VOLUME 38 | NUMBER 2 | FALL 2018

Research | Penn State

RE-IMAGINING ENERGY

Plenty of Energy

One of the pleasures of university life is witnessing the burst of energy every fall as students, faculty, and staff arrive ready to face the challenges of a new year. This year has been no exception, and this issue of *Research/Penn State* captures some of that spirit, highlighting a range of projects that go to the heart of our land-grant mission: using our resources and expertise to tackle complex problems for the benefit of society.

Forrest Briscoe and Barbara Gray, management experts, explore emerging issues of privacy and security related to the collection and use of our personal genomic information, a topic that is relevant to every one of us.

Historian Christina Snyder has written a book that reinterprets Jacksonian America through a fascinating lens, throwing fresh light on our beginnings as a multicultural, multiracial society, and offering important insights for the present day.

A Q&A format offers a chance to meet Paul Shrivastava, Penn State's first chief sustainability officer, and learn about his vision to integrate an ethos of responsible stewardship into all areas of university life.

Last but not least, a special section devoted to research in sustainable energy provides a glimpse at our vast expertise in this critical area. A dozen pages can hardly scratch the surface, but we hope this sampling conveys some idea of the important role Penn State is already playing in the world's energy future, and there is much more yet to come.

Neil A. Sharkey
Vice President for Research

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ON THE COVER:
View from the intake end of a wind tunnel during the 2018 U.S. Department of Energy Collegiate Wind Competition in May, where Penn State's student Wind Energy Club won second place. In the photo, a judge from the National Renewable Energy Laboratory inspects the Penn State team's turbine. A reflective honeycomb structure and colored lights inside the tunnel create the dramatic effect. (Photo by Werner Slocum / DOE/ NREL).

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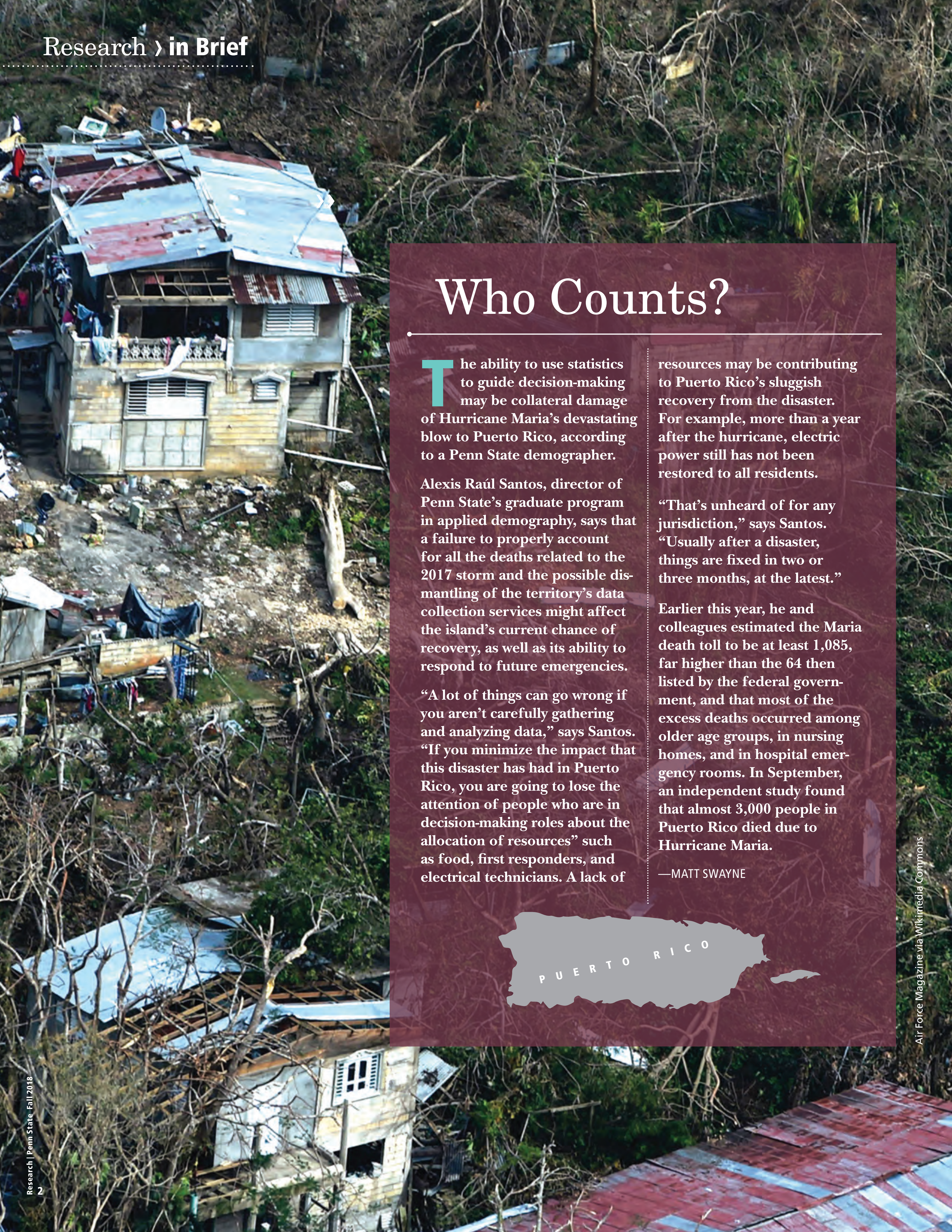
Patrick Mansell



Air Force Magazine via Wikimedia Commons

Who Counts?

The ability to use statistics to guide decision-making may be collateral damage of Hurricane Maria's devastating blow to Puerto Rico, according to a Penn State demographer.

Alexis Raúl Santos, director of Penn State's graduate program in applied demography, says that a failure to properly account for all the deaths related to the 2017 storm and the possible dismantling of the territory's data collection services might affect the island's current chance of recovery, as well as its ability to respond to future emergencies.

"A lot of things can go wrong if you aren't carefully gathering and analyzing data," says Santos. "If you minimize the impact that this disaster has had in Puerto Rico, you are going to lose the attention of people who are in decision-making roles about the allocation of resources" such as food, first responders, and electrical technicians. A lack of resources may be contributing to Puerto Rico's sluggish recovery from the disaster. For example, more than a year after the hurricane, electric power still has not been restored to all residents.

"That's unheard of for any jurisdiction," says Santos. "Usually after a disaster, things are fixed in two or three months, at the latest."

Earlier this year, he and colleagues estimated the Maria death toll to be at least 1,085, far higher than the 64 then listed by the federal government, and that most of the excess deaths occurred among older age groups, in nursing homes, and in hospital emergency rooms. In September, an independent study found that almost 3,000 people in Puerto Rico died due to Hurricane Maria.

—MATT SWAYNE

Family doctors often can't tell when kids' bad moods indicate more serious problems.

- ANNA SCANDINARO
Penn State College of Medicine

Fungus-infected "zombie" ants face no discrimination or hostility from nestmates.

- EMILIA SOLA GRACIA and DAVID HUGHES
Biology and Entomology
&
- EPHRAIM HANKS
Statistics

A new "slippery rough surface" (left) harvests more water from the air than other surfaces designed for that purpose (middle and right).

Xianming Dai/Nan Sun/Jing Wang/Tak-Sing Wong/Penn State

Rough and Ready

A surface inspired by pitcher plants and rice leaves excels at harvesting water from the air, according to researchers at Penn State and the University of Texas at Dallas.

"With an estimated 4 billion people living in a situation of water scarcity during at least part of the year, an inexpensive method for harvesting water from water vapor or from fog droplets in air could help alleviate the water scarcity issues in many regions of the world," says the project's leader, Tak-Sing Wong, the Wormley Family Early Career Professor in Engineering at Penn State.

Many water-harvesting technologies are not efficient. When water is attracted to a hydrophilic surface, it tends to form a sheet and cling to the surface, making it hard to harvest. Simon Dai, a post-doc in Wong's lab, combined features seen in natural systems to create slippery rough surfaces (SRS) that remedy that problem.

Dai made a pitcher plant-inspired slippery surface that would attract water, then added micro-scale grooves, like those found on rice leaves, that increased the area of the surface. The rate of water and fog harvesting is directly proportional to the amount of surface area on which droplets can form. The grooves whisk the water droplets away through capillary action or gravity.

Wong's team is working on optimizing and scaling up the SRS. Their goal is to create a highly efficient system that could collect more than 120 liters of fresh water per square meter of harvesting surface per day.

—WALT MILLS

BABY BRAIN GAIN ‹‹

Babies often amaze their parents when they seemingly learn new skills overnight—how to walk, for example. But their brains were probably prepping for those tasks long before their first steps occurred, according to researchers.

A team led by Koraly Perez-Edgar, professor of psychology at Penn State, is using new statistical analysis methods to compare what can be observed as infants develop new skills with unseen changes in electrical activity in the brain, or electroencephalography (EEG) power. They have found that while most babies appear to learn new skills in irregular bursts, their EEG power grows steadily behind the scenes.

Jelleke Vanooteghem on Unsplash

Perez-Edgar says the study supports long-standing but untested beliefs about how infants develop.

"This is a question that has bedeviled psychologists for most of the last century. Our data help show how behaviors that we can observe in children are indeed non-linear, showing up in spurts," Perez-Edgar says. "However, the underlying forces that help support this observed behavior can be linear. For a long time there was a debate over whether both of these things could hold true."

"Infant behavior varies so much from baby to baby, so it's helpful to understand what's going on beneath the surface," says graduate student Leigha MacNeill. "This multi-method approach gives us a better sense of where this variability comes from and can help us see what's happening in the brain when the infant isn't getting better at a task versus when there's rapid development."

—KATIE BOHN

POLENET

PUSHING BACK ‹‹

The bedrock beneath West Antarctica is rising rapidly in response to the ongoing melting of the West Antarctic Ice Sheet (WAIS), according to an international team of researchers. This rapid uplift may help stabilize the ice sheet against catastrophic collapse due to ice loss.

The weight of glaciers and ice sheets depresses the land beneath them, explains Andrew Nyblade, professor of geosciences at Penn State. As the ice melts, the Earth's surface rebounds with the reduced load. "As the Earth pushes back up from underneath, the bottom of the ice rises so it's harder for seawater to get underneath, slowing the melting process."

Bedrock's response to ice mass loss was thought to occur on a time scale of 10,000 years, but the researchers found that the ground under the rapidly melting Amundsen Sea Embayment in West Antarctica is rising at the rapid rate of 1.6 inches per year. The rate of uplift is controlled by the viscosity of Earth's mantle.

Using GPS measurements from POLENET, a National Science Foundation-funded network of GPS and seismic stations, the team estimated the viscosity of the mantle and found it much lower than the global average, explaining the rapid uplift. Seismic images support this estimate.

Although the rapid uplift could potentially slow the melting of the WAIS, scientists are cautious about making definitive predictions.

"The question is, how fast is the climate going to change, because if it continues to rapidly warm, the uplift might not happen fast enough to slow down the collapse of the ice sheet," says Nyblade.

—PATRICIA CRAIG

Made to Order

Much as a frame provides structural support for a house and the chassis provides strength and shape for a car, a team of Penn State engineers believe they have a way to create the structural framework for growing living tissue using an off-the-shelf 3D printer.

"We are trying to make stem-cell-loaded hydrogels reinforced with fibers like the rebar in cement," says Justin L. Brown, associate professor of biomedical engineering. "If we can lend some structure to the gel, we can grow living cells in defined patterns and eventually the fibers will dissolve and go away."

The method they use is a combination of 3D printing and electrospinning, a method that uses an electric charge to spin nanometer threads from either a polymer melt or solution.

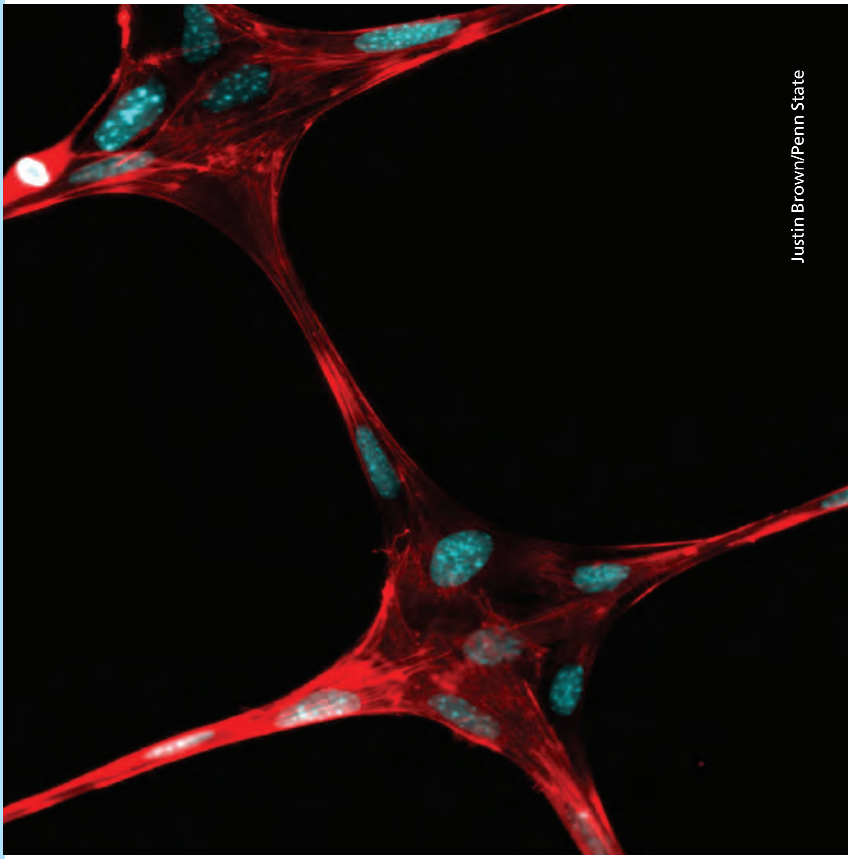
Currently, nearly all complex transplant tissues, from hearts and kidneys to tendons, come from living or dead donors. The researchers are looking for a way to grow replacement tissues reliably using inexpensive methods. The combination of 3D printing and electrospinning might also enable production of combined muscles and tendons, or tendons and cartilage, for example.

"If we could multiplex electrospinning with a collagen gel and bioprinting, we could build large and complex tissue interfaces, such as bone to cartilage," said Pouria Fattahi, doctoral student in bioengineering.

