Research | PennState

VOLUME 38 | NUMBER 1 | SPRING 2018

Saving the BAY

› ALSO IN THIS ISSUE

Teamwork Rules

As society's challenges grow increasingly complex, the power of teamwork becomes more and more important. Effective solutions require new and creative alignments, a combined expertise that spans disciplines and sectors. This approach has long been a hallmark of Penn State's research enterprise, and the stories in this issue of *Research/Penn State* provide a broad sampling of fresh examples.

***FaceAge*, a fascinating installation by laureate Andy Belser, stands powerfully for our work in intergenerational studies, a growing field that spans psychology, sociology, human development, and the arts, promoting health and learning across the lifespan as well as strong families and cohesive, livable communities.**

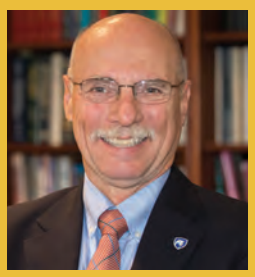
Partnerships are at the crux of Penn State's efforts to help clean up the Chesapeake Bay. Over the past decade, our College of Agricultural Sciences has emerged as a leader in bringing together diverse stakeholders from around the Commonwealth to address the difficult problem of nutrient pollution in the Bay and its tributaries.

Mónica Medina is one of four coral reef biologists who, with complementary expertise and collaborators around the world, have made University Park an unlikely center for coral research. And for teamwork writ large we hear from astrophysicist Chad Hanna on his role as part of a cast of over a thousand who are bringing about a brand new era in astronomy.

Finally, a conversation with associate vice president Jeff Fortin announces an exciting development in Penn State's long-standing commitment to partnering with industry.

Each of these stories illustrates both the growing necessity and the rich rewards of working together.

NEIL A. SHARKEY
Vice President for Research



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ON THE COVER:
A satellite image of the Chesapeake Bay shows the Susquehanna River flowing in from the northwest. Pennsylvania waterways supply half of the Bay's freshwater flow, and the largest share of its agricultural pollution. See story, page 30. Photo by Alamy.

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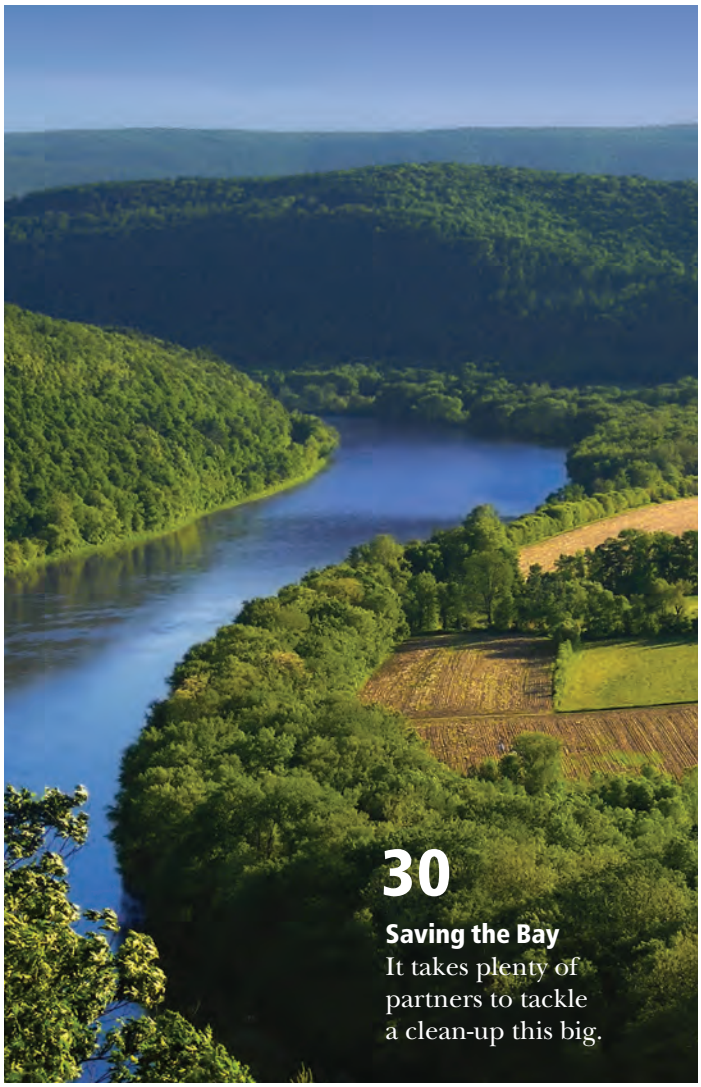


» Slowly Slipping

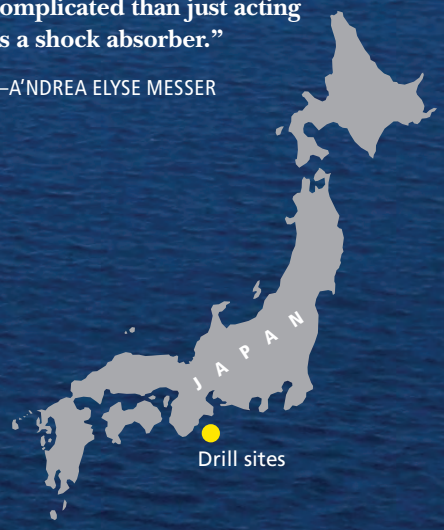
Studying slow-slip earthquakes in subduction zone areas may help researchers understand large earthquakes and the creation of tsunamis, according to an international team of researchers that used data from instruments placed on the seafloor and in boreholes east of the Japanese coast.

Two tectonic plates—the Pacific Plate and the Eurasian Plate—meet here, in a subduction zone where the former slides beneath the latter. This type of earthquake zone forms the "ring of fire" that surrounds the Pacific Ocean, because once the end of the plate that is sliding underneath reaches the proper depth, it triggers melting and forms volcanoes.

The researchers, Demian Saffer, professor of geosciences at Penn State, and Eiichiro Araki, senior research scientist at the Japan Agency for Marine-Earth Science and Technology, focused their study on slow earthquakes, slip events that happen over days or weeks. Recent research by other groups has shown that these slow earthquakes are an important part of the overall patterns of fault slip and earthquake occurrence at tectonic plate boundaries.

"Until we had these data, no one knew if zero percent or a hundred percent of the energy in the shallow subduction zone was dissipated by slow earthquakes," says Saffer. "We have found that somewhere around 50 percent of the energy is released in slow earthquakes. The slow slip could reduce tsunami risk by periodically relieving stress, but it is probably more complicated than just acting as a shock absorber."

—A'NDREA ELYSE MESSER



For this research, instruments were placed in holes drilled off the coast of Japan by the deep-sea drilling vessel *Chikyu*.

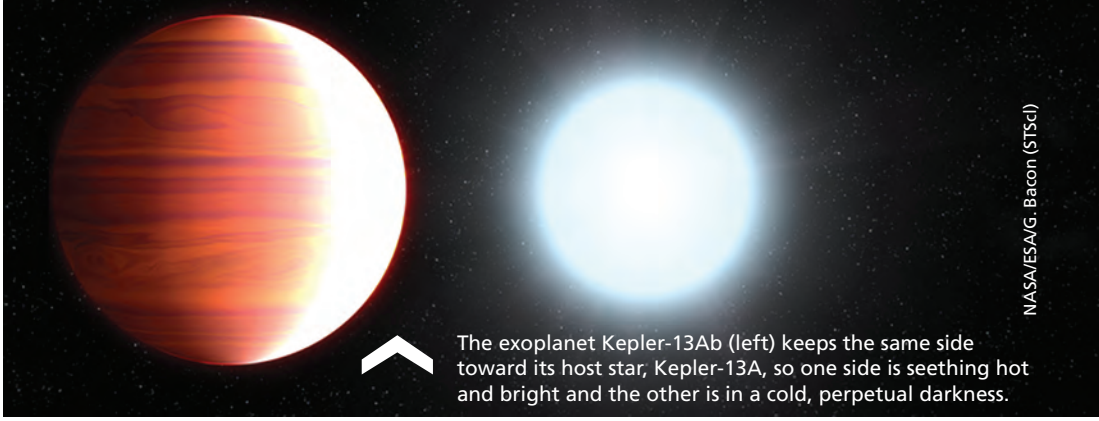
JAMSTEC

Three Mile Island nuclear accident may be linked to thyroid cancers in nearby counties.

- DAVID GOLDENBERG
Surgery

Health benefits of moderate alcohol consumption have probably been overstated.

- JEREMY STAFF
Criminology and Sociology



NASA/ESA/G. Bacon (STScI)

The exoplanet Kepler-13Ab (left) keeps the same side toward its host star, Kepler-13A, so one side is seething hot and bright and the other is in a cold, perpetual darkness.

Sunscreen Snow

Astronomers at Penn State have used the Hubble Space Telescope to find a blistering-hot giant planet outside our solar system where the atmosphere "snows" titanium dioxide, the active ingredient in sunscreen. These observations are the first detections of this "snow-out" process, called a "cold trap," on an exoplanet. The discovery provides insight into the complexity of weather and atmospheric composition on exoplanets, and may someday be useful for gauging the habitability of Earth-size planets.

"Understanding more about the atmospheres of these planets and how they work will help us when we study smaller planets that are harder to see and have more complicated features in their atmospheres," says Thomas Beatty, assistant research professor of astronomy at Penn State.

Beatty's team targeted planet Kepler-13Ab because it is one of the hottest of the known exoplanets. Its dayside temperature is nearly 5,000 degrees Fahrenheit. Kepler-13Ab is so close to its parent star that it is tidally locked, so one side always faces the star while the other side is in permanent darkness. The team discovered that the "sunscreen snowfall" happens only on the planet's permanent nighttime side.

The astronomers didn't go looking for titanium oxide specifically. Instead, their studies revealed that this giant planet's atmosphere is cooler at higher altitudes, which was surprising because it is the opposite of what happens on similar planets.

"Understanding what sets the climates of other worlds has been one of the big puzzles of the last decade," says Jason Wright, associate professor of astronomy. "Seeing this cold-trap process in action provides us with a long-sought and important piece of that puzzle."

—THOMAS BEATTY AND BARBARA KENNEDY

SPIT IN THE CUP «

Diagnosing a concussion can sometimes be a guessing game, but clues taken from small molecules in saliva may be able to help diagnose and predict the duration of concussions in children, according to a study done at Penn State College of Medicine.

Thinkstock

Researchers measured the levels of microRNAs — tiny snippets of noncoding RNA — in the saliva of concussion patients. They found that the presence of certain microRNAs in saliva was able to better identify concussions and more accurately predict the length of concussion symptoms than relying solely on patient surveys.

Steven Hicks, assistant professor of pediatrics, says the findings could result in a rapid, more fact-based way to diagnose and treat concussion patients.

"The tools we use to diagnose and manage concussions are subjective," Hicks says. "We do a physical exam and then have them answer a survey about their symptoms. Then, we make an educated guess about how long that child might continue to have a headache or feel nauseous. But those guesses aren't evidence-based and aren't always accurate.

"There's been a big push recently to find more objective markers," he adds. "Previous research has focused on proteins, but this approach is limited because proteins have a hard time crossing the blood-brain barrier. What's novel about this study is we looked at microRNAs instead of proteins, and we decided to look in saliva rather than blood."

—KATIE BOHN

Thinkstock

BABES ASLEEP ‹‹

The American Academy of Pediatrics (AAP) recommends babies sleep in the same room as their parents during their first year, to prevent sudden infant death syndrome (SIDS). But a study led by Penn State College of Medicine researchers has found that keeping a baby in the parents' room beyond the first four months is associated with less sleep and unsafe sleeping practices for the babies.

While room-sharing during the first six months is justified by the fact that 90 percent of SIDS cases occur then, Dr. Ian Paul, professor of pediatrics, says there's little evidence to support room-sharing after that.

The researchers used data from surveys of 279 mothers when their babies were 4, 9, 12, and 30 months old. At all four ages, babies who slept in their own room by 4 or 9 months of age got more sleep per night and had longer stretches of continuous sleep than those who had room-shared. That raises concerns about long-term effects on the childrens' health, says Paul, because inadequate infant sleep can lead to obesity and poor sleep later in life.

