Research *at* Penn

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Research at Penn

Advances in Knowledge from the University of Pennsylvania

Penn's Research Enterprise

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In all probability, Russian interventions influenced the result of the 2016 election. Democracy has been discriminatory since Ancient Greece. The trauma from police killings of unarmed African Americans is detrimental to the mental health of African Americans. The elderly homeless population in the United States will nearly triple by 2030. All politics is not local. Midday naps can increase sixth graders' IQ.

This is just a small slice of the riveting, groundbreaking, and innovative research findings featured in the 2020 edition of *Research at Penn*.

Published each year for the past 18 years, the brochure highlights research from each of the University's 12 schools.

With more than $1 billion in annual research and development expenditures, Penn is one of America's top research universities, known throughout the world for its interdisciplinary approach to scholarship. New knowledge generated by the University impacts the fields of science, medicine, technology, business, and beyond, and application of Penn expertise improves the lives of individuals and communities in the United States and around the world.

Peruse these pages to find out why human beings need more sleep when they are sick, how microscopic robots may one day replace dental scrapers, where in the Galápagos Islands developers should not build, what the tipping point is for social change, and other fascinating disclosures.

To stay abreast of all University research, visit Penn's research website: **www.upenn.edu/researchdir**.
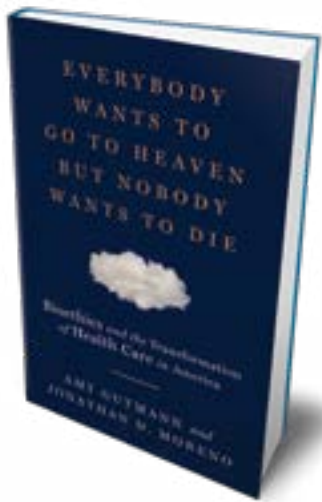
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Stimulating the Conversation about Health Care

Jonathan Moreno, left, and Amy Gutmann write about fairness in and access to health care, as well as experimental treatments, end-of-life care, and much more.

It's interesting, says Penn President Amy Gutmann, to reflect on her childhood years, back when black bag-toting pediatricians still made house calls. In the U.S., there was this ethos of blind trust, the belief that "the doctor is always right."

That was, Gutmann says, until she found out that the mythical black bag was a "mixed bag" at best.

The causes and effects of this shift, in Gutmann's words, "from blind trust to earned trust," are at the core of the emergence and growth of bioethics throughout the past half-century.

"A duty to tell was just the beginning," Gutmann and co-author Jonathan Moreno write in their book, "Everybody Wants to Go to Heaven But Nobody Wants to Die." "A responsibility to listen to what patients have to say remains an essential work in progress."

Gutmann, a political scientist, teamed up with medical ethics, health policy, and history and sociology of science expert Moreno, a Penn Integrates Knowledge Professor with appointments in the Perelman School of Medicine and the School of Arts and Sciences, to pen their book, which charts the evolution of bioethics, diving into its breadth and complexity. The duo's work together on President Barack Obama's Presidential Commission for the Study of Bioethical Issues (Gutmann was chair and Moreno was senior adviser) laid the foundation for the book.

The book's purpose? To spread awareness and understanding surrounding health care in America, from fairness and access, to experimental treatments and end-of-life care, to "nudging" and reproductive technology, and much, much more.

"Our goal is to stimulate conversation and discovery about some important matters of our health care and our humanity that we all face," they write. "Otherwise, those matters will be decided for us without our informed individual or collective consent."

Gutmann and Moreno purposely weave their own personal stories, as well as those from others, throughout the book, making it a relatable read. They begin by recalling what would today be considered appalling instances, which had an effect on their own grandmother and mother's health, respectively. They discuss the unavoidable moral choices that come along with medical progress, and talk in detail of the high price of unfair health care.

"We get some things so right in this country, which is the innovation part of health care," says Gutmann.

But, notes Moreno, "We have a health care system that's inefficient and inequitable. That's the worst of both worlds."

If the U.S. did better in access, it could do better in controlling costs, and vice versa, the authors explain.

"Everybody wants everything that's good about health care, but we don't want to face the questions of those things that are not good for us," says Gutmann, noting the reason for the book's title, the clever name of a blues song.

"When science partners with ethics," says Gutmann, "we can save lives, we can extend lives, and we can increase the quality of life.

Cancer Cells Attack Immune System with 'Drones'
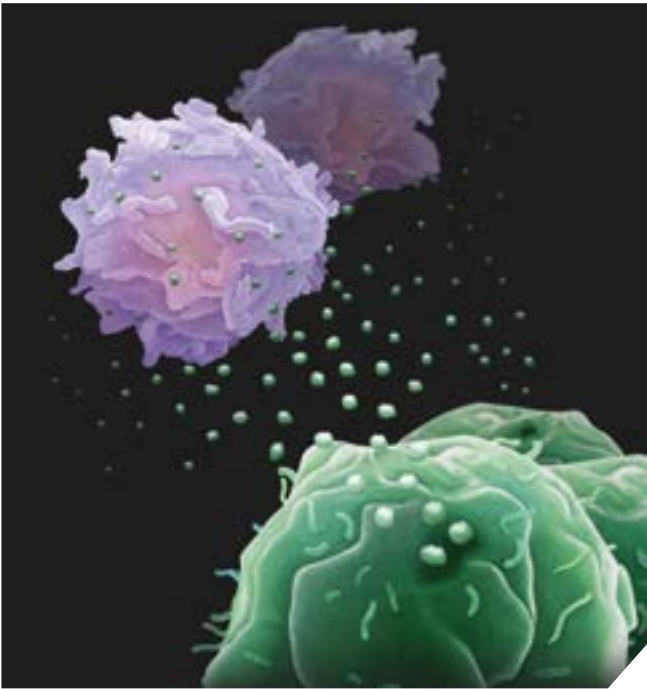
Cancer is often described in military terms: Patients "battle" and "fight" the disease, which insidiously takes over the body's systems from within. Researchers from Penn have now identified another weapon that cancer cells leverage in the war—they release biological "drones," or small vesicles called exosomes, into the blood, armed with the protein PD-L1, which cause T cells to tire before they have a chance to reach the tumor.

The collaboration between Wei Guo of the School of Arts and Sciences and Xiaowei Xu of the Perelman School of Medicine resulted in a publication in the journal *Nature* that has already been cited more than 150 times in one year, offering a new understanding of tumor immunology and current immunotherapies. While primarily focused on metastatic melanoma, the team found that breast, bladder, and lung cancers also release the PD-L1-carrying exosomes.

The work offers a paradigm-shifting picture of how cancers take a systemic approach to suppressing the immune system. It also points to a new way to predict which cancer patients will respond to certain checkpoint inhibitor drugs, which unleash the immune system to fight tumors, and a means of tracking the effectiveness of such therapies.

"Immunotherapies are lifesaving for many patients with metastatic melanoma, but about 70 percent of these patients don't respond," says Guo. "These treatments are costly and have toxic side effects, so it would be very helpful to know which patients are going to respond. Identifying a biomarker in the bloodstream could potentially help make early predictions about which patients will respond and, later on, could offer patients and their doctors a way to monitor how well their treatment is working."

"What we have found with these circulating exosomes is truly remarkable," adds Xu. "We collected blood samples from melanoma patients treated with checkpoint inhibitor therapy. This type of liquid biopsy assay allows us to monitor tumor-related immune suppression with time."

Exosomes are "treasure troves" of information about tumors, says Guo. The researchers foresee relying on exosomes as an accessible way of tracking the cancer-T cell battle through a blood test instead of the traditional, more-invasive tumor biopsy. They're currently working to improve the efficacy of these assays.

"Just as diabetes patients use glucometers to measure their sugar levels, it's possible that monitoring PD-L1 and other biomarkers on the circulating exosomes could be a way to keep tabs on treatment," says Guo. "It's another step toward precision and personalized medicine."

Single Gene Drives Need for More Sleep During Illness
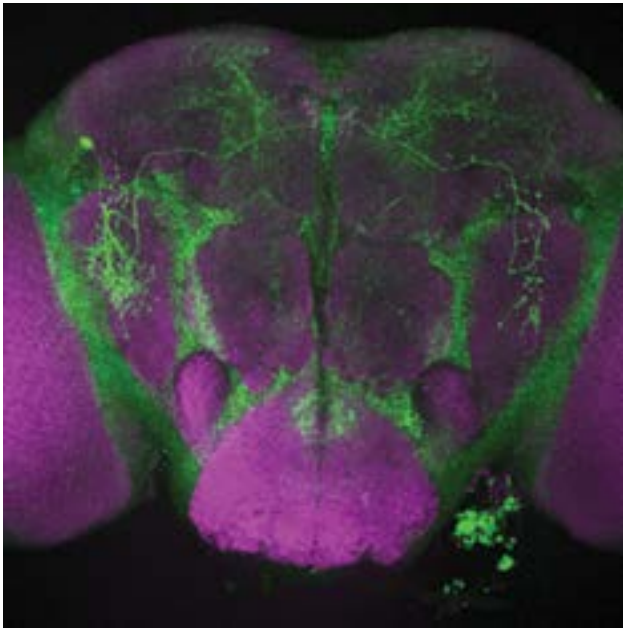
A brain showing nemuri *expression following infection. The horizontal green line reveals* nemuri-expressing *cells on either side.*

Why do humans need more sleep when they're sick and how do they get it? Amita Sehgal, a professor of neuroscience and director of the Chronobiology and Sleep Institute in the Perelman School of Medicine, may have an answer in a single gene called *nemuri*, findings she published in the journal *Science*.

In the body, *nemuri* fights foreign germs with its antimicrobial properties. But Sehgal's work showed it also drives increased sleep in fruit flies.

"It's one molecule with two functions," she says. "On one hand, it's killing the bug, on the other, it's inducing sleep."

Sehgal's research generally focuses on biological timing and circadian rhythms that affect physiology.

"As part of figuring out what makes you sleepy, we use fruit flies to identify genes that control sleep amount," she explains. "The idea is to find a gene required for a normal sleep amount so that when they lose it, they experience less [sleep] and when they increase expression of the gene, they sleep more."

With 14,000 fruit fly genes, Sehgal says it's challenging to know which to target first. So, through a process that propels mutagens randomly throughout an animal, she set out to examine as many as possible. With funding from the Howard Hughes Medical Institute and the National Institutes of Health, her team collected flies from labs worldwide, then screened 12,000 lines encompassing about 8,000 genes. Through that process, *nemuri* emerged.

Fruit flies are active in the morning and evening, then sleep at night and mid-afternoon. Their slumber is measured through behavior, with any period of immobility five minutes or longer counting as sleep.

Increasing expression of *nemuri* put the flies to sleep, so to rigorously test the gene's role in sleep, Sehgal's team removed it from a population subset. Those animals woke more easily and slept less following infection or to counteract lost sleep. In flies that retained *nemuri*, sleep deprivation stimulated gene expression in the brain, in neurons close to known sleep-promoting structures. And bacteria-infected flies given an abundance of the gene slept more and saw better survival rates.

"These results point to the idea that the immune system is an important regulator of sleep," Sehgal says.

Future work could focus on what happens in the brain when this molecule triggers sleep, why stress activates it, and whether comparable immune genes function similarly.

Brain Stimulation Decreases Intent to Commit Assault

Penn neurologist Roy Hamilton, left, setting up transcranial direct-current stimulation.

Stimulating the brain's prefrontal cortex, responsible for controlling complex ideas and behaviors, can reduce a person's intent to commit a violent act by more than 50 percent and increase the perception that such acts are morally wrong, according to research from Penn and Nanyang Technological University published in the *Journal of Neuroscience.*

"The ability to manipulate such complex and fundamental aspects of cognition and behavior from outside the body has tremendous social, ethical, and possibly legal implications," says Roy Hamilton, a neurologist at the Perelman School of Medicine.

For this work, Hamilton and Penn Integrates Knowledge Professor Adrian Raine conducted a double-blind randomized control trial on 81 healthy adults. Participants were randomly assigned to one of two groups. The experimental group received transcranial direct-current stimulation (tDCS) for 20 minutes; the placebo received a low current for 30 seconds, then nothing more.

After stimulation, the researchers presented participants with two hypothetical scenarios, one about physical assault, the other about sexual assault. They then asked participants to rate their likelihood of acting as the protagonist in each vignette and how morally wrong they considered the scenarios. Those in the tDCS group expressed significantly less intent to carry out physical and sexual assault than their control counterparts.

In theory, the results mean that simple biological interventions—separately or coupled with interventions like cognitive behavioral therapy—could reduce violent behavior.

"Much of the focus in understanding causes of crime has been on social causation," says Raine, who has appointments in the School of Arts and Sciences and the Perelman School of Medicine. "That's important, but research from brain imaging and genetics has also shown that half of the variance in violence can be chalked up to biological factors. We're trying to find benign biological interventions that society will accept."

