NAUTILUS

How Monsters Are Born

THE STORM THAT INSPIRED MARY SHELLEY p.20

$12

1 1 >

0 74470 29067 4

NOV/DEC 2015 Science Connected **NAUTIL.US**


Scientists
at Work
short videos
www.biointeractive.org/scientists
Experience science.
hhmi | BioInteractive

When Nature Betrays Us

THE HOLLYWOOD BLOCKBUSTER ***POMPEII***, released last year, was widely panned by critics but still managed to make $120 million in box office receipts and $40 million in profits. The critics should have saved their breath. We love natural disaster movies, and have had lots of practice making them.

By the start of World War II, filmmakers had retold the tale of Pompeii five times, and they have kept at it. The fact is, disaster is movie gold. From the late 1970s on, movies that "either stage or imply large-scale destruction of a global nature" were regularly among the top-10 box office hits in United States theaters, according to the film-studies lecturer Peter Kramer, quoted in a *Guardian* article last year.

While the instability of nature scares and fascinates us, we also idolize nature's permanence and purity. Nature, in the Romantic ideal, is a stabilizing counterpart to the tortured and unrooted existence of man: As Wordsworth put it, "Nature never did betray the heart that loved her." It's an idea that persists today in nature therapy, rewilding conservation, and even the word itself.

This combination of idealization, fear, and fantasy is well studied in psychoanalytic theory. It results from a difficulty integrating contradictory feelings, in this case that we rely on a world that can turn on us. "We are mercilessly exposed to nature's cruel whims," argues the philosopher Slavoj Zizek. "There is no Mother Earth watching over us." We may know it, but don't like to admit it.

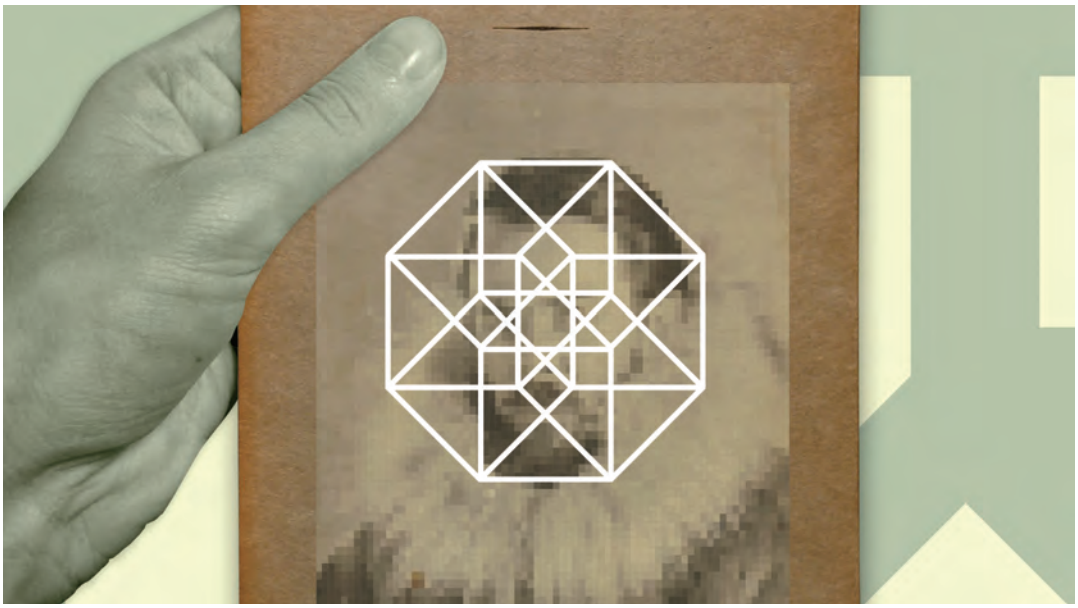
It's a tension that was present even at the dawn of the Romantic age. In 1815, Mount Tambora erupted in the East Indies, producing a 60-megaton aerosol layer that cooled the Earth for three years, and Europe by as much as 6 degrees Fahrenheit. As Gillen D'Arcy Wood describes in this issue, the consequent darkness, rains, crop failures, and starvation inspired both *Frankenstein*, and an early version of *Dracula*—the disaster movies of their age.

As we face a changing climate today, with all of the anxieties and dangers it presents, it is worth considering the identity we've created for Mother Nature, betrayals and all.

Welcome to the November/December *Nautilus* print edition.

—Michael Segal
Editor in Chief

Contents



Preludes

Themes

Each print edition identifies different themes in science and explores them from multiple perspectives.

COVER Wesley Allsbrook
BACK COVER Magoz

FRANCESCO IZZO

30

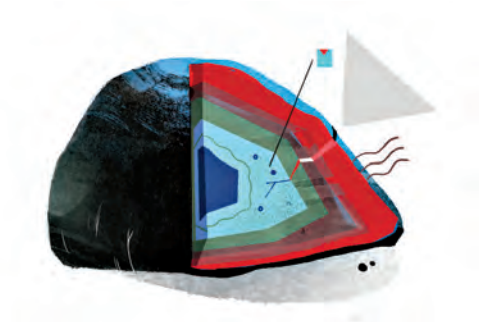
Identity

"His death underscored another loss, albeit a far more subtle one: that of my native tongue."

—Julie Sedivy, p. 34

THEME ART Jackie Ferrentino

31



Stress

"Facebook's News Feed didn't feel entertaining; it loomed like a long list of demands. *Cheer me up. Comfort me.*"

—Chelsea Wald, p. 114

THEME ART Molly Mendoza

Read *Science*

Reach the world.

When you subscribe to *Science,* you also become a member of the American Association for the Advancement of Science (AAAS), a nonprofit community of more than 100,000 members who believe in the power of science to make the world a better place. AAAS is hard at work promoting and protecting the scientific enterprise with programs impacting education, policy, and innovation worldwide.

With your AAAS/*Science* subscription you'll enjoy:

- 51 weeks of *Science,* and access to archived articles dating back to 1880
- Full access to the *Science* mobile site and apps
- Exclusive career tools, events, webinars, and blogs
- Members-only newsletters, alerts, and special publications

Show your support for science—and reap all the rewards of a *Science* subscription. Join hands with us today!

Visit promo.aaas.org/joinaaas. Together, we can make a difference.

Science
AAAS

NAUTILUS

EDITORIAL

Publisher & Editorial Director
John Steele

Editor in Chief
Michael Segal

Features Editor
Kevin Berger

Senior Editor
Ariel Bleicher

Art Director
Len Small

Production Editor
Liz Peterson

Senior Designer
Nicholas Garber

Consulting Designer
Francesco Izzo

Editor at Large
Meehan Crist

Social Media & News Editor
Claire Cameron

Assistant Editor/Video Production
Yvonne Bang

Assistant Editor
Brian Gallagher

Assistant Editor
Regan Penaluna

Editorial Interns
JoAnna Klein
Susie Neilson
Ankur Paliwal
Zach St. George

Illustration Fellow
Jackie Ferrentino

Director of Technology & Operations
Peter DuCharme

Finance Manager
Renata Guyfner

Marketing Intern
Chikaodili Okaneme

Design & Creative Consultant
Point Five Design

CONTACT

415 Madison Avenue, 13th Floor
New York, NY 10017
212 221 3870
info@nautil.us

SUBSCRIPTIONS

Visit shop.nautil.us

Nautilus has received financial support from:

John Templeton Foundation

SIMONS FOUNDATION

hhmi Howard Hughes Medical Institute

Published by:

NAUTILUS *think*

Letters

Reader responses to the September/October 2015 print edition.

"CAITLYN JENNER AND OUR COGNITIVE DISSONANCE"

While I appreciate the ideas offered, I think communication studies would offer some help to this article. The author fails to distinguish biological sex from the social construction of gender (masculinity, femininity, androgyny, etc.). As a communication scholar and instructor, I teach my students to recognize the limitations of words. Our words describe our experiences and those of our culture's history (Sapir-Whorf hypothesis). This corresponds to the author's discussion of perception.

—*Janine Armstrong*

"...SMART MACHINES WILL TAKE US WITH THEM"

Assuming that intelligence is somehow the teleological endpoint of evolution is incredibly anthropocentric, and pretty much wrong along every conceivable axis. Intelligence is an evolutionary response to a particular context and set of survival challenges. There's no objective reason it should be more prized than flight, speed, fertility, or resilience to radiation.

—*Wulfsten*

"THE GENIUS OF LEARNING"

To learn, you don't disengage your conscious thinking systems from those of your subconscious, you listen to what those systems have been thinking instead of treating the signals that are being sent to you as emotional nonsense. Of course my emotional brain has been telling me to write this, so who really knows.

—*Roy Niles*

"WILL THE EARTH EVER FILL UP?"

This ignores quality of life. Of course if people have a terrible quality of life we can load more people onto the planet. I would say right now the quality of life in both China and India is intolerable. We need to look to quality of life not to

how many people can functionally live in the world. Climate change is also impacting this equation. If we overheat the planet than the human population could go to zero. We are at maximum levels already.

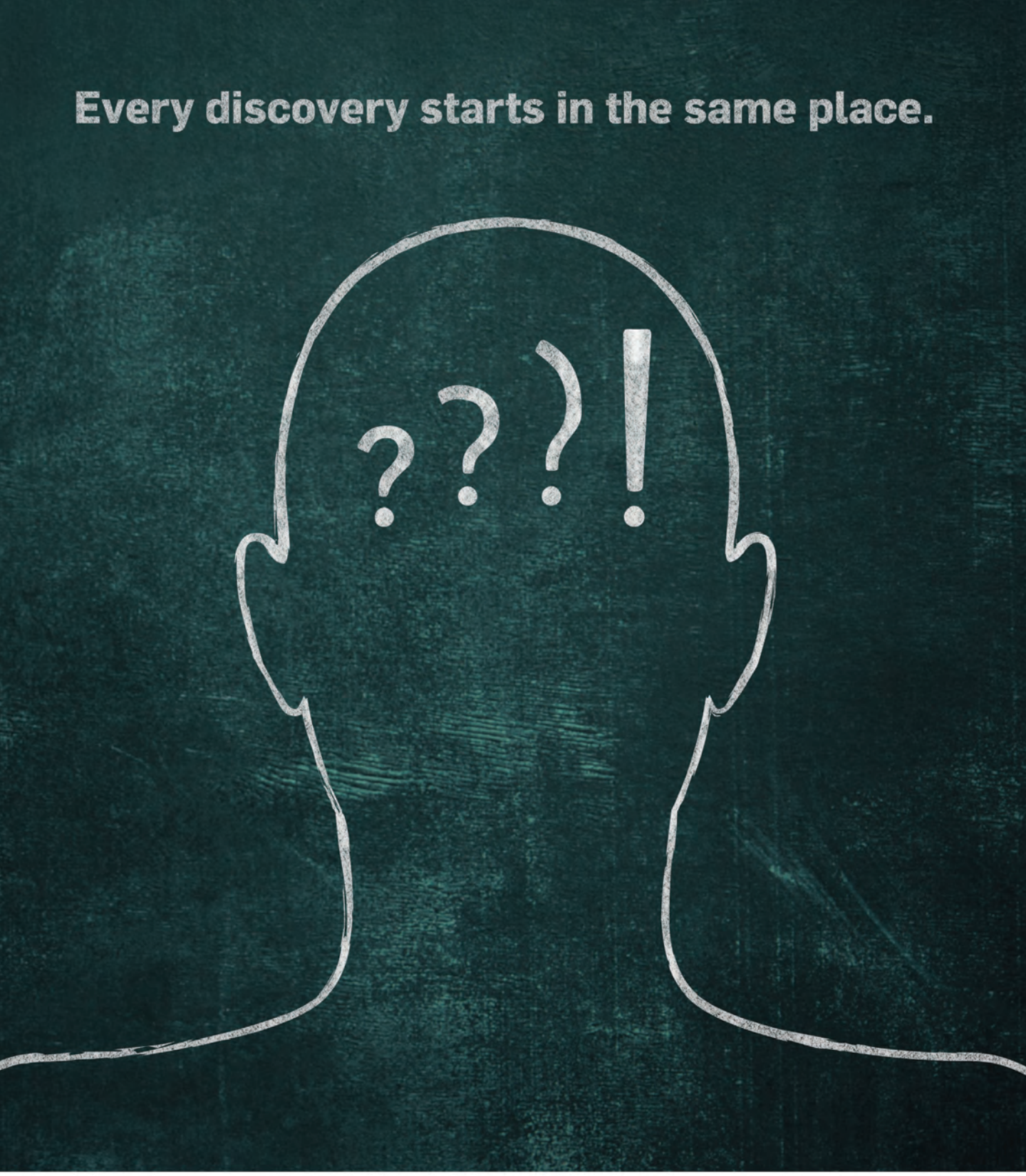
—*Drew*

CORRECTIONS

As originally published, "Why the Russians Decapitated Major Tom," which ran in the September/October 2015 print edition of *Nautilus*, incorrectly stated that the Baikonur Cosmodrome is larger than Belgium. It is about one-quarter of the size of Belgium.

In the September/October 2015 print edition of *Nautilus*, the article "Is Life Special Just Because It's Rare?" incorrectly stated that the Kepler observatory had stopped functioning. It has not.

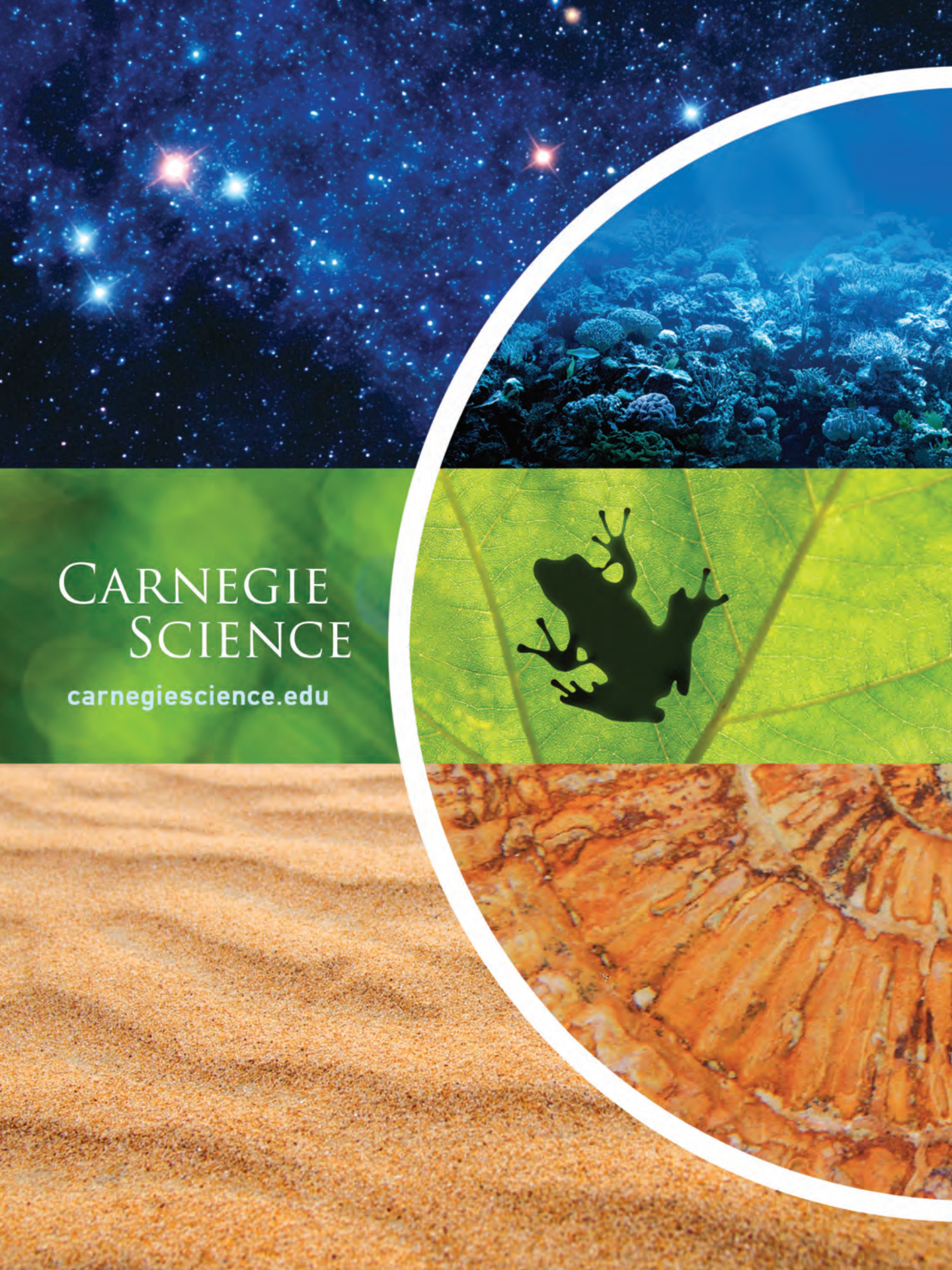
Nautilus *welcomes reader responses. Please email* letters@nautil.us. *All letters are subject to editing.*



Learn More. **Start Here.**

www.maxplanckflorida.org

MAX PLANCK
FLORIDA INSTITUTE FOR
NEUROSCIENCE


Carnegie
Science
carnegiescience.edu

Preludes

"The lights dimmed; a mud-spattered dog walked across the screen, and one by one, the viewers burst into tears."

SUSIE NEILSON
"Godzilla and Other Emotional Outlets" p.15

PHILOSOPHY

How We Decide About Others

We tend to believe people are good, and are like ourselves

CAN YOU EVER REALLY know another person? It's a deceptively simple question that has bewitched thinkers for ages and inspired a bottomless supply of self-help books. While we may not have an answer, we are starting to understand how we build an idea of who other people are.

Joshua Knobe, an experimental philosopher at Yale University, recently teamed up with colleagues in psychology and decided to crack the question by analyzing our ordinary use of the term. His approach seems straightforward, but what they found is almost as strange as the question is mysterious.

Knobe asked study participants to consider a number of brief scenarios in which a person undergoes changes in his beliefs or behavior. Sometimes the agent changes from good to bad, and other times from bad to good. Participants were then asked to rate how much the change reflects the agent's true self, if at all. Knobe found that participants were more likely to report that the agent is behaving as his true self when he does something morally good.

This tendency may be universal: Knobe and his colleagues found the positivity bias held across cultures in Russia, Singapore, Colombia, and the United States. They even found it among misanthropes. According to George Newman, a psychologist at Yale University and one of the study's authors, this suggests that there is something spontaneous and unmotivated about how we think about the true self of others.

But those beliefs are also informed by our personal convictions. In another experiment, Knobe presented participants with different scenarios in which an agent's behavior changed from liberal to conservative or from conservative to liberal. He found participants were more likely to say the change in the agent was authentic if it mirrored their personal political orientation.

There is something spontaneous about how we think about the true self of others.

"Whatever your beliefs are is what you'll regard as the true essence of the self," says Knobe.

Together these two experiments suggest that we see others' true selves as morally good, which seems like a good thing. But seeing the authentic self of others through our own lens can be a handicap. "What's sad is if we also don't have another way of seeing people," Knobe says, admitting, "it seems it's very hard for us to turn off this thing that we do."

—Regan Penaluna

PSYCHOLOGY

Godzilla and Other Emotional Outlets

Japanese culture has created unique ways of dealing with stress

TWO YEARS AND THREE months after the Tōhoku earthquake and tsunami, a crowd of people clutching handkerchiefs gathered around a TV screen in Atsuta Ward, Nagoya. "I am ready to bawl my eyes out," one of them joked. The lights dimmed; a mud-spattered dog walked across the screen, and one by one, the viewers burst into tears.

They were participants at a Rui-Katsu, or tear-seeking event, which have spread across

Japan in recent years, providing citizens with a much-needed emotional outlet. "Hiding one's anger and sadness is considered a virtue in Japanese culture," psychologist Yuhei Kayukawa told the *Japan Times*. Crying without concern for public image is important, he said.

Rui-Katsu may seem novel, but crying events are tapping into the same nerve as Tomoyuki Tanaka did 50 years ago. In 1954, the film director released *Gojira* to Japanese audiences, who watched "in relative silence, punctuated by violent weeping." Over the decades, Godzilla became one of the widest-exported Japanese characters in history. Since 1954, it has destroyed Tokyo no less than 28 times onscreen.

Historian Bill Tsutsui theorizes why the monster has become such a cultural obsession. "Godzilla is more than just a movie monster," he says. It is closely associated with the traumatic nuclear explosions at Hiroshima and Nagasaki. It was considered "impolite" to discuss these disasters. In this vacuum, Godzilla became a widely-accepted coping mechanism. "People had been holding this horror within them, and when they saw it onscreen they were able to get it out."

In a culture that stigmatizes individual vulnerability, Godzilla has allowed the Japanese to attach their sadness to a collective. This points to the unique role art plays in Japanese society, says Jave Yoshimoto, a Japanese-American artist whose work is a lasting "visual memory" of Tōhoku. "Western art is focused on the self," says Yoshimoto. "Japanese art is about [society.]" The film provokes a spirit of renewal: Though Tokyo is destroyed time and time again, it is always rebuilt.

Reality reflects fiction. In 2011, rescuers led an elderly couple out of a building where they had been trapped for three days. When asked, the man smiled and said he's okay; he lived through the 1960 tsunami, after all. "I'm fine," he repeats. Then he grins at the camera: "Let's rebuild again."

—Susie Neilson

ABOVE A woman cries as she watches a sad movie at a tear-seeking event in Tokyo in 2013. Some 100 people gathered to watch the short movies as a form of therapy.

SOCIOLOGY

Have You Heard the One About the Classless Society?

If you ever wonder whether you belong, try a joke

IN HER BOOK *Good Humor, Bad Taste: Sociology of a Joke,* Dutch sociologist Giselinde Kuipers investigates a specific kind of humor: the short humorous anecdote leading to a punchline. This type of joke is popular in the Netherlands—there's even a special word in Dutch for the genre, *mop*—and in the 1990s, there

was a popular TV show, *Moppentoppers*, where contestants competed to tell the best joke. The *mop* is conveniently concise, making it easy to track.

Kuipers sent out questionnaires asking responders to judge a series of Dutch TV shows, entertainers, writers, and presenters, along with 35 *mops* (including racist and sexist jokes, riddles, and of course jokes about Belgians). She received more than 300 responses. The results were clear: Men liked the *mops* far better than women, and among those men, the less educated they were, the more they liked them.

Although the Dutch tend to believe they live in a classless society, Kuipers writes that humor made clear to her the depth of the cultural divide there, and her place on one side of it. "If I told the interviewees that the educated, like my university colleagues, didn't tell many [*mops*], they were quite surprised," she writes. "They derived from this that university employees didn't like humor or that they were boring and serious." As one 49-year-old janitor told her, "Maybe laughing a bit more would do them good."

Her highly educated colleagues were equally bewildered by the *moppentoppers*. "If I run into someone at a party who's really into jokes, then I try to escape," a 40-year-old marketing researcher told her. "There's no way you can have a conversation with somebody like that."

Kuipers too, found her interviews with the *moppentoppers* trying. She struggled to talk to them; they, in turn, didn't want to share their jokes with her. "I had to go to great lengths to convince people that I was hard enough to hear certain jokes," she writes. "They admitted, sometimes even blushing, that it was embarrassing to tell me a certain type of joke."

Humor made clear to her the depth of the cultural divide.

The jokes reflect an identity that Kuipers doesn't share, both as an academic and as a woman. Told to an outsider, the *mops* lose context, even becoming embarrassing to the teller. Even when she convinced the *moppentoppers* to tell her their jokes, some adapted them to make them less transgressive. "The interviews had a very specific tinge—older men telling dirty jokes to a much younger woman," she says. "Sometimes that was awkward for both parties." Telling a joke can really put you in your place.

—Zach St. George

YOSHIKAZU TSUNO/AFP/GETTY IMAGES

ONE QUESTION

How has your scientific field shaped your idea of human identity?

Debra Lieberman

Evolutionary psychologist at the University of Miami

I'm interested in discovering how the mind works. In my research, I take an evolutionary approach, which means I consider how conditions that persisted over many thousands of generations shaped modern human behavior and the mental programs that give rise to behavior. One of the foundational principles of my discipline is that, in addition to humans sharing the same organs, limbs, eyes, and so forth, they also share a common evolved psychology. We call this the psychic unity of humankind, or, if you want to get technical, the psychic unity of mankind and womankind. This particular perspective is personally appealing because it suggests that biologically and psychologically we cannot be divided into arbitrary social classes such as race—together we are one human race.

HEALTH

This May Be the Most Neglected Disease on Earth

Podoconiosis affects millions, and it can be prevented by wearing shoes

MINTAMIR WAS IN HER mid-20s when her brother thought she was about to die. Her feet and lower legs had started to swell and disfigure. He took her to a church in Gondar city, in northern Ethiopia, where he'd heard there was holy water that might be of help. When they arrived, a priest at the church took water from a nearby stream and sprinkled it over Mintamir's feet while praying. They returned home to the Ehthiopian village of Gumbi.

Many believe that the disease is a result of witchcraft.

Time passed. Mintamir's feet swelled to about three times the normal size, and her skin roughened. Eventually her husband left. Friends turned away. Invitations to birthdays, weddings, and funerals stopped. Embarrassed, she rarely steps out of her hut. Others like her turn to begging or commit suicide.

They are suffering from a disease that few people have heard of, podoconiosis. It is a neglected disease. In fact, it may be the most neglected disease on Earth. The World Health Organization has a list of 17 "main" neglected tropical diseases, including dengue, trachoma, and lymphatic filariasis. Podoconiosis does not make the list. The global health agency does not yet have a formal program for it.

Many of these diseases don't satisfy the requirements to attract the international health community: being infectious, or global, or affecting enough people, or requiring drugs. Podoconiosis is not infectious. It does not kill; it just disfigures and disables. No pharma company will make a mint off the item at the core of prevention and treatment: shoes.

Podoconiosis, a lesser known form of elephantiasis, is not caused by bacteria, or viruses, or parasites, but by walking barefoot in red clay soil of volcanic origin—soil that is rich in minerals like amorphous silica, iron oxides, and quartz. Its treatment requires clean water and soap to wash the feet, bandages to compress the swelling, and shoes for protection.

About 6 million people are estimated to be suffering from podoconiosis, which primarily affects subsistence farmers in Africa, Central and South America, and South Asia. Almost half of the affected live in Ethiopia. Some simply cannot afford shoes; others think shoes are a sign of laziness. Many, including Mintamir, believe that the disease is a result of witchcraft. All five of her children wear shoes, but not to avoid the clay.

"I made sure that their feet stay protected from magic," she says.

—Ankur Paliwal

ONE QUESTION

How has your scientific field shaped your idea of human identity?

David Cicero

Clinical psychologist, University of Hawaii

Identity is a concept most of us take for granted: We know who we are and that we inhabit and control our own bodies. But in my research, I've learned that identity is tenuous—grasping it may be the difference between sanity and schizophrenia. Many people with the disorder, for example, have disturbances in their identities early in its onset—they lose track of themselves, forget their life stories, and suddenly need to pay attention to typically effortless behavior, like controlling body movements. Without a clear sense of who you are and where you've been, it's much more difficult to figure out where you're going.

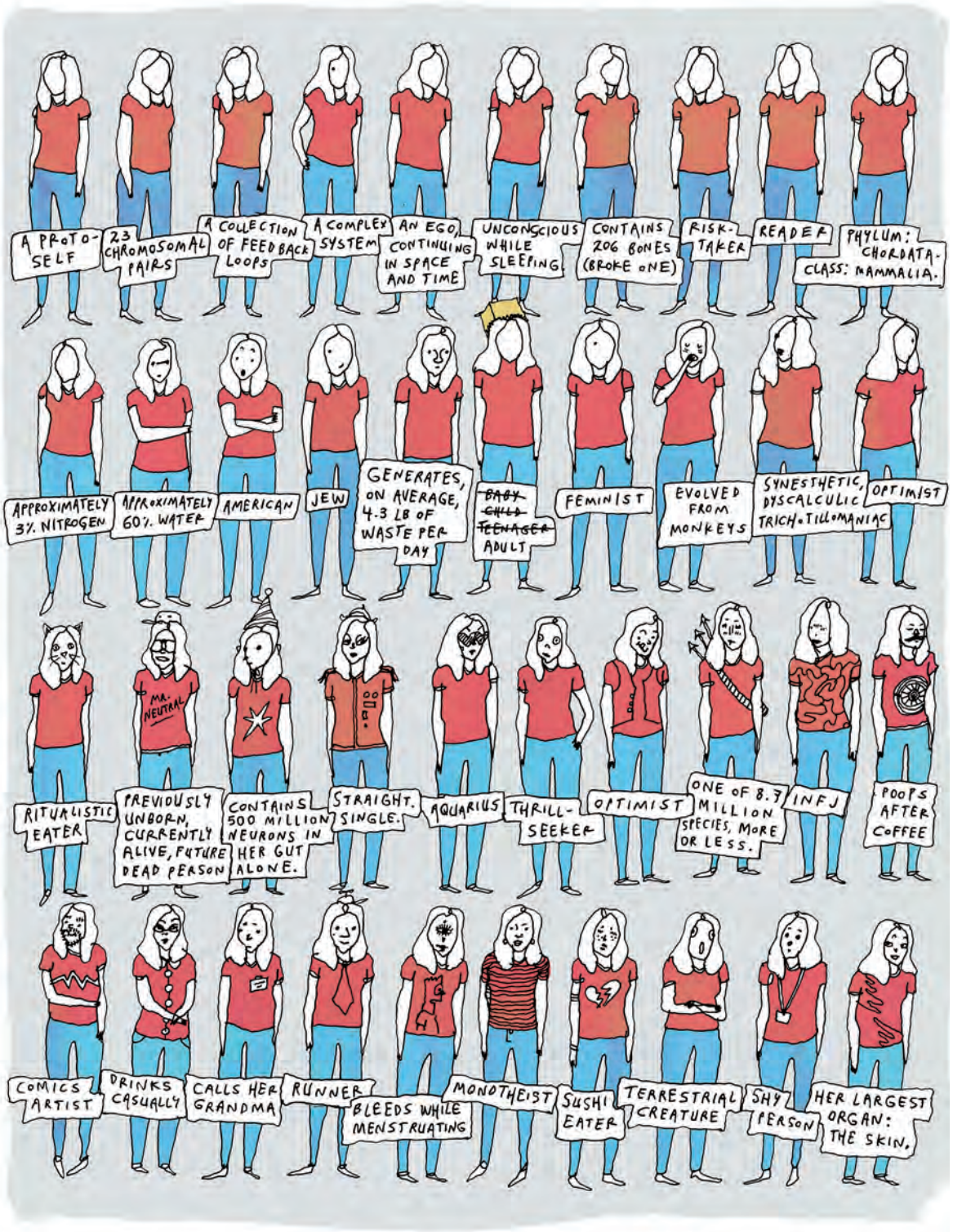


ILLUSTRATION BY LIANA FINCK

The Volcano That Shrouded the Earth and Gave Birth to a Monster

Three years of darkness and cold spawned crime, poverty, and a literary masterpiece

BY GILLEN D'ARCY WOOD

TWO HUNDRED YEARS AGO, the greatest eruption in Earth's recorded history took place. Mount Tambora—located on Sumbawa Island in the East Indies—blew itself up with apocalyptic force in April 1815.

After perhaps 1,000 years' dormancy, the devastating evacuation and collapse required only a few days. It was the concentrated energy of this event that was to have the greatest human impact. By shooting its contents into the stratosphere with biblical force, Tambora ensured its volcanic gases reached sufficient height to disable the seasonal rhythms of the global climate system, throwing human communities worldwide into chaos. The sun-dimming stratospheric aerosols produced by Tambora's eruption in 1815 spawned the most devastating, sustained period of extreme weather seen on our planet in perhaps thousands of years.

Within weeks, Tambora's stratospheric ash cloud circled the planet at the equator, from where it embarked on a slow-moving sabotage of the global climate system at all latitudes. Five months after the eruption, in September 1815, meteorological enthusiast Thomas Forster observed strange, spectacular sunsets over Tunbridge Wells near London. "Fair dry day," he

ILLUSTRATIONS BY WESLEY ALLSBROOK

wrote in his weather diary—but "at sunset a fine red blush marked by diverging red and blue bars."

Artists across Europe took note of the changed atmosphere. William Turner drew vivid red skyscapes that, in their coloristic abstraction, seem like an advertisement for the future of art. Meanwhile, from his studio on Greifswald Harbor in Germany, Caspar David Friedrich painted a sky with a chromic density that—one scientific study has found—corresponds to the "optical aerosol depth" of the colossal volcanic eruption that year.

For three years following Tambora's explosion, to be alive, almost anywhere in the world, meant to be hungry. In New England, 1816 was nicknamed the "Year Without a Summer" or "Eighteen-Hundred-and-Froze-to-Death." Germans called 1817 the "Year of the Beggar." Across the globe, harvests perished in frost and drought or were washed away by flooding rains. Villagers in Vermont survived on porcupine and boiled nettles, while the peasants of Yunnan in China sucked on white clay. Summer tourists traveling in France mistook beggars crowding the roads for armies on the march.

One such group of English tourists, at their lakeside villa near Geneva, passed the cold, crop-killing days by the fire exchanging ghost stories. Mary Shelley's storm-lashed novel *Frankenstein* bears the imprint of the Tambora summer of 1816, and her literary coterie—which included the poets Percy Shelley and Lord Byron—serve as tour guides through the suffering worldscape of 1815–18.

Considered on a geological timescale, Tambora stands almost insistently near to us. The Tambora climate emergency of 1815–18 offers us a rare, clear window onto a world convulsed by weather extremes, with human communities everywhere struggling to adapt to sudden, radical shifts in temperatures and rainfall, and a flow-on tsunami of famine, disease, dislocation, and unrest. It is a case study in the fragile interdependence of human and natural systems.

ON SUMBAWA ISLAND, the beginning of the dry season in April 1815 meant a busy time for the local farmers. In a few weeks the rice would be ready, and the raja of Sanggar, a small kingdom on the northeast coast of the island, would send his people into the fields to harvest. Until then, the men of his village, called Koreh, continued to work in the surrounding forests, chopping down the sandalwood trees vital to shipbuilders in the busy sea lanes of the Dutch East Indies.

On the evening of April 5, 1815, at about the time his servants would have been clearing the dinner dishes, the raja heard an enormous thunderclap. Perhaps his first panicked thought was that the beach lookout had fallen asleep and allowed a pirate ship to creep in to shore and fire its cannon. But everyone was instead staring up at Mount Tambora. A jet of flame burst skyward from the summit, lighting up the darkness and rocking the earth beneath their feet. The noise was incredible, painful.

