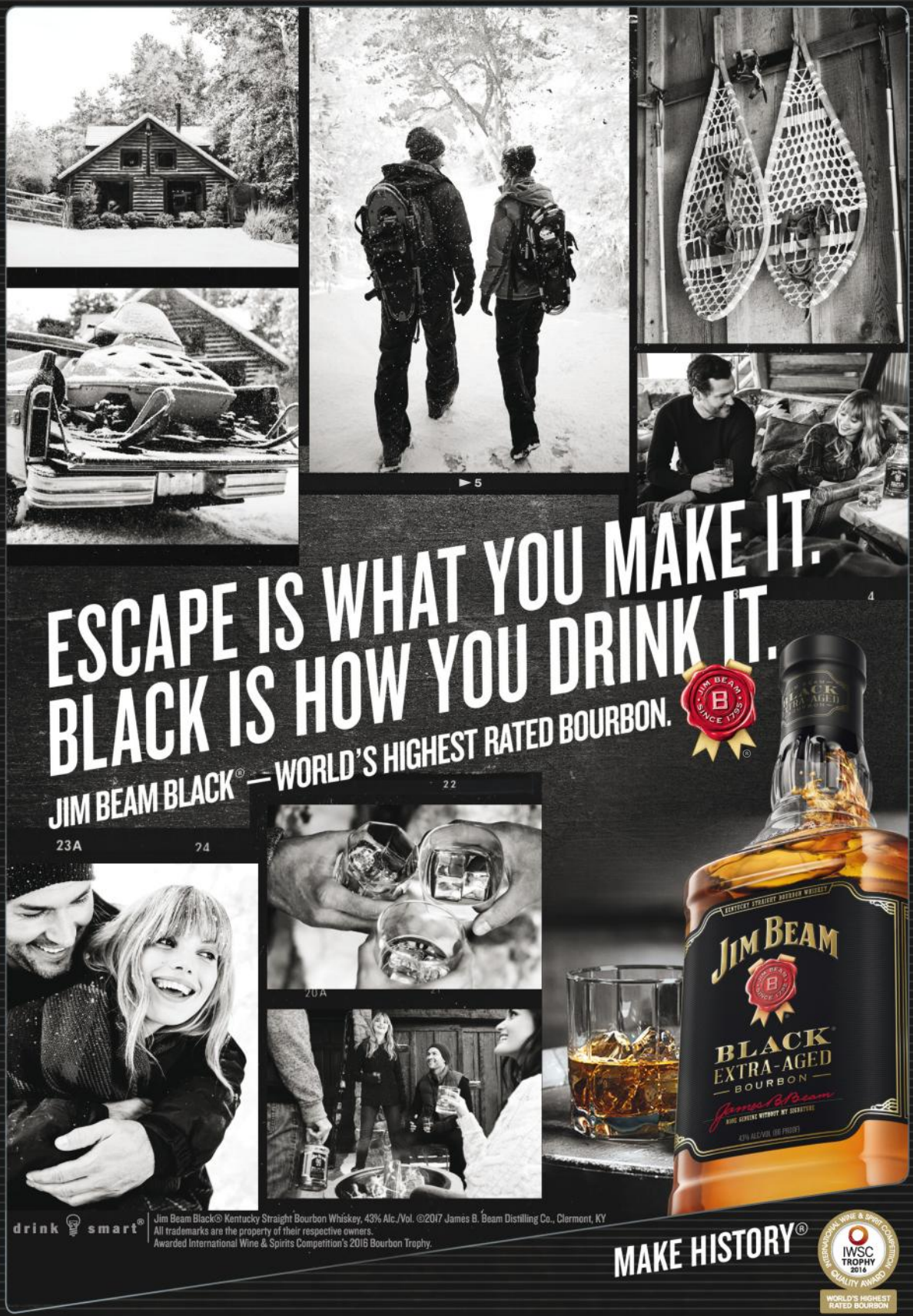

FLIGHT OF THE PTEROSAURS
WHY VACCINES MATTER
LAST LOOK AT NORTH KOREA
NATIONAL GEOGRAPHIC
THE SEARCH FOR
HAPPINESS
What we can learn from Costa Rica, Denmark, and Singapore — the most joyful places on the planet
BY DAN BUETTNER
NOVEMBER 2017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NOVEMBER 2017 • VOL. 232 • NO. 5 • OFFICIAL JOURNAL OF THE NATIONAL GEOGRAPHIC SOCIETY

FRONT

On the Cover A swimmer revels in the Llanos de Cortés waterfall, a favorite with locals around Bagaces, Costa Rica. That nation ranks as one of the happiest on Earth, says author Dan Buettner. *Photo by James Kaiser*

Corrections and Clarifications
Go to natgeo.com/corrections.

FEATURES

PHOTO: ADAM FERGUSON (RADDATZ)

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ELSEWHERE

BOOKS

ASTRONAUT CAPTURES 'VIEW FROM ABOVE'

NASA astronaut Terry Virts has been a space shuttle pilot, a crew member on a Soyuz spacecraft, and a commander on the International Space Station (left). He's spent more than 200 days in space – and during most of them, he's taken photos. The new book *View From Above* presents 300 of Virts's breathtaking images, as well as reflections on how life aloft has shaped him. It's available where books are sold and at *shopng.com/books*.

TELEVISION

'THE STORY OF US' CONTINUES

Morgan Freeman looks at the forces that shape societies around the globe – war and peace, love and belief, power and freedom – in the series *The Story of Us*. It airs Wednesdays through November 15 at 9/8c on National Geographic.

BOOKS

TAKE A BREW TOUR WITH 'ATLAS OF BEER'

Treat the beer fans on your gift list to "a globe-trotting journey through the world of beer." The new *National Geographic Atlas of Beer* brims with history, photos, and travel tips for drinking destinations. It's available where books are sold and at *shopng.com/books*.

NAT GEO WILD

BIG CAT DRAMA ON 'SAVAGE KINGDOM'

In wild, remote Botswana, lions, leopards, and wild dogs vie for dominance within their groups in *Savage Kingdom: Uprising*. The second installment of the hit television series airs Fridays at 9/8c, starting November 24 on Nat Geo WILD.

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PHOTOS: TERRY VIRTS, NASA; SCOTT SUCHMAN (BEER)


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STORIES OF SERVICE AND SACRIFICE

For more than a century this magazine has told stories of war and its consequences. That's also what journalist **Martha Raddatz** (right) did in *The Long Road Home,* her book about a deadly Iraq War ambush, its casualties, and its survivors. A scripted series based on the book premieres November 7 at 9/8c on National Geographic.

Susan Goldberg: You covered the Iraq War from the beginning. Why was this the story that you wanted to tell?
Martha Raddatz: On April 4, 2004, in Baghdad, a platoon of the 1st Cavalry Division was ambushed and lost eight guys—the largest loss of life for the division since Vietnam. Just hearing the details later, I had to write about it. Truly, even after years of doing this kind of work, it was my first time telling the story of people in the battle for their lives.

SG: What did you find especially moving?
MR: There's a quote in the front of the book from Lt. Col. Gary Volesky, who says, "Some guys have seen things that no one ever wants to see.... I understand now what it means when you go to a veterans' ceremony and you see the old veterans get together and hug and cry, and you never really understood it. I understand it now."

SG: For the 1st Cavalry Division the emotional impact of that loss must have been enormous. How did that play out?
MR: On one of my trips I saw Col. Robert Abrams, who's the son of Gen. Creighton Abrams [a U.S. commander during the Vietnam War]. I was asking him about this battle, and he said, "It's not us—it's the families." And he broke down in uncontrollable sobbing. He was just horrified that he'd done that. And I said, "Colonel Abrams, don't worry about it. It's a beautiful tribute to the men who died."

Abrams wrote an email that day to [his commander] Gen. Peter Chiarelli. The general showed it to us, and it said,

PHOTO: ADAM FERGUSON
THIS INTERVIEW WAS EDITED FOR LENGTH AND CLARITY.

Tasmanian Devil *(Sarcophilus harrisii)*
Size: Body length, males approx. 65 cm (25.6 inches); females approx. 57 cm (22.4 inches) **Weight:** Males approx. 14 kg (30.9 lb); females approx. 9 kg (19.8 lb) **Habitat:** Occurs throughout mainland Tasmania **Surviving number:** Estimated at 10,000 – 25,000 adults

Photographed by Heath Holden

WILDLIFE AS CANON SEES IT

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"General Chiarelli, I did an interview with Martha Raddatz today and I let the division down. I got emotional and I'm so sorry that I let you all down." And General Chiarelli wrote back to him and said, "You would have let us down if you'd done anything else."

SG: I'm about to cry.
MR: I know. How can you not?

SG: How well did you get to know the men who fought on April 4?
MR: Now I know them as guys in their minivans, with the car seats and their babies. I learned how they maintained their relationships with their families. I know the different personalities; they're unique. Robert Miltenberger is nothing like Troy Denomy. Troy Denomy is nothing like Eric Bourquin—that man has struggled. He will always bear the burden of feeling like guys gave their lives for him. He has smelled his newborn baby, and the reason he's been able to smell his newborn baby is because of the sacrifices of these men.

SG: What is the takeaway that you want people to have?
MR: That these are guys just like us; they could be your neighbor. That you should respect them. I don't think yellow ribbons and "Thank you for your service" do enough. I think, at the very least, you should understand what it is they do and what their families go through.

SG: What is your reaction to people who might say, looking at Iraq now, that their sacrifice was in vain?
MR: I hate that term, "sacrificed in vain." Your sacrifice is never in vain. It really isn't. They go over there because they're ordered to do that, because they signed up to do that. If Iraq goes to hell tomorrow, their sacrifice was not in vain. For that time they protected the people they were with; they fought to make those lives better. And they did the best they could.

SG: Have you kept in touch with the families of some of the men who died?

MR: Robert Arsiaga, who lost his life, I've been in touch with his family over the years. On the set in the last month of filming, [his mother] Sylvia was there. We walked out onto the set. It's Sadr City, and it's so realistic. As we walked through that town, she was crying, and she said, "So, this is what Robert saw? This is what he looked at his last night." We looked up at the stars, and she said, "I don't think he was afraid. And if he was afraid, he didn't run away. He kept going to try to rescue his brothers."

SG: This is a hard story to tell. How do you retain some objectivity as a journalist, yet get close enough to understand what people are going through?
MR: Journalists have to have a soul. They have to have something beyond the job they do, to understand, to be empathetic, to respect people. This story of what happened to those guys, objectivity aside, is about sacrifice and service. And it continues to this day, because those guys will not get over this. They're changed, and their families are changed.

***

Thank you for reading *National Geographic*.

Susan Goldberg, *Editor in Chief*

This scene, from the National Geographic series *The Long Road Home,* depicts a military vehicle entering Baghdad's Sadr City neighborhood in a re-creation of the events of April 4, 2004. The vehicle carries troops on their way to rescue comrades who'd been ambushed.

To our readers:
In our October 2017 issue, the opening quote of the cover story about Jane Goodall was reported incorrectly. What Jane Goodall actually told an audience at the Brooklyn Academy of Music in April 2015, based on a transcript, was: "For those of you who may hear a story twice, please forgive me. But sometimes special stories are nice to hear again... If I'm sitting around a campfire listening, and I don't hear my favorite story, I feel deprived. Please listen to some of these stories with that in mind." A corrected opening to the article is on the digital version of the story at *ngm.com.*

PHOTO: LYNSEY ADDARIO, NATIONAL GEOGRAPHIC

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VISIONS

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INDONESIA
Mount Bromo, on the volcano-dotted island of Java, erupted for exactly one year, from November 12, 2015, to November 12, 2016. The cone emitted varying levels of ash and heat, disrupting flights and local tourism.

PHOTO: REYNOLD RIKSA DEWANTARA

SUSTAINABILITY

ASSIGNMENT We asked to see your images of sustainability, the idea that the future of our planet depends on the way we live today.

Pichan Cruz
Singapore

Cruz was showing visitors around Gardens by the Bay, a sprawling 250-acre nature park in downtown Singapore. At the Cloud Forest, an indoor enclosure designed to mimic Asia's tropical mountain climates, Cruz pointed his camera at a group of people on the walkway above.

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Angiolo Manetti
Rome, Italy

Before visiting Iceland, Manetti researched places that could be photographically interesting. A series of 18th- and 19th-century houses in Glaumbær caught his eye. The houses, now part of a museum about Icelandic rural life, are built from the area's basic materials: stone, wood, and turf.

NIKKOR

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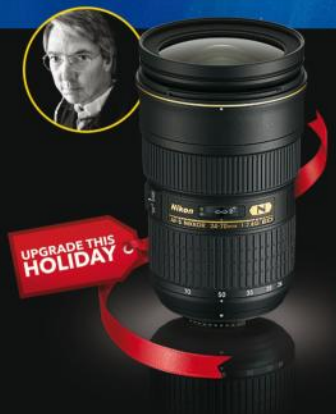

Dave Black captures defining moments with NIKKOR lenses — the only lenses in the world engineered to perfectly communicate and integrate with Nikon cameras. That's something no other lens manufacturer can deliver. The result is an instrument, unrivaled in performance and dependability, that doesn't just work, but works together at an even higher level.

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EXPLORE
SUSTAINABILITY

KELP IS ON THE WAY

By Catherine Zuckerman

Name the last place where you saw seaweed on the menu, not including a Japanese restaurant. Drawing a blank? That may be because, outside of Japan and other parts of Asia, seaweed's unique flavor and mouthfeel have not been widely embraced.

These marine plants and algae are sometimes called "sea vegetables"—but there are reasons beyond gastronomy to appreciate them. Kelp, in particular, has the potential to greatly reduce ocean acidification. Naturally occurring in cold, coastal marine waters, kelp grows quickly without the need for fertilizer, and it takes up carbon dioxide—which can exacerbate climate change—as well as excess nitrogen and phosphorus. The problem, though, is that there's not enough of it.

Enter kelp farming. China currently leads the industry, having produced more than seven million metric tons in 2015, says University of British Columbia marine ecologist Muhammed Oyinlola. Kelp farms have also been in operation for centuries in Japan and Korea.

If seaweed farming expands, Oyinlola says, it "could remove billions of metric tons of carbon dioxide from the atmosphere." And more kelp aquaculture could yield more biodiversity: In California alone, researchers have found that wild kelp "forests" can shelter more than 800 species of marine life.

Kelp and other algae are high in minerals and fiber and have gelling properties. Those traits have led to their use in cosmetic products and vitamins and as feed for farmed fish and livestock. Meanwhile, look for them as a fresh, sustainable food on ever more plates.

Wild seaweed can grow in warm or cold ocean waters. This mix of kelp, Irish moss, and sea lettuce was harvested off the coast of Maine.

PHOTO: REBECCA HALE, NGM STAFF

HOW TO KNOW URINE PARIS

By Daniel Stone

Along with haute cuisine and chic fashion, there's another long-standing tradition in Paris that's decidedly less pleasing. Since before the days of Napoleon, the city of love has battled the odorous scourge of *les pipis sauvages,* or wild peeing. The widespread practice of public urination is technically illegal. But that hasn't seemed to stanch the streams that pour into the streets, into planter boxes, and onto lampposts.

What's a city to do? Try to turn a public misdeed into something resembling a public service. Earlier this year, officials partnered with Faltazi, a French design agency with a fresh idea: installing public urinals in areas known for abundant urination. The receptacle, known as a Uritrottoir, or "sidewalk urinal," is filled with odor-fighting straw or sawdust. When it's full, after about 200 "deposits," a sensor alerts an attendant to empty the contents. The mixture is taken to a site where it becomes compost, and eventually, the compost becomes plant food—"but only for flowers," says cocreator Laurent Lebot. "Not for any fruits or vegetables."

Faltazi is testing two models at the Gare de Lyon train station in Paris and in two other French cities in hopes of answering several questions. Will people actually use the Uritrottoir? And if this works for men, could a model also be designed specifically for women to relieve themselves publicly but discreetly?

The devices aren't cheap, starting at nearly $5,000 each, plus maintenance. And they may encourage more public *pipis,* not fewer. But what if the result were Parisian streets filled with the scent of fresh bread and not the reek of urine? *Mais oui.*

Designed to both stand out and blend in, public urinals may finally help end Paris's centuries-old menace of street urination.

PHOTO: FALTAZI

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GROWN AT HOME

By Lindsey M. Roberts

In 1991 the United States attempted to undermine illegal drug production in Andean countries by boosting legal industries, like flower growing, with duty-free imports. Roses, carnations, chrysanthemums, and orchids began to be shipped north—and U.S. flower farming was hit hard.

The trade agreement has since expired, and U.S. floriculture is bouncing back. Consumers are being encouraged to select local flowers by groups like Slow Flowers, founded by writer Debra Prinzing, and Certified American Grown, which allows farmers to label their blooms as U.S.A. grown.

"The more awareness the American consumer has about where flowers come from, the better for all of us," says Andrea Gagnon, a flower farmer in Gainesville, Virginia. "It's just like asking, Is this a local tomato for my BLT? Now people can ask, Oh, is this a local dahlia?"

LOCAL VS. IMPORTS

Of the cut flowers sold in the United States, 71% come from Colombia; that makes it the top foreign source by a large margin.

PHOTO: REBECCA HALE, NGM STAFF
GRAPHIC: NGM STAFF. SOURCE: U.S. BUREAU OF ECONOMIC ANALYSIS

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STRAWBERRIES PRESERVED

By Daniel Stone

DAY 7

TREATED

Every fruit and vegetable breathes. Once a piece of produce is picked from a tree or plant, it continues to respire, aging slowly, until it begins to break down. Microorganisms then move in, causing it to spoil. Refrigeration can delay the process, but only so much.

Some scientists now think they can make your bananas, avocados, and other fresh produce last up to twice as long by delaying spoilage. Apeel, a start-up in Santa Barbara, California, has created a way to extract lipids from several popular crops and transform each type into a powder. Dissolved in water and applied to fruit or vegetables, it forms an edible barrier to lock moisture in and microorganisms out.

Farmers can apply a version of the solution in the field, or distributors can use the rinse on the packing line, extending a fruit's shelf life by days or even weeks. The FDA recognizes the process as safe, and earlier this year it was approved for use on organic produce.

Giving shoppers more time with their fresh food is one purpose. But Apeel's higher goal is to fight food waste and reduce the number of refrigerated trucks and ships that race between fields and stores to deliver food at its peak. The technology can also allow more crops to be delivered to more places farther and farther from where they're grown. "You can imagine a world without seasonality of fresh produce," says James Rogers, Apeel's CEO and a materials scientist.

In the meantime, who couldn't use a few extra days before that fruit in the fridge starts to mold?

DAY 7

UNTREATED

Unlike produce such as peaches or bananas, strawberries begin to decline as soon as they're picked. Scientists have created an edible, invisible barrier that can delay spoilage by slowing water loss and oxidation.

PHOTOS: APEEL SCIENCES


THE LONG ROAD HOME
NOVEMBER

PLANTING PEACE

By Nina Strochlic

Africa's most populous country can't feed itself. Despite boasting more than 80 million acres of arable land, Nigeria relies heavily on imported food. Meanwhile more than two million young Nigerians enter the workforce each year only to face a 25 percent youth unemployment rate. Extremist groups like Boko Haram pull recruits from this restless demographic.

Can encouraging youth to take up hoes instead of arms help resolve these issues? "Just as oxygen is to fire, so are unemployed youth to insurgencies," says Kola Masha, a Nigerian-American entrepreneur. "Why has it become so easy for disgruntled individuals to raise a mini-army? Because young people have limited economic opportunities."

Masha runs Babban Gona—Great Farm—which aims to lift young, small-scale farmers out of subsistence by boosting their yields and access to higher priced markets. Agricultural investment is the most effective form of foreign aid in reducing conflict—while other types of aid can exacerbate it, says Edwin Price, director of Texas A&M's Center on Conflict and Development.

Programs like Babban Gona are being launched across the continent. "Nigeria is seen as a trendsetter," says Evelyn Ohanwusi, who heads an "agripreneurs" project run by the International Institute of Tropical Agriculture. Using that program as a model, the African Development Bank aims to create 1.5 million agribusiness jobs for youth in the next five years across some 30 countries.

Nigerian farm laborers harvest tomatoes grown with the help of Babban Gona, which provides strategies to make land more productive. The majority of Nigerians are under age 24, but the average farmer is more than 50 years old. Founder Kola Masha wants his program to reach one million small-scale farmers by 2025 – and to reduce conflict and youth unemployment along the way.

