THE GREAT ECLIPSE OF 2017 PAGE 48 And what to expect for the next 1,000 years

SCIENTIFIC AMERICAN

SPECIAL REPORT
WHAT SCIENCE TELLS US ABOUT SCHOOL CHOICE
ON EDUCATION

THE NEW ORIGINS OF LIFE

Did volcanic hot springs harbor the first living organisms?

PLUS

BUILDING A BETTER HARVEST

How big data and microbes are reinventing agriculture PAGE 60

VOICES IN OUR HEADS

Our inner conversations reveal the hidden workings of the mind PAGE 68

REQUIEM FOR A PORPOISE

Scenes from a 21st-century extinction PAGE 30

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ON THE COVERS

When Charles Darwin suggested life on Earth began in a "warm little pond," he was not necessarily thinking of a volcanic landscape. Yet evidence from remote Australia, recounted in our story "Life Springs," indicates that ancient hot springs (*left*), geysers and calderas had the building blocks of early cells with potential to evolve. Compounds became concentrated in vesicles (*right*) made of lipids. Over time, heat and chemical energy caused the compounds in these vesicles to link into more complex molecular chains. **Illustration by Kenn Brown, Mondolithic Studios (*left*). Illustration by Mark Ross (*right*).**

COVER: CLADOGRAM DESIGNED BY DAVID HILLIS, ORIGINALLY PUBLISHED IN *LIFE: THE SCIENCE OF BIOLOGY*, 10TH EDITION.

Photograph by Christian Rodriguez

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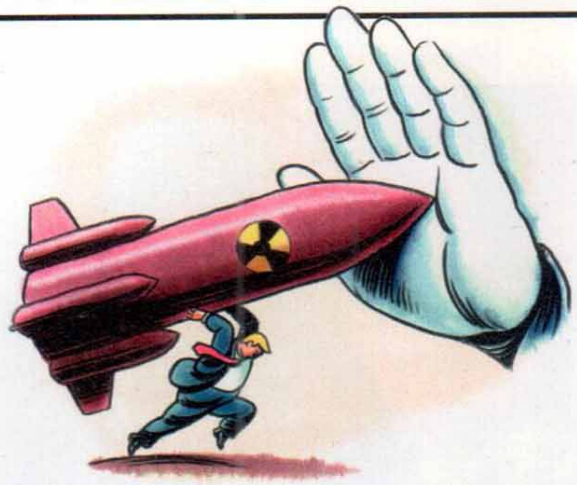

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ON THE WEB

Interactive Eclipse Portal
SCIENTIFIC AMERICAN has created an interactive map of when and where to view all the central solar eclipses occurring worldwide through the year 3000.
Go to www.ScientificAmerican.com/aug2017/eclipse

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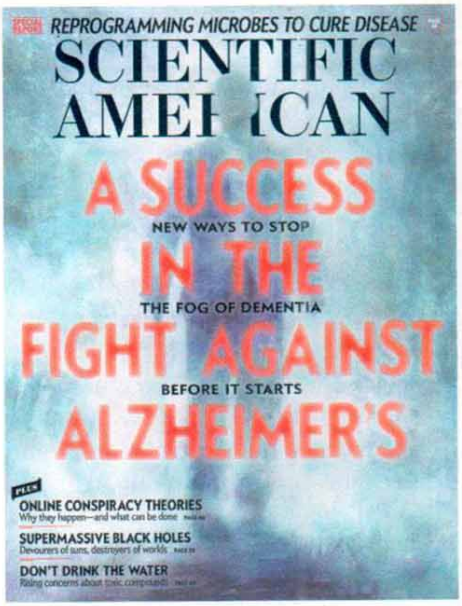


April 2017

"What can we do about how susceptible we are to conspiracy theories? I think we should focus on improving critical thinking skills in young people."

RICH DAVIS *RENTON, WASH.*

CATCHING A CONSPIRACY

In "Inside the Echo Chamber," Walter Quattrociocchi describes his and his colleagues' work on researching how conspiracy theories propagate online. The article reminds me of the elements necessary for an infection to successfully spread within a population. First, an agent must exceed a certain threshold of infectivity, a property called virulence. Second, vulnerable hosts must be available to become infected. If many in a population have acquired an immunity, then even if one person catches a given infection, it will be less likely to successfully propagate. Finally, there must be a vector or vehicle to physically spread the infectious agent. In this analogy, a certain audience may possess a host vulnerability to a given piece of misinformation, and the vehicle that spreads it is now ubiquitous in the form of social media.

We cannot remove social media—it is here to stay—and we cannot squelch ideas even if they are highly "virulent." So what can we do about how susceptible we are to conspiracy theories? It may take a generation, but I think we should focus on improving critical thinking skills in young people—kindergarten through college. We need to teach them to assess information analytically, to appreciate complexity, and to employ strategies against bias to mitigate the human tendency to seek simple answers and assign blame.

RICH DAVIS *Renton, Wash.*

I was surprised by the absence of a social psychologist among the breadth of disciplines represented in Quattrociocchi's own research group, although at least one was cited elsewhere. The results he described are consistent with social psychology research and theory dating back to the 1950s, and I would suggest that he add someone in that discipline to his team.

The echo chamber idea follows from social comparison theory (proposed by Leon Festinger in 1954), which tells us that when people want to learn the "truth" about issues, they look to others with whom they identify, typically those with like-minded beliefs and attitudes. The finding that debunking information actually increased conspiracy news consumption is exactly what cognitive dissonance theory (also proposed by Festinger, in 1957) would predict. When people perform an action consistent with their beliefs and are then confronted with information contradicting the implications of that action, they often resolve the contradiction by increasing the performance of the previous action.