Huge plumes of flame issued from the mountain for three hours, until the dark mist of ash became confused with the natural darkness, seeming to announce the end of the world. Then, as suddenly as it had begun, the column of fire collapsed, the earth stopped shaking, and the bone-jarring roars faded. Over the next few days, Tambora continued to bellow occasionally, while ash drifted down from the sky.

Meanwhile to the southeast in the capital Bima, colonial administrators were sufficiently alarmed by the events of April 5 to send an official, named Israel, to investigate the emergency situation at the volcano, on the Sanggar Peninsula. By April 10, the man's bureaucratic zeal had led him to the very slopes of Tambora. There, in the dense tropical forest, at about 7 p.m., he became one of the first victims of the most powerful volcanic eruption in recorded history.

Within hours, the village of Koreh, along with all other villages on the Sanggar Peninsula, ceased to exist entirely, a victim of Tambora's spasm of self-destruction. This time three distinct columns of fire burst in a cacophonous roar from the summit to the west, blanketing the stars and uniting in a ball of swirling flame at a height greater than the eruption of five days before. The mountain itself began to glow as streams of boiling liquefied rock coursed down its slopes. At 8 p.m., the terrifying conditions across Sanggar grew worse still, as a hail of pumice stones descended, mixed with a downpour of hot rain and ash.

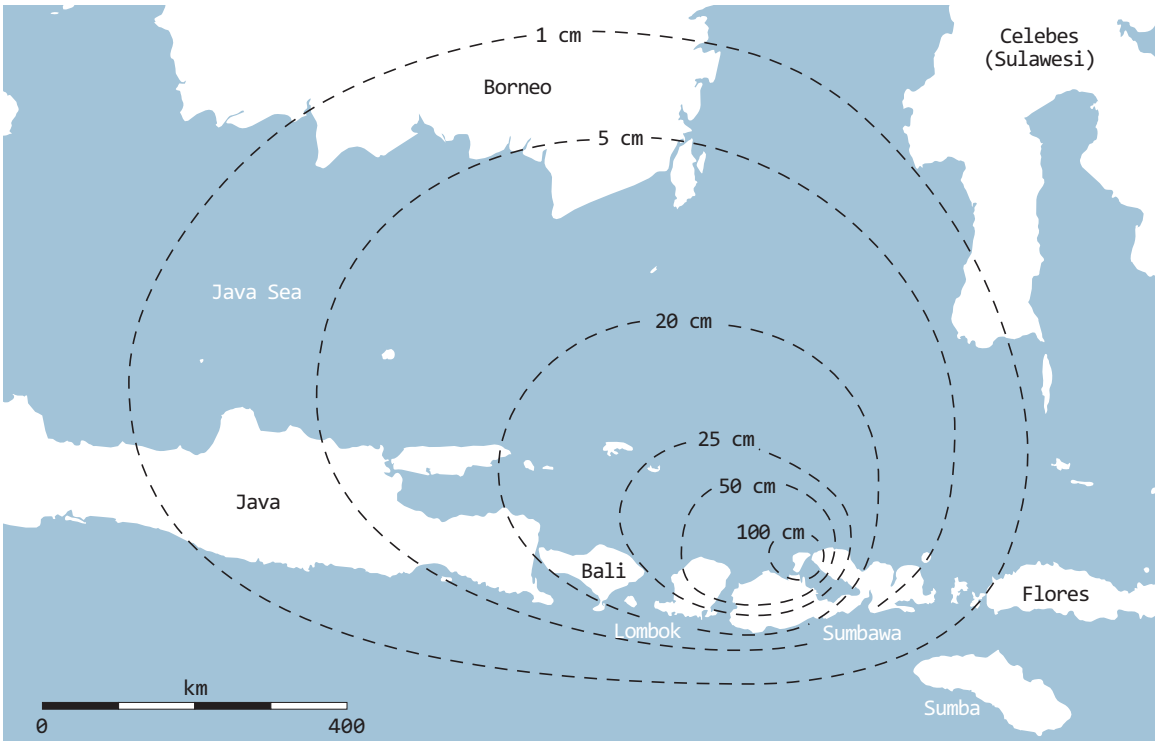
On the northern and western slopes of the volcano, whole villages, totaling perhaps 10,000 people, had already been consumed within a vortical hell of flames, ash, boiling magma, and hurricane-strength winds. In

The Tambora climate emergency offers us a rare, clear window onto a world convulsed by weather extremes. It is a case study in the fragile interdependence of human and natural systems.

2004, an archaeological team from the University of Rhode Island uncovered the first remains of a village buried by the eruption: a single house under three meters of volcanic pumice and ash. Inside the walled remains, they found two carbonized bodies, perhaps a married couple. The woman, her bones turned to charcoal by the heat, lay on her back, arms extended, holding a long knife. Her sarong, also carbonized, still hung across her shoulder.

Back on the mountain's eastern flank, the rain of volcanic rocks gave way to ashfall, but there was to be no relief for the surviving villagers. The spectacular, jet-like "plinian" eruption (named for Pliny the Younger, who left a famous account of Vesuvius's vertical column of fire) continued unabated, while glowing, fast-moving currents of rock and magma, called "pyroclastic streams," generated enormous phoenix clouds of choking dust. As these burning magmatic rivers poured into the cool sea, secondary explosions redoubled the aerial ash cloud created by the original plinian jet. An enormous curtain of steam and ash clouds rose and encircled the peninsula, creating, for those trapped inside it, a short-term microclimate of pure horror.

First, a "violent whirlwind" struck Koreh, blowing away roofs. As it gained in strength, the volcanic hurricane uprooted large trees and launched them like burning javelins into the sea. Horses, cattle, and people alike flew upward in the fiery wind. What survivors remained then faced another deadly element: giant waves from the sea. The crew of a British ship cruising offshore in the Flores strait, coated with ash and bombarded by volcanic rocks, watched stupefied as a 12-foot-high tsunami washed away the rice fields and huts along the Sanggar coast. Then, as if the combined cataclysms of air and sea weren't enough, the



RAIN OF ASH This map shows the density of ash fall issuing from Tambora's eruption. The thickness of the ash is shown in centimeters. Prevailing trade winds drove the ash clouds north and west as far as Celebes (Sulawesu) and Borneo, 1,300 kilometers away. The volcanic eruptions could be heard twice as far away.

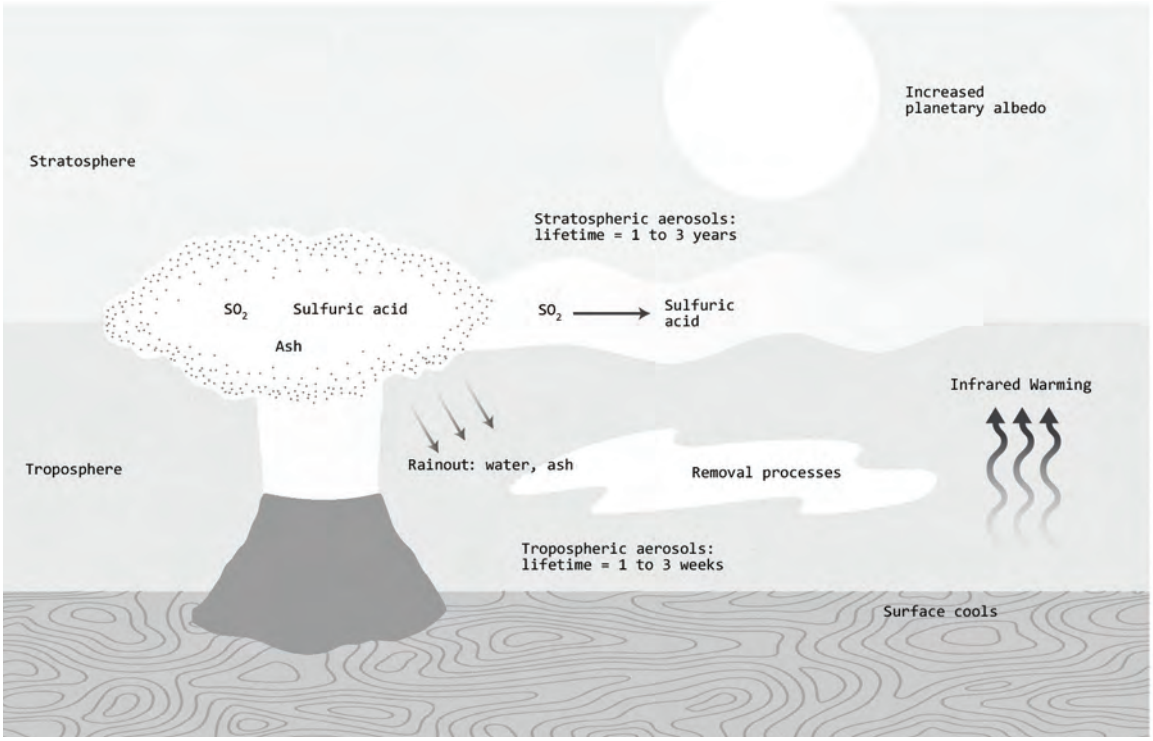
land itself began to sink as the collapse of Tambora's cone produced waves of subsidence across the plain.

On the sunless days following the cataclysm, corpses lay unburied all along the roads on the inhabited eastern side of the island between Dompu and Bima. Villages stood deserted, their surviving inhabitants having scattered in search of food. With forests and rice paddies destroyed, and the island's wells poisoned by volcanic ash, some 40,000 islanders would perish from sickness and starvation in the ensuing weeks, bringing the estimated death toll from the eruption to over 100,000, the largest in history.

While the skyward eruptions lasted only about three hours each, the boiling cascade of pyroclastic streams down Tambora's slopes continued a full day. Hot magma gushed from Tambora's collapsing chamber down to the peninsula, while columns of ash, gas, and rock rose and fell, feeding the flow. The fiery flood that consumed the Sanggar Peninsula, traveling up to 19 miles at great speeds, ultimately extended over a 216-square-mile area, one of the greatest pyroclastic events in the historical record. Within a few short hours, it buried human civilization in northeast Sumbawa under a smoking meter-high layer of ignimbrite.

Tambora's cacophony of explosions on April 10, 1815, could be heard hundreds of miles away. All across the region, government ships put to sea in search of imaginary pirates and invading navies. In the seas to the north off Macassar, the captain of the East India Company vessel Benares gave a vivid account of conditions in the region on April 11:

> The ashes now began to fall in showers, and the appearance altogether was truly awful and alarming. By noon,



THE BIG CHILL This diagram shows the penetration of volcanic matter into the stratosphere. As volcanic sulfur dioxide is chemically transformed into sulfuric acid, an aerosol layer forms, reducing incoming radiation from the sun and cooling the surface, even as the stratosphere itself is warmed.

> the light that had remained in the eastern part of the horizon disappeared, and complete darkness had covered the face of day ... The darkness was so profound throughout the remainder of the day, that I never saw anything equal to it in the darkest night; it was impossible to see your hand when held up close to the eye.

Across a 600-kilometer radius, darkness descended for two days, while Tambora's ash cloud expanded to cover a region nearly the size of the continental United States. The entire Southeast Asian region was blanketed in volcanic debris for a week. Day after dark day, British officials conducted business by candlelight, as the death toll mounted.

Months after the eruption, the atmosphere remained heavy with dust—the sun a blur. Drinking water contaminated by fluorine-rich ash spread disease and with 95 percent of the rice crop in the field at the time of the eruption, the threat of starvation was immediate and universal. In their desperation for food, islanders were reduced to eating dry leaves and their much-valued horseflesh. By the time the acute starvation crisis was over, Sumbawa had lost half its population to famine and disease, while most of the rest had fled to other islands.

Tambora's violent impact on global weather patterns was due, in part, to the already unstable conditions prevailing at the time of its eruption. A major tropical volcano had blown up six years prior, in 1809. This cooling event, hugely amplified by the sublime Tambora eruption in 1815, ensured extreme volcanic weather across the entire decade.

A flurry of research since the discovery of the 1809 eruption has resulted in the identification of the 1810–19 decade as a whole as the coldest in the historical

Tambora's influence on history does not derive from extreme weather events considered in isolation but in the myriad environmental impacts of a climate system gone haywire.

record—a gloomy distinction. A 2008 modeling study concluded Tambora's eruption to have had by far the largest impact on global mean surface air temperatures among volcanic events since 1610, while the 1809 volcano ranked second over that same period, measuring just over half Tambora's decline. Two papers published the following year confirmed the status of the 1810s as "probably the coldest during the past 500 years or longer," a fact directly attributable to the proximity of the two major tropical eruptions.

The spectacular eruption increased that cooling to a truly dire extent, contributing to an overall decline of global average temperatures of 1.5 degrees Celsius across the decade. One-and-a-half degrees might seem a small number, but as a sustained decline characterized by a sharp rise in extreme weather events—floods, droughts, storms, and summer frosts— the chilled global climate system of the 1810s had devastating impacts on human agriculture, food supply, and disease ecologies.

The Scottish meteorologist George Mackenzie kept meticulous records of cloudy skies between 1803 and 1821 over various parts of the British Isles. Where lovely clear summer days in the earlier period (1803–10) averaged over 20, in the volcanic decade (1811–20) that figure dropped to barely five. For 1816, the Year Without a Summer, Mackenzie recorded *no clear days at all*.

ON THE EVE OF THE SUMMER of 1816, 18-year-old Mary Godwin took flight with her lover, Percy Shelley, and their baby for Switzerland, escaping the chilly atmosphere of her father's house in London. Mary's young stepsister, Claire Clairmont, accompanied them, eager to reunite with her own poet-lover, Lord Byron, who had left England for Geneva a week earlier. Mary's other sister, the ever dispensable Fanny, was left behind.

The dismal, often terrifying weather of the summer of 1816 is a touchstone of the ensuing correspondence between the sisters. In a letter to Fanny, written on her arrival in Geneva, Mary describes their ascent of the Alps "amidst a violent storm of wind and rain." The cold was "excessive" and the villagers complained of the lateness of the spring. On their alpine descent days later, a snowstorm ruined their view of Geneva and its famous lake. In her return letter, Fanny expresses sympathy for Mary's bad luck, reporting that it was "dreadfully dreary and rainy" in London too, and very cold.

Stormy nor'easters are standard features of Genevan weather in summertime, careening from the mountains to whip the waters of the lake into a sirocco of foam. Beginning in June 1816, these annual storms attained a manic intensity not witnessed before or since. "An almost perpetual rain confines us principally to the house," Mary wrote to Fanny on the first of June from Maison Chappuis, their rented house on the shores of Lake Geneva: "One night we enjoyed a finer storm than I had ever before beheld. The lake was lit up—the pines on Jura made visible, and all the scene illuminated for an instant, when a pitchy blackness succeeded, and the thunder came in frightful bursts over our heads amid the darkness." A diarist in nearby Montreux compared the bodily impact of these deafening thunderclaps to a heart attack.

In fact, the year 1816 remains the coldest, wettest Geneva summer since records began in 1753. That unforgettable year, 130 days of rain between April and September swelled the waters of Lake Geneva, flooding the city. Up in the mountains the snow refused to melt. Clouds hung heavy, while the winds blew bitingly cold. In some parts of the inundated city, transport was only possible by boat. A cold northwest wind from the Jura mountains—called *le joran* by locals—swept relentlessly across the lake. The Montreux diarist called the persistent snows and *le joran* "the twin evil genies of 1816." Tourists complained they couldn't recognize the famously picturesque landscape because of

BRITISH LIBRARY

WORST OF TIMES Charles Dickens, whose grim weatherscapes and portraits of poverty are definitive representations of Victorian London, grew up under the ever-cloudy, bone-chilling atmosphere created by the Tambora eruption.

the constant wind and avalanches, which drove snow across vast areas of the plains.

On the night of June 13, 1816, the Shelleys' splendidly domiciled neighbor, Lord Byron, stood out on the balcony of the lakeside Villa Diodati to witness "the mightiest of the storms" that he—well-traveled aristocrat that he was—had ever seen. He memorialized that tumultuous night in his wildly popular poem "Childe Harold's Pilgrimage":

> The sky is changed—and such a change! Oh night,
> And storm, and darkness, ye are wondrous strong ...
> And now again 'tis black,—and now, the glee
> Of the loud hills shakes with its mountain-mirth,
> As if they did rejoice o'er a young earthquake's birth.

In Byron's imagination, the Tamboran storms of 1816 achieve volcanic dimensions—like an "earthquake's birth"—and take delight in their destructive power.

What caused the terrible weather conditions over Britain and western Europe in 1816–18? The relation between volcanism and climate depends on eruptive scale. Volcanic ejecta and gases must penetrate skyward high enough to reach the stratosphere where, in its cold lower reaches, sulfate aerosols form. These then enter the meridional currents of the global climate system, disrupting normal patterns of temperature and precipitation across the hemispheres. Tambora's April 1815 eruption launched enormous volumes of long-suppressed volcanic rock and gases more than 25 miles into the stratosphere. This volcanic plume—consisting of as much as 12 cubic miles of total matter—eventually spread across 386,000 square miles of the Earth's atmosphere, an aerosol umbrella six times the size of the cloud produced by the massive 1991 eruption of Mount Pinatubo in the Philippines.

In the first weeks after Tambora's eruption, a vast

GHOST STORY One night in 1816, in a villa on Lake Geneva, in the dark, dismal atmosphere created by Tambora's eruption, poets (at left) Lord Byron and Percy Shelley, and writer Mary Shelley, told ghost stories that gave birth to Frankenstein's monster and the Byronic Dracula.

YELLOW EYE An illustration from an 1831 edition of Frankenstein features this indelible line from the novel: "By the glimmer of the half-extinguished light, I saw the dull, yellow eye of the creature open."

volume of coarser ash particles—volcanic "dust"—cascaded back to Earth mixed with rain. But ejecta of smaller size—water vapor, molecules of sulfur and fluorine gases, and fine ash particles—remained suspended in the stratosphere, where a sequence of chemical reactions resulted in the formation of a 60-megaton sulfate aerosol layer. Over the following months, this dynamic, streamer-like cloud of aerosols—much smaller in size than the original volcanic matter—expanded by degrees to form a molecular screen of planetary scale, spread aloft by the winds and meridional currents of the world. In the course of an 18-month journey, it passed across both south and north poles, leaving a telltale sulfate imprint on the ice for paleoclimatologists to discover more than a century and a half later.

Once settled in the dry firmament of the stratosphere, Tambora's global veil circulated above the weather dynamics of the atmosphere, comfortably distanced from the rain clouds that might have dispersed it. From there, its planet-girdling aerosol film continued to scatter shortwave solar radiation back into space until early 1818, while allowing much of the longwave radiant heat from the earth to escape. The resultant three-year cooling regime, unevenly distributed by the currents of the world's major weather systems, barely affected some places on the globe (Russia, for instance, and the trans-Appalachian United States) but precipitated a drastic 5 to 6 degrees Fahrenheit seasonal decline in other regions, including Europe.

The first extreme impact of a major tropical eruption is felt in raw temperature. But in western Europe, biblical-style inundation during the 1816 summer

TOP LEFT: WIKIPEDIA
BOTTOM LEFT: BRITISH LIBRARY

growing season wrought the greatest havoc. Because of the tilt of the Earth in relation to the sun and the different heat absorption rates of land and sea, solar insolation of the planet is irregular. Uneven heating in turn creates an air pressure gradient across the latitudes of the globe. Wind is the weatherly expression of these temperature and pressure differentials, transporting heat from the tropics to the poles, moderating temperature extremes, and carrying evaporated water from the oceans over the land to support plant and animal life. The major meridional circulation patterns, measuring thousands of miles in breadth, transport energy and moisture horizontally across the globe, creating continental-scale weather patterns. Meanwhile, at smaller scales, the redistribution of heat and moisture through the vertical column of the atmosphere produces localized weather phenomena, such as thunderstorms.

In the summer after Tambora's eruption, however, the aerosol loading of the stratosphere heated the upper layer, which bore down upon the atmosphere. The "tropopause" that marks the ceiling of the Earth's atmosphere dropped lower, cooling air temperatures and displacing the jet streams, storm tracks, and meridional circulation patterns from their usual course. By early 1816, Tambora's chilling envelope had created a radiation deficit across the North Atlantic, altering the dynamics of the vital Arctic Oscillation. Slower-churning warm waters north of the Azores pumped overloads of moisture into the atmosphere, saturating the skies while enhancing the temperature gradient that fuels wind dynamics. Meanwhile, air pressure at sea level plummeted across the mid-latitudes of the North Atlantic, dragging cyclonic storm tracks southward. Pioneering British climate historian Hubert Lamb has calculated that the influential Icelandic low-pressure system shifted several degrees latitude to the south during the cold summers of the 1810s compared to 20th-century norms, settling in the unfamiliar domain of the British Isles, and thus ensuring colder, wetter conditions for all of western Europe.

Both computer models and historical data draw a dramatic picture of Tambora-driven storms hammering Britain and western Europe. A recent computer simulation conducted at the National Center for Atmospheric Research in Boulder, Colorado showed fierce westerly winds in the North Atlantic in the aftermath of a major tropical eruption, while a parallel study based on multiproxy reconstructions of volcanic impacts on European climate since 1500 concluded that volcanic weather drives the increased "advection of maritime air from the North Atlantic," meaning "stronger westerlies" and "anomalously wet conditions over Northern Europe."

> In Byron's imagination, the Tamboran storms of 1816 achieve volcanic dimensions—like an "earthquake's birth"—and take delight in their destructive power.

Back at the ground level of observed weather phenomena, an archival study of Scottish weather has found that, in the 1816–18 period, gale-force winds battered Edinburgh at a rate and intensity unmatched in over 200 years of record keeping. In January 1818, a particularly violent storm nearly destroyed the beloved St. John's Chapel in the heart of the city. The slowing of oceanic currents in response to the overall deficit of solar radiation post-Tambora had left unusual volumes of heated water churning through the critical area between Iceland and the Azores, sapping air pressure, energizing westerly winds, and giving shape to titanic storms.

It was in this literally electric atmosphere that the Shelley party in Geneva, with Byron attached, conceived the idea of a ghost story contest, to entertain themselves indoors during this cold, wild summer. On the night of June 18, 1816, while another volcanic summer thunderstorm raged around them, Mary and Percy Shelley, Claire Clairmont, Byron, and Byron's doctor-companion John Polidori recited the poet Coleridge's recent volume of gothic verse to each other in the candlelit dimness at the Villa Diodati. In his 1986 movie about the Shelley circle that summer, British film director Ken Russell imagines Shelley gulping tincture

of opium while Claire Clairmont performs fellatio on Byron, recumbent in a chair. Group sex in the drawing room might be implausible, even for the Shelley circle, but drug taking is very likely, inspired by Coleridge, the poet-addict supreme. How else to explain Shelley's running screaming from the room at Byron's recitation of the psychosexual "Christabel," tormented by his vision of a bare-chested Mary Shelley with eyes instead of nipples?

From such antics, Byron conceived the outline of a modern vampire tale, which the bitter Polidori would later appropriate and publish under Byron's name as a satire on his employer's cruel aristocratic hauteur and sexual voracity. For Mary, the lurid events of this stormy night gave literary body to her own distracted musings on the ghost story competition, instituted two nights earlier. She would write a horror story of her own, about a doomed monster brought unwittingly to life during a storm. As Percy Shelley later wrote, the novel itself seemed generated by "the magnificent energy and swiftness of a tempest." Thus it was that the unique creative synergies of this remarkable group of college-age tourists—in the course of a few weeks' biblical weather—gave birth to two singular icons of modern popular culture: Frankenstein's monster and the Byronic Dracula.

A week after the memorable night of June 18, Byron and Shelley almost came to grief sailing on Lake Geneva, caught unawares as another violent storm swept in from the east. "The wind gradually increased in violence," Shelley recalled, "until it blew tremendously; and, as it came from the remotest extremity of the lake, produced waves of a frightful height, and covered the whole surface with a chaos of foam." By some miracle they found a sheltered port, where even the storm-hardened locals exchanged "looks of wonder." Onshore, trees had blown down or been shattered by lightning.

The pyrotechnical lightning displays of June 1816 ignited the literary imagination of Mary Shelley. In *Frankenstein*, she uses the experience of a violent thunderstorm as the scene of fateful inspiration for her young, doomed scientist:

> When I was about fifteen years old … we witnessed a most violent and terrible thunderstorm. It advanced from behind the mountains of Jura; and the thunder burst at once with frightful loudness from various quarters of the heavens. I remained, while the storm lasted, watching its progress with curiosity and delight. As I stood at the door, on a sudden I beheld a stream of fire issue from an old and beautiful oak, which stood about twenty yards from our house; and so soon as the dazzling light vanished, the oak had disappeared, and nothing remained but a blasted stump.

She would write a horror story of her own, about a doomed monster brought unwittingly to life during a storm.

Frankenstein's life is changed in this moment; he devotes himself, with maniacal energy, to the study of electricity and galvanism. In the fierce smithy of that Tamboran storm, Frankenstein is born as the anti-superhero of modernity—the "Modern Prometheus"—stealer of the gods' fire.

TAMBORA'S INFLUENCE on human history does not derive from extreme weather events considered in isolation but in the myriad environmental impacts of a climate system gone haywire. As a result of the prolonged poor weather, crop yields across the British Isles and western Europe plummeted by 75 percent and more in 1816–17. In the first summer of Tambora's cold, wet, and windy regime, the European harvest languished miserably. Farmers left their crops in the field as long as they dared, hoping some fraction might mature in late-coming sunshine. But the longed-for warm spell never arrived and at last, in October, they surrendered. Potato crops were left to rot, while entire fields of barley and oats lay blanketed in snow until the following spring.

In Germany, the descent from bad weather to crop failure to mass starvation conditions took a frighteningly rapid course. Carl von Clausewitz, the military tactician, witnessed "heartrending" scenes on his horseback travels through the Rhine country in the spring of 1817: "I saw decimated people, barely human,

prowling the fields for half-rotten potatoes." In the winter of 1817, in Augsburg, Memmingen, and other German towns, riots erupted over the rumored export of corn to starving Switzerland, while the locals were reduced to eating horse and dog flesh.

Meanwhile, back in England, riots broke out in the East Anglian counties as early as May 1816. Armed laborers bearing flags with the slogan "Bread or Blood" marched on the cathedral town of Ely, held its magistrates hostage, and fought a pitched battle against the militia.

In his magisterial account of the social and economic upheaval in Europe during the Tambora period, historian John Post has shown the scale of human suffering to be worst in Switzerland, home to Shelley and her circle in 1816. Even in normal times, a Swiss family devoted at least half its income to buying bread. Already by August 1816, bread was scarce, and in December, bakers in Montreux threatened to cease production unless they could be allowed to raise prices. With imminent famine came the threat of "*soulèvements*": violent uprisings. Bakers were set upon by starving mobs in the market towns and their shops destroyed. The English ambassador to Switzerland, Stratford Canning, wrote to his prime minister that an army of peasants, unemployed and starving, was assembling to march on Lausanne.

Most shocking of all was the fate of some desperate mothers. In horrific circumstances repeated around the world in the Tambora period, some Swiss families abandoned their offspring in the crisis, while others chose killing their children as the more humane course. For this crime, some starving women were apprehended and decapitated. Thousands of Swiss with more means and resilience emigrated east to prosperous Russia, while others set off along the Rhine to Holland and sailed from there to North America, which witnessed its first significant wave of refugee European migration in the 19th century. The numbers of European immigrants arriving at U.S. ports in 1817 more than doubled the number of any previous year.

Devastated by famine and disease in the Tambora period, the poor of Europe hurriedly buried their dead before resuming the bitter fight for their own survival. In the worst cases, children were abandoned by their families and died alone in the fields or by the roadside. The well-born members of the Shelley circle were never reduced to such abysmal circumstances. They did not experience the food crises that afflicted millions among the rural populations of western Europe in the Tambora period. Yet the Shelleys' celebrated writings were enmeshed within the web of ecological breakdown following the Tambora eruption.

Byron and Percy Shelley were companions on a weeklong walking tour of Alpine Switzerland in June 1816, during which they debated poetry, metaphysics, and the future of mankind but also found time to remark on the village children they encountered, who "appeared in an extraordinary way deformed and diseased. Most of them were crooked, and with enlarged throats." In *Frankenstein*, the Doctor's benighted creation assumes a similar grotesque shape: a barely human creature, deformed, crooked, and enlarged. Like the hordes of refugees on the roads of Europe seeking aid in 1816–18, the Creature, when he ventures into the towns, is met with fear and hostility, horror and abomination. As the indigent Creature himself puts it, he suffered first "from the inclemency of the season" but "still more from the barbarity of man."

As remarkable a feat of literary imagination as *Frankenstein* is, Mary Shelley was not wanting for real-world inspiration for her horror story, namely the deteriorating rural populations of Europe, in the climatic upheaval of Mount Tambora.

GILLEN D'ARCY WOOD is the author of *Tambora: The Eruption That Changed the World*. He is a professor of English at the University of Illinois, Urbana-Champaign, where he directs the Sustainability Studies Initiative in the Humanities.

30

BEFORE THE SCIENTIFIC METHOD BEGINS, before the hypothesis is conceived, identity needs to be confronted. Reagents and particles, agents and actors, dependent and independent variables require labeling. Dotted lines are drawn and boundaries established.

Getting those identities right helps. But sometimes the greatest progress comes from realizing they're incomplete.

The discovery that light, electricity, and magnetism are not independent ushered in modern physics. Learning that we share nearly half our genes with the fruit fly reshaped our sense of belonging. Euler's equation, which reveals a hidden connection between pi and two other constants, is considered by some to be the most beautiful equation in mathematics.

Science has taken many of our putative identities and melted them together. But we are jealous of our human identities. Those, we'd like to think are different. We'd like to keep them intact and persistent.

Given what we know, is that a fool's errand?

Welcome to "Identity."

—MS

"I can still remember the sense of shock I felt when I realized I was experiencing the aural equivalent of a blind spot. It was as if a highly selective stroke had robbed me of the abiltiy to read the letter Z."

ALEXANDER GELFAND
"Drums, Lies, and Audiotape" p.50

Identity

ASKING WHO

The Strange Persistence of First Languages

After my father died, my journey of rediscovery began with the Czech language

BY JULIE SEDIVY

SEVERAL YEARS AGO, my father died as he had done most things throughout his life: without preparation and without consulting anyone. He simply went to bed one night, yielded his brain to a monstrous blood clot, and was found the next morning lying amidst the sheets like his own stone monument.

It was hard for me not to take my father's abrupt exit as a rebuke. For years, he'd been begging me to visit him in the Czech Republic, where I'd been born and where he'd gone back to live in 1992. Each year, I delayed. I was in that part of my life when the marriage-grad school-children-career-divorce current was sweeping me along with breath-sucking force, and a leisurely trip to the fatherland seemed as plausible as pausing the flow of time.

Now my dad was shrugging at me from beyond—"You see, you've run out of time."

His death underscored another loss, albeit a far more subtle one: that of my native tongue. Czech was the only language I knew until the age of 2, when my family began a migration westward, from what was then Czechoslovakia through Austria, then Italy, settling eventually in Montreal, Canada. Along the way, a clutter of languages introduced themselves into my life: German in preschool, Italian-speaking friends, the francophone streets of East Montreal. Linguistic experience congealed, though, once my siblings and I started school in English. As with many immigrants, this marked the time when English became, unofficially and over the grumbling of my parents (especially my father), our family language—the time when Czech began its slow retreat from my daily life.

Many would applaud the efficiency with which we settled into English—it's what exemplary immigrants do. But between then and now, research has shown the depth of the relationship all of us have with our native tongues—and how traumatic it can be when that relationship is ruptured. Spurred by my father's death, I returned to the Czech Republic hoping to

ILLUSTRATION BY SARAH MAZZETTI

reconnect to him. In doing so, I also reconnected with my native tongue, and with parts of my identity that I had long ignored.

WHILE MY FATHER was still alive, I was, like most young people, more intent on hurtling myself into my future than on tending my ancestral roots—and that included speaking the language of my new country rather than my old one. The incentives for adopting the culturally dominant language are undeniable. Proficiency offers clear financial rewards, resulting in wage increases of 15 percent for immigrants who achieve it relative to those who don't, according to economist Barry Chiswick. A child, who rarely calculates the return on investment for her linguistic efforts, feels the currency of the dominant language in other ways: the approval of teachers and the acceptance of peers. I was mortally offended when my first-grade teacher asked me on the first day of school if I knew "a little English"—"I don't know a little English," was my indignant and heavily accented retort. "I know a *lot* of English." In the schoolyard, I quickly learned that my Czech was seen as having little value by my friends, aside from the possibility of swearing in another language—a value I was unable to deliver, given that my parents were cursing teetotalers.

But embracing the dominant language comes at a price. Like a household that welcomes a new child, a single mind can't admit a new language without some impact on other languages already residing there. Languages can co-exist, but they tussle, as do siblings, over mental resources and attention. When a bilingual person tries to articulate a thought in one language, words and grammatical structures from the other language often clamor in the background, jostling for attention. The subconscious effort of suppressing this competition can slow the retrieval of words—and if the background language elbows its way to the forefront, the speaker may resort to code-switching, plunking down a word from one language into the sentence frame of another.

Meanwhile, the weaker language is more likely to become swamped; when resources are scarce, as they are during mental exhaustion, the disadvantaged language may become nearly impossible to summon. Over time, neglecting an earlier language makes it harder and harder for it to compete for access.

> His death underscored another loss, albeit a far more subtle one: that of my native tongue.

According to a 2004 survey conducted in the Los Angeles metropolitan area, fewer than half of people belonging to Generation 1.5—immigrants who arrive before their teenage years—claimed to speak the language they were born into "very well." A 2006 study of immigrant languages in Southern California forecast that even among Mexican Americans, the slowest group to assimilate within Southern California, new arrivals would live to hear only 5 out of every 100 of their great-grandchildren speak fluent Spanish.

When a childhood language decays, so does the ability to reach far back into your own private history. Language is memory's receptacle. It has Proustian powers. Just as smells are known to trigger vivid memories of past experiences, language is so entangled with our experiences that inhabiting a specific language helps surface submerged events or interactions that are associated with it.

Psychotherapist Jennifer Schwanberg has seen this firsthand. In a 2010 paper, she describes treating a client who'd lived through a brutal childhood in Mexico before immigrating to the United States. The woman showed little emotion when talking about events from her early life, and Schwanberg at first assumed that her client had made her peace with them. But one day, the woman began the session in Spanish. The therapist followed her lead and discovered that "moving to her first language had opened a floodgate. Memories from childhood, both traumatic and nontraumatic, were recounted with depth and vividness … It became clear that a door to the past was available to her in her first language."