PHOTO: JASON ANDREW

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Sources: MPA, Total (Duplicated) Magazine Media 360° Audience, Jan-May YTD 2017, Brand Audience Report; Simmons Research, Multi-Media Engagement Study, Spring 2016.

She Favors Seas, He Prefers Stars

Oceanographer **Sylvia Earle** earned the title "Her Deepness" for exploring Earth's oceans. Astrophysicist Neil deGrasse Tyson is more of a sky guy. When the two compare their interests, they discover a few things in common—and plan a field trip.

Neil deGrasse Tyson is the host of *StarTalk*, airing Sundays at 11/10c on National Geographic. Past episodes of *StarTalk* are available at *natgeotv.com*.

Neil deGrasse Tyson: Sylvia, I heard a rumor that you were born underwater. And that you had gills, and then you just had to pretend you were human and came out, and now it's just a charade when you're on dry land.
Sylvia Earle: I wish that was so!

NT: What happened to you early in life where all of a sudden being on dry land was not the priority?
SE: Well, I got knocked over by a wave when I was a little kid, on the New Jersey shore. I couldn't breathe—and then suddenly my toes touched the bottom and my head came out, and I realized that was kind of cool. It was fun. Then my family moved to Florida when I was 12, and my backyard was the Gulf of Mexico. You know, kids are naturally explorers. They are scientists from the get-go, always asking questions. Everything is new; everything is wonderful.

NT: See, as a city kid, all I can think of about the ocean is, I can't breathe there.
SE: But now you can. Inside a submarine—or thanks to the technologies that were developed before either of us came along. They started in the 1800s to supply air by a compressor down a tube into a helmet of sorts that people could wear. It's one way that sea and space come together: life-support systems.

NT: We have an interesting duality here with the challenges of accessing and surviving underwater and the challenges of accessing and surviving in space. Of course, it's far more expensive to go into space than to the bottom of the ocean.
SE: Getting to the bottom of the ocean is easy. Sometimes you don't come back…

NT: Getting to the deepest point of the ocean is a trivial exercise—but doing it without dying, that's the challenge?
SE: It is. And only three people have made that journey to the deepest place, 11 kilometers [or seven miles] down.

NT: This is the Mariana Trench, off of the Philippines.
SE: That's right. The first excursion was Jacques Piccard and Don Walsh in 1960. Then in 2012, filmmaker [and National Geographic Explorer-in-Residence] James Cameron contributed resources to build a submersible for one person, which is pretty gutsy. It went to the depths of the ocean and cruised around for nearly three hours. But most of the ocean has never been seen by anybody.

NT: Maybe it doesn't have the romance of the sky and the universe.
SE: I beg your pardon.

NT: Oops. I said that to the wrong person. OK, maybe it doesn't feel as limitless as the night sky.
SE: The problem is, people think that because it's our blue backyard, we know

PHOTOS: MARK THIESSEN, NGM STAFF (OPPOSITE); WILLIAM CALLAN, CONTOUR BY GETTY IMAGES (ABOVE)


SCUBAPRO

everything there is to be known. You look at the surface today, it likely looks pretty much the way it did a thousand years ago. But 90 percent of the ocean's fisheries have been overfished or fully exploited, mostly during the past 30 years. And though there are signs of coral reefs recovering, up to two-thirds of them have been seriously damaged. It's partly because the planet is warming and causing ocean acidification.

NT: Maybe it's out of sight, out of mind. You have this huge support to stop the deforestation of rain forests, to preserve lakes and rivers and wetlands. Is it because they're just more visible to us?
SE: Of course. And the thought is that the ocean is so big, so vast, so resilient, it's too big to fail. Right? But now we know it is failing. And why should we care about that? You know, who cares if there aren't any more tuna?

NT: You'll just eat the next fish.
SE: That's been the thought—but now there are no more "nexts" to go to. I mean, some fish species are decades old. They're not like a chicken that takes only months to mature. To make a pound of chicken takes maybe two pounds of plants; for a pound of cow, up to 20 pounds of plants. But the tuna gobbles decent-size fish that have eaten other fish, that have eaten other fish, every step of the way down to the plants. So that's tens of thousands of pounds of plankton funneled through this long and twisted food chain to a tuna, which is caught to yield a little piece of sushi that you don't really need. It's a choice.

NT: You're bumming me out. I'm not going to eat ever again after this conversation.
SE: You just have to eat with respect and know what you're eating. That's the key.

NT: So now we have to rethink our relationship to this planet.
SE: Correct. People say, why should I care about the ocean? Because the ocean touches you, whoever you are or wherever you are, with every breath you take. It's where most of the Earth's oxygen is generated, replenished by these tiny little green guys in the ocean, like phytoplankton. So we need to think of ourselves as a part of the system rather than the big boss of the universe. Now I have a question for you: When do we go diving in an ocean submarine?

NT: I want to make sure the submarine has done that before and it came back safely and there aren't hash marks on the side of people who died trying.
SE: Where's your sense of adventure?

NT: I like adventure, but I let other people get the bugs out. Then I'm there.
SE: All right, let's make it happen. Let's figure it out.

NT: We'll make a pact. Excellent. None of these one-way trips to the bottom of the ocean—a round-trip.
SE: A round-trip, yes. Those are the ones that count.

Sylvia Earle has been an ambassador for Rolex since 1982 and a National Geographic explorer in residence since 1998. This 1979 photo shows her in the armored diving suit in which she descended 1,250 feet to the ocean floor. She then spent about two hours exploring at a depth never before reached by a human in a diving suit.

THIS INTERVIEW, DRAWN FROM A TAPING FOR A *STARTALK* TELEVISION EPISODE, WAS EDITED FOR LENGTH AND CLARITY.

PHOTO: CHUCK NICKLIN, NATIONAL GEOGRAPHIC CREATIVE


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Photo Credit: Dani Bradford

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NATIONAL GEOGRAPHIC

Alexander Graham Bell with his grandson Melville. Beinn Bhreagh, Nova Scotia.

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A ONE-PARENT FAMILY, LITERALLY

By Patricia Edmonds

The Komodo dragon, the largest species of lizard now alive, can grow to 10 feet long and nearly 200 pounds. A muscular carnivore armed with sharp teeth, *Varanus komodoensis* dines on prey as large as deer, wild boar, and water buffalo.

As formidable as the Komodo dragon seems, it's very much at risk. On seven Indonesian islands that are the only places the species lives in the wild, humans burn its habitat to clear land and poach animals on which it preys. Even on land protected as Komodo National Park, officials reported just 3,013 Komodo dragons in 2016, down from 3,222 in 2013.

When her species needs replenishing, what's a mother dragon to do? She can reproduce the old-fashioned way, by mating with a male and laying eggs. Or she can lay eggs without having mated, through a sort of virgin birth process called parthenogenesis.

In 2006 at England's Chester Zoo, a female named Flora, who'd had no male contact, laid a clutch of viable eggs that tests showed had only her DNA. That was the first confirmation of parthenogenesis in captive Komodo dragons; scientists now believe it "happens very often," says Gerardo Garcia, Chester Zoo's curator of lower vertebrates and invertebrates.

How does it work? In humans, males have both male and female sex chromosomes. In Komodo dragons, females do—so Flora had within her the genetic materials needed for embryos to develop. This self-fertilization yields offspring that are "absolutely healthy," Garcia says—but every one is male.

Being able to reproduce both sexually and asexually gives the dragons an evolutionary edge, Garcia says. If no mate is handy, a female can bear sons parthenogenetically—and when they're older, they can be her mates. "It's not ideal" for keeping the gene pool diverse, he says. But it's a way for the species to continue.

VARANUS KOMODOENSIS

HABITAT/RANGE
Tropical-forest edge and grasslands of seven Indonesian islands

CONSERVATION STATUS
IUCN assesses it as vulnerable.

OTHER FACTS
One of about 80 species of monitor lizards, Komodo dragons have existed for perhaps 3.8 million years, fossils suggest.

NATIONAL GEOGRAPHIC
PHOTO ARK
JOEL SARTORE

JOEL SARTORE PHOTOGRAPHED THIS KOMODO DRAGON AT THE HOUSTON ZOO.

Denmark

These young men leap from a 16-foot-high diving platform into Copenhagen's harbor. A built environment that invites physical activity helps explain why Danes have among the lowest obesity rates in the world. The country frequently claims the top spot in the annual World Happiness Report, a reflection of its government-supported education, health care, and financial safety net.

CORY RICHARDS

THE WORLD'S HAPPIEST PLACES

What do Denmark, Costa Rica, and Singapore have in common? Their people feel secure, have a sense of purpose, and enjoy lives that minimize stress and maximize joy. Here's how they do it.

Costa Rica

Arenal Volcano looms above a horse grazing in the fertile northern lowlands. The country's mountainous terrain meant that it never developed large farms, as other countries in Central America did, so it was never dominated by a powerful landholding class. Costa Rica's small-property owners have elected presidents who've made education a priority, ensured clean water, instituted social security, and established free clinics in most villages.

ROBERT HARDING, AURORA

Singapore

The so-called Supertrees, glowing with solar-powered lights and supporting more than 200 varieties of plants, are a highlight of Gardens by the Bay. The exquisitely manicured 250-acre park built on reclaimed land showcases Singapore's ambition to be a global city rooted in traditional Asian values of harmony, respect, and hard work. The island nation typically ranks high in Asia for life satisfaction.

CORY RICHARDS


Bijbelse Reizen

BY DAN BUETTNER / PHOTOGRAPHS BY CORY RICHARDS AND MATTHIEU PALEY

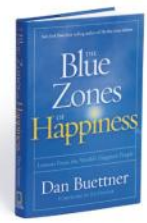
Who is the world's happiest person?

It may be Alejandro Zúñiga, a healthy, middle-aged father who socializes at least six hours a day and has a few good friends he can count on. He sleeps at least seven hours most nights, walks to work, and eats six servings of fruits and vegetables most days. He works no more than 40 hours a week at a job he loves with co-workers he enjoys. He spends a few hours every week volunteering; on the weekends he worships God and indulges his passion for soccer. In short he makes daily choices that favor happiness, choices made easier because he lives among like-minded people in the verdant, temperate Central Valley of Costa Rica.

Sidse Clemmensen is another possible candidate. With a loving partner and three young children, she lives in a tightly knit cohousing community with other families who share chores, childcare, and meals in a communal kitchen. She's a sociologist, a job that challenges and engages her every day. She and her family bicycle to work, the store, and the children's school, which helps keep them fit. She pays high taxes on her modest salary but gets health care and education for her family, as well as guaranteed retirement income. In Aalborg, Denmark, where she lives, people feel confident the government will make sure that nothing too bad happens to them.

And then there is Douglas Foo. A successful entrepreneur, he drives a $750,000 BMW and lives in a $10 million house. He's married, with four well-behaved children who excel at school. He put himself through school working four jobs and started a company that eventually grew into a $59 million multinational enterprise. He works about 60 hours a week between his business and his philanthropic pursuits. He's earned the respect of his employees, peers, and the larger community. He's worked hard to achieve his success, but as Foo readily admits, he probably couldn't have created this life anywhere other than Singapore.

Zúñiga, Clemmensen, and Foo illustrate three different strands of happiness that braid together in complementary ways to create lasting joy. I call them pleasure, purpose, and pride. They also live in countries that encourage those strands. By meeting each of these people and exploring their home countries, we'll discover the secrets to what makes the people in these places so much happier than those in other places.



Dan Buettner, a *New York Times* best-selling author, has been exploring what makes us healthy and happy for the past 15 years.

His fourth book, *The Blue Zones of Happiness,* just published by National Geographic, is available wherever books are sold.

To learn the secrets of happiness, join Buettner this June on a private jet trip to Bhutan, Denmark, Greece, and Japan. For more information, visit *natgeoexpeditions.com/bluezones.*

Consider Zúñiga, who like many Costa Ricans enjoys the pleasure of living daily life to the fullest in a place that mitigates stress and maximizes joy. Scientists call his type of happiness experienced happiness or positive affect. Surveys measure it by asking people how often they smiled, laughed, or felt joy during the past 24 hours. His country is not only Latin America's happiest; it's also where people report feeling more day-to-day positive emotions than just about any other place in the world.

Clemmensen represents a brand of happiness typified in the purpose-driven life of Danes. Like all forms of happiness, it assumes basic needs are covered so that people can pursue their passions at work and leisure. Academics refer to this as eudaimonic happiness, a term that comes from the ancient Greek word for "happy." The concept was made popular by Aristotle, who believed that true happiness came only from a life of meaning—of doing what was worth doing. Gallup measures this by asking respondents whether they "learned or did something interesting yesterday." In Denmark, a country that has most consistently topped Europe's happiness rankings for the past 40 years, society has evolved to make it easy to live an interesting life.

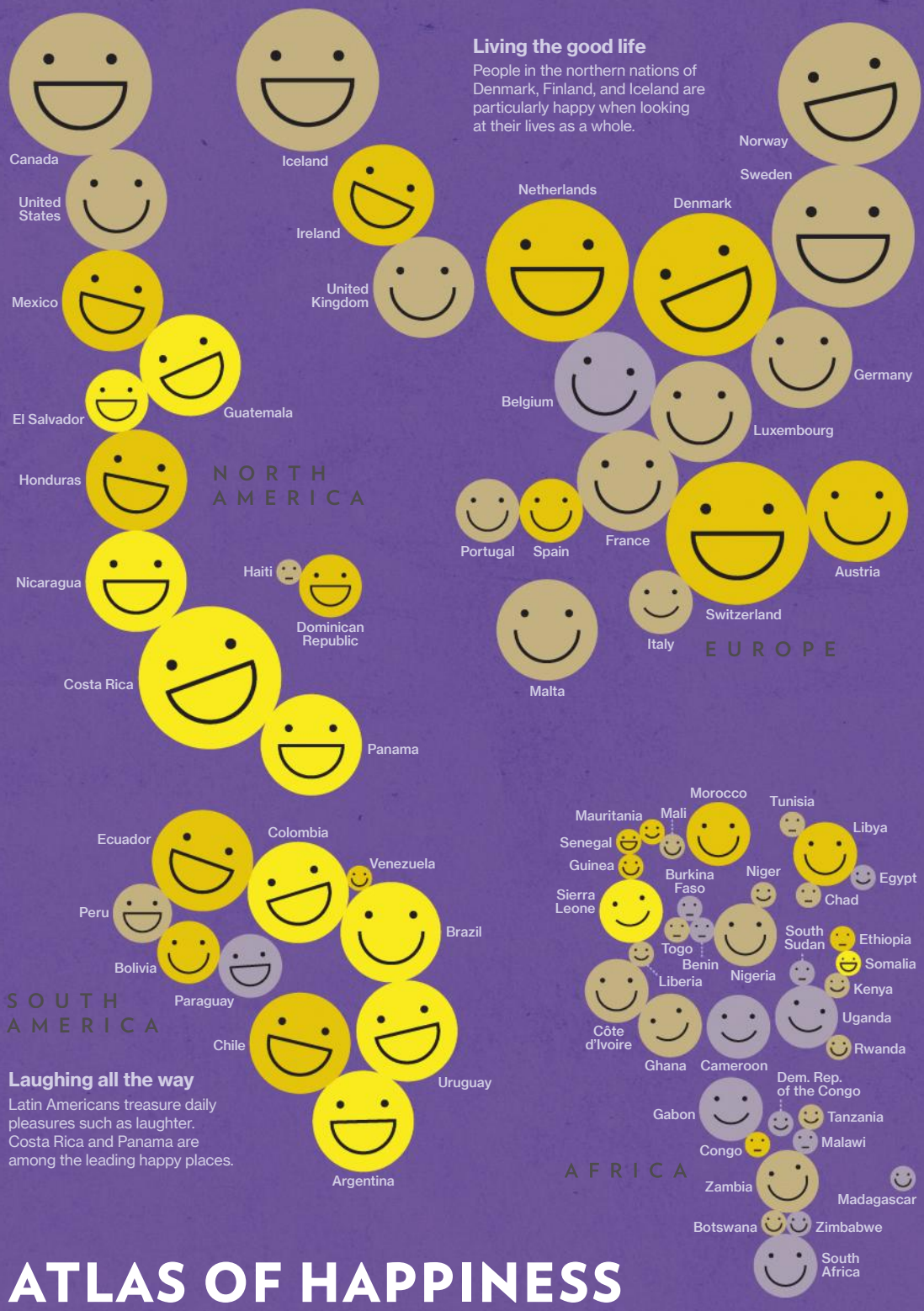
And true to Singapore's reputation for having a semi-fanatical drive for success, Foo—with all his ambition and accomplishments—represents the "life satisfaction" strand of happiness. Social scientists often measure this type of happiness by asking people to rate their lives on a scale of zero to 10. Experts also call this evaluative happiness. Internationally it's considered the gold standard metric of well-being. Singapore has most dependably ranked number one in Asia for life satisfaction.

The researchers who publish the annual World Happiness Report found that about three-quarters of human happiness is driven by six factors: strong economic growth, healthy life expectancy, quality social relationships, generosity, trust, and freedom to live the life that's right for you. These factors don't materialize by chance; they are intimately related to a country's government and its cultural values. In other words the happiest places incubate happiness for their people.

To illustrate the power of place, John Helliwell, one of the report's editors, analyzed 500,000 surveys completed by immigrants who'd moved to Canada from 100 countries over the previous 40 years, many from countries considerably less happy. Remarkably Helliwell and his colleagues discovered that, within a few years of arriving, immigrants who came from unhappy places began to report the increased happiness level of their adoptive home. Seemingly their environment alone accounted for their increased happiness.

Zúñiga, Clemmensen, and Foo pursue their goals intensely, but not at the expense of joy and laughter, and they look with pride on what they are doing and what they have already accomplished. They're able to do this, in many cases, because the places where they live—their nations, communities, neighborhoods, and family households—give them an invisible lift, constantly nudging them into behaviors that favor long-term well-being.

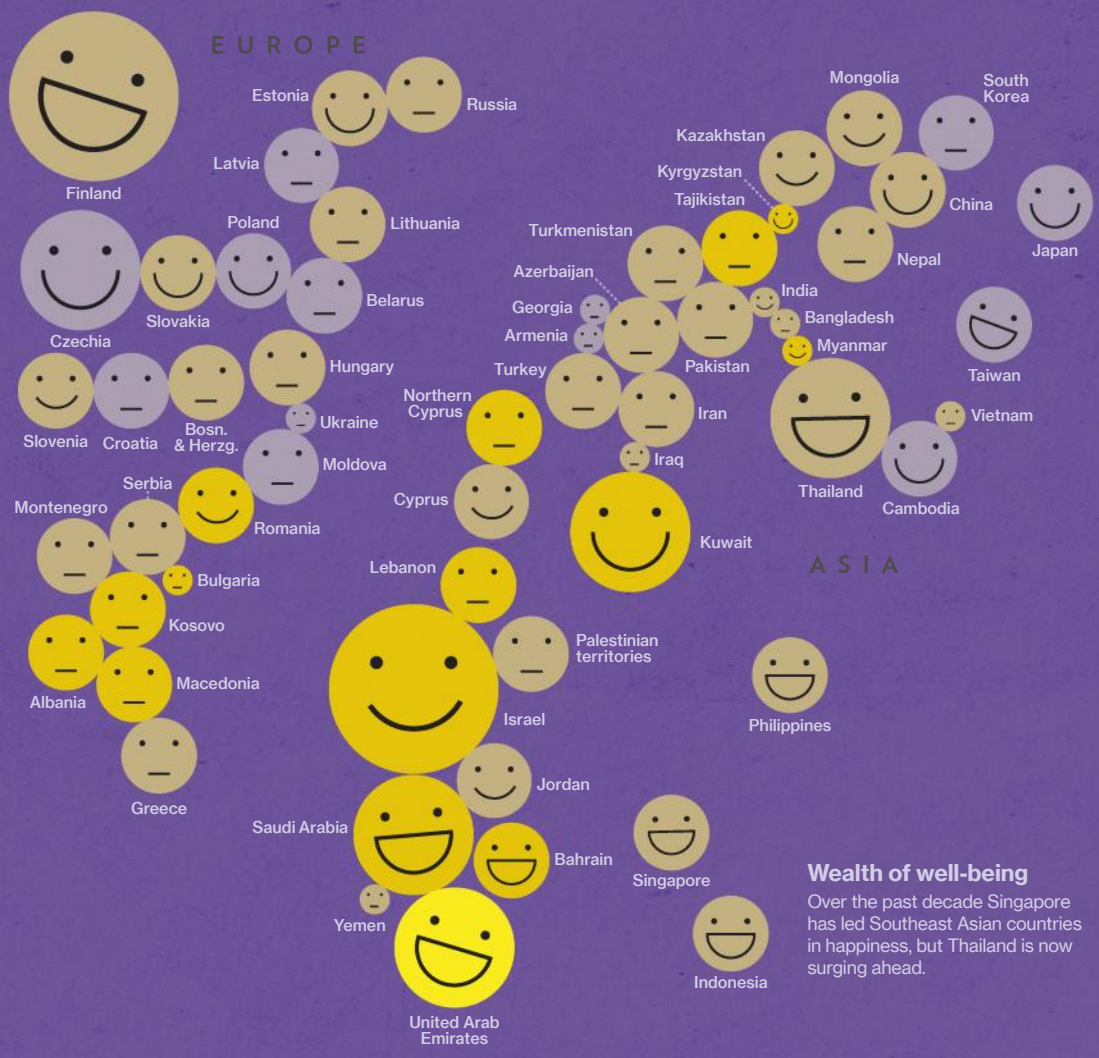
PEOPLE WHO LIVE IN THE WORLD'S HAPPIEST PLACES PURSUE THEIR GOALS INTENSELY, BUT NOT AT THE EXPENSE OF JOY AND LAUGHTER.



