UNIVERSITY OF PENNSYLVANIA / SCHOOL OF ENGINEERING AND APPLIED SCIENCE

Penn Engineering

ENGINEERING THE FUTURE OF FARMING

FALL 2023

CONTENTS

UP FRONT

ON CAMPUS

PENN ENGINEERING MAGAZINE

alumni@seas.upenn.edu
215-898-6564
www.seas.upenn.edu

Vijay Kumar
Nemirovsky Family Dean

Eleanor Brown Davis
Vice Dean, Development and Alumni Relations

EDITOR
Olivia J. McMahon

DESIGN
Landesberg Design

PRINTING
Brilliant Graphics

PHOTOGRAPHY AND ILLUSTRATION
Ryan Allen
Leslie Barbaro
Jay Fram
Kevin Monko
Alex Nabaum
Jeff Wojtaszek

COVER
Illustration by
Mark Frederickson

The future of farming as envisioned by researchers in the Internet of Things for Precision Agriculture, or IoT4Ag, Center is one where technology collects, communicates and harnesses real-time data to efficiently deploy resources and improve crop yields with the least possible impact on the environment.

FEATURES

Vijay Kumar
Nemirovsky Family Dean

FROM THE DEAN

Unprecedented Growth

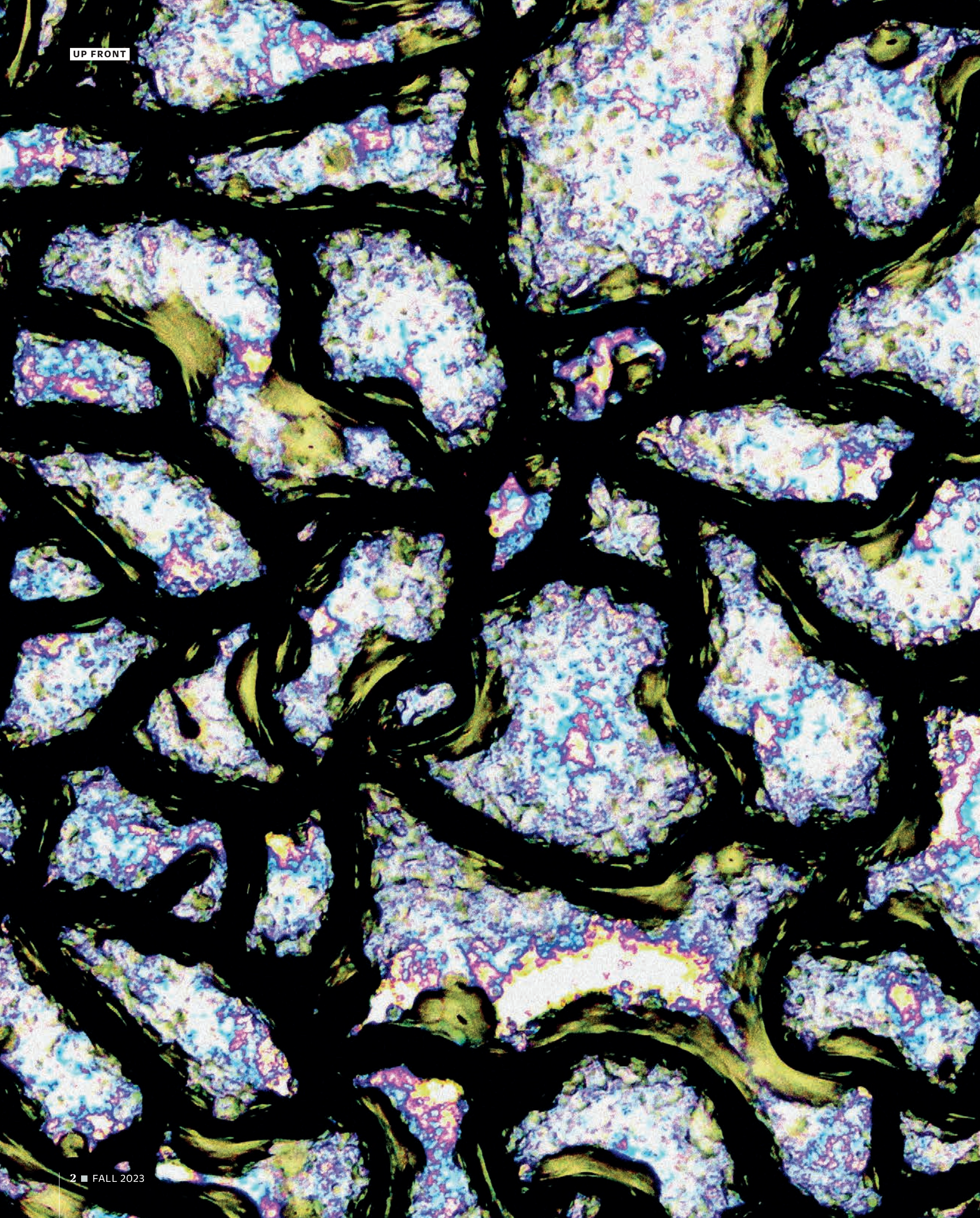
The past year has been exceptional for Penn Engineering. When welcoming our new students to campus at the beginning of the semester, I was proud to note that they have joined the School at the most exciting time in its history.

This year, we topped off not one, but two new buildings. In February, we celebrated the placement of the final steel beam on the new Vagelos Laboratory for Energy Science and Technology, or VLEST. Then in July, the completion of the mass-timber structure of Amy Gutmann Hall was joyfully observed. In a further expansion of the School's footprint, work on the new lab space for the Center for Precision Engineering for Health began with a ribbon-cutting ceremony in August.

These facilities, along with the record numbers of faculty we are recruiting to Penn Engineering, reflect our investments in areas that are critical to the future of humanity. Together, they represent the future of leading-edge research in our three Signature Initiatives: Energy and Sustainability, Data Science and Engineering Health. The opportunities created by these new spaces will impact education and research at Penn for decades to come.

Of the three initiatives, Energy and Sustainability represents our response to the biggest challenge of this century. I speak of course of climate change. Of the many efforts in the School in this space, as you page through this issue, I hope you will take the opportunity to learn about the Internet of Things for Precision Agriculture, or IoT4Ag, Center. The innovation produced in just three years by this $26 million NSF center, particularly in biodegradable sensors and batteries, is extraordinary. IoT4Ag shows the rapid progress that is possible through multidisciplinary collaborations toward a common goal.

This unprecedented growth and continued success for Penn Engineering is due in large part to the ongoing strength and support of our global community. The generosity and involvement of our alumni and friends demonstrate confidence in the ability of our students and faculty to change the world. I am gratified to know that this community is united by a single purpose: to analyze and create solutions for the world's most pressing problems so that we may each leave the School, and the world, a better place for having been a part of it.



THE BIG PICTURE

Nano Stained Glass

When William Powell, former lead nanotechnologist for NASA's Goddard Space Flight Center, said "nanotechnology is manufacturing with atoms," it is doubtful he meant to include the manufacture of art in that sentiment.

However, it was while Matthew Campbell, Research Assistant Professor in Mechanical Engineering and Applied Mechanics (MEAM), was working to develop highly reflective, lightweight films for laser-powered interstellar travel that the image you see here was created, albeit by accident.

As part of the Breakthrough Starshot Initiative, Campbell, then a postdoctoral researcher in the lab of MEAM Associate Professor Igor Bargatin, was collaborating to develop materials for a sail pushed not by wind, but by laser light. Such a sail could carry a microchip-sized probe at a fifth of the speed of light, fast enough to make the trip to neighboring star Alpha Centauri in roughly 20 years, rather than millennia.

Together with Pawan Kumar, a former postdoctoral researcher in Materials Science and Engineering (MSE) and Electrical and Systems Engineering (ESE), Campbell was fabricating the lightweight film prototypes using nanoscopically thin materials.

"One of our prototypes became corroded during a fabrication step and looked like this under the optical microscope," says Campbell. "The brightly colored regions are probably the result of nanometer-scale differences in the film's thickness, and the dark outlines may be caused by tiny cracks or surface roughness where the light isn't reflected as strongly."

The light sail work is a collaboration between the labs of Bargatin, Eric Stach, Robert D. Bent Professor of Engineering in MSE and Director of the Laboratory for Research on the Structure of Matter, and Deep Jariwala, Associate Professor and Peter and Susanne Armstrong Distinguished Scholar in ESE.

BREAKTHROUGHS

Targeting Pre-Eclampsia Helps To Close Gap in Health Equity

BY Melissa Pappas

Michael Mitchell

Kelsey Swingle

PRE-ECLAMPSIA IS A LEADING CAUSE of stillbirths and preterm births worldwide, occurring in 3% to 8% of pregnancies. A disorder characterized by high blood pressure in pregnancy, it results from insufficient vasodilation in the placenta, restricting blood flow to the fetus.

Currently, a health care plan for patients with pre-eclampsia involves diet and movement changes, frequent monitoring, blood pressure management, and can mean early delivery of the baby. These standards of care address symptoms of the condition, not the root cause, and further perpetuate inequities that stem from a lack of health care access.

A team of researchers, led by Michael Mitchell, Associate Professor in Bioengineering, and Kelsey Swingle, lead author and doctoral student in the Mitchell Lab, is hoping to close this longstanding gap in reproductive health care with targeted RNA, which could one day address the lack of therapeutics to stop or slow the progression of pre-eclampsia once it is diagnosed.

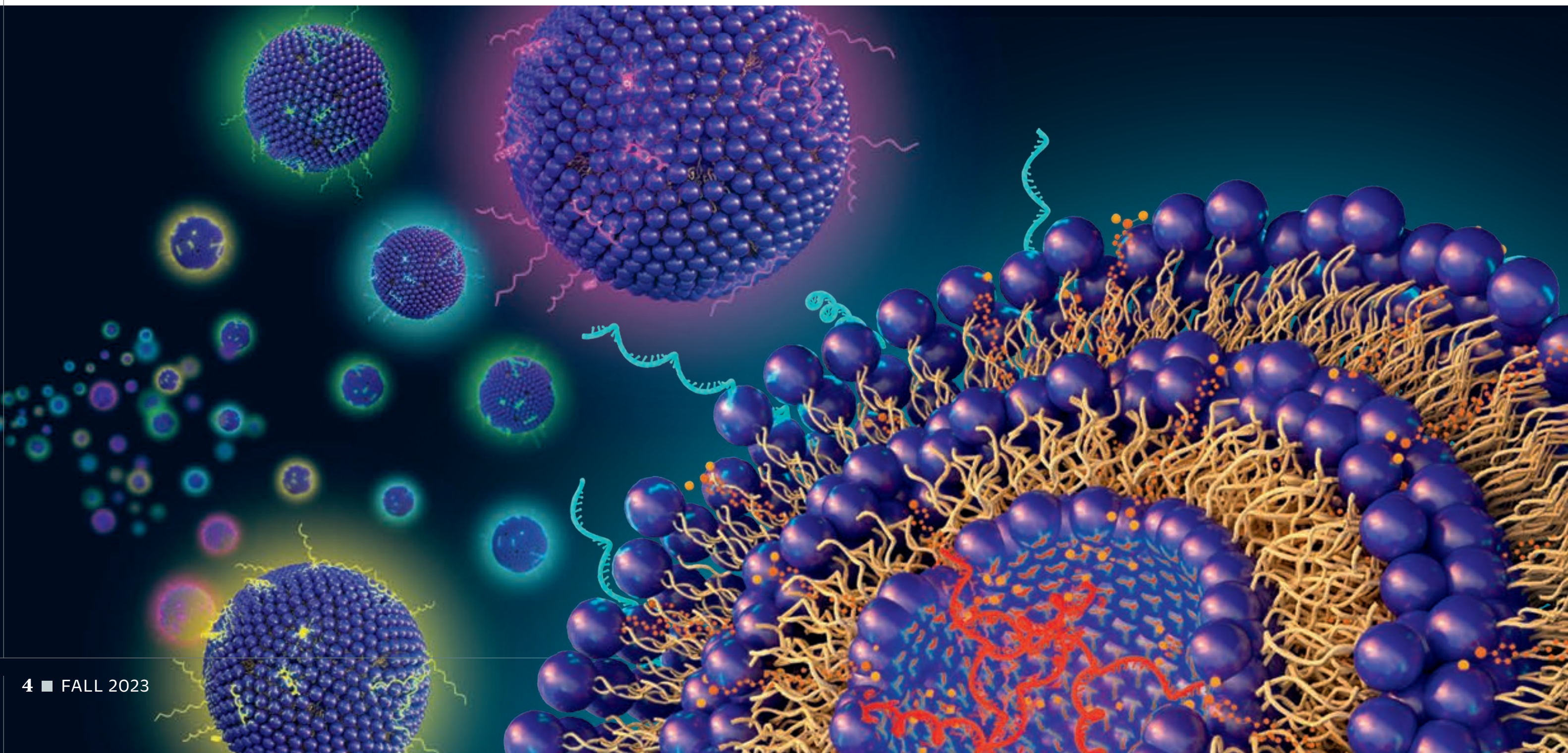
"Current health care for patients with pre-eclampsia is lacking," says Swingle. "Many times, the only thing doctors have been able to do is plan for an early delivery, resulting in premature birth, which comes with associated challenges. The status quo only worsens the health of patients and their babies in instances where prenatal and premature care are limited."

The development of the COVID vaccines demonstrated how lipid nanoparticles (LNPs) efficiently deliver mRNA to target cells. The success of LNPs is opening doors for a variety of RNA therapies aiming to treat the root causes of illness and disease. However, drug development and health care have consistently neglected a portion of the population in need of targeted care the most: pregnant people and their babies.

