CELEBRATING 125 YEARS OF EXPLORATION

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JANUARY 2013

NATIONAL GEOGRAPHIC

125TH ANNIVERSARY SPECIAL ISSUE

WHY WE EXPLORE



Heading Off to the STARS

The WILDEST PLACE on Earth

SURVIVING Antarctica

The SECRET WORLD of Microbes

This type of interstellar spacecraft could reach the closest stars within a human lifetime.

THE FURTHER WE GO, THE MORE WE UNDERSTAND.

THE ROLEX EXPLORER II IS DESIGNED TO WITHSTAND THE MOST EXTREME CONDITIONS FACED BY TODAY'S EXPEDITIONS. FOR ALAIN HUBERT, ITS LEGENDARY RELIABILITY MAKES IT ESSENTIAL EQUIPMENT ON HIS RECORD-BREAKING POLAR TREKS.



OYSTER PERPETUAL EXPLORER II

TIME TO EXPLORE

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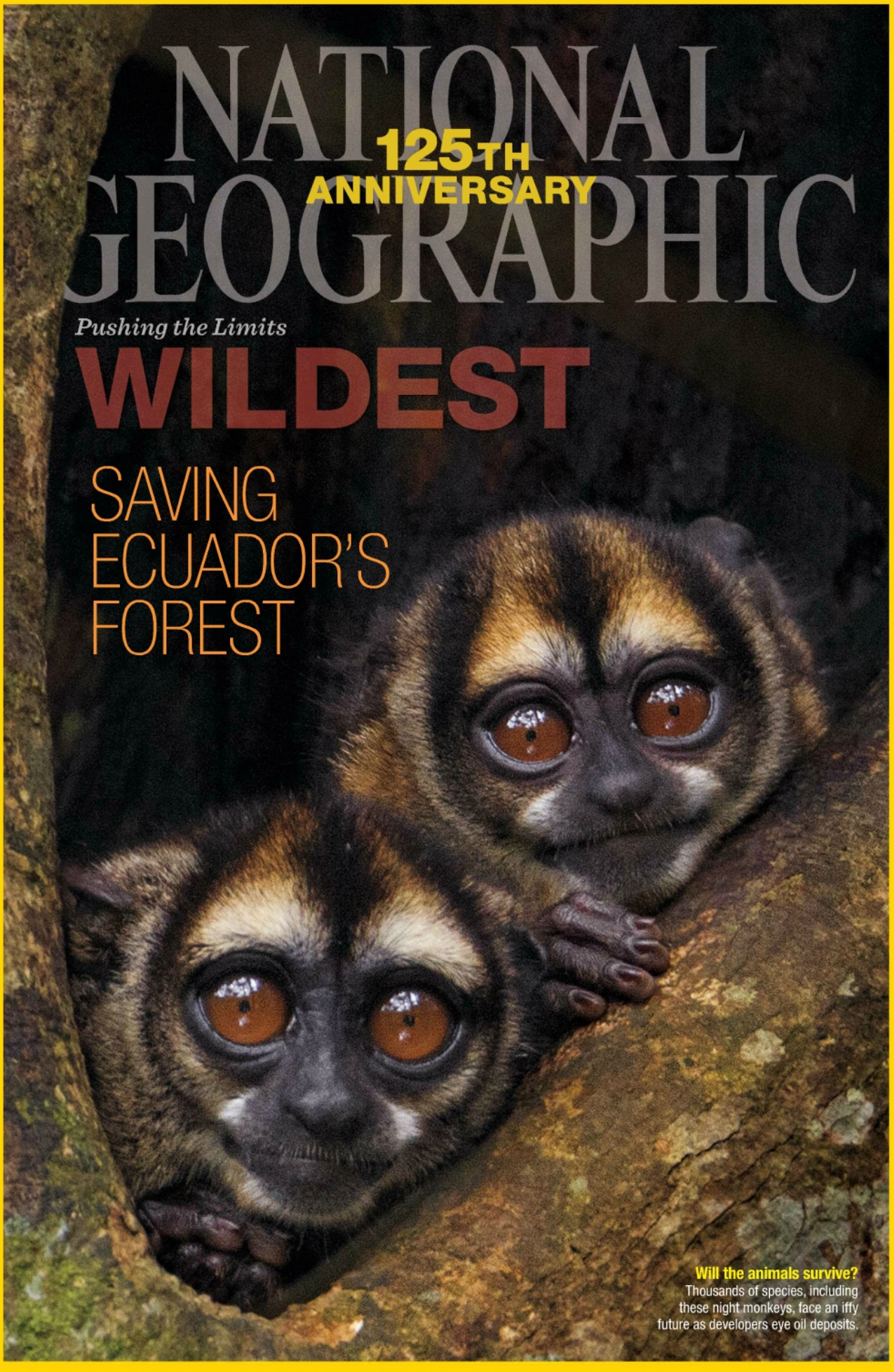
NATIONAL GEOGRAPHIC

125TH ANNIVERSARY

Pushing the Limits

WILDEST

SAVING ECUADOR'S FOREST



Will the animals survive?
Thousands of species, including these night monkeys, face an iffy future as developers eye oil deposits.

THE CLOSER WE LOOK, THE MORE WE SEE.

ROLEX ENGINEERED THE ORIGINAL MILGAUSS IN 1956 WITH A MAGNETIC SHIELD. IT SWIFTLY BECAME KNOWN AS THE WATCH TESTED AT CERN, THE WORLD'S PREEMINENT PARTICLE PHYSICS LABORATORY. THE ACCURACY OF THE CURRENT MILGAUSS AMID DISRUPTIVE MAGNETIC FIELDS ENSURES ITS PLACE AS THE REFERENCE WATCH OF CHOICE. ROLEX IS A PROUD SUPPORTER OF CERN.



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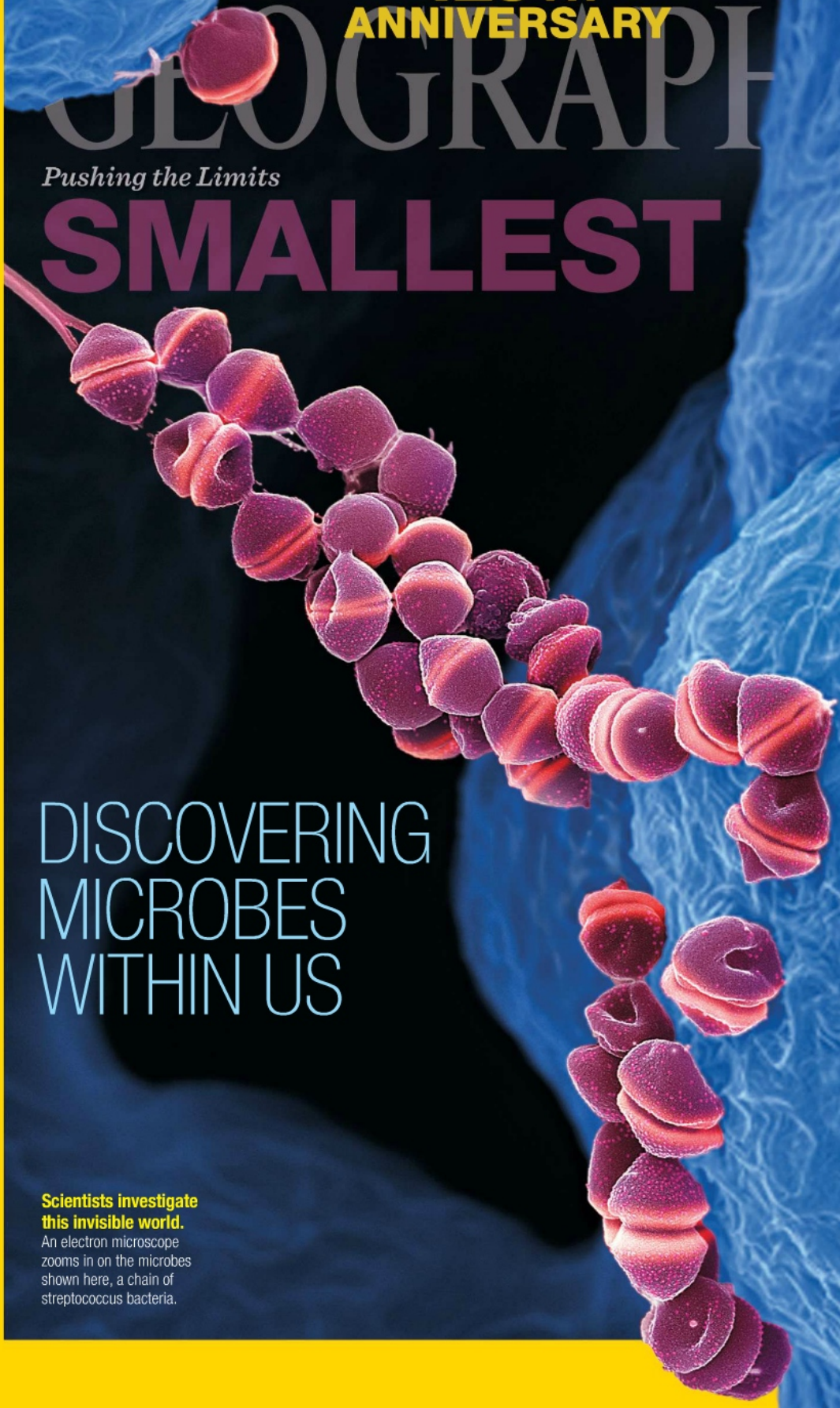
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Pushing the Limits

SMALLEST



DISCOVERING MICROBES WITHIN US

Scientists investigate this invisible world. An electron microscope zooms in on the microbes shown here, a chain of streptococcus bacteria.

THE HIGHER WE CLIMB, THE MORE WE OVERCOME.

IN 1953, SIR EDMUND HILLARY AND TENZING NORGAY ACHIEVED THE FIRST SUCCESSFUL ASCENT OF MOUNT EVEREST, ON AN EXPEDITION EQUIPPED WITH ROLEX WATCHES. THE EXCEPTIONAL RELIABILITY OF THEIR TIMEPIECES INSPIRED THE ROLEX EXPLORER, WHICH SOON BECAME THE STANDARD WATCH FOR THE WORLD'S MOST INTREPID MOUNTAINEERS.



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HIGHEST



UP ON EARTH'S ROOF

Cory Richards conquers Pakistan's Gasherbrum II.
The mountaineer's images of a drama-filled Mount Everest trek will highlight our June 2013 issue.

THE DEEPER WE DIVE, THE MORE WE DISCOVER.

A ROLEX DEEP SEA SPECIAL FIRST DESCENDED TO THE OCEAN'S DEEPEST DEPTHS IN 1960. FIFTY-TWO YEARS LATER, ROLEX RETURNED TO THE MARIANA TRENCH WITH AN EXPERIMENTAL ROLEX DEEPSEA CHALLENGE WATCH, JOINING JAMES CAMERON ON HIS HISTORIC SOLO DIVE AND REINFORCING ROLEX'S REPUTATION AS A PIONEER OF DEEP-SEA EXPLORATION.



OYSTER PERPETUAL ROLEX DEEPSEA

TIME TO EXPLORE

ROLEX

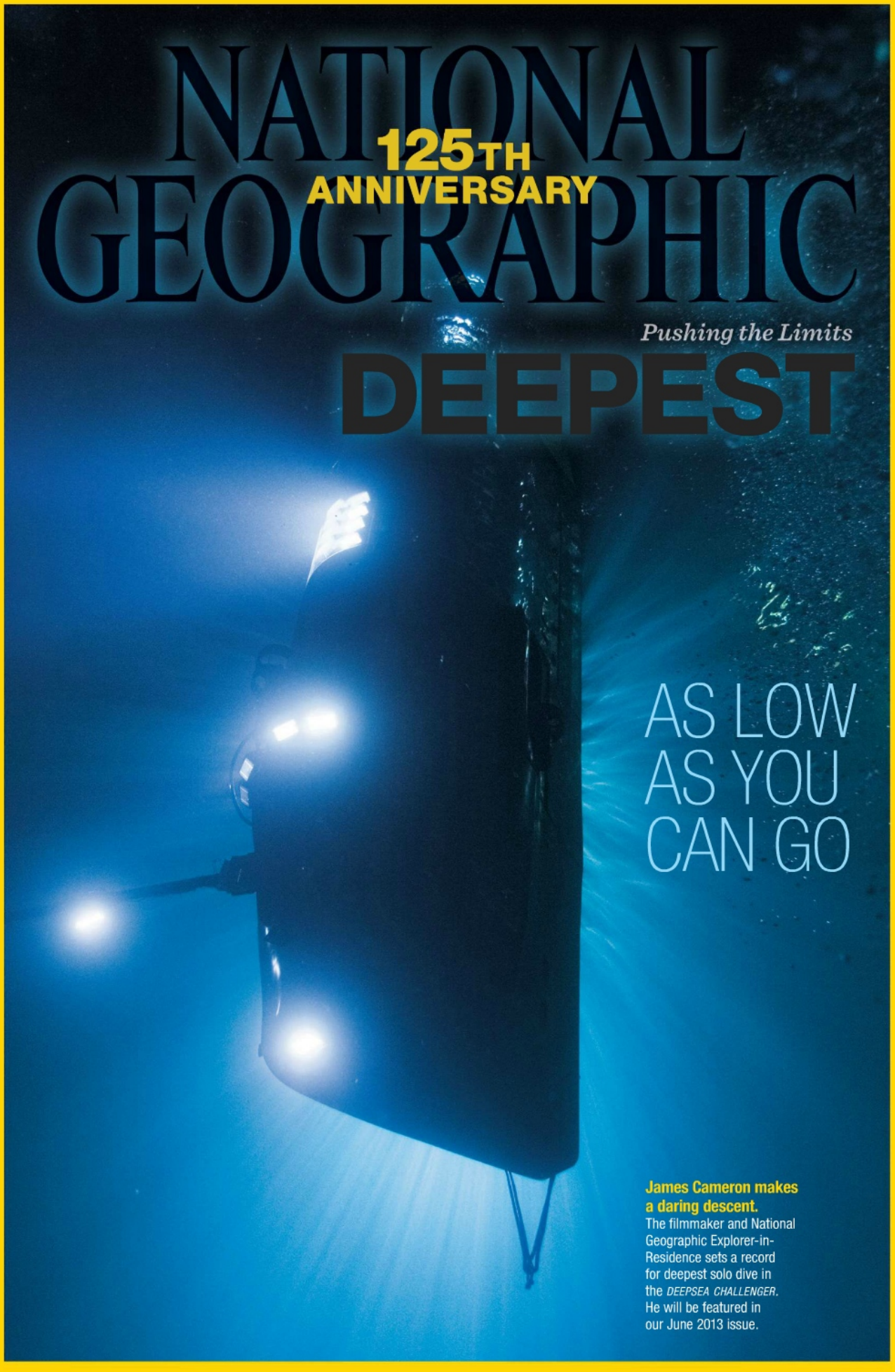
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DEEPEST



AS LOW AS YOU CAN GO

James Cameron makes a daring descent.
The filmmaker and National Geographic Explorer-in-Residence sets a record for deepest solo dive in the *DEEPSEA CHALLENGER*. He will be featured in our June 2013 issue.



ROLEX OYSTER, 1926



TIME TO EXPLORE.

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WITH A SHARED PASSION FOR EXPLORATION, ROLEX CONGRATULATES THE NATIONAL GEOGRAPHIC SOCIETY ON ITS 125TH ANNIVERSARY, AND LOOKS FORWARD TO BEING THERE, WHEREVER MAN DARES TO GO NEXT.

ROLEX



Amami Jay *(Garrulus lidthi)*
Size: Head and body length, approx. 38 cm (15 inches); tail, 16.9 - 19.3 cm (6.7 - 7.6 inches)
Weight: 176 - 216 g (6.2 - 7.6 oz) **Habitat:** Subtropical evergreen broadleaf forest and woodland around human cultivation and habitation **Surviving number:** Estimated at 5,000 or more

Photographed by Norio Yamagata

WILDLIFE AS CANON SEES IT

Invaded. The Amami jay's life was upended with the appearance of the Indian small mongoose, named "One of the Worst Invasive Species in the World" by the International Union for Conservation of Nature. Endemic to Japan's Amami Islands, the jay ranges in search of acorns, plants, insects, spiders and reptiles. Its foraging is perilous, however, as every time it touches the forest floor it risks falling prey to a mongoose. Efforts to control mongoose populations have met with success and the bird is no longer hunted for its feathers, but continued predator control and habitat protection are vital to its survival.

As we see it, we can help make the world a better place. Raising awareness of endangered species is just one of the ways we at Canon are taking action—for the good of the planet we call home. Visit **canon.com/environment** to learn more.

Canon

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NATIONAL GEOGRAPHIC

"I've been jailed, chased by elephants, sprayed with cobra venom."
page 60



In 2007 environmental scientist Tim Jarvis reenacted the epic Mawson Antarctic trek (see story listing, below). One big difference: A film crew followed Jarvis.

JOHN STOUKALO

January 2013

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Keeping an Eye on the Pole
Buoyant and steered by the current, a new vessel will gather critical data about Antarctic climate.

Scat Journal ▸
To conservation biologists, an animal's droppings pack a history of its diet, territory, and sexual state.

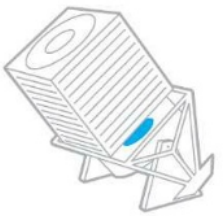
Explorers Quiz ▸
The first in a series. Test your knowledge of Easter Island, Teddy Roosevelt, and the space shuttle.

New Light on Dark Energy ▸
This mysterious force causes our universe to expand ever faster. Experts are making a sky map to learn more.

Monsters on Maps
Why did old-time cartographers depict leviathans and dragons? Turns out there are a couple of reasons.







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Flashback

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Polar Adventure
Video
Watch Mawson's team battle the elements.



Exploring Yasuní
Video
Follow our photographers into Ecuador's wild park.



Risk Takers
Video
Hear from the explorers profiled in this issue.

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Wide World

Let me tell you about a photo that hangs in my house. It was taken by W. Eugene Smith, and its title is "The Walk to Paradise Garden." It shows his two young children, hand in hand, on a dirt path in the woods, emerging from shadows into the light of a clearing. It reminds me of myself as a young boy exploring the wilderness of my backyard in southwestern Oregon. My backyard had this: my favorite black walnut tree, deer tracks, a hornet's nest, squirrels.

Exploration is as near as your backyard.

I would wander its seven acres, hoping to see a cougar (I never did). Or go down to Griffin Creek, hoping to discover an arrowhead (I often did). Years later, I understood that what my backyard contained, most of all, was the infinite horizon of possibility.



W. Eugene Smith photographed "The Walk to Paradise Garden" in 1946.

There is another layer to Smith's photograph that also speaks to the power of exploration. Smith had been seriously wounded while covering World War II in the Pacific. He hadn't shot a photograph in a long time. He was in pain and deeply troubled.

"I followed my children into the undergrowth…How they were delighted at every little discovery!" Smith wrote. Then, an epiphany. The sight of his children so engrossed in their small expedition, so in thrall to discovery, lifted him out of darkness. "I wanted to sing a sonnet to life and to the courage to go on living it."

You will read in these pages about explorers who go to the deepest, coldest, highest places on Earth and beyond, but the truth is that exploration is as near as your backyard—and it can be profoundly life affirming.

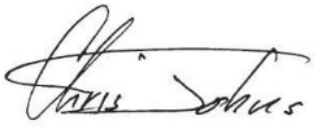


PHOTO: W. EUGENE SMITH, BLACK STAR

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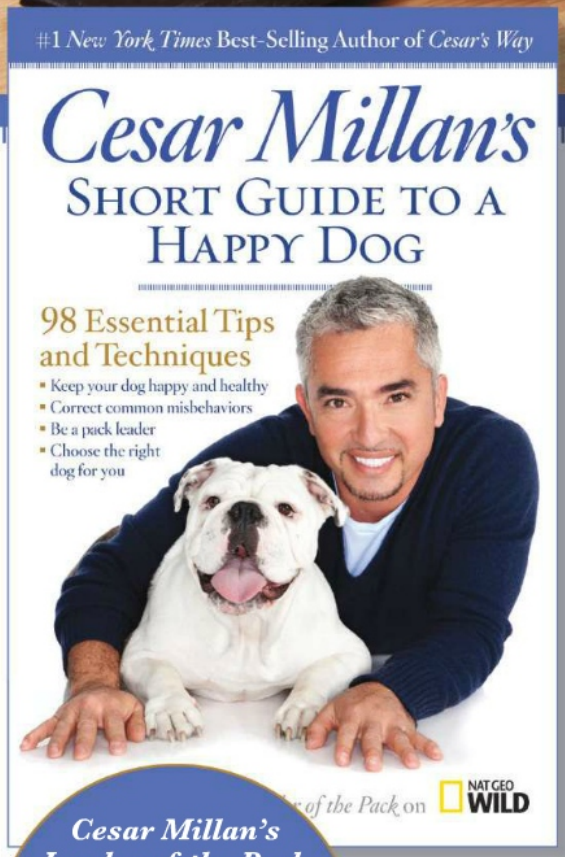
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Extreme Weather

Very, very early Wednesday morning, August 29, 2012, while sitting in the dark (I had no power), I anxiously awaited Hurricane Isaac, making its way through our area. I tried a little reading with my flashlight to keep my mind off the rising water and picked up my new *National Geographic.* The rain wouldn't stop, and the tide was rising in the bayou. I saved your article to read when the power came on. I appreciate recognizing El Niño and La Niña, melting ice, and greenhouse gases. Anyone who does not believe the Earth is warming or rejects that notion has not been in a weather disaster.

CAROLYN ROUSSEAU
Slidell, Louisiana

Writer Peter Miller attributes the river crest forecast of 42 feet to the U.S. Army Corps of Engineers, when it is actually the National Weather Service that makes these forecasts.

LEE ROBERTS
U.S. Army Corps of Engineers
Nashville District
Nashville, Tennessee

We missed the opportunity to clarify that while the Army Corps of Engineers alerts the National Weather Service (NWS) to dam releases occurring in an area, it is the NWS that actually predicts potential flood crests.

In 2012 North America experienced a record: lowest number of tornadoes since 2002. Don't you hate it when nature doesn't follow preconceived notions?

RON ANDREA
Elmont, Virginia

Texas Drought

This article reminded me of dust storms of the 1930s. Farmers were harrowing the soil too fine—when they left chunks of earth, the wind didn't carry it away. Wonder if the same problem exists now.

BILL GALLAGHER
Cheshire, Connecticut

Drought and extreme weather are issues confronting many, especially in the Southwest. But one rarely sees a reference to the explosion of population in that area and how that impacts an existing bad situation.

RODNEY RUTH
Allendale, New Jersey

Yemen

Two pictures of children in your September issue separately point to the triumph of the human spirit over the constructs of war and military might: One of a boy flying his kite, the only spot of bright color in the grim rubble of the war-devastated city of Sadah; the other a boy boldly standing to face the wind on the centuries-old ruins of the Roman fort at Corbridge, England.

MELANIE RODENBOUGH
Greensboro, North Carolina



FEEDBACK *Readers responded to our coverage of extreme weather fluctuations around the world.*

"Severe and strange weather has been going on forever. What's new is there are more people today to report the weather."

"The article presented the consequences of our shortsighted systems as inevitable. They are not."

"I wonder how these articles are received. Is there any hope for rational discussion?"

"I believe this is a crisis for the entire planet, requiring all of us to step up."

EMAIL ngsforum@ngm.com **TWITTER** @NatGeoMag **WRITE** National Geographic Magazine, PO Box 98199, Washington, DC 20090-8199. Include name, address, and daytime telephone. Letters may be edited for clarity and length.

GRAPHIC: LAWSON PARKER, NGM STAFF

The invention of the year is great news for your ears

Perfect Choice HD™ is easy to use, hard to see and costs far less than hearing aids… it's like reading glasses for your ears™!

New Personal Sound Amplification Product is an affordable alternative

Over the years, technology has made the way we live easier, safer and more convenient. In many cases, it's even made many products more affordable… (remember how much the first VCR used to cost?). Unfortunately, the cost of hearing aids never seemed to come down. Now, a new alternative has been invented… it's called Perfect Choice HD™.

"Reading glasses for your ears"

Perfect Choice HD is NOT a hearing aid. Hearing aids can only be sold by an audiologist. In order to get a hearing aid, you had to go to the doctor's office for a battery of tests and numerous fitting appointments. Once they had you tested and fitted, you would have to pay as much as $5000 for the product. Now, thanks to the efforts of the doctor who leads a renowned hearing institute, there is Perfect Choice HD. It's designed to accurately amplify sounds and deliver them to your ear. Because we've developed an efficient production process, we can make a great product at an affordable price. The unit has been designed to have an easily accessible battery, but it is small and lightweight enough to hide behind your ear… only you'll know you have it on. It's comfortable and won't make you feel like you have something stuck in your ear. It provides high quality audio so sounds and conversations will be easier to hear and understand.

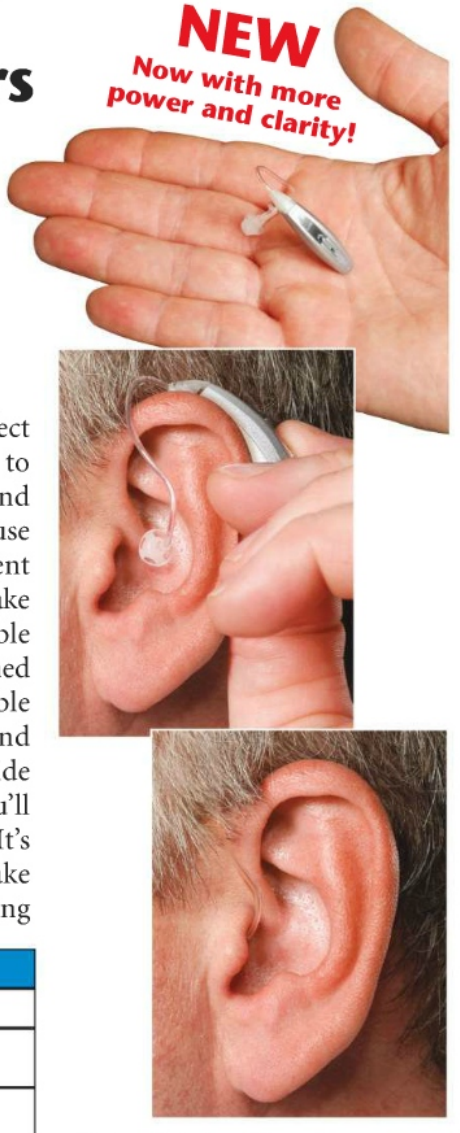
Perfect Choice HD feature comparison

	Perfect Choice HD	Others
Lightweight and Inconspicuous	YES	Some
Easy Toggle Switch Adjustment	YES	Few
Tests and Fittings Required	NO	Most
Affordable	YES	as much as $5000
Friendly Return Policy	**YES**	**Rarely**

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Shafqat Hussain
National Geographic
Emerging Explorer

EXPERTISE
Snow leopard conservationist

LOCATION
Banak La, Pakistan

Facing a Glacier

We were on the scent of snow leopards. But first my team and I had to cross a glacier. On the other side was a 16,000-foot Karakoram pass, and beyond that, we suspected, a snow leopard trail. Before setting out, we had asked the locals if we needed crampons or other climbing gear. They assured us we didn't, so we took only a rope for this walk across the side of a mountain covered in ice. There were also chunks of ice in a crevasse lake below—the air temperature was hovering around 14°F.

The three of us looped the rope around our stomachs to bind ourselves to each other—if one slipped, the others could stop his fall. Our local guide followed, gripping the rope in his hands. If we'd had a longer rope, we could have sent one man across, and the other three could have stabilized him. But our rope was 60 feet, and the ice field was three times that. Midway across, one of us slipped. He could have taken all of us down into the lake but jammed his walking stick in the ice and arrested about ten feet down. We pulled him up and walked on. Already halfway, it was useless to go back. Somehow we made it across.

I later thought how stupid it was to have tied ourselves together. If one had gone all the way down, we all would have. This is one of the most popular mountaineering regions in the world, and trained climbers have suffered worse on the five 8,000-meter peaks that surrounded us. Villagers underestimate these risks, because they don't have access to equipment anyway. Our guide had figured a way around our recklessness. When I asked why he'd led us up under such treacherous conditions, he said, "That's why I didn't tie myself in. I just held on to the rope." What would he have done if we fell? He replied: "I would have let go."



ART: ISTVAN BANYAI. PHOTO: REBECCA HALE, NGM STAFF

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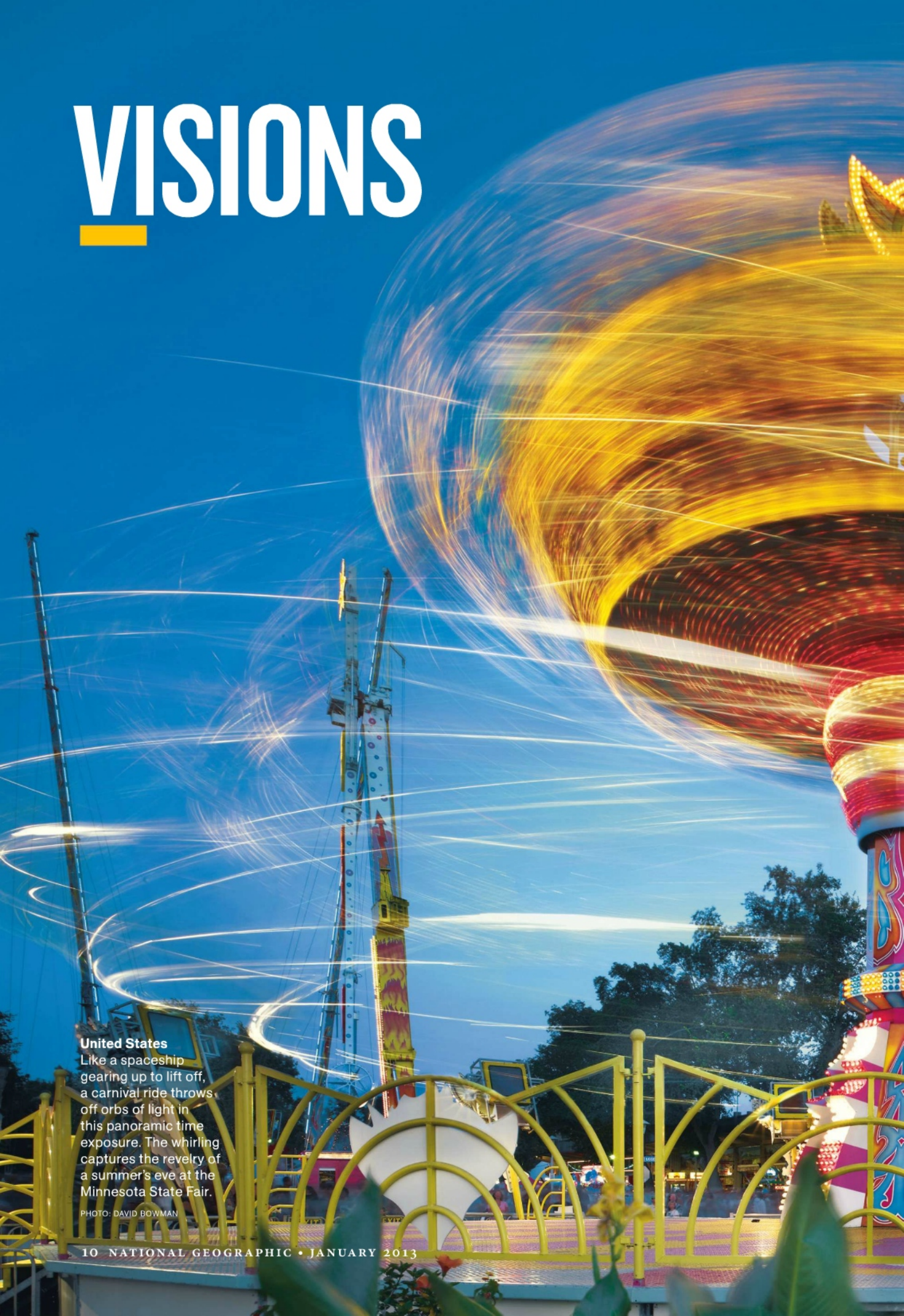
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VISIONS



United States
Like a spaceship gearing up to lift off, a carnival ride throws off orbs of light in this panoramic time exposure. The whirling captures the revelry of a summer's eve at the Minnesota State Fair.