This work is ongoing, with the researchers now exploring ways to modify the protocol and deliver stimulation to affect the behavioral effects elicited.

"This is not the magic bullet to wipe away aggression and crime," Raine says. "But could tDCS be offered as an intervention for first-time offenders to reduce their likelihood of recommitting a violent act?" The researchers aren't ruling out anything, but recognize the need to replicate their findings.

"Perhaps," Hamilton argues, "the secret to holding less violence in your heart is to have a properly stimulated mind."

A Path Forward for a Parasite Vaccine
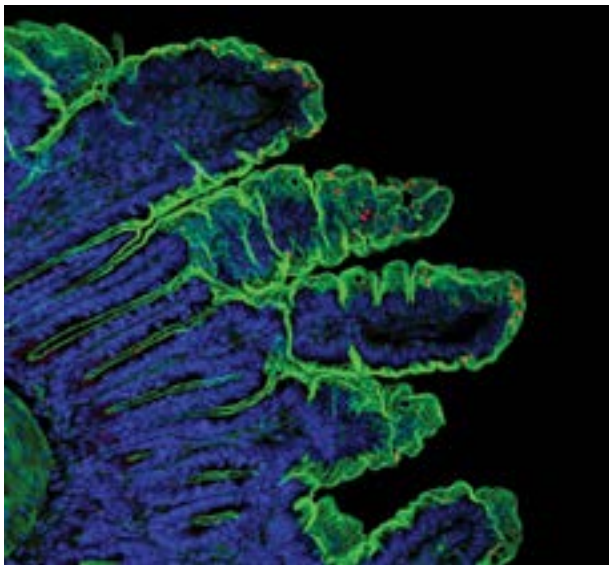
Red dots indicate Cryptosporidium tyzzeri parasites in a section of intestine from an infected mouse.

There's no vaccine and no effective treatment for the intestinal parasite Cryptosporidium, the leading cause of waterborne disease from recreational waters in the United States and an important contributor to early childhood mortality around the world.

Surprisingly, the parasite strains that infect humans don't do such a good job at infecting mice. To study the disease, researchers have had to rely on mice with defective immune systems, a model that made it difficult to understand how to elicit an immune response that could protect children.

But that is set to change. Using a species of Cryptosporidium that naturally occurs in mice, a team led by researchers from the School of Veterinary Medicine has developed a model of infection that affects immunologically normal mice. They show that mice develop immunity to the parasite after infection, and that a live, attenuated vaccine offers the animals protection against it. Their findings appear in the journal Cell Host & Microbe.

"We now have a fantastic mouse model that mirrors the human disease," says Boris Striepen, a biologist at Penn Vet and senior author on the study. "It's a powerful lab model, where we can introduce changes at will and test the importance of different components of the immune response to infection, which is just what we need to develop an effective vaccine."

Mice that received the experimental vaccine, which used a weakened version of the parasite, were as protected from infection as those that had already weathered an initial infection, the researchers found.

"We were able to show that the mice were protected —not by sterile immunity—but by very robust protection from disease, which is exactly what is observed in children," says Adam Sateriale, first author on the report and a postdoctoral researcher in Striepen's lab.

Encouraged by their findings, the researchers are continuing to probe the pathways involved in conferring immune protection against Cryptosporidium infection, and are sharing their model with colleagues to aggressively pursue a vaccine or other treatments for the disease.

"We're building up an interdisciplinary effort that can overcome the challenges of working on these complex investigations," says Striepen. "And hopefully this will lead to advances that protect children."

The Benefits of a Midday Nap

Nn
nap

Ask any parent whether napping benefits a child, and you'll likely hear a resounding "yes." Now, research from Penn and the University of California, Irvine, published in *SLEEP,* backs that up.

A study of nearly 3,000 10- to 12-year-old fourth, fifth, and sixth graders revealed a connection between midday napping and greater happiness, self-control, grit, fewer behavioral problems, and higher IQ, the latter particularly for sixth graders.

The most robust findings were associated with academic achievement, says Penn Integrates Knowledge Professor Adrian Raine, who holds appointments in the School of Arts and Sciences and the Perelman School of Medicine.

"Children who napped three or more times per week benefit from a 7.6 percent increase in academic performance in grade six," he says. "How many kids would not want their scores to go up by 7.6 points out of 100?"

Sleep deficiency and daytime drowsiness are surprisingly widespread, says Jianghong Liu, a professor of nursing and public health in the School of Nursing and the study's lead author. What's more, the negative cognitive, emotional, and physical effects of poor sleep habits are well-established, yet most research focuses on children preschool age and younger.

In places like the United States, napping stops as children get older, but in China, the practice continues through elementary and middle school, even into adulthood. So, Liu, Raine, and others turned to the China Jintan Child Cohort Study, which follows participants from toddlerhood through adolescence.

From 2,928 children, the researchers collected data about napping frequency and duration once participants hit grades four through six, as well as outcome data on psychological and physical measures when they reached grade six. The researchers also asked teachers for behavioral and academic information, then analyzed associations between each outcome and napping.

The first-of-its-kind study, funded by the National Institutes of Health, found that the more students slept during the day, the greater napping benefits they experienced.

"The midday nap is easily implemented," Liu says, "and it costs nothing."

Future directions could look at why children with better-educated parents nap more than those with less-educated parents, or the feasibility of scaling up nap interventions. Ideally, a randomized controlled trial would get at causation questions like whether napping leads to academic achievement.

An App for Sex Education

In the United States, the bulk of new sexually transmitted diseases each year occur in 15- to 24-year-olds. For queer males in this group, Presidential Professor of Nursing José Bauermeister created a National Institutes of Health-funded, app-based intervention called My Desires and Expectations (myDEx).

"It's a comprehensive sex-education platform that not only talks about HIV prevention—testing for it, using condoms—but also about communicating about safety and expectations in a virtual world," he says. Six myDEx modules cover topics like sexuality and consent, with exercises that teach users about intimacy, commitment, and passion.

Though myDEx isn't yet available to the public, a randomized, 180-participant pilot comparing it with a similar Centers for Disease Control and Prevention tool offered promising results.

"We saw improvements in users' confidence, better psychological and emotional regulation around meeting partners online," Bauermeister explains. "Ours is a more comprehensive, holistic approach, and it was encouraging to see it had so much traction and appeal."

Up next, Bauermeister is working on a plan to scale up the app, and in the future, to potentially create versions geared toward other groups.

How Police Brutality Influences Black Mental Health

The initial traumas of police killings of unarmed African Americans are distressing enough for people directly involved; what's less considered, however, is how that damage can also reverberate.

The Perelman School of Medicine's Atheendar Venkataramani, an assistant professor of medical ethics and health policy, co-led research published in *The Lancet,* in partnership with Jacob Bor, an assistant professor at the Boston University School of Public Health, studying the effects of these killings on African-American mental health. The study examined a national, randomized survey of 40,000 African Americans interviewed within—on either side of the event—three months of a police killing of an African American in their state. They posed the question: "Thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?"

The result: an average of 1.7 additional poor mental health days per person every year, amounting to 55 million poor mental health hours for African Americans. Put in context, diabetes results in 75 million more poor mental health hours per year among African Americans.

"The scale of the responses, if you look at the population as a whole, did surprise us," Venkataramani says. "When we put it all together, the number of poor mental health days in a year was really high; that burden was pretty similar to the mental illness that comes from a chronic illness like diabetes—a disease prevalent in the African-American population."

He adds: "That was surprising because our [study's final] number was probably an underestimate."

Venkataramani suspects their count was an underestimate because the study marked police killings on a state level, which made it difficult to account for more local exposures as well as the fact that some police killings were reported as national events. "Because you can't pin down exactly the geographic location it matters most," he explains, "that would lead us to underestimate the effect."

The idea to study the problem came in part from the team's observation that people, including their own friends, family members, and clinic patients, would report anxiety when the topic of the killings came up. Venkataramani was also motivated by the general notion that "a lot of things that affect population health and mental health occur outside of the health care system"—and, thus, remain unstudied.

He's encouraged by the increased dialogue that has come from the study, he says, and is hopeful that it can ignite a movement to address structural racism as a driver of this problem—as well as allow mental health interventions to be deployed during these moments of crisis.

Next, Venkataramani hopes to study inter-generational consequences of these mental health effects, and also how multiple killings may or may not layer to compound these adverse effects.

An Army of Microrobots can Wipe Out Dental Plaque

The Geography of Opioids
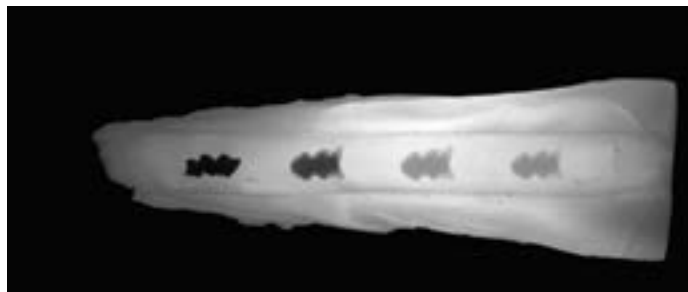
The team's microrobots were effective at cleaning hard-to-reach surfaces. This time-lapse image shows one of the molded, helicoid-shaped robots traveling inside a tooth canal.
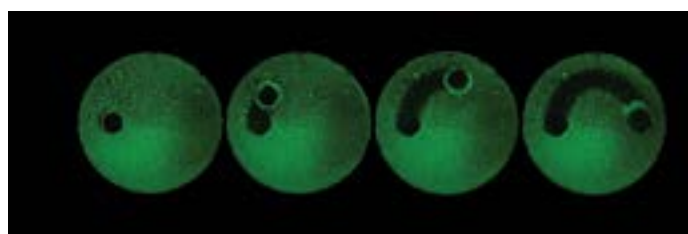
With a precise, controlled movement, microrobots cleared a glass plate of a biofilm.

A team of engineers, dentists, and biologists from Penn developed a microscopic robotic cleaning crew that could one day replace the mechanical scraping of plaque that is a ubiquitous—and typically unpleasant—feature of most dental visits.

With two types of robotic systems—one designed to work on surfaces and the other to operate inside confined spaces—the scientists showed that robots with catalytic activity could ably destroy biofilms, sticky amalgamations of bacteria enmeshed in a protective scaffolding. Such robotic biofilm-removal systems could be valuable in a wide range of potential applications, from keeping water pipes and catheters clean to reducing the risk of tooth decay, endodontic infections, and implant contamination.

The work, published in *Science Robotics*, was led by Hyun (Michel) Koo of the School of Dental Medicine and Edward Steager of the School of Engineering and Applied Science.

"This was a truly synergistic and multidisciplinary interaction," says Koo. "We're leveraging the expertise of microbiologists and clinician-scientists as well as engineers to design the best microbial eradication system possible. This is important to other biomedical fields facing drug-resistant biofilms as we approach a post-antibiotic era."

"Treating biofilms that occur on teeth requires a great deal of manual labor, both on the part of the consumer and the professional," adds Steager. "We hope to improve treatment options as well as reduce the difficulty of care."

Together, the cross-school team designed, optimized, and tested two types of robotic systems, which the group calls catalytic antimicrobial robots, or CARs, capable of degrading and removing biofilms.

Both types of CARs effectively killed bacteria, broke down the matrix that surrounds them, and removed the debris with high precision, even on hard-to-reach parts of a human tooth.

To move the innovation down the road to clinical application, the researchers are receiving support from the Penn Center for Health, Devices, and Technology, an initiative supported by the Perelman School of Medicine, Penn Engineering, and the Office of the Vice Provost for Research. They also hope to advance CARs and other innovative dental technologies through a new University center that will connect engineers with dental scientists to design valuable new devices for oral health care.

Location matters when it comes to opioid prescribing practices. A team from the Perelman School of Medicine led by M. Kit Delgado and Jeanmarie Perrone found dramatic geographic variation in opioid prescribing rates for a minor injury in a study published in the *Annals of Emergency Medicine*. Patients who sought care for a sprained ankle in states that were found to be "high prescribers" of opioids were approximately three times more likely to receive a prescription for the drugs than those treated in "low-prescribing" states, the team found.

"Opioid prescribing for these minor injuries is still common and far too variable," Delgado says.

Curbing Methane Emissions, Starting with Cows

Dipti Pitta's team has been adding an enzyme powder to cow feed that cuts methane emissions by 30 percent.

Our love for hamburgers and ice cream plays a role in climate change. Livestock, mostly cattle raised for dairy and beef products, produce 25 percent of methane emissions in the United States. Methane makes up 14 percent of greenhouse gas emissions globally and is 28 times more potent than carbon dioxide at trapping heat in the atmosphere.

