New Zealand's **Jade Country**

NGM.COM MARCH 2014

NATIONAL GEOGRAPHIC

THE TRUTH ABOUT BLACK HOLES

THE HORSE
in Native American Culture

BLUEFIN TUNA
Sushi's Prized Fish

Florida Scrub-jay *(Aphelocoma coerulescens)*
Size: Body length, 26 - 28 cm (10.2 - 11.0 inches); wingspan, 34 - 41 cm (13.4 - 16.0 inches); tail, 12.9 - 14.5 cm (5.0 - 5.7 inches) **Weight:** 72 - 79 g (2.53 - 2.79 oz) **Habitat:** Low-growing oak scrub on well-drained sandy soil **Surviving number:** Estimated at 6,000 - 9,000

Photographed by Tom Vezo

WILDLIFE AS CANON SEES IT

Help is here. Florida scrub-jay group members pitch in to help parents guard and feed chicks in the nest. In fact, male helpers are so dedicated to the role that they defer breeding until they have established their own territory. Cooperation is also the name of the game when foraging, as birds take turns scanning for predators while the rest of the group searches out arthropods, acorns, small vertebrates and virtually anything edible. But faced with serious threats in the form of habitat loss and degradation, the species as a whole still needs all the help it can get.

As Canon sees it, images have the power to raise awareness of the threats facing endangered species and the natural environment, helping us make the world a better place.


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VOL. 225 • NO. 3

NATIONAL GEOGRAPHIC

You just pass through, unaware that you're now lost to the rest of the universe.
page 102

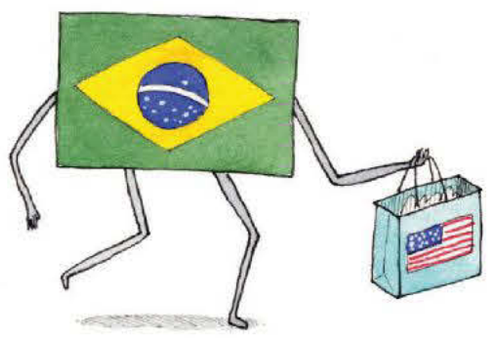
March 2014

It's a good deal for both parties: The bat, a Cuban species, gets nectar; pollen from the blue mahoe tree's flower sticks to the fur and will be spread when the bat departs.

MERLIN D. TUTTLE

OFFICIAL JOURNAL OF THE NATIONAL GEOGRAPHIC SOCIETY

March 2014



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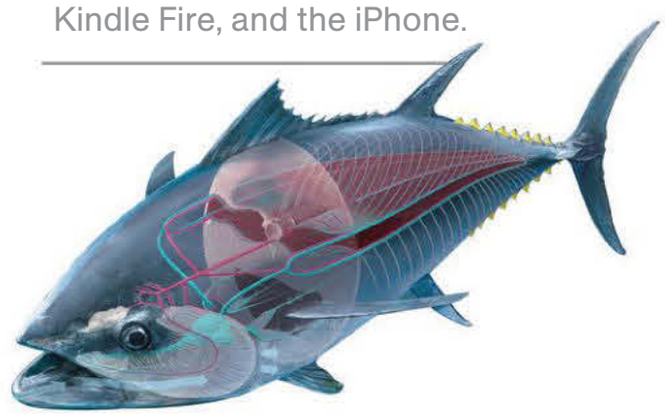

Bluefin Tuna
Animation
Explore the traits that make the tuna a super fish.

Black Holes
Animation
Black holes can't be seen. Watch how they're found.

Bat Echo
Video
Bats fly in for a floral treat.

On the Cover In this illustration, as in space itself, a black hole is revealed by the power of its pull on nearby stars and other celestial matter.
Art by Mark A. Garlick

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A Heritage of Horses

I grew up in Central Point, Oregon. From my house I could see Upper Table Rock, a plateau once occupied by the Rogue River Indians. As a kid I'd heard stories about a vicious raid by a white mob and how the Indians leaped from the rock rather than be captured. It was part of the mythology of the landscape, though I've never been able to verify it.

What is true is that my father, who was a social studies teacher, made sure I understood Native American history in the most positive way. He wanted me to look beyond myths to the truths of their culture. Among Native American accomplishments and skills, he told me, were their adoption of the horse and their deep, almost mystical, connection to that animal.

I later saw those skills for myself as a Seattle newspaper photographer. I was shooting the Omak Stampede Suicide Race—the same event David Quammen writes about this month in "People of the Horse."

It's a story full of soul, as Erika Larsen's photographs show. Horses, Quammen explains, transformed Native American culture. More than just a symbol of wealth and pride, the horse embodied values including discipline, concern for other creatures, and continuity of knowledge between generations.

Randy "Leo" Teton—here with his horse Geronimo—is a member of Idaho's Shoshone-Bannock Tribes.

PHOTO: ERIKA LARSEN

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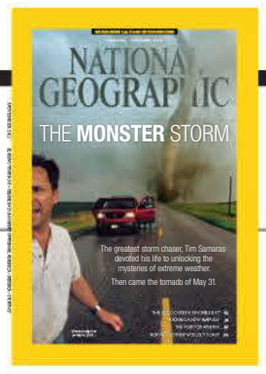

The Last Chase

When I saw the photo of Tim Samaras on the cover of the November issue, I thought that Samaras was running away from the tornado in the background. But after reading the article and seeing the entire photo inside the pages, I quickly realized he wasn't running from anything—he was telling somebody in his crew to get the equipment in place fast, so they could get the critical tornado information. May he rest in peace, and may we all pass doing what we love, as Tim Samaras did. Godspeed, Tim.

BOB FIELDS
Maitland, Florida

I'm blown away. The iPad is the only way to convey this powerful story. It's like reading in 3-D.

HUGH C. DAMON
Honolulu, Hawaii

Robert Draper's story left me with a sick regret over the useless sacrifice of the lives of Tim Samaras and his son. Just for some additional data on tornadoes? There is no romantic stoicism here. My sympathy is with the innocent victims of such storms who try to seek refuge, not with those who recklessly tempt death.

MICHAEL LANDAU
Rome, New York

Your story reflected his deep respect for nature and his lack of concern about the dangers underlying his data collection. His passion was evident, as was the unrelenting and unpredictable power of the peril he was attempting to understand.

GEORGE W. SUNDIN
Williamston, Michigan

FEEDBACK *Readers responded to our story about Tim Samaras's final storm chase.*

"Your coverage of the El Reno tornado was absolutely incredible, and I applaud your team for it."

"Irresponsible, glory- and attention-seeking, not internationally relevant subject matter worthy of the magazine."

"Without a doubt they died too soon, but they died doing what they loved. Their passion and expertise are an example for us all."

"Did we really need 36 pages on an adrenaline junkie?"

"Draper's graphic description of how ferocious that storm was had adrenaline rushing through my body as if I were right there in Oklahoma that memorable day."

"I mean, yeah, tornadoes are an adrenaline rush, but is there really that much more to learn about them?"

I couldn't stop reading about the freakish gargantuan tornado overtaking the doomed scientists and other victims. It held a fascinating, horrifying, and melancholy power that lingered. I hope Tim Samaras's goal of getting better tornado data can be achieved without further loss of life.

KENDAL STITZEL
Fort Collins, Colorado

Since I lived through the Waco, Texas, tornado in 1953, when 114 were killed, a severe weather alert gets my full attention. I have friends who say they sleep right through a storm—understandably, I cannot. Maybe articles as detailed and vivid as this will save lives.

JIM FITZHENRY
Salado, Texas

Corrections

NOVEMBER 2013, "THE LAST CHASE" Tim Samaras had seen two F4 tornadoes, not one, as stated on page 50.

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GRAPHIC: ÁLVARO VALIÑO

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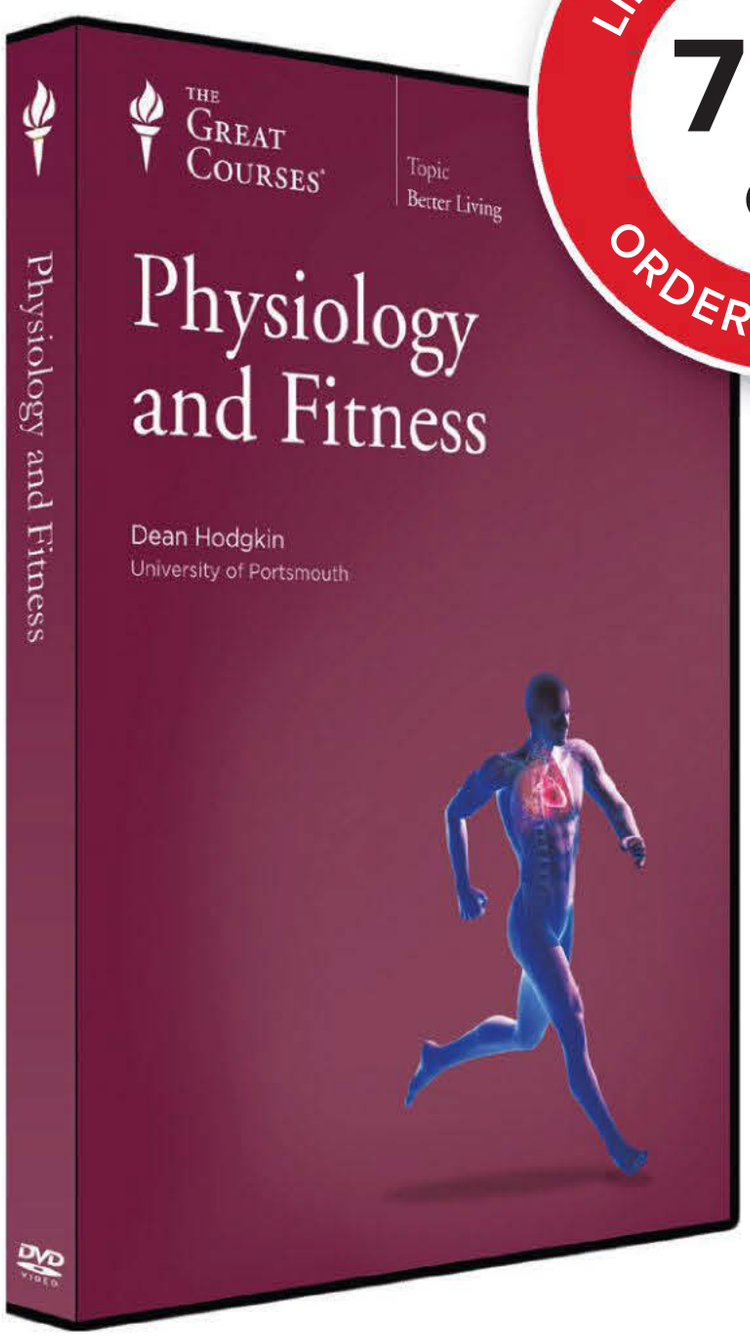

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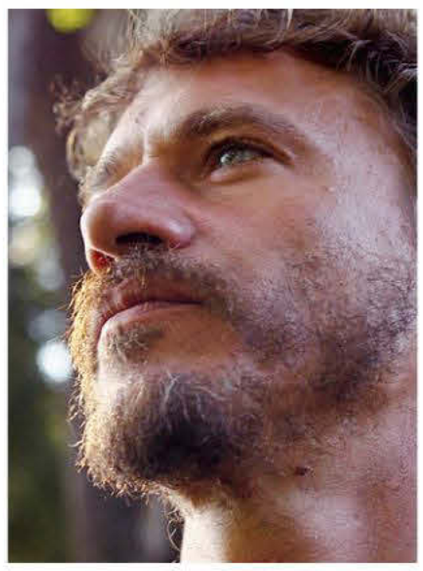

Steve Boyes
National Geographic Emerging Explorer

EXPERTISE
Conservation Biologist

LOCATION
Botswana

Curiosity and a Cat

Every year my team delves deeper into the Okavango Delta—a 10,000-square-mile fan of channels, floodplains, lagoons, and islands. Within its maze there are more than 2,000 lions, plus leopards, hippos, crocodiles, and nearly 80,000 elephants.

The local Bayei people are descendants of hippo hunters, so they have taught us to respect that animal's natural rhythms. When we pole into the delta, we wait until nine to set out. That's when the hippos come off the islands and go into deeper water. They return again around five. We're off the water before they get back.

Before we had the help of the Bayei, we had a steeper learning curve. One morning my brother and I heard lions calling from behind camp. They seemed to be on an island to the far right of us. We were barefoot and having our morning coffee but wanted a closer look. Soon we were hundreds of feet from camp in our underpants. We didn't have a spear.

Suddenly a pair of lions popped up. The lioness stilled and stared us down. I knew that we had to give her a reason for us to be there that didn't involve her. We didn't want her to perceive us as a threat. My eyes latched on to an extremely large piece of elephant dung. I took a few steps toward her, trying to move purposefully, and picked up the dung. I fixed all my attention on it to indicate that this was a very special piece of elephant dung—a very good reason for being there indeed.

Somehow it worked. The lioness let me walk back to camp with my prize. We kept that piece of dung in camp for the rest of the season to remind us about consequences. Now we aren't so reckless.

ART: ISTVAN BANYAI. PHOTO: NEIL GELINAS

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VISIONS

Namibia
Some 300 people a month trudge up the sandy slopes of desert dunes near Swakopmund for the novelty of “sandboarding.” Fans say sand is a bit slower than snow—but much softer if you fall.

PHOTO: THOMAS DRESSLER

Portugal
Plummeting from a 95-foot precipice would unnerve most mortals, but “in that moment, everything is calm,” said Colombian diver Orlando Duque during the 2012 Red Bull Cliff Diving World Series. The nine-time world champion placed second.

PHOTO: DEAN TREML, AFP/GETTY IMAGES

United States
Joining hands in a heads-first free fall to form a human snowflake, 138 skydivers set a world record at Skydive Chicago in August 2012. The upside-down photographer bit a switch in his mouth to trigger a helmet camera.

PHOTO: BRIAN BUCKLAND

This section features photographs chosen by our editors and one chosen by our readers via online voting. For more information, go to *yourshot.nationalgeographic.com.*

EDITORS' CHOICE **Chris Matthew Brady** San Diego, California

As he drove near a wildfire in Borrego Springs, California, Brady stopped at one of several dinosaur sculptures in the area. He set his tripod to take some long exposures—80 in all. To light the eye of the dinosaur, he mounted a laser pointer on another tripod nearby.

READERS' CHOICE

Andrew Inaba
Bellevue, Washington

Under a pile of avalanche snow in the Cascade Range, Inaba found a tunnel that had been carved by summer runoff and wind. While he prepared his shot, he says, "water rained intensely from the ceiling."

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NATIONAL GEOGRAPHIC

Your Shot assignment

Ivan Lesica
Queens, New York

Lesica stopped on New York's Williamsburg Bridge to point his camera into a viewing box containing several pieces of multicolored glass. He captured part of the Manhattan skyline, including the Empire State Building.

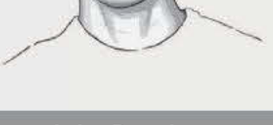
National Geographic's Your Shot puts you behind the camera and out in the field. This past November, the Lexus GX sponsored a three-week assignment, Spontaneous Adventure—and adventures were had! We received nearly 9,000 submissions from around the world.

The Spontaneous Adventure assignment was curated by National Geographic adventure photographer John Burcham. He and *National Geographic* editors then wove the finalists into a story, which you can see at *ngm.com/yourshot*. Here are some of their top picks.

Vedrana Tafra Split, Croatia

To photograph wild horses in the Krug Mountains in Bosnia and Herzegovina, Tafra went with a guide who knew the area. They slowly approached a group of horses at a watering hole and also this pair on a hill.

"Being spontaneous can feel a little unnerving, but once you do it, you won't be disappointed. Be prepared, though—you don't want to miss the shot because you forgot your favorite lens."



John Burcham

First Prize

Karl Ander Adami Tallinn, Estonia

While Adami was visiting his grandmother in western Estonia, he we
where he collected mushrooms, leaves, and berries. Then he arrang
floor to take a portrait of fall.

nt for a walk in a forest,
ed them on a wooden

Hung Tran The
Hanoi, Vietnam

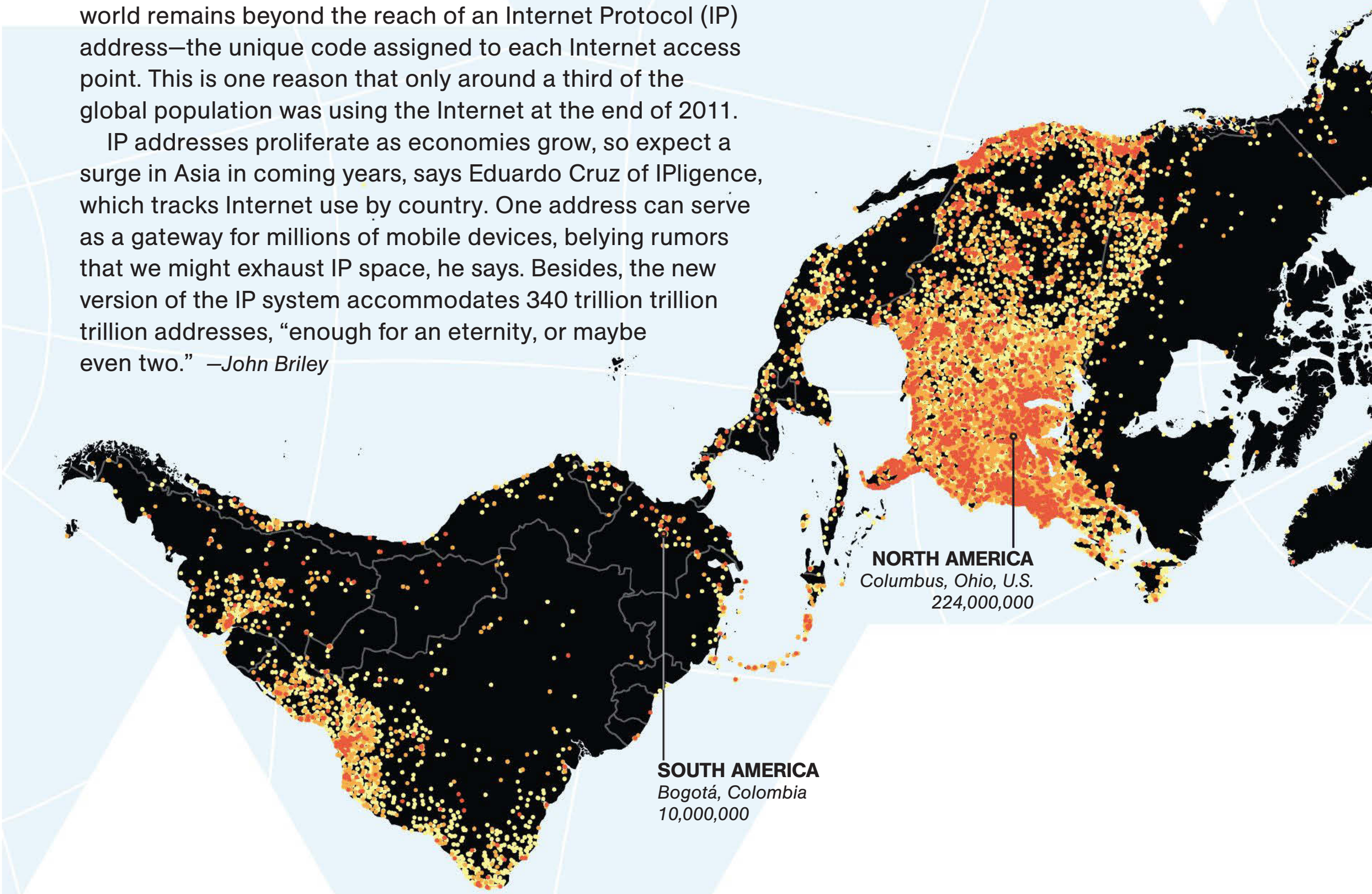
Tran The, an occasional sports photographer, captured this midair twist at a diving competition in Hanoi. This particular athlete won a gold medal.

NEXT

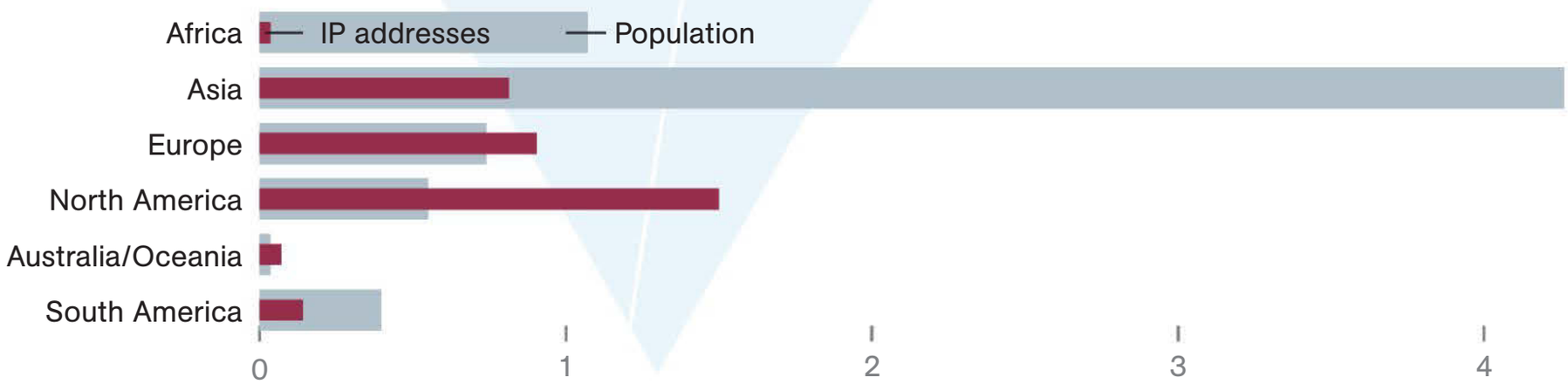
Wiring the World

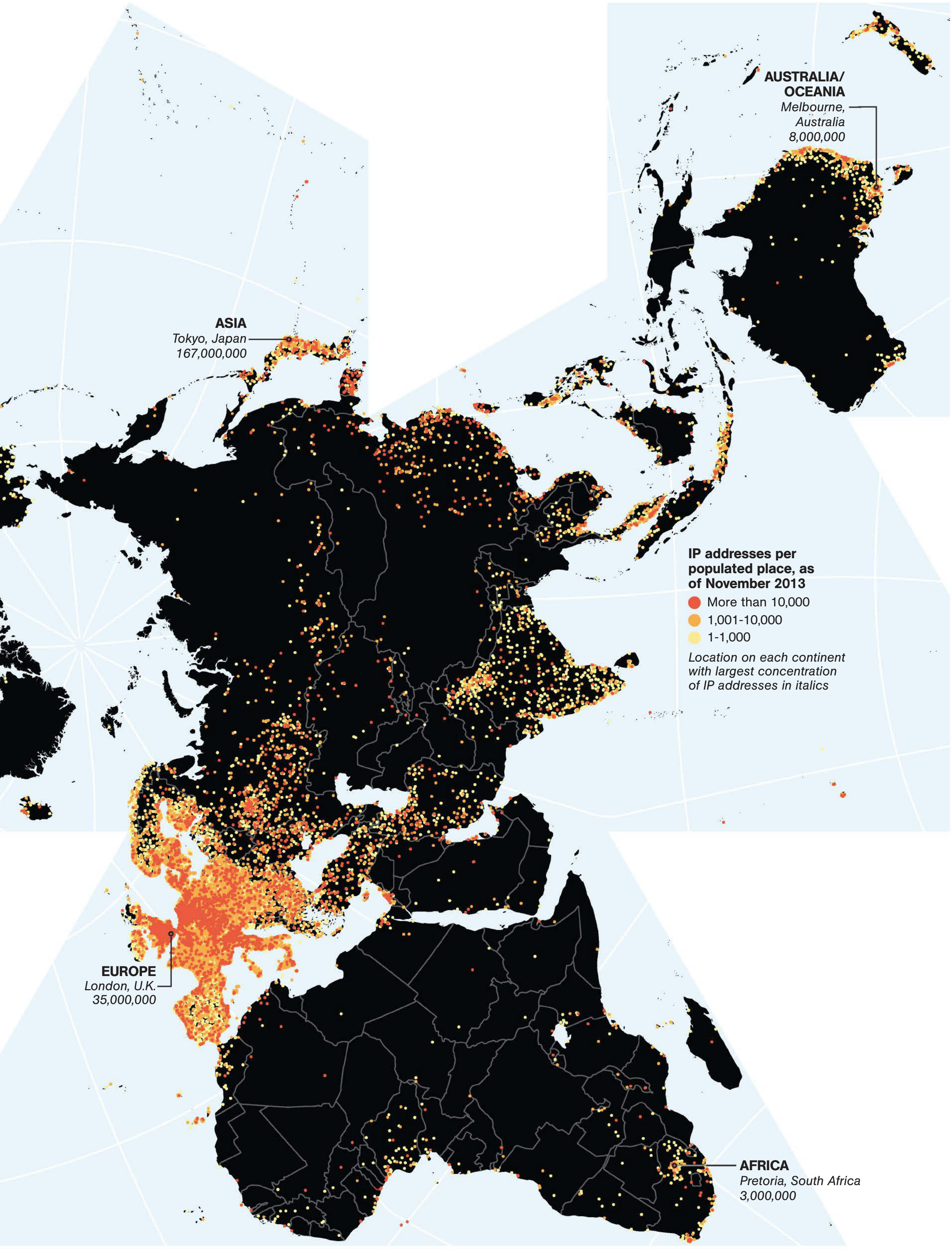
When you can hop online and order coconut oil direct from Fiji, you might conclude that the Internet knows no bounds. But much of the world remains beyond the reach of an Internet Protocol (IP) address—the unique code assigned to each Internet access point. This is one reason that only around a third of the global population was using the Internet at the end of 2011.

IP addresses proliferate as economies grow, so expect a surge in Asia in coming years, says Eduardo Cruz of IPligence, which tracks Internet use by country. One address can serve as a gateway for millions of mobile devices, belying rumors that we might exhaust IP space, he says. Besides, the new version of the IP system accommodates 340 trillion trillion trillion addresses, "enough for an eternity, or maybe even two." *—John Briley*



IP addresses and population (2013)
By continent, in billions



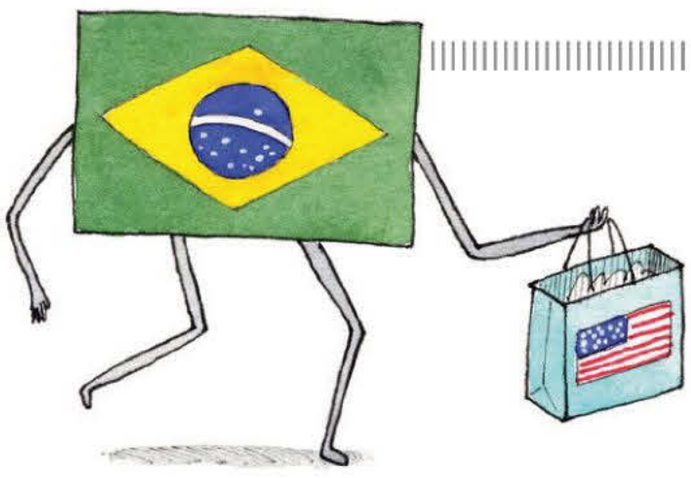


JASON TREAT, LAUREN E. JAMES, NGM STAFF; JONATHAN K. NELSON
SOURCES: IPLIGENCE; POPULATION REFERENCE BUREAU

Preparations for this home rink in Ramsey, Minnesota, start in October. "Our family uses it almost every day," says owner Aaron Davis.

Skate Watchers Lately outdoor ice-skating rinks are melting faster than the winter cold is lasting—making them a prime indicator of climate change. That's the idea behind RinkWatch, a citizen science website created by Haydn Lawrence, Robert McLeman, and Colin Robertson of Canada's Wilfrid Laurier University.