In one of the first studies of its kind, the Penn Engineering team developed an LNP with the ability to target and deliver mRNA to trophoblasts, endothelial cells and immune cells in the placentas of pregnant mice.

Once these cells receive the mRNA, they create vascular endothelial growth factor (VEGF), a protein that helps expand the blood vessels in the placenta to reduce blood pressure during pregnancy and restore adequate circulation to the fetus. The researchers' successful trials in mice may offer a promising future for pre-eclampsia treatments in humans.

RYAN ALLEN



> “In pre-eclampsia, babies that are born early can be affected with stunted or abnormal growth and physiological development. A treatment that resolves the issue at the source would allow for higher quality of life and health for patients and their babies over the long term. Addressing this research gap is one way I can be an advocate for women’s health equity.”
>
> Kelsey Swingle

This is the first time LNP-assisted delivery of mRNA to the placenta has been shown.

“With no previous research to start from, our first challenge was to figure out which LNPs would actually travel to and target the placenta,” says Swingle. “We started by creating a library of LNPs using our knowledge from the work we did on LNP delivery to the liver. It turns out the liver and the placenta are actually very similar. They both receive high blood flow and contain intricate trees of blood vessels.”

By pairing a subject’s natural blood flow to the womb with a highly specific ionizable lipid in the LNP, the research team was able to target and deliver VEGF to placental cells in pregnant mice via a simple tail vein injection.

“The COVID vaccines were administered as intramuscular injections, a shot in the arm,” says Swingle. “This treatment would be administered intravenously. That means a patient would be able to be treated via a simple, noninvasive, and pain-free IV drip.”

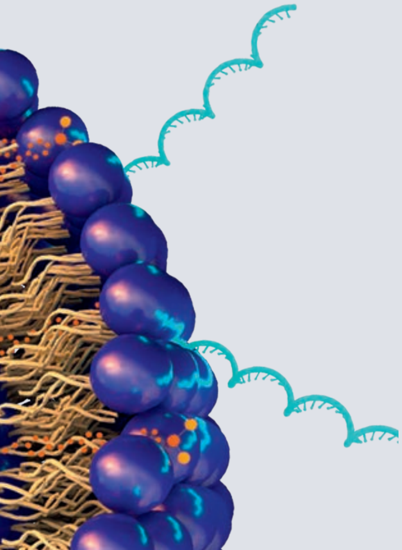
Pregnant people were neglected in the clinical trials for the COVID vaccines, leaving many uncertain about how to safeguard their health and that of their babies. This oversight is not new. The majority of drugs on the market have not been tested in pregnancy, and disorders during pregnancy are frequently untreatable before birth.

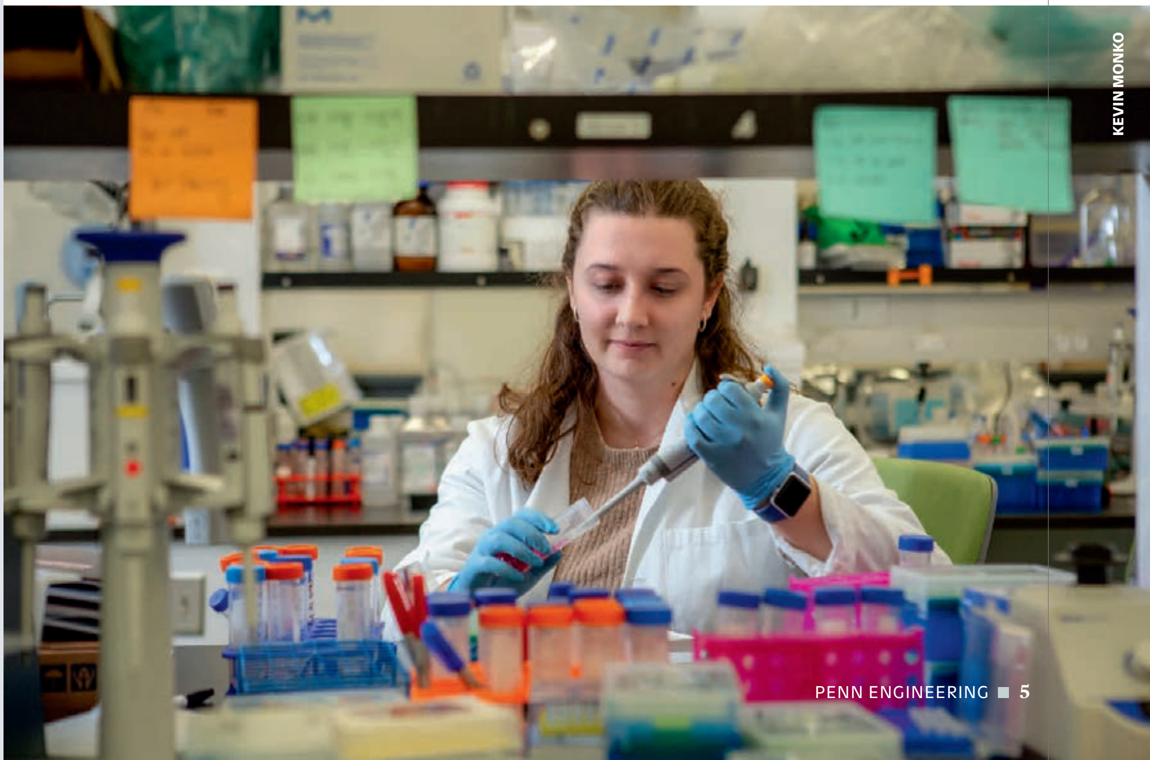
The treatment presented in this groundbreaking study contributes to addressing health inequities for women, a major motivator for Swingle.

“I was inspired to research targeted therapies for maternal and fetal health in the spring of 2021 when people were making decisions about getting the COVID vaccine and patients had questions about safety that we could not answer,” she says. “In pre-eclampsia, babies that are born early can be affected with stunted or abnormal growth and physiological development. A treatment that resolves the issue at the source would allow for higher quality of life and health for patients and their babies over the long term. Addressing this research gap is one way I can be an advocate for women’s health equity.”

The new approach to LNP development for RNA therapies is also opening new doors for hard-to-treat diseases. This study is just one example of where this work is headed.

“Researchers have been doing a lot of work on the mechanisms and movements of drugs into cells, but there is not a lot out there on how therapies can be targeted to treat the root cause of diseases and conditions, particularly during pregnancy,” says Mitchell. “We now have a new LNP platform and can plug and play different RNA therapeutics to begin to develop successful therapies for many pregnancy conditions. This work is leaping off that platform, and we are excited to take the next steps.”

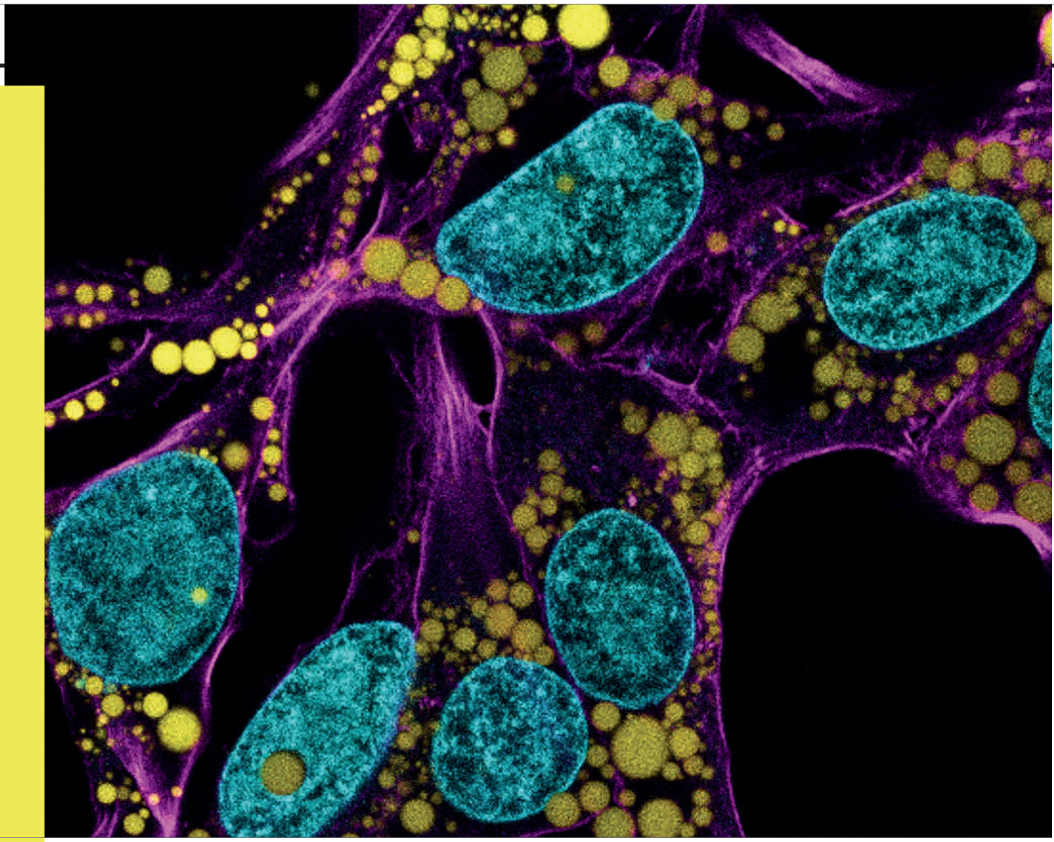




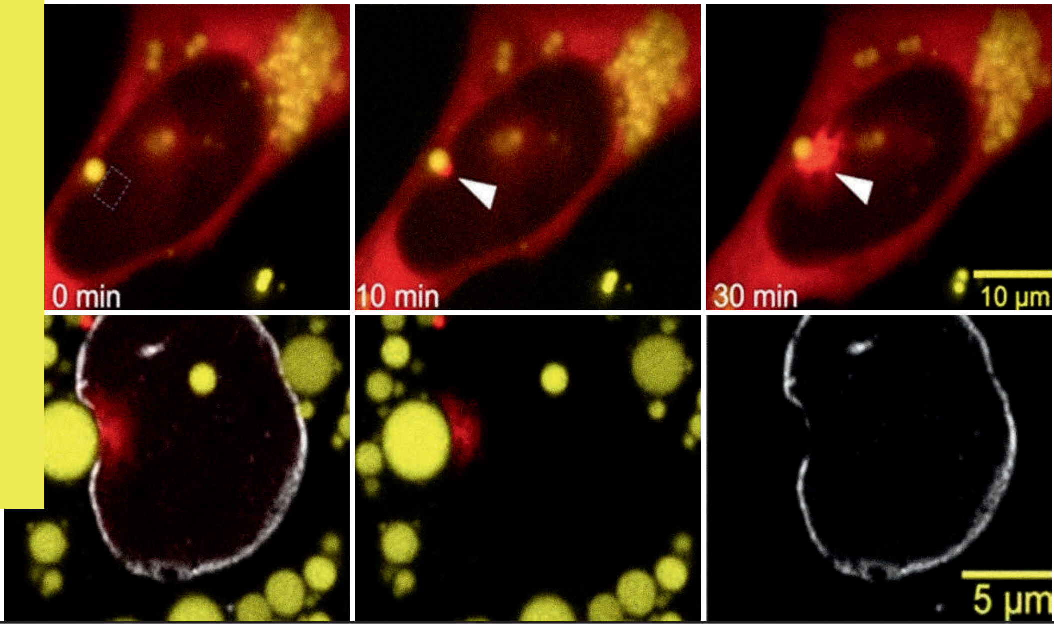
KEVIN MONKO

Fat Droplets Reveal DNA Danger

THE FAT-FILLED LIPID DROPLETS (pictured in yellow) found inside different cell types are tiny spheres many times smaller than actual fat cells. The lab of Dennis E. Discher, Robert D. Bent Professor in the Departments of Chemical and Biomolecular Engineering, Bioengineering, and Mechanical Engineering and Applied Mechanics, is the first to discover these droplets' surprising capability to indent and puncture the cell nucleus, the organelle that contains and regulates a cell's DNA. This groundbreaking work on the physics of these droplets reveals them to be a potential cause of the elevated DNA damage that is characteristic of many diseases, including cancer.



"Intuitively, people think of fat as soft," says Discher. "And on a cellular level it is. But at the small size of a droplet, it stops being soft. It can deform. It can damage. It can rupture."



INSIDE ENGINEERING

BIOENGINEERING

New Single Cell Analysis Tool

The lab of Arjun Raj, Professor, has developed ClonoCluster, an open-source tool that combines unique patterns of gene activation with clonal information, producing hybrid cluster data that can quickly identify new cellular traits that can be used to better understand resistance to some cancer therapies.

CHEMICAL AND BIOMOLECULAR ENGINEERING

Glassy Discovery

Work from Professors John Crocker and Robert Riggleman has shown that metadynamics, a computational approach to exploring energy landscapes, can be used to find rare low-energy canyons in glassy materials. This may have a wide range of useful applications, potentially reducing the computational cost of training future AIs.

