interactions happen below the surface of our skin."

One of Perreault's newest studies looks deep below the skin to the brain's most hidden part: the brainstem. Researchers know little about this region because it's difficult to access and too buried to record easily. Forming a connection between the brain and the spinal cord, the brainstem coordinates many important involuntary reflexes, including the startle response experienced when hearing an unexpectedly loud sound.

"While many reflexes, including a startle, are stereotyped, there are many automatic responses at the interface of involuntary and voluntary control," Perreault says. "These subconscious responses are fast enough to be considered reflexive, but share many of the task-specific complexities normally attributed to volitional movements."

Perreault has spent years exploring how these automatic responses contribute to our ability to regulate limb mechanics and movements. Those studies have recently led him to the brainstem. His team has found that the brainstem contributes to movements throughout the arm and hand, contrary to earlier beliefs.

The brainstem allows, among other things, for the rapid response to external stimuli. Perreault's work with stroke subjects provides strong evidence that some of these rapid reactions can be elicited without input from higher brain centers. In fact, his team has demonstrated that by activating the brainstem through loud noises to invoke a startle response, it is possible to get brain injury survivors to move as quickly as unimpaired subjects.

Perreault's team is using these findings to expand our understanding of brainstem function and of how that function influences our ability to interact with the physical world. He imagines that this understanding may eventually lead to novel interventions for stroke rehabilitation.

RIC PARTNERSHIPS ACROSS NORTHWESTERN ENGINEERING

HAND MODEL

WENDY MURRAY, associate professor of biomedical engineering and physical medicine and rehabilitation, focuses on hand function. She has created a model to understand and improve what happens during hand surgery and seeks to quantify the mechanics of the muscles in the hand.

BRAIN GAMES

MATTHEW TRESCH, associate professor of biomedical engineering and physical medicine and rehabilitation, studies how the brain controls joints. His particular interest lies in how the brain actively regulates the stresses and strains within the knee to minimize injury.

STIMULATING WORK

In collaboration with Perreault and Tresch, KEVIN LYNCH, chair and professor of mechanical engineering, recently finished a study that used electrical stimulation to reanimate paralyzed arms. Already showing promise in human subjects, the system could allow paralysis patients to perform daily tasks such as eating, combing their hair, and turning a doorknob.

ON A ROLL

Ironically, the people who most need wheelchairs or prosthetics are sometimes the least able to operate them.

"We have this paradox," says Brenna Argall. "The more motor-impaired a person is, the more limited they are by the control signals they can provide. Yet, they may need even more complex help because they face a wider mobility gap. That's where robotics autonomy comes in."

With a joint appointment with RIC and the Department of Electrical Engineering and Computer Science, Argall is developing an autonomous wheelchair and a robotic arm for patients with motor impairments.

Similar to the technology used in a driverless car, Argall's wheelchair uses sensors and artificial intelligence to share control with a human. The infrared and ultrasonic sensors allow the wheelchair to sense obstacles in its path to avoid collisions and navigate difficult spaces, such as narrow doorways. The wheelchair is currently being tested with RIC patients.

"Smart wheelchair research has been around for 25 years," says Argall, an expert roboticist. "But there haven't been any transitions to the commercial market, often because the robotics was not robust enough. Within the past five to ten years, robotics autonomy has reached the point where we have technology that is robust enough to operate out in the world."

Using machine learning, Argall's wheelchair learns from its interactions with a human being over time. If the patient's impairments worsen because of a degenerative disease or improve with physical therapy, the wheelchair naturally adapts to those changing abilities.

"We don't want to present a static machine," Argall says. "We want it to adapt seamlessly over time without needing to bring it back to the lab for adjustments to new circumstances."

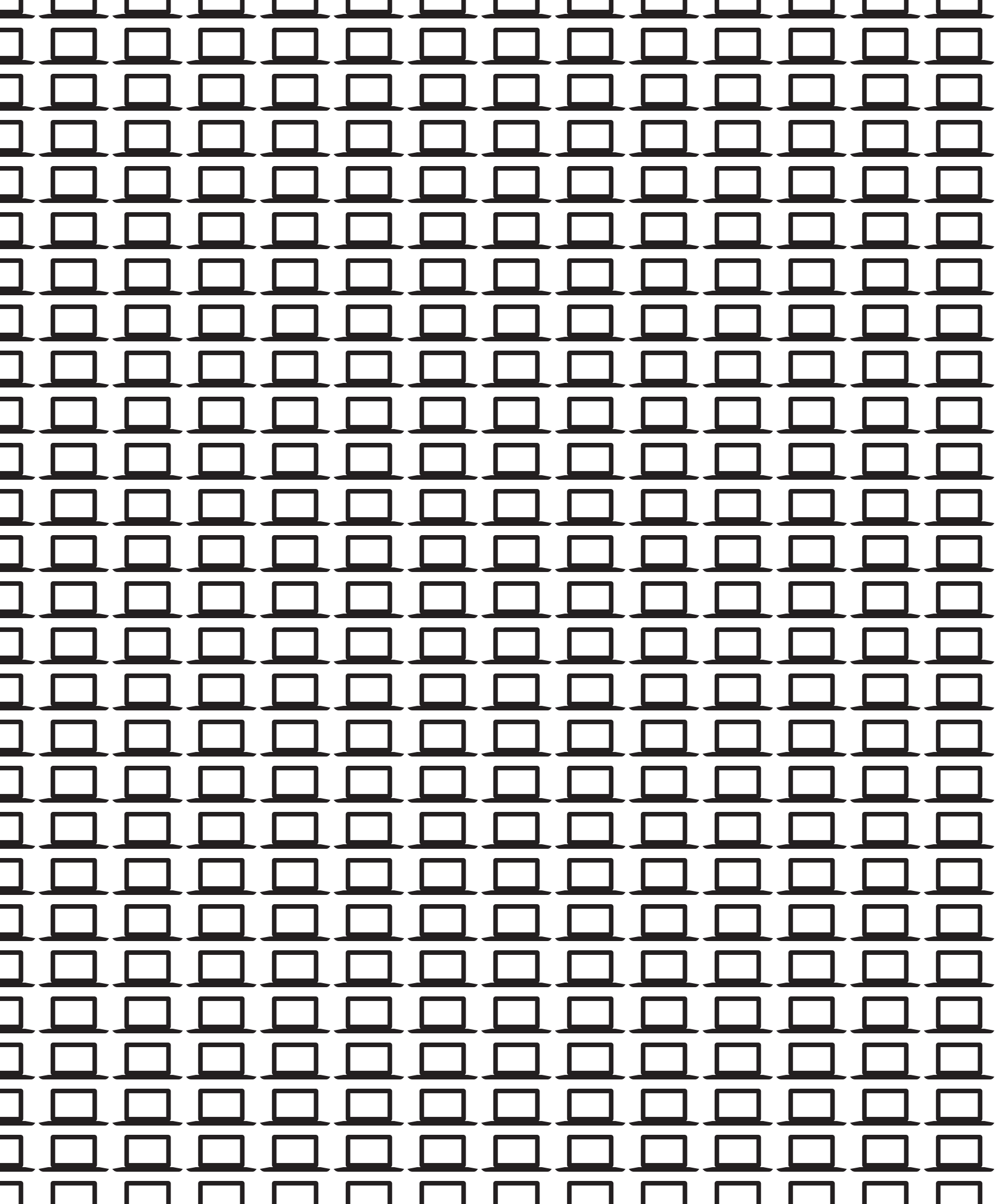
Argall's robotic arm uses similar sensors as the wheelchair, but instead of avoiding objects, the arm locates objects to grab. Argall's group performed an exploratory study with the arm at RIC in summer 2015.

The goal for both projects is to make machines that are not too complex for patients to handle. Instead, the users should feel comfortable and in control.

"It's not that we're trying to take humans out of the loop," she says. "We're trying to use robotics autonomy to bridge the control gap and make machines that are accessible and easy to operate."

AMANDA MORRIS

Photographs by Sally Ryan



COMPUTER SCIENCE FOR EVERYONE. IF YOU CAN FIND A SEAT.

THE MORE TECHNOLOGY BECOMES EMBEDDED IN DAILY LIFE, THE GREATER THE DEMAND FOR COMPUTER SCIENCE COURSES.

Standing room only. That's a phrase not often associated with a computer science class, but it describes what's on the verge of happening in Northwestern Engineering's popular computer science course CS 111: Fundamentals of Computer Programming.

"THE EXCITEMENT AND DEMAND FOR COMPUTER SCIENCE FROM OUR STUDENTS INSPIRES US TO IMAGINE NEW WAYS OF TEACHING AND LEARNING BOTH IN THE CLASSROOM AND BEYOND."

LARRY BIRNBAUM PROFESSOR OF COMPUTER SCIENCE

And this is not your typical classroom. CS 111 is held in Ryan Family Auditorium in the Technological Institute, a space usually reserved for large events like commencement, speeches, and even small concerts. But it is the only space large enough to accommodate all the students who want to enroll in this course.

