Research | Penn State

VOLUME 39 | NUMBER 2 | FALL 2019

RETURN & GET IT

12 Making Space to Create in an African Scrapyard

› ALSO IN THIS ISSUE

Choosing Empathy
Smarter Buildings
Metabolic Conversations

All to the Good

Ed. Note: Lora G. Weiss became Penn State's senior vice president for research on September 16, replacing the retiring Neil Sharkey. Most recently interim senior vice president of the Georgia Institute of Technology and interim director of the Georgia Tech Research Institute, Weiss earned her doctorate in acoustics at Penn State in 1993 and was for 16 years a member of the faculty in the College of Engineering and at the Applied Research Laboratory.

It is extremely gratifying to return to Penn State and reacquaint myself with the impressive research that is conducted here every day. The labs that I have visited and the people whom I have met so far are testaments to the breadth and depth of expertise that resides within our University. I am honored to join this community of exceptional talent as we advance our research portfolio, not just by solving problems, but also by anticipating the hardest challenges and making impressive breakthroughs, like those that are featured in this issue of *Research/Penn State* magazine.

Sez Atamturktur and a team of her engineering colleagues are developing advanced cyber-physical systems, including the smart buildings and microgrids that are transforming our nation's infrastructure by optimizing energy use and providing safe, comfortable, and sustainable environments for living and working. Meanwhile, Nilanjan Ray Chaudhuri is working to protect our power grid from catastrophic failures.

Psychologist Daryl Cameron, a research associate at the Rock Ethics Institute, is probing the science of empathy and uncovering clues about why people sometimes make the choice to avoid sharing others' feelings.

Toxicologist Andrew Patterson is employing a powerful new tool to eavesdrop on the complex molecular "conversations" that guide cellular processes, helping to determine health and identify diseases within the human gut.

Finally, architects DK Osseo-Asare and Yasmine Abbas are recognizing and nurturing creativity and opportunity in a notorious e-waste dump in West Africa, a place where others have seen only problems.

Like the exceptional research enterprise that they are a part of, these individuals and their projects span the gamut of disciplines and approaches. When reading these stories, you will recognize that they all share one thing in common—a focus on helping people by solving real-world problems at home and abroad.

Thanks for welcoming me back to Penn State.

Lora Weiss

LORA G. WEISS
Senior Vice President for Research

More research news: **news.psu.edu/topic/research**

Keep up with Penn State research between issues! Sign up for the Research & Discovery News. Curated news and features delivered to your inbox twice a month:
tinyurl.com/RDNewsSubscribe

Research/Penn State digital edition:
research.psu.edu/ovpr/magazine

More research news:
news.psu.edu/topic/research

facebook.com/pennstate

twitter.com/psuresearch

Research/Penn State is published by the Office of the Vice President for Research at The Pennsylvania State University. The magazine samples the diversity and drama of Penn State's $927-million-a-year research program as a public service to inform, entertain, and inspire the University community. Opinions expressed do not reflect the official views of the University. Use of trade names implies no endorsement by Penn State.

Publisher: **LORA WEISS**
Senior Vice President for Research
Director of Research Communications: **DAVID PACCHIOLI**

Editor: **CHERIE WINNER**
Designer: **KEVIN CARLINI**
Photographers: **PATRICK MANSELL, MICHAEL GARRETT, MICHELLE BIXBY**
Contributors: **KATIE BOHN, KRISTA WEIDNER**

ON THE COVER:
Using recycled materials and homemade equipment, a welder assembles a support beam for a community "maker space" in Accra, Ghana. See story, page 12.

(courtesy of Agbogbloshie Makerspace Platform)

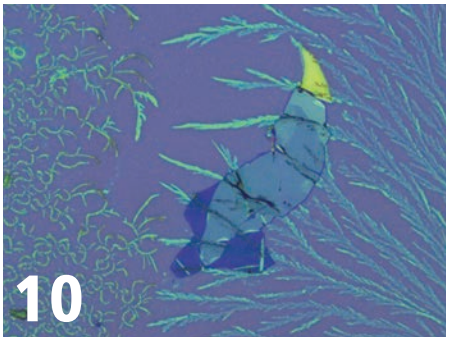
PennState

Member, University Research Magazine Association

FSC www.fsc.org MIX Paper from responsible sources FSC® C013022

Research | Penn State
VOLUME 39 | NUMBER 2 | FALL 2019

2
In Brief
A new phase of matter, volcano plumbing, blood clots, and other news highlights from Penn State Researchers.



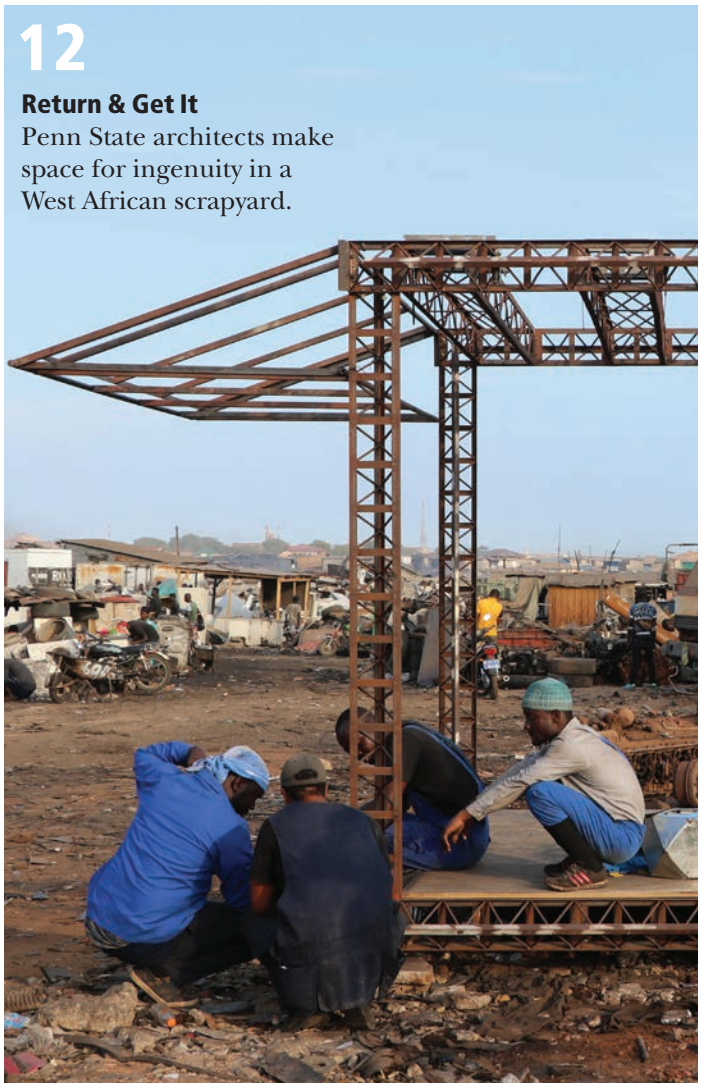
10
At Large
When a protein sample dried up, an intriguing image emerged.

36
In Touch With
Nilanjan Ray Chaudhuri on protecting the nation's power grids.

20
The Empathy Option
Why do we choose to be empathetic, or not?

24
From the Ground Up
To solve our energy challenges, start with buildings and communities.

30
Listening to Your Gut
Decoding the chemical conversations of your metabolism and your microbiome.



12
Return & Get It
Penn State architects make space for ingenuity in a West African scrapyard.

A 3D image of a stable supercrystal created by zapping a layered material with a split-second laser pulse.

›› Let There Be Light— and a New Phase of Matter

A new state of matter with long-term stability—a "supercrystal"—was recently created by a multi-institution team led by Penn State and Argonne National Laboratory.

"We are looking for hidden states of matter by exciting electrons into a higher state using a photon, and then watching as the material falls back to its normal state," says Penn State team leader Venkatraman Gopalan, professor of materials science. "The idea is that in the excited state, or in a state it passes through for the blink of an eye on the way to the ground state, we will find properties that we would desire to have."

The team first made a structure of single atomic layers of lead titanate, which has positive and negative electric poles, and strontium titanate, which is non-polar. The two were stacked in alternating layers atop a crystal substrate whose crystals were intermediate in size between the two layered materials. That mismatch created "frustration" in the material, as the strontium titanate layer tried to stretch to conform to the structure of the substrate, and the lead titanate had to compress to conform to it.

The researchers then zapped the material with a split-second laser pulse, driving it into a new state of matter, a supercrystal whose unit cell—the simplest repeating unit—had a volume one million times larger than the unit cells of the original two materials.

Unlike earlier work, in which the supercrystal state existed for only a fraction of a second, the supercrystal produced in this case is stable. It survived for more than a year at room temperature. Heating it to about 350 degrees Fahrenheit destroyed it.

—WALT MILLS

L-Q Chen Group/ Penn State

Getty Images/ LuckyBusiness

Best Path to Success for Young Athletes? Don't Specialize too Soon

It may be tempting for parents or coaches to urge young children to specialize in one sport to help maximize their chance at making it to the big leagues, but that might not be the best path to success.

In a study that looked at the sports histories of 91 professional and collegiate ice hockey players, Penn State College of Medicine researchers found that on average, the athletes played multiple sports as kids, starting at the age of 4.5 years, and the vast majority didn't focus solely on ice hockey until age 14. Only 12 percent of these elite athletes specialized in their sport before 12 years of age.

Matthew Silvis, professor of family and community medicine and of orthopaedics and rehabilitation, said the results help dispel a belief among many parents and coaches that kids have to specialize in a sport at an early age in order to succeed.

Silvis, who is team physician for the American Hockey League's Hershey Bears, says early specialization also comes with mental and physical health risks. Aside from possible burnout from focusing on one sport, he says, "You are consistently placing your body through the same movement patterns and demands. It puts you at risk of an overuse injury."

By contrast, he says, playing multiple sports can actually help young athletes develop skills and work different muscle groups in ways that will serve them well later on.

—KATIE BOHN

COOL ZONE AFFECTS JET STREAM

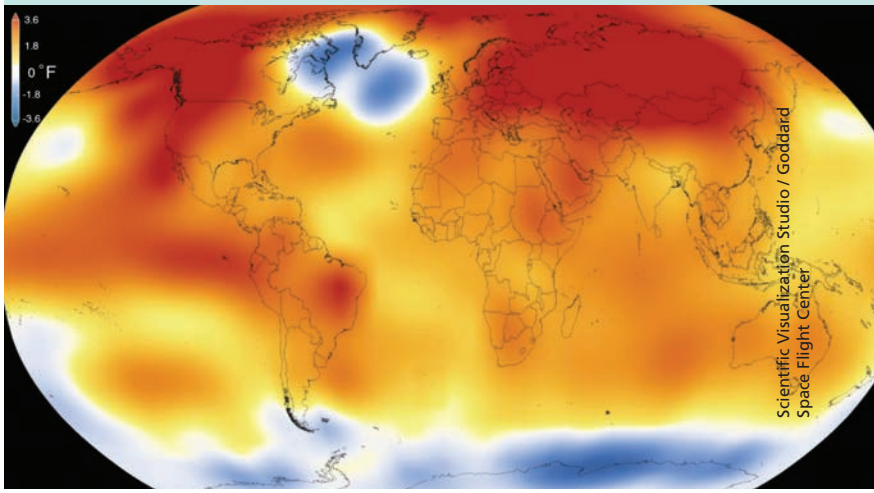
The North Atlantic warming hole (NAWH), a region of reduced warming in surface waters of the North Atlantic Ocean, will significantly affect the North Atlantic jet stream and could affect the North Atlantic storm track in the future, according to climate simulations by scientists at Penn State, Columbia University, and Columbia's Lamont-Doherty Earth Observatory.

Sea-surface temperatures are projected to continue increasing in most of the world's oceans as a result of global climate change. However, just south of Greenland lies a "hole" of cooler sea-surface temperatures. "It's called a 'hole' because there is a lack of warming," says Melissa Gervais, assistant professor of meteorology and atmospheric science, Penn State. Development of the hole has been linked to an influx of cold fresh water from melting Arctic sea ice and to a slowdown of currents bringing warm water from the tropics northwards.

Gervais used the Community Earth System model to investigate the impact of the warming hole on atmospheric circulation.

"We found that this region of the ocean is a really important place for forcing the jet stream that goes across the North Atlantic Ocean," she says. "The hole seems to be elongating the jet and shifting it a little bit north." Jet streams, high altitude currents of wind flowing more than 30,000 feet above the Earth, transport air masses and drive weather patterns. Gervais says the warming hole could influence mid-latitude atmospheric circulation, which has big implications for northern Europe, but which has so far received little attention.

