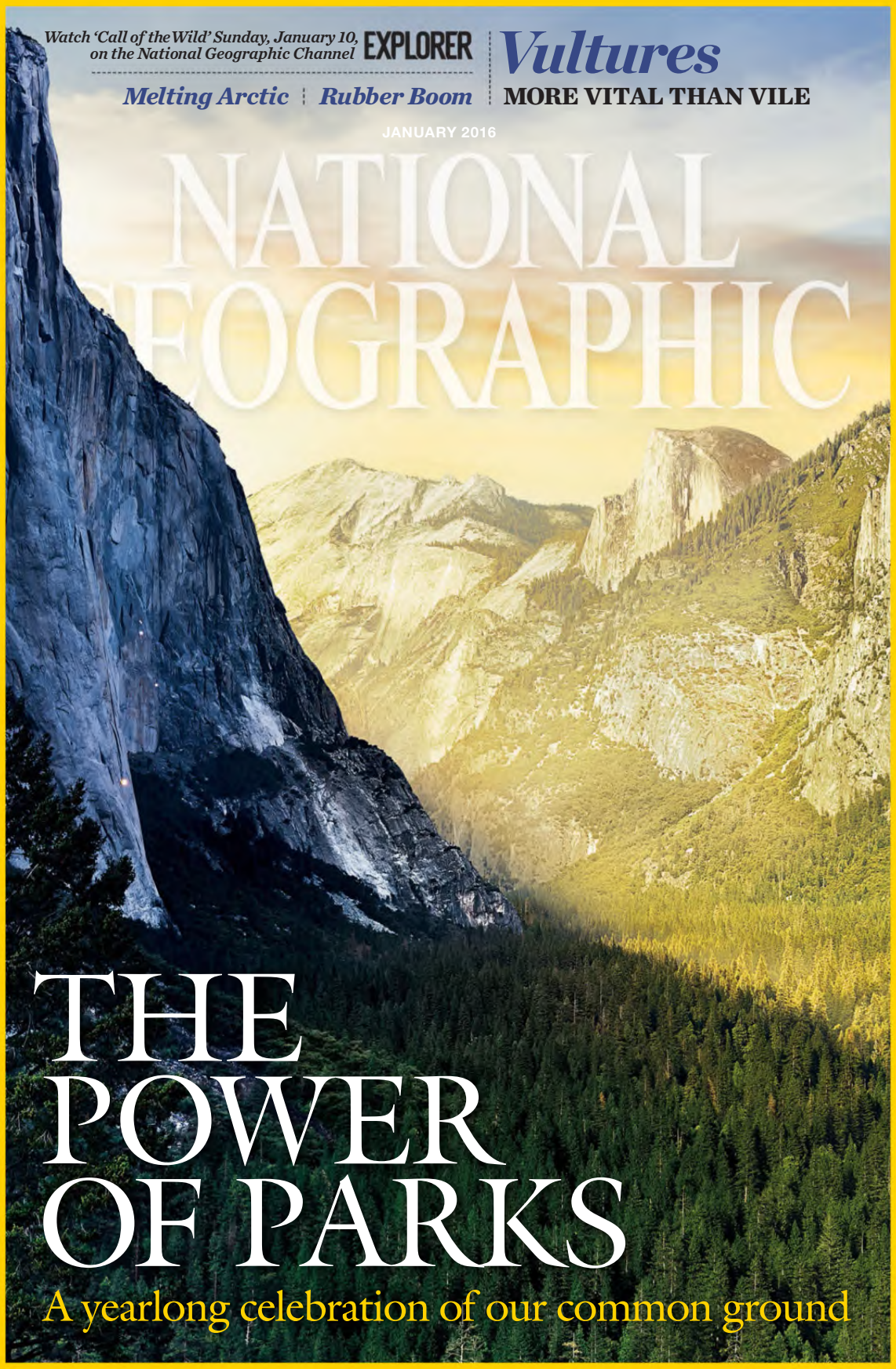
Watch 'Call of the Wild' Sunday, January 10, on the National Geographic Channel
EXPLORER
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Rubber Boom
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MORE VITAL THAN VILE
JANUARY 2016
NATIONAL GEOGRAPHIC
THE POWER OF PARKS
A yearlong celebration of our common ground

THERE IS NO AWAY.

If only there were a magical place we could send all our garbage, where it would never come back to haunt us. Sadly, this "away" doesn't exist. Nobody understands this better than our National Parks. Each year, visitors add over 100 million pounds of trash to our nation's landfills. Despite this, there is reason to celebrate. Over a decade ago, Subaru became the first U.S. auto manufacturer to become zero landfill, and now, in collaboration with the National Park Service and the National Parks Conservation Association, Subaru is leveraging that same environmental expertise to help the parks get to zero, too. It won't be easy, but with your help, we believe we can make sure these crown jewels of America are gleaming for generations to come.

Get involved, and see the documentary series at subaru.com/environment.

SUBARU
Confidence in Motion

The future of our parks rests in the hands of our kids.

AMERICA'S NATIONAL PARKS teach invaluable lessons about our planet, our history, and ourselves. In the past 100 years, our parks have become treasured landmarks for recreation, classrooms for biodiversity, shining examples of our country's great outdoor spaces, and bridges connecting us to the world of nature. However, if we want to keep them unspoiled for 100 more years, we need to educate the next generation to be stewards for their preservation.

Did you know, each year visitors to our National Parks generate 100 million pounds of trash?

That's why, with support from Subaru, National Geographic has developed a series of engaging educational activities, designed to inspire and guide the next generation of national park visitors and outdoor adventurers. Learning how to explore green spaces, discovering how to read maps, and understanding how to keep our parks clean are just some of the lessons we can teach our younger generation.

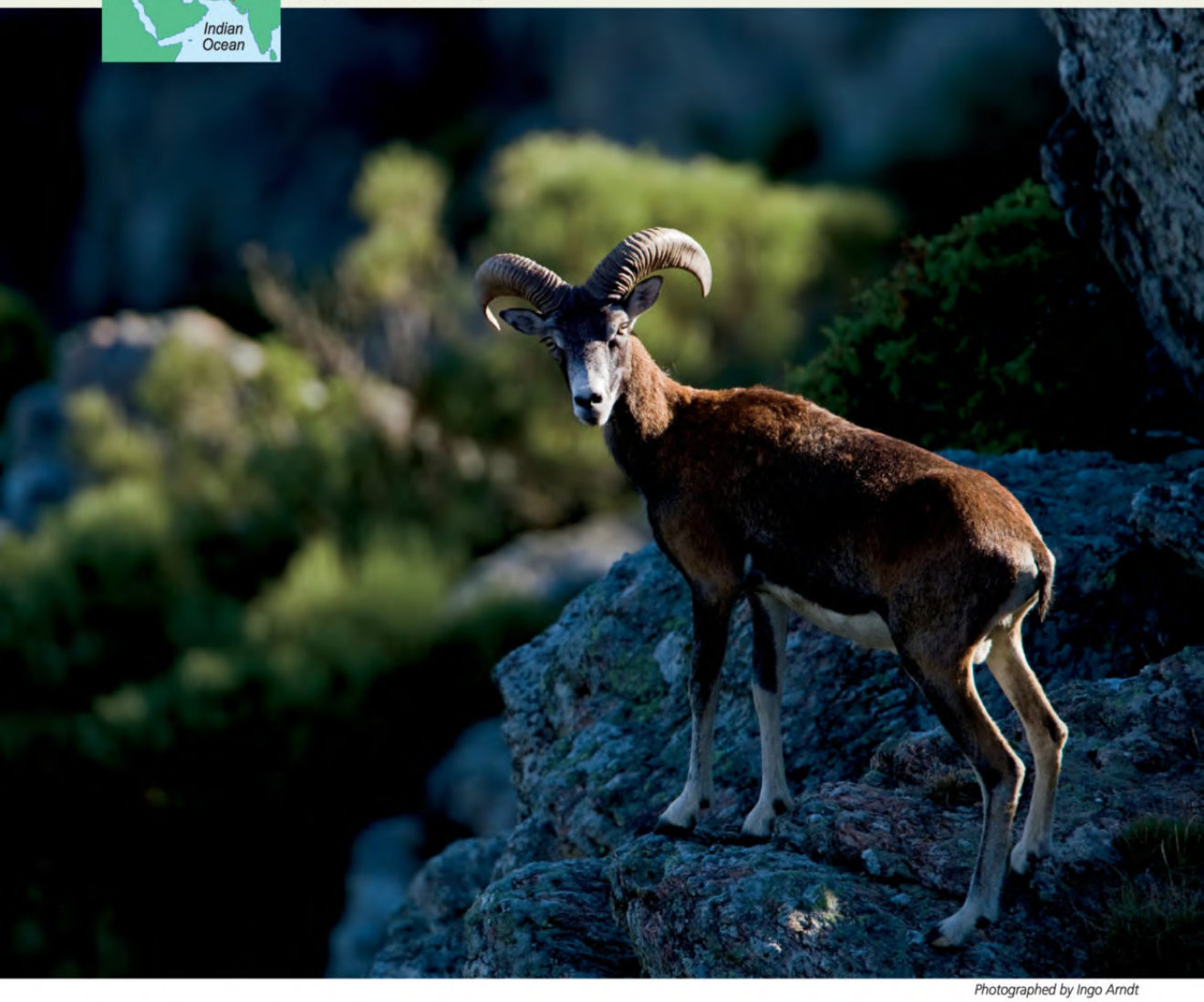
Teach the next generation how our actions impact nature and the most responsible way to enjoy, care for, and preserve our parks for the future. To download these free educational materials, visit natgeoed.org/loveyourpark.

WITH SUPPORT FROM

NATIONAL GEOGRAPHIC

SUBARU Loves the Earth

Mouflon *(Ovis orientalis)*
Size: Body length, 110 - 145 cm (43.3 - 57.1 inches) **Weight:** 25 - 87 kg (55 - 191 lb)
Habitat: Grasslands, agricultural fields and woodlands **Surviving number:** Unknown; populations declining



Photographed by Ingo Arndt

WILDLIFE AS CANON SEES IT

Family ties. The mouflon is closely related to domestic sheep, and still lives in the areas from which its cousins radiated into central Europe and Africa. Males and females separate into unrelated foraging groups and graze on grasses, grains and leaves, coming together only during breeding season. But populations have suffered major declines in the past few generations as mouflon habitat shrinks and poachers go after meat that is very similar to that of domestic sheep. In this case, a family resemblance is proving deadly.

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

EOS System

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NATIONAL GEOGRAPHIC

JANUARY 2016 • VOL. 229 • NO. 1

Flies swarm the head and mat the chest of this Rüppell's vulture, photographed in the Serengeti National Park in Tanzania.

On the Cover By digitally combining some of the 1,036 images he took over 26 hours, Stephen Wilkes created this day-to-night scene of Yosemite National Park in California. *Composite photo by Stephen Wilkes*

Corrections and Clarifications Go to *ngm.com/more.*

For the People's Benefit

After 55 years of travel across the country and around the world, last year I finally made it to one of America's iconic places—Yellowstone, the first national park and the ideal of what protected lands should be for sheer grandeur, conservation, and outreach. Why did I wait so long?

The inscription on the Roosevelt Arch, at Yellowstone's north entrance, is a quote from the act that created the park in 1872: "For the Benefit and Enjoyment of the People." Those words ring true today. Joining a half dozen National Geographic photographers assigned to shoot the Greater Yellowstone ecosystem from the Grand Tetons in Wyoming to its northern border in Montana, my husband and I canoed tranquil rivers searching for otters. We hiked a landscape alive with burbling pools and spouting geysers. We spotted wolves, eagles, and bison. We returned to our "real" lives renewed, grateful for the time, the quiet, the beauty—and more mindful than ever of the urgent need to preserve these lands and animals.

With her husband, Geoffrey Etnire, Susan Goldberg visited geysers and other natural wonders in Yellowstone.

That urgency informs and inspires this issue. It celebrates the 100th anniversary of the National Park Service and kicks off our yearlong exploration of what writer and environmentalist Wallace Stegner called "the best idea we ever had."

National Geographic and the parks share a rich history, beginning with the magazine's founding in 1888. Perhaps the most significant event in that history was a two-week trip into the Sierra Nevada that Gilbert H. Grosvenor, the magazine's longtime editor, took with the industrialist-outdoorsman Stephen Mather. Devoting the entire April 1916 issue to what he had seen, Grosvenor exhorted readers to cherish the richness of wilderness and support an agency to preserve and manage it. Then he went one step further, sending a copy of that "Land of the Best" issue to each member of Congress. The federal law establishing the National Park Service passed almost five months later.

In this centennial year *National Geographic* will examine the state of the 408 U.S. national parks as well as parks around the globe. With unmatched photography, historical expertise, and robust digital storytelling, we'll look at everything from parks threatened by development and climate change to whether Millennials will unplug long enough to connect with nature. And in May we'll devote a special issue entirely to Yellowstone.

We hope you enjoy our parks stories, in this issue and all year. Thank you for reading *National Geographic*.

Susan Goldberg, *Editor in Chief*

PHOTO: MICHAEL NICHOLS, NGM STAFF

Photo: Ben Canales, Uncage the Soul | Design: Cara Bunch, Push & Pull Design Studio

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NATIONAL GEOGRAPHIC

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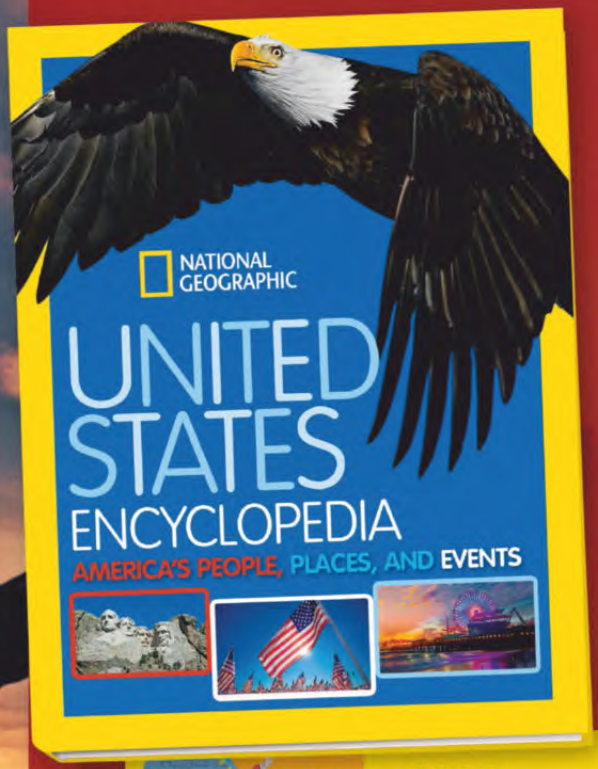

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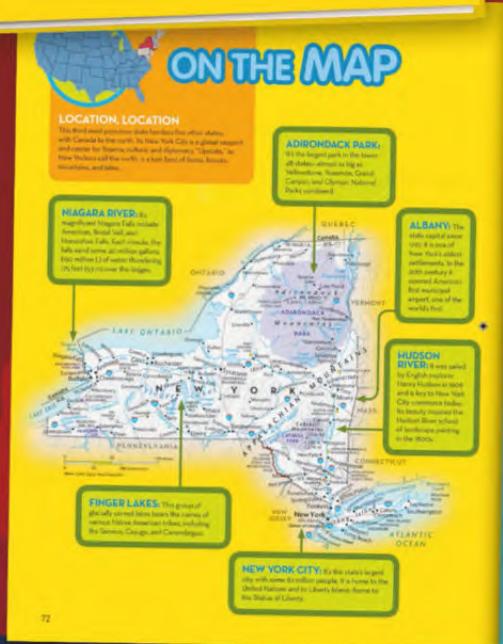
- where is the only place crocodiles and alligators co-exist



NATIONAL GEOGRAPHIC

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Why I Explore, and Why You Should Too

Swiss pilot **Bertrand Piccard** is a third-generation explorer. His father was an undersea scientist, his grandfather a balloonist. Now 57, Piccard circled the world in a propane-powered balloon in 1999, then turned to a cleaner goal: making the trip on solar power alone. His aircraft, *Solar Impulse 2,* will continue its flight, from Hawaii to the U.S. mainland, this spring.

You've done work all over the planet. Where is exploration needed most?
Quality of life. If you look at the ocean, Earth, and space, there's been a lot of exploration in those places. But now we have to conquer the quality of life on this planet. Humankind is at a crossroads: If we want to survive, we need clean technology and renewable energies. But we also need human rights. We need medical research. We need to fight against poverty. We need better governance on this planet. I think this is where explorers really need to focus. That's really the challenge of the 21st century.

We see only your work that goes right. How much of it goes wrong?
Even when you have plans, things happen as they happen. If everything happens according to plan, it's a business plan, not an adventure. Exploration is not only when you have a big success and can wave the flag of triumph. Exploration has a lot to do with preparation, frustration, disappointment, and unpredictability. When you accept all of that, then maybe you can get to a success.

What's your advice to young explorers?
Explorers are famous people. When you're famous, it's your responsibility to help other people live better and protect their environment and actively contribute to the wealth of the world. For example, next I may work on a remote-controlled plane that would replace satellites. It would be a cheap solution—a way for developing countries to have telecommunications, mobile phones, and Wi-Fi. When you're an explorer, don't do it only for yourself. Do it to be useful to humankind.

PHOTO: LUCA LOCATELLI

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EXPLORE

Nat Geo Wild

To Flap or Glide?

Walk through the understory of a neotropical rain forest and you'll see an unusual sight—brown or clear-winged butterflies gliding just above the forest floor, "like leaves floating on a stream," says University of New Orleans entomologist Phil DeVries.

They're demonstrating something called the ground effect. It's an aerodynamic phenomenon that occurs whenever wings are near a fixed surface, which increases lift and decreases drag. If you've been on a plane as it lands, you may have felt a brief floating sensation. That's the ground effect.

In a recently published study, DeVries and colleagues found that all but one species of Haeterini butterflies glide near the ground in this energy-efficient manner. Their evolutionary secret: forewings longer than those of their relatives, which favor flapping flight. *—Jeremy Berlin*

Sex, habitat, and wing shape (right) separate the flappers (A group) from the gliders (B group) in Haeterini butterflies and their Satyrini relatives.

All butterflies are shown to scale.

Butterfly Forewing Shape

A. Flapping flight
More than five inches above the ground

B. Gliding flight
Less than five inches above the ground

PHOTOS: REBECCA HALE, NGM STAFF, AT DEPARTMENT OF ENTOMOLOGY, NATIONAL MUSEUM OF NATURAL HISTORY, SMITHSONIAN INSTITUTION. GRAPHIC: NGM ART. SOURCE: PHIL DEVRIES

Gruber photographed this shark with a biofluorescent camera that casts a blue light, which the shark's skin reemits as green.

Sharks Go With the Glow

Marine biologist David Gruber specializes in finding life-forms that biofluoresce—creatures whose uniquely structured skin absorbs undersea deep-blue light and reemits it as neon green, red, or orange. Gruber, whose work is supported by the National Geographic Society, has found biofluorescence in jellyfish, corals, a sea turtle, and more than 200 fish and shark species. Now the diver-scientist is expanding his research beyond how these fish look to explore how they see.

Gruber had a Cornell University eye specialist examine a "brilliantly fluorescent" swell shark (above). Humans' eyes see a broad spectrum of colors. This shark "sees only in the blue-green range," Gruber says, but in that range it sees acutely. Armed with an underwater camera that mimics the shark's vision, he hopes to learn how biofluorescence helps the shark with camouflage, mating, and more.

Meanwhile, Gruber says, the shark's-eye-view camera fosters "a sense of empathy with these animals, to see how they see the world." *—Patricia Edmonds*

CATS DIG THEIR OWN KIND OF MUSIC

People who leave the radio on for their cat while they're out aren't doing Tabby a favor, a recent study suggests. Researchers tracked how cats respond to music for humans versus music composed with the high pitch of feline voices and the tempo of purring or suckling. Cats mostly ignored classical works and overwhelmingly responded to the tunes created for them, in some cases even rubbing against the speaker. "We're trying to get people to think more carefully about why they're playing music," says University of Wisconsin psychologist Charles Snowdon, "and who it's really benefiting." *—A. R. Williams*

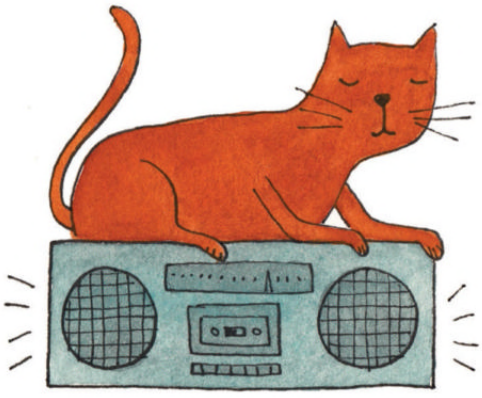

PHOTO: DAVID GRUBER. ART: MARC JOHNS

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NATIONAL GEOGRAPHIC

Towering Above

The foundation of China's 21st-century growth is concrete. Literally. The country's cement production has spiked 3,000 percent since 1980. Since 2012, China has made more cement than the U.S. has since 1900.

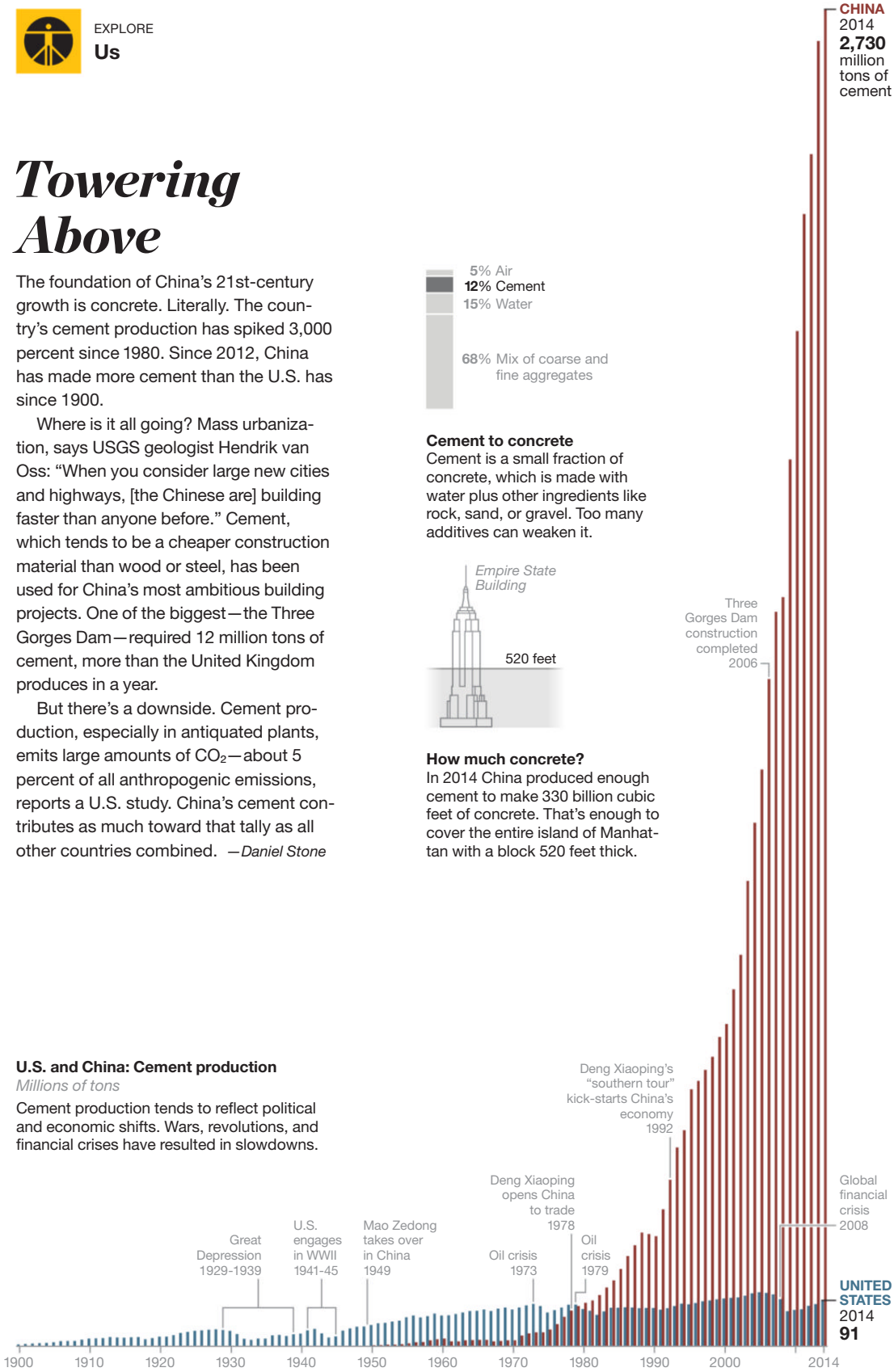
Where is it all going? Mass urbanization, says USGS geologist Hendrik van Oss: "When you consider large new cities and highways, [the Chinese are] building faster than anyone before." Cement, which tends to be a cheaper construction material than wood or steel, has been used for China's most ambitious building projects. One of the biggest—the Three Gorges Dam—required 12 million tons of cement, more than the United Kingdom produces in a year.