A first language remains uniquely intertwined with early memories, even for people who fully master another language. In her book *The Bilingual Mind*, linguist Aneta Pavlenko describes how the author

ADRIAN GIDDINGS/FLICKR

Vladimir Nabokov fled the Russian revolution in 1919, arriving in the United Kingdom when he was 20. By the time he wrote his memoir *Conclusive Evidence* in 1951, he'd been writing in English for years, yet he struggled writing this particular text in his adopted language, complaining that his memory was tuned to the "musical key" of Russian. Soon after its publication, he translated the memoir into his native tongue. Working in his first language seems to have prodded his senses awake, leading him to insert new details into the Russian version: A simple anecdote about a stingy old housekeeper becomes perfumed with the scents of coffee and decay, the description of a laundry hamper acquires a creaking sound, the visual details of a celluloid swan and toy boat sprout as he writes about the tub in which he bathed as a child. Some of these details eventually made it into his revised English memoir, which he aptly titled *Speak, Memory*. Evidently, when memory speaks, it sometimes does so in a particular tongue.

Losing your native tongue unmoors you not only from your own early life but from the entire culture that shaped you. You lose access to the books, films, stories, and songs that articulate the values and norms that you've absorbed. You lose the embrace of an entire community or nation for whom your family's odd quirks are not quirks all. You lose your context. This disconnection can be devastating. A 2007 study led by Darcy Hallett found that in British Columbian native communities in which fewer than half of the members could converse in their indigenous language, young people killed themselves six times more often than in communities where the majority spoke the native language. In the Midwestern U.S., psychologist Teresa LaFromboise and her colleagues found that American-Indian adolescents who were heavily involved in activities focused on their traditional language and traditions did better at school and had fewer behavior problems than kids who were less connected to their traditional cultures—in fact, cultural connectedness buffered them against adolescent problems

more than having a warm and nurturing mother. Such benefits appear to span continents: In 2011, the Australian Bureau of Statistics reported that aboriginal youth who spoke their traditional language were less likely to binge drink or use illegal drugs.

Why is a heritage language so conducive to well-being? Michael Chandler, one of the authors of the suicide study, emphasizes that a sense of cultural continuity makes people resilient by providing them with a cohesive self-concept. Without that continuity, he warns, aboriginal youth, who have typically experienced plenty of turbulence, are in grave existential danger. They risk losing "the thread that tethers together their past, present, and future."

AS MY SIBLINGS AND I distanced ourselves from the Czech language in our youth, a space widened between us and our parents—especially my father, who never wore English with any comfort. Memories of our early family life, along with its small rituals and lessons imparted, receded into a past that drifted ever further out of reach. It was as if my parents' life in their home country, and the values that defined that life, didn't translate credibly into another language; it was much easier to rebel against them in English. Even the English names for our parents encouraged dissent: The Czech words we'd used—*Maminka*, *Tatinek*—so laden with esteem and affection, impossible to pronounce with contempt, had no corresponding forms. In English, the sweet but childish *Mommy* and *Daddy* are soon abandoned for *Mom* and *Dad*—words that, we discovered, lend themselves perfectly well to adolescent snark.

I watched as my father grew more and more frustrated at his powerlessness to pass on to his children the legacy he most longed to leave: a burning religious piety, the nurturing of family ties, pleasure in the music and traditions of his region, and an abiding respect for ancestors. All of these became diluted by the steady flow of new memories narrated in English, laced with Anglophone aspiration and individualism. As we entered adulthood and dispersed all over North America into our self-reliant lives, my father gave up. He moved back home.

For the next two decades, I lived my adult life, fully absorbed into the English-speaking universe, even adding American citizenship to my Canadian one. My dad was the only person with whom I regularly spoke Czech—if phone calls every few months can be described as "regularly," and if my clumsy sentences patched together with abundant English can be called "speaking Czech." My Czech heritage began to feel more and more like a vestigial organ.

Then my father died. Loss inevitably reveals that which is gone. It was as if the string section of the orchestra had fallen silent—not carrying the melody, it had gone unnoticed, but its absence announced how much depth and texture it had supplied, how its rhythms had lent coherence to the music. In grieving my father, I became aware of how much I also mourned the silencing of Czech in my life. There was a part of me, I realized, that only Czech could speak to, a way of

MEMORIES The author in the arms of her father, Ladislav Sedivy, together with her mother Vera and her older siblings, Marie and Silvester. This photo was taken several months before the family's departure from their Czech home.

You lose the embrace of an entire community. You lose your context.

being that was hard to settle into, even with my own siblings and mother when we spoke in English.

After my father's death, my siblings and I inherited a sweet little apartment in a large compound that has been occupied by the Sedivy family since the 1600s, and where my uncle still lives with his sprawling family. This past spring, I finally cleared two months of my schedule and went for a long visit, sleeping on the very same bed where my father and his brothers had been born.

I discovered that, while I may have run out of time to visit my father in his homeland, there was still time for me to reunite with my native tongue. On my first day there, the long drive with my uncle between the airport and our place in the countryside was accompanied by a conversation that lurched along awkwardly, filled with dead ends and misunderstandings. Over the next few days, I had trouble excavating everyday words like *stamp* and *fork*, and I made grammar mistakes that would (and did) cause a 4-year-old to snicker. But within weeks, fluency began to unspool. Words that I'm sure I hadn't used in decades leapt out of my mouth, astounding me. (Often they were correct. Sometimes not: I startled a man who asked about my occupation by claiming to be a savior—*spasitelka*. Sadly, I am a mere writer—*spisovatelka*.) The complicated inflections of Czech, described as "character-building" by an acquaintance who'd learned the language in college, began to assemble into somewhat orderly rows in my mind, and I quickly ventured onto more and more adventurous grammatical terrain. Just a few weeks into my visit, I briefly passed as a real Czech speaker in a conversation with a stranger. Relearning Czech so quickly felt like having linguistic superpowers.

Surprised by the speed of my progress, I began to look for studies of heritage speakers relearning childhood languages that had fallen into disuse. A number of scientific papers reported evidence of cognitive remnants of "forgotten" languages, remnants that were visible mostly in the process of relearning. In some cases, even when initial testing hinted at language decay, people who'd been exposed to the language earlier in life showed accelerated relearning of grammar, vocabulary, and most of all, of control over the sounds of the language.

One of the most remarkable examples involved a group of Indian adoptees who'd been raised from a young age (starting between 6 and 60 months) in English-speaking families, having no significant contact with their language of origin. The psychologist Leher Singh tested the children when they were between the ages of 8 and 16. Initially, neither group could hear the difference between dental and retroflex consonants, a distinction that's exploited by many Indian languages. After listening to the contrasting sounds over a period of mere minutes, the adoptees, but not the American-born children, were able to discriminate between the two classes of consonants.

This is revealing because a language's phonology, or sound structure, is one of the greatest challenges

PHOTO COURTESY OF JULIE SEDIVY

for people who start learning a language in adulthood. Long after they've mastered its syntax and vocabulary, a lifelong accent may mark them as latecomers to the language. Arnold Schwarzenegger was the star of many American movies and the governor of the country's biggest state, but his Austrian accent is a constant reminder that he could never run for president. The crucial timing of exposure for native-like speech is evident in my own family: I can pronounce the notoriously difficult "ř" sound in Czech—as in the name of the composer Dvořák—but my brother, born three years after me, in Vienna, cannot.

Phonology's resistance to both attrition and later learning may be due to the fact that the sound structure of a language is fixed in a child's mind very early. Before 6 months of age, infants can distinguish most subtle differences in speech sounds, whether their language makes use of those distinctions or not. But over the second half of their first year, they gradually tune their perception to just the sounds of the language they hear around them. Children who hear only English lose the ability to distinguish between dental and retroflex sounds. Children learning Japanese begin to hear "r" and "l" as variants of the same sound. Linguist Pat Kuhl, who has studied this phenomenon for decades, describes the process as one of perceptual narrowing and increasing neural commitment, eventually excluding native-like perception of other languages.

One of the most striking examples of the brain's attunement to native sounds is apparent in languages such as Mandarin, where varying the tone of an utterance can produce entirely different words. (For instance, the syllable *ma* can mean "mother," "hemp," "horse," or "scold," depending on the pitch contour you lay over it.) When Mandarin speakers hear nonsense syllables that are identical except for their tones, they show heightened activity in the left hemisphere of the brain, where people normally process sounds that signal differences in meaning—like the difference between the syllables "pa" and "ba." But speakers of non-tonal languages like English have more activity in the *right* hemisphere, showing that the brain doesn't treat tone as relevant for distinguishing words. A recent study found that Chinese-born babies adopted into French homes showed brain activity that matched Chinese speakers and was clearly distinct from monolingual French speakers—even after being separated from their birth language for more than 12 years.

THE BRAIN'S DEVOTION to a childhood language reminds me of a poem by Emily Dickinson:

> The Soul selects her own Society—
> Then—shuts the Door—
> To her divine Majority—
> Present no more—
>
> Unmoved—she notes the Chariots—pausing—
> At her low Gate—
> Unmoved—an Emperor be kneeling
> Upon her Mat —
>
> I've known her—from an ample nation—
> Choose One—
> Then—close the Valves of her attention—
> Like Stone—

Those of us who received more than one language before the valves of our attention closed may find, to our surprise, that our earliest language lingers on in our soul's select society, long after we thought it had faded.

I've become aware of the deep sense in which I belong to the Czech language, as well as the extent to which my formative memories are tinged by its "musical key." For me, the English phrase "pork with cabbage and dumplings" refers to a concept, the national dish of the Czechs. But hearing the Czech phrase *vepřo-knedlo-zelo* evokes the fragrance of roasting meat, pillowy dumpling loaves being pulled steaming out of a tall pot and sliced with sewing thread, and the clink of the nice china as the table is dressed for Sunday dinner, the fulcrum of every week.

Since coming back from the Czech Republic, I've insisted on speaking Czech with my mother. Even though it's more effortful for both of us than speaking in English, our conversation feels softer, more tender this way. English was the language in which I forged my independence, the language of my individuation—but it was in Czech that I was nurtured, comforted, and sung to.

It has also gotten easier to hear the timbre of my father's voice in my mind's ear, especially when working in my garden. It's no accident that many of my conversations with him, and more recently with my

uncle, have been on the subject of horticulture. My father's family has lived for centuries in the fertile wine and orchard region of Moravia, and on my recent visit, I saw my relatives gaze out at their land with an expression usually reserved for a beloved spouse or child. Throughout my own life, I've given in to the compulsion to fasten myself to whatever patch of land I happened to be living on by growing things on it, an impulse that has often conflicted with the upwardly and physically mobile trajectory of my life. It's an impulse I submit to once again, living now in the lee of the Rocky Mountains; neither grapes nor apricots will thrive in the brittle mountain air, but I raise sour cherries and saskatoons, small fruits native to western Canada. As I mulch and weed and prune, I sometimes find myself murmuring to my plants in Czech as my father did, and the Moravian homestead doesn't seem very far away.

My newly vocal native tongue, and along with it, the heightened memory of my father's voice, does more than connect me to my past: It is proving to be an unexpected guide in my present work. I've recently left my job as an academic linguist to devote more time to writing, and I often find myself these days conjuring my father's voice by reading a passage in Czech. Like many Czechs I've met, my father treated his language like a lovely object to be turned over, admired, stroked with a fingertip, deserving of deliberate and leisurely attention. He spoke less often than most people, but was more often eloquent. I may never regain enough of my first language to write anything in it worth reading, but when I struggle to write prose that not only informs but transcends, I find myself steering my inner monologue toward Czech. It reminds me of what it feels like to sink into language, to be startled by the aptness of a word or the twist of a phrase, to be delighted by arrangements of its sounds, and lulled by its rhythms. I've discovered that my native language has been sitting quietly in my soul's vault all this time.

JULIE SEDIVY has taught linguistics and psychology at Brown University and the University of Calgary. She is the co-author of *Sold on Language: How Advertisers Talk to You and What This Says About You* and more recently, the author of *Language in Mind: An Introduction to Psycholinguistics*.

ADDITIONAL READING

Hallett, D., Chandler, M.J., & Lalonde, C.E. Aboriginal language knowledge and youth suicide. *Cognitive Development* **22**, 392-399 (2007).

Hernandez, A.E. *The Bilingual Brain* Oxford University Press, New York, NY (2013).

Pavlenko, A. *The Bilingual Mind* Cambridge University Press, Cambridge (2014).

Singh, L., Liederman, J., Mierzejewski, R., & Barnes, J. Rapid reacquisition of native phoneme contrasts after disuse: You do not always lose what you do not use. *Developmental Science* **14**, 949-959 (2011).

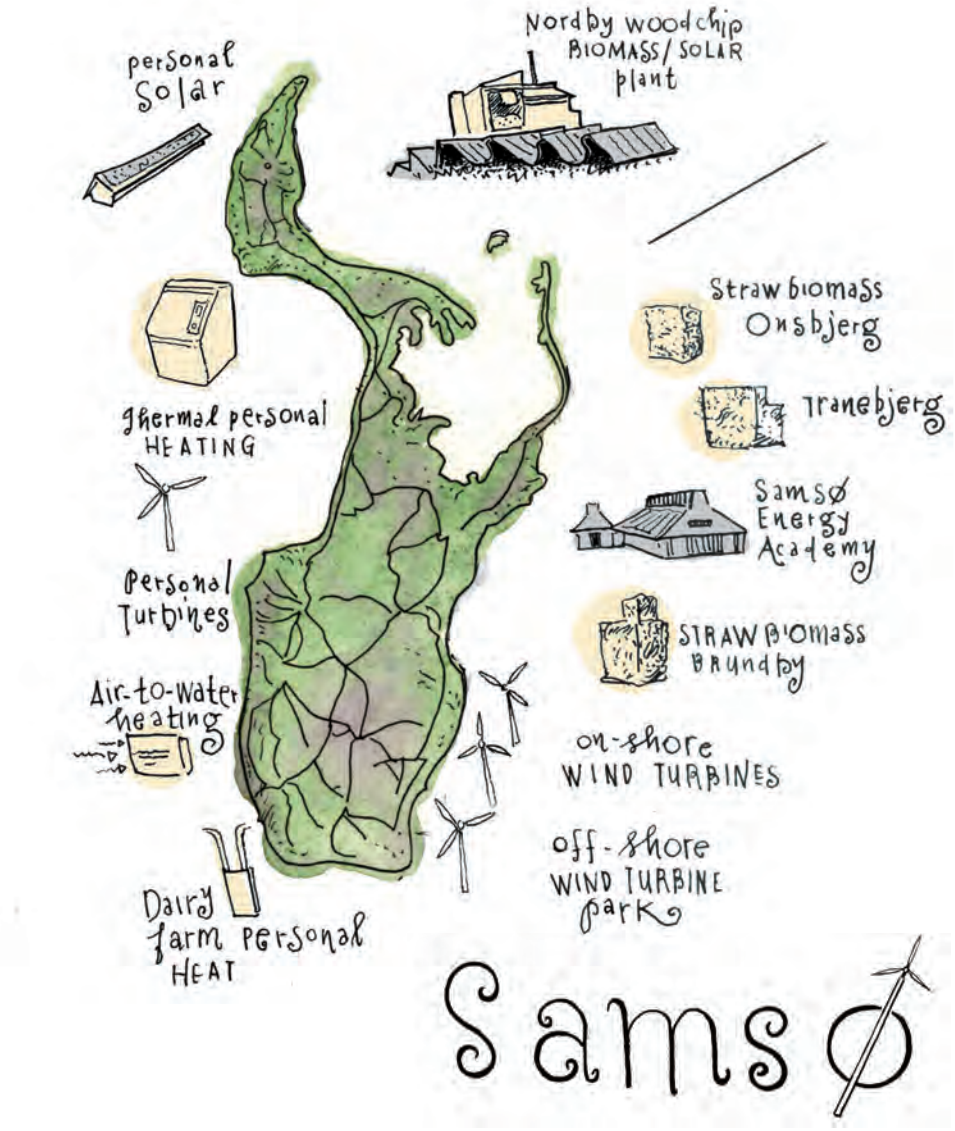
Slavkov, N. Language attrition and reactivation in the context of bilingual first language acquisition. *International Journal of Bilingual Education and Bilingualism* **18**, 715-734 (2015).

Wang, Q., Shao, Y., & Li, Y.J. "My way or mom's way?" The bilingual and bicultural self in Hong Kong Chinese children and adolescents. *Child Development* **81**, 555-567 (2010).

Blowing Off the Grid

Samsø runs on renewable energy—and makes money doing it

by STEVE BRODNER



THE STORY BEGAN WITH Svend Auken, our brave Minister for the Environment," says Soren Hermansen, who runs the Energy Academy on the Danish island of Samsø, an emerald comma in the Kattegat Sea. "When he returned from the United Nations climate change conference in 1997, he announced, 'Now we need to start the green revolution in Denmark.' That was very brave and very crazy."

To get people excited about the idea, Auken set up a competition between municipalities for the best plan for going carbon-neutral in 10 years. When Samsø won, it became Denmark's "renewable-energy island." Hermansen, then a teacher, rock musician, and self-described rabble-rouser, took it upon himself to see that his native island lived up to its new name.

He brought consultants—and beer—to community meetings to try to convince his neighbors, many of them conservative farmers, to take up the cause. But the consultants weren't getting through. So Hermansen sent them home. "Instead of telling people what they should do, I had to address the fear of change." He told them that renewable technologies—wind turbines, solar arrays, biomass plants—would bring jobs and, better yet, money. Through subsidies, the government guaranteed a stable price for wind-generated power for 10 years, meaning investors could recoup their costs after seven or eight and start making a healthy profit.

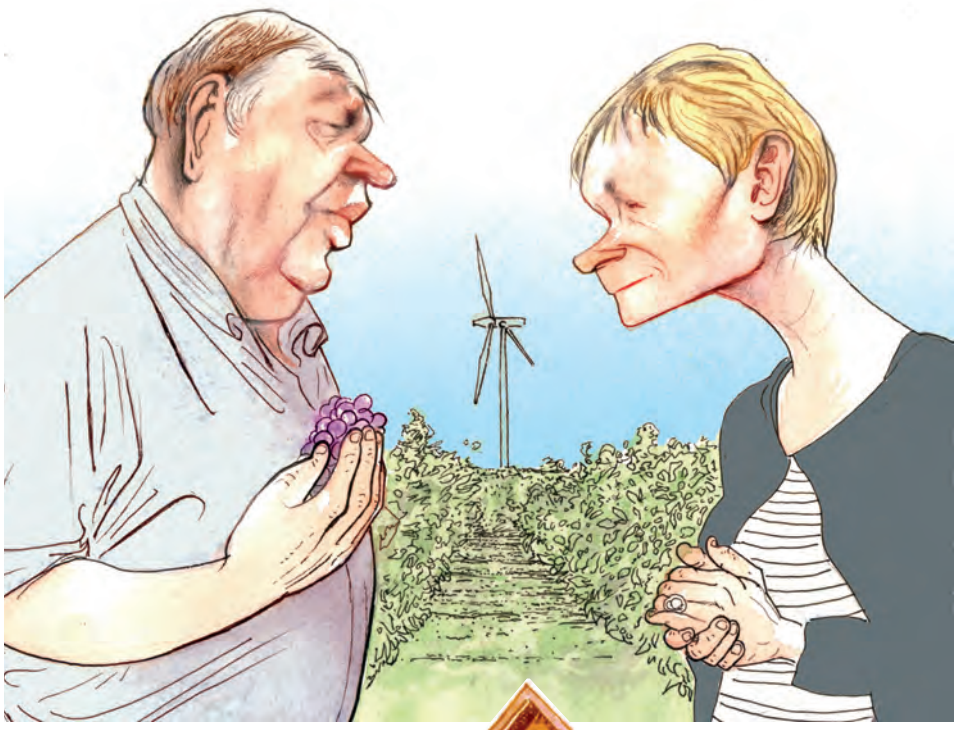
That perked up their ears. Meeting by meeting, Samsingers—farmers, plumbers, schoolteachers, grocers—began to band together behind the project. When it finally got off the ground in the late 1990s, Samsø was putting 11 tons of carbon dioxide into the atmosphere every year. But by 2001, residents had cut their fossil fuel use by half. In 2003, they began exporting electricity to the mainland. Today the island produces from renewable sources 25 percent more energy than it consumes.

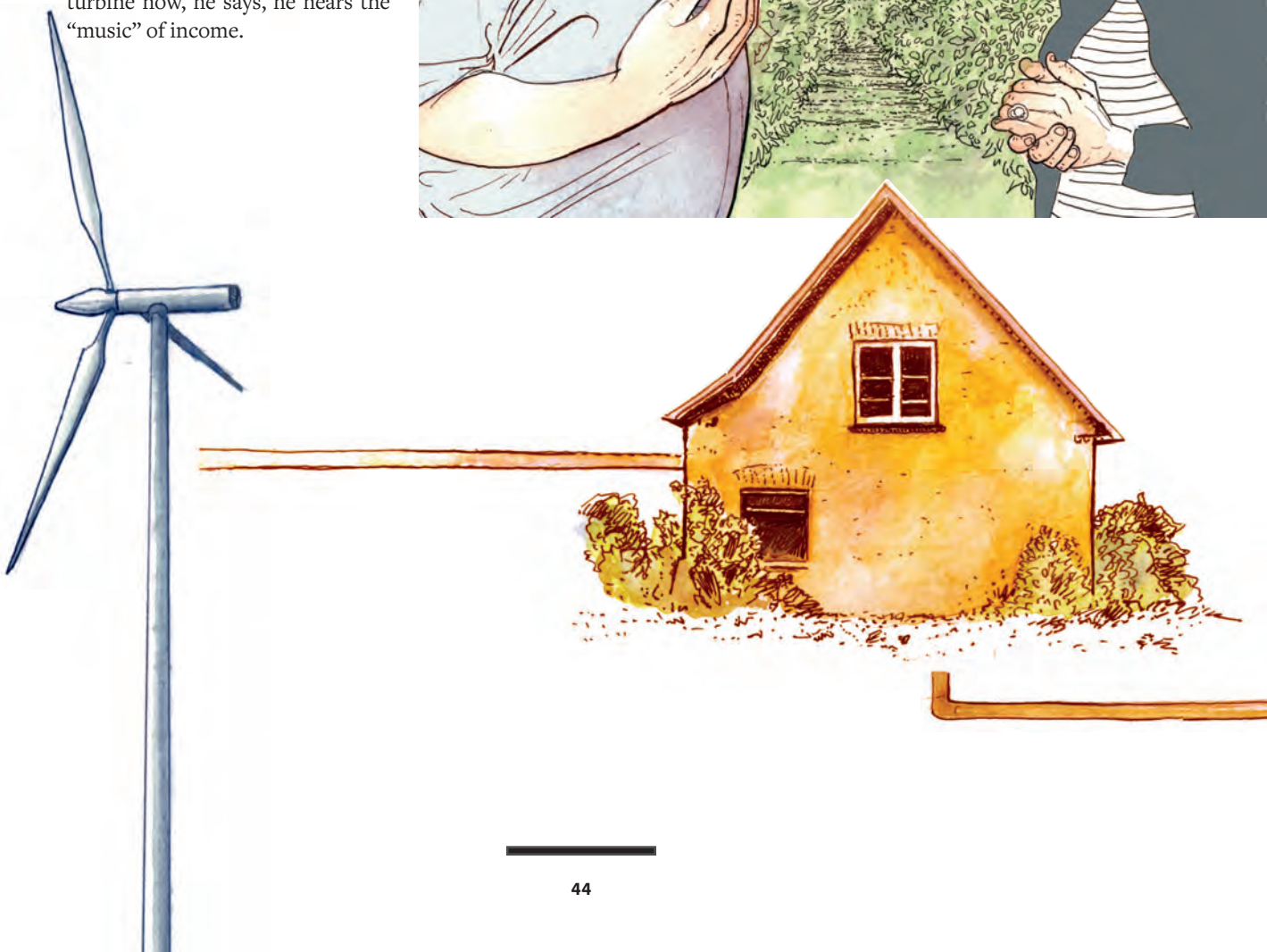
What makes Samsø's story so remarkable, however, isn't this fast transformation from carbon polluter to renewable-energy producer. It's how it happened: Samsø owes its success not to a collective environmental idealism, but to its residents' brass-tacks business sense.

"THE WIND ALWAYS BLOWS HERE," a grain farmer on Samsø told me. The steady resource allows the island to generate around 105 million kilowatt-hours per year with 11 land turbines, 10 offshore ones, and a smattering of micro-models. Residents use only about 24 percent of this electricity. They sell the rest.

Ole Kaempe, a teacher on the island, and his wife Hedvig Hauge can see the turbine in which they invested from their farmhouse, whirring away beyond their vineyard. "Two of the wind turbines were offered to everybody; you could buy shares," Kaempe says. "There was a lottery because too many people wanted in."

Listening to the low drone of his turbine now, he says, he hears the "music" of income.





TWO DECADES AGO, MOST Samsingers heated their homes with oil hauled in on tankers. Then Hermansen and others got together and calculated that residents could save up to 50 percent on their heating bills if they replaced their furnaces with pumps that drew hot water, through underground pipes, from district heating plants.

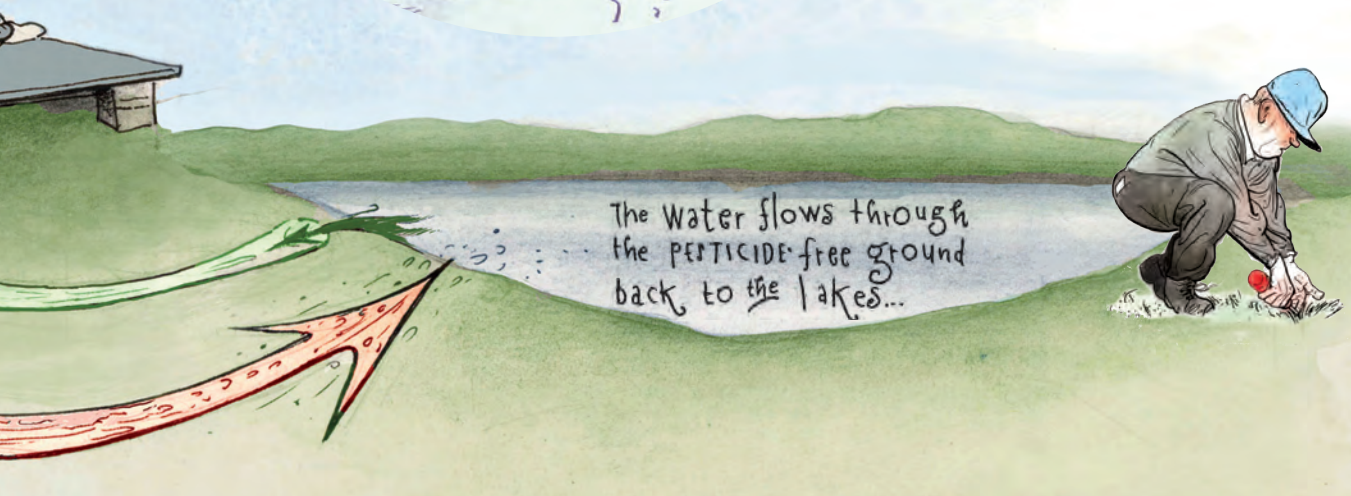
Arne Jensen runs three plants fueled by straw bales, which he buys from local farmers. (A fourth plant burns wood chips.) "It takes two and a half kilos of this stuff to replace one kilo of oil," he says. "This plant processes 1,600 tons a year. If they replaced that with oil, they would have to spend 20 million Danish krones [about $2.9 million], five times as much. That would be 20 million going out of the community. Instead, the money stays here."

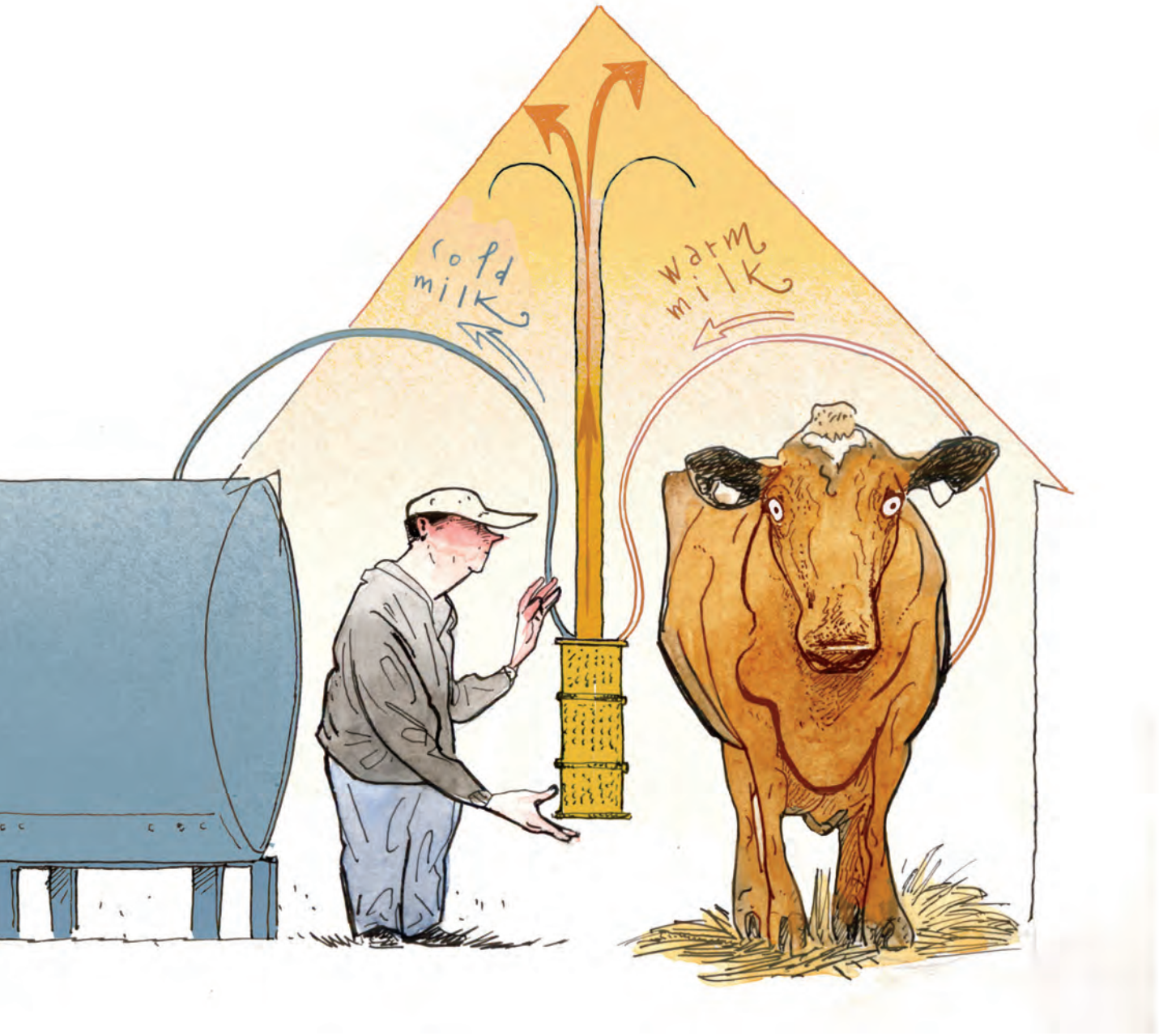
The process is also, more or less, carbon neutral. The CO_2 released during burning simply displaces the carbon that would have entered the atmosphere naturally, as the straw decomposed. Even the ash is repurposed as fertilizer.

SAMSØ GOLFKLUB, TUCKED IN the island's northeast corner, is a kind of microcosmic showcase of the community's embracement of sustainability. The club's carts and mowers are solar-powered, and golfers carry hand-held weeders so they can do spot maintenance as they play.

Meanwhile, sheep graze the course's organically grown greens, fertilizing them and keeping them tidy. They are an ancient Scandinavian breed that doesn't require shearing. Instead, they shed their wool, and employees pick it off the course. At club parties, members dine on lamb from the herd.

Which then, being extremely clean and full of nutrients, attracts NEW forms of wild life (Grebes and green frogs).





SOME RESIDENTS HAVE FOUND ways to draw cheap energy from unusual sources. Kasten Christiansen, a dairy farmer, warms his home with the milk from his cows. "We have 2,000 liters of milk we have to chill every day from 37 to 4 degrees Celsius for storage and delivery. It comes here to this cooler, and the heat pump takes the difference in temperature between the warm milk and the refrigerant and makes the heat for the house. We've got pipes in the ground as well, in case we don't have enough from the milk. In the winter when it gets below zero, we need the ground heat. In the spring, summer, and fall, there's enough from the milk alone."

NOT EVERYONE IS HAPPY with how things have shaken out. Jørgen Tranberg, a beef rancher on Samsø, owns two wind turbines—one on shore, one off—and a 6-kilowatt solar system. He warms his home with geothermal heat and sells straw to the district biomass plants. "I have spent 28 million Danish krone [$4 million] in energy, and that you don't do just for fun. I was just a simple farmer!"

For 10 years, he profited handsomely. But then his wind subsidies expired, and the government began erecting giant offshore turbine farms, increasing Denmark's electricity supply and thereby driving down prices. "Right now, *nothing* is worth investing in!"

Michael Kristensen, a project manager at Samsø's Energy Academy, believes Samsingers can lessen the loss from falling wind-energy prices by creating more demand. "In the windy winter season, we actually sometimes pay to export electricity to our neighbor countries," he says. "We could use this energy in electric vehicles, for making biogas for the ferry, and in the district heating plants."

To stay true to its title of "renewable-energy island," however, Samsø may need more help from the government. The island's turbines are getting old and in desperate need of maintenance, but with electricity prices so low, residents like Tranberg are hesitant to buy replacement parts. Without incentives such as subsidies, Kristensen says, "there is a real threat that if an old turbine breaks down, it will be torn down instead of repaired."

BUT IF THE SAMSØ MODEL can endure anywhere, it will be in places like Denmark, where tariffs on fossil fuels are driving investment in alternatives, says Jesper Kristensen, a development manager at the Energy Academy. "You can say that we have a good model here for the rest of the world."

STEVE BRODNER is an illustrator and journalist. He has created visual essays for *The New Yorker*, *The New York Times*, *Texas Monthly*, and *Esquire*, among other publications. He is currently at work on a book about the United States presidents. This piece was reported with help from Erik Petri and Cynthia Rose.

Drums, Lies, and Audiotape

When I received an invitation to play drums in Ghana, I gladly accepted. Then something went wrong.

BY ALEXANDER GELFAND

MY WIFE INGRID AND I had been in Aburi, Ghana for just over a week when our host, Kwame Obeng, informed me that I'd be joining the royal drummers for a performance at the chief's palace the following afternoon, in celebration of an important holy day.

