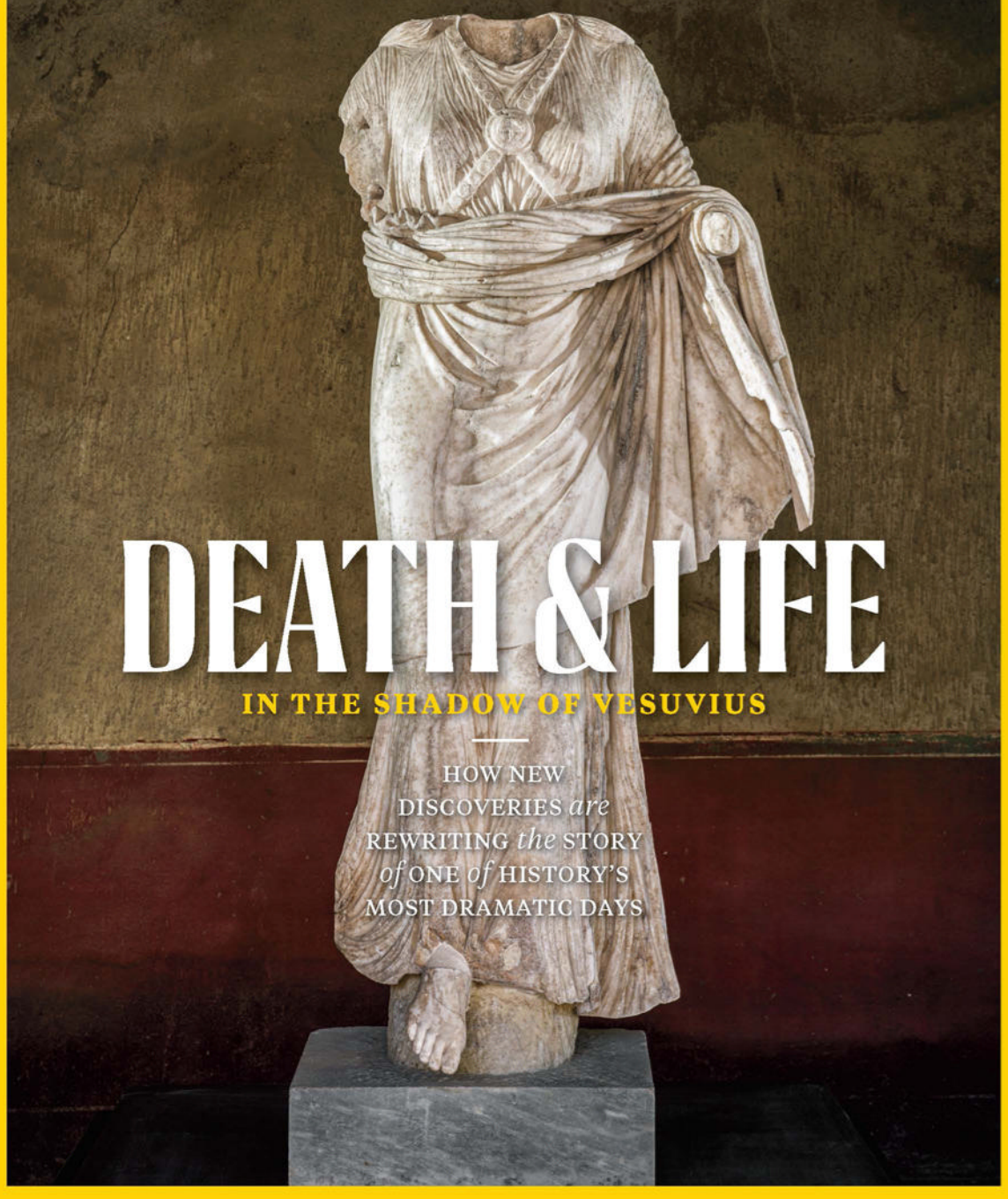
VOLUME 250 AUGUST 2026 NUMBER 02

MYSTERIES *of the* EVERGLADES | ONE PHOTOGRAPHER—*18,000* SPECIES

NATIONAL GEOGRAPHIC



DEATH & LIFE

IN THE SHADOW OF VESUVIUS

HOW NEW DISCOVERIES *are* REWRITING *the* STORY *of* ONE *of* HISTORY'S MOST DRAMATIC DAYS



OVERSEAS DUAL TIME CARDINAL POINTS – NORTH
Reference 7930V, titanium
Calibre 5110 DT/3



VACHERON CONSTANTIN
GENÈVE

ONE OF
NOT MANY.



FROM *the* EDITOR

NATHAN LUMP

ONE OF THE things I am often struck by in our stories is how so many of them are the product of persistence. The people whose work we bring to life in these pages are tenacious. The time, effort, courage, and sheer dedication they exhibit make great things happen, and I believe we are all beneficiaries, in one way or another, of the passion that animates what they do.

This issue offers a case in point. Our cover story takes a fresh look at the ancient communities—Pompeii, famously, but there are others—destroyed by the monumental eruption of Mount Vesuvius in A.D. 79. That catastrophic incident is one of history's most studied natural disasters, but thanks to the persistence of archaeologists and researchers, we are still uncovering finds that present new insights. One of my favorite parts of our feature details the painstaking work researchers are doing to decipher the writing on fragile papyrus scrolls that miraculously survived the eruption. Although discovered years ago, they were impossible to read, but now technology, including AI, is making that a reality.

We also bring you this month a glimpse into the wild world of Joel Sartore, whose photos we often share in the magazine. This year marks the 20th anniversary of Joel's Photo Ark project, an endeavor that is the very embodiment of persistence, an attempt to document every animal species living in the world's zoos, aquariums, and wildlife sanctuaries. Joel's work is no mere stunt or vanity project: His mission in capturing the essence of these remarkable creatures, many of which are endangered, is to inspire us to protect them. He has photographed more than 18,000 animals so far. If that's not commitment, I don't know what is.

I hope you enjoy the issue.

PHOTO: MARK THIESSEN, NGM STAFF

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Wildlife photographer Joel Sartore is on a quest to make intimate portraits of some 25,000 animal species. Twenty years into his Photo Ark project, global biodiversity has never been so in need of a champion.

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ON THE COVER At Oplontis, a seaside resort buried by the eruption of Mount Vesuvius in A.D. 79, a marble sculpture of the goddess Nike, recovered from the ruins, is now on display. *Photograph by* PAOLO VERZONE



The new Museum of Exploration uses projected video to highlight the species photographed by Joel Sartore.

BRINGING A GROUNDBREAKING PHOTO COLLECTION TO LIFE

This month's profile of wildlife photographer and National Geographic Explorer **Joel Sartore** ("Revealing Every Animal on Earth," p. 64) marks the 20th anniversary of his Photo Ark project, an ambitious quest to capture portraits of every species in human captivity. Over two decades, Sartore has photographed some 18,000 animals. This summer the project comes to life at the new National Geographic Museum of Exploration, in Washington, D.C., where an exhibition will feature giant projections of Sartore's photos—along with interactive explanations of how the images have become powerful tools for the protection of species at risk. Meanwhile, National Geographic Books has published an anniversary edition of *Photo Ark: Animals of Earth* that pairs Sartore's portraits with new essays by the writer Sy Montgomery. Reserve tickets for the Museum of Exploration at *natgeo.org/moe.*

"The first time I saw Zahia's troupe shooting, I was full of adrenaline—it was like me being on top of that horse."



To document big changes in the Moroccan sport of *tbourida*, photographer **Chantal Pinzi** (above) embedded with teams of rifle-toting horsewomen—including one led by legendary rider Zahia Aboulait—for this month's feature ("The Rise of Morocco's Horsewomen," p. 94).

PHOTOS: REBECCA HALE, NGM STAFF (EXHIBIT); MARWA ELMAITE

Why Tom Hiddleston Can't Stop Thinking About Pompeii

National Geographic's docudrama series *Pompeii: Out of Time with Tom Hiddleston* unveils the latest insights into the eruption of Mount Vesuvius, also the subject of the cover feature ("The Day the World Exploded," p. 18). We asked host and Executive Producer Hiddleston—a classics student at the University of Cambridge before becoming an award-winning actor—what fresh lessons Pompeii offers.

The show dramatizes the lives of everyday people before the eruption. Why?

That's what Pompeii evokes for me. It's not about the statues of the high-status figures, the generals and the consuls and the emperors. The plaster casts [of victims of the eruption, made by archaeologists] are ordinary people. Fathers and mothers and children and teachers and uncles and the family dog. And I find that's what's so moving.



Hiddleston and crew meet with survival psychologist Sarita Robinson inside a Pompeii villa.

PHOTO: PAOLO VERZONE, NATIONAL GEOGRAPHIC

What surprised you most?

I had always presumed that the volcano erupts and the city's buried, and there was nothing they could do. But not everyone was buried. And that image of a full-scale humanitarian crisis where you have hundreds if not thousands of refugees who are fleeing and looking for a new home—that's a very resonant contemporary image, and I hope it's one that inspires great empathy.

Why does this era endlessly fascinate us?

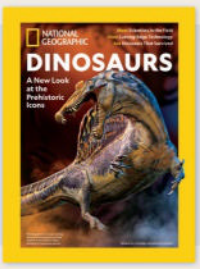
We tell stories about the past to understand something about our present, and a place like Pompeii is a gateway where the 2,000 years that exist between us compress, so it all feels like it happened yesterday.

THIS INTERVIEW HAS BEEN EDITED FOR LENGTH AND CLARITY.

Pompeii: Out of Time with Tom Hiddleston *is streaming on Disney+. Check local listings.*

NEW ON NEWSSTANDS

Dinosaurs: A New Look



Technologies like lidar and high-res CT scanners are helping usher in a new golden age of dino research, with scientists uncovering as many as 50 previously unknown species a year. This special issue reveals how these new discoveries are changing our understanding of the prehistoric giants we thought we knew.

NATIONAL GEOGRAPHIC EXPLORERS

These contributors have received funding from the National Geographic Society, which is committed to illuminating and protecting the wonder of our world. Learn more about the Society's support of Explorers at *natgeo.com/impact*.



Where a Photographer Found Botanical Bliss

Growing up in Cali, Colombia, Juanita Escobar saw plenty of orchids—her mother had a side job cultivating and selling the elegant plants. But Escobar had never encountered anything like the explosion of colors she found shooting this issue's story on Daniel Piedrahíta, a Colombian orchid collector turned maverick conservationist ("The Quest to Save the World's Rarest Orchids," p. 58). At Piedrahíta's sprawling sanctuary, Escobar hardly knew where to point her camera. "Your eyes are constantly hyperactive," she says.



Writer Alexandra Marvar, who also visited Piedrahíta's conservatory, used watercolors to capture details of the orchids in her reporter's notebook.

Paolo Verzone
"The Day the World Exploded," p. 18

For this month's cover story, Verzone photographed artifacts from Pompeii and other sites destroyed by Mount Vesuvius. Many were sourced from museum storerooms; others are now in the hands of researchers who are using innovative technologies to unravel ancient mysteries.

Mac Stone
"The Mystery Forests of the Marshlands," p. 118

A South Carolina-based photographer, Stone has been at work documenting the Florida Everglades for more than 15 years. In this issue, he takes readers inside forested wetlands called cypress domes. For one shot, he waded in alligator-filled waters to score a breathtaking close-up of the creatures.

Rob G. Green
"How I Got the Shot," p. 116

An Explorer since 2022, Missoula, Montana-based Green ventured far from home to take his photograph in this issue. In China's Giant Panda National Park, Green and his team installed camera traps to capture one of the country's most iconic creatures in the wild.

PHOTOS: LUCA ZANETTI (TOP); REBECCA HALE, NGM STAFF



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IN FOCUS

JUST IN FROM OUR PHOTOGRAPHERS



WILDLIFE

In the Falkland Islands (Islas Malvinas), these month-old elephant seals take one of their first dips in the ocean. Photographer **Matty Smith** was there to document the moment the mothers depart this famous breeding ground and return to the South Atlantic, leaving hundreds of babies, newly weaned, to fend for themselves. “The pups were super friendly, trying to climb on me, trying to climb on my camera,” Smith says. These playful pups live off their blubber reserves until they learn to swim and start hunting for fish.



FAMILY

In his workshop in Malta, Mario Pandolfino, a 76-year-old toymaker and inventor, poses with his son, Matthew, 41, an artist and set designer. Photographer **Valery Poshtarov** made this portrait as part of a series he calls Father and Son. He's traveled to 15 countries, asking his subjects to hold hands, something they may not have done in decades. "I'm giving them this safe space," he says, "to build or rebuild a connection."

HIS FUTURE CAN BE YOUR LEGACY

You can leave the world better than you found it. When you leave a gift to the **National Geographic Society** in your will or trust, or by beneficiary designation, you can protect critical animal species for generations to come.



NATIONAL GEOGRAPHIC
PHOTO ARK
JOEL SARTORE

Bornean clouded leopard, *Neofelis diardi borneensis*

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OCEANS

Near Baja California in Mexico, a group of striped marlins corral hundreds of smaller fish into a dense formation known as a bait ball, before feasting on their prey. Photographer **Brooke Pyke** used her underwater camera to capture “these majestic, agile hunters” as they chased the fish to the surface, she says, much like dogs herding sheep. As the marlins took turns swooping in to feed, a few sea lions joined the fray, diving headlong into the ball and dispersing the fish.


EDEN
cleanfix



CITIES

Originally nicknamed the Garden City of India for its farms and parks, Bengaluru has been transformed by the tech industry into the country's version of Silicon Valley. National Geographic Explorer **Sayan Hazra** photographed this recently designed pocket of native plants in the growing metropolis as part of his project documenting green spaces in urban areas. "The cultivating, planting, watering, fertilizing, and pruning" of these gardens, Hazra says, goes largely unnoticed by most residents. But this invisible choreography supports an essential source of biodiversity and calm in the booming city.



THE DAY THE WORLD EXPL

It was one of history's most dramatic moments—but the eruption of Mount Vesuvius wasn't a single disaster. New evidence reveals how three settlements in the shadow of the volcano faced three distinct fates, reshaping our understanding of how ancient Romans lived and died.

Words by **SAM KEAN**
Photographs by **PAOLO VERZONE**

ODED



In A.D. 79, Mount Vesuvius blew its top, raining ash over the Campania region of Italy, near modern-day Naples, and burying surrounding communities beneath as much as 60 feet of volcanic debris.



Systematic excavations of Pompeii began in 1748, and while approximately two-thirds has since been unearthed, a swath of the ancient city remains unexcavated.



Outside, the world was vanishing.

A scum of ash was thickening on the surface of the Gulf of Naples, and black fumes were swallowing the sky above. Here, in a waterfront warehouse in the Roman town of Oplontis, five dozen people cowered in terror. Some clutched gold coins and jewelry—family wealth snatched up in panic. Others gripped common iron tools and little more. One young woman hugged her swollen belly, terrified for the unborn child inside. Their ages and social classes varied widely, but they'd likely all gathered in a storeroom on the water's edge for the same reason: to await a rescue boat they were increasingly fearful would never come.

What happened that day in A.D. 79 began with a single event, the eruption of Mount Vesuvius. But each settlement in the volcano's shadow—including the most famous, Pompeii—experienced a distinct catastrophe depending on its location relative to the volcano and the timing, speed, and direction of the material Vesuvius spewed. A handful of lucky folks within those communities escaped. But many suffered agonizing deaths: some when pebble-size pumice called lapilli rained down for hours, collapsing buildings onto them; others when superheated avalanches of ash, gas, and rock known as pyroclastic currents scorched everything in their path. The commercial hub of Pompeii largely escaped the pyroclastic currents but disappeared beneath more than 10 feet of wind-borne lapilli. Heaps of ash then hardened around the dead, leaving cavities that, when filled with plaster in later centuries, produced the now iconic casts of their death throes. The posh coastal retreat of Herculaneum was mostly spared the lapilli but got pummeled by pyroclastic currents that carbonized organic materials like papyrus and entombed the city beneath 60 feet of stone. Oplontis, situated between Pompeii and Herculaneum, was hit by both, preserving an elaborate frescoed villa as well as the skeletons of dozens of victims.

No one waiting for help in that storeroom made it out alive. By the time any rescue boat could have arrived, the men, women, and children huddled there would already have been buried beneath 30 feet of debris, where they remained for the better part of 2,000 years.

