

NATIONAL GEOGRAPHIC

Fabulous Fungi

How these marvels are shaping life on Earth, and our future

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Scenes in Stone

New revelations from an ancient synagogue

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Fashion's Graveyard

Where clothes reach the end of the line

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Going the Distance

The perilous and inspiring journey of whooping cranes

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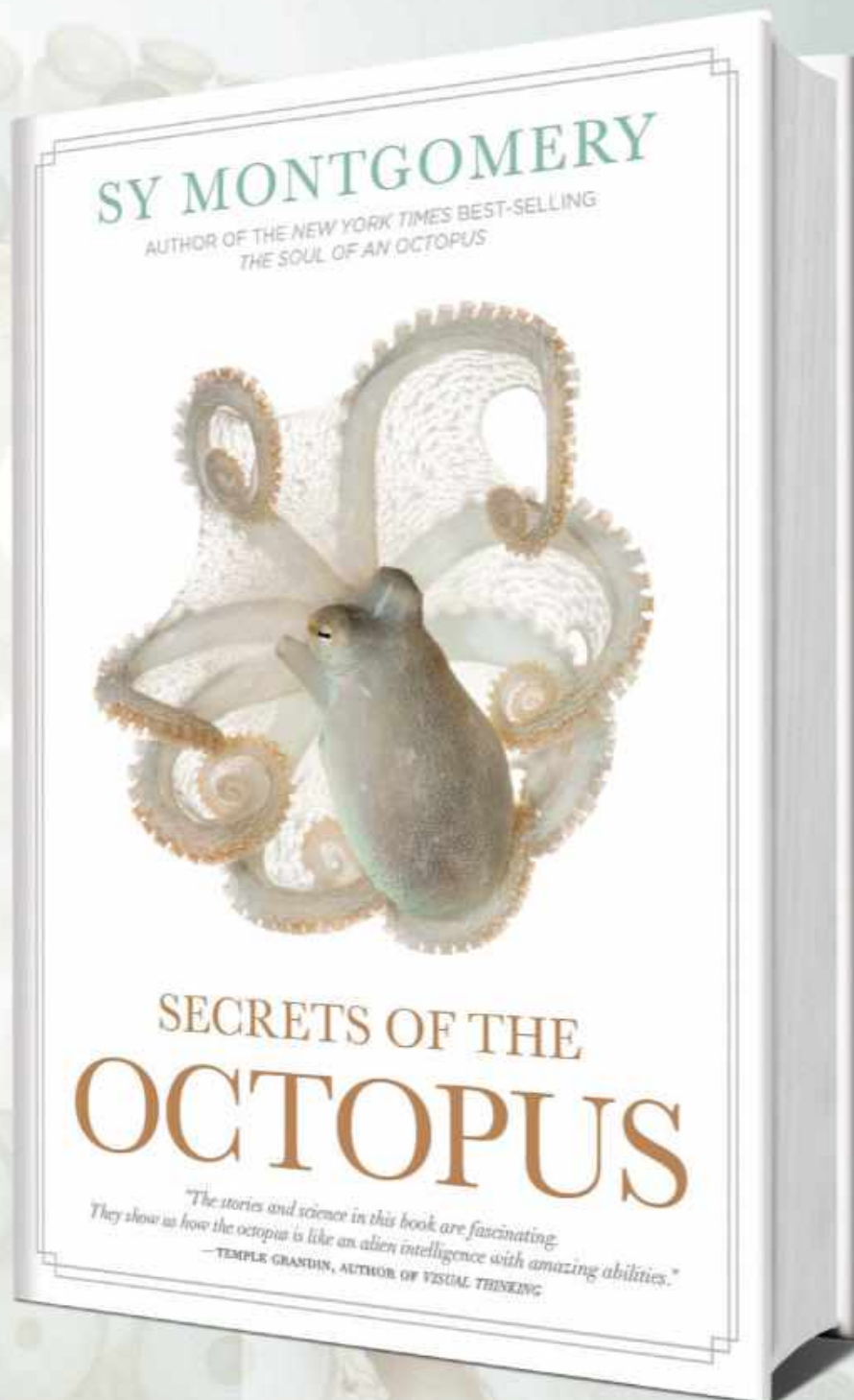
UNDERWATER WONDERS

"Montgomery writes with brilliance, humor, and a rich empathy that makes the reader look at the world of sea creatures in an entirely new way. It's a marvel."

—**SUSAN ORLEAN**, author of
On Animals and *The Orchid Thief*

"Secrets of the Octopus is an engaging deep dive into an eight-armed force of intelligence."

—**CARL SAFINA**, author of
Becoming Wild and *Alfie & Me*



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FROM *the* EDITOR

NATHAN LUMP

IN 2022, DURING MY FIRST WEEK as *National Geographic's* editor in chief, I met Harvard associate and mycologist Giuliana Furci at the National Geographic Society's Explorers Festival in Washington, D.C. At this annual event, Explorers from all over the world gather to share their work and insights.

Furci, who had traveled from her home in Chile, is one of those incredible humans with whom, in the space of just a few minutes, you can go from small talk to soulful conversation—in this case, about fungi and their unsung place in our ecosystems and lives.

At the time, I was in the process of moving to D.C. from Seattle, where I lived surrounded by a

forest that had taught me to pay attention to fungi. The elegant white winglike ones extending from decaying logs. The crinkly ones that popped up in fairy circles. The bright blue ones and orange ones and black ones.

Perhaps because of that connection, my talk with Furci sparked the idea for this month's cover story. The piece shares the most fascinating aspects of these organisms, from making up the mycobiome in our bodies to their use in fashion to how they're affected by climate change.

I hope you enjoy the issue.

A handwritten signature in black ink, appearing to read 'Nathan Lump'.

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Most of us don't give much thought to these organisms, but we should. Not only do they live within us; they also make much of life on Earth possible.

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In Wisconsin, the historic observatory housing the world's largest refracting telescope is restored and drawing new visitors.

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When archaeologists began excavating a site in Israel's Galilee, they found a fifth-century synagogue—with remarkable mosaics—giving clues about ancient Jewish life.

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Although these images appear to be beautiful abstracts, they depict the dizzying paths of flying insects.

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A best-selling author reveals sources of her creative inspiration, which include a familiar yellow-bordered magazine.

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GOING THE DISTANCE

By tracking wild whooping cranes, scientists are unraveling mysteries of the birds' 5,000-mile round-trip migrations—and aiming to boost their conservation success.

134 **NEW FROM NATIONAL GEOGRAPHIC**

ON THE COVER The mushrooms of Kallipefki, Greece, are just a small part of the vast world of fungi—wondrous and surprising, and with the potential to affect our lives in ways we're only beginning to understand. *Photograph by* AGORASTOS PAPATSANIS

IN FOCUS

JUST IN FROM OUR PHOTOGRAPHERS

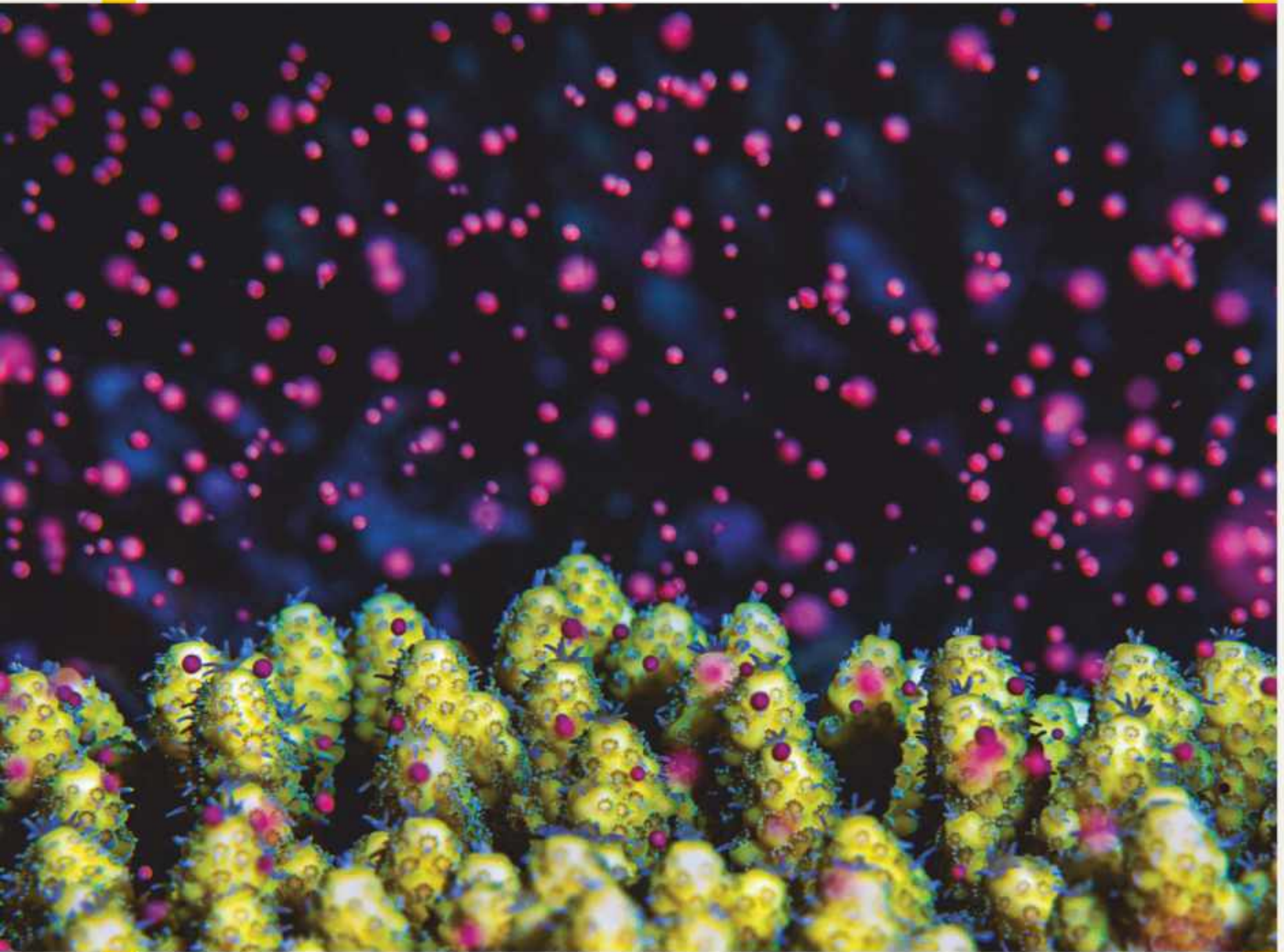


SCIENCE

“The Finding Darwin expedition provided me with a PROFOUND IMMERSION into how he slowly constructed his thoughts and the *legacy of scientific knowledge* he left in Patagonia.”

MARCIO PIMENTA, *Photographer and National Geographic Explorer*

During his solo journey tracing the travels of Charles Darwin, supported by the National Geographic Society, Pimenta encountered this life-size replica of a *Patagotitan* dinosaur in Trelew, Argentina, home of the Egidio Feruglio Paleontological Museum.



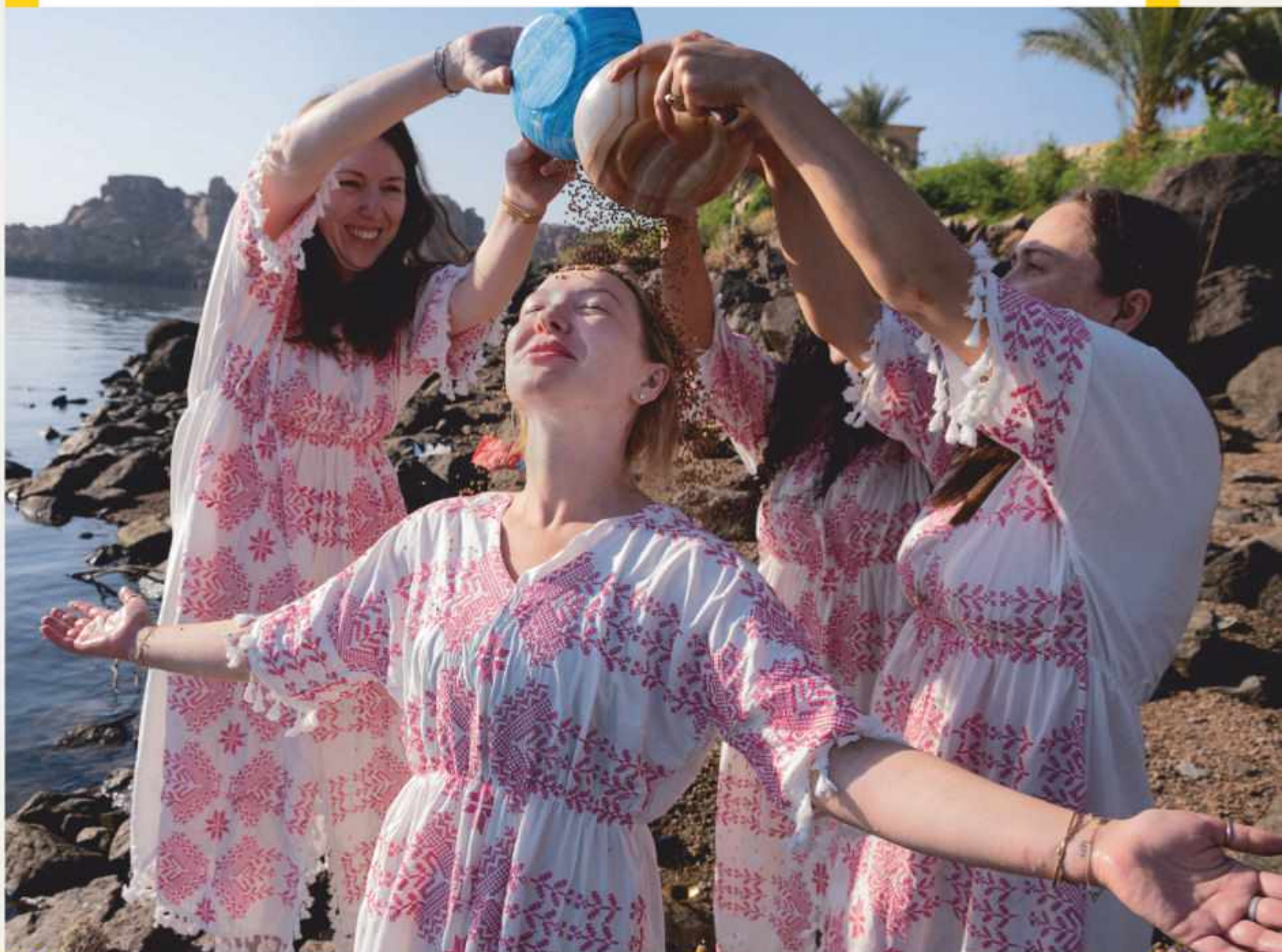
OCEANS

“Witnessing the *synchronized elegance* of thousands of corals creating life NEVER CEASES TO AMAZE.

This enchanting phenomenon imparts a *unique aesthetic sensation*, as if you’re gazing upon an underwater, inverted, colorful snowstorm.”

TOM SHLESINGER, *Photographer*

In the Red Sea, branching corals release egg-and-sperm bundles into open water, where they will mingle and match. This “broadcast spawning” event occurs only once a year for a few minutes at night.



CULTURE

“I learned about a group of women dedicated to the EGYPTIAN GODDESS ISIS. Their reverence for the waters of the Nile and its history is representative of the *importance of the Nile* to Egyptians and the world.”

MATT MOYER, *Photographer and National Geographic Explorer*

Vera Novitskaya welcomes an offering as part of a ritual at the Temple of Philae near Aswan. Moyer captured this scene while working on a National Geographic Society-funded project about Egypt’s looming water crisis.





ENVIRONMENT

“The Everglades watershed can be *an overwhelming place* in its breadth and the issues it faces. I started working on a series isolating subjects against white backgrounds to **DISTILL COMPLEX ISSUES** into simple visual narratives.”

MAC STONE,
Photographer and National Geographic Explorer

Clinging in clusters to pickerelweeds and bulrushes, non-native island apple snail eggs, which are bright pink, vastly outcompete the pale pink native apple snail eggs in number (composite of 10 images).

SHE'S A BIT OF A LEGEND



RENEGADE
NELL

ORIGINAL SERIES
April 17



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CONTRIBUTORS



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.

Tamara Merino, p.76

Merino's photography has taken her to opal mines in Australia, migrant processing centers on the U.S.-Mexico border, and, for this feature on fashion waste, to the Atacama Desert in Chile. An Explorer since 2020, she visited subterranean communities in Utah, Andalusia, and the Australian outback for her project Underland. Her latest project: capturing images of her newborn daughter, Ona.



Paolo Verzone, p.52

For this issue, Verzone, who lives in Italy and Spain, photographed a stunning synagogue in Israel. His images of the new Grand Egyptian Museum

in the November 2022 issue were awarded first prize for science and natural history by Pictures of the Year International.



Phyllis Ma, p.16

Images from Ma's ongoing series, *Mushrooms & Friends*, frame this month's story on "mycotextiles," part of our larger look at the hidden kingdom of fungi.

Work by the New York-based photographer has appeared in outlets such as the *New Yorker*, *Le Monde*, and the *New York Times*.



Rene Ebersole, p.112

A National Magazine Award-winning journalist, she has traveled to some of the world's most remote places for *National Geographic*, including northern

Canada's vast boreal forests, where she reported this issue's story about the migrations of whooping cranes.



John Bartlett, p.76

Since moving to Chile in 2018, the British-born writer has traversed the length of the country to cover subjects ranging from fashion waste to Haitian refugees.

"Still," he says, "my favorite achievement is playing for Chile's national cricket team at the 2023 South American championships."



AGORASTOS PAPATSANIS (CORAL SPINE AND PARASOLS)



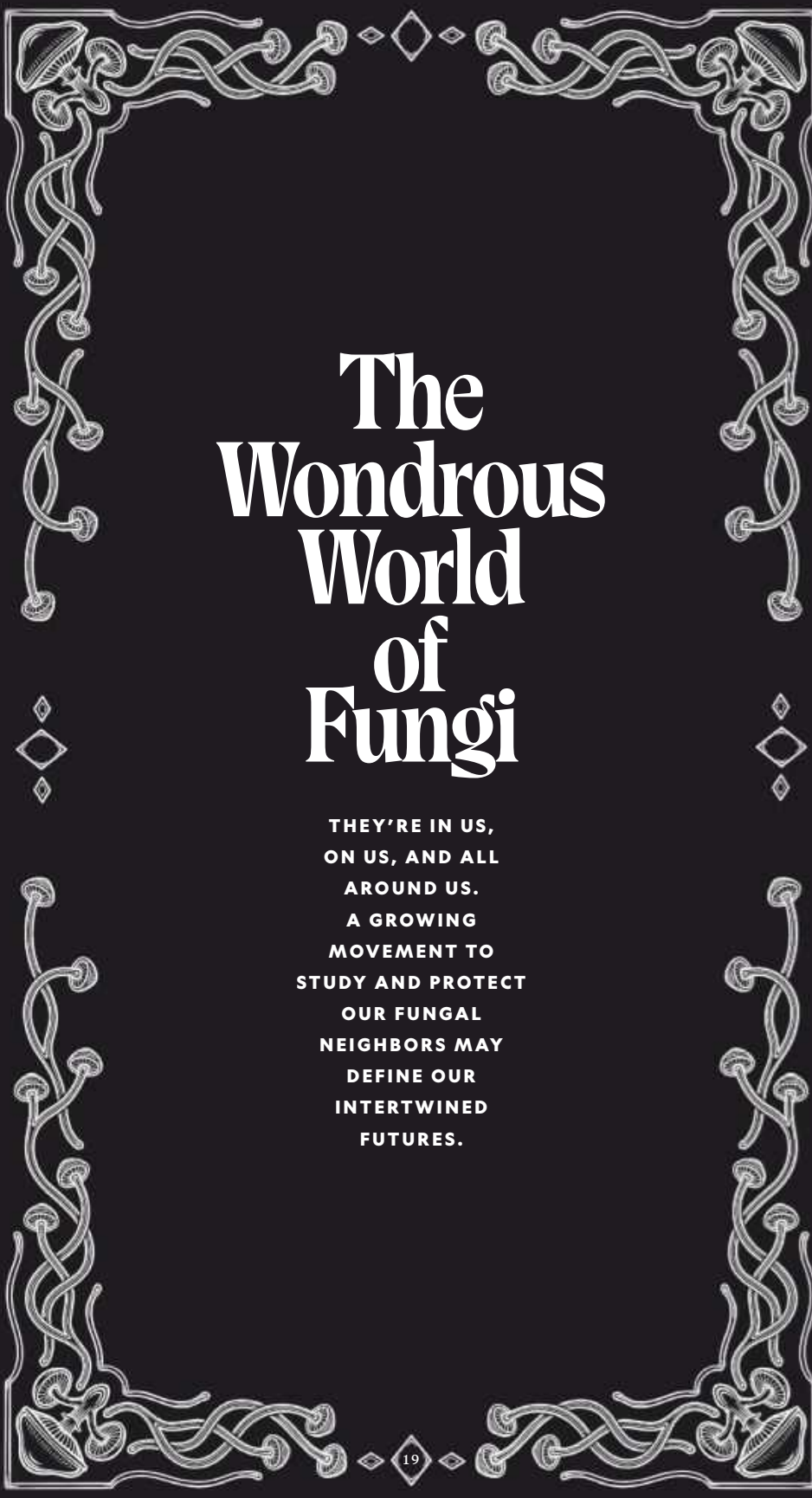
**MACROLEPIOTA
PROCERA**

While delectable, the parasol mushroom—seen here among pines at dusk—is a risky pick, as it can be mistaken for poisonous look-alikes such as the death cap mushroom.

Far left

HERICIUM CLATHROIDES

The aptly nicknamed coral spine fungus cascades from a tree in the Chalkidiki Peninsula of Greece.



The Wondrous World of Fungi

THEY'RE IN US,
ON US, AND ALL
AROUND US.
A GROWING
MOVEMENT TO
STUDY AND PROTECT
OUR FUNGAL
NEIGHBORS MAY
DEFINE OUR
INTERTWINED
FUTURES.

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CALOSCYPHA FULGENS
Though *fulgens* is Latin for “dazzling,” these orange-hued mushrooms, found here on Greece’s Mount Olympus, are a pathogenic fungus, killing and mummifying the dormant seeds of conifers.



AGORASTOS PAPATSANIS

FLORA. FAUNA. FUNGA.

THE CASE FOR FUNGI to be considered their own kingdom within the natural world was simple: Without them, much of life as we know it on this planet—starting with the ability of plants to live outside of water—would not exist.