The influence of computer technology in virtually every aspect of daily human life has created a swelling demand for computer science courses everywhere. At Northwestern alone, the number of computer science majors has exploded—tripling in just the past five years. And it's not only the majors who want to learn about the burgeoning field. CS 111 is Northwestern Engineering's most popular class for non-majors, who come from nearly every school within the University.

CS 111 and another popular course, CS 101: Computer Science for Everyone, are spreading the subject to all types of engineers and beyond. Both classes are open to all Northwestern majors, have no prerequisites, and are accessible to students of all skill levels. The classes provide a critical introduction to a powerful field.

"The excitement and demand for computer science from our students inspires us to imagine new ways of teaching and learning both in the classroom and beyond," says Larry Birnbaum, professor of computer science and director of the division. "Computer science has the potential for collaborating with nearly every discipline at Northwestern."

PROGRAMMING FOR EVERYONE

With the influx of value-laden big data that companies now have available, employees with programming skills are hotly sought after to find meaningful insights and trends within the slog of numbers. This is true across practically every field, from sociology and linguistics to finance and athletics. Entrepreneurs hoping to launch the next big app or Internet startup also find enormous advantages in learning how to program. And students from all backgrounds see value in having this all-important skill in their back pockets to develop new and exciting projects on a whim.

"Computer science allows you to build anything," said freshman Anna Furlong, who studies math and computer science. "You can come up with an idea, spend an afternoon coding, and have a prototype quickly. Anything is possible."

To keep up with the ever-changing nature of computer science and to satisfy the booming interest in programming, professors Ian Horswill and Sara Sood revamped CS 111 in the fall of 2015. This included the decision to teach with Racket, a general-purpose programming language compatible with both Windows and Mac OS. Students in the class use the language to design simple tools and games as well as practice diagnostics to find and fix bugs hidden within the code.

But Horswill emphasizes that it is not enough to just write code that works. Students need to learn how to write code that is clear, concise, and elegant and in a way that humans can understand. For this, they need familiarity with human psychology.

"I wanted to make a course that was about ideas rather than punctuation marks," he says. "A lot of software development is about human psychology. But that often gets lost in the rush to explain all the punctuation marks."

PHILOSOPHY FOR EVERYONE

With philosophy as its soul, CS 101: Computer Science for Everyone defies the misconception that computer science is solely about coding. Offered every fall, the class introduces both majors and non-majors to the core ideas that drive the field and how computer science interacts with everything else in the world.

WHAT'S THE RACKET?

Last year, CS 111 instructors started teaching the course with Racket, a general-purpose programming language in the Scheme family. Northwestern Engineering Professor Robert Findler co-developed both Racket and Scheme, the programming language previously used in the class. Here are some reasons why Racket works well in the classroom:

- Racket is naturally cross-platform, performing well in Windows, Mac OS, and Unix.
- It was designed with beginning programmers in mind.
- It is not restricted to a specific programming style.
- It features an extensive library that is thorough and approachable.
- It can be used to create new languages.
- Its interactive mode encourages experimentation.
- It is open-source, so it may be subsequently improved by outside developers.
- Racket is equally unknown. Most students in the class will start at a fair and equal point.

"Computer science can expand to include anything," says Jason Hartline, associate professor of computer science, who teaches the course. "It can help us better understand the world around us."

Each week, the course features different guest professors from the department who present the computer science topics in which they conduct research. Birnbaum, for example, presents on artificial intelligence and machine learning; Fabián Bustamante lectures about systems and networks; and Brenna Argall talks about robotics. These guest lectures change regularly to keep the content fresh.

There are no textbooks, as Hartline prefers to keep class discussions current and sometimes even ripped from the headlines. When Facebook was outed for using an algorithm to customize users' news feeds in order to control their moods, for example, Hartline brought the discussion to class. He also uses TED Talks and articles from popular media.

BEYOND PROGRAMMING

"You learn about topics on a broad scale," says Alec Reinke, a sophomore in mechanical engineering. "I was surprised to learn how many different fields of computer science there are."

This broad approach is by design. When Hartline redesigned the course four years ago, he wanted to give students a deeper understanding of computer science beyond programming. He has long noticed how computer science touches unexpected areas of life, and looks for ways to use it as a tool to understand complex environments. His own research introduces design and analysis methodologies from computer science to understand and improve outcomes of economic systems. In Hartline's world, economic systems work like computers, and economic factors, such as a country's gross domestic product, are the computation's outcome.

Historically, most introductory classes have focused on coding. While it's undoubtedly a critical skill, programming is only a portion of computer science. Hartline likens it to a high school biology course.

"Biology classes aren't just centered around one skill like dissecting a frog," Hartline says. "Students don't go to class every day to learn more specialized methods to get better and better at dissecting. Computer science also has very many advanced topics, such as cryptography and machine learning. These are very different from programming."

MEETING THE DEMAND

Horswill and Sood have found a way to manage the escalating number of students who want to learn. In past quarters, students met in discussion groups led by a teaching assistant, but those sections were still overwhelmed with 80 students.

CODE NOT INCLUDED

Professor Jason Hartline wants his students to know that computer science is more than programming. Here are some other topics within the realm that Hartline teaches in CS 101:

- THEORY OF COMPUTATION
  what computers can compute
- ALGORITHMS FOR EFFICIENT COMPUTATION
  what to tell a computer to compute
- PROGRAMMING LANGUAGES
  how to tell a computer what to compute
- ARTIFICIAL INTELLIGENCE
  how a computer can perform like a brain
- COMPUTATIONAL BIOLOGY
  how DNA-based biological systems are like programs
- COMPUTER SYSTEMS
  how computers work together in networks, such as the Internet
- COMPUTER VISION AND GRAPHICS
  how computers gather and convey useful visual information
- HUMAN-COMPUTER INTERACTION
  natural ways to get what is needed from a computer

Thanks to funding from Charlene and Bob Shaw ('70), the department was able to hire 18 peer mentors to lead small tutorials with just six students each. The department also introduced an advanced section to challenge students who enter the class with programming experience.

An introductory course to computer programming, CS 111 is required for all computer science majors, but half of the class comprises non-majors—a proportion that grows every quarter. This winter quarter 2016, the class reached nearly 350 students—another number that steadily continues to grow.

Some take both courses to explore the world of computer science, dipping a toe into the vast field to decide if it's something they want to pursue. Others are simply interested in learning more about topics, such as algorithms, that are seeping into our everyday lives and becoming prominent in the daily lexicon.

"More and more, computer science is becoming something that everyone should know to be a functioning person in society," Hartline says. "You should understand that you are regularly interacting with learning algorithms. And you should know what that means."

Sood agrees. "Programming has moved into many fields beyond computer science. It has become necessary to have at least a basic introduction."