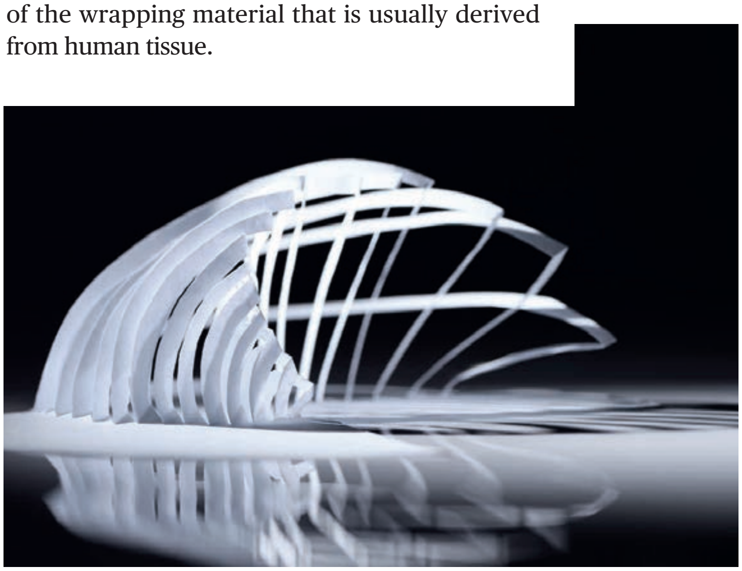
COMPUTER AND INFORMATION SCIENCE

Securing the Census

Michael Kearns, National Center Professor of Management & Technology, and Aaron Roth, Henry Salvatori Professor of Computer & Cognitive Science, have demonstrated that U.S. Census statistics can be reverse-engineered to reveal protected information about individual respondents, affirming the need for enhanced "differential privacy" measures to protect personal data.

Using Kirigami in Breast Reconstruction

FOR BREAST CANCER PATIENTS WHOSE treatment includes mastectomy, complications caused by implant malposition can arise following reconstructive surgeries. In order to keep implants in place more effectively, the lab of Shu Yang, Joseph Bordogna Professor and Chair of Materials Science and Engineering, has used a papercutting technique known as kirigami to cover implants, shown here in a reconstruction model with a seamless architecture pattern made of white paper. Together with computational modeling, kirigami can provide surgeons with an easier-to-use, stretchable material that can better wrap around implants, thereby reducing the risk of malpositioning while also reducing the demand of the wrapping material that is usually derived from human tissue.



Understanding the Movement of Cholera

THOUGH ADVANCES IN SANITATION HAVE had a major impact in reducing infections from waterborne pathogens such as cholera, the illnesses remain a challenge, especially for populations without access to reliable sanitation infrastructure. Work led by Paulo Arratia, Professor in Mechanical Engineering and Applied Mechanics, uses fluid mechanics to understand and predict the movement of microscopic bacteria through flowing water. The group's computational simulations and experiments with *Vibrio cholerae* create a path for technologies that both contain and disburse masses of bacteria before they can pose a threat to humans, laying the foundation for water security interventions.

ELECTRICAL AND SYSTEMS ENGINEERING

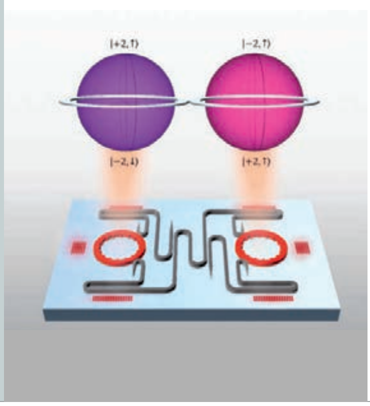
Network Theory in Public Health

Shirin Saeedi Bidokhti, Assistant Professor, and Saswati Sarkar, Professor, have applied techniques from network and information theory to pandemic control and prevention, demonstrating the potential to deliver life-saving benefits while accommodating unequal access to medical resources, reluctance, budgetary constraints, testing errors and local practices.

MATERIALS SCIENCE AND ENGINEERING

New Quantum Chip

The lab of Liang Feng, Professor, has created a chip containing a hyperdimensional microlaser that outstrips the security and robustness of existing quantum communications hardware. Their technology communicates in "qudits," doubling the quantum information space of any previous on-chip laser and makes for robust quantum communication technology better suited for real-world applications.



MECHANICAL ENGINEERING AND APPLIED MECHANICS

Squeezing Molecules To Reduce Waste

Robert Carpick, John Henry Towne Professor, has collaborated to produce a novel mechanochemistry method to manufacture existing and even new industrial chemicals that uses organic chemistry and nanotechnology to push molecules together, creating those chemicals without the need for costly solvents that pollute the environment.

IN QUESTION

Can Humans Learn To Spot Fake Text?

BY Devorah Fischler

Daphne Ippolito

Liam Dugan

Chris Callison-Burch

You can play *Real or Fake Text?* at roft.io:

THE MOST RECENT GENERATION OF chatbots has surfaced longstanding concerns about the growing sophistication and accessibility of artificial intelligence.

Fears about the integrity of the job market — from the creative economy to the managerial class — have spread to the classroom as educators rethink learning in the wake of ChatGPT.

Yet while apprehensions about employment and schools dominate headlines, the truth is that the effects of large-scale language models such as ChatGPT will touch virtually every corner of our lives. These new tools raise society-wide concerns about AI's role in reinforcing social biases, committing fraud and identity theft, generating fake news, spreading misinformation and more.

A team of researchers, led by Chris Callison-Burch, Associate Professor in Computer and Information Science (CIS), is seeking to empower tech users to mitigate these risks. In the largest-ever human study on AI detection, the group demonstrated that people can learn to spot the difference between machine-generated and human-written text.

"We've shown that people can train themselves to recognize machine-generated texts," says Callison-Burch. "People start with a certain set of assumptions about what sort of errors a machine would make, but these assumptions aren't necessarily correct. Over time, given enough examples and explicit instruction, we can learn to pick up on the types of errors that machines are currently making."

"AI today is surprisingly good at producing very fluent, very grammatical text," adds Liam Dugan, a doctoral student in the Callison-Burch Lab. "But it does make mistakes. We prove that machines make distinctive types of errors — common-sense errors, relevance errors, reasoning errors and logical errors, for example — that we can learn how to spot."

The study leverages data collected using *Real or Fake Text?*, an original web-based training game developed by the team.

Daphne Ippolito, the study's co-leader and a former doctoral student in the Callison-Burch Lab, originated the idea for *Real or Fake Text?* while co-teaching a special topics course on text generation with Callison-Burch during the spring of 2020. Ippolito suggested to Dugan, then a master's student in the course, and fellow student Arun Kirubarajan that the duo develop a gamified platform for detecting generated text as their final project. "After Arun and I finished the project and seeing its potential, Daphne worked with us to flesh it out into a bona fide research paper," says Dugan.

Real or Fake Text? transforms the standard experimental method for detection studies into a more accurate recreation of how people use AI to generate text.

"In standard methods, participants are asked to indicate in a yes-or-no fashion whether a machine has produced a given text," says Ippolito, now an Assistant Professor at Carnegie Mellon University. "This task involves simply classifying a text as real or fake, and responses are scored as correct or incorrect, which is not ideal for training users."

In contrast, the Penn team's model significantly refines the standard detection study into an effective training task by showing examples that all begin as human-written. Each example

ILLUSTRATION BY **ALEX NABAUM**

then transitions into generated text, asking participants to mark where they believe this transition begins. Trainees identify and describe the features of the text that indicate error and receive a score.

The study's results show that participants scored significantly better than random chance, providing evidence that AI-created text is, to some extent, detectable.

"Our method not only gamifies the task, making it more engaging, it also provides a more realistic context for training," says Dugan. "Generated texts, like those produced by ChatGPT, begin with human-provided prompts."

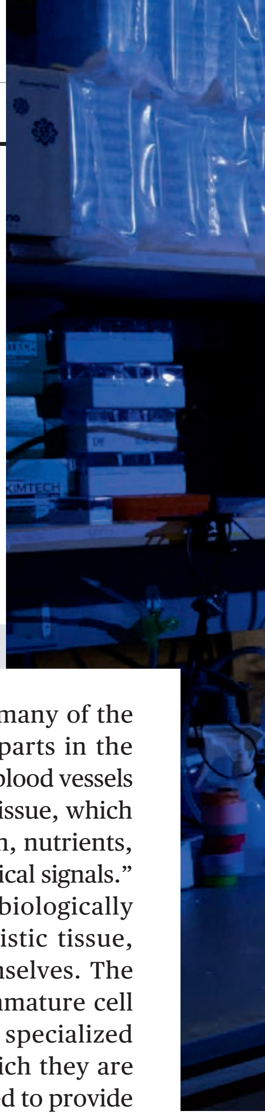
The study speaks not only to artificial intelligence today, but also outlines a reassuring, even exciting, future for our relationship to this technology.

"Five years ago," says Dugan, "models couldn't stay on topic or produce a fluent sentence. Now, they rarely make a grammar mistake. Our study identifies the kind of errors that characterize AI chatbots, but it's important to keep in mind that these errors have evolved and will continue to evolve. The shift to be concerned about is not that AI-written text is undetectable. It's that people will need to continue training themselves to recognize the difference and work with detection software as a supplement."

"People are anxious about AI for valid reasons," says Callison-Burch. "Our study gives points of evidence to allay these anxieties. Once we can harness our optimism about AI text generators, we will be able to devote attention to these tools' capacity for helping us write more imaginative, more interesting texts."

"My feeling at the moment is that these technologies are best suited for creative writing," he continues. "News stories, term papers or legal advice are bad use cases because there's no guarantee of factuality."

"There are exciting, positive directions that you can push this technology in," says Dugan. "People are fixated on the worrisome examples, like plagiarism and fake news, but we know now that we can be training ourselves to be better readers and writers."



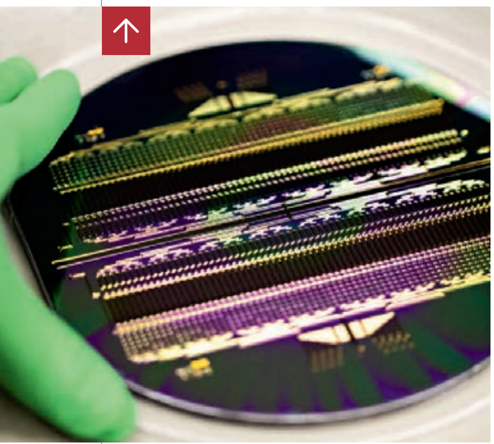
IN PRACTICE

Building Tiny Organs

BY David Levin

MORE THAN 34 MILLION Americans suffer from pulmonary diseases like asthma, emphysema and chronic bronchitis. While medical treatments can keep these ailments in check, there are currently no cures. Part of the reason, notes Dan Huh, is that it's incredibly hard to study how these diseases actually work. While researchers can grow cells taken from human lungs in a dish, they cannot expect them to act like they would in the body. In order to mimic the real deal, it's necessary to recreate the complex, 3D environment of the lung — right down to its tiny air sacs and blood vessels — and to gently stretch and release the tissue to simulate breathing.

Vivodyne's latest organ-chip technology puts hundreds of individually addressable culture chambers on a single 6-inch, disc-shaped device, meaning users can run 256 independent experiments simultaneously.



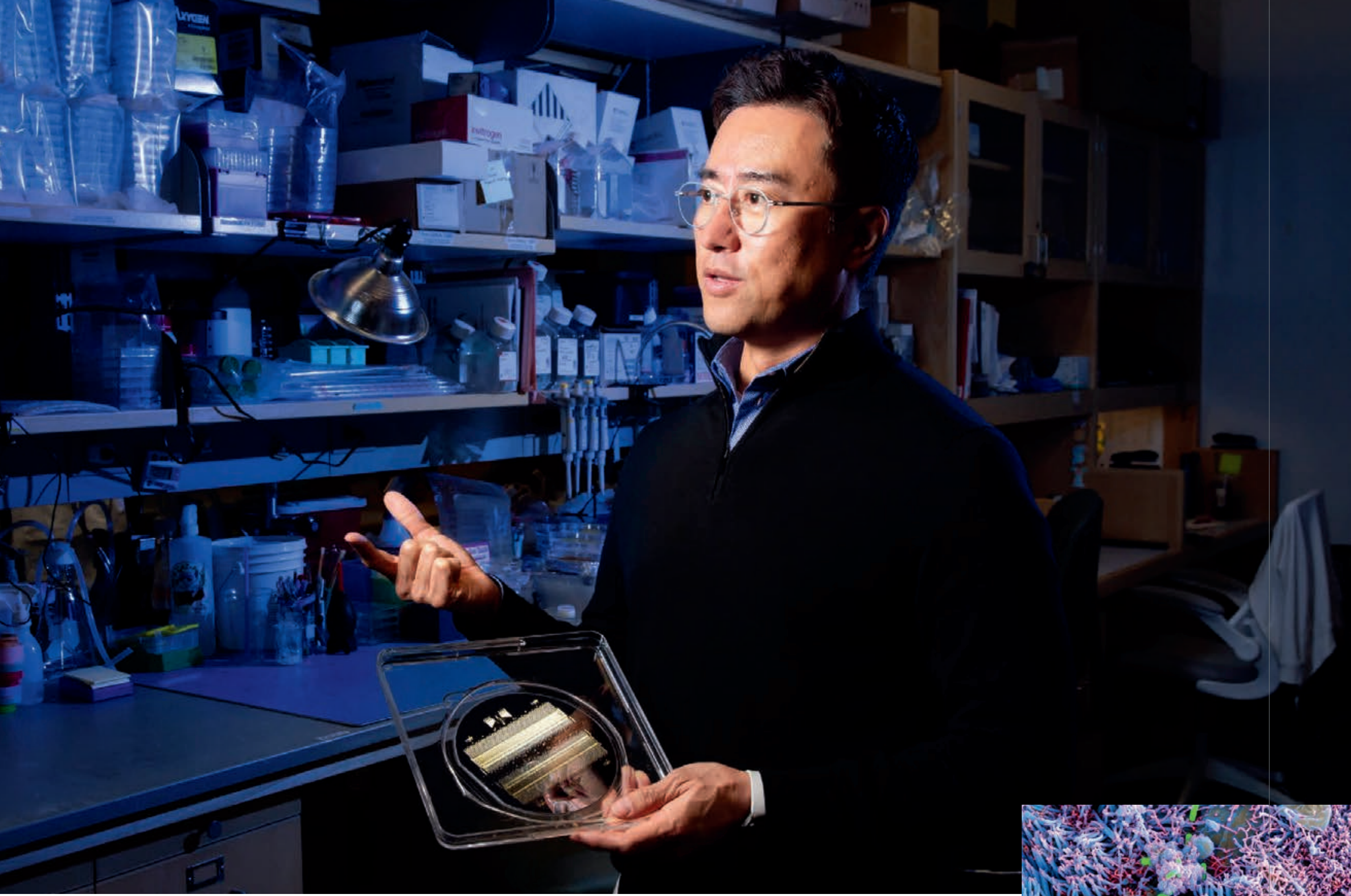
Huh, Associate Professor in Bioengineering, is the cofounder of Vivodyne, a Penn Engineering biotech spinoff that is creating tissues like these in the lab. Vivodyne uses a bioengineering technology that Huh has been developing for more than a decade. While a postdoctoral fellow at Harvard's Wyss Institute, he played a central role in creating a novel device called an "organ on a chip," which, as the name implies, assembles multiple cell types on a tiny piece of engineered plastic to create an approximation of an organ.

