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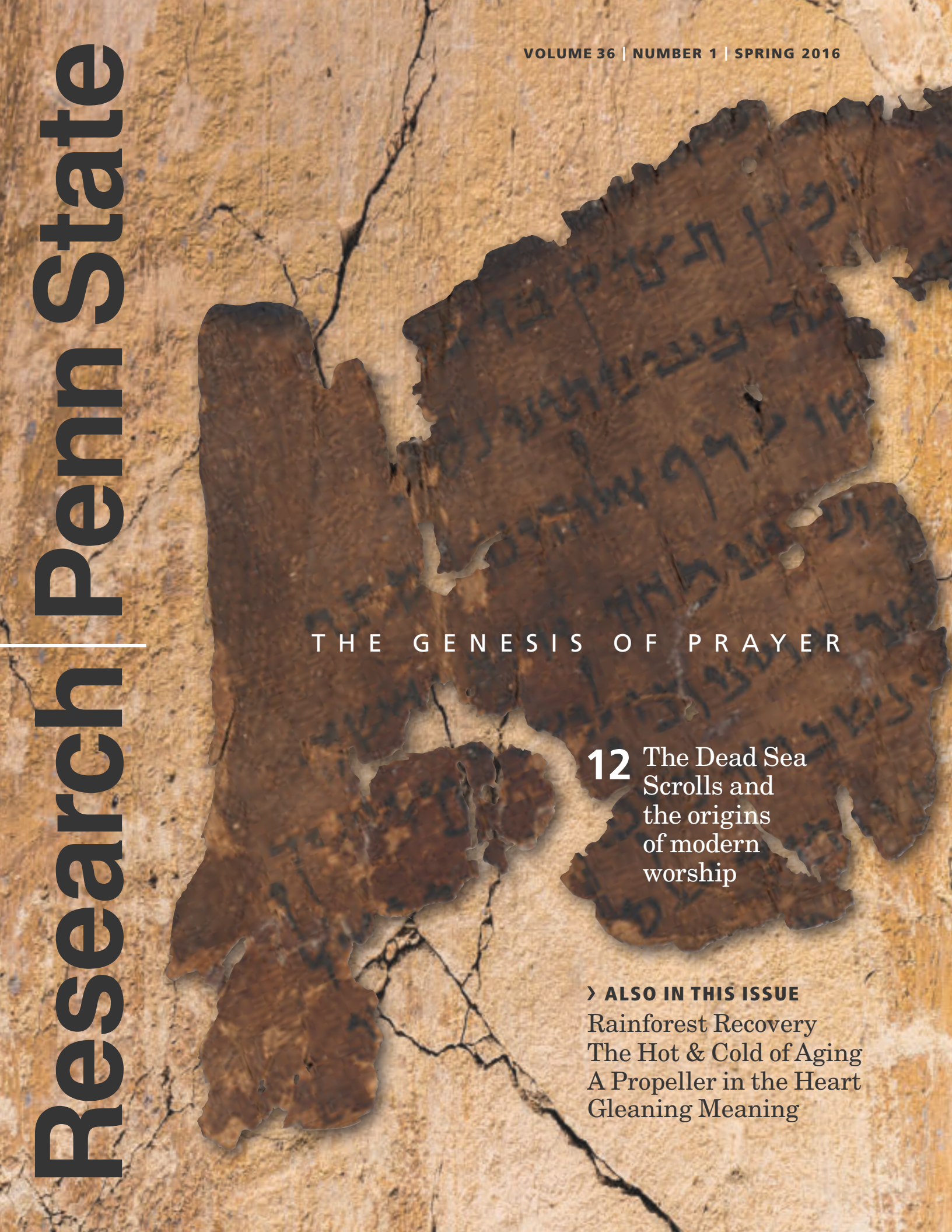

THE GENESIS OF PRAYER

› ALSO IN THIS ISSUE

Tools of **Discovery** ›

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.

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ON THE COVER:
A fragment of parchment bears sacred writings of an ancient religious community—and clues to the origins of group prayer. See story, page 12. Courtesy of The Leon Levy Dead Sea Scrolls Digital Library; IAA, photo: Shai Halevi

The nature of human creativity and innovation is reflected in the progressive, step-wise improvements in the tools we devise and employ. We use old tools to make new ones, and the discoveries rendered with new tools reveal new paths, leading to new ideas, the next new tools, and so it goes. We are descended from a long line of creative tool makers and users; nowhere is this more evident than at a major research university.

As this issue of *Research Penn State* attests, here at Penn State we have as many amazing tools as we have talented people to use them. I have had the good fortune of witnessing many of these tools in action.

Larry Kenney's work exploring age-induced decrements in body temperature regulation relies on a suite of advanced tools, from room-sized environmental chambers to laser instruments able to non-invasively measure the flow of blood in tiny vessels of the skin. Rob Kunz and his colleagues used the wealth of sophisticated design and manufacturing tools available within our Applied Research Laboratory to invent a new implantable device that could one day prolong thousands of lives by maintaining circulation in the presence of a compromised heart. Linda Collins and other scientists at the Methodology Center apply new statistical tools to address difficult problems in behavioral and medical science. The evolution of remote sensing tools has been essential to the dramatic success of the institute Chris Uhl started to slow deforestation in the Amazon. Not least, Daniel Falk's work in deciphering the Dead Sea Scrolls relies on relatively new imaging techniques to make blackened scrolls readable, enabling the discovery that the ancient authors of those scrolls viewed prayer as their most effective tool of war against the forces of darkness.

Neil A. Sharkey
Vice President for Research

THANK YOU to all of our readers who filled out the email survey after our October issue. Your responses were encouraging and thoughtful, and we are addressing your concerns and suggestions. On page 32 you'll find one of our first improvements, a redesigned "In Touch With" feature. We hope you enjoy it. As always, comments are welcome any time, at **editor@research.psu.edu.**

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

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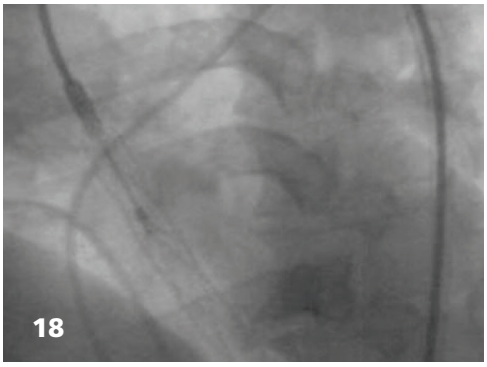

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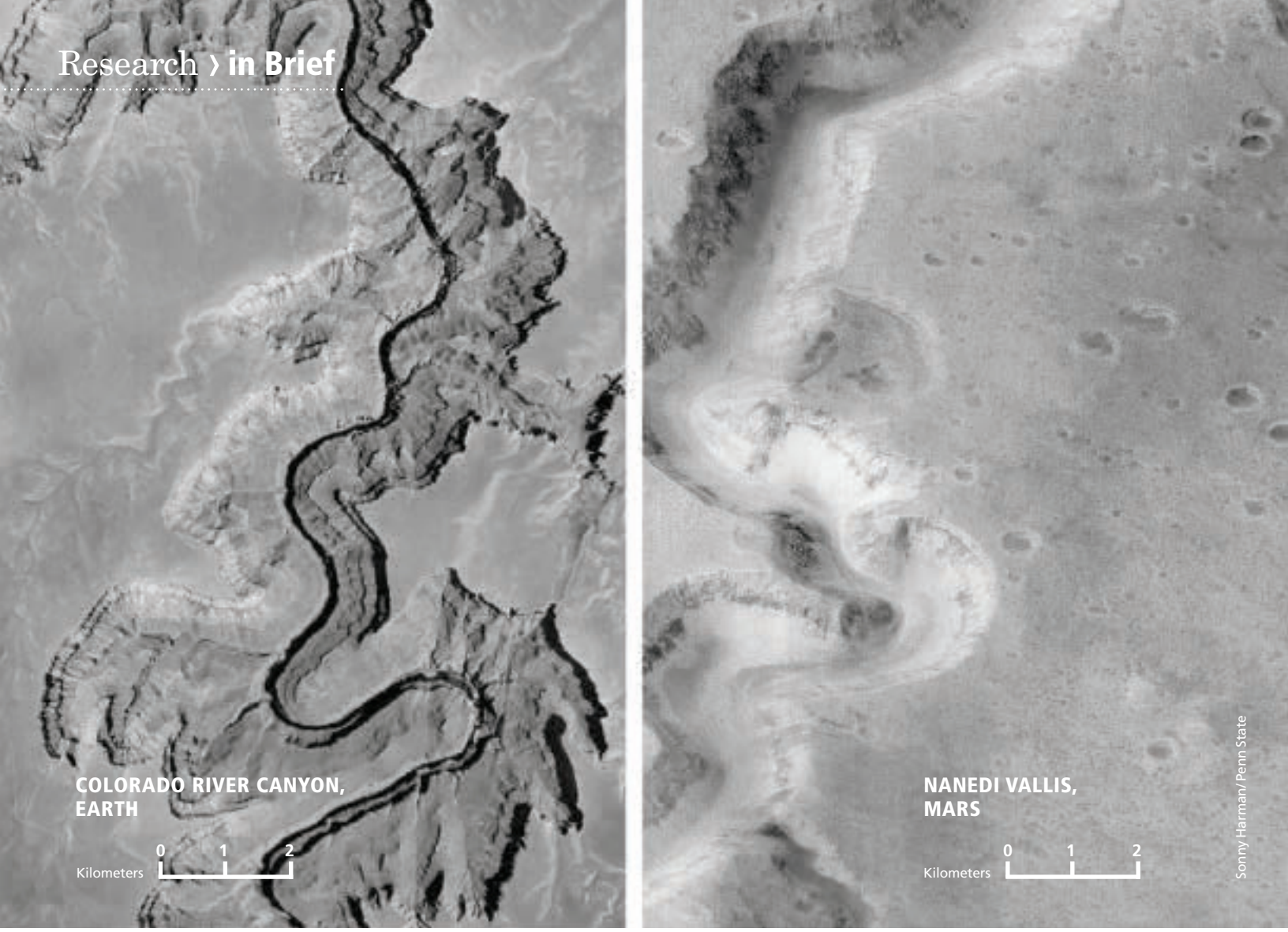

Climate Models Help Explain Formation of Mars Valleys

EXTENSIVE VALLEY NETWORKS ON MARS WERE PROBABLY CREATED BY RUNNING water billions of years ago, but the source of that water is unknown. Now, a team of Penn State and NASA researchers is using climate models to determine whether and how greenhouse warming might have been the source of the water.

Previous studies supported the likelihood that flowing water existed on early Mars, but it's not known how surface warming occurred to produce liquid water, and how much water was really there.

One hypothesis claims that intense bombardment of Mars by asteroids led to a temporary warming and resultant rainfall that carved the Martian valleys. However, that would not have generated enough water to do the job, according to **James Kasting**, Evan Pugh Professor of Geosciences, Penn State.

In 2014 a research group led by Kasting proposed that early Mars was warmed by a dense atmosphere of greenhouse gases, specifically carbon dioxide and hydrogen. They have since focused on hydrogen because other greenhouse mechanisms have largely been ruled out.

This year Kasting's group used a mathematical climate model that simulates aspects of atmospheric chemistry to determine whether Martian "air" could have contained enough hydrogen to drive warming. The model suggested that volcanic activity caused by plate tectonics would have been needed to produce that much hydrogen. Because it's not known yet whether early Mars had plate tectonics, the team will look into other ways hydrogen might have built up in the atmosphere.