It's been at least 400 million years since mycorrhizal fungi helped plants colonize the Earth's land, thanks to a pretty basic trade-off: Fungi tend to form a symbiotic relationship with different plants and animals, and they move by eating and expanding outward. For most plants today, that means fungi live within their root systems, metabolizing sugar from photosynthesis while helping them access water and critical nutrients.

But that's only the beginning of what these tiny marvels can do. From yeast to mold to mushroom, the variety among fungi isn't just remarkable but also far wider than the diversity that exists among plants and vertebrates. There are around five million species of fungi, yet roughly 90 percent remain undocumented. Fungi are in our air, in our water, and even on our skin and within our bodies. Still, researchers have only scratched the surface of why they're so critical to keeping ecosystems in balance.

"Fungi can show you that life begins even when another one ends," says mycologist Giuliana Furci, a Harvard University associate and National Geographic Explorer, about their crucial role in our planetary life cycle. As founder of the Fungi Foundation, she has spent the past 14 years leading the campaign for their inclusion in conservation policy.

For Furci, the aha moment arrived when, during a research trip as a university student in Chile, she came across an arresting orange mushroom and, upon further research, realized that not only were there

no mushroom field guides for the country but there were no mycology programs at all. She vowed to change that and has since been documenting Chile's native fungi.

Now dozens of mycologists are amplifying the call for "funga"—a new term for the regional fungi population—to be provided the same level of research funding and biodiversity conservation as flora and fauna. Simultaneously, fungi figureheads like Paul Stamets, who appeared in the 2019 documentary *Fantastic Fungi*, and Merlin Sheldrake, author of the best-selling 2020 book *Entangled Life*, have found their own ways to share the benefits and wonder of this hidden world.

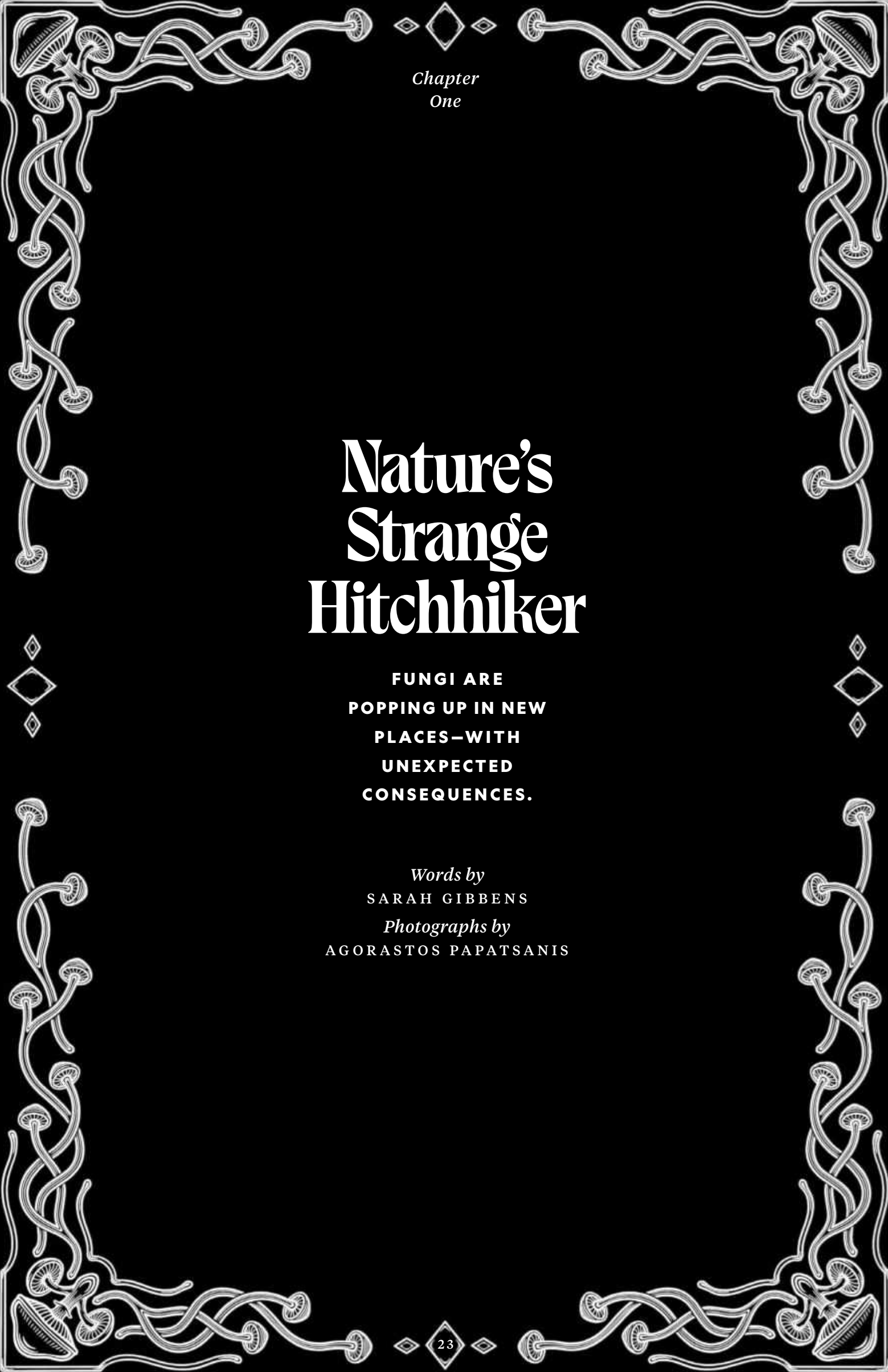
Not surprisingly, more international policy gatekeepers—such as Mexico's Secretariat of Environment and Natural Resources, the National Biobank of Thailand, and Italy's Institute for Environmental Protection and Research—and the International Union for Conservation of Nature are publicly pushing for funga's inclusion in their own environmental conservation work. So too is the National Geographic Society, which recently added funga to its definition of "wildlife" to invite grant applications in this area and open up more opportunities for future Explorers.

In the pages ahead, you'll learn more about why this effort is so important to our lives, from invasive species that can signal how we'll navigate a warming and changing world, to the complex "mycobioome" of bodily based fungi that offer new insight into how deadly diseases like cancer may spread (and some hints about treatment), to harnessing mycelium as a more eco-friendly fashion material. The world is a bigger petri dish than almost anyone ever imagined.

The future is funga. Now is the time to understand what it holds. —NICK MARTIN



LACCARIA
AMETHYSTINA
Under the galaxy
purple cap of
this toxic beauty,
the mushroom
accumulates high
levels of arsenic.



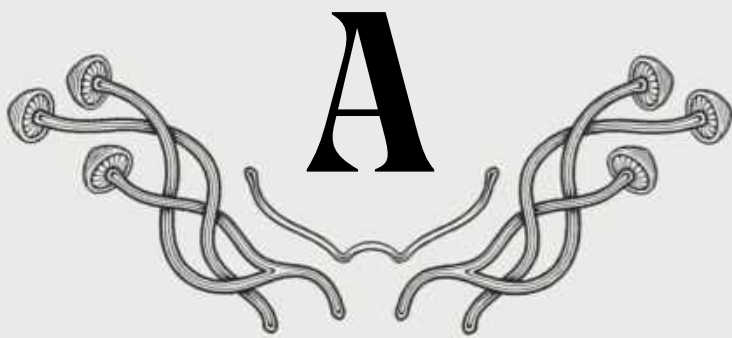
Chapter
One

Nature's Strange Hitchhiker

**FUNGI ARE
POPPING UP IN NEW
PLACES—WITH
UNEXPECTED
CONSEQUENCES.**

Words by
SARAH GIBBENS

Photographs by
AGORASTOS PAPATSANIS



ANNE PRINGLE WAS SURVEYING mushrooms at a field site in Tomales Bay State Park, just north of San Francisco, when she found herself in a predicament. She was surrounded by a sea of one of the world's most dangerous mushrooms: *Amanita phalloides*, commonly known as the death cap.

"I couldn't put my foot down without stepping on them," Pringle says. "It was just a valley of death. A total infestation."

That was 20 years ago, when Pringle, now a mycologist at the University of Wisconsin-Madison, was doing research at the University of California, Berkeley. Despite its proliferation, there was a rumor that the deadly mushroom hadn't originated on the Golden Coast. Six years and much DNA sequencing later, Pringle proved the rumor true: North America's death cap mushroom was an invader, a fungal species likely native to Europe.

Now found thousands of miles outside that original range, death caps are the culprit behind most mushroom-related poisonings. Their powerful toxins start to attack the human body in as little as six hours after they're consumed, causing abdominal pain, nausea, and vomiting that, if untreated, can result in fatal liver failure. Last August three people in Australia died from ingesting death caps, victims of an alleged poisoning. The mushroom—about five inches tall with a greenish yellow-white cap—can be easily mistaken as edible. In British Columbia, a child died after eating one in 2016; in Northern California, 14 people fell severely ill in 10 separate incidents during one particularly scary week in 2017.



**OUDEMANSIELLA
MUCIDA**

Porcelain mushrooms, like these "towering" from a beech tree on Mount Olympus, reach between one and three inches tall.

But death caps didn't evolve to kill people. These mushrooms are mycorrhizal fungi. They spring from a tangle of fungal threads that grow in soil and curl around tree roots, helping the trees take up nutrients. This activity underfoot both intrigues and worries scientists, like Pringle, who say we know too little about the fungal kingdom and what happens when these underground networks are rewired.

Over the past century, our world has become more connected than ever, and fungi, like the death cap, have embarked on countless global journeys, hitching a ride on imported plants or simply wafting hundreds of miles in the wind.



Now climate change is allowing many of these organisms to thrive in ecosystems that were once too cold and dry. If history is any indication, we may not be ready for what's in store.

I **IN A SENSE**, fungi are a hidden earthly dimension we're only now learning how to see. They thrive in soil and grow edible stalks like plants, but many of their characteristics are distinctly unplantlike. Where plants have cell walls made of cellulose, fungi have chitin, a type of fiber also found in the exoskeletons of insects and crustaceans.

And fungi are heterotrophs—capable of eating other organisms, often breaking down wood and dead plant matter by releasing and reabsorbing enzymes. Without fungi, dead plants and animals would pile up on forest floors, and most trees would struggle to find the nutrients they need to survive.

“They're probably closer to animals than you think,” says Rabern Simmons, the curator of fungi at the Purdue University Herbaria.

For more than a billion years, fungi have evolved to live in specific environments, sometimes in partnership with just one other species. But when a fungus is moved anywhere from dozens to thousands of miles

away, these complex relationships can go haywire. “It’s a perfect storm with fungal pathogens,” says Stephen Parnell, an epidemiologist at the University of Warwick who models the spread of plant disease.

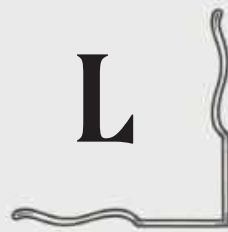
Diverse strategies for reproduction help a fungus survive. Airborne spores from different species can intermingle in a new habitat, or the mushrooms might fuse together the threads that form their underground networks. But in a pinch, many can simply reproduce asexually.

With climates and landscapes changing at record pace, says Parnell, these reproductive traits make fungi uniquely—and worryingly—adaptable. In new environments, foreign fungi can spread voraciously and remake the topography around them.

American chestnut trees were once giants of Appalachia, growing a hundred feet tall and 10 feet wide. In the early 20th century, however, the fungus *Cryphonectria parasitica* landed on American soil. In Japan and China, the fungus was only a nuisance to Asian chestnut trees, but for the American chestnut it caused deep cankers that slowly choked it of water and nutrients. An estimated four billion trees died over the following century as a result.

As the last great American chestnut trees withered, frogs and other amphibians faced a similar peril with a fungal pathogen known as chytrid. Believed to have originated on the Korean Peninsula, the fungus lived in harmony with local amphibians. But over the past 150 years, chytrid has spread around the globe and is now associated with the decline of at least 500 amphibian species; it’s caused 90 species to disappear from their habitats. It’s been described as the worst wildlife disease in history.

“We’re moving biological material across the world in a matter of hours, across continents that were long separated,” says Ben Scheele, an ecologist at the Australian National University. “We essentially have re-created dysfunctional Pangaea.”



LAST AUTUMN, Pringle and one of her students spent weeks collecting hundreds of death cap mushrooms from golden-hued forests in the United Kingdom, Hungary,

France, and Poland. These samples could help scientists better understand why death caps thrive in some ecosystems and don’t in others.

Researchers are looking for a predator or pathogen they can replicate to stop the mushrooms from invading forest floors, a method called biocontrol. But Pringle says one of the most effective ways to keep fungi in the right environment is prevention: Monitor imports of foreign species, and test them for fungi.

When fungal diseases can’t be prevented in an environment, treating them can become an immense undertaking. To restore the American chestnut, several scientists have been working on decades-long breeding projects, one of which involves a controversial genetically modified tree. And while individual frogs can be cured of chytrid, eradicating the fungus in environments where it’s introduced is nearly impossible. Last year, new research on how death caps produce their powerful toxin opened the door to a possible antidote.

Some start-ups and nonprofits have promising solutions for helping fungi help us. Funga, a company in Austin, Texas, identifies native fungi that can assist trees in storing more carbon. SPUN, a scientific research organization, is mapping the world’s fungi to identify regional hot spots in need of conservation. At least 350 species are already at risk of going extinct, though the real figure is likely much higher.

For Simmons at Purdue’s Herbaria, winning the race against the biodiversity clock is critical—for humanity and fungi alike. “We’re finding things that are beneficial to humanity in some way, whether it be the production of compounds like biofuels or compounds that are understood to have medicinal purposes.”

What’s kept protected, he adds, may one day solve the next problem we might create.



The Forgotten Fungal Detective

HOW A PIONEER
OF MODERN
MYCOLOGY SHAPED
THE U.S. RESPONSE
TO POTENTIALLY
DEVASTATING
PLANT DISEASES

THE NATIONAL CHERRY

Blossom Festival in Washington, D.C., has been a source of pride and tourism dollars for nearly a century. But when Japan's original gift of 2,000 cherry trees arrived in the United States as a gesture of friendship in late 1909, that future seemed far from bright. The trees were riddled with insects, and several had ring-shaped dead spots on their bark—often a symptom of a contagious fungal disease.

After inspecting the consignment, the U.S. Department of Agriculture's "mycologist in charge," Flora Patterson, filed a curt letter to her superiors. She identified the fungus as a type of *Pestalozzia*, but, she wrote, it was "impossible to decide with the limited time available" if the species was already indigenous to the U.S. In academic parlance, she and her team were sounding the alarm. After a flurry of diplomatic letters to Tokyo, President William Howard Taft approved the trees' destruction on January 28, 1910, and the shipment was set ablaze on the National Mall.

It was a radical move. But by the early 1900s, fungal stowaways had already led to an outbreak of chestnut blight, which would wipe out many existing U.S. forests. Shortly before the cherry trees arrived, Patterson and several of her employees had been tasked with investigating other import threats and found a potato wart fungus

that could have severely damaged the food supply.

Patterson's fungal detective work helped encourage Congress to pass the Plant Quarantine Act of 1912, which mandated that all U.S. ports inspect and detain suspicious plants. The law opened up her access to new samples: Over the course of her career, she would bolster the burgeoning National Fungus Collections with more than 90,000 new specimens for study. Japan also eventually sent replacement cherry trees.

"It's thanks to people like Flora, who had the foresight to know we should collect and preserve them, that we are able to go back in time and see what a predominant disease-causing fungus was back then," says Lisa Castlebury, the current USDA director of the collections, which are located in Beltsville, Maryland.

Today that cache makes up the world's largest fully searchable fungus database, with roughly a million samples. And much of Patterson's work is still part of it. Individual specimens and their carefully dried plant hosts are stored in envelopes on stiff paper alongside detailed, handwritten notes from Patterson and other scientists. "It's an intersection of natural history and other history—the

history of the specimen," Castlebury says. Scientists can now compare the collections' samples against suspicious spots, growths, or discolored plants to help speed identification.

When Patterson held Castlebury's job a century ago, her day-to-day tasks varied: Fungal enthusiasts often showed up to the USDA's offices to ask for help identifying mushrooms they'd foraged. During World War I, Patterson furthered that work, co-authoring a USDA guide to teach the public which backyard mushrooms could be eaten. Her team also identified several new plant diseases and conducted experiments to fumigate emerging pathogens.

Described in a 1914 newspaper article as the "shield between the American farmer and the plant-disease germs of Europe," Patterson was unlike many other women of her era because her work was well documented. (Female scientists at the USDA were allowed to publish under their own name, according to research by Western Connecticut State University fungal ecologist Hannah Reynolds.) Yet Patterson's most lasting mark remains largely unseen. Fungal hitchhikers are now routinely detected and quarantined or destroyed at ports and airports due partly to the protocols she helped enact. No public bonfires required.

—DINA FINE MARON



PLUTEUS CERVINUS
Ushering in the next generation and growth cycle, spores of a deer mushroom on Mount Olympus shake free and dance in the air beneath its gills.



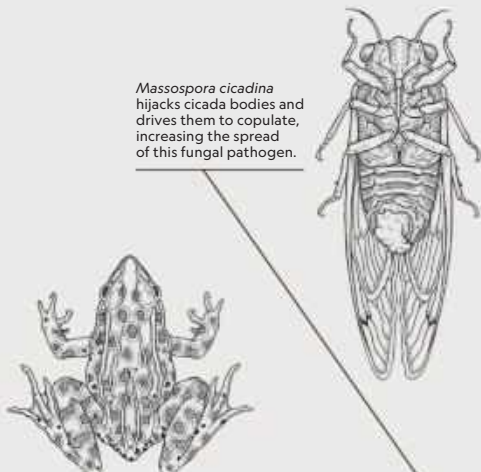
Chapter Two

The Hidden Kingdom

*a. Xylaria polymorpha; b. Termitomyces reticulatus; c. Armillaria mellea;
d. Cantharellus cibarius; e. Leucoagaricus americanus;
f. Cordyceps militaris; g. Auricularia auricula; h. Morchella esculenta*

A common thread

The fungal kingdom encompasses seemingly endless forms, but nearly all its members share one trait: cell walls made of chitin. This solid but flexible substance also makes up exoskeletons in arthropods such as insects and shellfish.



Massospora cicadina hijacks cicada bodies and drives them to copulate, increasing the spread of this fungal pathogen.

Batrachochytrium dendrobatidis is an aquatic fungus that attacks frogs' skin and is responsible for the decline of more than 500 amphibian species.

Aphelidium, one of the earliest diverging branches of fungi, is parasitic and kills algae.

CHYTRIDIOMYCOTA
These ancient aquatic fungi feature spores that retain a tail, or flagellum, which makes them mobile.

ZOOPAGOMYCOTA
Sometimes parasitic, sometimes symbiotic with their hosts, these fungi have lost their flagellated spores.

MUCOROMYCOTA
This phylum's fungi include organisms that evolved mutually with plants, forming networks with their roots.

Rhizophagus irregularis may have helped plants colonize land by breaking down organic matter in soil and sharing nutrients with them.

Ustilago maydis destroys corn, but the resulting growths taste like truffle and are enjoyed as the Mexican delicacy *huitlacoche*.

Puccinia graminis, also known as stem rust, preys on wheat and other grains and can destroy entire fields of crops.

Cryptococcus neoformans is a fungal pathogen that can be fatal in those with weakened immune systems, especially HIV-positive individuals.

Cantharellus, or chanterelles, grow only on trees and are some of the most commonly harvested edible mushrooms.

Amanita phalloides, one of the deadliest known mushrooms, is often fatal if ingested. This has earned it a nickname: the death cap.

Phallus impudicus, a stinkhorn, is known for its phallic shape and foul odor; the latter attracts flies to disperse its spores.

Most mushrooms
The class Agaricomycetes contains many of today's most commonly recognized mushrooms.

LATER STAGE DIVERSITY
Fungi called Dikarya have hyphae that are divided into compartments they can close to protect the larger fungal network from damage. They typically have a fruiting body that releases spores for reproduction.

FIRST FUNGI
Most early diverging fungi are aquatic. They explore and feed using filaments known as hyphae. The single-celled nature of these hyphae makes them highly vulnerable to injury or death.

In general, orders that appear to the right of the curve diverged from the common fungal ancestor later.

The fungal family tree

Sometimes beneficial, other times deadly, fungi have shaped life on Earth for over a billion years. They're in the food we eat and the air we breathe, and more than 90 percent of plants need them for water and nutrients. Our understanding of these organisms is infinitesimal: Of at least five million species, only about 150,000 have been identified and classified in a family tree.



Genetic relatedness
Orders that branch closer to the top of the curve are more genetically similar.

Age of divergence
Earlier

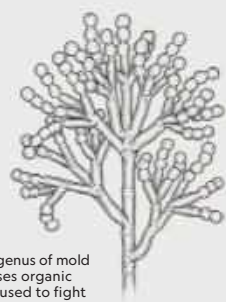
Later



Saccharomyces cerevisiae, or common yeast, is used for fermentation, from leavening bread to making beer and wine.



Morchella esculenta, or morels, are edible mushrooms foraged in woodland environments and prized by chefs.

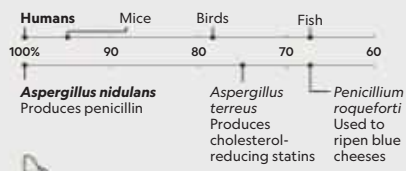


Penicillium is a genus of mold that decomposes organic matter, can be used to fight bacterial infections, and even gives flavor to soft cheeses.

Genetic diversity

Fungal variety is extreme. For example, the fungus that makes penicillin is as genetically different from the one that ripens blue cheeses as humans are from fish. This may be one reason around 2,000 new species are classified every year.

Genetic divergence from index species by average protein similarity



Letharia vulpina, the wolf lichen, long used to poison wolves and other predators, is being tested for its medicinal potential.



Xylaria polymorpha, or dead man's fingers, is a soft rot fungus that digests dead wood and gets its name from its black, finger-like fruiting bodies.

Most lichens
Lecanoromycetes is the largest class of lichens, which coexist with bacteria or algae.

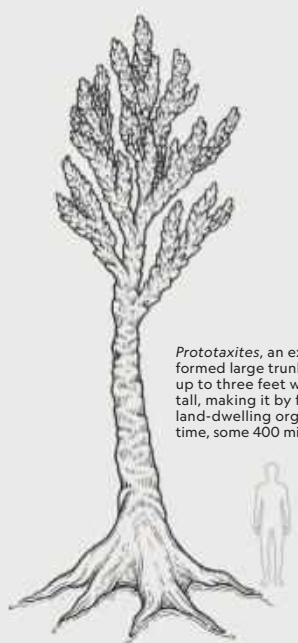
Chlorocibaria turns wood a blue-green color; used as a dye for centuries, it's now being explored as a treatment for ailments such as osteoporosis.

