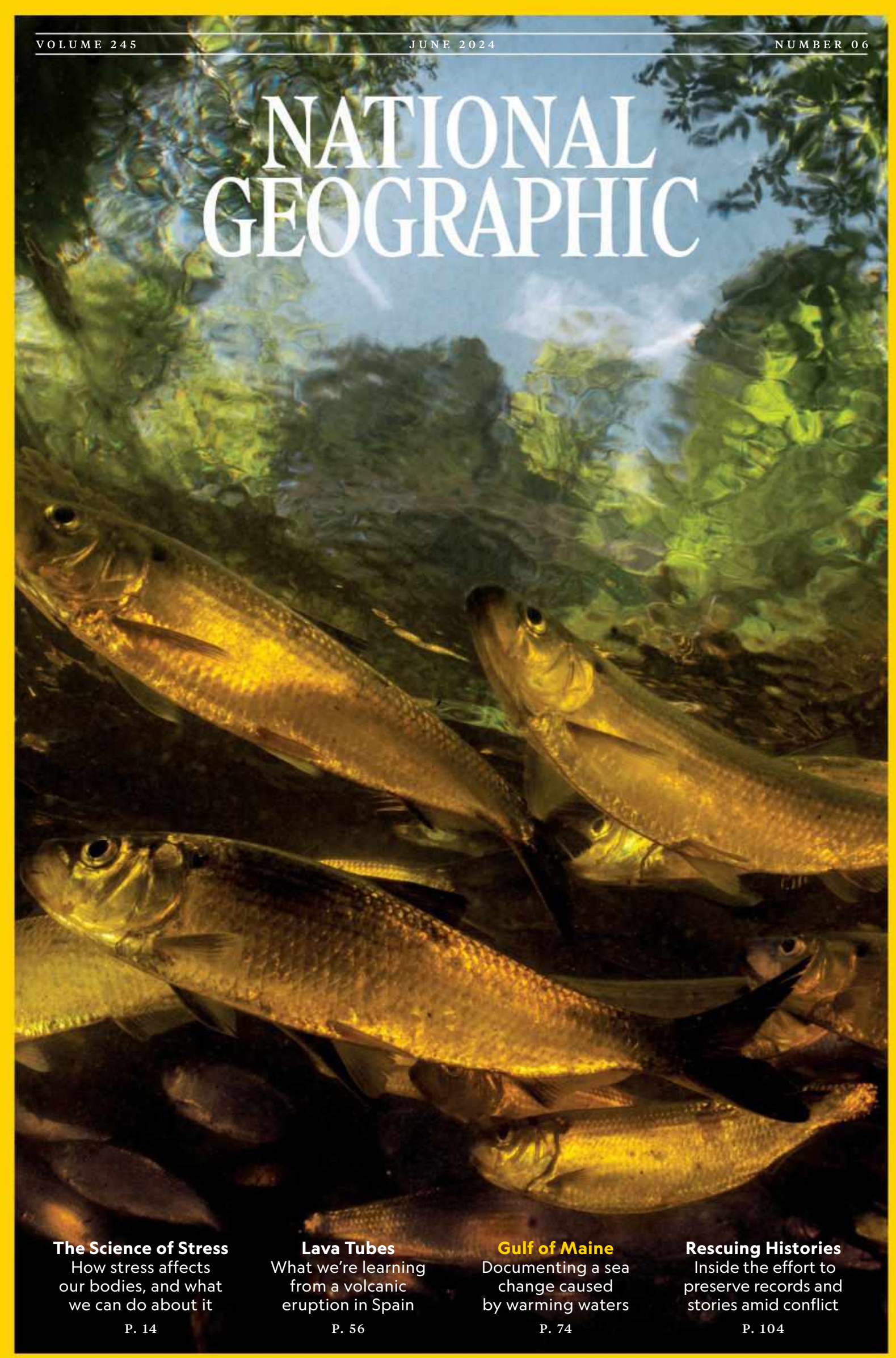
VOLUME 245 JUNE 2024 NUMBER 06

NATIONAL GEOGRAPHIC



The Science of Stress
How stress affects our bodies, and what we can do about it
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Inside the effort to preserve records and stories amid conflict
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ROLEX NATIONAL GEOGRAPHIC EXPLORER OF THE YEAR 2024

Protecting river dolphins. It takes so much more than just tracking them in the wild. It requires determination, patience and international diplomacy. Colombian marine biologist Fernando Trujillo has brokered groundbreaking regional and international agreements for their protection. For his passionate work, he has won the prestigious Rolex National Geographic Explorer of the Year Award. Presented by Rolex, it recognizes a member of the National Geographic Explorer community who shines a light on important challenges facing our planet. **Congratulations, Fernando Trujillo.**

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EXPLORER 40

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FROM *the* EDITOR

FOR ABOUT AS long as I can remember, "I'm so stressed" has been a common response to the question "How are you?" Back in my college days, we used to joke that, for some students, this answer was a kind of boast, implying that they were overloaded with very important things to do, which in turn made them important.

In more recent years I've watched that morph into "hustle culture"—the notion that working as much and as hard as you can is the way to get ahead. This approach, of course, is practically synonymous with stress. And I think that's one reason the hustle is now challenged as much as (or more than) it is celebrated.

It's increasingly clear chronic stress isn't good for our physical and mental well-being. This month's lead story looks at what science has been learning about why it's bad, and just how bad it is. Persistent stress can have devastating effects on development, health, and longevity—which makes taking that deep breath even more crucial than we thought.

Other great stories this month include preserving the history of places torn by conflict, advances in volcanology, and chronicling change in the Gulf of Maine.

I hope you enjoy the issue.

PHOTO: MARK THIESSEN

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FEATURES

ON THE COVER

SUBSCRIBER EDITION Alewives, shown migrating through waters that empty into the Gulf of Maine, have made a comeback.
Photograph by BRIAN SKERRY

NEWSSTAND EDITION Long-term stress can trigger a host of health problems, including brain aging and heart disease.
Art by VIOLET FRANCES

STRONG CHARACTER, TO THE LAST DROP.

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ANIMALS

"When I photograph animals in the lab, I sometimes have to sit for hours. They are CONSTANTLY MOVING, hiding their little heads or stretching over the edge of the bowl. But sometimes they twist themselves into *surprisingly beautiful* knots."

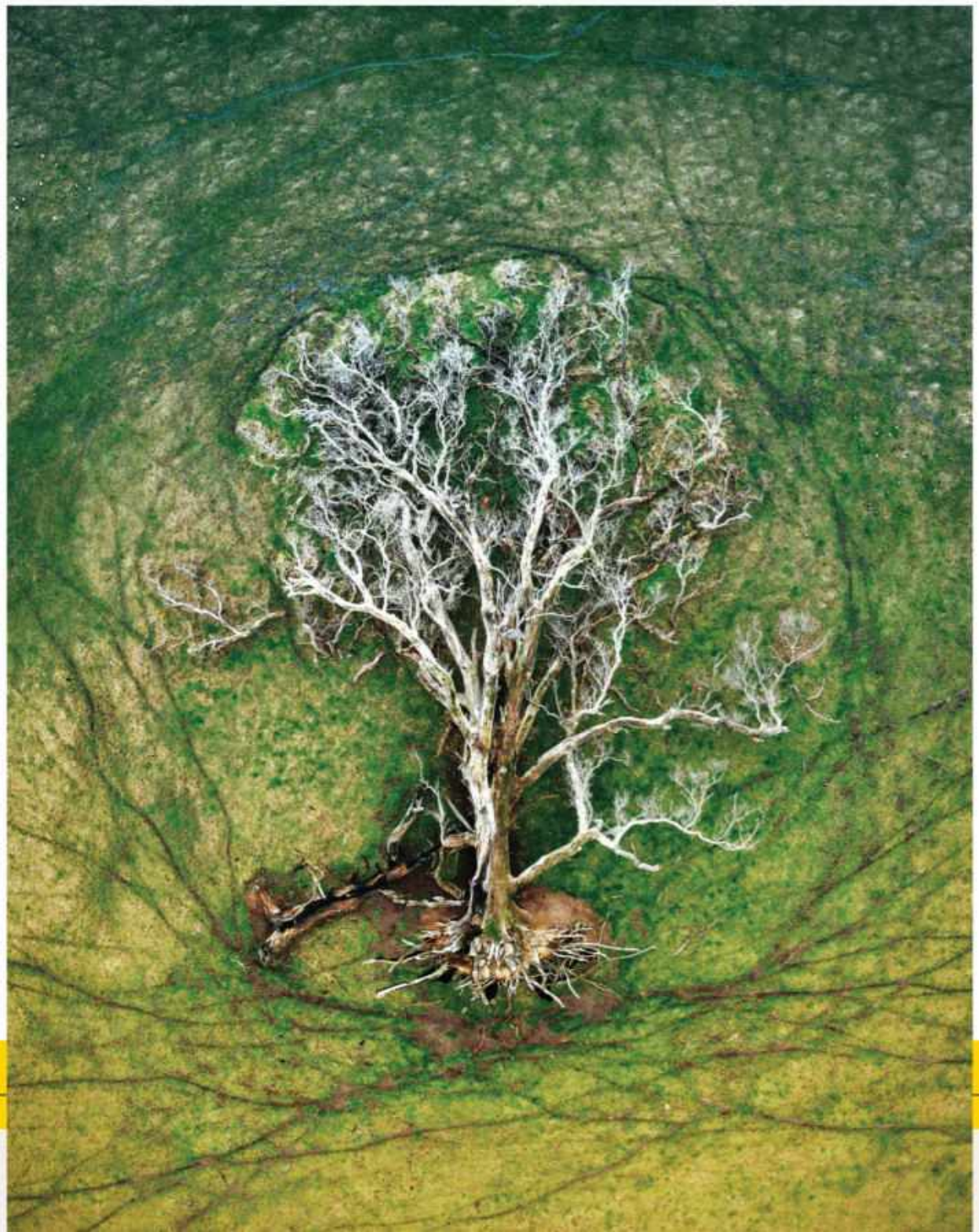
ALEXANDER SEMENOV, *Photographer and National Geographic Explorer*

At a research station in a remote region of Russia, Semenov documented this *Alitta virens,* a worm that lives under rocks or mud on the ocean floor. The image is part of a project revealing the hidden world of Arctic seas, supported by the National Geographic Society.

"From this *vantage point,* you can see small pools of water that have collected in the sheep tracks above the tree, reflecting the blue of the sky. The overall effect is one of RENEWAL AND CONNECTION."

JULIE KENNY, *Photographer*

The aerial view of a fallen tree in the Aboriginal region of Minang Boodja in Western Australia's South West reminded Kenny of the tree of life, a powerful symbol in many cultures around the world.



ADVENTURE

"Darby's ponytail flying behind her lends the image a little *extra vertigo*. Her descent was one of THE BEST out of the three kayakers I worked with that day."

MICHAEL CLARK,
Photographer

Top whitewater kayaker Darby McAdams braves the Lower Mesa Falls on the Henry's Fork of the Snake River in Idaho. To show her full trajectory, Clark created this composite of nine images.

Return to the Wild: Connecting with Heritage in Canada

Above: Matricia Bauer of the Warrior Women collective in Alberta recently launched a herbology business founded on harvesting medicinal plants and crafting culinary bitters. **Below:** Matricia, together with Mackenzie Brown, drum with visitors to Jasper, Alberta. Together, these two warrior women take every opportunity to share their culture— in fact, Matricia's motto is to "indigenize the world, one drum beat at a time." **Words by:** Jon Heggie

With timeless precision, the chisel blade carves a delicate slither of curling wood, each cut helping to transform nature into art. "Here, in our area we carved house posts," explains Xwalacktun, an artist of the Squamish Nation. "They were for teaching and passing on knowledge to others who aren't here yet." It's an important part of the rich Indigenous heritage that Sir Ranulph Fiennes and Joseph Fiennes experience as they travel across Canada in the documentary Return to the Wild.

"One of the most beautiful aspects of Indigenous culture is storytelling," enthuses Mackenzie Brown, a Cree woman, drummer, singer, and storyteller living in the enigmatic shadow of the Canadian Rockies. "We have beautiful creation stories, stories about the constellations, and stories about our spectacular nature." These form an essential Oral Tradition, passing on histories, legends, and family remembrances as powerfully as the written word. Often with no real beginning, middle or end, Cree stories are so layered with meanings that each listener interprets them their own way, making them a deeply personal experience.

The art of memorizing, retelling, and embellishing these stories is passed down through the generations, but Mackenzie does more than keep the traditions and tales alive: She actively shares them with visitors through cultural experiences. For her, it's important to widen people's understanding of Indigenous culture, "learning about Indigenous storytelling, truth and reconciliation, our connection to the plants, the flora, and fauna."

Many Indigenous stories reflect the strong bond between people and nature, something especially close to the heart of Cree Knowledge Keeper, Matricia Bauer. "I look at the flora through an Indigenous lens," she explains, "teaching people about what we have in our forests and how we have relied on it for thousands of years for medicine." Across Canada, more than 400 plant species are used in traditional medicines, their harvesting, preparation, and application a revered specialism.

Whether it's chewing yarrow leaves to treat a cough, or an infusion of wild ginger to cure a headache, the efficacy of a plant is often attributed to its particular organic compounds. But potency varies from plant to plant, depending on its genetics, lifecycle stage, location, and even recent weather, making Matricia's Traditional Knowledge invaluable. "Practicing these things brings me a lot of joy," she says. "And living here in Jasper, it's such a tourist place that I'm able to share my culture with other people."

It's an experience Xwalacktun can relate to. "As an artist I pay attention to my surroundings, land, air, water," he muses. "I like sharing with the public what our artwork is as Coast Salish people." While 5,000-year-old petroglyphs constitute Canada's oldest surviving art, the magnificently carved poles of the Pacific Northwest are an artform dating back at least 2,500 years. These extend beyond totem poles to include memorial posts and the house posts carved by Xwalacktun.

House posts serve a structural function, but also traditionally included representations meaningful to a household. Xwalacktun's current carving is topped by a thunderbird to honor a former chief, and includes four eagle feathers representing the seasons, a bear signifying family strength, and the Salish eye symbolizes looking into the spirit world. Beyond aesthetics, the carvings have deep cultural meaning. "It is our written language," explains Xwalacktun.

Experiences such as these are indicative of the strong connection that the Indigenous Peoples in Canada have with their heritage. And storytellers, Knowledge Keepers, and artists like Mackenzie, Matricia, and Xwalacktun do more than preserve their customs: By actively sharing them they are fostering a wider appreciation of the rich culture of Canada—the ancient traditions at the heart of the country.

Top: Xwalacktung's studio at Squamish Lil'wat Cultural Centre is filled is filled with mementos from his 53 years of carving wood. **Bottom:** Canada's breath-taking natural wilderness is an inspiration for new and returning visitors alike, as well as a place of deep natural and spiritual connection for its Indigenous Peoples.

Fernando Trujillo, shown in the Amazon River, has made conservation of river dolphins—depicted on his kerchief—his life's work.

COLOMBIAN MARINE biologist Fernando Trujillo has been named the 2024 Rolex National Geographic Explorer of the Year. This award is given by the National Geographic Society to an intrepid Explorer who highlights vital issues facing our planet and inspires others to act. "His work in South America enhances protections for endangered wildlife and supports sustainable practices for the betterment of local communities," says Jill Tiefenthaler, CEO of the Society.

Trujillo has dedicated his life to saving the Amazon's river dolphins, and he was given another name by the Tikuna Indigenous people who live along the Amazon River in Colombia: *omacha*. At first he didn't understand why. But after Trujillo figured out the reason, he realized the moniker was so apt he adopted it for his conservation organization. Omacha, in Tikuna culture, is the name of a dolphin that can transform into a man.

"For me, it's a kind of magic to find dolphins in the forest," he says. But these freshwater mammals are threatened by fisheries, mining, and deforestation. Trujillo, who's part of the National Geographic and Rolex Perpetual Planet Amazon Expedition—a two-year scientific exploration of the river basin—collaborates with residents to develop dolphin-friendly practices that won't interfere with subsistence fishing. He's also helped create policies such as the 2023 Global Declaration for River Dolphins, which aims to preserve cetaceans in rivers around the globe. **—RACHEL HARTIGAN**

Look for more information about our Amazon expedition in coming months, including a special issue this fall. We'll also launch an immersive digital experience at *natgeo.com* in September, and a documentary will premiere October 10 on National Geographic and stream on Disney+ and Hulu.

PHOTO: JORGE PANCHOAGA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NATIONAL GEOGRAPHIC EXPLORER

This contributor has received funding from the National Geographic Society, which is committed to illuminating and protecting the wonder of our world.

Brian Skerry, p.74
An Explorer since 2014, Skerry first dived in the Gulf of Maine more than 40 years ago. In this issue, he shares how the area has become a harbinger of climate change. Skerry has contributed more than 30 features to the magazine. His last story was "Secrets of the Whales" in 2021, which accompanied the Emmy Award–winning documentary series that he produced. It's available to stream on Disney+.

Nina Strochlic, p.104
One of Strochlic's most recent features for *National Geographic* took readers on a journey along the Appian Way. To research this month's story on at-risk archives, she was awarded a grant from the Alicia Patterson Foundation, which funds independent investigative reporting projects.

Yudhijit Bhattacharjee, p.14
He's written more than a dozen *National Geographic* features, many of which delve into the science of human experience, including our cover story on stress. A contributing writer at the *New York Times Magazine* and author of *The Spy Who Couldn't Spell,* he manages stress by singing.

Arturo Rodríguez, p.56
"My hometown is nestled within a volcanic crater," says this La Palma native. He has spent his career abroad, documenting elections in Haiti, refugees in Africa, and war in Myanmar, but returned to capture the recent eruption.

Diana Markosian, p.104
With her camera, the Moscow-born photographer has explored the worldwide fascination with the Virgin Mary, searched for her estranged father in post-Soviet Armenia, and, for this issue, documented efforts to preserve history.

PHOTOS (CLOCKWISE FROM TOP): STEVE DE NEEF; JENNIFER DIMASCIO; DIANA MARKOSIAN; ARTURO RODRÍGUEZ; REBECCA HALE

‘OVER THE PAST FEW YEARS, PSYCHOLOGICAL STRESS ACROSS THE GLOBE DUE TO A INCLUDING THE LONG-LASTING CIVIL UNREST, ESCALATION ACROSS THE GLOBE, AND TRIGGERED MAJOR ENVIR PERTURBATIONS. THE CONSEQ SCALE INCREASE IN STRESS TO BE APPRECIATED, BUT WE ARE FACING A SECOND ANXIETY DISORDERS, INCLU ANXIETY, AND POSTTRAUMATIC

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DA AKIL & ERIC J. NESTLER

tress: Vulnerability, resilience, and major depression." *PNAS*, November 2023

TAKE THIS STRESS LEVEL QUIZ

The Perceived Stress Scale measures the degree to which situations in one's life are regarded as stressful. While two people could have the same experiences, their perceptions of how that stress affects them can vary greatly. Developed by psychologists in 1983, the questionnaire remains one of the most widely used stress perception assessment instruments in the world. Take our adapted quiz below to see how you measure up.

1.

FILL OUT THIS QUESTIONNAIRE

For each question, choose from the listed responses and circle your score.

In the last month, how often have you...	0 Never	1 Almost Never	2 Sometimes	3 Fairly Often	4 Very Often
...been upset because of something that happened unexpectedly?	0	1	2	3	4
...felt that you were unable to control the important things in your life?	0	1	2	3	4
...found that you could not cope with all the things you had to do?	0	1	2	3	4
...been angered because of things that were outside of your control?	0	1	2	3	4
...felt that difficulties were piling up so high you couldn't overcome them?	0	1	2	3	4
...felt nervous and stressed?	0	1	2	3	4

	4 Never	3 Almost Never	2 Sometimes	1 Fairly Often	0 Very Often
...felt confident about your ability to handle your personal problems?	4	3	2	1	0
...been able to control irritations in your life?	4	3	2	1	0
...felt that you were on top of things?	4	3	2	1	0
...felt that things were going your way?	4	3	2	1	0

2.

CALCULATE YOUR PERCEIVED STRESS LEVEL

Starting from the left, use your scores from the 10 questions to fill in the dots (example: three filled dots for a score of 3). The total number of filled-in dots shows your stress level.

Your stress level is considered to be in the low range and is generally perceived to be manageable.

If you spend months in this elevated state—the most common level for adults—you might benefit from stress-reduction techniques.

High stress is expected at times, but continuously experiencing these levels without relief can lead to adverse health consequences.

THE SCORES ON THE SELF-ASSESSMENT DO NOT REFLECT ANY PARTICULAR DIAGNOSIS OR COURSE OF TREATMENT. THEY ARE MEANT AS A TOOL TO HELP ASSESS YOUR LEVEL OF STRESS.

GRAPHIC: ALBERTO LUCAS LÓPEZ, NGM STAFF; KELSEY NOWAKOWSKI. SOURCES: SHELDON COHEN AND OTHERS, *JOURNAL OF HEALTH AND SOCIAL BEHAVIOR*, DECEMBER 1983; WENDY BERRY MENDES, YALE UNIVERSITY

THE NEW SCIENCE OF STRESS

WORDS BY
YUDHIJIT BHATTACHARJEE
PHOTOGRAPHS BY
BRIAN FINKE

The defense mechanism affects our health at every age—and researchers are striving to understand precisely how.

MORE THAN a half centur ago, a long-term study—on of the first sizable studie of its kind—led to a surpri ing discovery. In 1967, researchers in th United Kingdom began tracking the healt of some 17,500 British civil servants ag 40 to 64 in the Whitehall area of Londo The researchers found that employees wh ranked low in the hierarchy, such as offic support staff, died earlier and at a high rate than senior civil servants who occupie the upper echelons of society. Inexplicably, th lower-ranked employees suffered a greate incidence of coronary heart disease.

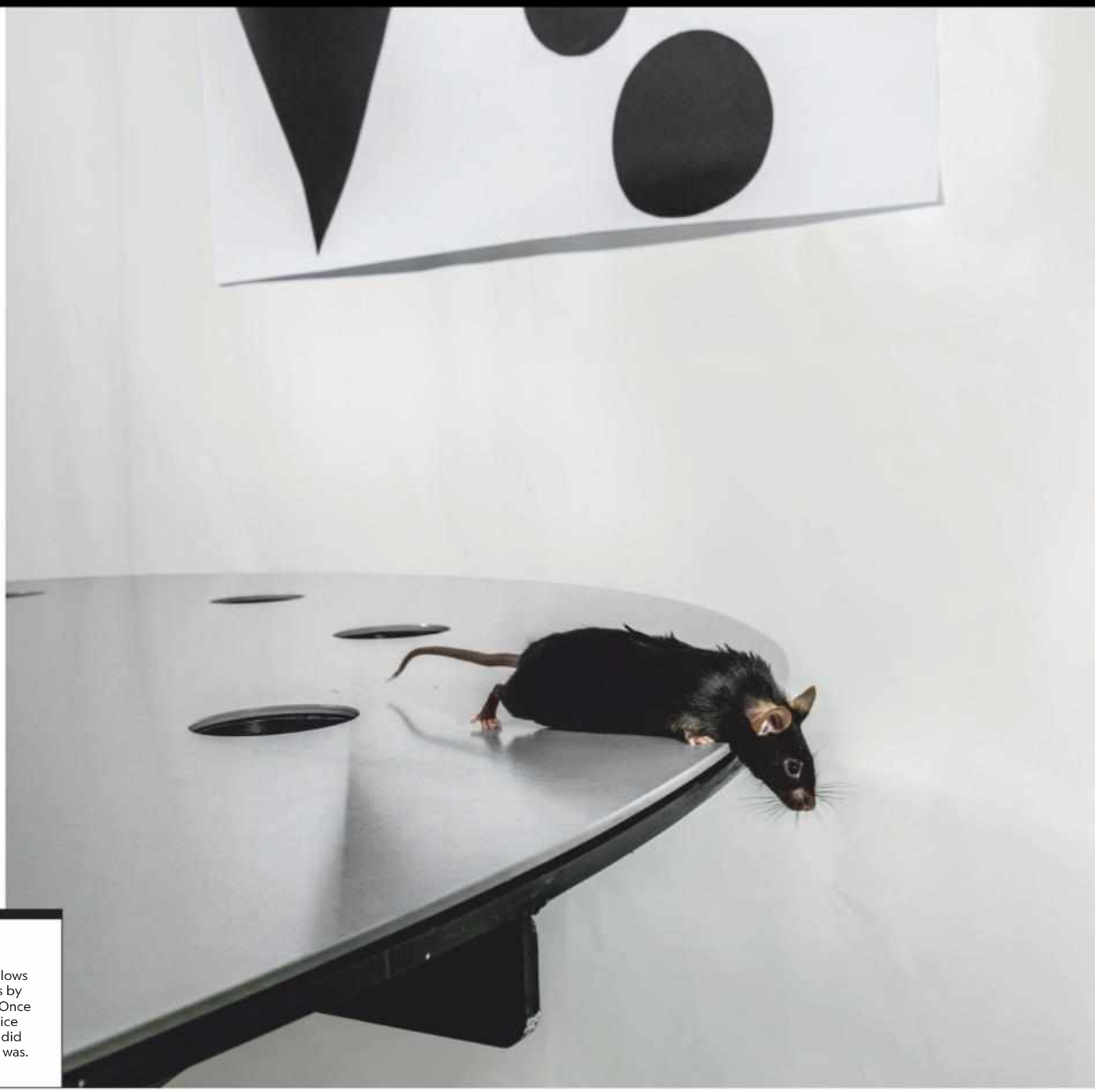
In a follow-up study of 10,300 civil servan ages 35 to 55, researchers identified a possib explanation for this status-related disparit The lower-ranked ones tended to have le influence over decision-making at work. A a result, many felt stressed, and that seeme to take a toll on their health.

