Research | Penn State

VOLUME 35 | NUMBER 2 | FALL 2015

A BLOW TO The Head

› ALSO IN THIS ISSUE

Engaged **Scholarship ›**

Every issue of Research/Penn State is filled with examples of our faculty and students living out this great University's core values, pursuing its mission and bringing new knowledge to bear on society's most pressing problems. This one is no exception.

Nina Jablonski, one of our most distinguished academics, has gone far beyond positing the first comprehensive theory of human skin color to explore the health and social implications of human diversity. Driven by a strong sense of the responsibility she believes all scholars share, Nina has become an important public voice in our country's ongoing conversation about race.

Researchers at the Center for Sport Concussion Research are using the latest technology to get a better handle on a commonly misunderstood problem that affects 1.7 million people every year in the U.S. alone: traumatic brain injury.

Plant scientists Jonathan Lynch and Kathleen Brown are combining low- and high-tech methods to better understand the root structures of subsistence crops and help small farmers in developing countries adapt to climate change.

Finally, engineer and entrepreneur Khanjan Mehta is an inspiring example of engaged scholarship. Our interviewer reached him via Skype in Zambia, where he and his students were building low-cost greenhouses to grow fresh food for pregnant women who would otherwise have few nutritional choices.

Khanjan, who has been leading similar projects around the world for over a decade, has learned that a systemic approach is vital to sustainable success. "This philosophy of engagement I think is critical," he says, "and that's also something that really sets our program apart."

He has it right; true engagement portends success. At Penn State we are constantly seeking new ways to effectively engage our students, faculty, and staff in discovery for the public good. From basic science breakthroughs to translation and sustainable implementation, we are making a difference.

Neil A. Sharkey
Vice President for Research

WE NEED YOUR HELP: We would like to hear from readers about how we're doing and where we might improve. Within the next two weeks, some of you will be receiving an email survey from us. It should take just a few minutes to complete, and your answers will help us make sure that we're bringing you the interesting, informative stories about intellectual activity at Penn State that you value. And, of course, comments are welcome any time, at **editor@research.psu.edu.**

For more research news and features visit us online at: **www.rps.psu.edu**

Research/Penn State is published by the Office of the Vice President for Research at The Pennsylvania State University. The magazine samples the diversity and drama of Penn State's $801-million-a-year research program as a public service to inform, entertain, and inspire the University community. Opinions expressed do not reflect the official views of the University. Use of trade names implies no endorsement by Penn State.

Publisher: **NEIL SHARKEY**
Vice President for Research
Director of Research Communications: **DAVID PACCHIOLI**

Editor: **CHERIE WINNER**
Production Manager: **KERRY NEWMAN**
Designer: **KEVIN CARLINI**

ON THE COVER:
At Penn State's Center for Sport Concussion Research and Service, a young athlete navigates through a virtual scene to test his balance, kinesthetic sense, and other brain functions. See story on page 20. Photo by Patrick Mansell.

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Jim Marden, Penn State (2)

Libellula pulchella

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Parasitic protozoans in a dragonfly gut

Dragonfly Gut Infections Suggest Environmental Role in Obesity

Obesity and diabetes are not just problems of modern-day humans and their domesticated pets. Insects also are affected by these health conditions, and intestinal infections by protozoans are the cause, according to Penn State researchers. Their research suggests that intestinal infections may contribute to metabolic diseases in humans as well.

Ruud Schilder, assistant professor of entomology and biology, is looking at whether the environmental conditions in which dragonflies (*Libellula pulchella*) live make them susceptible to parasitic protozoans, and how infection by protozoans affects dragonflies' flight performance and energy use.

Schilder notes that an infectious origin of obesity has been suggested for several species of vertebrates and is now an emerging field of research, known as "infectobesity." Yet, other than his work in this area, this phenomenon has not been examined in invertebrates.

"Our preliminary data indicate that infected dragonflies display a very similar shift in the composition of their gut microbiome [the collection of microorganisms in the gut] to that which has been linked to the development of obesity in humans and other mammals," he says. "It suggests that the occurrence of metabolic disease may be widespread in nature.

"I think our work makes a pretty good case for the need for a comparative approach to studying infectious origin of metabolic diseases that includes nonmodel and naturally occurring invertebrate systems."

—SARA LAJEUNESSE

Keep Calm and Carry On

Reacting positively to stressful situations may play a key role in long-term health, according to researchers.

In a study measuring adults' reactions to stress and how it affects their bodies, researchers found that adults who fail to maintain positive moods such as cheerfulness or calm when faced with the minor stressors of everyday life appear to have elevated levels of inflammation. Furthermore, women can be at heightened risk.

United Kingdom Government

Inflammatory responses are part of the body's ability to protect itself via the immune system. However, chronic inflammation can undermine health, and appears to play a role in obesity, heart disease, and cancer.

Nancy Sin, postdoctoral fellow in the Center for Healthy Aging and department of biobehavioral health, Penn State, and her colleagues, showed that the frequency of daily stressors was less consequential for inflammation than how an individual reacted to those stressors.

Sin's findings also highlight the important, but often discounted, contributions of positive affect in naturalistic stress processes.

"Positive emotions, and how they can help people in the event of stress, have really been overlooked," she says.

—MARJORIE S. MILLER

How green tea seems to kill oral cancer cells


Deathtiny42

A compound found in green tea may trigger a cycle that kills oral cancer cells while leaving healthy cells alone, say Penn State food scientists.

Earlier studies had shown that the compound, epigallocatechin-3-gallate (EGCG), kills oral cancer cells without harming normal cells, but researchers did not understand why, says **Joshua Lambert**, associate professor of food science. The current study with cultured cells shows that EGCG may trigger a process in mitochondria that leads to cell death.

"It looks like EGCG causes the formation of reactive oxygen species in cancer cells, which damages the mitochondria, and the mitochondria respond by making more reactive oxygen species," says Lambert. At the same time, the cancer cell reduces the expression of anti-oxidant genes, further lowering its defenses. "So it's turning off its mechanism of protection at the same time that EGCG is causing this oxidative stress," he says.

A protein called sirtuin-3 is critical to the process, he adds. "It plays an important role in mitochondrial function and in anti-oxidant response in lots of tissues in the body, so the idea that EGCG might selectively affect the activity of sirtuin-3 in cancer cells—to turn it off—and in normal cells—to turn it on—is probably applicable in multiple kinds of cancers."

If tests in animals and humans are successful, the discovery could lead to anti-cancer treatments that are as effective as current treatments without the harmful side effects on healthy cells.

—MATT SWAYNE

A BOULDER THAT COULD STOP A TRUCK

Boulders can be effective barriers to protect embassies and other buildings from large-vehicle impacts, and a simple model may be sufficient to select the right size boulder for the job.

A team led by **Tong Qiu**, assistant professor of civil engineering at Penn State, studied landscape anti-ram barrier systems, typically constructed of a boulder embedded in soil.

The team constructed a model incorporating truck, boulder, and soil. The research sponsor, the U.S. Department of State, "wanted a quick assessment tool to be able to size a boulder for embassy protection," says Qiu. "You use this to come up with a rough estimate."

The researchers performed a full-scale field test at Penn State's Larson Transportation Institute, using trucks weighing about 15,000 pounds and traveling about 30 miles per hour to crash into two boulders — one American black granite, weighing over five tons, and one Rockville white granite, weighing over 25 tons. The team recorded the crashes with high-speed cameras, then used image analysis to study the impact, including boulder displacement.

The larger boulder moved only slightly and successfully stopped the truck, as the model predicted. The smaller boulder dislodged from the soil when struck. The team concluded that as long as a boulder does not rotate too much due to vehicle impact, their model can accurately predict an appropriate boulder size for a barrier. Indeed, the model has already been deployed at an embassy overseas.

—LAUREN MILIDEO


Alexander Allen Brown, The Larson Institute

Kim Traynor

Picts Provide Glimpse of Non-Roman Britain

History has never been too kind to a group of early British Isle inhabitants referred to as the Picts, but the often mischaracterized, always mysterious people may serve as a historical laboratory to explore how the island's culture might have developed without Roman intervention, according to Penn State historian **Benjamin Hudson** in his book, *The Picts* (Wiley Blackwell, 2014).

Although the Picts' legacy stretches back centuries before the first encounter with Rome, the group enters the historical record as Roman forces begin to push their empire's frontiers into northern England, says Hudson, professor of history and medieval studies.

"The big myth is that the Picts were somehow different from the native Britons," he says. "They weren't different — they were merely Britons that the Romans didn't conquer."

Roman historians portrayed the Picts as warriors and savages. More recent historians may have created an image of the Picts as helpless victims of progress and warfare. The truth, according to Hudson, is probably much more nuanced.

As much as they are known for their body art, the Picts are also known for the variety and quantity of their sculpture and artwork, a legacy that belies their early reputation as barbarians.

The Scots, who invaded the territory controlled by the Picts in the mid-ninth century A.D., eventually absorbed the once-fierce people into their own culture.

"The Picts didn't go out with so much of a bang as they went out with a whimper," says Hudson.

—MATT SWAYNE

SEEING IS NOT REMEMBERING ‹‹

What we remember about an experience may depend on what we think we'll be asked to remember, according to Penn State psychologists.

"In some cases, people have trouble remembering even very simple pieces of information when they do not expect to have to remember them," says **Brad Wyble**, assistant professor of psychology.

He and **Hui Chen**, postdoctoral fellow in psychology, tested the memories of 100 undergraduate students. Participants were shown four characters on a screen, arranged in a square — for example, three numbers and one letter. After the characters disappeared from the screen, the participants were asked which corner the letter had been in. They rarely made an error on this simple task.

After doing the test several times, participants were shown a screen that displayed four different letters and were asked which letter had been in the corner on the previous test. This time only 25 percent of participants gave the correct answer — no more than if they had simply guessed, indicating that a person may use a piece of information to perform a task ("where was the letter?") but be unable to recall what that information was ("what letter was it?") as little as one second later.

Chen and Wyble found similar results when they tested for the ability to recall a number rather than a letter or the color of the character in the corner. They coined the term "attribute amnesia" to describe the phenomenon.

When the researchers asked the same follow-up question on subsequent trials, participants did dramatically better, probably because they had faced the question before and were primed to remember that information.

"It seems like memory is sort of like a camcorder," says Wyble. "If you don't hit the 'record' button, it's not going to 'remember' what the lens is pointed at. But if you do hit the 'record' button — in this case, you know what you're going to be asked to remember — then the information is stored."

—VICTORIA M. INDIVERO

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Cocoa bean pods from a chocolate (cacao) tree

Mmmm! Researchers Find Gene that Controls Melting Point of Cocoa Butter

Researchers in Penn State's College of Agricultural Sciences have discovered a gene involved in determining the melting point of cocoa butter, a critical attribute of the substance widely used in foods and pharmaceuticals.

"The 'snap' and 'melt' of chocolate are two very important textural features that determine the appeal of chocolate to consumers, and having new varieties of the cocoa plant that produce butter with different melting points would be a valuable resource to control those characteristics," says **Mark Guiltinan**, professor of plant molecular biology. "Medical applications could include production of drug-delivery products with slower release of drugs than is possible with current cocoa-butter-based systems."

