

2015 | 2016

Executive Vice President for Research and Partnerships

# LIFE•OLOGY

**PURDUE**  
UNIVERSITY

# TABLE OF CONTENTS

## animalia

<i>Aedes aegypti</i>   Richard Kuhn   Michael Rossmann .....	3
<i>Canis lupus familiaris</i>   Marguerite O’Haire .....	4
<i>Danio rerio</i>   Marisol Sepúlveda   Jennifer Freeman   Sara Wirbisky ...	4
<i>Drosophila melanogaster</i>   Vikki Weake .....	5
<i>Homo sapiens</i>   Kenneth Ferraro .....	6
<i>Homo sapiens</i>   Laura Zanotti .....	7
<i>Homo sapiens</i>   Bumsoo Han .....	8
<i>Homo sapiens</i>   Bill Watson .....	8
<i>Ixodes scapularis</i>   Catherine Hill .....	9
<i>Homo sapiens</i>   Nana Gletsu-Miller .....	10
<i>Sus scrofa domestica</i>   Kolapo Ajuwon .....	11
<i>Eugomphodus macrotis</i>   William Zinsmeister .....	12
<i>Lates niloticus</i>   Jennifer Johnson .....	12
<i>Odontodactylus scyllarus</i>   Pablo Zavattieri .....	13

## plantae

<i>Sorghum bicolor</i>   Mitch Tuinstra .....	15
<i>Glycine soja</i>   Jianxin Ma .....	16
<i>Juglans regia</i>   Keith Woeste .....	17
<i>Mucuna pruriens</i>   Chris Rochet .....	18
<i>Acacia koa</i>   Shaneka Lawson .....	19
<i>Glycine max</i>   Punya Nachappa .....	19

## fungi

<i>Tyromyces fissilis</i>   Vilas Pol .....	21
<i>Moniliophthora roreri</i>   Catherine Aime   Jorge Díaz-Valderrama ....	22
<i>Saccharomyces cerevisiae</i>   Mark Hall .....	23
<i>Saccharomyces cerevisiae</i>   Nancy Ho .....	24
<i>Botrytis cinerea</i>   Tesfaye Mengiste .....	25

## protista

<i>Plasmodium falciparum</i>   Phil Low .....	27
<i>Naegleria fowleri</i>   Andrew Whelton .....	28
<i>Trichonympha</i> sp.   Michael Scharf .....	29

## archaeobacteria eubacteria

<i>Staphylococcus aureus</i>   Mohamed Seleem .....	31
<i>Vibrio cholerae</i>   Jacqueline Linnes .....	32
<i>Bordetella pertussis</i>   Zhilan Feng .....	33
<i>C. rodentium</i>   Chang Kim .....	34
<i>Lactobacillus</i>   Yava Jones-Hall .....	35
<i>Legionella pneumophila</i>   Jiazhang Qiu   Zhao-Qing Luo .....	36

## awards

Jian-Kang Zhu .....	37	Milind Kulkarni.....	42
Arvind Varma.....	38	Barrett Caldwell.....	42
Linda Prokopy .....	39	Natalia Dudareva.....	42
Monika Ivantysynova.....	39	Rebecca Kramer.....	43
Douglas Powell.....	39	Jonathan Freeman.....	43
Phillip Wankat.....	39	Karen Foli.....	44
Charles Bouman .....	40	Michael Rossmann.....	44
Sherry Harbin.....	40	Kathleen Howell.....	44
Jeffrey Dukes .....	40	Arun Bhunia.....	45
David Bahr.....	40	TJ Boisseau.....	45
Bruce Craig.....	41	Angelica Duran.....	45
Laurence Baker Leonard.....	41	Melanie Shoffner.....	45
Timothy Zwier.....	41	Brian Smith.....	45
Arezoo Ardekani.....	42		

**NOTE FROM THE EDITOR:** For centuries scientists have sought to classify the diversity of life on earth. Until the 1960s, scientists used the two kingdom system of classification first proposed by Linnaeus — *Plantae* and *Animalia*. Then Whittaker proposed the five kingdom system of classification that most of us are familiar with. New molecular tools later allowed scientists to add a layer above kingdoms to the classification scheme, the domain. In 1990, Woese and colleagues proposed a three-domain system using evidence from RNA and cell wall components, dividing *Monera* (bacteria) into the separate domains of *Archaea* (ancient bacteria) and *Bacteria* — both of which have cells that do not contain a nucleus, and are sometime described as *prokaryotes* (“before the kernel”). The third domain contains all of the *Eukarya*, the *eukaryotes*, those organisms with cells that have a nucleus and membrane bounded organelles. As new methods and technologies become available to enhance our understandings of the structures of organisms and their relationships with one another, these taxonomic systems continue to evolve. We hope you enjoy reading the following selected research stories based on a six-kingdom system theme.

**SPECIAL THANKS** to Denise Zielinski, continuing lecturer in the Department of Biological Sciences at Purdue University, for her contributions to the taxonomic descriptions contained in this report.

2015 | 2016





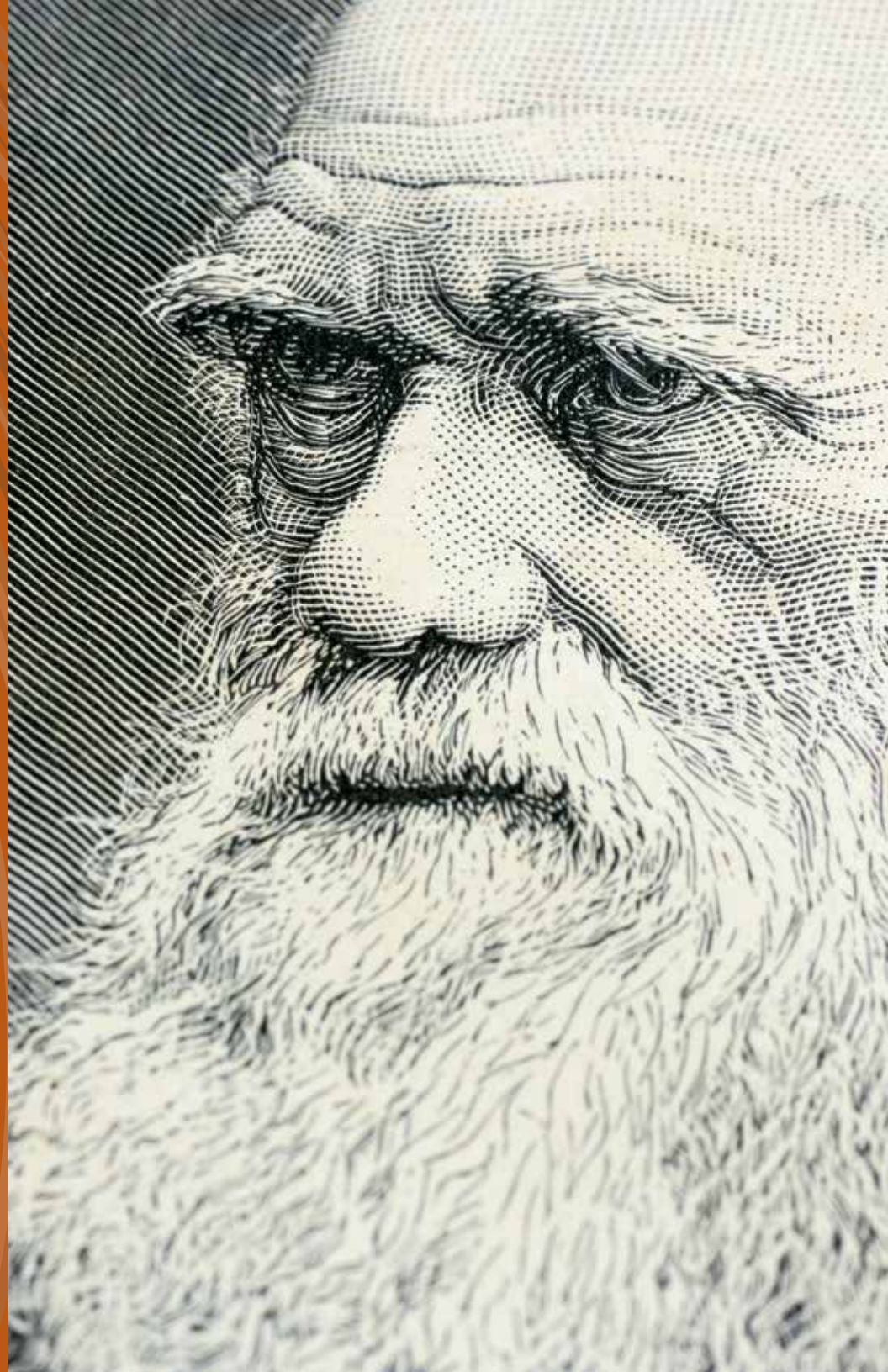
**LIFE·OLOGY**





There is grandeur in  
this view of life,  
with its several powers,  
having been originally  
breathed into a few  
forms or into one;  
and that, whilst this  
planet has gone cycling  
on according to the  
fixed law of gravity,  
from so simple a  
beginning endless  
forms most beautiful  
and most wonderful  
have been, and are  
being, evolved.”

Charles Darwin,  
*On the Origin of Species* | 1859







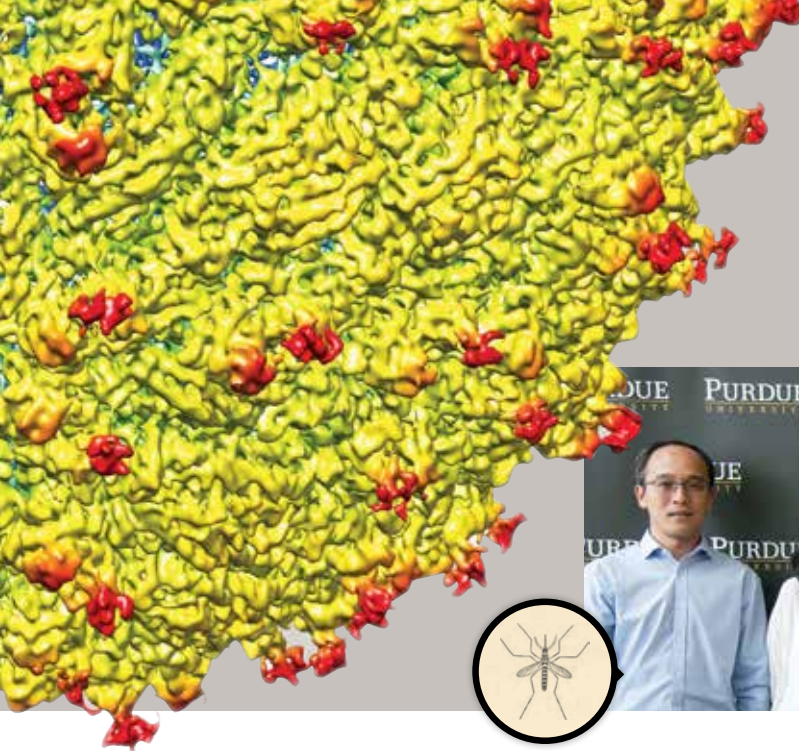
# LIFE•OLOGY

## *animalia*

### **Animalia**

noun, [an-uh **mey**-lee-uh]

*Animalia is the taxonomic kingdom comprising all animals – from humans, insects and worms to jellyfish and sponges. They are complex multicellular organisms lacking rigid cell walls, which allows them to adopt diverse shapes. Animals are heterotrophs, relying on other living things for sustenance. Invertebrates, animals without backbones, comprise about 97 percent of the animal kingdom and vertebrates comprise the remaining 3 percent. The oldest fossilized animals, sponges, date to 635 million years ago.*



Together, these researchers became the first in the world to crack the code of another flavivirus, Zika.

PHOTO BY MARK SIMONS



Zhenguo Chen | Devika Sirohi | Richard Kuhn | Michael Rossmann | Thomas Klose | Lei Sun

## CRACKING ZIKA'S CODE

*Aedes aegypti* | Michael Rossmann, who was the first to map the common cold virus at an atomic level, is a pioneer in using supercomputers to reveal the structure of viruses. Richard Kuhn, who teamed up with Rossmann to determine the structure of the West Nile virus, is an international expert in flaviviruses such as dengue, West Nile and chikungunya.

Together, these researchers and their collaborators, postdoctoral scientists and graduate students became the first in the world to crack the code of another flavivirus, Zika. And they did it in just a few short months, providing timely insights for the development of effective antiviral treatments and vaccines against the mosquito-borne illness, which has already infected thousands on multiple continents and led to the birth defect

microcephaly among some babies born to infected mothers.

“Getting the structure puts us in a good position to find a drug against the virus,” says Rossmann, the Hanley Professor of Biological Sciences.

The researchers began their marathon in fall 2015, acquiring samples from the Zika outbreak in French Polynesia. After being purified, frozen and placed on grids, the samples were ready for microscopic analysis. Using a new direct counting electron detector that attaches to the university’s electron microscope in Hockmeyer Hall, the researchers generated hundreds of thousands of images of the virus from various orientations. Then, after analyzing data sets with Purdue’s supercomputers, the researchers worked day and night to

turn individual projections into a 3-D representation that was officially revealed last March.

Illnesses like Zika — which is transmitted via mosquitoes like the *Aedes aegypti* — have a devastating domino effect; as more people get infected, more mosquitoes pass the disease on to other people, ultimately cascading into large-scale outbreaks. The association with birth defects brings great urgency for new strategies to contain its spread.

“Knowing the structure provides a huge platform for us to begin to do new experiments,” says Kuhn, former head of Purdue’s Department of Biological Sciences and director of the Purdue Institute of Inflammation, Immunology and Infectious Disease (PI4D).





PHOTO BY ENIK PINDLETON

Marguerite O'Haire



## PAWS FOR PTSD

*Canis lupus familiaris* | Seeking a proven researcher, the Human-Animal Bond Research Initiative Foundation turned to Marguerite O'Haire, who studies the effects of companion animals on humans. The foundation asked her to apply for a competitive grant to study the effects service dogs have on post 9/11 war veterans with post-traumatic stress disorder and/or traumatic brain injury.

The Purdue assistant professor in the College of Veterinary Medicine applied for and landed the grant, along with funding from Newman's Own Foundation.

Her team conducted a series of surveys with participants and their spouses in the K9s For Warriors program, creating two control groups — one, vets with service dogs; the other, those on the waiting list. Their goals: to expand today's knowledge on whether specially trained service dogs can help reduce stress, anxiety and depression, and to cite specific scientific evidence of the dogs' potential effectiveness with war veterans. Such evidence is needed to support expanded funding for service dogs.

"We evaluated depression, social

functioning, sleep and emotional wellbeing," O'Haire says. "We also collected salivary cortisol to measure stress."

Study results, now being analyzed, will next be peer-reviewed, then findings will be released.

"It is rewarding to give veterans a voice to express what they feel happens with their service dogs or why they applied for one," O'Haire says. "Through standardized survey and physiological measures, we are finding out the effects of service dogs and what can make the experience better."

## FISHING FOR ANSWERS IN ATRAZINE

*Danio rerio* | As tropical freshwater fish native to the Himalayas, zebrafish (*Danio rerio*) — with their characteristic five uniformly wide blue stripes — are a well-accepted biomedical research model for disease, birth defects and other illnesses. Although the studies are done with fish, the area of interest is human health. In the case of Purdue researchers Jennifer Freeman and Marisol Sepúlveda, zebrafish served as a model for studying the effects

of the agricultural herbicide atrazine on embryonic development.

Embryos are the most vulnerable to any form of environmental stressor. Freeman, an associate professor of toxicology, and Sepúlveda, a professor of forestry and natural resources, exposed embryos to atrazine right after fertilization. As soon as the female laid the eggs and the male fertilized them, the eggs were collected and dosed with atrazine.