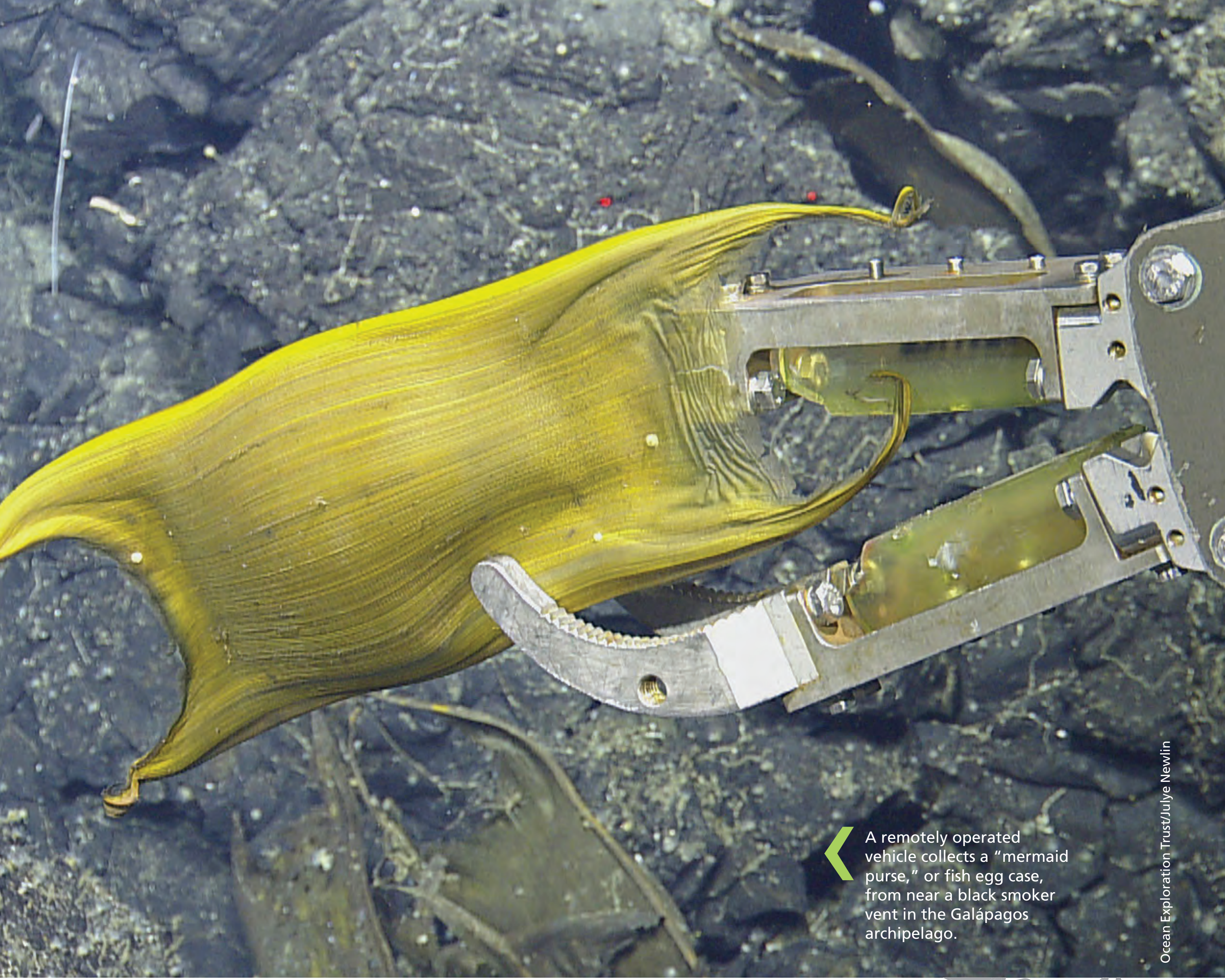
If two different tissues, such as muscle and tendon, are needed, the 3D printer can alter the pattern of threads in such a way that the transition could be seamless with the appropriate cells, resulting in a naturally formed, two-part tissue replacement.

—A'NDREA ELYSE MESSER

These stained cells (red cytoplasm, blue nuclei) are growing on 3D-printed fibers that guide them to form a pattern matching a specific tissue in the body.



Justin Brown/Penn State



A remotely operated vehicle collects a "mermaid purse," or fish egg case, from near a black smoker vent in the Galápagos archipelago.

Ocean Exploration Trust/Julye Newlin

» Nursery at Sea

The Pacific white skate, a cartilaginous fish related to rays and sharks, uses volcanic heat emitted at hydrothermal vents to incubate its eggs, according to an international team of scientists. This is the first time such behavior has been seen in marine animals.

Deep-sea hydrothermal fields are regions on the sea floor where boiling-hot water emerges after being heated by magma below Earth's crust. "Most animals that live there are highly evolved to live in this environment," says Charles Fisher, professor and Distinguished Senior Scholar of Biology at Penn State. "This study is one of the few that demonstrates a direct link between the vent environment and animals that live most of their life elsewhere."

The researchers used a remotely operated vehicle (ROV) to survey in and around a hydrothermal field in the Galápagos archipelago. They found 157 egg cases, almost all in water warmer than that in non-hydrothermal areas. "We realized that this was not the result of a single animal, but rather a behavior shared by many individuals," says Fisher. They collected four with the ROV's robotic arm. DNA analysis revealed that they belonged to *Bathyraja spinosissima*, one of the deepest-living species of skates. It was not previously known to occur near vents.

Because deep-sea skates have very long incubation times, estimated at over four years, the researchers believe they are using the hot vents to accelerate embryo development.

—GAIL MCCORMICK AND *NATURE RESEARCH*

» Put a Lid on It

How do you put a 13-ton hat on a giant statue? That's what a team of researchers is trying to figure out with their study of Easter Island statues and the red hats that sit atop some of them.

"Lots of people have come up with ideas, but we are the first to use archaeological evidence," says Sean W. Hixon, graduate student in anthropology, Penn State.

Rapa Nui—Easter Island—sits in the Southern Pacific Ocean more than 2,000 miles from the coast of Chile. The island was first inhabited in the 13th century by Polynesian travelers.

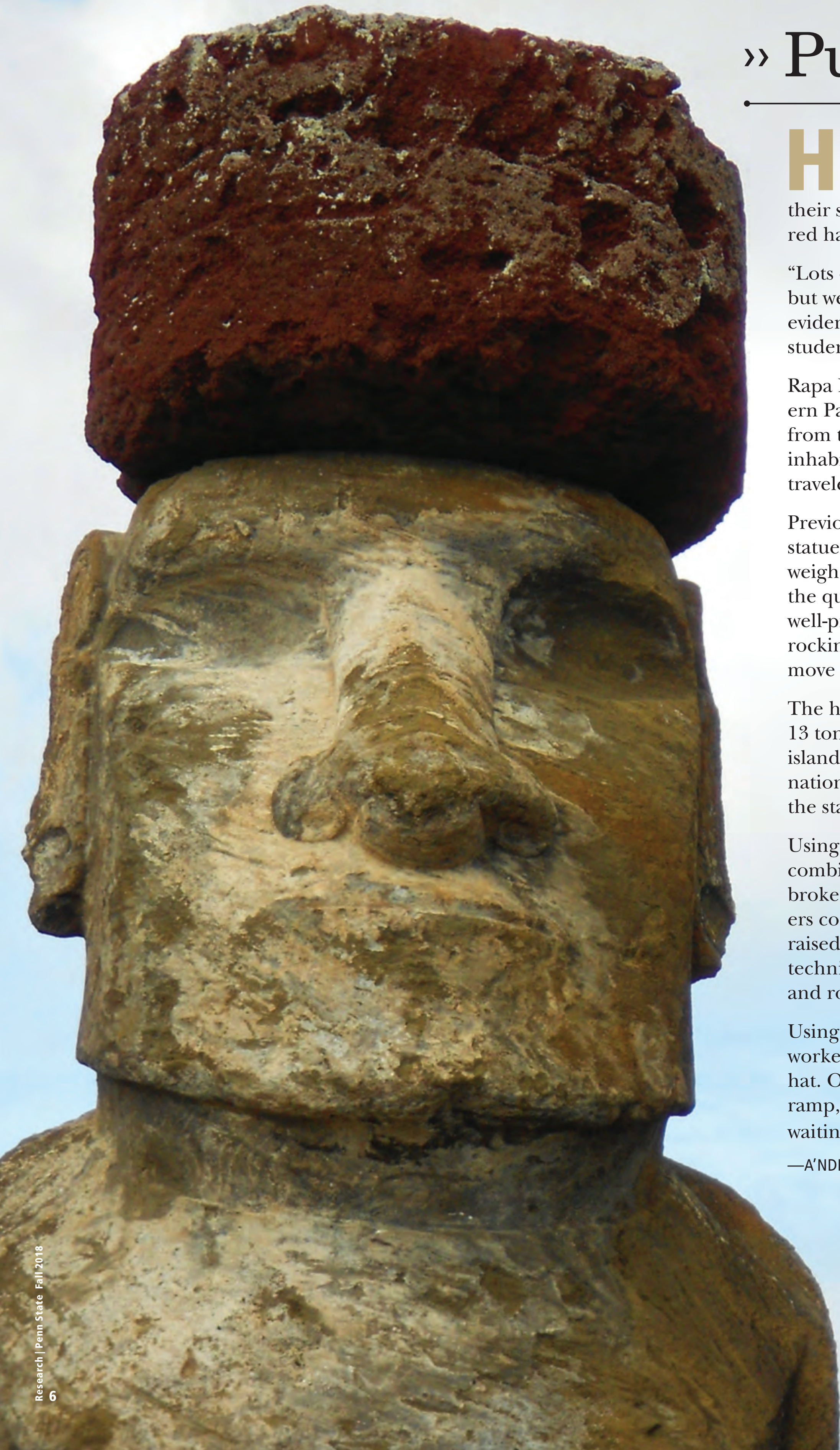
Previous research determined that the statues, which can be up to 33 feet tall and weigh 81 tons, were moved into place from the quarry where they were carved, along well-prepared roads, using a walking/rocking motion, similar to the way we move a refrigerator.

The hats, up to 6.5 feet across and weighing 13 tons, might have been rolled across the island, but once they arrived at their destination, they still needed to be lifted onto the statues' heads.

Using photogrammetry and 3D imaging, combined with careful study of remnants of broken or abandoned statues, the researchers concluded that the hats were most likely raised by parbuckling, a simple and efficient technique for rolling objects using a ramp and rope.

Using this technique, they say, 15 or fewer workers could raise the largest preformed hat. Once the hat was at the top of the ramp, it was tipped up onto the statue's waiting head.

—A'NDREA ELYSE MESSER



‹ The pukao, or hat, on this statue is made of red scoria from a quarry 7.5 miles from the statue.

Sean Hixon/Penn State

Due to climate change, Lancaster County corn yields and dairy farms could be in jeopardy by 2050.

- HEATHER KARSTEN
Crop and Soil Sciences

A cocoa pod killed by the fungus that causes black pod rot.

Cocoa CRISPR

Use of the powerful gene-editing tool CRISPR-Cas9 could help to breed cacao trees that exhibit desirable traits such as enhanced resistance to diseases, according to Penn State plant scientists.

The cacao tree, which grows in tropical regions, produces the cocoa beans that are the raw material of chocolate. Reliable productivity is essential to the multibillion-dollar chocolate industry. But each year, several plant diseases severely limit global production, with 20 to 30 percent of cocoa pods destroyed before harvest, notes Andrew Fister, postdoctoral scholar in plant science.

"Because diseases are a persistent problem for cacao, improving disease resistance has been a priority. But development of disease-resistant varieties has been slowed by the need for sources of genetic resistance and the long generation time of cacao trees."

The researchers recently demonstrated the feasibility of using cutting-edge CRISPR technology to improve *Theobroma cacao*.

"Compared to conventional breeding and other techniques, CRISPR speeds up the process and is much more precise," says Mark Guiltinan, leader of Penn State's endowed cocoa research program.

The program's ultimate goals are to help raise the standard of living for smallholder growers and stabilize a threatened global cocoa supply, according to co-director Siela Maximova.

"Any production increases in the last 20 years have been mostly due to putting more land into production," says Maximova. "But land, water, fertilizer, and other inputs are limited. To enhance sustainability, we need plants that are more vigorous and disease resistant and that produce more and better-quality beans."

—CHUCK GILL

DISEASES OF BEES ‹‹

An international team of researchers has discovered evidence of 27 previously unknown viruses in bees. The finding could help scientists design strategies to prevent the spread of viral pathogens among these important pollinators.

To investigate viruses in bees, the team collected samples of DNA and RNA, which is responsible for the synthesis of proteins, from 12 bee species in nine countries across the world. Next, they developed a novel high-throughput sequencing technique that efficiently detected both previously identified and 27 never-seen-before viruses belonging to at least six new families in a single experiment.

Among the new viruses the team identified is one that is similar to a virus that infects plants. "It is possible that bees may acquire viruses from plants, and could then spread these viruses to other plants, posing a risk to agricultural crops," says Christina Grozinger, director of the Center for Pollinator Research at Penn State.

Beyond identifying the new viruses, the team also found that some of the viruses exist in multiple bee species—such as in honey bees and in bumble bees—suggesting that these viruses may freely circulate within different bee populations.

"This finding highlights the importance of monitoring bee populations brought into the United States due to the potential for these species to transmit viruses to local pollinator populations," says David Galbraith, research scientist at Bristol Myers Squibb and a recent Penn State graduate. "We have identified several novel viruses that can now be used in screening processes to monitor bee health across the world."

—SARA LAJEUNESSE

Altered body odor reveals malaria infection even in absence of symptoms.

- CONSUELO DE MORAES and MARK C. MESCHER
Biology

Not a Simple Story

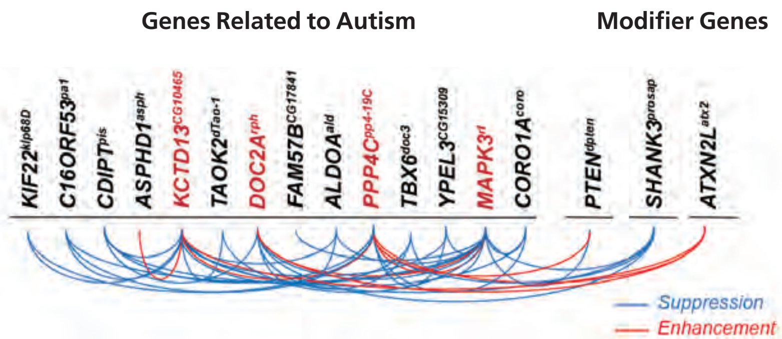
Genes in a large chromosomal region interact with each other to modulate the symptoms of autism, according to a study led by Penn State scientists. The research demonstrates the utility of the fruit fly as an experimental model for understanding the complex causation of human neurodevelopmental disorders.