The project allows users of the home ice rinks popular in colder climes to log the skateability of their backyard ice. According to recent reports, fewer rinks are maintaining optimum skating temperatures throughout the winter. With a cultural staple on the line, RinkWatch has caught on in Canada and the northern United States. "If you took outdoor skating from us, it would be like taking cowboy hats from Texans or the Red Sox from Bostonians," says McLeman. "Life would go on, but there would be something missing." *—Rosemary Hammack*



Foreign Exchange **Visiting Brazilians spend about nine billion dollars a year in the U.S. on everything from iPhones to baby gear. Prices are high in Brazil, and "even with plane tickets and hotels it can still be cheaper to shop in the States," says the U.S. Embassy's Dean Cheves. To encourage tourism, the U.S. has sped up visa processing for Brazilians from 120 days to two days; roughly 5,000 Brazilians apply daily. To cope with the extra baggage, airlines take on additional fuel for return trips.** ***—Daniel Stone***

PHOTO: ERIKA LARSEN. ART: MARC JOHNS

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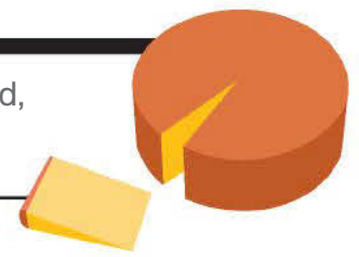


Sticking Points

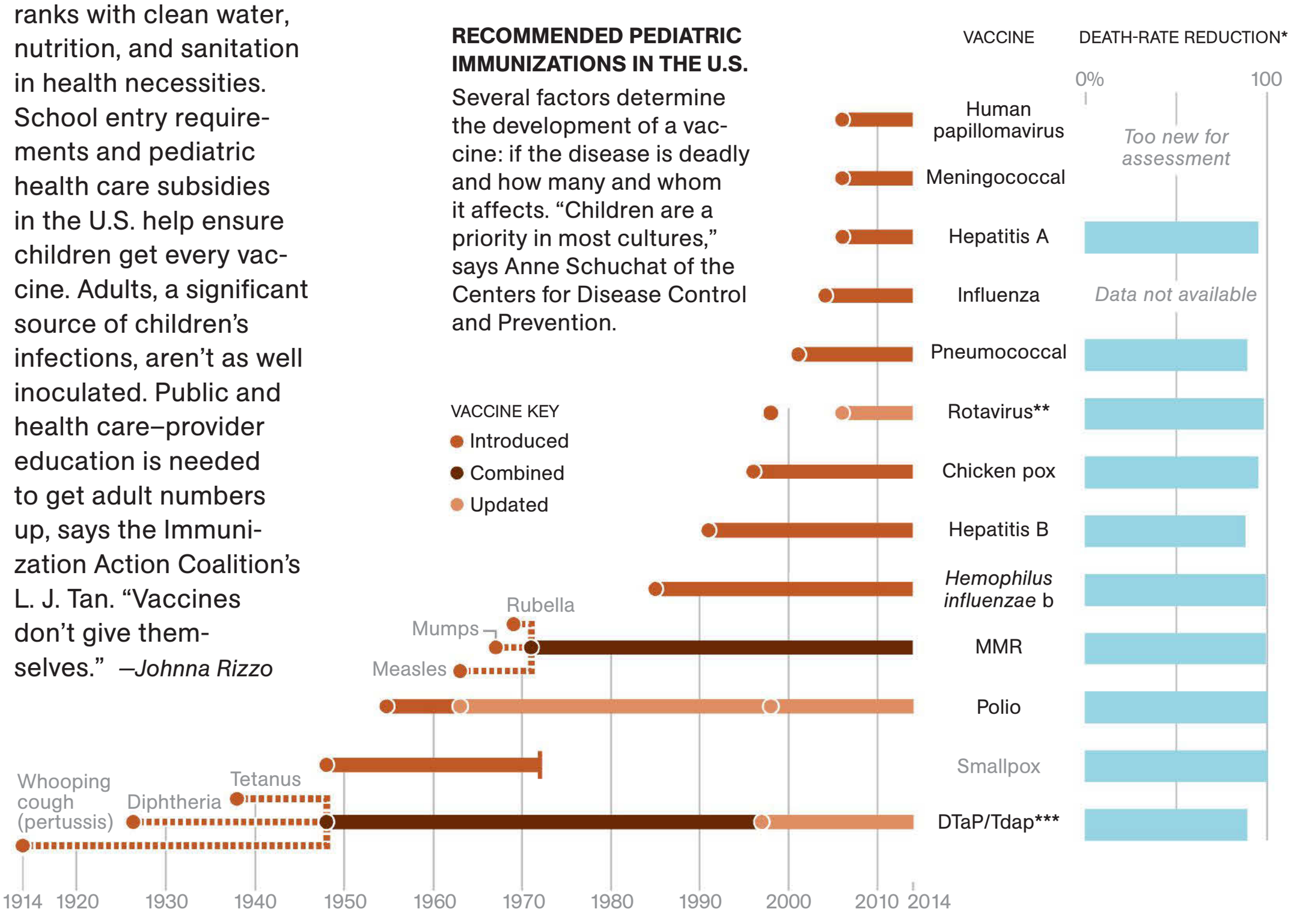
Since Edward Jenner dosed an eight-year-old boy with cowpox from a milkmaid's hand in 1796 to prevent him from catching smallpox, immunizations have had a substantial success record. They are credited with reducing diphtheria, measles, mumps, and rubella incidences in the U.S. by 99 percent. Later incarnations of smallpox vaccines eventually led to that disease's global eradication in 1979.

According to researchers, immunization ranks with clean water, nutrition, and sanitation in health necessities. School entry requirements and pediatric health care subsidies in the U.S. help ensure children get every vaccine. Adults, a significant source of children's infections, aren't as well inoculated. Public and health care–provider education is needed to get adult numbers up, says the Immunization Action Coalition's L. J. Tan. "Vaccines don't give themselves." —*Johnna Rizzo*

NEW YORK, 1920s

RECOMMENDED PEDIATRIC IMMUNIZATIONS IN THE U.S.

Several factors determine the development of a vaccine: if the disease is deadly and how many and whom it affects. "Children are a priority in most cultures," says Anne Schuchat of the Centers for Disease Control and Prevention.



*As of 2012; baseline years vary
**Hospitalizations
***Reduction shown as average of three diseases

GRAPHIC: LAWSON PARKER, NGM STAFF. SOURCE: CDC
PHOTO: METLIFE ARCHIVES. ART: MESA SCHUMACHER

Meet the Beauty in the Beast

Discover this spectacular 6½-carat green treasure from Mount St. Helens!

For almost a hundred years it lay dormant. Silently building strength. At 10,000 feet high, it was truly a sleeping giant. Until May 18, 1980, when the beast awoke with violent force and revealed its greatest secret. Mount St. Helens erupted, sending up a 80,000-foot column of ash and smoke. From that chaos, something beautiful emerged… our spectacular ***Helenite Necklace***.

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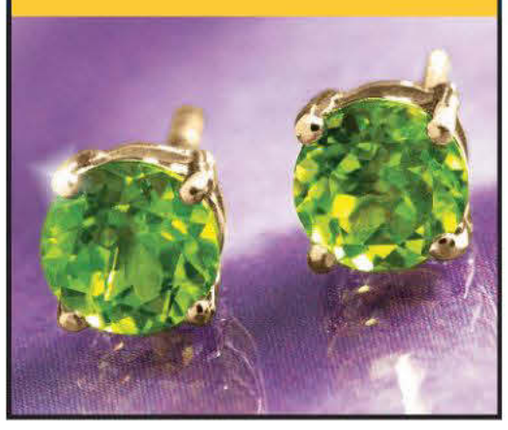

Helenite is produced from the heated volcanic rock of Mount St. Helens and the brilliant green creation has captured the eye of jewelry designers world-wide. Today you can wear this massive 6½-carat stunner for ***only $149***!

Make your emeralds jealous. Our ***Helenite Necklace*** puts the green stone center stage, with a faceted pear-cut set in .925 sterling silver finished in luxurious gold. The explosive origins of the stone are echoed in the flashes of light that radiate as the piece swings gracefully from its 18" luxurious gold-finished sterling silver chain. Today the volcano sits quiet, but this unique piece of American natural history continues to erupt with gorgeous green fire.

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Necklace enlarged to show luxurious color.

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- 18" gold-finished sterling silver chain

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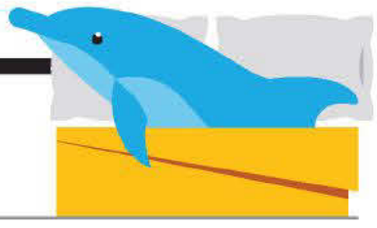

Spitting Image

Since at least the 17th century, art conservators have turned to products like glue, ashes, onions, and even beer to clean blemishes from works of art. Now they have gels and lasers. Yet one old-fashioned item is still in vogue: saliva.

Last summer a Massachusetts conservator used her own saliva to clean Padihershef, a 2,500-year-old Egyptian mummy. Enzymes in human spit dissolve and lift oils, including fingerprint grease. Saliva is more viscous than water, so it doesn't seep into paint cracks. "We tend to use saliva when there's grime, soot, or nicotine," says Andrea Chevalier, an Ohio conservator with the Intermuseum Conservation Association. The process is slow. A worker can spend up to five hours on a standard portrait, gently rolling moistened cotton swabs over dirty areas. It's helpful, Chevalier says, to have a glass of water by your side. *—Eve Conant*

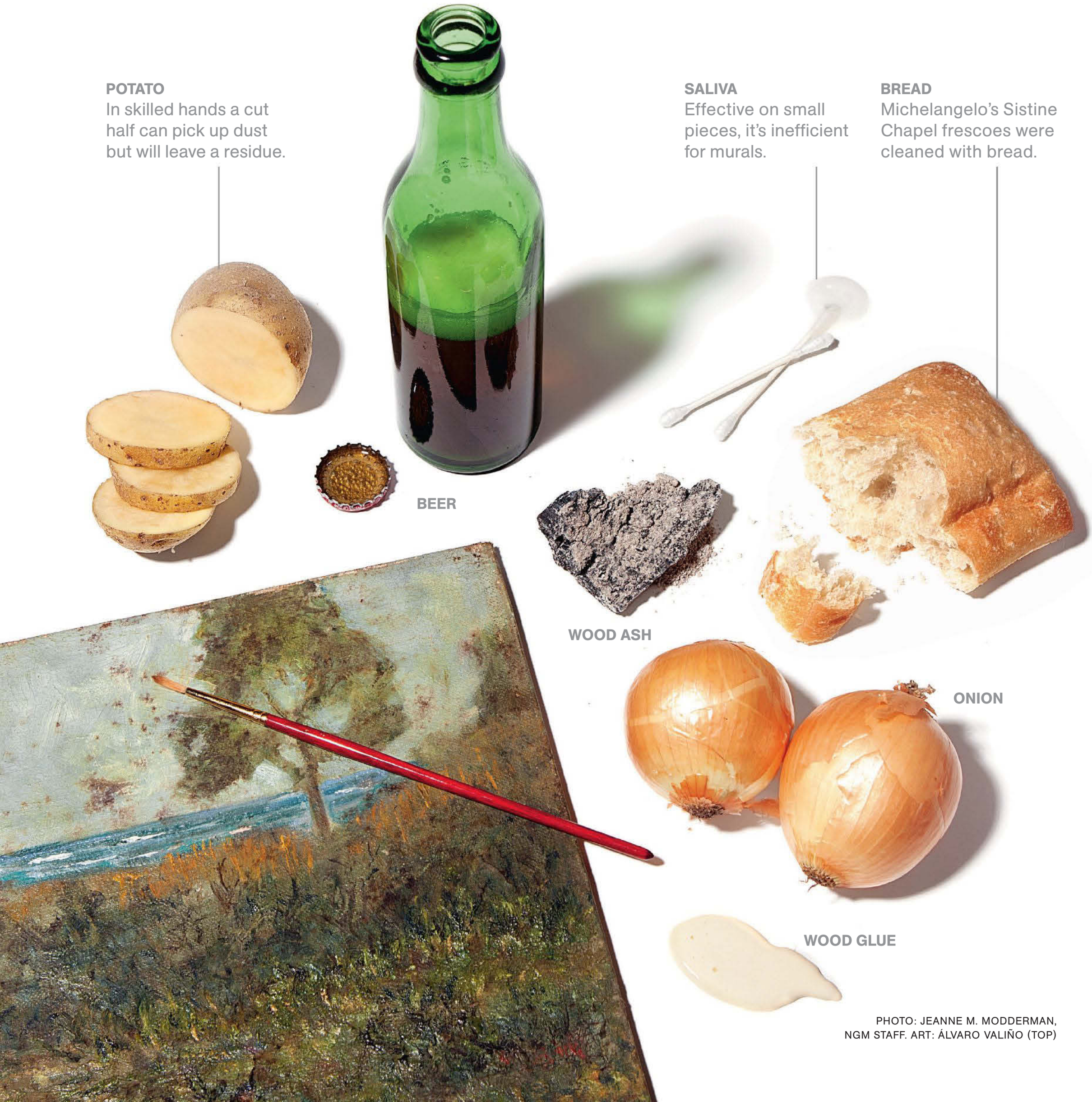

PHOTO: JEANNE M. MODDERMAN, NGM STAFF. ART: ÁLVARO VALIÑO (TOP)

For people with a higher risk of stroke due to Atrial Fibrillation (AFib) not caused by a heart valve problem

I was taking warfarin. But I wondered, could I shoot for something better?

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3. Unlike warfarin, there's no routine blood testing.

ELIQUIS and other blood thinners increase the risk of bleeding which can be serious, and rarely may lead to death.

Ask your doctor if ELIQUIS is right for you.

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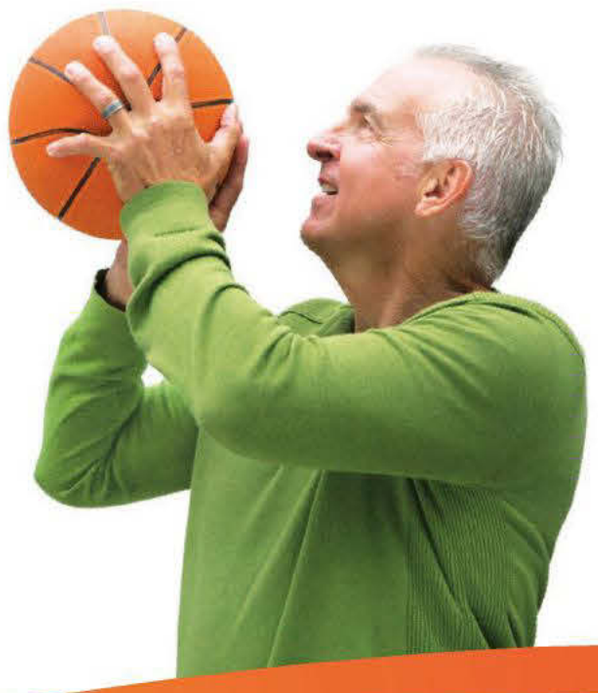
IMPORTANT SAFETY INFORMATION:

- **Do not stop taking ELIQUIS without talking to the doctor who prescribed it for you. Stopping ELIQUIS increases your risk of having a stroke.** ELIQUIS may need to be stopped, prior to surgery or a medical or dental procedure. Your doctor will tell you when you should stop taking ELIQUIS and when you may start taking it again. If you have to stop taking ELIQUIS, your doctor may prescribe another medicine to help prevent a blood clot from forming.
- **ELIQUIS can cause bleeding which can be serious,** and rarely may lead to death.
- **You may have a higher risk of bleeding if you take ELIQUIS and** take other medicines that increase your risk of bleeding, such as aspirin, NSAIDs, warfarin (COUMADIN®), heparin, SSRIs or SNRIs, and other blood thinners. **Tell your doctor about all medicines, vitamins and supplements you take.** While taking ELIQUIS, you may bruise more easily and it may take longer than usual for any bleeding to stop.
- Get medical help right away if you have any of these signs or symptoms of bleeding:
  - unexpected bleeding, or bleeding that lasts a long time, such as unusual bleeding from the gums; nosebleeds that happen often, or menstrual or vaginal bleeding that is heavier than normal
  - bleeding that is severe or you cannot control
  - red, pink, or brown urine; red or black stools (looks like tar)
  - coughing up or vomiting blood or vomit that looks like coffee grounds
  - unexpected pain, swelling, or joint pain; headaches, feeling dizzy or weak
- **ELIQUIS is not for patients with artificial heart valves.**
- **Before you take ELIQUIS,** tell your doctor if you have: kidney or liver problems, any other medical condition, or ever had bleeding problems. Tell your doctor if you are pregnant or breastfeeding, or plan to become pregnant or breastfeed.
- **Do not take ELIQUIS if you** currently have certain types of abnormal bleeding or have had a serious allergic reaction to ELIQUIS. A reaction to ELIQUIS can cause hives, rash, itching, and possibly trouble breathing. Get medical help right away if you have sudden chest pain or chest tightness, have sudden swelling of your face or tongue, have trouble breathing, wheezing, or feeling dizzy or faint.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch, or call 1-800-FDA-1088.

Please see additional Important Product Information on the adjacent page.

Individual results may vary.



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IMPORTANT FACTS

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The information below does not take the place of talking with your healthcare professional. Only your healthcare professional knows the specifics of your condition and how ELIQUIS® may fit into your overall therapy. Talk to your healthcare professional if you have any questions about ELIQUIS (pronounced ELL eh kwiss).

What is the most important information I should know about ELIQUIS (apixaban)?

Do not stop taking ELIQUIS without talking to the doctor who prescribed it for you. Stopping ELIQUIS increases your risk of having a stroke. ELIQUIS may need to be stopped, prior to surgery or a medical or dental procedure. Your doctor will tell you when you should stop taking ELIQUIS and when you may start taking it again. If you have to stop taking ELIQUIS, your doctor may prescribe another medicine to help prevent a blood clot from forming.

ELIQUIS can cause bleeding which can be serious, and rarely may lead to death. This is because ELIQUIS is a blood thinner medicine that reduces blood clotting.

You may have a higher risk of bleeding if you take ELIQUIS and take other medicines that increase your risk of bleeding, such as aspirin, nonsteroidal anti-inflammatory drugs (called NSAIDs), warfarin (COUMADIN®), heparin, selective serotonin reuptake inhibitors (SSRIs) or serotonin norepinephrine reuptake inhibitors (SNRIs), and other medicines to help prevent or treat blood clots.

Tell your doctor if you take any of these medicines. Ask your doctor or pharmacist if you are not sure if your medicine is one listed above.

While taking ELIQUIS:

- you may bruise more easily
- it may take longer than usual for any bleeding to stop

Call your doctor or get medical help right away if you have any of these signs or symptoms of bleeding when taking ELIQUIS:

- unexpected bleeding, or bleeding that lasts a long time, such as:
  - unusual bleeding from the gums
  - nosebleeds that happen often
  - menstrual bleeding or vaginal bleeding that is heavier than normal
- bleeding that is severe or you cannot control
- red, pink, or brown urine
- red or black stools (looks like tar)
- cough up blood or blood clots
- vomit blood or your vomit looks like coffee grounds
- unexpected pain, swelling, or joint pain
- headaches, feeling dizzy or weak

ELIQUIS (apixaban) is not for patients with artificial heart valves.

What is ELIQUIS?

ELIQUIS is a prescription medicine used to reduce the risk of stroke and blood clots in people who have atrial fibrillation.

It is not known if ELIQUIS is safe and effective in children.

Who should not take ELIQUIS?

Do not take ELIQUIS if you:

- currently have certain types of abnormal bleeding
- have had a serious allergic reaction to ELIQUIS. Ask your doctor if you are not sure

What should I tell my doctor before taking ELIQUIS?

Before you take ELIQUIS, tell your doctor if you:

- have kidney or liver problems
- have any other medical condition
- have ever had bleeding problems
- are pregnant or plan to become pregnant. It is not known if ELIQUIS will harm your unborn baby
- are breastfeeding or plan to breastfeed. It is not known if ELIQUIS passes into your breast milk. You and your doctor should decide if you will take ELIQUIS or breastfeed. You should not do both

Tell all of your doctors and dentists that you are taking ELIQUIS. They should talk to the doctor who prescribed ELIQUIS for you, before you have **any** surgery, medical or dental procedure.

Tell your doctor about all the medicines you take, including prescription and over-the-counter medicines, vitamins, and herbal supplements. Some of your other medicines may affect the way ELIQUIS works. Certain medicines may increase your risk of bleeding or stroke when taken with ELIQUIS.

How should I take ELIQUIS (apixaban)?

Take ELIQUIS exactly as prescribed by your doctor. Take ELIQUIS twice every day with or without food, and do not change your dose or stop taking it unless your doctor tells you to. If you miss a dose of ELIQUIS, take it as soon as you remember, and do not take more than one dose at the same time. **Do not run out of ELIQUIS. Refill your prescription before you run out. Stopping ELIQUIS may increase your risk of having a stroke.**

What are the possible side effects of ELIQUIS?

- See **"What is the most important information I should know about ELIQUIS?"**
- ELIQUIS can cause a skin rash or severe allergic reaction. Call your doctor or get medical help right away if you have any of the following symptoms:
  - chest pain or tightness
  - swelling of your face or tongue
  - trouble breathing or wheezing
  - feeling dizzy or faint

Tell your doctor if you have any side effect that bothers you or that does not go away.

These are not all of the possible side effects of ELIQUIS. For more information, ask your doctor or pharmacist.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.

This is a brief summary of the most important information about ELIQUIS. For more information, talk with your doctor or pharmacist, call 1-855-ELIQUIS (1-855-354-7847), or go to www.ELIQUIS.com.

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Now, to honor over four decades of Chinese giant pandas at the National Zoo, the China Mint and the Smithsonian Institution are releasing a first-ever special issue Panda Silver Proof exclusively through GovMint.com. Struck in one full ounce of 99.9% pure proof silver—the finest silver available—each Smithsonian Panda Silver Proof features the National Zoo's current panda pair: Mei Xiang and Tian Tian. The obverse of this massive 40mm silver proof depicts the Great Wall of China alongside the iconic Smithsonian Castle on the National Mall in Washington, D.C. It's a **world's first**!

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This summer, Mei Xiang gave birth to a new giant panda cub. Mama and baby have already captivated millions through the National Zoo giant panda webcam online. Mei Xiang and Tian Tian, the cub's father, are depicted on the Smithsonian Panda Silver Proof at rest within their National Zoo habitat.

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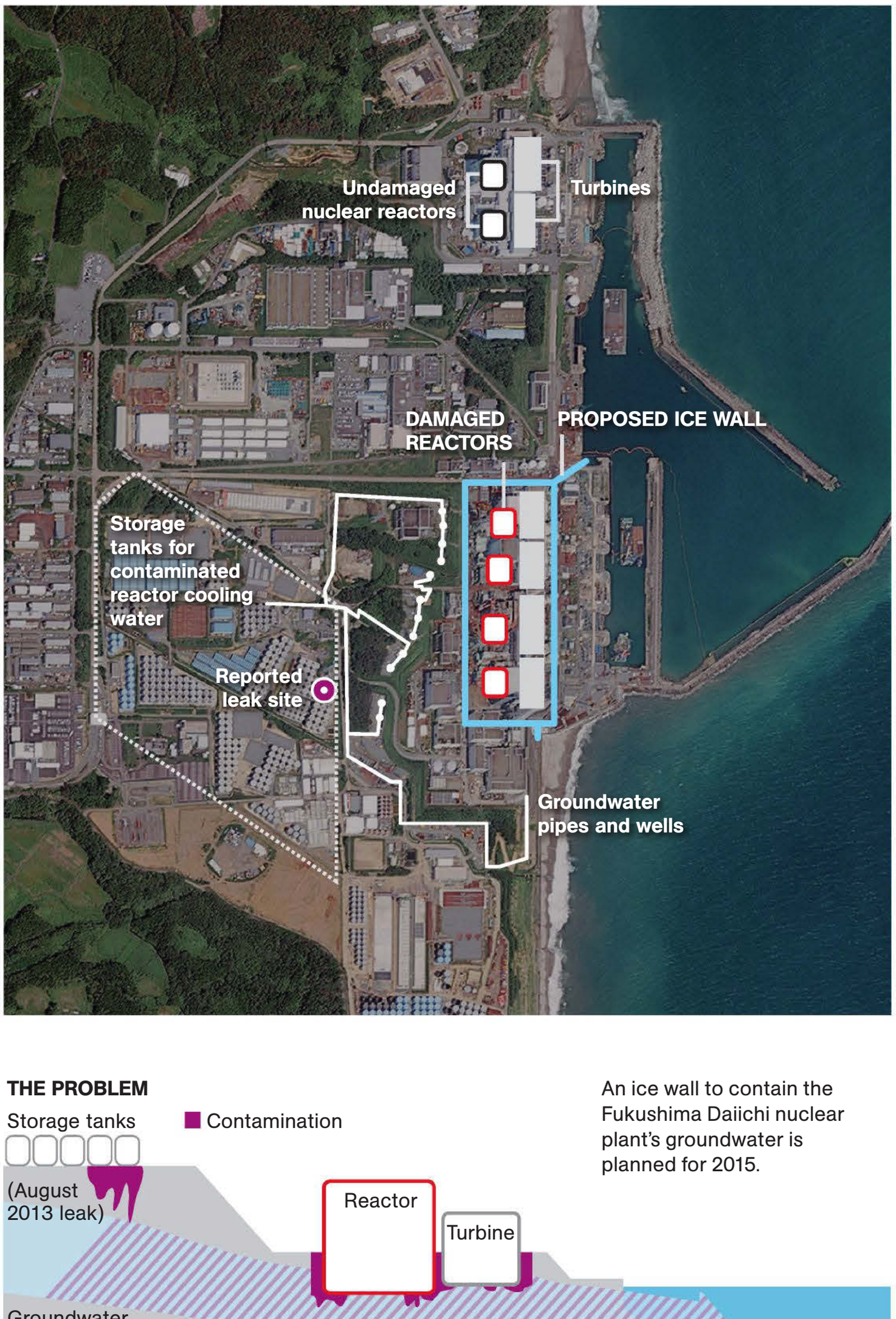
A New Nuclear Freeze

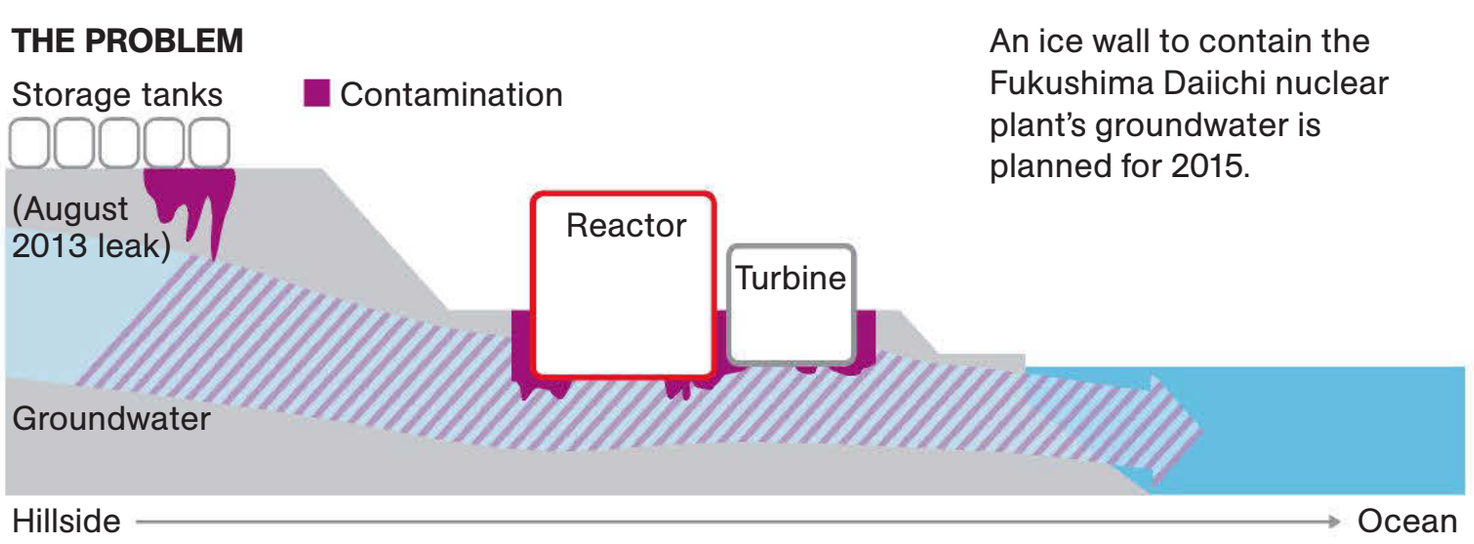
On August 19, 2013, a huge leak of contaminated water—about 80,000 gallons—was discovered at Japan's earthquake-ravaged Fukushima Daiichi power plant. Groundwater seeps continue. Now an underground ice wall is being proposed to contain them.