But there's a downside. Cement production, especially in antiquated plants, emits large amounts of CO_2—about 5 percent of all anthropogenic emissions, reports a U.S. study. China's cement contributes as much toward that tally as all other countries combined. *—Daniel Stone*

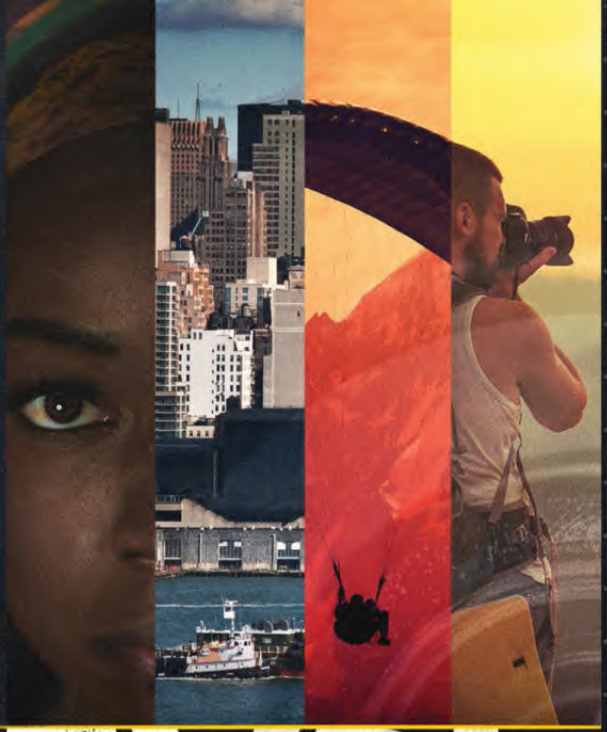
Cement to concrete
Cement is a small fraction of concrete, which is made with water plus other ingredients like rock, sand, or gravel. Too many additives can weaken it.

How much concrete?
In 2014 China produced enough cement to make 330 billion cubic feet of concrete. That's enough to cover the entire island of Manhattan with a block 520 feet thick.

U.S. and China: Cement production
Millions of tons
Cement production tends to reflect political and economic shifts. Wars, revolutions, and financial crises have resulted in slowdowns.



GRAPHIC: MATTHEW TWOMBLY, NGM STAFF. SOURCES: USGS; ORVILLE SCHELL, ASIA SOCIETY



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A comprehensive look at the scientific connections between Humans & the Natural World.

SUNDAY JANUARY 10

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natgeotv.com/Explorer

Seated in heaven, Mary and Jesus prepare to receive the soul of Thomas, Earl of Lancaster. Scenes leading to his demise are below, clockwise from top left.

This section shows the aftermath of the earl's defeat in battle in 1322. "Here I am taken prisoner," says the inscription underneath.

The earl is hauled before a tribunal. "I am judged," says the text. Forbidden to argue his case, he is sentenced to death.

The earl is beheaded with a sword near his castle at Pontefract. Two words are all that's needed to explain the scene: "The death."

Mounted on a horse, the condemned earl rides through a hostile crowd to his execution. "I am under threat," says the text.

Relic of a Rebellion

A rare five-inch-tall metal panel from the 14th century, rescued from a onetime riverbank of the Thames in London, is both a religious artifact and a piece of political propaganda. Crowned by a scene from heaven, four sections show the capture, trial, final journey, and execution of Thomas, Earl of Lancaster. A description in garbled medieval French runs beneath each scene.

The earl was a cousin of King Edward II of England—and his enemy. Allied with a group of barons, he tried to curtail the king's power. Edward defeated him and had him executed. Miracles were soon associated with the earl's tomb. Devotional panels such as this one were then created to hang in the homes of supporters. "It was a big political statement for Thomas of Lancaster and against the king," says Sophie Jackson, an expert at the Museum of London Archaeology. As the political climate changed in favor of the throne, the panel may have been thrown away. "Perhaps people didn't want to be seen owning something which aligned them so much with this particular person." *—A. R. Williams*

PHOTO: ANDY CHOPPING, MOLA (MUSEUM OF LONDON ARCHAEOLOGY)


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Now, more than ever, our planet needs our help. That's why the National Geographic Society is expanding its commitment to protect our oceans, save wildlife, and fund researchers and explorers who are pushing the boundaries of knowledge. As a nonprofit organization, we believe in the power of science, exploration, education, and storytelling to change the world. Join us, and let's change it together.
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Health and Climate

The higher temperatures and more extreme weather that come with climate change likely will have wide-ranging and mostly negative consequences for human health. They threaten air and water quality along with our ability to produce food, and they're sure to promote the spread of diseases like dengue fever.

Governments, especially in developing countries with weak health care infrastructure, need to prepare for this volatility, says Raman Velayudhan of the World Health Organization. But that takes resources many don't have. —*Kelsey Nowakowski*

DENGUE FEVER AND CLIMATE CHANGE

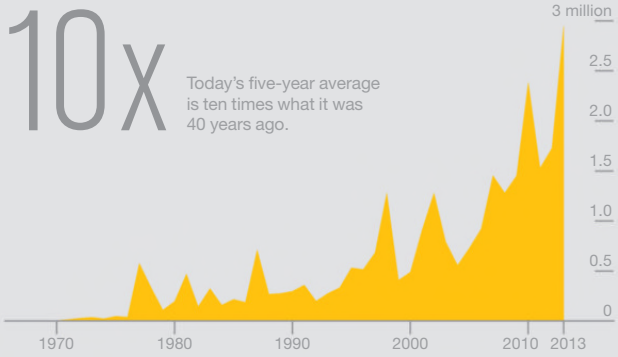
Malaria affects more people globally, but dengue fever is the fastest growing vector-borne disease. It causes fever, headache, muscle and joint pain and can be fatal. Yet this viral disease has been neglected: Vaccines are only now on the horizon.

DENGUE FEVER CASES

Number reported to WHO

10x

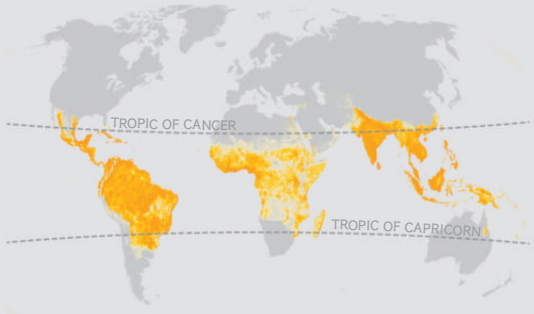
Today's five-year average is ten times what it was 40 years ago.



GEOGRAPHIC SPREAD

Before 1970 dengue was reported in only 9 countries; today it's in 128. Rapid urbanization and warming temperatures are expanding its range.

Risk of dengue occurrence
0% 99%



THE POTENTIAL DAMAGE

250,000

NUMBER OF ADDITIONAL DEATHS CAUSED BY CLIMATE CHANGE IN 2030

Shrinking food supplies and deteriorating water quality and sanitation may increase deaths.

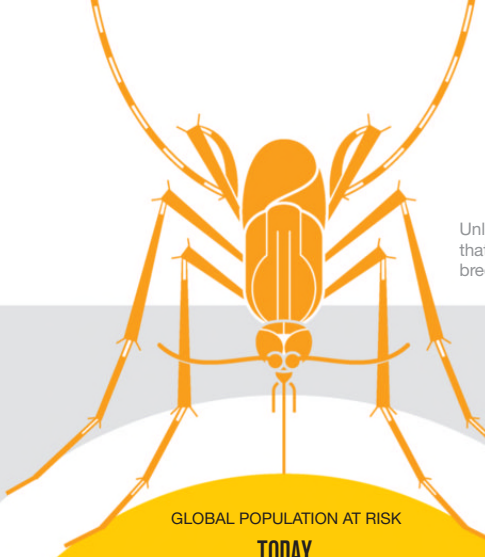
Cause of death

38%	Childhood undernutrition
24%	Malaria
19%	Diarrhea
15%	Heat exposure (among the elderly)
4%	Other

DIRECT HEALTH SERVICE COSTS PER YEAR BY 2030*

$2-4 billion

*Doesn't include costs due to agricultural, water, and sanitation changes



Unlike the mainly nocturnal species that spread malaria, the mosquito that carries the dengue virus bites mostly during the day and often breeds in urban areas in man-made containers, increasing risk.

GLOBAL POPULATION AT RISK

TODAY

4 billion

(More than half the world's seven billion people)

NUMBER INFECTED

390 million

(70 million more than the U.S. population)

UP TO 500,000 SEVERE CASES A YEAR

12,000 DIE EACH YEAR

2085

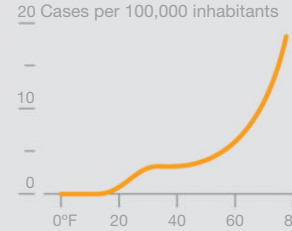
6 billion

Of them, one billion could be at risk because of climate change alone.

MEXICO

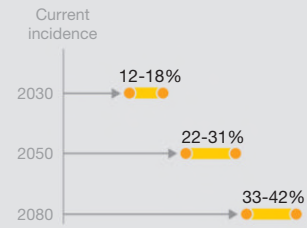
Data collected in Mexico from 1985 to 2007 indicates that higher minimum temperatures increase dengue cases. Warming temperatures may prove devastating in countries without the resources to cope with the disease.

THE TEMPERATURE CONNECTION



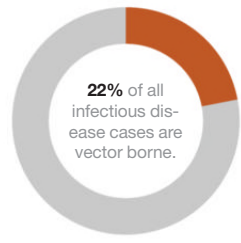
THE OUTLOOK

Projected increase in dengue infections due to climate change



VECTOR-BORNE DISEASES

Many illnesses caused by pathogens and parasites are transmitted by bloodsucking insects. Their ranges could expand as the planet warms.



1 million

of the more than one billion people infected die every year.

GRAPHIC: ÁLVARO VALIÑO. SOURCES: WHO; FELIPE J. COLÓN-GONZÁLEZ AND OTHERS, *PLOS NEGLECTED TROPICAL DISEASES,* 2013; SAMIR BHATT AND OTHERS, *NATURE,* 2013

ACTOR PORTRAYAL

Indication and Limitations of Use

Trulicity is a once-weekly injectable prescription medicine to improve blood sugar (glucose) in adults with type 2 diabetes mellitus. It should be used along with diet and exercise. Trulicity is not recommended as the first medication to treat diabetes. It has not been studied in people who have had inflammation of the pancreas (pancreatitis). Trulicity should not be used by people with a history of severe gastrointestinal (GI) disease, people with type 1 diabetes, or people with diabetic ketoacidosis. It is not a substitute for insulin. It has not been studied with long-acting insulin or in children under 18 years of age.

Important Safety Information

Tell your healthcare provider if you get a lump or swelling in your neck, have hoarseness, trouble swallowing, or shortness of breath while taking Trulicity. These may be symptoms of thyroid cancer. In studies with rats or mice, Trulicity and medicines that work like Trulicity caused thyroid tumors, including thyroid cancer. It is not known if Trulicity will cause thyroid tumors or a type of thyroid cancer called medullary thyroid carcinoma (MTC) in people. Do not take Trulicity if you or any of your family members have ever had MTC or if you have Multiple Endocrine Neoplasia syndrome type 2 (MEN 2).

Do not take Trulicity if you have had an allergic reaction to dulaglutide or any of the other ingredients in Trulicity.

Trulicity may cause serious side effects, including:

- **Inflammation of your pancreas (pancreatitis).** If you have pain in your stomach area (abdomen) that is severe and will not go away, stop taking Trulicity and call your healthcare provider right away. The pain may happen with or without vomiting. It may be felt going from your abdomen through to your back.
- **Low blood sugar (hypoglycemia).** If you are using another medicine that can cause low blood sugar (such as insulin or a sulfonylurea) while taking Trulicity, your risk for getting low blood sugar (hypoglycemia) may be higher. Signs and symptoms of low blood sugar may include dizziness, blurred vision, anxiety, irritability, mood changes, sweating, slurred speech, hunger, confusion or drowsiness, shakiness, weakness, headache, fast heartbeat, or feeling jittery. Talk to your healthcare provider about low blood sugar and how to manage it.
- **Serious allergic reactions.** Stop taking Trulicity and get medical help right away if you have symptoms of a serious allergic reaction, such as itching, rash, or difficulty breathing.

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- You may lose a little weight*

*Trulicity is not a weight loss drug. In studies, people who lost weight lost 2-6 lbs on average.

- It's taken once a week and works 24/7, responding when your blood sugar rises
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†In a study, 94% of people said it was easy to use.

- **Kidney problems (kidney failure).** In people who have kidney problems, diarrhea, nausea, and vomiting may cause a loss of fluids (dehydration). This may cause kidney problems to get worse.
- **Severe stomach problems.** Trulicity may cause stomach problems, which could be severe.

Tell your healthcare provider if you:

- have or have had problems with your pancreas, kidneys, or liver.
- have severe problems with your stomach, such as slowed emptying of your stomach (gastroparesis) or problems with digesting food.
- have any other medical conditions.
- are pregnant or plan to become pregnant, or if you become pregnant while taking Trulicity. It is not known if Trulicity will harm your unborn baby.
- are breastfeeding or plan to breastfeed. It is not known if Trulicity passes into your breast milk. You should not use Trulicity while breastfeeding without first talking to your healthcare provider.
- are taking other medicines including prescription and over-the-counter medicines, vitamins, and herbal supplements. Trulicity may affect the way some medicines work and some medicines may affect the way Trulicity works.
- are taking other medicines to treat diabetes, including insulin or sulfonylureas.

The most common side effects with Trulicity may include: nausea, diarrhea, vomiting, decreased appetite, and indigestion. Talk to your healthcare provider about any side effect that bothers you or does not go away. These are not all the possible side effects of Trulicity. Call your doctor for medical advice about side effects.

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

Please see next page for additional information about Trulicity, including Boxed Warning regarding possible thyroid tumors including thyroid cancer.

Please see Instructions for Use included with the pen.

DG CON ISI 20APR2015

Trulicity is available by prescription only.

Lilly

once weekly
trulicity®
(dulaglutide) injection
0.75 mg/0.5 mL, 1.5 mg/0.5 mL

Information for Patients about Trulicity (dulaglutide):

This is a brief summary of important information about Trulicity (Trū-li-si-tee). Please read the Medication Guide that comes with Trulicity before you start taking it and each time you get a refill because there may be new information. This information is not meant to take the place of talking with your healthcare provider or pharmacist.

What is Trulicity?

Trulicity is a once-weekly, injectable prescription medicine that may improve blood sugar (glucose) in adults with type 2 diabetes mellitus, and should be used along with diet and exercise.

- It is not recommended as the first choice of medicine for treating diabetes.
- It is not known if it can be used in people who have had pancreatitis.
- It is not a substitute for insulin and is not for use in people with type 1 diabetes or people with diabetic ketoacidosis.
- It is not recommended for use in people with severe stomach or intestinal problems.
- It is not known if it can be used with long-acting insulin or if it is safe and effective for use in children under 18 years of age.

What is the most important information I should know about Trulicity?

Trulicity may cause serious side effects including possible thyroid tumors, including cancer. Tell your healthcare provider if you get a lump or swelling in your neck, hoarseness, trouble swallowing, or shortness of breath. These may be symptoms of thyroid cancer. In studies with rats or mice, Trulicity and medicines that work like Trulicity caused thyroid tumors, including thyroid cancer. It is not known if TRULICITY will cause thyroid tumors or a type of thyroid cancer called medullary thyroid carcinoma (MTC) in people.

Who should not use Trulicity?

Do not use Trulicity if:

- you or any of your family have ever had a type of thyroid cancer called medullary thyroid carcinoma (MTC) or if you have an endocrine system condition called Multiple Endocrine Neoplasia syndrome type 2 (MEN 2).
- you are allergic to dulaglutide or any of the ingredients in Trulicity.

What are the possible side effects of Trulicity?

Trulicity may cause serious side effects, including:

- **Possible thyroid tumors, including cancer**. **See** "**What is the most important information I should know about Trulicity?"**
- **inflammation of the pancreas (pancreatitis).** Stop using Trulicity and call your healthcare provider right away if you have severe pain in your stomach area (abdomen) that will not go away, with or without vomiting. You may feel the pain from your abdomen to your back.
- **low blood sugar (hypoglycemia).** Your risk for getting low blood sugar may be higher if you use Trulicity with another medicine that can cause low blood sugar such as sulfonylurea or insulin.

Signs and symptoms of low blood sugar may include: dizziness or light-headedness; blurred vision; anxiety, irritability, or mood changes; sweating; slurred speech; hunger; confusion or drowsiness; shakiness; weakness; headache; fast heartbeat; feeling jittery.

- **serious allergic reactions.** Stop using Trulicity and get medical help right away, if you have any symptoms of a serious allergic reaction including itching, rash, or difficulty breathing.
- **kidney problems (kidney failure).** In people who have kidney problems, diarrhea, nausea, and vomiting may cause a loss of fluids (dehydration) which may cause kidney problems to get worse.
- **severe stomach problems.** Other medicines like Trulicity may cause severe stomach problems. It is not known if Trulicity causes or worsens stomach problems.

The most common side effects of Trulicity may include nausea, diarrhea, vomiting, decreased appetite, indigestion.

Talk to your healthcare provider about any side effect that bothers you or does not go away. These are not all the side effects of Trulicity.

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

Before using Trulicity tell your healthcare provider if you:

- have had problems with your pancreas, kidneys, or liver.
- have severe problems with your stomach, such as slowed emptying of your stomach (gastroparesis) or problems digesting food.
- have any other medical conditions.
- are pregnant or plan to become pregnant, or if you become pregnant while taking Trulicity. It is not known if Trulicity will harm your unborn baby.
- are breastfeeding or plan to breastfeed. It is not known if Trulicity passes into your breast milk. You should not use Trulicity while breastfeeding without first talking to your healthcare provider.
- **are taking other medicines**—including prescription and over-the-counter medicines, vitamins, and herbal supplements. Trulicity may affect the way some medicines work and some medicines may affect the way Trulicity works.
- are taking other medicines to treat your diabetes including insulin or sulfonylureas.

Before using Trulicity, talk to your healthcare provider about low blood sugar and how to manage it.

How should I use Trulicity?

- Read the **Instructions for Use** that comes with Trulicity**.**
- Use Trulicity exactly as your healthcare provider tells you to.
- Your healthcare provider should show you how to use Trulicity before you use it for the first time.
- Trulicity is injected under the skin (subcutaneously) of your stomach (abdomen), thigh, or upper arm. **Do not** inject Trulicity into a muscle (intramuscularly) or vein (intravenously).
- **Use Trulicity 1 time each week on the same day each week at any time of the day.**
- You may change the day of the week as long as your last dose was given **3** or more days before.
- If you miss a dose of Trulicity, take the missed dose as soon as possible, if there are at least 3 days (72 hours) until your next scheduled dose. If there are less than 3 days remaining, skip the missed dose and take your next dose on the regularly scheduled day. **Do not** take **2** doses of Trulicity within **3** days of each other.
- Trulicity may be taken with or without food.
- **Do not** mix Trulicity and insulin together in the same injection.
- You may give an injection of Trulicity and insulin in the same body area (such as your stomach), but not right next to each other.
- Change (rotate) your injection site with each weekly injection. **Do not** use the same site for each injection.

Do not share your Trulicity pen, syringe, or needles with another person. You may give another person an infection or get an infection from them.

Your dose of Trulicity and other diabetes medicines may need to change because of:

- change in level of physical activity or exercise, weight gain or loss, increased stress, illness, change in diet, or because of other medicines you take.

For more information go to www.Trulicity.com or call 1-800-LillyRx (1-800-545-5979).

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Eli Lilly and Company, Indianapolis, IN 46285, USA

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DG CON BS 01MAY2015
Trulicity (dulaglutide) DG CON BS 01MAY2015

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— Jeff from McKinney, TX

It's Enough to Make You Blue in the Face

Time to take a stand against overpriced watches with the Stauer Urban Blue. AND, get a FREE pair of Flyboy Optics® Sunglasses as our gift to you!

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"Blue watches are one of the growing style trends seen in the watch world in the past few years"—WATCH TIME®, Sept. 2015

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Stauer. A Different Tale to Tell.

Central African Republic

A startling request from a prison's 'worst inmates'

PETER GWIN *Magazine Senior Editor*

From Gwin on assignment: "Sssssss, monsieur. Sssssss, monsieur." The hissing comes from the padlocked door of the cell holding the "stubborn ones," says the prison warden in Berbérati, a Central African Republic town near the border with Cameroon.

The inmates poke their fingers through the cracks, trying to motion me to come near, possibly to whisper an alibi or maybe to slip them some cash or the ballpoint pen I'm nervously clicking. The warden ignores them and continues his tour of the rest of the prison, organized around an open concrete yard.

"Here is where the [male] inmates sleep," he says matter-of-factly, motioning to a dank room off the yard. "And here is where the women sleep. We lock them in their room at night so they are separate from the men."

In the far corner of the yard two naked men bathe themselves, splashing water from a bucket and vigorously rubbing their skin. A fire smolders in another corner. The sweet, pungent smell of cassava flour and human sweat hangs in the air. The eyes of all the prisoners follow us as we move around the yard. I ask the warden about the men in the padlocked cell.

"Some are bandits," he says with a dismissive wave. "Two are anti-Balaka," members of a movement of Christians and animists who joined forces to fight a Muslim-led rebellion.