ATLAS OF HAPPINESS

What does it take to be happy? Every year the Gallup World Poll tries to figure that out using dozens of questions to measure happiness in over 140 countries. Three of its themes are the focus here: how people see their lives as a whole, their daily happiness, and their physical health. One thing is clear: Different cultures have different ideas about what it means to thrive.

DATA ARE NOT AVAILABLE FOR SOME COUNTRIES. SELECT TERRITORIES ARE INCLUDED.



Wealth of well-being

Over the past decade Singapore has led Southeast Asian countries in happiness, but Thailand is now surging ahead.

Back to basics

North Africa's better infrastructure – paved roads, piped water, and cell phone coverage – helps raise happiness levels compared with the south.

PERCENTAGE CONSIDERED THRIVING

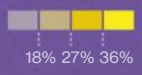
Life as a whole

People reflect on their lives and rate them from zero to 10. Those who respond seven or above are considered to be thriving.

DAILY HAPPINESS IS SCORED 0 TO 100, BY COUNTRY.

Daily happiness

People are asked five questions to determine if they're happy in the moment. For example: Does their day include laughter?



PERCENTAGE CONSIDERED THRIVING

Physical well-being

People are queried on their health. Data are converted into a scale from "suffering" to "thriving."

MANUEL CANALES AND THEODORE A. SICKLEY, NGM STAFF. SHELLEY SPERRY. SOURCE: GALLUP WORLD POLL, 2015-16

COSTA RICA

FEELING JOY EVERY DAY: HEALTH, FAITH, FAMILY

Taking a spontaneous midday break from the restaurant she runs in Limón, María del Carmen Yoursrecha Paterson (at right) dances to pulsating music in a nearby bar. For Costa Ricans, living moment to moment comes naturally, as does taking the time to socialize with family and friends. MATTHIEU PALEY

Let's return to Alejandro Zúñiga, who works as a produce vendor at the central market in Cartago, a city just east of San José, Costa Rica's capital. For decades the husky 57-year-old has been a fixture at the market, showing up day after day to sell avocados, socialize, and try out new jokes. Everyone there knows him. Whenever any of the five dozen or so other vendors falls ill or has a family emergency, it's usually Zúñiga who takes up a collection to help. He organizes weekend trips to cheer on the city's beloved but often hapless soccer team, C.S. Cartaginés. He's a charismatic friend and a natural leader.

One night a few years ago, Zúñiga got a call from a friend with exciting news. "You've won the lottery!" he shouted.

Zúñiga had bought the winning ticket and was about to receive 50 million colones (then about $93,000). But Zúñiga didn't believe his friend, a well-known practical joker. Besides, he wasn't in the mood. It

Only three students attend school in La Central, a farming village about an hour from Cartago. Here they eat lunch with their teacher in a restaurant. The crucifix was removed from the church for safekeeping when nearby Turrialba Volcano erupted. Primary and secondary education is free and mandatory, and the country's literacy rate is 97.8 percent.

MATTHIEU PALEY

had been a long day, and he hadn't sold all of his avocados. "I thought it was an ugly joke," he recalled. "I was down to my last eight dollars."

He hung up on his friend.

When Zúñiga showed up for work the next day, the vendors erupted in applause. News of his winning had spread. Each week he bet on the same number; this time his number had come up.

Giddy, Zúñiga strode past the produce stalls with an alpha male's long-armed lope and high-fived his friends and colleagues. They knew that Zúñiga had never had it easy. He'd grown up in shantytowns, quit school at 12 to earn a living, struggled with alcohol, and lost the love of his life at age 20 when she left him.

Now that he'd struck it rich, his fellow vendors assumed they'd lose him to a new, more affluent life. But in the weeks after his win, Zúñiga surprised his friends by returning to the market, hawking his produce and playing practical jokes. Quietly, though, he was giving away his fortune: a million colones to the friend who'd sold him the lottery ticket, a million to a food-stall owner who'd fed him in lean times, and another million to a market beggar he knew. The rest he gave to his mother and to the four mothers of his seven children. Within a year he was broke again.

And yet, he insisted, "I couldn't be happier."

To understand Zúñiga's resilience, you need to know more about Costa Rica, where an alchemy of geography and social policies has created a powerful blend of family bonds, universal health care, faith, lasting peace, equality, and—a quality that Zúñiga possesses in spades—generosity. This all culminates in an especially rich recipe for enjoying life day by day—the pleasure strand of happiness. Here this combination—all statistically associated with well-being—delivers more happiness per GDP dollar than just about anywhere else.

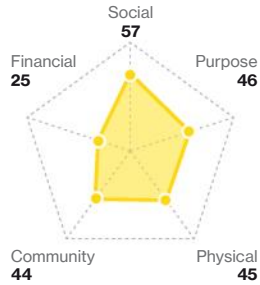
Consider Zúñiga's situation. Although he has no car, no expensive jewelry, no fine clothes or big electronics, he doesn't need any of those things for happiness or a sense of self-esteem. He lives in a country that, for most of the past century, has believed in supporting every citizen. Unlike most of Central America, where land barons and the military-backed presidents who served their interests dominated after independence, Costa Rica took a different path. With rugged, ravine-etched mountain ranges and a lack of cheap indigenous labor, conditions there discouraged the rise of large haciendas. Instead small-property owners and independent-minded

HAPPINESS FACTOR

COSTA RICA

Gallup divides its surveys into five categories that contribute to well-being. Costa Ricans are perennial leaders when it comes to social relationships, a sense of purpose, and physical health.

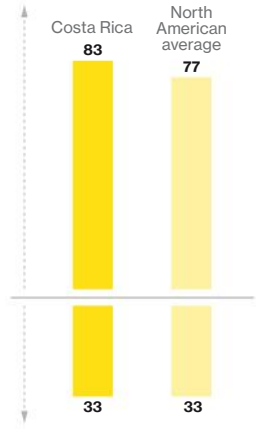
PERCENTAGE OF POPULATION THRIVING IN EACH CATEGORY



EMOTIONAL POLL

Five questions each about daily positive and negative experiences are used to create countries' scores from zero to 100.

POSITIVE EMOTION SCORE



NEGATIVE EMOTION SCORE

GALLUP WORLD POLL, 2015-16

Central Valley farmers thrived after discovering an international market for coffee. Costa Ricans elected teachers as presidents, who, unencumbered by corrosive colonial institutions, introduced policies that launched an upward spiral of well-being and thus the environment for the Latin American character to thrive.

In 1869 Costa Rican law made primary school mandatory for every child, including, notably, girls. By 1930 the literacy rate was among the highest in Latin America. At the same time, the nation invested in supplying clean water for rural villages, stemming deadly childhood illnesses, such as cholera and diarrhea, and ensuring that children's lives got off to a healthy start. The 1940s brought the beginnings of social security and an end to the army. By 1961 came legislation on universal health care, leading to free primary care clinics in most villages.

And that commitment continues today. On a crisp winter morning not long ago, I followed a medical technician named Ileana Álvarez

Ileana Álvarez Chaves, a medical technician who works with Costa Rica's government health care program, checks on the vital signs of Mayela Orozco, 68, a widow who lives alone. Over a year Álvarez Chaves will visit every house in Paraíso. The program's focus on preventive care has reduced infant mortality and increased life expectancy.

MATTHIEU PALEY

Chaves as she toted a backpack and a small cooler of vaccines on her rounds through the leafy Central Valley town of Paraíso. She works with Equipos Básicos de Atención Integral en Salud (EBAIS), the national system that was set up in the mid-1990s to support the health of every Costa Rican. (Health and happiness are inextricably linked.)

Small teams including a doctor, a nurse, a recordkeeper, and several technicians are assigned the care of about 3,500 people. Álvarez Chaves's quota called for her to visit as many as a dozen homes a day. At each one she'd spend 30 minutes to update medical histories, take blood pressures, give vaccinations, dispense advice, and check for standing water (where Zika virus–bearing mosquitoes breed).

At the Hernández Torres home, Álvarez Chaves counseled a young mother on a healthy diet for her two-year-old son and left behind vitamins and antiparasitic pills. As she walked through the house, she noted the white bread and milk on the kitchen table. "Try to eat more beans, fruits, and vegetables," she advised. At the home of 89-year-old Aurora Brenes, Álvarez Chaves inventoried medicines, took blood pressure readings, and set up an appointment for Brenes with her team's doctor. "I can often catch diseases before they erupt into full-blown diabetes or a heart attack," she said. "Many of my clients are lonely, and they just appreciate someone who cares."

Since 1970 Costa Rica has seen life expectancy jump from 66 years to 80 years and infant mortality drop by a factor of seven. The death rate from heart disease for men is about a third less than that in the United States, even though Costa Rica spends one-tenth as much per capita on health care as the United States. As former president José María Figueres, who implemented the EBAIS program, told me, the nation's health care system works so well because it aims to keep people healthy in the first place. "In the U.S., incentives are aligned to drive up costs," he said. "Here for years the emphasis has been on the preventive health system because, quite frankly, the objective of a good health policy is for people not to get sick."

In short Costa Rica's social system takes care of most people's needs, said Mariano Rojas, a Costa Rican economist and happiness expert at the Latin American Faculty of Social Sciences in Mexico City. "It leaves them feeling safe, comparatively healthy, free of most of life's biggest worries, while providing an environment where most people can still make a living."

IN COSTA RICA AN ALCHEMY OF GEOGRAPHY AND SMART SOCIAL POLICIES HAS CREATED A POWERFUL BLEND OF FAMILY BONDS, UNIVERSAL HEALTH CARE, FAITH, PEACE, EQUALITY, AND GENEROSITY.

DENMARK

WITH BASIC NEEDS COVERED, PURSUING PASSIONS IS EASIER.

On a farm north of Copenhagen, schoolchildren harvest vegetables that they raised and will cook and eat as part of a program designed to inspire a deeper appreciation of the environment. Such communal activities are quintessentially Danish. Cohousing arrangements are popular, and most adults belong to clubs. CORY RICHARDS

In similar ways Denmark supports the well-being of people like Sidse Clemmensen. I met her on my third trip to Denmark to explore that nation's unique brand of happiness—one that seems to enable people to live a purposeful life better than anywhere else. Sitting in her kitchen sipping tea, the 35-year-old working mother with short brown hair wore a sleeveless blouse, Moroccan slippers, and a diamond stud in her nose.

"The state provides me with everything I need," Clemmensen said. "My children are happy. I have a great husband. And I love my job. I know that nothing too bad can happen to me."

Clemmensen and her family are one of 22 households in a shared housing community called a *bofællesskab* in the city of Aalborg. Each family owns a small Lego-like house, but together they share a huge garden, laundry room, workshop, storage area, parking facility, and dining hall, where they can opt in to communal meals. (Each family

A Cuban immigrant, embracing the Danish passion for socializing, dances with his daughter, who is half Danish, on a lawn near a swimming area in Copenhagen that is a popular gathering place. The Danish people have typically welcomed immigrants, although the recent refugee crisis has somewhat dampened that enthusiasm.

CORY RICHARDS

cooks one or two meals a month for the whole community and then eats the rest of its meals free.) Perched on a low hill overlooking rolling pastures, the complex is within biking distance of the neighborhood elementary school and the university.

In Scandinavian fashion the cohousing complex offers an elegant mix of private and public, an apt metaphor for Danish society as a whole, with its emphasis on trust and community. Denmark's societal evolution may be traced to the Second Schleswig War, in 1864, said Peter Gundelach, a sociologist at the University of Copenhagen, when Denmark lost a quarter of its territory to Prussia. "With that defeat we lost our ambition to be a world superpower," he said. "It humbled us. Our government began to strengthen our national identity and build inwardly instead."

Danes grow up believing they have the right to health care, education, and a financial safety net. University students draw a government stipend in addition to free tuition. New parents can take a yearlong government-paid parental leave at nearly full salary; this includes gay and lesbian parents. People work hard in Denmark, but on average less than 40 hours a week, with at least four weeks of vacation a year. The price for such lavish benefits is one of the world's highest income tax rates, which starts at 41 percent and tops out at 56 percent—a field leveler that makes it possible for a garbageman to earn more than a doctor.

"Danish happiness is closely tied to their notion of *tryghed,* the snuggled, tucked-in feeling that begins with a mother's love and extends to the relationship Danes have with their government," said Jonathan Schwartz, an American anthropologist based in Copenhagen. "The system doesn't so much ensure happiness as it keeps people from doing what will make them unhappy."

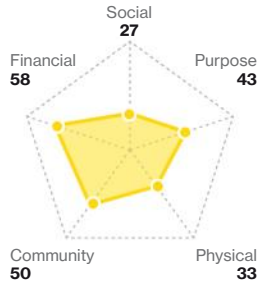
Setting aside time for self-fulfillment is another key ingredient of Danish happiness. More than 90 percent of Danes belong to a club or an association—from cold-water swimmers to rabbit breeders—and more than 40 percent volunteer for civic groups. Danish society, it seems, encourages the kind of balance between engaging work and rewarding play that results in a sense of time described as flow. "The Danes seem more aware of the total needs of a person than most other places," said Mihaly Csikszentmihalyi, a psychologist at Claremont Graduate University in California. "People need to be challenged. It's in our genes. We develop self-confidence through adversity. They're the building blocks to happiness."

HAPPINESS FACTOR

DENMARK

At least half of Danes are thriving in the categories of financial well-being and community engagement. They also score high marks when it comes to finding purpose and meaning in daily activities.

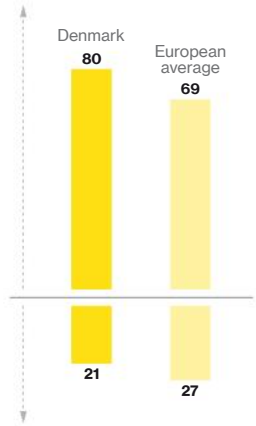
PERCENTAGE OF POPULATION THRIVING IN EACH CATEGORY



EUROPEAN EMOTION

Denmark is the European leader in daily positive experiences; Belarus ranks lowest.

POSITIVE EMOTION SCORE



NEGATIVE EMOTION SCORE

GALLUP WORLD POLL, 2015-16

SINGAPORE

A CLEAR, SAFE PATH LEADS TO SUCCESS.

To celebrate graduation, army recruits march eight hours overnight to the world's largest floating stage. National service – mandatory for men – engenders a sense of purpose, pride, and unity, creating bonds among the country's main ethnic groups. The army is a symbol of security, which Singaporeans highly value. MATTHIEU PALEY

Singapore has developed its own approach to happiness, as personified by Douglas Foo. I first met Foo when I visited Singapore in 2008. He had a reputation for being hugely successful, community minded, consummately principled, and irrepressibly affable. But his clearest expression of happiness, I discovered, was neither his expensive sports car nor his trophy case of business awards. It was his laugh: a widemouthed, back-tilted howl of joy.

Foo runs Sakae Sushi, Singapore's largest chain of quick-service sushi restaurants, but he still finds time to volunteer for 22 organizations. During his 14-hour workdays he wears tailored blue suits and presides over a dozen meetings with a mix of earnest ceremony, careful consideration, baritone decisiveness, and pandemic humor. His gift for defusing tension with spontaneous laughter coupled with a herculean work capacity has earned him all the trappings of Singaporean success. And while Foo will tell you he's happy, he still feels he hasn't yet arrived.

Three family members pray over an urn with the ashes of a relative as they participate in a dramatic interment ceremony, replete with a laser show, at an opulent columbarium. For many Singaporeans, wealth – and showy displays of it – are essential aspects of their formula for happiness.
CORY RICHARDS

"In the scope of things I'm just an insect," he said with a grave expression on his round face. Then, realizing his own hyperbole, he cracked up.

Foo, 48, is at an age that straddles the desperate-to-survive generation that founded Singapore in the 1960s and the 20-somethings who will marshal in a new future. In just over half a century, the 30-mile-long nation has transformed itself from a large fishing village into a country of 5.8 million people living amid thousands of high-rises and more than 150 shopping malls, a metropolis graced by tidy, tree-lined streets.

Success for Singaporeans lies at the end of a well-defined path: Follow the rules, get into the right school, land the right job, and happiness is yours. (It's traditionally summed up as the five *C*'s: car, condominium, cash, credit card, and club membership.) In a system that aspires to be a meritocracy, talent and performance are rewarded, in theory. You'll hear Singaporeans complain about rising prices and their overworked lives, but almost all of them say they feel safe and trust one another.

The architect of this social experiment was the late Lee Kuan Yew, who led Singapore's independence movement in 1965. Overwhelmingly loved by Singaporeans, he famously endorsed strict laws and corporal punishment for violent crimes.

With a keen appreciation for traditional Asian values, Lee set out to build a society based on harmony, respect, and hard work. Anyone who made an effort to work, no matter how lowly the job, was guaranteed a livable wage. His "workfare" program supplemented low salaries with housing and health care subsidies.

Although the population is largely composed of Chinese (74.3 percent), Malays (13.4 percent), and Indians (9.1 percent), Lee's government retained English as a lingua franca to help ensure no ethnicity would have the upper hand. He guaranteed religious freedom and equal education for all, and he subsidized homeownership. Most Singaporeans own a flat in government-developed housing, usually a high-rise unit. By law such buildings must reflect the ethnic diversity of the country—so Singapore has no racial or ethnic ghettos.

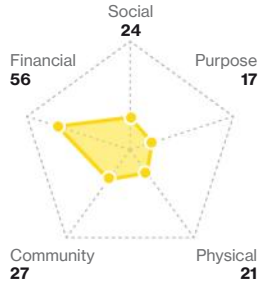
As a result the people of Singapore today exemplify the third strand of happiness—what experts call life satisfaction. You score high when you're living your values and are proud of what you've accomplished. You tend to be financially secure, have a high degree of status, and feel a sense of belonging. To achieve this type of happiness can take years, and it often comes at the expense of enjoying moment-to-moment daily pleasures.

HAPPINESS FACTOR

SINGAPORE

Singapore's economic stability has helped the country consistently rank high when it comes to financial well-being. But all that striving for wealth comes at some cost to the other happiness factors.

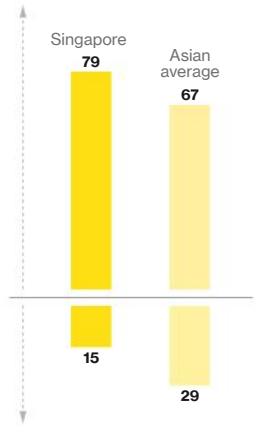
PERCENTAGE OF POPULATION THRIVING IN EACH CATEGORY



HAVING NICE DAYS

Singapore is one of five nations reporting the fewest negative daily experiences.

POSITIVE EMOTION SCORE



NEGATIVE EMOTION SCORE

GALLUP WORLD POLL, 2015-16


MICHAEL K

Many Singaporeans love to shop, and there are more than 150 malls in the tiny city-state. The Shoppes at Marina Bay Sands is one of the main tourist attractions, with its luxury stores, upscale restaurants, and sampans to ride on a canal. Singapore ensures that everyone who works has a decent wage, health care, and a place to live. It also encourages enterprise and entrepreneurship, minting many millionaires.