—CARRIE LEWIS

Slick Invention

The leaves of the lotus flower, and other natural surfaces that repel water and dirt, have been the model for many types of engineered liquid-repelling surfaces. As slippery as these surfaces are, however, tiny water droplets still stick to them. Now, Penn State researchers have developed nano/micro-textured, highly slippery surfaces able to outperform these naturally inspired coatings, particularly when the water is in the form of vapor or tiny droplets.

Enhancing the mobility of liquid droplets on rough surfaces could improve condensation heat transfer for power-plant heat exchangers, create more efficient water harvesting in arid regions, and prevent icing and frosting on aircraft wings.

"This represents a fundamentally new concept in engineered surfaces," says **Tak-Sing Wong**, assistant professor of mechanical engineering and a faculty member in the Penn State Materials Research Institute.

"Our surfaces combine the unique surface architectures of lotus leaves and pitcher plants in such a way that these surfaces possess both high surface area and a slippery interface to enhance droplet collection and mobility. We have demonstrated for the first time experimentally that liquid droplets can be highly mobile when in the Wenzel state," a physical state in which liquid droplets typically stick to rough surfaces.

The researchers used micro- and nanoscale etching techniques on a silicon surface to make Wenzel-state droplets mobile. They say the same design principle can be easily extended to metals, glass, ceramics, and plastics. A U.S. provisional patent has been filed for their work.

—A'NDREA ELYSE MESSER

Xianming Dai, Chujun Zeng, and Tak-Sing Wong/Penn State

PURPLE POTATOES PACK POWERFUL PUNCH

COMPOUNDS FOUND IN PURPLE POTATOES MAY HELP KILL COLON CANCER STEM CELLS AND limit the spread of the cancer, according to food scientist **Jairam K.P. Vanamala** and colleagues at Penn State and the University of Colorado.

Colon cancer is the second leading cause of cancer-related deaths in the U.S. and responsible for more than 50,000 deaths annually, according to the American Cancer Society. Attacking stem cells is an effective way to counter cancer, says Vanamala.

"You might want to compare cancer stem cells to roots of weeds. You may cut the weed, but as long as the roots are still there, the weeds will keep growing back and, likewise, if the cancer stem cells are still present, the cancer can still grow and spread," he says.

In an initial study, the researchers found that an extract from baked purple potato suppressed the spread of colon cancer stem cells while increasing their mortality in a lab dish. The team then tested the effects of eating baked purple potatoes on mice with colon cancer and found similar results. For a human, the effective portion size would be about the same as eating a medium-size purple-fleshed potato for lunch and dinner, or one large purple-fleshed potato per day.

Stephen Lea

Vanamala says purple potatoes may contain several substances that work on multiple pathways to help kill the stem cells, including anthocyanins and chlorogenic acid. They also contain resistant starch, which bacteria in the gut can convert to short-chain fatty acids that regulate immune function in the gut and suppress chronic inflammation.

—MATT SWAYNE

COPS, NOT DOCS

Poor schools that have more black and minority students tend to punish students rather than seek medical or psychological interventions for them, according to a Penn State sociologist.

"There's been a real push toward school safety and there's been a real push for schools to show they are being accountable," says **David Ramey**, assistant professor of sociology and criminology. "But any zero-tolerance policy or mandatory top-down solutions might be undermining what would be otherwise good efforts at discipline, and not establishing an environment based around all the options available."

According to the study, schools and school districts with a greater percentage of black students had significantly higher rates of expulsions and suspensions, as well as higher rates of referrals to law enforcement and arrests. Schools and districts with larger black populations also have lower enrollment in government programs designed to stop discrimination against students with disabilities.

Parental reaction to the increased media attention on school shootings and violence at inner city schools in the late 20th century is one reason that school officials adopted zero-tolerance policies.

"In the late '90s crime declined massively, but media coverage of crime did increase in scope," says Ramey. "We started seeing reports of school shootings and terrorism and that created a push to create the perception of safe schools, which included police in the schools and metal detectors at the doorway."

Ramey collected data from 60,000 schools in more than 6,000 school districts for the study.

—MATT SWAYNE

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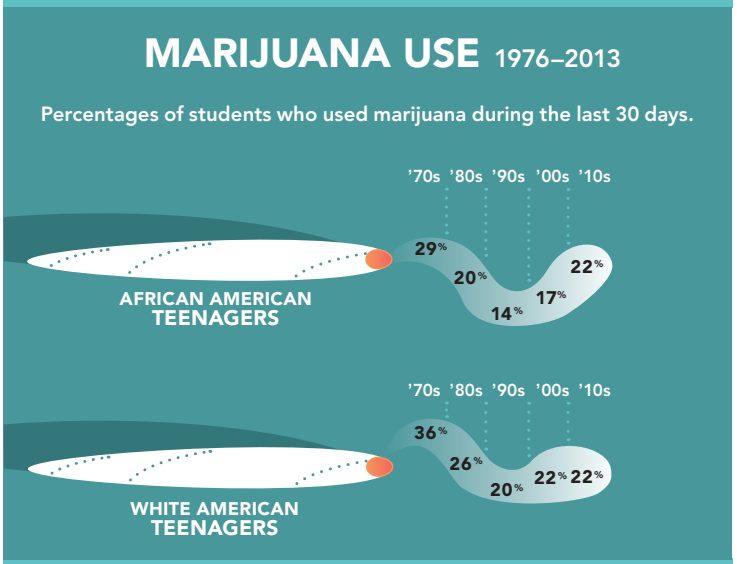
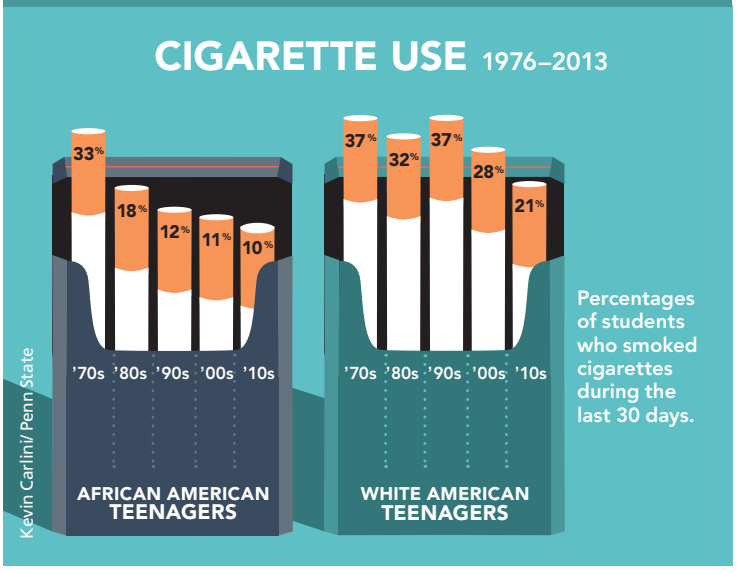
Smells Like Teen Substance Use

Penn State researcher **Stephanie Lanza** analyzed data collected from nearly 600,000 U.S. high school seniors surveyed between 1976 and 2013, focusing on rates of use of alcohol, cigarettes, and marijuana during this span. Among her findings were that cigarette and alcohol use are stable or declining. Marijuana use, although still well below late-1970s levels, is currently on the rise.

—VICTORIA M. INDIVERO





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» Driving Farther to Fish

Scientists have explained the potential effects of climate change on trout before, but now a study by Penn State researchers describes the expected impact of warming waters on the humans who enjoy trying to catch the trout.

Eastern brook trout live in small cold-water streams and lakes throughout the Appalachian Mountains, from Maine to Georgia. Warming air temperatures over the next several decades are expected to reduce their cold-water habitat, shrink their distribution, and provide fewer angling opportunities.

Using models they previously developed to predict stream temperature and brook trout habitat, fisheries ecologist **Tyler Wagner** and former doctoral student **Tyrell DeWeber** identified streams likely to support wild brook trout under current and future climate scenarios. They then calculated the distance required to drive from the centers of 23 cities in current brook trout range to the ten nearest stream segments likely to have wild brook trout.

Currently, the average driving distance ranged from 4 to 87 miles. Under warmer conditions predicted to occur by 2100, that distance would increase by an average of almost 164 miles. For example, the route from Philadelphia to the nearest brook trout stream was predicted to cover 249 miles rather than the current 48 miles.

Trips from more northern cities were predicted to lengthen by a smaller amount, because nearby streams will likely still support brook trout, but anglers in cities farther south could face much longer drives, because brook trout will probably be lost from nearby streams.

—JEFF MULHOLLEM

Sassy Frass

In a deception that likely has evolved over thousands of years, a caterpillar that feeds on corn leaves induces the plant to turn off its defenses against insect predators, allowing the caterpillar to eat more and grow faster, according to chemical ecologists in the College of Agricultural Sciences. In this case, the agent of deceit is the caterpillar's feces, or "frass."

Fall armyworm larvae are voracious feeders on leaves in the confined whorls of corn plants, and by necessity the insects defecate nearby in the crevasses where the leaves meet the stalks. Copious amounts of frass accumulate in these clefts and can remain there for a long period of time.

Caterpillar frass is composed of molecules derived from the host plant, the insect itself, and associated microbes, and it provides abundant cues that may alter plant defense responses, says lead researcher **Swayamjit Ray**, a doctoral student in plant biology.

"It turns out that the caterpillar frass tricks the plant into sensing that it is being attacked by fungal pathogens and mounting a defense against them, thereby suppressing the plant's defenses against herbivores," says **Dawn Luthe**, professor of plant stress biology. "Plants cannot defend against both pathogens and insect attackers simultaneously."

The research may lead to the isolation of specific components that could be incorporated into an ecologically sustainable anti-pathogen agent that could be sprayed on crops, Luthe says.

—JEFF MULHOLLEM

Swayamjit Ray/ Penn State

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›› Stress for Success?

Rats exposed to frequent physical, social, and predatory stress during adolescence solved problems and foraged more efficiently under high-threat conditions in adulthood compared with rats that developed without stress, according to Penn State researchers. The results may provide insights into how humans respond to adolescent stress.

"Unpredictable stress can have dramatic and lasting consequences, " says **Lauren Chaby**, doctoral student in neuroscience and ecology. "Unpredictability is part of what can make stress so toxic. We tried to use a range of stressors so the rats couldn't predict which stressor was going to come next."

Chaby exposed adolescent rats to a variety of stressors such as smaller or tilted cages, social isolation or crowding, and predator scents or vocalizations. After the rats reached adulthood, she tested their ability to manipulate novel objects to obtain food rewards under both standard and high-threat conditions. Many studies investigating the consequences of stress during early life test adult animals only under standard, "safe," conditions with little noise or external threats.

"So you have this relaxed situation that they're trying to solve these tasks in," says Chaby. "We wanted to test them in conditions that were consistent with their rearing conditions."

Under high-threat conditions, adult rats stressed during adolescence started foraging sooner, visited more food patches, and obtained 43 percent more food than adult rats that had not been stressed when young. These results suggest that growing up in a stressful environment can prepare rats for a stressful, high-predation environment in the future, Chaby says.

—GAIL MCCORMICK

BIOPLASTIC, HEAL THYSELF

A MULTIPHASE POLYMER DERIVED FROM THE genetic code of squid repairs itself when treated with warm water and light pressure, according to an international team of researchers. The discovery may someday extend the life of medical implants, fiber-optic cables, and other objects that are hard to repair in place.

"What's unique about this plastic is the ability to stick itself back together with a drop of water," says **Melik Demirel**, professor of engineering science and mechanics, Penn State. "There are other materials that are self healing, but not with water."