The researchers focused on a large deletion on human chromosome 16 that has been associated with autism, epilepsy, intellectual disability, and obesity. The region includes 25 individual genes. Although some diseases are caused by loss or change of a single gene, that is rare, says Santhosh Girirajan, associate professor of biochemistry and molecular biology and of anthropology. "The deletion on chromosome 16 is associated with many different symptoms that are present to varying degrees, or sometimes not at all, depending on the individual. This led us to believe that there is not a single causative gene, but many that interact in complex ways."

To try to identify how the deletion on chromosome 16 causes variable symptoms, the researchers turned to the fruit fly, *Drosophila melanogaster*. They used a technique called RNA interference to reduce the expression of each of the 14 genes in the fly that are counterparts to genes in the chromosome 16 deletion, and then monitored neural development. They then tested some of the genes in combination with each other, with the other fly counterpart genes, and with 50 other genes. Some combinations made symptoms more severe, some made them less severe, and some had no effect.

"Understanding the interactions among many genes will help us identify appropriate targets for possible treatment of these neurodevelopmental disorders," says Girirajan.

—SAM SHOLTIS



Genes associated with autism interact in complex ways, either enhancing (red) or suppressing (blue) each other. (Girirajan Laboratory/ Penn State)

Older adults may misremember new information, rather than completely forget it.

- NANCY DENNIS and CHRISTINA WEBB
Psychology

Fetal exposure to male hormones changes girls' interests but not their gender identity.

- SHERI BERENBAUM
Psychology

Expecting a stressful day messes up your mind whether stressful events happen or not.

- JINSHIL HYUN
Human Development and Family Studies
&
- JOSHUA M. SMYTH
Biobehavioral Health and Medicine

ON TARGET ‹‹

A new approach to killing the gut microbe *Clostridium difficile* while sparing other bacteria may provide a new way to treat the most common hospital-acquired bacterial infection in the United States.

C. difficile is a normal part of the gut microbiome, along with "good" bacteria that keep it and other "bad" bacteria in check. But if a patient takes an antibiotic for an infection anywhere in the body, the antibiotic kills many types of bacteria, including the good ones in the gut. That allows *C. difficile* to thrive, resulting in severe gastrointestinal symptoms. Treating the *C. difficile* outbreak with a conventional antibiotic can make the problem worse, due to the drug killing good as well as bad bacteria in the gut.

metamorworks/ Getty Images

Scientists at Penn State and the University of Arizona created three new antibiotics that specifically target *C. difficile*. "These drugs can zero in on and kill *C. difficile* bacteria while leaving other bacteria alone," says Arun Sharma, associate professor of pharmacology, Penn State College of Medicine.

Their approach, called antisense therapy, works by binding to DNA and preventing the expression of critical genes that are specific to *C. difficile*. The team tested three forms of the new drug to see how much of it was required to kill *C. difficile* bacteria, whether it was toxic to human colon cells, and whether it harmed other bacteria normally found in the gut.

—KATIE BOHN

Steven Greybush

On this image of Mars, the black arrows show winds associated with traveling weather systems linked to the formation of dust storms. The equator runs across the center of the image and the planet's poles are at the top and bottom of the image. Layered shapes at top show areas of temperature anomalies.

›› Red Dust

Mars has been experiencing a dust storm that covers about 15.8 million square miles, roughly the size of North and South America combined. This storm may not be good news for NASA's solar-powered rover Opportunity, which is at the heart of the storm, but one Penn State professor sees it as a chance to learn more about Martian weather.

Steven Greybush, assistant professor of meteorology and atmospheric science, says that observations of such storms provide a wealth of data that allows researchers to more accurately model atmospheric conditions on the planet and could help with planning future NASA missions.

Greybush is working on a tool called Ensemble Mars Atmosphere Reanalysis System. The system combines data from orbiting spacecraft with computer simulations to create maps of winds, temperature, pressure, and dust at hourly intervals over six Martian years (about 11.4 Earth years). With that information, Greybush can follow the evolution of dust storms and track how they grow from local to planetary scale, compare the current storm to previous ones, and gain insights into the variability of Mars' weather patterns over time.

"A lot of storms begin in the northern hemisphere and then fizzle out, so why did *this* northern storm make it past the equator and become so large?" Greybush asks. "The last global storm was in 2007. Each storm is unique, and this provides a new example for case studies."

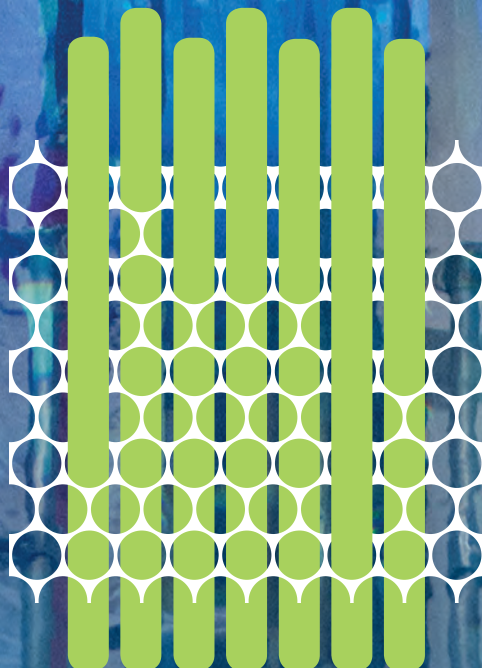
Because Mars shares similar characteristics with Earth, the method may also assist in the study of weather patterns here.

—MIRANDA BUCKHEIT

SHADES OF BLUE ‹‹

Gently spread by a researcher, the wing of an eastern bluebird offers clues to the bird's age and fitness. This bird was captured as part of a study at the Russell E. Larson Agricultural Research Center on how chronic noise from Marcellus Shale gas transport affects breeding behavior of songbirds. Ecologists Julian Avery and Margaret Brittingham, with graduate student Danielle Williams, play recordings of gas compressor noise near nest boxes, then track the behavior of individual birds. They have found that birds don't avoid nesting in noisy areas, but those who do nest there hatch fewer eggs and raise smaller broods.

Photo by Julian Avery
(instagram.com/evolutionavery/)



NUCLEAR OPTIONS

Breazeale Reactor puts atomic science to work for research

BY CHERIE WINNER

Behind a security gate in the southeast corner of the University Park campus sits the Breazeale Nuclear Reactor, one of Penn State's oldest and most renowned research facilities.

"This was one of the first licensed research reactors in the nation," says Kenan Ünlü, who has been director of the university's Radiation Science and Engineering Center since 2008.

The impetus to build a reactor here sprang from President Dwight Eisenhower's push to develop peacetime uses of nuclear technology. In a speech before the United Nations in 1953, Eisenhower proposed diverting much of the world's stockpile of fissionable material away from the production of weapons and toward more productive ends. Penn State's reactor went into service a year and a half later.

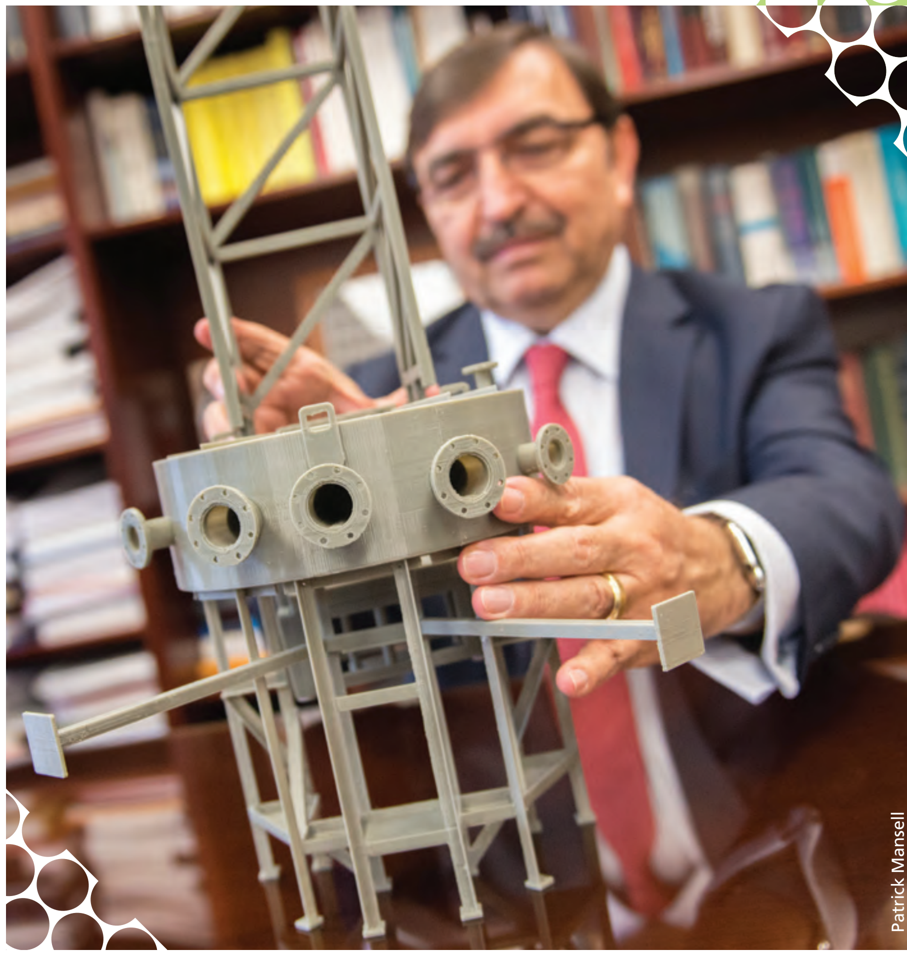
"For the first time, neutrons and gamma rays were available for civilian scientists," says Ünlü. "A vast expansion of fundamental research started at that time."

HOT CELLS AND COOL TOOLS

One of just a dozen active research reactors at U.S. universities, the Breazeale Reactor gives scientists the ability to conduct experiments using neutrons or gamma rays emitted from fission reactions. Neutron-based research begins in the main reaction pool, where 72,000 gallons of water cool the reactor core and act as a barrier to prevent radiation from escaping into the air. The fission reaction in the core is powered by fuel rods of uranium zirconium hydride and is moderated by neutron-absorbing rods of boron carbide. Human operators control the reaction from a console in a nearby room.

Patrick Mansell

RSEC director Kenan Ünlü displays a model of the new beam ports and moderator tank that were installed in the reactor pool (left) this year.



For some research, neutrons generated at the reactor core travel through pipes, called neutron beam ports, into an experimental bay. Irradiated samples can be moved to one of two heavily-shielded chambers called "hot cells" that allow researchers to use mechanical hands to safely handle highly radioactive samples. The manipulator hands are so deft they can pick a needle up off the floor, says Ünlü.

In a smaller pool in another building, cobalt-60 serves as the source of gamma rays. They have been used to generate mutations in seeds, which are then screened for useful properties, and to sterilize items that would not survive treatment by heat or chemicals: pollen and royal jelly for research on honey bee colony collapse, culture chambers used to study breast cancer cells, and materials that will be used in orthopedic implants.

FAR-RANGING RESEARCH

The facility serves both academic and commercial researchers. It produces isotopes for industrial use and medical research. Neutron imaging has been used to look for flaws inside enclosed metal components and to check the integrity of NASA space suits. Commercial clients use the reactor's neutron beam to test how susceptible memory chips and microprocessors are to "soft errors" that occur due to environmental radiation. These transient faults do no permanent damage to hardware, but can cause glitches in a device's operation; minimizing them is critical for production of dependable electronics.

A technique called neutron activation analysis (NAA) can detect trace elements in a sample without destroying the sample in the process. This is especially valuable to archaeologists and others working with irreplaceable specimens. Knowing the trace elements within a clay, wooden, or metal artifact can help pinpoint where the material originated, providing clues about trade routes in ancient times.

Trace elements can also tell us about the global impacts of local events. Doing NAA on dated wood samples from Cornell scientist Peter Kuniholm, Ünlü found that individual growth rings contain gold spewed out by volcanoes. Their analysis pinpointed the eruptions of the Indonesian volcanoes Tambora (1815) and Krakatoa (1883). That's amazing, Ünlü says, because the wood was from trees growing in Turkey—which means the gold from those eruptions had traveled through the atmosphere almost all the way around the world before ending up in the air and soil the trees were growing in.

The Breazeale Reactor has been upgraded several times during its 63-year history, and this year, with funding from the U.S. Department of Energy, it underwent a major renovation that increases the number of neutron beam ports and gives researchers the ability to do additional techniques for materials characterization.

Through its role in research and as an essential resource for more than 20 Penn State courses, such as radiation detection, reactor physics, and nuclear security, says Ünlü, the Breazeale Reactor continues to fulfill the vision Dwight Eisenhower presented in his "Atoms for Peace" speech at the U.N.

Ike came to campus to see the reactor in 1955—his brother Milton was president of the University at the time—and repeated the speech at commencement.

Nuclear power, Eisenhower said, "must be put into the hands of those who will know how to…adapt it to the arts of peace…If the fearful trend of atomic military build-up can be reversed, this greatest of destructive forces can be developed into a great boon, for the benefit of all mankind."

RE-IMAGINING ENERGY

In the push for sustainable power, Penn State's wide-ranging expertise is yielding solutions.

As the land-grant university for the energy-rich state of Pennsylvania, it isn't surprising that Penn State counts among its core strengths a broad and deep expertise in energy-related research.

Elements of that expertise have been present from the very beginning, as Penn State researchers contributed significantly to theoretical and practical advances in mining, fuel science, engine technology, and petroleum engineering. In recent years, the University's efforts have evolved to embrace both strategies for transitioning away from fossil fuels and the quest for clean, renewable energy. Today, in areas from materials science to policy, from environmental chemistry to architectural and electrical engineering, the range and quality of our expertise make Penn State not just a national but a world leader in energy research.

