

HOW WILL CHINA
FEED ITSELF?

WHAT MAKES
BIRDS SMART

A WILD UTOPIA:
THE FALKLANDS

NATIONAL GEOGRAPHIC

THE
NEW

BIG BROTHER

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society, satellites,
cameras, and phones
are tracking us
more than we
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On the Cover More than 1,700 satellites owned by government, academic, and private entities orbit above us. They gather images and other data, broadcast information, and monitor locations and communications.
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MAPPING THE MAYA WORLD

Though remnants of Maya cities rise imposingly from Central America's jungles (right), a great deal more of the ancient civilization has remained unexplored. Now researchers are changing that. They're employing aerial lidar sensing equipment to create a "treasure map" of the cities and landscapes that the Maya created. See the discoveries that are astounding archaeologists in *Lost Treasures of the Maya*, airing February 6 at 10/9c on National Geographic.



NAT GEO WILD

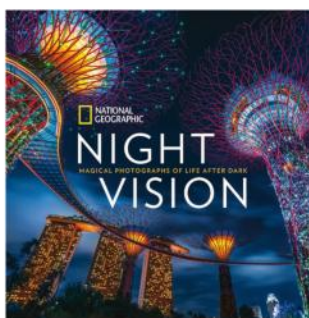
DOGS DOMINATE, FROM 'BARKFEST' TO WESTMINSTER SHOW

Nat Geo WILD's annual "BarkFest" returns February 9-16. Shows include *Road to Westminster Dog Show*, which follows a group of owners and dogs as they vie for the top prize in the 2018 Westminster Kennel Club Dog Show.

BOOKS

THE DARK BEAUTY OF NIGHT VISION

Revel in the beauty of the world after dark—starlit skies, glowing cities, nocturnal animals—with the new National Geographic photography collection *Night Vision*. Available where books are sold and at shopng.com/books.



BOOKS


JOURNEYS MADE FOR SWEETHEARTS

For intrepid couples who like adventure and culture on their getaways, *Ultimate Journeys for Two* is the ideal gift. This guide to hidden-gem destinations is available where books are sold and at shopng.com/books.

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| WHY CITIES ARE LEADING THE WAY

As New York City's mayor from 2002 to 2013, **Michael Bloomberg** pushed sustainability. Now 75, the businessman and philanthropist has co-authored a book, *Climate of Hope*, in which he says that "cities, businesses, and citizens can save the planet." Although I was an editor at Bloomberg News for several years, I hadn't talked in depth with its outspoken founder until we sat down for this interview.

Susan Goldberg: Roughly two-thirds of people will live in cities by 2050. There are 31 cities now that are considered megacities, with 10 million people or more; by 2030 there'll be 41 cities of that size. Why are people flocking to cities?
Michael Bloomberg: The marketplace is clearly saying this is where we want to be. Big cities provide culture; they can be much more cosmopolitan and give you a faster pace of life. It's not for everybody; some people want a different pace, and there's nothing wrong with that. I had the governor of Montana sitting right here yesterday—the whole population

of the state is about a million people. I mean, that's smaller than the Bronx! The beauty of the world is diversity. The beauty of America is basically we get along. There's lots of places in the world where diversity is not exactly tolerated.

SG: I have an off-the-wall question. Say your doctor tells you that you have developed life-threatening allergies to New York, London, and Boston, but your mental health is dependent on living in a big city. Where would you go?

MB: Well, one of the things to consider is suicide.



SG: No, no, no! That's not a good answer. *[Laughs.]*

MB: If I could speak Turkish, Istanbul. If I could speak Japanese, Tokyo. If I could speak German, Berlin. If I could speak French, I'd think about Paris, but Paris is a little bit small.

SG: What made you name those spots?

MB: Cosmopolitan cities. Istanbul really is. Tokyo is less so but exciting—there's just so much going on. In Berlin everything is open; if you're a prude, you shouldn't go there. But to me, New York has got everything you want. Far and away the best government job in the whole world—if you know how to use it—is the mayor of New York City. You have what is essentially a large army in the NYPD. You have a budget bigger than the GDP of most countries. Culture: There are great museums in London and Paris and a few other places, but New York can stand up with any of them.

SG: As people flock to cities, what happens to the people who are squeezed out by gentrification?

MB: I've always thought that culture attracts capital more than capital attracts culture. So if you want to bring Detroit back, you get young artists to move there and then people will follow them. Take a look at Greenwich Village; it used to be an artsy community, but no artist can afford to live there anymore. I'm sympathetic to people who get pushed out, and what I tried to do was build more housing and improve transportation to make this city better for everybody.

SG: What's an example of the kinds of things cities can do to become more environmentally friendly?

MB: The press made fun of me when I was on the flat roof of a five-story building with Al Gore and we painted the roof white. They had a field day—this bozo is doing this! But take a look next time you drive across the Queensboro Bridge or fly out of LaGuardia—every building roof is painted white now. And if one isn't, I guarantee it's an empty building.

SG: Why do you paint the roof white?

MB: Because it reflects the heat and reduces your electricity bill by 25 percent instantly. Forever. For the cost of two cans of paint. And they just laughed and made fun of Gore and myself, but the public isn't stupid.

SG: Are there other simple fixes that individuals can do?

MB: Sure. I can buy a more fuel-efficient car. I can convert my incandescent bulbs to LEDs. I can put some insulation in. I can turn off the air conditioner when I'm not home. There's a little bit of altruism—I want to save the world—but I think economics are really what drive these decisions.

SG: Talk about the role that cities' big employers play in the environment.

MB: Why will a corporation be environmentally friendly? Today, if you go and recruit on campus for the best and brightest, they interview you. They ask, What are you doing for the environment? Employees want to work for an environmentally friendly company. And then there are the investors. If you talk to the managers of the big pensions and endowments, they want socially responsible investing: We don't buy coal stocks, gun stocks, tobacco stocks.

SG: Who is making the biggest impact in creating sustainable cities?

MB: All this progress is not made by the federal government—not the last administration, certainly not this administration—and not made by the state governments. There are a handful that do a little bit; [California governor] Jerry Brown has tried to do some real things. But it's the local governments, the local companies, and the local nonprofits—that's where the progress is made.

Thank you for reading *National Geographic*.

Susan Goldberg, *Editor in Chief*

66%

of the world's population will live in an urban area by 2050.

41

cities will have more than 10 million inhabitants in 2030, up from 31 in 2016.

10
MILLION

people will be added to the population of Delhi, India, by 2030, for a total of more than 36 million.

| VISIONS

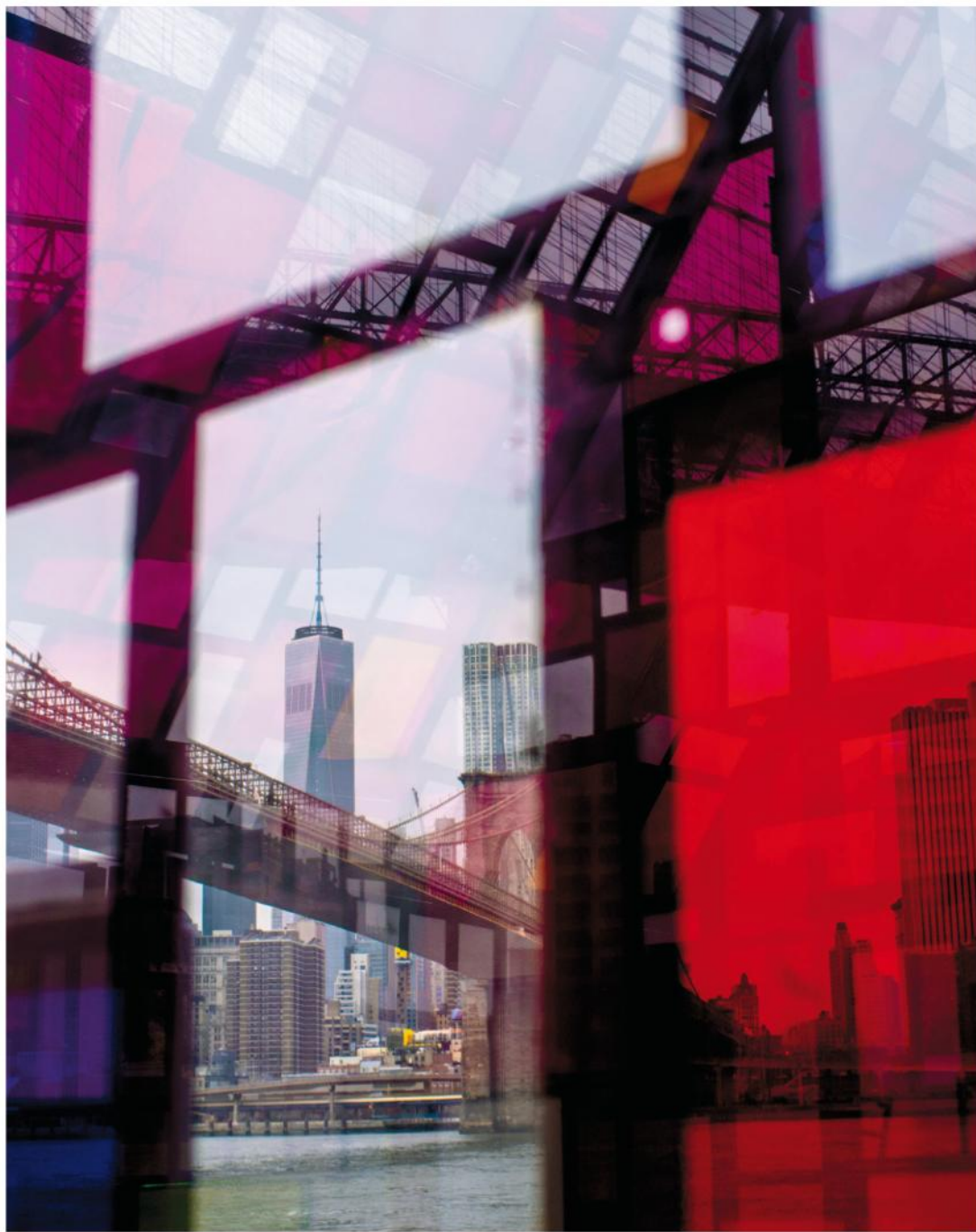




Hong Kong

Home to seven million people in just 426 square miles, Hong Kong is one of the world's most densely populated cities. A long exposure on a rainy day captures part of its skyline, reflected in a recreation area that had become soaked by a typhoon.

PHOTO: SPREEPHOTO/GETTY IMAGES



Dave Paek
Queens, New York

One day while walking in Brooklyn Bridge Park in an area known as Dumbo, Paek photographed Manhattan through a glass sculpture. He then forgot about the image. Several months later his wife remarked that he'd captured something special: an original view of a world-famous skyline.

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EXPLORE CITIES



HOW LIDAR CAN BE HELPFUL

BUILDING INTEGRITY

Tunneling under cities for subways or sewers can cause damage to overlying buildings. Evaluating building facades during excavation can help identify vulnerable parts of historic properties.

URBAN PLANNING

Where will shadows be cast? Will a street have too much wind for pedestrians to walk? Where is a flood likely to start? Developers can benefit from a detailed geometry of how a city lives and breathes.

DISABILITY ACCESS

A high curb or a single step into a restaurant may prevent access by people with limited mobility. Data collected can help inform new development or be used in a mobile app that suggests the best route.

TREE TRIMMING

A comprehensive map of a city's trees can identify which ones are likely to interfere with power lines and which should be trimmed ahead of storms that could knock them down on houses or cars.



BETTER THAN A BIRD'S-EYE VIEW

By Daniel Stone

Satellite images let us see Earth from above. But a technology closer to Earth can give us a much more detailed look.

Aerial “light detection and ranging,” also known as lidar (rhymes with eyedar), works by sending laser pulses from a plane, helicopter, or drone. The device then receives information back about the surfaces below.

In the past, the highest resolution for lidar was about 40 points per square yard. But a team of researchers at New York University has increased the resolution to 280 points per square yard, resulting in a view from above—especially in urban areas—that’s far more detailed than ever before and true to cracks, curbs, and building facades.

What’s wrong with traditional images from space or miniature scale models? Lidar produces not just an image but a high-resolution geometric representation of a city in motion. Slight slopes in pavement reveal how floodwater will move, and pockets of particulates can identify air pollution.

“Let’s say you worked in public health and you knew there was a high concentration of asthma in one neighborhood,” says NYU’s Debra Laefer, professor of urban informatics. You could start looking at corners where trucks idle, she says. Where is that pollution going? Can we change the vegetation on the roof, the water flow, which roads trucks use?

Collecting data from the air isn’t cheap. But a lidar scanner can be affixed to craft that fly for other purposes, such as police or paramedic helicopters. The team started with a scan of Dublin’s city center (pictured here). Future flights are possible for more cities—as is releasing the data to city planners, businesspeople, and anyone else who might serve a community.



HOW IT DIFFERS

Google Earth renderings (like the one of Dublin at left) use high-altitude imagery to create an approximation of the surfaces below. Lidar, by comparison, captures topography from much lower and provides precise data in space and time.



WELCOME TO TRADE CITY

By Catherine Zuckerman

Sure, that stuffed animal you just won at the fair was probably made in China. But where? There's a good chance that it came from Yiwu, which is about three hours south of Shanghai. Many of the world's cheap goods originate there—everything from holiday baubles and hair accessories to belts and toy bulldozers.

A relatively small city of 1.2 million residents, Yiwu has become an

important destination. In 1982 the municipality established Yiwu International Trade City. This sprawling wholesale market displays an endless variety of items throughout some 70,000 stalls, to dizzying effect.

Today buyers from all over come to examine samples of its million-plus products before placing bulk orders. "Each of these samples will be manufactured for an agreed price in a factory, usually close to Yiwu," says photographer Richard Seymour, who documented the site in 2014. Then the merchandise is loaded into shipping containers—more than 1,500 are filled daily—and sent across the world to be sold.

At the wholesale market known as Yiwu International Trade City in China, thousands of stalls—like this one packed with hats—display all manner of inexpensive goods, from plastic plants to beach balls.



OUR NUTTY NEIGHBORS

Squirrels aren't natural city slickers. In the mid-1800s the tree-dwelling rodents were released in America's urban areas to "create pockets of rural peace and calm," says University of Pennsylvania historian Etienne Benson, who studied our relationship to squirrels over the course of five years. The creatures became nuisances instead, and by the 1970s many parks prohibited feeding them. Today, says Benson, "people's experiences with squirrels depend on their real estate investments." —*Nina Strochlic*

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THE COLDEST CITY IN THE WORLD

By Patricia Edmonds

Earth's highest city, its most crowded city, its most polluted city: Geneva-based photographer Steeve Iuncker sought them out. For a project Iuncker calls *Villes Extrêmes*—Extreme Cities—he wanted to photograph ordinary life in cities that set extraordinary records or embody stark superlatives. That's how he ended up in Yakutsk, Russia.

The capital city of the vast (1.2 million square miles) Siberian region known as the Sakha Republic, Yakutsk is widely identified as the world's coldest city. "No other place on Earth experiences this temperature extreme," Iuncker says. Though temperatures during the

brief summer can exceed 85°F, winter temperatures regularly fall to -40°F, he says—and the lowest ever recorded was a staggering -83°F.

Among the extreme cities, this one was especially challenging to capture, Iuncker says: "Everything is ice, fog, and shadows" that obscure vistas and landmarks. When he braved the cold to step outside, frost instantly coated his camera, and its mechanisms froze to a halt.

Iuncker says his photo project explores this question: Do extreme environments trigger extreme emotions or behaviors in inhabitants? Not in Yakutsk, it seems. It's often too cold to break ground for construction or graves, too cold for airplanes to fly or crops to grow. Markets like the one seen here may not have fresh vegetables, Iuncker says—but they have very fresh, very cold fish "arranged like bunches of flowers."

Nearly 300,000 people live in Yakutsk, reputed to be the world's coldest city. Its port on Russia's Lena River is a source of the fish that fill markets—and stay rigidly cold in winter.



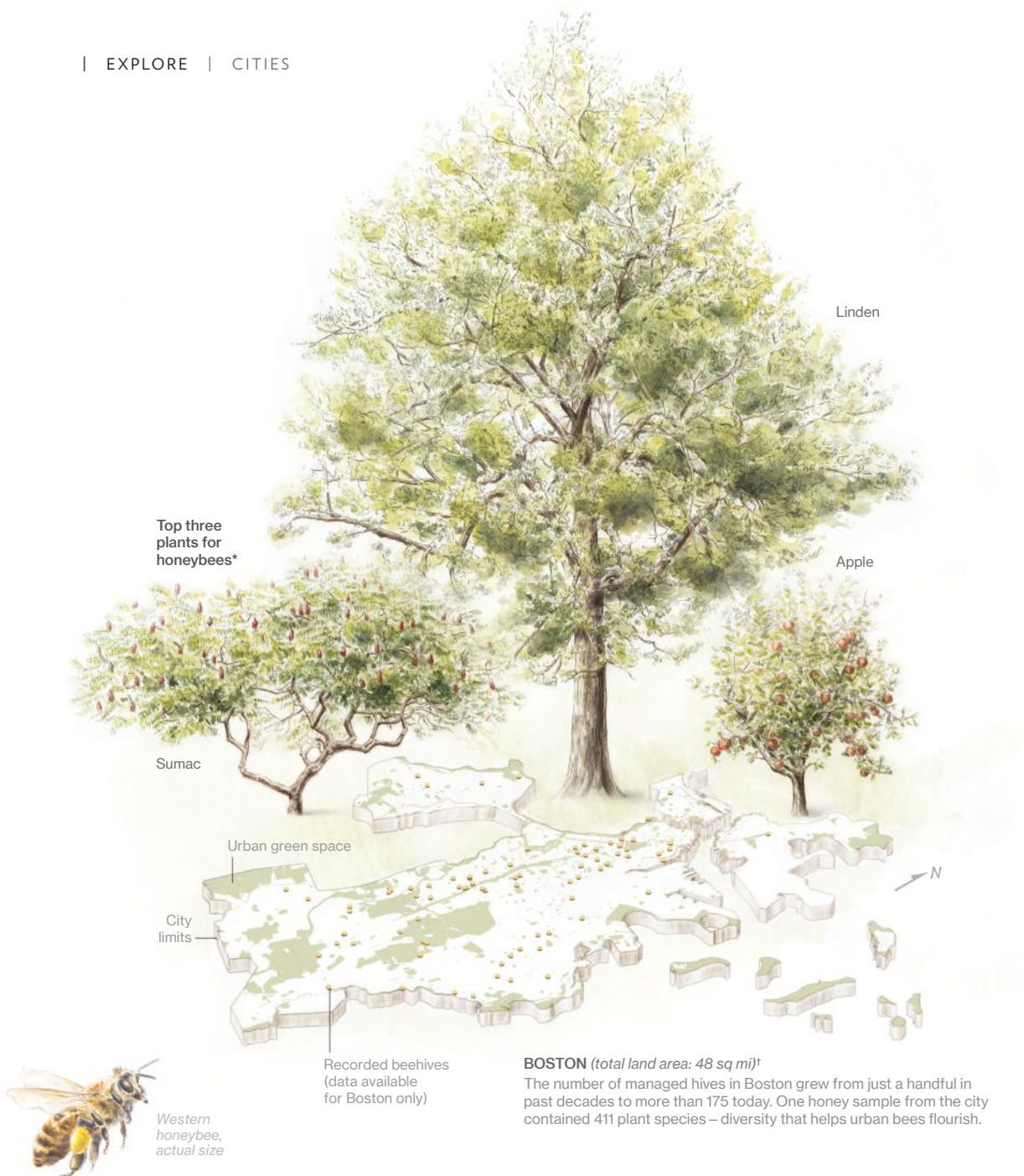
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Top three plants for honeybees*

Linden

Apple

Sumac

Urban green space

City limits

Recorded beehives
(data available
for Boston only)

BOSTON (total land area: 48 sq mi)*

The number of managed hives in Boston grew from just a handful in past decades to more than 175 today. One honey sample from the city contained 411 plant species—diversity that helps urban bees flourish.

Western
honeybee,
actual size

A DOLLOP OF SWEET SCIENCE

By Kelsey Nowakowski

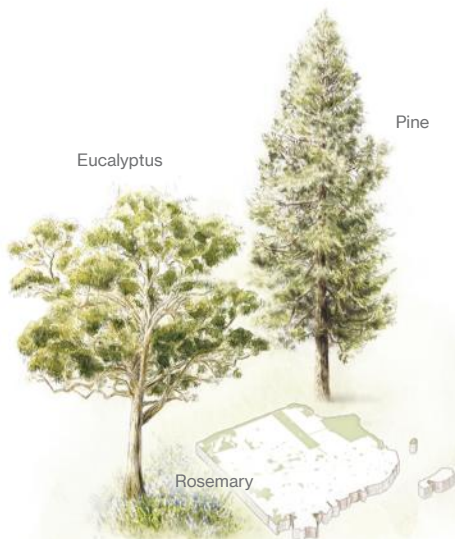
Like wine and beer, honey has an array of flavor notes that can be tricky to pinpoint. A honey's taste is influenced by the types of nectar and pollen bees collect. But until recently scientists couldn't say precisely what bees fed on or where.

Now, by sequencing the genetic material in honey, scientists can tell which plants are in the sweet stuff. Noah Wilson-Rich, founder of the Best Bees Company, an urban beekeeping service,

heads a study profiling the DNA of honey from major U.S. cities.

Samples are taken from hives in city centers. DNA tests reveal how many plant species honeybees visit within the foraging range of three to five miles, showing what plants they prefer. Wilson-Rich says higher plant diversity in urban areas could be one reason that city hives are healthier and more productive than many rural ones.

*RESULTS BASED ON PRELIMINARY DATA. PLANTS NOT DRAWN TO SCALE
†CITIES NOT DRAWN TO SCALE



Eucalyptus

Pine

Rosemary

SAN FRANCISCO (47 sq mi)
Hospitable climate and residents combine with no restrictions to make the city a haven for bees.



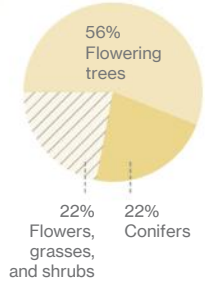
Linden

Cypress

White sweet clover

SEATTLE (84 sq mi)
A leader in urban farming and sustainability, Seattle was an early adopter of beekeeping regulation.

What's in city honey?
A high diversity of plants – even nonflowering ones – helps bees thrive in cities. Insects that feed on sap-producing plants such as conifers expel honeydew, a sweet secretion that bees collect and make into honey.



Locust

Linden

Stonecrop

NEW YORK (303 sq mi)
Even luxury hotels host hives: The InterContinental in Times Square uses its rooftop honey in cocktails.



Cedar

Clover

Egyptian grass

WASHINGTON, DC (61 sq mi)
In a test to see where bees can prosper, D.C.'s wastewater treatment plant has four hives on its roof.



Sweet chestnut

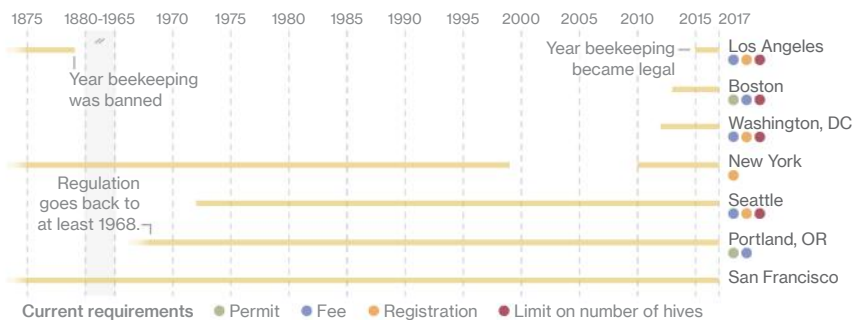
Rose

Begonia

PORTLAND, OR (133 sq mi)
It's called the City of Roses, and the flower is the most prominent plant in its honey DNA.