In a previous study, Guiltinan's laboratory identified a gene family, stearoyl-acyl carrier protein desaturase (SAD), that is involved in production of the lipids that make up cocoa butter. The new research examined activity of the SAD gene family in various tissues of the plant. It revealed that a single gene, TcSAD1, is responsible for the melting point of cocoa butter.

In addition to contributing to new confectionary and cosmetic products, the finding could lead to new varieties of the cocoa plant that could extend the climate and soil-nutrient range for the crop and increase the value of its yield.

—JEFF MULHOLLEM

More Power to You

Ultra-high-efficiency solar cells similar to those used in space may now be possible on your rooftop, thanks to new microscale solar concentration technology developed by an international team of researchers.

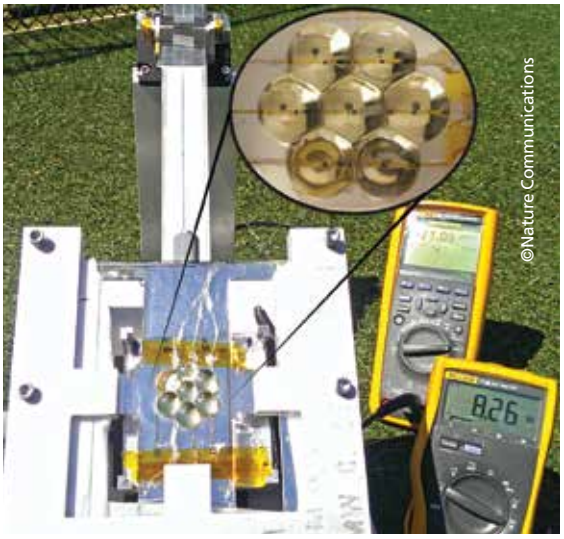
"Concentrating photovoltaic [CPV] systems leverage the cost of high-efficiency multi-junction solar cells by using inexpensive optics to concentrate sunlight onto them," says **Noel Giebink**, assistant professor of electrical engineering at Penn State.

The researchers reduced the size, weight, and cost of the system by combining miniaturized gallium arsenide photovoltaic cells with 3D-printed plastic lenslets and a moveable focusing mechanism.

The researchers embedded the cells between arrays of plastic lenslets. Each lenslet in the top array acts like a magnifying glass and is matched to a lenslet in the bottom array that functions like a concave mirror. With each tiny solar cell located in the focus of this duo, the sunlight striking it is intensified more than 200 times. The sheet bearing the solar cells tracks the sun over the course of a day by sliding sideways between the lenslet arrays.

"The vision is that such a microtracking CPV panel could be placed on a roof in the same space as a traditional solar panel and generate a lot more power," says Giebink. "The simplicity of this solution is really what gives it practical value."

—A'NDREA ELYSE MESSER



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Prototype of new solar panel during an outdoor test. In the close-up, the small black dots under each lenslet are the solar cells.

A caravan moves across the Lee Adoyta region in the Ledi-Geraru project area near the early ***Homo*** site.

Erin DiMaggio

Precise Dating Pushes Age of Earliest Known Hominin Fossil to 2.8 Million Years

A lower jaw with teeth that was recently found in the Afar region of Ethiopia has been dated to between 2.8 and 2.75 million years ago, making it the earliest known fossil of the genus *Homo*.

Erin DiMaggio, research associate in the department of geosciences, Penn State, and lead author on the study, says the international team of geoscientists and anthropologists dated many other fossils in the vicinity to help reconstruct the environment in which the hominin individual lived. Hominins are the group of primates that includes humans—*Homo sapiens*—and their ancestors after the human evolutionary line split from the line that evolved into chimpanzees.

Directly dating fossils that old is impossible, so the researchers used a variety of methods, including argon-40/argon-39 radiometric dating of volcanic ash above and below the fossils, to establish the oldest and youngest dates when the animals that became the fossils could have lived.

Other fossils found in this area and dating within 2.84 to 2.54 million years ago included those of prehistoric antelope, elephants, hippopotamus, crocodiles, and fish. This assemblage of fossils suggests that the area was likely similar to present-day African locations like the Serengeti Plains or the Kalahari—an open habitat of mixed grasslands and shrublands with trees lining rivers or wetlands.

—A'NDREA ELYSE MESSER

TRACING THE ORIGINS OF THE HUMAN NERVOUS SYSTEM

A BURST OF EVOLUTIONARY INNOVATION IN the genes responsible for electrical communication among nerve cells occurred over 600 million years ago in a common ancestor of humans and the sea anemone, according to research led by **Timothy Jegla**, assistant professor of biology at Penn State.

The new research focuses on the genes that encode ion-channel proteins that allow potassium to flow out of nerve cells, stopping the cell's electrical impulses. "It appears that animals such as sea anemones and jellyfish are using the same channels that shape electrical signals in our brains in essentially the same way," says Jegla. "Humans and sea anemones went their separate ways evolutionarily speaking roughly 600 million years ago, so we know that the mechanisms we use to generate impulses in our neurons must be at least that old."

The team then tried to trace these channels back even further in evolutionary time —to the very origins of the nervous system in an ancient group of animals called comb jellies. "Most of the channel types found in humans were missing," says Jegla. The implication is that many of the mechanisms that control electrical impulses in human neurons were not present in the earliest nervous systems.

The researchers are now interested in figuring out what drove the burst of innovation in ion channels in our common ancestor with sea anemones. "Our current favorite hypothesis is that neurons capable of directional signaling might have evolved at this time," says Jegla. In humans, most nerve cells have separate regions for incoming and outgoing signals. This allows for directional information flow and highly complex circuits, but it requires a huge diversity of ion channels to shape the electrical signals as they pass through the nerve cells.

"If our hypothesis turns out to be correct, we may be able to gain some important insights into how nerve cells and circuits evolved by studying sea anemones," says Jegla.

—SAM SHOLTIS

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National Park Service

Group Living Helps Wolves Survive Chronic Illness

Gray wolves in Yellowstone National Park have given researchers the first evidence from wild mammals that living in a group can reduce the impacts of a chronic disease.

The research shows that living in a group can help individuals with mange survive longer than they would if they lived alone.

"Social living might help individuals cope with a variety of other chronic conditions — including other infections, physical injuries, or noninfectious diseases — for which having access to supportive care and resources can make a big difference for survival," says **Emily Almberg**, research scientist at Penn State and the lead author of the study.

The researchers found that lone wolves infected with mange died at a rate five times higher than uninfected wolves living alone, but that wolves with mange that were living in a pack with at least five healthy members died at the same rate as their uninfected companions. The researchers think infected pack members benefit from group efforts to acquire food and defend their territory.

In this study, wolves in a pack with an infected member did not have a higher risk of becoming infected themselves. But, Almberg says, in some situations and some species, social living does bring an increased risk of disease transmission.

"What we've under-appreciated in the past are the ways in which social species might compensate for this increased disease risk," she said.

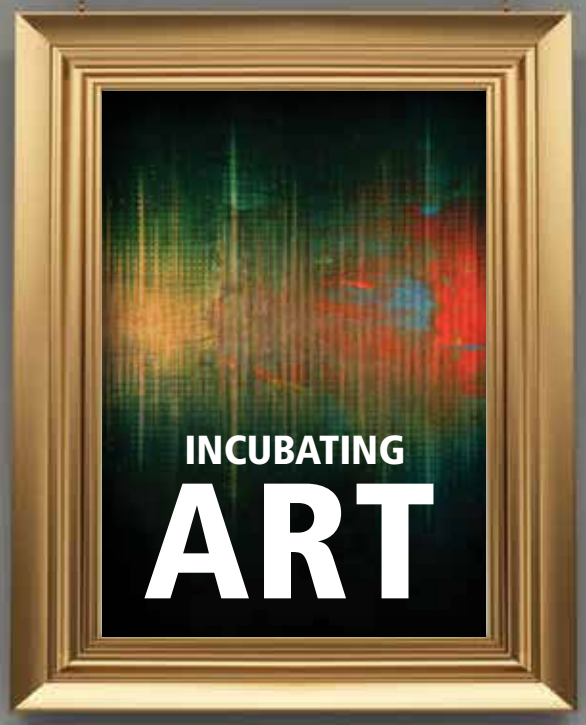
—BARBARA K. KENNEDY

DIG THAT CLAM ‹‹

THE MANTLE OF A GIANT CLAM *(Hippopus hippopus)* glimmers in the waters off Palau. The soft tissue of the mantle extends past the shell margin to intercept water and sunlight in the gentle currents along the reef. Water flows in through the blue slit at the far left and passes over the clam's gills, which filter plankton and extract oxygen from it before sending the water back out through the large hole at right. The clam also gains nourishment from photosynthetic algae that live inside it. Penn State biologist Todd LaJeunesse recently identified a new species of these symbiotic algae, which he and colleagues named *Symbiodinium tridacnidorum*.

—SARA LAJEUNESSE

Photo by: Todd C. LaJeunesse



INCUBATING ART

BY CHERIE WINNER

SONIFICATION

Mark Ballora, associate professor of music technology, collaborates with scientists to convert complex data into sounds, to reveal patterns that otherwise would be hard to detect. Among others, he worked with ecologist Michael Sheriff to "score" the body temperature and hibernation patterns of Arctic ground squirrels. Image courtesy of Mark Ballora.

PENN STATE HAS A NEW INCUBATOR. IT'S NOT for business start-ups or tech transfer ventures. It's for artists.

The Arts and Design Research Incubator, or ADRI, was established in 2014 to support projects within the College of Arts and Architecture, with an eye toward launching them onto a bigger stage.

"The idea is to embed projects for about two years and get them into the river of larger funding," says **Andy Belser,** professor of theatre and director of ADRI. "We're not the place to have projects that just sit down within Penn State and stay here. This is really looking out into the world. Getting pieces *out* is the idea."

The first four embedded projects, now wrapping up, have already produced several installation works and public presentations and a play that has been performed (to good reviews) in New York.

The ADRI provides space in which to work, promotion for performances and exhibitions, and modest funding for equipment and travel.

"Seed money is a huge problem in the arts," says Belser. A grant of $10,000, which would barely get a science project off the ground, can make all the difference in the world to a project in the arts.

"We're a step along the way," he says. "A really important step."

HATCHING A PLAN

The incubator grew out of discussions between Belser and **Andrew Schulz**, associate dean for research in the College of Arts and Architecture, who both arrived at Penn State in the fall of 2013 eager to find new ways to encourage research in the college. They looked closely at interdisciplinary labs at Harvard, Stanford, and MIT that bring artists together with thinkers and creators in a wide range of other fields.

FACE.AGE

Andy Belser's *Face.Age* is a multimedia installation created from filmed encounters in which young (18-22) and older (70+) people examined and touched each other's faces. Moving and still images allow a closer study of faces than is afforded in social settings. Image courtesy of Andy Belser.

EMBODIED MIND, DAMAGED BRAIN

Bill Doan, professor of theatre, delved into the nature of consciousness while writing a play about coming to grips with his sister's ultimately fatal brain injury. [Read more about Doan's experience in A Blow to the Head, page 20.] Image courtesy of Bill Doan.