This section captures only a sliver of that expertise, briefly sampling some of the more innovative ideas of Penn State researchers working together to solve questions of how best to generate, store, incorporate, and distribute sustainable sources of energy and mitigate the effects of atmospheric carbon.

It's far from a comprehensive view. But we hope it's enough to glimpse the imagination required to face this global challenge, and the role Penn State can play in solving it.

Patrick Mansell

Looking toward the sun from the underside of an array of photovoltaic cells

GENERATING ENERGY

Fast-growing global demand, combined with rising environmental challenges, requires new and cleaner sources of energy. Penn State researchers are working on a broad range of innovative technologies to efficiently harvest the sustainable energy of natural processes and power our future. Here are a few outstanding examples.

WHERE the RIVERS MEET the SEA

At the places where fresh and saltwater meet, there are vast amounts of potential energy to be tapped—enough to supply up to 40 percent of global electricity needs.

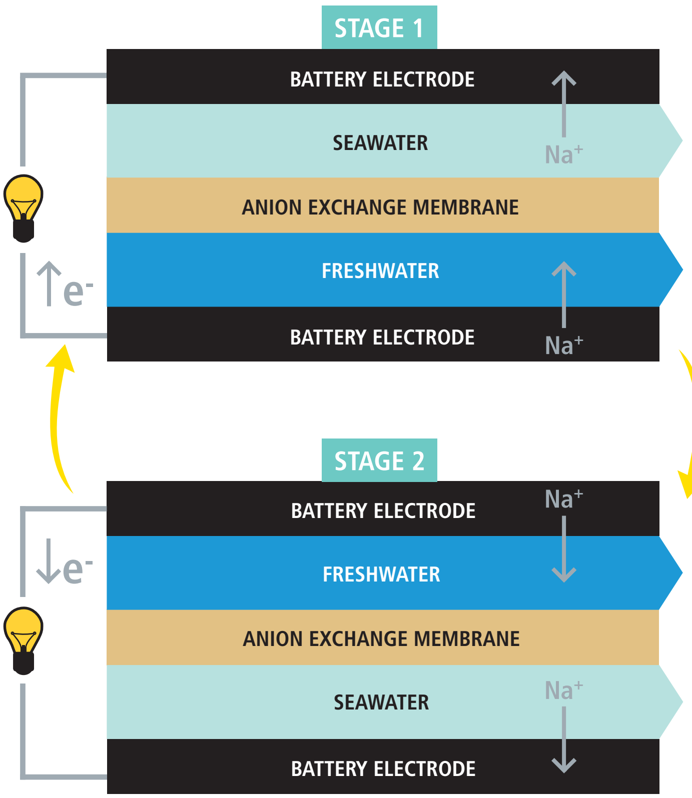
Mixing takes energy, Chris Gorski explains. "Normally, where a river meets the sea, that energy gets dissipated as heat. But there are ways to try to capture it."

For Gorski, an assistant professor of environmental engineering, the best way is through electrochemistry. With Penn State colleagues Bruce Logan and Taeyoung Kim, he has devised a flow cell that exploits differences in salt concentration to create an electric current. "It's really similar to the way a battery operates," Gorski says.

Already, they have demonstrated twice the power density achieved by previous technologies. Now, with an NSF Early Career award, Gorski will focus on maximizing that efficiency even further.

But will this idea ever get out of the lab? Practically speaking, "Solar and wind are getting so cheap that it's going to be tough to compete with them," Gorski admits. "But there are locations where you can't do solar or wind. These places might be good candidates for salinity gradient energy."

—DAVID PACCHIOLI



HOW IT WORKS

STAGE 1 Saltwater and freshwater are flowed through opposite sides of a cell, separated by an anion exchange membrane that only allows negatively charged ions to pass through it. Each side contains a battery electrode made of copper hexacyanoferrate, a metal-based material that can efficiently incorporate sodium into its crystal structure.

The difference in salinity creates an electrochemical voltage. In the freshwater channel, sodium present in the electrode is released into the water, causing an electron to pass through the circuit.

On the saltwater side, the electrode takes up sodium ions from the salty water, which is balanced by receiving the electron released by the other electrode. The flow of electrons from one side to the other creates an electrical current.

STAGE 2 When the system reaches a state of equilibrium—the saltwater electrode is saturated with sodium ions, and the freshwater electrode has given up all the sodium ions it can—the flow of water through the cell is switched, with the saltwater side now receiving freshwater and vice versa. The switching perpetuates the reaction, maintaining the current.

Giebink Lab

FOCUSED on a SOLUTION

A concentrating photovoltaic system with embedded microtracking can produce over 50 percent more energy per day than standard silicon solar cells, according to the engineers who recently field-tested a prototype unit.

In contrast to silicon solar panels, which currently dominate the market at 15 to 20 percent efficiency, concentrating photovoltaics (CPV) focus sunlight onto smaller but much more efficient solar cells like those used on satellites, says Chris Giebink, Charles K. Etner Assistant Professor of Electrical Engineering. Current CPV systems enable overall efficiencies of 35 to 40 percent. But these systems tend to run large—the size of billboards—and have to rotate to track the sun during the day.

"What we're trying to do is create a high-efficiency CPV system in the form factor of a traditional silicon solar panel," Giebink says.

To do this, his team embedded tiny multi-junction solar cells, roughly half a millimeter square, into a sheet of glass that slides between a pair of plastic lenslet arrays. The whole arrangement is about two centimeters thick and tracking is done by sliding the sheet of solar cells laterally between the lenslet array while the panel remains fixed on the roof. An entire day's worth of tracking requires only one centimeter of movement.

Over the course of a day's testing, Giebink reports, their prototype reached 30 percent efficiency, in contrast to 17 percent for a commercial silicon cell. The CPV system produced 54 percent more energy than the silicon.

Major challenges lie ahead in scaling the system and proving long-term reliability, but with the right engineering, Giebink says, it could be useful in applications ranging from rooftops to electric vehicles —really anywhere it's important to generate a lot of solar power from a limited area.

—A'NDREA ELYSE MESSER

A BIGGER HARVEST of ENERGY


Miao Meng

A prototype device that generates electricity from vibrations is about the size of a large wristwatch.

A wearable energy-harvesting device developed by researchers from Penn State and the University of Utah could generate energy from the swing of an arm while walking or jogging. The device, about the size of a wristwatch, produces enough power to run a personal health monitoring system.

"The devices we make using our optimized materials run somewhere between five and 50 times better than anything else that's been reported," says Susan Trolier-McKinstry, the Steward S. Flaschen Professor of Materials Science and Engineering and Electrical Engineering.

Energy-harvesting devices are in high demand to power the millions of devices that make up the internet of things. Many take advantage of the so-called piezoelectric effect, whereby certain crystals can produce an electric current when compressed or change shape when an electric charge is applied.

In this work, Trolier-McKinstry and her former doctoral student, Hong Goo Yeo, took a well-known piezoelectric material, PZT, and coated it on both sides of a flexible metal foil to a thickness four or five times greater than in previous devices.

Greater volume of the active material equates to generation of more power, Trolier-McKinstry explains. By orienting the film's crystal structure to optimize polarization, they were able to markedly increase energy-harvesting performance.

The researchers then designed a wristwatch-like device that incorporates the PZT/metal foil materials for maximum efficiency.

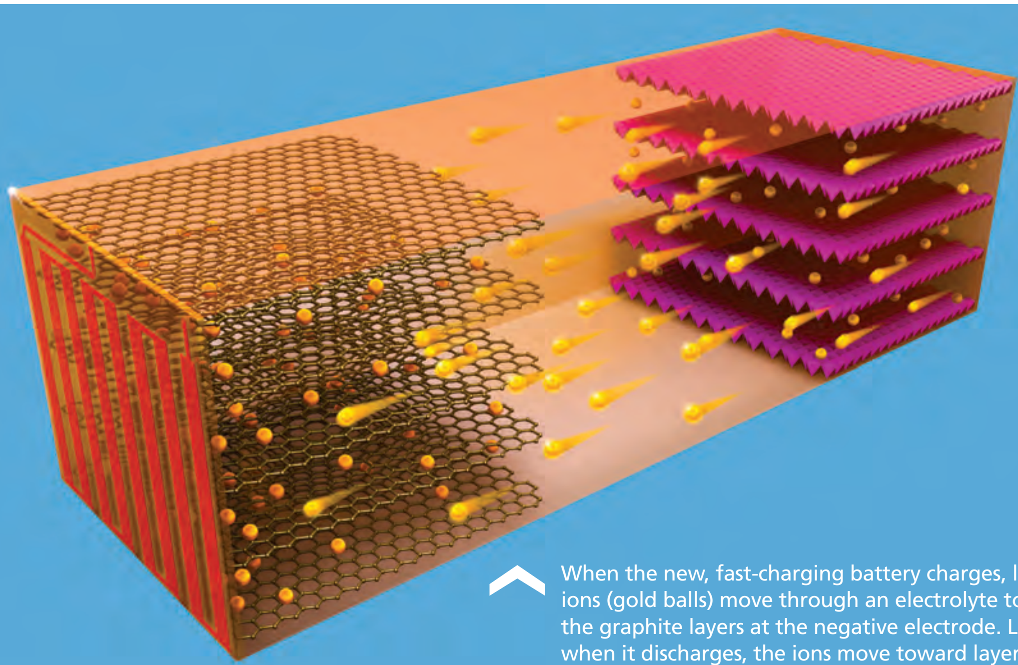
In future work, the team believes they can double the power output already achieved by using cold sintering, a low-temperature synthesis technology developed at Penn State. In addition, the researchers are working on adding a magnetic component to the current mechanical harvester to scavenge energy over a larger portion of the day when there is no physical activity.

—WALT MILLS

STORING ENERGY

"The beauty of batteries is you don't have to think about them," says Chris Rahn, a mechanical engineer whose research focuses on battery systems. Rahn drives an electric car to work and has solar panels on his home. "When I make my daily commute, I'm not burning any fossil fuels," he says. "It's amazing that you can have the sun shine on a panel on your house, charge the battery in your car with that solar energy, and then drive. It's revolutionary."

The past few years have brought a surge in battery technology. Here's a sampling of how Penn State researchers are changing the battery landscape.



When the new, fast-charging battery charges, lithium ions (gold balls) move through an electrolyte toward the graphite layers at the negative electrode. Later, when it discharges, the ions move toward layered oxides (pink) at the positive electrode.

Penn State

TIME to RECHARGE

Lithium-ion batteries came on the scene in the late 1990s and soon became ubiquitous. Used to power devices such as laptops and smartphones, rechargeable lithium-ion batteries are popular because they're lightweight, store a lot of energy, and can run for a long time.

Despite the advantages of lithium-ion batteries, they don't handle high temperatures well and occasionally burst into flames. "Safety is an issue whenever you have high-energy-density batteries," explains engineer Chao-Yang Wang. "When a lot of energy in a small volume is released all at once, that's a problem." Yang's lab works at the materials and cell level on the thermal management of batteries, designing less flammable materials.

They recently received a $1 million grant from the U.S. Department of Energy to work on fast charging of electric car batteries and have developed a technology that allows car batteries to be charged within ten minutes. "You can then drive 250 miles on that charge," he says. "Yes, that's a limited range, but you can charge up again in the few minutes it takes to get a cup of coffee and check your messages." Because it can be charged so quickly, it can be smaller than electric vehicle batteries currently in use—which makes it safer as well.

—KRISTA WEIDNER

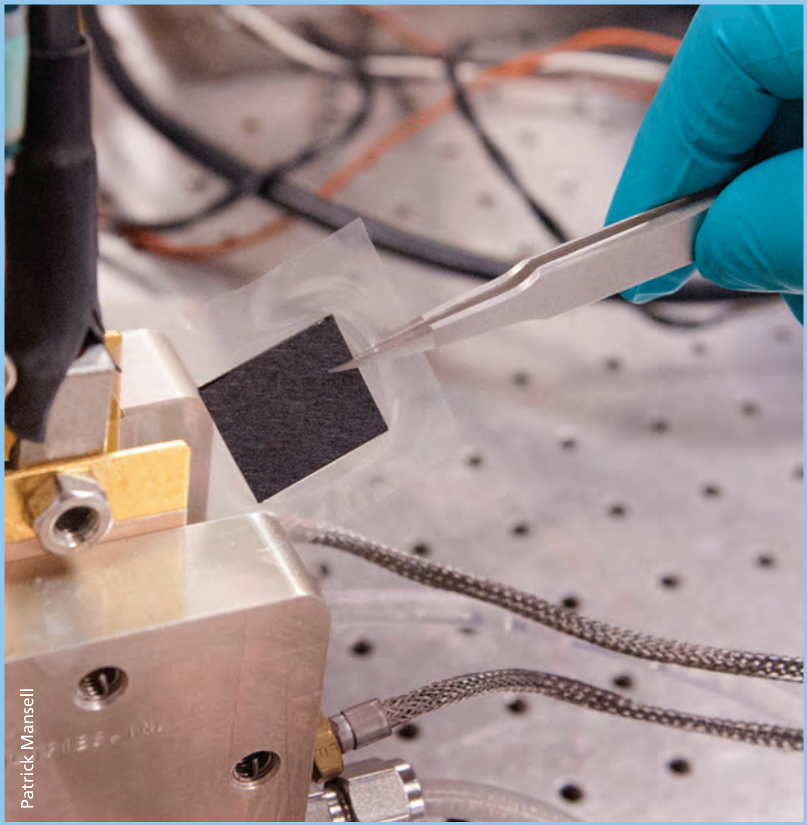
START ME UP

Wang and his colleagues have also developed a battery that won't freeze in cold climates, a feature that could make the use of electric vehicles more widespread. Like conventional car batteries, current electric vehicle batteries work poorly in extreme cold. They take hours to charge, and even when fully charged, they may not be able to start the car because the movement of ions within the battery slows down significantly.

The new all-climate car battery warms itself up, allowing it to charge fast or promptly start the car no matter the outside temperature. The remote key used to unlock the car doors "could also trigger the pre-heat switch," says Wang, "and by the time the person sits on the driver's seat, some seconds later, the battery has already warmed up and is ready to drive away"—even at ambient temperatures as low as minus 45 degrees Fahrenheit.

—KRISTA WEIDNER

Getty Images



Patrick Mansell

BETTER POLYMERS for BIGGER BATTERIES

Materials scientist Mike Hickner and his group work at a molecular level to make better large-scale batteries—those that power buildings, water treatment plants, and neighborhoods.