"While those chips represented a major innovation," says Huh, "they still weren't truly lifelike. They lacked many of the essential features of their counterparts in the human body, such as the network of blood vessels running between different kinds of tissue, which are essential for transporting oxygen, nutrients, waste products and various biochemical signals."

At Vivodyne, Huh is taking a biologically inspired approach to making realistic tissue, making the cells do the work themselves. The team places progenitor cells (an immature cell type that can become any kind of specialized cells present in the organ from which they are derived) into a gel-like media designed to provide the environment reminiscent of that seen in naturally developing tissues. Using this bioengineered, body-like environment, the team can jump-start the progenitor cells, steer their development into different types of specialized cells and gradually let them self-assemble into tiny organ-like structures.

"Optimizing this process is a lot of work," says Huh. "But the end result is that we can now reverse-engineer these beautifully complex human tissues in plastic devices the size of a memory stick that we can use for a wide variety of scientific experiments."

Using their unique method, Vivodyne can grow structures that replicate either healthy organs or those with a specific disease. The team has already created a variety of models that mimic the functional elements of different organs, such as human lungs, liver, brain, gut and pancreas, and have even used their process to create an artificially grown human eye with a bioengineered cornea, artificial tear ducts and a mechanical sliding eyelid. Together, these advances provide an innovative and robust way to study diseases as disparate as cancer, diabetes and dry eye syndrome.



Now, Vivodyne is working to take this technology to the next level. “This is still largely confined to academic research,” says Huh. “The engineering complexity of organ-chip prototypes developed in academic labs poses major challenges to conducting a large number of simultaneous experiments in a reproducible manner. This problem makes it difficult to generate sufficient amounts of data often required for real-world applications. Resolving this fundamental issue was the main reason we started Vivodyne.”

To address the throughput issues, Huh and Vivodyne are working to put hundreds of identical mini organs on a single chip, a development that could let scientists quickly study a wide range of diseases and test new drugs to treat them. “Using our new technology, we can create up to 256 individually addressable culture chambers on a single 6-inch, disc-shaped device, meaning users can run 256 independent experiments simultaneously,” says Huh. “We can also stack five or more of these devices together, which adds up to more than 1,000 concurrent experiments. That’s orders of magnitude higher than the current state of the art.”

Vivodyne also offers end-to-end automation with a machine containing a computer-controlled, industrial robotic arm and microscopy to automate the entire process of tissue engineering and analysis in real time without human error. Using AI and machine learning-based approaches, the team is working to harness the power of the large amounts of high-quality biological data generated by these models.

Vivodyne’s approach has led to collaborations with several major pharmaceutical companies, including GlaxoSmithKline, AstraZeneca and Genentech, to conduct pilot studies of its technology. It’s a big vote of confidence for the young company, and Huh is quick to point out that his colleagues in the University have played a critical role in its success.

“Developing this technology is a great example of the opportunity for interdisciplinary collaboration at Penn,” he says. “Being part of Penn Engineering has played an indispensable role in the success of our work to date, and I look forward to continuing to enjoy and benefit from this rich environment.”

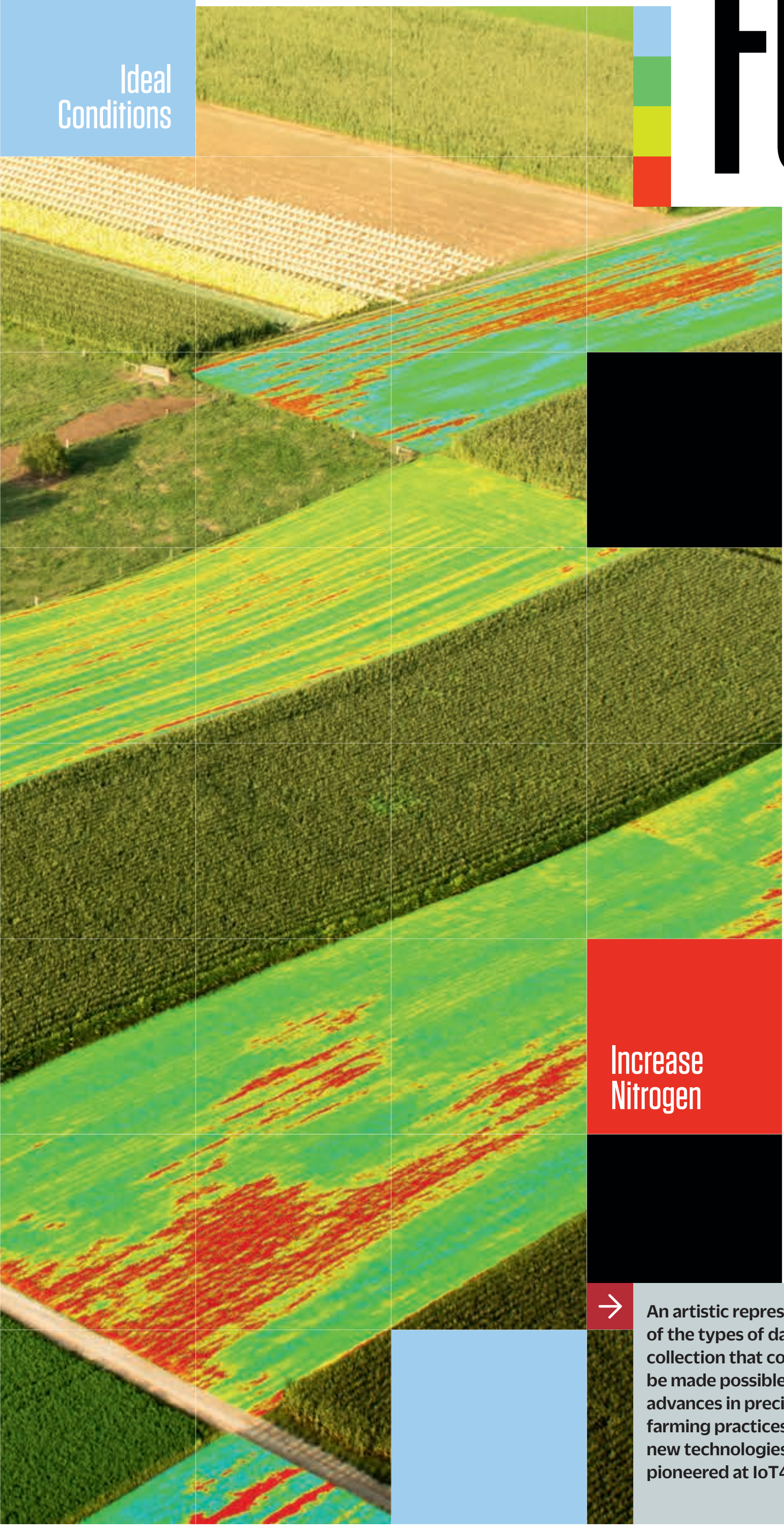
Vivodyne’s model of the human lung airways allows scientists the opportunity to study aspects of complex diseases, like chronic bacterial infection by *Pseudomonas* bacteria in the lungs of patients with cystic fibrosis.

Image courtesy of Vivodyne

PHOTOS BY **LESLIE BARBARO**


Decrease
Moisture
Increase
Moisture
Decrease
Nitrogen

CHALLENGE ACCEPTED: ENGINEERING the FUTURE of FARMING



An artistic representation of the types of data collection that could be made possible with advances in precision farming practices and new technologies being pioneered at IoT4Ag.

BY Olivia McMahon

Over the next 25 years, the world's population, currently hovering around 7.8 billion, is expected to grow by nearly 25% to 9.7 billion people. This means that existing global problems such as food, energy and water security are only going to become more acute.

"Just consider water alone. Agriculture accounts for 70% of global water usage," says Cherie Kagan, Stephen J. Angello Professor in Electrical and Systems Engineering (ESE) and Director of the Internet of Things for Precision Agriculture (IoT4Ag) Center at Penn. "When we were looking at opportunities to unite research excellence across disciplines in Penn Engineering and to tackle a societal grand challenge, agriculture and its importance to global food, energy and water security came to the forefront."

On its face, a university located on nearly 300 acres within a major East Coast city isn't where you'd expect to find a center focused on agriculture. But when you dig beneath the surface, Penn Engineering's expertise in areas like sensors, robotics, materials, manufacturing and data science, together with a proven track record of collaboration, make it the ideal institution to lead such an effort.

IoT4Ag, established in September 2020, just closed out its third year as Penn's first NSF Engineering Research Center (ERC). The Center's members from Penn Engineering and its three partner institutions across the U.S. have leveraged their collaborative expertise to produce new technologies aimed at creating the farm of the future: one that would collect, communicate and harness real-time data to efficiently deploy resources and improve crop yields with the least possible impact on the environment.

NEXUS OF INNOVATION

"IoT4Ag is the quintessential example of the School's Energy and Sustainability Signature Initiative," says Vijay Kumar, Nemirovsky Family Dean of Penn Engineering and member of IoT4Ag. "Not only are there significant advances in sensor, battery and biodegradable technologies coming out of the Center, but these advances are coming together to produce pathbreaking, data-driven solutions that will change agriculture and how it impacts the planet for decades and even centuries to come."

As an ERC, IoT4Ag is led by Penn and spans across three collaborating campuses: the University of Florida, Purdue University and the University of California, Merced. The Center's goals are not only focused on R&D for new technologies but also include inspiring and training a diverse workforce and building an innovation ecosystem that facilitates the transfer of technology from the lab to the market.

"We want to make sure that the work in the Center is greater than the sum of its parts so that we can achieve something big," says Kevin Turner, Professor and Chair of Mechanical Engineering and Applied Mechanics and the Convergent Research Director for IoT4Ag. "An Engineering Research Center is the premier center program within the NSF Engineering Directorate, and Penn being the lead institution for IoT4Ag is a reflection of the significant investment in research that Penn Engineering has made over the past two decades."

Research in the Center is organized into three thrusts, with the first focused on sensors and robotics technologies, the second being communication and power solutions and the third on developing data-driven models and decision frameworks. "For the Center to realize its full potential, you need all of these things to come together," continues Turner, who also serves as the Penn Site Director for IoT4Ag. "As individual technologies are developed in the thrusts, they are integrated into systems that are deployed in test fields at our collaborating institutions to demonstrate and assess the efficacy of the technology."

"When we were looking at opportunities to unite research excellence across disciplines in Penn Engineering and to tackle a societal grand challenge, agriculture and its importance to global food, energy and water security came to the forefront."

CHERIE KAGAN

PHOTO BY **LESLIE BARBARO**

NOT SUSTAINABLE

In addition to water use issues, the agricultural industry faces other concerns: the land available for farming is shrinking rather than growing, energy costs are one of the largest expenses on a farm, and overuse and leaching of fertilizers and other chemicals is expensive and not environmentally sound.

"We know that watering, and applying nitrogen treatments at the right times and in the right amounts, will improve crop yield," says Troy Olsson, Associate Professor in ESE and Thrust 1 Co-Lead for IoT4Ag. "Chemicals, which have gotten more expensive with riskier supply chains, are overapplied because farmers can't afford not to do so. The result is that the yields are high, but so are the resource expenditures."

One method to determine conditions on a farm uses sensors. However, sensors today undersample the large scale of farms because they are deployed at the acre-scale or greater, cost hundreds of dollars, are big and require power sources and radio infrastructure to communicate.

"Many of the mechanisms available to view the status of crops on a farm are only visible once damage has occurred; there is no early warning system," says Olsson. "Waiting for symptoms to manifest in order to determine there is a problem in agriculture, just as in health care, can mean it's far too late."

"Today, there is very limited data available to a farmer to control things like irrigation," he continues. "The situation is even worse when we get into stressors like soil nutrient levels because current soil testing involves shipping samples to a lab. Data comes back weeks later and it's only from the spots that were sampled, not the entire farm."

"There have been tremendous advances in agriculture over the past century," adds Turner. "The amount of food that we produce per acre of land has grown substantially over the past 100 years. But as you look toward the future, the challenge is feeding a growing population on less land while using fewer resources. New technologies are needed to overcome this challenge."

"The amount of food that we produce per acre of land has grown substantially over the past 100 years. But as you look toward the future, the challenge is feeding a growing population on less land while using fewer resources. New technologies are needed to overcome this challenge."

