VOLUME 245 MAY 2024 NUMBER 05

NATIONAL GEOGRAPHIC

Secrets of the Octopus
Why these sea creatures are so much more than meets the eye
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The Flamekeepers
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Toward a new understanding of extraordinary Indigenous art
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ROLEX AND NATIONAL GEOGRAPHIC
PERPETUAL PLANET AMAZON EXPEDITION

DAWA YANGZUM SHERPA,
INTERNATIONAL
MOUNTAIN GUIDE

FRANCESCO SAURO, EXPLORER

CRISTIAN DONOSO, EXPLORER

GHISLAIN BARDOUT,
EXPLORER

WHAT DO THEY SEEK?

Explorers, adventurers, scientists. Men and women who always broadened the horizons, for all humankind to share. Rolex was at their side when they reached the deepest point in the oceans, the highest summits of the Earth, the deepest jungles and both poles. But now that we know, more than ever, that our world has its limits, why do they continue to venture out there, again and again? Certainly not for kudos, accolades, or an ephemeral record. What they truly seek is to understand more intimately how complex and delicate our planet is, to document its change and how together, we can affect it for the better. So as long as they need it, we will be at their side. Because today, the real discovery is not so much about finding new lands. It's about looking with new eyes at the marvels of our planet, rekindling our sense of wonder, and acting to preserve our pale blue dot in the universe…
Doing our very best for a Perpetual Planet.

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FROM *the* EDITOR

IN 2021, BOTH IN this magazine and on the National Geographic channel, we kicked off our *Secrets of* series—which takes a closer look at superstars of the animal kingdom. *Secrets of the Whales* brought you deep into the ocean to encounter the behaviors of these extraordinary marine mammals. Last year we showcased elephants—majestic, highly intelligent, and resilient in the face of many challenges.

This year in *Secrets of the Octopus,* we're back to the sea but with a very different creature. The first time an octopus really caught my attention was in 2008, when Otto became a news sensation. At an aquarium in Germany, he was throwing rocks at the sides of his tank and squirting water at the light above it to short-circuit the electrical system. Staff at the aquarium described Otto as "bored," and frankly, who among us wouldn't be in his situation?

Science has discovered a lot about these incredible invertebrates in recent years. They're masters of camouflage, devoted parents, and problem-solving wizards. This is just the start of what you'll learn in these pages. If our feature leaves you wanting more, be sure to check out *Secrets of the Octopus,* streaming on Disney+.

I hope you enjoy the issue.

PHOTO: MARK THIESSEN

DIRIYAH

THE CITY OF EARTH

At-Turaif,
UNESCO World Heritage Site
The birthplace of the Kingdom
A 300-year-old legacy

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WATER FROM THE CHALK
England's cherished chalk streams, clear and spring fed, have suffered from pollution, dredging, and damming. Now restoration efforts are bringing them back.

134 *NEW FROM NATIONAL GEOGRAPHIC*

ON THE COVER A male California two-spot octopus curls some of his eight arms. Octopus arms, each of which can have hundreds of suckers, are used for not only touch but also taste.
Photograph by DAVID LIITTSCHWAGER

GOD KNOWS WHO DID IT

Parental Control Advised

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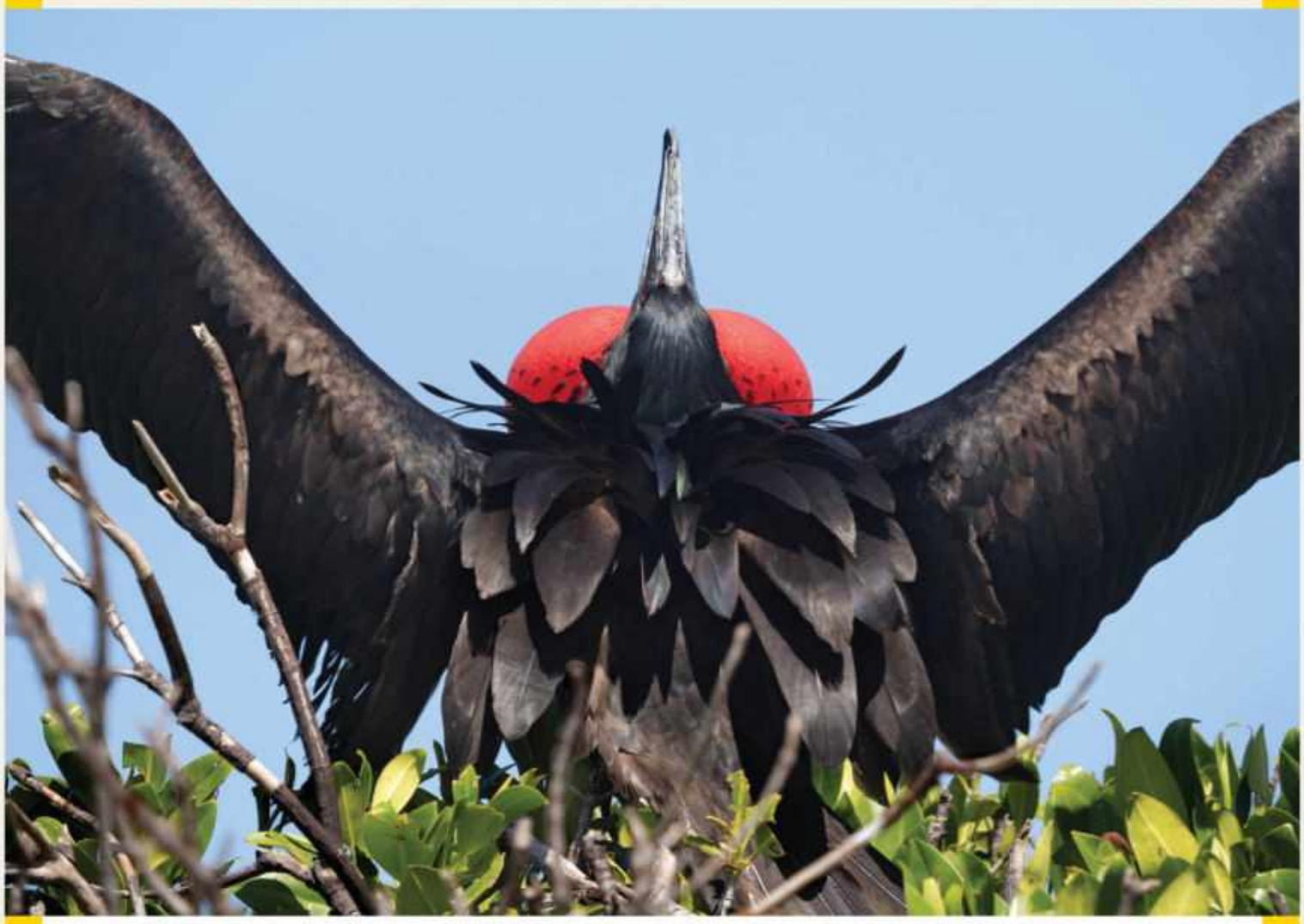
IN FOCUS

JUST IN FROM OUR PHOTOGRAPHERS



ANIMALS

"Watching these *great frigatebirds* showing off to passing females made me think of guys STRUTTING THEIR STUFF in a dance hall to attract a potential partner."

DAVID TIPLING, *Photographer*

During a mating display on Cosmoledo Atoll in the Seychelles, a male great frigatebird spreads his wings, raises his bill, and inflates his red gular pouch.

ADVENTURE

“I’ve been learning to re-embrace *time to be bored,* as it’s in these moments that my mind can REST AND WANDER through a myriad of ideas. The idea behind this image came from boredom.”

KRYSTLE WRIGHT,
Photographer

In Long Canyon near Moab, Utah, climber Angela VanWiemeersch ascends the route known as the Seventh Serpent. Wright highlighted its crack formation with LED light tape.

MAY

OCEANS

"Reefs are stunning at a distance, with a blizzard of COLORFUL FISH swarming over different shaped corals, but the closer you look, the more *beauty and life* is revealed."

ALEX MUSTARD,
Photographer

Three common ghost gobies, barely visible, perch atop a sea fan in the Molucca Sea's Lembeh Strait in North Sulawesi Province, Indonesia.

CULTURE

"As a child growing up in the U.S., I was taught to think of rocks as INANIMATE. But the Indigenous people of the Sierra Nevada consider rocks to be *as alive as animals or plants,* and they form an intrinsic part of their spiritual life."

STEPHEN FERRY, *Photographer and National Geographic Explorer*

Francisco Chaparro (at right), a spiritual authority, or mamo, of the Arhuaco people, and his apprentices collect barnacles for ritual use at a sacred site on Colombia's Caribbean coast. The image is part of a project, funded by the National Geographic Society, to study the Black Line, the perimeter of Indigenous ancestral territory.

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PHONE EMAIL

ONE UNUSUAL TEAM joining National Geographic's two-year exploration of the Amazon River Basin: scientist Ruthmery Pillco Huarcaya and her canine tracking companion. The two first set eyes on each other at an animal shelter in Cusco, a historic city perched in the Peruvian Andes. Something about this mutt reminded Pillco of herself—whippet-thin, tough, persistent. A family had already expressed interest in the dog, but Pillco won her case. With an important new job, the shelter's dog would help the cause of Amazonian conservation in Peru.

National Geographic Explorer Ruthmery Pillco Huarcaya trained her dog, Ukuku, to track elusive bears in the Peruvian Andes to further research and conservation.

"She's going to be a hero," Pillco promised. She took the dog home to her apartment, where she began teaching Ukuku—the name she chose—how to sniff out bear scat on mountain trails. *Ukuku* is a word for "bear" in Quechua, the Indigenous language of Pillco's childhood. She grew up a few hours' drive from Cusco, in a village where storytelling gives special power to the black Andean bear, the animal Pillco now studies as a field biologist for the Peruvian nonprofit Conservación Amazónica ACCA and as part of the National Geographic and Rolex Perpetual Planet Amazon Expedition.

The research project, involving more than a dozen scientists, includes the river's high mountain origins, where cloud moisture and droplets of melting snow form the very beginnings of the world's greatest freshwater river system. The Andean bears' role in this elaborate ecosystem is crucial, Pillco believes. Because they eat seeds in the lowlands and climb long distances to defecate in the mountains, they're helping preserve forests by dispersing tree seeds at cooler, higher altitudes as the climate warms.

Pillco knew a tracking dog would be vital, and by the time she moved into her mountainside field station and lab last year, Ukuku was well on the way to fulfilling her job description: Andean bear tracker, on call 24/7. When the station alarm sounds, signaling that a camera trap has captured a bear for temporary collaring and study, usually the first beings on the trail—day or night—are the Quechua biologist and her beloved *perrita valiente,* her brave little dog. **–CYNTHIA GORNEY**

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

This article was supported by Rolex, which is partnering with the National Geographic Society on science-based expeditions to explore, study, and document change in the planet's unique regions.

PHOTO: THOMAS PESCHAK

Nichole Sobecki, p.108

This Nairobi-based photographer focuses on links between nature and people, such as the future of lemurs in Madagascar. An Explorer since 2021, she covered cheetah trafficking for us that year.

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.

Stephen Alvarez, p.84

Alvarez's latest feature builds on his work as founder of the Ancient Art Archive, which preserves and shares humanity's oldest stories. An Explorer since 2018, he shot his first *Nat Geo* article in 1995.

Charlie Hamilton James, p.116

Born in Kent, England, Hamilton James has long been an admirer of chalk streams. An Explorer since 2014, he has photographed more than a dozen *National Geographic* features.

Matthieu Paley, p.54

Paley, an Explorer since 2019, specializes in photographing little-known communities, including Zoroastrians. Much of his coverage spotlights the people and peaks of the western Himalaya.

David Liittschwager, p.16

An Explorer since 2018, he has made seven books of photography and dozens of museum exhibitions on natural history. This month's article on octopuses is his 18th for the magazine.

Sy Montgomery, p.16

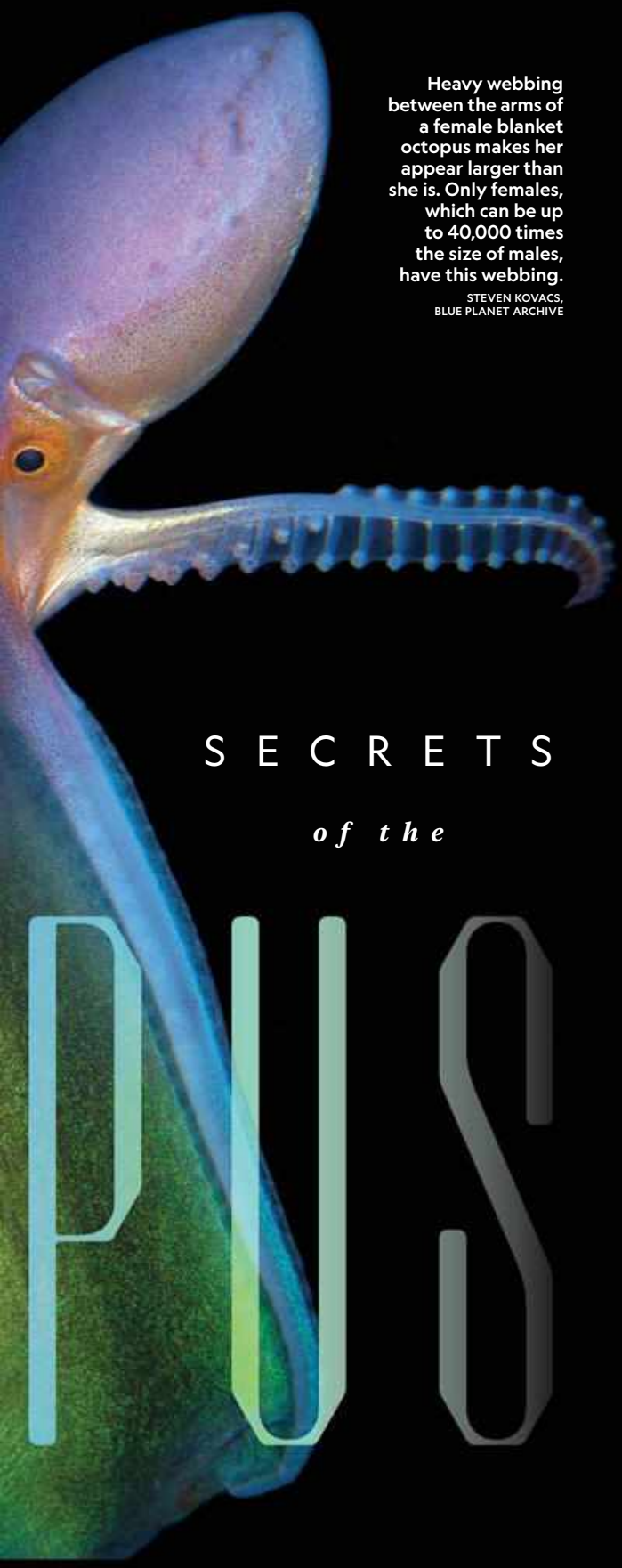
Researching articles, scripts, and books, she's been to the Amazon, Borneo, and Papua New Guinea. Her bestseller *The Soul of an Octopus* was a National Book Award finalist, and her book *Secrets of the Octopus* pairs with a new Nat Geo TV series of the same name.

Kate Nelson, p.84

A Tlingit tribal member, she's a 2024 40 Under 40 honoree of the National Center for American Indian Enterprise Development. Her stories often amplify Indigenous voices and topics, such as this issue's feature on ancient art created by Native Americans.

PHOTOS (FROM TOP, LEFT TO RIGHT): ROG AND BEE WALKER; STEPHEN ALVAREZ; JO CHARLESWORTH; MAREILE PALEY; SUZIE RASHKIS; JEANNE URDA; KATE NELSON

MASTER OF DISGUISE, CUNNING ESCAPE ARTIST, SELFLESS PARENT: THE OCTOPUS IS AN EXTRAORDINARY CREATURE.



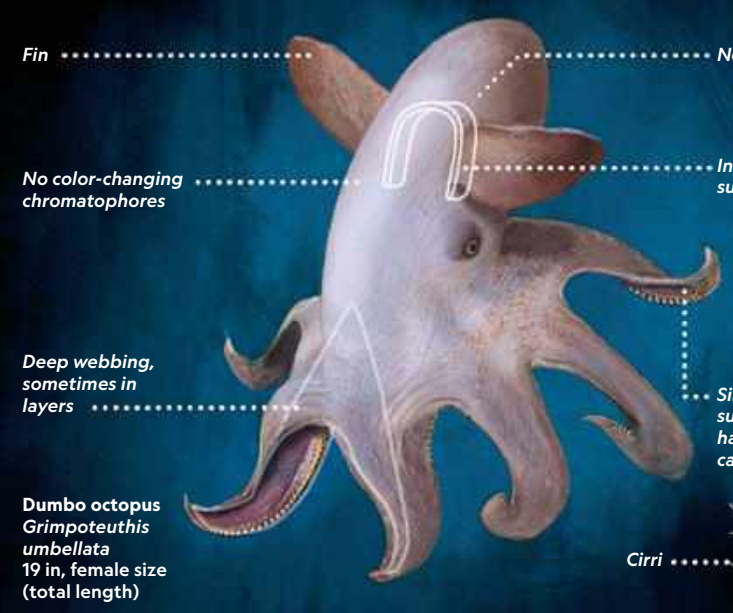
Heavy webbing between the arms of a female blanket octopus makes her appear larger than she is. Only females, which can be up to 40,000 times the size of males, have this webbing.

STEVEN KOVACS, BLUE PLANET ARCHIVE

SECRETS *of the* OCTOPUS

OCTOPUS SUPERPOWERS

Graphic by FERNANDO G. BAPTISTA *and* LAWSON PARKER



Dumbo octopus
Grimpoteuthis umbellata
19 in, female size (total length)

Suborder Cirrata

Elusive and difficult to study, many of these octopuses can be found at depths reaching 23,000 feet.

45 species

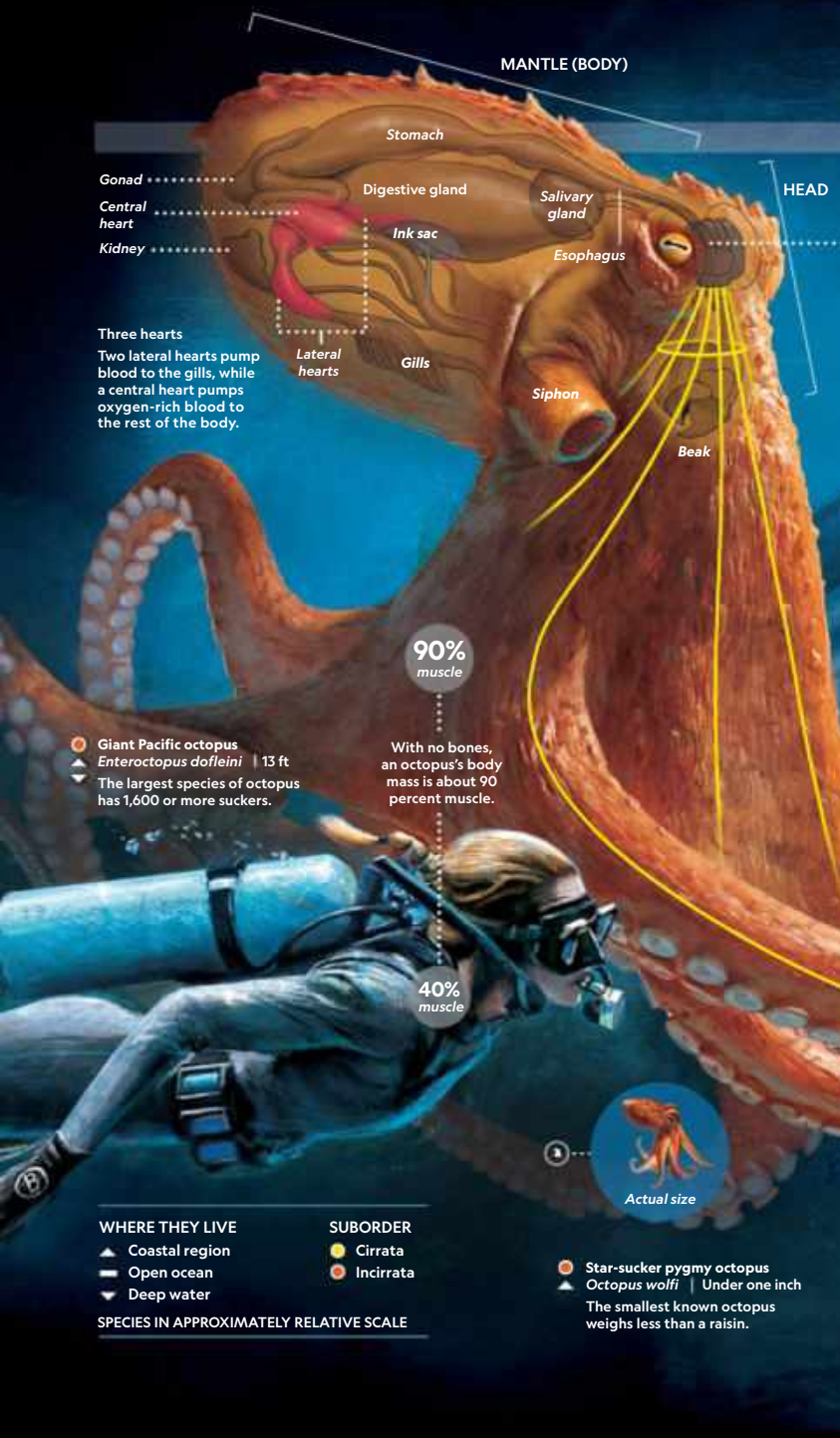
OCTO

MEASURING UP

There is no perfect way to gauge intelligence, but neurons are a proxy for neurological complexity.