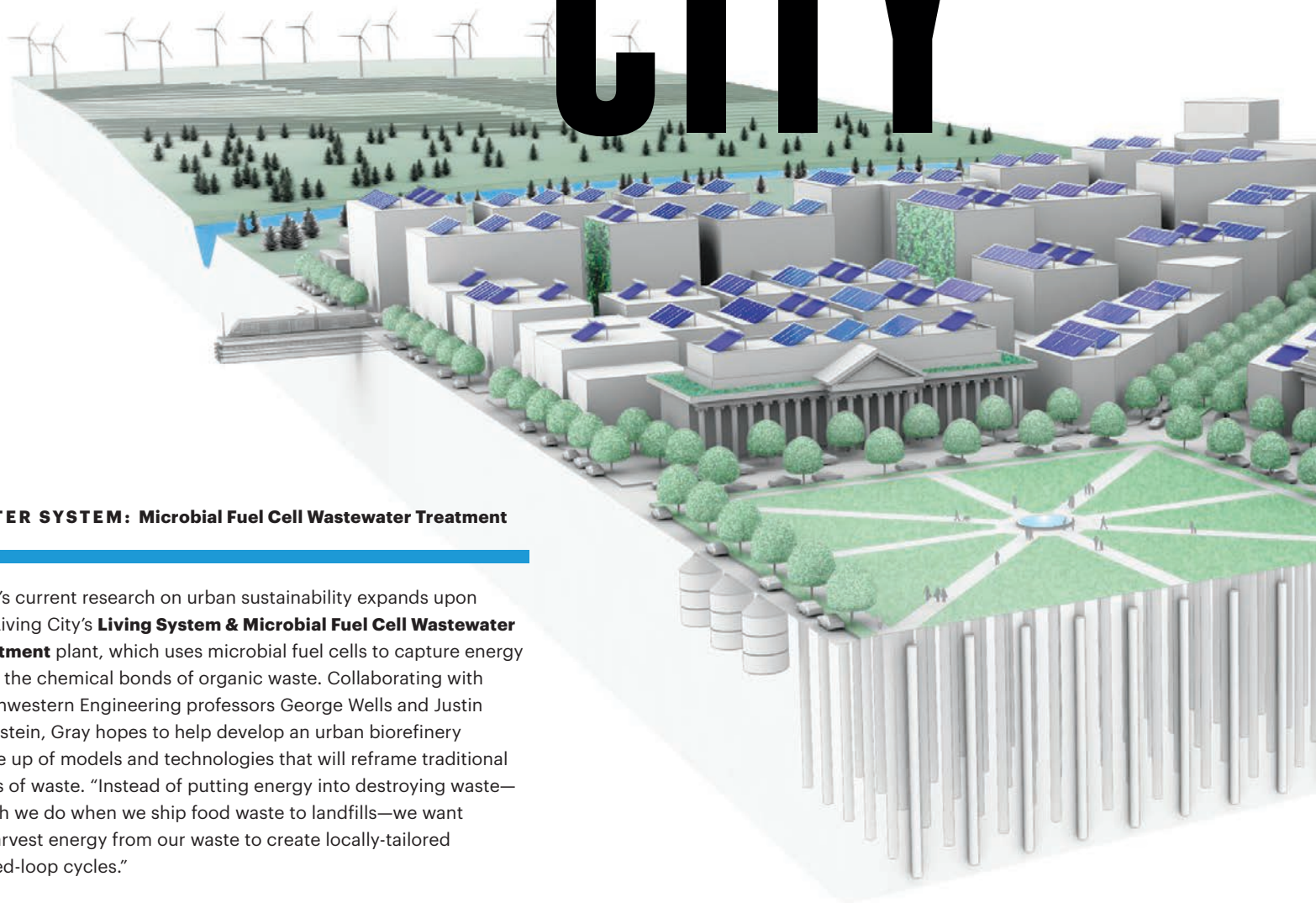
AMANDA MORRIS

THE LIVING CITY

SURVIVING AND THRIVING IN TUNE WITH NATURE

The connectedness of the Living City's energy and water systems is reflected in its **Geothermal Park**. "Open space needs to function as more than just a deterrent for automobile use or simply as recreational space," Gray says. "The Geothermal Park operates as a pivotal component of the city's energy and water systems." Above ground, the open park offers space for outdoor recreation, and is also equipped to manage rainwater runoff as part of the Living City's stormwater management system. Underground, cisterns house excess stormwater, and geothermal heat pumps provide energy to meet the demand for hot water.

ENERGY SYSTEM: Geothermal Park



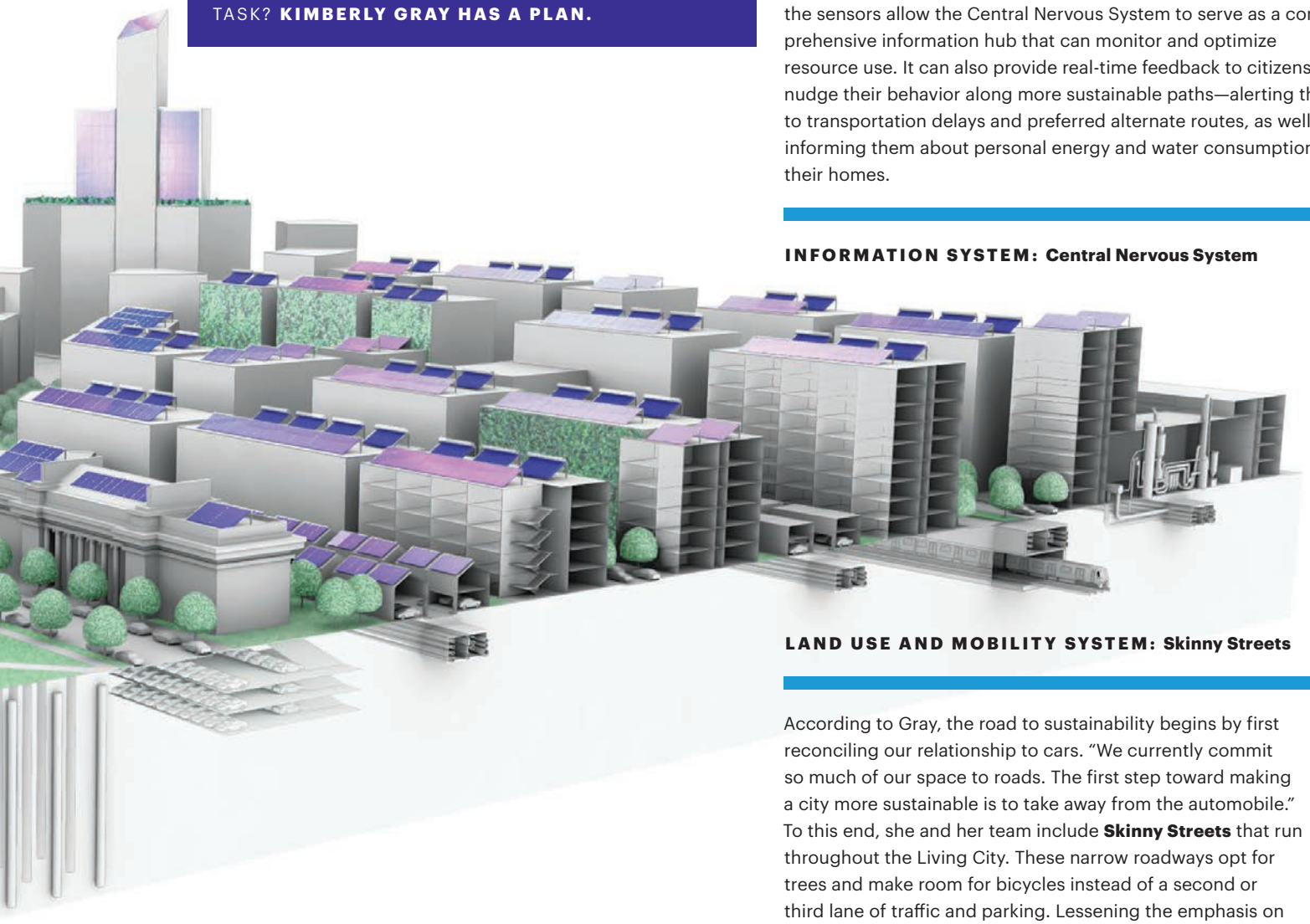
WATER SYSTEM: Microbial Fuel Cell Wastewater Treatment

Gray's current research on urban sustainability expands upon the Living City's **Living System & Microbial Fuel Cell Wastewater Treatment** plant, which uses microbial fuel cells to capture energy from the chemical bonds of organic waste. Collaborating with Northwestern Engineering professors George Wells and Justin Notestein, Gray hopes to help develop an urban biorefinery made up of models and technologies that will reframe traditional ideas of waste. "Instead of putting energy into destroying waste—which we do when we ship food waste to landfills—we want to harvest energy from our waste to create locally-tailored closed-loop cycles."

"HOW DO YOU MAKE CITIES MORE SUSTAINABLE?" THAT'S THE SIMPLE YET DAUNTING QUESTION NORTHWESTERN ENGINEERING'S KIMBERLY GRAY HEARD IN 2011 WHEN SHE ANSWERED A PHONE CALL FROM THE CHAIR OF THE BUSINESS ADVISORY COMMITTEE FOR THE ASIA-PACIFIC ECONOMIC COOPERATION (APEC).

THE GRAVITY OF THE QUESTION WAS NOT LOST ON GRAY. AFTER DECADES OF RAPID URBANIZATION COUPLED WITH THE GROWING IMPACT OF CLIMATE CHANGE, THE NEED FOR ENVIRONMENTALLY SUSTAINABLE INFRASTRUCTURE THAT SUPPORTS EQUITABLE AND ECONOMICALLY PROSPEROUS LIVING HAS NEVER BEEN GREATER.

BUT HOW DOES ONE TACKLE SUCH A MONUMENTAL TASK? **KIMBERLY GRAY HAS A PLAN.**



PORTRAIT OF THE LIVING CITY DOUG FARR AND HIS ARCHITECTURE FIRM, FARR ASSOCIATES, drew "A Portrait of the Living City" based on the team's design to offer a glimpse into how sustainable land, water, and energy practices could be implemented in an urban environment.

The Living City relies on a **Central Nervous System** to manage the primary energy, water, and transportation systems, as well as a wealth of other city functions. Gray says the Central Nervous System takes full advantage of today's smart technologies through the use of sensors placed throughout the city. Data received from the sensors allow the Central Nervous System to serve as a comprehensive information hub that can monitor and optimize resource use. It can also provide real-time feedback to citizens to nudge their behavior along more sustainable paths—alerting them to transportation delays and preferred alternate routes, as well as informing them about personal energy and water consumption in their homes.

INFORMATION SYSTEM: Central Nervous System

LAND USE AND MOBILITY SYSTEM: Skinny Streets

According to Gray, the road to sustainability begins by first reconciling our relationship to cars. "We currently commit so much of our space to roads. The first step toward making a city more sustainable is to take away from the automobile." To this end, she and her team include **Skinny Streets** that run throughout the Living City. These narrow roadways opt for trees and make room for bicycles instead of a second or third lane of traffic and parking. Lessening the emphasis on vehicular travel encourages more citizens to walk, reduces the carbon footprint from automobiles, and commits more land for green space development.

THE CALL TO REINVENT CITIES

Cities cover only two percent of Earth's land surface, yet are home to half of the planet's population. That means 3.5 billion people live in a combined area less than half the size of the contiguous United States.