Ambrosiella roeperi forms a symbiotic relationship with the ambrosia beetle: The fungus feeds the beetle, which disperses the fungus.



ASCOMYCOTA
These sac fungi form spores in pouches and often reproduce asexually. Known as spore shooters, they scatter their progeny via wind and water.

Cordyceps is a genus of parasitic fungi that have been used in Chinese medicine for 2,000 years; many species grow on insects, ultimately killing them.



Prototaxites, an extinct fungus, formed large trunklike structures up to three feet wide and 26 feet tall, making it by far the largest land-dwelling organism of its time, some 400 million years ago.

Distant relatives

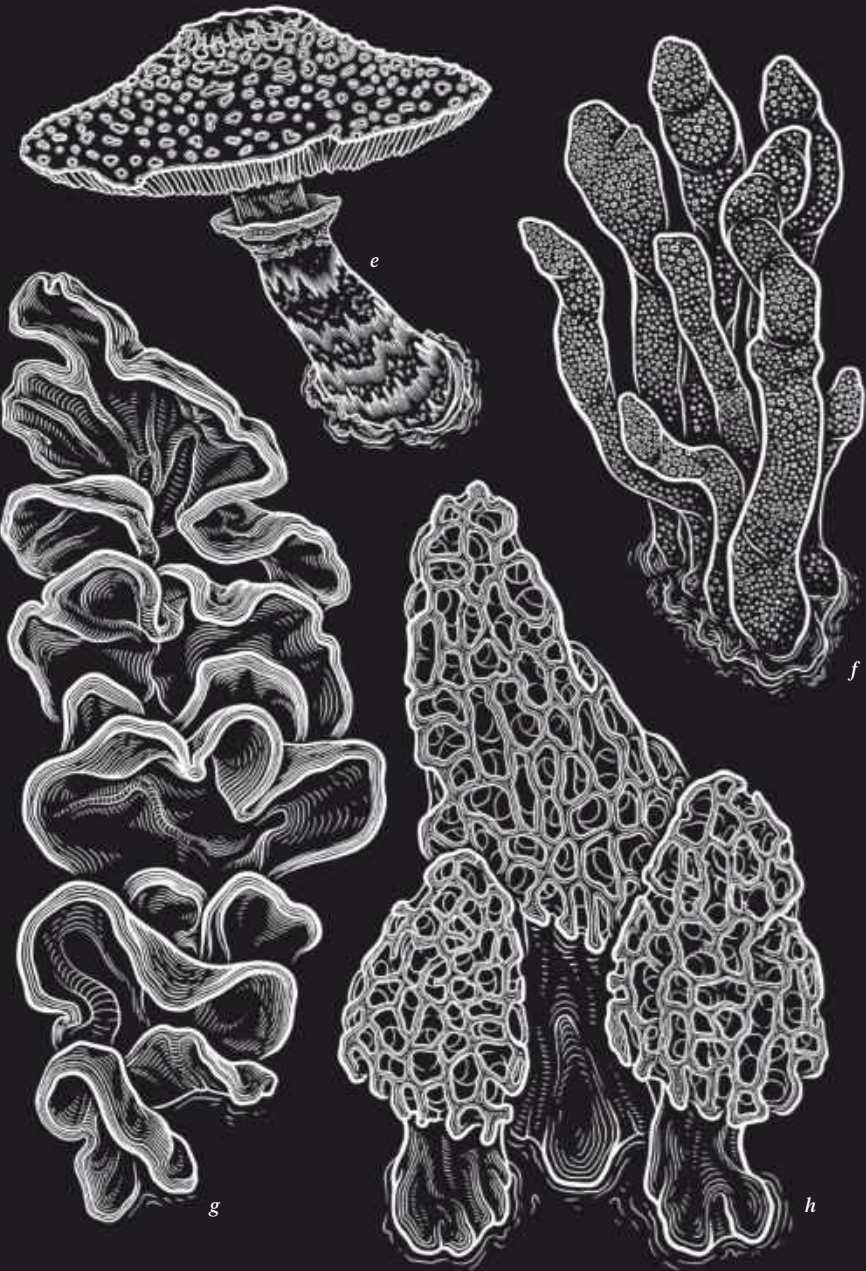
Fungi are biologically closer to animals than they are to plants. Both acquire energy by absorbing or consuming dissolved molecules. A key difference: Animals, including humans, digest food internally, while fungi secrete enzymes to break down food externally.



Last common ancestor
Evolutionary relationship among plants, fungi, and animals

Waste recyclers
Many fungi in *Sordariomycetes*, derived from the Latin *sordēs* (filth), grow in animal feces.

REPORTING: BRANDON SHYPKOWSKI
SOURCES: TIMOTHY JAMES, UNIVERSITY OF MICHIGAN; ANTONIS ROKAS, VANDERBILT UNIVERSITY; JASON STAJICH, UNIVERSITY OF CALIFORNIA, RIVERSIDE



Much more than just mushrooms, fungi are organisms more closely related to humans than to plants. Despite being recognized as their own kingdom on the tree of life, only a small fraction of them are known to scientists.

Graphic by JASON TREAT
Illustrations by KATY WIEDEMANN



PSILOCYBE CYANESCENS

Photographed in a studio, these intertwined wavy caps are among the many species of psychedelic mushrooms found along the west coast of North America.



PHYLLIS MA

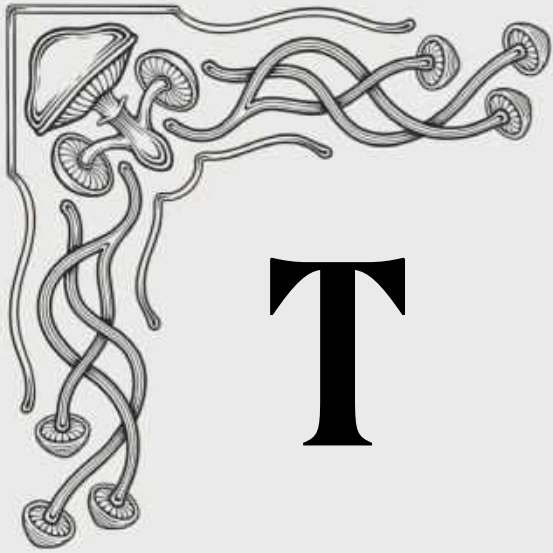
Chapter
Three

The Fungus Within Us

DOES THE FUNGAL
KINGDOM HOLD THE
KEY TO UNLOCKING
THE NEXT WAVE
OF ADVANCEMENTS IN
CANCER RESEARCH?

Words by
LANGDON COOK

37



TWO YEARS AGO, medical researchers taking a close look at cancer cells announced they had found a strange and surprising neighbor: fungi. But these fungi didn't just live near tumors—they offered clues about how deadly the cancer might be. *Candida* yeasts associated with colon cancer were predictive of metastatic growth, while with gastrointestinal cancer, they correlated with poor survival rates.

It's still too early to know if the fungi fuel the disease or if the disease is somehow incubating the fungi. But at the very least, these discoveries hint that there may be a new way to diagnose people earlier and better understand their prognosis.

"Initially, we were astounded," says Iliyan Iliev, an immunologist at Weill Cornell Medicine in New York and one of the researchers who made the fungi-cancer connection. In addition to *Candida*, his team found several other fungal species that were associated with the disease, such as *Blastomyces* in lung cancer and *Malassezia*, a variety of yeast, tied to breast cancer.

Part of that surprise, for many, might be because of another link between fungi and our health. Medicinal mushrooms are sold throughout the world in various forms, from tinctures and capsules to powders and teas. They sustain a \$30 billion business that's expected to double by 2032, in part because of their cancer-fighting association.

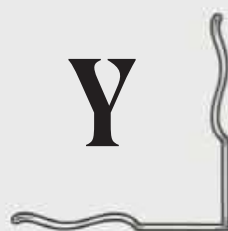
Even so, researchers are still at an early stage of understanding the true benefits of

medicinal mushrooms. In 2022, scientists in India and Belgium published a comprehensive survey of peer-reviewed literature on the topic. While at least 32 species showed promise, according to the report, only around a dozen had been clinically tested for their potentially therapeutic properties.

"Mushrooms produce a wide range of chemicals not readily found in other organisms," says Walter Luyten, a professor emeritus at the Belgian university KU Leuven who contributed to the report. Some of these naturally derived compounds interact with the immune system to, as the report notes, "exhibit potent antitumor activity," meaning they might slow the growth of certain cancers or even keep them from forming. Species such as reishi (*Ganoderma lucidum*) and maitake (*Grifola frondosa*), to name just two, have shown promise in clinical studies.

Though mushrooms are vastly understudied, Luyten and his team called them "one of the best gifts of nature for new ... pharmaceuticals," if we can better understand them.

This is the paradox of medicinal fungi: It's a mysterious realm that could help or hurt us. Understanding this difference, and how best to harness what we're learning, hinges on exploring a broader frontier called the mycobiome.



YOUR BODY IS certainly no stranger to good or bad fungi. The yeast in your stomach that helps regulate digestion? That's a good thing. The fungal infection on your skin

that causes athlete's foot? Not so much. Among the trillions of tiny microbes that live on or inside each of us in a delicate balance, there are bacteria, viruses, and single-celled protozoans, all of which are part of what's known as your microbiome. Fungi are also included in that universe, but in recent years researchers have assigned them a separate designation—the mycobiome—in recognition that these organisms work quite differently.

Siew Ng, director of the Microbiota I-Center

at the Chinese University of Hong Kong, says our body's fungal community is a "small but crucial component" of the gastrointestinal microbiome in particular. But while gut fungi such as *Candida*, *Saccharomyces*, and *Cladosporium* are all fundamental to our health, they have also been linked to diseases. *Candida*, for instance, can overpopulate and cause dysbiosis, a disorder associated with many health issues, including colorectal cancer. In other words, good fungi can become too successful and run amok, and turn into bad fungi.

For Deepak Saxena, a microbiologist at New York University, the life-altering question is simple: Why do some fungi inhabit tumors? Saxena's research group was the first to identify fungi in pancreatic cancer, finding in 2019 that a *Malassezia* yeast can migrate from the small intestine to the pancreas and inhabit cancer cells. Saxena hypothesizes that the fungi's presence in the pancreas might be because of either immunosuppression or some other kind of altered environment that tumors help create. In lab experiments with mice, Saxena has seen the use of anti-fungal treatments arrest tumor progression, although plenty of research has shown that what works in mice often isn't directly transferable to humans.

For mushroom experts, it's not as simple as using one thing to treat another either. Ng says that traditional varieties like reishi and turkey tail (*Trametes versicolor*) have immune-boosting properties that have been shown to enhance the efficacy of chemotherapy. Numerous studies also indicate that many mushroom species do, in fact, contain anticancer compounds, including biologically active carbohydrates and terpenes that stimulate the immune system. Still, there are questions about what dose is most effective and whether any of these would work as a stand-alone treatment.

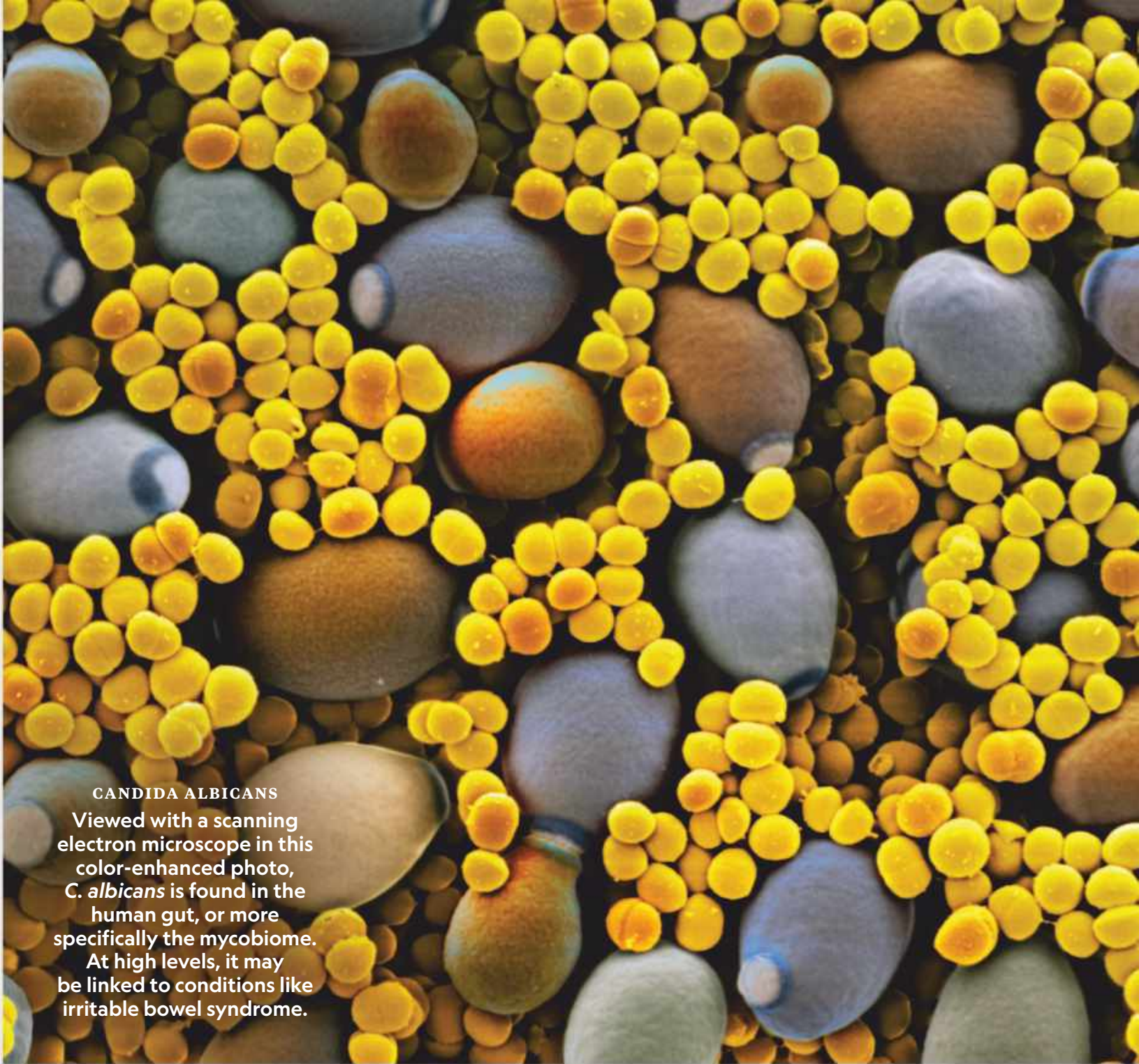
In the meantime, there are no mushroom-based cancer drugs or immunity boosters on the market today that have been approved by the U.S. Food and Drug Administration. That



Shroom Science Simplified



THE GRANDDAUGHTER of a licensed traditional herbal doctor, Ophelia Chong began cultivating fungi in Los Angeles nine years ago. She injects live mushroom tissue into a liquid culture of water mixed with honey, dextrose, or malt extract. (Sugar feeds the developing fungi.) After several weeks on a magnetic stir plate, the resulting mix is moved to a bag of grain and then soil, where it will eventually produce mushrooms for personal medicinal and culinary use.



CANDIDA ALBICANS

Viewed with a scanning electron microscope in this color-enhanced photo, *C. albicans* is found in the human gut, or more specifically the mycobiome. At high levels, it may be linked to conditions like irritable bowel syndrome.

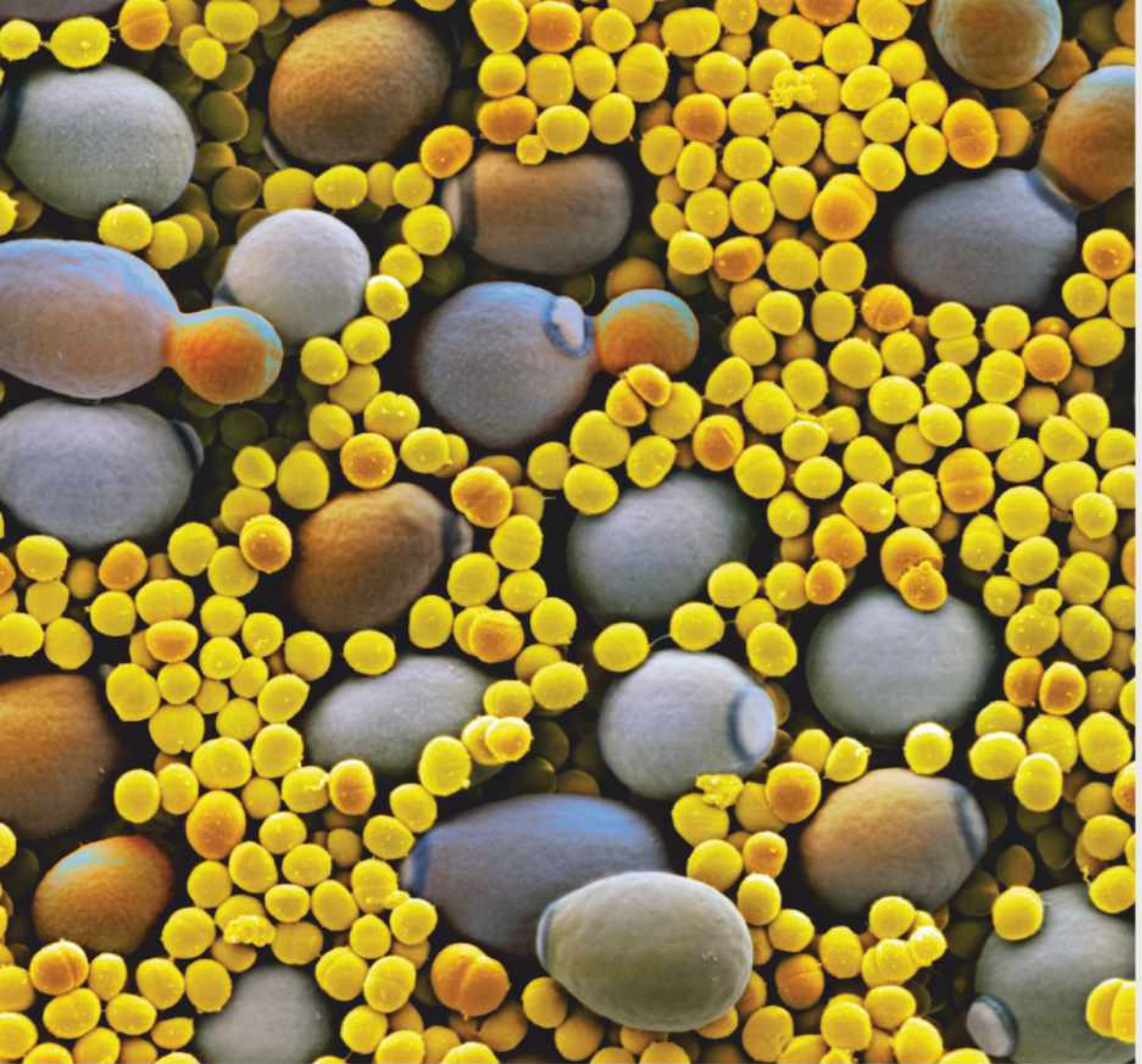
makes any mushroom-related remedy sold over the counter with health claims essentially “try at your own risk.”

For some people, however, that seemingly untapped potential has led them to seek another kind of guidance.

O **ON AN OVERCAST DAY** this past October near Port Angeles, Washington, Robert Rogers tromped through a shady, wooded area followed by a dozen intrepid foragers who had signed up for his specially guided tour as part of the annual Olympic Peninsula Fungi Festival. He pointed to a

fan-shaped fungus the size of a half-dollar growing on a decayed nurse log. Its earthen-hued bands resembled the plumage of a game bird. This is what turkey tail looks like in the wild, he told the crowd.

Rogers isn't a doctor. He's a self-described clinical herbalist and the author of *The Fungal Pharmacy*, a field guide to identifying mushrooms and lichens with purported health benefits. And he's one of many ad hoc enthusiasts who have compiled research about incorporating fungi into everyday health routines, often as a preventive measure. Most commonly consumed mushrooms—even the ubiquitous grocery store button—have phytonutrients beneficial to our health. When it comes to



cancer, however, medicinal fungi such as turkey tail are not exactly assassins. “They don’t kill cancer cells on sight,” he explains. “They encourage the immune system to do the job.”

More specifically, Ng says, turkey tail has been shown to increase the production of cytokines, which aid the body’s cellular response to fighting a foreign pathogen or tumor. Used traditionally for centuries, a chemical from the mushroom has been the focus of more than four dozen clinical trials to date.