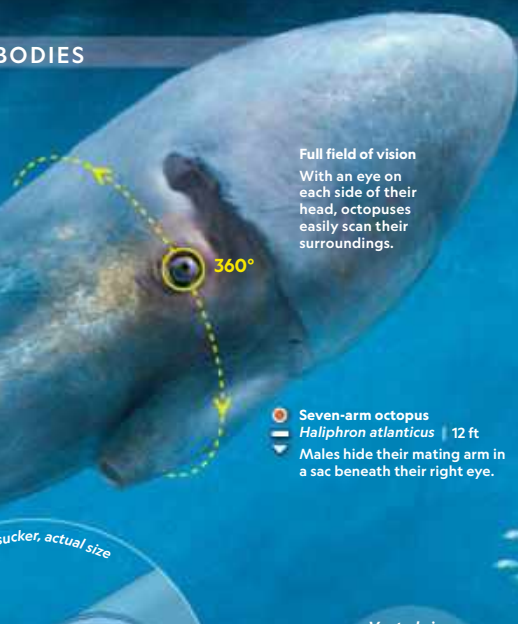
millions of neurons	Zebrafish	Mouse	Ferret
	0.1	71	404

SECRETS OF THEIR BODIES



Three hearts
Two lateral hearts pump blood to the gills, while a central heart pumps oxygen-rich blood to the rest of the body.

Big brained
Their brain-to-body ratio is the largest of any invertebrate. The beak breaks food into small pieces, as the brain constricts the esophagus.



Full field of vision
With an eye on each side of their head, octopuses easily scan their surroundings.

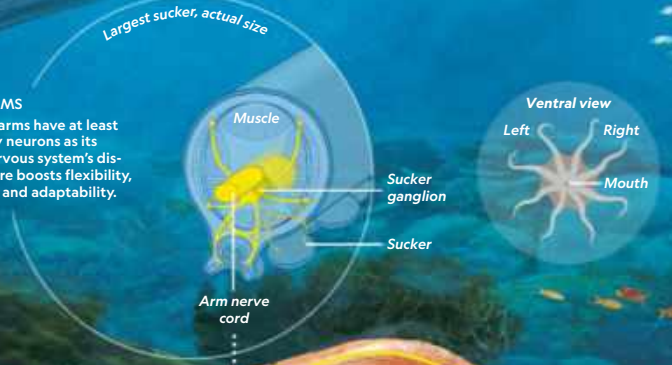
Seven-arm octopus
Haliphron atlanticus | 12 ft
Males hide their mating arm in a sac beneath their right eye.

Giant Pacific octopus
Enteroctopus dofleini | 13 ft
The largest species of octopus has 1,600 or more suckers.

With no bones, an octopus's body mass is about 90 percent muscle.

Star-sucker pygmy octopus
Octopus wolfi | Under one inch
The smallest known octopus weighs less than a raisin.

SMARTER ARMS
An octopus's arms have at least twice as many neurons as its brain. The nervous system's distributed nature boosts flexibility, coordination, and adaptability.



Greater argonaut
Argonauta argo | 12 in
Females make a shell to carry incubating eggs.

WHERE THEY LIVE
- Coastal region
- Open ocean
- Deep water

SUBORDER
- Cirrata
- Incirrata

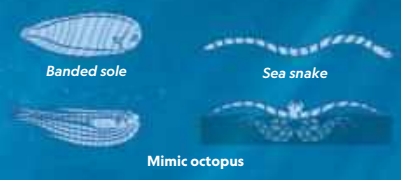
SPECIES IN APPROXIMATELY RELATIVE SCALE

SECRETS OF THEIR DEFENSES

SHAPE-SHIFTING

In fractions of a second they can change their look and movements to resemble animals that predators avoid, buying time to flee.

Mimic octopus
Thaumoctopus mimicus | 19 in
This disguise artist transforms both its look and movements.



Glass octopus
Vitreledonella richardi | 18 in
It's a translucent, luminescent deepwater dweller.

GLOWING IN THE DARK

There are a few known cases of transparency and bioluminescence in octopuses. Glowing is thought to attract prey and mates.

Blanket octopus
Tremoctopus violaceus
This species is an extreme example of size difference between the sexes.

Female 39 in

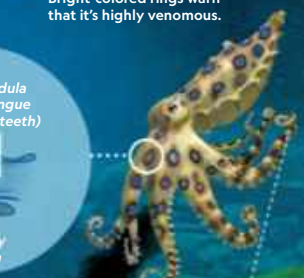
Male 1 in

COLOR CHANGING

They can change the color, pattern, and texture of their skin to match their surroundings in the time it takes a human to blink.

TOOL USE

Smaller blanket octopuses carry venomous jellyfish tentacles to outwit and sting predators.



Greater blue-ringed octopus
Hapalochlaena lunulata | 4.5 in
Bright-colored rings warn that it's highly venomous.

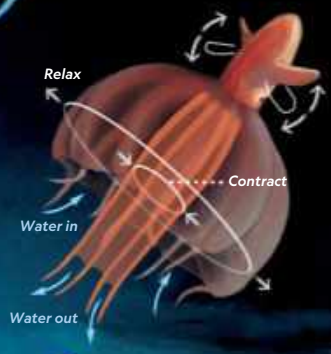
VENOM AND INK

Venom of varying toxicity levels can paralyze prey and aid digestion; ink can be shot into water to confuse predators.

SECRETS OF THEIR MOVES

JET PROPELLING

An octopus takes in water through mantle openings, then expels it via a narrow siphon—propelling itself in the opposite direction.



Glowing sucker octopus
Stauroteuthis syrtensis | 20 in
It leverages deep webs, as jellyfish do, for swimming.

WALKING AND CRAWLING

Quick to tire (one heart even stops during swimming), they crawl on the seafloor, which preserves energy. A few species walk on two arms.

A specialized tip, usually on the male's third right arm, delivers sperm.

LIFE CYCLE

A male transfers sperm to a female's oviduct through openings in her mantle.

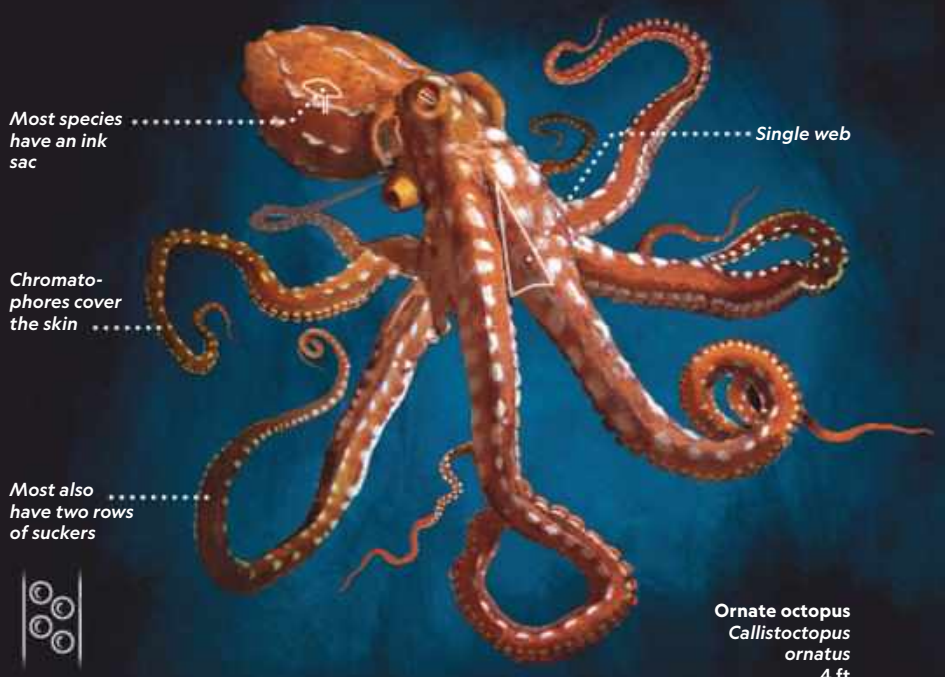
Over days and weeks, the female can lay thousands of eggs. She strings chains of them in a den and cares for them.

She never leaves her eggs, even to eat. Exhausted and depleted, most octopuses die once their brood has hatched.

TEXT: EVE CONANT, NGM STAFF

SOURCE: JANET VOIGHT, FIELD MUSEUM OF NATURAL HISTORY

In Earth's oceans, from coastal waters to extreme depths, some 300 known species of octopus thrive. The earliest ancestors of today's cephalopods appeared about 530 million years ago, uniquely evolving into highly intelligent creatures with complex behaviors and skills.



Ornate octopus
Callistoctopus ornatus
4 ft

Suborder Incirrata

It contains the majority of known octopus species, most of which live in coastal areas.

255 species

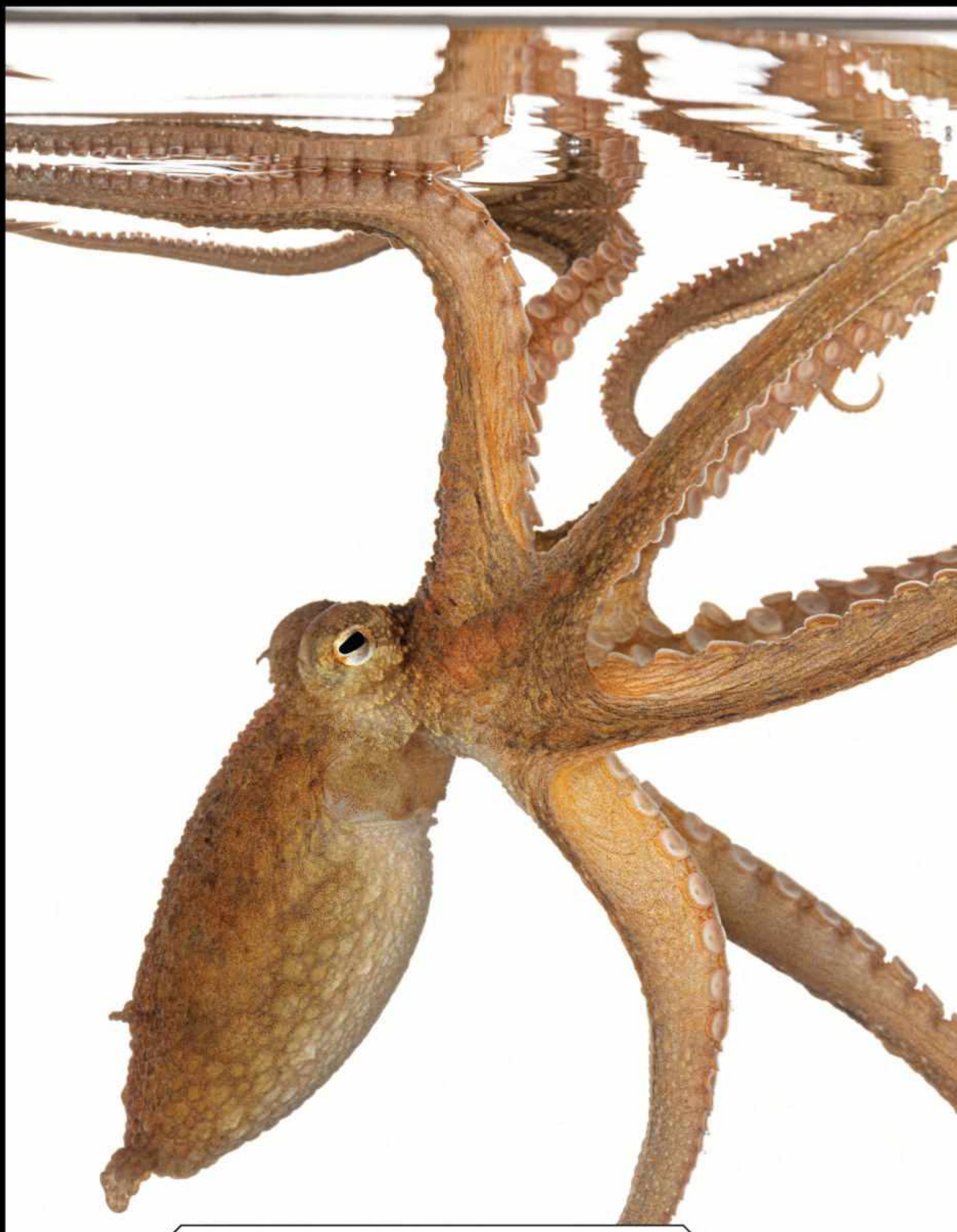
P O D A

Counts are estimates for the brain; the octopus count is for its body's highly distributed nervous system.

A day octopus hunts in the shallows among the Comoro Islands in the Indian Ocean off the coast of Africa. Octopuses are abundant in shallow, tropical waters.

GABRIEL BARATHIEU, MINDEN PICTURES


NATIONAL GEOGRAPHIC'S EMMY
AWARD-WINNING SERIES
IS BACK WITH *SECRETS OF*
THE OCTOPUS, FEATURING MARINE
BIOLOGIST ALEX SCHNELL.
THE THREE EPISODES ARE
STREAMING APRIL 22
on
Disney+
and
HULU



QUICK CAMOUFLAGE

The brain sends neural signals to special pigment-filled sacs and muscle bundles in the skin to instantly change the octopus's color, pattern, and texture to blend into its surroundings, such as plants, rocks, or corals.

A FRESH PERSPECTIVE

New research is changing the way we see these clever, adaptable cephalopods.

Words by RACHEL FOBAR
Photographs by DAVID LIITTSCHWAGER

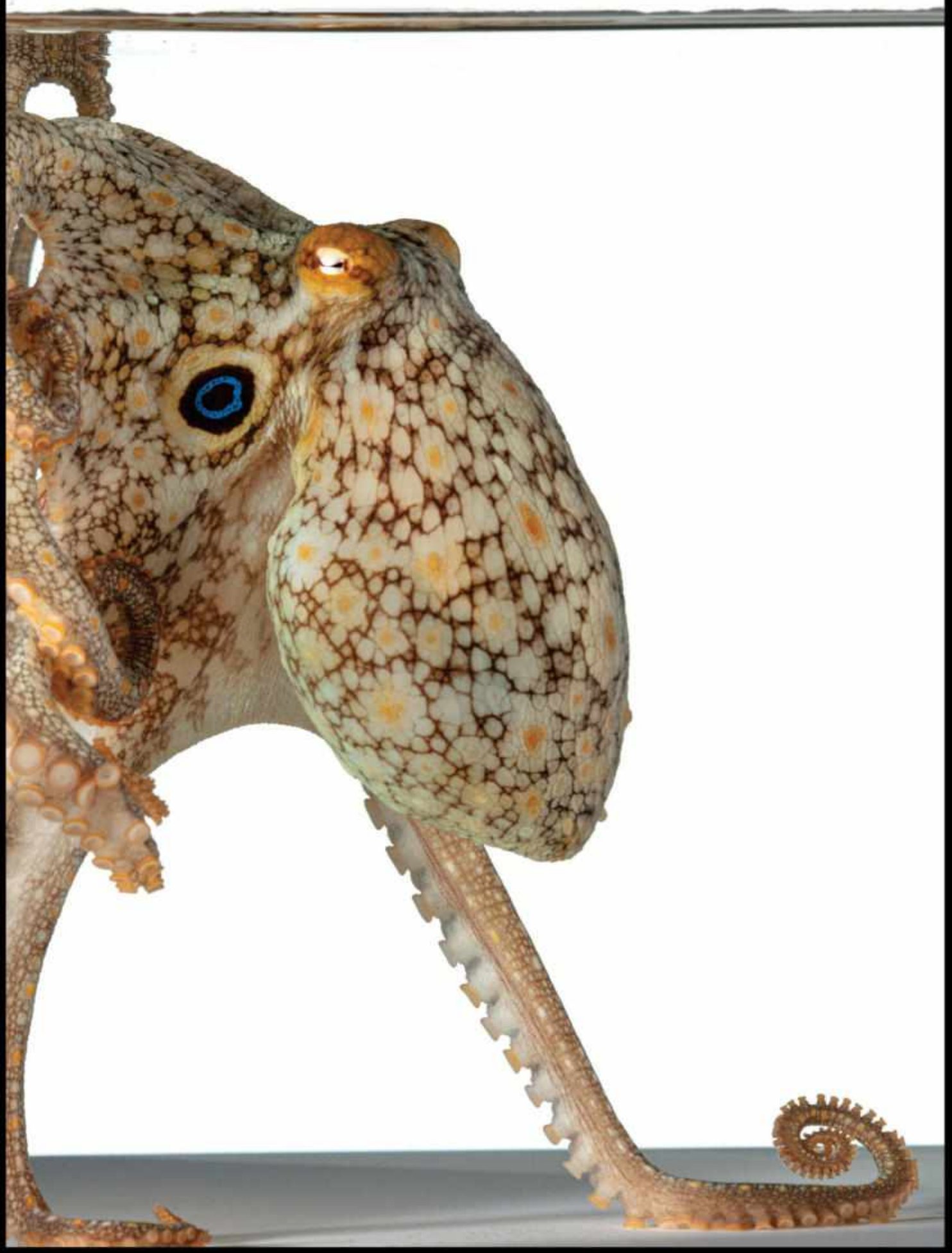
WITH THEIR BULBOUS MANTLES, squirming arms, and clouds of ink, it's no wonder that octopuses—from the kraken to Ursula in *The Little Mermaid*—have inspired folklore for centuries. But in reality, these cephalopods are smart, curious, and full of personality. For these images, photographer David Liittschwager spent weeks at Roger Hanlon's laboratory in Woods Hole, Massachusetts, and at Anna Di Cosmo's laboratory at the University of Naples Federico II in Italy, where he documented octopuses changing the color and texture of their skin, choosing meals, and exploring their tanks. He learned their skin is sensitive to light, and they can taste and "smell" with their eight arms, which can have hundreds of suckers each. "Can you imagine what that might be like," he asks, "to have skin that can see and 1,600 tongues and noses?" Researching the roughly 300 octopus species offers benefits from understanding the evolutionary origins of the human brain to imagining an alien form of intelligence.

OODLES OF OFFSPRING

Around 50 hatchling California two-spot octopuses swim in a beaker. Females typically produce 300 eggs and tend them for a month or so before dying. Most two-spot octopuses live for about a year.

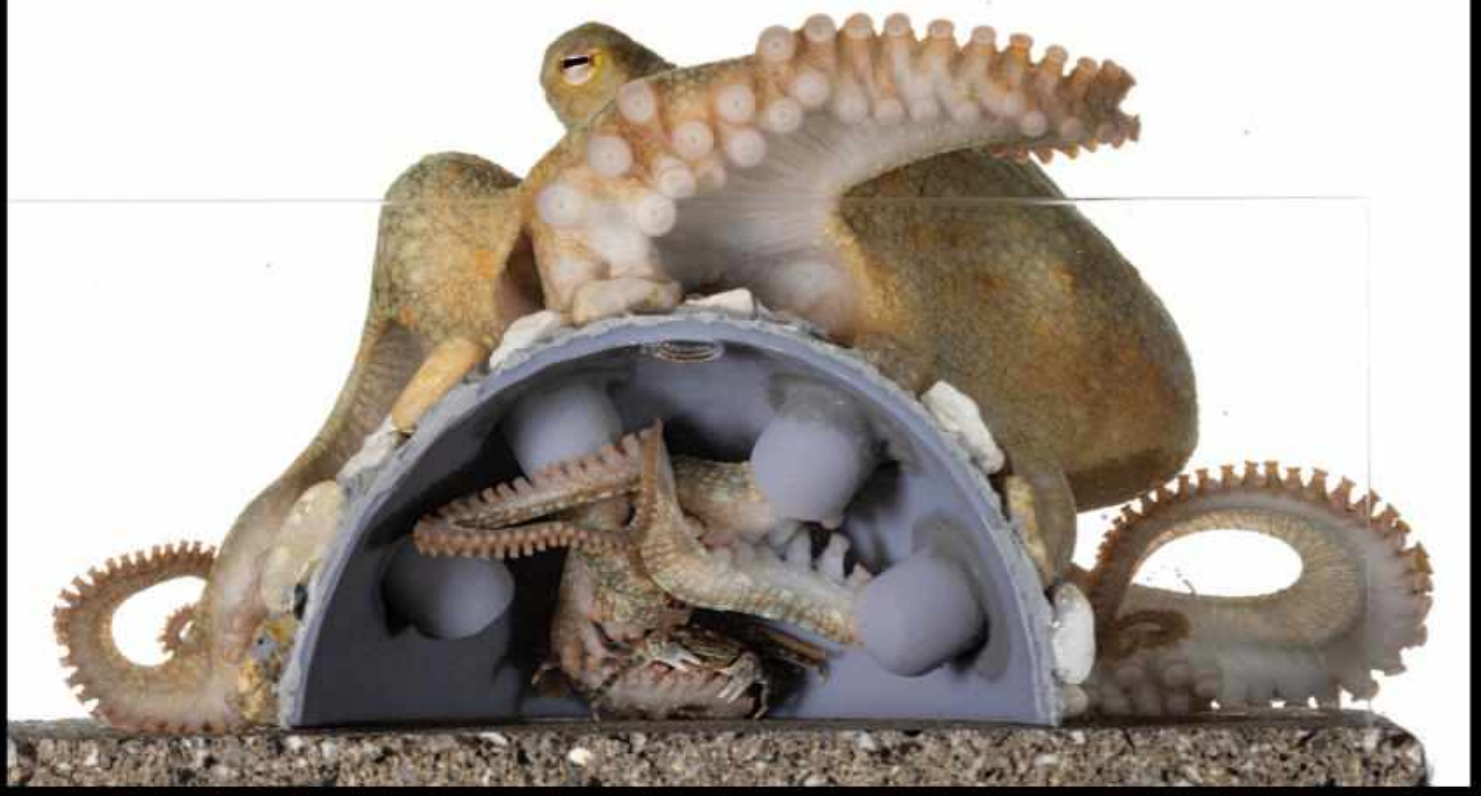
HIGH-RES VISION

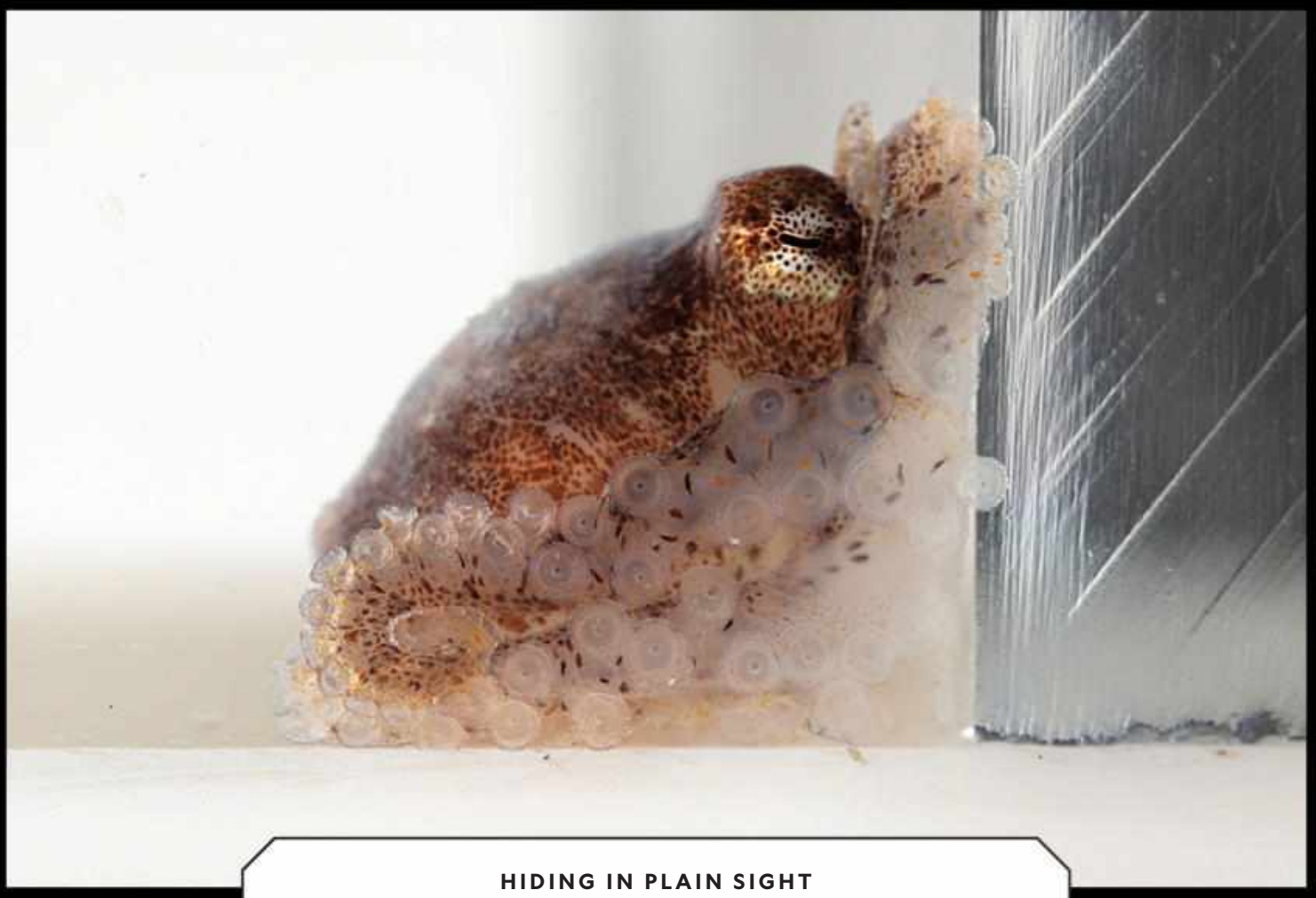
Cephalopods, like humans, have camera-like eyes that focus light with a lens. The two-spot octopus gets its name from the ocelli, or iridescent blue spots, which are false eyes to startle predators that approach closely; the real eyes are above them.



