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ANNUAL REPORT

EXECUTIVE VICE PRESIDENT FOR RESEARCH AND PARTNERSHIPS

THIS IS US

PURDUE UNIVERSITY®

150 YEARS OF GIANTLEAPS

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MIDWEST

NORTHEAST

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Purdue's sister land-grant institutions are *italicized* throughout this report.

150 YEARS OF GIANT LEAPS

THIS IS US

In 1862, President Abraham Lincoln signed into law the Morrill Act, designed to make higher education more affordable and accessible for the working class by granting states public lands to use in establishing colleges for agriculture and the mechanical arts.

Conceived of during the Civil War, the Morrill Act was itself revolutionary. Until land-grant institutions such as Purdue appeared in the latter part of the 19th century, American universities were out of reach to all but the upper and ruling classes. When Purdue University opened in 1869, its primary aim was to teach subjects such as engineering, the natural sciences, agriculture and military science to people who otherwise could not have afforded it.

The original tripartite mission of the land-grant institutions — learning, discovery and engagement — catered to the needs of a burgeoning industrial society. Today that mission is still highly relevant, but it has expanded to reflect contemporary needs.

Making education affordable is still paramount, but so is equipping graduates to be globally engaged citizens. Research to help the state's residents and businesses is still essential, but lines of inquiry have broadened into addressing some of the world's most pressing problems. Inspired by Purdue alumnus Neil Armstrong, we refer to these challenges as Giant Leaps: promoting health and longevity, creating a sustainable planet and economies, venturing further into our solar system, and balancing the promises and threats of technology. Finally, land-grant institutions today are reaching out to partners not only around their states but also around the world, and the idea of engagement is taking root at universities in other countries as well.

The 2017-18 EVPRP annual report celebrates Purdue's 150th anniversary through the lens of our Morrill Act heritage. THIS IS US is not only about the land-grant ideal, which democratized education and research in the United States, but also about Purdue — our unique blend of faculty from more than 100 countries who form research alliances here and beyond in order to make Indiana, our country and our world a better place.

PURDUE UNIVERSITY

BALANCING ACT

CONWAY, ARKANSAS | In early 2016, the community of Conway, Arkansas, nearly doubled its number of hospital beds when the state's largest health system opened a 260,000 square-foot facility four miles away from the local independent hospital. Lured by attractive architecture and handsome benefit packages, many staff left to take jobs at the new facility — only to later return to their original employer.

Anecdotally, the CEO heard that his returning employees were just not happy with the new hospital's culture, specifically its lack of work-life balance. To find out how well his own facility ranked on the work-family culture scale, he reached out to **Benjamin Dunford**, an associate professor of management and a faculty affiliate of the Regenstrief Center for Healthcare Engineering in Purdue's Discovery Park. The results have relevance well beyond the Conway hospital's walls.

Surveying 680 hospital employees nested within 60 hospital departments, Dunford and his collaborators found that departments with a high level of positive work-family culture — as defined by their employees — were more likely to also have higher levels of employee engagement, organizational pride, confidence in management and leadership, and intention to stay. A key finding: departments varied widely in their scores, meaning that an overall positive score for a hospital could mask key differences among departments.

Helping employees balance their work and family needs is increasingly important for not only attracting and retaining key talent in healthcare but also for enhancing patient care; naturally, more satisfied employees can mean more satisfied patients. And yet, despite administrators' efforts to develop a unified work-family culture, departments often take on their own cultural norms, Dunford says. Ultimately, that could widen the disparities, leading to some departments being deemed more family-friendly than others.

"The key to instilling a positive, organization-wide work-family culture may be through a department-by-department focus," says Dunford, whose research in the area is ongoing.

PHOTO BY VINCENT WALTER

SUSTAINABILITY | CARLA JOHNSON

PHOTO BY VINCENT WALTER

GEAR UP

LAFAYETTE, INDIANA | A national program established to increase the number of students who are prepared to enter and succeed in postsecondary education is making a difference right here in Indiana. Now, halfway through a seven-year, $24.5 million grant from the U.S. Department of Education (the largest grant ever awarded to the College of Education), the Indiana GEAR UP program is positively influencing the futures of students in 23 schools across the state, including Tecumseh Middle School and Lafayette Jefferson High School.

GEAR UP (Gaining Early Awareness and Readiness for Undergraduate Programs) starts in seventh grade and follows a cohort of students through their first year of postsecondary education. In Indiana, it is led by a collaborative team from Purdue University and the Indiana Commission for Higher Education.

Carla C. Johnson, professor of science education, is executive director and principal investigator of Indiana GEAR UP. Already, she has seen measurable results.

"Our partner schools have shown gains in their mathematics and science state assessment scores," Johnson says. "This is pretty big."

While the number of Indiana college students needing remediation has dropped in recent years, college preparedness remains a critical issue. To help ensure that more Hoosier students get into college and are ready to succeed, the GEAR UP team designs research-based interventions, and then trains educators to implement these ideas across the state.

Along with school-day activities, GEAR UP offers STEM summer camps and after-school programs such as "homework diners" in which parents, students and staff chat over meals. Teachers in partner schools also benefit from research-based professional development.

While team members help prepare 7,000 Indiana students for the future, they are also gathering valuable data that could influence STEM education nationwide — another example of how Purdue is leading the way in transformative education, Johnson says.

PAST AND FUTURE

INDIANAPOLIS, INDIANA

Through the remainder of this century, temperatures will continue to rise and precipitation patterns will change significantly, both as a result of human-induced climate change. What will those changes mean for Indiana?

That's the question the Indiana Climate Change Impacts Assessment team is answering through a series of reports that detail what Hoosiers can expect in the coming decades. The Purdue Climate Change Research Center (PCCRC) in Discovery Park is leading the statewide research effort that draws on the knowledge of more than 100 scientists and experts from more than 40 universities and stakeholder organizations. Key partners include the University of Notre Dame, Indiana University, Indiana University Purdue University Indianapolis, the Marion County Public Health Department, the U.S. Forest Service and Purdue University Northwest.

A 2018 report on how Indiana's climate has changed over the last century and expectations for the future laid the groundwork for detailed projections for water resources, health, energy, forest and urban ecosystems, aquatic ecosystems, tourism and recreation, agriculture and infrastructure. **Melissa Widhalm**, PCCRC operations manager, was the report's lead author.

A few key findings: the frost-free season has lengthened by nine days since 1895, which is increasing the growing season but also the potential for invasive species. And in Indianapolis, heavy rains are sending 8 billion gallons of untreated sewage into the White River each year, a costly mitigation issue for the city.

The studies show that there will be other significant changes as well, but the changes also offer opportunities for the state and its residents to plan ahead and adapt.

"Climate change will have impacts across many different aspects of our lives in Indiana. Our work will guide efforts to maintain the economic competitiveness of the state, protect our environment and the health of our people, and really just prepare Hoosiers for the climate that's ahead of us," says **Jeff Dukes**, PCCRC director, professor of forestry and natural resources and professor of biological sciences.

PHOTO BY VINCENT WALTER

SUSTAINABILITY | MELISSA WIDHALM + JEFF DUKES

PHOTO BY JOHN UNDERWOOD

HOME DELIVERY

CHICAGO, ILLINOIS | When physician Joseph DeLee rented a cluster of tenement rooms on Maxwell Street in 1895, obstetrics was a woefully undervalued medical specialty. Medical students received most of their childbirth training on mannequins, occasionally paying a seasoned mother to allow them to attend her birth at home. Hospitals were the place of last resort for women who couldn't afford a home birth, and their unsanitary conditions were leading to 20,000 postpartum infection deaths each year in the United States.

DeLee envisioned something better at what eventually became the Chicago Maternity Center (CMC): a clinic providing low-cost prenatal care and home delivery along with hands-on experience for physician residents and midwives. Drawing from the most sterile practices of the day, nurses turned their patients' homes into labor and delivery wards. "They would put newspapers down, they would put on gloves, and use a giant light," says **Wendy Kline**, the Dema G. Seelye Chair in the History of Medicine in the College of Liberal Arts.

Ironically, DeLee was not a home-birthing proponent; he saw his work as a stopgap measure until hospital obstetrics improved. However, the center long outlived its founder, delivering babies for another 30 years after DeLee's death. And while the CMC mainly treated nonwhite mothers from the poorest neighborhoods, some of the physicians the center trained later delivered babies for white, suburban moms, many of whom learned about home birth through the La Leche League, founded in the Franklin Park suburb in the 1950s.

"We assume that these two models are different, that doctors and midwives will never get along. One is seen as more scientific while the other as more spiritual," Kline says. "But when you look at the history of it, 70 to 80 years ago, there was a lot more collaboration between doctors and midwives. And even today, science shows that states with more collaborative models have better outcomes."

SPACE EXPLORATION | FRONT: RODGER DYSON + YUHAN ROH + JESSICA HOKE + ALIABDULLAH SAROYA + ALEX KRIVITSKY + PAUL NELSON · BACK: COLFAX PUTT + ALEXANDER KIRTLEY + RICHARD BROOKES

PHOTO PROVIDED

FLIGHT PLAN

CLEVELAND, OHIO | Rush hour in 2050: the skies over the city are crowded with passenger vehicles. Traffic control requires a smooth flow of personal flyers at different altitudes. What's a personal pilot to do? That was the futuristic scenario a team of Purdue undergraduates faced in a contest that challenged them to develop a comprehensive plan for integrating flying vehicles into the existing infrastructure of a city. The students won top honors in the NASA University Student Design Challenge sponsored by NASA's Glenn Research Center in Ohio, receiving a personalized tour of its testing facilities as part of their prize.

The team was asked to come up with solutions for a variety of factors, including traffic management, autonomy, propulsion, noise, cost and safety. The eight-member Purdue team led by aeronautical and astronautical engineering senior **Yuhan Roh** prevailed. They designed a personal air vehicle powered by a rotating drum with adjustable-pitch airfoils, and devised a communication system with an array of antennas for managing traffic flow.

The students delivered such a thoroughly thought-out and professional report that major commercial aviation players asked to see it, says team adviser **Guillermo Paniagua**, a professor of mechanical engineering and of aeronautics and astronautics.

"This was as close as it could be to a real project in industry or in a national lab. Sometimes in engineering we focus so much on tiny details that we miss the big picture," says Paniagua. "The team looked at the problem from a holistic view with the right level of detail."

ALWAYS READY

NEW LONDON, CONNECTICUT | In June 1943, at the height of the United States' involvement in World War II, the U.S. Coast Guard Academy on the banks of the Thames River became the official indoctrination center for the United States Coast Guard Women's Reserve.

Persuaded by posters with such slogans as "Make a Date with Uncle Sam," women aged 20-50 joined the force by the thousands with Purdue's own **Dorothy Stratton** at the helm. Stratton, who had taken a leave of absence from her duties as Purdue's first full-time dean of women, named the group SPARS — an acronym that not only called to mind the spar, or pole, on which a ship's sail is hoisted but also the Coast Guard's motto, "Semper Paratus," which means "Always Ready."

At first, military officials assumed the women had few useful skills to offer beyond typing and switchboard duties. Stratton's recruits soon put those ideas to rest, demonstrating abilities from marksmanship to radio operation. Ultimately, more than 10,000 enlisted women and 1,000 women officers served in SPARS across the United States in dozens of capacities, paving the way for the modern Coast Guard, which today places no restrictions on the positions that women can hold.

Always ready for the next challenge, Stratton left the military in 1946 with a Legion of Merit medal, returning to Purdue briefly before becoming director of personnel at the International Monetary Fund. She next served as director of the Girl Scouts of America and later as representative for the International Federation of University Women at the United Nations.

In 2006 at the age of 107, Stratton passed away in Lafayette, Indiana. Two years later, the U.S. Coast Guard named a national security cutter the USCGC Stratton in her honor.