As for the connection between fungi and cancer cells, Iliev concedes that he initially considered it to be “biologically improbable,” but he’s since shifted toward “cautious optimism” about unraveling more mysteries

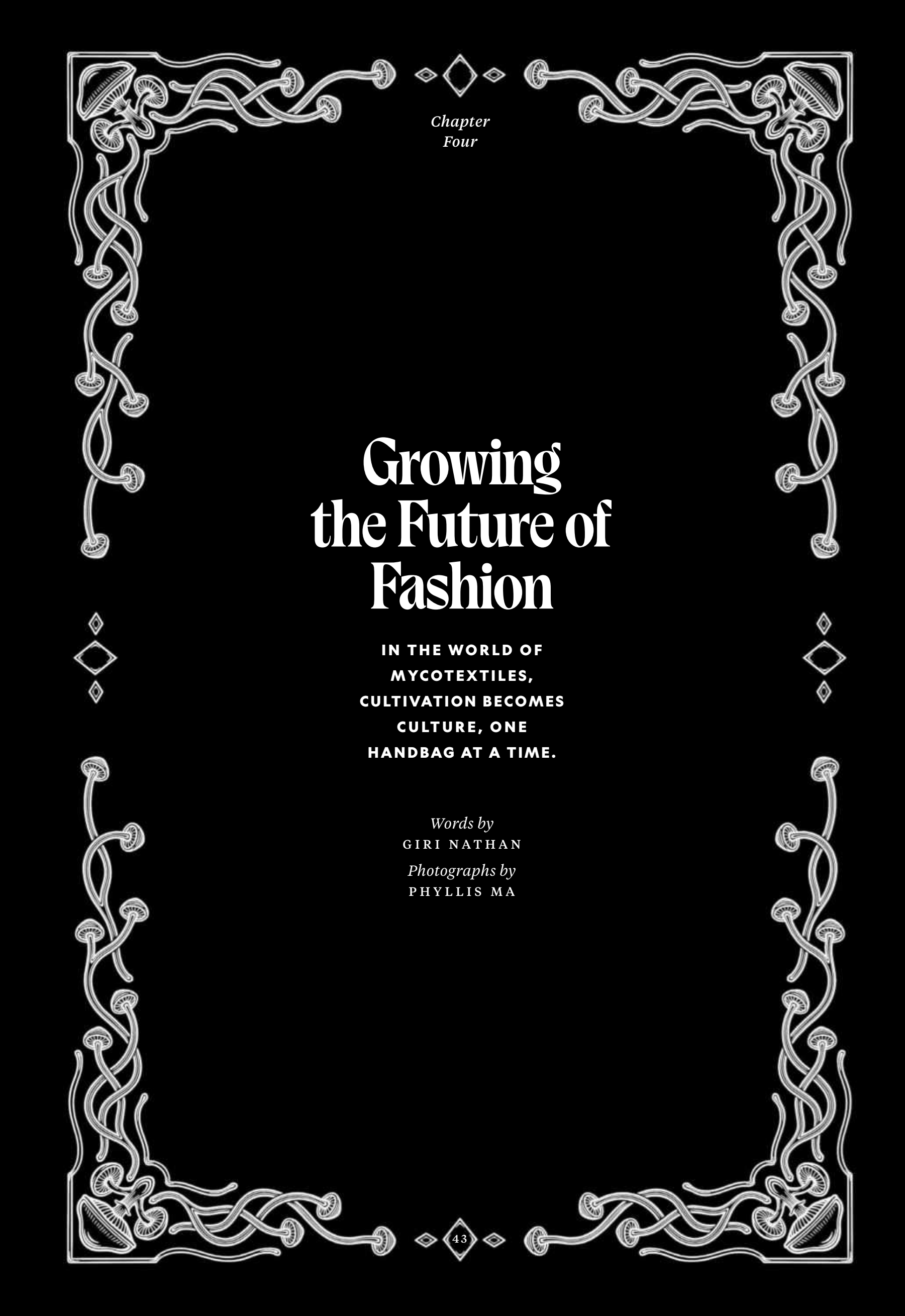
of the mycobiome. In another recent study, researchers at NYU, including Saxena, found that there are 20 distinct types of fungi that may someday be useful in distinguishing between people with cancer and those without, pushing forward the idea that early testing of fungi might pave the way for better diagnoses and treatment.

Compare the potential advances of medicinal fungi to the advent of penicillin. One of the great fungi-based infection fighters of the modern age, it was discovered accidentally nearly a century ago, after a physician let mold grow in a petri dish of *Staphylococcus* bacteria. Who knows what other connections we might find now that we’ve started looking?

GANODERMA SESSILE

When not in the studio for its close-up, this species (pictured specimen was cultivated) can be found in the northeastern United States on oak, maple, and beech trees.





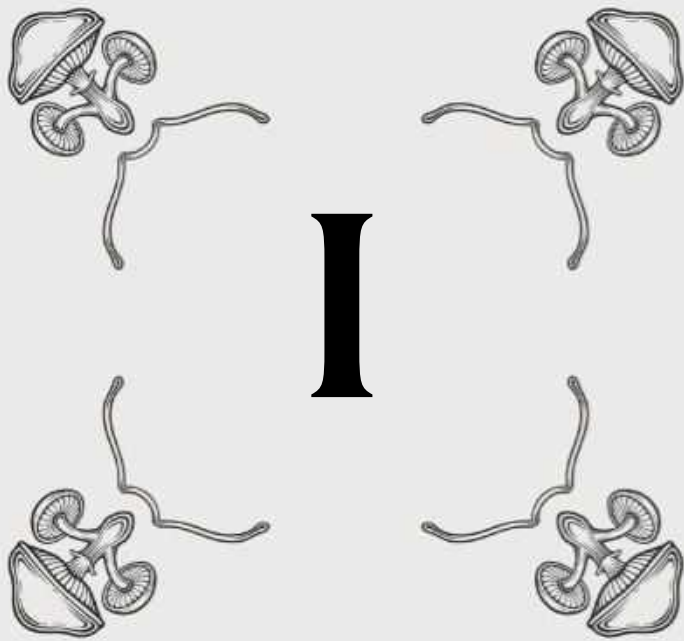
*Chapter
Four*

Growing the Future of Fashion

**IN THE WORLD OF
MYCOTEXTILES,
CULTIVATION BECOMES
CULTURE, ONE
HANDBAG AT A TIME.**

Words by
GIRI NATHAN

Photographs by
PHYLLIS MA



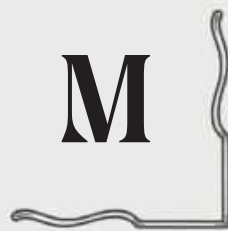
IN PRESENT-DAY ROMANIA, a dwindling number of artisans practice what's thought to be a centuries-old craft. They search the forest for hoof fungus, which grows within trees and sends out shelflike mushrooms a few inches wide. The fungus is pried off trunks and, with a sickle, shaved lengthwise into thin strips the color of gingerbread. Those strips are then hammered and stretched to form broad, feltlike sheets called amadou, which can be crafted into hats, bags, jewelry, and ornaments.

These products are beautiful and eco-friendly, if painstaking to forage for and create. As far back as 1903, Tlingit artisans in what is now the state of Alaska were crafting pouches out of a sturdy matlike material. A 2021 study in the journal *Mycologia* suggests that these “mats” were produced by the agarikon fungus, a hardy polypore native to old-growth forests in the Pacific Northwest. But, again, the artisans' process was about foraging for materials, not cultivating them for mass production.

Today, inside a 136,000-square-foot facility in Union, South Carolina, the biotechnology company MycoWorks is pioneering a more intentional and scalable approach. Beneath dim red lighting that resembles a darkroom's, stacks of metal trays are arranged in tall columns. Large mechanical arms whirl about, ready to pluck them individually for close inspection by a small team of technicians who wear sterile suits and examine the contents with flashlights.

Each tray is incubating mycelium, a mesh of fine filaments that, for fungi, are roughly analogous to a plant's root system. Mycelium is a structural marvel—simultaneously soft, dense, and strong—which makes it a great potential replacement for leather. Coaxing mycelium to grow in predictable ways may be a complex task, but recent advances in biotech have opened up a cottage industry for mycotextiles.

The early efforts appear to be more ethical, environmentally sustainable, and efficient than the multibillion-dollar industry that is animal leather. And MycoWorks is just one of a wave of innovators, all of which are betting big that a better understanding of mycelium can redefine the limits of fashion and design.



MYCOWORKS CO-FOUNDER

Phil Ross has been experimenting for more than 30 years with *Ganoderma*, a genus of fungi that grow a lot like hoof fungus in the wild. As an artist in his San Francisco apartment, he learned how to manipulate the fungi into a range of forms: In 2009 he constructed a “teahouse” made of bricks that could be removed and brewed into tea.

Ross first considered mycological-based construction materials, but an inquiry from a shoe company in 2015 helped him and co-founder Sophia Wang refocus on fashion. The material that MycoWorks now produces is called Reishi, borrowing the Japanese word for *Ganoderma*. In recent years, MycoWorks products have been used in designer bags for Hermès and upscale pillows for Ligne Roset.

The low-energy operation starts with agricultural waste, like sawdust and bran, which is heated to eliminate any existing microbial life that might be competition for the fungus. Once sterilized, the substrate goes into “deep-dish, lasagna-like trays” of varying sizes, says Ross. Then *Ganoderma* joins the party, digesting and growing through the biomass. In some cases, fabric can be added to the tray as a scaffolding for the mycelium to weave around, creating a

composite material. The sheet of mycelium is eventually peeled off the sawdust block, and growth comes to a halt. From there, it can be “tanned” to yield a material easily mistaken for traditional leather before being crafted into, say, a purse or hat.

MycoWorks CEO Matt Scullin, who has a background in materials science, praises the “wet spaghetti” structure of mycelium, which is composed of filaments—called hyphae—that entangle one another and branch off in treelike patterns while leaving empty space between the cells. The result accounts for some of Reishi’s most appealing properties. “It has a bit of a velvety touch to it,” Scullin says. “It has a bounce. It has an absorptivity to the oils and heat that emanate from your fingers when you touch it.”



WHILE MYCELIUM CAN BE grown in mechanized warehouses, Aniela Hoitink, the founder of the Dutch company Neffa, short for New Fashion

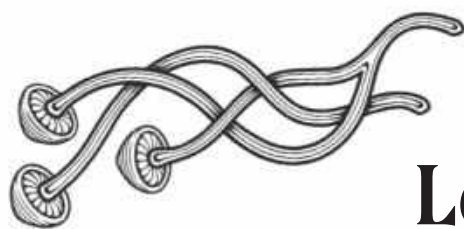
Factory, uses a liquid-culture technique to create bags, crop tops, even lampshades.

On a recent day, she held up a small black handbag as proof of that proprietary process. Neffa uses bioreactor tanks—basically a fermenting system similar to a brewery’s—to concoct a mycelial slurry that is strained out of the liquid and then poured onto a mold to dry into any desired form.

“You can really design from the product, rather than designing from the material,” Hoitink says, flexing and stretching the bag’s glossy black material that’s somewhere between plastic and leather, almost reminiscent of licorice. “Technically, the bottom [of the bag] needs to be the strongest. So you could say, OK, we add a little bit more biomass here so that it’s thicker and sturdier.”

This basic process allows Neffa versatility with minimal labor. Most important, Hoitink says, is that the liquid-culture process affords a freedom to experiment with speculative ideas. “Because it’s a slurry, you can add ingredients a bit easier,” she says. The company’s next step, she suggests, may be to infuse the materials with branded aromas or even skin-care compounds that treat conditions like psoriasis.

That’s just one way these products may differ from standard leather. Both companies



Tricks of the Fungal Leather Trade



GROWN FROM A STRAIN of *Ganoderma*, MycoWorks’s patented leatherlike material is achieved by encouraging the fungus’s strands of mycelium to spread, says CEO Matt Scullin. In nature, when a mycelium reaches the end of its food source, it reproduces; through an interplay of temperature, light, and humidity, MycoWorks can manipulate the mycelium’s growth to create the desired shape, size, and texture.



are thinking about their eco-footprint and the complete life cycle of their goods too. MycoWorks's Reishi, for example, is fully biodegradable—allowing for a future in which disposing of an old pair of shoes might mean simply composting it.

WHILE LARGER COMPANIES hope to use fungi to generate wholly new environmentally friendly materials at scale, independent designers are exploring their potential to modify or break down the planet's extant heaps of discarded fabric. Helena Elston, a New York-based designer, was studying fashion in London a few years ago when she devised an ethical response to the waste in her industry. She finds an old garment or stitches one together with scrap material, sterilizes it, and then adds an appliqué of mycelium.

Over the ensuing months, she'll watch as the mycelium wends its way through the material. Sometimes it selectively eats at the natural fibers and ignores the synthetic

ones. Sometimes it swirls dye into eddies of startling new color. In past experiments, Elston allowed the mycelium to break down the existing material completely. "It feels like it has this intellectual understanding that we as humans don't have," she says. "The most beautiful pieces have come out of me not being in control."

Maggie Paxton, a mycophile in New York who hunts new pigments on her foraging walks, treats silk gowns with mushroom dyes for the American fashion house Coach. Recently, she took earth balls—mushrooms that resemble old golf balls, as if aged to a dull brown—and boiled them in a stockpot. She was startled to discover this dye turned her silk "the prettiest petal pink"—a color that might inspire a future collection.

Many designers still seem surprised enough by the behavior of fungi that they talk as if they're collaborating with a vibrant, alien intelligence. "That's the whole excitement about the field in general," Paxton says. "We have no idea what magic is lying there right before us." The goal is to keep finding out. □



**TOLYPOCLADIUM
PARADOXUM**
A mycoparasite
found in China,
Japan, and Korea,
T. paradoxum,
pictured in studio,
overtakes
a host cicada.

Top left

GANODERMA SESSILE
A pathogenic
fungus, *G. sessile*
(featured specimen
was cultivated)
feeds on the roots
of deciduous
hardwood trees.

EYE *to the* SKY

In Wisconsin, the world's largest refracting telescope is once more open to visitors.

Words by BILL NEWCOTT

Photographs by
CHRISTIE HEMM KLOK

→ **INSIDE THE DOME** of Yerkes Observatory, tucked along the shore of Wisconsin's Geneva Lake, in the town of Williams Bay, it is emphatically 1897. The still-rotating metal half sphere is dominated by an enormous, lovingly polished refracting telescope—a 60-foot-long, six-ton contraption with two 40-inch lenses at one end and an eyepiece at the other. The thing is almost ridiculously fanciful.

If an astronomer or a visitor wants to look through that eyepiece, an operator flips an

ancient switch and the dome's entire circular floor—at 75 feet in diameter, one of the world's largest elevators—rises 23 feet to give the person access. Then, in a maneuver familiar to any backyard stargazer, the viewer takes hold of the massive telescope with two hands and physically shifts the impeccably balanced device toward the desired point of light.

Ironically, the cost of maintaining all this low-tech equipment is dauntingly high. Today, as tour groups shuffle through



Top

For his 1921 U.S. tour, Albert Einstein (seventh from right) insisted on visiting Yerkes (*left*).

Above

This Milky Way image, from Yerkes's archive of over 175,000 glass plates, is by astronomer E. E. Barnard, who discovered dust clouds in our home galaxy.

Yerkes, it's easy to forget that the observatory nearly met with a wrecking ball after the University of Chicago closed it in 2018.

They call Yerkes the birthplace of modern astrophysics, but when I visited the facility about two years ago, it looked more like a place teetering on extinction. The monumental telescope was draped in thick, clouded plastic sheeting that movie gangsters tend to use to wrap the bodies of their victims. It was a humbling state for a precision device that was once a magnet



Yerkes's \$15 million renovation included repairs to its three signature domes. The largest, 90 feet in diameter, rotates on 36 wheels.

for the elite of astrophysicists and theoretical astronomers—Albert Einstein, Edwin Hubble, Gerard Kuiper, and Carl Sagan among them.

But even as I tried to make out the telescope above, Yerkes was being reborn thanks to a \$15 million facelift—inside and out—financed by a nonprofit group that took possession of the building in 2020. For the first time in more than a century, the observatory—including its 50-acre grounds—is open for public tours of its working space-science facility.

Over the past few years, Yerkes staff have been preparing for what they expect to be one of the busiest days the institution has ever seen: North America's total solar eclipse on April 8, 2024. Williams Bay will see 90.2 percent totality, and Wisconsinites who don't want to drive hundreds of miles to witness complete darkness could find no more compelling a setting for near totality than here beneath these storied domes.

But the glories of Yerkes are not confined to the heavens: The building itself is a thing of beauty. Festooned with elaborate Victorian-era stone carvings, Romanesque arches, and terra-cotta figures, the landmark observatory was created by George Ellery Hale and Charles Tyson Yerkes—two men with very different agendas.

Hale, an astrophysicist, had the then revolutionary notion to establish a facility that housed both an observatory and an academic institution at which physicists and chemists applied their discoveries to new theories about astrophysics. Financier Yerkes, on the other hand, was one of Chicago's most hated businessmen. He poured money into the observatory to rehabilitate his image, but it didn't work—and he ended up moving to New York.

Yerkes's face, however, is depicted on the observatory's exterior columns—albeit with a sinister smile and devilish horns. “The artists had fun with that,” notes



Terra-cotta globes, complete with zodiac signs, were restored prior to being placed once again above Yerkes’s entrances.

Dennis Kois, executive director of the Yerkes Future Foundation, which inherited the observatory from the university. “Nobody liked Yerkes.”

The telescope’s 500-pound lens—cast in France, ground in Massachusetts—made the instrument the biggest ever version of the handheld, two-lens, direct-view telescope used by Galileo in 1609. Because Yerkes’s was one of the first large telescopes designed for photography, its tube needed to rotate with absolute precision to follow star tracks—a feat accomplished by a team

of men who turned the gargantuan device one click at a time.

Even after reflector telescopes, which use mirrors to collect and focus light, became the favored tool for space studies, Yerkes’s staff continued to publish influential papers. Its archives hold thousands of research works—including Hubble’s original 1920 doctoral thesis.

In 2018 the university began winding down its Yerkes presence. Astronomers comparing present-day star positions with where they were a century ago still referenced Yerkes’s 175,000 photographic plates, but the halls, once bustling with scientists, fell silent. When the call went out to support the restoration project, the influx of cash from astronomy and architecture enthusiasts across the United States, including many from the neighboring town of Lake Geneva—for nearly 200 years a playground of the Chicago rich—was overwhelming.

“People have always wanted to visit here,” Kois says. That almost mystical appeal persists today, whether visitors are star buffs or not. “There’s something about looking directly into a beam of light that has traveled millions of light-years just to end up at the back of your eyeball.” □

TRAVEL TIPS



WHAT TO KNOW
Yerkes is less than two hours’ drive from Chicago and Milwaukee. Its guided 1.5-hour tour “Space & Spaces” is offered daily (\$43/adult). Other events include concerts and readings. Check program dates and buy tickets at yerkesobservatory.org.

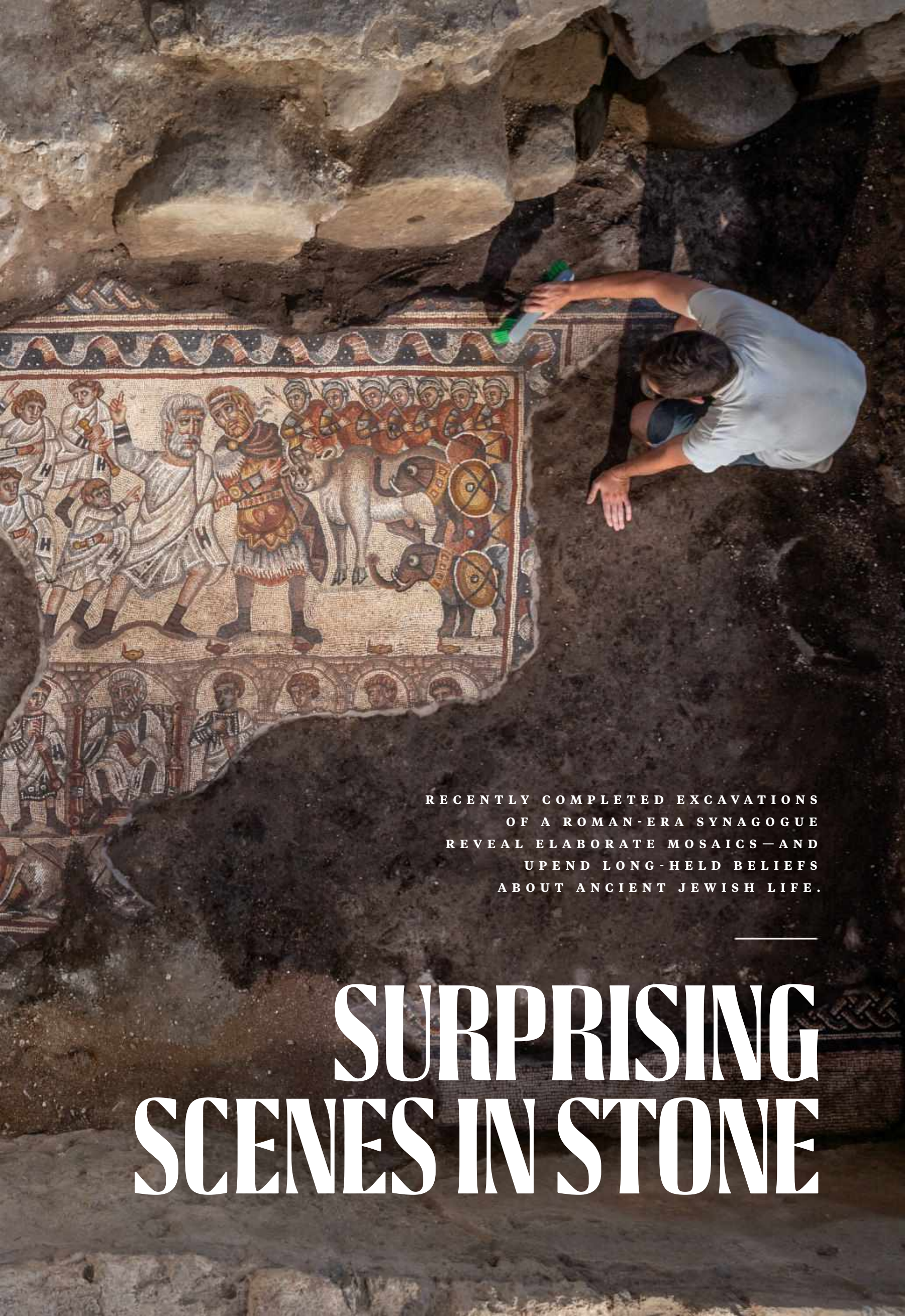
WHERE TO STAY
Opened in 1968 in Lake Geneva, Grand Geneva Resort & Spa is a marvel of Frank Lloyd Wright-inspired architecture.

WHERE TO EAT
Mars Resort, on nearby Lake Como, is a classic Wisconsin supper club.

Mosaics uncovered on the floor of a fifth-century synagogue in Israel's Galilee include a woman's face and a dedication in Hebrew (below). The scene next to it may show the high priest of Jerusalem meeting with Alexander the Great.

MARK THIESSEN





RECENTLY COMPLETED EXCAVATIONS
OF A ROMAN-ERA SYNAGOGUE
REVEAL ELABORATE MOSAICS—AND
UPEND LONG-HELD BELIEFS
ABOUT ANCIENT JEWISH LIFE.

SURPRISING SCENES IN STONE



WORDS BY ANN R. WILLIAMS
 PHOTOGRAPHS BY PAOLO VERZONE

WHEN ARCHAEOLOGIST JODI MAGNESS climbed to the sunny hilltop overlooking the Sea of Galilee in the summer of 2010, she was unsure what she might find there. An ancient Jewish village known as Huqoq once stood on the site in northeastern Israel, but all that remained above ground was a jumble of centuries-old building stones, modern debris, and wild mustard plants.

Magness, a professor of early Judaism at the University of North Carolina at Chapel Hill and a National Geographic Explorer, had spent years leading excavations



Student volunteer Anna Lafleur, sweeping off a newly uncovered wall, lives in Canada but was born here in Galilee. “When the opportunity to excavate was presented, I knew I wanted to be a part of it,” she says.



in Israel and suspected that this hilltop was worth exploring. By the following summer, she and her team had discovered a stone wall running north to south some seven feet below ground. Several pieces of evidence—including a main doorway oriented toward Jerusalem—revealed that it was the perimeter of a synagogue that had been constructed some 1,600 years

ago, in the early fifth century. Similar buildings of that era had floors paved with flagstones. But as the team kept digging, they unearthed more and more small mosaic stones, called tesserae—a hint that something truly special might lie beneath.