In the highest levels of atrazine concentration, the researchers found a noticeable effect on the reproduction of the fish. While the level of exposure was ten times higher than the approved level of safe drinking water, atrazine in drinking water has been shown to spike that high.

Collaboration was key in such an in-depth research study. "We have a lot of overlapping interests, and I think that our interests really complement each other well with what we do," says Freeman. "Both of us have strong interests in molecular toxicology, and the endocrine system, and the reproduction system. Our lab focuses more on the neuroendocrine component, and Marisol's lab focuses on the reproductive aspect, and combining those works really well."

Marisol Sepúlveda | Jennifer Freeman | Sara Wirbisky

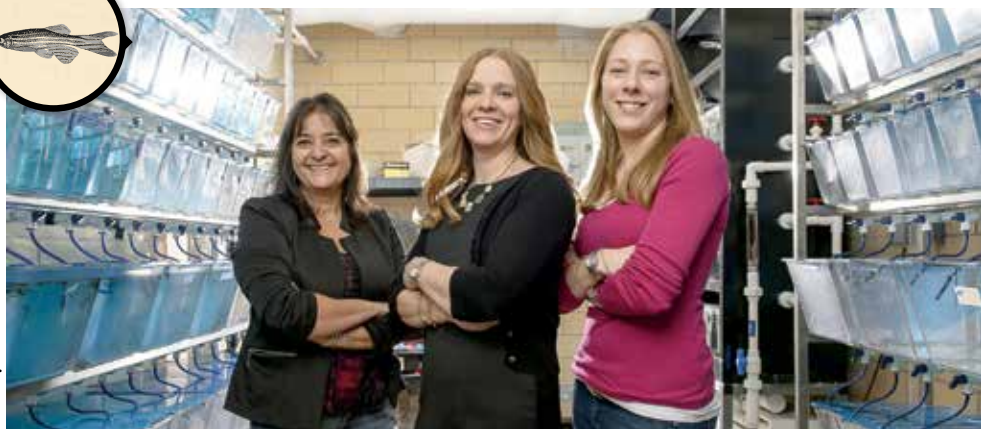


PHOTO BY CHARLES JISCHE



Vikki Weake



## WHAT FRUIT FLIES CAN TELL US ABOUT HUMAN EYESIGHT

### *Drosophila melanogaster*

Fruit flies (*Drosophila melanogaster*) have compound eyes with hundreds of tiny lenses. Humans have camera-type eyes, each with a single lens, cornea and retina. Surprisingly, those multifaceted bug eyes can teach us a lot about why people are more likely to develop eye diseases as they age, says Vikki Weake, an assistant professor of biochemistry.

“Seventy-five percent of human disease-related genes have orthologs in fruit flies, meaning that they evolved from the same ancestral genes,” Weake says. And inside their photoreceptors, the specialized neurons in eyes, fruit flies share many of the same proteins as humans. The insects

also have short life spans, so the genetic changes they experience with aging happen in just 30 to 50 days.

Inside her lab in Purdue’s Biochemistry Building, Weake and her team house hundreds of flies in neatly arranged test tubes. Once the flies grow old, they extract their DNA. Then, with the help of Purdue’s supercomputers, they sort through tens of thousands of genes, looking for subtle changes.

“Our working hypothesis is that there are changes in the mechanism of transcription — how genes are expressed. There are large protein machines that make a copy of the DNA onto RNA, which is then made

into the protein which in turn does all the jobs in a cell,” Weake says. Because light-sensing proteins in photoreceptors must continually regenerate, over time, small defects in protein production can affect the neuron’s function.

Aging is the leading risk factor for blindness. “If we can identify the mechanism that causes transcription to become defective as photoreceptors age, we might be able to target drugs to deal with that,” Weake says. “By delaying the transcription problem, we could give people another five to ten years of healthy eyesight.”



## CONNECTING THE DOTS

*Homo sapiens* | Similar to a child's chickenpox triggering shingles later in life, so, too, can childhood poverty and abuse lead to physical illnesses later in life. That's the analogy Kenneth Ferraro uses as he explains his work with researchers from two other universities to learn more about disease origins in adults.

PHOTO BY VINCENT WALTER



A distinguished professor of sociology, his work as director of Purdue's Center on Aging and the Life Course prompted his exploration. Can ongoing poverty, physical violence or verbal abuse early in life lead to adult illnesses, such as cancer or heart disease? Yes, the researchers found.

"We are thinking beyond chemical or biological exposure and considering negative social issues," says Ferraro. "We are trying to connect the dots."

The researchers used data from the National Survey of Midlife Development in the United States of 1,748 adults collected in two waves a decade apart to find the link. They recently published what they learned in *The American Sociological Review*.

"Now that we have identified some of the early origins of adult disease, we are focusing on resources," he says, in an attempt to curb occurrences of illness.

"Those might include richer support networks or mental health services. We hope our research will be useful for people recovering from misfortune or a life of poverty, uncertainty or abuse."



Kenneth Ferraro



## INDIGENOUS PEOPLES, INFLUENCE AND CLIMATE CHANGE

*Homo sapiens* | From rainforests dense with plants to freshwater lakes teeming with fish, Indigenous Peoples live and work on land abundant in natural resources. But these environments are increasingly vulnerable to climate change, threatening the livelihoods and cultures of people who rely on them.

Through their Presence2Influence project, Laura Zanotti, an associate professor of anthropology, and her research partner, Kimberly Marion Suiseeya of Northwestern University, study how Indigenous Peoples are working to transform their presence at climate change talks into influence. They've been taking their research around the world, traveling to such events as the 2015 United Nations Climate Change Conference in Paris and the 2016 World Conservation Congress in Honolulu, Hawaii.

The United Nations has identified Indigenous Peoples and women as two groups most affected by environmental

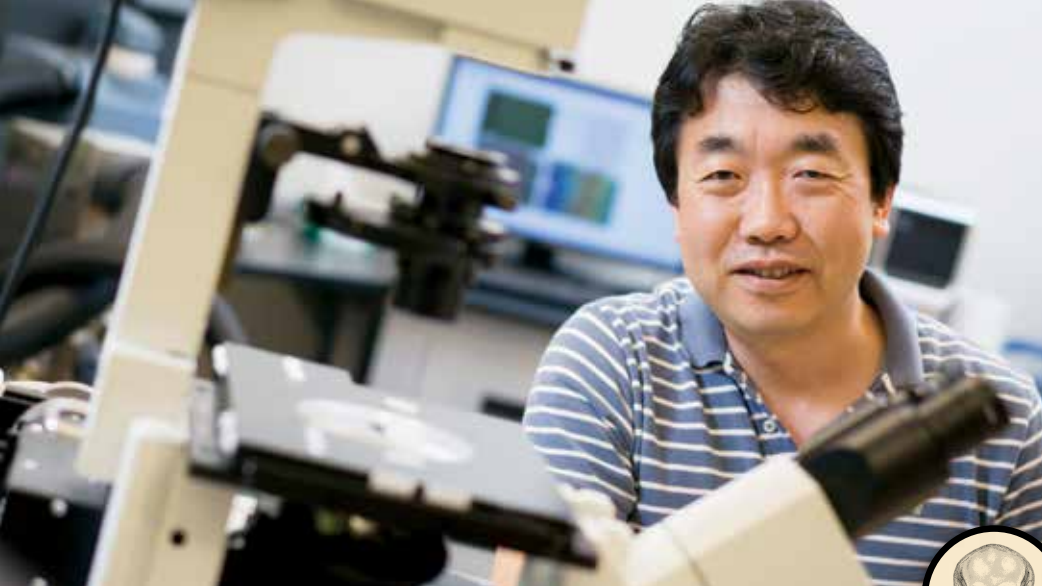
change, including climate change. "While Indigenous Peoples make up approximately 5 percent of the global population, they constitute more than one-third of the world's poorest people and govern, occupy or use nearly 22 percent of global land area," says Marion Suiseeya.

Underrepresented groups are starting to gain a seat at the table, but their influence on decision outcomes remains mixed. That's why Suiseeya and Zanotti are looking for subtle indicators of change. Through the new method of collaborative event ethnography, a team based approach in which researchers collect and analyze everything from audio recordings to tweets, they hope to gain insight into the micropolitics of climate negotiations.

"This method is useful for illuminating and unpacking the practices of Indigenous Peoples at sites of international relations that largely remain hidden," says Zanotti.

Kimberly Marion Suiseeya | Sarah Huang | Laura Zanotti | Scott Benzing | Elizabeth Wulbrecht | Suraya Williams | Fernando Tormos





Bumsoo Han



## FIGHTING CANCER ON A MICROCHIP

*Homo sapiens* | For all we know of cancer today, some cancer treatment is still a trial-and-error process, with clinicians trying different types of chemotherapy drugs separately or in cocktails, hoping that one will work.

For patients battling serious side effects, that's a gut-wrenching situation. For those with aggressive tumors who don't have much time to get the drug right, that's a potentially life-or-death matter.

Bumsoo Han wants to help change that, and he is using his expertise in heat and mass transfer and fluid mechanics to do so.

Typically, researchers test new drugs in petri dishes or small animal models, but neither predicts very accurately how humans respond to anti-cancer therapies. Collaborating with other researchers, Han has created a tumor-microenvironment-on-chip (T-MOC) device where he can culture cancer cells in 3-D.

Measuring about 1.8 inches square, the new system is designed to more closely mimic the complex environment around human tumors, including barriers that prevent targeted delivery of medications.

In recent studies, Han cultured three types of human breast cancer cell lines on the T-MOC platform, discovering that each type of cancer cell responded differently to the medication. If further research bears out, his device could one day be used to tailor cancer treatments to individual patients and different cancers.

"There are approximately 30 different types of FDA-approved chemotherapeutic drugs for breast cancer, and it is very difficult for doctors to choose effective ones," says Han, professor of mechanical engineering and courtesy professor of biomedical engineering. "I hope our platform will be able to screen down those choices to improve the treatment outcome as well as patients' quality of life."

PHOTO BY VINCENT WALTER

## SERIOUS LEARNING

*Homo sapiens* | Minecraft. Lemonade Stand. The Sims. To some parents, they may be educational distractions. To Bill Watson, they are learning opportunities.

"When you play a game, you are going to learn," he explains. "If the game is designed with educational content in mind, you have to learn that content in order to win the game."

Watson is an associate professor and director of the Purdue Center for Serious Games and Learning in Virtual Environments in the Department of Curriculum and Instruction, where he and his colleagues use a lab to design, develop and evaluate serious games and virtual environments in education. Games that require strategy, thinking and reflection are better than "twitch" games, he says, in which players essentially "run over to something and blast it."

Bill Watson



Some games have been leveraged and adapted by educators to teach students important lessons: Lemonade Stand for basic economics and The Sims for sociology, for example.

But even games that aren't intended for education may serve as learning tools. "This may be something never considered by the game designer, but by putting a lens on it you can use this as a tool to promote different sorts of learning," he says.

To help children pull the appropriate information from games, Watson suggests that parents speak to them about how they played, why they decided what they did, and what they would do the same or differently next time. "You're doing problem-solving when you're learning how the game system works and how to win it," he says.

PHOTO BY KEVIN O'SHEA (UTAP)



PHOTO BY VINCENT WALTER



Catherine Hill

## USING GENOMICS TO STICK IT TO THE TICK

*Ixodes scapularis* | Armed with barbed mouthparts and sophisticated spit, ticks (*Ixodes scapularis*) employ strategies that have served them for millions of years — stealthily hitching onto a host, slicing through its skin to bloodfeed and secrete saliva potentially spiked with pathogens.

But despite ticks' ability to transmit a mind-boggling variety of bacteria, viruses and parasites that can cause debilitating and sometimes deadly illnesses, tick research has lagged far behind that of other vectors, such as mosquitoes.

Purdue University entomologist Catherine Hill is changing that.

This year, Hill led an international team of nearly 100 scientists to produce seven

papers on tick genetics, including the complete genome sequence of the deer tick (*Ixodes scapularis*), the species that transmits Lyme disease. The publications are the culmination of a decade-long effort to equip scientists with desperately needed tools to advance the study of ticks and tick-borne diseases.

"The genome provides a foundation for a whole new era in tick research," says Hill, principal investigator of the genome team, professor of medical entomology and Showalter Faculty Scholar. "Now that we've cracked the tick's code, we can begin to design strategies to control ticks, to understand how they transmit disease and to interfere with that process."



## BARIATRIC SURGERY'S NUTRITIONAL COMPLICATIONS

*Homo sapiens* | Bariatric surgery — in which a surgeon makes the stomach smaller, fooling someone into feeling full with less food — has become a popular weight-loss option in the United States. And the surgery works, with patients losing about 10 percent of their body weight within the first month, 25 percent over six months and eventually reaching a level of mild obesity within one to two years, down from having severe obesity.

But while the surgery helps reduce the risk of serious health issues such as heart disease, diabetes and stroke, there are drawbacks as well: because people are eating less, they are taking in fewer essential vitamins and minerals.

"With the weight loss, patients often feel so good after surgery that they soon stop going to their doctors for checkups and monitoring. Over time we see nutritional deficiencies," says Nana Gletsu-Miller, assistant professor of nutrition science, who has observed low levels of iron, vitamin D, B vitamins, zinc and copper among people she has studied. These deficits can lead to health issues such as fatigue, anemia, hair loss, neurological problems, and problems with mood and mental function.

Now Gletsu-Miller is focusing on some related questions: Can foods within the diet realistically prevent iron deficiency or are iron supplements the way to go? What are

the risks and benefits of taking iron and other supplements? Why do some people develop iron deficiency but not others? What are the biological or genetic mechanisms involved?

She is also collaborating with Thomas Redick, assistant professor of psychological sciences, and Mario Ferruzzi, adjunct professor of food science. They assist her with assays for measuring cognitive function and novel techniques for measuring nutritional health.

"We link the biological findings to everyday functions that affect quality of life," she says. "We can use our understanding of what is going on to help others."

PHOTO BY VINCENT WALTER

Nana Gletsu-Miller





PHOTOS BY VINCE WALTER

Kolapo Ajuwon



## BETTER GUTS FOR PIGS AND HUMANS

*Sus scrofa domesticus* | Pigs offer humans more than a lesson in mud running, fun as that is. Studies of *Sus scrofa domesticus* are modeling the benefits of eating fermentable fiber from an early age on to curb obesity and provide other health benefits.

Those are the findings of Kolapo Ajuwon, associate professor of animal sciences, who studies swine digestive systems and metabolism — which closely resemble humans'. His 200-some subjects live and are fed various types of fiber at the Purdue Animal Sciences Research and Education Center.

"Fiber works two ways. It provides good bacteria, and it can protect the liver, muscles and fat tissues," Ajuwon says. "The benefits go beyond what happens in the stomach."

Especially valuable: Fermentable fibers, found in chicory, certain roots, tubers and some fruits that contain inulins, also called prebiotic fibers.

"Fermentable fiber makes your gut healthy. First, you have to have a healthy gut with good bacteria. That is ground zero. That can produce compounds that go all over your body to prevent obesity," he says.

"Almost everything we're learning has immediate application for humans. With these findings, we expect that health-conscious consumers will increase fiber and select specific types of fiber."

He's also looking at fiber impact on the gut/brain axis — "How our gut talks to our brain, how the brain regulates what we eat and how much, and how fiber affects that."



PHOTO BY VINCENT WALTER



## TREASURES OF ANCIENT ANTARCTICA

William Zinsmeister

*Eugomphodus macrota* | Paleontologist William Zinsmeister made more than 20 field trips to Antarctica, Seymour Island and the Southern Hemisphere over 30 years. On some trips, he shipped as many as 40 cases of fossils home, eventually amassing a collection of some 50,000 fossils. He has described 300 new species that provide invaluable insight into the world and its creatures 145 to 34 million years ago.