Just that morning the town's prosecutor had told me that the prison's worst inmates had participated in the burning, looting, and lynching that left the Muslim quarter of the town an empty ruin. Afterward they had formed gangs to raid the camps of refugees who had fled across the border to Cameroon.

The warden leads us out of the yard, and we pass the cell once more. The fingers poke through the cracks beseechingly. "Sssssss, monsieur! Sssssss, monsieur!" they hiss. "Some soap, please. Some soap."

Problem inmates—escapees and the violent—share a prison cell in Berbérati, a town in the Central African Republic ravaged by ethnic violence.

Peter Gwin, NGM Staff
@petergwin

Greece

A ferry ride prompts poignant questions

MATTHIEU PALEY *Photographer*

From Paley's travel journal: In July my family—including my sons, ages four and eight—left our home in Turkey to visit Greece. On our way, we boarded a ferryboat that shuttles passengers

NGM MAPS

from Greek islands in the Aegean Sea to Athens on the mainland. Entering a passenger lounge, I wondered why so many people were asleep on couches or slumped in chairs. Soon I learned they were migrants—mainly Afghans, Iraqis, and Syrians—taking the opportunity to get some sleep during their arduous journey to Europe.

I speak Farsi, and many of them spoke English, so I heard their stories. They were exhausted from days in makeshift camps on Lesbos and Chios islands, where they arrived after a dangerous crossing from Turkey.

Were they refugees escaping war or simply people looking for a better and safer future? Who can say? But throughout the ferry, I saw travelers drawing strength from each other. A father hugged his young daughter; nearby, newlyweds tended to their month-old baby, born during their journey.

I viewed all this through my camera lens—but also through the experiences of my young sons. As an Afghan man spoke with me, he swept my four-year-old into an embrace. He could not help hugging my child, he explained, because he had to leave his family behind.

My eight-year-old, meanwhile, was playing cards with a young Iraqi. The boy said his family left their home because it wasn't safe; my son, shaken, turned to me to help him understand. But how could we explain this tragedy to an eight-year-old, when we can hardly make sense of it ourselves?

On a ferryboat to Athens, photographer Matthieu Paley saw many weary migrants from Iraq, Syria, and Afghanistan, including two young girls fast asleep on a dining table.

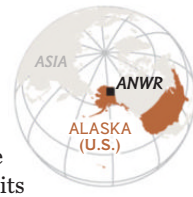
Matthieu Paley
@paleyphoto

Alaska

A new way to measure glaciers' retreat

KIT DESLAURIERS *Ski Mountaineer*

By Daniel Stone



For years Kit DesLauriers has been drawn to the wildness of the Arctic National Wildlife Refuge (ANWR). She wasn't there for the oil deposits—long its claim to political fame—but to study the area's terrain, and specifically its retreating glaciers.

In hopes of charting glaciers' change, DesLauriers and colleagues climbed several glaciers with a device designed to use radar to take measurements. For some reason—DesLauriers joked that she may have "stepped on the antennas"—the device didn't work.

DesLauriers's team returned with new equipment, an airplane, and a grant from National Geographic. This time they would measure glaciers from the air—more efficient than climbing—with a method called aerial photogrammetry. New coordinates helped the team spot changes in the glaciers of even a few centimeters. This allowed them "to make much better maps with much lower cost equipment much more quickly," says glaciologist Matt Nolan of the University of Alaska Fairbanks.

To verify the data, DesLauriers climbed and skied two remote peaks, Mount Chamberlin, long believed to be the tallest mountain in the U.S. Arctic, and Mount Isto. One surprising thing her measurements showed: Mount Isto is actually taller, by more than 70 feet.

Her Rack Versus His

Obviously, scientific accuracy is important. But did a zoo's website have to upend a beloved Christmas folktale by publishing this sentence: "Rudolph the red-nosed reindeer must have been a female"?

Now, now. Compose yourselves. This all can be explained.

Rangifer tarandus includes the caribou of North America and the reindeer of Eurasia. Reproductive biologist Peter Flood of the University of Saskatchewan, Canada, says it is the only deer species in which both sexes grow antlers—and in which annual rack-shedding cycles separate the bulls from the cows.

In spring both sexes begin to grow antlers that, by fall, harden to bone. Flood says adult males' antlers are rightly called weapons of sex, used to drive off other bulls in rut. Once the cows are pregnant, adult bulls' testosterone levels drop, triggering a bone cell change that makes their antlers fall off, usually in November or December. Young males keep their antlers somewhat longer—but pregnant cows keep their racks all winter and into spring, the better to fend off threats and guard feeding sites. Only after they give birth, typically in April or May, do they shed their antlers (which nonpregnant cows did some weeks earlier).

So to give Santa's sleigh pullers their due, let us clarify. Reindeer still antlered on Christmas Eve may be adolescent males—but could very well be females, and pregnant ones at that. *—Patricia Edmonds*

HABITAT/RANGE
Tundra and taiga zones of Eurasia and North America

CONSERVATION STATUS
Least concern

OTHER FACTS
Climate warming in *Rangifer tarandus*'s range causes more melting and re-icing of snow, making it harder for them to dig for food.

NATIONAL GEOGRAPHIC
PHOTO ARK
JOEL SARTORE

This female reindeer was photographed at the Miller Park Zoo, Bloomington, Illinois.

"The passion of all the explorers, for what they do, is awe-inspiring. Their work teaches respect for animals, different cultures, lifestyles... I wanted to support National Geographic to make sure this work continues long after I'm gone."

—Cecilia Sestak, who included the National Geographic Society in her estate plans.

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Islands

Assignment Your Shot editors visited Hawaii Volcanoes National Park for the NatGeo BioBlitz. They asked members to share photos of islands.

EDITOR'S NOTE

'I wanted photos that went past island clichés. The grandness and scale of this banyan in contrast to the lone woman give me not only a view of wildness but also a sense of peace.'

Jeanne Modderman, Your Shot *photo editor*

Rochelle Potter
Kailua-Kona, Hawaii

When Potter and her friend were driving on the north side of the Big Island of Hawaii, they passed a large banyan tree with splayed roots. "I shouted that we had to stop," says Potter. She asked her friend—who is five feet nine—to climb the roots. Then Potter aimed her camera up.

As you age, your risk of getting pneumococcal pneumonia increases. It's a serious disease that could put you in the hospital. Symptoms include coughing, fever, chest pain, and difficulty breathing. If you are 50 or older, one dose of the PREVNAR 13® vaccine can help protect you. Even if you've already been vaccinated with another pneumonia vaccine, PREVNAR 13® may help provide additional protection. Immune response may be lower if given within one year after another pneumonia vaccine. Ask your doctor or pharmacist if PREVNAR 13® is right for you.

Prevnar 13®
Pneumococcal 13-valent Conjugate Vaccine
(Diphtheria CRM_{197} Protein)

GET THIS ONE DONE.

INDICATION FOR PREVNAR 13®

- Prevnar 13® is a vaccine approved for adults 50 years of age and older for the prevention of pneumococcal pneumonia and invasive disease caused by 13 *Streptococcus pneumoniae* strains (1, 3, 4, 5, 6A, 6B, 7F, 9V, 14, 18C, 19A, 19F, and 23F)
- Prevnar 13® is not 100% effective and will only help protect against the 13 strains included in the vaccine

IMPORTANT SAFETY INFORMATION

- Prevnar 13® should not be given to anyone with a history of severe allergic reaction to any component of Prevnar 13® or any diphtheria toxoid–containing vaccine
- Adults with weakened immune systems (eg, HIV infection, leukemia) may have a reduced immune response
- In adults, immune responses to Prevnar 13® were reduced when given with injected seasonal flu vaccine
- In adults, the common side effects were pain, redness, or swelling at the injection site, limitation of arm movement, fatigue, headache, muscle pain, joint pain, decreased appetite, chills, or rash
- Ask your health care provider about the risks and benefits of Prevnar 13®. Only a health care provider can decide if Prevnar 13® is right for you

You are encouraged to report negative side effects of vaccines to the US Food and Drug Administration (FDA) and Centers for Disease Control and Prevention (CDC). Visit www.vaers.hhs.gov or call 1-800-822-7967.

Please see Important Facts for Prevnar 13® on the adjacent page.

Pfizer

IMPORTANT FACTS

Prevnar 13® (pronounced "Prev • nar 13")
Generic Name: Pneumococcal 13-valent Conjugate Vaccine (Diphtheria CRM_{197} Protein)

WHO SHOULD RECEIVE PREVNAR 13® (Pneumococcal 13-valent Conjugate Vaccine [Diphtheria CRM_{197} Protein])?

- Prevnar 13® is approved for adults 50 years and older for the prevention of pneumococcal pneumonia and invasive disease caused by the 13 vaccine strains
- Prevnar 13® is a vaccine also approved for children 6 weeks through 17 years of age for the prevention of invasive disease caused by the 13 strains of *Streptococcus pneumoniae* included in the vaccine, and for children 6 weeks through 5 years for the prevention of ear infections caused by 7 of the 13 strains
- Prevnar 13® is not 100% effective and will only help protect against the 13 strains included in the vaccine

Adults 50 years and older:

- A single dose of Prevnar 13® is recommended for adults aged 50 years of age and older

Children 6 weeks through 5 years of age:

- Prevnar 13® is recommended for children 6 weeks through 5 years of age
- Prevnar 13® is given as a 4-dose series at 2, 4, 6, and 12 to 15 months of age
- ***Transition schedule:*** Children who have received 1 or more doses of Prevnar® (Pneumococcal 7-valent Conjugate Vaccine [Diphtheria CRM_{197} Protein]) may complete the 4-dose immunization series with Prevnar 13®
- ***Catch-up schedule:*** Children 15 months through 5 years of age who are considered fully immunized with Prevnar® may receive 1 dose of Prevnar 13® to elicit immune responses to the 6 additional strains
- The immune responses from the transition or catch-up schedules might be lower for the 6 additional strains (types 1, 3, 5, 6A, 7F, and 19A) than if your child had received the full 4 doses of Prevnar 13®

Children 6 years through 17 years of age:

- In children 6 years through 17 years of age, Prevnar 13® is given as a single dose

WHO SHOULD NOT RECEIVE PREVNAR 13®?

Children or adults who have had a severe allergic reaction to any component of Prevnar 13® or any diphtheria toxoid–containing vaccine should not receive Prevnar 13®

BEFORE STARTING PREVNAR 13®

Tell your health care provider or your child's health care provider about all medical conditions, including:

- Previous allergic reactions to other vaccines
- Especially tell the health care provider if your child or you are taking medicines that can weaken the immune system, such as steroids (eg, prednisone) and cancer medicines, or are undergoing radiation therapy
- If you are pregnant or nursing, or if you plan to become pregnant

WARNING

- A temporary pause of breathing following vaccination has been observed in some infants born prematurely. Decisions about when to give Prevnar 13® to infants born prematurely should be based on consideration of the individual infant's medical status, and the potential benefits and possible risks of vaccination
- The safety and efficacy of Prevnar 13® when given to persons with a weakened immune system (such as HIV infection, damaged spleen, cancer, or kidney problems) is not known. Children or adults with a weakened immune system may have a reduced response to Prevnar 13®

WHAT ARE THE POTENTIAL SIDE EFFECTS?

- In adults, the common side effects were pain, redness, or swelling at the injection site, limitation of arm movement, fatigue, headache, muscle pain, joint pain, decreased appetite, chills, or rash
- The most commonly reported serious adverse events in children were bronchiolitis (an infection of the lungs) (0.9%), gastroenteritis (inflammation of the stomach and small intestine) (0.9%), and pneumonia (0.9%)
- In children 6 weeks through 17 years, the most common side effects were tenderness, redness, or swelling at the injection site, irritability, decreased appetite, decreased or increased sleep, and fever. Most commonly reported side effects in children 5 years through 17 years also included hives

WHAT SHOULD I KNOW ABOUT RECEIVING PREVNAR 13® WITH OTHER VACCINES?

- In adults, immune responses to Prevnar 13® were reduced when given with injected seasonal flu vaccine
- When given within 1 year following pneumococcal polysaccharide vaccine, immune response to Prevnar 13® may be lower

ADDITIONAL IMPORTANT INFORMATION

- The safety and effectiveness of Prevnar 13® when used in children less than 6 weeks of age is not known
- In a study in which children received acetaminophen prior to Prevnar 13®, immune responses to some strains in the vaccine were lower compared with responses among children who received acetaminophen after vaccination only as needed
- Ask your health care provider about the risks and benefits of Prevnar 13®. Only a health care provider can decide if Prevnar 13® is right for you or your child

NEED MORE INFORMATION?

- This is only a summary of important information. Ask your health care provider or your child's health care provider for complete product information
- Go to www.Prevnar13.com or call 1-800-666-7248

Urgent: Special Driving Notice

To some, sunglasses are a fashion accessory…

But When Driving, These Sunglasses May Save Your Life!

Studies by the National Highway Traffic Safety Administration (NHTSA) show that most (74%) of the crashes occurred on clear, sunny days

Drivers' Alert: Driving in fall and winter can expose you to the most dangerous glare… do you know how to protect yourself?

In the fall and winter, the sun is lower in the sky so it rises and sets at peak travel periods. During the early morning and afternoon rush hours many drivers find themselves temporarily blinded while driving directly into the glare of the sun. Deadly accidents are regularly caused by such blinding glare with danger arising from reflected light off another vehicle or snowy and icy pavement. Yet, motorists struggle on despite being blinded by the sun's glare that can cause countless accidents every year.

Not all sunglasses are created equal. Protecting your eyes is serious business. With all the fancy fashion frames out there it can be easy to overlook what really matters—the lenses. So we did our research and looked to the very best in optic innovation and technology.

Sometimes it does take a rocket scientist. A NASA rocket scientist. Some ordinary sunglasses can obscure your vision by exposing your eyes to harmful UV rays, blue light, and reflective glare. They can also darken useful vision-enhancing light. But now, independent research conducted by scientists from NASA's Jet Propulsion Laboratory has brought forth ground-breaking technology to help protect human eyesight from the harmful effects of solar radiation light. This superior lens technology was first discovered when NASA scientists looked to nature for a means to superior eye protection—specifically, by studying the eyes of eagles, known for their extreme visual acuity. This discovery resulted in what is now known as Eagle Eyes®.

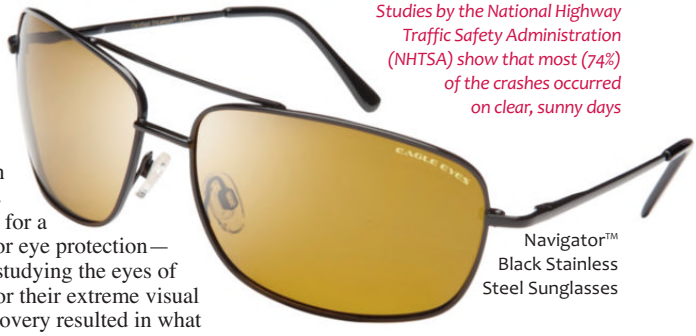
Slip on a pair of Eagle Eyes® and everything instantly appears more vivid and sharp. You'll immediately notice that your eyes are more comfortable and relaxed and you'll feel no need to squint. These scientifically designed sunglasses are not just fashion accessories for the summer; they are necessary to protect your eyes from those harmful rays produced by the sun in the winter.

The Only Sunglass Technology Certified by the Space Foundation for UV and Blue-Light Eye Protection. Eagle Eyes® features the most advanced eye protection technology ever created. The TriLenium® Lens Technology offers triple-filter polarization to block 99.9% UVA and UVB—plus the added benefit of blue-light eye protection. Eagle Eyes® is the only optic technology that has earned official recognition from the Space Certification Program for this remarkable technology. Now, that's proven science-based protection.

The finest optics: And buy one, get one FREE! Eagle Eyes® has the highest customer satisfaction of any item in our 20 year history. We are so excited for you to try the Eagle Eyes® breakthrough technology that we will give you a **second pair of Eagle Eyes® Navigator™ Sunglasses FREE—a $99 value!**

That's two pairs to protect your eyes with the best technology available for less than the price of one pair of traditional sunglasses. You get a pair of Navigators with stainless steel black frames and the other with stainless steel gold, plus two micro-fiber drawstring cleaning pouches are included. Keep one pair in your pocket and one in your car at all times.

Your satisfaction is 100% guaranteed. If you are not astounded with the Eagle Eyes® technology, enjoying clearer, sharper and more glare-free vision, simply return one pair within 60 days for a full refund of the purchase price. The other pair is yours to keep. No one else has such confidence in their optic technology. Don't leave your eyes in the hands of fashion designers, entrust them to the best scientific minds on earth. Wear your Eagle Eyes® **Navigators** with absolute confidence, knowing your eyes are protected with technology that was born in space for the human race.



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THE POWER OF PARKS

A yearlong exploration

THIS LAND IS YOUR LAND

A national park is more than just a scenic place. It's a nation's common ground.

Standing tall on the aptly named Grandeur Point, a cowboy surveys the Grand Canyon around 1935. President Theodore Roosevelt called the steep-sided gorge in Arizona "a natural wonder which is in kind absolutely unparalleled throughout the rest of the world."

HULTON ARCHIVE/GETTY IMAGES


55-2519
KAN. '38

Visitors to Yellowstone National Park feed a black bear in a circa 1939 photo. Though a draw for tourists, the practice was unhealthy for bears and unsafe for people. In 1970 new policies rehabituated bears to natural foods and greatly reduced human-bear conflicts.

WENDELL CHAPMAN, NATIONAL GEOGRAPHIC CREATIVE

"Looks cold but is warm and fine" reads the caption that accompanied this circa 1920 photo of bathers in Mount Rainier National Park. In 1899, when the 370-square-mile site in Washington State was designated, only four other national parks had been established.

ASAHEL CURTIS PHOTO COMPANY/
NATIONAL GEOGRAPHIC CREATIVE

A hundred

By David Quammen
Photographs by Stephen Wilkes

in the early months of 1916, America stood possessed of a magnificent, visionary, slightly confused and inchoate idea: national parks. These would be parks for the American citizenry, not pleasure grounds or private hunting reserves for nawabs and kings; parks to be shared, even, with visitors from around the world.

At that point 14 national parks already existed in the United States, the oldest being Yellowstone, which had been set aside by federal law, back in 1872, as the first national park anywhere in the world. The other U.S. parks, representing a diverse sample of majestic landscapes, all west of the Mississippi, included Yosemite in California (originally a state park, nationalized in 1890), Wind Cave in South Dakota (1903), Glacier in Montana (1910), and Rocky Mountain in Colorado (1915). There were also 21 national monuments—a form of protection more easily achieved because it could come by presidential decree under the Antiquities Act (passed in 1906), as robustly exploited by Theodore Roosevelt during his last three years as president. That early list of national monuments included Devils Tower, Chaco Canyon, Muir Woods, and the Grand Canyon.

What the country did not have in 1916, but now realized it needed, was a coherent definition of what a national park is or should be, supported by a single agency empowered to manage, defend, and oversee the expansion of its scattered patchwork of parks and parklike monuments. In August of that year—a time when European civilizations were gruesomely entangled at the first Battle of the Somme—Congress passed an act, and President Woodrow Wilson signed it, creating a National Park Service within the Interior Department. Stephen Mather, a Californian who had gotten rich selling borax but who cared deeply about conservation, became the first NPS director. His assistant and sidekick was an impecunious young lawyer named Horace Albright, son of a mining engineer, who would serve as superintendent of Yellowstone beginning in 1919 and eventually succeed Mather as NPS director. These two crucial men and their many allies mustered support for the system and for adding new units, but the project of defining a national park's essence didn't end with their work.

The early parks in the American West had been established primarily to protect scenic wonders, splendors of soaring rock and tumbling water and perennial ice, severe places that offered little prospect for economic exploitation—except maybe in the form of tourism as envisaged by railroad tycoons. That perceived dearth of business opportunity, plus the patriotic savor of touting America's natural "cathedrals" in counterpoint to the cathedrals and monuments of old Europe, made creating parks easier than it would be later. Another factor was the negative example of Niagara Falls,

years ago,

where the best overlooks had been bought up and fenced by private operators, turning a national icon into a cheesy, for-profit peep show. Heaven forbid that should happen to Old Faithful or the Yosemite Valley. Protection of living creatures—the American bison in Yellowstone, the gigantic Sierra redwoods later known as sequoias—became part of the idea too. But it wasn't until 1947 that any U.S. national park was approved largely for the protection of wildlife. That was Everglades National Park, a vast wetland in Florida, lacking mountains or canyons but full of birds and alligators.

Since then, our national parks have gradually taken on the high purpose of preserving nature's diversity—native fauna and flora, ecological processes, free-flowing waters, geology in its raw eloquence—as exemplars of Earth's interactive complexity, not just as scenic wonderlands. Now they teach us as well as delight us. They inspire active curiosity as well as passive awe. They help us imagine what the American landscape and its resident creatures looked like before railroads and automobiles and motels existed. Repeat: They help us imagine. They carry a glimpse of the past into the present and—if our resolve holds and our better wisdom prevails—they will carry that into the future.

The way so far has been a stumbling, incremental process, fraught with politics and economics and conflicting ideals, that has brought us to where we are now. National parks were a good idea that has gotten better, and a big idea that has gotten bigger. The system now includes not just parks proper and national monuments but also battlefields, forts, seashores, scenic rivers, grave sites, and other significant places (some still privately owned) that are recognized as national historic landmarks, as well as noteworthy paths through landscape and history, such as the Selma to Montgomery National Historic Trail in Alabama. Jon Jarvis, the current director of the National Park Service, says that its purpose is to tell America's story, not simply protect parcels of landscape. "If not us, who else? It's our job." As we celebrate the centennial, we also should remember that, although one act of Congress and a presidential signature can put a park on the map, the work of preserving these places and their stories falls to us too, as citizens, as owners, and it's never done. □

NATIONAL PARK SERVICE

ANYWHERE WILD

In March 1868 a 29-year-old John Muir stopped a passerby in San Francisco to ask for directions out of town. “Where do you wish to go?” the startled man inquired. “Anywhere that is wild,” said Muir. His journey took him to the Yosemite Valley in California’s Sierra Nevada, which became the spiritual home of Muir’s conservation movement and, under his guidance, the country’s third national park. “John the Baptist,” he wrote, “was not more eager to get all his fellow sinners into the Jordan than I to baptize all of mine in the beauty of God’s mountains.” Today around four million people a year follow their own thirst for the wild to Yosemite.

For this Yosemite vista photographer Stephen Wilkes took 1,036 photos—some at 3 a.m., when the full moon lit the face of El Capitan—over 26 hours. Then he digitally combined select images to make this panorama. Learn more about Wilkes’s composite technique on page 144.

THE COVENANT OF THE PARK

Every year the 5,700-square-mile Serengeti National Park in Tanzania plays host to millions of wildebeests, zebras, and gazelles and the predators that follow their migration. The Maasai word for Serengeti means "the place where the land runs on forever." But like any protected area, the Serengeti is essentially an island, a primeval world that has survived into the 21st century. It exists only because humans have agreed—or have been forced to agree—not to conduct business as usual within its boundaries. That covenant is always open to challenge and, for the sake of future generations, must always be renewed.

To capture life around a watering hole in Tanzania's Serengeti, Wilkes spent 30 hours inside a crocodile hunting blind raised on an 18-foot-high scaffold. Using equipment powered by solar panels, he took 2,260 photographs to create this image.