PURDUE ARCHIVES AND SPECIAL COLLECTIONS

HEALTH & LONGEVITY | DOROTHY STRATTON

NATIONAL ARCHIVES

NATIONAL ARCHIVES

SUSTAINABILITY | NADIA BROWN + NATASHA DUNCAN

PHOTO BY VINCENT WALTER

TAKING IT TO THE STREETS

WASHINGTON, DC | On January 20, 2017, hundreds of thousands of visitors sporting red caps and waving American flags lined the path from the Washington Monument to the U.S. Capitol, celebrating the inauguration of the 45th president. Less than 24 hours later, half a million demonstrators swelled the same walkways in pink hats and handmade signs for the historic Women's March, protesting the incoming administration's agenda and advocating for causes ranging from climate change to reproductive rights.

Armed with notepads and cell phones, a group of Purdue undergraduate researchers took to the streets and buildings of the nation's capital that weekend to see if the country really was as divided as social media and cable TV had made it appear to be. The short answer, after 220 interviews with citizens and politicians and three months of analysis: actually, yes.

"I think it's a question of whether these results can be generalized to a larger population or was it just the politically active who were thinking this way?" says trip co-leader **Natasha Duncan,** interim associate dean of academic affairs in the Honors College. In fact, some social scientists theorize that as people engage more in activism, they become more entrenched in their own points of view.

For many of the student researchers, however, the trip had the opposite effect. As qualitative researchers looking for the nuance and complexity within answers, they found their own beliefs evolving. "If you grow up in a household of a particular political party, you grow up thinking that and you tune into TV shows that reinforce that perspective," says co-leader **Nadia Brown**, associate professor of political science and African American studies. "This experience taught them to see both perspectives and to be critical of both. You could see the lightbulbs going off."

THE MOTHER OF MODERN MANAGEMENT

PROVIDENCE, RHODE ISLAND | Imagine trying to manage a household of 12 children. Now imagine that it's the early 1900s and there are no dishwashers or clothes dryers to make life more convenient.

For working parents **Lillian and Frank Gilbreth**, who lived in a sprawling house in Rhode Island's capital city, their solution was an endless series of timed motion studies, captured on film with their own children as test subjects, to find the "one best way" to approach any chore. Their work at home and in businesses across the U.S. not only brought them fame in the popular literature through two books penned by their children, "Cheaper by the Dozen" and "Bells on Their Toes," but also earned Lillian the moniker "the Mother of Modern Management."

While Frank studied the technical aspects of worker efficiency, Lillian, who had a PhD in psychology from Brown University, focused on the human element. Writing extensively on employee satisfaction, she argued that more satisfied workers would naturally be more efficient and productive.

After Frank's untimely death at the age of 56, Lillian carried on with her research, consulting and teaching, following in her husband's footsteps by lecturing at Purdue University and consulting with companies around the country. A pioneer in ergonomics, she obtained patents for household items including the egg keeper and butter tray inside refrigerators — although she famously could not cook. While consulting with General Electric, she interviewed thousands of women, introducing the idea of a kitchen "work triangle" and redesigning spaces to accommodate various disabilities.

In 1935, Lillian became the first woman to achieve full professor status in Purdue's engineering program. Along with establishing a time-and-motion study laboratory in the School of Industrial Engineering, she lectured and consulted on careers for women.

Lillian retired from Purdue in 1948. Two decades later, at the age of 89, she became the first woman elected into the National Academy of Engineering.

WIKIMEDIA COMMONS

RISK

CAPE CANAVERAL, FLORIDA | Pioneering NASA astronauts **Virgil "Gus" Grissom** and **Roger Chaffee** shared a love of space exploration and a proud legacy as Purdue graduates. They were among the first of Purdue's 24 alumni to go into space, and lost their lives alongside fellow astronaut Edward White II in a quest to advance the nation's standing in the Cold War race to the moon. Grissom Hall and Chaffee Hall on the West Lafayette campus are named in their memory.

Grissom (BSME '50), a native of Mitchell, Indiana, was chosen in NASA's inaugural year (1959) as one of the original seven Mercury astronauts. The second American in space, he flew aboard Liberty Bell 7, which launched in 1961, and was the first person to enter space twice during the Gemini III flight in 1965.

Grissom enlisted as an aviation cadet during his senior year in high school, hoping to fly in World War II. He missed that opportunity because the war ended before he could train, but found his way back to the Air Force after graduating from Purdue. He served as a pilot in the Korean War, a flight instructor, and then as a test pilot before being recruited into the nation's new space program.

Chaffee (BSAE '57), from Grand Rapids, Michigan, was in the third group of astronauts, selected by NASA in 1963. The two Purdue graduates teamed together as members of the first Apollo flight, the mission to put man on the moon. Grissom, the commander, and Chaffee, a pilot on his first space flight, died along with White on January 27, 1967 in the Apollo spacecraft when a flash fire erupted during a launch pad test at Kennedy Space Center, Florida. They were unable to open the capsule's escape hatch and perished in the fire.

The son of a barnstorming pilot, Chaffee joined the U.S. Navy after graduating from Purdue, and served as a safety officer and quality control officer, logging more than 2,300 hours flying time, including more than 2,000 hours in jet aircraft. Both men knew the risks of their work.

"If we die, we want people to accept it," Grissom once commented. "We're in a risky business, and we hope that if anything happens to us it will not delay the program. The conquest of space is worth the risk of life."

SPACE EXPLORATION | GUS GRISSOM + EDWARD WHITE II + ROGER CHAFFEE

NASA

PHOTO BY VINCENT WALTER

SUSTAINABILITY | LEVON ESTERS

PARTNERING FOR DIVERSITY

NORMAL, ALABAMA | Food science. Biotechnology. Horticulture. Normal. Nashville. Greensboro. Last June, two dozen agricultural life sciences undergraduate and graduate students flew in from select universities across the U.S. for five days of professional development workshops and meetings with faculty members, graduate students and various affinity organizations. They were part of a project led by **Levon Esters**, an associate professor in agricultural sciences education and communication.

In partnership with several historically Black land-grant universities (HBLGUs) through the Mentoring@Purdue (M@P) Summer Scholars Program, Esters and his team aim to bring more underrepresented minority students to Purdue for advanced studies in agricultural life sciences. Last year, students visited from *Alabama A&M University*, *Florida A&M University*, *Langston University*, *North Carolina A&T State University*, *Tennessee State University,* *Tuskegee University,* and *Southern University and A&M College*. With the help of a $92,000 grant from the U.S. Department of Agriculture's National Institute of Food and Agriculture, Esters and colleagues have expanded the summer program that brings students from HBLGUs to Purdue to familiarize them with the graduate school setting. Through this grant, he and his colleagues also developed a resource guide that introduces the idea of graduate school early and offers tips for the application process.

Graduate school can help underrepresented minorities gain advanced skills necessary to address 21st century global grand challenges, says Esters, adding that greater participation from underrepresented populations is critical to developing innovations that address societal problems.

"There has been a lack of diversity in the STEM-based, agricultural, and life science disciplines, and we are developing strategies and mechanisms that will enhance or increase diversity. Our hope is to build a pipeline with these universities to Purdue to enhance diversity across the board," Esters says. "Having individuals with diverse perspectives that represent different racial and ethnic backgrounds also enhances our ability to tackle major global challenges."

HEALTH & LONGEVITY | HERMAN SINTIM + MOHAMED SELEEM

PHOTO BY VINCENT WALTER

TACKLING SUPERBUGS

ATLANTA, GEORGIA | From the CRE (carbapenem-resistant Enterobacteriaceae) bacteria in an NFL locker room in Atlanta to MRSA (Methicillin-resistant Staphylococcus aureus) in the neonatal intensive care unit in Irvine, California, superbugs have been sickening and even killing people from coast to coast at alarming rates in recent years.

At least two million people in the United States are infected with antibiotic-resistant bacteria every year, and one percent of those cases is untreatable. If new antibacterial drugs are not available soon, the annual death toll could swell to a projected 10 million globally by 2050, according to a review by the United Kingdom government.

Herman Sintim, the Drug Discovery Professor of Chemistry, and **Mohamed Seleem**, a professor of microbiology in the Department of Comparative Pathobiology in the College of Veterinary Medicine, have taken one significant step in tackling the growing problem.

Last year, they discovered a new molecule that, in initial testing, is as potent as other commercial antibiotics but less susceptible to resistance. The new drug treats two different drug-resistant pathogens, including drug-resistant Staphylococcus aureus infections. In its current form, it is already 32 times more potent than a common antibiotic that is no longer effective against certain strains of drug-resistant staph infections.

Sintim says that the innovation behind developing a new drug comes from evaluating an initial "hit," or compound, among thousands and deciding which one to develop. "Our lead compound has potency similar to fusidic acid, an antibiotic that is common in Europe for treating skin infections," he says. "And we hope to make it even better."

The researchers, both members of the Purdue Institute for Drug Discovery, are seeking partners to fund more testing. Ultimately, says Seleem, "we would like to modify our drug to have activity against other antibiotic-resistant pathogens."

IN KATRINA'S WAKE

GULFPORT, MISSISSIPPI | When Hurricane Katrina roared ashore on August 28, 2005, with 125 mph winds and 30-foot storm surges, it was Mississippi, not Louisiana, at ground zero. Plowing up the western half of the state, the tempest devastated town after town, leaving $30 billion of damage in its wake.

But while other studies after Katrina focused exclusively on the businesses that survived, **Sandra Sydnor, Maria Marshall** and **Holly Schrank** also wondered about the ones that didn't. Traveling a 10-county region several years after the hurricane, they cross-referenced business names from public records, and then hired the *University of Wisconsin Survey Center* to conduct telephone interviews of business owners. A total of 499 owners with either demised or operating businesses provided telephone responses.

Not surprisingly, businesses that ceased operations immediately were more likely to have experienced catastrophic building damage or a loss of inventory, crops, equipment or employees. However, businesses that reopened but eventually closed told a different story: weakened by exogenous shocks such as Katrina and the Deepwater Horizon oil spill in 2010, they were hit by endogenous factors as well, such as operational inefficiencies and cash-flow problems. "We call these cascading events, a series of smaller events that bring businesses to their knees," says Schrank, a professor emeritus.

It's easy to think that survival equates with recovery, says Marshall, a professor of agricultural economics and director of the Purdue Initiative for Family Firms. "But even some businesses operating up to a decade later were only open by the skin of their teeth," she says.

While contributing to the growing body of resilience literature, the team's framework expands on the idea of survival and demise, opening up the opportunity to really understand how both can take multiple paths — or occur in multiple ways — says Sydnor, associate professor of hospitality and tourism management.

The research was supported by the National Science Foundation's Civil, Mechanical and Manufacturing Innovation program and the USDA National Institute of Food and Agriculture.

PHOTO BY VINCENT WALTER

BRAIN-LIKE

DURHAM, NORTH CAROLINA | Advanced computers have beaten humans at high-level cognitive tasks, but they haven't yet beaten them in efficiency. Computers consume hundreds of thousands of watts of power; in contrast, the human brain requires only around 20 watts to complete similar tasks. Researchers at Purdue's Center for Brain-inspired Computing Enabling Autonomous Intelligence (C-BRIC) are focused on enabling a new generation of autonomous intelligent systems to perform brain-like functions with brain-like efficiency.

They are supported by $32 million from the Defense Advanced Research Projects Agency and the Semiconductor Research Corp. (SRC), a nonprofit research corporation rooted in Durham, North Carolina, via its Joint University Microelectronics Program (JUMP).

The team, which includes researchers from a consortium of universities, will develop neuro-inspired algorithms, architectures and circuits to enable intelligent autonomous systems for perception, reasoning and decision-making, which today's standard computing is unable to do efficiently, says **Kaushik Roy**, C-BRIC director and the Edward G. Tiedemann Jr. Distinguished Professor of Electrical and Computer Engineering.