Demirel and his colleagues found that the ring teeth of many kinds of squid from around the world contain proteins with self-healing properties. To avoid depleting squid populations, and to have uniform material to work with, the researchers used biotechnology to produce the proteins in bacteria. The proteins were then combined into a two-part copolymer consisting of a soft, amorphous segment that provides the self-healing ability and a more structured segment that provides strength. The copolymer can be molded using heat or cast by solvent evaporation.

The researchers created a small dog-bone shaped sample of the material and then cut it in half. When they applied water at about 113 degrees Fahrenheit—slightly warmer than body temperature—and light pressure with a metal tool, the two halves reunited. Strength tests showed that the sample was as strong after healing as it was before being cut.

—A'NDREA ELYSE MESSER

Demirel Lab/ Penn State

A drop of warm water and light pressure allowed this sample of the new polymer to heal itself after being cut in half.

Patrick Mansell

Critical Feedback

Everyone may be a critic, but now Penn State researchers are paving a way for machines to get in on the act.

James Wang, professor of information sciences and technology, and **Jia Li**, professor of statistics, have developed an algorithm that analyzes the arrangement of visual elements -- the composition -- of digital photographs. It also offers feedback and provides examples of similarly composed pictures of high aesthetic value. The researchers recently received a patent for the system.

Training a machine to become an art critic is not easy. A machine must be trained with examples of highly-regarded photographs in order to recognize good compositional elements, says Li.

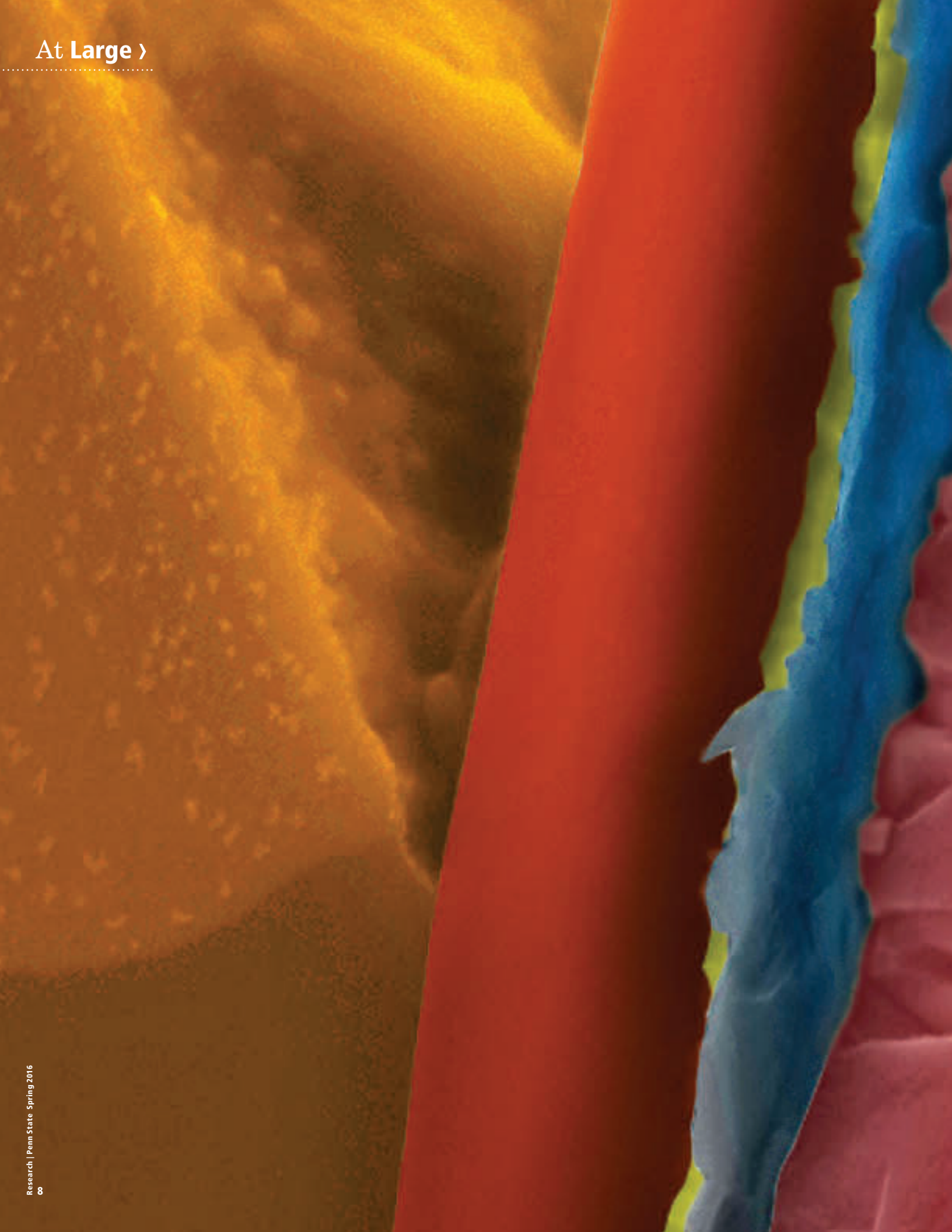
The software the team developed relies on psychological theories of human vision, including Gestalt psychology, as well as on the opinions of people to help classify images.

"Aesthetics is, of course, subjective," says Li. "What one person might find pleasing may not be pleasing to another, but there are elements that many good photos have in common."

The software performs a pixel-by-pixel analysis to extract features from a photograph and then uses statistical analysis to classify and compare it to pictures judged to be highly aesthetic.

Wang says he doubts the application will replace photographers any time soon. "Our goal from the beginning was to *help* photographers," he says.

—MATT SWAYNE



CAKED LAYERS ‹‹

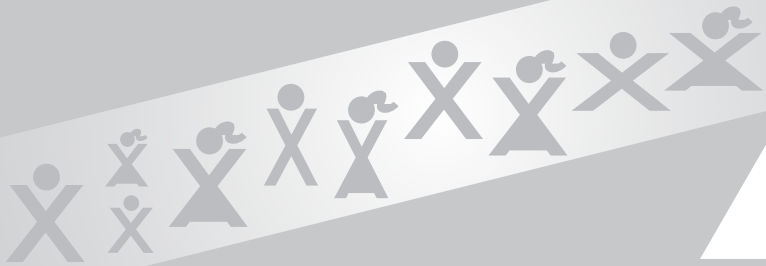
A COLORIZED IMAGE FROM A SCANNING ELECTRON microscope reveals the layers in a thin film designed to be part of a miniature ultrasound device that could be used to detect cancers of the skin or eye. The deep pink portion at right, made of lead, titanium, and zinc, converts pressure changes into electricity. A layer of platinum (blue) transfers the electrical signals to a wire or other structure. Titanium oxide (chartreuse) makes those layers stick to silicon dioxide (deep orange) that rests on a silicon wafer (gold). Etching has removed portions of the wafer, freeing small areas of the film to vibrate, like a drumhead, in response to ultrasound waves. The blue layer is 100 nanometers thick. The film and image were created by Flavio Griggio during his graduate work with **Susan Trolier-McKinstry**, director of the Smart Materials Integration Lab.

Photo by: Flavio Griggio

GLEANING MEANING

The Methodology Center invents ways to answer thorny questions about human health and behavior.

BY SARA LAJEUNESSE



TWO TEENAGERS TRY CIGARETTES AT A PARTY. A few years later, one has become a pack-a-day smoker. The other smokes now and then. Why is one addicted to nicotine, while the other can take it or leave it?

These types of questions can be almost impossible to answer given the many factors—age, diet, stress level, family history, socioeconomic level, and so on—that influence human health and conduct.

"If you're studying plants, you can set up the experiment so the plants are all the same except for the one variable you want to study," says **Linda Collins**, director of the Methodology Center in the College of Health and Human Development at Penn State. "Plants also won't get up and walk away, or refuse to participate in the study. But humans are complex creatures; they're difficult to study."

Collins and her colleagues in the Methodology Center invent new ways to design experiments and analyze complex data, often adapting existing statistical methods and applying them, for the first time, to thorny problems in behavioral and medical science. Their work enables scientists at Penn State and around the world to answer questions that could not have been answered before.

FINDING WHAT WORKS

Center researchers expanded the use of a technique called latent class analysis to study links between teen alcohol use and sexual activity. The technique, which allows investigators to identify potentially significant subgroups within a population of interest that are not immediately obvious, helped them pinpoint what drinking

Patrick Mansell

Linda Collins (l) and Stephanie Lanza

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behaviors are more likely to lead to risky sexual behavior by teens. Now, Center researchers are pioneering methods to create an online intervention to prevent those behaviors in college students. Their ultimate goal is to curb the spread of sexually-transmitted infections.

"First, we want to determine the effectiveness of the various components of the intervention," says Collins, who is leading the effort. One component is a lesson on how to stay safe while having a good time. Another describes the behavior of participants' peers regarding alcohol use and unprotected sex.

Collins and her colleagues assign all possible combinations of the components to different study participants. They then survey participants before, during, and after the assigned intervention to see which components have the best outcomes regarding alcohol use and sexual activity. The researchers will then revise or eliminate the components that are less effective, and repeat the experiment, eventually zeroing in on the best combination. "After it's tested and we have a final product, the intervention could potentially be implemented widely in universities across the nation," says Collins.

SHARING THEIR SKILLS

The Center offers resources for scientists through its website, including instructional videos and software programs that are available as free downloads, and provides training in the form of courses, seminars, and workshops for faculty and graduate students at Penn State and elsewhere.

"Our students learn to speak the languages of statistics, behavioral science, developmental research, and prevention simultaneously," says Collins. "Being able to walk in all those worlds is really valuable. When they graduate they're at a big advantage for jobs."

The center's work is especially valuable for medical and social scientists trying to bridge the gap between research and practical application. For example, half of those addicted to opiate analgesics—morphine, methadone, and oxycodone—relapse within three months of being released from a drug rehabilitation center. The sooner those individuals can be identified, the sooner their treatment can be adjusted to make relapse less likely. Is it possible to predict who will relapse and who won't, as early as their first days in rehab?

Roger Meyer, professor of psychiatry at Penn State Hershey Medical Center, thinks it is.

"Our hope is that by examining changes in patient mood, stress, craving for drug, and sleep we will be able to predict with 90 percent accuracy which patients are likely to relapse, so we can do a better job of helping treatment facilities help patients," he says.

Meyer is working with **Stephanie Lanza**, scientific director of the Methodology Center, to gather the complex data needed to reveal who is most likely to relapse. They are using a time-varying effect model, which Lanza created with Center investigator **Runze Li**, to examine differences in relapse rate associated with a variety of factors that shift over time. Ultimately, the team hopes to provide rehabilitation centers with tools that will enable them to better assist their patients.

This project would not be possible without the Center's unique expertise, says Meyer. "What Stephanie and the other researchers in the Methodology Center can do statistically is on the cutting edge. They provide tremendous value to other researchers and are a critical bridge to translational research in clinical medicine."

For information on Methodology Center seminars and workshops, go to methodology.psu.edu/training

Linda Collins is Distinguished Professor of Human Development and Family Studies and professor of statistics. Stephanie Lanza is professor of biobehavioral health; Runze Li is Verne M. Willaman Professor of Statistics and professor of public health sciences. The Methodology Center is a National Institute on Drug Abuse Center of Excellence.

THE GENESIS OF PRAYER

ראשית תפלה

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BY CHERIE WINNER

THE HEBREW BIBLE PROVIDES TEN COMMANDMENTS ABOUT FUNDAMENTAL MORAL ISSUES AND MORE THAN 600 LAWS ABOUT ALMOST EVERY ASPECT OF JEWISH RELIGIOUS PRACTICE, FROM WHAT MAY BE EATEN TO CARING FOR THE POOR.

But that long list of rules has a curious omission, says Penn State scholar **Daniel Falk**.