While migration from rural to urban areas unfolded gradually over the 20th century in post-industrialized economies like the United States, Japan, and Western Europe, demographic shifts are happening today on a scale never experienced before. According to projections by the United Nations Population Fund, 5 billion people will reside in urban environments by 2030.

Asia continues to experience the most drastic boom in population growth. There, urban environments capable of housing hundreds of thousands of people are constructed in a matter of days. These new metropolises, of course, face the same problems that plague many established cities: inefficient public transportation, poorly managed food and energy supply, and the handling of waste.

> "THERE'S AN OLD ENGINEERING TENET THAT SAYS, 'IF IT IS NOT BROKEN, DON'T FIX IT.' I THINK CITIES ARE BROKEN, BUT THEY HAVE AN ENORMOUS OPPORTUNITY TO BE REINVENTED AND FLOURISH."
>
> **KIMBERLY GRAY** CHAIR OF THE DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

ANSWERING THE CALL

When that phone call came in 2011, Gray, now the chair of the Department of Civil and Environmental Engineering, recognized an opportunity to draft a plan that could support municipalities in their efforts to construct communities more sustainably. Her inspiration was simple: let's partner with nature to do the work.

"Cities need to transform themselves by operating more like nature," Gray says. "We need to remake the human use of materials and energy in cities to mimic the closed loop cycles found in natural ecological systems."

Gray, who has worked to develop technologies that both protect the environment and enhance public health, knew she needed a team with expertise beyond her knowledge of technological infrastructure, particularly in the fields of design and policy. She connected with Douglas Farr, founder of the sustainability-focused architecture firm Farr Associates, and Northwestern Pritzker School of Law professor David Dana, whose environmental law background would guide how to best implement the team's vision.

"Architects consider the aesthetic side of cities. Lawyers understand policy and how to best implement your ideas," Gray says. "It was so much fun to be able to collaborate across these disciplines and learn their perspectives throughout the process."

BUILDING THE LIVING CITY

The team's urban sustainability blueprint, called the Living City, combines Gray's familiarity with sustainable infrastructure, Farr's experience in environmental design, and Dana's knowledge of the political feasibility of the plan.

At its core, the Living City integrates four interdependent systems that, if adopted, would help a city maximize its sustainability potential:

A SENSOR-BASED **INFORMATION SYSTEM** THAT SERVES AS THE "CENTRAL NERVOUS SYSTEM," MONITORING AND REGULATING MAJOR CITY FUNCTIONS

A SYNERGISTIC **ENERGY SYSTEM** THAT HARNESSES THE FULL POTENTIAL OF WIND, SOLAR, AND GEOTHERMAL ENERGY SOURCES WHILE ALSO RECYCLING WASTE HEAT

AN INTERCONNECTED **WATER SYSTEM** THAT RECYCLES WASTEWATER AND STORMWATER, AND USES CISTERNS AND ROOFTOP VEGETATION TO MANAGE STORMWATER

A **LAND USE AND MOBILITY SYSTEM** THAT REDISTRIBUTES LAND RESOURCES TO PRESERVE FUNCTIONAL GREEN SPACE AND CREATE DENSER URBAN LANDSCAPES THAT ENCOURAGE WALKING AND MASS TRANSIT

"You can't think of these systems in a silo," Gray says. "Like nature, we envisioned a system of linked resource cycles. Electric automobiles are a major aspect of transportation, but they are also an integral part of the energy system and make the feasibility of renewable energy more likely."

Where most cities today use materials and energy in a linear fashion—resources are used, and then discarded as waste—the Living City overhauls these practices in favor of decentralized technologies that integrate within natural ecosystems to allow for resource cycling and recovery.

"We use many things once or twice and throw them away," Gray says. "Nature runs on renewable energy and the constant reuse of materials. Even what you think of as waste, like soil, has a function—it supports the growth of new plants."

While Gray notes the initiatives outlined in their plan aren't exhaustive, they represent tangible technological enhancements that cities could implement today. Within its sustainable infrastructure, the Living City incorporates a smart grid that regulates home and building outlet plugs when not in use, building rooftops fitted with solar panels and vegetation plots, and a microbial fuel cell wastewater treatment plant that degrades organic waste while producing energy to sustain its own operations.

SUSTAINABILITY BY 2030?

When Gray's team presented its vision of the Living City to APEC representatives in 2012, she was confident widespread urban sustainability could be achieved by 2030. She's less optimistic about her prediction today, but that has not stopped her research efforts, nor weakened her belief that sustainability won't be achieved without cooperation.

"The path to making our cities sustainable isn't dominated by technology, but rather human behavior," says Gray. "We have the technologies to remake our waste cycles and reduce our carbon footprint, but that undertaking requires coordination among political, economic, legal, and social frameworks. That remains an ongoing challenge."

Despite the obstacles to achieve urban sustainability, Gray points to Portland, Oregon as an American city that has employed economic incentives, education outreach, and regulations to improve sustainability. The city's urban growth boundary (UGB) preserves surrounding rural landscapes through zoning limits to potential land development. The resulting urban space is noticeably dense, and has helped Portland earn its "20-minute city" nickname; many citizens enjoy a maximum 20-minute commute to work, school, or most businesses.

"Our way of handling resources and waste has provided us with a high quality of living, and sustainability requires fundamental changes that many would find threatening," Gray says. "There is an assumption sustainable living will undo our quality of life, but the potential is there to improve it."

For Gray, that potential motivates her to continue to refine and expand upon the ideas in what she refers to as the Living City 2.0.

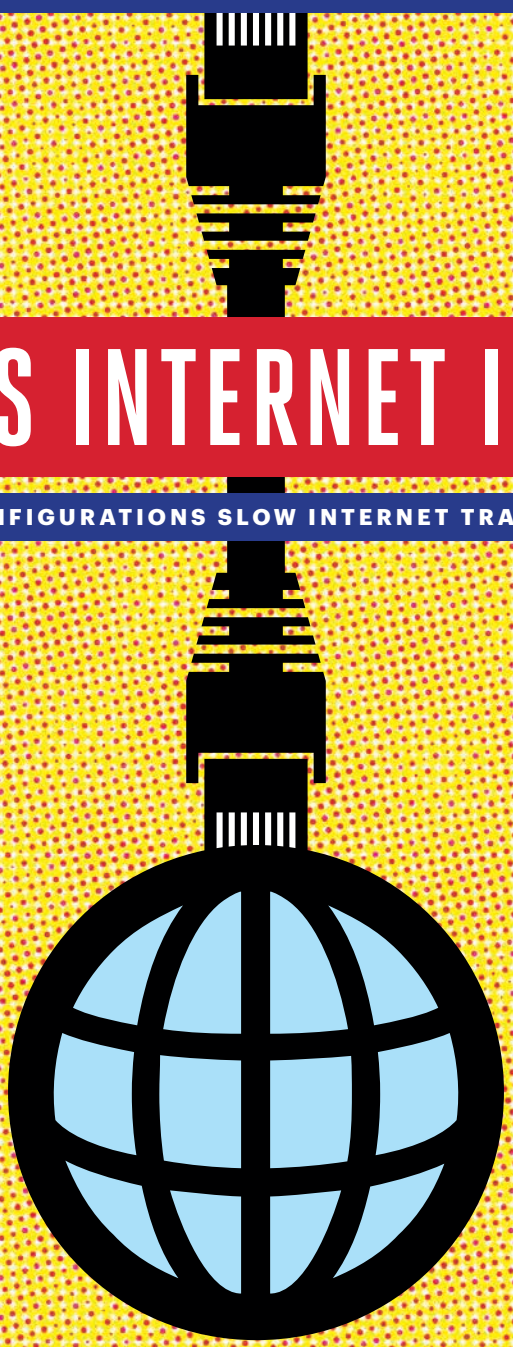
"There's an old engineering tenet that says, 'if it is not broken, don't fix it,'" Gray says. "I think cities are broken, but they have an enormous opportunity to be reinvented and flourish."

ALEX GERAGE

Photograph by C. Jason Brown

CUBA'S INTERNET ISSUES

RESEARCH SHOWS THAT MISCONFIGURATIONS SLOW INTERNET TRAFFIC TRAVELING TO THE ISLAND



"IF YOU'RE TRYING TO CONNECT ANYWHERE, YOU EITHER HAVE TO CONNECT THROUGH THESE MARINE CABLES OR UP TO THE SATELLITE. IF YOU GO UP TO THE SATELLITE, IT TAKES SIGNIFICANTLY LONGER."

FABIÁN E. BUSTAMANTE PROFESSOR OF COMPUTER SCIENCE

In December 2014, President Barack Obama made history by announcing plans to reestablish diplomatic relations with Cuba, including loosening economic restrictions. Two months later, American companies like Netflix and Airbnb announced plans to expand into the once-embargoed island.

"Our first reaction was: 'Really?'" says Northwestern Engineering's Fabián E. Bustamante. "As a business model, Netflix and Airbnb rely on most people having Internet access. That's not quite the case in Cuba, so it really didn't seem to make much sense."