The researchers represent expertise ranging from machine learning, computational neuroscience and theoretical computer science to neuromorphic hardware, distributed computing, robotics and autonomous systems.

"We are excited to bring together a multi-disciplinary team with expertise spanning algorithms, theory, hardware and system-building, which will enable us to pursue a holistic approach to brain-inspired computing, and to hopefully deliver efficiency closer to that of the brain," Roy says.

C-BRIC includes academic teams of researchers from *Pennsylvania State University*, *University of Illinois*, Massachusetts Institute of Technology, Princeton University, Georgia Tech, University of Southern California, Portland State University and Arizona State University.

PHOTO BY VINCENT WALTER

TECHNOLOGY | KAUSHIK ROY

SUSTAINABILITY | SONGLIN FEI

PHOTO BY VINCENT WALTER

WESTWARD HO

KNOXVILLE, TENNESSEE | Scientists have long believed that rising temperatures have caused many tree species to move north. And that's true, but not the whole story.

Songlin Fei, an associate professor in the Department of Forestry and Natural Resources, along with scientists from *North Carolina State University* and the U.S. Forest Service Southern Research Station in Knoxville, Tennessee, have shown for the first time that precipitation change is a major driver of tree migration. While most studies have linked temperature to tree movement, Fei and colleagues showed that declining precipitation in the southeastern portion of the country is pushing some tree species to the west.

The findings, based on an analysis of 86 eastern U.S. tree species, show that evergreen species are moving north in response to rising temperatures. But most deciduous trees, such as maple and oak, are following moisture to the west. This divergence of species movements will have a significant effect on the makeup of forests and is key knowledge for those tasked with protecting ecosystems and biodiversity in a changing climate, according to Fei.

"Trees are the foundation of a forest ecosystem. If they are changing, that affects not only wood products but also species that depend on these trees for habitats. This also has potential impacts on carbon, water and many other ecosystem services," Fei says.

"As these species diverge, we may need to change from managing particular species to managing forests as a whole."

Fei's research was supported in part by funding from the USDA National Institute of Food and Agriculture and the McIntire Stennis Cooperative Forestry Research Program.

CULTURALLY CONNECTED

ACOMA PUEBLO, NEW MEXICO | Geoscience education that is place-based and culturally relevant for nonmajority students could help Indigenous students connect their culture with the geology around them. That is the goal of **Darryl Reano,** a PhD candidate in the Department of Earth, Atmospheric, and Planetary Sciences and a member of the Acoma Pueblo in New Mexico. His work focuses on increasing the number of nonmajority students in STEM disciplines, especially the geosciences.

The geoscience education modules create connections between geology and the local community, giving a more robust understanding of how science applies to everyday life, Reano says. He has implemented these new modules at Heritage University on the Yakama Indian Reservation in the state of Washington, as well as in undergraduate geology classes at Purdue University.

Reano's aim is to implement and evaluate geoscience educational modules developed using Indigenous research frameworks. The frameworks highlight the cultural connections of Indigenous students to Western scientific concepts within introductory geoscience course materials. He says it pushes the boundaries between Indigenous knowledge systems and Western science, emphasizing accountability and ongoing maintenance of relationships developed among researchers, Indigenous community members, local governing bodies and other stakeholders.

"The geoscience education modules are about how we understand and interact with the world — including the morals, ethics and how we define reality. It's multi-logical, not one universal truth," says Reano, who presented his research at the 2018 American Geophysical Union Annual Meeting in Washington, D.C.

"The modules do not define connections between any particular culture and geology, but learners are instead empowered to develop their own reflexive understanding of how Western science impacts their unique life experiences."

PHOTO BY VINCENT WALTER

SUSTAINABILITY | DARRYL REANO

HEALTH & LONGEVITY | CHI HWAN LEE

PHOTO BY VINCENT WALTER

EYES ON YOUR HEALTH

STILLWATER, OKLAHOMA | People with diabetes may soon be wearing soft contact lenses that can multitask — improving sight, monitoring glucose levels, and delivering drugs to the eyes all at the same time. Other patients may be fitted with a skin-like electronic smart bandage that can monitor medical conditions. These high-tech steps towards personalized medicine are the work of **Chi Hwan Lee**, an assistant professor of biomedical engineering and of mechanical engineering and a member of Birck Nanotechnology Center in Purdue's Discovery Park.

Lee's research group focuses on the development of advanced printing technology that enables the production of various kinds of wearable bioelectronics. His projects include an electronic bandage that can monitor electrophysiological signals, eye-wearable healthcare systems such as the soft contact lenses, and bio-integrated nano-systems. His electronic bandage uses a mesh of conducting nanowires embedded in a thin layer of elastic polymer to mimic the elasticity and sensory character of skin.

The bandage was created using Lee's own patented controlled interfacial debonding process, which allows the physical separation of thin-film electronics from their native fabrication wafers. The separated thin-film electronics can be then pasted onto various kinds of receiver substrates. The flexible bandage material, developed in collaboration with researchers from *Oklahoma State University*, is superior to existing approaches using gold, silver and copper that are susceptible to fracture from over-stretching and cracking.

Lee's most recent work has led to a novel method for attaching thin film sensors and other small devices to commercial hydrogel-based contact lenses, opening the door for numerous advanced eye-care applications that include controlled release of ocular drugs, eye-wearable night vision and augmented reality.

"My work is dedicated to developing mechanically stretchable materials, mechanics and assembly techniques for creating a novel class of wearable biomedical devices that can address the important biomedical engineering challenges facing our society and the many people in need," Lee says.

Lee's research is funded in part by the Air Force Research Lab and the National Science Foundation's Division of Civil, Mechanical and Manufacturing Innovation program.

LIQUID FUEL

LUBBOCK, TEXAS | Shale hydrocarbons, which are plentiful in the United States, may be the key to lowering the cost of the nation's electricity, chemicals and fuels, while lowering CO_2 emissions and transforming the nation from an energy importer to a leading exporter of energy resources by 2030.

The U.S. has some of the largest shale deposits in the world — estimated to power the country for more than 100 years at current consumption levels. In fact, new deposits were discovered near Lubbock, Texas, in 2016 and near Santa Fe, New Mexico, in 2017. Researchers at the Purdue-led CISTAR (Center for Innovative and Strategic Transformation of Alkane Resources) are tapping into this resource and developing novel technologies to convert light hydrocarbons into higher-value petrochemicals and liquid fuels including jet fuel, diesel and gasoline.

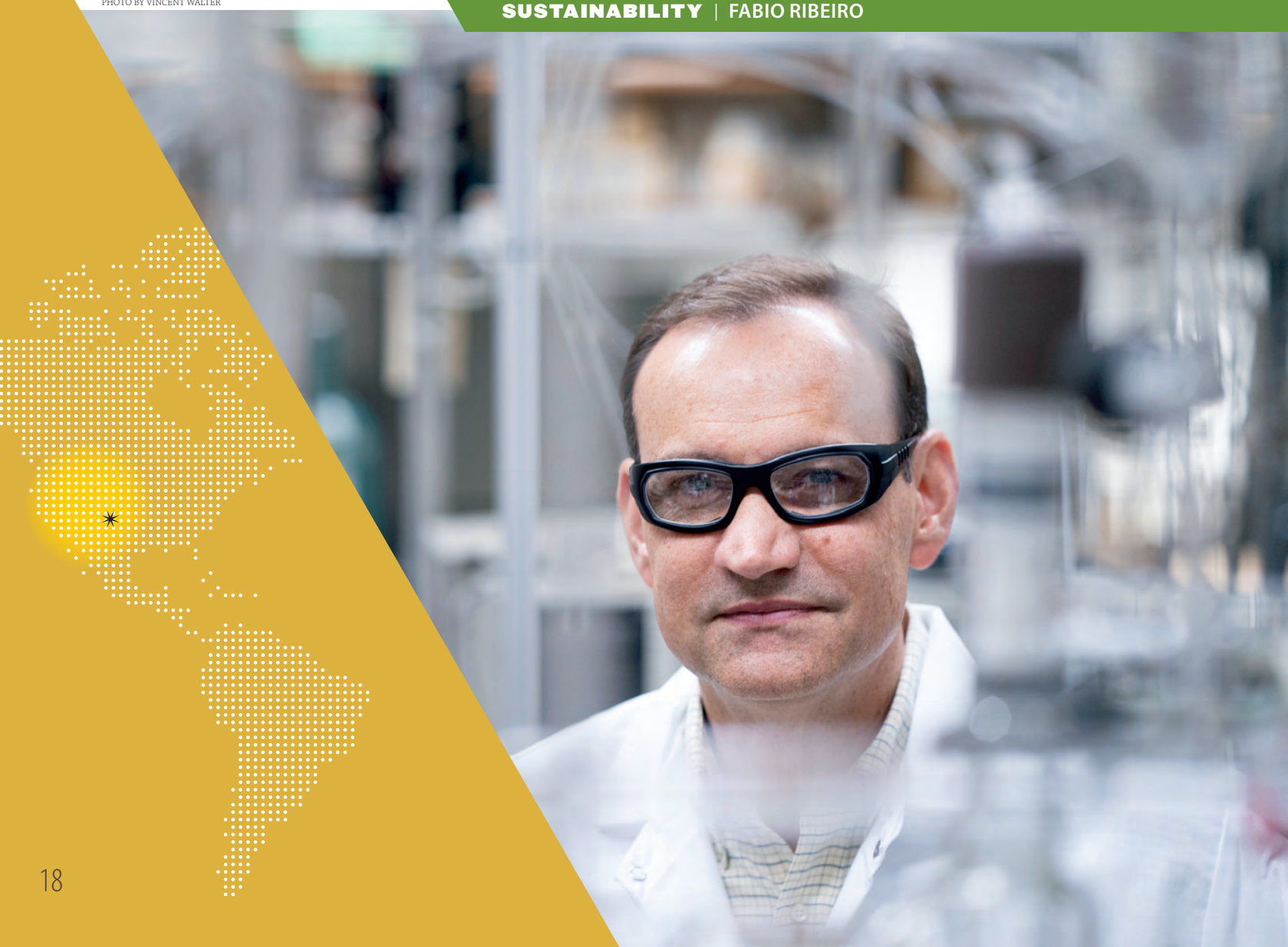
The researchers at CISTAR, a National Science Foundation Engineering Research Center (ERC), propose a new manufacturing model that may lead to more efficient alternatives to the current large refining and petrochemical plants. By situating advanced modular conversion units closer to the hydrocarbon source, the costly transportation of hydrocarbons may be alleviated. The conversion of light hydrocarbons to liquid fuels could inject $20 billion annually into the economy.

"We have a team of extraordinarily talented researchers focused on bringing to fruition new ideas that have the potential to convert, responsibly and efficiently, a huge but still underutilized hydrocarbon resource," says **Fabio Ribeiro**, CISTAR director and the R. Norris and Eleanor Shreve Professor of Chemical Engineering. "That will pave the way to a sustainable energy future."

The ERC includes researchers from the University of New Mexico, Northwestern University, the University of Notre Dame and the University of Texas at Austin, as well as partners from industry, national laboratories, and national and international research organizations.

PHOTO BY VINCENT WALTER

SUSTAINABILITY | FABIO RIBEIRO



SPACE EXPLORATION | BOILERS2MARS TEAM MEMBERS

PHOTO PROVIDED

DOWN TO EARTH

HANKSVILLE, UTAH | A team of Purdue students and alumni spent winter break 2017 on Mars — or the closest thing to it. They were suited up and lived in a small two-story habitat known as the Mars Desert Research Station (MDRS) in Utah.