On a hot day in June 2012, Bryan Bozung, a recent graduate of Brigham Young University, was carefully removing dirt from his excavation square when he scraped against something hard at floor level. He alerted Magness, and as she brushed away the remaining dirt,



Site conservator Christian de Brer gently removes dirt, salts, and mortar from a lion's mane. The mosaic artist who created this panel had likely never seen such a creature but was reproducing a popular decorative pattern.





Dawn's early light finds archaeologists already at work under the tents that shade the dig. "This is really the land of milk and honey," says director Jodi Magness, describing the nearby hills where orchards, cattle, and beehives flourish.





JONAH AND THE STORMY SEA

In the Bible, the Prophet Jonah refuses to preach against the sinful city of Nineveh, as God has commanded. Instead, he flees on a ship. God then whips up a violent storm, which threatens to wreck the ship. When Jonah confesses to the crew that the storm must be his fault, they throw him overboard to save their fragile vessel. Underwater, Jonah is swallowed by a big fish, often rendered as a whale. The interpretation at Huqoq, seen here, is the earliest known depiction of this tale in an ancient Jewish context. And it has a twist that appears in later Jewish and Islamic written sources: Jonah is swallowed by a succession of three fish **(1)**.

Located in the synagogue's nave, the panel presents a host of other intriguing details: A balding, bearded man dangling a looped rope into the sea **(2)** may be the ship's captain. His gray hair hints that he is older, and so presumably has years more experience than the rest of the crew.

A sailor at the top of the ship's mast points to a trio of harpies or sirens **(3)**, the personifications of tempestuous winds, standing on a cloud. The strange, hybrid creatures with the head of a woman and the wings, feet, and tail of a bird are playing a lyre and a flute, and dancing to the music.

Marine animals include what may be a sea snake wrapped around a barracuda **(4)**, an octopus **(5)**, a dolphin **(6)**, and fish that have been identified as red snapper **(7)** and sea bass **(8)**.

A fisherman casting a net from a small boat **(9)** and a man wringing water from a fishing net with a partner **(10)** (only partly preserved) represent tasks in the daily life of a mariner.

the two were stunned to see the face of a woman delicately traced in tesserae staring up at them. It was the first section of a mosaic to come to light.

Over the next decade, Magness returned to Huqoq each June with an international team of experts and student volunteers. She had originally planned to spend only five seasons excavating part of the site but quickly realized she was in for a much longer haul. The project goals would now have to include preserving whatever was left of the mosaic floor—and what was left, revealed slowly year after year, turned out to be extraordinary.

The outline of the synagogue, when fully exposed, was about 65 feet long by 50 feet wide. The entire expanse of the floor had been covered in expertly rendered mosaic panels, though only about half of that original floor remained intact.

“Usually in an ordinary church or synagogue you have one, two, or three scenes presented, but here you have many more,” says Gideon Avni, chief archaeologist with the Israel Antiquities Authority, which licensed the excavation. “It’s probably the best, most diverse concentration of mosaics in the country.”

Many of the surviving mosaics depict stories from the Hebrew Bible: Pairs of creatures such as camels, donkeys, elephants, and lions heading toward Noah’s ark. The Red Sea engulfing the Egyptian army. Carpenters and masons building the Tower of Babel. Samson carrying the gate of Gaza on his shoulders.

“There’s a lot of violence in these mosaics, a lot of blood and gore,” says Magness. “But there’s also some humor.” Among the most gruesome scenes: a depiction from the Book of Judges in which a Kenite woman named Jael hammers a tent stake through the head of the Canaanite general Sisera. By contrast, a whimsical twist on the story of Jonah portrays the hapless prophet being swallowed by three successively larger fish.

The mosaics also borrowed motifs from classical art, including cupids, theater masks, and the Greek god of the sun, Helios, who rides in his chariot surrounded by the symbols of the zodiac.

Huqoq may have been a village in the countryside, but it wasn’t isolated, says dig assistant director Dennis Mizzi, senior lecturer in Hebrew and ancient Judaism at the University of Malta. “It was connected with the wider Mediterranean world. That means the community was aware of a wide range of traditions and comfortable enough with ideas from outside its own area.”



Fritz Clingroth (right), from the College of Wooster in Ohio, and conservator Linda Roundhill study a mosaic depicting a hare and what may be a fox nibbling grapes, a scene that likely symbolized abundance.



While there are still questions about how exactly the synagogue originated, the discovery of its remains is now rewriting history, particularly our understanding of how Jews lived under foreign rule. Romans conquered the land east of the Mediterranean, including Galilee, in the first century B.C. Initially, they recognized Judaism as an ancestral religion. Jewish

people were allowed to live according to their own laws and were granted exemptions such as not having to worship the emperor.

“That really doesn’t change significantly until Christianity becomes a legal religion in the Roman Empire and then the empire’s official religion,” says Magness. “Once that happens, in the fourth century, legislation becomes increasingly restrictive of Judaism.”

New laws sometimes banned the construction of synagogues. “If you were going on the basis of that





According to the Book of Genesis, the Tower of Babel was built to reach the heavens. The Huqoq synagogue shows the tower in mid-construction and a diverse crew hard at work. Miners quarry stones; carpenters shape wood with a saw, a plane, and an adze; and masons use a complex pulley system to raise building blocks. But God punished this prideful act of humans by confusing their language. The resulting discord is evident in a fight between two workers (center left).

ODED BALILTY



alone, you would think that Jews were persecuted, that they were oppressed,” says Magness of the people in this region. But at Huqoq, the existence of a grand synagogue adorned with bold artistic expressions offers clear evidence that despite tensions, daily life in Galilee may not have been so dismal.

AMONG ALL THE MOSAICS, one panel is especially dazzling—and puzzling. More finely crafted than the rest of the floor, with large sections still intact,

it’s divided into three horizontal registers. At the bottom, defeated soldiers, a battle elephant, and a bull are dying from bloody spear wounds. In the middle, stone arches shelter men wearing tunics. And at the top, two male leaders are meeting, one in a tunic and the other in armor, each accompanied by his followers.

Magness thinks the one in armor



Archaeology resembles a playground game when team members use their combined muscle to pull a heavy stone away from an area to be excavated. Building blocks from the collapsed synagogue littered the entire site before work began here.

is Alexander the Great. His followers are soldiers with battle elephants. He wears the diadem and purple cloak of a king but is not identified by an inscription.

“There was only one Greek king in antiquity who was so great that he didn’t need a label,” Magness says. That being the case, this mosaic may represent an encounter between the high priest of Jerusalem and Alexander during the famed conqueror’s battles against the Persians in the fourth century B.C. The story—likely a cherished legend rather than truth—circulated in Jewish communities for centuries.

“The point of the legend is to show that even Alexander the Great, the greatest of the Greek kings, acknowledged the greatness of the God of Israel,” Magness suggests. This masterpiece, along with the rest of the mosaic panels, was probably laid by specialists from a local, family-owned workshop. An inscription by the main door lists several names of people identified as artisans, perhaps the very ones who created the floor.

“There appear to be brothers within a single family, as well as perhaps a couple of other figures,” says Ra’anan Boustan, a historian of Judaism at Princeton University. A senior artist would have designed the floor and traced out the figures in every panel. Experienced mosaicists fashioned details like faces, hands, and feet, while junior workers filled in backgrounds and the larger fields of color. They worked with stones from the region, cut into long rods on-site and then snipped into tiny cubes.

The quality of a mosaic depends on the size of the tesserae. The smaller they’re cut, the more details they create. Mosaic specialists measure the number of tesserae per square decimeter, about 15 square inches. In some places at Huqoq, the count is as low as 175; in others it’s around 230. But the mysterious three-tiered mosaic comes in at about 500. “The density readings in that area approximate what you would find in Constantinople, in imperial mosaics,” says Karen Britt, a mosaic specialist at Northwest Missouri State University.

But that’s not the only ostentatious part of the building. Judging from recovered flecks of colorful plaster, portions of the interior may have been brightly painted, inspiring dig members to dub it the “disco synagogue.” Magness herself calls it the kitschiest synagogue ever. Parts of the building’s interior were probably painted red, white, pink, and yellow—a theme that may have extended to the exterior.

Throughout the excavation, Magness and her team revealed the mosaics in sections, exposing different areas to be cataloged and photographed before covering them back up to protect them in place. After taking into account other finds in the region, Magness now believes that Huqoq's over-the-top design may be evidence of inter-Jewish competition. "All the villages in the area are building synagogues, and they're all pretty spectacular," she says. "But here people decided they were going to build the mother of all synagogues." Likely two stories tall and situated at a high point in the village, it must have been visible for a great distance.

SUCH A LAVISH STRUCTURE did not come cheap. Perhaps wealthy patrons underwrote the cost, but more likely, villagers of lesser means may have been making enough money to donate to a construction fund. At least in the fifth century, Jews in this remote part of the empire seem to have been prospering. But they may have had concerns about how long their religious freedom might last. And they appear to have expressed those concerns on the floor of their synagogue.

"I think they are grappling with the reality that they are in a rapidly Christianizing world," says mosaic specialist Britt. "One way of doing that is to say, look, this is not all that different from periods in the past when Israelites had to deal with other foreign powers, whether it's the Philistines, the Canaanites, the Babylonians, the Greeks, the Romans, and now Christian Romans."

Boustan, the historian of Judaism, agrees, adding that "the theme of God's deliverance through human warriors in the face of foreign domination is something that comes across very strongly."

And yet, some generations after it was built, the synagogue was mysteriously abandoned. Given the region's long history of catastrophic seismic activity, it's not hard to imagine an earthquake leaving the synagogue so damaged that it was thought to be unsafe even though it continued to stand. Eventually parts of the building collapsed, destroying sections of the mosaics. Another tremor may have delivered the final blow.

"It wasn't burned. It wasn't taken apart," says Martin Wells, the project's architecture specialist from Austin College in Texas. "My guess is an earthquake."

In any case, some 800 years after the synagogue was constructed, the region came to be ruled by the Mamluks, a Muslim dynasty based in Egypt. A Mamluk

In a scene from the biblical Book of Judges, Samson has used his mighty strength to kill this shield-bearing Philistine soldier, who has collapsed on the ground. Two other scenes also celebrate the legendary leader.

road, part of a network connecting Cairo and Damascus, ran right by the village and brought a flow of merchants and pilgrims. As the area became prosperous once again, the Jewish people who remained repaired the fifth-century synagogue while also expanding it and adding a thick, concrete-like base—which, fortunately, protected the mosaics.

Beginning in the 15th century, commercial traffic in the area slowed. The synagogue appears to have been abandoned again, and it gradually tumbled to the ground. So it remained until the archaeologists arrived.

Twelve years after they first started digging, Magness and her team completed their fieldwork in the summer of 2023. The site remains backfilled to protect the mosaics and has been turned over to the Israel Antiquities Authority and the Jewish National Fund to develop plans for tourism. IAA archaeologist Avni predicts this "jewel in the crown" of Israel's cultural heritage will become one of its greatest attractions.

The digging may be done, but there is much excavated material—now in storage in Jerusalem—to be analyzed, and many mysteries remain to be solved, Magness says. "My team and I will be coming back for years." □

Ann R. Williams specializes in writing about the ancient world and cultural heritage preservation.





BUGS *on the* MOVE

An innovative technique
reveals the flight paths of insects
in surprisingly artful ways.

Images by
XAVI BOU

→ **THE SMALL BODIES AND SPEEDY** movements of flying insects make them tough to track, but technological advances and some creative thinking have allowed Spanish photographer Xavi Bou to do just that. After spending 10 years concentrating on birds in flight for his Ornithographies project, he shifted his focus to bugs. For Entomographies, he uses high-speed video footage taken by Adrian Smith, an entomologist at North Carolina State University, to decode and document insect trajectories. Then Bou selects multiple frames and merges them into single images that convey the rapid motions through space and time of one or more animals. With Smith's help, Bou has mapped the aerial acrobatics of wasps, the leaps of leafhoppers, and the flutters of butterflies in stunning detail. In doing so, he hopes to raise awareness about the decline of key insect populations worldwide. "It's happening in front of our eyes, and we are not paying attention," Bou says. —ANNIE ROTH

ZEBRA LONGWING

This butterfly, found in many parts of the Americas, lives up to its name. The insect can soar to great heights with just a few beats of its supersize wings.



Clockwise from above

**MULTICOLORED ASIAN
LADY BEETLES**

A common ladybug species, these insects inhabit various regions around the world. They move slowly on land but can reach speeds of up to 37 miles an hour in the air.

TWO-LINED SPITTLEBUG

This insect, native to the eastern United States, is often called a pest because of its taste for turf. Spring-loaded hind legs can launch the animal into the air like a rocket.

**YELLOW-COLLARED
SCAPE MOTH**

Unlike most moths, this North American species can be seen flying during the day, with its iridescent blue-black wings that shimmer in sunlight.









**AILANTHUS
WEBWORM MOTHS**

These tropical moths have moved farther north in the U.S. Thanks to their larval host, the invasive tree of heaven, they are among the most widespread backyard moths in the country.

Francisco Ángel, a hospital worker and student, makes extra money by scouring mounds of clothes in the Atacama Desert for items to sell. Each week, shipments of used garments arrive in Chile at the free port of Iquique. Resellers buy some, but tons of clothes end up here.



FASHION'S DESERT

Clothing from many of the world's favorite brands lies in discarded heaps in Chile's Atacama Desert. How it got there tells the story of modern fast fashion.

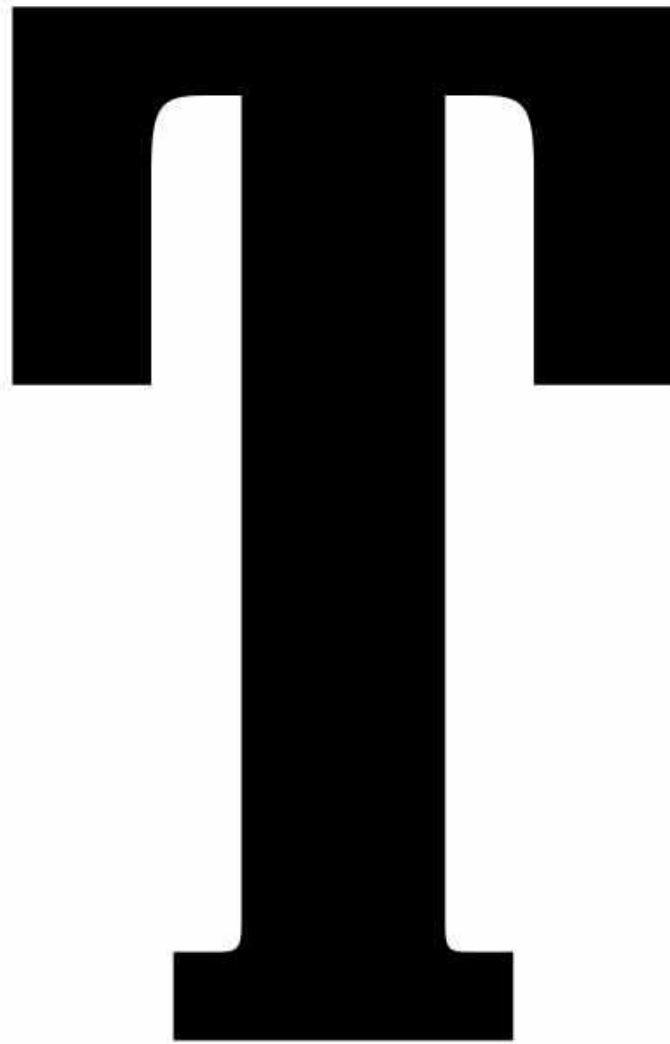


GRAVEYARD

WORDS BY
JOHN BARTLETT
PHOTOGRAPHS BY
TAMARA MERINO



Used shoes lie scattered among the piles of cast-off clothing. Critics blame northern Chile's growing clothing dump on the rise of cheap, mass-produced fashions and problems with global trade.



THE ATACAMA DESERT IN NORTHERN CHILE stretches from the Pacific to the Andes across a barren expanse of red-orange rock canyons and peaks. As one of the driest deserts on Earth, it's a bucket-list destination for stargazing tourists who come for some of the clearest views of the night sky. With its arid, rocky landscape so closely resembling Mars, the desert has even attracted the attention of NASA, which has tested rovers there.

But the Atacama has also attained a less wondrous distinction as one of the world's fast-growing dumps of discarded clothes, thanks to the rapid mass production of inexpensive attire known as fast fashion. The phenomenon has created so much waste that the UN calls it "an environmental and social emergency." The challenge is turning off that tap.

The numbers tell the tale. Between 2000 and 2014, clothing production doubled and consumers began buying 60 percent more clothes and

wearing them for half as long as they once did. Three-fifths of all clothing is estimated to end up in landfills or incinerators within a year of production—that can translate to a truckload of used clothing dumped or burned every second. Most of the facilities are in South Asia or Africa, where the nations receiving those loads cannot handle the amount. A landfill near Accra, Ghana’s capital, that is said to be 60 percent clothes and 65 feet high has gained international notoriety as a symbol of the crisis.

The scene in northern Chile has been dubbed in one online video “the great fashion garbage patch,” a terrestrial variation of the better-known Great Pacific Garbage Patch. Colossal piles of discarded clothes, with labels from all over the world, stretch as far as the eye can see on the outskirts of Alto Hospicio, a hardscrabble city of 120,000 residents. In one ravine, a pile of jeans and suit jackets, bleached by the harsh sun, rises above a mound of fake-fur coats and dress shirts, some still bearing price tags. Bottles, bags, and other trash are mixed in.

As images of the clothing heaps spread on the internet, many Chileans expressed surprise. “I was shocked to think that we were becoming the textile dump for developed countries,” says Franklin Zepeda, a director of a company that focuses on circular economic practices. But the story of how the South American nation came to be a repository for the world’s apparel rejects has as much to do with globalization and trade as it does with fleeting style trends.

AT FIRST GLANCE, IT MIGHT SEEM THAT AN isolated desert nearly a thousand miles from Chile’s population centers would be an unlikely destination for fast fashion’s discards, but the country is also home to one of South America’s largest duty-free ports—located in the coastal city of Iquique on the Atacama’s western edge. Millions of tons of clothes arrive annually from Europe, Asia, and the Americas. Last year’s tally was 46 million tons, according to Chilean customs statistics.

Duty-free ports encourage economic activity, as goods are imported and often

reexported without the usual taxes and fees. The duty-free port was established in Iquique in 1975 to help generate jobs and improve an ailing local economy. Chile became one of the world’s largest importers of used clothes, which transformed Iquique. As fast fashion exploded, so did imports.

“The *zona franca* [free zone] was a true revolution” for the city’s residents, says Bernardo Guerrero, a sociologist at Fundación Crear, an organization that studies Iquique’s history and culture. “They suddenly had access to things they could never have imagined, like their own car.” Apparel began washing in and out of Iquique like waves as global fashions changed. Guerrero recalls a time in the 1990s when almost everybody in the city wore the same style of puffer jacket after large shipments of them arrived. It was a sign of what was to come.

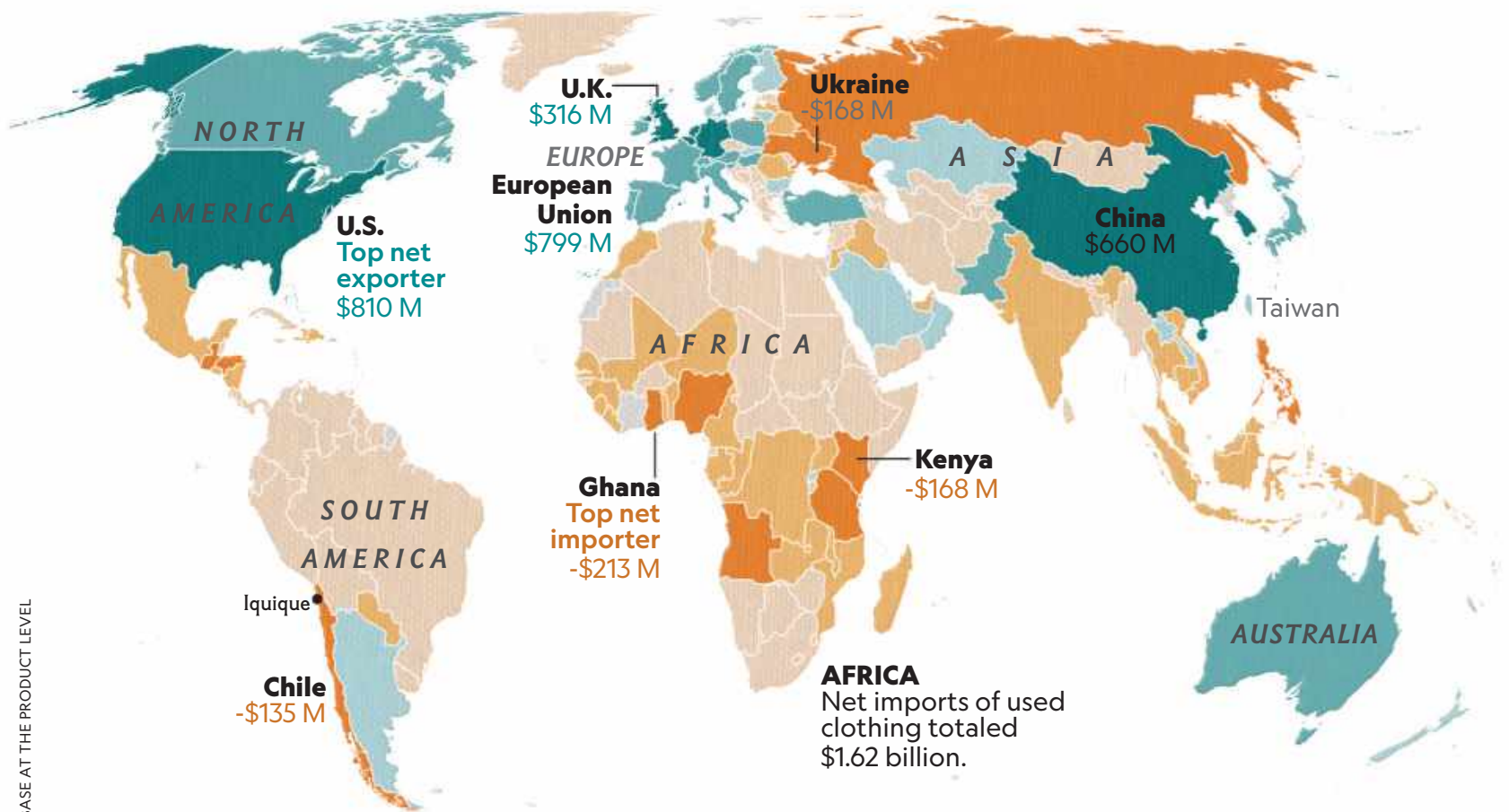
About 2,000 businesses of all types now operate in the duty-free zone; more than half are foreign. Hand-painted brand logos adorn warehouse doorways, and stacks of used cars—another major import—tower over the narrow streets. The free zone has also developed into a sorting depot for textile waste.