To see if these Internet-centric business ideas were feasible, Bustamante, professor of computer science, and his graduate student Zachary Bischof decided to measure Cuba's Internet performance. Not too surprising, they found that Cuba's Internet connection to the rest of the world was poor, perhaps even worse than expected.

Cuba's history with computing and the Internet is a complicated one. Cuban citizens were not even allowed to own a personal computer until 2008. Network availability has been problematic for such a long time that several makeshift "offline Internets" have appeared, with individuals distributing content through USB flash drives or CDs (a popular service known as "el paquete").

But things have been changing, if slowly. In February 2011, Cuba completed its first undersea fiber-optic cable with a landing in Venezuela, but it didn't activate it until two years later. Today, only one in four Cubans can get online, and a mere five percent of the population has Internet access at home.

"If you're trying to connect anywhere, you either have to connect through these marine cables or up to the satellite," Bustamante says. "If you go up to the satellite, it takes significantly longer."

"For one, it's much farther to travel," Bischof adds. "And the trip is on a very interference-rich environment, which includes cosmic rays."

Since March 2015, Bustamante and Bischof have conducted measurements to and from Havana to observe Internet traffic going in and out of Cuba. They are trying to characterize overall network performance (such as the time it takes for information to travel in either direction) and the paths the data travels.

Some of the early results showed that information returning to Cuba took a much longer route than the request took on its way out of the island. When a person in Havana searches for a topic on Google, for example, the request travels through the marine cable to Venezuela, then through another marine cable to the United States, and finally lands at a Google server in Dallas. When the search result travels back, it goes to Miami, up to the satellite, and then back to Cuba. While the request for information out of Cuba takes 60 to 70 milliseconds, it takes a whopping 270 milliseconds for the response to make its way back. For websites like CNN.com, this translates into a web page taking nearly a minute to load.

"It takes so long that it's almost useless," Bustamante says, noting that many people will abandon their search before getting a response and the whole exploratory aspect of web research is virtually gone.

Bustamante and Bischof say this could result from a configuration problem or routing policy and are exploring this further. For now, they can only say—with certainty—that Cuba's Internet performance appears to be among the poorest in the Americas, and its infrastructure would struggle to support web services hosted off the island, particularly network-intensive applications like Netflix. As always, understanding problems and diagnosing their causes is a first step toward a solution.

"Beyond access to Internet services like Netflix, continued societal progress in Cuba depends on better connectivity," Bustamante says. "To better understand how to enhance it, we first have to better understand what is available now and what are the main hindrances."

AMANDA MORRIS

BOTTLING THE SUN

SOSSINA HAILE'S RESEARCH BRINGS THE WORLD CLOSER TO LIQUID ENERGY FUELED BY THE SUN

It's not living. But it is breathing.

The solar reactor in Sossina Haile's laboratory is respiring oxygen. And with its every breath, the world comes another step closer to bringing the vision of liquid solar fuels to life.

"My lab does not have the total energy solution, but we do have a couple pieces of it," says Haile, Walter P. Murphy Professor of Materials Science and Engineering. "I can give you two components that will help you get to the end."

Those two components are hydrogen and carbon monoxide, which are basic ingredients for making fuels that can store solar energy. Haile can make both on demand.

HARNESSING THE POWER

Although the sun's energy is inarguably an enormous resource, researchers have long experienced difficulty harnessing it.

Solar cells, which have advanced significantly in recent years, still have major drawbacks. Cloudy days and nighttime ensure that sunlight is not always available. Even when the sun does shine, solar cells are inherently restricted to capturing only a small portion of the solar light spectrum. Possibly the most serious drawback of all, researchers have yet to find an ideal way to store energy captured by solar cells for later use. Even the best batteries have limited capacities and eventually self-discharge.

Solar fuels, on the other hand, do not share solar cells' more serious shortcomings. In particular, they can be stored as liquid for later use. And if sunlight is collected in the form of thermal energy, the resulting solar fuel uses its entire spectrum.

"The benefit of a liquid fuel is that storing it is easy," Haile says. "We store liquid all the time and could easily store solar fuels with our existing infrastructure."

The key to Haile's work lies in a ceramic material called cerium dioxide, or "ceria" for short. At ultrahigh temperatures, ceria exhales oxygen while its structure remains intact. Employing a giant, parabola-shaped mirror, a solar reactor focuses intense sunlight onto the ceria. Using the entire solar spectrum, the method reaches temperatures up to 1500 degrees Celsius, causing the ceria to release its oxygen.

"If you have ever used a magnifying glass to start a fire," Haile says, "then you have used the same technique on a smaller scale."

As the ceria cools, it dislikes the empty areas left in its structure from the exhaled oxygen atoms and wants to breathe them back in. At this point, Haile's team steams the ceria, causing it to inhale the oxygen from the water, leaving hydrogen behind. The team then collects the hydrogen, a precursor to liquid fuel.

GIVING ENERGY TO CO_2

Haile's group can perform the same process with carbon dioxide. If the gas is pumped near the ceria as it cools down, ceria will steal an oxygen atom to leave behind carbon monoxide. Researchers can then react hydrogen with carbon monoxide to make methane, a primary component of natural gas.

"Carbon dioxide is the end product of burning," she says. "So it does not have any energy content. We can convert it into something that carries energy and is useful."

This could potentially crack two parts of the carbon crisis with one solution: carbon dioxide could be collected from the air and turned into a clean liquid fuel that does not contribute to climate change. Haile says that while capturing carbon dioxide from the air is very difficult, if not impossible, using carbon dioxide from coal-fired power plants would be compatible with her process.

"WHILE I'M MOTIVATED TO MAKE A REAL DIFFERENCE TO SOCIETY, I ALSO WANT TO MAKE SURE TO DO THE FUNDAMENTAL SCIENCE. A TECHNICAL SOLUTION MAY BE GREAT TODAY, BUT THERE WILL ALWAYS BE A BETTER INVENTION TOMORROW. SO IT'S ABSOLUTELY CRITICAL TO ADVANCE UNDERLYING SCIENTIFIC PRINCIPLES THAT EXPLAIN WHAT WE ARE ABLE TO ACHIEVE. THIS SORT OF INSIGHT IS ESSENTIAL FOR ENABLING THE INVENTIONS OF THE MORE DISTANT FUTURE."

SOSSINA HAILE WALTER P. MURPHY PROFESSOR OF MATERIALS SCIENCE AND ENGINEERING

NEXT STEPS

Haile's team is now exploring the use of a different class of ceramics as the backbone of this research, which could produce more hydrogen more rapidly. She is also working to perfect a fuel cell that uses a unique electrolyte created in her laboratory. The fuel cell fills in the second half of the energy cycle, using solar fuel to produce electricity on demand. For both projects, she hopes that combining science and engineering will produce devices that will have societal impact—and advance the materials science field for future generations.

"While I'm motivated to make a real difference to society, I also want to make sure to do the fundamental science," Haile says. "A technical solution may be great today, but there will always be a better invention tomorrow. So it's absolutely critical to advance underlying scientific principles that explain what we are able to achieve. This sort of insight is essential for enabling the inventions of the more distant future.

AMANDA MORRIS

Photograph by C. Jason Brown

Joseph Hinrichs ('17 P) from Ford, Chris Haas ('93, '98) from 3M, Mike Diamond, Dean Julio M. Ottino, Tiernan Murrell, Spencer Williams, and Christopher Winchester from Altec.

WE WILL.

THE CAMPAIGN FOR NORTHWESTERN

Northwestern University launched the multi-year We Will campaign in March 2014. Here are some recent notable gifts to Northwestern Engineering's campaign.

NEW MAJOR GIFTS

Bill Bliss ('87) and **Jeanne Bliss** pledged $120,000 to establish the Bill and Jeanne Bliss Visiting Professorship Fund. This gift will support a visiting professorship within the Department of Electrical Engineering and Computer Science.

Two estate gifts bolstered the Johannes and Julia Weertman Graduate Fellowship Fund in the Department of Materials Science and Engineering. **Stephen T. Gonczy** ('78) made a $120,000 estate gift, and **Mark S. Pucci** ('82) made a $150,000 estate gift.

Gwynne Shotwell ('86, '88 MS, '19 P) and **Robert Shotwell** have pledged $150,000 to support the McCormick Dean's Fund, establish the Gwynne and Robert Shotwell Fund for Mechanical Engineering, and help fund the new autobays for the Solar Car, Formula SAE, and Mini Baja teams.

Harold Smith ('57, '81 P, '16 GP) pledged $125,000 to the McCormick Dean's Fund.

Joy Thornton-Walter ('57, '61) made a $500,000 bequest provision in honor of her late husband, **John Thornton** ('63).

William Woodburn ('75) made a $100,000 gift to the McCormick Dean's Fund to help support the new autobays for the Solar Car, Formula SAE, and Mini Baja teams.

The Boeing Company made a $700,000 contribution to support the NUvention Transportation Fund in the Farley Center for Entrepreneurship and Innovation.

Thanks to these and thousands of other donors, Northwestern Engineering has raised more than $138 million of its $200 million campaign goal to date.

If you would like to join in making a special gift to the campaign, please contact Patrick Hankey, development director, at 847–467–2950 or patrick.hankey@northwestern.edu.