Making city bees legal

Los Angeles outlawed hives in 1879 due to misguided fears that bees attacked fruit crops but joined other major U.S. cities when it legalized hives in 2015. Beekeeping was often present before city regulation. Currently most cities require that hives be kept a certain distance from property lines.



DAISY CHUNG AND CLARE TRAINOR, NGM STAFF. SOURCES: NOAH WILSON-RICH, THE BEST BEES COMPANY; USGS PAD-US; U.S. CENSUS BUREAU; DISTRICT OF COLUMBIA; CITIES OF BOSTON, LOS ANGELES, NEW YORK, SAN FRANCISCO, SEATTLE, AND PORTLAND, OREGON



SKYSCRAPERS BUILT ON SAND

By Nina Strohlic

Giant shopping malls and soaring hotels have redrawn the skylines of cities like Dubai and Abu Dhabi. In the sweltering desert, indoor ski slopes are dusted in snow and flower gardens bloom. “They are constructing an artificial world that is completely disconnected from nature,” says Roger Grasas, a Spanish photographer whose project “Min Turab”—an Arabic expression meaning “from the earth”—looks at the idiosyncratic landscapes of the oil-fueled development boom in the Gulf region.

These cities—like Dubai, Doha, and Abu Dhabi—“have in a way rejected the

past,” says Grasas. “Before the oil these were poor countries. [Now] they are relating the new with something better.”

Rapid development without regard for history or context was dubbed “dubaization” by Yasser Elsheshtawy, a former architecture professor at United Arab Emirates University. Open land has been covered with energy-guzzling high-rises that “enable inequality and segregation,” says Elsheshtawy, and historic neighborhoods are at risk. One silver lining, though, is that urban development has improved roads and public transportation, which benefits everyone.

Efforts to preserve “the odd fort, palace, or souk” are often geared toward tourism, Elsheshtawy says. But recently, as traditional architecture is disappearing, he’s perceived a newfound pressure to preserve “whatever is left.”

Man-made structures are increasingly at odds with the natural landscape in the Gulf states. Photographer Roger Grasas focuses on this “construction of an artificial world over the natural world.” Clockwise from top left: The world’s largest flower garden, in Dubai, U.A.E.; a poster of a car stuck on a hotel walkway in Manama, Bahrain; a seafood restaurant in Dammam, Saudi Arabia; and an artificial palm tree in Duruma, Saudi Arabia.

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DESIGNS FOR FUTURE SURVIVAL

By Nina Storchlic

The year is 2121. Stilted houses in Phnom Penh sit above urban farms fed by the Mekong River. Athens is smog free after a ban on cars, and Tokyo's families live in nuclear radiation-proof homes. In Greenville, South Carolina, off-the-grid homes are powered by solar energy, and water is filtered off the roof (below).

These cities of the future spring from the mind of Alan Marshall, an environmental social science professor at Mahidol University in Thailand. With the help of university students from around the world, Marshall imagined what cities that had successfully adapted to the next century's environmental threats would look like. He collected those visions in the book *Ecotopia 2121*—and published it 500 years after Thomas More first wrote of an imagined, perfect place in his book

Utopia. “The main thing about the utopian impulse is that things can change for the better,” says Marshall.

The Ecotopia project grew from Marshall's concern about the earthquakes that threaten his hometown of Wellington, New Zealand. Designs that anticipated potential disasters, he realized, could ensure the city's survival. He wondered what it would look like if the population embraced hobbit-style dwellings rather than high-rise apartment buildings. “We use fantasy as a way to make people think differently,” says Marshall, whose cityscapes combine rustic sustainability with futuristic design.

After years of working on solutions, Marshall has grown more confident that society will be able to prevent a dystopian future. Nevertheless he'll explore worst-case scenarios in “Frankencities,” his next project. “If we don't change our ways, this is what will happen to our cities—they'll become unlivable,” Marshall says. “It's scary, but it's not written in stone.”



In this futuristic vision of Ghana's capital of Accra, destructive urban flooding has taken its toll. In nearby forests, people build tree cabins that hover above the deluge-prone land.

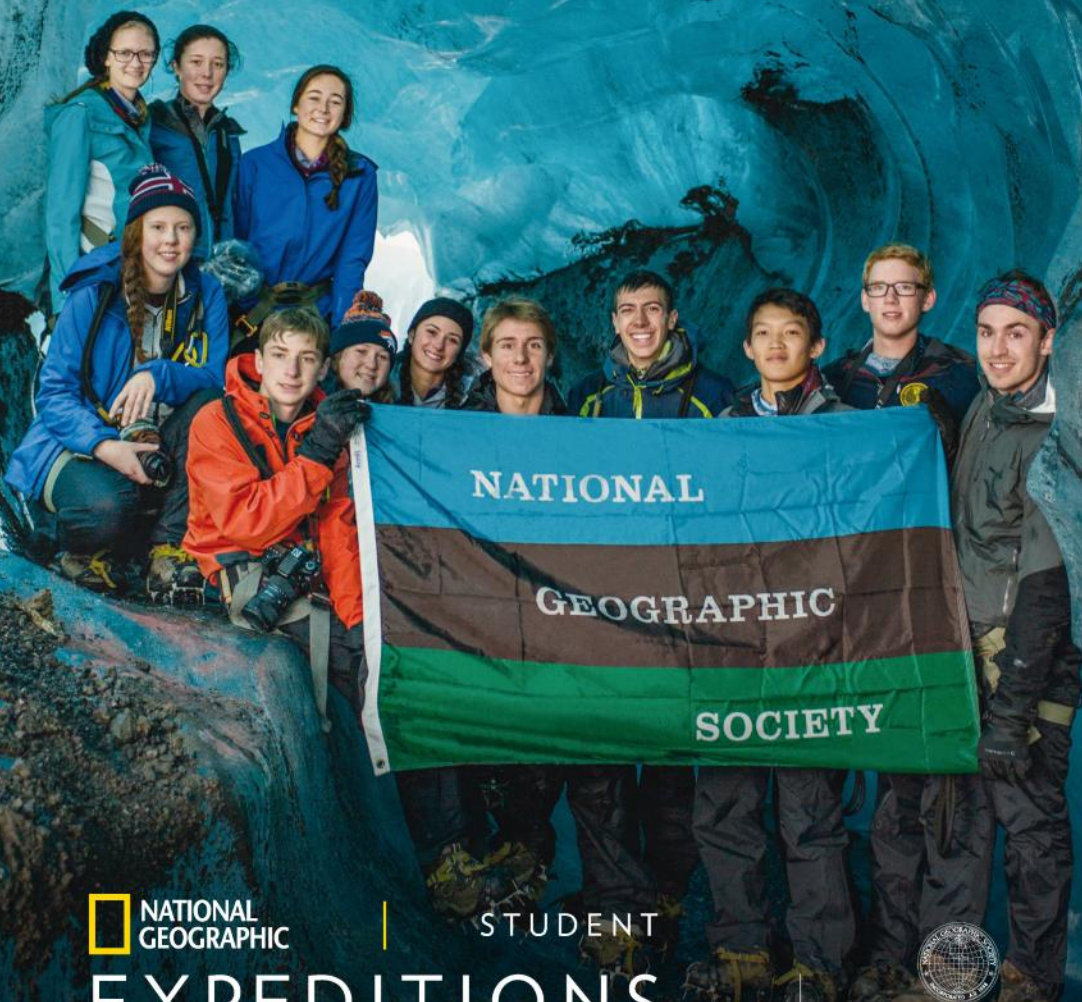


Hydrogen balloons suspend Singapore's residents over the rising sea. This space station-style city has an independent ecosystem that recycles air and water and grows its own food.

ILLUSTRATIONS: ALAN MARSHALL AND GIUSEPPE PARISI (BELOW); ALAN MARSHALL (TOP, BOTH)



OH, THE PLACES
THEY'LL GO



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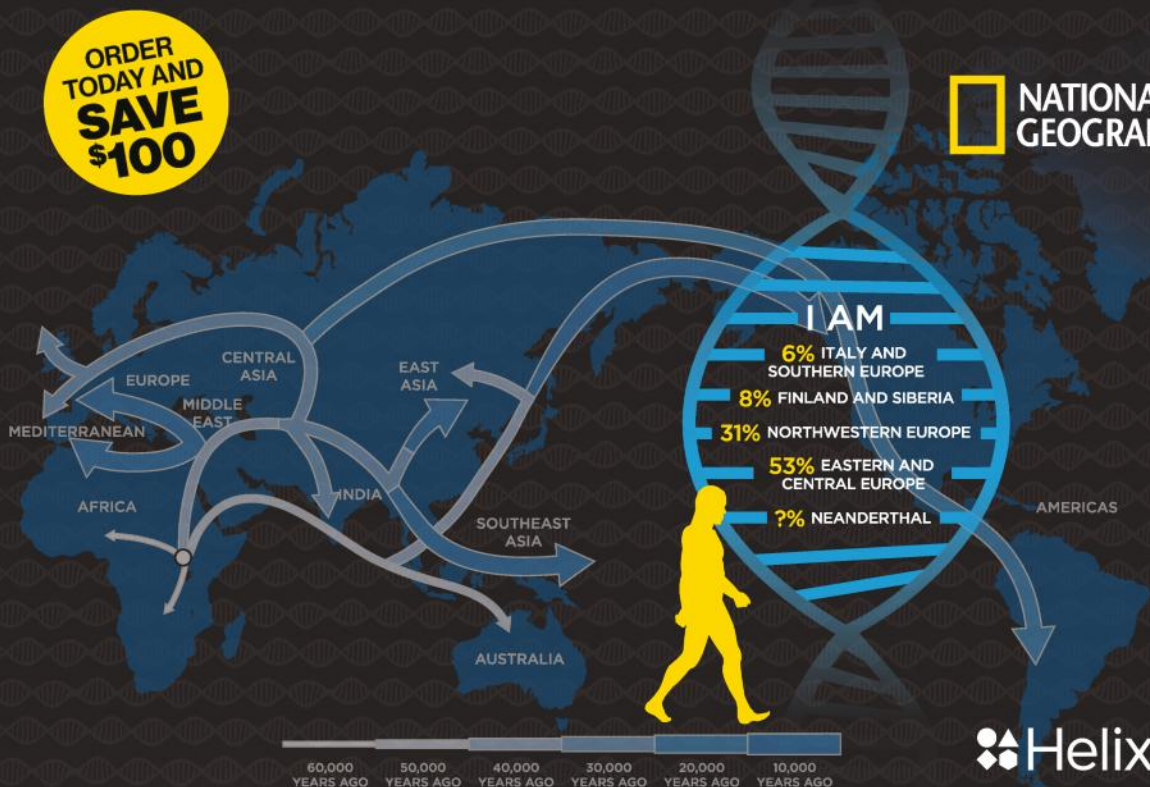
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MORE 'BURBS MAY MEAN LESS SEX

By Patricia Edmonds

When land developers remove native vegetation to put in subdivisions, some songbirds do just fine. These “adapter” species find alternative places to nest and may even thrive near humans, says John Marzluff, a wildlife science professor at the University of Washington.

But other species of songbirds flee in search of undisturbed habitat, even if it means leaving a mate and losing chances to reproduce, Marzluff says. In the face of urbanization, the “avoider” species—such as the Wilson’s warbler above—are known to decline.

Marzluff and his colleagues spent 12 years gathering data for one of the few studies that have been done on how urbanization affects songbird species’ dispersal. The researchers identified

three types of sites: forest reserves, existing subdivisions, and “changing sites” where forest was being turned into subdivision. There they caught and banded avoider and adapter birds—nearly 3,000 in all—then tracked where the birds went and whether they fledged broods.

The species studied typically stay with one mate in one area. But when development removed the low plants where avoiders like to nest, researchers saw the birds relocate and “divorce,” or not reunite with, their prior mate. When finding a new partner and new territory disrupts a breeding season, avoiders “often fail to produce young,” Marzluff says. “For a bird that lives five or six years, that’s a big hit.”

To thrive and multiply, avoider birds will need native habitat reserves. But many species of adaptable birds “do very well around us,” Marzluff says. “It’s important for people to realize that we can do a lot in our yards and neighborhoods to foster birds.”

WILSON'S WARBLER

HABITAT/RANGE

Prefer brushy, woodland areas; breed in Alaska, Canada, and northern parts of the lower 48 states; winter in the southern U.S., Mexico, and Central America

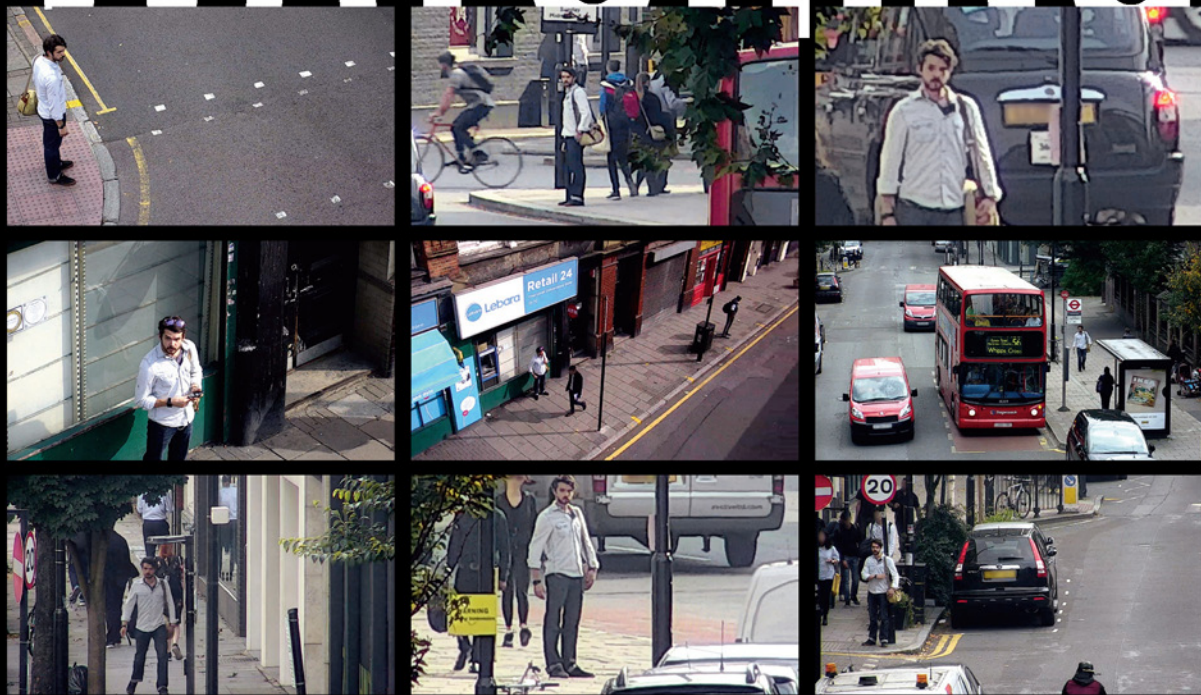
CONSERVATION STATUS

The IUCN assessment: least concern

OTHER FACTS

Females and males have similar coloring except for the males’ black cap.

THEY ARE WATCHING



A high-definition camera tracks a hired subject along a street in Islington, a borough in Greater London.

TOBY SMITH WITH ISLINGTON CCTV CONTROL ROOM



... and everything else on the planet.

Technology and our increasing demand for security have put us all under surveillance.

Is privacy becoming just a memory?



BY ROBERT DRAPER

About 10:30 on a Saturday morning in the north London borough of Islington, two men on mopeds race down the shopping corridor of Upper Street. Sheathed in helmets, gloves, and jackets, they look more like manic video game figures than humans. They weave through traffic and around double-decker buses at kamikaze velocity. Motorists flinch at their approach. The bikers pop wheelies and execute speedy figure eights along the busy street. Still, something more purposeful than joyriding would seem to be on their minds.

Two closed-circuit television system operators monitor Islington's control room, where they can watch images from the borough's extensive camera network. London's video surveillance helped solve the deadly 2005 terrorist bombings, which killed 52 people.

TOBY SMITH



After three or four minutes, they abruptly turn off Upper and onto a quiet and leafy residential avenue. They hop the curb and cut their engines. Dismounting on the sidewalk, their helmets still on, they fall into a lengthy conversation. Their dialogue is known only to them. But there is something the men themselves likely don't know: About a mile away, from a windowless room, two other men are watching them.

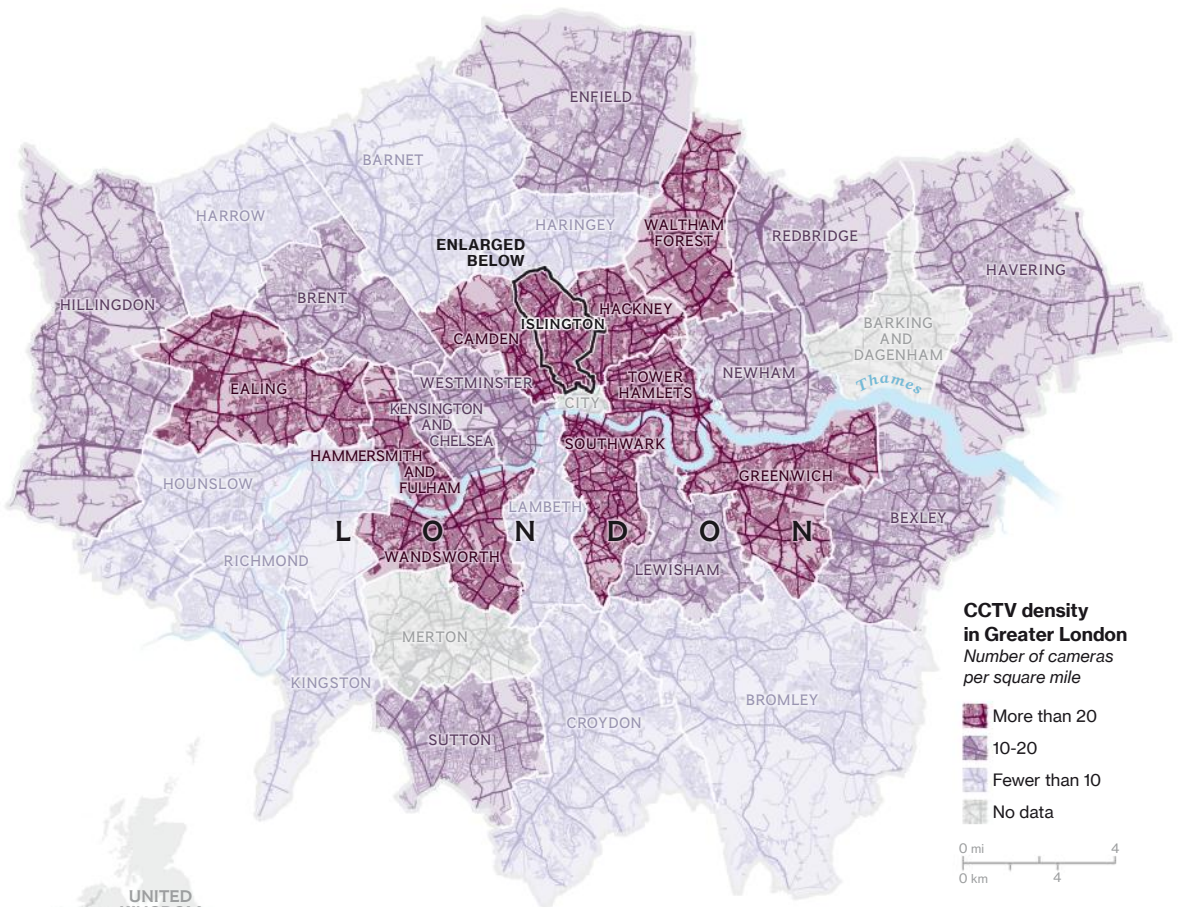
"They're moving," Sal says to Eric.

The two men sit 10 feet apart, behind a long console in Islington's closed-circuit television (CCTV) control room, painted and carpeted in gray, with no adornments. Sal is middle-aged, while Eric is decades younger. Both wear casual office attire. No small talk passes between them. As the two bikers take off, Sal types away at his

computer keyboard, prompting Camera 10 to appear on his screen. And there they are again, flying down Upper Street. As they disappear from Sal's view, Eric quickly locates them on Camera 163. With a joystick, he zooms the camera onto the moped pulling up the rear until its license plate is legible.

Sal radios the police station. "We have two suspicious mopeds doing wheelies on Upper Street."

Facing the men is an immense display with 16 screens. It conveys live images from Islington's network of 180 CCTV cameras. By visible evidence, this Saturday morning is a comparatively placid one. Earlier in the week a young man had died after being stabbed in a flat, and from the overpass at Archway Road, darkly referred to as "suicide bridge," another man had jumped to his



WATCHING

LONDON

London authorities were early adopters of widespread closed-circuit television (CCTV) surveillance after the city was targeted by terrorists using truck bombs in the early 1990s. From 2012 to 2015 the city saw a 72 percent increase in cameras, making up one-third of the U.K.'s cameras overall. Today Londoners are some of the most closely watched city dwellers in the world; as one example, the borough of Islington, just north of central London, monitors 180 cameras.

CCTV data for London and Islington are from 2015 and 2017, respectively. Islington map shows only fixed camera locations.

JASON TREAT AND RYAN T. WILLIAMS, NGM STAFF
SOURCES: BIG BROTHER WATCH; ISLINGTON COUNCIL; ORDNANCE SURVEY, U.K.

TAKING THE LONG VIEW

To demonstrate the capabilities of Islington's CCTV system, officials agreed to track a man hired by *National Geographic* as he strolled down Goswell Road. In these two views, a high-definition camera pulls back to offer the widest vantage and then zooms in for a close-up shot from a distance that's more than the length of three soccer fields.

TOBY SMITH WITH ISLINGTON CCTV CONTROL ROOM



death. Later today in Finsbury Park, the cameras would spend hours panning across 35,000 festivalgoers in search of pickpockets, drunken brawlers, and other assorted agents of petty mischief.

For the moment, however, the bikers are the only action in Islington. And though Sal and Eric—who have been doing this work for 15 and four years, respectively—pursue their quarry from one camera to the next with humdrum efficiency, I can almost see their blood quicken. For what we have here, they believe, are two members of gangs that have been plaguing Islington for more than a year. They snatch smartphones from pedestrians, then sell the items on the black market. It happens about 50 times a week in the borough of nearly 233,000 residents.

And yet to the uninitiated, the prospect of catching the bikers in an illegal act can feel almost irrelevant. Instead, I'm captivated by the basic spectacle of two people who appear to have no idea they're being watched everywhere they

go. Perhaps they're criminals. Perhaps they're sociopaths. Our surveillance is inconclusive on these matters. The only thing that's certain is that we see them but they don't see us. Like a deer framed in a hunting rifle scope, the bikers display no signs of their vulnerability. In this way they are profoundly exposed.

That evening a few miles away, I'm sitting in a mobile trailer in southwest London, just down the street from the Vauxhall Underground Station. Beside me is an affable young man who goes by the name of Haz. Several closed-circuit screens are arrayed in front of us, displaying images provided by 10 cameras aimed at two nearby nightclubs.