Since the first systematic excavations of the Vesuvius region in the 18th century, scholars have puzzled over the lives of the victims. Modern researchers, armed with tools like artificial intelligence and advanced DNA analysis, are uncovering what earlier generations could only guess at. Discoveries from these three sites are shining new light on life in the Roman Empire. In Oplontis, the skeletons in the storeroom promise rare insights into class and gender dynamics. In Pompeii, a buried latrine is spurring a first-of-its-kind genomic study about ancient diet and health. And in Herculaneum, researchers have gleaned clues about the era's philosophy and moral codes from a cache of carbonized scrolls that have recently been rendered readable with virtual unwrapping technologies.

What's emerging is a coherent story about a world not so distant from our own—a thriving society preoccupied with social inequities, health and wellness, and what it means to lead a fulfilling life.

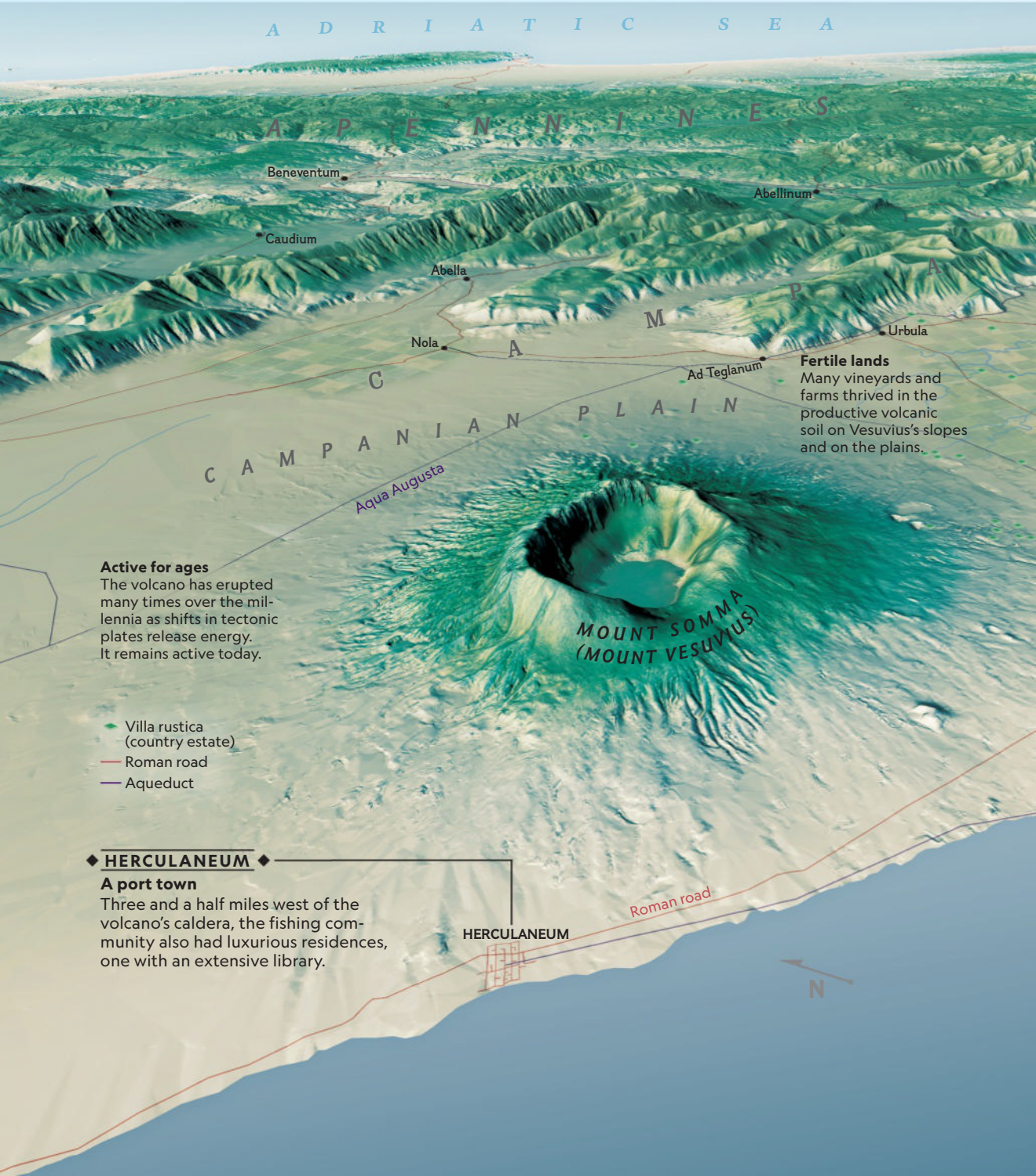


Two thousand years after Vesuvius erupted, preserved artifacts are still offering researchers new insights into different Roman Empire lifestyles. This marble statue of Nike (Victory) was found at the upscale Oplontis A villa.

LIFE BEFORE THE ERUPTION

AROUND HERCULANEUM, OPLONTIS, AND POMPEII

In the first century A.D., tens of thousands of people lived in this fertile region of central Italy nestled near Mount Vesuvius. Catastrophe struck in A.D. 79 when the volcano violently erupted, ravaging the countryside. Devastation was dependent on location, wind, and topography. Today researchers continue to delve into ruins for more discoveries.



The Heart of Roman Italy
The Roman region of Campania was rich and prosperous, both a popular destination for elite citizens and a hub of commerce, trade, and agriculture.



I O N I A N S E A

Gulf of Taranto

A P E N N I N E S

Nares Lucanae

Sele

P I C E N T I A N P L A I N

Salernum

Gulf of Salerno

Nuceria Alfaterna

L a t t a r i M o u n t a i n s

S A R N O P L A I N

Sarno

POMPEII

Stabiae

OPLONTIS

◆ POMPEII ◆

A prominent city
Five miles southeast of Vesuvius, this urban area was key to commercial and political operations for the surrounding agricultural region.

◆ OPLONTIS ◆

A coastal suburb
Four miles south of the volcano, two villas anchored the settlement—one opulent and the other an agricultural distribution center.

G u l f o f N a p l e s

SCALE VARIES IN THIS PERSPECTIVE. DISTANCE FROM HERCULANEUM TO POMPEII IS EIGHT MILES (13 KM).

MATTHEW W. CHWASTYK AND PATRICIA HEALY, NGM STAFF

SOURCES: TINITALY, NATIONAL INSTITUTE OF GEOPHYSICS AND VOLCANOLOGY; FLORIAN SEILER, SALVE PROJECT, GERMAN ARCHAEOLOGICAL INSTITUTE, BERLIN; UNIV. OF TÜBINGEN; LIBERA ESPOSITO, FRANCESCO FIORILLO, MICHELE GINOLFI, GUIDO LEONE, UNIV. OF SANNIO, BENEVENTO; ITINER-E, NATURE SCIENTIFIC DATA; NASA/JPL; GREEN MARBLE; USGS

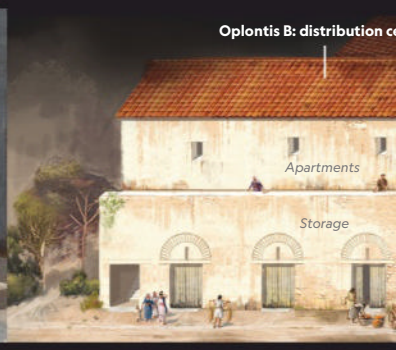
FROM DAILY LIFE TO

One eruption, three communities, three different outcomes

OPLONTIS

The suburb was a hub for industry, with an agricultural distribution center (likely for wine) and apartments known today as Oplontis B. It was destined to disappear beneath ash and rock.

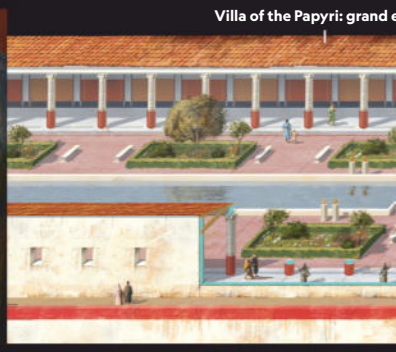




HERCULANEUM

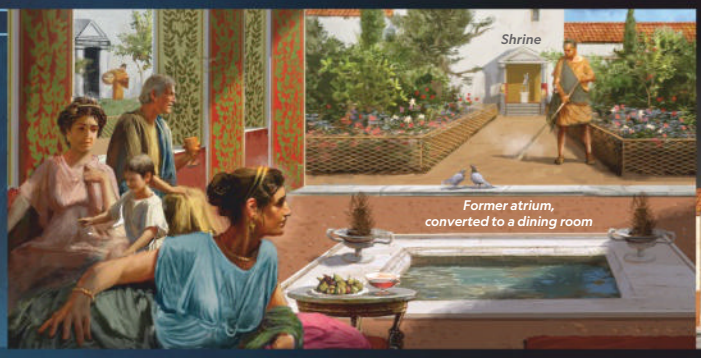
A fishing village as well as a bastion of culture, Herculaneum was home to the grand estate Villa of the Papyri, which contained a library of scrolls that would succumb to a searing avalanche.





POMPEII

The city blended private and public life under the same roof. Elite homes like Casa della Regina Carolina were used for social gatherings and business affairs—until pumice and ash entombed it all.





SOURCES: CAITLÍN EILÍS BARRETT, CORNELL UNIV.; CASA DELLA REGINA CAROLINA PROJECT; JOHN R. CLARKE, UNIV. OF TEXAS AT AUSTIN, MICHAEL L. THOMAS, UNIV. OF TEXAS AT DALLAS, OPLONTIS PROJECT;

SOPHIE HAY, ARCHAEOLOGICAL PARK
KENNETH LAPATIN, J. PAUL GETTY MU

Sometime around noon, Vesuvius erupted.

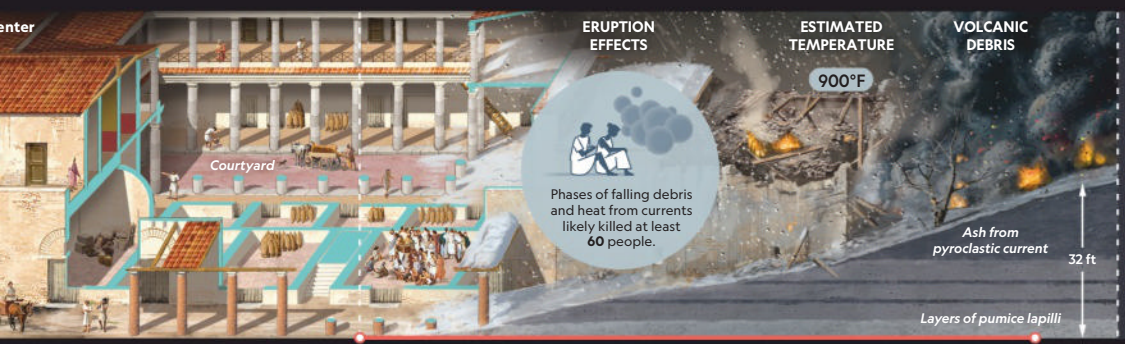
Time of day | Noon | FIRST DAY | Midnight | SECOND DAY | Noon | 8 p.m.

enter

ERUPTION EFFECTS

ESTIMATED TEMPERATURE

VOLCANIC DEBRIS



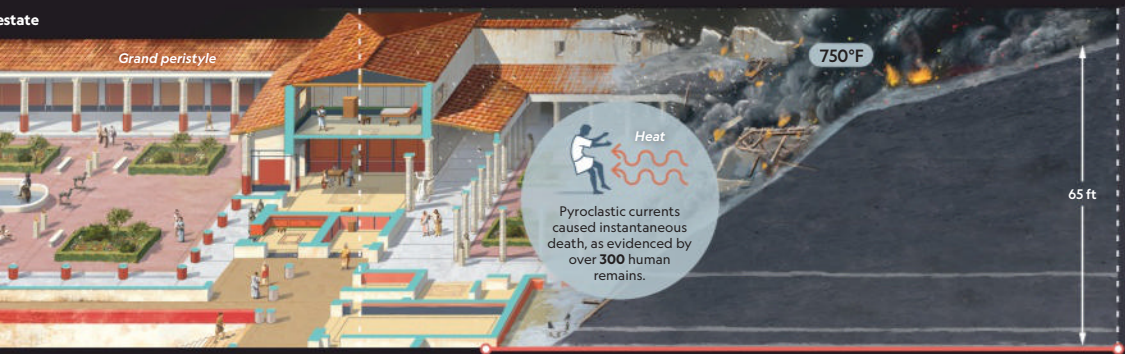
Eruption effects start — End

REMAINS PRESERVED

Volcanic ash helped preserve skeletal remains, which were found intact with jewels and coins. Nearby were foodstuffs.



estate



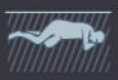
Currents of ash and gas carbonized organic materials—preserving wooden furniture, foods, fabric, and scrolls.



a: elite villa



Trapped in shallower layers of pumice and ash, most human remains and organic materials decomposed.

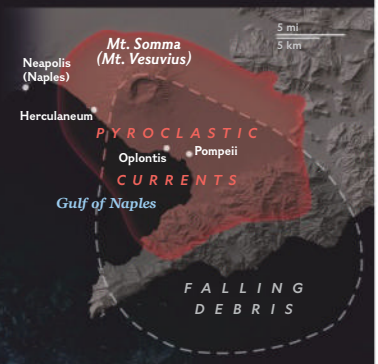


OF POMPEII; MANTHA ZARMAKOUPI, UNIV. OF PENNSYLVANIA; SEUM; CLAUDIO SCARPATI, UNIV. OF NAPLES FEDERICO II

DISASTER

There were warning signs before the eruption: Steam rose from Vesuvius's summit, the earth trembled. Then a column of ash and stone burst into the sky. Over the next 30 hours, fragments of pumice, called lapilli, covered the towns below and superheated avalanches of gas and ash known as pyroclastic currents raced down the mountainside.

Graphics and maps by
FERNANDO G. BAPTISTA, PATRICIA HEALY, *and* MATTHEW W. CHWASTYK

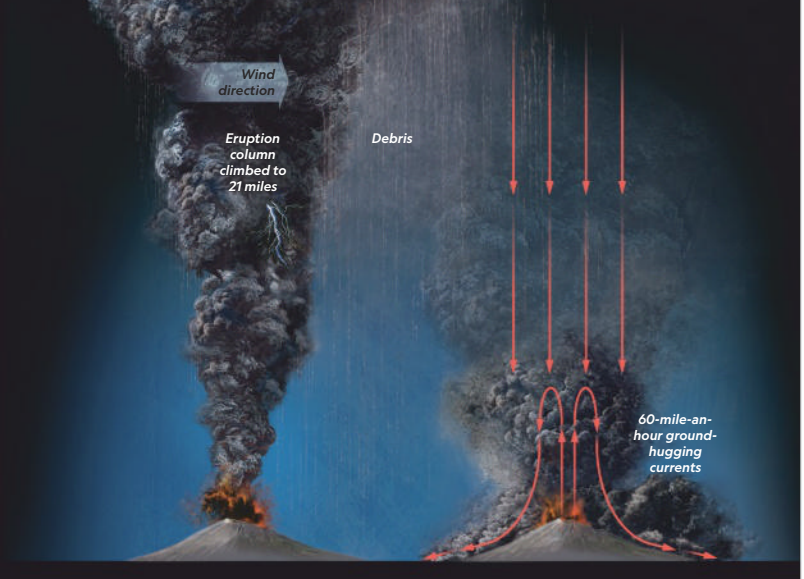


FIRST DAY

Falling debris
From midday into the evening, most debris from the eruptive column blew southeast, blanketing the terrain with lapilli.

SECOND DAY

Deadly avalanche
In the morning, the column collapsed, triggering the intense pyroclastic currents that charged down Vesuvius's slopes.