THE ORIGINAL PARK

"Today I am in the Yellowstone Park, and I wish I were dead." So Rudyard Kipling began his 1889 account of a tour in America's oldest national park. His disdain was aroused most by the "howling crowd" of tourists with whom he shared the visit. Attractions such as Old Faithful (left) still draw more than three million (mostly well behaved) visitors yearly to Yellowstone; the vast majority of them never go beyond a hundred yards from a paved road. If Kipling himself had ventured deeper into the 3,472-square-mile park to witness the splendor of its river valleys and mountain meadows, his rant might well have given way to rapture.

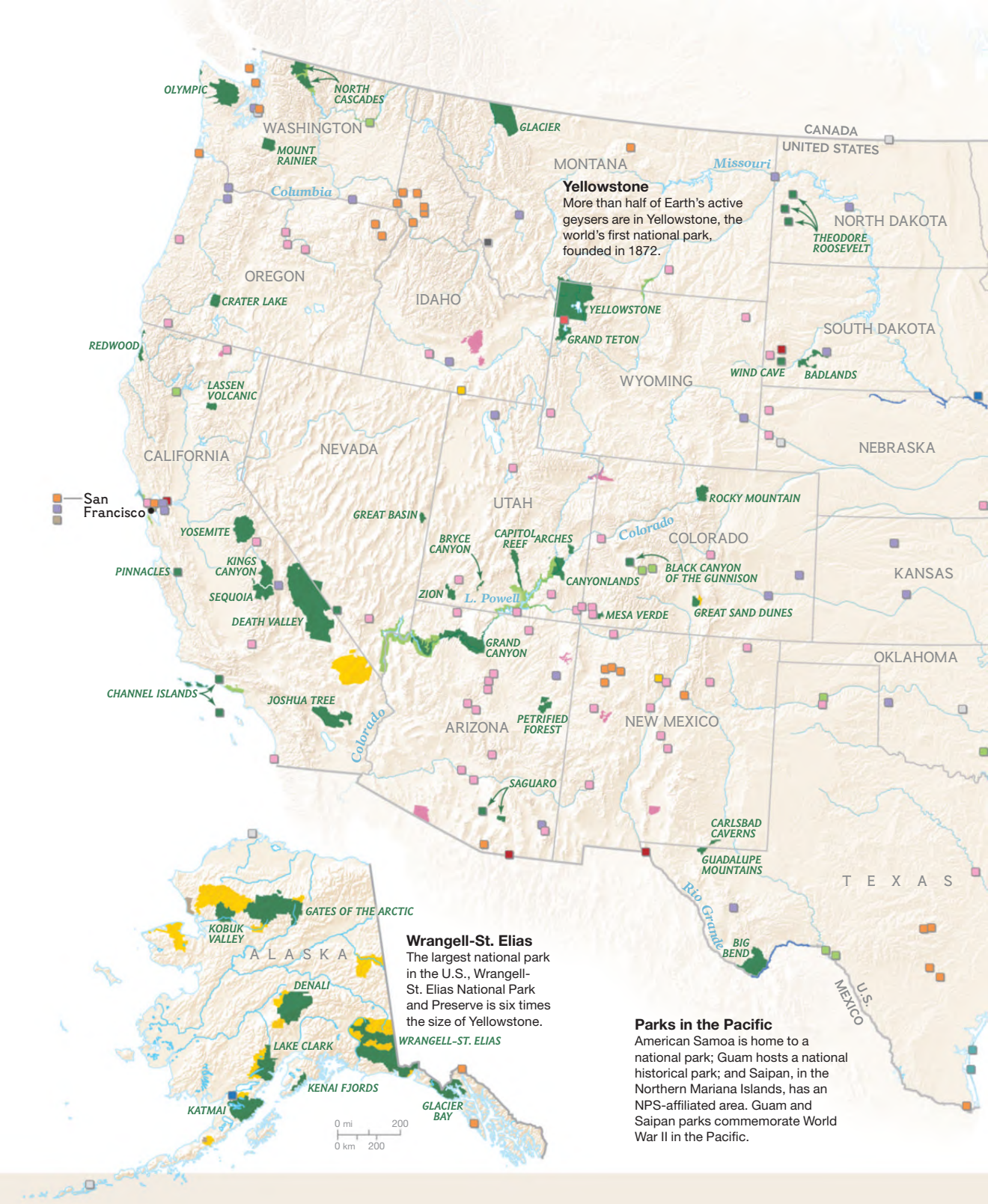
During 29 hours on the top of the Old Faithful Inn, Wilkes made 2,625 images of the geyser that's one of Yellowstone National Park's chief attractions. He saw a sunrise and a moonrise and put both into this composite.

URBAN RENEWAL On an April day cherry blossoms festoon West Potomac Park, part of the National Mall and Memorial Parks in Washington, D.C. While the grand parks of the West may elicit more gasps of awe, urban parks draw far more visitors. The National Mall hosts 24 million a year, almost twice the number of Yellowstone, Yosemite, and the Grand Canyon combined.

Wilkes doubts any tourist to Washington, D.C., has had quite this view of the National Mall and monuments. From 50 feet in the air on a crane parked in a softball field, he made 3,711 photos in 16 hours, digitally melding the best into a seamless panorama.

LITMUS TEST The Grand Canyon is the touchstone American park; whatever happens here could have repercussions throughout the park system. It has withstood threats from ranching, mining, and logging interests and a federal dam project. Today's challenges include a proposed town development on the South Rim and a tramway that would bring 10,000 visitors a day to the canyon floor.

On the Grand Canyon's South Rim, the Desert View Watchtower was Wilkes's perch as he made 2,282 photos over 27 hours. The tourists on the overlook put into perspective "just how big the canyon is," he says.



A CENTURY OF PARKS Over the past hundred years the National Park Service has grown from 37 protected areas to more than 400. From hallowed battlegrounds to Native American archaeological sites and breathtaking vistas, the NPS is working to ensure that the nation's historical and natural treasures will be available for generations to come.

MATTHEW W. CHWASTYK, NGM STAFF
SOURCE: NATIONAL PARK SERVICE

The Park Service has jurisdiction over multiple small park areas throughout the District of Columbia and adjacent regions.

Great Smoky Mountains
Some ten million people visit every year, making this the country's most visited national park.

Everglades
This park was established in 1947 to preserve and protect the area's unique wetland habitat and wildlife.

National Park Service Lands

- National park
- National lakeshore or seashore
- National monument
- National preserve or reserve
- National recreation area
- National river or national wild and scenic river and riverways
- Parkway
- National scenic trail held by the NPS
- National battlefield, battlefield park, battlefield site, or military park
- National historical park
- National historic site
- National memorial
- Other National Park Service property
- Affiliated area

Within sight of downtown Seoul, capital of South Korea and a hub of stressful modern life, salesman Sungvin Hong rests after a hike in Bukhan-san National Park. The park attracts some five million visitors a year.

This Is Your Brain On Nature

When we get closer to nature—be it untouched wilderness or a backyard tree—we do our overstressed brains a favor.

In Singapore, which aims to be a “city in a garden,” greenery cascading off a luxury hotel soothes a guest in a balcony pool—and people on the street below. “A concrete jungle destroys the human spirit,” former Prime Minister Lee Kuan Yew once said.

When gray winter encloses Sweden, ice-hole bathing is a welcome release for the bold. Joshua and Cecilie are enjoying a quick dip—"which feels much longer"—in Källtorpssjön, a lake near Stockholm, in February. "It is the way I immerse myself in nature when the elements are unkind," Joshua says.

By Florence Williams
Photographs by Lucas Foglia

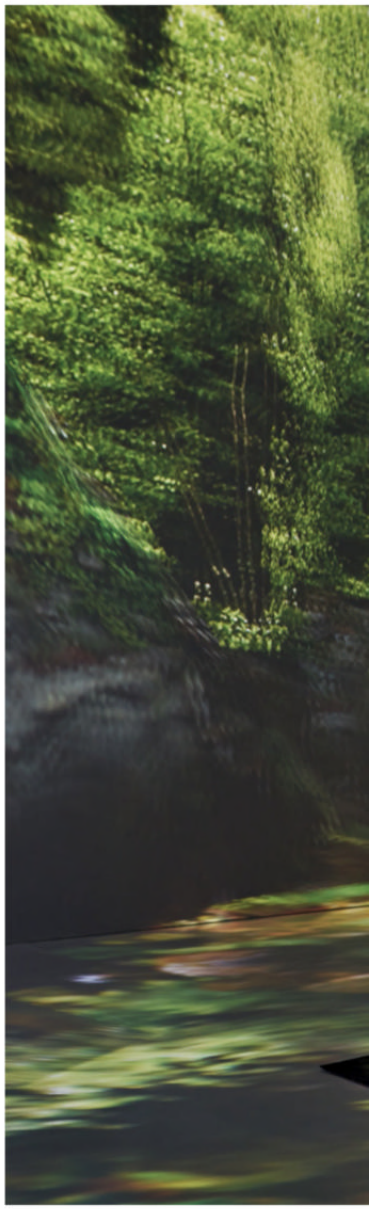
When you head out to the desert, David Strayer is the kind of man you want behind the wheel. He never texts or talks on the phone while driving. He doesn't even approve of eating in the car. A cognitive psychologist at the University of Utah who specializes in attention, Strayer knows our brains are prone to mistakes, especially when we're multitasking and dodging distractions. Among other things, his research has shown that using a cell phone impairs most drivers as much as drinking alcohol does. Strayer is in a unique position to understand what modern life does to us. An avid backpacker, he thinks he knows the antidote: Nature.

EXPLORER
The Channel series explores the "Call of the Wild" on January 10.

On the third day of a camping trip in the wild canyons near Bluff, Utah, Strayer is mixing up an enormous iron kettle of chicken enchilada pie while explaining what he calls the "three-day effect" to 22 psychology students. Our brains, he says, aren't tireless three-pound machines; they're easily fatigued. When we slow down, stop the busywork, and take in beautiful natural surroundings, not only do we feel restored, but our mental performance improves too. Strayer has demonstrated as much with a group of Outward Bound participants, who performed 50 percent better on creative problem-solving tasks after three days of wilderness backpacking. The three-day effect, he says, is a kind of cleaning of the mental windshield that occurs when we've been immersed in nature long enough. On this trip he's hoping to catch it in action, by hooking his students—and me—to a portable EEG, a device that records brain waves.

"On the third day my senses recalibrate—I smell things and hear things I didn't before," Strayer says. The early evening sun has saturated the red canyon walls; the group is mellow and hungry in that satisfying, campout way. Strayer, in a rumpled T-shirt and with a slight sunburn, is definitely looking relaxed. "I'm more in tune with nature," he goes on. "If you can have the experience of being in the moment for two or three days, it seems to produce a difference in qualitative thinking."

Strayer's hypothesis is that being in nature allows the prefrontal cortex, the brain's command center, to dial down and rest, like an overused muscle. If he's right, the EEG will show



Virtual nature is soothing too. Swedish researcher Matilda van den Bosch stresses her subjects with a math test and a simulated job interview. When she delivers them into a virtual forest with singing birds, their heart rate soon recovers its normal rhythm.

less energy coming from "midline frontal theta waves"—a measure of conceptual thinking and sustained attention. He'll compare our brain waves with those of similar volunteers who are sitting in a lab or hanging out at a parking lot in downtown Salt Lake City.

While the enchiladas are cooking, Strayer's graduate students tuck my head into a sort of bathing cap with 12 electrodes embedded in it. They suction-cup another 6 electrodes to my face. Wires sprouting from them will send my brain's electrical signals to a recorder for later analysis. Feeling like a beached sea urchin, I walk carefully to a grassy bank along the San Juan River for ten minutes of restful contemplation. I'm supposed to think of nothing in particular, just watch the wide, sparkling river flow gently by. I haven't looked at a computer or cell phone in days. It's easy to forget for a few moments that I ever had them.

IN 1865 THE GREAT LANDSCAPE architect Frederick Law Olmsted looked out over the Yosemite Valley and saw a place worth saving. He urged the California legislature to protect it from rampant development. Olmsted had already designed Central Park in New York City; he was convinced that beautiful green spaces should

Nature Nurtures Us

It boosts our mood too. According to the attention restoration theory, spending time in nature relieves the stress and mental fatigue caused by the "directed attention" that work and city life require.

Directed Attention

The ability to voluntarily focus attention and ignore distractions is crucial to solving problems and completing tasks. But modern life sometimes requires more of this resource than we have—and once it's depleted, prolonged and concentrated effort leads to mental fatigue, loss of effectiveness, and stress.

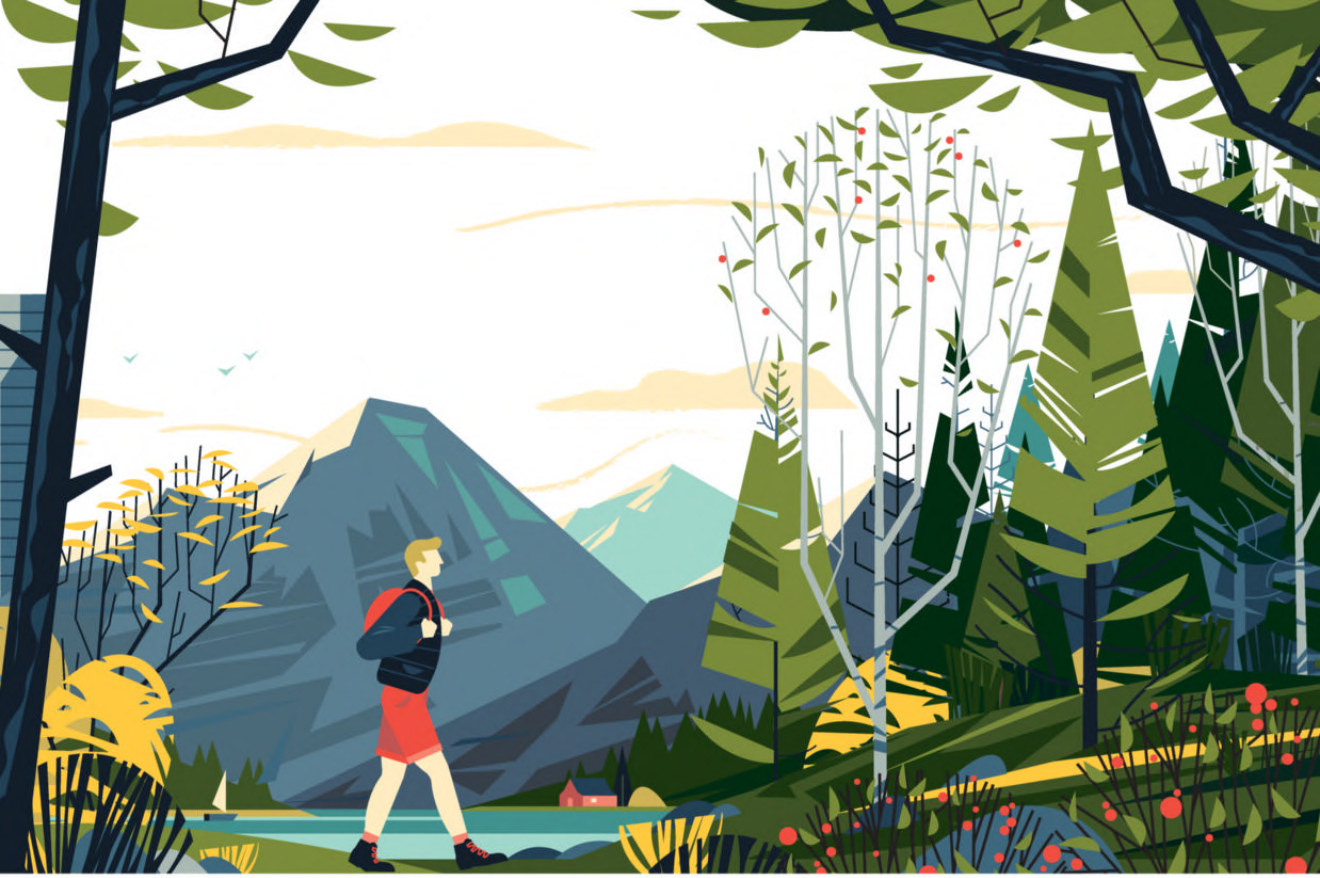
Nature can improve creativity by up to 50%

exist for all people to enjoy. "It is a scientific fact," he wrote, "that the occasional contemplation of natural scenes of an impressive character…is favorable to the health and vigor of men and especially to the health and vigor of their intellect."

Olmsted was exaggerating; his claim was based less on science than on intuition. But it was an intuition with a long history. It went back at least to Cyrus the Great, who some 2,500 years ago built gardens for relaxation in the busy capital of Persia. Paracelsus, the 16th-century German-Swiss physician, gave voice to that same intuition when he wrote, "The art of healing comes from nature, not from the physician." In 1798, sitting on the banks of the River Wye, William Wordsworth marveled at how "an eye made quiet by the power / Of harmony" offered relief from "the fever of the world." American writers such as Ralph Waldo Emerson and John Muir inherited that outlook. Along with Olmsted, they built the spiritual and emotional case for creating the world's first national parks by claiming that nature had healing powers.

There wasn't much hard evidence then—but there is now. Motivated by large-scale public health problems such as obesity, depression, and pervasive nearsightedness, all clearly associated with time spent indoors, Strayer and other scientists are looking with renewed interest at how nature affects our brains and bodies. Building on advances in neuroscience and psychology, they've begun to quantify what once seemed divine and mysterious. These measurements—of everything from stress hormones to heart rate to brain waves to protein markers—indicate that when we spend time in green space, "there is something profound going on," as Strayer puts it.

In England researchers from the University of Exeter Medical School recently analyzed mental health data from 10,000 city dwellers and used high-resolution mapping to track where the subjects had lived over 18 years. They



Involuntary Attention

Attending to the stimuli in peaceful, natural environments—trees, flowing water, mountain shadows—is a different type of experience. It doesn't require a prolonged effort or an act of will to avoid distractions. Researchers say this kind of focus allows the brain to disengage and restore its capacity for directed attention.

Forest walks can decrease one stress hormone by as much as 16%

found that people living near more green space reported less mental distress, even after adjusting for income, education, and employment (all of which are also correlated with health). In 2009 a team of Dutch researchers found a lower incidence of 15 diseases—including depression, anxiety, heart disease, diabetes, asthma, and migraines—in people who lived within about a half mile of green space. And in 2015 an international team overlaid health questionnaire responses from more than 31,000 Toronto residents onto a map of the city, block by block. Those living on blocks with more trees showed a boost in heart and metabolic health equivalent to what one would experience from a $20,000 gain in income. Lower mortality and fewer stress hormones circulating in the blood have also been connected to living close to green space.

It's difficult to tell from these kinds of studies why people feel better. Is it the fresh air? Do certain colors or fractal shapes trigger neurochemicals in our visual cortex? Or is it just that people in greener neighborhoods use the parks to exercise more? That's what Richard Mitchell, an epidemiologist at the University of Glasgow in Scotland, thought at first. "I was skeptical," he says. But then he did a large study that found less death and disease in people who lived near parks or other green space—even if they didn't use them. "Our own studies plus others show these restorative effects whether you've gone for walks or not," Mitchell says. Moreover, the lowest income people seemed to gain the most: In the city, Mitchell found, being close to nature is a social leveler.

WHAT HE AND OTHER RESEARCHERS suspect is that nature works primarily by lowering stress. Compared with people who have lousy window views, those who can see trees and grass have been shown to recover faster in hospitals, perform better in school, and even display less violent behavior in neighborhoods where it's common. Such results jibe with

ART: MARIE-LAURE CRUSCHI
SOURCES: DAVID STRAYER, UNIVERSITY OF UTAH; YOSHIFUMI MIYAZAKI, CHIBA UNIVERSITY

experimental studies of the central nervous system. Measurements of stress hormones, respiration, heart rate, and sweating suggest that short doses of nature—or even pictures of the natural world—can calm people down and sharpen their performance.

In Sweden physician Matilda van den Bosch found that after a stressful math task, subjects' heart rate variability—which decreases with stress—returned to normal more quickly when they sat through 15 minutes of nature scenes and birdsong in a 3-D virtual reality room than when they sat in a plain room. A real-life experiment is under way at the Snake River Correctional Institution in eastern Oregon. Officers there report calmer behavior in solitary confinement prisoners who exercise for 40 minutes several days a week in a "blue room" where nature videos are playing, compared with those who exercise in a gym without videos. "I thought it was crazy at first," says corrections officer Michael Lea. But he has experienced the difference. "There's a lot of yelling really loud—it echoes horribly," in the plain gym, he says. "In the blue room they tend not to yell. They say, 'Hold on, I got to watch my video.'"

Visits to parks are down. So are visits to the backyard. One survey found only 10 percent of American teens spend time outside every day.

A 15-minute walk in the woods causes measurable changes in physiology. Japanese researchers led by Yoshifumi Miyazaki at Chiba University sent 84 subjects to stroll in seven different forests, while the same number of volunteers walked around city centers. The forest walkers hit a relaxation jackpot: Overall they showed a 16 percent decrease in the stress hormone cortisol, a 2 percent drop in blood pressure, and a 4 percent drop in heart rate. Miyazaki believes our bodies relax in pleasant, natural surroundings because they evolved there. Our senses are adapted to interpret information about plants and streams, he says, not traffic and high-rises.

All this evidence for the benefits of nature is pouring in at a time when disconnection from it is pervasive, says Lisa Nisbet, a psychology professor at Canada's Trent University. We love our state and national parks, but per capita visits have been declining since the dawn of email. So have visits to the backyard. One recent Nature Conservancy poll found that only about 10 percent of American teens spend time outside every day. According to research by the Harvard School of Public Health, American adults spend less time outdoors than they do inside vehicles—less than 5 percent of their day.

"People underestimate the happiness effect" of being outdoors, Nisbet says. "We don't think of it as a way to increase happiness. We think other things will, like shopping or TV. We evolved in nature. It's strange we'd be so disconnected." But some people are starting to do something about it.

NOOSHIN RAZANI AT UCSF BENIOFF Children's Hospital in Oakland, California, is one of several doctors who have noticed the emerging data on nature and health. As part of a pilot project, she's training pediatricians in the outpatient clinic to write prescriptions for young patients and their families to visit nearby parks. It's not as simple as taking a pill. To guide the physicians and patients into a new mind-set, she says, "we have transformed the clinical space so nature is everywhere. There are maps on the wall, so it's easy to talk about where to go, and pictures of local wilderness, which are healing to look at for both the doctor and patient." The hospital is partnering with the East Bay Regional Parks District to provide transportation to parks and programs there for entire families.

In some countries governments are promoting nature experiences as a public health policy. In Finland, a country that struggles with high

After two years living in the wild, engineer Matthew Sakae Forkin is back in the San Francisco area. But he still gets away to California's Lost Coast to swing through trees. "When I'm in the wilderness and feel part of it," he says, "I'm in a state of flow, full of energy and passion and calm."

Inmates Vanessa Eranzo and Lauren Hughes (who've since been released) relax while working in a garden on Rikers Island, a New York City jail. Research suggests interacting with nature makes prisoners less violent.

rates of depression, alcoholism, and suicide, government-funded researchers asked thousands of people to rate their moods and stress levels after visiting both natural and urban areas. Based on that study and others, Professor Liisa Tyrväinen and her team at the Natural Resources Institute Finland recommend a minimum nature dose of five hours a month—several short visits a week—to ward off the blues. "A 40- to 50-minute walk seems to be enough for physiological changes and mood changes and probably for attention," says Kalevi Korpela, a professor of psychology at the University of Tampere. He has helped design a half dozen "power trails" that encourage walking, mindfulness, and reflection. Signs on them say things like, "Squat down and touch a plant."