Thus, a natural strategy for curtailing this important contributor to emissions is to target the source: cows. Dipti Pitta, an assistant professor at the School of Veterinary Medicine, is doing just that. With support from a three-year USDA National Institute of Food and Agriculture grant, she is studying how microbes in rumen, the large part of the cow's first digestive chamber, or reticulorumen, influence methane production, and how diet can bring those levels down.

"For both of these approaches, the unifying feature is trying to understand the mechanistic basis of methane production in the rumen," she says.

Microbes in the rumen assist in the cows' digestive process by breaking down plant material. In the process, some microbes release hydrogen as a byproduct. Methanogens, a type of microbe in the group known as archaea that are present in the rumen, consume this hydrogen.

However, methanogens convert hydrogen into methane, which the cows then emit.

Some cows naturally produce more methane, while others produce less. A focus of Pitta's research so far has been to identify and modify factors that influence these traits. One key strategy is to tweak their feed.

"By using certain types of food, we can influence the balance of microbes in the rumen so that methanogens are less able to compete for hydrogen," Pitta says. "And if we can divert hydrogen away from methane production, it could actually be used for the cow for more energy production."

Working with colleagues, Pitta has been testing dietary supplements that can inhibit methane production, including a synthetic compound that seems to safely reduce dairy cows' methane emission by 30 percent while maintaining or improving milk and meat production. The compound, an enzyme analogue-containing powder, is simply added to cows' food.

Coupled with selective breeding methods, the synthetic feed supplement has the potential to put a huge dent in overall methane emissions.

"This will allow us to produce more milk from fewer cows," Pitta says. "By using these methods, we could direct more energy to milk or meat production, instead of methane production. This is good for farmers and great for the environment."

Pitta would like to eventually incorporate natural products into cows' diets to reduce methane even further. She's now working on a project testing the use of seaweed as a source of cattle feed that could knock down methanogens in the rumen.

By maximizing the cows' efficiency, Pitta's findings may not only slash methane emissions but help farmers decrease costs as well.

"It's a win-win," she says.

Like a Triceratops on Two Feet

Small in stature and lacking the extensive frill of its relative *Triceratops,* the bipedal Chinese dinosaur *Auroraceratops rugosus,* first identified in 2005, nonetheless has strength in numbers. With fossils from more than 80 individual animals—from near-hatchlings to adults—the newly characterized species is one of the most completely known of the dinosaurs.

In a collection of articles published as Memoir 18 in the *Journal of Vertebrate Paleontology,* researchers including Penn's Peter Dodson of the School of Veterinary Medicine and School of Arts and Sciences, along with his former student and study lead Eric Morschhauser, now of Indiana University of Pennsylvania, describe this impressive assembly of specimens.

Digitizing Plant Collections to Shed Light on Urbanization

Images captured with a high-resolution camera allow botanists to study fine details of plant specimens.

The region encompassing Washington, D.C., Baltimore, Philadelphia, and New York City is dominated by the presence of humans. Often referred to as a "megalopolis," the Mid-Atlantic's urban influence is felt on all life forms, plants included.

An effort underway at the Morris Arboretum of the University of Pennsylvania has a goal of documenting and investigating that influence. The Mid-Atlantic Megalopolis (MAM) project, supported by a grant from the National Science Foundation, is creating digital records of more than a million plant specimens collected in five states—Maryland, Pennsylvania, Delaware, New Jersey, and New York—plus Washington, D.C.

The end result? A digital herbarium: a modernized, accessible database of plants collected during the past 400 years, featuring high-resolution images of the specimens, as well as a host of informative metadata (midatlanticherbaria. org).

This information has the potential to inform large-scale, "big data" studies of how plant communities have changed over time in response to urbanization. Which species thrive in soils disturbed by development? Which tolerate pollution? Which adapt to the urban "heat island" effect and which die out? The MAM team, led by principal investigator Cynthia Skema, a botanical scientist at the Morris Arboretum, hopes its digital collection will one day help address these questions and more.

Volunteers and staff have contributed to the digitization effort, photographing specimens, transcribing metadata to the database (sometimes deciphering the eccentricities of centuries-old handwritten notes about where and when the plant was found), and georeferencing the record, which entails estimating the coordinates of where the specimen was collected from the available location information—a time-consuming task for plants collected before the advent of handheld GPS units. Students in Skema's "Field Botany" course have added new plant sightings data to the virtual flora of the Mid-Atlantic that is associated with the digital herbarium, enriching specimen data with present-day observations.

Nearing the close of the three years of funding, the researchers are seeing their dataset inform research projects, such as one examining the biodiversity of urban parking lots. And though the digitization adds value to the collections, it is in no way meant to undercut the value of the physical specimen itself, Skema emphasizes. Physical specimens contribute myriad other data, opening up many other avenues for research questions. For example, scientists can conduct chemical analyses of the samples to look for pollutant levels as a proxy for air or soil pollution in certain areas at certain times.

"These collections are invaluable," Skema says. "Part of this work is convincing people—ecologists, developers, urban planners, the public—that natural history collections are critical to understanding our world."

Wallpaper Designs Help Scientists Discover New Type of Insulating Material
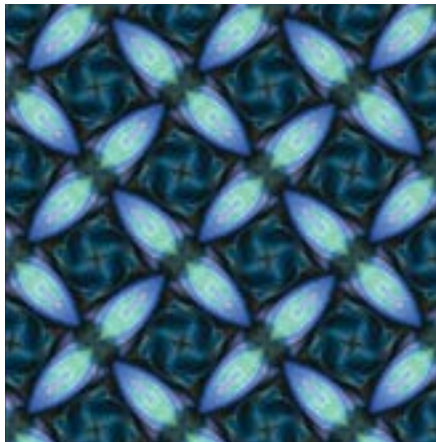
The unusual symmetries present in everyday wallpaper and wrapping paper played a role in the discovery of a new type of insulating material.

A team of researchers discovered a new type of insulating material, work that was made possible by a novel approach for assessing chemical structures by their mathematical properties, similar to those that underlie the repeatingpatterns seen in everyday wallpaperdesigns.

Charles Kane, the Christopher H. Browne Distinguished Professor of Physics in the School of Arts and Sciences, and Andrew M. Rappe, the Blanchard Professor of Chemistry, collaborated with researchers from Princeton, Sungkyunkwan University, Freie Universität Berlin, and the Max Planck Institute of Microstructure Physics.

The study, published in *Science,* analyzed the symmetries of the surfaces of 3D crystalline insulators, which have repetitive patterns in their 2D arrangement of surface atoms that are reminiscent of wallpaper. The different possible symmetry patterns, classified by the 17 wallpaper groups, allow new classes of topological insulators, which are insulators on the inside of the material but conduct electricity on their surface. This insight enabled the prediction of these new insulators in several known materials.

After finding this unique phase in lead-strontium (Sr_2Pb_3) crystals, researchers then constructed a physics-based framework for understanding and diagnosing symmetry-enhanced topological phases, structural symmetries that give the material unique properties. Using this theory, researchers can now search for these exotic phases in other materials.

"For the first time, we can directly relate the symmetry of a surface to the presence of desired topological surface states," says Rappe. "This allows an elegant and immediately useful means of designing desirable surface and interface states."

This research marks the completion of a decade-long search for an elusive 3D material that combines the unique electronic properties of 2D graphene and 3D topological insulators, a phase of matter whose discovery led to the 2019 Breakthrough Prize in Fundamental Physics shared by Kane and Eugene Mele, the Christopher H. Browne Distinguished Professor of Physics. Researchers hope to use the unique properties of these materials in applications such as super-fast quantum computers.

"You can think about a topological insulator like a Hershey's Kiss: The chocolate is the insulator, and the foil is a conductor," explains Kane. "We've been trying to identify new classes of materials in which crystal symmetries protect the conducting surface. What we've done here is to identify the simplest kind of topological crystalline insulator."

Is Roadside Dust Making us Sick?
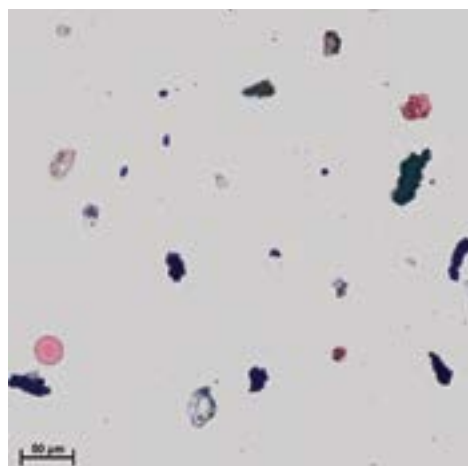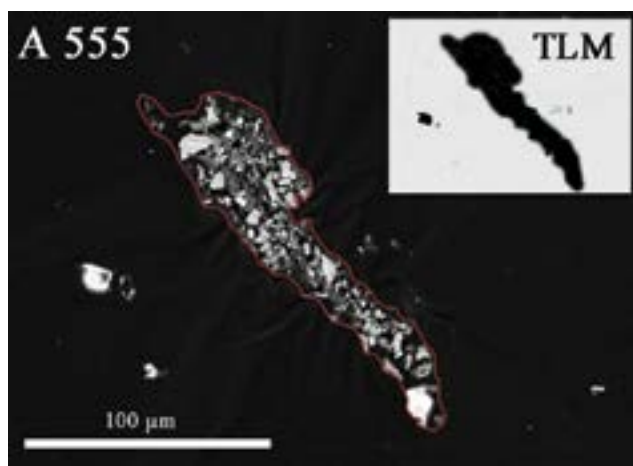
Researchers used optical and scanning electron microscopy to study the contents of dust along roadways.

Cars and trucks pollute the air; that's not news. However, research led by Penn's Reto Gieré, working with collaborators across the world, is helping to illuminate a significant source of traffic-related air pollution that most people overlook: particles from tires, brakes, and road material that can become suspended in the air and potentially inhaled by passersby.

"To understand the potential health implications of these dust particles, it's really important to investigate what's on the road," says Gieré, professor and chair of the Department of Earth and Environmental Science in the School of Arts and Sciences.

While regulatory efforts have helped make cars cleaner and more efficient, those restrictions do not address the pollution that arises from tire and brake wear. Increasing urban congestion stands to aggravate these as sources of pollution, possibly creating adverse health effects. About 4 million people die prematurely from air pollution each year.

Gieré teamed with colleagues from the Federal Highway Research Institute, the German Meteorological Service, and the University of Freiburg to sample and analyze the air along three roadsides.

In a report published in *Aerosol and Air Quality Research,* Gieré and

colleagues used powerful scanning electron microscopy to more precisely identify the makeup of the particles collected from the three roadways, each with different traffic patterns.

Ninety percent of the dust particles collected from the three sites were traffic-related. The slower moving traffic on the urban road generated fewer particles from brake wear but more from tires; the researchers noted that the tire rubber became encrusted with minerals and other materials from the roads. A highway with more stop-and-go traffic generated more brake particles.

Tire and brake pad manufacturers do not disclose all the contents of their products, but it's known that zinc, lead, antimony, cadmium, and silicates, including asbestos, are used by some. These chemicals can pose a health risk if they are released into the environment.

One strategy to reduce this contributor to air pollution would be traffic-calming measures, such as coordinated traffic lights that reduce the amount of starting and stopping that drivers must perform. Gieré and colleagues, including Ph.D. student Michael O'Shea, are also conducting similar experiments on the streets of Philadelphia and comparing the pollution levels between different neighborhoods.

Bots, Biases, and Binge Watching:
How AI Shapes the Modern World

A robot from Penn's Rehabilitation Robotics Lab. Whether the machines are commercially available, like this Baxter model, or made in-house here at Penn, fundamental research on artificial intelligence is key to creating machines that can work with, and for, people more effectively.

Artificial intelligence is no longer a futuristic concept flourishing solely in sci-fi worlds but has become an integral part of decision making in modern life.

"People are aware of AI that looks revolutionary, like self-driving cars, but there are many more subtle uses that are more pervasive," says Lyle Ungar, a professor with appointments in the School of Engineering and Applied Science (SEAS), the School of Arts and Sciences (SAS), the Perelman School of Medicine (PSOM), and the Wharton School. "As you go through life doing anything—making a credit card purchase, using a dating app, using Google Maps—all of these have huge amounts of AI helping you sort through the hopelessly large choices you have to make."

Despite AI's prevalence, there are still many misconceptions about what, exactly, AI is, and how computers and machines might shape future society. Part of this misconception stems from the phrase "artificial intelligence" itself. "True" AI is a machine that can learn and understand the same way that humans do. But in most modern applications, AI actually refers to machine learning.

"For many decades, machine learning was viewed as an important subfield of AI. One of the reasons they are becoming synonymous ... is because as more data has become available, and machine learning methods have become more powerful, the most competitive way to get to some AI goals is through machine learning," says Michael Kearns, SEAS professor and founding director of the Warren Center for Network and Data Sciences.