I

• OPLON

THE SEASIDE SUBURB WHERE T
THE ENSLAVED WERE TRAPI

In 1974, construction crews sinking pylons for a school gymnasium in the town of Torre Annunziata struck something unexpected. Instead of bedrock, they discovered an ancient Roman warehouse, which included that storeroom full of skeletons. It was a remarkable archaeological find: people from all walks of life, all killed in the same disaster and perhaps in the same instant. By the time of their death, Oplontis was a well-established suburb of Pompeii with one of the most elaborate villas in the entire Vesuvius region, a site now known as Oplontis A. An inscription on a clay amphora there links Oplontis A's owners to the Poppaea, the family of Roman emperor Nero's second wife. The home's grandeur is still overwhelming today: marble sculptures

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THE WEALTHY AND
PED TOGETHER

ountains, a 200-foot swimming pool,
masterpiece frescoes," says University
xas professor John R. Clarke, who leads
rations as co-director of the Oplontis
ct. The mostly intact frescoes, depict-
phinxes, centaurs, peacocks, figs, and
, have been found in many of the 103
s discovered here so far; the villa's west
is still being excavated. But there are
ous signs if you look closer. Damage
me frescoes marks where superheated
om pyroclastic currents tore through
. 79. Other walls show violent bulges,
ernias. And while the villa once sat on
foot cliff overlooking the Gulf of Naples,
us from the eruption pushed the mod-
horeline out half a mile.



Detailed "osteobiographies" of skeletal remains found at the Pompeian suburb of Oplontis could help illuminate the complexities of Roman social and gender dynamics.



Among the most lavish villas of the Vesuvius region was Oplontis A, pictured here, a resplendent home with a 200-foot pool and marble sculptures like this one of a satyr lunging at Hermaphroditus.



Around 300 yards east sits a large warehouse now known as Oplontis B. It stood two stories tall, with more than 70 rooms arranged around a central courtyard; townhouses with shops surrounded it. Some 1,600 clay amphorae turned up, many stacked upside down to dry, suggesting merchants bottled wine there. Piles of now carbonized pomegranate skins, commonly used in leather tanning, hint at other crafts. But the most prized discovery from Oplontis B lay in a dark, cavelike storeroom on the ground floor. Because the bodies of the Oplontis victims were buried by ash topped off with pyroclastic material, their bones remained intact. Whereas ancient cemeteries were often segregated by class, the freak destruction of Oplontis preserved a diverse array of people in one spot, leaving behind one of the most scientifically valuable assemblages of Roman dead.

Today Oplontis B's courtyard looks bucolic, with stately columns and mossy stones. A block of amphorae sits to one side, fused together in volcanic deposits. However, the upper story is too unstable to visit, and has been taken over by noisy pigeons. For years the place was easy to overlook, but Valeria Amoretti, a bioarchaeologist who heads the Applied Research Laboratory at Pompeii, sees something rich in these ruins. "We are so focused on Pompeii," she says. "Sometimes we forget to take a look at the suburbs."

Despite good intentions, excavators in the 1980s failed to document the storeroom skeletons in the detail scientists would today. They didn't always distinguish carefully between bodies lying atop each other, and bones from individuals became mixed up. The situation left behind—scores of specimen bins full of skeletal parts in plastic bags—has become a literal puzzle to sort out.

The remains now reside in Amoretti's lab, where her team is reassembling the skeletons piece by piece, work that could deepen our understanding of gender, class, and the prevalence of violence in the ancient world. On a recent visit, one of Amoretti's graduate student researchers, Valentina Giacometti, pulled out several bags. One held half a jawbone, another the shattered fragments of a spine. Giacometti has spent years laying the pieces out on tables, fitting them back together. While earlier excavators counted 54 victims, Amoretti's crew has identified at least 60—including toddlers and unborn children. They were found in two distinct clusters: Roughly 20 victims were positioned deep within the barrel-vaulted room, clutching tools and lanterns. The rest were near the door, perhaps first in line for a rescue boat, and laden with coins and jewelry, including gold necklaces, a silver snake bracelet, and an emerald- and pearl-encrusted pendant. To some, this disparity suggests two social groups: laborers and enslaved people in the

When Vesuvius erupted, pumice and ash rained over Oplontis, protecting its famed fresco of Hercules in the Garden of Hesperides (right) from oxidation and erosion once superheated torrents of rock, ash, and gas called pyroclastic currents swept in.

That same airtight seal carbonized organic material like pomegranates (below) used in leather tanning.







back, merchants or elites at the front. Even in the face of death, it seems, the hierarchies of Roman life held firm.

This class division remains a theory, although work emerging from Amoretti's lab could put that supposition on secure footing. Once Giacometti has sorted out which bones belong to which individuals, the team can compile what scholars call osteobiographies—personal histories of people as inscribed on their bones. As one example, Giacometti tilts a teenage boy's skull, pointing out faint ripples on his front teeth, a possible sign of childhood malnutrition. Scars on weight-bearing bones can reveal a life of physical toil. On other victims, Giacometti has noted repeated fractures and blunt-force trauma—maybe a tally of violence. With the data in hand, other researchers can also explore social and gender dynamics. If female skeletons bear marks of manual labor, that would broaden understandings of the work they performed in Roman society. If any of the jewelry-laden bodies show signs of malnourishment in childhood, that could point to an enslaved person who later rose in status—evidence of class mobility that modern minds rarely associate with enslavement.

Over the past few decades, archaeology has broadened its horizons to document the lives of vulnerable and overlooked populations. The Oplontis skeletons afford a rare opportunity to compare the bones of men and women from different social strata—a bustling blend of merchants, laborers, enslaved people, and wealthy elites, united in violent death.





Early excavations revealed Oplontis A's remarkably intact frescoed porticoes. Archaeologists later exploring Oplontis B made an equally arresting discovery: a storeroom with a raft of skeletons, remains that are now under the care of the Applied Research Laboratory at Pompeii.

II

HERCULANEUM

THE COASTAL RETREAT WITH AN ANCIENT LIBRARY FINALLY YIELDING ITS SECRETS

The items looked like trash—nothing but scorched bundles of old cloth. But when diggers excavating a villa in Herculaneum in 1750 took a closer look, they were surprised to realize that they'd actually found papyrus scrolls. The scholars brought in to examine the scrolls—estimated to number between 650 and a thousand, some whole and some in fragments—were both thrilled and frustrated. On the one hand, they represented the only known library to survive from antiquity, a sensational find. Yet the scrolls were so delicate that they could barely be handled safely, much less unwrapped and read. A veritable time capsule from the past, only we lacked the tools to open it.

At least until recently. Thanks to new technologies, the stories and accounts recorded in these age-old scrolls are beginning to trickle out.

We normally think of natural disasters destroying objects; rarely do we consider how they preserve them. When Vesuvius erupted, hot pyroclastic currents swallowed up and sealed off Herculaneum, eventually forming 60 feet of overlying rock. Organic material there—wax tablets, wooden cradles, loaves of bread—didn't decay so much as bake into carbonized fossils. The scrolls met the same fate. Today all but a few of them reside in Naples, locked in cabinets deep inside a national library. Most look warped and charred, others look as if somebody stepped on a burrito, then



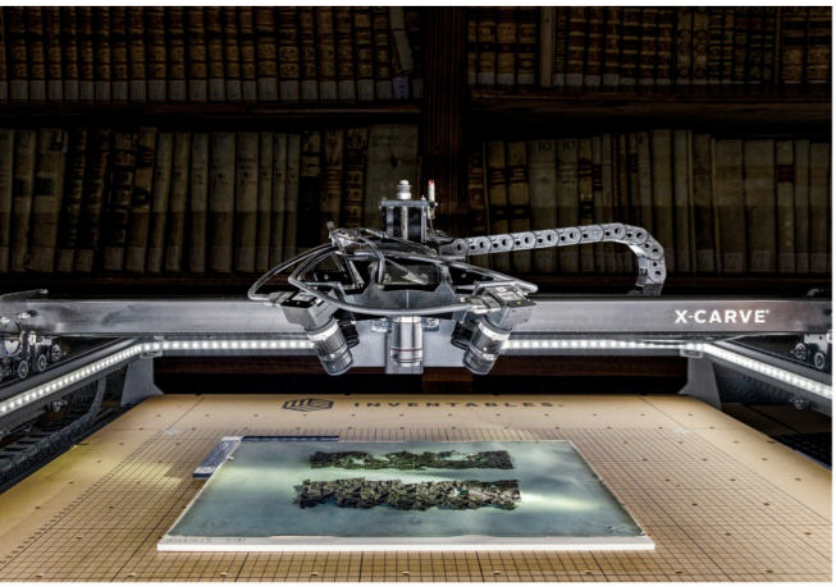
Pyroclastic currents from Vesuvius, reaching 750 degrees Fahrenheit, baked organic matter in an instant—reducing papyrus scrolls from Herculaneum's Villa of the Papyri library to carbonized, coal-like husks before sealing them under ash.



Recent technological advances have allowed papyrologists like Rossella Villa to read the Herculaneum scrolls scorched by Vesuvius. Here she prepares a work from Greek philosopher Philodemus, written some 100 years before the eruption, for spectral scanning at the National Library of Naples.



These ancient scrolls, which would crumble or turn to ash if physically unrolled, are virtually unwrapped using a combination of 3D imaging and artificial intelligence. Photogrammetry equipment also helps digitize them. The one below, written in Latin between the end of the first century B.C. and the eruption in A.D. 79, is about the legendary Battle of Actium, where Octavian's maritime fleet, led by Marcus Agrippa, defeated the combined fleets of Mark Antony and Cleopatra.





blowtorched it. Their tight black wrappings are incredibly delicate—as fragile as butterfly wings, a conservator once said.

Over the centuries, scholars tried several times to coax the scrolls open, using everything from infusions of mercury to a machine that tugged the ends with silk threads and deposited the crumbling flakes onto adhesive pig-bladder membranes. From this work, they learned that the collection consisted mostly of Greek-language works by Philodemus, a first-century B.C. Epicurean philosopher known for his musings on topics like theology and morality. Despite a few triumphs, most attempts at unrolling only destroyed the papyri without yielding much, and officials finally banned all such attempts a quarter century ago. The equivalent of thousands of pages of text—more than the collected works of Shakespeare—seemed destined to remain forever mute.

Then, in the early 2000s, a computer vision specialist at the University of Kentucky named Brent Seales developed a plan to virtually unwrap the scrolls. He would first capture 3D images of their internal layers using x-ray



tomography, similar to a hospital CT scan. Software would then "segment" the scan into patches, flatten them for easier reading, and scour them for ink. Over the past several years, Seales has expedited the laborious process by training AI programs to do various tasks, including detecting and enhancing ink, which can impart a distinct texture to papyrus, like dried mud.

He also publicly released his team's images of the scrolls, inviting programmers worldwide to tinker with the ink-detection algorithms. To incentivize this work, he partnered with two Silicon Valley financiers in 2023 to launch the Vesuvius Challenge, which offered cash prizes for hitting certain milestones, like reading the first letters. Seales can still recall the thrill he felt nine months later, when a trio of college and Ph.D. students successfully excavated 2,000 Greek letters across 16 partial columns of text—making those passages visible for the first time in two millennia. "The rocket was lit," he remembers thinking.

Dozens more scrolls have since been scanned and fed into Seales's program, though



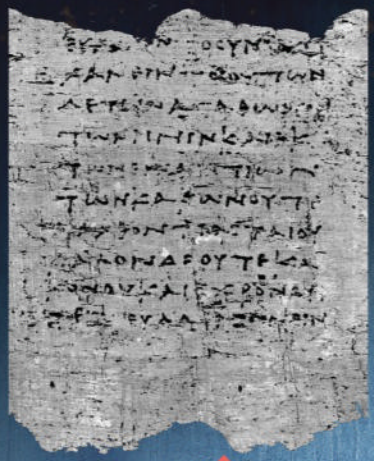
Two thousand years later, the carbonized scrolls from Herculaneum are readable again. A portion of this one describes Cleopatra contemplating death.



SECRETS IN THE SCROLLS

Herculaneum's millennia-old papyrus scrolls were too charred to open—until scientist Brent Seales and his team invented a way to read them. Here's how they virtually unwrapped one.





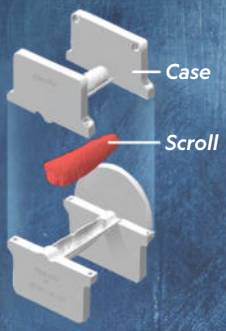




The scroll is 3 ft long unwrapped.

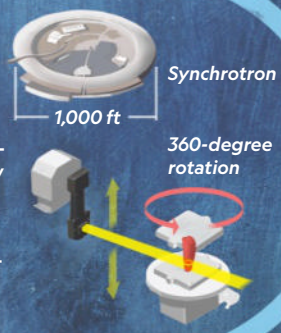
1 Bracing the scroll

The team 3D printed a protective case to keep the carbonized scrolls from crumbling.



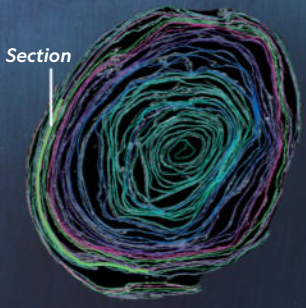
2 Imaging the interior

Researchers used a massive particle accelerator called a synchrotron to x-ray the scroll with a precision beam, creating a 3D scan at the cellular level.



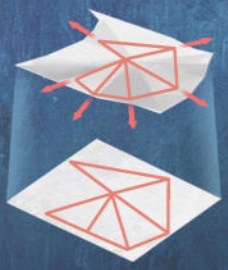
3 Separating into sections

An AI program identified layers of papyrus within the scanned scroll, then put those layers into smaller sections for ideal legibility.



4 Smoothing out wrinkles

An algorithm helped virtually flatten out creases to remove distortions from the crinkled papyrus.



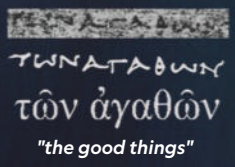
5 Detecting ink

The team trained an AI model to recognize ink textures on papyrus to uncover markings.



6 Ready to read

The resulting image clearly showed individual letters—ready for papyrologists to read and interpret.



GRAPHIC: FERNANDO G. BAPTISTA AND PATRICIA HEALY. SOURCES: BRENT SEALES AND CHRISTY CHAPMAN, UNIV. OF KENTUCKY. IMAGES COURTESY THE NSF-FUNDED EDUCELAB AT THE UNIV. OF KENTUCKY AND THE VESUVIUS CHALLENGE; PAOLO VERZONE

it's not as if whole texts just magically pop out now. Due to ancient damage, papyri are often missing words or whole columns. And the AI has limits: It scrutinizes each pixel and declares it ink or not-ink but cannot recognize letters, much less interpret passages. That work falls to scholars like Federica Nicolardi, a papyrologist and professor at the University of Naples Federico II who served as a judge on the Vesuvius Challenge.

The longest digitally unwrapped scroll, an astonishing 20 feet, initially presented a mystery. Given the holes in certain words, a researcher on Nicolardi's team, Maria Chiara Robustelli, spent several minutes puzzling over each one—and when she finally did decipher them, the words seemed wildly out of place. "I was confused because I expected something different, philosophical words or something," Robustelli says. Instead, she found terms like *koureion* ("barbershop") and *myropolion* ("perfume shop"). Equally confounding was a phrase another scholar identified: *methyskesthai* ("to get drunk"). What kind of philosophy was this? Nicolardi's team eventually traced the passage to *Characters,* a work on ethics written by a student of Aristotle's in the fourth century B.C. It came from a section on *bdelyros* (the "repulsive man"), which criticizes busybodies who start frivolous lawsuits or boast about drinking at social haunts like barbershops and perfumeries. The overall scroll, they determined, was a previously unknown portion of a larger work by Philodemus called *On Vices*. It dissects character flaws and moral failings, and offers guidance on becoming a better human being. This work seems to have a practical, everyday bent—a contrast to the often esoteric academic philosophy of modern times.

Another digitally unwrapped scroll considers whether scarce goods provide more pleasure than abundant ones. Its thesis remains unclear—members of Nicolardi's team have a 20-euro bet on what the title will be—but the text discusses sensory perceptions and again draws on examples from daily life, including music, bread, and even capers. The scroll offers glimpses of the author's character as well: He disparages those who disagree with him as "stupid" and "fools." This was no-holds-barred philosophy. Recently, Nicolardi determined that one scroll on theology by Philodemus was titled "On Gods, Book 8." Books 1 and possibly 3 were known before this, but no others—meaning her team has seemingly proved, in a single stroke, the existence of several completely unknown works, any of which could expand our knowledge of the Greek pantheon of gods. The scrolls could also illuminate the inner workings of ancient libraries. The ragged shapes of certain scrolls fit together like jigsaw puzzle pieces, leading scholars to conclude that they were shelved side by side when pyroclastic currents from Vesuvius washed over and warped them. Knowing the contents of neighboring scrolls could in turn reveal the library's filing system—by topic, by language, by genre, or by something else entirely.