MATTHIEU PALEY

WHERE IS THE HAPPIEST PLACE IN THE UNITED STATES?

Singapore's story, like those of Costa Rica and Denmark, illustrates how a relatively small (about six million people), prosperous nation can achieve a high level of well-being when guided by enlightened leaders. And yet what works for such societies might not easily translate into solutions for a sprawling, diverse, argumentative, freedom-loving nation like the United States. Could such a tumultuous place, with its racial, ethnic, religious, economic, and political diversity, learn anything useful from Denmark's wealthy, relatively homogeneous, consensus-seeking social democracy? Likewise, could the United States really emulate the day-to-day joy of Costa Rica? Or the values-driven security of Singapore?

Erik Gordon, the owner of Carabiner Coffee, serves climbers from a vintage Volkswagen van at Castle Rock, just a 20-minute drive from Boulder. Happiness for many of the city's residents arises from its small-town character and its close proximity to nearby mountains.
MATTHIEU PALEY

There's reason to think so—if a community like Boulder, Colorado, is any indication. If Americans want to feel more joy in their lives, pursue their purpose more rewardingly, and find greater satisfaction in achieving their goals, they could listen to the citizens of Boulder talk about how to shape their community to support, rather than hinder, their collective happiness. Indeed, since the U.S. isn't one of the top 10 happiest places, it might do well to look to local bright spots to inform national policy.

That's what I learned from Ruth Wright, an 88-year-old citizen activist, one chilly spring afternoon as we strolled down Pearl Street, the city's main pedestrian mall. It was two o'clock on a workday, and a hard mountain sun was beating down on the brick pavement. Men in puffy down jackets huddled in conversation, dreadlocked students tapped on computers at outdoor cafés, and only a few people in office-friendly plaids seemed to be moving with any destination in mind.

Decades ago, when the City Council decided to allow high-rise buildings downtown that would have interfered with the mountain view, Wright led a successful campaign to ensure no building would cut Boulderites off from nature. It was the beginning of a career of questioning the unquestioned virtue of development. Her public service led her to the state legislature, where she represented much of Boulder for 14 years, with a stint as minority leader.

As we passed through the historic section of downtown, Wright frowned at a new glass-and-brick structure, occupied by eco-chic outdoor-clothing boutiques and organic foodie emporiums, whose presence she found jarring. At the next intersection she gestured toward the end of Pearl Street. "My life's work has been in preserving that," she said, pointing to where the pine-dotted Rocky Mountains towered majestically over the rooftops.

As stunning as the setting is, Boulder's appeal is more than just skin-deep. Besides being a college town, an adventure destination, and a haven for elite athletes, it produces the highest level of well-being for its residents. "People there live better lives than residents of any other city for which we have results," said Dan Witters, a research director at Gallup, which since 2008 has surveyed more than 2.5 million people in American communities.

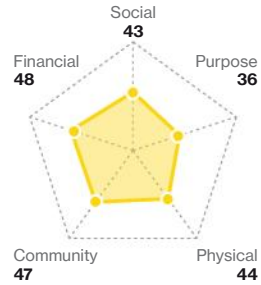
Witters created the Gallup–National Geographic Index, designed to assess 18 of the most important indicators of well-being. His analysis included obesity rates, absence of pain, feelings of safety and security, whether people use

HAPPINESS FACTOR

BOULDER, COLORADO

People in Boulder seem to have learned the secret to living a balanced life. Many thrive in four out of five measures of well-being, especially in community engagement and financial health.

PERCENTAGE OF POPULATION THRIVING IN EACH CATEGORY



GALLUP-SHARECARE WELL-BEING INDEX, 2016

STATES OF BLISS

How happy are people where you live? Check out our state-by-state happiness map at *natgeo.com/happieststates.*

their strengths and accomplish their goals, and whether they learn something interesting daily. He even included dentist visits, which, counter-intuitively perhaps, are strongly associated with happiness. Among 190 U.S. metropolitan areas, Boulder came out on top. (Charleston, West Virginia, had the lowest scores.)

Boulder's quality of life might not have turned out as well if it weren't for people like Wright. During the late 1960s developers approached the city for approval to build some high-rises. Wright feared they would destroy the character of her community—a place where downtown high-tech workers can take a nature hike during their lunch hour. In 1971, a few months after the council adopted a plan to allow buildings as high as 14 stories, she championed a ballot measure that limited building heights to five stories. "Had I lost, Boulder would be a forest of high-rises crisscrossed by traffic-jammed streets," she said. "Here in Boulder we had a jewel to preserve."

In the decades since, the community has diligently protected its quality of life. Boulder taxpayers have voted for 300 miles of bike routes that web the city, and yellow lights blink at crosswalks, reminding motorists that pedestrians have the right-of-way. As a result Boulder residents bike to work at one of the highest rates in the nation—17 times more than the national average. This makes for cleaner air, fewer accidents, and fewer overweight people.

A progressive food policy has also helped. The city matches the federal Supplemental Nutrition Assistance Program (SNAP) dollar for dollar to encourage fruit and vegetable consumption. Last year Boulder became one of the nation's first cities to approve a soda tax aimed at reducing consumption of sugar-sweetened beverages. Officials plan to use the revenue from the soda tax to fund health programs for children.

Still, change continues to threaten Boulder's way of life. The civic-minded hippie generation that spawned companies such as Celestial Seasonings herbal-tea company and WhiteWave health food company are now giving way to Google and tech venture capital firms. A highly paid, more driven culture is replacing the laid-back, outdoorsy one. For all of its list-topping well-being scores, Boulder has curiously high levels of stress. "It's not Zen Boulder anymore," Witters said. On any given day 49 percent of people surveyed in Boulder report feeling stress, higher than the national average. "But it's productive stress," he added.

Lila Sophia and David Tresemer dine alfresco on an organic farm outside Boulder. The meal was prepared with ingredients raised there. New research by the World Well-Being Project, based at the University of Pennsylvania, shows that people who have access to exercise and healthy foods are somewhat more likely to be happy.
MATTHIEU PALEY

Ruth Wright has felt that stress too, but in a good way, she said. On the last day we met, she arrived brandishing a newspaper with the headline "Boulder extends height limit." Two nights earlier she'd testified at a six-hour City Council meeting to fend off developers, joining a majority of speakers who urged that a moratorium on buildings higher than 40 feet continue for at least 15 more months. The council voted eight to one for the extension. Wright had prevailed again. When I pointed out that her life didn't seem to include much day-to-day joy, she corrected me. "For me fun is getting things done," she said.

And there, in a nutshell, was the Boulder brand of happiness: a community of fit, successful, mission-driven people with a clear vision of the good life, even if they don't completely live it yet. Pleasure, purpose, pride—the three strands of happiness.

Photographers **Cory Richards** and **Matthieu Paley** are frequent *National Geographic* contributors. In shooting this story, Richards said, he realized that while happiness comes and goes, contentment allows us to accept those fluctuations. And Paley said he was reminded that we need to make time every day to socialize with our families and friends.

PTEROSAURS

Weirdest Wonders on Wings

New discoveries are changing old views of pterosaurs, the biggest, meanest, most bizarre animals that ever flew.

Nearly as tall as a giraffe and with the wingspan of an F-16 fighter, *Quetzalcoatlus northropi* was one of the largest flying animals of all time. This life-size model being painted at a Minnesota studio is bound for a cultural center in Kuwait.

Fur-like fibers left subtle impressions on portions of this *Jeholopterus* fossil discovered in China. The insulating fuzz is a sign that later pterosaurs were perhaps warm-blooded.

INSTITUTE OF VERTEBRATE PALEONTOLOGY AND PALEOANTHROPOLOGY, BEIJING

By Richard Conniff
Photographs by Robert Clark

Most people respond to the word 'pterosaurs' with a puzzled expression, until you add, 'like pterodactyls.'

That's the common name given to the first pterosaur discovered in the 18th century. Scientists have since described more than 200 pterosaur species, but popular notions about pterosaurs—the winged dragons that ruled Mesozoic skies for 162 million years—have remained stuck. We invariably imagine them as pointy-headed, leather-winged, clumsily aerial reptilians, with murderous proclivities.

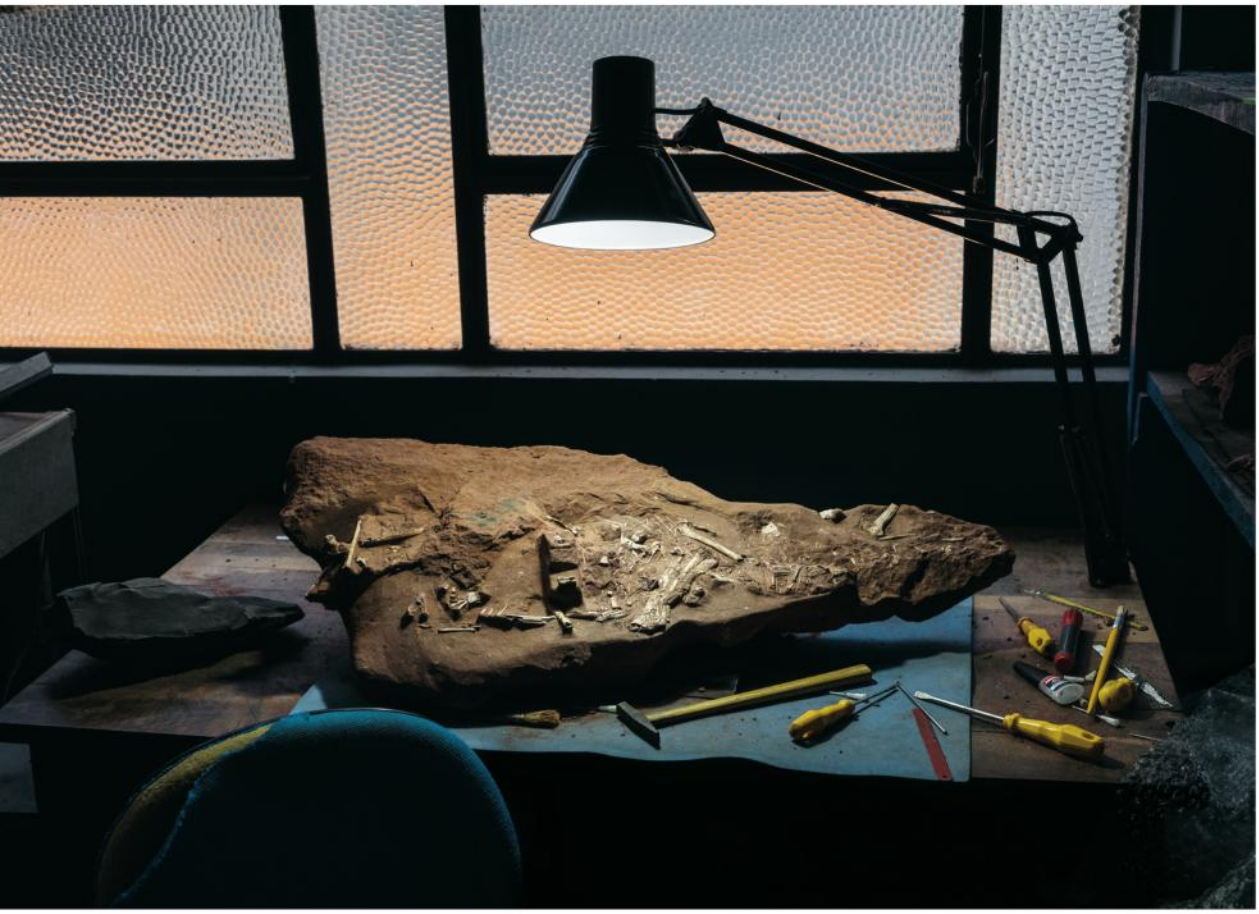
Take a look, for example, at the 1966 film *One Million Years B.C.,* in which a squawking, lavender pterosaur carries Raquel Welch off to feed the nestlings. (Spoiler alert: She lives.) For an update, turn to 2015's *Jurassic World,* and you'll find that pterosaurs are still plucking humans skyward, the sad lot of the perennially typecast. (A minor point: The last pterosaurs went extinct 66 million years ago, eons before the first humans showed up at the party.)

But a rush of fossil discoveries has brought to light surprising new pterosaur shapes, sizes, and behaviors. Some paleontologists now suspect that hundreds of pterosaur species may have lived at any one time, dividing up habitats much as modern birds do. Their world included monsters like *Quetzalcoatlus northropi,* one of the largest flying animals yet discovered, nearly as tall as a giraffe, with a 35-foot wingspan and a likely penchant for picking off baby dinosaurs. But it also included pterosaurs the size of sparrows that flitted through primeval forests and may have fed on insects, large pterosaurs that stayed on the wing across oceans for days at a time like albatrosses, and pterosaurs that stood in briny shallows and filter fed like pink flamingos.

Among the most exciting finds is an assortment of fossilized pterosaur eggs. Scans of intact eggs have revealed the world of embryos inside the shell and helped explain how the hatchlings developed. One egg even turned up in the oviduct of a *Darwinopterus* pterosaur from China, along with another egg apparently pushed out by the impact that killed her. "Mrs. T" (for Mrs. Pterosaur) thus became the first pterosaur indisputably identified by sex. Because she lacked a head crest, she provided the first solid evidence that for some male pterosaurs, as for some modern birds, big, brightly colored crests probably functioned as a sexual display device. These discoveries have given pterosaurs a vivid new life as real animals. They've also given pterosaur researchers an almost insatiable appetite for more.

HEADING OUT into the geological layer cake of Big Bend National Park in southwestern Texas, British pterosaur researcher Dave Martill proposes a "to do" list for this brief reconnaissance: (1) Find a rattlesnake to admire. (2) Find a complete *Quetzalcoatlus* skull sitting on the ground. The odds are almost infinitely better for item one. But he and Nizar Ibrahim, a fellow paleontologist, promptly fall into a detailed discussion about how to obtain a research permit in the event of item two.

This is the first rule of pterosaur research: You must be an optimist. Thinking you'll go out on a given day and find any trace of pterosaurs is like buying a Powerball ticket and then arguing about how to spend the winnings. Pterosaur fossils are vanishingly rare. Their whole splendid world, built on bones that were hollow and with paper-thin walls, has long since collapsed into dust. Scarcity is especially the rule for *Quetzalcoatlus,* which is known from only a few



The bones of *Caiuajara dobruskii* await study at a museum in Brazil. A surge of fossil finds has upended scientists' views of pterosaurs. Says one expert: "They aren't the animals we thought they were."

fragments discovered at Big Bend in the 1970s.

Martill and Ibrahim spend three days bone hunting among the fissured hillsides. They cross and recross the promisingly named Pterodactyl Ridge, frequently consulting the "X marks the spot" on maps left by the discoverer of *Quetzalcoatlus*. They decipher the nuances of geological strata ("Look at that Milankovitch-controlled cyclicity!" Martill exclaims, referring to the way the Earth's shifting movements show up in the rock), and they conjure up forgotten worlds. On a sandstone ridge with no obvious way down, Martill remarks, "Haven't found a mountain yet we can't fall down," plunges forward, and emerges unscathed below.

They do not, however, stumble across any rattlesnakes, nor even the faintest whiff of a pterosaur. The femur of a giant dinosaur, perhaps an *Alamosaurus,* turns up, by way of consolation. But dinosaurs are not pterosaurs or vice versa. Leaving the park, the two paleontologists are already mapping out a return search for *Quetzalcoatlus,* permanently hooked on the tantalizing pterosaur mix of extreme variation in shape, size, and behavior glimpsed through the rarest of fossil remains.

Scientific ideas about pterosaurs have often been wildly varied—even on such basic questions as what they looked like or how they behaved. That's partly because researchers have had to build their hypotheses on just a handful of specimens, often with critical details missing. It's also because pterosaur anatomy is frankly weird and seemingly ill suited to life on land or in the sky. Some scientists have depicted pterosaurs dragging themselves along the ground on their bellies. Others have imagined them walking upright on their hind legs like zombies, with their strangely elongated forelimbs sticking straight out and their wings folded capelike behind. Still others have depicted pterosaurs walking on all fours, with their wings neatly folded up at their

CENPALEO, UNIVERSIDADE DO CONTESTADO, BRAZIL

Bristling with teeth for catching fish, this *Anhanguera piscator* fossil retains its true-to-life shape – a prize for paleontologists. Its skull and other bones (overleaf) were found in a fossil-rich region of Brazil.

NSM-PV 19892, NATIONAL MUSEUM OF NATURE AND SCIENCE, TOKYO (BOTH)

Pterosaurs' hollow, ultralight bones aided flight but make 3-D fossils like *Anhanguera piscator* rare. Most pterosaur fossils that survive are crushed flat and, says one observer, "look like prehistoric roadkill."

Giants of the Skies

Pterosaurs achieved powered flight tens of millions of years before birds or bats. These winged reptiles were the first vertebrates and largest animals ever to fly, thanks to strong limbs for launching, ultralight skeletons, and specially adapted wings.

A branch alone

PTEROSAURS OVER TIME

They ruled the skies for 162 million years, evolving from small, long-tailed forms into diverse shapes, some as large as airplanes. Pterosaur fossils have been found all over the world, and evidence is growing that hundreds of species may have lived at any one time in a wide variety of environments.

First pterosaurs

Dimorphodon macronyx

Wingspan: 4 ft | Weight: 4 lbs

Many Triassic and early Jurassic pterosaurs like *Dimorphodon* were small, with partially hollow bones, sharp teeth, and long, stiff tails.

Anurognathus ammoni

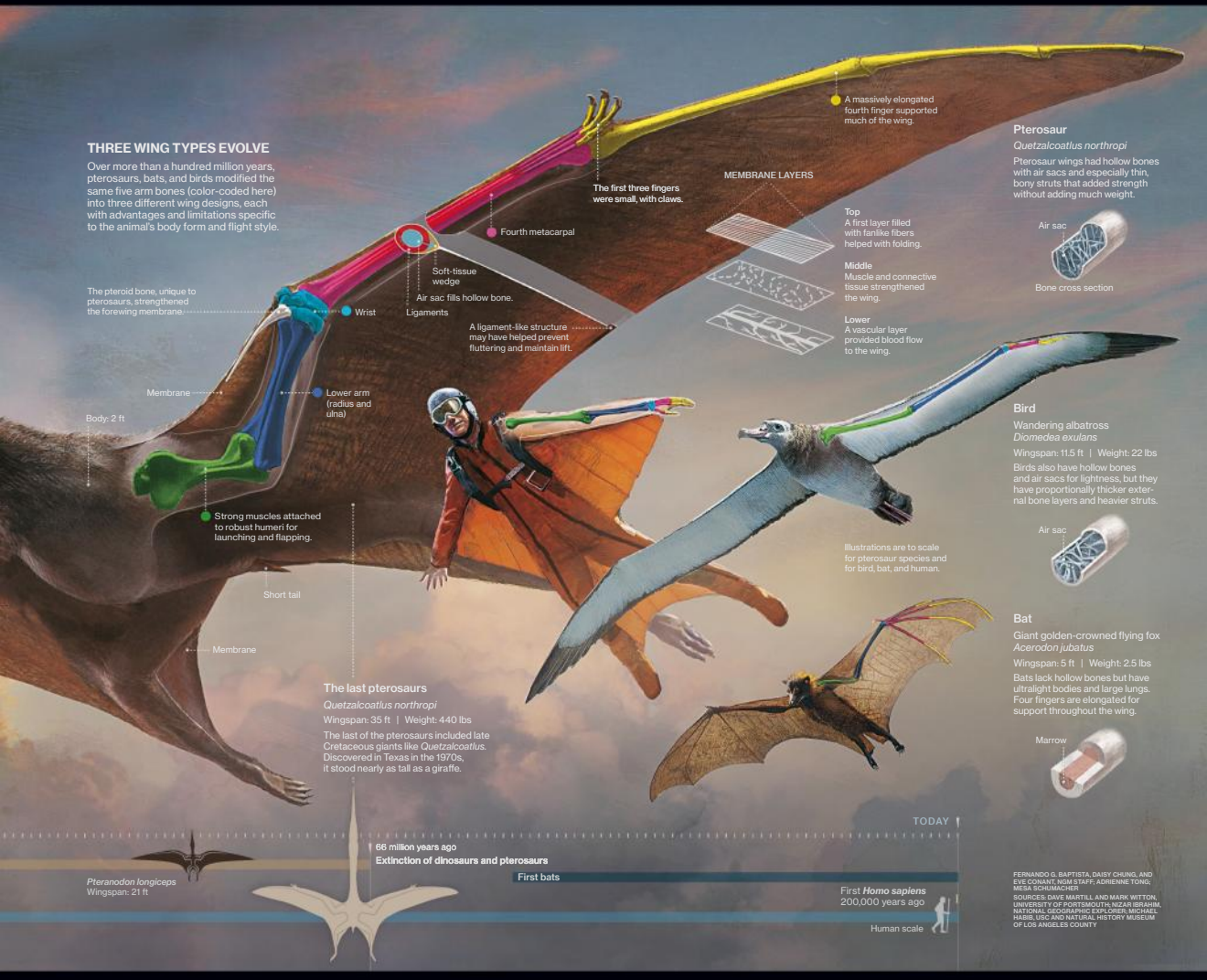
Wingspan: 2 ft | Weight: 0.2 lb

One of the smallest pterosaurs, the agile *Anurognathus* had strong wings and a broad head, which likely helped with catching insects.