In these flow batteries, a polymer membrane separates the anode and the cathode to allow ions to flow back and forth during charging and discharging, while ensuring the active redox molecules are not lost. Hickner uses polymer chemistry to modify the membrane's transport properties, designing next-generation membranes in iterative testing with cell engineers. "We like to send samples out and have the battery engineers break them and help us improve our materials," says Hickner. "This back-and-forth is a real competitive advantage for my group."

Hickner and his group are also beginning to explore using 3D printing technology to create battery membranes. "3D printing allows us to make unusual shapes and make them quickly," he says. "In my lab, we have people who know about molecules, and we have students interested in 3D printing, so we can integrate ideas from different disciplines."

—KRISTA WEIDNER


Getty Images

INTO the FUTURE

Getty Images

"These latest advances are just the beginning of smart batteries," Rahn says. "On the horizon is a whole new world of batteries that can live a long time, operate at all temperatures, and charge quickly. When it comes to car batteries, this will eliminate what we call 'range anxiety'—fear that your car battery will run out before you can recharge. In fact, one day we might see drivers of gasoline-powered cars having range anxiety because gas stations will be disappearing."

Yang agrees that battery technology will change the future. "Before long, and it's already starting, we'll have battery-powered robots working diligently, cleaning the house, doing laundry, cooking for us, transporting people."

—KRISTA WEIDNER

The BEST CENTER: From MATERIALS to SYSTEMS

The multidisciplinary Battery Energy Storage Technology (BEST) Center brings together researchers from across the University who look at battery technology at all levels, from materials to power cells to systems, and collaborate on new approaches.

"The work we do at BEST leads to real-world impact," Rahn says. He and Chao-Yang Wang direct the BEST Center. "If you're a materials person and demonstrate something on a small scale, you always wonder, can we scale up? Can we make this into a commercial product? So, for example, after Chao-Yang builds a good cell, he turns it over to me and I assemble it into a system. We have the whole chain here to test out any idea."

"As a one-stop-shop, the BEST Center is unique. We're always talking to each other. We couldn't do these things by ourselves."

—KRISTA WEIDNER

This battery, developed by scientists at BEST and the Pacific Northwest National Laboratory, uses a solid, sodium-based material as the electrolyte. Batteries like this could replace the more combustible lithium ion batteries now used in consumer electronics.

Liam Jackson

CATCHING CARBON

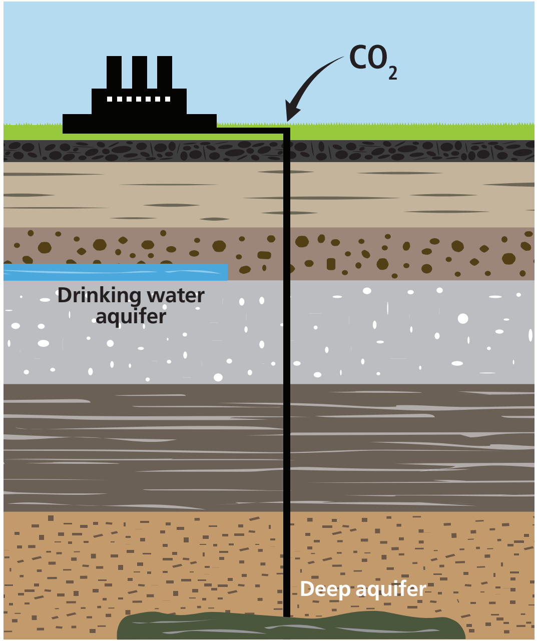
Fossil fuels make up 82 percent of the energy we use in the United States. When we burn these fuels, we send carbon that was buried in the subsurface hundreds of millions of years ago up into the atmosphere as carbon dioxide. Atmospheric CO_2 levels are rising and contributing to climate change. Simply put, we need to find ways to reduce the levels of this heat-trapping gas in the atmosphere. Penn State researchers are working on a variety of possibilities for capturing, storing, and using carbon dioxide. Here are a few examples of their work.

CAPTURE IT

One promising method builds on the natural process of degradation of organic material, which releases CO_2 and methane into the atmosphere. Called bioenergy with carbon capture and sequestration (BECCS), it harnesses the power of anaerobic digesters—microorganisms that break down organic waste—and "captures" the gases they produce. "This mix of concentrated CO_2 and methane is called biogas," explains agricultural and biological engineer Tom Richard, whose research group works on optimizing this process for larger-scale carbon capture. "We can separate the two gases, put the methane into the natural gas pipeline system—natural gas is about 90 percent methane—and inject the concentrated CO_2 deep underground rather than letting it escape to the atmosphere."

Although some facilities such as wastewater treatment plants and large dairy farms use commercial anaerobic digester systems, in the form of lagoons, tanks, or silos, they're expensive to maintain. Richard's goal is to make these systems more cost-effective using biomimicry, by adapting the simple yet efficient ruminant system of the cow.

—KRISTA WEIDNER



STORE IT

Inside the Earth there's ample storage space for liquified carbon dioxide. The trick is to find the places where it will stay put.

At high temperatures and under high pressure, carbon dioxide becomes a supercritical fluid that can be injected underground into sites such as rock formations, coal seams, and mile-deep aquifers with unusable, briny water. Environmental engineer Li Li and her group create models to learn how liquid CO_2 moves through, and interacts with, brine and various types of rock. "There's a lot of capacity in deep geological formations, but it's a complex system," says Li.

A primary goal is to evaluate the risks of injecting liquid CO_2 underground by comparing laboratory models with real-world constructs.

—KRISTA WEIDNER

USE IT

Chunshan Song doesn't see carbon dioxide as a waste product. To him, it's a raw manufacturing material. A worldwide expert on carbon use, The distinguished professor of fuel science sees potential for using CO_2 to create fuels and products.

"In our lab, we use a catalyst to make CO_2 react with other molecules such as hydrogen to break the bond of the CO_2 molecule and reorganize the carbon," he explains. Then, that carbon can be used to create sustainable fuels, chemicals, and materials that are traditionally produced from petroleum—things like plastic water bottles, carpet, and wrinkle-resistant fabrics.

To capture CO_2 for manufacturing, Song and his colleagues developed a novel technology that uses super-absorbent materials in a power plant's exhaust stream. A pilot research facility in North Carolina, supported by the Department of Energy, demonstrates how these materials capture and concentrate CO_2 efficiently.

—KRISTA WEIDNER

THE BUILT ENVIRONMENT

Almost 40 percent of the energy we use goes to heat, cool, light, and power appliances in the buildings we live and work in.

Penn State is taking aim at that figure by making its buildings more energy efficient through green design of new buildings, targeted retrofits of older ones, and designing and testing innovative power systems and appliances. These efforts have made the University a global leader in sustainable building practices. Here are a few examples.

Michelle Bixby

URBAN EXPERIMENTERS

In addition to making sure that new buildings on Penn State campuses merit LEED certification for energy efficiency, the University also owns two buildings at the Philadelphia Navy Yard that function both as practical workspaces and as "living laboratory" experiments in sustainability.

The former naval shipyard was decommissioned in the 1990s and has been resurrected as a commercial and industrial center. Covering almost 2 square miles—bigger than the central downtown area—and providing jobs for more than 13,000 employees, the Navy Yard has become an economic boon for Philadelphia.

Penn State is an important part of the mix, says sustainable energy program manager Lisa Shulock. "Penn State created and has helped nurture a group of professionals who are all connected here in what we call the Navy Yard energy ecosystem," she says. The University also has skin in the sustainability game: Its two buildings at the Navy yard provide real-life, real-time tests of energy systems.

The newly-built 7R building includes an electric microgrid designed to minimize use of fossil fuels while creating a pleasant indoor environment. *[Read more about 7R on page 25.]* Then there's building 661, a squat brick structure built in 1942 and used as a rec center for Naval officers. By the time the University bought it in the early 2000s, it was in very bad shape.

Penn State didn't just *renovate* 661; using commercially available products and techniques, it retrofitted the entire 36,000-square-foot structure to house offices, conference rooms, and meeting spaces while also testing the performance of three kinds of heating and cooling systems. There's a big educational component, as well: Penn State holds classes there, and the University offers internships to college students and workforce training to electricians and other professionals adapting to new energy technologies.

Shulock, assistant research professor Mark Stutman, and their colleagues are documenting the performance of the systems in 661. So far, even though its systems are still being optimized, 661 has been using about half as much energy as a conventional building of comparable size.

—CHERIE WINNER

GOING GLOBAL

In May, 2018, Penn State President Eric Barron signed a memorandum of understanding with the United Nations Economic Commission for Europe, making Penn State the lead institution in the Global Building Network, a U.N. initiative that encourages and supports the use of energy-efficient building practices worldwide.

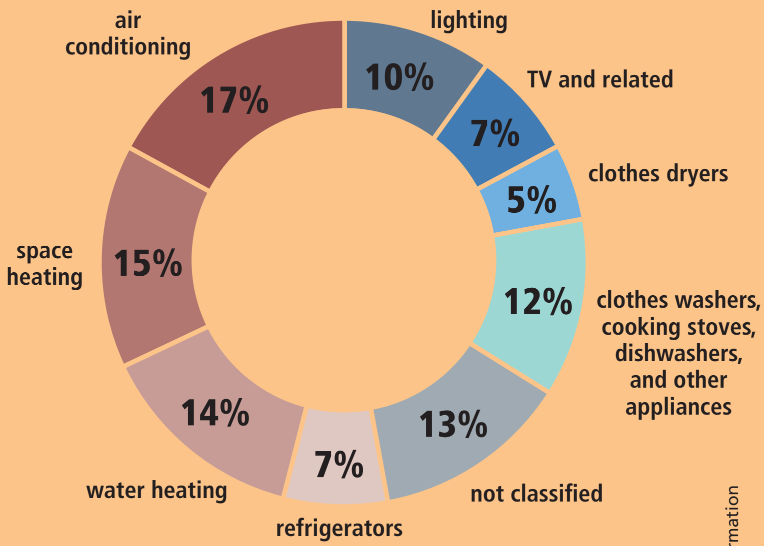
The selection of Penn State was due in large part to the quality of its Architectural Engineering program, one of the best of its kind in the U.S. Penn State is also a leader in erecting high-performing buildings at its campuses statewide.

"The two threads of the work that we do here—the energy-efficient buildings and especially retrofits of existing buildings, and the electric microgrid in building 7R—are strategies for being able to accommodate the next 30-some years of population growth around the globe," says Stutman. "If buildings continue to be built with 'business as usual,' the greenhouse gas impacts are going to be pretty devastating to future generations."

—CHERIE WINNER

The Millenium Science Complex (top), housing the Materials Research Institute and The Huck Institutes for the Life Sciences, and Lewis Katz Building, housing the Law School and School of International Affairs, are among the LEED-certified buildings at University Park. Photos by Patrick Mansell.

Residential electricity use, 2015



US Energy Information Administration

COOL RUNNING

Consider the energy costs of a modern home or office building: Refrigeration and air conditioning account for about one-quarter of the electricity used there. But conventional cooling technology, based on compression of refrigerant gases, has not changed much since the 1890s. In addition to hogging electricity, vapor compression is loud, bulky, and a major contributor to global warming.

Materials scientists have long dreamed of a more elegant solution—a solid-state cooling device that exploits the properties of thermoelectric materials. As Qiming Zhang explains it, these materials couple thermal and electrical properties so that the temperature of the material changes when electricity is applied. No greenhouse gases or bulky compressors are required.

Thermoelectric ceramics showed promise, but didn't cool enough. In 2003, Zhang, distinguished professor of electrical engineering, got the idea to try something different. He read up on the literature, and predicted he could make a polymer that would have a cooling effect ten times that seen with ceramics. In 2008, with funding from the Department of Energy, he succeeded.

The new material could offer a host of applications: silent-running refrigerators; quiet, energy-efficient air coolers small enough to install in rooms or even in clothing.

Now the main task is to scale up manufacturing and make it cost-effective to produce. Zhang thinks that is do-able, but it will take a sizeable investment.

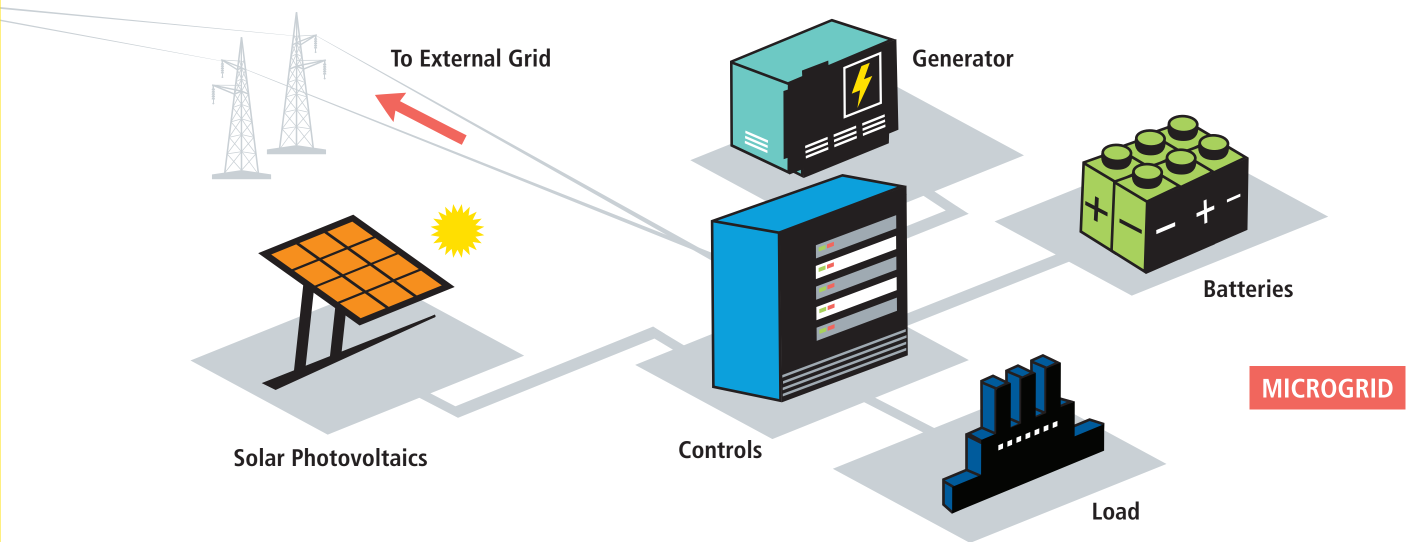
"What we need is a tabletop device to demonstrate that this can work," he says. "Once its market potential becomes clear, solid-state cooling could take off like liquid crystals did a few years ago. I believe this could be a truly transformative technology."