“In essence, we are just recycling the world’s clothes,” says Mehmet Yildiz, who arrived in Chile from his native Turkey two decades ago and operates a clothing import business named Dilara. Yildiz brings in clothes from the United States and Europe, most of them from thrift stores such as Goodwill. Once the garments reach Iquique, workers separate them into four categories, ranging from premium to poor quality. Yildiz then exports the best to the Dominican Republic, Panama, Asia, Africa—and even back to the U.S. for resale.

CLOTHING THAT THE IMPORTERS DON’T WANT ends up in the hands of truck drivers who ferry it a few miles to the dump outside Alto Hospicio, where it goes through another cycle of sorting and resale in small shops and street markets or at La Quebradilla, a huge open-air market. There, a roaring used-clothes trade continues on a half-mile-long strip of

GLOBAL HAND-ME-DOWNS

Used clothing is a commodity traded around the world. In 2021 the European Union, the United States, and China exported \$2.3 billion worth of discarded garments, capturing some 44 percent of the export market.



MAP: MATTHEW W. CHWASTYK; NGM STAFF. SOURCE: CEPII, BACI INTERNATIONAL TRADE DATABASE AT THE PRODUCT LEVEL

some 7,000 stalls. A recent visit turned up faded T-shirts commemorating the 2001 U.S. Open golf tournament, a jacket emblazoned with the logo of a Texas police force, and a wool hat with the badge of a California university, among a sea of other castoffs.

Clothing that doesn't sell at the market is destined for the desert, and much of it is made from synthetic materials that won't biodegrade. Scavengers salvage what goods they can. On a cool afternoon, a woman named Génesis rummaged through a pile of formal clothes, nurses' uniforms, underwear, and Crocs, taking fleeces and blankets for the cold nights and earmarking the better garments to sell at La Quebradilla,

where they may fetch a handful of coins.

"Everything is useful to me," she said brightly, laughing as she imagined herself in a brand-new summer dress printed with strawberries. "We're lucky to have found this."

AS HELPFUL AS RESALE MARKETS MIGHT'VE been in an earlier era, they've been overwhelmed by the sheer scale of the mounting discards. New efforts, large and small, are under way to deal with clothing waste, and attention to the mess in the desert may inspire additional projects.

In 2018, Franklin Zepeda founded a start-up that manufactures building-insulation panels

A woman sells tea from a cart in La Quebradilla, a market in Alto Hospicio. Merchants there pay \$20 for 1,320-pound bales of used clothing and resell the garments for roughly 12 cents to two dollars each.





THE TOLL OF TEXTILES

Fashion may strive for glamour, but the industry is one of the world's largest greenhouse gas polluters. Over the past two decades, the number of new garments made per year has nearly doubled. Fast fashion purchases are soaring, as is the speed at which people discard cheaply made clothes. Low prices belie the environmental cost of producing the huge volume of fabric needed to feed the growth, with impacts varying by fabric type. Producing cloth from natural fibers (cotton, wool, hemp) and those made from wood pulp ("man-made cellulosic fibers," or MMCFs) uses the least energy but requires more water than cheaper synthetics such as polyester and nylon. Hemp—the most sustainable in the quilt shown here—accounts for just 0.26 percent of global textile production.

GLOBAL FIBER PRODUCTION
Polyester has the highest proportion of recycled fibers.

127.8 million tons in 2022

7.9% recycled

HIGHER IMPACT

LOWER IMPACT

FOUR ENVIRONMENTAL IMPACTS OF FIBERS

● Natural fiber ● Synthetic

ENERGY CONSUMPTION

Every year the global fashion and shoe industries use twice as much energy as all of India does.

POLYAMIDE

Also known as nylon, this material has an elastic structure that is commonly used in tights and sportswear.

72.6 kWh per pound of polyamide

Polyamide is made from petroleum, using an energy-intensive process.

WOOL

Cashmere, fleece, and tweed are all examples of this animal fiber, which accounts for one percent of global textile production.

54.4

POLYESTER

Clothing of this oil-based textile is the most widely produced in the world and requires a high amount of energy to create.

49

MMCFs

Viscose, lyocell, and modal are types of this potentially environmentally friendly fiber typically made from wood pulp.

38.5

COTTON

It accounts for 85 percent of natural fiber production.

21.8

HEMP

A quick grower, it requires less water than most fibers.

10



CO2 EMISSIONS

The industry's annual share of carbon greenhouse gas emissions is on par with aviation's: around 2 percent.

17 pounds per pound of wool

Wool production emits nearly eight times as much carbon as cotton production does.

8.3

3.3

3.3

3.1

2.2



FRESHWATER CONSUMPTION

It takes 2,000 gallons of water to make one pair of jeans—the equivalent of drinking eight cups of water a day for 10 years.

186.8 gallons per pound of cotton

The most water-intensive material in this study, cotton accounts for about 25 percent of global fiber production.

63.5

11

10.7



WASTE BUILDUP

The majority of discarded clothing, much of it polyester, ends up in landfills or incinerators.

59.5 million tons of polyester produced annually

Burned polyester releases greenhouse gases; when landfilled, it leaches chemicals into the soil.

29.7

7.7

6.7

WHAT IS AVAXHOME?

AVAXHOME-

the biggest Internet portal,
providing you various content:
brand new books, trending movies,
fresh magazines, hot games,
recent software, latest music releases.

Unlimited satisfaction one low price

Cheap constant access to piping hot media

Protect your downloadings from Big brother

Safer, than torrent-trackers

18 years of seamless operation and our users' satisfaction

All languages

Brand new content

One site



AVXLIVE **ICU**

AvaxHome - Your End Place

We have everything for all of your needs. Just open <https://avxlive.icu>





Workers sort apparel at Ecocitex, a factory in Santiago that recycles discarded clothing. Some items will be turned into yarn, others cut up and used as stuffing for cushions.



Ecocitex workers organize tangles of raw yarn made from recycled clothes. Next, the material will be processed by a machine that will further refine it, yielding strong, finished yarn.



from textile waste. “I was motivated by the idea that there was a vast quantity of waste that could perfectly be transformed into raw materials to make new products, reducing the amount of clothes in our desert,” he says.

Another start-up, Ecocitex, based in Santiago, makes yarn from discarded clothes. “Our mission is to eliminate textile waste from Chile,” says Rosario Hevia, Ecocitex’s owner. “It made me so angry that there wasn’t a solution, so I’ve thrown myself into solving it.” Meanwhile, in Iquique, the clothing importer Dilara plans to open a recycling plant this year to make fillings for couch cushions from used clothes.

These are small but crucial steps. The most promising solution—one that can handle the problem’s scale—lies in the hands of the Chilean government. The World Bank forecasts 3.4 billion tons of garbage will be created every year by 2050. As it piles up, many countries are requiring manufacturers to take responsibility for their products at the end of those products’ lives. Policies known as extended producer responsibility have been adopted in India, Australia, Japan, Canada, and some U.S. states.

In 2016, Chile passed a version into law, calling it Extended Liability of the Producer, or Ley REP for short. The law makes producers and importers accountable for six categories of waste: lubricant oils, electronics, batteries, small batteries, containers and packaging, and tires. Initially, textiles were not listed.

Tomás Saieg, who heads the Chilean environment ministry’s Circular Economy Office, says a team is working to add three more product types to the Ley REP, including textiles.

“The most important thing is to turn off the tap, so to speak, so that these clothes don’t keep ending up in the desert,” he says. “Converting Chile from a junkyard into a recycling hub would be the dream.”

In the meantime, must-have trends blink in and out of fashion, online sales keep churning, and mountains of forgotten clothes continue to grow amid the red sands of the Atacama Desert. □

Mountains of discards reshape the landscape outside Alto Hospicio. Each year tons of clothing is added. Much of it is made from nonbiodegradable synthetics and will remain part of the Atacama for generations.







1919

Debut Drawing

Paleoartist Charles R. Knight carefully studied dinosaur fossils before creating this fierce, iguanaesque *Albertosaurus*.



1942

Battle Royale

Reflecting new knowledge about *T. rex*, Knight showed them in combat using their "double-edged, dagger-like teeth."



1978

The Heavyweight

The *T. rex* dominating our August 1978 cover, drawn by Roy Andersen, is much bulkier than earlier depictions.

1999

Fine Feathers

After a discovery linked carnivorous dinosaurs to eagles and other modern birds, this *T. rex* illustration included a downy fuzz covering the youngster.



2003

Just a Nip

Research suggested theropod *Aucasaurus* raided the nests of much larger sauropods, which helped clarify the Cretaceous-era food chain.



EVOLVING BEASTS

Staying on the edge of dinosaur discoveries
means the view is always changing.

Words by
DANIEL STONE



→ **WITH A FOURTH** *Jurassic World* movie in the works, our fascination with dinosaurs shows no signs of slowing, especially for series’ superstars *Tyrannosaurus rex* and other theropods. Ever since these beasts were first unearthed more than a century ago, *National Geographic* has been reporting on them, pairing the latest science with vivid illustrations. With every new discovery, our depictions must evolve.

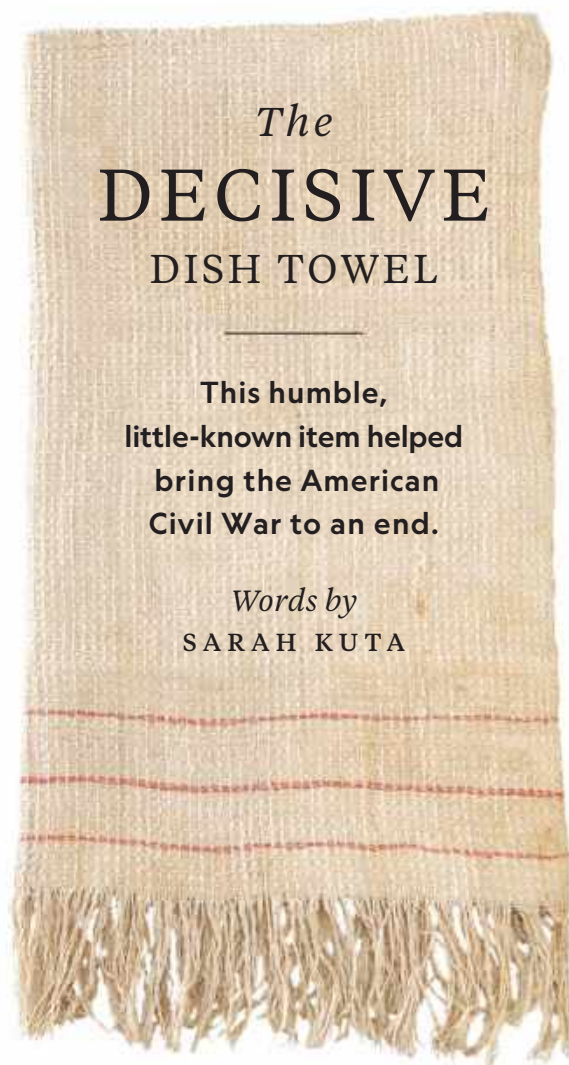
Starting in 1919, a magazine feature laid the foundation, describing an *Albertosaurus* as a “powerful flesh-eater” that was “capable of destroying any of its herb-eating relatives.” Twenty-three years later, battling *T. rexes* appeared in our pages standing some “twenty feet in height.” Three and a half decades after that, a 1978 cover story reported that *T. rex* was even larger, “fifty feet and six tons of bad news.” Until the late 1990s, most dinosaurs were shown with scaly reptilian skin, but theropod skeletons found in China suggested young *T. rexes* had feathers. That led to another new conclusion: “We can now say that birds are theropods just as confidently as we say humans are mammals.”

And theropods may not have been the unstoppable killers of human fantasy. Discoveries in 2003 revealed that they were selective in their violence and submissive at times. In 2020 we reported that paleontology was in the midst of “another revolution—one fueled by a wealth of fresh fossils and innovative research techniques.” Even the latest renditions won’t necessarily be definitive but will be steps toward a clearer picture of these marvels from the past. □

→ **WITH UNION** troops surrounding his Confederate Army in Appomattox, Virginia, on April 9, 1865, Gen. Robert E. Lee decided he had no choice but to initiate surrender talks. He sent a staff officer across enemy lines to ask for a cease-fire until he could meet with Lt. Gen. Ulysses S. Grant. To pass safely, Confederate officer Capt. R.M. Sims carried a fringed white dish towel with three thin red stripes running across the bottom.

Today, half of that towel—known as the Confederate flag of truce—sits inside a glass case in the Smithsonian Institution's National Museum of American History, on display as part of the exhibit "The American Presidency." Now discolored with age, this often overlooked artifact played a key role in one of the most pivotal moments in the nation's history. "It's a national treasure," says James Ferrigan, a consulting vexillologist and an officer of the North American Vexillological Association, a nonprofit dedicated to the study of flags. "It's the flag that began the discussion that ended the bloodiest conflict in American history."

WHY A DISH TOWEL? Throughout history, flags of truce—also known as flags of parley—were nearly always household items like towels, sheets, and pillowcases. "No army in the world issues this flag because it's counterproductive to morale," says Ferrigan. "And so, if things aren't going



The
DECISIVE
DISH TOWEL

This humble,
little-known item helped
bring the American
Civil War to an end.

Words by
SARAH KUTA

your way and you have to go chat with the guy with the bigger guns and more guys, well, then, you have to find something."

In this case, Sims's dish towel signal enabled Lee to meet cordially with Grant at Appomattox Court House, where Lee and his troops formally surrendered, a moment that many people consider to be the Civil War's de facto conclusion. But there was more tragedy ahead. Five days later, John Wilkes Booth shot and killed President Abraham Lincoln. Fighting between the North and

South dragged on for another year and a half, until President Andrew Johnson formally declared the end of the conflict in August 1866.

Much to Sims's chagrin, the flag of truce eventually ended up in Union hands. "Colonel Whitaker asked me if I would give him the towel to preserve that I had used as a flag. I replied: 'I will see you in hell first; it is sufficiently humiliating to have had to carry it and exhibit it, and I shall not let you preserve it as a monument of our defeat,'" Sims wrote in a May 1886 letter describing his role in the surrender.

After the war, Gen. Philip Sheridan presented the flag to Gen. George Custer's wife, Elizabeth, "in appreciation of the loyal service performed by her husband." Upon her death, she bequeathed it to the United States National Museum, the precursor to today's national museums. It's been part of that collection since 1936. (Somewhere

along the way, it was cut in half; the missing piece's location remains a mystery.)

THOUGH THE SURRENDER occurred nearly 160 years ago, the dish towel's symbolism continues to evolve over time. "The amazing thing about objects is they come to carry, physically and metaphorically, the emotions and importance of a moment, which is why we save them," says Lisa Kathleen Graddy, the curator in the Smithsonian's political history division who put together the "American Presidency" display. "But the interpretation depends on who's looking at it: It could be seen as a moment of bitterness or a moment of victory."

The same is true for a better-known remnant of the Civil War: the Confederate battle flag. While the flag of truce remains largely unknown, the Confederate battle flag has become an enduring—and ubiquitous—symbol of racism. Artist Sonya Clark, a professor of art and the history of art at Amherst College, explored the contrasting legacies of the flags in her 2019 exhibit,

"Monumental Cloth, the Flag We Should Know," held at the Fabric Workshop and Museum in Philadelphia. With that show, she asked viewers to imagine a world in which the peace-brokering flag of truce—instead of the divisive Confederate battle flag—dominated the American narrative.

Five years later—as the deaths of George Floyd and many others have sparked an ongoing U.S. reckoning on race amid President Biden's warning that white supremacy has become the "most dangerous terrorist threat to our homeland"—Clark's feelings about the flag's meaning have gotten more complex. "What progress have we made?" she asks. "Really, what was surrendered?" □



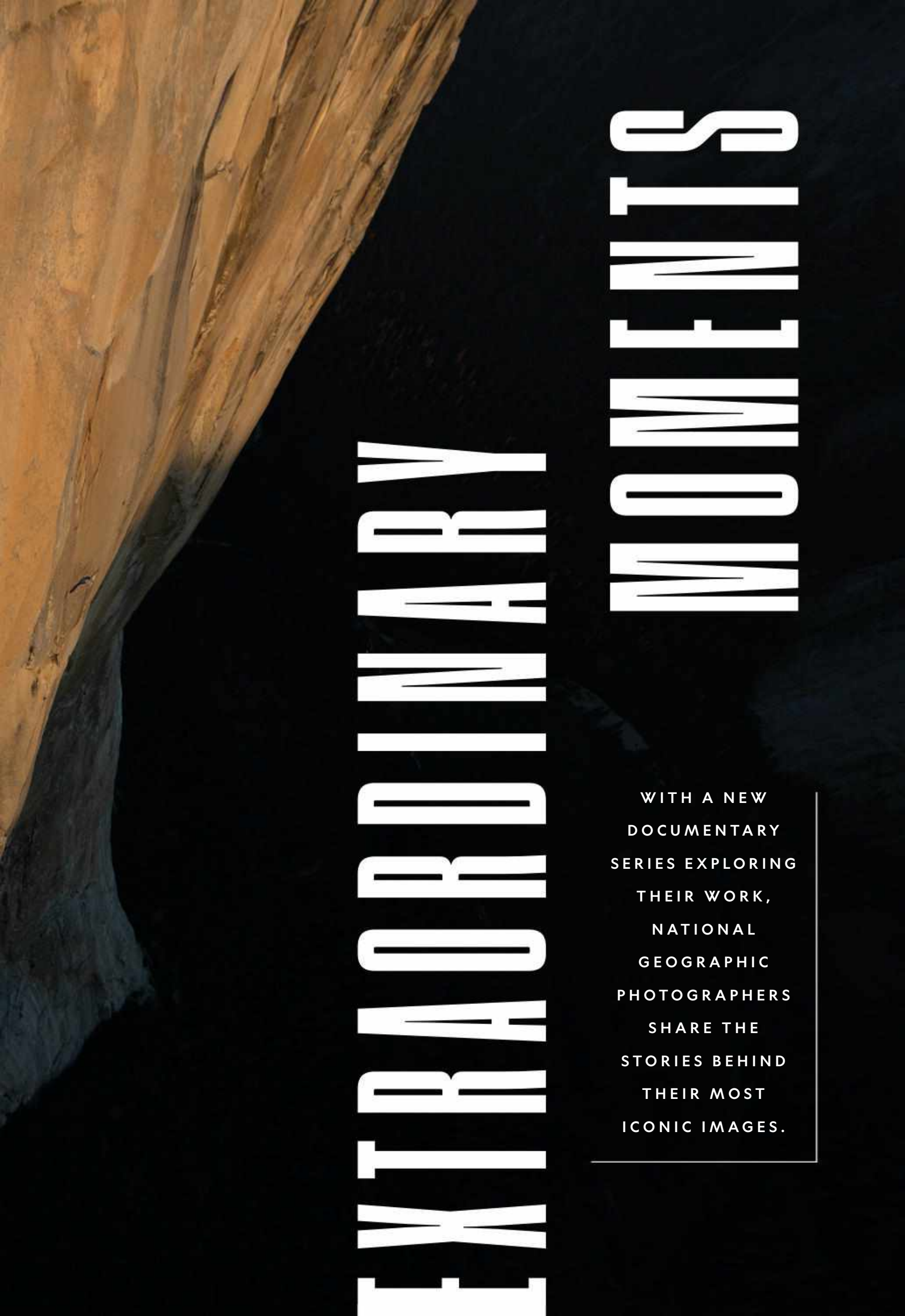
The surrender of Confederate general Robert E. Lee to Union general Ulysses S. Grant at Appomattox Court House in April 1865 was captured in newspapers and paintings, including "Let Us Have Peace" by Jean Leon Gerome Ferris.



Jimmy Chin

YOSEMITE NATIONAL
PARK, CALIFORNIA

Alex Honnold navigates
El Capitan's Traverse
pitch without safety gear.
Jimmy Chin, who took this
photo in 2017 for *National
Geographic*, says the best
photographers share a
"commitment bordering
upon obsession with what
they are shooting."



EXTRAORDINARY

MOMENTS

WITH A NEW
DOCUMENTARY
SERIES EXPLORING
THEIR WORK,
NATIONAL
GEOGRAPHIC
PHOTOGRAPHERS
SHARE THE
STORIES BEHIND
THEIR MOST
ICONIC IMAGES.

W

WHAT KIND OF PERSON chases a tornado, or dives among sharks, or travels into a conflict zone, all for a photograph? Jimmy Chin—mountain climber, skier, photographer, filmmaker—wondered this as a child growing up in Minnesota, flipping through the pages of his family’s copies of *National Geographic*. When he picked up photography in his twenties, his goal was to shoot for the magazine.

Joining the ranks of *National Geographic* photographers in 2002, he has since shown how far—or high—he’ll go for a picture. As his friend and fellow climber Alex Honnold attempted a ropeless ascent of the El Capitan rock formation in Yosemite National Park in 2017, Chin dangled from a safety line nearby, more than 2,000 feet above the valley floor. Honnold’s death-defying feat also became the Oscar-winning National Geographic documentary *Free Solo*, directed by Chin and Elizabeth Chai Vasarhelyi, his wife and creative partner.

For a new series, the two National Geographic Explorers turned the camera on photographers. In March they debuted *Photographer*, six episodes that embed viewers with “some of the world’s most

extraordinary visual storytellers,” as Chin describes them. “We’ve always been interested in stories about people who are pushing the edges of the human experience.” Doing something that’s never been done, or capturing an image that’s never been seen, arises from the “same instinct,” he explains.

Dedication to craft unites the show’s featured photographers. From the tiniest animals to a final flight into space, the following images sample their work and the stories behind them.

—HICKS WOGAN



Follow these and other storytellers in the National Geographic series *Photographer*, streaming March 19 on Disney+ and Hulu.



Anand Varma

MONTRÉAL, QUÉBEC

National Geographic Explorer Anand Varma took thousands of frames of a ladybug clutching a braconid wasp's cocoon for the cover of the November 2014 issue. The wasp larva developed inside the spotted lady beetle; just before the wasp emerged to spin a cocoon, it paralyzed its host.

Something in the process made the ladybug twitch like a zombie. Readers wrote to Varma confessing that they used to dislike insects but his picture had opened their eyes. Or, as Varma puts it, "I used to think bugs were gross, but now I think they're cool."