It will work like this: Coolant is pumped at -20ºF to -40ºF through pipes reaching a hundred feet deep to freeze any water in the soil. The pipes also make the soil's air pockets so cold that any future liquid trying to pass will freeze too.

The ice wall would help keep clean groundwater from coming into the plant and water carrying radioactive particles from getting to the ocean. Water moves through soil about four inches a day, says engineer Ed Yarmak, who designed an ice wall for a facility in Tennessee. It's not perfect, he adds, "but it's the barrier with the best chance of working." *—Johnna Rizzo*

PHOTO: DIGITALGLOBE/SCAPEWARE3D/ GETTY IMAGES. GRAPHIC: LAWSON PARKER, NGM STAFF. SOURCE: TEPCO



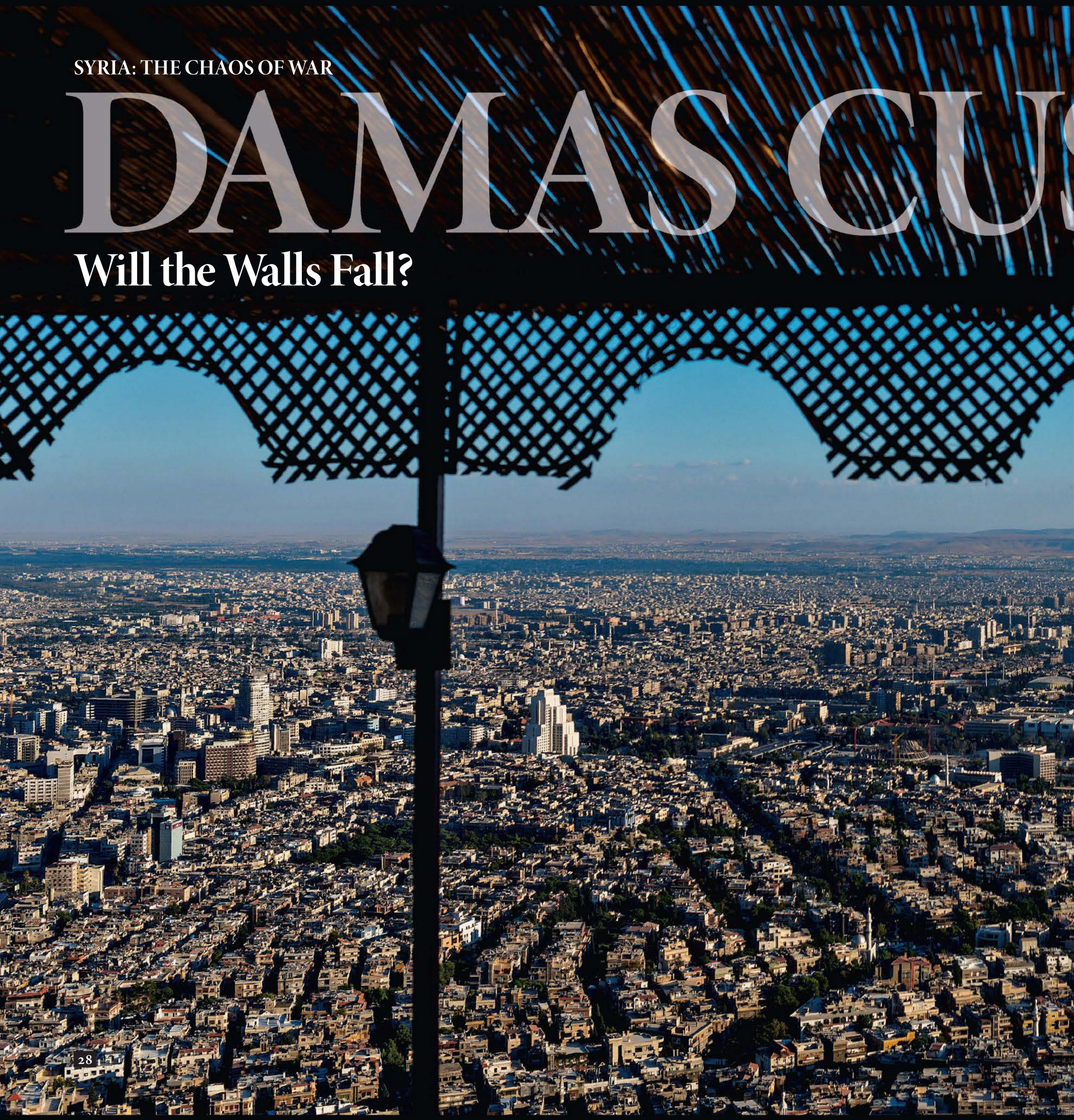


An ice wall to contain the Fukushima Daiichi nuclear plant's groundwater is planned for 2015.

SYRIA: THE CHAOS OF WAR

DAMASCUS

Will the Walls Fall?



Protests against the Syrian government three years ago sparked a continuing battle for control of the country. Here in the capital the army shells rebel-held neighborhoods from the mountain where this photo was taken. With the conflict cracking around them, city residents wait for peace and hope their distinctive culture survives.

On the front line of the conflict a Syrian security forces officer patrols the shattered suburb of Tadamun. Sometimes he hears rebels shouting from their positions, just blocks away. Fearing for the safety of his family, he asks not to be identified by name—just an alias, Abu Aksam.

By Anne Barnard

Photographs by Andrea Bruce

In the rectangular courtyard of the Umayyad Mosque, the heart of Old Damascus, women swathed in black sit and chat on the cream-colored stone floor, polished smooth by the comings and goings of generations. The sky overhead is an identical rectangle of blue. Children chase one another into shady corners, as pigeons swoop in and out, drawn, the women in black like to say, to the holiness of the place.

Within the mosque's sturdy Roman walls, this quintessentially Damascene mix of ancient grandeur, restfulness, and quotidian bustle continues undisturbed for now, despite the rumbles of shelling in the distance—dispatches from the civil war that is ravaging the city's ramshackle outskirts. But step out through the mosque's towering gate, and it becomes clear that the Old City of Damascus, though mostly undamaged physically, has changed.

Beneath the remnants of a Roman colonnade, Mohammad Ali, 54, wielding a hefty Polaroid he has been carefully keeping going for a quarter century, shoots a photo of a grim-faced family taking a breather from war-torn Aleppo. His usual clients—tourists, foreign students, and well-dressed families out for a stroll—are long gone. Today many of the families browsing the bright blue Iranian pottery and bouquets of colorful shawls are Syrians forced from homes in outlying neighborhoods that have become battlefields. They live crammed into rented rooms, shop fronts, and offices in the capital's shrinking zone of safety. In the city center, men with guns patrol the streets; they belong to the growing neighborhood militias that some residents trust and others fear. Bracing for the unknown, fearing the worst, sinking into economic hardship, the Old City hunkers behind ancient walls that are reclaiming, metaphorically for now, their original role as fortifications. Beyond the walls military checkpoints create another barrier, keeping rebels out of government-held central Damascus.

Along French colonial boulevards, in busy vegetable markets, in largely empty nightclubs, there is a sense of waiting within a bubble of provisional safety. Mortar shells land with increasing regularity in downtown Damascus, attacks that the government blames on rebels. (Most of the shelling heard in the city is outgoing—the odd spectacle of the government wrecking the suburbs of its own capital, many of which have remained in rebel hands for more than a year.) Mount Qasiyun, the city's twinkling nighttime backdrop, was a breezy aerie where couples went to feast on fruit platters at cafés overlooking Damascus. Now it is a citadel from which government troops fire barrages of shells.

Much has already been lost. But the singular culture of Damascus, viewed for centuries in the Arab world as a beacon of refinement and

NGM MAPS

Grief floods the faces of mourners at the funeral of a relative. According to his family, 29-year-old Elias Francis was driving to a job interview in Jordan when he was kidnapped—a constant hazard in Damascus these days. His body, bearing signs of torture, was later found and sent home.

civilization, offers one of the few hopes for saving Syria. Given the country's arbitrary colonial borders and contentious modern history, Damascus, for many Syrians, comes as close as anything to embodying a shared national idea. For centuries Sunnis, Shiites, Christians, and Jews have traded, worked, and lived together here, not without conflict but with a common relish for city life and business. (Only a few Jews remain; most left after the founding of Israel, when the government began viewing them with suspicion.) Later, after 1970, waves of Alawis, a long-oppressed group from the coastal mountains, came to Damascus, drawn to new opportunities under the rule of President Bashar al Assad's family, which hails from their sect, an offshoot of Shiite Islam.

Those who live in Damascus and love it best stand united in their desire to preserve it. Even as a once peaceful popular movement for political rights, dignity, and justice takes on an uglier sectarian tone—deepening fears of another Sarajevo, another Baghdad—people here say they cannot imagine attacking one another. Yet Damascenes are divided on who most threatens their world. Just beneath a carapace of fear—of the rebels, of the government, of foreign intervention, of general chaos—bubble political views so divergent that it can be hard to picture how the gap might be bridged. (Small wonder that few in the city are willing to have their full names printed.)

"Every stone is a heritage—every sculpture, every roof, every fountain," says Ghazi H., a secular Christian in his 30s who has spent much of his life in the Old City. His schoolmates of all religions used the Umayyad Mosque courtyard as a study hall. As a teenager, he explored a Muslim quarter newly opening to the outside world: Cafés proliferated, boys and girls walked together without incident—although older people looked askance at them. As an adult, he salved boredom by hunting for "hidden treasures"—a courtyard in a boarded-up mansion, a small carving on an old house. But how people define the Old City's heritage depends on their political outlook, and it is darker and more complex than most acknowledge, Ghazi says. "Everyone uses history to make their own points."

Anne Barnard is the Beirut bureau chief for the New York Times. *Photographer Andrea Bruce has worked extensively in the Middle East.*

The Old City's twisting alleys, where houses lean into one another and vines dangle across narrow streets, developed that way in part so that neighboring but segregated ethnic enclaves could protect their territories. "It symbolizes how these divided groups can live together even though they don't like each other," says Ghazi. Passing through a Shiite quarter, he notices posters on the walls commemorating fallen fighters for Assad, and he knows that some passing Sunnis from a neighboring quarter may be quietly cheering the deaths. Yet the two groups still greet each other and visit each other's shops. "That's what the Old City symbolizes," Ghazi says, sitting in the courtyard of his now deserted hotel. "And if you go back in history, it has always been symbolizing this same thing. It was Christian, and when the Muslims came, they converted many churches to mosques"—the Umayyad Mosque, where a church once stood, still houses a shrine to John the Baptist—"and life has continued."

The Old City "symbolizes how these divided groups can live together even though they don't like each other."
—Ghazi H., a secular Christian in his 30s

In quieter times Assad embraced a version of the Damascene identity. He attended interfaith musical performances and took (disputed) credit for the refurbishing of the Old City, as entrepreneurs opened cafés and boutique hotels, like Ghazi's, in traditional houses. This urban renaissance ushered in another phase of change: Large Muslim families cashed in on their increasingly valuable properties and built larger homes in suburbs now torn by war. Assad cultivated an image as an everyman by walking Old City streets en route to favorite nightspots like the Piano Bar. Supporters of the government here see him as the guardian of the city's multiculturalism, fighting a foreign-inspired, extremist uprising bent on driving out minorities and imposing religious rule. Supporters of the rebels reject this as hateful nonsense, viewing the fighters—mostly poor Sunnis from the provinces—as ordinary Syrians who are themselves inextricably part of the cultural mosaic. Damascenes who oppose Assad say he has stoked sectarianism and, to stay in power, would be willing to lay waste to the city.

That is what happened in the northern city of Aleppo after the summer of 2012, when rebels entered its Old City and the government did not hesitate to shell it. Aleppo's Umayyad Mosque was heavily damaged, along with crusader castles, Roman ruins, mosques, and churches across the country. "If they try to enter, I will be the first person to confront them," says a Damascus shopkeeper who opposes Assad, fearing the destruction of the graceful Qasr al Azm, an Ottoman palace; the domed Khan Asad Pasha, where merchants used to unload their caravans; the Chapel of Ananias, the reputed site of the baptism of the Apostle Paul. "There is no military objective here. Freedom is needed, but not in this way."

Yet even here violence has come to seem a necessary evil. In a shabby living room in a sagging house overlooking Street Called Straight—where the Bible says God sent Paul after striking him blind on the road to Damascus—Leena Siriani serves coffee in the brown-striped cups she has used since her marriage in 1975. She fled her home in the rebel-held city of Homs because of the fighting and shelling. Yet as she listens to the whistling of shells and the thud of their impact, she cheers them on. "May God give you power," she says, as if to the soldiers firing them. "I hope they are hitting the terrorists and the saboteurs."

Down a nearby alley, where shoppers peer at gold bracelets, olive soap, and mounds of cumin, a wiry spiceseller in his mid-30s whispers a different story. He comes from one of those bombarded suburbs, and most of the people he knows there have taken up arms. "All day long you hear shells coming out from here and landing there,"

he says with vehemence. "Then they tell you that the threat comes from *there,*" he says, pointing to the suburbs. "How? Should I be afraid of my own family?" He explains that he fled to protect his daughters, leaving behind a decent job selling cars. Now he earns just seven dollars a month. He feels guilty living behind government lines, he says, not like "a real man." Casting his eyes furtively about, he mutters, "I will join the people there sooner or later."

JUST OFF STRAIGHT STREET, in his 400-year-old mansion encrusted with relief paintings of flowers and lined with photographs of his ancestors, Samir Naasan, 65, keeps a Kalashnikov that he vows to use if rebels come. He has taken down the crystal chandeliers, because of the explosions. He shuffles around in a Puma sweat suit and sneakers, a tuft of his hair jutting off at an angle. From an old leather trunk he pulls snapshots of heads of state, including a sitting President Richard Nixon, visiting his house. Digging deeper, he finds photos of the craft workshops that made his family rich a century ago, where Jews hammered brass, Christians tooled wood for mosaics, and Muslims wove brocade.

To him, his family—which also owns the Piano Bar, President Assad's hangout, across the street—embodies Damascene cosmopolitanism. That makes his prescription for the crisis all the more jarring. "If I were Bashar al Assad," he says, "in 20 days I would finish it, even if I have to kill five million Syrians." As for the Syrian masses, he adds, "better they should die than live poor."

Then he heads out for drinks and meze at Qasr al Kheir, a restaurant in a courtyard with patterned tiles, mosaics, and a stone fountain. Its name means "palace of goodness," and over the speakers Edith Piaf is singing "La Vie en Rose." The place is empty except for an engagement party. As the music shifts to thumping Arabic wedding tunes, Christian women in short skirts hold hands with Muslim women in head scarves and men twirling prayer beads, all dancing a traditional line dance, the *dabke*. The next song praises President Assad and the army. The dancers whoop and stomp.

This is the bargain that Damascus and Syria made: live under an iron fist in exchange for a social safety net and a space for religious and cultural, if not political, pluralism. Then Syrians took peacefully to the streets in early 2011, claiming that a family mafia oppressed not only the Sunni majority but all citizens. The government responded with overwhelming force, and its opponents turned to arms.

Now Assad's long-standing claim—after me, Islamic extremists—has proved true in many parts of the country. How and why will be long debated. But as both sides grow exhausted, forced to face the real prospect of demolishing all they are fighting for, perhaps resolution lies somewhere in the Damascene model of coexistence. Or simply in shared love for the millennia-old city that no one wants to see die.

For now, Damascus focuses on survival. Merchants, unable to flee because their cash is tied up in inventory, tenderly fold and unfold brocade shawls that were made in now destroyed suburban workshops. For Ghazi H., comfort is found in Abu George's cubbyhole bar. Even when shelling prompts other places on Straight Street to close early, the bar glows like a fire on a cold night. The patrons, nowadays mostly neighborhood Christians, wax nostalgic for the Muslims from the suburbs who would drop in to drink out of sight of judging neighbors. They rarely come now—they would have to cross the front lines.

For Ghazi, what is slipping away is the Old City's special flavor. "This period, it made me lose the feeling for things," he says. "Now I walk—I don't look. It took the spirit from the Old City. You think, Which is more important, the people or the rocks? Losing someone close to you, or losing the minaret of the Umayyad Mosque? For sure, the people are more important."

Sometimes he wonders if people like him will be driven out, or he even catches himself thinking a decisive battle would be worth it if it ended this period of uncertainty.

And if either of those things happens, will the ancient city of Damascus be destroyed forever? He says no. "It will change," he says. "Like it has changed in the past." □

A traditional café serves as a refuge from the current turmoil. Beneath a portrait of President Bashar al Assad, men

while away an afternoon playing backgammon and puffing at water pipes filled with flavored tobacco.

Patriotism and support for the president's regime are instilled at an early age. At a government-run elementary school, students salute, sing, and march in place as the national anthem plays over a loudspeaker. Many children now living in Damascus come from elsewhere and were displaced by the war. In the heart of the Old City (below) boys idly chase the pigeons that flock to the square outside the Umayyad Mosque.

A summer swimming class at the Sheraton hotel preserves a slice of the good life for the children of businessmen, politicians, and others in elite professions. But the rest of the city lives on edge, with little relief from the relentless conflict and its deadly consequences. After traveling down ancient Straight Street (below), the funeral procession for Elias Francis nears its destination, the Greek Catholic al Zaitoun church.

The families of these Palestinian cousins came to Syria after fleeing the ongoing conflict in their own homeland.

Now they share half a room in this unfinished office building, where they moved when their suburban homes were bombed.

SYRIA: THE CHAOS OF WAR

Journey Without End

Photographs by Lynsey Addario

By the end of 2013, Syria's bloody and complex civil war had displaced some nine million men, women, and children (map, right). Although most of them have relocated to less troubled parts of the country, roughly one in four has fled altogether, desperate to escape the violence and chaos and the mounting shortages of food, medicine, and other necessities. This relentless exodus has created a humanitarian crisis for neighboring countries and is spilling into Europe and beyond. And as the conflict enters its third year, there is no sign of resolution in sight.

Photographer Lynsey Addario has documented the struggles of the displaced in Syria as well as in the four nations that have seen the greatest influx. The man pictured above is one of the millions, shown after he crossed into northern Iraq last August. Waiting for his brother, he sits with the belongings he could carry, surrounded by the trash of those who came before him. According to the Office of the UN High Commissioner for Refugees, 3,000 to 6,000 people leave Syria every day. But borders are tightening, and it is getting harder and harder to find a safe place to land. *—Carolyn Butler*

MAP: JEROME N. COOKSON AND ALEXANDER STEGMAIER, NGM STAFF; MORGAN P. JAROCKI
SOURCES: HUMANITARIAN INFORMATION UNIT, U.S. DEPARTMENT OF STATE; UN OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS; UNHCR

DISPLACED BY WAR

Syrians are seeking safer ground within their country and outside its borders: Approximately 6.5 million residents are "internally displaced persons," and over two million have become refugees. Some return home briefly to check on property or relatives. Others move back after finding life in a camp or host community more difficult than expected. Nonetheless, refugee numbers are soaring.

Black Sea

0 mi 100
0 km 100

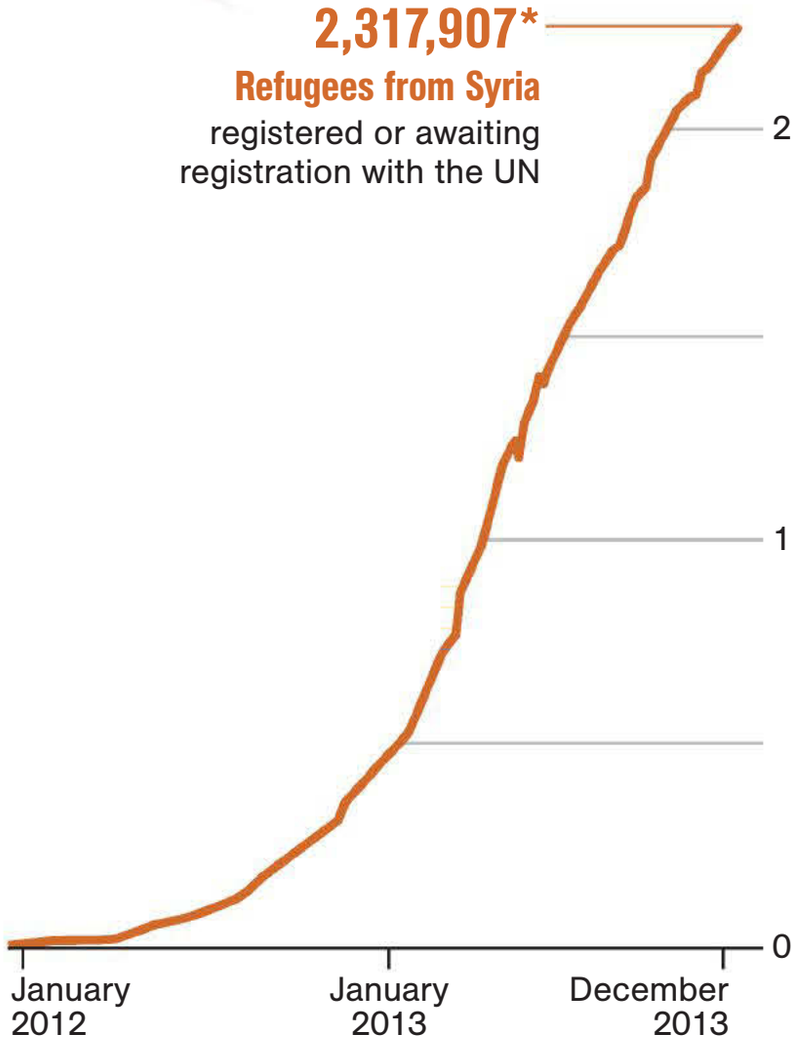
TURKEY
553,281
Refugees

Gaziantep
Adana
Ceylanpınar
Al Qamishli
Ras al Ayn
Aleppo
Ar Raqqah
Mosul
Erbil
Kawergosk
NORTHERN CYPRUS
Latakia
Nicosia
CYPRUS
SYRIA
6,500,000
Internally displaced persons (IDPs)
Dayr az Zawr
Hamah
Homs
LEBANON
842,482**
Euphrates
Tigris
Beirut
Saadnayel
Damascus
Boundary claimed by Syria
S Y R I A N
IRAQ
207,053
Baghdad
Mediterranean Sea
Irbid
D E S E R T
WEST BANK
Zaatri
Amman
Jerusalem
GAZA STRIP
ISRAEL
JORDAN
567,111
EGYPT
130,841
Red Sea

Syrian internally displaced persons (IDP) camp
Other Syrian IDP location
Syrian refugee camp or transitional site
Syrian refugee camp or transitional site under construction
Area of conflict and displacement
Area with refugees

Camp status and refugee and IDP figures as of December 16, 2013
*Includes 17,139 refugees in North Africa
**There are no formal Syrian refugee camps in Lebanon.

2,317,907*
Refugees from Syria
registered or awaiting registration with the UN



TURKEY After bombs from a government air strike rained down, families fled their town of Ras al Ayn, Syria, where the Free Syrian Army had been fighting these government forces as well as Syrian Kurds. The villagers crossed into Ceylanpınar, Turkey, many with nothing but the clothes on their backs. The country currently shelters more than half a million registered Syrian refugees; roughly a third live in 21 camps. Turkey says it has spent two billion dollars to assist Syrian refugees and estimates that more than 150,000 in the country haven't been officially accounted for.


UNHCR
The UN Refugee Agency

TURKEY Workers load precious bags of flour provided by the Turkish Red Crescent onto a truck bound for Syria (above). There was an international outpouring of some $850 million in humanitarian aid for Syria last year and another $2 billion to assist refugees and host countries with emergency food, medicine, schooling, and more. Yet the relief effort is sorely underfunded. Aid officials worry that a lack of basic health, educational, psychological, and other services will have devastating implications for Syria as well as the larger Middle East. **IRAQ** At daybreak a family of Syrian Kurds sleep in the open air to escape the stifling heat of tents at the Kawergosk camp outside Erbil, in northern Iraq (bottom left). These refugees were part of a wave of 60,000 who arrived in August during a month-long opening of two crossings. Because of security concerns, the borders are now tightly regulated again. **LEBANON** At age 15, Raeda lost sight in one eye after being hit by shrapnel during an explosion near her family's home in Aleppo, Syria. Today she helps her parents by caring for her brother Khaled, in a tent they rent on farmland near Saadnayel, Lebanon; 11 relatives live in the improvised quarters. Aid workers worry about the "lost generation" of Syrian children who've been displaced or forced to flee the country. Many have witnessed or suffered unspeakable horrors. They have limited or no access to education and could be forced into child labor as well as early marriage and other forms of sexual exploitation.

JORDAN Syrian men and boys queue up to collect their daily bread—four pitas a person—at the Zaatri refugee camp, which opened in July 2012. The UN World Food Programme hands out 25 tons of bread every morning in the span of two hours. The largest Syrian refugee camp in the Middle East, Zaatri is home to more than 100,000. The site has trailers, tents, schools, hospitals, and a maternity clinic as well as myriad businesses started by residents, selling everything from haircuts to coffee. Yet many refugees face sanitation and electricity issues and must deal with gangs and a thriving black market.

LEBANON Refugee women in Saadnayel prepare a funeral meal in honor of their relative, a Free Syrian Army fighter killed in Aleppo, Syria. The number of refugees grew from 100,000 to 800,000 in this tiny country in a year's time. The government has not set up formal camps. Refugees often mix with locals, staying in rented homes or with families. But a third live in garages, building shells, and other vulnerable accommodations. "There are thousands of examples of generosity shown by the Lebanese people to Syrian refugees of a kind I've never before witnessed," says Ninette Kelley, a UN representative. "But as more refugees come in, tension has risen."

It is jade country. It is home to four national parks, which contain the highest mountains, longest glaciers, and tallest forests in New Zealand. It is Te Wahipounamu—the place of greenstone.

Beech boughs and a broadleaf sapling overhang Lake Ada on Milford Track, a popular hiking trail.

Where greenstone grows

Glacier-scoured lowlands north of Jackson Bay are a legacy of the Pleistocene epoch and its ice sheets. Here the Waiatoto River breaks through a gravel bulwark to meet the Tasman Sea.

By Kennedy Warne
Photographs by Michael Melford

Jeff Mahuika bends down suddenly. Among the thousands of river pebbles at our feet, he has seen something my eyes have missed. His fingers grasp the edge of a stone and pry it gently from the gravel that all but hides it from view. It is a finger-long sliver of pounamu—greenstone, or jade—and as he holds it to the light, it gleams a cool gray green.

He passes it to me, and I stroke its river-smoothed skin. "Our people have a tradition that you don't keep the first piece you find," he says. "So I'm giving it to you." A thought comes to me. Mahuika is a master carver of greenstone. I hand the stone back to him and say, "If you drill a hole in it, I will wear this pounamu around my neck, to bind me to this place."

Te Wahipounamu, the place of jade. Since 1990 this southwestern edge of New Zealand has enjoyed World Heritage recognition for its four national parks and interconnecting tracts of conservation land. Of all the wilderness areas in my country, this is the one I return to most often, to breathe its mountain air, wade its rivers, hike its forests, and absorb its presence.

The carver and I are walking in the Cascade Valley, an hour beyond the end of the coast road, where it terminates south of Haast. Over our shoulders the Red Hills Range glows dark crimson in the afternoon sun. The pounamu in the rivers comes from those hills. The same tectonic forces that built the mountains made the stone.

We pace the riverbanks, heads down like wading birds, looking but not looking, because Maori believe pounamu is not found, it reveals itself. Revelation, however, is complicated by the fact that there are many green stones that are not greenstone, or nephrite, as geologists call it. I discover I am an expert in locating these look-alikes—the fool's gold of the jade enterprise.