CHARLES PAVITT *Department of Communication, University of Delaware*

TRIAL JUDGMENT

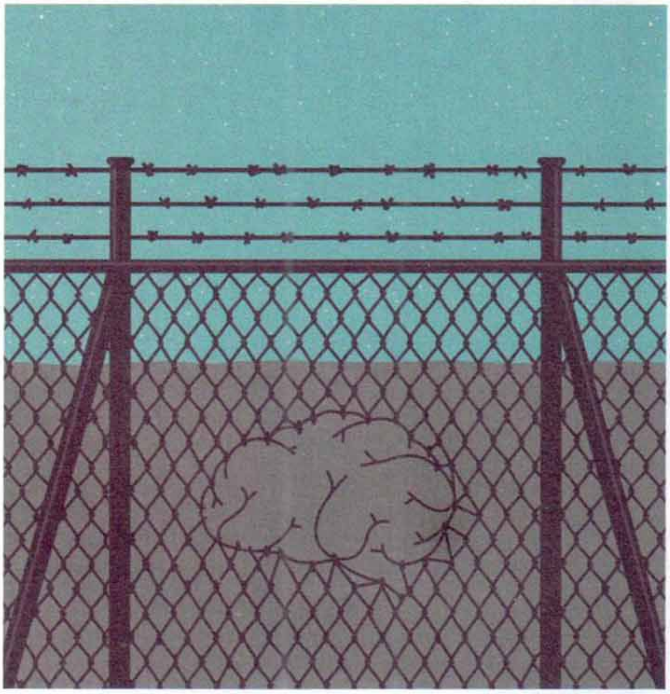
In "A Rare Success against Alzheimer's," Miia Kivipelto and Krister Håkansson describe a clinical trial on improving cognition in subjects aged 60 to 77 that they are involved in. The 631 individuals in the treatment group were directed to follow a regimen of a particular diet, including a vitamin D supplement, exercise and cognitive training, and the control group received health advice. Both groups were followed for cardiovascular health. The treatment group showed significant improvement during the two years of the investigation, and the control group also showed improvement, to a lesser degree.

There is no way to know which of the measures produced the observed effect. For a scientific study, one would expect the outcome to have been compared with groups receiving only one of each intervention. Moreover, although the authors describe selecting subjects with a high possibility of developing dementia and report that those with a gene variant linked to Alzheimer's risk "seemed to receive somewhat more benefit," the study did not involve any individuals who had the disease. It is disappointing that it thus did not truly address the possible effect these interventions might have on Alzheimer's. Obviously this is not possible with such a short study period, and it is comforting that the participants are now being followed for an additional seven years.

JENS CHRISTIAN JENSENIUS
Professor emeritus, Department of Biomedicine, Aarhus University, Denmark

I have co-authored two *Scientific American* articles in the past, and I find that Kivipelto and Håkansson's study falls short of being "a gold-standard clinical trial," as they state in their article. The authors' failure to cite the amounts of variance explained by each of their variables, independently or in conjunction with other variables, makes their conclusions equivocal. At best, their data confirm validity for a limited number of factors previously found in association with Alzheimer's but do not show that these are either primary causal factors or that they contribute to the disease with known amounts of impact (that is, the association may be purely incidental).

Further, with the gold-standard label of authenticity and the prestige of being a *Scientific American* cover story, this article could disturbingly imply that those suffering with this debilitating disease are, in some way, responsible for their condition—that had they maintained the specified diet, exercise routine, and so on, Alzheimer's could have been avoided. The risk of causal attribution may be said to exist in any research on factors associated with a medical condition, but avoiding it



The Right to Cognitive Liberty

A new type of brain-imaging technology could expose—even change—our private thoughts

By Marcello Ienca

The idea of the human mind as the domain of absolute protection from external intrusion has persisted for centuries. Today, however, this presumption might no longer hold. Sophisticated neuroimaging machines and brain-computer interfaces detect the electrical activity of neurons, enabling us to decode and even alter the nervous system signals that accompany mental processes. Whereas these advances have a great potential for research and medicine, they pose a fundamental ethical, legal and social challenge: determining whether or under what conditions it is legitimate to gain access to or interfere with another person's neural activity.

This question has special social relevance because many neurotechnologies have moved away from a medical setting and into the commercial domain. Attempts to decode mental information via imaging are also occurring in court cases, sometimes in a scientifically questionable way. For example, in 2008 a woman in India was convicted of murder and sentenced to life imprisonment on the basis of a brain scan showing, according to the judge, "experiential knowledge" about the crime. The potential use of neural technology as a lie detector for interrogation purposes has garnered particular attention. In spite of experts' skepticism, commercial companies are marketing the use of functional MRI- and electroencephalography-based technology to ascertain truth and falsehood. The military is also testing monitoring techniques for another reason: to use brain stimulation to increase a fighter's alertness and attention.

Marcello Ienca is a Ph.D. candidate at the Institute for Biomedical Ethics at the University of Basel and is chair of the Student/Postdoctoral Committee at the International Neuroethics Society.

Brain-reading technology can be seen as just another unavoidable trend that erodes a bit more of our personal space in the digital world. But given the sanctity of our mental privacy, we might not be so willing to accept this intrusion. People could, in fact, look at this technology as something that requires the reconceptualization of basic human rights and even the creation of neurospecific rights.

Lawyers are already talking about a right to cognitive liberty. It would entitle people to make free and competent decisions regarding the use of technology that can affect their thoughts. A right to mental privacy would protect individuals against unconsented-to intrusion by third parties into their brain data, as well as against the unauthorized collection of those data. Breaches of privacy at the neural level could be more dangerous than conventional ones because they can bypass the level of conscious reasoning, leaving us without protections from having our mind read involuntarily. This risk applies not only to predatory marketing studies or to courts using such technology excessively but also to applications that would affect general consumers. This last category is growing. Recently Facebook unveiled a plan to create a speech-to-text interface to translate thoughts directly from brain to computer. Similar attempts are being made by companies such as Samsung and Netflix. In the future, brain control could replace the keyboard and speech recognition as the primary way to interact with computers.