The research station, which was built by the nonprofit Mars Society in 2001, includes an 8-meter-wide habitat, an astronomical observatory, a laboratory and a greenhouse. Crew members must wear flight suits — including air tanks and bulky gloves — whenever leaving the station for extravehicular research activities.

The facility is located in Mars-like terrain, an isolated area of red hills and canyons on the San Rafael Swell in south-central Utah, and allows field studies to be simulations of an actual space mission.

Boilers2Mars team members developed experiments including a study of human pathogen/plant interactions; a "lost astronaut" exercise that involved navigation via radio beacons; use of virtual reality for training; and a study of yoga for stress relief.

The crew spent 125 person-hours exploring the terrain, and covered a total of 138 kilometers in a rover. They also sequenced 636,445 strands of DNA from microbes in the habitat and collected 86 geological spectra.

Aspiring astronaut **Cesare Guariniello** (PhD AAE '16), a research associate in the School of Aeronautics and Astronautics now completing a master's degree in planetary geology, was the crew geologist. He investigated the suitability of certain minerals for resource extraction on Mars. Guariniello returned to MDRS in early 2019, leading another Boilermaker student and alumni mission to the faux red planet.

"MDRS is helping prepare us for future human exploration of Mars. By simulating long-term isolation of entire astronaut crews, we can work out better methods for living and operating on the Martian surface," says **Briony Horgan**, an assistant professor of earth, atmospheric and planetary sciences and one of the team advisers. **Marshall Porterfield**, a professor of agricultural and biological engineering, also advised the team.

PREDICTING PREDATORS

VENTURA, CALIFORNIA | A team comprising a psychologist, a machine learning expert, a digital forensics specialist and four students has created a tool to help law enforcement analyze internet chats between sex offenders and minors.

Chat Analysis Triage Tool (CATT) uses artificial intelligence to assess the likelihood of a suspect meeting a minor for a sexual encounter in the real world. Law enforcement agencies are typically overwhelmed with investigations into sexual predators and must often rely on gut feelings to predict which ones are most dangerous. CATT helps take much of the guesswork away, says **Kathryn Seigfried-Spellar**, assistant professor of computer and information technology and one of the principal investigators.

"We had this theory that they use a mechanism called self-disclosure to build trust: the sex offender will give a sad story and hope that the minor reciprocates," she says. "Self-disclosure is a natural part of healthy adult relationships, too; we tend to bond with other people through the events in our lives."

The team's observations come from an analysis of online conversations provided by law enforcement across the country. Using natural language processing software, they fed data into computers, which looked for patterns. Over time, as the software analyzed more and more data, it was better able to predict which of the offenders would seek an encounter in real life with their victims. Initially their work was done in partnership with the Ventura County Sheriff's Department, and then the researchers collaborated with other affiliates nationwide from the Internet Crimes Against Children task force program.

Another significant finding the team made during the software development phase: sexual predators know that they are being monitored and will try to disguise key words that officers are scanning for. "Some of the words that are being used are not real words," says co-PI **Julia Taylor Rayz**, associate professor and assistant head of the Department of Computer and Information Technology. "The predators know that the cops are there to catch them and they are using computerized techniques. They try to misspell words and pull words together."

Because CATT is searching for the language of intent, not simply key words, it's designed to outsmart even the most sophisticated of predators. As the tool expands into more law enforcement communities, the amount of data will continue to grow, allowing the team to capture variations in dialect and regional differences in predator strategy.

Marcus Rogers, a professor of computer and information technology with extensive experience in digital forensics tool development, is also involved in the research. All three investigators are part of the Purdue Polytechnic Institute.

PHOTO BY VINCENT WALTER

TECHNOLOGY | MARCUS ROGERS + KATHRYN SEIGFRIED-SPELLAR + JULIA TAYLOR RAYZ

QUANTUM LEAPS

REDMOND, WASHINGTON | Headquartered in a forested basin north of Seattle, Microsoft Corp. rose to prominence during the personal computer boom of the 1980s. Nestled in the fertile lowlands of northern Indiana, Purdue University was the first college in the United States to establish a computer science department, which it founded in 1962. Together, these two institutions are aiming to bring quantum computers out of the lab and into the world through the development of a "topological qubit."

Michael Manfra, the Bill and Dee O'Brien Chair Professor of Physics and Astronomy, professor of materials engineering and professor of electrical and computer engineering, is leading the multi-year, multi-million-dollar project at Station Q Purdue, one of Microsoft's six international research sites for quantum computing.

"Try to remember the world before digital computers and how different the world is today. Twenty years after the realization of quantum computers, the world will change just as much," Manfra says. "We have to break new ground in science to make this technology. It's not just about applying the ideas that already exist and making them more efficient — it will be a revolutionary change."

Station Q Purdue is part of Microsoft's worldwide collaborative effort to build a topological quantum computer that is robust against decoherence, the loss of information before computation is complete. In theory, the scalable topological quantum computer that Purdue and Microsoft are developing will be more stable and accurate than the quantum technologies of today.

"Our expertise here at Station Q Purdue is materials physics," Manfra says. "We know how to design, make and measure materials with the special topological properties that shield against decoherence. My hope for the Microsoft program is that within a year's time we have a well-demonstrated topological qubit, which would be a major scientific accomplishment."

TECHNOLOGY | MICHAEL MANFRA

PHOTO BY VINCENT WALTER

COWBOY IN THE CLOUDS

CHEYENNE, WYOMING | Aviation pioneer and Purdue graduate **Ralph S. Johnson** was a maverick of the skies, a cowboy in the clouds. He was also an engineer who dedicated his life to making sure flight was safe for everyone else.

Born in June 1906 in Goodland, Indiana, Johnson came into the world just three years after the Wright brothers made history's first flight. He worked his way through Purdue as a food service employee and joined the U.S. Army Air Corps as a pilot after graduation. From 1935 to 1947, he was chief test pilot for United Airlines — making more than 7,000 test flights — at the company's maintenance base in Cheyenne, Wyoming.

Johnson's gifts to aviation included a method of deicing planes, a checklist that standardized cockpit procedures, and a landing technique still in use. His stabilized approach to landing opened the door for commercial passenger flight by making landings safer and less scary for the average citizen. Some of these inventions paved the way for modern space flight as well.

When United moved its base to San Francisco, Johnson opted to stay in Wyoming, where he developed spraying equipment that was used to adapt warplanes for use in agriculture aerial applications. He also started several businesses, including Aeronautic Services Corp., Master Equipment Corp. and Teton National Insurance Co., and served two terms in the Wyoming State Legislature.

In addition to a long career in the aviation industry, Johnson owned a variety of surplus WWII aircraft, operating an entire squadron of 22 of them from three main bases in Georgia, Arizona and Wyoming, and reportedly bombing fire ants and forest fires until the age of 82. He died in 2010 at the age of 103.

Johnson's personal papers are located in Purdue University Archives and Special Collections. In the article "Happy Landings" for the Purdue Journal of Undergraduate Research, Matthew Meyer (BA '16, history) included the following statement from the aviation great about what spurred his many innovations: "Nothing was reliable then. That's what interested me most in aviation, so I dedicated my life to trying to eliminate unfortunate variables related to aviation, and trying to improve every facet of flying."

PURDUE ARCHIVES AND SPECIAL COLLECTIONS

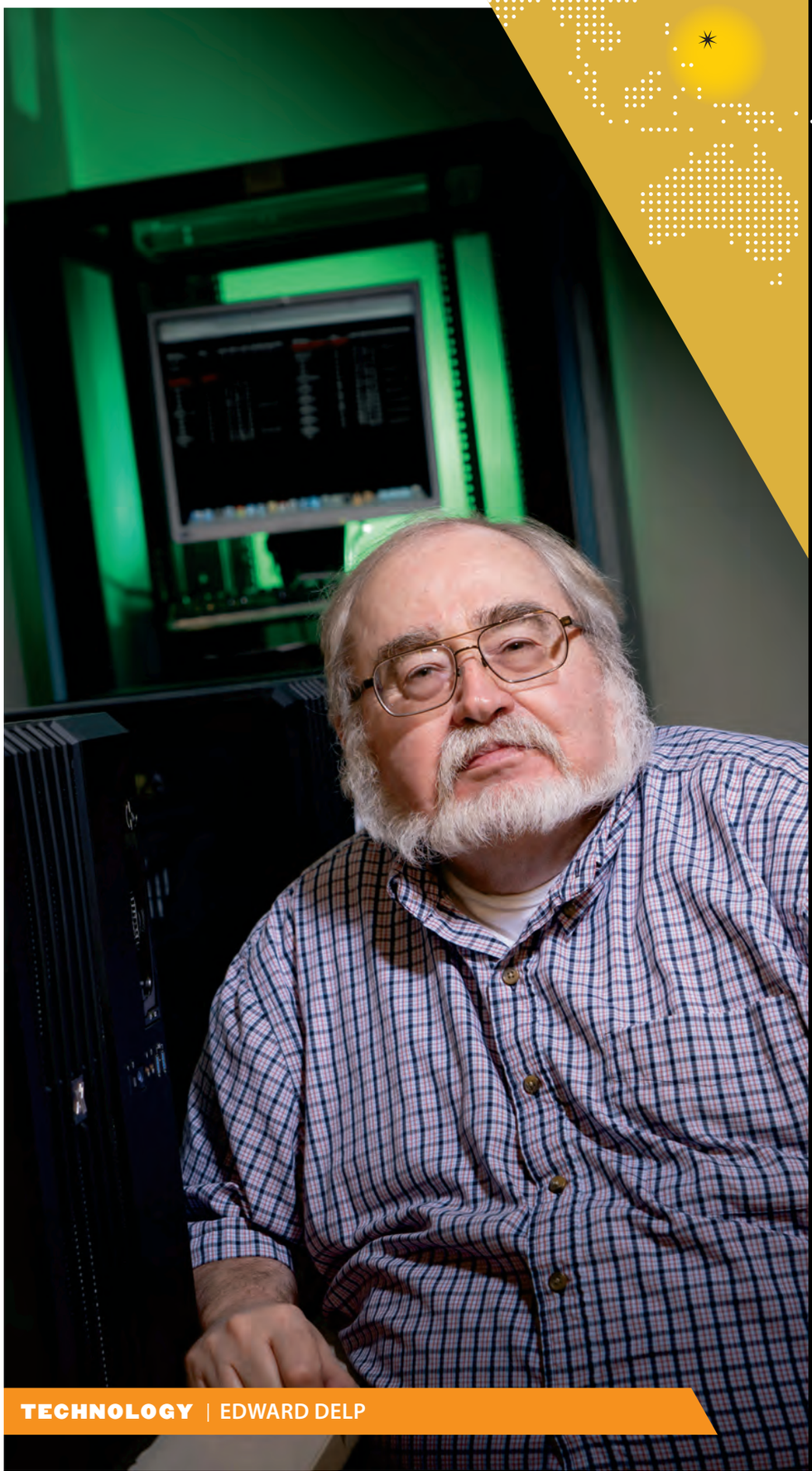
PICTURE THIS

MANGILAO, GUAM | By putting mobile devices into the hands of children as young as 3, researchers are able to get a more accurate picture of their dietary habits — literally. The technology allows young subjects to take pictures of the food they are eating, which provides valuable dietary information for researchers.

Edward Delp, the Charles William Harrison Distinguished Professor of Electrical and Computer Engineering, professor of biomedical engineering and professor of psychological sciences, has teamed for the last decade with nutritionist Carol Boushey, formerly of Purdue and now at the *University of Hawaii* Cancer Center, to develop the mobile dietary assessment tool. Known as the Technology Assisted Dietary Assessment (TADA) system, it consists of a cellphone app that allows users to take images of their food at a meal. The images are then analyzed, and researchers can tell what type of food was on the plate and the amount.