It's not as if I was unprepared. I'd first met Obeng three years earlier, when he came to Toronto to coach a drumming troupe made up of Ghanaian immigrants and a lone Westerner (myself). We became close: Obeng called me *mi nua*, or "my brother," in Twi, the language of his ethnic group, the Akan. And when his visa expired after a year, he invited me to continue studying with him back home in Aburi, a small town nestled in the verdant Akuapem Hills. Two years later, I took him up on his invitation. And now it was time to show him what I could do. What happened next was a complete surprise to me. I would never find out if it was a surprise to Obeng.

The day of the performance, Obeng stationed me and his nephew, a young man named Kwame Antwi, at a pair of enormous, barrel-shaped *bommaa* drums standing side by side. Each *bommaa* was carved from a 5-foot length of hollowed-out tree trunk, and both were painted a lustrous black and wrapped in red velvet fastened with brass studs. Just in front of us and to our left, Obeng himself stood before a pair of massive, goblet-shaped *atumpan* drums with antelope-skin heads. Directly behind us, a quartet of young boys and middle-aged men played three smaller drums and an iron bell. They were the rhythm section, while the two Kwames and I formed the front line.

As the performance began, Kwame Antwi and I began bashing away at the thick cowhide heads with long, L-shaped sticks fashioned from tree branches. We made quite a pair: him long and lean and dark, me short and soft and very, very white. The raised platform at the opposite end of the courtyard gradually filled with chiefs and palace officials draped in togas and dresses, all in different colors: turquoise, scarlet,

ILLUSTRATION BY DANIEL HERTZBERG

cobalt, maroon. There was very little chitchat. Instead, our audience listened in silence as we played the drums, and various notables got up to make speeches and offer prayers to their ancestors.

The rhythms played on the big *bommaa* drums consist of several sets of patterns that are executed in unison by both drummers, each one longer and more complicated than the last. At first, I was able to match Antwi stroke for stroke. But as we moved into the longer and more complex material, things went completely off the rails. Suddenly, Antwi seemed to be adding rhythms that I'd never heard before. I tried to keep up with him, to imitate his hand movements even if I couldn't quite make out what he was playing.

But I couldn't. Standing there in front of the assembled royals, the truth slowly dawned on me: The rhythms I was supposed to play in public in Aburi were not the same as the ones that Obeng had taught me in Toronto, and which he had repeated for Ingrid and me during a brief private lesson just the previous day. Instead, they included swathes of material that were radically different from anything he'd shown us thus far; so different that I couldn't figure them out, let alone execute them, in the heat of the moment. But no one else seemed willing to admit it.

"Alex, what is wrong?" Antwi asked as the two of us sat down next to Ingrid during a break. "You played these yesterday, no problem."

"The rhythms are different," I said, still in shock at having totally blown my public debut.

"What?"

"These rhythms are different. They aren't the ones I played in Toronto. They aren't the ones we played with Obeng in our lesson yesterday."

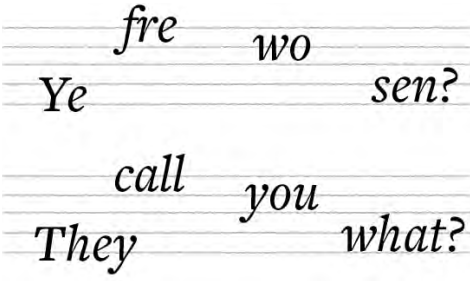
"Of course they are the same," said Antwi. "Only faster!"

That would be the standard line from our Ghanaian friends for the next several months: The rhythms are the same, only faster! But they weren't. As our hosts continued to insist that they had taught me the correct rhythms, I flubbed performance after performance: at rituals, at funerals, sometimes for enormous crowds. I couldn't stop performing—we'd traveled thousands of miles to learn this music, and our presence in the ensemble was a source of prestige for Obeng—but the chiefs and palace officials who knew *fontomfrom* best must surely have realized that I was perpetually botching it, even if they were unfailingly polite, saying only "*woaye ade!*" ("well done!") after every attempt.

I had no choice but to soldier on at the drums. While I did, I also struggled to comprehend what was happening. Eventually I boiled it down to two choices: Either we had radically divergent ideas about what constituted musical sameness and difference, about what gave a piece of music its unique identity and aural signature; or Obeng was intentionally hiding the full rhythms from Ingrid and me for unknown reasons. Was it deception or mental disconnect?

MY CONFUSION—and my sudden incompetence—would not have been such a big deal if the style of music we were playing, called *fontomfrom*, were just background music, the Akan equivalent of cocktail piano. But it wasn't. Every time chiefs appeared in public on official business, the royal drums came out. They were a vital element of regalia, a principal accoutrement of office. Perhaps even more importantly, the big *bommaa* and *atumpan* drums didn't just make music for dancing. They talked. Literally.

Twi is a tone language, like Mandarin Chinese: Each syllable has its own pitch, each word or phrase its own unique melody. Change those tones, alter those melodies, and the meaning of the words changes, too. Something as simple as asking a person's name becomes an exercise in birdsong (below).



By imitating the tones and rhythms of Twi, the Akan can "speak" with their musical instruments—their horns and trumpets, their drums and bells—almost as clearly as they do with their mouths. The *atumpan*, which produce two distinct pitches, are particularly well suited to this task; but the *bommaa* can do it, too.

AUTUMN DRUMS Drums are an integral part of the Ashanti yam harvast ceremony, shown here in a 19th-century illustration.

WIKIPEDIA

That was why the crowd at the palace had been so quiet: They were listening to what the drums had to say. The phenomenon, widespread in both West and Central Africa, is known as surrogate speech. It can add a layer of semantic depth to even the simplest music.

Every time that the chief, Nana Djan Kwasi, got up and walked around the courtyard, for instance, the two Kwames and I engaged in a little call-and-response.

Kwame Obeng: *bom bom*

Kwame Antwi and me: *BRRM BRRM!*

The rhythmic phrase *bom bom BRRM BRRM*, *bom bom BRRM BRRM* had a nice beat to it, and could just have been pleasant filler, something to play while the chief moved from place to place. And on one level, it was. On another, though, it was an earnest plea from the principal talking drums in the ensemble: *Nana, bre bre! Nana, bre bre!* "Chief, slowly! Chief, carefully!" If a chief stumbles in public, it's a sign of bad luck. So we were asking him to watch his step.

The drums didn't just speak to the living, but also to the dead: the revered ancestors who have left this earthly plane, yet continue to influence the affairs of their kin. The Akan believe that their ancestors are forever watching over them, and must forever be placated with prayers, offerings, and other remembrances. They also believe that their ancestors are particularly sensitive to the sound of the drums. That's one of the reasons why Akan drummers normally take great care to avoid mistakes. You wouldn't want to anger your ancestors by saying the wrong thing. In the old days, a sloppy royal drummer was likely to have an ear cut off. So when I butchered my part alongside Antwi that day at the palace, I wasn't just making the group sound bad—I was sticking a wrench in the gears of a rich cultural system where speech, art, and religion are all intertwined. Little wonder my heart was pounding in my ears as I walked away from the drums, the echoes of my mistakes still ringing through the courtyard.

This music was important. Why, then, did Obeng insist on withholding information that would have

prevented us from blowing almost every performance we gave while we were in Ghana? Did he have some ulterior motive? Or was there some basic aspect of Akan music that rendered it opaque to us on a fundamental level—culturally, psychologically, or even neurologically?

INGRID AND I were both graduate students at the University of Illinois before we left for Ghana in the summer of 1997. I was a Ph.D. candidate in ethnomusicology, a kind of musical anthropology, and Ingrid was completing a doctorate in percussion. In other words, we weren't exactly musical hacks. But the difficulty of *fontomfrom* was unexpected, and exceptional.

Unlike the drumming that often accompanies African dance classes in the West, *fontomfrom* doesn't have a particularly strong groove. But like most West African drumming, it does contain many different moving parts, from the long, complex patterns played on the *bommaa* and *atumpan* to the short, highly repetitive patterns played on the smaller drums and the iron bell. All of these rhythms interlock; often, they complete one another, the sounds of one drum filling in the silences of the others to produce unexpected patterns, like individual strands in a tapestry.

Fontomfrom rhythms can also be curiously ambiguous. For instance, you might think you're playing a waltz (ONE two three, ONE two three), while the guy next to you sounds as if he's playing a march (ONE two, ONE two). In fact, if you listen to him long enough, you might change your mind and decide that you, too, are really playing a march. In that sense, playing in a *fontomfrom* ensemble is like being inside a sonic version of an Escher lithograph: As you shift your attention from one part to another, the entire picture seems to change.

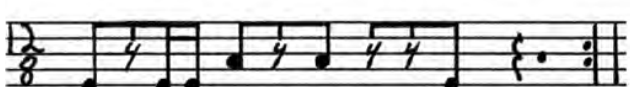
The *bommaa* patterns that I was suddenly expected to play in Ghana, however, were in a league of their own. Bits of them weren't just rhythmically ambiguous; they were rhythmically dysfunctional. A musicologist would say they were ametric, or lacked a clear relationship to any kind of steady pulse whatsoever. But there was definitely some kind of logic to them, because whenever two drummers who actually knew what they were doing took over at the *bommaa*, they not only managed to play in perfect unison; they also coordinated their entrances and exits against the matrix of the other drummers' parts with flawless consistency. Clearly, they knew—and heard—something we didn't.

It didn't help that Ingrid and I could barely hear the *bommaa* rhythms at all. While we were usually paired with an experienced court drummer in performance,

Attempting to decipher those brief, puzzling segments was like trying to ctach a falling knife.

PROBLEMS IN THE CLASSROOM
Kwame Obeng gives the author and his wife a lesson in *bommaa* rhythms in Aburi.

we were also constantly being told to play "louder," "faster," and "with more force," which only made it harder for us to make out the rhythms that our partners were playing (and easier for everyone else to hear our mistakes). Not that it would have been easy under other circumstances: It is hard to describe just how loud a *fontomfrom* ensemble is, with its clangorous iron bell, its piercing small drums, its booming *atumpan*, and its thunderous *bommaa*. To make matters worse, Nana Djan Kwasi's palace courtyard was an enormous echo chamber. We taped every performance we gave at court, but the sound of the big drums ricocheting around the concrete walls and corrugated metal roof completely overloaded our microphones, turning all of our recordings into a howling mess.



AN *ATUMPAN* PHRASE The Twi phrase *Obren tenten kwa*, as it is played on the tuned *atumpan* drums. The drummed rhythm captures the number of syllables in the spoken phrase; the two pitches represent different tone levels (high and low); and the rolled "r" in *Obren* is mimicked through the use of sixteenth notes. *Obren tenten kwa* means "He is tall for nothing," and refers to an 18th-century chief whose height did him little good in battle.

Toward the end of our stay, a friendly sub-chief at the court of Nana Djan Kwasi allowed us to record Obeng and the rest of the royal drummers under more controlled conditions in a nearby village. With the help of these tapes, Ingrid nearly got the rhythm down. She was able to sing long stretches of it under her breath as she listened along: "Da da, da da, da DA da da DA ..."

"Hey, Al, it's actually starting to make sense! "I can follow along with most of it now."

"Me, too," I said. "But there are a few places where they still lose me."

"You mean like here?" Ingrid said, cueing up a segment of the tape for me.

"Yeah," I said, squinting slightly. "What the hell is that?"

Western music has evolved in concert with its own notation system, so that Western musicians tend to hear what they can read, and read what they can hear. It did not evolve to reflect the rhythmic subtleties of *fontomfrom*. There were, we discovered, brief snippets of those *bommaa* rhythms that we could not notate accurately; as far as our musical system was concerned, they did not exist. Perhaps as a consequence, we couldn't quite hear them, either: They sounded blurry, like figures in an Impressionist landscape. The problem was almost certainly not with our ears, but with our brains.

Bill Thompson, a psychologist at Macquarie University in Australia who specializes in music perception and cognition (and whom I once served as a graduate assistant at York University in Toronto), suggests that we may have lacked a mental template, or schema, for categorizing these rhythms, and were therefore unable to perceive them clearly. "Rhythm is an interesting case," Bill told me, "because my sense is that the capacity to 'hear' a particular rhythmic pattern is first and foremost equivalent to the ability to 'predict' what will come next at varying time spans." In the absence of such a schema, Bill adds, "we cannot predict what will come next, and have the experience of 'not being able to hear the rhythm.' Of course we 'hear' the rhythm in a literal sense, but we just can't predict the unfolding pattern." The ethnomusicologist David Locke, a specialist in West African drumming at Tufts University, experienced something similar when studying a form of *fontomfrom* played by an ethnic group known as the Ga. Echoing Thompson, he believes that a "lack of organizing features of mind" can make it "hard to even perceive what the ears are receiving."

Whatever the reason, attempting to decipher those brief, puzzling segments was like trying to catch a falling knife. I can still remember the sense of shock I felt

when I realized that I was experiencing the aural equivalent of a blind spot. It was as if a highly selective stroke had robbed me of the ability to read the letter Z or see the color purple. Those rhythms, some of them passing in the blink of an eye, were literally beyond my ken.

So it may not have mattered whether Obeng had taught us everything we needed to know; I doubt we could have played it even if he had. But the question remained: Why didn't Obeng *acknowledge* that the patterns he taught us in private were not the rhythms we were expected to play in public?

AFTER SOME EFFORT, Ingrid and I managed to persuade Kwame Antwi, my partner at the big *bommaa* drums, to teach us the extended patterns that we were supposed to play during public performances—the ones that Kwame Obeng refused to admit even existed, and that I couldn't mimic, no matter how hard I tried. But the experience only left us more confused than ever. Rather than playing what we so dearly wanted to hear, or even running through what Ingrid called the "ridiculous baby-version" of the *bommaa* rhythms that Obeng insisted on showing us in our lessons, Antwi played yet another simplified variation of them. Antwi's lesson-version was slightly more complicated than Obeng's, but still nothing like the real deal. Yet when I said as much, Antwi steadfastly maintained his innocence.

"Yes, it is the same," he said.

"It doesn't sound the same. And it isn't what Kwame Obeng shows us in our lessons with *him*, either," I said.

"Yes, they are the same!" he insisted.

"The same as what?" I wanted to scream.

Maybe the problem was the surrogate speech function of *fontomfrom*. What if those elusive rhythms had no semantic content, so that Obeng and Antwi didn't consider their absence (or presence) to constitute a meaningful difference? That might render the "lesson patterns" and the "performance patterns" equivalent to our teachers, even if they seemed like obviously distinct entities to us. Or perhaps the two Kwames evaluated musical identity according to some other criteria altogether—criteria that were as foreign to us as the mystery rhythms themselves.

Desperate for insight, Ingrid and I turned to J.H.K. Nketia, a renowned ethnomusicologist who was then director of the International Center for African Music

"You will go even if you don't wish to go."
"You fall, you will fall."
"Have you killed the little children?"
"Just now, just now."

AT THE PALACE Kwame Obeng at the *atumpan* drum.

and Dance at the University of Ghana. Nketia was my hero: An Akan from the Ashanti region, he did fieldwork in Akuapem in the 1950s, and wrote the seminal work on Akan drumming. He didn't so much as blink an eye when we told him about the simplified *bommaa* rhythms that Obeng and Antwi tried to pass off as the real thing in our lessons. But he did smile a bit.

"They may be simplified, but they are still the same," he said.

"Because they share certain rhythmic motifs?" Ingrid asked.

"Yes, there is that. But not just that," he said. "A piece consists of a number of different elements that lend it identity. If those elements are present, it is the same. If not, it is different. This is a concept you will have to struggle with."

But which elements make up a rhythm's identity? When Obeng came to Toronto, he taught me and my fellow drummers both basic and alternate versions of the accompanying patterns played on the smaller instruments, spelling the differences out clearly. In Aburi, however, Obeng didn't even acknowledge the differences between the basic *bommaa* rhythms we learned in our lessons—rhythms he had previously taught me in Toronto, and that I had performed at events in Canada and the United States—and the lengthier and more complex ones we were supposed to play in public. If I knew what Obeng was paying attention to in each example, maybe I could understand the stark differences between them. But I didn't know, and maybe, given the sheer difficulty of recognizing *fontomfrom* rhythms to begin with, I couldn't.

Or, maybe our teachers were just screwing with us.

MANY AFRICAN SOCIETIES shroud their traditional lore in secrecy, and the guardians of those

ALEXANDER GELFAND

secrets—elders, priests, chiefs—often reveal them gradually, divulging them in bits and pieces as a person ascends through ever higher levels of trust. This can be because the information itself is inherently sensitive, and also because its esoteric nature lends power and prestige to those who possess it. "Studies of secrecy in Africa show that the content of a secret there is less important than the use of secrecy as a strategy," the art historian Mary H. Nooter (now Mary Nooter Roberts) wrote in her book *Secrecy: African Art That Conceals and Reveals*. "Although the content of a secret may be guarded and concealed, the secret's existence is often flaunted. To own secret knowledge, and to show that one does, is a form of power."

Could that describe how musical knowledge was treated in Akuapem? Perhaps Obeng was unwilling to teach us the missing rhythms because they constituted some kind of privileged information. And maybe their status as an open secret—one that he and the other court drummers would play in public, but that we were not allowed to learn in private—served to highlight his own authority, and our own status as neophytes.

We had already experienced this dynamic of concealment and revelation first-hand. During our time together in Toronto, Obeng had never so much as mentioned to me that the smaller instruments in the *fontomfrom* "spoke" just like their larger cousins. Then, one day in Aburi, when Ingrid and I were at the palace helping Obeng move the *fontomfrom* drums around, he casually revealed what the iron bell and the three small drums were saying. It was a full-blown conversation:

Wanko a wobeko.

Woto, wobeto.

Wawie moframma kum?

Pren pren, pren pren.

"You will go even if you don't wish to go."

"You fall, you will fall."

"Have you killed the little children?"

"Just now, just now."

"What does it mean?" Ingrid asked. "Why were they killing the children?"

"It is about the old days, when the ancestors made 'medicine,' " Obeng said. He went on to describe how human beings were once sacrificed at the palace, something I'd previously only read about in anthropological studies and historical texts. Needless to say, we were both taken aback—especially me. For several years, I thought that I'd been tapping out some harmless dance rhythms, when in fact I had been participating in a brief audio play about the ritual slaughter of children.

I don't know why Kwame Obeng chose that particular moment to enlighten us, but I doubt it was happenstance. Perhaps, unbeknownst to us, Ingrid and I had somehow demonstrated our worthiness.

Another time, at a funeral, I asked Kwame Antwi if the small ornament that he and many others wore on the straps of their sandals meant anything.

"Yes," he said.

"What?" I asked.

"*Aburuburuw nkosua*," he said. "It is the name of a bird's egg."

"Is that some kind of proverb?"

"Yes."

"What does it mean?"

"I do not know. We will have to ask Kwame Obeng."

So we did.

Obeng responded in Twi: "If it is written, it is written; if it is God's will, then it will happen."

I turned back to Antwi.

"Does everyone know what these ornaments are called?" I asked.

"Yes," he said.

"But do they know what it means?"

"No. Very few know that; only those who move with the royals."

Antwi was Obeng's nephew and his lieutenant in the palace ensemble. By any reasonable standard, he spent a lot of time moving with the royals. But even he didn't know something as basic as the meaning of a proverb that was literally stuck to his feet most of the time.

Did the missing complexities in the music represent my own mysterious proverb, something I had not yet earned the right to learn? Was this all part of the process, by which I could only demonstrate my worth by figuring out the music on my own? Or was Obeng reluctant to teach me the missing rhythms for other reasons, yet equally reluctant to explicitly turn me down?

THAT'S AS FAR AS I GOT. Eighteen years later, the reasons for Obeng's behavior remain as inscrutable to me in hindsight as those puzzling *bommaa* rhythms proved

to be when I first encountered them.

And that is a lesson in itself.

As a musician and an ethnomusicologist, I assumed that with enough time and effort, I'd eventually grok both the music and the musical behavior of our hosts. In a way, I had to believe this; doing so was central to my own sense of identity, as it probably would be to anyone doing fieldwork in cultural anthropology. Certainly, none of my mentors in graduate school had raised the possibility that I (or anyone else, for that matter) might be confronted by a group of people whose music and motives would prove so stubbornly resistant to analysis and explication. In this age of extreme interconnectedness, when once-remote lands are only a cheap flight or a webpage away, it is tempting to think that all barriers to cross-cultural understanding are gradually disappearing; that there are no longer such things as strangers, just people we have not yet Googled or seen on the Discovery Channel.

This is an illusion. Make no mistake: There are plenty of people, living in plenty of places, who remain giant puzzles to us, cheap airfare or no. And that is by no means a bad thing. Quite the opposite—it is a testament to the range of human diversity, and to the limits of human understanding. My experiences in Aburi may have been frustrating, but I learned a lot. I no longer assume that all barriers to cross-cultural communication can be overcome. Nor do I assume that I can really, truly get into someone else's head and see (or hear) the world as they do by sheer force of reason and will—including my own friends and family.

For these reasons, and also for the sheer intensity of our time there—we witnessed animal sacrifice and spirit possession, encountered cultural riches and material poverty rarely seen in the West, and suffered radical culture shock of a sort neither of us had experienced before, and haven't again since—Aburi still fills me with a sense of awe. And I know that Ingrid feels the same way. When we talk about the things that shaped us as individuals and as a couple, we always return to Ghana, and the mystery of those *bommaa* rhythms.

ALEXANDER GELFAND is a freelance writer and recovering ethnomusicologist based in New York City. He is working on a memoir of his time in Ghana.

How To Solve the World's Hardest Logic Puzzle

Get out your pencil and paper—this one's tough

BY BRIAN GALLAGHER

WHILE A DOCTORAL STUDENT at Princeton, studying under a founder of theoretical computer science, Raymond Smullyan would occasionally visit New York City. On one of these visits, he met a "very charming lady musician" and, on their first date, Smullyan, an incorrigible flirt, proceeded very logically—and sneakily. He broke the ice with a disguised logical trap.

"Would you please do me a favor?" he asked her. "I am to make a statement. If the statement is true, would you give me your autograph?"

Content to play along, she replied, "I don't see why not."

"If the statement is false," he went on, "you don't give me your autograph."

"Alright ..."

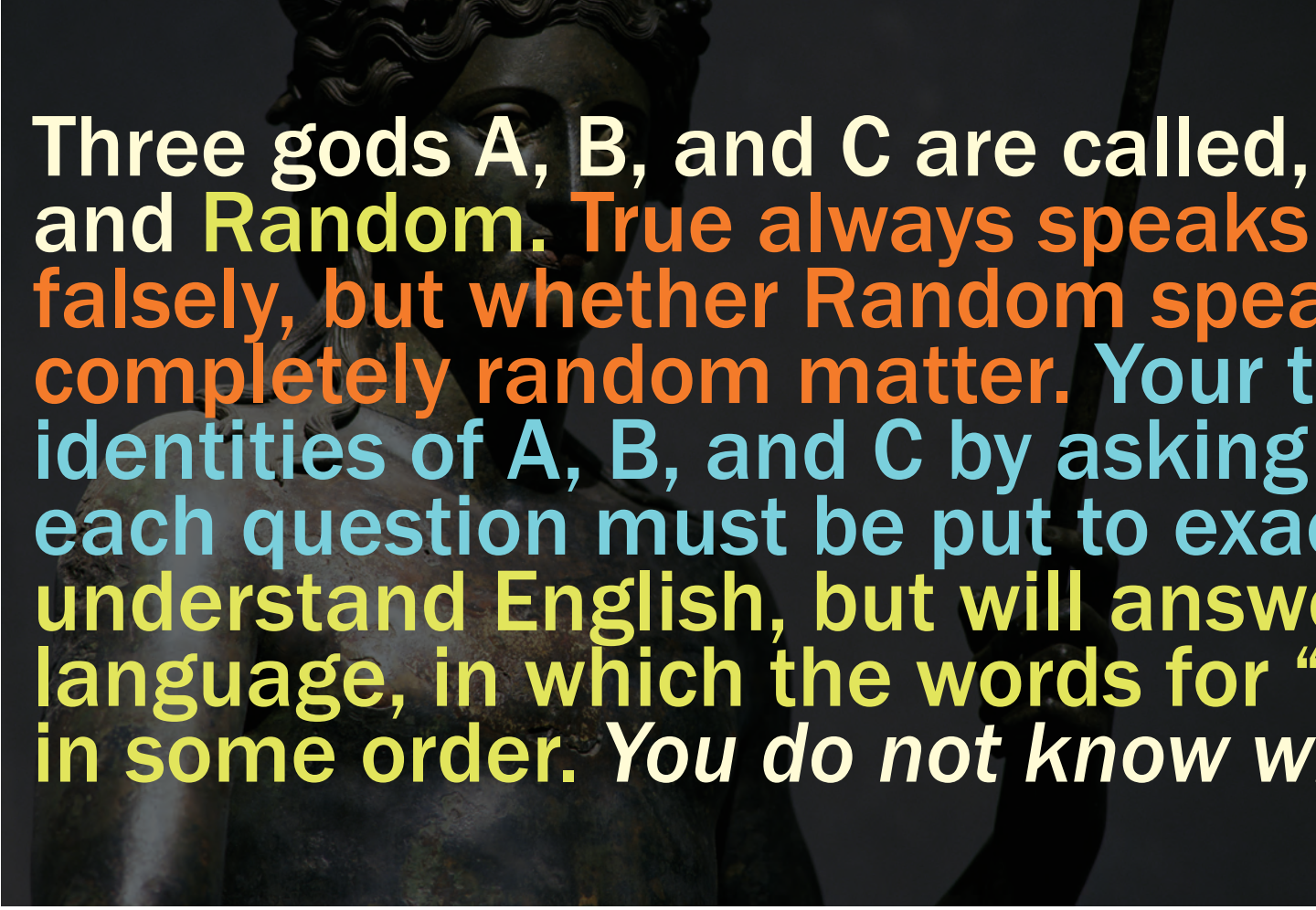
His statement was: "You'll give me neither your autograph nor a kiss."

It takes a moment, but the cleverness of Smullyan's ploy eventually becomes clear. Per their agreement, his statement can't be true. But in order for it to be false, Smullyan had to end up with a kiss. It was the beginning of a beautiful romance—the two would eventually marry.

Smullyan is known for this playfulness, something that carries into his books on math and logic, which have titles like *To Mock a Mockingbird, Alice in Puzzle-Land*, and *What Is the Name of This Book?* Now an emeritus professor of philosophy at Indiana University, he's nearly a centenarian. Over that time, along with being an accomplished pianist and magician, he's made fundamental contributions to modern logic and written about Taoist philosophy and chess. "He is the undisputed master of logical puzzles," a former Ph.D. student of his once said.

Part of his legacy is what the late MIT philosopher of logic George Boolos called "The Hardest Logical Puzzle Ever." It goes like this:

DE AGOSTINI / ARCHIVIO J. LANGE



Three gods A, B, and C are called, in some order, True, False, and Random. True always speaks truly, False always speaks falsely, but whether Random speaks truly or falsely is a completely *random* matter. Your task is to determine the identities of A, B, and C by asking three yes-no questions; each question must be put to exactly one god. The gods understand English, but will answer all questions in their own language, in which the words for "yes" and "no" are "da" and "ja," in some order. *You do not know which word means which.*

One approach to the solution, proposed by Boolos, is to combine the solutions to three simpler puzzles. The first is one of Smullyan's classic knights and knaves riddles, introduced in his book, *What Is the Name of This Book?* In the puzzles, knights always tell the truth, knaves always lie, and your task is to find out who's who. The solution is to ask a question like, "Are you a knight if and only if two plus two is four?"

IN THE SECOND PUZZLE, you know you're asking a knight—but he only responds with "da" and "ja." The strategy here is a variant of that in the first puzzle: you ask, "Does 'da' mean 'yes' if and only if two plus two is four?"

The third puzzle tosses in the element of randomness: Suppose I place three cards in a row in front of you—two aces and a jack—face down. You don't know how they're ordered, but I do. You can ask one yes-no question, while pointing at one of the cards. If you happen to point at one of the two aces, I'll answer the question truthfully, like a knight; if you point at a jack instead, I'll answer "yes" or "no" at random, like Random. Where will you point, and what will you ask?

The answer: Point to any card and ask if one of the other cards is an ace.

Now, to solve the Hardest Logic Puzzle Ever, you just need to combine the solutions to these three simpler ones. That, we'll leave up to you.


WEARY

The Science Hidden In Your Town Name

How place names encode ecological change

BY ELI KINTISCH

UNUSUALLY HEAVY WINTER RAINS have flooded the town of Chertsey, west of London, twice in the past three years. Only its old center—a raised plot on the bank of the River Thames where Anglo-Saxon monks built an abbey in the seventh century—has remained consistently dry. For most residents, the rising waters, often stinking with sewage, have come as an unwelcome surprise after centuries of a relatively dry, stable climate. They seem to have forgotten, or perhaps never knew, this telling fact about the place they call home: In Old English, Chertsey means "Ceorot's island."

The name harkens back to the Early Medieval Period, when Germanic tribes began to settle, and name, many of the places dotting maps of modern Britain. Back then, water was ubiquitous. Sediment deposits dating to this era paint a picture of overtopped riverbanks and runoff rushing down slopes. "Anglo-Saxon England was a water world," says Richard Jones, a landscape historian at the University of Leicester. He studies how early English settlers used place names, or toponyms, to encode practical information about their watery environment. For instance, Byfleet, a village in southern England, indicates a "tidal creek," or "estuary"; Buildwas, in the west, describes "land subject to rapid flooding and draining"; and Averham, in the east, a "settlement at the floods."

But starting around the 11th century, the British landscape got drier as its climate stabilized and glaciation drew moisture from the biosphere, and many of these toponyms lost their original meaning. Development spread from "island" sanctuaries like Chertsey Abbey into newly parched floodplains once composed of forests, fields, and marshes. Over time, Britons' close relationship with water, and their deep understanding of its patterns, dried up with the land.

Now, as the planet warms, Britain may be returning to a wetter, more volatile climate. In the last decade, England and Wales have seen some of the worst flooding on record. And as winter storms get stronger and

ILLUSTRATIONS BY JOHN HENDRIX

more frequent, often swelling rivers and tributaries beyond their capacity, Chertsey and other waterlogged places are reclaiming their medieval identities. "These names are once again accurately describing the behavior of water in England," Jones says.

Beyond offering a glimpse into past landscapes, he argues, toponyms could help today's communities adapt to their changing environment. "We may have a lot to learn from the Anglo Saxons and their ability to live in a watery place," Jones says. Their knowledge, preserved in names passed down over centuries, could inform where urban planners build new subdivisions, install barriers or drainage systems, or restore wetlands.

Perhaps by examining our past, we can better prepare for the future.

PLACE NAMES ARE AMONG the things that link men most intimately with their territory," wrote British archaeologist Jacquetta Hawkes in 1951. "As the generations pass on these names from one to the other, successive tongues wear away the syllables just as water and wind smooth the rocks." The English toponymist Margaret Gelling called these timeworn names "signposts to the past," as they have long guided scientists in reconstructing forgotten histories and landscapes. Where you find a form of the Old English *weard-setl*, for example, you will likely find a place where a "guard house" once stood. Likewise, *ceaster* identifies the site of a "walled town," *hlæw* a "burial mound," *æcer* a "plot of cultivated land."

But researchers like Jones are finding that place names can also be used to track environmental change. In a 2010 study of wetlands along the coast of southwest Spain, scientists analyzed some 700 toponyms on maps dating to 1869. From ecological records, such as naturalist accounts, aerial and satellite photographs, and rain and temperature measurements, they knew that the land had gotten drier, starting around the mid-20th century. After the Spanish Civil War, which ended in 1939, the government, facing a resource shortage, aggressively planted pine and eucalyptus trees in this strip of mosquito-ridden bogs and brooks. The new managed forests, along with reduced rainfall and warmer temperatures, gradually sapped moisture from the soil.

And as water features shrank or disappeared, their names changed too: *Arroyo Harinoso* (Floury Brook) became *Arroyo del Pino* (Pine Brook); *Laguna de la Higueruela* (Stinking Clover Lagoon), once one of the region's largest peat bogs, was reduced to a smattering of small water holes, including Reedy Lagoon, Moor Thicket Lagoon, and Puddles. Local toponyms can thus provide a detailed and enduring portrait of a landscape in flux, the researchers argued in the journal *Climatic Change*. "Although they cannot be used as proxy data"—data gathered from natural resources

These names are once again accurately describing the behavior of water in England.

WATER WORLD Eton College, flooded here in the 1930s, has Old English roots meaning "river settlement."

such as sediments, tree rings, and fossil pollen—"they can be used to mark climate changes or turning points," they wrote.[1]

Another study, published in 2007, found that toponyms can offer a quick, reliable record of how animal populations shift over time. For nearly two decades beginning in 1985, Swedish ecologist Johan Spens sought to reconstruct the distribution of brown trout in northern Sweden over the past three centuries using historic maps, interviews with local fishermen and fishing-rights owners, and gillnet surveys. Talking to an elder fisherman, he was surprised to learn that an old traditional name for this species was *Rö*, a common prefix of lake names in the area. Comparing these toponyms to population data, he found that nearly one-third of all lakes with past or current brown trout populations included *Rö* in their names—*Rödingtjärnen*, for instance. Even more remarkable, any given *Rö* lake had a 92 percent chance of containing brown trout at one time or another. (The odds were only 11 percent for any random lake, *Rö* or no *Rö*.)

Spens concluded that lake names could help identify historic trout populations that have since gone extinct, as well as the disturbances, such as from predators or human industry, that led to their decline. Lake names, he proposed, could also help guide modern population surveys, allowing ecologists to accomplish in a couple of months what would typically take five years using random sampling. "With the *Rö*-names," he wrote, "fishers from hundreds of years back in time are communicating to us and saying: 'This lake is characterized by its richness in brown trout. There are good habitat conditions for this species here.' "[2]

The meanings and messages behind toponyms will become increasingly significant as global warming and other environmental changes render many of them obsolete. In Montana, for instance, Glacier National Park, which had 150 glaciers in the mid-1800s, at the end of the Little Ice Age, now has 25 and will probably have none by 2030. In Barrow, Alaska, whose centuries-old Inuit name, *Ukpeagvik*, means "the place where we hunt snowy owls," the species' numbers appear to be declining, according to ornithologist Denver Holt, who has observed wildlife in the area for 25 years. And in northeast Siberia, there is a bulge in the Kolyma River called *Kray Lesa* ("Forrest's Edge"), which once marked the border between the boreal forest and tundra. But in recent decades, as average temperatures have risen, that boundary has shifted a dozen or so miles north.

Other places, including coastal towns and island nations, are slowly disappearing as sea level rises and the land sinks. One day in the not-so-far future, the names of these doomed places will bring to mind the single most salient fact about them: They are gone.