Tupandactylus navigans

Wingspan: 10 ft | Weight: 24 lbs

This species is one of a group of pterosaurs that developed prominent crests, which may have functioned as devices for sexual display.



FERNANDO G. BAPTISTA, DAISY CHUNG, AND EVE CONANT, NGM STAFF; ADRIENNE TONG; MESA SCHUMACHER
SOURCES: DAVE MARTILL AND MARK WITTON, UNIVERSITY OF PORTSMOUTH; NIZAR IBRAHIM, NATIONAL GEOGRAPHIC EXPLORER; MICHAEL HABIB, USC AND NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY

A *Rhamphorhynchus* pterosaur and a fierce fish collided as they pursued the same prey – the pterosaur from the air above, the fish from the water below. They died, sank to the seafloor, and fossilized together.

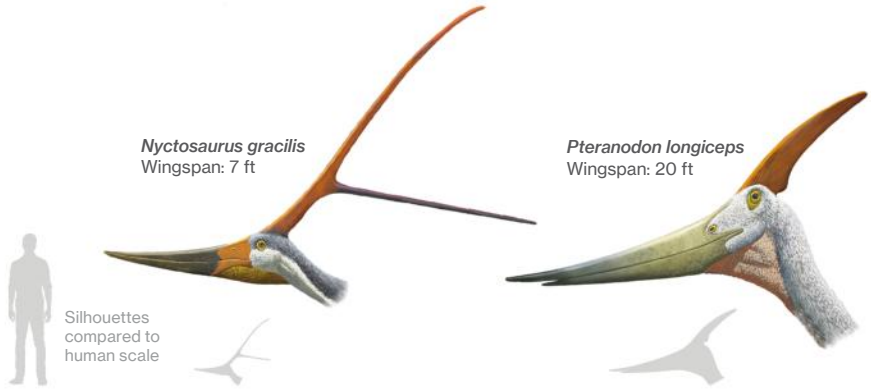
UV PHOTOGRAPH BY HELMUT TISCHLINGER

A jumble of bones discovered in Brazil turned out to be at least 47 pterosaurs of a single species, *Caiuajara dobruskii*. The bone bed offers strong evidence that some pterosaurs lived and died in colonies.

CENPALEO, UNIVERSIDADE DO CONTESTADO, BRAZIL

Pterosaurs in Profile

Beak shape may have varied based on dietary needs. The purpose (and actual coloring) of pterosaur crests is unknown, but they may have been useful for attracting mates.



sides, but stumping along as if trying out forearm crutches for the first time. Some researchers thought pterosaurs were so aeronautically awkward that they could become airborne only by hanging upside down from cliffs and plummeting into flight.

"It's not uncommon for the head and neck to be three or four times the length of the torso," says Michael Habib, who studies pterosaur anatomy and movement. Even scientific illustrators often get it wrong. "They basically take a bird model and put a membrane wing and a crest on it, but pterosaur proportions were not birdlike."

Habib, who works at the Natural History Museum of Los Angeles County, set out to reconsider pterosaur biomechanics, combining an intensely mathematical approach with hands-on anatomical knowledge from his other job: teaching in the human cadaver lab at the University of Southern California's medical school.

Like most researchers, Habib figures the first pterosaurs emerged roughly 230 million years ago from light, strong reptiles adapted for running and leaping after prey. Jumping—to catch an insect or dodge a predator—evolved into "jumping and not coming down for a while," Habib theorizes. Pterosaurs probably glided at first, and then, tens of millions of years before birds or bats, they became the first vertebrates to achieve powered flight.

With the help of aeronautical equations that they applied for the first time to biology, Habib and his fellow biomechanists dismissed the cliff-hanging hypothesis. They also demonstrated that taking off from land with an upright, bipedal stance, as other researchers had proposed, would have shattered the femurs of larger species. Launching from a four-point stance made more sense, Habib says. "You want to get over the forelimbs and punch up into the air, like a pole-vaulter." To take off from water, marine pterosaurs used their wings like paddles to push off the surface and flap into the air—"like Michael Phelps doing a butterfly stroke," Habib says. And like Phelps, they had big, muscular shoulders—often combined with "freakishly small feet" on their hind limbs to minimize drag.

Pterosaurs are looking less like a train wreck in the sky and more like sophisticated aviators.

Pterosaur wings consist of a membrane attached to each flank from shoulder to ankle and held out by a spectacularly elongated fourth finger running along the wing's leading edge. Beautifully preserved specimens from Brazil and Germany revealed that the wing membrane was threaded with muscles and blood vessels and reinforced with fibrous cords.

Researchers now think pterosaurs could make subtle adjustments to the shape of their wings in different flight conditions by contracting the wing muscles or by moving their ankles in and out. Changing the angle of a wrist bone called the pteroid may have given them the equivalent of the leading-edge slats on a passenger jet, for increased lift at low speeds. Pterosaurs also devoted more muscle to the business of flying, and a larger proportion of their body weight, than do birds. Even their brains appear to have evolved for flight, with enlarged lobes for processing complex sensory data from the wing membrane.

The result is that pterosaurs have begun to look less like a train wreck in the sky and more

ART: RAÚL MARTÍN. RESEARCH: MESA SCHUMACHER. SOURCES: DAVE MARTILL AND MARK WITTON, UNIVERSITY OF PORTSMOUTH; NIZAR IBRAHIM, NATIONAL GEOGRAPHIC EXPLORER; MICHAEL HABIB, USC AND NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY

like sophisticated aviators. Many species appear to have evolved for flying slowly but with great efficiency for long distances and for soaring on the weak thermals over oceans. A few may even have been "hyper-aerial," according to Habib. For example, *Nyctosaurus,* an albatross-like marine pterosaur with a nine-foot-plus wingspan, had a glide ratio—the distance it could travel forward for every meter of drop—"well within the range of a modern racing sailplane, things that we have manufactured to be high-efficiency soaring planes," says Habib.

"OK, the wing stuff is good," a paleontologist remarked after a recent talk by Habib. "But what's up with those heads?" *Quetzalcoatlus,* for instance, is thought to have had a skull up to 10 feet long on a torso a quarter of that length. *Nyctosaurus* had an outsize head, plus a huge mast sticking out of the top, possibly with a crest attached. It looks like something Dr. Seuss invented.

Habib's reply has to do partly with pterosaur brains, which added minimal weight to those huge heads. It also has to do with pterosaur bones, which were hollow, like bird bones, only more so. The bone walls were just a fraction of an inch thick, made of crisscrossing, laminated layers to resist bending and breaking—some researchers call them "plywood bones"—and they had struts across the hollow middle to prevent buckling. That allowed pterosaurs to balloon out the bone, expanding certain anatomical features without adding much weight.

Their skulls, ornamented with crests and keels, and those great, gaping mouths achieved proportions Habib calls "ridiculous," even "stupid." This has led him to a sort of Big Bad Wolf hypothesis: "A big head gives you a big mouth, which is good for eating things," he says. "And a big head is good for sexual display." Pterosaurs, he told his questioner at that talk, "were giant flying murder heads."

On a busy street in downtown Jinzhou, a commercial hub for northeastern China, Junchang Lü, one of the country's foremost paleontologists, leads visitors down the dimly lit hallway of an ordinary office building. The director of the Jinzhou Paleontological Museum, who keeps an office here, swings open the door of a windowless little storage room to reveal what would be any other museum's star attractions: slabs of stone containing exquisitely detailed fossils of feathered dinosaurs, primitive birds, and especially pterosaurs, covering every inch of shelf and most of the floor.

Propped against the back wall, a slab that comes almost up to Lü's shoulder displays an alarmingly large pterosaur—a *Zhenyuanopterus,* with a 13-foot wingspan and tiny chicken feet on its hind legs. The long, thin head, turned to one side, is all basket mouth, a cross-stitching of needle teeth that become longer and overlap at the killing end. For catching fish while swimming on the surface, says Lü. It's one of almost 30 pterosaur species he has described since 2001, with others still awaiting scientific recognition on the shelves.

The Jinzhou museum turns out to be one of 10 such fossil museums scattered around Liaoning Province, the mother lode of modern pterosaur discovery and part of China's recent rise to the forefront of fossil hunting. Other paleontologists whisper that it's also the Wild West, with enterprising farmers doing much of the collecting, to the detriment of scientific research. Commercial collectors often buy up prize specimens to sell illegally into international trade.

In addition, Liaoning is the main collecting site in a rivalry outsiders liken, a little unfairly, to the notorious 19th-century "bone wars" combat between pioneering American paleontologists Othniel Charles Marsh and Edward Drinker Cope. This rivalry pits Lü, of the Chinese Academy of

Geological Sciences, against Xiaolin Wang, whose specimen-crammed office is at the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) in Beijing. Like Marsh and Cope, the two worked together in the beginning, then went their separate ways in a spirit of muted hostility. ("One mountain cannot contain two tigers," says Shunxing Jiang, a paleontologist who works at IVPP.)

In the 16 years since then, each has repeatedly one-upped the other, producing a combined total of more than 50 new pterosaur species—almost a quarter of all known pterosaurs. Some of those species will perhaps turn out to be invalid, as happens after every great burst of paleontological discovery. But each side also has many more discoveries still to come.

"They'd have to work nine to five for 10 years" to describe what they already have on hand, an outsider remarks, enviously. Hearing this, Jiang lifts his eyebrows, a little anxiously, and says, "I think 10 years is not enough."

The bone-wars comparison is, however, a stretch, given the infighting that's common in this contentious, esoteric field. "We're a very small group, and we don't really get along," one pterosaur specialist says. The field, says another, "has a reputation for people who viciously despise one another." Pterosaur researcher A will readily volunteer that B is "a waste of carbon," while C independently remarks of A that certain people "would happily see him at the bottom of the ocean." Their combat is a natural by-product of all those optimistic hypotheses built on fragmentary evidence, and it makes the Chinese rivalry look like a tea party. Lü shrugs off talk of mutual loathing, and Wang manages to avoid talking about it at all.

Their success, in any case, probably has as much to do with being in the right place at the right time as with competition. China is one of just five places in the world—together with Germany, Brazil, the United States, and England—that have produced 90 percent of all pterosaur fossils. That's not because those five countries were the only places pterosaurs existed in such diversity and abundance. Fragmentary fossils have turned up almost everywhere, even in Antarctica. Instead, paleontologists think the pterosaur diversity that used to exist everywhere is simply better preserved in those places by some quirk of geology.

This is nowhere more beautifully true than in Liaoning. In the early Cretaceous, Lü says, Liaoning's temperate forests and shallow freshwater lakes supported a rich ecological community, including dinosaurs, early birds, and a large variety of pterosaurs. Violent storms and ashy volcanic eruptions now and then killed some animals suddenly and in large numbers, perhaps slamming them out of the air onto the mudflats. These catastrophic events buried the victims quickly, sometimes anaerobically, with sediments that have preserved specimens intact and in fine detail for more than a hundred million years. Paleontologists call such sites *lagerstätte,* from the German meaning roughly a "storehouse" of lost life. The results now turn up on hilly farms and eroding cliff faces all over Liaoning. They don't look like much at first, a slab with a hint or two of bone. But after a preparator working at a microscope has meticulously removed eons of hardened sediment, they begin to take shape again. To a beginner's eye, they look as if someone has played pick-up sticks with an odd assortment of lizard skulls and walking poles. Or as if Wile E. Coyote has gone off a ski slope and gotten squashed flat beneath a huge boulder: legs akimbo, mouth agape, long, bony wing fingers all higgledy-piggledy askew.

The sight of so many weapons, so much hunger, such vibrant life frozen in stone is poignant.

When you look at them one after another, though—at, say, the Beipiao Pterosaur Museum or at a recent pterosaur show at the Beijing Museum of Natural History—the fossils begin to make sense as individual species in all their

An ordinary guy with an extraordinary eye for fossils, Ray Stanford has found hundreds of stone slabs bearing the tracks of pterosaurs and other extinct animals near his home in the Washington, D.C., area.

former diversity. There's the widemouthed, frog-faced pterosaur named *Jeholopterus* (also known as the "Cookie Monster" pterosaur), thought to have snapped up dragonflies and other insects in ancient forests. There's *Ikrandraco,* named for the aerial mountain banshees in the movie *Avatar* and thought to have flown low over the water, using a sort of keel on its lower jaw to skim beneath the surface for fish. There's *Dsungaripterus,* from northwestern China, with a long, thin, upturned beak for probing for shellfish and other invertebrates, to be crushed up by its knobby teeth.

The sight of so many weapons, so much hunger, such vibrant life now frozen in stone is unmistakably poignant. Something about pterosaurs ultimately made them vulnerable. Maybe the food they depended on vanished during the great extinction at the end of the Cretaceous, 66 million years ago. Or maybe their evolution to increasingly gigantic size left the likes of *Quetzalcoatlus* vulnerable, whereas some smaller birds could hide out during the catastrophe. For pterosaurs, in any case, it was the end-time.

But as you study their beautifully preserved remains in a museum, something peculiar happens: You start to wonder if *Nemicolopterus* is sidling off the edge of its piece of shale in pursuit of missing body parts. You wonder if you just saw the toe bones of *Kunpengopterus,* dark brown and standing out on the rock surface like embossed lettering, begin to twitch. By a trick of the eye or the mind, it can seem—at least momentarily—as if the pterosaurs, this bizarre and bountiful expression of the great life force of the planet Earth, might yet rise up from the rock and again take wing. □

Writer **Richard Conniff**'s most recent book is *House of Lost Worlds: Dinosaurs, Dynasties, and the Story of Life on Earth.* Photographer **Robert Clark**'s latest book is *Evolution: A Visual Record.*

The Mission to Save Africa's Okavango Delta

An ambitious expedition through one of the world's great delta regions reveals the threats it faces—and the wealth of life it sustains.

Complex, ever changing patterns of water and land support the bountiful wildlife and vegetation of Botswana's Okavango Delta. By opening trails that become channels, elephants add to the dynamism.

Hippos, abundant in the delta and in the rivers that feed it, graze by night on land and rest by day in water. Males fight over territory, females protect their young – and their long, self-sharpening canine teeth can be lethal to intruders.

National Geographic's Okavango Wilderness Project is an effort to survey, and ultimately help protect, the delta's headwaters. It began in 2015 with an expedition on Angola's Cuito River, so narrow here, near its source, that the team's loaded boats had to be dragged for eight days.

By David Quammen
Photographs by Cory Richards

Seen from space, high above Africa, the Okavango Delta resembles a gigantic starburst blossom pressed onto the landscape of northern Botswana, its stem angling southeastward from the Namibian border, its petals of silvery water splayed out for a hundred miles across the Kalahari Basin. It is one of the planet's great wetlands, a vast splash of life-nurturing channels and lagoons and seasonal ponds amid a severely dry region of the continent.

This delta doesn't open to the sea. Contained entirely within the basin, it comes to a halt along a southeastern perimeter and disappears into the deep Kalahari sands. It can be thought of as the world's largest oasis, a wet refuge supporting elephants, hippos, crocodiles, and wild dogs; lechwe and sitatungas and other wetland antelopes; warthogs and buffalo, lions and zebras, and birdlife of wondrous diversity and abundance—not to mention a tourism industry worth hundreds of millions of dollars annually. But from high in space, you won't see the hippos on their day beds. You won't see the wild dogs hunkered in shade beneath thorn scrub or the glad expressions on the faces of visitors and local entrepreneurs. Another thing you won't see is the source of all that water.

The water comes almost entirely from Angola, Botswana's complicated neighbor, two countries away. It begins in the moist highlands of Angola's rainy center and flows toward the country's southeast, quickly in one major drainage, the Cubango, and more slowly in another, the Cuito, where it pools into source lakes; percolates slowly through grassy floodplains, peat deposits, and underlying sand; and seeps into tributaries. The Cuito and Cubango Rivers converge at the southern Angolan border, forming a bigger river, the Okavango, which flows across the Caprivi Strip, a narrow band of Namibia, and into Botswana. On average, 2.5 trillion gallons of water a year flows in.

Take away that liquid gift, rendered by Angola to Botswana each year, and the Okavango Delta would cease to exist. It would become something else, and that something would not include hippos, sitatungas, or African fish eagles. If southern Africa were a vast golf course, Okavango with the faucets closed would be one of its sand traps.

Changes now occurring or foreseeable in southeastern Angola—in land use, water diversion, population density, and commerce—make this dark prospect a real possibility. That's why the

Society Grant Your National Geographic Society membership helped fund this project.

Project leader Steve Boyes (right) takes a break with National Geographic filmmaker Neil Gelinas. Among all the challenges Boyes has faced in more than 10 years of field science aimed at safeguarding the Okavango – diplomacy, capsized boats, land mines – an attack of sweat bees is just one more thing.

Cuito and Cubango Rivers, two remote waterways, have quietly attained high interest in certain circles. That's why an international group of scientists, government officials, resource planners, and hardy young explorers, brought together by a fervent South African conservation biologist named Steve Boyes, with support from the National Geographic Society, has embarked on a grand effort of exploration, data gathering, and conservation advocacy called the Okavango Wilderness Project. These collaborators recognize that the well-being and future of the Okavango Delta is at stake—and that the well-being and future of southeastern Angola, a hard landscape, a poor cousin to glorious Okavango, is at stake too.

"We're on borrowed time," Boyes told me, as we sat at a campsite along the Cubango River earlier this year after a long day of paddling our *mokoro*s (Okavango-style canoes) downstream. Having grown up in Johannesburg, with a passion for nature, Boyes worked for years at various jobs—a bartender at wineries, a naturalist and guide, a camp manager in the Okavango Delta. Along the way he finished a doctorate. By 2007 he had become acutely aware of the water-source issue and tried to raise the alert among people of Botswana but mostly met fatalism.

"They were just not interested," he said, recalling a typical reaction: Yeah, Angola is such a terrible, bad place, and it's such a shame the river may die. That goaded him to action. He began looking north, toward the headwaters. "We are going to do this," he vowed. "We're going to try and understand what this system is about." In fact he hoped not just to understand it but to help preserve it.

ANGOLA IN 2017 may seem an unlikely site for visionary conservation efforts, yet it could also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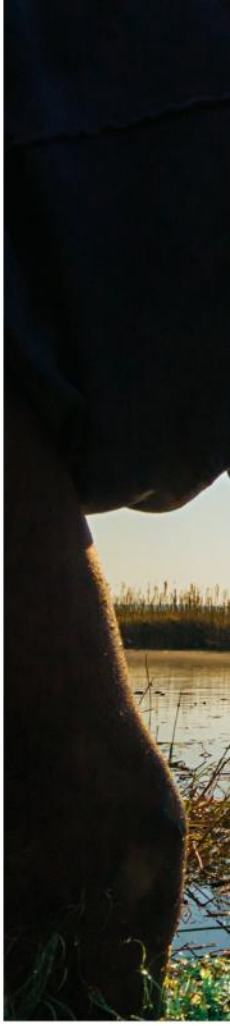
Field observations and a few preserved specimens are emblematic of the diversity of amphibians and reptiles in the rivers flowing into the delta. Through 2016 the expedition surveys had identified 64 reptile and 35 amphibian species in the wider region, including water snakes, lizards, toads, and the darker, yellow-flecked Angolan river frog, which is unique to the country.