"There is not a single law about prayer," he says. "No law governing what time you should pray or what you should pray."

A few hundred years B.C., communal prayer was not part of regular Jewish observance. It's not that people didn't pray, says Falk. They prayed often, both alone and in groups, but mainly in response to specific situations. They cried out to God for help in times of distress and they offered prayers of thanksgiving in times of great joy. But to gather every day for prayer, as a regular practice, was probably not done. It was certainly not required by religious laws.

By around A.D. 200, when the compilation of Jewish law known as the Mishnah appeared, that had changed. The first line of the Mishnah asks, "From what time in the evening must one recite the Shema?"

"It *begins* with a law about prayer!" says Falk. "Not only that you should pray, but that you should pray at a certain time and you should pray a certain prayer. If you jumped straight from the Hebrew Bible to that, you would wonder, 'I didn't even know I was *required* to pray.' "

The duty to pray fell on communities as well as on individuals. Sabbath services, which in earlier times featured prayers by religious leaders, now involved specific prayers by the entire congregation. No special circumstances were required: The community prayed together weekly and even daily as a matter of course, regardless of outside events.

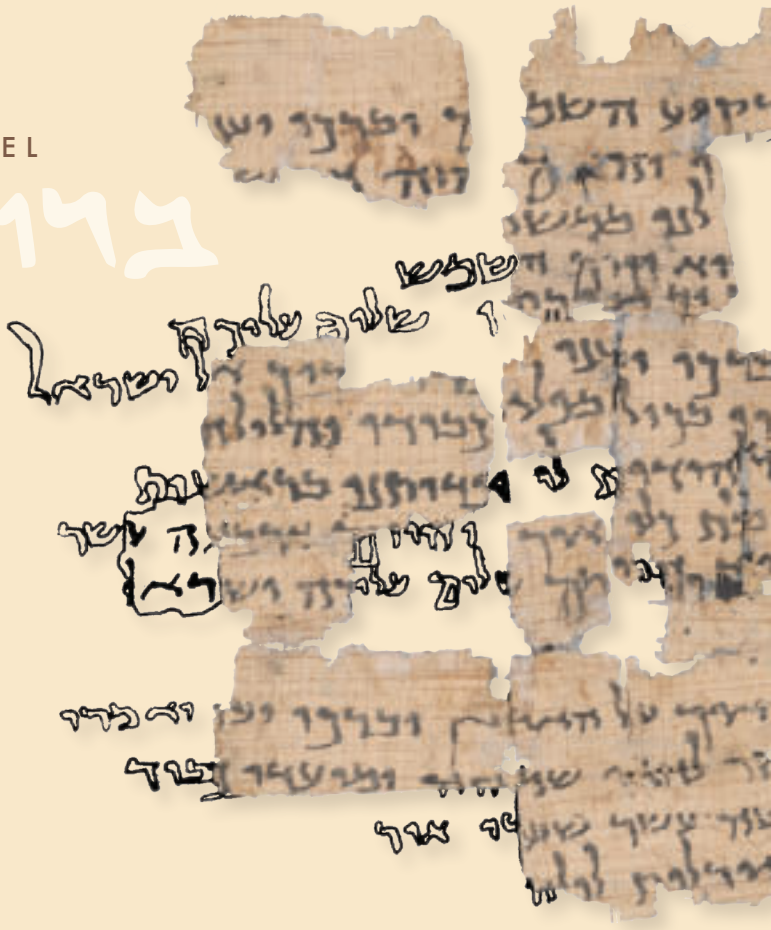
"The obligation on the people—not on officials—but that *the people as a whole* have an obligation to honor God and to bring the community needs before God in a disciplined fashion, is really quite remarkable," says Falk. "There's been some massive religious revolution, and we know almost nothing about how or when that came about."

Courtesy of The Leon Levy Dead Sea Scrolls Digital Library; IAA, photo: Shai Halevi

Ancient writings found in caves near the Dead Sea—some on bits of parchment that look like burnt toast—offer clues to the origins of communal prayer.

BLESSED BE THE GOD OF ISRAEL

בָּרוּךְ אֵל וְיִשְׂרָאֵל



FRAGILE FINDS

Falk, a professor of classics and ancient Mediterranean studies, looks for insights into the development of Jewish prayer in the collection of ancient documents known as the Dead Sea Scrolls. Written over a span of more than two hundred years, gathered and protected by a small community in a desert outpost in the kingdom of Judea, the scrolls are a window onto what was happening in the larger society at the time. They contain the earliest-known versions of many of the texts that later became standard parts of the Hebrew Bible (known to Christians as the Old Testament). They also contain hymns, commentaries, and hundreds of prayers.

The scrolls were discovered in the late 1940s in caves near the ruins of a settlement called Qumran, along the northwest shore of the Dead Sea. Scholars estimate the total number of scrolls to be over 900, of which about 90 percent are parchment made of animal skins. The rest are made of papyrus. The scrolls range in size from about four inches high and a couple of feet long to what Falk calls "deluxe versions" about 18 inches high and 30 feet long.

Photographs and paintings of the caves often show tall ceramic jars that were used to store the precious documents. Unfortunately, only about one percent of the scrolls were found, relatively intact, inside jars.

"The vast majority were just in tatters on the floors of the caves," says Falk. "So they were in caves, which protected them, but some caves protected them better than others. There were bats in there, and wild animals, and the bat excrement and urine and insects and all this did a real number on them."

By the time of their discovery, many of the scrolls had fallen apart. Many of those made of papyrus had disintegrated into fragments no bigger than a thumbnail. Tens of thousands of fragments were removed from the caves, mostly by resourceful Bedouin, and somehow survived their convoluted paths to museums and private collections. Today, most of the Dead Sea Scrolls reside at the Shrine of the Book, a museum and study center in Jerusalem.

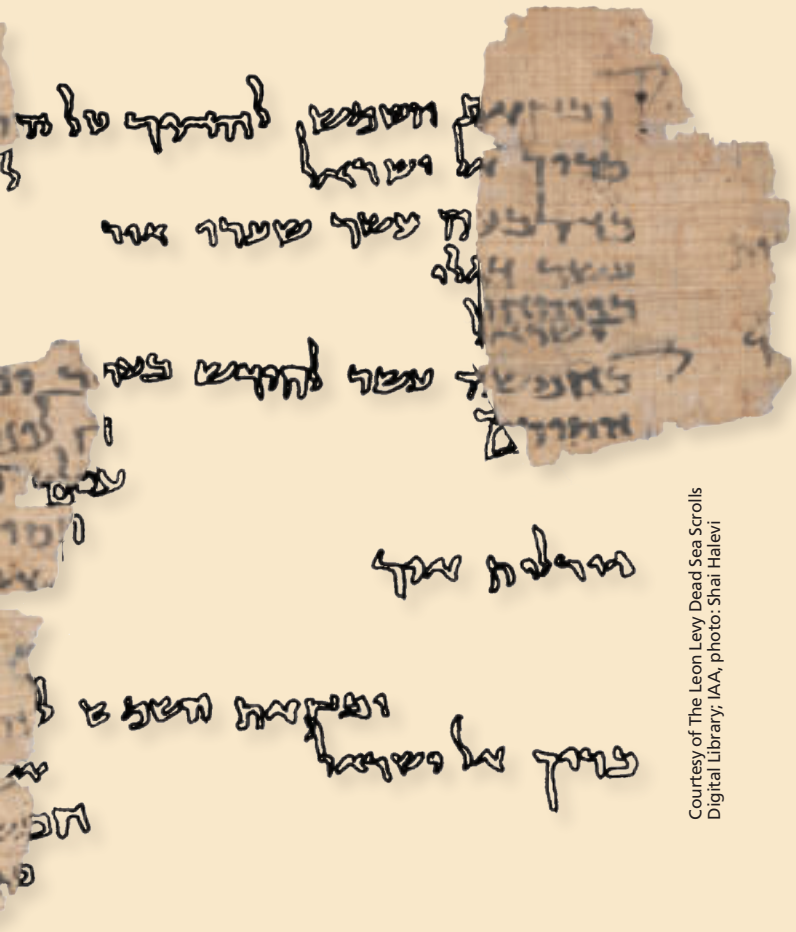
Falk began studying the scrolls as a graduate student at Cambridge University in the early 1990s—just the right time, it turns out. In the decades since their discovery, access to the scrolls had been tightly controlled by a small committee of experts.

"There were scholars who had gone their whole career working on the scrolls, and never actually got to see them," he says. By the late '80s, pressure from academics and from a public fascinated with the ancient texts had begun to pry open the gates, giving access to a whole new generation of researchers.

Falk's first project focused on two fragments of a skin scroll. The originals had turned dark—a natural reaction of aging leather—and "were almost totally useless," says Falk. "They looked like burnt toast."

To get a better look at what was written on the blackened scrolls, conservators photographed them under infrared light, which produces a black and white image that makes the writing much clearer. The images available to Falk at the time were grainy thumbnail copies of infrared photos. He enlarged and edited those, a process that involved translating, grappling with missing or unreadable chunks of text, and interpreting what they said.

When he presented his work to other researchers in the field, the leader of the Dead Sea Scrolls Publication Project invited him to join the project. He has been a member of the International Team of Editors of the Dead Sea Scrolls ever since.



Courtesy of The Leon Levy Dead Sea Scrolls Digital Library; IAA, photo: Shai Halevi

Badly-degraded papyrus scrolls are pieced together by lining up fibers in the papyrus and common phrases in the prayers inscribed on them. Here, Penn State scholar Daniel Falk has filled in some of the gaps in a prayer text. The phrase "Blessed be the God of Israel" (added by Falk at lower right of illustration) was often used at the beginnings of prayers.

BOTH SIDES NOW

Today Falk works primarily with papyrus scrolls. Papyrus doesn't darken with age like leather, but it doesn't hold together as well, either.

"A lot of the texts I'm very interested in are in really horrid shape, just hundreds and hundreds of little pieces," he says. Not only that, but some of the papyrus fragments have writing on both sides. Such two-sided scrolls, called opisthographs, were found in significant numbers at Qumran, but are extremely rare elsewhere.

Daniel Falk

Patrick Mansell

"I've talked with other papyrologists about this, and it's almost unheard of," says Falk. "You do find re-use, but in almost all other cases in the ancient world, it's re-use of something which was deemed to be garbage." With the Qumran documents, the religious texts on both sides were read and used during the same period. The two sides were usually written by different hands, in some cases as much as 100 years apart. "So someone has a scroll of prayers [recorded by someone else], but then chooses to copy another prayer on the back side," he says. "I've hypothesized that this is a personal collection—someone's making their own prayer scroll."

He thinks many of the one-sided prayer scrolls might also have been personal books rather than community resources. They're small enough to be carried in a pocket, and they have more corrections and less-polished writing than the bigger, better-executed scriptural scrolls. Falk calls them "budget scrolls."

Taken together, the prayer scrolls reveal a religious group for whom prayer had become a required part of daily life. While modern synagogue practice uses many of the same prayers every day, with something added for special occasions, the Qumran community had "an entirely different prayer for every single occasion, for every day of the week, for every month, for every festival," says Falk.

The prayers feature motifs common in synagogue prayer today, including pleas for the restoration of Israel and for God to remember the history of his dealings with Israel and have mercy on the people. The themes of sin, redemption, and God's grace, often considered hallmarks of Christian worship, are also prominent. In his classes, Falk sometimes presents writings from the Christian apostle Paul and the Dead Sea Scrolls side by side, with identifying words removed, and asks his students to choose which is which. They find it very hard to do.