CONNECTING IN HONG KONG

More than 70 Northwestern alumni and friends gathered at The American Club in Hong Kong on January 21 for "Innovation at Northwestern." Hosted by Northwestern Engineering, the Northwestern Alumni Association, and the NU Club of Hong Kong, the event featured a cocktail hour, video presentation, and remarks from Dean Julio M. Ottino on Northwestern's efforts to implement cross-disciplinary activities to support innovation. Also in attendance was Medill School of Journalism, Media, Integrated Marketing Communications Dean Brad Hamm. The visit was part of Northwestern Connects, a series of networking events held on the same night in cities around the world.

CLASS NOTES

BUILDING ON A WHOLE-BRAIN FOUNDATION

AT WALSH CONSTRUCTION, **LAUREN KEELEY** ('10) TACKLES SOME OF THE COUNTRY'S BIGGEST CONSTRUCTION PROJECTS.

"MY WHOLE-BRAIN ENGINEERING EDUCATION MOTIVATES ME TO CHALLENGE ESTABLISHED BEST PRACTICES."

When she was studying civil engineering and economics at Northwestern, Lauren Keeley ('10) felt comfortable in the sprawling hallways and limestone walls of the Technological Institute. Now, as a member of the project management team at Walsh Construction, one of the nation's top contractors, she's building structures that dwarf Northwestern Engineering's landmark building.

How did you get your start at Walsh Construction? What is your role today?

I interned with Walsh the summer before my senior year at Northwestern and started full-time after graduation. As an assistant project manager in heavy/civil construction, I work with other managers, project engineers, superintendents, field crews, and designers. Together, we build from the ground up to deliver a quality project to the client.

You worked on the 2,100-foot long, cable-stayed Abraham Lincoln Bridge project to help connect Louisville, Kentucky with Jeffersonville, Indiana. What role did you play?

My primary responsibility was to manage construction of the reinforced concrete structures on the main span, the towers. I was involved in final design development and eventually the day-to-day construction of the three, 240-foot tall structures on the bridge.

I was also involved in planning, geometry control, quantity tracking, cost management, scheduling, material procurement, and subcontractor management—primarily on the main span, but also on the approach structures.

The support from the people of Louisville and Jeffersonville for the bridge has been remarkable. Nearly 50,000 people participated in a "Walk the Bridge" event before it officially opened to traffic. The hope is the six-lane bridge will ease vehicle congestion and revitalize economic development between the two cities in the years to come.

How has your background as a Northwestern engineer helped you in the construction industry?

In construction, decisions need to be made quickly, and any problems that arise need to be solved even quicker. When I have concrete trucks waiting to discharge, an inspector challenging the job details, and a crew waiting on me for direction, I simply say, "We'll make it work."

Fortunately, Northwestern taught me how to think and ask the right questions, a real benefit in a fast-paced environment. My whole-brain engineering education motivates me to challenge established best practices. At Walsh, I always look for more efficient and cost-effective ways to manage resources, or new approaches to improve collaboration with others—all to deliver a better end product.

Now that the Abraham Lincoln Bridge is complete, what's next for you?

I'm transitioning to a new role within Walsh to work on the Central Terminal Building Replacement Project at LaGuardia Airport in New York City. The project is one of the largest public-private partnership contracts in the country. While I expect to find some similarities to my work on the Abraham Lincoln Bridge, I'm looking forward to expanding my career experience into airport construction and building on what I've learned.

ALEX GERAGE

THRIVING IN THE VC WORLD

IN VENTURE CAPITAL FOR THE LAST THREE DECADES, **BRET MAXWELL** ('81) LEANS OFTEN ON THE ANALYTICAL SKILLS HE SHARPENED AT NORTHWESTERN.

For Bret Maxwell, engineering has never been about designing a tangible product or improving manufacturing processes.

Engineering is a mindset, insists 57-year-old Bret Maxwell. It's a way of thinking about the world and its possibilities that fits perfectly into his role as managing general partner at MK Capital, a Chicago-based venture capital firm that funds upstart companies in the cloud infrastructure, digital media, software, and educational technology sectors.

To date, MK Capital has invested upwards of $200 million in firms like GameFly, the nation's leading video game rental and subscription service; DramaFever, a leading online video platform for international television shows and movies; and Smoothstone, a cloud-based communications provider that scored a $120 million deal from West Corporation in 2011.

A former Entrepreneur-in-Residence at Northwestern and an advisory board member at Northwestern Engineering's Farley Center for Entrepreneurship and Innovation, Maxwell discusses his time at Northwestern and how his engineering education drives his investment success.

Was a career in business always the plan?

Not at all. I actually entered McCormick as a biomedical engineering major along with—it seemed—about two-thirds of the rest of my freshman class. In the late 1970s, you could only do one of two things with biomedical engineering: go to med school or teach biomedical engineering. During my freshman year, I volunteered 16 hours a week in the emergency room and operating rooms at Evanston Hospital and realized I didn't have the bedside manner to be a doctor.

How did you land in industrial engineering?

I was in the freshman engineering program and confessed to one of the professors that business was far more appealing to me than medicine. He suggested I switch to industrial engineering and consider the 3/2 program, which would allow me to earn my MBA from Kellogg after completing all of my engineering classes, in a total of 5 years. That suggestion turned out to have a profound impact on my life and career.

How does your engineering background apply to venture capital?

Above all, McCormick helped me develop the analytical skills to frame issues, which helps me better understand a business's potential. When you're investing in a business, that ability to analyze its prospects is not just important, it's critical. And once we have invested with an entrepreneur, those skills are very valuable in growing the business as well.

What do you most enjoy about the VC world?

Without a doubt, it's working with entrepreneurs who start as small businesses with nothing more than fire and passion, but who then turn their businesses into something much larger.

Take a company like ADAR IT, a bootstrapped firm founded by Northwestern Engineering alum Vadim Vladimirskiy ('02). Vadim has built his cloud-based infrastructure company into a fascinating business that's making significant headway, creating jobs, and solving real-world problems for many other companies. All of the businesses we invest in at MK Capital face ups and downs, but to watch them grow and succeed is a rewarding and remarkable process.

DANIEL P. SMITH

"ABOVE ALL, MCCORMICK HELPED ME DEVELOP THE ANALYTICAL SKILLS TO FRAME ISSUES, WHICH HELPS ME BETTER UNDERSTAND A BUSINESS'S POTENTIAL."

LEADING BY DESIGN

HUGH EKBERG (MMM '94)
HAS A TRACK RECORD OF TRANSFORMING BUSINESSES THROUGH ENGINEERING AND DESIGN THINKING.

Hugh Ekberg has thought like an engineer since he was a kid, when he and his brothers would spend hours tearing down engines for fun and rebuilding them to make go-karts and minibikes.

"Taking apart your own toys to fix them was something you did for enjoyment," Ekberg remembers. "I've always been a tinkerer; I like to understand how things work."

Ekberg's passion and aptitude for engineering and design thinking has taken him from building go-karts to building businesses as president of Kitchen & Bath Americas at Kohler Co., one of the oldest and largest privately held US companies and an industry leader in kitchen and bath products.

Headquartered in Kohler, Wisconsin, the company has come a long way since the days when its founder first covered hog scalders in enamel and marketed them as bathtubs. Ekberg's challenge is to lead the well-established brand in adapting to the demands of today's ever-changing marketplace.

"The advent of the Internet and consumers' greatly enhanced ability to gain information and form opinions are very powerful forces," Ekberg says. "We need to make sure we're interacting with the customer in that space and changing our mindset for how we communicate, how we serve, and the experiences our products deliver."

This atmosphere of change makes "the world of toilets, showers, faucets, and sinks quite exciting" for an engineer who has always had management dreams.

A HEAD FOR BUSINESS

After graduating from MIT with a degree in mechanical engineering, Ekberg made a decision that would change the course of his career. Instead of taking one of the offers he received for engineering positions, he joined Procter & Gamble (P&G) as a production manager.

"I went directly into the manufacturing world," he says. "You use your engineering education constantly in that space."

Applying his knowledge to the company's liquid laundry detergent business, Ekberg coordinated new product development launches for brands such as Tide and Era. During critical-path meetings at manufacturing facilities, he identified a gap in his financial analysis and marketing strategy skill sets.

"I found it frustrating that I couldn't contribute much to the conversation because I didn't have enough expertise in those broader business areas," he remembers. "I decided I needed to fast-track my knowledge base."

Although Ekberg had developed a deep respect for operations and manufacturing at P&G, the experience convinced him that he wanted to pursue a general management path. He looked at universities that offered joint master's programs in business and engineering for those wanting to pursue business leadership roles in manufacturing companies.

He felt Northwestern's dual-degree MMM Program, which at the time awarded an MBA from Kellogg and a Master of Engineering Management from McCormick, was the best complement to the experience and education he already had. The program was still somewhat new, and Ekberg enjoyed the opportunity to help shape the program in its early stages.

"We were a little outside the norm," he recalls. "There was a core group of us who knew we wanted to stay in the world of manufacturing and operations, but we wanted to be business leaders. We were part of creating something that continues to evolve and become better."