—PATRICIA CRAIG



Scientific Visualization Studio / Goddard Space Flight Center

A map of global sea-surface temperatures shows warmer water in reds. The North Atlantic Warming Hole, a region of cooler water south of Greenland, is the blue area at top center.

The best drink to douse burn from chili peppers: *milk*.

- ALISSA NOLDEN *and* JOHN HAYES
Sensory Evaluation Center

Targeting Key Enzyme May Halt Spread of Ovarian Cancer

Preventing an enzyme from doing its job kept a certain type of ovarian cancer cell from growing and dividing uncontrollably in a lab study from Penn State College of Medicine.

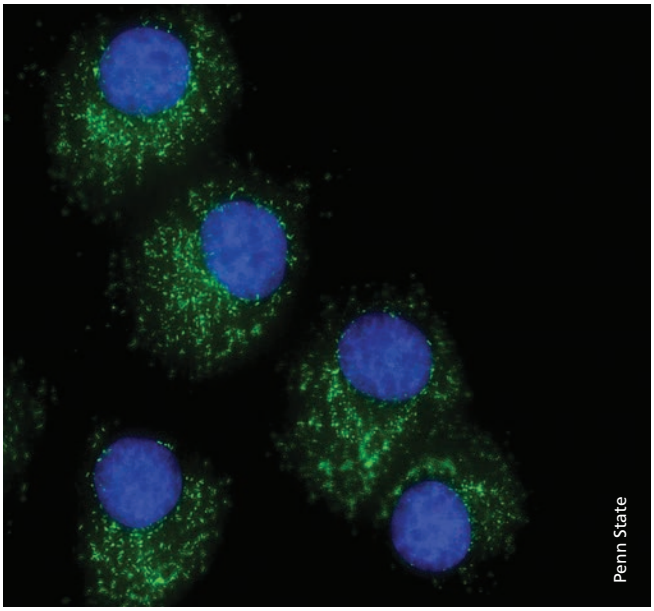
Doctoral student Erika Dahl; Katherine Aird, assistant professor of cellular and molecular physiology; and other researchers in Aird's lab have identified a way to put high-grade serous ovarian cancer cells in a "sleep state" called senescence, in which they no longer divide and grow.

Working with cell cultures, the researchers used spectrometry to evaluate the metabolic differences between normal and cancerous cells. They found that to generate sugars needed for energy production, the cancerous cells relied on the citric acid cycle rather than glycolysis, the pathway preferred by normal cells.

"Many therapies target glycolysis, but that may not be the best approach," Dahl says, because targeting glycolysis could also damage healthy tissue. She found that inhibiting the enzyme isocitrate dehydrogenase 1 in the citric acid cycle halted cell division in the cancer cells. The research further found that this method also arrested proliferation of cancer cells that had spread to other parts of the body, suggesting it might be effective in fighting late stages of the disease, when patients are typically diagnosed with ovarian cancer.

Aird says the FDA has already approved a drug that targets the enzyme, and that long-term goals of her lab is to try to repurpose the drug as a treatment for this form of ovarian cancer.

—ZACHARY SWEGER



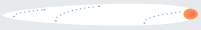
Fluorescence images of ovarian cancer cells studied in the Aird lab. Nuclei are stained blue, the cytoplasm green.

Odd eating behaviors kids don't outgrow may signal autism.

- SUSAN MAYES
Psychiatry
&
- KEITH WILLIAMS
Penn State Children's Hospital

Forcing a smile for customers is linked to drinking more after work.

- ALICIA GRANDEY
Psychology



Some cannabinoids inhibit colon cancer cells in culture.

- KENT VRANA
Pharmacology

A MODEL FOR SUSTAINABLE FORESTS? «

Native forests make up only one percent of the landscape in South Africa but could play a key role in identifying sustainable development practices that can be used to counter climate change, according to a Penn State researcher.

"As we think about pathways for reducing atmospheric carbon dioxide concentrations, one of the available approaches is to use the natural world as a sponge," says Erica Smithwick, professor of geography. The challenge, she says, is to use forests to store carbon while also meeting local community needs.

As trees grow, they absorb and store carbon through photosynthesis. In 2011, Smithwick tagged and measured trees in the Dwesa-Cwebe nature reserve in the Eastern Cape Province. She remeasured the trees five years later and analyzed the forests' carbon content.

Erica Smithwick assessing carbon stocks in the Dwesa-Cwebe nature reserve in South Africa.

Smithwick found that the coastal, indigenous forests store a moderate to large amount of carbon. They are also a biodiversity hotspot and thus important for conservation. The local communities depend on the forests for resources such as medicinal plants, fuelwood, and timber, as well as their spiritual needs.

Smithwick notes that the high level of forest productivity, or how quickly the forests grow, and small amount of human use of forest resources suggest that humans are not negatively influencing the Dwesa-Cwebe forests.

"We have to recognize the importance of these natural forests and their biodiversity and carbon values, but we also have to situate that in a sustainable development challenge," says Smithwick. "The forest in South Africa is a good case study for how we start to think about balancing these considerations."

—FRANCISCO TUTELLA

USGS Hawaiian Volcano Observatory

Pressure changes in the summit reservoirs of Kilauea may help predict eruptions in the volcano's East Rift Zone better than current methods.

›› Volcano's Plumbing May Signal Pending Eruptions

A volcano will not send out an official invitation when it's ready to erupt, but new research suggests that scientists who listen and watch carefully may be able to pick up signs that an eruption is about to happen.

According to Christelle Wauthier, assistant professor of geosciences, pressure changes in summit reservoirs of Hawaii's Kilauea volcano helped explain the number of earthquakes, or seismicity, in the volcano's upper East Rift Zone. Such seismic activity may predict magma movements and resulting eruptions better than current methods, says Wauthier.

A summit reservoir is an underground chamber holding hot magma; pressure changes there cause stress in the surrounding earth that can trigger small volcano-tectonic earthquakes, most of which can't be felt by humans but can be detected by seismic monitoring equipment.

The team analyzed seismic and global positioning satellite data collected by the U.S. Geological Survey Hawaiian Volcano Observatory from mid- to late-2007. They observed physical changes to the mountain's shape, especially ground surface deformations at the summit, and looked at how those factors correlated with models of the stress changes caused by inflations and deflations of the summit reservoir.

This study challenges the view that seismic activity in the rift zone is due mainly to the volcano's gradual slip toward the sea. For volcanoes with good seismic networks, says Wauthier, this approach could be used to determine whether small earthquakes are due to magma movement, which might signal a coming eruption.

—MATT SWAYNE

The black form of the bumble bee (right) is similar to other bees in the Pacific coastal region, and the red form (left) is similar to other bees in the Rocky Mountain region.

Li Tian/ Penn State

» How the Bee Got its Stripes

Researchers have discovered a gene that drives color differences within a species of bumble bee and helps to explain the highly diverse color patterns among bumble bee species as well as how mimicry—individuals in an area adopting similar color patterns—evolves.

The most common bumble bee color patterns feature red around a bee's tail, thought to advertise its dangerous sting, says Heather Hines, assistant professor of biology and of entomology. In spite of the great diversity available, color patterns tend to converge toward similarity within particular geographic regions. This is an example of Müllerian mimicry, where similar, often vibrant, color patterns are used among multiple species to warn predators of a dangerous feature.

"Studying these mimicry systems allows us to see how natural traits evolve. It can also tell us about how traits are encoded in the genome: Is there only one way to make a trait, or do different species arrive at similar traits through different genetic pathways?" says Hines.

The research team investigated the genetic basis of color in the species *Bombus melanopygus*, which exhibits two regional color patterns. Those in the Pacific coastal region are black in the mid-abdomen, whereas those in the Rocky Mountain region are red. Previous studies suggested that a single gene was driving this color change.

The researchers performed a genome-wide association study, looking for variation in the DNA sequence associated with variation in the trait. They identified a regulatory region that changes expression of a gene called "Abdominal-B," which drives the shift in color.

This change resulted in Abdominal-B being expressed in an unusual location late in pupal development, when that pigment is starting to show up in the bee. Abdominal-B is usually expressed closer to the tail of the bee, but in red-striped bees it is expressed in segments further up, causing a mid-abdominal color shift.

According to the researchers, this change was not responsible for color shifts in ten closely related species of bumble bees with similar red and black color variation. It is likely that these other species undergo genetic changes that target other regulatory regions of the same gene or different genes entirely.

"This tells us that the basis for color patterning in *Bombus melanopygus* arose independently from patterning in other species," said Hines. "Bumble bees do not share this similarity in color pattern because they all inherited it from a common ancestor, so there must be many diverse routes to mimicry."

—GAIL MCCORMICK

Key steps in the origin of life could occur in a variety of conditions.

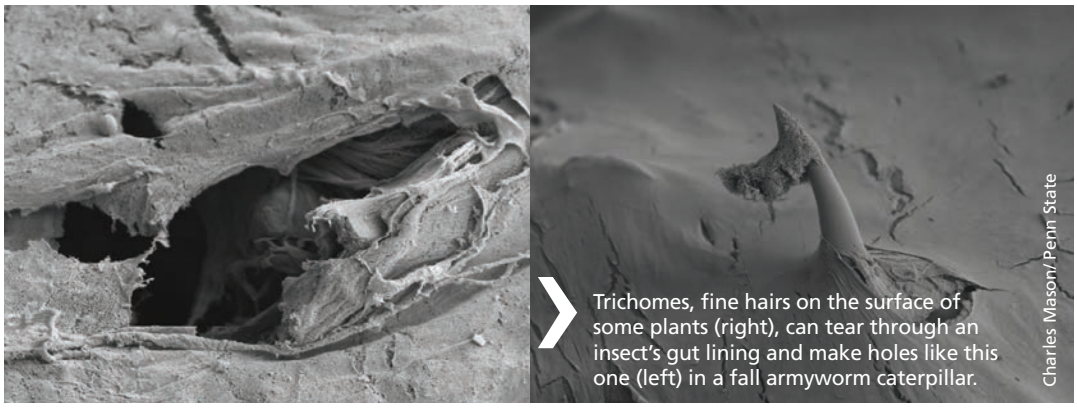
- CHRISTOPHER HOUSE
Geosciences

Synthetic fabrics shed microfibers that add to plastic pollution.

- MELIK DEMIREL
Engineering Science and Mechanics

Avocado seed extract shows promise as an anti-inflammatory.

- JOSHUA LAMBERT, GREGORY ZIEGLER, and RACHEL SHEGOG
Food Science



Trichomes, fine hairs on the surface of some plants (right), can tear through an insect's gut lining and make holes like this one (left) in a fall armyworm caterpillar.

Charles Mason/Penn State

Plants Give Insects "Leaky Gut"

Plants may protect themselves against insect attacks with a multipronged strategy that includes inducing "leaky gut syndrome," according to researchers at Penn State.

"We found that a combination of physical and chemical defenses in corn plants can disrupt the protective gut barriers of fall armyworms, creating opportunities for gut microbes to invade their body cavities," says Charles Mason, postdoctoral scholar in entomology. "This can cause septicemia, which can kill the insect, or simply trigger an immune response, which can weaken the insect."

The researchers reared fall armyworms in the lab and inoculated them with one of three types of naturally-occurring gut bacteria. They fed the larval insects on one of three types of maize: one that produces enzymes that make holes in insect gut linings; one with many elongated trichomes, or fine hairs that occur on the surface of the plant; and one with just a few short trichomes. The team used scanning electron microscopy to evaluate the effects of each treatment on the worms' gut linings.

All three types of gut bacteria decreased the ability of fall armyworm larvae to damage maize plants, especially when elongated trichomes and enzymes, defenses that can perforate gut linings, were present.

The study could aid the development of insect-resistant crops, says Mason. "It may be advantageous to 'stack' plant defenses that target the insect gut in order to create a 'leaky gut' that exposes the insect to microbial assaults on their immune system."

—SARA LAJEUNESSE

HOW DIGITAL TECH IS CHANGING SCIENCE «

In today's digital age, artificial intelligence and big data are helping people navigate the world in new ways. As a data ethicist, Fred Fonseca, associate professor of information sciences and technology, explores the ethical dimensions of how we gather, manage, and use all that information.

With the rise of big data, for example, many scientists and analysts are foregoing formulating hypotheses in favor of making inferences from data that are already available on particular problems.

"Normally, in science, theory drives observations. Our theoretical understanding guides both what we choose to observe and how we choose to observe it," Fonseca explains. "Now, with so much data available, science's classical picture of theory-building is under threat of being inverted."