Over the five decades since, scientists an medical researchers have established beyon doubt that persistent stress can poison ou overall health. In addition to increasing th risk of cardiovascular disease, stress has bee shown to play a role in obesity and diabete Scientists have also learned that stress has th capacity to weaken the immune system, lea ing us more vulnerable to infectious disease

We all experience stress differently and widely varying degrees. The basic concep of stress as a demand for change imposed b

MEMORY LOSS

In an Amsterdam lab, a mouse searches for t it to escape a maze. Researchers stressed m limiting nesting material, to see the effects grown, the mice were tested in the maze. In with easier infancies, the mice reared by str poorly, taking longer to remember where th



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*Believe
in yourself *

various challenges in our normal lives and environment was first proposed by endocrinologist and stress-research pioneer Hans Selye. Starting with his landmark 1936 study, Selye found that different kinds of very unpleasant stimuli—loud noises, intense light, or extreme temperatures—compelled laboratory animals to do everything possible to try to adapt. In modern society, perceived stressors may range from mundane, day-to-day hassles such as being stuck in traffic to extreme, life-changing events such as divorce or the death of a loved one. The result is "feeling like you don't have the necessary resources to meet that demand for change," says University of Chicago psychologist and neurologist Greg J. Norman, a leading researcher on stress.

When we feel stressed, our body releases adrenaline, which makes our pulse race, breath quicken, muscles contract, and blood pressure spike. This reaction is accompanied by a surge in cortisol, a hormone that contributes to the feeling of being in fight-or-flight mode. The alarm one might feel when caught unprepared for an impromptu presentation is an example of acute stress, a defense response that is dramatic psychologically and physiologically but that you can recover from swiftly once the perceived threat has passed.

Chronic stress, on the other hand, is an unrelenting circumstance that offers little chance for a return to normalcy. That's what makes it more toxic. "You're living in a kind of permanent state of … this isn't just a challenge, this is dangerous," Norman says. Financial strain is one such chronic stressor, having a bully for a boss is often

TAKING A TOLL

Detention center officers participate in an active shooter training session at a former middle school in Texas. Law enforcement officials have a higher risk of cardiovascular disease compared with the general population. Even situations that officers know are drills have been shown to increase physiological stress markers.

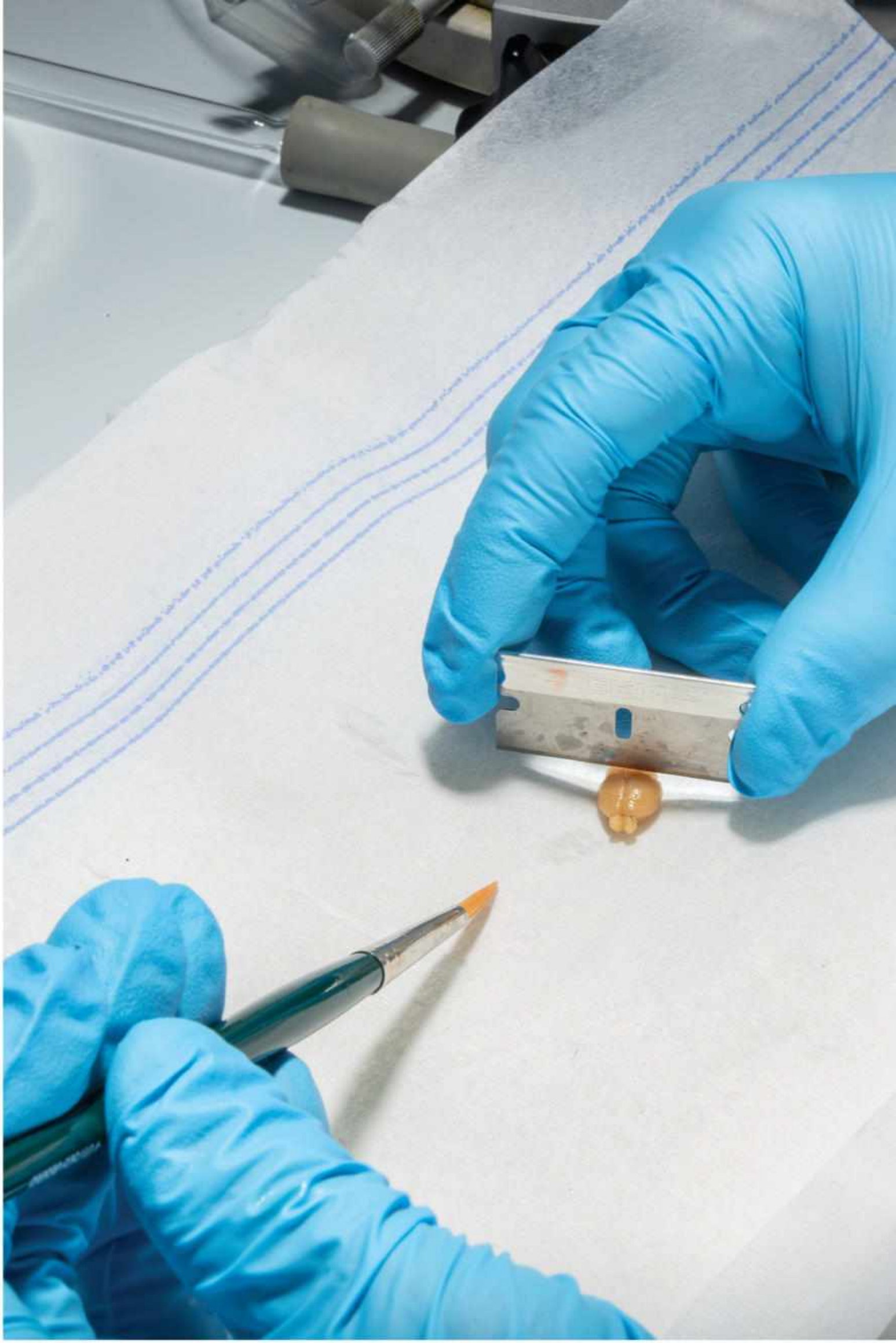
another. Some forms of stress, though, may be ones we don't recognize until they're already harming us, like social isolation, prevalent in the elderly and experienced across all ages during the COVID-19 pandemic. A 2023 national survey by the American Psychological Association (APA) found that, since the start of the pandemic, stress has taken a serious toll, with the incidence of chronic illnesses and mental health problems going up significantly, especially among those ages 35 to 44.

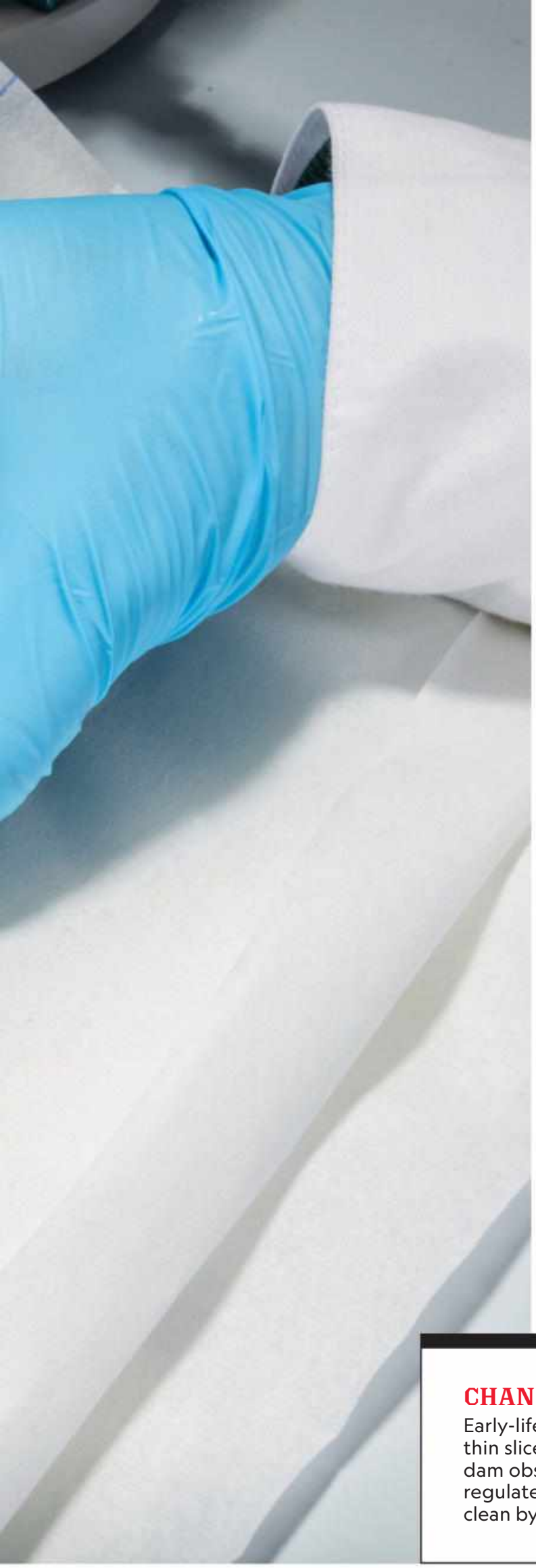
Today chronic stress seems to be increasing worldwide, as people grapple with rapid socioeconomic and environmental change. The Gallup 2023 Global Emotions Report stated that stress is near record levels in many countries, especially Afghanistan under the Taliban and Sierra Leone, where the rising cost of living sparked deadly protests in 2022. Stress tends to be higher and its impact more severe among marginalized, lower-income communities that have fewer resources to treat it. Yet even those living in relative prosperity aren't immune to stress. A third of the 2023 APA survey respondents said they "feel completely stressed out no matter what they do to manage their stress."

As stress ratchets up to what feels like unbearable levels, researchers are striving to learn more about the precise mechanisms through which it affects our body and mind. The hope is that by unlocking more about how stress works physiologically, we can find ways to prevent it from permanently harming people. So far, one of the major realizations is that stress doesn't just have varying forms or intensities. It harms all of us in different and powerful ways—and at every age.

INVISIBLE IMPACTS

Raising triplets Hays, Presley, and Millie is challenging for Caitlin and Chris Nichols of Lawrenceville, Georgia. Born prematurely, the children have long-term health problems. Caregivers of chronically ill children face health difficulties themselves: Telomeres—protective caps at the ends of chromosomes—are shorter than expected, a possible sign of stress-related aging.





Early Childhood

TENS OF THOUSANDS OF ORPHANS and abandoned children who grew up in Romania's understaffed and underequipped orphanages from the late 1960s to the 1990s experienced unimaginable neglect and abuse. When scientists studied babies who were being raised in these orphanages, they found they weren't developing normally. The electrical activity of their brains was weaker compared with babies raised in Romanian households. Many of the children who had grown up in the orphanages went on to develop psychiatric disorders, and many were handicapped by severe cognitive impairments. Today the tragic experience of some of these orphans is viewed by child development experts as a grim example of how stress endured in early life can leave an indelible mark on the brain.

These studies made a deep impression on Aniko Korosi when she was working on her Ph.D. on the neurobiology of stress. Now a researcher at the University of Amsterdam, Korosi has been conducting experiments on mice to elucidate that link between early-life stress and brain development, and she may have found a surprising connection between stress and the resulting nutrient composition in the brain. Mice pups typically spend the first three weeks of life in their mother's care. "The first of these three weeks, we put them in a cage where they have less nesting and bedding material," Korosi explains. This is stressful for the mother because she's constantly scrounging for nesting material that isn't there. "Because of that, her behavior becomes erratic and she's less good at caring for her pups," Korosi says. After this first,

CHANGES TO THE BRAIN

Early-life stress alters the way mouse brains operate. Examining thin slices of brain tissue, researchers at the University of Amsterdam observed abnormalities in microglia—cells whose job is to regulate the immune reaction in the brain and to keep the brain clean by removing dying neurons and other waste.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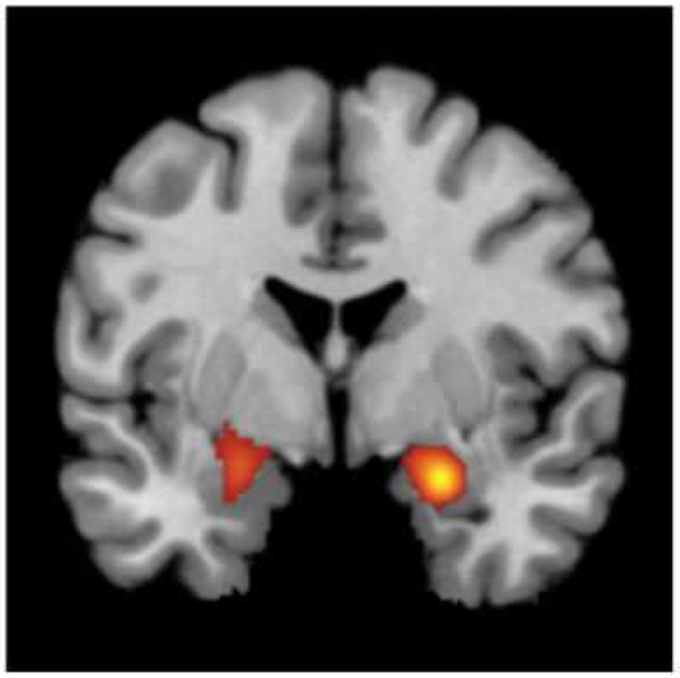
unhappy week, the mouse and her pups are moved to a comfortable cage. “Now the maternal care returns to normal.”

Eventually the pups catch up in weight to pups comfortably housed since birth. But when tested on learning and memory tasks four months later, mice reared in adversity for the first week of life perform poorly compared with normal mice. “Chronic stress in adulthood has an impact, but it can often be temporary and can resolve by itself,” Korosi says. “Chronic stress in early life has more serious and lasting effects, because that’s when a lot of connections are being laid down in the brain.”

One material change Korosi and her colleagues noticed in mouse pups that had been exposed to stress was the nutrient composition of their brains. The levels of certain fatty acids and amino acids during that first week were lower compared with those of pups being raised in a stress-free environment. “It was



T.C. HEIN AND C.S. MONK, *JOURNAL OF CHILD PSYCHOLOGY AND PSYCHIATRY*, MARCH 2017

A VULNERABLE AGE

High school junior Zainab Khorakiwala undergoes a functional MRI as part of a study by Harvard’s Stress and Development Lab examining how everyday stress affects teens’ brain development. A brain scan (right) from a different study into individuals who were maltreated as children shows that their brains react strongly to emotional stimuli.

THE CHRONIC STRESS EFFECT

Stress can be brief, situational, and galvanizing—a positive force that motivates and enhances performance. It can also be deadly over extended periods of time. When stress becomes chronic, it can kick off a cascade of negative impacts on health and well-being. See below how stress alters a body's systems—and what adverse effects can follow.

ALTERED SYSTEMS

Long-term activation of the stress response system can disrupt almost all of the body's systems and how they act upon each other. Four primary systems are outlined here.

AUTONOMIC NERVOUS

The balance between our sympathetic (fight-or-flight) and parasympathetic (rest-and-digest) systems is disrupted.

HPA AXIS

Activation of the hypothalamic-pituitary-adrenal axis leads to chronically elevated levels of hormones called glucocorticoids.

CARDIOVASCULAR

Average systolic and diastolic blood pressure rises. Adaptive blood pressure responses to acute stress are blunted.

IMMUNE

Receptors on immune cells become desensitized to chronically elevated glucocorticoid levels, disrupting regulation of inflammation.

CONSEQUENCES

Long-term stress can affect how people respond emotionally, physiologically, and behaviorally to their environs and increases susceptibility to disease.

BRAIN AGING

Hypervigilance and other changes in the brain may contribute to accelerated cognitive decline.

INSOMNIA

Falling asleep takes longer, and sleep is fragmented.

HEART DISEASE

Cholesterol and triglyceride levels rise; plaque deposits build up in arteries.

GUT DISORDERS

Symptoms of Crohn's disease, irritable bowel syndrome, and other issues worsen.

MORE BELLY FAT

Excess fat surrounds internal organs, raising the risk of stroke and a host of disorders, including those of the heart and liver.

DIABETES

Hyperglycemia (high blood sugar) and insulin resistance become more likely.

SKIN CONDITIONS

Psoriasis and eczema flare-ups can be triggered.

GRAPHIC: ALBERTO LUCAS LÓPEZ, NGM STAFF; KELSEY NOWAKOWSKI
ILLUSTRATION: VIOLET FRANCES
SOURCE: NAT. INST. ON AGING STRESS MEASUREMENT NETWORK

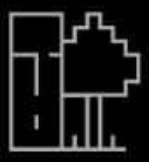
STRESS BUSTERS

Explore these seven evidence-based strategies to manage both day-to-day and chronic stress. All have been shown to improve brain health and immune function and to regulate stress hormones.

SUPPORTIVE RELATIONSHIPS
Connect with family, friends, and neighbors in person or virtually. Get involved in your community.

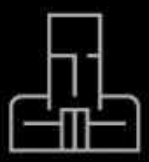
BALANCED NUTRITION
Eat regular meals that include a variety of whole grains, fruits, and vegetables.

PHYSICAL ACTIVITY
Find joyful ways to move your body every day; schedule time to get up and stretch while at work.



TIME IN NATURE
Get outside, breathe fresh air, and feel the sun on your skin. Smell flowers, listen to birds, try gardening.

REGULAR SLEEP SCHEDULE
Create a calm, distraction-free, safe place for sleep. Try to go to sleep and wake up at the same time each day.



RELAXATION TECHNIQUES
Take deep breaths and turn your attention to how you are feeling. Meditation and prayer can also be helpful.

MENTAL HEALTH CARE
Seek resources and support if needed. Plan ahead for what to do when stressed, angry, or overwhelmed.

really striking," Korosi says. She wondered if it was possible to normalize a stressed pup's development by feeding it a diet rich in specific nutrients its brain would be lacking. The supplemented diet was first fed to the mothers so it would pass through their milk and was continued for two weeks in the now weaned mice pups' feed. The researchers waited a few months before testing the now adult mice in learning and memory. Unlike stressed mice that never received an enriched diet, these mice did not display cognitive impairments. "I was surprised that changing the nutrition could have such a powerful effect, because it's such an easy intervention," Korosi says.

Of course, it's one thing to draw conclusions from mice and another to apply those insights to humans. Korosi and her colleagues are studying humans too. They've recently been investigating whether nutritional deficiencies in the milk of stressed human mothers could be the mechanism by which the damaging effects of stress were being passed on to the brains of their offspring. The researchers have found evidence supporting that hypothesis in a study that analyzed the composition of milk taken from moms of newborns in Amsterdam. "We see that indeed the milk of the mothers that underwent stress have different fatty acid composition, different amino acid composition," says Korosi.

If further studies provide more evidence of the nutritional pathway, she says, there will be a strong basis for supplementing the diets of infants born to mothers living in stressful conditions with specific nutrients. "If you envision that there is a metabolic deficit, then maybe just healthy eating is not sufficient," she says. "It might need to be very specific concentrations of a certain nutrient for a certain period."

Adolescence

LIKE MANY HIGH SCHOOL STUDENTS, Zainab Khorakiwala often feels overwhelmed trying to keep up with academics and still have a social life. She's a junior at a competitive school in

Lexington, Massachusetts, where "getting even a B plus or an A minus on something is considered bad," she says, adding that grades were especially important as she'd soon be applying to colleges. Khorakiwala describes herself as a worrier. When I spoke to her last December, she was feeling stressed because she'd missed a couple of days of school the week prior. "I had a lot of work to catch up on, plus after-school activities," she told me. "It got too much. I felt like I didn't have any time."

Khorakiwala is one of 150 adolescents who are subjects of a Harvard study led by Katie McLaughlin, a psychologist now at the University of Oregon. The research aims to measure how common, everyday stressors that teenagers experience affect their emotional, cognitive, social, and brain development. McLaughlin is interested in understanding how mental health problems arise in adolescents as they're going through what is a particularly vulnerable time in their lives, transitioning from being kids to becoming adults. "Research has shown that most mental health problems begin in the relatively quick aftermath of a stressful life event, typically within a month or two," McLaughlin says. "So if you are a teenager, it could be your boyfriend or girlfriend breaks up with you, or you don't make it onto the soccer team after months of practicing, or your best friend rejects you, or your friend group starts excluding you."

McLaughlin's study tracks the lives of teenage subjects from a variety of socioeconomic backgrounds, bringing them into the lab every month for an in-depth stress interview.

PROTECTING THE NEXT GENERATION

Carline Raphael (at left), a public health worker in New York City, visits with new mother Marisela Bravo Berrera and her two-month-old daughter, Angel, to give advice on breastfeeding and good sleep habits for newborns. Research shows chronic stress alters the nutritional components of breast milk, so stress management for mothers of infants is key to the babies' healthy development.


NYC

DAMAGED DNA

Tufts University doctoral student Ursula Beattie holds a recently captured sparrow. For a study, she subjected similar birds to stress, such as being in a cage rolled around the lab. Blood samples reveal harm to their DNA, suggesting that repair mechanisms become overwhelmed.

Researchers ask them about their life over the previous month, their relationships, happenings at their schools, in their neighborhoods, and in their families. The subjects wear devices allowing the researchers to monitor their patterns of sleep and physical activity. From the teenagers' smartphones, the researchers collect information about behaviors such as engagement on social media and contact with friends. They also conduct functional MRI scans of the subjects to assess neural activity. "What we are curious about is when a person is experiencing more stress than is typical for them, what are the changes that we see in things like social behavior, sleep, physical activity, and most

A PERMANENT RECORD

In a separate study, Beattie measured sparrows' feathers for corticosterone—the stress-related hormone in birds. "We like to compare it to tree rings, which can give information about how a tree grew retrospectively," she explained. The feathers chronicle a stressful moment in time.

importantly, their brain," McLaughlin says.

She and her colleagues are still collecting data for the current study, but a smaller, precursor study tracking 30 teenagers offers clues about what the researchers might learn. In that study, McLaughlin found that the extent of stress a subject experienced in the month before a lab visit changed how that teen's brain responded to emotionally impactful information such as a picture of a threatening face. The brain's prefrontal cortex, which helps regulate emotions, showed less activation when the subject had experienced higher levels of stress. "What that might suggest is perhaps consistent with what you experience in your own life:

COMPROMISED IMMUNITY

Before her husband, Tommy, who suffers from Alzheimer's disease, moved to an assisted-living facility this year, caring for him took nearly all Ellen Ebe's time and energy. She participated in an Ohio State University study on how such caregiving affects the body's ability to fight disease, as well as the risk of depression and anxiety.

When you're really stressed, you have a harder time controlling your emotional reactions," McLaughlin says. "You might be more likely to snap at a partner or somebody in your family."

McLaughlin is optimistic that data from the current study will help pinpoint changes in behavior as well as brain activity that predict the emergence of mental health problems like anxiety and depression. This could enable the development of targeted interventions delivered to teenagers at just the right time, she says. If the identified marker of stress was a sudden decrease in sleep duration or a sharp decline in social interactions, for example, it would be possible to push the intervention out to the individual on their smartphone. "Like, here's a reminder about good sleep hygiene, or this might be a good time to check in with your counselor at school about what's been going on in your life," McLaughlin explains.

Adulthood

PSYCHOLOGIST JANICE KIECOLT-GLASER and her virologist husband, Ronald Glaser, began exploring the impact of stress on physiology at Ohio State University (OSU) back in the early 1980s, when the field was still relatively young. "We wanted to see if more commonplace events made a difference in terms of stress," says Keicolt-Glaser, now an emeritus professor at OSU. But over the years, as they too grew older, their work evolved to encompass some key stressors of adulthood, especially how they may have an even more distinct effect on the immune system.

At first they looked at medical students. Through blood draws, the researchers found the students' immune systems were less robust when they were taking exams than during non-exam times. The researchers went further, investigating whether stress altered the body's response to vaccines. They gave students what was back then a three-shot sequence of the hepatitis B vaccine, timing the shots for when they were taking exams. "We looked at who developed antibodies between the first and the second inoculation, which were a month apart," Kiecolt-Glaser says. "Students who were more stressed and more anxious didn't have measurable antibodies." The third shot in the sequence helped them develop immunity.

They also turned their attention to older caregivers, a notably stressed segment of society. Researchers applied the flu and pneumonia vaccines to individuals responsible for a spouse with dementia. Unlike medical students taking exams, who were likely stressed only in the short term, these people were experiencing unrelenting stress. When tested at set periods after inoculation, they had fewer antibodies compared with a control group—they couldn't maintain their protective response. "That gave us good evidence that the changes brought on by stress were biologically meaningful," Kiecolt-Glaser says.

With their colleagues, Glaser and Kiecolt-Glaser dug deeper, doing punch biopsies—making small wounds—on the arms of two groups of volunteers: those caring for spouses with dementia, and similar-aged adults who didn't have such caregiving duties. "Caregivers took 24 percent longer

time to heal the same standardized wound than non-caregivers," Kiecolt-Glaser notes.

Not long after Glaser and Kiecolt-Glaser began their stress work in the 1980s, researchers led by Sheldon Cohen, now an emeritus professor of psychology at Carnegie Mellon University, delivered cold-causing viruses into the nostrils of about 400 adult volunteers in the U.K. after they'd answered questions as to how stressed they were. "The more stress they reported prior to our exposing them to a virus, the higher the risk was for them to develop a cold," says Cohen. But our understanding of how different variations of stress can hurt health continues to evolve. In a later study, Cohen and his colleagues showed that the duration of the stress mattered: The longer it went on, the greater the susceptibility to falling sick from exposure to viruses. Not all types of stress were the same, the researchers found. "People who suffered from chronic economic stress or chronic interpersonal stress were the ones who were really at high risk," Cohen says.