Haz is here a couple of weekends a month. The nightclubs, Lightbox and Fire, wish to avoid legal troubles from drug deals by their patrons, so they've commissioned a mobile CCTV operator and former policeman, Gordon Tyerman, to have his man Haz keep an eye on the crowds. Occasionally a clubgoer happens to notice one of



WATCHING

SHOOTERS

Shooter Detection Systems in Boston, Massachusetts, has invented a wall-mounted device (above) designed to find an active shooter inside a building. The system uses acoustic software to identify the sound of gunshots and infrared muzzle-flash detectors to verify the shots and then automatically provides security officers with a map that shows their precise location.

ROBERT CLARK





the cameras and responds by thrusting a middle finger or an exposed breast into Haz's field of vision. Otherwise, the thousands of young men and women entering and exiting the clubs are his unwitting entertainment.

"This is the best, most exciting job I've had so far," Haz says. "It's so unpredictable. Everything's quiet, and then suddenly a fight breaks out."

Haz sits in the trailer for 10 hours straight, eyes trained on the patrons. If he sees the makings of a drug deal or a fight, he notifies the club's in-house security by walkie-talkie. It amazes him how indiscreet drug dealers can be—with the bulges in their socks and their melodramatic handovers—despite the presence of security guards. "We ask them, 'How stupid can you be?'" he laughs. "And they take it as a challenge."

Tonight there are no drug deals, no fights, only the random foolishness of the young and inebriated. They stagger with linked arms down the middle of the street. They paw at each other. They get sick on the sidewalk. In their sudden aloneness, they break out in sobs. Though Haz maintains that he's gained "invaluable skills from this job," chiefly the skills he's honing are those of Vauxhall's invisible, after-hours anthropologist.

"There's stuff you see on CCTV," he marvels, "that makes you think, 'That's not adult behavior.' They tend to forget who they are."

But do they really tend to forget who they are? Or do they simply tend to forget that someone might be watching?

I**N 1949, AMID THE SPECTER** of European authoritarianism, the British novelist George Orwell published his dystopian masterpiece *1984*, with its grim admonition: "Big Brother is watching you." As unsettling as this notion may have been, "watching" was a quaintly circumscribed undertaking back then. That very year, 1949, an American company released the first commercially available CCTV system. Two years later, in 1951, Kodak introduced its Brownie portable movie camera to an awestruck public.

Today more than 2.5 trillion images are shared or stored on the Internet annually—to say nothing

WATCHING

CRIME

Peter Gold returns to the New Orleans street where he was shot while trying to rescue a woman who was being abducted at gunpoint. Gold, then a 25-year-old medical student, intervened

when he saw a man later identified as Euric Cain attempt to drag the woman into a vehicle. The 2015 incident was captured on a video camera; it shows Cain shooting Gold in the stomach and then trying twice to shoot him in the head as he lay curled on the sidewalk. Both times, the gun jammed. Like the business owner who installed this camera, more cities and private citizens are turning to street-level surveillance to fight crime.

MAX AGUILERA-HELWEG (BELOW); NEW ORLEANS POLICE DEPARTMENT





WATCHING

FACES

Face-scanning technology is evolving rapidly and is increasingly employed in high-security facilities such as airports and government offices. Now some stores are even using it to identify returning customers or shoplifters.



1 Finding a face

Systems extract patterns from an image and compare them to a model of a face. When patterns start to resemble the model, the system signals it has homed in on a face.



Personal devices
Smartphones use face recognition for apps and security, such as unlocking the phone.



Checkpoint cameras
Faces are recorded at customs and security checkpoints, and the images are archived.



Other cameras
Laptop, video, and thermal cameras used in some security systems can capture face images.



CCTV cameras
Systems can isolate and track individuals by face, gait, and clothing color and pattern.

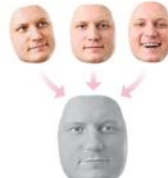
Face imagery captured when a person poses for the camera, such as at security checkpoints, is easier to analyze; imagery captured from CCTV cameras may require advanced methods and detailed analysis.

2 Creating a face template

Algorithms build more informative and accurate digital representations – called face templates – using thermal, geometric, and other data, either separately or combined.



Geometric
Spatial relationships between facial features, such as the center of the eyes and tip of the nose, are calculated.



Photometric
Algorithms can build a face even if an image is obscured by poor lighting or distorted by odd angles or expressions.



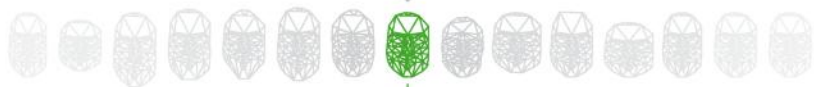
Skin-texture analysis
Pores, wrinkles, and spots are mapped and analyzed; the technology can even differentiate between twins.



Thermal sensors
This technology can provide further information despite obstacles such as heavy makeup or disguises.

3 Identifying a face

Once a face template is created, it can be compared with databases (such as for mug shots) to verify a person's identity or recognize an individual in CCTV footage.



Identity confirmed

JASON TREAT AND RYAN T. WILLIAMS, NGM STAFF.
PHOTO (POSED MODEL): GETTY IMAGES. SOURCES: U.S. GOVERNMENT ACCOUNTABILITY OFFICE; ANIL K. JAIN AND DEBAYAN DEB, MICHIGAN

of the billions more photographs and videos people keep to themselves. By 2020, one telecommunications company estimates, 6.1 billion people will have phones with picture-taking capabilities. Meanwhile, in a single year an estimated 106 million new surveillance cameras are sold. More than three million ATMs around the planet stare back at their customers. Tens of thousands of cameras known as automatic number plate recognition devices, or ANPRs, hover over roadways—to catch speeding motorists or parking violators but also, in the case of the United Kingdom, to track the comings and goings of suspected criminals. The untallied but growing number of people wearing body cameras now includes not just police but also hospital workers and others who aren't law enforcement officers. Proliferating as well are personal monitoring devices—dash cams, cyclist helmet cameras to record collisions, doorbells equipped with lenses to catch package thieves—that are fast becoming a part of many a city dweller's everyday arsenal. Even less quantifiable, but far more vexing, are the billions of images of unsuspecting citizens captured by facial-recognition technology and stored in law enforcement and private-sector databases over which our control is practically nonexistent.

Those are merely the “watching” devices that we're capable of seeing. Presently the skies are cluttered with drones—2.5 million of which were purchased in 2016 by American hobbyists and businesses. That figure doesn't include the fleet of unmanned aerial vehicles used by the U.S. government not only to bomb terrorists in Yemen but also to help stop illegal immigrants entering from Mexico, monitor hurricane flooding in Texas, and catch cattle thieves in North Dakota. Nor does it include the many thousands of airborne spying devices employed by other countries—among them Russia, China, Iran, and North Korea.

We're being watched from the heavens as well. More than 1,700 satellites monitor our planet. From a distance of about 300 miles, some of them can discern a herd of buffalo or the stages of a forest fire. From outer space, a camera clicks and a detailed image of the block where we work can be acquired by a total stranger.

Simultaneously, on that very same block, we may well be photographed at unsettlingly close range perhaps dozens of times daily, from lenses we may never see, our image stored in databases for purposes we may never learn. Our smartphones, our Internet searches, and our social media accounts are giving away our secrets. Gus Hosein, the executive director of Privacy International, notes that “if the police wanted to know what was in your head in the 1800s, they would have to torture you. Now they can just find it out from your devices.”

This is—to lift the title from another British futurist, Aldous Huxley—our brave new world. That we can see it coming is cold comfort since, as Carnegie Mellon University professor of information technology Alessandro Acquisti says, “in the cat-and-mouse game of privacy protection, the data subject is always the weaker side of the game.” Simply submitting to the game is a dispiriting proposition. But to actively seek to protect one's privacy can be even more demoralizing. University of Texas American studies professor Randolph Lewis writes in his new book, *Under Surveillance: Being Watched in Modern America*, “Surveillance is often exhausting to those who really feel its undertow: it overwhelms with its constant badgering, its omnipresent mysteries, its endless tabulations of movements, purchases, potentialities.”

The desire for privacy, Acquisti says, “is a universal trait among humans, across cultures and across time. You find evidence of it in ancient Rome, ancient Greece, in the Bible, in the Quran. What's worrisome is that if all of us at an individual level suffer from the loss of privacy, society as a whole may realize its value only after we've lost it for good.”

Is a looming state of Orwellian bleakness already a fait accompli? Or is there a more hopeful outlook, one in which a world under watch in many ways might be better off? Consider the 463 infrared camera traps the World Wildlife Fund uses in China to monitor the movements of the threatened giant panda. Or the thermal imaging devices that rangers deploy at night to detect poachers in Kenya's Masai Mara National Reserve. Or the sound-activated underwater camera

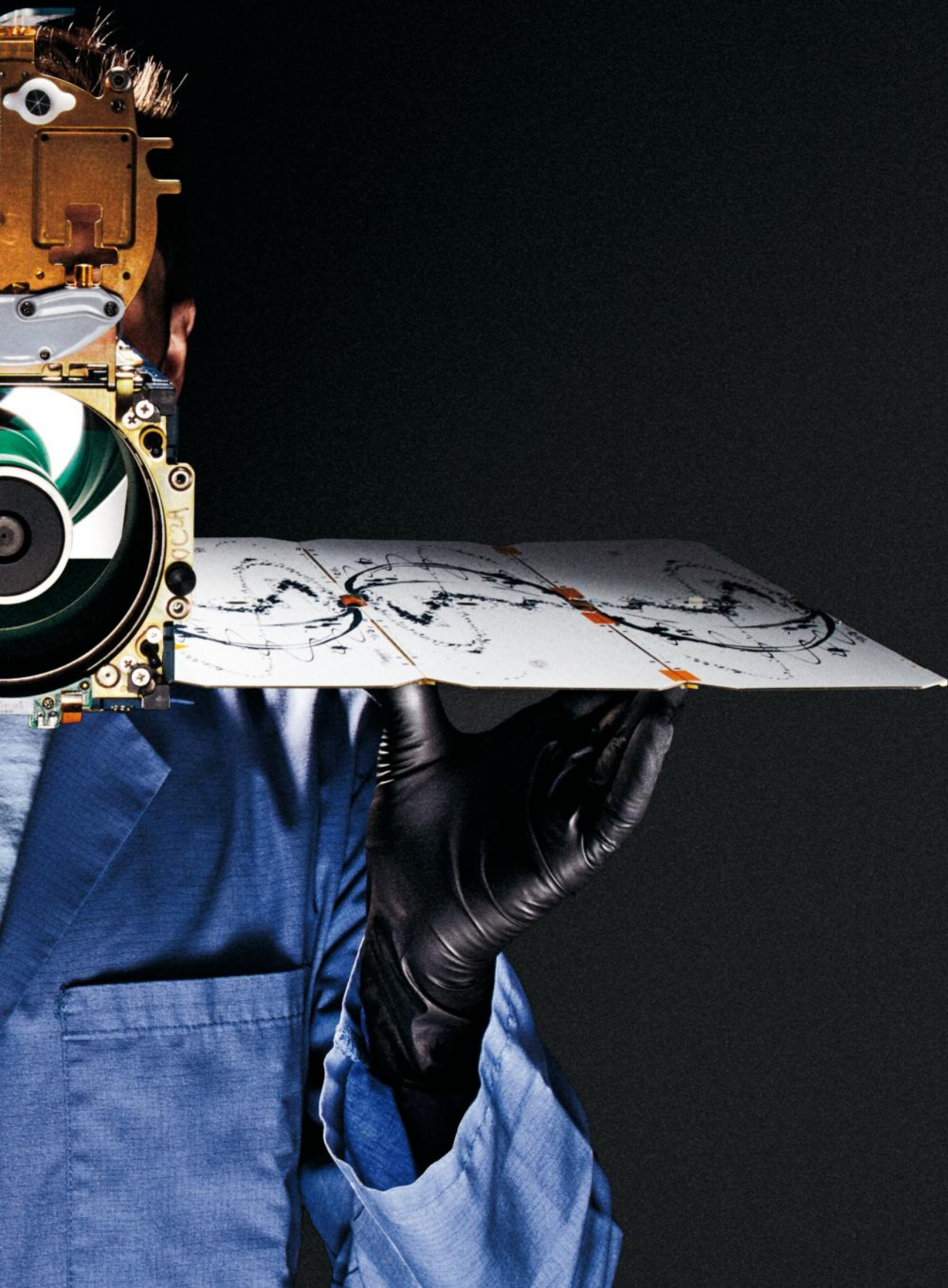
WATCHING

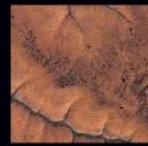
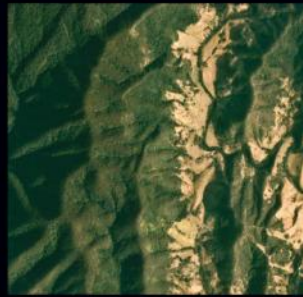
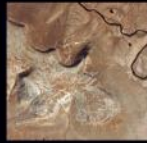
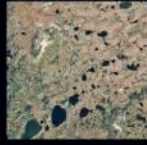
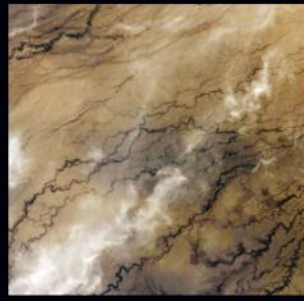
EARTH

Dino Bertolino, a senior spacecraft technician at Planet, holds a camera-equipped satellite, which the San Francisco company calls a Dove. Planet has more than 150 of these shoe box-size satellites operating in orbit, snapping two images a second. With this fleet, when conditions are optimal, the company can photograph the Earth's entire landmass in a day.

CRAIG CUTLER



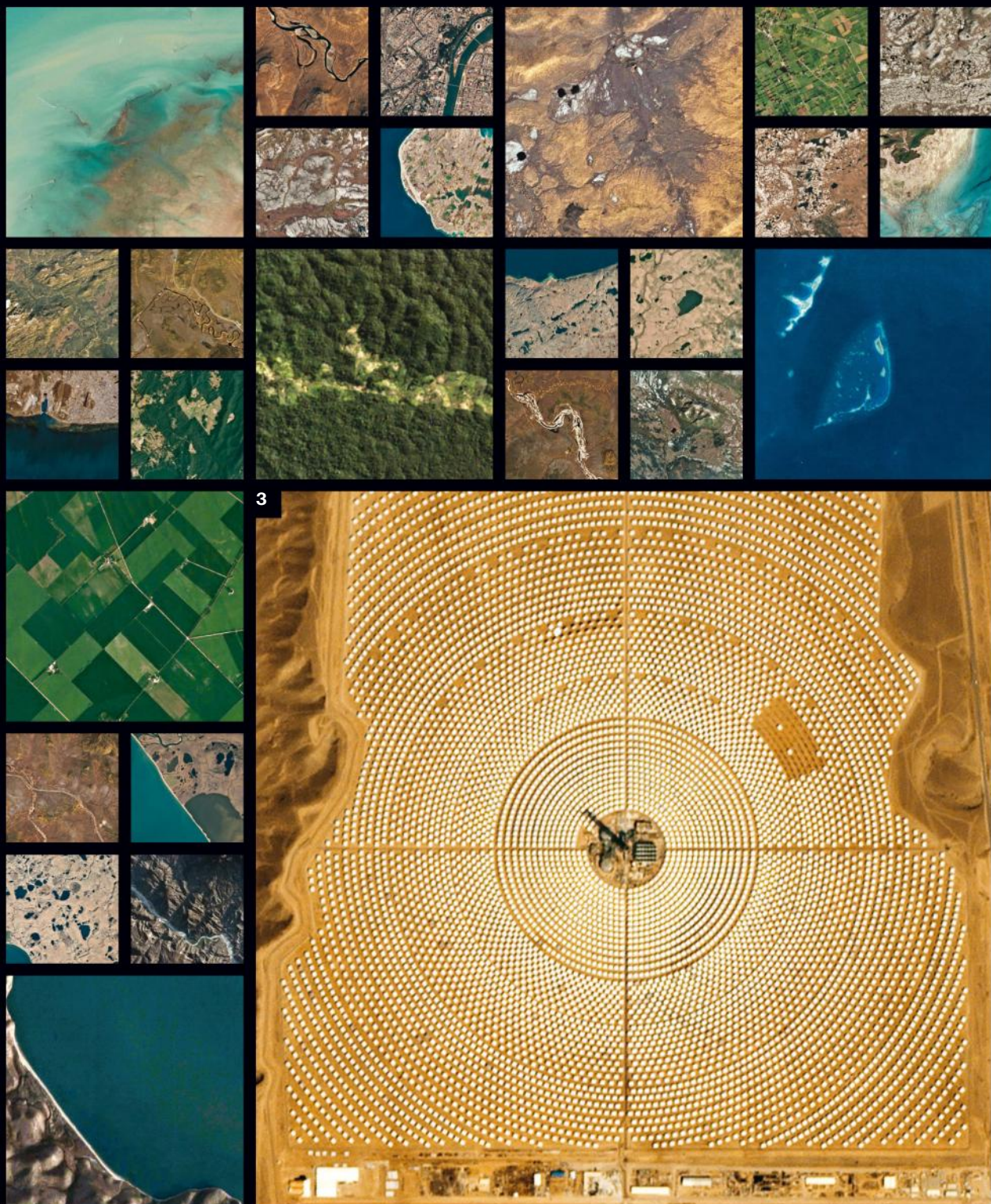




WATCHING

EARTH

These are a selection of images taken by Planet's Dove satellites that were operating on September 20, 2017.



1. PARIS 2. MOSCOW 3. NOORO III SOLAR PLANT, MOROCCO

133 Number of satellites transmitting images that day

10,000 Number of photos each satellite shoots in a day

1.3 MILLION Number of images collected in a day



April 23, 2017



April 26, 2017



April 27, 2017



WATCHING

EARTH

China's first aircraft carrier built from scratch is launched in Dalian, a port city on the Yellow Sea. These images, taken by Planet's Dove satellites, show the ship in a berth (far left), backing into the water (center), and docked (left). Planet can capture similar developments day by day, anywhere in the world.



system developed by UC San Diego researchers that tracks the nearly extinct vaquita porpoise in the Sea of Cortez. Or the “forest watcher” cameras installed to help protect the shrinking timberlands of Sri Lanka.

“If you want a picture of the future,” Orwell darkly warned in his classic, “imagine a boot stamping on a human face—forever.” This authoritarian vision discounts the possibility that governments might use such tools to make the streets safer. Recall, for example, the footage from security cameras that cracked the cases of the 2005 London subway and 2013 Boston Marathon bombings. Multitudes of more obscure episodes exist, such as that of Euric Cain, caught unambiguously on camera shooting a Tulane University medical student named Peter Gold in 2015 after Gold prevented him from abducting a woman on the streets of New Orleans. (Gold survived; Cain received a 54-year prison sentence for a crime rampage that included rapes, armed robbery, and attempted murder.)

At the Port of Boston, the Department of Homeland Security has tested a cargo-visualizing method invented by two MIT physicists, Robert Ledoux and William Bertozzi. Using a technique known as nuclear resonance fluorescence—in which elements become identifiable by exciting their nuclei—the screening device can, without opening a freight container, discern the elemental fingerprint of its contents. Unlike a typical x-ray scan, which shows only shape and density, it can tell the difference between soda and diet soda, natural and manufactured diamonds, plastics and high-energy explosives, and nonnuclear and nuclear material.

Does anyone doubt that a more closely inspected world over the past 150 years would have been a safer one? We might know the identity of Jack the Ripper, whether Lee Harvey Oswald acted alone, and if O. J. Simpson acted at all. Of course, public safety has been the pretext for surveillance before and since Orwell's time. But today such technology can be seen as a lifesaver in more encompassing ways. Thanks to imagery provided by satellite cameras, relief organizations have located refugees near Mosul, encamped in the

deserts of northern Iraq. And thanks to numerous space probes, scientists have proof that the world's climate is dramatically changing.

Could the great Orwell's imagination have failed? Could Big Brother save humanity, rather than enslave it? Or might both scenarios be true at the same time?

THERE IS AN APPETITE in the U.K. for surveillance that I haven't seen anywhere else in the world," said Tony Porter, the world's only known surveillance camera commissioner, as we sat in the cafeteria of a London government office with CCTV cameras peering at us from the corners. A former police officer and counterterrorism specialist, Porter was recruited four years ago by Her Majesty's Home Office, responsible for the security of the realm, to lend a semblance of oversight to the country's ever growing surveillance state. With a paltry annual budget of \$320,000, Porter and three staffers spend their workdays persistently urging, with some success, government and commercial users of surveillance cameras to comply with the relevant codes and guidelines. But beyond mentioning the names of the noncompliant in a report to Parliament, Porter's office has no powers of enforcement.

Nonetheless, his appraisal of the U.K. as the most receptive country in the world to surveillance technology is widely shared. London's network of surveillance cameras was first conceived in the early nineties, in the wake of two bombings by the Irish Republican Army in the city's financial district. What followed was a fevered spread of monitoring technology. As William Webster, a professor of public policy at the University of Stirling in Scotland and an expert on surveillance, recalls, "The rhetoric about public safety at the time was, 'If you've got nothing to hide, you've got nothing to fear.' In hindsight, you can trace that slogan back to Nazi Germany. But the phrase was commonly used, and it crushed any sentiment against CCTVs."

The city's original security infrastructure, known as the "ring of steel," was later expanded

and augmented by ANPR technology on major thoroughfares. Now spread throughout the country are 9,000 such cameras, which photograph and store 30 million to 40 million images daily of every single passing license tag, not merely those of speeders or known criminals. As former Scotland police counterterrorism coordinator Allan Burnett observes, "It would be very difficult today to go through Scotland and not be seen by an ANPR camera."

"I'm pretty sure we now have more CCTVs per capita than any other city on the planet," the former U.K. deputy prime minister, Nick Clegg, told me as he sat in his London office, watched by a camera across the street trained directly on his back. "And basically, it's happened without any meaningful public or political debate whatsoever. Partly it's because we don't have the history of fascism and nondemocratic regimes, which in other countries have instilled profound suspicion of the state. Here it feels benign. And as we know from history, it's benign until it isn't."

Elements of fear and romance help explain the profusion of surveillance in the U.K. This, after all, is a country saved by espionage: The museum commemorating the legendary World War II code breakers at Bletchley Park, 40 miles northwest of London, is today a much visited site. So, for that matter, is the London Film Museum's permanent exhibit on the dashing spy James Bond, a creation of the writer and former British naval intelligence officer Ian Fleming. Agent 007 is bound up in the nation's postwar self-appraisal, but so is the jolting reality that the U.K. was one of the first countries to face the constant fear of terrorist attacks. When it comes to protecting its people, the British government is viewed in a more appreciative light than perhaps those of other free societies. Even after the revelations by former U.S. National Security Agency contract employee Edward Snowden that American and British intelligence agencies had been collecting bulk data from their own citizens—a disclosure that triggered calls for reform by both political parties in the U.S.—Parliament essentially enshrined those powers in late 2016 by passing the Investigatory Powers Act with scant public outcry.