KEVIN TURNER

Nationwide Collaboration

While Penn Engineering possesses many strengths in terms of developing the novel technologies needed to create the farm of the future, collaboration is key for the Center to succeed. Each collaborating institution possesses researchers working in all three thrusts, but expertise in agronomy is found at the test beds located at Purdue University, the University of Florida and the University of California, Merced. "The team is not solely engineers, there are agronomists and agricultural engineers, disciplines we don't really have on Penn's campus," says Kagan. "With Florida, you get the southern part of the U.S., in Merced, you get the West, and in Purdue you get the Midwest, with all three representing different climates and different cropping systems to put the Center's technology into practice."

CHANGING WHAT'S POSSIBLE

To engineer the farm of the future, IoT4Ag researchers envision fields with precision sensors that are low-cost, deployed widely and that work with farming infrastructure and local communications systems that would provide better data to advise prescriptive treatments, perhaps even at the plant level, for problems that could be mitigated immediately.

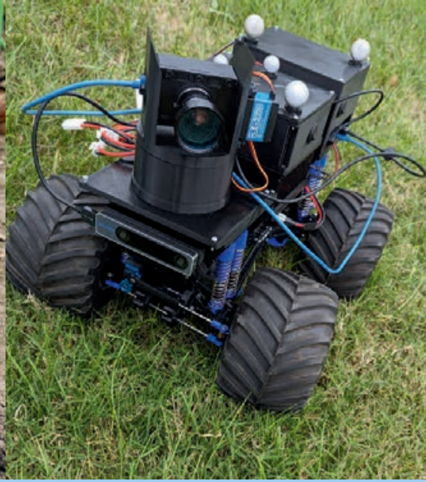
"In large agricultural fields, there is limited infrastructure," says Turner. "Power is limited, and wireless communication technology is even more scarce." To work within the constraints of farms and their rural settings, IoT4Ag researchers focused their efforts on developing novel sensor technologies, first producing a low-cost, fully biodegradable soil moisture sensor [see sidebar].

"Our goal is to widely deploy sensors that, instead of costing hundreds of dollars, cost a penny, are passive in their power use or have biodegradable batteries, and can biodegrade into the soil instead of needing to be collected," says Olsson, who together with Turner developed IoT4Ag's biodegradable moisture sensors.

To augment the capabilities of the sensors and make them multi-use, technology will be needed in the form of processing chips and batteries. Labs across the Center are addressing this need by developing biodegradable batteries and small silicon chips that would allow sensors the ability to measure quantities of chemicals such as phosphates that aren't easily collected using passive monitoring techniques.

"Our goal is to widely deploy sensors that, instead of costing hundreds of dollars, cost a penny, are passive in their power use or have biodegradable batteries, and can biodegrade into the soil instead of needing to be collected."

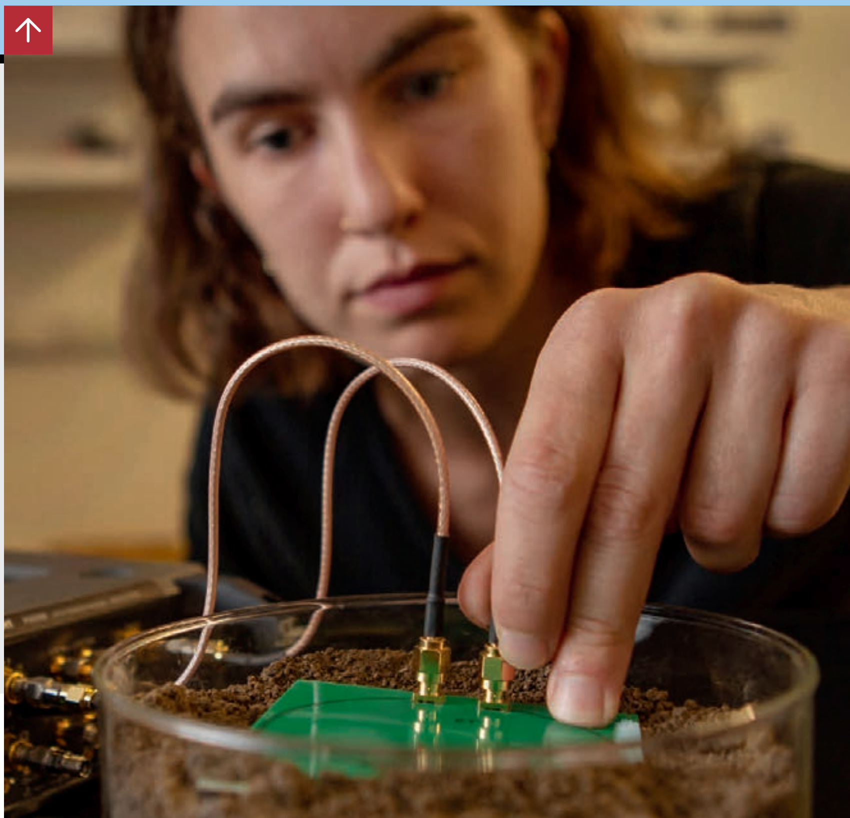
TROY OLSSON



Biodegradable Sensors

IoT4Ag has leveraged low-cost, high-volume technologies to develop fully biodegradable, passive soil moisture sensors measuring approximately three square inches that can be deployed beneath the ground. The sensors consist of a paper substrate infiltrated with cellulose nanofibrils (CNFs) on which inks made from non-harmful metal nanoparticles are screen printed to produce both the sensing element needed to measure soil moisture and the communication (antenna) needed to communicate with a reader. Working within the range of a tractor driving over the sensor, the reader interrogates and wirelessly collects the sensor's data. Following deployment in the soil, the sensors remain dormant until they are interrogated, which means they don't require a local power source. They instead reflect energy from the reader, much like RFID technology, in order to function. The sensor is currently being tested in soils for row crop farming, and IoT4Ag researchers are working to tailor the same technology for sensing nitrogen and other quantities applicable to agriculture.

Anne-Marie Zaccarin, doctoral student in Electrical and Systems Engineering, tests a soil moisture sensor in the lab of Troy Olsson.



IoT4Ag's biodegradable sensors (left) are placed beneath the soil and are activated by radio frequency (RF) signals. Additionally, small, networked ground robots (right) use cameras to monitor optical sensors (see opposite) in the under-canopy of crops.

In addition, Kagan and Turner are collaborating to develop colorimetric sensors that can stick to the leaves of plants and change color based on the measured target. If these sensors are passed over by a camera, they can be read.

The sensors being developed can be interrogated by adding cameras and radio-frequency reader technology to existing farm equipment, such as tractors, but another Penn Engineering strength, robotics, is key to data harvesting as well. Using drones, like those found in the lab of Kumar, expands the methods for reading the sensors and therefore monitoring field conditions, but drones come with their own limitations, namely how long they can stay in the air.

The lab of Sue Ann Bidstrup Allen, Professor in Chemical and Biomolecular Engineering and Workforce Development Co-Director for IoT4Ag, is working to create alternate battery technologies for drones to increase flight times. "Drones currently use lithium-ion batteries, which limit flights to 30 minutes or so, which is problematic for agricultural uses," says Bidstrup Allen. "We are looking at alternative chemistries, such as those currently being used in hearing aids, that could be used as energy sources."

To get the data from the field into the cloud and turn it into a useful tool, IoT4Ag members are collaborating to create an interface that will take the data measured in different areas, plus weather and other environmental data, and stitch it together, modeling it into a tool that could suggest how participating farmers could manage and deploy resources on their own specific farms.

IoT4Ag researchers have developed novel colorimetric sensors that can stick to the leaves of plants and change color based on the measured target, such as moisture and temperature levels, enabling precision monitoring of crop health.

FUTURE FARMERS

In addition to the interdisciplinary research at Penn, Purdue, Merced and Florida, IoT4Ag has partners in education, government, industry and the farming community at large. This not only ensures the Center will produce viable technologies, but that those technologies will be more readily adopted and that there will be individuals excited to pursue careers at the intersection of technology and agriculture. IoT4Ag participates in symposiums, conferences and other events for agriculture practitioners and offers courses to students across the four partner institutions.

KEVIN MONKO

> **"Young people can think of agriculture as an old-fashioned field, and they don't realize how high-tech it is getting. At the same time, they want to see that they can contribute to the betterment of mankind, and it's easy to see that linkage through agriculture."**

SUE ANN BIDSTRUP ALLEN

The mindset of any industry can be one of "if it works, don't break it," which can be a barrier to adoption of new methods. However, agriculture-rich schools like Purdue and University of Florida boast robust community extension programs, which are designed to bring new opportunities and technologies to farmers and individuals working in agriculture. They understand the local community and have existing, longstanding relationships.

"Trust is paramount," says Kagan. "Leveraging extension relationships where trust already exists allows us to work with early adopters who can act as ambassadors."

"Those partners are also an important way to receive feedback from the end-user community throughout the entire design process," adds Turner. "If we make something, but it doesn't work with current practices, nobody will adopt it."

The average age of the farmer is increasing, so exposing agronomy-centric ideas to students interested in STEM is critical, and IoT4Ag does just that at multiple levels in the educational journey. "Young people can think of agriculture as an old-fashioned field, and they don't realize how high-tech it is getting," says Bidstrup Allen. "At the same time, they want to see that they can contribute to the betterment of mankind, and it's easy to see that linkage through agriculture. If you want to be an engineer, knowing that agriculture is an option for an exciting career is key to the future of the industry."

To that end, Bidstrup Allen and her colleagues in Workforce Development oversee initiatives designed to spark interest in STEM and agriculture, including contributing lessons to a summer camp for underserved Philadelphia middle school students located in Penn's Morris Arboretum and run by ACLAMO, a nonprofit community service organization. IoT4Ag also welcomes local educators to Penn's campus to engage in its Research Experience for Teachers (RET) program, where educators can work in faculty labs on projects and advise the Center on its STEM activities to make them accessible to multiple age groups.

"A lot of students care about the environment, and they want to make a difference," says Kagan. "We are showing them that agriculture is a place that bridges both of those desires. The idea of introducing technology and innovation to agriculture may also be a way to bring the next generation back to the idea of farming."

> "Now that we are in year three, we have enough data where we can see a full picture coming together and we can start to build models from that to address key problems."
>
> CHERIE KAGAN

LOOKING AHEAD

As the Center enters its fourth year, researchers are excited by the emerging sensor technologies they've developed and are eager to see how they function once deployed, but just like farmers, they are beholden to the rhythms of nature.

"One of the challenges with agriculture that you don't have in normal lab settings is that there is a growing season each year, which differs in length and the crops that are farmed across the U.S." says Kagan. "I can go anytime to my lab and get data. On a farm, you have to collect data within the growing season. Now that we are in year three, we have enough data where we can see a full picture coming together and we can start to build models to address key problems."

"We aren't there yet, but we've made significant progress," notes Olsson. "We've taken the first step and shown that a biodegradable, low-cost, widely deployable soil moisture sensor is indeed possible, and getting it to longer ranges, reducing its size, and tailoring it to measure different targets, particularly nitrogen at multiple depths, is the next step we need to tackle."

IoT4Ag has laid its foundation and now it's a matter of execution, refining the technologies and turning toward the full system that the team is hoping to eventually put together. "I'm proud of the culture and the impact of the Center," says Kagan. "Members are learning a lot from one another and the communities they are connected with."

"In 50 years," predicts Turner, "you'll drive by a field that won't look much different than it does today, but it will have much better sense and response systems that lead to lower resource use and higher yield due to technologies that will be developed by this Center and others like it in the coming years."

"The impact of IoT4Ag will be developed over many years," adds Bidstrup Allen. "It takes time to make the changes we need to feed a hungry world."

Energy and Sustainability is one of Penn Engineering's three Signature Initiatives. Efforts in the School span across centers like IoT4Ag, individual faculty research projects, academic programs, student projects and even the School's physical plant. The array below shows just a few examples of the ways in which Penn Engineers are working toward a more sustainable, energy-secure future.

Pulling Water from Air

To collect atmospheric water without an external energy source, Shu Yang, Joseph Bordogna Professor and Chair of MSE, and Paulo Arratia, Professor in MEAM, have advanced sustainable building envelope tech by using kirigami, a material cutting and folding technique.

Current-Propelled Robots

Research from the GRASP Lab's Scalable Autonomous Robots Lab, led by M. Ani Hsieh, Associate Professor in MEAM, is using marine robots to map ocean currents, which would enable more energy-efficient exploration and monitoring of our oceans.

Turning Carbon Emissions into Rocks

The Clean Energy Conversions Lab, led by Jennifer Wilcox, Presidential Distinguished Professor of Chemical Engineering and Energy Policy in CBE, and Peter Psarras, Research Assistant Professor in CBE, is repurposing industrial waste, converting carbon dioxide into stable rocks.

Embodied Carbon Tech

Penn Engineering's Amy Gutmann Hall, set to achieve LEED Gold status, will be Philadelphia's first large mass-timber building, a construction technology that uses wood to achieve a design with a 70% lower embodied carbon footprint than a comparable steel and concrete building.

VIPER's Next-Gen Scientists

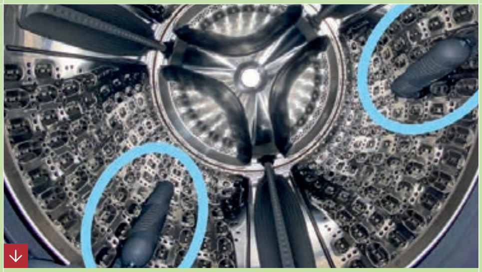
The Vagelos Integrated Program in Energy Research (VIPER) is a dual-degree program that prepares undergraduates to become energy science leaders and innovators through cutting-edge research experiences in alternative and efficient methods of production, conversion and use of energy.