In later work investigating precisely how stress was making individuals more vulnerable to illness, Cohen and his colleagues learned that when exposed to viruses, chronically stressed people tended to produce an excess of cytokines—proteins that serve as messengers of the immune system, traveling to sites of infection and injury and activating inflammation and other cellular processes to protect the body. But a surplus of cytokines rushing to the infected site isn't a good thing, as it causes excess inflammation, which is what produces the congestion, runny nose, and other symptoms of a cold. "Stress alters the immune system's ability to regulate pro-inflammatory cytokines," Cohen explains. Researchers still don't know enough about the mechanisms to

devise an intervention to reduce the inflammation appropriately, but in one way, these findings signal some hope: There are clear targets for more work to be done.

The Future

WHILE SCIENTISTS HAVE LEARNED about the effects of stress on every age group, the future of understanding and combating stress may lie in our DNA. Recently, researchers have been working to glean new insights about the profound toll this defense mechanism turned chronic condition can exact on a cellular level.

This past year, Ursula Beattie, a doctoral student at Tufts University, and her colleagues found possible evidence that stress can overwhelm DNA's repair mechanisms. In the lab, the team put sparrows through its own interpretation of Selye's original animal aggravations, or "chronic variable stress protocol"—a term that Beattie translates as "annoying the birds." Researchers go into the bird room and "tap on the cages with pens, roll the cages around in the room, play the radio loudly," Beattie explains. The idea is to cause distress but no physical harm. Blood and tissue samples from the sparrows after three weeks of this unpleasant treatment reveal damage to the DNA. "It's like if you had two pieces of string coiled up, just like DNA, and you took a pair of scissors and cut them," Beattie says.

While these kinds of double-strand breaks in DNA occur all the time in sparrows and other species, including humans, the damage is typically reversed through self-repair

REWIRING THE BRAIN
Inside the Computer Assisted Rehabilitation Environment Laboratory at Walter Reed National Military Medical Center in Bethesda, Maryland, Army veteran Wayne Christian walks toward an emotionally triggering photo of himself. Studies indicate that by helping patients confront traumatic memories and process the negative feelings around them, this advanced treatment reduces the symptoms of severe post-traumatic stress disorder.

HIGH RISK, FAST STRIDES

More than 200 women meet at the Benjamin Franklin Bridge in Philadelphia on a fall day to walk together. The Philly Girls Who Walk group gathers weekly for three-mile walks aimed at promoting physical and mental fitness. Worldwide, women and young adults are at the highest risk for work-related burnout, and exercise is one way to alleviate it.

mechanisms. In a chronic-stress setting, "those repair mechanisms get overwhelmed, which is how we see a buildup of DNA damage," Beattie explains. The damage in the birds appears to be the most severe in cells of the liver, she adds, suggesting that for humans, too, the extent and type of damage inflicted by stress might be different for different tissues of the body.

Separately, Kiecolt-Glaser and psychologist Lisa Christian at OSU are conducting a longitudinal study to determine whether chronic stress makes sufferers age more quickly. Again, they're focusing on caregiving

THE NEED FOR CONNECTION

Older people often struggle with isolation, a source of chronic stress. Animal therapy offers an antidote. At a senior living center in Vancouver, Washington, residents are paid a visit by Beni, a therapy llama. They pet him and feed him carrots by hand or by holding them between their lips for Beni to remove with a kiss.

spouses, analyzing blood samples for markers such as the length of telomeres, a repeating sequence of DNA at the end of chromosomes that gets shorter with age. If results support a smaller, earlier study, it appears that not only are chronically stressed caregivers more likely to get sick and heal more slowly; they also show signs of accelerated aging.

We're still learning how deep chronic stress goes into our bodies. But these exploratory findings mean we're getting closer to solving the puzzle that is stress, which promises a future where we can better meet the ongoing demand for change. □

AN ANTIDOTE TO STRESS

Meditation, which has been practiced for millennia, provides many health benefits, including managing stress and anxiety.

GROWING UP IN INDIA, I would spend summer breaks visiting my grandparents in Kolkata. Each afternoon, my grandmother settled down on a floor mat, facing the family's worship room, where stone idols of Hindu deities sat on little wooden thrones. For half an hour, she would sit still, her eyes closed, fingers rolling her prayer beads, chanting Krishna's name in a barely audible whisper. As a little boy, I found this an opportune moment to tiptoe around her and help myself to the jar of delicious sweetened tamarind paste she kept on a shelf behind where she sat. But I never gave much thought to what she might be getting out of this daily ritual.

It's impossible to know, objectively, whether those afternoon meditation sessions helped my grandmother achieve some sort of communion with a higher power, but a growing body of scientific evidence suggests she benefited from it in multiple ways. The practice was likely an effective approach for her to manage her stress. It may have also helped slow down aging-related cognitive decline—a possible

ANCIENT PRACTICE
Devotees meditate at the BAPS Swaminarayan Akshardham complex in Robbinsville, New Jersey, the largest Hindu temple in the United States. More people are embracing meditative methods whose roots can be traced to Hinduism and Buddhism.

FOCUSED ATTENTION

An electroencephalogram measures the electrical activity of this volunteer's brain at the Alembic, a mind-body center in Berkeley, California. Individuals who meditate regularly show higher activation in their attention networks (the yellow areas below) than non-meditators.

explanation for why she remained mentally sharp until the very end. It also probably enhanced her ability to cope with pain.

Defined most broadly as the exercise of focusing one's attention on the current moment, meditation in some form has been practiced for millennia within religious traditions around the world. Many contemplative practices are rooted in a quest for spiritual enlightenment, yet meditators have long believed their practice has health benefits. Over the past three decades, research has begun to confirm those health claims. One recent study determined that a daily practice of mindfulness meditation—which was defined as attending keenly to one's thoughts and emotions for 45 minutes—relieved anxiety and acted as an antidepressant. Another found that mindfulness-based cognitive therapy—in which individuals learn to break negative thought patterns using breathing exercises and meditation—lessened the severity of treatment-resistant depression among adults, who were still taking medication during the study.

In fact, as meditation's popularity has grown along with awareness about the importance of mental health and stress relief, many are learning there are health benefits from doing breathing exercises for just a few minutes a day. Many U.S. schools now have programs that teach meditation to students, with the percentage of children ages four to 17 taking part in meditative practices such as mindfulness increasing ninefold from 2012 to 2017. Finding opportunities to learn and practice meditation has never been easier: Dozens of meditation apps such as Headspace and Calm offer people the option of using their smartphones—otherwise a source

KATHRYN DEVANEY AND OTHERS, *BRAIN SCIENCES*, APRIL 2021

A PLAYFUL PAUSE

Mila West-Rosenthal, nine, relies on a Breathe With Me Barbie to meditate in her playroom at home in Fairfield, Connecticut. A collaboration between toymaker Mattel and the meditation app Headspace, the doll is equipped with a button in its necklace that activates one of five guided sessions with light and sound effects. Mila likes the doll so much that she has two.

of distraction—to immerse themselves in sessions guided by instructors, with calming music playing in the background, at their own convenience.

"Twenty years ago, when I used to tell people I meditated, they would think I was in a cult or something," notes neuroscientist Kathryn Devaney, executive director of the Berkeley, California, Alembic body-mind center. "They would ask, What is that? And then something changed around six years or so ago. Now when I talk to people about meditation, the response I get often is 'Oh, I know I should be doing that.' And that's so different."

HIGH-TECH TOOL

For 10 minutes every day, entrepreneur Brian Mazza meditates at his home in Pelham Manor, New York, wearing a device called Muse 2, a headband that produces sounds and provides feedback based on measurements of electrical activity inside the brain. These sounds are supposed to assist the user in focusing the mind.

Now research aims to understand why meditating confers the benefits it does. Sara Lazar, a Massachusetts General Hospital neuroscientist, and her colleagues have done studies illuminating how meditation reduces anxiety, which has similar symptoms to stress. One compared two stress-reduction programs: one mindfulness based, in which 42 volunteers learned awareness meditation and yoga practices for eight weeks, the other exercise based, where 25 volunteers did light aerobic exercises. Both groups performed a fear-conditioning task similar to exposure therapy, in which an

A SENSE OF CALM

At the Howard R. Young Correctional Institution in Wilmington, Delaware, a group of incarcerated men are taught a form of meditation using rhythmic breathing, known as Sudarshan Kriya Yoga, which can improve people's ability to control their emotions.

anxiety-inducing stimulus is repeatedly presented in a safer environment until it no longer triggers anxiety. Volunteers were shown an image of a lamp that glowed blue, green, or yellow, receiving a mild electric shock with two of the colors. Later the same image was presented to them without the shock, to extinguish the "fear memory" and create a new "safety memory" associated with the lights.

Lazar and her colleagues found those who received the mindfulness-based stress-reduction training were better able to shed their fearful response to the shock-associated lamp colors. From brain scans, the researchers concluded that the volunteers' training had changed how their brains processed the "safety memory" and increased their ability to recall that the stimulus was no longer threatening.

Meditation's benefits may extend beyond stress and anxiety reduction. Fadel Zeidan, a neuroscientist at the University of California, San Diego, studies how mindfulness can help reduce pain. In a recent study, Zeidan and colleagues used functional MRI scans of volunteers' brains during meditation and pain to understand how meditation works to alleviate discomfort. Volunteers were assigned to two groups—one went through mindfulness meditation training and a control group listened to a pretty tame book *(The Natural History and Antiquities of Selborne,* a classic of 18th-century nature writing).

First the volunteers rated their pain after a hot probe pressed to their calf produced 100 seconds of intermittent heat pain across five minutes (they could move their leg away at any time). Then they went through the same process again, but this time the mindfulness group was asked to meditate during the painful heat, while those in the control group were asked to rest with their eyes closed.

Volunteers who meditated reported feeling less pain. "We see a 33 percent drop in pain intensity and unpleasantness during meditation, while the pain levels in the control group actually go up," Zeidan says.

Why does meditation provide relief? Zeidan says analysis of the meditators' scans showed pain relief induced by meditation was associated with reduced activation in neural networks involved in self-awareness. The greatest decrease in activation is seen in the medial prefrontal cortex—a neural hub that plays a prominent role in self-reflection and valuing oneself. "During the meditation, the self-value is deactivating," Zeidan says. "And the more it goes down, the greater the analgesia, the greater the pain relief." Pain signals are still being received by the brain, but "they are not going into the brain networks that are saying, This is my pain," he explains. In essence, mindfulness appears to help detach the self from the suffering.

Last November I traveled to a prison—a place presumably rife with stress. Yet I was at the Howard R. Young Correctional Institution in Wilmington, Delaware, to watch meditation teachers from the International Association for Human Values lead a session for about 20 incarcerated men. IAHV was founded by spiritual leader Gurudev Sri Sri Ravi Shankar, who has popularized Sudarshan Kriya Yoga (SKY), a technique using rhythmic breathing to focus the mind. Like other forms of meditation, SKY promises to give practitioners the ability to stay calm and be less reactive in stressful situations. More than 800,000 imprisoned people

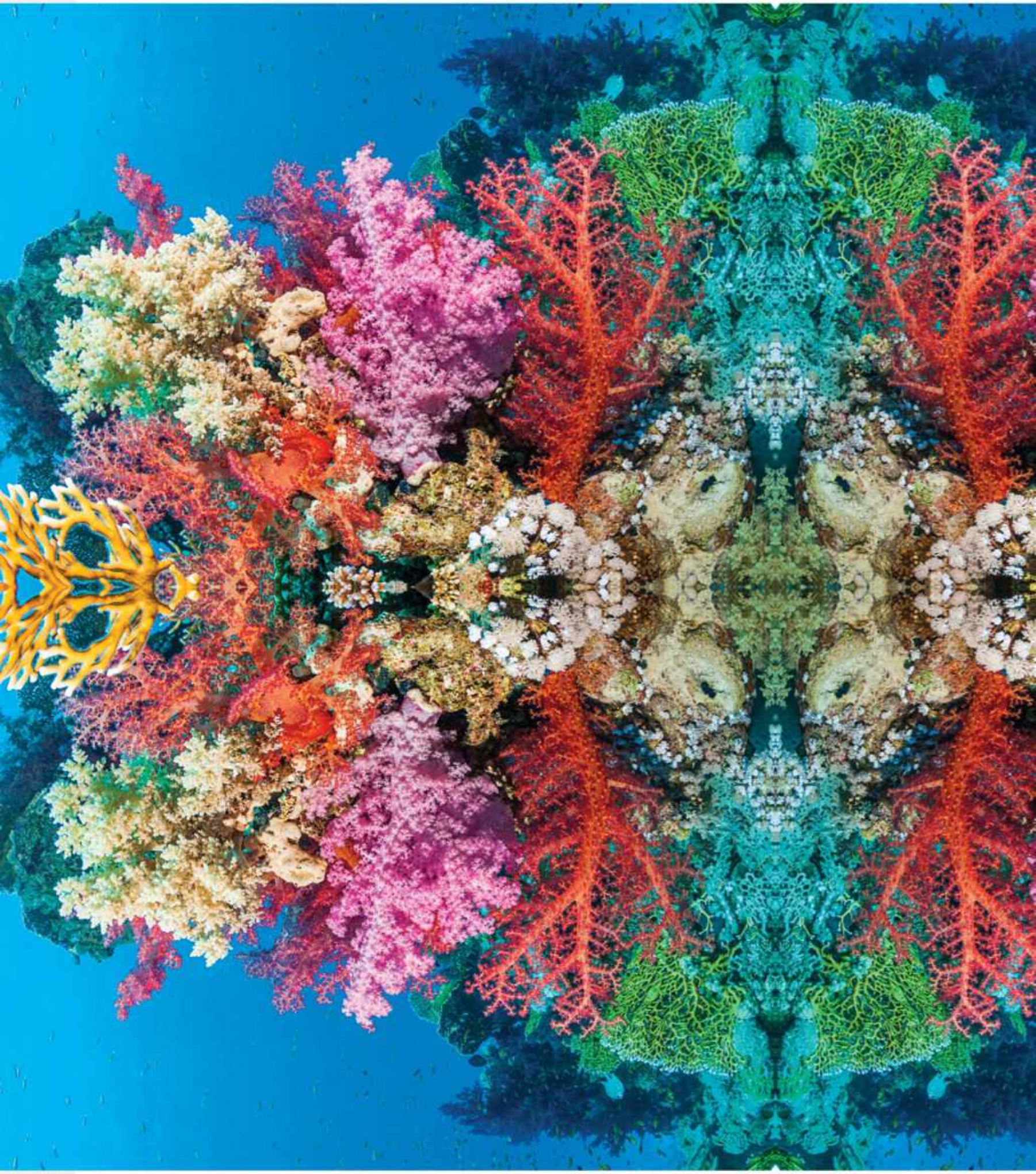
and correctional officers in 60 countries have gone through the IAHV program.

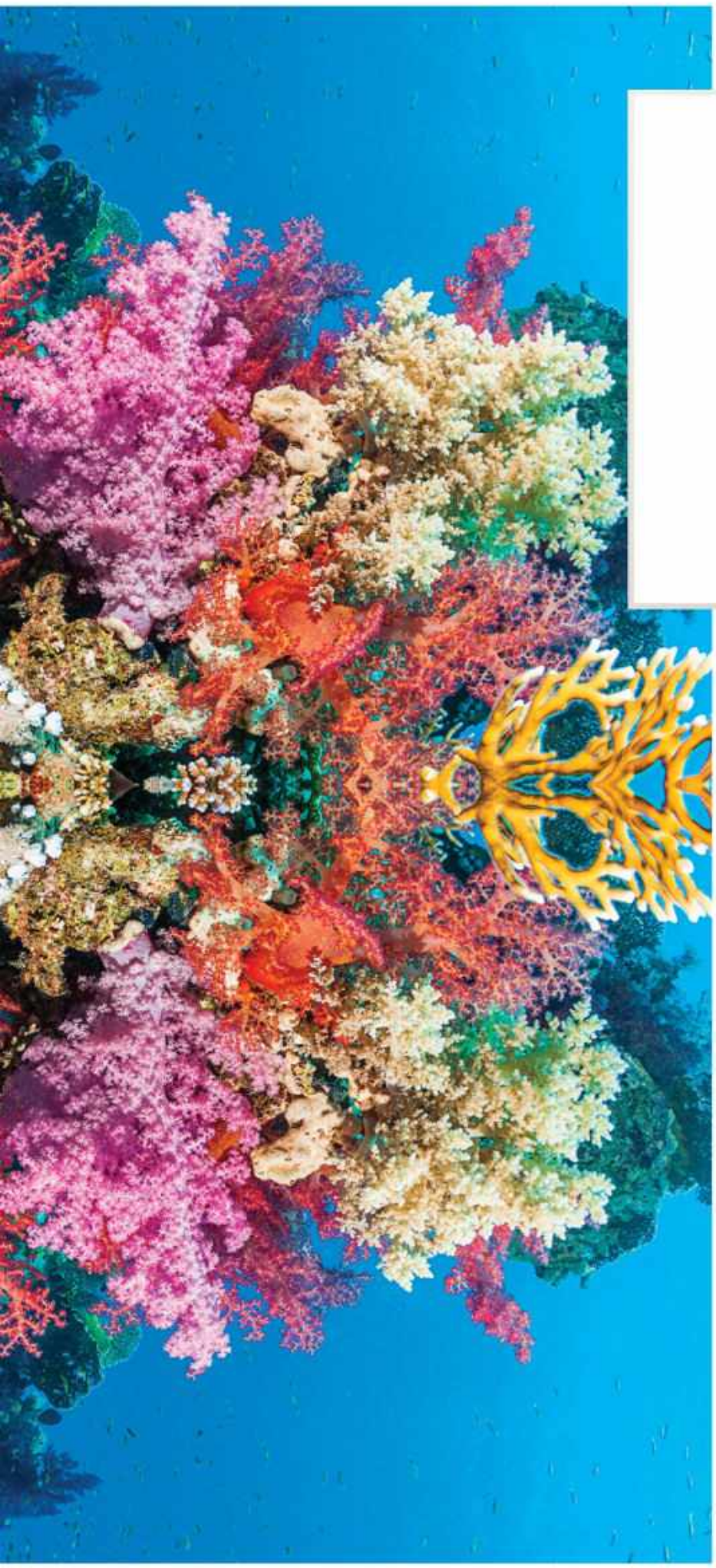
Some at the session I attended had already received training in the technique and were striving to apply it to their daily lives. (Prison authorities allowed me to interview them on condition I not use last names.) I spoke to Jorge, a short man in his late 20s with a wispy beard and bright eyes, who was sent to the Wilmington prison for first-degree assault in 2016. He told me he was born in Puerto Rico and moved to mainland America at age five. Because he wasn't fluent in English, his peers laughed at him in school. "I didn't know how to respond," he told me. So he got into fights.

Jorge had heard about meditation years earlier while in a wrestling club. Somebody he knew there would meditate before matches and didn't seem to get agitated, even when losing. "I used to wonder, how come I'm so mad and he's always calm?" Jorge said. The question had been partly answered, he said, by what he had been learning in the prison meditation program. And he'd begun applying that to his life. "When I feel like I'm getting flustered or angry, I just breathe," he told me.

On a recent trip to my family home in Kolkata, I stood quietly outside the worship room, right where my grandmother used to meditate. It had been 20 years since she died. There was no jar of tamarind paste for me to steal from. At 51, I was far more weighed down by life's stresses than I had been as a boy sneaking past my grandmother. Perhaps the time had come, I felt, to make it a daily habit to meditate. □

Photographer **Brian Finke** has covered the history of alcohol, the problem of food waste, and the science of taste for the magazine.





PHOTOS: NATURE PICTURE LIBRARY

CORAL

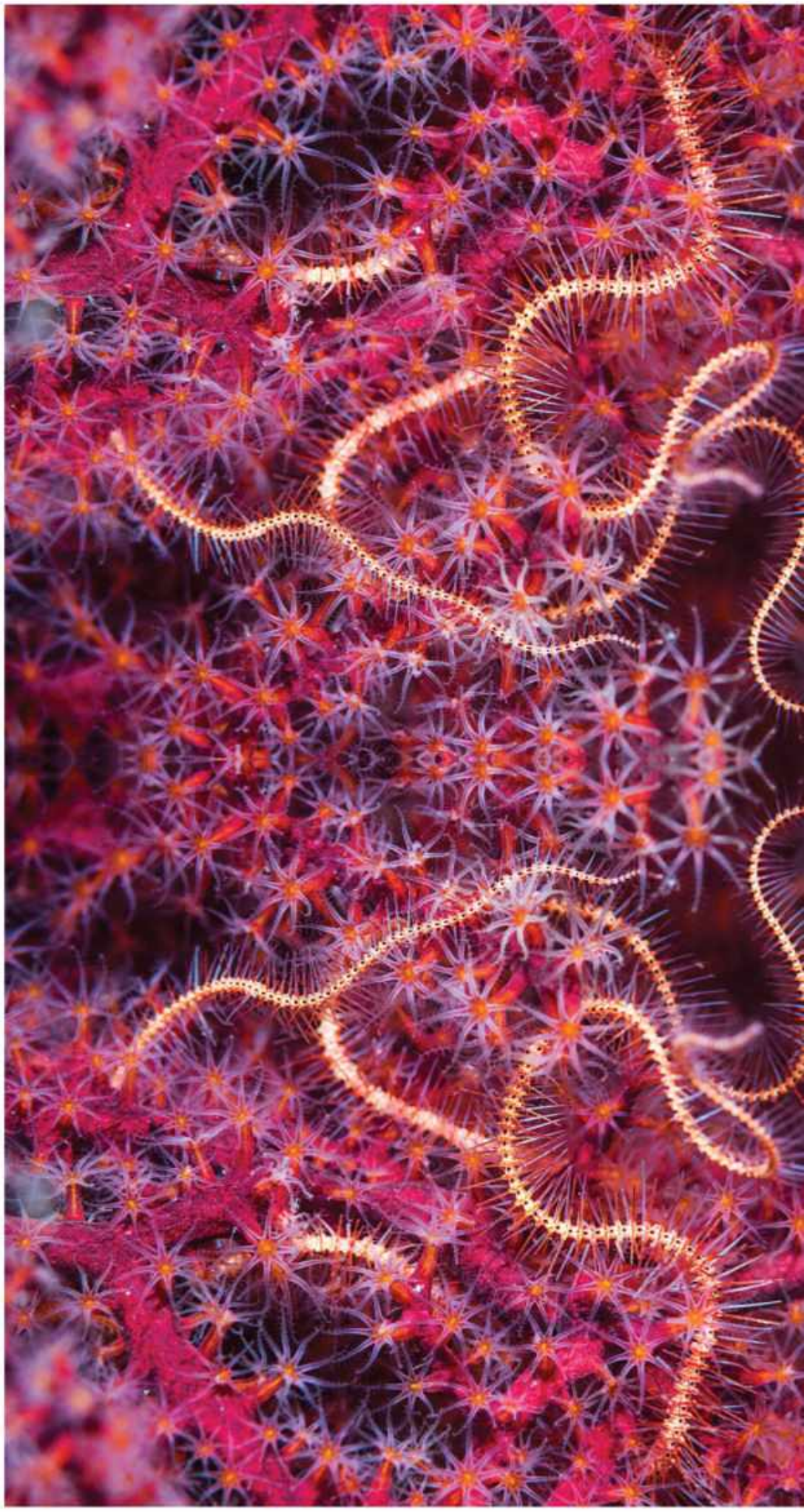
Kaleidoscope

Transforming her pictures of reefs into intricate designs, a photographer offers a new view of the vital ecosystems.