—DAVID PACCHIOLI

PULLING IT ALL TOGETHER

Shifting from fossil fuels to renewable energy sources requires more than the invention of better solar cells or batteries. Because photovoltaics and wind turbines depend on the time of day and the weather, we also need ways to combine different power sources and storage systems so we have steady, reliable service; and we need to integrate the new technologies with traditional power plants and electric grids.

Penn State scientists, policy experts, and physical plant managers are exploring how to navigate this transition so we can get the greatest value out of the green technologies that are becoming available.



DISTRIBUTED POWER and NEW CHALLENGES

The increasing popularity and affordability of alternative energy challenge our existing power systems in many ways. Where the traditional power grid has a central source of electricity—a large power plant—and a massive network of transmission lines carrying the electricity to customers, today, electrical supply is much more distributed, with many customers generating some or all of their own electricity with wind turbines or solar cells. At times, they still draw power from the grid, but at other times they send power back onto the grid or unplug from the grid completely.

That complexity doesn't fit well in the existing utility system, says Seth Blumsack, who studies the regulatory and market environments for new technologies.

"The business models and policies that support the traditional power grid are rapidly becoming outdated," he says. As more customers opt out, electric utilities lose income. They may struggle to keep their lines in good repair so they can continue to serve those who do not unplug.

Blumsack and his colleagues use models to simulate how grid systems might operate under different market conditions or policies. He emphasizes that regulations need to take into account that access to electricity is not just a market good; it has social value as well.

"As much as we want to encourage different technologies, when it comes down to it, there are certain things that we as a society are not going to tolerate," he says. "Electricity being broadly unaffordable is one of them. Massive blackouts are another. This is part of the challenge—how do you encourage that kind of sustainable transformation while at the same time maintaining accessible and affordable and highly reliable power? That's the big challenge."

—CHERIE WINNER

WELCOME to the MICROGRID

The ultimate in distributed energy is a microgrid, in which a small area like a community or a campus generates enough electricity on-site that it can survive without a connection to the external grid. It may still be connected to the grid, but it doesn't have to be—if the big grid suffers a massive blackout, in the microgrid area the lights will still be burning.

At the Philadelphia Navy Yard, Penn State is testing a building-scale microgrid that combines solar, gas, battery, and control technologies. Part of 7R, a new 20,000-square-foot classroom building that opened in 2016, the microgrid has a solar photovoltaic array backed up by a natural gas-fueled microturbine. "You can't count on solar being consistent all the time," says program manager Lisa Shulock. "It rains, it's cloudy, it's night—but if you have another resource locally, like this microturbine that can power up when the sun is going down, then you still see steady energy production."

The 7R microgrid was partially funded by the Pennsylvania Department of Environmental Protection as a demonstration project to show that a gas microturbine can actually increase the use of solar photovoltaic arrays. It does that because it's a CHP, or combined heat and power, system: The "waste" heat it generates is used to warm up water, which in turn can be used to heat or cool the building. Combining a gas-fueled microturbine with solar, says Shulock, "you can actually increase the amount of solar in the grid, because you have something to back it up when the solar goes away."


Michelle Bixby

When the solar cells generate more power than the building uses, the excess is stored in two banks of batteries, which provide power while the microturbine revs up. A lead-acid battery bank eases the transition from solar to gas during predictable, slower shifts, such as when the sun goes down. For times when solar array production drops more suddenly, such as when clouds roll in, the system draws on a bank of fast-responding lithium ion batteries.

The whole system is operated by a sophisticated micro-controller than can be programmed to optimize savings or power, minimize carbon-emitting fuels, supply power to the external grid when that would be profitable, or accommodate a range of other conditions and goals.

"When you combine all these technologies, you get the best of all worlds," says assistant research professor Mark Stutman.

—CHERIE WINNER

Building 7R (above and right) features passive solar design and a single-building microgrid that combines solar power, a gas microturbine, fast- and slow-responding batteries, and a sophisticated control system.

Michelle Bixby

Whose Genes Are They, Anyway?

BY CHERIE WINNER

YOU'VE SEEN THE ADS FROM COMPANIES THAT PROMISE TO TELL YOU, BASED ON YOUR DNA, WHERE YOUR ANCESTORS CAME FROM. YOU'RE EAGER TO TRACE YOUR FAMILY'S ROOTS, SO YOU ORDER A TEST KIT, SEND IN YOUR SAMPLE, AND AWAIT THE RESULTS.

Your involvement with the company may end there, but two Penn State researchers say that for your DNA sequence—your genome—the journey has just begun.

What you may not realize is that when you get your DNA sequenced, in most cases you don't own the sequence in a legal sense. The company that sequenced it does, or at least, in our current legal framework, it can act as if it does: It can sell or give your data to other organizations, which often are not bound by the agreement you signed with the sequencing company. Even if you pay for just the basic service that will allow you to sketch your ethnic background, the company may sequence your entire genome—and then pass that information along to others.

Its first stop will probably be a research institution, where it joins a database of thousands or millions of other genomes that researchers use to pinpoint genes that correlate with specific diseases or health risks. Those institutions, in turn, may partner with businesses that use the data to develop commercial products and services they can sell.

Jon Krause c/o TheiSpot.com

There is an infinite number of ways that people can capitalize on this information—for good or for ill. **- BARBARA GRAY**

"Many, many people do not understand what the potential uses of their DNA might be," says Barbara Gray, emerita professor of business in the Smeal College of Business.

She and Forrest Briscoe, professor of management and organization at Smeal, have built their careers studying organizational actions and decision-making, especially in situations that involve controversy and ethical choices. Genomics presents them with a whole new kind of challenge and opportunity.

"It's not too often that you get to study a new, emerging field of organizations, and on top of that, one that has a lot of interesting heterogeneity, like private sector firms from different kinds of industries, nonprofit organizations, universities, hospitals and health-care systems, and government agencies," says Briscoe.

Like ethnographers documenting an unfamiliar culture, he and Gray attend gatherings of people in the field, ask questions, and try to discern the relationships and value systems that underlie the conduct they observe. They hope to map the entire arena: who is creating genomic databases, where the data is housed, how it's secured, how it's being used and by whom, how all that is regulated, and who speaks for the individuals whose genomes are the raw material for the whole endeavor—all while the field continues to develop at a vertiginous pace.

A BOOMING BUSINESS

The first complete human genome sequence was published in 2003, after a 13-year international effort that cost $2.7 billion. Since then, sequencing technology has gotten faster and much less costly. At the same time, the advent of supercomputing centers that can analyze and compare millions of genomes has turned the mountain of raw genomic data into a motherlode of invaluable information. In 2017, investment in genomics businesses topped $3 billion.

Gray and Briscoe say the gleaming promise that justifies this level of investment is not genealogy, but health: the potential to create medical care tailor-made for each individual. Organizations from small startups to the National Institutes of Health are scrambling to compile genomic databases, the bigger the better. Their legal agreements with donors, and the security measures they employ to protect the data, are all over the map. There is no industry-wide standard.

Oddly, genetic data is not covered under HIPAA, the federal regulation that says health-care providers can't reveal your medical information to others without your consent. Your doctor needs your permission to tell someone else your blood pressure, but medical researchers can send your entire genome to others without telling you about it.

There's definitely an upside to making your genome available to researchers, say Briscoe and Gray: If your DNA isn't included, it can't be part of what the researchers discover. But there's a dark side, as well. What happens if insurance companies or employers gain access to your DNA data? The federal Genetic Information Non-discrimination Act, passed in 2008, bars employers from considering the genetic information of employees, job applicants, or members of their families, but a bill now before Congress, H.R. 1313 (the "Preserving Employee Wellness Programs Act") would get around that by allowing employers to "invite" employees to provide a DNA sample, and to charge those who say no up to 50 percent more for health insurance. In other words, your employer couldn't require you to provide a DNA sample, but could penalize you if you don't.

Their study is still young, but Gray and Briscoe have already learned enough to reach one conclusion: Unless a medical need arises, they won't be sending in their own cheek swabs for sequencing any time soon.

"There is an infinite number of ways that people can capitalize on this information," says Gray. "For good or for ill."

GREAT CROSSINGS

by Cherie Winner

In the heart of bluegrass country, in a weedy meadow a few miles west of Georgetown, Kentucky, stands an old stone building. Two-story, with shuttered windows flanking the centrally placed door, the 200-year-old structure is imposing, but not opulent. It suggests determination and resolve.

The building is the biggest physical remnant of Choctaw Academy, one of the United States' earliest and boldest experiments in finding common ground between whites and Native Americans. Built near the spot where bison once forded Elkhorn Creek, the Academy and its home community of Great Crossing sprang up where North met South and where East shaded into the Western frontier. The entire community dealt with diversity of all kinds, every day.

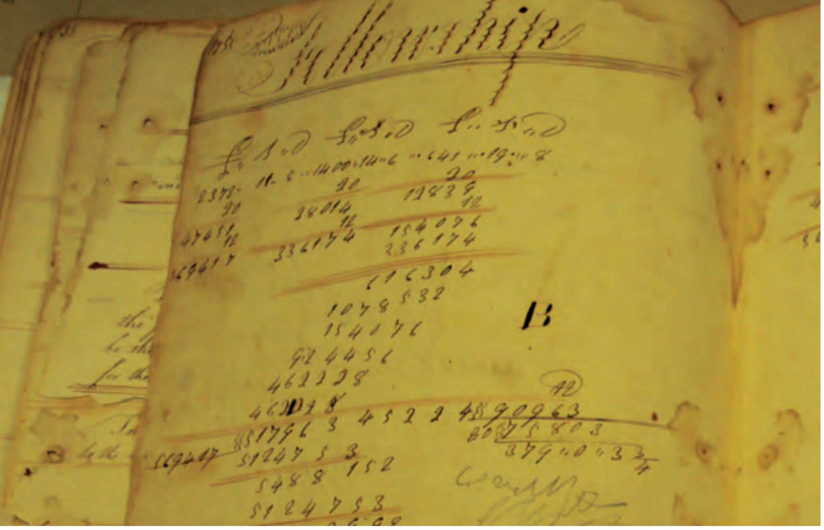
"Part of why I wanted to focus on this community is that it is an experiment," says Penn State historian Christina Snyder, who tells the story of Choctaw Academy in her 2017 book *Great Crossings: Indians, Settlers, and Slaves in the Age of Jackson*. "People at the time called it an experiment. It was seen as being a special place, a place where maybe Americans could think about a more inclusive way to build a nation.

"I look at how these different groups of people tried to find common ground. And ultimately, how that dream broke apart."

STORIES NOT TOLD

Snyder hails from the Deep South, growing up in Macon, Georgia, 85 miles southeast of Atlanta, right in the middle of the state. "It's a place where people are obsessed with history," she says. "I went to a high school that was founded in the 1870s. There were monuments to the Confederacy, monuments to the Civil Rights movement. Our train station still had extra bathrooms from when African Americans were not allowed to use the 'white' bathrooms." As a young white girl, she absorbed it all. "I felt history was very important, very present. And I could see how it shaped modern race relations," she says. But that public history largely left out the area's prior residents, despite the multitude of Indian place-names and the towering presence of a ceremonial mound created by the Mississippian Mound Builders who lived in the area a thousand years ago.

In 2011, when historian Christina Snyder first visited the site of Choctaw Academy, the last large structure remaining from the school was intact, though its roof was starting to sag. This building served as both dorm and classroom space. Photo by Christina Snyder.



Alfred Wade, a student at Choctaw Academy during its early years, carried his large, leather-bound math workbook on the "Trail of Tears" forced relocation. Each displaced Indian was allowed just 30 pounds of baggage, including clothes, household goods, tools, and everything else. The book now resides at the Oklahoma Historical Society in Oklahoma City. Alfred Wade Collection, Oklahoma History Center. Photo by Christina Snyder.

Among the stories Snyder did not hear as a child were the efforts Indian nations made to co-exist peaceably and productively with their new neighbors. "The Native people were working incredibly hard to try to find peaceful ways to live together—and they thought that education and economic interests were a form of common ground," she says.

Tribes in the Southeast had farmed the region for thousands of years before Europeans arrived. When white settlers moved in nearby with new and highly profitable practices, the tribes adapted. Their leaders gained recognition of their national rights via treaty with the young U.S. They established business relationships with their new neighbors, shifted away from communal property to individual holdings, and, in some cases, took up the enslavement of Africans.

Slavery in some form was not new to them; long before Europeans came to America, Indians had held other humans in bondage, mostly based on the capture of members of other tribes. Snyder explored this in her first book, *Slavery in Indian Country: The Changing Face of Captivity in Early America.* Although many of the captives suffered harsh treatment, they were not considered inferior by nature. Over time, either the captives themselves or their children or grandchildren became assimilated as full members of their new tribe. Snyder says this "open" form of slavery "was a short-lived experience, and there's no one class of people that are potentially slaves."

That changed when European settlers brought a very different form of slavery to the American colonies, the Caribbean, and Brazil. In this "closed" system, says Snyder, "slavery passes from one generation to the next and is settled on a particular group, and there's almost no way of escaping it. The idea is that race justifies all of this."

A DIFFERENT VISION

Choctaw Academy presented a very different view of race, at least with regard to Native Americans. The school was the brainchild of Richard Mentor Johnson, a local plantation owner and former Indian fighter. He had parlayed his claim that he killed Shawnee leader Tecumseh at the 1813 Battle of the Thames into a political career. By the 1820s he was a U.S. Senator, with his eye on even higher office. He saw an Indian school as a good source of revenue, but he also was, in many ways, a legitimate reformer of the era. He held progressive views of the inherent value of Indian lives and the power of education to improve their abilities and prospects.

The vision that embraced the intellectual potential of Native Americans did not extend to all of the community's members, however. The vast majority of the labor on Johnson's plantation and at the Academy—farming, carpentry, cleaning—was done by slaves.

Still, Johnson doesn't seem to have believed that the slaves' status was inherent in their race. The woman he considered his wife, Julia Chinn, was African-American and was, in fact, his slave. She was also the undisputed mistress of his household. When Johnson was out of town on political business, Chinn ran the plantation, handling accounts, negotiating with vendors, and supervising both free and slave workers. Johnson didn't hide her; she hosted major public events like the visit in 1825 of the Revolutionary War hero the Marquis de Lafayette. Johnson doted on their two daughters and made sure they were well educated by Academy tutors—and when they reached adulthood, he freed them.