STORYWALKS

Kimberly Powell, assistant professor of education and arts education, works with GIS tracking, video, and walking interviews with residents of the Japantown neighborhood in San Jose, California, to explore place-based narratives and how walking itself produces memories, civic identity, and stories.

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They made a deliberate decision to call the program here an incubator, says Belser. "We want this notion of, 'here's a project in its infancy, and here's what we do to encourage its growth.' The idea is that eventually, Penn State gets known for being a place where really creative interdisciplinary work is happening."

They also wanted the ADRI to challenge conventional views of what constitutes "research."

"We consider *all* the creative inquiry we do to be part of the research enterprise," says Schulz. "In my view, 'research' is fundamentally about the creation of new knowledge. Whether that means analyzing DNA in a laboratory or interpreting a 300-year-old cello concerto, you're creating new knowledge. It's a new way of understanding and thinking about the world."

The incubator strongly encourages projects that involve both art and science—but not in the way those two realms are usually combined.

"Often when artists or designers or musicians are drawn into interdisciplinary projects, it's at the end of a science project," says Schulz. "Scientists come to artists and say, 'You can help us disseminate this work or translate it for the general public.' The proposition we are testing is: What does it mean to bring artists and designers in at a much earlier stage, or even have them drive the process?"

CROSSING BOUNDARIES

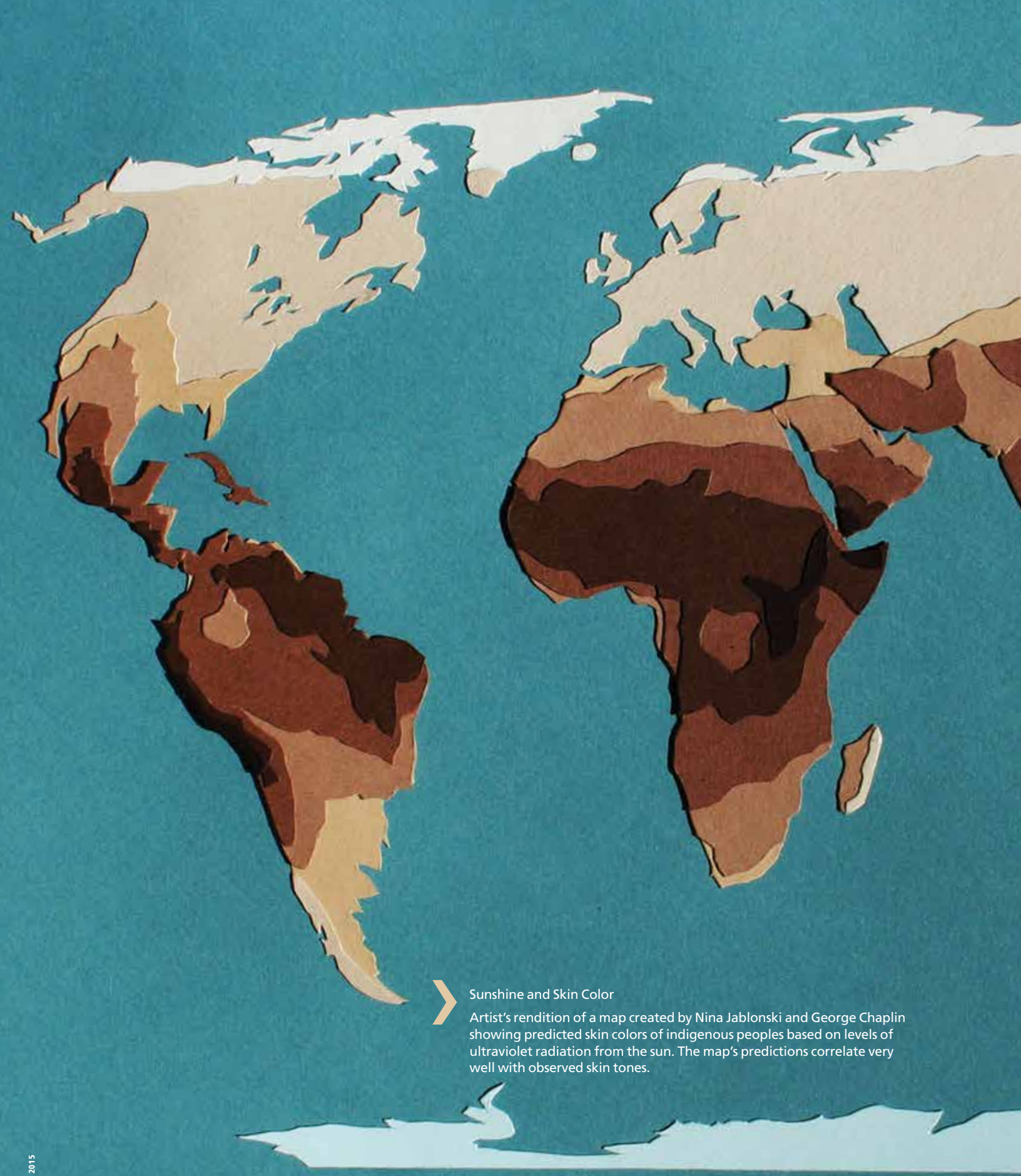
That approach is apparent in the program's first four embedded projects, which include combinations such as music with ecology, and theatre with neuroscience [see photos].

Traditionally, the various forms of inquiry have been handled in separate disciplines, with little interaction among them.

"We tend to put them in boxes," says Schulz. "You have 'research,' and that means the scientific enterprise. You have 'scholarship,' and that's history or what somebody does in a library or archive. There's 'creative inquiry,' which is the arts, and then there's 'innovation,' which usually means tech-transfer and bringing ideas to market.

"But I think it's more interesting if you get away from those boxes, because that's when the artist and the scientist realize that there's enough overlap to start to talk about what common questions they have. That's when the conversations can begin."

The ADRI was launched with financial support from the College of Arts and Architecture. The second round of ADRI applications will be announced this fall, with funding to begin in January 2016. To learn more about the program and its upcoming events, contact Andy Belser at ***awb15@psu.edu*** *and visit the ADRI website at* ***http://bit.ly/1Jvw1Do****.*



Sunshine and Skin Color

Artist's rendition of a map created by Nina Jablonski and George Chaplin showing predicted skin colors of indigenous peoples based on levels of ultraviolet radiation from the sun. The map's predictions correlate very well with observed skin tones.

CUT-PAPER ILLUSTRATIONS BY GAIL MCCORMICK

THE SEPIA RAINBOW

ANTHROPOLOGIST NINA JABLONSKI HAS SPENT TWO DECADES EXPLORING—AND SHARING—THE FASCINATING STORY OF HUMAN SKIN.

BY DAVID PACCHIOLI

Nina Jablonski's focus on skin began with a request to give a lecture. It was 1991, and she and her husband and collaborator George Chaplin had recently moved from Hong Kong to take positions at the University of Western Australia.

Jablonski, a primatologist and paleobiologist, was known at the time for her work on Old World monkeys. For this occasion, however, she'd talk about something else, one of the long-standing problems in anthropology: the evolution of human skin and skin color. As she dug in to prepare, she noticed a sizeable gap in the literature. Very little work had been done on skin color since the early 1970s, and most of what she did find was either outdated or just plain wrong.

Since that day, she says, "What started as an innocent, small project has grown into a sort of fractal universe, spinning out in all directions." Jablonski has authored dozens of papers, scores of talks, and two popular books on the subject of human skin. She has dived enthusiastically into public education, with frequent appearances on NPR and PBS and one memorable spot on the late, lamented *Colbert Report*. A TED talk she gave has garnered, at last count, over three-quarters of a million views.

Her curiosity has carried her from the natural history of skin to an exploration of its implications for human health. More recently she has been drawn to reflect on the societal implications of skin color. Since arriving at Penn State in 2006, Jablonski, now Evan Pugh Professor of Anthropology, has devoted much of her considerable energy to understanding the basis, and ramifications, of color-based racism.

The trail has led her into territory where not many academics are tempted to tread. But to her it feels like a natural, and necessary, extension. "I realized I couldn't keep talking about just the evolutionary and health aspects of skin color," she says, "when so much of it has to do with the way people treat one another."

FROM DARK TO LIGHT

One day in 1981, while teaching gross anatomy to a group of medical students at the University of Hong Kong, Jablonski was struck by an insight that has stayed with her.

As she told a New York Times reporter years later, the students had been presented with a cadaver to dissect, and they were squeamish about the task. But their attitude changed as soon as they managed to cut through the skin. Suddenly, what had seemed dauntingly human was merely a body to examine. "That moment," Jablonski said, "showed me how much of what we consider our humanity is imbued in our skin."

At the time, the evolution of skin color was regarded by many of her peers as an intractable problem. Theory held that darker skin had evolved to afford early humans—who had recently lost the cover of fur—a protection against skin cancer under the tropical sun. But skin cancers, Jablonski knew, almost always arise later in life, when an individual is past reproductive age. Blocking their occurrence would offer little or no evolutionary advantage.

NINA JABLONSKI

> ***"WE ARE IN THE MIDDLE OF A HUGE NEW EXPERIMENT IN HUMAN EVOLUTION."***

Her preparation for that lecture in Australia hinted at a different scenario. In a 1978 paper by two American medical researchers, Jablonski found evidence linking exposure to strong sunlight with low levels of folate, an essential B vitamin, in the blood. Other research tied folate deficiency in pregnant women to various birth defects. In men, she learned, folate is vital for sperm production.

These and other observations gradually led her and Chaplin toward a new hypothesis: that humans evolved the ability to produce melanin, the dark-brown pigment that acts as a natural sunscreen, as a way of safeguarding the body's store of folate.

At the outset, then, living near the equator, all humans would have had dark skin. But that's only half the riddle. Why and how did lightly pigmented skin come about? The answer, Jablonski reasoned, involves another key vitamin—and the history of human migration.

As she explains, the sun's ultraviolet rays, in addition to causing cell damage and other forms of harm, play a vital role in human health: They trigger the production of vitamin D in the skin. Vitamin D, as most of us learned in elementary school, is critical for strong bones and healthy teeth. More recent studies show its value in immune function and for fighting off certain cancers and even heart disease.

In tropical climes, enough UV penetrates even dark skin to provide an adequate dose of vitamin D. However, as our forebears began to migrate, wandering far from the equatorial sun, not enough UV could make its way through the protective melanin. At higher latitudes, particularly in winter, vitamin D levels dropped, to the point where health was compromised. Dark skin became a disadvantage. The evolutionary response, Jablonski says, was loss of pigmentation. Individuals with less melanin in their skin had a better chance of surviving where there was not as much sunlight available.

In the late 1990s, Jablonski and Chaplin found support for this idea in a set of NASA satellite data, which provided a precise record of surface-level UV radiation at every point on the globe. When they compared these data with geographical records of skin color variation, they found an overwhelming degree of correlation. Skin color was darkest where surface UV was strongest, the overlay clearly showed, and lightest where surface UV was weak.

After ten years of digging, the two had arrived at what amounts to the first comprehensive theory of human skin color. What Jablonski calls "this beautiful sepia rainbow" evolved as a response to human migration, local UV regimes, and the body's need for vitamin D.