DETECTING DINNER

Scientists hid a crab to see whether the octopus could locate prey without seeing it. Guided by chemical and touch receptors in its suckers, the octopus was able to find the crab and draw it out of the dome to get its meal.



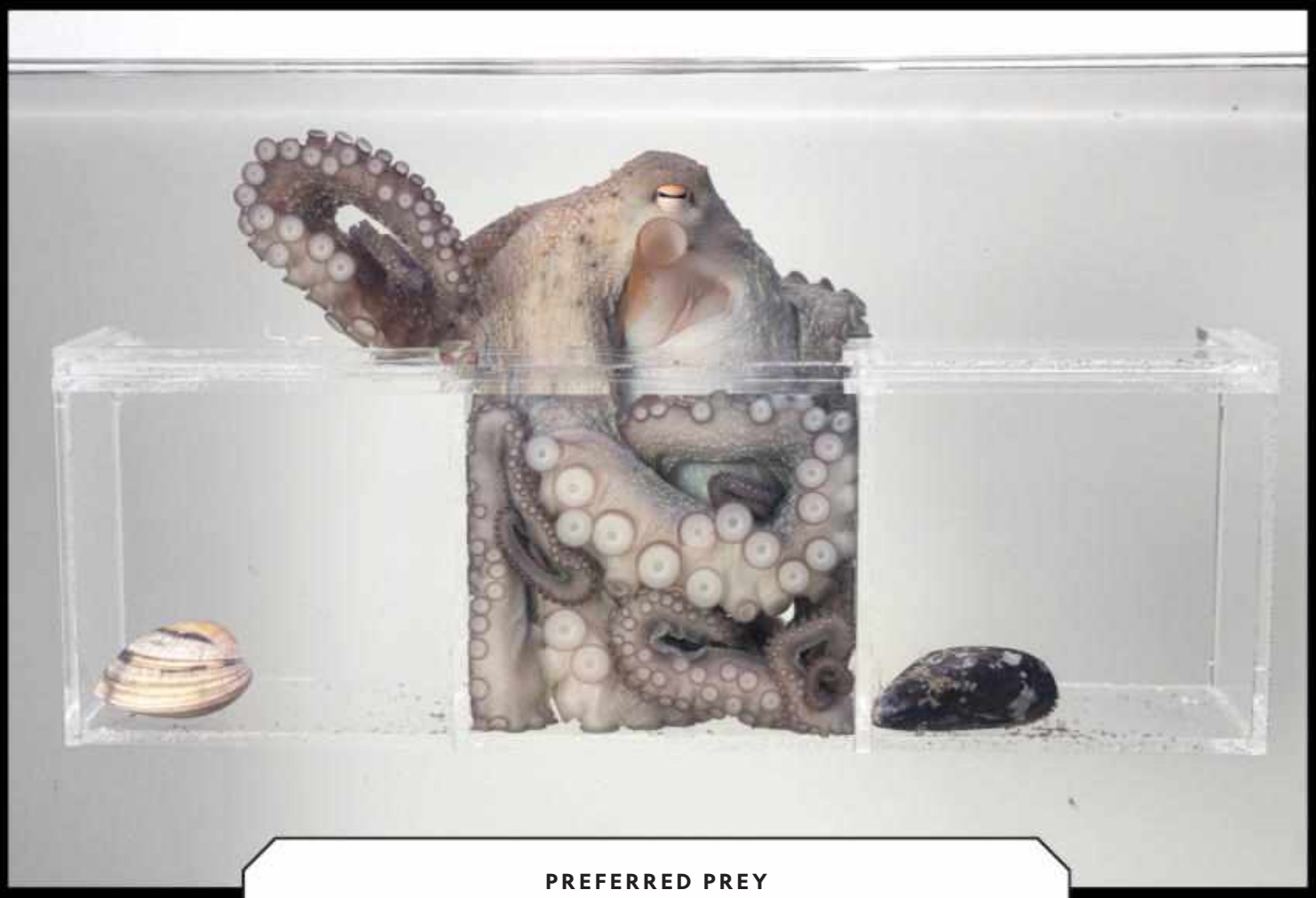


HIDING IN PLAIN SIGHT

Less than an hour after birth, a two-spot hatchling huddles against the wall of its tank. Found in coastal waters up to 50 feet deep, two-spot octopuses prefer rocky reefs and ledges with small caves to use as dens.

STRONG ARM TACTICS

Octopus arms bend, stretch, twist, and contract, helping them walk, swim, move objects, and subdue prey. The combination of muscles, nerves, and strong suckers offers a model for engineers building soft robotic arms.

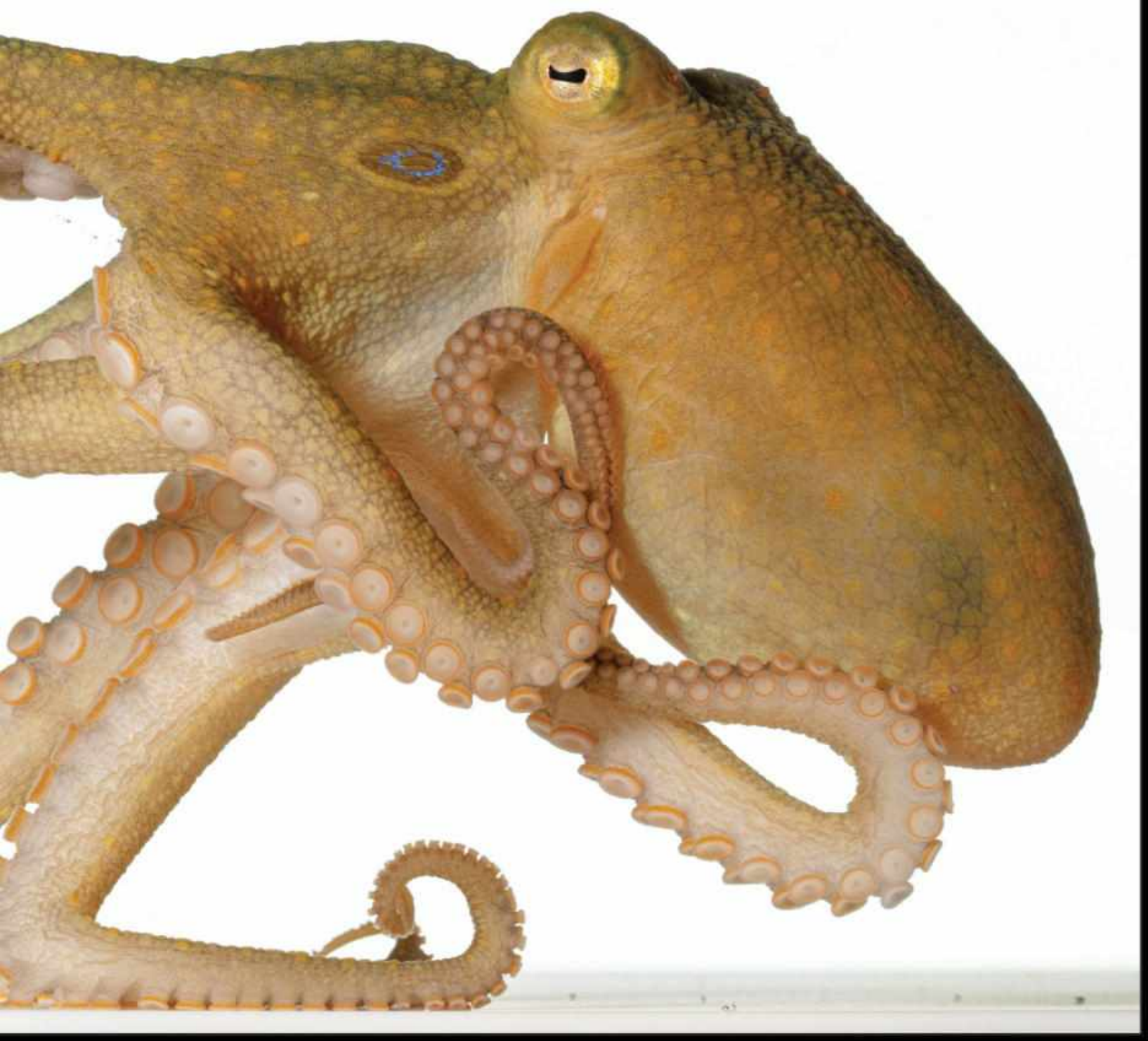


PREFERRED PREY

Feeding on a variety of fish, mollusks, and crustaceans, octopuses aren't picky eaters, but they do have favorite foods. This female common octopus, when offered a box containing a clam, an anchovy, and a mussel, went for the anchovy every time.

SUPERSMART

With hundreds of millions of neurons, octopuses display a range of complex behaviors. They solve puzzles, escape mazes, and might even dream. Yet how they became so smart remains an evolutionary mystery scientists are working to unravel.



UNDERWATER WONDERS

In an excerpt from her new book, *Secrets of the Octopus,* an animal lover offers insight into this 'strange, beautiful, curious creature.'

Words by SY MONTGOMERY

I'D NEVER MET anyone like Athena before.

Though she was an adult, she was only about four feet tall. She weighed a mere 40 pounds. And she was unusual in several other respects. She could change color and shape, taste with her skin, drool venom, spit ink, and jet about by squirting water through a siphon on the side of her head. Not to mention pour her baggy, boneless body through an opening the size of an orange. Her head wasn't even on top of her body, like mine. That spot was occupied by a body part known as the mantle, containing the organs of respiration, digestion, and reproduction. Her head was where you'd expect to find a torso. And her mouth was in her armpit.

Athena was a giant Pacific octopus, an *Enteroctopus dofleini*.

We met at the New England Aquarium in Boston, when senior aquarist Scott Dowd opened the heavy lid to her tank. Standing on a low step stool, I leaned over the water. The octopus changed from a mottled brown to a bright red with excitement as she spilled her liquid body out of her rocky lair. One of her glittering, silver eyes sought mine as her eight arms boiled up to the surface to meet me. With Scott's permission, I plunged my hands and arms into the numbing, 47°F (8°C) salt water, and I let her engulf my skin with her soft, questing, white suckers. She was both tasting and feeling me at the same time.

Athena didn't just welcome my company; she allowed me to touch her head. She had not allowed any visitor to do this before. Once we spent time together, as she tasted me and I stroked her, she changed color again. She turned white beneath my touch—the color, I later learned, of an octopus that feels calm.

It was clear to me that we had shared an illuminating exchange. Athena, to my surprise, was just as inquisitive about me as I was about her.

"But aren't they *monsters*?" my human friend Jody Simpson asked me the next day as I described my encounter with Athena while we walked our dogs through the woods. Jody is a good friend to many animals. She shares her home with two poodles and a cat. She is an accomplished horseback rider. She loves feeding wild birds. But an octopus? How could you have any kind of communion with an octopus?

Centuries of Western literature have portrayed octopuses as oceangoing demons. "No animal is more savage in causing the death

While hunting, day octopuses sometimes cooperate with groupers. The fish signals the presence of prey by pointing its head, leading the octopus to the location of the hidden meal.

GARY BELL, OCEANWIDE IMAGES

of a man in the water," wrote Roman philosopher and commander Pliny the Elder around A.D. 77, "for it struggles with him by coiling round him and swallows him with its sucker cups and drags him asunder." Because they are so different from us, because some species can grow so large, and because of their enormous strength (a single large sucker on a giant Pacific can lift more than 35 pounds, and the animal has 1,600 or more of them), octopuses can frighten and confuse humans—or at least those humans who don't get a chance to know one.

But I was mesmerized by Athena's otherness. According to almost every basic classification of animal life, she and I were opposites. She was a protostome—developing as an embryo mouth first. I am a deuterostome, developing back end first. She was an invertebrate, without bones. I am a vertebrate, scaffolded with a bony skeleton. She lived in water, I on land. She breathed water. I breathe air. The last time her kind and mine had shared a common ancestor, half a billion years ago, everybody was a tube.

Yet I was also struck by an unexpected sameness. Despite the yawning gap in our taxonomic classifications, it seemed possible that we could have a meeting of the minds. Perhaps we could even be friends.

And then, Athena began pulling me into her tank.

Equipped with hydrostatic muscles, more like those in our tongues than our biceps, an octopus of her size can, by some calculations, resist a pull 100 times her own weight. That would be 4,000 pounds. I weigh 125. But again, I was not afraid. I felt no malice on her part. Her pull was insistent but gentle. I didn't worry she wanted to eat me. I was comfortably aware that her beak, located in her armpit, and its adjacent venom glands were nowhere near the parts of the arms that were pulling on mine. Her tenacious tug was no threat. Instead, it was an invitation—one I was honored to accept.

And so this strange, beautiful, curious creature did pull me into her world—a world I explored for years after her death, and am exploring still. Octopuses, alas, do not live long. Giant Pacifics survive only three to five years, and Athena was already old for an

The elusive wunderpus octopus lives throughout the Philippines. It can contort its body to mimic other creatures, including the venomous lionfish.
DAVID LIITTSCHWAGER

The Maori octopus keeps a sharp eye out for its favorite meals—crabs, lobsters, and mussels—while watching for predators: sea lions and pilot whales.

KASPA BLEWETT

Most octopus species look for food at night, but the day octopus stalks its prey, like crabs, shrimps, and fish, in sunlight. To avoid detection, it changes its skin texture and color to mimic corals, rocks, and algae.
DAVID LIITTSCHWAGER

octopus when I met her. But over the course of the next three years, I got to know her successors at the aquarium, Octavia, Kali, and Karma, quite well. I visited every week to watch and feed and stroke and play with them.

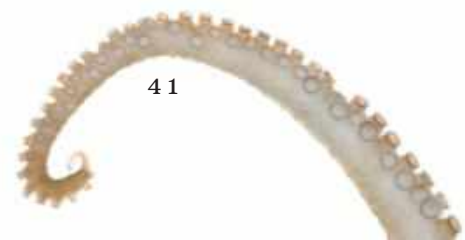
While all the octopuses I came to know were playful and intelligent, each displayed a distinct personality. When I first wrote of my friendships in a book published in 2015, its title, *The Soul of an Octopus,* gave some readers pause. How can an octopus have a soul? (Many scientists and philosophers don't believe in souls; some believe humans don't even possess consciousness—that it's just a made-up concept to help us handle the pointlessness of existence.) Octopuses are mollusks, relatives of brainless clams. Surely, some said, suggesting an octopus might have a soul, or a personality, or thoughts

or memories or emotions, was simply a product of a misguided propensity to wrongly attribute "human" feelings to nonhuman creatures, like a child pretends that a doll is really alive.

But the attitude that animals are automatons without thoughts or feelings is an idea behavioral scientists increasingly recognize as being as outdated as Pliny's *Naturalis Historia*. Jane Goodall's discoveries that chimps are smart enough to fashion tools, and their personalities distinctive enough for individuals to merit names, trashed the notion that humans alone possess mental experience. Science has since accumulated masses of data that support what many of us knew all along: that animals, from elephants and dolphins to fruit flies and cuttlefish, think, feel, and know. Even—and perhaps especially—octopuses.

These creatures are revealing a totally different path from our own that leads to advanced intelligence. If we follow that path, it may lead us further still, bringing us closer to understanding more secrets, including the shared experience of what it means to think, to feel, and to know. □

Secrets of the Octopus, a National Geographic book, is available now wherever books are sold.



A coconut octopus takes refuge in coconut shells but also in seashells like these and other detritus on the seafloor.

GREG LECOEUR

WAVES OF CHANGE

A conversation with marine biologist Alex Schnell, who advocates compassion and humane treatment for all animals

Octopuses aren't protected under the U.S. Animal Welfare Act because they don't have backbones. National Geographic Explorer Alex Schnell works to translate our understanding of animal minds into better protections for all creatures. Here she answers questions about how we perceive these alluring ocean dwellers. (This interview was edited for length and clarity.)

Octopuses are smart. Does that make us care about them more?
Humans feel greater empathy for related animals like orangutans, gorillas, and bears. As we shift away from species closely linked to us, our compassion diminishes. But research shows that as we learn more about these animals, our perceptions can change.

Traits of intelligence once thought to be uniquely human are now being discovered in distantly related species. We know octopuses show curiosity, can problem solve, use tools, and are rapid learners. The more we learn about them, the more it removes a barrier of otherness. And that can translate into conservation.

Having a backbone is considered a barometer for whether animals suffer. Can octopuses feel pain?
There's no smoking gun that definitively says yes. We call the ability to feel pain sentience. We've examined sentience among animals through a framework of neural and behavioral markers: Does the animal have a nervous system that can support sentience? Is the animal's behavior consistent with sentience? Do they choose to find pain relief? That's the gold standard.

Sentience is the capacity to have feelings both pleasant and unpleasant. Even animals that aren't cognitively complex can meet the criteria for sentience. We reviewed 170 cephalopod studies and found very strong evidence of sentience in octopuses. They met seven of eight criteria. Based on those findings, octopuses are now considered sentient beings under United Kingdom law.

One hundred years ago, it was commonly thought that animals were robots, unable to think or feel. We have better science and knowledge now. But I think that in another hundred years' time we're still going to look back and shudder at the way we treated animals.

How can we do better?
A contentious topic facing octopus welfare is octopus farming, which is an emerging industry. When evaluating farming a new species en masse, you have to consider a few things. They need to be suitable to being housed in a farming setting. Most octopus species, if put together, are prone to stress, cannibalism, and self-mutilation.

There are no methods of humane slaughter for octopus farming. Humane methods have been established in the lab, but these would render the protein inedible. Octopuses taken in the wild are suffocated on boats. Imagine doing that to one million of them. At this crucial moment, it's not about debating whether to eat octopus—it's about deciding whether to push them into mass production. We need to pay attention to the science to make more compassionate and informed decisions. And currently the science states that there is no ethical way of farming octopus. The industry can't thrive without institutional support from financiers, supermarkets, and ultimately consumers. —NATASHA DALY

Hiding from danger, a coconut octopus takes advantage of a clamshell. This type of tool use is seen as a mark of intelligence.