WATCHING

SATELLITES

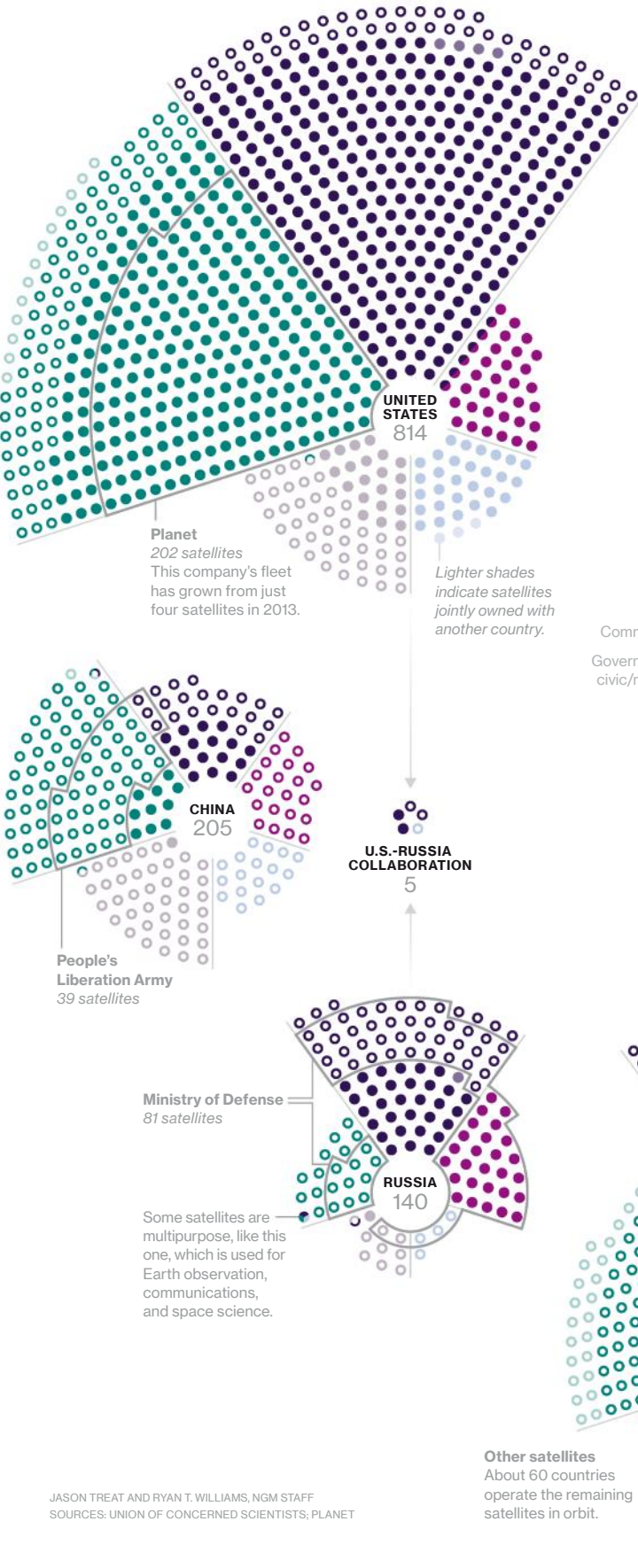
In the 1960s the U.S. Army Corps of Engineers built more than 270 concrete crosses, 60 feet wide, in the Arizona desert. The known dimensions helped calibrate the world's first spy satellites. To create the image above, two artists photographed the cross, tracked the trajectories of satellites that pass overhead, and drew arcs in the sky showing their paths.

JULIE ANAND AND DAMON SAUER

WATCHING

THE GLOBE

More than 1,700 satellites orbit above us, some as much as 100,000 miles overhead. They collect images and other data, broadcast information, track our locations, and even listen to our conversations. U.S. public institutions and companies operate most satellites, with commercial launches already far outstripping the government's.



- Commercial — ● **Earth observation**
Collect data for intelligence gathering and environmental monitoring
- Government/civic/military — ● **Communications**
Send point-to-point and broadcast transmissions
- **Navigation, timing, and tracking**
Track ships, aid navigation, and synchronize timing for computer systems
- **Technology development**
Test new technology and develop experimental payloads
- **Space science/other**
Collect data about space and pursue other scientific inquiries

As David Omand, the former director of the Government Communications Headquarters—one of the British intelligence agencies shown by Snowden to be collecting bulk data—put it to me: “On the whole we see our government as efficient and benign. It runs the National Health Service, public education, and social security. And thank God, we haven’t been through the experience of the man in the brown leather trench coat knocking on the door at four in the morning. So when we talk about government surveillance, the resonance is different here.”

That’s not by any means to say that a country like the United States, with its more skeptical view of big government, is wholly immune to surveillance creep. Most of its police departments are now using or considering using body cameras—a development that, thus far at least, has been cheered by civil liberties groups as a means of curbing law enforcement abuses. ANPR cameras are in many major American cities as traffic and parking enforcement tools. In the wake of the September 11 attacks, New York City ramped up its CCTV network and today has roughly 20,000 officially run cameras in Manhattan alone. Meanwhile, Chicago has invested heavily in its network of 32,000 CCTV devices to help combat the murder epidemic in its inner city.

But other U.S. cities with no history of terrorist attacks and relatively low violent crime rates also have embraced surveillance technology. I checked out the CCTV network that has quietly spread throughout downtown Houston, Texas. As recently as 2005, the city didn’t have a single such camera. But then Dennis Storemski, the director of the Mayor’s Office of Public Safety and Homeland Security, began touring other cities. “Basically, it was what I saw in London that got me interested in the technology,” he recalls. Today, thanks to federal grants, Houston has 900 CCTV cameras, with access to an additional 400. As in London, officials don’t monitor every camera every minute—and as such, Storemski says, “it’s not surveillance per se. We’ve wanted to take away the expectation that people are watching.” Perhaps for that reason, Houston’s CCTV reach will soon expand well beyond downtown, but—in

a state hardly known as trusting of government—without the slightest drama.

Similarly, the acquiescence among the British to the proliferation of cameras is as striking as any sound of silence could possibly be. CCTV and ANPR cameras—and the signs announcing them (though by no means all of them)—blend in as drab companions to the rest of the city’s infrastructure. During three weeks in London, I strolled through the quiet neighborhoods where Orwell and Huxley once resided. Orwell’s house, on Canonbury Square in Islington, is within view of several CCTV and ANPR cameras and is a mere four-minute walk from the borough’s control room. For its part, the former Huxley residence a few miles away is under constant watch in an impregnable steel-reinforced control room.

Outside of the city in the county of South Yorkshire, I visited Barnsley Hospital, where some security personnel are equipped with body cameras to discourage unruly behavior by patients or visitors. Similar cameras, it was reported during my stay, were being tested for use by schoolteachers. Given that an estimated 150,000 British police officers are already equipped with such devices, perhaps it’s an effortless next step to contemplate them on other authority figures, such as educators and nurses. From there, however, who’s next? Flight attendants? Postal workers? Psychologists? Human resource directors?

“Some local authorities are seeking to compel taxi drivers to use surveillance,” Porter, the surveillance camera commissioner, told me. “Considering that, and the use of body cameras in hospitals and schools, the question I’d put forward is: What kind of society do we want to live in? Is it acceptable for all of us to go around legitimately filming each other, just in case somebody commits a wrong against us?”

I thought about this last question during my final days ambling along the well-scrubbed streets of London, my eyes now keenly attuned to the cyclops-like glares from corners and lampposts. As my path inevitably led me to the famed Westminster Bridge over the River Thames, I found myself engulfed by tourists of various nationalities holding up smartphones in an attempt to produce the

WATCHING

THE SKY

Three telescopes of the Deimos Sky Survey, based in Spain, watch for close asteroids and man-made space debris that could damage satellites, as an airplane streaks across the sky. Noelia Sánchez Ortiz, an aerospace engineer, and Jaime Nomen, an astronomer and the head of the observatory, monitor the instruments.

LUCA LOCATELLI







WATCHING

POACHERS

In total darkness, a frame from a thermal imaging camera (above) shows rangers in Kenya's Masai Mara National Reserve chasing a poacher, who was soon caught. The devices, provided by the World Wildlife Fund to the Mara Conservancy, have allowed rangers (top right) to extend their work protecting wildlife into the night. By day, rangers rescue a male elephant calf (bottom right) that was separated from its herd and thus vulnerable to predators. The elephant was flown to an animal sanctuary.

CLOCKWISE FROM TOP RIGHT: PETE MULLER (TWO); WWF/MARA CONSERVANCY

ultimate London selfie. I ducked and turned and apologized before realizing it was futile. And these were just the cameras in front of my face. Were all of my movements being casually documented in this way? Did it really make any difference whether Big Brother was watching, given that everyone is already watching everyone else?

I'd been discussing society's growing pics-or-it-didn't-happen fixation with two keen observers. The first, Chloe Combi, is a former schoolteacher whose first book, *Generation Z: Their Voices, Their Lives*, is the fruit of hundreds of hours of interviews she conducted with British teenagers. They demonstrated a remarkable nonchalance about being photographed and filmed in almost

every conceivable setting. "You can watch a documentary of someone's entire life on their phone," Combi told me. "We live in a world where, increasingly, nothing remains secret. And one of the signs of true wealth and power may end up being that privacy will become a commodity only for those who have the serious money to buy it. For everybody else, all the world really will be a stage, with all the people on it self-consciously playing their role."

The futurist spectacle conjured up by Combi—one in which everyone is simultaneously voyeur and exhibitionist, 24/7—struck me as a somewhat egalitarian version of *1984* and *Brave New World*, yet no less dystopic. Are we already there, at the



PATROL
VEHICLE



endpoint of what University of Kansas sociologist William Staples in 2000 called the “state of permanent visibility,” except by our own acquiescence rather than by governmental force? Our visual constellation is replete with adorable babies, kittens, and elephants—but also ISIS beheadings, celebrities in sexual congress, double-speaking politicians, police shootings of unarmed civilians. Meanwhile, we’re seen, up close and far too personally, by airport-security screeners, “smart” billboards that tailor ads to us based on our appearance, and everyone who knows everyone who caught us on camera on a day when we could swear we were alone.

Whether this all adds up to a more enlightened

society, an overstimulated one, or a little bit of both is hard to say. I solicited the thoughts of Susan Greenfield, a research neuroscientist and renowned critic of social media obsessives, who also happens to be a member of the British Parliament. Baroness Greenfield’s assessment was no less stark than Combi’s. “The notion of privacy, of privation, is shutting something out,” she said. “We need to cut ourselves off. Everyone seems to think that it’s great to be connected and exposed all the time. But what happens when everything is literal and visual? How do you explain a concept like honor when you can’t find it on Google Images? The universe of the abstract is inexplicable. The nuance in life disappears.”

WATCHING

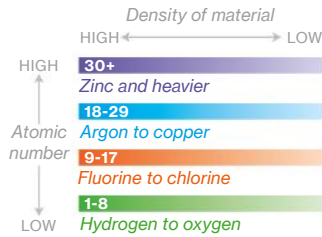
CARGO

Seaports handle roughly 80 percent of worldwide trade by volume and play a vital role in border security. In a pilot program at the Port of Boston, scientists and engineers have designed an advanced scanner that can identify the molecular makeup of substances with far more specificity than ever before, quickly differentiating, for example, between salt and cocaine.

HOW IT WORKS

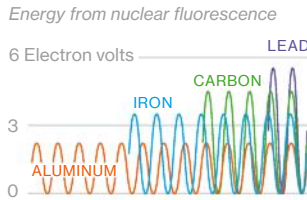
1 Creating a 3-D model

A scanner **A** bombards a truck and its cargo with high-energy x-rays. Sensors **B** then measure for backscatter radiation (see "Imaging With X-Rays," below) to create a 3-D model. The truck and its contents are identified by four categories (right) based on average atomic number (the number of protons).

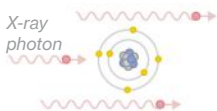


2 Hunting for contraband

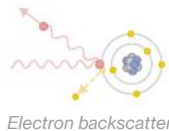
Algorithms then analyze the 3-D model for atomic numbers and densities that could indicate contraband, such as explosives and drugs. Suspicious material is further scanned by a detector **C** that measures specific combinations of elements based on how much energy they release.



IMAGING WITH X-RAYS



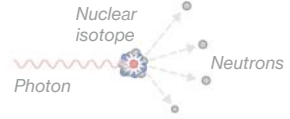
Transmission x-ray imaging
X-ray photons are sent through an object. Its density is determined by measuring the number of photons that successfully pass through it.



High-energy backscatter imaging
Higher energy x-ray photons are deflected, or backscattered, by the object's electrons and nuclei. The results can be used to determine the object's density and its atomic number.

3 Locating nuclear material

As the 3-D model is being created, a detector **D** scans the cargo for neutrons, produced when x-rays interact with nuclear material. When the data are combined with the 3-D model, an operator can pinpoint the location of any nuclear contraband.



When photons strike nuclear material, neutrons radiate outward.

Nuclear material detected

To avoid harmful doses of radiation, the driver pulls into the scanner, parks, and exits before the truck is sent through the system.

And so as I talked with Tony Porter in the cavernous and highly surveilled cafeteria of the Home Office, I found myself repeating something I'd expressed to him once before, months earlier: Didn't this whole fear-of-Big-Brother impulse seem rather quaint now?

"I now use that term in my speeches," the surveillance camera commissioner informed me with a pleased grin. Then he turned serious. Porter had recently visited the United Arab Emirates, a federation of monarchies that suppresses dissent and has a great deal of interest in surveillance technology. That struck Porter as ominous. "I get where you're coming from," he said. "But surveillance by the state is invasive, it's powerful, it's capable of connectivity beyond people's wildest imaginations. That's completely different from, say, a selfie.

"Look," he went on, "the real threat is when we move towards integrated surveillance. Large retailers are spending millions of pounds looking at every conceivable element of this. I'm a middle-aged fat guy; I walk into a supermarket and immediately on the intercom they start advertising for croissants. What if it gets more sinister, and from my Facebook profile they can target my daughter and ask where she shops? Who's going to regulate that? Or does it not need to be regulated? Is the horse already out of the barn? Is it already 'quaint'?"

THE SEEMINGLY MINUTE-BY-MINUTE advancements in surveillance technology can, to some civil libertarians, take on the appearance of a runaway bullet train. As Ross Anderson, professor of security engineering at the University of Cambridge, warns, "We need to be thinking ahead to the next 20 years. Because that's when you'll have augmented reality, an Oculus Rift 2.0, with at least 8,000 pixels per inch. So, sitting in the back of a lecture hall, you can read the text on a lecturer's phone. At the same time, the one hundred CCTVs in that lecture hall will be able to see the password you're punching into your phone."

Even Huxley, whose masterwork presents a

forbidding view of a hyper-industrialized London in the year 2540, didn't conceive of a world so acutely visualized that our most intimate secrets can't always be concealed. Where would that leave us? On the one hand, it stretches credulity to imagine the willful suppression of such tools. Says David Anderson, a London barrister who spent six years as the government's independent reviewer of counterterrorism legislation, "Either you think technology has presented us with strong powers that the government should use with equally strong safeguards, or you believe this technology is so scary we should pretend it's not there. And I'm firmly in the first category—not because I say government is to be trusted, but instead because in a mature democracy such as this one, we're capable of constructing safeguards that are good enough for the benefits to outweigh the disadvantages."

On the other hand, allowing such technological progress to find its way into a largely unregulated marketplace seems equally imprudent. Jameel Jaffer, the founding director of Columbia University's Knight First Amendment Institute, says, "I do think that we live increasingly recorded and tracked lives. And I also think we're only starting to grapple with the implications of that, so before we adopt new technologies or before we permit new surveillance forms to entrench themselves in our societies, we should think about what the long-term implications of those surveillance technologies will be."

How to craft such judgments? Endeavoring to do so is particularly nettlesome when a breakthrough occurs that explodes our notion of how we can view the world. In fact, a game changer of this sort has already emerged. The technology in question can monitor the Earth's entire landmass every single day. It's the brainchild of a San Francisco-based company called Planet, founded by two idealistic former NASA scientists named Will Marshall and Robbie Schingler.

Their headquarters resides in an unprepossessing warehouse in the gritty South of Market neighborhood. The tableau inside is textbook Silicon Valley: more than 200, mostly young techies in aggressively casual dress hunched silently

over their keyboards in an open work space, aside from a few conference rooms named after some of the company's heroes—among them, Galileo, Gandhi, and Al Gore. I sat in one of them overlooking the upscale employee cafeteria, where lunch would later be followed by a happy hour of Napa wines and California microbrews.

Marshall and Schingler joined me. The former is a lanky Brit with wire-frame glasses; the latter, a broad-shouldered and easygoing Californian. Both are 39 and seemed fully recovered from their dinner the previous evening to celebrate the fifth anniversary of when they started working full time at Planet. At NASA they had been captivated by the idea of taking pictures from space, especially of Earth—and for reasons that were humanitarian rather than science based.

They experimented by launching ordinary smartphones into orbit, confirming that a relatively inexpensive camera could function in outer space. “We thought, What could we do with those images?” Schingler said. “How can we use these things for the benefit of humanity? List the world’s problems: poverty, housing, malnutrition, deforestation. All of these problems are more easily addressed if you have more up-to-date information about our planet. Like you wake up in a few years and you find there’s a hole in the Amazon forest. What if we could have supplied information about this more rapidly to the Brazilian government?”

In storybook fashion, Marshall and Schingler developed their first model in a garage in Silicon Valley. The idea was to design a relatively low-cost, shoe box–size satellite to minimize the military-scale budgets often required for designing such technology—and then, as Marshall told me, “to launch the largest constellation of satellites in human history.” By deploying many such devices, the company would be able to see daily

changes on the Earth’s surface in totality.

In 2013 they launched their first satellites and received their first photographs, which provided a far more dynamic look at life around the world than previous global mapping imagery. “The thing that surprised us most,” said Marshall, “is that almost every picture that came down showed how the Earth was changing. Fields were reshaped. Rivers moved. Trees were taken down. Buildings went up. Seeing all of this completely changes our concept of the planet as being static. And instead of just having a figure about how much a country has been deforested, people can now be motivated by pictures that show the deforestation taking place.”

Today Planet has more than 200 satellites in orbit, with about 150 it calls Doves that can image

every bit of land every day when conditions are right. Planet has ground stations as far away as Iceland and Antarctica. Its clients are just as varied. The company works with the Amazon Conservation Association to track deforestation in Peru. It has provided images to Amnesty International

that document attacks on Rohingya villages by security forces in Myanmar. At the Middlebury Institute’s Center for Nonproliferation Studies, recurring global imaging helps the think tank watch for the sudden appearance of a missile test site in Iran or North Korea. And when *USA Today* and other publications wanted an aerial image of the Shayrat air base in Syria before and after it was bombed by the U.S. military last April in retaliation for a chemical attack on a rebel-held Syrian town, the news organizations knew whom to call.

Those are pro bono clients. Its paying customers include Orbital Insight, a Silicon Valley–based geo-spatial analytics firm that interprets data from satellite imagery. With such visuals, Orbital Insight can track the development of road or

**‘THE REAL THREAT IS
INTEGRATED SURVEILLANCE.
I’M A MIDDLE-AGED FAT GUY;
I WALK INTO A SUPERMARKET
AND IMMEDIATELY THEY START
ADVERTISING FOR CROISSANTS.’**

TONY PORTER,
U.K. SURVEILLANCE CAMERA
COMMISSIONER





WATCHING

ATMOSPHERE

These tiny U.S. Navy drones (basically just aerodynamic circuit boards) were designed to be carried aloft and then dropped as a swarm. They could be used for many applications, such as monitoring hurricanes, setting up a trip wire along a border, or guiding farmers as they seed a field.

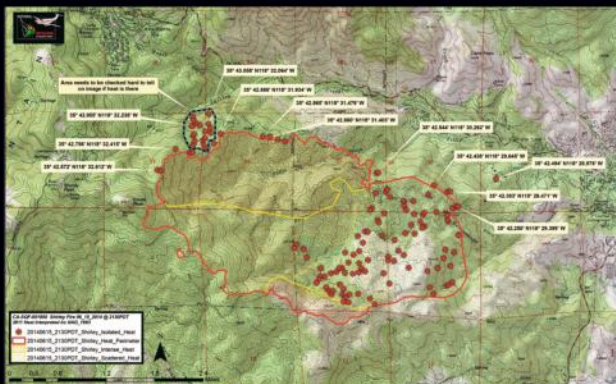
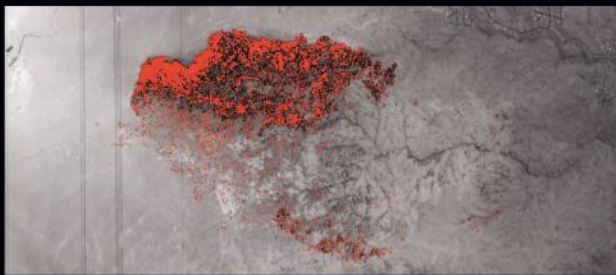
MARK THIESSEN, NGM STAFF

WATCHING

FIRES

In this photograph with a long exposure (right), a U.S. Forest Service airplane banks over a wildfire near Lake Isabella, California, in Sequoia National Forest, to take images (below) with a thermal infrared scanner. The data are overlaid onto maps (bottom) to provide accurate fire perimeters so firefighters can plan their attacks, predict fire behavior, and identify threats.

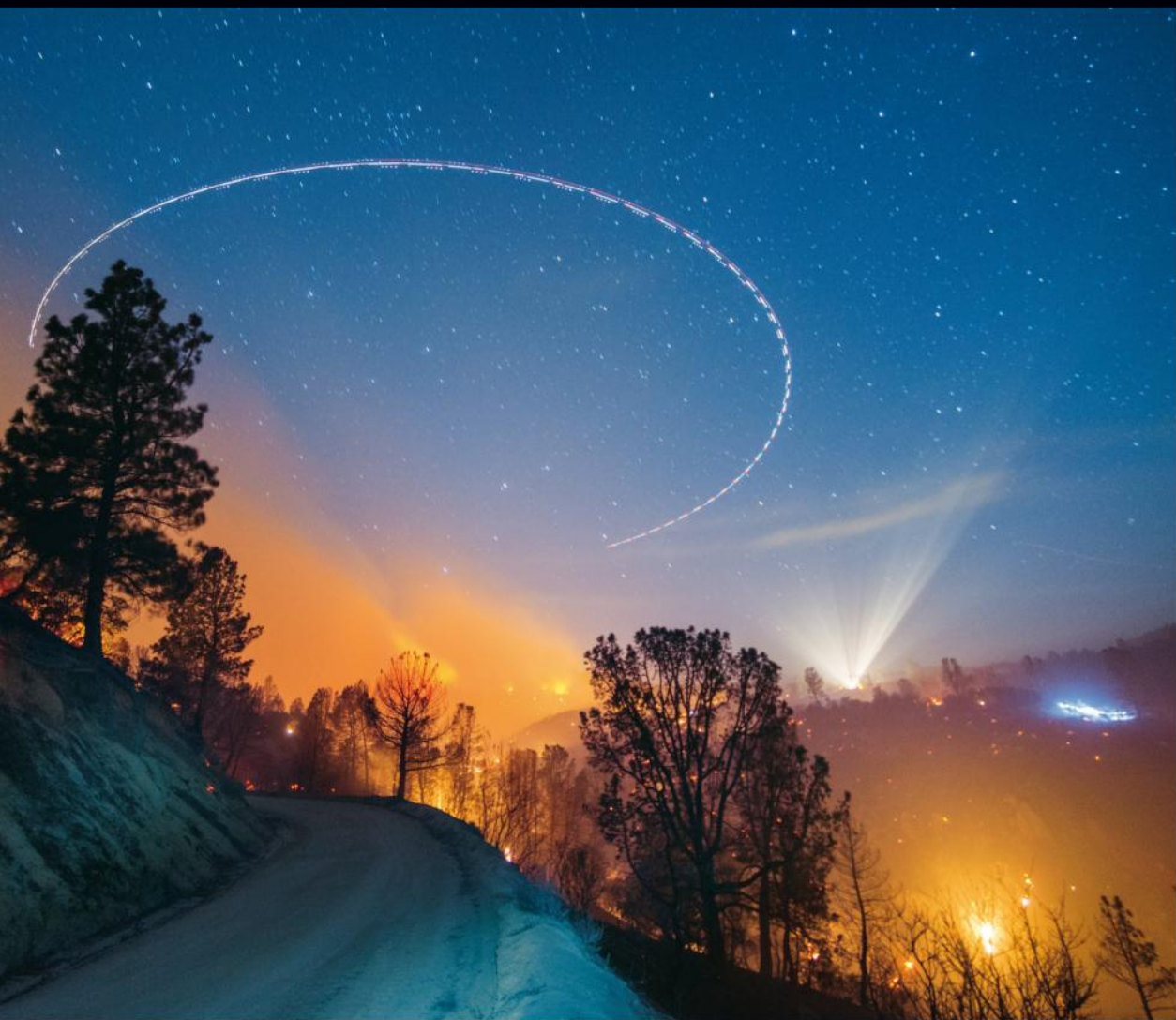
CLOCKWISE FROM RIGHT: STUART PALLEY; USDA FOREST SERVICE, NATIONAL INFRARED OPERATIONS (TWO)



building construction in South America, the expansion of illegal palm oil plantations in Africa, and crop yields in Asia. In the company's conference room, James Crawford, the chief executive, opened his laptop and showed me aerial views of Chinese oil tanks, with their floating lids indicating they were about three-quarters full. "Hedge funds, banks, and oil companies themselves know what's in their tanks," he said with a sly grin, "but not in others', so temporal resolution is extremely important." Crawford's firm also employs Planet's optical might to charitable ends. For example, it conducts poverty surveys in Mexico for the World Bank, using building heights and car densities as proxies for economic well-being.