One of the team's mobile food-record studies was conducted in collaboration with the *University of Guam* and focused on children ages 3 to 10 attending summer day camps there. The mobile tool was used to evaluate the outcome of an intervention to increase fruit and vegetable intake, especially fruits and vegetables locally grown in the U.S. island territory, such as mangoes, muskmelon, peppers and long beans. The results showed that children were able to successfully use the mobile device, although kids under the age of 6 needed adult prompting. Studies have also been conducted in locations ranging from Australia to the United States and have included adolescents.

"The current generation of children, born into the digital age, lends to a high level of technology readiness. Use of technologies, such as web- and mobile-based applications, may address many of the barriers to gathering accurate dietary data from children," the researchers report.



TECHNOLOGY | EDWARD DELP

PHOTO BY VINCENT WALTER

PHOTO BY VINCENT WALTER

TRAVEL IN THE AGE OF ZIKA

SAN JUAN, PUERTO RICO | From the cobblestone streets of the Old San Juan barrio to the pink sand beaches of Isla Verda, Puerto Rico's capital city is a popular destination for American tourists. But in 2016, as the Zika virus reached its zenith and the effects of the disease, including birth defects, came to light, those considering travel to the Caribbean and other affected areas were naturally concerned.

Purdue economists recognized that there were multiple layers to the Zika problem besides health concerns. The economies of many of the locations that were most threatened by the virus relied heavily on tourism. If Zika scared people away, it would be right at the time those destinations most needed a boost to help fund public health protections.

Nicole Widmar, professor of agricultural economics, and **Wally Tyner**, the James and Lois Ackerman Professor of Agricultural Economics, found that Americans most educated on Zika were also the most likely to travel. And those Americans reported concerns about traveling to areas in the United States known to be affected by the virus or thought to be a risk, including Puerto Rico, Texas and Florida.

The data they gathered also showed that despite concerns about Zika, most Americans don't protect themselves from mosquitoes, which carry a host of other serious diseases. That information suggests public health officials should develop new methods to educate Americans about the risks posed by mosquitoes not only abroad but also here at home.

"There is a good amount of Zika awareness in the U.S., but the same people worried about traveling to Zika-affected countries aren't preventing bites here at home," Widmar says. "From a public health standpoint, we can and should do more to inform people about prevention."

FOOD FOR BILLIONS

SHANGHAI, CHINA | In the last four decades, undernourishment in China has fallen dramatically as the country's economy has exploded. But with only 0.19 acres of arable land per capita and an expected population growth of 25 million by 2050, China — like the rest of world — will need crops that not only offer higher yields but also can withstand the stresses of a changing climate.

Often, however, the genes that allow a plant to deal with heat, drought or salinity are also tied to growth. Getting one has, in the past, meant sacrificing the other.

Now, Purdue plant scientists **Jian-Kang Zhu** and **Ray A. Bressan** have found a way to obtain both.

Using a new kind of gene-editing technology called CRISPR, they modified combinations of 13 different genes in a rice plant that are known to affect stress tolerance and plant growth. One of the varieties improved rice yield by as much as 31 percent in field trials with little effect on other characteristics.

The same results from more traditional breeding techniques could have taken decades. Zhu, a distinguished professor of plant biology; Bressan, distinguished professor of horticulture and landscape architecture; and colleagues at the Chinese Academy of Sciences achieved their results in two years.

"Combined with major, inevitable increases in the consumption of animal food products, global food security will be challenged if we are going to add as many as 3 billion more people to the planet," Bressan says. "There is presently not enough unfarmed arable land available to meet the challenge. We require new technologies to both increase caloric yields of present farmland and to produce calories on unfarmed, 'marginal' land. This work has demonstrated the potential of CRISPR to address those food security issues."

PHOTO BY JOHN UNDERWOOD

SUSTAINABILITY | RAY A. BRESSAN + JIAN-KANG ZHU

PHOTO PROVIDED

SUSTAINABILITY | JONATHON DAY

GREENER PASTURES

YOPAL, COLOMBIA | Nestled in the foothills of the Cordillera Oriental and resting at the edge of Colombia's vast green prairies, Yopal is a bustling city known for its white herons, natural water pools and tree-lined streets. Like the rest of the country's Orinoquía region, this metropolitan oasis is awakening after 50 years of conflict and preparing to welcome new visitors with the help of Purdue University.

A team of students led by **Jonathon Day**, an associate professor of hospitality and tourism management, collaborated with the people of the Orinoquía to ensure that the benefits of tourism would spread across the region — especially to small towns and microbusinesses — where residents are building new, post-conflict lives. The Purdue team also advised how to avoid the potential negative impacts that tourism can bring to small communities.

"In working with the people of the Orinoquía, we wanted to ensure the best possible outcomes," Day says. "Sustainable tourism is about making sure we look after the environment, our societies and people while we are growing the economy."

Day is part of a Purdue-Colombia initiative that began in 2016 to create a master plan for the Orinoco River watershed of eastern Colombia. Working side by side, Day's team and its Colombian counterparts have generated a plan for developing Yopal and nearby municipalities as a tourism destination, created a market framework for the entire Llanos ("The Plains") region of Colombia, and designed and integrated a tourism supply chain involving small- and medium-sized businesses.

"The work we do in sustainable tourism is designed to increase the economic side of things and also ensure a location is as appealing tomorrow as it is today," says Day, whose students have also supported similar sustainable tourism projects in Nepal and Indonesia. "Consumers are asking for authentic experiences. And by good fortune, those are the same sorts of experiences that often have the most benefit for the destination as well."

DRY SPELL

SAN ISIDRO, EL SALVADOR | Bounded by the Pacific Ocean to the south, El Salvador was once a lush landscape with plenty of water for its citizens. Today more than 90 percent of surface water is contaminated, and springs and other water sources are increasingly running dry as its burgeoning population competes for limited resources.

The residents of San Isidro in El Salvador have been in a decades-long battle over water rights that became deadly when community activists were killed as a result of their work to save local waters. The Purdue Peace Project (PPP) is now preparing to embark on a collaboration with local citizens in San Isidro to build social cohesion and prevent further violence related to water issues.

Stacey Connaughton, an associate professor in the Brian Lamb School of Communication and director of the PPP, first visited San Isidro in 2016 to begin building relationships with local, regional and national actors from multiple sectors. She has returned several times since.

The Purdue Peace Project is a University-based political violence prevention initiative with a mission to convene groups of local citizens and leaders in areas where clearly identified situations threaten to lead to political violence, and to encourage and assist these citizens in their efforts to bring about peaceful solutions.

"Tensions and conflicts often emerge around the issue of water, specifically local citizens' ability to access clean water. Tense relationships between different groups spill over into tensions during political campaigns and other facets of society," Connaughton says. "We hope that the chief impact of our collaborations in San Isidro will be the creation of a sustained network of diverse local individuals whose collaborations together can be shown to help reduce violence in their community now and in the future."

SUSTAINABILITY | STACEY CONNAUGHTON

PHOTO PROVIDED

FASTER IMAGING, BETTER DRUGS

HYDERABAD, INDIA | In drug discovery, researchers often use the light-scattering technique called Raman microspectroscopy to create images of the signature vibrations or "fingerprints" emitted by molecules. By imaging a molecule's emission on the electromagnetic spectrum, they can determine the crystal forms of pharmaceutical materials, which affect how quickly therapeutic molecules can dissolve and distribute throughout the body.

The technique is useful for characterizing new drugs, nanoparticles and tissue samples for cancer screens. But although sophisticated, it is slow, taking several minutes to hours to map the molecular composition pixel by pixel.

Teaming up with researchers at Dr. Reddy's Laboratories in Hyderabad, India, **Charles Bouman**, a professor of chemical and electrical engineering; **Garth Simpson**, a professor of analytical and physical chemistry; and **Gregery Buzzard**, a professor of mathematics, sought to speed up the technique by incorporating machine learning.

Similar to the board game, Battleship, their algorithm uses a few informative "hits" to target the most promising pixels to sample next. To test their approach, the researchers used the formula for a generic heart medication. In contrast to existing methods, their new one cut down Raman imaging time from 13 to two hours by reducing necessary sampling six-fold.

"By using this approach, manufacturers will be able to come up with more efficacious drugs faster and with longer shelf lives," predicts Simpson, who is also a member of the Purdue Institute for Drug Discovery.

The dynamic sampling technique is similar to what our brains do when we look at a room, says Bouman. "We look at the most important features and bounce back and forth, but our instruments typically take measurements from left to right," he says. "It's really the worst way, but by taking a few smart measurements, you can determine the most important place to take information next, more efficiently."

HEALTH & LONGEVITY | GARTH SIMPSON + GREGERY BUZZARD + ZHENGTIAN SONG + CHARLES BOUMAN

PHOTO BY VINCENT WALTER

PHOTO BY VINCENT WALTER

TECHNOLOGY | TOM HERTEL | front

Also pictured, seated right to left | Laura Bowling, Dominique van der Mensbrugghe, Jungha Woo, Lan Zhao, Iman Haqiqi, Jing Liu | Standing right to left | Uris Baldos, Johnathan Buzan, David Johnson, Matthew Huber, Carol Song

GLOBAL TO LOCAL TO GLOBAL

POTSDAM, GERMANY | Today our planet sustains more human life than ever before. By 2050, the global population is estimated to reach staggering new heights, just short of 10 billion. The United Nations' Sustainable Development Goals (SDGs) are an appeal to all nations to tackle this global grand challenge.

Of the 17 goals laid out by the UN, eight are closely tied to water, food and land. Can the future demands for food, fuel, clean water, biodiversity, climate change mitigation and poverty reduction be reconciled?

That is precisely the question that **Tom Hertel** seeks to answer. Hertel, distinguished professor of agricultural economics, maintains that sustainability is fundamentally a local concept, yet is driven by global forces. Pursuit of the SDGs will also have global consequences, and analysis of these complex issues requires what is called a global-to-local-to-global approach.

In fall 2017, Hertel co-hosted a workshop on university engagement with the SDGs as part of the Impacts World 2017 Conference in Potsdam, Germany. In this industrial city southwest of Berlin where over 450 participants had gathered from 68 countries, Hertel and Matthew Huber, professor of earth, atmospheric and planetary sciences, emphasized the need for academic institutions to employ open source, community-building approaches at local, national and global levels.

Hertel has already applied those principles to a research consortium he has built at Purdue. GLASS (Global to Local Analysis of Systems Sustainability) is designed to bridge local sustainability solutions with global drivers and consequences through data analysis and sharing. Leveraging Purdue's collaboration platform GeoHub, team members have created an online community where registered users can build upon each others' work. "It's a good place for collaborating on models. It's a good place for publishing your data and maps and comparing the results. And it's a good place for posting policy briefs that analyze tradeoffs and synergies," says Hertel, who, along with Huber and other collaborators, is also developing a virtual research center with three institutions in China to create more sustainability models.

SUSTAINABILITY IN A BAG

NAIROBI, KENYA | Farmers in Kenya may lose as much as 30 percent of their harvested crops each year, much of it to insect infestations and aflatoxins during storage after harvest. The country's president has made solving the problem a significant portion of his "Big Four" agenda to drive the country's near-term development, and Purdue scientists are playing a major role.

The Purdue Improved Crop Storage (PICS) team is working with the Kenyan government and development partners to improve access to its triple-bag technology. Invented by **Larry Murdock**, distinguished professor emeritus, the bags create a hermetic environment that prevents the growth of mold and kills the insects that would otherwise multiply and destroy the stored grain.

Supported by several Bill & Melinda Gates Foundation and USAID grants, the PICS team has introduced the technology to dozens of African and Asian countries, including 5 million farmers in 56,000 villages. More than 18 million bags have been sold by the private sector over the last decade, around 4 million in 2018.