The survey also found that babies who shared a room with a parent were more likely to have a blanket or other object that could increase the risk of SIDS.

Paul says the findings suggest the AAP should reconsider its recommendation and that parents should discuss safe sleep practices with their pediatrician.

—MATTHEW SOLOVEY

Through a Glass, Clearly

Gazing through the stained-glass windows of London's Westminster Abbey can evoke feelings as vivid as the windows themselves, but to John Mauro, professor of materials science and engineering, the windows sparked a quest to better understand the science behind the glass.

Other researchers had dispelled the myth that cathedral glass is thicker at the bottom because it begins to sag because of changes in its viscosity as it undergoes a slow transition from a solid to a liquid. But the investigations Mauro and three colleagues did of the 13th-century glass showed that previous estimates of glass flow rates were way, way off.

They found that the windows are transitioning to a liquid so slowly that it would take billions of years to produce even nano-scale changes to the shape of the glass.

Mauro says previous studies considered glass of modern composition, rather than real medieval cathedral glass with its chemically different composition. The studies were also based on measurements conducted decades ago in the former Soviet Union, and did not include explicit fluid-flow calculations.

The new work resulted in the Mauro-Allan-Potuzak (MAP) equation, which the researchers say more accurately captures the detailed viscous flow of glass, including how the viscosity of a piece of glass depends on the composition of that particular glass.

This research led Mauro to propose a new definition of glass that incorporates its hybrid liquid-solid nature: It has the atomic structure and viscous flow of a liquid but responds mechanically as a solid.

—DAVID KUBAREK

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In the northern part of their range, snowshoe hares undergo seasonal changes in coat color to blend in with their surroundings summer (above left) and winter (below left). In Pennsylvania, the southernmost part of their range, many snowshoe hares remain brown year-round. Those that turn white in winters with little snow (above) make easy targets for predators.

Diefenbach Lab/Penn State

» Your Hare Looks Different

Snowshoe hares in Pennsylvania, at the southern end of the hares' range, show adaptations in fur, behavior, and metabolism that suggest the species has some ability to adjust to a warming climate, according to researchers in Penn State's College of Agricultural Sciences.

Changes in winter temperatures and snow cover are predicted to become more pronounced in the future, especially in Arctic and Boreal regions, noted Duane Diefenbach, leader of the Pennsylvania Cooperative Fish and Wildlife Research Unit at Penn State.

"Understanding how a species has adapted to the different winter temperatures experienced across its range can offer insight into how a species might respond to future changes in winter conditions," he says.

The researchers compared winter coat characteristics, heat production, movement rates, and resting-spot selection of snowshoe hares in Pennsylvania's Pocono Mountains and Canada's Yukon. They found that hares in Pennsylvania differed from their northern counterparts in many ways: They were larger; had shorter, less dense fur; produced less heat; and chose resting spots that offered protection from predators over those offering thermal advantages.

The researchers also found that some of the Pennsylvania hares did not completely molt, or change coloration from brown to white, in the winter. That development would help them elude predators in areas with scant snowfall.

"Our results indicate that snowshoe hares may be able to adapt to future climate conditions via changes in pelage characteristics, metabolism, and behavior," says lead researcher, graduate student Laura Gigliotti. "Unfortunately, we don't know if they can adapt as quickly as climate change is occurring."

—JEFF MULHOLLEM

» Plastic Fantastic

Plastic Entanglements, a major loan exhibition organized by Penn State's Palmer Museum of Art, brings together sixty works by thirty contemporary artists to explore the environmental, aesthetic, and technological entanglements of our ongoing love affair with this paradoxical, infinitely malleable substance.

The exhibit was originally proposed by Jennifer Wagner-Lawlor, professor of Women's, Gender and Sexuality Studies and English. As an "ambassador" for the environmental NGO, Plastic Pollution Coalition, Wagner-Lawlor was introduced to a growing number of artists working with found and salvaged plastic as their primary medium. She was particularly interested in the effectiveness of art as a form of science communication, if not explicitly of environmental advocacy.

Isla, 2014, by Aurora Robson. Plastic debris (PET + HDPE), aluminum rivets, tinted polycrylic, and mica powder. Courtesy of the artist.

Researchers have created a flexible, biodegradable optical fiber that can deliver therapeutic light into the body.

- JIAN YAN
Biomedical Engineering
&
- ZHIWEN LIU
Electrical Engineering


USDA/Wikimedia Commons

Well-Organized Relief

Immediately following a major natural disaster, outside organizations rush to provide life-saving commodities to meet health, water, food, shelter, or other needs. That response is expedited by inventory prepositioned by dozens of governmental and non-governmental organizations acting independently.

At present, relief organizations manage hundreds of distinct items in dozens of warehouses globally in order to respond to events that vary in location, type, and scale, with no way to measure system-wide stockpile capacity in real time.

Research by Jason Acimovic, assistant professor of supply chain and information systems at the Penn State Smeal College of Business, and Jarrod Goentzel of MIT could help these organizations better coordinate their stockpiles, improving their response and cutting costs.

Acimovic, whose first experience in humanitarian logistics was in Liberia with Doctors Without Borders, and Goentzel proposed new metrics to assess relief inventory with respect to time- and cost-to-respond. Using algorithms previously developed for an online retailer, they analyzed data gathered from the United Nations Humanitarian Response Depot, the Centre for Research on the Epidemiology of Disasters, and other public sources. They found that repositioning existing inventory could enable the system to respond to disasters as quickly as before but at up to 20 percent lower cost. "Those savings would enable organizations to buy more supplies with the same donation budget," says Acimovic.

—ANDY ELDER

PLANTS CAN SMELL A PEST COMING

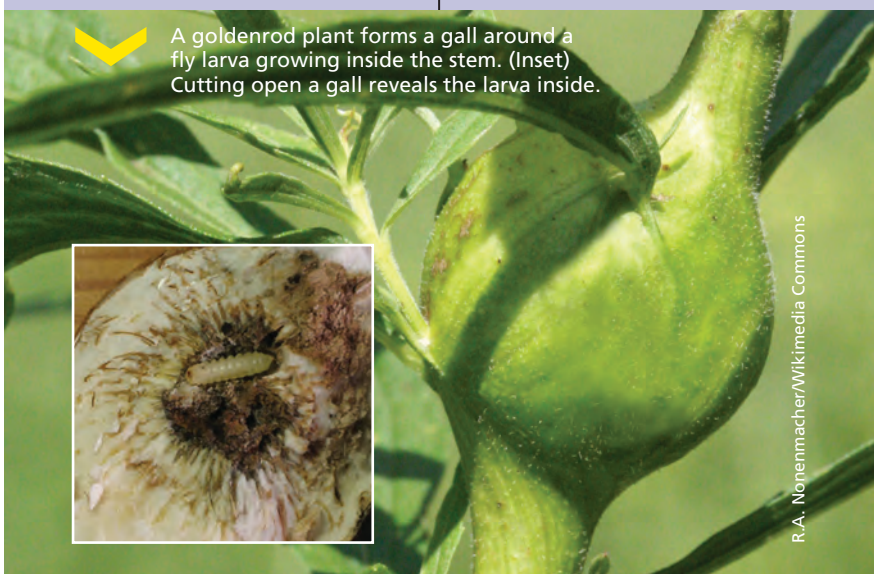
It cannot run away from the fly that does it so much damage, but tall goldenrod can protect itself by "smelling" its attacker and quickly initiating its defenses.

Gall-inducing flies (*Eurosta solidaginis*) in Pennsylvania feed only on tall goldenrod (*Solidago altissima*). Male flies emit a blend of chemicals that attracts females. After mating, the females deposit their fertilized eggs in the stem of a goldenrod. After the eggs hatch, the larvae feed on tissue inside the stem, causing the plant to grow a gall, or protective casing, around the larvae. That diverts energy away from seed production, reducing the plant's fitness, says John Tooker, associate professor of entomology.

Tooker, postdoctoral fellow Anjel Helms, and colleagues previously found that goldenrod plants exposed to chemicals from male flies produced more of a chemical that limited damage by herbivores. In their new study, they identified and quantified specific compounds put out by male flies, and exposed goldenrod plants to the individual compounds. They found that the plants responded most strongly to E,S-conophthorin, the most abundant compound emitted by the flies.

The results indicate a tight co-evolutionary relationship between the two species, says Tooker. "As the fly has adapted to take advantage of the plant, the plant has adapted itself to protect itself from the fly. We are hypothesizing that when the plant detects the fly, it up-regulates its defenses to prepare for attack"—and minimize damage from the fly and its larvae.

—SARA LAJEUNESSE


A goldenrod plant forms a gall around a fly larva growing inside the stem. (Inset) Cutting open a gall reveals the larva inside.

R.A. Nonenmacher/Wikimedia Commons

Women with Restless Legs Syndrome are 43 percent more likely to die of cardiovascular disease.

- XIANG GAO
Nutritional Sciences

Shoo, Fly!

Flies can be more than pesky picnic crashers, they may be potent pathogen carriers, too, according to an international team of researchers.

In a study of the microbiomes of 116 houseflies and blowflies from three different continents, researchers found that in some cases, the flies carried hundreds of different species of bacteria, many of which are harmful to humans. Because flies often live close to humans, scientists have long suspected they play a role in carrying and spreading diseases, but this study, which was initiated at Penn State's Eberly College of Science, adds further proof, as well as insights into the extent of that threat.


Thinkstock

"We believe that this may show a mechanism for pathogen transmission that has been overlooked by public health officials, and flies may contribute to the rapid transmission of pathogens in outbreak situations," says Donald Bryant, Ernest C. Pollard Professor of Biotechnology.

Blowflies and houseflies—both carrion fly species—are often exposed to unhygienic matter because they use feces and decaying organic matter to nurture their young. The study also indicates that blowflies and houseflies share over 50 percent of their microbiome, a mixture of host-related microorganisms and those acquired from the environments they inhabit. Surprisingly, flies collected from horse stables carried fewer pathogens than those collected from urban environments.

Flies may not be all bad, however. The researchers suggest they could turn into helpers for human society, perhaps even serving as living drones that can "sample" an environment and act as an early-warning system for diseases.

—MATTHEW SWAYNE

Maize was already domesticated and being raised as a staple crop in Central America 4,300 years ago.

- DOUGLAS KENNETT & KEN HIRTH
Anthropology

Similar plankton-like fossils from 3.4 billion years ago have been found in South Africa and Australia.

- CHRISTOPHER HOUSE
Geosciences

Unusual starlight pattern that sparked speculation is not due to an alien mega-structure.

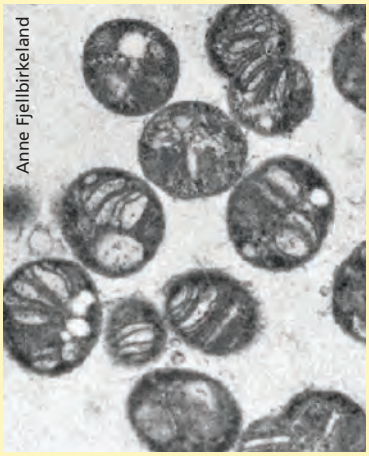
- JASON WRIGHT
Geosciences

I'LL JUST HAVE THE TANG®, THANKS ‹‹

A Penn State research team has shown that it is possible to use microbial reactors to rapidly break down human waste and convert it into an edible product that could be a valuable resource for astronauts on years-long missions to Mars or beyond.

"It's a little strange, but the concept would be a little bit like Marmite or Vegemite where you're eating a smear of 'microbial goo,'" says Christopher House, professor of geosciences.