But why did the library's owner possess so many works by a single author, especially a middling philosopher like Philodemus? Where's the Aristotle, the Homer, the Herodotus? Philodemus is known to have moved to Italy later in life, and Nicolardi suspects the Herculaneum library might be his archive, passed down to friends or family. Finding drafts and different versions of his treatises among the scrolls would lend weight to this idea.

Or something truly unexpected could emerge. After a morning examining the blackened scrolls, Nicolardi goes around the table, asking what each team member's dream discovery would be. They mention letters between famous philosophers, lost Latin epics, a catalog of the Herculaneum villa's library. Nicolardi also wants to dig for additional scrolls at Herculaneum. "Part of the villa has never been excavated," she notes, and it happens to lie next to where most of the original scrolls were found. More could easily turn up.

III

POMPEII

THE COMMERCIAL HUB WHOSE TINY BITS OF LIFE COULD UNLOCK BIG MYSTERIES

No one knows who lived at the stately mansion in southern Pompeii now known as Casa della Regina Carolina, after the queen of Naples who sponsored initial excavations there in the early 1800s. The home was distinguished above all by its approximately 8,000-square-foot garden, a meticulously landscaped oasis near two busy theaters, with trees, vines, flowering plants, and private shrines for prayer and reflection.

The home's second story was destroyed during the Vesuvius eruption, and almost all decoration on the first floor's walls has crumbled away. But the replanted garden remains a shady refuge amid the daily throngs of tourists, who hurry by without realizing the real treasure here lies below the surface.

Genetic archaeologists generally extract DNA from bones or other biological material, and have done so before at Pompeii. But a team co-led by Caitie Barrett, an archaeologist at Cornell University and a National Geographic Explorer, recently succeeded in taking DNA from soil samples of Casa della Regina Carolina's garden—discovering evidence for olives and grapes. Future work, there and elsewhere, could identify rare varieties or lost cultivars, hinting at households with a taste for the exotic. More important, this work proved something fundamental: that fragile DNA has very likely survived within the ancient soil at Pompeii.

Building on this study, Barrett and her colleagues now hope to piece together details



Vesuvius's eruption buried Pompeii in pumice lapilli. Later, heat and lack of oxygen carbonized the city's food, including this bread. These intact remains, along with surviving DNA, are helping scientists better understand ancient Rome.





Buried in up to 20 feet of pumice lapilli and ash, parts of Pompeii were remarkably preserved. This has brought into rare focus the routines and habits of ancient life, much of which unfolded here at the central forum: the heart of political, economic, and religious activity.

about the home's inhabitants—what they ate and drank, and potentially how they fell ill and cared for their sick. In fact, they're already extracting genetic material from a spot less glamorous than the garden: the home's latrine complex. Above ground, near the kitchen, two toilets occupied separate but adjacent rooms, like a modern restroom's individual stalls. But below ground, pits collecting human waste were connected.

Last summer, the team partially excavated one of those pits, about a yard wide. (Asked whether her crew smelled anything funny as they dug, Barrett laughed and recalled "a urine smell—very faint, very subtle.") Their samples are being analyzed by Flavio De Angelis and Eduardo Amorim, geneticists at Arizona State University who are searching for DNA from multiple organisms, including intestinal worms, to explore disease burdens in Pompeii. But their main focus is the gut microbiome: the diverse community of bacteria populating the human digestive tract that gets shed in stool. Two people's guts can carry significantly different bacterial mixes depending on diet. Certain species thrive on milk, others on sugars, fats, or proteins. By measuring the relative abundance of each bacterium's DNA in the latrine, the team hopes to reconstruct what the household ate and how varied their table was.

The latrines may also yield human DNA, which could reveal details about the home's inhabitants. Once a single grand home, the property had been divided into a larger unit and a smaller one by the time Vesuvius erupted. Each had its own latrine, and Barrett suggests that comparing DNA from both might reveal the relationship between the households. Finding similar DNA could suggest that the smaller one was an in-law suite. Mismatched DNA might indicate a rental property. Or the presence of many unrelated individuals could suggest something else. Perhaps the owner was an influential person receiving petitioners at home. "We're interested in telling the story of everybody else who would have been part of this house," Barrett says.



De Angelis and Amorim also hope their genetic analysis can provide insight into psychological ailments in the Roman era. The human gastrointestinal tract contains roughly 100 million neurons between the esophagus and rectum. Anything that affects them—including gut bacteria—could, in principle, affect brain function. "There is a direct connection between the gut microbiome and mental health," says De Angelis.

Studies among populations today have already identified associations between specific bacteria and conditions like bipolar disorder and schizophrenia, and also with diseases like Alzheimer's. The team's samples could reveal the presence of these ailments in the ancient world.

Although they lack the dazzle of Pompeii's most famous artifacts—breathtaking frescoes,



At the Pompeian house Casa della Regina Carolina, scholars are conducting unprecedented genomic studies of the garden and latrines, which could reveal more about ancient Romans' health.

sculptures, candelabras—DNA data from Casa della Regina Carolina are just as revealing. While a latrine might seem "gross and unbeautiful," Barrett says, "in many ways, we can learn more from things like toilets and trash heaps than we can from beautiful statuary."

Indeed, the discoveries emerging from Oplontis, Herculaneum, and Pompeii have deepened our understanding of everyone who lived there. The bones of laborers and enslaved people speak to the invisible, often backbreaking work that kept the Roman Empire running. The philosophy of the era, as reflected in the Herculaneum scrolls, includes instructions on practical, everyday matters. The wisps of DNA from latrines could reveal the sicknesses that darkened their days. These people were like us in so many ways, and if Vesuvius had stayed quiet, Pompeii and its sister cities might have thrived for years. Instead, the volcano destroyed them—and thereby preserved them for all of history. Even after 2,000 years, the most famous disaster in history continues to surprise us. ▯

JOURNEY DEEPER INTO POMPEII

In National Geographic's new docudrama series, actor Tom Hiddleston takes on the role of historical detective, joining some of the world's leading Pompeii experts as they piece together untold stories from the Vesuvius eruption. *Pompeii: Out of Time with Tom Hiddleston* is streaming on Disney+. Check local listings.



Discoveries emerging from the Vesuvius region are deepening our understanding of Roman wellness, class hierarchies, and gender roles. For instance, this Pompeian house belonged to Julia Felix, a businesswoman who owned a massive estate and commercial complex with luxury baths, apartments, and shops.



PORTAL TO THE PAST

The National Archaeological Museum of Naples is known for its dazzling collection of mosaics, statues, and frescoes recovered from the ashes of Vesuvius—but its storerooms hold an even greater trove. There, in areas generally off-limits to the public, National Geographic gained access to thousands of fragile archaeological treasures from Pompeii and Herculaneum that capture the customs and joys of ancient Roman life.



Frozen Mid-Game
This die made of bone is fused together with a hodgepodge of items in hardened volcanic material. Some objects are unidentifiable, while others, like nails, are clearly visible.



Vintage Wine

Numerous wine jugs, including bronze amphorae, from the region were preserved in Vesuvius's volcanic ash, revealing a vibrant wine culture that holds strong today. Vessels on the shelves to the left were also used to serve *mulsum,* a honeyed wine favored by wealthy elites.

A Fresco Saved

Featuring a classic Greek-style theater mask, this fresco was detached from a Pompeii wall possibly by 18th-century master restorer Joseph Canart, who removed murals in large single, unbroken pieces by cutting them out and mounting them on slate supports.



THE QUEST TO SAVE *the World's Rarest* ORCHIDS

In the face of an extinction crisis, one maverick botanist is turning his vast flower collection into a resource for science.

Words by
ALEXANDRA MARVAR

Photographs by
JUANITA ESCOBAR

THE BLOSSOMS OF the long-tail *Masdevallia* feel eerily similar to flesh. Tentacular tails hang from their petal-like sepals, which are shaded maroon, coral, and yellow—the palette of rotting fruit. A fly could mistake them for a feast. For tens of millions of years, this peculiar orchid, native to Colombia's fast-disappearing cloud forests, has survived thanks to its power to attract a pollinator. Today that pollinator is a 64-year-old man in reading glasses.

Daniel Piedrahíta owns 25,000 orchids—among the world's largest private, noncommercial collections—but right now, in a greenhouse outside of Medellín, Colombia, he is focused on this one alone. He gently pinches one of its tails, tilts its face upward, and with the tip of a wire, moves a pinhead of pollen from the center of one bloom to another. If this pollination process takes, a pod will form, filled with as many as a million dustlike seeds. Piedrahíta will pluck it, wrap it in foil, and deliver it to researchers in Medellín, who will try



Daniel Piedrahíta inspects an array of epidendrum orchids, a few of the 3,500 species represented in his orchid collection, in one of his greenhouses in La Ceja, Colombia. As extinction threatens orchid species, the collector has built up what he calls a "genetic bank."



to grow this wild, wily plant in a lab.

With habitat loss and black-market trade threatening extinction for an estimated half of the world's 30,000 known orchid species, private collections like Piedrahíta's offer an invaluable resource: genetic stores for research, propagation, and potential reintroduction. The only problem? Private collectors are often guarded, protective of hard-won knowledge about cultivation techniques and hesitant to invite scrutiny over where their specimens came from.

Not Piedrahíta. In a subculture of collectors who prize orchids for their rarity, he is devoted to coaxing some of his rarest specimens into abundance. At Alma del Bosque—or "soul of the forest," the arboretum and education center he opened last year—he is pollinating orchids and sharing his seeds and techniques with messianic zeal, part of a vanguard of collectors aiming to undermine black markets and ensure a supply of seedlings for future restoration projects. Partners at three Medellín labs are using his seed stock to propagate orchids that have never before been mass-produced—"the only chance," Piedrahíta says, "to not lose these species."

A commercial flower grower for the past 30 years, Piedrahíta caught orchid fever in the early 2000s, not long after he and his wife founded a hydrangea farm in the town of La Ceja, a hub of Colombia's cut-flower industry. The country is home to nearly a fifth of the world's orchid species, more than any other country, and most of its varieties are epiphytes—plants that attach to trees using specialized roots rather than growing out of soil. Piedrahíta started noticing them on birding trips in the Colombian wilds and was captivated by their cunning adaptations. Some masquerade as female insects so convincingly that males attempt to mate with them, emerging dusted in pollen. Others lure pollinators by mimicking the scents of chocolate, rotting fruit, or carrion. Piedrahíta was fascinated by the diligence orchids demand from a grower: In the time it may take a loblolly pine to grow two stories tall, an orchid seedling might produce a single flower. "When it finally blooms," Piedrahíta says, "it truly feels like magic."

His first time at a regional orchid show, he bought out a vendor's whole booth—some 250 plants. With hydrangea profits funding his new hobby, hundreds of orchids became thousands, acquired from commercial growers, traded with other obsessives, and occasionally rescued from a fallen branch.

Today Piedrahíta estimates his collection represents what he calls a "genetic bank"



NGM MAPS

Orchids found at Piedrahíta's Alma del Bosque reserve, clockwise from top left:

The Rothschild's slipper orchid is native to Borneo's Mount Kinabalu, where it is critically endangered.

Found in the Peruvian Andes, the Queen *Masdevallia* has flowers with long, tail-like appendages.

The orchid hybrid *Paphiopedilum* Clair de Lune was created by breeders nearly a century ago.

Venus slippers like this *Paphiopedilum* Pinocchio have a pouchlike lip to trap insects and release them coated with pollen.











of some 3,500 species—around a tenth of the family Orchidaceae. After years of keeping his orchids in greenhouses, he unveiled Alma del Bosque last summer, a massive pavilion beneath a 52-foot roof, with tours available for the public. Like Jurassic Park, its big black doors swing open to reveal an engineered wonderland: 11,000 square feet of tiered gardens and displays, with companion plantings and water features to create microhabitats in which a range of orchids can thrive.

Alma del Bosque is also the headquarters of Piedrahíta's project to cultivate a new generation of conservation-minded orchidists. Over the past five years, he's taught hundreds of students, in person and online, the orchid world's once guarded



Piedrahíta displays his collection at Alma del Bosque, the sanctuary he opened last year in the western Colombian Andes.

secrets, driven by the belief that every new grower cultivating uncommon orchids is helping disincentivize poaching in the wild. With his mentorship—and his pollen and seeds—several of his students have gone on to launch their own nurseries. One of them, 24-year-old Santiago Arango, now runs Medellín's Culto Orquídeas, with a staff of four, some 9,000 plants for sale, and customers all across Colombia. "People prefer to buy plants from the lab than to buy plants extracted from nature," Arango suggests. Meeting that demand, he says, "is the responsibility of all of us commercial cultivators."

Piedrahíta also provides his seeds to researchers at Medellín's CES University who are using them to develop techniques for in vitro propagation of rare orchids. Their current focus is a showy ivory specimen known as the white nun, Guatemala's national flower. It was poached nearly to extinction in most of its native habitat, although a reintroduction program is underway in Guatemala, using seedlings grown by a collector there. Piedrahíta hopes lab-grown plants made from his seed stock can help turn the white nun from a poacher's prize into a nursery staple—and that the same techniques might eventually support restoration efforts for other species in Colombia.

Using lab-grown orchids to replenish wild populations is still new science, tricky in part because the plants need sufficient genetic diversity to reproduce. But there have been glimmers of promise. In Florida, ghost orchids reintroduced to the Big Cypress Basin in 2018 have survived though not yet reproduced. In the United Kingdom, just last summer, a restoration program active since the 1990s yielded that country's first wild-grown lady's slipper orchid in nearly a century.

Piedrahíta is taking a long view, preserving threatened species to lay the groundwork for when the science catches up. "I'm a stubborn pioneer," he says. He has learned that loving orchids requires nothing if not patience. □

Alma del Bosque is roughly an hour's drive from Medellín, near the town of La Ceja. Book tours in advance at almadelbosque.com.

REVEALING

EVERY ANIMAL

ON EARTH



Twenty years ago, wildlife photographer Joel Sartore set out to capture portraits of every species in human care. Today, after 18,000 creatures, the conservation mission at the heart of his Photo Ark project has never been more urgent.

WORDS BY **DEVIN GORDON**



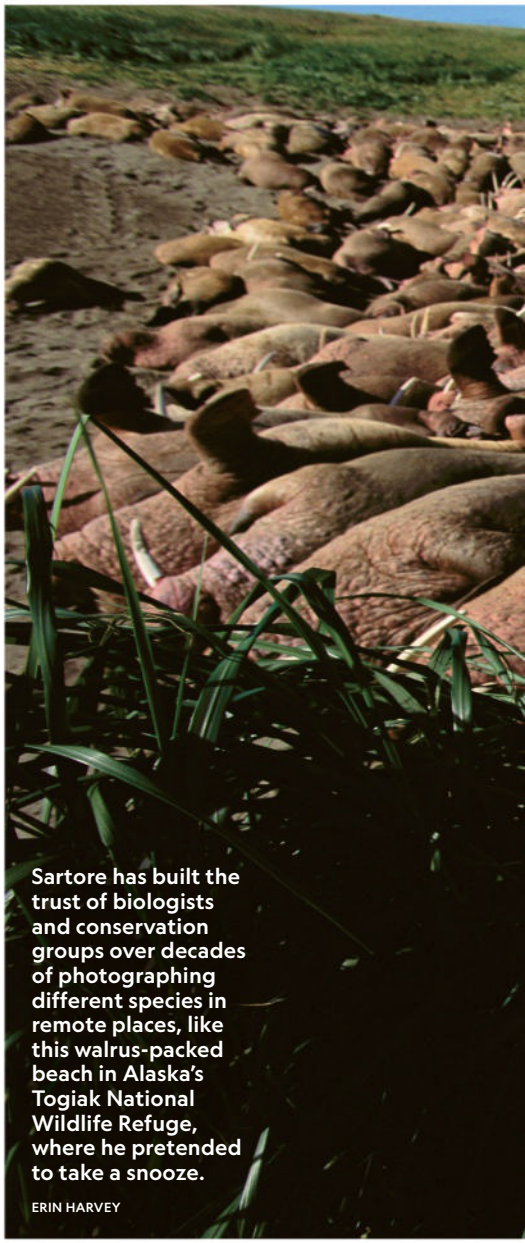
Joel Sartore's expanding archive relies on a global network of wildlife sanctuaries like Iowa Bird Rehabilitation in Des Moines, where he befriended this turkey vulture, a permanent resident.