IT WAS THE WINTER rains of 2007, which brought some of the worst flooding in a century to southern England, that sparked Jones' interest in British toponyms. At the time, he was pursuing a lectureship at the University of Leicester—where he now works—and was casting around for a research program to

PLANET NEWS ARCHIVE/SSPL/GETTY IMAGES

propose. With the floods on his mind, his thoughts turned to the subject of his undergraduate thesis: a medieval monastery in the village of Buildwas, recently drenched by the overflowing River Severn.

Poking into the town's history, he learned that the suffix of its name, *was*, from the Old English *waess*, means "land that floods and drains quickly." He knew that this root shows up in many other place names and began to look into their etymology. He learned, for example, that Arley meant a "woodland clearing where eagles could be found," and that Alderwasley designated a "pasture with alder trees where water can fill and drain." In medieval times, myriad marshes and woodlands along a river's edge helped absorb floodwater.

Jones had found his project: He would decipher and map the Old English names that identify modern Britain in hopes of gaining insight into Anglo Saxons' relationship to the land. How, for instance, had these early settlers, who had built a monastery in a floodplain, managed to thrive so close to water—a resource that was crucial for travel, for farming, and for powering mills, but was often destructive and unpredictable?

GLACIER-LESS PARK Scientists forecast that Glacier National Park will have no glaciers by 2030.

One option was to control the water's behavior. Some communities built flood banks and dykes, or set aside undeveloped land to serve as so-called water meadows, which soaked up floodwater like sponges. Another option was to settle in the highlands, away from water. But Jones, who had landed the teaching job, was struck by the fact that the Anglo Saxons mostly did neither. "Over time, they established the high water mark," he observes, and then "they located themselves just above it without the need for more defenses." Sometimes the difference between safety and submersion was just a few centimeters.

In lieu of modern mapping tools like lidar, the Anglo-Saxons simply read the landscape and grew to know it intimately. "Anglo-Saxon society was a more naturalistic world in which people were fully immersed and embodied in their environment," Jones wrote in an unpublished paper. "Modern western society," he laments, "has turned its back on the landscape." And as a result, "place names have become little more than convenient geographical tags."

"Everyone knows that our Prime Minister attended Eton College," Jones told me. "But I'd bet my bottom dollar that very few know that Eton means 'river settlement' even if they know that it is on the floodplain of the River Thames." Nor does the average visitor to Stockholm know that its name denotes "log islet." Or that Dublin means "black pool."

At the same time, the technical language that bureaucrats often use to warn the public about flood risk may be further alienating Britons from their environment, says John Curtin, Director of Incident Management and Resilience at the United Kingdom's Environment Agency. In public workshops, for example, the Agency was surprised that participants rated "abstraction and flow" as less significant than other water management issues, including chemical pollutants and sewage treatment. The

JASON PATRICK ROSS

workshops' organizers wondered if the problem might be the terminology. "It would have been interesting to see what would have changed if [abstraction and flow] had been called 'water supply' or 'availability of water,' " they wrote in a report.[3]

"The language that experts like me are using to describe the science is becoming a barrier to people's understanding of risk," Curtin says. According to the Agency, one in six homes in England are currently at risk of flooding from river swells or coastal surges, but surveys show that only 5 to 8 percent believe it. "We have a large at-risk population, but only a small population of them understand that," Curtin says. He applauds Jones' efforts to "connect people to the nature around them" and "bring back that awareness of place."

Together with colleagues, Jones plans to apply for a grant to test, using soil sampling, how closely place names actually reflect historic ecological features and events. Was Alderwasley really a water sink? Did Broadwas represent a wide land that flooded and drained? Was the River Blythe ("easygoing") calm and the River Bollin ("noisy") tumultuous?

Jones hopes that the results will inform studies of past ecologies while also helping to mitigate flood risk in modern times. Many clearings on the outskirts of British towns, for example, have the name *hamm feld* ("island field"), suggesting they once attracted floodwaters. If that's true, Jones says, they could be good places to restore wetlands, which can absorb water that would otherwise pool in buildings and streets.

But Jones would be satisfied if his work simply made his countrymen more aware of their homes' hydrological legacy. "I live in a place called Upton, which is just that," he says. The town lies three miles away from low-lying Averham ("settlement at the floods"). "I get the impression that had the residents of Averham known what their name implied, they might now be my neighbors."

ELI KINTISCH, a correspondent for *Science* magazine, writes about the Arctic, climate change, and oceans.

REFERENCES

1. Sousa, A. Garcia-Murillo, P., Sahin, S., Morales, J., & Garcia-Barron, L. Wetland place names as indicators of recent climate change in SW Spain (Donana Natural Park). *Climatic Change* **100**, 525-557 (2010).

2. Fishers' Knowledge in Fisheries Science and Management. United Nations Educational, Scientific and Cultural Organization. www.unesco.org (2007)

3. Public dialogue on Significant Water Management Issues. Environment Agency. www.gov.uk (2014)

How the Western Diet Has Derailed Our Evolution

Burgers and fries have nearly killed our ancestral microbiome

BY MOISES VELASQUEZ-MANOFF

FOR THE MICROBIOLOGIST Justin Sonnenburg, that career-defining moment—the discovery that changed the trajectory of his research, inspiring him to study how diet and native microbes shape our risk for disease—came from a village in the African hinterlands.

A group of Italian microbiologists had compared the intestinal microbes of young villagers in Burkina Faso with those of children in Florence, Italy. The villagers, who subsisted on a diet of mostly millet and sorghum, harbored far more microbial diversity than the Florentines, who ate a variant of the refined, Western diet. Where the Florentine microbial community was adapted to protein, fats, and simple sugars, the Burkina Faso microbiome was oriented toward degrading the complex plant carbohydrates we call fiber.

Scientists suspect our intestinal community of microbes, the human microbiota, calibrates our immune and metabolic function, and that its corruption or depletion can increase the risk of chronic diseases, ranging from asthma to obesity. One might think that if we coevolved with our microbes, they'd be more or less the same in healthy humans everywhere. But that's not what the scientists observed.

"It was the most different human microbiota composition we'd ever seen," Sonnenburg told me. To his mind it carried a profound message: The Western microbiome, the community of microbes scientists thought of as "normal" and "healthy," the one they used as a baseline against which to compare "diseased" microbiomes, might be considerably different than the community that prevailed during most of human evolution.

And so Sonnenburg wondered: If the Burkina Faso microbiome represented a kind of ancestral state for humans—the Neolithic in particular, or subsistence farming—and if the transition between that state and modern Florence represented a voyage from an agriculturalist's existence to 21st-century urban living, then where along the way had the Florentines lost all those microbes?

ILLUSTRATION BY KATHERINE DIEMERT

Earlier this year I visited Sonnenburg at Stanford University, where he has a lab. By then he thought he had part of the answer. He showed me, on his computer, the results of a multigenerational experiment dreamed up by his wife, Erica, also a microbiologist.

When the Burkina Faso study was published, in 2010, the question of what specific microbes improved human health remained maddeningly elusive, but evidence was beginning to suggest that diversity itself was important. So despite their relative material poverty, these villagers seemed wealthy in a way that science was just beginning to appreciate.

Where did that diversity come from? Humans can't digest soluble fiber, so we enlist microbes to dismantle it for us, sopping up their metabolites. The Burkina Faso microbiota produced about twice as much of these fermentation by-products, called short-chain fatty acids, as the Florentine. That gave a strong indication that fiber, the raw material solely fermented by microbes, was somehow boosting microbial diversity in the Africans.

Indeed, when Sonnenburg fed mice plenty of fiber, microbes that specialized in breaking it down bloomed, and the ecosystem became more diverse overall. When he fed mice a fiber-poor, sugary, Western-like diet, diversity plummeted. (Fiber-starved mice were also meaner and more difficult to handle.) But the losses weren't permanent. Even after weeks on this junk food-like diet, an animal's microbial diversity would mostly recover if it began consuming fiber again.

This was good news for Americans—our microbial communities might re-diversify if we just ate more whole grains and veggies. It was bad news, however, that the Western diet had triggered microbial extinctions. They saw what happened when pregnant mice went on the no-fiber diet: temporary depletions became permanent losses.

When we pass through the birth canal, we are slathered in our mother's microbes, a kind of starter culture for our own community. In this case, though, pups born to mice on American-type diets—no fiber, lots of sugar—failed to acquire the full endowment

AN INSIDE VIEW Microbiologist Justin Sonnenburg (left) is revealing how our refined Western diet may be upsetting ancestral metabolic processes and raising the risk of chronic diseases, from asthma to obesity. Graduate student Will Van Treuren looks on.

PHOTOGRAPHY BY PETER VAN AGTMAEL/MAGNUM PHOTOS, FROM STANFORD UNIVERSITY'S #NEXTGREATDISCOVERY SERIES

How did the microbiome of our ancestors look before it was altered by sanitation, antibiotics, and junk food?

of their mothers' microbes. Entire groups of bacteria were lost during transmission. When Sonnenburg put these second-generation mice on a fiber-rich diet, their microbes failed to recover. The mice couldn't regrow what they'd never inherited. And when these second-generation animals went on a fiberless diet in turn, their offspring inherited even fewer microbes. The microbial die-outs compounded across generations.

Many who study the microbiome suspect that we are experiencing an extinction spasm within that parallels the extinction crisis gripping the planet. Numerous factors are implicated in these disappearances. Antibiotics, available after World War II, can work like napalm, indiscriminately flattening our internal ecosystems. Modern sanitary amenities, which began in the late 19th century, may limit sharing of disease- and health-promoting microbes alike. Today's houses in today's cities seal us away from many of the soil, plant, and animal microbes that rained down on us during our evolution, possibly limiting an important source of novelty.

But what the Sonnenburgs' experiment suggests is that by failing to adequately nourish key microbes, the Western diet may also be starving them out of existence. They call this idea "starving the microbial self." They suspect that these diet-driven extinctions may have fueled, at least in part, the recent rise of non-communicable diseases. The question they and many others are now asking is this: How did the microbiome of our ancestors look before it was altered by sanitation, antibiotics, and junk food? How did that primeval collection of human microbes work? And was it somehow healthier than the one we harbor today?

FAMILY GARDEN The Sonnenburgs, to boost their own microbial diversity, took up gardening, got a dog, and began hand-milling grain to make bread. Erica Sonnenburg, a microbiologist, works in the family garden with daughters Claire and Camille.

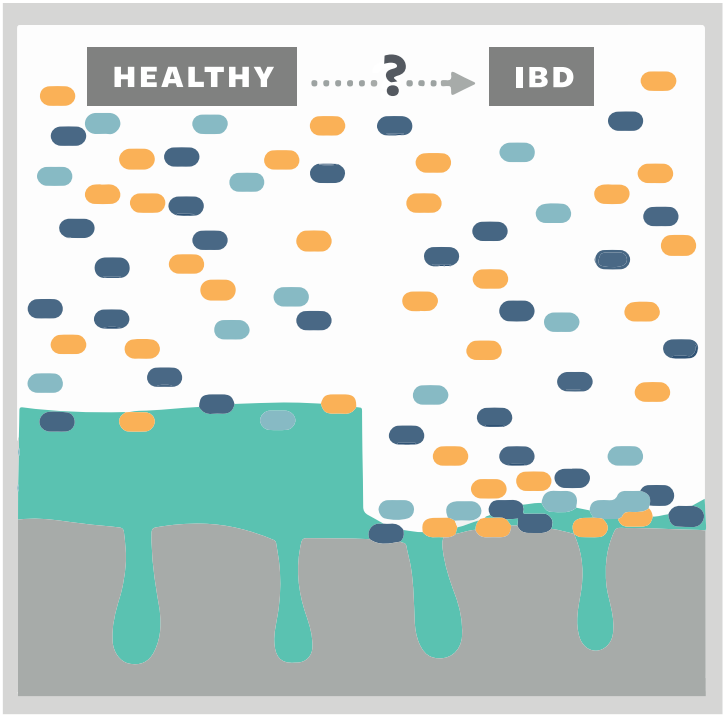
THE NATIONAL INSTITUTES OF HEALTH'S Human Microbiome Project, the first phase of which finished in 2012, was billed as a "road map" of human microbes. But as Maria Gloria Dominguez-Bello, a microbiologist at New York University who studies remote Amerindian communities, told me, the effort is "really the *American* microbiome project; it's not the *human* microbiome project."

So a remarkable and somewhat quixotic effort has begun to catalog and possibly preserve, before they disappear, the microbes of people who live in environments thought to resemble humanity's past—people whose microbiomes may approximate an ancestral state. Researchers are motoring down rivers in the Amazon, off-roading in the East African savanna, hiking into the mountain villages of Papua New Guinea. They see themselves as rushing to catalog an ecosystem that may soon disappear.

"It's really our last chance to harvest a lot of these microbes from around the world," Rob Knight, a microbiologist at the University of California, San Diego, told me. "We have to do it before it's too late—and it's very nearly too late."

He and others suspect these populations won't retain their traditional ways much longer. Antibiotics, thought to deplete microbes, are already used frequently in some communities. And as modernization and acculturation progresses—as these peoples move toward the sanitized, indoor-dwelling, junk food-eating reality that characterizes much life in developed nations today—some human microbes, or perhaps certain configurations of those microbes, may be lost forever.

For now, scientists are careful to characterize the quest as purely descriptive; they want to know how these human microbiomes affect our bodies. Yet a kind of microbial ark—a storage vault for potentially endangered human microbes—is perhaps implied. Martin Blaser, a microbiologist at New York University and Dominguez-Bello's husband, argues that because Westernized peoples may have lost important microbes, we may have to repopulate ourselves with microbes derived from more traditional-living populations—from, say, Amazonian Amerindians or African



HUNGRY MICROBES
A healthy gut hosts a number of microenvironments. A fatty diet lacking in fiber causes some of our internal, ancestral microbes to devour a mucus lining, potentially leading to inflammatory bowel disease.

Many who study the microbiome suspect we are experiencing an extinction within that parallels the extinction gripping the planet.

hunter-gatherers.

That's certainly a long way off. No one understands much about the dizzying variety documented so far—which microbes are good, which harmful, which irrelevant. One constant, though, is that people living subsistence lifestyles have tremendous diversity compared to westernized populations—up to 50 percent more species than North Americans or Europeans. That includes not only bacteria but eukaryotes—single-cell protists and large, multicellular worms. These organisms, which are often missing in the West, have historically been considered pathogens. But some evidence now suggests that they can favorably shape the microbiome, benefiting the host.

The other constant relates to diet and the soluble fiber that Sonnenburg studies. Whereas North American microbes orient toward degrading fat, simple sugars, and protein, the microbes of subsistence communities so far studied are geared toward fermenting fiber.

Most study subjects live in the tropics; their microbial communities may reflect tropical environments, not an ancestral human state. Yet even "extinct" microbiomes from higher latitudes—including from a frozen European mummy—are similarly configured to break down plant fiber, adding to the sense that the Western microbiome has diverged from what likely prevailed during human evolution.

The Sonnenburgs think fiber is so important that they've given it a new designation: microbiota-accessible carbohydrates, or MACs. They think that the mismatch between the Westernized, MAC-starved microbiome and the human genome may predispose to Western diseases.

Scientists studying these communities suspect that while mortality is high from infectious diseases, chronic, non-communicable diseases are far less prevalent. At the same time, researchers since the late 20th century have repeatedly observed that even in the West, people who grow up on farms with livestock, or exposed to certain fecal-oral infections, like Hepatitis A and sundry parasites—environments that, in their relative microbial enrichment, resemble these subsistence communities—have a lower risk of certain Western afflictions, particularly hay fever, asthma, and certain autoimmune disorders.

No one wants to bring back the killers of yore. But the suspicion—and the hope—is that beneficial microbes can be separated from the dangerous ones, and that "good" ones can be restored. Or perhaps we can simply treat the community we already harbor better by feeding it healthier fare.

The United States Department of Agriculture recommends between 25 and 38 grams of fiber for adults daily; most Americans consume substantially less fiber-rich food, including nuts, whole grains, certain fruits, and vegetables. The guideline stems, in part, from the research of an Irish-born physician named Denis Burkitt. While working in Uganda in the 1960s, Burkitt became convinced that the high-fiber African diet explained the Africans' relative lack of colon cancer.

The problem with the fiber hypothesis, however, has always been twofold. People who eat plenty of fiber seem to have a lower risk of many diseases, including heart disease and diabetes. But when scientists have fed fiber to volunteers, they haven't historically observed much benefit. And this underscores the real mystery: By what mechanism does fiber improve health?

Soluble fiber is an umbrella term for complex plant sugars—including some polysaccharides, oligosaccharides, and fructans. The molecules consist of simple sugars linked together in long, hard-to-dismantle chains. If you dump a load of fiber—or microbiota-accessible carbohydrates—onto a colonic community of microbes, those that specialize in fermenting it will bloom. And they'll start churning out short-chain fatty acids, including butyrate, whose smell you might recognize from aged cheese, and acetate, which gives vinegar its sharpness.

These acids, Sonnenburg thinks, are one of the

KRISTEN EARLE/SONNENBURG LAB

long-sought mechanisms by which fiber prevents disease. Rodent studies suggest that as they diffuse into circulation, they stimulate the anti-inflammatory arm of the immune system—cells that help you *not* attack tree pollen and other harmless proteins—preventing allergies and other inflammatory diseases. The calming effect reaches as far as the bone marrow and lungs, where, as a recent *Nature Medicine* study showed, the acids reduced animals' vulnerability to asthma.

As Justin Sonnenburg put it, "We have this unsupervised drug factory in our gut." The question facing microbiologists today is how to properly tend to that factory.

Here, studies of populations living more traditional lifestyles may provide clues. In the past, most people likely imbibed many times more fiber than today. If you eat minimally processed plants, which humans have for millions of years, you can't avoid fiber. Modern hunter-gatherers and horticulturalists certainly eat loads of it. The Hadza of Tanzania, for instance, consume at least 10 times more than Americans, in tubers, baobab fruit, and wild berries. Agriculturalists, like those Burkina Fasans, also eat more fiber than Western populations, in porridges and breads made from unrefined grains.

Given this constant supply of microbiota-accessible carbohydrates, human microbiomes of the past, the Sonnenburgs argue, likely produced a river of these short-chain fatty acids. That probably changed some with the transition to agriculture, which made diets less diverse. But an even more drastic shift occurred quite recently, with the advent and widespread adoption of refined foods. As a result, westernized populations, the Sonnenburgs think, have lost healthful, fiber-fermenting microbes. And we suffer from a kind of fermentation byproduct deficiency.

SO WHY CAN'T WE SUPPLEMENT our diet with short-chain fatty acids? When I visited Sonnenburg, he showed me one reason why: The ecosystem that produces the acids may be as important as the acids themselves. He brought up two cross-sectional images of fecal pellets still in mice intestines. Most microbiome analyses take a tally, from genetic markers, of what microbes are present and in what abundance. That's equivalent to imagining what a forest looks like from a pile of wood chips, and gives little sense of how the forest was organized. By some ingenious tinkering, though, one of Sonnenburg's post-docs had developed a way to freeze the ecosystem in place, and then photograph it.

> Our ancestral microbe variety may have faded over time due, simply, to our fiber-poor diet.

The resulting picture was unlike any rendition of the microbiome I'd seen before. One animal had eaten plenty of fiber, the other hadn't. In the fiber-fed ecosystem, similar bacteria clustered with one another, not unlike schools of fish on a reef ecosystem. An undulating structure prevailed across space. But in the non-fiber diet, not only was diversity reduced, the microbes were evenly distributed throughout, like a stew boiled for too long.

At this point, Sonnenburg sat back in his chair and went quiet, waiting for me to notice something. To one side of both images, microbes were mostly absent—the mucus layer on the lining of the gut. But that layer was twice as thick in the fiber-fed mice than the non-fiber fed. That difference amounted to about 30 nanometers, far less than the width of a human hair. But one day we may look back and shake our heads that Western diseases—from diabetes to colon cancer—stemmed from 30 nanometers of mucus that, somewhere along the way, went missing in the developed world.

We think of the Western diet—high in unhealthy fats, sugar, and proteins—as overly rich. But what's missing from the diet may be just as, and perhaps more, important than what's abundant.

Years ago, while still a post-doc, Sonnenburg discovered that something very odd occurs when those MAC-loving microbes go hungry. They start eating mucus. "This is the stage where you say, 'Oh my God. They're eating me.' " Sonnenburg said. "You can see it."

We need that mucus. It maintains a necessary distance between us and our microbes. And as it erodes with a poor diet, the lining of the gut becomes irritated. Microbial detritus starts leaking through. One of the more striking discoveries in recent years is that

INGETJE TADROS

you can see this stuff, called endotoxin, increase in the bloodstream immediately after feeding people a sugary, greasy, fast-food meal. The immune system responds as if under threat, leading to the "simmering inflammation" the Sonnenburgs think drives so many Western diseases.

We need inflammation to combat infections, or aid tissue repair. But chronic inflammation—a danger signal blaring indefinitely—can lead to all manner of cellular dysfunction, contributing to many degenerative diseases.

I came away from Sonnenburg's office with a sense that I'd glimpsed a principle underlying our relationship with microbes. Wringing calories from wild, fibrous fare required a village—microbes specialized in distinct tasks, but each also dependent on its neighbors. The difficulty of the job encouraged cooperation between microbes. When you withheld fiber, though, you removed the need for that close-knit cooperation. The mutually beneficial arrangements began to fray.

Sonnenburg's experiments help contextualize what others are finding in peoples who hunt and forage. The Hadza, one of the last remaining hunter-gatherers on Earth, live near Lake Eyasi in Tanzania, a region of east Africa thought to be the birthplace of our species. An analysis of their microbes published last year detailed an immensely diverse community, including a number of microbes new to scientists.

The Hadza harbor a variety of bacteria called treponema, which are absent in the developed world. They're spirochetes related to the pathogen that causes syphilis. Every rural, non-westernized group studied so far, including various Amerindian groups, also have treponemas, as do our primate relatives.

Cecil Lewis, a geneticist at the University of Oklahoma in Norman who studies the microbiomes of native people, including of Amerindian populations, suspects they may belong to an "ancestral microbiome"—a community that accompanied us since before we were human. Maybe anti-syphilis medication wiped them out in the West, Knight speculates. When I asked what they might do, or what their loss might mean, Lewis

HEALTHY FIBER In the past, most people likely consumed many times more fiber than today. Modern hunter-gatherers eat loads of it, more than Western populations. The Hadza of Tanzania consume at least 10 times more than Americans, in baobab fruit, (seen here), tubers, and wild berries.

and others responded that no one really knows.

Yet the treponemas have genes that help in breaking down complex carbohydrates, suggesting a role in fermentation. And that dovetails with the other striking feature of the Hadza and Amerindian microbiomes. Where we have just a few strains of, say, prevotella bacteria, the Hadza have a kaleidescopic variety. Again, diet is implicated. Breaking down tough, wild plants may require a diverse team of microbes. What happened to Western diversity? It's possible we've inadvertently killed that wealth, or never possessed it at all. But another possibility, as Sonnenburg's experiments suggest, is that because we haven't fed those microbes, we've lost them. Our ancestral variety may have faded over time due, simply, to our fiber-poor diet.

SONNENBURG'S MICE LIVE IN plastic bubbles, cut off from new sources of microbes. Humans do not. One outstanding question is whether, if I began eating wild tubers and baobab fruit, the microbial complexity necessary to ferment the new fare would simply appear, seeded from the environment.

Trials testing prebiotics, food for the fiber-fermenting bacteria, suggest that you can increase microbial richness with more fiber, and improve metabolic function. But here's the wrinkle: In studies from Europe, only individuals who already harbored a baseline diversity benefitted from these dietary interventions. Those whose microbial communities were too impoverished didn't—or couldn't—respond to the new diet. They seemed to lack the ability.

The Sonnenburgs point to these studies as evidence that we need the right microbes—their unique alchemical talents—to unlock nutrients from food. Where do we get them? Our particular genes can influence the makeup of our microbiome, perhaps influencing our propensity to develop disease or put on weight by shaping our microbial community. But another reason for lacking a bacterium is more straightforward: We may never have encountered it in the first place.

Those environments where a relatively prolific sharing of microbes still occurs—daycares, cowsheds, homes with lots of siblings, and homes with dogs—seem to protect against allergies, asthma, some autoimmune diseases, and certain cancers. These observations, often grouped under the rubric of the "hygiene hypothesis," appear to highlight a phenomenon separate from diet: access to microbial wealth, and possibly to unique microbial heirlooms.

Consider the spiral-shaped, stomach-dwelling bacterium *Helicobacter pylori*. For at least a century, *H. pylori* has been declining in the developed world. Most of our great-great grandparents probably had it; now less than 6 percent of children do. Unlike the microbes that interest Sonnenburg, *H. pylori* doesn't eat what we eat. It eats us, its host. And unlike microbes thought to jump aboard from food, water, soil, or other animals, *H. pylori* only comes from other people—particularly, scientists think, our mothers. It's a human-adapted microbe that's passed between generations.

H. pylori is infamous for causing ulcers and gastric cancer, but mounting evidence also suggests that, by subverting the immune system to ensure its own survival, the bacterium may protect against asthma, obesity, and possibly other inflammatory diseases. If there's an ecosystem restoration project implicit in the study of the ancestral microbiota, *H. pylori* serves as an important counterpoint to the emphasis on diet. You can eat all the fiber you want (unless your food is contaminated with feces) and you'll never re-acquire microbes like *H. pylori*. The only way to restore such microbes may be to deliberately reintroduce them.

Even that idea is complicated. Years ago, Dominguez-Bello discovered a unique Amerindian strain of *H. pylori* in an isolated Amazonian tribe, a bacterium whose ancestors had presumably come over the Bering land bridge with the forebears of native Americans some 15,000 years ago. The native strain was disappearing, however. When people of different ancestries mixed in South America, Dominguez-Bello found, imported strains outcompeted native ones. African and European *H. pylori* strains were driving Amerindian ones extinct.

Why did that matter? We may fare better with "our" particular microbes. A study on Colombians last year found that when people of primarily native American ancestry harbored imported European or African *H. pylori* strains, their risk of gastric cancer increased dramatically. The introduced bugs didn't match the native genotype. And that mismatch seemed to increase the risk of malignancy.

"This type of thing could be happening in many

microbes," Barbara Schneider, molecular biologist at Vanderbilt University in Nashville, and coauthor on the study, told me. "There's no reason to think that helicobacter should be unique."

We might call this the "family heirloom" problem. Some fraction of our microbes may be uniquely adapted to our particular genetic quirks—to our particular branch of the human family. Once they're lost, there may be no recovering these microbes. Meaning that, because I was born and grew up in the U.S., "my" helicobacters and treponemas may be gone forever.

In their recent book, *The Good Gut: Taking Control of Your Weight, Your Mood, and Your Long-term Health*, the Sonnenburgs argue forcefully that boosting fiber intake is the best way to cultivate a healthier community of microbes. Given the many unknowns, their advocacy surprised me. The science wasn't settled; what if they were wrong?

They'd fretted over this scientific uncertainty, they said, but decided that the diet they pushed—really a variant of the Mediterranean diet—would probably not cause harm, and would likely benefit adherents, even if everything they thought about the microbiome was wrong.

Not long after we spoke, Stephen O'Keefe, a gastroenterologist at the University of Pittsburgh, published what may be the best evidence yet (in people) that supports the Sonnenburgs' microbiota-accessible carbohydrates hypothesis.

O'Keefe has long puzzled over the high risk of colon cancer among African-Americans compared to native Africans. Like Burkitt 60 years ago, he suspected that a diet rich in fiber might explain what he quantified as a 65-fold disparity. To prove it, he put 20 rural South Africans on a high-fat, high-meat diet—including hot dogs, hamburgers, and fries; and he put 20 African-Americans on a high fiber African diet, including corn porridge, beans, and fruit. In contrast to earlier studies, however, his team visited the subjects at home, preparing their meals and supervising them.

Changes occurred quickly. Inflammation of the colon, which increases the risk of cancer, decreased in the African-Americans on the African diet; and it increased in the Africans on the American diet. Production of the fermentation by-product butyrate, thought to prevent colon cancer, increased in those eating African fare, and declined in those eating American-style. And here's what struck me: In the fiber-poor, meat- and fat-fed microbiome, O'Keefe saw a "loosening" of those tight-knit communities oriented toward fermenting fiber. He'd done in people what Sonnenburg had done in rodents—rattled the ecosystem—and it took just two weeks on an American-type diet. He also demonstrated that regardless of the microbes you may not have inherited, what you feed the microbes you have can make a big difference in how they behave.

Years ago, impelled in part by their oldest daughter's constipation problems, the Sonnenburg family revamped its diet. They threw out all processed foodstuffs, and began eating plenty of veggies and whole grains. They bought a dog. Justin Sonnenburg began hand-milling his own wheat berries for bread. He took up gardening. And when he compared his archived microbes from years ago with recent ones, he discovered that his microbial diversity had increased by half. "That's a huge difference," he told me, "as big as the difference between Americans and Amerindians."

It remains to be seen what detailed analysis will reveal about this diversification—how many came from his dog, from soil, from the sourdough he handles; how many might have been there all along in depressed numbers, and bloomed on a fiber-rich diet. What it showed the Sonnenburgs, however, was that without fully understanding how the microbiome works, you can still push it in a healthier direction.

"If we wait to the point where we are beyond a shadow of a doubt, with double-blind studies translated to regulations, we're going to be waiting decades," Sonnenburg told me. "But right now, all the arrows are pointing in the same direction, toward fiber."

MOISES VELASQUEZ-MANOFF is a journalist and author of *An Epidemic of Absence: A New Way of Understanding Allergies and Autoimmune Diseases.*

31

STRESS IS A COMPLICATED ADVERSARY. It is a silent killer, but a little bit is good for you. You can be stressed without knowing it, or feel more stressed than you are. Genetic and environmental factors combine in obscure ways to predispose some of us to stress, but not others.

Stress isn't so straightforward elsewhere, either. Organisms facing rapid environmental change might adapt by turning genes on and off, but we don't know if these epigenetic signals are inherited. Immense pressures inside stars and diamond anvils produce exotic states of matter whose physics are unclear.

All of which may be just as it should be. Pushing things and people past their usual boundaries has made the world the way it is, and naturally involves the unknown. Would we want it any other way?

Welcome to "Stress."

—MS

"When someone's early life is defined by a lack of money and resources, his or her conscious and biological drives can signal that trying to build a solid career before reproducing is likely a losing proposition."

MATTHEW HUTSON
"When Destructive Behavior Makes Biological Sense" p.106

Stress

STRAINED RELATIONS

The Secret, Stressful Stories of Fossils

A new field called paleoepigenetics is probing how evolution responds to sudden stress

BY FERRIS JABR

EVERY YEAR THE PALEONTOLOGIST Alan Cooper meets up with a band of miners in the Yukon. As the miners go about their work, spraying massive jets of water at frozen mud and silt to excavate gold, they also expose animal remains from the Pleistocene, between 2 million and 12,000 years ago. Back then, North America was a riot of big mammals. Antelope, camels, llamas, and indigenous horses roamed the vast plains; lions, saber-toothed cats, and dire wolves prowled for prey; and giant ground sloths lumbered along, stripping tree branches of leaves and fruit.

But, by the time the planet transitioned to the current geological epoch, the Holocene, the vast majority of those species had gone extinct, most likely due to climate change or hunting by humans. Climate change in the Pleistocene was "huge, frequent, and rapid," says Cooper, director of the Australian Centre for Ancient DNA at the University of Adelaide. "Sometimes a change of 10 degrees centigrade over a space of a decade or two." It's difficult for animals to cope with such dramatic shifts through standard evolution by natural selection, which often takes decades—even millennia—to spread advantageous genetic mutations and hone adaptations.

Yet, somehow, a few megafauna survived the mercurial Pleistocene, including a few species of bison. Their living descendants, the North American wood and plains bison, are the largest land animals on the continent today. A great puzzle for paleontology is what made the bison so resilient. How was it able to adapt when so many others failed?

Cooper thinks part of the answer lies beneath the Yukon permafrost. With the right techniques, he can pull a secret history from the DNA in the fossils he collects. Their genetic material conceals a dimension of evolution that scientists are just starting to understand, known as epigenetics. Epigenetic mutations are potentially heritable, but, in contrast to genetic mutations, they do not alter DNA sequences. Instead, they manifest themselves in patterns of molecules glued to DNA that help determine which genes are active. The

ILLUSTRATION BY REBEKKA DUNLAP

epigenome, as these patterns are known, is highly malleable, continuously adapting to an organism's physiology, as well as to fluctuations in its external environment. Some of these epigenetic adaptations become relatively stable.

If they consistently travel from one generation to the next in animals and people—which researchers still debate—they represent a neglected form of evolution, distinct yet parallel to typical genetic mutation. And even if they do not, widespread epigenetic changes within each generation could help groups of animals to swiftly adapt to environmental stress, such as big fluctuations in climate, dwindling food sources, or, in the case of people, prolonged warfare.

For the moment, though, the importance of epigenetics for long-term evolution is an open question. To help answer it, Cooper and other scientists in the young field of paleoepigenetics are extracting DNA from fossils and comparing epigenomes across great swaths of time. If a genome is like the primary historical account of how a species evolved—the one that most scholars reference—the epigenome is a palimpsest of crucial annotations and revisions that is still being discovered. Ancient epigenetics could help explain how the environment sculpts a species over time, why some species outlive others, and how species form in the first place. It won't be easy, though. For one thing, it's going to require an awful lot of digging.

ALTHOUGH RESEARCHERS have been recovering DNA from the remains of primeval creatures since the 1980s, resurrecting ancient epigenomes from fossils was not possible until about six years ago. Like the genome, the epigenome resides in a cell's nucleus, its genetic command center. Teams of enzymes zip about gluing and detaching various molecules to and from strands of DNA. You can think of these molecules as DNA's removable padlocks and welcome mats: They either block other cellular machines from accessing certain sequences, effectively silencing those genes, or encourage them. When looking for traces of these epigenetic markers in fossil DNA, researchers focus on the most durable one: methyl groups, which are usually tagged onto the nucleotide cytosine (the "C" in DNA's four-letter alphabet, GATC). In general, methylation silences genes.

When DNA has been sitting around for tens of thousands of years, it inevitably degrades. Cytosine often degrades into uracil, a nucleotide usually found in RNA. DNA sequencing machines misread these damage-produced uracils as thymines ("T"), so researchers often eliminate them with various chemical treatments. In 2009, Adrian Briggs was trying to do just this with Neanderthal DNA. At the time, he was a graduate student at the Max Planck Institute for Evolutionary Anthropology in Germany, studying under Svante Pääbo, the world's leading expert on ancient DNA. Despite Briggs' best efforts, the Neanderthal DNA sequences still contained an unexpectedly high number of thymines.