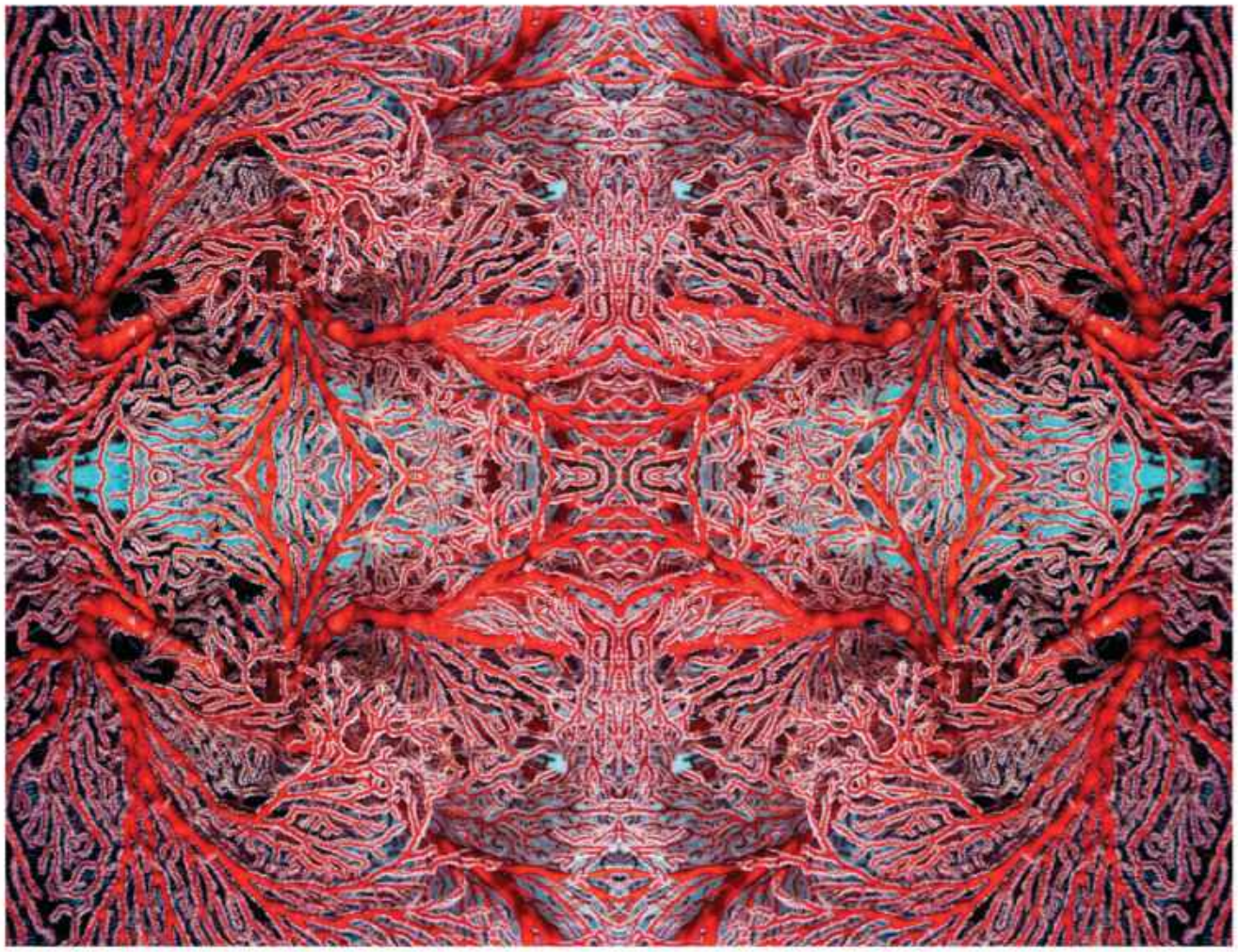
Images by
GEORGETTE APOL DOUWMA

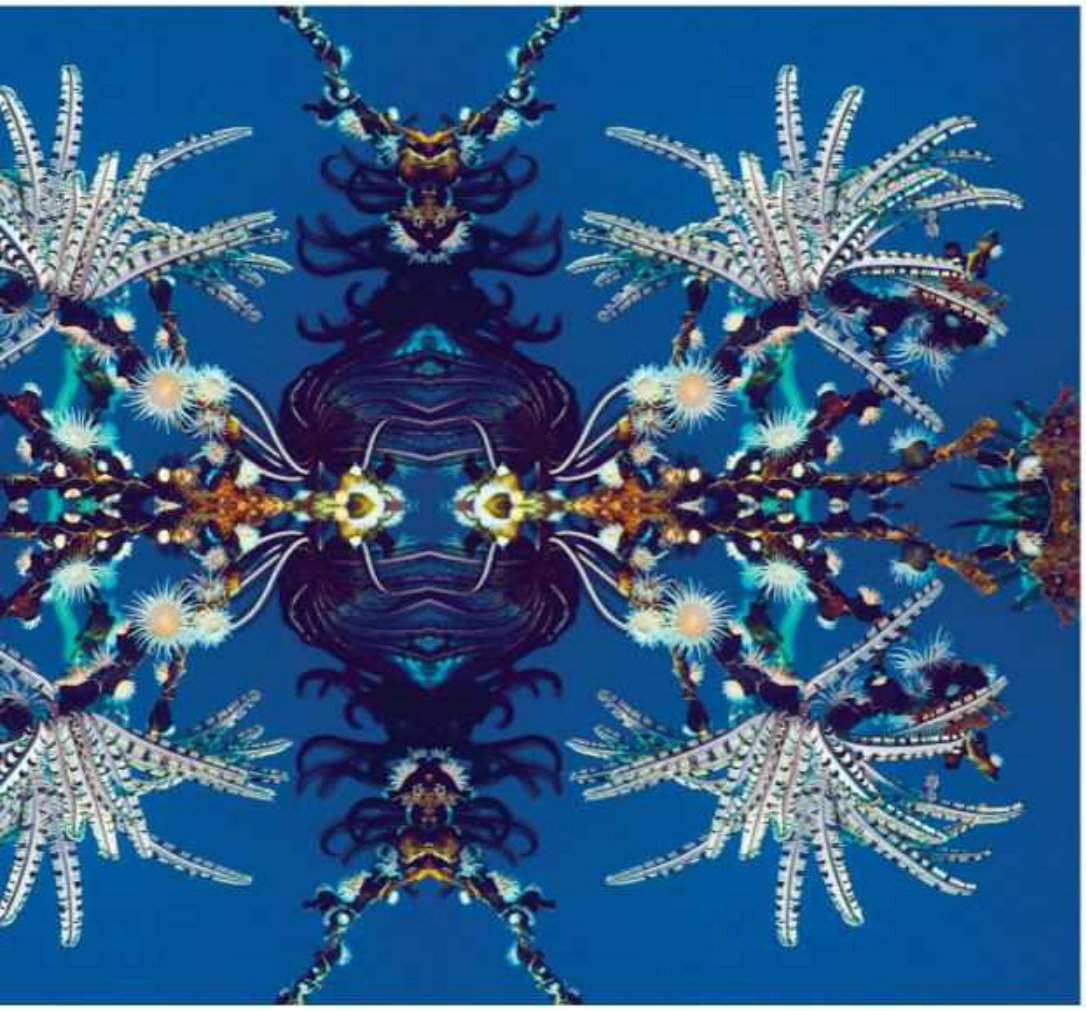
TEEMING WITH LIFE, coral reefs occupy less than one percent of the ocean floor but sustain 25 percent of marine species. These hubs of biodiversity now face existential threats, from ocean warming and acidification to destructive fishing practices and pollution. It's their stunning beauty that first caught the attention of photographer Georgette Apol Douwma during a trip to the Great Barrier Reef in the 1970s. Some 40 years, many scuba dives, and thousands of pictures later, Douwma began to reimagine her catalog by duplicating and reversing images to create symmetrical patterns similar to a kaleidoscope's. The results emphasize the vibrancy and brilliance of these vulnerable underwater wonders. –HICKS WOGAN

Photographer Georgette Apol Douwma's technique involves altering her earlier pictures, such as one taken in 2015 of corals in the Red Sea, to create new eye-catching displays.



BRITTLE STAR
Douwma estimates that she's made a thousand kaleidoscopic images, including this one photographed in Indonesia's North Sulawesi Province in 2018. "I got quite carried away," she says of the process.





Clockwise from top left

LYRETAIL ANTHIAS

A London resident and former BBC freelancer, Douwma focused on reefs around the world before hanging up her scuba gear in 2020 at age 79. In 2012 she captured a photo of these orange fish in the Red Sea.

CRINOID

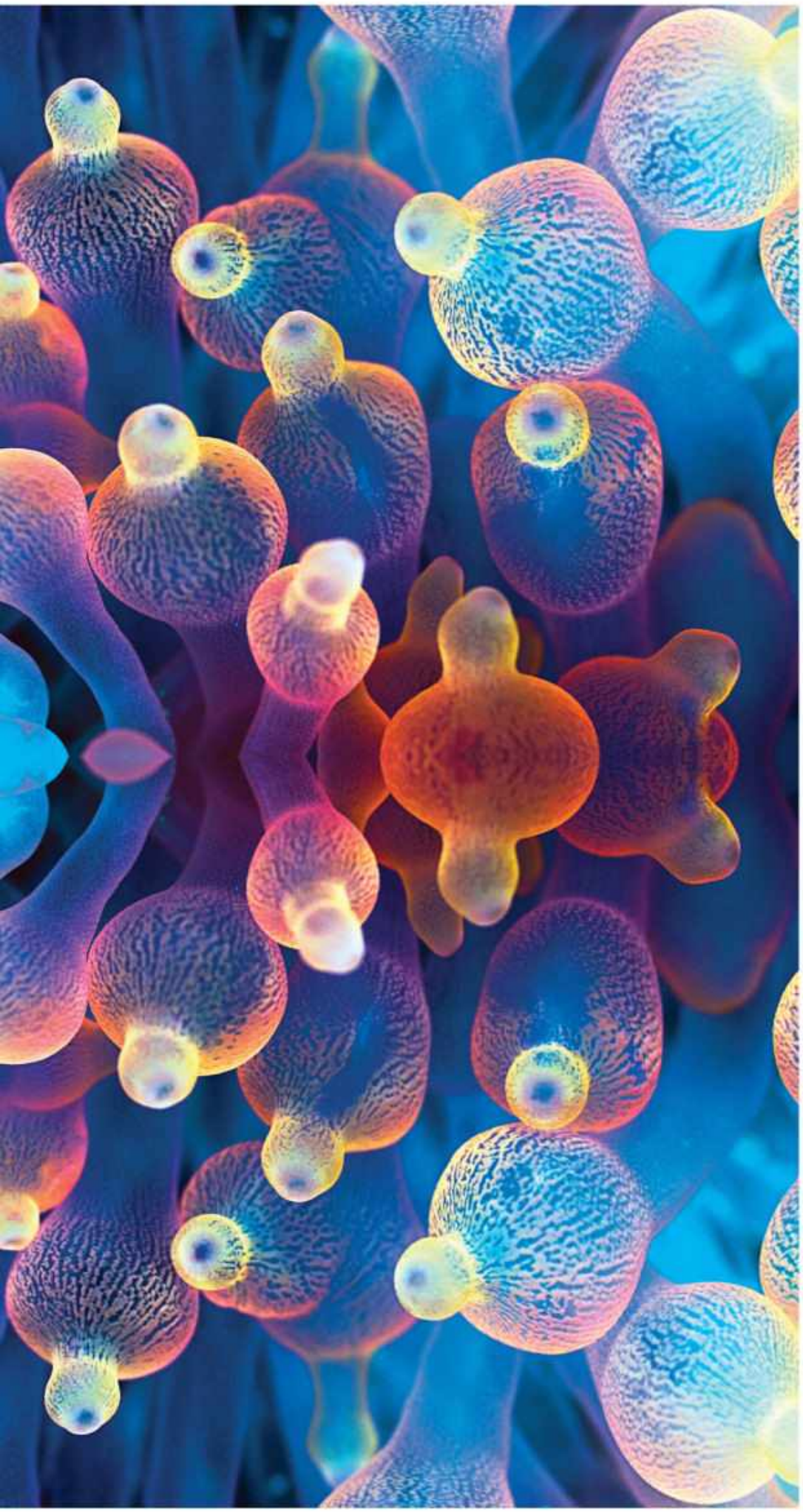
Douwma's favorite region to dive was Southeast Asia, including Thailand, the Philippines, and Indonesia—the country where she found this crinoid, along with gorgonian wrappers, in 2007.

YELLOWBACK FUSILIERS

Swimming past corals in Indonesia's West Papua Province, the school of fish appears to quadruple in number after Douwma edited a 2017 photograph.

GORGONIAN SEA FAN

To reveal bright colors that would otherwise look monochromatic underwater, Douwma used flashes with her subjects—this one also from West Papua Province, photographed in 2009.



BUBBLE-TIP ANEMONE

In this image based on a photograph taken in Indonesia in 2011, an anemone shows signs of bleaching after expelling the organisms that provided it with nutrients. Healthy examples support many species of anemonefish.

INTO THE FIRE

TUBES

A volcano in the Canary Islands pushed rivers of molten lava through the earth, carving out tunnels that stretch for miles. Now scientists and explorers trek through the cooling underground, looking for insights into life on this planet—and perhaps on others.

WORDS BY **EMMA LIRA**

PHOTOGRAPHS BY **ARTURO RODRÍGUEZ**

Military responders Armando Salazar and Álvaro Heredia measure and sample lava flows in October 2021. La Palma's 85-day eruption, after a 50-year dormant stretch, engulfed 2,800 buildings and displaced 7,000 residents.

Inside a lava tube opening registering about 140°F, cave specialists David Sanz Mangas, Eduardo Díaz Martín, and Octavio Fernández Lorenzo collect samples for testing lava composition. Since July 2022, the team has been exploring lava tubes produced by the Tajogaite volcano (background and previous photo). These openings are telltale signs of tubes.

Díaz operates a drone—a crucial tool in the precarious landscape—that helps guide Fernández as he attempts to place a temperature probe in a lava tube that's still cooling nearly two years after the eruption. Fernández must keep a safe distance from the unstable rim of the mouth.

WE COULD BE ON ANOTHER PLANET. A craggy, hostile surface stretches as far as the eye can see, framed by slopes of black ash. These are the new lava flows on La Palma, in the volcanic Canarian archipelago, off the coast of Morocco. They appeared in the fall of 2021, when, for three months, more than 50 billion gallons of molten rock erupted from the island's Tajogaite volcano.

Transit through most of the lava field is still reserved for scientists and environmental officials. I'm accompanying Octavio Fernández Lorenzo, vice president of the Canary Islands Speleology Federation. Alongside researchers from the Geological and Mining Institute of Spain (IGME), Fernández is responsible for exploring and surveying the tunnels that lava left in its wake. Known in most scientific literature as pyroducts or lava tubes, they have a more poetic name here on La Palma: *caños de fuego,* fire pipes.

Fernández hands me a helmet, checks our water supply, and heads toward a white fence where a sign warns us not to cross. The road that brought us to this place cuts off abruptly and disappears under the blanket of lava. It feels as if we're abandoning civilization.

Fire pipes can be found almost anywhere

on the planet where there is, or has been, volcanic activity. In contrast to typical caves, formed over millions of years, these cavities are made in a geological instant. But not all volcanoes create lava tubes. The eruption must be long enough to expel adequate lava. That lava must be hot enough and composed of the right materials to remain fluid. And it has to descend a slope, at the right speed.

At around 1800 degrees Fahrenheit, *pahoehoe*—"smooth" in Hawaiian—lava can flow. "It's the same word used to define a calm sea," says Fernández. I can picture it quite vividly. A sea of incandescent, syrupy lava advances, spilling downhill. The outer layer cools on contact with the air and begins to solidify, forming a crust that will become the roof of the tube. The lava continues to stream, unimpeded for miles, under that thermally insulated cover. When the eruption dies down and the channels drain, the result is a subterranean labyrinth of hollow tunnels separated from the surface only by the volcano's skin.

Leaning on a long white stick, which helps him move nimbly over hardened lava, Fernández looks a bit like a wizard from *The Lord of the Rings*. He studies our strides, as if he were the guardian of this newborn space. "Step where I step," he warns. "This whole environment is extremely fragile." It seems paradoxical that this imposing landscape, once capable of swallowing houses and

banana plantations, could now be vulnerable.

Our hike to the tube takes an hour along a slope of sharp, living rock. This is *aa* lava, a Hawaiian term for "rough and stony" that many believe sounds like what someone walking barefoot on this jagged surface might say. Phrases from Hawaii's active and intensely studied hot spots have been adopted by volcanology. Other languages have their own words that evoke images. For example, in Spanish this barren terrain is called *malpaís,* or bad land.

We walk slowly. Fernández picks up a tiny, immaculately white pyroclastic rock and hands it to me. It's what researchers call restingolite, after the eruption in the La Restinga region of the neighboring island of El Hierro in 2011, when hundreds of pieces of whitish rock were found floating on the ocean, giving rise to a scientific debate that, unlike the eruption, has yet to die down. One hypothesis for their origin: They're bits of the foundation on which La Palma grew, ancient ocean sediments from that two million-year-old seabed. Looking at the small fragment brings about an inexplicable feeling of vertigo. David Sanz Mangas, a geological engineer specializing in the study of extreme events and heritage at IGME, puts it this way: "It's like looking out a window into our past."

BARELY A MONTH INTO THE ERUPTION on La Palma, scientists detected lava tubes. They're not obvious to the naked eye; drone imagery captured during the eruption helped predict their possible routes. One tube was discovered in June 2022, six months after the eruption ceased, as workers were starting to build a new road over the hardened flow. When they came across a cavelike space, they had to pause. And that was when Sanz, who had relocated from Madrid to the Canary Islands to study the eruption's aftermath, joined the team and began exploring the newborn fire pipes of La Palma.

"Based on field data obtained in the Hawaiian archipelago, the place with the largest volcanic cavities in the world, we assumed exploration of the tubes could begin about two years after the eruption," he says. But here "we saw that, with difficulty, it was accessible."

Drones are crucial to fieldwork. "The first step was to begin a series of thermal flights that would monitor the open holes in the lava field," he says. "And to start exploring them little by little."

The so-called red tube is a product of the lava rivers that, three years ago, flowed down into the small town of Todoque. Today a pair of entrances about 200 feet apart allow air to circulate. "Instead of hot air coming out, the mouth sucks in fresh air from outside," Fernández says. "This is the best laboratory we have right now to learn how the lava flows cool." We turn our headlamps on, crawl in, and confront the surprising reddish color of the walls. On the ceiling we see dark brown lava stalactites hanging like droplets that solidified before they could fall and are now suspended forever. They look like melted chocolate.

Inside the tube, the air is cooler than the walls—anywhere from 120 to 210 degrees, according to a probe. We balance against these walls with our gloved hands as we move forward, step by step. The humidity and the mix of temperatures give the cave the pleasant sensation of a Turkish bath.

With a thermal drone, Fernández takes temperature readings. About a hundred yards in from the mouth, he tells us to stop: The heat is increasing significantly. Not far ahead, the tube narrows and exhales a temperature of more than 480 degrees. In the video feed, the air shudders like a mirage.

This mouth is just one of more than a hundred identified so far, mostly by drone flights overhead—though some remain too camouflaged to spot from the air. Just a tiny number have been explored. Openings are viable only if the temperature allows. In lava flows up to

MAP: CHRISTINE FELLENZ, NGM STAFF. SOURCES: OCTAVIO FERNÁNDEZ LORENZO, CANARY IS. SPELEOLOGY FED.; ISLAND COUNCIL OF LA PALMA; SPANISH MINISTRY OF AGRICULTURE; GEOTENERIFE; NASA/JPL

65 feet thick, cooling can go on for two and a half years; at 150 or 200 feet thick, it might be 20 years.

It's too soon to predict how far these tunnels reach. Scientists believe that this network may be composed of up to three overlapping levels. Sanz thinks it could be the most extensive tube system in Europe. That title is currently held by the Viento-Sobrado cave system beneath Mount Teide on the neighboring island of Tenerife. With more than 11 miles of tunnels, it was considered the largest volcanic tube in the world for a brief moment until, in 1995, a man named Harry Shick found a cave entrance in his yard on the island of Hawaii. It would turn out to be the access point to more than 40 miles of tubes, branching out from the Kilauea volcano.

THERE IS MUCH TO LEARN FROM THESE tunnels, and perhaps not just about our world. Ana Zélia Miller, a geomicrobiologist from Seville's Institute of Natural Resources and Agrobiology, is the daughter of artists. The course of her life changed when her parents gave her a microscope at the age of nine. Since then, she has focused her lens on those small life-forms that go unnoticed by the human eye. Her first discoveries were made in La Palma's fire pipes, studying their peculiarly gelatinous speleothems, or mineral deposit formations.

Miller's research on extremophile species, especially bacteria capable of obtaining the energy to develop from inorganic matter, led the European Space Agency to recruit her for its Pangaea-X project. The mission was to train astronauts in the collection and analysis of microbial samples on the nearby island of Lanzarote inside a lava tube whose conditions appear comparable to lava tubes on the moon and Mars.

Since 2009, when a Japanese space probe discovered the Marius Hills Skylight—a possible entrance to one of the moon's volcanic

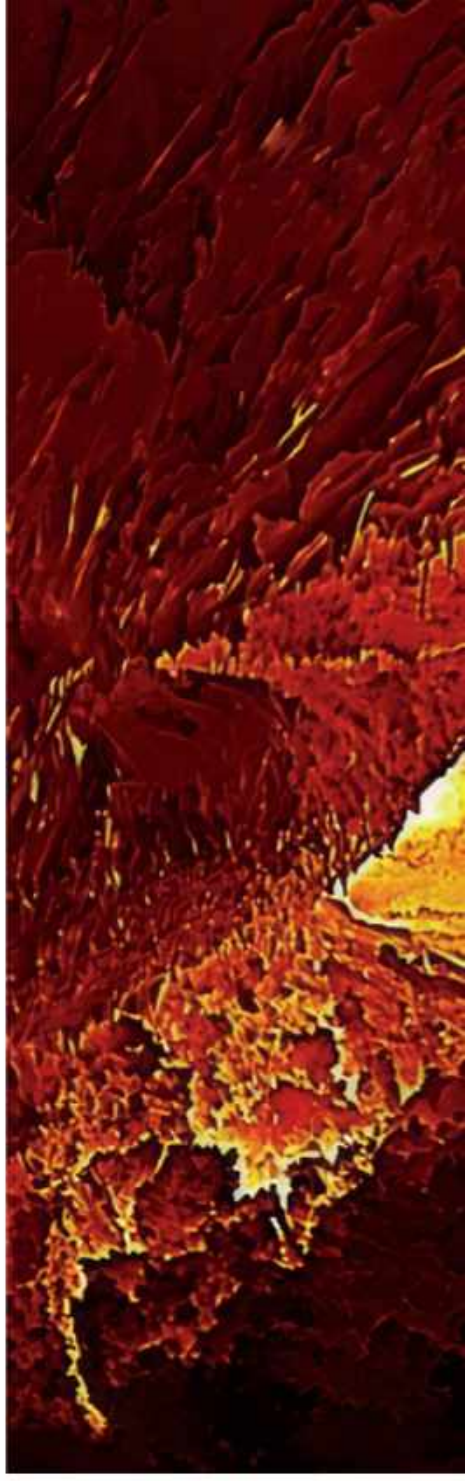
LAND OF LAVA

For nearly three months in 2021, lava flowed from the volcanic Cumbre Vieja ridge, covering more than 3,000 acres of La Palma. Recently, microbial life-forms have been discovered inside the still-cooling lava tubes that took shape in the extended eruption's wake.

tubes—the scientific community has been studying the similarities between terrestrial volcanic tubes and their planetary counterparts. For Miller, the question is no longer if we will find life on other planets, but when.

"Martian and lunar caves differ greatly from ours in terms of environmental conditions and gravity, which affect their size and stability. However, their formation and surroundings have more in common with terrestrial ones than one might think," says Francesco Sauro, a European Space Agency scientist and National Geographic Explorer. If there is, or has been, life in these otherworldly lava tubes, it could be microbial, as it is in the fire pipes of La Palma.

"The recent eruption on La Palma gives us a unique opportunity to learn about the pioneering microbiota in these newly formed lava tubes," says Miller. The island's volcanic tubes are already inhabited. Miller's team has identified known bacteria as well as other life—belonging to the phyla Pseudomonadota and Bacteroidota—which could ultimately be identified as new species.

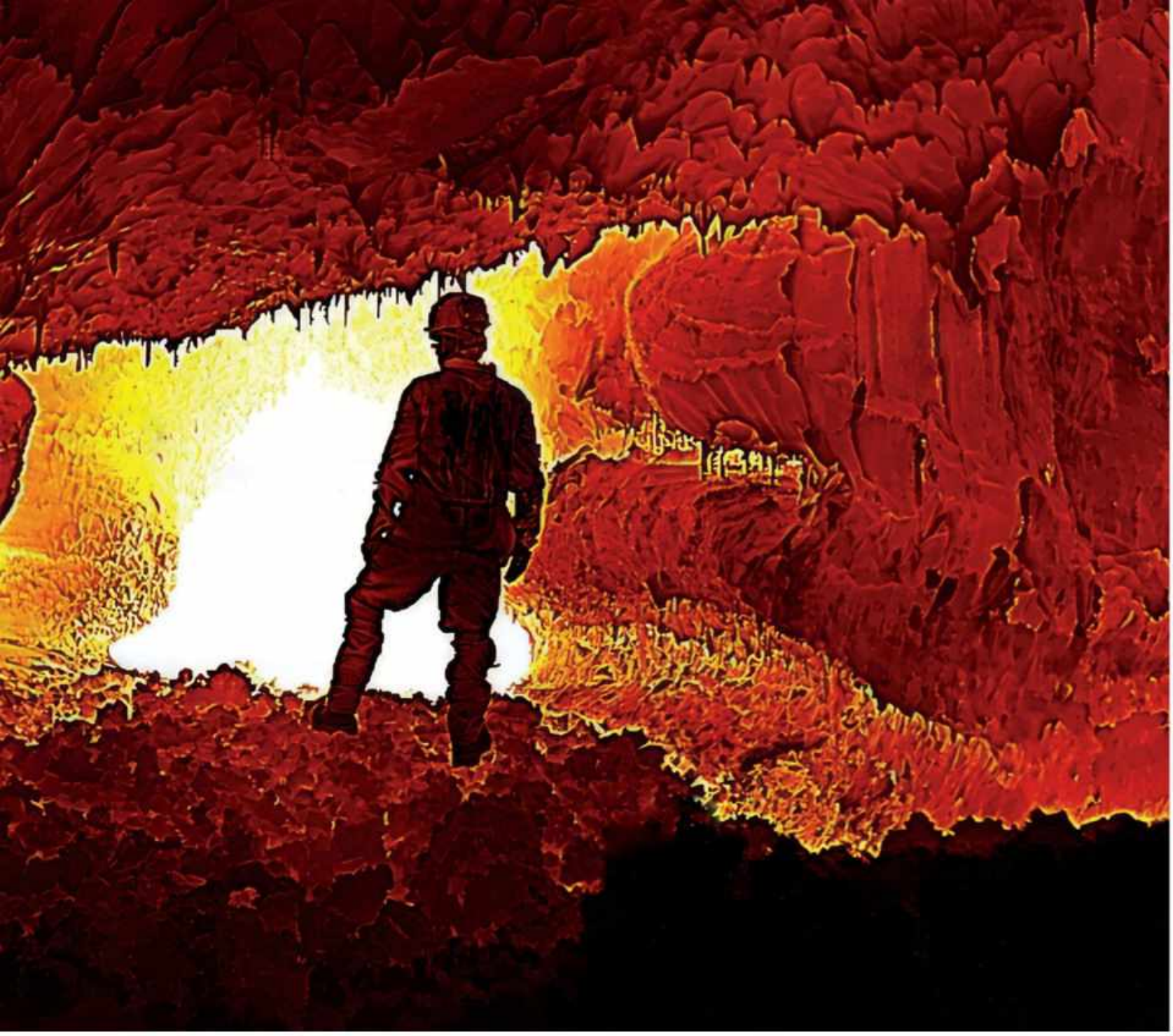


In a thermal image, Fernández stands below a tube's skylight. Drawing in outside air, these natural openings moderate temperatures and make exploration possible. A few yards farther in, the tube glows white-hot, becoming impassable. In cotton coveralls, Fernández senses when he's getting too hot: "It smells like ironing."