THE ACADEMY

Such was the community that welcomed the first class of Indian students in the fall of 1825. All 21 were Choctaw boys, sons of prominent families—the tribe's elite. Within a year, they were joined by boys from several other tribes in the Deep South and the Upper Midwest. Over the next 20 years, more than 600 students from 17 tribes attended Choctaw Academy.

Peter Pitchlynn, one of the first students at Choctaw Academy, went on to represent the Choctaw Nation in Washington, D.C. In 1842, the year this portrait was painted, he met Charles Dickens on a steamboat trip and the two spent hours discussing literature and politics. Painting by Charles Fenderick, Courtesy of the American Antiquarian Society.

Richard Mentor Johnson, founder of Choctaw Academy, served as Vice President of the United States from 1837 to 1841, but his public support of his mixed-race daughters ended his political career. This portrait is from 1843. Painted by John Neagle; via Wikimedia Commons.

The tribes paid a small fortune for the privilege; that first year, the Choctaw Nation paid $70,000, about $1.5 million in today's dollars. That was a big chunk of their tribal wealth, evidence of their belief that education was the way forward for their entire nation.

One member of the first class was 19-year-old Peter Pitchlynn, the eldest child of a white father and a mother from a prominent Choctaw family. He had a keen intelligence, a gift for public speaking, and a powerful sense of duty to his nation. He fully recognized his elite status within the tribe, and seemed to identify more with prominent whites than with people further down the social ladder: slaves. When the Academy opened, the Choctaw nation held fewer slaves than any other southern Indian nation (about 3 percent of their population, compared to 20 percent in the Chickasaw nation and 23 percent in white-dominant Kentucky), but Pitchlynn's family was the biggest slaveholder in the tribe, with 60 enslaved blacks. "Looking at a tri-racial environment complicates our view of race," says Snyder. "People are really complicated."

DEFINING A NATION

In the Academy's early years, pupils studied mathematics, geography, English grammar and literature, and the classics of Greece and Rome. Writings from those ancient empires were seen as being especially relevant to the new American empire. "At the time, Americans were not shy about using the term 'empire,'" says Snyder. "That's actually part of their enthusiasm for the opening of the frontier—that it was a great thing. Who else was going to spread liberty across the continent and even beyond?"

American leaders of the time believed that the U.S. would succeed where other empires had failed, she says. "American exceptionalism," which today usually refers to being a beacon of civil liberties, back then meant that the U.S. would be better than all earlier empires, which maintained their exalted positions for a few hundred years at most and then, beset by corruption, military over-reaching, or environmental disaster, declined—in most cases, disappearing forever. The U.S., they thought, would be immune to that fate.

Pitchlynn and other Native Americans had a very different view of empire and of historical time.

"They were reading the histories of ancient Greece and Rome, but they were drawing very different conclusions" than white Americans did, says Snyder. "They said, 'I see the mistake those empires made, and it's the same mistake you're making.'"

(Left) William Richardson, current owner of the property, and historian Christina Snyder at the Choctaw Academy site in 2018. Behind them is the small stone building where Julia Chinn lived. She was Richard M. Johnson's slave and mother of his two daughters.

(Right) After the roof of the large building collapsed in 2016, Richardson and supporters paid to have a protective shed erected above it to prevent further deterioration. Specialists in stone buildings are making plans to restore the structure, and a campaign is under way to have the site named a National Historic Landmark. Photos by Tom Eblen/ Lexington Herald-Leader.

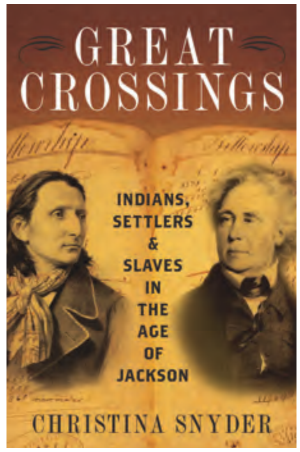
They also had a different perspective on history because of how long their nations had been here. Whites were newcomers with a shallow grasp of historical time, a description that still holds, says Snyder. "If we look at some of these areas in the Deep South, white families were there for just one generation before the Civil War. The 'Old South' is not actually that old."

REMOVAL—AND REBIRTH

Choctaw Academy's hopeful start soon came up against outside forces. In 1828, Andrew Jackson won the Presidency with the support of poor, rural whites who coveted the southern tribes' rich farmland and believed Jackson would deliver it to them. Jackson stoked racial animosity to justify displacing the Indians, and he admitted, or perhaps boasted, that the U.S. no longer had to abide by its treaties with the Native nations. "He felt that it was all about power—that Indian treaties are relics of a time when the United States was relatively weak and needed to appease Indian nations, and that now the U.S. was powerful enough that it no longer had to respect Indian treaty rights," says Snyder.

Just over a year after taking office, Jackson signed into law the Indian Removal Act and began what essentially was a process of deporting Native Americans from their own lands. The tribes were paid for their land—nowhere near what it was worth—and promised equivalent land holdings in Indian Territory (what is now Oklahoma). The Choctaws (including students at the Academy) were first to go on the "Trail of Tears," making the 500-mile trip during the winter of 1831-32. All but the very old and very young walked it. They were not allowed to take livestock. They *were* allowed to take slaves, who became a kind of living repository of their wealth. Whether intentionally or not, this policy helped spread the practice of slavery to the western territories.

Pitchlynn and his wife, young children, and their slaves were among those who endured the exodus. Many died on the journey, but their troubles didn't end when they reached Indian Territory. A flood washed out the first crop they planted. The next few years, the region suffered a drought even worse than the Dust Bowl of the 1930s. The relocated communities were hit by cholera, whooping cough, and smallpox. Skirmishes broke out with whites trying to claim the land for themselves.



Jacob Lee

Christina Snyder, McCabe Greer Professor of History at Penn State, received the 2018 Francis Parkman Prize from the Society of American Historians for her book, *Great Crossings.* She delved into sources no one had looked at carefully to write about Choctaw Academy, the people involved with it, and the larger national events of the time. Photo by Oxford University Press.

All told, more than 25,000 Indians—about one-fifth the total number living east of the Mississippi prior to removal—died during the trek west or from disease, famine, or violence after arrival.

But more survived, and when the drought ended and they were able to grow a decent crop and feed themselves well, they began to recover. They built homes, businesses, roads, towns—and schools. Peter Pitchlynn never wavered in his support for education—not the manual training Indian children were often forced into, but serious, intellectually ambitious learning like what he thrived on at Choctaw Academy. He helped the Choctaw Nation establish its own system of public schools, the first in the United States. It included a boarding school for girls and offered weekend classes for adult students. Basic education was free for all members of the tribe, and compulsory for children. The schools were so much better than those of nearby white communities that many white families paid a fee so their children could attend.

Most Native-focused histories of the period end with removal, says Snyder, because the event seems like a natural break in the timeline. She thinks that vastly oversimplifies the larger story. "One of the things this book does is to say, removal is a tragedy and it changes America forever, but Native peoples are still here. They adapt. They survive."

LATER YEARS

For a while, Richard Mentor Johnson did what he set out to do at Choctaw Academy—offer a first-rate education to Indian youths and make a good living from it. But when he ran into financial difficulties, he looked for relief to the Academy. After Chinn died during a cholera epidemic in 1833, he stayed in Washington to pursue his political career and left the school in the hands of a supervisor who had orders to cut costs and pocket much of the tuition and federal subsidy funds. Standards for housing, clothing, and polite behavior all declined, and the education offered there devolved into vocational training.

In 1836, Johnson ran as the vice-presidential candidate on the Democratic ticket with Martin Van Buren. They won despite vicious attacks on Johnson, not for having a slave concubine—a common practice in southern states—but for publicly acknowledging his daughters, and allowing them to participate in society as equals. At the next election, his personal life had become too big a liability, and the Democrats refused to re-nominate him. By then, beset by financial scandal and student complaints, Choctaw Academy was limping toward its end, which finally came in 1848. Johnson died in 1850.

Like Pitchlynn, Johnson defies easy labeling as a 'good guy' or 'bad guy,' says Snyder. He stuck by his daughters even when it cost him heavily in his political career. "We don't know how Julia Chinn felt about him, if she was forced into the relationship or if there was real love there," she says. "But we do know what he did for his daughters. That's actually the clearest sign of his more progressive ideas. His surviving letters to them are very loving. At the same time, he's a corrupt politician. He engages in extensive graft, to the detriment of the Indian nations."

RIPPLES IN TIME

Back in that Kentucky meadow where Native and white Americans tried for a time to make a bridge between them, the dorm/classroom building still stands. Its sagging roof beam finally gave way in 2016, timbers and shingles and stones from the upper walls tumbling into the spaces below. The top of the building has been covered by a protective shed to prevent further deterioration.

William Richardson, a local ophthalmologist, bought the property in 2012 and is leading a coalition that includes historians, masonry experts, and the Choctaw Nation, in an effort to restore it and turn it once again into a place of learning. Snyder is writing an application to have the site designated a National Historic Landmark, which would put it on the map as a travel destination and introduce visitors to a little-known but significant chapter in American history.

"Oftentimes, Native American history is separate from African American history, and sometimes even the narrative of U.S. history doesn't fully incorporate those perspectives," says Snyder. "The reason I chose to focus on Choctaw Academy is that you can see how these stories intersect, how they're all interconnected.

"This place is really at the heart of the debate about what the nation would be."

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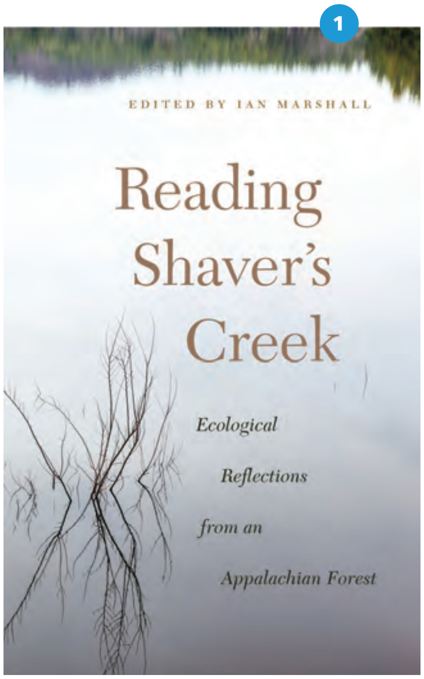

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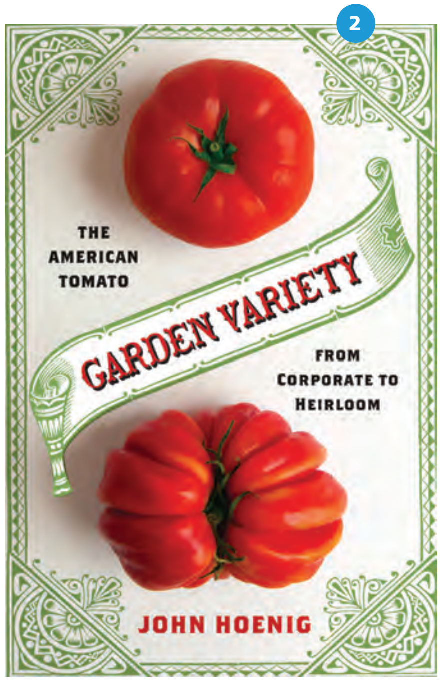

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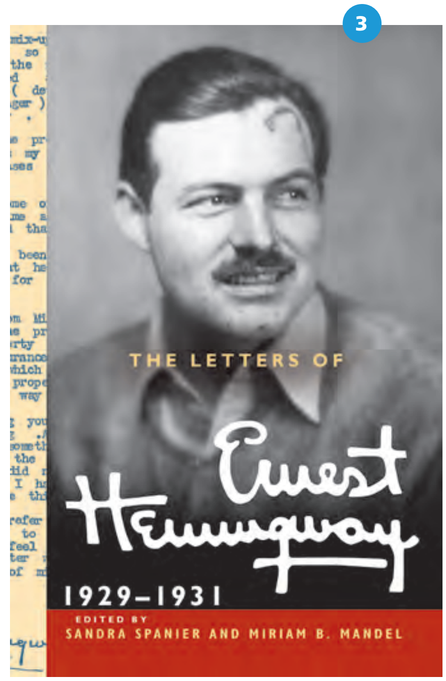

BOOKS BY
PENN STATE
FACULTY

4

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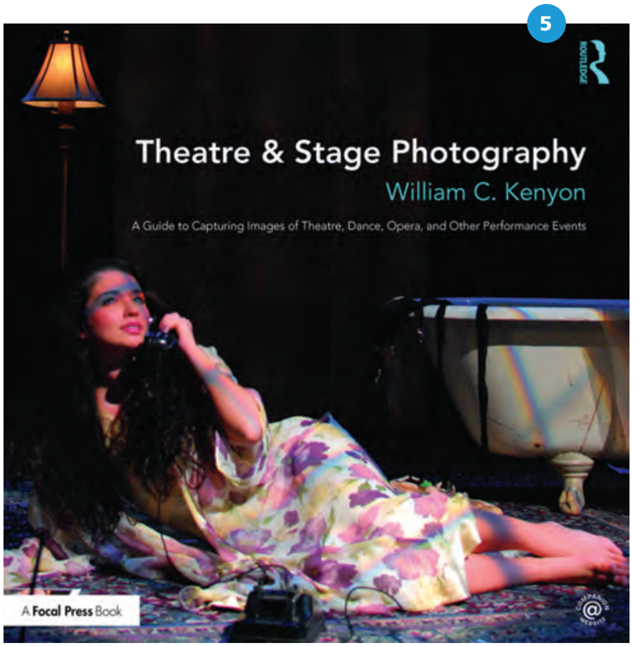

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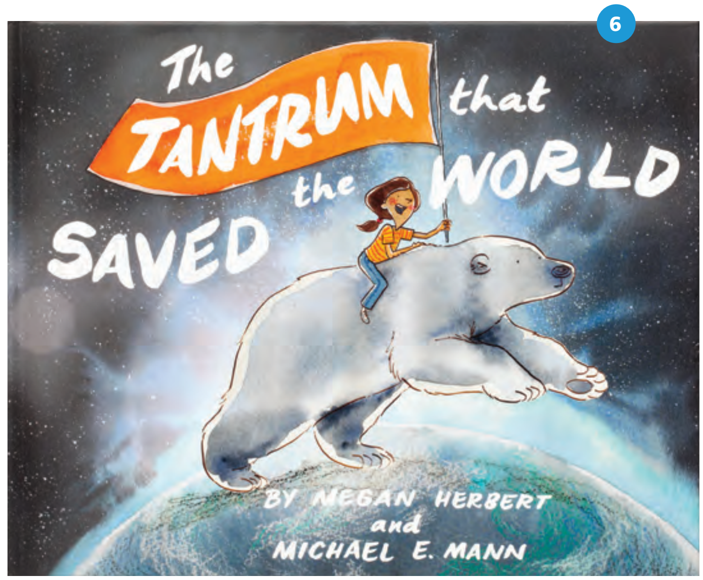

1

READING SHAVER'S CREEK

edited by Ian Marshall, professor of English and environmental studies, Penn State Altoona

What does it mean to know a place? What might we learn about the world by returning to the same place year after year? What would a long-term record of such visits tell us about change and permanence and our place in the natural world? This collection from Penn State University Press explores these and related questions through a series of reflective essays and poems on Pennsylvania's Shaver's Creek landscape written over the past decade. Collected as part of The Ecological Reflections Project—a century-long effort to observe and document changes to the natural world in the central Pennsylvania portion of the Appalachian forest—these pieces show how knowledge of a place comes from the information and perceptions we gather from different perspectives over time. Featuring contributions by nationally known nature writers and local experts, *Reading Shaver's Creek* is a unique, complex depiction of the central Pennsylvania landscape and its ecology.