If brain-scanning tools become ubiquitous, novel possibilities for misuse will arise—cybersecurity breaches included. Medical devices connected to the brain are vulnerable to sabotage, and neuroscientists at the University of Oxford suggest that the same vulnerability applies to brain implants, leading to the possibility of a phenomenon called brainjacking. Such potential for misuse might prompt us to reconceptualize the right to mental integrity, already recognized as a fundamental human right to mental health. This new understanding would not only protect people from being denied access to treatment for mental illness but would also protect all of us from harmful manipulations of our neural activity through the misuse of technology.

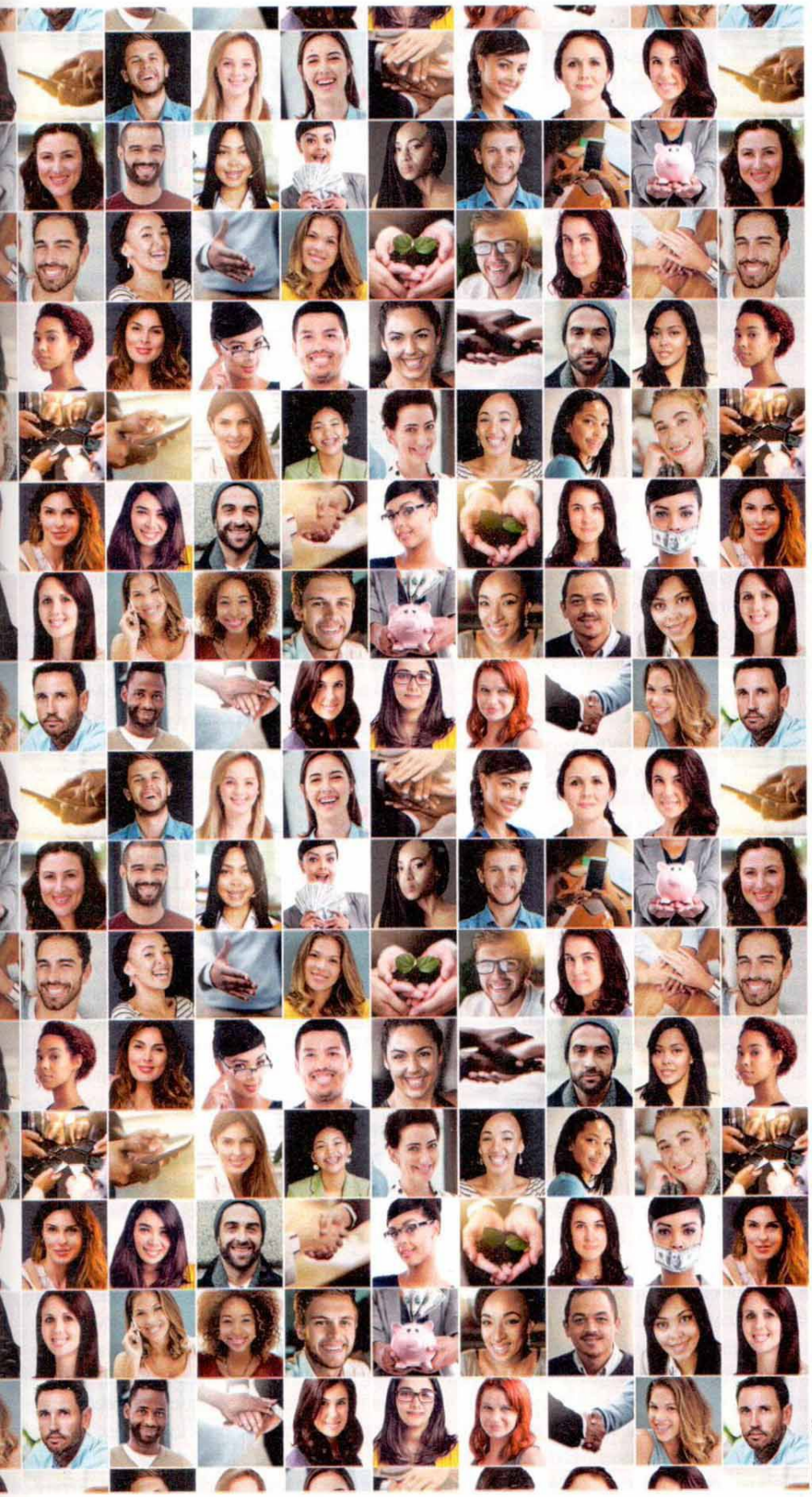
Finally, a right to psychological continuity might preserve people's mental life from external alteration by third parties. The same kind of brain interventions being explored to reduce the need for sleep in the military could be adapted to make soldiers more belligerent or fearless. Neurotechnology brings benefits, but to minimize unintended risks, we need an open debate involving neuroscientists, legal experts, ethicists and general citizens.

JOIN THE CONVERSATION ONLINE
Visit *Scientific American* on Facebook and Twitter or send a letter to the editor: editors@sciam.com

Illustration by Christian Dellavedova

ADVANCES

The primate brain has an uncanny ability to recognize faces. Now researchers are starting to crack that code.