"We think of Paul as talking about 'grace' over against 'law,' and that you can't earn favor with God. You have exactly that language in these prayers," he says. "Their approach to prayer is not 'I'm entitled to this.' They're really overwhelmed with their human frailty before God, and they're struck with awe that God would accept them. They say, 'There's nothing that we could do to earn favor with God; I am but a worm.' They sound almost Lutheran."

PEACE BE ON YOU ISRAEL

שלום עליכם ישראל

WHO WERE THE QUMRANITES?

As Falk read more of the scrolls and understood more about the prescribed cycle of prayers at Qumran, he started asking broader questions about what that way of worship meant for the community.

"Why would this way of life appeal to people?" he says. "It must have meant something. It must have worked for them, made sense of the world. So then I wanted to get at: How did prayer fit in there?"

Even in its heyday, Qumran was not a large settlement—its water supply could have supported 200 people, at most. The site today includes the caves where the scrolls were found and the ruins of several stone buildings.

"There's not a lot to see," says Falk. "You have to really use your imagination as to what this looked like and what it was like to live in. They mostly lived in caves or tents. The buildings seem to be all communal space."

The residents kept livestock and tended crops, but their main activity was religious devotion. Active for about 200 years, from roughly 130 B.C. until A.D. 69, Qumran was not an all-male enclave, as it has sometimes been depicted in popular accounts. Its cemetery has about 2,000 graves, of which 50 or so have been excavated by archaeologists. Most, but not all, of the bodies laid to rest there were men.

Who these people were and how they fit into the larger society in Judea at the time are still something of a mystery. They're often referred to as "Essenes," a Greek term that Falk is not entirely comfortable with.

"We have no texts where a group calls themselves Essenes," he says. In the scrolls, the people of Qumran call themselves the Sons of Light or the Children of the Renewed Covenant. Falk thinks they probably were related to the Essenes that were described by first-century Jewish historian Josephus and others, and that Qumran was either an offshoot of the larger movement or a sort of hub or retreat center where people whose primary home was elsewhere would come to stay briefly to fulfill a vow or other religious duty.

According to Josephus, Essenes were the most populous Jewish sect in Judea, numbering about 4,000. Their religious teachings were more strict than those of other Jewish groups, such as the Pharisees. The people at Qumran may have been even more legalistic in their interpretation of Jewish law, but were clearly related to the Essenes, Falk says.

"I have little doubt that if you could take Josephus by the hand and show him Qumran, and show him these texts, and ask, 'Are these the type of people you're talking about?' he'd say, 'Yeah, yeah, those guys!' "

APOCALYPSE THEN

Josephus didn't say a lot about the Qumranites' religious beliefs, other than to note their unusual practice of communal prayer at dawn. The scrolls reveal that in fact the Qumran community prayed together at both dawn and sunset, every day of the week. Falk thinks that practice stemmed from their belief that the world was engaged in an apocalyptic conflict between the forces of good and the forces of evil. The War Scroll, one of the best-preserved of the Dead Sea Scrolls, describes this battle, and many of the smaller prayer texts can be read as metaphors for it.

"They'll talk about day and night as the dominion of light and the dominion of darkness—exactly the same language they use in the cosmic sense of the dominion of good and the dominion of evil," he says. "You read the prayer texts, and they're talking about troop formations, gates, stations, rows, the good angels, and the bad angels. Coming out of this is a very active sense of the community under spiritual bombardment from these evil angels."

The warring angels were not winged cherubs or the souls of people who had died, but ferocious beings who did God's bidding. God controlled both sides; there was no Satan-like figure operating independently of God. The Qumranites believed that their present time was dominated by evil, and that until God eventually destroys the kingdom of darkness, it was their duty to fight for the forces of good.

And that is the key to what prayer meant for this group, says Falk. Scheduled group prayer was the community's way of joining the battle. Their prayers were their weapons.

"The way they actually carry on active war, both defensive and offensive, was through prayer," he says. "They're defending those boundaries between the kingdom of light and the kingdom of darkness."

COMING TOGETHER

Not all the prayers in the Dead Sea Scrolls deal with the cosmic conflict. All the types of prayer found in modern synagogue service are there, as is an elaborate schedule of

(Top) Side-by-side images of a parchment fragment photographed in visible light and in infrared, which makes parts of the original more legible, allow Daniel Falk to transcribe the text on the fragment. Photo by Patrick Mansell. (Bottom) Infrared image of the same fragment shown on page 13 and on the cover. Courtesy of The Leon Levy Dead Sea Scrolls Digital Library; IAA, photo: Shai Halevi

services, with the community gathering daily and on Sabbath and festival days to offer prayers as a group.

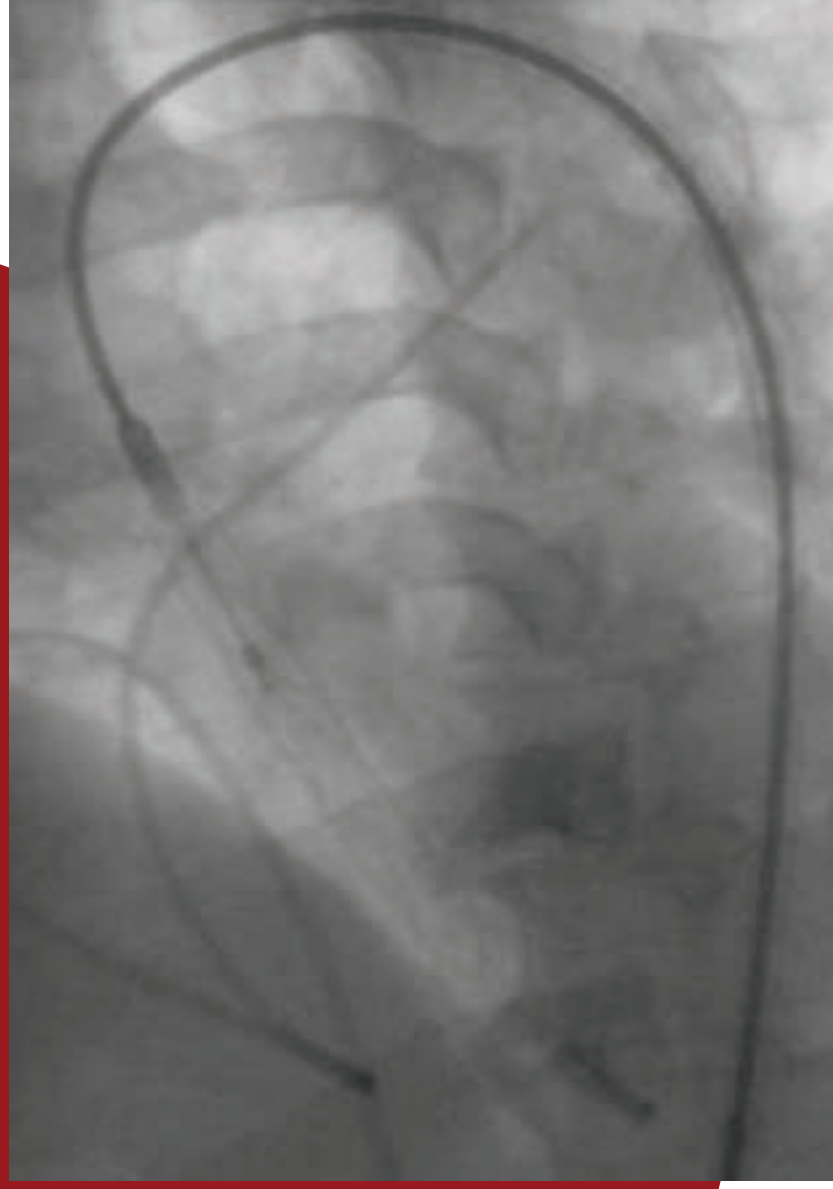
So by about the time Qumran became active, the major steps toward the kind of communal prayer and worship we're familiar with today had been taken. The group at Qumran probably didn't invent all those steps, says Falk, and the scroll prayers, some of which predate Qumran by a century or more, probably reflect developments in the larger Jewish community. However, so far we have no evidence that any other Jewish group of the time had daily communal prayer. "Which is quite a surprise for many, who tend to assume that what we see in synagogues today is roughly what was happening then," he says. "There is not a shred of evidence of that. This community may have been the first one to bring together a whole comprehensive cycle of prayer."

Unless earlier records are found, the Dead Sea Scrolls will remain our main source of information about the development of Jewish prayer, and much work remains to be done on the scrolls: piecing together more fragments, correcting previous errors in assembly, reaching agreement on their translation and meaning, and figuring out where the writings fit in the larger picture of the community's religious practice and, ultimately, what they mean for us today.

"Even in synagogue liturgy, prayer doesn't have the same meaning as it does for this group, where they're carrying on this cosmic battle," says Falk. "I think for them prayer as warfare was very meaningful and very real. They had a sense, which I think was carefully nurtured, of joining with the angels"—and in the process, they helped establish a form of group action and a way of relating to God that influenced later religious practice throughout the world.

"It's a stunning innovation, the idea that the whole community should gather regularly and pray," he says. "It was that form of worship that was directly taken up and continued in Christianity and Islam. One can argue that that form of worship is one of the most powerful influences on Western society, in terms of how communities work together."

Daniel Falk is professor of classics and ancient Mediterranean studies and the Chaiken Family Chair in Jewish Studies. He was recently chosen to be one of three co-editors of Dead Sea Scrolls Editions, a massive international project that will produce fifteen volumes over the next several years. The books will feature new critical editions made possible by improved reconstructions and new photographic techniques, and will include some previously unpublished texts.



"THIS IS THE FIRST DEVICE THAT ALLOWS A CARDIOLOGIST OR TECHNICIAN TO IMMEDIATELY STABILIZE SOMEONE WHO HAS HAD A SERIOUS HEART ATTACK."

IN A HEARTBEAT

BY KRISTA WEIDNER

(Top) X-ray of the new heart pump in a patient. The dark, curved structure is the power cable for the device. (Right) The pump on a mold of a left ventricle, in the same orientation as on the x-ray above. (Left) The tube housing the pump is just 3 mm in diameter before insertion. When it reaches the heart, it expands to allow the pump blades inside to start spinning. Photos courtesy of Rob Kunz.

"THIS DEVICE IS A TURBOMACHINE, JUST LIKE THE PROPELLER ON A SUBMARINE."

IN THE MOMENTS AFTER A HEART ATTACK, EVERY SECOND COUNTS. Medical professionals need to act quickly to stabilize the patient and prevent further damage to the heart. Often, that means opening up the chest cavity—a complex and traumatic procedure—and implanting a left ventricular assist device (LVAD) to help the weakened heart muscle keep pumping blood throughout the body.

Thanks to a new type of LVAD developed by Penn State researchers, such an invasive procedure might not be necessary for some heart patients. The tiny Heartmate PHP (percutaneous heart pump) is inserted into the femoral artery in the thigh and threaded up through the body into the left ventricle, where it keeps the blood flowing and thereby allows the heart to begin to heal right away. Recently approved for use in Europe, the device is currently undergoing trials for FDA approval in the United States. Once certified for use here, the pump has the potential to prolong the lives of tens of thousands of people each year.

"This is the first device that allows a cardiologist or technician to immediately stabilize someone who has had a serious heart attack," says **Robert Kunz**, principal investigator for the project. "Up until now, there was no question that if the patient's heart stopped, the surgeon was cracking open the chest and going in. This pump is designed to be inserted, deployed, and operating within minutes of a patient suffering a heart attack. It buys some time, several days up to a couple of weeks, for the doctor to assess the situation—to say 'We're good for now' while determining next steps."