In a recent paper, he proposes a concept to bridge the divide between theoretical thinking and a-theoretical, data-driven science, comparing data or artificial intelligence to a cane that a blind person might use to navigate the world.

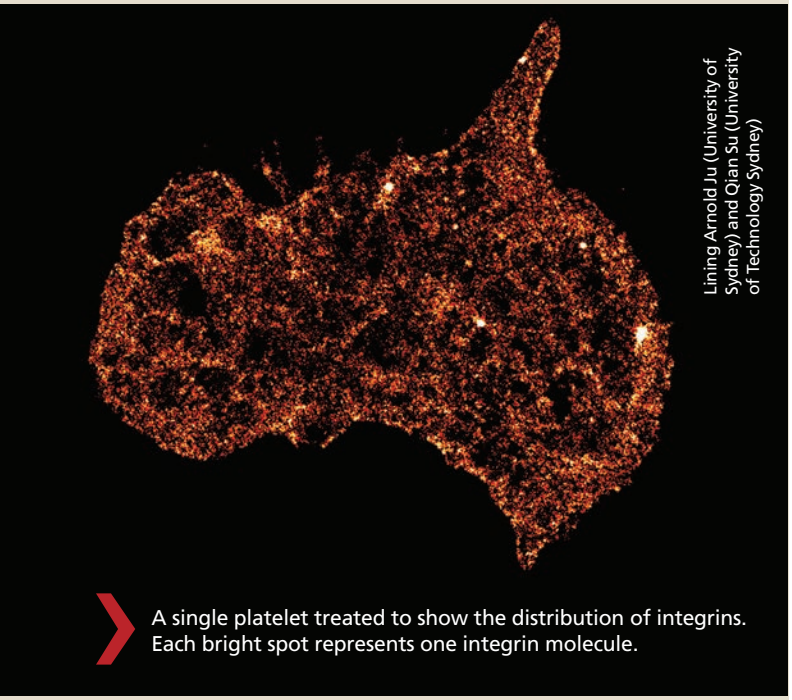
"Scientists use the really-existing data to feel along and interact with the really-existing world, engaging data not as a representation, but as an instrument to help facilitate their empirical thinking," he explains.

He proposes a practical reshaping of how analysts, practitioners, and scientists think about their work. With advances in artificial intelligence, and machines acting and thinking more like humans, he says, it's important to take time to reflect.

"It's all about values. We can have all kinds of data, but we need to know how we are using it."

—JESSICA HALLMAN

Getty Images/ monsitj



Lining Arnold Ju (University of Sydney) and Qian Su (University of Technology Sydney)

A single platelet treated to show the distribution of integrins. Each bright spot represents one integrin molecule.

THE CLOT THICKENS ‹‹

New research demonstrates how proteins called "integrins"—receptors in the outer membranes of cells that help cells bind to one another and interact with their environment—form an intermediate state between their active and inactive forms that promotes the aggregation of platelets, the cells that form blood clots.

Coagulation of platelets is key to stopping blood loss from a cut or wound, but over-activation of this process of thrombosis can lead to deadly blood clots, heart attack, or stroke. The new findings, by an international team from Penn State, the Scripps Institute, Georgia Tech, and the University of Sydney in Australia, take researchers one step closer to developing new anti-thrombotic drugs without the serious side effects that can cause fatal bleeding.

"We want to understand the mystery behind blood clots, using innovative biomedical engineering and novel statistical tools," says Lingzhou Xue, assistant professor of statistics at Penn State. "We've been working together for a long time to study how mechanical force triggers blood clotting at the molecular scale."

The researchers used a microfluidic channel to mimic the narrowing of vessels that causes blood clots and observe the activation of platelets at the single-molecule level. They also developed a biomechanical nanotool to observe how platelets harness mechanical force in blood flow to exert adhesive clotting functions.

The researchers say their finding has the potential to guide the development of new anti-thrombotic strategies, and may also help diabetic patients, whose platelets are resistant to conventional anti-clotting drugs.

—SAM SHOLTIS

Our National Crime

An interactive map of lynchings in the United States from 1883 to 1941 reveals the extent of this mob violence, and also underscores how economy, topography, and law enforcement infrastructure paved the way for these brutal outbursts, according to researchers.

Although often thought of as unique to the southern U.S., lynching was practiced across the country and, although Southern blacks were by far its most common victims, the violence left few races and ethnic groups unscathed, says Charles Seguin, Penn State assistant professor of sociology.

"I doubt many people today know that lynchings occurred in places like Chicago, Illinois; Duluth, Minnesota; or in Coatesville, Pennsylvania," says Seguin. "I think that Ida B. Wells-Barnett put it best when she said that lynching was 'our national crime.'"

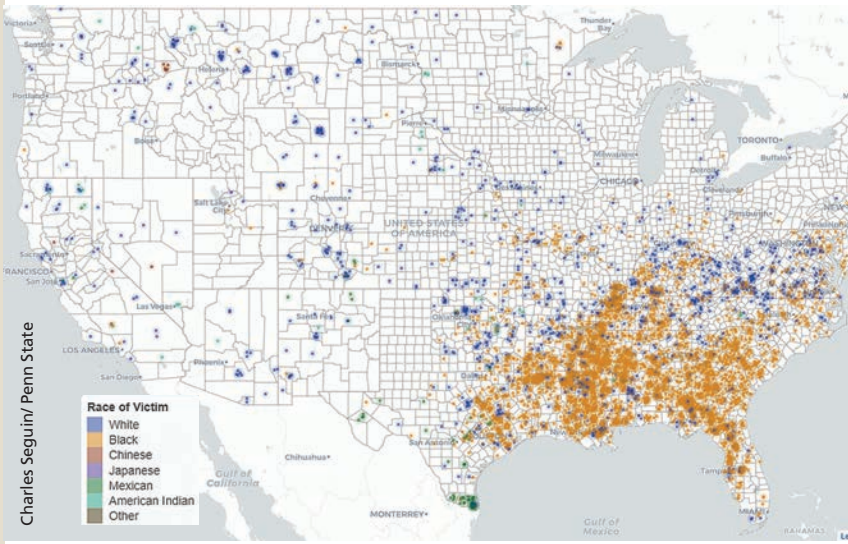
The researchers drew on data collected by the NAACP and Chicago Tribune, as well as lists published by historians. Of the 4,467 people listed as victims of lynching, 3,265 were black, 1,082 were white, 71 were Mexican or of Mexican descent, and 38 were American Indian.

The violence that extended to areas outside the deep South tended to center in areas where slavery-intensive industries—including cotton, tobacco and hemp farming—were located, and reflected the cultural and economic legacy of slavery.

In the American West, where more victims tended to be white, lynchings appear to be connected to a lack of law enforcement organizations in those areas. Elsewhere, the map shows that topography and its effects on land use may have played an underlying role in lynching patterns.

—MATT SWAYNE

A new study shows that lynching was widespread in the U.S. from 1883 to 1941. Although Southern blacks were by far its most common victims, the violence left few races and ethnic groups unscathed.



Charles Seguin/ Penn State

In a behavior known as "questing," a black-legged tick clings to a leaf with its hind legs and reaches out with its forelegs, ready to climb onto a potential host walking by.

CDC / James Gathany; William L. Nicholson, Ph.D.

›› Tale of the Ticks

The prevalence of the most abundant species of ticks found in Pennsylvania has shifted over the last century, according to Penn State scientists. The finding is important for assessing and reducing the risk of diseases caused by tick-borne pathogens.

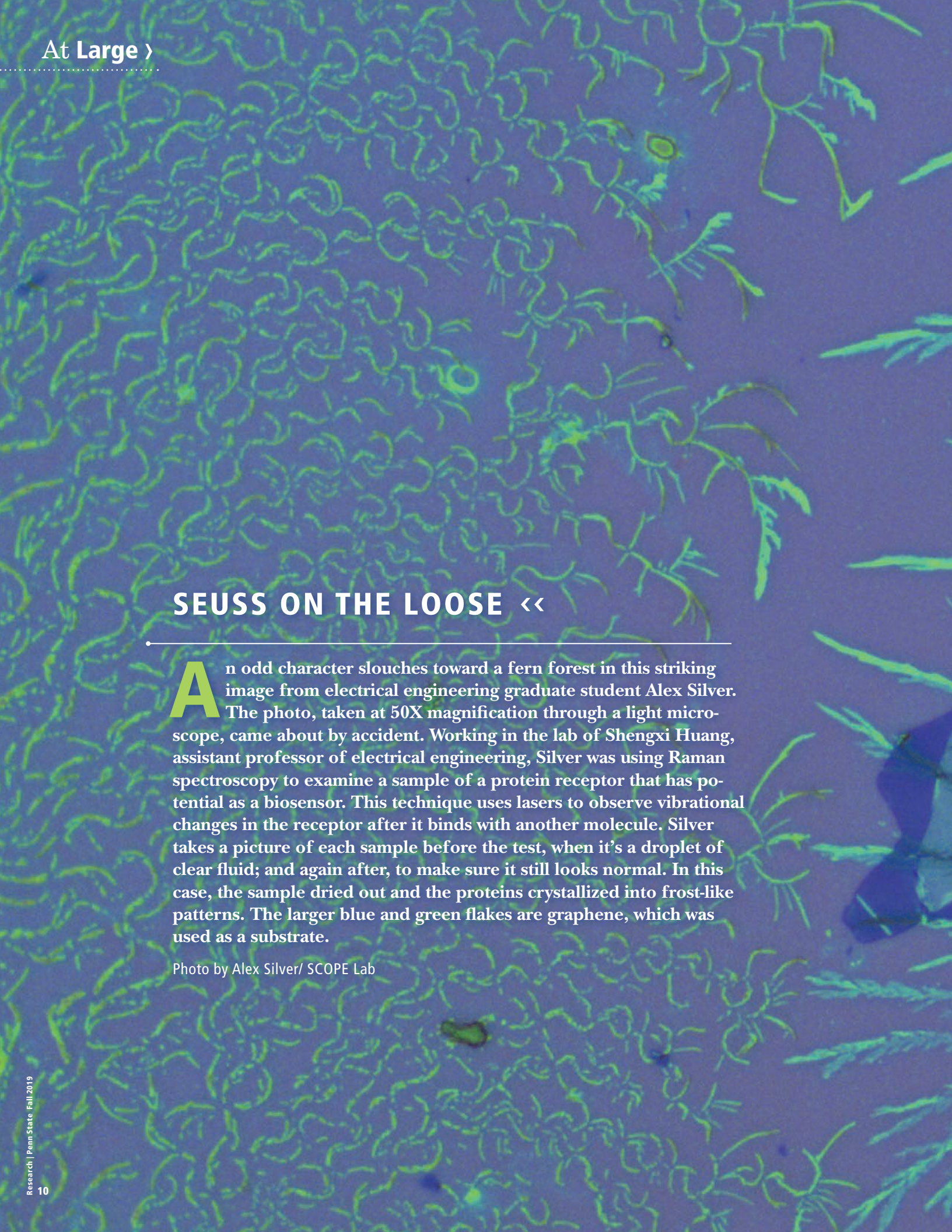
The Centers for Disease Control and Prevention reported a 3.5-fold increase in vector-borne diseases in the United States between 2004 and 2016, with more than 76 percent of cases caused by tick-borne pathogens. The vast majority of these cases are Lyme disease, attributed to the bacterium *Borrelia burgdorferi*. Pennsylvania has had the highest number of Lyme disease cases in the U.S since 2000.

The research team, led by Joyce Sakamoto, assistant research professor of entomology, compiled data from more than 7,000 tick specimens dating from 1900 and submitted by residents from all 67 counties in Pennsylvania.

"Based on these collections, there have been several shifts in the dominant species of ticks over the last 117 years," Sakamoto says. For example, the dominant species today is *Ixodes scapularis*, the black-legged tick, which is the primary vector of Lyme disease. But this tick was almost nonexistent in Pennsylvania as recently as the 1960s.

Sakamoto explains that the black-legged tick's population likely declined in the early 20th century because timber-harvesting practices destroyed habitat for deer and other wildlife that serve as hosts. As reforestation was achieved and habitat restored, the population of these ticks—which sometimes are called deer ticks—exploded. Blacklegged ticks now are found in every county in Pennsylvania.