Through conversations with colleagues, Briggs learned that only unmethylated cytosines degrade into uracil, whereas methylated cytosines decay into thymine. That was the likely source of the extra Ts. Briggs realized that he could turn this seeming nuisance into an advantage. First, he would get rid of all the uracils in his sample of Neanderthal DNA. Then he would compare the Neanderthal genome to the modern human genome, looking for locations where modern humans have a C and Neanderthals have a T. Some of those positions might represent a genuine mutation, but most would indicate a methylated Neanderthal cytosine that had degraded to thymine. Damage inherent to ancient DNA could open a window onto ancient epigenetics.

In 2010, Briggs, Pääbo, and their colleagues reported that they could reconstruct methylation patterns in DNA from the bones of a 40,000-year-old Neanderthal and wooly mammoth. It was an unprecedented achievement. Two years later, Cooper and his team

Widespread epigenetic changes could help groups of animals to swiftly adapt to environmetal change.

used a somewhat different and more precise technique to analyze methylation patterns in DNA from a 26,000-year-old Steppe bison fossil from the Yukon. Before sequencing, they used sodium bisulfite to convert all the unmethylated cytosines into uracils, leaving only undamaged methylated cytosines for the comparison. Regions known to be consistently and highly methylated in modern cattle were also highly methylated in ancient bison, suggesting that their reconstruction was accurate.

EVEN MORE TANTALIZING findings have emerged from human remains. Last year, Ludovic Orlando and his colleagues at the University of Copenhagen deduced the methylation patterns preserved in DNA from a 4,000-year-old Greenlander. Not only did the sites of methylation match those in DNA from the hair of living humans, they also made biological sense, permitting the expression of genes crucial for forming the proteins in hair.

Similarly, Liran Carmel and his team at The Hebrew University of Jerusalem found that most of the methyl groups in Neanderthal and Denisovan DNA synced up with those in the modern human genome, as would be expected for such closely related hominins. In some areas, however, there were clear differences, like with the HOXD10 and HOXD9 genes. Although these gene sequences themselves are identical in humans and Neanderthals, they are more methylated in the latter. They are also crucial for limb development, suggesting that epigenetics might be partly responsible for the evolution of gracile arms and legs in modern humans, as opposed to the somewhat shorter and stockier limbs of Neanderthals. Some researchers have proposed that Neanderthal anatomy was less energy efficient than our own, possibly giving us the advantage when hunting and migrating long distances to escape unfavorable conditions, such as drought or harsh winters.

Most recently, Rick Smith of The University of Texas, Austin investigated epigenetics in Native American remains between 230 and 4,500 years old. Using bisulfite sequencing, he was able to identify methylation signatures in 29 of 30 samples—an unprecedented success rate. He is particularly interested in whether violence, starvation, and other kinds of stress in the last few thousand years left epigenetic impressions in the DNA of Native American tribes. "A growing body of evidence says trauma, famine, and violence in living human populations have long-lasting epigenetic effects, especially if they are experienced early in life. We can look for similar epigenetic patterns in ancient DNA from societies where we have good records showing they went through similar stress."

STRESS CHANGES YOU Epigenetics may be partly responsible for the form of arms and legs in modern humans (right), which are more slender than in Neanderthals (left).

ENCYCLOPAEDIA BRITANNICA/UIG VIA GETTY IMAGES

ALTHOUGH MANY researchers are thrilled by the potential of paleoepigenetics, they are also quick to bring up a long list of important caveats. "We are in the birth of this field, and there's so many potential directions we could go, a lot of questions we can try and answer now. I'm really excited," says Smith. "But we should proceed with caution and be really careful

STORAGE ROOM Permaforst extending into Alaska and Canada's Yukon, pictured here, has preserved bone fragments that are hundreds of thousands of years old.

about the inferences we make."

Some of the challenges are technical: It is quite rare to recover enough DNA from truly ancient fossils to perform any kind of meaningful analysis. In their first study, for example, Cooper and his colleagues could only extract sufficient DNA from one of six bison skulls. The analysis itself is even trickier: "Almost anything you do affects your DNA methylation pattern," says Carmel, "but it's still not entirely clear how to interpret those patterns in all situations." Methylation signatures can vary immensely from one type of tissue to another, so the epigenetics of teeth, bone, or hair—the kind of tissues that survive the eons—might not be an accurate portrait of an organism as a whole. And different individuals of different ages within a single population may also have markedly different epigenetics, so drawing broad conclusions about an entire species based on one or two samples is tentative at best.

So far, researchers have tried to circumvent these difficulties by focusing on regions of the genome that are definitively known to be strongly or weakly methylated across a given species. In order to make confident conclusions about more variably methylated sections of the genome—the ones where they would expect to find signs of adaptation—they will have to patiently collect numerous specimens. "The only way to tackle this is to work on really huge numbers, hundreds of individuals, because that way you kind of average the biological factors that might be problematic," explains Orlando. "Then we are not just comparing individuals, but whole sets."

The even bigger dilemma is the ongoing debate about whether epigenetic changes are inherited, and how often they survive long enough to make a difference in evolution. Scientists have documented numerous cases of epigenetic inheritance in bacteria, fungi, and plants, but similar examples among animals are rarer and usually confined to laboratory experiments. A

ROBERT POSTMA/DESIGN PIC/GETTY IMAGES

BY THE HORNS Alan Cooper digging a bison skull out of the Yukon permafrost.

AUSTRALIAN CENTRE FOR ANCIENT DNA (ACAD)

few long-term studies of human health, most famously one that tracked families during and after the Dutch famine of 1944, suggest that a pregnant mother epigenetically transmits a susceptibility to poor health to both her children and grandchildren, but this effect seems to disappear in subsequent generations. Further complicating things, whereas the biological mechanisms underlying transgenerational epigenetics in microorganisms and plants are fairly well-established, they remain mysterious in animals.

Given these dilemmas and knowledge gaps, some geneticists are highly skeptical about the importance of epigenetics for long-term evolution. A review of epigenetics research published in *Cell* last year concluded that "environmentally induced epigenetic changes are rarely transgenerationally inherited, let alone adaptive, even in plants. Thus, although much attention has been drawn to the potential implications of transgenerational inheritance for human health, so far there is little support."

If epigenetic responses to stress are not inherited, then any intriguing discrepancies researchers spot in fossil DNA will necessarily be confined to particular individuals and single generations. Even without a legacy, however, epigenetic mutations could play a subtle and indirect role in evolution: If they give a creature a reproductive advantage within its own lifetime, then they contribute to the spread of that creature's genes. Some scientists have also proposed that environmentally-induced adaptations sometimes become genetically encoded: Perhaps, through unknown mechanisms, genetic mutations arise that increase the likelihood of establishing certain beneficial epigenetic patterns.

If epigenetic mutations themselves are inherited in animals and people, and survive for many generations, then they undoubtedly alter long-term evolution. The discrepancies Carmel discovered between the Neanderthal and human epigenomes hint at this possibility in our own evolutionary history, but these findings are based on just a few DNA samples. Until researchers amass sufficiently large libraries of ancient DNA, they cannot make more definitive conclusions. Which is why, every year, Cooper and his colleagues return to North America, roaming frigid black slopes and descending into caves in search of promising fossils. So far they have collected several hundred specimens spanning about 50,000 years.

Cooper's plan is to compare the epigenetics of bison that lived before and after specific periods of stress and see if he can tie any epigenetic mutations to anatomical adaptations that might have helped the animals survive. "It really is a hell of a challenge," he says, "but it looks very promising at the moment."

FERRIS JABR is a writer based in Portland. He has written for *The New York Times*, *The New Yorker*, *Scientific American*, *Wired*, *New Scientist*, *Popular Mechanics*, *NOVA Next*, and *The Awl*.

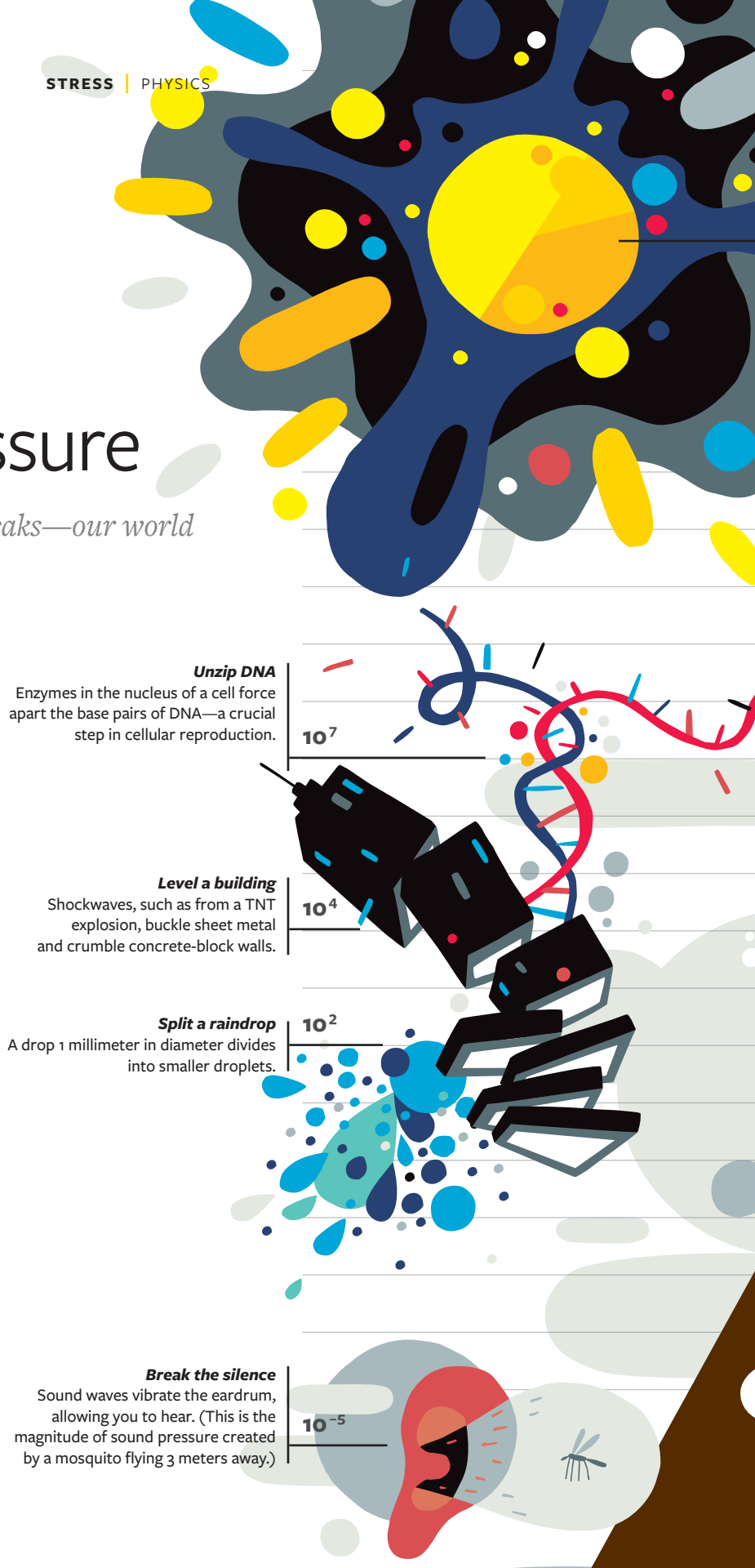
Under Pressure

How stress shapes—and breaks—our world

BY CONOR MYHRVOLD
ILLUSTRATION BY ALEX EBEN MEYER

PHYSICAL STRESS CAN operate in unexpected ways. For example, it takes more pressure to shoot a cork from a bottle of champagne than to raze a concrete building. If that seems counterintuitive, keep in mind that you don't need a lot of pressure to generate significant force. After all, the same amount of wind pressure that barely rustles your clothes can propel a yacht. That's because pressure measures a force's intensity across a given surface area: The more area you put under pressure, the more force you get.

Here are the magnitudes of pressure, in pascals, it takes to ...



Unzip DNA
Enzymes in the nucleus of a cell force apart the base pairs of DNA—a crucial step in cellular reproduction.

10^7

Level a building
Shockwaves, such as from a TNT explosion, buckle sheet metal and crumble concrete-block walls.

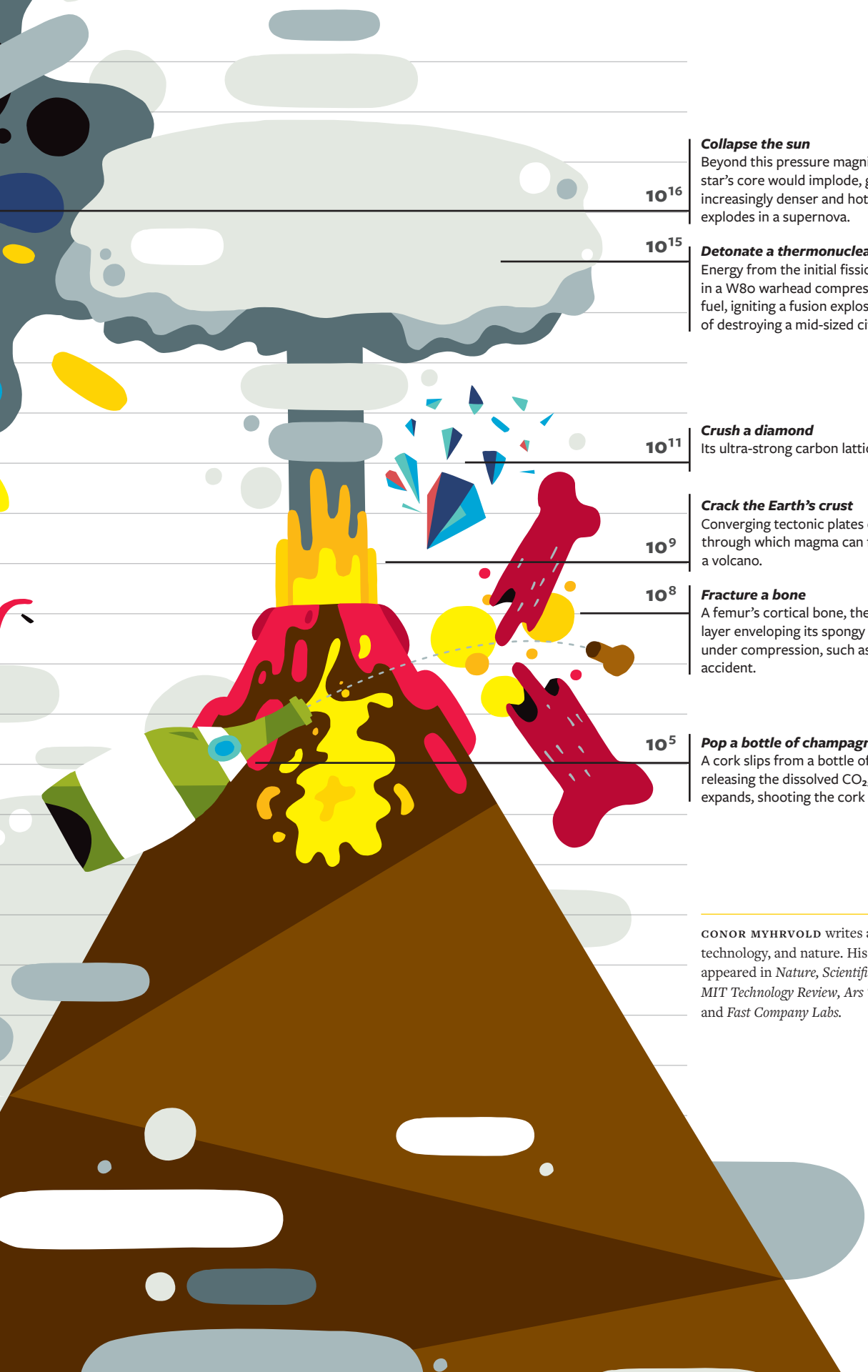
10^4

Split a raindrop
A drop 1 millimeter in diameter divides into smaller droplets.

10^2

Break the silence
Sound waves vibrate the eardrum, allowing you to hear. (This is the magnitude of sound pressure created by a mosquito flying 3 meters away.)

10^{-5}



10^{16}

Collapse the sun
Beyond this pressure magnitude, our star's core would implode, getting increasingly denser and hotter until it explodes in a supernova.

10^{15}

Detonate a thermonuclear bomb
Energy from the initial fission reaction in a W80 warhead compresses hydrogen fuel, igniting a fusion explosion capable of destroying a mid-sized city.

10^{11}

Crush a diamond
Its ultra-strong carbon lattice shatters.

10^{9}

Crack the Earth's crust
Converging tectonic plates create fissures through which magma can flow, forming a volcano.

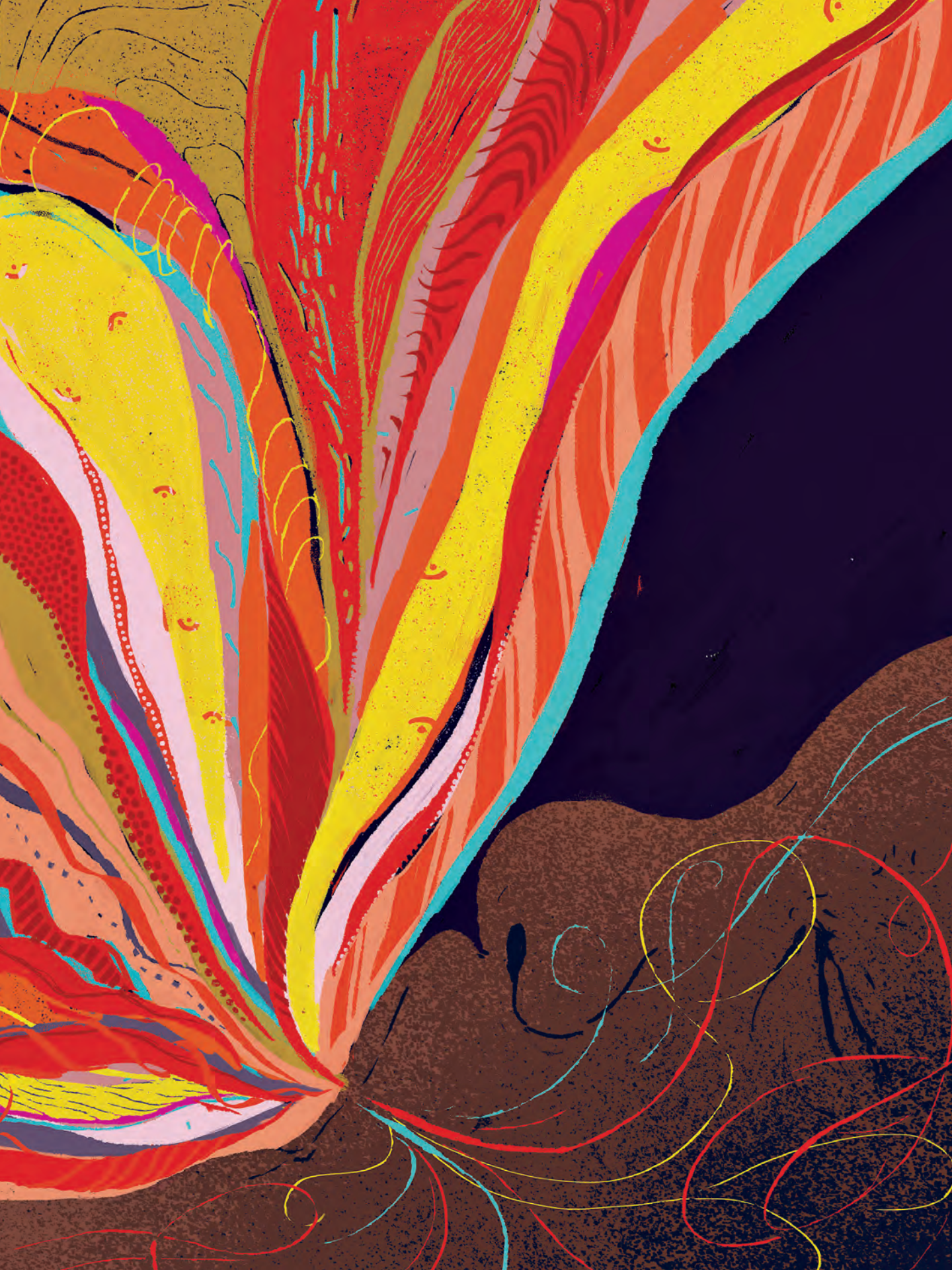
10^{8}

Fracture a bone
A femur's cortical bone, the dense outer layer enveloping its spongy interior, snaps under compression, such as during a car accident.

10^{5}

Pop a bottle of champagne
A cork slips from a bottle of bubbly, releasing the dissolved CO_2, which rapidly expands, shooting the cork into the air.

CONOR MYHRVOLD writes about science, technology, and nature. His other work has appeared in *Nature*, *Scientific American*, *MIT Technology Review*, *Ars Technica*, and *Fast Company Labs*.



When Stress Comes with Your Mother's Milk

Stress hormones in breast milk may help prepare us for a turbulent world

BY JENA PINCOTT

A FEW YEARS AGO, when my oldest daughter was still nursing, I went through a panicky phase. I had committed to a run of public-speaking engagements, and I constantly worried that I would flub them. Before each event, I pumped milk for the baby and left her with the sitter, who eventually confided that she dreaded my departures as much as I did. While I was away, she told me, my daughter was irritable and inconsolable. She would cry in the stroller; she would cry when held. Refusing to nap after feeding, she back-arched and bawled.

"We're like quantum particles!" I marveled. My daughter felt how I felt—from across the city.

"No," the sitter insisted, "it's the milk."

I flashed on all those times I had pumped between nervous preparations, my heart racing. Had I passed my stress on to my daughter through my breast milk?

When I posed this question to Laura Glynn, a psychologist at Chapman University, she said it was plausible. Along with the proteins, minerals, vitamins, fats, and sugars that nourish an infant, the antibodies that help fight infection, and the growth factors that aid in tissue development, milk contains a cocktail of hormones, including the stress hormone cortisol. The body circulates cortisol during trying or fearful situations—spats, traffic jams, sports competitions, deadlines. The hormone orchestrates aspects of metabolism and behavior, including triggering the release of sugars into the bloodstream, giving us that burst of energy we might need to fight or flee.

In nursing babies, cortisol gets a red-carpet welcome. An infant's intestinal tract responds to its mother's milk by sprouting receptors that detect the hormone, activating neurochemical signals that can travel all the way to the brain. These signals may influence a baby's stress response and the development of brain regions that regulate emotions such as fear and anxiety. Breastfed babies also have an average 40 percent more cortisol in their system than their formula-fed peers, suggesting that the increase comes from milk.

Scientists don't yet know the long-term effects of secondhand cortisol, or even whether its presence in

ILLUSTRATION BY VAHRAM MURADYAN

nursing babies can be described as stress. I can't say, for instance, whether the cortisol in my milk, possibly spiked by my own anxiety, caused my daughter to feel anxious. That's probably too simplistic a view.

But increasingly, studies by Glynn and others are showing that a mother's milk, in one way or another, helps to shape her child's behavior and temperament, and may deliver useful information about the environment she's growing up in. Perhaps my milk was sending my daughter a message: *Here's what you need to know about the world. Act accordingly*.

MOST EVIDENCE FOR THE LINK between milk cortisol and cognition comes from animals. Experiments on rats dating back to the 1980s show beneficial effects. When researchers spiked nursing mothers' water with corticosterone (the rodent equivalent of cortisol), mimicking mild stress, their pups learned faster, had better memories, and were less anxious and more exploratory during stress tests, suggesting a better ability to cope. One experiment found that male pups from corticosterone-dosed mothers grew extra cortisol receptors in a brain region involved in regulating the body's reaction to stress, which may help temper this response. In rodents at least, stress during motherhood seems to embolden offspring.

In primates, however, it appears to do the opposite. In a 2014 study, Katie Hinde, a behavioral biologist at Arizona State University, and her colleagues tested how cortisol levels in the milk of over 100 mother rhesus macaques correlated with their babies' temperament when put in a novel environment. Previous research suggests that human babies who cry or become agitated in unfamiliar situations are more likely than less-reactive babies to develop timid, shy personalities. Could cortisol be partly responsible? Hinde's study nudges the answer toward "yes." The higher the level of milk cortisol, her team found, the more nervous and timid a baby monkey acted in the presence of new things, such as a new toy or a stranger's face.

Glynn has observed a similar connection in humans. In studies published in 2007 and 2013, she and her colleagues tested cortisol levels in nursing mothers' blood and milk, respectively, and then surveyed them about their infants' behavior and temperament: How often during the past week did the baby startle to a loud new sound or sudden noise? When frustrated, how often did the baby calm down within five minutes? As in Hinde's macaque study, the results showed a significant association between high cortisol levels and nervous, jittery babies. (For unclear reasons, the second study found this trend only among girls, who also seem to be more sensitive to cortisol exposure in the womb.)

Of course, a link doesn't necessarily imply a cause. Maybe mother and child share genes that make both vulnerable to stress. Maybe stressed-out moms are more likely to rate their babies as fearful, or to treat their kids in a way that makes them more high-strung. Or maybe a fussy baby simply gives mom more stress, causing her cortisol levels to rise, rather than the other way around. Glynn considered these confounding factors and devised a solution: She tested and surveyed mothers with formula-fed babies, too. In this control group, the link between cortisol and temperament vanished.

The message, it seemed, was in the milk.

"DON'T LET THESE FINDINGS stress you out," Hinde insists. She doesn't want anxious moms like me to feel uneasy about breastfeeding. Cortisol levels don't always match feelings of psychological stress, she points out. And even the most zen-like nursing women have cortisol in their milk, which rises and falls with the rhythms of the day, as do the temperaments of their Buddha-like babies. On the contrary, she suspects that formula-fed babies may be missing out on important signals that hormones like cortisol convey. By better understanding these signals, scientists could create better formulas for mothers who can't nurse, or choose not to.

A mother's stress may nudge her baby one way or another, but cortisol alone doesn't dictate destiny.

ALEX LINGHORN/GETTY IMAGES

GOT STRESS? Studies suggest a link between high levels of stress hormones in breast milk and nervous, fussy babies.

The current consensus among those who study milk cortisol is that it serves an evolutionary purpose: to help babies adapt, physiologically and behaviorally, to the world in which they are born. Cortisol reflects a mother's circumstances—her resources, her social conflicts, and physical threats—and calibrates her baby's behavior accordingly. In the macaque study, for instance, Hinde's team found that monkey mothers with high levels of milk cortisol—those who tended to have more fearful babies—were also more likely to be new mothers. (Hormone levels were much lower in mothers who already had four or more children.) The reason for this, Hinde suspects, has to do with energy. Young mothers' bodies, including their mammary glands, are still developing, and so they have fewer resources than older moms to devote to milk production. As a result, their milk contains less energy. Perhaps the cortisol in it provides a warning: *Conserve energy by prioritizing growth, not play.* In other words, *be fearful*. Cautious babies are less likely to spend precious calories exploring, and instead will use most of this energy to grow and stay healthy.

Even in modern human societies, there may be conditions in which a wary vigilance could be advantageous. "Living in a very dangerous household or neighborhood, it might be safer than having a very surgent, outgoing temperament," Glynn says. And if a short-term spike in milk cortisol causes some stormy behavior in a baby—as my own experience might suggest—that, too, may have a silver lining. "A stressed mom may have a lot on her mind, and being fussy may be one of the tactics a baby uses to get the attention he or she needs from Mom and other caretakers," Hinde says. In our evolutionary past, this syncing may have meant survival.

Some experts suspect that moderate amounts of milk cortisol (in what's considered a normal range), together with the nurturing nature of breastfeeding, could help protect babies against the negative effects of stress later in life. A 2006 study of nearly 5,700 10-year-olds found that those who had been breastfed as infants were less anxious when confronted with a major stressor, such as parental divorce or separation. This link persisted even after the researchers adjusted for confounding factors, such as social class and education level.

There is some evidence that this resiliency stems from the fact that cortisol acts on the brain pathway responsible for blunting pain. Cortisol is also involved in the development of the body's central stress-response system, known as the hypothalamic–pituitary–adrenal axis. Low levels of the hormone during infancy may help habituate this system to mild stress, thereby training it to "dial down" the body's reaction to adversity.

If low or intermittent doses of milk cortisol can act as an inoculant against stress, what happens when mom's cortisol meter is chronically "turned to 11 with the knob broken off," as Hinde puts it? She hopes to get an answer when her young macaque subjects reach maturity. "When the data are in," she speculates, "we'll find that there are indeed some signatures that last a lifetime—or are even transmitted to the next generation."

However, she is quick to add that even if constant exposure to large amounts of cortisol during infancy turns out be harmful, other contributions to

development—such as nurturing and genetics—could compensate for or override any negative impacts. At the same time, other ingredients in breast milk may work alongside cortisol to influence infant temperament. For example, studies suggest that certain strains of *Bifidobacteria* and *Bacteroides*, which are transferred live in milk, produce molecules that may have a calming effect. Babies with more of these bacteria in their gut tend to be less anxious and fussy. Milk also contains complex sugars, known as human milk oligosaccharides, that feed a baby's microbiome, and each nursing mother has her own heritable, diet-dependent, ever-changing mix of 50 or so types. It's possible that this custom concoction further shapes her baby's disposition and mood by manipulating the gut flora.

A mother's stress, in other words, may nudge her baby one way or another, but cortisol alone doesn't dictate destiny. "This one hormone, in one aspect of parenting, is just one of the rivets holding the plane wing on. One rivet can break, and the plane still flies," Hinde writes in her blog "Mammals Suck...Milk." "Development is a multi-factorial system, and rarely is any one single aspect the linchpin."

AFTER MY STINT AS A PUBLIC SPEAKER ended, my daughter's fussiness subsided. She has since grown into a sweet, spirited 5-year-old, no harm done. Still, I can't help but wonder: Could my fluctating stress during her nursing days have anything to do with her abundant caution on the jungle gym? Or her composure during her first violin recital, despite a raging ear infection?

I wish for my children to encounter hardship in just the right doses: not so much that they become too fearful, nor so little that they become overconfident. But sooner or later, I know, life will throw some tough punches. It's comforting to think that my breast milk may have given my kids some of the first lessons on how to cope.

JENA PINCOTT is a science writer and author of *Do Chocolate Lovers Have Sweeter Babies?: The Surprising Science of Pregnancy*.

"WHY YOU DIDN'T SEE IT COMING"
ILLUSTRATION BY **JACKIE FERRENTINO**


RPM

What I Learned from Losing $200 Million

The 2008 financial crisis taught me about the illusion of control, and how to give it up

BY BOB HENDERSON

I'D LOST ALMOST $200 MILLION in October.

November wasn't looking any better.

It was 2008, after the Lehman Brothers bankruptcy. Markets were in turmoil. Banks were failing left and right. I worked at a major investment bank, and while I didn't think the disastrous deal I'd done would cause its collapse, my losses were quickly decimating its commodities profits for the year, along with the potential pay of my more profitable colleagues. I thought my career could be over. I'd already started to feel those other traders and salespeople keeping their distance, as if I'd contracted a disease.

I landed in London on the morning of November 4, having flown overnight from New York. I was a derivatives trader, but also the supervisor of the bank's oil options trading team, about a dozen guys split between Singapore, London, and New York. Until this point I'd managed the deal almost entirely on my own, making the decisions that led to where I ... *we* ... were now. But after a black cab ride from Heathrow to our Canary Wharf office, I got the guys off the trading floor and into a windowless conference room and confessed: I'd tried everything, but the deal was still hemorrhaging cash. Even worse, it was sprouting new and thorny risks outside my area of expertise. In any case, the world was changing so quickly that my area of expertise was fast becoming obsolete. I pleaded for everyone to pitch in. I said I was open to any ideas.

As I spoke, I noticed that one of the guys had tears welling up in his eyes. I paused for a second, stunned. Then my own eyes started to fill from a sudden wash of gratitude and relief that came, I think, from no longer being alone.

STRESS TESTING is a standard technique derivatives traders use to test how their portfolio will perform in an imagined "worst-case" scenario. The problem is that "worst-case" is subjective, making stress testing as much of an art as a science, and exposing the trader doing the testing to something called the "illusion of control."

ILLUSTRATION BY ROSS MACDONALD

The psychologist Ellen Langer coined the phrase in 1975 to describe "an expectancy of personal success probability inappropriately higher than the objective probability would warrant." Experimental evidence for the illusion goes back at least to 1965, when one research team found that college-educated employees of AT&T asked to press buttons to illuminate lights had the tendency to believe they had more control than they actually did, even when the lights lit randomly, and even when they used pen and paper to track their results.

In another study, done in 1992, a group of Israeli college students was found to be more willing to bet on dice, and to bet bigger, before they rolled than after, reflecting the belief that they had control over their rolls. Such a preference for prediction over postdiction had been observed before, but this study also found that the preference grew stronger when the students were threatened with an electric shock if they guessed wrong—evidence that stress amplifies the illusion of control.

Langer's work showed that the illusion is also intensified by "skill cues": circumstances that make people feel like they're engaged in acts of skill rather than luck. Such cues include competition, choice, and familiarity with the task at hand. Therefore people will tend to overestimate their prospects in a game of pure chance even more than usual if they face a nervous-looking opponent, or if they pick rather than get assigned a lottery ticket, or if they're given the chance to familiarize themselves with an apparatus that's simply spitting out random numbers.

Or, I might add, if they've toiled over complicated mathematical equations to back up their decisions.

I thought I knew what I was getting into. I'd helped my bank win the fateful deal by developing a complex option on crude oil, together with a risk management strategy. My equations told me how I could buy and sell simpler financial products over time to approximately offset my daily gains and losses on the option I'd sold.

While I was still executing the trade, I'd stress tested my strategy by imagining oil prices plummeting by 30 percent, option-implied volatilities spiking to record levels, and so on. The "worst-case" loss I derived in September was $30 million, less than a sixth of what I ended up losing in October alone.

And I still had 13 months to go before the option expired.

THE BIG DEAL Our deal with Mexico insured two-thirds of their oil exports, enough to fill more than 100 supertankers.

I WAS THE ARCHETYPAL physics Ph.D. hired by Wall Street for my experience modeling the universe with math, based on the belief that the same could be done for markets, particularly for derivatives. I had studied physics because I wanted to make sense of the world—if not to control it, then to at least control my experience of it, to organize it for the comfort that comes with order. When I ended up working for a bank after graduation, I found that I enjoyed it far more than I expected. As in physics, I still had the pleasure of figuring things out, and I still had a chance to get to the bottom of things, even if only in one small part of the world.