GETTY IMAGES

INSIDE

NEUROSCIENCE

Saving Face

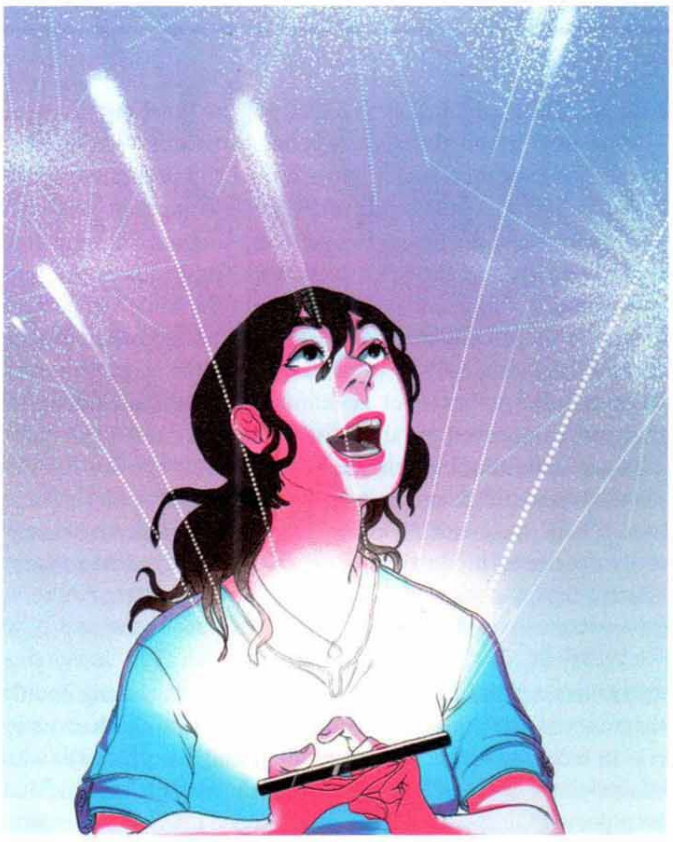
Scientists are closing in on the neural code for facial recognition

The brain has evolved to recognize and remember many different faces. We can instantly identify a friend's countenance among dozens in a crowded restaurant or on a busy street. And a brief glance tells us whether that person is excited or angry, happy or sad.

Brain-imaging studies have revealed that several blueberry-size regions in the temporal lobe—the area under the temple—specialize in responding to faces. Neuroscientists call these areas "face patches." But neither brain scans nor clinical studies of patients with implanted electrodes explained exactly how the cells in these patches work.

Now, using a combination of brain imaging and single-neuron recording in macaques, biologist Doris Tsao and her colleagues at the California Institute of Technology appear to have finally cracked the neural code for primate face recognition. The researchers found the firing rate of each face patch cell corresponds to a separate facial feature. Like a set of dials, the cells can be fine-tuned to respond to bits of information, which they can then combine in various ways to create an image of every face the animal encounters. "This was mind-blowing," Tsao says. "The values of each dial are so predictable that we can re-create the face that a monkey sees by simply tracking the electrical activity of its face cells."

Previous studies had hinted at the specificity of these brain areas for encoding faces.



Technology as Magic

The products that really wow us seem like pure wizardry

By David Pogue

We the people have always been helplessly drawn to the concept of magic: the notion that you can will something to happen by wiggling your nose, speaking special words or waving your hands a certain way. We've spent billions of dollars for the opportunity to see what real magic might look like, in the form of *Harry Potter* movies, superhero films and TV shows, from *Bewitched* on down.

It should follow, then, that any time you can offer *real* magical powers for sale, the public will buy it. That's exactly what's been going on in consumer technology. Remember Arthur C. Clarke's most famous line? "Any sufficiently advanced technology is indistinguishable from magic." Well, I've got a corollary: "Any sufficiently magical *product* will be a ginormous hit."

Anything invisible and wireless, anything that we control with our hands or our voices, anything we can operate over impossible distances—those are the hits because they most resemble magic. You can now change your thermostat from thousands of miles away, ride in a car that drives itself, call up a show on your TV screen by speaking its name or type on your phone by speaking to it. Magic.

David Pogue is the anchor columnist for Yahoo Tech and host of several *NOVA* miniseries on PBS.

For decades the conventional wisdom in product design has been to "make it simpler to operate" and "make it easier for the consumer." And those are admirable goals, for sure. Some of the biggest technical advancements in the past 30 years—miniaturization, wireless, touch screens, artificial intelligence, robotics—have been dedicated to "simpler" and "easier."

But that's not enough to feel magical. Real tech magic is simplicity *plus awe*. The most compelling tech conventions—GPS apps telling you when to turn, your Amazon Echo answering questions for you, your phone letting you pay for something by waving it at that product—feel kind of amazing every single time.

The awe component is important. It's the difference between magic and mere convenience. You could say to your butler, "Jeeves, lock all the doors"—and yes, that'd be convenient. But saying, "Alexa, lock all the doors," and then hearing the deadbolts all over the house click *by themselves?* Same convenience, but this time it's magical.

Now, creating magic requires a lot of extra effort; to make something seem nontechnological, the designers have to *hide* a lot of technology. I'd argue that Apple became so successful in part because early on, it became one of the primary vendors of magic. I'll never forget the first time I drew a picture with the mouse on the very first Mac. It was a program called MacPaint—black-and-white only, on a 512- by 342-pixel screen—but it took my breath away.

Apple has often been late to the party. Long before Apple introduced the iPad, other companies sold tablets. Well before the iPod debuted, pocket music players were available from rivals. And before the iPhone was even a twinkle in Steve Jobs's eye, you could buy touch-screen phones.

Why didn't those products set the world on fire? You know what I'm going to say: because they weren't magical.

The early tablets were thick and clunky and covered with buttons; the technology wasn't hidden enough. The early MP3 players were glitchy; nothing says "not magic" louder than the need to troubleshoot. And touch-screen phones weren't truly magical until they had *multitouch* screens like the iPhone's. The first time you tried zooming in on a photograph by spreading two fingers on the glass, you were sold. You *wanted* that product. It was magic that you could buy.

Fortunately, these days magic is everywhere, appealing both to our laziness and to our sense of wonder. It's in wireless charging and augmented reality. It's in voice control of our smart homes and in Fitbits that somehow know what sport you've just played for an hour. It's in summoning a car and driver with one tap on your phone. It's in software that recognizes the faces of your friends in your pictures.

Thank you, engineers and designers of the world, for taking on the role of creating magic. Right now we the people can use all of it we can get.