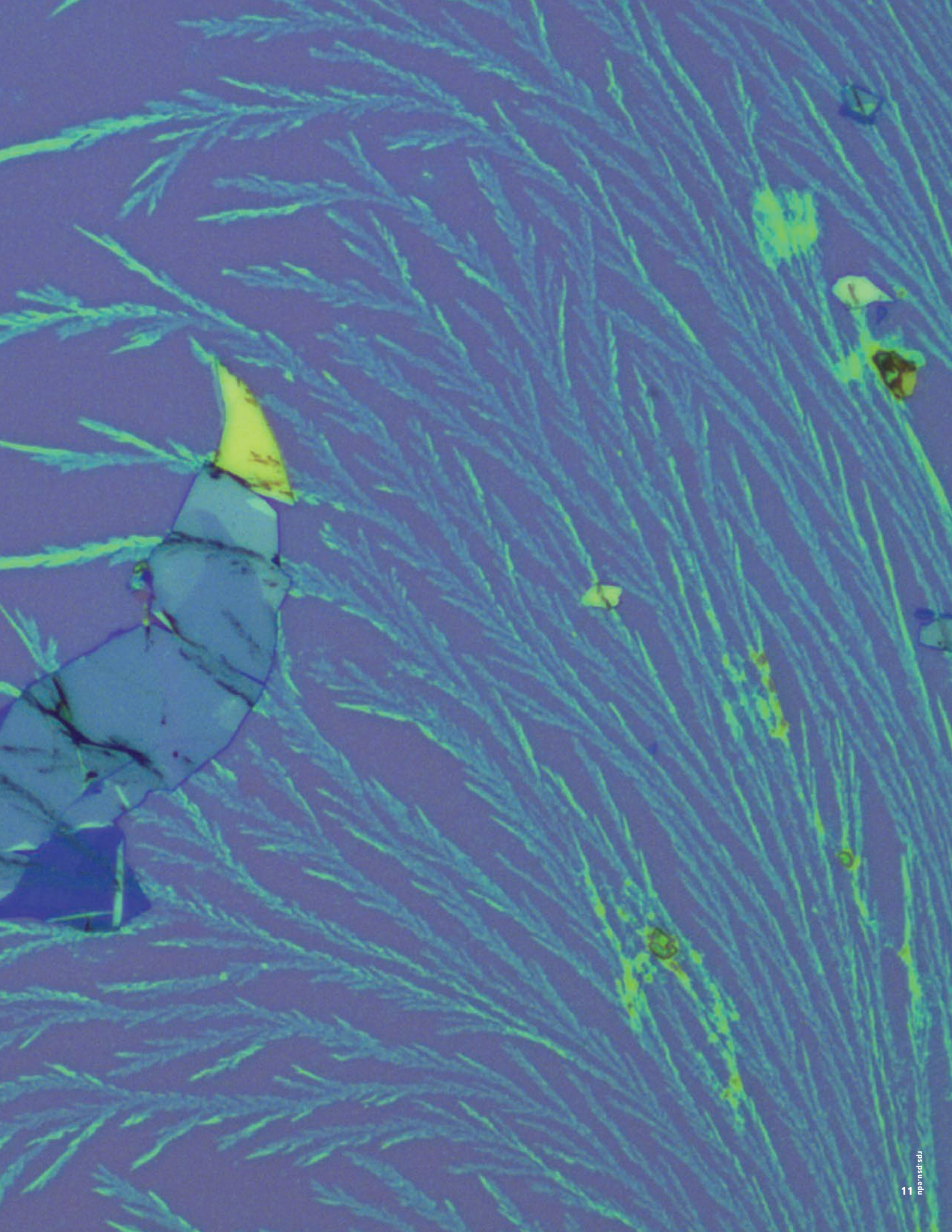
—CHUCK GILL



SEUSS ON THE LOOSE ‹‹

An odd character slouches toward a fern forest in this striking image from electrical engineering graduate student Alex Silver. The photo, taken at 50X magnification through a light microscope, came about by accident. Working in the lab of Shengxi Huang, assistant professor of electrical engineering, Silver was using Raman spectroscopy to examine a sample of a protein receptor that has potential as a biosensor. This technique uses lasers to observe vibrational changes in the receptor after it binds with another molecule. Silver takes a picture of each sample before the test, when it's a droplet of clear fluid; and again after, to make sure it still looks normal. In this case, the sample dried out and the proteins crystallized into frost-like patterns. The larger blue and green flakes are graphene, which was used as a substrate.

Photo by Alex Silver/ SCOPE Lab



RETURN & GET IT

Making space for ingenuity in a West African scrapyard

BY KRISTA WEIDNER

Search YouTube for content on Agbogbloshie—a 20-acre scrapyard in the city of Accra, Ghana—and you'll find documentaries with titles like "The Most Toxic Place on Earth," "ToxiCity," and "Welcome to Sodom."

"These are the images the media love to show around Agbogbloshie," says DK Osseo-Asare, assistant professor of architecture and engineering design at Penn State. "Young African men and boys burning wires and cables to recover copper and aluminum, using Styrofoam and old tires as fuel, creating clouds of toxic smoke, harming themselves and the environment, all to make a little money."

But those media tell a story that's incomplete, says Osseo-Asare, who is a Fulbright Scholar and TED Global Fellow.

In Agbogbloshie, more than 7,000 people retrieve scrap materials that have come from Accra, elsewhere in Ghana, and neighboring West African countries. Scrap dealers recover steel from cars, microwaves, and washing machines, and that steel becomes rods for new construction. Cookstoves are fashioned out of metal roofing sheets. Recovered aluminum is melted down and re-formed into decorations for buildings. Plastic that is sorted, washed, shredded, and even pelletized is sold to factories and used to help make new buckets and chairs.

As well as "traditional" scrapyard fare (like junk cars), Agbogbloshie includes electronic waste, or e-waste—phones, computers, appliances—that scrap dealers disassemble for parts that can be resold or re-used. "Make no mistake about it—there are young hackers in Agbogbloshie," Osseo-Asare says, "and I mean that in the very best sense of the word. With minimal formal training, they teach themselves the workings of electronics. These 'urban miners' know how to take apart computers and which components they can sell for profit. They also know how to put devices back together, how to give them new life.

"We want to show people this counter-narrative about Agbogbloshie. Young people there are already makers. We want to empower them to do their work in a way that's profitable and healthier for them and their environment."

AN ENDLESS STREAM OF OLD PHONES

To imagine how a multi-acre scrapyard of e-waste can come to exist, we need look no further than our newest devices—and that box or drawer full of old smartphones, tablets, and chargers. Planned obsolescence: It's the idea that our electronic devices and other products are meant to fail or become outmoded, so we will throw them out and purchase new ones.

Image courtesy of Agbogbloshie Makerspace Platform

"There's innovation and hope and possibility in Agbogbloshie. The workers there are not voiceless or powerless–they have agency." —DK OSSEO-ASARE

"We all know this," Osseo-Asare says. "Our televisions, our phones, our computers—we don't buy these things with the intention of keeping them for a long time—or even fixing them. When it breaks, you trash it and get a new one."

While this kind of design thinking is successful as a business model, it's often done at the expense of vulnerable populations and ultimately leads to more and more e-waste.

As smart technology accelerates in industrialized countries, it's also taken hold and is expanding in the developing world. "It's starting to happen in parts of Africa," Osseo-Asare says. "As billions of dollars are going towards smart technology, and building smart cities globally, e-waste all over the world is creating highly polluted environments where young, poor, vulnerable people are exploited."

To push back against that model, Osseo-Asare and his colleague, French architect and strategic designer Yasmine Abbas, delved into an approach called participatory design: working with local people to find solutions that empower them.

"The Agbogbloshie project emerged out of our ideas about participatory design," says Abbas, an assistant teaching professor of architecture who has done consulting in Europe, North America, the Middle East, Africa, and Asia, employing design thinking to drive urban innovation. "When we shared our ideas, people would tell us, 'This all sounds well and good, but it would make more sense if you could show an application of it.' So we set out to create a kind of case-study example to demonstrate what we're talking about. It began as an inquiry, wondering how we could put our theories into practice."

As Osseo-Asare and Abbas spent time in Agbogbloshie, observing and talking with the workers there, their inquiry led to the next question: What would happen if they connected self-taught urban miners and grassroots makers working in Agbogbloshie with students and young professionals in STEAM (science, technology, engineering, arts, math) fields?

Over the last several years, the researchers have collaborated with more than 1,500 young people—about half professionals, and half scrap dealers and grassroots makers from Agbogbloshie and beyond. "Scrap dealers and young students and recent grads in STEAM fields don't hang out in the same places," Abbas says. "Our goal was to bring together young people from different backgrounds that otherwise would never meet each other."

In interviews and conversations, the researchers and professionals sought to understand the activities and ambitions of the people who live and work in and around Agbogbloshie. "We worked with makers to spatially map the work areas so we could understand where different activities happen," Osseo-Asare says. "Where is scrap stored? Where do workers disassemble components? We collected data about the waste stream and modeled these flows all the way from the import of products, to their reuse or recycling, and ultimately to their export."

Conversations sprang up among scrap dealers and STEAM professionals about how they could collaborate to test and develop new machines and tools that change the way things are done in the scrapyard. Out of those conversations grew the Agbogbloshie Makerspace Platform (AMP).

MAKING CONNECTIONS

Part tech-startup, part design incubator, and part research project, AMP seeks to connect Agbogbloshie's e-waste, scrap, and recycling industry with technical skills and a social entrepreneurial framework. As one component of AMP, the researchers built a physical "makerspace"—a small, customizable kiosk that provides space for crafting, and was thus dubbed Spacecraft. Osseo-Asare and Abbas think of Spacecraft as a portal that connects local and global and connects making with remaking and unmaking.

For the first Spacecraft, constructed in Agbogbloshie five years ago, the team made a rule for themselves: Everything had to be made from scratch using only materials made in Ghana or sourced from the scrapyard. They used recovered steel, bolts taken from junk cars, and welding machines made right there in Agbogbloshie.

"These kiosks are open-source, which means anyone can use them," Osseo-Asare explains. "For example, each module includes a toolbox that makers can access. They can check out any tools they need, take them to where they're working, and then return them."

Clockwise, from lower right: **1**, A man cuts bits of metal from old electrical plugs. **2**, Recovered metal is melted down and cast into a variety of forms such as decorative fence finials. **3**, Engine parts were used to make dumbbells. **4**, Two men refurbish a computer with wire and other parts from discarded electronics. **5**, A good day's haul of re-usable wire. **6**, A boy strips insulation from copper wire. Images courtesy of Agbogbloshie Makerspace Platform.

Stephanie Swindle Thomas

Top: Every truckload of trash brought to Agbogbloshie is a trove of potentially useful materials. Bottom left: DK Osseo-Asare and Yasmine Abbas at University Park. Bottom right: A workman forges a coal stove from sheet metal recovered at the dump. Images courtesy of Agbogbloshie Makerspace Platform.

Left: A completed module at Agbogbloshie provides a meeting space and access to laptops. Right: Yasmine Abbas talks with a computer science student from Ashesi University in Accra. Images courtesy of Agbogbloshie Makerspace Platform.

With the help of laborers, the researchers built the first module, and then held workshops in it to explore different ways it could function. "We wanted to know who would use it, and how it would hold up," Osseo-Asare says. They tested the makerspace kiosk for three years, and based on the results of that testing, they've done some redesigning and upgrading for future modules.

"What matters to us, and what ultimately drives the design, is that these modules are available and cheap, so people with less means and education can use them easily," Abbas says. "We're always looking to improve the design and architecture of the kiosks, experimenting with different thicknesses of metal, finding ways to use fewer resources."

Osseo-Asare and Abbas are quick to point out that Spacecraft is not a traditional structure. "Think of it this way," Osseo-Asare says. "This piece of architecture is also equipment, or a machine. It can not only host something, but it can do something. It's an object that makers can hack."

Osseo-Asare and Abbas built another Spacecraft module this past year in Dakar, Senegal, in collaboration with a community arts and technology center. They held a workshop there for architects, students, and young makers, and since then, the module has served as home for a 3D printer, a pop-up shop, and a plant-growing space with embedded digital sensors. A third module, built in Agbogbloshie last summer, traveled to Germany for an international design exhibition, where it also hosted a maker workshop with architecture students to prototype a smart canopy device, or "scanopy," that collects data on air quality and environmental conditions. After remaining in Germany for an extended stay as a makerspace, that module will eventually return to Africa.

Plans are under way for new models of Spacecraft to incorporate additional plug-in elements such as a water collection and filtration system, a robotic arm, and solar-powered electricity generators.