The fossils include the bones of a 6-foot penguin, ancient sea stars and urchins, shark teeth, and other specimens dating to the Cretaceous-Paleogene boundary, which led to one of the biggest mass extinctions in earth history.

It was during this period that the earth's tectonic plates shifted and a single continuous land mass broke into the separate continents of Antarctica, South America, New Zealand and Australia. As part of this colossal event, the once-isolated Indian Ocean flowed into the Pacific, reshaping the climate, vegetation and fauna of South America.

In pursuit of biogeographic history studies, Zinsmeister, a professor of geology in the Department of Earth, Atmospheric, and Planetary Sciences, also collected fossils in Patagonia, Tierra del Fuego, Argentina, Chile, Australia and New Zealand. They are all part of the collection now housed at the Paleontological Research Institution at Cornell University. Like Zinsmeister, once a young graduate student enthralled with the fossils he studied at the Smithsonian, researchers consulting the Zinsmeister Collection can handle — not just look at photos and diagrams — history.

“The fossils provide important information about the history of climate, geography, oceanography and the effects of tectonics on the Southern Hemisphere,” Zinsmeister says. “They may also shed light on the future. You have to know what has been there before you interpret the history and future of the earth: where we came from, where we are, and then where we’re headed.”

## LIFE ALONG THE NYANJA

*Lates niloticus* | Gathering fish from nets pulled to shore, Ugandan women haul them to their camp's covers, where shallow fire pits await the catch. They place fish on grates, sometimes cover them with corrugated metal sheets, smoke them over a low fire, then pack them in cardboard boxes for shipping to local and regional markets.

This daily ritual captures the essence of their community along the littoral of Nyanja, also called Lake Victoria. Tasks, economic independence, culture and spirituality revolve around their fishing life.

Since 2007, Jennifer Johnson, assistant professor of anthropology, has been traveling there, making friends, building trust and learning about their lives. She's





earned the Ugandan name, Nansubuga, meaning she is a daughter of the Lung Fish Clan. “This has helped me build fictive kin networks and gain acceptance in places where I am visibly an outsider,” she says.

While overfishing, especially of *Lates niloticus* — the Nile perch — is a concern there, “The crisis is different for different people, and there’s more than the single story of declining exports,” she has found.

In her work, part of Purdue’s Building Sustainable Communities initiative, she’s learned about their trust-based economy, women’s vital roles and the importance of multiple fish species, beyond the Nile perch.

“People do what makes sense for them,” Johnson says. “There are important reasons why, and we benefit when we understand that.”

Jennifer Johnson



PHOTO BY VINCENT WALTER



PHOTO BY MARK SIMONS

Pablo Zavattieri



## MIMICKING NATURE’S STRENGTH

*Odontodactylus scyllarus* | “Nature uses efficient, elegant approaches to create materials,” Pablo Zavattieri says, pointing to the tiny dactyl club on the mantis shrimp he holds. “Can we replicate it?”

A civil engineering associate professor, he’s interested in the club’s strength and newly discovered sinusoidally architected helicoidal structure — a herringbone/spiral staircase pattern. “How the fibers are arranged is the new part,” he says, and his team would like to apply that to construction materials, sports helmets, body armor and other applications.

Zavattieri got involved when an interest in corals led him to read about *Odontodactylus scyllarus* tucked inside ocean rocks in home aquariums. Owners would hear knocking and often discover aquarium glass shattered by the shrimp’s dactyl club.

How did the clubs withstand the impact, he wondered, mentioning it to a colleague, David Kisailus at the University of California, Riverside, who was already researching it. Zavattieri joined him, private sector and other university researchers on the project. It is supported by the Air Force Office of Scientific Research and the National Science Foundation, through Zavattieri’s CAREER award.

Besides the unique structure, they found stress-resistant nanoparticles in the club’s outer layer.

“Purdue’s most important contribution was building computational and 3-D printed models and explaining how the material behaves, especially this mechanical hammer,” Zavattieri says. “It should shatter, but it doesn’t.”

Today, their quest continues to one day transfer nature’s design to manmade materials.

# LIFE•OLOGY

## *plantae*

### **Plantae**

noun, [**plan** tee]

*The Plantae kingdom is comprised of all plants. They are multicellular organisms that have rigid cell walls. Plants are autotrophs, producing their own food through photosynthesis. However, some living in nutrient poor environments are carnivorous. They cannot freely move through their environment once established, although seeds and spores may travel long distances. The oldest fossilized land plants, liverworts, date to 472 million years ago. There are currently about 400,000 identified plant species, although 20 percent are estimated to be threatened with extinction.*





PHOTO BY TOM CAMPBELL



Mitch Tuinstra

## SORGHUM AS BIOFUEL

*Sorghum bicolor* | Holding a seed head of mature sorghum, Mitch Tuinstra stands in a field of young sorghum plants at Purdue University's Agronomy Center for Research and Education (ACRE), where the Automated Field Phenotyping and Seed Processing Laboratory opened last fall.

At this state-of-the-art facility — the first of its kind in North America — Tuinstra and a team of leading scientists and engineers from the Colleges of Agriculture, Engineering and the Polytechnic Institute at Purdue and IBM will conduct research to develop superior strains of sorghum

for biofuels with support of a \$6.5 million grant from the U.S. Department of Energy.

"This research will enable the biofuels industry and academia to exploit the potential of new remote sensing technologies," says Tuinstra, a professor of plant breeding and genetics in the Agronomy Department and the Wickersham Chair of Excellence in Agricultural Research.

Sorghum, which requires less water and nitrogen than corn and can be grown on marginal land, has promise as a next-generation biofuel. But scientists

need to determine the essential genetic traits for maximizing yields. That's where phenotyping — the process of measuring and analyzing observable plant characteristics — comes into play.

Using Purdue's new phenotyping facility, Tuinstra and his cohort are developing a system of airborne and ground-based mobile sensors to collect data on growth, development and water tolerance of sorghum plants. Ultimately, their work could lead to sorghum with greater biomass yields to increase biofuels production.





## CRACKING THE ARMOR OF WILD SOYBEAN SEEDS

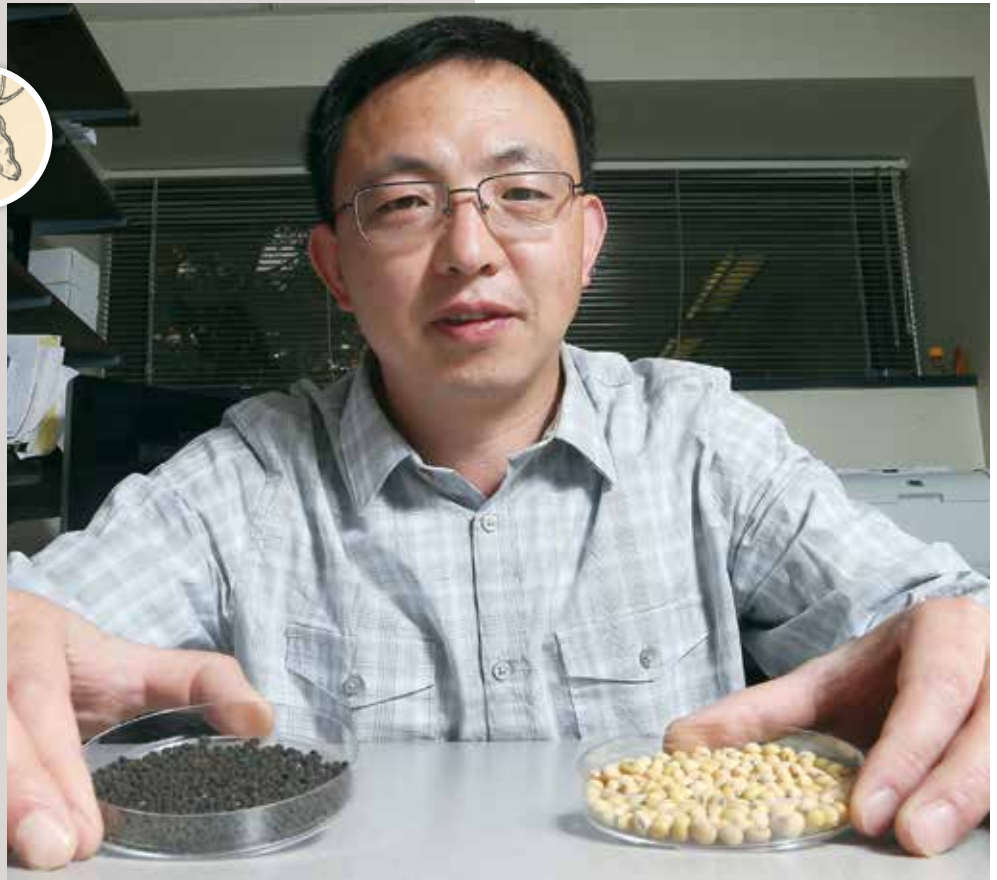
*Glycine soja* | Wild soybean seeds are expert survivalists. Encased in a tough, waterproof and airtight coat, they are well protected from severe conditions and inhospitable environments and can remain viable for many years.

But the hard skin that lends wild soybeans (*Glycine soja*) and many other undomesticated seeds their resilience is a thorny problem for agricultural producers. It prevents seeds from germinating quickly and in a predictable pattern.

Millennia ago, farmers in Asia recognized the value of seed permeability and artificially selected the trait to produce the predecessors of modern cultivated soybean varieties, whose seeds can begin absorbing water in 15 minutes.

But the genetic factors underpinning seed coat permeability remained a mystery until a team led by Jianxin Ma, a professor of agronomy, used a map-based cloning approach to hone in on *GmHs1-1* as the gene responsible for hard seededness.

Understanding the mechanism could help unlock the largely untapped genetic diversity of wild soybeans to enrich cultivated varieties, whose lack of genetic richness has hamstrung improvements



Jianxin Ma

in yields. *GmHs1-1* is also associated with the calcium content of soybeans, offering a genetic target for enhancing the nutrition of soy food products.

“This is the first gene associated with hard seededness to be identified in any plant species,” Ma says. “This discovery could help us quickly pinpoint genes that control this trait in many other plants. We’re also excited about the potential applications for modifying the calcium concentration in seeds.”

## WALNUT TREES, LANGUAGE AND THE SILK ROAD

*Juglans regia* | Once a native of an isolated portion of Asia, the large and vigorous common walnut tree (*Juglans regia*) is now cultivated worldwide for its straight-grained wood and omega 3-rich nuts. Researchers have found that the pattern of genetic diversity of this isolated tree may hold a key to understanding human migration, interaction and afforestation dating back to the Early Bronze Age.

Keith Woeste, a forest geneticist with the USDA Forest Service and Purdue assistant professor of forestry in the Department of Forestry and Natural Resources, is part of an international team studying the common walnut tree within the context of plant bio-cultural diversity. The team is seeking to understand the ways that human cultures have shaped and been shaped by the ecology of the landscapes in which they live.

Analyzing the genome of *J. regia*, along with ethno-linguistic and historical data, the researchers found that ancient trade routes such as the Persian Royal Road and Silk Road enabled the long-distance dispersal of the common walnut tree along the routes from Iran and Trans-Caucasus to Central Asia, and from Western to Eastern China.

“This finding helps us understand the history of how humans were able to use plants to help build stable, organized societies. Our results also reveal that what we might call a natural process or pattern cannot be understood without careful appreciation of how previous human cultures may have contributed to it,” Woeste says. “As we become more urban, our cultural memory often discounts the biology of the places that shaped us.”







PHOTO BY VINCENT WALTER



Chris Rochet

## EAST MEETS WEST: UNDERSTANDING PARKINSON'S DISEASE

*Mucuna pruriens* | Many drugs are available in the marketplace today to treat the symptoms of Parkinson's disease. But none slow down the disease itself, caused by the deterioration of neurons.

Chris Rochet, professor of medicinal chemistry and molecular pharmacology, thinks that some of the answers may lie in the lush landscapes of Nepal, a fertile country bordering both India and China.

Nepal, with lowlands, hillsides and some of the highest mountains in the world, has wide variations in climate, which produce many different types of plants.

"Within a limited geographical area, there is a lot of diversity in terms of the types of plants that grow, and therefore the types of traditional medicines that are derived from those plants," says Rochet. "It is a rich setting both from a traditional medicine and a cultural point of view."

Using an approach called ethnopharmacology, Rochet and his team (including graduate student Aurélie de Rus Jacquet) performed a study in which Nepalese residents and traditional healers were interviewed to discover which plants had been most successful in treating symptoms related to Parkinson's disease. They're now

studying extracts of those plants — such as the velvet bean plant (*Mucuna pruriens*) — to understand at a molecular level why they might not only reduce symptoms, but also may be protective against neuron degeneration.

Ultimately, Rochet hopes to work with colleagues in the Department of Medicinal Chemistry and Molecular Pharmacology to synthesize those protective molecules to produce new drugs that could slow the progression of this disease.



PHOTO COURTESY OF SHANEKA LAWSON

Shaneka Lawson  
ILLUSTRATION JANE HAWKEY



## SAVING HAWAII'S KOA TREE FROM EXTINCTION

**Acacia koa** | Leaving her vehicle where the dirt road ends, Shaneka Lawson steps through waist-high brush and along a machete-hacked path to reach the distant koa tree. The leaves she picks hold the secret to preserving the koa, Hawaiian culture and the indigenous economy.

“Hawaiians’ hopes rest on survival of the *Acacia koa*, which they call ‘Mother Tree,’” says Lawson, research plant physiologist in the USDA Forest Service’s Hardwood Tree Improvement and Regeneration Center at Purdue University.

Natives craft the hardwood, known for its various colors and intricate figure patterns, into fine furniture, musical instruments and jewelry. For many, that’s their sole source of income. But cattle grazing, overharvesting, invasive species and climate change have diminished the forests.

The leaves she picks — after a cumbersome planning and permission process — are stored in liquid nitrogen in the field and

shipped on dry ice to Purdue for RNA sequencing in her lab.

“I have several projects focusing on the tree’s genetics and genomics,” she says. One examines trees growing at different elevations; another is to identify genes that create the valued figure formations.

She has identified a suite of genes; next she’ll seek confirmation from collaborators.

“I love seeing something I’ve done benefit others,” says Lawson, who holds a Purdue doctorate. “I am truly in this to help someone other than myself.”

## UNDERSTANDING SOYBEAN’S ENEMIES

**Glycine max** | Growing up on a coffee plantation in India, a hot, humid landscape where bugs thrived, Punya Nachappa understood that pest and disease outbreaks are the number one enemy of farmers. During that time most of the research focused on using pesticides to get rid of insects and did not take into account insect biology. Today, she would like to develop alternative methods that take insect biology into account.

With a background in agriculture, specializing in entomology, Nachappa, an assistant professor of biology at Indiana University-Purdue University Fort Wayne, studies insects that transmit microbes or pathogens that cause diseases in plants such as soybeans (*Glycine max*).

The United States is the world’s top producer of soybeans, and Indiana’s production is fourth in the country. Coincidentally, a new soybean virus was

discovered her first year at Purdue, and it has become a big focus of her research. Nachappa wants to learn what types of insects transmit the soybean vein necrosis virus, where these insects live, and whether the virus has an impact on these insects. And why don’t these insects get infected when they are carrying a harmful pathogen?

When trying to understand the balance, Nachappa has found that insects carrying the virus have better reproduction rates than insects who do not. Understanding the interaction between the insect and virus, and what it means to growers, is her focus for the future.

“Right now, we know what happens externally at the insect and plant level,” says Nachappa. “I would like to understand more what’s happening at the genetic level: what kinds of genes and proteins are involved in the interaction between the insect and the virus, the plant and the insect, and getting to the next level of complexity.”