By 2008, I'd spent over a decade developing derivatives and trading strategies, most of them successful. And I was successful too, not for any ability to forecast the future, but simply for being careful and logical and systematic. Basically Wall Street rewarded me for doing the sorts of things I'd hoped to do in physics; the only difference was that I now applied probability theory to markets rather than quantum mechanics.

But until 2008, I'd never really experienced the extreme tail of a probability distribution firsthand. And that experience disabused me of more than one illusion.

The derivative I'd sold was an option, but it worked just like an insurance policy. The buyer was the government of Mexico, the sixth largest exporter of crude oil in the world at the time, and a country dependent on those exports for about a third of its federal budget. A crash in crude's price could cause deficits or the need for drastic cuts to social programs, neither of which was particularly palatable to the country's politicians. Traditionally, Mexico had used derivatives to lock in a minimum sale price for the crude it would sell the following year. In 2008, they covered a fraction of their 2009 exposure with me.

The option they bought from me was complex, or at least unusual, in that it was written on Maya crude, a heavy and sour grade comprising nearly 90 percent of Mexico's production. For years, Mexico had hedged using options on West Texas Intermediate (WTI), the United States crude most commonly quoted in the news as "the price of oil," and the most heavily traded commodity in the world, thanks to the extensive derivative market that trades on it. For Mexico, buying WTI

My eyes started to fill from a sudden wash of gratitude and relief that came, I think, from no longer being alone.

HARALD SUND/GETTY

options was convenient and cheap, like buying a suit off the rack. But it also exposed the country to the risk that Maya might underperform WTI in the event of a crash, in which case its off-the-rack insurance might fail to cover its made-to-order losses.

I got wind of the leak in an email from our head salesperson, who added the comment, "This press coverage is going to kill us."

Enter my bank and I, offering Mexico a custom suit in the form of an option on Maya. It cost more, but the strategists in Mexico's finance ministry liked it enough to pay the premium, and to let my bank participate for the first time in its annual hedging program. This was a big deal for my bank because it was vying to be the top commodities bank in the world, and Mexico's program was the largest and most prestigious of its kind. It was a big deal for me too, given its potential impact on my prospects for promotion and a bonus.

But there was a reason no other bank had sold Maya options to Mexico before, and it was the same reason I found myself contemplating a career change in November of 2008: Unlike WTI, there was no derivatives market on Maya, and therefore no opportunity for me to hedge my risk using standard derivative techniques. I had to improvise.

As with my stress testing, I depended on historical data—how Maya's value had changed in the past relative to that of other oil and refined products—to drive my hedging strategy, which involved proxying Maya with a basket of other hydrocarbons, including fuel oil. Fuel is a refined product like gasoline or diesel, but of lower quality and used to power ships. Very roughly, you could think of my proxy for Maya as a blend of WTI and fuel. The key was that, unlike with Maya, I could trade derivatives on fuel and WTI in the interbank market. The problem was what happened to that market as oil prices crashed.

As prices sunk lower and lower, and it became more and more likely that Mexico's insurance would pay off—so that I would effectively be responsible for buying the country's 2009 Maya at the price I'd guaranteed it—my strategy required me to sell more and more fuel to hedge my increasing exposure.

And therein lay the rub.

In markets, at least, size matters. I said earlier that I'd insured a fraction of Mexico's exports. What I didn't say was that that fraction was *two-thirds*: two-thirds of the world's sixth largest oil exporter's product, 220 million barrels, or around $17 billion worth, enough to fill 100 supertankers and then some. That meant I had to sell *a lot* of fuel. More, as I quickly and painfully found out, than the market could bear.

Through October, I couldn't sell fuel fast enough to keep up with my exploding exposure. Making matters worse, fuel's price fell far faster, relative to other oil products, than it ever had before. I lost money on all manner of risks in those weeks, but about half of the damage came from fuel.

And, adding insult to injury, part of the reason for fuel's exceptional weakness was my own feverish selling. The fuel market is small and the deal was ginormous, and so my sales flooded the market with both fuel and information about my position, weakening my bargaining power and making it harder to sell as the days went by. Hitting a market's ceiling like this was something that none of my methodologies accounted for.

Nor did they account for other information leaks, beyond fuel. The same week I landed in London, Mexico's finance minister broke with convention and—trying to reassure markets about his country's finances—spilled the beans about the deal to a reporter. I got wind of the leak in an email from our head salesperson, who added the comment, "This press coverage is going to kill us."

Yes.

SUCCESS IN "NORMAL" CIRCUMSTANCES says little about your chances in crisis, since in crisis the rules change. But it sure can make you feel confident—which is how I felt after the successes I'd had before 2008.

A 2014 study by Helena Matute, the director of the experimental psychology lab at the Unversidad de

COURTESY OF THE AUTHOR

Duesto in Bilbao, Spain, asked 50 pairs of participants to administer fictional medicine to fictional patients suffering from a fictional disease. Half had 30 doses of the medicine to disburse among 100 patients, and the other half had 70. Eighty percent of the patients recovered, regardless of whether or not they were given medicine.

Slightly less than half of the participants giving 30 doses believed that the medicine was effective, but more than two-thirds of the 70-dose crowd believed they'd played a role in patients' recovery. The experience of repetition, and greater personal involvement, strengthens the illusion of agency even with no causality. Success with *some* causality, like mine, surely must strengthen it even more.

This happens on the institutional level too, Exhibit A being the Federal Reserve, which has conducted stress tests on the biggest banks every year since the crisis. The Fed's goal is the same as mine was in September 2008: to calculate how bad things might get. In the Fed's case, that means testing what might happen to the banks' capital (assets minus debts) in a crisis when assets depreciate. Negative capital is called insolvency. For a bank, insolvency is a fast track to bankruptcy. In "supervisory" stress testing, regulators like the Fed—this is being done in Europe too—posit one or more worst-case scenarios and compute the consequences for capital, similar to how I tried to calculate how much I'd lose in a crash.

The Fed's first test in 2009 was an unmitigated success, widely credited with ending the most acute stage of the crisis. The test was based on a scenario in which the market tanked even further than it already had and a deep recession followed. The Fed concluded that several big banks would suffer capital shortfalls as a result, Bank of America leading the list with a deficit of $33 billion. The Treasury Department then topped off the needy banks with cash from its Troubled Asset Relief Program, reassuring markets and kick-starting a recovery.

Now, the Fed stress tests the big banks every year, partly because the chief piece of post-crisis financial regulation in the U.S., the 2010 Dodd-Frank Act, requires it. Banks have long operated under regulatory capital limits, such as minimum ratios of capital to assets. What's new since the crisis is that those minima have increased and that stress testing is used to regulate banks' capital plans—limiting share buybacks and dividend payments, for example—to try to guarantee that they'll have sufficient capital no matter what.

The Fed's test this year concluded that the 31 largest bank holding companies in the U.S., which account for more than 80 percent of the country's banking assets, would lose a grand total of $490 billion in its

POST-CRISIS The author unwinding on a hike, bike, and raft trip in Ecuador in 2009.

People would avoid cars, planes, marriages ... everything really.

worst-case scenario. And yet, for the first time in the tests' history, not a single bank failed the test by having its capital to asset ratio fall below the Fed's 5 percent hurdle. The implication was that the banks were finally under control.

Or was it just an illusion of control?

I took a look at the Fed's stress test scenario[1] myself recently, on the bank's website. My first reaction was that it seemed almost farcically fashioned to "fight the last war": The Dow drops by about half, U.S. GDP dips around 5 percent, unemployment spikes to 10 percent—basically it's the aftermath of 2008 all over again. It doesn't account for other potential calamities, like a breakup of the Euro, for example, or an emerging market crisis, or hyperinflation, or shock-induced feedback effects like the ones I faced with fuel.

There's also the inconvenient fact that both Fannie Mae and Freddie Mac were stress tested regularly by their regulator, and declared well capitalized—right up until they failed in 2008. The same was true for Iceland's banks.

I'M NOT ALONE in my skepticism. The former Fed economist Til Schuermann, who had a hand in designing the Fed's tests, thinks that they actually *add* risk to the system, rather than reduce it, a position he outlined in a 2013 *Wall Street Journal* op-ed. "The danger is that the financial system and its regulators are moving to a narrow risk-model gene pool that is highly vulnerable to the next financial virus," he wrote. "By discouraging innovation in risk models, we risk sowing the seeds of our next systemic crisis."

In other words, the Fed, by centralizing stress testing around its own approach, is incentivizing banks to follow suit, which may push them to accumulate similar exposures to one another and to manage them in similar ways, resulting in decreased diversification and increased risk. This is a question raised by particularly prescriptive rules like the Fed's 5 percent hurdle, which are simple to monitor but may be just as simple to game.

1. There are actually three, but the other two are a baseline scenario with no crisis, and a milder version of the one I describe.

What's more, the Fed's *own* incentives may support an illusion of control.

"They're grading their own papers and they always pass," said Kevin Dowd recently on a Cato Institute podcast. Dowd, another Fed stress test skeptic, is a professor of finance and economics at Durham University in England. "A central bank stress test can never be credible because of the incentives built in to get a pass result," he added.

Dowd reasons that, given the Fed's mandate to keep the financial system safe, it's motivated to find that it *is* safe, similar to the way that I was incentivized to get stress testing results that supported doing my potentially mega-profitable deal.

I got Dowd on the phone recently and asked him what the Fed could do to improve its tests.

"First off, don't do them," was his response.

So what model should the Fed use instead?

"I would not use any model at all. I do not believe financial risk modeling works," he replied.

"It takes a model to beat a model," I challenged, plagiarizing a phrase I'd learned from another professor of finance when I started in banking and which became something of a mantra of mine thereafter.

Dowd chuckled, but was unmoved. "I would always go for history over a model," he replied, before explaining that he'd look to what capital levels were in the 19th century, when banks were private companies and less subject to government regulation.

But even history requires a model to interpret it. Riccardo Rebonato, global head of interest rates and FX at Pimco, and author of one of the very few books dedicated to the art of stress testing, made this point when I called him, by asking me to imagine that a Martian had landed on Earth.

Suppose, he said, that the extraterrestrial and I both witnessed the same event: another human being pulling a penny from his pocket, flipping it four times, and having heads come up each time.

I, Rebonato guessed, wouldn't think much of this coincidence, because of my past experience with coins. Four heads in a row is not an especially rare event. So I'd probably still guess the odds of heads coming up a fifth time were 50-50.

But, he proposed, "The Martian knows absolutely nothing about coins. For all he knows coins are devices for producing heads when you flip them." Therefore the Martian would be more likely to bet on heads against me.

"The point of the story," Rebonato continued, "is

that you always come to data with a structural model behind"—meaning some preconception of causes and effects, and therefore some prejudice for how to interpret the data.

I understood immediately, having spent countless hours over many years struggling to extract probabilities and other forward-looking metrics from historical data. The biggest challenge was always that the answers depended so much on which timeframe you focused on. The past month? Year? Five years? And if you want to use data to estimate the probability of a very rare event, then you need a lot of data—the more rare, the more data—which means taking data from further back in the past, and the further back you go, the less relevant it probably is.

But what's the alternative to estimating probabilities? If we can't say anything about what the probabilities are, then we really are forced to worry about the absolute worst possible scenario. A trader would never sell options or short stocks, since his losses could be infinite. People would avoid cars, planes, marriages ... everything really, for fear of the worst possible result. We'd all be paralyzed.

Which is why Rebonato told me that professed ignorance of probabilities is "a form of tyranny that's an excuse for inaction." And why his favored approach to stress testing (a technique called Bayesian nets) doesn't involve trying to derive probabilities at all, but rather asks the user to just "produce your best-informed guess."

THE MOST STRESSFUL PART of my 2008 experience taught me how to guess.

The day after Lehman fell I lost $20 million, and the day after that $30 million—enough in two days to wipe out all the profits I'd made the previous year. (And that had been a pretty good year.)

But worse was that I felt trapped. My models showed I was destined to lose far more money in the coming weeks, no matter what I did. All roads seemed to lead to an unavoidable abyss. I could practically feel that hot hole breathing under my desk. I actually got dizzy, and lost my ability to think. When my boss stopped by to warn me that Goldman Sachs and Morgan Stanley looked likely to fall next, he seemed almost amused when he told me that I looked green.

I stumbled home early that day, mentally incapacitated for the first time in my career.

But stress had other effects too.

Psychologists say that the illusion of control can be adaptive, in the sense that it encourages a focus on problem-solving behaviors as opposed to emotional response. So once I got past flight and started to fight, I may have had a dose of delusional thinking to thank for the guesses I made next.

> You don't argue when someone's handing you a big check, but I wondered what the hell he was thinking.

The Sunday after Lehman fell, pacing my empty trading floor, I realized once and for all that my models and reports could no longer tell me what to do. The one unmistakable fact was that my risks would increase if oil continued its decline. I decided that when I came in on Monday, I'd place a big bet that WTI would do just that.

And on a Saturday morning bike ride up the Hudson, it occurred to me that Mexico might be willing to restructure its deal—selling us back the option it owned, and buying a new one—in a way that would lock in billions of profits for the country, while giving me a much needed windfall too. I dropped my bike in a bush and texted our salesperson about the idea.

There were many other decisions and guesses, some made alone, others with help from my team, and still others made by my boss. All were guesswork, none could I have anticipated in stress testing, and all involved abandoning my original strategy along with the illusion of control it gave me.

IN THEIR 2003 PAPER "Trading on Illusions," the organizational-behavior researcher Mark Fenton-O'Creevy and his colleagues argued that the stress, competition, and choice involved in trading financial instruments naturally give rise to illusions of control, something my

own experience affirmed. They also found that those illusions are *inversely* related to trader performance. They even got it down to a number: "An increase in illusion of control of one standard deviation is associated with a decrease in annual remuneration of £58,000 [$87,500]."

Having relinquished at least some of my illusions, I couldn't be sure that what happened next wasn't just dumb luck.

First, Mexico bought into my idea of a restructure, executed the trade, and allowed me to make enough on it to fill a good fraction of the hole left by *another* $200 million of losses I suffered that month on my original risk.

Then WTI continued its decline, hitting bottom in December at $33 and change. I made a killing on my short position, unwound it, and started making money on other bets, on fuel and volatility, for example. December went so well that I recouped most of my losses by the end of the year.

Then, in 2009, persistently low oil prices caused me to accumulate a massive position in Maya, all 220 million barrels, which strengthened significantly relative to my hedges, something that my original model said should happen, but which could have been more fluke than foresight. In any case, things went so well during the first quarter that one executive visiting from Singapore marveled at how I was "printing money faster than Obama."

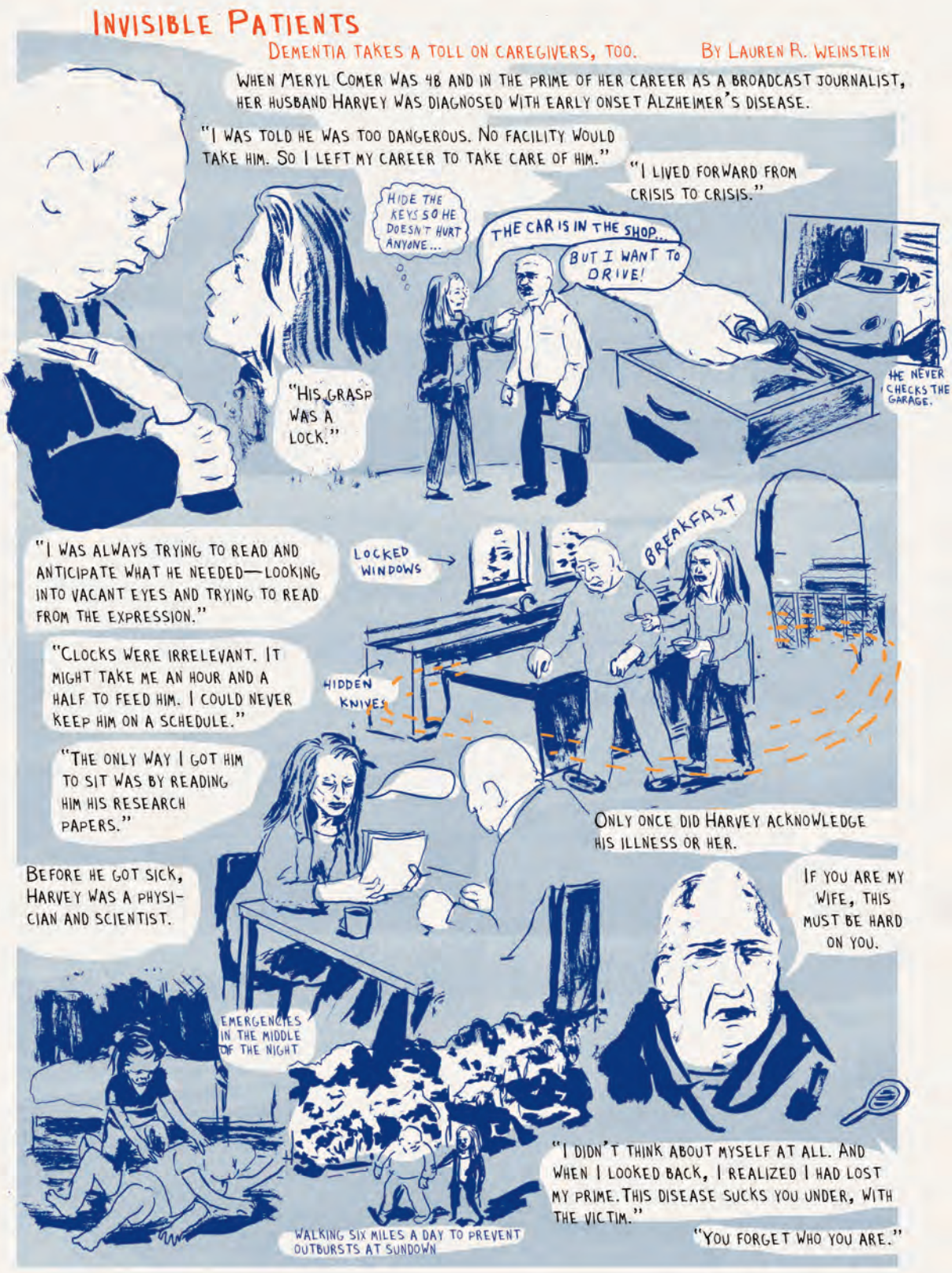
The deal matured in December of 2009, with happy repercussions all around. Mexico netted over $6 billion and kept its budget whole. *Futures and Options World* magazine bestowed its award for "Most Innovative or Creative Use of Derivatives" on the country and presented it to the minister of finance at a press conference in New York that some of my colleagues and I attended. The minister was lauded in the press for his prescience, and was ultimately made, as I heard was his ambition, the head of Mexico's central bank.

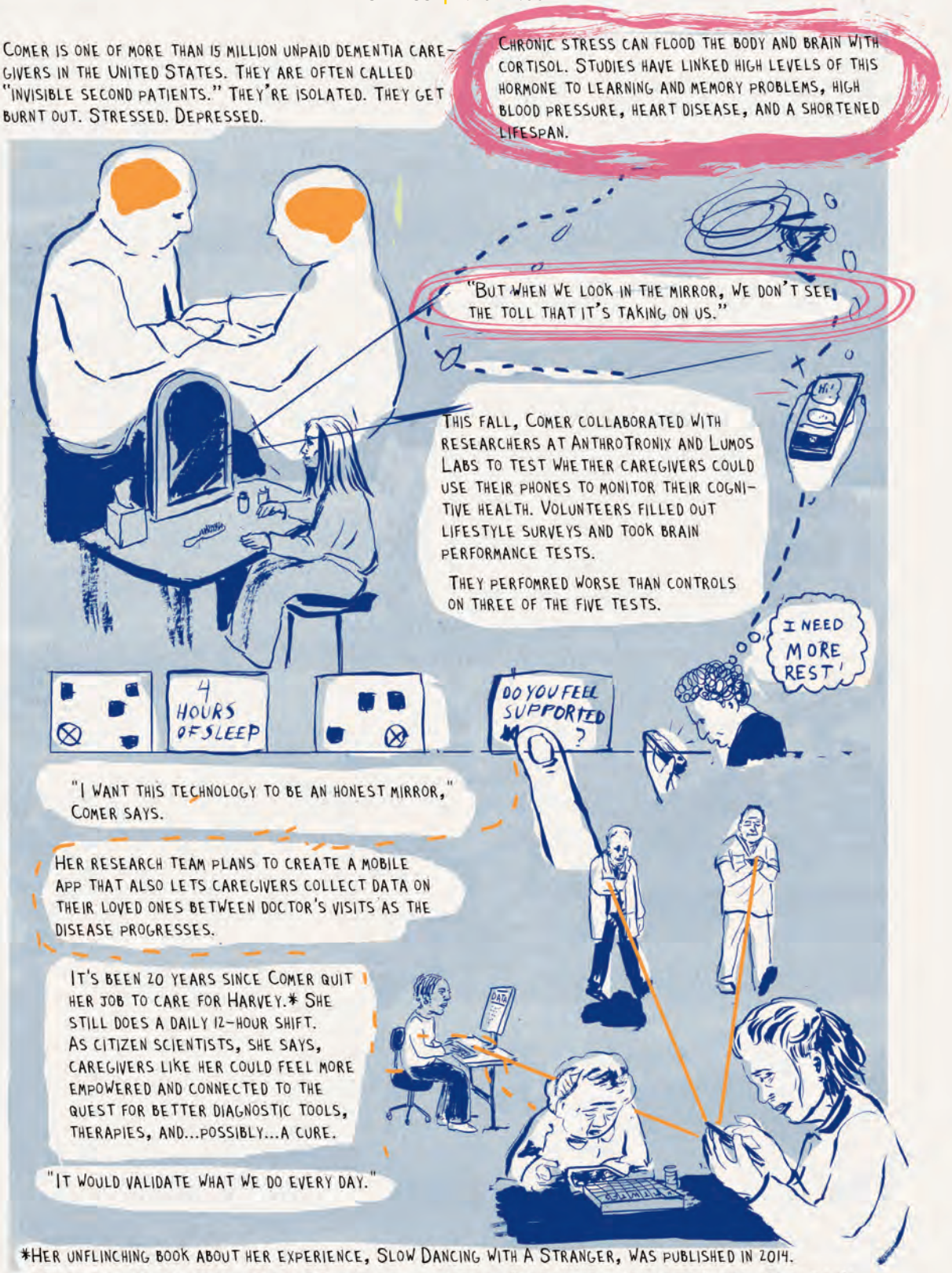
I got promoted too, paid a big bonus, and was told that I'd presided over the most profitable deal in my bank's history.

In the February 2010 meeting in which my boss gave me my number, he said that to his mind I'd earned it more for the part I'd played in winning the deal in the first place than by all the work I'd done after.

You don't argue when someone's handing you a big check, but I wondered what the hell he was thinking. To me, *everything* important had come after. Only by managing that monstrosity through the crisis did I come to fully appreciate how unlike physics markets are, how crucial to outcomes other people and luck are, and how, no matter how hard I worked or how much I prepared, there would always be some things I couldn't completely fathom.

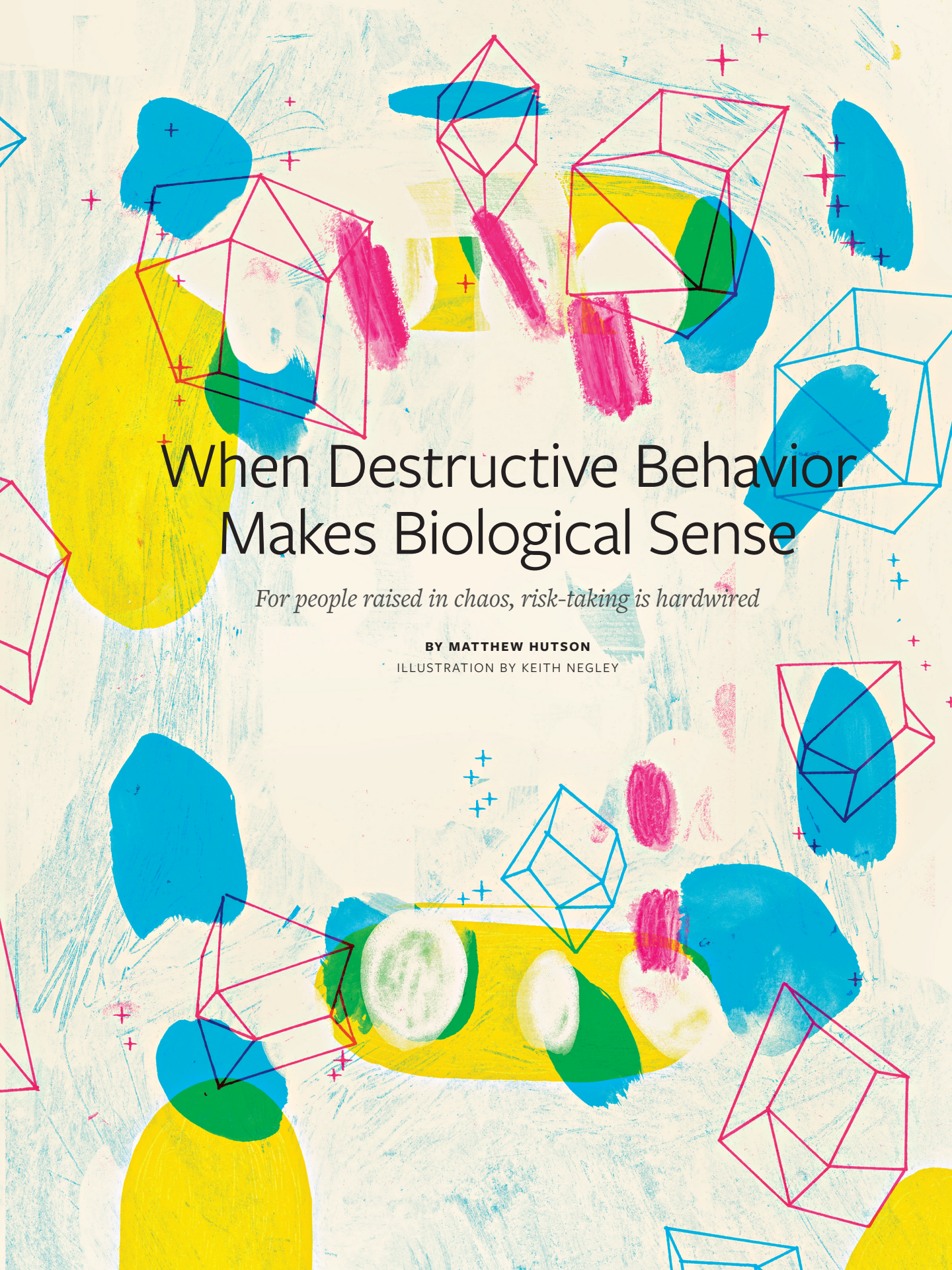
BOB HENDERSON studied physics, worked on Wall Street, and is now an independent writer focused on science and finance.


INVISIBLE PATIENTS
DEMENTIA TAKES A TOLL ON CAREGIVERS, TOO.
BY LAUREN R. WEINSTEIN
WHEN MERYL COMER WAS 48 AND IN THE PRIME OF HER CAREER AS A BROADCAST JOURNALIST, HER HUSBAND HARVEY WAS DIAGNOSED WITH EARLY ONSET ALZHEIMER'S DISEASE.
"I WAS TOLD HE WAS TOO DANGEROUS. NO FACILITY WOULD TAKE HIM. SO I LEFT MY CAREER TO TAKE CARE OF HIM."
"I LIVED FORWARD FROM CRISIS TO CRISIS."
HIDE THE KEYS SO HE DOESN'T HURT ANYONE...
THE CAR IS IN THE SHOP...
BUT I WANT TO DRIVE!
"HIS GRASP WAS A LOCK."
HE NEVER CHECKS THE GARAGE.
"I WAS ALWAYS TRYING TO READ AND ANTICIPATE WHAT HE NEEDED—LOOKING INTO VACANT EYES AND TRYING TO READ FROM THE EXPRESSION."
LOCKED WINDOWS
BREAKFAST
HIDDEN KNIVES
"CLOCKS WERE IRRELEVANT. IT MIGHT TAKE ME AN HOUR AND A HALF TO FEED HIM. I COULD NEVER KEEP HIM ON A SCHEDULE."
"THE ONLY WAY I GOT HIM TO SIT WAS BY READING HIM HIS RESEARCH PAPERS."
ONLY ONCE DID HARVEY ACKNOWLEDGE HIS ILLNESS OR HER.
BEFORE HE GOT SICK, HARVEY WAS A PHYSICIAN AND SCIENTIST.
IF YOU ARE MY WIFE, THIS MUST BE HARD ON YOU.
EMERGENCIES IN THE MIDDLE OF THE NIGHT
WALKING SIX MILES A DAY TO PREVENT OUTBURSTS AT SUNDOWN
"I DIDN'T THINK ABOUT MYSELF AT ALL. AND WHEN I LOOKED BACK, I REALIZED I HAD LOST MY PRIME. THIS DISEASE SUCKS YOU UNDER, WITH THE VICTIM."
"YOU FORGET WHO YOU ARE."



*HER UNFLINCHING BOOK ABOUT HER EXPERIENCE, SLOW DANCING WITH A STRANGER, WAS PUBLISHED IN 2014.

THIS ARTICLE WAS CREATED IN CONJUNCTION WITH THE VIDEO SERIES "THINK LIKE A SCIENTIST," PRODUCED BY DAY'S EDGE PRODUCTIONS AND THE HOWARD HUGHES MEDICAL INSTITUTE FOR NAUTILUS.



When Destructive Behavior Makes Biological Sense

For people raised in chaos, risk-taking is hardwired

BY MATTHEW HUTSON

ILLUSTRATION BY KEITH NEGLEY

ROBIN MARVEL WAS NEVER supposed to succeed. By the time she was a teenager she'd watched her mother be violently beaten by her father and a number of boyfriends, been sexually assaulted herself, moved haphazardly around the country, become an alcoholic, and gotten pregnant by her boyfriend.

"There was never any stability at all," Marvel says of her life with her mother. "I was always homeless, we were always being evicted or moving, the lights would be off for weeks. We would get kicked out of domestic violence shelters because she would break the rules."

Sometimes Marvel would come home to find cocaine and mounds of marijuana on the table. "My mom was extremely unstable. She would just wake us up in the middle of the night and say 'We're moving to Michigan.' Then the same thing would happen in Michigan—we'd just move back. I missed the first three months of third grade because we were living in a station wagon in Sacramento."

Having a daughter at 17 sobered Marvel temporarily, but in a few years she began drinking heavily again. "I wouldn't see my daughter for days," she says. "I was just being this really awful person. I maxed out credit cards. I had a car repossessed. I didn't understand the responsibility of paying bills and keeping good credit. And I didn't see the importance in it either. I didn't see the value in being able to build a financially responsible life."

Reflecting on her perspective at the time, Marvel says, "You have no control over life, it just kind of sucks. It was just kind of a normal thing for me to live in that horrible lifestyle."

Studies in social science and psychology have shown people like Marvel—people whose early existences are largely defined by a lack of resources, instability, and violence—often live foreshortened lives filled with risk-taking and even crime. Vladas Griskevicius, a social psychologist at the University of Minnesota's Carlson School of Management, wants to change the way we think about people like Marvel, and the seemingly senseless choices that they make.

"The takeaway message in most of psychology is that if you grow up in a bad environment, you're going to be deficient in some way," Griskevicius says. "That growing up poor or in harsh conditions prevents you from flowering and reaching your potential."

Drawing on core ideas in evolutionary biology and economics, Griskevicius has another story to tell. "People who grew up in a harsh environment are better adapted to thrive in that kind of environment," he says. When you are led to believe that life has no future, it makes sense to capitalize on what you can get in the present. Human decision-making, even when it seems irrational and reckless on the surface, is characterized, Griskevicius says, by a "deep rationality."

Studies by Griskevicius and other researchers can be seen as a response to the argument, the gist of the American Dream, that people can readily change their behavior with optimism and persistence. But the scientists' takeaway message doesn't rest on pessimism and futility. While adaptation to a harsh environment can lead to self-destruction, it can also sow the seeds of success.

GRISKEVICIUS' RESEARCH RELIES on "life-history theory," an evolutionary biological perspective explaining how quickly and how often organisms mate and reproduce. Every organism has limited resources in time, calories, or money, and must decide, consciously or not, where to allocate those resources. They either invest them in the future by building their own health and that of their offspring, as well as by developing relationships and knowledge, or they spend them on frequent mating, focusing instead on getting as many copies of their genes out there as they can before their lives end.

For instance, rabbits don't live long and don't have much control over their environment in the wild, so their approach to life is basically: Reproduce

> "Becoming a teenage parent may—however much most of us don't like it—be sensible from the perspective of the person whose future is precarious."

MEAN STREETS Coming down off of drugs, Cookie and Dave, two subjects of Jim Goldberg's celebrated 1995 photography book of homeless teens, can be seen as those adapted to thrive in desperate environments.

JIM GOLDBERG/MAGNUM PHOTOS

quickly—and often—before you die. This is a "fast life-history strategy." A study across 48 mammal species found that higher mortality rates predicted early maturation and large litters of small offspring, ensuring that not too much energy was invested in each baby.[1] On the other hand, later maturing animals, like elephants, have long, more predictable lives, so they produce one calf at a time and invest a great deal in each. They live a "slow life-history strategy."

Humans, in a life-history perspective, are closer to elephants than we are to rabbits. But there's variation within each species. People who grow up in harsh or unpredictable conditions often unconsciously adopt faster strategies for getting through life, while people raised in largely stable conditions adopt slower life strategies.

Jay Belsky, a professor of human development at the University of California, Davis, predicted 25 years ago that growing up under conditions of adversity would accelerate sexual maturation, a prediction borne out by research.[2] A 2010 study found that, on average, girls who grew up in a household lower in socioeconomic status (measured in the study as a combination of household income and father's education and occupation) had their first period at a younger age: Their bodies sensed instability and wanted to get on with things.[3]

Further, in a study across 170 countries, women who lived in countries with shorter life expectancies had their first baby at an earlier age.[4] The same pattern was found across Chicago neighborhoods.[5] Across counties in the United States, lower income and higher rates of violent crime were associated with mothers giving birth at a younger age.[6] In England, deprived areas led to lower ages at first birth, lower birth weight, shorter breastfeeding periods, and a higher rate of

reproduction.[7] Another study analyzed the causal pathway for such effects: Among English subjects, lower socioeconomic status in childhood led to greater childhood adversity, which led to increased emotional and behavioral maladjustment, which led to a younger age of reproduction.[8]

To Belsky, these findings make sense. "Becoming a teenage parent may—however much most of us don't like it—be sensible from the perspective of the person whose future is precarious," he says. Drawing an economic analogy, he notes that saving money is generally considered a worthwhile and honorable endeavor, unless you're in an inflationary economy.