Time and again I stoop to pick up a pretty sage green pebble.

"How about this one, Jeff? Nephrite?"

"Nope, leaverite," he says, as in, "Leave 'er right there."

When Maori were lords of this land, no resource was held in higher esteem than pounamu. In part the stone's stature arose from the uncountable hours needed to shape it into tools or ornaments, for pounamu is harder than steel. Working the stone over weeks or months imbued it with the life of its owner. In one tradition, when Maori died, their prized pieces of pounamu were buried with them, to be dug up later and passed on to a descendant. In this way pounamu transcended time, binding generations in a sacred embrace.

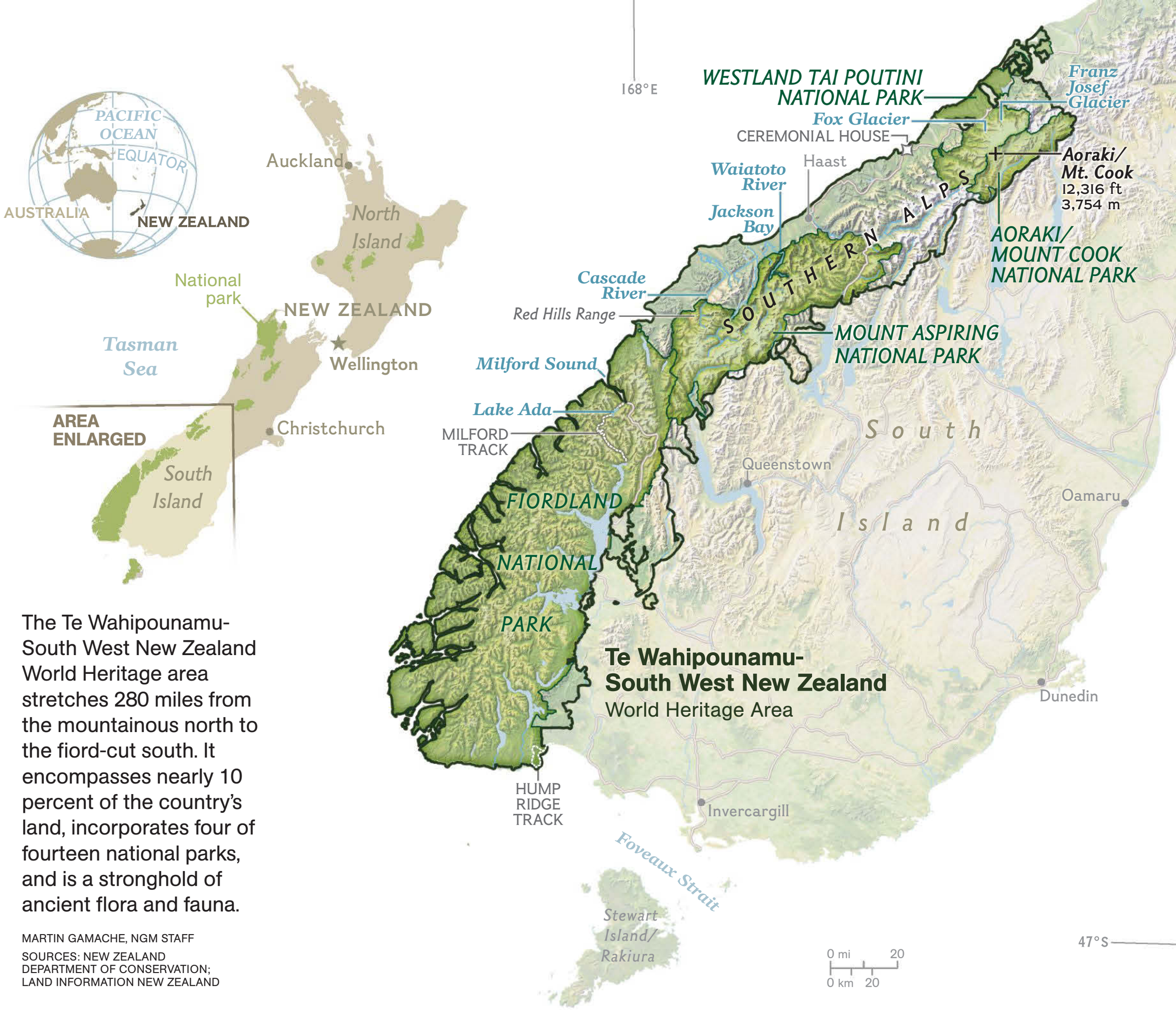
To handle such treasures today—in the form of chisels, ear pendants, fighting clubs—is to sense a link not just with the maker and owner but also with the physical ancestry of the stone. In the Maori world, objects speak to their origins: whalebone to the whale, wood to the tree, pounamu to its source river and mountain.

Water and ice scour the stone from its host rock; rivers carry it down to the sea. "The stone is always moving," says Mahuika. "In our stories we call it a fish. It's on a journey, just like we are."

We cross the Cascade River waist-deep, holding our arms out like wings, balancing against the current's muscular pull. It is spring, when the fry of native fish surge into Te Wahipounamu's rivers from the sea, heading upstream to grow to maturity in cool forest reaches. Catching these whitebait is a west coast religion. From dawn till dusk, coasters wade the river mouths with long scoop nets, sieving for 'bait. Later, in a tiny riverbank hut, or over a driftwood fire, butter will be melted in a frying pan and a mixture of egg and whitebait tipped in. Whitebait patties, food of the gods.

Maori call the commonest type of whitebait

This beachcombed jade, above, about 11 pounds, was photographed on a bed of river stones.



The Te Wahipounamu-South West New Zealand World Heritage area stretches 280 miles from the mountainous north to the fiord-cut south. It encompasses nearly 10 percent of the country's land, incorporates four of fourteen national parks, and is a stronghold of ancient flora and fauna.

MARTIN GAMACHE, NGM STAFF

SOURCES: NEW ZEALAND DEPARTMENT OF CONSERVATION; LAND INFORMATION NEW ZEALAND

inanga, and they use the same word for pounamu of a matching pearly gray, sometimes flecked with eyes, as if whitebait swam within the stone. In a world defined by mutual relationships, the Maori name for one thing often recalls another. Their name for the Southern Alps—the tumult of peaks that runs like a jagged spine through Te Wahipounamu—is also used for the wave-swept ocean.

The alps make this place what it is. Standing athwart the westerly gales of the latitude known as the roaring forties, they force moisture out of the clouds and drench the coast with rainfall. It is so wet here that in the less traveled south, moss grows on the asphalt of the roads.

During the last ice age alpine glaciers tattooed this region with lakes and chasms, and chiseled the fiords that give the southern swath of Te Wahipounamu its name, Fiordland. More than 3,000 glaciers remain in the World Heritage area. Two of the most famous—Fox and Franz Josef—plunge almost to sea level, where their snouts nuzzle the coastal rain forest.

These forests are a time capsule of Gondwana, the supercontinent that fragmented into the landmasses of today's Southern Hemisphere. When New Zealand split off from what is now Australia to begin its own journey into the Pacific, it created an ecological separation that endured 80 million years. That long solitude has made New Zealand a showcase of Gondwanan flora and fauna. South West New Zealand is its best window on that ancient world.

Maori maintain a presence here, though their numbers are thin. A symbolic moment came in 2005, when Mahuika's people opened a carved meetinghouse, their first ceremonial house in 140 years. It was a statement of survival and of hope but also an acknowledgment of human impermanence, a truth expressed in a Maori proverb: People come and go, but the land endures. ☐

Kennedy Warne dived into the seas of Arabia in our March 2012 issue. Michael Melford photographed America's historic Brandywine Valley in April 2013.

Ice Age remnants of crystalline rock dot the coast north of Haast. Te Wahipounamu is a window on Gondwana—the supercontinent that fractured into today's Southern Hemisphere landmasses. Stands of rimu trees, a type of conifer found only in New Zealand, are a Gondwanan signature.

New Zealand's alpine parrot, a feisty, inquisitive bird known by its Maori name, *kea,* has joined New Zealand's long list of species threatened by introduced predators. Glaciers face a threat of a different ilk: warming climate. The two most visited—Franz Josef and Fox (pictured)—are in retreat.

Hump Ridge Track, a three-day hiking trail created in 2001, includes steep climbs, long walks along the coast, and views of thick stands of lichen-festooned silver beech.

Aoraki/Mount Cook, New Zealand's tallest mountain at 12,316 feet, gives its name to a national park bristling with peaks higher than 10,000 feet—the pinnacle of Te Wahipounamu's sublime offerings.

A shimmering thoroughbred of the sea, the Atlantic bluefin tuna is uniquely designed to sprint at high speed, migrate over long distances, and survive the icy cold of deep water.

Quicksilver

Prized for sushi, the fast and powerful Atlantic bluefin tuna is being relentlessly overfished.

Keeping a tradition more than 3,000 years old, Spanish fishermen process a bluefin netted in the Mediterranean. They take only the largest fish and return the rest to the sea.

Bluefin tuna in an undersea pen in the Mediterranean are fattened for the booming sushi market. These fish were taken from the wild, reducing the potential breeding population.

By Kenneth Brower

Photographs by Brian Skerry

One moment the undersea is featureless blue, an empty cathedral, the sun an undulating hot spot in the vault of waves overhead, its beams radiating down as if from stained glass. The next moment the ocean is full of giant, bomb-shaped bluefin tuna, the largest measuring 14 feet long and weighing three-quarters of a ton. In the sea's refracted sunlight, their pale flanks flare and scintillate like polished shields. Their fixed fins—the long, curved anal fin and the second dorsal—flash like sabers. Their quick-sculling tail fins drive the formation forward at ten knots, with sprints to 25, a ceaseless, staccato beat. And just as suddenly they are gone. The ocean is empty again. Here and there a small galaxy of scales marks where a bluefin swallowed a herring. The victim's scales swirl in the turbulence of the departed tuna, now bearing off at high speed. Then each vortex slows and stops. The sinking scales gleam like diamonds from a spilled necklace. Then they dim. Finally they wink out with depth.

The true tunas, genus *Thunnus,* are supercharged fish, streamlined to perfection and jammed with state-of-the-art biological gear. The characteristics that distinguish the true tunas include great size, great range, efficient swimming stroke, warm bodies, large gills, finesse at thermoregulation, rapid oxygen uptake, high hemoglobin concentration, and clever physiology of the heart. All of these reach their apogee in the bluefin.

The three species of bluefin—the Atlantic, Pacific, and southern—have divided the world's oceans among themselves, and they roam all planetary seas except the polar. The bluefin is a modern fish, yet its relationship with humanity is ancient. Japanese fishermen have caught Pacific bluefin for more than 5,000 years. The Haida of the Pacific Northwest have hunted the same species for at least as long, based on the evidence of bluefin bones in their middens. Stone Age artists painted Atlantic bluefin tuna on the walls of Sicilian caves. Iron Age fishermen—Phoenician, Carthaginian, Greek, Roman, Moroccan, Turkish—watched from promontories for the arrival of bluefin schools at their Mediterranean spawning grounds.

"Bluefin helped build Western civilization," Stanford University professor Barbara Block, a preeminent scholar of this fish, told me. "Across all the Mediterranean, everybody netted giant

A bluefin almost ten feet long cruises by a diver as it searches for food in the Gulf of St. Lawrence. The tuna gather here in the summer and early fall to feed on oily herring and mackerel.

tuna. The bluefin have annual migrations in through the Strait of Gibraltar, and everyone knew when they came. In the Bosporus there were 30 different words for bluefin. Everyone put out net pens that had different names in the different countries. Penning created cash. Bluefin were traded. The coins of Greece and Celtic coins, they had giant bluefin on them."

"The king of all fish," Ernest Hemingway reported in the *Toronto Star Weekly* in 1922, after seeing Atlantic bluefin off Spain. Carl Linnaeus, the father of modern scientific classification, named the Atlantic bluefin in 1758. Linnaeus often resorted to repetition in flagging superlative animals. *Gulo gulo* he named the wolverine, king of the weasels. *Bison bison* he named the bison, king of the prairie. *Thunnus thynnus* he named the Atlantic bluefin: tuna of tunas.

THE DAY DAWNED RED-ORANGE over Cape Breton, Nova Scotia. It was cold in Port Hood, down on the village dock, but the eastern sky was encouraging, a long horizon of warm color. We cast off, and Dennis Cameron, captain of the *Bay Queen IV,* steered north toward the Gulf of St. Lawrence. Along the back wall of the boat's cabin, fishing rods were racked like rifles in an armory. In the open waters ahead, fishermen haul in the biggest bluefin tuna in the world.

To starboard passed the big island of Cape Breton. To port passed a small outlier, Port Hood Island, low and green, with a scattering of white clapboard houses. Cameron grew up on Port Hood Island in one of those houses. He remembers squirrel hunting in the woods, and beachcombing for old buoys and gaffs, and collecting stranded squid as bait for his father—a vanished way of life. The big lobster cannery on the islet closed long ago. The waterfront, crowded with fishing dories in the 1920s, a forest of masts, is now deserted. Twenty-odd families of fishermen and farmers survived through the 1950s but steadily thinned, and the island now has just one full-time resident.

And so it goes in fishing communities everywhere. The oceans are dying. The collapse of fisheries marks the decline, a steady funereal drumbeat: cod in the Maritime Provinces of Canada, anchovies off Peru, salmon off the Pacific Northwest, Patagonian toothfish in Antarctic waters, sharks in all the oceans.

Bluefin tuna are among the most overfished species on Earth. The stock that spawns on the western side of the Atlantic has been reduced by 64 percent since 1970. The *tonnara* of Sicily—the mazes of net pens in which, for millennia, Sicilians have collected giant bluefin to kill in the ritualized climax called *mattanza*—have been

Researcher Steve Wilson attaches a tracking tag to a bluefin while Robbie Schallert monitors the ventilation hose. In minutes the fish will be back in the Gulf of St. Lawrence.

folding one after another for decades, as have similar mazes, by different names, throughout the rest of the Mediterranean.

Cameron, like any son of a Canadian fishing family, is familiar with the vogues and vicissitudes of his profession. "We didn't fish tuna," he says of his father's generation. "Tuna fishing was more of a sport. Years ago they used to call it 'horse mackerel.' It was cat food back then, or fertilizer."

In January 2013 a single bluefin tuna sold in Tokyo for $1.76 million. The outrageous price was part publicity stunt, part Japanese ritual: The first tuna on the auction market each year is subject to a bidding war that's over the top, even by Japanese standards. Yet even the normal price of one medium-size bluefin—between $10,000 and $20,000, depending on quality—is a startling measure of how much 21st-century Japanese have come to treasure *maguro,* bluefin sushi. It is a measure, too, of what the bluefin tuna is up against if more than a handful are to see the 22nd century.

While Cameron steered toward deep water, Steve Wilson, a Stanford University researcher who works with the Tuna Research and Conservation Center (TRCC) in Monterey, California, checked the satellite tags he hoped to implant that day. Robbie Schallert, of the bluefin conservation group Tag-a-Giant and

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Kenneth Brower's latest book is Hetch Hetchy: Undoing a Great American Mistake. *Brian Skerry has spent more than 10,000 hours underwater.*

Out of water, the bluefin looks like some kind of wonderful machine, biologically inspired and poured of living metal.

Wilson's colleague at TRCC, unrolled a blue padded mat just forward of the "tuna door" in the transom at the stern. The mat did not read "Welcome," but that was the idea. We had come to tag and measure bluefin, not to kill them.

Eight miles offshore, drifting with three lines out baited with mackerel, we had a strike. Sheldon Gillis, Captain Cameron's assistant, fought the fish. There was a taut *twang* each time the bluefin took out line. Twenty minutes later, a good distance off the stern, the fish made its first appearance. Gillis judged it to be about 700 pounds. He reeled in furiously each time the tuna gave him the chance, and he was sweating now despite the cool of the morning. After another 20 minutes came the loud, slapping bang of tail fin against the stern. Hoisted aboard through the tuna door, the fish lay on its side, perfectly still and enormous on the mat. Out of water, it looked like some kind of wonderful machine, biologically inspired and poured of living metal.

Wilson and his tagging team worked efficiently and fast, like a crew swarming an underwater racing machine at a pit stop. A wet black cloth went over the eyes as blindfold. A green hose went in the mouth and began pumping seawater past the gills. A roll of measuring tape flew over the fish, tossed from one man to another. The tape was laid flush against the body between the tip of the nose and the point where the tail fin forked. This measurement, the curved fork length, or CFL, in this fish was 300 centimeters, just short of ten feet. CFL is an accurate predictor of a tuna's weight: 1,226 pounds in this case, nearly twice Gillis's original estimate. It was the third biggest bluefin ever tagged by the team in nearly 20 years of work.

Straddling the rear of the fish, Wilson drove in a titanium dart to anchor a satellite tag just forward of the second dorsal fin. Four team members took up positions at the corners of the blue mat and lifted. Clearing the deck, the mat became a hammock. Straining under the burden of the fish, the four men walked a semicircle of tiny mincing steps, rotating the fish 180 degrees to bring it around to face the tuna door. From the scimitar of the anal fin, Schallert snipped a sliver for DNA analysis. Then the two men at the tail hoisted their end of the mat. The tuna plunged through the doorway and back into the gulf, raising a splash like a horse diving off a pier. Two flicks of its tail fin and it was gone.

On his laptop the night before, Wilson had programmed the satellite tag on this fish to pop off on June 1 of the next year. Nine months and two weeks from this day, in whatever time zone the bluefin happened to be, the tag would send an electric current through the metal pin attaching it to the leader and dart in the fish. The electrolyzed pin would begin to corrode. Within a few hours it would sever. A bulb on top of the tag is made of foam that's incompressible and therefore buoyant at any depth. The tag would rise through the cathedral rays of the ocean toward the brightness of the vault. On breaking the surface, it would begin uploading the encoded secrets of this bluefin—its travels, its seasons, its dive patterns—to a small constellation of Argos satellites orbiting overhead.

BLOCK RUNS TRCC out of Hopkins Marine Station on Cannery Row, in collaboration with the Monterey Bay Aquarium next door. After the tag pops off at its programmed time, the satellite data rises from the Atlantic, jumps the continent to California, and comes home here to Hopkins Station for interpretation. Thirty years ago science was in the dark about the movements of tunas. Since then the mysteries of their migration, one after another, have *(Continued on page 86)*

A Who's Who of Tunas

Once a lowly sandwich filling, tuna has gone upscale. The largest members of the Scombridae family are now worth about $5.5 billion a year on the global market. These are the most popular.

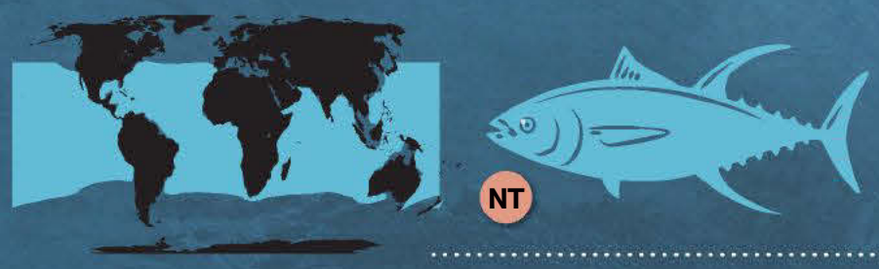
Threatened species status

- LC — Least concern
- NT — Near threatened
- V — Vulnerable
- E — Endangered
- CE — Critically endangered

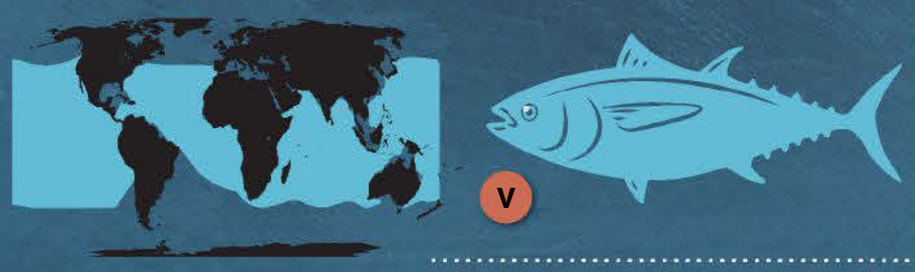
PRINCIPAL MARKET TUNAS *(Ranked by 2011 catch)*

Skipjack This cheap, plentiful fish ends up mainly in cans. The label "light meat" applies to skipjack and yellowfin.

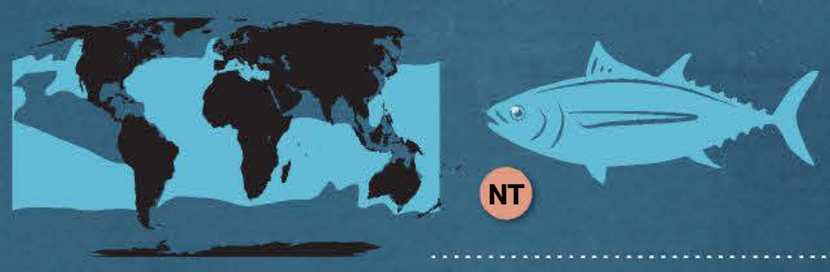
Yellowfin Of all the tunas, yellowfin have some of the highest levels of mercury. Their best meat is often served raw.



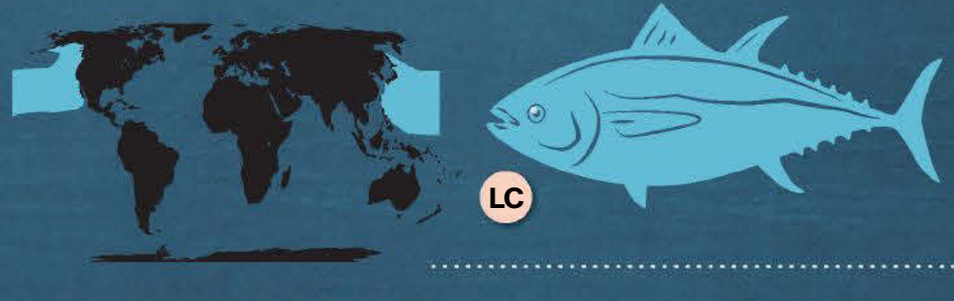
Bigeye This tuna has become increasingly popular for raw dishes in Japan as the price for bluefin has soared.



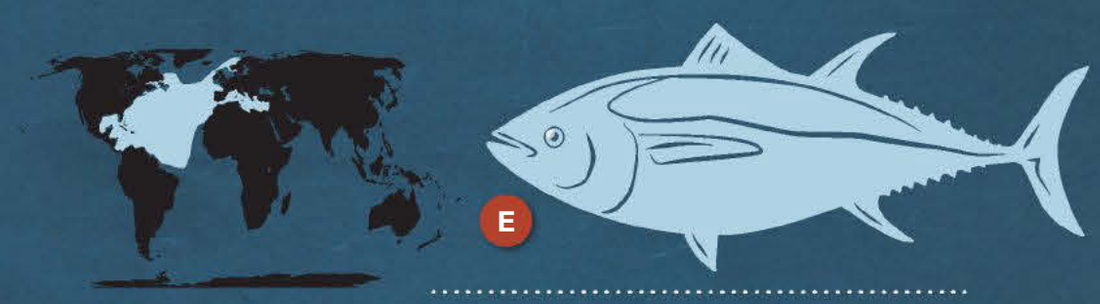
Albacore With its mild flavor and firm texture, this is the king of canned tuna—identified as "white meat" on the label.



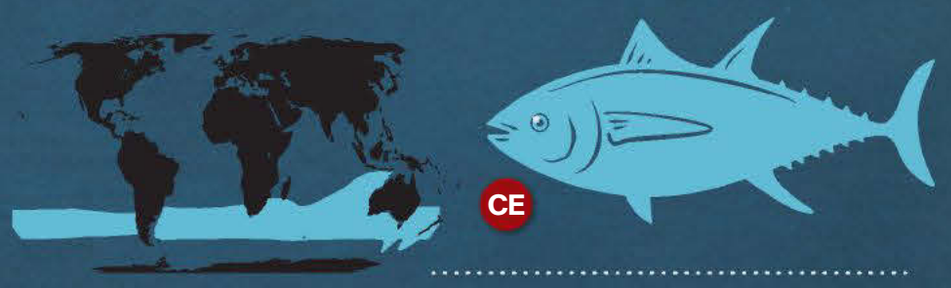
Pacific bluefin The 2012 assessment found this species to be at only 3.6 percent of historic levels. Its status will be revised.



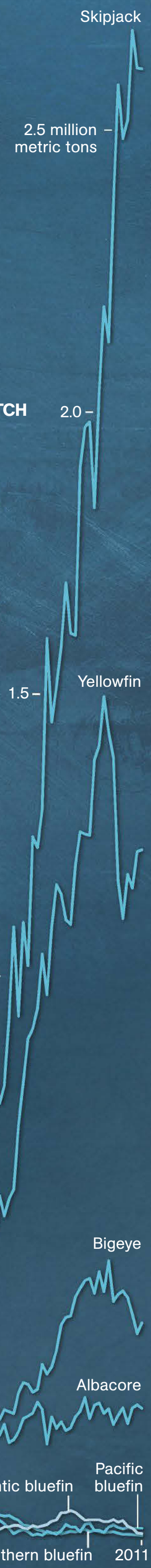
Atlantic bluefin These fish and their Pacific kin are highly coveted for raw dishes because of their buttery meat.



Southern bluefin Like other bluefin, these are both farmed and caught wild, mostly for the Japanese market.



GLOBAL ANNUAL CATCH



MAPS AND GRAPHIC: RYAN MORRIS, NGM STAFF. ILLUSTRATIONS: KIRSTEN HUNTLEY

SOURCES: FAO FISHERIES AND AQUACULTURE DEPARTMENT; INTERNATIONAL UNION FOR CONSERVATION OF NATURE AND NATURAL RESOURCES; SHANA MILLER, THE OCEAN FOUNDATION

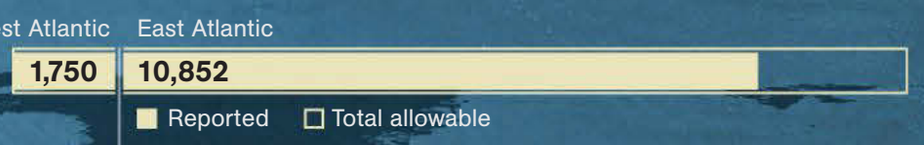
Epic Bluefin Migrations

Bluefin are highly migratory fish, crossing seas around the world in yearly cycles of spawning and feeding. At least two groups share the Atlantic. One spawns in the Gulf of Mexico, the other in the Mediterranean. The groups mingle in the center of the ocean. Some fish even spend years on the opposite side of the ocean from where they spawn.

Atlantic bluefin tuna ranges
The ranges below show the extent of tagging data collected by Barbara Block's team and the large area where the two stocks overlap.

- Western stock
- Eastern stock
- Overlap

Total catch by region 2012, *metric tons*



Gulf of St. Lawrence

NORTH AMERICA

EUROPE

18-month path of one eastern stock tuna

Gulf of Mexico
(spawning area)

18-month path of one western stock tuna

Mediterranean Sea
(spawning area)

ATLANTIC OCEAN

AFRICA

SOUTH AMERICA

The International Commission for the Conservation of Atlantic Tunas (ICCAT) oversees tuna fishing in the Atlantic. It sets quotas based on the flawed idea that the two groups of bluefin don't mix.