PETE MULLER



Subsistence fishing has long been important to villagers in the Cuito and Cubango watersheds. With better nets, they now get larger hauls and more fish to smoke and carry by motorbike or dugout canoe to area markets. Boyes and others worry that the harvests may not be sustainable.

offer unusual opportunities. It is ravaged by war but now at peace. From the early 1960s until the start of the new millennium, Angola was high on the list of nations you would not want to visit—unless you were a mercenary soldier or a diamond buyer. Once a Portuguese colony, it got its independence in 1975 after a bloody war of liberation, then was wracked by civil war for 27 years, a proxy battleground for the superpowers, pustulated with land mines, a scene of great suffering and strife.

But things have changed drastically since 2002, when the rebel party, UNITA, suffered a crushing defeat, after which oil in great quantities began flowing for export and business boomed. "The most important thing we have to tell the world is that Angola is now a stable country," the minister of the environment, Maria de Fátima Monteiro Jardim, told me recently at a gathering in Luanda, the capital. "We are committed to preserving nature," she said. What that commitment will mean to reality on the ground is a crucial unknown.

The Boyes team has the blessing of Angolan officialdom, along with international support, to pursue an extraordinarily ambitious study of the Cuito and Cubango Rivers, exploring every mile of them and some of their tributaries, surveying their wildlife, sampling water quality, noting human presence and impacts along the banks, creating a vast and publicly accessible body of data, and trying to comprehend just how the clean waters of southeastern Angola vivify the Okavango Delta in Botswana.

These survey expeditions, eight so far, have been arduous as well as thorough. The first began on May 21, 2015, when Boyes and his team, traveling with an escort of Land Rovers from HALO Trust, the international demining organization, and a big Russian cargo truck, arrived at the source lake of the Cuito River. They had brought several tons of gear and seven mokoros in which to ferry themselves and their stuff downstream. After paddling the length of the lake on their first day, they discovered that the Cuito at its outlet is a tiny stream, waist-deep but only a yard or so wide, and impossible for navigation by 20-foot-long mokoros. So they dragged the loaded boats downstream, slogging through high grasses alongside the little band of water, pulling like human oxen, and taking data as they went. These mokoros were fiberglass-and-wood models, not dugouts of ebony or some other tree like the Okavango originals, but were still very weighty when fully loaded. They dragged them each day for more than a week before the Cuito became navigable. Then they climbed aboard, with paddles and poles, but faced a new sort of challenge: crocodiles and hippos.

The Cuito along its upper reaches is essentially a wilderness river—clear water, banks lined with reeds, no villages, few signs of humans. On the morning of July 11, 2015, along a broad curve, something plunged through the reeds and into the water just ahead. Boyes, steersman in the lead boat, hollered "Croc," a relatively routine alert. He ruddered toward the mid-river channel, giving the animal space along the bank.

Suddenly a great bulge of water rose beside Boyes's boat as a distraught hippo surfaced—probably a young male, Boyes thinks. Turns out the right evasive line for a crocodile is the wrong

one for a hippo. Hippos own the deep water. And like crocs, they may kill hundreds of people each year. "It was a big mistake," Boyes told me later. "Completely our fault. We went right over the animal, defending itself."

The hippo drove its lower canine teeth (maybe a foot and a half long, and sharp) through the bottom of the boat. The upper jaw didn't quite catch the gunwale, so instead of biting the mokoro in half, the hippo just capsized the thing, sending Boyes and his bow paddler, Giles Trevethick, into the water. They clambered onto the hull, and a crew member quickly fired a bear-banger flare, meant to disrupt the attack. Boyes's younger brother Chris, his expedition chief, in a boat just behind, shouted "Swim!" Boyes and Trevethick got to shore, safe but shaken. Within two hours the boat was patched—using their fiberglass-repair kit—and the expedition was back on the water.

What's telling from this episode, besides the fast recovery, is how it exemplifies the Okavango Wilderness Project's harvest of data. From the observations gathered that hour, by electronic device and human eyeball, recorded instantly into an elaborate data-vacuuming system, we know that the Cuito River thereabouts has a strong current, a sandy bottom, and not much aquatic vegetation but harbors smallmouth bream, among other fish. We know that Trevethick made note of a pied kingfisher, then a malachite kingfisher, then a blacksmith lapwing, perched on shoreline limbs. We know the longitude and latitude at which the mishap occurred, to at least 12 decimal points of GPS accuracy. We know that Steve Boyes's pulse rate (as registered by his Suunto watch, also patched to the system) rose abruptly from 81 beats a minute to 208 beats a minute at 10:57 a.m. And we can assume that 208 is the normal heart rate for a healthy young man trying to outswim the watery gallop of a hippopotamus.

WHEN I JOINED Boyes's team on the Cubango River, almost two years later, their data-gathering regimen had advanced to include more categories

Lifeline to a Desert Delta

The waters of the Okavango River Basin flow from Angola's highlands through the arid Caprivi Strip of Namibia and into the meandering streams of the rare inland delta of Botswana, providing sustenance to unique ecosystems and about a million people along the way. But as pressure to develop once war-torn and remote regions of Angola grows, so does the risk to the sustainability of this oasis.

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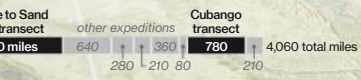
AVANGO EXPEDITIONS

al Geographic–funded scientists have so far com- eight survey expeditions over 4,000 miles by foot, helicopter, and bicycle, using drones, water sensors, a traps, and local expertise. The goals: to study ic species, conduct the first systematic source-to- urveys, and inform conservation strategies.



A Dynamic Water System

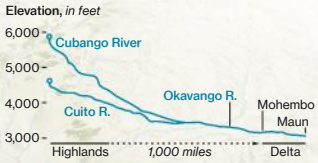
Water may be abundant upstream – three times as much rain falls in the highlands as in the delta – but variations in rainfall significantly affect water levels downstream. The dynamic system that's created nourishes one of the greatest concentrations of wildlife in Africa.

MOSAIC LANDSCAPE

The delta swells to life when floodwaters arrive from Angola. Plants and animals – from islands built by termites to meandering channels engineered by hippos, elephants, and buffalo – also regenerate and shape the delta.

DEPENDENT DELTA

Upstream rivers deliver some 2.5 trillion gallons of water every year. Gentle slopes, grassy floodplains, and absorbent sands slow the Cuito's journey, while the faster-flowing Cubango has a steeper and rockier descent.



Cuando
Zambezi
MAVINGA N.P.
LUENGUE-LUIANA NATIONAL PARK
ZAMBIA
NAMIBIA
ZIMBABWE
Victoria Falls
ANGOLA
CAPRIVI STRIP
BWABWATA NATIONAL PARK
MUDUMU N.P.
NKASA RUPARA N.P.
CHOBE NATIONAL PARK
OKAVANGO BASIN

Team arrives at the Andara rapids and islands, sacred burial sites for chiefs of the Hambukushu people.

Popa Falls
Mohembo
Okavango Delta
PANHANDLE
Gumare Fault
Ncamasere
Sand dunes
Gumare

Some 100,000 tourists a year visit safari lodges and camps in the delta area, making tourism one of Botswana's top industries.

MOREMI GAME RESERVE
Chief's Island
Kunyere Fault
Thamalakane Fault
Boro
Maun
Thamalakane

To Lake Ngami
40 miles

Team continues journey to Makgadikgadi Salt Pans, 120 miles away.

- Expedition route
- Tourist accommodation

Minefield
- Active
- Cleared

Irrigation scheme
- Established
- Proposed

Hydroelectric dam
- Proposed

SCALE VARIES IN THIS PERSPECTIVE.

NGM MAPS. SOURCES: JOHN MENDELSOHN, RESEARCH AND INFORMATION SERVICES OF NAMIBIA; NASA; USGS; UNIVERSITY OF MARYLAND; OKAVANGO RESEARCH INSTITUTE GIS LAB, UNIVERSITY OF BOTSWANA; OKAVANGO WILDERNESS PROJECT; PIOTR WOLSKI, UNIVERSITY OF CAPE TOWN; THE HALO TRUST; EIS NAMIBIA; MARTIN GAMACHE; ART OF THE MAPPABLE

lnerable Wetland

ystal clear water filtered by sandy soils, land is among the world's most productive stine. International, national, and local vation efforts help keep the delta healthy – as water keeps flowing in from Angola.

Termite mounds in the delta provide high ground for chacma baboons (left). Nile crocodiles (below left) and other aquatic animals navigate the interconnected channels, while the hooves and dung of buffalo churn and fertilize solid ground. In the changeable Okavango, life shapes landscape and vice versa.

BEVERLY JOUBERT, NATIONAL GEOGRAPHIC CREATIVE (BUFFALO)

of information. One morning I watched a young Namibian named Götz Neef assess his overnight catch in a fish trap: A largemouth bream, an electric elephantfish of the sort called a Churchill, a squeaker catfish, and more—weird creatures to me, subtle data points of biogeography to anyone who knows African fish. Such sampling and collections, analyzed by ichthyologists allied with the project, will help reveal how the fish fauna of the Cubango differ from that of the Cuito and how both may contain unique species or subspecies, distinct from anything else in the region.

NUMBER OF SPECIES IDENTIFIED

Approximately 353 plants, 115 fish, 407 birds, 68 mammals,

Along the Cuito, for instance, the researchers found what may be a new species of *Clariallabes,* an eel-like form of air-breathing catfish that seems adapted for wriggling through the saturated peat bogs. Other specialists, based in Angola, South Africa, and England, have also assisted the project with field collections—of amphibians, reptiles, insects, small mammals, plants—and continue the work of identification and analysis. Frogs and dragonflies, with their aquatic immature stages, are sensitive to pollution and can be especially telling as indicators of water quality. One group of peculiar rodents, known as *vlei* rats in the Afrikaans slang (suggesting that they inhabit transient ponds, or vleis) and notable for the smallness of their territories, seems to have diversified into more than one related species in the highlands.

"Angola is the missing link," a small-mammal biologist named Peter Taylor, one of the project's experts, told me, "for understanding the pattern of radiation of these beasts." Boyes's goal is to assemble such facts into a mosaic portrait of this two-river system, in its biological and hydrological particulars, to support protecting it for its own sake and the sake of the Okavango Delta.

Neef, besides trapping fish, also saw to the gathering of water-quality data from two delicate sensors as we paddled downstream. And he saw to the continuous photography—one 360-degree camera on a tripod, plus two DSLRs angled out from the bow of his mokoro, snapping frames at five-minute intervals. In the evenings at camp, as darkness fell, Neef deployed a bat detector, a little yellow box that captured high-frequency blurts of chiropterans, used later to identify the species. Other expedition members recorded data about birds, reptiles, human activity. Boyes himself was the principal ornithologist on the rivers, calling out sightings—giant kingfisher, hammerkop, white-fronted bee-eater, lilac-breasted roller—which a young Angolan biologist, Kerllen Costa, entered with GPS tagging into a tablet. Costa's sister, Adjany, is an ichthyologist and a National Geographic emerging explorer; also assistant director of the project, she serves as liaison to Angolan officials when she isn't aboard one of the expedition's mokoros. Boyes's team also includes field crew members from Zimbabwe, South Africa, Namibia, the U.S., and of course, Botswana, homeland of his most skilled mokoro boatmen, recruited from the Okavango Delta itself.

Captain of my mokoro was Tumeletso Setlabosha, known to everyone as Water, a small but powerful Wayeyi man who grew up in the central delta. His mother gave him the aqueous nickname because his birth occurred in a pool of water, when she was traveling through the lagoons. Asked his age, Water said he was 54 on land, but "when I'm paddling, I'm 25." He tolerated me in the bow of his boat for a week, as I gawked and scribbled notes and did my best with the paddle.

HUMAN PRESENCE along the upper Cubango is sparse, even though the end of the war has allowed people to return to their villages in these southern hinterlands once controlled by the UNITA rebels. Paddling between reed-lined banks, we saw the occasional beached mokoro, the lonely fishing camp, the cow here, the goat there, a few women washing clothes or making moonshine

(kashipembe) from jackal berries or other wild fruit in a simple still—and then, farther downstream, more people, more boats, more livestock, corn crops, a soccer field, a few motorbikes. At night, beyond the trill of crickets, we heard the roar of trucks, and the clatter of their springs taking washboard at full speed, on a bad but important dirt track paralleling the river. That road leads to a border crossing with Namibia, through which supplies can roll in and Angolan timber can roll out. Apart from timber and illegal bush meat and water, the Cubango Valley has little to offer the wider world. No one, it seems, has yet found diamonds or gold or oil in this corner of Angola. Clean water: That is the oil and the gold.

One day about noon we beached on the left bank above a small rapid, and because a fully loaded mokoro is too fragile and clumsy for white-water daring, we scouted the line. As we walked, Boyes spotted a hippo snare of stout wire, camouflaged with reed stems and placed along a haul-out path used by the animals. There is nothing more piteous than the howl of a hippo in a snare, he said, and clipped through the wire with his utility tool. Boyes has deep sympathy for the needs of people along the Cubango, and he recognizes that their progress toward better lives must be part of any arrangement for protecting the two rivers, the water flow, the biological riches of southeastern Angola, and the Okavango Delta. But hippo flesh for meat and hippo teeth to be sold as ivory are contraband commodities that the Cubango can't sustainably surrender.

Another day, we came off the water early to avoid camping near a village called Savate, a place known for the land mines still lurking around its perimeter. We beached upstream, at a dirt landing where it was cow pies, not mines, we had to avoid. Children watched us unload tons of gear—tents and tables and boxes of food, duffels, folding stools, fancy electronics. Women came with piles of washing to this, their regular laundry spot, and had to work around our flotilla of canoes. A tethered donkey grazed nearby. A donkey was wealth. After sunset, by the time our hearty dinner of beans and rice came off the campfire, smelling good, the children had disappeared. I wondered what impression of us they took.

SEEN FROM A CESSNA, 500 feet above northern Botswana, the Okavango Delta resembles a paisley carpet of ovals and streaks and patches, gentle rises and swales, a rich pattern textured largely in shades of green and brown. The lagoon waters appear almost black from overhead; the channels and oxbows gleam silver when reflecting a low afternoon sun. At the center of small islands, ringed by trees, lies the whiteness of precipitated salt. Aloft in your little plane, and moving slowly, you get a sense of the dynamic heterogeneity below, of how water has nudged and carved and shaped land over time, opening new channels, closing old ones, rising and falling by season, filling pans, then leaving them to dry, encircling islands, respecting subtle ridges, changing its imperatives and benefices from year to year, and thereby shaping an extraordinary ecosystem hospitable to fish and crocodiles and long-legged birds and mammals that don't mind having wet feet. That's how I saw the delta, after my time in Angola, thanks to John "Tico" McNutt, a veteran American conservation biologist.

64 reptiles, 35 amphibians, and 40 possible new species

McNutt, a friend of a friend, met me at the small airport in Maun serving Okavango tourism and flew us to the research camp from which he has worked for nearly three decades, studying the endangered African wild dog. With his breadth of curiosity and involvement, he probably

National Geographic's film ***Into the Okavango,*** following the team's 2015 "Source to Sand" journey, will be released early next year.

A blaze sweeps the Cuito floodplain near one of the team's campsites. Fire is a natural part of grassland and forest cycles, but human-set burns to drive game to hunters exacerbate erosion and siltation. Other upstream threats to the Okavango's lifeblood include fertilizer and pesticide pollution, river diversion for agriculture, and hydroelectric dams.

JAMES KYDD

understands the ecological and political dynamics of the delta as well as anyone. Besides showing me dog packs on the ground, he gave me four days of eye-in-the-sky perspective and commentary—even while flying the plane and listening for his collared dogs on the VHF telemetry receiver.

On the left, that's Chief's Island. On the right, the old Mogogelo floodplain, which once carried water almost all the way to his camp. We gazed down at large herds of lechwe, some reedbuck and impalas, termite mounds rising cream-colored at the center of small islands, hippo tracks like claw marks across the floodplain grasses, elephants casting long shadows in late afternoon. "There's no vultures," he remarked. "They should be roosting in these palm groves—should be vultures all over." But vultures are hated by poachers for giving away the positions of fresh elephant carcasses and are killed by poisoning the left-behind meat. The Okavango, even with the taps open, has its problems.

We flew north across low plains of reeds and papyrus, islands large and small, serpentine channels, until McNutt said: "Somewhere right here would be the fault line, where everything starts to distribute. From the panhandle."

The panhandle is a wide stretch of slow-moving water, contained by ridges that rise above swampy lowlands, beginning just south of the Namibia border and flowing southeast to that line McNutt mentioned, known to geologists as the Gumare Fault. Beyond the fault line lies a sunken, flat trough, partly filled with sediments but still nearly the lowest zone in the Kalahari Basin, across which the Okavango waters spread broadly into their flower-blossom shape. The blossom petals come to a dead stop, though, at another pair of diagonal faults, marking the southeastern boundary of the delta. Meeting those natural dams, what remains of the surface water slides westward into a linear lake, Lake Ngami, or sinks away into the sands. South of all this: salt pans and desert.

Amid the complexities of water delivery and biological enrichment, from the headwaters

The Makgadikgadi Pans are flat, salty remnants of an ancient lake, rich with life, that covered much of northern Botswana until faulting diverted the source rivers. Khoisan bushmen now lead tourists here, offering a vision of majestic desolation – and what the Okavango Delta might be without its water.

to the delta, from Angola through the Caprivi Strip to Botswana, several factors are especially fateful. The delta itself receives rainfall but not much, and mostly during the summer months of December through March. Angola's central highlands receive far more, a great wet bounty, roughly 50 inches annually, which saturates the peat deposits and sands of the upper Cuito floodplains and then slowly, after delay, flows down the Cuito and its tributaries. Those rains feed the Cubango too, but the Cubango River catchment lies on steeper, rockier substrate, so the seasonal rainwater comes gushing down fast.

The result of these asynchronies is that the Okavango Delta gets three separate pulses of water annually, giving it a longer and more varied supply of moisture than most freshwater wetlands enjoy. Freshwater coming in pulses, spread across the year, distributed in an ever changing pattern of channels and pans and lagoons, nurturing vegetation of many types, fertilized by the dung of elephants and hippos and impalas—all this is a good recipe for biological fecundity.

The biggest challenge faced by the Okavango Wilderness Project is not just to understand this complex system—that's hard enough—but to persuade Angolan officialdom, and the Angolan people, to preserve the Cuito and Cubango Rivers roughly as they are, flowing free and clean, without much pollution or diversion, through landscapes mostly undamaged by timber harvest, charcoalmaking, forest burning for hunting drives, commercial extraction of bush meat, agricultural schemes demanding high inputs of fertilizer, mining, or other destructive uses. It's an urgent task and not an easy one.

Some optimists propose that landscapes along the Cuito and Cubango could become international tourism destinations themselves, sites of high-end lodges drawing visitors to see restored populations of magnificent wildlife, such as the Angolan giant sable, that were mostly lost during the decades of war. Maybe such attractions could be included in a regional circuit, they suggest, along with more famous camps in the Okavango. Another hope is that the Botswana government and its tourism industry might recognize the jeopardy of their wonderland—recognize that without the Cuito and the Cubango, there is no Okavango Delta—and act with foresight, offering a compact of payments to Angola for continued delivery of the water. Call it ransom or call it a "water bond" (as Steve Boyes does), it seems rational. Rationality and foresight might be improbable expectations when it comes to intergovernmental relations over resource issues, but the Okavango Delta itself is an improbable phenomenon deserving exceptional concern, imagination, and effort.

Meanwhile the changes in Angola, as Boyes told me, are happening fast. "If we started this work in three years' time, there'd be nothing left to protect." The future is coming like a river that flows through other people's lives. □

Contributing writer **David Quammen**'s new book, on the molecular "tree of life," will be published by Simon & Schuster in 2018. **Cory Richards** has photographed nine stories for the magazine. His previous article, "Myanmar's Toughest Climb," ran in September 2015.

Two goats, Bella (left) and Ella, graze by the water in Freeborn County, Minnesota. Farm animals competing at county fairs are sometimes sold at market for their milk or meat. Others, like Bella, get a reprieve and return to their home pasture.

The Unchosen

The competition is fierce at the county fair animal contests in Minnesota. Few are winners. What happens to the others?

Story and Photographs by R. J. Kern

County fairs are a little like beauty pageants for animals. The way we selectively breed goats and sheep has shaped the course of their evolution.