The Brain in the Machine

All programs are made of algorithms, "recipes" that tell the computer how to complete a task. But in machine learning, instead of detailed step-by-step instructions, algorithms are "trained" on large datasets, such as 100,000 pictures of cats, "learning" which features of the image make up the animal. They can use that knowledge to decide whether a new image contains a cat.

Computers excel at these pattern-recognition tasks because they can search an enormous number of possible solutions. According to SEAS Associate Professor Shivani Agarwal, "We aren't designed to look at 1,000 examples of 10,000 dimensional vectors and figure out patterns, but computers are terrific at this."

Pattern recognition by itself, however, isn't "true" intelligence, Agarwal adds, because computers don't have the ability to reason.

Researchers in fields like computer vision, crucial for applications like self-driving cars and facial recognition, are using enormous datasets to train computer programs that can respond to and interact with the world. SEAS Professor Jianbo Shi does this via first-person GoPro videos. "It's one thing to look at somebody do something," Shi says. "It's another thing to experience it from your own point of view."

Research in natural language processing is working to clarify ambiguous words and phrases to help humans communicate with computers, work that is especially important as voice-recognition platforms like Alexa and Siri become more popular. Ani Nenkova, an associate professor in SEAS, trains programs on word-representation datasets curated by humans that tell the computer what words and phrases mean in specific context. The long-term goal is to develop algorithms that can analyze and understand text without a human "translator." "Being able to make inferences about language is important," she says, "and if we want agent-human interaction, that's absolutely a must."

Robotics research is also at the forefront of work strongly linked to AI. "We look at robotics as embodied AI," says Kostas Daniilidis, a professor in SEAS. "Something which has sensors to receive [information] and motors to interact with the world."

To give robots experience in chaotic, real-world settings, Daniilidis and Shi are collaborating with SAS Physics Professor Vijay Balasubramanian to create "curious" robots that will "explore" a new environment to complete future tasks more efficiently. To do this, the researchers have programmed a robotic arm to move around randomly and explore a box of assorted items like toys and clothes. Each new foray into this research moves AI one step closer to broad inclusion in everyday life.

The Human Driver

As artificial intelligence progresses, some AI-enabled practices have raised serious concerns, like the ability to create deepfake videos that put words in someone's mouth or the growing use of facial-recognition technology in public places. Automated results that turned out to reflect racial or gender bias have prompted some to say the programs themselves are racist.

"We know when there's something formal like a computer program that outputs a recommendation, people tend to assume that it's somehow more objective, somehow more value-neutral," says Lisa Miracchi, a philosophy professor in SAS who works with robotics to create more intelligent machines. "But if there are biases in datasets or the way the datasets are collected, they're going to be carried through or even magnified by the program."

The problem is more accidental than malicious, says Aaron Roth, an associate professor in SEAS and, with Kearns, co-author of the recent book "The Ethical Algorithm." An algorithm is a tool, like a hammer, but although it would make no sense to talk about an "ethical" hammer, it's possible to make an algorithm better through more thoughtful design.

"It wouldn't be a moral failure of the hammer if I used it to hit someone. The ethical lapse would be my own," Roth says. "But the harms that algorithms ultimately do are several degrees removed from the human beings, the engineers, who are designing them."

Experts across disciplines, from engineering and computer science to philosophy and sociology, are working to translate vague social norms about fairness, privacy, and more into practical instructions for computer programs.

Roth says he's heartened by the progress on the topic of data privacy, which has emerged as a concept called "differential privacy." This means that algorithms get written in a way that makes it impossible for an observer to discern whether an individual's data was used. The idea, which, according to Roth, began in obscure math papers, will soon be used to safeguard the privacy of responses to the 2020 federal Census.

"For algorithmic fairness, we're not there yet," Roth says. "It would be premature to say there are solutions right now, but looking at what happened with differential privacy, it's a roadmap."

The Virtual Assistant

Even as the technical and ethical issues surrounding AI evolve, people are already feeling its effects. One way is through reviews and recommendations. "About 70 percent of the time people spend on YouTube is attributed to recommendations," says Wharton Marketing Professor Kartik Hosanagar, who studies consumption on social media and streaming platforms. "For Netflix, about 80 percent of the streaming video hours people view is now influenced by recommendations."

These influences are also driving purchases in a big way, explains Hosanagar. Algorithms and AI tend to propel what will pop up when, through two types of filtering methods. The first, called collaborative filtering, is the "people who bought X also bought Y" approach. The alternative, called content-based filtering, takes cues from the first product to recommend a second one, "if you like X, you might also like Y," requiring a much more in-depth knowledge of both products at play.

Companies, which frequently employ a hybrid of the two methods, constantly tweak the algorithms they use for their recommendation engines because these suggestions matter to their bottom line. "It's modern AI," Ungar says. "It's interactive, human-based. Humans generate the reviews—even, typically, the fake ones—and it's me reading those reviews," but the decision-making process gets influenced by some back-end algorithmic acrobatics.

Diagnostic Copilot

In the world of health care, AI can mean providing physicians a natural language processing tool that scans countless medical records for patterns in a patient population or helps in making a diagnosis. "When a doctor is trying to figure out what's wrong with you, AI can look at the patient's full history and offer [a range of differential diagnoses] to help the doctor consider alternatives," says Ross Koppel, a sociologist and adjunct professor in SAS who teaches about biomedical informatics. "That's a really good use of AI."

For the past three years, that's been happening in the Radiology Department at the Hospital of the University of Pennsylvania. "We're training the computer to do what humans do, but better and faster," says Suyash Mohan, an associate professor of radiology at PSOM. "When a new patient gets an MRI, the machine extracts all features on the images and feeds out a differential diagnosis."

From there, it's up to the practitioner to decide how to proceed, Mohan adds, noting, "The first shot is taken by a trainee, which is a computer, and then you, the physician, can say, 'I agree or disagree.' That's where natural intelligence comes in." He's seen it succeed both experimentally and in practice.

In one study Mohan and colleagues conducted, more than 2,400 MRI scans were interpreted by two radiology residents, two neuroradiology fellows, and two neuroradiology attendings, then their performance was compared to an algorithm. The computer performed at a level between the residents and fellows, in other words, better than a relatively new trainee but not as well as a fully trained physician working in the field. Mohan predicts that within the next decade or so, AI will become more a part of daily radiology practice, helping to accurately diagnose conditions based on MRI images.

Free Will and the Future of AI

Anything but the most basic uses of artificial intelligence in applications like health care are still a few iterations away, but AI remains a powerful tool to be wielded wisely and understood clearly. For applications with AI already in play, like autocompletion or virtual assistants, the technology continues to improve. "You can see them gradually getting more and more useful," Ungar says. He suspects a subtle, almost imperceptible, shift toward AI pervasiveness during the next decade or two.

That doesn't, however, mean the end of free will or human choice. "These algorithms are valuable because they can make decisions at a scale at which no human can," Hosanagar says. He stresses that people should become more active users, understanding how the algorithms affect their choices and demanding at least a modicum of control.

Researchers like Agarwal emphasize the importance of establishing core principles for AI that clearly define success and failure in AI platforms, and that indicate when algorithms work well and when their use might be harmful.

"We want to improve quality of life by doing things that were not possible earlier, but we need to have principles," Agarwal says. "Once we have a clear understanding of the principles, we can design the algorithms accordingly and implement them with computers. Computers are really at our beck and call. The challenge is for us as humans to come together and decide what is acceptable for us to ask of them."

TOP: The research group of Ani Nenkova, an associate professor at SEAS, works at the interface of computational linguistics and AI, and is focused on developing ways to help computers better analyze text for less apparent metrics such as quality and style.

Computer scientists Michael Kearns (right) and Aaron Roth (second from left) are at the forefront of the effort to ensure engineers are building algorithms that reflect society's values, and to help translate those values into specific instructions for a computer program.

Across campus, researchers like computer scientist Lyle Ungar are working to better understand how artificial intelligence affects everyday life now and in the future.

'Swiss Cheese' Solutions to Complex Math Equations
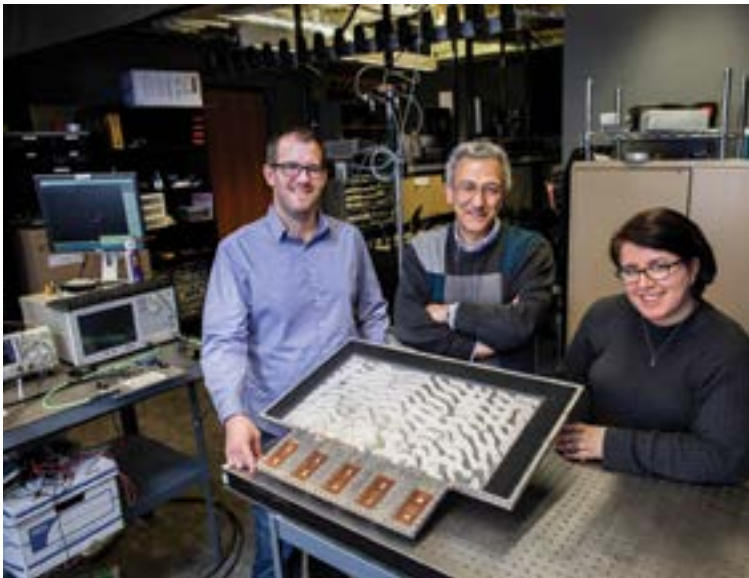
Nader Engheta (center), the H. Nedwill Ramsey Professor in the Department of Electrical and Systems Engineering, and lab members Brian Edwards and Nasim Mohammadi Estakhri conducted the pathbreaking work in Engheta's lab.

A team of engineers has designed and created a material that can solve complex math equations without electricity. The "Swiss cheese" metamaterial, a synthetic composite designed to have properties that don't exist in naturally occurring materials, is a proof-of-concept device that demonstrates how these materials could be used to perform analog computations more efficiently than digital computers.

The device was made by Nader Engheta, the H. Nedwill Ramsey Professor in the Department of Electrical and Systems Engineering in the School of Engineering and Applied Science, and lab members Nasim Mohammadi Estakhri and Brian Edwards. Building off their previous work that provided a theoretical foundation for this design, the group's publication in *Science* demonstrates the real-world usability of such a device for the first time.

Engheta's group conducted their proof-of-concept experiment on microwaves, which have longer wavelengths that are easier to capture, since the size and pattern of the material must be proportional to the signal's wavelength. Comprised of a block of dielectric material with holes carved into the polystyrene plastic, the "Swiss cheese" bends the shape of an incoming microwave as it passes through the device and performs what's known as photonic calculus.

After encoding parameters into the microwave and sending it through the device, the metamaterial's unique structure manipulates the wave so it exits with the solution to a predetermined equation.

"Controlling the interactions of electromagnetic waves with this Swiss cheese metastructure is the key to solving the equation," Estakhri says. "Once the system is properly assembled, what you get out of the system is the solution to an integral equation."

"This structure," Edwards adds, "was calculated through a computational process known as 'inverse design,' which can be used to find shapes that no human would think of trying."

Being able to make materials that can efficiently solve integral equations, foundational problems that scientists and engineers deal with daily, would be incredibly useful.

"Even at this proof-of-concept stage, our device is extremely fast compared to electronics," Engheta says. "With microwaves, our analysis has shown that a solution can be obtained in hundreds of nanoseconds, and once we take it to optics, the speed would be in picoseconds."

As a leader in the field of metamaterials, Engheta is interested in using metamaterials to create analog computers that run on light instead of electricity. Now, the group's design strategy could be scaled down to fit onto a microchip for reading light waves.

This work also provides a fresh perspective for thinking about how analog computers could be used and created in the future.

"We could use the technology behind rewritable CDs to make new Swiss cheese patterns as they're needed," Engheta says. "Some day you may be able to print your own reconfigurable analog computer at home."

Building a Portable Diagnostic Test, One Drop at a Time
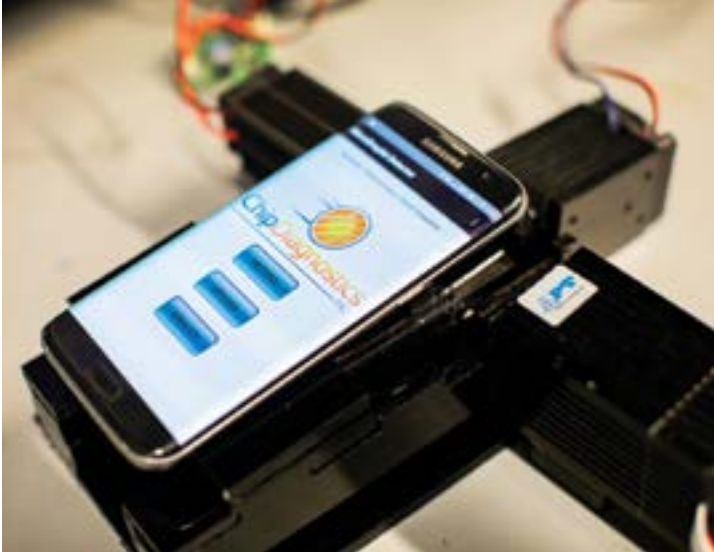
A team of Penn researchers has created a handheld diagnostic that can detect rare proteins in blood. Using off-the-shelf equipment, the diagnostic can determine the precise number of proteins in a sample using an approach that is more sensitive than existing commercial technologies.