LA PALMA'S VOLCANO ROUTE, AN old hiking trail that reveals the island's distinctive landscape, is open again. From there, a path, still carpeted with ashes, leads to another partially explored tube, known by scientists as *hornito bonito*—pretty little oven. We come across a group of tourists who have hiked to see the main cone of the volcano, recently named Tajogaite, "cracked mountain" in the island's native language. The rest of the area requires accreditation, and even a gas meter and masks, because conditions can vary from one moment to the next.

The ash field is deserted, as unspoiled as the eruption left it, and covered with small craters. Each one houses a rounded stone, like an oyster with a pearl. The stones are viscous fragments spat out by the volcano, smoothed by friction with the air. Volcanic bombs, says Fernández. He takes one in his hands to show me and then puts it back in its place. They are part of this virgin landscape, at least until someone decides to start taking them as souvenirs.

"The ideal would be to create a network of marked and monitored trails so that everyone could enjoy this new geological richness, without damaging it and without encountering any risk," Fernández says. He pays close attention to our steps and turns at any suspicious creak. The layer of hardened lava is a thin biscuit, not even two inches thick. Underneath there may be a bubble, a crack where the temperature can exceed 900 degrees.

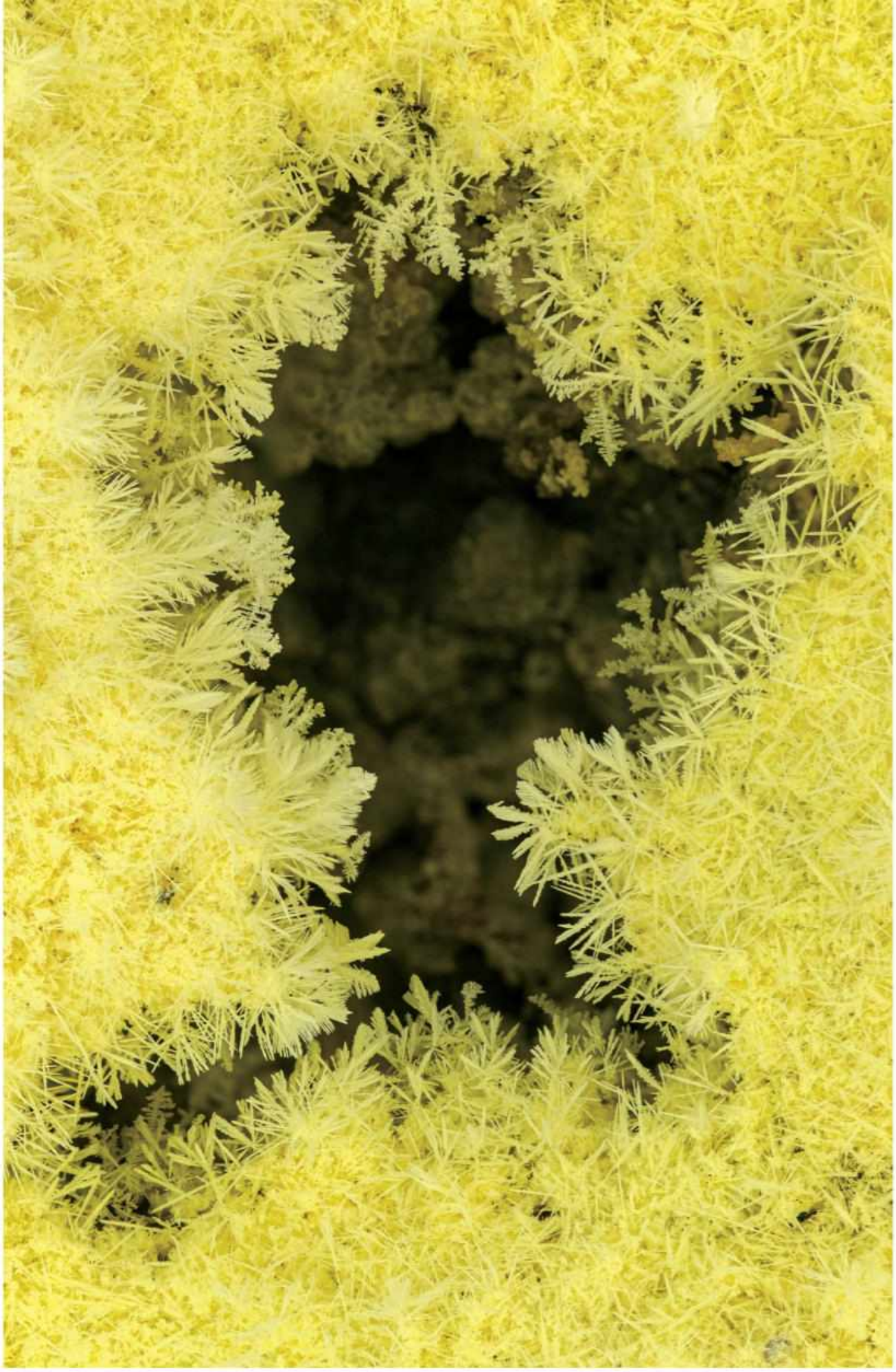


The hornito bonito rises up like an artisanal oven or a sandcastle. “The hornitos are like mini-volcanoes,” explains Fernández. “This one was formed in just three days.” It appeared right above the north face of the volcano’s main cone, when a jet of lava shot a hundred feet into the air. As it lost strength, gases began to bubble up, expelling spatters that piled up until they formed a truncated, conical tower.

A nearby entrance is a huge hole that descends into the tube, giving an idea of the lava waterfall that must have circulated, the edges solidifying around it. A light white powder seems to settle on everything, condensing into tiny white stalactites, as thin as needles—researchers are still studying their composition. They are ephemeral minerals, doomed to transform and disappear with every drop of water. Maybe by the time we know what they are, they won’t exist anymore.

The earth here gives you a sense of reverence toward places touched by disasters. I turn my headlamp off to feel the darkness. The silence and the solitude are breathtaking. Eventually, we cross the lava field back to our cars. It’s raining, and the puddling water kicks up clouds of steam. Our clothes are soaked, but I don’t feel cold. Heat is still emanating from the living rock. □

Writer **Emma Lira’**s first novel was set in the Canarian archipelago. She regularly retreats to the island of Tenerife.



COMPOSITES OF 29 FOCUS-STACKED IMAGES (SULFUR) AND 20 FOCUS-STACKED IMAGES (SPIDER)

After escaping from a vent, sulfur vapor crystallizes over time. A native *Oxyopes* spider species (right) is an early recolonizer. Scientists are probing not only how life thrives in lava but also whether such extreme volcanic environments may be analogous to ones elsewhere in the solar system.

Scientists named the red tube for its hue, thought to be surface oxidation. Beyond the point reached by Fernández, temperatures rise above 200°F. He has helped map more than half of La Palma's 200 known caves.

BACK FROM THE BRINK

For the saiga antelope, the future looks promising.

Photograph by
JOEL SARTORE

DIGESTION
As ruminant grazers, saigas convert plants that many other animals can't eat into nutrients. They're also important seed dispersers, bolstering biodiversity in their ecosystems.

THE AMERICAN GREAT PLAINS have their bison, and the Serengeti has its wildebeests. But on the steppes of Central Asia, saiga antelope make the ground tremble. While this floppy-nosed ungulate had appeared to be on a collision course with extinction because of disease and poaching, recent population estimates offer hope. In late 2023 the International Union for Conservation of Nature announced that saigas number about 1.9 million, prompting a change in status from critically endangered to near threatened. The saiga boom is an indication that 20 years of global efforts have managed to decrease poaching for the traditional-medicine trade. While the species isn't completely out of danger yet, signs point to a remarkable conservation success story in the making. **–JASON BITTEL**

NATIONAL GEOGRAPHIC
PHOTO ARK
JOEL SARTORE

The National Geographic Society funds Explorer Joel Sartore's Photo Ark project, which aims to document every species living in the world's zoos, aquariums, and wildlife sanctuaries.

PELAGE
Sand-colored fur allows saiga antelope to blend in with their environment and hide from predators such as wolves, foxes, and eagles. A thick winter coat also helps insulate them from wide swings in temperature.

HORNS
Only males have horns, which they use to battle each other for access to females. Demand for the horns in China, Singapore, Vietnam, and Malaysia has led to poaching.

NOSE
The saiga's schnoz may look silly, but it filters out dust and dirt during the summer months. In the winter, complex nasal passages warm up ice-cold air before it reaches the animal's lungs.

NGM MAPS

SCIENTIFIC NAME
Saiga tatarica

TYPE
Mammal

DIET
Herbivore

AVERAGE LIFE SPAN
10 to 12 years

SIZE
Average of 2.5 feet tall at the shoulders and up to 90 pounds

MYTHBUSTING

GRIPES GALORE

The ‘world’s oldest complaint letter’ became an internet sensation. Here’s the real story behind the ancient tablet.

Words by
ERIN BLAKEMORE

ABOUT 3,770 YEARS AGO, a disgruntled trader named Nanni fired off a litany of woes about a transaction gone awry, giving a piece of his mind to the allegedly unscrupulous merchant—a fellow Babylonian by the name of Ea-nasir.

Though this took place in the ancient city of Ur (in what is modern-day Iraq), the complaint, etched on a clay tablet, still resonates with today's consumers. It includes claims of shady financial dealings, low-quality product, and a serious lack of customer service. The artifact has earned a Guinness World Record as the world's oldest complaint letter, while Nanni's grievances from four millennia ago have prompted a seemingly endless string of memes, comics, and comparisons on the internet.

'I SHALL INFLICT GRIEF ON YOU!'

The infamous tablet, now in the collections of the British Museum, was discovered in Ur about a century ago. An expedition led by archaeologist Sir Leonard Woolley unearthed what may be the home of Ea-nasir, including a slew of business documents recorded in cuneiform writing on small clay tablets. Among them was Nanni's palm-size complaint, inscribed in Akkadian, the language spoken in Mesopotamia at the time, and dating to 1750 B.C.

The letter, dictated by Nanni, slams Ea-nasir for promising "fine-quality copper ingots," then failing to follow through on the deal. Instead, Nanni complains, the merchant has sent low-grade copper, treated him and his messenger with contempt, and taken his money. When Nanni's messenger attempted to dispute the quality of the copper with Ea-nasir, Nanni claims, the messenger was dismissed: "If you want to take them, take them," Ea-nasir reportedly said. "If you do not want to take them, go away!"

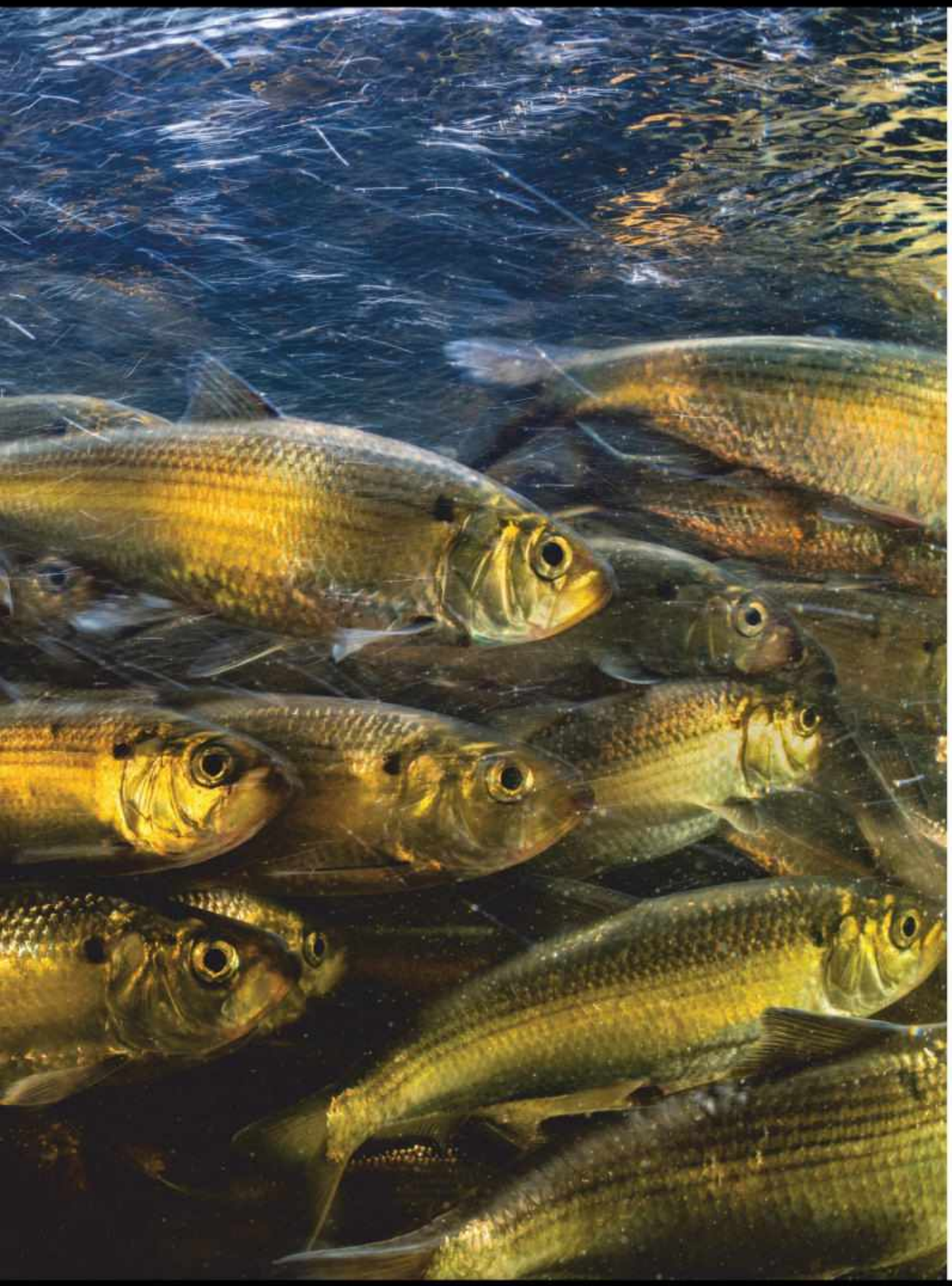
Nanni is livid, about both the copper and the merchant's treatment of his assistant. "I will not accept here any copper from you that is not fine quality," he fumes. Nanni concludes angrily: "Because you despised me, I shall inflict grief on you!"

A NOTORIOUS MERCHANT

As it turns out, Nanni wasn't the only one with a complaint against the merchant. The British Museum has even more evidence of Ea-nasir's seemingly crooked copper dealings. On another tablet, someone named Imgur-Sin exhorts Ea-nasir to "transfer good copper to Niga-Nanna ... Give him good copper, so that I will not become upset! Do you not know that I am weary?" The copper baron's reputation for inferior product had obviously gotten around Ur. In yet another communiqué, a trader named Nar-am demands: "Give [Igmil-Sin, Nar-am's messenger] very good copper! Hopefully the copper in your care has not gone out."

Given the durability of Ea-nasir's customer service problem, perhaps it's only fair to let him have the last word. Remarkably, a note from the beleaguered Babylonian survives—and unsurprisingly, it's full of copper-caused drama. In the letter, Ea-nasir tells a man named Sumum-libsi and a coppersmith not to overreact when two other men come to them in search of some missing metal. "Do not be critical," advises Ea-nasir. "Do not worry ..." Solid advice from one of history's most questionable salesmen. ▯

PHOTO: THE TRUSTEES OF THE BRITISH MUSEUM. NGM MAPS



A large school of alewives migrates upstream through Mill Brook, an inland stream with waters that eventually flow into the Gulf of Maine. These fish live in the ocean but return to fresh water to spawn. Once depleted, the species rebounded after dam removals in the area, and now feed a variety of other fish, birds, and mammals.

NATIONAL GEOGRAPHIC

WORDS AND PHOTOGRAPHS BY
BRIAN SKERRY
As told to Anna Peele

DEGREES OF CHANGE

06.2024

National Geographic photographer Brian Skerry has been diving in the Gulf of Maine for more than 40 years. After learning that these waters were warming faster than almost any other part of the ocean, he set out to document the rapid shift and its astonishing ripple effects.

HOW SHIFTING CURRENTS ARE WARMING THE GULF

The Gulf of Maine resembles a deep tub, its shallow banks inundated by cold Arctic waters. But melting freshwater glaciers and other effects of climate change are altering long-established currents, according to the Gulf of Maine Research Institute, causing temperatures to warm three times as fast as other ocean waters.

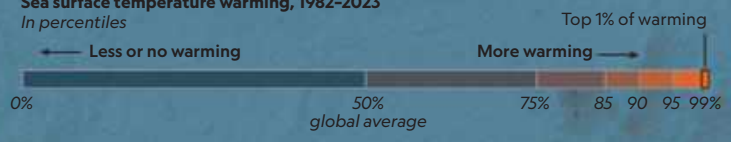
SOREN WALLJASPER, NGM STAFF
SOURCES: ANDREW PERSHING AND ADAM KEMBERLING, GULF OF MAINE RESEARCH INSTITUTE; OCEAN SURFACE CURRENT ANALYSES REAL-TIME; GENERAL BATHYMETRIC CHART OF THE OCEANS

Outgoing cold
Melting Arctic glaciers are pushing much of the Labrador Current's frigid, dense water deep into the Atlantic. As a result, less of it hugs the Maine coastline.

Incoming warmth
The Gulf Stream once passed swiftly through here. Now, possibly due to water from the north that's less saline and thus less dense, it's spiraling warmth toward the coast.

IN HOT WATER

Parts of the northwest Atlantic, especially the Gulf of Maine and the Labrador Sea, have been heating up faster than 99 percent of the world's oceans.

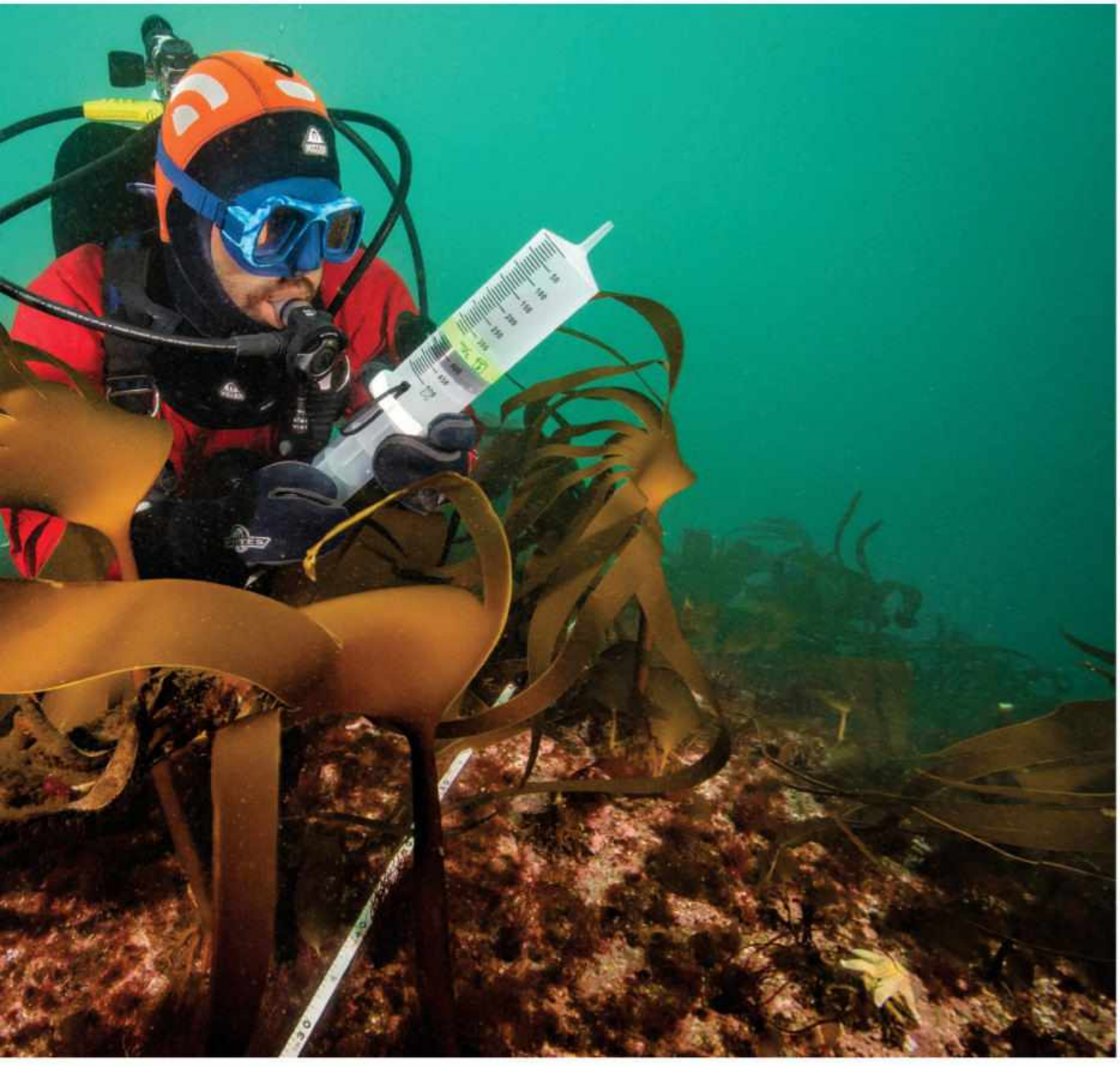


THE BOUNTY OF THE GULF OF MAINE. The sea within a sea, as it's often called, is a body of water that extends 36,000 square miles along the eastern seaboard of North America, from Cape Cod, Massachusetts, to New Brunswick, and encompasses the coastlines of New Hampshire, Maine, and Nova Scotia. Indigenous Americans who have lived in this region for more than 12,000 years learned the gulf's natural rhythms and sustainably harvested its rich waters. Europeans who began to settle in the area in the 15th century recorded tales of an endless abundance, with cod that measured up to five feet long. Before the American Revolution began, giant lobsters and thick schools of fish would have had a front-row seat to the Boston Tea Party.

I think of the Gulf of Maine as having been created from a perfect recipe that required a precise series of ingredients and steps. There is a robust watershed with many rivers flowing into the sea and a unique blend of currents that bring and mix nutrients, including upwelling from the continental shelf, the Gulf Stream, the Labrador, and counterclockwise coastal currents. Because of the Gulf of Maine's geographic location in a temperate zone, a seasonal stratification that separates water into warmer and cooler layers also occurs here. The result has historically been the proliferation of life. But things have changed.

Over the centuries, the rise of sophisticated commercial fishing fleets has led to a steep decline in marine

Marine ecologist Douglas Rasher collects water samples from a kelp forest near Winter Harbor. Along the southernmost coast of Maine, these essential marine habitats appeared healthy a few years ago but are now vanishing.



wildlife. Atlantic cod, its supply once believed to be inexhaustible, is now at one percent of colonial levels. So within just a couple hundred years, we have removed 99 percent of this species from the region. In the past four decades spent exploring these waters, I have witnessed how such declines have made the ecosystem weaker and more vulnerable in ways I never imagined.

I grew up in a working-class town in Massachusetts, about 40 miles from the ocean, but my parents would take me to the beach in summertime. As early as I can remember, I fell in love with the sea. My dream was to be an ocean explorer and photographer, sharing all that I saw and learned. In my 26 years of capturing images for *National Geographic,* I've been fortunate to work on all seven continents and in nearly every marine ecosystem from the Equator to the poles. I have always felt, however, that the ocean suffers from a bit of a curse in that its exterior hides what

lies beneath—both the exquisite natural beauty and the ongoing devastation.

That's why the most crucial part of my job doesn't really happen *in* the water. Before each expedition, I first dive as deeply as possible into the world of researchers who dedicate their lives to understanding marine animals and their relationship to the environment. Only then can I bring the right visual context. Whether they're images of orcas using different feeding strategies in order to share the rich complexity of whale culture or photos of a five-day-old harp seal pup falling through thin ice to show how deadly our warming planet has become for some species, my goal is to help people understand what's happening in our world.

Years ago, I moved to the coast of Maine to more frequently explore these waters. In doing so, I saw signs of a looming threat. People in marine science and conservation communities had grown alarmed after reading

Jocelyne Coombs and her father, Herman, trap lobsters near Orrs Island, Maine. She plans to carry on the family tradition, but biological models predict that lobsters may become scarcer as these waters continue warming.

It became common knowledge among locals that the Gulf of Maine was warming faster than 99 percent of the world's oceans.

a 2015 paper by ANDREW PERSHING (1), then chief scientific officer at the Gulf of Maine Research Institute. Within a few years, it became common knowledge among locals that the Gulf of Maine was warming faster than 99 percent of the world's oceans.