When I moved to Minnesota from Denver, I wanted to capture this notion of competitive livestock lineage. There's a Will Ferrell movie about race-car driving called *Talladega Nights*. In it his dad tells him, "If you ain't first, you're last." That's the mind-set at these county fairs—owners want a grand-champion animal, but most animals don't win. I think we all know what it's like not to be chosen, whether for prom or the basketball team or a job. But what does it look like?

At fairs I would watch the judges line up the animals and rank them. Then I'd approach the handlers of unchosen contestants and ask if I could create a stylized portrait of them and their animal. The studio-style backdrop adds some formality, but the manure and hay on the ground show the rawness of the setting. I asked the kids to imagine themselves as next year's champion, and right away you could see their confidence.

The disappointment of not winning didn't linger long. For extra perspective I thought I'd also try to photograph the kids and their unchosen animals in their home pasture (at least the ones that weren't sold at the fair). But it was kind of like interviewing a college senior two months after graduation; many of them had moved on to the next thing.

Small rural communities are changing, and the county fair isn't necessarily the highlight of a kid's summer the way it used to be. Hopefully county fairs will still be around in a hundred years, and young people will still be learning the lessons that come with raising and showing animals—although it's easy to see that this way of life is becoming lost as kids leave the farm. We should all be concerned about what this means for sustainability and stewardship of the land. □

AS TOLD TO NINA STROCHLIC

At the Freeborn County Fair, 15-year-old Louis Wagner and Bella, nicknamed Dumb, competed for a spot at the state fair in St. Paul, Minnesota. Louis chose the 1994 Jim Carrey film *Dumb and Dumber* as a namesake for his goat. "Once you name an animal, you connect with it," says R. J. Kern, who photographed the pair in 2016.

Annabelle (right), an Angora goat whose coat is used to produce mohair, moseys with Prancer through the snow in Anoka County. After photographing unchosen animals at 10 Minnesota county fairs, Kern crisscrossed the state to visit their homes.

Kol Heinicke, age eight, shows Annabelle, his goat, at the Anoka County Fair. "You can tell he cared about the animal deeply," Kern says. County fairs are changing as urbanization claims rural populations. While the number of retirement-age farmers increases in Minnesota, census data show the number of new farmers declining.

The Minnesota State Fair is one of America's largest fairs, attracting nearly two million visitors a year. But small county fairs – like the Clay County Fair, where Rylee Story-Poppel, age three, showed her sheep, Nelly – face an uncertain future. Some of the local grandstands Kern visited held just a few spectators.

Nelly (left) and her then mate, Redrock, graze in their home pasture in Clay County. The fact that sheep and goats were among the first animals that humans domesticated drew Kern to photograph them. "We've evolved with this unique kinship," he says. "It's a reciprocal relationship."

R. J. Kern's book, *The Sheep and the Goats*, will be published in spring 2018 by Kehrer Verlag.

Why Vaccines Matter

Here's a way to save hundreds of thousands of young lives: Give children in poor countries the shots that rich countries take for granted.

PAKISTAN Karachi shopkeeper Ghulam Ishaq didn't trust the polio vaccine. Now he blames himself for the double misery of his four-year-old daughter, Rafia: one leg withered by polio, the other broken by a car she couldn't dodge.

DEMOCRATIC REPUBLIC OF THE CONGO (DRC)
Coolers full of vaccine strapped to their motorbikes, Doctors Without Borders workers cross a river near Monga while a measles outbreak is under way there. On their arduous 10-hour circuit of affected villages, they must keep the vaccine perfectly chilled.

UGANDA On Mount Morungole, Makerere University researcher Sadic Waswa Babyesiza examines a bat he just caught. With a team from the Field Museum of Chicago, he's prospecting for the wild hosts of malaria, Zika, and other pathogens. The results may help in developing vaccines.

By Cynthia Gorney
Photographs by William Daniels

Go see the child, Samir Saha said. Just sit with her. Probably the siblings will be there too, the brother and sister whose lives are also altered permanently. 'This is why the vaccine is so important,' Saha said. 'We want to reduce this number to a minimum, if not zero. So no other children will be like this.'

It was a little after dawn in Dhaka, the capital of Bangladesh, and Saha was in the back seat of his car, brooding. A uniformed driver threaded the Toyota through a cacophonous mess of jitneys, motorcycles, rickshaws, trucks, and battered buses with passengers hanging out the doors. "We could save the life, but we could not…" He left the sentence unfinished. "You'll be seeing the scenario," he said. "You'll understand."

Saha is a microbiologist, internationally renowned for his research on a bacterium called pneumococcus. The laboratory he founded is wedged into one corner of Dhaka Shishu, the biggest children's hospital in Bangladesh. Just down the hall, rows of beds fill the open wards; during family hours, each bed seems to hold both a sick child and many attentive relatives. Inside the lab, white-jacketed men and women spend their days in intimate study of pneumococcal cells: hunting for them in vials of blood and other bodily fluids, smearing them into petri dishes, peering at them through microscopes.

Pneumococcal bacteria are ubiquitous in the modern world; easily spreadable through sneezing or casual contact, they can live without ill effect in the nasal passages of people with healthy immune systems. But when our defenses fail us, pneumococcus can migrate, multiply, and set off life-threatening infectious disease. Young children are especially vulnerable. Young children in places without ready access to antibiotics and good medical care are the most vulnerable of all. At the start of the 21st century, as the world's first effective children's vaccine became available in the United States and Canada, pneumococcal disease was killing more than 800,000 children worldwide every year—more than three-quarters of a million infants and kids under five, that is,

BANGLADESH Sanjida Sahajahan, 11, was a healthy toddler when the common bacterium pneumococcus devastated her brain. International aid is helping Bangladesh pay for the vaccine against such infections – too late for Sanjida but perhaps in time to protect thousands of other young people.

dying not from some headline epidemic like Ebola or Zika but from a common organism that blew up into pneumonia (infected lungs) or meningitis (infected brain lining) or a mortal assault on the bloodstream. The vast majority of those deaths were occurring in impoverished countries such as Bangladesh.

In 2015 pneumococcal conjugate vaccine, as the children's formulation is called, reached the Bangladeshis, and Saha's research team is intently tracking its progress. If PCVs prove as effective around the world as vaccine experts hope, they promise both a greatly lowered mortality rate—that's many thousands of small children staying alive instead of dying before they're old enough to start school—and much less nonmortal sickness. Less of the rapid pneumonia breathing; less of the fever, the sucking chest, the rattling cough, the blue lips, the bedside watch by parents pulled away from the paid work that supports their other children. Less … *suffering,* I kept hearing Saha and his Bangladeshi colleagues say, as though sensing that an outsider might need help appreciating the stakes.

Because from the vantage of a country like the United States, it can be easy to imagine that the most pressing vaccine challenge of 2017 lies in convincing certain communities of skeptical parents that they really ought to inoculate their kids. Those efforts are important, to be sure. But

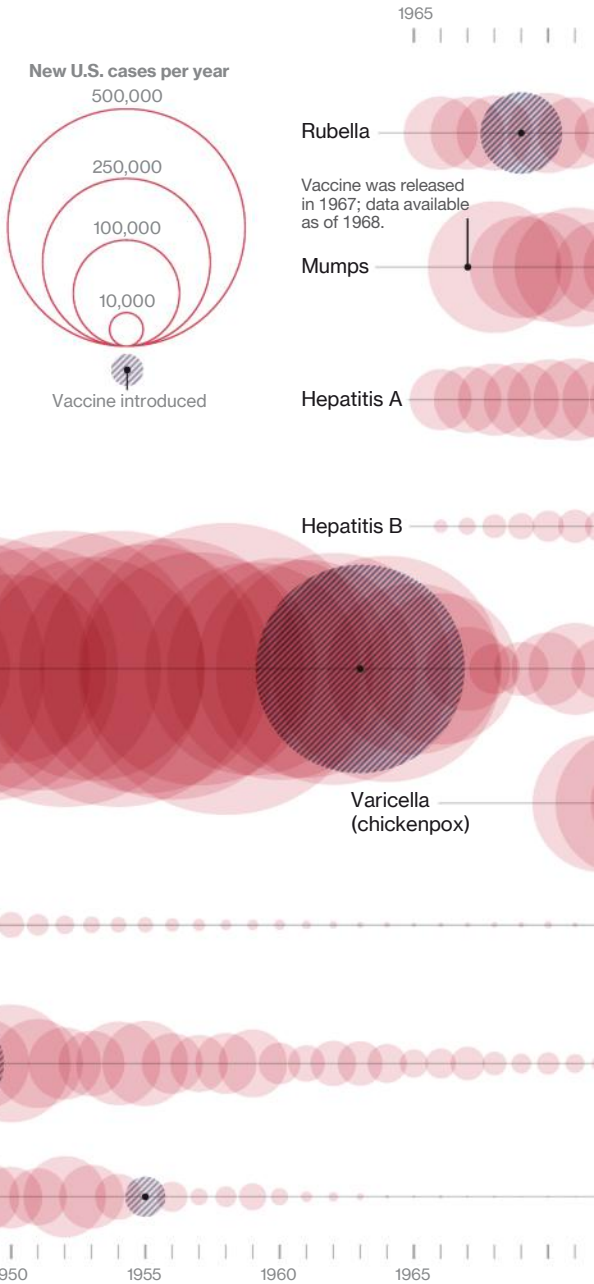
DRC In 2016, with a yellow fever outbreak spreading from neighboring Angola and vaccine in short supply, health workers struggled to inoculate all 350,000 residents of the city of Matadi. Here they improvise a clinic in an abandoned truck.


Rico em vitam

CASE STUDY: U.S.

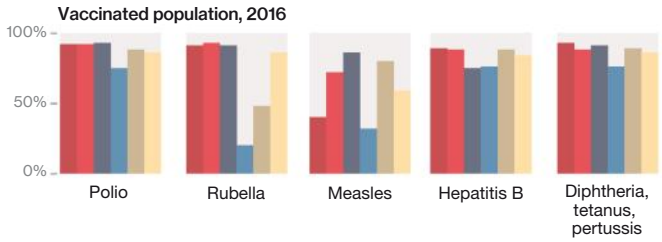
Vaccine Victories

Since the 1940s, as new vaccines have been released (striped circles), the incidence of infectious diseases that once afflicted hundreds of thousands of Americans – mostly children – has plummeted. Polio and rubella are gone from the U.S.; diphtheria is rare. It used to kill up to 15,000 a year.

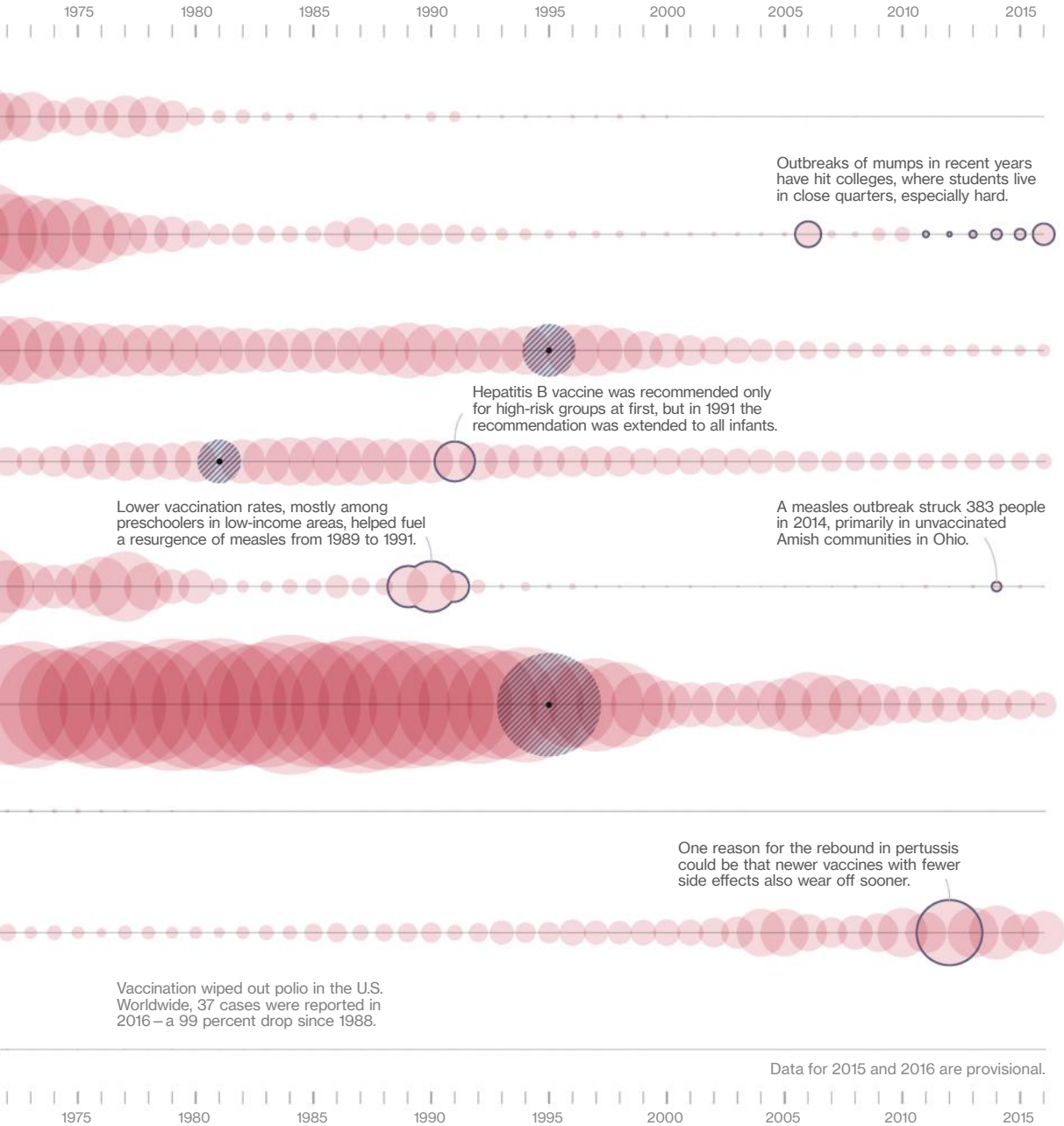


Protecting the world

About 85 percent of infants worldwide are now vaccinated against polio as well as diphtheria, tetanus, and pertussis. Vaccines save two to three million lives a year.

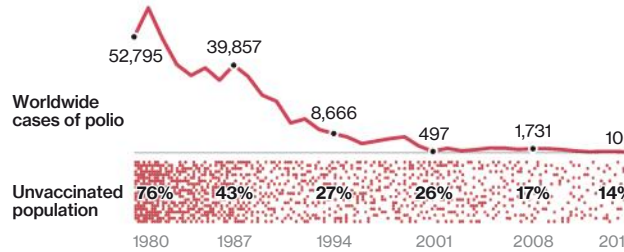


*The first pertussis vaccine was licensed in 1914 but mass distributed only in 1948, when it was combined with diphtheria and tetanus vaccines.



Safety in numbers

It's called herd immunity: A disease can all but vanish from a population before everyone is vaccinated – because a high immunization rate reduces the spread of infection.



MONICA SERRANO, NGM STAFF. KELSEY NOWAKOWSKI
SOURCES: U.S. CENTERS FOR DISEASE CONTROL AND PREVENTION; WORLD HEALTH ORGANIZATION; IMMUNIZATION ACTION COALITION

even more urgent—more ambitious, more complex, involving many governments and billions of philanthropic dollars—is the international collaboration to get new vaccines to children in the developing world, where to this day the suffering caused by vaccine-preventable disease is as vivid and nontheoretical as the frantic families Saha sees every day in the halls of Dhaka Shishu.

This is why he was sending me to Sanjida Sahajahan, 11 years old, the middle child of a rickshaw repairman and his wife. Go now, Saha said, as we pulled up to the hospital's main gate; when you come back, we shall discuss what you observed. Jamal and Tasmim will accompany you. That van in the parking lot is waiting.

THE HOSPITAL VAN BUMPED through crowded Dhaka streets that kept narrowing until we were inching past market displays: piles of sweet potatoes and used clothes and car parts. The road ran out of vehicle room. We got out to walk. Jamal Uddin is a physician, Tasmim Sultana Lipi a community health worker, and the two of them knew the right muddy passageways to follow. Along metal-roofed buildings to either side, barred windows offered glimpses of family after family inhabiting separate single rooms.

Lipi nodded toward one of the doorways and ducked in. Observing neighborhood protocol, we all removed our shoes.

Sanjida, who had been carried into Dhaka Shishu at the age of three with what turned out to be pneumococcal meningitis, was propped up in a small plastic armchair beside the family bed. Meningitis is an inflammation, sometimes irreversibly destructive, of the membranes that surround the brain and spinal cord. Sanjida has no control over her head, her grimaces, or the sounds she makes—mewling cries, mostly, as she is unable to form words. Her mother, Nazma, had been outside with the baby when we arrived; in these rooms nine families share two toilets and a single tap, and now Nazma hurried in, holding the baby in one arm, wiping dry her face. She lowered herself onto a stool. She took Sanjida's hand.

In Bangla she told us the story: their bright, talkative three-year-old's unexplained fever; the neighbors urging acetaminophen, for sale in a shop nearby; the fever receding after the pills; the fever rising again. A few days later came the first convulsion and the terrified journey to the hospital—by bus and motorcycle taxi, as a rickshaw repairman doesn't have the means to summon an ambulance. By the time doctors saw Sanjida, she was losing consciousness. Her last understandable words, Nazma said, were "Hug me. I feel very bad."

Sanjida's father, Mohammad, stood quietly while Nazma spoke. Their 14-year-old son came in and picked up the baby and stood too; there was nowhere else to sit. A disassembled wheelchair had been shoved beneath the bed—a charity gift, Nazma said, very nice idea, but their living quarters were too small. A wall cabinet held toys and dishware, and now Mohammad

BELGIUM These steel vats in a new GSK building near Brussels began producing key ingredients for making polio vaccine in 2017 — six years after construction began. To maintain sterility, workers enter and exit through air locks.

pulled from a drawer a creased yellow card: Sanjida's national health record. Here was her birth date, in September 2005.

And here, the first markings dated six weeks later, were the notations for Sanjida's vaccinations. Like her older brother, Sanjida received every inoculation then in Bangladesh's national immunization plan, on schedule and for free: whooping cough, measles, diphtheria, tuberculosis, tetanus, hepatitis B, polio. No smallpox; worldwide vaccination had already erased that disfiguring contagion from the planet by 1980, two centuries after the English physician Edward Jenner published his famous treatise on deliberately infecting children with cowpox, a mild virus that turned out to stimulate immunity against the far more serious smallpox.

An extraordinary global health history had been abbreviated, in a way, on Sanjida's little yellow card. No one can tally accurately the total number of lives saved by widespread vaccination, but it remains one of the greatest achievements of modern medicine. Measles, for example, was killing more than two million children a year worldwide in the 1980s; by 2015, according to the World Health Organization, vaccination had dropped the death toll to 134,200. Mass vaccination has ended polio in all but three countries; Bangladesh and its giant neighbor India were pronounced polio free in March 2014.

And when I asked Nazma how she first learned about vaccines—what gave her the idea that taking healthy babies for injections was a good idea?—she looked startled. Then she responded with a passionate outpouring that Uddin and Lipi distilled into English: *But every Bangladeshi knows this.*

On television—the Sahajahans' is crammed in atop that wall cabinet—popular singers and athletes in public service ads praise the lifesaving gift of inoculation. Encouragements to vaccinate trumpet from thousands of minarets, like calls to prayer; Bangladesh is predominantly Muslim, and while pushing for polio inoculation in the late 1980s, health officials and Islamic leaders together came up with a plan for "mosque miking." Once, in a village outside Dhaka, the local imam proudly pushed up a sleeve to show me the trace of his last tuberculosis vaccination. Protecting one's health is part of a religiously observant life, he explained, and faithful parents are obliged to do the same for their children.

Delivering vaccines in Bangladesh isn't easy. The terrain is crisscrossed by flooding rivers and barely passable roads, and the vaccines must be kept at just the right cold temperature to preserve their potency. Maintaining this "cold chain" is an urgent priority for immunization programs in all countries with hot climates and shaky power grids; a single faulty chiller or a rural power outage can wreck a whole batch of vaccine. But Bangladesh has worked hard to preserve the cold chain, equipping local health centers with solar panels, pressing bicycles and riverboats into service to ferry vaccines to the most remote clinics.