Perhaps no one has embraced the medicalization of nature with more enthusiasm than the South Koreans. Many suffer from work stress, digital addiction, and intense academic pressures. More than 70 percent say their jobs, which require notoriously long hours, make them depressed, according to a survey by electronics giant Samsung. Yet this economically powerful nation has a long history of worshipping nature spirits. The ancient proverb *"Shin to bul ee*—Body and soil are one" (not body and soul) is still popular.

At the Saneum Healing Forest, east of Seoul, a "health ranger" offers me elm bark tea, then takes me on a hike along a small creek, through shimmering red maples, oaks, and pine-nut trees. It's autumn, and the changing foliage and crisp air have lured scores of urban refugees to the woods. Soon we come upon a cluster of wooden platforms arranged in a clearing. Forty middle-aged firefighters who have been diagnosed with post-traumatic stress disorder are paired off on the platforms as part of a free three-day program sponsored by the local government. In North America groups of men in the woods likely would be hunting or fishing, but here, after a morning of hiking, they practice partner yoga, rub lavender massage oil into each other's forearms, and make delicate dried flower collages. Among them is Kang Byoung-wook, a weathered 46-year-old from Seoul. Recently returned from a big fire in the Philippines, he looks exhausted. "It's a stressed life," he says. "I want to live here for a month."

At the Twin Oaks Communities Conference in Louisa, Virginia, where people from around the world come to talk about ecovillages, cooperative housing, and how to live closer to nature, a conference attendee immerses herself in the communal mud pit.

Saneum is one of three official healing forests in South Korea, but 34 more are planned by 2017, meaning most major towns will be near one. Chungbuk University offers a "forest healing" degree program, and job prospects for graduates are good; the Korea Forest Service expects to appoint 500 health rangers in the next couple of years. It's a cradle-to-grave operation: Programs include everything from prenatal forest meditation to woodcrafts for cancer patients to

forest burials. A government-run "happy train" takes kids who've been bullied into the woods for two days of camping. A hundred-million-dollar healing complex is under construction next to Sobaeksan National Park.

Korea Forest Service scientists used to study timber yields; now they also distill essential oils from trees such as the hinoki cypress and study them for their ability to reduce stress hormones and asthma symptoms. In the new industrial city of Deajun, I pay a visit to the forest minister, Shin Won Sop, a social scientist who has studied the effects of forest therapy on alcoholics. Human well-being, he tells me, is now a formal goal of the nation's forest plan. Thanks to the new policies, visitors to Korea's forests increased from 9.4 million in 2010 to 12.8 million in 2013.

"Of course we still use forests for timber," Shin says. "But I think the health area is the fruit of the forest right now." His agency has data suggesting that forest healing reduces medical costs and benefits local economies. What's still needed, he says, is better data on specific diseases and on the natural qualities that make a difference. "What are the main factors in the forest that are most responsible for the physiological benefits, and what types of forests are more effective?" Shin asks.

In a “forest kindergarten” in Langnau am Albis, a suburb of Zurich, Switzerland, children spend most of the school day in the woods, regardless of the weather. They learn whittling, fire starting, and denbuilding; they’re able to explore. Supporters say such schools foster self-confidence and an independent spirit.

MY OWN CITY BRAIN, which spends much of the year in Washington, D.C., seems to like the Utah wilderness very much. By day, on David Strayer's camping trip, we hike among flowering prickly pear cacti; by night we sit around the campfire. Strayer's students seem more relaxed and sociable than they do in the classroom, he says, and they give much better presentations. What's going on inside their brains and mine?

A lot of different things, judging from the neuroscience research that's starting to come in. Korean researchers used functional MRI to watch brain activity in people viewing different images. When the volunteers were looking at urban scenes, their brains showed more blood flow in the amygdala, which processes fear and anxiety. In contrast, the natural scenes lit up the anterior cingulate and the insula—areas associated with empathy and altruism. Maybe nature makes us nicer as well as calmer.

It may also make us nicer to ourselves. Stanford researcher Greg Bratman and his colleagues scanned the brains of 38 volunteers before and after they walked for 90 minutes, either in a large park or on a busy street in downtown Palo Alto. The nature walkers, but not the city walkers, showed decreased activity in the subgenual prefrontal cortex—a part of the brain tied

Delaney Doyle holds edible daylilies she picked from her family's land in the mountains of eastern Kentucky. The Doyles live off the grid, surrounded by forest. But scientific evidence indicates that even a trip to the backyard or a city park provides health and psychological benefits.

to depressive rumination—and from their own reports, the nature walkers beat themselves up less. Bratman believes that being outside in a pleasant environment (not the kind where you're getting eaten alive by gnats or pummeled by hail) takes us outside of ourselves in a good way. Nature, he says, may influence "how you allocate your attention and whether or not you focus on negative emotions."

Strayer is most interested in how nature affects higher order problem solving. His research builds on the attention restoration theory proposed by environmental psychologists Stephen and Rachel Kaplan at the University of Michigan. They argue that it's the visual elements in natural environments—sunsets, streams, butterflies—that reduce stress and mental fatigue. Fascinating but not too demanding, such stimuli promote a gentle, soft focus that allows our brains to wander, rest, and recover from what Olmsted called the "nervous irritation" of city life. "Soft fascination…permits a more reflective mode," wrote the Kaplans—and the benefit seems to carry over when we head back indoors.

A few years ago, for example, in an experiment similar to Bratman's, Stephen Kaplan and his colleagues found that a 50-minute walk in an arboretum improved executive attention skills, such as short-term memory, while walking along a city street did not. "Imagine a therapy that had no known side effects, was readily available, and could improve your cognitive functioning at zero cost," the researchers wrote in their paper. It exists, they continued, and it's called "interacting with nature."

A few months after our Utah trip, Strayer's team sent me the results of my EEG test. The colorful graph charted the power of my brain waves at a range of frequencies and compared them with samples from the two groups that had stayed in the city. My theta signals were indeed lower than theirs; the soft fascination of the San Juan River had apparently quieted my prefrontal cortex, at least for a while.

So far, says Strayer, the results are consistent with his hypothesis. But even if the study bears it out, it won't offer anything like a full explanation of the brain-on-nature experience. Something mysterious will always remain, Strayer says, and maybe that's as it should be. "At the end of the day," he says, "we come out in nature not because the science says it does something to us, but because of how it makes us feel." □

MARK MAHANEY

Photographer **Lucas Foglia** grew up on a family farm in New York and currently lives in San Francisco. His work is exhibited and collected internationally. This is his first feature for *National Geographic* magazine.

Maddie Roark swims among lily pads in her family's pond in western North Carolina. Her father runs an outdoor education center. In a recent study, some 70 percent of U.S. mothers reported that they played outside every day as children; only 31 percent of their children do.

Bloody Good

Vultures do the dirty work of cleaning up after death. With their numbers plummeting, we're learning how much we need to keep them alive.

Even Darwin called them "disgusting." But vultures are more vital than vile, because they clean up carcasses that otherwise could rot and spread pestilence. Here a Rüppell's vulture *(Gyps rueppelli)* rips tissue from the trachea of a dead wildebeest.

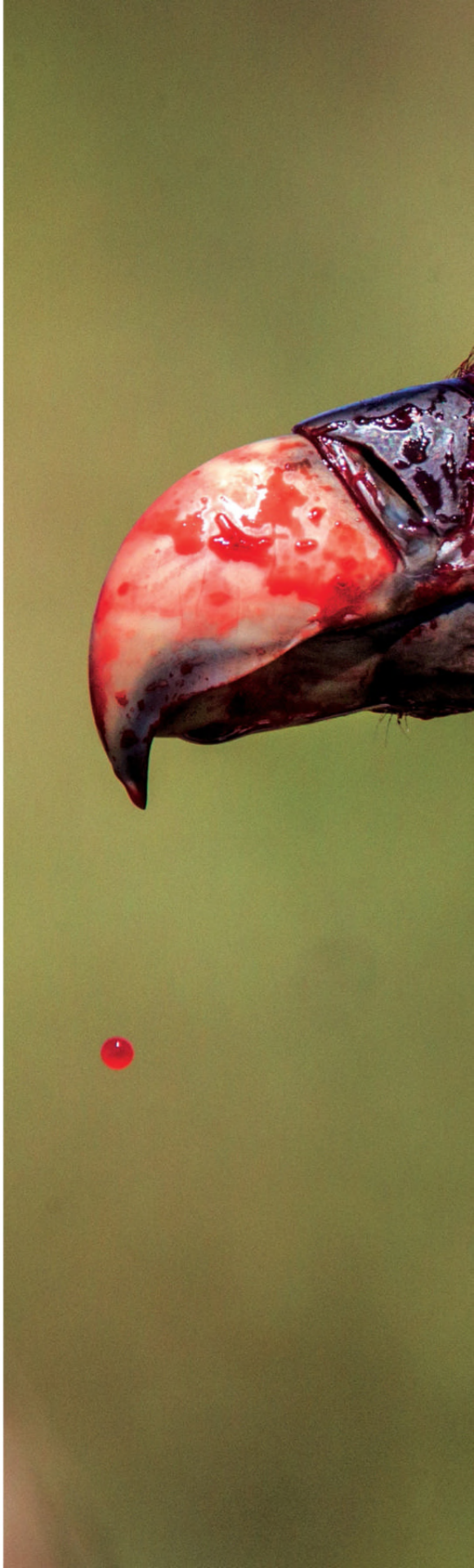
A Rüppell's vulture lays claim to a dead zebra in Tanzania's Serengeti National Park, while other Rüppell's and white-backed vultures *(Gyps africanus)* move in for a piece of the action. More vultures will likely join the banquet. They can strip a carcass clean in minutes.

A vendor in Durban, South Africa, proffers vulture heads for sale as muti—traditional medicine. Dried and smoked, vulture brains are also thought to provide visions of the future. The birds' own prospects are bleak. Six of eight species in the country are endangered.

By Elizabeth Royte
Photographs by Charlie Hamilton James

At sunset the wildebeest seems doomed: Sick or injured, it's wandering miles from its herd on the Serengeti Plain of Tanzania. By sunrise the loner is dead, draped in a roiling scrum of vultures, 40 or so birds searching for a way to invade its earthly remains. Some of the scavengers wait patiently, with a Nixonian hunch, eyes on their prize. But most are engaged in gladiatorial battle. Talons straining, they rear and rake, joust and feint. One pounces atop another, then bronco rides its bucking and rearing victim. The crowd parts and surges in a black-and-brown wave of undulating necks, stabbing beaks, and thrashing wings. From overhead, a constant stream of new diners swoops in, heads low, bouncing and tumbling in their haste to join the mob.

Why the fuss over a carcass so large? Why the unseemly greed? Because the wildebeest is tough-skinned and wasn't killed by carnivores, it lacks an opening wide enough for general admission. And so the boldest birds compete furiously for access. As the crowd cackles and caws, a white-backed vulture snakes its head deep into the wildebeest's eye socket and hurriedly slurps,



Blood drips from a Rüppell's vulture's beak as it pauses mid-meal. The neck and head of Rüppell's are sparsely feathered, the better to keep gore, guts, and fecal matter from clinging after a deep carcass dive.

Vultures are both lovers and fighters. They probably mate for life, which can be 30 years in the wild, and are attentive to their partners. But in a scuffle around a carcass (right), they're aggressive competitors, with other species and their own kind. Lappet-faced vultures (*Torgos tracheliotos,* above) are known for being particularly affectionate.

with grooved tongue, whatever it can before being ripped from its place at the table. Another white-backed tunnels into a nostril while a Rüppell's vulture starts at the other end; it's eight inches into the wildebeest's anus before another bird wrenches it away, then slithers its own head, like an arm into an evening glove, up the intestinal tract. And so it goes—40 desperate birds at five golf-ball-size holes.

Eventually, two lappet-faced vultures make their move. These spectacular-looking animals stand more than a yard tall, with wingspans of nine feet. (In treetops, they make stick nests as big as king-size beds.) Their faces are pink, their bills large and deeply arched, and their powerful necks festooned with crepey roseate skin and a brown Tudor ruff. While one lappet hammers a hole in the wildebeest's shoulder, the other excavates behind a sinus, in hopes of finding juicy botfly larvae. Sinews and skin snap. Now a white-backed rams its head down the wildebeest's throat and yanks out an eight-inch length of trachea, ribbed like a vacuum hose. But before the vulture can enjoy it, the four-foot-tall marabou stork that's been stiffly lurking snatches the windpipe away, tosses it once for perfect alignment, and swallows it whole. Thanks to the labors of the lappets, which favor sinew over muscle, the wildebeest is now wide open. Heads fling blood and mucus into the air; viscera drip from vulture bills; two birds play tug-of-war with a ten-foot rope of intestine coated in dirt and feces.

As the wildebeest shrinks, the circle of sated birds lounging in the short grass expands. With bulging crops, the vultures settle their heads atop folded wings and slide their nictitating membranes shut. No more sound, no more fury. As placid as suburban ducks, they rest, at peace with the world.

THE VULTURE MAY BE the most maligned bird on the planet, a living metaphor for greed and rapaciousness. Leviticus and Deuteronomy

classify vultures as unclean, creatures to be held in abomination by the children of Israel. In his diary during the voyage of H.M.S. *Beagle* in 1835, Charles Darwin called the birds "disgusting," with bald heads "formed to wallow in putridity." Among their many adaptations to their feculent niche: the ability to vomit their entire stomach contents when threatened, the better to take quick flight.

Revolting? Perhaps. But vultures are hardly without redeeming values. They don't (often) kill other animals, they probably form monogamous pairs, and we know they share parental care of chicks, and loaf and bathe in large, congenial groups. Most important, they perform a crucial but massively underrated ecosystem service: the rapid cleanup, and recycling, of dead animals. By one estimate, vultures either residing in or commuting into the Serengeti ecosystem during the annual migration—when 1.3 million white-bearded wildebeests shuffle between Kenya and Tanzania—historically consumed more meat than all mammalian carnivores in the Serengeti combined. And they do it fast. A vulture can wolf more than two pounds of meat in a minute; a sizable crowd can strip a zebra—nose to tail—in 30 minutes. Without vultures, reeking carcasses would likely linger longer, insect populations would boom, and diseases would spread—to people, livestock, and other wild animals.

But this copacetic arrangement, shaped by the ages, is not immutable. In fact, in some key regions it's in danger of collapse. Africa had already lost one of its eleven vulture species—the cinereous vulture—and now seven others are listed as either critically endangered or endangered. Some, like the lappet, are found predominantly in protected areas (which are themselves threatened), and other regional populations of the Egyptian and bearded vulture are nearly extinct. Vultures and other scavenging birds, says Darcy Ogada, assistant director of Africa programs at the *(Continued on page 88)*

In the Serengeti a golden jackal takes umbrage at an immature white-backed vulture butting in on its meal of dead wildebeest. Earthbound carnivores such as jackals and hyenas have limited territories in which to find food. Aloft, vultures have a much better view of the daily menu: They can spot a carcass 20 miles away.

EATER OF THE DEAD

The only land-based vertebrates that can thrive solely on scavenging, vultures are crucial to ecosystem balance. Because they can quickly devour large amounts of flesh and their stomach acids neutralize pathogens, vultures may help limit the spread of bacteria and diseases such as anthrax and rabies. But their numbers have been plummeting worldwide, with several populations at risk of collapse.

Bald head
Baldness in many vulture species is related to thermoregulation and hygiene. Head feathers would catch gore and viscera.

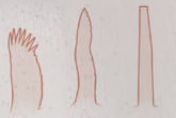
Eyes
Compared with raptors that hunt, vultures have less powerful eyesight but still excel at spotting carcasses and converging scavengers.

Crop
Some vultures can s
to 20 percent of the
weight in consume
in this enlarged sec
their esophagus.

Suited for Scavenging

Vultures' bulk allows them to survive on body reserves between discoveries of carrion. Anatomical adaptations help them expend as little energy as possible when soaring on thermals over ranges—up to 185,000 square miles—in search of food.

Wings
Broad wings and long primary feathers, compared with other soaring birds, enable energy-efficient gliding on even the weakest air currents.



Beak
Hooked bills help with ripping meat. Still, only the largest vultures can tear open a carcass, allowing smaller vultures to access innards.

Nostrils
Turkey and yellow-headed vulture species have a keen sense of smell, unique among birds, with nostrils not divided by a septum.

Tongue
Vultures have adap
like deep grooves a
backward-facing ba
for quickly gulping l
portions of carrion.

23 Species of Vulture

- Critically endangered
- Endangered
- Near threatened
- Least concern

Categories reflect global population rankings. Regional rankings may differ.

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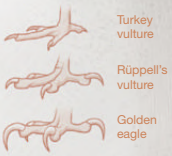
Gut
Highly corrosive, bacteria-killing stomach acids give vultures a high tolerance to toxins in decaying flesh.

Feet
Vultures spend more time on the ground than other raptors, and have developed flatter feet and shorter, less curved claws.



States of Decline

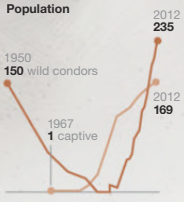
There are 23 species of vulture divided into two families by hemisphere, New World and Old World, each facing threats.

RECOVERING
When counts of California condors began in the early 1900s, the birds' ranks had already been decimated. After decades of conservation efforts, numbers are growing, but lead poisoning from spent ammunition in scavenged carcasses is still a threat.

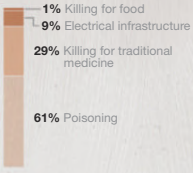
DECLINING
Poisoned by herders aiming to protect their livestock and by poachers afraid that circling vultures will give away their location, some groups are shrinking by as much as 50 percent a decade. Traditional healers believe vulture brains grant the ability to see the future.

CRASHED
India's populations plunged in the mid-1990s. Hindu belief prohibits consumption of beef, so cows that die are disposed of outdoors. Vultures died of kidney failure after eating cows that had been treated with the bovine drug diclofenac. The drug was banned in India in 2006.

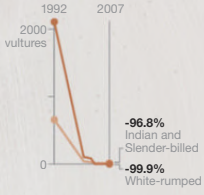
California Condor Population



Causes for Decline in African Vultures



Birds Counted in India Transect Surveys



MATTHEW TWOMBLY AND LAUREN C. TIERNEY, NGM STAFF; MESA SCHUMACHER. ART: MATTIAS SNYGG
SOURCES: DARCY OGADA, PEREGRINE FUND; SIMON THOMSETT, NATIONAL MUSEUMS OF KENYA; STEVE KIRKLAND, U.S. FISH AND WILDLIFE SERVICE; BIRDLIFE INTERNATIONAL; VIBHU PRAKASH, *JOURNAL OF THE BOMBAY NATURAL HISTORY SOCIETY*, 2007

A young Rüppell's vulture reaches in to grab a morsel of zebra in the Serengeti. Older and more dominant birds have taken their fill of the choice meat, leaving the skin and bones for youngsters and white-backed vultures. Watch a video of the feast at *ngm.com/more.*

A Rüppell's vulture glides in to join the party at a carcass in the Serengeti. Adult Rüppell's have a wingspan of up to eight feet. Riding thermals 12,000 feet or more above sea level, Rüppell's vultures can eat in four African countries in a single foray. The dominant species in East Africa, the white-backed and Rüppell's, can glide more than a hundred miles a day.

Peregrine Fund, "are the most threatened avian functional group in the world."

On a sunny March day Ogada is traveling with her colleague Munir Virani in the Masai Mara region of Kenya. Virani is here not to study his beloved birds but to speak with herdsmen about their cows. Livestock husbandry, it turns out, is essential to vulture welfare. As our truck weaves through flocks of sheep and goats, Virani explains how the Maasai have in recent years leased their land, which rings the northern section of the Masai Mara National Reserve, to conservancies established to protect wildlife by excluding pastoralists and their livestock. Some Maasai claim the conservancies have lured more lions and other carnivores to the area. (The conservancies are contiguous and unfenced.) Meanwhile populations of wildebeests and other resident ungulates in the Mara ecosystem are facing threats from poaching, prolonged drought, and conversion of savanna to cropland and real estate. This in itself would be bad news for vultures, but there's worse.

Virani asks every Maasai we meet: Have you lost any livestock to predators recently? The answer is always, "Yes, and my neighbors have too." Usually the lions attack at night, when the cattle are penned inside bomas—corrals ringed with thorny brush. The lions roar, then terrified cattle stampede, crash through the boma gate, and scatter. Dogs bark, waking their owners, but it's usually too late. The killing of a single cow represents a loss of 30,000 shillings ($300), a significant blow to families that use livestock as currency (a bull can be worth 100,000 shillings).

Next comes retaliation: The men tie up their dogs, retrieve what's left of the lion's kill, and sprinkle it with a generic form of Furadan, a cheap, fast-acting pesticide that's readily available under the table. The lion returns to feed, most likely with its family, and the entire pride

Society Grant Your Society membership helped conserve threatened vultures in India and Kenya.

succumbs. (Researchers estimate that Kenya loses a hundred lions a year in these conflicts. The country has roughly 1,600 lions left.) Inevitably vultures also visit the livestock carcass, or they eat the poisoned lions themselves. Whatever the vector, the birds, which can feed in "wakes" of more than a hundred individuals, all die as well.

It's hard to believe that just a few granules of a compound designed to kill worms and other invertebrates can lay low an animal whose gastric juices are acidic enough to neutralize rabies, cholera, and anthrax. Indeed, Furadan was scarcely on Ogada's radar until 2007, when she began receiving emails from colleagues about poisoned lions. "That raised some eyebrows," she says. Tourism is Kenya's second largest source of foreign income, and lions are the nation's star attraction. In 2008 scientists and representatives from conservation groups and government agencies convened in Nairobi to share information on poisonings and plan a response. "Jaws dropped," Ogada remembers. "The problem was far larger than any of us, working locally, knew." Once Ogada and others began to study the problem, they estimated that poisoning accounts for 61 percent of vulture deaths, Africa-wide. The anthropogenic threat is compounded by vultures' reproductive biology: They don't reach sexual maturity until five to seven years of age, they produce a chick only once every year or two, and 90 percent of their young die in the first year. Over the next half century vulture numbers on the continent are projected to decline by 70 to 97 percent.

AS BAD AS THE AFRICAN SITUATION appears, it has been worse elsewhere. In India populations of the most common vultures—white-rumped, long-billed, and slender-billed—declined by more than 96 percent in just a single decade. Then in 2003 researchers from the Peregrine Fund definitively linked bird carcasses with cattle that had been treated with an anti-inflammatory called diclofenac. Initially prescribed for arthritis and other pain in humans, the drug had been approved for veterinary use in 1993. In vultures, diclofenac causes kidney failure: Autopsies reveal organs coated with white crystals.

The Indian die-off received a lot of attention because its downstream effects were so startling. India has one of the largest cattle populations in the world, but most Indians don't eat beef. After millions of vultures fell victim to poisoning, dead cattle started piling up. Then the dog population—released from competing with vultures for scavenged food—leaped by 7 million, to 29 million animals over an 11-year period. The result: an estimated 38.5 million additional dog bites. Rat populations soared. Deaths from rabies increased by nearly 50,000, which cost Indian society roughly $34 billion in mortality, treatment expenses, and lost wages. India's Parsi community in Mumbai was alarmed to note another change. The corpses they ritually place on elevated stone platforms for "sky burial"—in which vultures liberate the souls of the dead so that they can reach heaven—were taking months longer to disappear, because there were no vultures left to feed on them.