"We don't see the Spacecraft modules as the miracle solution to the Agbogbloshie problem," Abbas says. "We see them as a way in which we can spark conversations, ideas, and actions. For me it's important to have something physical, something tangible that people can identify as a common space—a space that enables these interactions to happen.

"I like the idea that this is reconfigurable architecture that is mobile, and it becomes a portal to allow people from different worlds to come together and imagine different futures. As researchers, we've been sort of the glue or energy that brings those people together, but then the Spacecraft can act as a portal or a bridge to further those connections."

A DIGITAL COMPONENT

As well as the Spacecraft modules, AMP will include a digital information-sharing platform that lets workers communicate with each other to match needs with services. The digital piece, in the form of a mobile app for Android phones, is still in the works but will become an integral part of the project. "As we spent time in Agbogbloshie, we soon realized that throughout the entire ecosystem, everyone was searching for something," Osseo-Asare says. "Makers are searching for materials, parts, components, tools, and blueprints. End users are looking for someone who can repair a blender or an iron. And then there are scrap dealers who are seeking to collect scrap, process it, and turn it back into an input for new making.

"This is reconfigurable architecture that becomes a portal to allow people from different worlds to come together and imagine different futures." —YASMINE ABBAS

"We tried to untangle that knot of not knowing to allow people to find what they need to make what they want to make."

The researchers also want the app to help scrap dealers in particular gain a better understanding of the hazards of some of the materials they work with. "We built the app specifically with the needs of the scrap dealers in mind first," Osseo-Asare says, "because in addition to arming them with the information and technology they need to do their work more efficiently, we also want them to think about how to green their recycling processes. And for that they need incentives."

For example, burning wire is the fastest and cheapest way to extract valuable copper. It's a toxic process, both for people and the environment, but scrap dealers have not had an incentive to do it any other way. "But that doesn't mean it's not possible," Abbas says. "It's totally possible to extract copper in an environmentally friendly way, by shredding and stripping wires instead of burning them. And there are some buyers who will pay more for clean copper than for burned copper. So the idea behind the app is to help these people connect."

Osseo-Asare and Abbas emphasize that AMP—its components, activities, and goals—is a vast and far-reaching project. "It's not a neat and concise design project, with perfectly finished products," Osseo-Asare says. "It's ongoing research-based design activity embedded within the community of Agbogbloshie. We're constantly exploring alternative futures around design production and knowledge sharing."

As the project garners global attention—Spacecraft was recently featured at an international "Digital Imaginaries" exhibit in Karlsruhe, Germany—the researchers are encouraged about increasing awareness of Agbogbloshie's potential. "When we started our project, it seemed like everyone was saying that Agbogbloshie is horrible, it's a dump and nothing else," Osseo-Asare says. "Now, many people are saying, It's not all horrible, it's a scrapyard."

In many conversations, Osseo-Asare says, AMP is being used as an example of what can be done. In fact, based on the researchers' road map for AMP, the government of Ghana is collaborating with the German government to develop an e-waste upcycling platform. "There's dialogue happening, and it's exciting."

MOVING FORWARD BY GOING BACK

Sankofa is a word in Ghana's Twi language that translates into "return and get it." There's a symbol for Sankofa, depicting a bird, feet firmly planted forward, turning its head to retrieve an egg from its back.

Osseo-Asare and Abbas often draw on Sankofa to explain their work. "A lot of young people in Africa think innovation is from the West, and so they overlook knowledge that exists in their own backyard—in their culture, in their community," Osseo-Asare says. "Because it looks different from Western innovation, they tend to denigrate it. But Sankofa shows us that for a successful future, we have to draw on the past—our own past—to access that knowledge.

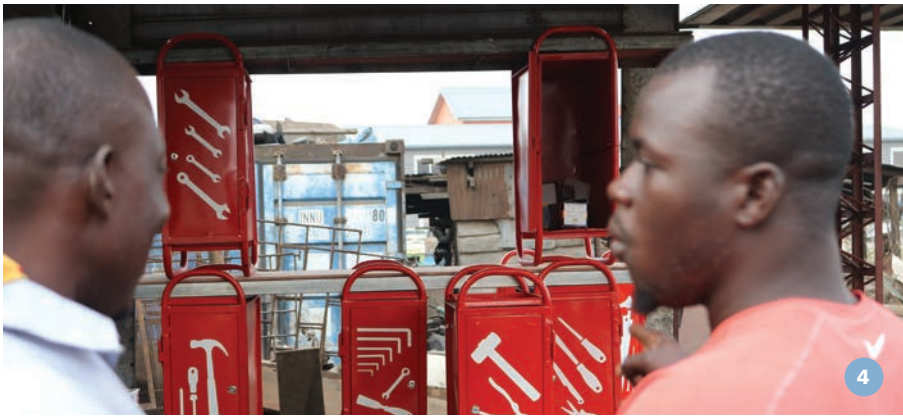
"Agbogbloshie reminds us that making is a cycle. It extends to remaking and unmaking, recovering the materials we need to make something anew. Let's not call Agbogbloshie a dump. A dump is a place where you throw things away and leave them forever. A scrapyard is where you take things apart to remake something new."

Recognizing the importance of scrapyards as part of a city's natural cycle is a big step toward making recycling more sustainable, Abbas adds. "Recycling is vital for protecting lives and the environment, and for people to see that, we need to change mindsets. We need to give value to that space."

As she and Osseo-Asare continue their work, they can see progress toward the five goals they've set for emerging makers in Agbogbloshie: to efficiently gather the resources and tools they need; to learn by doing and from others; to produce more and better products; to be able to trade to generate steady income; and ultimately, to amplify their reputations and potential as makers.

"There's innovation and hope and possibility in Agbogbloshie," Osseo-Asare says. "The workers there are not voiceless or powerless—they have agency. As we work with the populations there, we want to make sure that agency is used for good. Our goal is always to harness the spirit of Sankofa to empower makers at the grassroots."

Yasmine Abbas is assistant professor of architecture in the Stuckeman School of Architecture and Landscape Architecture. DK Osseo-Asare is assistant professor of architecture and engineering design in the Stuckeman School and in the School of Engineering Design, Technology and Professional Programs, and associate director of Penn State's Alliance for Education, Science, Engineering and Design with Africa.



Clockwise from bottom: **1**, Four men erect a module in Dakar, Senegal, to be used as a stage. DK Osseo-Asare is at far right. **2**, A musician prepares to perform on the stage. **3**, The module was later disassembled, moved to another neighborhood in Dakar, and reassembled to serve as a "pop up" storefront. **4**, A module at Agbogbloshie offers toolboxes for use by the local community. Images courtesy of Agbogbloshie Makerspace Platform.

Getty Images/ Nadia Bormotova

Digging into the science of how and why we choose to be empathetic

The Empathy Option

BY KATIE BOHN

You're flipping through the television channels when you hear the familiar beginning strains of a Sarah McLachlan song. You hastily click to the next channel, before the haunting images of homeless animals appear.

Or you're scrolling through the news one morning when a headline makes you pause—a mass shooting, perhaps, or a tsunami halfway across the globe that's left thousands homeless, injured, or dead. You keep scrolling, unable to stomach such horrible news first thing in the morning.

Daryl Cameron, assistant professor of psychology and research associate in the Rock Ethics Institute at Penn State, wants to understand when, how, and why people choose to avoid empathy in their daily lives.

Often conflated with compassion—sympathy or concern for others' suffering or misfortune—empathy is the experience of understanding and actually sharing the feelings of someone else. Empathy, Cameron says, can be thought of as feeling *with* a person, rather than feeling *for* them.

But aren't feelings automatic, something that happens without conscious effort? Sometimes, but Cameron also says that we often make a choice of whether—and toward whom—we're empathetic. Across several studies, he and his colleagues have demonstrated that we do indeed opt out of being empathetic, and they're closer to understanding one reason why. And while it can seem like a negative thing, Cameron says the fact that we do have the ability to choose has an up-side.

"If our goal is to inspire more empathy to bridge social divides," he says, "then maybe knowing how and why people sometimes choose to *not* feel it could suggest a lever for pushing people in the opposite direction—to choose empathy."

Daryl Cameron, assistant professor of psychology, is investigating why we choose to be empathetic in some situations, and how feelings of empathy can be encouraged. Photo by Patrick Mansell.

THE QUESTION OF CHOICE

Cameron's interest in the science of empathy was piqued in college while earning dual degrees in philosophy and psychology.

In grad school, he came across a paper suggesting that while people may feel immense empathy for an individual undergoing hardship or tragedy, empathy decreases as the number of victims rises.

At the time, Cameron says, some experts suggested that our empathy systems simply can't process mass suffering, so they shut down. Others have argued that empathy isn't even worth cultivating—that it's biased and unsustainable and doesn't lead to positive change.

Cameron disagrees with both views.

"It seems a bit fatalistic and defeatist to say that empathy for large numbers [of people] just isn't how we're wired," he says. "Research on emotion regulation and mindfulness meditation suggests that people do have ways to change how they relate to their own emotions. Maybe if we further explored such possibilities, new avenues would open up for encouraging empathy."

With his colleagues at the time, Cameron performed several experiments and found that empathy can be boosted by changing the way people think about it. In one study, tweaking participants' expectations—convincing them that empathy would be emotionally rewarding instead of just exhausting—made participants more likely to humanize someone experiencing drug addiction. In another, earlier study, participants had greater empathy for mass suffering when they were convinced that it would not cost them financially.

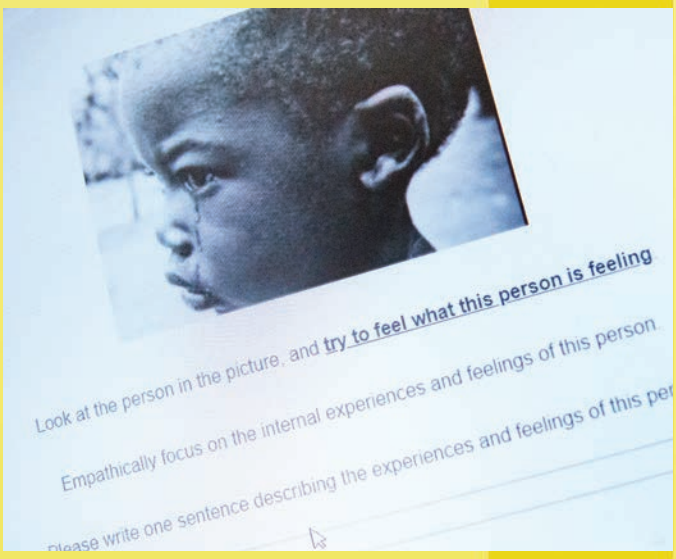
Encouraged by the results, Cameron founded the Empathy and Moral Psychology Lab at Penn State. The lab explores the mechanisms involved in empathy, moral decision-making, and other ethical questions. Most recently, the lab zoomed in on not just whether and when people choose to be empathetic, but also why.

"It's easy to think that people might avoid empathy because they just don't want to feel bad," Cameron says. "But what if it's because empathy is effortful, taxing, and fatiguing? It's hard work to try to get inside someone else's head and feel what they're feeling. One might be afraid of getting it wrong, or not knowing someone well enough to know what they're feeling."

WHAT'S IN IT FOR ME?

As we go about our day, we are constantly weighing our options. You may change your route to work to avoid a construction delay, or choose a lunch spot depending on who you may run into there. Cameron says this weighing of costs and benefits also applies to situations that may trigger empathy.

"If I'm watching TV and see a sad commercial for a charity organization like the SPCA, I may choose to keep watching and feeling that empathy, or I may choose to change the channel," Cameron says. "This decision is based on costs and benefits. I might think it could be too emotionally exhausting to keep watching, or that I'll be compelled to spend money and help. There's all these interesting considerations about why we have these empathy gaps."



In one experiment, participants chose a card from one of two virtual decks (left) and then were shown a photo of a person (right). Those who chose from the "Describe" deck were asked to describe the person's appearance. Those who chose from the "Feel" deck were asked to try to feel what that person was feeling, a task they later said took more effort than simply describing the person. Photo by Patrick Mansell.

To dig into why people may choose to avoid situations they think will evoke feelings of empathy, Cameron and his fellow researchers conducted several studies using a task they developed to capture these choices in action.

Participants were asked to choose a card from one of two decks: one labeled "feel," the other, "describe." They were then shown a photo of a person. Participants who drew from the description deck were asked to simply describe the person's appearance. Those who drew from the empathy deck were asked to try to experience and describe the person's feelings.