Kunz is not a surgeon himself. He's an aerospace engineer, which at first blush may seem like an improbable match with biomedical research. But in fact, the six-millimeter-wide blood pump is essentially a miniature propeller, and Kunz and his research team applied the same suite of strategies and tools to developing the pump that they use for designing submarine and torpedo propellers. "This device is a turbomachine, just like the propeller on a submarine," Kunz says. "When it comes to fluid dynamics, the equations are the same—no matter what the fluid. In this case it's blood."

Work on the heart pump began in 2004, when Kunz and his research group were approached by Datascope, a medical technology company, to collaborate on the project. A multidisciplinary team including fluid dynamics researchers, materials scientists, engineers, structural mechanics experts, and machinists started designing prototype pumps as well as heart models to measure performance.

The pump's components include a tiny, rapidly spinning, collapsible impeller that is housed within a collapsible cannula, or tube. With an elastic consistency similar to that of a pencil eraser, the impeller's blades can fold down for insertion into a three-millimeter-diameter sheath, yet are firm enough to pump more than four liters of blood per minute with a pressure rise of one-tenth of an atmosphere–the capacity of a healthy adult male's heart. "Once the cannula has been threaded through the femoral artery into the heart," Kunz explains, "a cardiologist pulls a control cable to push it out and—poof—it deploys and the impeller expands to about six millimeters and starts spinning."

Because of its small diameter, the impeller has to spin fast: nearly 20,000 revolutions per minute (RPM)—more than half the rotation rate of the space shuttle's main engine. And that poses a challenge: Putting a spinning propeller into relatively stagnant blood spells trouble for red blood cells, which are critical for carrying oxygen. The researchers had to figure out a way to minimize red blood cell damage, which reduces their ability to transport oxygen and releases hemoglobin, which can harm kidneys and other organs.

"We knew we had to distribute the power that we were adding to the blood in a way that wouldn't cause a lot of shear, which is stress encountered by the blood cells as they're flowing through the impeller blades," Kunz says. "So we went through several designs, revising the shape of the blades according to our results. Some of our early designs were terrible—they just demolished the blood. Gradually we improved it, contouring the blades, reshaping the tip, adjusting speed."

The final product can be a lifesaver for heart attack sufferers, allowing the heart to function while the patient awaits heart bypass surgery or a heart transplant. In the best-case scenario, a patient can heal on his own and be weaned off of the pump. The pump can also provide support during a heart catheterization procedure, Kunz says. "Catheterization can be traumatic to the heart and can cause things to get worse, and the pump can be a valuable just-in-case measure."

For Kunz and his team, creating the Heartmate PHP provided a new opportunity to pursue technologies outside their normal expertise, including circulatory system physiology, blood cell mechanics, and biochemistry. "This was an exciting project for us," Kunz says. "We look forward to the day when it's in the marketplace in the United States, saving people's lives."

Thoratec, one of a few companies in the world that sees blood pump devices through manufacturing, development, and clinical trials to commercialization, bought the blood pump project from Datascope in 2011.

Robert Kunz, professor of aerospace engineering, is senior scientist and head of the Computational Mechanics Division at Penn State's Applied Research Lab.

ECOLOGIST **CHRIS UHL** WENT TO BRAZIL TO SEE THE DESTRUCTION FIRST-HAND. TWENTY-FIVE YEARS LATER, HIS RESPONSE HAS BORNE AMAZING FRUIT FOR THE AMAZON RAINFOREST – AND THE WORLD.

Courtesy of Imazon

NOW

THEN

Joel Sartore/www.joelsartore.com

BACK TO THE FOREST

BY DAVID PACCHIOLI

"TAKE A GAS MASK."

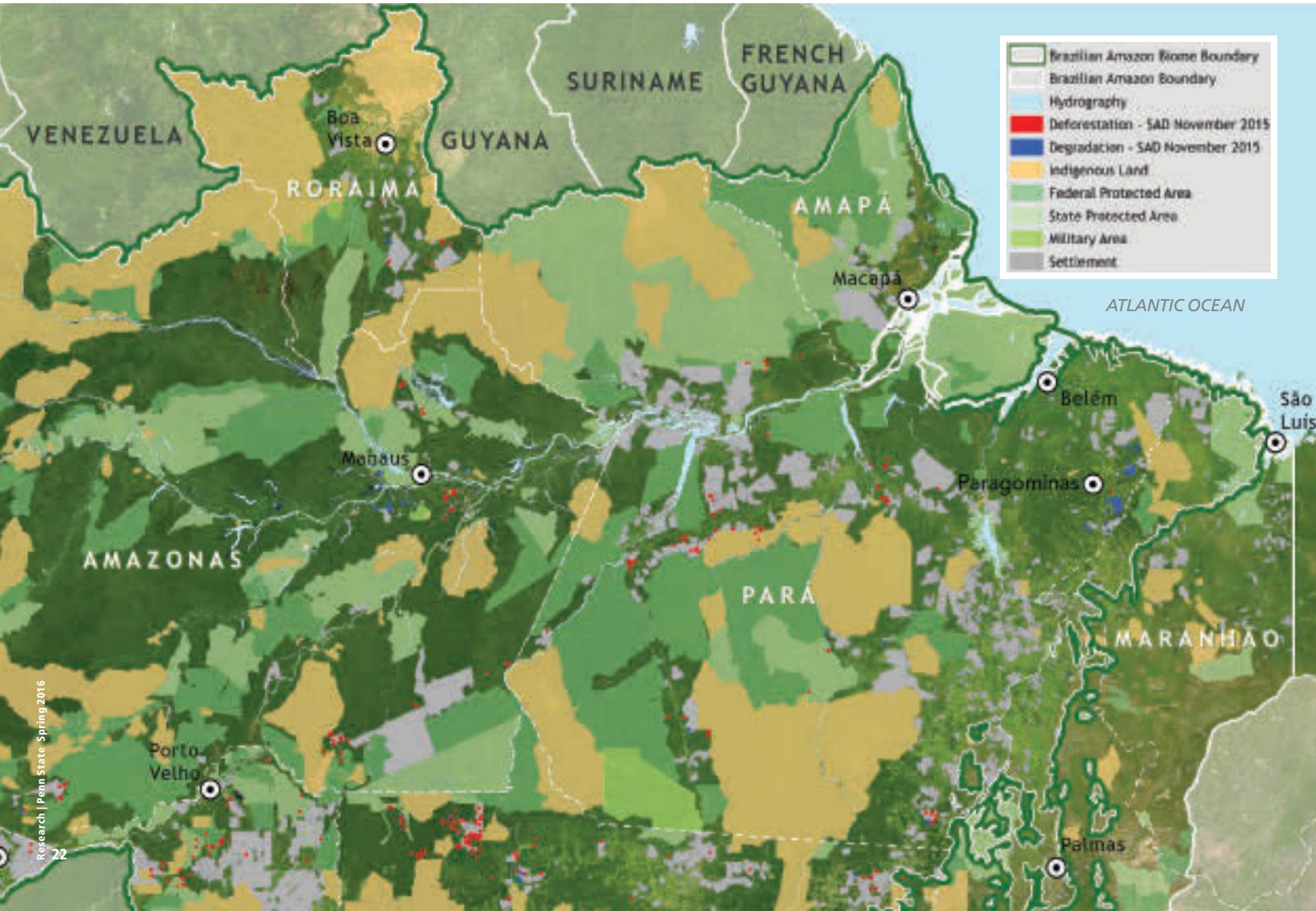
THAT WAS THE BRUSQUE ADVICE I GOT AS I BOARDED THE BUS FOR PARAGOMINAS. THE YEAR WAS 1996, AND PENN STATE ECOLOGIST CHRIS UHL HAD INVITED ME TO BRAZIL TO VISIT IMAZON, THE SMALL RESEARCH INSTITUTE HE HAD FOUNDED NEAR THE MOUTH OF THE AMAZON.

The prospects for the rainforest seemed bleak, and Uhl wanted me to witness the epicenter of that bleakness. In an article for this magazine, I described arriving in Paragominas late at night:

The sharp smell of woodsmoke began to seep through the bus' sealed windows. Outside, the night sky was nearly black, but the hanging smoke was even blacker. Soon, in the hills on either side of the highway, there began to appear a strange orange glow, as if the hills themselves were burning. These, I realized, were the mounds of burning sawdust.

Chris Uhl and guide on the Amazon River near Belém, 1996. Courtesy of Imazon

(Below) Deforestation report for the Brazilian Amazon, November 2015. Imazon's Deforestation Alert System detected 99 square kilometers of deforestation in the region during that month, indicated in red. The group's monthly reports have been critical to enforcement efforts against illegal deforestation activity. Courtesy of Imazon



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"IT WAS WAY TOO EARLY TO WRITE OFF THE AMAZON AS A SYSTEM THAT WAS IRREVOCABLY DAMAGED."

At the time, Paragominas boasted well over 200 operating sawmills, many of them illegal. It was the largest raw-lumber producer in Brazil, and a grim and violent place. A decade later, it would sit atop the federal government's "black list" of counties with the highest rates of deforestation.

That was then. Today, the smoke has cleared and the sawmills are gone, replaced by clean industry and manicured parks. Incredibly, Paragominas is officially a Municipio Verde, or "Green Municipality," a model for sustainable development. Deforestation there has essentially stopped.

Since 2004, in fact, there has been an 80 percent drop in deforestation across the whole of the Brazilian Amazon, a figure touted as the single greatest reduction of carbon emissions ever achieved by humankind.

This remarkable transformation is due to a convergence of factors, both political and economic. But Imazon, the innovative organization that Uhl willed into life 25 years ago, has played a critical role in bringing it about.

UNDERSTANDING THE PROBLEM

It started in the mid-1980s, when Uhl, a 35-year-old associate professor, and Dan Nepstad, a Yale grad student, found themselves working in the degraded pasturelands surrounding Paragominas. Uhl had considered becoming a medical doctor before getting his Ph.D., and was fascinated by the emerging field of disturbance ecology. "I was drawn to the areas that had been wounded," he says.

Prevailing wisdom held that those wounds would never heal, that the slash-and-burn practices of the loggers and ranchers flooding into the area would soon turn the fragile rainforest into a desert. After seven years on the ground, however, Uhl and Nepstad were surprised by the resiliency they saw. Given half a chance, the forest had the capacity to come back. "It was way too early to write off the Amazon as a system that was irrevocably damaged," Uhl says.

Their findings acutely challenged the status quo – and an overheated political climate made things even stickier.

"It was a difficult time in Brazil, especially in the Amazon region," says Adalberto Verissimo. Now Imazon's co-director, Verissimo was then an agronomy student from Brazil's impoverished northeast, keen to do whatever he could to save the rainforest. The military dictatorship that had held power since before he was born had just ended, and democracy was re-emerging. The country would soon have its first presidential election in a generation.

The building of the Trans-Amazonia highway had opened the interior to unprecedented development, but by the late 1980s government investment in the region had dried up, and the newly profitable logging industry had devolved into a free-for-all. "There was no government intervention, for good or for bad," Verissimo says. Meanwhile, rising criticism from abroad stoked anger at foreign interference.

A NEW KIND OF NGO

What was missing from that volatile mix, Uhl thought, was reliable scientific data. Very little careful work had been done on deforestation, and important facets of the problem had been misunderstood or ignored. Armed with a grant from the MacArthur Foundation, he and a colleague from the University of Wisconsin, Toby McGrath, conspired to start a new kind of non-governmental organization, or NGO. Instead of pushing political action, it would focus on research – but research squarely aimed at solving a dire real-world problem. Its sole purpose would be to provide the kind of high-quality information that Uhl believed would enable policymakers and other stakeholders to make environmentally conscious decisions, and stop the destruction.