The researchers drew inspiration from bacteria-covered, fixed-film filters used to treat fish waste in aquariums. In the new system, certain microbes break down the waste using anaerobic digestion. Methane generated during that process is then used to "feed" a different kind of microbe, *Methylococcus capsulatus.*


Anne Fjellbirkeland

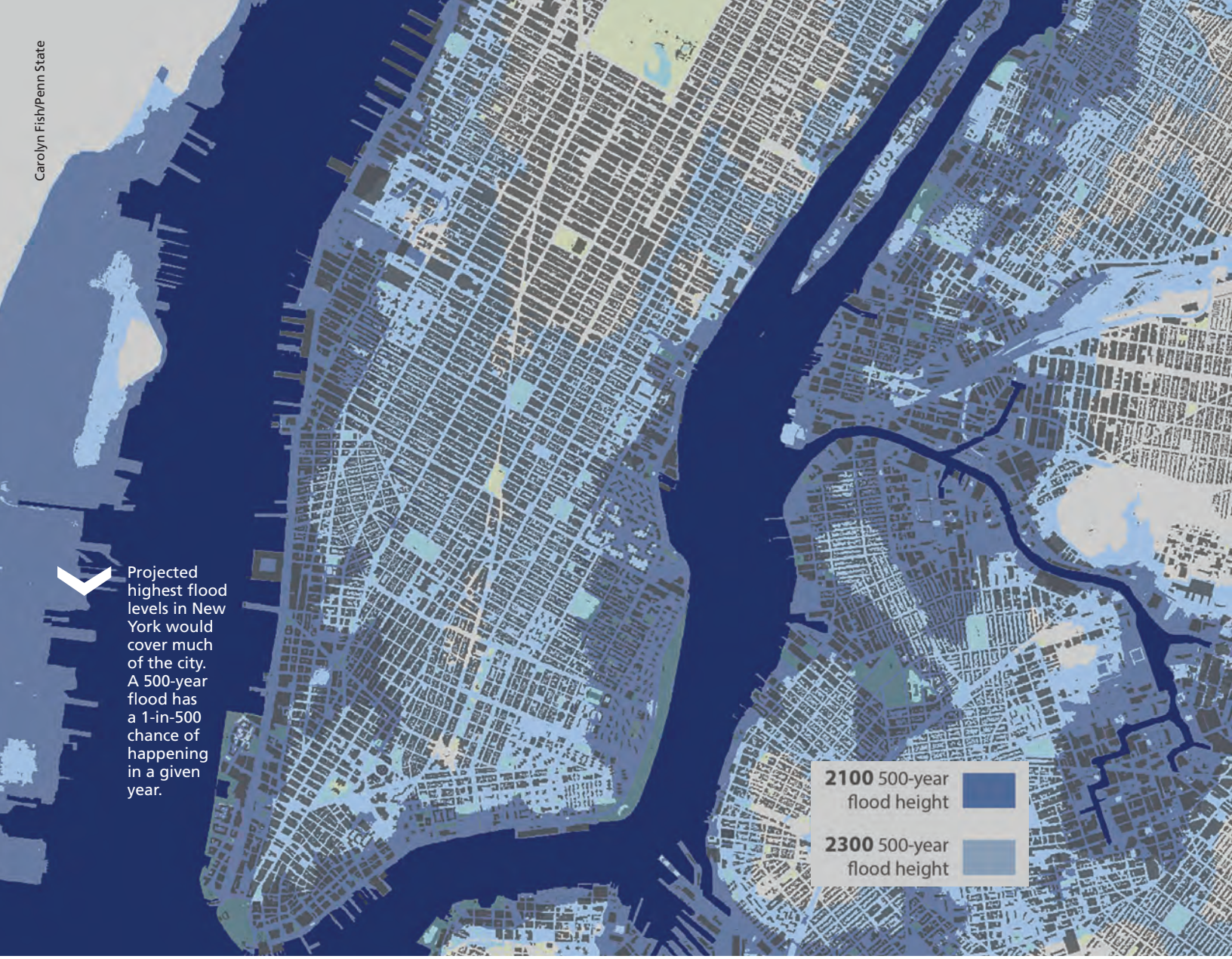
"Anaerobic digestion is something we use frequently on Earth for treating waste," says House. "What was novel about our work was taking the nutrients out of that stream and intentionally putting them into a microbial reactor to grow food."

At 52 percent protein and 36 percent fats, the *M. capsulatus* goo produced in the new system is a potential source of nutrition for astronauts. The process is also fast, converting up to 59 percent of waste solids in 13 hours, compared to existing waste management treatment, which can take several days.

"That's why this might have potential for future space flight," says House. "It's faster than growing tomatoes or potatoes."

—LIAM JACKSON

Electron micrograph of the bacterium *Methylococcus capsulatus*.



Carolyn Fish/Penn State

Projected highest flood levels in New York would cover much of the city. A 500-year flood has a 1-in-500 chance of happening in a given year.

» City and the Sea

Rising sea levels caused by a warming climate threaten greater future storm damage to New York City, but the paths of stronger future storms may shift offshore, changing the coastal risk for the city, according to a team of climate scientists.

"If we cause large sea-level rise, that dominates future risks, but if we could prevent sea-level rise and just have the storm surge to worry about, our projections show little change in coastal risk from today during most years," says Michael E. Mann, distinguished professor of meteorology. "While those storms that strike New York City might be bigger and stronger, there may be fewer of them as changing storm tracks increasingly steer the storms away from NYC and toward other regions."

The researchers looked at the history and future of both sea level and storm surge, from preindustrial times through 2300, in models that had been run for the full period. They focused on results from simulations with rapid carbon dioxide release, often referred to as "business-as-usual" simulations.

In agreement with previous work, the models show that warmer future conditions allow stronger storms. But the models also show that the warming causes storm tracks to shift offshore and northward, away from New York City.

"If a shift occurs toward less common but possibly larger storms, it poses special challenges for coastal planners, and highlights the value of additional progress in understanding and projecting the tracks as well as the strength of these storms," says Mann.

—A'NDREA ELYSE MESSER

BELLY UP ‹‹

When a male eastern fence lizard (*Sceloporus undulatus*) noticed a potential meal flying by, he lifted up enough to reveal the patches of bright blue on his belly and throat, which are usually visible only during contests with other males and courtship displays to females. Photographer Braulio Assis captured the scene at Standing Stone State Park in Hilham, Tennessee. Assis, a doctoral student in ecologist Tracy Langkilde's lab, is studying why the blue coloration also appears on some female fence lizards. Females with blue patches mate less often—the males seem to prefer females that do not have the usually-masculine trait—but have skills that may enhance their survival, such as the ability to run faster.

Photo by Braulio Assis/Langkilde Lab

With a text alert on a morning in August, astronomy entered the era of talkies.

LISTENING TO THE UNIVERSE

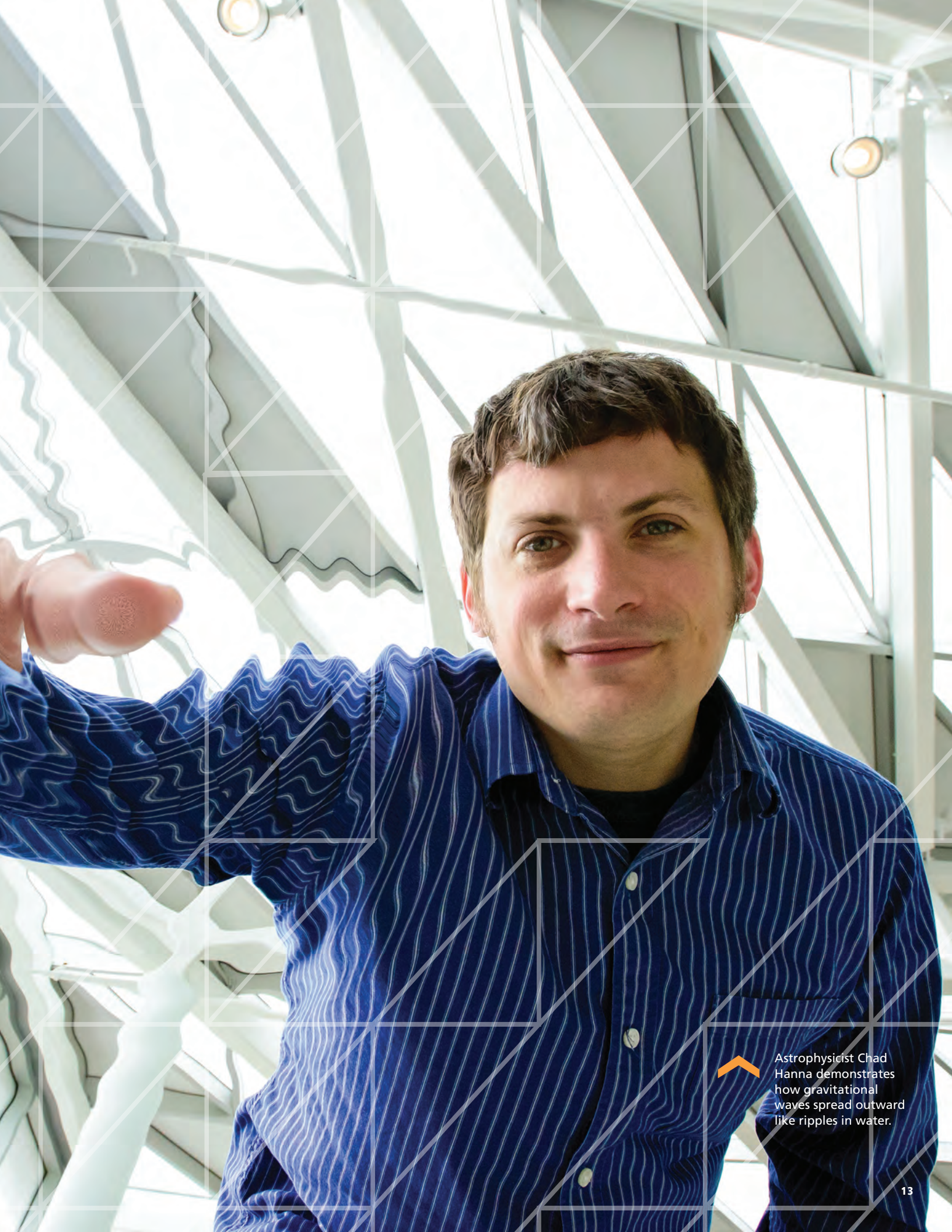
BY CHAD HANNA

The 2015 discovery of gravitational waves is one of the biggest science stories of recent decades. Penn State astrophysicist Chad Hanna, a member of the international research team that studies gravitational waves, reflected on the group's achievements and the birth of "multi-messenger astronomy." This piece is adapted from two articles he wrote for the online news site ***The Conversation***.

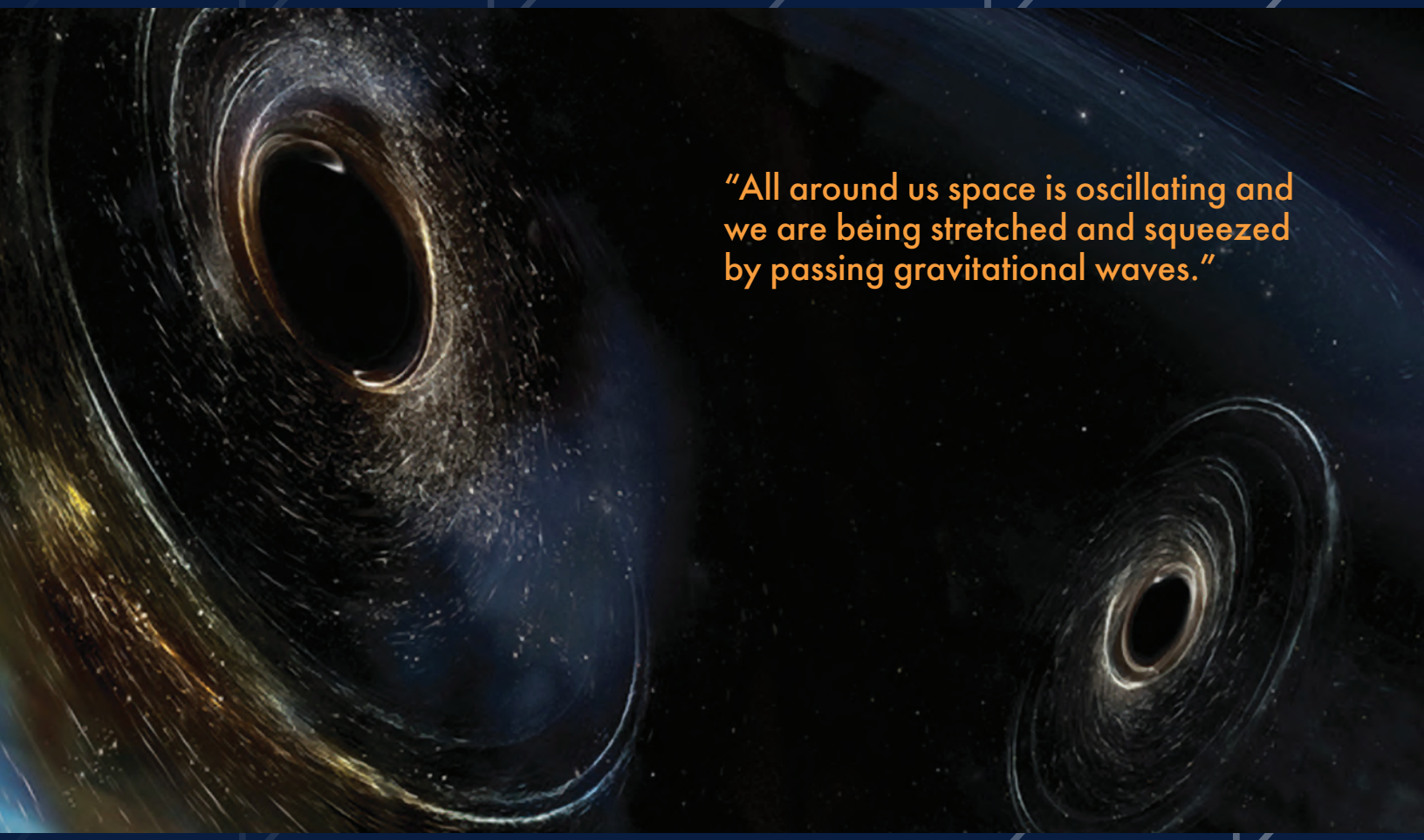
Like many of my colleagues working for the Laser Interferometer Gravitational-Wave Observatory (LIGO), the morning of Monday, September 14, 2015 caught me completely off guard. LIGO had just started listening for gravitational waves, one of the last unproven predictions of Einstein's theory of general relativity—and within its first few days of gathering data, it had found one.