CHRIS BUCK (BOTH)

THE

PHOTO ARK is photographer Joel Sartore's crusade to document the complete spectrum of our planet's animal kingdom, one species at a time. That makes Sartore the modern-day Noah of this almighty zoological project, supported by the National Geographic Society, that's celebrating its 20th anniversary. And if you know him, this fits. Sartore has got a secular, science-driven kinship with his predecessor: Noah didn't favor any of God's creatures for cosmetic reasons, and neither does Sartore. His operation, based in Lincoln, Nebraska, just does its job, chipping away at its task, gathering up all of the species, great and small, splendid and unsightly, as many as it possibly can, before it's too late.

The first animal that Sartore brought aboard the Photo Ark, so to speak, back in 2006, was a naked mole rat—a bald, buck-toothed rodent that he photographed in the kitchen of Lincoln Children's Zoo. Such a humble, homely creature turned out to be an apt start, says Sartore, a National Geographic Explorer. Of the more than 18,000 animal images he's accumulated since, mainly of creatures living in sanctuaries or under human care, the vast majority "are just not on



Sartore has built the trust of biologists and conservation groups over decades of photographing different species in remote places, like this walrus-packed beach in Alaska's Togiak National Wildlife Refuge, where he pretended to take a snooze.

ERIN HARVEY



anybody's radar. They're not polar bears or tigers. They're minnows and they're sparrows and they're things that live high up in the trees or in the soil. They're not things that get photographed much."

For every far-flung voyage to snap a photograph of, say, some majestic bird of paradise in New Guinea, Sartore and his scrappy team will make multiple stops along the way to shoot an insect



Early in his career, Sartore faced off with a caiman in Bolivia's Madidi National Park, before he began focusing on animals in human care to build the Photo Ark.

JOEL SARTORE WITH
ROSA MARIA RUIZ



73
COUNTRIES VISITED

From Chile to Madagascar to Kazakhstan, Sartore has traveled to more than a third of the world's nations to capture the animal kingdom's diversity.

450
POUNDS OF GEAR

The Ark team brings plenty of equipment to photo shoots, including multiple cameras, light stands, shooting tents, and black and white backgrounds. (Even, sometimes, a plexiglass tank.)

under a porch light or a moth that happened to land on someone's shoulder. Every marathon trip is a sprint, because many of the Ark's inclusions are just barely staving off extinction. Some vanished soon after Sartore reached their sole survivor, like Toughie, a Panamanian tree frog about the size of a fist, that lived to be at least 12 years old in a silver trailer called the FrogPOD that was permaparked at the Atlanta Botanical Gardens. Toughie's species, the Rabbs' fringe-limbed tree frog, along with dozens of others in the mountains of Panama, has been wiped out over the past 20 years by something called the chytrid fungus. Toughie escaped to Atlanta, but his species' unique mating call vanished from the night chorus back in Panama before anyone could record it. A sound—a type of communication—was gone forever.

On the day of Toughie's shoot, Sartore asked his caretaker, an amphibian conservationist named Mark Mandica, how it felt "to be in charge of the last of something. And he said, 'Every morning when I go into work, Joel, I'm sick to my stomach because I'm afraid this is going to be the day.' " One rainy morning a few months later, Mandica had just arrived outside the FrogPOD when he heard a sound he'd never heard before—"like a dog barking," Sartore says—and he knew it could only be one thing. "Frogs like to call and breed in the rain," Sartore explains, "and it could probably smell the wet air, hear the rain." Mandica managed to record about 10 seconds on his phone. Less than two years later, in 2016, Toughie died. The previous year, his image from the Photo Ark had been projected onto the facade of St. Peter's Basilica in Vatican City, along with an audio broadcast of his barking call, for an audience of the pope. It's a tale that Sartore returns to often in lectures and at conferences and fundraisers as the Photo Ark's legend has grown in the conservation community. It's also a mantra—an orienting rationale of sorts for the entire project—that he repeats just as often: *Because this is what extinction looks like.*

Every image in the Ark represents Sartore's best effort to put paddles to our hearts, to jolt them by confronting us with irrevocable death. He knows just how hard it is to deny the soul of a creature when it's staring right into yours.

One plot point in Noah's story that the Bible really skates past is how exactly he went about tracking down all those distant species and managing the sheer logistics of getting everyone aboard before the weather turned foul. If Sartore's version is any clue, it must've been quite an operation.

Sartore's core Ark team includes his family. Son Cole, 33, will take over when his knees give out, he says. For now, Cole does tons of technical work—building out sets, rigging lights, testing shots, capturing video—as well as the occasional shoot ("usually the animals he finds most interesting," Sartore says). His wife, Kathy, pitches in with the thicket of scheduling and also functions as a sort of external hard drive for Sartore's decades of travel memories. Among other staff, he employs a database manager in Lincoln and a couple of self-trained taxonomists and self-described "zoo nerds."

Pierre de Chabannes, a former drummer and wildlife photographer based in France, joined the Ark team in 2015 after a single record-setting day of shooting at a bird sanctuary outside Paris: During the marathon session, he helped Sartore identify and photograph 51 different species of birds, the most Sartore had logged in one go. "The aviaries [at this location] are made only for displaying a huge number of birds," de Chabannes says, "[so] there's no names on them at all." He wound up spotting each species by sight, then cross-checking for matches against the wish list on Sartore's laptop. "I kept birds coming for, like, seven hours," he says. "I didn't even have dinner."

On the drive back to Paris, while de Chabannes was behind the wheel, "Joel was flashing his computer screen at me whenever I had a little bit of time, and I would tell him the scientific name and conservation status for all those species." Sartore stayed up until dawn double-checking de Chabannes's memory and didn't spot a single mistake. The next morning, he asked de Chabannes to come aboard the Ark as one of its taxonomists.

But what really keeps Sartore's

calendar full with shoots for six months out of the year is his staggering global network of sources and contacts. Name any species of animal you want to find—Sartore knows a guy, or a gal. The names of institutions in cities worldwide come tumbling out of him in conversation.

Sartore's network is the human architecture that keeps the Photo Ark sailing onward, but he assembled it long before the idea occurred to him, over the course of 17 years working for *National Geographic*. The project began as a bittersweet by-product of family hardship: In 2006, Kathy was diagnosed with breast cancer, and the treatment required seven months of chemotherapy and multiple surgeries. The Sartores had three young kids, 11, nine, and two. Joel wasn't going anywhere. Already he'd been feeling a gnawing sense of futility about the work he was doing, the seed of something you can hear more palpably in his voice now—a hint of exasperation that still, after all this time, so few people are seriously reckoning with what's at stake.

During those first few months of his wife's treatment, while he was at home caring for his family, his thoughts kept turning to John James Audubon, the famed ornithologist, who'd painted several species of birds that soon went extinct, and now those paintings are the only documentation we have left. One day it struck him: What if he made his own version of Audubon's paintings, a series of portraits, a single image for each animal? Like an ark. An idea to

6
MONTHS OF STENCH
That's how long the stink lingered after a pygmy hippo at Omaha's Henry Doorly Zoo & Aquarium sprayed Sartore's background with feces and urine.

BEFORE THEY VANISH

Among the more than 18,000 animals that Joel Sartore has photographed are some of the most threatened species on Earth. During the 20-year project, some have disappeared, others are rapidly slipping toward extinction. Here are a small number of the ever growing category of vulnerable animals—photographed with Sartore's urgent hope that portraits might galvanize protection.

Photographs by **Joel Sartore**



Grey-shanked douc langur
Pygathrix cinerea
CRITICALLY ENDANGERED
Marked by striking orange collars, these primates are hunted for their meat in Vietnam.
PHOTOGRAPHED AT ENDANGERED PRIMATE RESCUE CENTER, NINH BINH, VIETNAM

1.
Utah prairie dog
Cynomys parvidens
ENDANGERED
This smallest prairie dog species, which makes its home in the southwestern United States, is distinguished by a black spot above the eyes.

2.
Thick-billed parrot
Rhynchopsitta pachyrhyncha
ENDANGERED
Found in the mountains of Mexico, these parrots nest in old woodpecker holes.

3.
Emperor penguin
Aptenodytes forsteri
ENDANGERED
The largest penguin species, the emperors in Antarctica can weigh 90 pounds and travel long distances by sliding on their bellies.

4.
Red handfish
Thymichthys politus
CRITICALLY ENDANGERED
This creature from the Tasmanian coast uses modified fins to walk along the seafloor.

5.
Luristan newt
Neurergus kaiseri
VULNERABLE
Marked by an orange-red dorsal stripe, this salamander lives in Iran's southern Zagros Mountains.

6.
Blyth's tragopan
Tragopan blythii blythii
VULNERABLE
This pheasant in the eastern Himalaya and beyond is known for its elaborate courtship displays.

7.
O'ahu tree snails
Achatinella sowerbyana
CRITICALLY ENDANGERED
Native to the Hawaiian islands, the striking gastropods average less than an inch in length.

8.
Transcaspian urials
Ovis vignei arkal
VULNERABLE
Relatives of modern domestic sheep, these animals are found in west-central Asia.

9.
Sunflower sea star
Pycnopodia helianthoides
CRITICALLY ENDANGERED
Located in the Pacific Ocean between Alaska and Mexico, the stars grow up to 24 arms and feed on clams and crabs.

10.
Bornean clouded leopard
Neofelis diardi borneensis
ENDANGERED
This fearsome predator is elusive, and little is known about its habits in the wild.

11.
Gharial
Gavialis gangeticus
CRITICALLY ENDANGERED
One of the largest crocodilian species, gharials live on the Indian subcontinent.

12.
Costa Rican lemur leaf frogs
Agalychnis lemur
CRITICALLY ENDANGERED
These nocturnal Central American tree frogs are threatened by deforestation and chytrid fungus.

13.
Longhorn fairy shrimp
Branchinecta longiantenna
ENDANGERED
The soft-shelled Californian crustaceans hatch from eggs and reach maturity in under two months.

14.
Western long-beaked echidna
Zaglossus bruijnii
CRITICALLY ENDANGERED
The "spiny anteaters" from New Guinea, Australia, and Indonesia are the only egg-laying mammals apart from the platypus.

15.
Spiny turtle
Heosemys spinosa
ENDANGERED
This Southeast Asian turtle is known for its shell's sharp edges, which can defend against predators but also smooth with age.

16.
Northern bald ibis
Geronticus eremita
ENDANGERED
Once depicted in Egyptian hieroglyphs, the regal birds are now largely confined to a migratory route between Syria and Ethiopia.



LEVELS OF THREAT

Species extinction risk, reflected on the International Union for Conservation's Red List, is based on criteria including size of population reduction, range decline, and number of mature individuals. The threatened animals in this grid are classified as follows:

VULNERABLE	ENDANGERED	CRITICALLY ENDANGERED
High risk of extinction in the wild	Very high risk of extinction in the wild	Extremely high risk of extinction in the wild


3
9
10
7
11
12
13
14
15
16

Bornean rhinoceros
Dicerorhinus sumatrensis harrissoni
CRITICALLY ENDANGERED

The Photo Ark team travels the globe to gain access to critically endangered animals like Pahu, a female Bornean rhinoceros. This smallest rhino species in the world no longer has sufficient numbers to breed in the wild, making Pahu among the rarest creatures in the Ark.

PHOTOGRAPHED AT KELIAN SUMATRAN RHINO SANCTUARY, INDONESIA



PHOTOGRAPHED AT 1. PARAGONAH, UTAH; 2. WORLD BIRD SANCTUARY, ST. LOUIS COUNTY, MISSOURI; 3. SEAWORLD, SAN DIEGO; 4. UNIVERSITY OF TASMANIA'S INSTITUTE FOR MARINE AND ANTARCTIC STUDIES, HOBART, TASMANIA; 5. PRIVATE COLLECTION, TENNESSEE; 6. SAN DIEGO ZOO; 7. SNAIL EXTINCTION PROTECTION PROGRAM, HONOLULU; 8. MANAGEMENT OF NATURE CONSERVATION, ABU DHABI; 9. NATIONAL MISSISSIPPI RIVER MUSEUM AND AQUARIUM; 10. TAMAN SAFARI PRIGEN, INDONESIA; 11. KUKRAIL GHARIAL AND TURTLE REHABILITATION CENTRE, LUCKNOW, INDIA; 12. AMPHIBIAN FOUNDATION, ATLANTA; 13. SAN LUIS NATIONAL WILDLIFE REFUGE; 14.BATU SECRET ZOO, INDONESIA; 15. ZOO ATLANTA; 16. HOUSTON ZOO



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



▲ Sartore photographed Earth's last Rabbs' fringe-limbed tree frog at the Atlanta Botanical Garden two years before it died in 2016. A projection of the portrait made it all the way to St. Peter's Basilica in Vatican City.

JOEL SARTORE

keep him busy—to keep him sane, productive—became a passion project, then a full-time occupation, then a life's calling.

Now, at 64, two decades into the work, he's thinking about how to keep it going with so much left to be done. Old species go extinct, and sometimes new ones splinter off or sprout up. Eighteen thousand photographs is a drop in a bottomless bucket. It helps, though, that the project is a global institution now. Everyone in the conservation world knows about the Photo Ark and its potency in the fight against extinction.

And every so often, the Ark shows up just in time to be a savior. Sandra Sneckenberger, a biologist with the U.S. Fish and Wildlife Service based in Vero Beach, Florida, had spent years trying to rally support for the imperiled Florida grasshopper sparrow—an ordinary brown bird from afar, she says, but "a work of art" up close. Meanwhile, the sentinel species' numbers kept dropping, at one point as low as about



75 individuals, and "just pennies were being spent. It just wasn't getting any traction." Out of desperation, she emailed Sartore. He replied within five minutes.

Over more than two decades with the Fish and Wildlife Service, Sneckenberger has worked so often with Sartore that she jokes she's the "Florida branch" of the Photo Ark. The sparrow was one of their earliest collaborations. Within a year of the shoot at Kissimmee Prairie Preserve State Park, she says, her team received more than one million dollars in funding to rescue the sparrow, and its plight even reached the cover of *Audubon* magazine. "We [are] doing captive breeding, genetics—all these things that were absolutely not possible," she says. "Without [Joel], I'm sure that there would be no Florida grasshopper sparrow."

SHORTLY AFTER the calendar turned to 2026, Sartore and the core Ark team departed for a three-week trip across Australia, from Alice Springs Desert Park in the center of the outback to a lab in Hobart, Tasmania, collecting animals at their standard sprint-against-the-clock pace. "We reached out to 135 locations," Sartore says, "and we ended up going to 36." At some stage along the way, the Photo Ark crossed another milestone—species number 18,000—but when you're moving so fast and logging so many animals, things get fuzzy. (Which creature was the landmark photo? Does it really matter?) And Sartore isn't above putting his thumb on the scale in order to lend some attention to a species whose existence might depend upon it.

And so, at some point it was decided: Photo Ark entry number 18,000 would be the critically endangered red handfish, a reef species decimated by habitat destruction. "[It] walks on the ocean floor, little bitty thing"—about three inches long—"like a frogfish or scorpion fish," Sartore says. "It's really cool-looking and cute as can be." But only about 520 remain, and many of them are at the University of Tasmania in Hobart, which is where one of them posed for Sartore, scampering along the bottom of a little plexiglass container. An image in the Photo Ark can't offer the same divine reassurance that a ride aboard Noah's ark provided. It's more like a Hail Mary—one last long shot. But he chose the red handfish because this is what survival looks like.

So much of the Ark's mission is a race to capture something before it's lost, but every now and then, Sartore's photographs represent a rediscovery, a chance at rebirth—lost but now found. Like the Lord Howe Island stick insect, a four-to-five-inch "tree lobster" native to the sheer cliff face of Ball's Pyramid, about 500 miles northeast of Sydney. Long believed extinct, the Lord Howe stick insect was miraculously rediscovered by a team of researchers in 2001 during a frightful night climb and later reintroduced to

951

WILDLIFE FACILITIES PHOTOGRAPHED

Sartore photographs his subjects at rehabs and sanctuaries in addition to zoos. Sometimes he joins researchers working in the field.