Led by David Issadore, an assistant professor in the departments of Bioengineering and Electrical and Systems Engineering in the School of Engineering and Applied Science, the team included former Issadore group members Eshwar Inapuri and Venkata R. Yelleswarapu, Joshua R. Buser at Chip Diagnostics, and Jonathan Baron of the Perelman School of Medicine. Their work was published in the *Proceedings of the National Academy of Sciences.*

Using a standard cell phone camera and strobing LED lights, in combination with microfluidic droplet generators made in their lab, single proteins can be detected in a matter of minutes. The system is more than 1,000 times more sensitive than current state-of-the-art single-protein tests.

"By a thousand times more sensitive, we mean that if we had a vial of blood with only a few of the relevant proteins, we can accurately count those proteins, whereas a traditional test couldn't reliably tell the difference between that vial of blood and one with none of the protein in it," says Issadore.

The system works by separating the blood sample into microdroplets, each containing a single protein, or none if the protein is not present. Microdroplets that contain a target protein are tagged with a fluorescent marker and are measured by a microchip etched with hundreds of microdroplet generators to answer, Issadore says, "tens of millions of yes-or-no questions" in parallel.

Other ultrasensitive protein diagnostic technologies use costly optics and fluid handlers, making them bulky and expensive tools that can only be used in a laboratory. In contrast, the relatively inexpensive handheld system created by Issadore's lab could be used as a point-of-care device.

The lab's spin-off company, Chip Diagnostics, based at the Pennovation Center, is working to produce test kits for cancer diagnostics and brain injury. By creating more sensitive blood tests for these debilitating conditions where blood biomarkers may only be present in small numbers, their new diagnostic tool could make a lifesaving difference.

Organs-on-a-Chip Land on the International Space Station

On May 4, 2019, a rocket delivered two "organs-on-a-chip" experiments, designed by Dan Huh of the School of Engineering and Applied Science and G. Scott Worthen of the Perelman School of Medicine, to the International Space Station to study why astronauts get sick more easily in orbit. One experiment used lung cells to see what happens during a bacterial infection, and a second used bone marrow, the source of white blood cells, to see how this organ behaves in space. These data can help researchers understand space travel's impact on human health.

"We are thrilled with this rare opportunity to probe one of the potential major health issues in space using our organ-on-a-chip technology," Huh says.

Miniature Marine Robots, Powered by Currents, Map the Ocean
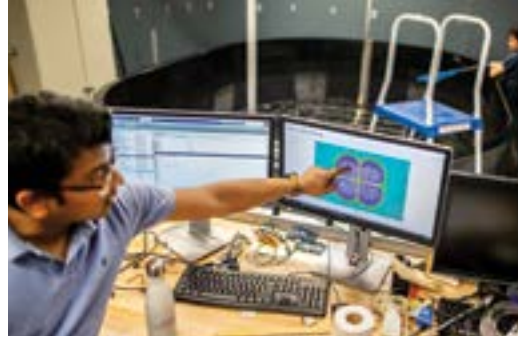
Postdoc Dhanushka Kularatne tests the fleet of marine robots in the Scalable Autonomous Robots Lab.

Engineers are testing a team of several small, ocean-savvy robots at Penn's Scalable Autonomous Robots Lab. The miniature marine robots leverage water currents for energy-efficient locomotion to travel over greater distances and for longer time periods to monitor the health of the ocean.

Led by Research Associate Professor M. Ani Hsieh in the Department of Mechanical Engineering and Applied Mechanics at the School of Engineering and Applied Science, along with postdocs Dhanushka Kularatne and Xi Yu, the goal of this work is to use these tiny autonomous fleets to track everything from shifts in ocean current patterns that affect our day-to-day lives on land to the spread of contaminants from an oil spill.

"The applications really require the robots to perform long-term and large-scale tours," says Yu, who sees this project as a powerful way to combine theoretical and applied research. "To achieve this, we utilize the oceanic flow whenever possible."

To test their ideas and refine the algorithms that drive the marine robots, researchers use an ocean-simulating indoor pool lined with motors that generate artificial currents. It's the perfect setting to test search strategies that the fleet will need to estimate and navigate in a complicated, ever-changing environment.

"Ocean dynamics change based on place and time, so this is a very complex system that exhibits various spatial and temporal scales," Hsieh says. "A single robot simply wouldn't provide enough measurements to enable a good reconstruction of how the currents change. This is why using a swarm is truly advantageous."

Each robot is equipped with a micro-controller board that holds memory and data processing systems, an inertial measurement unit, and a radio module. This allows the fleet's movement to track the evolving current patterns and lets each robot send and receive messages to other members in the swarm.

The team hopes to see their marine robots deployed to track the spread of contaminants in the ocean or atmosphere, or estimate the spread of debris from a maritime accident for search-and-rescue teams.

"If you now have the ability to do this online, with a team of robots constantly monitoring oceans, you have the ability to do real-time forecasting and real-time predictions," Hsieh says.

A New Hardware Platform for Quantum Computing

Atomic spins trapped in hexagonal boron nitride are sensitive to magnetic fields. Their states can be accessed using lasers, allowing them to be used as qubits.
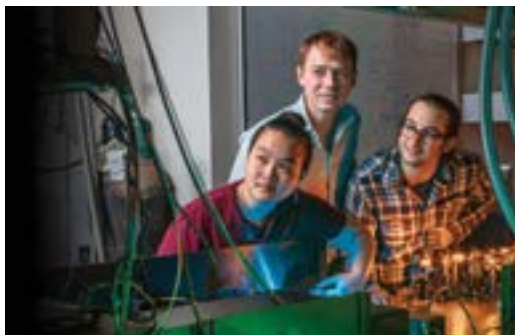
From left, lab member Tzu-Yung Huang, engineer Lee Bassett, and lab member David Hopper at work in the Quantum Engineering Laboratory.

Penn engineers recently discovered a potential new hardware platform for quantum computing. By trapping electrons in atom-scale defects of hexagonal boron nitride—a one-atom-thick semiconductor—the researchers were able to isolate electron spins and optically detect quantum states at room temperature.

Published in *Nature Communications,* the work was led by Lee Bassett, an assistant professor in the Department of Electrical and Systems Engineering in the School of Engineering and Applied Science, and former postdoc Annemarie Exarhos. Lab members David Hopper and Raj Patel also contributed to this work.

While quantum computers can carry more information than traditional binary systems, new hardware is needed to access and measure individual quantum states. Many of the 3D materials that have been studied as possible platforms, such as bulk diamond, have significant disadvantages, such as only working at extremely low temperatures, which has motivated research on 2D quantum computing materials.

With advances in nanotechnology providing entire libraries of new 2D materials to study, Bassett and his team looked for a material that resembled a flat version of bulk diamond. They focused on hexagonal boron nitride, a material with a honeycomb structure that is widely used as a dielectric layer in electronics.

The team focused on one of hexagonal boron nitride's lesser understood properties: Structural defects that emit light. Their research was the first to show that for certain defects, the intensity of emitted light changes in response to a magnetic field, producing a signal that could be used as a qubit, a unit of quantum information. The next steps are to determine what makes certain defects responsive to magnetic fields in hopes of finding ways to recreate those defects and exert more precise control on the platform's output.

"This study is bringing together two major areas of scientific research," Bassett says. "On one hand, there's been a tremendous amount of work in expanding the library of 2D materials and understanding the physics that they exhibit and the devices they can make. On the other hand, there's the development of these different quantum architectures. And this is one of the first to bring them together to say, 'Here's a potentially room-temperature quantum architecture in a 2D material.'"

Structures of the Future
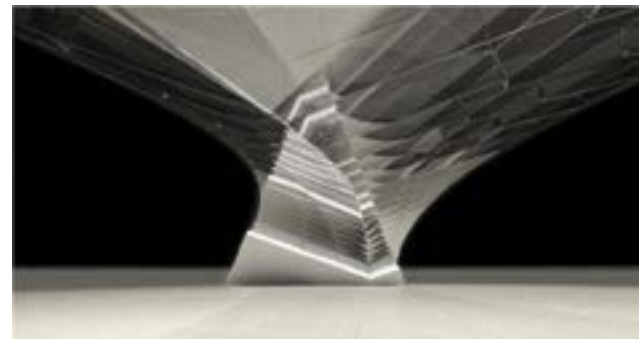
Masoud Akbarzadeh, an assistant professor of architecture in structures and advanced technologies in the Stuart Weitzman School of Design, is leading a team of researchers in mathematics, structural engineering, and architecture to develop highly efficient building structures using innovative construction methods and materials to reshape the future of construction.

Assembled as the Polyhedral Structures Lab, the group has, as one example, worked toward imagining an ultra-thin, transparent funicular glass bridge with no metal connections. A single construction unit of the bridge is made of one-centimeter-thick glass panels attached with a unique glass adhesive. Each unit alone can take up to 35 kips of static loads in compression—equivalent to 10 SUVs stacked on top of each other. That project will showcase at the Glasstec Trade Fair in 2020 in Dusseldorf, Germany.

Designing for People and Nature in the Galápagos Islands
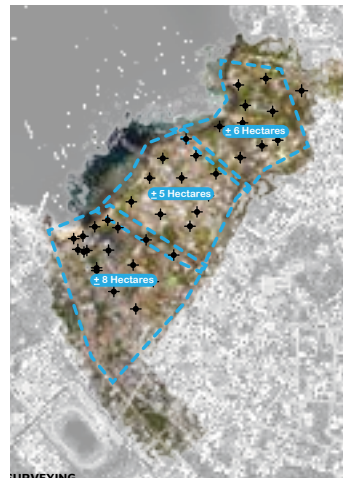
ABOVE: A georeferenced model of Puerto Baquerizo Moreno's shoreline and tide gauge. The model will help the Ecuadorian Navy establish a common tide datum across the archipelago—a feature critical to accurate sea level rise and tsunami event modeling.

RIGHT: A map depicting the extent of Puerto Baquerizo Moreno's shoreline drone aerial survey.

Ninety-seven percent of the land in Ecuador's Galápagos Islands is a protected national park; the remaining 3 percent is available for development. Since the park was established in 1959, the population on the five inhabited islands—Baltra, Santa Cruz, San Cristóbal, Isabela, and Floreana—has exploded to more than 30,000 residents, primarily because of employment opportunities in the tourism industry.

Karen M'Closkey, an associate professor of landscape architecture at the Stuart Weitzman School of Design, says San Cristóbal Island, the Galápagos' second-most populous isle, is being developed in a way that dangerously disregards topography and water flow, especially in Puerto Baquerizo Moreno, a town of more than 8,000 residents. Buildings are being constructed on or too close to ravines, which will cause progressively more problems as the town grows.

Along with groups of Penn students, M'Closkey traveled to San Cristóbal in 2017 and 2018 to study how Puerto Baquerizo Moreno is currently growing. The fixed boundary of the national park limits the space where the human population can grow, which has caused officials to build in places they shouldn't, such as low-lying areas.

"The town is at the lowest land," M'Closkey says. "Precipitation is seasonal. They have a wet season and a dry season, so you can get a lot of rain in the highlands and when it tries to come down through those

ravines, it needs room. And if you're building right up against the ravines, and channelizing them, they're doing what we've done in [the United States], which is why we have these catastrophic floods."

Puerto Baquerizo Moreno faces a shorter term threat of rainfall flooding, and longer term risks due to climate change. By century's end, M'Closkey says most of the populated areas would be unaffected by rising sea levels, but a large storm or tsunami, or the effects of an increasingly erratic El Niño, could do major damage. Other faculty members, Keith VanDerSys and Michael Luegering, have mapped the land-water interface to model the effects of such events.

Solutions include building more densely in places to leave more land for water to be absorbed, no longer building on the ravine, moving some buildings away from the ravine, limiting impervious surfaces, and increasing the height limit to allow for taller buildings.

M'Closkey says the overall landscape framework of her research is a "where not to build plan" so it will cost the government nothing.

The issues facing the Galápagos stem from an importation of bad practices, M'Closkey says, and are not unique to the Islands. Many other growing places in the world experience similar dilemmas.

"Given that the Galápagos Islands are held up as an exemplar for nature conservation, they could also set a standard for landscape architecture, which is humans and nature together," she says.

The Transformation of America's Teaching Workforce

One of the largest workforces in America is undergoing major changes. Richard Ingersoll, a professor of education and sociology at the Graduate School of Education, in the latest edition of his groundbreaking work on the nation's elementary and secondary teachers, points to serious implications of these changes for the nation's schools and taxpayers.