IDENTIFYING OPPORTUNITY

Seeking a leadership role, Ekberg turned his focus to the private equity space after Northwestern, joining American Industrial Partners and serving as corporate manufacturing manager of Easco Aluminum, one of its portfolio companies. "It was a chance to get a higher-level position with more authority, more decision-making power, and more ability to truly influence the business," he explains.

The company was considering going public, which provided great learning experience for Ekberg, who was challenged to improve Easco's operational efficiency. The position afforded him what he was looking for—responsibility and decision-making authority.

After that company went public, Ekberg began looking for new challenges, and in 1995 joined Hirsh Industries, a manufacturer and marketer of home and office organization and storage products. Over the next five years, during a period of rapid growth, he rose from head of operations to president.

"We went from being a $25 million company to about $120 million in four years, through both organic growth and acquisitions," he says. "It was outstanding experience in terms of running a business."

Always seeking to stretch himself, Ekberg looked for opportunities to buy his own company after ten years at Hirsh. A search firm suggested he talk to The Weitz Company, a general contractor, design-builder, and construction manager trying to decide what to do with a business it had purchased. Not exactly what Ekberg was looking for, the company and its management team so impressed him that in 2006 he made the "crazy decision to go join a construction company" as supply chain president, and ended up on the company's board of directors.

Although it was an industry Ekberg knew little about, he considers the move one of his best decisions. "It reminded me that the most important thing you can do as a business leader is continue to learn and improve," he shares. "The best way to do this is put yourself in uncomfortable situations, because that's where you're going to grow and advance. If you work hard and deliver results, you're going to get opportunities to take on new challenges."

"THE ENGINEERING DISCIPLINE IS A TURBO BOOSTER TO CREATIVITY, IN TERMS OF BEING ABLE TO THINK ABOUT WHAT'S POSSIBLE AND WHAT CAN BE DONE DIFFERENTLY."

That next opportunity came calling in 2011 when a recruiter from Kohler contacted him. "I knew in my heart of hearts that I was a brand guy—I never got that out of my system ever since P&G," he says. "It was a pretty easy decision to join a great company with a great brand like Kohler."

TRANSFORMATION THROUGH DESIGN

Believing nothing is perfect, Ekberg applies the lessons he learned at Northwestern to identify problems and opportunities for improvement at Kohler.

"The engineering discipline is a turbo booster to creativity, in terms of being able to think about what's possible and what can be done differently," he explains. "In business today, the need for constant transformation becomes more and more a requirement for success."

Ekberg has applied design thinking and systematic problem-solving throughout his career. What he enjoys most at Kohler is using that approach to build strong teams that maximize individual strengths to achieve shared goals.

"Design thinking doesn't just involve designers or engineers or marketers and it doesn't just involve products—it requires all the disciplines challenging each other and working together to design solutions to complex business and product opportunities," he says. "Design thinking isn't about getting to quick solutions; it's about exploring what's possible. That's the real power and benefit."

His passion for design has led him to serve on the board of Northwestern's Master of Product Design and Development Management Program. As a proud Northwestern Engineering alumnus, he wants to contribute something to the university that gave him so much. As a businessman, staying connected to the University is critical for his continued development.

"I enjoy the exposure to the design community and the design world," he says. "It's a group of people with outstanding minds and ways of thinking that are different from mine. I want to continue to hone my ability to think like a designer because it enhances my ability to think like an engineer and be a better business leader."

SARA LANGEN

A BEAUTIFUL DAY IN THE NEIGHBORHOOD

MICHAEL CRUZ ('02) helps fuel the ascent of Trunk Club with a mixture of technological expertise, entrepreneurial drive, and customer focus.

As a child growing up in Guam, Michael Cruz ('02) became fascinated with the manufacturing process while watching *Mister Rogers' Neighborhood*.

"Mr. McFeely, the *Neighborhood* mail carrier, would play a videotape showing how something was made, and I would be amazed at how everyday things could be created automatically," Cruz says.

Fast forward to his days as an industrial engineering major at Northwestern, where Cruz's fascination with process intensified as he embraced courses on logistics and optimization.

Today, Cruz has parlayed his childhood fascination and undergraduate studies into an executive role at the personal shopping service Trunk Club. There Cruz blends his technical acumen and earnest entrepreneurial spirit to help fuel Trunk Club's evolution as a powerful retail brand. The Chicago-based service connects customers with a personal stylist, who ships them a selection of handpicked clothing. Customers then have 10 days to decide what to keep and what to send back.

"I've learned that as much as I love programming and processes, I love building teams and companies even more," says Cruz, Trunk Club's vice president of engineering.

That self-realization began taking root at Northwestern.

An engineering entrepreneurship class with Professor William White ignited Cruz's deeper passion in business. Along with two fraternity brothers, Cruz launched his first entrepreneurial venture, a DVD rental store at the Norris Center on the Evanston campus. Although the enterprise eventually withered in the shadow of Netflix, Cruz relished the experience.

"Anytime you have ambiguity, that's the fun," Cruz says. "That's when you learn a lot about yourself and what it takes to thrive."

In fact, it was the prospect of ambiguity that encouraged Cruz to apply to Trunk Club's job posting on Craigslist that simply read, "Engineer." Intrigued by the company's prospects, and even more by its people, Cruz joined Trunk Club in November 2011 as its first engineer.

At the time, the two-year-old company was struggling to secure stable footing. The company had only a few dozen employees and, according to Cruz, "nascent" technology.

Cruz immediately set about to elevate Trunk Club. He led several iterations of technology to arrive at the current user experience, learning how to apply innovative retail and e-commerce models to IT, how to deal with post-merger integration following Nordstrom's 2014 acquisition of Trunk Club, and how to hire and motivate a growing technology team, which now numbers 70.

And he accomplished it all while maintaining Trunk Club's signature brand of personalized service. "Even while we're scaling, the customer relationship has to feel rich and personal, and that makes for a massive technical challenge," Cruz admits.

Though he faces a multi-faceted and complex challenge, touching everything from the user interface to supply chain, operations, and finance, Cruz has embraced that challenge and stands as a key player in Trunk Club's continued development. The company now employs more than 1,300 and has been growing steadily year over year.

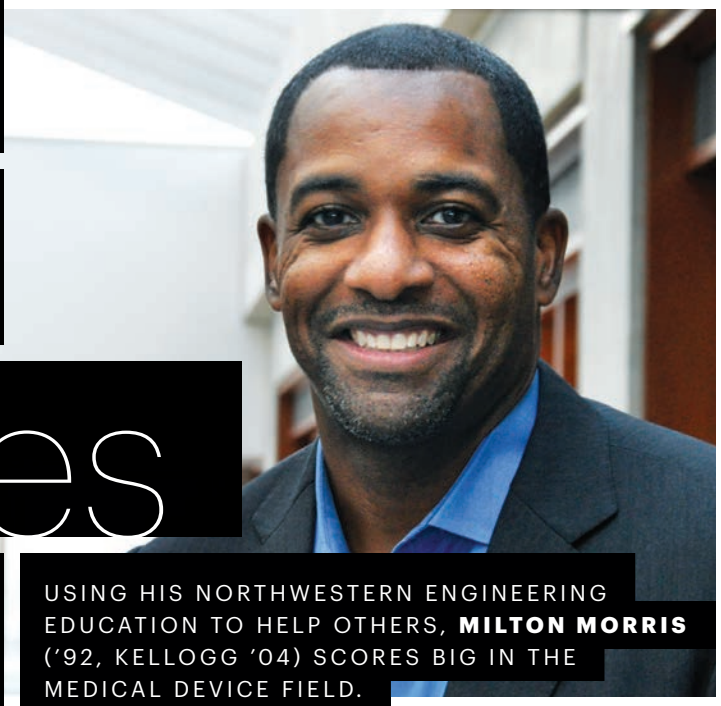
"It's exciting to know I played a role in helping Trunk Club get here," Cruz says.

Mr. McFeely would be impressed.

DANIEL P. SMITH

"ANY TIME YOU HAVE AMBIGUITY, THAT'S THE FUN. THAT'S WHEN YOU LEARN A LOT ABOUT YOURSELF AND WHAT IT TAKES TO THRIVE."

When Plan B Becomes Plan A



USING HIS NORTHWESTERN ENGINEERING EDUCATION TO HELP OTHERS, **MILTON MORRIS** ('92, KELLOGG '04) SCORES BIG IN THE MEDICAL DEVICE FIELD.

A talented high school athlete, Milton Morris often found himself pulled out of class by a college recruiter or coach trying to persuade him to play football at one university or another. As he considered the scholarships and financial aid offers coming in from around the country, a teacher gave him advice that changed everything.

Morris recalls, "She said, 'I really hope you go to Northwestern; football is a very difficult thing to do professionally, and if you went to Northwestern, it would open up opportunities that you'd never have at some of those other schools.' Her advice stuck with me."

Although Northwestern's football team may have been less of a gridiron powerhouse compared to some other schools, Morris felt that playing in the Big Ten Conference would give him the chance to prove to himself whether professional football was a possibility. And if it wasn't, he knew Northwestern would equip him to pursue a different dream.