I now felt an urgency to share the wonder of my native waters—to focus on the beautiful wildlife that remains while highlighting the effects of climate change. To get it right, to make sure my images were representative of that change and its enormous impact on the region, I contacted many scientists and experts who have spent decades studying the gulf.

My original plan was to visit the most spectacular locations I had dived in decades past—places like Eastport, Maine, where the extreme tides of Passamaquoddy Bay exchange water and nutrients multiple times a day. I remembered Eastport as a cold-water kaleidoscope of fish species and invertebrates that could be seen easily just by making a dive from the beach. But when I got there, it was like a ghost town. The abundance of life that I had seen before was gone. Where exotic-looking creatures once carpeted the bottom, now there was only mud. Water temperatures were noticeably warmer.

THE SINGULAR MIX OF ELEMENTS that made the Gulf of Maine a fertile oasis is the reason it is now warming faster than almost anywhere else. These waters are also a harbinger for what

(1) Pershing's report, "Slow Adaptation in the Face of Rapid Warming Leads to Collapse of the Gulf of Maine Cod Fishery," sparked research that shows how these waters have continued warming at an alarming rate.

Rare North Atlantic right whales glide through Cape Cod Bay in Massachusetts. These whales, some of the most endangered in the world, feed primarily on tiny creatures called copepods. As water temperatures rise, copepods have become leaner, imperiling the whales and larval lobsters that depend on them.

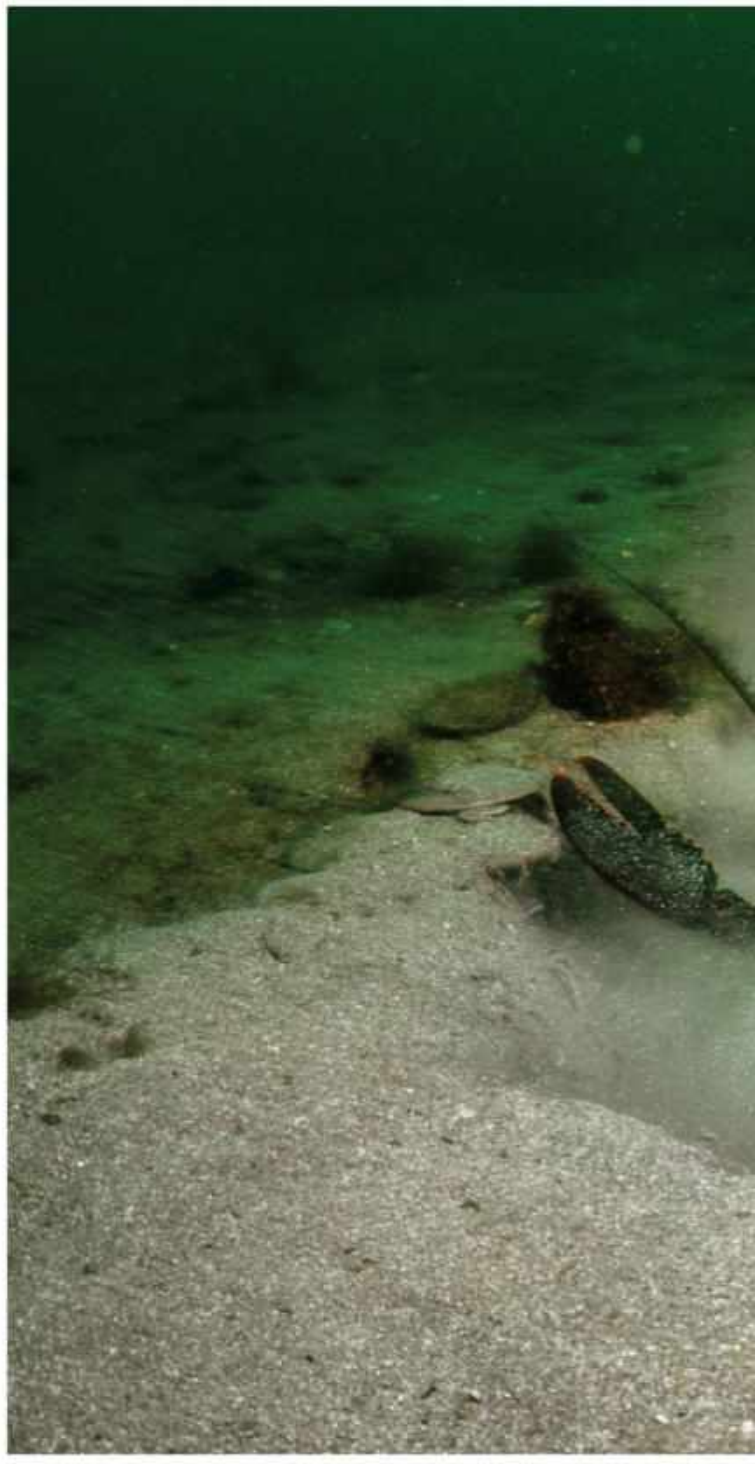
BRIAN SKERRY AND STEVE DE NEEF, TAKEN UNDER THE AUTHORITY OF NMFS MMPA/ESA PERMIT NO. 21371

the rest of the world might see. According to **CHARLES TILBURG (2),** an oceanographer and the director of marine and environmental programs at the University of New England, the gulf works "like a bathtub: If you turn down the cold water and turn up the hot water, the bathtub's going to get warmer." Tilburg has spent about 15 years tracking how the frigid Labrador Current is weakening, providing less cold water to the gulf, while the hotter Gulf Stream is shifting slightly north and adding warmer water to the region.

But despite the collective stresses of overfishing and climate change, there are some species that have benefited, if only temporarily.

So far, temperatures in the Gulf of Maine have stayed suitable for lobster reproduction—the lobster-fishing industry appears to be flourishing. But scientists have identified some troubling changes. When temperatures rise to more than 73 degrees Fahrenheit near the coast, female lobsters stay farther offshore, where offspring they release might not intersect with currents that can carry them to the food sources and habitats that are more conducive to survival. These so-called larval lobsters eat zooplankton. Their preferred prey is *Calanus,* a two-to-three-millimeter copepod that is made up of mostly fat to sustain them through the winter. **DAVID FIELDS (3),** a professor of oceanography at Bigelow Laboratory for Ocean Sciences, calls it "the French butter of copepods," good for bulking up little lobsters.

As the water warms, *Calanus* copepods no longer need as much fat and grow smaller. That means the baby lobsters lose out on nutrition. Additionally, the warming water has shifted the *Calanus*'s migration period, which is putting it out of sync with the release of larval lobsters. So even though female lobsters are producing the same number of eggs as before, fewer are surviving into adulthood. In 2023, Maine saw the lowest lobster haul in 15 years, mimicking what's been happening off the coasts of New York, Connecticut, and Rhode Island.



There's more bad news for lobsters. The same carbon emissions behind climate change affect not only the ocean's temperature but also its chemistry. The water is becoming more acidic. Fields says anything with a calcium exoskeleton or chitinous shell, from coral reefs to copepods, can get eroded by such acidification. It could potentially threaten a young lobster's fragile exoskeleton in 10 or 20 years.

Other disturbing trends have

(2) More than 60 rivers flow into the Gulf of Maine, adding water that is on average warmer than the ocean, Tilburg explains. Meanwhile, the region's relatively shallow waters also absorb atmospheric heat.

(3) Fields has found that copepods are 73 percent lipids, providing critical nutrition for the animals that eat them. These zooplankton are crucial to the survival of not just lobsters; they're the primary food for endangered North Atlantic right whales.

Two lobsters fight over a burrow near the Isles of Shoals. The species has been booming, and typical rocky shelters—where lobster predators also lurk—are becoming overcrowded.

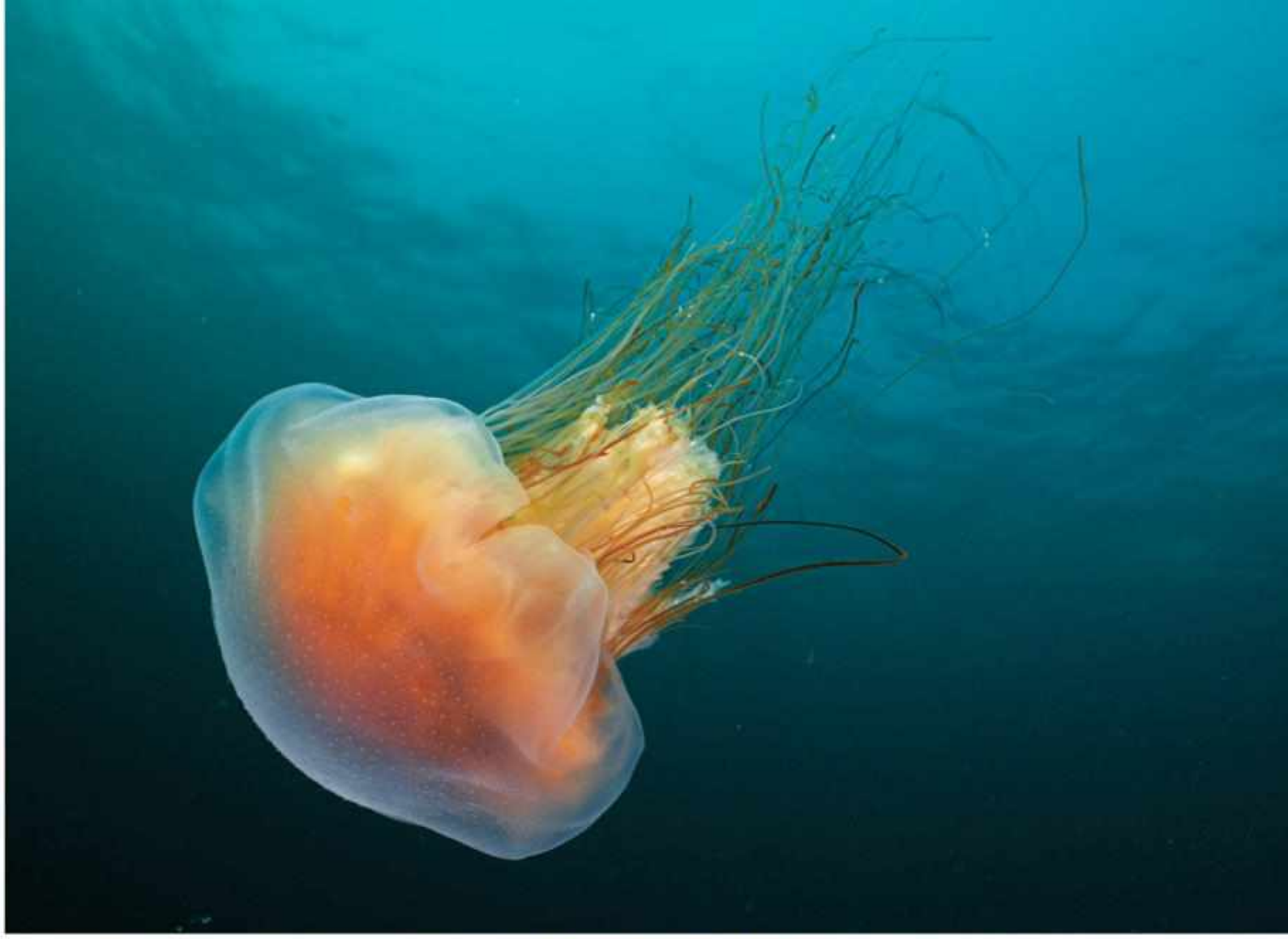
surfaced. **WIN WATSON (4),** a marine biologist and emeritus professor at the University of New Hampshire, has studied the changing pH that may endanger lobsters' ability to smell. That could make it harder for them to find food, detect predators, or sense each other's pheromones during mating season, which has already gotten more difficult because female lobsters prefer colder temperatures, while males are fine in warmer water. Mates are literally drifting apart.

On this ocean planet, what happens underwater clearly has consequences on land. For example, the changes occurring with fish populations in the Gulf of Maine are having a direct impact on seabirds. Tern parents see silver fish reflecting sunlight in the ocean and bring them back to their chicks. When parents hunt their typical prey, such as hake or herring, the hatchlings can swallow these slender, silver fish easily. But as the water warms, terns can choose their

(4) Watson has published dozens of scientific papers about lobster biology. Over the years, his research group used ultrasonic tracking, underwater video, and acoustic monitoring to study how lobsters move across the ocean floor and communicate with one another.

Sea smoke rises over the ocean near Whaleback lighthouse at the mouth of the Piscataqua River in Kittery, one entrance to the Gulf of Maine. This fog forms when very cold air moves over warmer water, mixing with a shallow layer of warmer air above the ocean's surface. As the warmer air cools, the excess vapor condenses.

Among the marvels that still exist within the Gulf of Maine are gray seals. One approached photographer Brian Skerry with wide-eyed curiosity during a recent dive at the Isles of Shoals.



On other dives in the region, Skerry encountered wondrous creatures, including this bioluminescent lion's mane jellyfish (top) and a species of filamentous nudibranch, or sea slug (bottom).

prey from a larger range of silver fish such as the wider-bodied butterfish, which have shifted north from the mid-Atlantic.

Though some adult birds still find appropriate prey, to many, a silver fish may simply be a silver fish. **ELIZABETH CRAIG (5),** director of seabird research at the Shoals Marine Laboratory, which is largely funded by the New Hampshire Fish and Game Department, has found that the chicks are unable to swallow the butterfish. They're not getting enough food, and many remain smaller and either die before they leave the nest or are too weak to migrate.

It's a poignant reinforcement of what we already know: Ocean ecosystems are in decline. I'm seeing dramatic ecological changes that should take millions of years, and yet they're happening in my lifetime. But there are success stories. Plenty of evidence shows that when we permanently protect places in the ocean, remove obstacles, and give marine

A common tern tries to feed its chick a butterfish, but the offering is too wide to swallow. Butterfish now outnumber the slender silver fish that terns favor, such as herring and sand lance.

Ocean ecosystems are in decline. I'm seeing dramatic ecological changes that should take millions of years happening in my lifetime.

life a chance, nature finds a way: It is resilient, and it can heal. But nature needs a little help.

THE ALEWIFE IS ONE story of hope in the Gulf of Maine. This species of fish is an important source of protein for many animals as it migrates from the freshwater ponds where it spawns to the ocean and then back again. In the ocean and in estuaries, where rivers flow into the sea, alewives are eaten by other fish and by birds such as eagles, ospreys, and cormorants. As they migrate into streams in the forest, they can become food for animals such as raccoons and foxes. Finally arriving at their spawning ponds, they must avoid predators like freshwater bass. Survivors of this gauntlet go back to the ocean, with their fry following a few months later.

Alewives had virtually disappeared from the gulf because dams kept them from migrating. The removal of dams in key rivers such as the Penobscot and Presumpscot, done largely in hopes of restoring Atlantic salmon populations, resulted in the revival of the alewife's ancient migratory route; runs of fish in the millions now occur every spring. One beautiful experience I've had in recent years was photographing alewives at the base of a waterfall in Mill Brook Preserve, a tributary of the Presumpscot. The fish gather there to rest before going up the falls. Lying with my camera in only two feet of water, I was surrounded by thousands of alewives

(5) Craig recently published a paper showing how butterfish migration, because of warming oceans, appears to be having an impact on tern chick survival: Nearly 80 percent of the butterfish delivered to chicks by their parents don't get eaten.

Seafood harvesters with Bangs Islands Mussels have been raising blue mussels in Maine's Casco Bay for more than a decade. The mollusks are grown on vertical lines that are attached to a raft and can be winched up for cleaning and sorting. Only those of a certain—larger—size are kept for sale, while the rest are returned to the water.

swirling around me, the way I imagine the river would have been long ago.

Perhaps the most special place I have explored in this region is Cashes Ledge, a unique underwater mountain range in the middle of the Gulf of Maine. **JON WITMAN (6),** a marine ecologist at Brown University, calls it a time machine to when the gulf was packed with marine life.

As Witman has documented, Cashes has one of every kind of offshore or subtidal marine habitat that exists off the coast of New England, with species rarely seen elsewhere. Because of the ledge's submerged rocky ridges, waves and currents push large amounts of plankton to the creatures that eat it; Witman says it's like a food elevator.

In order for climate stability to even be possible, researchers say, we need to protect a minimum of 30 percent of key habitats in the ocean. Today only about 8 percent are formally protected. For Witman, who has been studying Cashes since the 1970s, designating the area as a marine sanctuary feels more urgent than ever. By protecting it, we would help ensure healthy fishery stocks in the future. The fish biomass in Cashes is 300 times that on the coast; animals that live there obviously don't just stay in one place, so they propagate and spill over.

Cashes also contains the largest kelp forest off the coast of the eastern United States. That's important because kelp serves as both the base of the food chain and a distinct ecosystem. As a diver, I've marveled at the vastness of this amber- and crimson-colored forest swaying so far beneath the surface. For his part, Witman compares the underwater journey to Cashes to a drive through the plains of Iowa for hundreds of miles and coming across a huge mountain with a forest. And like the woods on land, kelp forests capture carbon. The ocean is the greatest carbon sink on our planet, and its phytoplankton give us every other breath that we draw.

Exactly how big a role kelp plays in that process is being studied by scientists like **DOUGLAS RASHER (7)** of Bigelow Laboratory for Ocean Sciences. He has spent nearly 10 years studying coastal kelp forests from the southern tip of Maine to its northern borders with Canada and documented their steady decline.

Rasher's research also shows just how fast things continue to change. He's seen some study sites shift from a forested to deforested state in the span of a five-year research grant.

ONE OF THE WAYS fishers have sought to mitigate potential economic damage from native species decline is by transitioning into new and sustainable ventures. Colleen Francke grew up on Cape Cod inspired by women in the fishing business. After a back injury ended her 10-year lobstering career, she launched Summit Point Seafood to grow kelp, which has a lower cost barrier than mussels or oysters. Francke submerges long lines seeded with kelp in the fall, then in spring sells the harvest to companies that make products like veggie burgers or that use the superfood to provide nutrients and a salt alternative to traditionally kelp-free fare like bread.

Another operation, Bangs Island Mussels, a family business in Casco Bay off the coast of Portland, farms kelp in conjunction with growing mussels. The company uses a method known as integrated multi-trophic aquaculture, which allows these two species to grow in harmony with each other. It has a series of large rafts offshore equipped with vertical lines seeded with mussel spat—the scientific term for tiny juveniles—that will mature and be harvested for sale to restaurant wholesalers and distributors. Going out on the water with the Bangs Island harvesters was like watching

(6) Witman is the lead scientist on the effort to achieve permanent conservation protection for Cashes Ledge, in partnership with Conservation Law Foundation.

(7) Rasher has found that warming seawater temperatures result in an invasive red "turf" that replaces habitats as kelp dwindles. This kind of underwater deforestation destroys healthy ecosystems.

craftspeople create something beautiful with their hands. The operations produce a renewable resource that may actually be beneficial to the environment.

Co-owner and CEO Matt Moretti is concerned that it will become harder for mussels to survive long enough to grow their shells in the wild because of ocean acidification. Bangs Island Mussels is developing nursery technology at its indoor facility for baby mussels, so that they have the best chance of surviving their vulnerable pre-shell period. Mussels can grow in captivity until their exteriors are thick enough to handle a more acidic ocean.

Meanwhile, some fishers are diversifying by looking to create new markets for species that have not traditionally been commercially harvested. A couple of my neighbors, Sam Sewall and Mike Masi, have teamed up to build a green crab business called Shell+Claw. Green crabs, an invasive species, live mostly in estuaries.

Green crabs were introduced into the Gulf of Maine in the 1800s, brought in by the ballast water of ships. Until recently, their population was kept in check because of the cold winters, but with climate change yielding milder temperatures, their numbers have exploded. They dig into the mud and cut off the roots of eelgrass, which captures nitrogen and carbon and acts as a nursery for estuarine species, and smooth cordgrass, which critically stabilizes riverbanks and fights erosion.

Green crabs also eat clams, historically the second or third most valuable fishery in Maine. Shell+Claw's business idea is to mitigate the damage caused by green crabs while creating another source of income for its partners who are willing to experiment. Working with researchers, Masi has started to figure out when the crabs molt, thus becoming soft-shell crabs that are edible. The goal is to mimic what's being done in Venice, Italy, where a similar type of crab is sold as a delicacy. Masi, a former marine biology teacher at the local high school, says harvesting these crabs is probably always going to be a supplemental business for fishers. But clam prices are at their lowest when green crabs are molting in late spring, so the venture can dovetail economically and give clams a chance to recover their population.

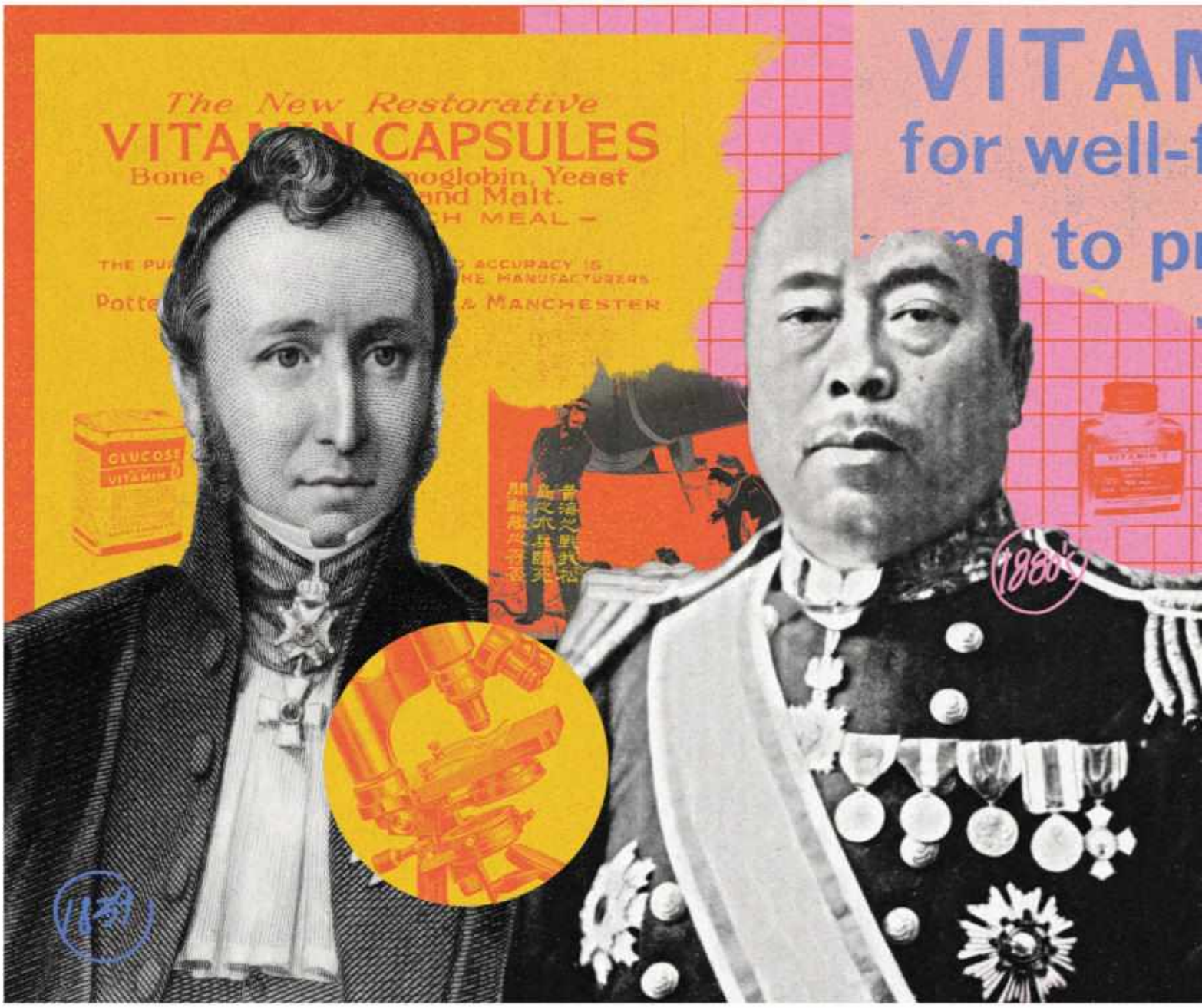
In order for climate stability to even be possible, researchers say, we need to protect a minimum of 30 percent of key habitats in the ocean.

When the shedding begins, Masi and Sewall—a 27-year-old former student of Masi's and fourth-generation lobsterman—immediately take the soft-shell green crabs to high-end seafood places in Boston and Portsmouth, New Hampshire, that are paying a premium to fry them up as sliders or tempura.

So perhaps there is hope for the Gulf of Maine. As I continue to explore these waters, I am troubled by much that I see; the warning signs mirror obvious trends in scientific data. I often think about what the Native tribes—the Wampanoag, Abenaki, Passamaquoddy, and Mi'kmaq—must have seen long ago, and I dream about traveling back in time, hundreds of years, to dive in those waters teeming with life.

Although we have lost so much over the centuries and are facing serious threats today, I still find magic in the Gulf of Maine. My hope is that, armed with the knowledge of the past and the science of today, we can save what remains. And allow it to rebound. □

A cunner hovers amid several large kelp fronds at Cashes Ledge, a marine area that researchers have identified as a vital sanctuary and hedge against climate change. Cashes's kelp forest, which supports marine life while absorbing carbon from the ocean, is the largest off the coast of the eastern United States.



NOT SO ELEMENTARY

Vitamins are familiar, everyday essentials. But their discovery and naming involved multiple scientists and a surprising backstory that continues to inspire nutritional breakthroughs.

Words by ERIN BLAKEMORE

For more than a century, many scientists contributed to the discovery of vitamins, including (from left) Gerardus Johannis Mulder, Kanehiro Takaki, and Christiaan Eijkman.