The Bangladeshi inoculation program is widely respected for its remarkable reach, in fact, and on the way back to Dhaka Shishu, the three of us silent and sad in the hospital van, I understood what Samir Saha most wanted me to see. By 2005, when the infant Sanjida got all her shots, the new vaccine against pneumococcal infection was routinely being injected into children all over the United States and was spreading fast across the developed world. The problem was in places like Bangladesh, which needed the vaccine far more desperately but couldn't pay what the manufacturer had decided to charge.

VACCINES, WITH VERY FEW EXCEPTIONS, are made by private companies, in business to return a profit. Until recently, their manufacture worldwide has been dominated by a few U.S. and European pharmaceutical giants. As officials of these companies point out when advocacy organizations like Doctors Without Borders press them to lower their prices (or else open their books to prove why they can't), developing a new vaccine is especially expensive. After all, it typically involves injecting a disabled germ or fragment of a germ into healthy trial participants—followed by a drawn-out process of watching and waiting to make certain the vaccine isn't harmful, that it stimulates an immune response against the infectious germ, and that the people who receive it contract the disease less often than those who don't. All that takes years.

For a pneumococcal vaccine that worked right

PAKISTAN Seeking out the unvaccinated inside a train at Karachi's main station, a health worker finds a boy who lacks the mark on his finger that would indicate he's previously been inoculated against polio. The oral vaccine has to be dispensed quickly, before the train pulls out.

in children, it took decades. Good adult vaccines were on the market by the early 1980s, but they never set off the hoped-for immune response in small kids. It wasn't until the late 1990s that researchers finally found a way to biologically amend, or "conjugate," the contents of those adult vaccines so they would be recognized by immature immune systems.

Pneumococcus presents another vexing challenge: Saha and other scientists have identified nearly a hundred versions, or serotypes, of pneumococcal cells. Serotypes can be geographically distinct, and for reasons not yet fully understood, only a small number are dangerous. (Serotype 1, for example, causes comparatively little disease in the United States but is a prime source of pneumococcal illness and death in Africa and South Asia.) So a finished vaccine that works for children and targets exactly the right serotypes is really multiple vaccines, individually amended and tested and then mixed into one vial.

All these complications helped make the first children's pneumococcal vaccine one of the most expensive in history. Called Prevnar, it was launched in early 2000 by the American pharmaceutical company Wyeth (which was later taken over by Pfizer). It was formulated to work against the seven serotypes responsible for most of the disease—in the United States, that is, which could absorb a children's vaccine priced at

PAKISTAN Only three countries still report polio cases: Afghanistan, Nigeria – and Pakistan, where violent resistance to inoculation has killed scores of vaccinators in recent years. In Karachi vaccinators make house calls under police escort.

'When I started work on this, what kept me up at night was the inequity. The chances of a kid dying of pneumococcal disease in the rich world were a hundredfold less.'

Orin Levine, Gates Foundation

$232 per four-dose course. Among the dangerous kinds of pneumococcus that vaccine was *not* formulated to fight off was serotype 1. Yet the poorest regions of Africa and South Asia are precisely where any pneumococcal infection is likeliest to kill a child or leave her crippled for life—not just because parents can't reach a doctor in time but also because the bacteria do extra damage inside small bodies already weakened by malnutrition, other lingering diseases, and too much exposure to cook-fire smoke.

"When I started work on this, what kept me up at night was the inequity," says Orin Levine, vaccine delivery director at the Bill and Melinda Gates Foundation. Years ago a colleague of his watched a woman in a Mali hospital lose a daughter to pneumococcal pneumonia; she'd lost another daughter the same way. Levine still remembers the mother's name. His own daughters were about the same age.

"The chances of a kid dying of pneumococcal disease in the rich world were a hundredfold less," he says. "Why was it that my kids could get the vaccine when Tiemany Diarra's kids, Mali's kids, needed it more and didn't get it?"

He knew the answer, of course: The surest economic return to vaccine manufacturers doesn't come from meeting the most critical need.

IMAGINE LEVINE'S FRUSTRATION echoed by a world of vaccine experts, and you understand the impetus behind the Global Alliance for Vaccines and Immunisation, or Gavi. This multibillion-dollar public-private collaboration got under way in 2000, just as PCVs reached the U.S. market. Kicked off in part by a $750 million pledge from the Gates Foundation, Gavi channels wealthy nations' resources—private philanthropy plus government aid from such countries as the United States, the United Kingdom, and Norway—into vaccine support for poorer countries that apply for the aid. Gavi helps negotiate with vaccine companies to slash prices specifically for those large-volume sales; subsidies from the donor fund then reduce the cost to developing countries even further, so that they pay a small fraction of the usual market price.

"It's been absolutely transformational—the financial muscle and the dedication that global actors and manufacturers and countries have agreed to," says Katherine O'Brien, a pediatrician and pneumococcus expert who directs the International Vaccine Access Center at Johns Hopkins University. Gavi wasn't assembled just to help with pneumococcal vaccine, O'Brien points out; the alliance concentrated at first on making established childhood inoculations like tetanus and hepatitis B more accessible.

PCVs joined the vaccine list only in 2010, after years of continued testing and negotiation. But the demand from developing countries was so high that soon Gavi was devoting a half billion donor dollars a year to PCV support—the alliance's single biggest financial commitment. A special arrangement with Pfizer and GSK, the only companies currently making PCVs, is supposed to ensure there will be enough supply; both have promised to produce as much vaccine, at the Gavi-arranged discount, as each of the receiving countries agrees to buy.

With those deals in place, the manufacturers have also developed new formulations that extend the effectiveness of PCVs to include children a long way from the U.S. and Europe. In 2010 Pfizer released a new blend called Prevnar 13, designed to work against serotype 1 and five others not targeted in the original mix. The GSK product, introduced in 2009, also is configured to fight serotypes prevalent in Africa and Asia. And since March 2015, when Bangladeshi health officials received their inaugural delivery of

Gavi-discounted PCV, vaccine shipments have arrived by air freight every three months from a GSK distribution center in Belgium.

"Small chiller boxes," Saha told me. "Like when you are going camping. But these are a little more sophisticated, with monitoring systems for the temperature."

The vaccines, health officials say, are reaching families all over the country. Bangladesh, at least so far, has experienced no surge of "vaccine hesitancy," as global health experts prefer to call the problem of parents declining to vaccinate their children. Elsewhere in South Asia, suspicion and hostility have troubled recent inoculation campaigns; in Pakistan, for example, polio vaccinators a few years ago were turned away or attacked amid rumors both false and true. (False: that the vaccines were part of a Western plot against Islam. True: that the CIA used house-to-house vaccinators to hunt for Osama bin Laden.) And in parts of India, a measles-rubella vaccination campaign foundered earlier this year, after anonymous posts on social media claimed the vaccines were dangerous or even meant to sterilize the children of religious minorities.

Even in vaccine-receptive Bangladesh, Saha told me, he's heard people wonder about the merits of adding PCVs to the already ambitious national inoculation effort. "I was on a talk show on the TV," he said. "A banker's wife, a powerful person, said, 'Why are you talking about vaccines so much?' " Pneumonia and other pneumococcal infections are treatable with penicillin, the banker's wife objected; Saha had just said so himself. "And my answer was: 'Oh, madam. You want to wait until pneumonia develops, and *then* you should treat it?' "

Had she walked the Dhaka Shishu wards with Saha, this woman would have seen listless children lying under oxygen masks, the families gathered at their bedside or crowded somberly in the hallways, waiting for antibiotics to take hold. And those are the families who have made it to the hospital. "For the remotest places," Saha said, "this"—the preemptive strike of a working vaccine—"is the only tool we have." In the villages and poorest city slums, pneumococcus-sickened children still die by the thousands at home.

Sanjida Sahajahan made it to Dhaka Shishu, but doctors could do little for her. Saha carries special frustration about her case. His lab identified the pneumococcus that infected her brain: serotype 1, one of the varieties not targeted in the inaugural version of Prevnar. So even if Bangladesh had been able to afford the vaccine in 2005, it would not have protected Sanjida—because the manufacturer had launched a lifesaving product not meant for her part of the world.

"And it's not only that child who is nonfunctional," Saha said. "The mother is nonfunctional. She cannot go anywhere. Each and every member of that family is really half dead."

He was quiet. "We gave them a wheelchair," he said. "Was she using it?"

It was in pieces, I said, under the bed. Saha winced. But the two-month-old baby, Jannat—the parents showed us her health card too, I told him, and its new column with the check mark in place: pneumococcal conjugate vaccine. If the inoculation does its job, Jannat will be protected from the pathogen that devastated her sister, and when Saha thought about all this, the grief and hope all shoved together inside that very small home, he sighed. "We should still look at how many children we lost, and how many were disabled like this, in those 10 years while we were waiting for the vaccine," he said. "But thank God we have got the vaccine now."

THE SPRAWLING GSK CAMPUS in the Belgian city of Wavre is the biggest vaccine production facility in the world. The day I met Luc Debruyne, the company's global vaccines president, I'd already been obliged twice to change clothes. Each vaccine's biological and mixing work is hermetically contained inside its own separate building, and stepping into one of these dedicated structures requires a complete switch to clean-room suit, cleansed white shoes, and protective goggles and cap over eyeglasses and hair.

Those buildings, along with other parts of the company's vaccine operation, represent an investment of more than five billion dollars over the past decade, Debruyne said. "It *is* a profitable

ITALY Beatrice Vio began fencing at age five. At 11 she contracted meningococcal meningitis, which spread through her blood and left her a quadruple amputee. Now 20, she's a gold medalist in wheelchair fencing for the Italian Paralympic team – and a fierce campaigner for early vaccination.

business," he added. "It needs to be profitable to be sustainable, to be able to offer massive volume and affordable pricing to the developing world."

The children's pneumococcal vaccine GSK delivers to Dhaka is a global production: Mixing starts at the company's plant in Singapore, vaccine batches are sent to Belgium and then France for processing, and the vials are finally returned to Belgium for shipping. As I peered through those goggles at the great silvery machines and vats at Wavre, though, the product under preparation was another GSK offering—a vaccine against a pathogen called rotavirus, the leading cause of children's diarrhea, which sickens millions every year. In the poorest countries of sub-Saharan Africa and South Asia, it kills by the hundreds of thousands. Many children in Dhaka Shishu are struggling to recover from it.

Bangladesh has Gavi approval to start receiving GSK's rotavirus vaccine, probably sometime next year. After the negotiated discount and additional financial support, the government will pay about 50 cents for each two-dose course of a vaccine that currently costs an American physician $220. For an impoverished health system, that's irresistible, but there's a colossal catch. Gavi aid is supposed to be temporary—a means for poor countries to help more children grow up healthy, and in doing so help improve the countries' own economies to the point where they

can finance important vaccines on their own.

Once a recipient country rises above the world's lowest per capita income levels, the Gavi subsidy is supposed to be phased out. "It's called 'transitioning,'" says Doctors Without Borders vaccine policy adviser Kate Elder. "But I've heard ministers of health call this being expelled." Even though leaders of GSK and other major U.S. and European vaccine manufacturers have promised to maintain impoverished-country discounts, losing the subsidy still means a comparatively huge cost increase. In Bangladesh, for example, it could push the GSK pneumococcal vaccine cost from 60 cents to $9.15 per child.

That still looks like a bargain to an American doctor paying more than 50 times that much. But Doctors Without Borders and other critics argue that the prices big American and European drug companies charge for children's vaccines are unacceptably high, even at a discount. A third of the world's countries have not yet brought PCVs into their immunization programs; a key reason is long-term cost. From the drug companies, Elder says, "we get this a lot of the time: 'Why aren't you just celebrating the kids who do have access now?' And we say, 'Yes, but we want more.'"

One remedy may lie in emerging competition from outside the U.S. and Europe—from pharmaceutical companies in India, Brazil, Vietnam, Cuba, South Korea, and even Bangladesh, where a Dhaka enterprise now sells nearly a dozen kinds of vaccine, using ingredients shipped in from other countries. An enormous Indian manufacturer called the Serum Institute produces from scratch more than a billion doses a year of relatively inexpensive vaccines, shipping them throughout India as well as abroad. Disease experts at the Gates Foundation and PATH, a global health nonprofit also based in Seattle, are helping Serum develop its own children's pneumococcal vaccine. Trials are under way in India and Africa, and that vaccine could be on the market by 2020.

SAMIR SAHA IS 62 NOW, with no imminent plans for retirement. It's too soon to assess definitively the success of PCVs in Bangladesh, but the last time we walked through Dhaka Shishu together, he was upbeat. Only three pneumococcus patients were in the general ward that day, none appeared in grave danger, and one of Saha's researchers was at a computer working on a bar graph that showed a tantalizing case drop for autumn 2016—one short bar, dwarfed by much taller ones from the six preceding autumns.

Saha pulled up a chair and looked closely at the graph. Let's wait and see next year, he said. But he was smiling. "Good for the patients," he said. "Less pneumonia in the hospital. Less death." He waved his arm toward all the researchers bent over microscopes. "Jobless!" Saha joked, and his smile broadened. "All of them will be jobless!" □

Contributing writer **Cynthia Gorney**'s last piece for the magazine was on widows. French photographer **William Daniels** focuses on humanitarian issues, including life-threatening diseases such as malaria.

A Last Glance at North Korea

Before the United States banned travelers from visiting the closed nation, a small group of Americans rushed there for a look.

A North Korean sailor chafes at being photographed aboard the U.S.S. *Pueblo,* a U.S. spy ship. The North Korean military captured the *Pueblo* and its crew in 1968. It is now part of a war museum in Pyongyang, the capital.

BY **DANIEL STONE** PHOTOGRAPHS BY **DAVID GUTTENFELDER**

For all its restrictive laws, its harsh ruler, and its reputation as the Hermit Kingdom, North Korea has long been open to visitors. For years Chinese tour companies have taken foreigners into the country—including roughly 1,000 Americans a year—for a curated tour of daily North Korean life. Americans have been able to spend time at North Korean amusement parks, schools, and subway stations. Almost all left without incident.

That changed this year. The June 19 death of American college student Otto Warmbier, who had been detained in Pyongyang and then convicted of stealing a propaganda poster from a hotel, increased tension between North Korea and the United States. As Pyongyang's continued development of nuclear weapons heightened the prospect of war, the U.S. State Department restricted the use of American passports for travel to North Korea.

Before the travel ban took effect on September 1, photojournalist David Guttenfelder joined a group, including six Americans, eager to see the world's most secretive nation. For almost 20 years Guttenfelder has been one of the few Western journalists allowed inside North Korea. He has made more than 40 trips, some for *National Geographic,* to document daily life there.

All the travelers said they were motivated by curiosity, and almost all reported being surprised by what they saw. "It was completely different from anything I was expecting," said Amy Kang, a Korean American who went on the trip with her husband. After all the stories she had heard about the repressive regime and the lack of freedom, she was intrigued to find in Pyongyang an element of normalcy: people with jobs and families, like anywhere else. She spoke with a woman who named several of her favorite American movies.

Brad Yoon, a Southern California Uber driver, was struck by the collective discipline. "People are nationalistic, truly proud of their country and military, and have a genuine admiration for their leadership," he said. (He had told his parents he was going to China so they wouldn't worry.)

Of course, being a tourist meant staying in a bubble of predictability and calm. No sudden movements were allowed, no surprises. There were supervised visits to a grocery store, a bowling alley, a brewery, and a circus. No one mentioned the country's nuclear threats or Supreme Leader Kim Jong Un's war of words with U.S. President Donald Trump. During the trip, in late August, North Korea's military shot a missile over Japan, drawing international rebuke. Guttenfelder learned of it on Twitter, via his cell phone's limited 3G coverage. No one with him, including his handlers, knew about it.

One could, however, sense the tension over potential conflict. To Guttenfelder, the North Koreans seemed tenser than during his previous visits. On the roads there were more propaganda billboards than usual, bashing the U.S. In the airport a piece of art showing children building missiles out of blocks seemed fitting.

The tour included a visit to the Demilitarized Zone (DMZ), the border area that cuts across the 38th parallel, where North and South Korean soldiers stare stone-faced at each other, on alert for war at any moment. For the American tourists the impending travel ban also brought an urgency to buy keepsakes. At various stores and roadside stands, they and other tourists huddled over stamps, art, ginseng products, and North Korean alcohol. One especially popular souvenir: anti-American propaganda posters. □

Pyongyang's 30-story Chongnyon Hotel overlooks a mosaic of former leaders Kim Il Sung and Kim Jong Il.

NGM MAPS

Above: Amy Kang, a Korean-American tourist, takes a selfie at a monument declaring “One Korea!” in Panmunjom, along the border in the Demilitarized Zone. She and her husband wanted to see North Korea in person. Below: Dancers in Pyongyang, some in traditional clothing, mark the annual International Youth Day, which was established by the United Nations to encourage young people to build peaceful societies.

Above: Thrill seekers ride an Italian-built roller coaster at the Kaeson Youth Park. The amusement park is popular among North Koreans and helps support the regime's claim that the country is technologically advanced. Below: A train conductor stands in a Pyongyang subway station in front of a statue of Kim Il Sung. Kim, North Korea's first leader, was the grandfather of the current supreme leader, Kim Jong Un.

A traffic officer stands in an intersection in Kaesong. The city, the capital of the Koryo dynasty from the 10th to 14th centuries, is now home to 12 UNESCO World Heritage landmarks, including palaces and tombs.

FURTHER

A GLIMPSE OF WHAT'S NEW AND NEXT

SAND TRICKS

By Nina Strochlic

The deserts of Uzbekistan are said to be haunted by devious spirits who send travelers off course and pinch their supplies.

While tracing the ancient Silk Road through Central Asia on foot, *National Geographic* writer Paul Salopek (right) was regaled with tales of these jinn. One night, under clear skies in the sprawling Qizilqum desert, Salopek and his guides discovered they were not immune to the spirits' mischief: A cache of water drums buried in advance of their arrival had been emptied.

"Fortunately, with modern technology like satellite phones, I knew my parched Uzbek walking partners and I wouldn't suffer the same fate as so many earlier Silk Road travelers who tried to cross the Qizilqum and didn't make it," Salopek says. "As for jinn, I think we carry such spirits—called impulses, good and bad—within all of us."

Salopek is following the footsteps of human migration from Africa to South America on a journey called Out of Eden. In 2016 he spent four and a half months walking across Uzbekistan, where he encountered the Silk Road's modern incarnation: a multi-trillion-dollar Chinese-led effort called the Belt and Road Initiative, which is a web of infrastructure connecting Asia, Europe, Africa, and the Middle East.

To go FURTHER along the old Silk Road, read Paul Salopek's feature article in the December issue of *National Geographic*.

PHOTO: JOHN STANMEYER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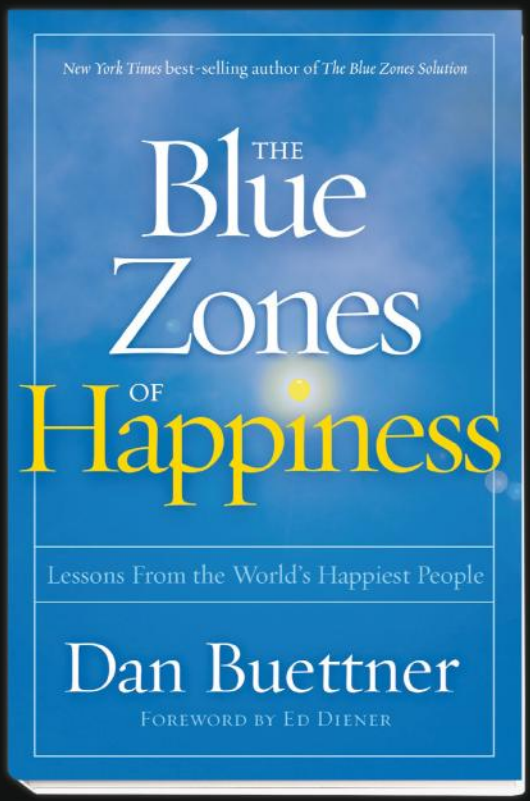

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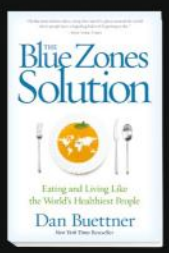

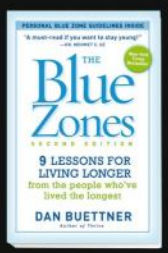

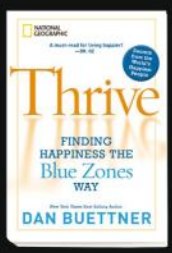

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