"Some people may think the task seems unnatural or different to how we typically think about empathy," says Eliana Hadjiandreou, a graduate student and co-author on a paper about the work. "But it's not unlike an everyday situation where you choose to change the channel to avoid feeling for someone, or you cross the street to avoid someone who is homeless."

The researchers found that over several trials, the study participants vastly preferred the description deck, choosing it more often than the empathy deck.

Graduate student Julian Scheffer, also a co-author on a paper about the work, noted that it wasn't just empathizing with suffering that proved to be hard for people in these studies.

"We also asked participants to empathize with positive targets, maybe someone who is smiling and more joyful," Scheffer says. "We thought that empathizing with more positive emotions may be easier, but we found it to be just as effortful and difficult. Participants avoided empathizing with positive emotions as well as negative ones."

Cameron says their work suggests that people who choose to avoid feeling empathy may do so because it's just plain hard work.

THE CURRENT STATE OF EMPATHY

With the rise of social media, it's easier than ever to see what people choose to be empathetic about. People may post condolences for the victims of shootings in Paris and Christchurch while staying silent about bombings in Sri Lanka. The divide between political parties seems wider than ever. And debates rage about whether people in need deserve assistance from the government.

On top of that, some research suggests that empathy is declining. A 2010 meta-analysis of survey data found a 40 percent drop in self-reported empathy among college students between the 1970s and the early 2000s.

But Cameron says the empathy forecast isn't as bleak as it may appear. In the empathy deck work, when participants were randomly assigned to a condition in which they were told they were skilled at empathy, he reports, those individuals were more likely to choose the empathy option.

For another thing, just because empathy is hard work doesn't mean everyone will avoid it. Cameron says the perceived effort required may make engaging in empathy *more* rewarding for some people.

"There are plenty of cases in which people like doing effortful things, like charity marathon runners or people who like reading thousand-page Victorian novels," Cameron says. "For some, it's the effort itself that makes something worthwhile."

Additionally, Cameron says because empathy seems to be malleable, there's always the hope that it can increase. And changing the way we think about empathy may also help break down barriers.

"Part of it may be letting go of inhibitions a little bit," he says. "People may see roadblocks to empathy, whether it's they themselves thinking it's too hard, or other people telling them it's not worth it, or thinking it will make them seem weak. Getting past those personal and social inhibitions may be key. When we do that, maybe we can see more openings for boosting empathy."

And that is something to be hopeful about.

Energy resilience begins with our buildings.

from the ground up

BY CHERIE WINNER

Sez Atamturktur has a problem with buildings.

Not buildings themselves; she is an architectural engineer, after all. Her problem is with buildings as we currently think of them, design them, and most of all, power them.

Atamturktur, Harry and Arlene Schell Professor and head of Penn State's department of architectural engineering, thinks our national conversation about energy issues starts from the wrong vantage point, with residential and commercial buildings viewed as passive consumers of electricity that is produced far away and distributed by centralized systems.

"Almost everybody starts from the power grid and looks down," she says. "In our department, we start from the building, and look upwards to the grid."

In her view, thinking about energy from the ground up doesn't just change how we see the problems; it also changes what we're able to come up with as possible solutions.

SEALING THE ENVELOPE

The rationale for focusing on buildings first is a matter of simple arithmetic: They consume about 40 percent of the primary energy we use in the United States—coal, gas, oil, nuclear, hydroelectric, wind, and solar—and a full 70 percent of all the electricity. "So we can continue to improve the efficiency of planes and trains and automobiles all we want," says James Freihaut, professor of architectural engineering. "But if we want to conserve energy and stop global warming, we've got to make the buildings a lot better."

Individual subsystems (lights, heating, cooling) have gotten more efficient, he says, but buildings as a whole have not improved much over the last 70 years. He attributes that to a fragmented design process, lack of integration of the systems, and lack of regulations setting efficiency and performance goals.

Freihaut leads several projects at the Philadelphia Navy Yard aimed at making buildings and communities more energy efficient and more resilient in the face of shortages and blackouts. One focuses on individual buildings, using insulation, low-E windows, and other "passive" measures to make the envelope—the barrier separating indoors from out—as snug as it can be. In a nifty experiment, he and his colleagues built two small houses, one to current code and one with an improved envelope. They put 600 pounds of ice in each, closed the doors and windows, and let them sit in the midsummer heat. After three weeks, there was no ice left in the conventional house—but 400 pounds remained in the passive house.

"Not only did it isolate the inside from the outside, the temperature swings were much lower, meaning that I could predict exactly how much energy demand there was in that building as a function of weather conditions," says Freihaut. In a real-life situation, that would allow a builder to install smaller, less energy-intensive heating and cooling systems and let them operate more efficiently.

Getty Images/bruev

Local generation of electricity, whether through renewable sources or fossil fuels, is much more efficient than producing it at power plants far from the consumers who will use it.

For James Freihaut, improving our energy resilience is a perfect example of what a land-grant university should do: make a difference for people, communities, the economy, and the planet. "We do the laboratory work, all the way up to prototype demonstrations, to actual, real applications," he says.

TAKE A DEEP BREATH. OR NOT.

While improving the building envelope reduces energy use and keeps buildings more comfortable for their human occupants, by reducing outdoor air exchange it contributes to a different problem: indoor air pollution.

"We spend more than 20 hours every day in the indoor environment," says Donghyun Rim, assistant professor of architectural engineering. "Indoor air is actually most of the air we are breathing over our life, and often we see more than 10 times higher pollution levels in the indoor environment compared to the outdoor environment."

Rim has measured pollutants in a variety of buildings including homes, classrooms, and day-care centers, where toddlers spend up to nine hours a day. Indoor air hazards include pollutants that drift in from outside, plus a host more: dust mites, fungi, and harmful substances we generate ourselves through daily activities such as cooking and cleaning.

One of the worst is nanoparticles between one and 100 nanometers (nm) in size. (For comparison, human hairs range from about 17,000 to 181,000 nm diameter.) Dangerous on their own, these tiny bits of matter can also carry pesticides, plasticizers, flame retardants, protein allergens, and other chemicals deep into our lungs, our bloodstreams, and other tissues in our bodies. They're especially worrisome because the damage they do is not immediately apparent. Rim and Freihaut, who also works on indoor air quality, say recent studies link nanoparticles to cognitive problems and to a wide range of slow-simmering health problems, including asthma, Parkinson's disease, autism, and dementia.

Flinging open the windows to let outdoor air blow through can help, but only in areas where the outdoor air is relatively clean and only when temperatures are mild. What we need, say Rim and Freihaut, are sensors to monitor a building's air, and systems to filter out, dilute, or inactivate any harmful substances and microbes present.

ELECTRICITY BEGINS AT HOME

Many of us have made our homes and workplaces more efficient, but Freihaut and Atamturktur say that if we're serious about cutting our energy use, we need to address the massively inefficient way we produce electric power and get it to consumers.

When a conventional generator burns fuel to create electricity, 60 to 65 percent of the energy in that fuel is lost as heat. It goes into the air or a nearby river, lake, or ocean. When we transmit the electricity to customers many miles distant, we lose another 5 to 15 percent. "With electricity coming from central power plants, at your building you only use about 30 to 35 percent of the primary energy that was used to make the electricity," says Freihaut. "You threw two-thirds of it away. And buildings use 70 percent of all our electricity. This is a problem."

It's so wasteful, he says, that an all-electric building *can't* be deemed energy-efficient, no matter how good its individual systems are, if its power comes from a central grid. "If I stop my calculations at the wall of the building, I have a super-efficient electric building, but from a global, environmental, cultural perspective, it doesn't help until we go to an all-renewable-energy electric grid system."

Until we have such a system, their interim solution, and the subject of a test project at the Navy Yard, is to make electricity with a Combined Heat and Power (CHP) system located close to the consumers who will use it. CHP generates power by burning a fuel such as natural gas to run a turbine, just like traditional generators do. But instead of losing almost two-thirds of the energy in that fuel by spitting out heat, it uses the heat to do other work.

"I capture as much of that heat as I can, instead of throwing it into some river," says Freihaut. "There are technologies where I can actually convert heat into cooling. So I can use it for making domestic hot water, I can use it for space heat, I can use it to make space coolant, I can use it to run refrigerators."

The project at the Navy Yard goes a step further by including solar panels to generate electricity when the sun is shining and banks of batteries to store excess electricity from the panels. Freihaut calls it a "hybrid" CHP system. With the ability to store electricity until it's needed, and a gas generator to produce more when the sun is not shining, a hybrid CHP is cushioned against the ups and downs of a solar-only system. A CHP generator could also be paired with other renewable sources such as wind turbines. Such hybrid systems could provide a bridge to an all-renewable energy infrastructure.

At the MorningStar solar home in University Park, Donghyun Rim describes how ozone in the air interacts with our own skin and clothing to produce other substances, some of them harmful to human health.

SCALING UP

Another program at the Navy Yard deals with the next step—how an entire community can become more energy-efficient and -independent. "Suppose I have a whole bunch of buildings that are individually efficient; is that it?" asks Freihaut. "Can I save any more energy or use less fossil fuel to operate these buildings? How do I do that?"

What we need, say Freihaut and Atamturktur, is a way to fill the gap between individual buildings and the central power grid. Their answer: microgrids.

A microgrid distributes electricity to customers within a few miles, at most, of where the power was generated. That saves the energy that would be lost during long-distance transmission. Freihaut oversees Penn State's microgrid at the Navy Yard, a test project providing electricity from the hybrid CHP system to stores, office buildings, and small businesses. In the works for five years, it is now nearly ready to go into full operation. "If we can show that it works in a real system, this could be a path to greater use of renewables," says Freihaut.

This kind of "distributed energy" arrangement has been used by rural co-ops and municipal grids for decades to bring electricity to homes, businesses, and small communities that were deemed too spread out or too far from the main grid to be worth the cost of running lines to them. These small grids are already substantial players on the national energy scene. According to Freihaut, in the U.S. there are about 2,000 municipal grids serving nearly 50 million people, about one-seventh of our total population. About 600 rural co-ops supply 56 percent of the land area in the country. In Pennsylvania alone, we have 13 rural co-ops and 35 towns with their own municipal grid. Currently, these systems plug into the central grid, but with options like CHP and hybrid systems becoming more affordable, many are considering switching to produce their own electricity, locally. They won't lose their connection to the big grid, but they'll be able to "island"—operate independently of it—in the event of damage to the central grid.

GETTING SMART

To get the most out of these new kinds of systems, our buildings need to be smarter, says Atamturktur; not smart in the sense of having a refrigerator you can talk to or a webcam by the front door, but smart as a quality deep in the bones of the building, an intelligence that senses its own actions and interacts with its human occupants.

Michael Garrett

(Above) Freihaut and Rim open a chamber in which they test techniques for removing or de-activating harmful substances in indoor air.

(Left) Freihaut at the East Campus Steam Plant at University Park, where a CHP system burns natural gas to generate electricity, then captures the hot exhaust to make steam that helps heat buildings on campus. The plant operates at 80 percent efficiency, much higher than a conventional power plant.

Our current buildings are rudimentary cyber-physical systems—mechanical structures with a few basic cyber elements such as timed thermostats and daylight-sensitive outdoor lights. But they're actually quite dumb, says Atamturktur. A truly smart building will be able to sense who is in it and what their needs are at different times throughout the day. Instead of a simple timer set to turn up the heat when people are expected to be in the building and turn it down again when the building is expected to be empty, sensors would detect when people actually are in the building, how many of them are present, where they are, and what equipment they are using, and adjust the heat, humidity, lighting, and air flow accordingly. In effect, our buildings will be keeping tabs on us and responding to us in real time, without direct, intentional input from us.

Has anyone ever told her that this sounds a little creepy?

"Oh, it *is* creepy!" she agrees. "But it's no more creepy than self-driving cars."

Or ordinary, person-driven cars, says Freihaut. Today's average car carries about a hundred sensors that constantly monitor everything from internal cabin conditions to whether you're driving up or down a hill, the load on the engine, and whether the headlights need to turn on, he says. "In five or 10 years, there will be 200. Your car has what, maybe 15, 25 square feet of seating space? How many sensors per square foot do we use in buildings? Very, very few. The building industry is way behind on this. We're the last to really employ information technology in any sophisticated way."

HOW WE GET THERE

Freihaut thinks we already have engineering solutions—*practical* solutions—to many of the energy challenges we face, and that the rest are within reach in five to 10 years, if we invest the time and effort needed to develop them. At the top of his list is a safe, affordable way to store energy at the building itself, so that heat generated by a CHP turbine can be banked for later use.