The Future of Energy Research

The new Vagelos Laboratory for Energy Science and Technology (VLEST), a Penn Engineering and Penn Arts & Sciences collaboration, is on track for LEED Platinum status, a Penn first, due to its high-performance façade and energy recovery systems that lower energy consumption by 63%.

LEARN MORE

Learn more about Penn Engineering's Energy and Sustainability Signature Initiative.



Trapping Microplastics

2022 MSE alums Sarah Beth Gleeson, Shoshana Weintraub and Julia Yan cofounded the startup Baleena while undergraduates, creating an in-drum laundry device to capture microfibers, the small strands of plastic that shed from synthetic clothing, to reduce microplastic pollution in water.

COMING TOGETHER TO TRANSFORM TECH

Penn HCI researchers work to enhance and redefine our relationship with computers and devices.

BY Janelle Weaver

Modern life involves nearly constant interaction with devices and technology. For users, not only is an understanding of how to perform these interactions with confidence and security important, but an awareness of how those interactions affect us and our communities is critical.

This is true across the full spectrum of our experiences with technology. The recent explosion of large language models like ChatGPT is one example. With such technology increasingly used by everyone from undergraduate students for homework help, to professional programmers writing code for critical systems, to hiring managers reviewing resumes, understanding the situated, real-world use of these tools and their effects is paramount. Answering these questions is the domain of a subfield of computer science called Human-Computer Interaction (HCI).

PHOTO BY JEFF WOJTASZEK

Danaë Metaxa (left) and Andrew Head (right)

In the last year, Penn Engineering was fortunate to welcome not one, but two computer scientists with expertise in HCI, launching the School's Human-Computer Interaction Group. Since, Andrew Head, Assistant Professor in Computer and Information Science (CIS), and Danaë Metaxa, Raj and Neera Singh Term Assistant Professor in CIS, have been seizing the opportunity to advance the HCI Group's overarching goal of understanding, designing and engineering technologies with the human-centered goal of making a positive impact on individuals and communities.

In broad terms, HCI is a field of study that focuses on improving interactions between people and computers through the design of technology that satisfies users' wants and needs. "HCI is a discipline founded at the intersection of several fields, including computer science, psychology and media studies, among others," says Metaxa. "It's incredibly broad as a subfield, encompassing everything from wearable haptic interfaces to analyses of political persuasion in social media."

Located within the CIS department, the HCI Group supports research projects that cover a variety of topics spanning the development of new patterns of interaction with computers, refining the interfaces of existing applications, and understanding the effect that computers and their applications have on people.

"In my research, I explore the future of reading," says Head. "As our computers get better at understanding the texts humans write, we can open the doors to the complex, everyday texts people need to understand. Could our reading interfaces help us understand our medical records? How about tricky math equations, or tangled source code? I explore how modern techniques from AI and program analysis can enhance reading experiences in these settings."

"In my research," says Metaxa, "I develop and deploy methods for studying bias and representation in algorithmic content, focusing on high-stakes social settings like politics and employment, and especially on the experiences of marginalized people. This includes the identification of biases in existing systems, as well as the design of interventions and building of new systems that try to remedy those issues."

In addition, the HCI Group offers a range of courses at the graduate and undergraduate levels, including "Introduction to HCI" and more specialized courses. For example, a graduate seminar titled "Algorithmic Justice" examines a growing body of work at the intersection of technology and social justice. A range of areas are included under this umbrella, including tech ethics, design justice and algorithmic fairness, as well as work on equity, bias, diversity and representation in computer science and other related disciplines.

SPANNING THE GAMUT

In the short time since its inception, the HCI Group has launched a rich portfolio of projects. Within Metaxa's group, researchers are developing new insights about the nature of representation in online settings, both emerging and established. One illustration of this research is a project titled "Sociotechnical Audits: Broadening the Algorithm Auditing Lens to Investigate Targeted Advertising." In that work, the team built a system to measure the targeted web ads received by a diverse group of people, and also experimented with showing them different ads, getting at the question of whether surveillance-heavy ad targeting systems actually benefit users. Their findings indicate that much of the efficacy of targeted ads is driven by prior exposure, suggesting that more privacy-preserving policies should be pursued for online ads.

CIS doctoral student Princess Sampson examines the impact of people's identities on their interactions with algorithmic systems. "Engineering with inclusion and agency in mind enables better algorithmic outcomes for everyone," says Sampson, who led an empirical study titled "Representation, Self-Determination, and Refusal: Queer People's Experiences with Targeted Advertising," which found that LGBTQ+ perspectives highlight the risks of an online advertising industry that doesn't allow end-users to curate their ads or understand how they're being targeted.

> “Penn Engineering is a great home for this work since it allows us to draw on strengths from across campus, including in our own department.”
>
> **Danaë Metaxa**
> *Raj and Neera Singh Term Assistant Professor in CIS*

Inspired by models of community-driven filtering for email and social media, Sampson is now building Admix, a system for people to collaboratively archive and filter their online ads. “We aim to empower people to collectively combat the wide spectrum of issues presented by online ads, on their own terms,” says Sampson.

In Head’s group, researchers are developing tools to help readers understand complex texts. CIS doctoral student Litao Yan explores how tools can help programmers understand code generated by programming assistants like GitHub Copilot. “As AI programming assistants make their way into the editors of millions of programmers, these programmers find themselves with an entirely new obligation,” says Yan. “They must understand the code that their AIs have generated.” Yan developed an extension to a code editor that automatically explains the code that programming assistants generate with AI to keep programmers engaged in understanding the code their programming assistant is generating.

Meanwhile, CIS doctoral student Hita Kambhamettu is exploring how AI-assisted reading tools can help patients understand their health records. “Electronic health records have become a crucial interface in health care for documenting a patient’s medical history and establishing common ground between providers and patients,” she says. Kambhamettu conducted an observational study of patients as they read their records to understand the challenges patients face while reading them. She is now building medical reading interfaces that incorporate AI to explain the jargon and data that appear in health records.

Other students in the group are developing tools to help people understand math equations, computerized proofs and complex instructions. Across the gamut of projects, the theme is to develop new paradigms for transforming complex texts so that they might be better understood.

PULLED TO PENN

Supporting a strong team of talented students was one major reason Metaxa was excited at the opportunity to start a new group at Penn. “When I was an undergraduate at Brown and the Computer Science department made its first HCI hire, I got to see professor Jeff Huang, who advised my senior thesis, build his group from the ground up, and I relish the opportunity to do the same here at Penn,” says Metaxa. “What’s more, I’ve known Andrew since the beginning of our doctoral programs — we were both in California, he at Berkeley and I at Stanford — and the chance to work so closely with him in building this group sounded like, and indeed has proven to be, a wonderful experience.”

According to Metaxa, the strength and interdisciplinary research interests of the faculty in the School are invaluable. “Situated as one of 12 very strong schools within the University, Penn Engineering is a great home for this work since it allows us to draw on strengths from across campus, including in our own department,” says Metaxa. “For instance, I have a secondary appointment in Annenberg. For my Ph.D., I was co-advised by a computer scientist and a communications scholar. Penn allows me to continue having connections in both worlds. And within our department, we have colleagues with co-appointments in a range of areas, including the School of Medicine, Wharton and others.”

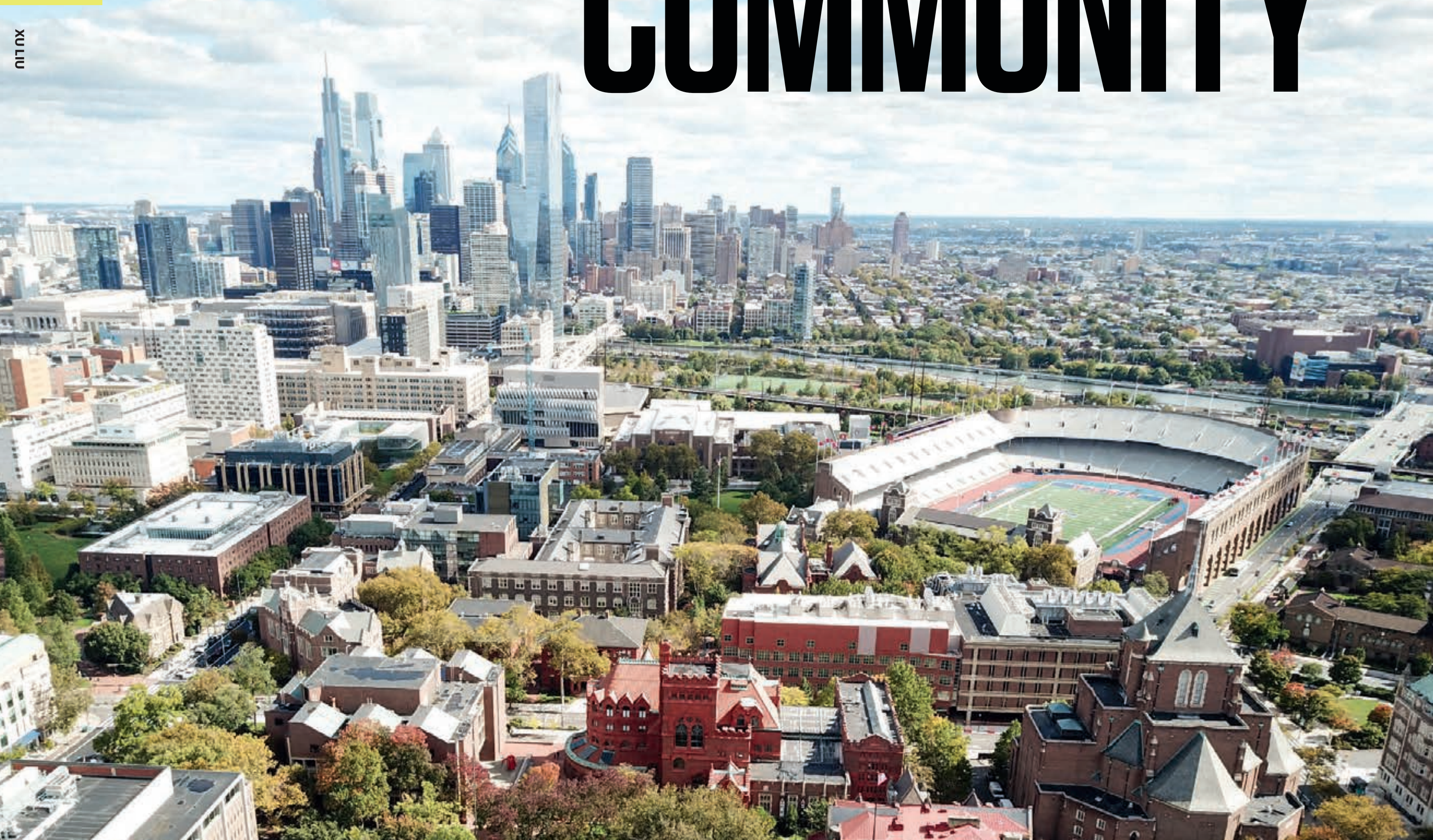
“Penn is an amazing place for HCI,” says Head. “Danaë and I have had great agency to build the HCI Group from the ground up, and we now have a home for our research teams where students develop strong roots in our discipline. Many of our students are building bridges into other disciplines like programming languages, health informatics, NLP and communications. This has made for a rich research environment where we work on problems that matter, with the methods it takes to make a difference.”

Head and Metaxa are excited to continue growing HCI. “We opened the doors to HCI in our department, and students have come in. We now regularly welcome students from wide disciplinary backgrounds across the University into our courses,” says Head. “There is nothing more exciting than making spaces for students to critically examine how technology can be developed to better serve people.”

Penn Engineering's PESTLE program facilitates student engagement in local community service programs.

BY Amy Biemiller

FROM CAMPUS TO COMMUNITY



XU LIU

> "I realized it's not only what I can do with my knowledge, but how I can help my community and inform my personal development."

Andres Vidal

Master's Student, Chemical and Biomolecular Engineering

During his time at Penn, Vidal has participated in volunteer opportunities that include being a demo speaker and leader for a demonstration on biopolymers and encapsulation for BETA Day, which features activities that introduce middle and high school students to concepts in genetic engineering, biomaterials and robotics.

JUST AS HE ROSE TO TELL some local middle schoolers about engineering as a career path, Andres Vidal, a master's student in Chemical and Biomolecular Engineering, hesitated. "Do I really have anything to offer these students?" he thought.

That volunteer experience taught Vidal more about himself than he expected. "As I talked, I felt excited about the subject and realized that my career path is something that I enjoy and know a lot about. By volunteering, I realized it's not only what I can do with my knowledge, but how I can help my community and inform my personal development."

For Penn Engineering students like Vidal, finding ways to volunteer and make a difference in the communities around Penn's campus is now easier than ever. The Penn Engineering Student Learning and Engagement (PESTLE) program is an online resource that helps connect them to a variety of volunteer activities. Students can choose and register for a service opportunity and track and submit their service hours, a critical efficiency as Penn Engineering encourages all students to volunteer at least 20 hours during their time on campus.

THE PESTLE PORTAL

Ask any engineering student what motivates them to pursue a career in engineering, and you'll often hear a common theme: the desire to make a meaningful impact on communities and individuals. However, becoming a skilled engineer who can make that impact requires more than the technical expertise gained in the classroom; it also involves cultivating essential "soft skills," which can be developed through volunteer experiences.