SKIN COLOR AND HEALTH

With the modern age, of course, the pace of human migration has accelerated tremendously. Humans roam the globe as they will. The majority of them now live indoors, and in cities. "We are in the middle of a huge new experiment in human evolution," says Jablonski.

The abruptness of change creates what she calls "mismatches" between skin color and environment: Think of fair-skinned people moving from England to Australia, for example, or dark-skinned people of African descent dwelling in Canada or Scandinavia. The upshot of these discrepancies, Jablonski says, has been a rise in health problems.

Some of these problems, like skin cancer, are relatively easy to spot and solve with protective measures. Others are more insidious. For dark-skinned people living in areas of high latitude—and spending more and more time indoors—vitamin D deficiency poses a stealthy but growing threat. "We are just beginning to explore the broader health implications," Jablonski says. For her, the perfect laboratory for this exploration is South Africa.

"This is a country that has been a melting pot of humanity not just for a few decades but for thousands of years," Jablonski explains. "It has this deep, complex history, a very heterogeneous population—and a fascinating climate. The southern part is strongly seasonal, with a pronounced winter and a pronounced summer." Last but not least, South Africa is a country that for decades has experienced a high prevalence of deadly infectious diseases, including HIV, AIDS, and tuberculosis.

In a study recently concluded on the outskirts of Cape Town, Jablonski was able to show how these several factors may be intertwined. She and her colleagues tested healthy young individuals of the Xhosa and Cape Mixed ethnic groups, both of whom have darker skin than the area's indigenous Khoisan people. The darker skin, she suggests, is an indication of recent migration into the region—and a mismatch with local levels of UV radiation.

As expected, the researchers found that their Xhosa and Cape Mixed subjects exhibited vitamin-D deficiency in winter, when UV levels are lowest and people spend most

Cut-paper illustrations by Gail McCormick, from photos by Patrick Mansell.

of their time indoors. Then, when the team exposed both winter and summer blood samples from the two groups to cultures of HIV, they found that the cells in the vitamin D-deficient winter samples were significantly more likely to get infected. Administering high-dose vitamin-D supplements before the samples were taken reversed these effects.

To her, the study points to a clear progression from UV-pigmentation mismatch, to vitamin D deficiency, to serious immune-system compromise. "But what's most exciting," she says, "is that we might have here the basis for a public health mediation in the form of seasonal vitamin D supplementation for at-risk groups."

EVOLUTION AND PREJUDICE

After publication of her first book on the subject, *Skin: A Natural History*, in 2006, Jablonski began to lecture frequently about the evolution of skin color. She found her audiences eager to hear more about how that story fit with our society's concept of race, if it fit in at all. It's a topic many anthropologists shy away from, but Jablonski realized that her vantage point could be uniquely valuable.

"I am talking about humans from the perspective of deep evolutionary time," she says. "There are certain things that we can look at—patterns of pigmentation, distribution of fossils and of populations of ancient humans—that are pretty much beyond question. By looking at them, we can begin to understand how humans came to be as diverse in appearance as they are today. Then, having understood the mechanisms, we can look at what's happened in the more recent past."

One of the most important findings from recent genetic work, she says, is that the same skin colors have evolved multiple times in human history. In South America and Polynesia and the Mediterranean, for example, people have evolved highly tannable skin, and they've done so independently, in each instance involving different genes. Similarly, lightly pigmented, or what Jablonski calls de-pigmented, skin has evolved not just once or twice, but probably at least three times. "For an evolutionary biologist, any time you find evidence of this kind of convergent evolution it's very exciting," she says. "The same mechanisms are operating in a repeatable and predictable fashion. You may have two people of identical skin color whose pigmentation genes are very different."

Other studies have shown that the genes that determine pigmentation are different from those that code for things like facial features. "That means there's no such thing as a racial complex of color, hair, eyes, nose shape, or whatever," Jablonski says. "These things travel independently of one another in human evolution."

Biologically, in fact, there is no such thing as race at all. Which is not to say, she hastens to add, that race isn't a real and enduring force in people's lives—a matter, too often literally, of life and death. What's left to understand, she argues, is the social construct. And for Jablonski, the initial question to be answered was how that construct arose in the first place. Her 2012 book, *Living Color*, documents her exploration.

Jablonski traces the class meaning of skin color in traditional agrarian societies, where light skin was the privilege of those not forced to work in the sun. She recounts the first meetings between European explorers and the native peoples they encountered—the astonishment at seeing human beings who looked so different, which soon gave way to disapproval and condemnation of the Other. "The negativity of the explorers' written accounts had a disproportionate effect on how Europeans framed their ideas of dark-pigmented people," she says.

More disturbing, in her eyes, is the history of scientific racism. By the mid-18th century philosophers like Immanuel Kant were pondering the origins of human diversity. "Kant defined four races and grouped them hierarchically, with the European race at the top," Jablonski says. "His ideas have no basis in experimental observation—they reflect his own, emotionally-based agenda." But Kant's prominence gave his writings extraordinary influence on other Enlightenment thinkers, some of whom in turn reinterpreted Biblical allusions regarding light and dark in order to justify their views.

"So you have this whole set of cultural memes that begin to take on a life of their own," Jablonski says. "Not coincidentally, these were really crystallized at the height of the transatlantic slave trade. What you have is a nexus of unfavorable forces that promoted the rigid definition and hierarchical installment of races based on imperfect and emotionally based data and commercial gain."

DE-INSTALLING RACE

Jablonski calls the historical linking of skin color with character "humanity's greatest intellectual fallacy."

BIOLOGICALLY, IN FACT, THERE IS NO SUCH THING AS RACE AT ALL.

George Chaplin and Nina Jablonski

Courtesy of Nina Jablonski

Cut-paper illustration by Gail McCormick, from photo by Patrick Mansell.

The question now, she says, is "How can we retrieve this? How do we begin the long-term process of de-installing race from our national and, indeed, global consciousness?"

The answer, she firmly believes, is to make race education prominent in the classroom. In a recent interview on NPR she talked about introducing discussions of race into primary schools—not bogging down in details of evolutionary biology, but teaching the basics of how human diversity came about, and how people have thought about race through the centuries.

"It needs to be part of the educational landscape," she says. "And it has to begin early. Often by the time we talk about these things, when kids come to college, the horse is out of the barn. We're trying to reverse years of prejudice. We need to try to prevent many of these misconceptions and racial biases from being installed in the first place."

She is currently working with historian and filmmaker Henry Louis Gates Jr. to develop a national curriculum focused on human diversity, with the dual purpose of getting kids thinking about race and sparking their interest in science. The three-year program recently received funding from the Robert Wood Johnson Foundation, and will be piloted in summer camps including Penn State's popular "Science U."

In South Africa, where she has worked for over a decade, Jablonski is collaborating with a writer and an illustrator to produce a graphic novel on the evolution of skin color. The target audience is middle-school students. She has already landed a South African publisher, and hopes eventually to bring out an edition in the U.S.

Jablonski has also convened the "Effects of Race" initiative, bringing together an international cast of scholars and artists at Stellenbosch Institute for Advanced Study in Stellenbosch, near Cape Town, to look for fresh insights into issues of race. One current project hopes to inform the South African government's efforts to update its categories for the classification of its people, which persist from the apartheid era.

Back home, she is proud to be talking and working with colleagues across Penn State. "With Paul Taylor and Robert Berlusconi in philosophy, Sam Richards in sociology, Gary King in biobehavioral health—among others—we have quietly built up a group of really influential scholars here who are working on complementary projects, coming from different perspectives to look at racial inequality, how it came about, and what can be done to change it. They are also expert public communicators."

Jablonski herself feels a strong responsibility to continue with her busy public schedule. "The buck has been passed on this topic for generations," she says. "I think everyone who has the ability to speak outside the academy should do so.

"I'm under no illusions," she quickly adds. "It's taken us over two hundred years to get into this mess, and it's going to take us a long time to get out of it. But we have to start. This has to be a national priority. If we don't begin to grasp this nettle now, I'm afraid we're doomed."

AS THE PLANET WARMS AND SEA LEVELS RISE, HOW WILL COASTAL TOWNS ADAPT?
THE FIRST STEP IS ACCEPTING THAT DISASTERS REALLY CAN HAPPEN HERE.

DELUGE

BY CHERIE WINNER

Inch by inch, the sea is moving up the beach, and storms are coming.

We've seen the images of disappearing glaciers and morose polar bears on their shrinking floes. Climate change is melting the world's ice, and sea levels are on the rise. Homes, businesses, roads, power lines, anything close to the shore will be in danger.

Those who live near a coast know this. If they've lived there long enough, they can see it out their own windows.

The sea is moving up the beach, and storms are coming.

But a funny thing happens on the way to the future. Most people don't think the catastrophes will happen to them.

Aftermath of Hurricane Sandy storm surge. iStockphoto.

"IT'S CALLED OPTIMISM BIAS," says Penn State geographer **Brent Yarnal**. "People tend to be very optimistic about the familiar."

This is not a matter of doubting climate change or the predictions of rising seas. Research in his lab has shown that even people who are very concerned about climate change tend to be more worried about faraway places like low-lying island nations than about their own back yards.

"It's 'We'll be fine, things aren't going to be as bad here, and if we do have problems, we'll be able to handle it. But those poor people over there…' "

While that empathy is admirable, Yarnal says, "it also means that people are usually less willing to take action to adapt in their home area."

For the past several years, Yarnal and his students have been investigating how people in Sarasota County, on Florida's Gulf Coast, perceive the climate-related risks facing them.

"Florida is Ground Zero," he says. "Sea-level rise is going to affect Florida the most, of any place in the nation. It could become a huge problem. It really could overwhelm our financial capabilities as a nation."

He's less concerned with the rising sea level itself, which communities can adjust to over decades, than with the possibility of massive hurricane-driven storm surges that could wipe out whole neighborhoods within a few hours.

"The extreme events are what really kill people, destroy infrastructure, and are the bigger danger," he says. "That's what I worry about."

Brent Yarnal

Storm surge, the inland push of water from the sea, is especially destructive when a storm's landfall coincides with high tide. Based on wind speed, Hurricane Sandy was just a Category 1 storm when it hit the Northeast coast in October 2012, but because of the distance it traveled over the ocean (where it generated huge waves) and the fact that it struck at high tide, it produced a storm surge 13 feet high. The surge killed 117 people and caused an estimated $65 billion damage to property.

Sarasota's own storm history plays into residents' optimism bias, says Yarnal. The last time the area suffered a direct hit from a major storm was in 1944, when the Category 3 Pinar del Río hurricane killed nine. A comparable storm today would likely inflict many more casualties: The population of the county has grown from about 19,000 then to about 400,000 today, largely through immigration of retirees from points north.

"The majority of those people are elderly," says Yarnal. "They're becoming less able, mentally and physically, to deal with emergency situations. And probably more important, most of them don't have any experience with hurricanes."

He and his students are working on ways to improve residents' perception of their risk, so the community can better prepare for major storms. They've developed interactive maps that let people see how far inland the normal tides will come with varying amounts of sea-level rise, and how far into town a storm surge will travel and how deep it will be with storms of varying strength. One scenario, with the near-4-foot rise in sea level possible for the area by the end of the century, showed that storm surges will cause about a full category more damage than they do now. That is, a Category 2 hurricane will deliver what today is a Category 3-level storm surge, and on up the scale.