PHOTO COURTESY OF PUNYA NACHAPPA



Punya Nachappa



# LIFE•OLOGY

## *fungi*

### **Fungi**

noun (plural)

[**fuhn** jahy, **fuhnng**-gahy]

*Fungi are the taxonomic kingdom comprised of yeasts, mildews, molds and mushrooms. They may be unicellular (yeasts) or multicellular (all others), and have cells with walls. Like animals, they are heterotrophs, decomposing other organisms and absorbing nutrients through their cell walls. Fungi may live in beneficial associations with plant roots and make water and nutrients more available to the plant. They are not mobile, but their spores can disperse long distances. The oldest fossils of fungi date to 460 million years ago.*

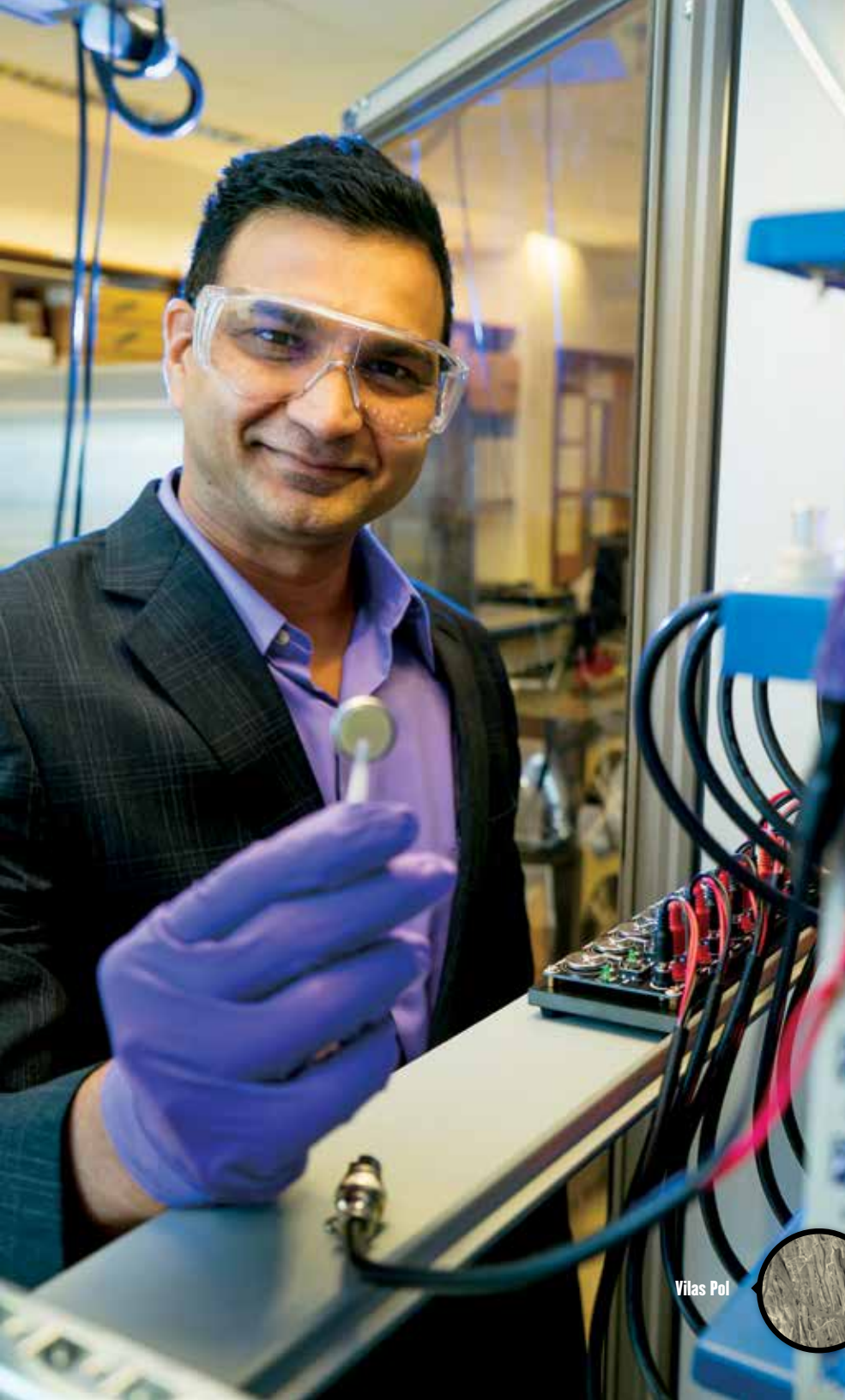


PHOTO BY VINCENT WALTER

## COOKING UP NEW BATTERIES WITH WILD MUSHROOMS

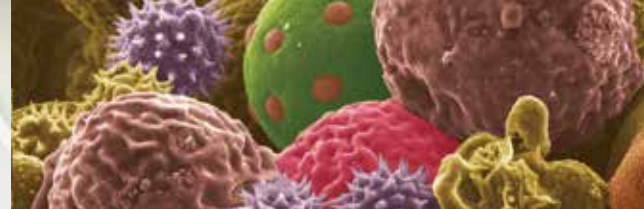
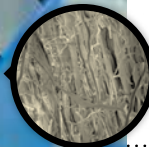
*Tyromyces fissilis* | A wild mushroom in a researcher's backyard provided inspiration and feedstock for a new electrode material of an energy storage device that improves battery performance and safety. It was a fortuitous find by researchers Vilas Pol and Jialiang Tang, who are on a quest to use renewable resources while improving energy storage and were looking for an alternative source for carbon fibers.

The complex and intertwined fibrous structure of the fungus, *Tyromyces fissilis*, forms a conductive interconnected network that allows for faster electron transport. That could help meet the future energy storage demand and power output needed for next-generation energy-storage technologies.

Pol, a professor of chemical engineering, and doctoral student Tang converted the mushroom's fibrous structure into carbon microfibers through a solid-state controlled pyrolysis process. They then modified the microfibers with cobalt oxide nanoparticles to create battery anodes that outperform conventional graphite electrodes used for lithium-ion batteries.

"As a research group with a strong emphasis in renewability, we are accustomed to taking inspiration from nature and utilizing natural products in our energy storage research," Tang explains. "We seek to improve battery performance and safety through new electrode fabrication and battery-cell design. We also hope to bring down the cost of battery electrodes and to improve their environmental footprint by using renewable resources."

Vilas Pol







Catherine Aime | Jorge Diaz-Valderrama

Image courtesy of Wikimedia Commons.

## CHOCOLATE-ATTACKING FUNGUS DITCHES SEX FOR CLONING

*Moniliophthora roreri* | Chocolate lovers, beware. A fungal disease that threatens the global supply of cacao has developed the ability to clone itself.

Frosty pod rot, a fungus that destroys cocoa pods, has decimated cacao plantations throughout the Americas over the last 60 years, dropping yields in some areas by up to 100 percent and forcing many growers to abandon their operations altogether.

Understanding the fundamental biology of the fungus could help disease control efforts, but researchers have long been stumped by the reproductive habits of the fungus — known as *Moniliophthora roreri* —

which appear to deviate from those of sister species.

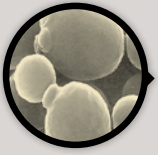
Digging into the genomics and population genetics of *M. roreri*, Catherine Aime, professor in the Department of Botany and Plant Pathology and director of the Purdue Herberia, and doctoral student Jorge Díaz-Valderrama found that the fungus has all the right mating gear: two seemingly compatible mating types — the fungal equivalent of sexes — and apparently functional sex pheromone receptors. But they couldn't find any indication that the mating types were recombining in the field or lab, and no records of *M. roreri* mushrooms exist. These are signs that the fungus has ditched sex in favor of cloning,

a reproductive shortcut that fungi use when they're well suited for their environment.

"In terms of resources, sex is expensive while cloning is a cheap and easy way to produce a lot of offspring," Aime says.

But it's too early to start hoarding Hershey's. The findings could help improve efforts to create cacao varieties resistant to the disease and advance the search for *M. roreri*'s weak spots.

"We're working on identifying biochemical components that could be useful for controlling frosty pod rot and protecting vulnerable cacao-growing regions," Díaz-Valderrama says.



## BREWING BEER, STUDYING CANCER

*Saccharomyces cerevisiae* | Beer. Wine. Cancer research. Mark Hall and other scientists at the Purdue University Center for Cancer Research are studying baker's yeast (*Saccharomyces cerevisiae*), which is used to make bread, beer and wine, as a model to understand the basic principles of cell division control that are often defective in cancer.

"Amazingly, the process of cell division is mostly the same in species as different as humans and fungi," says Hall, associate professor of biochemistry. "Yeasts are easy to grow and to manipulate genetically, and much of what we know about human cell division has come from pioneering studies using yeast."

Hall says his research is a perfect fit with one of the primary missions of the Center for Cancer Research — to understand the biological basis for cancer formation.

"That essentially describes what my lab is interested in," he says. "We look at what enzymes and cellular processes can contribute to cancer formation by destabilizing the genome when they become defective."

Hall's work can be applied to several areas of cancer detection and treatment, including the identification of diagnostic cancer biomarkers and therapeutic agents. For instance, his team has been studying

ways to inhibit certain enzymes to sensitize cancer cells to certain chemotherapies.

Hall, who watched his father-in-law struggle and eventually pass away during a fight with pancreatic cancer, says he hopes to help other patients who are fighting similar health battles.

"I hope to one day be able to say that I made an important contribution to our understanding of cancer, either through the discoveries in my lab or indirectly through the students that I mentored," Hall says.

PHOTO BY VINCENT WALTER **Mark Hall**







Nancy Ho | President Barack Obama

## FROM THE LAB TO THE WHITE HOUSE

*Saccharomyces cerevisiae* | The East Room of the White House sparkled with massive cut-glass chandeliers and stately gold drapes — a departure from Nancy Ho's typical work environment in her lab, surrounded by test tubes and Petri dishes.

This day in May 2016 was no ordinary work day. Ho was at the White House to accept one of eight National Medal of Technology and Innovation awards presented by President Barack Obama.

"These scientific laureates exemplify the American spirit and ingenuity that have enriched our society and the global community in profound and lasting ways," Obama said that day. "Their ambition and accomplishments are an inspiration to the next generation."

A research professor emerita in the School of Chemical Engineering, Ho was recognized for using *Saccharomyces cerevisiae* to develop a yeast-based

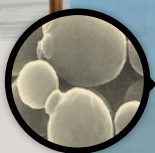


PHOTO BY DAVE UMERGER

Nancy Ho

technology that co-ferments sugars from plants to make ethanol — and for making it commercially, environmentally and economically viable. It's marketed through her company, Green Tech America Inc., where research on improvements continues.

The award caps decades of study and work that began when Ho was a curious, contemplative child in China. "I've always loved science," she says. "I dreamed and thought about how things worked. Science was easy, and math was my toy."

Created in 1980 and administered for the White House by the U.S. Department of Commerce's Patent and Trademark Office, the medal recognizes lasting technological contributions.

PHOTO BY VINCENT WALTER

## FIGHTING PLANT DISEASES

*Botrytis cinerea* | Grapes shriveled and gray on the vine. Tomatoes on the stem with fuzzy gray blotches. The plant pathogen *Botrytis cinerea* has struck, bringing gray mold disease, blight, loss of food sources and economic hardship.

An indiscriminate attacker, this pathogen goes after some 200 plant varieties.

"It affects the plant's stem, fruit and leaves," says Tesfaye Mengiste, professor of botany and plant pathology. "We want to understand the plant's own mechanism involved in fighting the mold at the molecular level, and to use this basic knowledge to generate plants that fight the mold."

Through molecular, biochemical and genetic studies, his team identified genes — MED18, HOOKLESS1 and two methyl transferases — that regulate

a plant's timely defense against fungal infection. With these fundamental findings, published in *Nature Communications* and *The Plant Cell*, Mengiste hopes to find ways to fend off mold and other diseases.

While his Lilly Hall lab staff have numerous projects, sorghum, which is important for food and feed, and tomatoes, which are also globally significant, are primary.

"We have identified major genes and are looking for natural variants that are mold-tolerant," he says.

Using genetic technological advances to identify naturally resistant plants, he says, "We can breed or select plants that resist disease. We have the foundation for future progress." An example: current field research in Africa to identify grain mold and anthracnose resistance in sorghum.

Tesfaye Mengiste





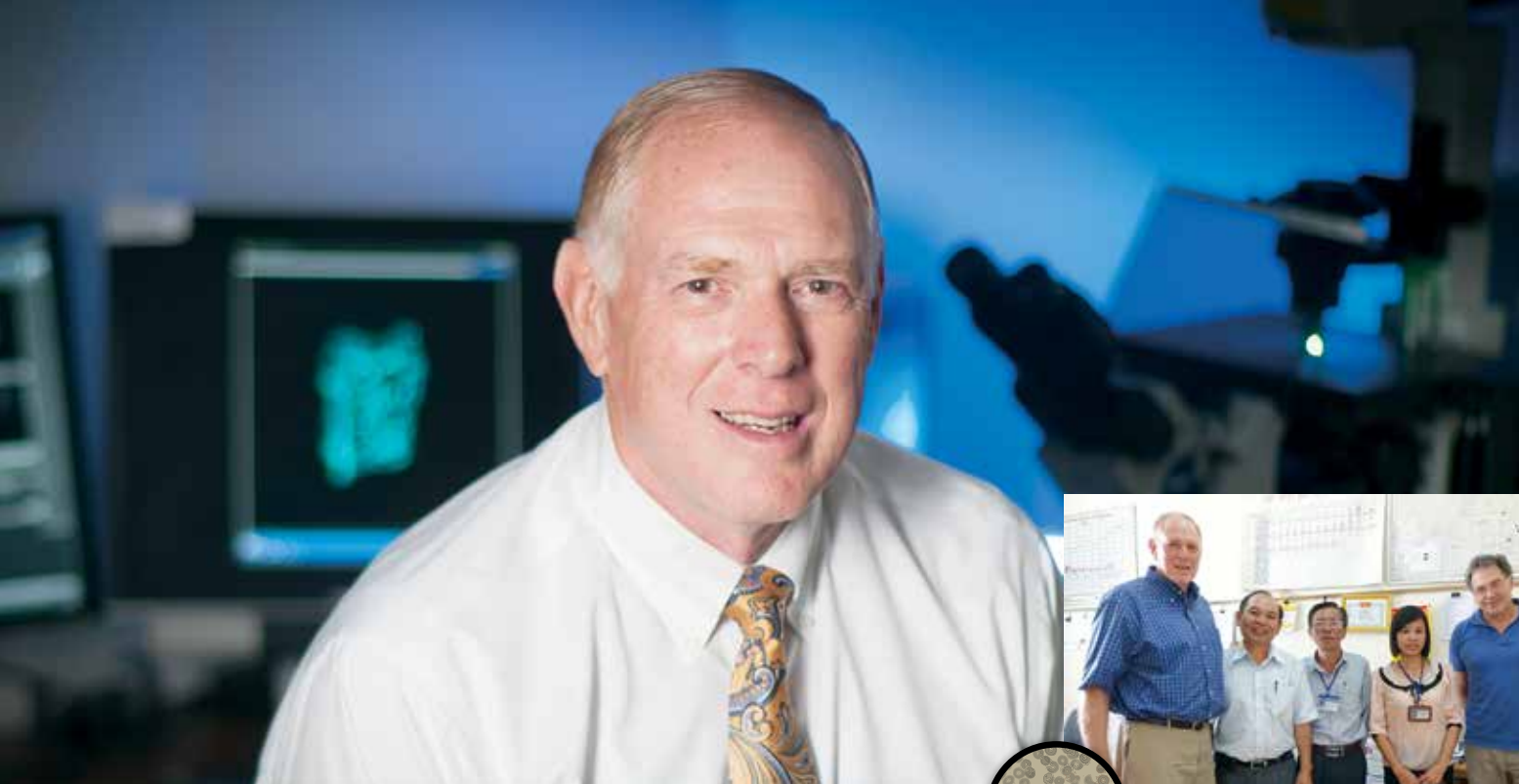
# LIFE•OLOGY

## *protista*

### **Protista**

noun, [proh-**tis** tuh]

*Protista are a very diverse group of eukaryotic organisms that are usually single-celled and microscopic (e.g. an amoeba), but may be large and multicellular (e.g. kelp). Protists live in wet or moist habitats. Some, such as algae, use photosynthesis for sustenance, while others, such as Plasmodium which causes malaria, may be parasites. Still others engage in mutually beneficial relationships, such as the protists that live in the guts of termites and help them digest wood. Fossilized protists dating to 1.8 billion years ago have perforated calcareous shells, similar to those that form the White Cliffs of Dover. The classification of protists into a single kingdom continues to be studied and debated.*



Phil Low

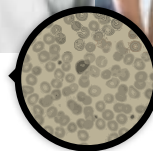


PHOTO COURTESY OF PHIL LOW

## HARNESSING A PARASITE'S VULNERABILITY

*Plasmodium falciparum* | Away from its bustling cities, Vietnam is a bucolic paradise of shimmering gold rice paddies, cone-hatted farmers and quietly grazing water buffalo. But its natural beauty belies a hard truth of rural life: When villagers get sick, their first recourse is often a concrete infirmary nestled in the jungle, with a garden of medicinal plants, a couple of metal beds and a handful of basic commercial medicines.