"To solve the world's most pressing problems, our students must learn about the context in which those problems have evolved," says Sonya Gwak, Director of

PORTRAITS BY **KEVIN MONKO**

Eddy Yang

Senior, Computer Engineering

In his role as Operations Lead for Penn Electric Racing (PER), Yang invited Philadelphia Auto and Parole to the group's new car reveal on campus last year and also facilitates the ongoing cooperation between PER and The Workshop School, a hands-on, project-based high school in West Philadelphia.

"Once you volunteer, you expand your perspective a bit and you can hone other soft skills like time management and communication."

Student Life in Penn Engineering. "By engaging with our Philadelphia community, our students learn how they can make a difference right now. That will help our students become the global citizens we aspire for them to be."

PESTLE offers a fast, digital way for students to find one-time service events or ongoing initiatives that are coordinated by student organizations, the School or through University partnerships with local community centers. Students can also use the portal to log volunteer hours that they carry out on their own, such as tutoring in local schools.

"I am happy that as a School, we have the vision and resources to support our students' energy and motivation to engage outside the classroom," says Gwak.

MAKING COMMUNITY SERVICE ACCESSIBLE

From sharing with youth about engineering and other STEM disciplines to cleaning up local parks and helping to distribute groceries and meals to families near campus in West Philadelphia, Penn Engineering students who take advantage of volunteer activities get to practice so much more than social good.

"An education is largely based on theory, training and preparation for a career. Volunteering is about making a tangible difference immediately and learning empathy early," says Melanie Hilman, a doctoral student in Bioengineering.

Finding volunteer options can be time-consuming for any Penn student, especially if they are new to campus or are unfamiliar with the city. With PESTLE, the opportunities are just a mouse click away.

"I think the PESTLE program is great because it provides opportunities directly to students and makes it easy for students to get started with community service," says Eddy Yang, a senior in Computer

Melanie Hilman

Doctoral Student, Bioengineering

As both a Penn Engineering undergraduate and graduate student, Hilman has participated in a number of volunteer activities on campus, including time spent with Penn GEMS, a STEM-focused camp experience where Philadelphia-area middle school students participate in hands-on engineering activities in bioengineering, nanotechnology, materials science, graphics and computing.

Engineering. “Once you volunteer, you expand your perspective a bit and you can hone other soft skills like time management and communication.”

BUILDING ON A LEGACY OF CIVIC ENGAGEMENT

Volunteerism is hardwired into the University of Pennsylvania experience, dating from its founding and its founding father, Benjamin Franklin, who maintained that one purpose of education is to be able to serve humanity.

“Several years ago, the idea for PESTLE germinated with a discussion among the members of the Technical Advisory Board, particularly Michael Glassman and Rohan Amin,” explains Gwak. “Our alumni expressed how important service to the community is as a central tenet of an engineering education. They envisioned an integrated experience, which PESTLE now is, that would help students find those volunteer experiences and allow them to engage, serve and grow as engineers.”

In a fireside chat with students, Amin noted, “My passion for community service started at Penn when I did some volunteer work and realized that one person could have a real positive impact. I’ve carried that with me as I developed my career, and now as a parent, I share that with my sons.”

Amin (ENG’02) is currently the Chief Product Officer for Chase. As a student at Penn, he was part of a team that volunteered to build computer labs for schools in West Philadelphia, helping teachers take advantage of technology and incorporating that into their classroom curricula.

“There was certainly a social benefit outcome with that project, but there was also a personal development opportunity. The experience helped me focus on people and their needs, ultimately leading me to find my broader purpose,” says Amin. “Penn will give you a fantastic education. It will also open doors for you to the wider world, starting with the local community. By putting yourself out there as a volunteer, you’ll gain perspective and clarity of purpose.”

“Being a mentor for students is incredibly gratifying for me, especially when the students are able to act on my words and pave their own paths.”

CAMERA ROLL

LEARN MORE

View the complete timeline and celebration wall online:

history.seas.upenn.edu

OUR HISTORY

Penn Engineering continues to enhance physical spaces in the School to ensure that they reflect a more balanced and truthful picture of the past while also inspiring and empowering future innovators, leaders and problem-solvers. In breaking down gatekeeping-based measurements of scientific impact and significance, the School can honor its history while acknowledging that there is still more to be done.

A new celebration wall of notable Penn Engineering alumni adorns the West Entrance of the Towne Building.

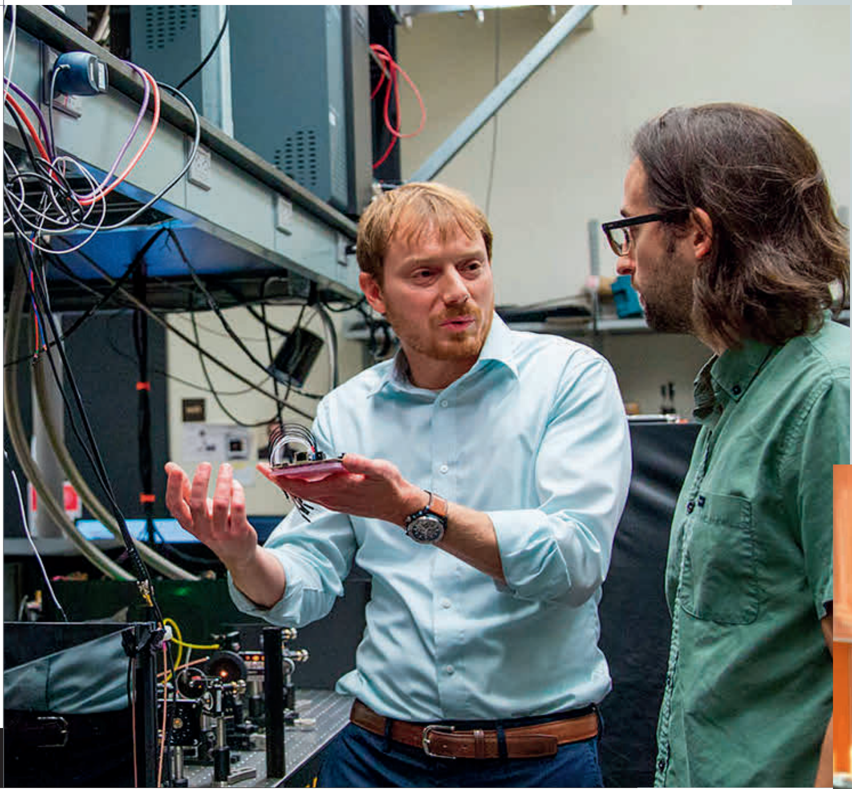
THE RUIA FOUNDATIONS TIMELINE

Penn Engineering is grateful to Atul A. Ruia (EAS'93, W'93, PAR'25, PAR'27) and Gayatri Ruia (PAR'25, PAR'27) for their generous support of a new historical timeline display in the Moore Building. This installation celebrates the achievements of the past while the School works toward attracting a more diverse, inclusive student body that reflects — and will help lead — a diverse world.

PHOTOS BY **KEVIN MONKO**

New Center for Quantum Information, Engineering, Science and Technology

In June, Penn announced the formation of a new Center for Quantum Information, Engineering, Science and Technology, or Penn QUIEST, that seeks to realize practical quantum technologies like quantum computers, quantum networks and quantum sensors. QUIEST is a transdisciplinary field that draws from physics, materials science and information science, and the new center brings together faculty from Penn Engineering and Penn Arts & Sciences to work toward its goals. Penn QUIEST will be led by Director Lee C. Bassett, Associate Professor in Electrical and Systems Engineering.



Honoring Cora Ingrum and Donna Hampton

On May 13, Cora Ingrum and Donna Hampton, former long-term staff in Penn Engineering's Office of Diversity, Equity and Inclusion, were honored with painted portraits in the Towne Building. The first women of color and first staff members to receive this honor, the two women share a combined 90-plus years of guiding generations of underrepresented groups at Penn. The portrait of Ingrum, who served as the office's inaugural Director, was painted by Patricia Watwood, and Hampton's is by Ashon Crawley, whom Hampton mentored.

Mark Allen Elected to the National Academy of Engineering

Mark Allen, Alfred Fitler Moore Professor in Electrical and Systems Engineering, was elected to the National Academy of Engineering (NAE) for "contributions to the technology and commercialization of Micro-Electro-Mechanical Systems (MEMS) for health care." Election to the NAE is among the highest professional distinctions accorded to an engineer.

ERIC SUCAR

Nader Engheta Receives Benjamin Franklin Medal

Nader Engheta, H. Nedwill Ramsey Professor in Electrical and Systems Engineering, was selected to receive a 2023 Benjamin Franklin Medal, one of the world's oldest science and technology awards. Engheta, who was honored for "his transformative innovations in engineering novel materials that interact with electromagnetic waves in unprecedented ways, with broad applications in ultrafast computing and communication technologies" joins a prestigious list of prior winners of the Franklin Medal, including Albert Einstein, Nikola Tesla, Alexander Graham Bell and Max Planck, who are honored for their achievements in extraordinary scientific, engineering and business leadership.

Topping Off the Future of...

ENERGY SCIENCE AT PENN: Vagelos Laboratory for Energy Science and Technology

ON FEBRUARY 3, 2023, a ceremony was held during the placement of the final steel beam on the Vagelos Laboratory for Energy Science and Technology (VLEST), a collaboration between Penn Engineering and Penn Arts & Sciences. This event celebrated a milestone in the construction of a building that will serve as an advanced energy research laboratory and home to both the Vagelos Institute for Energy Science and Technology and the Vagelos Integrated Program in Energy Research (VIPER) undergraduate dual-degree program. The 110,000-square-foot facility, located at 32nd and Walnut Streets, will house spaces and technologies that are essential to Penn Engineers as they pursue advances in sustainable energy research and education.

DATA SCIENCE AT PENN: Amy Gutmann Hall

ON JULY 26, 2023, two years after the project ceremonially broke ground at 34th and Chestnut streets, members of the Penn community gathered for the signing and placement of the final wood panel of Amy Gutmann Hall, signaling the completion of the new Penn Engineering building's frame. The 116,000-square-foot, six-story building will be a hub for data science on campus and will support research that advances graphics and perception, privacy and security, computational social science, data-driven medical diagnostics, scientific computing, and machine learning. It will also allow for the development of safe, explainable, and trustworthy artificial intelligence technologies.

NEW FACULTY

Zeenat Bashir

Senior Lecturer
Chemical and Biomolecular Engineering

Ph.D. in Molecular Microbiology
University of Nottingham, UK

Matthew Campbell

Research Assistant Professor
Mechanical Engineering and Applied Mechanics

Ph.D. in Mechanical Engineering
Stanford University

Devin Carroll

Lecturer
Mechanical Engineering and Applied Mechanics

Ph.D. in Mechanical Engineering and Applied Mechanics
University of Pennsylvania

Surbhi Goel

Magerman Term Assistant Professor
Computer and Information Science

Ph.D. in Computer Science
University of Texas at Austin

Lei Gu

Assistant Professor
Electrical and Systems Engineering

Ph.D. in Electrical Engineering
Stanford University

Eric Huang

Senior Lecturer
Materials Science and Engineering

Ph.D. in Chemical Engineering
University of Minnesota

Yuanwen Jiang

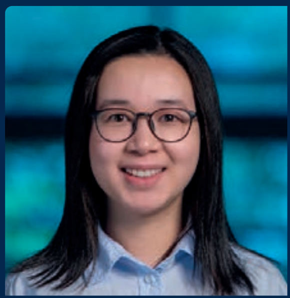
Assistant Professor
Materials Science and Engineering

Ph.D. in Chemistry
University of Chicago

Gushu Li

Assistant Professor
Computer and Information Science

Ph.D. in Electrical and Computer Engineering
University of California, Santa Barbara



Lingjie Liu

Aravind K. Joshi Assistant Professor
Computer and Information Science

Ph.D. in Computer Science
University of Hong Kong

Jérémie Lumbroso

Practice Assistant Professor
Computer and Information Science

Ph.D. in Computer Science
Sorbonne University

Ryan Marcus

Assistant Professor
Computer and
Information Science

Ph.D. in Computer Science
Brandeis University

Pratyush Mishra

Assistant Professor
Computer and
Information Science

Ph.D. in Computer Science
University of California, Berkeley

Nathaniel Trask

Associate Professor
Mechanical Engineering
and Applied Mechanics

Ph.D. in Applied Mathematics
Brown University

René Vidal

Rachleff University Professor
Electrical and Systems
Engineering; Radiology

Ph.D. in Electrical Engineering
and Computer Science
University of California, Berkeley

Erik Waingarten

Assistant Professor
Computer and
Information Science

Ph.D. in Computer Science
Columbia University

Mingmin Zhao

Assistant Professor
Computer and
Information Science

Ph.D. in Computer Science
Massachusetts Institute
of Technology

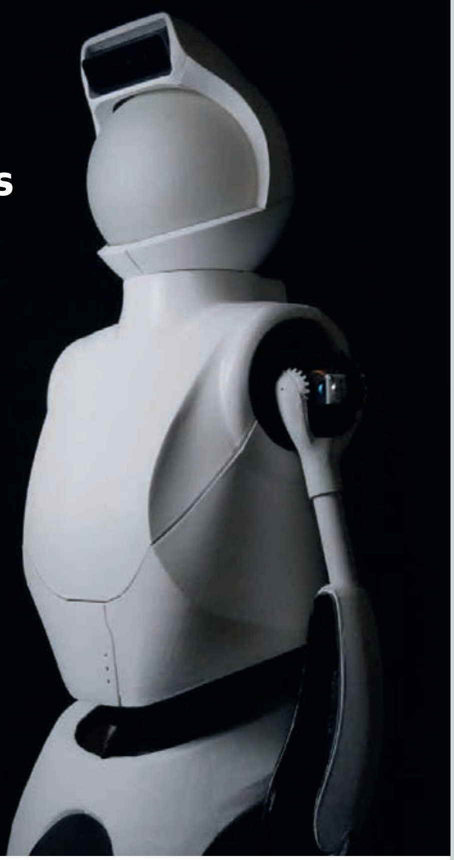
Two New PIK Professors

PENN ENGINEERING WELCOMED two new Penn Integrates Knowledge (PIK) professors, Gregory Bowman and René Vidal. Bowman, an expert in biophysics and data science, is the Louis Heyman University Professor, with joint appointments in Bioengineering in Penn Engineering and in Biochemistry and Biophysics in Penn Medicine. Vidal, a global pioneer of data science, is the Rachleff University Professor, with joint appointments in Electrical and Systems Engineering in Penn Engineering and in Radiology in Penn Medicine.