Yarnal and his group have met with community leaders, businesspeople, and residents to discuss the maps. A few years earlier, in an effort to prevent urban sprawl, city planners had set a "growth boundary" that calls for almost all businesses and major infrastructure to stay within a few miles of the coast. The maps show that their boundary closely coincides with the predicted surge zone.

"That was a real game-changer," Yarnal says. "The local economy, the local tax base, access to hospitals, potable water, all of those things are tremendously at risk—and the risk is growing over time. It really made them think about changing their 2050 plan."

They've made one change already—they've revised the plans for a new lift station, which moves sewage to a treatment plant, to ensure it will still function in the event of a big storm surge. That's promising, says Yarnal, who has a house in Sarasota himself. He and his wife plan to retire there, and his daughter and grandkids have already moved to Florida.

Yarnal, upbeat and optimistic by nature, is realistic about the risks of living in a place where disaster is just one big storm away. Climate models can't tell us yet whether Atlantic hurricanes will become more frequent, but we do know they will probably become more intense.

"We might have fewer hurricanes," he says, "but they might all be Hurricane Andrews."

Andrew hit south Florida in August 1992, destroying 63,000 homes and 70,000 acres of Everglades trees. Yet it was not a bad year for hurricanes: There were only six tropical storms in the Atlantic that year, and only two of those were prominent enough to be named.

"There were only two," says Yarnal. "One was Andrew, Category 5, and it hit our mainland.

"You only need one Andrew in a season to ruin your whole day."

How long does a concussion patient need to sit out before it's safe to go back into the game?

A BLOW TO THE HEAD

BY SARA LAJEUNESSE

LACING UP HER HIGH TOPS ONE BLUSTERY MORNING IN FEBRUARY 2009, KRISTA KREBS HAD NO IDEA HER career as a high-school athlete would be over precisely 45 minutes later. "It wasn't the way I imagined senior year to end," she says.

The moment occurred when she was chasing down a basketball during a routine scrimmage. As she bent low to grab the ball, a racing teammate arrived at the spot at the same time. The teammate's shoe slammed into Krebs's left temple. The blow left Krebs with a concussion from which she has still not recovered, even after pursuing a variety of treatments. Six years later, Krebs continues to suffer from a constant headache and from episodes—which include slurred speech, slumping over, trouble walking, and muscle weakness—when she works too hard.

ILLUSTRATION COURTESY OF WILLIAM DOAN

A second concussion within days of the first can cause collapse and even death.

A SILENT EPIDEMIC

According to the Centers for Disease Control and Prevention, in the United States an estimated 1.7 million people suffer a concussion, or traumatic brain injury, each year. Most recover fully, but some suffer side effects for the rest of their lives. Although the media tend to focus on sports-related concussions, these account for only about 15 percent of the total. Falls, especially by children and older adults, account for far more—40 percent, or about 680,000 concussions per year. Other causes include unintentional blunt trauma to the head (15 percent), motor vehicle crashes (14 percent), and assaults (10 percent).

With concussions so common, it's surprising to learn that scientists and medical professionals don't know much about them. According to **Dr. Wayne Sebastianelli**, Kalenak Professor and medical director of orthopaedic surgery at University Park, there isn't even a satisfactory definition for the term. "We do know that concussions involve a disconnect between the brain's processing of information and the energy that's required to do that processing," he says. "So if one part of the brain is injured, all the surrounding areas have to work harder to try to get normal information processed, but to do that, they require more energy, which takes away energy that's needed for the injured part to heal. It creates a negative cycle."

Semyon Slobounov, professor of kinesiology at Penn State, adds that the severity of a concussion is difficult to diagnose because symptoms—which can include headaches, dizziness, nausea, difficulty concentrating, difficulty balancing, light sensitivity, seizures, depression, and personality changes—can vary widely by individual and by the location and severity of the injury.

This lack of understanding about the biology of concussions means that no good treatments exist. The prescription is usually rest and relaxation to give the brain a chance to recover. "In the past, people often blew off concussions as badges of honor and went right back into the game," says Sebastianelli. "But we now know that the effects of a concussion can become worse if the brain isn't given adequate time to recover."

Worse indeed. In fact, a second concussion within days of the first can cause cerebral edema and herniation, leading to collapse and even death. So how long does a patient need to sit out before it's safe to go back into the game? Determining that, according to Slobounov, is one of the goals of his and his colleagues' research in Penn State's Center for Sport Concussion Research and Service in the College of Health and Human Development.

BASELINE TESTING

Try this: Stand up and put one foot directly in front of the other, heel to toe. Now imagine maintaining that stance while the room around you rocks, dips, and sways. "It's not as easy as it seems to stay balanced," says research technologist **Katie Finelli**.

Finelli is responsible for administering this balance test to patients before and after they become injured. The test is set in a virtual-reality environment viewable by looking through 3D glasses at the image of a room projected onto a screen. She also administers a virtual-reality memory test in which a computer directs patients through a series of 3D hallways and rooms on the screen. The patient must pay close attention and then repeat the route using a joystick navigation device. Finally, Finelli oversees a reaction test in which patients must move their bodies in specific ways in response to the movement of a 3D room projected onto the screen. "We place an accelerometer on the patient's head so we can track his or her head movements," she says. "For balance, we monitor displacement from the patient's starting point, and using that raw data we score him or her, with 10 being wonderful and zero being can't stand up."

The virtual-reality tests were developed by HeadRehab LLC, a Chicago-based company that sponsors laboratory and clinical research into head trauma. The Penn State research team pioneered their use in a program that aims to get a better handle on the symptoms being experienced by an athlete with a concussion and to enable doctors to provide proper treatment. A concussed soccer player may appear to be fine after a week of rest, but if the tests reveal that his ability to balance still lags behind his pre-concussion ability, he should rest a while longer.

(Top) Research technologist Katie Finelli administers a balance test to a young athlete prior to hockey season. (Bottom) Finelli monitors his performance as the athlete uses a remote control device to navigate through a virtual scene that tilts and sways. The harness is a safety measure to prevent falls. Photos by Patrick Mansell.

"Concussion is not a badge of honor. It's an injury."

"Our baseline-testing program uses a combination of virtual-reality testing, plus computer-based cognitive and standard balance testing, to examine executive function, reaction time, memory, and balance—really all the symptoms of concussive injury," says Slobounov.

The team's patients include both Penn State athletes and younger athletes from the surrounding community. The services are provided free of charge for the former and for a small fee for everyone else. Penn State athletes are required to take the computer-based cognitive and standard balance tests before their practice seasons start. The virtual-reality test is optional. "This year, 70 percent of our student athletes participated in the virtual-reality test," says **Tim Bream**, director of athletic training services and head football athletic trainer at Penn State. He notes that over the last three years for all varsity sports—plus rugby, a club sport—the average number of concussions diagnosed at Penn State per year was around 30, or three percent of student athletes.

Bream says the computer-based cognitive test and standard balance test are part of the protocol that Penn State uses to determine when and if athletes can return to play. "We use the tests every day until the students are symptom free," he says. "Once they are symptom free, they start another part of the protocol, which is light exercise, followed by heavier exercise, followed by an examination by a physician."

Slobounov says that the virtual-reality tests, which are now being used in some form by numerous other colleges and universities, are important because they reveal cognitive and motor abnormalities that do not show up in traditional tests. This is key because, as his research has demonstrated, some patients who do not exhibit symptoms may harbor problems that will surface years down the road.

To examine these hidden abnormalities, Slobounov conducts the virtual-reality testing in conjunction with electroencephalogram (EEG) imaging and sometimes with other imaging techniques, such as functional magnetic resonance imaging (fMRI). "We are looking at the relationship between how the patient performs on the test and what is going on in his or her brain," he says. "It's the most robust way to test structural and functional abnormalities."

THE EMOTIONAL TRAUMA OF BRAIN INJURY

While most victims of traumatic brain injury recover all or some of their cognitive function, a significant percentage either never improve, or decline and die.

Samantha Hall was one of those who lost her life, passing away last winter after two years in a vegetative state following a car accident. "You're left with this curled up body in a bed that weighs less than 80 pounds," says her brother **William Doan**, professor of theatre and of women's studies. "You think, 'How can that be my sister?'"

As Doan grieved over Samantha's condition, he spent countless hours learning about diffuse axonal injury, the form of concussion she suffered, in which the damage is widespread rather than focused in one area of the brain. "I wanted to find out what my sister could be feeling and experiencing, because early on she was in what would be considered a minimally conscious state, where there seemed to be some verifiable form of awareness," he says. "There was even a brief window where we were able to get her to blink once for yes and twice for no. But then her eyes would glaze over. You could literally see her go from awareness to lack of awareness. I became desperate to understand. If she's not coming to the surface anymore, does that mean she doesn't hear me?"

At the same time Doan was searching for answers, he was also functioning as an artist, writing poems and eventually a play about the experience. His play, *Drifting*,

Dr. Wayne Sebastianelli

Senior Krista Krebs has excelled at Penn State despite ongoing effects from a concussion she suffered almost seven years ago. "It's a new normal for me," she says. Photo by Patrick Mansell.

is set in a hospital room. The patient, who represents Doan's sister, is in a coma and periodically has out-of-body experiences in which she converses with her brother. "The conversations are part memory, part fantasy," says Doan. "Writing the play in this way gave me an opportunity to explore what my sister might be experiencing."

So far, the play (directed by Andrew Belser, professor of theatre at Penn State) has been performed off-Broadway in New York City and for students at the Penn State College of Medicine. Doan says the process of writing it helped him and his family when the time came to remove his sister's artificial nutrition and hydration.

"It was important for us to fully understand the situation so we could make the best possible decision," he says. "With 'Drifting,' I really want my audience to understand the complexity of living in a world that essentially chooses to save life no matter what the cost. That isn't always the best course of action."

A NEW NORMAL

Doan's sister did not survive her extensive head trauma. Most concussions are much less severe, which makes them survivable—but can also make them easy to shrug off as being "not that serious."

All concussions are serious, says Sebastianelli, and how they are managed is crucial. The key to recovery, where recovery is possible, is what he calls "relative rest."

"Essentially, it's activity below a level that creates symptoms," he explains. "If you can walk and not get a headache, then you can walk. If you get a headache when you walk, you shouldn't walk." Other symptoms to watch for include dizziness, sensitivity to light, and inability to concentrate. The relative rest might apply to mental work, too—taking a break from academics, working on your computer, even from playing video games or reading.

As the brain recovers and the symptoms abate, the patient can gradually start doing more—although for some, like Krista Krebs, problems linger. She rested and got treatment for an extended time after her injury, and delayed going to college for a year. She entered Penn State as a part-time student in the fall of 2010 and has excelled, scoring a near-perfect 3.99 grade-point average and doing creative work as an app developer during internships. Even so, she faces daily reminders of her concussion.

"What's hardest is when I'm going to sleep at night, when I realize my head still hurts and I have to get up and do it again tomorrow," she says. "But then I wake up as I've done for thousands of days in a row now, and I just carry on. It's a new normal for me."

Most people who suffer a blow to the head can eventually return to a normal that's just like their old normal. But their recovery depends on taking the trauma seriously.