And when patients are infected with malaria (*Plasmodium falciparum*), even when drugs like dihydroartemisinin, piperaquine and chloroquine are available, too often the parasites are resistant, leaving the patient to his or her own natural defenses.

Phil Low is out to change that. Low, the Ralph C. Corley Distinguished Professor of Chemistry and the director of the Purdue Institute for Drug Discovery, has identified an enzyme that, when turned off, keeps anything from coming in or out of the red blood cell, and when turned on, causes the membrane to fall apart. The malaria parasite, he's discovered, turns on the enzyme in order to promote the membrane fragmentation that will release all of its progeny from the red blood cell, thereby enabling them to infect other red cells.

Low, in collaboration with Dr. Franco Turrini from Italy, has harnessed this vulnerability, creating an inhibitor of the enzyme that blocks the release of the parasite's offspring from the red blood cell,

ultimately killing the parasite within its host. He and Turrini are now collaborating with Dr. Huynh Dinh Chien at the University of Hue in Vietnam, to test the drug on patients in Vietnam.

So far, they are seeing promising results. If further testing bears out, the drug will next be tried in combination with other malarial drugs.

"We are very excited about the potential efficacy of our drug because it targets a red blood cell enzyme and not a parasite enzyme, so we anticipate that the parasite will be unable to develop resistance," Low says.



## CHANGING THE TRAJECTORY OF DRINKING WATER GUIDELINES

*Naegleria fowleri* | Insidious and invisible to the naked eye, the brain-eating amoeba *Naegleria fowleri* can lurk in water heaters and pipes, become airborne when the faucet is turned on, and can be inhaled through the nose, where it easily migrates into the brain, killing 97 percent of its victims.

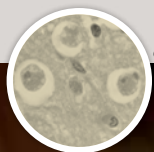
Dormant water pipes, un-chlorinated water filters and hoses left in the sun all create hospitable environments for *N. fowleri* and other disease-causing organisms, but that doesn't mean these pathogens will colonize — and even if they do multiply, they won't necessarily infect anyone. All

that randomness can be frightening, but Andrew Whelton believes that some science-based recommendations could be created to protect people from a variety of deadly pathogens including *Pseudomonas aeruginosa*, *Legionella* and *Mycobacterium avium*.

In 2015, Whelton teamed up with graduate student Karen Casteloes and Randi Brazeau of the Metropolitan State University of Denver, publishing guidelines for health officials and drinking water providers on how to decontaminate plumbing systems after chemical contamination. He is now pursuing similar research for biological contaminants.

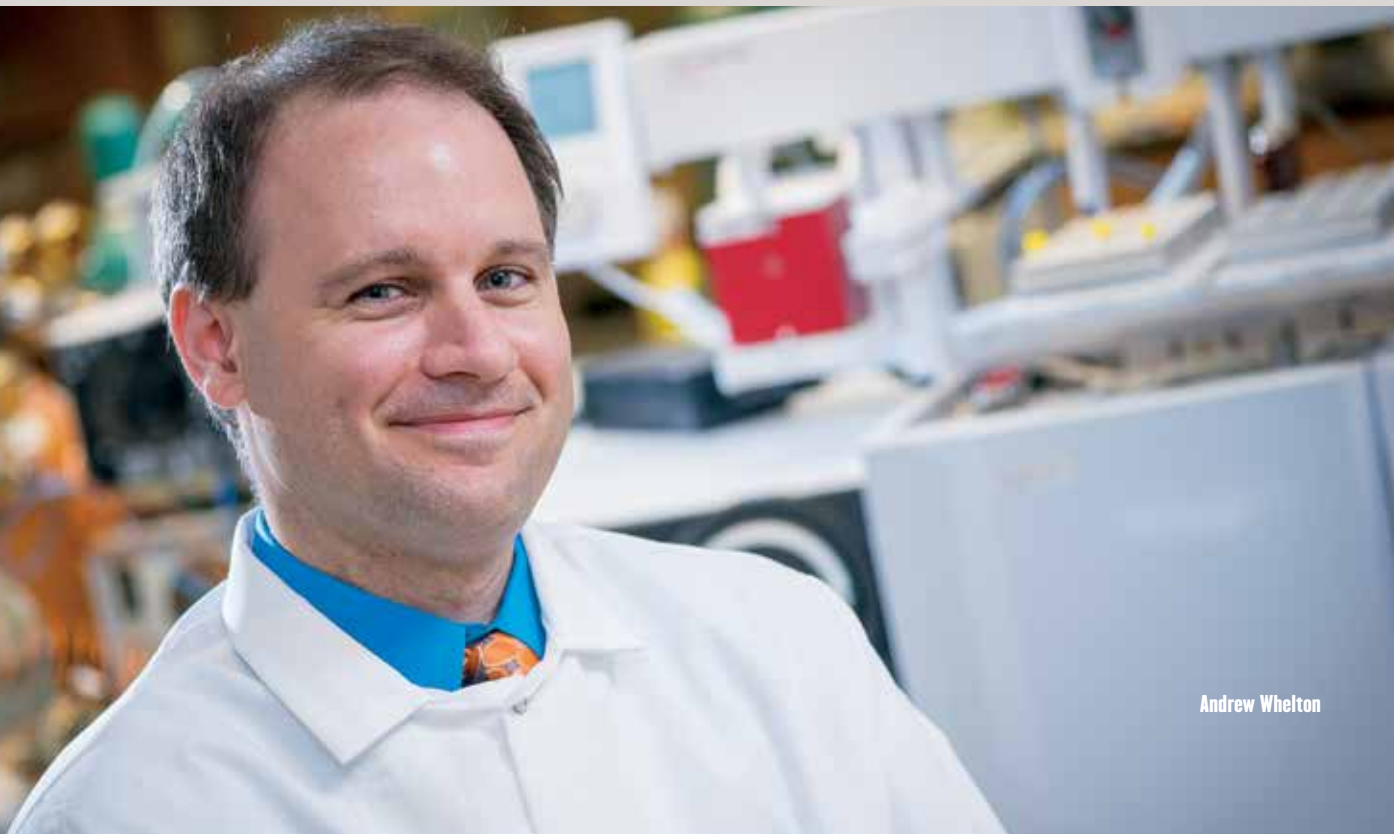
“Right now, there's a poor understanding on when water will go bad after it comes into a building,” says Whelton, assistant professor of civil engineering and environmental and ecological engineering. “Next time you turn on the faucet, ask yourself how long that water has sat in the pipes.”

There are also marked inconsistencies between municipalities, states and the federal government when it comes to drinking water guidelines and standards — largely, he says, because of the lack of science behind many of the recommendations. “We have an opportunity with our research and teaching efforts to change the trajectory.”



CDC

PHOTO BY VINCENT WALTER



Andrew Whelton



PHOTO BY TOM CAMPBELL



Michael Scharf

## TAKING ON TERMITES

*Trichonympha* sp. | With mouths that tear through wood and disease-fighting microbes in their gut warding off attacks, termites have long been free to ravage homes, especially in hot, moist climates.

Their reign of destruction may soon be over, thanks to researchers who identified how to strike down termites' ability to resist fungal diseases, leaving the eyelash-sized villains defenseless to invaders.

Entomology professor Michael Scharf and his research team found that a small dose of the insecticide imidacloprid could destroy

the termite's disease-fighting protist gut symbionts, such as *Trichonympha* sp., for example, weakening its defenses against fungal pathogens.

With that information, researchers believe they can minimize the use of pesticides — an environmental positive, leaving termites to forests where their work is valued in breaking down plant fibers and dead and decaying trees.

“Eventually we hope to have an insecticidal cocktail that will include fungal pathogens as well as materials that kill the termites’

beneficial gut microbes,” Scharf says. “A big part of our motivation is to find friendly ways to keep them out of the house, with more targeted placements and less impactful ways to keep termites in check.”

That may take a while, Scharf says of the work with Drion Boucias at the University of Florida and their joint publication in PLOS ONE. What's most important, Scharf says: “We’ve made a discovery, and we’re learning new things.”



# LIFE•OLOGY

*archaebacteria*  
*eubacteria*

## Archaeobacteria

noun [ahr-kee-bak **teer**-ee-uh]

*Archaeobacteria are ancient bacteria that live in harsh environments such as those with high temperature, salt, methane, acid or sulfur levels. They contain unique isoprenoid lipids, in their cell membranes. Overall, their genes share similarity with both bacteria and eukaryotes. The oldest fossil records for archaeobacteria date to 3.8 billion years ago.*

## Eubacteria

noun, [yoo-bak **teer**-ee-uh]

*The taxonomic kingdom eubacteria (true bacteria) is largely comprised of bacteria that we are familiar with from health and disease, and cyanobacteria, those that produce their own food through photosynthesis. The composition of their membranes differs from archaeobacteria. Eubacteria may be beneficial, such as those that produce antibiotics or reside in our gut, or may cause illness, such as methicillin-resistant *Staphylococcus aureus* (MRSA). The oldest cyanobacteria fossils date back to 3.5 billion years ago and are responsible for beginning to contribute oxygen to the earth's atmosphere.*

## REPURPOSING DRUGS TO FIGHT MRSA

*Staphylococcus aureus* | While Mohamed Seleem claims “there’s nothing fancy about it,” his 3,000 square feet of Lynn Hall lab space, some of it shared, houses biosafety cabinets, walk-in coolers, a dark room, radioactive room and equipment needed for bacteriology and molecular assays.

There, he, six graduate students and two scientists don white coats, goggles and gloves for their microbiology, cell culture, molecular biology work and screening 3,200 of some 4,000 approved drugs for possible treatment against bacteria and fungi.

Among their breakthroughs: determining that auranofin, a drug currently approved to treat rheumatoid arthritis, and ebselen, an organoselenium compound studied for its anti-inflammatory, anti-atherosclerotic and antioxidative properties, could be effective in better treating bacterial and fungal infections.

Significantly, that includes the often-deadly bacteria methicillin-resistant *Staphylococcus aureus* (MRSA). Burdened by its long name, global health threat and high incidences of death, the acronym-turned-nickname most pronounce “mersuh” brings dread, fear and a rush to apply an arsenal of largely ineffective antibiotics. Sometimes called the “super bug,” MRSA can strike anyone from middle-school wrestlers to hospital patients.

“I love research, I love the discovery,” says Seleem, an associate professor of microbiology in the College of Veterinary Medicine. “I love finding things that would be helpful and applicable in other areas. It’s my passion.”

An early discovery was one of those accidental occurrences that ends up making a great story. “In an experiment in the lab, a miscommunication between me and an undergraduate student prompted use of the wrong control,” Seleem says. “Without expecting it, that gave us a drug that killed bacteria. Next, we needed to learn how, so we expanded the application to see how we could use that clinically.”

Finding new ways to fight MRSA and other infections has “so much potential,” he says, because no drug has ever been repurposed as antibacterial. “With resistance on the rise, it’s important to find new ways to treat and conquer microbial infections.”

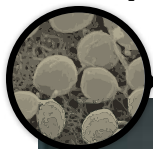
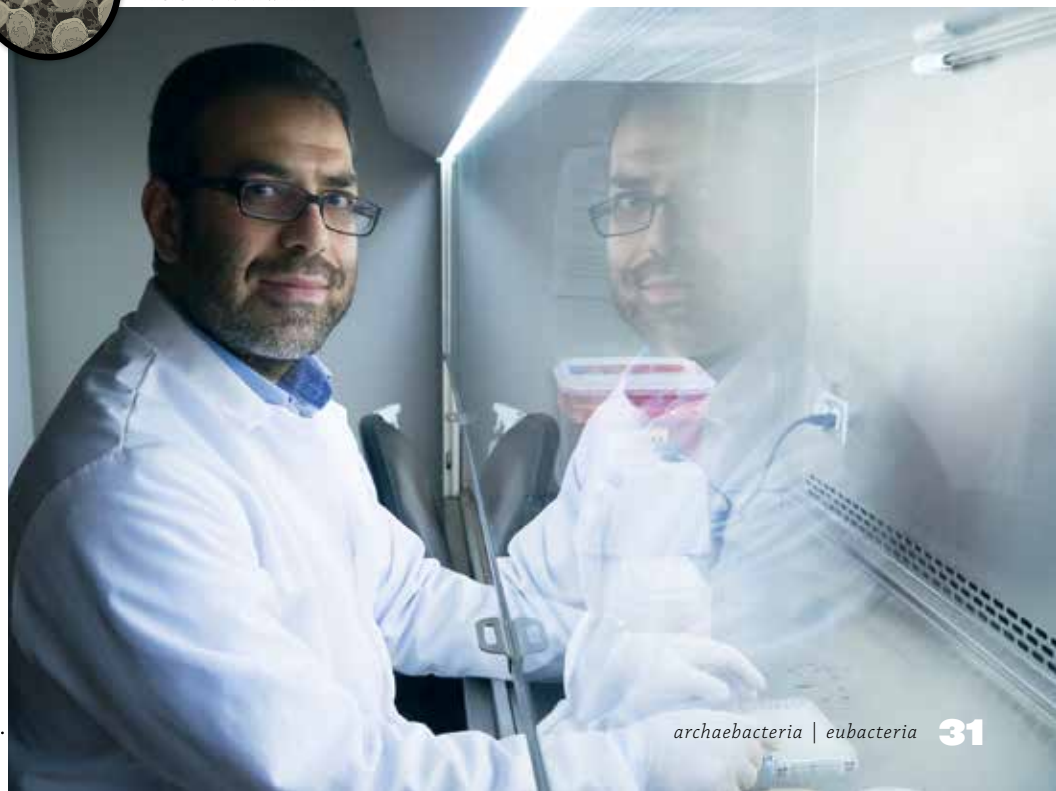


PHOTO BY VINCENT WALTER



Repurposing rather than starting from scratch saves on drug development costs and shortens the approval time, which means treatment for MRSA could be achieved sooner rather than later. The findings have been patented through the Purdue Research Foundation Office of Technology Commercialization and are available for commercial licensing.

Seleem’s work has been supported by a National Institutes of Health grant and a Purdue incentive grant.

Next on his list: securing the 800 remaining approved drugs, and continuing his research to find drugs that could be repurposed to treat deadly bacteria and fungi.