0 mi 500
0 km 500

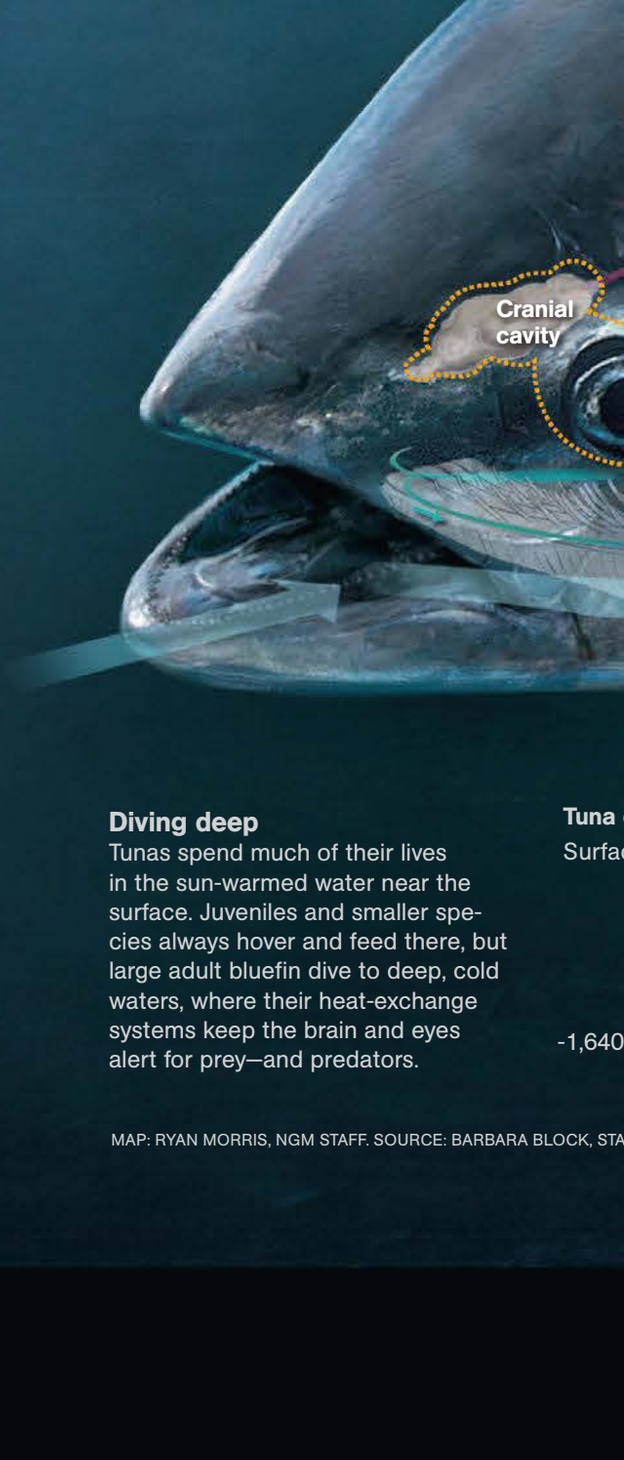
The Super Fish

BREATHING

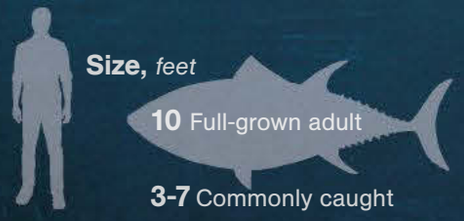
A bluefin swims with its mouth open, forc
the gills in a process called ram ventilatio
up to 30 times more surface area than th
and they extract nearly half the oxygen di
water. If the tuna ever stops swimming, it

Tuna key

- Arteries carry oxygenated blood away from the heart
- Veins carry deoxygenated blood toward the heart
- Heat-exchange system
- Retractable fins fit into grooves on the body



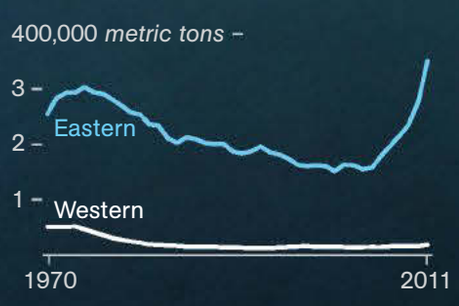
Size, *feet*



Speed, *mph*
8 Standard
25+ Fastest

Age, *years*

Breeding populations
ICCAT's most recent assessment shows a spike in the eastern population, a result of lower catch quotas. But scientists say the true increase is likely smaller.



Diving deep
Tunas spend much of their lives in the sun-warmed water near the surface. Juveniles and smaller species always hover and feed there, but large adult bluefin dive to deep, cold waters, where their heat-exchange systems keep the brain and eyes alert for prey—and predators.

Tuna
Surfa
-1,640

SOURCE (BREEDING POPULATIONS AND TOTAL CATCH): ICCAT

MAP: RYAN MORRIS, NGM STAFF. SOURCE: BARBARA BLOCK, STA

ing water past
n. Its gills have
ose of other fish,
ssolved in the
suffocates.

BODY HEAT

Tunas are unique among bony fish in their ability to keep key parts of their body warm. Rather than lose heat to cold water in the gills like most fish, tunas have heat-exchange systems that retain metabolic heat produced in the tissue. These systems are present in three areas (orange outline, below).

SWIMMING

The bluefin is one of the fastest fish in the ocean, thanks to a combination of physical characteristics. Its large tail maximizes thrust, while the tapered shape of its body minimizes drag. For optimum streamlining, some fins retract into a groove. Others fold into a depression in the body.

Two stiff fins (here and below) stabilize the fish.

A tight range of motion keeps the tail fin in less-turbulent water behind the body.

White muscle
70°F

Red muscle
88°F

Internal organs

Heart

Blood picks up oxygen in the gills.

Fin dynamics,
top view at right

Bony flat areas near the tail reduce turbulence.

Top and bottom finlets direct water flow, likely increasing lift and reducing drag.

Swimming patterns,
top view
(not to scale)

Mackerel

Tuna

Cross section

Red muscle

White muscle

depth ■ = Temperature

ce 70°F

Tuna

Water

ft 40°F

◂ 24 hours ▸

Heat-exchange system

Tunas rely on a network of tightly packed, parallel blood vessels that allow the transfer of heat between warm and cool blood moving in opposite directions. As a result, heat is retained in the tissues of the body that produced it rather than being lost through the gills.

Most fish

Gills Tissues

Tuna

Gills Tissues

Cool blood

Warm blood

Heat is transferred between blood vessels

Muscles and motion

Tunas have a greater proportion of red muscle fiber than do other fish, favoring long-distance swimming over short bursts. And while most fish swim by undulating along their entire length, a tuna's body remains relatively rigid while only its tail whips back and forth, reducing drag.

NFORD UNIVERSITY. GRAPHIC: FERNANDO G. BAPTISTA AND LAWSON PARKER, NGM STAFF; SHIZUKA AOKI. SOURCES: BARBARA BLOCK, STANFORD UNIVERSITY; BRUCE COLLETTE, IUCN TUNA AND BILLFISH SPECIALIST GROUP; DON STEVENS, UNIVERSITY OF GUELPH

The tunas are supercharged fish, streamlined to perfection and jammed with state-of-the-art biological gear.

Spanish fishermen haul in tuna that they have trapped in a maze of nets set in the Mediterranean. This ancient technique, known as *almadraba,* is dying out as bluefin numbers dwindle. In the Gulf of St. Lawrence, where this giant feeds (flap), bluefin fishing is done mostly by rod and reel.

A voracious predator, the bluefin feeds mainly on small fish, crustaceans, and squid. But it too is pursued relentlessly as the human appetite for its flesh continues to grow.

The good news is that Atlantic bluefin populations, if allowed to rebound, could grow to five times their present size.

been solved by tagging technology pioneered by Block and others.

The interior of Block's lab makes a sort of gallery. The walls and cabinet doors, plastered with charts, maps, and illustrations from scientific journals, amount to an exhibit. If it had a title, it might be called "State of the Bluefin."

The state of the bluefin is not good. One poster, "Estimated Spawning Stock Atlantic Bluefin Tuna (1950-2008)," shows a graph of the spawning biomass of Gulf of Mexico breeders atop a similar graph for the Mediterranean breeders. Both populations are represented by lines in the shape of eels, and both eels are diving toward the bottom of their graphs. They have plunged past the dotted line representing sustainable yield and are headed for a spot where the kilotons of spawning biomass read zero.

The art on the maps is a kind of pointillism. The locations of bluefin, as reported by the many electronic tags deployed by the lab over the years, are represented as a proliferation of small circles in many colors. The maps of most interest to Block show the distribution of bluefin in relation to something called the ICCAT line.

The fisheries for the Atlantic bluefin tuna are managed by the International Commission for the Conservation of Atlantic Tunas. ICCAT stock assessment models make use of a dotted line dividing the North Atlantic vertically. Drawn in 1981, this demarcation follows the meridian at 45° west longitude and divides the western stock of Atlantic bluefin from the eastern. The lab's pointillist maps show a curious thing. The positions of electronically tagged western bluefin, represented as reddish-orange circles, pack the Gulf of Mexico, the spawning grounds for this stock, and from there spill eastward into the Atlantic. They cross the ICCAT line with impunity and spread all the way to Portugal and Spain. The positions of tagged eastern-breeding bluefin, represented as white circles, pack the Mediterranean, spawning grounds for this stock, and from there spill westward, crossing the ICCAT line to fill the coastal waters of the United States and Canada.

The ICCAT line, the maps testify, is a fiction. Scientists once believed that each stock stayed on its own side of the ocean, but no one believes that now. Everywhere in the Atlantic, all across the feeding grounds of this species, the eastern and western stocks mix. It seems that only in their respective spawning grounds are they separate.

The fact of this mixing was well established by Block, other taggers, and DNA researchers more than a decade ago. It has yet to be incorporated in ICCAT models. The best estimates today are that around half of the bluefin caught off the eastern shores of North America originated in the Mediterranean, yet any of these tuna, if caught in the west, are still counted as fish of western origin. The ICCAT line is not just a dull management tool—it is no tool at all. The ICCAT model fails, as well, to make any allowance for illegal fishing, though studies indicate that the illegal take is large.

For most of its history, ICCAT has ignored the advice of its scientific panel, the Standing Committee on Research and Statistics (SCRS). For the eastern stock that breeds in the Mediterranean, the much larger population, ICCAT has routinely set quotas far higher than science recommends. In 2008 the SCRS issued its most alarming assessment yet on the status of the eastern stock. The actual catch, the scientists reported, was likely more than double the 28,500 metric tons of the allowable catch, and more than quadruple a level that was sustainable. They recommended closing the fishery through

the main spawning period and reducing the allowable catch to 15,000 metric tons or less. ICCAT, as usual, ignored this plea.

The same year, ICCAT commissioned an independent review of its policies. The review panel, composed of eminent fisheries managers and fisheries scientists from around the world, was not gentle. It found that ICCAT stewardship of the eastern stock was an "international disgrace" and a "travesty of fisheries management." The U.S. National Oceanic and Atmospheric Administration and the International Union for Conservation of Nature have chimed in with similar sentiments. Environmentalists joke that ICCAT stands for International Conspiracy to Catch All Tuna, but it's no joke. It describes reality better than the official version.

The good news is that a faction of fisheries biologists believe that Atlantic bluefin populations, if allowed to rebound, could grow to five times their present size and with wise management could yield healthy quotas forever.

In 2009 Monaco, in response to the decades of mismanagement, proposed that the Atlantic bluefin be listed on Appendix I of CITES, the Convention on International Trade in Endangered Species. Such a listing would have meant an international ban on trade in bluefin, and CITES delegates from fishing nations rallied to defeat the proposal. But ICCAT had its wake-up call. That same year, for the first time, it followed scientific advice in setting quotas for eastern bluefin. In 2011, to address illegal fishing, it began testing a system that would electronically track caught fish from ocean to market, and early in 2014 the system is to be fully implemented. In 2015 ICCAT is committed to revising its antiquated stock-assessment protocols.

This is movement in the right direction, but ICCAT's structure and governance remain unchanged, vulnerable to political pressure from fishing interests in its member states. Tuna science, always politicized, has recently become much more so. As it is no longer possible for ICCAT to simply ignore scientific advice, there is now an effort to massage the science. "There are inherent uncertainties about these stock assessments," Amanda Nickson, director of global tuna conservation at the Pew Charitable Trusts, told me. "We're seeing a mining of the areas of uncertainty to justify increases in quota."

Industry-funded biologists propose that there might be undiscovered spawning grounds for Atlantic bluefin. It is possible, of course, but there is no real evidence for the proposition. The idea seems awfully convenient for an agenda favoring business as usual.

HOPKINS STATION, established by Stanford University in 1892, was the first marine lab on the West Coast. Its weathered buildings, like the abandoned canneries immediately eastward, are relics of the age of sardines, a boom time that busted 60 years ago. The place is full of ghosts. Chief among them is Ed Ricketts, the inspiration for "Doc" in John Steinbeck's *Cannery Row*. At night this maverick ecologist would leave Pacific Biological Laboratories, his rickety one-man enterprise at 800 Cannery Row, and sneak into the Hopkins library to do research. Ricketts and the sardine fishery went out together. The man was killed in 1948 at a Monterey train crossing, and the last canneries, hit by the locomotive of overfishing, closed a few years later. By the 1980s sardines had shown a fragile recovery, but now the stock is crashing again.

A short stretch of beach and rocky shore separates Hopkins Station and the Monterey Bay Aquarium. Ricketts must have walked a nearby span of beach in his nighttime raids on the library. At the border between Hopkins and the aquarium, in an annex the two institutions operated jointly, are three large, waist-deep tanks stocked with young Pacific bluefin. Block and her colleagues worked out their tag-implantation techniques with the predecessors of these fish.

The bluefin tuna, if it is to have a future, will need wise management informed by good science. Here in Monterey the consequences of the opposite are hard to miss. Directly below the tanks of endlessly circling bluefin are rows of cement pilings, the ruins of cannery piers that reach out into the bay for wide, silvery rivers of sardines that are no longer there. □

STAR

Superheated gas swirls around our galaxy’s central black hole, Sagittarius A*.

EATER

Albert Einstein thought that a black hole—a collapsed star so dense that even light could not escape its thrall—was too preposterous a notion to be real.

Einstein was wrong.


Something
is there, at
least in a
mathematical
sense. Something
not just small
but also
unimaginably
heavy.

Hidden Hole

Viewed through an amateur telescope, the Milky Way's dusty center sweeps diagonally across the sky, draping stellar nurseries. Behind the veil lurks the supermassive black hole at the center of our galaxy.

STÉPHANE GUISARD, EUROPEAN SOUTHERN OBSERVATORY

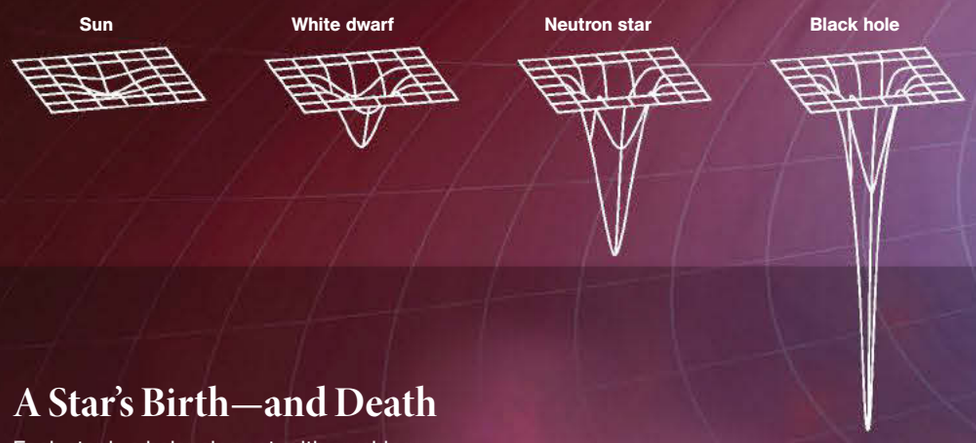
Insatiable Force

Although their name suggests emptiness, black holes are the most densely filled objects in the universe, giving them enormous gravitational pull. Stellar black holes, formed from the collapse of giant stars, can compact the mass of ten suns to the size of New York City. Supermassive black holes at the center of galaxies can have the mass of billions of suns. Their origin remains a mystery.

The Power of Gravity

Einstein showed a century ago that the mass of stars, planets, and all other matter exerts a gravitational force, bending space like a rubber sheet. The greater the mass of an object, the more powerful the effect. The immense mass of a black hole generates a gravitational "sink" from which not even light can escape.

Approximate size of Earth if it collapsed to a black hole; it would weigh the same as Earth today.



Sagittarius A*

In 1974 scientists discovered a very compact source of radio waves originating from a region in the Sagittarius constellation, 26,000 light-years from Earth. Dubbed Sagittarius A* (Sgr A*), the source is now known to be a supermassive black hole at the center of our galaxy weighing more than four million suns.

1 ACCRETION DISK

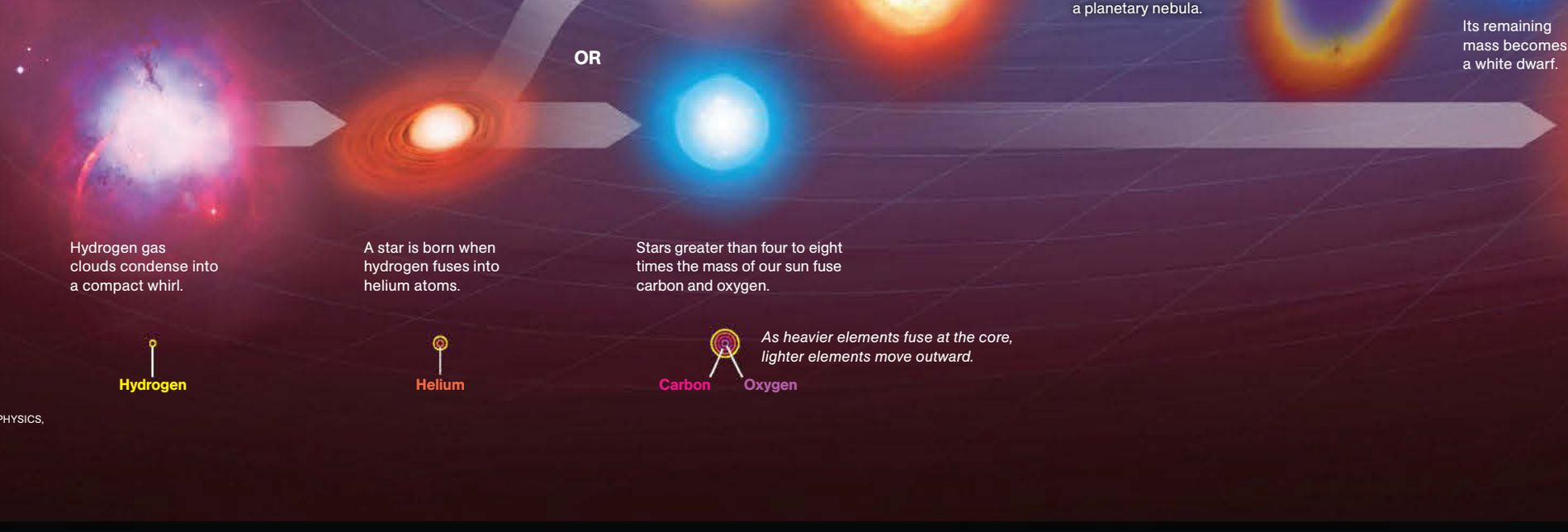
A whirling disk of superheated gas and dust likely spins at near light-speed around Sagittarius A*. The disk emits heat, radio noise, and x-ray flares but is placid compared with accretion disks in other galaxies.

2 X-RAY JETS

Though tranquil today, Sagittarius A* may have fed on a star or gas cloud a hundred times the mass of the sun as recently as 20,000 years ago. The meal produced x-ray jets blasting outward from the black hole's poles, which are tilted 15 degrees from the plane of the galaxy.

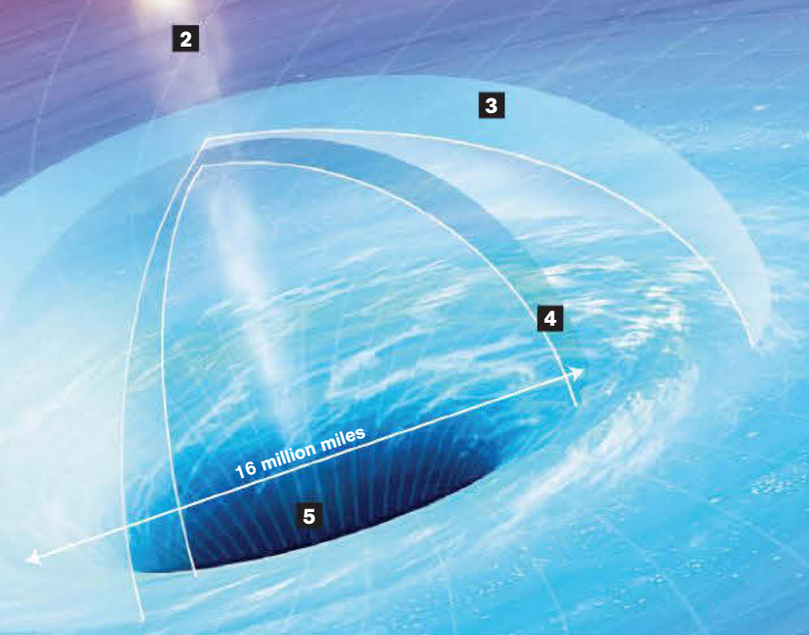
A Star's Birth—and Death

Each star is a balancing act, with crushing gravity pulling inward against an interior nuclear blast furnace pushing out. When the star's fuel is exhausted, gravity wins and the star implodes. But its fate and the elements it forges before its collapse are foretold by its original size. The more massive the star, the more violent its ending.



Venture to the event horizon and beyond on our digital editions.

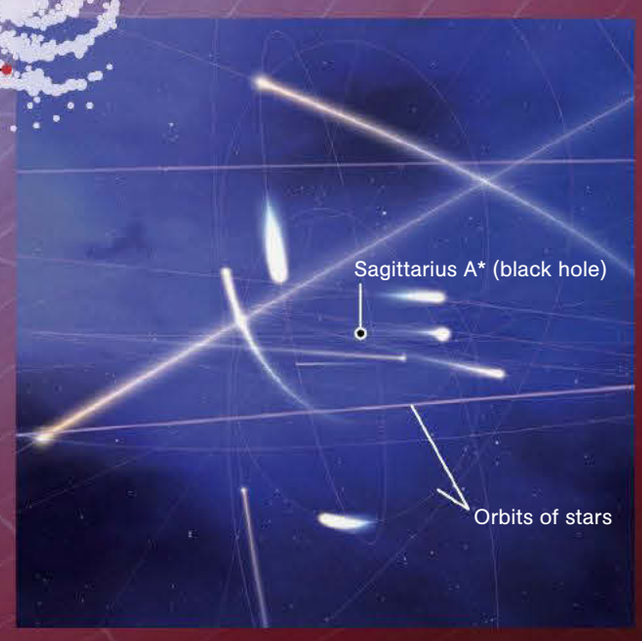
JASON TREAT AND ALEXANDER STEGMAIER, NGM STAFF
ART BY MARK A. GARLICK
SOURCES: AVERY BRODERICK, PERIMETER INSTITUTE FOR THEORETICAL PHYSICS, UNIVERSITY OF WATERLOO, CANADA; UCLA GALACTIC CENTER GROUP



THE MILKY WAY

Approximate area enlarged

Our solar system



Perceiving the Invisible

Black holes can't be seen, but their location can be plotted by measuring their effect on the orbits of surrounding stars. Clouds of interstellar gas and dust are pulled in, and whole stars that venture too close are torn apart and devoured.

3 STATIC LIMIT

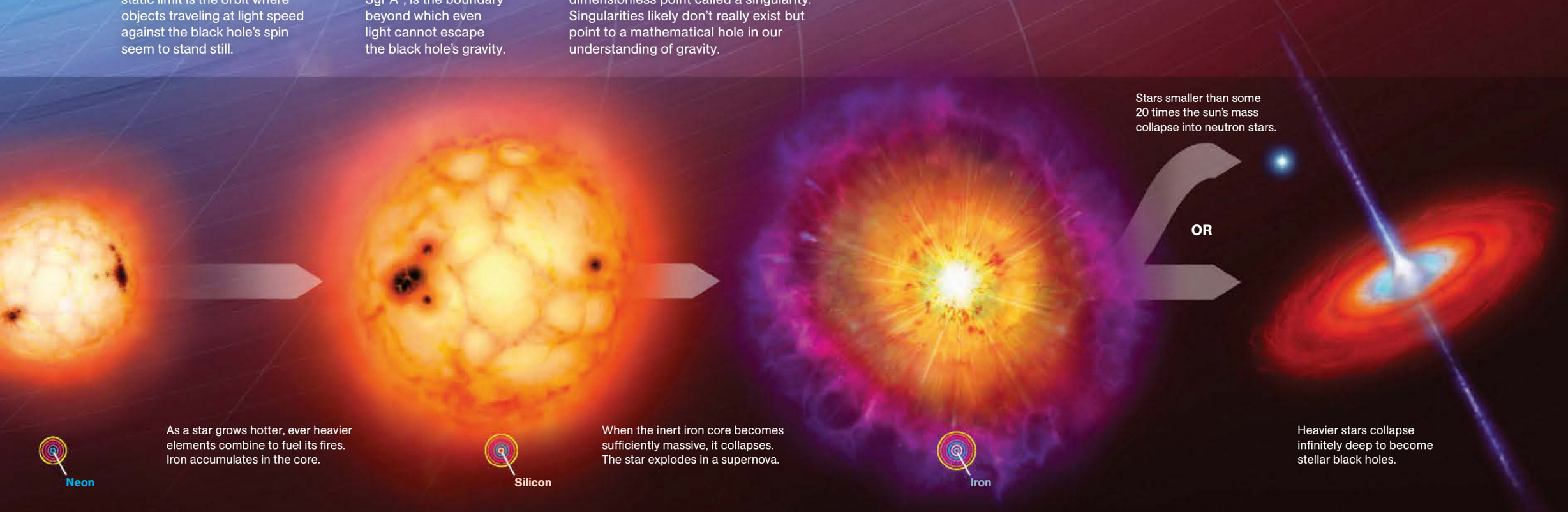
A black hole's spin can twist space, speeding or slowing matter orbiting nearby. The static limit is the orbit where objects traveling at light speed against the black hole's spin seem to stand still.

4 EVENT HORIZON

The event horizon, extending some eight million miles around Sgr A*, is the boundary beyond which even light cannot escape the black hole's gravity.

5 THE SINGULARITY

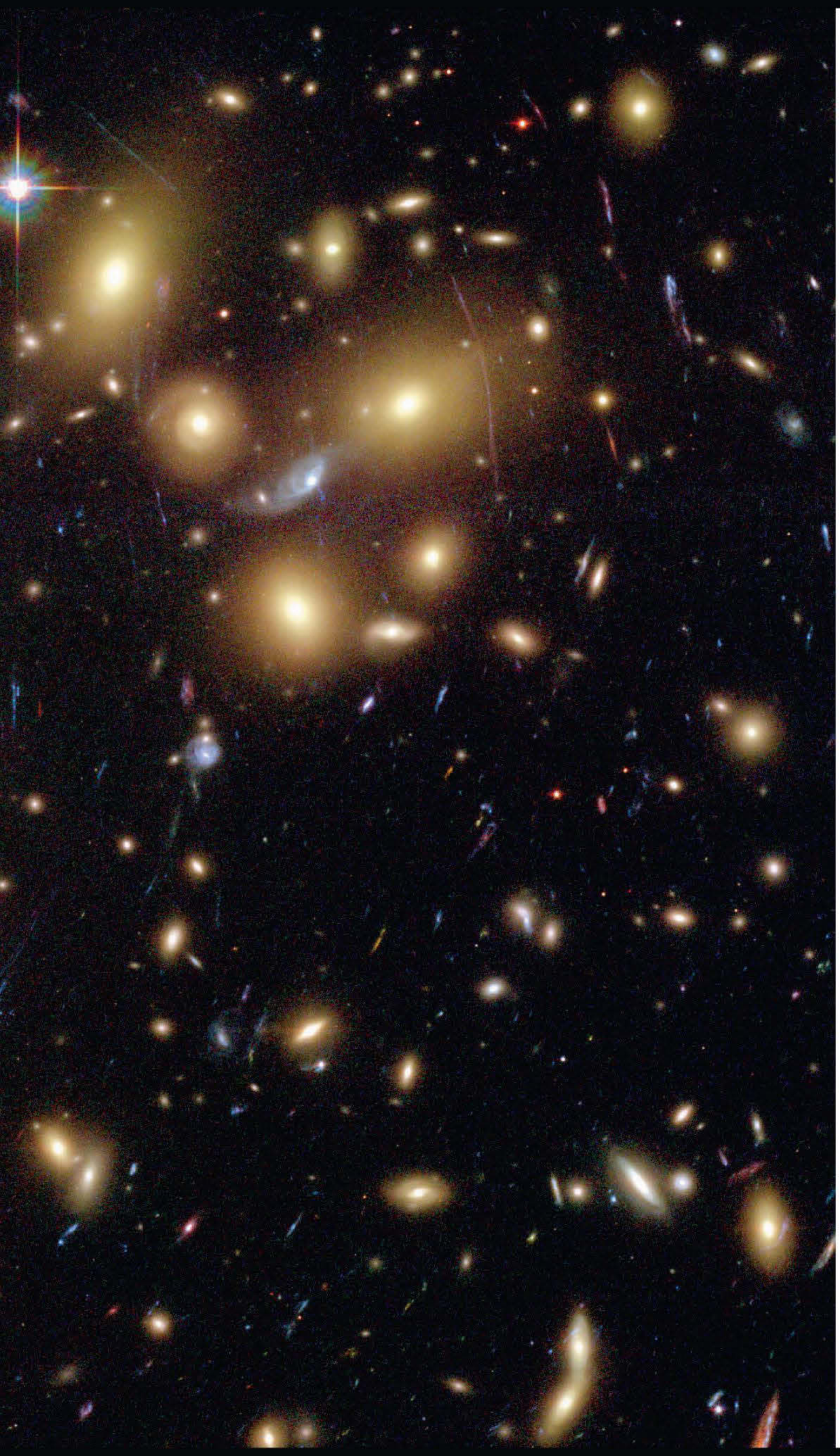
According to Einstein's equations, at the center of a black hole a star's entire mass has collapsed into an infinitely dense, dimensionless point called a singularity. Singularities likely don't really exist but point to a mathematical hole in our understanding of gravity.