The new report shows America's schools are hiring more teachers than ever, yet are struggling to keep them in the classroom. More teachers today are female, young, have little experience, and quit at high rates. There has been a significant increase in the number of minority teachers, despite the fact that it is those teachers who are leaving the profession the fastest.

The updated analysis is based on national data collected over 30 years by the U.S. Department of Education's National Center for Education Statistics. Ingersoll's original report on the teaching force was released seven years ago.

The implications are important, especially the sharp increase in the total number of teachers. In the most recent year of data available, 2015-16, there were 4 million public and private elementary and secondary school teachers, an increase of more than 400,000 since 2011-12. During the past three decades the number of teachers has increased at more than twice the rate as the number of students. "I don't see that it will be sustainable," Ingersoll says, noting that teacher salaries are the largest part of a school system budget.

While the diversity of the teacher workforce still doesn't reflect the student population, another surprising discovery in the update was the dramatic surge in minority teacher hires in public schools, from 305,000 in 1987-88 to 760,000 in 2015-16.

"There has been something of an unheralded victory here. There has been a huge increase in the numbers of minority teachers, suggesting that minority teacher recruitment initiatives have worked," Ingersoll says.

A third trend is teacher turnover. School leaders are challenged to find ways to keep teachers in the classroom. One in 10 teachers quits after a year, and between 40 and 50 percent of new teachers leave teaching within five years. The problem is especially acute in low-income rural and urban schools, which tend to receive fewer resources than schools in the suburbs.

"We conclude teacher recruitment initiatives are worthwhile and it seems to have worked, but we need to work on improving teacher retention," he says. And the data certainly provide some answers in how to improve the retention of teachers, minority teachers in particular. Most simply put, it is a matter of improving the job conditions in schools.

"I study these problems, but as a former schoolteacher, I also care about these issues," he says. "I am hoping our research can illuminate the problems and also help."

All Politics is No Longer Local
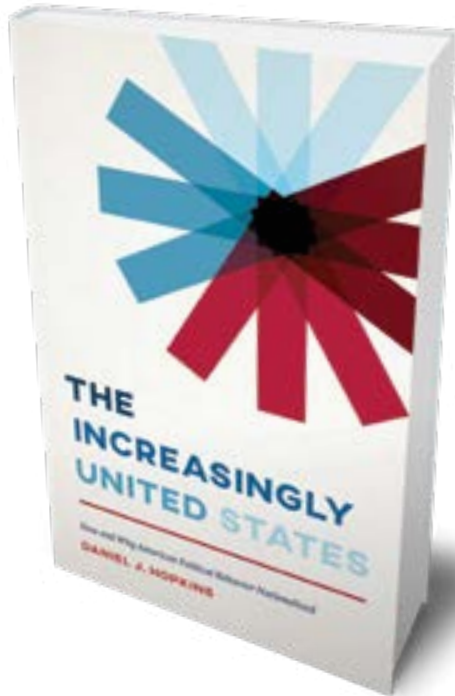
As a graduate student in 2002, studying local politics and passionate about its impact on day-to-day life, Daniel Hopkins, a professor of political science in the School of Arts and Sciences, was struck by the volume of national political study that was emerging.

From that, he began asking questions about nationalization, or the idea that Americans have begun paying more attention to—and become more engaged with—national-level politics over local.

"I wanted to make sense of that," he says.

After enough research, he knew he had a book. He began working on it in 2012 and wrote it in five years; the result, "The Increasingly United States," was published by the University of Chicago Press.

As he pored through reams of survey and search data, evidence suggested that his hypothesis was correct—that Americans truly have pivoted to a national focus. Voter turnout in city mayoral elections, for example, has declined both in absolute terms and relative to turnout for national elections.

"You often hear that presidential turnout isn't what it once was, but if you dig into the numbers, the drop in turnout in states and localities has been much more pronounced," Hopkins explains.

This is, he says, true at levels as granular as the number of online searches for governors versus president.

"Everywhere I have looked, there's clear evidence that Americans' knowledge about politics is increasingly knowledge about federal politics, in Washington, D.C.," Hopkins says. "As citizens, we are learning less and less about what's happening in states and localities."

The culprit, he suggests, isn't so easy to pinpoint. Some of it may boil down to how nationalized the economy has become—that citizens, whether in Wisconsin or California, may be seeking out a Chipotle or Walmart rather than local brands. But he further cites the changing media environment as a significant cause: Paradoxically, he says, the internet has centralized news media—an atmosphere in which *The New York Times* and Fox News have a tremendous share of web traffic and match a trend of making money on broad populations.

"As media markets have nationalized, if you want to build a dominant media brand, you don't want to be constrained geographically," he says. "You want to go after sports fans, liberals, and conservatives across the country and maybe even internationally."

The book shows the consequences of these shifts and how they affect citizen engagement. Hopkins anticipates that future study will examine how politicians behave differently with fewer local watchdogs.

A Tipping Point for Social Change

How many people need to take a stand before a social norm, such as workplace sexual harassment, is no longer considered "normal" and social change can occur? Just 25 percent of the population, according to research published in the journal *Science* from Damon Centola and colleagues in the Annenberg School for Communication.

Decades of social science research have hypothesized that such a tipping point exists, that small pockets of a larger group can force big change, but historically they've been challenging to prove or identify. That's partially because in real life, for any given event, there's no rewind button to go back and test whether a larger activist group would've made a difference in swaying public opinion.

"What we were able to do in this study was to develop a theoretical model that would predict the size of the critical mass needed to shift group norms," says Centola, who directs Annenberg's Network Dynamics Group. The researchers then tested the model experimentally.

Recruiting several hundred participants online, Centola and collaborators created 10 independent communities of people who were then given a financial incentive to interact and agree on a common naming convention for a picture of a face they were shown. Each group quickly came to a consensus, establishing a dominant social norm. A small number of "activists" then joined each community—for half, they made up 17 to 22 percent of the population, and for the other half, they were 25 percent or more—with the objective of altering the established behavior.

A clear dividing line emerged: None of the five groups below the 25 percent threshold moved the needle in changing the norm. All five above it succeeded.

"When a community is close to a tipping point to cause large-scale social change, there's no way they would know it," Centola says. "Just below a tipping point, their efforts will fail. But remarkably, just by adding one more person and getting above the 25 percent tipping point, their efforts can have rapid success in changing the entire population's opinion."

These findings have important implications for changes in workplace culture, civility in online discussions, and accepted behavior in neighborhood communities. Although changing people's underlying beliefs can be challenging, Centola's results offer direct evidence that a committed minority, sometimes of even just a few people, can affect change.

The People of the Middle East: A History
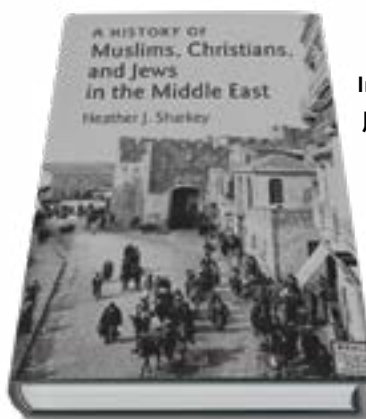
In her book "A History of Muslims, Christians, and Jews in the Middle East," Heather Sharkey, a professor in the Department of Near Eastern Languages and Civilizations in the School of Arts and Sciences, explores the fascinating and complex history of the region's diverse people.

Sharkey examines societies in the Ottoman Empire before World War I, when there were more substantial Christian and Jewish communities in most of the Middle East than today. For example, the Jewish population in Egypt peaked in the 1920s and '30s at more than 85,000, compared to only a few Jews who live in the country today.

Writing the book required a process of "un-learning" what she thought she knew about how religion worked as a mode of belief and as a shaper of laws and government policies in the Islamic Middle East, Sharkey says.

Central to the book is the study of how, over many centuries, successive Muslim rulers, including the sultans of the Ottoman Empire, treated Christians and Jews as *dhimmis,* meaning protected but subordinate people, who could live peaceably in Islamic societies.

"Many of my students assume, perhaps because of the continuing nature of the Arab-Israeli and Israeli-Palestinian conflicts, that Muslim-Jewish animosity has been a constant feature of Middle Eastern societies, and that current problems reflect those tensions from the past," Sharkey says. "That also requires some un-learning. For while there were social hierarchies and inequalities, relations between Muslims, Jews, and Christians were calm in most places and times."

The book traces how Islamic policies toward non-Muslims as subordinates shifted over time and affected relations between Muslims and other communities. Sharkey explains that as the Ottoman Empire began to lose territories, the influence of the European Enlightenment and greater contact with Western European societies prompted Christian and Jewish populations in Islamic countries to call for social parity.

"They started to say, 'We don't want to be subordinates. We want equality,'" Sharkey says. "Some began to subscribe to ideas of citizenship that emerged from the French Revolution and to agitate for what we would today call fuller civil rights."

In the 20th century, the new Middle Eastern countries that emerged from former Ottoman lands became less religiously diverse than ever before as a result of wars, migrations, and displacements.

Sharkey's book arose from a seminar she teaches on the history of Muslim, Christian, and Jewish relations in the modern Middle East. She originally created a syllabus based on close readings of excerpts from articles because there were no books surveying what she wanted to teach. An editor from Cambridge University Press saw her class listed on Penn's website and commissioned the book.

The 'Crisis' of an Aging Homeless Population

Homelessness in the United States may get worse before it gets better.

Through research conducted in partnership between Penn, the University of California, Los Angeles, New York University, and Boston University, Professor of Social Policy Dennis Culhane in the School of Social Policy & Practice and other researchers uncovered that the elderly homeless population in the U.S. will nearly triple by 2030.

"We had identified several years ago that the population that has been experiencing homelessness since the mid-1980s—when [homelessness] emerged as a significantly new problem—has been dominated by people from a particular birth cohort: 1955 to '65," Culhane explains. "It's unusual that a social problem would uniquely affect a particular group, and we've been tracking that for some time."

This demographic, Culhane says, struggled to enter the labor market as it came of age into a recessed economy in the early 1980s, and many responded by entering the underground economy during the crack epidemic. Pile on the era of mass incarceration, he says, and it was a recipe for a heightened rate of homelessness.

The study, "The Emerging Crisis of Aged Homelessness," examined Boston, New York City, and Los Angeles County homeless populations, and projected that the national population of homeless people 65 or older would increase from 40,000 today to 106,000 by 2030. The estimated cost of their care, including shelter, nursing homes, and hospitalization, is $5 billion annually.

To draw up possible solutions, the team gathered data about current homeless populations and their use of health and shelter services. They applied their demographic projections and came up with a synthetic cost of housing placement for people who are elderly and homeless, and then accounted for how much those housing placements would cost versus the ballooning costs of services if people were left homeless. The result: New York City and Los Angeles had positive returns on investment of $1.13 for every dollar they spent. Boston, meanwhile, had a negative return of 90 cents for every dollar they spent.

"But that's because we didn't have the Medicare claims," Culhane says of the Boston result. "Had we had Medicare claims, we think we would have broken even."

Culhane says the main takeaway from their research is that aged homelessness is an "urgent crisis."

"I think the import of the study is that we need to mobilize our community resources to get these housing investments in place; these people are very expensive users of services, consuming a lot of societal costs. We could be spending it a lot smarter, while avoiding the trauma of homelessness. And we could possibly even save money if we mobilize resources efficiently."

Policy progress, he says, will primarily need to happen on a state level.

'Cyberwar': Hacking, Trolls, and the 2016 Election
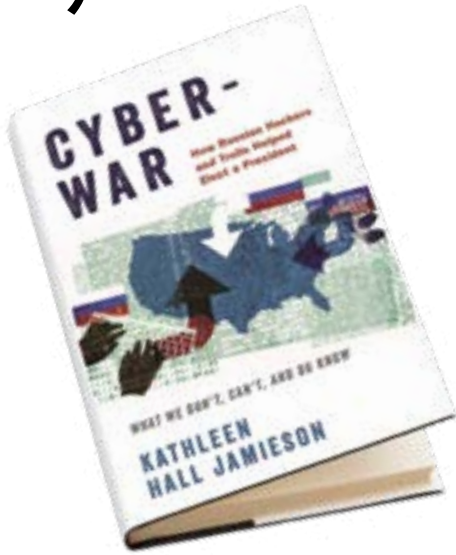
Did Russian hackers and trolls help elect Donald Trump? It's a big question, and one that Director of the Annenberg Public Policy Center and Professor of Communication Kathleen Hall Jamieson was surprised no one seemed to be attempting to answer.

In the midst of working on a book about changing discourse norms, while on sabbatical, she received a call in late October 2017 from a *Washington Post* editor who asked her to write an op-ed—on the back of Congressional hearings with tech executives—about whether Russian trolls helped elect President Trump. Jamieson wrote the op-ed, but the question continued to nag her, and so in the middle of the night, 10 days later, she took to her computer to draft out scenarios in which Russians—whether through trolls or hacking—made the difference in the election.