"Creating a culture of awareness of head injury is very, very important, so that it can be appropriately recognized and treated," says Sebastianelli. "Concussion is not a badge of honor. It's an injury."

Research in the Center for Sport Concussion Research and Service has been supported in part by the National Institutes of Health, the National Football League, and Penn State's College of Health and Human Development.

Patrick Mansell

GOING DEEP

Penn State scientists are helping crops survive drought and poor soils by redesigning their roots, from external architecture to internal anatomy.

BY CHERIE WINNER

Photos by Patrick Mansell

AMONG THE LIKELY EFFECTS OF CLIMATE CHANGE, PERHAPS THE ONE WITH THE MOST POTENTIAL TO DEVASTATE HUMAN AND NATURAL COMMUNITIES IS DROUGHT—not just a dry season or two, but a prolonged lack of rainfall over vast areas, lasting years or even decades.

Drought is already making itself felt in Europe, Australia, and the United States. Much of the American West and Southwest is several years into a deep drought, and by 2060 the Midwest is expected to experience conditions that rival the Dust Bowl. But it is developing countries that are suffering the most, with drought so severe that it has disrupted societies, spawned or worsened civil strife, and led to the forced migration of millions of people no longer able to find water or grow food in their homelands.

Penn State crop scientist **Jonathan Lynch** has spent his career exploring how to make crop plants better able to grow in dry, low-nutrient soils, as a way to fight the chronic food shortages that plague much of the world. He has never considered himself a climate-change scientist, but in recent years his work has taken on new urgency due to the global changes we're seeing.

"If you're a small farmer in Rwanda and you only have half an acre of land to feed your family, and your crops are only yielding ten percent of what they should because of drought and poor soil, that's a serious problem," says Lynch. "Right now there are about 850 million chronically hungry people on Earth. 850 million! Chronic malnutrition is the leading cause of childhood deaths in the Third World. It's already a massive problem, and climate change has barely begun to sink its teeth into these agricultural systems yet.

"An important way to address this challenge is to develop plants that can tolerate these stresses."

WHERE THE GOOD THINGS ARE

Plant breeders worldwide have been trying to do that by improving the efficiency of physiological processes such as photosynthesis.

Those are good improvements for plants that are well-watered and in nutrient-rich soil, says plant biologist **Kathleen Brown**, but in poor soils or drought conditions, having souped-up physiology won't help. What will help is enabling the roots to reach more sources of water and nutrients in soils that have little of either.

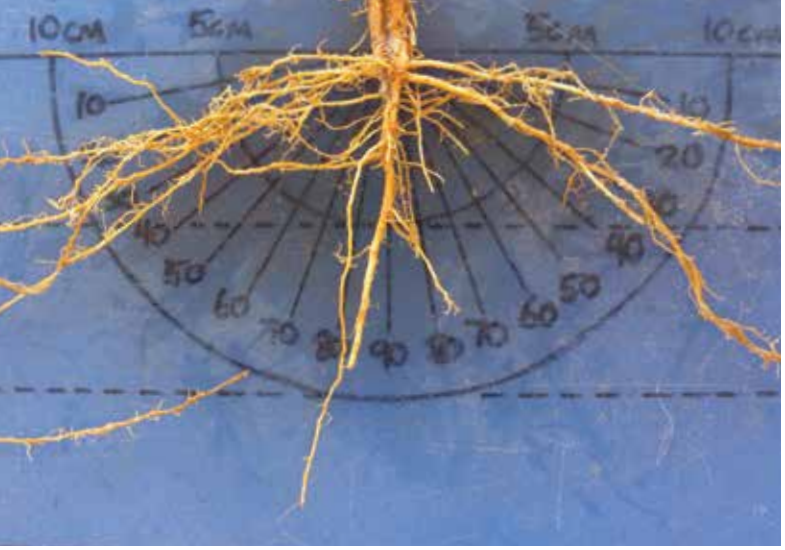
So Brown, Lynch, and their students at the Roots Lab at Penn State study how root structure can improve the ability of key crop plants—primarily corn (*Zea mays*) and the common bean (*Phaseolus vulgaris*) — to produce good yields under stressful conditions.

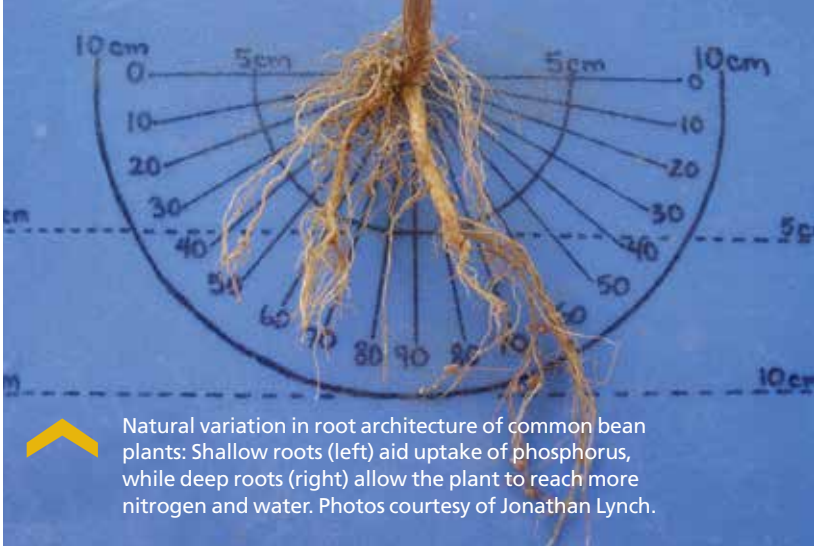
That may sound simple, but it gets complicated in a hurry. For one thing, most of the root features known to enhance resilience to poor conditions are not controlled by a single gene and therefore are hard to select for. A plant may have to have a whole suite of genetic variations to produce the kinds of roots that will enable it to grow deep enough to access water deep below the surface.

"If Nature could improve drought tolerance in plants by changing one gene, that would have been figured out, like, 300 million years ago," says Lynch. "It's more complex than that."

Another challenge is that not everything the plant needs can be found with the same root characteristics. Fertilizers and natural decomposition of the previous year's crop residue deliver nitrogen and phosphorus to the soil surface. Nitrogen almost immediately moves down, riding along with water as it seeps deep into the soil. Phosphorus, though, stays near the surface.

Plant scientist Kathleen Brown and graduate student Molly Hanlon.





Natural variation in root architecture of common bean plants: Shallow roots (left) aid uptake of phosphorus, while deep roots (right) allow the plant to reach more nitrogen and water. Photos courtesy of Jonathan Lynch.

"It stays stuck to the soil particles, so it can't move freely," says Brown. "If the root isn't extremely close, microscopically close, to phosphorus, it doesn't get it. If the plant has used up all the phosphorus around it, it has to keep growing and exploring new soil to keep getting phosphorus."

So for the plant, the architecture of its roots is a tradeoff—make lots of branches that stay near the surface, to find phosphorus, or send roots deep enough to reach water and nitrogen. Individual plants tend to do one or the other, but not both. That makes it unlikely that any single variety of a crop plant will solve all of the problems that might arise in a given location, but a combination of varieties could shield farmers from total disaster.

"If you can be guaranteed of always having some yield, especially if the people are really poor, that can mean the difference between starvation and eating," says Brown. "It's important that they have some resilience, that a weather event isn't going to totally wipe them out."

GOOD ROOTS, CHEAP

Whether a plant goes deeper or reaches more soil near the surface, it is growing more root tissue—and roots have a cost, says Brown.

Every cell in the plant, including in the roots, requires water and nutrients. A cell that photosynthesizes, transports water, or brings in resources from the soil earns its keep. But in a root, most of the uptake of water and nutrients occurs at the growing tip. Some occurs in a short zone just behind the tip where tiny root hairs develop. Farther up the root, where lateral branches form, there's almost no uptake. If the growing tip is two feet underground, that means that a foot to a foot and a half of that root is not actively bringing in water and nutrients. The cells in that part of the root still use water and nutrients, though—and the metabolic cost of maintaining those cells limits how much root the plant can grow.

In the late 1800s, biologists recognized that many aquatic plants have a lot of what looks like empty space in their roots. They figured out that this aerenchyma ("air tissue") enables the plants to live in standing water by allowing transport of oxygen into the submerged roots. The roots start out packed with cells, but as they mature most of the cells die, leaving only channels for transport of fluid and the structural parts that support the lower end of the root.

Several years ago Brown and Lynch realized that roots of plants adapted to other kinds of stresses—high temperatures, nutrient shortage—also tend to contain a lot of aerenchyma. They hypothesized that the ability to make lots of aerenchyma could enable a plant to grow more or longer roots and thereby handle a variety of stressful conditions.

"Having aerenchyma means the root doesn't cost as much," says Brown. "If you can make roots cheaper, then you can grow more roots, and if that root growth goes in the right direction to get the resource you're missing, you can benefit."

In computer simulations developed by the lab, plants with more root aerenchyma obtained more nutrients and grew better in low phosphorus and low nitrogen environments. Then the team confirmed this in real life: In field tests with maize grown in drought conditions, natural variation in the amount of root aerenchyma resulted in an eight-fold difference in yield.

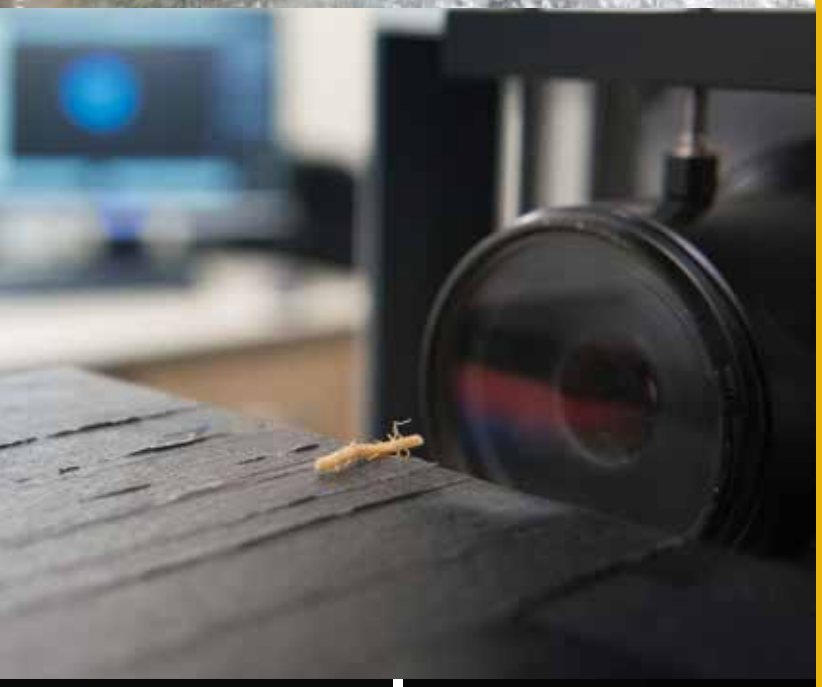
TAKING IT GLOBAL

Over the past several years, Lynch, Brown, and their colleagues have identified the genetic basis for aerenchyma in maize, shallow (phosphorus-seeking) root architecture in common bean, and other valuable traits. They are helping plant breeders develop strains of both crops that combine a desired root architecture with the ability to make aerenchyma, and testing them on farms and agricultural stations in Africa, Asia, Latin America, Arizona, and Pennsylvania.