ALEX MUSTARD, NPL/
MINDEN PICTURES

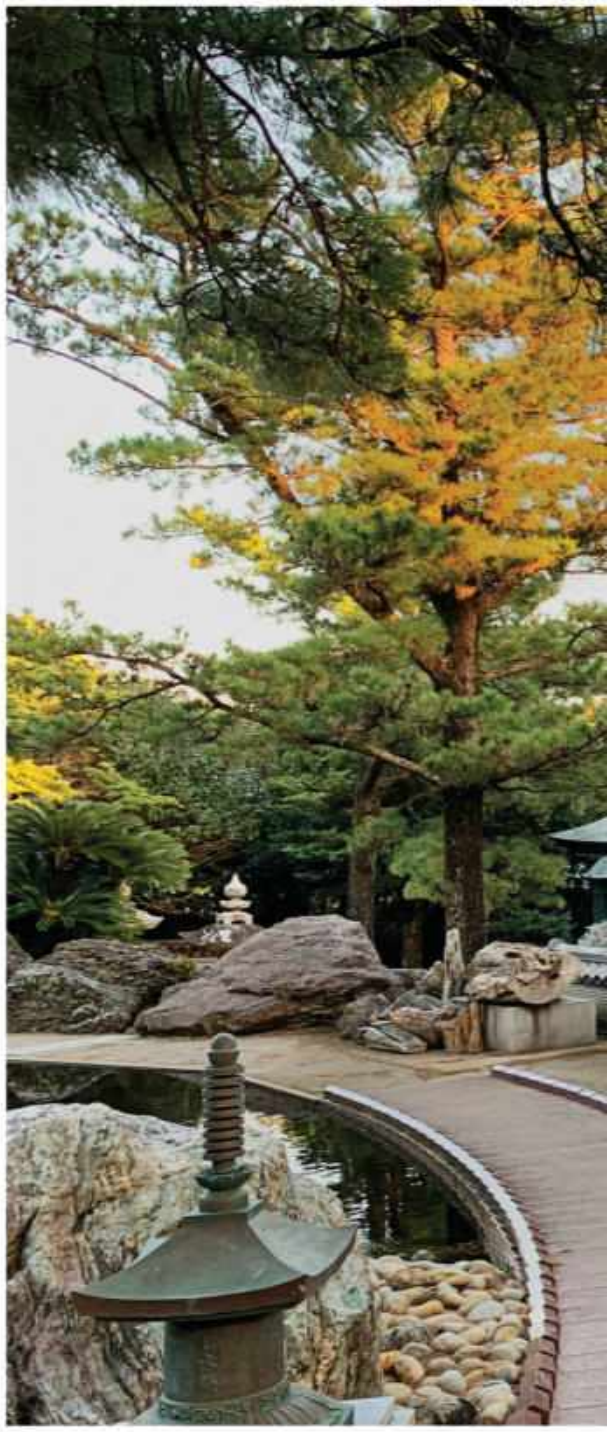
A young octopus's translucent skin reveals its digestive system. Orange dots in the mantle are chromatophores, organs that help the animal change color.

MAGNUS LUNDGREN, NPL

TRAIL *of* BLESSINGS

Japan's most famous pilgrimage route visits 88 temples in the footsteps of a celebrity monk born 1,250 years ago.

Words by
NORIE QUINTOS



→ **BOW RESPECTFULLY** at the temple gate. Cleanse hands and mouth at the fountain. Sound the bell. Leave a name slip with your wish in the main hall, light a candle and three sticks of incense, toss coins in the offering box, and chant sutras. Get your pilgrimage book stamped. Exit the gate, and bow again. Follow the red markers to the next temple.

Repeat 87 times.

Or not. On the Shikoku Henro, one of the longest pilgrim routes in Japan, there are many ancient customs but few hard-and-fast rules. You don't even have to walk it: Many Japanese now take cars or bus tours; others ride trains or bikes. You can tackle the trail counterclockwise instead of clockwise. Or break the circuit into segments. You can wear the traditional white vest or look like an ad for REI—as most of us did on the small-group tour I joined last September to hopscotch a section of seven temples.

"Buddhism is more a way of life than a religion that tells you what you can or can't do," said David Moreton, a Shikoku-based researcher specializing in the Henro. "However, showing respect is important."

Travelers' interest in long-distance walks is at an all-time high. The famed Camino de Santiago in Spain saw a record 446,000 pilgrims last year. The Henro sees a fraction of that.

PHOTOS: DAVID MADISON, GETTY IMAGES (TEMPLE, BOOKLET); JOHN LANDER, ALAMY STOCK PHOTO (HIKER)

Clockwise from above

At the southernmost point of Shikoku, the Temple of Everlasting Happiness (Kongofukuji) is 38th of the 88 temples that make up the Shikoku Henro trail. At each temple, pilgrims can receive unique red stamps and hand-drawn calligraphy in their pilgrimage booklets. The traditional vest, hat, and staff identify a hiker as a pilgrim, known as *o-henro-san*.

Nevertheless, the numbers of walkers and foreign visitors seem to be rising.

The circular route crosses all four prefectures of Shikoku, Japan's fourth largest island. As befits its evolution over a millennium, the Henro is a bit of a patchwork. The road to enlightenment runs through small family farms, busy highways, and suburban streets punctuated by vending machines. But the route also reveals expansive coastal views and Edo-period landscapes straight out of a Hiroshige woodblock print.

The most obvious place to start was Temple 1, in Tokushima Prefecture in the island's northeast. Next to its carp-filled pond, Jun Hashiba, a guide for Kyoto-based tour company Oku Japan, attempted to answer questions about how a Japanese monk born in the eighth century inspired the development of an over 700-mile circuit of 88 temples still in use more than a thousand years later. "Everyone knows Kukai; we study him in school," said Hashiba.

Born on this island, Kukai founded one of the country's more popular sects of Buddhism, called Shingon. He's revered, but not only for his esoteric teachings, which are aptly named. "We mostly admire him for his abilities as a poet, scholar, and artist; he was a great calligrapher," said Hashiba. The peripatetic and polymathic Kukai's real-life feats morphed into the stuff of legend and eventually led to the popularization of the current route. Hashiba suggested the real answers would come once we started walking.

The four-mile section from Temple 20 to Temple 21 was lined with cathedral-high cypress, cedar, and bamboo. Rope-garlanded boulders, the embodiment of deities, kept us company, as did vermilion-bibbed stone statuettes, called *jizo,* which are guardians of children and travelers. Kukai, also called Kobo Daishi, was here too, personified in the pilgrim's walking staff inscribed with words that translate to "traveling together."

"When I walk, I sometimes think too much, but I keep walking, and then I think of nothing—in a good way," said Tomoko Imaizumi, a guide who has made the pilgrimage four times.

At the Temple of the Great Dragon (21), a part of which dates from the 12th century, it was easy to see why so many religions built their altars atop mountains. In his writings, Kukai claimed to have climbed to the hilltop aerie and chanted mantras a million times. Despite Shingon Buddhism's opacity, at its core is this: that everything is part of a cosmic whole and that enlightenment

TRAVEL TIPS

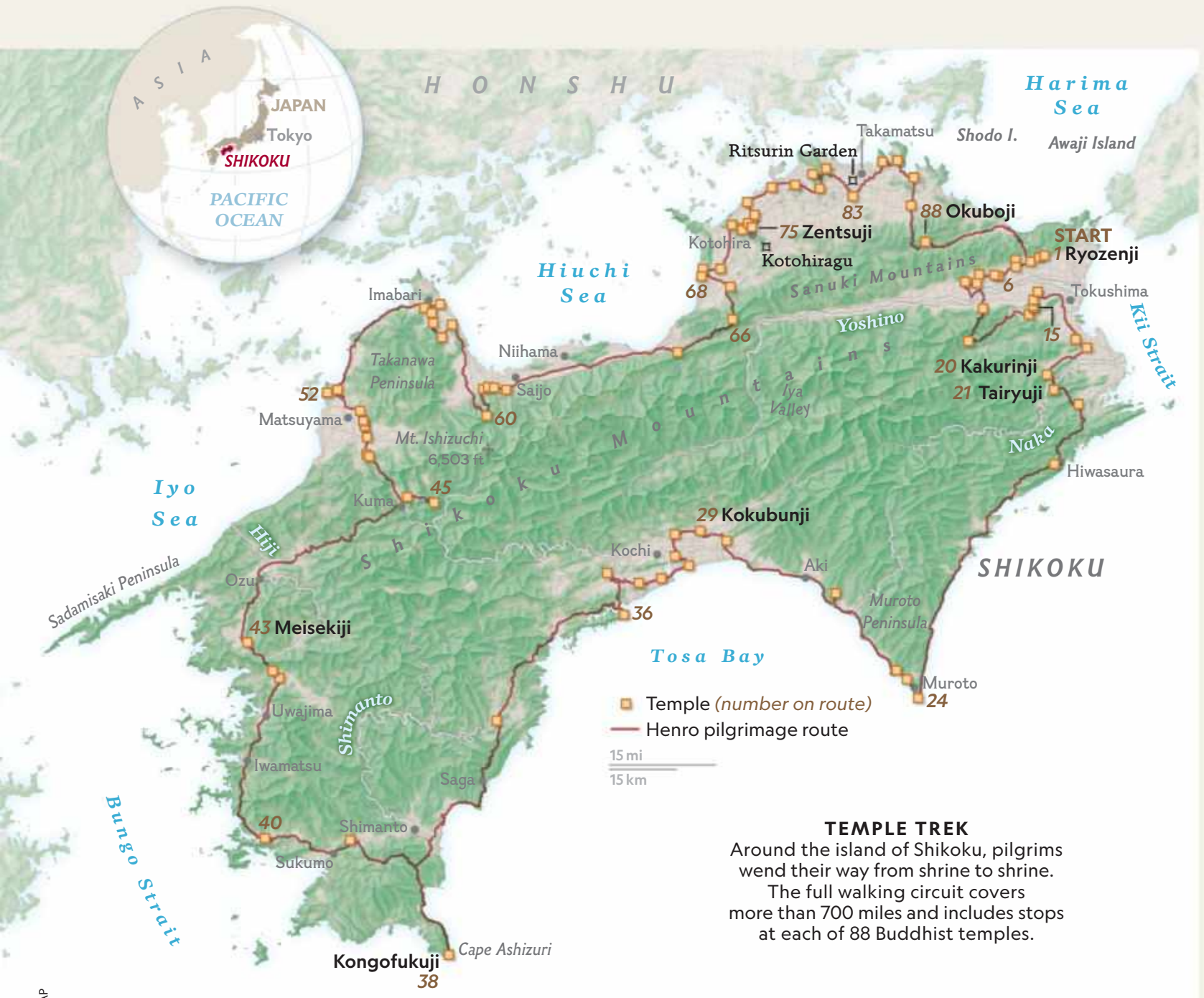
WHAT TO KNOW
Shikoku is accessible from Tokyo by air, rail, or road. Walking the Henro takes about six weeks to complete on average. No special training is required, though you'll need to be adventurous and reasonably fit. Visitors can find information at *shikokuhenrotrail.com*. To mark Kukai's 1,250th, temples will offer special stamps and stamp booklets until December 2024.

TOP TEMPLES
Awa Kokubunji (15) is one of only three Zen temples. Kakurinji (20) and Tairyuji (21) are known for the excellent hiking between them. Kongofukuji (38), at Cape Ashizuri, is wildly scenic.

OUTFITTERS
Various operators, including National Geographic Expeditions and Shikoku Tours, offer guided and self-guided tours ranging from one day to more than 10 days.

WHEN TO GO
Best times to visit are March to May for cherry blossom season and October to November for peak fall foliage.

SHIKOKU ATTRACTIONS
Don't miss the vine bridges of the Iya Valley, the hilltop shrine Kotohiragu, and the celebrated Ritsurin Garden.



TEMPLE TREK
Around the island of Shikoku, pilgrims wend their way from shrine to shrine. The full walking circuit covers more than 700 miles and includes stops at each of 88 Buddhist temples.

can be achieved by ordinary people. "I have received so many blessings from the Henro," said Kizumi, a woman I met at Temple 6 (Temple of Everlasting Joy). She didn't give me her last name, but she did press into my hand a pale green friendship bracelet made of string.

Indeed, pilgrims along the trail invariably spoke of the kindnesses of the locals. This is the culture of *osettai,* a unique feature of the Shikoku pilgrimage. "I experience this almost every day as a pilgrim," said Imaizumi. "Usually it's a mandarin or some sweets; one time a woman stopped her car and jumped out to give me 300 yen."

Close to the Vulture Peak Temple (1), our group met Ranshu Yano, master of the dwindling art of *ai-zome.* The Tokushima region produces natural indigo for dyeing. Indigo textiles were once used in samurai clothing.

Yano invited us into his workshop to watch a portion of the painstaking process. He slid the lid off a large vat. The blue stew needed to be inspected, stirred, and allowed to ferment.

"It's a living thing," he said, holding up permanently blue hands. "I have to feel it." The finished textiles are fashioned into exquisite kimonos.

On the Henro, gifts come in all forms, not least of which is the chance to connect with people still tied to the land, still bound to artistry and traditions long abandoned in other places. "People have been doing what I do for a thousand years," Yano said. "I stand in the middle, between the past and the future." ◻

MAP: MATTHEW W. CHWASTYK, NGM STAFF. SOURCES: HENRO.ORG; GREEN MARBLE; © OPENSTREETMAP

Jupiter's STORMY STRIPES

NASA's Juno spacecraft has spent more than seven years orbiting the solar system's largest planet. Its detailed images of Jupiter's turbulent atmosphere are helping scientists understand the forces behind the colossal storms roiling the gas giant.

By MATTHEW W. CHWASTYK

THE RED TEMPEST

At the edges of this 10,160-mile-wide storm, winds can surpass 400 miles an hour. Observing it for centuries, astronomers have noted changes in the storm's size and shape. The cause of its red hue remains a mystery.

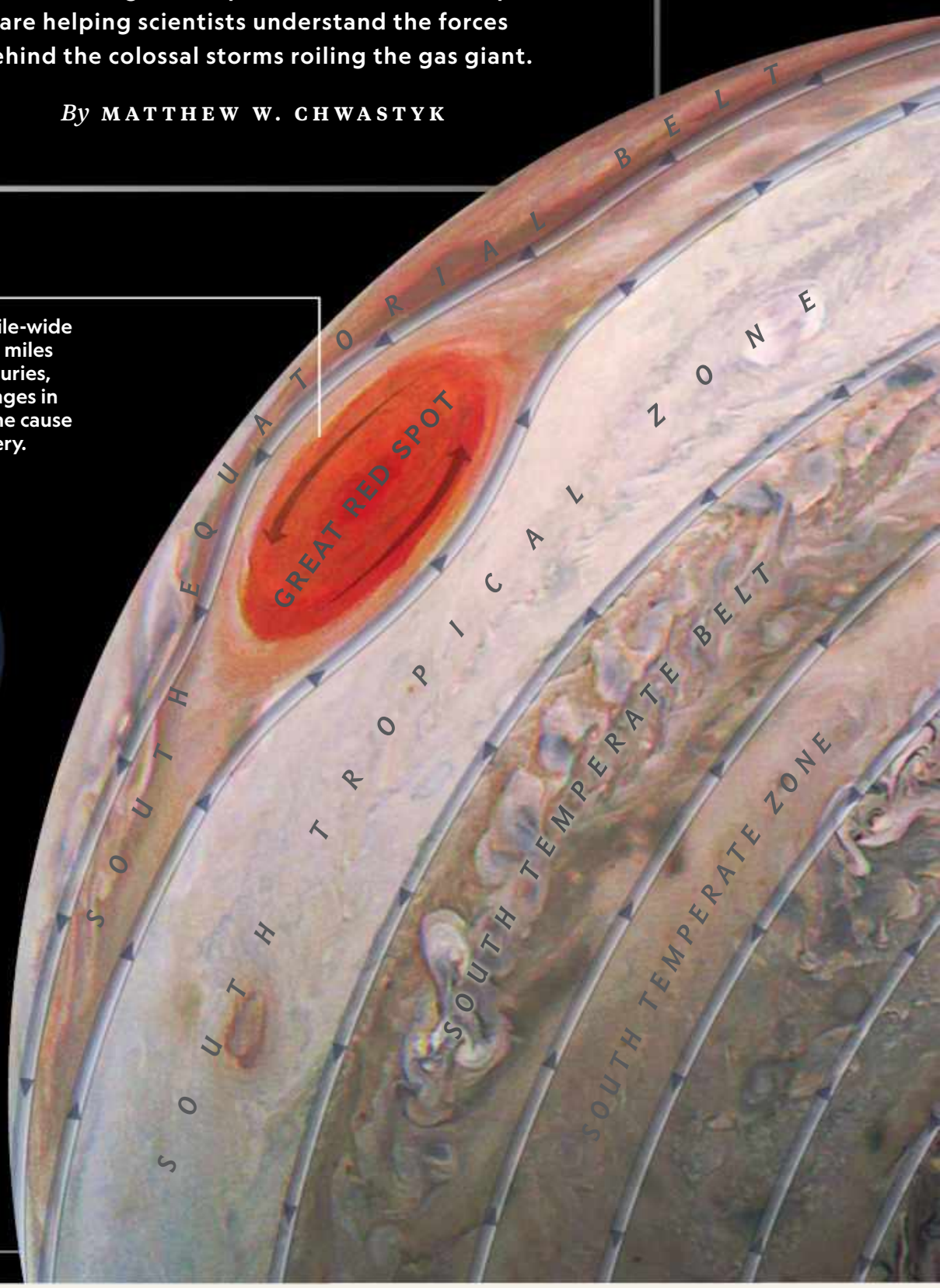
Earth at the same scale and orientation

JUPITER BY THE NUMBERS

Length of day:
9 hours, 56 minutes

Rotational speed:
28,273 mph at equator

Temperature at upper layer of atmosphere:
-258°F

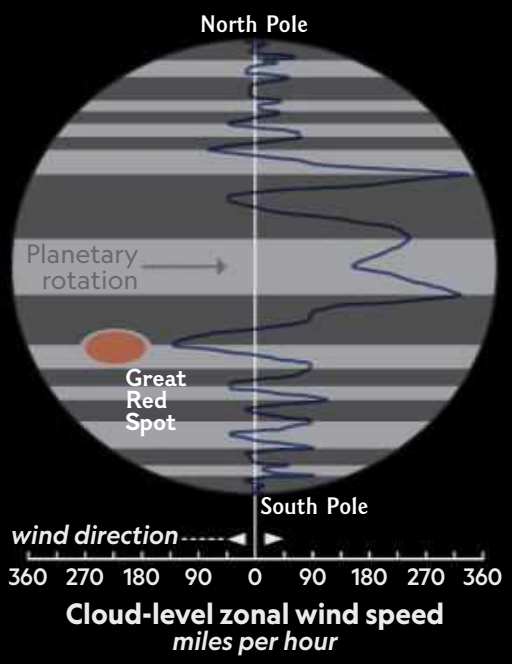


CONTAINED CHAOS

Jupiter's rotation, the fastest of the eight planets, projects immense energy into the atmosphere. Zonal wind speeds can top 300 mph.

Zones
Light stripes show cooler, rising gases with high clouds of tiny ammonia ice crystals.

Belts
These darker bands of sinking atmosphere provide a view into Jupiter's deeper layers.



Direction of jet stream

Storm
3,700 miles across

WHITE OVAL

SOUTH SOUTH TEMPERATE BELT

SOUTH SOUTH TEMPERATE ZONE

Storm
2,750 mi across

SOUTH POLAR REGION

Powerful jet streams, more than 1,800 miles deep, bound the northern and southern limits of zones and belts.

Juno revealed that Jupiter's poles are encircled by perpetually whirling cyclones: nine in the north and six in the south.

SOURCES: NASA/JPL; MALIN SPACE SCIENCE SYSTEMS; SCOTT BOLTON, SOUTHWEST RESEARCH INSTITUTE

KEEPERS OF

Eroding citadels in Uzbekistan harbor remnants of a fire temple built by Zoroastrians, who revere fire as a sacred element.

MATTHIEU PALEY

THE FLAME

An ancient religion founded
in Central Asia faces a vexing question:
how to keep the fire of faith burning.

Words by KRISTIN ROMEY

Photographs by MATTHIEU PALEY *and* BALAZS GARDI

Early one morning last December, Aaria Boomla rose from her hard guesthouse bed in the small coastal town of Udvada, India.

It was nothing like her soft bed at home, seven hours away in Pune. She dressed and brushed carefully around her two missing front teeth while silently practicing the lines of scripture she'd been memorizing for months. At age seven, the elder of two children, she was about to join her family as a follower of one of the world's oldest religions.

The sun came up hot and hazy as Aaria and her family and friends walked along a dirt road to the Iranshah Atash Bahram, a large white stone-and-wood temple complex enclosed behind high walls. The entrance gate, flanked by two enormous sculptures of human-headed, winged bulls, was minded by an attendant who ensured that only those of sufficient ritual purity could enter the temple precinct—one of the most sacred places in all of India.

According to tradition, Aaria's Zoroastrian ancestors had arrived on the Gujarat coast 1,300 years ago seeking protection from religious persecution by invading Arab Muslims. Here, on the shores of the Arabian Sea, they revived the tenets and rituals of their faith, including a fire sourced from 16 different fires, sparked by everything from a blacksmith's forge to lightning. That fire has burned continuously ever since, under the careful tending of white-veiled *mobeds,* or priests.

Farzin Yezishne, a Zoroastrian *mobed* (priest), performs a blessing ceremony at a home in Karachi, Pakistan. He wears a veil to protect the purity of the fire.

MATTHIEU PALEY

To prevent decomposing bodies from defiling earth, water, or fire, Zoroastrians here in Karachi and in India expose their dead to the elements in circular towers known as *dakhmas,* where the remains break down naturally.

MATTHIEU PALEY

Today it's for an ever dwindling community of faithful.

Inside the temple precinct, Aaria bathed in sacred water, took three sips of purified bull's urine, donned a fresh set of white clothes, then joined the mobeds. They gathered around the fire, which burned in a silver urn. Prayers rose into the air, words from a language last in everyday use 3,500 years ago. "*Fravaraane mazdayasno Zarathushtrish Vee-daevo Ahura-tkaesho,"* Aaria recited: "I confess myself to be a worshipper of the Creator Ahura Mazda, a follower of the religion revealed by the Prophet Zarathushtra."

Aaria and her family are among a small and shrinking number of orthodox believers in the corner of the world where Zoroastrianism first appeared and spread. Fewer than 100,000 adherents remain in and around the fringes of the former Persian Empire, in Iran, India, and Pakistan. But in the past century, the faith has traveled far from its origins—to places like Los Angeles, Mexico City, and Stockholm—and inspired new, progressive communities where anyone who follows the tenets of the ancient prophet Zarathushtra can be considered a Zoroastrian.

IN MUCH OF THE world's imagination, Zoroastrianism conjures up something ancient, and maybe a bit exotic. But the basic tenets are fundamental to people everywhere: good versus evil, resurrection, and the afterlife. At its core is *humata, hukhta, hvarshta:* "good thoughts, good words, good deeds."

According to tradition, Zarathushtra—Zoroaster in Greek—was a disillusioned priest of an ancient polytheistic religion who, after immersing himself in a river, received a revelation from Ahura Mazda, the Supreme Being.

A brief history of Zoroastrianism

1700 B.C.
Beginnings
The Prophet Zarathushtra teaches the tenets of Zoroastrianism in Central Asia sometime between 1700 and 1000 B.C.