Mohamed Seleem



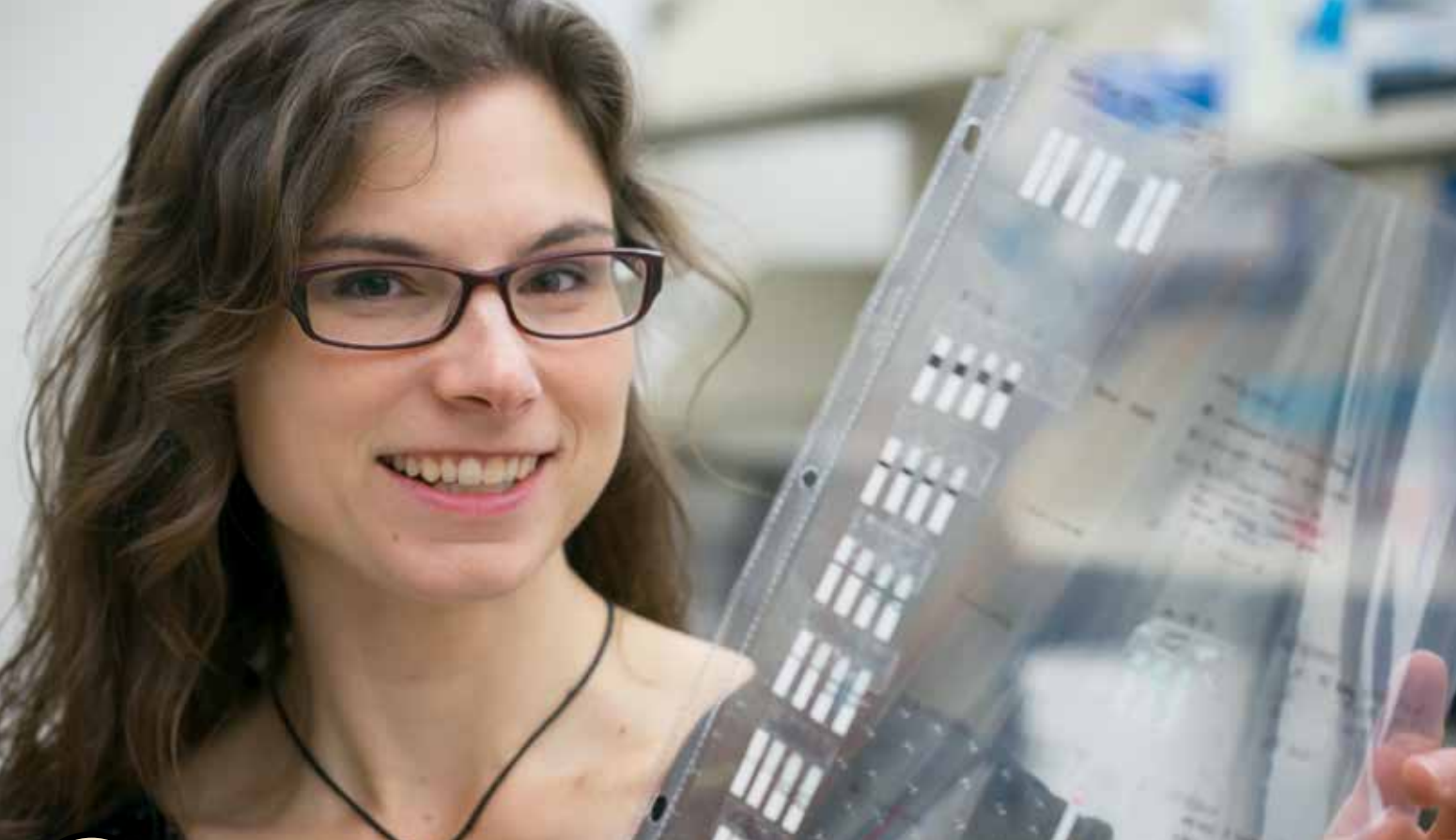


PHOTO BY VINCENT WALTER

Jacqueline Linnes

## BETTER HEALTH ON THE GO

*Vibrio cholerae* | Imagine diabetics no longer having to prick their fingers to test their blood sugar. Elderly patients wearing a temporary tattoo that shows their doctors if they've taken their medicine. These far-fetched ideas are becoming a reality, thanks to Purdue researchers looking into new diagnostic platforms and low-cost devices.

One of those innovators is Jacqueline Linnes, assistant professor of biomedical engineering, who specializes in creating paper-based devices to instantly diagnose diseases in the field that previously took

days in a lab. She is collaborating with other researchers to make a quantitative test that will empower officials to track water quality, helping to prevent cholera's spread in Haiti.

Linnes is also working with researchers in Kenya on a tool to diagnose neonatal sepsis, a major cause of newborn illness and mortality around the world, particularly in low-income countries.

The goal of her lab is simple: to create real-time detection technologies to prevent, diagnose and better understand the pathogenesis of diseases. To that end,

she is creating a breathalyzer to replace a traditional diabetes glucometer requiring finger pricks and a liquid bandage to detect drug overdose in real time.

"Anything we can do to empower patients to take control of their health and do a better job staying healthy while reducing medical costs is good; if you can keep people healthy, it's cheaper all around," says Linnes. "I'm excited to develop high-tech solutions and combine these with low-tech innovations so that we can make robust devices for anybody, anywhere in the world to use."

## UNRAVELING THE MATH OF DISEASE IMMUNITY

*Bordetella pertussis* | When children become infected with *Bordetella pertussis*, the bacteria damage the lining of their lungs, making it impossible to clear mucus and other microbes from their airways. Kids gasp, wheeze and cough uncontrollably, occasionally suffering seizures and brain damage.

Immunization can greatly reduce the risk of developing whooping cough, but it's only 60-90 percent effective. When pertussis resurged in Sweden despite high rates of whole cell vaccination, vaccination was discontinued, the disease became endemic and clinical trials of new acellular vaccines were conducted. Sweden introduced an acellular vaccine in 1997.

Swedish researchers collected cord blood samples from maternity hospitals along with blood samples from preschoolers, older children and adults. Those samples served as data points for a new study conducted with the help of mathematical epidemiologist Zhilan Feng and her colleagues in Sweden and at the U.S. Centers for Disease Control.

"The difficulty of this work is that immune mothers provide immunity to infants, but it decays," says Feng, a professor of mathematics. "Infection also can provide immunity, but that wanes, too. Re-infection can happen whenever immunity wanes. Our model is complicated mathematically."

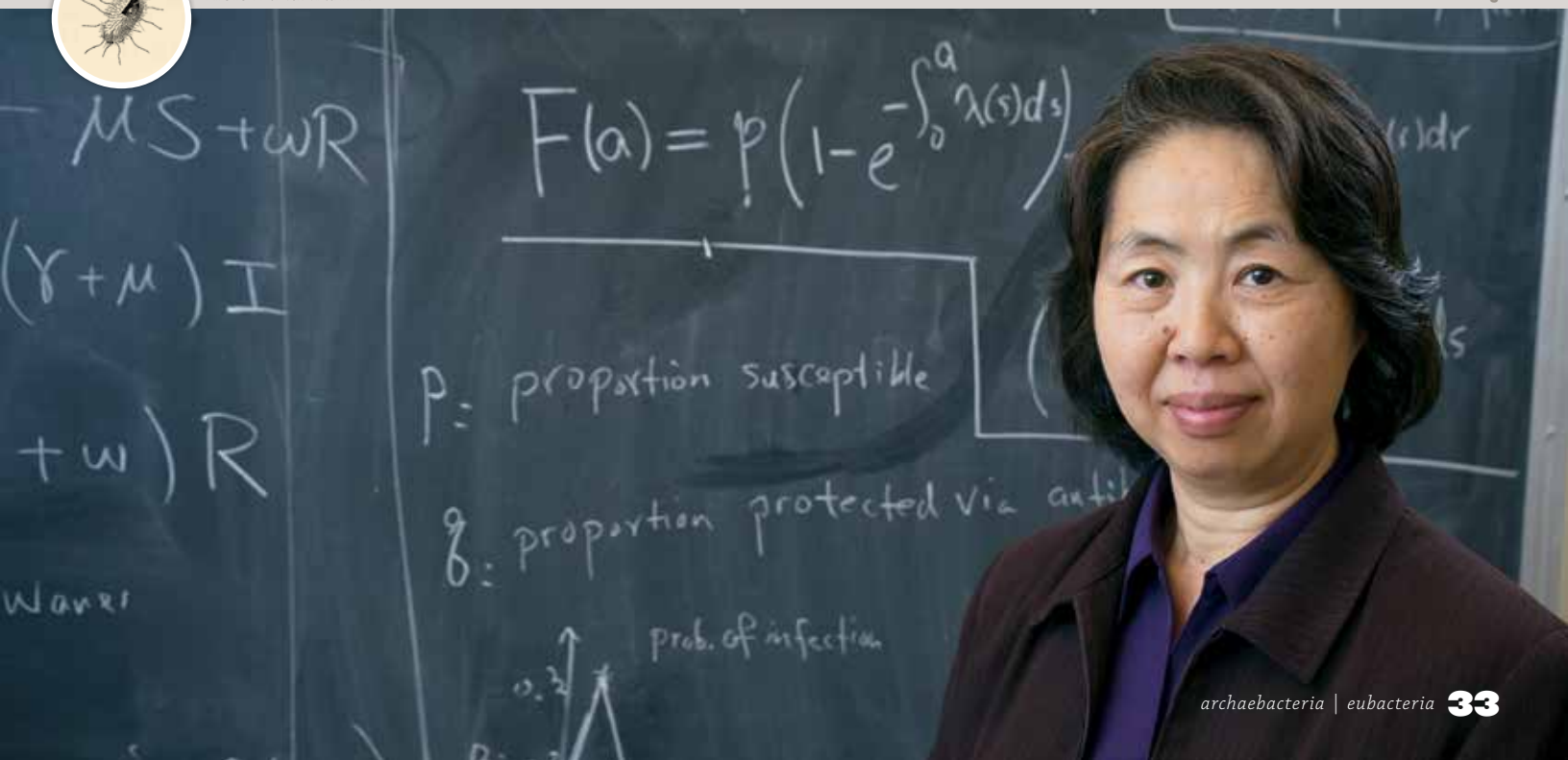
To help Swedish officials determine if and when a booster vaccination might be helpful, Feng and her collaborators devised a way to calculate rates of infection by age, accounting for maternal antibodies that were passively acquired. Their results showed that children, adolescents and young adults had higher infection rates than older people.

"I believe that our results are very important in terms of understanding this disease," Feng says. "And that this kind of work can provide useful information for policy makers in identifying critical groups for vaccination."



PHOTO BY VINCENT WALTER

Zhilan Feng





## VITAMIN A KEY TO COMBATING NASTY BACTERIA



*C. rodentium* | Study, identify connections, then apply the knowledge. Dressed in crisp white lab coats and bright blue gloves, Chang Kim and his Immunology and Hematopoiesis Lab team do just that as they achieve breakthroughs that may stave off inflammatory bowel diseases, *E. coli* infections and even cancer in humans.

One recent finding — Vitamin A's key role in boosting immune systems — began by examining the bacterium *C. rodentium*. When that nasty invader strikes a mouse and adheres to its intestinal walls, the tiny creature suffers inflammation, lesions, gastrointestinal disease, diarrhea and weight loss. For immunodeficient individuals due to congenital or environmental issues such as nutritional insufficiency, it's deadly.

What could counter such an attack? “Enhanced immunity,” says Kim, professor of immunology in the College of Veterinary Medicine and a program leader in the Purdue Institute of Inflammation, Immunology and Infectious Diseases.

How? With retinoic acid, he found, which is produced when a mouse consumes and metabolizes Vitamin A. The acid signals innate lymphoid cells, which promote immunity, to travel to the intestines and fight off infections.

The potential impact on human health? Huge. What his team is learning with mice can be applied to humans.

“The more we learn, the better we can prevent or treat infections, inflammations and autoimmune diseases,” Kim says.

“We are not doing clinical research. Our role is to make fundamental discoveries and let others develop therapies.”

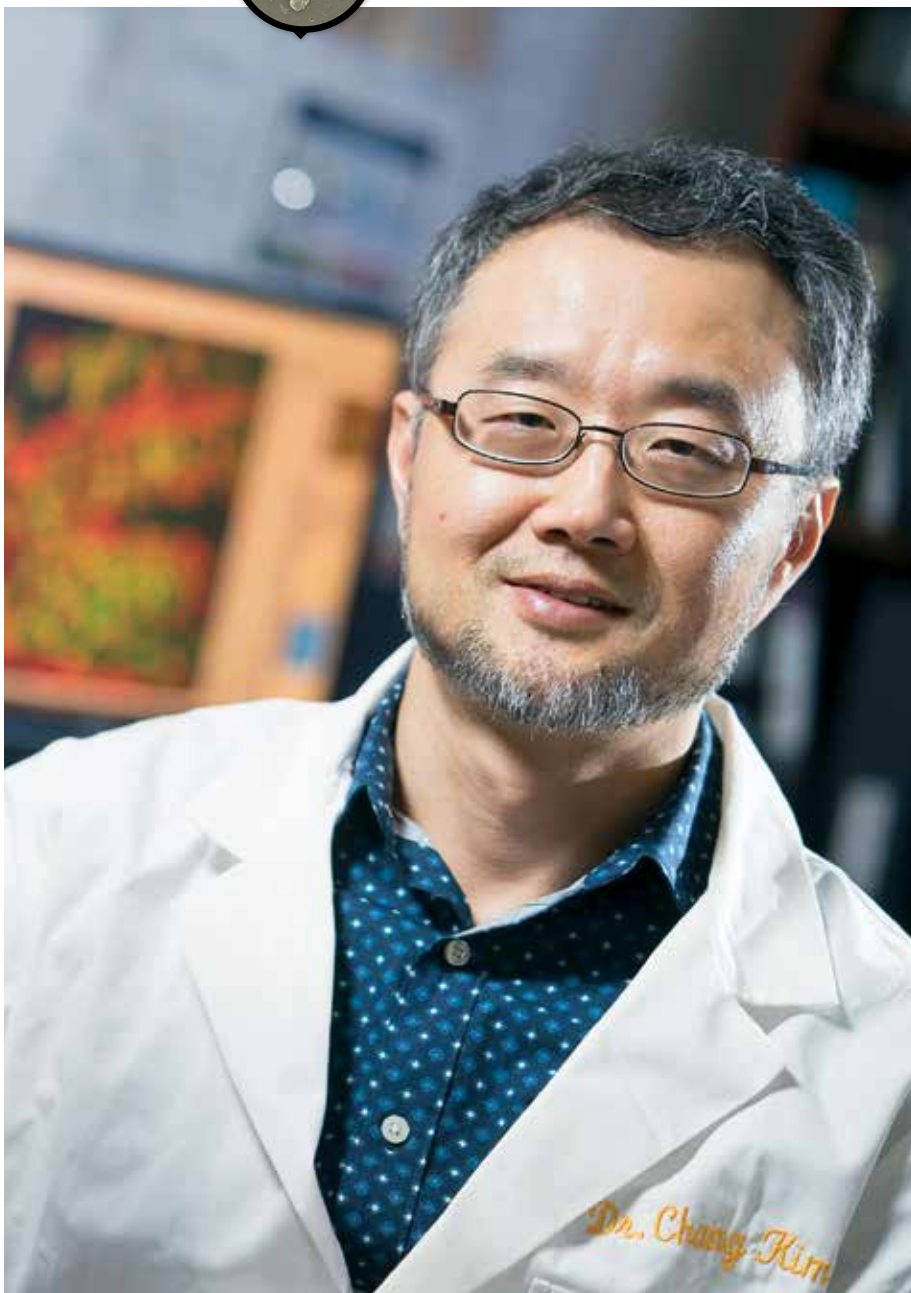


PHOTO BY VINCENT WALTER

Chang Kim



PHOTO BY VINCENT WALTER

Yava Jones-Hall

## WELCOME NEWS FOR INFLAMMATORY BOWEL DISEASE

*Lactobacillus* | At least 25 million Americans with inflammatory bowel disease (IBD) — maybe as many as 45 million, says the International Foundation for Functional Gastrointestinal Disorders — will welcome news from Purdue's Histology Research Laboratory.