"Just a simple hot water tank doesn't cut it," he says. "We need to invent a material that can safely store energy at a high temperature and that doesn't take up a lot of space."

He likens this challenge to one tackled by scientists in the space program's early years—inventing a lightweight, extremely heat-resistant material to keep manned vehicles from burning up during re-entry. "They invented these little tiles that are a quarter of an inch or so thick, and it's 3,000 degrees out there and it's only 100 degrees in the capsule," he says. "That's a hell of a material! How much money did we spend inventing that? Don't tell me we can't afford to do research to invent a new material that we need to conserve 40 percent of all the energy used in this country."

Even more than scientific and engineering solutions, he says, what we need most, and might be hardest to achieve, is support for these efforts: public awareness and a desire to improve on our current systems; a regulatory climate that doesn't prop up the old systems and penalize new ventures into renewables; and, most of all, leadership. That could come from many sources: small communities with their own power grids showing how well a decentralized system works; government officials more focused on solving problems than on scoring political points; scientists and engineers who push us to see old problems in new ways.

Atamturktur, speaking from her office in a 110-year-old building at University Park, says researchers in her department are doing that with every major building system. She believes architectural engineers hold a unique responsibility. "The products we make have such a long-term effect on humanity," she says. "Every tiny bit of improvement that you make stays with you for decades."

Penn State

Sez Atamturktur

the human dimension

After earning her Ph.D. from Penn State, Atamturktur spent several years developing models to determine how well predictive models of engineering systems would perform in various scenarios, such as the shielding materials used in nuclear power plants—a field where precise and accurate predictions are absolutely essential. Now she is bringing that level of rigor to models for building systems. "Modeling and simulation are so important for everything this department works on," she says. "However, models are inaccurate and imprecise representations of reality. What designers predict with current models of energy usage and what really happens in the end don't often match." Then builders and consumers become disillusioned with the whole effort of designing energy-efficient buildings.

Even the best current models leave out one major factor: human behavior. To address that omission, Atamturktur is enlisting researchers from social and behavioral sciences in the effort to better understand the relationship between architectural design, building systems, and human comfort and performance. She's aiming for the development of cyber-physical-*human* systems that include us as essential parts of a building's design and function. What it comes down to, she says, is, "How can the building influence the people in it, and how can the people influence the building?"

Andrew Patterson is training a powerful new tool on the microbiome and cell metabolism.

Listening to your gut

BY DAVID PACCHIOLI

By now most of us know we're not alone. From one perspective, in fact, our bodies are merely the host for a teeming biological horde. Many aspects of our lives—not only the presence or absence of certain diseases, but conditions like obesity, sleep patterns, even mood—may be determined, to a surprising extent, by the microbes living inside of us.

Although the concept of the microbiome, the sum total of our resident bacteria, viruses, and fungi, has only recently been popularized, "It's not a new idea that microbes have influence in the body," Andrew Patterson says. "But it's only now that technology is allowing us to see how microbes exert that influence, and to measure it."

Patterson, Tombros Early Career Professor and professor of molecular toxicology at Penn State, is using one of the newer and more promising of these technologies, called metabolomics, to learn about the microbiome of the human gut.

Metabolomics is the measurement of all the chemical products of metabolism present in a given biological sample, typically blood, urine, or another bodily fluid. These "metabolites," teased apart and painstakingly identified, provide a window into cellular processes, and can therefore be important indicators of disease, or of an individual's response to a drug, an environmental toxicant, or even the chemical compounds in our diet.

Researchers in the field speak of the "unique chemical fingerprints" cellular processes leave behind. To use another metaphor, a metabolomic sample is like the transcript of a conversation—a precise account of the complex molecular signaling between resident microbes and host cells that ends in a physiological response.

Patterson relates the concept in still more common terms. "Today, you go to the doctor, you give blood, and they screen for maybe a dozen things," he says. "We're just doing that on an orders-of-magnitude larger scale, looking at as much as we possibly can."

BIRTH OF A TECHNOLOGY

True metabolomics has its roots in the 1970s, when advances in mass spectrometry and other analytic techniques began to allow for increasingly sensitive measurement and separation of complex chemical samples.

Sam Falconer c/o TheISpot.com

Patrick Mansell

Andrew Patterson, Tombros Early Career Professor and professor of molecular toxicology.

Powerful bioinformatics tools developed over the next few decades then enabled pioneers in the field to start building databases of metabolites. The first draft of the human metabolome, consisting of some 2,500 metabolites, was completed at the University of Alberta in 2007, and similar efforts were undertaken for other plant and animal species.

By 2009, Jeffrey Peters, now distinguished professor of molecular toxicology and carcinogenesis and deputy director of the Penn State Cancer Institute, had recognized in the emerging technology an opportunity to expand interdisciplinary research at Penn State. "It is becoming increasingly clear that integration of genomics, transcriptomics, proteomics, and metabolomics will be required to allow for the most comprehensive approaches for disease prevention and treatment," Peters wrote in an early draft proposal. A timely investment in metabolomics, he argued, could make Penn State a leader in the field.

Peter Hudson, then director of the Huck Institutes for the Life Sciences, was an indispensable advocate. "Peter was able to get support from the various colleges, Agricultural Sciences, Eberly [College of Science], Health and Human Development, Medicine—they all got behind the idea," Peters recalls. In Hudson's vision, the proposed Metabolomics Core Facility would be a natural fit for the sort of interdisciplinary collaboration that Penn State is known for; it would be staffed by leading experts and outfitted with a full range of state-of-the-art instrumentation. Patterson was identified as the right person to lead the initiative: An alumnus of Penn State, he was then employed as a postdoc at the Laboratory of Metabolism at the National Cancer Institute, one of the top metabolism laboratories in the country.

One of the projects Patterson had embarked on at NCI illustrates both the promise of metabolomics and some of its challenges. He, section head Frank Gonzalez, Curtis Harris, chief of the Laboratory of Human Carcinogenesis, and the rest of their team were looking for a noninvasive way of detecting lung cancer, the leading cause of cancer deaths in both men and women worldwide. They decided to analyze urine samples from a cohort of over 1,000 patients, spanning differences in race, ethnicity, smoking status, stage of cancer, and other factors, such as diet and medications. It was a needle-in-a-haystack approach—exactly the sort of thing metabolomics affords.

"We went in blindly, looking to see if we could find a metabolite that all these people had in common," Patterson says. "You're just generating a huge amount of data and then seeing what shakes out of it." The number of variables present complicated matters, making it difficult to separate any signal they might find from the surrounding noise.

"Another problem, and this is true of metabolomics in general, is that the existing databases are still relatively small," Patterson says. The largest, the Human Metabolome Database, now has over 114,000 metabolites, but there are untold numbers that have yet to be identified.

Despite these obstacles, when the mass spectrometry data came back, the researchers were able to tease out a compound of amino acid and sugar that appeared to be shared across all their samples. Creatine riboside, they called it. When they looked through the databases for a match, however, there was none to be found. Theirs was an entirely new metabolite.

BIOMARKERS AND BILE ACIDS

It took over a year to confirm what they had discovered. Patterson had by then moved to Penn State, and he and Philip Smith, an Army mass spectrometry expert who had been hired as director of the brand-new Metabolomics Core Facility, set about recreating the compound in the lab. They tried any number of routes, mixing different amounts of creatine and ribose together in different forms, at different temperatures, then running the results through their mass spec and NMR machines. "We're not synthetic chemists, by any stretch," Smith says with a wry smile.

Patrick Mansell

TODAY, YOU GO TO THE DOCTOR, GIVE BLOOD, THEY SCREEN FOR MAYBE A DOZEN THINGS. WE'RE JUST DOING THAT ON AN ORDERS-OF-MAGNITUDE LARGER SCALE.

-ANDREW PATTERSON

In the Metabolomics Core Facility, vials filled with extracts of bodily fluid wait in an auto-sampler. Each sample will be passed through a chromatography system that sorts the complex mixture into its constituents. Droplets of the separated sample are then misted into the mass spectrometer for analysis.

Finally, they hit on the right sequence of steps. A chemist back at NCI was then able to refine their results and synthesize a pure version of the molecule. "Once we had that," Patterson says, "we could come back and compare it with all our samples, and we found out that indeed we had what we thought we had."

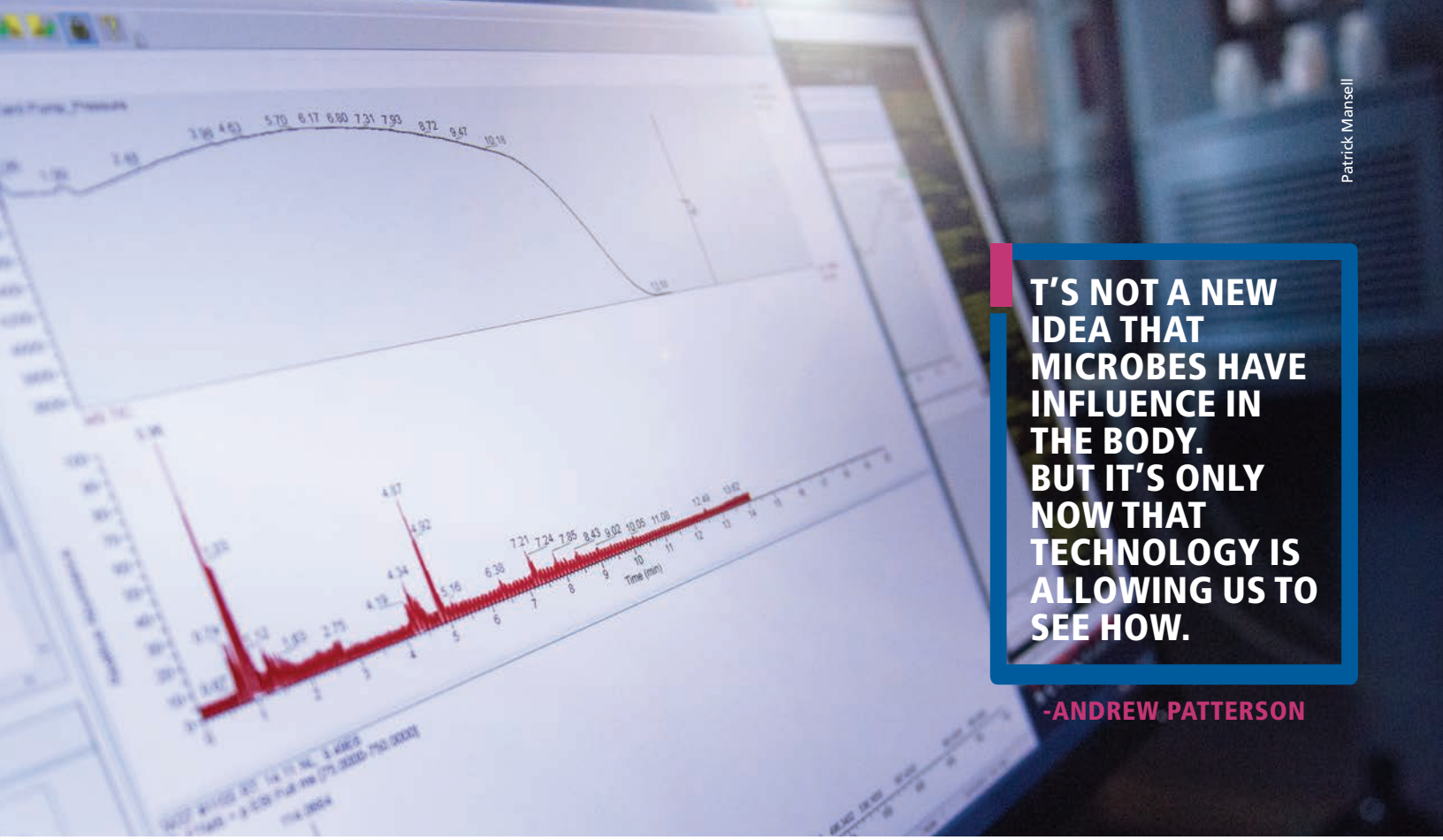
Creatine riboside has since been found in tumor tissue as well as in urine, and also associated with several other types of cancer. "It may be not just a good biomarker for early stage lung cancer, but a general marker of cancer," Patterson says. He is working with Peters and others at the Penn State Cancer Institute to set up a clinical trial, screening lung-cancer patients at Hershey Medical Center for the presence of the metabolite.

In the meantime, Patterson has shifted his emphasis away from cancer. He's now using metabolomics to learn how the presence or absence of certain types of bacteria in a person's digestive tract can affect processes associated with drug metabolism, obesity, diabetes, and fatty liver disease.