PHOTO: DAVID BOWMAN


FISH & CHIPS
PlayStation



Benin
At a vodun celebration in Ouidah, sequined masquerades known as Egungun embody the spirits of ancestors with ties to Nigeria's Yoruba culture. Some masked spirits bless the living; others entertain with intricate dances.

PHOTO: DAN KITWOOD, GETTY IMAGES

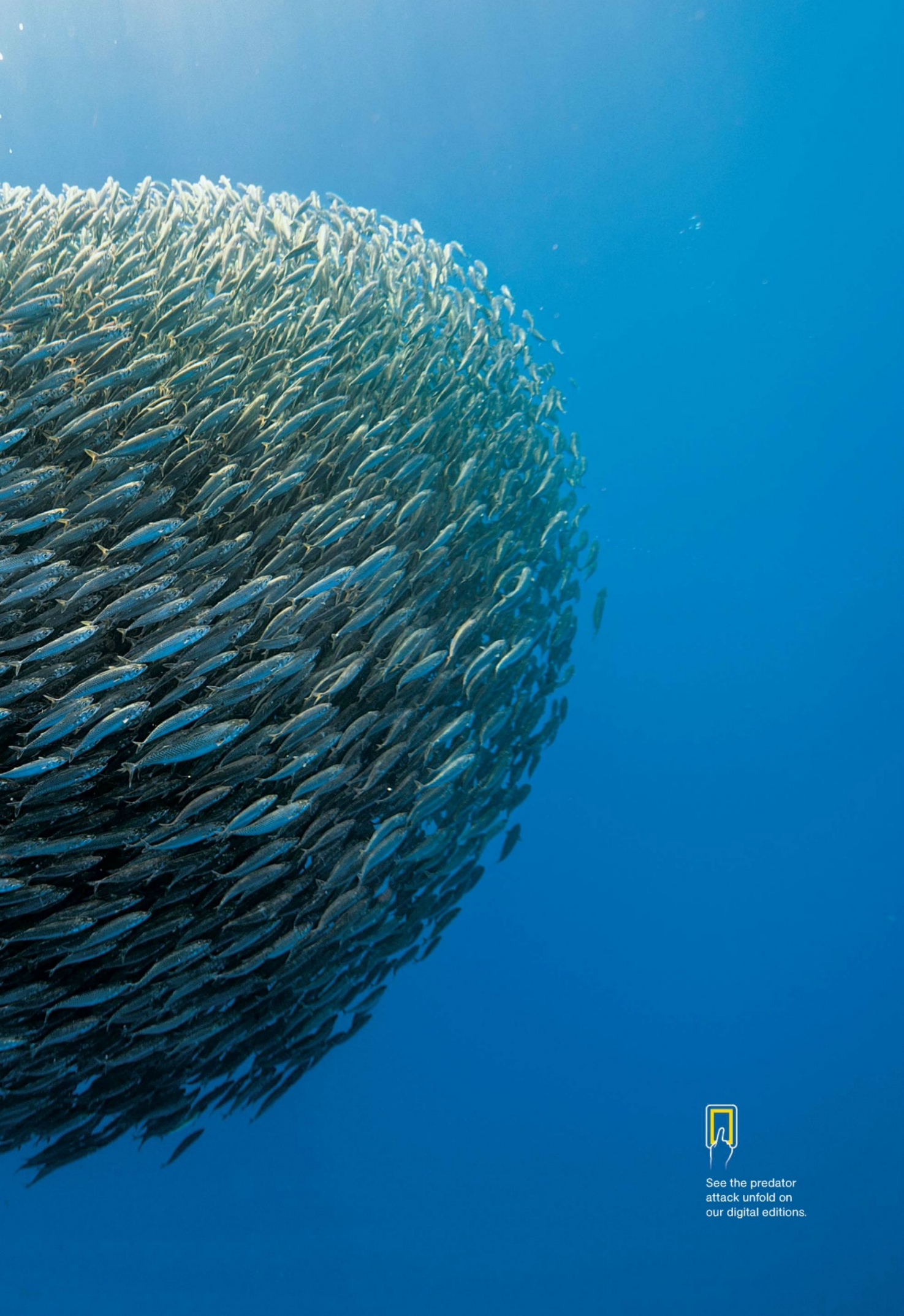




Atlantic Ocean
Swelling to more than 30 feet across, a school of blue jack mackerel achieves a harmony that belies its purpose: safety from predators. The fish broke apart and re-formed off the Azores as dolphins, birds, and sharks pecked away at the pack.

PHOTO: CHRISTOPHER SWANN, BIOSPHOTO

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This page features two photographs: one chosen by our editors and one chosen by our readers via online voting. For more information, go to ngm.com/yourshot.



EDITORS' CHOICE **Trisha Ratledge** Carlsbad, California

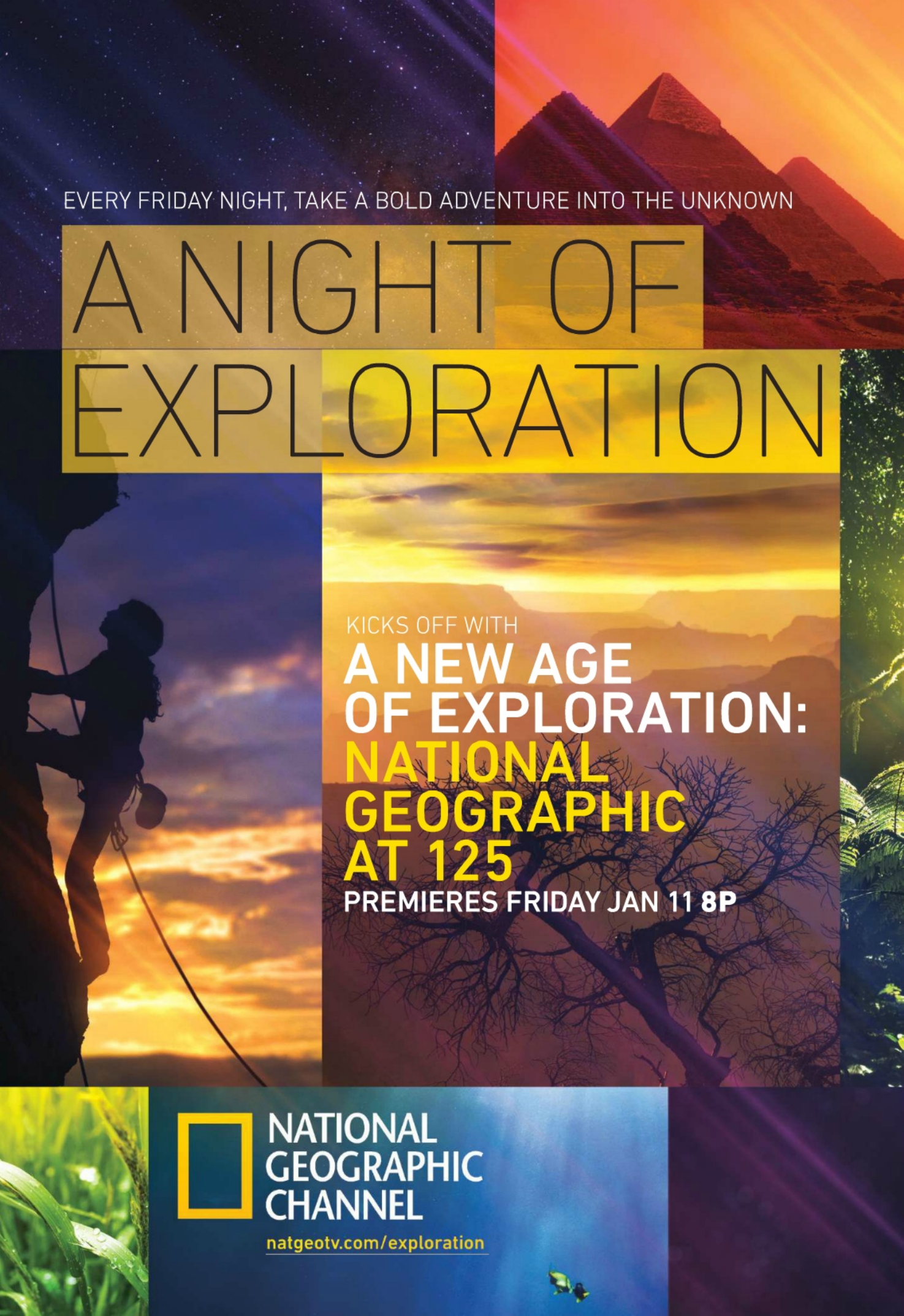
Seeing her 14-year-old daughter laughing and twirling in Tokyo's Mori Tower was the most poignant moment for Ratledge during a family trip. "It represented Emma literally dancing from one important stage in her life—middle school—to the next, high school," says the journalist mother.



READERS' CHOICE

Shelley Smart
Goolwa, Australia

This chunk of Antarctic ice, rising some 60 feet, greeted Smart and her mother when they toured the continent aboard a Russian icebreaker. The marine biologist and environmentalist says: "Antarctica is where you go when you want to discover what Earth used to be like."


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PLAN FOR A BETTER WORLD



PHOTO: NEL CEPEDA

In 2007, Pat Minnick decided to establish a charitable gift annuity to support National Geographic. She now receives a guaranteed life income and is a direct part of the Society's efforts to inspire people to care about the planet. She says, "I feel good knowing that National Geographic is doing so much to protect endangered wildlife."

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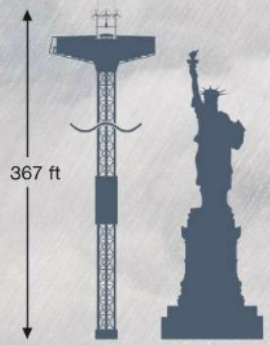
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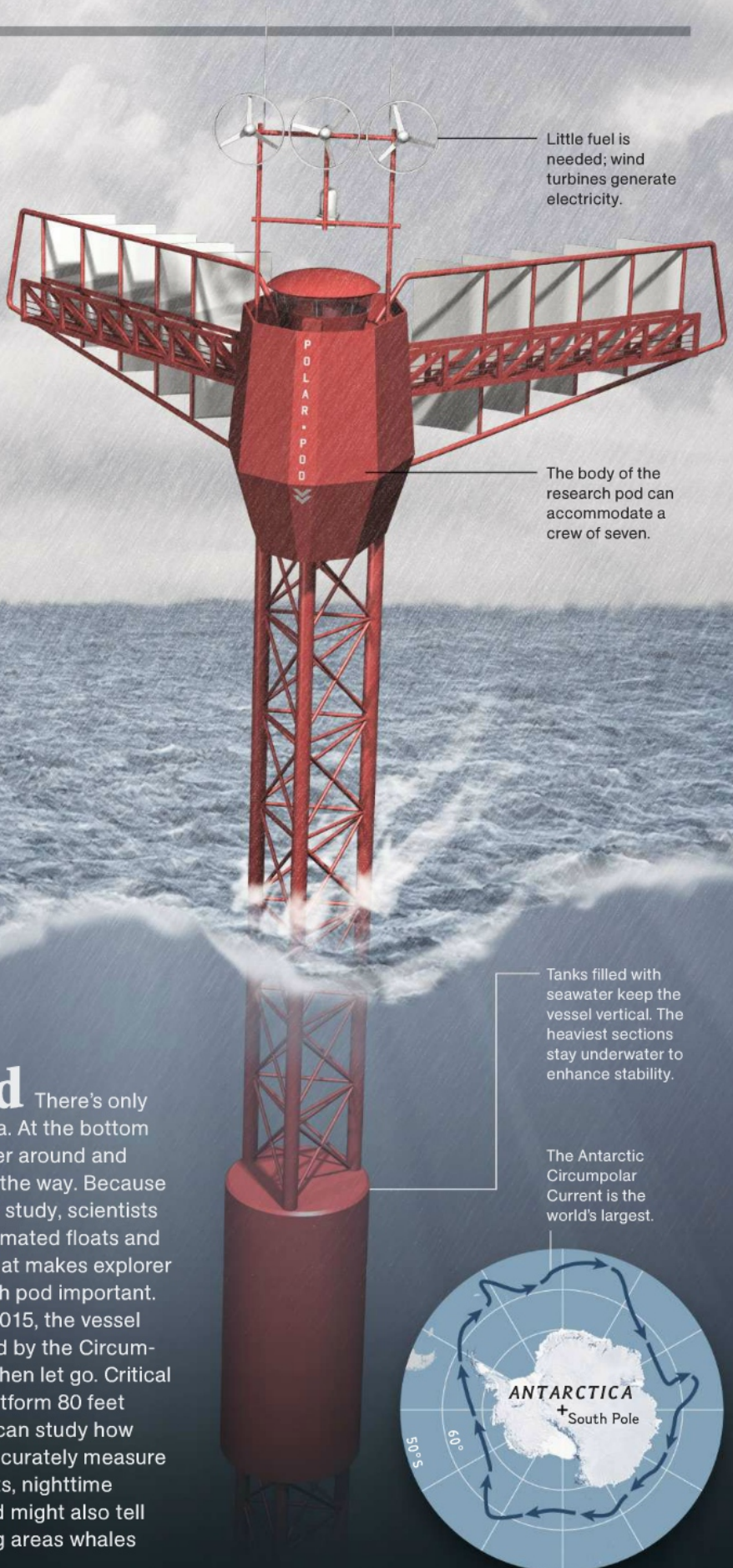
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NEXT





Antarctic Pod

There's only one current that circles Antarctica. At the bottom of the planet, wind whips the water around and around without any land to get in the way. Because these waters are so dangerous to study, scientists depend largely on data from automated floats and summer research ships. That's what makes explorer Jean-Louis Etienne's new research pod important.

Scheduled to be deployed in 2015, the vessel will act like a buoy and be steered by the Circumpolar Current—it'll be towed out, then let go. Critical to Etienne's design is a stable platform 80 feet above the water, so researchers can study how the ocean and air interact plus accurately measure salinity, temperature, and currents, nighttime and daytime, year-round. The pod might also tell scientists more about the feeding areas whales depend on. *—Gretchen Parker*

ART: DON FOLEY. MAP: INTERNATIONAL MAPPING
SOURCES: JEAN-LOUIS ETIENNE; LAURENT MERMIER, SHIP STUDIO

You can learn a lot about a species by what it leaves behind.

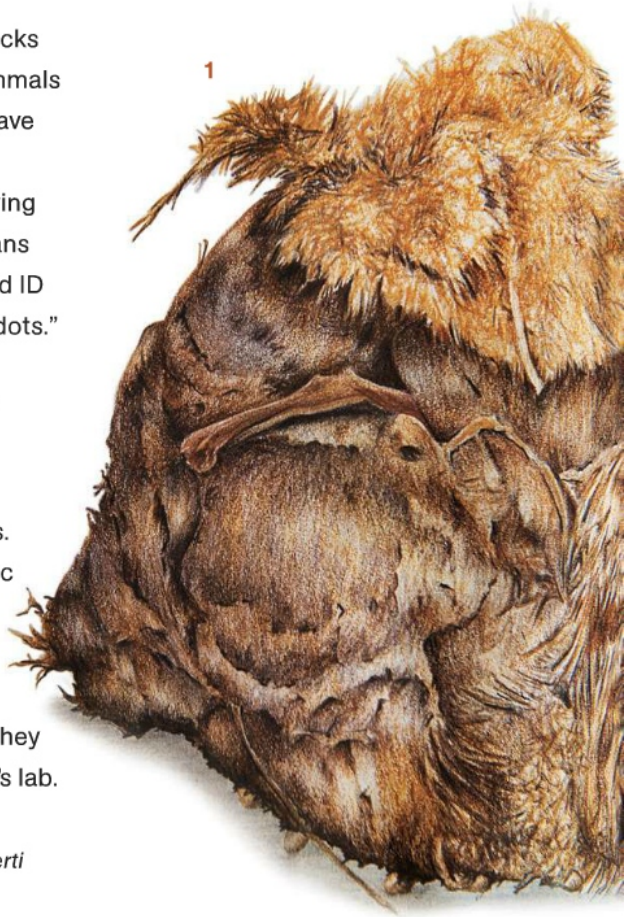


SCATOLOGY | To conservation biologists like Samuel Wasser, an animal's droppings are hardly waste. Each pellet or patty packs a history of its host's diet, territory, and sexual state. Most mammals can sniff out this info; human trackers—with less keen noses—have had to rely on other methods. Enter Wasser. His University of Washington lab has pioneered more advanced means of studying scat, including hormone profiles and DNA extraction. That means less need for dart guns. "Once we had DNA," he says, "we could ID an animal without seeing it. Essentially, we could connect the dots."

For the past decade Wasser has been connecting elephant "dots" across Africa. He collects the animals' dung, genotypes the samples, and adds the information to a growing genetic reference map. By matching DNA from seized tusks with DNA from dung sites, he can even pinpoint ivory-poaching hot spots.

But the map has gaps. In the heart of the Democratic Republic of the Congo, where few elephants remain, Wasser had little data. So in March 2011 he enlisted two National Geographic grantees, Trip Jennings and Andy Maser, for what Maser calls "CSI: Elephant." The duo found fresh samples. More important, they taught locals how to collect dung and send it directly to Wasser's lab.

Now Wasser is picking through their finds. With each new shipment, he gathers hope for elephants—in heaps. *—Oliver Uberti*



Herbivores defecate more than carnivores because they eat more. Large bull elephants consume up to 650 pounds of vegetation a day and defecate more than a third of it.

SCAT FACTS

	1	2	3
Animal	*African elephant*	*Lion*	*Large-spotted genet*
Contents	*Leaves, bark, bulbs, seeds, roots*	*Hair, hooves, bones, digested meat, blood*	*Feathers, grass, insect parts, rodent hairs*
Distinguishing features	*Barrel-shaped, fibrous pieces; several per site*	*Tapering, sausage shaped, with hair*	*Sausage shaped, with a point at one end*

Appearance may vary based on habitat, age of sample, and what an individual animal has consumed.
*Drawings are proportional.



Scat studies drawn with watercolor crayons fill the journals of Karen Comins, a former co-manager of Ishasha Wilderness Camp in Uganda.

4	5	6	7	8
Yellow baboon	*Spotted hyena*	*Topi*	*Warthog*	*African buffalo*
Fruits, seeds, bulbs, insects, digested meat	*Bones, hooves, hair, scavenged meat*	*Grass*	*Grass, roots, bulbs, sometimes leaves*	*Grass, reeds, leaves, other parts of plants*
Segmented, similar to human waste	*White when dry, from digested bones*	*Small heaps of 15 to 30 pellets*	*Kidney shaped, with defined segments*	*Wet patties in wet season, firmer in dry*

ART: KAREN COMINS

EXPLORE

This quiz is the first of seven to run in 2013 to celebrate National Geographic's 125th anniversary. The next will appear in March.

THE LURE OF LONG DISTANCES

Great journeys have a powerful hold on the human imagination. We love the idea, if only from an armchair, of cutting loose from the comforts of everyday life and venturing into uncharted worlds—with no certain destination and no guarantee of safe return. This quiz celebrates that bold impulse.

1. A DARING VOYAGE IN OPEN CANOES ACROSS THOUSANDS OF MILES OF OCEAN BROUGHT THE **ORIGINAL SETTLERS TO EASTER ISLAND.** THIS TINY PACIFIC "NAVEL OF THE WORLD" IS **CLOSEST TO THE LONGITUDE OF WHICH CITY?** A. Honolulu, Hawaii B. Juneau, Alaska C. Santiago, Chile D. Moab, Utah

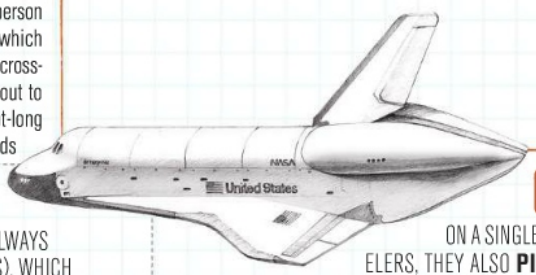


2. MARS HAS BEEN AN OBJECT OF COLORFUL SPECULATION EVER SINCE THE EGYPTIANS NOTED ITS PRESENCE IN THE NIGHT SKY ALMOST 3,500 YEARS AGO. **NAME THE FIRST OF NASA'S ROBOTIC ROVERS** TO SEND BACK DETAILED CLOSE-UPS AFTER TOUCHDOWN ON THE RED PLANET: A. Curiosity B. Opportunity C. Sojourner D. Asimov

3. IN ABOUT 325 B.C. THE **GREEK EXPLORER PYTHEAS** DARED TO SAIL OUT OF THE MEDITERRANEAN INTO THE NORTH ATLANTIC BEYOND, AND MIGHT HAVE **GOTTEN AS FAR AS ICELAND. WHAT IMPORTANT DISCOVERY DID HE MAKE IN HIS TRAVELS?** A. The Earth is round. B. The Celts were ferocious warriors who nailed enemies' heads over their doors. C. Northern regions were inhabited by "a monstrous white bear." D. The tides are associated with the phases of the moon.



4. IN 1914, AFTER A FAILED BID FOR A THIRD TERM AS PRESIDENT, **TEDDY ROOSEVELT UNDERTOOK A PUNISHING EXPEDITION IN BRAZIL, DOWN THE** UNMAPPED RIVER OF DOUBT AND ON TO THE AMAZON. NAME THE **"EVIL" AND "FEROCIOUS"** ADVERSARY HE LATER WROTE ABOUT: A. Piranhas capable of stripping a person to the bone B. An electric eel, which killed one of his boatmen on a river crossing C. A political consultant sent out to savage his reputation D. A 20-foot-long black caiman weighing 3,000 pounds



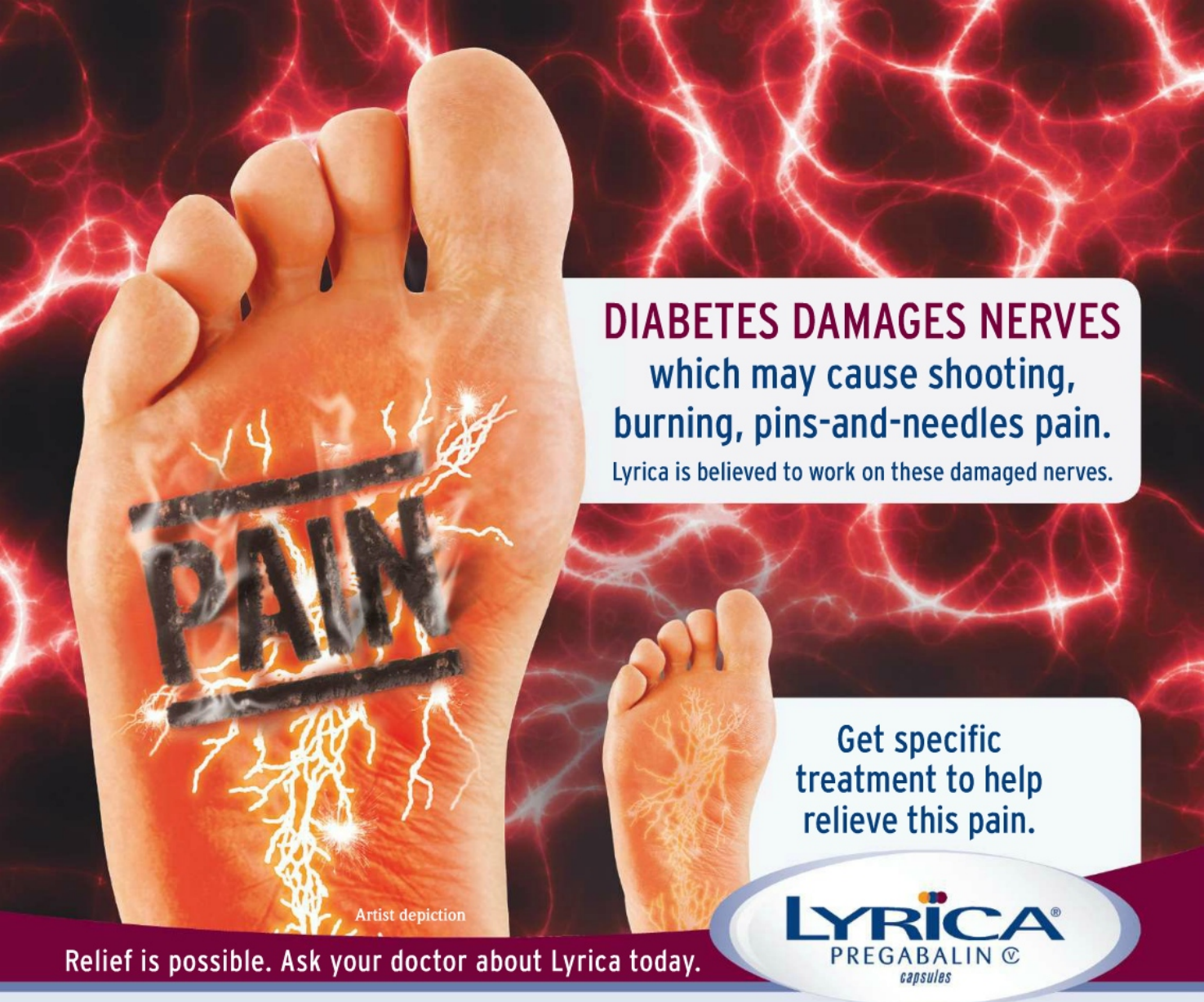
5. OTHER SPECIES ARE ALSO **SPECTACULAR TRAVELERS** (THOUGH THEY ALWAYS FORGET TO PACK THEIR CLOTHES). WHICH OF THESE ANIMALS REGULARLY MAKES THE **GREATEST LONG-DISTANCE MIGRATION ON EARTH?** A. Bar-tailed godwit B. Arctic tern C. Sooty shearwater D. Humpback whale

6. THE SPACE SHUTTLE ASTRONAUTS JOURNEYED UP TO 4.3 MILLION MILES ON A SINGLE FLIGHT. BUT LIKE ALL ADVENTUROUS TRAVELERS, THEY ALSO **PINED FOR SMALL REMINDERS OF LIFE BACK HOME.** NAME THE ARTIST WHOSE MUSIC WAS AT THE TOP OF THE CHARTS FOR **SPACE SHUTTLE WAKE-UP CALLS:** A. Elton John, whose hits include "Rocket Man" B. Aaron Copland, composer of "Fanfare for the Common Man" C. Paul McCartney, whose songbook includes "Off the Ground" and "Soggy Noodle" D. Dean Martin, who sang "Volare"

FIND ANSWERS ON PAGE 27.

CUT HERE

HANNAH TAK, NGM STAFF. PHOTOS (FROM TOP): STEVE WISBAUER, STOCKBYTE/GETTY IMAGES; MARIE HÉLÈNE CINGAL. ART: SHIZUKA AOKI



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Please see Important Risk Information for Lyrica on the following page.

To learn more visit www.lyrica.com or call toll-free 1-888-9-LYRICA (1-888-959-7422).

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IMPORTANT FACTS

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(**LEER**-i-kah)

IMPORTANT SAFETY INFORMATION ABOUT LYRICA

LYRICA may cause serious, even life threatening, allergic reactions. Stop taking LYRICA and call your doctor right away if you have any signs of a serious allergic reaction:

- Swelling of your face, mouth, lips, gums, tongue, throat or neck
- Have any trouble breathing
- Rash, hives (raised bumps) or blisters

Like other antiepileptic drugs, LYRICA may cause suicidal thoughts or actions in a very small number of people, about 1 in 500.
Call your doctor right away if you have any symptoms, especially if they are new, worse or worry you, including:

- New or worsening depression
- Suicidal thoughts or actions
- Unusual changes in mood or behavior

Do not stop LYRICA without first talking with your doctor.

LYRICA may cause swelling of your hands, legs and feet.
This swelling can be a serious problem with people with heart problems.

LYRICA may cause dizziness or sleepiness.
Do not drive a car, work with machines, or do other dangerous things until you know how LYRICA affects you. Ask your doctor when it is okay to do these things.

ABOUT LYRICA

LYRICA is a prescription medicine used in adults 18 years and older to treat:

- Pain from damaged nerves that happens with diabetes or that follows healing of shingles
- Partial seizures when taken together with other seizure medicines
- Fibromyalgia (pain all over your body)

Who should NOT take LYRICA:

- Anyone who is allergic to anything in LYRICA

BEFORE STARTING LYRICA

Tell your doctor about all your medical conditions, including if you:

- Have had depression, mood problems or suicidal thoughts or behavior
- Have or had kidney problems or dialysis
- Have heart problems, including heart failure
- Have a bleeding problem or a low blood platelet count
- Have abused prescription medicines, street drugs or alcohol in the past
- Have ever had swelling of your face, mouth, tongue, lips, gums, neck, or throat (angioedema)
- Plan to father a child. It is not known if problems seen in animal studies can happen in humans.
- Are pregnant, plan to become pregnant or are breastfeeding. It is not known if LYRICA will harm your unborn baby. You and your doctor should decide whether you should take LYRICA or breast-feed, but not both.

Tell your doctor about all your medicines. Include over-the-counter medicines, vitamins, and herbal supplements.
LYRICA and other medicines may affect each other causing side effects. Especially tell your doctor if you take:

- Angiotensin converting enzyme (ACE) inhibitors. You may have a higher chance for swelling and hives.

BEFORE STARTING LYRICA, continued

- Avandia® (rosiglitazone)*, Avandamet® (rosiglitazone and metformin)* or Actos® (pioglitazone)** for diabetes. You may have a higher chance of weight gain or swelling of your hands or feet.
- Narcotic pain medicines (such as oxycodone), tranquilizers or medicines for anxiety (such as lorazepam). You may have a higher chance for dizziness and sleepiness.
- Any medicines that make you sleepy

POSSIBLE SIDE EFFECTS OF LYRICA

LYRICA may cause serious side effects, including:

- See "Important Safety Information About LYRICA."
- Muscle problems, pain, soreness or weakness along with feeling sick and fever
- Eyesight problems including blurry vision
- Weight gain. Weight gain may affect control of diabetes and can be serious for people with heart problems.
- Feeling "high"

If you have any of these symptoms, tell your doctor right away.

The most common side effects of LYRICA are:

- Dizziness
- Blurry vision
- Weight gain
- Sleepiness
- Trouble concentrating
- Swelling of hands and feet
- Dry mouth

If you have diabetes, you should pay extra attention to your skin while taking LYRICA and tell your doctor of any sores or skin problems.

HOW TO TAKE LYRICA

Do:

- Take LYRICA exactly as your doctor tells you. Your doctor will tell you how much to take and when to take it. Take LYRICA at the same times each day.
- Take LYRICA with or without food.