2

GARDEN VARIETY: The American Tomato from Corporate to Heirloom

by John Hoenig, adjunct lecturer in history

Where would American food be without the tomato? In its various forms, the tomato represents the worst and best of American cuisine, from the nearly tasteless corporate tomato to the luscious fruits of home gardens and farmers' markets. In *Garden Variety*, published by Columbia University Press, John Hoenig explores the path by which, over the last 200 years, the tomato went from a rare seasonal crop to America's favorite vegetable. As food production, processing, and distribution became increasingly centralized, the tomato remained king of the vegetable garden and became the centerpiece of alternative food cultures.

Drawing on seed catalogs, menus, and cookbooks, and tracking efforts to find new ways to prepare and preserve tomatoes, Hoenig challenges the extent to which corporate agriculture dominated 20th-century American kitchens, emphasizes the importance of tomatoes to numerous immigrant groups, and invites us to rethink the history of our foodways and to take the opportunity to expand the palate of American cuisine.

3

THE LETTERS OF ERNEST HEMINGWAY (1929-1931)

edited by Sandra Spanier, Liberal Arts Professor of English, and Miriam B. Mandel

In this, the fourth volume of *The Letters of Ernest Hemingway*, editors Sandra Spanier and Miriam B. Mandel capture an important turning point in Hemingway's life as he, for the first time, begins to contend with celebrity. The new book, published by Cambridge University Press, picks up in April 1929, just as Hemingway is returning to Paris with his second wife and just before Scribner's Magazine serialized his novel *A Farewell to Arms*. In addition to coping with his newfound fame, the letters, to correspondents including John Dos Passos, F. Scott Fitzgerald, James Joyce, Archibald MacLeish, Ezra Pound, Thornton Wilder, and the legendary editor Maxwell Perkins, show Hemingway reflecting on mortality, depression, his professional persona, and international politics. Spanier serves as general editor of the Hemingway Letters Project, directing an international team of scholars working to collect and publish more than 6,000 letters from Ernest Hemingway in a projected 17-volume series.

4

SHALE PLAY

by Julia Spicher Kasdorf, professor of English and women's studies, and Steven Rubin, associate professor of art

In their new book *Shale Play*, from Penn State University Press, poet Julia Spicher Kasdorf and documentary photographer Steven Rubin explore the small towns, farms, and forests of Pennsylvania to tell the stories of these places and the working people who inhabit them. The term "shale play" refers to a region exploited for its natural gas by means of hydraulic fracturing and horizontal drilling. Amid polarized claims about fracking and the pressure to develop gas fields, this book shares stories from everyday life in the Marcellus Shale Play. Kasdorf and Rubin follow in the footsteps of the documentarians of the 1930s, recording the experiences of workers on pipelines and well pads, landowners and leaseholders, waitresses, ministers, farmers, retired miners, teachers, and neighbors. The resulting collage of oral and pictorial testimony vividly reveals the natural beauty of rural places as well as the disturbance and spectacle fracking creates.

5

THEATRE AND STAGE PHOTOGRAPHY: A Guide to Capturing Images of Theatre, Dance, Opera, and Other Performance Events

by William Kenyon, associate professor of theatre

The dramatic, and often complex, lighting of stage events presents challenges even for seasoned shutterbugs. In *Theatre and Stage Photography*, William Kenyon, head of the lighting design program at University Park, helps photographers of all skill levels capture excellent images in this difficult lighting environment. The book also applies to other "available light" situations where flash cannot be used or would ruin the effect the photographer is trying to achieve.

Early chapters will be helpful to beginners, while experienced photographers (and even pros) will find much of value in later chapters. The book, published by Routledge, features photos from Kenyon's long career in professional theatre and illustrations by his wife, Jenny Kenyon, an instructor of design and scenic art at Penn State. The author has also started a companion website (stagephoto.org) where visitors can view galleries and videos and share information about technology and techniques.

6

THE TANTRUM THAT SAVED THE WORLD

by Michael Mann, Distinguished Professor of atmospheric science, and Megan Herbert

One day, a polar bear shows up at Sophia's house asking if it can come inside. Its habitat melted and the bear needs a new home. So starts *The Tantrum that Saved the World*, a children's book about how climate change is affecting creatures and communities around the world. When more climate refugees show up—honeybees confused by the seasons, a flamingo whose breeding ground was lost, an i-Kiribati family whose house was submerged by seawater— Sophia throws a tantrum to make the world's decision-makers take notice.

Penn State scientist Michael Mann and writer/illustrator Megan Herbert created the story as a way to discuss climate change with their own children. Published by World Saving Books and printed on recycled paper with biodegradable ink, the book includes a scientific section that shows the human and animal characters in their native habitat. An action-oriented poster outlines what children can do in their daily lives to make a difference.

In spring 2017, Penn State hired its first chief sustainability officer, Paul Shrivastava, with the aim of integrating sustainability into all areas of the University, including research, teaching, student life, community engagement, and operations. He previously served as executive director of Future Earth, a global research network. Shrivastava recently sat down with writer Rachel Garman to discuss the University's sustainability strategy and some of its key initiatives.

WHY DID PENN STATE HIRE A CHIEF SUSTAINABILITY OFFICER?

From our origins as a land-grant university with special strength in agriculture and engineering, sustainability has deep roots at Penn State. In recent years, Penn State has made a public commitment to sustainability through the themes of our strategic plan, which include stewarding our natural resources and the well-being of our communities. There was also a conversation going on about the United Nations' Sustainable Development Goals and our global presence. These conversations came together and created the impetus for hiring Penn State's first chief sustainability officer. We are the first university in the Big Ten to establish such a position.

HOW DOES SUSTAINABILITY SUPPORT THE UNIVERSITY'S MISSION?

It's part of our land-grant mission to support the Commonwealth in being more responsible in our use of resources like food, energy, and water, and in reducing waste. Thanks to our presence in 24 communities and numerous Extension offices, we can help make the entire Commonwealth of Pennsylvania more sustainable. We also have research and teaching presences in Africa, China, South America, and other parts of the world. So we can also be contributing to global sustainability. We are uniquely positioned to implement these goals because of our interdisciplinary nature—we have colleges that cover everything from business and economics to climate and environmental sciences and the humanities.

WHAT IS PENN STATE'S STRATEGY FOR INTEGRATING SUSTAINABILITY ACROSS THE UNIVERSITY?

We think of sustainability as a spice that needs to be put into every dish being cooked at the University. Our approach is to work with individual units to adopt and organically grow sustainability from within. Each unit will develop its own approach and plans for sustainability, and we assist by providing advice, tools, resources, and programs. Penn State also established a policy, in 2007, that any new or renovated building on every campus must be LEED certified.

WHAT IS A LEED BUILDING, AND HOW DOES IT PROMOTE SUSTAINABILITY?

Leadership in Energy and Environmental Design [LEED] is an international standard for buildings maintained by the U.S. Green Building Council. LEED buildings follow stringent standards for green design concepts and materials and result in energy savings and improved air quality, among other benefits. Penn State now has 31 LEED buildings, with more on the way, on several campuses. Two recent examples include the Millennium Science Complex and renovations to the Business Building, which have both met standards that include reducing water consumption by 20 percent, reducing greenhouse gas emissions, and reducing the amount of construction waste. (See pages 22-25 for more about university buildings.)

WHAT'S ON THE HORIZON FOR SUSTAINABILITY AT PENN STATE?

There's a whole new kind of architectural design called regenerative buildings, or living buildings. Living buildings go beyond net zero energy and produce additional energy, plants, and food so they are net additive to the environment. They combine solar energy, plant growth, office spaces, entertainment spaces, and conference spaces. So there might be a café in the building and a green roof growing all the fresh produce. We'd like to have regenerative buildings on campus that could be living labs for our own students and faculty members.

PAUL SHRIVASTAVA on SUSTAINABILITY

WHAT ARE SOME OTHER KEY SUSTAINABILITY PROJECTS GOING ON AT PENN STATE RIGHT NOW?

A great example is the Sustainability Experience Center, a 9.4-acre piece of land by Beaver Stadium that functions as a living lab for both hands-on teaching and innovative research. While elements of the center have been around since 2000, the space has grown to include the MorningStar Solar Home [shown here], the "living machine" experimental waste water treatment facility, a community garden, and the Chevrolet Solar Carport. We plan to move the Student Farm to this site. We also welcome new projects to join us and invite the public to come see our work in action.

SO SUSTAINABILITY REALLY TOUCHES ALL CORNERS OF THE UNIVERSITY.

Yes, that's one of the key messages of our vision. We are slowly trying to embed the concepts of sustainability into the DNA of the University so this gets done organically within every unit. It's a long-term project, and I know it's not going to happen tomorrow or next year. But if we stay with it and persist, we're only limited by our imagination.

Michelle Bixby

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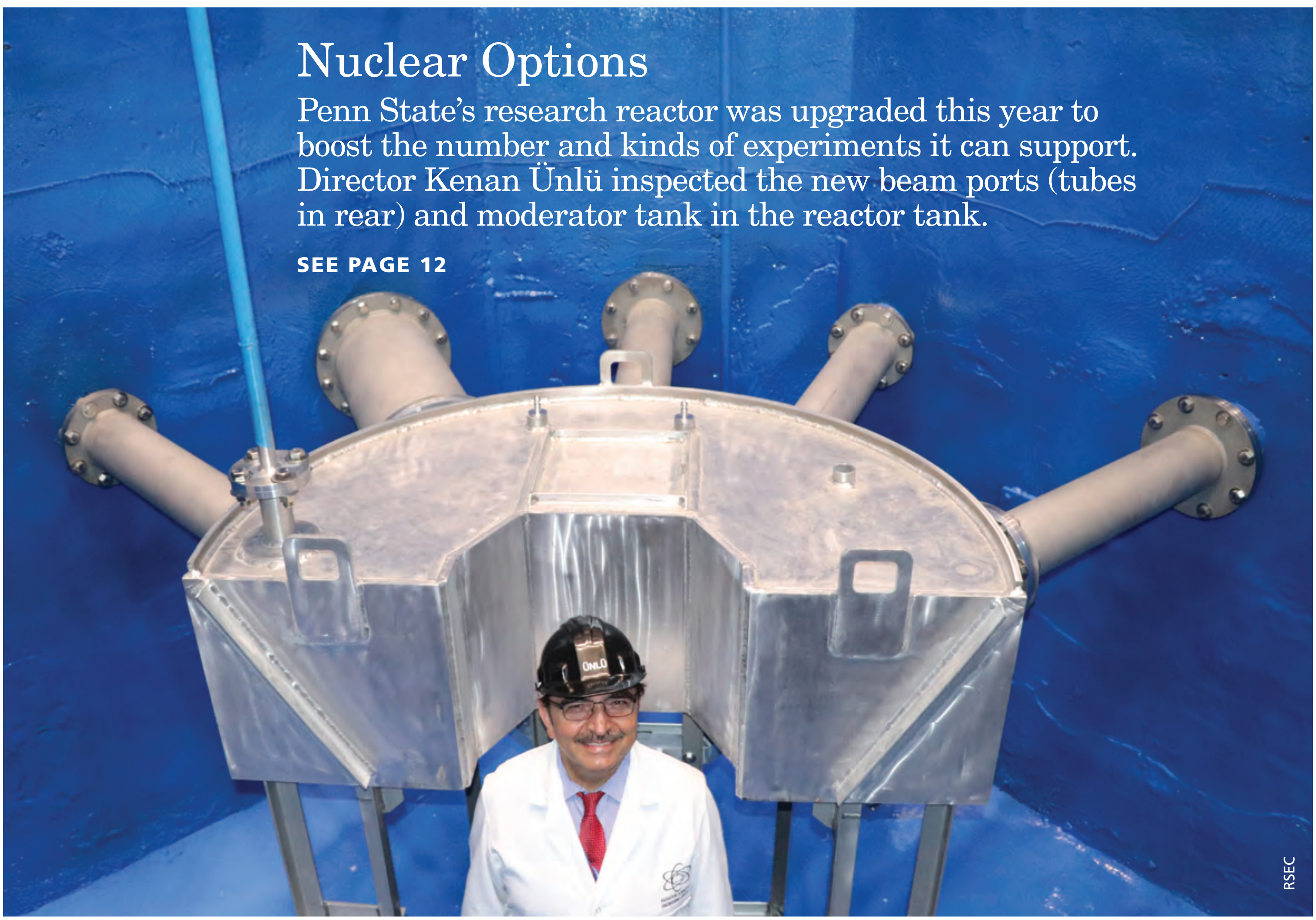

Nuclear Options

Penn State's research reactor was upgraded this year to boost the number and kinds of experiments it can support. Director Kenan Ünlü inspected the new beam ports (tubes in rear) and moderator tank in the reactor tank.

SEE PAGE 12