Gravity Distorts

A view through the massive galaxy cluster called Abell 1689 shows light from more distant galaxies smeared by the sheer force of Abell's gravity. The gravity of black holes is immensely more powerful, allowing no light to escape.

NASA/EUROPEAN SPACE AGENCY/ HUBBLE HERITAGE TEAM



By Michael Finkel
Art by Mark A. Garlick

OUR STAR, THE SUN, WILL DIE A QUIET DEATH.

The sun's of only average mass, starwise, and after burning through the last of its hydrogen fuel in about five billion years, its outer layers will drift away, and the core will eventually compact to become what's known as a white dwarf, an Earth-size ember of the cosmos.

For a star ten times as big as the sun, death is far more dramatic. The outer layers are blasted into space in a supernova explosion that, for a couple of weeks, is one of the brightest objects in the universe. The core, meanwhile, is squeezed by gravity into a neutron star, a spinning ball bearing a dozen miles in diameter. A sugar-cube-size fragment of a neutron star would weigh a billion tons on Earth; a neutron star's gravitational pull is so severe that if you were to drop a marshmallow on it, the impact would generate as much energy as an atom bomb.

But this is nothing compared with the death throes of a star some 20 times the mass of the sun. Detonate a Hiroshima-like bomb every millisecond for the entire life of the universe, and you would still fall short of the energy released in the final moments of a giant-star collapse. The star's core plunges inward. Temperatures reach 100 billion degrees. The crushing force of gravity is unstoppable. Hunks of iron bigger than Mount Everest are compacted almost instantly into grains of sand. Atoms are shattered into electrons, protons, neutrons. Those minute pieces are pulped into quarks and leptons and gluons. And so on, tinier and tinier, denser and denser, until…

Until no one knows. When trying to explain such a momentous phenomenon, the two major theories governing the workings of the universe—general relativity and quantum mechanics—both go haywire, like dials on an airplane wildly rotating during a tailspin.

The star has become a black hole.

What makes a black hole the darkest chasm in the universe is the velocity needed to escape its gravitational pull. To overcome Earth's clutches, you must accelerate to about seven miles a second. This is swift—a half dozen times faster than a bullet—but human-built rockets have been achieving escape velocity since 1959. The universal speed limit is 186,282 miles a second, the speed of light. But even that isn't enough to defeat the pull of a black hole. Therefore whatever's inside a black hole, even a beam of light, cannot get out. And due to some very odd effects of extreme gravity, it's impossible to peer in. A black hole is a place exiled from the rest of the universe. The dividing line between the inside and outside of a black hole is called the event horizon. Anything crossing the horizon—a star, a planet, a person—is lost forever.

Albert Einstein, one of the most imaginative thinkers in the history of physics, never believed black holes were real. His formulas allowed for their existence, but nature, he felt, would not permit such objects. Most unnatural to him was the idea that gravity could overwhelm the supposedly mightier forces—electromagnetic, nuclear—and essentially cause the core of an enormous star to vanish from the universe, a cosmic-scale David Copperfield act.

Einstein was hardly alone. In the first half of the 20th century most physicists dismissed the idea that an object could become dense enough to asphyxiate light. To lend it any more credence than one would give the tooth fairy was to risk career suicide.

Still, scientists had wondered about the possibility as far back as the 18th century. English philosopher John Michell mentioned the idea in a report to the Royal Society of London in 1783. French mathematician Pierre-Simon Laplace predicted their existence in a book published in 1796. No one called these superdense curiosities black holes—they were referred to as frozen stars, dark stars, collapsed stars, or Schwarzschild singularities, after the German astronomer who solved many theoretical equations about them. The name "black hole" was first used in 1967, during a talk by American physicist John Wheeler at Columbia University in New York City.

Around the same time there was a radical shift in black hole thinking, due primarily to the invention of new ways of peering into space. Since the dawn of humanity, we'd been restricted to the visible spectrum of light. But in the 1960s x-ray and radio wave telescopes began to be widely used. These allowed astronomers to collect light in wavelengths that cut through the interstellar dust and let us see, as in a hospital x-ray, the interior bones of galaxies.

What scientists found, startlingly, was that at the center of most galaxies—and there are more than 100 billion galaxies in the universe—is a teeming bulge of stars and gas and dust. At the very hub of this chaotic bulge, in virtually every galaxy looked at, including our own Milky Way, is an object so heavy and so compact, with such ferocious gravitational pull, that no matter how you measure it, there is only one possible explanation: It's a black hole.

These holes are immense. The one at the center of the Milky Way is 4.3 million times as heavy as the sun. A neighboring galaxy, Andromeda, houses one with as much mass as 100 million suns. Other galaxies are thought to contain billion-sun black holes, and some even ten-billion-sun monsters. The holes didn't begin life this large. They gained weight, as we all do, with each meal. Black hole experts also believe that small holes roam the galactic suburbs, common as backyard deer.

In the course of a single generation of physicists, black holes morphed from near jokes—the reductio ad absurdum of mathematical tinkering—to widely accepted facts. Black holes, it turns out, are utterly common. There are likely trillions of them in the universe.

NO ONE HAS EVER SEEN a black hole, and no one ever will. There isn't anything to see. It's just a blank spot in space—a whole lot of nothing, as physicists like to say. The presence of a hole is deduced by the effect it has on its surroundings. It's like looking out a window and seeing every treetop bending in one direction. You'd almost certainly be right in assuming that

a strong yet invisible wind was blowing.

When you ask the experts how certain we are that black holes are real, the steady answer is 99.9 percent; if there aren't black holes in the center of most galaxies, there must be something even crazier. But all doubt may be removed in a matter of months. Astronomers are planning to spy on one while it eats.

The black hole at the center of the Milky Way, 26,000 light-years away, is named Sagittarius A*. Sgr A*—that's the standard abbreviation; its surname is pronounced A-star—is currently a tranquil black hole, a picky eater. Other galaxies contain star-shredding, planet-devouring Godzillas called quasars.

But Sgr A* is preparing to dine. It's pulling a gas cloud named G2 toward it at about 1,800 miles a second. Within as little as a year G2 will approach the hole's event horizon. At this point radio telescopes around the world will focus on Sgr A*, and it's hoped that by synchronizing them to form a planet-size observatory called the Event Horizon Telescope, we will produce an image of a black hole in action. It's not the hole itself we will see but likely what's known as the accretion disk, a ring of debris outlining the edge of the hole, the equivalent of crumbs on a tablecloth after a hearty meal. This should be enough to dispel most doubts that black holes exist.

More than merely exist. They may help determine the fabric of the universe. Matter hurtling toward a black hole produces a lot of frictional heat. Slide down a fire pole; your hands get hot. Same with stuff sliding toward a black hole. Black holes also spin—they're basically deep whirlpools in space—and the combination of friction and spin results in a significant amount of the matter falling toward a black hole, sometimes more than 90 percent, *not* passing through the event horizon but rather being flung off, like sparks from a sharpening wheel.

This heated matter is channeled into jet streams that hurtle through space, away from the hole at phenomenal velocities, usually just a tick below the speed of light. The jets can extend for millions of light-years, drilling straight through a galaxy. Black holes, in other words, churn up

ANYTHING CROSSING THE EVENT HORIZON—A STAR, A PLANET, A PERSON—IS LOST FOREVER.

TEXT SOURCES: ABHAY ASHTEKAR, PENNSYLVANIA STATE UNIVERSITY; AVERY BRODERICK AND LUIS LEHNER, PERIMETER INSTITUTE FOR THEORETICAL PHYSICS; NEIL CORNISH, MONTANA STATE UNIVERSITY; ILYA MANDEL, UNIVERSITY OF BIRMINGHAM, ENGLAND

old stars in the galactic center and pipe scalding gases generated in this process to the galaxy's outer parts. The gas cools, coalesces, and eventually forms new stars, refreshing the galaxy like a fountain of youth.

IT'S IMPORTANT TO CLARIFY a couple of things about black holes. First is the idea, popularized in science fiction, that black holes are trying to suck us all in. A black hole has no more vacuuming power than a regular star; it just possesses extraordinary grip for its size. If our sun suddenly were to become a black hole—not going to happen, but let's pretend—it would retain the same mass, yet its diameter would shrink from 865,000 miles to less than four miles. Earth would be dark and cold, but our orbit around the sun wouldn't change. This black hole sun would exert the same gravitational tug on our planet as the full-size one. Likewise, if the Earth were to become a black hole, it would retain its current weight of more than six sextillion tons (that's a six followed by 21 zeros) but be shrunk in size to smaller than an eyeball. The moon, though, wouldn't move.

So black holes don't suck. Easy. The next topic, time, is way more of a mind bender. Time and black holes have a very strange relationship. Actually time itself—forgetting about black holes for a moment—is an unusual concept. You probably know the phrase "time is relative." What this means is that time doesn't move at the same speed for everybody. Time, as Einstein discovered, is affected by gravity. If you place extremely accurate clocks on every floor of a skyscraper, they will all tick at different rates. The clocks on the lower floors—closer to the center of the Earth, where gravity is stronger—will tick a little slower than the ones on the top floors. You never notice this because the variances are fantastically small, a spare billionth of a second here and there. Clocks on global positioning satellites have to be set to tick slightly slower than those on Earth's surface. If they didn't, GPS wouldn't be accurate.

Michael Finkel wrote on Australian Aboriginals in the June 2013 issue. Illustrator Mark A. Garlick's latest book is Cosmic Menagerie.

Black holes, with their incredible gravitational pull, are basically time machines. Get on a rocket, travel to Sgr A*. Ease extremely close to the event horizon, but don't cross it. For every minute you spend there, a thousand years will pass on Earth. It's hard to believe, but that's what happens. Gravity trumps time.

And if you do cross the event horizon, then what? A person watching from the outside will not see you fall in. You will appear frozen at the hole's edge. Frozen for an infinite amount of time.

Though technically not infinite. Nothing lasts forever, not even black holes. Stephen Hawking, the British physicist, proved that black holes leak—the seepage is called Hawking radiation—and given enough time, will evaporate entirely. But we're talking trillions upon trillions upon many more trillions of years. Long enough so that in the far future, black holes may be the only objects remaining in our universe.

WHILE AN OUTSIDE OBSERVER would never see you slip into a black hole, what would happen to you? Sgr A* is so large that its event horizon is about eight million miles from its center. There's some debate in the physics community about the moment you cross over. It's possible there exists what's called a fire wall, and that upon reaching the event horizon, you promptly burn up.

General relativity theory predicts, however, that something else happens when you cross the event horizon: Nothing. You just pass through, unaware that you're now lost to the rest of the universe. You're fine. Your watch on your wrist ticks along as usual. It's often said that black holes are infinitely deep, but this is not true. There is a bottom. You won't live to see it. Gravity, as you fall, will grow stronger. The pull on your feet, if you're falling feet first, will be so much greater than the tug on your head that you'll be stretched until you're ripped apart. Physicists call this being "spaghettified."

But pieces of you will reach the bottom. At the center of a black hole is a conundrum called a singularity. To understand a singularity would be one of the greatest scientific breakthroughs in history. You'd first need to invent a new theory—one

that went beyond Einstein's general relativity, which determines the motion of stars and galaxies. And you'd have to surpass quantum mechanics, which predicts what happens to microscopic particles. Both theories are fine approximations of reality, but in a place of extremes, like the interior of a black hole, neither applies.

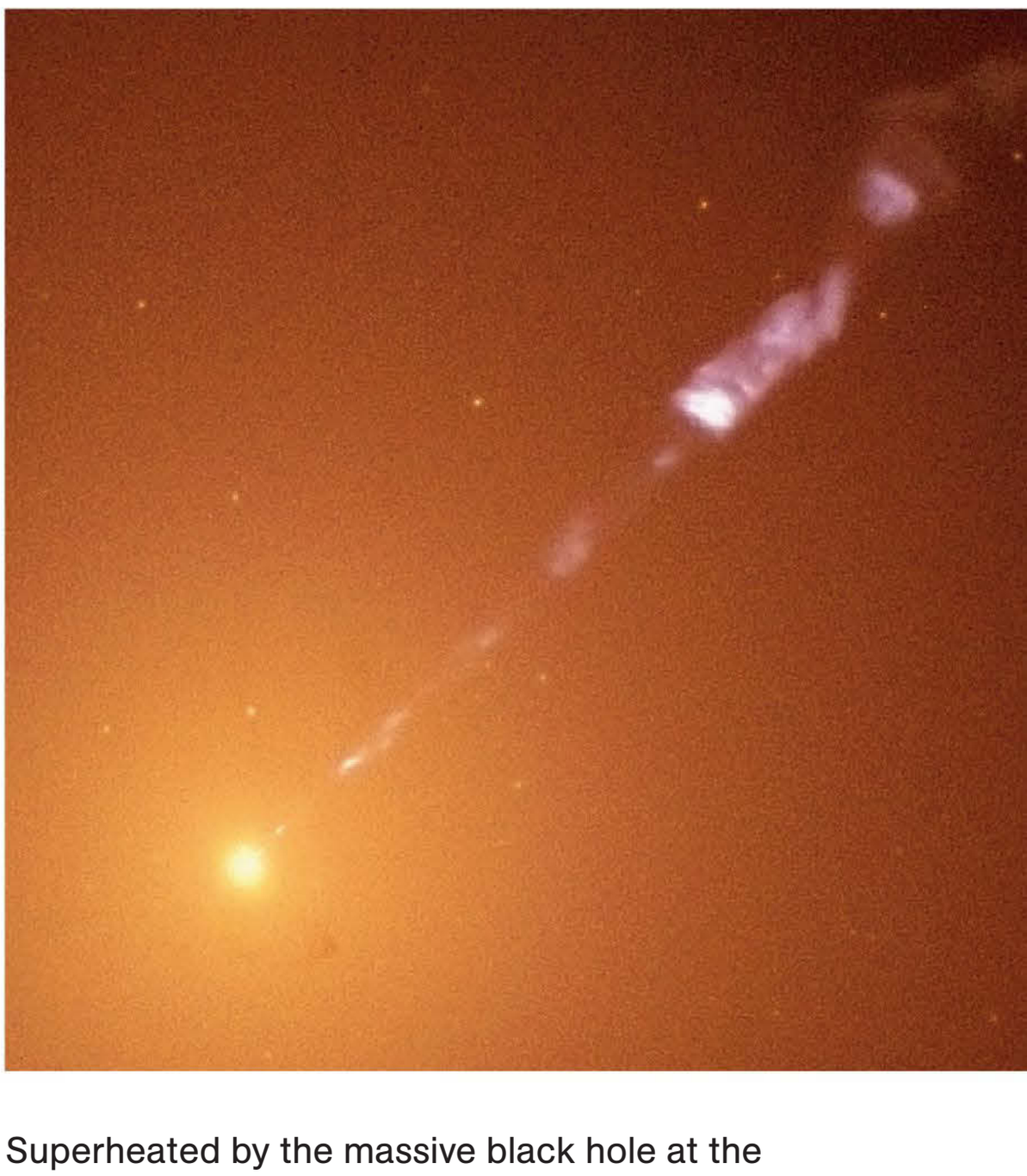
Singularities are imagined to be extremely tiny. Beyond tiny: Enlarge a singularity a trillion trillion times, and the world's most powerful microscope wouldn't come close to seeing it. But *something* is there, at least in a mathematical sense. Something not just small but also unimaginably heavy. Don't bother wondering what. The vast majority of physicists say, yes, black holes exist, but they are the ultimate Fort Knox. They're impenetrable. We will never know what's inside a singularity.

But a couple of unorthodox thinkers beg to differ. In recent years it's become increasingly accepted among theoretical physicists that our universe is not all there is. We live, rather, in what's known as the multiverse—a vast collection of universes, each a separate bubble in the Swiss cheese of reality. This is all highly speculative, but it's possible that to give birth to a new universe you first need to take a bunch of matter from an existing universe, crunch it down, and seal it off.

Sound familiar? We do know, after all, what became of at least one singularity. Our universe began, 13.8 billion years ago, in a tremendous big bang. The moment before, everything was packed into an infinitesimally small, massively dense speck—a singularity. Perhaps the multiverse works something like an oak tree. Once in a while an acorn is dropped, falls into the ideal soil, and abruptly sprouts. So too with a singularity, the seed of a new universe. And like a sapling oak, we'll never send a thank-you note to our mother. For the message to escape our universe, it would have to move faster than the speed of light. Again, sound familiar?

The evidence for what could reside in a black hole is compelling. Look to your left, look to your right. Pinch yourself. A black hole might have originated in another universe. But we may be living in it.

BLACK HOLES ARE BASICALLY TIME MACHINES.



Superheated by the massive black hole at the center of galaxy M87, a jet of gas shoots out across several thousand light-years.

NASA/HUBBLE HERITAGE TEAM

Tune in to the National Geographic Channel on March 10 for the series premiere of *Cosmos: A SpaceTime Odyssey.*

Horses forever changed life on the Great Plains. They allowed tribes to hunt more buffalo than ever before. They tipped the balance of power in favor of mounted warriors. And they became prized as wealth. For Native Americans today, horses endure as an emblem of tradition and a source of pride, pageantry, and healing.

PEOPLE OF THE HORSE

ZODA, WHOSE NAME MEANS “GRAY” IN HIDATSA, SERVES IN A YOUTH WELLNESS PROGRAM IN NORTH DAKOTA.

Destiny Buck, of the Wanapum tribe, rides her mare, Daisy, in the yearly Indian princess competition in Pendleton, Oregon. Embraced first for war, hunting, and transport, horses became partners in pageantry and a way to show tribal pride.

Nakia Williamson rides a cross between an Appaloosa and the hardy Akhal-Teke from Turkmenistan, one of the world's oldest breeds, renowned for courage and endurance. The horse he's leading at his home in Lapwai, Idaho, is his full Appaloosa.

BY DAVID QUAMMEN PHOTOGRAPHS BY ERIKA LARSEN

In September 1874, in the panhandle of Texas, the great Comanche equestrian empire came to an ugly and sorrowful end. This event boded deep changes on the Great Plains, because the Comanche had been among the first tribes, and the most successful, to adopt the horse after its arrival with Spanish conquistadores. They had become proficient, expert, ferocious, and even lordly as horseback warriors, terrorizing their Indian neighbors, making wrathful assaults to stem the trend of white settlement and buffalo slaughter, and eventually bedeviling the U.S. Army. And then, on September 28, 1874, the largest remaining body of Comanche fighters (along with a number of Kiowa and Cheyenne allies) was caught, amid their tepees, with their families, in an undefended bivouac at a place called Palo Duro Canyon.

The attack was executed by the Fourth Cavalry under Col. Ranald Slidell Mackenzie, serving out of Fort Concho, in West Texas. Having surprised the Comanche and others and driven them from their encampment, Mackenzie's men burned the tepees, destroyed the stockpiled food and blankets, and regrouped on the canyon rim with more than a thousand captured horses. The Indians had fled on foot. Mackenzie marched his troops back to their camp, 20 miles away, and there on the following morning he ordered all the horses, except a few hundred spared for use, shot. "The infantry roped the crazed horses and led them into firing squads," according to S. C. Gwynne's book on the Comanche, *Empire of the Summer Moon*. "The result was a massive pile of dead horses"—1,048, the records say. They rotted there, and their bones bleached for years, "a grotesque monument marking the end of the horse tribes' dominion on the plains." Some remnant of the Comanche, led by their great war chief Quanah Parker, walked 200 miles east to Fort Sill, in what was then Indian Territory, and surrendered.

Almost a century and a half later, a historian of the Comanche named Towana Spivey, himself of Chickasaw lineage, sat in the front yard of his home in Duncan, Oklahoma, and recounted these events to me. With the slaughter of the horse, he said, "the backbone of the resistance" was shattered. All their buffalo robes, all their food, their tools of survival, their means of transport and war fighting and nomadic mobility—gone. Quanah himself in custody. "It was a dramatic blow for the Comanches."

That's the famously grim story of Palo Duro, but the reality, Spivey explained, was worse. "We hear about that huge kill-off and the impact it had in Palo Duro Canyon," Spivey said. What we don't hear, he added, is that by June 1875, the Army had gathered another 6,000 to 7,000 Comanche horses back at Fort Sill. Colonel Mackenzie was now the commander there, and following guidance from Gen. Philip Sheridan, on the logic that these animals were too expensive to feed and too valuable to release, he ordered them also killed. His men took the horses to a place called Mackenzie Hill and began shooting them, using single-shot Springfield rifles, Sharps rifles, and

Woodrow "Woody" Teton of the Shoshone-Bannock Tribes, astride Little Joe, heads for an elk hunt on the Fort Hall Reservation in Idaho. Horses and rifles together transformed native cultures during the 19th century. Quarter horses like Little Joe are a breed valued for cattle work and hunting.

seven-shot Spencer repeaters. "Shooting horse after horse became a major problem," Spivey said. It was wasteful, clumsy, absurd. Finally, to save labor and ammunition, an auction was held. Comanche ponies went to white bidders. When that didn't entirely clear the corrals, the shooting resumed.

THESE TWO SLAUGHTERS of 1874 and 1875, crushing the Comanche resistance, did not finish the story of horses among Native American people. They were only the end of the beginning. Other tribes had mounted up. From the southern plains, this new animal, this new technology, this new way of hunting and fighting and traveling, had spread northward, from the Comanche and the Jumano and the Apache and the Navajo to the Pawnee, the Cheyenne, the Lakota, the Crow, and more. Not every tribe embraced it fully. The Mandan traded horses through their agricultural villages on the upper Missouri but never took to the equestrian life themselves. Is that one reason the Mandan were virtually wiped out by smallpox, a disease more devastating to sedentary communities than to nomads? Some historians think so.

Horses had opened new possibilities. They allowed men to hunt buffalo more productively than ever before, to range farther, to make devastating raids against other tribes. They relieved women of some onerous duties, such as lugging possessions from camp to camp. They tipped the balance, in population growth and territorial expansion, between hunting tribes and farming tribes, favoring the former. They also replaced the only previously domesticated animal in North America, the dog, which was much smaller and weaker and had to be fed meat. A horse could live off the land, eating what people and dogs didn't want: grass. When drought or winter snows made grass unavailable, it could even survive on cottonwood bark.

David Quammen's award-winning book Spillover *examines diseases passed from animals to humans. Erika Larsen photographed Garrison Keillor's "Personal Geography" in the February issue.*

The new animals were so prized that they began to fill a more abstract cultural role: as accrued wealth. If a man was savvy, ambitious, and lucky, he could amass a large herd; his excess horses could then be sold or traded or given away (in exchange for heightened prestige) or, if he let his guard down, stolen. Accrued wealth ushered in social stratification, and for the first time on the Plains there were rich Indians and poor Indians. Along with that novelty had come another: the acquisition of firearms from white traders, often in barter for beaver pelts, buffalo robes, or horses. These were momentous changes, bringing glorious highs and inglorious side effects, including the overharvest of buffalo even before market hunters arrived. Horsemanship also led to new severities of intertribal warfare as well as to resistance against white settlers and the Army, and eventually toward the sad endings at sites such as Palo Duro Canyon, the Bear Paw Mountains in Montana (where Chief Joseph's Nez Perce were attacked as they tried to escape to Canada), and Wounded Knee in South Dakota.

The negative aspects of the horse revolution have passed into history, but horses remain vastly important to many Native Americans, especially the Plains tribes, as objects of pride, as tokens of tradition, and for the ancient values they help channel into a difficult present: pageantry, discipline, prowess, concern for other living creatures, and the passing of skills across generations.

THE PENDLETON ROUND-UP is a big-league, all-comers rodeo held each September in Pendleton, Oregon, not far from the Umatilla Indian Reservation. It includes a war dance competition and several Indian relay race events, as well as a nightly show called the Happy Canyon pageant. It begins with a grand parade through town presenting Indian riders in full regalia, and a ride-in to the arena led by local chiefs, followed by the resplendently attired young girls of the Indian court. In a trailer back by the corrals, a 50-ish woman named Toni Minthorn, official chaperone to the court, stitched repairs on the soft buckskin cover of a ceremonial saddle while

describing to me her sense of mission. "My goal is to get princesses back on horses," she said.

Toni's mother had been a Happy Canyon princess in 1955, then Toni herself in 1978. Before that, she had grown up as a sort of equestrian tomboy, skijoring on sleds behind the family horses, jousting with hemlock spears, roughhousing on horseback with her brother and three sisters. Where did she get her riding skills? "I was born with 'em."

Toni continued multitasking as she spoke, sewing the saddle, giving style and makeup advice to this girl or that, issuing further instructions through her Bluetooth. Her family home during childhood, in a little place called Spring Hollow, hadn't included modern comforts or toys for the kids, although there was plenty of venison and elk. Little Toni didn't have a doll. When her classmates at school heard that, they pitied her corrosively. You don't have a doll? "I felt like I was the poorest kid who ever walked the Earth." What do you do? they asked. We ride. Your family has horses? Yeah, she told them, 47 head. You have 47 horses? You must be rich! "And I didn't feel poor anymore."

ANOTHER IMPORTANT CONCLAVE is Crow Fair, held during mid-August in Crow Agency, Montana, attracting competitors from Pine Ridge in South Dakota, Fort Hall in Idaho, and elsewhere. On the hot afternoon I arrived, the organizers were bustling, the crowd was large and merry. A baritone announcer welcomed us to this year's installment of the Crow Nation's "all-Indian rodeo" and its attendant encampment, proudly styled as the "Teepee Capital of the World." The program would include track races at five furlongs, sprint races, bull riding, saddle bronc, team roping, ladies' breakaway (women's calf roping), and one magnificently wild enterprise, the Indian Relay, touted as "the most exciting five minutes in Indian Country." On a given day those five minutes might only be three, not counting time spent catching runaway horses and collecting fallen contestants out of the dirt.

The Indian Relay is a team competition, each team comprising one rider, three horses, and three courageous comrades to hold, catch, and control the two extra horses as the rider leaps from one to another, making a single circuit of the track on each. None of the horses is saddled. With at least five teams in each heat working to execute these bareback transfers, stopping horses from full gallop and starting others, all within a crowded stretch of track, the Indian Relay can get messy. But when it's not messy, it's sublime.

An adroit relay rider can pull one horse up short, slide off, take a few running strides, swing up onto the next horse, grab the reins, and gallop away. A team that makes three such transfers smoothly might win the relay by ten lengths, no matter who has the fastest horses. But that's the ideal race. In the first heat I saw at Crow Fair, two riders bumped on the back stretch and fell, one remained down, and the announcer called for an ambulance to go out. "This is a tough business," he said, his emollient voice sounding unapologetic. "Only the toughest Indians are involved. If it were easy, choirboys would do it."