Don't:

- Drive a car or use machines if you feel dizzy or sleepy while taking LYRICA.
- Drink alcohol or use other medicines that make you sleepy while taking LYRICA.
- Change the dose or stop LYRICA suddenly. You may have headaches, nausea, diarrhea, trouble sleeping, increased sweating, or you may feel anxious if you stop taking LYRICA suddenly.
- Start any new medicines without first talking to your doctor.

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A perforated metal plate (right) collects extragalactic light for analysis.

Light and Dark

Astronomers can see that our universe is expanding at an increasing rate, and dark energy is what they call the mysterious accelerant. To shed light on its nature, researchers with the Baryon Oscillation Spectroscopic Survey (BOSS) are mapping the sky over the Northern Hemisphere with New Mexico's Sloan telescope, one metal plate at a time.

Every manhole-size disk, customized for each of the telescope's viewing angles, is perforated with a thousand tiny holes corresponding to the locations of previously identified galaxies. With the plate attached to the base of the telescope, the holes help funnel the light of each galaxy into instruments that yield data being used to map the universe's structure and motion. BOSS leader David Schlegel says the full survey, due to be completed in 2014, will hint at the composition of the universe—including the dark energy that's pushing it apart. *—Elizabeth Preston*

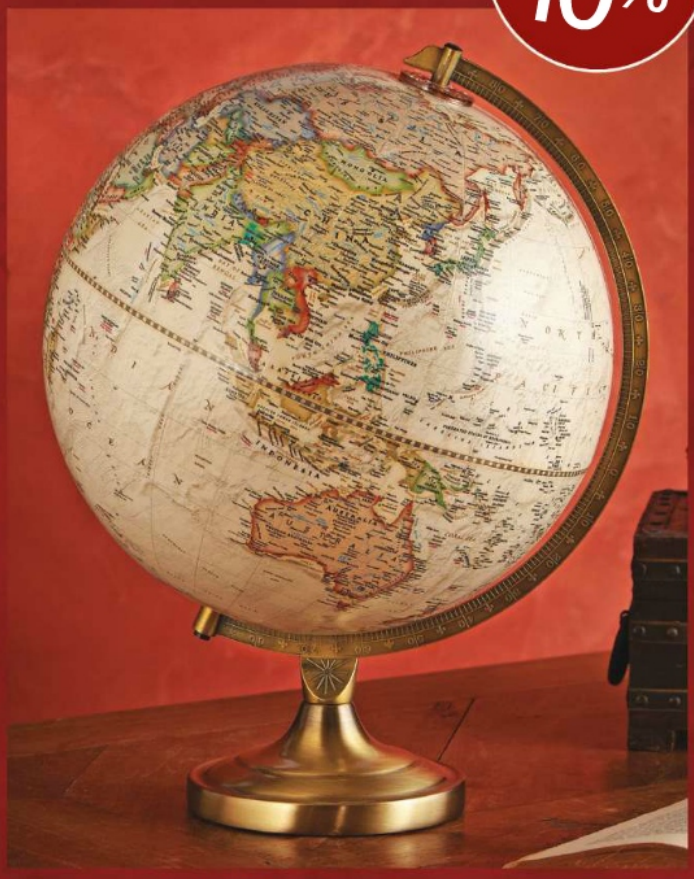
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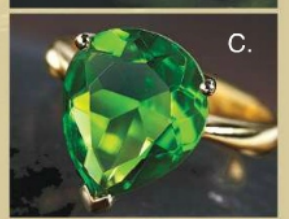
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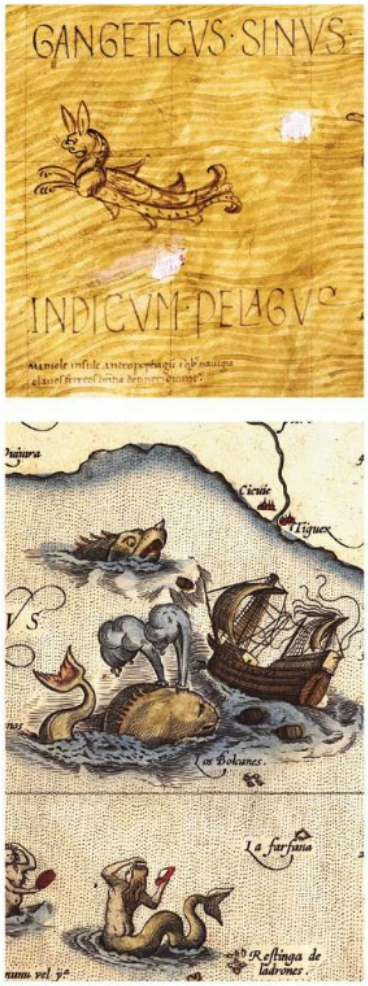
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Map Monsters

What compelled cartographers to include leviathans, sirens, and sea dragons on maps of yore? "The motivation varied to some extent depending on the period," says researcher Chet Van Duzer, author of the upcoming *Sea Monsters on Medieval and Renaissance Maps.*

Early medieval period mapmakers, Van Duzer says, actually believed in the dangers they depicted. Their illustrations were warnings. In the 16th century cartographic creatures were made increasingly whimsical in order to lure map buyers—the more marvelous the monster, the better. By the 17th century sea monsters were singing their swan song. Increasing confidence on the high seas led cartographers to make maps teeming with triumphant ships, with far fewer sirens in sight. —*Sean Rameswaram*



Sea monsters splash (clockwise from top left) on the 1460 Madrid manuscript of Ptolemy's Geographia, *Mercator's 1572 Europe map, Monte's 1590 atlas, and Ortelius's 1570* Theatrum Orbis Terrarum.

ANSWERS FOR EXPLORERS QUIZ

1. (D) Easter Island (109° 37' W) lies almost directly south of Moab, Utah (109° 75' W). The original Polynesian settlers are thought to have reached the island more than 800 years ago, after traveling about 2,400 miles from the Marquesas Islands.
2. (C) Sojourner arrived on the Martian landscape on July 4, 1997, after a voyage of about 312 million miles aboard NASA's Mars Pathfinder. It was named for abolitionist Sojourner Truth, whose own voyage of discovery, on foot, in 1826, covered only 11 miles. But it took her from slavery to freedom.
3. (D) Pytheas is thought to be the first to connect the tides with the phases of the moon. The extreme tidal changes in northern waters probably made the moon's influence more apparent, especially after he'd seen the minimal tides of the Mediterranean.
4. (A) "Piranhas," wrote Theodore Roosevelt, "are the most ferocious fish in the world… They will snap a finger off a hand incautiously trailed in the water… They will rend and devour any wounded man or beast." In fact, piranhas generally do not bother people and should have been the least of Roosevelt's worries. On the expedition he would encounter dangerous rapids and deadly disease—but lived to recount his adventures in *Through the Brazilian Wilderness.* The River of Doubt in Brazil is now called the Rio Roosevelt in his honor.
5. (B) The arctic tern takes the prize, with an average annual migration of almost 44,000 miles from its breeding grounds in Greenland to the Antarctic shore of the Weddell Sea and back again. On the return flight, the birds add hundreds of miles to their journey by looping out over the Atlantic, rather than following a straight line, perhaps to take advantage of prevailing winds.
6. (C) Paul McCartney—with the Beatles, Wings, or solo—has awakened 12 shuttle crews, and he played "Good Day Sunshine" live for the crew in 2005. Also popular with shuttle crews: the Beach Boys ("I Get Around"), U2 ("Beautiful Day"), and Louis Armstrong ("What a Wonderful World"). Dean Martin was a hit on the final day of many flights when he sang, "Goin' back to Houston."

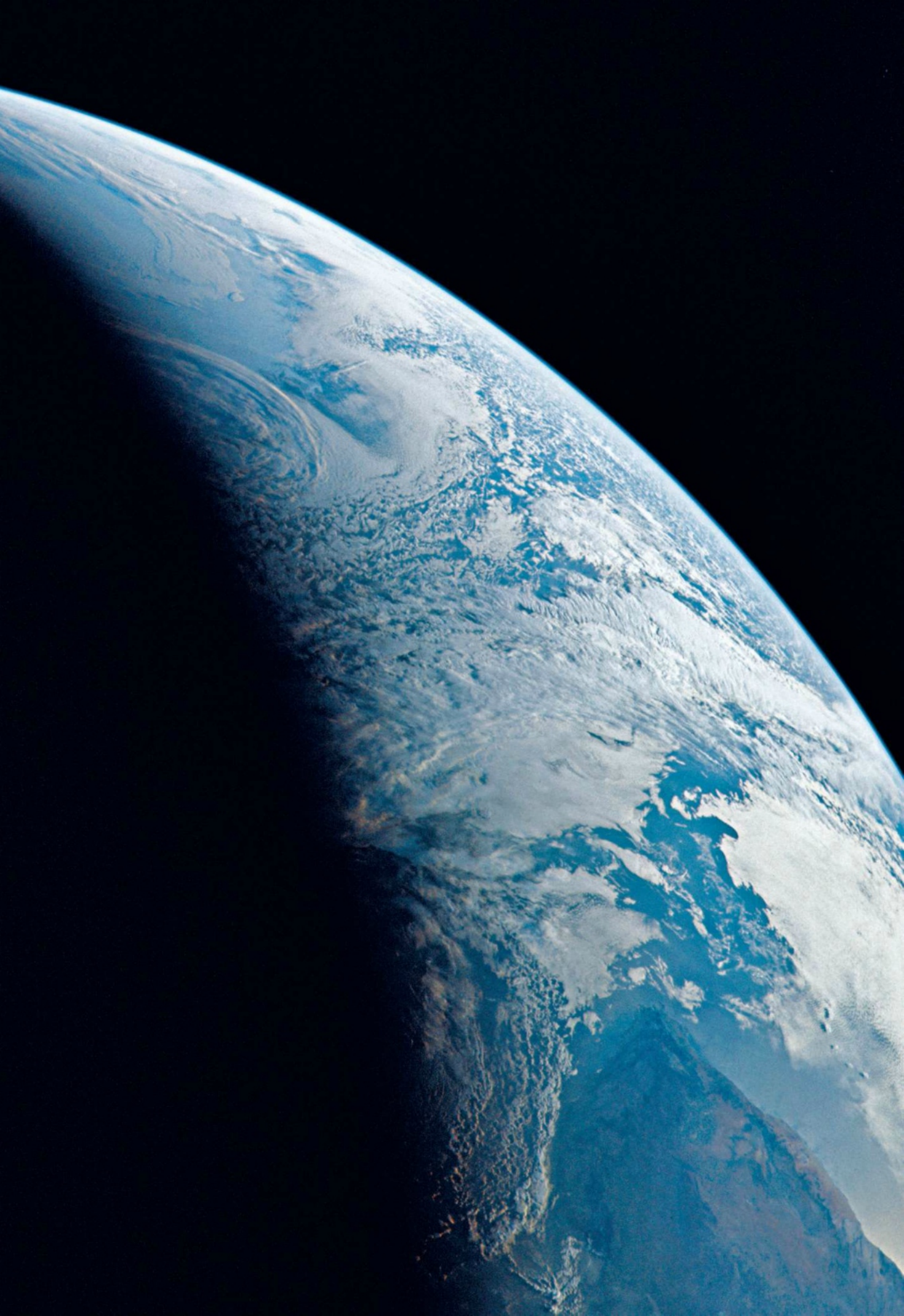
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THE NEW AGE OF EXPLORATION

Ever since our species left Africa some 60,000 years ago, the urge to push beyond what's known—to discover new lands and opportunities—has shaped human culture. And that impulse is still strong.

As we celebrate the National Geographic Society's 125th anniversary, we're kicking off a year of stories about the new age of exploration. In this issue we consider the origins of our restless spirit; we examine new realms of life at the microscopic scale; we reach deep into the universe, searching for worlds like our own; we urgently document nature's diversity, even as it vanishes before our eyes. Exploration is alive. Turn the page and begin the journey.

VIEW OF EARTH FROM APOLLO 11. PHOTO: NASA

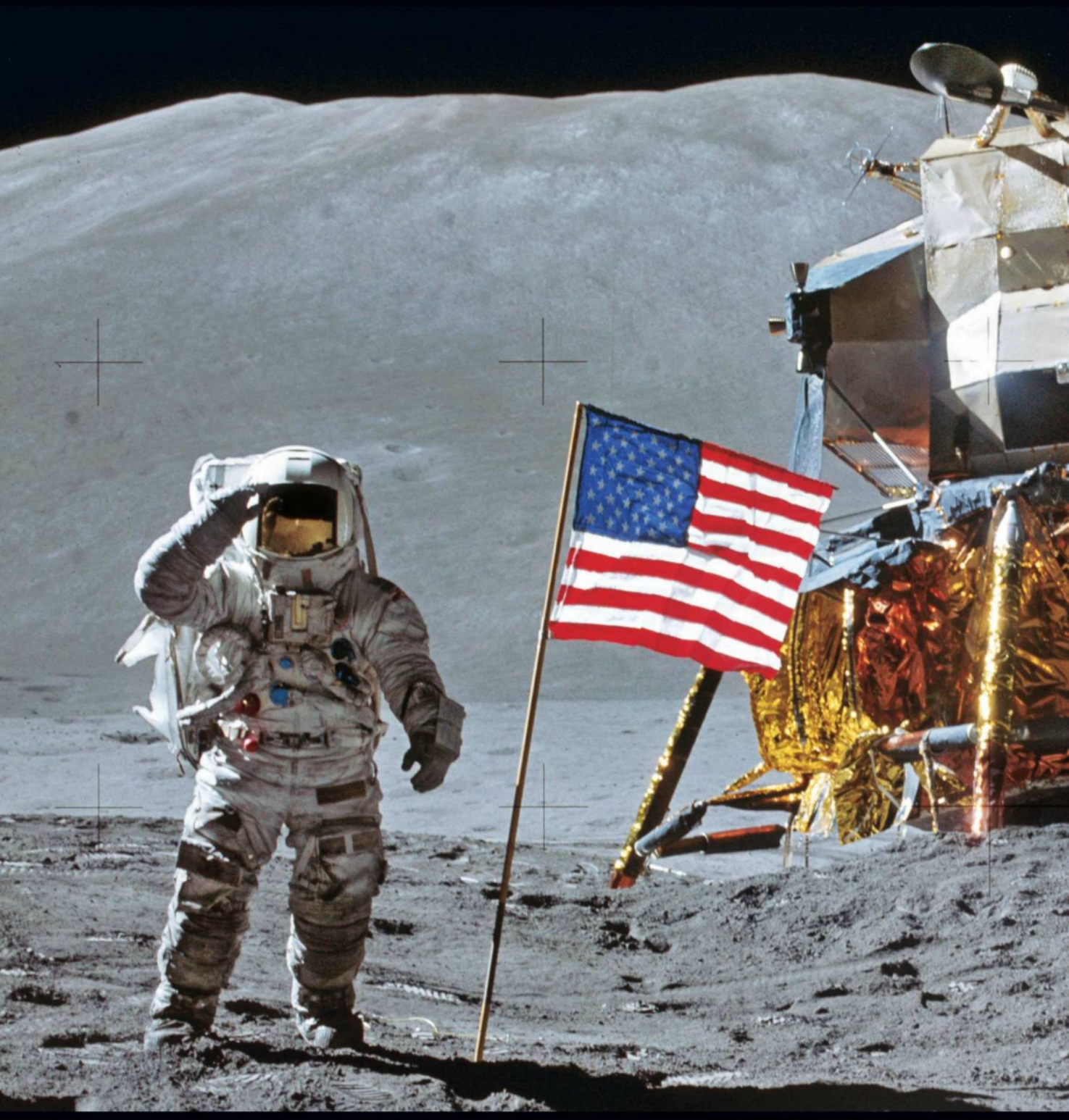


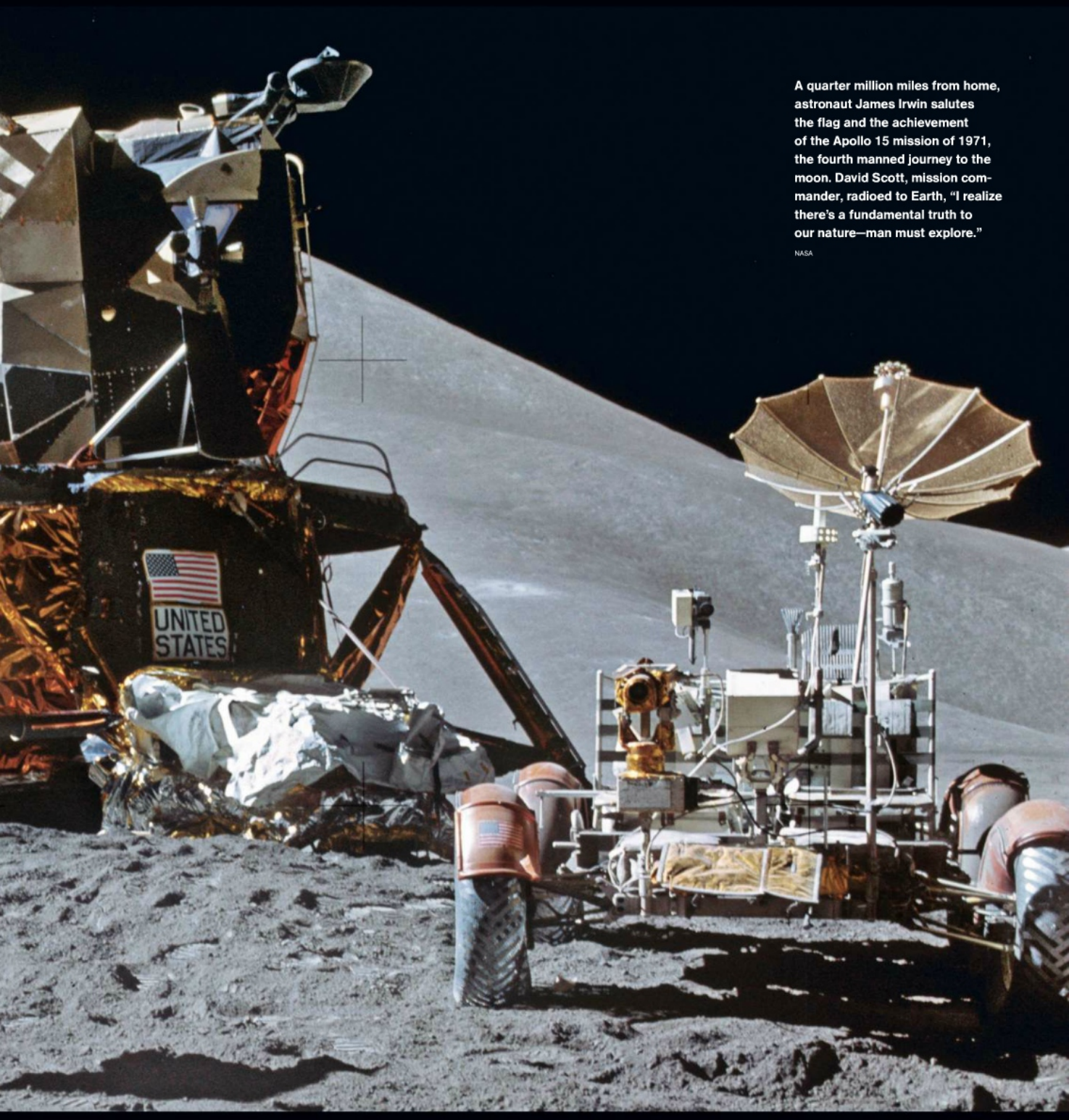




A fast-moving party of more than a dozen adults and adolescents left footprints in volcanic ash in the Pleistocene, providing ancient evidence of modern humans on the move in East Africa. The tracks are preserved at Engare Sero in Tanzania beneath a still active volcano.

ROBERT CLARK





A quarter million miles from home, astronaut James Irwin salutes the flag and the achievement of the Apollo 15 mission of 1971, the fourth manned journey to the moon. David Scott, mission commander, radioed to Earth, "I realize there's a fundamental truth to our nature—man must explore."

NASA



Overcome by the shock of survival, Cory Richards photographed himself minutes after digging out from an avalanche on Gasherbrum II. His party (below) achieved the first winter ascent of the 26,362-foot peak in Pakistan.

CORY RICHARDS (BOTH)




s hard to explain;
hat comes with
he planet."

A team of scientists pitches camp in a lethal environment of heat and toxic gases. Photographer Carsten Peter documents their efforts to fathom the fiery workings of Nyiragongo volcano in the Democratic Republic of the Congo.

CARSTEN PETER



"The places I explore often seem to belong to another planet. I feel small, totally in awe of the forces of creation."

—CARSTEN PETER





“Every time I go in the water I don’t know what I’ll find. And always I return amazed at the animals that let me into their world.”

—BRIAN SKERRY

Curious creatures meet 70 feet deep off the remote Auckland Islands, 300 miles south of New Zealand. In these unfished waters, Brian Skerry photographs a diver encountering a southern right whale that may have never seen a human before.

BRIAN SKERRY, NATIONAL GEOGRAPHIC STOCK





Confronted by a 130-foot waterfall in his way, Ben Stookesberry rappels down a cliff with his kayak on the Rio Alseseca in Mexico, a river never explored in its entirety. He has made 124 first descents on wild rivers.

LUCAS J. GILMAN

> “Fifty years ago we didn’t have the technology to run these rivers. Fifty years from now many could be dammed. Now is the time to explore them and hope others follow.”
>
> —BEN STOOKESBERRY



RESTLE GENES

The compulsion to see what lies beyond that far ridge or that ocean—or this planet—is a defining part of human identity and success.

By David Dobbs

IN THE WINTER OF 1769, the British explorer Captain James Cook, early into his first voyage across the Pacific, received from a Polynesian priest named Tupaia an astonishing gift—a map, the first that any European had ever encountered showing all the major islands of the South Pacific. Some accounts say Tupaia sketched the map on paper; others that he described it in words. What's certain is that this map instantly gave Cook a far more complete picture of the South Pacific than any other European possessed. It showed every major island group in an area some 3,000 miles across, from the Marquesas west to Fiji. It matched what Cook had already seen, and showed much he hadn't.

Cook had granted Tupaia a berth on the *Endeavour* in Tahiti. Soon after that, the Polynesian wowed the crew by navigating to an island unknown to Cook, some 300 miles south, without ever consulting compass, chart, clock, or sextant. In the weeks that followed, as he helped guide the *Endeavour* from one archipelago to another, Tupaia amazed the sailors by pointing on request, at any time, day or night, cloudy or clear, precisely toward Tahiti.

Cook, uniquely among European explorers, understood what Tupaia's feats meant. The islanders scattered across the South Pacific were one people, who long ago, probably before Britain was Britain, had explored, settled, and mapped this vast ocean without any of the navigational tools that Cook found essential—and had carried the map solely in their heads ever since.

Two centuries later a global network of geneticists analyzing DNA bread-crumb trails of modern human migration would prove Cook right: Tupaia's ancestors had colonized the Pacific 2,300 years before. Their improbable migration across the Pacific continued a long eastward march that had begun in Africa 70,000 to

50,000 years earlier. Cook's journey, meanwhile, continued a westward movement started by his own ancestors, who had left Africa around the same time Tupaia's ancestors had. In meeting each other, Cook and Tupaia closed the circle, completing a journey their forebears had begun together, so many millennia before.

Cook died in a bloody skirmish with Hawaiians ten years later. (The Hawaiians snatched a boat; Cook lost his temper and fired upon them; although he killed one and his crew killed several others, the Hawaiians caught him in the surf and stabbed him to death.) His death, some say, brought to a close what Western historians call the age of exploration. Yet it hardly ended our exploring. We have remained obsessed with filling in the Earth's maps; reaching its farthest poles, highest peaks, and deepest trenches; sailing to its every corner and then flying off the planet entirely. With the NASA rover Curiosity now stirring us all as it explores Mars, the United States, along with other countries and several private companies, is preparing to send humans to the red planet as well. Some visionaries even talk of sending a spacecraft to the nearest star. (See "Crazy Far," page 68.)

NASA's Michael Barratt—a doctor, diver, and jet pilot; a sailor for 40 years; an astronaut for 12—is among those aching to go to Mars. Barratt consciously sees himself extending the journey Cook and Tupaia took in the Pacific.

"We're doing what they did," he says. "It works this way at every point in human history. A society develops an enabling technology, whether it's the ability to preserve and carry food or build a ship or launch a rocket. Then you find people passionate enough about getting out there and finding new stuff to strap a rocket to their butts."

Not all of us ache to ride a rocket or sail the infinite sea. Yet as a species we're curious enough, and intrigued enough by the prospect, to help pay for the trip and cheer at the voyagers' return. Yes, we explore to find a better place to live or acquire a larger territory or make a fortune. But we also explore simply to discover what's there.

"No other mammal moves around like we do," says Svante Pääbo, a director of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, where he uses genetics to study human origins. "We jump borders. We push into new territory even when we have resources where we are. Other animals don't do this. Other humans either. Neanderthals were around hundreds of thousands of years, but they never spread around the world. In just 50,000 years we covered everything. There's a kind of madness to it. Sailing out into the ocean, you have no idea what's on the other side. And now we go to Mars. We never stop. Why?"

Why indeed? Pääbo and other scientists pondering this question are themselves explorers, walking new ground. They know that they might have to backtrack and regroup at any time. They know that any notion about why we explore might soon face revision as their young disciplines—anthropology, genetics, developmental neuropsychology—turn up new fundamentals. Yet for those trying to figure out what makes humans tick, our urge to explore is irresistible terrain. What gives rise to this "madness" to explore? What drove us out from Africa and on to the moon and beyond?

IF AN URGE TO EXPLORE rises in us innately, perhaps its foundation lies within our genome. In fact there *is* a mutation that pops up frequently in such discussions: a variant of a gene called *DRD4,* which helps control

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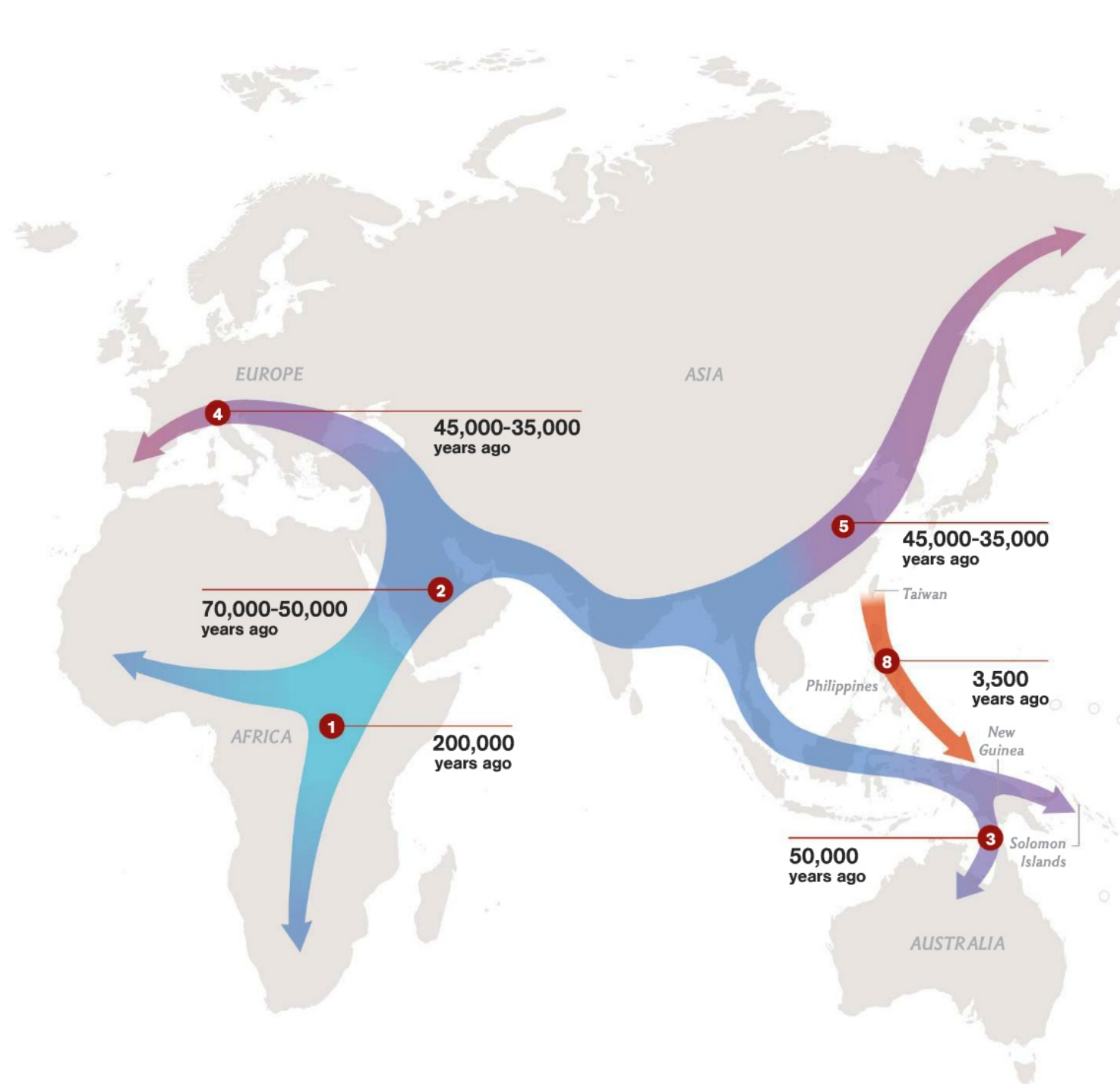
David Dobbs wrote on the teenage brain in the October 2011 issue. He is working on a book about the genetic and cultural roots of temperament.



AFRICA For conservationist Michael Fay, shown here leading an expedition through the Goualougo Triangle of central Africa, the urge to explore a wilderness is inseparable from the desire to help save it. His 2,000-mile trek led to the creation in 2002 of 13 national parks in Gabon.