550 B.C.
Spread
Cyrus the Great founds the Achaemenian Persian Empire, where Zoroastrianism flourishes.

330 B.C.
Conquest
Alexander the Great defeats the Achaemenids and destroys 20 of the 21 books of the Avesta, or Zoroastrian scripture.

247 B.C.
Revival
The Parthian Empire, founded by Arsaces I, revives Zoroastrianism and expands from Mesopotamia westward to India and China.

A.D. 224
Zenith
The Sassanian Persian Empire makes Zoroastrianism its state religion. Jews, Christians, and others are still allowed to practice their faith freely.

Achaemenian Empire at its height, ca 500 B.C.

Sassanian Empire at its height, ca A.D. 620

It's unclear where and when Zarathushtra might have lived. Many scholars draw clues from Zoroastrian scripture, the Avesta, to place him in Central Asia, possibly modern Afghanistan or Tajikistan, around 1700 to 1000 B.C. He was said to have led just one follower at first, his cousin. But by the sixth century B.C., Zoroastrianism had become tied to the Achaemenian Persian Empire, one of the world's oldest and largest superpowers, and the tenets of Zarathushtra would eventually spread to lavish Silk Road entrepôts in western China and tiny mountain shrines in the Balkans.

The Zoroastrian belief in one supreme being and good versus evil had a profound influence on the Abrahamic religions—Judaism, Christianity, and Islam. Cyrus the Great, the founder of the Achaemenian Persian Empire, freed the Jews from captivity in Babylon in 539 B.C. and returned them to Jerusalem, where they rebuilt their temple. Their exposure to Zoroastrianism in Babylonia and Persia, many scholars believe, helped solidify basic elements of Jewish belief, including an afterlife and final judgment. The ancient Greeks noted the wisdom of Zoroastrian sages, which gave rise to the Three Wise Men of the New Testament. And scholars note the similarity between Zoroastrian and Muslim practices of praying five times a day, and the ritual ablution that accompanies these prayers.

The Zoroastrian god is not a negotiating or punishing deity. There's no notion of original sin that requires repentance. Rather, the Zoroastrian god is more like the force of gravity, indifferent to your daily well-being. Your job is to fight for *asha* (truth, righteousness, and order) and against *druj* (filth, lies, and chaos). After death, your soul, or *urvan,* reunites with your guardian spirit, or *fravashi,* and lives on

A.D. 651

Arrival of Islam
Arab armies overthrow the Sassanian Empire. New Muslim rulers increasingly oppress Zoroastrians, and many flee to India.

A.D. 721

Sacred fires
An Atash Bahram, the highest grade of fire, is kindled in India and still burns today at the Iranshah temple. The flame at Yazd, Iran, is believed to date to A.D. 470.

A.D. 1218

Mongol invasion
Zoroastrian communities along Asia's Silk Road suffer heavy casualties at the hands of the Mongols.

A.D. 1979

Islamic revolution
The shah of Iran is overthrown, and new leaders establish an Islamic republic. Many Zoroastrians flee to Europe and North America.

A.D. 2024

Zoroastrians today
Communities are concentrated in India (in Mumbai and Gujarat state), Iran, and North America. Others are thinly scattered worldwide.

NGM MAPS

In Mumbai, India, Parsi mobeds confer after seven-year-old Shayaan Gazdar's initiation ceremony, or *navjote*. Among the most orthodox Parsis (Indian Zoroastrians of Persian descent), only children of Zoroastrian parents can take part in religious rituals.

MATTHIEU PALEY

in a world of song or a world of purgatory. Then comes the final battle, when good triumphs over evil and everyone is resurrected to live in a perfect world free of war, hunger, and earthly desires.

The teachings of Zarathushtra, in a sense, created the "bookends" of the Abrahamic faiths, says Jamsheed Choksy, a professor of Central Eurasian studies at Indiana University Bloomington. "You start with the discussion of good versus evil, and that humans have a role—that we're not just walking through life. And at the other end, the reward is that everything will be made right; evil will be defeated."

For non-Zoroastrians like me, there's only so much of the community that's accessible. Strict purity laws prohibit outsiders from entering the Iranshah temple complex as well as the other smaller fire temples in Udvada. On the morning of Aaria's initiation, Zarine Bharda pulled up to another fire temple on a white scooter, with a daughter around Aaria's age in her sidecar. Bharda, dressed all in white, declined my sweaty handshake with an apologetic smile. "If I shook your hand, I'd have to give myself another head bath before I enter the temple," she explained, pointing to the white kerchief tied around her hair.

A former engineer from a Zoroastrian family in Canada, Bharda is now a women's wellness coach. Because she's married to a mobed at the Iranshah temple, she must observe the strictest purity obligations. During menstruation, for instance, she leaves her home for another apartment in town, with separate sets of clothes and dishes. "It's easier," she said.

More white-clad worshippers approached the temple, and Bharda's daughter tugged impatiently at her mom's sleeve. It was time to go inside.

Ramiyar Karanjia, the principal of a seminary in Mumbai, guides future mobeds as they memorize some 350 pages of the Gathas—accounts of the Prophet Zarathushtra. In Parsi communities, only sons of mobeds may enter the priesthood, though women are taking on priestly roles outside of India.

INDIA'S ZOROASTRIANS—known as Parsis—claim to be the true custodians of the religion. In the Islamic Republic of Iran, the former center of the Persian Empire, Zoroastrians have been persecuted and forced to take many of their practices underground. Zoroastrianism claimed millions of followers at its height; now there are possibly 15,000 to 25,000 adherents left in Iran. Parsis number around 50,000 in India, concentrated mostly around Mumbai and the state of Gujarat, with less than a thousand more in neighboring Pakistan. The most orthodox of them consider only the children of Zoroastrian parents to be true Parsis, and they frown on marriage outside the faith. These restrictions, coupled with a decreasing birth rate, have led to a rapid decline of the Parsi population.

MATTHIEU PALEY

Ramiyar Karanjia is the principal of a Parsi seminary in the leafy enclave of Dadar in central Mumbai, where the sons of mobeds undergo rigorous training in religious literature and rituals alongside classes in math and geography. A lean, soft-spoken man, Karanjia attended the same boarding school as a child 50 years ago, memorizing scripture and undergoing arduous purification ceremonies required of future mobeds. These include a 25-day isolation inside a fire temple where prepubescent boys are prohibited from touching anything or anyone, or eating between sunrise and sundown.

The core scripture, the Avesta, contains 17 Gathas, the words delivered from Ahura Mazda to his prophet, Zarathushtra. The oldest passages are in Old Avestan, a language believed to have been spoken in Central Asia during the Bronze Age some 3,500 years ago. Then there is the Vendidad, mostly a compendium of ecclesiastical and social laws that's considered to be one of 21 books that made up the original Zoroastrian corpus. It's the only one that survived fully intact following the sack of the Persian Empire by Alexander the Great—or "Alexander the Accursed," as he's known in these parts—in 330 B.C. Maybe 10 percent of Zoroastrian scripture in Avestan survives to this day, said Karanjia.

Zoroastrian communities look to their mobeds for leadership. In Parsi tradition,

Well-wishers greet Parsi groom Zaran Dalal (center) at his Mumbai wedding. Both bride and groom are Zoroastrians, but marriage outside the faith, though discouraged, is becoming more common.

MATTHIEU PALEY

Doongerwadi forest in Mumbai was established by Zoroastrians around 1670 to dispose of their dead.

MATTHIEU PALEY

only the sons of priests can become priests. A mobed may make only 50,000 rupees a year, Karanjia explained—about $600, a meager sum even in the poorest parts of India—and there's no medical plan or pension. So most mobeds serve part-time and enter other professions.

Not long ago, more than two dozen students attended the Dadar seminary. "Presently we have just 14," lamented Karanjia. The only other Parsi seminary hasn't had any students in almost a decade.

The small number of seminary candidates is a reflection of a low fertility rate in Parsi communities. Religious leaders and researchers note that Parsi men and women tend to marry older, if at all, and have fewer children than they once did. It's estimated that for every Parsi born into the community, four pass away. Jiyo Parsi, a program launched in 2013 and sponsored in part by the Indian government, promoted larger Parsi families with financial incentives, counseling, fertility treatments, and cheeky ad campaigns. "Be responsible. Don't use a condom tonight," urged one poster. Some Parsis are humorously fatalistic about the future of their community. "You know that movie *Four Weddings and a Funeral*?" a Parsi journalist asked me. "With us, it's Four Funerals and a Wedding."

Rohinton Nariman, a mobed and former Indian Supreme Court judge, conceded that bias against intermarriage will doom the

Parsis pioneered the textile industry in western India, home to Mumbai's Mangaldas fabric market.

Parsis. "North America is the only place now which is accepting both the spouses as well as the children," he said. "And I'm sure Zoroastrianism will flourish there."

BEHNAM ABADIAN'S TROPHY warehouse sits in an unassuming industrial park in Glendale, California. Inside, the shelves are filled with dazzling bronze, glass, and zinc confections bound for corporate executives, professional athletes, and Scientologists. Abadian is a civil engineer who left Iran the day Iraq invaded in 1980, eventually marrying "a Muslim woman in a Catholic church in New York City," he said. Today he's a trustee of the California Zoroastrian Center, and he distributes progressive-minded books on the faith for his brethren in North America. Apart from the books, Abadian is particularly proud of his latest work: a 10-foot-tall bronze statue of Cyrus the Great.

I joined Abadian and his friend Arman Ariane for lunch at a popular Persian restaurant near the trophy warehouse. Inside, waiters carrying platters of flatbread and grilled meats maneuvered between packed tables of dressed-up families. It was the weekend of Nowruz, the Zoroastrian New Year that begins on the spring equinox in March.

While it's impossible to say how closely Cyrus the Great followed the tenets of Zarathushtra, modern Zoroastrians point

A shepherd rests beside the Bartang River in Tajikistan. Zoroastrians believe the Prophet Zarathushtra received his revelation from the Supreme Being Ahura Mazda in this mountainous region sometime between 1700 and 1000 B.C.

MATTHIEU PALEY

with pride to the way the Persian king restored the temples of many faiths under the guardianship of one of the world's first superpowers—creating, essentially, the first multireligion empire. "And it led to the world's first declaration of human rights," said Ariane, a fashion designer and owner of Xerxes for Gents, a clothing store in nearby Claremont. Originally from Iran, Ariane was attending boarding school in Austria when Ayatollah Khomeini seized power in early 1979. Ariane found himself without a home, so he worked as a truck driver for a year, then restarted his life in Los Angeles delivering pizza.

WHILE THE FIRST Zoroastrian populations appeared in North America in the 1950s following the independence and partition of India and Pakistan, they saw exponential growth during the 1970s and '80s, fueled both by Iranians fleeing the 1979 revolution and subsequent war with Iraq and by the economic migration of Zoroastrians from South Asia. Today it's a stable community rather than one declining under the burden of ethnoreligious restrictions, notes Choksy, the professor of Central Eurasian studies. Families are younger, intermarriage more common. "The perspective is very much one of a younger community that sees possibilities," Choksy said.

The Federation of Zoroastrian Associations of North America (FEZANA) was established in 1987 as a sort of umbrella for two dozen Zoroastrian groups across Canada and the United States. Ariane plays a role in a number of Zoroastrian organizations in California and beyond, and helps run a Facebook group for converts. The group is one of many Zoroastrian communities that thrive online, including the Norway-based Great Return, which is initiating Zoroastrians around the world.

Younger Zoroastrians tend to meet up on WhatsApp and Instagram, according to Arzan Sam Wadia, a New York–based architect and current president of FEZANA who also runs Return to Roots, which connects young Zoroastrian adults in the diaspora to their ancestral communities in India.

Today more than 25,000 Zoroastrians live in North America. How many more, and how quickly that number is growing, is hard to say. Iranian Zoroastrians don't necessarily want to be counted, Wadia explained: "They'll say, 'Here is my membership money, don't take my phone number, don't take my email address.' They still have the Big Brother kind of fear."

At the same time, newly arrived Indian Zoroastrians in North America as well as second- and third-generation descendants may avoid joining their local communities because of the

An image of the Prophet Zarathushtra hangs in a shrine built around an old well in Mumbai. Scholars believe Zoroastrianism influenced the Abrahamic religions—Judaism, Christianity, and Islam—with concepts of heaven and hell, resurrection, and a single, all-powerful deity.

BALAZS GARDI

looming influence of Parsi orthodoxy. “They’ll say, Oh, but I married a Hindu, I married an American guy, so I’m not going to be allowed,” said Wadia. “I’ll say, Who told you that? Everybody is allowed. Even non-Zoroastrians can enter our place of fire and actually worship. We are not going by the same set of standards and rules that we have in India.”

Ariane calls himself a Zoroastrian by choice, having grown up in a secular household with Muslim parents. He finds solace in the faith’s emphasis on free will and personal responsibility.

“We are in the driver’s seat, and we have to take control. We can make this a better world and not have to wait for a savior to show up,” he said. “Many religions are waiting for a savior to come and solve all the problems. And you’re forgetting that it’s us who needs to make the move.

“We were given brains and knowledge,” he continued. “It’s our responsibility to use it for good things.”

To progressive followers like Ariane, Zoroastrianism is open to all, unencumbered by the restrictions and rituals put on the religion in later literature. The focus of the faith rests on the Gathas, hymns reflecting the conversations between the Prophet Zarathushtra and the Supreme Being, Ahura Mazda. Gathas are devoid of commandments. Zoroastrian prayer is mostly a series of meditations on what one should do. “What do the millennials call it?” Ariane asked. “Manifesting?”

Seven-year-old Aaria Boomla departs the Iranshah Atash Bahram, one of India's holiest sites, after being formally inducted into Zoroastrianism. The sacred fire at this temple has burned for 1,300 years.

MATTHIEU PALEY

BALAZS GARDI

MALABAR HILL is one of the priciest neighborhoods in the growing megacity of Mumbai, where more than 20 million residents vie for living space in ever higher apartment buildings. But Doongerwadi forest, 55 acres of wooded calm where Parsis have disposed of their dead for centuries, remains a respite in the center of the chaos. "These are the lungs of Mumbai," said Rashneh Pardiwala, waving her hand at the tall banyan and mango trees around us. Pardiwala, a Parsi, is the founder of India's Centre for Environmental Research and Education. She grew up near these woods as a practicing Zoroastrian.

The faith's scriptures outline the care that must be taken to avoid defiling water, earth, and fire. One way Zoroastrians did this for millennia was by placing dead bodies on mountaintops and in *dakhmas,* or "towers of silence," where the flesh is eaten by scavengers. The Parsis started building their towers of silence three centuries ago in Doongerwadi, on what was then the outskirts of Mumbai. Today, the five circular towers are overshadowed by enormous apartment blocks. A stone wall encircles the precinct, accessed by a single road that ends atop a hill dotted with a few low-slung buildings.

Non-Zoroastrians attending burials in Doongerwadi are allowed only in two open-air guest pavilions and are prohibited from going anywhere near the towers. Even Parsis

Family and friends celebrate Nowruz (Zoroastrian New Year) at the home of Arman Ariane (second from right) in Claremont, California. In contrast to India's Parsis, who don't seek or accept converts, most Zoroastrian groups in North America are open to all.

are prohibited from exploring the forest and disturbing the purity of the soil beyond the paths to the towers. But Pardiwala persuaded the community board that manages the forest to allow her to study a five-acre parcel. Since then, she's revived parts of the forest with more than 12,000 saplings from more than 50 types of native trees.

In the hushed, green expanse of Doongerwadi, surrounded by the vastness of modern Mumbai, there's a constant reminder of the endless march of progress and its unintended consequences, which can alter even the most ancient of religions. The native vultures that Zoroastrians have relied on to dispose of their dead are long gone from the forest, inadvertently poisoned by a drug used to treat Indian cattle in the 1990s. Caretakers now rely on solar concentrators to hasten decomposition—and reduce complaints from neighbors.

Pardiwala and I settled in on heavy wooden benches in Doongerwadi's century-old guest pavilion, recently renovated by her family. Her mother, she quietly noted, died just before its completion and was unable to see how it turned out. "Look at the stained glass," she said, pointing up at a colorful panel depicting mobeds praying over a sacred fire and a dog—believed to be a steadfast spiritual friend of Zoroastrians, which helps guide the human soul from this life to what follows.

For more than three millennia, followers of Zarathushtra have memorized and repeated the Ashem Vohu, one of the faith's most important prayers. One translation goes like this:

> Righteousness is the best good and it is happiness.
> Happiness is to her/him who is righteous
> for the sake of the best righteousness.

In the chaotic first decades of the 21st century, as old orders collapse and truth, asha, is increasingly difficult to discern from lies, druj, there's solace in this prayer, both in the simplicity of its message and the challenge it poses. It's a challenge that Zoroastrians have aspired to meet for millennia—from the spiritual leaders of an empire and the tenders of centuries-old fires to modern generations trying to nudge the universe toward a more perfect order.

Enormous crows swooped between Doongerwadi's soaring trees, filling the air with their insistent caws. Suddenly, two white-veiled mobeds emerged from a nearby building with a leashed dog. They're followed by the body of a recently deceased Parsi, wrapped in a white shroud and carried on a metal bier. "Stand up," Pardiwala whispered. The funeral procession moved past us and up the hill toward a tower of silence. A handful of other dogs lazing in the shade got up and trotted behind the procession. Then all disappeared into the forest and the golden afternoon light. □

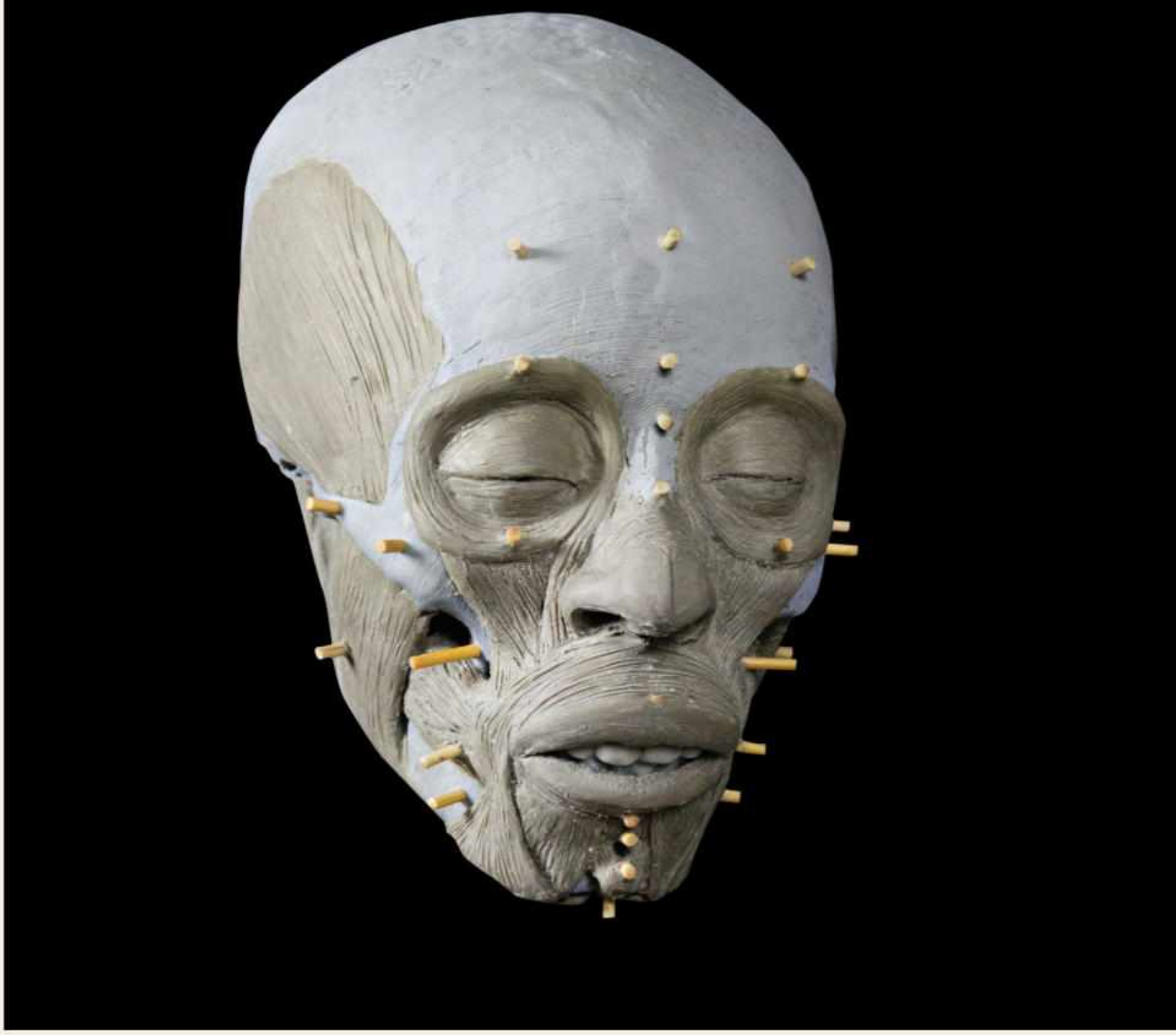
Praying before the flame of their faith, Setareh Mandegarian and son Kiyan Khadem light a candle in celebration of Nowruz at the California Zoroastrian Center in Westminster.

BALAZS GARDI

BACK *to* LIFE

More than 500 years after her death in the Andes and nearly three decades after her discovery, we're finally able to put a face on the Ice Maiden of Ampato.

Words by
ERIN BLAKEMORE



SOMETIME IN THE MID to late 1400s, a 15-year-old girl was escorted up an Andean peak and sacrificed to Inca gods. Buried on the mountain with a variety of offerings, the young woman's body naturally mummified over time, with her hair, her fingernails, and the colorful robes she wore on her last day intact. But at some point across the centuries, her face became exposed to the elements, her features slowly vanishing over seasons of sunlight and snowfall.

Now that long-lost face has been recovered, thanks to painstaking archaeological analysis and forensic reconstruction. A striking 3D bust of the young woman, known today as the Ice Maiden of Ampato, is the centerpiece of a new exhibit in Peru and part of an ongoing effort to understand the practice of human sacrifice in the Andes half a millennium ago.