Later I talked with Thorton (they call him "Tee") Big Hair, a burly but gentle-spirited young man who was serving as racing commissioner for that year's Crow Fair. He wore a blue T-shirt, a straw cowboy hat, and a world champion belt buckle for Indian Relay, won in Sheridan, Wyoming. Too big to be a rider, Tee was the current "world champion catcher," he bragged mildly, and had been knocked down by the arriving horse, aw, who knows how many times. Right now he was jubilantly energized (and, I suspect, relieved) by how well the day's races had gone, and he assured me that the two fallen riders were

A HORSE COULD LIVE OFF THE LAND, EATING WHAT PEOPLE AND DOGS DIDN'T WANT: GRASS.

APSÁALOOKE (CROW) HORSE MASK, CA 1860, MONTANA

DEBORAH MAGEE (AMSKAPI PIKUNI), BLACKFEET HORSE MASK, 2008, MONTANA

Elaborate horse masks, impractical in battle, were, and still are, used for parades and memorial processions. An Appaloosa named Harley (left) models a Cayuse mask from the late 1800s. Above, clockwise from left: Masks, antique and modern, may incorporate ermine hide fringing and buffalo horns; ermine, brass bells, and porcupine quillwork; buffalo hide and horn and grouse and eagle feathers; wool cloth, flicker feathers, glass beads, and dyed horsehair.

NEZ PERCE HORSE MASK, 1875-1900, IDAHO OR WASHINGTON

LAKOTA HORSE MASK, CIRCA 1860, NORTH OR SOUTH DAKOTA

ABOVE, CLOCKWISE FROM TOP LEFT: WALTER LARRIMORE, 9/9831, NATIONAL MUSEUM OF THE AMERICAN INDIAN, SMITHSONIAN INSTITUTION; ERNEST AMOROSO, 26/7200, NATIONAL MUSEUM OF THE AMERICAN INDIAN, SMITHSONIAN INSTITUTION; WALTER LARRIMORE, 11/4898, NATIONAL MUSEUM OF THE AMERICAN INDIAN, SMITHSONIAN INSTITUTION; JOHN BIGELOW TAYLOR, T0097, EUGENE AND CLARE THAW COLLECTION, FENIMORE ART MUSEUM, COOPERSTOWN, NEW YORK. OPPOSITE (MASK): TAMÁSTSLIKT CULTURAL INSTITUTE, 1996.016.0001, PENDLETON, OREGON

Horses came to California with Spanish missionaries and traders.

Spanish horses captured in the 1680 Pueblo Revolt were traded to other tribes, helping the horse move north.

Approximate route and arrival of horses

Apache Tribal location at time of contact with horses

1700s

AMERICAN ORIGINALS

The Nez Perce tribe nurtured the spotted Appaloosa; saddlebreds sprang from the southern U.S. The versatile quarter horse spread from east to west and is called the first all-American breed.

1600s

INTO THE MIX

In the effort to create new American breeds, colonists often turned to the Canadian horse—sent to Quebec from France and known for its strength—and later to the swift English Thoroughbred.

EARLY INDIAN BREEDS

In the 1600s southeastern tribes became adept at crossbreeding Spanish horses for key traits: The marsh tacky was agile in swamps; the Choctaw's stamina served well in farm fields and on trade routes.

Continuing today

American quarter horse

Saddlebred

Appaloosa

Marsh tacky

Canadian

Choctaw

English Thoroughbred

Sulphur

SPANISH MUSTANG

Some 30,000 wild horses now roam the West. With striping on their legs, Utah's Sulphurs still have the look of a primitive breed.

RETURN OF A NATIVE

The horse originated in North America nearly two million years ago and spread to Eurasia over the Bering land bridge. Then, about 10,000 B.C., horses vanished from the New World, possibly killed for food by humans who had come to the continent from Eurasia. When the horse returned with European conquistadores and colonists (map), it transformed the culture of many tribes. In turn, Native Americans and settlers changed the horse, developing new breeds from Old World stock (bottom).

1493-1500s

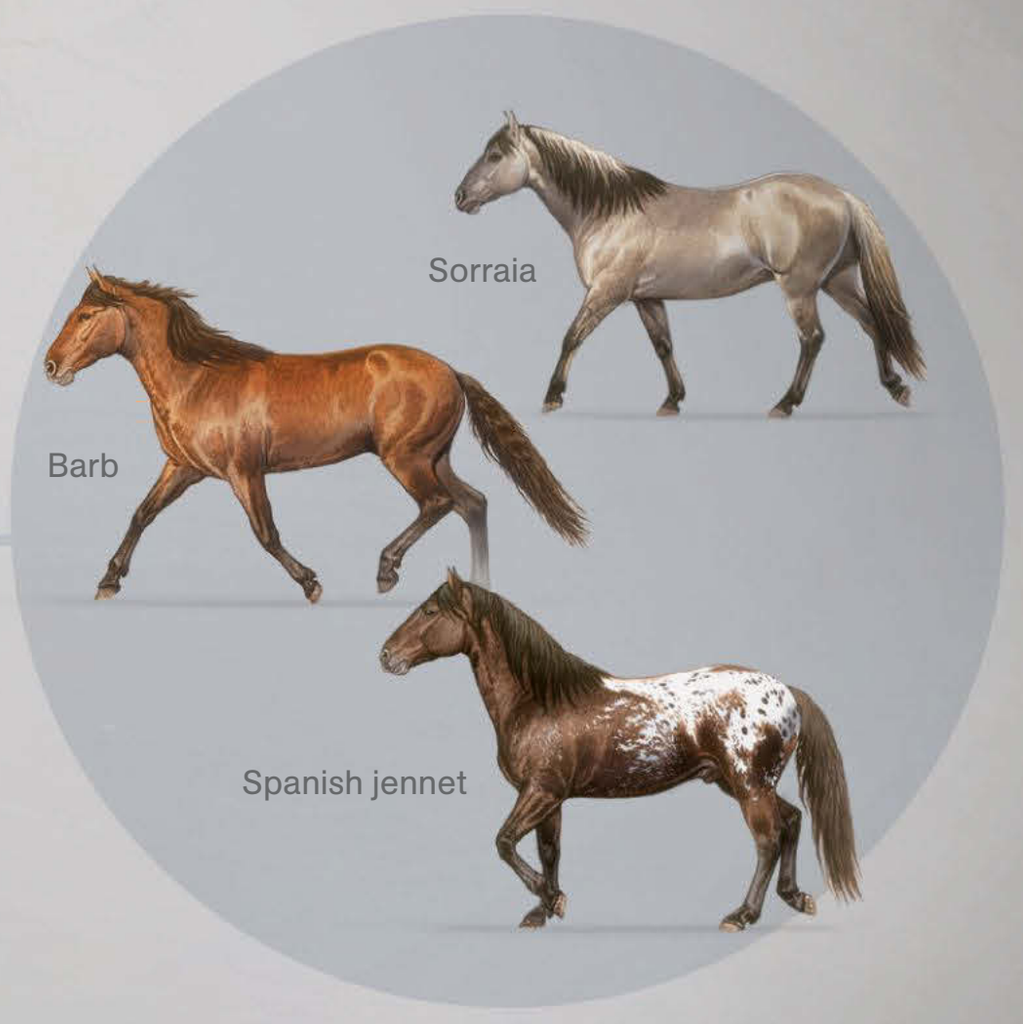
COLONIAL SPANISH
Expeditions carried a variety of Iberian breeds to the Caribbean. As the herds grew, Spaniards seeking gold and glory took horses to mainland North America. The first to do so: Hernán Cortés in 1519.

DOMESTICATED

By 1529 so many horses had escaped that Mexican cattlemen set rules for capturing and branding the runaways, which came to be called mustangs, from the medieval Spanish word *mestengo,* for "stray."

WILD

Old World stock



FERNANDO G. BAPTISTA AND MATTHEW TWOMBLY, NGM STAFF; PATRICIA HEALY; DEBBIE GIBBONS, NG STAFF (MAP). ALDO CHIAPPE (HORSE ART). SOURCES: EMIL HER MANY HORSES, NATIONAL MUSEUM OF THE AMERICAN INDIAN; PHILLIP SPONENBERG, VIRGINIA TECH; JEANETTE BERANGER, LIVESTOCK CONSERVANCY

OK. Horse racing ran strongly in Tee Big Hair's blood, I learned from conversations with him and his family over the course of a couple days. His uncle Henry "Hank" Rides Horse, Jr., for instance, trained horses all over the state for racing. His uncle Byron Bad Bear raised sorrel paints.

Dennis Big Hair, Tee's father, a 71-year-old patriarch, wore his hair short-cropped beneath his white Resistol, his sizable belly belying his own early history as a skinny young racer. I sat with him in the stables area, near the biscuits-and-gravy stand run by his wife. At age 14, Dennis told me, he'd won the Crow Indian Derby, among the oldest of traditional Crow races. He won a Governor's Handicap around the same time, and yes, he also rode Indian Relay. Weighed about 99 pounds then, Dennis recalled wistfully, compared to about 250 now, and his trick was to ride right up close to the next horse, bounce off, take two strides, hop onto the next from behind, and be off. Like in the movies. It was fast. Nobody does that nowadays, he said with a touch of curmudgeonly disdain. That and raiding (surreptitiously stealing horses from other tribes) were two fine old traditions, fallen away.

Part of the somber context of Crow Fair is that it's held just two miles from the Little Bighorn Battlefield, where a memorial to Indian warriors in that battle graces a knob just below Last Stand Hill. At the Indian memorial there are paintings, a roster of the fallen, and inscriptions, including a nostalgic quote from Sitting Bull: "When I was a boy the Lakota owned the world. The sun rose and set on their lands. They sent 10,000 horsemen to battle." Before the program begins down at the rodeo grounds, or during a lull, you can sneak up and see the spot where the brash Colonel Custer got himself killed.

The dark memory of Little Bighorn seems forgotten once events in the arena begin. But there still can be somber moments. On the afternoon following my chat with Tee Big Hair, a Thoroughbred named Ollie's Offspring broke its leg at the shin, from sheer effort, just 20 yards short of winning the last race, and a collective groan of dismay went up from the grandstand. The horse had to be shot, before 5,000 people, and dragged away by tractor.

When I spoke again with Tee the next morning, he seemed shaken. "It hurt my heart," he said. His dad had advised him to view it philosophically, in the Crow way: When a death like that happens, the unlucky horse is taking some person's place. Someone in the family needs help, and the horse's death moves that person closer toward finding what's needed. But that's hard to accept, Tee told me, because of his feelings for these animals and what they do. He clasped a fist to his chest. "It's true love, that's it. You take care of your horse."

SOME RIDERS PRAY IN A SWEAT LODGE BEFORE THE RACE. OTHERS WEAR HELMETS AND HOPE FOR THE BEST.

INDIAN RELAY isn't the only event that echoes the rough-and-tumble horse skills of the Native American past. At the Omak Stampede, held in Omak, Washington, adjacent to the Colville Indian Reservation, the finale each night is a heat of the famous (in some circles, infamous) Suicide Race. Dreamed up by a white publicist in 1935, the Suicide Race has its roots in old endurance races. This equestrian melee is open to anyone crazy enough to ride a horse over a steep plunge—down a 62-degree slope, which for a horse might as well be a cliff—into the Okanogan River.

Some riders pray in a sweat lodge before the Suicide Race or decorate their horses with eagle feathers. Others just wear helmets and life jackets and hope for the best. More than a dozen horses hit the water at nearly the same instant, swim the depths, clamber up the far bank, and gallop into the rodeo arena toward a finish line under the lights, by which point their riders—at least the most skilled and the luckiest—are

drenched but still aboard. The Humane Society deplores this spectacle because in the past several decades more than 20 horses have died. Horses die in conventional races too, as I saw at Crow Fair. On the night I watched the Suicide Race, one horse and one rider were injured, but there were no fatalities.

The official race veterinarian, Dan DeWeert, had his own perspective: "This is a great race, when I don't have to do anything."

The next afternoon I fell into conversation with an amiable, gray-haired woman named Matilda "Tillie" Timentwa Gorr at her beads-and-weaving booth in the Indian encampment. With the drumming of the powwow throbbing in our ears, she told me a bit about her family. They were horse people, going back at least to her grandfather, Chief Louie Timentwa, a breeder and dealer who'd kept 300 head. Many of those horses had been gathered as mustangs from the mountains round about. When her father was a young man, Tillie recollected, her Grandpa Louie would send him out with this instruction: Don't come home on the same horse. "And he never did," she said. Her dad would lasso a mustang, blindfold it, hobble it, and get a saddle on. Then he'd free the hobble, jump aboard, pull off the blindfold, hang tight through the bucking, and eventually ride that mustang home. His own horse would follow on its own.

But horse skills weren't confined to the male side of the family. Tillie's daughter Kathy rode the Suicide Race the year she turned 18, no longer needing parental consent. She had a bad ride, Tillie explained: Got hit from behind, the horse tumbled, Kathy broke her leg, and the horse had to be put down. Tillie never let her ride the race again.

Another keeper of cultural memory was Mary Marchand, a forceful octogenarian matriarch with 211 descendants, and an elder of the Colville Confederated Tribes. Mary and one of her sons, an urbane man named Randy Lewis, visiting from Seattle in braids and turquoise, relaxed with me in folding chairs overlooking the Suicide Race chute as we talked of the old days. Mary has since died, mourned by many, but that day she was keen and lively, wearing a blue brocade blouse, a necklace of beads and carved elk horn, and a visor in lavender reading "Harvard." By her recollection, the old endurance races would cover maybe five miles through the mountains, with riders jumping their horses over boulders and logs, charging downhill, sometimes swimming a river. Those were "flint hoof" horses, Randy said, descended from mustangs, born and conditioned to run unshod across rock. There was no prize money for such a race, Mary explained. The winner got first pick from a barrel of salmon.

How far back, I asked, do those races go?

"Oh, boy…," she said, momentarily adrift in time and memory.

So Randy spoke up: "Since horses."

THE CUSTOMS may be tribal, but there's an extra passion for these animals that seems to flow like lifeblood through certain families. Tee Big Hair's extended clan is one instance. Another came to my attention by way of a young Blackfeet woman named Johnna Laplant. She's a racer from Browning, Montana, tall and graceful enough to star in basketball. My first glimpse of her was at the Pendleton Round-Up. She wore blue colors and rode a dark brown Thoroughbred gelding in the Ladies' Race, which is a bareback and Indian-dominated event. She rode fiercely and won.

Then came the trouble. A fallen rider, a riderless horse, outriders chasing it down, lariats whirling—all of which made it difficult for her and several others to stop their horses after the finish. With outriders pursuing, Johnna's horse got confused and just kept racing. Meanwhile another young woman, small, aboard a bay Thoroughbred, let her horse get turned backward and start galloping the wrong way around the track. Worse still, she was on the rail, not on the outside where a reversed horse should be. We could all see what was coming, thousands of us in the stands, thinking, no…no…no…until it happened. The bay dodged one oncoming horse and ran head-on into Johnna's gelding. She flew through the air. Both horses, and the other woman, also went down. Johnna stayed down. The gelding scrambled up, but clumsily, putting

Jones Benally received this gelding, Moonwalker, pictured here just outside the Navajo Nation in Arizona, from a patient for his services as a medicine man. By tribal tradition, lightning is thought to be the spark of all creation.

Spur White Clay shows off his stunt-riding skills to his siblings at his home on the Crow Reservation in Montana. For many Native American children, horses are more familiar than bicycles. Some kids start with miniature horses, fashionable among the Crow.

Jim, a quarter horse stallion, is a gift from bride Krystal Alden's family to groom Paul J. Hill, here in their hometown of Lame Deer, Montana. When a Cheyenne woman gets married, tradition calls for the husband to receive a steed to help him hunt and provide for the family.

no weight on its right front leg, which seemed to be broken. They took Johnna off on a stretcher.

Many months afterward, I met Johnna in Missoula, Montana, and she told me that the brown gelding had survived. His leg hadn't been broken after all; it was just a muscle injury, from which he slowly recovered. As for her: a concussion and a cut scalp, under her hair in the back where a horse stepped on her head, and lots of blood. But now she was fine and had been racing over the recent summer. She had won the Ladies' Race again at Pendleton. And she'd been serving as a holder on the relay team of her cousin, a fellow named Narsis Reevis.

Narsis, 30, another lanky equestrian athlete, was a key part of Johnna's whole story. He had been there when she fell at Pendleton, one of the first to reach her. He had shaken that off, when he knew she wasn't badly injured, and ridden to victory in the Indian Relay himself. He was a masterful relay rider, whose height allowed him to use the same technique as old Dennis Big Hair: leaping onto the new mount over its behind. Johnna had grown up in the same household as Narsis, and more like a big brother than a cousin, he had taught her to ride. "Narsis was always around," she said. "If it wasn't for him, I wouldn't know a thing about horses."

I visited Narsis up in Browning, a reservation town just east of Glacier National Park. He told me about his grandfather, an old working cowboy named Lloyd "Curly" Reevis, who had welcomed Narsis around the corral when he was a tot. Curly had done rodeo in his day, especially as a roper. "That's all I grew up on, was good rope horses," Narsis said. "A lot of speed, and good rein on them." His uncles Steve and Tim Reevis had also been there, fine riders, helping the little kid learn. Steve later did stunt riding in the movie *Dances With Wolves*, and Tim worked for nine years in a Wild West Show at Euro Disney. But it was Curly, the grandfather, who held this eclectic mix of influences together.

Curly Reevis was a dignified 79-year-old of sturdy physique the day I met him, wearing a black cowboy hat and a black jacket, with deep wrinkles and long ears and a flash of sly wit in his eyes. He took off the hat, leaned forward over his elbows on a cluttered desk, and told me a bit about Reevis family history. First thing to know: The lineage is half French (maybe "Riveaux") and half Southern Blackfeet. Second thing to know: horses. "We had horses all over," he said of his own childhood. Horses in the corral, horses running wild; go up on a hill, look around, and you saw horses. Curly's granddad owned a passel. His father and uncles purveyed bucking horses to the local rodeos—simple events, you showed up on Sunday and tried to ride the broncs. "On the reservation, that was our life," he said.

That was their life: family and horses. It echoed what Toni Minthorn had said, at Pendleton, about the poor little girl with no doll but 47 horses. And it gave context to—it placed in time—something that Curly's great-granddaughter Johnna told me. Just as Narsis had taught Johnna to ride, and Uncles Tim and Steve had taught Narsis, and someone had taught Curly, or at least allowed him to teach himself, so Johnna was now teaching her young cousins. Reservation girls of six and eight, older boys, showing new confidence and blossoming talent on horseback, with tutelage from a homegrown hero, the tall girl-cousin who has won twice at Pendleton. It may not be an eternal chain of connectedness, but it's a precious one.

You embrace skills and a passion that have come down from your ancestors; you learn the skills from your elders and make the passion your own; you become proficient, then expert, then generous with your expertise; you care for your animals smartly and lovingly; you pass the favor along to younger kin. You make your family proud and whole. That's the ultimate Indian relay. □

Brooke Taylor stands with Prairie, a registered Appaloosa, near West Yellowstone, Montana. They're taking part in an annual retracing of a portion of the 1,170-mile route Chief Joseph and the Nez Perce bands took through the northern Rockies in 1877, as they tried to escape peacefully from the Seventh Cavalry.

Call of the Bloom

Some tropical flowers reflect sound so nectar-seeking bats can find them more easily.

This flower's shape and exposed position cater to a bat's ears.

PLANT: *CRESCENTIA CUJETE*
BAT: *GLOSSOPHAGA COMMISSARISI*

***WERAUHIA GLADIOLIFLORA* RANGE**
ALL MAP DATA: TROPICOS

Merlin Tuttle filleted this flower to document the bat's tongue siphoning nectar as the flower's anthers stamp its forehead with pollen. He photographed wild bats in temporary cages.

PLANT: *WERAUHIA GLADIOLIFLORA*
BAT: *LONCHOPHYLLA ROBUSTA*

By Susan McGrath
Photographs by Merlin D. Tuttle

Nature's inventiveness knows no bounds.

Consider the case of the nectar-drinking bat and the night-flowering vine whose lives intertwine in the lowland tropical forests of Central America.

Glossophaga commissarisi, a tiny, winged mammal with a body no bigger than your thumb, flits among the flowers of *Mucuna holtonii,* lapping nectar, much as hummingbirds and bumblebees do. In exchange it pollinates the plant. In daylight flowers can flaunt their wares with bright colors such as scarlet and fuchsia, but at night, when even the brightest hues pale to a moonlit silver, *Mucuna* flowers resort to sound to catch the ear of nectar bats.

At La Selva Biological Station in northern Costa Rica a vigorous old *Mucuna* has woven a leafy ceiling above a forest clearing and lowered dozens of flowers into the opening on long, green stalks. The flowers dangle at staggered heights in the vaulted clearing like chandeliers in a shadowy ballroom, each palm-size inflorescence a whorl of pale yellow, pea-pod-shaped buds on arched stems.

At dusk the vine's buds ready themselves for bats. First the topmost, greenish petal that caps a bud slowly opens vertically, to stand atop the blossom as a glossy beacon. Below the beacon petal, two tiny side petals wing apart, revealing a crack at the top of the pea pod. From this slit wafts a faint, come-hither scent of garlic, a long-distance signal that draws the *Mucuna*'s winged servants into earshot.

Bats use high-frequency sound as a tool. With their vocal cords, they bang out short, swift bursts through their nostrils or mouths, molding airwaves and interpreting the pattern changes that ricochet back to their sensitive ears. The incoming information is processed fast and continually, allowing bats to adjust their course in mid-flight as they streak through the air after a mosquito or race among flowering trees.

Most bats feed on insects, and they often use powerful, long-range calls, pumped out with every upstroke of their wings. Nectar bats send gentle but very sophisticated calls, which scientists refer to as frequency modulated. These calls trade distance for detail. Most effective within 12 feet, they reflect back pictures that convey precise information about a target's size, shape, position, texture, angle, depth, and other qualities only a nectar bat can interpret.

In the darkened *Mucuna* ballroom at La Selva a beacon petal's cupped shape acts as a mirror, fielding bat calls and bouncing information back hard and clear. With eyes and ears and nose leaf trained straight on the beacon, a bat snaps onto the blossom in a high-speed embrace.

The fit is exact. The bat crams its head into the cupped opening, hooks thumbs onto the beacon's base, tucks its tail, whips its hind feet up. Braced high on the pea pod, it thrusts its snout into the garlicky opening. The bat's long tongue springs a hidden switch, exploding the pea-pod keel. As it laps deep in the flower's nectary, spring-loaded anthers burst from the keel and gild the bat's tiny rump with a spray of golden pollen.

Bang! Bang! Bang! Bang! Ten blossoms detonated and licked dry, and the bats are gone. Their high-octane metabolism and meager sugar-water diet don't allow for lingering. Each bat makes several hundred flower visits every night. *Mucuna holtonii,* with their exploding mechanism and generous snort of nectar, are among the rare flowers that warrant actual landings. (Nectar bats can empty the flowers of less lavish species in a hover lasting a mere fifth of a second.)

Susan McGrath wrote about polar bears in the July 2011 issue. Merlin Tuttle is the founder and former director of Bat Conservation International.

Echoes from this waxy, bell-shaped flower draw a pollen-dappled bat straight up from below.

THE 40 OR SO SPECIES of the subfamily Glossophaginae are the aerial elite of nectar-drinking bats. They belong to the family of New World leaf-nosed bats, native to the tropics and subtropics of the Western Hemisphere. Their fleshy nose embellishments—the eponymous nose leaves—fine-tune the bats' virtuoso echolocation calls.

Nectar bats evolved in fruitful partnership with specific families of flowering plants, a relationship biologists call chiropterophily—from Chiroptera, the mammalian order of bats, and phily, from *philia,* Greek for "love." But this is no love story. The driving force behind the bat-flower partnership is not romance but the primary business of life: survival and reproduction.

Trading nectar for pollination is a delicate transaction, one that presents plants with a quandary. It behooves night-flowering plants to be thrifty with their nectar, because well-fed bats will visit fewer flowers. But if a plant is too stingy, a bat will take its services elsewhere. Over millennia, bat-pollinated plants have evolved a neat solution: They sidestep the problem of nectar quantity (as well as quality) by investing instead in maximizing the bats' foraging efficiency.

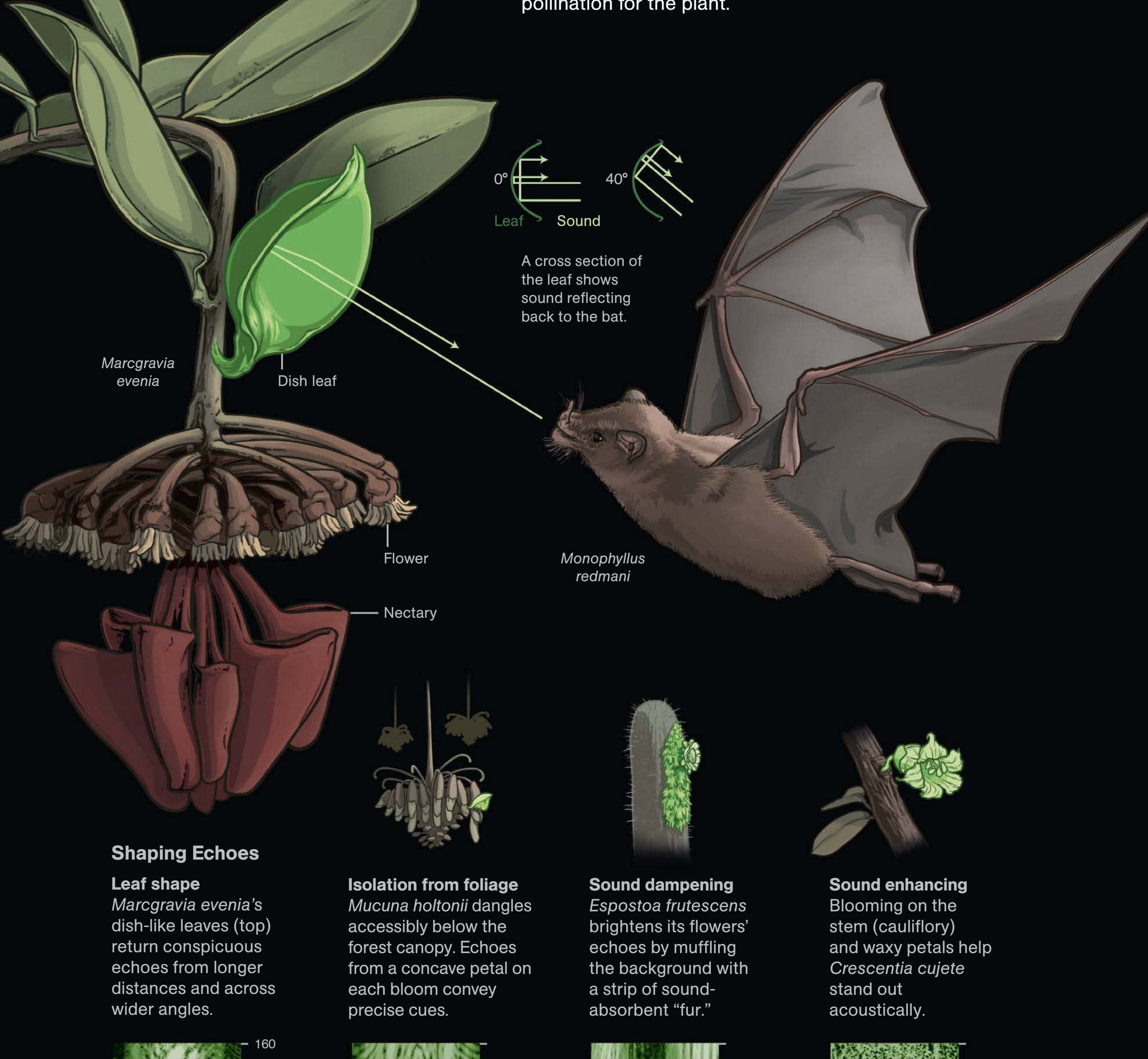
So plants that flower at night proffer their wares in exposed, fly-through positions—easy for bats to find and drink from and removed from cover for arboreal predators such as tree snakes and opossums. They spike their flowers' scent with sulfur compounds—long-distance signals irresistible to nectar bats. (But not to humans: Bat-flower perfume has been variously described as nasty; somewhat reminiscent of cabbage, kohlrabi, and garlic; and like damp, decaying leaves, sour milk, rotten urine, opossum, skunk, carcass, and corpse.) The *Mucuna* vine and certain other plants go one step further. They shape their flowers to catch a bat's ear.