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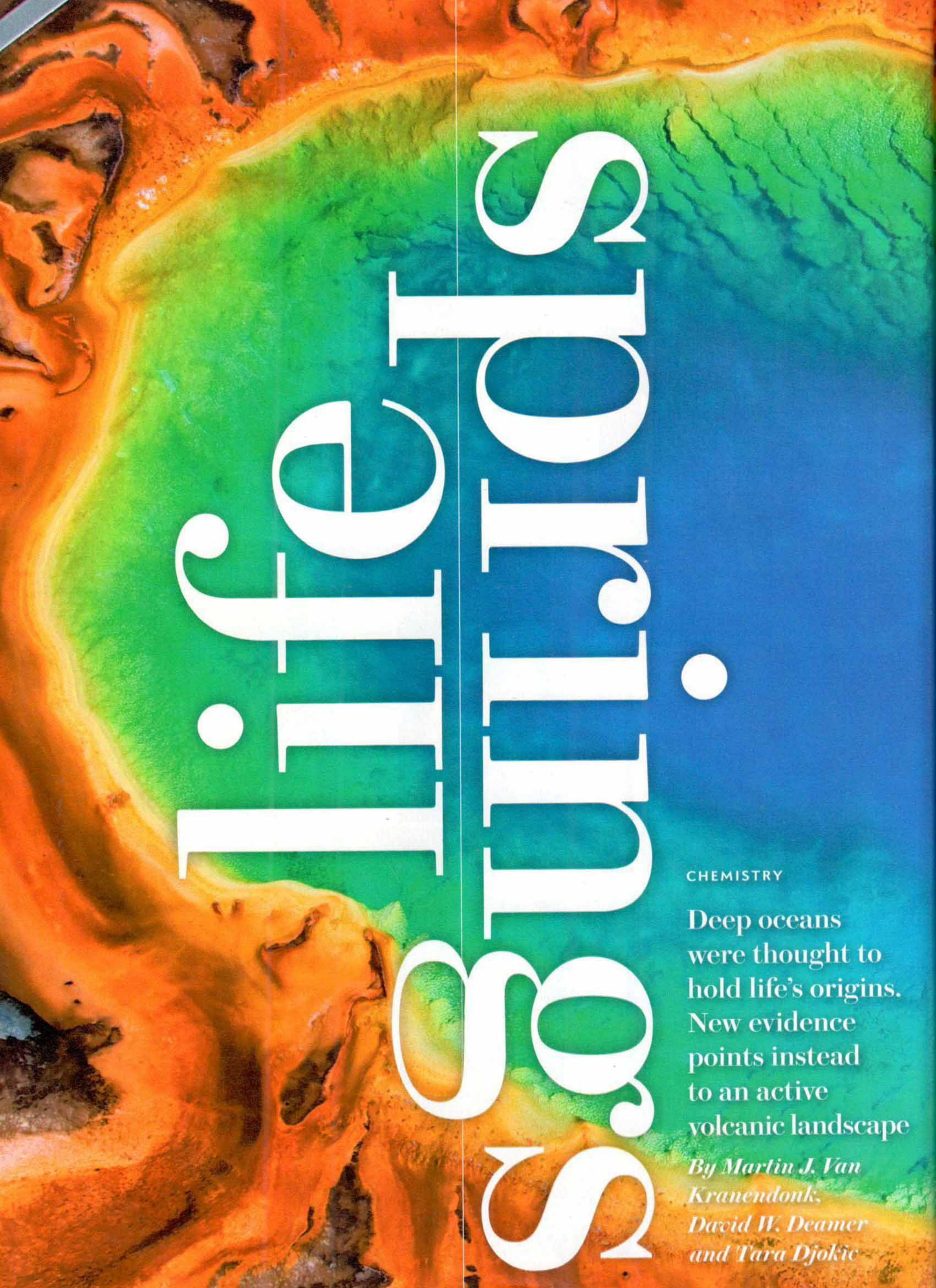
READ MORE ABOUT MAGICAL TECHNOLOGIES ON THE HORIZON:
scientificamerican.com/aug2017/pogue