Research has shown the bags can be used to store cowpeas, common beans, maize, sorghum, rice, wheat and many other crops. The PICS team has also found ways to improve manufacturing and supply chain logistics to increase access to the technology.

Now, PICS Global, a new private company leading the commercialization of the PICS technology, is exploring licensing deals that would improve farmers' access to the bags around the world, including Kenya, other parts of Africa, Asia, the Caribbean, and Central and South America.

"We want to improve the livelihoods of smallholder farmers and consumers in developing countries," says **Dieudonné Baributsa**, PICS director and an associate professor of entomology in the College of Agriculture. "We should be able to help them benefit from what they produce and improve their income, food security, nutrition and health."

PHOTO BY OREN DARLING

SUSTAINABILITY | DIEUDONNÉ BARIBUTSA + LARRY MURDOCK

MISSING LINKS

OSLO, NORWAY | Long before the characteristic tremors, slowness and stiffness of Parkinson's disease begin to show, damage to the brain has already begun from a protein called alpha-synuclein, which spreads from brain cell to brain cell, killing neurons in its wake. Treatments can relieve symptoms temporarily but are helpless to stop the disease from progressing further.

New hope could be on the horizon, however, from the unlikeliest of places: an asthma inhaler.

An international team of scientists that included **Jean-Christophe "Chris" Rochet**, professor of medicinal chemistry and molecular pharmacology, examined epidemiological data from the Norwegian Prescription Database (NorPD), a catalog of all prescribed drugs dispensed at pharmacies to people in Norway since 2004. Evaluating over 100 million Norwegian prescriptions for a common asthma medication, albuterol, for a period of 11 years, they found that the use of albuterol cuts the risk of developing Parkinson's disease in half. The research, published in Science, was recognized by Technology Networks as one of the top 10 drug discoveries for 2017.

The discovery could help lead to the prevention of Parkinson's disease. "The burning need for Parkinson's disease is to develop strategies to stop the underlying nerve damage," says Rochet, who is also the director of the Purdue Institute for Integrative Neuroscience. "All that exists for patients is an assortment of symptomatic therapies that help manage symptoms for a period of time, but these drugs, although they are in a sense miracle drugs, stop working because we can't stop the underlying nerve degeneration."

Rochet's work focuses on identifying molecules that can prevent alpha-synuclein proteins from forming harmful clusters that kill neurons. He hopes to help develop a usable drug that will stop Parkinson's disease from progressing. Albuterol had previously never been examined for a relationship with Parkinson's disease, and Rochet plans to continue examining other currently available medications for these missing links.

PHOTO BY VINCENT WALTER

AT THE NEXUS

AREQUIPA, PERU | Hovering at 7,500 feet above sea level and bordered by three volcanoes, the city of Arequipa presides over the surrounding region of the same name, a province with fertile soils and rich copper and molybdenum deposits. But while the region's natural resources have spurred economic and social growth, mining and farming have taken a toll on this southwestern area of Peru, threatening its future.

Looking for constructive solutions, officials with the Universidad Nacional de San Agustín (UNSA) in Arequipa turned to the Center for the Environment (C4E) in Purdue's Discovery Park for assistance. Together, the two have created the Arequipa Nexus Institute for Sustainable Food, Energy, Water and the Environment.

Modeled after Discovery Park, the institute could lead to a culture of next-generation sustainability thinking that other developing economies could model as well, says **Tim Filley**, C4E director; professor of earth, atmospheric and planetary sciences; and a professor of agronomy.

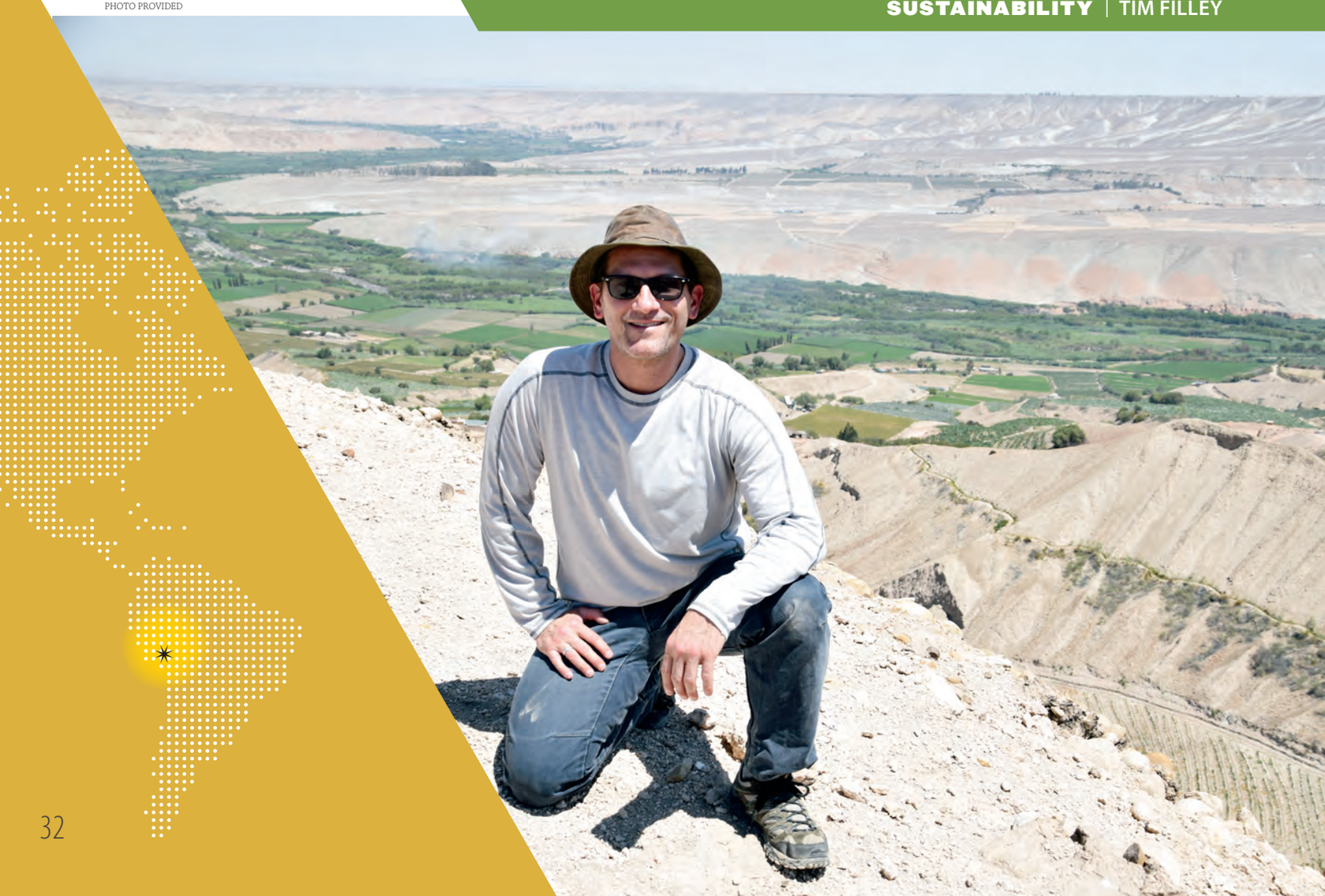
"The vision for the institute and this first phase of research support is more than a collection of research and capacity-building projects. It's a deeply intentional research network for addressing past, present and future linked socio-economic and environmental challenges," Filley says. Its core idea, which it shares with Discovery Park, is that science-based decision-making is essential to a sustainable and profitable future.

Since the institute's launch in spring 2018, the partners have been creating a research infrastructure and setting up interdisciplinary projects that integrate the social and physical sciences to address challenges in food security and safety, water quality, energy efficiency and soil health. Among the initial projects: strengthening Arequipa's grape and wine industry through advancements in sustainable agriculture; designing net-zero energy buildings; and creating robotic water-quality monitoring and distribution systems.

In the future, the Purdue-UNSA team plans to create a Nexus Institute building in the Majes agricultural valley of Arequipa to house the research activities. It will be equipped with state-of-the-art instrumentation, conference facilities and residential quarters for visiting scientists.

PHOTO PROVIDED

SUSTAINABILITY | TIM FILLEY



TOP OF THE WORLD

AOSTA VALLEY, ITALY | In bygone days, women might be arrested for wearing pants in public. Fortunately, **Annie Smith Peck** escaped such a charge when she donned a tunic, climbing boots and pants to scale the 14,692-foot Matterhorn in the Alps in 1895.

That feat was but one of her daring adventures, which spanned education, mountaineering, lecturing and suffrage work — even planting a votes-for-women flag at one peak.

Born in 1850 in Rhode Island, Peck rebelled against tradition at a young age, advocating for women's equality and suffrage. She applied to Brown University, attended by her father and brother, but was denied admission because of her gender. Instead, she earned a teaching degree in 1872 at Rhode Island Normal School, taught school and then was the first woman admitted to the American School of Classical Studies in Athens, Greece.

Still yearning for a full university degree, she next enrolled at the University of Michigan, where she earned a bachelor's degree with honors and, in 1881, her master's.

Coveted degrees in hand, she accepted a post that same year at Purdue University. She taught Latin and elocution for the next two years. At Purdue, she heard a male professor lecture on his Matterhorn climb, proclaiming that "women would be forever banned because of their weaker conditions."

Rising to the challenge in 1883, Peck began a quest to climb the world's mountains.

She spent the rest of her life combining mountaineering with education and writing. Her travel books and lectures, infused with the knowledge of archaeology and anthropology, promoted Pan-Americanism (peace among the Americas) and geographic education.

She reached her first summit in 1888, becoming the first woman to ascend California's Mount Shasta. Others, among many, included an 1897 first-woman climb of Mexico's Pico de Orizaba and Mount Huascarán in Peru in 1908, achieving a record altitude for any person in the Western hemisphere. Its northern peak was named Cumbre Aña Peck in her honor.

Her last climb, at age 82, was Mount Madison in New Hampshire. The former Boilermaker educator died in New York in 1935 at age 85.

PURDUE ARCHIVES AND SPECIAL COLLECTIONS

SUSTAINABILITY | Annie Smith Peck

KENNETH FERRARO

PEIDE YE

FERRARO PRESENTED WITH LU ANN ADAY AWARD

The university's highest honor in humanities and social sciences, the Lu Ann Aday Award, was presented to **Kenneth Ferraro** in 2018 for his innovative work and impactful contributions to the fields of sociology and gerontology.

Ferraro, a distinguished professor of sociology and director of the Center on Aging and the Life Course in the College of Liberal Arts, is a pioneer in research on aging and health. His research has shown that dysfunctional conditions during childhood and adolescence substantially increase the risk of heart disease, cancer and other chronic and acute illness later in life.

"Dr. Ferraro's work provides authoritative evidence for informing public policy," said Suresh Garimella, executive vice president for research and partnerships.

The Lu Ann Aday Award was established in 2017 by Purdue alumna Lu Ann Aday, the Lorne D. Bain Distinguished Professor Emerita in Public Health and Medicine at the University of Texas School of Public Health-Houston. The recipient is selected by faculty representatives from the humanities and social sciences and is approved by the Purdue president and executive vice president for research and partnerships.

YE RECEIVES ARDEN L. BEMENT JR. AWARD

The Arden L. Bement Jr. Award was bestowed upon **Peide Ye** in 2018 for his field-defining work in synthesizing and applying novel electronic materials to achieve record device performance. Each year, the Bement Award is given in recognition of a Purdue faculty member for recent outstanding accomplishments in the pure and applied sciences and engineering.

Ye, the Richard J. and Mary Jo Schwartz Professor of Electrical and Computer Engineering in the College of Engineering, is recognized nationally and internationally for his work in semiconductor technologies and is credited with a series of research breakthroughs. Each one was significant enough to be deemed "field-defining."