UNTIL 1999 no one had any inkling that plants use shapes that reflect sound to streamline bat foraging. That year biologists Dagmar and Otto von Helversen, of the University of Erlangen in

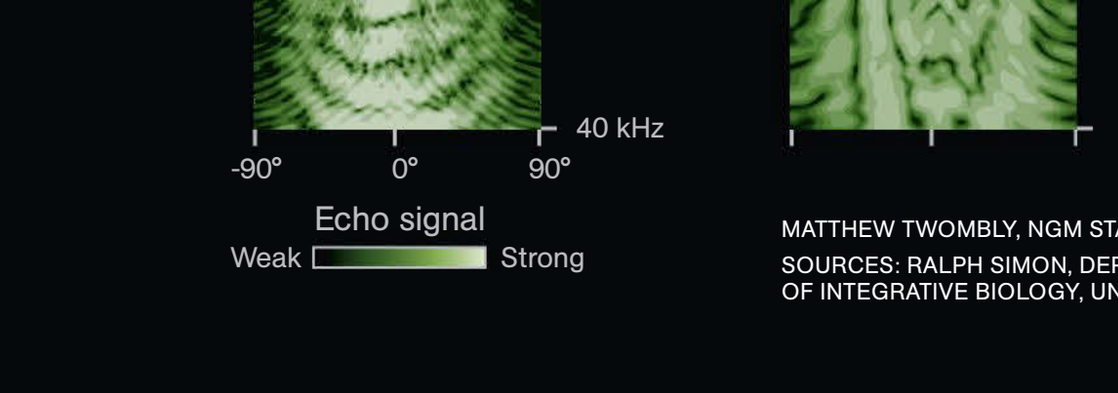
PLANT: *MERINTHOPODIUM NEURANTHUM.* BAT: *HYLONYCTERIS UNDERWOODI*

Form feeds function

Nectar bats make several hundred flower visits nightly to fuel their roaring metabolism. In the tropical forests of Central and South America, plants have found unique ways to attract bats. The flowers of these plants shape the echoes of bats' calls, providing sound cues that streamline foraging—a strategy that pays off in improved pollination for the plant.

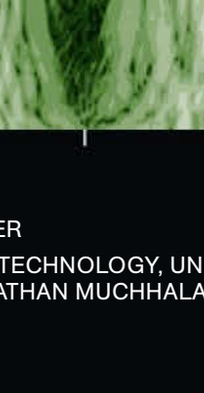


Shaping Echoes



Leaf shape
Marcgravia evenia's dish-like leaves (top) return conspicuous echoes from longer distances and across wider angles.

Isolation from foliage
Mucuna holtonii dangles accessibly below the forest canopy. Echoes from a concave petal on each bloom convey precise cues.



Sound dampening
Espostoa frutescens brightens its flowers' echoes by muffling the background with a strip of sound-absorbent "fur."

Sound enhancing
Blooming on the stem (cauliflory) and waxy petals help *Crescentia cujete* stand out acoustically.

MATTHEW TWOMBLY, NGM STAFF; MESA SCHUMACHER

SOURCES: RALPH SIMON, DEPARTMENT OF SENSOR TECHNOLOGY, UNIVERSITY OF ERLANGEN; MERLIN D. TUTTLE, DEPARTMENT OF INTEGRATIVE BIOLOGY, UNIVERSITY OF TEXAS; NATHAN MUCHHALA, UNIVERSITY OF MISSOURI–ST. LOUIS

Germany, were studying acoustics in bats at La Selva. It occurred to Dagmar that *Mucuna*'s beacon petal bore a striking resemblance to a sound beacon—a conspicuous acoustic signal, the aural equivalent of a lighthouse's beam. Field tests with modified *Mucuna* beacons clinched the theory.

The von Helversens followed their observation with a broader investigation into flower echoes, using a colony of captive bats at their lab in Erlangen. Under their supervision, Ralph Simon, an undergraduate research assistant, trained bats to drink from randomly placed nectar feeders flagged with various shapes. Rounded hollow forms proved easiest for bats to find.

Simon subsequently found such forms on flowers in nature, including one with a dish-shaped beacon he first spotted in a photo in a nature magazine. (The plump, red, nectar-containing structures on the flower had caused the editors to misidentify it as a fruit.) Intrigued, he traveled to Cuba, where the flower had been photographed. Crouched in a forest alone at night, the elated scientist watched bats drink nectar as the flower dusted them with its golden pollen, confirming his supposition.

Does a dish-shaped leaf really help bats locate a flower more easily? Back in the lab, Simon found that a replica of a dish-shaped leaf atop the feeder halved the bats' search time; a flat, unmodified leaf replica barely improved search time over an unmarked feeder.

"A normal, flat leaf just twinkles once as a pulse bounces off it," Simon explains, "but the dish-shaped leaf sends echoes back strongly, multiple times, from a pretty wide angle as the bat approaches. It's like a real beacon, because it has an echo with a unique timbre, which stands out like a colored flower in green vegetation."

By now a graduate student, Simon next built a mobile robotic bat head. He mounted a small ultrasonic speaker and two receivers in the triangle formed by a bat's nose and ears. He fired complex, frequency-modulated sounds—like those of a nectar bat—through the robotic nose at flowers attached to a rotating stand and recorded their echoes in the electronic bat ears. He thus collected the echo-acoustic "signatures" of flowers from 65 species of bat-pollinated flowering plants. Every flower Simon tested had a unique and conspicuous acoustic fingerprint.

Overall, Simon found that bat flowers share several general sound adaptations. They all have waxy surfaces that are highly sound reflective, and their sizes and shapes are remarkably consistent from specimen to specimen. Using echo fingerprints of 36 bat flowers from 12 species as a basis for comparison, Simon (Dr. Simon, by this time) wrote a program that classified 130 new flowers to species level based on sound alone. The program confirmed what the bats have long known: Some flowers speak their language.

WHY DO PLANTS INVEST so much in attracting and rewarding bats? "It's because bats are most effective pollinators," Simon says. "They're worth it."

A 2010 study by evolutionary ecologist Nathan Muchhala, of the University of Missouri–St. Louis, comparing hummingbirds and nectar bats in Ecuador found that on average bats deliver ten times the number of pollen grains their avian counterparts do. And bats carry pollen long distances too. Hummingbirds are thought to deliver pollen within a radius of about 700 feet. The longest-haul trucker among nectar bats, *Leptonycteris curasoae,* forages as far as 30 miles from its roost. For tropical forest plants, which are often widely dispersed at low densities, the bats' range confers a big advantage. This long-range pollinating is ever more important as forests become increasingly fragmented through deforestation.

It was in the 1790s that the Italian biologist Lazzaro Spallanzani was ridiculed for suggesting that bats use their ears to see in the dark. A century and a half later, in the late 1930s, scientists discovered how bats do it. Now, 75 years along, we know that in step with bats' ability to "see" with sound, plants themselves have shaped their flowers to be heard, becoming as brilliant to the bat's ear as their brightly colored daytime counterparts are to the eyes of their pollinators. In such intricate interactions, nature reveals its most profound magic. □

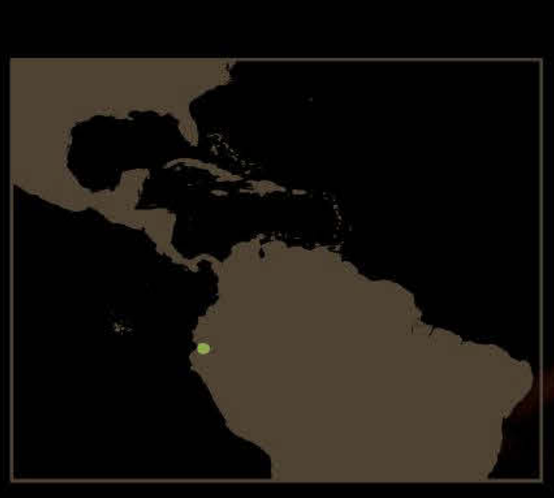
BLUE MAHOE TREE RANGE

A pollen-gilded bat emerging from a flower of the blue mahoe tree demonstrates the carrying capacity of fur. This bat lives in eastern Cuba in a colony more than one million strong—a pollinating powerhouse.

PLANT: *TALIPARITI ELATUM*
BAT: *PHYLLONYCTERIS POEYI*

A sound-deadening backdrop heightens this flower's echoes. As wildlands fall and plants become more isolated, nectar bats show their value: Some carry pollen 30 miles nightly.

PLANT: *ESPOSTOA FRUTESCENS*
BAT: *ANOURA GEOFFROYI*



OLD MAN CACTUS FLOWER RANGE

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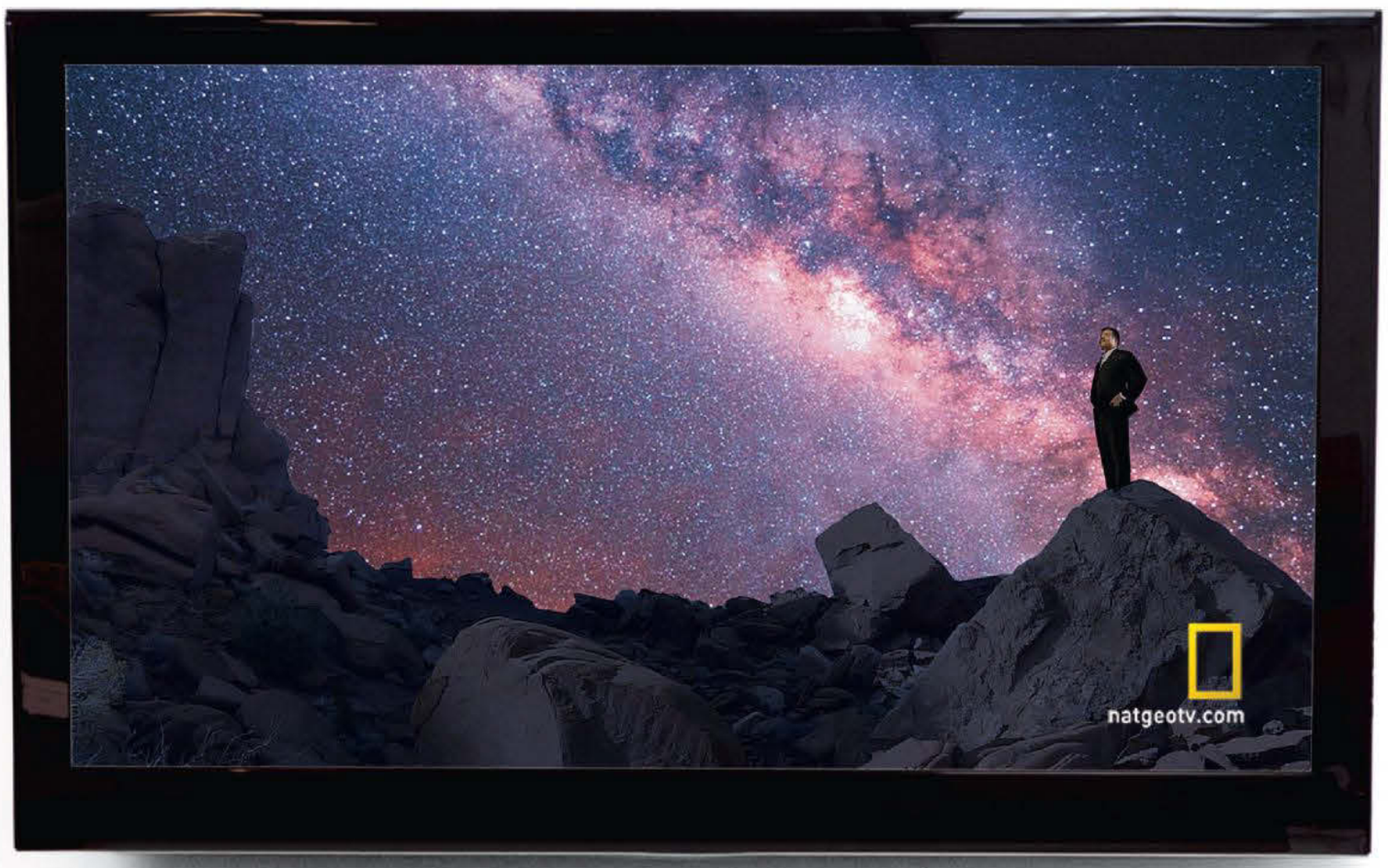


Cosmos: A Space-Time Odyssey

This month the National Geographic Channel invites you to experience the universe like never before. Hosted by astrophysicist Neil deGrasse Tyson (left), this new series draws on the latest rigorous science and pays homage to the show that inspired it, Carl Sagan's 1980 hit, *Cosmos: A Personal Voyage.*

SPECIAL EDITION

JESUS AND THE APOSTLES Christianity's first centuries are the focus of this special edition. In it you'll explore the life and times of Jesus and find profiles of the Apostles as well as an in-depth look at the Gospels. On sale March 11 on newsstands and at *shopng.com/specialeditions.*

LECTURE

STRANGER IN A STRANGE LAND Jodi Cobb has spent her career photographing secretive groups, like the geisha of Japan. Join her for a retrospective of her groundbreaking work. For dates see *nglive.org*.

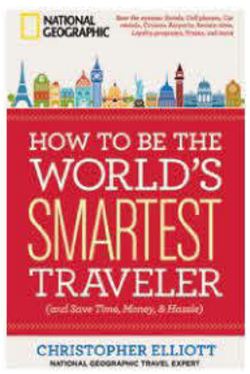
BIOBLITZ

GOLDEN GATE NATIONAL PARKS BIOBLITZ The beaches and redwood forests around San Francisco are home to a wide range of creatures. Help count them all at the BioBlitz on March 28 and 29. More at *nationalgeographic.com/bioblitz.*

MOVIE

PANDAS: THE JOURNEY HOME This new film tracks the efforts under way at China's panda conservation center in Wolong. Follow along as researchers work to help the species survive in its natural habitat. Visit *nationalgeographic.com/movies* for theater listings.

Book of the Month



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PHOTOS: SETH REED (TOP); YANG DAN

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Not Over the Hump

What's a camel doing inside a Damascus meeting hall? Photographer Andrea Bruce knows the answer. One night in the walled Old City she was taking photos of a group of five pro-government fighters. The men, part of a neighborhood guard created so the military could attend to more serious matters, had spent the evening at checkpoints inspecting cars for guns and bombs. Around midnight they headed to the hall, where they typically gather to drink tea. Eager for comic relief after the tense evening, one fighter (in foreground, below) stares into the eyes of a camel that has been brought in from a nearby stable, says Bruce, "as a joke."

It's no laughing matter for the camel. This fighter and his comrades, one of whom is seen at left, are planning to sacrifice it. Their dear friend, the owner of the hall, was detained by Syrian authorities, who accused him of storing weapons for rebel fighters. The owner was expected to be released soon; these fighters hope to celebrate the occasion by slaughtering the young camel for a feast.

Bruce spent days persuading these men and others to let her document their lives. "Suspicions run deep," she says. Nerves are frayed, friends are separated. Battle lines of flipped cars and stacked furniture divide the city from its own suburbs. "It is such a city in waiting." *—Eve Conant*

Listen to an interview with Andrea Bruce on our digital editions.

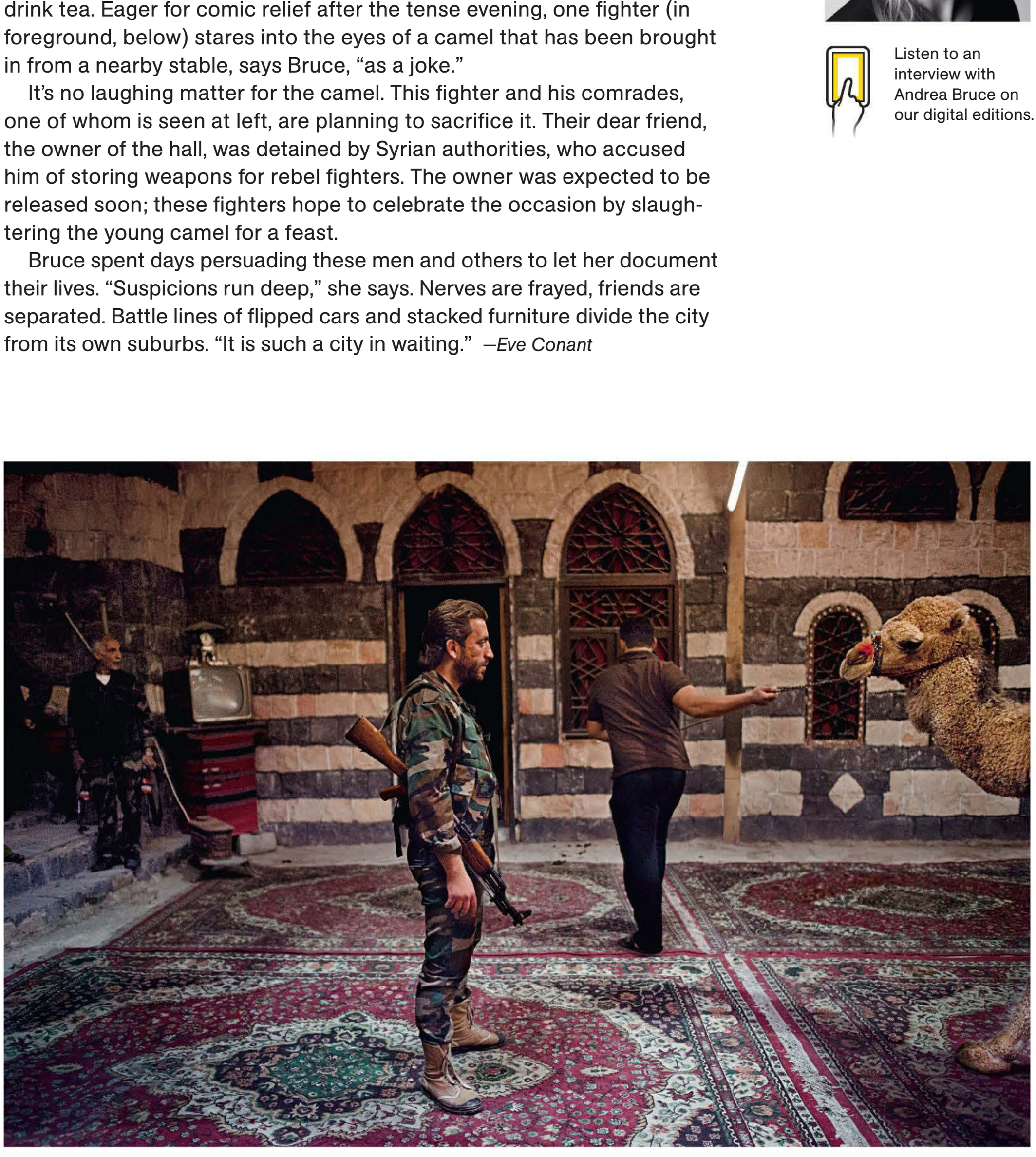

PHOTO: MARK THIESSEN, NGM STAFF (TOP)

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FOUND

Stock Tip A cattle auction draws a crowd on tiny Grimsay Island, part of the Outer Hebrides. The shaggy double coats of Highland cattle, native to Scotland, are well suited to the region's cold, wet, windy weather.

This photo first ran in *National Geographic*'s May 1970 story "Scotland's Outer Hebrides," but the magazine had made mention of the breed decades earlier. According to "The Taurine World," an article in the December 1925 *Geographic,* "Few of these cattle have found their way from the Scotch Highlands for they do not satisfactorily adjust themselves to strange conditions." Apparently they adjusted. Today many purebred Highlands live outside Scotland—an estimated 25,000 in the United States alone. The breed is especially prized for its meat, which is lower in fat and cholesterol than most other beef. *—Margaret G. Zackowitz*

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PHOTO: KENNETH MACLEISH, NATIONAL GEOGRAPHIC CREATIVE

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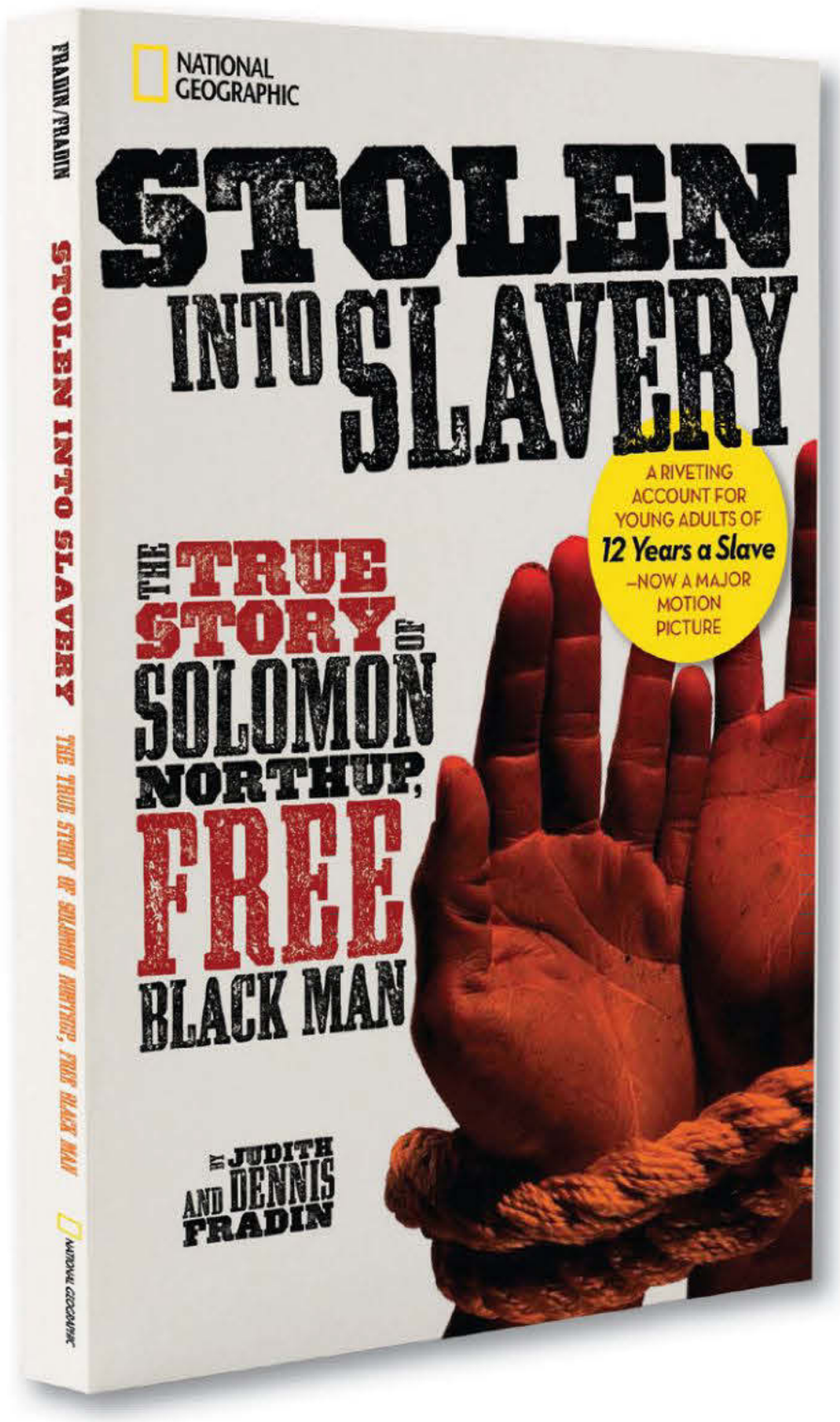
TOYOTA
Let's Go Places

CONGRATULATIONS

12 Years a Slave

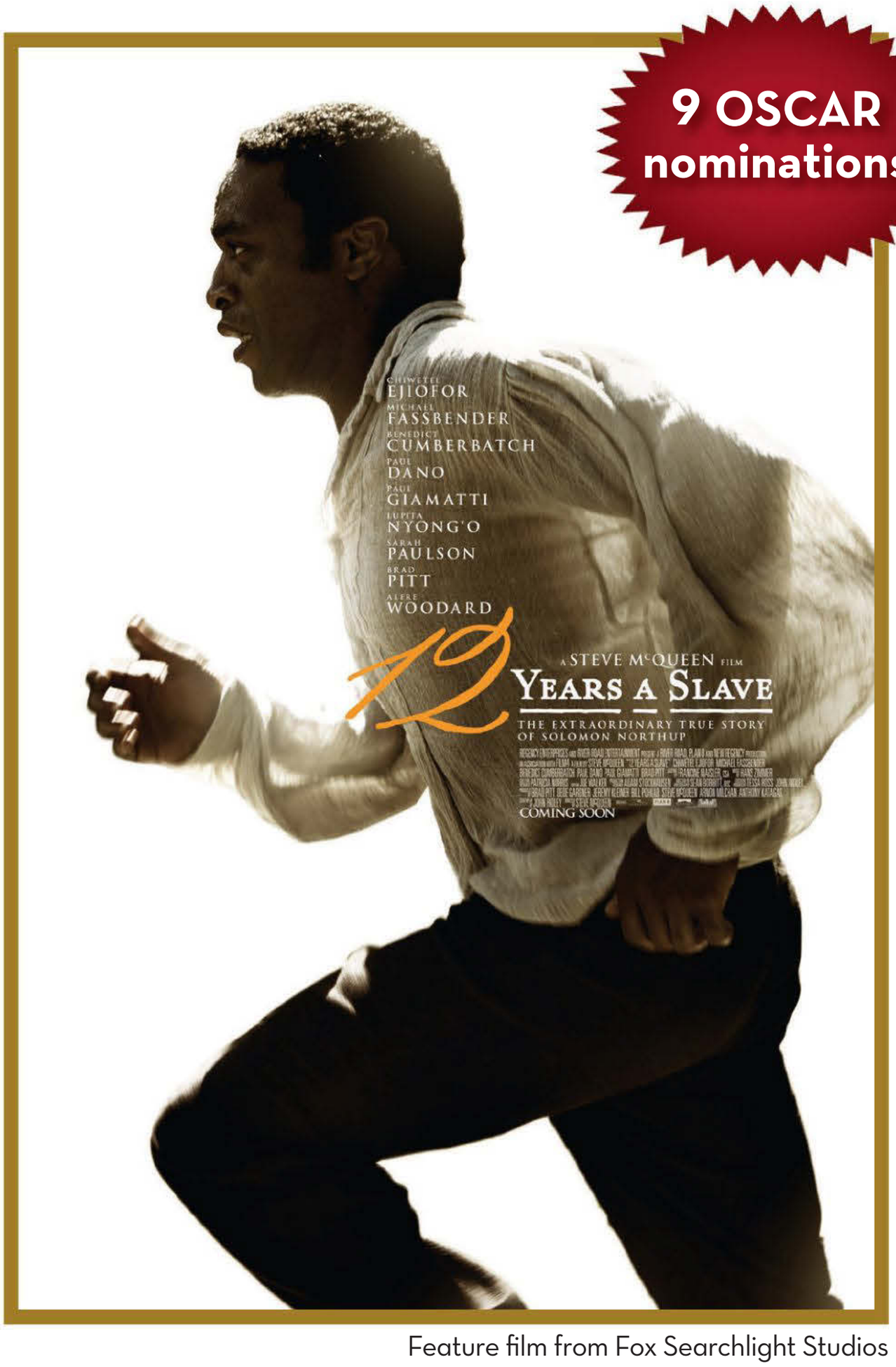
GOLDEN GLOBE AWARD-WINNER

Best Motion Picture



Stolen Into Slavery
tells this story in a way that
is impactful and accessible
for children ages 10 and up.

9 OSCAR nominations



Feature film from Fox Searchlight Studios

Download the FREE companion guide, written by child psychologist Adele Brodkin, to help you discuss this sensitive subject with children.

www.StolenIntoSlavery.com

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