TAKING CONTROL Robin Marvel has overcome her turbulent childhood by realizing she didn't have to be a victim of it. "I started learning that I was in control of my happiness," she says.

Griskevicius has used an economic model to understand similar life circumstances and how people's life choices might help them adapt. "The heart of economics is how people make tradeoffs, because everyone has limited resources," he says. "The math underlying all economic theory and all life-history theory is essentially the same—they're just looking at different types of resources."

For one of their papers, Griskevicius and his collaborators looked at what drives family-planning decisions. In an experiment, they had undergraduate participants state at what age they wanted to get married and at what age they wanted to have their first child. They also reported their family's financial status growing up. Those who grew up poor wanted to get married and have kids earlier than those who grew up wealthy. A companion experiment found that the lower a subject's household income growing up, the less the subject wanted to pursue education and a career before starting a family.

According to Griskevicius, these studies show that when someone's early life is defined by a lack of money and resources, his or her conscious and biological drives can signal that trying to build a solid career before reproducing is likely a losing proposition. The wise decision appears to be: Get married early and have kids fast.

The studies reveal two other important phenomena. Before answering the questions, the subjects read a fake newspaper article about an increase in violence in the U.S. Other subjects in the same study read a less threatening article. For these other subjects, childhood family income had no effect on family planning. It was the slight sense of threat that had a unique influence. Second, subjects also reported their *current* financial status. Unlike their childhood financial status, this had little effect on when they wanted to start a family, suggesting that life-history strategy gets locked in early.

A longitudinal study further explored the effect of early conditions.[9] Using data on 165 young adults, researchers found that difficult conditions over the first five years of life—but not conditions over the next 10 years—were associated with delinquent, aggressive, and criminal behavior at age 23, as well as the number of sexual partners they'd had. The study revealed the effect of childhood socioeconomic status was smaller than the effect of childhood unpredictability: moving around a lot, having father figures come and go, having a mother with inconsistent employment.

Together, poverty, violence, and uncertainty all point to a fast life-history strategy: seizing the moment

SARAH BROWN

"I remember sitting in my living room and looking around and going, 'This is not the way I want my story to end.'"

with little regard for a future that may not arrive.

Aurelio José Figueredo, a psychologist at the University of Arizona who studies life-history theory, puts the strategy in a stark light. "I am reminded of the slogan 'Live fast, die young, and leave a good-looking corpse,' " he writes in an email. "It is not about a long, happy, or healthy life: Those are slow life-history values. Think Thomas Hobbes: 'Nasty, Brutish, and Short.' "

IN THEIR BOOK, *The Rational Animal*, Griskevicius and Douglas T. Kenrick feature a host of high-profile people who grew up in fast-life situations, then became wildly successful, only to take an enormous fall.

M.C. Hammer grew up with eight siblings and a single mother in a housing project in East Oakland, California. He went on to earn tens of millions of dollars in music but quickly spent it all; several racehorses later, he was millions in debt. Mike Tyson, one of the most successful boxers of all time, grew up with a single mother in a tough Brooklyn neighborhood. He too earned a fortune before, two Bengal tigers later, he found himself millions in debt. The authors also spotlight Larry King, who grew up with a single mother in another poor Brooklyn neighborhood. After making it big as a radio and TV host, he too, several ex-wives later, had to declare bankruptcy.

"Looking through an evolutionary lens," Griskevicius and Kenrick write, "it becomes clear why these three men started spending their monetary windfalls as soon as the money hit their bank accounts: Their brains were calibrated to live fast because they did not know what tomorrow would bring."

In the lab, Griskevicius and his colleagues identified the kinds of decisions that cause such downfalls. They found that threatening cues like stories about violence and economic recession led those who'd grown up relatively poor to take risks (gambling on large monetary rewards rather than settling for smaller ones),[10] prefer immediate gratification (choosing smaller amounts of money now over larger ones later), and tend toward excess consumption (yearning for luxury items at the expense of savings).[11] The experiments raise the question of why people from more stable, financially secure lives, when faced with the same cues, don't make the same rash decisions. (Well, not as often.) In fact, in some studies, threatening cues *reduced* the rash decisions of those from stable childhoods.

In a 2014 paper, Griskevicius and Chiraag Mittal provided an explanation. They found that a threatening cue—an article about an economic recession—led subjects from a poor background to prefer immediate rewards over larger delayed ones, and led subjects from a wealthier background to prefer the delayed rewards.[12] The mediating effect, they discovered, was a sense of control, a belief that one can achieve things one sets one's mind to. Uncertainty leads those from difficult backgrounds to become more impulsive and less persistent. It leads those from less tumultuous backgrounds to become less impulsive and more persistent. Mittal and Griskevicius explain that those from stable backgrounds may overestimate their sense of control in a time of uncertainty because it recalls a strategy that has worked for them for most of their lives. They save up and invest in the future, for a period when times will be less hard. For those from unstable backgrounds, their way of life is constantly telling them to expect calamity.

Those born to a fast life-history strategy, though, don't always crash and burn. In one of their papers, Griskevicius and Mittal quote 50 Cent: "You can take me out of the 'hood, but you can't take the 'hood out of me." For many fast life strategists, that might turn out to be a death sentence, but in the rap star's case, a fast life-history may have been a professional advantage. Not only did his experiences give his lyrics street credibility—he grew up in a blighted neighborhood in Queens, New York, and sold drugs at the age of 12—but his gambling instinct undoubtedly helped him to put the rap game in a chokehold, allowing him to succeed in an industry where timidity gets you nowhere.

"It is plausible that 50 Cent and others may have

GET RICH OR DIE TRYIN' Life-history theorists point to rap artist 50 Cent as somebody whose live-fast-die-young behavior is a natural response to an upbringing of violence and turmoil.

found ways to boost their own sense of control in order to become less impulsive," Mittal explains. "Another possibility is that 50 Cent's early success created a more financially stable and predictable world for him, which in turn reduced impulsive tendencies." In one of their experiments, Mittal and Griskevicius showed that when subjects recalled being in control of a situation, the difference between people from low and high socioeconomic classes was erased. Given that fast life-history strategies are triggered in uncertain situations, a stable environment can work wonders.

To Belsky, the social message of life-history theory is clear. "We can't expect people who grow up under adversity, who are impoverished, who live in a dangerous and hostile world, who can't walk the streets without fear, to be 'moral upstanding citizens' because we want them to be," he says. "Biology may be saying, take the risk, take advantage of others, hit first and ask questions later. That creates an imperative on our part to say, if we want good citizenry, we need to provide good conditions, so they can learn that the future is predictable, that others care for me, that I can control my destiny."

AT AGE 23, MARVEL felt like a victim and was full of self-pity. But her husband was a terrific cheerleader, and her oldest daughter gave her inspiration. One day something clicked. "I remember sitting in my living room and looking around and going, 'This is not the way I want my story to end,' " she says. "I was looking at my daughter and I wanted to be a good example for her."

On her aunt's bookshelf she found a book called *The Art of Happiness*. "I started reading it, and that was when I started learning that I was in control of my happiness." She read more self-help books and found ways to manage her stress. "I do have stressful days," she says, "but I have really programmed myself with a new train of thinking."

Soon, Marvel decided she wanted to share her newfound wisdom with others, and wrote a newsletter on empowerment. When local businesses declined to stock the newsletter, she almost gave up. That's when her husband suggested she start a website. The site got a great response. Marvel realized there weren't any good hands-on workbooks for her five daughters, so she decided to write one herself. Her effort was welcomed by a small publisher, and today, at age 36, Marvel has written five books for kids and adults, with a sixth to be published this year.

"A lot of times people feel limited, and don't know they can become something, because it was just a certain way for so long," she says. Nobody has told them they're worth anything. "I want to be that voice."

At home in Hersey, Michigan, Marvel gives her daughters the stability and mental tools she never had. Each morning, she sits down with her 4-year-old and asks her a question: "Today's your day. Who's in charge of your day?"

MATTHEW HUTSON is a science writer who's written for *Wired*, *The Atlantic*, and *The New York Times*. He is the author of *The 7 Laws of Magical Thinking*.

MAARTEN DE BOER/GETTY IMAGES

REFERENCES

1. Promislow, D.E.L., & Harvey, P.H. Living fast and dying young: A comparative analysis of life-history variation among mammals. *Journal of Zoology* **220**, 417–437 (1990).

2. Belsky, J. The development of human reproductive strategies: Progress and prospects. *Current Directions in Psychological Science* **21**, 310–316 (2012).

3. James-Todd, T., Tehranifar, P., Rich-Edwards, J., Titievsky, L., & Terry, M.B. The impact of socioeconomic status across early life on age at menarche among a racially diverse population of girls. *Annals of Epidemiology* **20**, 836–842 (2010).

4. Low, B.S., Hazel, A., Parker, N., & Welch, K.B. Influences on women's reproductive lives: Unexpected ecological underpinnings. *Cross-Cultural Research* **42**, 201–219 (2008).

5. Wilson, M. & Daly, M. Life expectancy, economic inequality, homicide, and reproductive timing in Chicago neighbourhoods. *British Medical Journal* **314**, 1271–1274 (1997).

6. Griskevicius, V., Delton, A.W., Robertson, T.E., & Tybur, J.M. Environmental contingency in life history strategies: The influence of mortality and socioeconomic status on reproductive timing. *Journal of Personality and Social Psychology* **100**, 241-254 (2011).

7. Nettle, D. Dying young and living fast: Variation in life history across English neighborhoods. *Behavioral Ecology* **21**, 387–395 (2010).

8. Nettle, D., Coall, D.A., & Dickins, T.E. Early-life conditions and age at first pregnancy in British women. *Proceedings of the Royal Society B* **278**, 1721–1727 (2011).

9. Simpson, J.A., Griskevicius, V., Kuo, S.I., Sung, S., & Collins, W.A. Evolution, stress, and sensitive periods: The influence of unpredictability in early versus late childhood on sex and risky behavior. *Developmental Psychology* **48**, 674–686 (2012).

10. Griskevicius, V., Tybur, J.M., Delton, A.W., & Robertson, T.E. The influence of mortality and socioeconomic status on risk and delayed rewards: A life history theory approach. *Journal of Personality and Social Psychology* **100**, 1015–1026 (2011).

11. Griskevicius, V., *et al*. When the economy falters, do people spend or save? Responses to resource scarcity depend on childhood environments. *Psychological Science* **24**, 197–205 (2013).

12. Mittal, C., & Griskevicius, V. Sense of control under uncertainty depends on people's childhood environment: A life history theory approach. *Journal of Personality and Social Psychology* **107**, 621–637 (2014).


23
19
4
HA HA
LOL

Is Facebook Luring You Into Being Depressed?

Social media encourages us to follow those we envy

BY CHELSEA WALD

IN HIS FREE TIME, Sven Laumer serves as a referee for Bavaria's highest amateur football league. A few years ago, he noticed several footballers had quit Facebook, making it hard to organize events on the platform. He was annoyed, but as a professor who studies information systems, he was also intrigued. Why would the young men want to give up Facebook? Social scientists had been saying the social network was a good thing.

"At the time, the main paradigm in social networking research was that Facebook is a positive place, it's a place of happiness, it's a place where you have fun, you get entertained, you talk to friends, you feel amused, accepted," says Hanna Krasnova, an information systems researcher at the University of Bern in Switzerland. Influential studies had shown that the social capital we earn on social media can be key to our successes, big and small. Our virtual connections were known to help us access jobs information, emotional support, and everyday favors. "Everyone was enthusiastic about social media," Laumer says.

Laumer, an assistant professor at Otto-Friedrich University in Germany, suspected that quitting Facebook was a classic response to stress. He knew other researchers had looked at something called "technostress," which crops up in workplaces due to buggy interfaces or complex processes. But that didn't really fit with Facebook, which is easy to use. Something else seemed to be stressing people out. "We thought there was a new phenomenon on social media in particular," Laumer says.

Through probing interviews, surveys, longitudinal studies, and laboratory experiments, researchers have begun to shift the paradigm, revealing that Facebook, Twitter, Instagram, Snapchat, and their ilk are places not only of fun and success, but of dark, confronting, and primal human emotions—less Magic Kingdom and more creepy fun house. In many ways, researchers say, these

ILLUSTRATION BY JACKIE FERRENTINO

platforms are giant experiments on one of our species' most essential characteristics: our social nature. So it shouldn't be a surprise there are unintended consequences.

"No one constructed something to make people feel bad or good," says Ethan Kross, a social psychologist at the University of Michigan. "But, what we're looking at is, how does it actually play out and impact people in daily life?"

One consequence may be that using Facebook can lead you to feel a little bit sadder—a phenomenon popularly known as "Facebook depression." In their 2013 study of Facebook, Kross and his colleagues text messaged 82 people—mostly undergraduates recruited in Ann Arbor, Michigan—five times a day to ask how much they had used Facebook and how they felt. "What we found was that, the more people reported using Facebook during one moment in time, the more their self-reported mood declined from the beginning of that period to the end," Kross says.

WHY? LAUMER AND HIS colleagues noticed that, for some of the participants, Facebook's News Feed didn't feel entertaining; it loomed like a long list of demands. *Cheer me up. Comfort me. Wish me a happy birthday. Fund my Kickstarter. Like this new profile picture. Read my new feature in* Nautilus. Social networking sites blast users with requests in ways never before possible. Requests don't go out one-to-one; they go out like buckshot, one-to-many. No wonder people get stressed by them. Stress is what arises when people feel that they don't have the resources or ability to cope with some perceived threat—in this case, the threat of what Laumer calls "social overload."

Ironically, social overload is the flip side of what other researchers have found to be one of the most positive aspects of social media: social sharing. Sharing one's problems with others online can reduce stress associated with everything from everyday pressures to life transitions to natural disasters, says medical sociologist Shelia Cotten of Michigan State University, who, in one study, found that Internet use can decrease loneliness in older Americans. "There's a whole lot of social support that gets exchanged that can have very beneficial aspects to your health and well-being and can help to alleviate stress." The problem is, as you're alleviating your stress, you're putting it onto others.

Sociologist Keith Hampton of Rutgers University, who has conducted social media surveys for the Pew Research Center, calls this second-hand stress "the cost of caring." It should be no surprise, he says, that women tend to pay this price more than men, since they carry much of the burden of care for family and friends both online and off. "When you're aware of bad things happening to people you know, not only does it bring stress to your life, but it also allows you to provide them with social support and empathy," he says.

But not all friends are created equal online. On social media, we can keep adding contacts ad infinitum—including people we rarely or never see in real life. "For the first time in modern history, ties are persistent in a way they haven't been before," Hampton says. Laumer and his colleagues found social overload

BAD CONNECTION Communicating with family and friends via text can be dehumanizing. "It doesn't convey the same kind of uniquely human qualities, qualities of thinking and feeling, that your voice does," says behavioral scientist Nicholas Epley.

is more likely to strike people who have more Facebook-only friends.

That makes sense. In the 1990s, anthropologist Robin Dunbar proposed that human beings have the time and bandwidth to sustain 100 to 200 friendships at a time. In a recent study involving 1.7 million users, Dunbar and his colleagues found that Twitter users maintained "stable social relations" with about that same number on average. But if we have about 150 friends we regularly contact and think about on Facebook or Twitter, and they all regularly put out social support requests, then we're already juggling more demands than our ancestors ever would have. Where do we fit in our real friends? Many overwhelmed users consider just quitting wholesale. "Social overload has a strong effect on exhaustion," Laumer says.

On top of that, studies have confirmed what's plain to every user: Friends tend to post the things that make them look good. In one *Portlandia* skit, Fred Armisen's character takes his new flame on a weekend trip to Italy. They sleep through the whole thing in a hotel and end up miserable. Earlier they had posted a bunch of photos of themselves smiling and looking happy. When he gets home and watches his friend (Carrie Brownstein) scroll through the photos, congratulating him on his trip, he tells her, "Everyone on the Internet, they're not having as great a time as you think they are." She replies, "I guess people are just cropping out all the sadness."

Truth be told, even if people aren't cropping out the sadness, and instead posting dull or disparaging things about their daily lives, we're unlikely to pay attention. Humans automatically linger on people of high status—especially people who look attractive or rich (cue the Kardashians). Charlotte Blease, a cognitive scientist who studies depression, sees social status at the root of our social media malaise. In a 2015 paper called "Too Many 'Friends,' Too Few 'Likes'? Evolutionary Psychology and 'Facebook Depression,' " Blease, a researcher at the University of Leeds and Harvard Medical School, turns to our ancestral environments for an explanation.

> Facebook, Twitter, Instagram, and their ilk are places not only of fun and acceptance, but of dark and primal human emotions—less Magic Kingdom and more creepy fun house.

One evolutionary explanation for depression, Blease tells us, is known as the "social competition theory." It holds that depression is an adaptive suite of behaviors—withdrawal, slumped posture, low self-esteem—that enabled our ancestors to retreat from antagonistic social encounters and "signal inaction to dominant others without incurring physical damage." In other words, get depressed, stay alive. "It acts as a sort of deescalating strategy, an involuntary response where you're almost just putting your hands in the air," Blease says.

This adaptive behavior—assuming deference and low social status—has stayed with us. In modern environments it can be triggered when we sense we're being outcompeted by those of high social status or prestige. "We're drawn to those kind of individuals, which then may perpetuate the feeling of, 'I'm a loser compared to these people,' " Blease says.

Of course, social comparison could also turn us an ugly shade of green. Evolutionarily speaking, envy, like mild depression, is probably adaptive—it motivates us to learn from others and set higher goals. But envy is also painful, which makes it hard to study, says Krasnova. "It is a very tricky feeling, so we don't want to admit envy, usually—not to anybody that we feel envious of, and not even to ourselves," she says. "Sometimes the feeling could get so suppressed we don't know what we're feeling and why we're feeling so angry or so sad, or so irritated or stressed."

GETTY IMAGES

When Krasnova and her colleagues asked 357 subjects—mostly from Germany, where she was working—how they felt after using Facebook most recently, only 1.2 percent of them said envious. So she rephrased the question: "Many users report feeling frustrated and exhausted after using Facebook. What do you think causes these feelings?" In this case, the most popular response (29.6 percent) was envy. Not only is envy a common feeling for people using Facebook; it's "rampant," she says.

Examples are omnipresent. Parties we wished we were invited to. Awards our colleagues have won. In Paula Hawkins' psychological thriller *The Girl on the Train*, protagonist Rachel Watson is still smarting from her recent divorce when she goes on Facebook and sees her ex-husband's baby announcement. She's devastated.

Krasnova notes that one way people find temporary relief for the pain of envy is by bolstering their own self-presentation. That threatens to generate an "envy spiral" on social networks, she warns. "Users are exposed to positive content, they post even more positive things, then their recipients post even more positive things. And so on. And then this world of Facebook becomes more and more detached from reality."

Instead of bringing us closer to our friends, this detached world can insert distance. In her book, *Reclaiming Conversation*, psychologist Sherry Turkle of the Massachusetts Institute of Technology talks about the tension between "our desire to express an authentic self and the pressure to show our best selves online." But studies show we don't actually present our best, most sympathetic selves when we write, although we think we do. Behavioral scientist Nicholas Epley of the University of Chicago had business-school students do an "elevator pitch" in several formats. While the students felt that they presented themselves better in a written pitch, the evaluators judged them more favorably in a spoken pitch.

This also applies to Facebook: A recent study that echoes Epley's results showed that our friends think we are better in person than in our profiles. "At the most extreme level, our data suggest that text is somewhat dehumanizing—that is, it doesn't convey the same kind of uniquely human qualities, qualities of thinking and feeling, that your voice does," Epley says.

GETTY IMAGES

STATUS UPDATE Mundane life can barely compete with social media for grabbing our attention. Especially when social media offers an endless stream of inherently magnetic people of high status.

The Facebook of the envy spiral can even turn us against each other. "Our research clearly shows that in many cases [self-promotional] information is seen negatively and interpreted very judgmentally," Krasnova says. Some researchers warn we are growing more narcissistic—and correspondingly less empathetic—as a result of the time we spend managing our image online. "There's little data that suggests that narcissism is a great thing," Epley says. "It's pretty good in the short run; not so good for you in the long run in terms of your relationships."

Perhaps the most intriguing finding in the recent literature, however, is that people do themselves the most harm when they're not posting. For a study published this year, Kross and his colleagues, including first author Philippe Verduyn, a psychologist from Maastricht University in the Netherlands, invited 84 University of Michigan undergraduates to a lab, where they instructed half of the subjects to use Facebook actively and half to use it passively. Active use is "posting status updates, chatting, responding to a comment," Verduyn explains, while passive use is "scrolling through news feeds, looking at pictures, and looking at status

updates." A few hours after the session, the active users felt the same, yet the passive users felt a drop in mood. "When you're just passively using Facebook, you develop more feelings of envy, which in turn lead people to feel worse over time," Kross says.

On the one hand, the finding is a good thing. It means that there's a way to escape the Facebook blues without losing access to social media's positive benefits: Be more active. On the other hand, very few of us take advantage of that loophole.

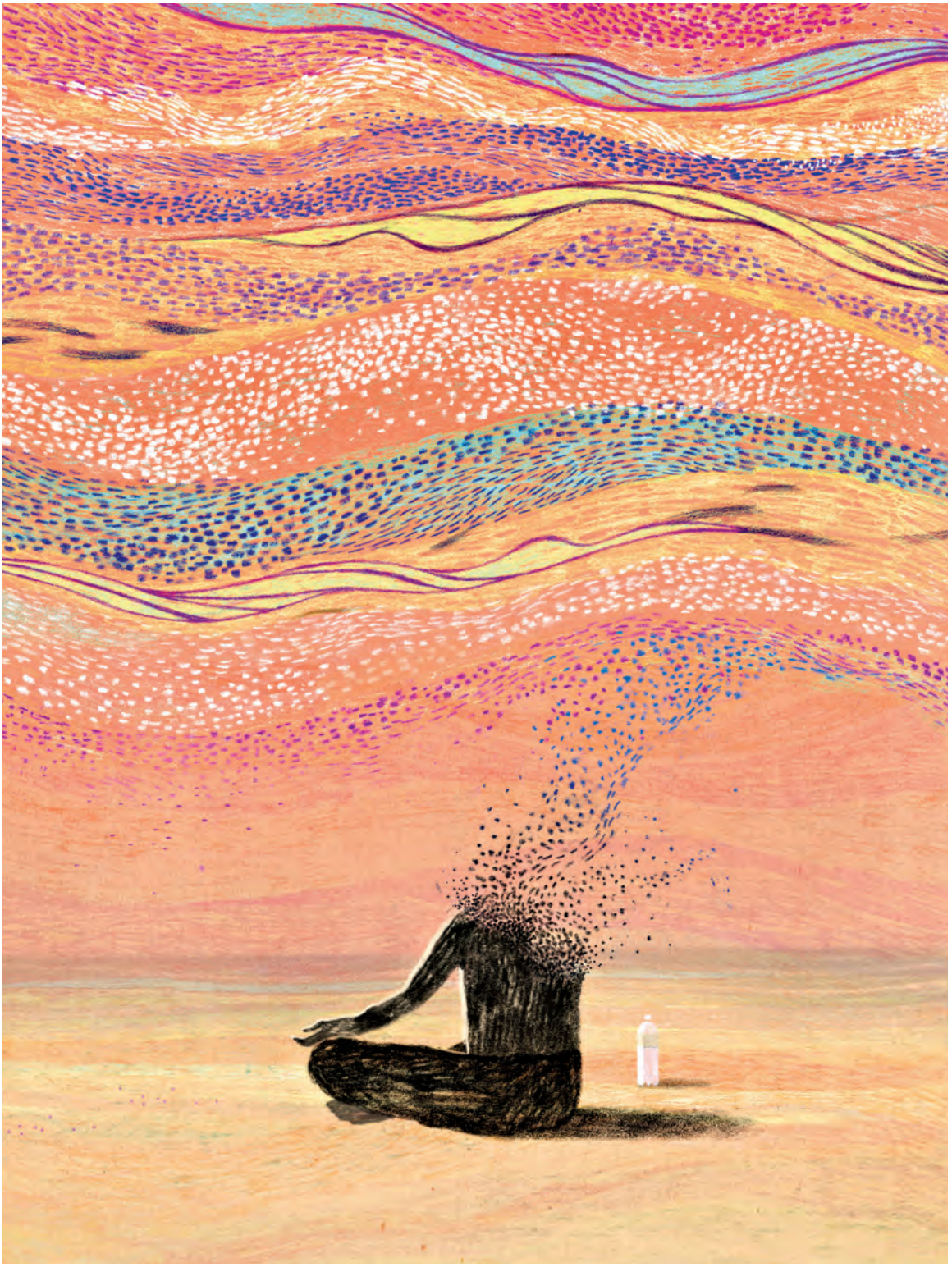
Verduyn and his colleagues found that subjects were about 50 percent more likely to use Facebook passively than actively. And that's not limited to millennials. Market research firm GlobalWebIndex reports that only 52 percent of Facebook users were active users in 2014, down from 70 percent in 2012. It's not clear why people are so passive. Maybe it's just a lot less work to browse than post, but other lines of research on Facebook's dark sides indicate that people worry about unintentionally insulting someone, putting their relationships or jobs at risk, or just looking like a loser wasting time online. The specter of public shaming looms over every post. Whatever the reason, Kross says, "most of the time that people are using [social media], they're using it in a way that is potentially harmful"—that is, passively.

Fortunately, social-networking research is one scientific field where findings can be translated into practice at light speed. Studies in the pipeline will likely reveal both beneficial and harmful behaviors that go beyond the passive and active dichotomy, as well as elucidate outcomes for different groups of users—people from different cultures, different age groups, and with different psychological predispositions. Scientists still lack a comprehensive picture of how social media technologies work on human nature, but "the hope is, by identifying the mechanisms that push people to feel worse, we can begin to come up with a formula for an optimal way to interact with the technology," Kross says.

Some of Facebook's features can already help put the research to use. In 2011 the site introduced "friend lists," which we can use to restrict our social support requests to the people who are most likely to care, sparing the rest of our contacts from social overload. In 2013, we got "unfollow," which can help us reduce overload and envy for ourselves. The 2014 "nearby friends" and this year's "video calling" features could increase the frequency of face-to-face interactions, which in Kross's studies consistently lift mood. Soon, the anticipated "reactions" buttons—alternatives to the "like" button, including "love," "yay," and "sad"—may provide more options for active behaviors.

The most important feature we can implement, however, may be one intrinsic to the user not the technology: empathy. An extraordinary achievement of human civilization is that, every day, people suppress the instinct to outcompete others in order to build meaningful and rewarding relationships. Yet online, with those seemingly harmless #nofilter travel pics, flawless #iwokeupthisway selfies, and relentlessly positive #humblebrags, we inadvertently make our friends feel like losers and contribute to a swirling vortex of envy, in which we ourselves risk drowning. The growing body of research on social media's dark sides, Krasnova says, gives us the chance to build a new social media etiquette, one that will reattach the world of Facebook to reality and pay off in true friendships, full of both the costs and the benefits of caring. We should grab that opportunity—not because it will make our stress go away, but because some stress is the kind worth having.

CHELSEA WALD is a science writer in Vienna, Austria. She recently wrote for *Nautilus* about why almost every language has a word for red and why our brains hate slowpokes.



"AN ATHEIST'S GUIDE TO SPIRITUALITY"
ILLUSTRATION BY **DADU SHIN**

Join the Revolution in engineering education!

Olin College
of Engineering

olin.edu

The Academy fosters vital communities and spurs scientific advances by working with investigators, researchers, policymakers, industry leaders and funders to exchange ideas and forge partnerships across a wide range of scientific disciplines.

The Academy hosts more than 100+ conferences, symposia and discussion groups annually.

FEB 22 2016
Regenerative Medicine
www.nyas.org/RegMed

MAR 22 2016
Neuronal Connectivity in Brain Function and Disease
www.nyas.org/NeuroNet

MAR 30 – TO – APR 1 2016
Sohn Conference: Pediatric Cancer in a Post-Genomic World
www.nyas.org/Sohn2016

APR 13-14 2016
Disease Drivers of Aging Summit
www.nyas.org/Geroscience2016

MAY 18-20 2016
The Addicted Brain and New Treatment Frontiers
www.nyas.org/Addiction2016

For a full list of Academy programing, visit us at www.nyas.org

BECOME A MEMBER OF THE NEW YORK ACADEMY OF SCIENCES
Join our Membership community to receive discounted or free admission to Academy events, plus free digital access to our publications, eBriefings and other resources. To learn more, visit us at **www.nyas.org/join**

facebook.com/NewYorkAcademyofSciences @NYASciences The New York Academy of Sciences


Just Think.
We promote science, education, and the literary arts to expand public understanding of fundamental questions of scientific inquiry and their connection to culture. Through the creation of print, electronic, and visual media of the highest quality and depth, NautilusThink seeks to connect science to our everyday lives and explore the frontiers of scientific, mathematical, and philosophical inquiry and the human spirit.
Learn more at nautilusthink.org
NAUTILUS think

Issue Index

Visit **subscribe.nautil.us** for single issues, subscriptions, and more.

NUMBER 01 | FALL 2013

01 **HUMAN UNIQUENESS**
What makes you so special

02 **UNCERTAINTY**
Inside our indeterminate world

03 **IN TRANSIT**
The elements of motion

NUMBER 02 | WINTER 2014

04 **THE UNLIKELY**
Chasing the odds

05 **FAME**
The evolution of celerity

06 **SECRET CODES**
Stories hidden and revealed

NUMBER 03 | SPRING 2014

07 **WASTE**
Endings and beginnings

08 **FAME**
The places that matter

09 **TIME**
Mysteries of the moment

NUMBER 04 | SUMMER 2014

10 **MERGERS & ACQUISITIONS**
How nature comes together

11 **LIGHT**
Fields of vision

12 **FEEDBACK**
What goes around comes around

NUMBER 05 | FALL 2014

13 **SYMMETRY**
Structure takes wing

14 **MUTATION**
Engines of change

15 **TURBULENCE**
Out of order

NUMBER 06 | WINTER 2015

16 **NOTHINGNESS**
Peering into the void

17 **BIG BANGS**
Suddenly, a new world

18 **GENIUS**
Off the pedestal

NUMBER 07 | MAR/APR 2015

NUMBER 08 | MAY/JUNE 2015

NUMBER 09 | JULY/AUG 2015

NUMBER 10 | SEP/OCT 2015

NUMBER 11 | NOV/DEC 2015

"Perhaps by examining our past, we can better prepare for the future."

ELI KINTISCH
"The Science Hidden In Your Town Name" p. 62

SUBSCRIPTIONS
Nautilus is distributed by The MIT Press. Subscription and address changes should be addressed to MIT Press Journals, One Rogers St., Cambridge MA 02142; phone 617-253-2889, US/Canada 800-207-8354; fax 617-577-1545; email: journals-cs@mit.edu.
Visit shop.nautil.us for more information and to subscribe.

NUMBER 11
November/December 2015

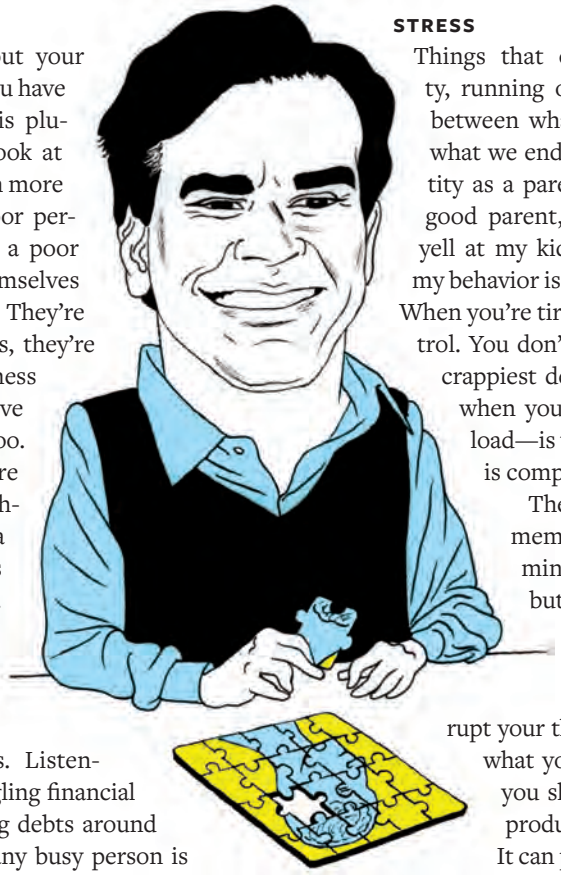
Nautilus (ISSN 2372-1758) is published bimonthly: January/February, March/April, May/June, July/August, September/October, November/December.
415 Madison Ave, 13th floor,
New York, NY 10017

POSTMASTER
Send address changes to:
MIT Press, One Rogers St.
Cambridge MA 02142

Sendhil Mullainathan

Behavioral economist, MacArthur Fellow, and co-author of Scarcity *reflects on the themes in* Nautilus.

INTERVIEW BY YVONNE BANG



IDENTITY

When you introspect about your own identity, you realize you have many identities. Identity is plural and shifting. But we look at others and rarely give them more than one. If you saw a poor person on the street, they're a poor person to you. But to themselves they're not a poor person. They're 'Sixers fans, they're parents, they're music lovers. All the richness of self-labels that you give yourself, that person has too. Even among those who are trying to be sensitive to others, there is almost always a destruction of the richness of other people's identities.

In India, I've had conversations with low-income people about how they think about their finances, their lives. Listening to them talk about juggling financial responsibilities and moving debts around was eerily familiar. What any busy person is doing—navigating time burdens, making ends meet—is exactly what low-income individuals are doing. To see one's own cognitive process intimately reflected in the cognitive process of someone who's financially poor, doing the same kind of juggling that I do, ultimately shaped my own life and studies.

STRESS

Things that overload our minds—poverty, running out of time—create a wedge between what we might want to do and what we end up doing. I can have an identity as a parent, and I can intend to be a good parent, but in a heated moment, I yell at my kids. I then feel guilty because my behavior is inconsistent with my identity. When you're tired, you have the least self control. You don't think clearly. You make the crappiest decisions. Same thing happens when your bandwidth—your cognitive load—is taxed. Pretty much everything is compromised.

The Zeigarnik effect, a feature of memory, is really interesting. Your mind is focused on one thing, but there is another part of your brain that is inadvertently doing a bunch of work. This part of the mind will interrupt your thoughts and say, "I don't care what you're doing, this is something you should think about." It's super productive, yet also super intrusive. It can prevent you from enjoying the moment. You might take four days off of work, but you're not able to immerse in that time because you're thinking, "I have so much work to do!" But you can change. It's as simple as saying, "I accept I will not get this done." It's painful to accept, but it can transform you.

ILLUSTRATION BY ANDY FRIEDMAN