"Dr. Ye continually breaks through the boundaries in microelectronics, and the outcomes definitively impact the performance of our computing technologies," said Suresh Garimella, executive vice president for research and partnerships.

The Arden L. Bement Jr. Award was established in 2015 by Arden Bement, distinguished professor emeritus, and his wife, Louise Bement. The recipient is approved by the Purdue president and executive vice president for research and partnerships, following committee review of colleague nominations.

DUDAREVA HONORED WITH HERBERT NEWBY MCCOY AWARD

Purdue University named **Natalia Dudareva** as the recipient of the 2018 Herbert Newby McCoy Award for her significant breakthroughs in plant biotechnology. The award is Purdue's most prestigious recognition in the natural sciences.

NATALIA DUDAREVA

A distinguished professor in the Departments of Biochemistry and Horticulture and Landscape Architecture, Dudareva revealed that active biological mechanisms are involved in transporting plant volatiles (scents) from plant cells to the atmosphere, a process formerly thought to occur solely by diffusion. These biosynthetic pathways underpin plants' strategies for attracting pollinators; communicating with other plants; and defending themselves from pathogens, parasites and herbivores.

"Dr. Dudareva's research findings have disrupted conventional wisdom, leading to profound implications for plant health and productivity with a resulting impact on commercial crop and plant industries," said Suresh Garimella, executive vice president for research and partnerships.

The Herbert Newby McCoy Award was established in 1964 by Ethel Terry McCoy in honor of her husband, a distinguished Purdue University alumnus. The recipient is approved by the Purdue president and executive vice president for research and partnerships, following committee review of colleague nominations.

GARIMELLA ELECTED FELLOW, NATIONAL ACADEMY OF INVENTORS

Suresh V. Garimella, executive vice president for research and partnerships and the R. Eugene and Susie E. Goodson Distinguished Professor of Mechanical Engineering, was chosen in 2018 as a fellow of the National Academy of Inventors (NAI).

Fellows of the NAI are inventors of U.S. patents who have been nominated by their peers for outstanding contributions in patents and licensing, noteworthy discovery, significant effect on society, and support and enhancement of innovation.

Garimella's research group has filed at least 16 successful U.S. patents, including one for modular jet impingement cooling apparatuses with exchangeable jet plates and methods. The patented work was filed by the National Science Foundation Compact, High-Performance Cooling Technologies Research Center (CTRC), which Garimella founded in 1999 and serves as its director.

"Contributing to society through inventions that lead to patents is extremely gratifying, and I've been fortunate enough to work with creative students, collaborators and sponsors who have made this work possible," Garimella said.

SURESH V. GARIMELLA

EJETA APPOINTED CHAIR OF THE WORLD FOOD PRIZE LAUREATE SELECTION COMMITTEE

The World Food Prize Foundation in 2018 appointed **Gebisa Ejeta,** distinguished professor of agronomy, executive director of the Purdue Center for Global Food Security, and 2009 World Food Prize Laureate, as chair of the organization's Laureate Selection Committee.

Ejeta will guide the committee in selecting the World Food Prize winner each year. Only two other individuals have held the position: Norman Borlaug, founder of the World Food Prize,

GEBISA EJETA

LINDA WANG

and M.S. Swaminathan, the prize's first recipient.

Ejeta earned his PhD in plant breeding and genetics from Purdue University. In the ensuing decades, his work with sorghum and plant genetics has taken him around the world and across disciplines.

In 2009 Ejeta received the World Food Prize for his development of sorghum hybrids resistant to drought and Striga, a parasitic weed native to Africa, Asia and Australia, which devastates crops like sorghum.

CHEMICAL ENGINEERING RESEARCHERS WIN AT 2018 MOBILE WORLD CONGRESS

A chemical engineering research team headed by **Linda Wang** received a silver prize in the 2018 Mobile World Congress Scholar Challenge for its project, "Waste Coal Ash Could Provide Wealth of Rare Earth Elements."

Wang, the Maxine Spencer Nichols Professor of Chemical Engineering, and graduate students Hoon Choi, David Harvey and Yi Ding were honored during the Mobile World Congress meetings in Barcelona, Spain.

Rare earth elements, which largely consist of Lanthanides (Lns), a series of 15 metallic elements, are essential components of cellphones and other electronics. Wang's team is developing new efficient and inexpensive technologies that could allow the extraction of rare earth elements from waste coal ash. The innovation could enable the U.S. to enter the $4 billion rare earth element production market while recycling coal ash in an environmentally friendly way.

BERTINO ENTERS ISSA HALL OF FAME

Elisa Bertino, the Samuel D. Conte Professor of Computer Science, was elected in 2017 to the Information Systems Security Association's (ISSA) Hall of Fame.

Bertino, who is also the director of the Cyber Space Security Lab (Cyber2Slab) and the research director of CERIAS (the Center for Education & Research in Information Assurance & Security), leads a large number of research projects. Her work focuses on the security of the Internet of Things (IoT), data security and privacy on the cloud, data trustworthiness, protection from insider threat, digital identity management, and privacy and security for mobile systems. She also leads research projects in cyberinfrastructure for scientific research.

ISSA's Hall of Fame selection is a lifetime achievement award that recognizes individuals who demonstrate exceptional qualities of leadership in their own career, as well as an exemplary commitment to the information security profession.

THREE DESIGNATED AS AAAS FELLOWS

With accolades for their notable achievements in science, three Purdue professors in 2017 became fellows of the American Association for the Advancement of Science, the world's largest multidisciplinary general scientific society. They were among the 396 named worldwide for their efforts in furthering scientifically or socially distinguished science applications for the benefit of all people.

Sylvie M. Brouder, professor of agronomy, the Wickersham Chair of Excellence in Agricultural Research, and an Extension educator, specializes in the study of plant nutrition, nutrient management and cropping systems. She was recognized for her distinguished contributions to the field of plant nutrition and agroecology, particularly for rigor in developing evidence-based practices and knowledge translation for agricultural sustainability. Her recent research has explored future climate change and the efficiency of plant macronutrient use.

Thomas Hertel, a distinguished professor of agricultural economics, founder and executive director of the Global Trade Analysis Project, fellow and past president of the Agricultural and Applied Economics Association, and inaugural recipient of the Purdue

University Research and Scholarship Distinction Award, has contributed to the quantitative analysis of global food security, environmental security and international trade issues. He also studies the impacts of climate change and climate policy on agriculture and poverty.

Zhong-Yin Zhang, distinguished professor and head of the Department of Medicinal Chemistry and Molecular Pharmacology, the Robert C. and Charlotte P. Anderson Chair in Pharmacology, and director of the Purdue Institute for Drug Discovery, was recognized for his work in protein phosphorylation and cellular signaling, particularly in defining structure and function, and for therapeutic targeting of protein tyrosine phosphatases. His research may lead to effective treatments of cancer, diabetes and obesity, autoimmune disorders, neurodegenerative disorders and infectious diseases.

WORK-FAMILY RESEARCHER BECOMES ACADEMY OF MANAGEMENT FELLOW

Ellen Ernst Kossek was elected in 2018 as a fellow of the Academy of Management (AOM) for her significant contributions to the science and practice of management.

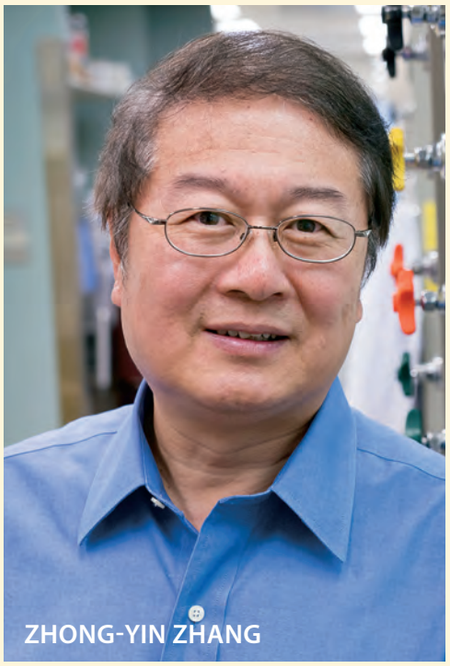
Kossek, the Basil S. Turner Professor of Management and research director of the Susan Bulkeley Butler Center for Leadership Excellence, was among nine new fellows selected by the organization, which has nearly 20,000 members in more than 120 countries. Dan Schendel, a pioneer in the field of strategic management, is the only other faculty member from Purdue's Krannert School of Management to have become an AOM fellow.

Kossek has published more than 90 refereed journal articles, 10 books, 30 book chapters, and numerous technical reports and teaching aides. Her research focuses on organizational and leader support of work-life and gender diversity, flexibility and boundary management, and interventions. She is considered


ELISA BERTINO


SYLVIE M. BROUDER

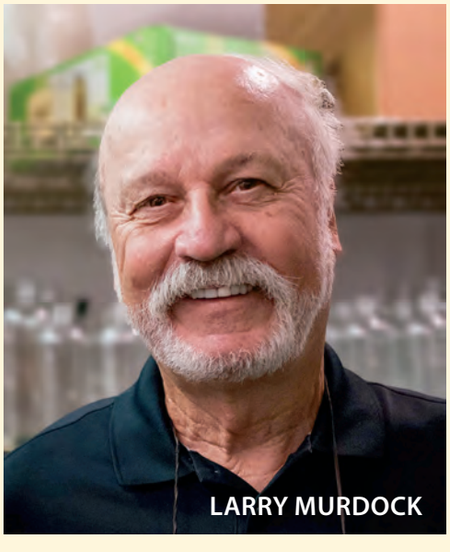

THOMAS HERTEL


ZHONG-YIN ZHANG


ELLEN ERNST KOSSEK


RAJ GOUNDER


STEPHEN BYRN


LARRY MURDOCK

a leader in the field of work and family research.

GOUNDER NAMED 2018 SLOAN FELLOW

Rajamani "Raj" Gounder, the Larry and Virginia Faith Assistant Professor of Chemical Engineering, received a $65,000 Sloan Research Fellowship in 2018. He was among 126 researchers in the United States and Canada selected for Sloan Research Fellowships that year.

Gounder leads an experimental research group specializing in three main areas: the synthesis of inorganic catalysts with tailored properties, the characterization of catalyst active site and support structures, and the evaluation of catalytic function, using fundamental kinetic and mechanistic descriptors. His team seeks to apply these tools within fuel and chemical production and environmental protection.

Gounder and his group are viewed at the research forefront of the science and technology of heterogeneous catalysis. In 2017, Gounder co-led a team of researchers from Purdue, the University of Notre Dame and Cummins, Inc. seeking to improve catalyst designs for pollution-control systems for diesel exhaust. They uncovered an essential property of the catalyst that functions in converting nitrogen oxides.

BYRN AND MURDOCK RECEIVE MORRILL AWARDS

The Morrill Award recognizes full-professor faculty who best exhibit excellence in, and synergies among, all three dimensions of their profession — teaching, research and engagement — with evidence of the impact or potential impact of their work on society. The award is the highest career-achievement recognition for a faculty member at Purdue University.

The Office of the Provost bestowed the 2018 Morrill Awards on **Stephen Byrn** in the College of Pharmacy and **Larry Murdock** in the College of Agriculture.

Byrn, the Charles B. Jordan Professor of Medicinal Chemistry, studies solid-state pharmaceutics and small-molecule stability in the drug-development process and in designing formulations.

Byrn and his team employ in their research X-ray diffraction, solid-state nuclear magnetic resonance spectroscopy, and dissolution. His current research focuses on a new method for formulating anticancer drugs that are more patient-friendly with fewer side effects.