More than 100 years ago, Einstein hypothesized that gravitational waves are formed when matter and energy warp space and time. The effects he predicted sound bizarre: As a gravitational wave passes by, the distance between objects changes ever so slightly. All around us space is oscillating, distances are changing, and we are being stretched and squeezed by passing gravitational waves. Only the most extreme objects in the universe can bend space enough to produce ripples that are measurable here on Earth. The effect is so tiny that until now we had no instruments that could detect it. Advanced LIGO was designed to change all of that by directly measuring tiny ripples in space itself.

Michelle Bixby



Astrophysicist Chad Hanna demonstrates how gravitational waves spread outward like ripples in water.



"All around us space is oscillating and we are being stretched and squeezed by passing gravitational waves."

This was LIGO's first day on the job. We had worked toward this moment for over a decade, but it was so early in LIGO's first official observing run that I hadn't even had a chance to enable my text message alerts! Instead, I read about the event on my phone as I walked to campus hours after it had been observed. Like others on the team, I thought this signal was just a test of the system, nothing to get excited about. Then, just before 2 p.m., we received word that no tests had been performed. The signal was real!

At first it was unclear which of many possibilities could be responsible. It would have to be a major astronomical event that released immense amounts of energy, such as a binary merger, a nearby supernova, or some unforeseen occurrence. Over the next several weeks, the LIGO team verified that the signal, which we labeled GW150914, could only have been caused by a gravitational wave generated by the merger of two black holes that released energy as they smashed together. Einstein had been right. Again.

Last fall, the Nobel Prize in physics was awarded to three of the founders of our international collaborative effort—Rainer Weiss, Kip Thorne, and Barry Barish—in recognition of this first observation that confirmed Einstein's revolutionary theory.

LIGO LOGISTICS

The LIGO Scientific Collaboration, of which I am a member, includes more than 1,000 people from dozens of institutions and 15 countries. There are two LIGO instruments, one in Louisiana and one in Washington state. We also work with the Virgo Collaboration that operates a detector in Italy and the GEO600 detector team in Germany. And it took all of us to detect and analyze that first gravitational wave.

GW150914 stretched and squeezed our nearby space by about 1 part in 10^{21}. This is equivalent to squeezing the entire Milky Way galaxy by a typical person's height. As you might imagine, it is nearly impossible to measure such a small change. To do so, LIGO uses high-power lasers, ultra-high vacuum, and some of the most advanced optics ever built.

The basic idea is simple: LIGO has two 4-km-long arms, built at 90 degrees with respect to one another. A high-power laser beam is split in two to travel down each arm separately. When each beam gets to the end of an arm, it's reflected back by a mirror. If one arm momentarily becomes longer than another, due to the change in space caused by a gravitational wave, then the laser light from the two arms will get out of sync.

Artist's conception showing two merging black holes similar to those that produced gravitational waves detected by LIGO.LIGO/Caltech/MIT/Sonoma State (Aurore Simonnet)

The two arms of a LIGO detector, built perpendicular to each other, extend 4 kilometers (about 2.5 miles) from the lab facility. This is the detector in Louisiana. Caltech/MIT/LIGO Lab

We continuously record the recombined laser light, which encodes how the gravitational wave causes space to stretch and squeeze at frequencies that are very similar to what the human ear can hear. That's why we often think of LIGO as "listening" to the universe. In fact, you can literally listen to the gravitational waves detected with LIGO using headphones.

The LIGO detectors, for the most part, are sensitive to sources all over the sky, which means a single detector can't tell from which direction a gravitational wave arrived. However, using multiple detectors around the globe, we can localize the source of a given signal.

Our aim was to be able to know within seconds that a gravitational wave had reached the Earth. Then we could immediately inform other astronomers, who could point their telescopes in the direction of the event in the hope that the gravitational wave would have an electromagnetic counterpart. Having information from multiple channels would be a bit like having both sound and picture when watching a film—it would give us a more complete impression of the event, a better idea of what happened.

We knew that gravitational waves had the potential to provide something like a soundtrack for our universe, but the 2015 breakthrough and four subsequent gravitational wave observations were never associated with electromagnetic counterparts because they all sprang from binary black holes.

A NEW ERA

That all changed last year. My phone now enabled to receive LIGO alerts, on August 17, 2017 at 8:47 a.m. EDT, I received a text message that indicated a gravitational wave candidate had been identified. Not only that, but this new observation, GW170817, had a coincident gamma-ray burst.

The burst was detected by the Fermi Gamma-ray Space Telescope in low Earth orbit, that happened to be pointing in the direction of the new gravitational wave when it arrived at Earth. That was a stroke of luck, but for all that had gone right that morning, a few things were bound to go wrong.

Around the time that the new signal arrived at the LIGO Washington detector, the LIGO Louisiana detector suffered from a burst of instrument noise. Data from the Virgo detector in Italy was clean, but the transatlantic data transfer had stopped due to a network connection outage.

Despite these problems, the LIGO rapid response team quickly notified our over 70 observing partners all over the world. It turned out that the instrumental noise in the LIGO Louisiana data affected only the very end of the detected signal, which lasted more than 100 seconds. Eventually, we were able to analyze all three gravitational wave detector data streams to figure out when the signal arrived at each one. Then we triangulated the gravitational wave source to a sufficiently small area on the sky that astronomers could survey the entire region.

We had the gamma-ray data, but astronomers using ground-based telescopes had to wait for nighttime to look for other kinds of signals. About 10 hours after the initial alert, we got the first news of a visible light counterpart: A new bright spot that hadn't been there previously was spotted in a galaxy in the direction of the gravitational wave. Over the coming weeks, we learned that there were ultraviolet and X-ray counterparts and even radio waves that together allowed us to confirm that the gravitational wave was due to the collision of two neutron stars. Each observation revealed a new part of the story. Astronomy had entered the era of talkies!

To be able to observe and document the merger of two neutron stars was a tremendous achievement. We were lucky to pin down the location of the gravitational wave quickly enough to identify the observational counterparts in time to capture their views of the event.

Next time around, we hope that gravitational wave identification can happen even sooner and at a more favorable time of day so we don't miss out on the earliest optical emission. Perhaps one day we'll even be able to use the early gravitational wave emission leading up to a neutron star collision to predict where on the sky they'll merge, and have telescopes already pointed in that direction, ready for the show.

A newly discovered reef offers lessons in resilience

BURIED TREASURE

BY DAVID PACCHIOLI

Varadero reef, hidden under murky water near the busy port of Cartagena, is one of the best coral reefs in the Caribbean. Courtesy of Mónica Medina.

The bay of Cartagena might be the last place you'd expect to find a coral reef. The skyscrapers and hotels of resort-heavy Bocagrande hug the nearby beach. Cruise ships and freighters ply the busy harbor. The vibrant, historic city itself is both Colombia's leading tourist destination and one of its major ports.

At one point, indeed, this shallow bay was virtually covered in coral. But that began to change when the Spaniards arrived in 1533. As they discovered the riches of the South American interior, Spanish engineers built the Canal del Dique, diverting the mighty Magdalena River to carry out silver and gold. Emptying into the bay, the canal brought two other things as well, both detrimental to marine invertebrates: fresh water, and tons and tons of sediment. Today, five hundred years later, almost all the coral is gone. But there at the mouth of the bay, hidden beneath ten feet of water so murky and foul you might blanch to stick your elbow in it, lives a square kilometer of reef that is one of the best in all the Caribbean.

Varadero reef has long been known to the inhabitants of the local island communities. Descendants of slaves brought to build the sturdy stone forts that still overlook the harbor, they have always fished the reef for their food. But it was only in 2013 that Varadero was discovered by science. That's when local biologists went diving for an example of a degraded reef, one they thought might be overgrown with invasive sponges. What they found instead was a veritable coral garden, with over 30 species covering up to 80 percent of its surface.

Mónica Medina found out about Varadero a year later. A coral microbiologist at Penn State, she had gone to a conference in Cartagena to give a talk about her work. When the conference was over, a colleague insisted on taking her out to the spot.

"What's crazy is that you swim down and you can't see the person next to you, it's so murky," Medina says. "There's this dirty layer of fresh water on top, and then it gets clear and there's an amazing reef down there."

UNDER THE MICROSCOPE

Medina's first thought was automatic: Why is this reef doing so well? Corals, she knew, depend like no other animal on the presence of sunlight. More precisely, the microscopic algae that live within corals depend on sunlight to generate, via photosynthesis, the energy that corals require to live and grow. Corals, therefore, do best in crystal clear waters, shallow enough for sunlight to easily penetrate. How could a reef be thriving here, starved of light and choked with sediment and pollution?

It's a question whose answers may have global implications. With reefs around the world dying off in response to rising ocean temperatures, resilience has become a key concept among coral biologists. As Medina and others have shown, some species of coral have the ability to survive in less-than-optimal conditions, while others perish. What gives these hardier specimens the strength to adapt and bounce back? Pinpointing what makes them different could be vital for coral's survival.

As a microbiologist, Medina was most interested in Varadero's microbiome, the dizzyingly complex community consisting of all the bacteria, archaea, and fungi living within the corals that make up the reef. Like human guts and public toilet handles, each individual coral hosts its own microscopic menagerie, shaped by where it lives and what sorts of organisms it has encountered. Coral that could succeed in this challenging environment, she reasoned, ought to have a very unusual microbiome indeed.

Back in 2007, Medina, then at the University of California at Merced, was one of the first to use next-generation gene sequencing technology to look at microbiomes in corals. That early work she calls comparatively crude: "We just grabbed pieces of coral from a dozen or so species and ground them up and sequenced them, as deeply as we could," she says. Even so, "We uncovered a vast microbial diversity." Subsequent refinements showed that each part of a coral—its skeleton, the soft tissue, and the mucus the animal secretes—harbors its own separate community.

Over the past few years Medina has worked with Rebecca Vega-Thurber of Oregon State University to catalogue the biodiversity of coral microbiomes around the world, and she fully expected to find a distinctive signature in those able to survive at Varadero. The question was, why? Was it simply because these corals had acclimated so well to their atypical environment? Or were they in fact genetically different?

An increase in freighter traffic has brought plans to dredge Cartagena's harbor, threatening both the reef and the fishing communities that depend on it. Photo by Carter Hunt.