After researchers proved that diclofenac was to blame for the vulture die-off, in 2006 veterinary use of the drug was banned in India, Pakistan, and Nepal. (It's still given to cattle clandestinely.) Bangladesh followed suit in 2010, and in mid-June 2015, a coalition of conservation groups urged the European Commission to ban the drug's use in animals. A response is pending. In combination with captive-breeding programs and vulture "restaurants," which serve safe meat from farms or abattoirs to wild birds, the campaign has done some good. Nine years on, Indian vulture declines have slowed, and in some regions their numbers have even begun to increase. But the population of the three hardest-hit species remains a small fraction of its former millions.

OGADA ISN'T HOPEFUL that Africa will follow India's lead in responding to the vulture crisis. "There has been little government action to conserve vultures in Kenya," she says, "and no political will to limit the use of carbofurans,"

Conservationists in Namibia use a car side-door mirror on a pole to peek into a lappet-faced vulture's nest in a tree. If they find a chick that's old enough, they'll retrieve it, wing tag it, and put it back. Females may lay only one egg every year or two, so every chick's survival is critical to the population's future.

Like gargoyles carved in stone, Cape vultures *(Gyps coprotheres)* glower down from an artificial nesting cliff near Magaliesburg, South Africa. The breeding, research, and rehabilitation facility is run by VulPro, a group working to restore African vulture numbers.

VulPro founder Kerri Wolter brings a Cape vulture, its wing injured when it flew into a power line, to a veterinarian near Pretoria. Poisoning by poachers is the biggest threat to African vultures, but power-line collisions pose another. Conservationists are urging Africa's power companies to help find solutions to the threat their lines present to vultures and other birds.

the chemical family that includes Furadan. And although vultures in India face just one major threat—unintentional poisoning—vultures in Africa face many more.

In July 2012, 191 vultures died after feasting on an elephant that had been poached and then sprinkled with poison in a Zimbabwean national park. A year later roughly 500 vultures were killed after feeding on a poison-laced elephant in Namibia. Why do poachers, intent on ivory, target vultures in this way? "Because their kettling in the sky over dead elephants and rhinoceroses alerts game wardens to their activities," Ogada says. Ivory poachers now account for one-third of all East African vulture poisonings.

Cultural practices have also taken a toll on vultures. According to André Botha, co-chair of the vulture specialist group at the International Union for Conservation of Nature, many of the birds found at poached carcasses are missing their heads and feet—a sure sign they've been sold for muti, or traditional healing. Shoppers at southern African markets have little trouble buying body parts believed to cure a range of ailments or impart strength, speed, and endurance. Dried vulture brain is also popular: Mixed with mud and smoked, it's said to conjure guidance from beyond.

Still, the biggest existential threat to African vultures remains the ubiquitous availability and use of poisons. FMC, the Philadelphia-based maker of Furadan, began buying back the compound from distribution channels in Kenya, Uganda, and Tanzania—and suspended sales in South Africa—following a *60 Minutes* segment on lion poisonings in 2009. But the compound, in generic form, persists. Agriculture is the second largest industry in Kenya, and the nation has a long history of using toxins to combat outbreaks of disease and pests. Anyone can walk into a Kenyan agro-veterinary shop and, for less than two dollars, buy highly toxic pesticides off the shelf—to kill insects, mice, feral dogs, hyenas, leopards, jackals, and even fish and ducks meant

for human consumption. (Poachers claim, erroneously, that removing the animal's entrails, then slowly roasting the carcass, detoxifies the flesh.)

"You cannot have agriculture in the tropics without pesticides," Charles Musyoki, former head of species management for the Kenya Wildlife Service, says. "So we need to educate the public about their correct and safe use."

What the public understands now is that carbofurans are cheap, reliable, and—compared with stalking and spearing a predator—risk free. To date, the government hasn't prosecuted a single poisoner of vultures. "Poisoning predators is just part of the culture," Ogada says with a shrug. Indigenous groups have always protected their herds, and the descendants of Europeans—who introduced cheap synthetic poisons in the first place—have been slaughtering mammalian and avian carnivores in Africa for more than 300 years.

AFTER A LONG DAY of speaking with Maasai herdsmen, Virani and Ogada are eager for the sun to set, not to escape the heat but to witness the flicking of an electrical switch. In the gloaming, Virani parks his jeep outside a compound that sits in the pounded dust bowl between the 50,000-acre Mara Naboisho Conservancy, to the east, and the 400,000-acre Masai Mara reserve, to the west. Under a velvet sky glimmering with stars, Virani stares at a boma and, when a dozen lightbulbs strung between fence posts blink on, breaks into a grin.

Balloon safari operators, who ascend before daybreak, have complained about this nighttime light pollution. But to Virani these flashing bulbs, connected to a solar battery, are a minor miracle, the safest, most cost-effective way to keep predators away from cattle pens and short-circuit the retaliatory poisoning that's decimating vultures.

"The lights cost between 25,000 and 35,000 shillings per boma," Virani says—between $250 and $350, with the Peregrine Fund picking up half of that. "Prevent one cattle predation, and they've paid for themselves." In their first six months of deployment in this part of the Mara, lion attacks on 40 bomas with arrays went down by 90 percent. So far, carnivores and elephants—which commute between the conservancies and the reserve, often through Maasai vegetable patches—are still avoiding the lights, but lack of maintenance and mismanagement of the systems (siphoning power to charge phones, for example) have reduced their effectiveness. Still, demand for the arrays far outpaces supply.

ON THE SERENGETI, about 150 miles to the south of the Masai Mara, the sun rises on three adult hyenas, shoulder deep in yet another dead wildebeest. Now and then the feathered audience that has gathered at this theater-in-the-round advances toward the stage, only to be rebuffed by the principal actors raising their chins and curling their black lips. The vultures take the hint. There is, between the four-legged and the two-, a palpable respect: Hyenas rely on vultures to locate kills, and vultures rely on hyenas to quickly bust them open.

Eventually the hyenas are full enough to retreat, cuing the birds to swarm. Now the carcass rocks back and forth as two dozen vultures rip, slurp, pry, and tug. Suddenly a lappet drops out of the sky, then bashes skulls with two other lappets standing innocently on the periphery. The aggressor wheels, ducks its head, raises its massive wings, then mounts the wildebeest in triumph. "They are the most amusing animals," Simon Thomsett, a vulture expert affiliated with the National Museums of Kenya, says,

HECTOR SKEVINGTON-POSTLES

A photojournalist specializing in wildlife and conservation, **Charlie Hamilton James** evaded a charging rhino, fought off illness from a tick bite, and drove through vulture feeding frenzies to photograph this story.

Did you use any unconventional techniques to create these images? I modified a small camera and placed it in a dead zebra. I triggered it from a hundred yards away. The vultures composed these images by kicking and scuffling, knocking my camera around the zebra's rib cage.

Sprinkled on carrion, a few ounces of the insecticide carbofuran (above) can kill a hundred vultures. Poisoned birds that are caught quickly or haven't consumed too much may be saved if given a dose of the drug atropine and fed charcoal, which absorbs the poison. At right, a white-backed vulture recovers at the VulPro facility. The bird was later released.

binoculars to his eyes. "You certainly couldn't spend this long watching a lion."

Hours pass, the bloody players come and go: hyenas, jackals, storks, scavenging eagles, and four species of vulture. Despite the apparent hysteria, everyone gets a chance, partitioning the carcass in time and space according to social status and physical ability.

Both Thomsett and Ogada, who often collaborate, have spent much time pondering what would happen if vultures were subtracted from this cast of characters. Running field experiments with goat carcasses over a two-year period, Ogada learned that in the absence of vultures, carcasses took nearly three times as long to decompose, the number of mammals visiting carcasses tripled, and the amount of time these animals stayed at the carcass also nearly tripled.

Why do these data matter? Because the longer jackals, leopards, lions, hyenas, genets, mongooses, and dogs commune with one another at a carcass, the more likely they are to spread pathogens—which die in vulture stomachs—to other animals, both wild and domesticated. By eating wildebeest placenta, Thomsett tells me from his perch in the jeep, vultures also prevent cattle from contracting malignant catarrh, an often fatal herpes virus. And by reducing carcasses to bones within hours, they suppress insect populations, linked with eye diseases in both people and livestock.

"Vultures are more important, in terms of services to humanity, than the 'big five' that everyone comes here to see," he says. Their loss, scientists believe, would likely set off an ecological and economic catastrophe.

Although poisoning is the proximate driver of Africa's vulture decline, the plain-speaking Thomsett stresses its root cause: too many people. Kenya's population is expected to reach 81 million, from today's 44 million, by 2050. And the Maasai are among the fastest growing groups in the country.

Thomsett lowers his binoculars and expands on the list of anthropogenic threats to Kenya's vultures. Farmers are planting corn and wheat around protected areas to feed the growing population, he says. Less grassland means fewer ungulates for vultures to eat. The government hasn't been able to stop drilling for geothermal wells within 300 meters (328 yards) of endangered Rüppell's nesting sites, he continues. Vultures are also killed in collisions with high-tension power lines. The Kenya Wildlife Service has yet to write, let alone implement, a strategic plan for vulnerable vulture species. (Such a plan is imminent, the service's Charles Musyoki told me.)

In December 2013 Kenya passed an act that imposes a fine of up to 20 million shillings ($200,000) or life imprisonment on anyone linked with killing an endangered species. And the Kenya Wildlife Service is said to be planning a campaign to shift the public's perception of vultures. But without better investigating and enforcement of anti-poisoning laws, to say nothing of convicting perpetrators, Ogada and Thomsett agree, such campaigns won't be nearly enough to save the region's birds. More immediately effective, they say, would be for the government to accept an offer from a landowner in southwestern Kenya. He has offered to sell land containing one of the nation's most important breeding cliffs for the critically endangered Rüppell's vulture.

Thomsett continues to observe the vultures wallowing in putridity, making detailed sketches of their heads and feet in a thick notebook, until the birds have eaten their fill and the wildebeest resembles a wrinkled blue-gray rug, with hooves. In the days to come, any remaining scraps of skin and sinew will be ravaged by the elements, by insects, fungi, and microbes. The ungulate's larger bones will persist for years, but in the meantime its basic building blocks will cycle on—in the soil, in vegetation, and in every glorious vulture that fed on its prodigal abundance today. □

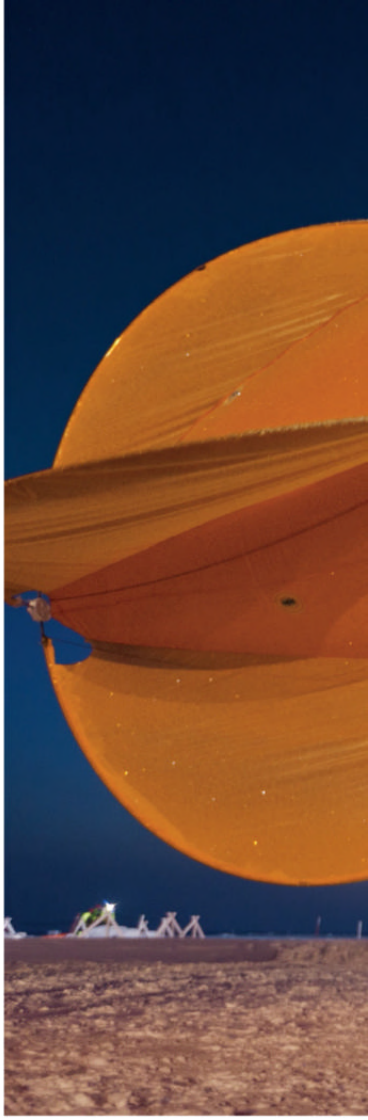
INTO THIN ICE

The Arctic ice pack is dwindling. What will that do to the planet?

To track changes in sea ice, the Norwegian research vessel *Lance* drifted along with it for five months in 2015, on a rare voyage from Arctic winter into spring. In late February the sky hints at the coming of the sun.

In early March, after shoveling away three feet of snow, scientists from the *Lance* melt a hole through the ice to collect plankton and water samples. Most Arctic fieldwork is carried out between spring and fall.

Tailing a Norwegian Coast Guard icebreaker that was following "leads"—fractures in the ice—the *Lance* penetrated to 83 degrees north. Much of the thick, perennial ice in the Arctic has given way to thinner floes that form and melt within a single year.



In the 1890s the Norwegian ship *Fram* (above) drifted for three years in the Arctic ice, hoping to reach the North Pole. With the Pole on its way to becoming an open-water tourist attraction, at least in summer, scientists on the *Lance* (right) studied how the loss of ice affects the environment. One of their tools: a tethered, instrument-laden balloon.

NATIONAL LIBRARY OF NORWAY

By Andy Isaacson
Photographs by Nick Cobbing

The sea ice that blankets the Arctic Ocean isn't the unbroken white mantle depicted in maps. It's a jigsaw puzzle of restless floes that are constantly colliding, deforming, and fracturing from the force of wind and ocean currents. Last February I stood shivering on the deck of the *Lance,* an old Norwegian research vessel, as it picked a path through a labyrinth of navigable fractures. A barren white plain of ice and snow extended to the horizon in every direction. The ship's steel hull shuddered and screeched as it plowed through floating chunks of jagged ice. The *Lance* was seeking a solid patch of ice to attach to—the last one had shattered—so that it could resume its erratic drift across the frozen sea, charting the fate of Arctic sea ice by going with the floe.

The Norwegians have done this before, more than a century ago, when polar explorer Fridtjof Nansen and the *Fram* were locked in pack ice for nearly three years during a vain attempt to drift across the North Pole. But the Arctic is a different ocean now. The air above it has warmed on average about 5 degrees Fahrenheit in the past century, more than twice the global average. Much less of the ocean is covered by ice, and much more of that ice is thinner, seasonal ice rather than thick, old floes. A feedback loop with far-reaching consequences has taken effect: As white ice is replaced in summer by dark ocean water, which absorbs more sunlight, the water and air heat further—amplifying the ongoing thaw.

"The Arctic warms first, most, and fastest,"

explains Kim Holmén, the long-bearded international director of the Norwegian Polar Institute (NPI), which operates the *Lance*. Climate models predict that by as early as 2040 it will be possible in summer to sail across open water to the North Pole.

Arctic sea ice helps cool the whole planet by reflecting sunlight back into space. So its loss inevitably will affect the climate and weather beyond the Arctic, but precisely how remains unclear. Better forecasts require better data on sea ice and its shifting, uneven distribution. "Most scientific cruises to the Arctic are conducted in summer, and this is where we have the most field data," says Gunnar Spreen, an NPI sea-ice physicist I met on board the *Lance*. "The continuous changes that occur from winter into spring are a huge gap in our understanding."

On the *Lance*'s five-month mission its rotating crew of international scientists would investigate the causes and effects of ice loss by monitoring the ice across its entire seasonal life cycle—from the time when it formed in winter until it melted in summer.

A few days after photographer Nick Cobbing and I joined the ship by icebreaker and helicopter from Longyearbyen, on the island of Spitsbergen in the Svalbard archipelago—the base for NPI's Arctic operations—the *Lance* steamed to 83 degrees north, just west of Russian territory. The scientists singled out a half-mile-wide floe of predominantly seasonal ice that they hoped to study. The crew tethered the vessel to the floe with nylon ropes attached to thick metal poles driven into the ice. They shut off the main engine. Isolated and in near darkness, we began

SEPTEMBER 2015
At summer's end Arctic sea ice had shrunk to its fourth smallest extent since satellites began measuring it in 1979. The past nine years were the nine smallest. One reason: the low concentration of ice. Light blue areas are mostly water.

Cycling Toward Oblivion

Every winter almost the en
surface of the Arctic Ocea
over. The ice typically reac
maximum extent in March
right), then starts to melt, r
to its minimum in Septemb
But the melt season is now
weeks longer than it was ju
decades ago. Less ice sur
summer to thicken the foll
winter. The summer ice is
concentrated, with more o
between floes. Because o
absorbs more solar heat, r
melts, creating a positive f
that amplifies the warming
melting. The Arctic will cor
freeze in winter—but it cou
free in summer by 2040.

LAUREN E. JAMES, JASON TREAT, AND RYAN WILLIAMS, NGM STAFF

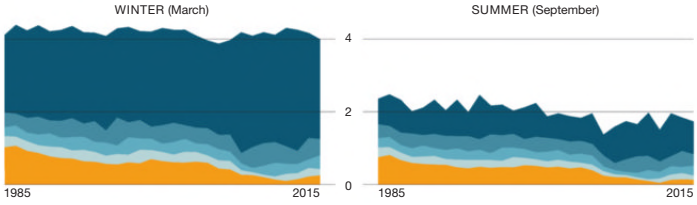
SOURCES: MARK TSCHUDI, CHARLES FOWLE
JAMES MASLANIK, COLORADO CENTER FOR
RESEARCH, UNIVERSITY OF COLORADO BOU
STEELE AND WENDY ERMOLD, POLAR SCIEN
UNIVERSITY OF WASHINGTON; JULIENNE STR
SNOW AND ICE DATA CENTER; CLAIRE L. PARI

Winter Ice: Younger, Thinner

Maps of the Arctic in March and charts of the ice's age (right) show a 75 percent decline in the oldest, thickest ice—ice that has survived at least four summers and is into its fifth year or more. Most sea ice now freezes and melts in less than a year.

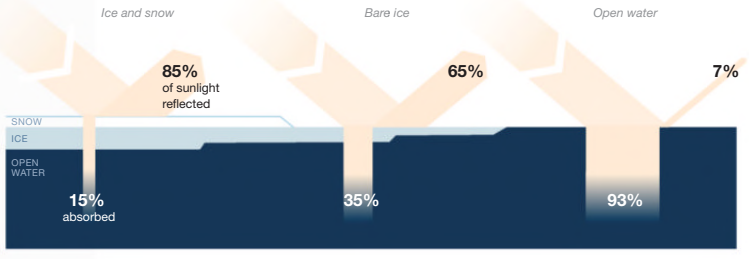
Age of ice
- 0-1 years
- 1-2 years
- 2-3 years
- 3-4 years
- 4+ years

Average ice extent *in million square miles*



Albedo Effect

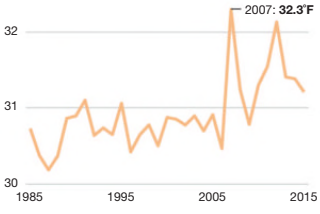
Ice and snow reflect some 85 percent of solar radiation; open water is dark and absorbs 93 percent. As the water warms, it melts more ice—a feedback whose effects reach beyond the Arctic.

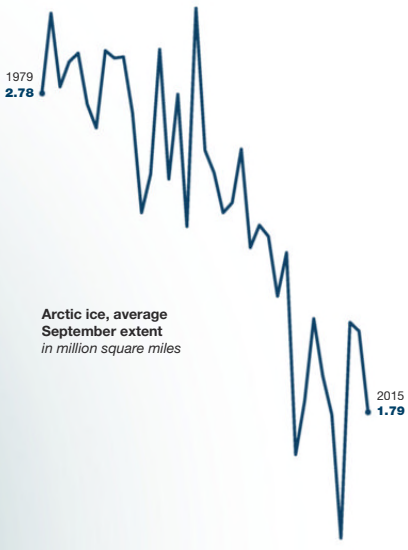


Warmer Waters

Sea-surface temperatures in the Arctic are increasing. The warmer water makes it harder for sea ice to form and to survive. Seawater freezes at about 28.4 degrees Fahrenheit.

Mean Arctic Ocean surface temperature, September *in degrees Fahrenheit*





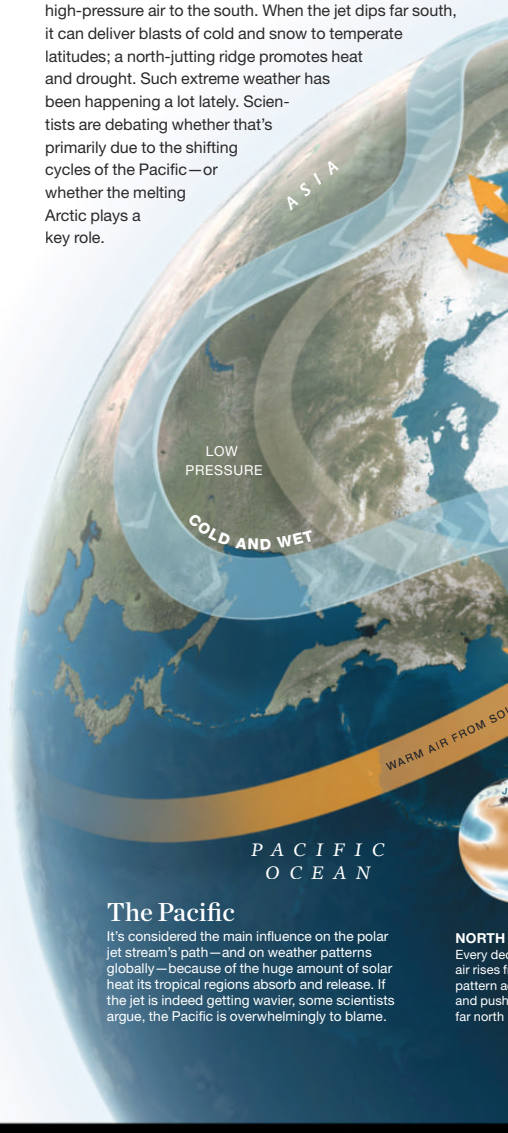
Arctic ice, average September extent
in million square miles

DISAPPEARING ICE

Since satellites began regularly measuring Arctic sea ice in 1979, it has declined sharply in extent and thickness. Much of the ice that's there in winter is thin stuff that doesn't survive the summer. The loss of ice is affecting the entire Arctic ecosystem, from plankton to polar bears. And some scientists think that, by altering the jet stream, it's affecting weather—and people—around the Northern Hemisphere.

Extreme Weather: An Arctic Connection?

The polar jet stream is a high-altitude air current that separates low-pressure Arctic air—aka the polar vortex—from warmer, high-pressure air to the south. When the jet dips far south, it can deliver blasts of cold and snow to temperate latitudes; a north-jutting ridge promotes heat and drought. Such extreme weather has been happening a lot lately. Scientists are debating whether that's primarily due to the shifting cycles of the Pacific—or whether the melting Arctic plays a key role.



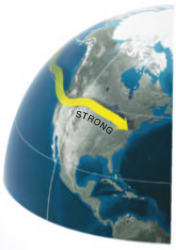
The Pacific

It's considered the main influence on the polar jet stream's path—and on weather patterns globally—because of the huge amount of solar heat its tropical regions absorb and release. If the jet is indeed getting wavier, some scientists argue, the Pacific is overwhelmingly to blame.

NORTH
Every de
air rises f
pattern a
and push
far north

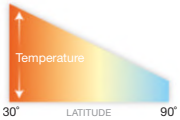
The Arctic

The Arctic is warming faster than the rest of the planet, in part because of the feedback caused by the loss of sea ice. According to a controversial theory, Arctic warming is causing the jet to slow down and meander more. The result: unseasonable weather that sits in one place for a long time.



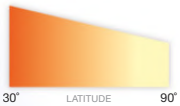
STRAIGHTER JET STREAM

The jet stream gets most of its energy from the temperature contrast between the air masses it separates. A strong jet is a straighter jet that keeps cold air bottled up in the Arctic.



WAVIER JET STREAM

As the Arctic warms faster than the midlatitudes, the temperature contrast decreases. That weakens the jet, letting Arctic air flow south—over eastern North America, for instance.