1,215

PHOTOGRAPHED SPECIES THAT ARE ENDANGERED OR EXTINCT*

Threatened creatures like the yellow-tailed woolly monkey, starry sturgeon, and Chinese pangolin occupy a special place in Sartore's archive.

*INCLUDES ANIMALS ON THE IUCN RED LIST THAT ARE ENDANGERED, CRITICALLY ENDANGERED, EXTINCT IN THE WILD, AND EXTINCT



Young grizzly bears trained for the movie industry inspect Sartore in the Los Angeles Basin during a *National Geographic* assignment in 2000.

JOEL SARTORE



the world through Sartore's camera lens. Or consider another coproduction with Sneckenberger: the Florida bonneted bat, which has thick round ears and a snout. It looks more like a bulldog than a bat. Some had feared the creature to be extinct as recently as 1979, but Sartore's photograph for the Ark, also taken this year, is visual testament of the bat's fragile resurrection.

And what about species number 19,000? Or the next major milestone, number 20,000? Sartore keeps a mental list of animals he and his colleagues often refer to as their "drop-everything" species. In other words, they'd drop everything in their lives for the opportunity to meet them in the flesh. Number two on his list: the Tonkin snub-nosed monkey, a blue-faced, puffy-lipped primate (definitely go look it up) native to northern Vietnam. And number one: the Javan rhino, found only in Indonesia's Ujung Kulon National Park on the far western tip of the island of Java.

"There's been 60 or less my entire life," he says. The Indonesian government, though, has been making noises about launching a breeding center, a development with drop-everything potential. "So we shall see. I'm patient. We're willing to wait years to get access to animals. At the Photo Ark," he says, "we play the long game."

Sartore estimates that even at his breathless pace, banking a reasonably representative sample of the Earth's animal species will take at least another 25 years. Sounds like he and Cole have their work cut out for them. □

WELCOMING CREATURES ABOARD THE ARK

Sartore sends his collaborators a how-to guide ahead of every shoot for the Photo Ark so that he can move efficiently, get the shot fast, and minimize stress on the subject. The strategies vary by species—but if it's a cat, he has probably packed Zyrtec, because he's allergic.













◀

1. For smaller animals, such as these black flying foxes at an Australian bat rescue center in Queensland, he'll use a soft table-top shooting tent.

2. His favorite subjects tend to be unheralded ones, like these baby common opossums at Cetas-IBAMA rehab center in Manaus, Brazil, scrambling around the photo tent.

3. The Photo Ark project requires plenty of flexibility, in this case capturing close-ups of a Hall's New Guinea crocodile at Pematang Siantar Zoo in Indonesia. Sartore will often spend months arranging permissions for a 15-minute photo session.

4. On certain shoots, all Sartore really needs is a solid white or black background and cooperative subjects, like these slender-tailed meerkats at the Miller Park Zoo in Bloomington, Illinois.

5. Sartore photographed monarch butterflies at Sierra Chincua in Mexico in 2010.

6. To prevent the spread of disease at a rare-pheasant center in China, Sartore (center) and son Cole (at right) had to be fumigated several times on the day of the shoot.

1. JOEL SARTORE; 2. JOEL SARTORE; 3. COLE SARTORE; 4. JOEL SARTORE WITH MATT GERBATSCH; 5. JOEL SARTORE; 6. ELAINE KIM



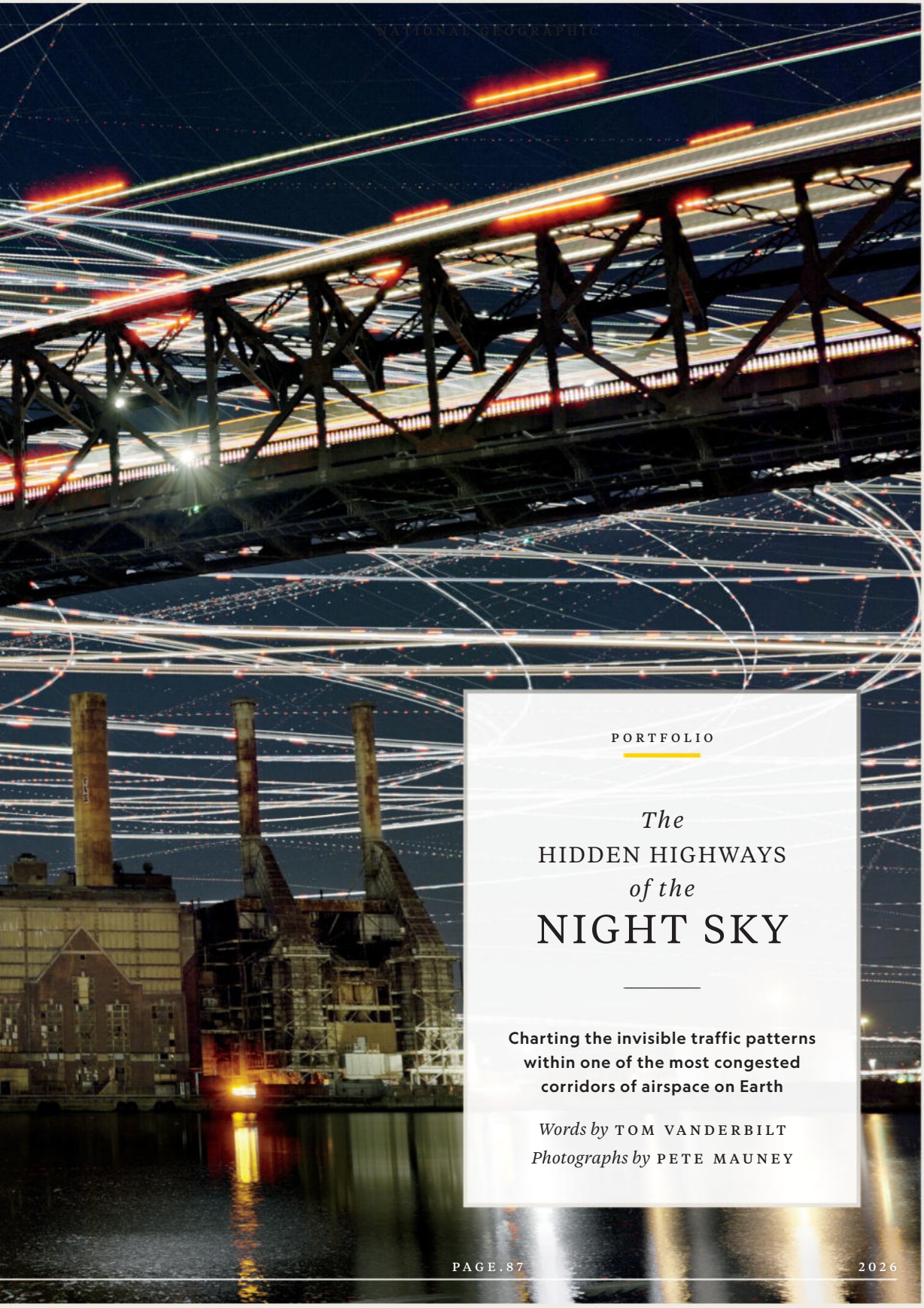


Sartore gets acquainted with white pelicans at Iowa Bird Rehabilitation. Besides visiting zoos and aquariums, he goes to wildlife rehabbers, birdbandings, bioblitzes, and more. "The whole point is to show the world what biodiversity looks like while there's still time to save it," he says.

CHRIS BUCK



Photographer Pete Mauney has spent years perfecting a technique to reveal airplane flight paths. Here, lines of air traffic cut above New Jersey's Pulaski Skyway.



PORTFOLIO

The HIDDEN HIGHWAYS *of the* NIGHT SKY

Charting the invisible traffic patterns within one of the most congested corridors of airspace on Earth

Words by TOM VANDERBILT
Photographs by PETE MAUNEY



→ **IT ALL STARTED WITH FIREFLIES.** In the early 2010s, photographer Pete Mauney was at his home along the Hudson River, in the town of Tivoli, New York, and he had a simple but frustrating goal: to make the perfect image of the lightning bugs in his backyard. In his attempt to capture their frenetic, flickering, seemingly random flights, Mauney used a process borrowed from the art of astrophotography called image stacking. It's essentially what an iPhone camera does on low-light mode when it blends a series of underexposed photographs together to negate the noise. It should have been straightforward. But as he opened his lenses to the night sky and undertook this



collaborative effort between man and firefly (“albeit with my collaborator being unaware of it,” he jokes), he faced a persistent, vexing problem: What should he do about the annoying airplanes that kept getting in his pictures?

This problem, it turned out, was also a revelation. As a teenager in Montclair,

For hours at a time, Mauney positions his cameras in places like Newark Liberty International Airport’s long-term parking lot and captures planes streaming in and out of the busy terminals.

New Jersey, Mauney would hike up the cliffs overlooking the town and watch the steady flow of airplanes coming in and out of Newark Liberty International Airport. He idly contemplated capturing the air traffic on film. "But I didn't have money or technology or really anything at that point," he says. Now, almost four decades later, with the tools and know-how, he realized he could return to that ridge and finally capture the stream of planes.

These days, planes are nearly as common in the sky as stars. After a brief dip in air travel during the pandemic, the numbers of passengers and flights have bounced back to record-setting highs, with more people than ever soaring through the clouds. At one point in July 2024, nearly 15,000 passenger planes were in the sky at once—and that's not even counting all the single-engine aircraft, helicopters, drones, military jets, and so on. But with the naked eye, we generally see just one at a time cutting through the clouds, thousands of feet overhead.

To turn this scattered, scarcely visible traffic into dramatic tracings of light, Mauney stations his camouflaged cameras on tripods in set positions for hours and captures hundreds or even thousands of exposures, later stacking the images in postproduction to create a single shot. Some images reveal traffic patterns, with bending bands from aircraft all taking the same departure route before veering toward their destinations. Others, such as those with the occasional Christmassy





Newark is the 14th busiest airport in the United States, with roughly 1,100 planes departing each day.

The long exposure time required to capture a night's worth of air traffic means Mauney's cameras occasionally pick up ground-level movement too, such as cars or these holiday lights in Carteret, New Jersey.







streaks of green, white, and red, show physical navigational tools pilots still rely on in the digital age—green lights always shine on the starboard wing, red lights on the port side, and a white taillight on the rear. Then there are the images where straight bands from arriving airplanes converge with the curved orbits of stars.

The lengthy nocturnal stretches make the work possible but also significantly trickier. While one might think airplanes would behave with a certain level of predictability and rhythm, Mauney notes that with long-exposure shots, just about anything can go wrong. To his eye, part of the appeal is that "I don't control the subject



matter," he says. Air traffic controllers may change active runways because of strong wind gusts, or a curious law enforcement officer might stop by to ask some questions about what exactly Mauney's up to. But for Mauney, it's all a worthy part of his effort "to turn what I see as chaos into some form of order." ▯

In this image of New York City, the curved lines show planes departing John F. Kennedy International Airport, while the lines cutting across the middle are planes headed for LaGuardia Airport.



For centuries, the equestrian sport of tbourida was reserved for men. Now female riders are bringing the hard-charging tradition to a new generation.

Words by
Aida Alami

Photographs by
Chantal Pinzi

THE RISE OF MOROCCO'S HORSEWOMEN



A *tbourida* performance culminates with a team of rifle-toting riders firing a single synchronized shot. Here, Noura Lebdaoui, second from left, restrains her horse after firing. Lebdaoui rides with one of Morocco's few all-female troupes, challenging perceptions of what was long considered a masculine tradition.

When Zahia Aboulait was a young girl, she loved nothing more than tagging along

with her father to the rural Moroccan festivals called *moussems,* watching him perform with his *tbourida* troupe. Tbourida, a centuries-old equestrian tradition, is a spectator sport that finds teams of riders making a faux cavalry charge across a dirt track, leading their horses with taut, synchronized precision. The cavalcade ends when the riders—acting in unison, their horses at a gallop—raise a set of antique-style rifles and together fire a single thundering volley. The practice takes its name from the Arabic word for "gunpowder," and although it's performed elsewhere in North Africa, it is particularly beloved in Morocco. Aboulait's father was a farmer who rode in a troupe as a hobby, and Aboulait, who rarely missed a moussem, loved every part of it: the smell of the horses, the crack of the muskets, the flowing and finely embroidered robes of the men.

Back then, tbourida riders were almost exclusively men. But one day in 1999, a rider in her father's troupe didn't show up, and Aboulait, then 14 years old, asked to take his place. She'd been riding horses since she was six, and watching and learning tbourida about as long. Her father, who encouraged his daughter's passion, didn't see a problem letting her ride. He lent her one of his long traditional robes, called a djellaba, and she wore it over her sweatpants and sneakers. When she pushed her luck further and asked for a gun, he gave her one and showed her how to load the black powder (no bullets). What Aboulait remembers about riding that day is how people in the crowd, who'd likely never seen a female rider, took photos of her by the hundreds.

In the 27 years since, women have gained a foothold in tbourida. These days, Aboulait is one of her country's best known female riders, the leader of her own all-women troupe—one of no more than a dozen found across Morocco out of perhaps a thousand total troupes—and part of a small circle of veteran women who've helped change minds about what the tradition can look like. Now, even as tbourida videos surge on social media, putting the sport in front of new global audiences, Aboulait finds herself transitioning from a pioneer to a mentor, training the next generation of young women to carry on a custom with deep historical roots.

Tbourida has been practiced in Morocco since at least the 16th century, evolving from a military exercise into a sport that blends the equestrian customs of the country's Arab and Indigenous Amazigh populations. Recognized by UNESCO as a vital piece of intangible cultural heritage, it's sometimes known as fantasia, an exoticizing nickname bestowed by the 19th-century French and largely derided in Morocco. Participants, both human and equine, typically don elaborate traditional garb, and riders carry slender, muzzle-loading rifles that evoke an earlier era. Any given performance lasts only a few

Tbourida dates to the 16th century, and today's riders honor the heritage with traditional attire that often includes antique-style North African Arab swords.







‘It’s a tradition, a heritage that we have to preserve.’
—Ghita Jhiate

Ghita Jhiate clutches the reins of her horse, Zher, while bathing him before a tbourida performance. Stallions are typically used in the sport. For the past two years, Jhiate and Zher have ridden in a troupe, or *sorba,* led by Zahia Aboulait, one of the first riders to form an all-women tbourida troupe in the mid-2000s.



Women's sorbas began forming in Morocco roughly 20 years ago, and today the original female tbourida riders find themselves mentoring a new generation. In the capital, Rabat, many riders in Bouchra Nabata's sorba were too young to mount a horse when she founded her troupe in 2007. Current members include (clockwise from bottom left) Doha Naji, Hiba Essallak, Marwa Essallak, Marwa Elmaite, Ikhlass Guemiri, Laila Nabata, and Mahjouba Nabata (in orange).





seconds, a barrage of hoofbeats and anticipation building toward that one perfect salvo. When the synchronicity of horses, riders, and rifles is perfect, the crowd erupts. Troupes are judged on their precision, pageantry, and horsemanship.

For centuries, says Rutgers University sociologist Zakia Salime, tbourida was considered "a masculine performance," an exhibition of warrior skills from which women were traditionally excluded. The first women's tbourida troupes, Salime says, began forming in the mid-2000s. The shift was what she calls "a quiet revolution," not the result of protest or agitation. Nor was it precipitated by any one change to rules or policy, says University of Nebraska-Lincoln anthropologist Gwyneth Talley, a National Geographic Explorer who has studied women's tbourida troupes. The emergence of women riders did coincide, Talley points out, with a campaign by the first female president of Morocco's national equestrian foundation, a member of the country's royal family, to champion women's participation in equestrian sports.

Aboulait kept riding with her father's troupe, called a *sorba,* until she was in her 20s. But she was still a teenager when she founded a sorba of her own, made up of women riders (troupes with both men and women remain rare). They encountered little outright resistance, Aboulait says, and though the occasional male rider can be hostile, many are supportive and courteous, offering to lend rifles or allow her sorba to ride first.