A RACE AGAINST TIME

Approaching the answer has meant racing against time. Ironically, Varadero's discovery coincides with a period of great ferment in Colombia, triggered by the signing of a historic peace accord after more than a half-century of bloody conflict. With increased security and a new spirit of optimism, investor confidence is surging, and the long-suppressed forces of economic development have been unleashed. The resulting rapid growth threatens something that the long shadow of violence had managed to protect: Colombia's amazing biodiversity.

The bay of Cartagena, in particular, is undergoing a boom in shipping and luxury tourism. The swell of traffic has engendered plans for dredging to widen its shipping channels, and the current blueprint for that improvement slices right through the heart of Varadero. The reef that survived unnoticed for so long is suddenly in danger of being destroyed.

Throughout 2014 and 2015, Medina and Penn State colleagues Roberto Iglesias Prieto and postdoctoral fellow Joe Pollock worked with a team of Colombian and U.S. biologists to map and survey the reef, detailing its structure and composition and cataloguing the varieties of life they found there. But a much more thorough study would be required if the fuller lessons of Varadero were to be learned.

Local opposition to the government's development plan had not yet gained much traction, so Medina quickly applied to the National Science Foundation for a so-called RAPID grant, reserved for urgent action in the face of impending disaster. When that request was denied, she took her case to journalist Lizzie Wade, who wrote about Varadero for the journal *Science*.

"That story kind of helped us get NSF's attention," Medina says. "It also made the local news take notice, which has helped our Colombian colleagues hold the fort and be more vocal." Soon after the story appeared, Medina and Iglesias Prieto reworked their proposal, and this time the emergency grant was awarded.

CLOUDS AND SUN

When they returned to Colombia and began to dig deeper, Medina and Iglesias Prieto discovered that Varadero's story is more complicated than they had first thought. To explain, Iglesias Prieto produces a pair of aerial photographs of the reef, one taken in December 2014 and the other in January 2015. In the earlier photo, the water surface is impenetrable, a murky cloud. In the second, it is nearly transparent—plenty clear enough to show the outline of a reef.

"The first time I went there, the conditions were like this," he says, pointing to the opaque version. "But what we are learning is that the optical properties of the water here change very rapidly." Varadero, in other words, is not always shrouded in turbidity—sometimes the water above it is clear. It all depends on the volume of the sediment plume pouring from the canal, and the prevailing circulation in the bay.

"We don't yet know how much of the time it is one, and how much the other," Iglesias Prieto says. "What we know is that the transition in either direction can take place in a few minutes."

He and his students have placed sensors in the bay to record these shifts, and are working with ocean circulation experts on computer models to predict them. In the meantime, there is rich evidence to be gleaned from the coral itself.

Corals grow by depositing calcium carbonate to build new skeleton. This calcification depends heavily on the energy produced by the coral's symbiotic algae. Under cloudy skies, photosynthesis tails off, and so does calcification. Conversely, where sunlight penetrates, growth speeds up. It's been known since the nuclear testing at Bikini atoll during World War II that an x-ray of a coral skeleton will reveal bands of annual growth, like tree rings, corresponding to the duration and intensity of seasonal sunlight the animal has absorbed. But that same skeleton, Iglesias Prieto says, may also record changes in light occurring on much shorter timescales—perhaps even those related to the clouds of sediment.

While he continues to examine the skeletal physiology, he and Medina have also been testing her hypothesis about Varadero's microbiome, comparing bacterial samples taken there to samples from three nearby reefs, each a little farther out to sea and therefore less exposed to sediment and pollution. What they have found confirms her suspicion: The Varadero samples are much different from those taken only a few kilometers away.

Analysis is ongoing, but Medina thinks it unlikely that the corals themselves are genetically distinct. "The reefs are so close together, there's no barrier to prevent gene flow between them," she explains. "I suspect that these corals must have interbred in the past, but once they were settled in these different environments, the demands on them were different. One environment is nutrient-rich, the other nutrient-poor; one has very large oscillations in light availability, the other has always the same light. I think all of this plays out in the microbiome."

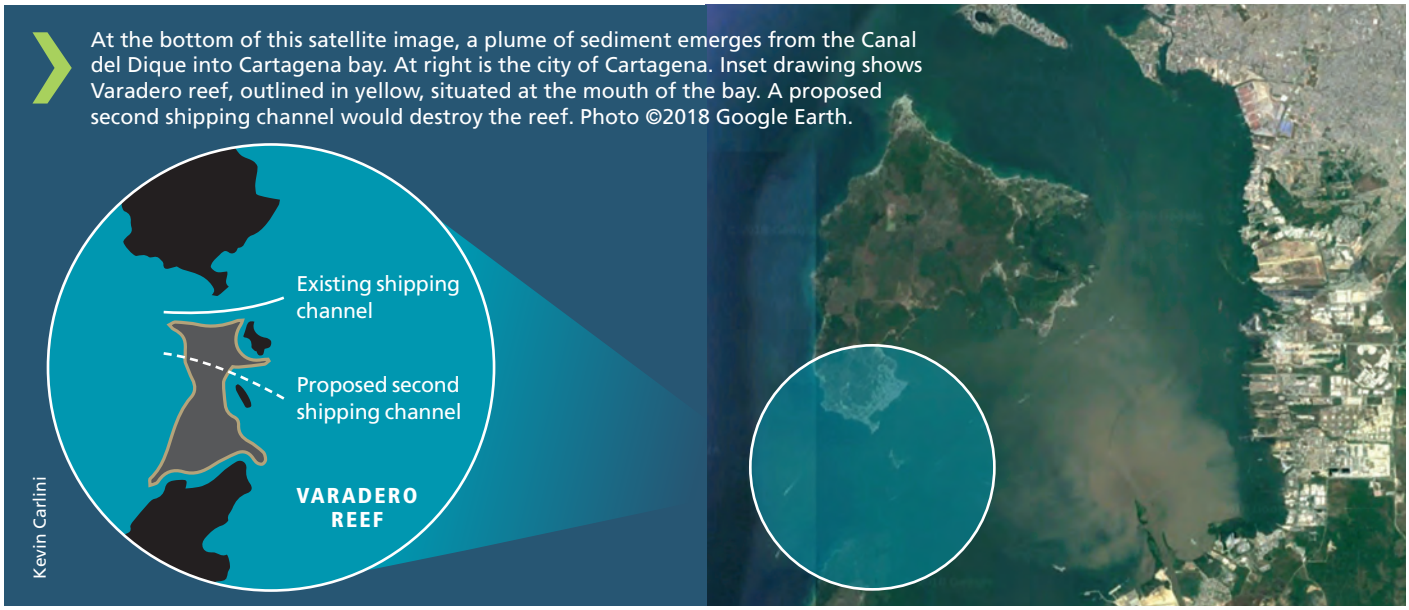
To determine how stable their differences might be, Medina and Iglesias Prieto next transplanted small samples of coral from each of the four reef sites to all of the others. Although it's early to say whether the microbiomes contained in these samples are morphing to match their new environments, the researchers have already noticed that transplants from Rosario and Baru survive better on Varadero than the Varadero samples do on these "cleaner" reefs.

"That surprised us," Medina says. "But what we've seen is that when the circulation is right, there is actually very clean water—and good light—over the reef. When it's not, the dirty water contains all kinds of little critters for them to feed on. It looks like they're having the best of both worlds."

COMING HOME

Recent reports of a Brazilian reef thriving under heavy sediment at the mouth of the Amazon suggest that Varadero might not be as unusual as Medina and others originally believed. There could be coral reefs lurking elsewhere in unlikely spots where no one has thought to look for them. But to Medina, that only makes this one more important. "Given the fact that more and more locations may be facing this sort of pollution, understanding reef response is critical, especially that of a reef that has withstood so many years of abuse," she says.

She is also interested in the human populations that have depended on Varadero—that handful of poor fishing communities, cut off from the mainland, that have existed here for centuries. Can they, like the reef itself, survive the coming wave of development?



At the bottom of this satellite image, a plume of sediment emerges from the Canal del Dique into Cartagena bay. At right is the city of Cartagena. Inset drawing shows Varadero reef, outlined in yellow, situated at the mouth of the bay. A proposed second shipping channel would destroy the reef. Photo ©2018 Google Earth.

Kevin Carlini

"Until very recently, these people have been completely ignored," Medina says. "Now the resort chains are moving in. Approvals have been given for 16 marinas." With tenuous rights of ownership and no political voice, she fears these communities will be lost in the fray. "If the reef is destroyed, they will have nothing," she worries.

Medina has enlisted Penn State anthropologist Carter Hunt, an expert on the social and environmental consequences of tourism, to document life in these settlements at this moment of looming change, and to help explore the interrelationships: how human-caused disturbance can impact a natural system and how the human communities that rely on that system are affected in turn.

With Hunt's help, and that of two other Penn State social scientists, Leland Glenna and Larry Gorenflo, Medina and Iglesias Prieto hope to examine these coupled impacts in real time, combining the historical and genetic evidence recorded in the coral itself with dusty archival documents that detail the environmental history of the bay, and overlaying that with the present-day ethnography.

For Medina, however, Varadero is more than a case study. She was born and raised in Colombia, leaving for graduate school in the U.S. in 1992. "I always wanted to go back when I finished my Ph.D.," she says, "but it was a particularly bad time." Abductions and assassinations were a frequent occurrence—even her own grandfather was kidnapped, though later released.

In the years since, a chance to do research in Colombia "was something I always longed for," Medina says. That Varadero should come along, at this turning point, "seems like a dream. It's the ideal project, a chance to do what I do, and to bring it a new meaning. Because I can help these communities. Already, I think we've helped them find their voice." Though the outlook for Varadero is still very much in doubt, "I am more hopeful than I was when we started," she says.

To Medina, to be clear, this project is critical from a scientific point alone. "But it's also a way for me to contribute," she says. "To the peace process, and in general. It brings me home."

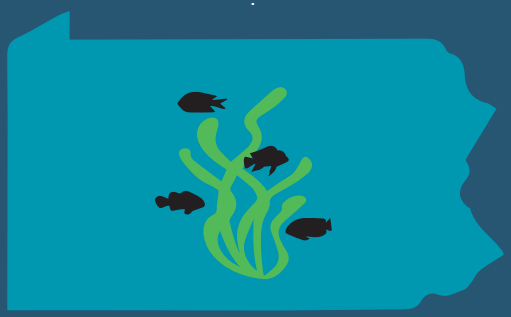
Courtesy of Mónica Medina.

Mónica Medina, left, and Roberto Iglesias Prieto examine specimens in a shared lab space at University Park. Photo by Patrick Mansell.

WHAT'S A CORAL REEF BIOLOGIST DOING IN THE MIDDLE OF PENNSYLVANIA?

How about *four* coral reef biologists? Unlikely as it may seem, Penn State's coral reef group is one of the largest—and best—in the United States. Some of the credit goes to Chuck Fisher, professor and distinguished senior scholar of biology, and for decades the University's lone marine biologist.

Fisher studies mostly the deep ocean, and is known for important contributions to our understanding of hydrothermal vents and the amazing organisms that populate these hot spots on the ocean floor. Recently, he spearheaded efforts to document the effects of the Deepwater Horizon oil spill. But Fisher was trained in shallow reef biology, and he knows well the importance of coral reefs, one of the most diverse—and fragile—ecosystems on the planet.



Coral reefs provide vital habitat for a cornucopia of marine life, protect vulnerable coastlines against tropical storms, and generate billions of dollars in economic value via fishing and tourism. Their potential for biomedical discovery has hardly been tapped. Yet their continued existence is in serious jeopardy in many places around the world, due to overfishing, pollution, and rising ocean temperatures. "Coral reefs are in the forefront of the danger zone," Fisher says. "Understanding them is critical to understanding the impacts of global warming."

Penn State's current flush of expertise in this area began almost by chance. Iliana Baums, a specialist in the evolution and spread of coral populations around the world, arrived here when her husband joined the department of geography in 2006. Two years later, Todd LaJeunesse was a young assistant professor weary of life in Miami when he learned that Penn State was looking for a microbial ecologist. LaJeunesse, who studies the microscopic algae that the corals need for their survival, fit the bill, and his work nicely complemented what Baums was already doing.