Illustration by Jay Bendt

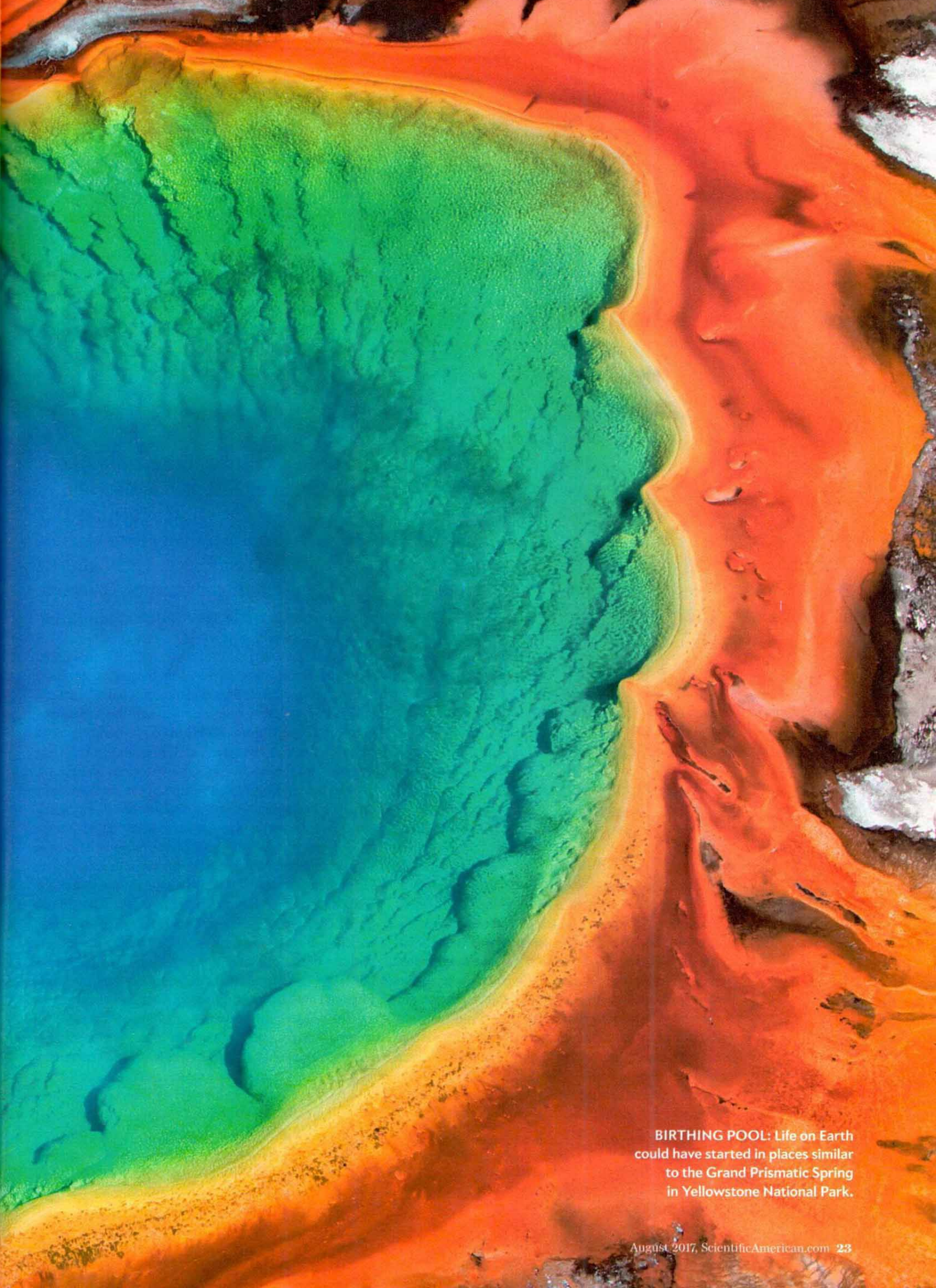


life springs

CHEMISTRY

Deep oceans were thought to hold life's origins. New evidence points instead to an active volcanic landscape

By Martin J. Van Kranendonk, David W. Deamer and Tara Djokic



BIRTHING POOL: Life on Earth could have started in places similar to the Grand Prismatic Spring in Yellowstone National Park.

FISHERMEN on the choppy Sea of Cortez haul in corvinas. Fishing has been blamed for killing off the vaquita, but organized criminals and corrupt government officials are also suspect.

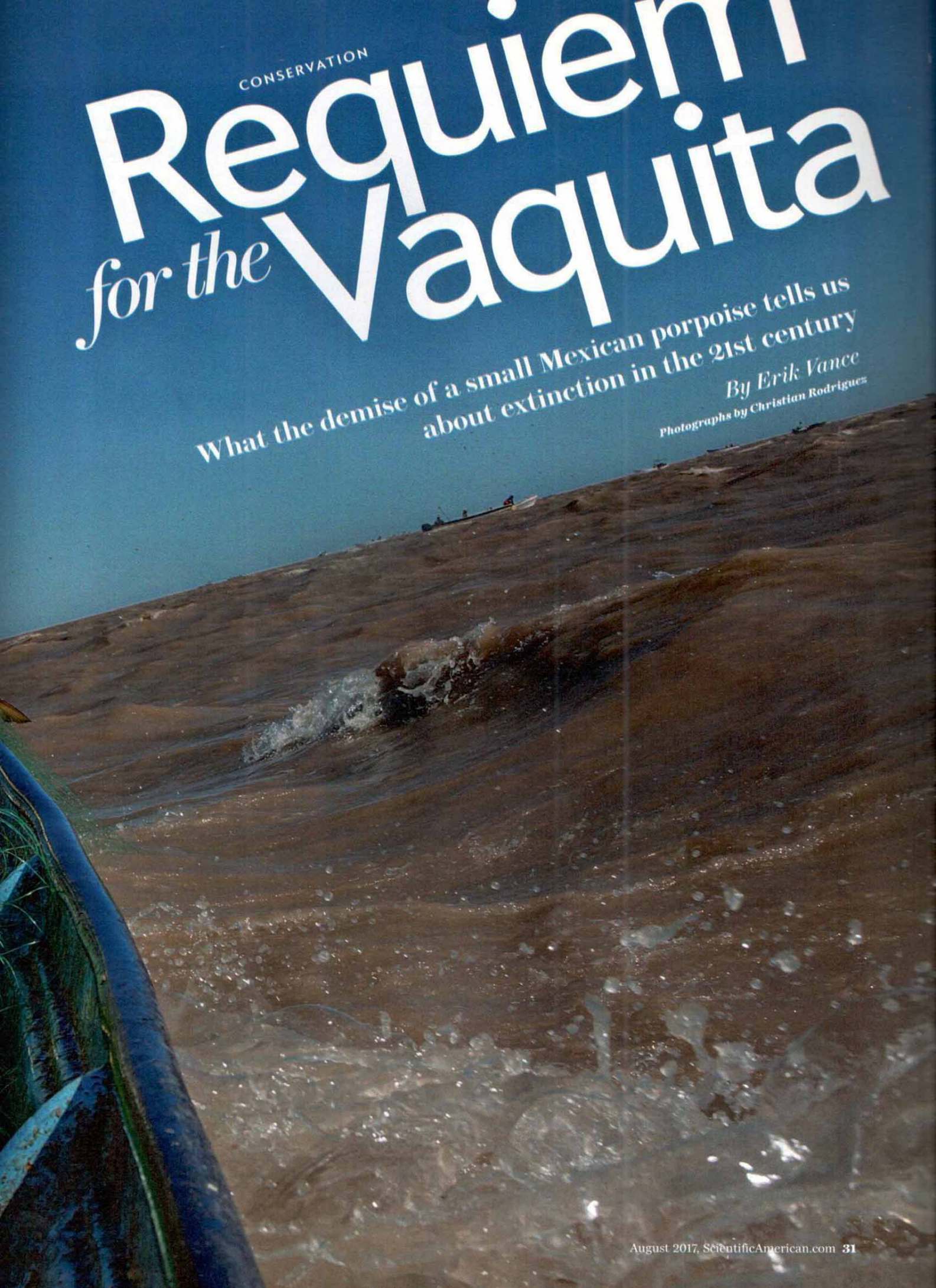
CONSERVATION

Requiem for the Vaquita

What the demise of a small Mexican porpoise tells us about extinction in the 21st century