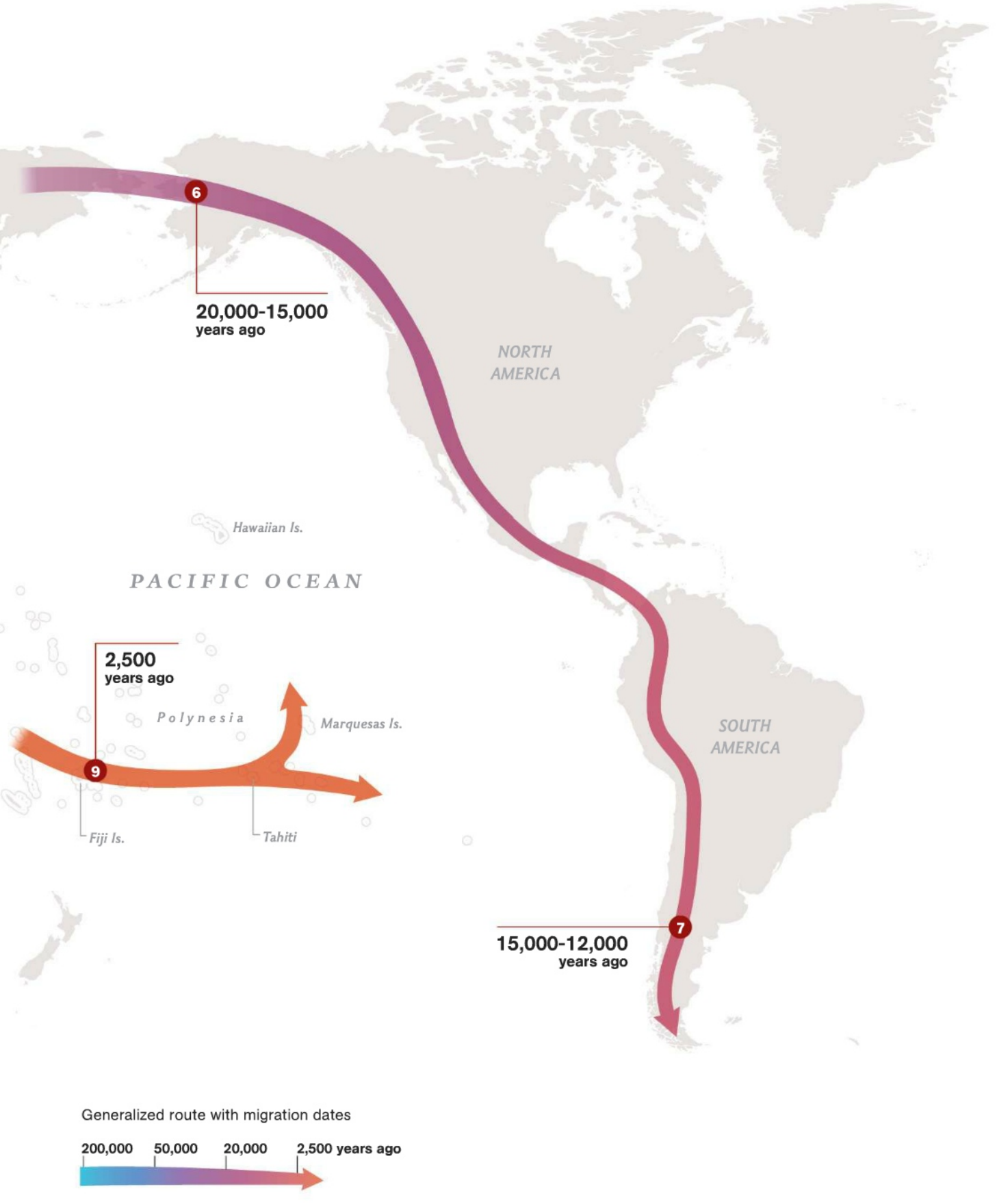
MICHAEL NICHOLS, NATIONAL GEOGRAPHIC STOCK





GLOBAL JOURNEY

Once modern humans began their migration out of Africa some 60,000 years ago, they kept going until they had spread to all corners of the Earth. How far and fast they went depended on climate, the pressures of population, and the invention of boats and other technologies. Less tangible qualities also sped their footsteps: imagination, adaptability, and an innate curiosity about what lay over the next hill.



MAP: INTERNATIONAL MAPPING

SOURCES: CHRIS STRINGER, NATURAL HISTORY MUSEUM, LONDON; SPENCER WELLS, NG STAFF

"No other mammal moves around like we do," says evolutionary geneticist Svante Pääbo. "There's **A KIND OF MADNESS** to it."

dopamine, a chemical brain messenger important in learning and reward. Researchers have repeatedly tied the variant, known as *DRD4-7R* and carried by roughly 20 percent of all humans, to curiosity and restlessness. Dozens of human studies have found that *7R* makes people more likely to take risks; explore new places, ideas, foods, relationships, drugs, or sexual opportunities; and generally embrace movement, change, and adventure. Studies in animals simulating *7R*'s actions suggest it increases their taste for both movement and novelty. (Not incidentally, it is also closely associated with ADHD.)

Most provocatively, several studies tie *7R* to human migration. The first large genetic study to do so, led by Chuansheng Chen of the University of California, Irvine in 1999, found *7R* more common in present-day migratory cultures than in settled ones. A larger, more statistically rigorous 2011 study supported this, finding that *7R,* along with another variant named *2R,* tends to be found more frequently than you would expect by chance in populations whose ancestors migrated longer distances after they moved out of Africa. Neither study necessarily means that the *7R* form of the gene actually made those ancestors especially restless; you'd have to have been around back then to test that premise with certainty. But both studies support the idea that a nomadic lifestyle selects for the *7R* variant.

Another recent study backs this up. Among Ariaal tribesmen in Africa, those who carry *7R* tend to be stronger and better fed than their non-*7R* peers if they live in nomadic tribes, possibly reflecting better fitness for a nomadic life and perhaps higher status as well. However, *7R* carriers tend to be less well nourished if they live as settled villagers. The variant's value, then, like that of many genes and traits, may depend on the surroundings. A restless person may thrive in a changeable environment but wither in a stable one; likewise with any genes that help produce the restlessness.

So is *7R* the explorer's gene or adventure gene, as some call it? Yale University evolutionary and population geneticist Kenneth Kidd thinks that overstates its role. Kidd speaks with special authority here, as he was part of the team that

discovered the *7R* variant 20 years ago. Like other skeptics, he thinks that many of the studies linking *7R* to exploratory traits suffer from mushy methods or math. He notes too that the pile of studies supporting *7R*'s link with these traits is countered by another stack contradicting it.

"You just can't reduce something as complex as human exploration to a single gene," he says, laughing. "Genetics doesn't work that way."

Better, Kidd suggests, to consider how groups of genes might lay a foundation for such behavior. On this he and most *7R* advocates agree: Whatever we ultimately conclude about *7R*'s role in driving restlessness, no one gene or set of genes can hardwire us for exploration. More likely, different groups of genes contribute to multiple traits, some allowing us to explore, and others, *7R* quite possibly among them, pressing us to do so. It helps, in short, to think not just of the urge to explore but of the ability, not just the motivation but the means. Before you can act on the urge, you need the tools or traits that make exploration possible.

Fortunately for me, I had to wander only a floor down from Kidd's office to find someone who studies such tools: developmental and evolutionary geneticist Jim Noonan. His research focuses on the genes that build two key systems: our limbs and our brains. "So I'm biased," he says, when I press him about what makes us explorers. "But if you want to boil this down, I'd say our ability to explore comes from those two systems."

The genes that build our human limbs and brains, Noonan says, are pretty much the same as those that build the same parts of other hominids and apes. Each species' limbs and brains end up different largely because the construction projects directed by these developmental genes start and stop at different times. In humans the result is legs and hips that let us walk long distances; clever, clever hands; and an even cleverer brain that grows far more slowly but much larger than other ape brains. This triad separates us from other apes and, in small but vital developmental details, from other hominids.

Together, says Noonan, these differences compose a set of traits uniquely suited for creating explorers. We have great mobility, extraordinary dexterity, "and, the big one, brains that can think imaginatively." And each amplifies the others: Our conceptual imagination greatly magnifies the effect of our mobility and dexterity, which in turn stirs our imaginations further.

"Think of a tool," says Noonan. "If you can use it well and have imagination, you think of more applications for it." As you think of more ways to use the tool, you imagine more goals it can help you accomplish.

This feedback loop, Noonan points out, helped empower the great Anglo-Irish explorer Ernest Shackleton—and saved him when he and his crew were stranded on Elephant Island in 1916. After polar ice crushed their ship, Shackleton, 800 miles from anywhere with 27 exhausted men, little food, and three small open boats, conceived an insanely ambitious sea voyage. Using a handful of basic tools to modify a 22-foot lifeboat, the *James Caird* (another tool), for a task absurdly beyond its original design, he gathered his navigational instruments and five of his men and executed a trip that few would dare imagine. He reached South Georgia, then returned to Elephant Island to rescue the rest of the crew.

Shackleton's adventure shows starkly, says Noonan, a dynamic that has driven human progress and exploration from the start: As we leverage dexterity with imagination, we create advantages "that select for both traits."

NOONAN MAKES A GOOD CASE that our big brain and clever hands build a capacity for imagination. Alison Gopnik, a child-development psychologist at the University of California, Berkeley, says humans also possess another, less obvious advantage that fosters that imaginative capacity: a long childhood in which we can exercise our urge to explore while we're still dependent on our parents. We stop nursing roughly a year and a half sooner than gorillas and chimps, and then take a far slower path to puberty—about a decade, compared with the three to five years typical for gorillas and chimps. Dental evidence from Neanderthals suggests they too grew up faster than we do. As a result, we have an



SOUTH AMERICA These granite spires in Chile's Torres del Paine National Park no doubt looked just as wild and formidable when the first humans reached Patagonia some 12,000 years ago, marking the farthest stop on the out-of-Africa migration. Today the restlessness that carried our ancestors to the ends of the Earth drives a new age of explorers into the unknown.

MARIA STENZEL, NATIONAL GEOGRAPHIC STOCK



Dozens of studies have found that the gene makes people **MORE LIKELY TO TAKE RISKS** and generally embrace movement, change, and adventure.

unmatched period of protected "play" in which to learn exploration's rewards.

"I wrote a book called *The Scientist in the Crib* that looks at this," says Gopnik. "It could just as well have been titled *The Explorer in the Playroom.*"

Many animals play, says Gopnik. Yet while other animals play mainly by practicing basic skills such as fighting and hunting, human children play by creating hypothetical scenarios with artificial rules that test hypotheses. *Can I build a tower of blocks as tall as I am? What'll happen if we make the bike ramp go even higher? How will this schoolhouse game change if I'm the teacher and my big brother is the student?* Such play effectively makes children explorers of landscapes filled with competing possibilities.

We do less of this as we get older, says Gopnik, and become less willing to explore novel alternatives and more conditioned to stick with familiar ones. "It's the difference," she says, "between going to your usual, reliable restaurant versus a new place that might be great or awful." During childhood we build the brain wiring and cognitive machinery to explore; if we stay alert as adults, this early practice allows us to spot situations in which it pays to shift strategies. *Might there be a Northwest Passage? Could we get to the Pole easier on dogsleds? Maybe, just maybe, we could land a rover on Mars by lowering it from a hovercraft on a cable.*

"We carry this forward," says Gopnik. And the people who keep this spirit of playful engagement with the possibilities of the moment closest at hand—the Cooks and Tupaias, the Sally Rides and Michael Barratts—are the explorers.

IN THE 1830S IN THE deep forests of Quebec, Canada, a restless population of pioneers began a lengthy, risky experiment. Quebec City, built by the French by the St. Lawrence River, was growing fast. To the north, along the Saguenay River, stretched a vast, nearly untouched forest. This rich but brutal country soon attracted loggers and young farming families with a taste for work, risk, and opportunity. Up the valley they went, building one small village after another, creating a wave of settlement moving up

the Saguenay. From a biologist's point of view, such a migratory wave can concentrate not just particular types of people on its frothy front edge; it can also concentrate and aid the expansion of any genes that may encourage those people to migrate.

Sometimes a gene rides such a wave passively, more or less by accident—the gene just happens to be common in the leading migrators, so it becomes common in the communities they establish. For instance, if genes for curly hair had been especially common in the Europeans who first started spreading across North America, curly hair would have become more common in North America as those settlers spread across the continent. The gene doesn't necessarily bestow an advantage; it just becomes more common because so many people in the front edge have it and then reproduce.

But a migratory wave can also allow genes friendly to migration to drive their own selection. A notable, if noxious, example is the South American cane toad. Introduced to northeastern Australia in the 1930s, it now numbers more than 200 million and is advancing across the continent at 30 miles a year. The leading toads hop on legs that are 10 percent longer than those of their 1930s ancestors—and measurably longer than the legs of toads even a mile behind them. How so? Toads that are both restless and long legged move to the front, bringing any restless, long-legged genes with them. There they meet and mate with other restless, long-legged toads to create restless, leggy offspring that move to the front and repeat the cycle.

Laurent Excoffier, a population geneticist at the University of Bern, thinks something similar occurred with the Quebec loggers. In a 2011 paper Excoffier and some colleagues analyzed centuries of Quebec parish birth, marriage, settlement, and death records and found that the pioneer families behaved and bred in a way that spread both their genes and the traits that drove them to the front. These wave-front couples married and mated sooner than did couples back home, perhaps because they were more impatient folks to begin with and because the frontier gave them access to land and a social atmosphere favorable to starting sooner. This alone produced more children than the "core" families who stayed behind did (9.1 per family versus 7.9, or 15 percent more). And because these children in turn proved likelier to marry early and have more children, each pioneer couple left behind 20 percent more offspring altogether. Twenty percent more offspring produces a huge evolutionary advantage. In this case it rapidly raised the share of these families' genes and cultures within their own population—and thus within North America's larger population.

Excoffier believes that if this "gene surfing," as some call it, happened often as humans scattered around the globe, it would have selected for multiple genes that favor curiosity, restlessness, innovation, and risk taking. This could, he says, "help explain some of our exploratory behavior." Exploration may thus create a self-reinforcing loop, amplifying and spreading the genes and traits that drive it.

THERE IS ANOTHER self-reinforcing dynamic operating in exploration—an ongoing conversation between culture and genes, wherein genes shape what sort of culture we create and the culture in turn shapes our genomes.

This is culture in a broad sense—shareable knowledge, practices, or technology that people use to adapt to an environment. These things exist only because our genetic traits evolved to the point where we could create them, and we reshape them constantly. But this changing culture can likewise shape our genetic evolution, sometimes in stunningly quick and direct ways.

The classic culture-gene example is the rapid rise of a gene for digesting lactose. If you lack this gene, you'll have trouble digesting milk after infancy. If you have it, you'll easily digest milk all your life. Almost no one carried this gene 15,000 years ago, because it gave no advantage. It was just a mutation floating around. But when early farmers in Europe started raising dairy cattle about 10,000 years ago—a culture utterly novel then, an entirely different way of living—this gene suddenly gave people access to a reliable year-round food source. They could survive food shortages that starved other people. This

The first time a **HUMAN ANCESTOR USED A ROCK** to smack open a nut, she opened the way to a culture that may have increasingly selected for genes underlying dexterity and imagination.

advantage rapidly spread the gene throughout Europe, even as it remained rare most other places. Culture and genes started selecting for each other: A new culture made a gene more valuable, and as the gene spread through the population, it made dairy-farming culture more important.

You can see signs of this dynamic—genes and cultural bits affecting each other's value—almost everywhere in complicated human behavior and particularly in exploration. The first time a human ancestor used a rock to smack open a nut, she opened the way to a culture that may have increasingly selected for the genes studied by Jim Noonan that underlie dexterity and imagination. Rising powers of dexterity and imagination in turn accelerated the development of culture. Ernest Shackleton, as Noonan notes, drew heavily on this, exploiting a culture of ships, tools, innovation, and way finding—to say nothing of British stoicism—to explore new ground and get back home. In Gopnik's explorers in the playroom, an ancient human culture of cooperative child raising—by mother, father, grandparents, other kin—has maximized the value of genes that allow a long period of brain development. And Quebec's pioneer families leveraged their most restless genes and traits by creating a subculture that placed premiums on curiosity, innovation, toughness, and a willingness to take risks—as well as the crucial physical culture of axes, adzes, pikes, and peaveys they used to build homes and harvest wood, and the sleds, wagons, and canoes they used to travel.

With his ships, his compass and sextant, and his mandate from his king, Cook too leveraged his smarts and curiosity to bring home a map of a world previously uncharted. His return fattened the value of both England's imperial marine culture and the genetic traits he'd displayed in his relentlessly curious and risky journeys.

BUT WHAT OF TUPAIA? His genes and culture, it seems, took a more puzzling path to their meeting with their British counterparts. In fact the Polynesians' spread across the Pacific represents one of the oddest of the movements that took modern *Homo sapiens* out of the African

homeland and around the globe. It began as the first and one of the fastest, slowed to a halt, and then finished in a record sprint.

Their journey began about 60,000 years ago, when one of the first migratory pulses shot from Africa across the Middle East and along Asia's southern coast. They reached Australia and New Guinea—more accessible then because of low ocean levels—in only 10,000 years. For another 10,000 years these people spread through this island region, sometimes called Near Oceania, until they reached the curved chains of the Bismarck and Solomon Islands. There they stopped dead.

Up to that point, says Ana Duggan, who is studying this migration at the Max Planck Institute for Evolutionary Anthropology, "the islands they moved among were generally intervisible." That is, land was always in sight: The island in front of you would rise up from the horizon before the one you'd left sank behind.

Sail beyond the Solomons, however, and you could go weeks without spotting land. Neither the navigation these Near Oceanians used nor their boats—probably fairly crude rafts or dugout canoes—could cope. So they stayed put, limited to their line of sight.

"This next part," says Duggan, "is a bit controversial," though it's supported by most Polynesian scholars and a growing confluence of linguistic, archaeological, and genetic evidence. According to this "out of Taiwan" theory, some 3,500 years ago the Near Oceanians received visitors from the north—a coastal people known as the Austronesians (confusing, since they come from Asia) who had left Taiwan and south coastal China a thousand years earlier and spread slowly through the Philippines and other islands off Southeast Asia before reaching Near Oceania. Once there, they mixed and mated with the native population. Over the next few centuries this meshing of genes and cultures created a new people called the Lapita. Soon after that, the Lapita people started sailing eastward across the Pacific.

What got them started again? It probably wasn't new genes. None of the incoming Austronesian ones jump out as restless-gene candidates. In fact the *7R* and *2R* variants were less common in the Asians than in the Near Oceanians. But the Asians brought something else that was decidedly new.

"They brought a better boat," says Duggan.

These boats were ships, really: long canoes with sails, outriggers, and far greater speed and range. They allowed the Austronesians to sail in high winds and higher seas. These craft must have stunned the locals. The excitement the ships created, traceable today in the Polynesian culture and the longevity of its marine vocabulary, would have conferred great status. The motivation to explore increases, as does the reward. Like today's astronauts, the Pacific Island boatbuilders and sailors would have enjoyed a social cachet that enhanced mating opportunities, commanded social and economic support, and created a motivating force that might coddle any number of restless genes. As anthropologist and National Geographic Explorer-in-Residence Wade Davis puts it, "When you set sail to find new lands, you became mythologized—even if you didn't come back." And so Tupaia, riding in the DNA of his ancestors, headed east.

A proper sailing craft like the ship the Polynesians developed makes a near-perfect metaphor for the larger powers we gain through culture. It gives our malleable genomes, imaginative minds, and clever hands the power to transform even the strongest forces in our environment—wind, water, current—from threat to opportunity. Let the wind rise to a howl and raise a great sea; we needn't stay home or become flotsam, for we can change tack, trim sail, and become what amounts to a different vessel. To the Lapita looking out from the eastern tip of the Solomons, a vast ocean before them, such a boat would offer something like a new set of legs. Tiller in hand and new isles in their minds, they could press on in their journey around the globe.

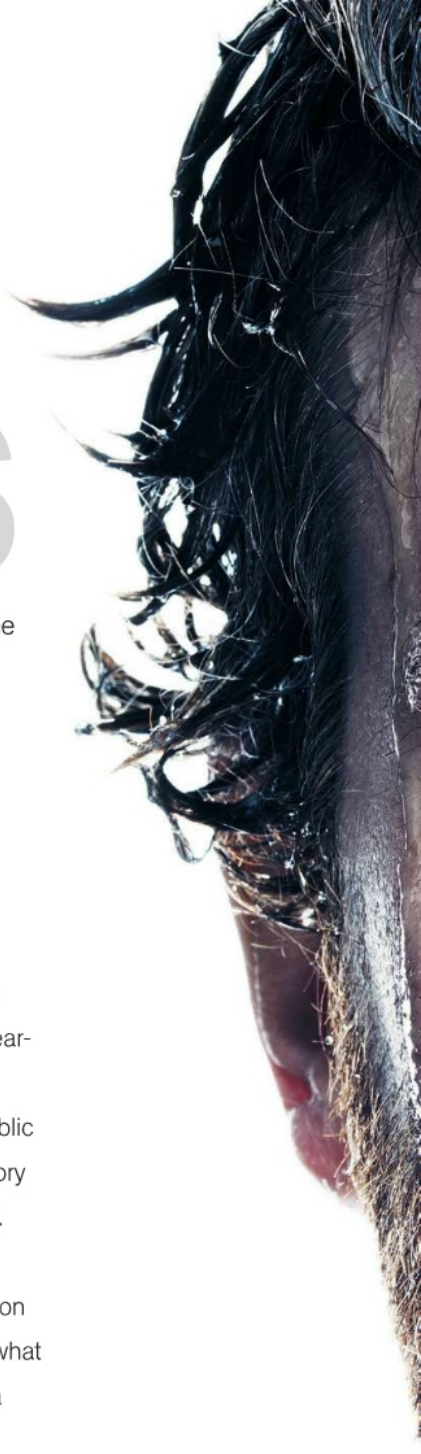
It's enough to move even a Max Planck geneticist. Ana Duggan, telling me of these boats in Leipzig, confessed she was by nature not the sailing type. But this bigger boat we were talking about—just the idea of that boat—seemed to rouse her inner mariner.

"If someone pulled up to shore in one of those and said, 'Look at my big fancy boat. I can go far,'" she mused, "I'd get in." □

RISK TAKERS

We begin a yearlong series profiling men and women who press the limits in the name of exploration, even when it puts them in jeopardy.

By Pat Walters Photographs by Marco Grob



Extreme Kayaker

TRIP JENNINGS has paddled white water to explore rivers around the world and in 2008 made a first descent of the notoriously turbulent lower Congo River. The 30-year-old Oregonian now travels by foot, motorbike, and plane as well, heading to remote spots in the name of conservation: collecting elephant scat in the Democratic Republic of the Congo for a DNA map of elephant populations, used to trace the source of ivory sold by poachers; documenting a threatened Alaska salmon migration last summer.

You filmed the salmon run from a plane flown by explorer Mike Fay.
Mike's a talented but crazy pilot. We're flying 10 feet off the river with 200-foot trees on either side, which is terrifying. The whole time I was staring at an iPad showing me what was coming through the cameras mounted on the plane. At times it could feel like a video game. When I'm paddling my kayak, at least I have the veil of control.

With or without your kayak, you go way off the beaten track.
It's crucial to get to those last places that are unspoiled, to document them, to show them to the rest of the world in the hope they can stay unspoiled.

That's not always an easy job.
In the Congo I've been held up at gunpoint, facedown in the sand. My last time there, a warlord issued a death threat to any conservationists working in the area.

Are you afraid that you might die on one of your trips?
I guess I'm not that afraid of death. That said, I don't want to die on an expedition. I want to die old and in a bed, not in a plane in the wilderness or shot by a poacher.

Pat Walters is a staff producer of NPR's Radiolab. *Photographer Marco Grob won an Emmy in 2012 for "Beyond 9/11: Portraits of Resilience." His videos of the risk takers featured in this issue can be viewed on our digital editions.*



Snake Hunter

ZOLTAN TAKACS was fascinated with snakes as a boy in Hungary and still is. An expert in toxins, he's traveled to more than a hundred countries and caught thousands of reptiles, collecting their venom for screening to see if it can be turned into a lifesaving drug. He himself is allergic to venom.

Do you have a death wish?
Listen, I like my life and I don't want to die. I have a family, who I love very much. And I have to be careful, because three colleagues of mine passed away from snakebites. The last thing I want is one day not to return.

Have you ever been bitten by a snake?
Six times, all my fault. I got my first bite when I was 15. The most recent was in the Brazilian Amazon in 2008, by a not very toxic snake. But I had a terrifying allergic reaction in the middle of nowhere.

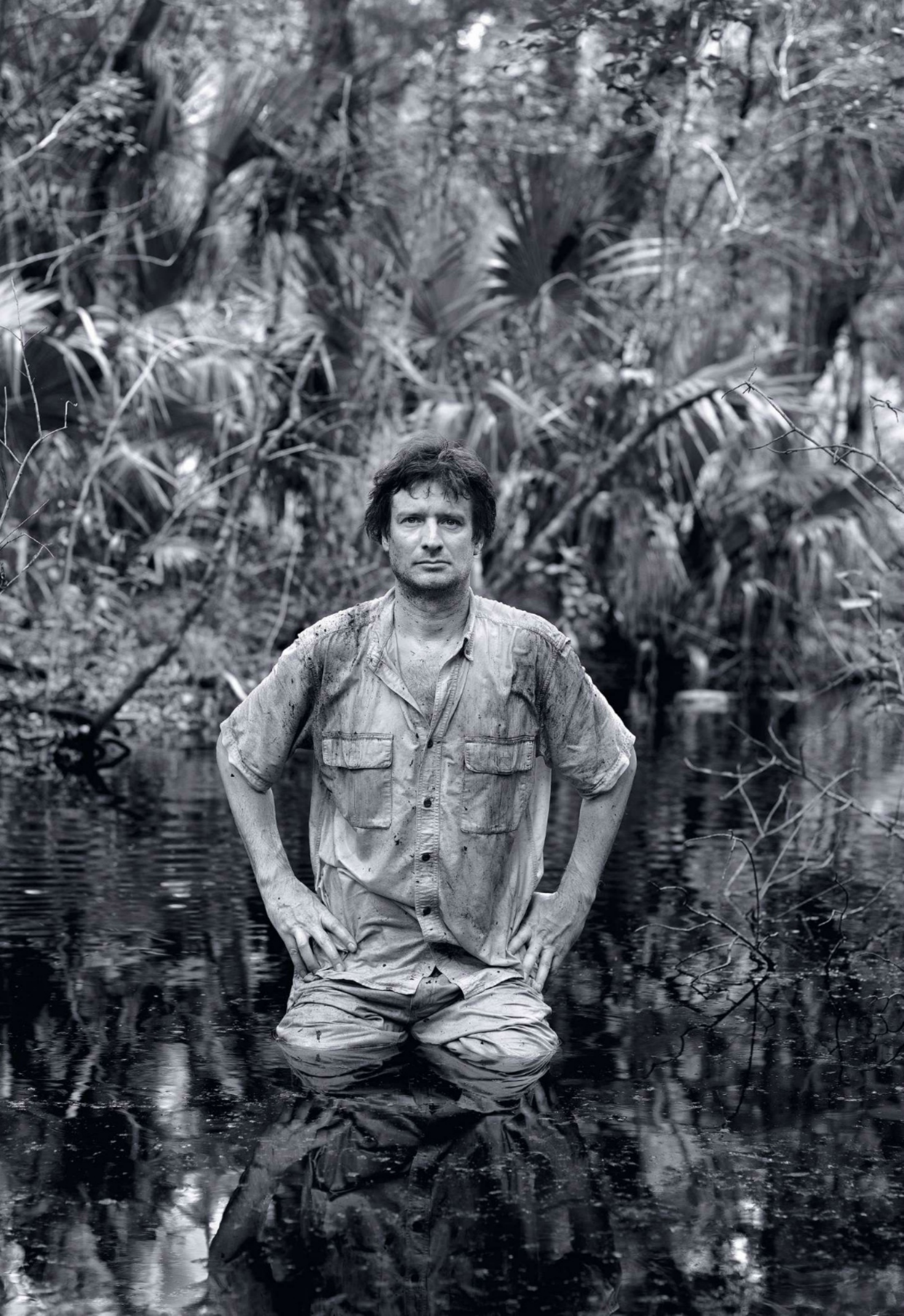
What makes the risk worth it to you?
My ultimate goal is to push a toxin into medical use. Toxins have yielded about a dozen medications, and some are lifesavers. If anybody faces a deadly heart attack, there are three drugs of choice, and two are reptile-venom derived. There are a hundred thousand different venomous animal species with 20 million different toxins. Imagine how many potential medications you could find.

Is there a typical day in the field?
There is no typical day. I go to the far corners of the Earth. I fly small planes. I scuba dive. I sleep in the middle of the rain forest or in the desert. Obstacles vary: from infections to crocodiles, from civil wars to landslides to pirates. I've been jailed, chased by elephants, sprayed with cobra venom.

Lab work must seem dull by comparison.
Hardly. The lab gives meaning to what I do. You're the first person to see what nature's been working on for hundreds of millions of years. We take this to the drawing board and perfect the toxins for medical applications.

But first you have to go get the toxins.
Right. There's no way you can do this unless you put yourself on a plane, travel to a rain forest, turn on your flashlight, and start the night search for vipers.





Ice Investigator

LONNIE THOMPSON has been climbing to mountaintop glaciers from Peru to China for the past 38 years, pulling crucial climate data from deep inside the ice. A glacier that's hundreds of feet thick can contain thousands of years of information: layers of snow and dry-season dust. Some say Thompson has spent more time above 18,000 feet than anyone alive—1,099 days, at last count. His data show the planet is warming at a historic rate. As a result the ice is melting—and his vital, dangerous work is taking on new urgency. Thompson heads next to Tibet, where he believes he'll find the oldest ice on the planet, perhaps going back a million years.

Lots of people climb to above 18,000 feet. But you stay for weeks on end.
When we drilled on the glacier Dasuopu in the Himalaya, we were up there for six weeks, at 23,500 feet. Climbers don't do that.

You must run into challenges.
Getting six tons of camping and drilling equipment up to 23,500 feet is one. Lightning is another. I mean, you're up there with this drill that's basically the world's highest lightning rod. I've had lightning come down ten feet in front of me. And of course you have avalanches. Huge storms. Wind. You can be pinned down for three or four days. Or blown away. I feel fortunate to have made it to 64 years old.

You had a heart transplant last year.
Would I have the heart problems I have, had I not climbed so many mountains? It's unknowable. My dad died at 41 from a heart attack, and congestive heart failure is genetic. Maybe I'm living longer because I climb mountains.

Why do you keep working?
When I go back to Quelccaya in Peru, where I've been 26 times, it's like visiting a patient dying of cancer. You know there's no hope; you can only watch it shrink away. So my work has become a salvage operation—to capture history before it disappears forever.

You've said data alone won't change human behavior.
It's human nature to deal only with what's on our plate today. When people lose their houses or crops to fires, droughts, tornadoes—when they lose everything they've worked for—they'll say, Whoa! What's going on here? And that's already starting to happen. At some point the discussion will change very rapidly. It'll seem like it happened overnight.



Cat Detective

JAROSLAV FLEGR found out in 1990 that he was infected with *Toxoplasma gondii,* a parasite that typically lives (and reproduces) in cats. The Czech evolutionary biologist learned that the parasite often jumps from cat to human via litter boxes or contaminated water, but what truly fascinated him was how it jumps from cat to cat: It uses rats. When "toxo" infects a rat, it hijacks its brain, making the rat more active, less risk averse, even sexually attracted to the scent of cat urine—in sum, more likely to get eaten. This knowledge gave Flegr a radical idea he decided to explore: Maybe toxo was controlling his brain too. Colleagues told him he was crazy. As it turns out, his hunch was right.