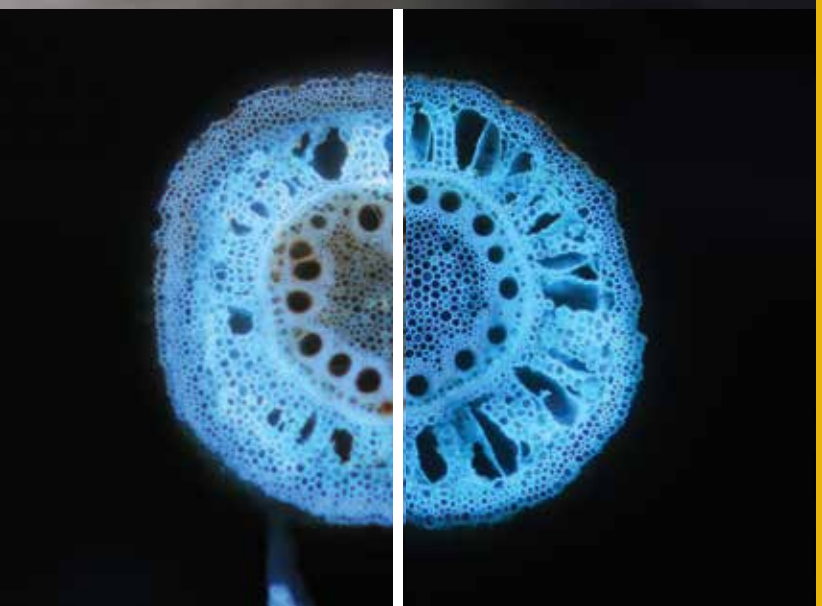
With their focus on the structure of roots beginning to pay off, Lynch is more convinced than ever that the Roots Lab team can help relieve the persistent lack of food in so much of the Third World—and reduce the suffering that will ensue if predictions of severe drought later this century are borne out.

"We can solve this problem," says Lynch. "We can develop plants that need less water and less nutrients and that grow better in these stressful environments. And such plants are going to be really useful even in America and other rich nations in the future, because of climate change.

"We shouldn't feel helpless. This is something we can tackle."



Patrick Mansell (2)



Jonathan Lynch

LOW TECH AND HIGH

Studying roots can be tricky. You can't just look at the visible part of the plant and know what's going on below ground. To evaluate the overall architecture of a plant's roots, the Roots Lab team uses a low-tech but highly effective technique they call "shovelomics": When test plants have grown big enough to have well-developed roots, the researchers dig up the whole root system, carefully clean off the dirt, and assess the number and length of the roots and their angle of growth.

The Roots Lab has also developed computer modeling software that lets them compare how root architecture and anatomy affect a plant's ability to explore the soil and take up water and nutrients.

With SimRoot, a researcher defines the extent and direction of root growth. Then the program shows a 3D simulation of what the root architecture will look like and calculates how nutrient uptake will change over time. With RootSlice, a researcher can find out how features of the root's internal anatomy, such as amount of aerenchyma, will affect the root's function and how efficiently it can explore the soil.

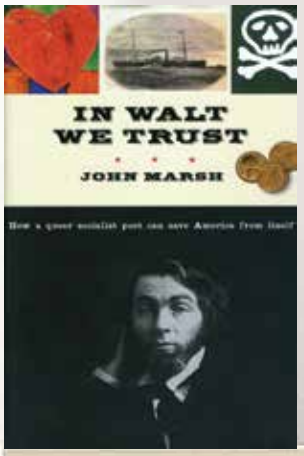
In 2011, the team came up with a new way of getting a detailed look at the internal anatomy of roots. The conventional method involved using a fine blade to take very thin cross-sectional slices from a root, mounting the slices on a glass slide, and examining them under a microscope. Since each root might be several inches long and each section was just a tenth of a millimeter thick, this technique was not nearly efficient enough to handle the huge numbers of samples they generated each year.

At the suggestion of Lynch's son Galen, who was then an undergraduate at Penn State, the team began working with Ben Hall, a graduate student in the Applied Research Lab, and Hall's adviser Ted Reutzel on a method using a laser instead of a blade. The laser cut beautiful sections, says Brown, but the big breakthrough came when they realized they didn't have to collect and examine sections at all. They could just have the laser ablate, or vaporize, thin sections from the root, and have a camera take a picture of the fresh surface after each pass of the laser. The digital images are then manipulated with computer software to create a 3D image of the root that allows scientists to tally the number and size of cells, volume of aerenchyma, and other traits.

This process, called laser ablation tomography (LAT), was patented by Hall, Reutzel, and Jonathan and Galen Lynch. In 2014, Hall launched Lasers for Innovative Solutions, a startup venture based on LAT technology, with support from the Ben Franklin TechCelerator program at Penn State's Innovation Park.

(Top) Washing the root crown of a freshly dug maize plant. (Middle) Piece of maize root undergoes laser ablation tomography, which yields detailed images (bottom) of its internal structure. Root segments with more aerenchyma (open space, right) have much lower metabolic costs than roots with little or no aerenchyma (left).

BOOKS



IN WALT WE TRUST: How a Queer Socialist Poet Can Save America from Itself

by John Marsh, associate professor of English

Life in the United States is shot through with uncertainty, writes John Marsh. "For many, our lives, public and private, have come to feel like the discomfort and unease you experience the day or two before you get really sick. Our life is a scratchy throat." Marsh offers an unlikely remedy for this widespread malaise: the poetry of Walt Whitman.

Mired in personal and political depression, Marsh turned to Whitman—and it saved his life. *In Walt We Trust: How a Queer Socialist Poet Can Save America from Itself*, he says, is a book about how Walt Whitman can save America's life, too.

Marsh identifies four sources for our contemporary malaise (death, money, sex, democracy) and then looks to a particular Whitman poem for relief from each. When he was at his lowest, Marsh writes, Whitman showed him how to accept and even celebrate death. "Just as important, though, he can show us how to live: how to have better sex, what to do about money, and, best of all, how to survive our fetid democracy without coming away stinking ourselves."

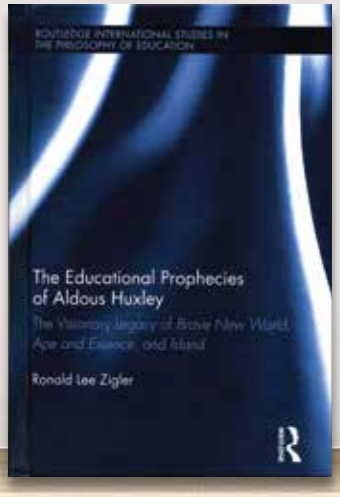
THE EDUCATIONAL PROPHECIES OF ALDOUS HUXLEY: The Visionary Legacy of *Brave New World*, *Ape and Essence*, and *Island*

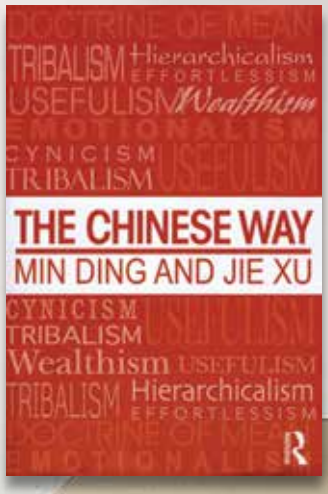
by Ronald Lee Zigler, associate professor of educational psychology, Penn State Abington

Can democracy survive the modern world's population growth, political tensions, environmental destruction, and technological and cultural changes? Aldous Huxley explored various answers to that question in three novels he wrote over a 30-year span.

Ronald Zigler reflects on Huxley's visions in *The Educational Prophecies of Aldous Huxley: The Visionary Legacy of 'Brave New World,' 'Ape and Essence' and 'Island.'*

He draws parallels between our society today and those depicted by Huxley, two of them dystopian and the third, *Island*, a more hopeful vision of a society that manages its complex problems in a way that preserves the precarious democracy. The culmination of 40 years of reflection about American history, education, and culture, Zigler's book suggests how we might avoid the more tragic futures Huxley imagined and maintain our free, open, and democratic society.





THE CHINESE WAY

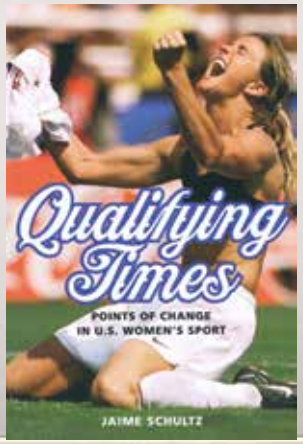
by Min Ding, professor of marketing and innovation, and Jie Xu

Westerners who do business in China, invest in Chinese stocks, or simply want to better understand the world's most populous country would do well to steer clear of over-simplifications of modern Chinese culture.

In *The Chinese Way*, Min Ding and his co-author, Jie Xu of Fudan University in Shanghai, offer a guide to modern Chinese society that is designed to help Westerners navigate a world they have learned about primarily from superficial and distorted accounts.

In the style of an anthropological study of an unfamiliar society, Ding and Xu gathered first-hand accounts from Chinese scholars, businessmen, and government officials. They then augmented those findings with data from public sources such as newspapers and blogs to describe the modern way of life in China and how it affects social conventions; political, religious, and economic beliefs; and arts, education, and communications.

BY PENN STATE FACULTY



QUALIFYING TIMES: Points of Change in U.S. Women's Sport

by Jaime Schultz, assistant professor of kinesiology

Jaime Schultz has published *Qualifying Times: Points of Change in U.S. Women's Sport*, a book exploring U.S. women's sports through historical "points of change"—technologies and trends that dramatically influenced both women's participation in sports and cultural responses to women athletes.

Beginning with the seemingly innocent ponytail, Schultz challenges the reader to look at the historical and sociological significance of now-common items, such as sports bras and tampons, and ideas, such as gender verification testing and competitive cheerleading. She considers both Title IX and the 1950s dominance of Soviet women athletes as important catalysts.

These points of change increased women's physical freedom and sporting participation, she writes, but also posed challenges. Tampons encouraged menstrual shame, sex testing—a tool never used with male athletes—perpetuated narrowly defined cultural norms of femininity, and the late-twentieth-century aesthetic fitness movement fed into an unrealistic beauty ideal.

The book received an honorable mention PROSE Award from the Professional and Scholarly Publishing Division of the Association of American Publishers in the category of U.S. history.