By Erik Vance

Photographs by Christian Rodriguez



PALEOANTHROPOLOGY

Our Cousin

SUM OF ITS PARTS:
Reconstruction of the pieces of Neo's skull reveals the visage of *Homo naledi*. To read more about the new discoveries, visit www.ScientificAmerican.com/neo

Neo

A remarkably complete skeleton and, at last, an age for mysterious *Homo naledi*

By Kate Wong

IN 2015 LEE BERGER of the University of the Witwatersrand, Johannesburg, and his colleagues caused a sensation when they unveiled more than 1,500 human fossils representing some 15 individuals, male and female, young and old, discovered in South Africa. It was one of the richest assemblages of human fossils ever found, recovered from a chamber deep inside an underground cave system near Johannesburg called Rising Star. The team deduced that the bones belonged to a new species, *Homo naledi,* which had a curious mix of primitive traits, such as a tiny brain, and modern features, including long legs. The scientists determined it was a capable climber and long-distance walker and surmised that it had disposed of its dead in the pitch-dark, hard-to-reach chamber.

Yet for all that the researchers were able to glean from the bones, the discovery was perhaps best known for what they could not ascertain: its age.

That eagerly awaited piece of the puzzle has finally fallen into place. In papers published online May 9 in eLife, the team reports it has dated the remains of *H. naledi* to between 236,000 and 335,000 years old—surprisingly young for a species with such a small brain. The researchers also announced the discovery of yet more fossils of *H. naledi* in a second chamber in Rising Star, including a skeleton of an adult male they nicknamed Neo, "gift" in the local Sesotho language.

Kate Wong is a senior editor for evolution and ecology at *Scientific American.*

The findings raise intriguing questions about the origin and evolution of our genus, *Homo.* Despite the young age of the bones, the scientists maintain that *H. naledi*'s primitive features link it to much earlier members of the human family, and they argue that this species might even be a direct ancestor of *Homo sapiens.*

Berger and his collaborators also note that the new dates for *H. naledi* indicate it lived at a time when human ancestors were making sophisticated stone tools in the Middle Stone Age tradition. Many of the sites where archaeologists have discovered these tools do not contain any human fossils. Experts have typically assumed that large-brained humans made the implements. But if *H. naledi* was around at that time, as the authors suggest, it cannot be excluded as the toolmaker. In that case, scientists will need to reconsider the enduring notion that brain size drives complexity of behavior. Paleoanthropologist Mark Collard of Simon Fraser University in British Columbia, who was not involved in the new work, thinks there is good reason to do so: "The history of paleoanthropology is littered with deeply rooted assumptions that have been overturned by new discoveries." SA

JOHN HAWKS University of the Witwatersrand, Johannesburg

A MATTER OF CHOICE

Studies show that school vouchers lead to lower math and reading scores. So why has the Trump administration embraced them?