The purity of his vision was regarded by many as naïve—even McGrath soon left the project. The best way to pull it off, Uhl decided, would be to draft young Brazilians fresh out of school, a dozen students whose idealism and passion might as yet be undimmed. But that choice presented huge challenges of its own, since Uhl's charges were as green as they were eager. Most of them, moreover, coming of age at such a turbulent time, had to be convinced that impartial research, not activism, was the surest way to effect change.

Not surprisingly, the first few years were a period of intense struggle. "It was the hardest time of my life," Uhl says. "My hair went from blond to gray in about three years." Verissimo, his first recruit, remembers it as a kind of boot camp.

"We spent a lot of time in the field, just understanding the reality of the forest," he says. "Getting close to the problem. This was something Chris stressed."

At the same time, they were getting a crash course in academic practice. "We were 20, 21, 22 years old, and we had to learn how to write papers that would be publishable in quality journals, how to present our work at conferences. It was a very high standard we had to achieve in a short period of time."

Uhl was inspiring, encouraging—and relentless. "We would do things 30 or 40 times before they were good enough," Verissimo says. And while they were earning their academic chops, they also had to learn to see beyond good guys vs. bad guys.

"It was not a conscious ideological choice," Uhl remembers. "Imazon was so field-based that if we wanted to learn about logging, we had to go out and meet loggers. When we did, we saw these men for what they were—tough, hard-working survivors, just trying to carve a life out of this wilderness. They cared about what they were doing, and they wanted to learn. There was a rapport that developed, based on this trust that was established face to face."

Instead of treating loggers as the enemy, the Imazon team undertook to help them, by demonstrating that logging could be done sustainably, with far less waste, and without sacrificing profit or the well-being of the forest. The team produced training manuals and best-practices videos grounded in painstaking comparative research. They developed a comprehensive forest-management plan that became widely adopted, and is still in use today.

TOOLS OF CHANGE

By the time I visited Brazil, the training phase was pretty much complete. The young scientists and policy analysts I met at Imazon's modest headquarters in the city of Belém were a formidable group. Several, including Verissimo and eventual co-director Carlos Souza Jr., would soon leave for the U.S. to start graduate training at Penn State. Their work had already started to transform logging practice, and given them a taste of success.

"The big card we had was that Imazon was respected," Uhl remembers. "The quality of the work, the seriousness of the researchers, their dignity, their poise—they were just a class act." In the ensuing years, these attributes would prove vital to the role the institute would play in shaping Brazil's environmental policy.

From the logging project, Imazon turned to a second major focus: identifying and prioritizing vast unclaimed areas of forest to protect them against haphazard development. "Nobody was talking about this at the time," Verissimo says, "but we realized that if we wanted to stop deforestation we would have to close the frontier."

Beginning in the mid-1990s, the institute produced a series of maps and reports proposing a tiered system of conservation units. When, in 2003, the federal government finally moved to create large-scale environmental reserves, Imazon's information proved vitally important. By 2006, nearly half a million square kilometers—an area well over the size of California—had been set aside for preservation.

At the same time, Imazon was pushing ahead in the area of remote sensing, pioneering the use of satellite imagery for essentially real-time monitoring of forest destruction. The Deforestation Alert System (SAD), spearheaded by Souza and launched in 2007, provides government agencies and the media with monthly reports of deforestation activity. The availability of these data has been a game changer, for the first time putting teeth into government enforcement efforts and enabling crackdowns on illegal logging and ranching.

SOMETHING FOR THE WORLD

In 2010, Imazon won the prestigious Skoll Award for Social Entrepreneurship, a major international honor. Its work has been celebrated in *The Economist* and the *New York Times*, and the latest iteration of the SAD is supported by a partnership with Google. Now 25 years old and with a staff of about 40, the institute recently expanded its monitoring efforts to include all South American countries that are part of the Amazon Basin, and Verissimo recently laid out an ambitious goal for the decade ahead: reducing deforestation to zero.

When he and Souza traveled to Oxford, England, to accept the Skoll Award, "there were a thousand people in the audience," Verissimo remembers. After the screening of a video describing their work, the researchers were treated to a standing ovation that went on for several minutes. "This told us we had done something important for the world, something that has resonance across the globe," he says.

Chris Uhl

Bernardo Esteves, Revista Piaui

MUCH OF IMAZON'S IMPACT CAN BE TRACED TO THE FOUNDATION UHL STRUGGLED TO BUILD.

Once a hellscape of rapid deforestation, Paragominas is now officially a Municipio Verde, or Green Municipality, a model for sustainable development. Since 2004, there has been an 80 percent drop in deforestation in the Brazilian Amazon.

Uhl, for his part, has not returned to Brazil since 1997. Having birthed Imazon and helped it gain its feet, he left and never looked back. The time came, he says, when he realized that his next call was to devote himself to raising ecological consciousness back home.

He has done that in several ways, first by leading a three-year student-driven research project that wound up laying the groundwork for Penn State's institutional commitment to sustainability, and then, over the last 10 years, by transforming BiSci 3, the basic environmental science course for non-majors, into something he likes to call "Awaken 101."

He marvels quietly that the organization he launched has had such an impact on the life of the rainforest. Yet much of that impact, Verissimo says, can be traced to the foundation Uhl struggled to build, and the culture he worked so hard to create.

"Get close to the problem. Focus on the long term. Anticipate trends. Offer solutions. Try to work across the aisle.

"These are the things Chris taught us," Verissimo says. "This is what we have always done. These are the elements of our success."

Chris Uhl is professor of biology.

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THE HOT AND COLD OF GROWING OLD

WHEN THE FIRST HEAT WAVE OF SUMMER ARRIVES, A GRIM TALLY WILL START: THE NUMBER OF PEOPLE WHO DIE AS A RESULT.

According to the Centers for Disease Control, we can expect high temperatures to kill nearly 700 people each year in this country alone, most of them over 70 years of age. The vast majority won't die of heat stroke, heat exhaustion, or dehydration. They will die of heart-related problems, including heart attacks and heart failure.

The reason, says Penn State physiologist **Larry Kenney**, is that we cool ourselves largely by pumping more blood to the skin, where the heat it carries can be lost to the environment. During hot weather, the increase in blood flow to the skin is huge, up to 20 times as much as in cooler weather. Even at rest, if we're very hot, we may be pumping nearly two gallons of blood to our skin every minute.

That creates a strain on the heart that can be a particular problem for older people, as their hearts work harder trying to pump more blood to the skin. To make matters worse, the blood vessels in older skin don't dilate as well as the vessels in the skin of younger people. They can't accommodate the greater flow and can't return as much blood to the heart.

"It's kind of a double-whammy," says Kenney. "Older adults don't pump as much blood to the skin, but the left ventricle is still trying to contract very forcefully to do that. So in some older individuals who have heart failure, who had had a heart attack, or who just have a weak left ventricle, all of a sudden they're putting much more stress on the heart"—sometimes with disastrous results.

BY CHERIE WINNER

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"WHILE SWEATING IS NOT ALWAYS DIRECTLY RELATED TO HOW OLD WE ARE, THE ABILITY TO CONSTRICT AND DILATE THE BLOOD VESSELS IN THE SKIN REALLY IS."

SWEATING THE DETAILS

Kenney has worked on the effects of age on temperature regulation since 1983, when he received his first National Institutes of Health grant for the research. Initially he focused on sweating.

"There was an old notion that as people age, sweat glands actually atrophy and don't function anymore—that the elderly don't produce as much sweat. That would lead to less evaporative cooling," he says.

His lab found that while we do tend to sweat less as we age, that's only partly due to age-related changes in the glands. It's also due to changes in our activities.

"Sweating as a means of thermoregulation is much more affected by aerobic fitness level, how acclimated you are to the heat, how well hydrated you are, whether you have a sedentary lifestyle, et cetera," he says—things that often *accompany* aging but are not directly *caused by* aging.

Those early studies showed, however, that the ability to lose heat through our skin *is* directly related to age.

"While sweating is not always directly related to how old we are, the ability to constrict and dilate the blood vessels in the skin really is," says Kenney. "So for the past 15 years or so, we've focused on that aspect of temperature regulation."

UNIQUELY HUMAN

Human skin responds rapidly and precisely to changes in both heat and cold, with tiny vessels called arterioles dilating or constricting to help dissipate heat or conserve it. The mechanisms that allow humans to achieve this precise control, and the magnitude of changes in skin blood flow, set us apart from our nearest relatives as much as walking upright and having opposable thumbs.

"It's a uniquely human system," says Kenney. "There's not any other animal that regulates their skin blood flow the way humans do." Some other mammals change the flow of blood to their skin, but by completely different mechanisms and often only in certain parts of the body. Rats control blood flow to their tails; rabbits change blood flow to their ears. But only humans increase skin blood flow over their whole bodies, and by such a large amount.

The rise in skin blood flow can be so dramatic that it increases the diameter of our limbs enough that Kenney can measure it with a strain gauge wrapped around a forearm. "It's very subtle," he says. "It's in the fractions of a percent change in circumference of the strain gauge—but the more blood that flows to that forearm, the more the strain gauge stretches."

In recent years, his lab has turned to laser techniques to more precisely measure blood flow in the skin. With laser Doppler flowmetry, a researcher shines a laser into an area of skin about the diameter of a pencil. Red blood cells flowing through tiny vessels there reflect the light. The amount of change in the reflection indicates how many red blood cells are moving through the area.

Another technique, laser speckle imaging, uses dots, or speckles, of reflected laser light to show relative changes in blood flow across a larger area of skin—an entire hand or foot, for example. "All pictures are made of speckles," Kenney says—think of pixels on a computer screen. "If it's a biological tissue, those speckles move and change, and they change with blood flow." He uses a special camera to track that movement in real time. In the resulting images, the speckles are color-coded to indicate how many of them were moving in each portion of the image. Areas of dilation (more flow) show up bright red and yellow, while areas where the vessels were constricted (less flow) are a calm dark blue.

COOL TOOLS

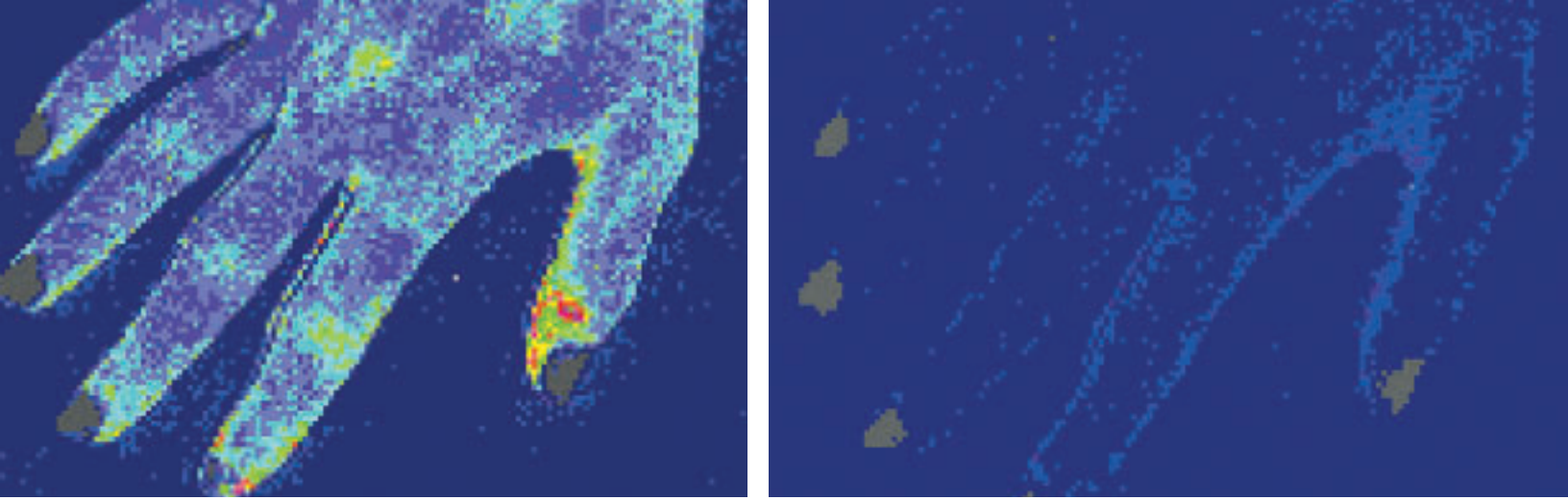
Because these large changes in skin blood flow and the molecular mechanisms that control them are unique to humans, Kenney can't use mice or other lab animals for his studies. He relies on human volunteers willing to be heated up or cooled down while exercising or going through other experimental approaches. For his experiments, the "older" category starts at age 65; some of his volunteers are in their 90s.