Meanwhile, Planet's marketing team spends its days gazing at photographs, imagining an interested party somewhere out there. An insurance company wanting to track flood damage to homes in the Midwest. A researcher in Norway seeking evidence of glaciers eroding. But what about ... a dictator wishing to hunt down a roving dissident army?

Here is where Planet's own ethical guidelines would come into play. Not only could it refuse to work with a client having malevolent motives, but it also doesn't allow customers to stake a sole proprietary claim over the images they buy. The other significant constraint is technological. Planet's surveillance of the world at a resolution of 10



feet is sufficient to discern the grainy outline of a single truck but not the contours of a human. Resolution-wise, the current state of the art of one foot is supplied by another satellite imaging company, DigitalGlobe. But for now, only Planet, with its formidable satellite deployment, is capable of providing daily imagery of Earth's entire landmass. "We've run the proverbial four-minute mile," Marshall said. "Simply knowing it's possible doesn't make it any easier."

Still, Planet has blazed a trail. Others someday will follow it. When they do, how will they harness the power to see so much of the globe, every single day? Will their aims be as benevolent as those of Planet? Will they try to perfect satellite

photography that's higher in resolution and thus in invasiveness? Marshall doesn't see how this is possible. "To identify a person from 300 miles away, you'd need a camera the size of a bus," he told me. And in any event, he added, an American firm seeking to accomplish that would encounter considerable federal regulatory hurdles.

Of course, regulations can be changed. So can the boundaries of our technological limits. Just a year or two ago, the owner of the largest number of functioning satellites in orbit was the U.S. government, with roughly 170. Now Planet prevails over the heavens in greater numbers than the most powerful nation on Earth.

Who is next in line to be the Biggest Brother?

ON A BRACING AUTUMN EVENING in San Francisco, I returned to Planet to see the world through its all-encompassing lens. More than a dozen clients would be there to show off how they're using satellite imagery—what it meant, in essence, to see the world as it's changing.

I zigzagged among semicircles of techies gathered raptly around monitors. Everywhere I looked, the world came into view. I saw, in the Brazilian state of Pará, the dark green stretches of the Amazon jungle flash red, prompting automatic emails to the landowners: *Warning, someone is deforesting your land!* I saw the Port of Singapore teem with shipping activity. I saw the croplands of southern Alberta, Canada, in a state of flagging health. I saw an entire network of new roads in war-ravaged Aleppo, Syria—and for that matter, a new obstruction in one of those roads, possibly a crater from a bomb attack. I saw oil well pads in Siberia—17 percent more than in the previous year, a surprising sign of stepped-up production that seemed likely to prompt frantic reassessments in the world's oil and gas markets.

A tall young man named John Goolgasian wanted to show me how his less than year-old Virginia-based outfit called GeoSpark Analytics was matching crime data with Planet images. After a few clicks, we were staring at neighborhoods in Nigeria that had been overtaken by the extremist group Boko Haram. More clicks and the crescent-shaped coastline that materialized was one I'd visited nine years before: Mogadishu, Somalia, bearing fresh scars from that week's deadly bomb attacks by al Shabaab. A few more clicks and the image was even more familiar: my neighborhood in Washington, D.C.—specifically, a few blocks from my house, where a burglary report had just been called in.

Planet's hosts halted the show-and-tell to say a few words. Andy Wild, the chief revenue officer, spoke of the new frontier in a slightly quavering voice. It was one thing to achieve, as Wild put it, "a daily cadence of the entire landmass of the Earth." Now the custodians of this technology had to "turn it into outcomes." Tom Barton,

WATCHING

THE STREET

Dubbed the "fifth largest intelligence agency," more than 850,000 volunteers—retirees outfitted with official red vests or armbands—are the eyes and ears of their Beijing, China, neighborhoods. Out in force on holidays, they help direct traffic, give visitor information, and check in on the infirm. But they're most known for monitoring the streets for suspicious behavior.

MARK LEONG



the chief operating officer, said, "I hope one year from now, we're here saying, 'Holy shit, we really did change the world.'"

I was pondering the implications of this when a young woman showed me what was on her laptop. Her name was Annie Neligh, an Air Force veteran who now leads "customer solutions engineering" at Planet. One of Neligh's customers needing a solution was a Texas-based insurance company. The company suspected that it was renewing insurance policies for homeowners who weren't disclosing that they'd installed swimming pools—a 40 percent loss on each policy for the company. So it had asked Planet to provide satellite imagery of homes in Plano, Texas.

Neligh showed me what she'd found. Looking at a neighborhood of 1,500 properties, we could



clearly see the shimmering shapes of 520 small bodies of water—a proportion far in excess of what the insurance company’s customers had claimed. Neligh shrugged and offered a thin smile. “People lie, you know,” she said.

Now her client had the truth. What would it do with this information? Conduct a surprise raid on the somnolent hamlets of Plano? Jack up premiums? Order images that might show construction crews installing new Jacuzzis and Spanish tile roofs? The future is here, and in it, truth is more than a kindly educator. It is a weapon—against timber poachers and burglars and mad bombers and acts of God, but also against the lesser angels of our nature. People lie, you know. The age of transparency is upon us.

As I walked back to my hotel, I thought about

the two moped riders in Islington, as I often had in the months since I surveilled them. I wondered if they had been arrested. I wondered if they were guilty of anything at all, apart from the crime of being conspicuously interesting on an otherwise dull morning. I wondered if they would ever know that unseen strangers had been watching them, just as a stranger might now be watching me—someone somewhere squinting into a CCTV monitor at the spectacle of a lone figure walking fast on a dark and otherwise vacant street on a chilly night without a coat on, as if in flight from something. □

Robert Draper is a contributing writer for the magazine. His previous feature, about young technology entrepreneurs in Africa, ran in the December 2017 issue.

A large colony of albatrosses is shown on a rocky coastline. The birds are densely packed on the ground, many sitting on nests. In the foreground, a large, dark wing of an albatross is visible, extending across the top of the frame. The background features a blue ocean and a sky with scattered white clouds. The overall scene is a vibrant and detailed depiction of a wildlife colony.

Where Wildlife Is in Charge

The Falkland Islands, an isolated archipelago in the South Atlantic best known for sheep and a very brief war, offer a living lesson in the power of preservation.

Steeple Jason, one of the more remote islands, hosts the world's largest colony of black-browed albatrosses. Once used to graze hundreds of sheep and cattle, it's now a nature reserve. About 70 percent of the black-browed albatross population nests in the Falklands.




Gentoo penguins swim at the fastest speed clocked for a bird: 22 miles an hour. They'll spend the entire day hunting in the ocean, generally close to shore, and trying not to be hunted by seals, sea lions, and orcas. The Falkland Islands shelter the most gentoo breeding pairs in the world.







An underwater photograph of a kelp forest. The scene is dominated by large, dark brown tree kelp stalks that rise from a rocky seabed. The kelp has long, thin, green blades that create a dense canopy. In the foreground, a large, dark brown, heart-shaped sun star is attached to a rock. The seabed is covered in colorful, low-growing marine life, including red and orange corals and sponges. The water is clear and blue, with light filtering through the kelp canopy. In the top right corner, there is a block of white text.

A sun star clings to tree kelp in the chilly South Atlantic off the coast of Bird Island in what looks like an underwater rain forest. The ridges that form the Falklands force nutrients up from the deep, creating a rich marine world that attracts all manner of fish, mammals, and birds.

Story and Photographs by Paul Nicklen

On the rocky shores of Steeple Jason, a distant island in the Falklands archipelago, I am awed by the magnificence before me. More than 440,000 black-browed albatrosses, the world's largest colony, nest on steep cliffs. Along the beach below, southern rockhopper penguins call loudly. The always relentless striated caracaras—known as Johnny rooks—scout for penguin chicks or carrion to eat.

The frigid waters host South American fur seals, orcas, Commerson's dolphins, Peale's dolphins, and sei whales. Underwater I swim through a majestic kelp forest that sways gently. Gentoo penguins dart above me, southern sea lions in hot pursuit. Lobster krill line up on the seafloor, pincers raised, as if for battle.

The imagery is fitting. I am, after all, in the Falklands. War is a common theme. About 250 miles off the coast of Argentina, the British territory consists of more than 700 islands and islets, sparsely settled by about 3,200 people. Best known for the long history of disputes over the land, involving France, Spain, Argentina, and the United Kingdom, the archipelago wears the scars of war openly. The last conflict, when Argentina invaded the islands it claims as the Malvinas in 1982, ended after a brief but intense engagement with the United Kingdom. Roughly 20,000 land mines have not been accounted for, burned-out helicopters mar the landscape, and the Royal Air Force still has an active airfield on East Falkland.

But for all the conflict—and despite extensive sheep farming—the islands appear surprisingly utopian. From the nutrient-rich ocean waters to the rain-sprinkled mountains, I've rarely encountered such an intact ecosystem in almost three decades as a photographer.

Steeple Jason and neighboring Grand Jason, two islands untouched by war, might be the greatest Falklands success stories. Sheep and cattle grazed relentlessly on the otherwise uninhabited islands for nearly a century before a British bird lover acquired them in 1970. He turned the islands into a private sanctuary, and the vegetation began to recover. In the 1990s, New York hedge fund pioneer Michael Steinhardt bought the islands, and in 2001 he and his wife, Judy, donated them to the Wildlife Conservation Society, which owns and

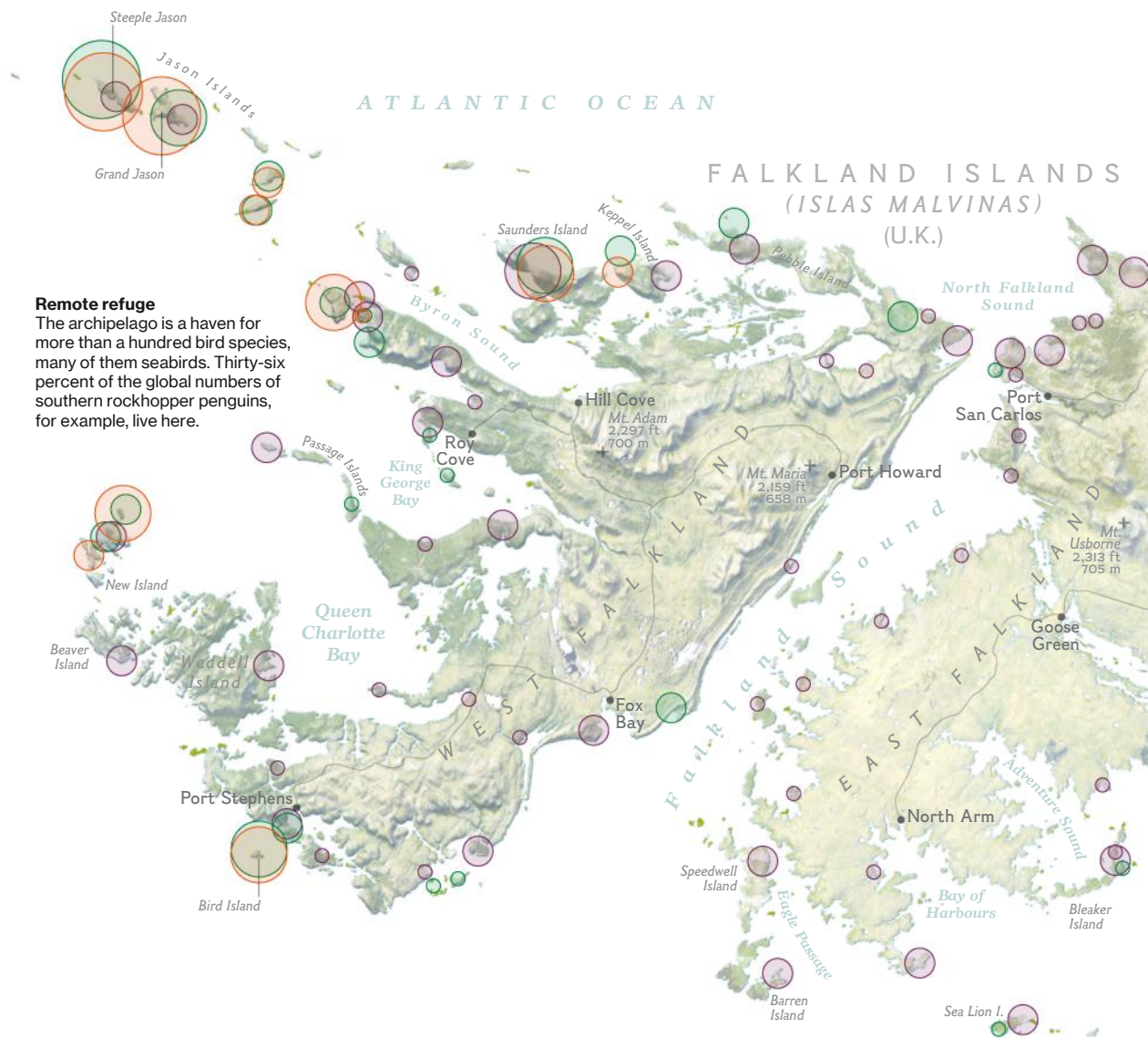


■ Society Grant

Your National Geographic Society membership helped pay for photography for this feature.



A male southern sea lion, about nine feet long and 800 pounds, looms over a female and two pups on an island informally known as Stick-in-the-Mud. The population declined in the mid-20th century when the animals were hunted and also had trouble finding food in a period of warm ocean temperatures. Now they're the most abundant marine mammal in southern South America, with about 7,500 in the Falklands.



Remote refuge
The archipelago is a haven for more than a hundred bird species, many of them seabirds. Thirty-six percent of the global numbers of southern rockhopper penguins, for example, live here.

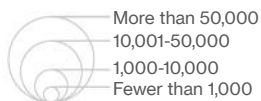
Sanctuary at Sea

About 3,200 people call the long-contested Falkland Islands home, leaving much of the British territory to wildlife. The habitat is so vital to certain seabird species that harm to their environment can affect their worldwide numbers.

Breeding colony species

- Black-browed albatross
- Gentoo penguin
- Southern rockhopper penguin

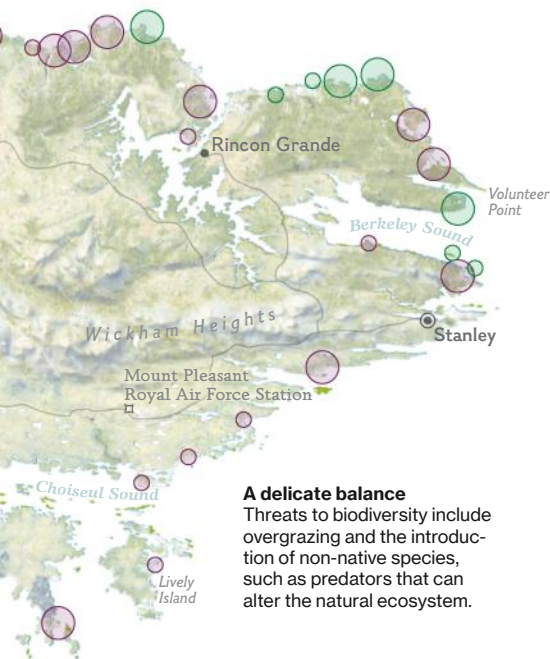
Number of breeding pairs*



*LOCATION DATA ARE FROM 2015. BREEDING-PAIR ESTIMATES ARE BASED ON THE LATEST ISLANDWIDE CENSUS, FROM 2010.

LAUREN C. TIERNEY AND IRENE BERMAN-VAPORIS, NGM STAFF
SOURCES: FALKLANDS CONSERVATION; FALKLAND ISLANDS GOVERNMENT MINERAL RESOURCES DEPARTMENT; IBRU, DURHAM UNIVERSITY, U.K.; INSTITUTO GEOGRÁFICO NACIONAL, REPÚBLICA ARGENTINA; ESRI





A delicate balance
Threats to biodiversity include overgrazing and the introduction of non-native species, such as predators that can alter the natural ecosystem.

CONTRADICTION CLAIMS

Britain and Argentina warred over the islands in 1982, and both claim them. Tensions remain as interest in oil and gas exploitation grows.

- Claimed by Argentina
- Claimed by United Kingdom
- U.K. oil and gas exploration areas



manages them. Researchers and tourists have been allowed only on carefully controlled visits.

Fast-forward to today, and the resiliency of nature is in evidence everywhere around me. The diversity on display is as if the Pacific Northwest, the West Indies, and Antarctica had collided in the South Atlantic. On five-mile-long Steeple Jason, 48 bird species have been observed. But the extraordinary profusion of Falklands wildlife still faces man-made risks: pollution, degraded habitat, oil slicks, baited hooks dragged behind fishing vessels, and, notably, climate change. The ocean may cool around the islands and warm farther away, disrupting the food web that nourishes seabirds and marine mammals. Increased oil exploration near the islands has also raised concerns about a devastating spill. The Falkland Islanders, though, have a growing incentive to embrace conservation. With more than 60,000 tourists visiting a year, ecotourism is now the second largest source of revenue, behind fishing and ahead of sheep farming.

As a trained biologist, I can't help but be obsessed with the difference between the islands left alone and the islands touched by our heavy hand. What can we learn from Steeple Jason's abundance? There is hope, and there is healing, if we choose to let nature be. Exploring the island's sloping grasslands and looming mountains is like walking back a thousand years in time. The ecosystem pristine. The wildlife extravagant. The animals unafraid of us.

Mischievous Johnny rooks try to steal items out of my camera bag. Albatrosses hover overhead, suspended on the constant updrafts that blow off the Atlantic. One taps the back of my head lightly with its feet as it passes above me. I imagine it does so on purpose; these are precise birds. Where else can animals feel so free to engage in play with the likes of us? More important, how can we help them remain so unafraid? If we keep treating our fragile Earth simply as a place for resources to be extracted, it will continue to suffer. I see Steeple Jason as a testament to Earth's resiliency but also a call for urgency. We need more Steeple Jasons, more places where we stop waging war on the environment and give nature the time it needs to flourish. □


Paul Nicklen, a photographer, filmmaker, and marine biologist who was raised in the Canadian Arctic, has documented wildlife around the world for *National Geographic*.



Eggshells lie scattered where they were discarded by predators, including brown skuas, which dine primarily on other birds. On Steeple Jason, birds are the main threat to albatrosses and penguins. Adult albatrosses and penguins guard their nests until chicks can defend themselves.





An underwater photograph showing two Peale's dolphins in the lower-left corner, swimming towards the right. The water is a clear, vibrant green. Large, brownish-yellow kelp fronds are visible in the upper and middle sections of the frame, extending from the top towards the center. The lighting is bright, creating a clear view of the dolphins and the surrounding marine environment.

Near New Island, Peale's dolphins swim by kelp growing close to shore, where they often search for food. Native to the Falklands and southern South America, they typically travel in groups of between two and 20. They can be acrobatic and appear to enjoy surfing the bow waves of boats.



King penguins stroll on the white sand of Volunteer Point on East Falkland island. Small numbers were seen in the islands in the 1860s, but in the 1970s the population began to increase steadily. A thousand breeding pairs now frequent the beach, which became a private reserve 50 years ago.





FEEDING CHINA

In spring, farmers plant seedlings in their plots in the traditional Laohuzui rice terraces, some still prepared with plows drawn by water buffalo. China has turned more to industrialized agriculture, but small farmers still play a critical role.



The nation's booming appetite is reshaping its agriculture—and the world's.





A couple enjoy afternoon tea at a luxury hotel in Shanghai with a view of the new financial district. As the Chinese become wealthier, their tastes are becoming more Western. The country is consuming more meat, dairy, and processed foods.





This chicken-processing factory northwest of Shanghai, one of China's largest, employs about 1,500 workers and handles more than 10,000 birds an hour. Operated by CP Group, a Thai conglomerate, the plant supplies fast-food restaurant chains.



By *Tracie McMillan*
Photographs by *George Steinmetz*

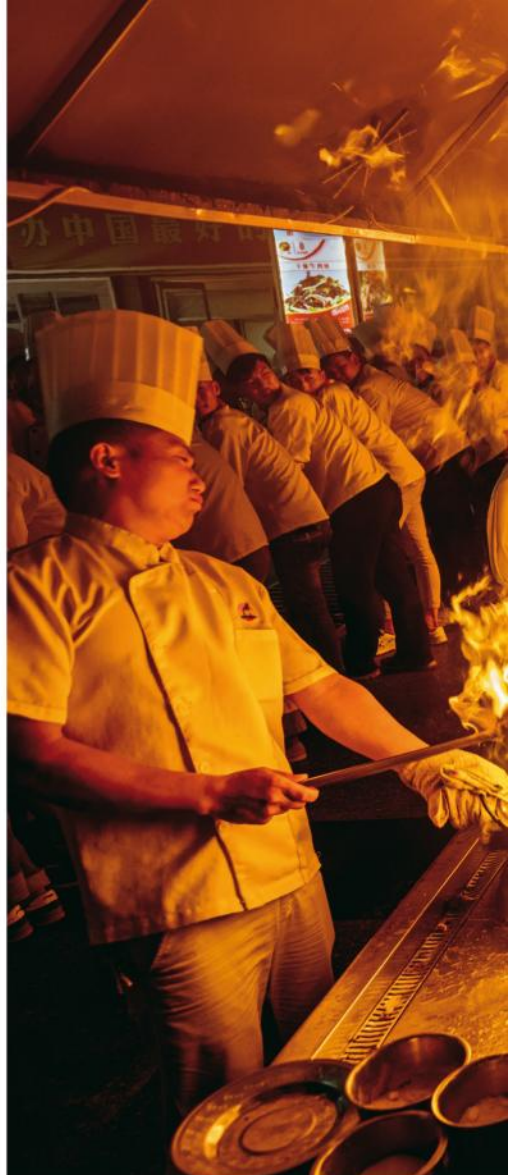
Watching Jiang Wannian and Ping Cuixiang harvest a sixth of an acre of daikon seed in the north-central province of Gansu feels a little like traveling back in time.