In 2012, Fisher was at a meeting in Puerto Rico when he happened to hear a presentation on coral microbiomes by Mónica Medina of the University of California at Merced. He was impressed enough to ask Medina to repeat the talk at University Park, and subsequently to push for her hiring. When Medina agreed to come east, Fisher remembers, "That's when we knew we had something."

The arrival of Roberto Iglesias Prieto from the National Autonomous University of Mexico in 2016 rounded out the group. A veteran field researcher whom Fisher calls "probably the top coral physiologist in the world," Iglesias Prieto had been working for 20 years at a research station near Cancun—an idyllic spot, to be sure, but he missed the stimulation of a major university campus. In the small world of coral reef biology, he and Fisher and LaJeunesse had all trained under the eminent Robert Trench at the University of California at Santa Barbara, and Iglesias Prieto had also known and collaborated with Medina for years. "We thought if we could get Roberto, we could have the best coral reef group in the U.S.," Fisher says. "And now we do."

"The group is strong, really strong," Medina agrees. "We complement each other well, and we all have projects going with each other. We're being recognized as a hub, and because of that we're attracting amazing students."

To the familiar question, "Why central Pennsylvania?," LaJeunesse offers a ready answer. "With an airport close by, State College is as good as anywhere in the world for coral reef biology," he says. "Better, when you look at Penn State's research facilities." His fieldwork takes two or three weeks a year; for the rest, he says "We've got a wonderful DNA core facility, some of the best genomicists in the world, people in bioinformatics who are at the top of their field. Why *not* here?"

Iglesias Prieto, for his part, has been most impressed by the opportunities for cross-disciplinary exchange. "I've enjoyed every minute," he says. Well, maybe not *every* minute. For a native of Mexico City and long-time resident of Cancun, there is one significant hardship associated with doing coral reef research in central Pennsylvania. It sets in around December.

MENDING THE GAP

Assigned partners chat during a break in filming *FaceAge*, a video installation that examines attitudes about youth and aging. Photo by *FaceAge* Creative Team.

OLD AND YOUNG COME TOGETHER THROUGH ART, CULTURE, AND SPORT

It's such a simple gesture, a hand reaching out to stroke a cheek.

Between friends and loved ones, it conveys caring, trust, tenderness. Between people who met just a few hours ago and who think they don't have much in common, it can feel scary, threatening, too intimate.

It can also dissolve the emotional and perceptual barriers between the people involved. Andy Belser had that in mind when he brought together pairs of strangers, separated by a gulf of decades, for three days of revelation and reflection that resulted in a video installation called *FaceAge*.

Belser, professor of theatre and the 2017-18 Penn State Laureate, designed the project to bring together people of different generations in a way that would take them deeper than a typical social exchange.

"In our culture, young people don't tend to approach old people and older people don't tend to approach younger people," he says. "*FaceAge* is intentionally trying to help communities of people take the time to see one another differently."

BY CHERIE WINNER

A father and his twin sons receive guidance from Matt Kaplan (right) in Kaplan's intergenerational karate class. Photo by Patrick Mansell.

WHAT WE'VE LOST

Belser, now in his mid-50s, says he's always felt at ease with people much older than himself. He grew up in central Pennsylvania, in a large extended family whose members routinely lived into their 90s. "When I was 16, one of my best friends was 72," says Belser. "He had an orchard that I worked on, and he took a liking to me and we went out golfing a lot, and I didn't think anything of it."

But in the past few decades that kind of familiarity has become much less common, with interactions among generations no longer built into daily life. Now, many kids don't know any elders they aren't related to; some don't even see their own grandparents more than once or twice a year.

The cost to all of us is enormous, says Belser. Seniors become cut off from younger people at the time of life when they have the most experience to contribute but also are most in need of support. Youngsters have lost the example and refuge of elders who could offer a long perspective and a sympathetic ear during difficult times.

"I think seniors were intended to have a lifelong impact on the kids around them," says Ken Pendleton, director of the Centre County Office of Aging, one of 52 local agencies on aging across the state. "And that would be their legacy: to help move those children forward."

Over the past several years, Penn State has become a leader in intergenerational work, with researchers in fields ranging from information sciences to sociology exploring relationships between old and young. Matt Kaplan, a professor of agriculture and extension education, is especially interested in getting elders and youngsters together in ways that address local problems, such as how seniors can help at-risk kids in elementary school classrooms, or how seniors and kids together can create an urban garden to provide fresh produce to their community. He designs programs, studies which approaches work in given situations, and shares his findings with colleagues via scientific journals and with the public via extension and the Web.

He even brings generations together in his personal time. A black belt in karate, he runs a family-oriented dojo in State College where most of the students come in intergenerational pairs: parent and child or grandparent and grandchild. He got the idea after seeing parents drop their kids off at youth soccer and then go off to play soccer or softball in an adult league. "Parents are always saying they want more time with their kids," he says. "Why not learn a martial art together?"

Pendleton welcomes the ideas and energy generated by Kaplan's efforts. "We've become so segregated that the process of coming together naturally has been broken," he says. "Matt's work is about putting the pieces back together."

In the first Weaving Wisdom workshop, elders and children teamed up to weave bracelets based on kente cloth. Photo by Patrick Mansell.

INTERSECTING STRANDS

Three years ago, Kaplan launched the Intergenerational Leadership Institute (ILI) to teach senior volunteers how to develop programs for other seniors and younger people. Participants learn how to identify local issues, what's needed to address them, and some approaches to working with elders and kids. Kaplan encourages the ILI "Fellows" to tap into their own expertise and interests to come up with program ideas.

At the first meeting of one ILI class, three students discovered they shared an interest in woven things. Sandy Lopez was wearing earrings and a bracelet of woven sweetgrass made by Gullah artists from the Low Country of South Carolina, where she had lived for many years. Fran Scalise, who lives in South Carolina part-time and has long been fascinated by sweetgrass basketry, recognized them right away. Grace Hampton, recently retired from her position as senior faculty mentor at Penn State, was familiar with Gullah basketry and also had deep knowledge of kente cloth and other fabrics of West Africa.

The three hit it off, and soon zeroed in on baskets and fabrics as vehicles for their project. It didn't take long for them to find a larger context.

"When we first started looking at the baskets, we were looking at the *objects*," says Lopez. "But we quickly shifted to looking at who made the objects, and where they were made. It became more an idea of, how can we help transmit culture? How can we transmit a love of culture and history? And do all this in a way that gets seniors and young people to want to share stories and learn new things together?"

In the summer of 2017 they hosted a day of "Weaving Wisdom" workshops at Schlow Library in downtown State College. In the morning, they introduced adult attendees to sweetgrass baskets and kente cloth. In the afternoon, kids joined the group. They learned that the original baskets, wide and shallow, were an essential tool that rice-growers used to separate the grains from the chaff, and that the weaving techniques used to make them were brought here by slaves from West Africa, whose descendants became the Gullah. They learned that the colors and patterns of kente cloth represent life events or qualities of character the wearer aspires to. With the help of an adult partner, each child wove a kente-style bracelet, choosing colors to represent themselves and their family. More than 75 people participated.

It's not always easy getting such programs off the ground, says Kaplan. He cites a project created by two other ILI Fellows, Christine Tyler and Dorothy Christensen. Their project, SAVOR (Sharing and Valuing Our Relationships), brings college students together with elders who have been isolated for a long time, to share a meal and an activity such as a sing-along or drum circle. "What I wasn't prepared for was how hard it is to get these older people there," says Kaplan. "Some don't answer the door even if you call them and tell them who will be coming to pick them up." The solution, he says, is patience, building trust, and gentle persistence. "You have to work with them over time. You can't just put out flyers announcing the dinner, because those won't appeal to the people who are most vulnerable and probably need the program the most."

The Weaving Wisdom team is planning new workshops for the summer of 2018, this time featuring Early American and Amish quilts. Like sweetgrass baskets and kente cloth, such quilts often carry cultural meaning, not least in the way they were made. Traditionally, young girls sat alongside their mothers, grandmothers, and other adult women for hours, learning needlework skills and absorbing lessons about how to work hard, how to deal with setbacks, where they fit in the community. Adults would do well to keep this in mind when they're with youngsters, says Hampton. "Sometimes you don't know what you're transmitting."

A NEW KIND OF VOLUNTEER

Like many ILI Fellows, Hampton, Lopez, and Scalise came into the program with professional experience they could draw on. That was part of the appeal for them. After spending decades teaching or managing others, says Hampton, "it's hard to just stop when you reach retirement. It was beneficial to us to have a meaningful outlet for our skills, knowledge, and creative energy."

Pendleton, whose agency oversees about 850 active senior volunteers working with 70 local organizations, says the ILI goes beyond traditional forms of volunteering where you show up and are told what to do.

It demands thought and creativity—and it benefits the volunteers almost as much as it benefits the people the volunteers are helping.

"It's easy to buy into the myth that what you've learned is suddenly out of date and no longer relevant," he says. "The fact is, the overwhelming majority of your life's experiences are applicable to today—and this program harnesses that wealth of information in a way that is useful."

Kaplan agrees. "Some older adults report feeling under-utilized," he says. "It's not painful in an explicit way, but it's regretful, to not have pathways to be relevant and powerful. The ILI creates a little bit of a bridge and a home."

It also offers a partial solution to problems many communities face as their citizens age. The loss of traditional family structures leaves many elders reliant on community resources. As Baby Boomers retire—10,000 a day for the next 20 years, nationwide, says Pendleton—local agencies will struggle to keep up with their needs for health care, transportation, and general support. "We're happy to try to help anybody who has need," he says. "It's just that, can we help everybody?"

Through ILI, senior volunteers help local agencies by reaching more people who need support, making their communities more cohesive and livable for everyone. People who see elders in general as a burden on local budgets and services are missing the point, says Pendleton; given the opportunity, seniors can be a tremendous resource.

FACING ASSUMPTIONS

Much of intergenerational work involves dealing with preconceptions. It's easy to make assumptions about people and groups we don't know well, and in most cases the groups will remain different in key respects: men and women, black and white, native-born and foreign-born. In the case of generations, though, younger people will become elders themselves one day; their beliefs about aging necessarily involve assumptions about how their own lives will change as they age.

Confronting those assumptions was the impetus behind *FaceAge*, says Belser. The idea for the project came to him while visiting the Face Aging Institute at the University of North Carolina Wilmington, where he worked before coming to Penn State in 2013. The Institute develops software to map and predict the changes in people's faces as they age, primarily for use in criminal forensics. "I saw it, and was just so moved by this question of, how do our faces change, and how do *we* change, as we age?"

In *FaceAge*, Belser put the participants in situations where they almost had to consider the prospect of their own aging. In one setting, they were filmed through a two-way mirror as they responded to their own reflection and to computer-generated images of how they are likely to look when older. That provoked feelings some of the younger participants seemed reluctant to face. Belser thinks their reluctance stems, in part, from an oddity of human psychology. "A researcher at Princeton found that when we imagine ourselves as ten years older, we imagine a stranger," he says. "We *don't* imagine ourselves. People of these students' ages, they think 50 is 'the frontier.' So they don't plan for it. And they certainly don't have a way to consider how aging will unfold slowly and maybe even beautifully."

One of the film's most profound revelations—to its young participants as well as to viewers—is that all the elders in it share one thing: They are contented and at ease with their lives. They're *happy*.

It's called the aging paradox, says Belser. While popular culture tells us we're happiest in our 20s and early 30s and pleasure in life goes steadily downhill after that, research shows that most people get *happier* as they get older. Despite the loss of loved ones, their physical ailments and limitations, and inevitable regrets, those 65 and over are happier than young adults and more generous in their views of others.

Which puts a whole new slant on intergenerational programs, says Belser. "We should get younger people and older people together, so the younger people can begin to understand that growing older isn't just a process of loss. It's a process of gaining joy, happiness, wisdom."

INTO THE CLASSROOM

Watching *FaceAge* is an active, almost inter-active, experience. It shows on three large screens, and the visual story you see depends on which screen you're watching at any given moment. In the fall of 2016, Belser gave University Park a preview of the film. He set up a tented theater space in the HUB where visitors could immerse themselves in the 56-minute film, which ran in a continuous loop.

Amy Lorek (back) looks on as Andy Belser (center) speaks in her class, which was inspired by Belser's video installation *FaceAge*. Photo by Patrick Mansell.