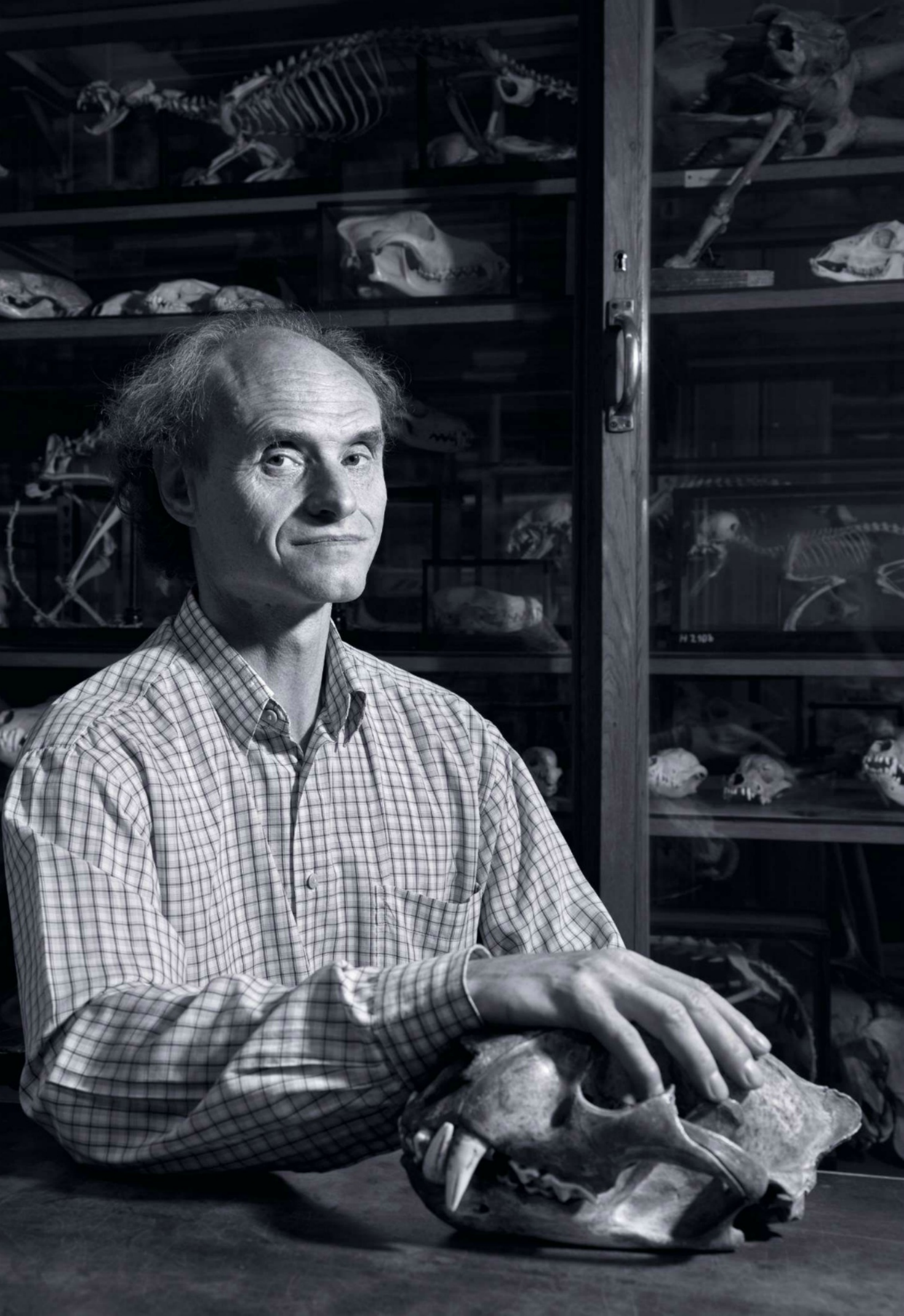
How many cats do you have?
I have two.

Why did you think that toxo was controlling you?
I thought it might explain some of my strange behaviors—ones that are nonadaptive for me but adaptive for a parasite that needs to get to a new host. I would cross the street in traffic but not jump out of the way when cars honked. Later I found that people infected with toxo are 2.6 times more likely to get into a traffic accident.

So toxo does something to the brain that makes people reckless?
Actually, in humans, we found that it greatly slows reaction time, which can influence the risk of a traffic accident. Infected people also tend to be less conscientious. And our male subjects considered the scent of cat urine to be quite pleasurable.

Top scientists now accept your theory—but at first people called it crazy.
For many people this phenomenon was difficult to believe—even for me, at first, it was difficult to believe what I was observing was real. But it is. And with toxo potentially responsible for hundreds of thousands of deaths a year—and perhaps many cases of schizophrenia as well—it's important too. Yet there's still no cure for it.

Counterintuitive hypotheses are your trademark. What are the challenges?
When I send papers to top journals, they're often rejected out of hand by editors, without any formal review. The danger of making interesting claims—like when I said that Darwinian theory is not quite correct and can be improved—is that you won't be considered a serious scientist. If I studied, say, molecular interactions, maybe I would be more famous. But I like problems nobody else is studying. And I'm very comfortable doing what I do.



War Zone Doctor

JILL SEAMAN has spent decades exploring the most effective way to bring modern medicine to the beleaguered people of South Sudan. In 1989 she arrived in the midst of one of the worst epidemics to hit Africa—from a tropical disease called kala-azar—and a brutal civil war. Today the war is over, South Sudan has declared independence, and the epidemic has subsided, but violence, disease, and perhaps worst of all, fear, still plague the region that has become Seaman's second home.

What were things like when you arrived?
More than half of the population in the region was already dead. You'd walk through villages where nobody was alive. You would see the ashes from a fire. You might walk over bones. But there was nobody. It was silent and eerie and devastating.

You had to fight the cause of all this death. Can you describe the enemy?
Kala-azar is transmitted by the bite of a sand fly and gives you fever, wasting, a big spleen. After many weeks you will die. In 1989, when I came into South Sudan with Doctors Without Borders, there were no people treating patients in the bush. And so research was needed to give high-tech treatment and to do high-tech diagnostics out of a mud hut. Most of our research was aimed at that, and it continues to be that way today.

But over the past 20 years, you've eliminated the disease?
Well, no. It's hard to compare the epidemic to now, because now there is health care. But just in the past three years we've had another outbreak. This past year we treated 2,500 people. And that's a huge number of patients.

Your clinic's been bombed and burned. But you insist you're not a risk taker.
I'm not. I'm *serious.* I have a passion for health care and for Sudan. I can tell you lots of things that have happened that are scary, like a massacre in a town just north of us that killed maybe 200 people in a couple of hours. They just shot at people, at women washing their clothes. But that has nothing to do with why I'm here.

But you are there. And it is risky, no?
The thing is, it's not that I'm taking risks. *Everybody*'s taking risks. *Life* is a risk. Everybody who lives there, they know that life could be gone in an hour. And yet they live. And they are happy. And I get to touch millions of people and hopefully help them. How could I be more lucky?







A 22nd-century dream: An unmanned probe powered by nuclear fusion explores a new solar system, after traveling several decades from Earth at 100 million miles an hour.

THE NEW AGE OF EXPLORATION

CRAZY FAR

To the stars, that is. Will we ever get crazy enough to go?



Thousands of colonists might live on this interstellar *Mayflower* for a journey lasting generations. The ship has its own ecosystem and artificial gravity from its rotating cylindrical hull. A sister ship looms in the giant window.

By Tim Folger
Art by Stephan Martiniere

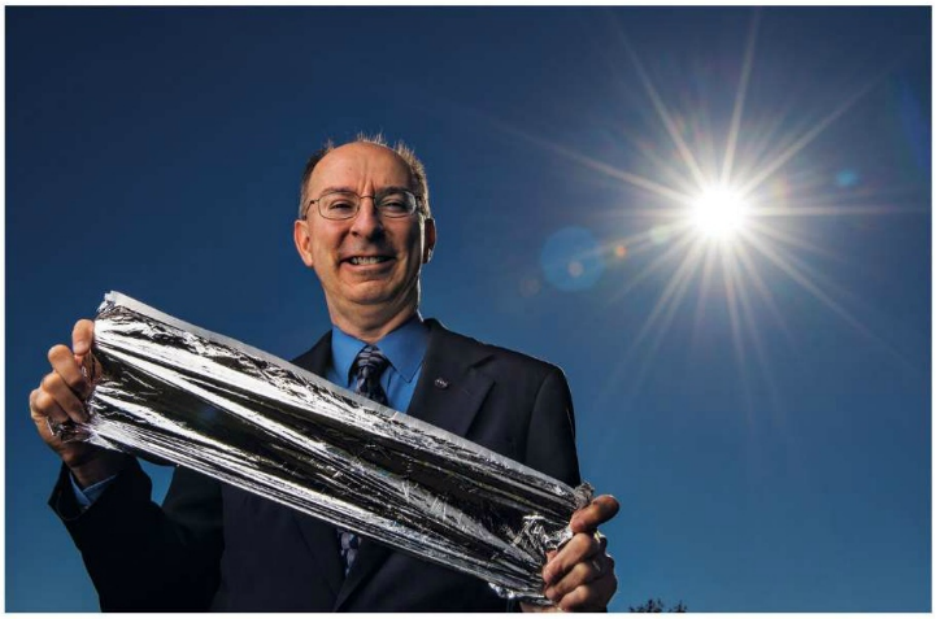
On the edge of a parking lot at the Marshall Space Flight Center in Huntsville, Alabama, stands a relic from a time when our future as a spacefaring species looked all but inevitable, as clear and grand as a rocket ascending over Cape Canaveral.

"This is not a model," NASA physicist Les Johnson says as we gaze at the 35-foot-tall assemblage of pipes, nozzles, and shielding. "This is an honest-to-goodness nuclear rocket engine." Once upon a time, NASA proposed to send a dozen astronauts to Mars in two spaceships, each powered by three of these engines. Marshall director Wernher von Braun presented that plan in August 1969, just two weeks after his Saturn V rocket delivered the first astronauts to the moon. He suggested November 12, 1981, as a departure date for Mars. The nuclear engines had already passed every test on the ground. They were ready to fly.

Thirty years after the Mars landing that never was, on a humid June morning, Johnson looks wistfully at the 40,000-pound engine in front of us. He heads a small team that assesses the feasibility of "advanced concepts" in space technology—and NERVA, the old nuclear engine, just might qualify. "If we're going to send people to Mars, this should be considered again," Johnson says. "You would only need half the propellant of a conventional rocket." NASA is now designing a conventional rocket to replace the Saturn V, which was retired in 1973, not long after the last manned moon landing. It hasn't decided where the new rocket will go. The NERVA project ended in 1973 too, without a flight test. Since then, during the space shuttle era, humans haven't ventured more than 400 miles from Earth.

All of which might seem to make the question Johnson and I have spent the morning discussing—will humans ever travel to the stars?—sound a little out of touch.

Why did it seem more reasonable half a century ago? "Of course we were crazy in a way," says physicist Freeman Dyson of the Institute for Advanced Study in Princeton. In the late 1950s Dyson worked on Project Orion, which aimed to build a manned spacecraft that could go to Mars and the moons of Saturn. Instead of using nuclear reactors to spew superheated hydrogen, as NERVA did, the Orion spacecraft would have dropped small nuclear bombs out the back every quarter of a second or so and surfed on the fireballs. "It would have been enormously risky," says Dyson, who planned to go to Saturn himself. "We were prepared for that. The mood then was totally different. The idea of a risk-free adventure just didn't make sense." A few years after Orion ended, Dyson outlined in *Physics Today* how a



One way to power a starship, says NASA's Les Johnson, might be with a sail filled by the faint pressure of sunlight or laser light. The sail would be hair thin and shiny to reflect the light. It would also be the size of a small country.

bomb-powered spacecraft might travel to a star.

These days it's easier to outline why we'll never go. Stars are too far away; we don't have the money. The reasons why we might go anyway are less obvious—but they're getting stronger. Astronomers have detected planets around many nearby stars; soon they're bound to find one that's Earthlike and in the sweet spot for life, and in that instant they'll create a compelling destination. Our technology too is far more capable than it was in the 1960s; atom bombs aren't cutting-edge anymore. In his office that morning, Les Johnson handed me what looked like a woven swatch of cobwebs. It was actually a carbon-fiber fabric sample for a giant spaceship sail—one that might carry a probe beyond Pluto on rays of sunlight or laser beams. "Be very careful with it," Johnson said. "This is a material that might help us get there."

To get to the stars, we'll need many new materials and engines but also a few of the old intangibles. They haven't vanished. In fact, they almost seem to be bursting forth again in the imaginative space vacated by the space shuttle, which in 2011 joined the Saturn V as a museum exhibit. In the conversation of certain dreamer-nerds, especially outside NASA, you can now hear echoes of the old aspiration and adventurousness—of the old craziness for space.

LAST SPRING, three weeks before I met with Johnson, SpaceX, a private company based near Los Angeles, used one of its own rockets to launch an unmanned capsule that docked with the International Space Station. SpaceX leads several other companies in the race to replace the shuttle as the space station's supply ship. A month before that, a company called Planetary Resources, backed by billionaire investors such as Google's Larry Page and Eric Schmidt,

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Tim Folger wrote about tsunamis last February. Artist Stephan Martiniere's science fiction movie credits run from Star Wars *to* Total Recall.

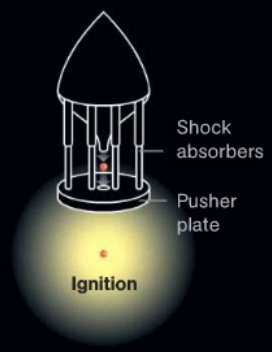
On our digital editions you can listen to Stephan Martiniere talk about his starship paintings.

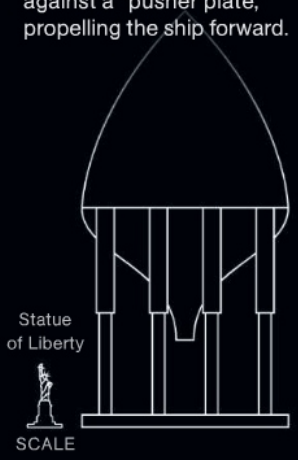
MICHAEL A. SCHWARZ

Four Ways to Propel a Starship

NUCLEAR PULSE

In this scheme, pioneered by Project Orion in the 1950s, thermonuclear bombs expelled by the spacecraft would explode against a "pusher plate," propelling the ship forward.





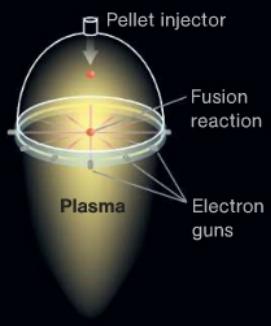
Pros: Feasible with near-term technology

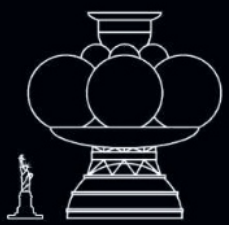
Cons: Massive radiation hazard and other dangers; relatively slow

Travel time to nearest star: Centuries

NUCLEAR FUSION

Deuterium pellets injected into a reaction chamber 250 times a second would be heated by electron guns until the deuterium nuclei fused—and the pellets exploded. Powerful magnets would channel the blasts out the back.





Pros: Less dangerous than bombs or fission reactors

Cons: Deuterium is rare, and fusion reactors don't really work yet

Travel time to nearest star: Decades

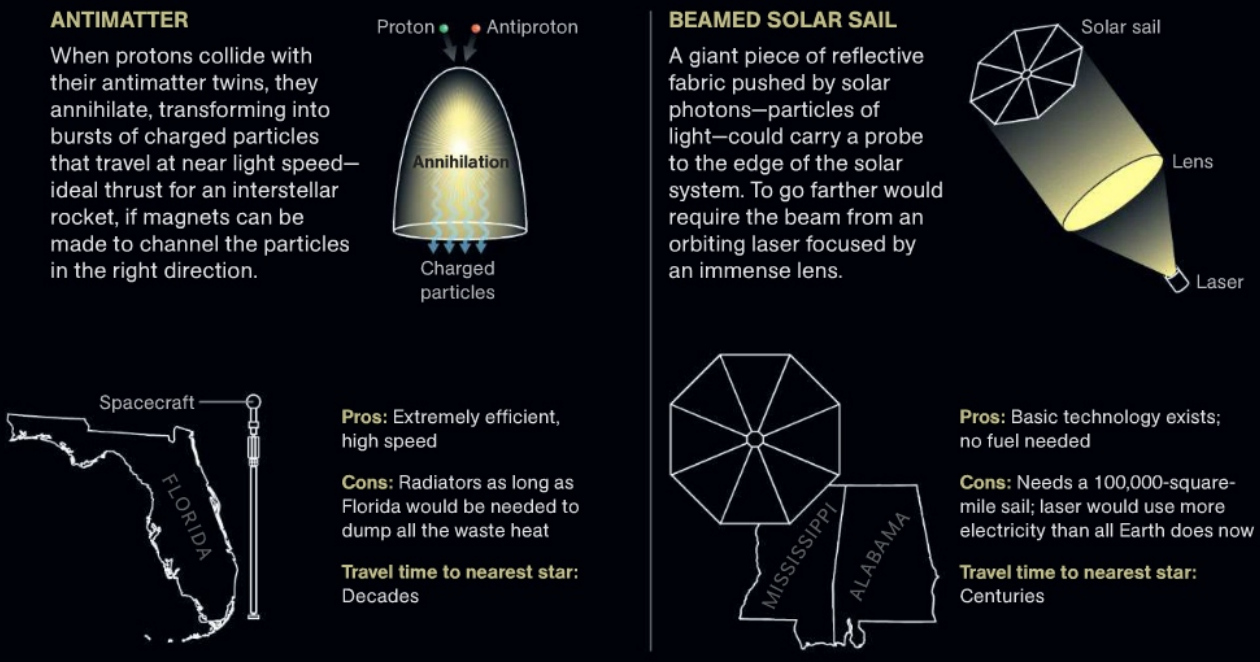
announced plans to use robotic spacecraft to mine asteroids for precious metals. Working with Virgin Galactic, a company whose main business is space tourism, Planetary Resources expects within the next year or two to launch a lightweight telescope into low Earth orbit. "We hope by the end of the decade that we will have identified our initial targets and begun prospecting," says Peter Diamandis, the firm's co-founder.

"We're going to look back at this decade as the dawn of the commercial space age," says Mason Peck, NASA's chief technologist. "It's about companies large and small finding ways to make a market out of space. The energy we see now—the economic motivation to go into space—we haven't seen that before."

Economics has long spurred exploration on Earth. Medieval merchants risked the hazards of the Silk Road to reach the markets of China; Portuguese caravels in the 15th century sailed beyond the bounds of the known world, searching less for knowledge than for gold and spices. "Historically, the driver for opening frontiers has always been the search for resources," says Diamandis. "Science and curiosity are weak drivers compared with wealth generation. The only way to really open up space is to create an economic engine, and that engine is resource extraction."

One resource he and co-founder Eric Anderson have their eyes on is platinum, so rare on Earth that it currently fetches $1,600 an ounce. Sending robots a million miles or more to extract and refine ore on asteroids in near-zero gravity, or to tow an asteroid closer to Earth, will require technology that doesn't yet exist. "There's a significant probability that we may fail," Anderson said at the press conference in April. "But we believe that attempting this and moving the needle for space is important. Of course we hope to make a lot of money."

Elon Musk, the 41-year-old founder of PayPal, Tesla Motors, and SpaceX, has already made a lot of money, and he is devoting a sizable portion of that fortune to his own space program. The new rocket SpaceX is developing, the Falcon Heavy, will be capable of carrying twice the payload of the space shuttle, he says, for about one-fifth the price. His goal is to reduce launch costs by a further factor of 50 or 100, to $10 to $20 a pound, by developing the first fully reusable rockets. "This is extremely difficult, and most people think it's impossible, but I do not," Musk says. "If airplanes had to be thrown away after every flight, no one would fly."



For Musk, it's all part of a much grander plan: establishing a permanent human colony on Mars. NASA has had enormous success on Mars with unmanned rovers, most recently Curiosity, but has repeatedly pushed back a manned mission. Musk thinks SpaceX could land astronauts on Mars within 20 years—and then keep landing them for decades after that.

"The real thing that's needed is not to send one little mission to Mars," he says. "It's ultimately to take millions of people and millions of tons of equipment to Mars to make it a self-sustaining civilization. It will be the hardest thing humanity has ever done, and it's far from certain that it will occur.

"I should emphasize this is not about escaping Earth. It's about making life multiplanetary. It's about getting out there and exploring the stars."

THE FASTEST spacecraft ever built—the Helios 2 probe, launched in 1976 to monitor the sun—attained a top speed of 157,000 miles an hour. At that rate, a spacecraft headed to Proxima Centauri, the nearest star, would take more than 17,000 years to make the 24-trillion-mile journey, a temporal span equal to the one that separates us from Cro-Magnon cave painters. Those inescapable facts lead even some of the staunchest advocates of human spaceflight to conclude that interstellar travel, aside from robotic probes, will remain forever in the realm of science fiction. "It's Mars or nowhere," says Louis Friedman, an astronautics engineer and one of the founders of the Planetary Society, a space-exploration advocacy group.

Some scientists, however, find the prospect of eternal confinement to two small planets in a vast galaxy just too depressing to contemplate. "If we start now, and we have started, I believe we can achieve some form of interstellar exploration within a hundred years," says Andreas Tziolas. A physicist and former NASA researcher, Tziolas is a leader of Icarus Interstellar, a nonprofit organization that aims, as its mission statement says, "to realize interstellar flight before the year 2100." It is now collaborating with former shuttle astronaut Mae Jemison. In early 2012 the Defense Advanced Research Projects Agency (DARPA) awarded her $500,000 for something called the 100 Year Starship project. "Our task is not to launch a starship but to make sure the technologies and abilities exist within the next hundred years to do that," Jemison says.

Tziolas thinks we could develop a starship

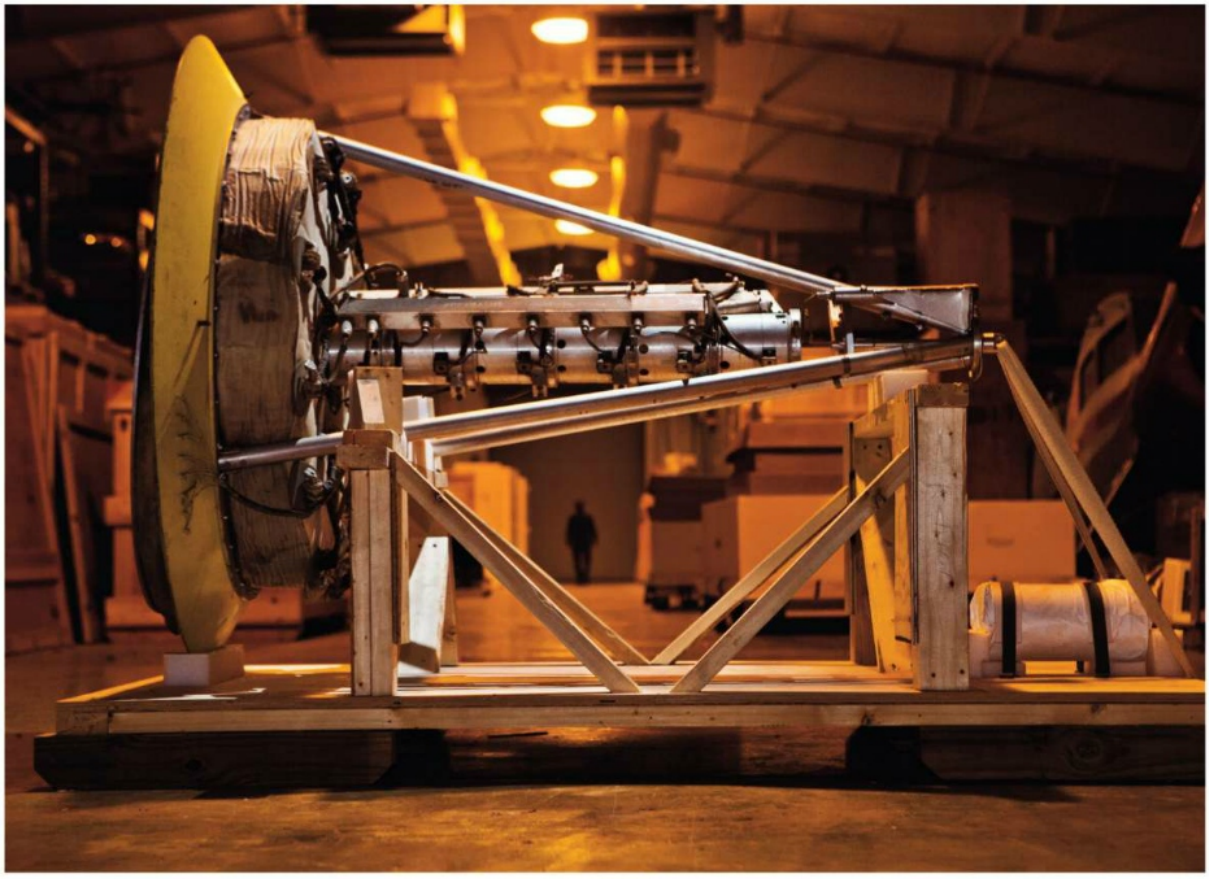
JASON TREAT, NGM STAFF. SOURCES: LES JOHNSON, NASA MARSHALL SPACE FLIGHT CENTER; GREGORY MATLOFF, NEW YORK CITY COLLEGE OF TECHNOLOGY; ROBERT H. FRISBEE, JPL/CALTECH





This 3,400-square-foot Mylar solar sail was tested in 2005 in a vacuum chamber at NASA's Plum Brook Station in Sandusky, Ohio. NASA plans to launch Sunjammer, a probe with a sail four times as big, on a yearlong cruise toward the sun in 2014.

NASA MARSHALL SPACE FLIGHT CENTER



To Saturn and beyond, pushed by nuclear bombs exploding behind it, was the plan for Project Orion—but it went no further than this seven-foot model, called Hot Rod, which now sits in a Smithsonian storage facility in Maryland.

engine that harnesses nuclear fusion, the energy source of stars and hydrogen bombs. When the nuclei of small atoms such as hydrogen fuse, they release enormous energy—much more than is released by the nuclear fission of large atoms such as uranium, the energy source of nuclear power plants and of the old NERVA. While physicists have built fusion reactors, they haven't yet found a way to make one that yields more energy than it consumes. "I have faith in our ingenuity," Tziolas says. Only seven decades elapsed between the discovery of subatomic particles and NERVA, he points out; by 2100, he thinks, we should be able to create a fusion engine that could propel a starship to a top speed of 15 to 20 percent of the speed of light.

That would allow it to reach the nearest star in another few decades—if its machinery could last that long. "Twenty years is getting near the upper limit for how long you can design a spacecraft to reliably operate," says Les Johnson. NASA asked Johnson to look into a 20-year mission, not to a star but to the edge of interstellar space—to the region known as the heliopause, several times as far as Pluto, where the sun's influence is balanced by that of other stars. "The thought was, you don't want to immediately start talking about going to the nearest star," says Johnson. "It's over four light-years away. It's just…daunting, unfathomable." Johnson's task was to plan a realistic mission with a technology that's at least close to existing—a first small step toward the stars.

Right now, fusion engines aren't close to existing; a nuclear engine like NERVA would be too expensive; chemical rockets might reach the heliopause but could never carry enough fuel to reach a star in a reasonable amount of time. (The Voyager spacecraft, were it headed the right way, would drift by Proxima Centauri in 74,000 years.) In the end Johnson's team settled on the most evocative technology: a solar sail. Sunlight, like all light, consists of particles called photons, which exert pressure on everything they touch. At Earth's distance from the sun, the pressure is only about a tenth of an ounce spread over a football field. But a large, thin sheet of reflective

MARK THIESSEN, NGM STAFF

fabric, unfurled in the vacuum of space, will feel this gentle force and will slowly accelerate.

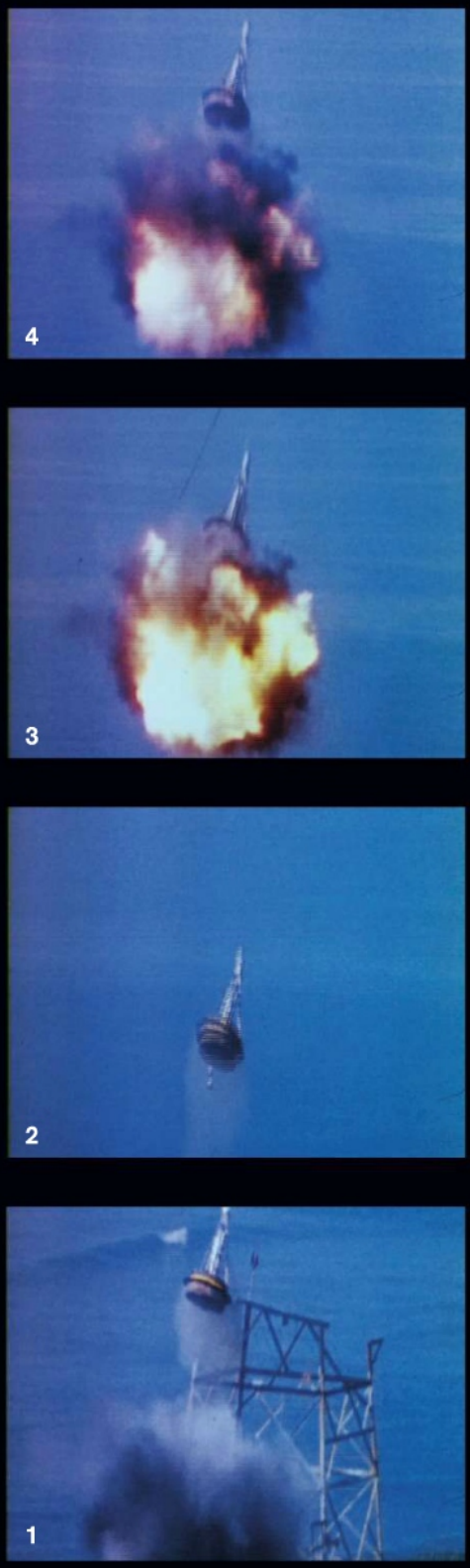
NASA launched a 110-square-foot light sail in 2010 that survived for several months in low Earth orbit. It hopes to launch a sail in 2014 that measures a bit under a third of an acre and weighs just 70 pounds. Movable vanes on the corners will allow ground control to maneuver the Sunjammer, which on its yearlong mission will tack some two million miles upwind toward the sun. A 16-billion-mile mission to the heliopause would require a disk-shaped sail 1,500 feet in diameter. After a year or two of sailing, the spacecraft would exceed 100,000 miles an hour.

Proxima Centauri lies 1,500 times farther still. "To sail to another star," Johnson says, "we'll need a sail the size of Alabama and Mississippi combined. We don't know how to build that yet." What's more, sunlight alone couldn't push the sail to the star within a human lifetime, or even many lifetimes; you'd need powerful space-based lasers. "If you take the total energy output of humanity and put it in a laser on a satellite," says Johnson, "then you could get trip times of a few decades to Proxima Centauri." And that's to send a robot the size of Johnson's desk.

What about humans, with their need for 24/7 life support? Johnson throws up his hands. "When you start thinking about what it takes to supply people," he says, "and how big the spacecraft would have to be and how much energy it would have to have, you enter the realm of science fiction."

TO BUILD A STARSHIP, you first have to build a future that converts fiction into fact, and that takes a lot more than rocket science. The task isn't figuring out right now how to design a starship; it's continuing to build the civilization that will one day build a starship. Framed like that, more expansively, it begins to seem less impossible. But it's a 100-year project or maybe a 500-year project, depending on your craziness level. Johnson's level is lowish.

"I don't know what the world will be like in 500 years," he says. "If we have fusion power plants, and space-based solar panels beaming energy down, and we're mining the moon and have an industrial base in low Earth orbit—maybe a civilization like that could do it. We'll have to be a civilization that spans the solar system before we can think about taking an interstellar voyage." □



In a 1959 test flight, the Project Orion model rose 350 feet on sequential blasts of plastic explosive. In the second frame, a bomb is about to go off under the model. The real Saturn-bound Orion would have been 200 feet tall and weighed 4,000 tons.

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THE NEW AGE OF EXPLORATION

RAIN FOREST FOR SALE

Demand for oil is squeezing the life out of one of the world's wildest places.



From the bromeliads, ferns, and orchids that cover a kapok tree 160 feet above the forest floor to the jaguars that prowl below, Ecuador's Yasuní National Park is home to countless plant and animal species. All of them now face threats from oil development.

STEVE WINTER



Cobalt-winged parakeets flock to a pool. Scientists have identified nearly 600 species of birds in the park. Insects are so diverse that there may be 100,000 species in the space of two and a half acres, including those shown here with other creatures (gatefold flaps).

TIM LAMAN; DAVID LIITTSCHWAGER (FLAPS). ANIMALS PICTURED ARE IDENTIFIED ON OUR DIGITAL EDITIONS AND AT NGM.COM.