"Our broad hypothesis is that these bacteria modify our host cells in order to promote an environment that is good for themselves," he says. One way they do this is by making ligands, small signaling molecules that bind to specific cellular receptors and hijack the cell's activity. Among the favorite targets for these disruptions are bile acids.

There are over 150 types of bile acid in the human gut, Patterson explains. Released by the liver, they play an important role in digestive processes, particularly in dissolving fat. Recently, however, it has become clear that some bile acids also act as signaling molecules or are toxic to bacteria. Some bacteria, in turn, have developed ways to protect themselves from harm by modifying bile acid exposure. For the human or animal host, "this modification can have significant effects on lipid and glucose metabolism."

In one instance, a colleague studying tempol, an antioxidant compound commonly used to reduce the side effects of radiation therapy, noticed that mice given the drug did not gain weight like other mice, even when fed a high-fat diet. After trying unsuccessfully to determine why this was so, he turned to Patterson and his colleagues at NCI.



Patrick Mansell

T'S NOT A NEW IDEA THAT MICROBES HAVE INFLUENCE IN THE BODY. BUT IT'S ONLY NOW THAT TECHNOLOGY IS ALLOWING US TO SEE HOW.

-ANDREW PATTERSON

Andrew Patterson examines a tubing line that carries samples from the chromatography system at right into the mass spectrometer at left.

Patrick Mansell

Readout from the mass spectrometer provides a record of the metabolites measured in a given sample. The data from these instruments are then mined to identify important chemical features that may be associated with a disease or experimental treatment.


Patrick Mansell

Philip Smith, director of the Metabolomics Core Facility.

Gut samples showed that giving mice tempol resulted in a sharp drop in *Lactobacillus*, a type of bacteria that is capable of modifying bile acids. As it turns out, reducing Lactobacillus allowed one specific bile acid, tauro-beta muricholic acid, to increase. The team's analysis showed that this increase inhibited the activity of the farnesoid X receptor (FXR), which regulates the metabolism of bile acids, fats, and glucose in the body. Without FXR, the mice's digestion of fat was significantly altered, and obesity was curtailed.

Building on this finding, Patterson and colleagues at Hershey and NCI have developed a pill modeled after tauro-beta muricholic acid, intended to target FXR directly. In mouse trials, the drug has proved effective in lessening weight gain and insulin resistance in the face of a high-fat diet. Patterson has formed a company, Heliome Biotech, to commercialize the discovery.

A WHOLE NEW PERSPECTIVE

With the establishment of the Metabolomics Core Facility in University Park, Penn State has indeed carved out a niche in this emerging field.

"We've been able to attract a lot of collaboration, from here and elsewhere, because we have a really unique set-up that allows us to do a lot of different things," Patterson says. "We have an expertise in the microbiome space that few others have right now."

The facility is administered jointly by the Huck Institutes of the Life Sciences and the Penn State Cancer Institute, reflecting high hopes for the potential of metabolomics as a tool for personalized medicine. Because it provides direct evidence of cellular processes, Patterson says, "It gives us a whole new perspective from which to look at health and disease."

There are significant challenges, however, to the technology's wider use. One of them is cost. "It's an extremely expensive undertaking," Patterson acknowledges. "It costs millions of dollars to outfit these labs, because you need different platforms to be able to measure the metabolites in as comprehensive a way as possible."

Even if a sample gets a good, thorough analysis, he adds, a single snapshot is of limited use for evaluating physiological processes. "The key to understanding what's going on is to be able to measure changes over time," he says. Doing that would require a massive increase in routine clinical screenings, and raise issues of consistency and reproducibility that have yet to be addressed.

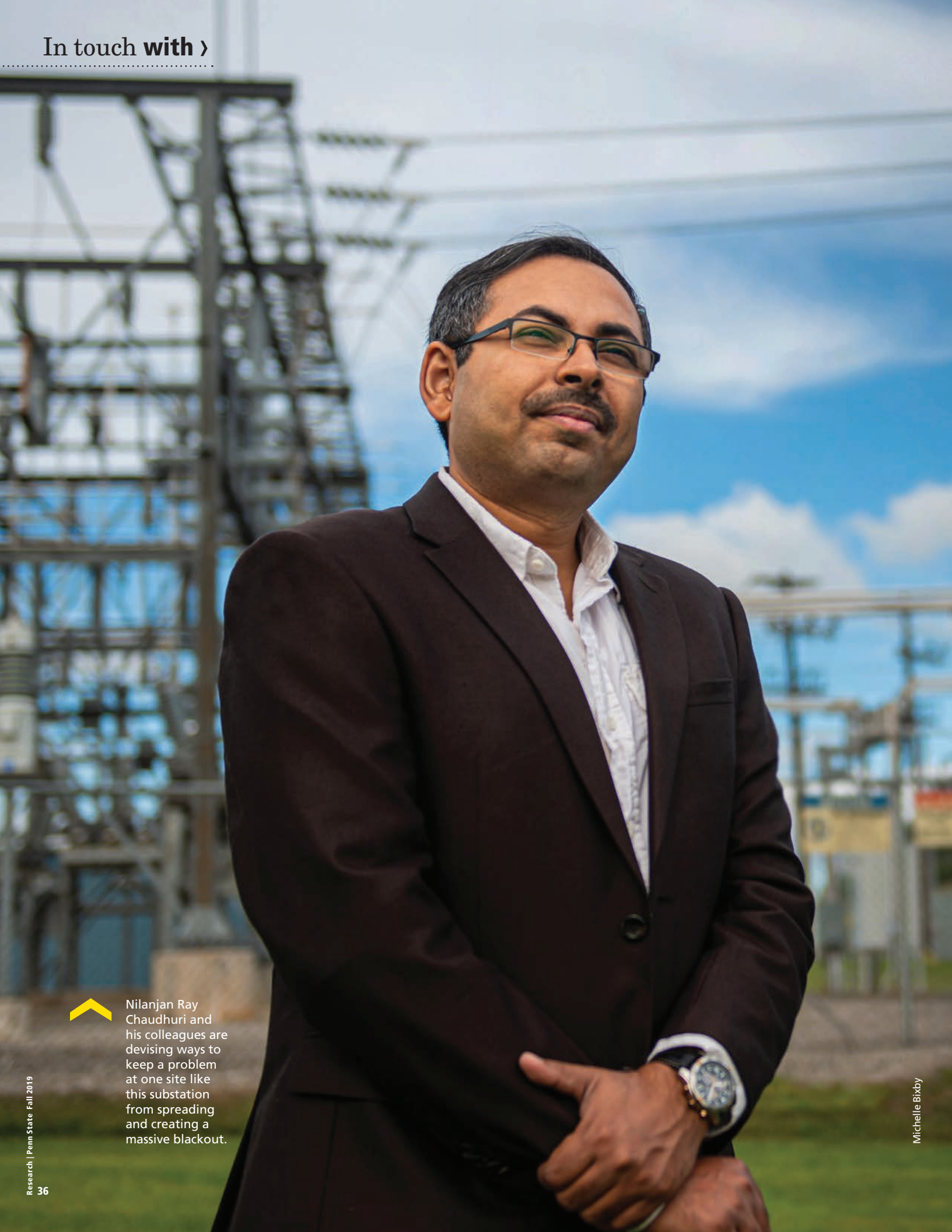
Not to mention capacity. "You're talking about millions of data points for each sample," Patterson says. "Then combine that with the data available from genomics, transcriptomics, and proteomics. The biggest challenge will be how to integrate all of that in a way our human brains can make sense of." But if and when it can be done, he adds, "The possible applications of metabolomics are endless.

"Right now we're using it to identify biomarkers, and to search out metabolic pathways. But it can also help us to better understand how the body responds to daily exposures to drugs and environmental chemicals."

One day, Patterson hopes, he'll be able to use metabolomics to predict how a patient will respond to a given drug, allowing treatment choices to be tailored to the individual, and the individual's microbiome.

"That's the thing that probably excites me the most," he says. "We're finding that drugs and chemicals that were thought to work only through our host cells actually very profoundly influence the microbes we carry as well.

"The understanding that toxicology is dictated not only by our genetics but also by the microbes residing inside us is a completely untapped area."



Nilanjan Ray Chaudhuri and his colleagues are devising ways to keep a problem at one site like this substation from spreading and creating a massive blackout.

Michelle Bixby

NILANJAN RAY CHAUDHURI ON PROTECTING THE POWER GRID

Power outages are frustrating for everyone involved, and large-scale outages—blackouts—can cripple a city, a region, or even an entire country for days. Electrical engineer Nilanjan Ray Chaudhuri, an expert on power grids, heads a team that won a $999,000 grant from the National Science Foundation to explore ways to prevent and deal with the "cascading failures" that lead to massive blackouts. The project combines Chaudhuri's knowledge of power systems with the communications and networking expertise of colleagues Tom LaPorta and Ting He. Chaudhuri recently sat down with Cherie Winner to describe some of the challenges involved, and how he and his colleagues plan to address them.

COULD YOU GIVE AN EXAMPLE OF "CASCADING FAILURE?"

The power grid is more than a physical system. It is reliant on a cyber layer—sensor networks, communications, algorithmic layer, all talking to each other. A failure in any one of those could start a blackout.

In the 2003 blackout in the northeastern U.S., the energy management system software was supposed to be updated or upgraded, and it faced issues. It was out of service for hours. So the operators in the control centers had no clue that lines were getting overloaded, power was getting re-routed, and which way.

SO THE OPERATORS WERE NOT GETTING THE DATA THEY NEEDED TO MANAGE THE SYSTEM.

They need a near-real-time snapshot of the system's status. And they're not getting it—and they don't know they're not getting it. And everything went wrong from there, because when the system came back on, the operators were taking all the wrong decisions. All these very complex interactions can spread, one failure causing the other. That's how, from one region of failures, this can become a much bigger problem.

HOW ARE YOU AND YOUR COLLEAGUES APPROACHING THESE ISSUES?

We want to come up with a more realistic model of cascading failure in a power grid coupled with the communication network on which it depends. The three legs of the project are modeling, preventive control, and restoration. We perform different 'what-if' scenarios. What if a major component like a generator or transformer or transmission line fails? What if two such components fail at the same time? Or three? People have tried to use very simple models, which are easy to analyze but give you wrong results in later stages of a blackout. A quite detailed model is going to give you results that are closer to reality—*if* you could do the computations. Can we determine the stage of cascading failure up to which I can trust my simple model, and beyond that point, I will use a more complex model?

After cascading happens, you want to bring power back as soon as you can. There, our goal is to develop approaches where you can estimate the state of the system with partial visibility. You know your system is down; you do not know which parts of your system are down, because your sensors are also down.

THEY DEPEND ON THE POWER THAT THEY'RE SUPPOSED TO BE MONITORING.

Interesting, right? What people have done is to provide backup power supplies, but of course, batteries also have a certain capacity. If they start dying, then you start getting blind.

The other aspect is how we can strategically place the control center, where you have all the information coming in. Then you need to find out the minimum number of communication links to the control center that need to be preserved no matter what, so that at least that information continues to come to your control center.

ARE THERE ANY NEW DANGERS TO THE POWER GRID THAT WE NEED TO CONSIDER?

One new dimension is cyber-attack on sensors, and how that can negatively impact a cascading failure, and then how we can have redundancies or appropriate placement of sensors that can help us avoid cascading failure *in spite of* cyber-attacks.

Another is natural disaster, which is becoming more important now because of climate change and the types of weather patterns we are observing. Previously, we did not consider lightning striking at the same time in many places in our what-if scenarios. Of late, these extreme events are becoming more and more common. We might have four weather fronts with significant thunderstorm potential across a region, and we're having lightning strikes continuously. Or there is a flood or high gale which is physically damaging the network. Now you're talking about whether you're ready for three or more components going out just because of a weather front. We need to talk to weather experts and try to develop models that can take input from weather-related variables.

Nilanjan Ray Chaudhuri is assistant professor of electrical engineering and computer science. Tom LaPorta is William E. Leonhard Endowed Chair, Evan Pugh Professor, and director of the School of Electrical Engineering and Computer Science. Ting He is associate professor of computer science and engineering.

Research/Penn State
The Pennsylvania State University
401 James M. Elliott Building
120 South Burrowes Street
University Park, PA 16801

Nonprofit Org.
U.S. Postage
PAID
State College, PA
Permit No. 1

PennState

facebook.com/pennstate twitter.com/psuresearch More research news: **news.psu.edu/topic/research**