Today Aboulait lives in Casablanca, where she works in business administration and raises three children. But in the summers, she travels the moussem circuit, leading a group of younger women whom she has personally picked and trained to be tbourida riders. As troupe leader, or *muqadema,* she is in charge of far more than riding at the front of the line. She's responsible for matching her riders with suitable borrowed horses when they don't have their own. She tends to the group's wardrobe and finances. She leads training and warm-up sessions, ensuring her riders learn to maneuver their horses and rifles in perfect sync.

Tbourida, Aboulait stresses, is all about discipline—and the payoff for her sorba's rigor comes in its consistently high scores. "We have a very good reputation," Aboulait says. "We must protect it."

For 26-year-old Ghita Jhiate, who's been riding alongside Aboulait for two years, the muqadema is more than just a role model—she is something like a legend. Growing up in urban Marrakech, Jhiate got to ride horses while visiting family in the countryside, but her father refused to let her take lessons when she was a teenager. That didn't stop her fascination with tbourida, which Jhiate marveled at when her family went to moussems outside the city. And although Jhiate had never seen her ride, she'd heard

NGM MAPS

stories about Zahia Aboulait, the region's first female muqadema. "And I would say, 'I want to become Zahia,' " Jhiate remembers.

In her 20s, Jhiate bought her own tbourida rifle, called a *moukahla*. She finally took riding lessons, then saved enough to buy her own horse, which she boarded outside Marrakech. She named him Zher, which means "luck."

An online acquaintance shared Aboulait's phone number, but Jhiate never worked up the courage to call. Then one day her phone buzzed, and when she looked down, she froze—it was the muqadema calling. Aboulait had heard about Jhiate through a rider they both knew. Would the young equestrian ride with Aboulait's sorba at one of Morocco's largest and most prominent festivals?

Five days later, in the middle of the night, Jhiate arrived with Zher at the Moussem Moulay Abdellah Amghar, an annual week-long event where more than a hundred tbourida teams compete before crowds of thousands. She found Aboulait waiting outside a tent she shared with the troupe. They exchanged a few words, then Jhiate went to sleep beside a group of strangers. The next day, she rode for the first time alongside her hero—and the women she now considers sisters.

Aboulait, Jhiate says, has taught her "what it means to be a rider." She admires how her muqadema balances family, career, and an infectious devotion to the sport. "When we turn around and we find Zahia happy," Jhiate says, "when we find her laughing, we are happier than her."

Aboulait has purposely kept her troupe small. Some sorbas have over two dozen riders; hers currently has fewer than a dozen. These days, she says, she meets young people whose interest in the sport seems driven by the prospect of posting pictures and videos to social media, where the short, colorful spectacle of tbourida plays well. Aboulait says she prefers troupe members who are in it for the work. Her sorba does take videos of its performances—not necessarily to post but to watch afterward, like game tape, studying what the members could improve.

Before each ride, the group washes together, the Muslim ritual cleansing called *wudu*. Then the women say a *dua,* or prayer, asking for a safe ride. It's important, Aboulait says, that they get on their horses with peaceful minds and with harmony among the riders. They wear sunscreen but not makeup, which Aboulait says would shift attention to individuals rather than the group. She mourns some of what she sees as modern erosions of the tbourida tradition. For example, she says, boys used to have to learn much more before being allowed to ride. Leaders of sorbas were expected to be ceremonious hosts in their moussem tents, providing guests with food. It's not so much that Aboulait is nostalgic, she says, as that she is simply protective of standards.

And after all these years, she doesn't think of herself as being particularly revolutionary for having helped bring women into the sport. One of the beautiful things about tbourida, Aboulait says, is that it erases differences among its participants. At moussems, a roster of a hundred troupes might include only a couple composed of women, but she feels a kinship with all of her fellow riders. Tbourida brought her and her father together. These days it is cementing bonds between her and her young protégées. "Age, social, cultural," she says. "Everybody speaks the same language." □



Left

The women of Zahia Aboulait's sorba—including Ilham Mahfoud Salam, center left, and Siham Aboulait, center right—pray for safety before each show. Tbourida is typically performed at rural fairs called *moussems,* which honor a local saint.

Below

Ikrati Talid rides in an all-women sorba based in the inland city of Marrakech. She often takes the role of lead rider, or *muqadema*.

'It makes you proud. Apart from the sporting aspect, there is something Moroccan about it, something that belongs to us.'

—Zahia Aboulait





In the Nabata family stable in Rabat, riders prepare for a training session. Male tbourida riders are more likely than women to own the horses they use, says anthropologist Gwyneth Talley, a National Geographic Explorer who's spent time with the Nabatas' sorba. Often, a muqadema must borrow horses for her riders.





Chaymae Saad Eddine, a rider with Aboulait's sorba, adjusts her reins before a performance at a moussem in the coastal town of Sidi Rahal. Horses are adorned with lavish, often hand-embroidered tack.



‘I’ve shared everything with my horse: my money, my expenses, my love, and even my moments of sadness.’

—Hind Al-Rami

Below

Hind Al-Rami, of Casablanca, formed her own all-female tbourida troupe with her sister. Al-Rami says taking part in tbourida estranged the sisters from their family, who feel women shouldn’t ride.

Right

Marwa Essallak (at left), Hiba Essallak (center), and Marwa Elmaite, who ride with Bouchra Nabata’s sorba, help fasten each other’s headscarves before a training session.






OCP
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Aboulait's troupe makes a rehearsal run at the Moussem Moulay Abdellah Amghar, one of the largest and most prestigious festivals for tbourida. Last year's moussem welcomed 130 male and three female sorbas. Troupes with a mix of men and women are rare.



Tbourida riders' antique-style rifles are loaded with black powder. Saad Eddine and Lebdaoui, from Aboulait's troupe, discharge rifles that misfired during a performance.





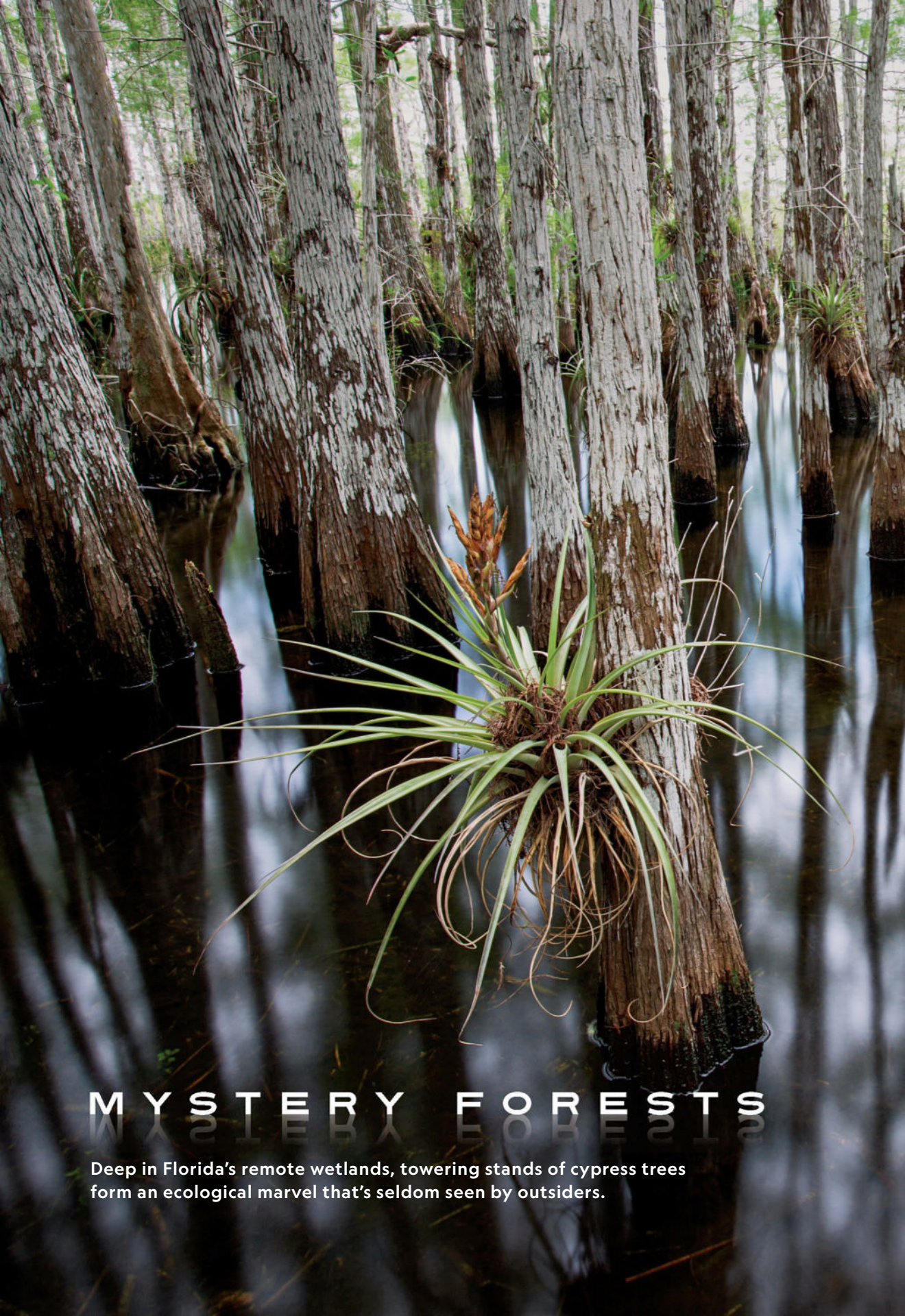


A RARE *Look at an* ELUSIVE GIANT PANDA

To capture an image of China's famous black-and-white bear, an inventive photographer first had to find one.

Photograph and words by
ROB G. GREEN

"IN CHINA, IMAGES OF giant pandas are everywhere: on road signs, backpacks, key chains, storefronts, teacups. But seeing one in the wild is notoriously difficult—even in Giant Panda National Park. Last fall, I spent three weeks in the preserve, located in central China, with two forest rangers and three fellow photographers and National Geographic Explorers. Our goal was to set up two camera traps to document any of the 30 uncollared and untagged bears believed to live in the 125-square-mile Wanglang section of the park, a mountainous area with dense bamboo and old-growth conifer forests. Perfect for bears that crave solitude. Each day, we inspected bite marks on bamboo, panda droppings, and paw prints. Following those clues, I placed one camera trap facing a narrow gap between two trees, seemingly the only path a passing panda could take. Three months later, at 2:30 a.m., the phone rang. It was Xiaodong Sun, one of my partners in China. He told me to open my email, and—*boom!*—there it was: a young panda staring me in the face." **–AS TOLD TO GORDY MEGROZ**



MYSTERY FORESTS

Deep in Florida's remote wetlands, towering stands of cypress trees form an ecological marvel that's seldom seen by outsiders.



Mini-wetlands called cypress domes, found throughout Florida, teem with life. Inside this one in Everglades National Park, *Tillandsia* air plants sprout from the trees.

OF THE MARSHLANDS

Words by MICHAEL ADNO | Photographs by MAC STONE

WHEN I FIRST SAW THEM,

rising from the horizon, the trees in the distance looked like a lime-green stadium. The towering formation represented the telltale signpost for an isolated and almost secret sort of wetland, the remnant of a 6,000-year dance still happening in South Florida. Usually seen at a distance from the road, these curious assemblages known as cypress domes mark the edges of the Everglades' central nervous system, the 50-mile-wide river that runs from Lake Okeechobee down to the southern tip of Florida. To most, they're an unknown archipelago set deep in the subtropic borderlands. Those who have entered one will tell you they're a bit spooky, otherworldly even. In March, I was hiking across rocky terrain on a trail 50 miles west of Miami called the Gator Hook. After picking my way through clusters of small trees, I ventured into the heart of a cypress dome, an ecological mystery that has haunted me for decades.

I'd known their doughnut-like shape since I was a kid, spying the domes in the distance when I traveled with my parents between Sarasota and Key West. I'd see those curious arrays of trees in the distance and wonder what they looked like inside. Later, I made my own periodic pilgrimages to the Keys. I started fishing out of the island community of Chokoloskee in the western Everglades,



From above, Florida's Big Cypress National Preserve resembles a vibrant green moonscape flecked by domes. In the centers, the water can pool so deep that cypress seeds can't take root.



learning the backcountry north of the coast, and hiking into remote strands of the watershed looking for orchids. A decade ago, I started to write about the place, spending more time there, but as familiar as I got with it, those far-off domes still seemed mystical. Now, a fire burning nearby in the Big Cypress National Preserve pushed me east to a vein of crushed limestone called Loop Road. Even in the dry season, this area can be covered in a slow-moving sheet of water, sometimes up to four feet, but with an extreme drought blanketing South Florida, I found my way much deeper into the backcountry than I'd normally be able to hike.

As I turned south toward the dome, I saw butterfly orchids and air plants perched on the trees along its rim. And as I entered the shady half-acre wetland through a break in the dwarf cypresses that mark its edge, I





Alligators can serve as surprising engineers within the cypress domes, burrowing into the muck and enlarging areas where water and fish can gather. This mother alligator guards her hatchlings under cypress roots in Everglades National Park.

was surrounded by gargantuan bald cypress trees, their bases reminiscent of ancient redwoods, littered with cyan and magenta lichen, their bark dripping with air plants just beginning to flower in delicate sprays of fuchsia, chartreuse, and lavender. I remembered then the first time I hiked alone into a dome north of the Big Cypress Reservation. That feeling of pure wonder and terror, a sensation of being watched by a panther or water moccasin. That green pool of shadows, lit up by orchids and bromeliads teeming with novelty, stayed with me, like a secret I kept.

A light rain began to fall, and the shallow pool of water in the middle of the dome, about the size of a garage, reflected the drifting clouds above. Around it, a bundle of pond apple trees swayed in the wind, and I wondered how many alligators lurked in the water. I was in another world here, inside something that felt immediately sacred. As thunder growled farther west, I was finally learning why these intricate, isolated pockets of the Everglades had always felt so mysterious to me. But soon, as I started to discover their unexpected wonders, that shapeless fascination grew into something else entirely.

In the Everglades, an area twice the size of Delaware and composed of nearly a dozen different habitats, there's a lot to find

THE MAKING OF A CYPRESS DOME

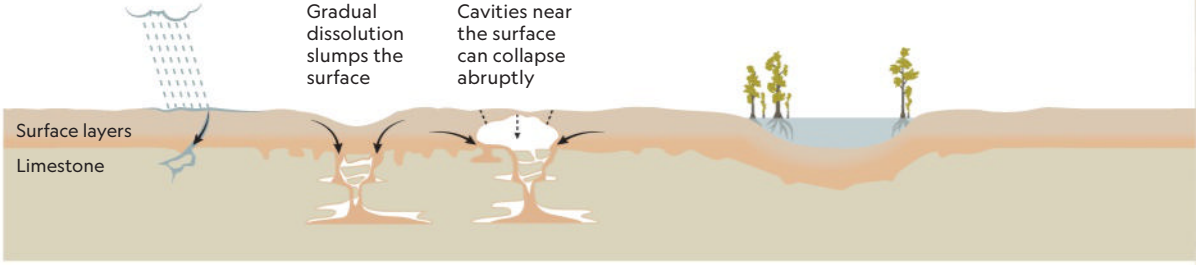
The most common type of still-water swamp in Florida today, cypress domes started forming about 6,000 years ago. Heavy logging in the early 1900s claimed many of the trees, but some that survived are now hundreds of years old. Still developing today, domes emerge in natural depressions where water collects and remains for at least 200 to 300 days a year.