Soon after, she realized her op-ed had actually outlined what would eventually be published by Oxford University Press as "Cyberwar: How Russian Hackers and Trolls Helped Elect a President."

"I realized nobody was studying the electoral effects of the Russian intervention," Jamieson explains. "So, I kicked over my sabbatical project and wrote 'Cyberwar.'"

The book, which won the American Association of Publishers' R.R. Hawkins Award, builds on five decades of political communication scholarship to make the case that the Russian interventions, in all probability, did influence the result of the 2016 election. The core of the argument: Media coverage of the hacked content changed the media agenda in ways that reduced Democratic nominee Hillary Clinton's popular vote support enough to decide the election by 78,000 votes in three battleground states.

While social media posts and ads from Russian trolls may not have been enough on their own to sway the election, she concludes, the WikiLeaks hacks were. That's largely, she says, because of several happenings, including the news media's hastiness in reporting hacked content without labeling it as coming from the Russians via WikiLeaks, and questions about the hacks that were used to grill Clinton during two high-viewership debates. In addition, the hacks may have influenced then-FBI Director James Comey's decision to make public the reopened investigation into Clinton in the final weeks of the campaign.

In the moment, she says, it was easy to take for granted how significant it all was.

"You start to assume the disclosed private content hack [from the Democratic National Committee and Clinton campaign chair John Podesta] was inevitably going to be there," Jamieson says. "But it was only there because of the Russians, aided by Julian Assange and the press."

A new 2020 edition of her book, with a chapter called "#DemocracyRIP," analyzes what Russian trolls intended to accomplish with their interventions and adds other updates.

She's hopeful the book will lead media to prepare for 2020 by asking what lessons they learned from their largely uncritical coverage of the hacked content in 2016.

Holistic Approach to Criminal Defense Could Be a Game-Changer

Paul Heaton, academic director of the Quattrone Center for the Fair Administration of Justice at University of Pennsylvania Carey Law School, alongside co-authors from the RAND Corporation, found that a holistic approach to indigent defense not only reduces prison sentences, but also taxpayer cost.

"There's a growing movement within the public defender community to try and think holistically," says Heaton, who co-led the 11-year study. "That means helping clients to address not only their criminal matter, but also the underlying problems that lead them to come into contact with the criminal justice system to begin with. It's become a buzzword, but it seems intuitive that a holistic model might be helpful."

Now, there's evidence to bolster those hunches. In research published in the *Harvard Law Review*, Heaton's team looked at more than 500,000 cases in the Bronx involving low-income criminal defendants with court-appointed lawyers. Some defendants had more traditional public defenders, while others were provided holistic representation that included other professionals like social workers, housing advocates, or civil attorneys. Clients were quasi-randomly assigned to attorneys, making it possible to cleanly measure the effects of holistic defense as compared to traditional representation. The holistic approach reduced clients' likelihood of a prison sentence by 16 percent and average sentence length by 24 percent, translating to 1.1 million fewer jail days over the study's 11-year period and $165 million in reduced incarceration costs. Although serving much less time than their counterparts, people with a holistic defense were no more likely to commit additional crimes after returning to the community.

The study came about, Heaton says, when a Bronx public defender requested help after reading a prior study of his comparing public defenders with private appointed counsel. At the time, some public defenders in the Bronx already worked holistically, but lacked numbers to back up effectiveness. The biggest challenge in setting up the study, Heaton says, was getting New York City criminal justice agencies to collectively agree to share data.

The actionable response to the study has been swift, he says.

"Austin, Texas, the largest U.S. city without a public defender, is working to set up a new office and they've used the research to design their public defender with holistic principles in mind," he says. "Here in Philadelphia and in other places like Virginia and New York, the research has prompted public defenders to begin thinking about how to get social services experts and professionals with multidisciplinary skillsets involved with clients and cases. So, I think it's been well received, to have evidence and use that to advocate for changes to make public defense better."

Next, Heaton plans to study how holistic defense influences outcomes beyond the criminal justice system like health, housing, and earnings.

The Discriminatory Origins of Democracy

Democracy, a concept founded on deliberation and citizen participation, has never been for all people. Michael Hanchard, a professor of Africana studies in the School of Arts and Sciences, says unequal democracies started with Ancient Greece, where access to citizenship was denied to women, slaves, and foreigners.

"Idealizations of the Greek polis as the cradle of democracy obscure how central slaves were to the practice of freedom, and how the omission of several categories of people from citizenship and the polis required exclusionary regimes," he says.

In his book, "The Spectre of Race: How Discrimination Haunts Western Democracy," Hanchard, a scholar of comparative politics who specializes in racial hierarchy, citizenship, social movements, and nationalism, examines the ways in which democratic institutions have promoted undemocratic ideas, such as slavery, discrimination, and other exclusionary practices.

He says modern democracies, including the United States, the United Kingdom, and France, profited from slave labor, empire, and colonialism. He offers historical context on how democracy has generated political differences and inequality, tracing patterns from Ancient Greece, through the 19th and 20th centuries, up to present times.

Hanchard highlights the idea of "difference" as a form of political distinction in democracies, how the roots of social inequality are often tied to the economic sphere, and how political inequality is the result of deliberate decisions to exclude specific groups from participation.

"Gendered disparities are perhaps the most obvious," he writes, suggesting that there are no reasonable explanations

Righting Constitutional Wrongs in Federal Indian Law

"why women across the ages and spaces have been subordinated in economic, social, and material relations."

Additionally, Hanchard explains in the book how political scientists like former U.S. President Woodrow Wilson believed that a requirement for a successful model of democracy was that the society must be homogenous, and established "racial regimes" to maintain the political and economic privilege of dominant groups at the expense of subordinate ones.

"Racial and the ethno-national hierarchy provided the rationalization for the institutionalization of political inequality based on the premise that racially and ethno-nationally divergent groups could not share the same state," Hanchard says.

In America, this hierarchy has encompassed many marginalized groups throughout history.

Jewish people, African Americans, Native Americans, Latinos, and Italian Americans "have direct historical experience with both rhetorical and formal barriers to participation in the U.S. polity and full citizenship," Hanchard says.

After reviewing the field of comparative politics from its genesis to new approaches following World War II through today, Hanchard's core argument is that the contemporary version of comparative politics as a field in political science has largely ignored colonialism, racism, and imperialism.

When Maggie Blackhawk, an assistant professor of law, began her first year teaching at University of Pennsylvania Carey Law School, it included an introductory class on constitutional law. In doing so, far removed from her own time as a constitutional law student, she noticed something remarkable during preparation: Constitutional law almost entirely excluded Native peoples, Native nations, and American colonialism.

It was, she says, surprising and "pretty inaccurate."

In her paper, "Federal Indian Law as Paradigm within Public Law," published in the *Harvard Law Review*, Blackhawk recognizes an incomplete binary paradigm of black/white that shifted constitutional law after Reconstruction, Jim Crow segregation, and, specifically, the Brown v. Board of Education, Dred Scott v. Sandford, and Plessy v. Ferguson Supreme Court cases. Blackhawk suggests the binary paradigm is a narrow framework to understand oppression of minorities and could be more inclusive—one that considers the nation's history with colonialism and dominance of Native populations and resources.

"[That binary] may have led to a shallow understanding of certain areas of American constitutional law, as well as some misunderstandings, to where we've really not begun to understand certain areas of our constitutional law," Blackhawk says. "We've left out not only our own history, but a huge body of law and the realities of ongoing American colonialism."

Her analysis notes that, unlike decisions like Dred Scott and Plessy, cases like United States v. Rogers, which established the plenary power doctrine and fueled the construction of detention centers on Native reservations, are still recognized as good law. And that has consequences: In 2018, the doctrine that Rogers created—the plenary power doctrine—was invoked to uphold the so-called Muslim travel ban. This legal argument was also used to make the case for Japanese internment during World War II. Two of the 10 internment camps were actually established on Native reservations.

Further, "the last three administrations have pointed to the Indian Wars as precedent for the executive action in the War on Terror," she adds.

"In many ways, because we haven't confronted this history and law, it's still hurting us. We're still relying on these problematic doctrines to strip power from Native nations and to subordinate other people today."

Blackhawk says her paper has led to fruitful discussions since it was published.

"I think that, for constitutional scholars and historians, there's a lot of agreement that we need to start to look beyond slavery and Jim Crow as the only constitutional wrongs in the history of this country," she says. "And to look into the wrongdoing that was the history of American colonialism, to better understand the state of United States constitutional law at present."

Declassified Spy Images Reveal Hidden Archaeology
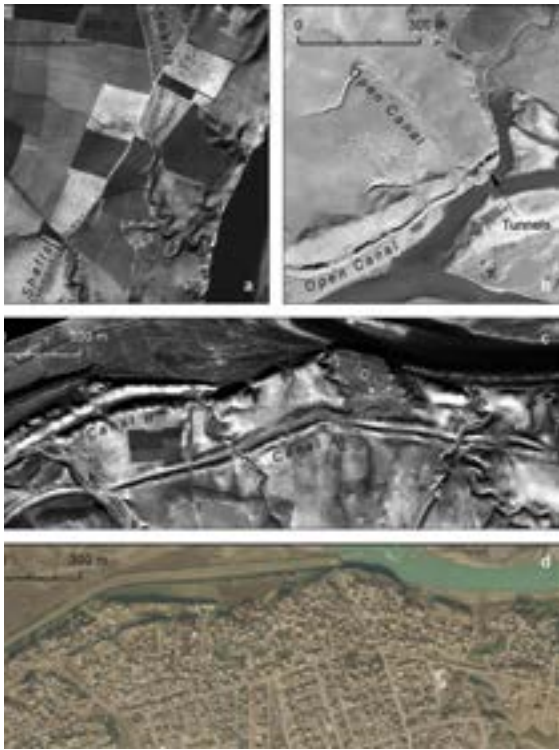
Ancient sites in Northern Iraq: (a) A subterranean canal above Nimrud, January 1960; (b) Assyrian canals, tunnels, and sites at Negub, October 1959; (c) Canals and site at Upper Zab River, January 1960; (d) Digital Globe showing modern town of Khabat, June 2016.

In the 1950s and early '60s, the United States flew U2 spy planes across Cold War hotspots, including the Middle East, taking images of military facilities and other strategic sites that they wished to monitor. In many cases the camera kept recording between the intended targets, capturing thousands of additional photos, including of archaeological sites.

For decades, all film and documents from these missions remained classified. They became public in 1997, but even then, weren't indexed or scanned.

Until recently, most historical aerial documentation came from the U.S.-run CORONA spy satellite program. But only the highest-resolution CORONA images, taken between 1967 and 1972, were sharp enough to show details of ancient sites.

Knowing the potential of the U2 image set, Penn landscape archaeologist Emily Hammer and a Harvard colleague began sifting through the film in the National Archives and Records Administration (NARA). Analyzing thousands of frames, they discovered prehistoric hunting traps, 3,000-year-old irrigation canals, and 60-year-old hidden marsh villages. The work, published in the journal *Advances in Archaeological Practice,* represents the first archaeological use of U2 spy plane imagery and a new window into history.

"The photos provide a fascinating look at the Middle East several decades ago, showing, for example, historical Aleppo long before the massive destruction from the ongoing civil war," says Hammer, an assistant professor in the Department of Near Eastern Languages and Civilizations in the School of Arts and Sciences.

Hammer has conducted research in the Middle East for years and has used CORONA spy satellite imagery extensively. However, many of those images didn't date back as far as she wished.

"We knew that U2 spy planes must have taken thousands of images across large parts of the Middle East, but there was no easy way to access or reproduce the film negatives," Hammer says.

Through a complicated process in the NARA Aerial Film Section that involved unspooling hundreds of feet over light tables, photographing negatives in pieces, and then merging the frames back together before geo-referencing them to warp them into real-world space, the work revealed many important archaeological features.

In eastern Jordan, the researchers found prehistoric hunting traps called desert kites, many of which had been destroyed or dismantled from agricultural expansion. In northern Iraq, the discovery of a canal system provided insight into the Neo-Assyrian Empire, and in southern Iraq, the U2 images revealed recent Marsh Arab communities, which disappeared after hydroelectric dams impounded the rivers and former President Saddam Hussein's government deliberately drained the marshes.

It's a photographic trip back in time for Hammer.

"The activities of ancient human communities frequently left large-scale traces on the landscape," she says. "You can't see these patterns when you're standing on top of them, but just like stepping back from the blobs of paint on an Impressionist painting reveals the full picture, aerial and satellite imagery allow the patterns to emerge."