Dani Smith Bassett Receives Heilmeier Award

DANI SMITH BASSETT, J. Peter Skirkanich Professor in Bioengineering, was the recipient of the 2022-23 George H. Heilmeier Faculty Award for Excellence in Research for “groundbreaking contributions to modeling and control of brain networks in the contexts of learning, disease and aging.” The Heilmeier Award, named for the late George H. Heilmeier, a Penn Engineering alumnus and member of the School’s Board of Advisors, honors a Penn Engineering faculty member whose work is scientifically meritorious and has high technological impact and visibility.

TONY AND TRACY PHOTOGRAPHY



GRASP Lab Collaborates in $5M Effort To Accelerate Robotics Research

PENN ENGINEERING'S GENERAL Robotics, Automation, Sensing and Perception (GRASP) Lab is partnering in a $5 million National Science Foundation effort to accelerate human-robotic-interface research by designing a new standardized humanoid robot to distribute to the scientific community. The project involves Quori robots, a low-cost humanoid robot for human-robot-interaction research, with GRASP designing a new version of the robot, Quori Version 2.

Demystifying Grad School To Enhance Diversity in STEM

NEARLY 70 STUDENTS from around the country came to Penn in October for DEEPenn STEM, short for Diversity Equity Engagement at Penn in STEM, an initiative designed to prepare students from backgrounds underrepresented and marginalized in STEM fields to pursue graduate studies. During the event, Penn Engineering hosted sessions that highlighted graduate opportunities in engineering and technology in the School.

IN MEMORIAM

Honorable Harold Berger

THE HONORABLE HAROLD BERGER (EE'48, L'51), a Penn Engineering alumnus and long-time member of the School's Board of Advisors, passed away on August 26, 2023, at the age of 98.

Judge Berger graduated from Penn Engineering in 1948 with a bachelor's in Electrical Engineering and from Penn Law in 1951. After his first two years in Penn Engineering, Judge Berger served in the U.S. Army during World War II, notably having tested V-2 rockets with Wernher von Braun (post surrender to the Allies) at White Sands Proving Grounds in New Mexico. After his service, he returned to complete his undergraduate degree. Penn Engineering's Harold Berger Distinguished Lecture and Award, named in his honor, is awarded by the School to a technological innovator who has made a lasting contribution to the quality of our lives.

Judge Berger was Of Counsel and Executive Shareholder Emeritus of the Philadelphia-based law firm Berger and Montague, P.C. Previously, he served as Judge of the Court of Common Pleas of Philadelphia, Chairman of the Federal Bar Association's National Committee on the Federal and State Judiciary, and Chair of the Aerospace Law Committees of the American, Federal and Inter-American Bar Associations. In 2021, Judge Berger was awarded a Special Philadelphia City Council Resolution recognizing his many achievements in public service, academia and the national legal community.

Cynthia Buoni

CYNTHIA "CINDI" BUONI, a longtime member of the Penn Engineering staff, passed away on September 22, 2023, at the age of 67.

Buoni was an integral part of Penn Engineering for 40 years. She first joined Penn as a staff member in the Wharton School in 1974, after which she came to Penn Engineering in 1983. Her many roles during her time in the School include her most recent position as Registrar for Penn Engineering, which she held until her retirement in June.

Buoni's contributions to Penn Engineering include the implementation of many of the systems and processes that are relied upon today for the success of students, faculty and staff in the School. Most recently, she was instrumental in the pivot to online instruction and subsequent hybrid environments during the COVID-19 pandemic, and she worked to ensure Penn Engineering was part of the development and launch of Pennant and many other academic affairs tools used by the entire campus community. In 2021, Buoni was selected as the recipient of the Penn Engineering Staff Recognition Award, the highest award presented to staff in the School.

Due to her many years at Penn, Buoni possessed unparalleled institutional knowledge and above all was a kind and compassionate advisor, providing a listening ear to thousands of students during her decades in the School.

Kenneth R. Laker

KENNETH R. LAKER, Professor Emeritus in Electrical and Systems Engineering, passed away on August 2, 2023, at the age of 76.

Laker earned a bachelor's in Electrical Engineering from Manhattan College in 1969, and master's and Ph.D. degrees in Electrical Engineering from NYU in 1970 and 1973, respectively. After graduating, he served in the U.S. Air Force as First Lieutenant, working with the Air Force Cambridge Research Labs. Laker later worked at Bell Labs before joining the Penn Engineering faculty in 1984 as Professor and Chair of the then-named Electrical Engineering department. In 1990, Laker became the Alfred Fitler Moore Professor of Electrical Engineering, which he held until he retired and earned emeritus status in 2016.

Laker's research was in mixed mode integrated circuit design and testing, with a focus on high-performance, low-power data acquisition and radio-frequency systems, which have many important applications and present challenging obstacles for design, implementation and testing. Laker was also very active with the IEEE, where he served as president and in 2018 was elected to the IEEE's Technical Activities Board Hall of Honor.

Laker also served on the boards of AANetcom and DFT Microsystems, the latter of which he co-founded in 1997. He wrote four textbooks, authored more than 100 peer-reviewed articles, and filed six patents. Laker received numerous honors and awards, among those the 1994 AT&T Clinton Davisson Trophy for his patent in switched capacitor circuits, and the 1998 IEEE Circuits and Systems Darlington Award.

Charles J. McMahon

CHARLES J. MCMAHON (MtE'55), Professor Emeritus in the Department of Materials Science and Engineering, passed away on December 10, 2022, at the age of 89.

McMahon attended the University of Pennsylvania on an NROTC scholarship, where he earned a bachelor's degree in Metallurgical Engineering in 1955. After completing his degree, McMahon served aboard the battleship USS New Jersey and later as a communications officer and cryptographer on the minesweeper USS Thuban. Following three years of active duty, he enrolled at MIT, where he earned an Sc.D. in Physical Metallurgy in 1963.

McMahon then returned to Philadelphia to complete a postdoctoral fellowship in the newly formed Department of Metallurgy and Materials Science (now the Department of Materials Science and Engineering) in Penn Engineering. A year later, he joined the faculty of that department, where he remained throughout his career, serving as Chair from 1987 until 1992.

McMahon was one of the world's leading authorities on steel fracture, contributing directly to saving lives on bridges and in buildings, as well as on ships. McMahon was elected to the National Academy of Engineering (NAE) in 1980. He was a pioneering educator who authored two textbooks aimed at introducing principles of materials science to undergraduates by examining the properties of familiar technology, mainly the structural components of the bicycle. He was an early adopter of interactive digital media, and his work as an educator was recognized by Penn Engineering's S. Reid Warren, Jr. Award in 1992 and the University's Lindback Award for Distinguished Teaching in 2001.

Alan Myers

ALAN MYERS, Professor Emeritus in Chemical and Biomolecular Engineering, died on September 12, 2022, at the age of 89.

Myers earned a bachelor's in Chemical Engineering from the University of Cincinnati in 1960 (which awarded him a Distinguished Alumnus Award in 1977), and a Ph.D. from the University of California, Berkeley in 1964. After graduating, he joined the Penn Engineering faculty as an Associate Professor in the then-named Chemical Engineering department, where he remained throughout his career. In 1972, he was promoted to full professor.

At Penn, Myers was named Chair of the Department of Chemical and Biochemical Engineering, now Chemical and Biomolecular Engineering, in 1977. In 1983, he received Penn Engineering's S. Reid Warren, Jr. Award in recognition of his work as an educator and mentor.

Myers conducted prestigious research on the thermodynamics of surfaces, the interactions of unlike molecules absorbed in a solid surface, gas storage by adsorption in micropores, and adsorptive separation of mixtures. He co-wrote three books and received the 1997 Institute Award for Excellence in Industrial Gases Technology from the American Institute of Chemical Engineers (AIChE). Myers co-founded the International Adsorption Society in 1983, a nonprofit professional association dedicated to serving people, firms and organizations who seek to advance the art, science and technology of adsorption and related subjects.

Jay Zemel

JAY ZEMEL, Professor Emeritus in Electrical and Systems Engineering, passed away on July 20, 2023, at the age of 95.

Zemel earned bachelor's, master's and Ph.D. degrees in Physics from Syracuse University in 1949, 1953 and 1956, respectively. While working toward his Ph.D., he took a part-time research position in the Naval Ordnance Laboratory in Silver Spring, Maryland, and after its completion he rose to become a supervisory research physicist and head of the Surface and Film Group. In 1966, Zemel joined the Penn Engineering faculty in the then-named Moore School of Electrical Engineering as the RCA Professor of Solid State Electronics. In 1994, he was named the H. Nedwill Ramsey Professor of Sensor Technologies, which he held for two years until his retirement, when he earned emeritus status.

Zemel's career at Penn spanned nearly 60 years and was dedicated to work in sensors, sensor systems and thin films. In 1969, Zemel was selected to direct the new Solid State Electronics Lab at The Moore School, later reorganized into the Center for Sensor Technologies. He served as Chair of Electrical Engineering (now Electrical and Systems Engineering) from 1972 to 1977.

Zemel was a fellow of IEEE, held 26 patents, authored more than 120 peer-reviewed journal articles and book chapters, and served as the editor-in-chief of the journal *Thin Solid Films*. Over his long career, he mentored a great number of students, particularly undergraduate students during their Senior Design projects, something he continued to prioritize long after becoming an emeritus professor.

WHY I GIVE

Paul S. Angello

PAUL S. ANGELLO (EE'72) is a retired partner of Stoel Rives LLP in Portland, Oregon. After graduating from Penn, he went on to earn a J.D. from the University of Southern California in 1981 and joined Stoel Rives in 1985, where he founded and built the firm's patent practice. While practicing, Angello leveraged his engineering foundation in patent prosecution and litigation matters, including patent infringement lawsuits. He also secured for clients hundreds of patents on inventions relating to numerous engineering and technical disciplines. Angello's gifts to the School include the Stephen J. Angello professorship, named for his father and currently held by Professor Cherie Kagan in Electrical and Systems Engineering (ESE), and the Dorothy M. Angello administrative suite in ESE, which he named for his mother. He is also active in supporting Engineering Annual Giving.

What drew you to engineering and eventually to Penn Engineering?
The influence of my dad — he never let me buy anything; I always had to build it. Automobile engine analyzers, electric guitar amplifiers, transistor radios, you name it. I was always mechanically and electrically oriented and felt that engineering lent itself to my natural abilities. My dad was also a graduate of Penn Engineering and was very Penn-centric, so I grew up coming to campus with him.

Why did you decide to go into law?
While I was working as an engineer at Hughes Aircraft Company, I started to recognize things about my skillset: I was a good writer and had a detective side to me that I wanted to pursue. After working with patent attorneys to patent my own inventions, I became interested in patent law.

How did Penn Engineering contribute to your success as a patent attorney?
The foundation, the focus and the ability to relate to inventors and technical expert witnesses. Many attorneys in my field characterize themselves as attorneys who happen to be engineers, but I'm the opposite: I'm an engineer who happens to be a patent attorney. I've set up electrical labs for demonstrations to opposing counsel to cause dismissal of patent infringement lawsuits and used my knowledge of engineering and science fundamentals to solve patent law problems with technological solutions rather than by primarily arguing over patent case law.

What would you like to say to current students?
Penn Engineering has remained consistent in its high-quality faculty and resources. Take full advantage of these while on campus and, after you graduate and you are in the place to do so, think about what was made available to you at Penn and contribute to the cause so other students coming behind you can have those opportunities as well. I chose to honor my mother and my father in my giving because they were instrumental in helping me to get to where I am, but I encourage all alumni to find a way to give that is meaningful and keeps them connected to the School and its future success.

HONOR ROLL

Download the 2023 Honor Roll and learn more about the ways that you can give to Penn Engineering.

dar.seas.upenn.edu/honor-roll/

PHOTO BY **JAY FRAM**

Penn Engineering Board of Advisors

Penn Engineering
UNIVERSITY of PENNSYLVANIA

Non Profit Org.
U.S. Postage
PAID
Permit No. 2563
Philadelphia, PA

School of Engineering and Applied Science
University of Pennsylvania
123 Towne Building | 220 South 33rd Street
Philadelphia, PA 19104-6391

www.seas.upenn.edu

Innovation & Impact: Penn Engineering's Podcast

Penn Engineering is proud to introduce its new podcast series titled *Innovation & Impact*, which centers on relevant, thought-provoking topics that highlight innovation, with the opportunity to hear members of the community and their collaborators focus on and discuss the impact of their research and educational activities.

Each episode is hosted by a member of the School's faculty and brings together additional Penn faculty as thought leaders for inspiring, interdisciplinary conversations on current tech issues and how our engineers are tackling them through innovative approaches.

Subscribe to *Innovation & Impact* on Apple Music, Spotify or your favorite listening platforms, or use the provided QR code to find the episodes on Penn Engineering's YouTube channel.