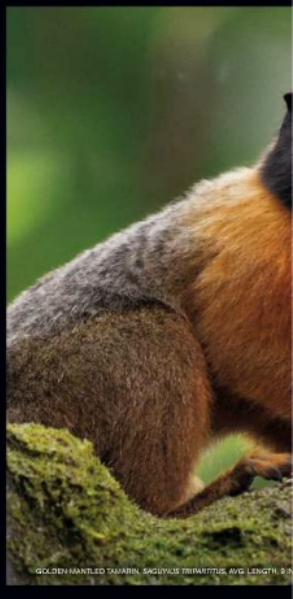




RED HOWLER MONKEY, *ALOUATTA SENICULUS*, AVG. LENGTH, HEAD AND BODY, 19 INCHES



PYGMY MARMOSET, *CEBUELLA PYGMAEA*, AVG. LENGTH, 5 INCHES



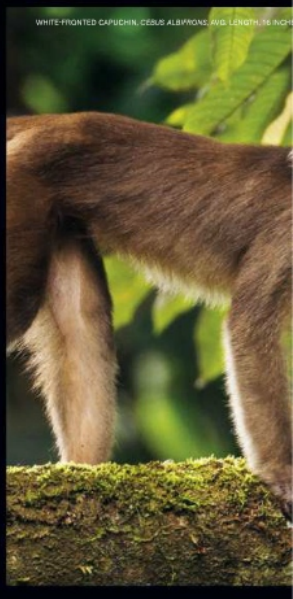
GOLDEN-MANTLED TAMARIN, *SAGUINUS TRIPARTITUS*, AVG. LENGTH, 9 IN



NOISY NIGHT MONKEY, *AOTUS VOCIFERANS*, AVG. LENGTH, 14 INCHES



EQUATORIAL SAKI, *PITHECIA AEQUATORIALIS*, AVG. LENGTH, 16 INCHES



WHITE-FRONTED CAPUCHIN, *CEBUS ALBIFRONS*, AVG. LENGTH, 16 INCH





POEPPIG'S WOOLLY MONKEY, LAGOTHRIX POEPPIGII, AVG. LENGTH, 19 INCHES



COMMON SQUIRREL MONKEY, SAIMIRI SCIUREUS, AVG. LENGTH, 12 INCHES





RED TITI, CALLICEBUS DISCOLOR, AVG. LENGTH, 13 INCHES



WHITE-BELLIED SPIDER MONKEY, ATELES BELZEBUTH, AVG. LENGTH, 20 INCHES

Ten monkey species—all pictured here—live in Yasuní. Two more have been reported, but scientists have yet to confirm their presence.

TIM LAMAN (ALL)





A jaguar on the hunt trips a camera trap at a spot frequented by p
favorite prey. To the Waorani, one of the native groups in this area
spirits that visit shamans in dreams to tell them where game is pl

STEVE WINTER



piglike peccaries, a
, jaguars are ancestral
entiful in the forest.





The pheasant-size hoatzin fans its feathers, often while strutting along a branch, but flaps its wings clumsily when it takes to the air. It lives near swamps, digests food by fermentation like a cow, and is so odd that scientists can't decide how to classify it.

TIM LAMAN



Armed with spear, shotgun, and machete, Minihua Huani (at left) and Omayuhue Baihua search for animals near the Waorani community of Boanamo. Villagers are allowed to hunt in the park, their ancestral territory. Many still do, to provide food for their families.

IVAN KASHINSKY



Author Scott Wallace and a team of photographers journey into the heart of the Amazon, where big oil is threatening one of the last wild frontiers.

THE LEAVES ARE STILL dripping from an overnight downpour when Andrés Link slings on his day pack and heads out into the damp morning chill. It's just after daybreak, and already the forest is alive with hoots and chatter—the deep-throated roar of a howler monkey, the hollow rat-a-tat-tat of a woodpecker, the squeal of squirrel monkeys chasing each other from branch to branch. A strange, ululating chant starts up in the distance, fades out, then builds again.

"Listen!" says Link, grabbing my arm and cocking an ear. "Titi monkeys. Can you hear? There are two of them, singing a duet." He imitates the high-pitched, rhythmic cry of one of the monkeys, then the other. Only then can I distinguish the two separate strains that make up the counterpoint chorus.

This raucous celebration is the daily background music for Link as he heads out on his morning commute through what may be the most biodiverse spot on Earth. Link, a primatologist from Universidad de los Andes, is researching the white-bellied spider monkey,

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Scott Wallace is the author of The Unconquered: In Search of the Amazon's Last Uncontacted Tribes. *Photographers were assigned by specialty: Tim Laman (primates and birds), Ivan Kashinsky and Karla Gachet (culture), David Liittschwager (microfauna), Steve Winter (big cats).*

Follow the photographic team into the field with video on our digital editions.



The Waorani were once seminomadic, living in houses thatched with palm leaves, like these in the community of Cononaco Chico. Today most have settled permanently and live in homes made of wood and concrete.

IVAN KASHINSKY



and he's on his way to a salt lick a half hour's walk away, where a group often congregates.

Giant kapok and ficus trees with sprawling buttress roots soar like Roman columns straight into the canopy, their bifurcating branches draped with orchids and bromeliads that sustain entire communities of insects, amphibians, birds, and mammals. Strangler figs coil around their trunks in a tightening embrace. There is so much life here that tiny killifish are wriggling in a shallow puddle created by animal tracks.

We turn down a slope into a forest studded with bizarre-looking *Socratea* trees, commonly called walking palms, with four-foot-high stilt roots that allow the trees to shift location slightly in a quest for light and nutrients. It's one of the untold millions of evolutionary adaptations unfolding all around the Tiputini Biodiversity Station (TBS), a facility operated by the Universidad San Francisco de Quito on 1,600 acres

(650 hectares) of pristine jungle on the edge of Yasuní National Park, which encompasses nearly 3,800 square miles (9,800 square kilometers) of prime rain forest habitat in eastern Ecuador.

"You could spend your entire life here and be surprised by something every day," Link says. There are ten primate species in the forest around TBS, and a greater variety of birds, bats, and frogs than almost anywhere else in South America. There are as many insect species in a single hectare of the rain forest here as are known in all of the U.S. and Canada combined.

Yasuní's location nurtures this abundance. The park sits at the intersection of the Andes, the Equator, and the Amazon region, an ecological bull's-eye where extremely rich communities of plants, amphibians, birds, and mammals in South America converge. Downpours are a near-daily occurrence throughout the year, and there are few discernible changes of season. Sunlight, warmth, and moisture are constants.

This part of the Amazon is also home to two indigenous nations, the Kichwa and the Waorani, who live in settlements scattered along the roads and rivers. The first peaceable contact between the Waorani and Protestant missionaries took place in the late 1950s. Today most Waorani communities participate in trade and even tourism with the outside world, as do their former tribal enemies, the Kichwa. But two groups of Waorani have turned their backs on such contact, preferring to wander the upland forest in a so-called Zona Intangible—Untouchable Zone—set up to protect them. Unfortunately, this zone, which overlaps the southern sector of Yasuní, does not include the entirety of their traditional range, and the nomadic warriors have attacked settlers and loggers both inside and outside the zone, some as recently as 2009.

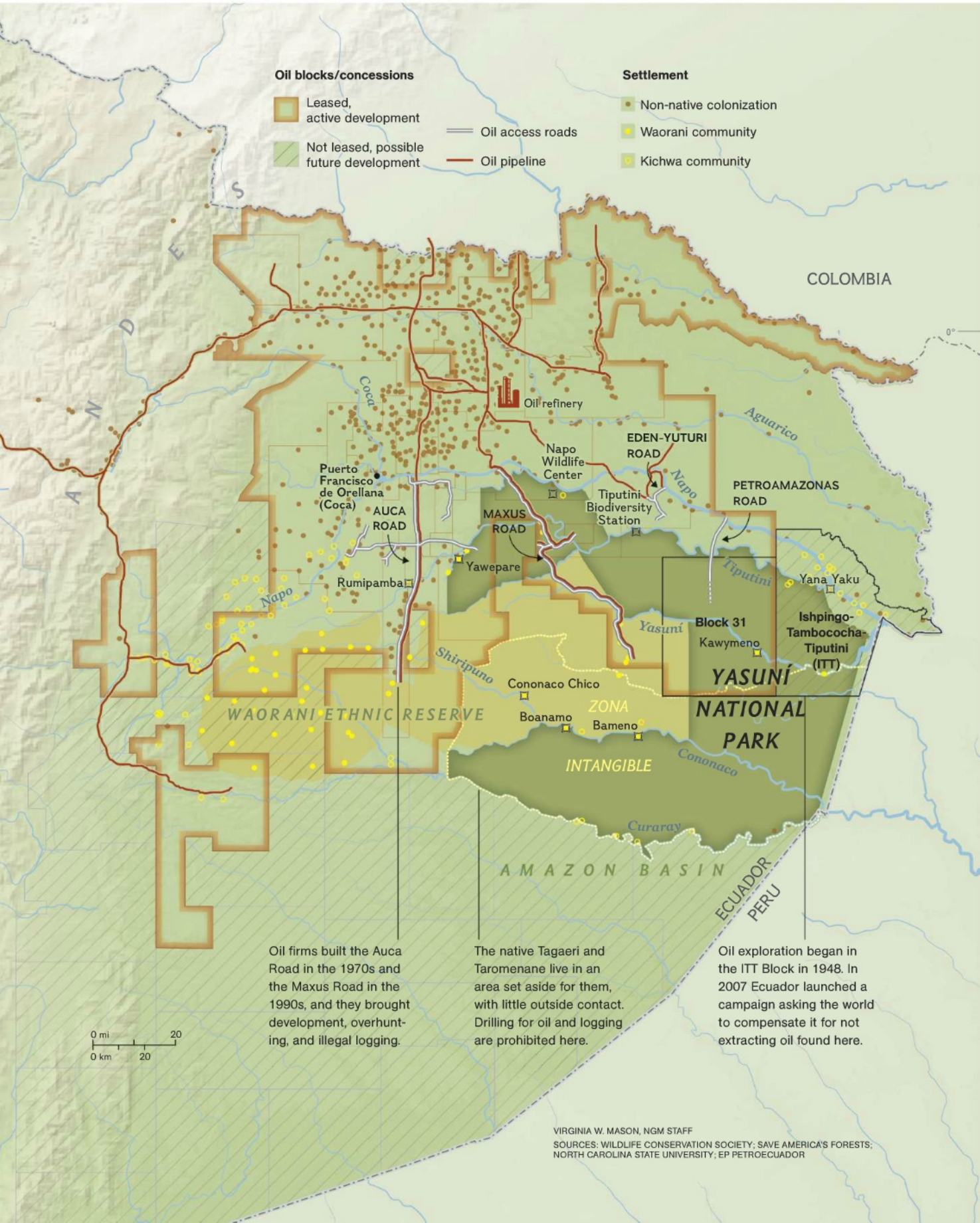
Far beneath the ground, Yasuní harbors yet another treasure that poses an urgent challenge to the precious web of life on the surface: hundreds of millions of barrels of untapped Amazon crude. Over the years, oil concessions have been drawn over the same territory as the park, as economic interests have trumped conservation in the struggle over *(Continued on page 108)*

The Lure of Oil

In eastern Ecuador the government has created a complicated geography in which parkland, areas for native people, and blocks for oil exploitation overlap. All have conflicting interests. The Ishpingo-Tambococha-Tiputini (ITT) Block is the big prize on the horizon. Covered in mostly unexplored forest and still protected for now, it holds an estimated 850 million barrels of untapped reserves. Oil companies have been prospecting in the region since the 1940s and are now closing in on the ITT.



The warm, wet climate in the region where the Equator crosses the Andes is the perfect environment for an abundance of species.



Oil firms built the Auca Road in the 1970s and the Maxus Road in the 1990s, and they brought development, overhunting, and illegal logging.

The native Tagaeri and Taromenane live in an area set aside for them, with little outside contact. Drilling for oil and logging are prohibited here.

Oil exploration began in the ITT Block in 1948. In 2007 Ecuador launched a campaign asking the world to compensate it for not extracting oil found here.

VIRGINIA W. MASON, NGM STAFF

SOURCES: WILDLIFE CONSERVATION SOCIETY; SAVE AMERICA'S FORESTS; NORTH CAROLINA STATE UNIVERSITY; EP PETROECUADOR





More than 12 miles of a road being built by the Petroamazonas oil company have been cleared inside the park. Conservationists are concerned because the road is meant to move oil workers and machinery into ecologically vulnerable Block 31. It may also eventually reach—and spoil—the still pristine block to the east.

IVAN KASHINSKY



Men from the community of Rumipamba, in the background, clean up the remnants of a 1976 oil spill. They're glad for the work, which pays $450 a month, but they and their families suffer health problems like chronic skin rashes, possibly caused by exposure to the oil. Many people fear such pollution could occur in Yasuní if developers drill for oil.

KARLA GACHET







Like many Waorani today, these two families blend old and new. Returning home to Bameno, their community on the Cononaco River, they bring the fruits of a traditional hunt: peccary, monkey, and deer. But the clothing and boats come from the outside world.

KARLA GACHET

President Correa has offered to leave untouched an estimated 850 million barrels of oil inside Yasuní's ITT Block **IN RETURN FOR $3.6 BILLION** from the rest of the world.

(Continued from page 100) Yasuní's fate. At least five active concessions blanket the park's northern section, and for a poor country like Ecuador the pressure to drill has been almost irresistible. Half of the nation's export earnings already come from oil, nearly all of it from its eastern provinces in the Amazon.

In a proposal first put forward in 2007, President Rafael Correa has offered to leave indefinitely untouched an estimated 850 million barrels of oil inside Yasuní's northeastern corner in a tract known as the ITT Block (named for the three oil fields it contains: Ishpingo, Tambococha, and Tiputini). As payment for preserving the wilderness and preventing an estimated 410 million metric tons of fossil fuel-generated carbon emissions from entering the atmosphere, Correa has asked the world to ante up in the fight against global warming. He is seeking $3.6 billion in compensation, roughly half of what Ecuador would have realized in revenues from exploiting the resource at 2007 prices. The money would be used, he says, to finance alternative energy and community development projects.

Hailed by supporters as a milestone in the climate change debate when it was first proposed, the so-called Yasuní-ITT Initiative has been hugely popular in Ecuador. National polls consistently show a growing awareness of Yasuní as an ecological treasure that should be protected. But the international response to the initiative has been tepid. By mid-2012 only about $200 million had been pledged. In response Correa has issued a succession of angry ultimatums, leading detractors to liken his proposal to blackmail. With the initiative stalled and Correa warning that time is running out, activity on the oil frontier continues to advance through eastern Ecuador, even within Yasuní's limits. Every day, another bit of the wilderness succumbs to the bulldozers and backhoes.

A half hour after setting out from the TBS laboratory, Andrés Link reaches the mouth of a low cave at the bottom of a steep ravine. This is the salt lick he was looking for, but there are no monkeys here this morning. "They are afraid of predators," he says, looking up through the canopy at the milky white sky. "When it's overcast like this, they don't like to come down." The monkeys may be wary of jaguars or harpy eagles. But Link's mind is on a more long-term and potentially definitive threat to the animals: the advancing oil frontier.

"You can see there is great interest in finding the oil," he says. "The fear I have is that you need very little to get something started, and then…" His voice trails off, as if the thought were too painful to articulate.

BACK AT THE TBS LABORATORY that evening, I sit on the deck with founding director Kelly Swing to talk about the changes he's seen as the oil frontier closes in. "We definitely feel the pressure," Swing says, looking out into the darkening forest. "It's close enough to make us nervous."

The nearest production facilities are only eight miles to the northeast in a concession operated by the state oil company, Petroamazonas. The scientists tell him they often hear the hum of generators while out in the forest, and low-flying helicopters scatter their study animals in panic with increasing frequency. The faint light from gas flares tarnishes an otherwise breathtaking view of the nighttime sky from the station's observation tower, perched 120 feet off the ground in the branches of a majestic kapok.

The success or failure of the Yasuní-ITT Initiative will likely have no direct impact on this immediate patch of forest, he says. But Swing fears

the initiative's collapse could deal a body blow to conservation efforts and unleash a tide of oil development that could sweep into the southern half of Yasuní, perhaps even into the Untouchable Zone itself.

"Over time the oil concessions have become like stepping-stones," he says. "As each one is developed, there's mounting pressure to develop the remaining blocks farther east and south."

Ecuadorian officials insist that oil extraction can be done responsibly, even in sensitive habitats. They say current practices mark a vast improvement over the highly polluting methods that prevailed in the 1970s and '80s, when U.S. oil giant Texaco allegedly left behind contaminated sites that have embroiled Chevron, Texaco's parent company, in a multibillion-dollar lawsuit with indigenous communities. But development has far greater consequences for species-rich environs like Yasuní, Swing says, starting with countless millions of insects, many undoubtedly unknown to science, scorched each night in undulating gas flares.

In forests impacted by oil development, perhaps 90 percent of the species around denuded sites die, he says. "You have to ask: Is that acceptable? To whom is that acceptable?"

A FEW DAYS LATER I join a team of biologists from the Wildlife Conservation Society (WCS) as we board a boat in a light drizzle to journey eastward down the Tiputini River. White-bark *Cecropias* line the twisting river, which follows part of the northern boundary of the backward-C–shaped national park. Above us the high branches of massive kapok trees are dripping with oropendola nests.

Except for the blare of our own outboard, the river appears to be entirely free of human presence. Or so it seems, until we round a bend and come upon a long motorized barge pulled up against the riverbank. The place is swarming with workers in hard hats and high boots, the exposed earth red and raw, pocked with the treads of earthmovers. A similar gash on the opposite bank—broad and blood red—creates the impression that the road has jumped the river as if by magic, entering the national park of its own accord. I lift my camera to snap a picture, prompting a pair of soldiers aboard the barge to shout: "Forbidden to take photos!"

Officials in blue coveralls and helmets are tight-lipped when we clamber through the boot-sucking ooze and climb aboard the barge. But a tall man of broad girth offers me a beefy paw and a warm welcome. "I'm one of the bad guys," he says in English with a laugh, before I even get his name. Robin Draper, 56, seems as surprised by our sudden appearance as we are by this entire operation. "We've been here for weeks, and you're the first boat that's come down this river," he says.

Draper, a native of Sacramento, California, and a veteran of the Prudhoe Bay oil fields in Alaska, is the owner-operator of the barge, named *Alicia,* and is working on contract for Petroamazonas. Operating largely outside the public eye, the state oil company is evidently moving at full throttle into Block 31. Environmentalists celebrated a few years ago when they stopped another oil company, Petrobras, from building the same road. But the concession has since reverted to Petroamazonas, and now the nine-mile road south from the Napo to the Tiputini Rivers is finished, Draper says. What's more, bulldozers have already advanced deep into the forest on the other side of the Tiputini.

It's a move that's bound to stir controversy, because it represents a fresh intrusion into the park. Critics have also contended that Block 31's known reserves of 45 million barrels are too small to justify a massive investment in the concession. The real reason for going into Block 31, they say, would be to lay the infrastructure for an eventual move into the ITT Block next door, making it as much a menace to the credibility of the initiative as it is to the wildlife and to the isolated indigenous groups that wander its upland forests. Recent reports point to the possible presence in the area of such groups, which the government is duty-bound to protect.

Though Draper has no opinion about that, he says the company is doing its best to minimize disturbance in the area, starting with the use of



his barge. "They aren't going to build a bridge across this river," he tells us over a cup of coffee in *Alicia*'s wheelhouse. "There will be a barge here forever." Draper describes a "completely new roadbuilding process" under way on the far side of the river, where workers are laying down a synthetic material over swampland and forest that could eventually be rolled up and removed. His Ecuadorian colleagues refer to the road as a *sendero ecológico*—an ecological path—when they speak to local natives hired on as manual laborers. "The idea is that someday you can turn the road back to nature."

But Draper isn't convinced. "Their heart's in the right place," he says. "But the way I see it, we shouldn't even be here."

BACK ON THE RIVER, I ask Galo Zapata, one of the WCS biologists on our boat, how this new road is likely to affect the rain forest. "I'm sure



Home alone in Bameno, children under the age of 14 fend for themselves while their parents and older siblings attend a party in Kawymeno, two days away by foot. Mostly self-sufficient, they have a grandfather nearby for emergencies.

IVAN KASHINSKY

the company will do its best to control access to the road," he says. "But they're not going to stop the Kichwa and Waorani from settling on it."

This has all happened before, he explains. When oil companies built the Maxus Road (named after Maxus Energy Corporation, a U.S. oil exploration firm) into Yasuní in the 1990s, measures were taken to block access to outsiders, but natives living within the park moved their villages to the road and began hunting animals to sell on the black market. "With all the people who will move here, there will be a big demand for bush meat. It will be bad for the large birds and animals. The social impacts will be bad. The story will repeat itself."

As we proceed downriver, the landscape levels out until it resembles a vast lowland swamp studded with *açaí* palms. Our GPS indicates we've crossed into the ITT Block, ground zero of the oil controversy. We pull ashore at a low bank, where a hand-painted billboard marks the small Kichwa community of Yana Yaku.

Community leader César Alvarado emerges from under the low thatching of his house and tells us about the time, when was he was a young child, that the oil companies arrived. The first men came in helicopters that buzzed the tall morete palms beyond the village before touching down, he says. Then came barges laden with housing units for the workers and tractors that mowed down the forest and hauled in the big rigs. "There was an entire town of workers," he remembers, sweeping his hand out toward the tangled undergrowth. "They were friendly. They shared their food with me."

Now 49, Alvarado, barefoot and thin in a loose-fitting tracksuit, leads us down a muddy path past Yana Yaku's rough-hewn shacks. He wants to show us what all those workers came here to do so long ago, and the solitary monument they left behind. We enter a shady clearing and behold an astonishing sight. It appears to be some kind of sculpture, an abstract crucifix assembled from pipes, valves, and elbow joints. Standing nearly 15 feet high, it's tarnished and moss covered, like a lost idol from a Steven Spielberg movie. But it's hardly forgotten. This is





After a day's work, Waorani gather in a communal house to share a meal and tell stories. Omayuhue Baihua, seated beneath the radio, has brought home a monkey from a hunt. His wife, Tepare Kemperi, is stewing it over a fire for dinner.

IVAN KASHINSKY

How many oil workers did Kemperi and his comrades kill that day? **HE COUNTS ON HIS FINGERS.** Five, maybe six. "We killed them so they would never come back," he says.

the central axis around which the entire Yasuní-ITT question revolves—a capped exploratory well for the Tiputini oil field. Along with others like this one, it's the reason officials know the ITT Block holds more than 20 percent of Ecuador's petroleum reserves, roughly 850 million barrels of Amazon crude. A more inconspicuous testament to Ecuador's prospective oil wealth could scarcely be imagined.

What happens if the workers come back? I ask. Is Alvarado in favor of them pumping the oil from beneath his village? "We want health and education for the community," he says. "If they take care of the environment, then we'll be for it."

FOR MOST WAORANI, by contrast, such a future does not look nearly as inviting. On a sticky, overcast morning, I set off from the city of Coca with native guides in a truck to journey south down the so-called Auca Road. Built by Texaco in the 1970s to move drill rigs to the oil fields and lay pipeline from them, the road split former Waorani territory straight down the middle. Adding insult to the injury, the company christened the road Auca, the name applied to the Waorani by their enemies, meaning "savage." We're bound for the bridge at the Shiripuno River, the gateway to the Untouchable Zone, where at least two Waorani groups, the Taromenane and Tagaeri, live in voluntary isolation from the rest of the world.

Careering down the winding asphalt, we pass a landscape of denuded hillsides and ranchos that bear witness to the uncontained rush of land-hungry settlers that followed the road's construction 40 years ago. Several impoverished Kichwa and mestizo communities lie strewn along feeder tracks branching off the Auca.

At a place where the road bends sharply to the right and disappears in a spray of foliage, we jog left and follow tire tracks up a steep hill. I've heard that uncontacted Indians have recently turned up outside the exclusion zone, in an area where oil development is in full swing. Soon we're navigating a labyrinth of back roads serving a growing sprawl of oil wells and pumping stations. We fishtail around a hairpin turn and come face-to-face with a high wall of jungle, where the road abruptly ends. Ahead to the right, a new drill rig rises behind a chain-link fence. A sign on the gate identifies the site as the Nantu E oil well. Off to the left, a knot of thatched shacks sits back in the woods—the Waorani village of Yawepare.

Yapping mongrels surround us as we hop down from the truck. A muscular man in shorts and a tight T-shirt wants to know my business. Satisfied that I am not from the oil company, he suggests we talk in the open-air communal hut nearby. His name is Nenquimo Nihua, he says in fluent Spanish, and he's currently serving a two-year term as the community chief.

"This is a dangerous area," Nihua warns. Tensions have been on the rise since oil workers arrived a few months ago to work on the well next door. Villagers here are worried that the racket created by heavy vehicles and machinery could provoke a violent response from uncontacted groups in the surrounding jungle. The isolated groups feel their land is shrinking. "They're being flushed out of the forest," he says. "We don't want conflict with them. We want them to feel *tranquilos*."

Nihua confides that some of the nomadic tribesmen are actually his relatives. "My mother-in-law has a brother in the isolated group," he says. In fact, two dozen of them stood on this very spot just three weeks ago. Nihua's father saw them with his own eyes. He'd gotten up in the

middle of the night, alarmed by barking dogs, and gone out for a look. Turning a flashlight at the communal hut, he was startled by the sight of the naked warriors—all men, all brandishing spears and blowguns. They'd just entered the hut, and it appeared as though they intended to stay the night. Heart racing, his father retreated back into the house without speaking a word. It was best to leave them alone, he said.

"They came here to rest," Nihua adds. By the next morning the warriors were gone.

Despite their family ties, many civilized Waorani fear attack by the Taromenane and Tagaeri. Yet the nomadic clans are also a source of pride, a potent symbol of tribal resistance, and a reminder of their ancestral traditions. Nihua says he and his family leave axes and machetes in the woods for their relatives to take. They plant gardens to feed them and run armed patrols to guard against intruders who would bring them harm. "We're taking a stand here," Nihua says, his chest swelling. "No more oil development. No more colonizers entering here. No more loggers."

NEAR THE END of the Auca Road we come to a wobbly bridge and off-load our gear into a skiff to continue down the Shiripuno River to the Cononaco River and on into the Untouchable Zone. Since outsiders are permitted to enter the zone only at the invitation of the Waorani, I have arranged to make this part of my journey with Otobo Baihua, a Waorani guide.

Short and robust, with broad shoulders and a quick smile, Otobo, 36, says he once worked for the oil companies, but he quit to seek a more eco-friendly living. "Much contamination," he says in broken Spanish. "I saw many animals die. It made me sick." Now he operates an ecotourism business, taking adventure travelers to visit his people deep inside the exclusion zone.

A spectacular panorama of wildlife unfolds before us: monkeys swinging through the canopy, toucans yelping in the treetops. A large capybara slides lazily into the water. Otobo stops to point out sites where, in bygone times, Waorani warriors ambushed oil workers and where, more recently, the Tagaeri and Taromenane have impaled illegal loggers with spears before retreating into the forest shadows.

Around campfires in riverside settlements, the Waorani share stories over the next few nights of their turbulent history and their abiding distrust of the oil companies. They describe the paradise they lost to big oil and the paradise they still share with their reclusive relatives. Two days later we reach our final destination, the village of Bameno. Concrete-block buildings and wooden huts flank a 1,800-foot-long (560-meter) grass airstrip. There we find Penti Baihua, Otobo's cousin and a community leader, locked in vigorous discussion with a gathering of villagers near the airstrip. He's barefoot and bare-chested, with wavy black hair and an easy smile. He breaks away to welcome us.

"The ITT is only a small part of Yasuní," he says, when I ask him about the initiative. He's especially worried because the Waorani don't have specific, government-recognized ownership rights to the land that lies within the Untouchable Zone. "They will conquer this space, one oil well at a time, if we don't have that document," he says. "We don't know what plans the government has for our territory."

Penti leads us across the soggy runway to a communal hut on the far side of the village. He wants me to meet his uncle, a silver-haired man named Kemperi. One of the very last jaguar shamans of the Waorani, Kemperi is widely revered for his ability to communicate with the forest spirits. Dressed in shorts and a blue T-shirt, he has long gray tresses framing a broad smile of brilliant white teeth. He does not know how old he is, he says, but he was already an adult when he joined a war party that ambushed and killed several Shell oil workers in the 1940s.

Twelve workers in all perished at the hands of indigenous warriors. The company later abandoned operations in eastern Ecuador, and it wasn't until the missionaries subdued the "Auca" that oil exploration resumed here.

How many did Kemperi and his comrades kill that day? He counts on his fingers. Five, maybe six. "We killed them so they would never come back." Despite the violence he describes,



A fiery glow in the sky over Yasuní, revealed in a long exposure, comes from the flares of oil wells burning off gas. With oil operations creeping ever closer, the possibility of destruction hangs heavily over the last untouched corner of this primeval forest.

TIM LAMAN





he speaks with the easy laugh of an old combat veteran recounting his younger days in the war. But what about today, what if the men with the hard hats and uniforms return?

"If they come back, we will kill them," he says matter-of-factly. "We will do as our parents and grandparents taught us."

AFTER NEARLY THREE WEEKS of traveling by truck, boat, and bush plane through Yasuní, I head for the capital city of Quito, high in the Andes. I've been offered the opportunity to speak directly with President Correa about his struggling Yasuní-ITT Initiative. Guards snap to attention as I pass the colonnades of the colonial-era Carondelet Palace and enter a lavish room of gold-trimmed furniture and brocade curtains.

Charismatic, articulate, and intelligent, Correa, 49, gets right to the point during our talk.



Nine-year-old Daniela Cupe Ahua daydreams as her sister-in-law tends to babies. In keeping with Waorani custom, this extended family live together. Their house, near the Maxus Road, uses store-bought blankets as walls.

KARLA GACHET

The Yasuní-ITT Initiative, he says, is still on the table. "We've always said that if we didn't receive the necessary support for the initiative within a reasonable period, we would have to exploit the oil," he says, "with the greatest environmental and social responsibility."

The initiative poses a real dilemma, he continues. "Ecuador is a poor country. We still have children without schooling. We need health care, decent housing. We lack many things. What would suit the country most would be to exploit the resource. But we also understand our responsibility in the fight against global warming, the principal cause of which is the burning of fossil fuels. That's the dilemma."

As we wrap up the interview, Correa sounds like a man who's already made up his mind. "I insist that we are going to exploit our natural resources, as all countries in the world do," he states. "We cannot be beggars sitting on a sack of gold." Nonetheless, he finishes by saying that he'd be willing to consider putting what is widely known in Ecuador as Plan B—exploiting the oil in the ITT—to a popular vote.