BEYOND DEPORTATION: The Role of Prosecutorial Discretion in Immigration Cases

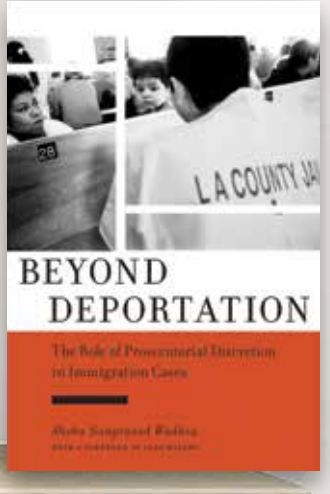
by Shoba Sivaprasad Wadhia, professor of law

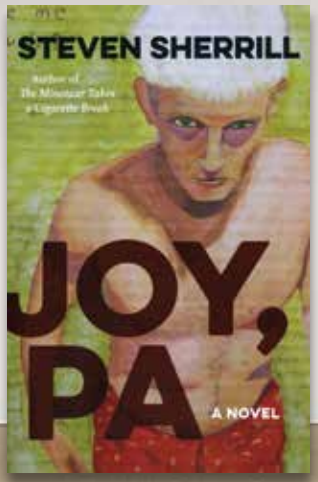
While political candidates rant about how to keep the U.S. from being victimized by evil, freeloading immigrants, federal officials have long pursued a more rational approach to deciding who may legally stay and who may not.

Prosecutorial discretion regarding which cases to pursue can ensure that individuals with desirable qualities are protected from deportation, while those who represent a real threat to the community or the country are identified and speedily removed, writes Shoba Sivaprasad Wadhia in *Beyond Deportation: The Role of Prosecutorial Discretion in Immigration Cases.*

Wadhia delves into the history of prosecutorial discretion in the immigration system, from the 1970s case involving John Lennon that brought the longstanding practice to public awareness, to "deferred action," a form of temporary permission to stay in the country, established by the Obama administration.

Prosecutorial discretion protects would-be immigrants from a one-size-fits-all deportation policy and allows government resources to be focused on truly dangerous individuals, writes Wadhia. Drawing on her years as an immigration attorney and adviser, she also advocates stronger standards, accountability, and transparency around the practice.





JOY, PA

by Steven Sherrill, associate professor of English and integrative arts, Penn State Altoona

Steven Sherrill's new novel, *Joy, PA*, witnesses the dismantling of the American dream.

The Augenbaughs live in a broken and decaying town where the last vestiges of country-club wealth run up against the terrible realities of working-class poverty. Abigail, a fervent believer in the apocalyptic teachings of a radio preacher, is desperate to save her son from Judgment Day as she readies herself for the Rapture—due to arrive in just a few days. Her husband, Burns, has moved to the basement to live out his days in a medicated stupor, unable to cope with memories of his service in Iraq. Caught between the suffering of his mother and father, 10-year-old Willie fights the inherited demons that have savaged his parents' tenuous grasp on reality.

The somber drama surrounding the Augenbaughs plays out with a lyrical beauty, and Sherrill's empathetic portrait of alienation elicits hope and sympathy amidst shattered but no-less-dignified lives.

Sherrill is the author of *The Minotaur Takes a Cigarette Break, Visits From the Drowned Girl,* and *The Locktender's House.*

KHANJAN MEHTA

Materials Research Institute, Penn State

Khanjan Mehta, assistant professor of engineering design and director of the Humanitarian Engineering and Social Entrepreneurship (HESE) program at Penn State, helps students solve problems in developing nations in ways that benefit local economies and are self-sustaining. HESE ventures range from telemedicine systems and ruggedized biomedical devices to affordable greenhouses and solar food dryers.

Via Skype from Zambia this past June, Mehta spoke with editor Cherie Winner about the program's aims and approaches.

WHAT ARE YOU DOING IN ZAMBIA NOW?

My team just got back from a clinic about 45 minutes away where they are building a greenhouse to provide food for women waiting to deliver babies. These women travel long distances to reach the clinic and they eat maize meal in a porridge form for breakfast, lunch, and dinner. We are trying to improve their nutrition.

WHAT'S THE BASIC PHILOSOPHY OF THE PROGRAM?

We are all about the execution, all about how to get things done and build enterprises that address socio-economic problems and can be sustained without charity. The technology is just 10 percent. The other 90 percent is supply chains and contracts and figuring out how to hire people, finding the talent, marketing and sales and getting things up and running. It's all about venture creation.

HOW DO YOU CHOOSE THE COMMUNITIES AND PROBLEMS TO WORK WITH?

That's a million-dollar question! These are very complex problems and contexts. I can't imagine saying, 'OK, here is Zambia, and we're going to try to solve this problem of infant mortality.' It's a big, hairy, slimy problem, and it's not just going to go away. I can't think about, 'How can I solve this problem once and for all?' What I can do is say, 'Look, here is where things are right now, and here is a way that we can make things better in a sustainable fashion, while creating jobs and improving livelihoods. That's a step forward, that's a step up. You take a lot of these little steps and when you look back, you realize how far you've come.

MUCH OF THIS WORK IS NOT TRADITIONAL ENGINEERING. HAVE YOU HAD TO LEARN A LOT ABOUT OTHER FIELDS?

It's been an *immense* learning curve. The month I spent in Kenya ten years back, my first time there, was a complete game-changer for me, because I saw project after project after project that all kinds of organizations had initiated, and every single thing was failing. That's when I started getting interested in a different narrative. Instead of 'let's teach them how to fish,' well, these people are already excellent fishermen. They know how to fish. It takes much more than that. There is a very wide range of cultural, social, economic, political challenges that they face. So I decided to take a more systemic approach to how we develop sustainable enterprises, because ultimately everybody needs to make money and go back home and put food on the table. That philosophy of engagement is critical, and that's also something that really sets us apart from other efforts of this nature across the U.S.

YOU'VE SAID THIS PROGRAM IS UNIQUE IN THAT YOU CAN DRAW ON THE EXPERTISE OF MATERIALS SCIENTISTS TO DEVELOP PRODUCTS THAT WILL HOLD UP IN HARSH CONDITIONS.

That's the beauty of being at Penn State: There is an expert on every subject matter that you might need, and everybody is very happy to give you an hour or two of their time to advise you on specific issues. The Materials Research Institute has been a great partner. In the law school, there is the International Sustainable Development Projects Law Clinic, and they help us with our contracts and our licensing agreements. We needed a little adult supervision there because we wanted to do it right or we could be in trouble. And there they were!

HOW ELSE DOES HESE DIFFER FROM SIMILAR PROGRAMS?

We also have a significant research emphasis. We make up new ways of working, new ways of thinking, and then we validate them and publish them. All the students who complete the program typically have one or more publications by the time they are done. For the students it's a step toward building a career doing this kind of high-impact work.

WHAT DO THE STUDENTS FIND MOST CHALLENGING?

The number one thing is the need to keep pivoting. So we're going in a certain direction, and all of a sudden something happens, and we have to change course. We were supposed to be in Kenya in May to do assessments of our greenhouses and healthcare ventures, but we had to pivot because of the terrorist attack there in April. It's very frustrating, because every few days, every few hours sometimes, you're changing plans and trying new things. Students especially struggle with that early on. They have this notion, OK, here is a problem; there has to be a solution; I'll develop a solution and I'm done. And in this world, you're never, ever done.

Alexis Arra, now a junior in the graphic design program at Penn State, won the Betreff Gentner Prize in the 2015 "Water is Life" international student poster competition in Berlin. Arra says her concept for the poster reflects the scarcity of water in many developing nations, how hard it is for people there to obtain clean water, and how differently those of us in wealthier countries think of water. The contest drew more than 4,800 entries from 81 countries; just five prizes were awarded. Image courtesy Alexis Arra.

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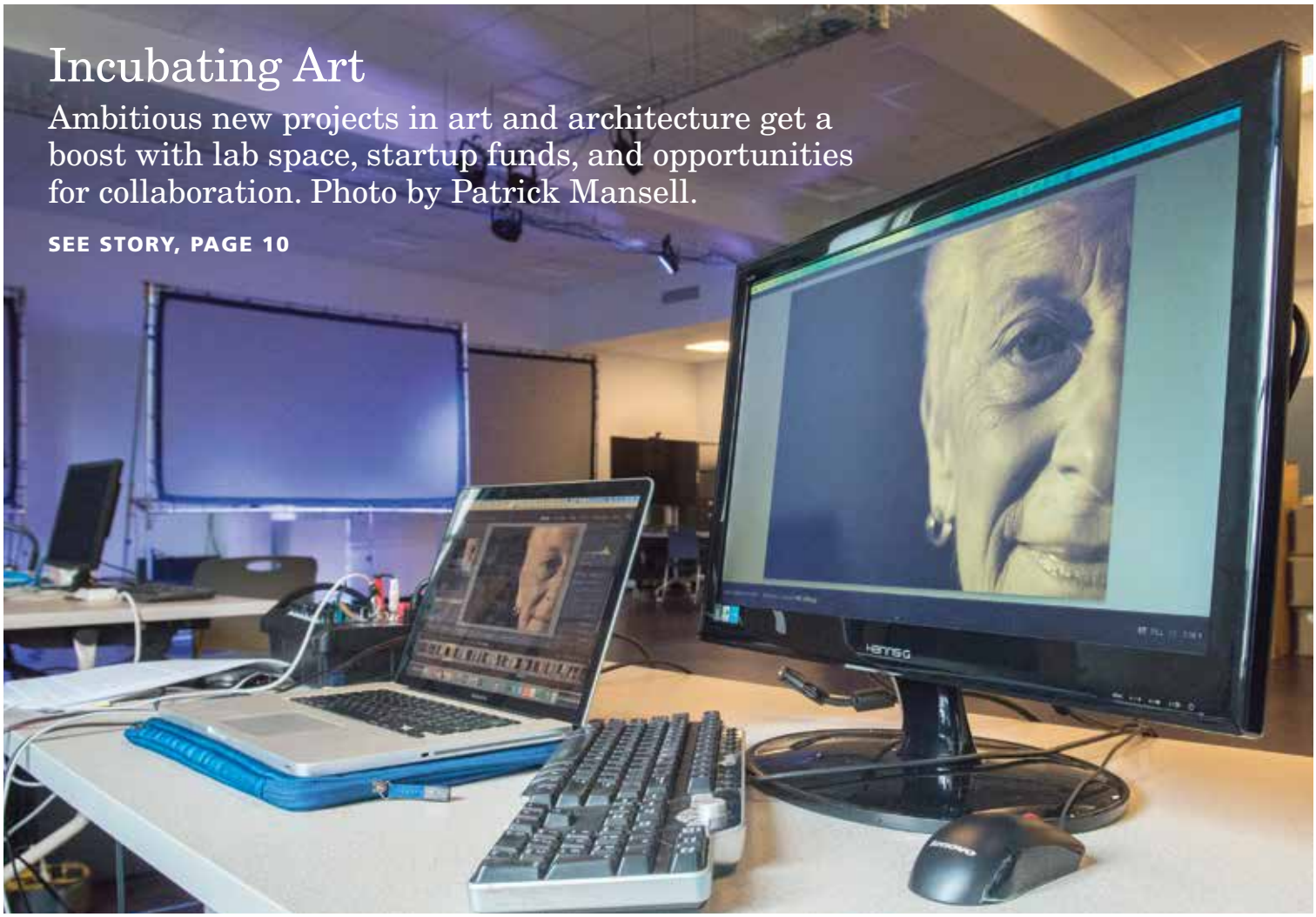

Incubating Art

Ambitious new projects in art and architecture get a boost with lab space, startup funds, and opportunities for collaboration. Photo by Patrick Mansell.

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