ANAND

VARMA

BRYSLE WRIGHT



“

It's a tough thing to see because you feel this contradiction. On one hand it's just like, Oh my God, I can't believe I'm witnessing this absolute phenomenon. But then at the same time, particularly when it's going through a town, you realize, Well, this is absolutely destroying lives.



Krystle Wright

IMPERIAL, NEBRASKA

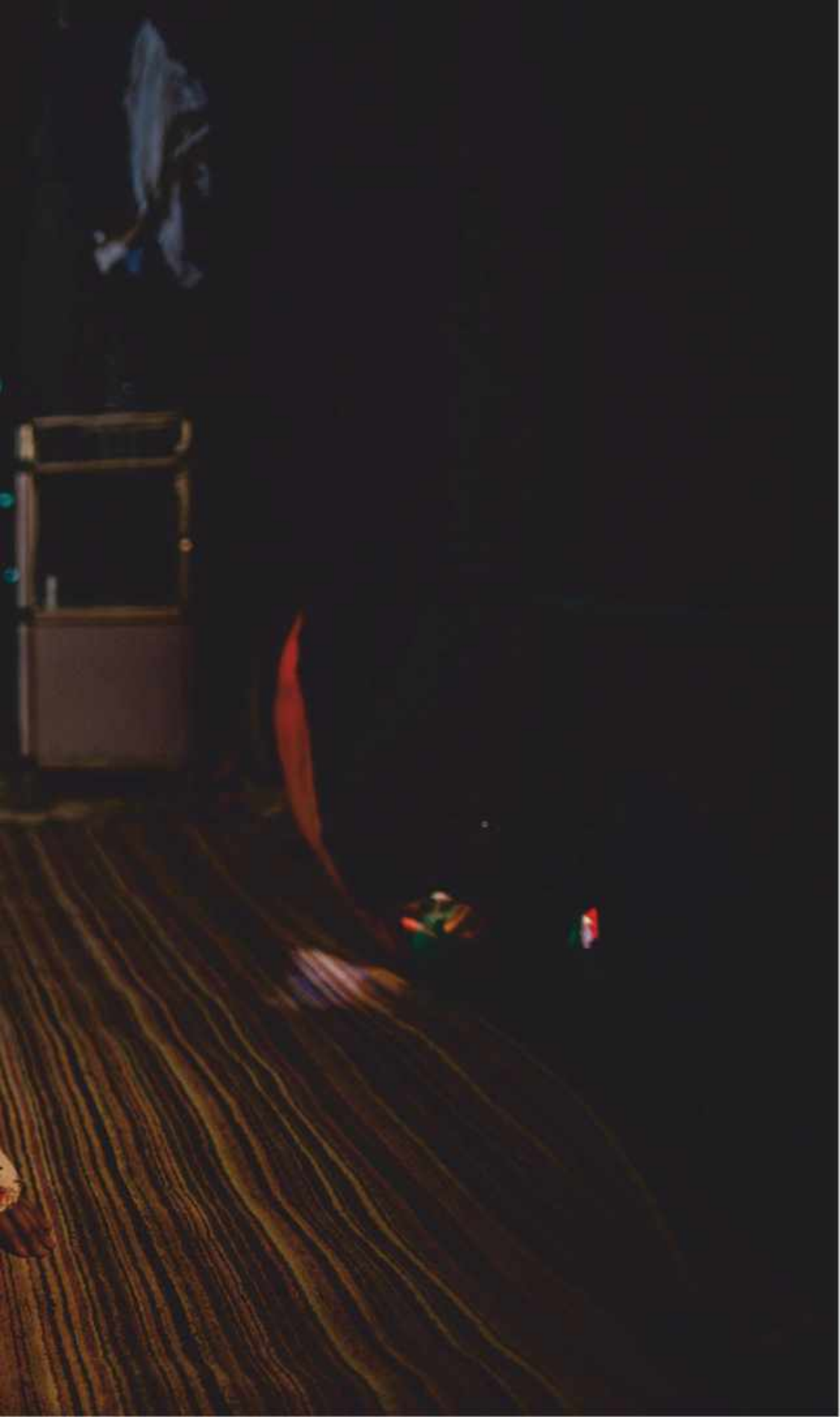
Photographer Krystle Wright and fellow storm chasers arrived on the scene just as a supercell storm spitting lightning threatened a farm with a UFO-like “mother ship” formation in May 2019.

The team’s timing that day was “sheer luck,” Wright recalls. After retreating from a storm in Colorado that pounded their SUV with hail, they crossed into Nebraska and caught up to this system at the apex of its power.



“

If you want to be able to capture the right emotion, to capture the image, you have to respect the people and you have to gain their trust. It's not something you buy or you sell. It's something you invest. It's a long-term investment.



Muhammed Muheisen

AL MAFRAQ, JORDAN

Zahra Mahmoud, photographed here at age seven in 2018, lives in a tent in Jordan. Muhammed Muheisen, a National Geographic Explorer who documents refugee crises, met Zahra and her family in 2015, soon after they fled the war

in their native Syria. Every year he visits them at the encampment and photographs Zahra, now a teenager. Muheisen says he'll continue telling the family's story until they're in a more permanent living situation.

MUHAMMED MUHEISEN

MITTERMEIER

CRISTINA

Cristina Mittermeier

GALÁPAGOS ISLANDS

In 2021 photographer Cristina Mittermeier and her partner, Paul Nicklen—both National Geographic Explorers—were diving together in the Galápagos Islands to promote the expansion of a protected marine reserve.

As an ocean current pulled Mittermeier toward a reef and a large shark patrolled the area, she focused on the scene above her: a school of brightly colored cardinalfish darting from the path of a Galápagos sea lion.





“

[Photography is] a very challenging job, to be gone all the time, months on end, to be so engaged in something that's pretty isolating. To be a photographer, you're a lone wolf. So when Paul and I met and we started working together, it was almost like finding your life jacket in the middle of the ocean.

—CRISTINA MITTERMEIER

Paul Nicklen

**NUNAVUT TERRITORY,
NORTHERN CANADA**

As Arctic sea ice disappears, hungry polar bears are increasingly forced to hunt seals in open water. In 2004 Nicklen photographed a male swimming beneath a floating piece of ice, its image reflected on the water's surface. To get the angle, Nicklen leaned far over the side of the small boat from which he was observing the bear and dunked his camera underwater.

PAUL NICKLEN



DAN WINTERS

“

My primary work is portrait work. But the other stuff is just really my passion. I've been fortunate enough to work with NASA in an official capacity, which is kind of amazing. I don't think I would've imagined as a kid working with NASA.

Dan Winters

**KENNEDY SPACE
CENTER, FLORIDA**

On May 16, 2011, the space shuttle *Endeavour* blasted through clouds for the final mission of its 19-year career. The day before the launch—the craft's 25th—Dan Winters positioned sound-triggered cameras around the launchpad. He manually operated another camera, which he used to make this image, lowering its exposure level to create a darker, more dramatic scene. When the rocket boosters roared, the cameras clicked.

IMAGINING

Other LIVES

For one writer, *National Geographic* was a childhood portal into our world's endless possibilities. It was also an inspiration for her latest book.

Words by
TARA CONKLIN

Illustration by
DADU SHIN

→ **BEFORE HE WENT TO COLLEGE**, my father worked on a cargo ship that took him to the Soviet Union, Denmark, Finland, the United Kingdom, and France. As a young child, I would sit beside him on the living room couch, a photography book or a *National Geographic* open on our laps, looking at the images of distant places and people and listening to him talk about his own travels.

The photographs I loved best captured moments that evoked stories—a *National*

Geographic picture of a Tibetan shepherdess, her clothes brilliantly colored against a stark backdrop; Harriet Tubman's fierce gaze in an article about the Underground Railroad; or Dorothea Lange's iconic "Migrant Mother," the face drawn, the eyes haunted.

With each image, there was a suggested intimacy, a glimpse into the inner workings of someone else's unique, mysterious existence. In my memory, the photographs and my father's stories blend together. Did I see



a picture of the rope bridge across the Zambezi River, or did my father tell me about the time he crossed it? Did my father once see a Japanese snow monkey, or did we look together at a photo of this extraordinary creature, its eyes sad, lashes fringed white with ice?

It was these moments and this imagining that made me a writer. I didn't realize it then, but the storytelling instinct that first took hold with a *National Geographic* in front of me would become my livelihood and my organizing principle. Those images made me feel part of a wider community. We are all connected, I thought then as a child. We are all searching for the same essential things: love, safety, family, joy. And everyone, everywhere has a larger story about how to find them.

Thirty years after looking at that photo of Harriet Tubman, I wrote my first novel, *The House Girl*, which featured the Underground Railroad and became a surprise *New York Times* bestseller. I wrote another best-selling novel, *The Last Romantics*, which took inspiration from a family tragedy. And then, in the midst of COVID quarantine, I began writing a third novel, called *Community Board*, about a young woman who retreats to her childhood home in wintry New England to recover from an unexpected loss and find her way back into life. In creating my character, Darcy, I took inspiration from those long-gone afternoons on the couch at home.

I GREW UP IN A small town in western Massachusetts where the snow was measured in feet and we'd eat raspberries straight off the bush all summer long. It was a lovely, peaceful, picturesque place, but my father's stories had planted in me a wanderlust seed that grew quick and strong.

As I moved into adolescence, like so many of us, I began to chafe against my family and my town, which felt too

constricting, too small. When the weather allowed, I would climb out my bedroom window and onto the steep roof, pushing myself up to a higher, flatter part where I could watch the stars and ask myself: Where will I go? Who will I meet? Who do I want to become?

I left Massachusetts as soon as I could to study, work, and travel in Costa Rica, New Zealand, Moscow, London, and throughout Europe. I loved this peripatetic life, meeting new people, working diverse jobs in different cities, but eventually I yearned for a home and relationships I could sustain over the long haul. And so 15 years ago, I settled with my family in Seattle, the city where my children have grown into teenagers and my writing career has flourished.

When I began writing *Community Board*, it was 2020 and the world had changed, suddenly and irrevocably. I worried—as we all worried—about our kids, our livelihoods, the safety of family far away, of elderly and other vulnerable populations. The book takes place before the pandemic, but I found myself imposing on my protagonist the same questions I was asking myself: How do we find inspiration when we're afraid and alone? How do we forge connection when we are filled with anxiety? How do we step outside ourselves to engage with a world that seems dangerous and cruel?

As quarantine days stretched into weeks and then months, something unexpected began to happen in my little neighborhood in Seattle. It started small—neighbors waving sparklers across our street to celebrate a five-year-old's birthday—but then grew. Food deliveries, check-ins, impromptu outdoor concerts, bottles of wine left on doorsteps, phone calls that stretched for hours. I noticed small acts of kindness and grace happening all around me, between friends, neighbors, and strangers.

This sense of being part of a wider community reminded me of that feeling I'd had

sitting on the couch at home as a child. We are all in this together. Across the street, across the city, or across the globe. This was the message I wanted to convey through Darcy's story.

When I imagined Darcy's childhood home, I couldn't help but envision stacks and stacks of *National Geographic* magazines. And Darcy, in her self-imposed isolation during a long cold winter, decides to read them all. She reads about Viking ships and scientists off the Chilean coast and poet Pablo Neruda and the brilliant quetzal bird, and within these stories she finds the inspiration to reimagine herself and rejoin the outside world.

One of the last stories she reads is about Djenné, a city in Mali where every year before the rainy season, residents come together to replaster and repair the central mosque, first built in the 1200s with sun-baked mud bricks, knowing all the while that they'll have to do it again next year. The project is an act of renewal, a task undertaken by individuals for the good of the community. In Djenné, "architecture is a verb as well as a noun," reads the photo caption.

So too are commune, join, adventure, love.

DARCY BEGINS TO VENTURE outside her house, to overcome her grief and reengage with the people around her. She meets a spry elderly widow who wants to escape her assisted living residence; a dad of three sons with plans to build a state-of-the-art neighborhood playground; a rookie police officer who tracks down a rogue drone circling Darcy's block; and others, each weirder and more wonderful than the last. As the book progresses, she finds that overcoming her grief and rediscovering herself is a process she can't do alone—she needs connection with the people around her.

Home is baked into our DNA. No matter how long we've lived elsewhere, no matter

I would climb out
my bedroom
window and onto
the steep roof,
PUSHING MYSELF
up to a higher,
flatter part where
I could watch
the stars and ask
myself: *Where
will I go? Who will
I meet? Who do I
want to become?*

how many years have passed since we last set foot inside the house or apartment, town or city where we grew up, certain elements remain part of us. All these years later, while I no longer climb onto my roof to gaze at the stars, I still ask questions of myself and my place in the wider world. I still work to understand this seemingly universal desire to feel at home within myself and know my purpose within my community. To explore this never ending, frustrating, and beautiful search for ourselves and our place—that is why I write. For us all, imagining the lives of others is also a way of imagining a richer, fuller life for ourselves. □

Tara Conklin is a *New York Times* best-selling author based in Seattle. Her new novel, *Community Board*, is out now.

GOING



THE



DISTANCE





INSIDE THE INCREDIBLE MIGRATION OF ENDANGERED WILD
WHOOPING CRANES, WHICH MUST FLY NEARLY 5,000 MILES ACROSS NORTH
AMERICA EACH YEAR TO ENSURE THE SURVIVAL OF THE SPECIES



A young whooping crane (center) and its parents high-step through wetlands in Wood Buffalo National Park, Canada.

(Previous photo)

Whooping cranes arrive at a rainwater basin wetland in Nebraska to roost for the night.

PHOTOGRAPHED ON LOCATION
WITH PERMISSION OF THE PARKS
CANADA AGENCY, IN WOOD
BUFFALO NATIONAL PARK



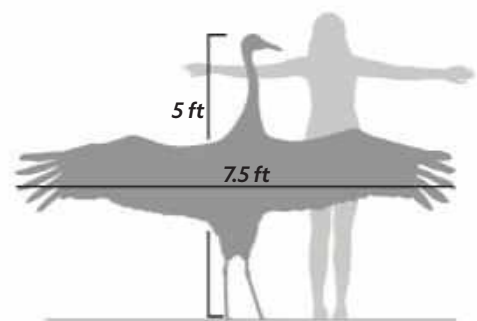
Words by RENE EBERSOLE
Photographs by MICHAEL FORSBERG

WE WERE
800 FEET UP
IN THE AIR,
FLYING IN
A HELICOPTER

with an international team of scientists over the vast boreal forest encompassing Canada's Wood Buffalo National Park, when one of them shouted the alert. "Bird at nine o'clock!"

Pilot Paul Spring circled the helicopter left, tilting for a clearer view of one of the countless pools of water stretching to the horizon. Rimmed in sand and tamarack trees, the surface glowed iridescent. In the middle of the wetland, we could make out a pair of snowy white specks, though they stood roughly five feet tall at ground level.

"There's a chick," said Environment and Climate Change Canada (ECCC) wildlife biologist John Conkin, training his binoculars on a rust-colored bird, slightly shorter than its parents, high-stepping in the marsh. Spring spotted a semidry piece of land and brought us to the ground. Conkin, his ECCC ecologist



Massive Marvels
Whooping cranes are North America's tallest birds.

NGM STAFF. SOURCE: INTERNATIONAL CRANE FOUNDATION



In protected areas of northern Canada, whooping cranes build their nests from surrounding vegetation. Crane mothers most often lay two eggs, but usually only one chick survives.

colleague Mark Bidwell, and the other crane catchers, U.S. Geological Survey biologist Dave Brandt and Canadian wildlife veterinarian Sandie Black, piled out of the chopper.

They had only 12 minutes to track down and capture the elusive target: a wild whooping crane chick designed for traversing boot-sucking mud, woody brambles, and bulrushes. Any longer and the team would have to call off the chase to avoid stressing the birds too much.

As the researchers vanished into the bush, Spring and I eased off the ground and zoomed up to 500 feet for an aerial assist. Sensing the humans' approach, the crane parents flapped

their giant black-tipped wings and departed, no doubt reluctantly leaving their flightless offspring behind. "I've got eyes on the chick," Spring said to the group, who could hear him through the walkie-talkies attached to their vests. "It's just below the chopper. Come toward the chopper."

The team crashed through the underbrush, trying to push forward faster than the soggy terrain could pull them down. In a well-practiced maneuver, Conkin approached the chick; got hold of its beak, head, and legs; and carefully tucked the bird under his arm.

Six minutes, 36 seconds: bird in hand. Now

came the more technical part. Panting and sweaty, the group unpacked their gear. Brandt, a seasoned wildlife biologist who has banded at least 150 wild whooping cranes in his career, held the chick on his lap, supervising Conkin as he affixed a transmitter to one leg and color bands (blue, yellow, green) on the other.

Meanwhile, veterinarian Black performed a checkup, examining the bird's eyes and taking stock of its body condition. She collected biological samples—blood, feathers, saliva, and oral and fecal swabs—for testing at the lab to reveal things such as the bird's sex and if it had been exposed to harmful chemicals or diseases, including highly pathogenic avian influenza (HPAI). Then Bidwell moved in to help slip a camouflage Velcro harness around the chick and weigh it on a hanging scale.

They spoke in low voices. When their work was done, Brandt cradled the chick like a football and carried it to the edge of the marsh. There he gently set it down and dashed away. That chick—now known to the annals of science as 15J—fled in the opposite direction, pausing briefly to ruffle its feathers and shake its new leg jewelry before receding into the safety of the marsh, reuniting with its parents.

These whooping cranes embody one of North America's greatest conservation success stories. Yet they remain the rarest of 15 crane species found throughout the world and are still endangered. Scientists estimate that more than two centuries ago, some 10,000 whooping cranes lived in North America. But they were no match for steady habitat loss and hunters in the 1900s who killed them for food, sport, and plumes to supply the millinery trade during the gilded age. By 1941, there were only 16 migratory whooping cranes left, all of them traveling a seasonal gauntlet of nearly 2,500 miles from northern Canada to the Texas Gulf Coast.

Over the past 70 years, a raft of protections provided by grassroots conservation, legislation, habitat preservation, captive breeding, and research have slowly brought the population back. Today there are more than 800 birds, with over 530 in the central

flyway migratory flock and much of the rest divided almost evenly between captivity and experimental reintroduction programs in Louisiana and Wisconsin. Still, many crane experts say it's too soon to remove the birds from the endangered species list. The whooping crane recovery plan, written under the authority of the Endangered Species Act, has three main strategies to build both ecological and genetic stability. The first is to grow the migratory central flyway population large enough to survive a potentially catastrophic event, such as an outbreak of deadly bird flu. The second is to maintain a captive population to provide further insurance against calamity. And the third is to establish two additional self-sustaining wild flocks to help restore whooping cranes to other areas of the country where they lived historically.

Based on the current rate of population growth, some say the earliest we could plan for a victory party—albeit very tentatively—is about 2050. “The central flyway flock is half-way there,” George Archibald, co-founder of the International Crane Foundation, told me. “And neither of the experimental flocks are self-sustaining at this moment.”

Only about one-third of chicks like 15J survive to reach their breeding age of four or five years. They're killed by predators such as bobcats or coyotes or die of fatigue and starvation during migration. They face man-made dangers including polluted wetlands, poaching, and power lines that kill millions of birds each year.

Considering the whooping cranes' plight, I wanted to get a closer look at the efforts to save them. They are the polar bears of the bird world. If they disappear, we will have failed to save one of the planet's most beautiful species, a symbol of hope and an ambassador for vanishing wilderness—and all of the species that live there. My visit to Wood Buffalo National Park sparked a monthslong journey—with several important detours—as I tracked 15J's hazardous trip.

EVEN AFTER MORE THAN a century of research, bird migration remains one of nature's greatest mysteries. How do the animals navigate over long distances? Is their migration route encoded in their genes or learned? Can they adapt their migrations to avoid modern-day threats, including energy development and increasingly extreme weather?

Technological advances in satellite telemetry and long-term monitoring are helping crane biologists unravel some of these mysteries. Since 2009, 178 cranes from the central flyway flock have been fitted with solar-powered tracking devices that collect location data. In addition to being granted the rare opportunity to fly with crane biologists in Wood Buffalo National Park, I was given a chance to receive updates about 15J and the cohort of 17 other "J-birds" tagged in August 2022.

The first update arrived a few weeks later around lunchtime one day in mid-October. I was at my desk sipping a cup of soup in New York; 15J was airborne and moving south, beyond the park, an area larger than Switzerland, with no cell coverage. Likely motivated by cooling temperatures and high northwest winds, she and her parents departed from Wood Buffalo and arrived the next evening, more than 500 miles away, in Saskatchewan.

Like many other whooping cranes leaving the park, 15J and her parents took a long pit stop there, resting and refueling in the prairie potholes, shallow wetlands created by receding glaciers about 10,000 years ago, and on the northern edge of the Great Plains. Millions of birds stopping over in this region increasingly face threats such as runoff from farming chemicals including fertilizer and pesticides. But in early fall, it also provides birds with a buffet of leftover waste grain in the agricultural fields as well as insects, amphibians, and other small creatures in the wetlands. The cranes typically linger in these vital staging grounds for a few weeks.

On November 3, 15J and her parents crossed the U.S. border into North Dakota, starting their

southbound push. Three days and 300 miles later, 15J's transmitter pinged a tower in South Dakota. As the birds gradually worked their way down the flyway, they stayed in some places for days and barely touched down in others. On November 14, almost 300 miles and another state south, they stopped for a night along Nebraska's Platte River, where cranes roost on shallow mid-river sandbars and forage in braided side channels, agricultural fields, and wet meadows.

Conservation photographer Michael Forsberg, who's documented whooping cranes for the past four years, saw 15J there in the pale light of one morning, probing for food along the river with her parents and a lone sandhill crane. He texted me from the river: "I just spent the last two hours with 15J on the Platte. Can't believe it. They just took off. They're heading to where it's warmer. It's cold here. The river's freezing up. It's starting to snow."

As the number of healthy whooping cranes increases, however, such pit stops may hold a more existential threat. A year earlier, biologists surveying birds on the Platte had counted a group of more than 46 whooping cranes—the biggest flock of migrating wild whoopers that anyone alive today has witnessed in the United States. Some experts said the sighting was a

THEY ROOSTED FOR A NIGHT
ALONG NEBRASKA'S PLATTE
RIVER. AS THE NUMBER OF
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A MORE EXISTENTIAL THREAT.





During the spring migration, whooping cranes mingle with hundreds of thousands of migrating sandhill cranes on Nebraska's Platte River. The Platte and other wetlands in the Great Plains are vital bird stopovers.

sign the cranes are learning to once again flock together in a large group, a natural tactic for survival, but one that also prompted concern. When such a large percentage of a population clumps in one place, there's the risk that an extreme weather event or disease outbreak could severely knock their numbers back.