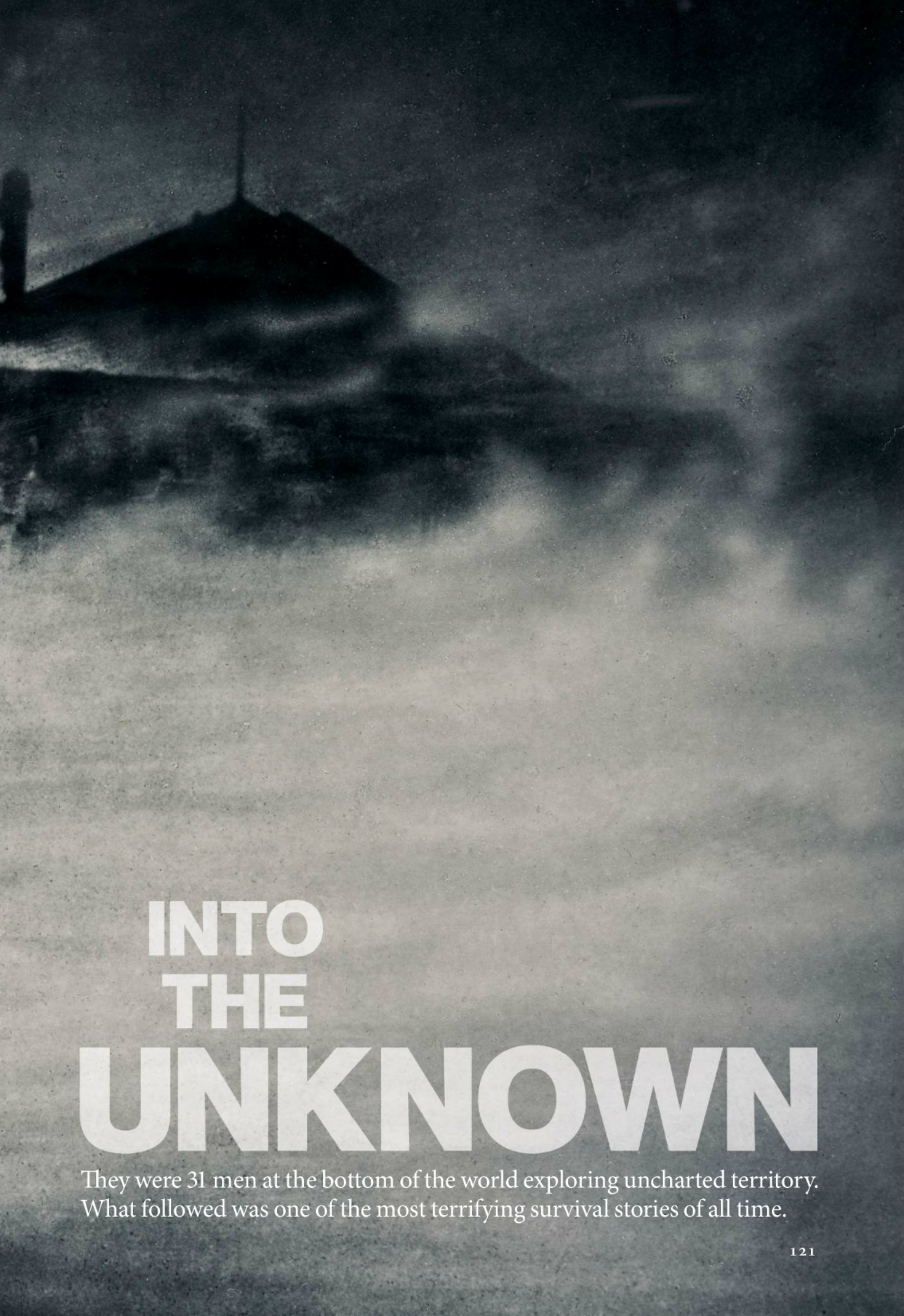
ON THE STEPS outside the presidential palace, I think about the road I saw under construction in Block 31 and the violation of the wilderness it represented. Regardless of the outcome of the ITT Initiative, significant portions of Yasuní will remain under siege. "If the Yasuní-ITT Initiative fails, we'll figure out how to save part of it," Kelly Swing had told me as we sat on the deck of the research station, as though he too were already looking beyond the decision. "My main concern is that with each compromise with development, we end up with less for nature." A breeze rustled the treetops. Somewhere a macaw shrieked. "Should we use our capacity to tame nature and commandeer all the resources for ourselves and take it right up to the breaking point?" Swing asked. "Will we even know where that breaking point is?" □

We thank the Kichwa community of Añangu and the staffs of the Napo Wildlife Center and the Tiputini Biodiversity Station for their support.



Two men lean into a blizzard to chop ice for drinking water, an essential daily chore during a three-year Australian-sponsored scientific expedition to Antarctica from 1911 to 1914.

ALL PHOTOS FROM MITCHELL LIBRARY, STATE LIBRARY OF NEW SOUTH WALES, UNLESS OTHERWISE NOTED



INTO THE UNKNOWN

They were 31 men at the bottom of the world exploring uncharted territory. What followed was one of the most terrifying survival stories of all time.

Bred for strength and endurance, with thick fur to prevent frostbite, Greenland huskies pull a sledge on the ice early in the Australasian Antarctic Expedition. Of 38 dogs that began the expedition, only two survived to return home.





By David Roberts
Photographs by Frank Hurley



Mawson heard the faint whine of a dog behind him. It must be, he thought, one of the six huskies pulling the rear sledge. But then Mertz, who had been scouting ahead on skis all morning,

stopped and turned in his tracks. Mawson saw his look of alarm. He turned and looked back. The featureless plateau of snow and ice stretched into the distance, marked only by the tracks Mawson's sledge had left. Where was the other sledge?

Mawson rushed on foot back along the tracks. Suddenly he came to the edge of a gaping hole in the surface, 11 feet wide. On the far side, two separate sledge tracks led up to the hole; on the near side, only one led away.

It was December 14, 1912. Thirty years old, already a seasoned explorer, Douglas Mawson was the leader of the Australasian Antarctic Expedition (AAE), a 31-man team pursuing the most ambitious exploration yet of the southern continent. Let Scott and Amundsen race for the South Pole. Mawson was determined to discover everything he could about a 2,000-mile-long swath of Antarctica that was terra incognita, and to wring from it the best scientific results—in terms of geology, meteorology, magnetism, biology, atmospheric science, and glaciology—ever obtained on a polar journey.

Having built a hut on the shore of a cove they named Commonwealth Bay, the men of the AAE had wintered over in what was later proven to be the windiest place on Earth (at least at sea level), with gusts up to 200 mph. At times, the gales were so strong they knocked the men off their feet and sent them sliding across the ice.

Setting out in November 1912, Mawson's sledging party was one of eight three-man teams sent off on journeys in all possible directions. For his own Far Eastern Party, he chose 29-year-old Swiss ski champion Xavier Mertz and 25-year-old Belgrave Ninnis, an eager, likeable Englishman serving in the Royal Fusiliers. Hoping to connect the unmapped interior with the heights of far-off Oates Land, discovered by Robert Falcon Scott's party only the year before, Mawson was bent on making the deepest push of all into the unknown.

By the morning of December 14, 35 days out, the trio had reached a point nearly 300 miles from the hut. The men had crossed two major glaciers and scores of hidden crevasses—deep fissures in the ice camouflaged by thin snowbridges. Just after noon that day, Mertz had held up his ski pole, signaling yet another crevasse. Mawson judged it to be only a minor nuisance, as his sledge glided smoothly across the bridge. He called out the usual warning to Ninnis, and, in a last glance back, saw that his teammate had corrected his path to cross the crevasse head-on rather than diagonally.

Now Mawson and Mertz cut away the fragile

David Roberts is the author of Alone on the Ice, *a new book on Mawson's survival trek. Frank Hurley, who died in 1962, was 26 when he joined the AAE.*



Download one of our digital editions to watch rare footage of the expedition in Antarctica.



A sledge crew peers into a crevasse covered by a snowbridge only moments before. Douglas Mawson's team traversed many crevasses before one swallowed colleague Belgrave Ninnis, six dogs, and vital gear, including their tent and most of their food.

lip of the open crevasse, roped up, and took turns leaning over the abyss. What they saw appalled them. One hundred fifty feet down, a husky lay moaning on a snow shelf, its back evidently broken. Another dog, apparently dead, lay beside it. A few pieces of gear lay scattered on the same shelf.

There was no sign of Ninnis or the sledge.

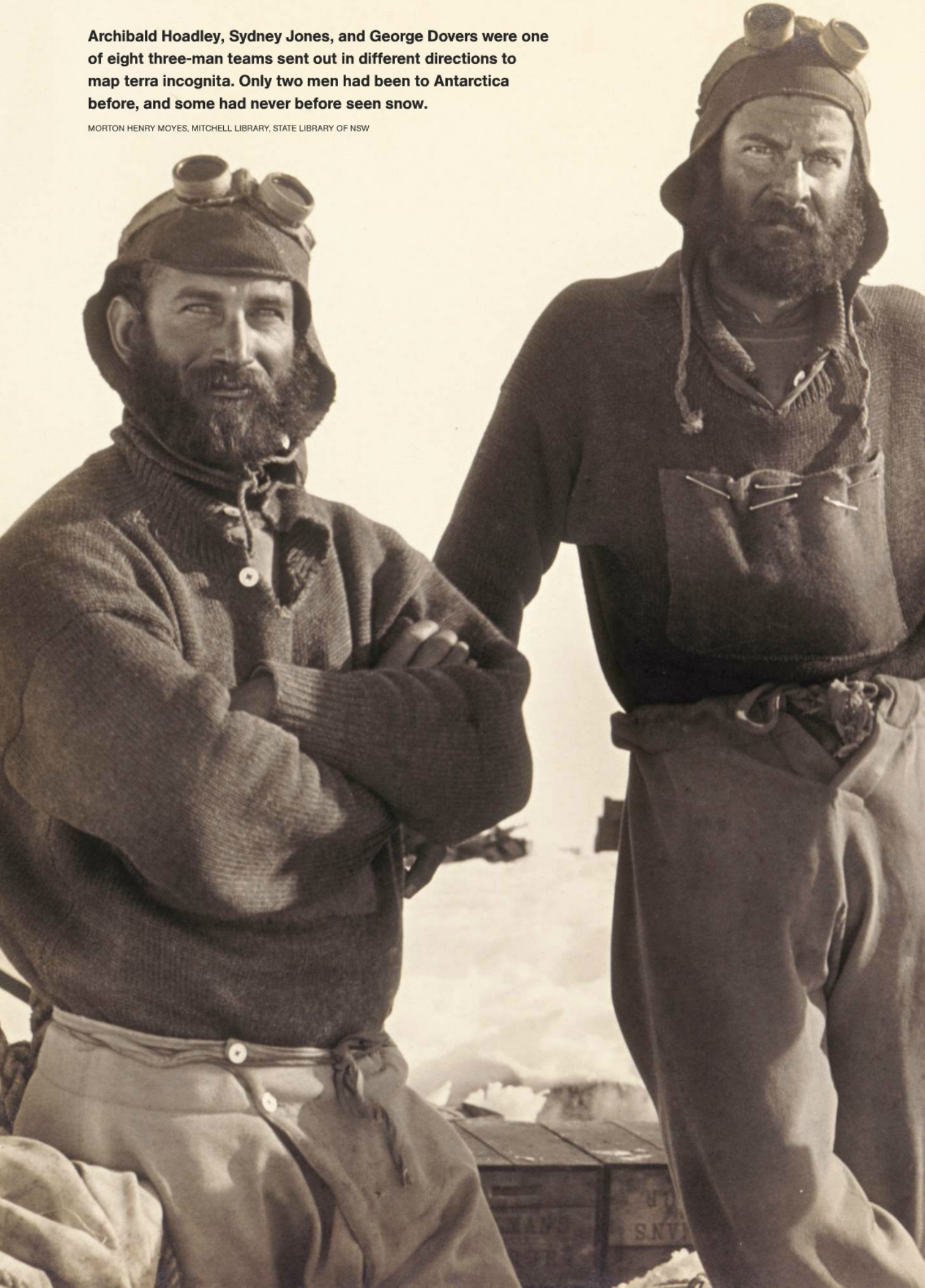
For three hours, Mawson and Mertz called into the depths, hoping against hope for an answering cry. They had far too little rope to lower themselves into the crevasse to search for their companion. At last they accepted the inevitable. Ninnis was dead. Gone with him were the team's most valuable gear, including their three-man tent, the six best huskies, all the food for the dogs, and nearly all the men's food.

THE TWO MEN might have perished the first night if they hadn't improvised a shelter. With the temperature just above 0°F, they pitched a spare tent cover over a frame concocted of sledge runners and Mertz's skis. Inside this gloomy cave, they laid their reindeer-skin sleeping bags directly on the snow. So cramped and flimsy was their "tent" that only one man could move at a time, and neither could rise higher than a sitting position.

In the first days of their homeward dash, driven by adrenaline, they made excellent mileage. But during the next two weeks, the dogs gave out one by one. When George, then Johnson, then Mary could no longer pull, they were loaded on the sledge and carried to that night's camp, where the men shot them with the rifle. Desperate to hoard their tiny supplies of pemmican, biscuits, raisins, and cocoa, the men ate the tough, stringy dog meat, then threw the bones and skin to the remaining huskies, which fought ravenously over every scrap.

Navigating with a theodolite and dead reckoning, Mawson steered a homeward course as much as 25 miles south of their outward track, hoping to skirt the worst of the crevasses and the heads of

STAMP: AUSTRALIAN POSTAL CORPORATION. ABOVE: ANDREW WATSON, NATIONAL GEOGRAPHIC STOCK



Archibald Hoadley, Sydney Jones, and George Dovers were one of eight three-man teams sent out in different directions to map terra incognita. Only two men had been to Antarctica before, and some had never before seen snow.

MORTON HENRY MOYES, MITCHELL LIBRARY, STATE LIBRARY OF NSW


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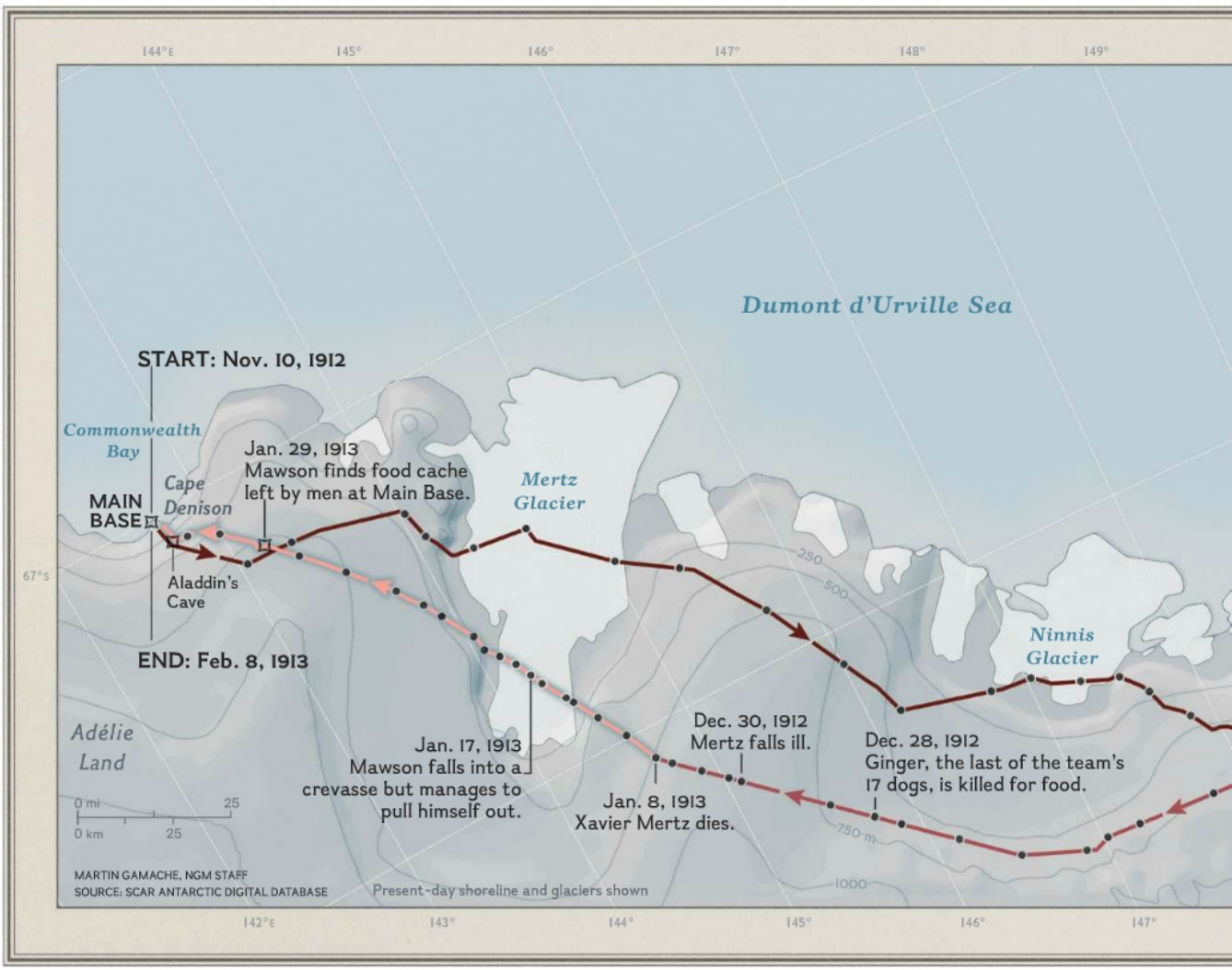
the two big glaciers. He tried to bolster his partner's spirits, promising him a safe return to Australia. At 1 a.m. on December 25, Mawson woke Mertz to wish him a merry Christmas. "I hope to live to share many merry Christmases with my friend Mawson," Mertz wrote in his diary.

By now, only Ginger, the pluckiest of the surviving dogs, could haul. The two men put on their chest-and-hip harnesses and pulled the sledge alongside her, exhausting themselves after only a few miles' run. Crossing wind-carved ridges of hard snow known as sastrugi as high as three and a half feet, they repeatedly fell down and often capsized the sledge. To save weight, they threw away gear—their alpine rope, the rifle, the extra sledge runners, and, most painfully, Mawson's camera and the film packs that held the visual record of the trio's pioneering journey.

Something was wrong with Mertz. He was rapidly losing strength. Too weak to move on January 2, he could manage only five miles the next day before giving up, forcing Mawson to pitch the tent. In disbelief that his fingers had been frostbitten, Mertz surprised Mawson by biting off the tip of one. Mawson knew that their only hope was to keep moving, but on January 5, Mertz refused. It would be suicide, he said.

Though racked with pain himself, Mawson persuaded Mertz to ride the sledge. Summoning extraordinary powers, Mawson pulled the terrible load by himself for two and a half miles. In his diary that night, he wrote, "If he cannot go on 8 or 10 m[iles] a day, in a day or two we are doomed. I could pull through myself with the provisions at hand but I cannot leave him."

By January 7, the men had covered some 200 miles of their return trek, with 100 still to go. But as they tried to pack up that morning, Mawson discovered that his teammate had "fouled his pants." As a nurse might tend a baby, Mawson undressed Mertz, cleaned up the mess, and put him back in his sleeping bag. That afternoon, he



tried to lift Mertz to a sitting position to drink cocoa and weak beef broth, but the man started raving deliriously and again soiled himself.

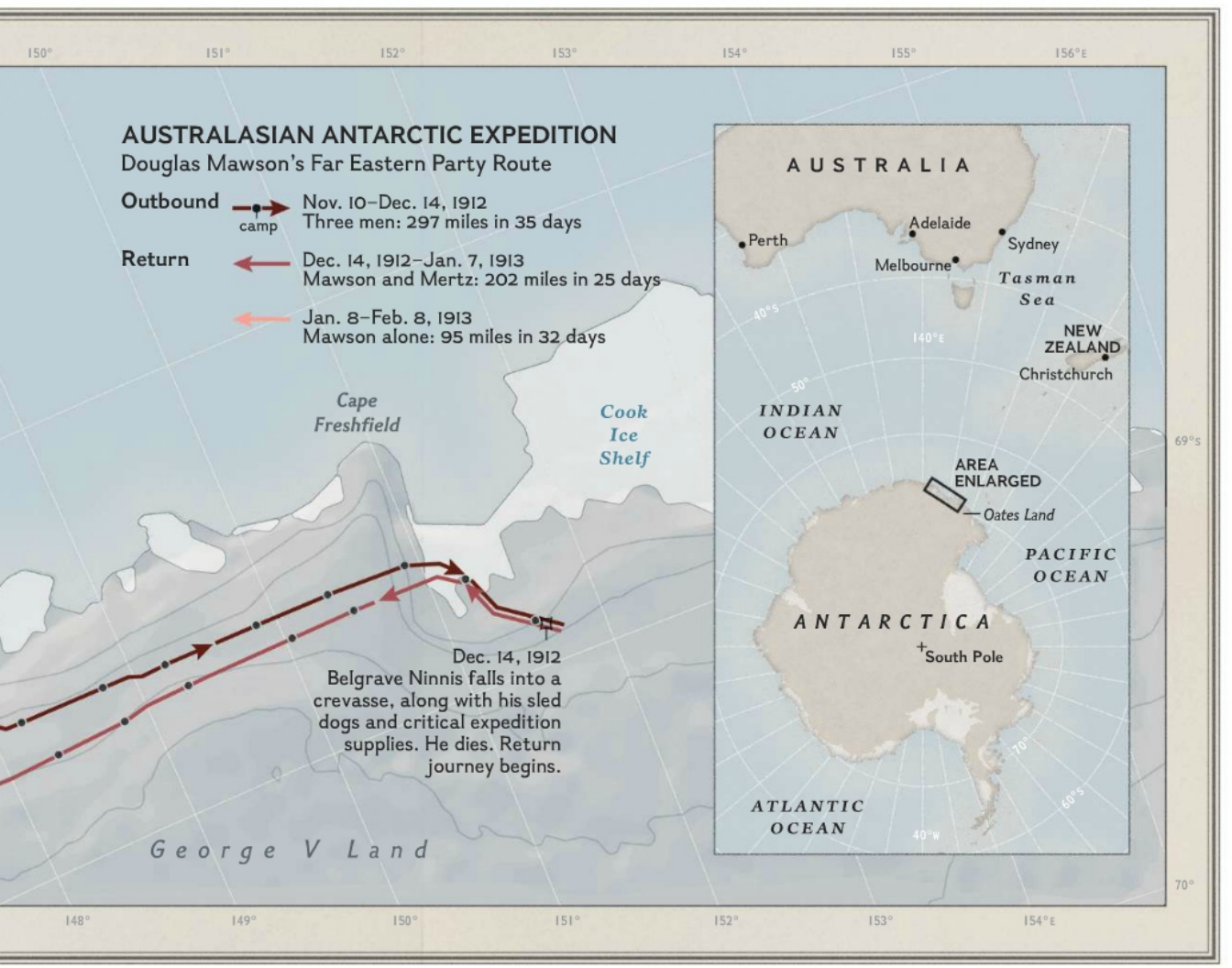
At 8 p.m., Mertz pulled himself half out of his sleeping bag and flailed about in a wild frenzy, breaking one of the tent poles. For hours he raved in German. Mawson held him down, hoping to calm him, then stuffed him back into his bag. At 2 a.m. on January 8, Mertz died in his sleep.

MAWSON BURIED HIS FRIEND, still in the sleeping bag, beneath a mound of snow blocks atop which he fixed a rude cross made of discarded sledge runners. Many years later, some researchers speculated that Mertz's debilitation was caused by poisonous overdoses of vitamin A from the huskies' livers. But if so, why did the condition affect Mertz so much more drastically than it did Mawson? Other experts suggested that Mertz's collapse was due simply to hypothermia, overexertion, and near starvation.

Whatever its cause, Mertz's death now threatened Mawson's survival as well. The food was almost gone, and his own physical state was deplorable, with open sores on his nose, lips, and scrotum; his hair coming out in clumps; and skin peeling off his legs. And he still had a hundred miles to go. "I am afraid it has cooked my chances altogether," Mawson wrote in his diary. But he added, "I shall do my utmost to the last."

Using only the serrated blade of his knife, he cut the sledge in half. Then he fashioned a makeshift sail by sewing Mertz's jacket to a cloth bag. Three days after Mertz's death, Mawson discovered to his horror that the soles of his feet had completely detached from the skin beneath them, which spurted pus and blood. He taped the dead soles to his feet, and put on six pairs of wool socks. Every step thereafter was an agony.

Mawson was now in a race against time, as well as miles. The expedition's relief ship *Aurora*





In summer, a crew pitches a tent during a gale—a task that could take more than an hour in the incessant winds. Besides the bitter cold and strict food allotments, there was the ever present fear of getting lost.





Anchored off Cape Denison, the supply ship *Aurora* was the expedition's only lifeline home. As Mawson raced to meet it at the tail end of his punishing solo slog to the Main Base, he spied the ship departing for Australia. He'd missed it by a mere five hours.



was scheduled to arrive at Commonwealth Bay on January 15 to pick up the men and steam toward home in Australia. But as the days ticked by, Mawson was still more than 80 miles from the hut, and he was growing weaker by the hour.

One day, plowing through deep snow, he broke through a snowbridge covering a hidden crevasse. Suddenly he was falling unchecked through space. Then a fierce jolt halted his plunge. The 14-foot harness rope attaching him to the sledge had held, but now Mawson was sure that his weight would pull the sledge in on top of him. He thought, So this is the end.

Miraculously, the sledge stuck fast in the deep snow, anchoring him. But as his eyes adjusted to the semidarkness, Mawson saw how hopeless his predicament was. He dangled free in space, the crevasse walls too far away to reach even with the wild swing of a boot. His first thought came as a searing regret that he had not had the chance to eat the last ounces of his food before he died.

His only chance to escape was to pull himself hand over hand up the harness rope. Providentially, he had tied knots in the rope at regular intervals. He seized the first knot and pulled himself upward, then lunged for the next. Even for a fit, healthy man, such a feat would have been barely possible; yet Mawson pulled, rested, and lunged again. He reached the lip of the crevasse and tried to roll onto the surface above.

That effort broke loose the overhanging lip. Mawson fell all the way to the end of his harness rope. Despair overwhelmed him. He pondered slipping out of the harness to plunge to the bottom of the crevasse, ending things at once rather than by strangling or slowly freezing. At that moment, a verse from his favorite poet, Robert Service, flashed through his mind: "Just have one more try—it's dead easy to die, / It's the keeping-on-living that's hard."

The words spurred him to "one last tremendous effort." As he reached the lip, he thrust his legs out first, then pulled the rest of his body free from the crevasse. He rolled over and passed out, waking an hour or two later to find his body covered with a dusting of new-fallen snow.

MAWSON WAS NOW CONVINCED he had no chance to survive. Besides, the deadline to reach the hut had come and gone. For all he knew, the *Aurora* had steamed away with all the other AAE hands on board. What drove him onward was the hope of leaving his diary, along with Mertz's, in a place where searchers might eventually find them and learn the story of the doomed Far Eastern Party.

Yet on January 29 a minor miracle occurred. Just north of his track, Mawson saw something dark loom through the haze. It was a snow cairn covered with a black cloth. Inside, he found a message from three teammates who had been out searching and a bag of food—blessed food! From the note, Mawson learned that he stood only 28 miles from the hut.

It would take him ten days to cover that short distance, as he waited out a prolonged blizzard. At last, on February 8, he began the last descent. Before he could see the hut, he caught sight of a distant speck on the horizon. As he feared, it was the *Aurora,* leaving Commonwealth Bay for good. Was he alone? Then the hut sprang into view, and outside it, three men working at some task. Mawson stopped in his tracks and waved for 30 seconds. The men were too far away to hear his shouts. At last one of them glanced up and saw the apparition on the horizon.

Mawson had missed catching the *Aurora* by a mere five hours. Instead, he and six men deputized to stay on to search for Mawson's party were condemned to spend another year in the windiest place on Earth.

Now the men at the hut rushed up the icy slope to embrace their leader. The first to arrive was Frank Bickerton, a stalwart 24-year-old British engineer who had been in charge of another of the exploring parties. From 50 yards off, Mawson recognized Bickerton. And from the startled look on Bickerton's face as he beheld the gaunt, ravaged countenance of the man staggering toward him, he knew exactly what Bickerton was thinking: Which one are you?

ANOTHER TEN MONTHS PASSED before the *Aurora* returned. When Mawson finally reached Australia in February 1914, he was greeted as a national hero and knighted by King George V. He spent the rest of his career as a professor at the University of Adelaide. Although he would lead two more Antarctic expeditions, his life's work became the production of 96 published reports that embodied the scientific results of the AAE.

When Mawson died in 1958, all Australia mourned its greatest explorer. □



Adélie penguins provided a source of food for the expedition's humans as well as its dogs. They also provided dubious amusement: The crew would sneak up on penguins standing near cliffs and knock them into the ocean. Below, a team member explores a massive ice cave less than a mile from Main Base hut, on the easternmost edge of Cape Denison.





SMALL

SMALL WORLD

They're invisible. They're everywhere. And they rule.



STREPTOCOCCUS

A colorized electron microscope image captures delicate chains of streptococcus in a laboratory sample. Though some strep infections can be deadly, many strains are harmless—among the thousands of benign beings that make their home in our bodies.

MARTIN OEGGERLI, WITH SUPPORT FROM SCHOOL OF LIFE SCIENCES, FHNW

By Nathan Wolfe

Breathe in. Feel the air pass through your nostrils and move into your nose. Your diaphragm contracts, pulling the air deep into your chest. Oxygen floods into tiny cavities in your lungs and travels into your

capillaries, ready to fuel every cell in your body. You're alive.

So is that breath you just took. When we inhale, our nostrils capture millions of invisible particles: dust, pollen, sea spray, volcanic ash, plant spores. These specks in turn host a teeming community of bacteria and viruses. A few types may trigger allergies or asthma. Far more rare are inhaled pathogens that are themselves the agents of diseases, such as SARS, tuberculosis, and influenza.

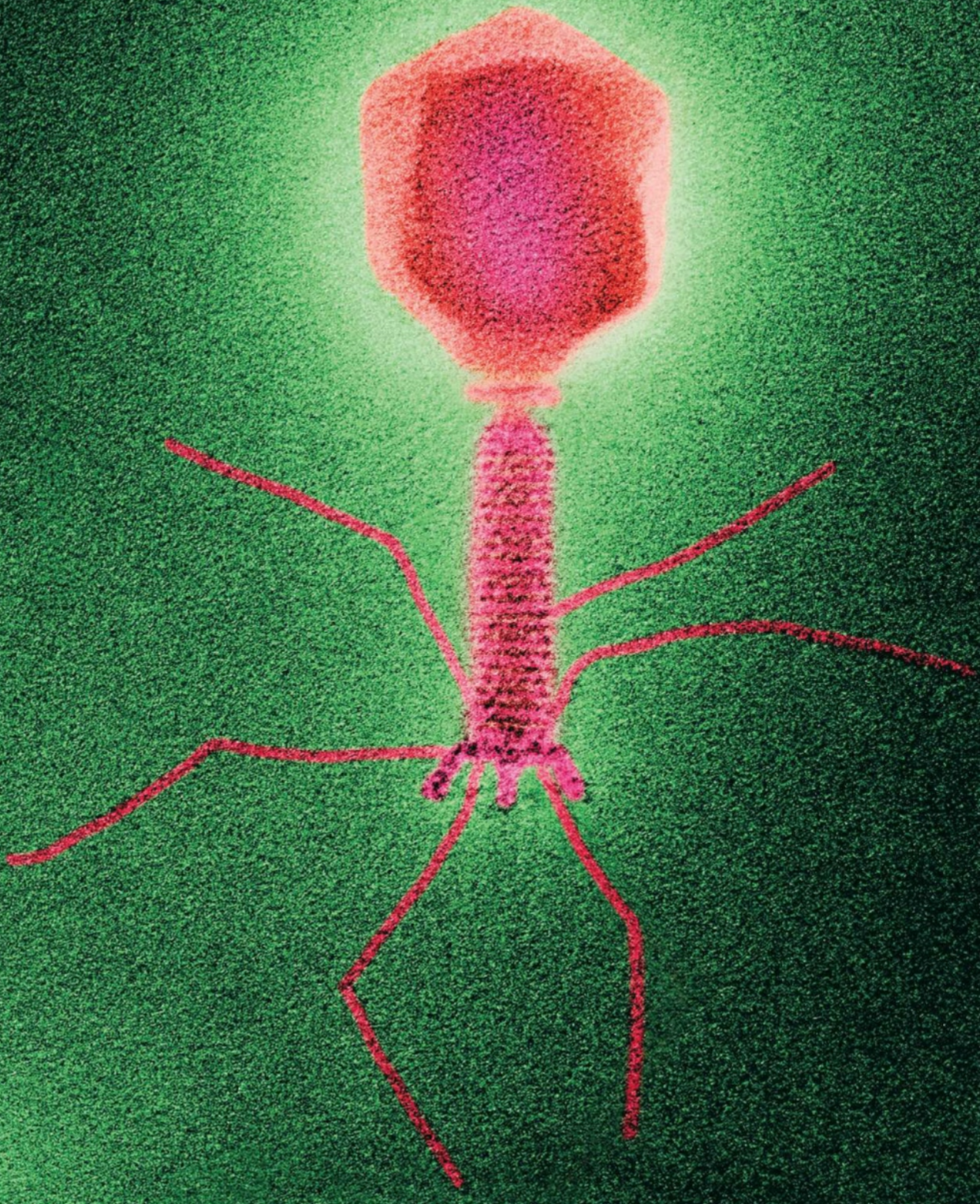
Over the past 15 years I've spent a lot of time poking cotton swabs up human noses, pig snouts, bird beaks, and primate proboscises, looking for signs of such agents before they cause deadly pandemics. As a result, I've come to think of air as the medium for the next pandemic rather than the means to sustain life. But breathe easy: Most of the microbes in the air do us little or no harm, and some almost certainly do us good. The truth is, we still understand precious little about them.