The face of the Ice Maiden (above) was reconstructed from a 3D copy of her skull (left) using a technique that extrapolates how soft tissue and muscle drape the bone. The girl was 15 when she was sacrificed on Mount Ampato in Peru.

PHOTOS: OSCAR NILSSON (SKULL); DAGMARA SOCHA, UNIVERSITY OF WARSAW

A SACRIFICIAL OFFERING

When National Geographic Explorer Johan Reinhard encountered the mummy, also known as Juanita, atop 20,700-foot Mount Ampato during a 1995 expedition, he knew almost immediately that he had found something spectacular.

"At first it looked like one big bundle of textiles," Reinhard recalls. But then he saw the wizened face amid the folds of fabric. Here was a young victim of the mysterious Inca ritual known as *capacocha*.

The practice sacrificed mostly children and young women, who were offered to the gods not only in response to natural disasters or simply to please them but also to consolidate state power in far-flung provinces of the Inca Empire. Capacocha played an important part in sustaining the empire and involved feasts and grand processions to accompany the children, who appear to have been chosen for their beauty and physical perfection. Being selected for sacrifice, researchers believe, would have been considered a deep honor by the child's family and community.

Most of the information that's known about capacocha, however, is secondhand. Dagmara Socha, an archaeologist with the Center for Andean Studies at the University of Warsaw, studies the ritual and commissioned the facial reconstruction of the Ice Maiden of Ampato. "No European colonist ever saw the ceremony," she explains.

Despite gaps in the historical record, the high-altitude archaeological discoveries of more than a dozen Inca children on Ampato and other Andean mountains provide critical evidence for what happened during these rituals.

The means of sacrifice varied, perhaps because of customs related to specific gods. Some children were buried alive or strangled; others had their hearts removed. The Ice Maiden's life ended with a single blunt-force blow to the back of her skull.

PHOTO: JOHAN REINHARD. NGM MAPS

IN SEARCH OF THE ICE MAIDEN

Oscar Nilsson knows the girl's skull well: He spent months with a replica of it in his Stockholm studio, eventually fashioning a sculpture of her that, glimpsed from afar, almost seems alive.

It was a two-step process, says the Swedish archaeologist and sculptor. First, Nilsson immersed himself in the world of his subject with an archaeologist's eye for detail, digesting as much data as possible to understand what she might have looked like. Even without her mummified face, he could extrapolate the likely depth of the facial tissue that once draped those bones—using everything from CT scans to information about diet and disease—to make educated guesses about her face.

Then came the handiwork. Nilsson printed a 3D replica of the Ice Maiden's skull, plugging wooden pegs onto its

"At first it looked like one big bundle of textiles," recalls National Geographic Explorer Johan Reinhard of the mummy found in 1995. Reinhard's climbing partner, Miguel Zárate (left), is shown during the moment of discovery.

surface to guide the depth and placement of each handcrafted, plasticine clay muscle. Eyes, masseters, a nose, the delicate ropelike tissues that constitute a human face—each was added in turn. After using a mold to make a silicone bust, he added hundreds of individual hairs and pores in shades of brown and pink. It took 10 weeks.

A STAR ATTRACTION

The resulting sculpture, wrapped in robes woven by women from Peru's Centro de Textiles Tradicionales del Cusco, is the main attraction of "Capacocha: Following the Inca Gods," which opened in November 2023 at the Museo Santuarios Andinos in Arequipa.

The Ice Maiden reconstruction is displayed alongside her mummified remains and accompanied by the stories of 18 additional children selected for capacocha atop Ampato and other Andean mountains. Their ages range from eight to about 16, and the mummies and skeletal remains of several are featured as 3D models in the exhibition, which also showcases holographs of some of the sacred items buried alongside them.

These natural mummies offer scientists intriguing clues about their last days. When Socha and colleagues conducted toxicological and forensic analyses of the remains of a toddler and four six- to seven-year-old victims of capacocha, the researchers found that they were well nourished in the months before their sacrifice. They were also fed coca leaves, ayahuasca vine, and alcohol in the weeks before their deaths—perhaps not so much to intoxicate them as to keep them sedated and anxiety free while the timeline hurtled toward their sacrifice.

"We were really surprised" by the toxicology results, Socha says. "It wasn't only a brutal sacrifice. The Inca also wanted the children to be in a good mood. It was important to them that they go happily to the gods." High altitude, psychotropic substances, the dramatic view, the knowledge the afterlife was near—all must have made for an astonishing ceremony, says Reinhard. "The whole phenomenon must have been overpowering."

During the last phase of Nilsson's reconstruction, he spent hours contemplating, and attempting to capture, the young girl's presence half a millennium after her death. The result is both unsettlingly realistic and jarringly personal. "She was an individual," the forensic reconstructionist says. "She must have understood her life would end on the mountaintop in a couple of weeks. We can only hope that she believed in the afterworld herself."

For Reinhard, the Ice Maiden's story came full circle when he finally saw the face of the girl he carried down the mountain on his back decades ago. "It brings her back to life," he says. The reconstruction focuses as much on her culture and daily life as on her violent death.

But Nilsson never forgot the way the Ice Maiden died, even as he revived her through his reconstruction. More than anything, he says, he wanted to convey a sense of being frozen—a nod not just to her icy, mummified future but also to a girl teetering on the edge of eternity, though still very much alive.

"She knew she was supposed to smile, to express pride," he says. "Proud to be chosen. But still very, very afraid." □

For millennia, Indigenous peoples etched and painted their stories across the landscape of present-day North America. Today, as more artworks are revealed, Native and non-Native experts are bringing a rich cultural heritage into view.

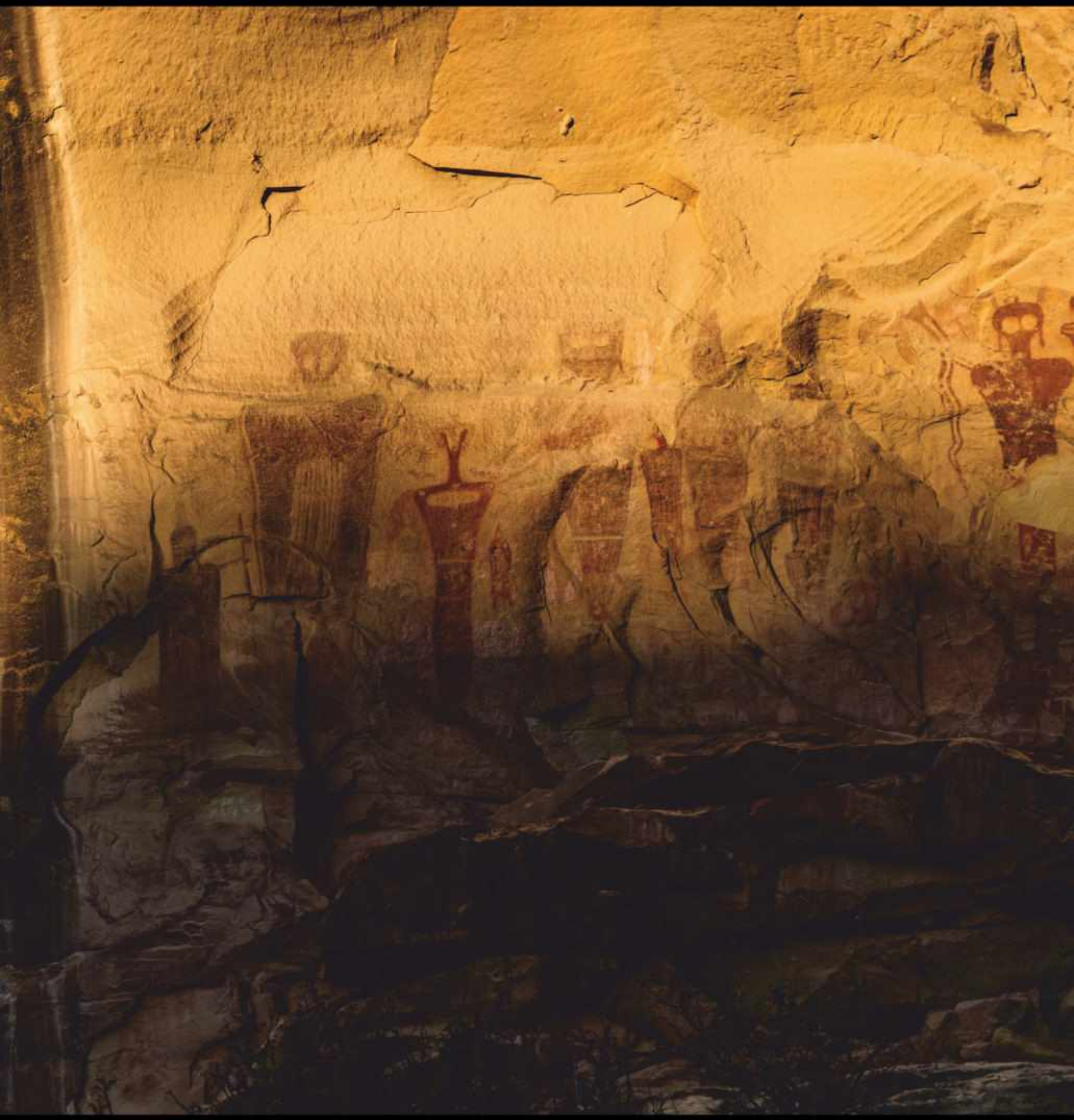
STORIED ROCK

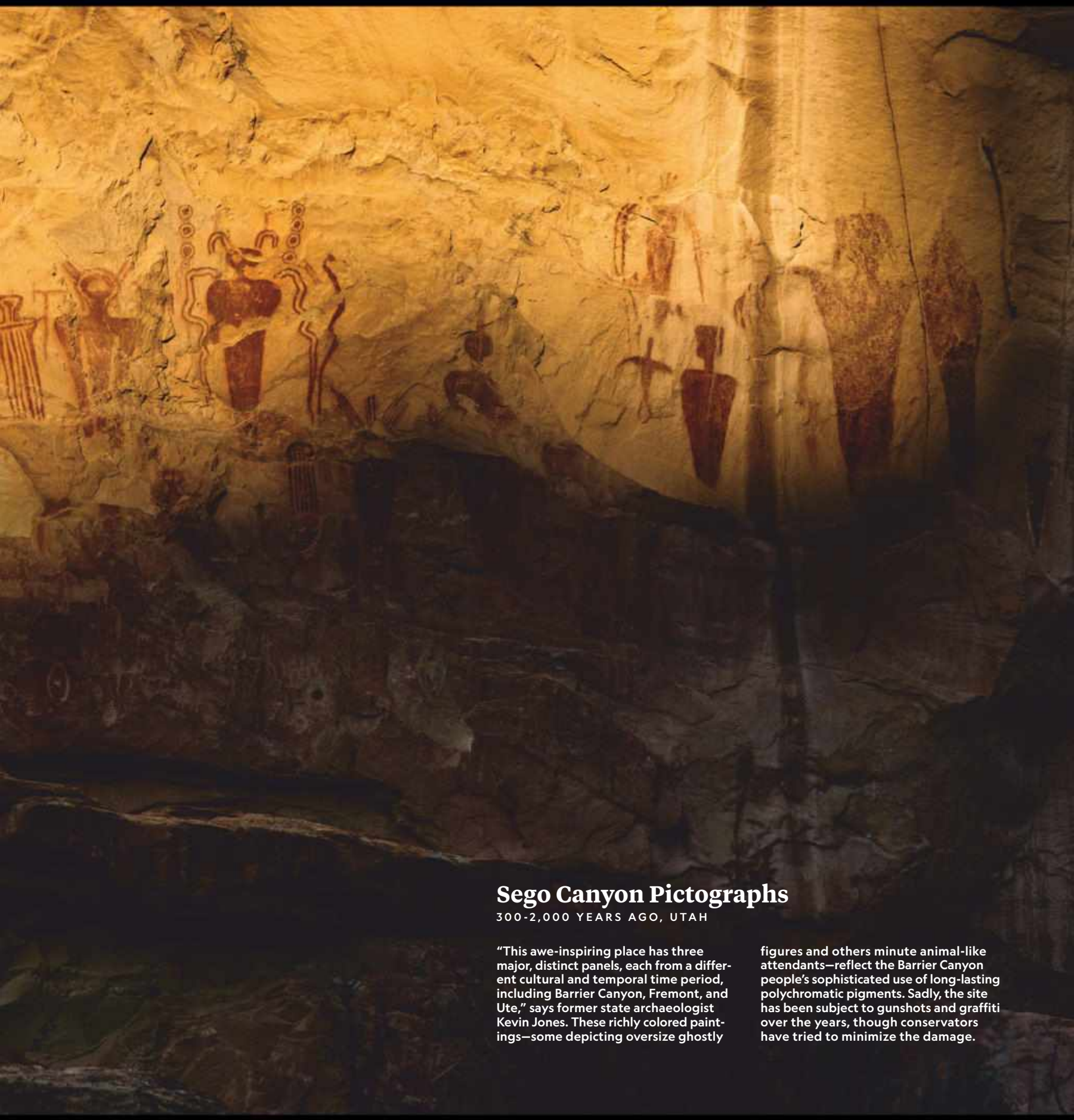
WORDS BY **KATE NELSON**
PHOTOGRAPHS BY **STEPHEN ALVAREZ**

Three Rivers Petroglyph

800-1,400 YEARS AGO, NEW MEXICO

Created by the Jornada Mogollon people, this carving, thought to be of a large cat with a rattlesnake tail, is one of 21,000 densely packed petroglyphs spanning one mile of basaltic ridge set against the picturesque Sierra Blanca.





Sego Canyon Pictographs

300-2,000 YEARS AGO, UTAH

"This awe-inspiring place has three major, distinct panels, each from a different cultural and temporal time period, including Barrier Canyon, Fremont, and Ute," says former state archaeologist Kevin Jones. These richly colored paintings—some depicting oversize ghostly figures and others minute animal-like attendants—reflect the Barrier Canyon people's sophisticated use of long-lasting polychromatic pigments. Sadly, the site has been subject to gunshots and graffiti over the years, though conservators have tried to minimize the damage.

‘None of us want to fade away without having made our mark on the landscape.’

ARCHAEOLOGIST JOE WATKINS (CHOCTAW NATION)

NATIONAL PARK SERVICE

Immortalized in gypsum-rich deposits, these footprints at New Mexico’s White Sands National Park are more than 20,000 years old and upend previous assumptions about the duration of human life in North America. “It’s geographical, geological, and climatological happenstance that they are there,” says Watkins. “You can see this path that people took 20,000 years ago as they walked across the landscape.”

THERE IS SO MUCH WE KNOW FOR CERTAIN A ANCIENT INDIGENOUS AR

When preci was it mad What exac did it mean t creators

And yet there is still so much to be learned from these works carved into rock, painted on stone, drawn in mud, or built into the Earth’s surface. Perhaps most important is that thriving Native American societies, including my own, have inhabited Turtle Island, as many tribal peoples prefer to call North America, for tens of thousands of years.

Considered alongside a contemporary Native reckoning—with historic Indigenous representation across everything from politics to pop culture—these sophisticated petroglyphs, pictographs nect our pa Native-desc art represe revitalizati ways that v colonialism

“We’re s our religio language; e stands the says Chief E Tribe, whos Serpent Mo

Halo Shelter Pictographs

2,000 YEARS AGO, TEXAS

One of the best preserved examples of Pecos River-style Shelter’s limestone wall, features a complex hundred-foot anthropomorphic, or human-like, figures intermixed with enigmatic icons. “These represent ancestral deities and s with the artists’ sacred stories,” says artist turned archae founder of the Shumla Archaeological Research & Educa organization’s extensive radiocarbon dating indicates tha was planned out and painted in a single episode, requirin effort away from hunting and gathering.

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Ben Barnes of the Shawnee
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Americans have forgotten that land itself can be sacred, that spaces can be holy. Here in the Americas, our holy spaces are Indigenous."

Photographer Stephen Alvarez has been documenting natural wonders for nearly three decades. He founded the nonprofit Ancient Art Archive in 2016 to act as a living record of prehistoric paintings and engravings worldwide. Now he has focused his lens on America's murals—an effort to put this nation's 250th anniversary, in 2026, in the context of millennia-old history. "The landscape tells its own story," says Alvarez. "What happened to it over time, who lived there, and what they did. You cannot separate the artwork and the landscape."

For the archaeologists, anthropologists, ethnographers, artists, and other knowledge keepers—both Native and non-Native—who have spent much time studying and preserving these artworks, they are masterpieces, as well as miracles, withstanding the elements for centuries so people may wonder at and about them today.

"None of us want to fade away without having made our mark on the landscape," says archaeologist Joe Watkins (Choctaw Nation), who works on Alvarez's Mural of America project. "Rock art gives us an opportunity to share insights from people who no longer walk this Earth."

For everyone, this artwork is a call to recognize and revere the legacies that ancient Indigenous peoples left behind. It's an urging to acknowledge the traumas that our communities have endured on Turtle Island and beyond. And it's a reminder that Native Americans have long been here—and that our voices, stories, and art from the past matter just as much as what we're creating today and what we'll create tomorrow. □

19th Unnamed Cave

1,500-2,000 YEARS AGO, ALABAMA

DRAWING: JAN SIMEK

By the time they noticed faint tracings on this subterranean mud surface, cave explorer Alan Cressler and archaeologist and University of Tennessee professor emeritus Jan Simek had spent years studying cave art together

in areas unreachable by natural light. But it wasn't until photographer Stephen Alvarez produced a 3D model using photogrammetric technology that they could actually visualize this six-foot-tall anthropomorph in regalia. It's one of thousands of intricate, extremely fragile drawings known as mud glyphs adorning the ceiling of a 5,000-square-foot chamber that's just two feet high in spots—requiring its Indigenous artists to lie down to draw these works by torchlight.

Rochester Panel

700-4,000 YEARS AGO, UTAH

On a narrow peninsula above the confluence of Rochester Wash and Muddy Creek, this sacred site is home to 13 panels of Barrier Canyon- and Fremont-style petroglyphs and pictographs. The main panel shows more than a hundred figures, including mythical beasts and more recognizable animals

and plants. Spiritual elder Larry Cesspooch (Ute Indian Tribe) and archaeologist Jamie Hollingsworth (Navajo Nation) explain the rainbow could indicate a connection to the spiritual world, a blessing, a protective force, or perhaps a more literal plea for rain in an arid climate.

Tolar Petroglyphs

400-500 YEARS AGO, WYOMING

Added to the National Register of Historic Places a decade ago, this sandstone rock formation features more than 30 petroglyphs scattered across 500 feet. As Watkins explains, ancient Indigenous artworks often reflect a "connection of people to place," including the flora, fauna,

and cosmology of an area. That's exemplified in this depiction of a horse and rider created by Plains tribes artists, which pays homage to Indigenous peoples' long-standing relationship with equines. The outcrop also includes carvings of anthropomorphs, warriors, bears, and other cultural motifs.

Serpent Mound Effigy

900 YEARS AGO, OHIO

In 2021, the Shawnee people returned to their ancestral homelands to reclaim the world's largest remaining earthwork effigy, whose origins have long been the subject of pseudo-scientific theories. "Our people built this—not giants, not ancient aliens," says Chief Barnes.

“This magnificent work of civil engineering was a massive community endeavor. I want my people to experience the ceremony of going home and seeing this sacred serpent built with soil that our ancestors held in their hands.”

Blythe Intaglios

450-2,000 YEARS AGO, CALIFORNIA

Some of the most notable of the American West's hundreds of geoglyphs, these giant distinct figures—six in total, with the largest measuring 171 feet long—were designed by scraping away the dark desert varnish to reveal lighter-colored stone. Though the artists behind these so-called Nasca

Lines of North America, and their intentions, remain unknown, the Mohave and Quechan peoples of the Lower Colorado River believe the human figures represent Mastamho, the Creator of all life, while the animal figures represent Hatakulya, who helped in the creation.

Three Rivers Petroglyphs

800-1,400 YEARS AGO, NEW MEXICO

Set along the eastern edge of the Tularosa Basin, part of the Rio Grande Rift, this site is one of the Southwest's most notable petroglyph areas. The more than 21,000 carvings vary in their symbology and technique, with some appearing as scratches, and others, such as the bighorn sheep pierced by

a spear and arrow (at left), made using two rocks as a hammer and chisel. Rock art researcher Margaret Berrier thinks that given the lack of nearby habitation sites, this was likely a seasonal gathering place for trading and ceremonies.

Hog Springs Pictographs

LESS THAN 2,000 YEARS AGO, UTAH

The mysterious Moki Queen got her informal title thanks to a series of white dots arching above her head that many viewers construe as a crown, says archaeologist Kevin Jones. The animal-like figure by her side is often interpreted as a dog. Because of its proximity to Highway 95 and the

popular Glen Canyon National Recreation Area, this elaborate, oversize Barrier Canyon-style painting has captured the attention of many adventurers. Other pictographs and petroglyphs adorn nearby canyon walls.

Wedding Rocks Petroglyphs

200-500 YEARS AGO, WASHINGTON STATE

Hikers consider themselves lucky to stumble upon these unmarked petroglyphs located along Olympic National Park's Pacific coast. Best seen at low tide, the 40-some etchings by Makah artists depict whales, hunters, ships, and other motifs. According to tribal oral history, a mudslide partially

destroyed the village of Ozette, one of the Makah Tribe's five permanent settlements. Then, in 1970, a severe storm battered the coastline and surfaced about 55,000 preserved artifacts bearing similar iconography. Many of these objects are now on display at the Makah museum in nearby Neah Bay.

LENDING AID *to* LEMURS

A scientist is betting on 'bacon bugs' to help Madagascar's critically endangered primates.

Words by
DINA FINE MARON

Photographs by
NICHOLE SOBECKI

→ **"THIS IS HOW** I got my eye amoeba," Cortni Borgerson says, staring up into the massive branches of a 100-foot-tall tree in search of a rare red ruffed lemur, a cat-size primate that lives only in this area of northeastern Madagascar.

She and Pascal Elison, a Masoala National Park tour guide, had raced to the area a few minutes earlier, as the animal's roar-shriek echoed through the forest. Dodging face-size leaves, scurrying over slippery tree roots, and carefully avoiding any vines that might be thorny, poisonous, or both, they ran while scanning the canopy above them for glimpses of reddish brown fur.