In a dry valley ringed by dusky mountains, on a brick-paved lot, Jiang drives a rusted tractor over a hip-deep mound of dried plants. As they crush down, Ping, Jiang's wife, plunges a home-made pitchfork into the straw and arranges it for another pass. Eventually Jiang and Ping work side by side, wiry figures with tawny skin. It's hot, but they are swaddled in clothes to protect themselves from the dust and the sun. They have handsome faces, taut and lined from years of laboring outdoors, and they turn them skyward as they throw fine chaff up and watch ruddy seed rain down. This rhythm continues for hours. In a singsong voice Ping encourages the wind, murmuring, "Blow, blow!" Machines can do this work in minutes, but they are too expensive for Jiang and Ping. Instead they still thresh the daikon by hand, just as farmers did centuries ago.

Jiang and Ping represent one story of China and its farms. More than 90 percent of all farms in China are less than 2.5 acres, and the average farm size is among the smallest in the world. But this is not the only story. Over the past four decades China has caught up to the agricultural development that took the Western world 150 years to achieve—and reimagined it to boot. Every kind of agriculture is now happening all at once: tiny family farms, gleaming industrial

meat factories and dairies, sustainably minded high-tech farms, even organic urban ones.

China is grappling with a daunting conundrum: how to feed nearly one-fifth of the world's population with less than one-tenth of its farmland, while adapting to changing tastes. Thirty years ago about a quarter of the country's people lived in cities, but by 2016, 57 percent of the population was urban, living in a China that is wealthier and more technologically advanced, with a diet that increasingly resembles that of the West. The Chinese eat nearly three times as much meat as in 1990. Consumption of milk and dairy quadrupled from 1995 to 2010 among urban





Using superheated woks, students at Shandong Lanxiang Senior Technical School are learning how to stir-fry. The school's 5,500 future chefs are taught to prepare foods in the traditional way as well as for the changing Chinese palate.

residents and nearly sextupled among rural ones. And China now buys far more processed foods, increasing about two-thirds from 2008 to 2016.

Because China's agricultural resources are so modest, supplying this new diet means heading abroad, leading the government to encourage—and help—Chinese companies to acquire farmland and food companies in places like the United States, Ukraine, Tanzania, and Chile. But China has long prized self-sufficiency in staple grains, as an ideology and a response to political isolation, and this has implications for fields at home too. In 2013 President Xi Jinping, discussing food policy with rural officials, told them, “Our rice bowl

should be mainly loaded with Chinese food.” This raises a tricky question: If the Chinese are going to feed themselves and eat more like Americans, what does that mean for the way they farm?

THE MISMATCH BETWEEN agricultural supply and demand in China can seem insurmountable. There are 334 million acres of arable land, of which roughly 37 million are polluted or set aside for restoration. There are 1.4 billion people to feed, but the giant farms that fuel Western diets are nearly impossible to replicate here. That is partly because much of China's terrain is mountains or desert but also because the

farmland is split among about 200 million farms. China's agricultural landscape looks less like a blanket of green than a patchwork quilt.

Jiang and Ping's patches adjoin their village—mud-walled houses arrayed in clutches along paved streets that dead-end in cornfields. Their area is known as Team Seven, a remnant of the collective period under Mao Zedong, when the state told farmers what to farm and took most of what they produced. Jiang and Ping lived through the great famine in the late 1950s and early 1960s; Jiang can recall eating boiled bark and leather belts when food ran out. After the collective system ended in 1981, the state kept ownership of the land but distributed the rights to cultivate it equally among villagers.

That process gave Jiang and Ping less than three acres divided among four sites. They dispatch their daughter, a 36-year-old tour-company worker visiting her parents from Kunming,

The small fragmented nature of Chinese farms is the crucial difference from Western ones, and it's antithetical to the way much of the industrialized world produces food. If China is to meet its changing appetites with domestic crops, "there are a number of changes that we need," says Huang Jikun, an agricultural economist at Peking University. Irrigation must be upgraded, he says, and technology and mechanization need to expand. But the first thing that feeding China from home requires, he says, is enlarging the country's small farms.

The solution might seem simple: replace the patchwork quilt with a vast blanket that can be mowed down in one fell swoop. But Huang cautions that big isn't always best. China's staple crops of corn, rice, and wheat all yield the most food per acre at modest scales: One study suggested the sweet spot is between five and 17 acres. "If you've got a very small farm, a farmer

ONE CHALLENGE: GETTING MORE OUT OF CHINA'S PATCHWORK

1,200 miles away, to show me their farm. Under hot, clear skies Jiang Yuping, wearing white jeans, knockoff Vans, and a melon-colored off-shoulder blouse, leads me to the end of the street. I see a tiny, mud-walled building adjacent to an irrigation canal and ask why an outhouse is placed so close to water. She blinks. "It's like a temple for worship," she says, eyeing me skeptically. As I apologize, she turns to point out her family's stevia fields, an acre patch of short, emerald-hued plants bound for sweetener. We walk farther, and she shows me the family's half acre of flaxseed, planted beneath a factory's spindly chimney. A couple kilometers down a two-lane highway are the daikon, lettuce, and corn plots. Later she talks about her parents and how she wishes their farm could be more like an American one. "Look at China: Most land is difficult to manage," she tells me. "There is a waste of human labor and resources."

is out there weeding and working very intensely," notes Fred Gale, a senior economist at the U.S. Department of Agriculture, and crop yields per acre will reflect that, often being higher than if a large machine is used. China's plan is not to merge the holdings of small farmers like Jiang and Ping into Kansas-style farms. That would be nearly impossible logistically and would also spur social disruption by uprooting millions of farmers. For now, at least, the idea is to cluster adjoining fields into farms about the size of a Walmart Supercenter parking lot.

Spend a few days with Jiang and Ping, and it can be hard to fathom that China also has some of the most sophisticated industrial farms in the world. The epitome of that is in the meat and dairy industries, which officials have modeled after those in the West. To see for myself, I had to go to eastern China, where I visited a four-year-old dairy bigger than most in the United States.

WALKING THE LENGTH OF A COW BARN and processing plant at Modern Farming's Bengbu Farm in Anhui Province, the largest dairy farm in China, took me almost five minutes. It was dim and cool, and there was a sweet smell, half animal and half decay, that wasn't quite unpleasant. The cows, black-and-white mottled Holsteins, were quiet. They poked their heads through slotted metal fencing to reach feed along the concrete walkway and eyed me, a white-clad interloper in sterile coveralls, galoshes, bonnet, and face mask, with mild interest. The farm, nearly 600 acres, has eight enormous barns built to hold 2,880 milking cows each. Other barns and sheds hold calves and pregnant cows, putting the farm's maximum bovine population at 40,000, among the largest in the world. Part of industrial agriculture's allure is the sheer scale of it, and China has succumbed to this as it has expanded its meat and dairy production. China has always

SYSTEM OF SMALL FARMS.

prized pork in its diet, and hogs were traditionally raised—and slaughtered—in backyard plots; as recently as 2001, farms with more than 50 hogs made up just a quarter of the market. By 2015 an estimated three-fourths of China's hogs were being produced on such farms. An expanding appetite for poultry and eggs also has been answered by industrial farms. But perhaps the most surprising industrialization has been at dairy farms like the one I visited in Bengbu. Traditional production had been household based, as hogs were, but after a 2008 food-safety scandal involving fatally contaminated infant formula, China pushed the industry to modernize. In 2008 nearly one in six dairy farms held 200 or more cows. By 2013 more than one in three did.

It's difficult to overstate the importance of food safety to Chinese consumers. Besides fatal levels of melamine in baby formula, scandals have included long beans treated with a banned

pesticide and adulterated fox meat passed off as donkey. A 2016 McKinsey & Company study found that nearly three-quarters of Chinese customers worry that the food they eat is harmful to their health. The vast number of small farms makes China's food system "almost completely unmanageable in terms of food safety," says Scott Rozelle, an expert on rural China at Stanford University. Industrial dairies and slaughterhouses make traceability and accountability for quality possible, and this is something Chinese consumers want. Indeed a colloquial phrase traditionally used to describe being at ease, "Put your heart down," has been repurposed. Farmers repeatedly assured me that I could put my heart down with their food; it was, in other words, safe to enjoy.

At Modern Farming's dairy, officials introduced me to an employee, Zhang Yunjun, whose family home had been where the offices now stand. The Bengbu farm displaced about a hundred villagers, and the government moved them a little way down the road. People in the village cooperated willingly when officials promised jobs at the dairy, new housing, and regular increases to the rental fee for their land. Before the dairy Zhang had worked about six acres with two relatives, growing peanuts and wheat. Now 55, he tends to bedding in the barns and earns more than twice what he did farming. "People are very happy," he says. "It was really hard working as a farmer. Now I can make much more."

Nearly every proponent of large-scale farms told me some version of this story, saying that big farms are effective solutions to poverty in rural areas. Farmers, the thinking goes, can work for the big farm and rent out their land, earning two incomes at once. But the reality doesn't always match the sales pitch. "They do employ people, but it's very limited," says Ye Jingzhong, a rural sociologist at China Agricultural University in Beijing. "If they want to make a profit, the first thing they want to cut is the labor employment. And they can only employ a very limited amount of low-paid farmworkers."

As the sun began to set, I visited the displaced villagers and found their enthusiasm for the dairy much thinner than Zhang's. They live in a gridded





Side by side with suburban housing just north of Kunming in Yunnan Province, these greenhouses grow high-value crops such as fruits and vegetables. In the relatively mild climate, crops are raised year-round.



An aerial photograph showing a vast outdoor dining area. The ground is paved with a light-colored, grid-like pattern. Numerous round tables are arranged in a regular grid, each surrounded by people. The tables are covered with various dishes, including what appears to be crayfish. The overall scene is a busy, organized outdoor dining event.

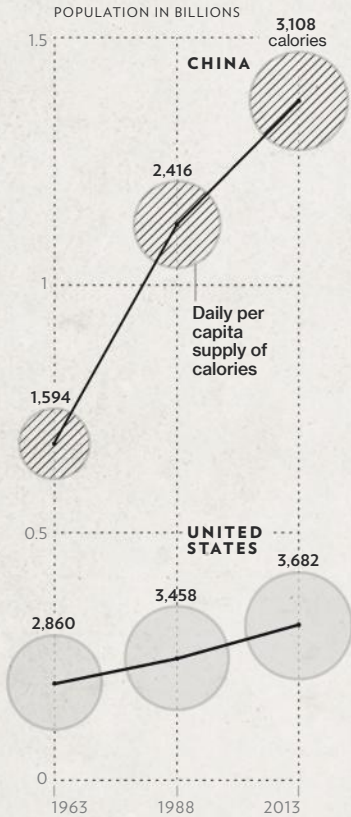
At an annual festival in Xuyi County, northwest of Shanghai, 10,000 people dine on the area's specialty: crayfish. The thriving industry raises an estimated 100,000 tons of the shellfish a year in local lakes.

AN APPETITE FOR MORE

Sweeping reforms starting in the late 1970s have transformed China from an isolated, centrally controlled economy into an increasingly market-oriented juggernaut. Agricultural and industrial modernization has fueled continuing migration to cities, rising incomes, and a growing appetite for a more westernized diet among China's 1.4 billion people.

More people and food

Economic and food-production reforms have helped China's growing population double its supply of daily calories.



RUGGED WEST
Though rich in resources like coal and oil, much of the region is plateau or desert. It is home to just 6 percent of the population.

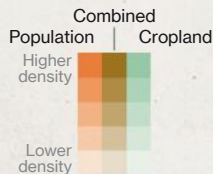


Craving protein

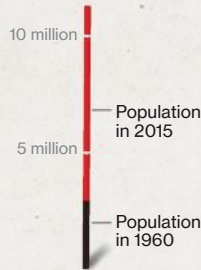
China has overtaken the United States in its daily supply of calories from meat, poultry, seafood, and offal.



LIMITED LANDS
Combined areas (brown) indicate where people (orange) are encroaching on finite cropland (green).



HIGH GROWTH
Urban areas with a population of three million or higher in 2015

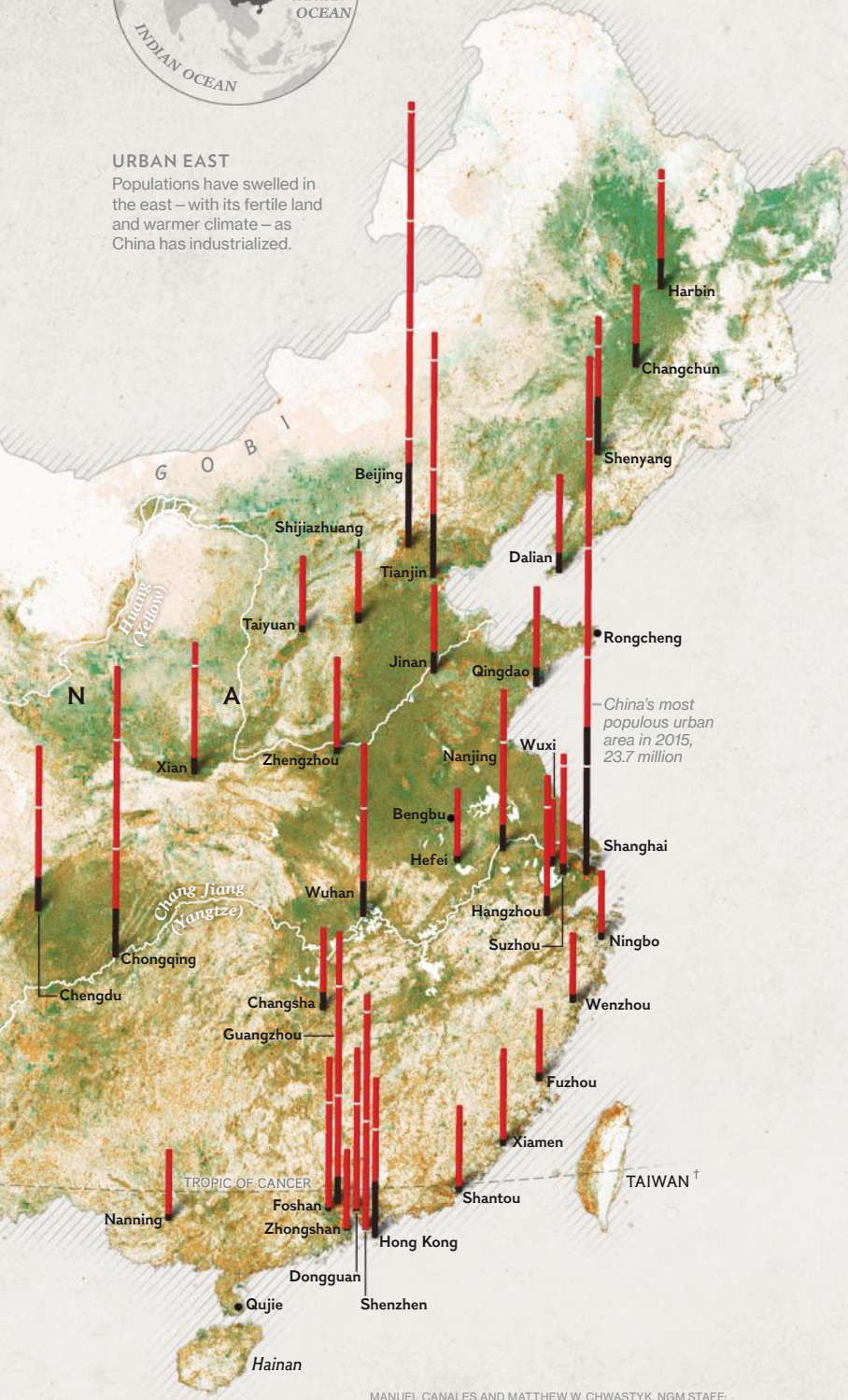


†THE PEOPLE'S REPUBLIC OF CHINA CLAIMS TAIWAN AS ITS 23RD PROVINCE. TAIWAN'S GOVERNMENT (REPUBLIC OF CHINA) MAINTAINS THAT THERE ARE TWO POLITICAL ENTITIES.



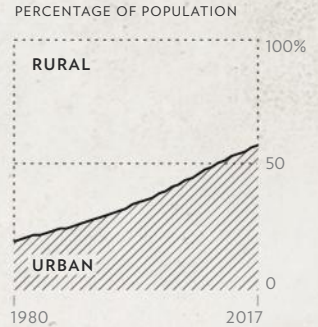
URBAN EAST

Populations have swelled in the east – with its fertile land and warmer climate – as China has industrialized.



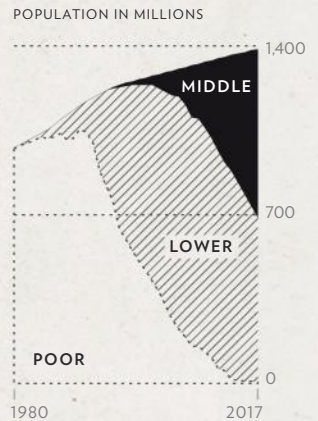
Urban migration

China's cities have grown by roughly 600 million people since 1980. Most are seeking better jobs and wages in the industrial sector.



Rising incomes

Half of China's population has now joined the global middle class, and hundreds of millions have moved out of poverty.*



THE RICH, AT 0.2 PERCENT OF THE POPULATION, ARE NOT SHOWN ABOVE.

Economic boom

China has been counted among the world's fastest growing economies for nearly four decades.



MANUEL CANALES AND MATTHEW W. CHWASTYK, NGM STAFF; AMANDA HOBBS

SOURCES: FOOD BALANCE SHEETS, FAOSTAT (CALORIES); HOMI KHARAS, BROOKINGS INSTITUTION (INCOME); WORLD URBANIZATION PROSPECTS, UNITED NATIONS POPULATION DIVISION (RURAL AND URBAN POPULATIONS); WORLD BANK AND OECD NATIONAL ACCOUNTS DATA (GDP); LANDSCAN (2016); UT-BATTELLE, OAK RIDGE NATIONAL LABORATORY; EARTHSTAT.ORG; FRED GALE, USDA

*"GLOBAL MIDDLE CLASS" REFERS TO PEOPLE MAKING \$11 TO \$110 A DAY, "LOWER" TO THOSE EARNING \$2 TO \$11 A DAY, AND "POOR" TO THOSE EARNING LESS THAN \$2 A DAY, MEASURED IN 2011 U.S. DOLLARS, ADJUSTED FOR PURCHASING POWER PARITY.

cluster of flat-roofed, two-story apartment buildings painted yellow, surrounded on three sides by peanut and corn fields. Across the road, the dairy's alfalfa fields roll into the distance. A woman hanging laundry in her small concrete yard told me the water now smelled funny. Several people told me the dairy didn't hire many workers, their homes were crumbling, and rental income had not budged in four years. Everyone complained about an inescapable stench from manure sprayed on the fields. Nobody I talked with seemed happy about having moved, but hardly anyone seemed all that upset either. The overriding sentiment was simply resignation.

For most rural Chinese these agricultural projects are at best double-edged swords, just as they are elsewhere in the world. Big animal farms can offer some Chinese an escape from the grinding toil of peasant life, but they also bring significant environmental and health risks. A 2010 census of pollution by the Chinese government found agriculture to be the largest polluter of water, greater even than manufacturing. And with all of China's pollution challenges, it's hard to see how large-scale animal production will escape the pollution and public health problems attributed to, say, dairies in California—which are smaller than the mega-farms in China.

The government says it recognizes the dangers and emphasizes addressing animal waste in a sustainable way. These concerns are shared by many of the agribusinesses in China, including Modern Farming. In Bengbu the company installed a biogas digester to turn manure into enough energy to meet one-third of its needs there and uses the by-products to fertilize its fields. "Almost no waste," says Liu Qiang, the mild-mannered, bespectacled guide who took me around the farm. The whole thing, from the fields to the barns, the milking parlors to the bottling plant, he says, is "a demonstration for this country."

ACROSS HANGZHOU BAY from Shanghai, at the edge of a shimmering expanse of mudflats, a Thai animal-feed conglomerate is building a megafarm with a sustainable bent. In exchange for a break on the rent and a 20-year contract,



Charoen Pokphand, or CP Group, is converting 6,425 acres of filled-in mudflats outside the city of Cixi to food production. The goal is "to create value for society in all directions," says Wang Qingjun, a senior vice president dressed in loose slacks and shirtsleeves.

This is what China's agricultural future looks like too: a transnational corporation sinking billions of yuan into an agrifood complex comprising fields, farms, factories, corporate offices, and even, eventually, employee housing ranging from apartments to waterfront villas. Last summer, rice paddies covered 3,600 acres. Of those, 115 acres were grown organically and stocked



At an automated farm owned by CP Group, three million hens lay about 2.4 million eggs a day. Robots detect and remove dead birds, enabling a single worker to tend 168,000 chickens. Northeast of Beijing, it's the largest such facility in Asia.

with crabs that are sold for food. There are produce greenhouses, broccoli fields, drones to distribute chemicals, a near-finished dumpling factory, and a one-million-hen egg factory slated to triple in size—large enough to justify a temperature-sensitive robot to automatically cull dead birds. CP Group also expects to harvest enough chicken manure annually to produce 22,000 tons of organic fertilizer.

Last year the company built a vertical farm, an airy, translucent box housing six 30-foot towers with rotating shelves of plant beds, akin to Ferris wheels. When I visited, they held bok choy, amaranth, and garlic chives. The controlled

environment allows for targeted fertilizer application, eliminates the need for most pesticides, and produces quadruple the yield of a field with the same footprint, Wang says. This is remarkably promising for a country with too little farmland, particularly one where farmers add to the country's pollution woes by using three times as much fertilizer as needed. It also sets up CP Group to comply with the government's goal, announced in 2015, of capping fertilizer and pesticide use by 2020.

The complex is largely an exercise in applying manufacturing logic to food, and Wang, who struck me as part pragmatist, part dreamer, envisions

Workers in Rongcheng, on the Yellow Sea, hoist seaweed to dry on rotary racks. A common food in the Chinese diet, it is usually added to pork or soup or used in a cold vegetable dish. Different kinds of seaweed are also harvested to feed to abalones.





it as a paragon of vertical integration. “The relationship of human and land should be in harmony,” he says. He sees the food-manufacturing system that CP Group is building as a way to accomplish that. For eggs that means growing grain for poultry feed, breeding chickens, then slaughtering and processing them once they are spent. Dumpling dough will be made from CP Group wheat and filled with the company’s meat and produce. To sell its products, the company has its own grocery stores. It’s an impressive vision, if nothing goes awry. But if, say, listeria were to end up in its fruits, contamination could spread far more widely and rapidly than in a decentralized system—as Americans have learned.