Volunteers often recline or sit, and can watch movies (comedies, mostly), read, or just hang out—unless they're in one of the studies looking at how well they dissipate heat generated by exercise.

In that case, they sit or recline on a clinical bed outfitted with pedals, something like a recumbent bicycle, or walk or jog on a treadmill. In some experiments, the subjects breathe through an apparatus that allows Kenney's team to measure cardiac output at the same time they measure skin blood flow.

The researchers most often make that measurement on the inner surface of the forearm. They place on the skin a small donut-shaped device that can heat or cool just the dime-sized area inside the ring. Kenney can then use one of the laser techniques to measure the blood flood in that area.

(Above) A volunteer reads while scientists test how blood vessels in her skin respond to various treatments. (Top) Four small rings placed on her forearm isolate the skin inside each ring from the skin around it. Tiny amounts of test substances are infused via thread-like microdialysis tubing inserted through the skin in each ring. The white cables lead to laser Doppler probes that measure skin blood flow at each site. A laser goes into the skin and is reflected by red blood cells moving through blood vessels in the area. The reflections are detected by the probe, and changes in blood flow are recorded on a graph. Photos by Patrick Mansell.



Laser speckle images of a hand with normal blood flow (left) and experimentally blocked blood flow (right). Brighter colors indicate more flow. Images courtesy Larry Kenney.

He can also infuse small amounts of a test substance just under the skin, to see how the substance affects flow and determine what molecules are involved in the process. Volunteers can have up to six rings set up on their arm at one time. That allows Kenney to compare blood flow under different treatments in the same part of the body, at the same time, in the same volunteer. "That's important, because if we compare my blood flow to yours, we don't know if a difference we see is because of the drug or just inherent variability in the way you and I respond," he says. "In our experiments, everybody serves as their own control."

Some experiments take place in two environmental chambers in Noll Laboratory that were specially built to study responses to environmental conditions. Each room has two layers of walls, one a couple of inches inside the other. Air that has been heated or cooled, humidified or dried, flows down from pores in the ceiling and back up through the space between the side walls, keeping the room at a constant temperature and humidity, with no hot or cold spots. Kenney can even add sun-mimicking lamps or make it "rain" inside the rooms.

"The range of temperature in here goes from about 40 degrees Fahrenheit to about 165 degrees Fahrenheit," he says. "We can also change the humidity from very dry to very humid, so we can simulate an Arizona day or a Florida day."

In other experiments, volunteers wear a water-perfused suit, a Lycra outfit that resembles scuba wear. It's the same kind of suit worn by astronauts and fighter pilots to help them stay at a comfortable and safe temperature. Sewn into the suit is a network of narrow tubing. During an experiment, cold or warm water is pumped through the tubing to lower or raise the volunteer's body temperature. A zippered flap in the suit gives researchers access to the skin on the forearm so they can measure blood flow under various conditions.

WHAT STOPS WORKING

Through dozens of series of experiments, Kenney, faculty collaborator **Lacy Alexander**, and their postdocs and students have explored why, as we age, the small vessels in our skin dilate less when we're heated up and constrict less when we're cooled. What, exactly, changes in older skin—and is there anything we can do about it?

They've found that one key is the small molecule nitric oxide (NO). Made in cells that line the blood vessels, NO plays a big role in vascular health in general.

"If there's a lot of nitric oxide present, the vessels are healthy and they're able to dilate appropriately," says Kenney. "If you don't have as much nitric oxide, the vessels are more constricted. That's what happens in hypertension, that's what happens with high cholesterol in some cases, and that's what happens in aging."

His group has traced the chemical pathways involved in nitric oxide production and found that at several steps, age-related changes limit the amount of NO we produce.

"With aging, multiple redundant changes occur in the skin, and they're all conspiring against the ability to dilate and constrict skin blood vessels," he says.

One of the most critical changes is a loss of BH4 (tetrahydrobiopterin), a cofactor necessary for the production of nitric oxide. Infusing BH4 directly into a small area of aged skin makes the vessels in that area respond like those of a 20-year-old, and taking BH4 in a pill enhances skin blood flow all over the body. Unfortunately, Kenney says, BH4 is made by only one company in the world and is very expensive—the yearly cost for one person would run into hundreds of thousands of dollars.

But he and former graduate student (now postdoctoral researcher) Anna Stanhewicz, who did the BH4 studies, realized that BH4 is chemically related to one of the B vitamins.

"There's kind of a back-door way for the body to create BH4, and that is by taking folic acid in our diet," says Kenney. Folic acid, also known as vitamin B9, can have serious side-effects when taken in too-large amounts, but it's readily available, and it's cheap. "We're talking about pennies," says Kenney. "So we're closer to identifying affordable intervention strategies."

DEEPER IMPLICATIONS

Age-related changes in the nitric oxide pathway and other control mechanisms also limit the ability of vessels in our skin to constrict, which in turn makes us less able to stay warm in cold weather. As we get older, winters feel colder. Fortunately, we have easy ways to compensate: Turn up the heat, put on warmer clothing, drink hot tea or cocoa.

Even if cold snaps make us more uncomfortable as we age, they are not as likely to kill us as heat waves are. Kenney says the ability of older people to cope with high temperatures will become even more important in coming years because of increasing numbers of elderly people—"over 80" is the fastest-growing demographic group in the world—and the rising temperatures associated with climate change.

"The effect on human health isn't so much that the *average* temperature on Earth is going up by a degree or a fraction of a degree every decade or so," says Kenney. "The real danger is that when the average temperature shifts, so do the extremes. An increase in global temperature is associated with more frequent heat waves and more severe heat waves, and there's a lot of evidence showing that that's happening."

Almost every summer in the past decade has brought at least one exceptionally deadly heat wave somewhere in the world. One of the worst hit Europe in 2003, during the hottest summer recorded in more than 400 years. Health officials reported that it caused 70,000 deaths, nearly 15,000 in Paris alone. Again, most of the victims were elderly.

Kenney's work on thermoregulation has led him so deep into the details of how fine vessels dilate and contract that its significance now reaches beyond people's ability survive a heat wave.

"It really plays into vascular health in general," says Kenney. "We're now using the skin circulation as a model for studying what's going to happen to the coronary arteries, what's going to happen to the carotids, what's going to happen to those bigger, more important vessels later on in life—because the changes we see in the skin precede and mimic things that happen with cardiovascular disease."

W. Larry Kenney is holder of the Noll Chair in Human Performance and professor of physiology and kinesiology, w7k@psu.edu.

(Top) Research associate professor Lacy Alexander helps a volunteer don a water-perfused jacket. (Middle) Tubing sewn into the jacket will carry warm or cold water, to raise or lower the volunteer's body temperature. (Bottom) Larry Kenney, director of the Human Thermoregulation Laboratory, says aging-related changes in skin circulation can tell us a lot about circulatory problems elsewhere in the body. Photos by Patrick Mansell.

SHOBA SIVAPRASAD WADHIA ON

IMMIGRATION

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Shoba Sivaprasad Wadhia is the founding director of the Center for Immigrants' Rights Clinic at Penn State Law. She spoke with editor Cherie Winner about her work and about some of the hot-button political issues involving immigration.

WHAT DO YOU THINK OF PROPOSALS TO BAR POTENTIAL IMMIGRANTS BASED ON THEIR NATIONALITY OR RELIGION?

We already have per-country caps in our immigration system. With individuals who are seeking a permanent visa through employment or family, no more than 'X' percentage of these visas can go to nationals of a particular country. We have not historically seen an outright ban on an entire religion. That, in many ways, is unprecedented—and it raises a host of questions ranging from whether it's constitutional to whether it can even work. I find it hard to believe that a court would uphold the constitutionality of a such a ban. Our refugee law protects people fleeing from persecution on account of race, religion, nationality, political opinion, or membership in a particular social group, so a ban would undercut our own principles around refugee protection. Many who are from countries like Syria are fleeing persecution, and we have obligations, both morally and legally, to protect them.

Patrick Mansell

WHAT ABOUT FEARS THAT SOME REFUGEES COULD BE TERRORISTS?

Fear has never been a good foundation for making immigration law or policy. The public deserves to feel safe and to have faith that our government adequately screens individuals before they are admitted into the U.S. Having said that, a proposal that prohibits immigration based on someone's religious practice is the wrong way to handle major questions of national security. We are not going to find the next terrorist by placing a religious test on people who are arriving in the U.S. In the case of refugees, they are *the* most-screened immigrant population to the U.S. Most refugees wait for two years or more before they are admitted. The refugee program would be the *last* program that a terrorist would try to use.

CAN INDIVIDUAL STATES IMPOSE THEIR OWN IMMIGRATION STANDARDS?

As a general matter, states don't have the legal authority to ban certain groups of people from entering and residing there, because immigration is a federal responsibility. But states can make the lives of immigrants more difficult. States and localities do play an important role in welcoming immigrants into their communities. It was heartening to see that our leaders in Pennsylvania have embraced Syrian refugees and stated publicly that they would welcome refugees here. That inclusivity is important for individuals who are leaving their homeland, who in some cases have spent a year or more in a refugee camp, afraid about their future and what comes next, who have maybe fled threats of death and violence and who just want safety for themselves and their family.

TELL ME ABOUT THE CENTER FOR IMMIGRANTS' RIGHTS CLINIC.

It's where law students step out of the classroom and take on a lawyering role by working on projects or individual cases related to immigration or immigrant rights. In an individual case, that might be interviewing a client, understanding the nuances of interviewing somebody who has no more than an elementary-school education, who is traumatized, and who doesn't speak English. For a policy project, it might include understanding the politics of a particular immigration issue, like asylum, and working in a professional manner with national nonprofits that we represent, in producing a white paper or a report on the issue.

YOUR BOOK IS ABOUT PROSECUTORIAL DISCRETION—WHAT IS THAT?

Prosecutorial discretion refers to a decision made by the immigration agency on whether or not to enforce the law against a person or a group of persons. There are up to 12 million people who are living in the United States without authorization, and the government has the resources to remove about 400,000, or less than four percent of that population. So it has to prioritize who will be a target for removal, and who will not. It's not terribly different from the criminal justice system, where a prosecutor is not going to bring charges against every single person who fishes without a license or who drives over the speed limit. A grant of prosecutorial discretion does not have the security of a formal legal status. I sometimes call it 'immigration purgatory.' It can be revoked at any time; it is a *temporary* protection from removal. It's still powerful to people who previously had been living under the shadows or who have been unable to work or drive. It opens all kinds of doors, even though it's not a permanent door.

Shoba Wadhia studies how decisions about immigration cases are made. Her first book, Beyond Deportation: The Role of Prosecutorial Discretion in Immigration Cases, *was published last year by NYU Press.*

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The Hot and Cold of Growing Old

Why do summers feel hotter and winters feel colder as we age? Can we do anything about it? Laser speckle image courtesy of Larry Kenney.

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