→ **VITAMIN C TO FIGHT A COLD?** Carrots for vision-boosting vitamin A? Fatty fish—and sunlight—for bone-building vitamin D? We all know that vitamins are critical for our health, but how did they get their names, and, more important, when were they found in the first place?

Though humans have always understood there's a connection between diet and health, it took thousands of years for modern nutrition research—bolstered by advances in chemistry, physics, and biology—to emerge. Early experiments focused largely on the element nitrogen, first discovered in 1772, and whether its presence or absence in foods caused animals and humans to be healthy or sick.

Then in 1838, Dutch chemist Gerardus Johannis Mulder proposed the existence of a compound he called protein, which he argued played a "principal role" in nourishment. For decades, historian Kenneth Carpenter writes, protein was considered the "true nutrient" for human health, despite emerging knowledge that fruits, vegetables, and milk eased conditions such as scurvy and rickets. While these afflictions were common among those with limited diets, researchers still blamed other factors, including infection, tainted food, and even sea air.

Meanwhile, sailors on lengthy voyages had long been suffering from another ailment: beriberi, which can cause heart failure and a loss of sensation in the legs and feet. Japanese naval physician Kanehiro Takaki had a pivotal theory. In the 1880s he noticed that poor people were likelier than their richer counterparts to develop the disease, and he suspected a lack of protein in their diets might play a role.

Dutch army doctor Christiaan Eijkman conceived his own theory about beriberi after experiments with chickens. The birds that ate the white rice common on Japanese naval vessels had similar symptoms, while those fed brown rice stayed healthy.

Eijkman pursued that line of research and discovered that prison populations fed white rice were also afflicted with beriberi. Was the processed grain part of the problem?

Polish chemist Casimir Funk zeroed in on the hull and bran removed to make

This discovery revolutionized scientific thought, suggesting that *diseases might be caused by nutritional deficiencies*—and cured by newly found compounds.

white rice and began his own experiments with pigeons in the early 20th century. Pigeons fed only white rice became ill, but they improved when they ate rice bran and yeast. The discovery confirmed Takaki's theory that diet and beriberi were linked. But the culprit wasn't a lack of protein. It was the lack of another substance, Funk theorized in 1912: a nitrogen-containing compound he called vitamine, a combination of the Latin word for "life" and "amine," the name for a compound that contains nitrogen.

This discovery revolutionized scientific thought, suggesting that diseases might be caused by nutritional deficiencies—and cured by adequate amounts of the newly found compounds. "A monotonous diet ought to be avoided," Funk declared.

Researchers rushed to isolate other micronutrients associated with afflictions such as rickets, scurvy, goiters, and more. Around the time Funk coined vitamine, American nutrition scientist Elmer McCollum conducted feed experiments with different animals and discovered that an "accessory" substance present in some fats was essential to rat growth. That fat-soluble substance became known as vitamin A.

McCollum and others did further experiments with Funk's rice bran–derived nutrient, naming it vitamin B. It turned out that the substance was actually eight water-soluble vitamins that were each given an individual name, such as thiamine, and numbered in order of discovery.

The *e* in vitamine was dropped after scientists recognized that not all the compounds were amines containing nitrogen. But the custom of naming vitamins

alphabetically in order of discovery continued. Today four fat-soluble vitamins—A, D, E, and K—are considered essential to human growth and health. So too are nine water-soluble vitamins: B1 (thiamine), B2 (riboflavin), B3 (niacin), B5 (pantothenic acid), B6 (pyridoxine), B7 (biotin), B9 (folate), B12 (cobalamin), and C.

One vitamin jumped ahead in the alphabet. Given its discovery date in 1929 by Danish researcher Carl Peter Henrik Dam, vitamin K likely would have been labeled with an earlier letter. But Dam's research revealed that the substance was essential for blood coagulation—a word that starts with *k* in Scandinavian languages and German—and he proposed the new name instead.

The last essential vitamin, B12, was discovered in 1948. Since then, researchers have focused on the health benefits of vitamins, learning more about the links between deficiencies and disease and using the substances to treat conditions such as pellagra and anemia. It appears unlikely that scientists will ever discover a new essential vitamin; all of our nutritional deficiencies seem to be accounted for.

That doesn't mean nutritional discovery has halted. In fact, this type of research is more advanced than ever, allowing scientists to delve into the secrets of even tiny traces of micronutrients that affect human health. If the golden age of vitamin discovery is considered to be an appetizer of sorts, then scientists are hunkering down for the main course—a rapidly evolving understanding of the many ways food shapes our health and our lives, one microscopic substance at a time. ▯

Clockwise from right: Casimir Funk identified the first vitamin, later called B. Carl Peter Henrik Dam found K, and Elmer McCollum discovered A.

ILLUSTRATIONS BY MAX-O-MATIC. SOURCE PHOTOS: SCIENCE PHOTO LIBRARY (MCCOLLUM); BETTMANN ARCHIVE/GETTY IMAGES (FUNK); SCIENCE HISTORY IMAGES/ALAMY STOCK PHOTO (DAM). BACKGROUND: ALAMY STOCK PHOTO (TWO); SCIENCE HISTORY IMAGES/ALAMY STOCK PHOTO; SCIENCE MUSEUM GROUP (TWO); UNDERWOOD ARCHIVES/GETTY IMAGES

PREVIOUS PAGE SOURCE PHOTOS: UNDERWOOD ARCHIVES/GETTY IMAGES (MULDER); NATIONAL DIET LIBRARY, JAPAN (TAKAKI); NATIONAL LIBRARY OF MEDICINE (EIJKMAN). BACKGROUND: ALAMY STOCK PHOTO; ALBUM/BRITISH LIBRARY/ALAMY STOCK PHOTO; BLANK ARCHIVES/GETTY IMAGES; ALLAN CASH, ALAMY STOCK PHOTO; CHRONICLE/ALAMY STOCK PHOTO; HEIN NOUWENS, SHUTTERSTOCK; SCIENCE MUSEUM GROUP (FOUR)

RESCUING HISTORY

WHEN A PEOPLE'S STORIES ARE AT RISK, WHO STEPS IN TO SAVE THEM?

Words by
NINA STROCHLIC

Photographs by
EMILY GARTHWAITE
in Kurdistan **&**
DIANA MARKOSIAN
in Somaliland and Kosovo

Mam Ali stands atop Peris Mountain in northern Iraq. The mountains have long been home to Kurds who still fight for a nation of their own. A Kurdish archive seeks to preserve stories like his.

A snapshot of relatives serving as *peshmerga* soldiers on Mount Karox was among the last things Faruk Sadri, a Kurdish midwife, grabbed as she fled Saddam Hussein's 1988 attack on her village.

Seddiq Salih had a favor to ask. It was dusk, and we were standing in his family's small orchard on the outskirts of Slemani, a city known as the cultural capital of Iraqi Kurdistan.

I'd been granted a meeting later that night with a secretive elder sheikh rumored to possess one of the finest collections of Kurdish manuscripts. Seddiq, a mild-mannered 65-year-old with a permanent smile, now looked serious. "Ask him: 'You have collected so many manuscripts, why not give some to Zheen?'"

Zheen, which means "life" in Kurdish, is the name of an archive that Seddiq and his brother Rafiq have spent more than two decades building. An assemblage of books, manuscripts, newspapers, letters, diaries, and other documents dating back to the 19th century, it presents the twisting saga of the Kurds, often described as one of the world's largest ethnic groups without a state. Collecting these artifacts is a calling that has taken the brothers across the parts of Turkey, Iran, Syria, and Iraq that compose greater Kurdistan—a mountainous region where up to 35 million people of different religions and customs identify themselves as Kurdish.

The Kurds' story zigzags from life in the mountains overlooking Mesopotamia, to medieval conquests led by the famous warrior Saladin, to betrayal after World War I when the Allied powers denied them a state of their own, to the bloody campaign in 1988 by then president Saddam Hussein to wipe them out in Iraq. It's a history that has made them cautious and distrustful. It has also infused the Salih brothers with a sense of mission. The Kurds may be without a state, but if Seddiq and Rafiq persevere, their people won't be without a richly documented story.

As we lingered in the cold night air, I was surprised by Seddiq's request. He and Sheikh Mohammed Ali Qaradaghi

had known each other for more than 20 years. He explained that the sheikh never allowed anyone to see his full collection. It was said to hold hundreds of documents spanning 400 years, and Seddiq was fixated on what it might contain. A diary recording critical political events, a lost masterpiece of poetry, a secret diplomatic letter?

In the business of archiving, every lead offers the tantalizing promise of a fresh piece of the collective story. And the Kurds' story, Seddiq said, had been suppressed for generations. "This work we do is a war. A very peaceful war," he told me.

"Please ask him."

Like a detective, an archivist collects evidence to create a full picture of events. Imagine trying to tell the history of the United States from only the British point of view. And think how our understanding of history would change if Abraham Lincoln's Gettysburg Address, the writings of Che Guevara, or the speeches of Nelson Mandela had been lost. The story gains context and nuance with each infusion from its myriad communities: the creation stories of the First Australians, the paintings of Frida Kahlo, the music of Aretha Franklin.

Most developed countries have sprawling, well-funded repositories. Even small developing nations such as Guinea-Bissau and Palau maintain modest national archives. But what about groups like the Kurds who fall between the cracks of officially recognized nations, people living in places shattered by conflict, whose culture and history are excluded from the prevailing narrative?

Their history often ends up shoved into bags and boxes and tucked away in attics. My grandparents fled Poland after the Holocaust, and growing up, I'd marveled at the line on their visa application where a U.S. immigration official had marked their nationality as "without." The only documented evidence of their lives as Jews in Poland, and our family's centuries in Europe, was a clutch of documents we kept in a yellowing suitcase: a temporary Polish passport, identity cards from the concentration camps, a handful of photographs.

For years, I've searched for the ways "stateless" people seek to reclaim their stories after displacement and destruction. In the young nation of South Sudan, I followed archivists who had gathered rotting documents from basements in an attempt to build a national identity. In refugee camps and on migrant trails, I asked the displaced what they'd brought from home.

For many, these items are a means of maintaining their identity when officially they may not have one. And sometimes, everyday civilians, under extraordinary conditions, risk their lives to save them. In Kurdistan, Kosovo, and Somaliland—regions still struggling for their nationhood—I found these people.

The stories they are holding close, or attempting to piece back together, are not static, said Anne Gilliland, a professor at UCLA who studies the role of archives and memory in war zones, frozen conflicts, and unrecognized states. They're alive. And in war they're often targets. "Obliterating a record is a way of obliterating people," Gilliland told me.

That puts the people who save them on the front lines of a quiet but crucial battle over history and memory.

In the business of ARCHIVING, every lead offers the tantalizing promise of a fresh piece of the collective story.

PART 1 •

KURDISTAN

WEARING A LONG white robe and prayer cap, Sheikh Mohammed Ali Qaradaghi ushered me into his home in a well-to-do Slemani neighborhood. He fingered a string of amber prayer beads as he described his more than 20 years as a consultant for the Iraqi House of Manuscripts in Baghdad. During those years, he'd learned of historical Kurdish documents held by antique dealers and private estates. He began to buy them for himself, ensuring they wouldn't be lost or taken out of the country. Later, Saddam's regime jailed him as a Kurdish activist, using his collection as evidence of his guilt.

As Seddiq had predicted, the sheikh was reluctant to say how many manuscripts he had. He agreed to show me just one book. It had a handmade brown cover and was filled with pages of handwritten Kurdish script and colorful flourishes. "It's a *kashkul,"* he said, describing a scrapbook of favorite poems, scriptures, and vignettes from Kurdish literature. This one had belonged to a Kurdish writer a century ago. In other kashkuls the sheikh had found unpublished poems from Nali and Salim, beloved Kurdish poets.

I took this moment to pose Seddiq's question: Why not donate some of his collection to Zheen? The sheikh was known to be generous with scholars, often lending manuscripts to be studied and copied. But the originals lived with him. Shouldn't this unique book be in a Kurdish national archive?

His son, Amjad, spoke up: "We want a national archive to be under government authority, not a party, not a person. Once that's in place, he'd be happy to give his collection."

Later, when I relayed the sheikh's answer, Seddiq wasn't surprised. Persuading scholars to part with their collections has been difficult, in part because Seddiq isn't a professional historian—he's a retired geologist. He launched Zheen as a side project after U.S.-led coalition forces halted Saddam's crackdown on the Kurds in 1991. As an autonomous Kurdish government within Iraq took shape, Seddiq began to feel that while the Kurds were no longer at risk of being erased, their history was.

In the late 1990s, he and his brother started collecting books written by Kurdish historians and literary figures. They tracked down old issues of Kurdish periodicals, including an edition of *Zheen,* an early Kurdish-language magazine published from 1918 to 1919 and the name they took for their project.

"Because Kurds weren't independent, other people wrote their history for them," Seddiq said, referring to Ottoman, British, and Iraqi chronicles. "The Kurdish voice is missing. That's what we're looking for."

Eventually, the local government donated a four-story building in downtown Slemani. The regional government provides funding for 14 staff members' small salaries.

Among the treasures on Zheen's shelves are 1,300 original manuscripts and hundreds of rare books, including a later copy of the first known book published about Kurdish history, *Sharafnama,* written in Persian in 1597.

Over time Zheen has dedicated rooms to the private collections of various intellectuals and politicians and digitized documents from the British colonial period. To date, it has amassed an archive containing more than 72,000 books, nearly 2,000 Kurdish magazines and newspapers, thousands of

NGM MAPS

photographs, and hours and hours of audio and video recordings.

And they're continually searching for more. They appeal to the families of historical figures and scour markets and the internet.

One September morning I accompanied Seddiq to meet the daughter of Rafiq Hilmi, a Kurdish historian, poet, and political activist who served as a translator for British colonial leaders during the early 20th century.

At a well-appointed home, she greeted us wearing all black, her white hair pinned in an elegant loop against the nape of her neck. Seddiq introduced us and told me that her name, ironically, was Zheen, the same as the archive. "We named ourselves after you," he teased her.

Shenah Abdullah, an anthropologist who works at the Kurdistan Institution in Slemani, accompanied us. Four years ago, she and Seddiq had come to discuss acquiring Zheen's father's papers, and Shenah noticed other boxes tucked into a corner. Their contents sketched the remarkable life of Zheen's older sister Nahida, a trailblazing world traveler and writer who had died a few years earlier.

Soon Shenah was immersed in Nahida's world. Handwritten letters and diaries detailed her love life, newspaper clippings announced her arrival at Clark University in Massachusetts in 1949, and postcards told of friendships from Oregon to Damascus. Though Nahida hadn't studied anthropology, she wrote prolifically about the food, language, and customs of every place she visited.

Never had Shenah read such a

KURDISH HOMELANDS

Some 35 million Kurds reside today in the mountains spanning Turkey, Syria, Iraq, and Iran. An ethnic minority, they have long sought a country of their own. From the Ottoman Empire in the early 1500s to the countries that succeeded it, Kurdish-populated areas, with the exception of northeastern Iraq, lack autonomy.

*KURDISH POPULATION FIGURES ARE ESTIMATES.
MATTHEW W. CHWASTYK, NGM STAFF

SOURCES: CIA WORLD FACTBOOK; UN WORLD POPULATION PROSPECTS; KURDISTAN REGIONAL GOVERNMENT; YEREVAN SAEED, AMERICAN UNIVERSITY

RUSSIA

Sea

El'brus
18,510 ft

CAUCASUS MOUNTAINS

Caspian Sea

GEORGIA

Kura

Tbilisi

Sinop

Samsun

Pontic Mountains

Trabzon

Kurds within Armenia
1.1% (31,000)

2.8 million

ARMENIA

Yerevan

Kars

AZERBAIJAN

Baku

Kurds within Turkey
19% (16.3 million)

85.8 million

Kızılırmak

Erzincan

Euphrates

Ağrı

Mt. Ararat
16,854 ft

Aras

NAXÇIVAN (AZERB.)

Kayseri

Tunceli

Bingöl

Murat

Lake Van

Elazığ

KURDISH-INHABITED AREA

Taurus Mts.

Ceyhan

Van

Lake Urmia

Kurds within Iran
10% (8.9 million)
includes population in eastern Iran

Tabriz

Diyarbakır

Batman

Siirt

Atatürk Res.

Hakkari

Urmia

89.2 million

Adana

Gaziantep

Şanlıurfa

Mardin

Dihok (Dahuk)

Elburz Mountains

Al Qamishli

Peris Mt.

Afrin

Heshtika

Antakya

Al Hasakah

MESOPOTAMIA

Mosul

Mt. Karox

Qazvin

Aleppo

Hewler (Erbil)

Idlib

Ar Raqqah

Tigris

Tehran

SYRIA

Dayr az Zawr

Kirkuk

Slemani (As Sulaymaniyah)

Hamah

Helebce (Halabjah)

Tartus

Kurds within Syria
10% (2.3 million)

KURDISTAN REGION

Kurdish autonomy in northern Iraq, established after the 1991 Gulf War, was made formal in Iraq's 2005 constitution.

LEBANON

Euphrates

Samarra

Beirut

23.2 million

IRAN

Damascus

Kurds within Iraq
15–20% (6.9–9.2 million)

*Kurdish percentage of country's population

Baghdad

Ilam

Zagros Mountains

Karkheh

ISRAEL

SYRIAN DESERT

Karbala

Al Kut

Amman

JORDAN

IRAQ

46.2 million

Total population of country; size of graphs proportional

Dead Sea

Jerusalem

SAUDI ARABIA

Ahvaz

An Nasiriyah

Shatt al Arab

Basra

KUWAIT

Kuwait City

Persian Gulf

1923: REDRAWING THE MAP

Turkey rose from the fallout of the Ottoman Empire's defeat in World War I. The Treaty of Lausanne, between the new country and the Allied powers, saw Turkey relinquish former dominions, such as Iraq and Palestine, but didn't provide for a Kurdish state as previously promised by the Allies.

Former extent of the Ottoman Empire, 1914

Boundaries of 1923 are shown; dashed lines were undefined.

Cousins in Heshtika village in the Zagros Mountains dress up for Ramadan's end. The historical accomplishments of Kurdish women are starting to come into view in preserved documents.

detailed account from a Kurdish woman's perspective. This archive told a story few people knew. Seddiq agreed, and Nahida's collection became the first woman's library added to the Zheen archive.

In the doorway to Zheen Hilmi's home, Shenah kissed the older woman's cheeks and squeezed her hands. We were led into a living room, and sat under a wall covered with black-and-white family portraits. Zheen has no children, and these visits were welcome company.

She ferried platters of flatbread, truffles, and dainty walnut pastries from the kitchen as Seddiq repeated a question he'd asked Zheen many times: Is there anything else she might consider donating?

At first, Zheen claimed there was nothing left. Seddiq politely pressed the question. It was a familiar dance between them.

Finally, much poking around in boxes and bookshelves in the upstairs bedrooms unearthed two new treasures: a marbled notebook filled with her father's handwritten account of the British Empire's rule, and a small black diary of Nahida's.

As an anthropologist, Shenah had grown convinced the heritage they gathered was not just for Kurdistan. It was to draw out the similarities of a global citizenry. To tie a connective string between an Amazonian tribe who sang songs on the hunt and a Kurdish farmer who hummed melodies as he sowed his fields. Or perhaps to show how women's contributions to history had been hidden in diaries and letters in Kurdistan, in Uganda, in the Soviet Union.

"These records are not just ours," she said. "They're the world's."

Photographer Emily Garthwaite found these images (above and right) in an antique shop in Hewler, Iraqi Kurdistan's capital. "They were in a box," she said. "Their subjects' identities and stories are now lost."

Garthwaite decorated the images with herbs and flowers from the region. Kurds are known as mountain people, she noted. “This seemed like a way to honor them and at least restore a bit of their story.”

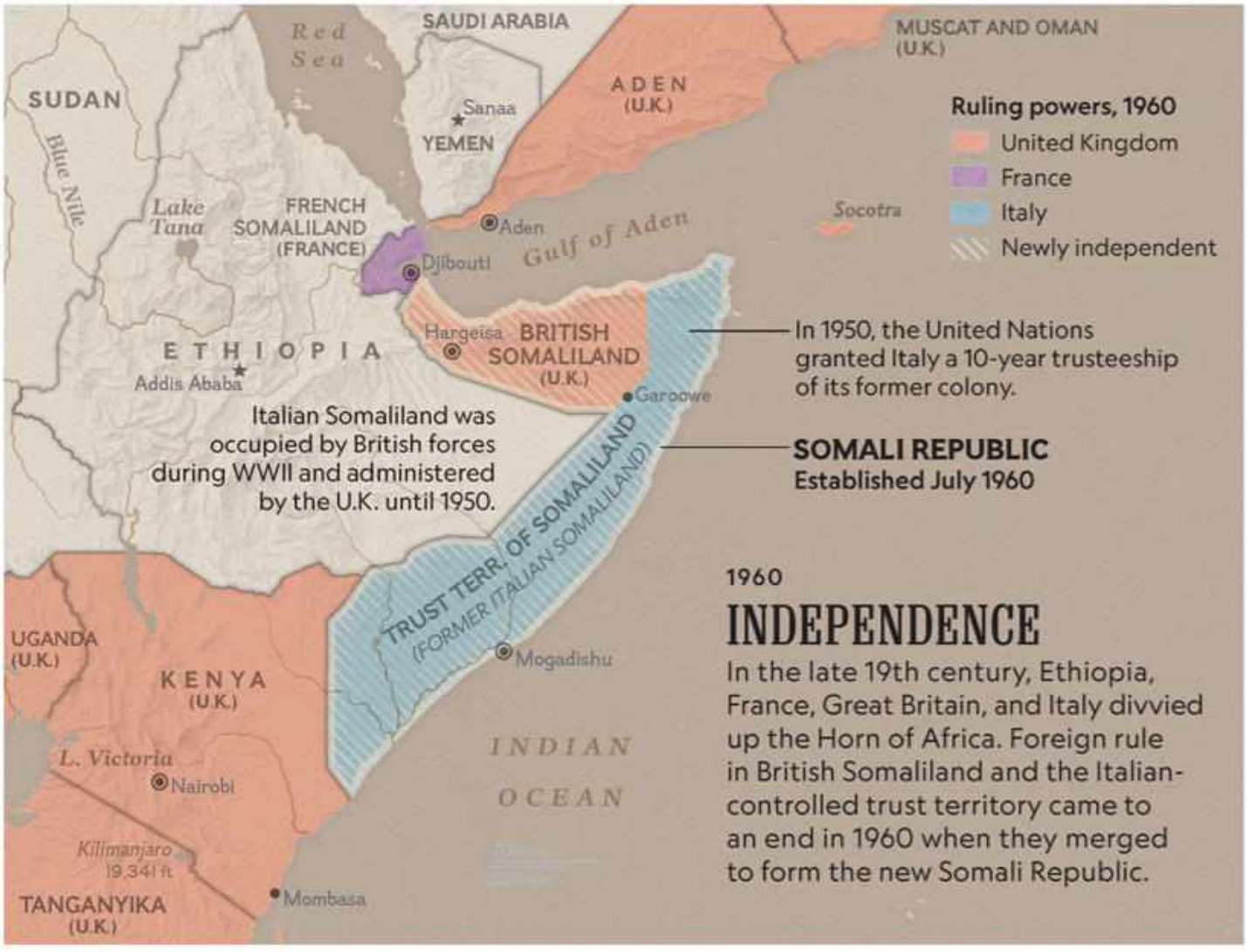
PART 2 •

SOMALILAND

AFTER THE SUNSET prayer on an evening in May, when everyone else had gone, Hafsa Omer placed three cassette tapes on her desk. Her office occupied one side of a small building on the grounds of the Hargeysa Cultural Center, in the capital of Somaliland, which has existed as a self-declared republic since breaking away from Somalia in 1991. Once, the region was called the land of the bards, and its capital was known as the home of literature. With the war's end, little evidence of that heritage remained.

But now it was quiet. Hafsa liked to work late so she could listen to the cassette tapes cluttering her desk without bothering her colleagues. Her job was to study the handwritten labels, decipher lyrics distorted by crackles and clicks, and determine which old songs, poems, or plays they held.

She started interning at the center after high school, and now worked full-time archiving the thousands of tapes lining the walls. They offered a soundscape of a nation she never knew—when plays premiered at the National Theater, music shops blasted their offerings on every corner, and poets recited verse that



MAPS: MATTHEW W. CHWASTYK, NGM STAFF. SOURCES: CIA WORLD FACTBOOK; UNITED NATIONS

criticized the government.

Every time she popped one of the cassettes into the player, a surprise awaited. Tonight she hit PLAY, and out poured a flood of salutations, announced in the old style.