Suddenly, there's a sound like the patter of rain on leaves, and then a loud *crack* as something hits the ground nearby. "Lemur diarrhea," says Borgerson, a primatologist

On Madagascar's Masoala Peninsula, a red ruffed lemur, a commonly hunted species, perches high in the forest canopy.

and National Geographic Explorer, who recalls the splash that once landed on her face and likely gave her the amoeba. Besides pathogens, the poop often includes nuts from one of the area's colossal trees and nutrients that support future forest growth.

Wild lemurs are found only in Madagascar, where they act as essential seed dispersers and pollinators that encourage healthy ecosystems. At the same time, the red ruffed lemur is critically endangered, becoming increasingly hard to spot because of hunting and habitat loss.

While hunting lemurs has been illegal since the 1960s, when other foods are scarce, people trap and eat them. One reason: Bushmeat consumption improves infant survival rates, says the Chicago Field Museum's Steve Goodman, a Madagascar expert. United Nations figures say almost half the country's children suffer from chronic malnutrition, and in this region, called the Masoala Peninsula, nearly 90 percent of locals have eaten lemur, according to Borgerson's research. Red ruffed lemurs and white-fronted brown lemurs are the most likely to end up in people's dinner pots, because they're relatively easy to catch and are considered particularly tasty. What's more, in Malagasy cities, lemur meat is now offered as a clandestine luxury

The nonprofit National Geographic Society helped fund field reporting for this article.

Left
Be Noel Razafindrapaoly (with stick), Velombita Dede, and Cortni Borgerson examine an animal trap.

Right
A local soccer team's jerseys feature the sakondry, an insect that's now increasingly farmed.

food, though on a much smaller scale than in the rural areas.

Martin Baba, sector chief for a vast swath of Masoala National Park, says he and his team regularly find lemur traps in the woods—contraptions made from ropes, string, and bait. "It's really frustrating," he says, and almost impossible to catch culprits in the dense forest, but "the problem is there isn't enough meat here."

Borgerson, who speaks fluent Malagasy and splits her time between working in Madagascar and teaching at Montclair State University in New Jersey, wants to help save lemurs from hunting without leaving Masoala communities hungry. That's why she's turned to bugs. They've been a food source in Madagascar for at least 400 years, and a specific type called sakondry could be a game changer for lemurs, she says.

Closely related to the cicada, the peculiar-looking bug has a unicornlike pink protrusion in the front (its nose) and a white fluffy backside that strongly resembles a feather boa. The fluff is constantly shed on nearby plant vines. "We're not sure, but we think it's a lung irritant to keep predators away," Borgerson says. Nicknamed the "bacon bug" for its meaty flavor and fat content, the creature has long been considered a delicacy in the area, but it wasn't farmed. Now that's changing.

ONE SEPTEMBER AFTERNOON, in a village abutting Masoala National Park, 14-year-old Kalandy plucks sakondry off lima bean plants in her yard. The plants are flourishing thanks to seeds and guidance supplied by Borgerson. Kalandy rinses the bugs and quickly cooks them with salt before offering photographer Nichole Sobecki and me a taste. I pop one, whole, into my mouth. It does taste unctuous—like bacon. It's also reminiscent of popcorn. "I may have added too much salt," Kalandy says, giggling.

Borgerson was first exposed to these bite-size bugs as a "drunk food" that locals snacked on while drinking. Curious, she spent several years learning more, and in 2019 she launched bug farm training in three communities in northeastern Madagascar—going from home to home with local hires to distribute bean seeds and

NGM MAPS

teach people how to tend to the plants and the bugs they attract.

Why sakondry? They're easy to work with, are quite tasty, and have few predators. They're also fast-growing—it takes only 72 days from hatching to harvesting. Since the bugs drink only a small amount of their hosts' sap, the plants continue to grow and serve as human sustenance themselves. The only real catch is that the plants may not survive well everywhere in the country because of climate differences. Borgerson is also studying how densely they can be grown to boost bug yield. Charles Welch, the conservation coordinator at Duke University's lemur center, says sakondry farming probably won't be enough on its own to combat lemur hunting, but it's certainly "part of the solution."

Grasshoppers and locusts are "meat and potato" bugs in Madagascar, but sakondry are more like prime rib, says California Academy of Sciences entomologist Brian Fisher, who helped with Borgerson's early work. Sakondry are so in demand that sometimes they're priced on par with beef. Borgerson says her program isn't focused on commercial sales but on saving lemurs.

In just three years, the project has reduced lemur hunting by at least 50 percent in pilot communities and spared at least 58 individual lemurs, according to the International Union for Conservation of Nature, which helped fund the work.

"I'm excited about this new idea," says Malagasy primatologist Jonah Ratsimbazafy. And the program is expanding. Tim Eppley, chief conservation officer for Malagasy nonprofit Wildlife Madagascar, says his group is planning to partner with Borgerson to bring the bug farming to at least 3,000 more households in northeastern Madagascar in 2024.

Part of the sakondry's popularity, say Borgerson and Be Noel Razafindrapaoly, country manager for Borgerson's project, is that the bug is "clean"—it crawls on host plants rather than in the dirt. Sakondry have become an integral part of everyday life here too. In Kalandy's village, members of the leading men's soccer team dubbed themselves "Sakondry" and hired an artist to paint the bug on the back of each of their jerseys. "It's not a silver bullet," Borgerson says, but the bug farming offers "natural fat and national identity."

In the village near Masoala National Park, Velombita Dede, the most productive sakondry farmer, grows bean plants to lure the bugs. Last year, Dede says, he had enough sakondry to help feed his extended family of eight, alongside the local staple of rice. He harvested 800 bugs a month and sold the excess. To better attract sakondry, he says, he uses handmade wooden supports that keep the plants upright, and now he trains others in his village.

With their ostentatious anatomy, the insects lining his plants look like they're queued up to get into a fancy bug club. As we watch, the wind scatters bits of white fluff, like dandelion seeds, onto nearby plants studded with more bugs of varying sizes. The biggest ones, at about two inches long, are ready to harvest. ▯

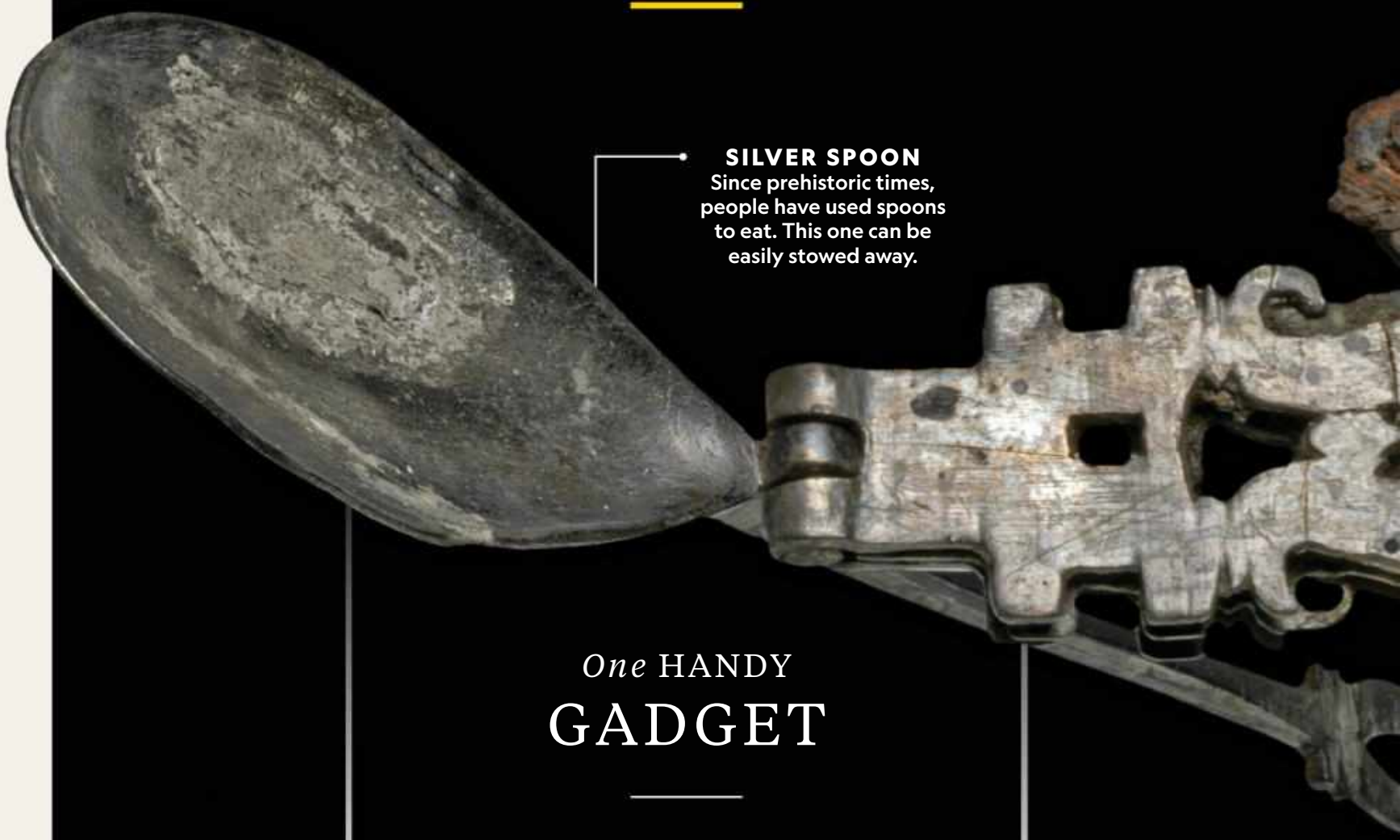
Kalandy rinses the bugs and *quickly cooks* them with salt before offering photographer Nichole Sobecki and me a taste. I pop one, whole, into my mouth. It does taste unctuous—LIKE BACON. It's also reminiscent of popcorn.

Right

With its long pink nose and fluffy rear end, the sakondry stands out but has few predators.

Below

When farmed and consumed, these nutritious insects, aka bacon bugs, may help combat chronic malnutrition among the Malagasy people and relieve hunting pressure on endangered lemurs.



SILVER SPOON
Since prehistoric times, people have used spoons to eat. This one can be easily stowed away.

One HANDY GADGET

Words by
BECKY LITTLE

WHAT
Portable multi-tool

WHEN
A.D. 200-300

WHERE
Mediterranean region

→ **LONG BEFORE** Switzerland began issuing "Swiss army knives" in the 19th century, a skilled artisan in the Roman Empire made a similar device containing not only a blade but also a spoon, fork, pick, spatula, and spike. It's "one of the most complicated" folding utensils that we have today from the Roman Empire, says Anastasia Christophilopoulou, senior curator at the Fitzwilliam Museum in Cambridge, England. When the tool was acquired in the 1990s, parts of its story were incomplete. Later analysis revealed the tool was at least 1,700 years old. Most ancient Roman folding knives are made of bronze, but this one contains silver, a soft metal, suggesting it was a luxury item and used sparingly. "We think this was something that a person would have used in the context of showing off," Christophilopoulou says. "It's not an object used every day—it is a special object." □

PHOTO: FITZWILLIAM MUSEUM, UNIVERSITY OF CAMBRIDGE

SLICE AND DICE
In its prime, the knife was likely used for meal preparation or dining instead of as a weapon.

MYSTERY TOOL
Eating or personal hygiene? This spike might have speared food or cleaned ears.

EXTRACTOR
This tool's shape is ideal for removing snail meat from shells. It could also have been a toothpick.

GOOD TINES
Romans may have used forks to serve food rather than to carry it to their mouths.

SCRAPING BY
A diner could have gotten that last bit of sauce or paste out of a narrow bottle with this small flat disk.

WATER *from the* CHALK

Welling up through white porous rock, England's chalk streams are prized by anglers and poets alike. Now supporters are wading in to help them thrive.

Words by **ADAM NICOLSON**
Photographs by **CHARLIE HAMILTON JAMES**

Simon Cain, a pioneer of river restoration, fishes the Bourne Rivulet in Hampshire. The small chalk stream was overly deep from dredging and cloudy with silt until Cain restored its gravel bed and revived its ecology.

Riverkeepers cut water crowfoots back in the Hampshire Avon. Such plants provide shade and shelter for river life, but summer excess can make fishing impossible.

Step into the water

of an English chalk stream,

two or three feet deep, shaded

by willows and alders,

and you feel the pressure

and cold of it around

your knees and thighs.

THE GRAVEL UNDERFOOT IS DAPPLED with sunlight reaching down to the river floor. All around you the motion of the water is sustained and untroubled, the current never urgent. Because chalk streams are spring fed and little silt finds its way into them, visibility is aquarium clear. The trout within them seem to hang in air.

These streams take their quality from the rock over which they run: alkaline, mineral rich, with dissolved calcium carbonate but almost no sediment, flowing to the sea over many miles of clean flint-gravel bed. Bubbling up from springs that emerge from deep aquifers in the chalk, they run through valleys fringed with water mint and clusters of water forget-me-nots, often thick with life-sheltering weeds. Not subject to the surges of rivers that run over harder rocks, they flow steadily through the English chalk country, whose gentle landforms billow across the nation's southern and eastern reaches.

Chalk is a pure type of limestone composed of tiny shells of marine organisms. Deposits are found worldwide, but

The River Anton in Hampshire is healthy enough to support brown trout and grayling, but murky water is a sure sign of trouble, including polluted runoff from roads and farms.

in England the geological ripples from the rising of the Alps some 40 million years ago brought a wide swath of it to the surface. It's porous and fractured, with up to 40 percent of its bulk made up of spaces between the rock grains. Rain that falls on chalk sinks into the ground, sometimes taking months to percolate through the hills. In that way, the rivers have a kind of steady maturity about them. Rainstorms produce no floods, and in drought the rivers continue to run. The water acquires the temperature of the rock—50 to 54 degrees Fahrenheit all year. This means that the plants and animals that live in the chalk streams can depend on continuity.

If you go snorkeling in a chalk stream, you'll find yourself "in another world, so absorbing that nothing else encroaches," says Nicola Crockford, inveterate river snorkeler and conservationist with the Royal Society for the Protection of Birds. There are flowering water crowfoots, whose white blossoms unfold first underwater, as well as patches of bright green starworts, with trout and grayling loitering in

their shadows. On the gravel bed, larval cases of caddis flies look like tiny sticks. Young trout parr, tiger striped and quivering, hold their own in some corner of the current, their bodies never still. Farther off in the green dark of the stream, larger fish melt carefully away.

Anyone connected with these rivers talks about them with undisguised love. Zam Baring, who with his brother and sisters runs the Grange at Itchen Stoke in Hampshire—one of England's leading sparkling wine vineyards—says his vines "have their heads in the chalky Hampshire downs and their toes in the sparkling headwaters of the River Itchen." To go wading deep in the tributary that runs below the vineyard, he says, is to "think you've gone to floaty heaven." A lifelong fisherman and co-vice chair of the Wessex Rivers Trust, Baring has helped lead numberless river restorations and celebrates even the smallest streams. "You'll find all kinds of beauties in a quarter inch of water," he says.

Russell Biggs, who champions the needs of chalk streams in the east of the country, says the tiny River Babingley saved his life. His waste-recycling business was struggling and driving him to despair. "I would get home and … " He pauses. "But then to come here, walk by the river … I think if I was in a flat in a city center, I just would not be around, put it that way. It gives you a reason."

THESE ARE NOT THE WATERWAYS of a remote wilderness. The fisherman, journalist, and author Charles Rangeley-Wilson calls chalk streams the rivers of "habitable" country. "It is beauty on your doorstep," he says. "But because they are on your doorstep, they are also very threatened."

Human damage began thousands of years ago and led to a crescendo of change and destruction in the mid-20th century. Cities and farms casually polluted them. Property owners dammed or widened them, slowing their current, ironing out their natural meanders, and removing fallen trees—which make life difficult for anglers but good for fish and other river life.

Slowing a river causes thick mats of silt to settle on the streambed and blanket the gravel, whose clean, aerated spaces the trout and salmon need to lay their eggs. Beneficial weeds—nurseries for invertebrates—grow only in bright, fast water. Without the weeds, the all-important insect life—the many different species of mayflies, stone flies, and caddis flies—collapses. Without the bug life, there is no fish life, no wild brown trout or grayling. Without the fish life, there is no otter life—and none of the magical, quick, quivering presence that gives the rivers their own life.

Miles of the Itchen and the famous River Test, which runs down through the Hampshire chalk to its mouth near Southampton, have been turned into easy-fishing parks with carefully mown banks, gingerbread fishing huts, and huge nursery-raised trout. Fees to fish the most celebrated stretches can run to more than $600 a day. The fast-bubbling water and the varied ecological niches of the natural stream have been erased.

There is also, inevitably in a crowded country, the pervasive influence of pollution. Detergents, microplastics, pharmaceuticals, and heavy metals, as well as waste that's flushed down toilets, all arrive in the streams. Fisherman Paul Jennings has seen his local sewage works discharge waste into the River Chess, north of London, for more than 90 days—68 days without a break. "It was dreadful. You didn't want to go into it. A smell. A muddy color. Nasty, gray, and horrible, with bits in it," he says.

"After rain, the first thing you see coming down the river is the diesel washed off the roads," says riverkeeper Peter Farrow, who works for a private estate that includes a stretch of the Test. Soil from careless plowing near the rivers chokes many of the clean gravels on which the fish rely. Overuse of phosphate and nitrate fertilizers in agriculture overstimulates the rivers, whose beds then clog with filamentous weeds, which

"smother invertebrate eggs, get in the gills of fish, and choke out the beneficial plants, the oxygenators," says freshwater ecologist Janina Gray, deputy CEO of the conservation group WildFish.

A political system that puts cheap tap water before river health has not helped. If anything is worse than a polluted chalk stream, it's a river that has been denied the water that is its very life—water that has been sucked from the underlying aquifers to service human needs. In some places, the water table has dropped more than 20 feet. "If you have a river that's dry, there is no point in worrying about water quality and habitat, because it's just not a river," says Rangeley-Wilson. "Flow is fundamental."

ALL ACROSS CHALK COUNTRY, river advocacy groups have emerged in the past few years. Forced to stay home during pandemic lockdowns, many people discovered their local rivers, and public pressure for change has never been more intense. Over the past 20 years or so, advocacy groups, water companies, and government departments have written a series of large-scale, multidecade plans for reservoirs, desalination plants, domestic water meters, and water transfer networks to reduce the amount of water taken from the chalk. Increasingly, rivers are having their natural form restored.

Simon Cain began almost single-handedly to invent chalk stream restoration in England after being jolted into action one grievous summer afternoon in 1984. As he fished the River Ebble in Wiltshire, "the water turned chocolate," he says. Upstream he could see a large orange machine moving its digger arm in and out of the riverbed. The Ebble was being dredged, with government funding, to lower the water table in the surrounding meadows, perhaps to make them suitable for arable crops. In the detritus, Cain spotted hundreds of rare and endangered crayfish "all grasping

STREAM SAMPLER

Although most stretches of chalk streams are privately owned, glimpses of their beauty can be enjoyed on long-distance footpaths and at bridge crossings, or for a fee with a fishing charter.

BEST WALKS

In Hampshire County, the **Test Way** begins at Inkpen and ends 44 miles later at Eling. The 32-mile **Itchen Way** traces its namesake from source to mouth, starting at Hinton Ampner and concluding at Sholing Station. To see a stretch of restored chalk stream, take a stroll along the **Nar Valley Way** from the pretty Norfolk County village of Castle Acre, where you'll find pubs, picnic areas, and restrooms.

QUICK LOOKS

For a snapshot of a classic chalk stream, stand on the bridge over the **River Avon at Breamore** in Hampshire, where the view includes trout-filled water and an ancient mill. Or try the footbridge over the **River Test at Whitchurch** in Shropshire. Local children have for years thrown bread into the water below the bridge, resulting in some of the fattest trout you'll ever see.

FISHING

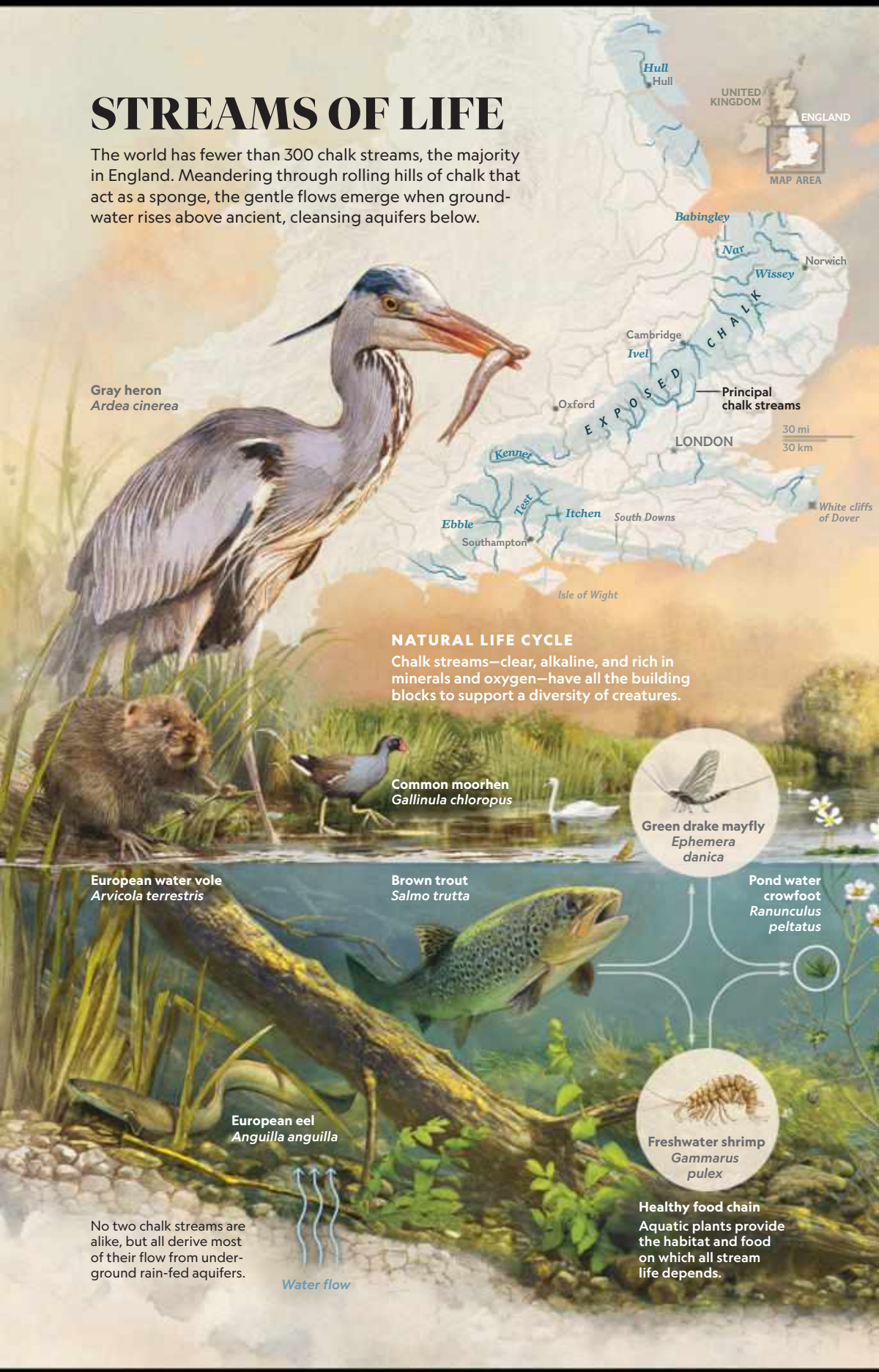
Day tickets to fish stretches of more than a dozen chalk streams are available at *fishingbreaks.co.uk* and other companies. Prices range from $100 to $600. Try **Coombe Mill** on the Avon ($200 to $300), where riverkeeper Martin Aris will introduce you to the mysteries and alluring habits of wild trout.