Nearly all the large-scale farms in China are run by the government, cooperatives, and businesses, but I also met Liu Lin, a farmer in Inner Mongolia who has become well-off by growing alfalfa for industrial dairies. As a teenager Liu heard a radio broadcast about American farming and its use of machines to till the land. This sounded better than breaking up soil by hand with a hoe, and he became obsessed. Over time Liu persuaded local governments to rent him about 2,470 acres. He bought sophisticated agricultural machines from the U.S. and Europe that, in four hours, could finish what had taken 30 workers 20 days to do.

By the time I met Liu last summer, his farm had several giant barns, barracks for workers, a set of offices and carpools, and a two-story villa overlooking a pond. I watched, impressed, as a French silage baler rumbled across a field. In 89 seconds it vacuumed up mowed alfalfa, compressed it into a 1,700-pound cylinder, encircled it in plastic, and discharged it onto the field.

Later Liu took his car, a Lexus SUV, to town to get it washed; his daughter-in-law drove me to meet him in her husband’s Lexus sedan, playing Amy Winehouse on the stereo. In the din of the car wash, I asked how much he earns: More than 10,000 yuan—\$1,505—a month? I couldn’t hear his response, but I saw him smile. Later my interpreter told me he had emphatically said, yes, he made more than that—a lot more.

I thought of Liu during my visit to CP Group’s



park and corporate offices, where it’s easy to intuit another less discussed selling point of giant farms: money. Experts may debate what size farm will produce the most food per acre, but industrial farms still generate profit far more readily than small ones. CP Group is working to ensure that; the group has hired leading American business academics, as well as consultants such as McKinsey & Company, to help it succeed.

When I visited the Cixi park in August, it was sweltering and humid, and Wang whisked me into a highly air-conditioned boardroom for a PowerPoint presentation. We moved on to lunch in an executive dining room with a wall



Noodles dry at a factory owned by COFCO, a state-owned enterprise, in Zhengzhou, in east-central China. Chinese consumers now eat some 90 million tons of processed food a year, increasingly preferring its convenience.

of windows overlooking the grounds, about a dozen of us seated at a heavy wooden table with a rotating center. I was given the seat of honor, at Wang's right, and we grazed on the 27 dishes arrayed on the lazy Susan, including grapes and dragon fruit from the park's greenhouses. Wang offered me red wine and, in keeping with Chinese custom, praised me warmly. It was the most lavish meal I ate in China.

EVEN AS CHINA STRIVES to scale up its agriculture, many affluent urbanites have leapfrogged ahead to a distrust of industrial farming. A compelling example of this can be found north

of Beijing, where Jiang Zhengchao, the son of Jiang and Ping, is helping build the latest addition to China's agricultural future. Behind two squat concrete buildings next to a roaring freeway, he tends five acres that make up his patch of China's agricultural quilt.

Jiang grows nearly a hundred crops—watermelon, eggplant, taro, and sweet corn among them. He takes some to wholesale markets, but his primary business is persuading middle-class Beijingers to pay him in six-month installments for weekly delivery of safe, farm-fresh food to their door. He also rents plots to people who want to grow food, and for an extra fee, he will tend





Calves live in hutches at Modern Farming's Bengbu Farm in Anhui Province. With at least 36,000 cows, it's the largest dairy operation in the country. Dairy consumption has skyrocketed in China since the 1990s.



In Qujie, in southern Guangdong Province, children eat a hearty breakfast of noodles, eggs, and meat outside their school. Many families now have two working parents, leaving less time to make meals at home the traditional way.

them. After beginning his business without pesticides and fertilizers, he now uses them sparingly; customers balked at pitted vegetables and undersized fruit. “I have this emotional bond” with farming, says Jiang, who has a degree in social work. He worked three years in an office, which he hated. Eventually he returned to farming—much to the dismay of his parents, who equate the fields with drudgery. “I cannot afford a luxury life,” he says, and he’s OK with that.

Jiang is part of a phenomenon of rural-born, college-educated Chinese going back to the fields. Though small in scale, it is still common enough that there’s a phrase for its participants,

fanxiang qingnian—young people returning to the countryside. They now have an organization dedicated to supporting their interests, Wotu Sustainable Agriculture Development Center, and a magazine catering to them called *Sustainable Farming*. China’s organic sector has boomed, with sales growing as much as 30-fold since 2006, according to a recent industry analysis. Researchers say that at least 122 community-supported agriculture (CSA) projects, with farmers following the same model as Jiang, have sprung up, but the movement claims there are hundreds. Nationwide a few Western-style farmers markets are operating, all in large cities.



For consumers the appeal of small farms is twofold. It's partly about trusting the farm to supply safe food. But smaller farms also reflect China's agricultural traditions, says Wen Tiejun, a leading scholar of rural China, and that appeals to rural and urban Chinese alike. "In Asia you have 40 centuries of agriculture," Wen says. "You not only get enough food for this big population but have a very good environment." People know and remember this, he says. In 2008 Wen helped found Little Donkey, a model organic farm in Beijing. The next year it became a CSA after one of his graduate students returned from Minnesota, where she'd studied with food activists.

This kind of food remains a minuscule share of China's market. But it suggests that many Chinese aren't completely sold on a future of industrial meals. Jiang Zhengchao understands why his parents would love to leave their farm behind, and he has no wish to repeat their hardships. But he's also skeptical that industrialized farms are necessary.

When I visited him, Jiang took me and some colleagues to dinner at a barbecue restaurant. We sat outside at a plastic table, watching a plump woman in a tight apron tend a narrow metal grill atop sawhorse legs. An industrial fan roared above it, spinning tendrils of smoke into the evening air. The woman brought us caramelized nuggets of pork and skewered chicken hearts, fibrous enoki mushrooms doused with sauce and black sesame, grilled garlic cloves, eggplant slick with oil and vinegar, boiled peanuts tossed with soy sauce. It was more meat than Jiang had eaten as a child but far less than is typical for Americans. As the light faded into dusk, elderly farmers loitered on a corner, selling off surplus scallions. Jiang told me he liked his life and later quoted poetry to illustrate what Americans tend to call living simply: an old but comfortable house, nothing too fancy, a beautiful space in the woods. "I don't think it's a bad thing in the old days that the people could support themselves from their own land," he says. "In China if you are a farmer, then people look down on you, but I just love it. Life is short, so I do what I like."

Jiang has seen the benefits of the changes that China's farms have undergone in the past four decades. Our meal with ample pork and chicken was part of that for him. So was the way his life encompassed a kind of time travel, looping between rural Gansu Province and hypermodern Beijing. But he wasn't sure he'd stick it out with the CSA; it paid so little and took so much work. Maybe, he told me, he'd go back to Gansu and try to start a big farm. □

Tracie McMillan, author of *The American Way of Eating*, wrote about hunger in the United States for the August 2014 issue of *National Geographic*. **George Steinmetz**, who has photographed assignments for the magazine for 30 years, is working on a long-term project about the global food supply.

Meet Figaro, a Goffin's cockatoo. He taught himself how to chop a piece of cardboard and make it into a tool. So forget about using 'birdbrain' as an insult. Birds, it turns out, are

Brainiacs

Toolmaking

At a research aviary in Austria, inventive Figaro shows off the device he made to retrieve a cashew. His first tool was a piece of bamboo to rake in a pebble he'd dropped outside the aviary fence.







Hunting and Navigating

Ellie, a northern goshawk owned by Lloyd and Rose Buck in England, tucks in her wings and streaks through narrow openings at high speed. Aeronautics scientists say the fierce predators assess the density of the trees and intuit how fast they can fly – ensuring that they'll find openings and not crash.



BY VIRGINIA MORELL

PHOTOGRAPHS BY CHARLIE HAMILTON JAMES



The American crows in Gabriella Mann's Seattle neighborhood love her, and the eight-year-old girl has the goods to prove it. She places a plastic jewelry box on a kitchen counter and lifts the lid.

Each small compartment holds a treasure, a gift, that the crows have given her: a gold bead, a pearl earring, a screw, a red Lego piece, colored and clear glass chips, a chicken bone, a pebble, a quartz crystal, and many more.

Though slightly soiled, all are stored as carefully as rare artifacts, dated, and categorized. Gabi selects two that she calls her First Favorites, and holds them up for me to admire. One is a pearly-pink heart charm, the other a tiny, silver rectangle with the word "BEST" engraved on one side. "It's because they love me," she says about the seemingly thoughtful objects, adding that she expects the birds will leave her a "FRIEND" charm one day. "They know everything I like—toys and shiny things—because they watch me. They're like spies."

Already that morning a crow—likely one Gabi's brother named Babyface, who has a recognizable patch of gray feathers—has brought her a dead stickleback fish, placing it where it couldn't be missed: on the stairs leading to the family's

backyard. "This is the second dead fish they've brought me. I don't know why," Gabi says as she tucks the stickleback's silvery remains in a plastic bag, affixes a dated label, and places the bag in the freezer. "They aren't my favorites. But this one's in better shape; the other one had its head cut off." Babyface also once left her the head of a baby bird. "Kind of gross." He brought a different—and from Gabi's viewpoint, more appropriate—gift that afternoon. She and her brother had dashed to the backyard to replenish the bird feeders. She filled one tray with peanuts in the shell and another with dog food. Two crows flew into the conifers. One was Babyface, and he was holding an orange object in his beak. He moved to an overhead cable, perched above

Offering Gifts

Young Gabi Mann befriended crows in her Seattle neighborhood, setting out nuts and dog food. In exchange they brought her gifts, including a pearlescent plastic heart, one of her favorites.



Gabi, and dropped the item so that it landed right at her feet. “Look! A toy!” she cried, scooping up a miniature rubber squid and spinning with joy—a dance Babyface watched from his perch. “See, he knows exactly what I like.”

Are the crows actually doing what humans do, bringing gifts to a friend because she’s been kind to them? Can a crow—or any bird—make decisions of this sort? Researchers studying crows, ravens, and other corvids (the family of songbirds that includes crows, jays, rooks, magpies, and others) say yes. Indeed the similarities among humans, other primates, and these birds have riveted scientists studying the origin of our—and other animals’—intellectual abilities. “Birds took a different evolutionary path from mammals but have arrived at seemingly similar cognitive solutions,” says Nathan Emery, a cognitive biologist at Queen Mary University, London, “so they offer a rare opportunity to understand what evolutionary pressures lead to certain mental skills.”

Even so, until this century most scientists would have scoffed at the notion of a choosy, generous crow because crows and all birds (and most mammals) were thought to be robotic simpletons, capable only of reacting instinctively to things that happened to them. Birds were dismissed as “birdbrains” even before the scientist Ludwig Edinger misinterpreted their neural anatomy, around 1900. He thought birds lacked a neocortex, the thinking area in the mammalian brain where much of our higher cognitive functioning—working memory, planning, and problem solving—occurs.

Despite this supposed mental deficit, birds were used throughout the 20th century by comparative psychologists in their animal cognition studies. They particularly favored common pigeons, whose brains are just about the size of a shelled peanut, and canaries and zebra finches, whose brains are even smaller. Pigeons, scientists discovered, have impressive memories,



Recognizing Faces

In 2006 wildlife biologist John Marzluff and one of his students at the University of Washington in Seattle donned masks like this and captured and banded seven crows. Today if Marzluff or another person puts on the mask, the crows in the area – not just the original seven – gather to scold, dive-bomb, and follow him. The crows don't pester people wearing other masks.

with an uncanny ability to distinguish human faces and expressions, letters of the alphabet, even paintings by Monet and Picasso. Other researchers revealed the remarkable memories of Clark's nutcrackers, scrub jays, and chickadees. Nutcrackers, for example, harvest and cache more than 30,000 pine seeds every autumn, distributing them in several thousand tiny caches they need to remember through the winter.

IN THE 1950S, researchers began studying how songbirds such as canaries, sparrows, and zebra finches learn their songs. They found striking similarities between birdsong and human speech. And then there was Alex, an African gray parrot whom comparative psychologist Irene Pepperberg taught to reproduce English sounds (Pepperberg emphasizes that Alex did not actually learn the English language). By the time of his death in 2007 at age 31, Alex had mastered roughly a hundred English sounds for colors, objects, numbers,

and shapes. He could clearly pronounce "green," "yellow," "wool," "wood," "walnut," and "banana," and used these sounds to communicate with people. He understood "same" and "different," could count to eight, and grasped the abstract concept of zero, or "none," as he called it. Alex used his talent to talk back, telling Pepperberg to "calm down" when she was in a bad mood, and asking to "go back" when he yearned for his home during an illness that kept him at the vet's. And he always wished her a good night, as he did just before he died. "You be good. See you tomorrow. I love you."

Yet because scientists misunderstood the avian brain, most of Pepperberg's discoveries about Alex were ignored or mocked; she feared that other researchers thought she was somehow giving Alex clues. "His brain was the size of a shelled walnut," Pepperberg concedes, "so some people thought I was making it all up or that he was cheating" (Pepperberg videotaped many experiments with Alex.) Of course, a cheating bird would also be an intelligent bird, but the upshot was simply that few scientists in cognition research recognized Alex's achievements—until a couple of years before he died. Alex's ability to imitate language—and apparently to use English words in the correct context—has spurred studies of parrots to better understand the origins of vocal learning, which is the ability to imitate purposeful sounds. This is a skill parrots share with songbirds, hummingbirds, humans, cetaceans, and a few other species.

The discoveries finally led an international team of researchers to reexamine the long-standing Edinger model of avian neural anatomy. In 2005 they issued their reevaluation, revealing that birds' brains do possess neural structures, called the pallium, that resemble the mammalian neocortex and other areas associated with sophisticated thinking. They supported adopting a new nomenclature and understanding of birds' neural anatomy.

"The parts of birds' and mammals' brains are arranged differently," explains Nicola Clayton, a psychologist at the University of Cambridge, in the United Kingdom, who studies corvid cognition. "Mammals' brains are layered like a club sandwich, while birds' brains are more like a

Bird Brainpower

Birds are far more intelligent than once believed, but not all are intellectual equals. Parrots, as well as birds in the corvid family, such as jays, ravens, and crows, are among the smartest species, thanks to proportionally large forebrains with densely packed neurons. They're also some of the most sociable, exhibiting interactive behaviors that might be expected of a primate.



Common name
Scientific name

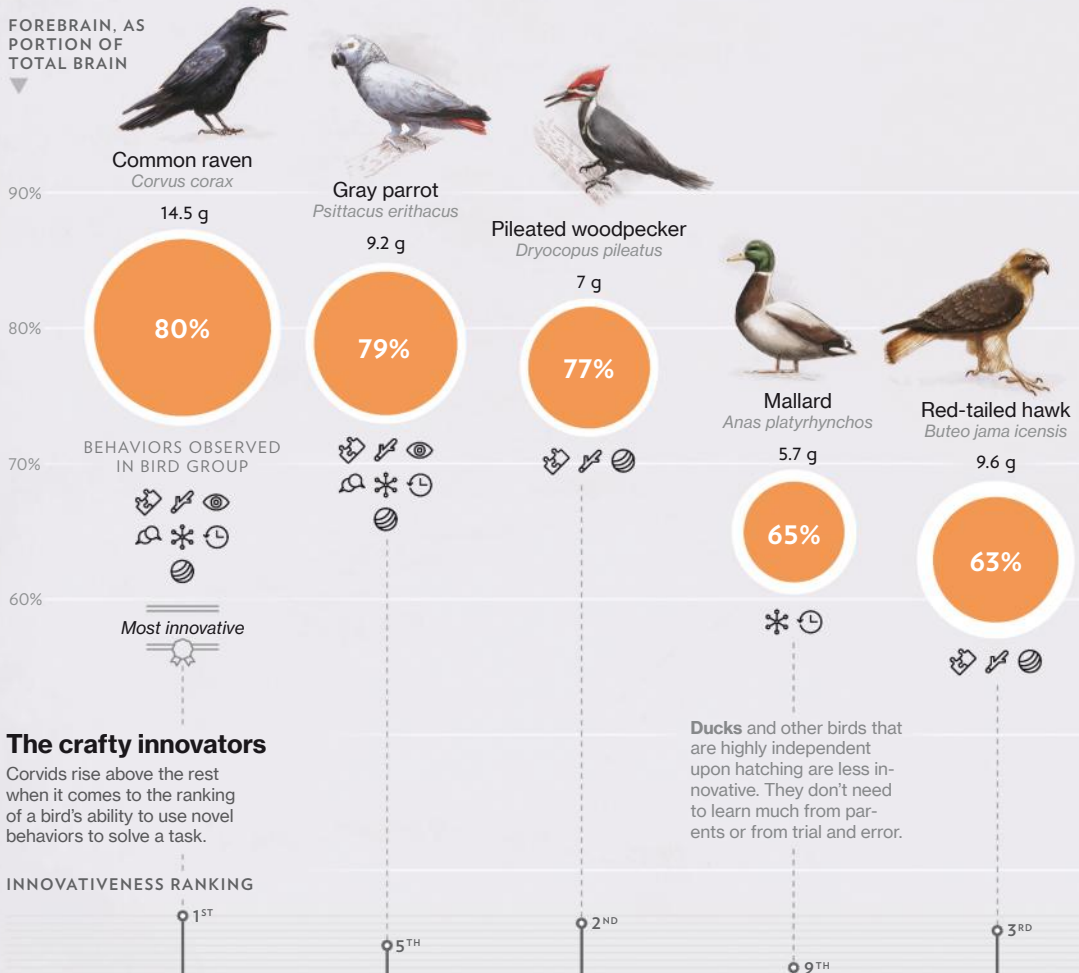
BRAIN MASS



The complex thinkers

Many brain structures involved in complex cognition are found in the forebrain. Scientists postulate that the bigger a bird's forebrain as part of its entire brain, the smarter the bird.

FOREBRAIN, AS PORTION OF TOTAL BRAIN



The crafty innovators

Corvids rise above the rest when it comes to the ranking of a bird's ability to use novel behaviors to solve a task.

Ducks and other birds that are highly independent upon hatching are less innovative. They don't need to learn much from parents or from trial and error.

Bird Behavior

Many skills displayed by birds are instinctual, but some birds are also capable of learning as they grow and adapt to their environments.



PUZZLE SOLVING
Some birds have the capacity to reason and make logical inferences.



USING TOOLS
Some can use objects – found or fashioned – to solve problems.



STUDYING OTHERS
Some species are able to learn through observing other birds' behavior.

Intellectual heavyweights

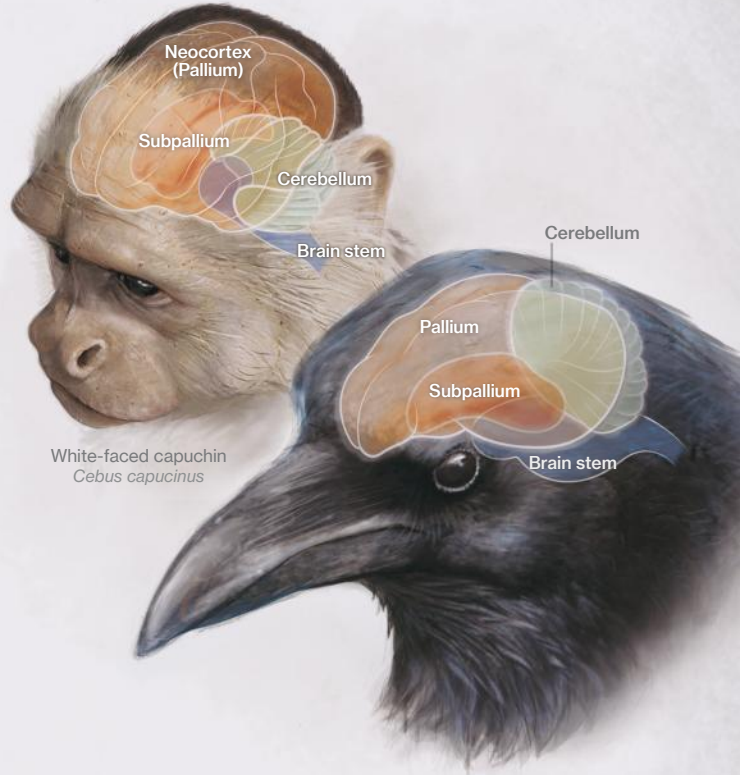
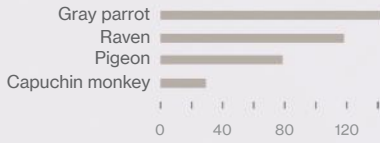
The forebrain's pallium and subpallium regions – responsible for higher-order function – evolved differently in birds and mammals. Birds' brains are smaller but more densely packed with neurons, the cells responsible for cognition.

FUNCTIONS

- Higher-order thinking; cognition
- Cognition and spatial orientation; control of voluntary movements
- Cardiac and respiratory processes

NEURON DENSITY

Pallium neurons (in millions) per brain gram



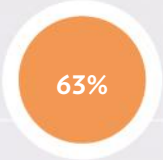
White-faced capuchin
Cebus capucinus

Common raven
Corvus corax



Great blue heron
Ardea herodias

9.3 g



4TH



Common cuckoo
Cuculus canorus

1.6 g



6TH



Chicken
Gallus gallus domesticus

2.5 g



Chickens can't be rated for innovativeness because domestication alters behavior.



Common pigeon
Columba livia

2.2 g

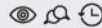


8TH



Anna's hummingbird
Calypte anna

0.2 g



7TH



VOCAL LEARNING

Some species learn vocalizations that can then be used in social interactions.



SOCIALIZING

Some species engage in complex social relationships within groups.



REMEMBERING

Some birds are even able to recall episodic experiences from the past.



PLAYING

Some birds engage in play fighting or other forms of social play.



Working Together

Keas, alpine parrots from New Zealand's South Island, are known for their curiosity, a hallmark of intelligence. Here at a research aviary in Austria, four keas (one not visible) figured out that to retrieve treats inside a wooden tower, they must cooperate by simultaneously pulling chains on opposite sides.

PHOTOGRAPHED AT THE KEA LAB, MESSERLI RESEARCH INSTITUTE, UNIVERSITY OF VETERINARY MEDICINE VIENNA



pizza. All the pieces are there, but they're not stacked." More recently other researchers discovered that the wiring that underlies long-term memory and decision-making is very similar in avian and mammalian brains.

Since then a steady stream of studies from the lab and in the wild has revealed just how bright birds are: Japanese tits, small East Asian songbirds, use their high-pitched *pi-pi* alarm calls to alert their fellows to predators, and have a kind of grammar, with syntactical rules for combining the *pi* notes with *dee-dee-dee* notes to summon the flock to drive off a predator. Green-rumped parrotlets in South America have calls that function as names. Parent parrotlets apparently assign the names to their chicks, much the way human parents give names to their children.

Male palm cockatoos on New Guinea court females with their calls and by fashioning drumsticks from twigs and seedpods and performing rhythmic drum solos on hollow trees—the first animal known to make a musical instrument. Curiously, Goffin's cockatoos, white parrots from Indonesia, make and use tools in captivity but aren't known to do so in the wild. "They really like new things and things they can manipulate, like zippers, locks, and shirt buttons," said Alice Auersperg, standing in her barn-size aviary in Austria while 14 hand-raised cockatoos flapped and whirled overhead. "They're like little, focused engineers."

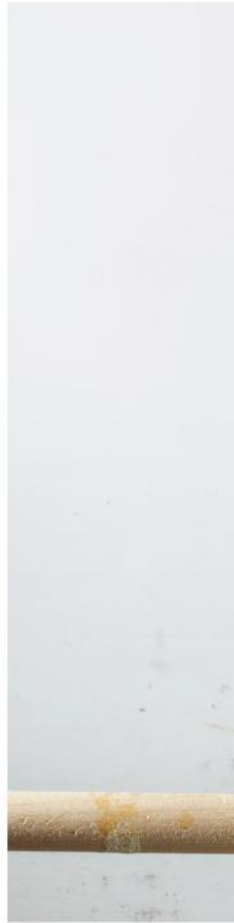
Auersperg, a cognitive biologist at the University of Veterinary Medicine in Vienna, had called her birds over to show me how clever they are at opening locks and inventing tools. She wanted one particular cockatoo, Muppet, but all 14 shoved their way into the test room.