Arctic Heat Pump

Ice-free water absorbs more solar heat in summer, then releases it in winter, as the water refreezes. Heat and water vapor rising from the ocean raise air pressure and moisture and may affect the jet.

GREENLAND

HIGH PRESSURE

ATLANTIC OCEAN

HIGH PRESSURE

UTH PACIFIC

Straighter jet stream

COLD AND WET

NORTH AMERICA

LOW PRESSURE

Wavier jet stream

HOT AND DRY

Sea-surface temperature anomalies

Warmer

Cooler

PACIFIC MODE

cade or so, warm rom a horseshoe cross the Pacific es the jet stream into Alaska.

EL NIÑO

When warm water sloshes into the eastern Pacific during an El Niño, the heat it releases can draw the jet stream south, carrying rain to California.

Extreme Persistence

Whatever their cause, big jet stream meanders move slowly around the planet. That means the weather they carry stays in one place for a long time. Think of California parched below a persistent high-pressure ridge or New England buried under polar vortex snows in early 2015.

Early winter 2012 ice extent shown

LAUREN E. JAMES, JASON TREAT, AND RYAN WILLIAMS, NGM STAFF

ART: NICK KALOTERAKIS

SOURCES: JENNIFER FRANCIS, RUTGERS UNIVERSITY; DENNIS HARTMANN, UNIVERSITY OF WASHINGTON

The upshot of all this, as ecologist Ian Stirling bluntly puts it: 'The Arctic

our wayward drift and our month-long shift in the ice desert.

Like homesteaders, the scientists established camps on the floe, pitching tents and laying electric cables. Physicists like Spreen mapped the ice topography with lasers and recorded the thickness and temperature of the snow on top. Oceanographers bored a hole through the ice to gather data about the water and the currents. Meteorologists erected masts carrying instruments to collect weather data and measure greenhouse gases. Biologists searched for ice algae, which look like dirt and live on the underside of the ice and in the channels of trapped brine left after newly formed sea ice expels salt. In a few weeks, after the returning sun cast aside the cloak of polar night and began filtering through the melting floe, the scientists would watch the ecosystem awaken.

Temperatures regularly plunged to 30 degrees below zero Fahrenheit. Scientists had to contend with numb fingers, snapped cables, and crippled electronic instruments, along with the danger of roving polar bears. "This is really extreme science," one researcher said.

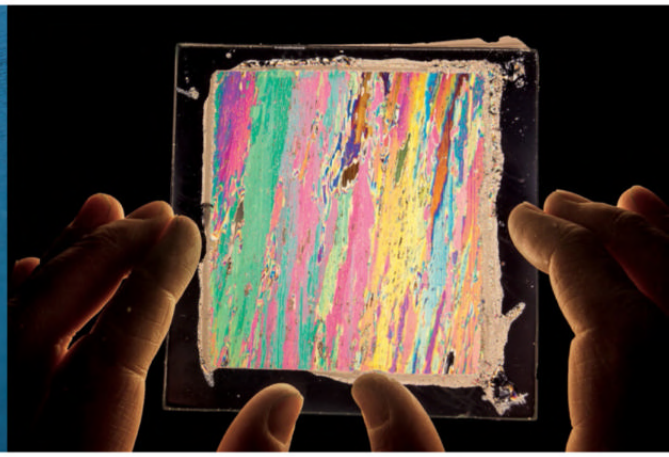
IN 2007 THE UN Intergovernmental Panel on Climate Change (IPCC) warned that the impacts of climate change in the Arctic over the next century "will exceed the impacts forecast for many other regions and will produce feedbacks that will have globally significant consequences." Nearly a decade later this grim forecast is already being borne out. Probably no region has been more affected by climate change than the Arctic. Permafrost is thawing, and the land is greening, as tree lines creep north and shrubs and grasses invade the tundra. Certain populations of polar bears, walruses, and caribou have suffered significant declines. National Oceanic and Atmospheric Administration (NOAA) oceanographer James Overland says, "The Arctic really is the canary showing that climate change is real."

Since 1979, when satellite records began, the Arctic has lost more than half its volume of ice, which has diminished in both overall area and thickness. The frozen area shrinks to its annual minimum in September, at summer's end. In September 2012 its extent was just half the average during the 1980s and '90s. The maximum ice extent in winter, usually reached in March, also is declining, though at a slower rate; its average thickness has decreased by half. What was once mostly a layer of 10- to 13-foot-thick ice floes that lingered for years—perennial ice—has given way to large tracts of thinner, less reflective ice that forms and melts during a single year. Sea-ice coverage has always fluctuated naturally, but there's little doubt among scientists that man-made greenhouse gases are now accelerating its decline. "Old, thick sea ice was a global reservoir for cold, but that is now changing," Overland says.

An entire ecosystem is melting away. The loss of sea ice may take a toll on some of the photosynthesizing organisms that fuel the marine food chain—single-celled algae that live under the ice and bloom in the spring when the light returns. Changes in the magnitude and timing of these blooms, as winter ice retreats faster and earlier, may throw off the life cycle of tiny, fatty zooplankton called copepods, which eat the algae and are in turn eaten by arctic cod, seabirds, and bowhead whales. For marine mammals such as the polar bear, Pacific walrus, and ringed seal, the loss of hundreds of thousands of square miles of sea ice has already been devastating. "It's like someone took the floor out from under you," says Kristin Laidre, a polar scientist at the University of Washington.

The assumption is that later this century, without a home field, these animals will simply lose all competitive advantage. Killer whales, for example, are likely to replace polar bears as the top marine predators, as bears retreat to the dwindling remnants of summer sea ice. Though polar bears sometimes spend time on land, where lately a few have been hybridizing with grizzlies, Ian Stirling of the University of Alberta, a leading polar bear expert, dismisses any notion that they could survive long-term on land as "wishful thinking." Ice-free conditions are likely to draw in other competitors—zooplankton

marine ecosystem as we know it now will no longer exist.'



The piece of ice at right froze fast on a cold, calm night; polarized light shining through the thin section reveals tightly packed columns of crystals. Algae bloom under Arctic ice and often inside it, in channels of trapped brine. The algae are grazed by small crustaceans like the amphipod *Eusirus holmi* (left), which are in turn eaten by fish. The ice supports a food web that reaches up to seals and polar bears.

PETER LEOPOLD, NORWEGIAN POLAR INSTITUTE (LEFT)

(maybe less fatty and nutritious ones), fish, seals—from more temperate waters.

Ice loss is also making the Arctic even more vulnerable to ocean acidification, another effect of rising atmospheric carbon dioxide. Cold water absorbs more CO_2 than warm water does, and more cold water is now open to the air. As the water acidifies, it loses carbonate. Within the next 15 years it may no longer contain enough for animals such as sea snails and Alaska king crabs to construct and maintain their calcium-carbonate shells.

The upshot of all this, as Stirling bluntly puts it: "The Arctic marine ecosystem as we know it now will no longer exist."

WARMER AIR ABOVE THE OCEAN basin is projected to spill down over the surrounding coasts of Russia, Alaska, and Canada, causing feedback effects as far as 900 miles inland, including accelerated melting of the Greenland ice sheet and large emissions of carbon dioxide and methane from thawing tundra. IPCC models forecast that the total loss of summer sea ice may in itself cause one-third of the warming of the Northern Hemisphere and 14 percent of total global warming by the end of the century.

How a rapidly warming Arctic will influence weather across the hemisphere is a bit hazier. Atmospheric scientists Jennifer Francis at Rutgers University and Steve Vavrus at the University of Wisconsin have suggested that people in the continental United States already may be feeling the effects of melting Arctic sea ice—especially in the past two winters in the east, which made "polar vortex" household words.

The polar vortex is the mass of cold air that's normally confined over the Pole by the polar jet stream—the high-altitude, fast-moving torrent of air that snakes around the Pole from west to east. The jet stream draws most of its energy from the contrast in temperature and pressure between the frigid air to its north and the warmer air to the south. As sea-ice loss amplifies the warming in the Arctic, the Francis theory goes, that contrast is reduced, weakening the jet stream's westerly winds. It becomes a lazier, more sinuous river, with large meanders that extend far to the south and north. Because the meanders advance slowly across the map,

In late April biologists Piotr Kukliński, Pedro Duarte, and Haakon Hop (left to right) prepare to dive through a hole in the ice, into a world just being awakened by the spring sun.

PETER LEOPOLD, NORWEGIAN POLAR INSTITUTE

whatever weather they enfold persists for a long time. During the past two winters the wavier pattern allowed Arctic air and extreme snow to beset New England and drought to linger over California. The melting Arctic may be affecting weather elsewhere too. Korean researchers have linked extreme winters in East Asia to air-circulation changes caused specifically by ice loss in the Barents-Kara Sea.

It's a neat theory, but parts of it remain "fuzzy," Francis admits. Also, many researchers who study atmospheric dynamics aren't buying it. A more plausible explanation for the wavier jet stream and the southward excursions of the polar vortex, some of them argue, is the influence of the tropical Pacific, which is a far more powerful source of heat than the Arctic. It will take years of data gathering and modeling to settle the debate.

In any case, as the warming of the planet continues, cold spells of any kind will become less common. Even if sharp limits on greenhouse gas emissions are adopted over the next 20 years, the decline of sea ice will continue for decades. "We're on a one-way trip and not going back," says Overland. A further rise of 4 degrees Celsius (7.2 degrees Fahrenheit) in the Arctic is all but assured by mid-century, he says, enough to keep the ocean ice free for at least two months of the year, enough to change the seasons there—"enough to affect everything."

IN LATE JUNE, during the final phase of their expedition, the scientists aboard the *Lance*

In a fracture behind the *Lance,* water vapor meets chill air and freezes to "sea smoke." As dark water replaces ice, the Arctic Ocean absorbs more heat in summer and releases more in fall and winter—perhaps affecting weather elsewhere.

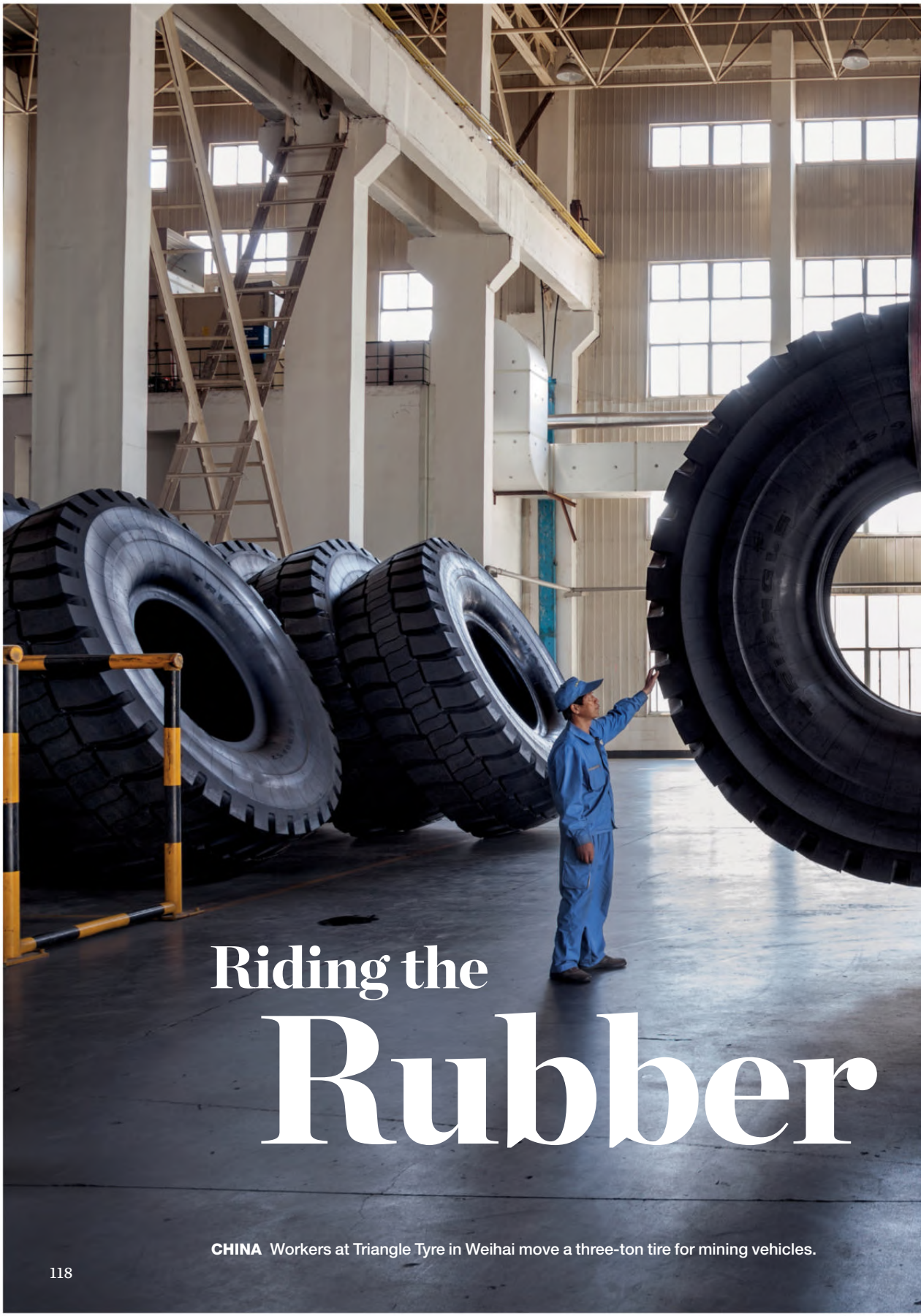
awoke to discover that the latest ice floe they'd attached to was disintegrating too. They scrambled to salvage their gear before it became flotsam. It was time to pack up anyway. The vessel by that point had spent 111 days in the ice, tethered to different floes for several weeks at a time—logging altogether some 4,000 nautical miles across the Arctic. Polar bears had crossed its path, sometimes pausing to play with the scientists' strange-looking electronic instruments. Storms had bulldozed huge blocks of ice high against the ship, elevating it above the surface. The *Lance*'s crew had bested the researchers in a soccer match on the floe. Over the next couple of years the 68 scientists involved will be hunkered in their warm labs, making sense of all the data they gathered.

One morning in March, under a dusky blue sky, I had joined Gunnar Spreen and another NPI researcher, Anja Rösel, on one of their periodic forays to measure changes in the ice floe's thickness. We each wore insulated armor—jumpsuit, balaclava, goggles, gloves, mittens over the gloves. The scientists brought along a snow-depth probe, a GPS device, and an orange plastic sled carrying the ice-thickness instrument, which works by inducing an electric current in the seawater below. I carried a flare gun and a .30-06-caliber rifle: bear protection. Following a mile-long path staked by bamboo poles, we trudged over dunelike snowdrifts and pressure ridges—slabs of sea ice pushed up by colliding floes—that looked like crumbling stone walls. Every few feet Spreen stopped and plunged the depth gauge into the snowpack until it beeped to indicate that the measurement was complete.

Arctic warming seemed an abstract concept that day—I couldn't really feel my toes—but across the icescape, Spreen saw evidence of change. "This is an unusual amount of snow," he noted. Two feet of it lay beneath our moon boots, twice the amount in a typical year. One data point doesn't make a trend, but this one was consistent with model forecasts: As sea ice shrinks, the extra heat and water vapor released from the open water into the lower atmosphere should generate more precipitation.

More snow falling on a glacier on land would be a good thing, because that's how glaciers grow—by accumulating layers of snow so thick that the stuff at the bottom gets compressed into ice. But sea ice forms when cold air freezes seawater, and snow falling on top of it acts as an insulating blanket that slows the growth of the ice. As it happened, two weeks after my walk with Spreen, the National Snow and Ice Data Center in Colorado announced that Arctic sea ice had already reached its maximum extent for the winter in late February—much earlier than usual. It was the lowest maximum the satellites had ever recorded. ▯

The drastic shrinking of Arctic sea ice led to big changes in the tenth edition of National Geographic's **Atlas of the World,** published in 2015. The first edition of the atlas was published in 1963.



Riding the Rubber

CHINA Workers at Triangle Tyre in Weihai move a three-ton tire for mining vehicles.

Boom

As global car sales soar, the demand for tires is transforming Southeast Asia's landscape. New plantations of rubber trees are lifting some out of poverty—but may also spark an ecological disaster.

CHINA Because rubber sap flows best at night, tappers in Xishuangbanna use headlamps to light the trees while they work, as shown in this time exposure. The latex drips into cups from incisions in the bark. A typical tree produces a few ounces' worth of rubber a day.

By Charles C. Mann
Photographs by Richard Barnes

CHINA Workers pour raw latex into tanks for processing in Xishuangbanna's Nabanhe National Nature Reserve, an innovative park that tries to protect the forest while allowing its inhabitants to tap rubber.

Sometimes you just want to spend a few hours washing your truck. It's a beautiful day, all of northern Thailand vibrant in the spring sun, so you drive your new Isuzu into the stream that runs through your village, Tung Nha Noi. Cows and people walk by as you stand in the water, a 21-year-old guy with a hot ride, sponging it so clean that the vehicle gleams like hope in the sun.

Not so long ago the chances that someone like Piyawot Anurakbranpot—"Chin" to his friends—would have a fancy truck at such a young age would have been close to zero. People in remote villages like Tung Nha Noi didn't have the money. But recently families like Chin's have become much more prosperous. The reason is visible in the hills behind him. Ten years ago they were covered with dense tropical forest—a profuse tangle of native vegetation. Now most of the slopes have been shaved as clean as a drill instructor's chin and replanted with a single species: *Hevea brasiliensis,* the Pará rubber tree. Night after night, Chin's family and tens of thousands of others in Southeast Asia go into plantations and tap their rubber trees, maple-syrup style. Thick white latex drips into buckets. The goo is coagulated into solids that are pressed into sheets and transported to factories, where they are processed into O-rings,

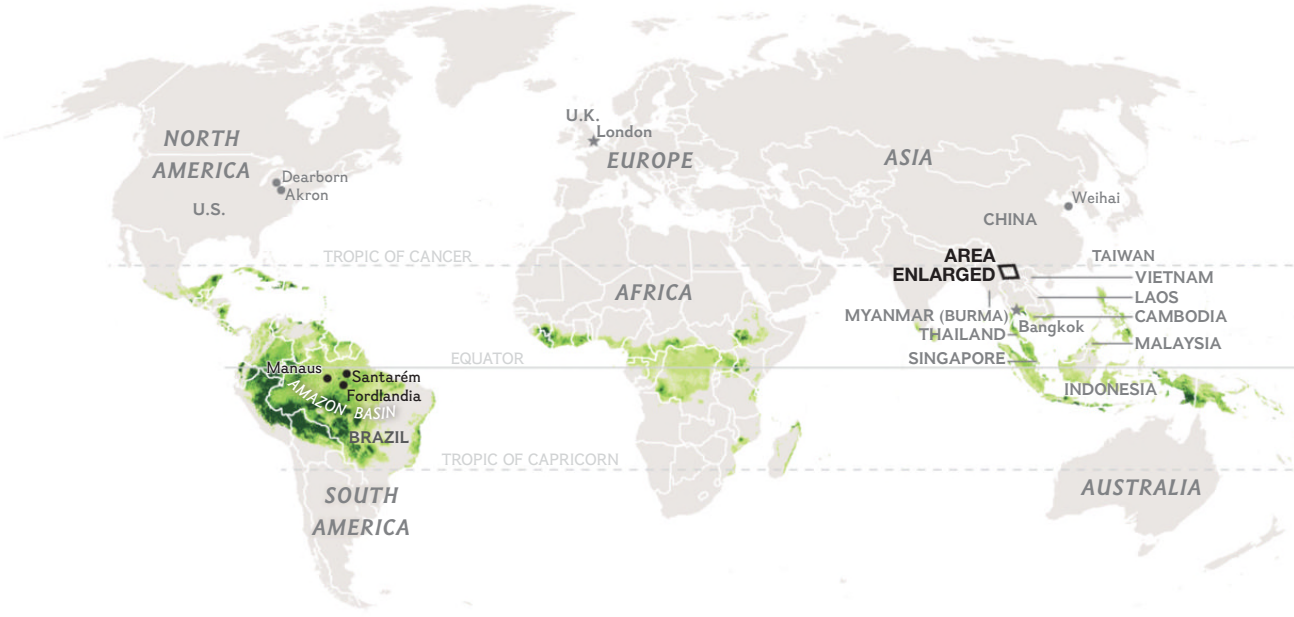
belts, gaskets, insulation, and tires—lots and lots of tires. About three-quarters of the world's rubber harvest goes to make automobile, truck, and airplane tires—almost two billion a year.

Because rubber is so common, so unobtrusive, so *dull,* it may not seem worth a second glance. This would be a mistake. Rubber has played a largely hidden role in global political and environmental history for more than 150 years. You say you want an industrial revolution? If so, you need three raw materials: iron, to make steel for machinery; fossil fuels, to power that machinery; and rubber, to connect and protect all the moving parts. Try running an automobile without a fan belt or a radiator hose; very bad things will happen within a minute. Want to send coolant around an engine using a rigid metal tube instead of a flexible rubber hose? Good luck keeping it from vibrating to pieces. Having enough steel and coal to make and drive industrial machinery means nothing if the engines fry because you can't cool them.

To the extent that most people think about rubber at all, they likely picture a product made from synthetic chemicals. In fact, more than 40 percent of the world's rubber comes from trees, almost all of them *H. brasiliensis.* Compared with natural rubber, synthetic rubber is usually cheaper to produce but is weaker, less flexible, and less able to withstand vibration. For things

Rubber's Reach

Native to South America, rubber trees thrive in warm, rainy climates, particularly around the Equator. New varieties bred to tolerate more extreme climates are allowing large-scale cultivation throughout Asia.



Historical suitability*

Low — Very High

Unsuitable

*REGIONS WHERE RUBBER WOULD NATURALLY OCCUR

THE AMERICAS

3% Competition from Asia and leaf blight epidemics caused by dense planting ravaged natural rubber production where trees were native.

AFRICA

5% Africa has areas that are well suited for growing rubber, but it lacks key infrastructure, such as roads and electricity, in many places.

ASIA

92% Widespread land conversion in areas prone to frost and water shortages is the result of a boom that may not be sustainable.

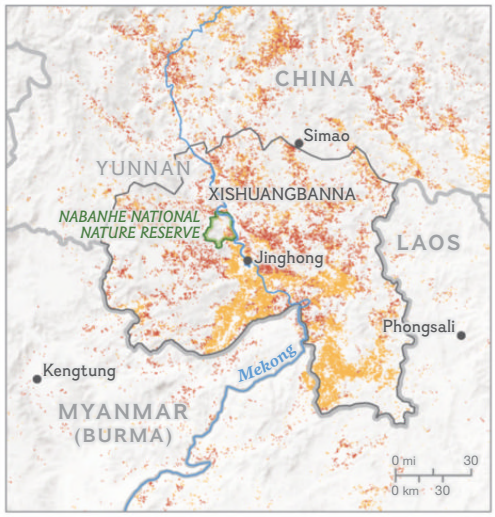
2014 PRODUCTION PERCENTAGES

that absolutely cannot fail, from condoms to surgeon's gloves to airplane tires, natural rubber has long been the top choice.