EAT, SLEEP, FISH

The **Bush Inn** pub at Ovington is an ideal place to start or finish a hike along the Itchen with a hearty meal. **Grosvenor Hotel** at Stockbridge on the Test is one of the upscale temples of dry fly-fishing and offers comfortable accommodations.

STREAMS OF LIFE

The world has fewer than 300 chalk streams, the majority in England. Meandering through rolling hills of chalk that act as a sponge, the gentle flows emerge when ground-water rises above ancient, cleansing aquifers below.



Gray heron
Ardea cinerea

100-60

STREAM FORMATION > DEPO

Europe
teemin
coccoli
sunken

Banded demoiselle
Calopteryx splendens

NATURAL LIFE CYCLE

Chalk streams—clear, alkaline, and rich in minerals and oxygen—have all the building blocks to support a diversity of creatures.

Eurasian otter
Lutra lutra

Common moorhen
Gallinula chloropus

Green drake mayfly
Ephemera danica

European water vole
Arvicola terrestris

Brown trout
Salmo trutta

Pond water crowfoot
Ranunculus peltatus

Three-spined stickleback
Gasterosteus aculeatus

Northern pike
Esox lucius

European eel
Anguilla anguilla

Freshwater shrimp
Gammarus pulex

Healthy food chain
Aquatic plants provide the habitat and food on which all stream life depends.

Beneficial gravel
Gravel beds provide habitat for varied invertebrate life and are important nesting locations for spawning fish.

No two chalk streams are alike, but all derive most of their flow from under-ground rain-fed aquifers.

Water flow

0 MILLION YEARS AGO

SITS

is covered by shallow seas
g with phytoplankton called
thophores. When they die, their
calcium shells turn to chalk.

65-3 MILLION YEARS AGO

UPLIFT AND EROSION

The African and Eurasian plates collide, lifting chalk layers into rolling hills that are slowly shaped by erosion.

2 MILLION-8,000 YEARS AGO

VALLEYS

Frozen ground and seasonal runoff during ice ages break up chalk and erode it into valleys.

8,000-1,000 YEARS AGO

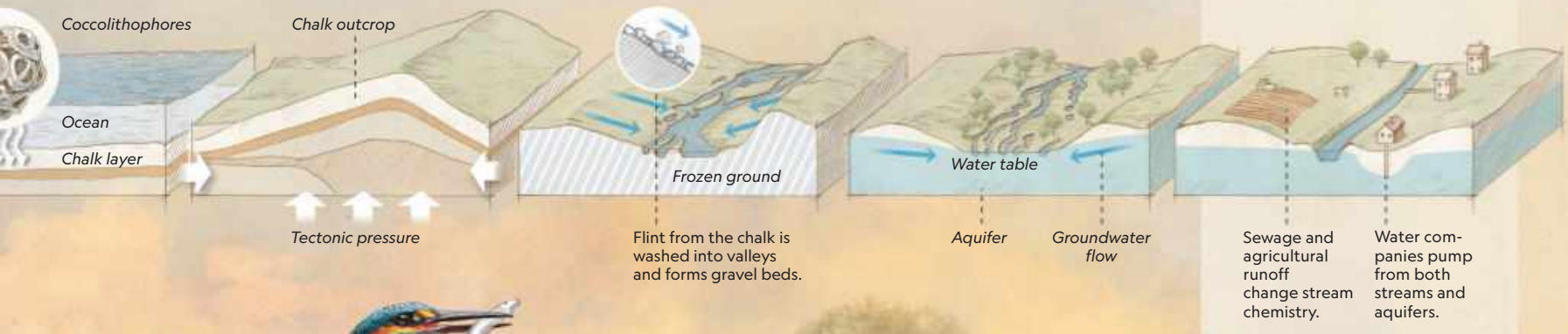
STREAMS

In a warmer climate, thawed chalk moderates groundwater flow. Plants and animals shape the flows into sinuous channels.

1,000 YEARS AGO-TODAY

HUMAN IMPACT

Activities such as milling, dredging, and straightening have modified at least 75 percent of chalk stream habitats.



Flint from the chalk is washed into valleys and forms gravel beds.

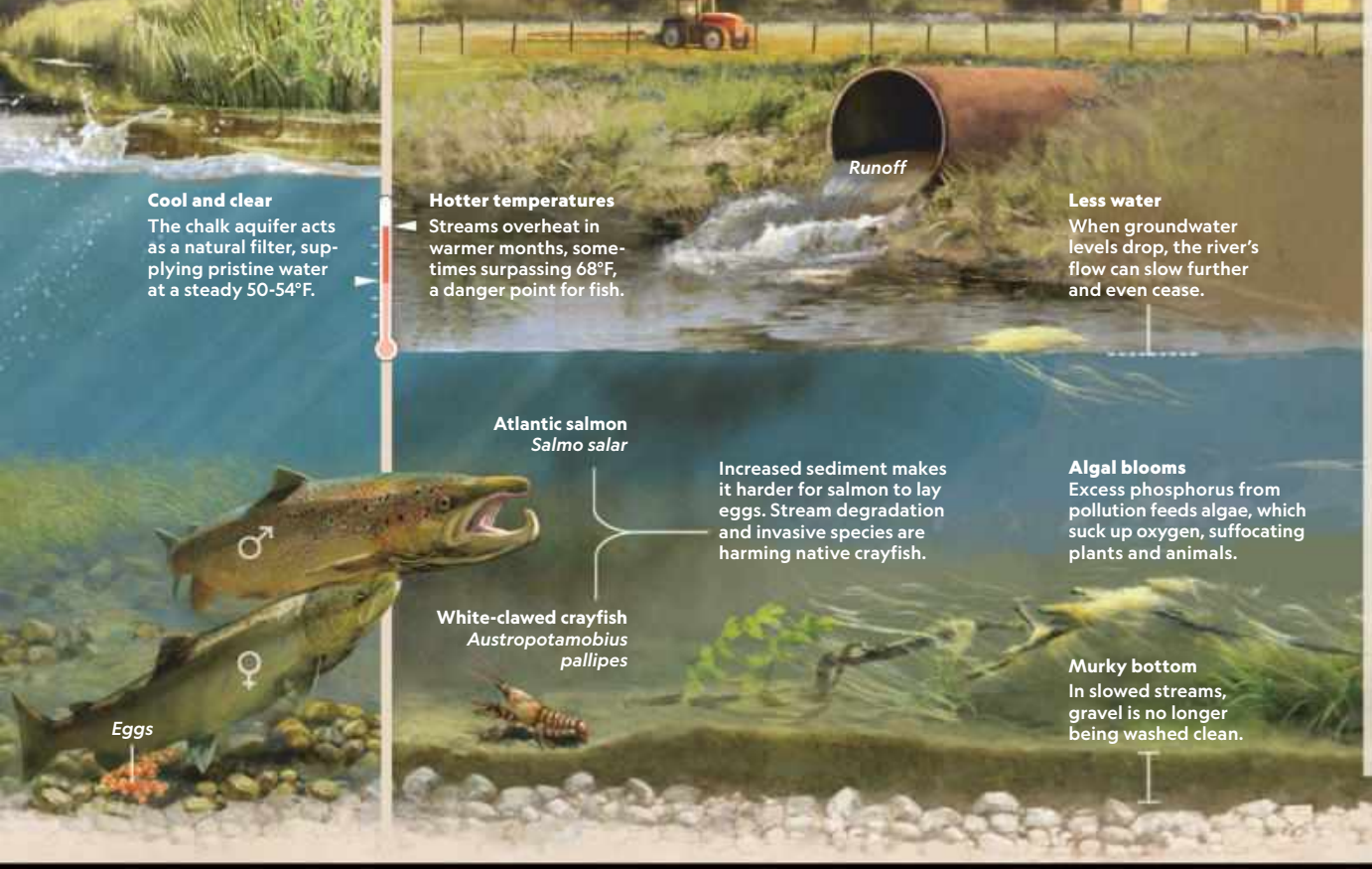
Sewage and agricultural runoff change stream chemistry.

Water companies pump from both streams and aquifers.

Common kingfisher
Alcedo atthis

THREATENED LIFE CYCLE

Chalk streams are low energy and gentle. Once damaged or modified, they lack the flow needed for self-repair.



Cool and clear
The chalk aquifer acts as a natural filter, supplying pristine water at a steady 50-54°F.

Hotter temperatures
Streams overheat in warmer months, sometimes surpassing 68°F, a danger point for fish.

Less water
When groundwater levels drop, the river's flow can slow further and even cease.

Atlantic salmon
Salmo salar

White-clawed crayfish
Austropotamobius pallipes

Increased sediment makes it harder for salmon to lay eggs. Stream degradation and invasive species are harming native crayfish.

Algal blooms
Excess phosphorus from pollution feeds algae, which suck up oxygen, suffocating plants and animals.

Murky bottom
In slowed streams, gravel is no longer being washed clean.

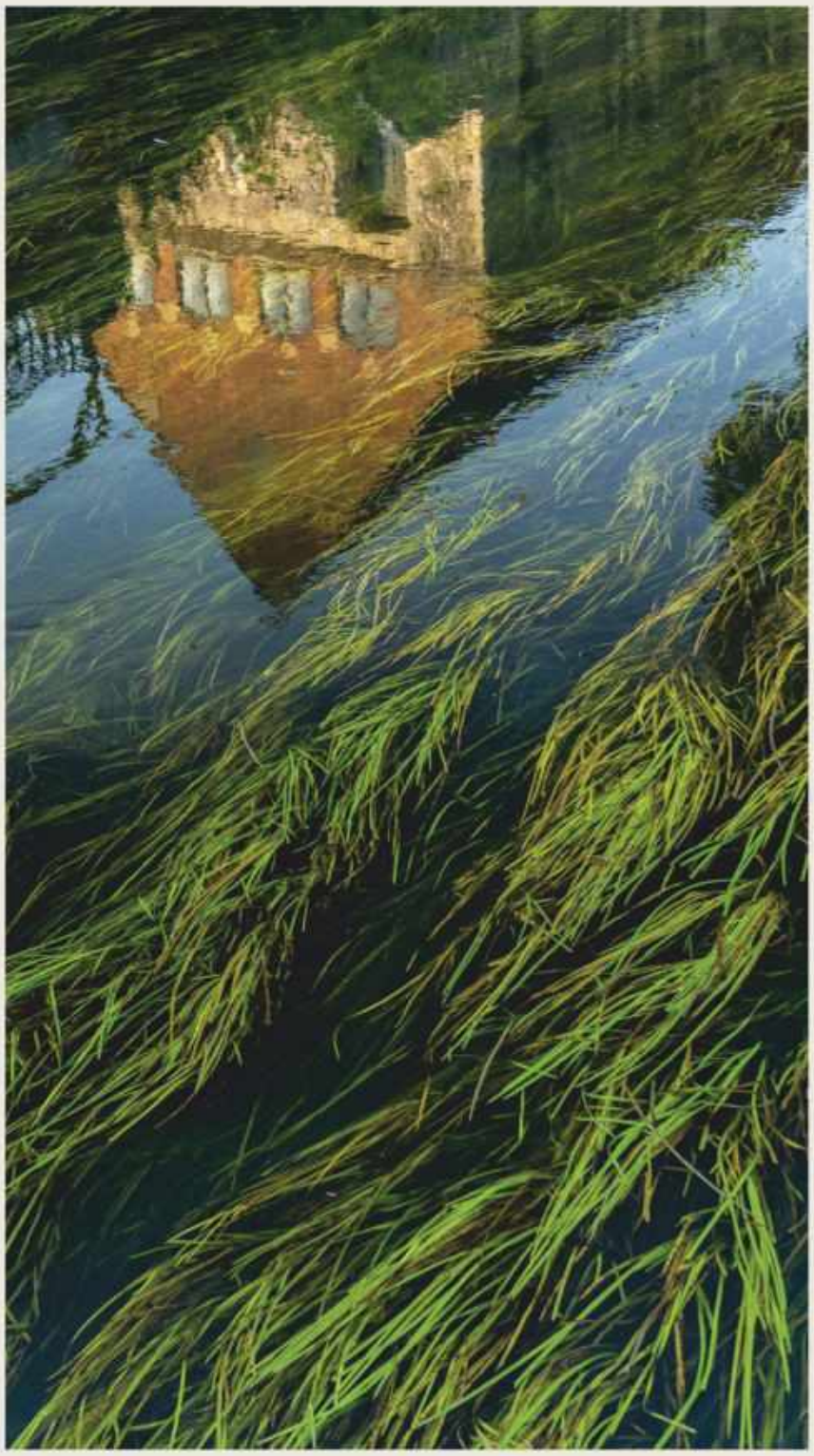
SAVING THE STREAMS

Adding woody material
Trees are introduced to create a diversity of flows and microhabitats.

Restoring natural shapes
Channels are narrowed and reshaped into their original winding forms.

FERNANDO G. BAPTISTA, SOREN WALLJASPER, AND EVE CONANT, NGM STAFF; LAWSON PARKER

SOURCES: DAVID SEAR, SCHOOL OF GEOGRAPHY AND ENVIRONMENTAL SCIENCE, UNIVERSITY OF SOUTHAMPTON; CHARLES RANGELEY-WILSON, CABA CHALK STREAM RESTORATION GROUP; KATE HEPPELL, CHILTERNS CONSERVATION BOARD



The glassy surface of the Great Stour reflects the ancient history of Canterbury, its banks home to monasteries, mills, breweries, and other centuries-old structures.

Poling a punt along the Great Stour is a popular way to see historic Canterbury. The classic children's book *The Wind in the Willows* celebrates such a chalk stream as a "sleek, sinuous, full-bodied animal."

at the evening air." Forty years later, the same stretch of the Ebble remains a sad and withered thing.

The three cardinal virtues of a healthy river are "gradient, velocity, and sinuosity," says Cain, who founded a company specializing in river restoration. Over the past decades, his firm has reshaped numerous rivers into healthier form, removing weirs and dams, roughening their flow, adding the twists and turns that create varied habitats for plants, invertebrates, and fish.

Many river restorers have followed in Cain's path, among them Rangeley-Wilson, who has worked with Cain to reinvigorate a stretch of the River Nar in north Norfolk. For centuries it had been trapped in a straight channel leading to a mill. With no gradient, no sinuosity, and no flow, the river had died a sluggish, silty death. But over the past few years, Rangeley-Wilson has been reconnecting the Nar to its valley, restoring its meanders, dragging in some trees to disrupt the flow and diversify the habitat, and allowing natural processes free rein. The

Left

Tree limbs are drawn by horse to the restored River Nar in Norfolk. Such woody debris diversifies water flow and habitat.

Below

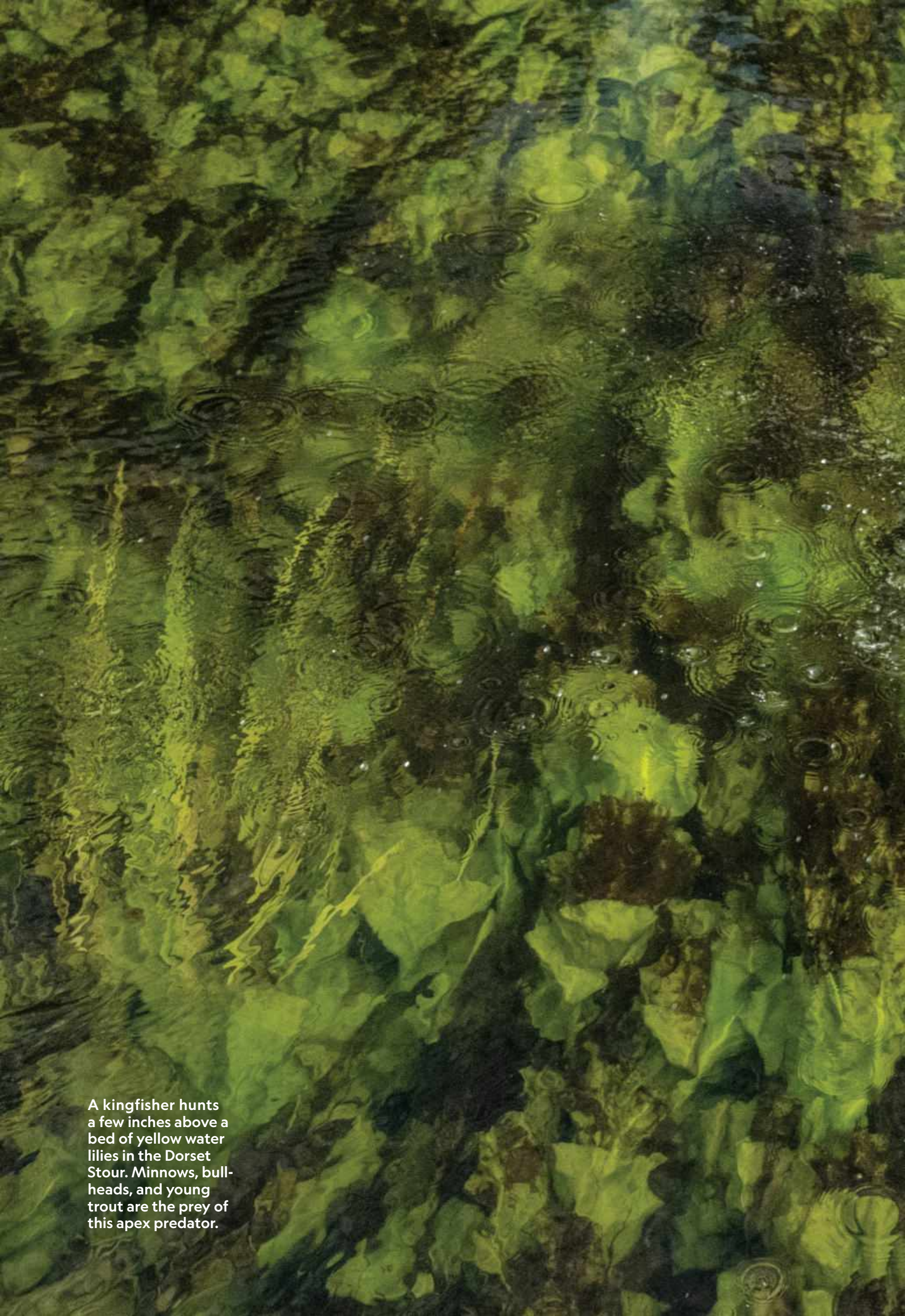
A mayfly alights on a water speedwell frond beside the River Itchen. The insect can spend two years underwater as a nymph but may live for no more than a few hours above it.

cost of restoration can run about $130,000 per mile of river, usually funded by government grants and support from landowners.

I went fishing with Rangeley-Wilson one afternoon, and as we came to a new bit of channel less than two years old, the river ran and chuckled loosely beside us. Within 30 seconds, Rangeley-Wilson had hooked a wild trout. Then another and another. All were small, only half a pound or so, but then he spotted something more. “Ooh, there’s a nice trout. He’s going to hide under the bank there.” He landed his fly, the rod bent, and he brought the trout into the gravel shallows. The river he had made was full of life.

Slipping the barbless fly from the trout’s jaw, he held it on the surface of the stream, allowing the water to lap over the red-and-black sprinkles of its body. Then he let it ghost away, an emblem of the beauty of these streams that will all, we hope, one day be restored to life. □

Author and journalist **Adam Nicolson** lives in Sussex, England, where he’s restoring a farm to a more natural condition.



A kingfisher hunts a few inches above a bed of yellow water lilies in the Dorset Stour. Minnows, bullheads, and young trout are the prey of this apex predator.

FROM OUR INSTAGRAM ACCOUNTS

PHOTOGRAPHER	*LIKES*	*WHERE*
Nora Lorek	83,380+	Gothenburg, Sweden

ONCE A MONTH Gothenburg's Capitol, an art house cinema, opens its doors to a canine audience. Dogs enter free with their owners; blankets and treats are provided. For Nora Lorek, who normally focuses on migration and human rights, the scene was irresistible. She set up a studio light between showings, and those who wanted a portrait of their pups got in line. Among the posers: Cloé, a Chihuahua, and her best friend, Eonni, a pug. "It felt better than the red carpet at the Oscars," Lorek says.

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THE MOONWATCH IN WHITE

Inspired by its history of space exploration, the most iconic chronograph on Earth now has a white dial. The Speedmaster Moonwatch has borrowed its latest look from the colours of astronaut spacesuits, while adding a glossy lacquered finish for the very first time. The white dial and red touches are also a tribute to the ALASKA I prototype that OMEGA produced in 1969, creating an authentic link to the Speedmaster's pioneering past. Worn on a comfortable and vintage-style bracelet, this stainless steel Moonwatch shines the spotlight on a new era of adventure.

OMEGA