1 Acidic water percolates through the ground.

2 The limestone bedrock dissolves, and sediment settles into the newly created spaces.

3 Either gradually or abruptly, a depression appears. Water pools, and cypresses sprout.

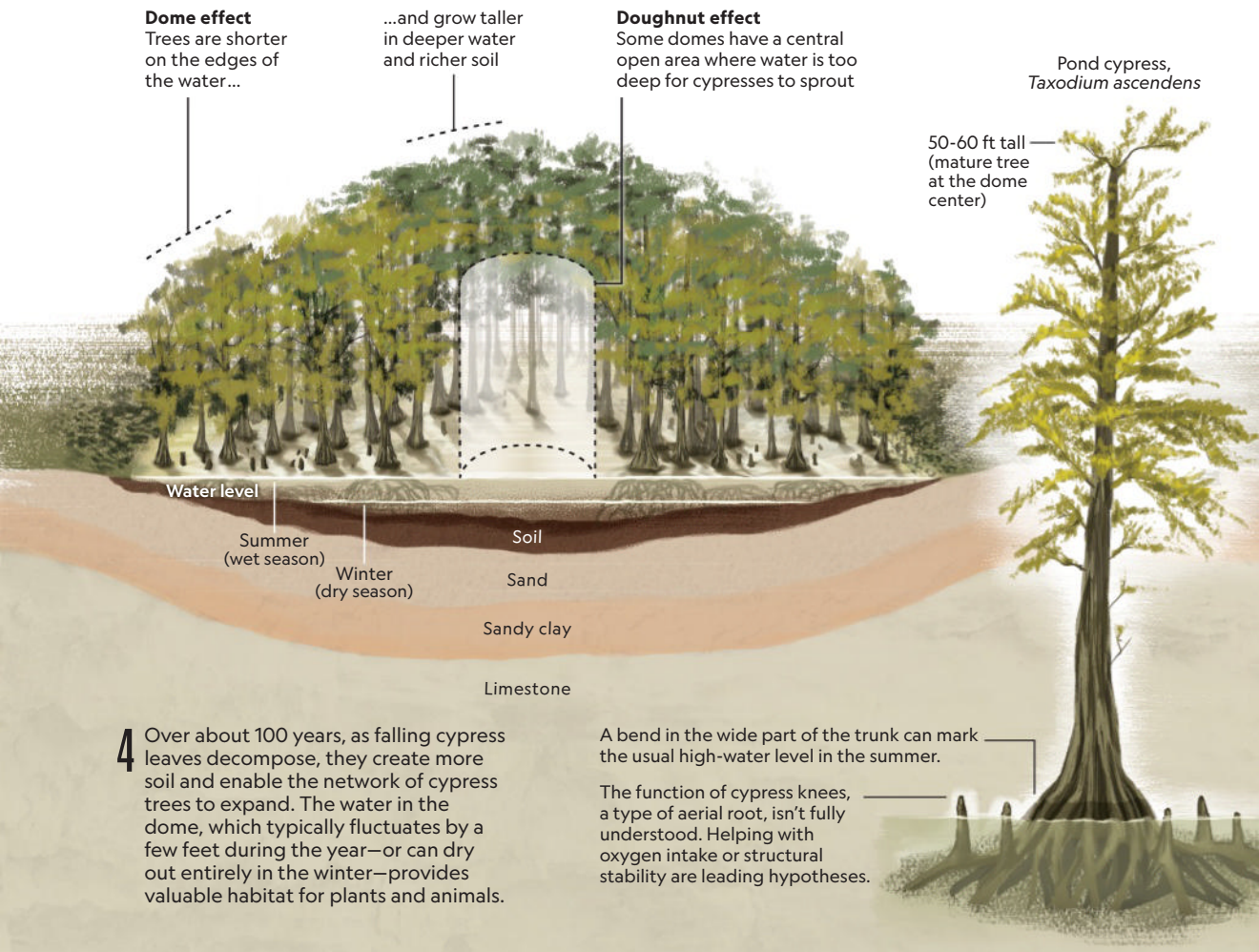


DIANA MARQUES, CHRISTINE FELLENZ, AND BRAD SCRIBER, NGM STAFF
SOURCES: CORTNEY CAMERON, UNIVERSITY OF ESSEX; U.S. FOREST SERVICE; USDA LANDFIRE

awe-inspiring. There are prehistoric fish that have traversed its borders for thousands of years, mostly unchanged by time. Spellbinding orchids named after ghosts and cigars. It's one of the few places where alligators coexist with crocodiles. Cypress domes, on the other hand, rarely garner the same fanfare, research, or protections as other elements in the watershed.

But in recent years, a host of revelations about the domes have clarified their significance. They play important physical, biological, and chemical roles, and provide a haven for endangered species. Although domes appear across parts of the American Southeast, they're heavily concentrated in South Florida. More than their larger counterparts, these "little no-name wetlands [are] orders of magnitude more important" ecologically, says Matt Cohen, an ecohydrologist and the director of the University of Florida's Water Institute. About 6,000 years ago, after the seawater that once covered South Florida had finally retreated, the Everglades ecosystem started to take shape. Not long before, the first signs of the cypress tree appeared.

The name comes from the ancient origin myth of Cyparissus, the boy who accidentally killed a tame stag and who in his grief was transformed into a cypress. The tale made



4 Over about 100 years, as falling cypress leaves decompose, they create more soil and enable the network of cypress trees to expand. The water in the dome, which typically fluctuates by a few feet during the year—or can dry out entirely in the winter—provides valuable habitat for plants and animals.





Cypress domes, such as this one in Cypress Creek Natural Area some 80 miles north of Miami, dot the horizon with their parabola-like outlines—a reflection of how the trees grow tallest in the middle where the soil is deepest. Fire can eliminate smaller cypresses around the edges, maintaining the domes' distinctive shape.

From top

Domes act like a sponge on the landscape, capturing floodwaters and other runoff. Aquatic vegetation—seen here inside a dome in Everglades National Park—helps filter sediment, nitrogen, and phosphorus from the water before it drains into the Biscayne aquifer, which provides drinking water for over five million people in southern Florida.

When water levels reach their peak at the height of wet season in August and September, fish such as the Florida gar can appear inside the domes.







the trees into a symbol of mourning and immortality—which is fitting considering that they're among the oldest living trees on the planet. Today the oldest surviving cypresses in the Southeast are thought to date back at least 2,000 years.

The Timucua people used cypresses to make dugout canoes, and the Seminole and Miccosukee have built their houses with them. Valued for its heartwood, the tree was harvested so voraciously by the lumber industry that by the early 20th century, most of Florida's old-growth stands of cypress had vanished.

Cohen, who has studied these wetlands for over two decades, told me that as the seasons passed and the rains came and went, a long interplay between the trees and the ground began. The leaves shed by the cypress trees decomposed in the water, generating carbonic acid that gnawed away at the limestone, creating more and more soil. Eventually, that depression in the bedrock held more water throughout the winter, enabling the trees to flourish as critters like alligators and wading birds found more habitat as well as forage during dry stretches. That continued for hundreds and then thousands of years until those once nascent cypress trees morphed into dense circular stands along the edges of a pool that can grow too deep for the trees to regenerate. From above, they can look like pockmarked canopies or neon doughnuts, but in profile, they reveal a rising and falling shape of taller, typically more mature trees closest to the center that precipitously drop back to dwarf trees along the rim.

"The cypress domes are self-creating," Cohen said. "How often do you get to really think about this notion that an ecosystem is its own engineer?" These ecological oddities have become a sign of how the natural world adapts: The domes in South Florida are products of the depressions in the bedrock that held water in the dry season, and can also be a product of the American alligator, which searches out these sinks in the dry season, excavating the soil further and in turn becoming a collaborative engineer of the Everglades.

Cohen explained how the trees toward the center of cypress domes grew larger by excavating a pool with the "rocket fuel" that the falling leaves and resulting acid produced in the standing water—etching a deeper depression in the limestone over time, collecting more water and soil. I learned how that process then created richer and deeper soil, and how the farther you traveled out from the center, the soil lost nutrition and depth, hence the smaller trees. The periodic fires that tore through parts of the Everglades, like the Big Cypress blaze in March, decimated the trees along the domes' borders, helping to mold their spherical shape. I learned how the same curves I saw above ground were echoed below in the soil and the erosion of the karst bedrock in a parabolic reflection.



In Big Cypress National Preserve, gators congregate in a cypress strand, a close relative to a dome. Both types of wetlands attract wildlife during dry season. But strands, unlike their smaller, circular counterparts, function more like a river.





Cypress domes harbor more than 300 plant species, including orchids, air plants, ferns, and Everglades daisies, seen here blooming inside a dome in Everglades National Park in springtime, before the canopy has filled with leaves.

Small depressional wetlands like these are, said Cohen, an "incredible mosaic of habitats on the landscape," where roughly one-third of Florida's critically endangered creatures live at some point in their life cycles. They are sanctuaries for salamanders and frogs, key components of the food chain, and serve as way stations for migratory birds that toggle between North and South America: one of the few places where you'll see a kettle of swallow-tailed kites in spring and fall. When you enter the emerald-tinged shadows of a dome, the plants inside can be very different from those in other domes. "That's kind of a feature, not a bug," Cohen told me. The diversity reflects the unique ecosystem cultivated inside each one.

The domes have the crucial ability to store water, which "dramatically alters the way floodwaters move," essentially capturing heavy rainfall and runoff, and making them increasingly valuable given the rampant development in South Florida. But he noted how these areas, when protected and allowed to behave naturally, act like a sponge, storing water and exchanging it with aquifers that provide drinking water for several million people. The domes are one of the first places where nitrogen, phosphorus, and sediment are retained, neutralized, and stored. Their peat-rich soils are remarkable carbon sinks too. Protecting one acre of these stands of trees has far more significant environmental benefits than protecting a space of similar size in a larger wetland. "They're truly underappreciated," says Cortney Cameron, a scientist who has studied the unique hydrology of the domes in Florida.

And still, there are fewer regulatory safeguards for them than for other wetlands. In 2023, the Supreme Court eliminated federal protections for wetlands without a "continuous surface connection" to oceans, lakes, streams, or rivers. By some estimates, more than half of wetlands throughout the United States, once protected under the Clean Water Act of 1972, are now potentially at risk. The cypress domes protected by state laws or located in national parks such as Big Cypress or Everglades National Park remain safe, but outside of Florida, a whole host of domes can now be razed and filled, eliminating some of the region's most critical habitats. "This incremental loss of storage and habitat has consequences," Cohen said. "It's death by a thousand wounds."



In South Florida, where climate change haunts every aspect of our lives and every season in subtle and sometimes volatile ways, cypress domes are under threat due to drier winters and hotter summers. This year, researchers in Florida revealed that the trees were acclimating to climate change by becoming more efficient in their uptake of water, a possible signal of their resilience in the face of inevitable shifts to the region. The domes may be a bulwark against the crisis, not only because of their carbon storage but also because in the dry season, they become an oasis: a buffet for wading birds feasting on fish trapped in their pools, a refuge for the hundreds of plants they support, and a haven for the alligators that can help create them and that depend on them for habitat.

The more time I spent hiking into different domes in southern Florida, the more awe I felt, and my sense of why the experience seemed like entering some holy or historic place grew. The intense diversity that lends the Everglades its character, the dizzying map of different ecosystems created by that dance between water and fire, soil and bedrock, became increasingly clear. It was that wild variety that Cohen told me formed the beating heart of the Everglades—what he called "hydrological heterogeneity." I pretended to understand. But after exploring enough domes, I could see how different each one was, the catalog of air plants in one, the hallucinogenic quality of others soaked in pink lichen, the chartreuse ferns in another. Each held this primordial feeling. The mystery of why each dome was so different only deepened that feeling.

I remembered the canopy of some lit up with raptors or wading birds, the sound of owls in others, the amber columns of light shaped by the green tendrils of the trees and the tannic water colored by their leaves. I thought about the ceremony we all participate in the farther into nature we go. Out of the mist, another world seems to appear, or rather, our world appears with clarity. Beneath a peal of thunder and the wildfire burning farther west, I stood inside that dome off Loop Road and wondered what other secrets it held. ◻

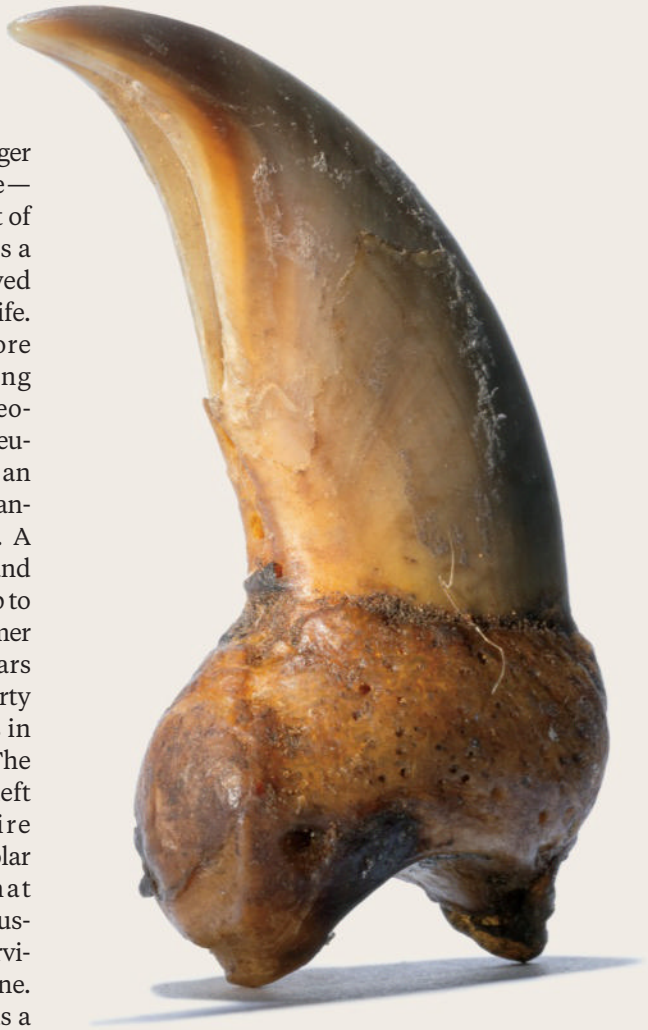
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A GRISLY TOKEN *of an*
EPIC SURVIVAL TALE

POLAR BEAR CLAW, 1884



AS LARGE as a human finger and as sharp as a needle—that's how one descendant of Adolphus Greely describes a claw from the bear that saved his great-great-granddad's life. In 1881, seven years before Greely became a founding member of the National Geographic Society, the Army lieutenant set out to establish an Arctic research station on Canada's Ellesmere Island. A steamship deposited him and two dozen men, but the ship to retrieve them the next summer never came. After two years stranded, Greely led his party south in small open boats in search of a supply cache. The paltry rations they found left the starving men in dire straits—until they shot a polar bear in April 1884. That extreme measure helped sustain Greely and six other survivors until their rescue in June. "Except for this kill," reads a timeworn label accompanying the trophy in our archives, "none of the party would have returned alive." –RACHEL SLADE

Discover this object and more at the new National Geographic Museum of Exploration in Washington, D.C. Visit *natgeo.org/moe*.

PHOTO: REBECCA HALE, NGM STAFF



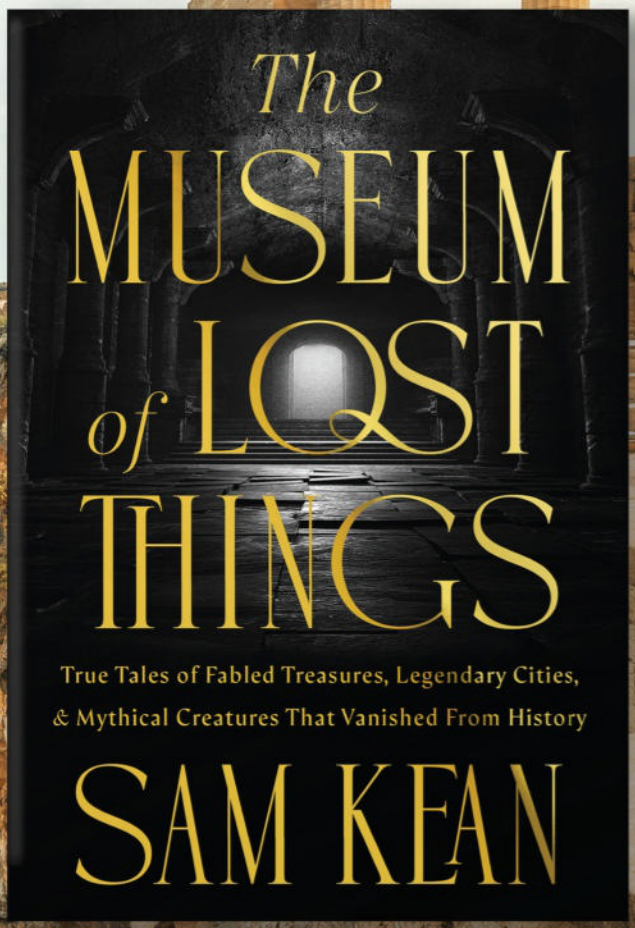
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