Byrn is also co-director of the Center for Biotechnology Innovation and Regulatory Science within the Purdue Polytechnic Institute. One of his center projects is a Master of Science degree program in biotechnology innovation and regulatory science at the Kilimanjaro School of Pharmacy in Tanzania, Africa. Byrn teaches students, who are primarily leaders in the African regulatory industry, there several times a year. The sustainable medicine program is aimed at addressing the lack of access to high-quality medicines in Africa.

Murdock, distinguished professor emeritus, has conducted agricultural research throughout his 40-year career, which has led to the successful commercialization of his invention, a system of insect-free cereal grain and legume storage in triple-layered, airtight, high-density polyethylene bags. With the Purdue Improved Crop Storage (PICS) technology, subsistence farmers can safely store food that will feed their families for long periods of time.

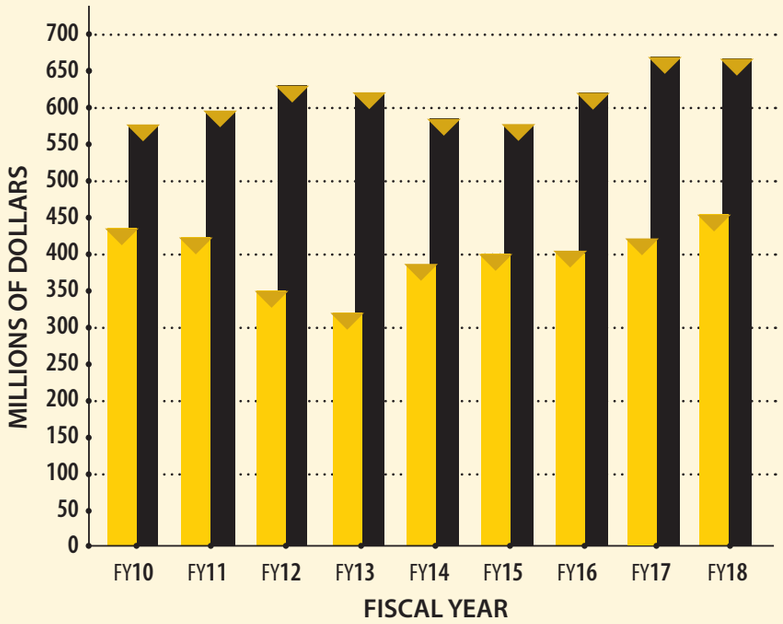
In early 2018, the PICS bag became commercially available for farmers worldwide. Through their commercialization, PICS bags have reached more than 5 million African farmers who live in 56,000 villages. See p. 30 for more on the PICS technology.

SYSTEM-WIDE SPONSORED PROGRAM AWARDS AND EXPENDITURES

Purdue University generated a university record of $454 million in system-wide sponsored research funding for fiscal year 2018.

As a leading research university in the state of Indiana with a global reputation of excellence, Purdue is dedicated to maximizing our resources to build a research enterprise that supports innovative and impactful research.

With these awards, faculty continue to push the boundaries of discovery and raise the profile of both the research and student experiences at Purdue University.

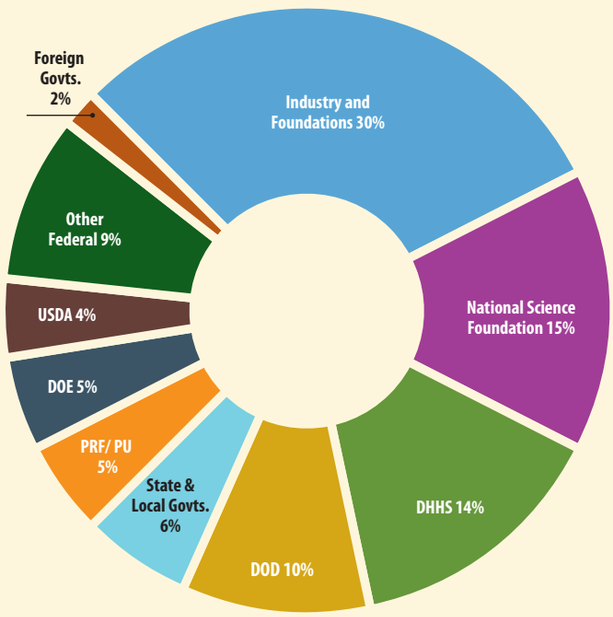


Total Awards: $454 million

Total Support Expenditures: $661 million

For fiscal year 2018, corporate and foundation funding of scientific and engineering research accounted for 30 percent of the total, and funding from the National Science Foundation and the Department of Health and Human Services/National Institutes of Health accounted for 15 percent and 14 percent of the total, respectively.

Funding from the American Recovery and Reinvestment Act of 2009 is included in this chart.



Committed sponsors partner with Purdue, enabling faculty and staff researchers to respond to 21st century grand challenges.

AWARD SPONSOR ABBREVIATIONS

DHHS	U.S. Department of Health and Human Services
DOD	U.S. Department of Defense
PRF/PU	Purdue Research Foundation/Purdue University
DOE	U.S. Department of Energy
USDA	U.S. Department of Agriculture

Sponsored Awards come from multiple sources.

FROM THE PRESIDENT

Purdue University's sesquicentennial is a time to celebrate the impact that Boilermakers have made over the last 150 years while also looking towards the future. From the small steps of one man or woman to the giant leaps for mankind, Purdue researchers continue to tackle some of the most daunting challenges facing our state, nation and world.

Mitchell E. Daniels, Jr.
President

FROM THE EXECUTIVE VICE PRESIDENT FOR RESEARCH AND PARTNERSHIPS

During the 2018 fiscal year, Purdue University's sponsored research programs achieved a record-breaking $454 million, an increase of $36 million over the previous year. This giant leap in research funding is due in large part to the tremendous talent and tenacity of our faculty, staff and students. I can't wait to see what the future brings.

Suresh Garimella
Executive Vice President for
Research and Partnerships

FROM THE PROVOST

Purdue University is redefining the role and scope of land-grant institutions and supporting global leaders in taking giant leaps to solve our world's problems. As we continue to reimagine our tripartite mission of learning, discovery and engagement, we are helping the citizens, firms and institutions of the world pursue contemporary notions of excellence, innovation and impact to enhance lives and livelihoods.

Jay Akridge
Provost and Executive Vice President
for Academic Affairs and Diversity

2017 | 2018

Office of the Executive Vice President for Research and Partnerships
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EA/EOU

LIST OF LAND-GRANT UNIVERSITIES INCLUDING HBLGUs AND TRIBAL COLLEGES WITH LAND-GRANT STATUS

Purdue's sister land-grant institutions are *italicized* throughout this report.

ALABAMA
Alabama A&M University, Normal
Auburn University, Auburn
Tuskegee University, Tuskegee

ALASKA
Ilisagvik College, Barrow
University of Alaska, Fairbanks

AMERICAN SAMOA
American Samoa Community College, Pago Pago

ARIZONA
Diné College, Tsaile
University of Arizona, Tucson
Tohono O'Odham Community College, Sells

ARKANSAS
University of Arkansas, Fayetteville
University of Arkansas at Pine Bluff, Pine Bluff

CALIFORNIA
D-Q University (Davis vicinity)
University of California System-Oakland as Headquarters, Oakland

COLORADO
Colorado State University, Fort Collins

CONNECTICUT
University of Connecticut, Storrs

DELAWARE
Delaware State University, Dover
University of Delaware, Newark

DISTRICT OF COLUMBIA
University of the District of Columbia, Washington

FLORIDA
Florida A&M University, Tallahassee
University of Florida, Gainesville

GEORGIA
Fort Valley State University, Fort Valley
University of Georgia, Athens

GUAM
University of Guam, Mangilao

HAWAII
University of Hawaii, Honolulu

IDAHO
University of Idaho, Moscow

ILLINOIS
University of Illinois, Urbana-Champaign

INDIANA
Purdue University, West Lafayette

IOWA
Iowa State University, Ames

KANSAS
Haskell Indian Nations University, Lawrence
Kansas State University, Manhattan

KENTUCKY
Kentucky State University, Frankfort
University of Kentucky, Lexington

LOUISIANA
Louisiana State University, Baton Rouge
Southern University and A&M College, Baton Rouge

MAINE
University of Maine, Orono

MARYLAND
University of Maryland, College Park
University of Maryland Eastern Shore, Princess Anne

MASSACHUSETTS
University of Massachusetts, Amherst

MICHIGAN
Bay Mills Community College, Brimely
Keweenaw Bay Ojibwa Community College, Baraga
Michigan State University, East Lansing
Saginaw Chippewa Tribal College, Mount Pleasant

MICRONESIA
College of Micronesia, Kolonia, Pohnpei

MINNESOTA
Fond du Lac Tribal & Community College, Cloquet
Leech Lake Tribal College, Cass Lake
University of Minnesota, St. Paul
White Earth Tribal and Community College, Mahnomen

MISSISSIPPI
Alcorn State University, Lorman
Mississippi State University, Starkville

MISSOURI
Lincoln University, Jefferson City
University of Missouri, Columbia

MONTANA
Aaniiih Nakoda College, Harlem
Blackfeet Community College, Browning
Chief Dull Knife College, Lame Deer
Fort Peck Community College, Poplar
Little Big Horn College, Crow Agency
Montana State University, Bozeman
Salish Kootenai College, Pablo
Stone Child College, Box Elder

NEBRASKA
Little Priest Tribal College, Winnebago
Nebraska Indian Community College, Winnebago
University of Nebraska, Lincoln

NEVADA
University of Nevada, Reno

NEW HAMPSHIRE
University of New Hampshire, Durham

NEW JERSEY
Rutgers University, New Brunswick

NEW MEXICO
Navajo Technical College, Crownpoint
Institute of American Indian and Alaska Native Culture and Arts Development, Sante Fe
New Mexico State University, Las Cruces
Southwestern Indian Polytechnic Institute, Albuquerque

NEW YORK
Cornell University, Ithaca

NORTH CAROLINA
North Carolina A&T State University, Greensboro
North Carolina State University, Raleigh

NORTH DAKOTA
Fort Berthold Community College, New Town
Cankdeska Cikana Community College, Fort Totten
North Dakota State University, Fargo
Sitting Bull College, Fort Yates
Turtle Mountain Community College, Belcourt
United Tribes Technical College, Bismarck

NORTHERN MARIANAS
Northern Marianas College, Saipan, CM

OHIO
Central State University, Wilberforce
Ohio State University, Columbus

OKLAHOMA
College of the Muscogee Nation, Okmulgee
Langston University, Langston
Oklahoma State University, Stillwater

OREGON
Oregon State University, Corvallis

PENNSYLVANIA
Pennsylvania State University, University Park

PUERTO RICO
University of Puerto Rico, Mayaguez

RHODE ISLAND
University of Rhode Island, Kingston

SOUTH CAROLINA
Clemson University, Clemson
South Carolina State University, Orangeburg

SOUTH DAKOTA
Oglala Lakota College, Kyle
Si Tanka/Huron University, Eagle Butte
Sinte Gleska University, Rosebud
Sisseton Wahpeton College, Sisseton
South Dakota State University, Brookings

TENNESSEE
Tennessee State University, Nashville
University of Tennessee, Knoxville

TEXAS
Prairie View A&M University, Prairie View
Texas A&M University, College Station

UTAH
Utah State University, Logan

VERMONT
University of Vermont, Burlington

VIRGIN ISLANDS
University of the Virgin Islands, St. Croix

VIRGINIA
Virginia Tech, Blacksburg
Virginia State University, Petersburg

WASHINGTON
Northwest Indian College, Bellingham
Washington State University, Pullman

WEST VIRGINIA
West Virginia State University, Institute
West Virginia University, Morgantown

WISCONSIN
College of Menominee Nation, Keshena
Lac Courte Oreilles Ojibwa Community College, Hayward
University of Wisconsin, Madison

WYOMING
University of Wyoming, Laramie

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