In that lab, Yava Jones-Hall, assistant professor of veterinary pathology, her collaborator Cindy Nakatsu, a professor of agronomy, and graduate student Ariangela Kozik studied gut microbiome in mice with colitis. They found tumor necrosis factor (TNF) contributes to inflammation and microbial alterations in IBD.

Using wildtype mice (WT) in one group and mice lacking TNF in a second, they studied how its presence or absence affects colonic microbiome before and after acute colitis. Inflammation in mice without TNF was less severe. Also, TNF-dependent and independent bacterial communities differed.

Mice without TNF had less *Firmicutes* phylum and greater *Bacteroidetes* phylum. Independent of TNF, the relative proportion of *Lactobacillus* was decreased in WT mice with colitis compared to healthy WT mice.

"We knew people probably had changes in their microbiome contributing to IBD," Jones-Hall says. "I'm excited to know that just one protein — TNF — can have such a dramatic effect."

Their recently published paper in PLOS ONE suggests that combining TNF inhibition and altering specific microbial communities may be a successful therapeutic IBD approach.

"We will next focus on what is the stronger contributing factor to IBD — TNF or changes in microbiome," Jones-Hall says.





PHOTO BY CHARLES JISCHKE

Jiazhang Qiu | Zhao-Qing Luo



## HARNESSING BACTERIA FOR HUMAN HEALTH

*Legionella pneumophila* | A protein normally used by bacteria to infect people may one day prove advantageous for human therapies.

*Legionella pneumophila*, a bacterium which can cause pneumonia, injects many proteins into lung cells to assist its own replication during an infection. One of these proteins, discovered in 2016 in the lab of Zhao-Qing Luo, is able to take advantage of an important human cell-signaling mechanism. The signaling mechanism is used by cells for multiple essential processes, including moving proteins, turning proteins on or off or labeling them for destruction.

Surprisingly, the bacterial protein found by Luo's group is able to manipulate the cell signaling mechanism by employing a tactic that has been known to require three different enzymatic proteins. The bacterial protein accomplishes the same feat in a single step without assistance from any other enzyme.

"If one enzyme could accomplish the same thing, it could potentially make the therapeutic goal easier to achieve," says Luo, a professor of biological sciences. The discovery of the specialized bacterial protein and its unique capability not only furthers bacterial pathogenesis and cell-signaling research, but also opens the door

for human therapy development because of the compact and condensed manner in which the newly discovered protein accomplishes its critical work.

The team's discovery was selected as one of the 10 "Signaling Breakthroughs" of 2016 by Science Signaling. "Given its importance in diseases and development, many companies are working to develop drugs to control this signaling process and use it to treat diseases," Luo says. "This could lead to a very precise way to target and treat diseases."

# 2015-2016 *awards*



Jian-Kang Zhu

## **ZHU RECEIVES PURDUE'S TOP RESEARCH HONOR IN NATURAL SCIENCES**

**Jian-Kang Zhu**, a Distinguished Professor of Plant Biology, Departments of Horticulture and Landscape Architecture and Biochemistry at Purdue University, and director of the Shanghai Center for Plant Stress Biology, Chinese Academy of Sciences, received the 2016 Herbert Newby McCoy Award, the university's top research honor in the natural sciences.

The award recognizes Zhu for his groundbreaking contributions that have furthered understanding of epigenetics in biology.

"Dr. Zhu is among the world's most highly cited biologists. His pioneering research has uncovered the signaling pathways that govern plant responses to environmental stress," says Suresh Garimella, Purdue's executive vice president for research and partnerships and the Goodson Distinguished Professor of Mechanical Engineering. "The scope of his research contributions on epigenetics and plant science has great potential to improve crop productivity and human health."





Arvind Varma

## VARMA RECEIVES PURDUE'S TOP RESEARCH HONOR IN PURE AND APPLIED SCIENCE, ENGINEERING

**Arvind Varma**, the R. Games Slayter Distinguished Professor of Chemical Engineering and the former Jay and Cynthia Ihlenfeld Head of the School of Chemical Engineering, received the 2016 Arden L. Bement Jr. Award.

The award, which acknowledges distinguished research in pure and applied science and engineering, recognizes Varma's pioneering contributions to the discipline of chemical-reaction engineering.

"Dr. Varma's accomplishments within the field of chemical reaction engineering include 294 journal articles, five books in which he was either a co-author or co-editor, and research that has generated 10 patents, provisional patents and invention disclosures," says Suresh Garimella, executive vice president for research and partnerships and the Goodson Distinguished Professor of Mechanical Engineering.

Varma also invented an award-winning method to generate hydrogen for portable fuel cells, receiving a Technology and Innovation Award from IndustryWeek magazine in 2005.

"I feel privileged for having the opportunity to work with and influence the careers of so many outstanding scholars in chemical engineering," says Varma, who came to Purdue in 2004 from the University of Notre Dame. "I am deeply honored and thank Purdue for this recognition."



Linda Prokopy

Among his accomplishments, Zhu has created novel technologies to manipulate gene expression in crop plants, permitting fundamental discovery in plant genetics to be implemented in crops. He is a pioneer in CRISPR-mediated manipulation of plant genes. The powerful gene-editing technology has permitted the plant genetic research community to manipulate genes outside model systems.

"It is gratifying to know that the Purdue community recognizes the important work in plant epigenetics by my team, which includes students and postdoctoral researchers," says Zhu, who arrived at Purdue in 2010. "I look forward to staying active in this research to help understand the epigenetic code of life for crop improvement and human health."

## PROFESSOR HONORED FOR RESEARCH IN SOIL, WATER RESOURCES MANAGEMENT

**Linda Prokopy**, a forestry and natural resources professor, received the 2016 Corinne Alexander Spirit of the Land-Grant Mission Award for her work in soil and water resources management.

The award is presented yearly to a Purdue faculty member in the colleges of Agriculture, Health and Human Sciences or Veterinary Medicine whose work exemplifies the university's land-grant mission of discovery, engagement and learning. Alexander's name was added to the award in honor of the agricultural economics professor who died last year.

Prokopy's programs have focused on the role of decision-making in natural resource management. Her research and extension work generally fit into three overlapping areas: conservation behaviors of farmers, agricultural adaptation to climate change and social dimensions of watershed management.

## MORRILL AWARDS HONOR PROFS FOR TEACHING, RESEARCH, ENGAGEMENT

Three professors whose careers have demonstrated excellence in their teaching, research and engagement missions received Purdue's Morrill Awards in 2016.

This was the fifth year of the award, initiated to honor the Morrill Act of 1862, which allowed for the establishment of land-grant colleges and universities.

**Monika Ivantysynova**, the Maha Fluid Power Systems Professor, School of Mechanical Engineering and Department

of Agricultural and Biological Engineering, specializes in modeling and simulation of pumps and motors. Her research has led to several new discoveries about the fundamental behavior of fluid film and its importance for the design and successful operation of positive displacement machines. Several industry sponsors have commercialized her inventions, including a novel concept for hydrostatic transmission that includes energy recovery features now used in garbage trucks commercialized by Parker Hannifin Corp.

**Douglas Powell**, Distinguished Professor of Human Development and Family Studies, focuses on improving the literacy and language skills of preschool children by developing interventions to enhance the skills of parents and teachers in promoting successful child development. His research is tied directly to his teaching, in which he emphasizes parenting, intervention science and literacy. Powell is currently leading a five-year translational research project aimed at developing and testing an evidence-based school readiness curriculum for the U.S. Department of Defense Child Development Program, which reaches about 95,000 military children and their families worldwide.

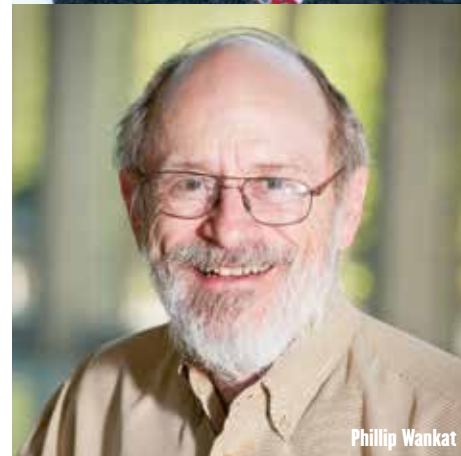
**Phillip Wankat**, the Clifton L. Lovell Distinguished Professor of Chemical Engineering and Engineering Education, has garnered a high number of awards and citations in both chemical engineering and engineering education. He has published more than 190 papers in chemical engineering and has secured two patents. An inaugural member of Purdue's Book of Great Teachers, he has spread the message of engineering education through



Monika Ivantysynova



Douglas Powell



Phillip Wankat





Charles Bouman

groundbreaking research articles, dozens of workshops, editorial work and course design. As associate dean, he played a pivotal role in the creation of Purdue's Department (now School) of Engineering Education.

## PURDUE INVENTORS HONORED BY NATIONAL ACADEMY

Two Purdue University professors were named 2016 fellows for their innovative research.

**Charles Bouman** is the Showalter Professor of Electrical and Computer Engineering and Biomedical Engineering. His research is on statistical signal and image processing in applications ranging from medical to scientific and consumer imaging; his work resulted in the first commercial model-based iterative reconstruction (MBIR) system for medical computed tomography and demonstrated its potential for dramatic X-ray dosage reduction.

**Sherry Harbin** is a professor of biomedical engineering and basic medical sciences. She developed the first standardized, fibril-matrix forming collagen polymers, otherwise known as collymers. Collymers undergo fluid to fibril-matrix transition as they self-assemble to form collagen fibrils similar to those found in the body's tissues. Collymer-based materials and tissues are fully customizable and readily facilitate encapsulation of therapeutic cells and drugs.



Sherry Harbin

## CLIMATE CHANGE RESEARCHER NAMED PUBLIC ENGAGEMENT FELLOW

The American Association for the Advancement of Science has named **Jeffrey Dukes** as a public engagement fellow. He is spending the 2016-17 academic year promoting climate change dialogue with the public.

Dukes is the director of the Purdue Climate Change Research Center in Discovery Park. His research group at Purdue examines how ecosystems and plant communities, in particular invasive species, interact with changes in the climate and atmosphere.

He is currently working with stakeholders and researchers to develop the Indiana Climate Change Impacts Assessment. He received his Ph.D. in biological sciences from Stanford University in 2000.

## PROFESSORS NAMED FELLOWS OF WORLD'S LARGEST GENERAL SCIENTIFIC SOCIETY

Four Purdue University professors were named in 2015 as fellows of the American Association for the Advancement of Science, the world's largest general scientific society.

**David Bahr**, head and professor of materials engineering in the College of Engineering, was recognized for significant contributions to research and education in materials science and engineering, particularly for advances in experimental studies of materials reliability across length scales.

**Bruce Craig**, professor of statistics and director of Purdue's Statistical Consulting Service in the College of Science, was honored for important contributions to science through collaboration between the biological sciences and statistics, and for administrative leadership and mentoring in statistical consulting and collaboration.

**Laurence Baker Leonard**, the Rachel E. Stark Distinguished Professor of Speech, Language and Hearing Sciences in the College of Health and Human Sciences, was recognized for distinguished contributions to the field of child language development and to the understanding and treatment of language disorders, including specific language impairment.

**Timothy Zwier**, department head and M.G. Mellon Distinguished Professor of Chemistry in the College of Science, was honored for distinguished contributions to the fields of molecular spectroscopy and chemical dynamics, particularly for the development of laser-based methods for single-conformation spectroscopy.



Jeffrey Dukes



David Bahr



Bruce Craig



Laurence Baker Leonard



Timothy Zwier





Arezoo Ardekani

## EARLY CAREER RESEARCHERS HONORED BY WHITE HOUSE

Two researchers were recognized in 2016 with Presidential Early Career Awards for Scientists and Engineers (PECASE), the highest honor given by the U.S. government to young researchers:

**Arezoo Ardekani**, an assistant professor in the School of Mechanical Engineering, and **Milind Kulkarni**, an associate professor in the School of Electrical and Computer Engineering.

Ardekani's work is pointing toward future approaches to fighting bacterial biofilms that foul everything from implantable medical devices to industrial pipes and boat propellers. Biofilms cost the nation billions of dollars annually due to human and animal infections, product contamination and biofouling of membranes.

Kulkarni's research interests include programming languages and compilers. He is interested in various facets that are necessary to unlock the potential of

complex computation platforms, including multicore processors, heterogeneous architectures, sensor networks and distributed systems. Kulkarni is developing automatic techniques for optimizing the complex, irregular problems that drive application domains, such as graph analytics, data mining, simulation and graphics.

## CALDWELL NAMED AS JEFFERSON SCIENCE FELLOW

**Barrett Caldwell**, professor of industrial engineering and aeronautics and astronautics (by courtesy), was named to the 2016-17 class of Jefferson Science Fellows (JSF), an initiative of the Office of the Science and Technology Adviser to the U.S. Secretary of State.

The JSF program was established in 2003 to further build capacity for science, technology and engineering expertise within the U.S. Department of State and the U.S. Agency for International Development. The JSF program is administered by the National Academies of Sciences, Engineering and Medicine and is supported through a partnership between the U.S. academic community, professional scientific societies, the U.S. Department of State, and the U.S. Agency for International Development (USAID).

Caldwell began his one-year assignment in Washington, D.C., in August 2016.

## DUDAREVA RECEIVES HUMBOLDT RESEARCH AWARD

**Natalia Dudareva**, distinguished professor of biochemistry and horticulture and landscape architecture, received the Humboldt Research Award in 2016 for her



Milind Kulkarni



Barrett Caldwell

work in improving the understanding of plant biology and biochemistry.

Given by Germany's Alexander von Humboldt Foundation, the award recognizes researchers whose discoveries, theories or insights have had a significant impact on their discipline and who are expected to continue producing field-advancing achievements in the future.

Dudareva explores the molecular mechanisms of plant metabolism and how plants produce volatile compounds, scent and taste components that are essential for successful pollination, fruit development and plant defense

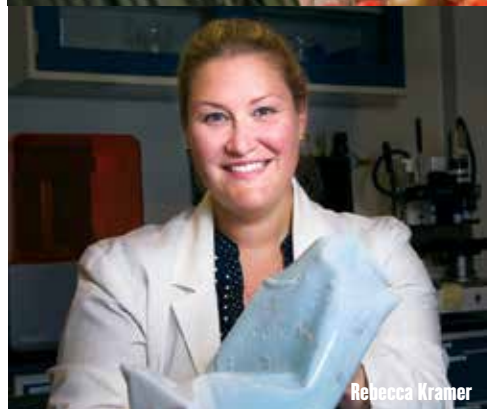
## PROFESSOR RECEIVES AIR FORCE GRANT FOR ROBOTICS RESEARCH

**Rebecca Kramer**, an assistant professor of mechanical engineering, has received a Young Investigator Research Program grant from the U.S. Air Force Office of Scientific Research. The award project focuses on robotic fabrics primarily for two applications: morphing aircraft wings and a "reactive automatic tourniquet" that can sense when the wearer is injured and automatically apply pressure to control blood loss.

The Young Investigator Research Program is open to scientists and engineers at research institutions across the United States who have received a doctorate or equivalent degrees in the last five years and show exceptional ability and promise for conducting basic research. Kramer, who has a Ph.D. in engineering sciences from Harvard University, was one of 58 researchers selected last year for the competitive award providing \$120,000 annually for three years.



Natalia Dudareva



Rebecca Kramer



Jonathan Freeman

## GRAD STUDENT STUDIES MUSICAL ARTISTS IN CAPE TOWN

**Jonathan Freeman**, a graduate student from Greenville, Miss., in American Studies, was one of several Purdue University students chosen for a Fulbright U.S. Student Program grant for the 2016-17 academic year.