"I poured everything I had into my books, so that when I graduated, engineering would be an option as well," he says. "So plan B really became plan A, and it's been a good one for me ever since."

A NATURAL FIT

Today, Morris applies the persistence and diligence he learned at Northwestern to guide him as president and CEO at NeuSpera Medical Inc., a startup medical device company. It's a natural fit for Morris, who grew up hanging out at the Cleveland Clinic, where his mother was a hematology lab supervisor for 27 years. After college, he earned a PhD in electrical engineering from the University of Michigan, where he worked in a medical engineering lab specializing in signal processing and algorithm development for implantable devices.

Continuing to use his engineering expertise to help others, Morris held high-level roles at several medical device companies, including senior vice president of research and development at Cyberonics, director of program management and operations at InnerPulse, and director of marketing at Boston Scientific. "Once you get into the business of extending and improving lives through your engineering ideas or the ideas of the teams you lead, it's very difficult to step away," he says.

THE INFLECTION POINT

Morris is leading NeuSpera's efforts to secure Series A financing for its miniaturized injectable neuromodulation technologies. Guiding the startup through this phase is a new adventure involving long hours, but it doesn't feel like work to Morris. "It's been everything I thought it could be—exciting and challenging at the same time."

Reflecting on his achievements, his thoughts return to Northwestern. Morris serves on the McCormick Advisory Council because he wants to help the school continue to offer students a place where they can achieve more than they ever thought possible.

"My entire expectation for myself changed in those four years at Northwestern," he shares. "Beyond just the engineering, which is fantastic, there was the self-perception and the level of expectation for what I should be able to do going forward. Now when I look back and think how did I get here, I always go back to Northwestern and say, 'It was then, that was the inflection point.'"

SARA LANGEN

IN MEMORIAM

TRANSPORTATION SCHOLAR AARON GELLMAN

Gellman had a "deep appreciation of the interplay of technology, economics, and policy"

Aaron J. Gellman, a transportation scholar, aviation expert, and former director of the Northwestern University Transportation Center, died January 11, 2016, at age 85.

In demand by the government, industry, and the media for his wide-ranging expertise, Gellman had more than 50 years of experience as an economist, strategist, consultant, and academic in the transportation industry. His research focused on transportation economics, regulation, and policy.

Gellman was a professor of management and strategy at Northwestern's Kellogg School of Management and a professor of industrial engineering and management sciences at the McCormick School of Engineering and Applied Science. Gellman joined the Northwestern faculty in 1992 and retired in 2014.

"Aaron was an intellectual powerhouse and a visionary with a deep appreciation of the interplay of technology, economics, and policy in the transportation industry," said Hani S. Mahmassani, current director of the Transportation Center.

"He also was an influential mentor and friend to many. Aaron will be missed by his friends, colleagues, and the wider transportation community who valued his expertise and enthusiasm," said Mahmassani, who also is the William A. Patterson Distinguished Chair in Transportation.

Gellman served as director of the University's Transportation Center from 1992 to 2000. Under his leadership, Chambers Hall, the Center's present home, was built and inaugurated in 1999. After his tenure as director, he became a professor of transportation at the Center.

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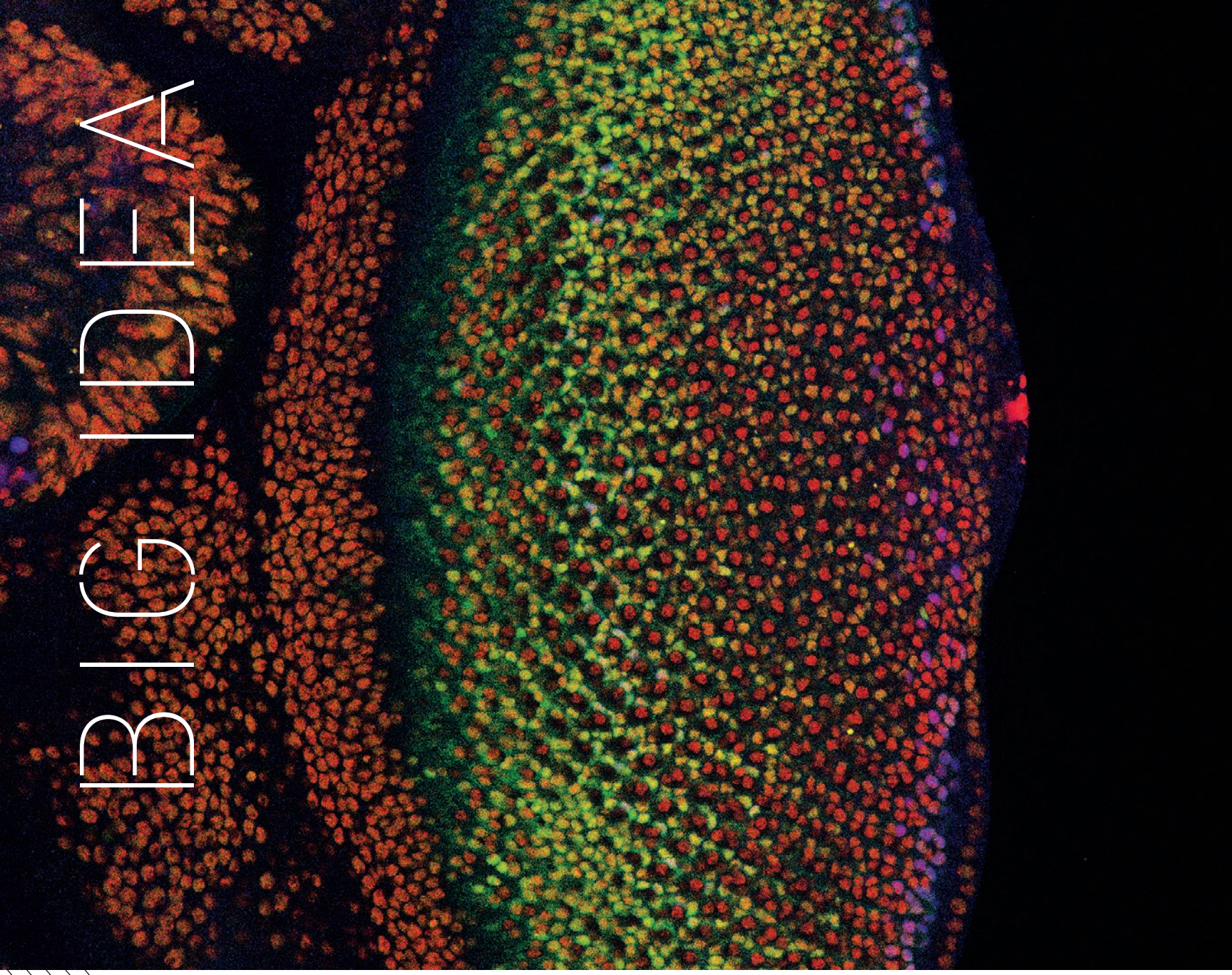
PROFESSOR WEI-CHUNG LIN

Wei-Chung Lin, associate professor of electrical engineering and computer science, passed away April 22. He was 63. He joined Northwestern in 1986 and made contributions to the fields of computer vision and computer graphics. He held a doctorate in electrical engineering from Purdue University. "Professor Lin was a colleague and friend to many and contributed significantly to research in medical image reconstruction," said Alan Sahakian, chair of the department.

BIG IDEA



IN THE BLINK OF AN EYE

Cancer cells are normal cells that go awry because of bad developmental decisions during their lives. By studying the fruit fly's eye, Northwestern researchers have gained insight into how developing cells switch to a specialized state and how this process might go wrong in cancer.

The fruit fly's eye (pictured above) is an intricate pattern of many different specialized cells, such as light-sensing neurons and cone cells. Led by Northwestern Engineering's Luís A.N. Amaral and biologist Richard W. Carthew, a multidisciplinary research team discovered that the levels of an important protein, called Yan, fluctuate wildly when a cell is switching from a more primitive state to a more specialized state. If the levels do not or cannot fluctuate, the cell does not switch and become more specialized.

The researchers also found that a molecular signal received by a cell receptor, called EGFR, is important for turning off the fluctuations, or noise. If that signal is not received, the cell remains in an uncontrolled state. By pinpointing this noise and its "off" switch, the research team can provide targets for scientists studying how cells can lose control and transform into cancer cells.

"Studying the dynamics of molecules regulating fly-eye patterning can inform us about human disease," said Nicolás Peláez, first author of the study and a PhD candidate working with Amaral and Carthew. "Using model organisms such as fruit flies will help us understand quantitatively the basic biological principles governing differentiation in complex animals."

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CS ON STAGE

Professor Ian Horswill stands before a class of nearly 350 students who are hungry to learn the ins and outs of coding. The popularity of the "CS 111: Fundamentals of Computer Programming" course mirrors students' booming interest in the burgeoning field. At Northwestern alone, the number of computer science majors has tripled in just the past five years. And the class attracts more than just the majors. CS 111 is the most popular class for non-majors, who come from nearly every school within the University.
See story page 28.

Photograph by Sally Ryan