By Peg Tyre

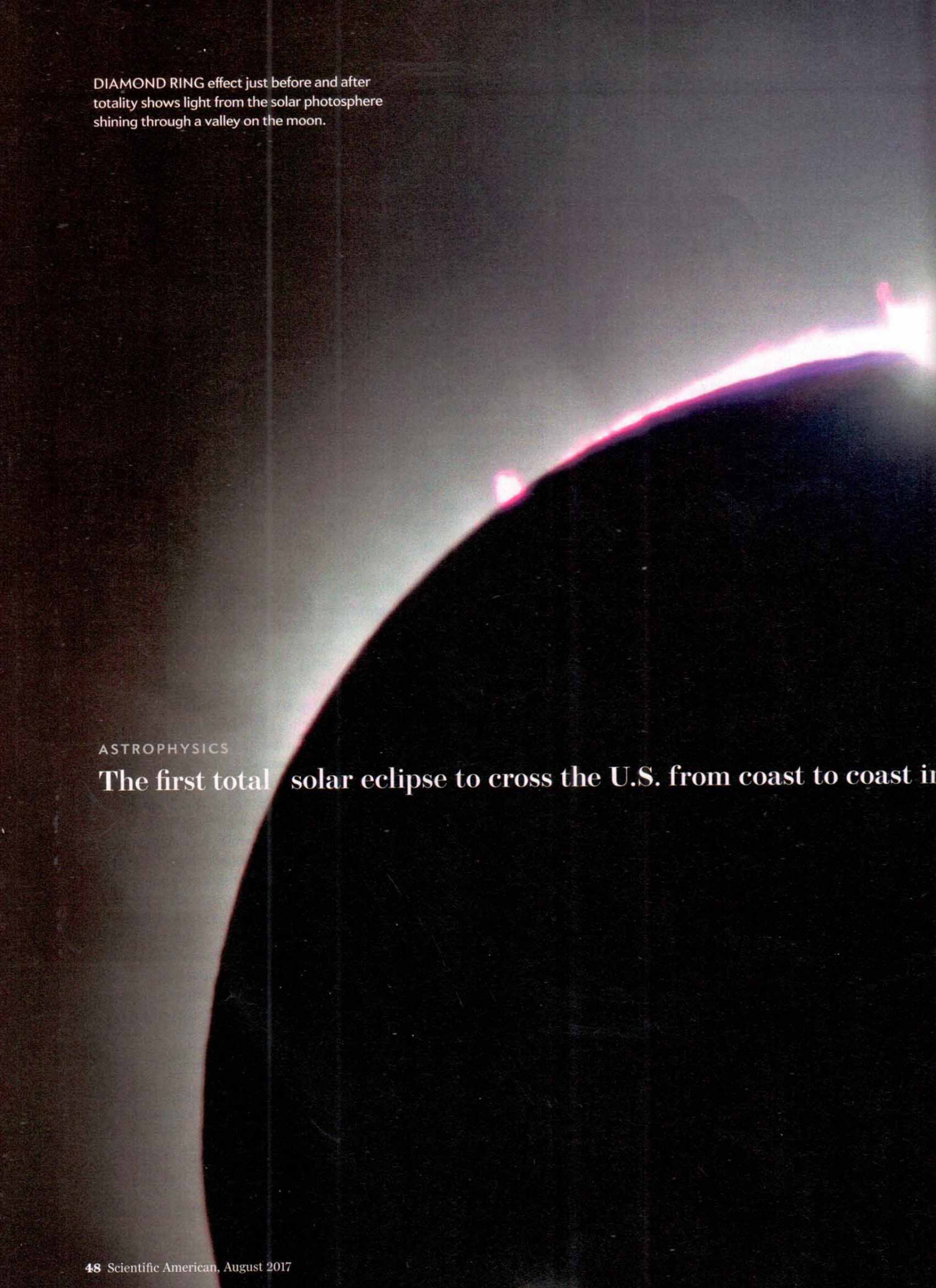
IN BRIEF

The concept of vouchers originated with economist Milton Friedman. In 1955 he argued that the government should not run schools but instead offer parents educational stipends.

Vouchers are the centerpiece of the Department of Education's school reform plan. Until now, Washington, D.C., has been home to the only federally funded voucher program in the U.S.

A handful of other cities and states have experimented with small programs. Studies have found mixed to negative results in reading and math but higher high school graduation rates.

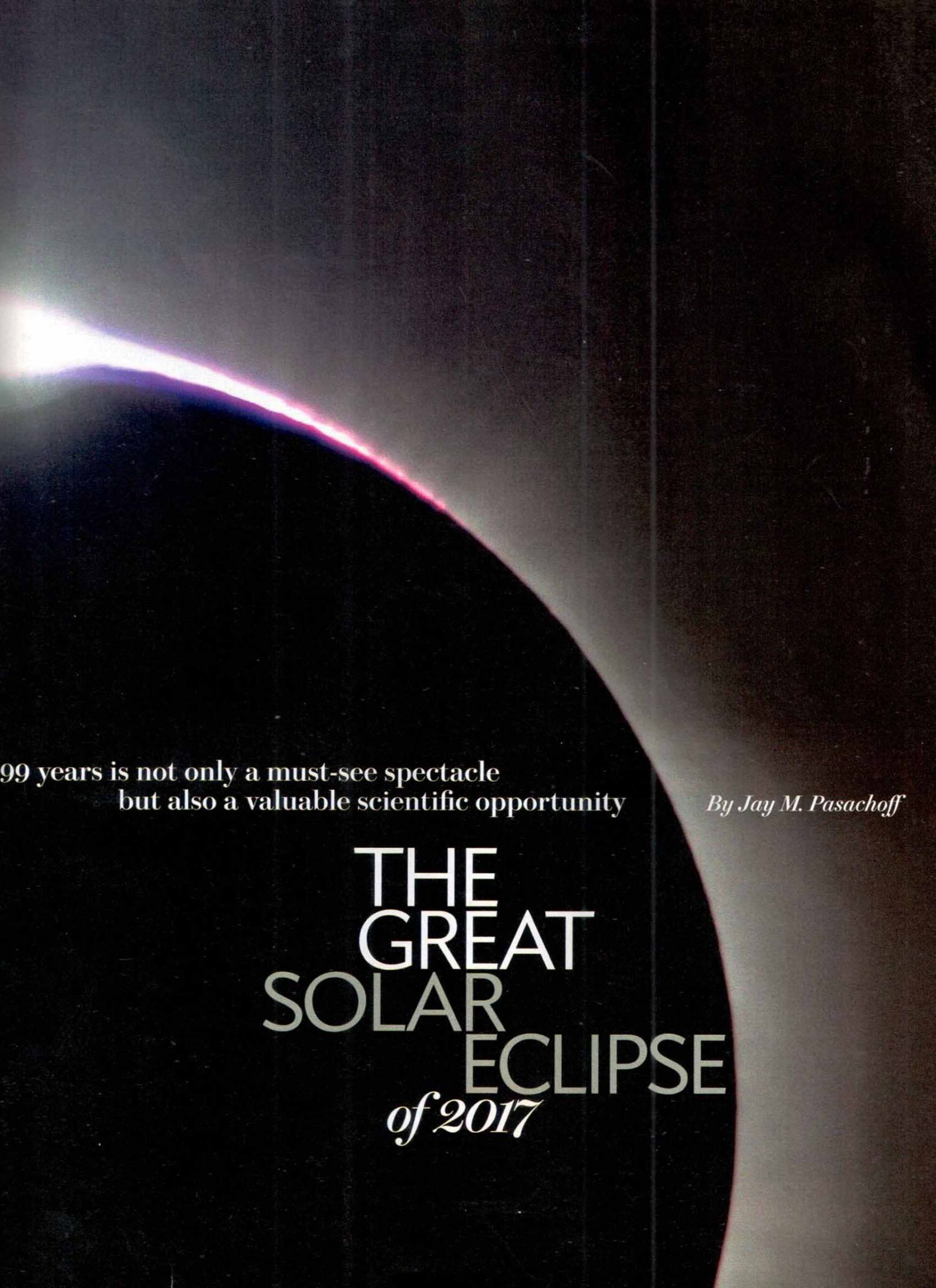
Illustration by Chris Gash



DIAMOND RING effect just before and after totality shows light from the solar photosphere shining through a valley on the moon.

ASTROPHYSICS

The first total solar eclipse to cross the U.S. from coast to coast i



99 years is not only a must-see spectacle
but also a valuable scientific opportunity

By Jay M. Pasachoff

THE GREAT SOLAR ECLIPSE *of 2017*

PSYCHOLOGY

TALKING TO OURSELVES

Studies of the conversations people have with themselves open a window on the hidden workings of the mind

By Charles Fernyhough

Illustration by Daniel Stolle