Belser noticed that many viewers sat through it more than once, or left after one viewing but returned later to see it again. “We had no idea they would do that,” he says. “People come back to it. It gives you infinite opportunities to change the narrative for yourself.”

Amy Lorek, an assistant research professor in the Center for Healthy Aging, set up a dialog wall just outside the tent, where viewers could post sticky notes to comment on *FaceAge*, aging issues in general, or comments from other viewers. Seeing how deeply people were affected by the film, she hatched an idea for a class based on the *FaceAge* model of pairing elders with young adults. With a small grant from the Schreyer Institute for Teaching Excellence, she offered the course for the first time in 2017, with 15 undergraduates from various majors and 15 older adults recruited through the Osher Lifelong Learning Institute (OLLI).

The partners created a video together and kept journals about their experiences in the class. A big part of the course was confronting the assumptions they came in with. That applied to both groups of students, says Lorek. “Undergraduates come with these very narrow experiences of older adults. But often times, older adults have narrowed their interactions to just their peer group.”

Many of the younger students said they don’t know any older adults that they’re not related to. Some came in expecting all elders to be like their grandparents—which was not always a good thing. Lorek recalls a female student who was moved by a passage in *FaceAge* where a young gay man worried about what his older partner, a straight woman, would think of him.

During the filming of *FaceAge*, one young man, touching the deeply-creased face of his 87-year-old partner, expressed surprise at how the skin felt. “Even the scars are soft,” he said. Photo by *FaceAge* Creative Team.

(From left) Sandy Lopez, Grace Hampton, and Fran Scalise, the creators of Weaving Wisdom, examine a quilt made in 1862 by Lopez's great-grandmother when her husband left their home in Massachusetts to fight in the Civil War. Photo by Patrick Mansell.

Lorek's student said she had recently told her grandmother she's gay, and the grandmother said she just hadn't met the right man yet. "That closed the door to the conversation," says Lorek. But sharing that in class opened a different door, one Lorek didn't even know was there.

"The student's partner said, 'I worked at the first gay bar here in State College.' So then they had this conversation about how things are different, how they're the same, and they had this connection that I would never have predicted. And the student came to understand that not all older adults are going to close the door and stop the conversation. Which may or may not counterbalance the weight of a grandparent, but it still is a positive experience."

It was important to Lorek that throughout their discussions, every person in the class be both a learner and a teacher. "I wanted the undergraduate students to believe that they had something to offer and then give them the chance to do that, and I wanted the older adults to not just be the 'wise sage.' That's one of the things we know from recent research: Learning new things contributes to healthy aging."

All the same, sometimes the elders were "wise sages." The simple fact that they had been through a lot, had made it to old age, and were happy with life in general made a big impression on their young partners. Late in the course, one of the elders said to her, "These students are so worried. About *everything*." The students hadn't talked about their worries with Lorek, "but at the end, they were writing things like, 'I just feel so much better. I realize that it's all going to be OK. Whatever happens.' I've come to appreciate that the students have anxiety about all the things that are coming up for them and that they're getting pressure about, and that the older community members offer them a reassuring voice that the students can come to hear: We went through this. We survived. We did fine. You will too."

The Weaving Wisdom team used sweetgrass baskets from South Carolina and colorful West African kente cloth to talk with kids about culture, history, and art. Photo by Patrick Mansell.

In the first Weaving Wisdom program, adults and kids teamed up to weave bracelets based on the colors and patterns of kente cloth. Photos by Patrick Mansell.

NEXT STEPS

Amy Lorek offered the course again this spring. So many undergraduates wanted to take it that she had to cap enrollment. Participants range in age from 19 to 92. Among the elders in her first class were Sandy Lopez and Fran Scalise of Weaving Wisdom, who were inspired by their experience in the class to come up with an ambitious new project: to work with OLLI to take elders and undergraduates to the Low Country to interview Gullah basket-makers. They hope to partner with an academic department whose students could use the trip as part of a research project.

The lead partner for *FaceAge* is ADRI, the Arts and Design Research Incubator in the College of Arts and Architecture, which provides seed money for projects with the goal of moving them off campus and into the wider world. By that measure, *FaceAge* is a spectacular success. What started as an artistic exploration of the fears and realities of aging has found audiences Belser never anticipated. He has been showing it at Penn State's Commonwealth Campuses, and it is now part of the first-year curriculum at Penn State College of Medicine. It's in demand by museums around the world that want to use it as a jumping-off point for community-engagement events. He's been invited to help develop versions of *FaceAge* in other countries or focusing on specific contexts, such as workplace issues. This October, it will be shown in Philadelphia at the national conference of Leading Age, a group of more than 6,000 agencies, nonprofits, retirement communities, and health-care providers.

Matt Kaplan is working with groups in Asia, Europe, and across the U.S. to develop ILI chapters in other cities, and demand is just as high for his other intergenerational projects. "When I started this kind of work in the late '80s, it was more like trying to convince people to take a chance and try something," he says. Now it's more an issue of, how can he work with everyone who has an interest in mending the rift between generations?

"It's more than any single program," he says. "It's a movement, and we're riding the wave."

The Center for Healthy Aging in the College of Health and Human Development is the lead community engagement partner for FaceAge *and a sponsor of the Intergenerational Leadership Institute. The lead research partner for* FaceAge *is the Penn State College of Nursing.*

SAVING the BAY

BY DAVID PACCHIOLI

WHEN MATT ROYER TEACHES UNDERGRADUATES ABOUT NUTRIENT POLLUTION, HE CALLS IT A NEXT-GENERATION ENVIRONMENTAL PROBLEM.

"I start with a history of the environmental movement," says Royer, director of Penn State's Agriculture and Environment Center. "Most of our current law was born out of those televised images from the 1960s, images of rivers catching on fire, smog inversions, oil spills on California beaches. Things that are easy to see, that have drastic, immediate impacts."

Nutrient pollution is not like that. Its impacts mount gradually, and they can be difficult to spot. But it's a major issue affecting water quality around the world: The U.S. Environmental Protection Agency names it "one of America's most widespread, costly and challenging environmental problems."

A wicked problem, academics have called it. Its sources are diffuse, and hard to regulate. The science is complex. And the politics are multi-layered and thorny, involving a wide range of stakeholders and competing interests.

PENN STATE'S COLLEGE OF AGRICULTURAL SCIENCES TAKES A LEAD ROLE IN CLEANING UP THE CHESAPEAKE.

Royer, an environmental lawyer who grew up on his family's poultry farm in Lancaster County, likes to say that we all contribute to nutrient pollution. We all use the bathroom, and rely on wastewater treatment, and eat farm-raised foods, and depend on the roads and paved surfaces that convey storm water into our streams. But in an agricultural state like Pennsylvania, the largest single source of nutrient pollution is the runoff of nitrogen and phosphorus from fertilizers applied to farm fields: nutrients that are vital for plant growth, but that in excess create blooms of algae that eat up oxygen and choke aquatic life.

These nutrients seep into groundwater and creeks, fouling drinking water and killing fish. The sediments that carry them coat stream beds, smothering habitat for insects and other creatures at the low end of the food chain. The pollution flows on into larger tributaries, proceeding downstream to join the Susquehanna River. Eventually, much of what washes from Pennsylvania's fields winds up in the Chesapeake Bay.

The Susquehanna River, seen here in Bradford County, runs past thousands of Pennsylvania farms on its way to the Chesapeake Bay. Photo by Nicholas A. Tonelli/Wikimedia Commons.

Volunteers in Lancaster County help to plant a riparian buffer on an Amish farm as part of Penn State's Greening the Lower Susquehanna initiative. Photo by Jennifer Fetter.

LAND TO WATER

With some 64,000 square miles of land draining into a shallow, narrow body of water just 200 miles long, the Chesapeake is in some respects a worst-case scenario. "The land-to-water ratio dwarfs that of almost every other water body in the world," Royer says.

The Bay watershed, home to 18 million people, spreads out across six states and the District of Columbia. It includes almost two-thirds of Pennsylvania, which supplies fully half of the Bay's freshwater flow and the largest share of its agricultural pollution.

Soil scientists and environmental engineers, wetlands ecologists, extension agents, and others, including many at Penn State, have been working on this problem since the 1980s. One outcome of their efforts has been the establishment of a set of best practices for farmers: steps aimed at limiting fertilizer use, maintaining soil health, and managing the storage of manure. "The idea was that if we put a lot of these best practices into place, we'd solve our environmental problem," says James Shortle, distinguished professor of agricultural and environmental economics. But the results have been mixed at best.

Part of the problem is limited resources. Because most Pennsylvania farms—large confined animal operations are the exception—are not regulated under the federal Clean Water Act, the state has relied heavily on incentives to convince farmers to adopt conservation measures. "The spending for this has been enormous," Shortle says, "and the reductions in pollution not that much."

Further, while environmentally conscious farming practices are critical for reducing the flow of pollution into the Bay, there are bigger issues they don't address, the economist Shortle says. One example: As a state dominated by animal-intensive agriculture, Pennsylvania imports vast quantities of corn from the Midwest for feed. That corn carries nitrogen and phosphorus from Midwestern soils. "Our animals use only about 30 percent of these nutrients, and the rest goes into the environment," he says. "Effectively, we're taking nutrients from the Midwest, and putting them into the Bay." A comprehensive solution, he argues, would involve policies aimed at addressing this kind of imbalance.

In 2005, when he became director of the College of Agricultural Science's newly formed Environment and Natural Resources Institute, Shortle made nutrient pollution his number one priority. To attack the problem effectively, he thought, would require a more coordinated approach, and he saw Penn State playing a critical role. "There's no single entity in the state apart from our College that has the scientific capacity combined with the connections and the trust of the agricultural sector to facilitate this," he says. At the time, however, the University had yet to assume such a role. "We were aware of the problem, we had certainly made noteworthy contributions to the science of the Bay, we had done some extension work, but on the whole Penn State was a non-player."

The immediate challenge, he knew, would be political. "Many people had been working on this problem for a long time, and there were a lot of silos built up around the Bay," Shortle says. "We had to find a way to get engaged." After consulting with colleagues, he decided to stage a conference, in Harrisburg. "But it wasn't going to be us lecturing everybody," he says. Instead, the College would invite a representative mix of the Bay's many and various stakeholders—elected officials, farmers, representatives from local, state, and federal agencies, conservation officers, environmental activists, and lobbyists—to come together in working groups, share ideas and concerns, and try to hash out solutions. The focus would be on collaboration.

It wasn't an easy sell. "We were bringing together groups that had never talked to each other, or if they did they were yelling at each other," Shortle says. "I remember some of them calling me and asking what the heck we were doing." In the end, however, that 2008 conference, "Agriculture in Balance," was a major step forward. "There was a recognition that our multiple interests—in a vibrant farm economy, beautiful rural landscapes, and water quality—could in fact co-exist. We came out of it with a shared vision for Pennsylvania agriculture."

With the subsequent creation of the Agriculture and Environment Center, the College established a platform for its ongoing efforts. The general premise, echoing research by Penn State geographer Denice Wardrop and others, was that addressing water quality problems in the Bay would require cleaning up the waterways that feed into it. To that end, the center would integrate research and extension, and put most of its emphasis on building community partnerships.

"WE NEED TO PUT THE MOST COST-EFFECTIVE SOLUTIONS IN THE PLACES WHERE WE HAVE THE BIGGEST PROBLEM." -JAMES SHORTLE

(Left) The Bay watershed, home to 18 million people, spreads out across six states and the District of Columbia. (Right) Susquehanna River just south of Three Mile Island, where the Conewago Creek drains into the river. Mud plumes are eroded sediment washed into the river after a heavy deluge of rain.

"We in Pennsylvania don't tend to connect with the Bay that much—we don't live on it, or recreate on it, most of us," Royer explains. "But we do care about our local streams. Our job at the center is to build capacity to address things at a local watershed level."

He's the right man to do it. In 2001, Royer and his father took it upon themselves to clean up their own home watershed, south of Hershey. Noticing the diminished health of their local creek, the two discussed what they could do about it. The younger Royer posted signs to advertise a community meeting, and a grassroots watershed restoration effort was born.