We have known about bacteria, which make up much of the mass of life on Earth, only since Antoni van Leeuwenhoek began training his microscopes on samples of pond water and saliva some 350 years ago. Viruses—much smaller than bacteria but far more numerous than all other life-forms combined—were discovered not much more than a century ago, when people were already driving around in automobiles. And it is only in the past few decades that we have come to realize how ubiquitous microbes are, flourishing from the tops of clouds to miles below the Earth's surface. We've just begun to understand how vital they are to our health and to the health of the Earth. We pride ourselves on having explored nearly every corner of this planet, but behind our world is a shadow world of microbes—and they are often calling the shots.

OUR PAST IGNORANCE of the microbial abundance on the planet stemmed in large part from our inability to grow most microorganisms in the laboratory. Lately DNA sequencing techniques have allowed us to study whole populations in a given environment without the need to culture any of them in a petri dish. In 2006, for instance, scientists at Lawrence Berkeley National Laboratory announced that air samples collected from San Antonio and Austin, Texas, harbored at least 1,800 distinct species of airborne bacteria, putting the richness of air in the same league as that of soil.

BACTERIOPHAGE
These bacteria-infecting viruses, phages for short, are the most abundant life-form on the planet, their number far exceeding that of stars in the universe. Trillions inhabit each of us.

DEPARTMENT OF MICROBIOLOGY, BIOZENTRUM, UNIVERSITY OF BASEL/PHOTO RESEARCHERS, INC
ALL IMAGES COLORIZED



Among them were bacteria from hayfields, sewage plants, hot springs, and human gums, as well as the oddly common bacteria found in deteriorating paint.

Many airborne microbes haven't come from very far away, but some have traveled enormous distances. Dust from deserts in China moves across the Pacific to North America and east to Europe, eventually circling the globe. Such dust clouds harbor bacteria and viruses from the soils where they originated, as well as other microbes they pick up from the smoke of garbage fires or from the mist above the oceans they cross. Take a breath, and you sample the world.

Above the air we breathe, the upper atmosphere also contains microbes, floating as high as 22 miles above Earth's surface. I believe they could go even higher, though it's hard to imagine they could live long so far from water and nutrients. Lower down, they appear to survive and even thrive. There is evidence that despite high levels of ultraviolet radiation that would kill most bacteria, some metabolize and perhaps even reproduce inside clouds. In fact they may play a part in the formation of snowflakes that require a nucleator, or small particle, to crystallize around. In 2008 Brent Christner of Louisiana State University and his colleagues showed that microorganisms were the most efficient ice nucleators present in snow. That's right—snow is literally alive.

Microbes don't just inhabit the air—they created it, or at least the part we most depend upon. When life began on Earth, the atmosphere had no significant oxygen. Oxygen is a waste product of photosynthesis, and we owe the invention of that process, about two and a half billion years ago, to cyanobacteria. These bacteria are directly responsible for as much as half of the oxygen made on Earth each year and indirectly for most of the rest. Hundreds of millions of years ago ancient forms of cyanobacteria made their way into cells that would evolve to become plants. Once embedded in those ancestor plants, they evolved into chloroplasts, the photosynthetic, oxygen-producing engines of plant cells. Together, free-living cyanobacteria and their long-lost chloroplast cousins in plants carry out the vast majority of photosynthesis on our planet.

BUT LET'S GET BACK TO YOUR NOSE. Those airborne microbes you unwittingly inhaled? They're just passing through. Your nasal passages also host a rich and complicated population of full-time residents. Three genera—*Corynebacterium, Propionibacterium,* and *Staphylococcus*—account for most of the bacteria in your nostrils. They form one community among the many that make up the human microbiome: the full genetic complement of bacteria and other organisms at home on your skin, gums, and teeth, in your genital tract, and especially in your gut.

All told, the microbes in your body outnumber your own cells by ten to one and can weigh as much as or more than your brain—about three pounds in an average adult. Each of us is thus both an organism and a densely populated ecosystem, with habitats harboring species as different from one another as the animals in a jungle and a desert. Even the resident microbes in the gum pockets around your teeth can vary greatly, suggesting, as David Relman of Stanford University puts it, that "each of our teeth is essentially an island, rocks in an intertidal pool."

For the most part, the microbes inhabiting our bodies are either beneficial ones or unobtrusive freeloaders. They help us digest our food and absorb nutrients. They manufacture vital vitamins and anti-inflammatory proteins that our own genes cannot produce, and they train our immune systems to combat infectious intruders. Resident bacteria on our skin secrete a sort of natural moisturizer, preventing cracks that could allow pathogens to penetrate.

We get our first dose of these microbial coconspirators as we pass through our mother's vaginal canal, where the bacterial population changes dramatically during pregnancy. For instance, *Lactobacillus johnsonii,* which

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Stanford University microbiologist Nathan Wolfe is the founder of Global Viral and the CEO of Metabiota. He is the author of The Viral Storm *and a National Geographic emerging explorer.*

normally lives in the gut and helps us digest milk, becomes more abundant in the vagina, exposing the baby to the bacterium, perhaps to help prepare the way for digesting breast milk.

Our bodies also host some pretty shifty characters. At any one time about a third of us harbor in our nostrils *Staphylococcus aureus,* a normally benign bacterium that can turn virulent. Usually competition from other members of the nostril community appears to keep this bacterium under control. But *S. aureus* can get nasty, especially when it ventures into other environments. In the skin it can cause everything from an occasional pimple to a life-threatening infection. Under certain conditions, the individual bacteria coalesce into a filmy mass that acts as a united front, invading new tissues and even infecting intravenous catheters and other hospital equipment. Superbug strains of *S. aureus* can cause lethal infections such as toxic shock syndrome or necrotizing fasciitis—flesh-eating disease.

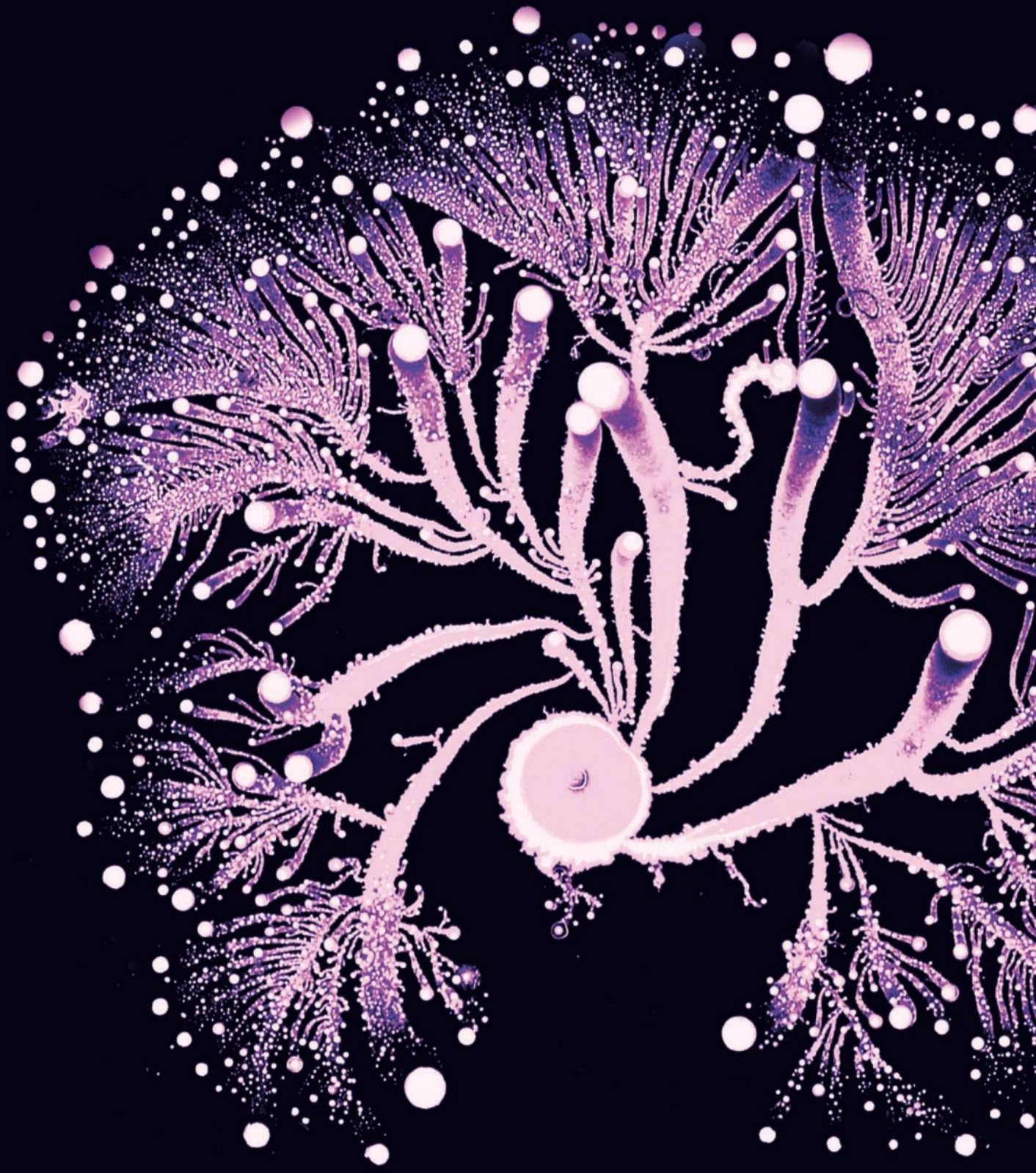
What makes these strains so dangerous is their resistance to antibiotics, those miracles of modern medicine that since the middle of the past century have saved millions of lives. The more we learn about our microbiota, however, the more we realize how easy it is for helpful microbes to get caught in the line of fire between an antibiotic and its intended target. Some 10 to 40 percent of children who are given a broad-spectrum antibiotic develop antibiotic-associated diarrhea, because their gut microbiota have been disturbed.

The widespread use of antibiotics early in life may have more profound effects over time. The stomach microbe *Helicobacter pylori* has long been known to provoke ulcers in some people but in most serves the useful function of regulating immune cells in the stomach. Martin Blaser, a microbiologist at New York University who has studied *H. pylori* for decades, notes that an ever shrinking share of adults is populated with the microbe, partly because of repeated high doses of antibiotics during childhood. Blaser believes the diminished presence of the bacteria and the rise in asthma in American youth might be related.

So should we treat our wheezing children with a healthy dose of *H. pylori*? It's often more complicated than that. As we learn more about the relationships between ourselves and our microbes—and their own complex relationships with one another—scientists are coming to see the microbiome the way ecologists have long viewed an ecosystem: not as a collection of species but as a dynamic environment, defined by the multitude of interactions among its constituents. This should mean greater care in the use of antibiotics and, increasingly, targeted probiotic treatments that don't just temporarily boost the numbers of one microbe or another but that shore up the whole population so that our health is improved. "We know how to disturb a community," says Katherine Lemon, a microbiome researcher at the Forsyth Institute in Cambridge, Massachusetts, and a clinician at Boston Children's Hospital. "What we need to learn is how to coax it back into a healthy state."

This perspective on our relationship with microbes—as fellow travelers to be cared for and managed to our benefit—is a far cry from my day-job view of them as killers to be hunted down and eradicated before they can spread. Both views are valid, of course. We should never let our guard down against the threat of infectious pathogens. But as we continue to explore the microbial world, our fear of the invisible beings around us, and in us, should be tempered with respect for what we are learning about them—and a rush of excitement for what remains to be discovered. □

All told, the microbes in your body **CAN WEIGH AS MUCH AS OR MORE THAN YOUR BRAIN—** about three pounds in an average adult.







CYANOBACTERIA
Tiny green cyanobacteria played an outsize role in Earth's history by creating the planet's oxygen-rich atmosphere through photosynthesis. Ancestral forms also evolved into chloroplasts, the cell parts that carry out photosynthesis in plants.

STEVE GSCHMEISSNER, PHOTO RESEARCHERS, INC

PAENIBACILLUS
A lab-grown colony of *Paenibacillus vortex* organizes into a fanlike pattern, with arms reaching out to scout for food. Bacteria can act collectively, communicating with chemical signals.

ESHEL BEN-JACOB AND INNA BRAINIS



1 IN 10 CELLS
in the body is human

Our Microbiome

In our bodies human cells are outnumbered ten to one by bacteria. Some eight million genes function in this invisible universe—more than 300 times the number in our own cells. Though some of our microbial tenants pose threats, we literally can't live without most of them. They help digest our food, guide our immune system, and ward off deadly germs.

THE BODY'S NEIGHBORHOODS

Different regions of our body have unique populations of bacteria, some more diverse than others.

TONGUE
7,947 species
Major player:
Streptococcus salivarius
This bacterium is an ally, helping prevent tooth decay, gum disease, and throat infections.

INNER ELBOWS
2,012 species
Major player:
Corynebacterium simulans
Generally beneficial, this species has antimicrobial properties that inhibit or kill more harmful pathogens.

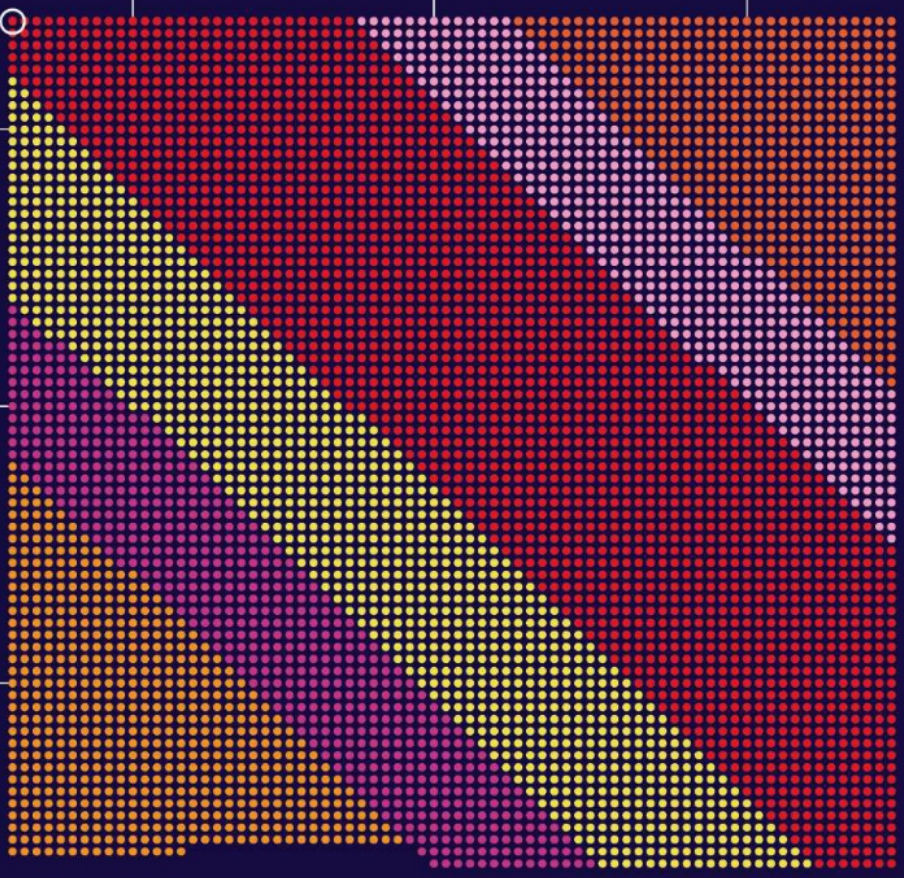
VAGINAL OPENING
2,062 species
Major player:
Lactobacillus acidophilus
Lactobacillus produces lactic acid, which maintains a low pH and inhibits the growth of harmful bacteria.

Four species of bacteria

THROAT
4,154 species
Major player:
Neisseria lactamica
Babies have more of this microbe than adults, perhaps because it may help build immunity against meningitis.

BEHIND THE EARS
2,359 species
Major player:
Propionibacterium acnes
Although associated with acne, this bacterium also inhibits the growth of fungi and yeast on the skin.

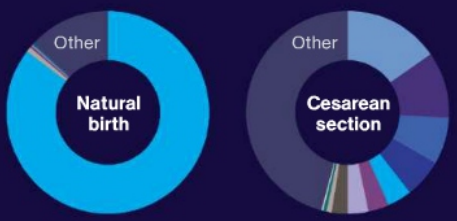
NOSTRILS
2,264 species
Major player:
Staphylococcus epidermidis
This species keeps the nostrils' teeming bacterial colonies in equilibrium and suppresses dangerous strains of staph.



BABY'S FIRST BUGS

The microbes that colonize an infant "teach" the immune system as it develops in the first three years of life and influence the baby's risk of allergies, eczema, and more.

Microbes from the mother's vagina make it easier for a newborn to live on the outside. Bacteria in the Lactobacillales order (bright blue) help the baby digest milk.



MICROBIAL DIVERSITY ON NEWBORN'S SKIN
Each color represents an order of bacteria.

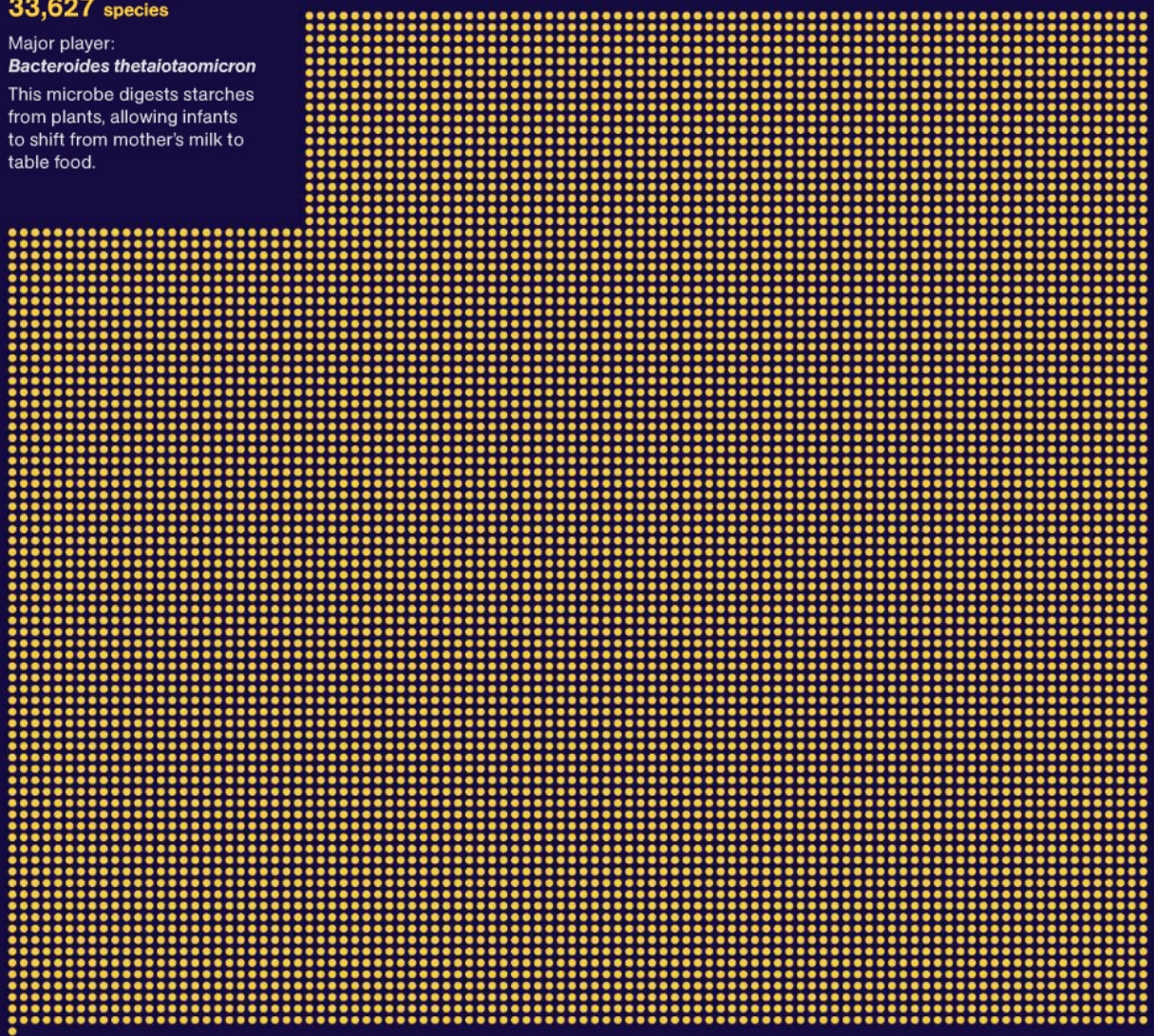
C-section babies have fewer lactobacillus bacteria and more potentially harmful microbes picked up from adult skin, including staphylococcus and *Acinetobacter.*

LARGE INTESTINE*

33,627 species

Major player:
Bacteroides thetaiotaomicron

This microbe digests starches from plants, allowing infants to shift from mother's milk to table food.



*Data taken from stool sample

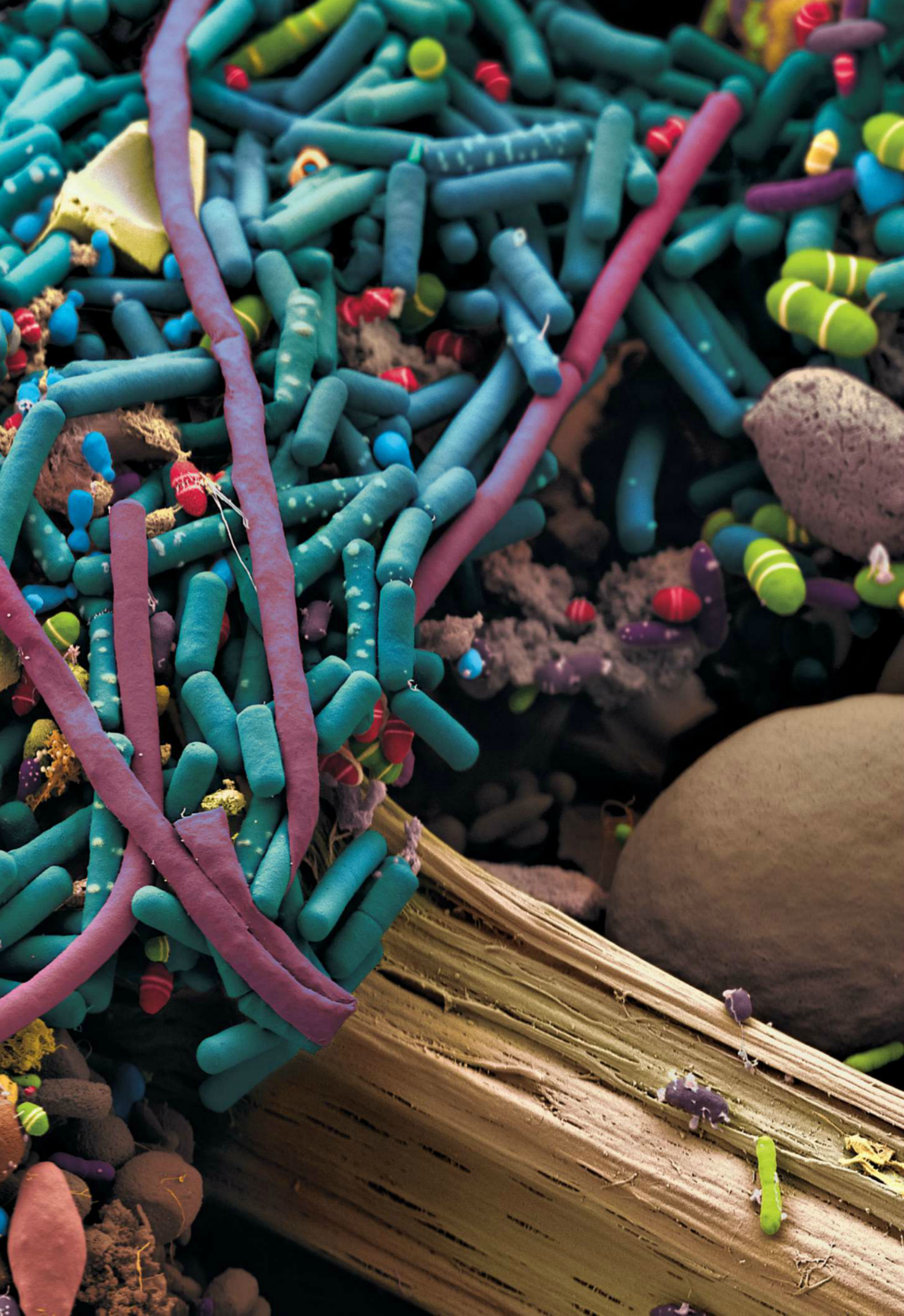
GRAPHIC: LAWSON PARKER, NGM STAFF. SOURCES: SUSAN M. HUSE, "A CORE HUMAN MICROBIOME AS VIEWED THROUGH 16S RRNA SEQUENCE CLUSTERS" (SPECIES COUNT); MARIA G. DOMINGUEZ-BELLO, "DELIVERY MODE SHAPES THE ACQUISITION AND STRUCTURE OF THE INITIAL MICROBIOTA ACROSS MULTIPLE BODY HABITATS IN NEWBORNS" (NEWBORN DATA)



INTESTINAL BACTERIA

The human gut teems with bacteria, many of their species still unknown. They help us digest food and absorb nutrients, and they play a part in protecting our intestinal walls. Gut bacteria may also help regulate weight and ward off autoimmune diseases.

MARTIN OEGGERLI, WITH SUPPORT FROM SCHOOL OF LIFE SCIENCES, FHNW



NG CONNECT

Every month this page features our staff picks of National Geographic Society products and events. For more go to *nglive.org.*

NATIONAL GEOGRAPHIC ON TV



The Next Frontiers

National Geographic has been exploring the world for 125 years. This special celebrates that spirit by taking you into the labs of scientific pioneers, including engineer Albert Yu-Min Lin (left), whose technological advances might help him locate the tomb of Genghis Khan. Witness Lin's work and more—from lightning chasing to DNA tracing—this month on the National Geographic Channel.

TRIP

TRAVEL WITH THE PROS There's a team of experts aboard every voyage of the *National Geographic Explorer.* This 148-passenger vessel can reach the far corners of the world and is fully equipped with underwater cameras, kayaks, and Zodiac landing craft. For departures bound for Antarctica, South America, and beyond, see *ngexpeditions.com/explorer.*

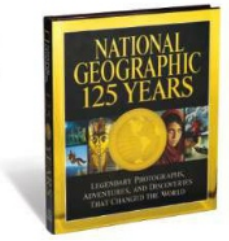
EXPEDITION



A WALK THROUGH TIME This month Pulitzer Prize-winning reporter Paul Salopek sets off on his quest to follow the path of human migration—on foot. Starting in Ethiopia, where modern humans first evolved, he'll walk out of Africa, through the Middle East, across Central Asia, north to Siberia, then sail the Bering Strait and traverse the entire Americas before finally reaching Patagonia. In all, the journey will take six or seven years to complete, and along the way Salopek will share stories, photographs, and videos at *nationalgeographic.com/outofeden.*

BOOK

125 YEARS This book documents the adventures, discoveries, and innovations that define National Geographic's quest to cover "the world and all that's in it." More than 600 photos accompany a rich chronicle of the Society's life so far. Find it in stores now ($50).



Free Download of the Month



Efterklang *Piramida*

In August 2011 the Danish band Efterklang visited Piramida, an abandoned mining settlement on Spitsbergen, Norway. After spending nine days exploring the ghost town, the indie rockers came back with more than a thousand field recordings, many of which have been incorporated into their new album. Download a song at *natgeomusic.net/free.*

PHOTOS: ALEXIS SIGGERS, NGT (TOP); NANCY STONE, *CHICAGO TRIBUNE* (SALOPEK)



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Fireside Spirit

Deep in the Amazon a Waorani woman prepares fish soup by her hammock, underneath a house on stilts in the village of Gabaro, Ecuador. Photographer Karla Gachet turns her lens at the only source of light in the darkness. The woman's husband, a shaman, is nearby but can't be seen—his fire has died out. As Gachet watches, the husband moans, mutters, makes animal noises. Villagers, who believe he's possessed by the spirit of the jaguar, gather to ask questions. Only the wife can answer; she's the go-between for the spirit and the curious neighbors. *—Luna Shyr*



BEHIND THE LENS

How did you feel in this woman's presence?

KG: I couldn't communicate with her, but her eyes were big and intense. When she talked, they grew wide open. They were these two black marbles. At one point they seemed almost all black, but that might have been part of my own imagination and fear. It was dark, we were in the middle of the jungle, and our guide said that the spirit mentioned outsiders who had come in and smelled really bad.

What outsiders did the spirit mean?

We think us. That day we bathed in the river. Our soap and shampoo smell bad to the spirit.

What did the Waoranis ask the spirit?

Hunting questions. The Waorani are still hunters, so it's important to them to find animals. The "spirit" said there would be animals in a certain direction. The next day the shaman's son went there and found peccaries [piglike mammals]. Someone went another way and didn't catch anything.

What was it like taking this photo?

It was eerie to be there. After we got back, I was alone at night looking at her pictures, and it gave me the chills. The image is so intense.



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Seating Arrangements

"United States Air Force pilots are finding it much safer and more comfortable to lie down while handling the controls of a plane," according to notes that accompany this 1949 photograph. "Shown here is the prone position pilot bed developed by Air Materiel Command's Aero-Medical Laboratory. The prone seat produces less fatigue on long flights and permits the pilot to withstand greater gravitational pull without danger of blackout."

Lying down didn't fly. Neck support for military pilots, as seen above, continues to be a concern, though. Recent studies by the U.S. Army Aeromedical Research Laboratory have covered neck stress caused by today's heavier helmets and the effects of head tilt in banking aircraft. *—Johnna Rizzo*

Flashback Archive Find all the photos at **ngm.com**.

U.S. AIR FORCE/NATIONAL GEOGRAPHIC STOCK

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