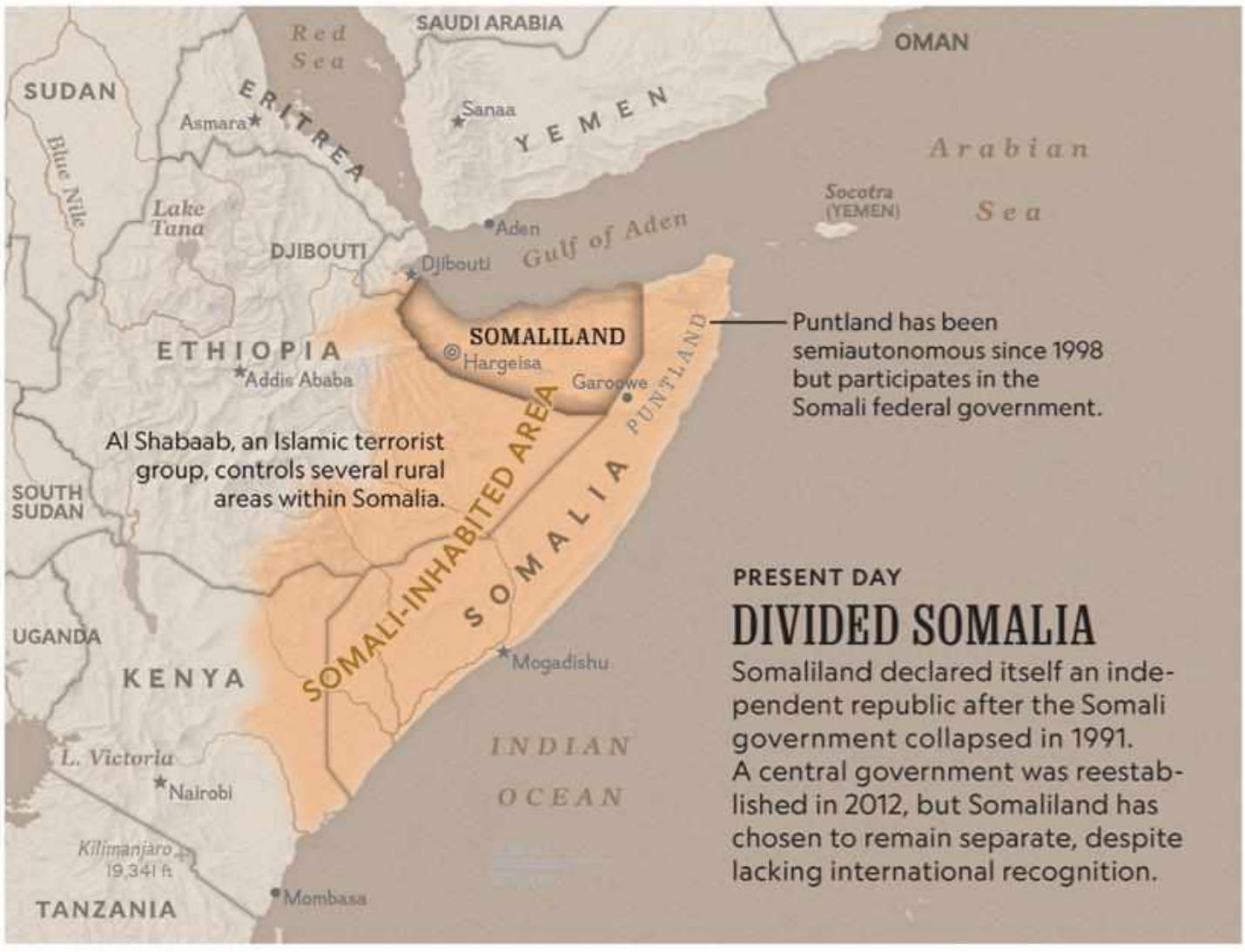
"I'm sending you a greeting wider than the ocean and sweeter than honey," it began. "A greeting that comes from the bottom of my heart. A greeting of siblings. The most graceful greeting that someone can send to someone else. I'm greeting you with flowers and wet leaves."

Before it ended, Hafsa began to cry.

Somaliland's current borders are based on an 1800s colonial division, which separated a British protectorate from Italian Somaliland. In 1960 the former colonies merged, creating the Somali Republic, but a secession movement brewed in what had been British Somaliland. In the 1980s, war erupted, and President Mohamed Siad Barre's government in the south launched a genocidal campaign against the Isaaq clan, Somaliland's majority ethnic group.

Somalis often say that their history was rarely written down. As far back as anyone can trace, Somalis have practiced an oral culture, and the traditions of live storytelling, singing, and reciting drama and poetry have remained a bedrock of their identity. The rise of cheap tape recorders made the cassette a ubiquitous part of Somali culture, and the 1970s and '80s became a golden era for Somali music.

By chance, I heard about an album containing songs from that era, *Sweet as Broken Dates: Lost Somali Tapes from the Horn of Africa*. The producer told me that as civil war ravaged towns and cities, Somalis saved their precious recordings by hiding them, burying them, or



PRESENT DAY

DIVIDED SOMALIA

Somaliland declared itself an independent republic after the Somali government collapsed in 1991. A central government was reestablished in 2012, but Somaliland has chosen to remain separate, despite lacking international recognition.

Dancers from the Halkar Academy pose outside Hargeisa, the capital of Somaliland. Since 2013, the academy has taught young Somalis traditional dance, music, and poetry to keep the culture alive.

smuggling them out of the country.

This led me to the Hargeysa Cultural Center, founded by Jama Musse Jama, a mathematician who'd been living in Italy since the war. When Jama returned home, he marveled at the capital's new buildings. But he also noted that not one was reserved for the arts. "We built beautiful structures, but we didn't heal our young people from the trauma we passed on," he told me. "We didn't give them something they feel proud of."

So in 2014 he founded the center for young Somalis to learn about their heritage. And the way to reach their souls, Jama reasoned, was through their ears.

He purchased a trove of 3,568 cassettes from a defunct music studio. In London, a scholar provided 70 recordings of poetry recited by members of Somaliland's nomadic desert tribes. Jama also received other collections that had been abandoned by their owners or tucked into bags as families fled the fighting. Soon 10,000 more cassettes filled a storage room in his home.

Occasionally, she'd insert a cassette and a message would play. These 'LETTER TAPES' had come from across the world.

He hoped these tapes could build a bridge to the past—revealing a vibrant Somali culture that younger generations would learn from and take pride in.

Hafsa, born in 2002, had no memory of a culturally flourishing Somaliland. After the war, an imported, stricter form of Islam took hold. Even her mother scolded her for listening to music instead of the Quran.

But at the cultural center, Hafsa entered a different world as she logged freshly digitized tapes, researching their contents and indexing the hundreds of singers, poets, composers, and religious scholars. She noted the songs' themes: love, lament, debate, patriotism, and *dagaalgelin*—tunes that encouraged people to fight against oppression. The music of her generation lusted after girls and new cars. But in the old songs she heard stories of love that bloomed during wartime.

Occasionally, she'd insert a cassette and a message would play. These "letter tapes" had come from across the world: Djibouti, Kenya, Italy, and Dubai, everywhere the Somali diaspora had fled.

One night, Hafsa's father went to the cupboard where he kept the family's passports and retrieved three cassettes to add to the archive. Two contained love songs. The third, recorded on January 25, 1985, was the one that made her cry.

The raspy voice belonged to her beloved aunt Khadija. It sent news to a brother in Dubai: One brother's farms were doing well, another's business went bankrupt, another had welcomed a new son, two sisters had gotten divorced. In the background, a baby cried. The tape continued: War seemed imminent. Government soldiers had arrived in their village and forced them to move, even taking their food. "What can we do?" Khadija said. "We don't know why we have this curse."

In turn, her sisters and nieces offered their wishes and news, often chastising the brother for not sending updates. "Why didn't you send us any cassette tapes?" one niece pleaded. They'd give the tape to a neighbor, a policeman who'd make sure it reached Dubai, another sister said. Then Khadija returned. "You can listen to our voices, and we can be your company," she said.

Khadija died suddenly in 2019, but hearing the familiar voice made Hafsa feel as though her aunt was still with her. She set the tape aside to add to the archive. It belonged with the other voices that told the history of their new nation.

Hafsa Omer (at left) enjoys playing basketball with her sister, Asma, when not working at the Hargeysa Cultural Center. There she catalogs cassettes containing music, poems, and letters that tell stories of Somaliland, a breakaway republic not recognized by UN member states.

PART 3 • # KOSOVO

IT WAS A HOT JUNE DAY in 1999 when Nehat Krasniqi returned to Kosovo's National Library in Pristina. The first things he noticed were the dirty clothes, beer bottles, and military maps that littered the reading rooms. In one of the last chapters of Yugoslavia's civil war, the Serbian military, backing Kosovo's ethnic Serbs, attacked ethnic Albanians attempting to create an independent nation. Roughly 13,500 people were dead or missing, the vast majority of them ethnic Albanians. Now the fighting had stopped, and people like Krasniqi were picking up the shattered pieces. Over the past decade, the National Library's distinctive downtown building—famous for its 99 domes—had at various times been inhabited by refugees and soldiers. As Krasniqi toured the rooms, he had only one question: Did the papers he'd once dedicated his life to saving survive Kosovo's war?

Like all students in Kosovo, Krasniqi had learned about the Roman and Ottoman conquests of the region, followed by the socialist rule of Josip Broz Tito's Yugoslavia. But during his doctoral research, Krasniqi was surprised to stumble upon numerous

MAPS: MATTHEW W. CHWASTYK, NGM STAFF. SOURCES: CIA WORLD FACTBOOK; KOSOVO AGENCY OF STATISTICS

manuscripts describing the history from the perspective of Albanian Kosovars—not their conquerors. These finds, he felt, were proof of a thriving intellectual past and the deep roots of Albanian language and culture. It was a story that didn't appear in Tito's authorized history.

As a specialist for the National Library, Krasniqi began traveling the country, gathering manuscripts that reflected this Kosovar identity. In towns that had been Ottoman trading posts, he found documents stuffed into attics and basements, coated with mouse droppings and cobwebs. He unearthed poetry and prose written by local authors in Ottoman Turkish, Arabic, and Persian. Once a young woman opened a yogurt container to reveal a 17th-century copy of *Cuneus Prophetarum,* a Catholic catechism that was among the first books written and printed in the Albanian language.

With hundreds of newly found manuscripts, he established a special collection at the National Library and set about translating and cataloging them. But in 1989, when Serbian president Slobodan Milošević invoked martial law, ethnic Albanians were dismissed from state jobs. Police arrived at the National Library and ordered Krasniqi to train his Serbian replacement.

Ten years later, after a NATO intervention ended the war, Krasniqi finally returned to the garbage-strewn library. He discovered that nearly all its Albanian-language books had been sent to pulping mills. But in his former office, he found his manuscripts in cardboard boxes. They'd been damaged by sun and water, but they'd survived.

"Milošević wanted to erase huge chunks of our

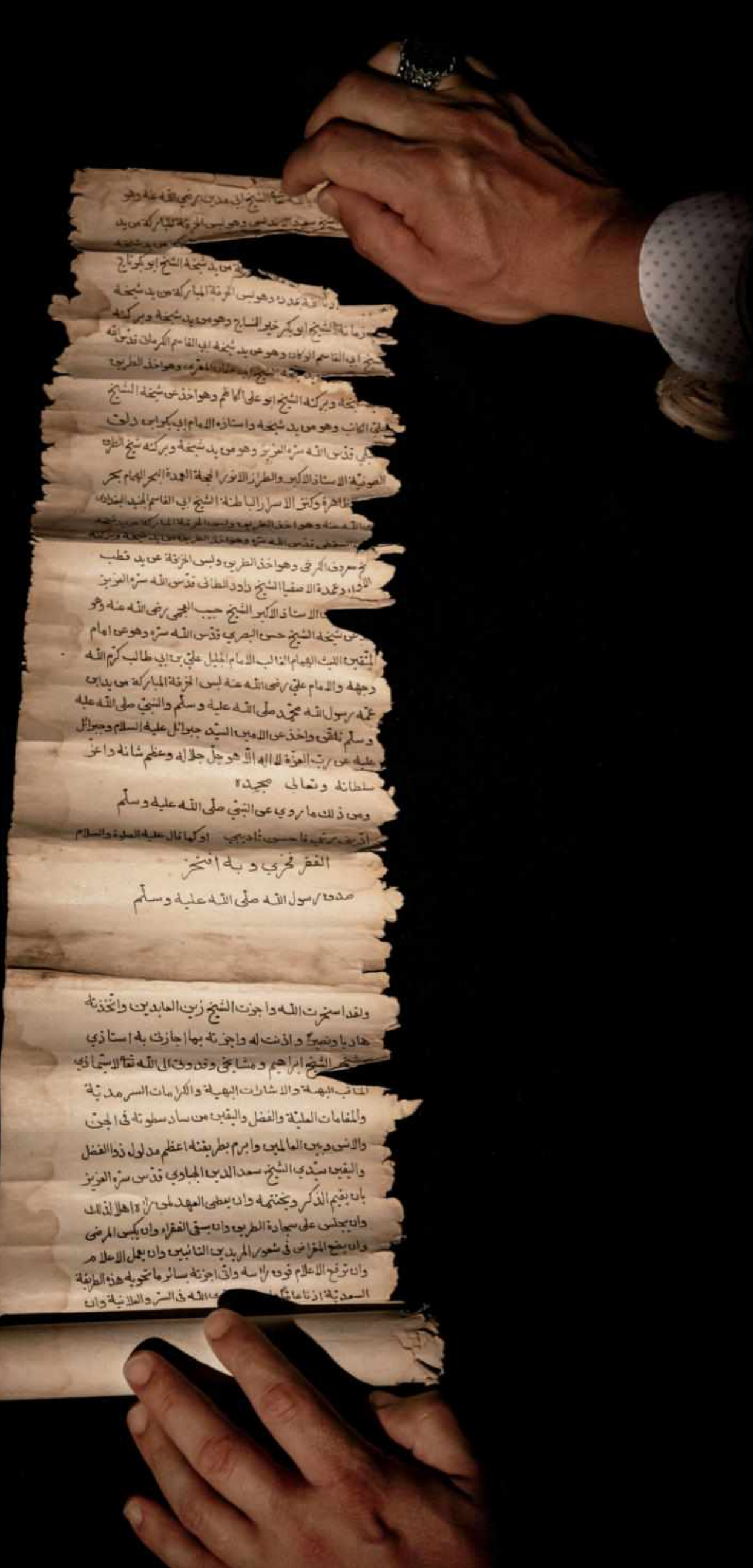
PRESENT DAY

KOSOVO EMERGES

Following the violent breakup of Yugoslavia during the 1990s, Kosovo's ethnic Albanians fought for independence from Serbia, which backed the minority ethnic Serb population. Kosovo declared independence in 2008, and more than 100 UN members have recognized it. Serbia continues to claim it as a province.

Dervishes unfurl a rare scroll at a Sufi *tekke,* or shrine, in Gjakova, Kosovo. For centuries, tekkes collected writings on a number of subjects—history, science, religion. Many were destroyed during the Kosovo War.

A dervish at the tekke of Sheikh Emin in Gjakova displays one of its oldest manuscripts. Gjakova, an Ottoman trading hub, attracted mystics and scholars from across the empire. They brought manuscripts written in an array of languages and translated them into Albanian. Now these works may shed light on a thriving intellectual past and the roots of the Albanian language.



Bedrije Mekolli, head of special collections at Kosovo's National Library, holds a German translation of a biography of Gjergj Kastrioti, who led a 15th-century Albanian rebellion against the Ottoman Empire. During the Kosovo War, Serb forces destroyed many of the library's Albanian-language books.

history," Krasniqi told me, "because that's how you can make a nation submissive, and keep it enslaved. Knowing your history is a fuel for freedom."

Determined to find what pieces of Kosovo's past survived, Krasniqi drove through the charred landscape. Homes and mosques lay in ruins, and the stench of corpses emanated from wells. Old documents were a low priority as people mourned the dead and tried to rebuild, but at each house Krasniqi made the same plea: If you have any old books or manuscripts, let the National Library buy them.

When I visited him in Pristina, Krasniqi, now 65, had retired from the library. Over espresso in a downtown café, he described his years ferreting out manuscripts after the war.

There was one place he couldn't bear to return to: The city of Gjakova had a renowned *tekke,* or Sufi temple, which was believed to be a birthplace of Albanian nationalism. Shaped by three brothers who revolutionized Albanian education, literature, and ideology in the 19th century, the Bektashi tekke had served as a center of political activism and religious study.

When Krasniqi visited before the war, he'd been awestruck by the ornately illustrated manuscripts, collections of poetry, and hundreds of codices on topics such as astronomy and medicine handwritten by revered scholars. One of the library's prized possessions was a copy of poems written by Shams i Tabrizi, the spiritual guide of the 13th-century poet Rumi, translated into Albanian. These were some of the rarest documents Krasniqi had ever seen. Because the dervishes were so secretive, few of the holdings had been studied. "There were manuscripts you couldn't even measure in gold," he recalled.

During the war, the tekke was burned, its library reduced to ash. It was, Krasniqi believes, one of Kosovo's greatest cultural losses. He had been too devastated to return, but now he offered to take me there to help me understand the destruction.

A week later, we stood in the arched entryway of a stucco building. A tall man with a flowing gray beard led us inside the rebuilt Bektashi tekke. Rauf Radonici was a longtime Sufi dervish who served the order. He pointed out photos that showed the tekke's skeletal postwar remains. He learned it had burned, he said, when he was living in a refugee camp in Albania in 1999. He'd wept so violently that people assumed his family had been killed.

Krasniqi brought up the precious manuscripts—had they all been destroyed?

"Yes," Radonici said, his hand over his heart. "That knowledge is lost forever."

He led us to a small office, and Krasniqi sighed as he scanned the modest collection of modern books. Then something caught his eye. Near the floor, a small stack of paper leaned against a bundle of leather-bound volumes. He gently lifted a page and inspected it closely. "This is very interesting, actually," he said. It was a handwritten copy of the first prayer in the Quran. Its curled lettering was a rare example of one of Kosovo's most beautiful styles of religious calligraphy.

These were donations, the dervish explained. After the war, he'd pleaded with the community to rebuild the tekke's library with whatever they could find.

With reading glasses perched on his nose, Krasniqi crouched to examine a tiny handwritten prayer book from 1816. This might be valuable, he said, passing it to the stunned dervish. He made a pile: fraying Ottoman tax records, religious scripture, personal letters.

Sweat beaded on Krasniqi's brow as he scanned the shelves. This was how he'd spent much of his career: looking for lost treasure. He pulled out two small books with elaborate designs. If they'd been better preserved, they could've been of huge artistic value, he said. Still, they were important enough to be kept aside.

We went downstairs for coffee, and Krasniqi seemed revived by the joys of discovering something new. For decades he had fought against the ravages of time and conflict, politics, ignorance, and even the indifference of his own country. But there were still jewels of history to be found, and people who would cherish them.

It is, as Seddiq Salih in Kurdistan told me, a peaceful war. He first drew that comparison over tea at an Italian-style café in a newly built development in Slemani.

A sign for the towering gray and white apartment buildings boasted of a "better life style." Around us, young people smoked hookahs and scrolled through Instagram. In comparison, Seddiq, a man his colleagues nicknamed "the encyclopedia," might seem like a relic, someone unearthing a bitter past while his nation tries to move on.

Seddiq's peaceful war was at times against an oppressor, at times against the apathy of his own people. Like Krasniqi in Kosovo and Jama in Somaliland, when he looked over the dotted-line borders of his nation, he saw the Kurds, and his life's goal of preserving their history, set against greater geopolitical interests. And he knew that at any moment his work could grind to a halt again.

Seddiq used to worry primarily about the archive's physical safety, but now many of the important manuscripts, books, and magazines have been digitized, and his fears have turned existential. He and his brother are getting older. They don't drive in the same car or travel abroad at the same time. Their work—persuading a nation, one person at a time, to trust them with its history—is exhausting. Who will dedicate their life to this cause for little money or glory after they're gone?

I thought back to how weary Seddiq had looked as we left the home of Zheen Hilmi, with two small books to show for nearly four hours of negotiation.

A few days later, at the Zheen library, I'd opened the diary of Nahida's that her sister had donated. It began on New Year's Eve, 1960, in Baghdad. Nahida, 32 at the time, was fretting about her father's strict rules and pining for an ex-boyfriend in Europe. She wrote that she'd confessed to him that she hoped to publish her memoirs—but only after she died. "Everybody will be whispering around me if I do it now," she told him.

The world hadn't been ready for her story then. It was as if Nahida had envisioned her notebook landing on a shelf at the Zheen archive one day, and her voice allowing future generations to glimpse a Kurdistan they'd never learned about in history books.

She might be pleased to know it has already done so: As she read Nahida's writing, the anthropologist Shenah Abdullah found traces of her own story—college in America, a pursuit of anthropology, the feeling of being torn between home and a new life. She was overwhelmed by how history echoes today, more than 60 years later. "It's almost like they're knitted together," she said. "No one ever tells the past without telling the present." □

Ferdonije Qerkezi has preserved her home in Gjakova as a living record of her husband and sons, who were taken by Serbs during the war. She invites visitors to see her boys' rooms, left undisturbed as a way of testifying to what happened and of keeping her family's memory alive.


THE EVENTS THAT OCCURRED AT THE HOUSE OF MILIM GERXHO
ON 27TH MARCH, 1999
On 27th March, 1999, there were twenty-three members present in our house
Out of the twenty- three members, eleven were men including fourteen year old Edmond, nine we
The Serb policeman turned to the owners of the house Hatixe and said, "Everything is good, there a
now." And that is what we did, we were inside.
While the rest of us were going inside, the policeman ordered Arbon to take our car out of the garage.
Arbon, Arbon did an sedated, took it out for them.
and the other for Sherden. The rest of us were ordered to go to the second basement. While they were
Bar but I do not keep any in my house". The policemen continued to drink juice. Dragoon later asked
Dragoon asked for water from Arbon and told him that you are a good waitress. Arbon brought his wife
Dragoon Ibeding knew Myrtoza Sulmoz, Sherden's son. He consistently called him CAR (emperor), and he
Myrtoza, in his how we called him, came to our second basement, Edi, his wife, asked, "Biz, who is
Know you?" Nzo answered, "He is Dragoon Ibeding from Mustrengro, he worked at the cultural palace. He
many times he would take food without paying for it, and saying: I will pay you next time."
Quietly on the first basement were Hatixe and Leonzen. On the second basement there was Myrtoza husb
heard Dragoon's voice, "Car, let go of the kid and come here." He asked him then since they leave to not cl
open. When the owner, Hatixe came in, Sherden's wife Dudlie asked him, "Mr. Hatixe, did they go?" Hatixe
we they were not they said to not be worried, that the police will keep an eye on us and will bring us flour so
everyone including the whole police station."
Then quietly we all got together on the second basement. A few minutes later, the same policeman came in.
they had masks on, with the same uniforms on, we recognized Dragoon from his eyes and his voice. They turn
"We are UCK. Do you love UCK?" "Do you love NATO?" "Do you love America?", then with the same tone of voi
go outside."
Then they turned towards the women and the children, with the guns on our face asked for our gold. All the w
necklace, earrings, everything we had we gave to them. The masked policemen filled a glass with our gold,
money, turning toward Yeshmije. She gave them 500 DM. Then they turned their gun on Mendutha's chest an
money. She did not have any money. Because they were so angry they shot at the floor, where the mark is still
they turned to Dudlie with the sharp knife on her throat and said to her that we are going to cut all the Albania
policement, also moved, turned to Edi and said, "Or give us money, or we will kill your little daughter." Edi sa
not my house and I do not have any money". Then the policement took the gun of the little girls' chest and said
have ten minutes to get your things ready and leave for Albania." It was about 19:00 o' clock in the evening. A
kids left not knowing where to go. As they were walking they decided to go into an apartment complex near the
owners, Qamil Hoxhaj-Ismaili opened his door to us. Qamil told us that he had a mentally retarded son and the g
after a day before.
All of us, the women, spent the night at his apartment, and the next day each one of us took different directions,
wife Dudlie, with her daughter in law Edi. The next day Qamil informed us that the police had left his son out, on
him without anyone asking "Father at the police station I heard the police had brought a lot of men with the sam
Constantly we kept looking for them.
On 7th May, 1999 Yeshmije Qerkezi, Kozim Qerkezi and Nysbreta Kumnova went to the house of Dragoon Ibeding. W
the door we saw Ilia Mirkoviq, his coworker, who turned to Kozim "Welcome Kozim", and Kozim replied "I have b
you". Ilia told them to come in. Once they were in, Dragoon turned to Yeshmije and asked her "Do you remember
Yeshmije replied: "Yes"
Dragoon asked: "Do you remember I gave chocolate to the kids?"
Yeshmije replied again: "Yes"
Kozim was a colligue with Dragoon before the war, they both worked at the 'Cultural Palace'. Kozim asked: "Dragoon,
my sons, Hatixe and his sons are?"
Dragoon replied, "If I come to your house by this evening I will bring you news, if not, then for the rest of your life you
what happened to them?"

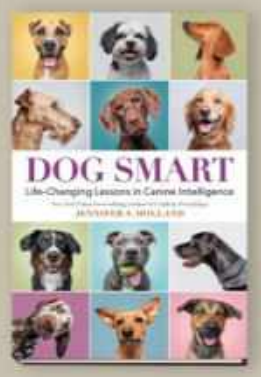
ON NEWSSTANDS

OUR RECENT SPECIAL ISSUE

Great American Parks showcases 50 iconic destinations, including Everglades National Park (above). The Florida wetland, home to more than 50 reptile species, as well as hundreds of bird species, is a UNESCO World Heritage site and an international biosphere reserve.

The publication celebrates a wide range of the country's best public spaces, from national parks like Yellowstone—designated the first in 1872—to urban oases such as Central Park in New York City. There are also lesser known treasures to discover: Nevada's Avi Kwa Ame National Monument, established in 2023, contains one of the world's largest Joshua tree forests. Not just beautiful places, these parks are for reflection too—about conflict, for instance, at the War in the Pacific National Historical Park in Guam, or colonialism at the San Juan National Historic Site in Puerto Rico. *Great American Parks* is available now.

BOOKS



Join author Jennifer Holland as she explores the world of canine intelligence—from nose knowledge to training acumen to emotional sensitivity—and finds out whether some breeds truly are smarter than others. Available May 21 wherever books are sold.

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NATIONAL GEOGRAPHIC
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NATURE IS IN THEIR NATURE

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RETURN TO THE WILD

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