Adopted by Penn State, the Conewago Creek Initiative eventually brought together over 30 public and private organizations, from the state Department of Environmental Protection to Trout Unlimited chapters to local high schools. With funding from the National Fish and Wildlife Foundation, teams of volunteers worked with residents and landowners to raise awareness about water quality issues and promote tried-and-true best practices, like streamside buffers and cover cropping, as well as innovations coming out of the latest Penn State research, like manure injection and low-protein feeds. In the end, the effort succeeded in substantially improving the local water quality in one of the more heavily agricultural watersheds in the state. Conewago Creek has since been designated a Chesapeake Bay "Showcase Watershed" by the U.S. Department of Agriculture, and Royer and his team have adapted the model for use in other local watersheds.

A POLLUTION DIET

In 2011, prompted by continued poor water quality in the Bay and its tributaries, the U.S. EPA established the Chesapeake Bay Total Maximum Daily Load. This comprehensive "pollution diet" mandates steep reductions in nutrient pollution to be accomplished by every state in the Bay watershed by 2025. For the first time, states are to be held accountable for nutrient pollution under federal law. For Pennsylvania, especially, that deadline presents an enormous challenge.

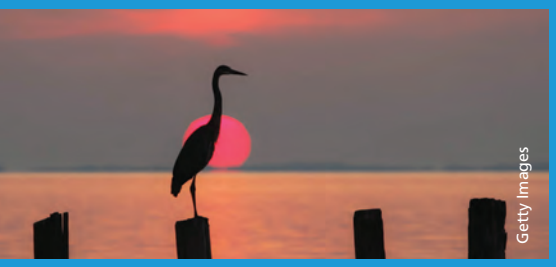
The sheer number of farms in Pennsylvania is one thing, Shortle says: The state has over 34,000 within the Bay watershed. Lancaster County alone has over 5,000, more than the entire state of Maryland. "In Pennsylvania, too, we have a lot of small farms," he adds, "and it's harder for them to comply. Reducing agricultural pollution is something that has economies of scale."

To meet the EPA mandate, he and Royer stress, will require a strategic approach. "We need to put the most cost-effective solutions in the places where we have the biggest problem," Shortle says. That means, for example, focusing incentive programs on our most agriculture-intensive counties—Lancaster and York—instead of making their application uniform across the state. But pollution "hot spots," Royer says, can also be pinpointed within local watersheds, and even within individual farms.

"WE'RE TRYING TO FIND THAT SWEET SPOT, WHERE YOU'RE MAXIMIZING CONSERVATION AND PRODUCTION AT THE SAME TIME." -MATT ROYER

Jim Harbach

Will Parson/Chesapeake Bay Program



Getty Images

A buffered stream on Brubaker Farm in Lancaster County, a 900-cow dairy farm. Buffering reduces erosion and runoff.

Steve Droter/Chesapeake Bay Program

"Depending on soil type, topography, the type of agricultural operation, and many other factors, what's needed varies to the point that it becomes almost site-specific." To strengthen the science behind this kind of precision conservation, Shortle and Rob Brooks, professor of geography and ecology, started the Center for Nutrient Solutions, one of four EPA-funded national centers for water research, in 2014.

The center encompasses water research from around the university, and includes partners at USDA and the University of Maryland. Shortle and colleagues are addressing system-level questions: the regional imbalances caused by importation of nutrients, and the deposition of nitrogen and phosphorus through air pollution. In addition, they are monitoring nutrient flow in four pilot watersheds—three in southeastern Pennsylvania and one in Maryland—and working with the USDA's Agricultural Research Service office, on the University Park campus, to model pollution entering the Bay. "We can use these models to explore different scenarios," Shortle says. "We can see which practices, in which places, give us the levels of reduction we're looking for."

In the spirit of partnership, the research is collaborative, involving community members whose insights are critical for understanding local constraints and finding solutions. One example is a project recently funded by the USDA to take a fresh look at riparian buffers, shaded zones of vegetation bordering farm streams that can be highly effective in reducing erosion and nutrient loss. Buffers can be expensive for farmers to install and maintain, and for this reason their adoption has faced some resistance. To address this, the new study, led by assistant professor of agricultural engineering Heather Gall, will begin with focus groups. Then Gall's team will evaluate a variety of flexible buffer designs, looking for alternatives that are both effective and affordable.

"It's always a give and take between what farmers might be interested in trying and what they can fit into their existing operations," Royer says. "We're trying to find that sweet spot, where you're maximizing conservation and production at the same time."

PA IN THE BALANCE

By early 2016, Shortle and Royer knew the time was right for another summit. Approaching the midpoint to the EPA's deadline, it had become clear that if Pennsylvania was going to have any chance of making the 2025 target, the state would have to sharply accelerate its pollution-reduction efforts. The name they chose for this follow-up conference, "Pennsylvania in the Balance," reflected their sense of urgency. The entire range of Bay stakeholders was once again invited, this time to Hershey. The object, again, was to sit down together and find a way forward. But the lead role this time would fall to those on the front lines: the farmers themselves.

Shortle and others were concerned that a strategy of pushing farmers to comply with ramped-up regulations was likely to be counterproductive. It would be better, they thought, to let farmers take the lead—identifying obstacles, proposing solutions they found workable, and embracing best practices because they wanted to, not because they were being forced to do so.


James Shortle


Matt Royer

"We wanted to tap into the stewardship ethic that farmers share," Royer says. That ethic showed in the results of a survey the College conducted, drawing responses from nearly 7,000 Pennsylvania farmers. Funded by the state's Department of Environmental Protection and Penn State, the first-of-its-kind survey sought to learn what farmers were doing on their own initiative to improve water quality on their farms. As Royer explains, the DEP tracks conservation practices implemented to reduce pollution, and reports those efforts to the EPA to document progress. But practices that farmers pay for themselves, without government grants, don't get counted. "The survey results confirmed what we suspected—that a lot is being done already," he says. "It's important that farmers get credit for that."

Conference attendees agreed that farmers who are leaders in their communities can play an outsized role in spreading acceptance of environmentally friendly practices. One such leader, Jim Harbach, sat on the panel that kicked off the meeting. Harbach and his family run Schrack Farms Resources, a 1,000-cow dairy operation in Loganton, Clinton County, that won the 2018 Innovative Dairy Farmer Award of the International Dairy Foods Association. He is also co-director of the Pennsylvania No-Till Alliance, a "farmer-to-farmer" organization that promotes the benefits of no-till farming and cover-cropping, practices that can dramatically improve soil structure, reduce erosion and prevent nutrient runoff. Harbach is passionate about spreading the gospel of good soil health.

"We got into no-till for all the wrong reasons," he says. "We were tired of picking rocks out of our fields. Then we saw what it was starting to do to the soil, and we realized we had an obligation to share our observations." Indeed, peer-to-peer education is vital in farming communities, where traditional ways can be hard to let go of, and change means risk. But meeting higher conservation standards also requires that farmers master a new type of expertise. Many simply don't have the technical know-how—or the time—to draw up and carry out the detailed conservation and nutrient management plans that are now mandated by the state, Harbach says, and a lack of qualified planners for them to call on exacerbates the problem. To address this shortage, the College developed a certificate program for training undergraduates as conservation technicians.

MOVING FORWARD

By all accounts, "Pennsylvania in the Balance" was a resounding success. "One of the really exciting things that came out of it," Royer says, "was the realization that farmers are eager to take the lead in solving this problem."

Kelly Shenk, the EPA's agricultural advisor for the Chesapeake Bay region, agrees. "It was the first time the agriculture community came together with a unified voice and said, 'Listen, we can figure this out,'" she says. "And it couldn't have happened without Penn State."

From Harbach's perspective, "It was a chance to sit down with high-ranking officials, with the EPA, and nobody was pointing any fingers. Everybody was working on finding solutions. That's created some good partnerships moving forward."

Progress is being made. Most of the indicators for nutrient pollution into the Bay seem to be turning slowly in the right direction, Royer says. But there's still a long way to go. He and Harbach are both involved in writing the agriculture component of the DEP's implementation plan, the document that will guide the final push to the 2025 EPA deadline. Both say the lessons of "Pennsylvania in the Balance" will be an important component.

"I think the conference has helped position Pennsylvania differently with regard to water quality issues," says Mary Seaton, assistant director of College Relations. "Instead of being the state that's a problem, we're viewed as a state that's working on some great new ideas. We've become a model for others, as far as getting people to work together constructively."

Seaton's comment might as well refer to the College's entire decade-long effort, assuming the leadership role that Shortle envisioned back in 2005. "It's been remarkable," Shortle says. "We have really elevated what we do. This has been a model engagement of our capacities in addressing a complex problem."

"It's a great example of what Penn State can provide, as a land grant institution," Royer adds.

"We can be a big part of the solution."

JEFF FORTIN ON INDUSTRY PARTNERSHIPS

Later this year, Penn State will welcome the U.K.-based corporation Morgan Advanced Materials to its brand-new, 30,000-square-foot building at Innovation Park. Jeff Fortin, associate vice president for research and director of the Office of Industrial Partnerships, spoke with us about the new building and how the companies that occupy it will benefit the University and the state.

WHAT'S SPECIAL ABOUT THE NEW BUILDING?

It's what they call a 'flex' building. Tenants can design their own space and can use it for a variety of things, from research and development to light manufacturing and prototyping. We want this building to house true research partners of Penn State, not just a company that's looking for office space.

TELL ME ABOUT THE FIRST TENANT, MORGAN ADVANCED MATERIALS.

They make sub-components for systems in the medical and transportation industries. They were looking for a location for a Carbon Science Center of Excellence, and they asked what our expertise is in materials. It turned out that over a ten-year period, we were number two in the volume of publications in that field, behind MIT. Our Materials Research Institute and the tools that we have in the Materials Characterization Lab appealed to them, too. That's an amazing facility. Advanced TEMs, SEMs, every kind of technique you can imagine, just about, we have there.

HOW WILL THE UNIVERSITY BENEFIT FROM HAVING THEM HERE?

They'll directly sponsor research with us. Our faculty love to work on real-world problems. With Morgan, they'll be working on technology that could go to market in, say, five years. Ph.D. students who spend their thesis years working on a real-world problem, they're going to get a job like *that*. Also, it's economic development for the local area and the state, because all their jobs here—about 25 people doing research—will be brand-new. They're also bringing us new industry contacts. Recently, Morgan brought 70 of their top scientists here from around the world for a conference on research and product development. While they were here, they visited campus and learned about our materials capabilities.

WILL PENN STATE OWN ANY PRODUCTS THEY DEVELOP?

We handle intellectual property differently than a lot of other universities. Instead of charging them a license fee for any intellectual property that's generated from research they sponsor with us, we tell companies that we can transfer ownership of those patents to them at no royalty—but if it does extremely well in the market, we would like a little bit back. That policy really is appealing to companies.

HOW WILL THAT POLICY HELP OUR RESEARCHERS?

We've had a history of being leaders in research but not so much in translating that research out into the commercial world. A faculty member may come up with a product or a new

technology that could solve a problem. They may have an interest in seeing their technology make it into the world, but translating something like that into a commercial product can be a little murky. We help them identify an industry partner or a team that can start a company with their technology.

MATERIALS SCIENCE SEEMS TO BE A MAJOR EMPHASIS IN THESE PARTNERSHIPS, SO FAR.

The whole state has this history of minerals and materials—powdered metal and ceramics in the northwest, steel and anthracite and coal in the southwest, and so on. There are already a lot of companies in the State College area based on materials, companies that are here because of technology that spun out of research here at Penn State. With all the materials expertise we have, I've been calling the area 'Materials Valley.' We're not only Happy Valley and Hockey Valley!

WHAT ABOUT OTHER AREAS OF RESEARCH?

We've already engaged with Morgan in areas beyond carbon. They joined our center on ceramics, they joined our center on 2D materials. They asked, do you guys do much with batteries? And we said, we have a battery research center! These relationships start in one area, but they evolve. That's one of the good things about Penn State—we have so much to offer. Sometimes I have to go find it, but I know it's there.

Penn State's Office of Industrial Partnerships connects companies and the University, with a focus on promoting research, helping companies solve their technical problems, and helping faculty members find business partners who can turn their ideas into commercially viable products, technologies, or services.

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Mending the Gap

An intergenerational karate class welcomes kids and their parents or grandparents. This mother and her adult son (behind her) have been coming since he was 12.

SEE PAGE 22

Patrick Mansell