Recently, HPAI has killed millions of other birds in 81 countries. Wildlife managers are on high alert for outbreaks in critically endangered bird populations, including whooping cranes. In Baraboo, Wisconsin, the International Crane Foundation has taken biosecurity measures to protect the cranes in its captive facility from exposure to wild birds that could transmit the virus. Today the organization still raises whooping cranes to be released into the nearby wetlands. It also supplies some eggs to a promising project in Louisiana that is reintroducing cranes to the same wetland from which they vanished some 70 years ago after hunting wiped them out.

WHILE 15J CONTINUED her November journey south, I boarded a plane to Louisiana to see the whooping crane class of 2022 graduate from the Freeport-McMoRan Audubon Species Survival Center in New Orleans, where the six-and-a-half-month-olds had become capable of flight, at which point they can be safely released into the wild.

Since the spring of 2011, the Louisiana Department of Wildlife and Fisheries has been leading this reintroduction project. In the first season, biologists released 10 captive-bred youngsters at the White Lake Wetlands Conservation Area in Vermilion Parish, about a four-hour drive west of New Orleans. They've since added more juveniles to the flock, which lives in Louisiana year-round, because some bird populations don't migrate if they've only ever known one place and their needs are met. The state closely monitors the birds, often with help from cooperative landowners who tolerate cranes foraging in their rice fields and crawfish



A 5,000-MILE JOURNEY

Every fall, whooping cranes undertake an arduous flight from Canada's subarctic boreal forests to the Texas Gulf Coast and return six months later. The landscape below them, once flush with wetland habitat, now has fewer stopover points because of expanding human development. This map tracks the annual path of 15J, as she headed south in late 2022, then north in mid-2023. Parents often accompany their offspring for most if not all of the trip.

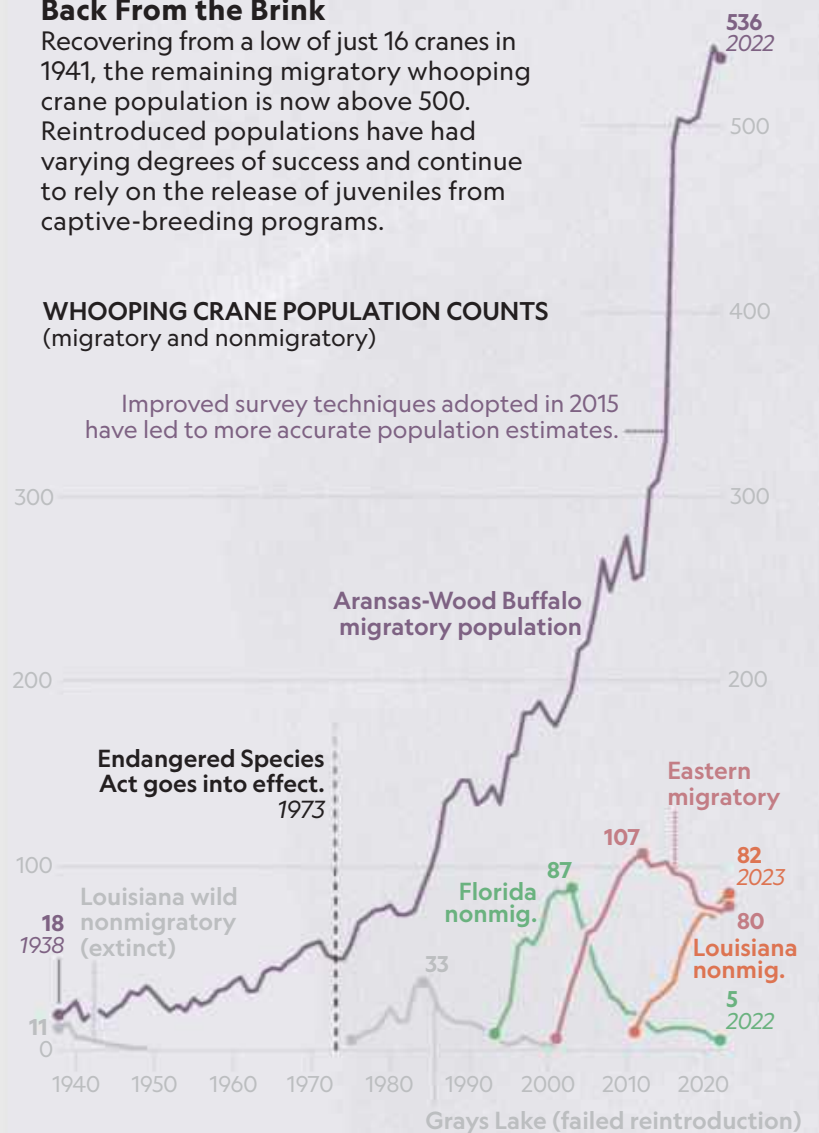
Concentration of wetlands



Back From the Brink

Recovering from a low of just 16 cranes in 1941, the remaining migratory whooping crane population is now above 500. Reintroduced populations have had varying degrees of success and continue to rely on the release of juveniles from captive-breeding programs.

WHOOPING CRANE POPULATION COUNTS (migratory and nonmigratory)



SOREN WALLJASPER, NGM STAFF

SOURCES: MARK BIDWELL, ENVIRONMENT AND CLIMATE CHANGE CANADA; ANDY CAVEN AND HILLARY THOMPSON, INTERNATIONAL CRANE FOUNDATION; CANADA CENTRE FOR REMOTE SENSING; U.S. GEOLOGICAL SURVEY



Confined to Corridors

Whooping cranes once soared across much of North America. Now they fly along narrow migration corridors and spend most of their time in protected areas at either end of their journey.



CRANE'S- EYE VIEW



CHRISTOPHER BOYER

Traveling north in a 1957 Cessna, from Aransas National Wildlife Refuge, Texas, to Canada's Wood Buffalo National Park in spring 2022, pilot Christopher Boyer and photographer Michael Forsberg (above) captured the landscape from the aerial perspective of migratory whooping cranes. On the roughly 2,500-mile trek, the transcontinental birds can face strong winds and blizzards, and must choose carefully where to stop for food and rest. In addition to naturally occurring rigors such as bad weather, drought, and predators, these cranes must surmount a host of human-caused environmental threats, from power lines and polluted wetlands to poaching and urban development. The annual journeys—totaling some 5,000 miles—are grueling, and only about one-third of chicks survive to breeding age.

3 Red River near Burkburnett, Texas, along the Texas-Oklahoma border



2 Intracoastal Waterway, Aransas National Wildlife Refuge



5 At Salt Plains National Wildlife Refuge, Oklahoma, near the Kansas border, the salt flats on the edge of Great Salt Plains Lake signal a good resting place.



ARANSAS NATIONAL WILDLIFE REFUGE, TEXAS

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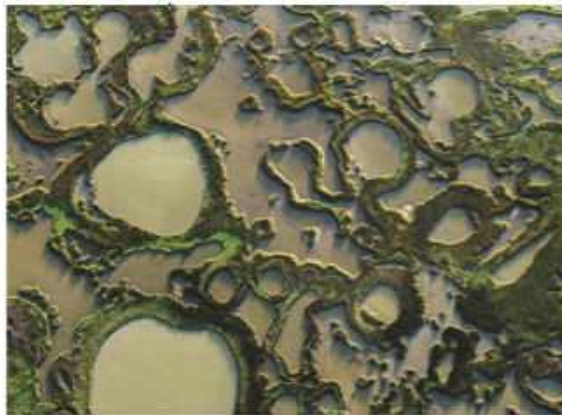
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7 & 8



1 The salt marsh wetlands of Aransas National Wildlife Refuge, Texas, are core wintering grounds. Established in 1937, this protected migratory bird sanctuary of 115,000 acres of Gulf Coast habitat fades into the distance as the spring migration begins.



6 Wind farm near Campbell, Nebraska



4 Farmstead near Alfalfa, Oklahoma

9 Middle Loup River Valley near Arcadia, Nebraska



10 Circular irrigation patterns in a grid of agricultural fields near Atkinson, Nebraska



12 The surface water in this prairie pot-hole wetland near Watrous, Saskatchewan, appears as an important oasis.



14 Tar sands open-pit mining operation near Fort MacKay, Alberta



9

10

11

U.S. CANADA

12 13

14

15 WOOD BUFFALO NATIONAL PARK, CANADA



7 The wide and shallow braided channels of the Platte River near Gibbon, Nebraska, offer plenty of places to spread out and safely roost.



8 Crop field alongside the Platte River being prepared for spring planting



11 Snowy bend in road near Kenel, Standing Rock Indian Reservation, South Dakota



13 Freight train near Allan, Saskatchewan



15 These reflective boreal wetlands of Wood Buffalo National Park, Northwest Territories, mark a return to familiar breeding grounds. This crucial seasonal refuge provides a safe place to build nests, raise chicks, and prepare for the autumn trip back to Texas.



Two adults and a juvenile, identifiable by its rust-colored plumage, migrate south over the central plains in late autumn. Parents teach their young about reliable pit stops on the journey.

ponds. Louisiana's flock is currently composed of about 80 birds. The goal is to establish a self-sustaining population of approximately 120 individuals, including 30 reproductive pairs, for a decade without restocking.

I arrived before dawn to witness the reintroduction day, when the cranes are rounded up from their grassy enclosures at the Species Survival Center and trucked down to White Lake to be released into the marsh. Richard Dunn, the center's assistant curator, met me inside the gate and laid out the plan. After catching 10 young cranes from their enclosures, a team of biologists would weigh them and do a health check. Then each bird would be tucked inside a cardboard box with breathing holes and loaded into a van for the drive to White Lake.

At White Lake, we were greeted by Eva Szyszkoski, a wildlife technician with the Louisiana Department of Wildlife and Fisheries. Szyszkoski oversaw the birds as they were banded and fitted with tracking devices. Then the cranes in their boxes were shuttled onto a flat-bottom boat and ferried down a long canal to an area of the marsh enclosed with netting. A decoy crane stood inside the enclosure, welcoming the young birds to their new home.

One by one, each crane was removed from its box and carried by a white-costume-wearing biologist, disguised to prevent the birds from imprinting on people. As the humans waded into the muck, cradling the cranes, the birds' heads bobbed on their long necks. Freed into the pen, they flapped their wings, stretching after a very long day.

The next morning, Szyszkoski returned to find them all milling around, looking a little antsy to fly. Soon the nets would be opened, inviting them to disperse throughout the area. It's not uncommon for many of these birds to die within their first year of being released. That may be partly because captive-raised cranes haven't experienced the wild before—they're naive, she said, and living in close proximity to people, which means a high chance of collision with power lines and fences. More than a dozen whooping



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Last fall, four men pleaded guilty to shooting and killing four whooping cranes in Oklahoma in late 2021. At the crime scene, the ground was littered with feathers from the dead birds.

ave been shot and killed over the project. Occasionally, some just without a trace.

MORE THAN 1,600 MILES into her journey, 15J was flapping a route through America's heartland. On November 15, her transmitter connected with a cell tower in Oklahoma, a state where one of the largest wind farms in the U.S. had recently come online. Policymakers and the energy industry reduce the country's carbon footprint,

there are concerns about how eco-friendly energy advancements and habitat disturbance may affect migratory birds such as whooping cranes. A recent study showed these creatures avoid wind farm areas, preventing them from using some important stopover sites. At least 5,500 turbines have been erected in the birds' migratory pathway, and over 18,000 more are planned. So far there've been no reports of whooping cranes being killed by turbines, but the accompanying increase in power lines is a major concern to conservation groups, who continue to advocate for careful site placements that may reduce the risk of potential

collisions and for making power lines more visible with reflective markers.

One day and 260 miles later, 15J arrived in Texas near Fort Worth. By Thanksgiving, her transmissions went dark. USGS biologist Dave Brandt told me she was likely out of range of a cell phone tower in the state's 115,000-acre Aransas National Wildlife Refuge, established in 1937 as a safe haven for migratory waterfowl and other wildlife. If so, that would mean her first fall migration was a success—she'd traveled some 2,500 miles over the course of about a month and could spend the winter resting along Texas's Gulf Coast.



(Top) In Louisiana, biologist Eva Szyszkoski interacts with birds that originated from a raise-and-release program, using a puppet to mimic adult crane behavior.
(Bottom) U.S. Geological Survey biologist Dave Brandt (left) and International Crane Foundation veterinarian Barry Hartup care for an injured whooping crane in Texas.

This picturesque vista of coastline, salt marshes, and tidal ponds is the winter stage where whooping cranes and their lifelong mates perform elaborate courtship dances, spinning in pirouettes, hopping and flapping, bobbing crimson-capped heads, and bugling their namesake calls.

But even on these wintering grounds there are threats, including coastal development and sea-level rise caused by climate change. Some scientists predict rising seas and subsequent saltwater intrusion will convert more than 50 percent of the Texas Gulf Coast's freshwater wetlands to open water by 2100. Meanwhile, freshwater inflows are declining because of persistent drought and thirsty cities such as San Antonio upstream. Changes to salinity in the coastal estuaries pose problems for blue crabs and wolfberry plants—primary food sources for whooping cranes. Some conservation groups have warned that without more thoughtful conservation of this larger ecosystem, the whooping crane could lose its only wintering home before the end of the century.

In December I met Brandt in Texas to attempt to locate 15J and other J-birds in their winter grounds. Standing along the Intra-coastal Waterway, we looked out over a salt marsh stretching at least a mile. It seemed like a large area but was a fraction of the historic marsh devoured by development in recent decades. Suddenly, two whooping cranes flew up from behind a grassy dune, white feathers gleaming in the sunlight. “They’re here because this just doesn’t exist anywhere along the coast anymore,” Brandt said of the rich habitat. “This portion of the peninsula has about 40 percent of the population wintering here.”

Shortly after dawn the next morning, we boarded a fishing boat and spent eight hours fruitlessly searching for 15J along the Aransas refuge and nearby shorelines. We did, however, find several other whooping crane families, including a male bird, 11J, tagged around the same time the previous August. He was walking along the salt marsh begging—*peep, peep, peep, peep*—for his parents to share the blue

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crabs and wolfberries in their beaks. They seemed intent on teaching him to find his own food.

Next evening, on my way home to New York, I got a text from Brandt: 15J's transmitter had “checked in,” revealing her location was within a mile of where we'd cruised along the coast.

Now another full migration cycle through spring and fall has passed. Each time, 15J has proved to be the most elusive traveler among the J-birds. I often receive updates about others almost daily, but I've heard about her only a handful of times. Whenever there's been a long gap, I've worried: Did she collide with a power line? Get eaten by a coyote? Was she shot by a poacher? Or did she succumb to an illness?

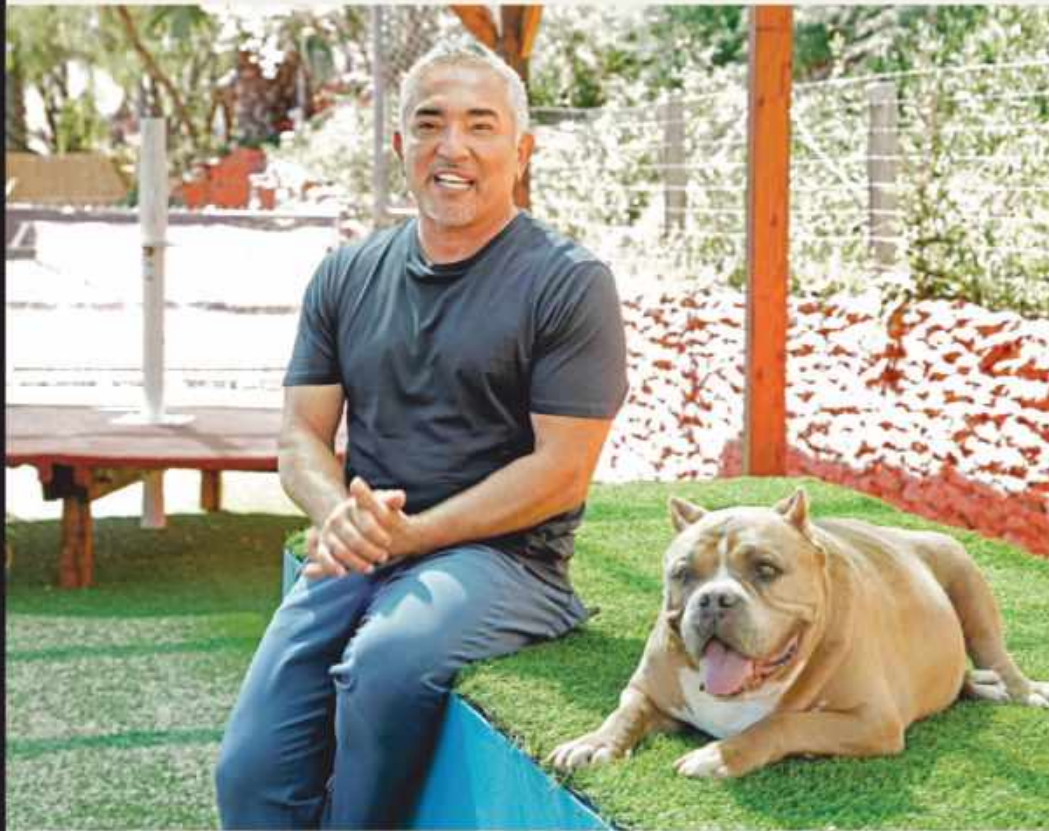
If all goes well, 15J will be among the now 536 recorded whooping cranes preparing to depart Texas this spring, when their instincts signal it's again time to arrow north. In the span of a month, they'll travel 2,500 miles to Wood Buffalo National Park, where many of the adults will build nests and lay eggs. With luck, in a few more years it will be 15J's turn to join that cycle too, helping her species continue its climb back from the edge of extinction. □

Michael Forsberg is a conservation photographer, co-founder of Platte Basin Timelapse, and always happy in the company of cranes.





In Aransas National Wildlife Refuge, Texas, whooping cranes prance alongside American white pelicans at sunrise. The nearly five-foot-tall birds need open spaces like this salt marsh pond to thrive.



TELEVISION

→ **AS CESAR MILLAN** likes to say, “I rehabilitate dogs, I train people.” In the new season of his show *Better Human Better Dog*, the behaviorist dives deep into the human concerns that affect his clients’ relationships with their beloved pups. His favorite method for figuring out what’s wrong is to watch people walk their dogs. Sometimes just a few minutes is enough for Millan to identify the problem. Perhaps a pet owner lacks confidence, and the dog is taking control. Or the owner is scared of other dogs, triggering the

pet’s aggression. Whatever the diagnosis, Millan is certain he has the solution: Train people to project calm, assertive energy—an approach that can translate to all facets of life. In this upcoming season, he’s going a step further by playing matchmaker to adoptive pet parents—because sometimes the dogs people want are not the dogs they need. The fourth season of *Better Human Better Dog* premieres April 12 at 9/8c on National Geographic. Previous seasons are now streaming on Disney+ and Hulu.

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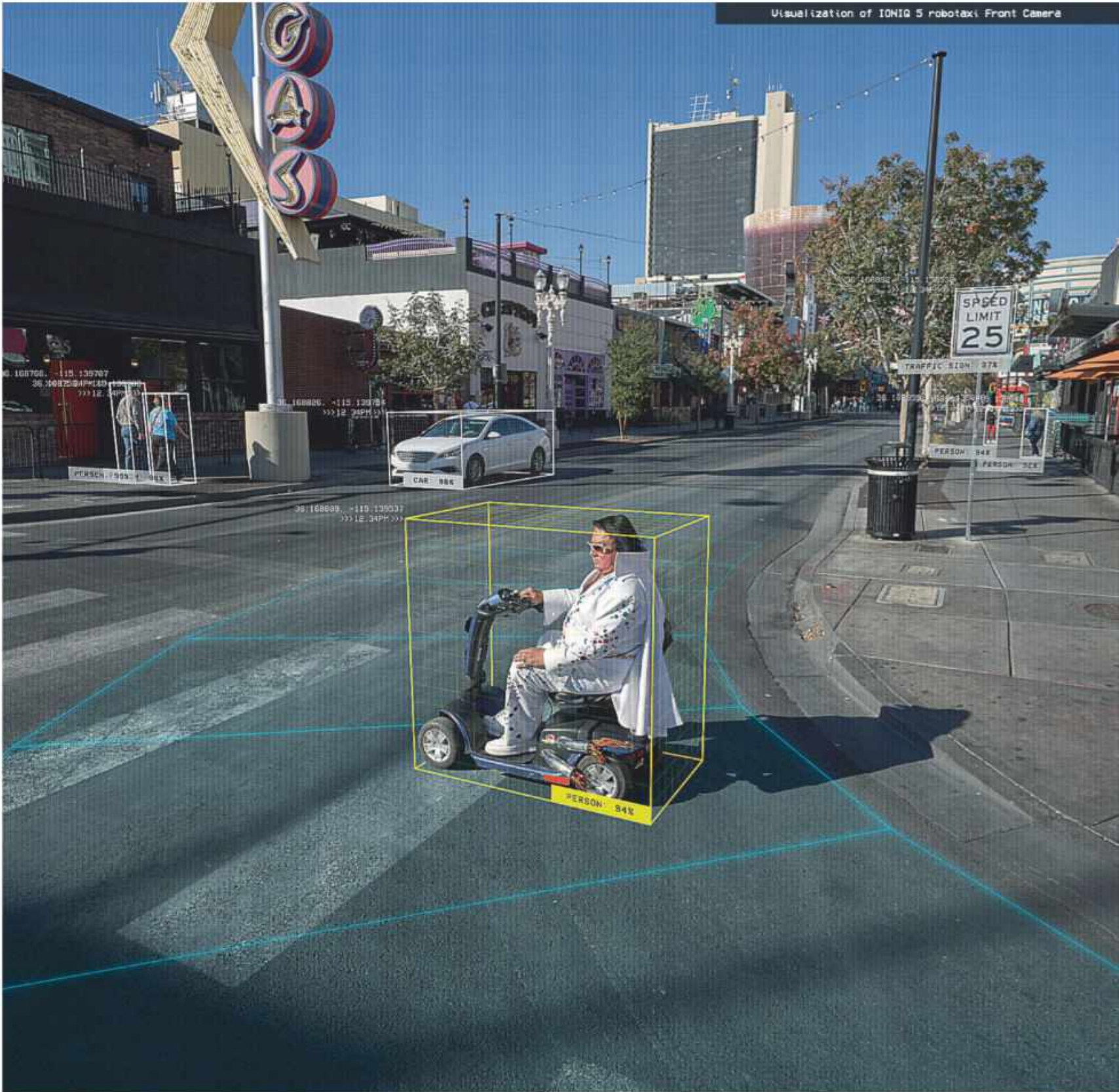


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The vehicle is not available for purchase. Picture for illustration purposes only.

 **HYUNDAI**