Iron can be found around the globe; so can fossil fuels. But rubber today is grown almost exclusively in Southeast Asia, because the region has a unique combination of suitable climate and infrastructure. Despite all the ups and downs in the global economy, the demand for tires continues to grow, which has created something akin to a gold rush in Southeast Asia. For millions of people in this poor part of the world, the rubber boom has helped bring prosperity; Chin does not have the only new pickup in Tung Nha Noi. And rubber has helped end the region's isolation. Brand-new "rubber highways"—the last finished in 2013—now connect previously remote plantations in Southeast Asia to tire factories in northern China.

But the consequences of the rubber trade are not purely economic. Southeast Asia's legions of Chins have set off what Jefferson Fox of the East-West Center in Hawaii calls "one of the biggest, fastest ecological transformations in human history." In China, Vietnam, Laos, Thailand, Cambodia, and Myanmar rubber farmers have cut or burned down forests and planted row after row after row of *H. brasiliensis.* In the process, they are converting one of the world's most diverse ecosystems into a monoculture as uniform as a Kansas wheat field, potentially threatening the basic ecological functions of an area inhabited by tens of millions of people. Each of the five tires on Chin's truck—one on each wheel plus a spare—is like a small patch of tropical forest, stripped and compressed into a glossy black ring. So is every tire on my car and yours.

LAUREN C. TIERNEY AND KELSEY NOWAKOWSKI, NGM STAFF. SOURCES: ANTJE AHRENDS AND OTHERS, *GLOBAL ENVIRONMENTAL CHANGE,* 2015; BIRDLIFE INTERNATIONAL



Rubber plantations in 2010, derived from satellite imagery
More than four years old Less than four years old

RISKY HABITAT

Rubber production in Southeast Asia has increased dramatically along with global car production. New plantations are popping up in regions ill suited for rubber—a trend that threatens livelihoods when crops fail. It also harms biodiversity when vital ecosystems, including natural forests, are cleared to make way for the thirsty cash crop.

MONOCULTURES ARE intensely productive—and intensely vulnerable. Just ask Henry Ford. Giant among industrialists, control freak extraordinaire, brilliant but possibly illiterate, Ford ran his own iron and coal mines, built his own power plants, logged his own timberlands. His River Rouge factory complex in Dearborn, Michigan, had a deepwater port, a steel foundry (the world's biggest at the time), and a hundred miles of interior railroad. Every type of material needed to manufacture automobiles was made at River Rouge save one: rubber. In 1927 Ford acquired nearly 4,000 square miles in the Amazon Basin, original home of *H. brasiliensis*.

Native peoples had used rubber for centuries to waterproof their clothing and make rough rubber boots. By the early 19th century North Americans were buying rubber from their southern neighbors to make boots and coats of their own. But these early rubber creations melted in the summer heat and lost their flexibility in the cold. Only in the 1840s, after the amateur U.S. inventor Charles Goodyear discovered how to stabilize rubber, did it become suitable for widespread use. Goodyear's discovery was called vulcanization. It opened the floodgates for a stream of inventions.

Realizing that rubber had been transformed from a curiosity into a valuable commodity, explorers went into the Amazon forest in search of the latex-bearing trees. Boomtowns sprang up, Manaus the most remarkable. In this Brazilian city encircled by vast forest, rubber barons threw up huge mansions, paraded their bejeweled mistresses, and built an ornate opera house of imported Italian marble.

European and North American governments didn't like depending on a commodity controlled by a nation that was out of their political control. Officials at England's Kew Gardens went looking for someone they could pay to bring rubber seeds out of the Amazon. Enter Henry Alexander Wickham, a man loathed in Brazil to this day.

Born in 1846, Wickham was an entrepreneur whose ambitions were as great as his inability to achieve them. In the 1870s he and his wife were struggling to establish a tobacco and sugar plantation in the lower Amazon town of Santarém. After being contacted by Kew Gardens, Wickham gathered three-quarters of a ton of rubber tree seeds, which he loaded onto a London-bound ship. British authorities were appalled when he showed up demanding payment for every one of his 70,000 seeds. Yet sprouts from the seeds eventually were transported to British, French, and Dutch colonies in Asia. Would-be rubber kings fanned out into the equatorial forest, axes flashing, torches flaring. By 1910 more than 50 million South American trees were growing in Asia. The following year, as Asian rubber flooded the market, prices in Brazil collapsed. To the nation's shock and fury, its hugely profitable rubber industry imploded within months.

In the following *(Continued on page 132)*

LAOS Farmers clear forest to grow rubber on land opened by a new road connecting plantations with tire factories in China. Ecologists fear that the destruction, and the trees' need for lots of water, will degrade ecosystems across Southeast Asia.


ISUZU
UW 5040

THAILAND Wading in the village stream, Piyawot "Chin" Anurakbranpot washes his new pickup—a symbol of the prosperity and consumer culture that the rubber industry has brought to parts of Southeast Asia once best known for opium poppies.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ESCOLAR

Brazil's Boom and Bust

Sun gleams on the wreck of Fordlandia's power plant (opposite, bottom) on the Tapajós River, in the lower Amazon Basin. Built by Henry Ford at great cost in the 1930s, Fordlandia was intended to be the world's biggest rubber plantation. Instead it was a catastrophe. Alienating his workers, the carmaker insisted that his Brazilian employees live on-site in U.S.-style bungalows, eat U.S.-style oatmeal, wheat bread, and canned peaches in the company cafeteria, attend U.S.-style square dances—and never drink alcohol. But his worst error was failing to hire a rubber botanist. If he'd hired one, he might have learned that the land (below, in 1931) was unsuitable for rubber—and that growing the trees close together made them vulnerable to South American leaf blight (above, an infected leaf). Ford dumped the property in 1945. Today the Rocha family (opposite, top), descendants of original workers, live nearby in a house originally built for U.S. managers.

THE HENRY FORD (ABOVE)

decades Southeast Asia became the hotbed of rubber production, as *H. brasiliensis* spread across much of what is now Malaysia, Indonesia, and the southern parts of Thailand, Cambodia, Vietnam, and Myanmar. Plantation owners, suddenly wealthy, snapped up real estate in Singapore. The ever itinerant Wickham, lionized as the creator of the new industry, took to wearing a nautilus-shell tie clasp, a waistcoat fastened with silver chains, and a luxuriantly curled mustache that hung below his jaw like a flowering tropical vine.

Wickham died in 1928, a year after Henry Ford obtained his land on the Tapajós River, in the lower Amazon Basin. Detesting his dependence on Asian rubber, Ford had decided to create his own supply. Thousands of workers hacked out a new, midwestern-style city from the rain forest, stocking it with rows of clapboard bungalows, Baptist churches, and a Main Street with American bakeries, restaurants, tailors, cobblers, and movie theaters. Fordlandia, as the project was quickly nicknamed, had the only 18-hole golf course in the Amazon. The scale was grandiose: The city was big enough to house several hundred thousand people. All told, Ford spent about $20 million to build it, close to $300 million in today's money.

The project was that rarest of events, an unqualified disaster. Incredibly, the company laid out a rubber plantation half the size of New Jersey without consulting a single person who knew anything about growing *H. brasiliensis*. For starters, the property was unsuitable for large-scale rubber cultivation. The soil was too sandy and the rainfall too seasonal. If a botanist had been on-site, Ford might have learned that there is a good reason that rubber trees are never found clustered together in the wild: They are too vulnerable to attack by South American leaf blight.

Microcyclus ulei, as biologists call it, looks at rubber trees the way ant armies look at frogs: as lunch. The fungus "doesn't kill trees straight out," historian Greg Grandin explains in his book *Fordlandia*. Instead its spores tunnel into leaves, consuming their nutrients until they fall off. When the leaves regrow, the fungus attacks again; the trees, Grandin writes, "grow successively weaker, either producing dwarf shoots or dying back altogether."

The battle is silent, protracted, and for the tree, almost invariably fatal. In the wild *Microcyclus ulei* spores can't spread easily from one rubber tree to another because the trees are widely dispersed in the forest. On a plantation, trees are close to one another, like dishes at a buffet, letting the fungus hop easily between them, one plate to the next. In creating his rubber plantation, Ford had effectively spent huge sums to create an enormous fungus incubator.

In 1935 the inevitable occurred. Fordlandia's rubber trees were denuded in just a few months—an ecological cataclysm, an economic ruin. Ten years later Ford quietly unloaded the land for pennies on the dollar. In the seven decades since, every attempt to create a rubber plantation in Central or South America has failed. In the end, the fungus always won.

AS YOU DRIVE INTO the outskirts of So Phisai, Thailand, the air smells like a nail salon. The smell is from formic acid, the chemical used to coagulate latex from rubber trees. You see new roofs with satellite dishes on almost every home. The smell of formic acid is also the smell of money.

Many of the people in So Phisai want, in effect, to be Sommai Kaewmanee. The son of landless migrants, he borrowed money in 1992 to plant the town's first rubber trees. At that time, he told me, everyone in So Phisai grew cassava, barely eking out an income. Young adults had to move to Bangkok to find decent jobs. Kaewmanee borrowed money to put about 1,500 trees on eight acres and persuaded three other farmers to join him, promising that people who planted rubber would become millionaires. (Most of them got pretty close, he told me.)

During my visit Kaewmanee showed me the books from his growing business. If the figures had been plotted on a graph, they would have mirrored those for global automobile sales: a wiggly but inexorable march upward. Rubber riches, slowly accumulating, bought him

a new home and a spiffy 4x4 vehicle and the portable electronic gadgets that his kids, home from school, were staring into. Kaewmanee had become the agricultural supervisor for his subdistrict, where 90 percent of the farmers grow *H. brasiliensis.* He now has about 75,000 trees. His nursery sells a million seedlings a year. Forestland is still available around So Phisai, he said, ready to be turned into tires.

Kaewmanee didn't know it, but his home and car were made possible by Chinese scientists. When rubber first came to Southeast Asia, it could grow only in the warm and wet equatorial forests of what is now Indonesia, Malaysia, and the southern tips of Thailand, Cambodia, Vietnam, and Myanmar—places that mirrored rubber's Amazonian home.

During the Korean War the United States imposed rubber sanctions on China. Furious, China developed varieties of *H. brasiliensis* that could grow in the relatively cool district of Xishuangbanna in Yunnan Province, on the border with Laos and Myanmar. Xishuangbanna represents just 0.2 percent of China's land area, but it houses many of China's species:16 percent of its plants, 22 percent of its animals, and 36 percent of its birds. All are now threatened by rubber. Armed with the new, cold-tolerant trees, the Chinese military established state-run plantations there. Small farmers later filled in most of the land that was left. Today you can stand on a hilltop in Xishuangbanna and see nothing but rubber trees in every direction.

It typically takes a month's worth of latex from four trees to make just one tire. Xishuangbanna isn't nearly big enough to satisfy Asia's demand. Promoted with state programs, sought after by Chinese corporations, *H. brasiliensis* has spread through Laos, Myanmar, Thailand, and Vietnam like suburban sprawl, replacing swaths of native forest along the way. Global natural-rubber production has jumped from 4.4 million tons in 1983 to more than 13 million tons today.

To grow that extra rubber, Southeast Asian farmers have cleared about 18,000 square miles, an area about the size of Massachusetts and Vermont put together. And that figure doesn't include the forest logged for new processing facilities, the new homes built in the forest for new rubber workers, or the roads cut to reach the new plantations.

A single errant spore of South American leaf blight reaching Southeast Asia could bring the automobile age to a screeching halt.

All that production—combined with a decline in demand—has made rubber prices fall in the past few years, but nobody expects the growth to stop. The boom means that a random visitor like me can drive around northern Laos at night and see fires in the hills—set by families burning patches of forest to make room for new plantings. It means teenage Thai boys drive by on motorcycles groaning beneath a half dozen garbage bags full of homemade balls of coagulated latex. It means entire farming villages that get up at two in the morning to tap rubber trees, because latex flows best before dawn.

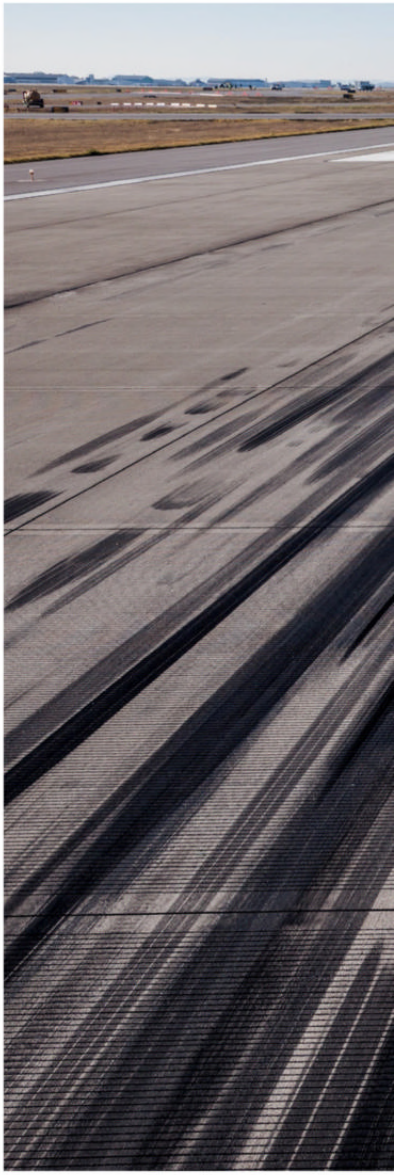
The ecological threat posed by the rubber boom goes beyond the loss of biodiversity. The rubber trees on these new plantations are descendants of the seeds that Henry Wickham spirited out of Brazil. As Henry Ford learned the hard way, they are terribly susceptible to blight. By the 1980s scientists were cautioning that a single errant spore of South American leaf blight reaching Southeast Asia could bring the automobile age to a screeching halt. "The potential of an economic disaster increases with every transcontinental flight landing in Southeast Asia," two researchers at Florida

U.S. Tubes of extruded latex wait to be cut into rubber bands at the Keener Rubber Company near Akron, Ohio. The factory is a remnant of the region's days as the "rubber capital of the world"—it once housed the four biggest tire firms on the planet.

A&M University, warned in 2012. A UN Food and Agriculture Organization report the previous year recommended that all air passengers bound for Southeast Asia who have been in South America's blight zone within the previous three weeks should be inspected. No such program has been enacted. Although scientists in Brazil have found and begun testing resistant varieties of rubber trees, no Asian breeding program for blight resistance has been established. In four visits to Southeast Asia I didn't encounter a single rubber farmer who was considering resistant varieties.

Even ecologists have devoted little attention to the threat. Instead they focus on "more immediate issues," says Xu Jianchu, of China's Kunming Institute of Botany, about 200 miles northeast of Xishuangbanna. Rubber tappers, working at night, fear encountering snakes in the dark, so they drench the hills with herbicides to wipe out snake-hiding ground cover. Species that depend on the destroyed plants quickly succumb too—a further loss of biodiversity. Rain erodes the exposed earth, threatening the soil.

Perhaps most serious, rubber trees consume a lot of water in the process of making latex. Producing tires is like taking groundwater from the hills and putting it on trucks for export. As a consequence, Xu says, highland wells and rivers are drying up. The industry response has been that "people can get water in plastic bottles," he says, with a grimace. Soon rubber will cover most of Southeast Asia. The problems will spread from China to much of Southeast Asia. "Unless governments step in, it will not stop."



U.S. Arriving jets leave traces of rubber at Nashville International Airport. Because they must not fail, airplane tires are usually made with natural rubber, which is stronger, more flexible, and better able to withstand vibration than synthetic rubber.

ON A FOGGY and distinctly cool day I drove to the Nabanhe National Nature Reserve in Xishuangbanna. With me were the reserve's research director, Liu Feng, and Gerhard Langenberger, an agroecologist at Germany's University of Hohenheim. The landscape switched back and forth between plantation and wildland in a way that reminded me, to my surprise, of the patchwork of fields and forest around my New England home. We were going to the reserve because Liu and Langenberger think it hints at how rubber could coexist with a natural ecosystem.

Unlike most nature reserves, Nabanhe is full of people. Its one hundred square miles include 33 small villages, with a total population of about 6,000. The land is divided into three zones. In the core, no human activity is allowed, as in a classic wilderness park. Surrounding that is a buffer zone, where people can live but are allowed only limited use of resources. And surrounding that is an experimental zone, where people can farm—that is, plant and tap rubber.

The balance is difficult to maintain, Liu said. That afternoon we saw villagers ripping out illegal rubber plants. The malefactors had been

turned in by their neighbors. Forestry police watched as the plants were dragged away. A few hours later we met some of the police for drinks and food in a kind of mountain saloon. One told me the villagers' punishment hadn't been severe—he just wanted them to be mindful of the rules.

Langenberger believes that scientists should provide the facts and then let locals decide how to manage the landscape. "I don't blame the farmers," he said. "They've been poor here for so long. Now they have a crop that lets them participate in the world market." Scientists can't—and shouldn't—"tell them to stop growing rubber," he said. The logic of conservation is to forbid all human activity in the name of preserving vital rain forest. The logic of industry is to cover every scrap of land with rubber trees. Langenberger hopes it might be possible to create a state of productive tension. The Nabanhe Reserve, he hopes, could help show the way, a small effort to make things work in this tiny corner of the interconnected world. □

MICHAEL LIONSTAR, VINTAGE

Charles C. Mann is a frequent contributor to the magazine. He's the author of *1491,* winner of the National Academies of Sciences' Keck award for best book of the year, and the best-selling *1493.*

Kingdom of Girls

By **JEREMY BERLIN**
Photographs by **KAROLIN KLÜPPEL**

In the lush jungles of northeastern India, hard against the Bangladesh border, is a tiny village with an unconventional social order. Mawlynnong is where about 500 members of the indigenous Khasi tribe still follow ancient matrilineal traditions. Where succession, money, property, and power pass from mother to daughter. Where girls—literally—rule their roosts.

Karolin Klüppel wanted to see this inverted world for herself. So for nine months spanning two years, the Berlin-based photographer lived with different Khasi families in the "unbelievably clean, calm, and peaceful" village. What she found was a culture in which youngest daughters (called *khadduh*) inherit wealth and property, husbands move into their wives' homes, and children take their mother's surname.

Girls go to school in the village until they're teens, though some move to the state capital at 11 or 12 for further education. After that they attend college or return to Mawlynnong, where they care for their parents. They may marry whomever they choose; there is no stigma attached to divorce or opting to stay single. But not having daughters can cause despair. Only girls can ensure continuity, so families without them are called *ïap-duh,* or "extinct," says North-Eastern Hill University anthropologist Valentina Pakyntein.

Such customs, she adds, have existed "for time immemorial." They may go back to when Khasis had multiple partners, which made it hard to determine paternity. Or to when male ancestors, off fighting wars, couldn't care for their clans or families.

Today men lead Mawlynnong's village council, but they rarely own property. Klüppel says some, upset by their second-class status, are calling for gender equality. But mostly she was struck by "the respect that Khasi men have for women," which is at the heart of this photo series. "I want everyone to know about cultures that are different from the patriarchal world we live in—and I want people to question that system." ▯

To make Khasi tradition visible, Klüppel "created portraits as a reference or allusion to the girls' surroundings and culture." That means a fish-drying device could be a necklace for Grace Tangsong, seven.

Anisha Nongrum, seven, wears a headdress of areca seeds, used in a chew called *kwai* (left). Ibapyntngen Khongjee, eight, hides in a mosquito net. Klüppel says these "powerful, self-assured" girls must often act responsibly. But "in their free time, they're children who jump in rivers, catch fish, run, scream, and get dirty."

The eldest of three siblings, Phida Nongrum, nine, plays with a balloon in her bedroom (above). One day her sister Anisha will be head of their household. Beslinda Khongdup, 12, reaches down to grasp cow legs, which Khasis sometimes use in soup. Most Indians are Hindu, but the villagers in Mawlynnong are Christians and therefore may eat beef.

Photography That Layers Time

For years photographer Stephen Wilkes dreamed of "compressing the best parts of a day and night into a single photograph." Now that digital imaging technology has caught up to his imagination, Wilkes is able to shoot thousands of images and meld them into time-spanning panoramas.

To make images like those on pages 32-45, Wilkes selects a vista, sets up his camera and computer gear, and establishes a fixed camera angle. After researching sun directions, moon phases, weather, and more, he chooses an hour to start; in Yosemite it was 3 a.m., when the full moon would light El Capitan's face. He then continuously shoots images through day and night, in whatever conditions nature gives him. "I have zero control," he says, "until the end of the process, when I have complete control."

Wilkes takes weeks to edit down the thousands of photos from a shoot to what he considers "the 50 best moments." He decides on the image's "time vector"—where in the image the day-night cycle will begin, and which way time will proceed: top to bottom, left to right. Then he digitally blends the photos to layer parts of some on parts of others, making a seamless composite image.

The Yosemite panorama, when read diagonally from the upper left-hand corner, proceeds from 3 a.m. one day to near dawn the next day. Along with spectacular scenery, most of Wilkes's images feature what he calls "the magical moments: People doing all the joyful things that people do to celebrate being in an extraordinary place." *—Patricia Edmonds*

Shots of the famous Half Dome from morning through midday captured the sunlight moving across it.

When winds briefly died down over Bridalveil Fall, a rainbow formed long enough to appear in just three frames.

Extremely sharp focus brings out details such as lights on El Capitan's face from climbers' suspended tents.

To craft "the human narrative," Wilkes shows visitors at all times of day. Here, a man tosses a child in the air.

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NATIONAL GEOGRAPHIC (ISSN 0027-9358) PUBLISHED MONTHLY BY THE NATIONAL GEOGRAPHIC SOCIETY, 1145 17TH ST. NW, WASHINGTON, DC 20036. ONE YEAR MEMBERSHIP: $39.00 U.S. DELIVERY, $44.00 TO CANADA, $51.00 TO INTERNATIONAL ADDRESSES. SINGLE ISSUE: $7.00 U.S. DELIVERY, $10.00 CANADA, $15.00 INTERNATIONAL. (ALL PRICES IN U.S. FUNDS; INCLUDES SHIPPING AND HANDLING.) PERIODICALS POSTAGE PAID AT WASHINGTON, DC, AND ADDITIONAL MAILING OFFICES. POSTMASTER: SEND ADDRESS CHANGES TO NATIONAL GEOGRAPHIC, P.O. BOX 62130, TAMPA, FL 33662. IN CANADA, AGREEMENT NUMBER 40063649, RETURN UNDELIVERABLE ADDRESSES TO NATIONAL GEOGRAPHIC, P.O. BOX 4412, STN. A, TORONTO, ONTARIO M5W 3W2. UNITED KINGDOM NEWSSTAND PRICE £5.99. REPR. EN FRANCE: EMD FRANCE SA, BP 1029, 59011 LILLE CEDEX; TEL. 320.300.302; CPPAP 0715U89037; DIRECTEUR PUBLICATION: D. TASSINARI DIR. RESP. ITALY; RAPP IMD SRL, VIA G. DA VELATE 11, 20162 MILANO; AUT. TRIB. MI 258 26/5/84 POSTE ITALIANE SPA; SPED. ABB. POST. DL 353/2003 (CONV L.27/02/2004 N.46) ART 1 C. 1 DCB MILANO STAMPA QUAD/GRAPHICS, MARTINSBURG, WV 25401. MEMBERS: IF THE POSTAL SERVICE ALERTS US THAT YOUR MAGAZINE IS UNDELIVERABLE, WE HAVE NO FURTHER OBLIGATION UNLESS WE RECEIVE A CORRECTED ADDRESS WITHIN TWO YEARS.

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