Inspired by his first trip to Cape Town, South Africa, as a Mellon Mays Undergraduate Fellow in 2011, Freeman is examining the role of African-

American musical recording artists in the anti-apartheid movement. Through the Fulbright grant, he is studying in Johannesburg, South Africa, at the University of the Witwatersrand during the 2016-17 academic year, researching numerous archives there.

After completing his Ph.D., Freeman plans to become a professor, bringing his unique perspective to educating others about African-American history and transnational social movements while contributing to both transnational scholarship and policy.





## FOLI INDUCTED AS FELLOW IN THE AMERICAN ACADEMY OF NURSING

**Karen Foli**, associate professor and director of the Ph.D. Nursing Program in the College of Health and Human Sciences, was inducted into the American Academy of Nursing 2016 Class of New Fellows.

The academy serves the public and the nursing profession by advancing scientific knowledge and influencing the development of effective health care policies and practices.

Foli's research centers around the transitions experienced by non-traditional families, specifically new adoptive and kinship parents, as a child is introduced into the home. She has commented on national policy in this area and advocated that mental health screenings include prospective and new adoptive parents. Foli received her Ph.D. in health communications from the University of Illinois, Urbana-Champaign.



## ROSSMANN RECEIVES INTERNATIONAL PRIZE IN BIOPHYSICS

**Michael Rossmann**, the Hanley Professor of Biological Sciences, was named a 2016 Laureate of the Raymond and Beverly Sackler International Prize in Biophysics. Rossmann was singled out for his pioneering contributions to high-resolution diffraction analysis of atomic structures of proteins and viruses.

Rossmann is a pioneer in using high-performance computing in concert with X-ray crystallography, cryo-electron microscopy and molecular biology to deduce the structure of viruses and their

component protein molecules. He led the research team that was the first to map the structure of a human common cold virus to an atomic level. He also discovered the Rossmann fold protein motif. In 2016, he co-led the team that was the first to crack the code of the Zika virus.

The Raymond and Beverly Sackler International Prize in Biophysics, given by Tel Aviv University, was established to promote originality and excellence of research in the field of biophysics.

## HOWELL NAMED ONE OF 30 MOST INNOVATIVE WOMEN PROFESSORS ALIVE TODAY

**Kathleen Howell**, the Hsu Lo Distinguished Professor of Aeronautics and Astronautics, was named in 2016 as one of 30 Most Innovative Women Professors Alive Today by Philadelphia, Penn.-based BestMastersDegrees.com.

The award recognized Howell as an innovative professor of aeronautical and astronautical engineering who has made waves in recent years for an efficient technique she developed that challenges the more traditional method of getting spacecraft to their destination. Rather than the current approach based on less-informed numerical searches and a reliance on propellant to power NASA spacecraft, Howell has found a way to use the unseen free energy of the solar system.

"The gravity fields of the system's different objects create natural pathways that a spacecraft can follow," says Howell, who also has received a Presidential Young Investigator Award and the Dirk Brouwer Award from the American Astronautical Society.





Arun Bhunia



TJ Boisseau



Angelica Duran



Melanie Shoffner



Brian Smith

## FACULTY TRAVEL WORLD THROUGH FULBRIGHT SCHOLAR PROGRAM

Five Purdue University faculty traveled the world over the last year through the U.S. Fulbright Scholar program: **Arun Bhunia, TJ Boisseau, Angelica Duran, Melanie Shoffner** and **Brian Smith**.

Bhunia, a professor of food science, used his Fulbright award to travel to Ukraine during summer 2016, where he lectured on new methods of microbiological studies and pathogenesis of foodborne microbial infections at the Medical Institute of Sumy State University. He will continue to research global health issues through 2021, using a long-term Fulbright grant.

Boisseau, associate professor and director of Women's, Gender and Sexuality Studies, is using her Fulbright award to coordinate a transnational feminist theory module for the United Nations University M.A. trainees program in Iceland.

Duran, a professor in English and the Comparative Literature and Religious Studies programs in the School of Interdisciplinary Studies, is residing in various states in Mexico, while she completes an archival and teaching project for her book project "Milton in Hispanoamerica."

Shoffner, associate professor of English Education, is a visiting professor in the Faculty of Letters at Babeş-Bolyai University in Cluj-Napoca, Romania, where she teaches courses as part of her project, "Adjusting the American Lens: Literature and Pedagogy as Cultural Study in Romania."

Smith, assistant professor of communication, is serving as a visiting professor at Johannes Kepler University in Linz, Austria, where he is also implementing his project, "Connecting for Social Media Influence: Creating a Collaborative Research Initiative Between JKU-Linz and Purdue University."

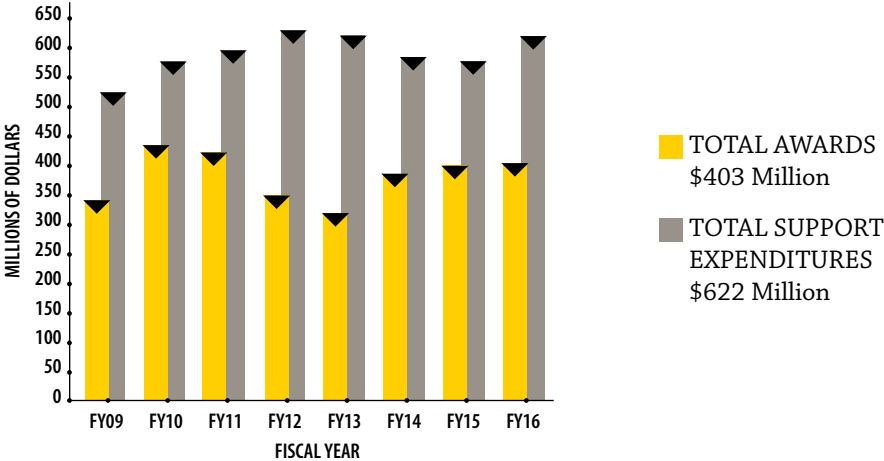


# SYSTEM-WIDE SPONSORED PROGRAM AWARDS AND EXPENDITURES

Purdue University continues to land significant funding in sponsored programs system-wide.

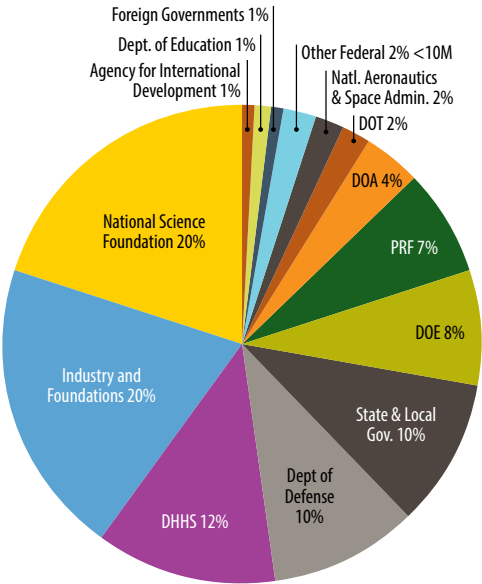
As a leading research university in the state of Indiana with a global reputation of excellence, Purdue is dedicated to maximizing our resources to build a research enterprise that supports impactful research. During FY 2016, Purdue received more than \$403 million in sponsored program awards system-wide.

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



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

## MULTIPLE SOURCES



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

- KEY:**
- DOT U.S. Department of Transportation
  - DOA U.S. Department of Agriculture
  - PRF Purdue Research Foundation
  - DOE U.S. Department of Energy
  - DHHS U.S. Department of Health and Human Services

Sponsored Awards come from multiple sources.



### **FROM THE PRESIDENT**

From patents to startup companies, Purdue University's upward trend in commercialization activities is evidence of the talent, knowledge and drive of our researchers. Thinking broadly and globally, they are creating innovations that are changing the world.

Mitch Daniels  
President



### **FROM THE PROVOST**

Today's challenges are larger and more complex than ever before, calling for research with a broader vision. Our researchers are embracing this new frontier, collaborating and welcoming different points of view in order to make life-altering discoveries.

Debasish (Deba) Dutta  
Executive Vice President for Academic Affairs and Provost



### **FROM THE EXECUTIVE VICE PRESIDENT FOR RESEARCH AND PARTNERSHIPS**

Purdue faculty, their research teams and university support staff work hard every day to improve lives around the world. Given their extraordinary accomplishments over the last year, I'm excited to see where their talents lead us in the future.

Suresh Garimella  
Executive Vice President for Research and Partnerships

**PURDUE**  
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## 2015 | 2016

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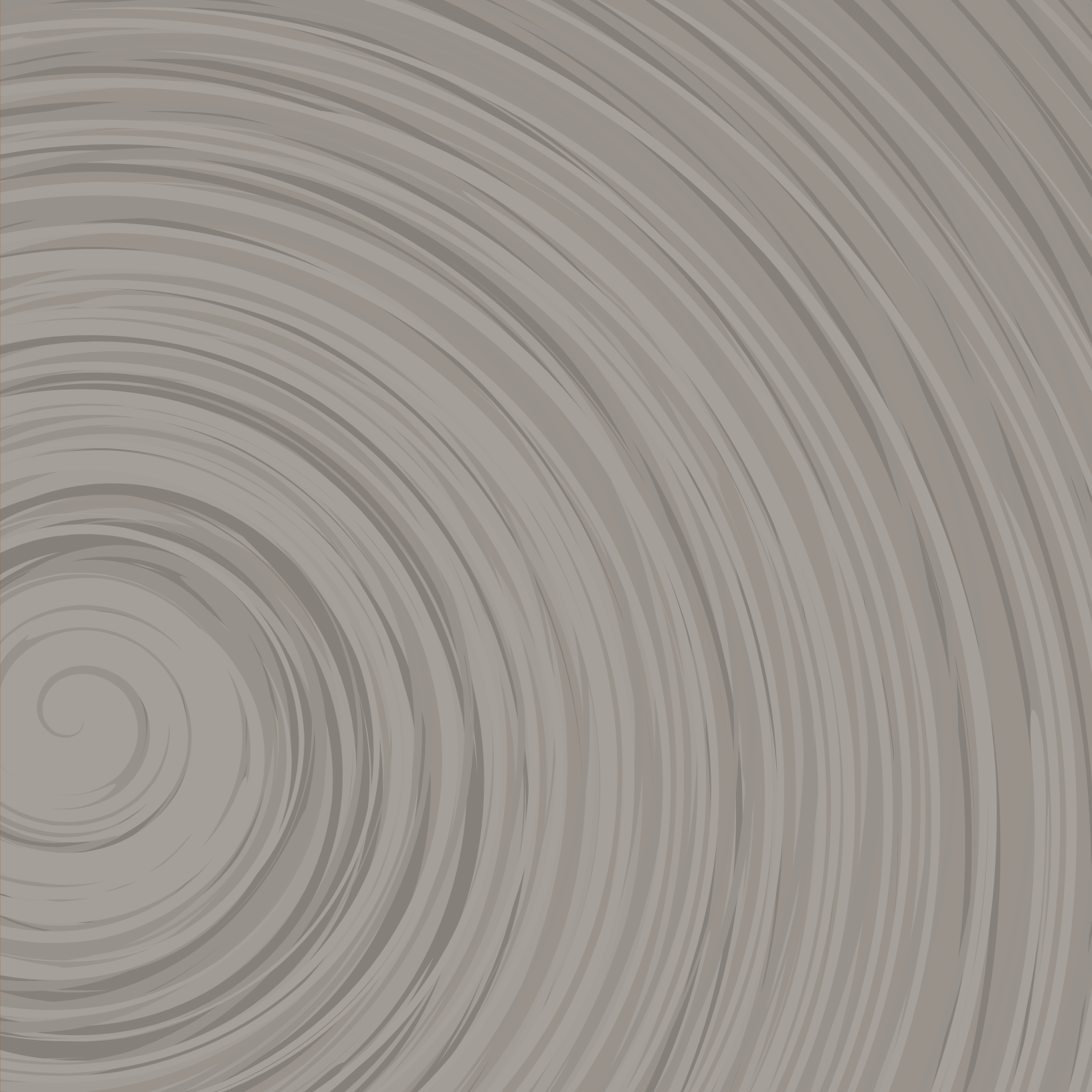
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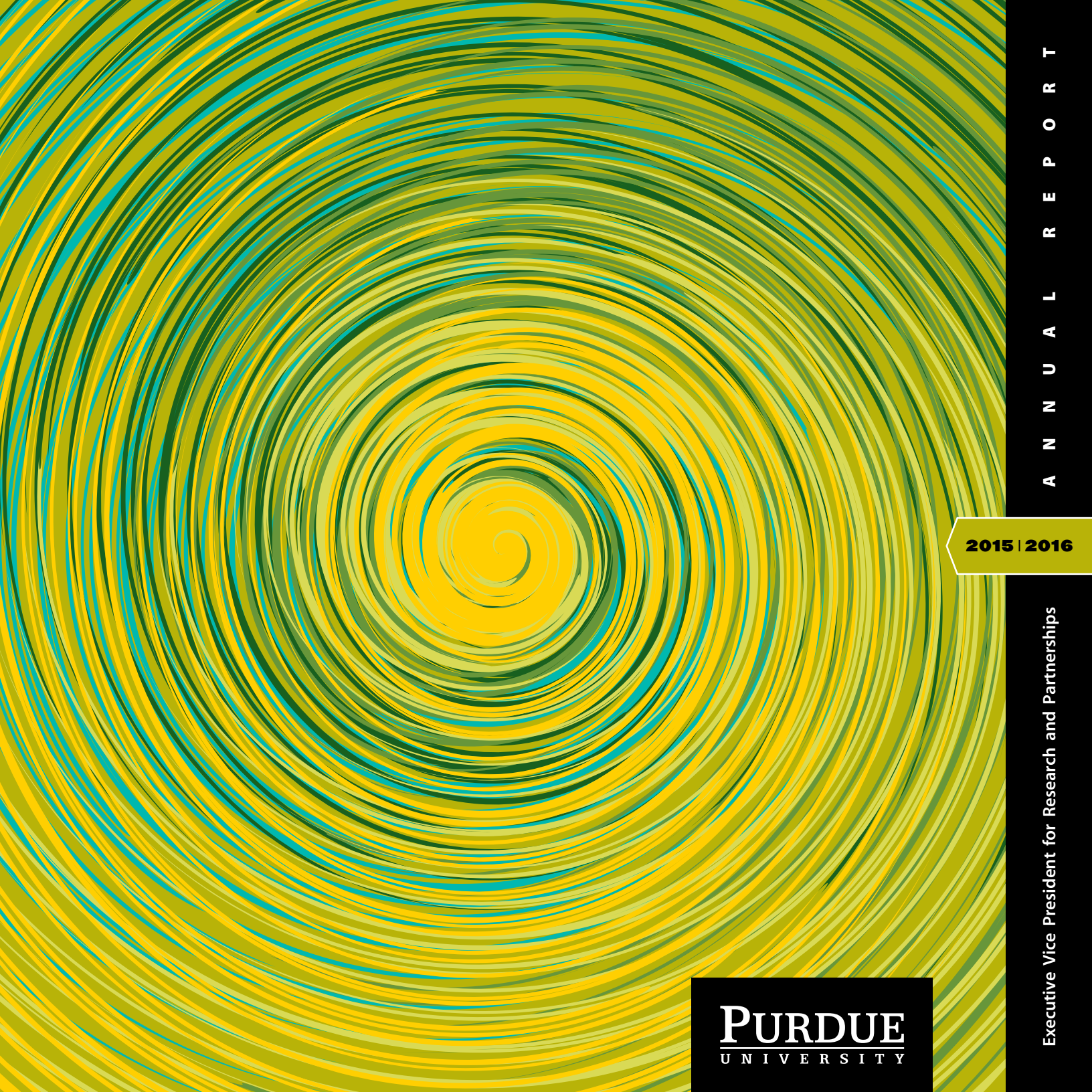
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