The Dangers of the 'Model Minority' Stereotype
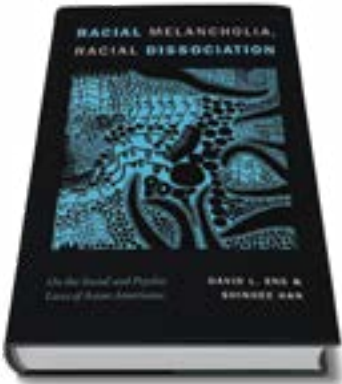
Asian Americans are often upheld as "model minorities"—hardworking, successful, and focused. They are included in diversity statistics, but usually ineligible for affirmative action programs.

In their book "Racial Melancholia, Racial Dissociation: On the Social and Psychic Lives of Asian Americans," David L. Eng, the Richard L. Fisher Professor of English in the School of Arts and Sciences, and psychotherapist Shinhee Han explore how this stereotype leads many to dismiss the struggles of young Asian Americans, a practice that is not only unfair but also potentially catastrophic.

Research has shown that Asian Americans are underserved by social services and are the poorest immigrant population in New York City. Asian-American college students are 1.6 times more likely to make a serious attempt to end their own lives.

"People don't think of Asian Americans as having any problems," says Eng. "About 25 percent of undergraduates at Penn are Asian American. That's a quarter of the school population that is not understood."

Eng and Han met when both were working at Columbia University in the late 1990s, drawn together by shared grief after a string of Asian-American students took their own lives and an aspiring Asian-American lawyer was killed by a former boyfriend.

For their book, the authors drew on 20 years of working with young Asian Americans—students for Eng and patients for Han—to compile their case studies and compose the accompanying analyses examining how changing patterns of immigration, assimilation, and racialization have affected their students and patients over two generations.

Students in Generation X (born between 1960 and 1980) are usually second-generation Americans who suffer from "racial melancholia," feelings of grief and loss that come from both racial mistreatment and the dislocations of immigration and assimilation that are passed down unconsciously from one generation to the next, Eng and Han found. Students in Generation Y (born between 1980 and 2000) include first-generation "parachute kids" whose parents send them to the U.S. and other Western countries for schooling, often on their own. They are more likely to grapple with "racial dissociation," not realizing that unacknowledged stresses related to race in our legally "colorblind" era of multiculturalism and globalization are the cause for the anxiety, panic, and psychic distress they endure, the authors concluded.

"Our vocabulary for discussing race is quite impoverished, and we remain locked into racial binaries of black and white," Eng notes. "The question of how Asian Americans fit into the U.S. racial landscape, socially and psychically, demands urgent attention."

Background in Foreground
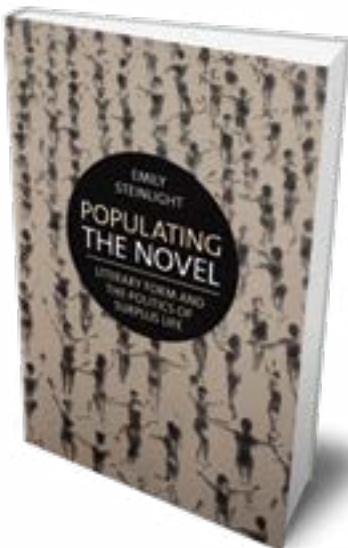
In "Populating the Novel: Literary Form and the Politics of Surplus Life," published by Cornell University Press, Assistant Professor of English Emily Steinlight argues the crowds that fill the pages of Victorian novels—those of Dickens, Gaskell, and beyond—aren't the backdrop of the stories, but the foreground. Drawing from analysis of primary sources and dialogue with literary scholarship, Steinlight hypothesizes that Victorian fiction found a way to organize collective life, despite its apparent focus on individuals and their stories, pushing narrative attention to the making and management of biological life in the aggregate just as Great Britain began documenting its populations.

How to Tell if a Company is a Good Employer for Women

What makes a company a good employer for women?

It's a simple question to ask, yet surprisingly difficult to answer.

A growing number of CEOs, investors, employees, and consumers are seeking the answer.

Wharton Social Impact Initiative Vice Dean Katherine Klein, doctoral candidate Shoshana Schwartz, and Wharton Social Impact Senior Director Sandi M. Hunt tackle the question head on in their report, "Four for Women: A Framework for Evaluating Companies' Impact on the Women They Employ."

Distilling the findings of hundreds of studies, Klein and her colleagues document the barriers and biases that too many women continue to experience at work. Good employers for women, they show, knock down these barriers and biases to create companies that really work for women.

Importantly, companies that are good employers for women are good employers for men, too. It isn't a zero-sum game.

The outcomes that make a company a good employer for women, as well as for men, are representation, pay, health, and satisfaction.

1) Representation. And not just in the board room and the C suite, but across all levels and units of the company. Too often women are represented only in "women's roles" and at the lowest levels of the company, limiting their power, influence, opportunities, and contributions.

2) Pay. Instead of equal pay for equal work, consider a more revealing statistic: a company's average compensation for men versus the same for women. A company with few women in executive positions will be more likely to have a larger gender pay gap.

3) Health. A good employer offers paid maternity leave. It's also aware that health is affected by workplace stressors, including sexual harassment, excessive demands, and erratic hours, and takes steps to ensure those issues don't arise.

4) Satisfaction. Measuring job satisfaction reveals a lot about an employer. Satisfaction is an undervalued metric. "It's a much more valid and instructive metric than many people recognize," Klein says.

"If a company does well on these four things, it has a very positive impact on the lives of the women who work there," Klein notes. "U.S. companies don't report these metrics publicly, but they have them and they should report them. Data sharing will drive improvements in the practices that matter most for women and for men, too."

Does Diversity Training Really Work?
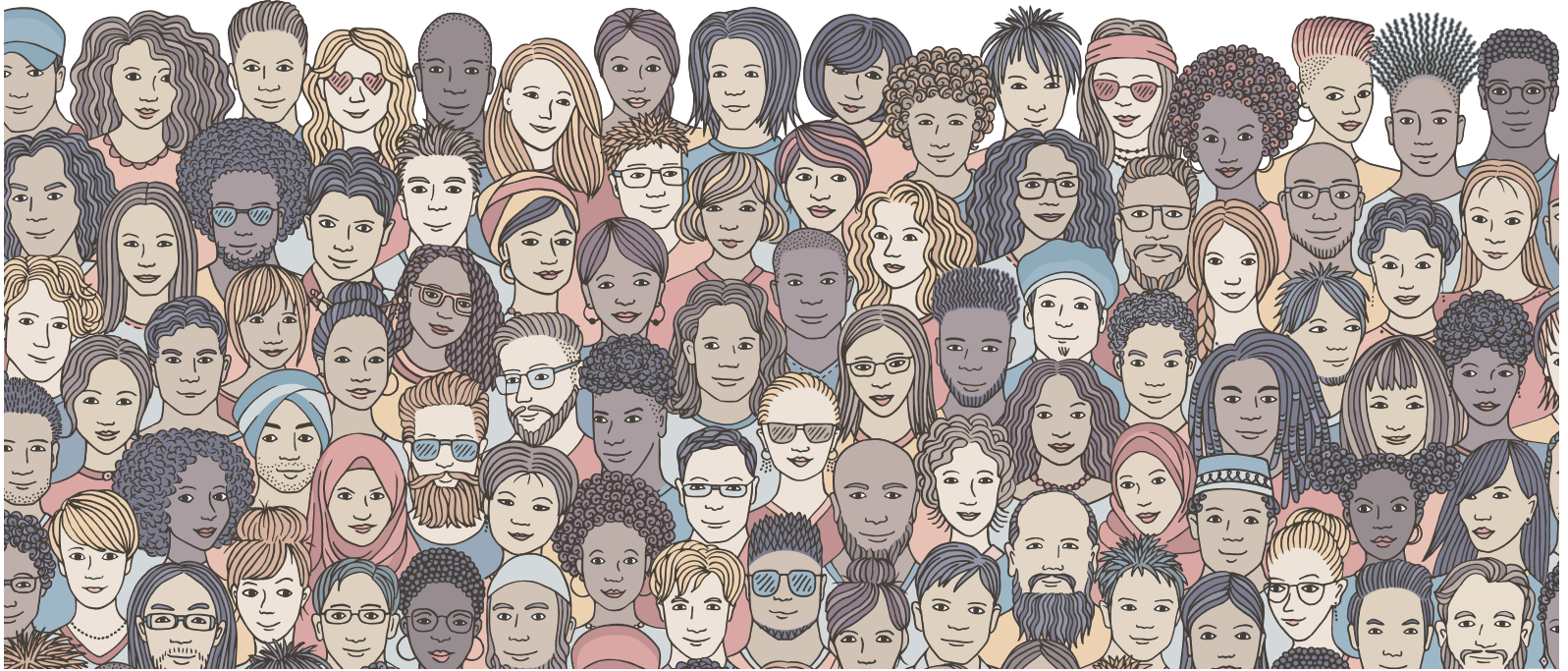
In 2018, two African-American men were arrested for allegedly trespassing in a Philadelphia Starbucks after taking seats and asking to use the bathroom without making a purchase. Starbucks responded to the angry outcry that followed by closing more than 8,000 U.S. stores for one day so its 175,000 employees could receive racial bias training.

The incident made new work on diversity training by a group of Penn-based researchers, published in the *Proceedings of the National Academy of Sciences,* all-the-more pressing. The group included Edward H. Chang, a doctoral candidate at Wharton, Wharton professors Katherine L. Milkman, Adam Grant, and Cade Massey, and Psychology Professor Angela Duckworth in the School of Arts and Sciences.

While diversity trainings are becoming common in workplaces, field experiments measuring them are not. The researchers partnered with a global organization to study how its employees' attitudes and behaviors changed after completing a state-of-the-art, hour-long, voluntary, online diversity training. More than 3,000 salaried employees were divided randomly into a treatment group and a placebo control group.

The program for the treatment group was developed using best practices to help participants identify and reduce their biases and stereotypes while also offering strategies for being more inclusive.

The control group received training on a topic unrelated to bias, stereotyping, or diversity. This allowed the researchers to isolate the causes of any post-training attitudinal and behavior changes.

While many participants reported more positive attitudes toward women and racial minorities after the training, those feelings generally did not result in more inclusive workplace behavior.

"We were disappointed to see how ineffective the training was," says Milkman. "While attitudinal change is great and we know that behavioral change starts with attitudinal change, we hoped for more."

Another takeaway: One of the post-training methods of measuring behavior change was tallying increases in participants' willingness to mentor women. Researchers uncovered that instead of promoting more mentoring in a top-down fashion, the training led women to "lean in" and seek more mentoring from their senior colleagues.

The research suggests that one hour of diversity training is not enough to substantively change behavior. "We need more structural change. Closing Starbucks stores for a few hours is unlikely to make much of a difference," Milkman says. "Training seems to be more of a PR solution than an evidence-based solution."

Why Monarchies Produce Better Standards of Living

In the 110 years between 1900 and 2010, monarchies had a better record than republics in protecting property rights of businesses and individuals, according to Mauro Guillén, the Zandman Professor of International Management at the Wharton School and a professor of sociology in the School of Arts and Sciences.

Guillén looked at data on 137 countries that included republics of different types and dictatorships. Published in *Social Forces*, his paper, titled "Symbolic Unity, Dynastic Continuity, and Countervailing Power: Monarchies, Republics, and the Economy," found that the long-term effects of monarchies are good for a country's economy and standard of living.

Guillén says the form of government has an immediate, direct effect on the protection of property rights. When companies and individuals feel that their property rights will not be abused or violated by the government, they are more willing to invest in the economy, create more jobs, and generate other economic boosters.

Social or political conflict in a country, politicians serving for unlimited terms, and a lack of checks and balances on the executive branch can lead to the undermining of property rights and have negative economic consequences.

Guillén says some of the chief benefits in countries with constitutional monarchies such as the United Kingdom, Sweden, and Denmark, are the crown's ability to compel politicians not to stay in power for too long and help a country navigate periods of uncertainty.

He says the U.K.'s Queen Elizabeth II has effectively exercised her constitutional role in keeping the country's prime ministers in check, and provided stability during the Brexit crisis.

Monarchies also tend to be hereditary and dynastic, which Guillén says gives them a long-term focus.

"If you focus on the long run, you are bound to be more protective of property rights," he says. "You're more likely to put term limits on politicians that want to abuse [their powers]."

Guillén says monarchies bring "a psychological mechanism" as well. If a prime minister knows there is a higher authority, even a pure figurehead like a king or queen, he or she will be a little bit more subdued.

"If there's nobody else higher or above you, then psychologically you are more prone to abuse your position," he says.

Guillén says he is aware that his finding that monarchies do a better job of protecting property rights is "very counterintuitive" because many people believe that kings and queens are arbitrary and absolute rulers. He is not advocating that every country in the world adopt a monarchy on the basis of his results, but says countries with high-performing constitutional democratic monarchies have no reason to get rid of them.

"There's no point in those countries in which the monarchy works well to organize a movement to get it abolished, because it does produce higher standards of living," he says.

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