"Ohhh," Auersperg sighed. "Some people have problems getting their birds to go into testing areas. I have problems keeping them out. They all want to do the tests." She picked up a long stick and gently poked at the cockatoos, encouraging them to return to the main aviary. "You have to have the personality of a strict kindergarten teacher to work with them," she said. "You must be consistent and firm, because they're always trying to take advantage."

Decision-Making

Zebra finches, found across Australia, form tight pairs and, unlike most birds, rarely stray. To find out if such bonded pairs can coordinate their behaviors and jointly solve problems, researchers at the University of Wyoming devised a special maze test. Each bird in this pair (the male is perched in the heart opening) has been trained on a separate part of the maze. Can they combine their knowledge to solve the task? The results of the test are due out later this year.

PHOTOGRAPHED AT THE ANIMAL BEHAVIOR AND COGNITION LAB, DEPARTMENT OF ZOOLOGY AND PHYSIOLOGY, UNIVERSITY OF WYOMING



Auersperg finally got all the birds except Muppet to leave the room. With hand signals, she asked Muppet to fly to the testing platform and wait, explaining that the birds can be taught commands such as "come," "go," and "stay" as easily as a dog. She placed a puzzle box containing a cashew nut on the platform. We—and Muppet—could glimpse the nut through a window in the box's door, but the door couldn't be opened until five locks were removed: a pin, a screw, a bolt, a wheel, and a bar. Each lock jammed access to the next lock, so they had to be opened in a specific sequence. Ten of the cockatoos had opened at least some of the locks, and Muppet and four others had succeeded in getting the nut. All worked persistently at the problem, sometimes solving it after a two-hour effort—a sign of their sophisticated cognition.

For this test, which was designed to see how flexible their minds are, Auersperg had removed the screw—the second lock in the series. Would



Muppet understand what had changed and begin with the third lock, the bolt? “We want to know if they’re solving the problem robotically or if they’re paying attention to how the locks work.”

Muppet studied the locks for a moment, then tackled the bolt, using his beak to pull it through a ring that kept it in check. Next he twisted off the wheel and pulled back the sliding bar. The door dropped open, and Muppet seized the nut.

“Once they figure out a problem, they usually remember how to solve it,” Auersperg said. “They know how each lock works, even if they’re out of sequence. I think they do understand the effect the locks have on each other; their minds are flexible that way.”

BIRDS—ESPECIALLY CORVIDS and parrots—are now celebrated as “feathered apes,” biologist Emery says. Emery, who began his career as a primatologist, coined that term for corvids in a paper he co-authored with Clayton, his wife.

They’d previously collaborated on a study that showed scrub jays didn’t instinctively re-hide nuts from other spying jays; they only began to move their stash after they stole nuts from their fellows. “It was the experience of stealing that changed the jays’ behavior,” Emery says. “You know, ‘It takes a thief to know a thief.’” Their study suggested that the jays might understand what another bird was thinking (and plotting), a type of reasoning that’s extremely difficult to study and demonstrate in other animals.

Emery and Clayton argue that corvids and apes evolved markedly similar complex cognitive abilities even though they’re distantly related—the two groups diverged more than 300 million years ago—because they face similar pressures. Both live in social groups, which require an understanding of others’ motives and desires, and they search for and process a range of foods, some of which can only be acquired by first making a tool. Chimpanzees, orangutans, and



Appreciating Music

Arnie, a European starling, lives with Lloyd and Rose Buck in Somerset, where he chatters in English and is happiest when Lloyd is playing the piano. There seems to be something about classical music that appeals to starlings: Mozart had a pet starling who sang some of his music. Arnie likes Mozart, Beethoven, Schubert, and Bach.





just one bird, the New Caledonian crow, excel at doing this in the wild.

These glossy black birds, which are ancestrally related to American crows, live only on two southwest Pacific islands in New Caledonia. There, one day in 1993, ecologist Gavin Hunt from New Zealand spotted a crow stashing something unusual in a tree; Hunt knocked the object to the forest floor.

“It was what we now call a ‘stepped tool,’” Hunt says, selecting it from a cardboard box. “As soon as I saw it, I knew it was a tool: something designed by someone for a specific purpose. If I’d found it at an archaeological dig, you’d say a human made it. But I found it in the forest, and a crow made it.”

Hunt handed me the crow’s tool, which was about six inches long, wide at one end and tapered at the other, with two saw-blade-like steps in between. Pale green in color, the tool was thin and flexible; it had been cut from a leaf of a pandanus shrub, a palmlike plant found on many tropical islands. A human might have used scissors to make this tool. The crow had used its beak. Pandanus leaves are fibrous and edged with tiny barbs.

“Because of these parallel fibers,” Hunt noted, “the birds can’t cut the leaves on the diagonal to make that tapered point. So they cut out steps, beginning at the narrow end.”

When finished, the crow holds the tool in its beak and flies to a tree or pandanus shrub to search the crowns for prey such as cockroaches and spiders. The crows also make hooked-twig tools for the same use and straight stick tools to poke into downed and rotting logs for wood-boring beetle grubs, which they try to fish or lever out with their tools. “They have traditions, and they keep them, just as humans do,” Hunt says. “So the stepped pandanus leaf tools and the hooked-twig tools

are standardized in terms of size and shape.”

Very few animals make their own implementations, especially any with set designs for particular tasks. Until Jane Goodall found that chimpanzees make tools, scientists thought humans were the only animal with this ability—and hypothesized that it helped drive the evolution of human intelligence.

“The discovery that New Caledonian crows do this too, and have a culture of toolmaking, is important because first, it’s something they do naturally in the wild, and second, it shows that this ability has evolved in animals that are not closely related,” says John Marzluff, a wildlife biologist at the University of Washington, Seattle, who studies crows and ravens. “That means this type of tool-manufacturing intelligence has evolved at least twice in entirely different types of brains.” Like chimpanzees who shape a twig into a tool for fishing termites from their nests, New Caledonian crows likely “intend to hunt grubs” when making one of their tools, Marzluff says. “That means they’re planning ahead.”

Corvids are like primates—including humans—in another way. They have large brains relative to their body size. Although brain size isn’t a measure of intelligence, we humans tend to expect a big-brained animal to be smart, because we like to think we are. A 150-pound human’s brain weighs about three pounds, which is 2 percent of total body weight. A raven’s brain may weigh just over half an ounce, but it accounts for 1.3 percent of the bird’s body mass. The size of ravens’ and crows’ brains is even more impressive when you consider their need to fly. “That’s why birds have hollow bones,” explains Alex Taylor, an evolutionary biologist at the University of Auckland who studies New Caledonian crows. “Birds are under pressure to have small bodies for flying, and yet have large brains. So when we see birds with large brains, it’s more remarkable than seeing it in mammals.” And whereas their brains may be nut size, birds make good use of the allotted space by packing in large numbers of neurons. Indeed, recent studies show that corvids, other songbirds, and parrots have neuronal densities that greatly exceed those of mammals.

Keeping the Beat

Snowball, a sulphur-crested cockatoo, wowed YouTube fans – and neuroscientists – when he rocked in time to the Backstreet Boys’ tune “Everybody” in 2007. He lives at Bird Lovers Only Rescue Service, a sanctuary in South Carolina, where director Irena Schulz cares for him and records his dances.



Solving Problems

The Bucks' captive raven, Bran, took about 30 seconds to figure out that to get the meat at the end of a string, he must pull the string up with his beak and secure it with his foot as he does so. "Ravens have the ability to test actions in their minds and project the outcomes of those actions," according to corvid researchers Bernd Heinrich and Thomas Bugnyar.



STILL, LARGE BRAINS are a kind of handicap for birds. So why do they have them?

Many researchers think that, as with primates, complicated societies are the real spur behind complex cognition. To test this in ravens, Thomas Bugnyar, a cognitive biologist at the University of Vienna, travels to the Austrian Alps each month to the Konrad Lorenz Research Center for studying animal behavior and cognition. Here, he and his colleagues have examined the social dynamics of a flock of a few hundred wild common ravens—large birds with black, iridescent feathers that are distributed across the world. Common ravens are closely related to American crows, the birds that Gabi Mann befriended.

Birds' societies differ from those of mammals in a fundamental way, Bugnyar stresses. "The most basic social bond in mammals is between mother and infant, but in birds it's the pair-bond. It's a bond that develops through learning."

Ravens begin trying to develop such social bonds when they're merely six months old, and before they're sexually mature. Most adult pairs are heterosexual, and the two adults work together to defend a territory for breeding and raising a family. Adults also form alliances with birds other than their mates to build social support networks. Ravens learn about each other—what other birds like or dislike, their personalities, who's brave and who's a coward—by watching them stash and give and steal from one another. "They can make an object in their stash more valuable just by showing it to another bird," Bugnyar explains.

Other ravens keep tabs on any budding relationships, and break them up if possible. Of approximately 180 "affiliative interactions" among 90 ravens that Bugnyar or his colleagues witnessed, "one quarter were broken up by a third party." That's because "alliances are powerful. Birds rise in the dominance hierarchy as soon as they form a social bond. The other birds want to prevent them from gaining that power." Ravens with numerous allies get first dibs on limited resources, such as food and nesting sites.

Further complicating matters, the ravens—like humans, chimpanzees, elephants, and

Showing Empathy

Scientists say that chickens, like these on Matt Sigel's Wyoming farm, are cognitively advanced. They live in hierarchical societies, track numbers and do basic math, and are likely to experience emotions, from boredom and frustration to happiness. And they show signs of empathy: If air is blown on chicks' feathers, which the birds don't like, their watching mother's heart rate goes up.



dolphins—live in a “fission-fusion society,” meaning that the larger flock splits apart in the day as individuals fly to other valleys in search of food, new territories, or companions. There are only seven to 10 mated pairs in Bugnyar's Alpine study group. The hundreds of other birds roost together in small groups at night, where they groom each other, play, squabble, and exchange information. “Usually they go only a short distance to check for food and, we think, social opportunities,” Bugnyar says.

In contrast, the breeding pairs rarely leave the area. All keep track of other birds' relationships as they try to figure out when it's most advantageous to aid or intervene with others. “The ravens must learn how to form social bonds and how to use these like tools if they are to successfully reproduce,” Bugnyar explains. “That's a lot of pressure, and I think it's led them to evolve their large brains and cognitive skills—at least, I think that's what my data will ultimately show.”



So why do crows in Seattle bother to present gifts to a human girl?

“I don’t know why they do it,” Bugnyar says. “Gift giving is in their natural repertoire. So it’s likely they give her gifts because they’ve learned that she is giving them food.”

“It’s a two-way communication,” agrees John Marzluff. “Gabi consistently provides food, and the crows regard the food as a gift. In exchange they bring her presents.” It’s rare for wild birds—other than crows and ravens—to offer objects to people. “When they bring gifts, people pay attention,” Marzluff says, “and the birds notice our response,” just as Babyface observed Gabi’s reaction when he dropped the toy squid. “It’s a reciprocal exchange; some might say it’s a way of thanking Gabi.” And the crows know Gabi, Marzluff says. He and his students carried out a series of experiments on his university campus that showed crows never forget a face. They recognize people who harassed them years before at

nesting sites and even pass this information on to their chicks and other crows.

Gabi and her family recently moved to Ithaca, New York. She’s traveled back and forth a few times, much like a raven on the wing, as her parents complete the transition. Each time they return to Seattle, Gabi sets out food for the crows, although at a neighbor’s home. She sees Babyface and his friends and says the birds know when she and her family are back: “They recognize our car.” When she leaves, she bids him and the others farewell. She thinks he worries about her, just as she worries about him. And she wishes for Babyface what she thinks he wishes for her: a good life with lots of friends, and stashes of bright objects and nuts in her new territory. □

Virginia Morell is the author of the *New York Times* best seller *Animal Wise: How We Know Animals Think and Feel*. Regular contributor **Charlie Hamilton James** is the National Geographic innovation in photography fellow.

| DISPATCHES | COLOMBIA

The Parent Trap

A program in Colombian high schools uses very needy robotic babies to discourage teen pregnancies.



At 3 a.m. Sara Gómez, 13, cares for her robotic baby at her home in Guamal, Colombia. Designed to mimic month-old infants, the babies help students learn about parenthood.

BY **DAVID BRINDLEY**
PHOTOGRAPHS BY **CHRISTIAN RODRIGUEZ**

Jefrin Bayona is already running late for school and it's just after 6 a.m. "I barely slept last night," the 15-year-old student says. "The baby woke me up at 10, 12, four in the morning." Classes start early here in the rural plains of northeastern Colombia. Standing in the dark kitchen of his home, Jefrin drags a hand down his tired face between sips of hot chocolate. Estiven, his infant son, silently sits in a baby carrier on the sparse living room floor.

Fortunately for Jefrin his early foray into fatherhood ends today. He's participating in an immersive school program that aims to prevent teenage pregnancy. "Estiven" is actually a robotic baby designed to simulate a needy one-month-old—crying at programmed intervals day and night to provoke students to feed and burp the baby and change its diaper. The responses are tracked and recorded, and students are graded on how quickly they react. A baby left unattended for too long will shut down, affecting the student's grade.

Jefrin has taken care of the baby for the past 48 hours, and the typically outgoing and buoyant teen is clearly exhausted. He arrives at school five minutes after the bell and hands the baby off to fellow student, and designated mother, Alexandra Guerrero, 15, for the next two-day shift.

Worldwide some 17 million teenage girls give birth every year, facing increased risk of health complications during pregnancy as well as life-long economic challenges for themselves and their families.

Education and dreams of advancement are often derailed for these young mothers. Latin America has the third highest teenage pregnancy rate in the world. While the global rate has declined over the past decade, the pace of decline in Latin America lags behind that of other regions.

In Colombia one in five mothers is between 15 and 19 years old; poor rural teens are at the greatest risk of early pregnancy.

That brings us here, to the low-slung concrete classrooms at a public school in the small town of Tame, Colombia. The program that Jefrin, Alexandra, and 100 of their ninth-grade classmates, ages 14 to 16, are enrolled in—with their parents' consent—aims to prevent early pregnancies. In addition to the two-day simulated-baby exercise, students undergo 30 hours of instruction, from basic sex education and contraceptive use to discussion of gender stereotypes and roles, domestic violence, and family budgeting. Students have to pass a final exam on these topics and write an essay or shoot a video on their experiences with the babies.

"Sex education and the baby simulation are both important; they reinforce each other," says Camila Guzmán, director of the program *¿Bebé? ¡Piénsalo Bien!*—or *Baby? Think It Over!*—in Colombia. "The objective isn't to scare the students. We want to create a consciousness about sex and pregnancy. It's OK for them to have kids—when they're ready."

The robotic babies were developed in the United States more than 20 years ago, and the program has been implemented around the world. But it is relatively expensive—costing more than \$100 per student here in Colombia and requiring multiple instructors. That raises questions of scalability in developing countries with scarce resources. Yet the program has proved effective. In a study of more than 1,400 student participants in one region of Colombia, the program reduced the teen pregnancy rate by 40 percent.

After the weeklong course Alexandra, who plans to pursue engineering in college but admits, "I really want to be an actress," is determined to delay motherhood. "I don't want to have a baby now. I'm not capable of taking care of it," she says. "Maybe when I'm 25 or 26 and I finish studying." □





Students at the Santo Domingo Savio school in Acacías, Colombia, participate in a weeklong sex education and teen pregnancy prevention program called *¿Bebé? ¡Piénsalo Bien!*—or *Baby? Think It Over!* Above: Martín Reina, 14, Danna Álvarez, 13, and Andrés Felipe Rondón, 13, awkwardly learn how to use condoms. Below: Julián David Velázquez, 13, cradles a robotic baby during class. Students spend 48 hours with their babies.





Above: Danna and her mother, Olga Alfonso, care for two robotic babies – assigned to Danna because Olga had twins. Below: Alexandra Guerrero, 15, falls asleep while feeding “Estiven.” Right: Co-parent Jefrin Bayona, 15, cares for Estiven while eating dinner at his home in Tame, Colombia. “It’s a huge responsibility,” Jefrin says of fatherhood. “I want to have kids, but only when I’m older and can take good care of them.”





FURTHER

A GLIMPSE OF WHAT'S NEW AND NEXT

NATURE'S URBAN INNOVATIONS

By Natasha Daly

Daan Roosegaarde—urban architect, innovator, and night diver—finds bioluminescent plankton inspiring. “They don’t have a battery, they don’t have an energy bill, they don’t have a maintenance contract,” he says. “What can we learn from them?”

That question drives Roosegaarde’s life’s work: drawing on nature to make cities more efficient and more beautiful without damaging our planet.

To emulate plankton that emit light, Roosegaarde and his colleagues embedded solar-powered stones in the bike path seen here. The path is in Nuenen in the Netherlands—onetime home of Vincent van Gogh—so the glowing stones were arranged to resemble the artist’s masterwork “The Starry Night.”

The Dutch innovator considers it “weird” that people focus on vehicles but neglect the surfaces they drive on: “Infrastructure defines our cities and landscapes way more than the cars.” He flips that focus with inventions for roads—paint that changes color when the temperature drops, lanes that charge the electric cars driving on them, and reflective lines powered by urban lighting.

In a nation that lies below sea level, Roosegaarde takes this work personally: “Without technology and good design,” he says, “we would literally drown.”

Daan Roosegaarde's solar-powered bike path glows at night from the energy it has collected during daylight hours.

PHOTO: MARC BOLSIUS



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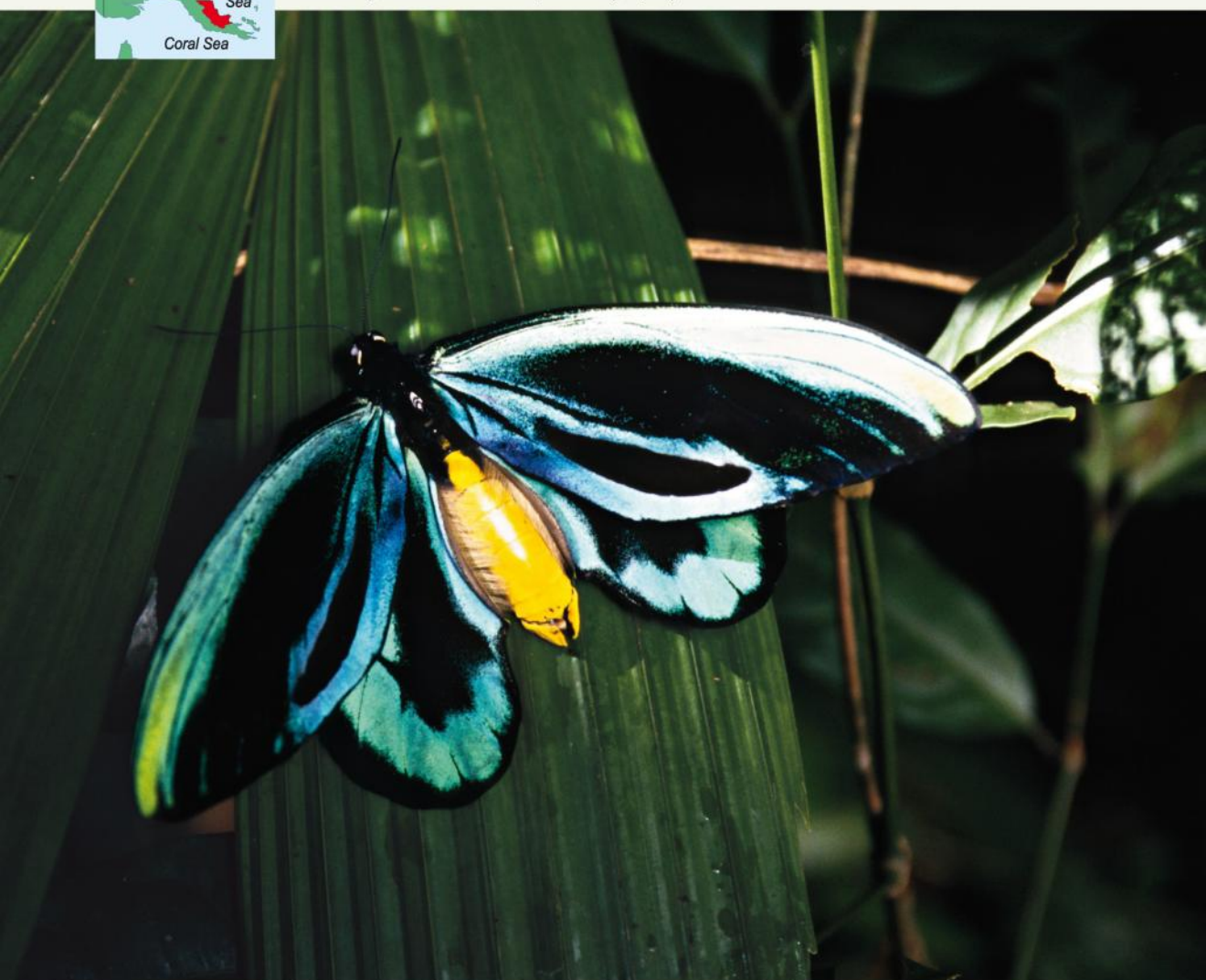


Queen Alexandra's Birdwing (*Ornithoptera alexandrae*)

Size: Body length, 8 cm (3.1 inches); forewing length, 11.9 cm (4.7 inches) **Weight:** 12 g (0.42 oz)

Habitat: Primary and secondary rain forest in the tropical mountains of Papua New Guinea

Surviving number: Unknown; declining rapidly



Photographed by François Gilson

WILDLIFE AS CANON SEES IT

A giant among butterflies. Queen Alexandra's birdwing is, in fact, the largest in the world. Females are bigger than males, but only males sport a bold bluish green. In their short 3-month adulthoods, females lay as many as 240 eggs each; growing larvae have a very specialized diet, eating *Aristolochia* vines exclusively. But the forest habitat

on which these rare butterflies depend is vanishing quickly, and they also continue to fall victim to the international trade in dried specimens.

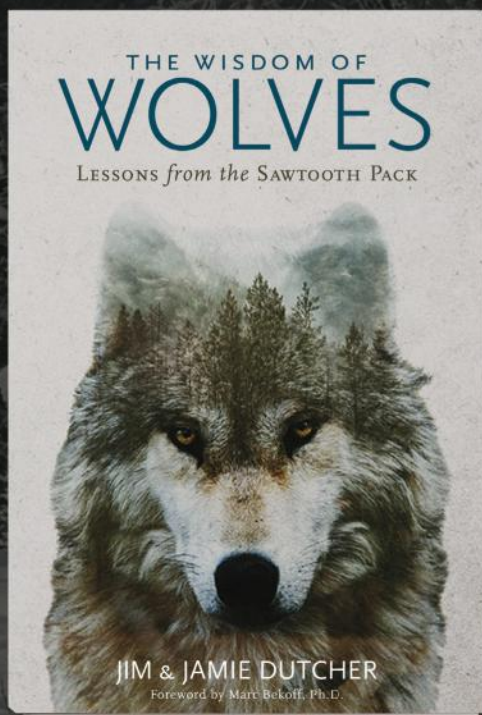
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